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A STUDY OF THE UZUMINE-SENGOSAWA STRUCTURAL BELT IN THE ABUKUMA PLATEAU, JAPAN

by

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(with 11 text-figures, 1 table and 5 plates)

Abstract

A conspicuous septa-like belt is found in the Uzumine-Sengosawa region being intruded by several large granitic bodies. Plutonic and metasomatic activity took place together with intense tectonism in this belt resulting in brecciation of the Gozaisho schist and the formation of migmatite, tonalite, granite and ore mineralization. The belt has the same character as the Koshidai-Takaboyama-Daioh·in Structural Belt proposed by Watanabe *et al.* (1978) and represents the extension towards the north of this last structural belt.

Introduction

A remarkable structural belt, namely the Uzumine-Sengosawa Structural Belt, which lies between large granitic masses in the central area of the Abukuma metamorphic terrain is defined and described in this paper. The belt runs from south to north through the Sengosawa dam site and the Uzumine district up to the village of Hiwada, Kohriyama City. At the Uzumine district the belt branches towards the north and it can be traced as far as the northwestern part of Miharu Town.

Previous to the present description, the "Koshidai-Takaboyama-Daioh·in Structural Belt" has been postulated by Watanabe *et al.* (1978) as one of major tectonic lines in the Abukuma metamorphic terrain. This structural belt is developed in the southern half of the Abukuma terrain, and its northern extension has been considered as being interruped by a large granite body of late Cretaceous age. On the other hand, an alignment of interspersed schists and serpentinite intrusive bodies located below the Tertiary deposits has been reported in the Nakadohri area, Fukushima Prefecture, and named as the "Nakadohri metamorphic rock belt" (Nakadohri Collaborating Research Group). This belt extends from Hiwada village towards the north and can be traced as far as the Kuriko district in the southern part of Yamagata Prefecture.

These two structural belts are separated by abundant granitic intrusives of younger age and by Tertiary and Quaternary deposits. However, the writers have found some migmatitic and metamorphic rocks in the Uzumine-Sengosawa region which is located between the two above-mentioned structural belts. A general outline of the regional geology together with a brief discussion about the geological meaning and implications of the "Uzumine-Sengosawa Structural Belt" will be given in this paper.

Since Minato (1960) first proposed the existence of the Abean orogeny, the Variscan orogeny in Japan, almost two decades have passed. Although since then numerous discussions concerning the late Palaeozoic orogeny have taken place among geologists, any

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consolidated view about the Abean orogeny has not yet been put forward. Since 1976 a collaborating research group for the project "Palaeozoic orogeny in north Japan" has been organized by Professor Minato and many stratigraphers and petrologists, mainly from the universities of Hokkaido and Fukushima, become engaged in studies of the Abukuma and the Kitakami terrains. The writers are members of the project and their work has mainly developed in the Abukuma terrain. The present paper is one of the results of this project.

Geologic Setting

The Abukuma terrain is located at the northeastern side (Pacific side) of Honshu and is well-known as one of the areas forming the basement of the Japanese Islands. This terrain extends for about 150 km in a N-S direction and for about 50 km in an E-W direction. Large volumes of metamorphic and plutonic rocks constitute almost the whole extent of the terrain which is known as the Abukuma metamorphic belt.

The geological study of this terrain was initiated by Koto's report on the Gozaisho and Takanuki districts located in the middle area of the belt (Koto, 1893). He described the metamorphic rocks as belonging to the Gozaisho series (mainly green schists) and the Takanuki series (mainly pelitic gneisses), and regarded them as Precambrian. Since then, a great number of geologists have studied several regions and many interesting views on the geology of the metamorphic and plutonic rocks have been published. An outline of the rock distribution in the whole extent of the terrain has been presented as a summary by Watanabe *et al.* (1955) and is compiled in the geological maps of Fukushima Prefecture and Ibaragi Prefecture both published in 1962 at 1:200,000 scale. Nevertheless, new data and interpretations have been more recently contributed mainly by Uruno, Kano and co-workers, Hunahashi and co-workers, and Yashima and his students from Fukushima University.

The terrain has been considered to be limited at its east and west sides by major tectonic lines, the Futaba and the Hatagawa tectonic lines in its eastern side and the Tanakura fracture belt in its western side. However, many small blocks and bodies of metamorphic and plutonic rocks belonging to the Abukuma metamorphic belt have been found in several places to the west, beyond the Tanakura fracture belt. The metamorphic rocks are predominant in the southern half of the terrain where they have been intruded by several isolated bodies of granites, diorites and gabbros. Granitic and dioritic masses are predominant in the northern half of the area. A large quartzdioritic to granodioritic intrusive body known as the "older granite" occupies most of the area and is accompanied by many granodioritic plutons, *i.e.* the "younger granite". Many gabbros and metagabbros and also present as small-sized bodies showing various lithologic appearances. Small amounts of gneisses, schists and limestones are also found as xenoblocks or roof-pendants in this area.

Due to the heterogeneous lithology of the southern area the attention of geologists has mainly centred there in the last years. Therefore, several famous regions such as the Gozaisho-Takanuki region, the Hanazono-Takaboyama region and the Hitachi-Nishidohira region have been surveyed in detail. However, the area lying among them remained as blank areas as far as geological description is concerned.

Among discussions referring to this metamorphic area, two conspicuous opposite opinions are recognized to exist concerning its phases of metamorphism. One is, so to speak, the single-phase metamorphism theory put forward by Miyashiro (1958), and the other is the poly-phase metamorphism theory maintained by Sugi (1933) and Kano and Kuroda (1968).

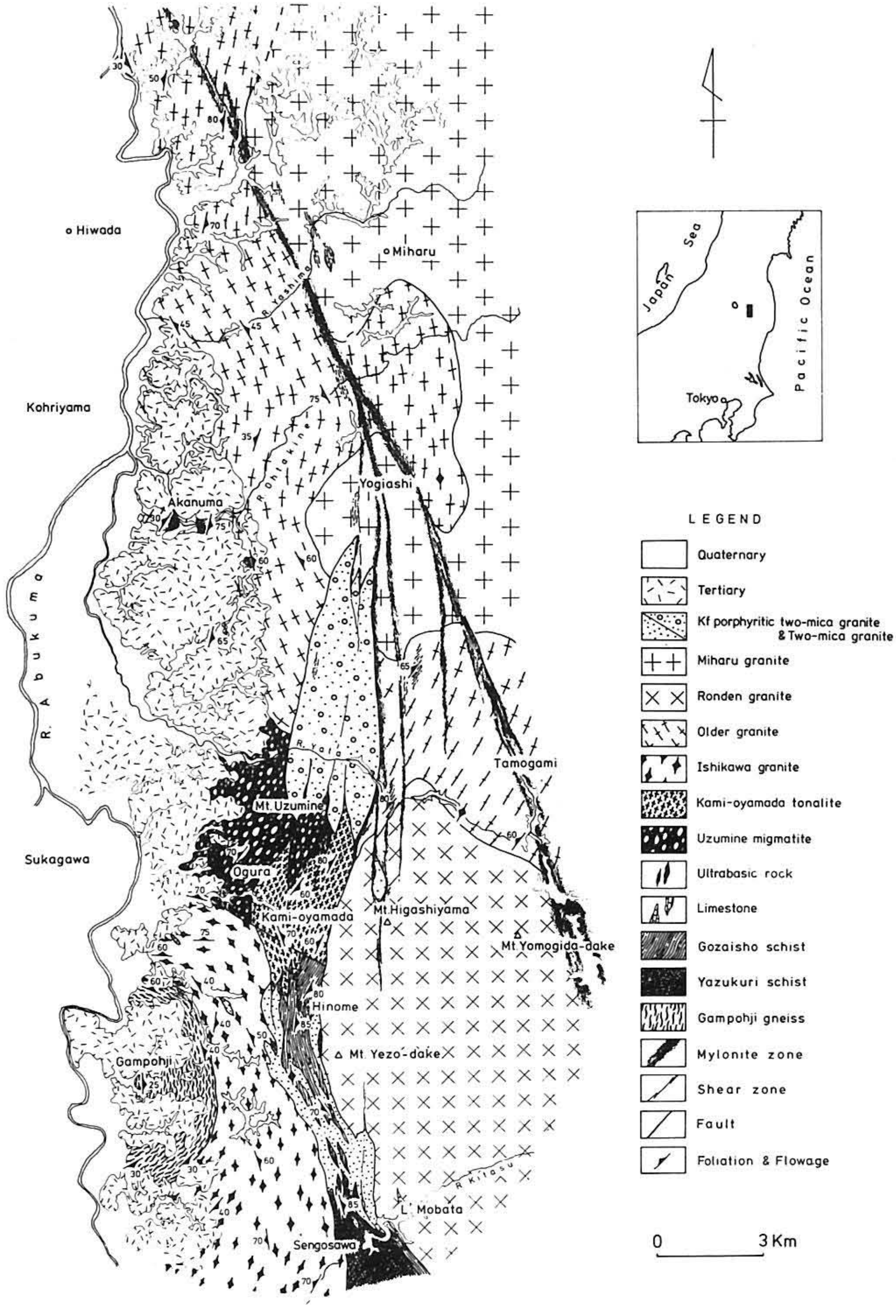
Alumino-silicate minerals such as staurolite and kyanite were found in river sand at several places in the terrain (Uruno and Earth Science Club of Miyagi-ken First Girls Senior High School, 1967; Uruno, 1977). This evidence has given support to the poly-phase metamorphism theory. Lately such alumino-silicates were confirmed at some outcrops (Shimaoka and Watanabe, 1975), and after that Watanabe *et al.* (1978) concluded that the rocks accompanying with some of these minerals were diaphthorites, although the exstence of those minerals had been reported first by Sugi (1933) and after Ono *et al.* (1953). However, there are many different opinions on the poly-phase metamorphism theory about the stages in the metamorphism and plutonism of the region and concerning the model of the orogenic movement which built up the Abukuma metamorphic belt. One of the most conspicuous of the unsettled problems referring to this terrain is the geologic relationship between the Gozaisho and the Takanuki series. Kano and his co-workers have proposed many interpretations on this problem and lately insisted that both metamorphic series were derived from conformable successive formations although metamorphosed in different stages (Kano *et al.* 1973). The theory that the Gozaisho memebers represent the metamorphic products of the Abean orogeny while the Takanuki members constitute the basement (Precambrian) was proposed by Hunahashi (Minato, Hunahashi, Watanabe and Kato, 1979).

