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On the Ryōke Granitic and Metamorphic Rocks in the Toyone-mura Area, Aichi Prefecture, Japan

By

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Abstract

The Ryōke zone in the Toyone-mura area, Aichi Pref. is composed of six types of granitic rocks and metamorphic complex, derived from basic igneous and Paleozoic sediments.

The granitic rocks are following: the Kamihara, the Tashika, the Kiyosaki, the Tenryūkyō, the Mitsuhashi and the Busetsu granites, the former three are quartz-dioritic, the fourth and the fifth are granodioritic and the last is granitic in composition.

The metamorphic terrain is divided into three zones by mineral assemblages in pelitic metamorphic rocks.

In this paper, the occurrences of each rock, its petrography and petrochemical characters are described.

Introduction

The Ryōke zone develops along the Inner border of the Southwest Japan, ranging from the south of the Suwa basin in Nagano Pref. to the Kunisaki peninsula of Kyūshū. It consists of various granitic rocks and their associated metamorphic complex derived from basic igneous and pyroclastic rocks and sedimentaries of Chichibu Permo-Carboniferous Series. Recent isotopic age-measurements suggest that the igneous activites of the Ryōke zone took place in the time of Cretaceous period. But the age of metamorphism is problematical as yet.

Geological and petrological studies of the Ryōke zone in central Japan have been made in many areas, such as: Dando-san district (H. KOIDE, 1958), Northern Kiso range (Y. ÔKI, 1959, 1961; M. KATADA, 1965, 1967), Minakata-Kashio district (T. YAMADA, 1957, 1967), Komagane district (Y. HAYAMA, 1959, 1960, 1964) and Niino district (Y. SAKAKIBARA, 1963, 1967; H. KAGAMI, 1968). Plutonism Research Group of Hokkaido Univ. (1964) carried out the structural study around Lake Sakuma. Geological map of the Ryōke zone in central Japan was compiled by Ryōke Research Group (1955).

KOIDE (1958), in the Dando-san district, recognized two stages of granitic intrusion and metamorphism, and classified the granitic rocks into two types:

"the older intrusives" and "the younger intrusives", the former is concordant to the surrounding metamorphics and the latter is discordant to them, giving contact effects to them. He divided the metamorphic terrain into three zones: schistose hornfels-, transitional- and banded gneiss-zone, according to the lithological features of the metamorphic rocks.

HAYAMA (1956, 1959, 1960), in the Komagane district, also recognized two stages of igneous action in connection with mylonitization related to the activity of the Median Tectonic Line; the earlier plutonism took place before and simultaneously with it, the latter after it. And he divided the metamorphic terrain into four zones bounded by the cordierite-, the first sillimanite- and the second sillimanite-isograde, with the increase of grade of metamorphism.

Considering the location in the Ryōke zone in central Japan, the Toyonemura area is a very favourable field to connect the Ryōke zone of the Tenryū-River area with that of the Mikawa plateau.

In this area, no detailed geological and petrological studies have been made; only the geological map of Toyohashi (scale 1:200,000) was presented by the Geological Survey of Japan (1898).

Since the summer of 1967, the author has studied the Ryōke zone in this area. In this paper, he describes the geology and petrography of this area, mentioning briefly the petrochemical characters of the granitic and metamorphic rocks.

Geology

(A) General geology

The surveyed area is situated in the southern central part of the Ryōke zone in central Japan. In this area, metamorphic rocks are rather predominant than granitic rocks; especially basic metamorphic rocks occupy a wide region.

The granitic rocks of this area are divided into the following six main types, according to the field occurrences and lithological characters.

1) The Kamihara granite.
2) The Tashika granite.
3) The Kiyosaki granite.
4) The Tenryūkyō granite.
5) The Mitsuhashi granite.
6) The Busetsu granite.

The mutual relations of the above-mentioned granitic rocks are not fully observed in the field. The field-evidences of them are the following: the Busetsu granite cuts the Tashika granite and the Mitsuhashi granite cuts the Kamihara granite.

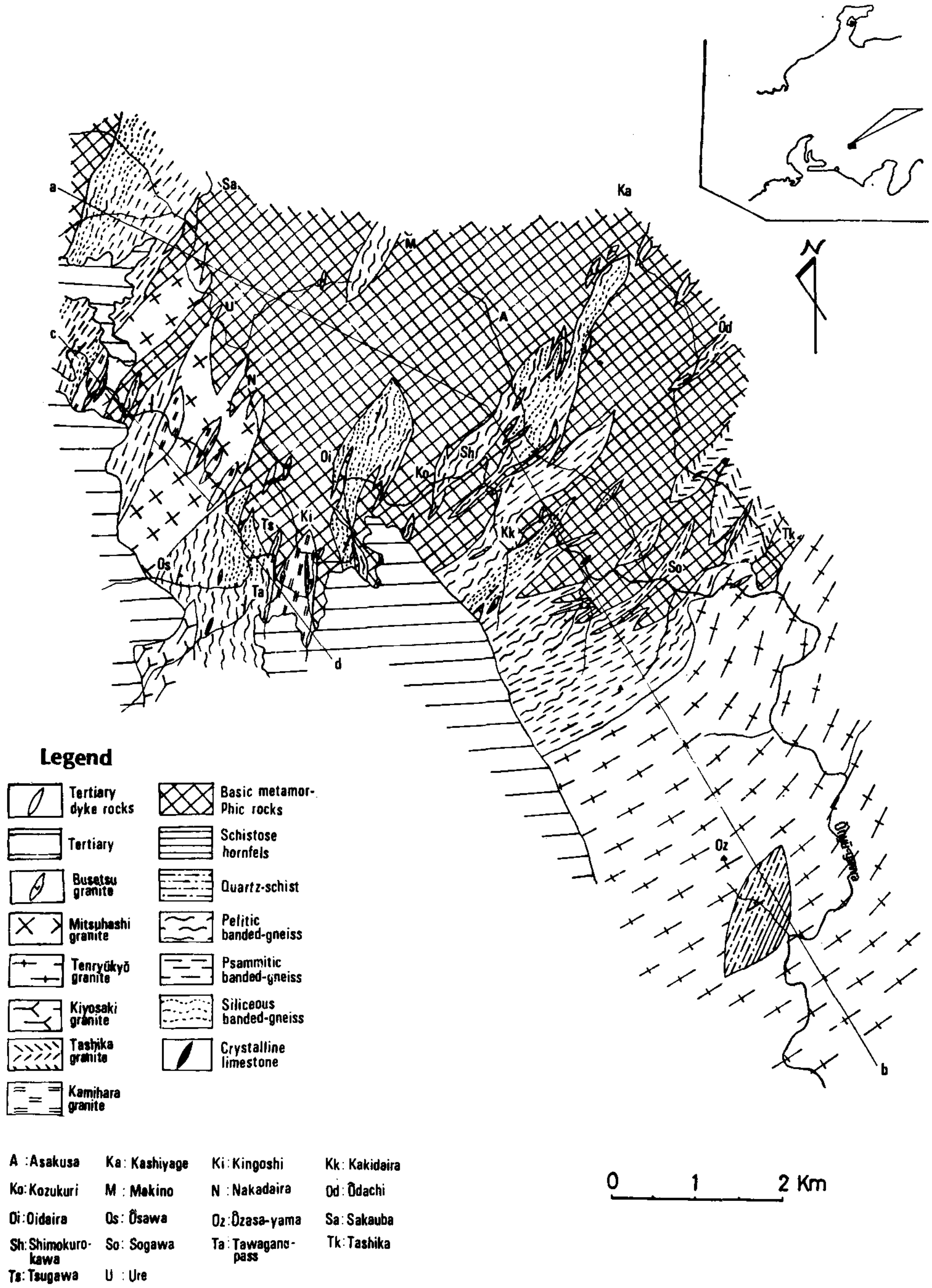

Fig. 1. Geological map of the Toyone-mura area.

Considering the correlative granitic rocks of other areas of the Ryōke zone, *it may be suitable to consider that the sequence of intrusions is (1) to (6).* But the relation between (1) and (2) is not obvious as yet.

The Kamihara granites occur in the south-western region of this area, as sheet-like masses in the metamorphic rocks, and also as xenolithic masses in the Mitsuhashi granites. They are gneissose and rather melanocratic rocks, sometimes showing faint banded structure.

The Tashika granites occur in the eastern part of the area, intruding between the basic metamorphic rocks. The rocks are, as a rule, somewhat melanocratic, coarse-grained and equigranular, and are almost always characterized by gneissosity. Near the basic metamorphic rocks, they are rich in ovoids of dark inclusion, and aplite-, pegmatite-veins with various widths traverse the granites.

