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Petrochemical Studies of the Ryôke Granitic Rocks from the River Koshibu District, Central Japan

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Abstract

The Ryôke granitic rocks of the River Koshibu district are divided into following four main types :

The older Ryôke granitic rocks
- Hiji granodiorites
- Minakata gneissose granites

The younger Ryôke granitic rocks
- Takisawa granodiorites
- Ikuta granites

The Minakata gneissose granites are specially heterogeneous and closely connected with the hornblende-biotite gneisses. Various rock-types of the granites are representatives of the different facies in the progressive granitization of the hornblende-biotite gneisses.

Petrochemical characters of these granitic rocks and chemical changes in the rock-series from the hornblende-biotite gneisses to the Minakata gneissose granites are discussed.

1 Introduction

Abundant granitic rocks are distributed in the Ryôke metamorphic belt running parallel to the Median tectonic line, and their mutual relations are very complicated.

In the latest about ten years, the geological relations of the granitic and metamorphic rocks have gradually been revealed by the members of the Ryôke Research Group and by other investigators in the River Tenryû district, Central Japan.

Since 1952, the present writer has studied geologically and petrologically the Ryôke granitic rocks in the River Koshibu district of the upper stream of the River Tenryû, and some interim reports were published in the course of the study (YAMADA 1957, YAMADA and ISHII 1961, ISHII and YAMADA 1962).

In the present paper, the writer describes mainly the petrochemical characters of the granitic rocks of the present district, and will give some genetical interpretations in connection with other Ryôke granitic rocks of Central Japan.

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2 General Geology

The River Koshibu district under consideration is situated within the north-eastern end of the Ryôke metamorphic belt as shown in Fig. 1.

The Ryôke metamorphic belt consists of various high temperature, low pressure type metamorphics such as biotite-schist, cordierite-gneiss, sillimanite-gneiss, and various kinds of granitic rocks. Abundant granites are exposed over a wide area within the belt, and the associated metamorphics are found isolated only in such areas as the Komagane～Ina district adjoining the north of the present district, the Dando district of Mikawa, the Kasagi district of Kinki, and the Yanai district of Chûgoku. In other regions the metamorphic rocks are distributed only as roof-pendants and xenolithic masses in the granites. A part of the large Komagane mass of metamorphics occupies the northern end of the present district.

The original rocks of the Ryôke metamorphics are composed mainly of the late Palaeozoic pelitic and psammitic rocks associating abundant chert, but basic rocks and limestone are scarce. In Central Japan, the metamorphic grade of the belt increases from the northwest to the southeast in the Komagane district (HAYAMA 1960), and from north to south in the Dando district (KOIDE 1958). The structural trend of the metamorphic rocks is generally N40°～60°E dipping northerly or southerly from 50° to 80° in the Komagane district, and N70°～90°E dipping northerly or southerly from 40° to 70° in the Dando district.

The granitic rocks associated with these Ryôke metamorphics are divided into two groups; namely the older Ryôke granites and the younger ones. The basis of division of the older and the younger is, however, not commonly used in the Ryôke belt. In the Dando district, KOIDE (1958) considered that the older

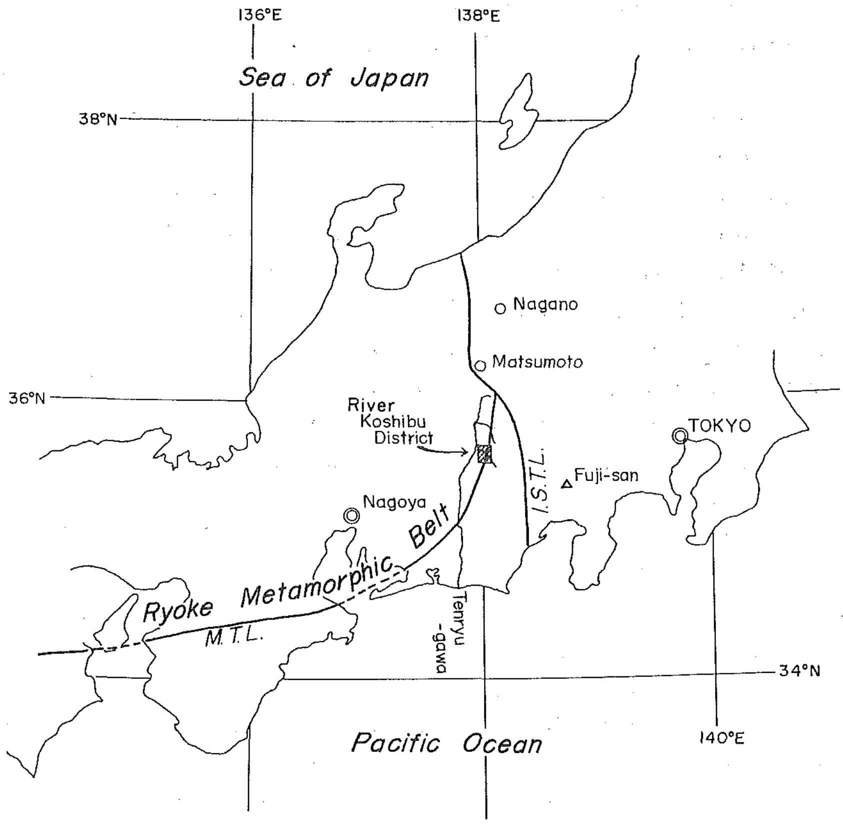


Fig. 1 Outline map of Central Japan, showing the situation of the River Koshibu district.
M. T. L.; Median tectonic line.
I. S. T. L.; Itoigawa-Shizuoka tectonic line.

granitic rocks were intruded in connection with the older Ryôke metamorphism of regional type and these metamorphics were affected by the residual solutions from the older intrusives, while the younger granitic rocks were intruded in connection with the younger Ryôke metamorphism and the older Ryôke metamorphics were locally metamorphosed again by the younger intrusives. The younger Ryôke metamorphism is characterized by "contact-metamorphism". The older intrusives of the Dando district are further divided into three types (the Kiyosaki granodiorites, Sumikawa granodiorites, and Busetsu granites) according to the sequence of intrusions, and the younger intrusives are represented by the Mitsuhashi granodiorites. In the Komagane district, on the other hand, the Ryôke granitic rocks are divided into two groups (the older granitic rocks and the younger ones) with regard to the "mylonitization" relating to the formation of the Median tectonic line (HAYAMA 1959). The older granitic rocks were intruded in the closing period of the "mylonitization", and they were more or less mylonitized. The younger granitic rocks were intruded posterior to "mylonitization". In other districts of the Ryôke belt, it is able to divide various granitic rocks into older and younger ones by means of the mutual relations in the field and of the petrographic correlations to those in the above mentioned area, respectively.

Generally speaking, the older Ryôke granites are widely distributed over the whole area of the metamorphic belt, while the younger granites are limited in distribution. The older granites are rich in rock types ranging from quartz-diorite, through granodiorite, to granite, and are characterized by distinct gneissosity parallel to the general structural trend of the metamorphic belt. The boundary between the older granites and the metamorphics is also harmonic with the general trend, whereas the younger granites are rather homogeneous and massive, and are commonly disharmonic intrusives.

On the eastern side of the Ryôke belt in the River Tenryû district is distributed the Kashio mylonite belt of several hundred meters wide*, which immediately contacts with the Sambagawa metamorphic belt consisted mainly of the crystalline schists of green schist facies and subordinate epidote-amphibolite facies. The sharp boundary between the Kashio mylonite belt and the Sambagawa metamorphic belt is represented by the Median tectonic line. The Kashio mylonite belt is also called the Kashio tectonic zone (GORAI 1955, HAYAMA et al. 1963). This narrow belt is characterized by peculiar mylonitized rocks called "porphyroid-like rocks" derived from one of the older Ryôke plutonic rocks intruded near by the Median tectonic line and also from subordinate Ryôke metamorphics. These rocks are strongly crushed and mylonitized during the consolidation of granitic rocks.

The River Koshibu district is mainly composed of various kinds of granitic rocks as shown in the annexed geological map, and these granitic rocks are divided into the following four main types according to the sequence of intrusion :

1) Hiji granodiorites.
2) Minakata gneissose granites.
3) Takisawa granodiorites.
4) Ikuta granites.

The Hiji granodiorites, have been studied by HASHIMOTO (1957), HAYAMA (1959, 1960), and KANISAWA (1961) in the type-locality, located further north of the present district. According to HAYAMA (1959), the Hiji granodioritic mass is complex one consisting of banded granodiorite, massive quartz-diorite, augite bearing biotite tonalite, garnet bearing trondhjemite, amphibolite, and meta-diabase. Of these

* The Kashio mylonite belt is more than 1 km. in width in the vicinities of Ochiai, south of Kashio, and it is the widest distribution of the belt in the River Tenryû district.

rocks the former three are in gradual transition one another, the former two being the principal rock facies in the Komagane district. The common characteristics of the Hiji granodioritic complex are the banded structure consisting of the alternation of light and dark colored bands, generally 1 cm in width, its slender distribution along the inner side of the Kashio mylonite belt, and the gradation into the Kashio mylonite in the eastern border.

The southern end of the Hiji granodioritic complex occurs in the northern part of the present district. In the vicinities of Shitoku, medium-grained, less-banded, schistose granodioritic facies predominates, but more basic and banded varieties carrying numerous diabasic xenoliths are found in the northeastern area of the present district. Excepting its distribution in the northern part, the wide exposure of the rocks is not found in the present district.

The other three rock types, the Minakata gneissose granites, Takisawa granodiorites, and Ikuta granites are exposed typically along the valley of the River Koshibu running from east to west in the middle portion of the present district.

The Minakata gneissose granites occupy the eastern half of this area. The term of "granites" is used here in a broad sense to include granite, adamellite, trondhjemite, granodiorite, and quartz-diorite. These rocks are mostly characterized by distinct gneissosity, some of which are remarkably porphyritic, carrying abundant phenocrystic feldspar. These rock-types are in gradual transition one another, and the gneissose granodiorite and porphyritic gneissose adamellite are predominant rock types.

The Minakata gneissose granites in question are closely connected with the hornblende-biotite gneisses characterized by extream gneissic appearance owing to the filmy arrangement of biotite flakes and by carrying fair amount of hornblende crystal without exception. The large masses of the hornblende-biotite gneisses are found in the Kadoishi-zawa, Mt. Takamori～Nakayama, and Matsuyoke～Karayama, but other small masses are found especially in the northern half of the present field. The hornblende-biotite gneisses gradually pass into the Minakata gneissose granites through various transitional granitic gneiss.

Besides the hornblende-biotite gneisses, there are many inclusions of such metamorphosed basic igneous rocks as meta-diabase and meta-gabbro and of ordinary Ryôke metamorphics. The local hybridization are observed in the contact between the Minakata gneissose granites and these xenoliths.

The Minakata gneissose granites have been described as porphyritic granite (Sugiyama 1939), as hybrid rocks (Takeda et al. 1951), as migmatite derived from gneiss (Ryôke Research Group 1955), and as schistose granite (Ishii et al. 1955). It may be designated as granitic gneiss or orthogneiss also. These confusions of designation may depend on the heterogeneity and the distinct foliated structure of the rocks in question. In the southern area of this field, the Minakata gneissose granites become generally more granitic and more porphyritic ones, and similar porphyritic gneissose granites are called the Tenryûkyô granite in the vicinities of Tenryûkyô (KOIDE 1942). Therefore, the Minakata gneissose granites of the River Koshibu district is the northeastern part of the Tenryûkyô granite, which is one of the largest batholithic granites of the Ryôke belt in Central Japan. Surely, some of the coarse-grained porphyritic facies of the Minakata gneissose granites occurring in the vicinity of Kuwabara are lithologically identical with the Tenryûkyô granites proper.

The boundary between this Minakata gneissose granites and the Ryôke metamorphics is comformable to the structure of the latter, and the inner structure of granites indicated by gneissosity and parallel arrangement of xenoliths has NE-SW trend consistent with the general trend of the neighbouring Ryôke metamorphic terrain.

The most porphyritic variety of coarse-grained gneissose granites is predominant in the eastern margin along the Kashio mylonite belt. It has been named "Augen gneiss" or „Augen granite". The mylonitic character of the Minakata gneissose granites is stressed near the Kashio mylonite belt.

At the Iwakura-zawa of Minakata, several masses of the Minakata gneissose granites elongated parallel to the shistosity of the Hiji granodiorites are found among the latter. Though it is difficult to make clear whether the former is invaded by the latter or *vice versa*. The boundary between the Minakata gneissose granites and the Hiji granodiorites is usually distinct, though not always clear-cutting, but sometimes gradational. Any proof of the contact effect cannot be found in both sides of the boundary. HAYAMA (1959) recognized the same relation in the contact between the Minakata gneissose granites and the Hiji granodiorites in the further north of the present field, though he also described that the Hiji granodioritic rocks were cut by the aplitic veins introduced from the Minakata gneissose granites at Momodaira.

These facts suggest that the intrusion of the Hiji granodiorites was immediately followed by that of the Minakata gneissose granites.

From the petrographic characters and the modes of occurrence, it is safely said that the Minakata gneissose granites of the present district belong to one of the older Ryôke granites.

Small masses designated as the Takisawa granodiorites occur in the vicinity of the Matsuyoke-bridge and Karayama, each of them having a closed outline as shown in the annexed map. The Takisawa granodiorites are composed mainly of coarse-grained biotite-hornblende granodiorite with subordinate medium-grained quartz-diorite and biotite-hornblende granite, and all of these are characterized by directional arrangement of hornblende prism. The elongation of these masses and their inner structure are generally concordant to the structural trend of the present field. In the vicinity of the Matsuyoke-bridge a narrow dyke of hornblende granite having similar petrographic characters with the Takisawa granodiorites is injected obliquely into the Minakata gneissose granites. Near Karayama, large xenolithic masses of the Takisawa granodiorites are found within the Ikuta granites, though any contact effects cannot be recognized in both sides of the boundaries. On the other hand, typical Ikuta granites gradually pass into somewhat basic, schistose varieties petrographically similar to the Takisawa granodiorites in several places of the western part of present district. There is no obstacle to treat the Takisawa granodiorites as a local facies of the Ikuta granites.