The Uzumine-Sengosawa area is located just on the northern extension of the boundary between the two members of the Takanuki-Gozaisho region. The region described in this paper has long been geologically ignored. Except for some reports about pegmatites, which are found in outcrops of workable size in several places of this region, only the geology around Mt. Uzumine district has described by Watanabe (1935), Kondo (1955) and Ogura (1958).

Geology and lithologic description

The rock types constituting the Uzumine-Sengosawa region can be divided as follows:

Alluvium and Diluvium
Tertiary volcanic sediments
Two-mica granite }
Miharu granite } Younger granite
Ronden granite }
Older granite
Ishikawa granite
Kami-oyamada tonalite
Uzumine migmatite
Serpentinite
Crystalline limestone
Gozaisho metamorphic rocks
Gampohji gneiss



Text-Figure 1 Geological map of the Miharu-Uzumine-Sengosawa district.

Yazukuri schist

The distribution of each rock type is presented in the geologic map (Fig. 1). A noticeable narrow septa-like zone consisting of schists, migmatite, tonalite and two-mica granites accompanied by small serpentinite blocks extend with a N-S trend from the southern border of the region, the Sengosawa district, up to the Mt. Uzumine district. The septa is sandwiched between large intrusive masses of granites; the younger granites, *i.e.* the Ronden and the Miharu granite, in the east side and the Ishikawa granite and the older granite in the west side. The zone has a width of 2-2.5 km and encloses rather small masses of pelitic and basic schists, the Kami-oyamada tonalite, and two-mica granites together with a migmatite mass which swells out towards the west at the Mt. Uzumine district and is accompanied by small serpentinite blocks. Some outcrops of serpentinite are known to occur below rhyolitic tuffs of Tertiary age around the village of Akanuma. They have intruded amphibole schists and are parallel to the direction of the latter roughly in a N-S trend. A large number of small xenoblocks of biotite schists, amphibole schists, biotite gneisses and crystalline limestones are found in the older as well as in the younger granite, just on the northern extension of this septa-like zone; these enclaves are regarded as a branched continuation of the zone. Some of these schists and gneisses have been transformed into hybrid rocks while the limestones were converted into skarns or crystalline rocks due to metasomatic reaction with the granites or to thermal effect of these intrusives.

The distribution of the granitic rocks is characteristic. The younger granites, *i.e.* the Miharu granite and the Ronden granite, intruded in the eastern part of the septa-like zone and are arranged with a N-S trend. The older granite and the Ishikawa granite are, in general, located in the western part of the same zone.

A remarkable mylonite zone crosses the region obliquely with a NNW-SSE trend. This mylonite zone continues further south down to the Negishi region where it appears as a simple fracture zone producing dislocation which affects even Tertiary sediments (Inokuchi, 1977, Machida, 1978). This mylonite zone was once referred as the central mylonite zone corresponding to the Hatagawa and Futaba tectonic line and the Tanakura fracture belt (Watanabe *et al.*, 1955). The granite have suffered effects of crushing and recrystallization along the mylonite zone up to 2 km in width. Seemingly subordinate mylonite zones branch towards the south from this main mylonite zone at around Yogiashi village. They run parallel and with a N-S trend along the eastern boundary of the above-mentioned septa-like zone or further east.

The Yazukuri schist

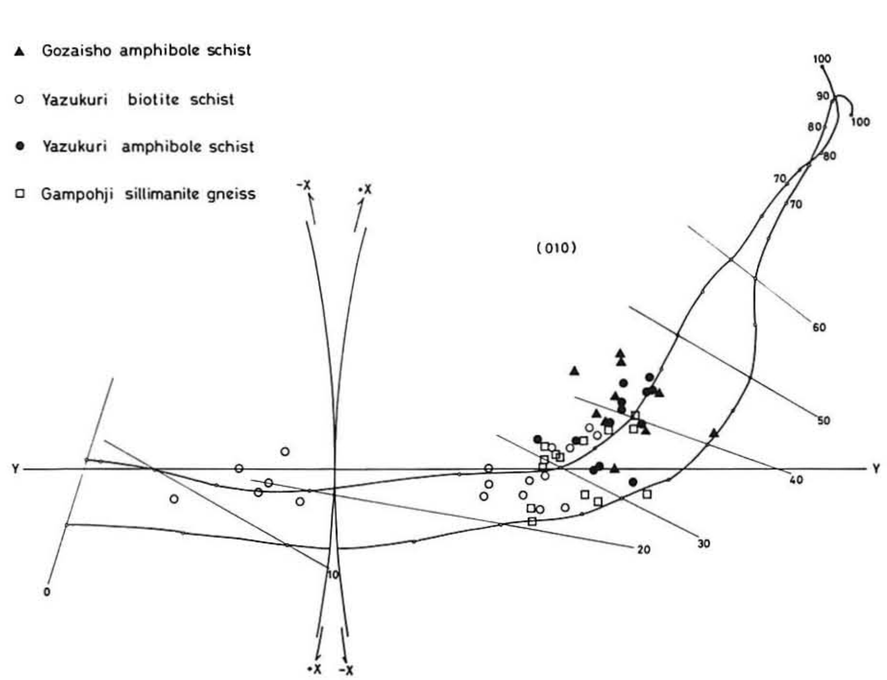
This schist is present at the southern border of the region in the Sengosawa district. The schist continuously extends towards the southeast forming a large unit known as the Yazukuri body (Uchiyama, 1977). A remarkable zone of microfolding, often accompanied with fracturing is present in the middle part of the body and has a width of 500 m extending in a SE direction from the Sengosawa district. The lineation is emphasized by a mainly parallel arrangement of the constituent minerals and its trend coincides with that of the axes of microfolds with a NNW direction and plunge of 20° to 50° towards the north at the Sengosawa district. In the schists, where microfolding is specially developed, undulation of the schistosity is observed obliquely crossing the above-mentioned linear structure. The following four types of rock can be recognized in the Yazukuri schist: biotite schist, amphibole schist, alumino-silicate porphyroblastic schist, altered pelitic and basic schist.

The biotite schist occupies about 60% to 70% of the whole Yazukuri schist in this region, and is characterized by a remarkable flat planar structure and a notable exfoliation on the fissility plane. A set of two kinds of lineations commonly appears on the foliation plane; one is formed by the parallel arrangement of biotite flakes and the other is determined by the axes of microfolds. In many cases these two lineations are parallel and show uniform trends. Besides them, another fold with its axis crossing obliquely to the above-mentioned linear structures, appears in several outcrops where microfolds are intensely developed.

Additionally, a notable fracture structure is developed in some localities. The rock is broken up and its schistosity is bent (Pl. 1, Fig. 1).

The mineral assemblage is quartz-plagioclase-biotite-muscovite-garnet-tourmaline and opaques. Quartz has a xenomorphic granular habit with fine to medium-grain size. Wavy extinction is remarkable. Equigranular, coarse-grained quartz with a rectangular shape, often formes characteristic domains or bands with a brickwork texture (Pl. 2, Fig 1) Plagioclase is present as dusty grains with a xenomorphic habit and size ranging from 0.2 to 0.3 mm. Its An-content varies between An 8% and An 37% and its structural state corresponds to the low-temperature type as shown in Figure 2. Reddish brown biotites show a distinct preferential orientation forming a banded structure together with muscovites. These biotites include many zircon grains and many halos are seen. Maximum size of the flakes is about 0.8 mm although those in the quartzofeldspathic bands are very fine. Abundant opaque minerals are present in the biotite bands. Muscovite is observed as flaky to tabular crystals with slight poeciloblastic character; its maximum size is about 1 x 1.2 mm. Preferential arrangement is not so distinct as in the case of biotite.

The amphibole schist is found in alternation with the biotite schist in bands of 5 to 50 m in thickness; its total volume representing about 30% of the whole Yazukuri schist. Microfolds or undulations are not observed in this schist. A preferential arrangement of the amphibole crystrals emphasizes the simple linear structure. The rock presents a granoblastic texture with a mineral assemblage consisting of amphibole-plagioclase-diopside-biotite-quartz and opaques. Amphibole is xenomorphic to hypidiomorphic granular with grain size ranging from 0.1 to 0.2 mm. A preferential orientation is well preserved. Pleochroism is as follows; X=pale yellow to pale brown, Y=deep green to greenish brown, Z=greenish brown to deep bluish green. Other optic constants are, $2Vx=52^{\circ}-68^{\circ}$ $c\wedge Z=11^{\circ}-23^{\circ}$. Plagioclase is present as xenomorphic to hypidiomorphic crystal. Zonation is usually absent. The projection of data on Burri *et al.*'s migration curve (Burri *et al.*, 1967) shows that points are scattered between the low- and high-temperature curves, and that the An-content is estimated as An 32-44% (Fig. 2). Quartz is xenomorphic with a rather coarse grain varying from 0.1 to 1.0 mm in size. Quartz bands develop with 1–2 mm thickness in which the quartz grains take a brickwork texture. Biotite-rich layers are often found in this schist and the biotite crystals show a remarkable preferential orientation. The biotite colour is greenish brown. Abundant opaques are present in these layers especially along the boundaries with amphibole-rich



Text-Figure 2 Projection of optical constants of plagioclases of metamorphic rocks on the Burri *et al.*'s migration curve.

layers. Accessory minerals are sphene, diopside, garnet and opaques.

The alumino-silicate porphyroblastic schist characterized by gigantic porphyroblasts of alumino-silicate minerals are known from two localities of the intense microfolding zone in the Yazukuri body. Altered pelitic and basic schists are found enclosing this type of schist. The mineral assemblage is plagioclase-quartz-muscovite-biotite-andalusite-sillimanite-kyanite (?)-tourmaline-garnet and opaques. Except for the difference in texture, the optical character and habit of constituent minerals are considerably the same as in the biotite schists. Andalusite, sillimanite and kyanite (?) have been detected as the alumino-silicate minerals. Andalusite is in long prismatic idiomorphic crystals of 1–3 cm x 0.5 cm in size, and is always found included by muscovite flakes of clotted nature when present in biotite-rich layers. Its optic axial angle is $2Vx=70°-84°$. Sillimanite is always found as fibrolite in biotite-muscovite layers while in quartzofeldspathic layers it appears as rather big needle-like crystals (Pl. 2, Fig. 3). Kyanite (?) is found as small grains included in big muscovite flakes. Its main optical constants are $2Vx=82°-83°$, and $a \wedge X=5°$ on (001). Andalusite and sillimanite are mainly found in the biotite-muscovite layers of the schist and show porphyroblastic features. Replacement by muscovite is widespread in them. Further examination of the kyanite (?) crystals is necessary.