The Tenryūkyō granites occupy the south-eastern part of the area, as a batholithic mass. The rocks are coarse-grained, and generally porphyritic. Marked porphyritic textures are due to the presence of large potash-feldspar cyrstals (1–3 cm in diameter.). Also, gneissose textures are commonly observed. Dyke-like and/or lenticular inclusions of metamorphosed basic igneous rocks, such as meta-diabase, and meta-sediments are common throughout the batholith.

Between the Tashika granite and the Tenryūkyō granite, there are basic metamorphic rocks, meta-diabase and meta-gabbro, therefore the contact relation of both granites is not recognized.

The Kiyosaki granite is distributed in the southern central part of the area, and it extends along the valley to Futto located at the south of the mapped area. Smaller lenticular masses of the Kiyosaki granite are injected in the banded gneisses and the basic metamorphic rocks. The rocks are medium-grained, dark grayish colored and gneissose, due to the parallel arrangement of colored minerals. A lot of xenolithes of basic igneous and meta-sediment are found in them.

The Mitsuhashi granite occurs in the western part of the area as two distinct bodies. Smaller stock- and dyke-like masses are found in the metamorphic rocks. At several places, the Mitsuhashi granite injects into the Kamihara granite, enclosing the latter. The rock is characterized by coarse-grained, leucocratic and massive appearance. Although its foliation is usually indistinct, it is recognized fairly clear about the basic facies.

The Busetsu grainte is exposed at only two localities as dyke-like mass. The one locality is at the north of Tashika, where the Busetsu granite cuts cleanly the Tashika granite, the other is the exposure along the road from Kakidaira to Sogawa, where it intrudes into the basic metamorphic rocks, about 3 m in width.

In the central part of the area, the metamorphic rocks are exposed over a wide area.

The structural trend of the metamorphic rocks is generally N10°–40°E, but in the south-eastern part, it is almost E-W. Dip is 30°–80° northerly and southerly.

In the western half part, the basic metamorphic rocks occupy the wide region. They are mainly composed of diabasic rocks, but meta-gabbroic rocks are also found locally. A small mass of hornblende-gabbro is observed at the outcrop along the road near Ure. There are, also, numerous small dyke-like and stock-like masses of diabasic rock, measuring from several meters to several tens in width, in the metamorphic rocks derived from sedimentaries.

The metamorphic rocks derived from sedimentaries are mainly the so-called banded-gneisses. Judging from the petrographical characters of them, the original rocks seem to consist of shale, or slate, and sandstone, both of which are usually closely associated, alternating in beds of various thickness. Siliceous sediments (chert) occur as intercalated layers. Limestone lens about 10 m in width, occurs near the Tawagane-pass. The metamorphics derived from basic pyroclastics and lavas are found nowhere in this area. At the south of the Ôzasa-yama, a mass of schistose-hornfels and quartz-schist, about 800 m in diameter, is found as a roof-pendant in the Tenryūkyō granite.

The metamorphic grades increase from both the east and the west sides to the central part, and the metamorphic terrain is divided into three zones.

At the southern and the western parts of this area, Shitara Tertiary sediments cover the Ryōke granitic and metamorphic rocks, and a good many dykes of basaltic and dacitic rock cut the Ryōke granitic and metamorphic rocks, and which are genetically connected with the volcanics of Shitara Tertiary Complex.

(B) Geological structure

Geological structure is briefly mentioned on the foregoing page. The metamorphic rocks show the general trend of N10°–40°E, but in the south-western part nearly of E-W. The granitic rocks are subconcordant to the general trend of the metamorphic rocks.

The detailed variations of dips are as follows:

1) In the eastern part of the line tying Kashiyage and Kakidaira, dips are 20°—40° westerly.
2) Between this line and the line tying Asakusa and Kozukuri, they are 35°–70° easterly.
3) From the latter line to Tsugawa, they are 70° westerly.
4) In the part from Tsugawa to Ôsawa, they are 45°–80° easterly.
5) In the part from Ure to Ôsawa, they are about 30° westerly.
6) To the west of Sakauba, they are 30°–40° easterly.

Judging from such a variation of dips, in this area, there are three synclines and two anticlines which have axes directing N10°–40°E.

The geological profiles are shown in Fig. 2.

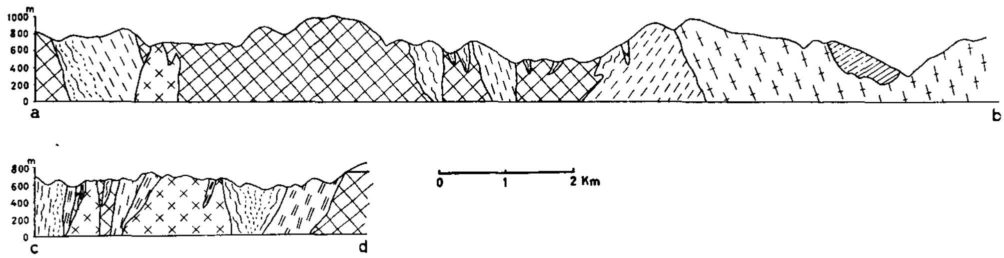

Fig. 2. Geological profiles. Legend; see Fig. 1.

The Granitic Rocks

Petrography

(a) The Kamihara granite

The Kamihara granite is rather melanocratic, medium- to coarse-grained rock, characterized by remarkable gneissosity. Some of them reveal the weak banded structure brought by alternations of dark colored basic layers and light colored quartz-feldspathic layers. Referring to modal composition, it is proper to call the rock tonalite or quartz-diorite.

In thin slice, the mafic components show strong tendency to form clots of several crystals, and show gneissosity.

The essential constituents are plagioclase, quartz, biotite, hornblende and a little amount of potash-feldspar.

Plagioclase: it is subhedral tabular and shows clear polysynthetic twinning. Sometimes weak zonal structure is observed, and it is of compositions An 36–45 ($n_1=1.546-1.551$).

Quartz: it occurs as interstitial crystal and shows undulatory extinction.

Biotite: biotite shows remarkable directional arrangement, and flocks together with hornblende. It is pleochroic with X=pale yellow, Y=Z=dark brown, and has index of refraction $\gamma=1.648$.

Hornblende: it is commonly anhedral and is corroded by plagioclase and quartz. Frequently it is poikilitic crystal enclosing small grains of quartz and biotite. Its pleochroism is as follows; X=yellow brown, Y=brownish green, Z=grass green. Optically negative with $2V=73°$, $\widehat{cZ}=18°$.

Potash-feldspar: it is ordinarily lacking. It occurs as interstitial crystal, if present.

Accessories are iron ore, apatite, epidote, allanite, zircon and augite.

(b) The Tashika granite*

* According to K. SUZUKI (personal communication), the Tashika granite may be correlated to the Miya granite. But the author has not yet had certain evidences.

The Tashika granite is medium- to coarse-granied, dark grayish colored and weakly gneissose. Judging from the modal composition, it is reasonable to call the rock quartz-diorite.

Under the microscope, although it exhibits granitic texture, in finer grained part it is granoblastic. Mafic minerals flock together and show a weak gneissosity. It is mainly composed of plagioclase, quartz, biotite and hornblende.

Plagioclase: it is subhedral tabular, and it shows clear polysynthetic twinning. Antiperthite and weak zonal structure are frequently observed. It often poikilitically includes other minerals, such as biotite and hornblende. It is of compositions An 45–60 ($n_1 = 1.551 - 1.560$).

Quartz: it occurs as interstitial crystal, and it corrodes other minerals. Undulatory extinction is usually observed.

Biotite: it is subhedral flakes, and flocks together with hornblende, forming mafic clots. The directional arrangement of biotite is remarkable. It is pleochroic with X=pale yellow, Y=Z=brown. The refractive index of biotite $\gamma = 1.636$.

Hornblende: it is usually corroded and has irregular form. Frequently it is poikilitic crystal enclosing quartz grains and biotite flakes. Pleochroism is as follows: X=yellow, Y=pale yellow green, Z=yellow green. $c \wedge Z = 18°$, $(-)\ 2V = 79°$.

Accessories: as accessories, sphene, zircon, apatite, epidote and iron ore occur.

(c) The Kiyosaki granite

The rock is medium-grained, neutral colored and fairly gneissose.

Under the microscope, it exhibits granitic texture, and mafic components have tendency to form clots. The essential constituents are plagioclase, quartz, biotite, hornblende and potash-feldspar. The latter two minerals are usually small in quantity, and sometimes they are lacking.

Plagioclase: it occurs as subhedral tabular crystal, and it is usually polysynthetically twinned. It is of compositions An 36–48 ($n_1 = 1.546 - 1.553$).

Potash-feldspar: it occurs as small interstitial crystal, if it is present. Perthite structure is often observed.