The Ikuta granites occupy the western half of the present field. They are composed mainly of medium～coarse-grained hornblende-biotite granodiorite with subordinate biotite granite and quartz-diorite, and are usually characterized by fairly massive appearance (in some cases slightly schistose and somewhat porphyritic), and by roughly idiomorphic biotite flakes and hornblende prisms. Although the foliation is usually indistinct, it is indicated by directional arrangement of basic schlierens and sub-parallel arrangement of xenoliths.

A lot of xenoliths of basic igneous rocks and the Ryôke metamorphics are found. These xenoliths are usually arranged parallel with the general structural trend of the neighbouring area. It is striking that the distribution of basic xenoliths is fairly limited in a zone in the vicinities of Kamitoge～Takisawa as if the structure and distribution of pre-existing rocks are preserved. Most of these xenoliths are more or less contaminated by the granites, and granitic rocks are also converted to more mafic rocks. In these contaminated granodioritic and quartz-dioritic rocks, cummingtonite appears frequently associating with hornblende.

Small xenoliths of the Ryôke metamorphics are common in the Ikuta granites. Pelitic gneisses are converted to compact hornfelsic rocks in which fresh cordierite porphyroblasts frequently occur. The boundaries between these hornfelsic gneisses and the Ikuta granites are rather sharp. On the other hand, psammitic gneisses are usually contaminated and converted to fine-grained granitic rocks which may correspond to the permiation-injection gneiss of the Dando district (Koide 1958). In siliceous hornfelsic rocks, green spinel and diopside are found (Kawada and Yamada 1957).

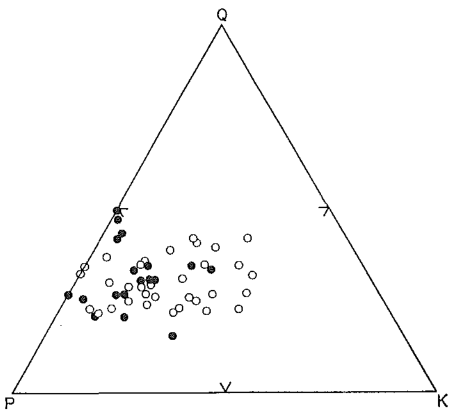
In the southern area of this field, the Ikuta granites are injected comformably into the Minakata gneissose granites, the boundaries between both rock-types being rather sharp. In the north of the River Koshibu, the Ikuta granites become somewhat porphyritic and schistose in appearance, and it is often difficult in the field to distinguish them from the porphyritic variety of the Minakata gneissose granites. At several places, the contacts of both rock-types are recognized, but we are unable to find any thermal effect on both sides. In the south of Shitoku, a continuous outcrop of the border of both rock-types is displayed along the River Shitoku. Here, the Ikuta granites gradually passes into the Minakata gneissose granites. In another contact, the Ikuta granites is injected clearly into the Minakata gneissose granites. Nevertheless, the distribution of the Ikuta granites is, as a whole, disharmonic with the general structural trend of the present district.

From the modes of occurrence, the Ikuta granites is evidently one of the younger Ryôke granites and it may be said, from the lithologic point of view, that the Ikuta granites corresponds to the Mitsuhashi granites of the Dando district.

3 Petrography of the Granitic Rocks

(1) *The Minakata Gneissose Granites.*

Though most of the Minakata gneissose granites are characterized by distinct gneissosity, they are divided, from their mineral compositions, into granite, adamellite, granodiorite, basic trondhjemite and quartz-diorite. Modal compositions of some representative rock-types are shown in Figs. 2A and 2B. It may



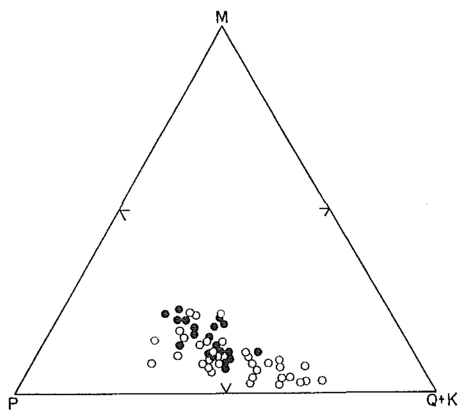


Fig. 2A Relation between plagioclase (P) : quartz+ K-feldspar (Q + K) : total mafic minarals (M) ratios.

Fig. 2B Relation between quarts (Q) : plagioclase (P) :K-feldspar ratios.

Open circle; Gneissose granites.
Solid circle; Hornblende-biotite gneisses.

Table 1 Average modes of the rock-series from the hornblende-biotite gneisses to the Minakata gneissose granites.

	1	2	3	4	5	6	7	8	9	10	11
Quartz	3.0	24.3	30.0	29.7	32.4	27.3	22.6	26.4	32.7	25.0	29.3
Plagioclase	44.6	48.4	44.7	45.1	44.9	52.8	48.4	52.4	37.9	33.7	32.3
K-Feldspar	—	5.6	7.0	14.4	14.7	7.3	14.7	13.0	23.1	35.7	34.0
Hornblende	30.7	5.8	3.7	3.0	0.7	7.3	1.3	2.2	—	1.0	—
Biotite	15.5	15.1	14.3	7.8	7.0	5.0	13.0	6.0	6.3	4.3	4.4
Magnetite	2.3	0.2	0.3	—	0.3	—	—	—	—	—	—
Titanite	2.6	0.4	—	—	—	—	—	—	—	—	—
Allanite	—	—	—	—	—	0.3	—	—	—	0.3	—
Calcite	1.3	—	—	—	—	—	—	—	—	—	—
Sericite	—	0.2	—	—	—	—	—	—	—	—	—

1 : Amphibolite
2 : Basic hornblende-biotite gneiss (color index 20<)
3 : Hornblende-biotite gneiss (color index 19–15)
4 : Hornblende-biotite gneiss (color index 14–10)
5 : Granitic gneiss (color index 10>)
6 : Gneissose granodiorite
7 : Porphyritic gneissose granodiorite
8 : Gneissose adamellite
9 : Porphyritic gneissose adamellite
10 : Gneissose granite
11 : Porphyritic gneissose granite

be said that the predominant rock-types are adamellite and granodiorite. Some of these are remarkably porphyritic in appearance, and in the marked porphyritic ones the gneissosity become sometimes rather indistinct. The grain-sizes of the Minakata gneissose granites are variable ranging from medium- to coarse-grained in general designation. Macroscopically the gneissose granites in question are very heterogeneous. Every hand specimen differs from each other in grain-size, in degree of gneissosity, and in mineral composition. The different rock-types are so intimately mixed that they cannot be mapped separately. Principal varieties of the gneissose granites are shown in Plate 2, and average mineral compositions of representative rock-types are tabulated in Table 1, No. 6~No. 11.

The microtexture of the gneissose granites is granoblastic to granitic, all gradations being observed between these extremities. Striking granoblastic texture predominates generally in finer-grained parts, while granitic texture predominates in coarser-grained and porphyritic parts.

The Minakata gneissose granites are closely accompanied by hornblende-biotite gneiss. The contacts between these two are observed at several places, and the former gradually passes into the latter through transitional granitic gneiss. This transition is rather abrupt around the small masses of hornblende-biotite gneiss, but is more gradual around the large gneiss-masses as found in the central part of the Minakata gneissose granites. Thus the fine-grained melanocratic hornblende-biotite gneiss, often carrying amphibolite lens, gradually passes into coarser-grained leucocratic one and is finally converted into granitic gneiss. Principal varieties of the hornblende-biotite gneisses are shown in Plate 1, and average mineral compositions of representative rock-types are tabulated in Table 1, No. 1~No. 5. In the basic hornblende-biotite gneiss, turbid relic of igneous plagioclase is scarcely found, though the microtexture is typically metamorphic. Medium-grained hornblende-biotite gneiss is characterized by a strongly gneissic appearance on account of the planar parallelism of hornblende and biotite.

Coarse-grained hornblende-biotite gneiss and granitic gneiss are characterized by the development of plagioclase porphyroblasts which often form light colored seams together with quartz, and some hand specimens of the gneiss look rather igneous, though all of which are characterized by typical metamorphic texture.

The gradual transitions of the fine-grained hornblende-biotite gneiss into the Minakata gneissose granites are completely recognized macroscopically and microscopically.

Judging from these facts, it may be said that various rock-types of the Minakata gneissose granites are representatives of the different facies in the progressive granitization of the hornblende-biotite gneiss, the hornblende-biotite gneiss having been changed gradually into the gneissose granites. The changes of mineral composition in the course of the granitization are shown in Table 1. In the early stage of the granitization, the fundamental change is the coarsening of mineral grains accompanied by a small decrease of mafic constituents and some increases of potash-feldspar and quartz, though the gneissosity is preserved as before.

The final stage of granitization is characterized by notable increase of potash-feldspar and by decrease of plagioclase. The ultimate products may be the porphyritic gneissose granite characterized by typical igneous appearances. In some places these granites seem to have been partly melted and mobilized reomorphically (GOODSPEED 1952, 1953) or intrusively.

The twin method proposed by GORAI (1950, 1951) is a valuable criterion by which the metamorphic granites can be distinguished from the magmatic ones. Some examinations were made on the Minakata gneissose granites under consideration. The results are shown in Figs. 3A and 3B, and are summarized as follows.

i) In the finer-grained and strongly gneissose varieties of the gneissose granites, the features of plagioclase-twinning are similar to those of the hornblende-biotite gneisses.

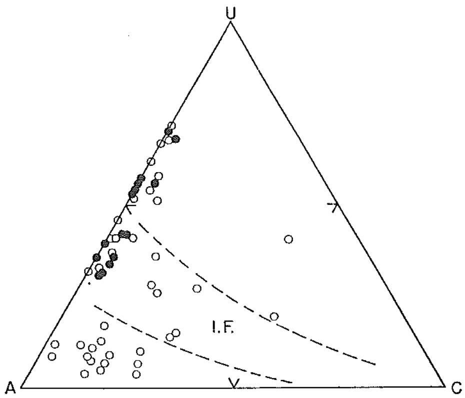


Fig. 3A U:A:C ratios of plagioclase twins in the Minakata gneissose granites and the hornblende-biotite gneisses.

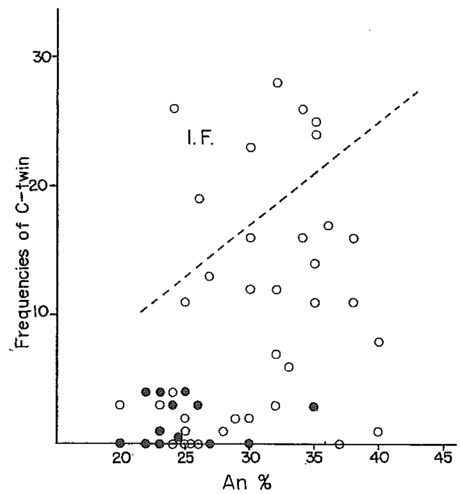


Fig. 3B Relationship between the An % of plagioclase and the frequencies of C-twin of plagioclase.

Open circle; Gneissose granites.
Solid circle; Hornblende-biotite gneisses.

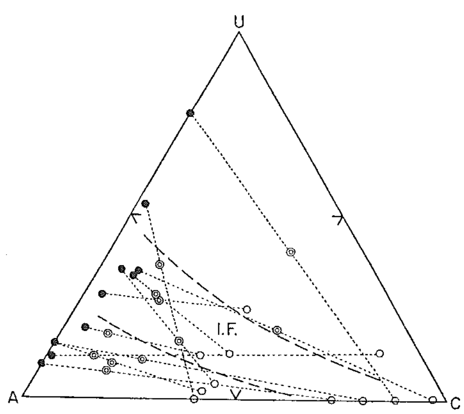


Fig. 4A U:A:C ratios of plagioclase twins in the porphyritic gneissose granites.

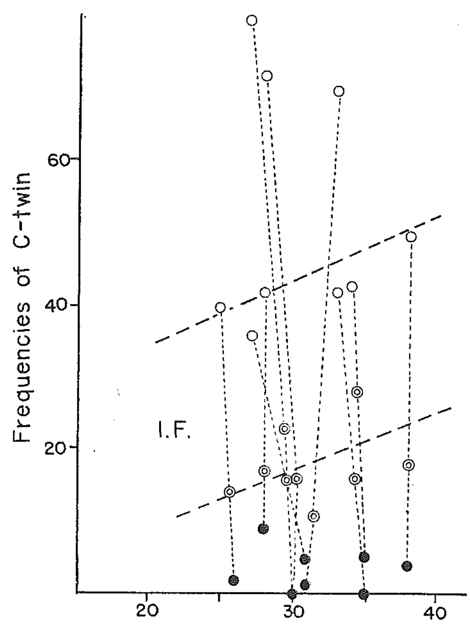


Fig. 4B Relationship between the An % of plagioclase and the frequencies of C-twin.

Open circle; Phenocryst plagioclase.
Solid circle; Groundmass plagioclase.
Double circle; Average of phenocryst and groundmass plagioclase.

ii) The coarser-grained and somewhat porphyritic varieties contain more or less C–twin, though they fall outside the typical igneous field.

iii) Some porphyritic and most granitic varieties fall within the igneous field. Such granites are re-examined in detail. In Figs. 4A and 4B, double circles show the U:A:C ratios and the relations between the average An % and the frequencies of C–twin of bulk plagioclase in porphyritic gneissose granties, solid circles showing those of groundmass-plagioclase and open circles showing those of phenocrystic plagioclase, respectively. As clearly indicated in the diagram, only the porphyroblastic plagioclases are prevalent in C–twin and the averages of groundmass and phenocryst plagioclases fall within the igneous field. Such granites were invaded often into the neighbouring rocks, and contain numerous displaced xenoliths. So the occasional development of liquid phase in the gneissose granites is suggested.

(2) *Xenoliths in the Minakata Gneissose Granites*

There are many inclusions of basic igneous rocks and Ryôke metamorphics in the Minakata gneissose granites. At the contact between these xenoliths and the Minakata gneissose granites, the former is hybridized in some degree by the latter.