The altered pelitic and basic schists are found close to the above-described alumino-silicate porphyroblastic schist and along the shear zone running in a NW-SE direction. North of the Sengosawa dam site, magnetite ore in a magnetite-garnet-quartz assemblage is known in the altered basic schist. The mineral assemblages of the altered rocks are different between those derived from pelitic schists and those originated from basic schists. In the former, muscovite-quartz is the fundamental association and several varieties of mineral assemblages are distinguished as follows;

Amphibole-diopside-epidote-garnet-quartz-opaques
Amphibole-diopside-muscovite-garnet-apatite-quartz-opaques
Actinolite-garnet-apatite-quartz-opaques

Gampohji gneiss

Coarse-grained, highly metamorphosed gneisses are distributed around the Gampohji-Kodaka district, in the south-western corner of the region. These gneisses can be divided into pelitic and quartzose types with almost equivalent volume. A small amount of amphibolite is found only at the northern part of the gneiss area intercalated with pelitic and quartzose gneisses although the characteristics of the rocks are not clearly seen because of intense deep weathering of the gneiss and the fact that the metamorphics are covered by Tertiary volcanic tuffs. The gneiss presents a half dome structure inclined towards the east with a moderate angle, and its wing is overlain by the intrusive mass of the Ishikawa granite. The relationship between gneissosity and flowage of the gneiss and the granite is fairly harmonic.

Sillimanite is present in moderate amount in the pelitic gneiss and the main assemblage is represented by sillimanite-muscovite-biotite-plagioclase and quartz. The gneiss has a distinct banded structure composed of biotite-muscovite and quartzofeldspathic bands. Plagioclase have a xenomorphic habit and their An-contents range from An 21-40% as shown in Fig. 2. Plots of values corresponding to some of their optical constants are scattered around the curves for low- and high-temperature types (Burri *et al.* 1967) and a tendency is observed for the plots of those individuals having high An-content to be concentrated on the low-temperature line and *vice versa.* Quartz is xenomorphic with 0.5-2.0 mm in size. Wavy extinction is rather distinct. Biotite is hypidiomorphic, reddish, and contains a large amount of pyrrhotites; the size of the flakes is about 0.1–1.0 mm and a preferential arrangement is not so distinct as in the case of biotite. Sillimanite corresponds to fibrolite forming clots with 1.0–2.0 mm in size, they are always found in biotite-muscovite rich bands.

The quartzose gneiss exhibits a peculiar texture and composition. It mostly consists of xenomorphic coarse quartz grains of blastic nature in which fine biotite flakes are included. The mineral assemblage is quartz-biotite-plagioclase-(potash feldspar)-(muscovite) and opaques. A conspicuous texture in which rectangular quartz grains are arranged in a brickwork texture is recognized. A parallel alignment of these quartz grains clearly marks the gneissosity. Biotite is reddish brown and appears in tiny flakes. It is usually found as inclusions in porphyritic quartz. In spite of confinement by quartz a parallel arrangement of biotite flakes is well preserved representing gneissosity (Pl. 2, Fig. 4) Plagioclase is fine xenomorphic and is commonly altered to an aggregate of sericite. Modal value of quartz often exceeds 70%. Accessory minerals are garnet, muscovite and opaques.

The Gampohji gneiss is correlated with the Takanuki gneiss due to its high grade metamorphic features and its characteristic composition. The wide distribution of quartzose gneiss would specially support this correlation, because enormous amounts of this same rock type characterize the Takanuki gneiss in the high grade zones of the Takanuki and Hanazono districts (Uchiyama, 1977, Takahata, 1979).

Gozaisho metamorphic rocks

Fine to medium-grained amphibole schists intercalated with thin layers of biotite schist are distributed with a N-S trend and with less than 1km in width on the western foot of Mt. Yezo-dake. The schists are intruded by a network of a two-mica granite which includes large strips of xenoblocks. The structure of the schists is simple with a N-S trend and a vertical to high angle inclination towards the east. A layer of the same schist, about 100–300 m in width, is also found along the southwestern boundary of the Ronden granite mass and its contact with the Yazukuri schist are characterized by a remarkable sheared zone. In addition to these outcrops, numerous xenoblocks and palaeosomes of these schists are found in the Uzumine migmatite, the older and the younger granites in the northern region, around the Akanuma, Yogiashi and Miharu districts. All these schists are correlatable with the Gozaisho schist from their composition and texture.

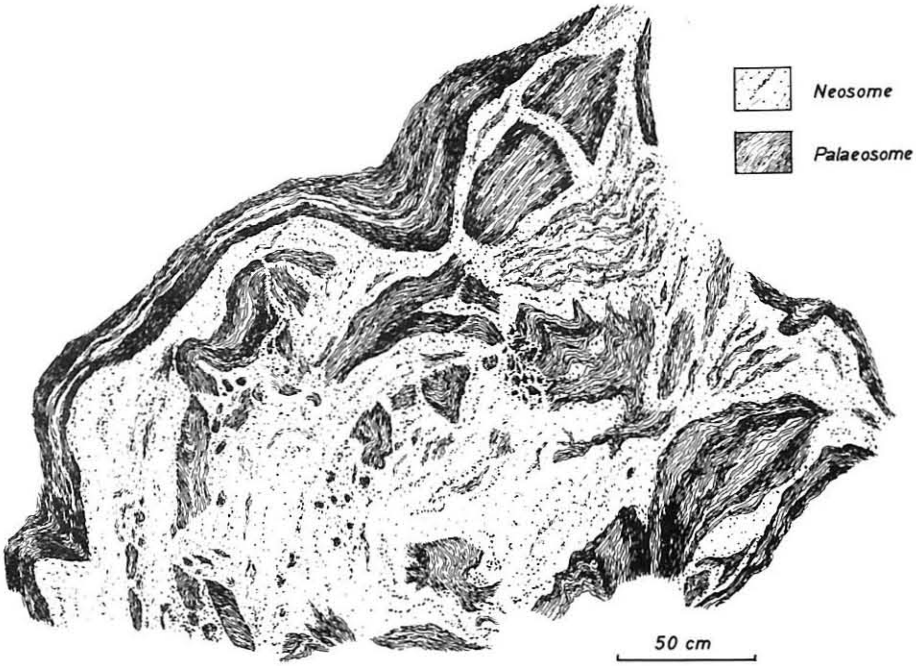
The schist unit is mainly composed of amphibole schist and contains a smaller amount of skarn rocks and minor amounts of biotite schist as intercalations.

The mineral assemblage of the amphibole schist is amphibole-plagioclase-epidote-(diopside) and opaques and the texture is granoblastic. A linear structure produced by the parallel arrangement of amphibole crystals is evident but a planar structure is not so distinctly developed as compared with that of the Yazukuri schist. Therefore exfoliation is weak. Domains consisting of epidote-diopside assemblage are often developed in the amphibole schist. Amphibole is hypidiomorphic with variable crystal-size: fine crystals are between 0.04–0.1 mm in size and those of blastic nature are of 0.2–0.4 mm in size. Pleochroism is as follows: X=pale yellow to pale brown, Y=brown to greenish brown, Z=pale greenish brown to bluish green. Other optical constants are; $2Vx=66°-86°$, $c \wedge Z=9°-19°$. Plagioclase is hypidiomorphic with 0.05–0.1 mm in size and zoning is very faint or absent; the An-content varies between 33–45% (Fig. 2). Epidote is 0.15 mm in size and shows a slight poeciloblastic nature.

Uzumine migmatite

The western part of Mt. Uzumine, where the Uzumine migmatite is distributed, is topographically represented by a low hill range widely covered by Tertiary volcanic sediments. Additionally, deep weathering took place intensively around this area. Although, as a result, outcrops are generally poor the occurrence of the migmatite is well observed in several localities.

The rock is characterized by abundant relics of various sizes derived from biotite schists, amphibole schists, biotite gneisses and limestones (Fig. 3). Most of these palaeosome materials are in harmonic arrangement with the tonalitic neosome and they often show an injection gneiss feature with their outlines being blurred towards the neosome. However, some of the palaeosome materials show agmatitic features with sharp outlines and arranged

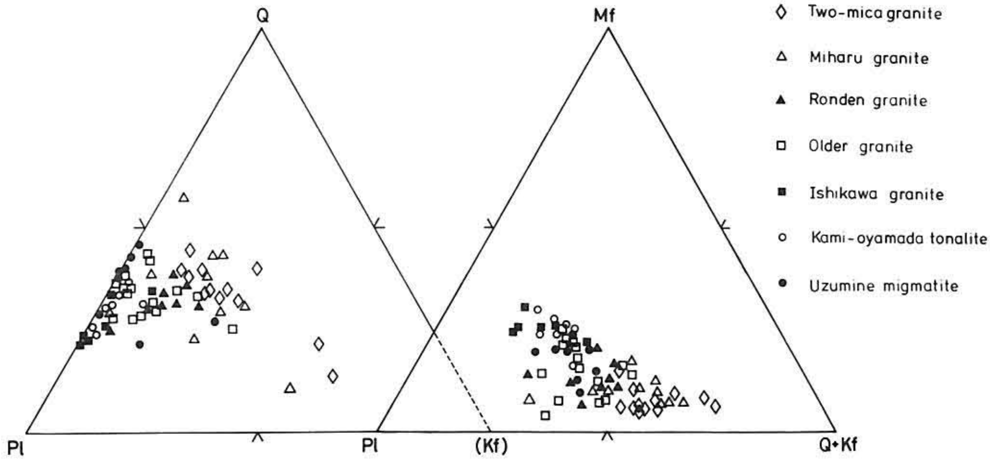


Text-Figure 3 A sketch showing an occurrence of the Uzumine migmatite.

subparallel in relation to the gneissose structure of the neosome (Pl. 3, Fig. 1) But, even in the palaeosome materials of the latter type, some features such as slight blastesis of their plagioclases and concentration of biotite on their margins would indicate that metasomatic reaction with the neosome has taken place. In some localities the tonalitic neosome is observed cutting the relictic gneisses and schists indicating that the migmatite has an intrusive nature, and is not an *in situ* migmatite. In general terms palaeosome materials derived from schists are distributed in the eastern part of the migmatite body while those derived from gneisses are found in the western part.