Quartz: it is interstitial and clear crystal without inclusions. It corrodes other minerals. It shows faint undulatory extinction.

Biotite: it occurs as slender flake. It flocks together and forms clots. It is pleochroic with X=yellow, Y=Z=deep brown. Index of refraction $\gamma = 1.654$.

Hornblende: hornblende occurs as ill-shaped crystal. Small slender flakes of biotite penetrate hornblende along its cleavages. It is pleochroic with X=pale greenish yellow, Y=yellowish green, Z=brownish green. $c \wedge Z = 17°$, $(-)2V = 73°$.

Accessories: zircon, apatite, iron ore and sphene are common accessories.

(d) The Tenryūkyō granite

The Tenryūkyō granite is characterized by the presence of porphyritic potash-feldspar crystals. It is coarse-grained, neutral colored and gneissose rock.

Under the microscope, it shows granoblastic texture except porphyritic potash-feldspar crystals. It is chiefly composed of plagioclase, potash-feldspar, quartz, biotite and hornblende. The last mineral is often lacking. Judging from the modal composition of the rock, it is granodiorite or adamellite. The salient gneissosity is based mainly on the directional arrangement of colored minerals.

Plagioclase: plagioclase is subhedral tabular, and shows clear polysynthetic twinned. Zoning is commonly observed, and the core suffers sericitization. It is of compositions An 28–46 ($n_1=1.542-1.552$).

Potash-feldspar: the porphyritic crystals are euhedral and perthitic, often twinned after Carlsbad-law. Faint microcline structure is sometimes observed. They include small grains of other minerals, such as biotite and plagioclase. The other groundmass crystals are interstitial.

Quartz: quartz is interstitial and interlocking, and it shows strong undulatory extinction.

Biotite: it is tabular. Twisted flakes are sometimes observed. The clots of biotite are widely present. Pleochroism is X=pale brownish yellow, Y=Z= dark brown. Index of refraction $\gamma=1.651$.

Hornblende: it occurs as unhedral crystal, corroded by quartz and plagioclase. It is closely associated with biotite. Pleochroism is as follows; X=yellow green, Y=green, Z=brownish green.

Accessories: sphene, allanite, epidote, zircon, apatite and iron ore.

(e) The Mitsuhashi granite

The Mitsuhashi granitic rocks are petrographically classified as follows; hornblende-biotite-granodiorite, biotite-adamellite, biotite-granite and garnet-biotite-granite～trondhjemite, among which the former two are prominent members. The latter two are found near the metamorphic rocks and also as dyke-like and/or stock-like masses usually as small scale in the metamorphic rocks.

1) Hornblende-biotite-granodiorite

It is medium- to coarse-grained, dark grayish colored and equigranular rock, and it is often heterogeneous, owing to the presence of basic patches.

In thin slice, it exhibits granitic texture, and is mainly composed of plagioclase, quartz, biotite, hornblende and a small amount of potash-feldspar.

Plagioclase: it is subhedral tabular, and shows clear polysynthetic twinning. Zoning is sometimes observed. It is of compositions An 23–43 ($n_1=1.540-1.549$).

Quartz: it occurs as interstitial crystal, and undulatory extinction is striking. Frequently it includes small grains of other minerals.

Biotite: biotite is usually subhedral tabular flakes. Bent crystals are sometimes found. It is pleochroic with X=very pale yellow, Y=Z=yellowish brown, and it has index of refraction $\gamma=1.659$.

Hornblende: it occurs as subhedral crystal, and it has a tendency to flock together with biotite and to form mafic clots. It is frequently poikilitic crystal, enclosing other minerals, such as biotite. It is pleochroic with X=pale greenish yellow, Y=grayish green, Z=green. $c\wedge Z=16°$, (−) 2V=54°.

Potash-feldspar: it occurs as interstitial crystal. Perthite structure and *moiré* appearance are commonly observed.

Allanite, apatite, zircon, epidote and muscovite are common accessories.

2) Biotite-adamellite

It is coarse-grained and grayish rock with weak gneissosity.

In thin slice, it exhibits granitic texture as a whole, but in finer grained part, granoblastic texture predominates. It is mainly composed of plagioclase, potash-feldspar, quartz and biotite.

Plagioclase: it occurs generally as subhedral or unhedral tabular crystal, showing polysynthetic twinning. Compositions range from An 18 to An 30 (n_1= 1.537−1.543).

Potash-feldspar: it is interstitial and poikilitic crystal. Sometimes large euhedral crystals are found, but all of them show interstitial relations to other minerals. And they are often twinned after Carlsbad-law. Faint microcline struture and perthite structure are frequently observed.

Quartz: it occurs as interstitial crystal and corrodes other minerals. It shows rather strong undulatory extinction.

Biotite: biotite is tabular and often forms clots. Sometimes wrinkled crystals are found. It is pleochroic with X=pale yellow, Y=Z=orange brown. Index of refraction $\gamma=1.657$.

Accessories: apatite, zircon, epidote and sphene are common accessories.

3) Biotite-granite

It is coarse-grained and leucocratic, and small biotite flakes are sporadically distributed. Gneissosity is nearly absent.

Under the microscope, it exhibits granitic texture, and is mainly composed of plagioclase, potash-feldspar, quartz and biotite.

Plagioclase: plagioclase is euhedral to subhedral tabular, showing clear polysynthetic twinning. It is often corroded by potash-feldspar and quartz, and narrow sodic rim occurs along its contact with potash-feldspar. It is of compositions An 15–23 (n_1=1.535−1540).

Potash-feldspar: it occurs as both interstitial and euhedral crystal. The latter is frequently twinned after Carlsbad-law and is pokilitic. Perthite structure and *moiré* appearance are usually observed.

Quartz: it is interstitial, and strongly corrodes other minerals. Undulatory extinction is common.

Biotite: it is tabular with irregular-shaped outline. It rarely forms clots. Pleochroism is as follows; X=very pale yellow, Y=Z=yellowish brown. Index of refraction $\gamma=1.663$.

Accessories: apatite, zircon, muscovite and iron ore commonly occur as accessories.

4) Garnet-biotite-granite~trondhjemite

Except the presence of garnet, it looks like the above described biotite-granite very much. It is also coarse-grained leucocratic rock, and red garnet is conspicuous to the naked eye.

In thin slice, the rock exhibits granitic texture, and is mainly composed of plagioclase, potash-feldspar, quartz and biotite. Potash-feldspar varies its quantity in each rock.

Plagioclase: it is euhedral to subhedral tabular, sometimes with weak zonal structure. Polysynthetic twinnings are generally observed. It is of compositions An 16–32 ($n_1=1.536-1.544$).

Potash-feldsar: it is not always found in all specimens. It is interstitial cystals, and is perthitic. Faint microcline *Gitter* structure is observed.

Quartz: quartz occurs as interstitial crystal, and it shows strong undulatory extinction. It often encloses small crystals of biotite and plagioclase.

Biotite: the characters of biotite are mostly similar to those of the biotite-granite. It is pleochroic with X=pale yellow, Y=Z=yellow brown. It has index of refraction $\gamma=1.665$.

Garnet: it occurs as subhedral crystal, with diameter 0.2–2.0 mm. Frequently it includes small quartz grains.

Epidote, muscovite, zircon and apatite are common accessories.

(f) The Busetsu granite

It is fine-grained, grayish or white colored and compact rock. Sometimes it carries small patches, composed of biotite flakes which are probably derived from sedimentaries.

In thin slice, it shows equigranular texture, tiny scaly biotite flakes are scattering. Essential constituents are plagioclase, potash-feldspar, quartz, biotite and muscovite. The last mineral varies its quantity in each rock.

Plagioclase: plagiclase is euhedral to subhedral tabular, sometimes it shows strong zonal structure, dirty core mantled by fresh rim. The composition of the former is An 41–44 ($n_1=1.548-1.550$) the latter An 23–35 ($n_1=1.540-1.545$). The core often suffers sericitization. Myrmekite occurs along the periphery of the plagioclase crystal which contacts with potash-feldspar.

Potash-feldspar: it is interstitial, and microcline *Gitter* structure is clearly observed.

Biotite: it is usually small slender flakes. They rarely flock to form clots.

It is pleochroic with X=pale yellow, Y=Z=light brown. Refractive index γ=1.651.

Muscovite: it is also small slender flakes, and is usually associated with biotite.

The common accessories are those of apatite, zircon, epidote and sphene.

Petrochemistry

Chemical analyses of three rock specimens of the Kamihara granite, one of the Tashika granite, four of the Mitsuhashi granite and one of the Busetsu granite were carried out, with the results shown in Table 1.

C.I.P.W. norms were calculated, and their results are also shown in the same table.