Most of the basic xenoliths are meta-diabase and their hybrid rocks. In many places, a complete passage is clearly exhibited between the meta-diabase and the Minakata gneissose granites with transitional quartz-dioritic rocks within rather limited zone. An example of the transition exhibited at Koshibukyô was already

Table 2 Average modes of the rock-series from the meta-diabase to the Minakata gneissose granites.

	1	2	3	4	5
Quartz	1.6	8.0	16.2	21.1	28.0
Plagioclase	34.2	33.7	34.0	36.1	40.2
K-feldspar	—	4.5	6.3	5.8	10.3
Hornblende	55.0	42.2	26.2	17.7	7.1
Biotite	2.9	10.1	14.8	14.9	13.9
Magnetite	5.0	—	0.2	—	—
Chlorite	—	—	2.0	3.4	—
Apatite	0.5	1.5	0.3	1.0	0.5
Titanite	0.8	—	—	—	—

1 : Amphibolite
2 : Meta-diabase
3 : Fine-grained quartz-diorite
4 : Gneissose quartz-diorite
5 : Gneissose granodiorite

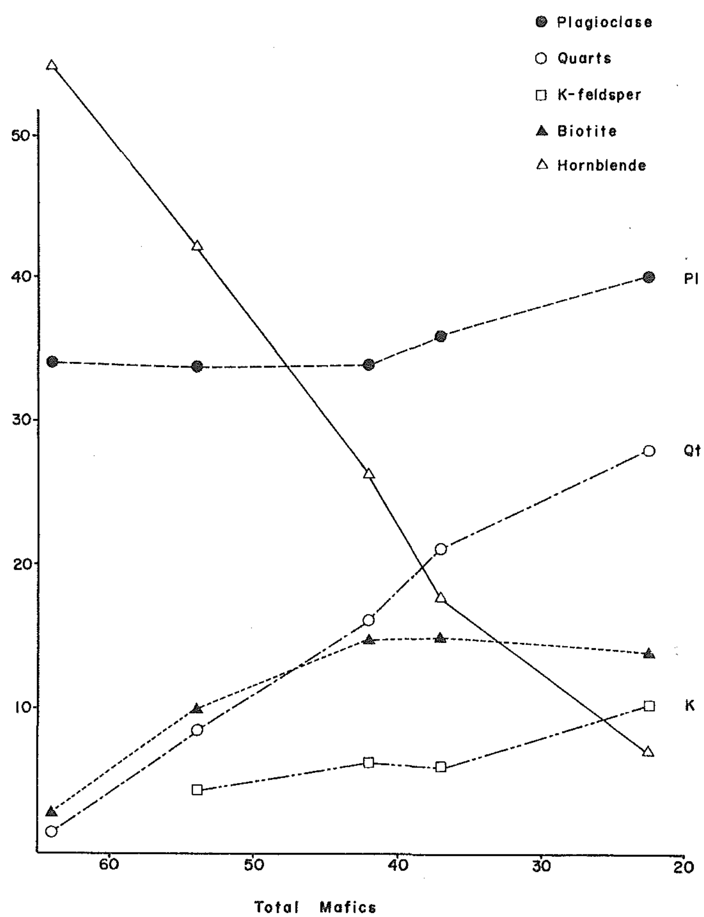


Fig. 5 Variation of average modes in the rock-series from the meta-diabase to the gneissose granites.

reported (Ishii and Yamada 1962). The changes of mineral composition in the hybridization series are shown in Table 2 and Fig. 5. In this case, it is demonstrated that the coarsening of mineral grains is accompanied by momotonous decrease of hornblende and increase of quartz, and by gradual increase of potash-feldspar and plagioclase, anorthite molecule of plagioclase gradually decreasing.

At the contact between the xenoliths of the Ryôke metamorphics and the Minakata gneissose granites, the transitional zone resulting from hybridization is limited, though the boundary between these two is not sharp but rather of rapid transition. In this case, the coarsening of sedimentogeneous gneiss is accompanied by the increase of quartz and decrease of muscovite and biotite along the margin of gneiss.

(3) *The Ikuta Granites*

General characters of the Ikuta granites have already been described. The granodiorite and granite are massive and homogeneous rocks having a typical igneous appearance characterized by typical granitic texture. The rocks contain stubby, euhedral hornblende prisms and sparse flakes of biotite.

The Ikuta granites consist mainly of plagioclase, quartz, potash-feldspar, biotite, and green hornblende with occasional augite, cummingtonite, allanite, apatite, titanite, and iron-ore as accessories. Plagioclase is fairly euhedral, quartz and potash-feldspar being interstital. Zonal structure of plagioclase is not remarkable. Potash-feldspar is usually poikilitic, including plagioclase and quartz grains. It is microperthitic, though microcline-lattice-structure is not detectable. Myrmekite is commonly formed in the margin adjacent to plagioclase. Undulatory extinction of quartz is not common. Cummingtonite is often found being enclosed in green hornblende, and parallel intergrowth of cummingtonite and hornblende is sometimes detectable.

Judging from the modes of occurrence and the petrographic characters, the Ikuta granites are one of the younger Ryôke granites and seem to be of typical magmatic origin.

4 Petrochemical Characters of the Granitic Rocks

(1) *Introductory Statements*

As stated before, the heterogeneity of the Minakata gneissose granites may be connected mainly with the progressive granitization from the hornblende-biotite gneiss, and subordinately with the local hybridization in the contacts with xenoliths of meta-diabases and Ryôke gneisses included in the gneissose granites. In order to clarify the chemical changes in the courses of granitization, and to compare the chemical characters of the gneissose granites, the final products of the granitization series, with those of the Ryôke granites, some chemical analyses were carried out.

Analysed specimens are classified as follows;

i–a) The continuous rock series from the hornblende-biotite gneiss containing amphibolitic lens to the granitic gneiss, collected from limited continuous outcrop.

i–b) The presumptive rock series from the hornblende-biotite gneiss to the porphyritic gneissose granodiorite. In this case, the specimens of the series are collected one by one within rather limited area, being collated with the rocks of the first series, and arranged in order of decreasing total mafic constituents.

i–c) The group of some representative rock-types of the gneissose granites collected one by one from different outcrops.

Table 3 Chemical compositions of the rock-series from the hornblende-biotite gneiss to the Minakata gneissose granites

No.	1	2	3	4	5	6	7	8	9	10
Samp. No	M329	M328	M322	M327	M366	5280815	5290317	M419	M426	M307
SiO_2	54.79	57.86	60.21	69.11	71.19	59.77	64.15	68.25	70.17	52.29
TiO_2	1.21	0.95	0.82	0.27	0.28	1.07	0.77	0.25	n.d.	0.89
Al_2O_3	15.69	17.95	14.76	14.92	14.87	17.26	15.62	16.17	16.86	16.68
Fe_2O_3	2.41	2.83	3.60	0.73	1.05	1.41	1.71	1.39	0.54	2.28
FeO	7.22	4.94	4.49	2.32	1.63	4.72	4.16	2.50	2.58	6.00
MnO	0.18	0.01	0.13	n.d.	0.05	0.12	n.d.	n.d.	n.d.	0.15
MgO	4.39	2.34	2.52	0.74	0.71	1.92	1.13	0.87	0.45	6.06
CaO	7.39	7.31	7.48	2.63	1.91	5.54	4.86	3.15	3.57	8.01
Na_2O	2.66	3.46	2.55	4.66	3.22	3.93	3.75	3.62	3.25	3.49
K_2O	1.12	1.37	0.68	2.70	4.14	1.93	3.40	2.27	2.17	1.30
H_2O^-	2.08	0.79	1.83	1.09	0.84	1.62	0.39	0.39	0.58	1.89
H_2O^+	0.43	0.23	0.64		0.45	0.42	0.19	0.67	0.19	0.64
P_2O_5	0.12	0.14	0.17	0.20	0.06	0.15	0.11	0.10	0.08	0.13
Total	99.69	100.18	99.88	99.37	100.40	99.86	100.24	99.63	100.44	99.81
Si	53.03	54.65	58.74	65.24	67.28	56.91	60.24	64.82	66.05	49.51
Ti	0.88	0.68	0.60	0.19	0.20	0.77	0.54	0.18	—	0.63
Al	17.89	19.98	16.97	16.59	16.56	19.36	17.29	18.09	18.70	18.62
Fe^{3+}	1.75	2.01	2.64	0.52	0.75	1.01	1.21	0.99	0.38	1.63
Fe^{2+}	5.84	3.90	3.66	1.83	1.29	3.76	3.27	1.99	2.03	4.75
Mn	0.15	0.01	0.11	—	0.04	0.10	—	—	—	0.12
Mg	6.33	3.29	3.66	1.04	1.00	2.72	1.58	1.23	0.63	8.55
Ca	7.66	7.39	7.82	2.66	1.94	5.65	4.89	3.21	3.60	8.12
Na	4.99	6.33	4.82	8.52	5.90	7.25	6.83	6.66	5.93	6.40
K	1.38	1.65	0.84	3.25	4.99	2.35	4.07	2.75	2.61	1.57
P	0.10	0.11	0.14	0.16	0.05	0.12	0.09	0.08	0.07	0.10
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Assoc. O	162.09	163.23	158.61		172.17	164.58	165.33	172.08	171.92	158.54
Assoc. OH	2.78	1.46	4.19		2.84	2.66	1.18	4.24	1.18	4.02
Total	164.87	164.69	162.70		175.01	166.65	166.51	176.32	173.10	162.56
Analyst	K.A.	T.Y.	K.A.	T.Y.	K.A.	H.O.	T.Y.	T.Y.	T.Y.	K.A.

M329 : Amphibolite (Nakayama, Ôjika)
M328 : Hornblende-biotite gneiss (Nakayama, Ôjika)
M322 : Hornblende-biotite gneiss (Nakayama, Ôjika)
M327 : Leucocratic granitic gneiss (Nakayama. Ôjika)
M366 : Fine-grained granitic gneiss (Nakayama, Ôjika)
5280815: Hornblende-biotite gneiss (Okeya, Ôjika)
5290317: Hornblende-biotite gneiss (Okeya, Ôjika)
M419 : Granitic hornblende-biotite gneiss (Ôkeya, Ôjika)
M426 : More granitic facies of hornblende-biotite gneiss (Okeya, Ôjika)
M307 : Amphibolite (Nakayama, Ojika)
Analysts : (T. Y.) T. Yamada, (K. A.) K. Aoki, (H. O.) H. Onuki, (M. I.) M. Ishii

Table 3 Chemical compositions of the rock-series from the hornblende-biotite gneiss to the Minakata gneissose granites
(Continued)

No.	11	12	13	14	15	16	17	18	19	20
Samp. No.	M309	M306	R101–1	R101–4	R101–2	M158	M012	M389	M430	M392
SiO_2	63.69	64.98	58.72	61.44	69.84	61.88	66.63	70.38	70.69	75.81
TiO_2	0.56	0.40	0.08	0.28	0.17	0.73	0.36	0.30	0.36	0.10
Al_2O_3	17.75	18.06	19.51	18.64	16.04	16.71	17.17	14.86	13.99	12.81
Fe_2O_3	1.43	1.37	2.03	0.56	0.34	2.53	1.58	1.16	1.38	0.76
FeO	3.11	3.06	5.66	4.56	2.65	5.10	1.90	2.20	2.05	0.68
MnO	0.09	n.d.	0.04	0.01	0.01	0.16	0.06	n.d.	0.07	0.03
MgO	1.29	0.51	2.66	2.50	1.01	1.18	0.44	0.54	0.75	0.88
CaO	4.20	4.93	6.06	5.80	4.00	4.91	3.73	2.80	2.47	0.28
Na_2O	4.24	4.46	2.25	3.47	3.42	3.72	3.67	4.15	3.48	2.83
K_2O	1.51	0.60	1.72	1.45	1.00	1.54	2.80	2.44	2.81	4.62
H_2O^-	1.28	0.43	0.22	0.33	0.37	1.17	0.98	0.47	0.90	0.73
H_2O^+	0.48	0.49	0.51	0.48	0.63	0.48	0.53	0.26	0.63	0.38
P_2O_5	0.11	0.15	0.04	0.02	0.02	0.01	0.07	0.41	0.09	0.01
Total	99.74	99.44	99.50	99.54	99.50	100.12	99.92	99.97	99.67	99.92
Si	60.40	61.46	55.87	57.76	66.48	59.14	63.25	66.32	67.71	72.10
Ti	0.40	0.28	0.06	0.20	0.12	0.52	0.26	0.21	0.26	0.07
Al	19.84	20.13	21.87	20.64	17.99	18.82	19.20	16.50	15.79	14.36
Fe^{3+}	1.02	0.98	1.45	0.40	0.25	1.82	1.13	0.82	0.99	0.54
Fe^{2+}	2.47	2.42	4.50	3.58	2.11	4.08	1.51	1.73	1.64	0.54
Mn	0.07	—	0.03	—	—	0.13	0.05	—	0.06	0.02
Mg	1.82	0.72	3.77	3.50	1.43	1.68	0.62	0.76	1.07	1.25
Ca	4.27	4.99	6.18	5.84	4.08	5.03	3.79	2.82	2.53	0.29
Na	7.79	8.18	4.15	6.32	6.31	6.89	6.75	7.58	6.45	5.22
K	1.83	0.72	2.09	1.74	1.21	1.88	3.38	2.93	3.43	5.60
P	0.09	0.12	0.03	0.02	0.02	0.01	0.06	0.33	0.07	0.01
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Assoc. O	168.08	169.61	166.15	165.93	174.42	167.40	170.89	171.24	173.54	175.66
Assoc. OH	3.04	3.10	3.24	3.00	3.94	3.06	3.36	1.64	4.02	2.42
Total	171.12	169.72	169.39	168.93	178.36	170.46	174.25	172.88	177.56	178.08
Analyst	K.A.	T.Y.	M.I.	M.I.	M.I.	K.A.	K.A.	T.Y.	K.A.	K.A.