Heterogeneous appearance is also one characteristic feature of this rock. The distribution of biotite flakes is uneven, but is producing a neat gneissose structure. The grain size of the constituent minerals is also heterogeneous even in the extent of a thin section. Porphyritic garnets of dark red colour with 10–15 mm in size are commonly found in this rocks. Their occurrence is also biased and large number of these big garnets are known especially to occur in places where a great amount of palaeosome material has remained. The trend of the gneissose structure of this rock is approximately NNE-SSW and its inclination is towards the west with steep angle to almost vertical.

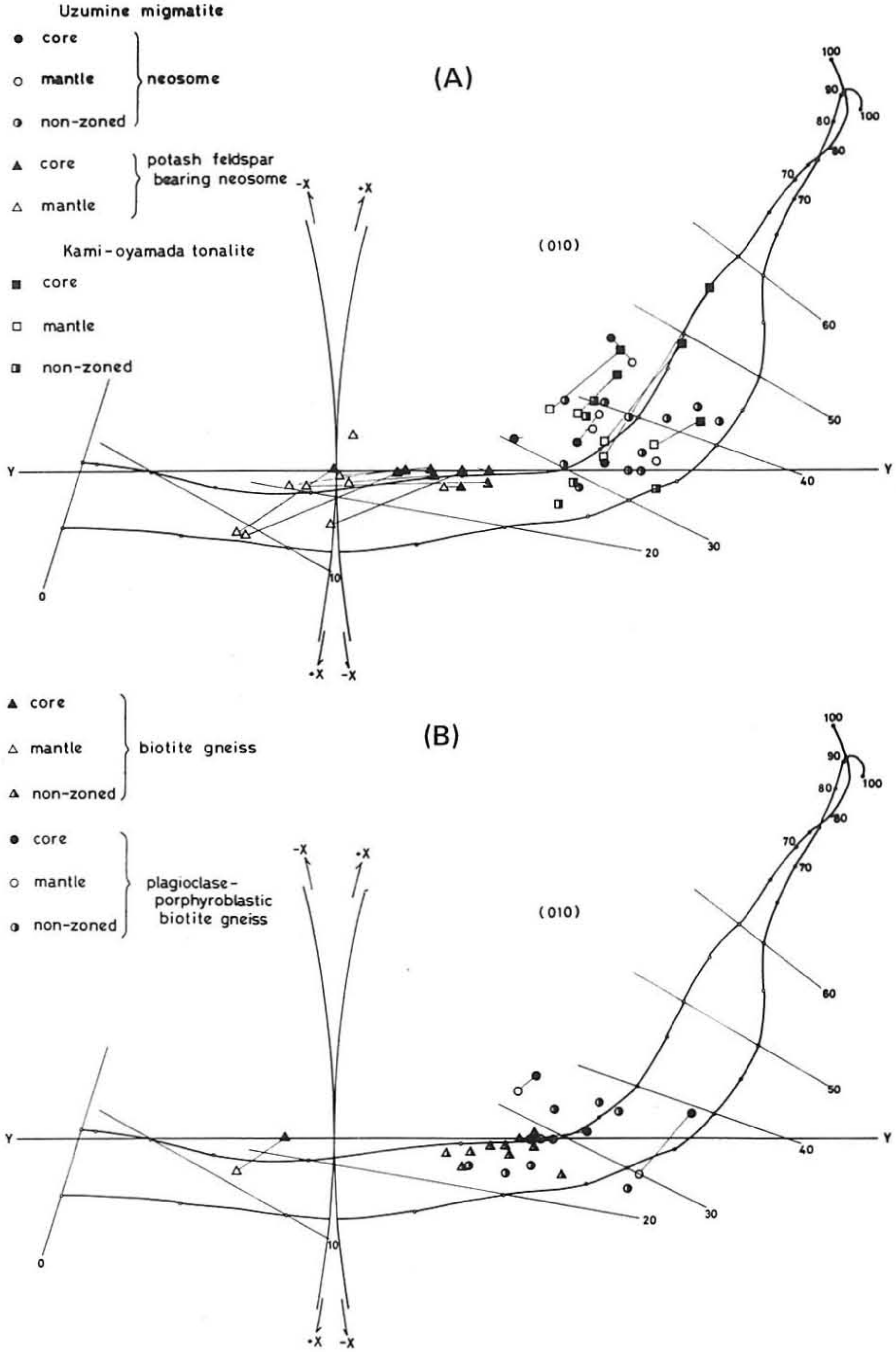
The main mineral assemblage of the neosome is plagioclase-quartz and biotite with sphene, zircon, apatite, amphibole, garnet and opaques as accessories. Their modal composition is given in Figure 4. Plagioclase is the main constituent mineral of this rock and its modal ratio often exceeds 50%. It presents a hypidiomorphic habit with rounded outline and its crystal size is about 1–4mm × 0.5–2 mm. Zonal structure is commonly weak or



Text-Figure 4 Volumetric proportion of constituent minerals in the migmatite, tonalite and granites. Q: quartz, Pl: plagioclase, Kf: potash feldspar, Mf: biotite and hornblende

absent but in some specimens it is rather clear. The An-content ranges from An 22% to An 27% in the core and from An 9% to An 24% in the mantle. Projections of values corresponding to some of their optical constants on the migration curve of Burri *et al.* (1967) show that points representing the core tend to fall near the low-temperature curve while those representing the mantle are near the high-temperature curve (Fig. 5-A). Samples containing plagioclase individuals in which the twinning plane is bent or slightly dislocated are often found (Pl. 4, Fig. 1) In these specimens quartz grains show intense wavy extinction or blocky extinction. These fractures indicate that some tectonic movements took place after the formation but before consolidation of the migmatite. Xenomorphic, irregular shaped quartz, is filling up interspaces among plagioclase crystals. Its crystal size varies between 0.5–3 mm; wavy extinction is notable and often blocky extinction is also observed. Biotite is hypidiomorphic flaky with 0.5–1 mm in size and reddish brown in colour. Preferential arrangement of biotite is rather weak in those areas where coarse plagioclase is abundant. However, a fairly distinct parallel arrangement of biotite is still retained in fine-grained parts. Minor amounts of potash feldspar are found in every specimen as accessory, but in one extreme case microclinic potash feldspar exceeds 20% in modal ratio forming poeciloblastic crystals. The optical angle of these microclinic potash feldspars is $2Vx=62^\circ-78^\circ$.

The palaeosome materials present various sizes from a few centimeters to several tens of meters. These last, which could be called xenoblocks, are known to occur around the summit of Mt. Uzumine and show similar features to the amphibole schist belonging to the Gozaisho schist. Besides them, a xenoblock showing peculiar lithofacies of plagioclase porphyroblastic gneiss with migmatitic features is known in the vicinity of Ogura village. The gneiss is sandwiched between small serpentinite bodies. The rock is characterized by a large amount of plagioclase porphyroblasts of rather idiomorphic appearance (Pl. 3, Fig. 1). The mineral assemblage of this rock is plagioclase-quartz-biotite and minor amount of microclinic



Text-Figure 5 Projection of optical constants of plagioclases of the migmatite and the tonalite on the Burri *et al.*'s migration curve.

(A): the Uzumine migmatite and the Kami-oyamada tonalite.

(B): the palaeosome materials and plagioclase porphyroblastic biotite gneiss in the Uzumine migmatite.

potash feldspar as an accessory. The plagioclases attain about 2 mm x 5 mm in size and have preferential orientation parallel to the elongation of the xenoblock. Zoning is very weak; the An-content is An 14–39% in the core and An 14–37% in the mantle (Fig. 5–B). Bending and dislocation of twinning planes is common. Quartz with strong wavy or blocky extinction fills up interspaces between plagioclases. Recrystallization of quartz grains is recognized at places showing little mylonitic features (Pl. 4, Fig. 2). Reddish biotite flakes are arranged along the contact planes of blastic plagioclases. Allanite, zircon, apatite and opaques accompany the main minerals.

The rock has been described as the older granite by Kondo (1955) and as the older schistose granodiorite by Ogura (1958). However the above-described features prove that the rock is suitable to be considered as a migmatite and the writers assign to it the new name of Uzumine migmatite in this paper.

Kami-oyamada tonalite

A fine to medium-grained rather melanocratic tonalite with a distinct flow structure is intruded at the southern base of Mt. Uzumine where it forms a comparatively small mass. Its flow structure extends parallel to the direction of the Uzumine-Sengosawa zone; it plunges towards the west in the eastern half of the intrusive mass and to the east in the western half.

Although this rock has been described as belonging to the same granitic mass here referred as the Uzumine migmatite under the names of older granite (Kondo, 1955) and older schistose granodiorite (Ogura, 1958), its structure, mineral assemblage and lack of gneiss and schist relics prove that this rock constitutes an intrusive body independent from the Uzumine migmatite. Therefore the writers have named it as the Kami-oyamada tonalite in this paper.

The rock consists of an assemblage of hornblende-biotite-potash feldspar-quartz and plagioclase. Quartz is xenomorphic and shows intense wavy extinction; its crystal size varies from 0.4 mm to 3 mm. It fills up interspaces between crystals of plagioclase, biotite and hornblende. Plagioclase is hypidiomorphic with a crystal size of 1.4–2.2 mm x 0.5–1.0 mm; zonal structure is distinct but the difference in An-content between core and mantle is not too intense with a core An 25–55% and a mantle An 25–40% as shown in Figure 5–A. In some crystals bending and dislocation are evident. Biotite is dark reddish brown and about 1.5 mm x 0.4 mm in size; its preferential arrangement is fairly distinct. Hornblende is xenomorphic to hypidiomorphic with pleochroism of X=pale yellowish green, Y=pale greenish brown, Z=brownish green. Other optical constants are: $2Vx=51°–64°$ $c\Lambda Z=11.5°–17°$. It frequently contains sphene, allanite and opaques.