Comparing the chemical compositions of the granitic rocks of the Toyone-mura area with correlative ones of other areas, the Kamihara granites have high K_2O content for acid facies, the Busetsu granite is richer in CaO and poorer in MgO, and the Mitsuhashi granites have wide range of composition, especially in alkalies contents.

The Tashika granite has a rather singular chemical composition, *i.e.* rich in alumina and lime, poor in iron.

On the triangular diagrams of normative orthoclase, albite and anorthite, and of normative quartz, albite and orthoclase, the Mitsuhashi granites are scattering in wide area (Fig. 3 and Fig. 4).

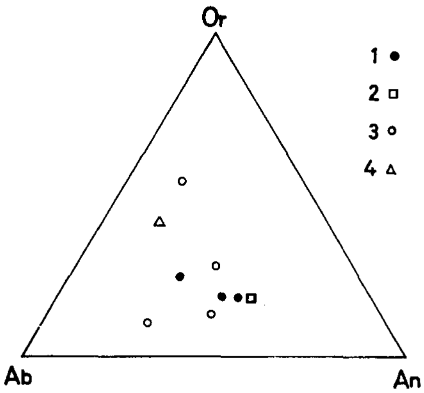

Fig. 3. Triangular diagram showing the ratios of normative orthoclase (Or), albite (Ab) and anorthite (An) of the granitic rocks of the Toyone-mura area.
1: Kamihara granite
2: Tashika granite
3: Mitsuhashi granite
4: Busetsu granite

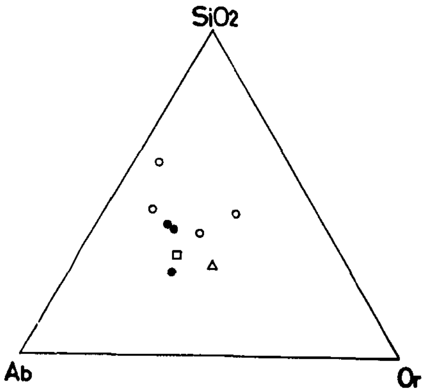

Fig. 4. Triangular diagram showing the ratios of normative quartz (SiO_2), albite (Ab) and orthoclase (Or) of the granitic rocks of the Toyone-mura area. Symbols; see Fig. 3.

Table 1. Chemical compositions of the granitic rocks of the Toyone-mura area.

	1			2	3				4
	(1)	(2)	(3)†	(4)*	(5)	(6)	(7)	(8)	(9)‡
SiO_2	60.90	62.26	63.88	59.44	64.91	67.42	75.90	76.24	71.79
TiO_2	0.79	0.90	0.65	0.60	0.41	0.25	0.07	0.20	0.26
Al_2O_3	16.53	16.13	15.91	18.77	17.99	16.51	13.17	12.88	13.24
Fe_2O_3	2.25	1.69	1.28	0.77	1.05	0.48	0.57	1.41	1.59
FeO	4.22	4.82	4.08	3.80	3.95	3.12	0.85	1.16	1.75
MnO	0.14	0.16	0.08	0.27	0.18	0.08	0.02	0.04	0.09
MgO	3.18	2.56	2.49	2.91	0.46	1.02	0.26	0.16	0.33
CaO	5.88	5.21	4.20	7.39	5.11	4.49	1.63	2.34	3.02
Na_2O	2.45	2.73	3.55	2.50	3.12	2.17	2.16	3.33	3.11
K_2O	1.86	1.89	2.52	2.10	1.31	3.15	5.33	0.88	4.31
$H_2O(+)$	1.31	1.65	1.42	1.21	0.75	1.35	0.74	0.41	0.86
$H_2O(-)$	0.21	0.05	0.31	0.14	0.09	0.18	0.06	0.03	0.04
P_2O_5	0.10	0.09	n.d.	n.d.	0.18	0.02	n.d.	n.d.	n.d.
Total	99.82	100.14	100.37	99.90	99.51	100.24	100.76	99.08	100.39
Q	20.31	22.02	13.69	15.16	28.27	25.15	38.84	48.54	21.54
Or	11.30	11.30	15.34	12.41	7.89	18.66	31.19	5.00	29.33
Ab	21.44	23.43	36.31	21.17	26.53	22.68	18.37	28.73	30.03
An	28.80	25.42	20.57	34.28	24.77	23.29	8.07	11.83	10.83
C	—	0.44	—	—	2.48	1.40	0.92	2.17	—
Wo	—	—	0.35	1.17	—	—	—	—	2.66
En	8.05	6.52	6.38	7.29	1.12	2.55	0.60	0.40	0.92
Fs	4.95	6.30	4.51	5.46	5.77	5.07	0.92	0.66	1.51
Mt	3.29	2.59	1.90	1.87	1.64	0.70	0.93	2.11	2.65
Il	1.54	1.69	1.26	1.22	1.21	0.47	0.15	0.46	0.52
Ap	0.31	0.31			0.31	0.03			

Analyst;T. KUTSUKAKE

1. Kamihara granite
   (1) Specimen No. 68050407, collected near Tsugawa.
   (2) Specimen No. 68050410, collected near Kingoshi.
   (3) Specimen No. 69112603, collected about 2 Km west of Nakadaira.
2. Tashika granite
   (4) Specimen No. 69121405, collected about 1 Km north of Tashika.
3. Mitsuhashi granite
   (5) Hornblende-biotite-granodiorite, Specimen No. 68050312, collected about 500 m south of Nakadaira.
   (6) Biotite-adamellite, Specimen No. 68050304, collected about 1 Km north of Nakadaira.
   (7) Biotite-granite, Specimen No. 68032311, collected near Nakadaira.
   (8) Garnet-biotite-trondhjemite, Specimen No. 68032309, collected near Nakadaira.
4. Busetsu granite
   (9) Specimen No. 69121404, collected about 500 m north of Tashika.

† Includes V 220 p.p.m., Cr 13 p.p.m.
* Includes V 216 p.p.m., Cr 31 p.p.m.
‡ Includes V 36 p.p.m.

The Metamorphic Rocks

(A) Metamorphic rocks derived from sedimentaries

As already mentioned, in this area, sedimentary metamorphics distribute mainly in the south-eastern part, but also they occur in the eastern and in the western parts as smaller masses.

The metamorphic grades become higher from both the eastern and the western sides to the central part. The metamorphic zoning is shown in Fig. 5. From the lithological features of the metamorphic rocks, the rocks of zone I are schistose hornfelses and quarts-schists, and those of zone II and zone III are banded-gneisses. Discrimination between zone II and zone III is mainly upon the crystal habits of sillimanite; in zone II it is replacing andalusite, on the other hand, in zone III it is fibrolite, having no connection with andalusite.

The mineralogical variations with increasing grade of metamorphism are summarized in Fig. 6.

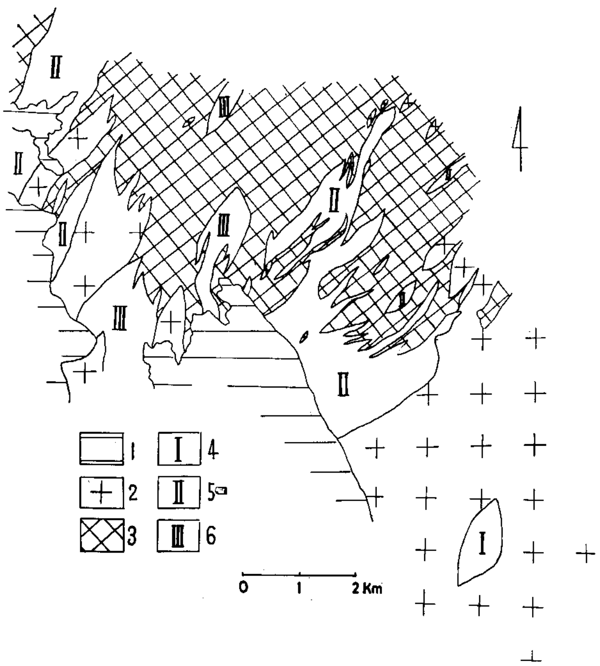

Fig. 5. Zones of progressive metamorphism in the Toyone-mura area.
1: Tertiary 2: Granitic rocks 3: Basic rocks
4: Zone I 5: Zone II 6: Zone III

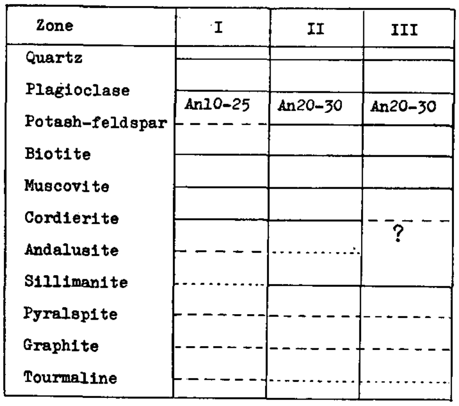

Fig. 6. Mineralogical variations with increasing grade of metamorphism in pelitic, psammitic and siliceous rocks of the Toyonemura area. A full line indicates that the mineral concerned is common and abundant, a broken line indicates that it is common but not abundant, and a dotted line indicates that it is rare.