M309 : Hornblende-biotite gneiss (Nakayama, Ôjika)
M306 : Granitic gneiss (Nakayama, Ôjika)
R101–1: Hornblende-biotite gneiss (Okeya, Ôjika)
R101–4: Granitic gneiss (Okeya, Ôjika)
R101–2: Gneissose granodiorite (Okeya, Ôjika)
M158 : Porphyritic gneissose granodiorite (Ôkubobora, Nakagawa)
M012 : Porphyritic gneissose granodiorite (Kuwabara, Nakagawa)
M389 : Porphyritic gneissose granite (Koshibukyô, Ôjika)
M430 : Porphyritic gneissose granite (Okeya, Ôjika)
M392 : Coarse-grained gneissose granite (Koshibukyô, Ôjika)

Table 4 Chemical compositions of the rock-series from the meta-diabase to the Minakata gneissose granites

No.	1	2	3	4	5	6	7	8
Samp. No.	M414	M415	M413	R-5	R275	R272	R284	R252
SiO_2	50.38	69.83	70.27	43.81	48.18	53.26	55.16	66.78
TiO_2	1.79	0.36	0.85	0.23	0.64	0.38	0.13	0.40
Al_2O_3	18.38	15.07	13.12	15.43	19.30	18.42	18.05	15.28
Fe_2O_3	2.77	1.57	1.33	6.01	3.18	3.21	3.05	1.83
FeO	8.64	1.88	3.02	12.75	8.03	6.17	5.95	3.47
MnO	0.23	0.04	0.06	0.17	0.02	tr.	0.01	0.02
MgO	3.88	1.02	1.32	6.39	6.36	5.48	4.26	1.68
CaO	7.21	2.97	2.68	10.43	9.42	8.30	6.94	4.30
Na_2O	0.95	3.32	3.00	1.71	2.00	2.25	2.64	3.45
K_2O	1.14	2.15	1.86	0.48	1.10	1.18	1.70	1.30
H_2O^-	3.23	1.06	1.61	0.48	0.52	0.32	0.23	0.12
H_2O^+	1.07	0.66	0.55	1.72	0.78	0.78	1.00	0.88
P_2O_5	0.23	0.06	0.05	tr.	0.07	0.13	0.01	0.10
Total	99.90	99.99	99.72	99.61	99.60	99.88	99.13	99.61
Si	50.44	66.79	68.22	42.90	45.70	50.32	52.60	63.65
Ti	1.35	0.26	0.62	0.16	0.46	0.27	0.09	0.29
Al	21.69	16.98	15.01	17.80	21.57	20.51	20.27	17.16
Fe^{3+}	2.09	1.13	0.97	4.42	2.27	2.28	2.19	1.31
Fe^{2+}	7.23	1.50	2.45	10.43	6.37	4.87	4.74	2.76
Mn	0.19	0.03	0.05	0.18	0.02	—	0.01	0.02
Mg	5.79	1.45	1.90	9.32	8.98	7.71	6.05	2.39
Ca	7.73	3.04	2.79	10.94	9.57	8.40	7.09	4.39
Na	1.84	6.15	5.64	3.25	3.67	4.12	4.88	6.37
K	1.46	2.62	2.30	0.60	1.33	1.42	2.07	1.58
P	0.19	0.05	0.04	—	0.06	0.10	0.01	0.08
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Assoc. O	165.90	173.90	174.49	157.85	158.15	161.82	163.86	172.11
Assoc. OH	7.14	4.20	3.56	11.22	4.94	4.90	6.34	5.58
Total	173.04	178.10	178.05	169.07	163.09	166.72	170.20	177.69
Analyst	H. O.	K. A.	H. O.	M. I.	M. I.	M. I.	M. I.	M. I.

M414: Meta-diabase (Kuwabara, Nakagawa)
M415: Gneissose granodiorite (Kuwabara, Nakagawa)
M413: Fine-grained gneissose granodiorite (Kuwabara, Nakagawa)
R-5 : Amphibolite (Koshibukyô, Ôjika)
R275: Meta-diabase (Koshibukyô, Ôjika)
R272: Fine-grained quartz-diorite (Koshibukyô, Ôjika)
R284: Gneissose quartz-diorite (Koshibukyô, Ôjika)
R252: Gneissose granodiorite (Koshibukyô, Ôjika)

Table 5 Chemical compositions of the rock-series from the Ryôke gneiss to the gneissose granites

No.	1	2	3
Samp No.	M720	M722	M721
SiO_2	60.82	68.20	75.50
TiO_2	1.05	0.54	0.21
Al_2O_3	15.86	14.83	13.44
Fe_2O_3	1.16	1.66	0.35
FeO	4.54	2.45	1.20
MnO	0.08	0.12	0.02
MgO	2.17	0.51	0.49
CaO	2.98	3.64	2.96
Na_2O	2.39	4.34	3.59
K_2O	5.47	2.03	0.96
H_2O^-	2.42	0.97	0.91
H_2O^+	0.38	0.60	0.26
P_2O_5	0.13	0.11	0.02
Total	99.45	100.00	99.91
Si	58.96	64.81	71.99
Ti	0.76	0.39	0.15
Al	18.11	16.60	15.10
Fe^{3+}	0.85	1.19	0.25
Fe^{2+}	3.68	1.94	0.95
Mn	0.06	0.10	0.02
Mg	3.13	0.72	0.70
Ca	3.09	3.70	3.02
Na	4.49	7.99	6.63
K	6.77	2.46	1.17
P	0.10	0.09	0.02
Total	100.00	100.00	100.00
Assoc. O	164.93	170.82	177.47
Assoc. OH	2.46	3.80	1.64
Total	167.39	174.62	179.11
Analyst	H. O.	H. O.	K. A.

M720: Muscovite-biotite gneiss (Koshibukyô, Ôjika)
M722: Granitic gneiss (Koshibukyô, Ôjika)
M721: Porphyroblastic gneiss (Koshibukyô, Ôjika)

Table 6 Chemical compositions of the Ikuta granites.

Samp. No.	E336	M098	5282702	I-1	I-2	I-3	M423
SiO_2	67.31	69.91	64.25	67.19	70.74	74.86	70.51
TiO_2	0.19	0.25	0.10	0.23	0.20	0.19	0.93
Al_2O_3	16.64	16.12	19.75	16.75	16.50	12.14	14.54
Fe_2O_3	0.86	0.96	1.18	1.20	0.89	0.86	0.22
FeO	3.07	2.44	2.32	2.79	2.32	0.96	2.46
MnO	0.04	tr.	0.01	0.05	0.01	0.02	tr.
MgO	0.27	0.31	0.78	0.78	0.41	0.31	0.36
CaO	4.41	2.65	4.28	3.90	3.55	0.98	1.87
Na_2O	3.79	3.86	3.98	3.31	3.40	3.43	5.71
K_2O	2.78	3.42	2.02	2.25	1.89	4.63	2.34
H_2O^-	0.36	0.26	0.28	0.84	0.50	0.63	0.32
H_2O^+	0.18	0.25	0.57	0.45	0.12	0.54	0.46
P_2O_5	0.05	0.07	0.12	0.03	0.03	0.05	0.20
Tatal	99.95	100.50	99.64	99.77	100.56	99.60	99.92
Analyst	K.Y.	T.Y.	T.Y.	H.S.	H.S.	Y.K.	T.Y.

E336 : Coarse-grained hornb.-biot. granite (Nichô, Ikuta) Kawada and Yamada, 1957
M098 : Coarse-grained hornb.-biot. granite (Shitoku, Nakagawa)
5282702: Hornb.-biot. granodiorite (Tamura, Toyo-oka)
I-1 : Fine-grained granodiorite (Koshibu-gawa, Nakagawa) Shibata et al, 1960
I-2 : Coarse-grained granodiorite (Koshibu-gawa, Nakagawa) Shibata et al, 1960
I-3 : Coarse-grained hornb.-biot. granite (Kenashiyama, Takagi) Kawano, 1939
M423 : Biot.-hornb.-granodiorite (Matsuyoke, Ôjika)

Analysts (K.Y.) Kawano and Yamada
(Y.K.) Y. Kawano
(H.S.) H. Shibata
(T.Y.) T. Yamada

ii-a) The continuous rock series from the meta-diabase containing amphibolite, through gneissose quartz-diorite, to the gneissose granodiorite, collected at the contact of the meta-diabase and the gneissose granites.

ii-b) The continuous rock series from the meta-diabase, through the gneissose granodiorite, to the gneissose granites. In this case, the transition is rather rapid than in the case of ii-a).

iii-a) The rock series from the muscovite-biotite gneiss of normal Ryôke metamorphics, through the granitic gneiss, to the porphyroblastic gneiss or gneissose granites, collected in the margin of xenolith contained in the Minakata gneissose granites.

iii-b) The rock series of regionally metamorphosed Ryôke gneisses distributed in the Komagane district in the north of the present district, all of these gneisses being the rocks of 2nd sillimanite zone (Hayama 1960). In the highest grade part,

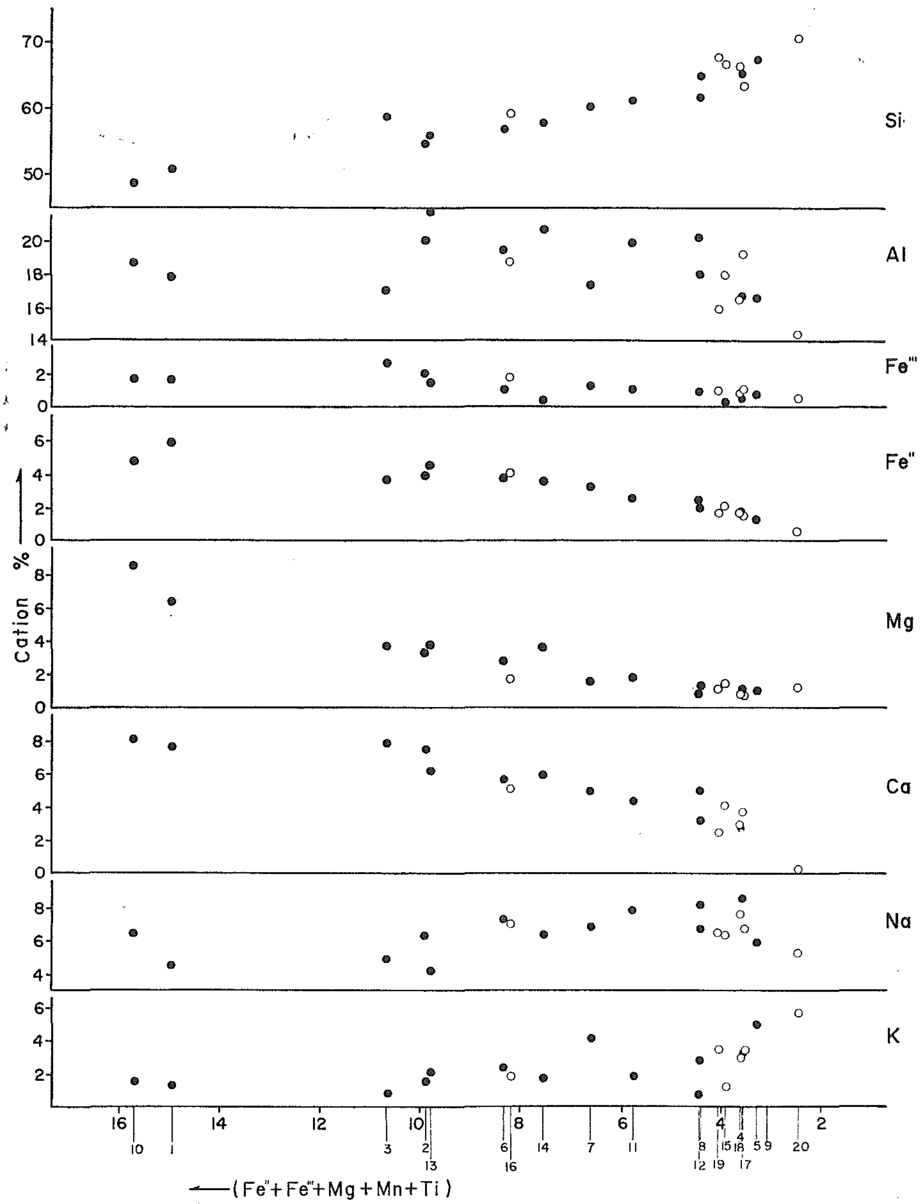


Fig. 6 Changes in major elements in the rock-series from the hornblende-biotite gneiss to the Minakata gneissose granites. Smalll numbers under the abscissa correspond to those in Table 3. Open circles show the quartz-diorite, granodiorite, and granite having a igneous appearance.