The bending and dislocation observed in plagioclases together with the strong wavy extinction of quartz crystals let to conclude that a tectonic movement took place before the consolidaion of the rock. In addition to this it is worth-while mentioning that Ogura (1958) has described pink coloured biotite granites with mylonitic structure which are aligned in a N-S trend as spindle-shaped small bodies in the middle part of this tonalite. These pink coloured biotite granites can be regarded as an intensively sheared lithofacies of the tonalite, and as an indication that notable tectonic movements took place after the intrusion of this body but before the consolidation of it all this resulting in the generation of this sheared lithofacies.

Ishikawa granite

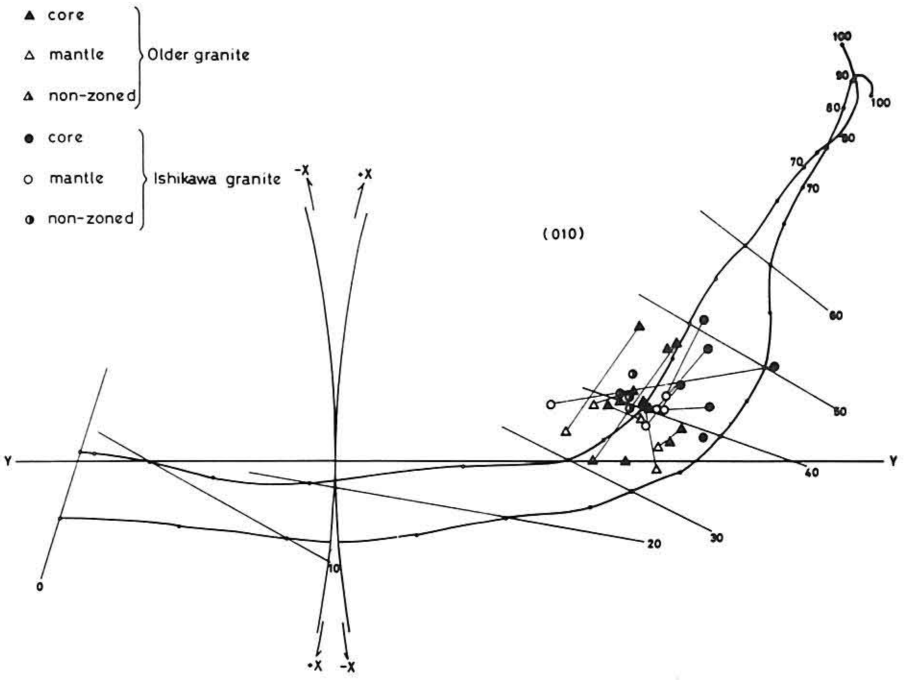
A coarse-grained quartzdiorite called the Ishikawa granite is intruded between the Gampohji gneiss and the Yazukuri schist, although for a long distance the granite is separated from the Gozaisho schist by a two-mica granite of dyke form. The Ishikawa granite is intruded in harmonic relation to the basement Gampohji gneiss, and it shows a half dome structure together with the gneiss in this area, and the granite give the thermal effect to the Yazukuri schist with 10–20 m width along contact zone forming coarsening the grain-size of the constituent minerals and veined greiss-like appearance to the latter. The granite extends further south beyond the mapped region as far as the surroundings of Hanawa Town, approximately 30 km to the south, where it has a N-S trend and appears as club-shaped mass according to the Geological map of Fukushima Prefecture (1962) and Maruyama (1970).

The granite is coarse-grained, has a rather melanocratic appearance and a distinct flow structure. Large idiomorphic amphibole crystals characterize the granite and a considerable amount of basic enclaves are present. The rock is made up of an assemblage of biotite-hornblende-quartz and plagioclase and shows an almost homogeneous lithofacies all over the region. The modal value of total mafic minerals exceeds 20% and the amount of hornblende predominates over that found in other granitic rocks in this region. Plagioclase makes about 47–57% in modal ratio and this amount is also much higher than in other granitic rocks of the area (Table 1). Quartz is xenomorphic, irregular in shape and with a variable size of 0.2 mm x 0.2–1 mm. It fills up interspaces between other constituent minerals though often small grains are contained in big hornblende crystals. Plagioclase is hypidiomorphic with 1 mm x 2 mm as the most usual size; oscillatory zoning is common and its An-content in the core is An 40–52% while that in the mantle is An 37–42%. The plots of optical parameters on the migration curve concentrate around the low-temperature curve and in the middle field to the high-temperature one (Fig. 6). Preferential arrangement parallel to the flow structure of the rock is evident. Biotite is dark brown with 2 mm x 4 mm as maximum size. Several flakes are usually concentrated together with hornblende forming a flow structure. Hornblende developes up to 3 mm x 6 mm in size with idiomorphic habit and poecilitically contains small crystals of plagioclase, quartz and biotite. Its pleochroism is X=light green to pale brown, Y=greenish brown, Z=deep greenish brown. Other optical constant are: $2Vx=49°–65°$, $c\Lambda Z=11°–20°$. Orthoclase, epidote, sphene, zircon, apatite and opaques are accessories.

Older granite

The older granite occupies the northern half of this area and is intruded by the younger granite (the Miharu and the Ronden granite) and the two-mica granite. This type of granite builds up a vast massif extending towards the north. The region being described corresponds to the southwestern margin of this huge massif.

The rock is medium-grained and bluish gray in fresh outcrops with a weak, but always



Text-Figure 6 Projection of optical constants of plagioclases of the Ishikawa and the older granites on the Burri *et al.*'s migration curve.

visible, flow structure. The flow structure can be roughly traced following a N-S trend with some degree of undulation. The predominant lithofacies is quartzdioritic but in the western part, facing the River Abukuma, it changes to granodioritic nature. Transition between these lithofacies is quite gradual.

The mineral assemblage of the granite is hornblende-biotite-potash feldspar-quartz and plagioclase. The modal ratio of hornblende ranges from 2.1–6.5%, but in specimens near basic enclaves its content increases up to 11.2%. Modal ratio of potash feldspar is about 1.2–2.8% in quartzdioritic rocks but in granodioritic ones it increases up to about 17–27% (Table 1). Some amount of variation in the modal ratio is also observed in quartz, plagioclase and biotite according to the variation in lithofacies. Grain size of constituent minerals is variable in one specimen and also in the extent of a thin section. Mylonitic or fracture features are observable not only in one specimen collected from the vicinity of the mylonite zone but in several specimens found in more western areas. Remarkable wavy extinction, crushing and recrystallization are seen in quartz grains and bending and dislocation of crystals are evident in plagioclase and biotite from these specimens (Pl. 5, Fig. 1).

Though every main constituent mineral shows xenomorphic to hypidiomorphic features, plagioclase presents rather idiomorphic prismatic form with 2.0 mm × 3.2 mm as maximum size. Zoning is distinct and partially oscillatory, and the composition is An 33–46% in the core and An 31–46% in the mantle with minor differences existing from core to mantle (Fig. 6). Orthoclase with partial microclinic features is intersticial and has 2Vx=60°–74°. Biotite is brown to dark brown and shows a tendency to associate with hornblende, sphene and opaques to form zones of mafic minerals concentration. Hornblende developes as coarse crystals with 2.3 mm x 4 mm as maximum size and with pleochroism X=pale brown, Y=brownish green, Z=deep brownish green to deep greenish brown. Other optical constants are: 2Vx=58°–70°, $c \wedge Z$=7°–19°. Sphene, allanite, zircon, apatite and opaques are accessories.

Miharu granite

The Miharu granite intrudes irregularly the older granite in the northern half of the region. Its outcrops continue beyond the region towards the north and form a considerably larger mass extending in a north-south direction. The rock is evidently intruded by the potash feldspar porphyritic two-mica granite, in the southern part of Yogiashi village. Several xenoblocks of limestone, amphibole schist and pelitic schist in various sizes are enclosed accompanied by fracture line passing through Yogiashi and the west of Miharu Town. All of these xenoblocks, except for limestone, are fractured or strongly bent. Although their detailed occurrence could not be studied because of deep weathering, their concentrated occurrence on this zone indicates that the Uzumine-Sengosawa zone extends as far as this region. Small amounts of basic enclaves are commonly present in this granite, although these basic enclaves are ordinarily lacking in other younger granites in Abukuma terrain.

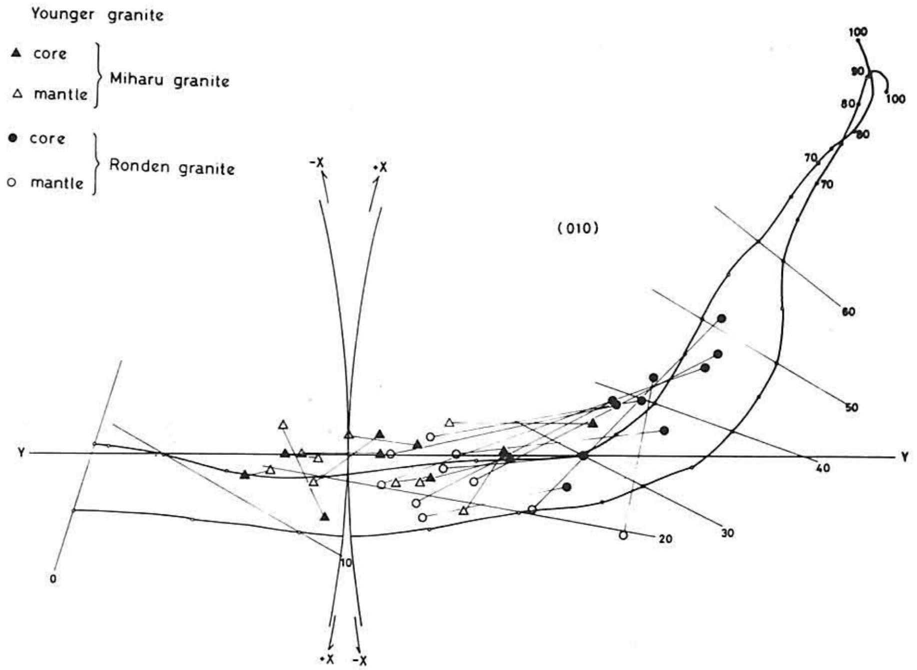
Two types of lithofacies are distinguished in this mass; biotite granite or granodiorite and potash feldspar porphyritic biotite granite. Porphyritic potash feldspars are pale pink orthoclase showing partial microclinic features and idiomorphic habit and having a size of 1.0 cm x 2.5 cm. The main mineral assemblage is (hornblende)-biotite-potash feldspar-quartz and plagioclase in the two above-mentioned facies. The modal value of potash feldspar varies strongly even in non-porphyritic facies. The mode of quartz is also variable from one specimen to another while that of plagioclase is rather constant (Table 1). Mylonitic or sheared features are discernible with different degrees of intensity in almost every specimen, and they are reflected in quartz and plagioclase as a dislocation or recrystallization of the crystals (Pl. 5, Fig. 2). Quartz commonly shows a sutured texture and intense wavy extinction and its grain size is extremely variable. Apart from these sheared specimens, quartz in rocks free from tectonic deformation has rounded blastic shape with 3.5 mm x 4 mm as maximum size. In such crystals wavy extinction is weak. Plagioclase presents a xenomorphic to hypidiomorphic habit with sutured boundaries with quartz. Zoning is evident with composition An 15–35% in the core and An 17–28% in the mantle (Fig. 7). Defromation and fracture is also common in plagioclase. Biotite is dark brown and bending of the flakes is clearly observed. Potash feldspar is orthoclase with partial microclinic features even in individual; the optic angle is 2Vx=56°–64°. The volume of potash feldspar increases with the extent of deformation. Rather fresh hypidiomorphic hornblende is found in some specimens and deformational effects are absent in these crystals. Sphene, garnet, apatite, zircon and opaques are accessories.