Petrography

(I) Zone I

(a) Schistose hornfels

It is fine-grained, purplish black rock with faint silky luster, and is always characterized by marked schistosity.

Under the microscope, schistose structure is also well observed, which is mainly brought by parallel alignment of biotite flakes. The chief constituents are quartz, plagioclase, potash-feldspar, biotite, muscovite, cordierite and andalusite with small amount of sillimanite, graphite, tourmaline, zircon and apatite.

Quartz: it is granular crystal and forms mosaic. Weak undulatory extinction is observed.

Plagioclase: it is present sporadically in small quantity. It ordinarily shows simple twinned, but zoning is not commonly observed. It is of compositions An 15–25.

Potash-feldspar: it considerably varies its quantity in each rock. Faint microcline structure is recognized.

Biotite: biotite occurs as small slender flake, parallel arrangement is remarkable. It is pleochroic with X=pale yellow, Y=Z=reddish brown. Index of refraction $\gamma=1.636$.

Muscovite: it occurs also as small slender flake, usually associating with biotite. Large poikiloblastic crystals are often observed. Sometimes shimmer aggregates of sericitic mica after aluminous silicate are found.

Cordierite: it occurs as medium or large porphyroblast and carries biotite flakes and quartz grains.

Andalusite: it is not always found. When it occurs, it is large porphyroblast, including small grains of other minerals such as quartz and biotite. It is often replaced by shimmer aggregate of sericitic mica and/or partly sillimanite.

Sillimanite: it occurs as fibrous or felty crystal, replacing mica and andalusite. Long prismatic crystal is sometimes found.

(b) Quartz-schist

This rock is derived from psammitic sediments, occurring as alternating with the schistose hornfels from pelitic sediments.

It is medium-grained, grayish colored rock. Schistose structure is usually weak.

In thin slice, it exhibits granoblastic mosaic texture, and parallel arrangement of mica flakes is recognized. It is mainly composed of plagioclase, potash-feldspar, quartz, biotite and muscovite with small amounts of iron ore, zircon and apatite.

Quartz: it occurs as granular mosaic crystal, and frequently it includes small flakes of biotite. It shows undulatory extinction.

Plagioclase: it is subhedral and shows simple twinning. Zoning is uncommon. It is of compositions An 10–15.

Potash-feldspar: it varies its quantity in each rock, and it is often dirty.

Biotite: it is small slender flakes, and its directional arrangement gives the rock schistose structure. It is pleochroic with X=pale yellow, Y=Z=light brown. Index of refraction $\gamma=1.629$.

Muscovite: it is present in small quantity, and it is short slender flakes. Frequently it is intergrowthing with biotite.

(2) Zone II

(a) Pelitic banded gneiss

The rock is characterized by banded structure due to alternation of white to light gray, quartz-feldspathic layers and dark biotitic seams. The width of the both layers is several milimeters to several centimeters. Frequently the layers show ptygmatic foldings of several centimeters to several tens in length.

In thin slice, commonly it displays a marked gneissosity, brought about by parallel alignment of abundant biotite and musvovite flakes. Quartz and feldspars form a granular mosaic. The rock is mainly composed of quartz, plagioclase, potash-feldspar, biotite, muscovite, sillimanite, andalusite and cordierite with small amounts of graphite, zircon and apatite. Garnet is sometimes found.

Quartz: it is small granular crytstal, forming a mosaic. It encloses dusty materials and flakes of micas. Undulatory extinction is usually observed.

Plagioclase: it occurs as granular single crystal or simply twinned crystal. It has compositions of An25±.

Potash-feldspar: it is small in quantity. It occurs as unhedral crystal. *Moiré* appearance is frequently observed.

Biotite: it occurs as slender flake, and its parallel arrangement is remarkable. It is pleochroic with X=pale yellow, Y=Z=red brown, having index of refraction $\gamma=1.641$. Dissociation of biotite to sillimanite along its cleavage is sometimes observed.

Muscovite: although frequently it is poikiloblastic tabular crystals, ordinarily it shows slender shape and parallel-intergrowthes with biotite. Optically negative with $(-)2V=33°$.

Andalusite: it is unstable relict, and is replaced partly or entirely by sillimanite and/or muscovite.

Sillimanite: as mentioned above, sillimanite occurs as two types: one is replacing andalusite, which is felted crystal, the other is dissociation product of biotite, which is fibrous. It is usually pale brown in color.

Cordierite: it is unhedral and elongate grains. Lamellar twinning is common in parts of grains. Frequently it alters to pinite and/or is replaced by schimmer aggregate of sericitic mica.

(b) Psammitic banded gneiss

It shows less-developed gneissosity and banded structure than pelitic one, so that to call this rock "banded gneiss" is not suitable.

It is grayish colored, medium-grained rock, and sporadically distributed biotite flakes are conspicuous.

Under the microscope, it exhibits granoblastic texture, and not so remarkable parallel arrangement of mica flakes is recognizable. It is mainly composed of quartz, plagioclase, potash-feldspar, biotite and muscovite with small amounts of garnet, zircon and apatite.

Quartz: it is interlocking each other, and it shows strong undulatory extinction. Sometimes it includes a good many fine mica flakes in its core.

Plagioclase: it occurs as unhedral crystal, showing polysynthetic twinning and weak zoning. It often has turbid core. It is of compositions An25–30.

Potash-feldspar: it occurs as interstitial crystal. Usually it shows perthite structure and *moiré* appearance.

Biotite: it is small slender flakes, corroded by quartz. It is pleochroic with X=pale yellow, Y=Z=brown. Index of refraction $\gamma=1.639$.

Muscovite: it occurs also as slender flake. Frequently it is parallel intergrowthing with biotite.

(c) Siliceous banded gneiss

In certain cases, this rock shows remarkable banded structure. But usually biotitic black layer is thin or lacking. Black biotitic layers are probably inherited from argillaceous parts of banded chert. It is medium- to coarse-grained and gray to grayish white rock.

In this slice, it is chiefly composed of quartz, plagioclase, potash-feldspar, biotite and muscovite, with small amount of zircon, apatite and iron ore. Garnet is occasionally an important mineral, but it is wholly absent in some rocks.

Quartz: it occurs as large irregular shaped crystal with minute inclusions, and it is characterized by intense undulatory extinction.

Plagioclase: it occurs generally as turbid crystal due to secondary alteration. It is usually twinned after albite-law, and is of compositions An20–30.

Potash-feldspar: it is sporadically contained, and also it occurs as turbid crystal.

Biotite: biotite is small slender crystals, pleochroic with X=pale yellow, Y=Z=brown. Index of refraction $\gamma=1.637$.

Muscovite: it is usually a constant mineral, but it is small in quantity. It occurs as small slender flake, with $(-)2V=40°$.

Garnet: It occurs as small subhedral, crystal (diameter 0.2–0.5 mm) including minute grains of quartz. The swarming of a lot of garnet crystals is sometimes observed.

(3) Zone III

(a) Pelitic banded gneiss

It looks like that of zone II to the naked eye and also under the microscope. But, in thin slice, streaks of bundled fibrous sillimanite are characteristic.

It is mainly composed of quartz, plagioclase, potash-feldspar, biotite, muscovite and sillimanite. Cordierite is wholly replaced by shimmer aggregate of sericitic or muscovitic mica; therefore it is unable to ascertain that it is stable. Graphite, zircon and apatite are common accessories.

Quartz: it occurs as a granular crystal, including a lot of small flakes of biotite. It shows undulatory extinction.

Plagioclase: it also occurs as granular crystal, and it is simply twinned. Generally zoning is not observed. Myrmekite is sometimes found in the plagioclase crystal which contacts with potash-feldspar. It is of compositions An 25–30.

Potash-feldspar: it is sporadically present, and it is turbid crystal.

Biotite: biotite occurs as small slender flake. Its parallel arrangement is remarkable. It is pleochroic with X=pale yellow, Y=Z=red brown, having index of refraction $\gamma=1.638$–1.640.

Muscovite: it is also slender flakes, frequently it is intergrowthing with biotite. Sometimes large poikilitic crystals are found, of which the elongating direction is oblique to gneissosity. Optical constants are as follows; $(-)2V=39°$–$40°$, $\beta=1.594$–1.596, $\gamma=1.599$–1.600.