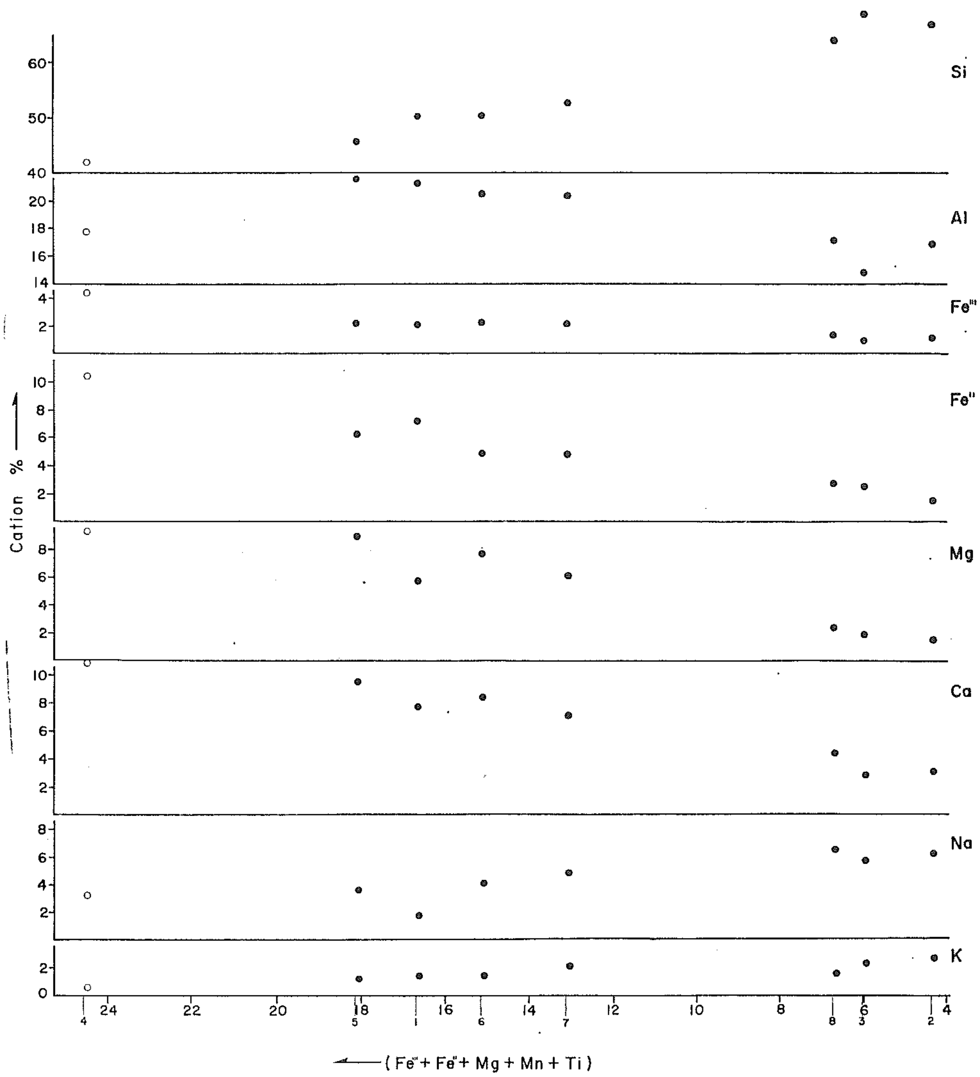


Fig. 7 Changes in major elements in the rock-series from the meta-diabase to the gneissose granites. Open circle shows the amphibolite lens in diabase.

these gneisses tend to have granitic appearance due to coarsening of mineral grains and development of plagioclase porphyroblasts, without any significant change of mineral composition. Chemical analyses of the major elements have not yet been obtained, but the original rocks of these gneisses seem not to be isochemical with the latter, because these specimens were collected along the dip side of the metamorphic formations.

iv) The group of some representative rock types of the Ikuta granites collected one by one from different localities.

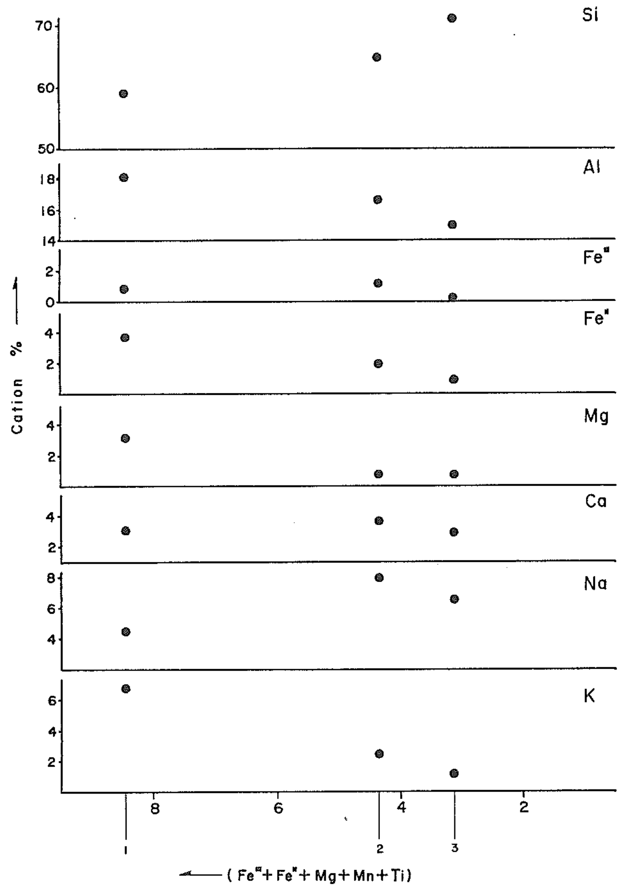


Fig. 8 Changes in major elements in the rock-series from the pelitic Ryôke gneiss to the porphyroblastic gneiss.

The major chemical compositions are tabulated in Tables 3 ~ 6, respectively, and their graphic representations of the former three groups are shown in Figs. 6~8, in terms of cation percentage after ESKOLA (1954). In these diagrams, the total cation percentage of mafic components is taken as abscissa, so the representative rock-types are plotted from left to right in order of decreasing mafic constituents and probably of advancing granitization. The writer has obtained only three new chemical data of the Ikuta granites, so all the published chemical data of the rocks are collected and tabulated together with those in Table 6.

The contents of some trace elements in the granitic and metamorphic rocks were estimated spectrochemically (YAMADA and ISHII 1961). Results obtained are expressed in ppm and are tabulated in Tables 7~10, the changes of Ni, Cr. Co, and V being shown in Figs. 9A~9C. Mark + in each table indicates the content below the limit of sensitivity, which is Ni; 3 ppm, Cr; 4 ppm, Co; 3 ppm, V; 10 ppm, Ga; 8 ppm, Pb; 15 ppm, and Sn; 25 ppm, respectively.

Table 7 Trace elements in the rock-series from the hornblende-biotite gneiss to the Minakata gneissose granites

No.	Samp. No.	Rock Names	Locality	C. I.	Ni	Cr	Co	V	Ga	Pb	Sn
1	M329	amphibolite	Nakayama	38	13	25	14	210	15	+	25
2	M328	hornb. -biot. gneiss	〃	21	10	10	7	180	22	+	25
3	M322	hornb. -biot. gneiss	〃	30	8	36	10	130	10	30	50
4	M327	leucocratic granitic gneiss	〃	8	6	7	+	30	10	+	+
5	M366	fine-grained granitic gneiss	〃	8	4	9	+	10	8	15	+
6	M130	amphibolite	Takekurasawa	49	+	13	45	10	12	22	+
7	M134	fine-grained hornb. -biot. banded gneiss	〃	22	+	20	9	17	18	17	+
8	M122	coarse-grained gneiss	〃	18	3	5	25	28	11	+	+
9	M133	granitic gneiss	〃	8	5	5	12	22	14	15	+
10	M307	amphibolite	Nakayama	44	28	240	11	300	14	+	+
11	M309	hornb. -biot. gneiss	〃	19	9	6	+	65	11	20	+
12	M306	granitic gneiss	〃	10	+	10	+	20	11	+	+
13	M308	aplitic vein in M307	〃	3	+	+	+	11	10	40	+
14	M081	hornb. -biot. gneiss	Ryûgataru	32	5	55	3	65	15	18	+
15	5280818	hornb. -biot. gneiss	Okeya		8	11	7	100	15	+	+
16	M419	granitic hornb. -biot. gneiss	〃	21	10	13	+	65	19	15	+
17	M426	more granitic facies of hornb. -biot. gneiss	〃	10	45	230	14	100	<8	+	+
18	M430	porphyritic gneissose granodiorite	〃	14	13	40	12	100	15	17	+
19	M389	porphyritic gneissose granite	Koshibukyô	4	7	25	+	10	14	22	+
20	M392	coarse-grained gneissose granite	〃	6	5	4	+	30	18	27	+
21	M012	porphyritic gneissose granodiorite	Kuwabara	14	5	25	3	30	17	15	+
22	M117	gneissose adamellite	〃	8	7	15	+	20	12	27	+
23	M137	fine-grained granite	Genbeijizawa	3	3	6	10	10	<8	18	+
24	M158	porphyritic gneissose granodiorite	Ôkubobora	14	11	35	11	90	12	16	+

Analyst: T. YAMADA + Below the limit of sensitivity

(2) Rock Series from the Hornblende-Biotite Gneiss to the Minakata Gneissose Granites

As seen from Table 3 and Fig. 6, Si increases regularly with advancing granitization. K is rather constant in the early stage, though it increases remarkably in the later stage of progressive granitization. One the contrary, Al, Fe^{3+}, Fe^{2+}, Mg, and Ca decrease with advancing granitization, especially the decreasings

Table 8 Trace elements in the rock-series from the meta-diabase to the Minakata gneissose granites

No.	Samp. No.	Rock names	Locality	C. I.	Ni	Cr	Co	V	Ga	Pb	Sn
25*	R 5	amphibolite	Koshibukyô	65	18	8	4	230	10	+	+
26*	R 287	meta-diabase	〃	50	25	100	23	230	50	+	+
27*	R 272	fine-grained qt.-diorite	〃	40	60	90	30	180	34	+	+
28*	R 284	gneissose qt.-diorite	〃	43	14	60	5	80	20	34	+
29*	R 7	gneissose qt.-diorite	〃	44	8	32	4	46	28	28	+
30*	R 252	gneissose granodiorite	〃	17	+	24	5	46	13	14	+
31	M114	meta-diabase	Kuwabara	28	8	50	5	180	14	15	+
32	M115	gneissose adamellite	〃	10	8	25	12	50	8	+	+
33	M100	leucocratic facies of M115	〃	10	4	20	4	30	10	+	+
34	M116	(intermediate zone) aplite	〃	8	5	12	+	15	10	30	+
35	M414	mata-diabase	Kuwabara		20	50	12	270	15	+	25
36	M413	fine-grained gneissose granodiorite	〃		4	15	5	35	<8	+	+
37	M415	gneissose granodiorite	〃	13	7	13	+	15	19	17	+
38	M164	meta-diabase	Ôkubobora	32	10	36	6	60	10	+	+
39	M166	gneissose granodiorite	〃	12	8	11	+	22	10	20	+
40	M167	fine-grained granodiorite	〃	13	7	7	9	50	<8	15	+
41	M400	qt.-diorite	Okeya	33	7	120	+	50	13	+	+
42	M730	coarse-grained porphyritic gneissose qt.-diorite	〃	26	6	15	40	22	12	+	+
43	M729	medium-grained gneissose granodiorite	〃	19	4	100	+	70	12	35	+

Analyst: T. YAMADA (* Analysed by H. ISHIKAWA) + Below the limit of sensitivity

of Fe^{2+}, Mg, and Ca are regular. The value of Al shows so large variation that it is difficult to see general trend, though it seems to be rather deficient in amphibolite and is rich in basic hornblende-biotite gneiss, thence it decreases generally towards the gneissose granites. Na ranges from 4.15 to 8.53 %, and increases generally with advancing granitization, but it decreases slightly in the final stage.

There is little difference in chemical compositions between the granitic rocks of the final product of granitization and the representative Minakata gneissose granites having a igneous appearance.

The amphibolite included in the basic hornblende-biotite gneiss may possibly be a local basification product from the hornblende-biotite gneiss, associated with the general granitization of the latter.

The increase of Si and the decreases of Fe^{2+}, Mg, and Ca are reflected mineralogically in the increases of modal quartz, and in the decrease of mafic

Table 9 Trace elements in the rock series from the Ryôke gneiss to the Minakata gneissose granites and in the Ryôke gneisses

No.	Samp. No.	Rock Names	Locality	C. I.	Ni	Cr	Co	V	Ga	Pb	Sn
44	M720	muscov.-biot. gneiss	Koshibukyô	32	8	210	7	90	22	40	+
45	M722	granitic gneiss	〃	12	6	20	3	210	9	+	+
46	M721	porphyroblastic gneiss (contaminated zone)	〃	12	3	7	+	25	11	+	+
47	M535	muscov.-biot. gneiss	Karayama	34	13	210	15	210	25	55	+
48	M534	hornfelsic gneiss	〃	29	10	130	3	120	19	+	+
49	M533	leucocratic medium-grained gneissose granite	〃	9	4	10	+	35	15	+	+
50	5280515	banded gneiss	Takatô		8	25	10	85	11	+	+
51	M615	siliceous gneiss	Shitoku		4	6	+	10	<8	23	+
52	M609	dark-colored coarse-grained pelitic gneiss	Nakawari		5	15	20	25	10	15	+
53	M593	more granitic muscov. -biot. gneiss	Momodaira		120	90	33	90	10	75	+
54	M584	feldspar-porphyroblasts granitic gneiss	〃		18	120	6	120	18	45	+
55	M619	Augen gneiss	〃		13	7	+	45	10	+	+

Analyst: T. Yamada + Below the limit of sensitivity

Table 10 Trace elements in the Ikuta granites

No.	Samp. No.	Rock Names	Locality	C. I.	Ni	Cr	Co	V	Ga	Pb	Sn
56	M098	hornb.-biot. granite	Shitoku	8	+	15	+	20	10	+	+
57	M004	hornb.-biot. granodorite	Kuwabara	10	+	12	7	75	12	+	+
58	M160	hornb.-biot. granite	Ôkubobora	6	+	7	+	+	10	+	+
59	M149	〃	Shitoku	5	4	+	+	+	<8	+	+
60	5282702	hornb.-biot. granodiorite	Tamura	15	11	8	+	16	8	+	+
61*	S-98	fine-grained granodiorite	Koshibugawa		+	5	+	36	27	15	+
62*	S-99	coarse-grained granodiorite	〃		3	9	3	26	26	19	+
63*	S-100	quartz-diorite	Takisawa		+	11	ε	100	13	17	+

Analyst: T. Yamada (*Analyzed by H. Ishikawa—Shibata, Okada, and Ishikawa, 1960)
+ Below the limit of sensitivity

minerals (specially of hornblende), and of An molecule in plagioclase, respectively. The decrease of An content in plagioclase is, however, not so striking in the course of granitization. The remarkable decrease of Ca and slight decrease of Na in the final stage of the granitization seem to be due to the decrease of modal plagioclase. The striking increase of K in the final stage corresponds to the increase of potash-feldspar.