	Sample no.	Qz	Pl	Kf	Bio	Mus	Hb	Others	Total
Uzumine migmatite	369-b-1	32.1	29.1	2.3	35.2			1.3	100.0
	369-b-2	47.2	32.9	0.3	19.1			0.5	100.0
	369-a-2	30.4	48.2	0.3	20.2			0.9	100.0
	369-a	35.9	51.4	0.3	12.4			Tr.	100.0
	1012a	17.7	51.0	10.3	20.2			0.8	100.0
	1012b	22.2	36.2	21.0	7.1	(Ga. 11.2)		2.3	100.0
	753a	38.7	51.2	0.2	0.2		9.1	0.6	100.0
	753b	17.3	45.6	0.2	33.3	0.3	1.0	2.3	100.0
	365a	23.4	55.9	0.5	19.0		0.1	1.1	100.0
	753c-a	35.2	43.6	0.1	19.8		0.3	1.0	100.0
	753c-b	29.9	46.2		20.4	0.1	2.5	0.9	100.0
	369c	39.7	45.0	0.1	14.4			0.8	100.0
Kami-oyamada tonalite	876-a	27.6	44.9	2.3	15.0	0.4	8.8	1.0	100.0
	1052	18.5	52.4	4.5	12.3		11.5	0.8	100.0
	1101	22.9	47.8	1.7	18.4		8.5	0.7	100.0
	370	17.9	50.2	1.3	17.6		11.2	1.8	100.0
	1027	24.8	49.0	9.3	10.8	0.2	2.1	3.8	100.0
	1026	21.9	48.3	1.5	15.8	1.6	9.6	1.3	100.0
	1056	25.2	46.0	2.2	18.7	5.4	0.7	1.8	100.0
Gampohji gneiss	506T	68.7	13.7	1.1	12.4	1.5		2.6	100.0
	509	74.8	12.6	0.1	11.4	1.0		0.1	100.0
	1073	71.4	10.1	1.4	15.7	0.8		0.6	100.0
	367	57.5	21.0		0.2		21.3	Tr.	100.0
	Kodaka-1	44.4	23.3	0.1	17.8	11.0		3.4	100.0
Ishikawa granite	1094	16.6	57.3	0.6	11.5		13.2	0.8	100.0
	1083	16.6	52.2		14.2		15.3	1.7	100.0
	501014	16.9	56.4	0.8	14.6		10.3	1.0	100.0
	Ta-3	27.1	42.8	7.6	11.8	0.7	9.3	0.7	100.0
	Tc	25.9	47.4	0.8	18.1		6.2	1.6	100.0
	502H	18.8	51.4	3.5	15.8	0.2	8.7	1.6	100.0
Older granite	599	27.4	46.9	2.8	15.6	0.1	6.8	0.4	100.0
	655	25.1	47.4	8.8	13.5		4.6	0.6	100.0
	636	28.2	47.5	3.8	14.5		5.6	0.4	100.0
	696	25.2	48.1	10.4	10.7	0.1	5.5	Tr.	100.0
	658	29.1	46.5	1.5	19.4	0.3	2.3	0.9	100.0
	665	28.1	38.5	17.0	12.5	0.1	2.1	1.7	100.0
	645	20.4	47.5	6.7	14.4	0.2	10.0	0.8	100.0
	664	21.0	37.2	27.3	10.0		2.9	1.6	100.0
	568	24.4	57.1	3.4	14.1		0.1	0.9	100.0
	824	33.2	46.5	12.6	7.3			0.4	100.0
	611	40.6	48.1	4.0	7.1			0.2	100.0
	360	37.3	45.9	4.7	10.2	0.3		1.6	100.0
	612	29.2	49.1	0.7	19.2	0.1		1.7	100.0
	816	25.5	62.5	8.5	1.2		1.7	0.6	100.0
	1071	32.3	56.4	3.5	7.5			0.3	100.0

	Sample no.	Qz	Pl	Kf	Bio	Mus	Hb	Others	Total
Miharu granite	683-b	26.5	63.2	2.5	7.4			0.4	100.0
	194	40.6	33.0	18.8	7.6			Tr.	100.0
	653	34.9	48.4	6.7	8.9	0.9		0.2	100.0
	615-a	50.6	32.8	3.7	12.7			0.2	100.0
	701	41.0	35.3	16.5	6.6			0.6	100.0
	232	20.4	47.7	22.0	6.8		2.2	0.9	100.0
	608	29.0	35.0	28.4	7.0			0.6	100.0
	639	34.3	37.5	17.0	10.0	0.1	1.0	0.1	100.0
	640	24.9	35.7	21.7	15.9		0.2	1.6	100.0
Ronden granite	1010	26.8	42.1	9.8	12.0		8.7	0.6	100.0
	1030	30.2	39.7	13.7	11.6		3.5	1.3	100.0
	581	33.7	42.9	10.6	12.5			0.3	100.0
	1051	26.6	51.6	9.3	12.1			0.4	100.0
	1050	28.4	46.0	14.5	9.6			1.5	100.0
	1113	28.6	52.3	12.1	5.1	1.2		0.7	100.0
	833	27.3	42.5	19.0	8.4	1.1		1.7	100.0
	861	21.2	60.4	4.5	10.7		2.2	1.0	100.0
Two-mica granite	1029a	31.7	39.2	23.3	2.5	3.3		Tr.	100.0
	1029-b	32.5	35.6	23.3	5.4	3.2		Tr.	100.0
	362-4-a	20.0	23.1	48.8	5.2	1.3		1.6	100.0
	Yezo-W	36.8	31.2	22.0	3.8	6.2		Tr.	100.0
	362-4-b	12.4	24.5	54.0	5.2	2.2		1.7	100.0
	1013	41.7	39.8	11.4	5.1	1.8		0.2	100.0
	504H	32.3	38.2	12.9	2.9	13.5		0.2	100.0
	1002	37.1	39.9	17.5	0.9	4.5		0.1	100.0
	362-3	37.8	43.7	12.2	2.6	3.7		Tr.	100.0
	1019	30.2	36.0	28.1	3.9	0.8		1.0	100.0
	515T	32.7	41.6	19.7	0.8	5.1		0.1	100.0
	1000	31.5	39.1	18.4	6.7	3.2		1.1	100.0

Table 1 Modal values of each lithofacies.

Qz: Quartz
Pl: Plagioclase
Kf: Potash feldspar
Bio: Biotite
Mus: Muscovite
Hb: Hornblende
Ga: Garnet

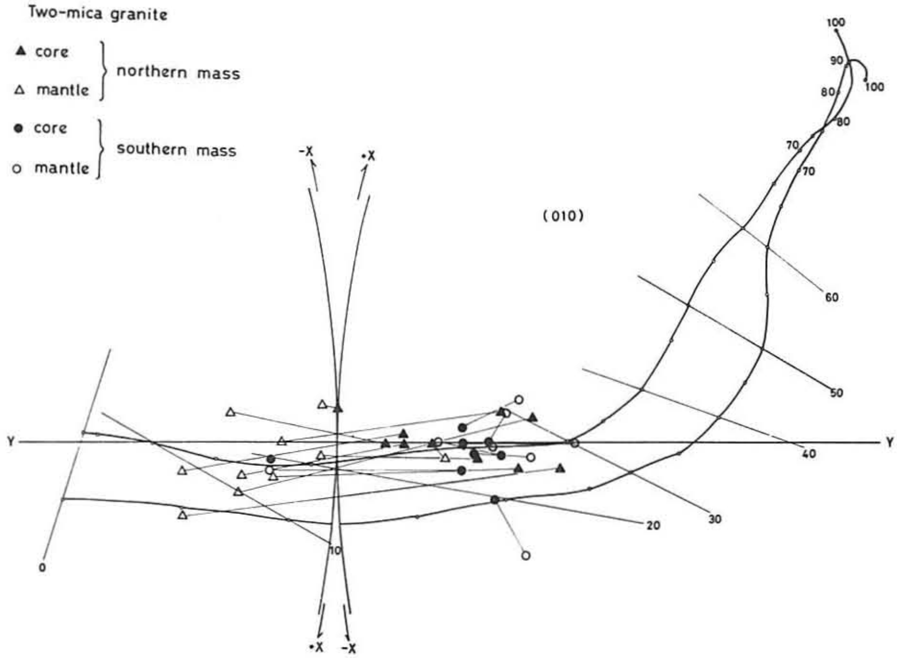


Text-Figure 7 Projection of optical constants of plagioclases of the Miharu and the Ronden granites on the Burri *et al.*'s migration curve.