Sillimanite: usually it occurs as fibrous crystal, being bundled and forming streak. It shows close association with muscovite, and is replacing the latter. Small needles of sillimanite are crowded into quartz grains.

(b) Psammitic banded gneiss

(c) Siliceous banded gneiss

These rocks are nearly the same both to the naked eye and under the microscope as those of zone II.

(d) Crystalline limestone

It is white colored, medium-granied rock. It is composed only of calcite

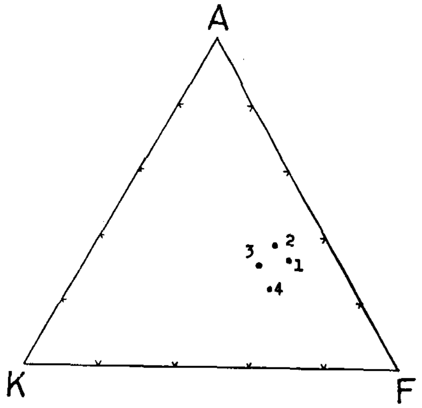

Fig. 7. AKF diagram for pelitic rocks of the Toyone-mura area. The numbers correspond to those of Table 2.

Table 2. Chemical compositions of pelitic metamorphic rocks of the Toyone-mura area.

Zone	I	II		III
	1	2	3	4
SiO_2	68.14	66.91	63.83	73.55
TiO_2	0.86	0.55	0.54	0.62
Al_2O_3	14.55	15.99	16.72	13.55
Fe_2O_3	0.64	0.55	0.39	0.22
FeO	5.16	4.10	4.75	2.67
MnO	0.01	0.06	0.07	0.20
MgO	1.38	2.25	2.37	1.59
CaO	1.68	2.68	1.35	0.89
Na_2O	2.07	1.90	1.10	0.72
K_2O	2.93	3.14	5.96	3.38
$H_2O(+)$	2.28	1.71	2.87	1.74
$H_2O(-)$	0.09	0.06	0.12	0.22
P_2O_5	0.18	0.17	n.d.	0.05
Total	99.97	100.07	100.07	99.40

Analyst; T. KUTSUKAKE

1 Sillimanite-andalusite-cordierite-muscovite-biotite-potash feldspar-oligoclase-quartz-schistose hornfels, Specimen No. 67122202, collected about 1 Km southeast of Ōzasa-yama.

2 (Andalusite)-cordierite-muscovite-biotite-potash feldspar-oligoclase-quartz-gneiss, Specimen No. 68032908, collected about 500 m southwest of Sogawa.

3 Sillimanite-cordierite-muscovite-biotite-oligoclase-quartz-gneiss Specimen No. 69121504, collected about 300 m southwest of Sogawa.

4 (Cordierite)-sillimanite-muscovite-biotite-potash feldspar-oligoclase-quartz-gneiss, Specimen No. 68050202, collected near Osawa.

crystals, several millimeters in grain size. Calcite grains are arranged in an equigranular, granoblastic mosaic. Minerals, such as diopside and wollastonite etc. are not found.

Petrochemistry

Chemical analyses of four specimens of pelitic metamorphic rock were carried out with the results shown in Table 2.

Table 3. Chemical compositions of biotite and muscovite, coexisting in banded gneiss of zone III.

	Specimen No. 68050202			
	biotite*		muscovite	
SiO_2	33.86		48.44	
TiO_2	2.03		0.46	
Al_2O_3	20.80		33.36	
Fe_2O_3	0.88		1.22	
FeO	18.47		1.40	
MnO	0.46		0.10	
MgO	8.55		1.20	
CaO	0.02		0.17	
Na_2O	0.24		0.89	
K_2O	8.78		8.64	
$H_2O(+)$	4.50		4.37	
$H_2O(-)$	0.52		0.60	
Total	99.23		100.87	
Si	5.007	8.000	6.411	8.000
Al^{IV}	2.993		1.589	
Al^{VI}	0.631	5.826	3.615	4.082
Ti	0.226		0.046	
Fe^{+3}	0.098		0.121	
Fe^{+2}	2.929		0.155	
Mn	0.058		0.011	
Mg	1.844		0.134	
Ca	0.004	1.726	0.024	1.712
Na	0.066		0.229	
K	1.656		1.459	
OH	4.441		3.862	
β			1.594	
γ	1.639		1.600	
(−)2V			39°	

* Includes V 724 p.p.m. Analyst; T. Kutsukake

The analyses of them are plotted on the AKF diagram (Fig. 7).

From these scarce data, whether chemical changes in the processes of metamorphism took place, is not detectable.

Brief survey on mica-mineralogy

One pair of biotite and muscovite coexisting in a pelitic gneiss of zone III were analysed with the results shown in Table 3.

It is remarkable that the ratio Na/K of muscovite is higher than that of biotite.

Silicification of banded gneiss

In the area around Tsugawa, banded gneisses are highly silicified, and it results in various kinds of silicified rocks.

In the early stage of silicification, the pelitic banded gneisses are impregnated by numerous quartz veinlets. As silicification advances, the black biotite rich part that seems to represent original banded gneiss, is now found in siliceous rocks as small lens.

Under the microscope, silicified rock exhibits unequigranular mosaic texture. Quartz is characterized by the presence of abundant inclusions composed of fine scaly biotite and black dust-like materials, occurring as large porphyritic crystals.

Chemical analyses of a specimen of the silicified rock and one of the original banded gneiss, which remains in the silicified rock, were carried out with the

Table 4. Chemical compositions of silicified rock and its related rocks.

	1	2	3
SiO_2	78.48	67.42	71.74
TiO_2	0.38	0.88	0.28
Al_2O_3	9.98	14.27	14.65
Fe_2O_3	1.05	1.63	1.25
FeO	1.95	4.95	1.52
MnO	0.07	0.22	0.05
MgO	0.82	2.33	1.17
CaO	1.81	1.88	3.57
Na_2O	0.97	1.67	2.73
K_2O	2.00	3.85	1.59
$H_2O(+)$	1.63	1.23	0.59
$H_2O(-)$	0.39	0.04	0.11
P_2O_5	0.05	0.02	0.06
Total	99.59	100.39	99.26

Analyst; T. KUTSUKAKE

1 Silicified rock, Specimen No. 68081903, collected near Tsugawa.
2 Banded gneiss, remained in silicified rock, Specimen No. 68081902, collected near Tsugawa.
3 Siliceous aplite-looking rock, Specimen No. 68081901, collected near Tsugawa.

results shown in Table 4. Also a specimen of siliceous aplite-looking rock which associates with silicified rock was analysed, the result of which is shown in the same table.

The silicification is probably due to the Mitsuhashi granite mass, occurring near this area.

(B) Basic metamorphic rocks

As previously described, in the western half of this area, the basic metamorphic rocks occupy the wide area. Also small dyke-like and stock-like masses are found in the metamorphics derived from sedimentaries.

They are mainly composed of diabasic rocks, but gabbroic facies are locally found. Hornblende-gabbro crops out as a small exposure near Ure. Frequently they are traversed by aplitic veins, some of which appear as interesting net-work veins as shown in Fig. 8 and Plate 26–Fig. 3. When aplitic facies increases in quantity agmatite-like fashion appears (Plate 27, Fig. 4).

Between the basic metamorphic rocks and the banded gneisses, pegmatite is developed, which intrudes into the banded gneisses as small veinlets (Fig. 9).

Fine-grained biotite-tonalitic rocks, which are probably derived from diabasic rocks by granitization, cut the diabasic rocks and enclose the latter. The boundary between both rocks is sharp, and small aplitic veinlets ramified into the diabasic rocks from the tonalitic rocks (Fig. 10).

Fig. 8. Net-work aplitic veins (An) in the metamorphosed diabasic rock (Dm), traversed by clean cut aplites (Ac).

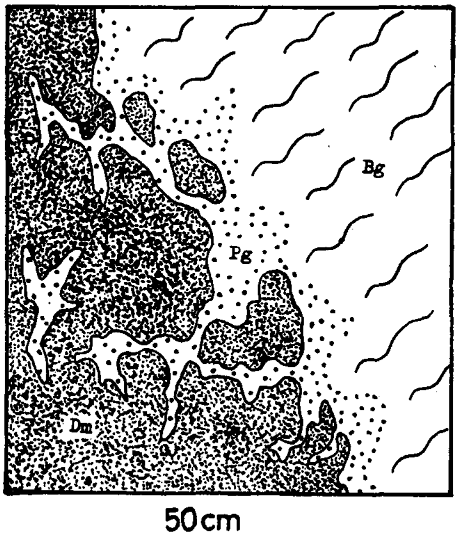

Fig. 9. Contact between metamorphosed diabasic rock (Dm) and banded gneiss (Bg), between them pegmatite (Pg) is developed.