With respect to trace elements shown in Table 7 and Fig. 9A, Ni, Cr, Co, and V seem to decrease with advancing granitization, though the variations of

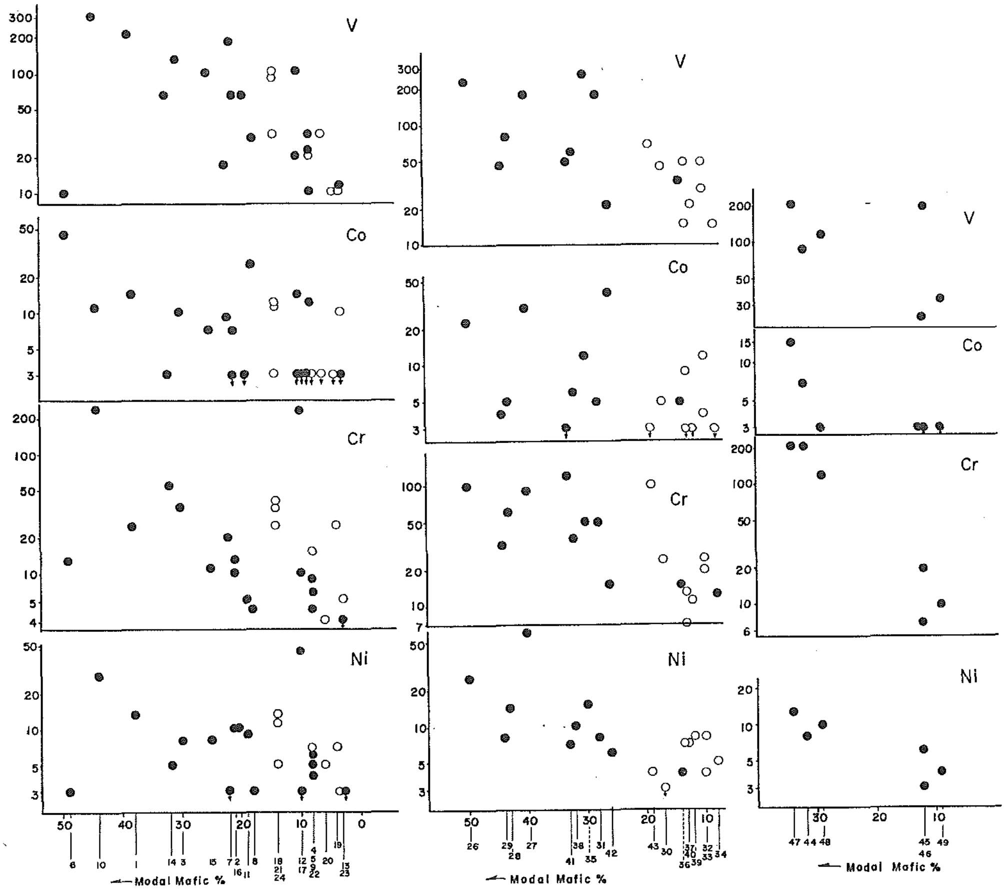


Fig. 9A Fig. 9B Fig. 9C

Fig. 9A Variations of Ni, Cr, Co, and V in the rock-series from hornblende-biotite gneiss to the Minakata gneissose granites. Small numbers under the abscissa correspond to the numbers in Table 7, respectively. Open circles show the representative rock-types of the Minakata gneissose granites having a igneous appearance.

Fig. 9B Variations of Ni, Cr, Co, and V in the rock-series from meta-diabase to the gneissose granites. Small numbers under the abscissa correspond to the numbers in Table 8. Open circles show the gneissose granites around the meta-diabase.

Fig. 9C Variations of Ni, Cr, Co, and V in the rock-series from the pelitic gneiss to the gneissose granites.

trace elements are fairly large in each rock-type and it is difficult to find a marked regularity with advancing granitization. Ga is constant throughout the granitization, ranging from 10 to 20 ppm, and Pb seems to increase in the final stage probably corresponding to the enrichment of potash-feldspar.

(3) Rock Series from the Meta-diabase to the Minakata Gneissose Granites

As seen from Table 4 and Fig. 7, excepting the amphibolite included in the meta-diabase*, Si, K, and Na increase regularly from diabase towards granitic rocks, whereas Al, Mg, Fe^{2+}, Fe^{3+}, and Ca decrease regularly and compensatively to the increase of Si and alkalis. In this case, the change of Al is highly regular without marked deviation as compared with the rock series from the hornblende-biotite gneiss mentioned above. It is striking, in Fig. 7, that the changes of every major elements are represented by straight lines, and there is no sign that certain elements vary strikingly only in the early or later stage in the rock series, or change irregularly. The final products of this series contain more Fe^{2+} and Ca and less K as compared with the final products of the rock series from the hornblende-biotite gneiss.

The above-mentioned regular changes are mineralogically expressed by the regular increases of modal quartz, potash-feldspar, and plagioclase and the regular decrease of hornblende. The variations of these constituent minerals are also represented by straight lines as shown in Fig. 5.

With respect to trace elements shown in Table 8 and Fig. 9B, it is clear that Ni, Cr, and V tend to decrease generally from the diabase to the gneissose granites. There is no marked tendency in the behavior of Co and Ga. Pb is concentrated in the final stage. There is no difference between the final products of this rock series and the representative Minakata gneissose granites in regard to their trace elements contents.

(4) *Rock Series from the Ryôke Gneiss to the Minakata Gneissose Granites*

Chemical analyses have been carried out only for one series. From Table 5 and Fig. 8, it is evident that Si increases regularly, and Al, Fe^{2+} and K decrease regularly from the pelitic gneiss to the porphyroblastic gneiss. The decrease of Mg is striking in the earlier stage and inconspicuous in the later stage. Na, Ca, and Fe^{3+} concentrate slightly in the intermediate rock. Such chemical changes are reflected mineralogically in the remarkable decrease of muscovite and biotite and increase of quartz in the earlier stage, whereas general coarsening of grain and the development of quartz-porphyroblasts in the later stage may coincide with the increase of Si and the complimentary decrease of Al, Ca, Na, and K. The porphyroblastic gneiss contains more Ca and Fe^{2+} and less K as compared with the Minakata gneissose granites, these characteristics being similar to those recognized in the final products from meta-diabase.

Concerning the trace elements, it is said from Table 9 and Fig. 9C that Ni,

* The amphibolite is included as schlieren, and may be derived by metamorphic segregation, so it is suitable to separate it from the successive transition from the meta-diabase to the gneissose granites.

Cr, Co, and V decrease regularly towards more granitic rocks, and Pb is contained only in the pelitic gneiss, its content being below the limit of sensitivity in the rocks having somewhat granitic appearance. Comparing the trace element contents in the xenolithic gneisses mentioned above with those in the Ryôke gneisses of the Komagane district, there is not any notable difference between both gneisses. Pb tending to concentrate in mica-rich facies of both gneisses.

(5) *The Ikuta Granites*

Chemical compositions are tabulated in Table 6. The Ikuta granites including the Takisawa granodiorites contain generally less MgO and somewhat more CaO as compared with the Minakata gneissose granites. This character is similar to that of the Mitsuhashi granites of the Dando district (KOIDE 1958), one of the younger Ryôke granitic rocks of Central Japan. This is demonstrated more evidently in Figs. 11B and 12B, and will be discussed in the subsequent section.

With respect to the trace elements shown in Table 10, it is safely said that the mean values of Ni and Cr are less than those of the Minakata gneissose granites, and coincide with the mean values of the Mitsuhashi granites (KURODA and GORAI 1956). As to the contents of other trace elements, there is no difference between the Ikuta granites and the Minakata gneissose granites.

5 Genetical Considerations

(1) *Chemical and Mineralogical Changes in Relation to Granitization*

The chemical and mineralogical changes are already described concerning the three rock series : namely that from the hornblende-biotite gneiss to the Minakata gneissose granites, that from the meta-diabase to the gneissose granites, and that from the pelitic gneiss to the gneissose granites, and it is recognized that the behaviors of each element are somewhat different in each rock series.

As described before, judging from the field and petrographic evidences, the principal process concerning the formation of the gneissose granites of the first series is the progressive granitization of the hornblende-biotite gneiss. This deduction will be re-examined from the petrochemical standpoints, comparing with other two rock series.

In the transition from the hornblende-biotite gneiss to the Minakata gneissose granites, it is evident that the increase of K is striking only in the final stage of granitization, although Na decreases in the final stage in spite of its general increase in the preceding stages. On the other hand, the increase of Si and the decreases of Fe^{3+}, Fe^{2+}, Mg and Ca are monotonous and regular with advancing granitization, Al also tending to decrease. These chemical changes are fairly well reflected in the mineralogical changes. In the transitions from the fine-grained basic hornblende-biotite gneiss to the coarse-grained granitic gneiss, the mineralogical changes are generally gradual and represented by slight decrease of hornblende and biotite, and by increase of quartz and potash feldspar, the coarsening of mineral grains being notably characteristic. The granitic gneiss has a granitoid appearance and their mineralogical and chemical compositions are similar to those of the Minakata gneissose granites. These hornblende-biotite gneiss and granitic gneiss grade into the gneissose granodiorite and gneissose adamellite without any significant change of chemical and mineralogical compositions excepting an increase of K and potash feldspar. In the final stage the increase of potash feldspar and decrease of plagioclase are striking, the ultimate products being highly granitic ones with vaguely foliated and porphyritic appearances. These gradations from the hornblende-biotite gneiss to the gneissose granites are not only observed locally around the small masses of gneiss, but are recognized in wide areas, extending over a hundred meters, and there are no evident differences in the tendencies of chemical and mineralogical changes between both cases.

It seems difficult to explain that these chemical and mineralogical changes were resulted from the simple mixing of basic hornblende-biotite gneiss and certain granitic materials. Especially in the earlier process of granitization, the coarsening of mineral grains in the hornblende-biotite gneiss is characteristic, and there is no evidence that any granitic magma or fluid played an important role in these chemical and mineralogical changes. During or after the formation of such transitional rocks as the coarse-grained leucocratic hornblende-biotite gneiss and granitic gneiss, the geological condition was sufficiently suitable for the granitization, these gneissic rocks having graded into various types of the Minakata gneissose granites having a granitic appearance.

In the later stage of granitization, the coarsening of grain in the gneissose granites is accompanied by slight increase of C-twin of plagioclase and potash feldspar. In the final stage, the gneissose granites was rendered somewhat mobile and moved reomorphically or intrusively.

Gorai (1960) has concluded that the feature of plagioclase twinning change gradually from more metamorphic to more igneous aspects, with the advance of granitization process, more granitized portions carrying generally more C-twin comparing with less granitized portions. He has considered that the granitization process may be operated under the presence of various amounts of magmatic phase and the compositional changes seen in migmatitic granites can be interpreted by the additive permeation of granitic material in magmatic state.

It is doubtless that the porphyritic and acidic varieties of the Minakata gneissose granites locally attained a considerable mobil-state, however, it is not certain whether the partial melt-phase was produced bit by bit in the gneissose granites during the advancing of granitization, or it happened the additive permeation of granitic material in magmatic state.

The porphyritic and acidic varieties of the Minakata gneissose granites differ from other gneissose granites in that the former is characterized by typical granitic texture, abundance of C-twin, occasional intrusive appearance, and presence of randomly orientated xenoliths. These facts give support to consider that the partial melt-phase was produced during the latest stage of granitization. It may also be considered that the additive permeation of granitic material in magmatic state occurred in such a stage.

The transition from the meta-diabase to the Minakata gneissose granites is rather local phenomena observed around the meta-diabase xenolith, and is generally limited in 2 m in width at most (ISHII and YAMADA 1962). As shown in Fig. 7, the chemical changes in the granitization series show the regular increases of Si, K, and Na which are compensated by the regular decreases of Al, Ca, Fe^{2+}, Fe^{3+}, and Mg. In the mineralogical changes, the regular increases of quartz and potash feldspar are in harmony with the regular decreases of hornblende and An content in plagioclase. These regular changes might have been derived by simple mixing of meta-diabase and granitic material.

Various transitional rocks between the meta-diabase and the surrounding gneissose granites may be resulted from the reaction of the meta-diabase and the additive granitic magma. This deduction is supported by the wider development of transitional rocks near the meta-diabase xenolith surrounded by the gneissose granites having distinct intrusive appearance.

On the other hand, the gradation from the muscovite-biotite gneiss to the porphyroblastic gneiss is observed in a narrower zone, 20 cm in width, acrossing the contact between the Minakata gneissose granites and the pelitic gneiss xenolith. As shown in Fig. 8, in the transformation from the muscovite-biotite gneiss to the granitic gneiss, the decreases of K, Fe^{2+}, Mg, and Al are reflected in the decreases of muscovite and potash feldspar, and the increases of Si and Na are jointed with the increases of quartz and sodic plagioclase. However, in the transformation from the granitic gneiss to porphyroblastic gneiss, the decreases of K, Na, and Al are reflected in the decreases of potash feldspar and plagioclase, the increase of Si corresponding to the development of quartz porphyroblast.

Similar phenomena have been reported from the Dando district (KOIDE 1958) as a type of polymetamorphism observed at the contact between the Ryôke gneiss and the Mitsuhashi granites, one of the younger Ryôke granites. KOIDE (1958) has pointed out that a kind of granitic transitional rock derived from the gneiss developes within a narrow zone along the contact with the Mitsuhashi granites, and the transitional rock is characterized by the formation of fine-grained plagioclase and development of quartz porphyroblast, some silicified rocks carrying no potash feldspar. He has concluded that the granitization or hybridization in the zone of polymetamorphism was taken place by the permeation of aplitic materials introduced from the Mitsuhashi granites.

Lastly, I would briefly touch upon whether the granitization of the hornblende-biotite gneiss (formation of the Minakata gneissose granites) took place in situ or not. As described before, the hornblende-biotite gneiss is rather exotic in the Ryôke belt of Central Japan. This gneiss carries sometimes relicted igneous plagioclase, and seems to have been formed from certain basic tuff or igneous rock, although there are much difficulties to infer detailed original characters. Amphibolite is often found in the hornblende-biotite gneiss. Although the boundary between these two rocks is usually rather distinct, the former seems to represent the less metamorphosed facies of the latter. Thus, relicted igneous plagioclase similar to one included in the hornblende biotite gneiss is also found in the amphibolite. It is noteworthy that amphibolite is hardly found in the Ryôke metamorphics of Central Japan, few thin beds of amphibolite originated from basic tuff or lava being found only in the Takato$\sim$Komagane district, north of the prenent district (HAYAMA 1959, 1960).