Ronden granite

The Ronden granite occupies the southeastern part of the region building up the mountainous highland including Mt. Yezo-dake, Mt. Higashiyama and Mt. Yomogida-dake. The Ronden granite intrudes the older granite and is clearly intruded by the two-mica granite. The granite is medium-grained and has a leucocratic appearance with porphyritic plagioclase as a rather uniform lithologic feature within the whole extent of the mass. Characteristically idiomorphic crystals of sphene, 8–10 mm in size, are found along the western boundary zone with the two-mica granite. These crystals are concentrated along cracks and joint-walls. An intense mylonite zone crosses along its eastern boundary. Constituent minerals in the rock along this zone have been deformed and broken in variable extent and in the extreme case they are crushed into powder-like fragments. Recrystallized quartz showing strong wavy extinction and sutured texture commonly fills up the interspaces between the constituent minerals (Pl. 5, Fig. 3).

The rock includes granitic to granodioritic lithofacies with an assemblage of (hornblende)-biotite-potash feldspar-quartz and plagioclase. The modal ratio of this rock is fairly constant, except for hornblende which appears in some specimens up to a content of 8.7% (Table 1). Quartz is xenomorphic with irregular shape and variable size averaging about 0.6 mm x 0.6 mm; wavy extinction is common. Plagioclase has hypidiomorphic to idiomorphic habit and shows porphyritic features. Oscillatory zoning is usually in every crystal and the maximum grain size is 4.5 mm x 2.8 mm. The composition is An 25–51% in



Text-Figure 8 Projection of optical constants of plagioclases of the two-mica granite on the Burri *et al.*'s migration curve.

the core and An 18–25% in the mantle. Difference in composition from core to mantle is considerably large (Fig. 7). Potash feldspar is orthoclase of poeciloblastic nature with 2Vx=62°–80°. It has been observed that the granites that suffered shearing effects tend to contain a larger amount of potash feldspar. Reddish brown to dark brown biotite occurs sporadically. Hornblende is hypidiomorphic with pleochroism X=pale brown, Y=brownish green, Z=dark brownish green. Other optical constants are: 2Vx=48°–56°, c∧Z=3°–18°. Epidote, muscovite, sphene, zircon, apatite, garnet and opaques are accessories.

Two-mica granite

Two masses of two-mica granite are intruded in the Uzumine-Sengosawa zone. The southern mass – with a dyke form and a N-S trend – intrudes the Gozaisho schists, the Ishikawa and the Ronden granites. Numerous pegmatites of various sizes accompany the main intrusive. On the contrary, the northern mass formes a massive body with a N-S elongated trend and intrudes the Uzumine migmatite, the Kami-oyamada tonalite, the older granite and the Miharu granite. The rock is characterized by gigantic porphyroblasts of potash feldspar, some of which exhibit distinct zonal structure (Pl. 5, Fig. 4). A detailed description of the zonation in this potash feldspar will be given in a forthcoming paper.

Both masses of two-mica granite present a rather aplitic texture characterized by an assemblage of muscovite-biotite-potash feldspar-quartz and plagioclase. Reddish garnet is commonly found as accessory. The modal values of quartz and plagioclase are almost equivalent while that of potash feldspar obviously differs between the northern and southern mass (Table 1). Quartz is xenomorphic and irregular in shape and often several crystals form a single blastic train with size about 0.8 mm x 0.8 mm. Wavy extinction is considerably strong. A great quantity of rounded shaped, small grains, with 0.1 mm x 0.1 mm in size are included in plagioclase and are arranged in its margin forming a zonal structure. Hypidiomorphic, rarely idiomorphic, plagioclase shows a clear zonal structure in which the core is dusty or is replaced by muscovite. The composition is An 23–31% in the core and An 5–24% in the mantle for the northern mass, and An 20–27% in the core and An 16–24% in the mantle for the southern mass (Fig. 8). Crystal size is commonly 0.4 mm x 0.4 mm. Potash feldspar consists of orthoclase and microcline. The optic angle is 2Vx=72°–80°. The porphyritic potash feldspar in the northern mass often shows a poeciloblastic nature containing numerous fine plagioclase and biotite crystals which are arranged in a concentric way; a zonal structure is thus outlined in the host crystal. The optic angle is 2Vx=60°–64°. Biotite is reddish brown, muscovite is present in small fresh flakes either as primary constituent or as a secondary mineral in the core of plagioclases and along its cleavages. Garnet, apatite and opaques are accessories.

Discussion

The conspicuous contrasting compostion of the original material between the Takanuki and the Gazaisho metamorphic rocks has been well-known since Koto's description, at the beginning of the geological study of the region. The existence of various opinions about the stages of metamorphism in both metamorphic units has been mentioned in a previous chapter. Although the contrast of the original materials in this terrain is one of the common ways to separate the metamorphic rocks into both members, there exist many practical instances where this creterion cannot be applied. This is particularly the case in the proximity of the boundary line between the two members where difficulties to distinguish one from the other are extremely great. Therefore the problem where to stablish the boundary line between both metamorphic units in the Takanuki-Gozaisho region has remained as a debatable question even in the type localities of both metamorphic rocks. Naturally, it admits a further discussion concerning the problem to which members belong the metamorphic rocks found in the Uzumine-Sengosawa region. The pelitic schists exposed around the Sengosawa dam site extend further towards the south and form a large mass (Uchiyama, 1977). The schists exhibit features of a high grade metamorphic rock often a gneissic appearance; they commonly contain abundant porphyritic alumino-silicate minerals. The existence of two sets of linear structures with oblique intersection, the parallel arrangement of the minerals and the undulation of the schistosity are characteristic of the schists in this place. These features indicate that the schists formed from previously existing metamorphic rocks through different tectonic movements even in this small region. Based on these reasons, one of the authors (Uchiyama), considered these schists as an uplifted body of the basement rocks in spite of the fact that Kano *et al.* (1973) regarded it as belonging to the Gozaisho member. Uchiyama (1977) named it as the Yazukuri type schist after the type locality of this rock around Yazukuri village located in a district south from the region described in this paper.

As to the detailed description of the Yazukuri schist, Uchiyama will present it in a futrue paper. On the contrary, the schist found around the western foot of Mt. Yezo-dake could be regarded as belonging to the Gozaisho member from their composition and texture. The predominant rock is an amphibole-rich schist with minor amounts of intercalated pelitic schist; the texture of the amphibole schist is uniformely granoblastic. In the Gozaisho district the texture of the amphibole schist is also granoblastic in the vicinity of the boundary line with the Takanuki metamorphic rocks although most of the Gozaisho schists show lepidoblastic texture (Uchiyama, 1977; Inokuchi, 1977; Machida, 1978). On account of the same reasons many amphibole schists found as xenoblocks in granites of the Uzumine-Sengosawa zone could also be regarded as derived from the Gozaisho member. Kondo (1955) reported a cordierite-sillimanite-andalusite-biotite gneiss from the north of Mt. Uzumine, and concluded that the rock was regenerated from biotite gneiss by poly-metamorphism due to intrusion of the younger granite. The younger granite referred to by Kondo might correspond to a two-mica granite described in this paper on account of the location of his description, although the writers have not yet found a gneiss with such a mineral assemblage in this area. However, from our present knowledge, Kondo's conclusion about the two-mica granite seems unacceptable because this last intruded in the latest stage of plutonic activity in this zone, later than the intrusion of the granodiotite (the younger granite in this paper) and intimately related to the formation of pegmatites as will be referred later. It may be estimated that the granite had not so high a potentiality to produce a metamorphic rock yielding sillimanite and andalusite on the country rock. This estimation is supported by the fact that in all places where the two-mica granite is seen intruding schists no thermal contact effects have ever been detected. The gneiss mentioned by Kondo has possibly derived from the Yazukuri schist or is a gneiss belonging to the Takanuki metamorphic rocks.

A similar sillimanite-biotite gneiss has been collected by us from northeast of Mt. Uzumine being caught in a shear zone in older granite and it can be concluded that the gneiss is derived from a Takanuki member or a Yazukuri one.

In the Uzumine migmatite, both amphibole schists and biotite gneisses are involved as xenoblocks and palaeosome materials with agmatitic or schollen structure, and they are considered as derived from the Gozaisho member and the Takanuki member respectively. The amphibole schists are abundantly found in the eastern part of the migmatite outcrop as briefly mentioned while the gneisses are generally present in the western part of the migmatite.

This mixed mode of occurrence of the basement rocks, that is, the Yazukuri and the Takanuki member and the Gozaisho member along narrow zones in the form of small xenoblocks and/or larger masses as mentioned above implies that the zone is a large fracture zone. Considering the fact that the Gampohji gneiss, the basement rock of the Gozaisho metamorphic rocks, is distributed west of this fracture zone beyond the Ishikawa granite mass, this fracture zone separates the Takanuki metamorphic rocks and the Gozaisho ones enclosing fragmental blocks of both members. Based on these reasons the writers concluded that the Uzumine-Sengosawa zone constitutes a distinct structural belt, not merely a fracture zone, and, consequently, propose the name of "Uzumine-Sengosawa Structural Belt" to nominate it.

Three epochs of plutonic activity took place in this structural belt. The first is represented by the formation of the Uzumine migmatite, and was followed by the intrusion of the Kami-oyamada tonalite. Two separate bodies of two-mica granite intruded at the latest stage.

The Uzumine migmatite mass we are now considering was described as schistose granodiorite intruded in the older stage by Ogura (1958) and as the older granite by Kondo (1955). Although the quality of the outcrops is poor and sufficient observation is impossible on account of the intense deep weathering in this destrict, the migmatite contains many palaeosome materials of pelitic schists, amphibole schists and biotite gneisses, and has a tonalitic or trondhjemitic nature containing characteristically large garnet porphyroblasts. This migmatitic nature is not compatible with that of the older or the younger granites in the Abukuma terrain, especially the occurrence of garnet porphyroblasts is characteristic restrictedly in rocks of migmatitic origin in this terrain. The boundary between palaeosome material and neosome in this migmatite is commonly irregular and the former often shows features characteristic of an injection gneiss. In some cases numerous agmatitic blocks of schist of different sizes are contained in a trondhjemitic neosome, a restricted metasomatic reaction between both lithofacies has taken place in these cases. Most of the neosome is trondhjemitic to tonalitic but some extreme specimens contain large potash feldspar of poeciloblastic nature and their modal ratio exceed 10% (Table 1). It is noteworthy that many palaeosome blocks of large size have their schistosity arranged in a N20° – 35°E direction although the structural belt as a whole extends roughly with a N-S or a NNW-SSE trend.