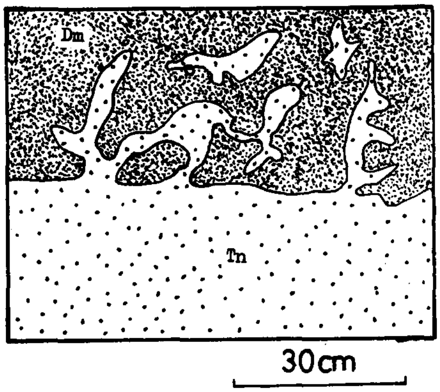

Fig. 10. Biotite-tonalitic rock (Tn) ramifies aplitic veins into metamorphosed diabasic rock (Dm).

Petrography

(a) Hornblende-biotite-diabasic rock

This is black to dark greenish colored, fine-grained massive and compact rock.

Under the microscope, usually it shows recrystallized granular texture, but sometimes it well preserves original igneous texture.

i) The rock preserving original igneous texture

It exhibits original diabasic ophitic texture. It is mainly composed of plagioclase, hornblende, biotite and interstitial quartz.

Plagioclase: it occurs as typical lath-shaped crystal. It is weakly zoned and shows twinning, having compositions of An 40–60.

Hornblende: it is subhedral prismatic and forms clots with biotite. Pleochroism is as follows; X=pale yellow green, Y=yellowish green, Z=brownish green. Optically negative with $2V=64°$ and $c \wedge Z=17°$.

Biotite: it occurs as irregular shaped crystal, corroded by other minerals. Pleochroic with X=pale yellow, Y=Z=light brown. Index of refraction $\gamma=1.644$.

Quartz: it shows an interstitial occurrence, but sometimes it is granular. It shows undulatory extinction.

As accessories, iron ore, sphene, zircon, allanite and apatite occur.

Such secondary minerals as chlorite, epidote and leucoxene are common.

ii) The rock exhibiting recrystallized granular texture.

It exhibits granoblastic texture. In other respects, it quite resembles i). It is mianly composed of plagioclase, hornblende, biotite and a small amount of quartz.

Plagioclase: it is wide lath-shaped or tabular, and is weakly zoned and twinned, having compositions of An 35–60.

Hornblende: it is subhedral granular and frequently forms clots with biotite, pleochroic with X=pale yellow green, Y=pale brownish green, Z=green.

$c\hat{}Z=18°$ and (−) $2V=68°$.

Biotite: it is larger than hornblende in size, and it occurs as small tabular flake. Pleochroism is as follows; X=pale yellow, Y=Z=light brown. Index of refraction $\gamma=1.641$.

Quartz: it is granular small crystals. It ordinarily shows undulatory extinction.

Accessory and secondary minerals are nearly the same with i).

iii) The rock exhibiting blastoporphyritic texture

This rock has two kinds of plagioclase: one is relict phenocryst where it is always euhedral and zoned with turbid core and fresh rim, about 1.5 mm in diameter, the other as groundmass where it has a diameter about 0.2 mm. The former is of compositions An 65–45 (from core to rim), the latter An 30–40. Relict phenocryst is frequently mantled by clear rim with distinct boundary.

In other respects, it is the same with i) or ii).

(b) Gabbroic rocks

The metamorphic derivatives of gabbroic rock are very locally developed, usually occurring as smaller gabbroic facies of the metamorphic derivatives of diabasic rock. Gabbroic rock is frequently assoicated with pockets of gabbro-pegmatite in which large prismatic hornblendes are well developed.

It is medium-grained, dark greenish colored and massive rock.

Under the microscope, frequently it exhibits poikiloblastic texture and large piokilitic biotite flakes are observed. It is mainly composed of plagioclase, biotite and hornblende with small amounts of interstitial quartz.

Plagioclase: it occurs as both euhedral porphyritic crystal and small lath-shaped crystal. The former is also poikilitic enclosing small grains of other minerals, such as biotite and hornblende, and shows clear polysynthetic twinning, having compositions of An 40–50. The latter is also twinned and weakly zoned, and is of compositions An 30–40.

Biotite: it is poikilitic tabular crystals, incuding a lot of crystals of plagioclase. Pleochroic with X=pale yellow, Y=Z=light brown. Index of refraction $\gamma=1.643$.

Hornblende: it occurs as ill-shaped crystal, and is strongly corroded by other minerals. It has a tendency to flock together with biotite. Pleochroism is as follows; X=pale yellow green, Y=yellow green, Z=green with brownish tint. Optically negative with $2V=66°$, $c\hat{}Z=19°$.

Quartz: it occurs as interstitial crystal with undulatory extinction. It is out of inclusions.

As accessories, iron ore, apatite, zircon and sphene are found.

(c) Hornblende-gabbro

It is medium-grained, grayish black colored and compact rock.

In thin slice, it exhibits, on the whole, gabbroic texture. It is composed of plagioclase, hornblende and biotite as essential constituents.

Plagioclase: it occurs as lath-shaped small crystal. It shows twinning and zoning. It is of compositions An 35–55.

Hornblende: it is large poikilitic crystals, enclosing small grains of other minerals, such as biotite and plagioclase. It is strongly corroded by plagioclase, and shows platy habit with irregular-shaped outline. It is paler in color with brownish tint and partly colorless (Fig. 11).

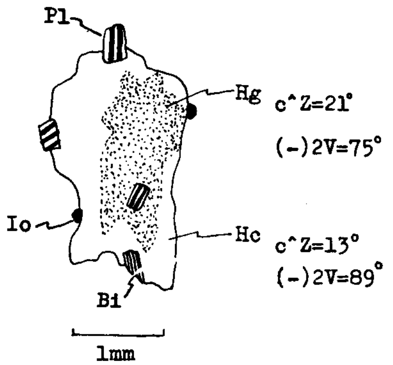

Fig. 11. Zoned hornblende in hornblende-gabbro, pale brownish core (Hg) is mantled by colorless rim (Hc). Pl: plagioclase, Bi: biotite, Io: iron ore.

Biotite: it occurs as small irregular shaped crystal, and associates with hornblende. Pleochroic with X=very pale yellow, Y=Z=orange brown.

Iron ore, apatite and sphene are common accessories.

(d) Net-work aplitic vein

This rock is fine-grained and leucocratic. Generally grain-sizes of minerals increase from margin to core of the vein.

It is essentially composed of plagioclase, microcline, quartz and biotite with small amount of zircon, sphene and apatite. Plagioclase is subhedral tabular and shows clear polysynthetic twinning and weak zoning. Microcline is interstitial crystals, and biotite arranges itself parallel to the stretch of vein. Biotite is slender flakes.

(e) Biotite-tonalitic rock

This rock is light colored, fine-grained and massive. It occasionally contains small blocks of diabasic rock or black patches consisting mainly biotite flakes.

In thin slice, it exhibits typical granitoid texture. It is composed mainly of plagioclase, quartz, biotite and potash-feldspar, of which the last mentioned mineral varies its quantity considerably in each rock.

Plagioclase: it is subhedral tabular and shows clear polysynthetic twinning. Zoning is common and turbid core is surrounded by fresh rim with distinct boundary. It is of compositions An 50–55 in zoned core and about An 25 in fresh rim and in small lath-shaped crystals.

Potash-feldspar: it occurs as interstitial small crystal.

Quartz: it is interstitial crystals with rather strong undulatory extinction.

Biotite: it is small slender flakes, and it often forms clots. Frequently trains of biotite flakes surround tabular crystal of plagioclase. It is pleochroic with X= pale yellow, Y=Z=deep brown. Index of refraction $\gamma=1.646$.

Accessories: As accessories, zircon, apatite, iron ore, epidote and sphene occur.

Petrochemistry

Chemical analyses of hornblende-biotite-diabasic rocks, aplitic vein and biotite-tonalitic rock are carried out, with the results shown in Table 5.

Hornblende-biotite-diabasic rocks are poorer in magnesia content and richer in potassium than ordinary diabasic rocks which have nearly the same silica contents. The introduction of potassium and removal of magnesium in the process of metamorphism must be supposed.

Table 5. Chemical compositions of basic metamorphic rocks in the Toyone-mura area.