In view of the above mentioned, the writer considers that the formation of hornblende-biotite gneiss and its granitization to form gneissose granites took place not in situ but in deeper level, where certain formations differing from the general Ryôke metamorphics were developed. The granitization products (Minakata gneissose granites) might have been invaded into the present position with the aid of melt-phase dispersed in the gneissose granites, accompanied by tectonic movement. The meta-diabase- and the Ryôke gneiss-xenoliths fell into the Minakata gneissose granite during the invasion of granites.

The Minakata gneissose granites is extended continuously to the vicinity of Tenryûkyô, where the porphyritic gneissose granites have been designated as the Tenryûkyô granite (KOIDE 1942). The typical Tenryûkyô granite exhibits more granitic features in macroscopic and microcopic appearances, but its chemical and mineralogical compositions are very similar to those of the Minakata gneissose granites. Furthermore, the most granitic and porphyritic varieties of the Minakata gneissose granite are hardly distinguished from the Tenryûkyô granite of its type-locality.

It may, therefore, be said that the Tenryûkyô granite represents the more granitic facies of the Minakata gneissose granites, namely the highly heterogeneous gneissose granite of the present district is a representative of less granitized marginal facies of the Tenryûkyô granite.

(2) *Behavior of Some Trace Elements in Relation to Granitization*

With respect to this problem, the writer already discussed in detail (YAMADA and ISHII 1961), therefore, only the essential points will be described here.

Firstly the bahavior of Ni, Cr, Co, and V may be examined. In the granitization series from the hornblende-biotite gneiss, the contents of Ni, Cr, Co, and V are higher and vary widely in the rocks of the early stage of the granitization, and they tend generally to decrease with advancing granitization (in Fig. 9A). The relation Cr>Ni>Co persists through the course of granitization. GORAI (1957, 1958) has pointed out that the granitic rocks produced from granitization process contain higher V and Cr, and the relation Cr>Ni persists in general, whereas in the granophyric or granitic rocks differentiated from basic magma, the relation Cr<Ni persists characteristically. Similarly, HIGAZY (1952b, 1954) has mentioned that the relative proportion Cr>Ni>Co is found to persist through the regional metamorphic and successive metasomatic (granitization) processes and it is inconsistent with the relation Co>Ni>Cr or Ni>Co>Cr in the late differentiates from fractionating basic magma (LUNDEGÅRDH 1949, HIGAZY 1952a).

Such relationships as described above have also been found in the rock series from the meta-diabase to the Minakata gneissose granites and from the muscovite-biotite gneiss to the porphyroblastic gneiss.

In order to examine the relation between Ni and Cr in the granitic rocks of the present district, their contents are plotted in Fig. 10. The contents of Ni and Cr in the granitic rocks connected with the meta-diabase are slightly higher than the other granitic rocks. The broken line in the Fig. 10 indicates the approximate boundary between the granitic rocks originated by granitization process and the granophyric rocks differentiated from basaltic magma (GORAI 1958),

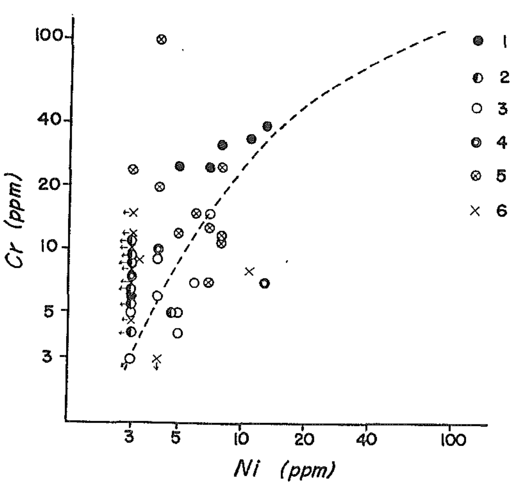


Fig. 10 Correlation diagram of chromium and nickel contents in various granitic rocks of the River Koshibu district. 1; Minakata gneissose granites, 2; Minakata gneissose granites (Data from KURODA and GORAI, 1955), 3; Granitic rocks derived from hornblende-biotite gneiss, 4; Granitic rocks derived from the Ryôke gneiss, 5; Granitic rocks derived from meta-diabase, 6; Ikuta granites.

however, some granitic rocks of this district are plotted in the latter field across the boundary.

The Ga content in all the analysed rocks of the present district is almost always 10～20 ppm, and does not vary noticeably with advancing granitization. RANKAMA and SAHAMA (1950) also pointed out the uniform distribution of Ga in the earth crust. RANKAMA (1946) described that Ga_2O_3 content in all the Pre-Cambrian granites of Finland is uniformly 0.01 per cent, and it is 0.001～0.002 per cent in the granites of Variscan age. According to HIGAZY (1954), the range in Ga of the Loch Doon Complex is 25～45 ppm. The paragneiss complex of Adirondack contains 5.7～35 ppm of Ga according to ENGEL and ENGEL (1958). SHIBATA et al. (1960) have also reported that the Ga content in the Japanese granites is mostly confined within the range from 10 ppm to 30 ppm. Such uniformity of Ga content is very noteworthy.

(3) *Some Considerations on the Chemical Composition of the Ryôke Granites of Central Japan*

All the analysed data on the major elements in the Ryôke granites of Central Japan (SUZUKI and NEMOTO 1935, KAWANO 1939, SHIBATA et al. 1954, 1955, SHIBATA 1956, KAWADA and YAMADA 1957, MURAYAMA and KATADA 1957, KOIDE 1958, ÔKI and SHIBATA 1958, SHIBATA et al. 1958, 1959, SHIBATA 1961, 1962, and SAKAKIBARA 1963) were collected together. We have examined the chemical chracteristics from various angles on some of these granites, which petrographic and geologic characters have been well-known and abundant data have been obtained covering the whole rock-masses (YAMADA and HAYAMA 1967).

The representative rock-masses of the Ryôke granites of Central Japan were grouped first by their petrographic and geologic characteristics, and the chemical characters of each group were compared one another. The granitic rocks treated here are divided into four groups as follows :

i) Older Ryôke granites; the Kiyosaki granodiorite, Busetsu granite, and older minor intrusives of the Dando district, Kadoshima granite of the River Tenryû district, and Ôtagiri granite of the Kiso mountains.

ii) Older Ryôke gneissose granites; the Sumikawa granodiorite of the Dando district, Inagawa granite of the Kiso mountains, the Tenryûkyô granite of the River Tenryû district, and the Minakata gneissose granite of the present district.

iii) Younger Ryôke granites; the Mitsuhashi granodiorite of the Dando district and the Ikuta granite of the present district.

iv) Younger Ryôke granites; the Kisokoma granite* of the Kiso mountains.

* SHIBATA (1962) has treated it as the fore-Ryôke granites, though, considering the existence of evident contact aureole in the Ryôke gneiss around the Kisokoma granite, we treat it as one of the younger Ryôke granites.

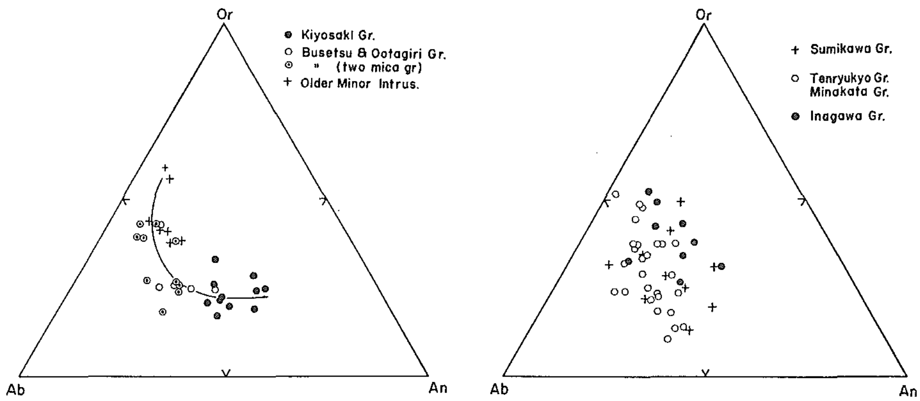


Fig. 11A Normative Or-Ab-An ratios of the older Ryôke granites.

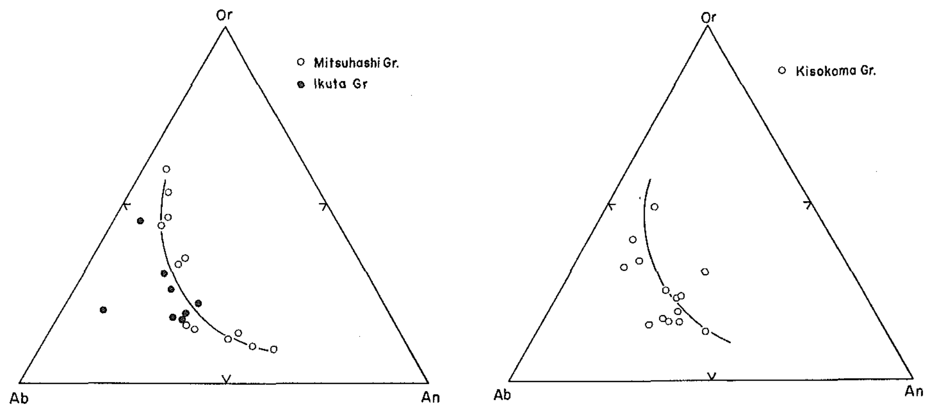


Fig. 11B Normative Or-Ab-An ratios of the Mitsuhashi and Ikuta granites and of the Kisokoma granite.

In order to infer a general petrochemical characters the groups mentioned above were compared on the variation diagram in which SiO_2 is taken as abscissa. The tendencies of each oxide are similar to those which SHIBATA has described already in his serial papers.

It was found that the changes of Na_2O content in each group are relatively small and rather uniform having no relation to the changes of SiO_2 content. If Na_2O is mostly fixed in plagioclase as Ab molecule, it is reasonably expected that the modal proportion of plagioclase in the rocks decreases at a certain ratio with the increase of Ab content in plagioclase (YAMADA and HAYAMA 1967). In Figs. 11A and 11B, the normative Or-Ab-An ratios of the groups from i) to iv) are shown respectively. In the diagrams of groups i), iii), and iv), the curved lines indicate the general trend in each group. The assumed relation between the Ab content

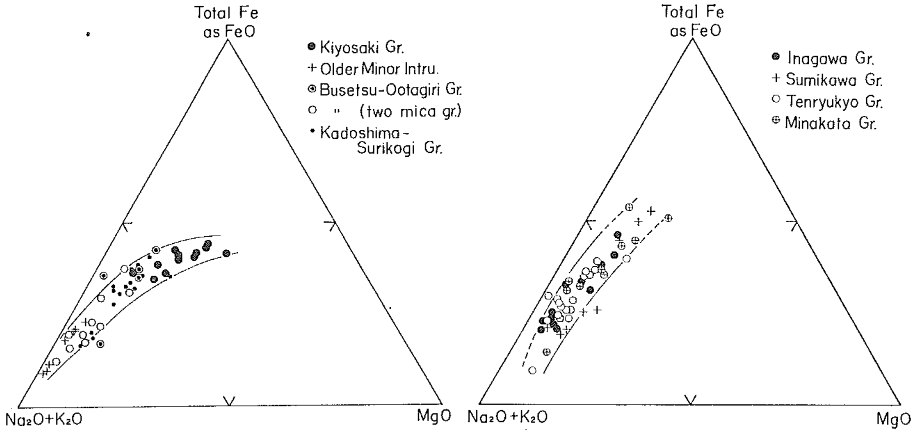


Fig. 12A MgO-total Fe-(Na_2O+K_2O) ratios of the older Ryôke granites.

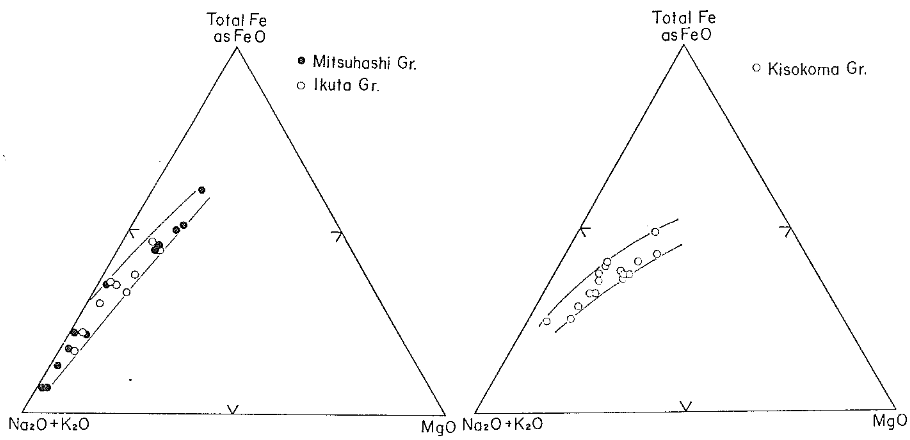


Fig. 12B MgO-total Fe-(Na_2O+K_2O) ratios of the Mitsuhashi and Ikuta granites and of the Kisokoma granite.

of plagioclase and the amount of plagioclase mentioned above are recognized here, respectively. Especially in the Mitsuhashi and the Ikuta granites the regularity is remarkable. On the other hand, in the group ii), namely the Sumikawa granodiorite, Inagawa granite, and Tenryûkyô granite, the normative feldspar ratios are plotted in wider area, and it is difficult to recognize the above regularity. The facts may suggest that in the groups i), iii), and iv) the crystallization of feldspar took place in equilibrium with a liquid phase, but the crystallization of feldspar in the group ii) did not take place under equilibrium condition.

The relations of MgO—(total Fe)—(Na_2O+K_2O) are indicated in Figs. 12A and 12B. Comparing these four diagrams, it is notable that the groups i) and iv) (the Kiyosaki granodiorite, Busetsu granite, Ôtagiri granite, and the older minor intrusives and the Kisokoma granite) are plotted on a narrow zone similar to the general trend of calc-alkali rock series, the group iii) (the Mitsuhashi and Ikuta granites) being plotted on a different narrow zone similar to the course of such late differentiates as the Skaergaard intrusion.