	1	2	3	4
SiO_2	50.01	51.69	71.66	61.22
TiO_2	0.98	1.39	0.32	0.63
Al_2O_3	18.89	15.56	14.29	19.87
Fe_2O_3	1.80	1.86	1.43	0.63
FeO	8.36	8.64	1.28	3.85
MnO	0.20	0.43	0.05	0.06
MgO	5.16	4.14	0.65	1.95
CaO	9.54	9.59	1.96	5.21
Na_2O	1.90	2.18	2.87	2.91
K_2O	1.30	1.91	2.83	1.49
$H_2O(+)$	1.61	1.18	0.84	1.38
$H_2O(-)$	0.51	0.66	0.86	0.07
P_2O_5	0.29	0.13	0.10	0.05
Total	100.56	100.42	99.14	99.32

Analyst; T. KUTSUKAKE

1 Hornblende-biotite-diabasic rock, blastoporphyritic texture, Specimen No. 68050409, collected about 500 m south of Kingoshi.
2 Ditto, granular texture, Specimen No. 68050311, collected near Nakadaira.
3 Aplitic vein in diabasic rock, Specimen No. 68050411, collected near Kingoshi.
4 Biotite-tonalitic rock, Specimen No. 68032703, collected near Asakusa.

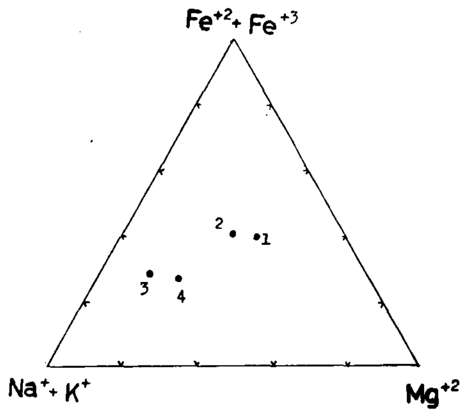

Fig. 12. $Mg^{+2}-Fe^{+3}+Fe^{+2}-Na^{+}+K^{+}$ diagram of basic metamorphic rocks. The numbers correspond to those of Table 5.

The analyses are plotted on Mg^{+2}-$Fe^{+2}+Fe^{+3}$-$Na^{+}+K^{+}$ diagram (Fig. 12). If biotite-tonalitic rock is a granitization product of hornblende-biotite-diabasic rock, increase of alkalies and decreases of magnesium and iron on granitization are evident.

Concluding Remarks

The Ryōke zone in the Toyone-mura area, Aichi Pref., Japan, consists of granitic intrusives and their assocciated metamorphic complex, derived from Paleozoic sediments and basic igneous rocks.

The granitic rocks are classified into six main types and the succession of their emplacement is as follows from the older one; the Kamihara granite, the Tashiko granite, the Kiyosaki granite, the Tenryūkyō granite, the Mitsuhashi granite and the Busetsu granite. In this area, two distinct stages of granitic intrusion are not recognizable, such as recognized in the Dando-san district studied by KOIDE (1958), and in the Komagane district studied by HAYAMA (1959, 1960).

Recently, YAMADA, N. *et al.* (1969) proposed a new division of the Ryōke granites; "Ryōke granites in stricter sense" and "post-Nōhi" granites, in connection with the Nōhi rhyolite. And, into the former group, they included the following type granites: (1) Hiji, Kamihara, Kiyosaki and Miya quartzdioritic rocks; (2) Tenryūkyō and Minakata granodiorites; (3) Mitsuhashi and Ikuta granodiorites. Distribution of these granitic rocks are limited within the area of higher metamorphic grade, namely sillimanite zone.

In the Toyone-mura area, the granitic rocks corresponding to (1), (2) and (3) occur, and the Busetsu granite that may be "post-Nōhi" granite is also found. From these points of view, the granitic rocks of this area have to be further investigated.

The metamorphic terrain is divided into three zones by mineral assembleges in pelitic rocks, mainly on the stability relation of andalusite and sillimanite; in zone I andalusite is stable and small amount of sillimanite is also present, in zone II andalusite becomes unstable and is replaced by sillimanite and in zone III andalusite wholly disappears and fibrous sillimanite is characteristic.

Zone I, zone II and zone III probably correspond to the cordierite-, the first sillimanite- and the second sillimanite-zone in the Komagane district (HAYAMA; 1956, 1960) respectively. And also, zone I may be correlated to the transitional zone, and zone II and zone III to the banded-gneiss-zone in the Dando-san district (KOIDE, 1958) respectively.

Basic metamorphic rocks, mainly composed of diabasic rocks, suffer metasomatism and granitization, forming various kinds of granitic rocks. Especially increase of potassium and decrease of magnesium are conspicous. Mechanism and quantity of metasomatism have to be made clear concretely in future.

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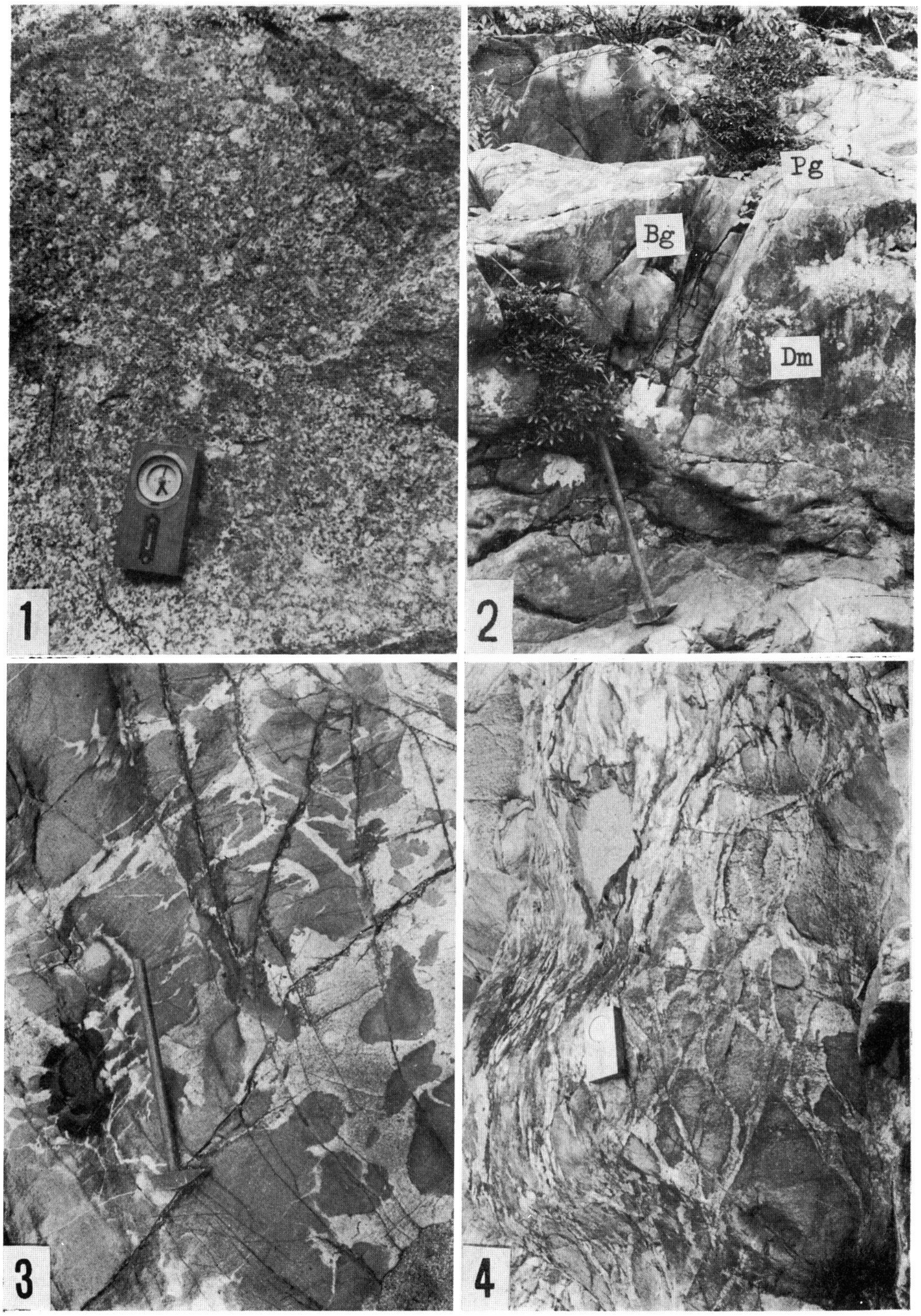
Explanation of Plate 27

Fig. 1: Tenryūkyō granite, porphyritic potash-feldspar crystals are conspicuous.

Fig. 2: Contact between the metamorphosed diabasic rock (Dm) and the banded gneiss (Bg). Pg: pegmatite.

Fig. 3: Net-work aplitic veins in the metamorphosed diabasic rock.

Fig. 4: Agmatite-like fashion of metamorphosed diabasic rock.



KUTSUKAKE: Ryōke Granitic and Metamorphic Rocks