On the other hand, the Sumikawa, Inagawa, Tenryûkyô, and Minakata granites are plotted in wider area, and the acidic members of these granies shift to somewhat Mg rich side as compared with normal fractionation course.

In the Ryôke belt of Central Japan, the Mitsuhashi and the Ikuta granites are typical granites having various magmatic features and these granites may belong to a co-magmatic type different from that of such older Ryôke granites as the Kiyosaki, Busetsu, and Ôtagiri granites, and also from that of the Kisokoma granite. The older Ryôke gneissose granites (Suikawa, Inagawa, Tenryûkyô, Minakata gneissose granites), on the other hand, may constitute a co-genetic group differing from each of the above two groups.

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(J) in Japanese

Explanations of Plates

Plate 1: Hand specimens showing the texture of representative rock-types of the hornblende-biotite gneiss.

Fig. 1.– Fine-grained hornblende-biotite gneiss. (Okeya, Ôjikamura)

Fig. 2.– Hornblende-biotite gneiss, typical of the gneiss in the annexed geological map. Note the coarsening of grain and seams of plagioclase porphyroblast. (Okeya, Ôjikamura)

Fig. 3.– Leucocratic hornblende-biotite gneiss. (Nakayama, Ôjikamura)

Fig. 4.– Granitic gneiss, typical of transitional rock from hornblende-biotite gneiss to gneissose granites. (Okeya, Ôjikamura)

Fig. 5.– Granitic gneiss, typical of transitional rock from hornblende-biotite gneiss to gneissose granites. Note the coarsening of grain and seams of plagioclase and potash-feldspar porphyroblasts. (Okeya, Ôjikamura)

Fig. 6.– Granitic gneiss. (Nakayama, Ôjikamura)

PLATE. 1

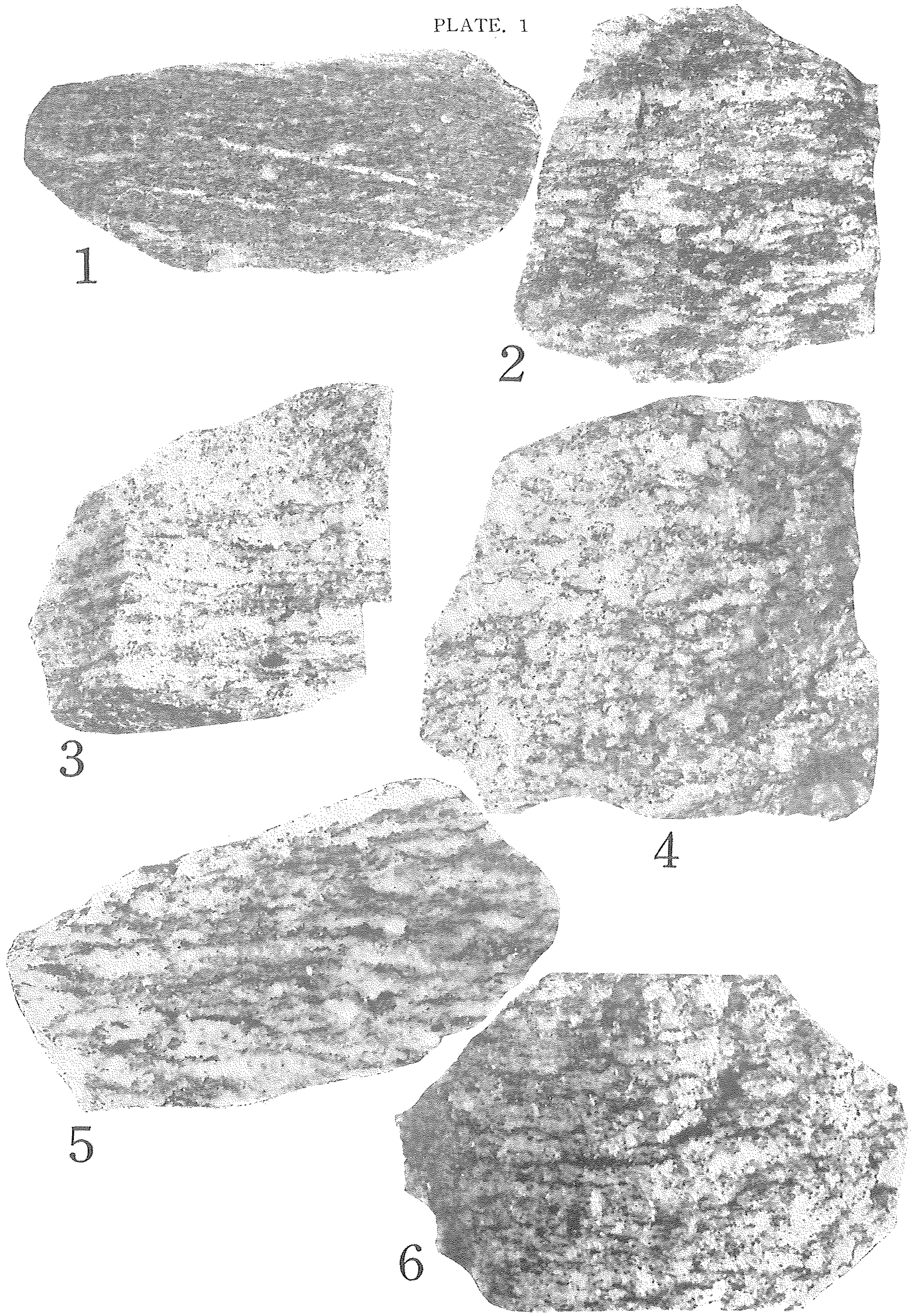


Plate 2: Hand specimens showing the texture of representative rock types of the Minakata gneissose granite.

Fig. 7.– Gneissose granodiorite. (Nakayama, Ôjikamura)

Fig. 8.– Porphyritic gneissose granodiorite. (Nakayama, Ôjikamura)

Fig. 9.– Porphyritic gneissose granodiorite. Note some mafic clots in upper left part. (Kuwabara, Nakagawamura)

Fig. 10.– Porphyritic gneissose adamellite. (Kuwabara, Nakagawamura)

Fig. 11.– Porphyritic gneissose granite. (Koshibukyô, Ôjikamura)

Fig. 12.– Gneissose adamellite. (Karayama, Matsukawa-chô)

PLATE 2

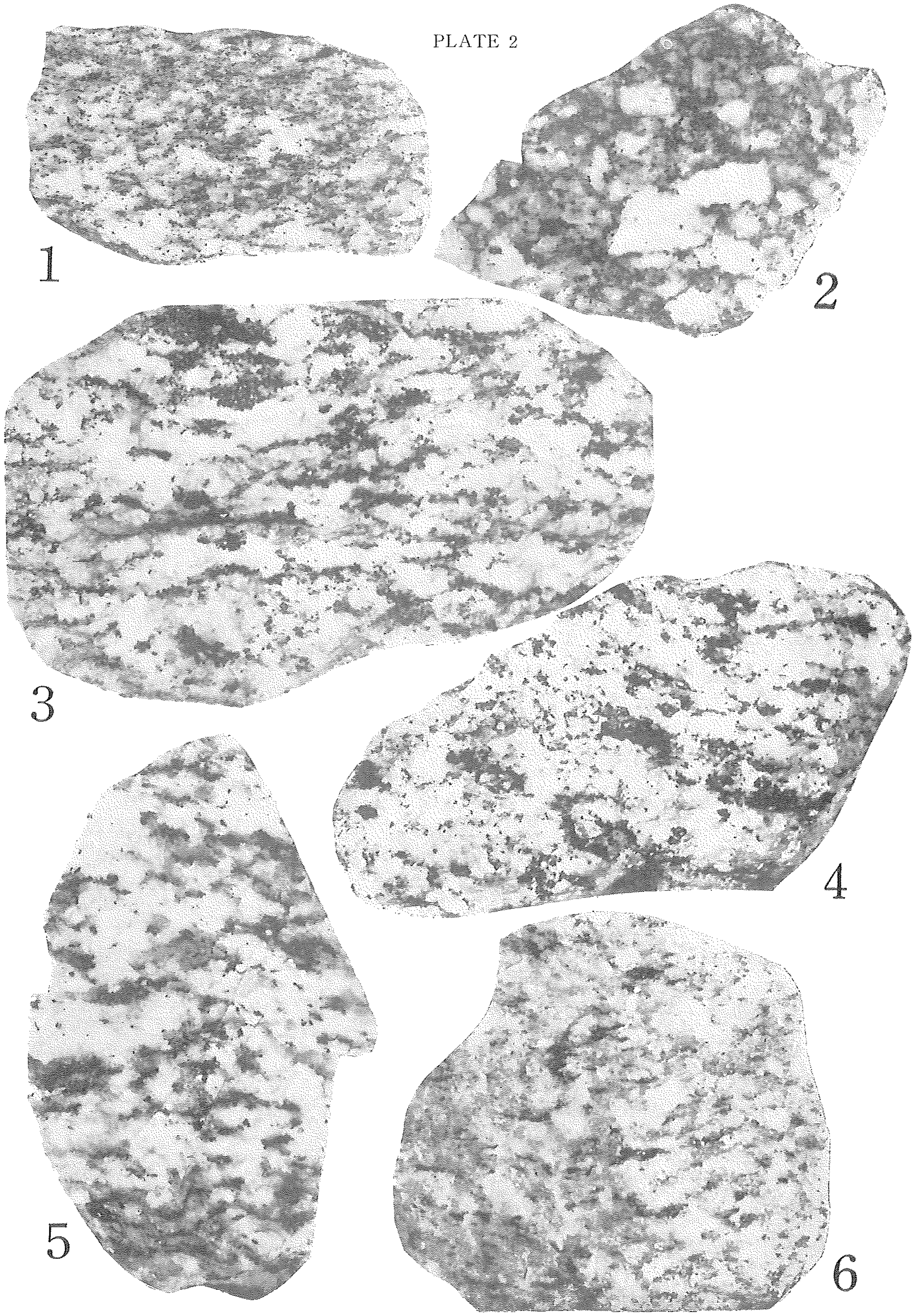


Plate 3: Hand specimens showing the texture of representative rock types of the Ikuta granites.

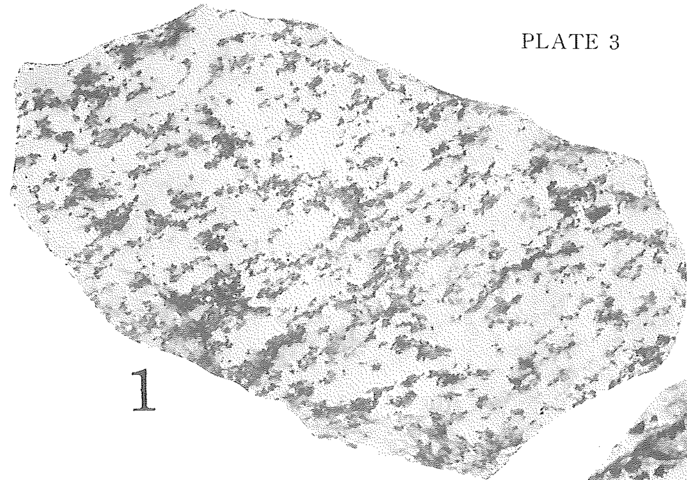
Fig. 13. – Medium-grained shistose granodiorite. (Kuwabara, Nakagawamura)

Fig. 14. – Hornblende-biotite granite. (Karayama, Matsukawa-chô)

Fig. 15. – Biotite granite. Note biotite clots in lower right corner. (Kuwabara, Nakagawamura)

Fig. 16. – Hornblende-biotite granodiorite. (Kuwabara, Nakagawamura)

PLATE 3



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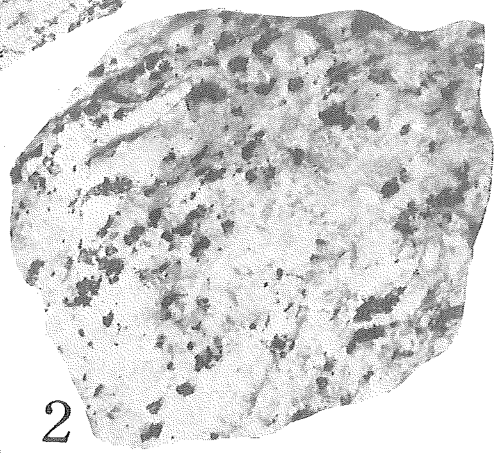

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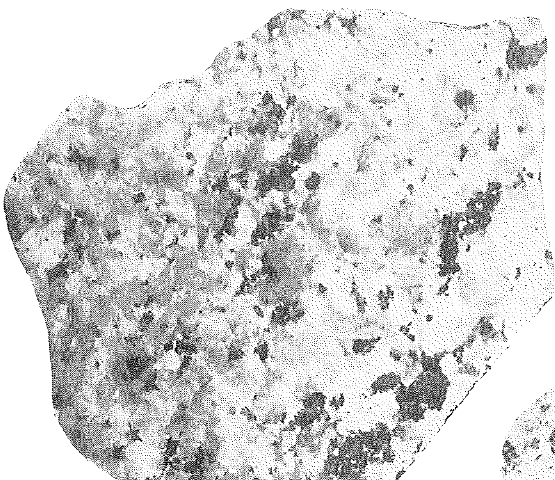

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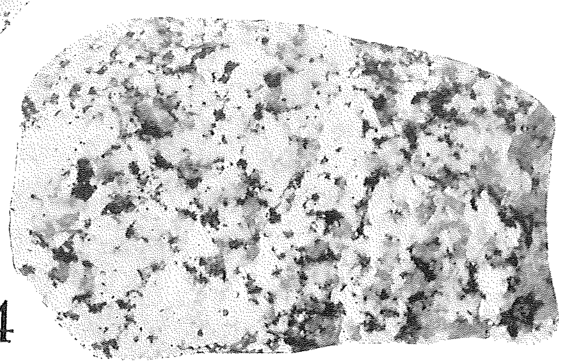

4

Geologic Map of the River Koshibu District, Nagano Prefecture (by T. Yamada)