In a slight contrast to that, plagioclase porphyroblastic gneiss with gneissosity in a N10° – 20°W direction is involved in the migmatite at Ogura village. The outcrop of this gneiss extends for about 30 m in width and is sandwiched between two small serpentinite masses with a N-S trend (Fig. 1). Among many palaeosome materials or blocks in the migmatite such plagioclase porphyroblastic one is only limitedly observed at Ogura village. In the Abukuma terrain a similar plagioclase porphyroblastic schist or gneiss is only known up to now at the Takaboyama and Hitachi districts (Watanabe, *et al.* 1978) and there the rock in intimately related with the formation of diaphthorite (Watanabe, personal communication). Therefore the writers consider that this rock has been possibly formed through slightly different processes than those which generated the palaeosome materials abundantly present in the migmatite.

The mode of zonation of the plagioclases in the Kami-oyamada tonalite is characteristic. Some plagioclases show a very weak zonation or a complate lack of this feature, nevertheless most of the plagioclases are clearly zoned with a gradual transition from core to mantle. An-compositions, even in zoned plagioclases, differ only in minor amounts from core to mantle. Kim and Hunahashi (1972), after examination of plagioclases of various origins, pointed out that plagioclases in the Precambrian granite generally lack zonation and that the zonation model become more complicated in those granites formed in a younger age; this tendency is specially.distinct in migmatites and tonalitic rocks. According to this conclusion, the features observed in plagioclases from the Kami-oyamada tonalite imply an intimate relationship between the tonalite and the Uzumine migmatite.

Two large masses of two-mica granite intruded north and south of the Uzumine migmatite and the Kami-oyamada tonalite in this belt. The northern intrusion is a large massive body characterized by gigantic potash feldspar crystals. The southern mass intruded the schists parallel or subparallel in relation to their fabric and was accompanied by many pegmatitic veins. These two-mica granites clearly intruded the Ronden granodiorite mass, and based on that fact, it is concluded that their intrusion took place in the latest stage of plutonic activity in this region. According to Yashima (parsonal communication), two-mica granites are known to appear with an interspersed distribution and a NNE-SSW trend along the western side of the Abukuma terrain facing the Nakadohri district, and they are intimately related to locarities of pegmatite swarms (Fig. 9). Looking from the geologic construction of the Abukuma terrain, the row of the two-mica granite bodies is crossed obliquely the Uzumine-Sengosawa structural belt although the two-mica granites intruded in harmonic relation with the trend of the structural belt in this Uzumine-Sengosawa region.

The existence of many plutonic masses of various stages along this narrow belt signifies that the plutonic activity took place repreatedly along the belt from the early stage of migmatization up to the latest stage of intrusion of the two-mica granites and pegmatites. The difference in the trends between the structural belt and the row of the two-mica granites, as mentioned above, implies that the plutonic activity in the later stage took place under a different tectonic control as compared with that of earlier stages.

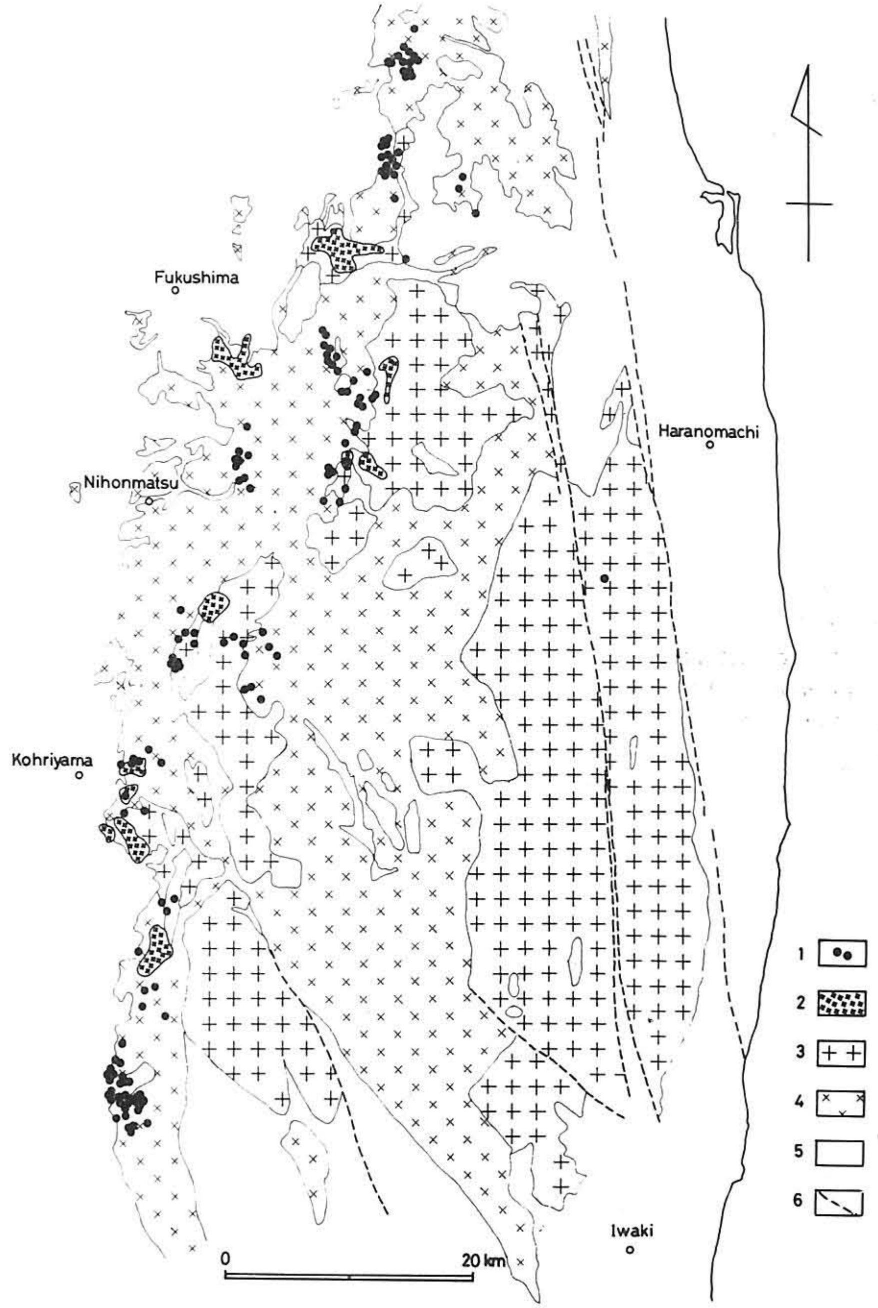
Watanabe *et al.* (1978) pointed out the following four phenomena as distinctive features of the Koshidai-Takaboyama-Daioh•in structural belt:

a) Basement rocks or diaphthoritic bodies are observed within the belt or along its extension line.
b) Plutonic activity took place along this structural belt and various products of it are found in the belt, among them mylonitic granite, metasomatic gabbro, granophyre, trondhjemite, tonalite etc.
c) Existence of metasomatic processes can be proved by the presence of alumino-silicate minerals bearing diaphthorites.
d) Ore mineralization of various kinds and scale took place and related alteration can be observed.

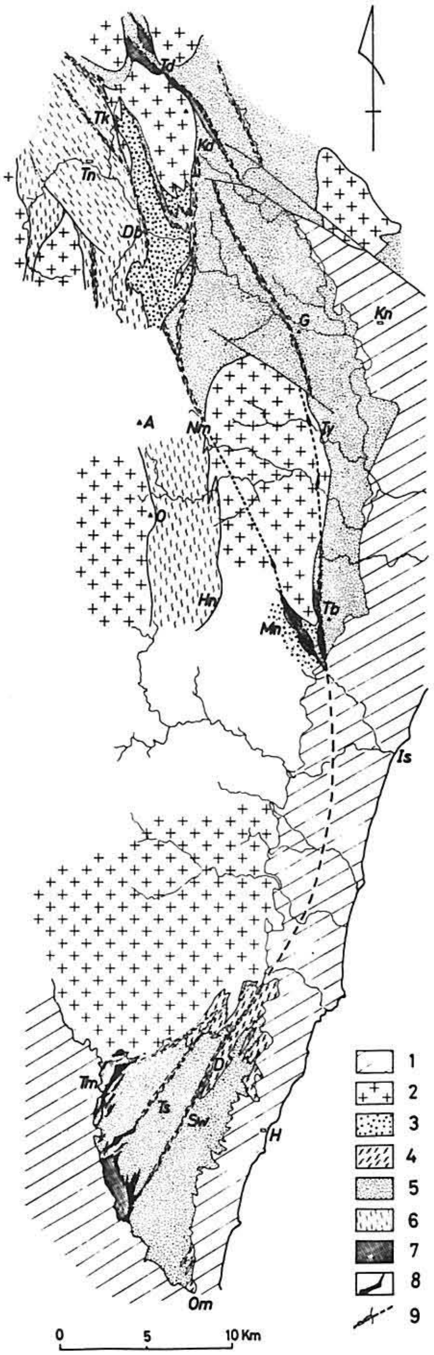
They mentioned that all of these phenomena were not always present at every studied region on the structural belt, but a combination of some of them could be observed in every region.

When examining the Uzumine-Sengosawa structural belt using the above listed criteria an equivalent nature between this structural belt and the Koshidai-Takaboyama-Daioh•in structural belt can be stated based on the following facts.

a) The Yazukuri schist is a basement rock deformed and recrystallized through uplift in the stage of the formation of the structural belt. Besides this, there are also some blocks or fragments of the basement rock in the Uzumine migmatite and in the older granite in the structural belt.
b) As to the products of plutonic activity which took place in this structural belt, the Uzumine migmatite and the Kami-oyamada tonalite can be mentioned. The two-mica granites represent the products of the latest stage, which intruded under a



Text-Figure 9 Distribution of two-mica granites and pegmatites in the Abukuma Plateau. The map is modified from the map given by the Nakadohri Collaborating Research Group (in Minato *et al.*, 1979). 1: pegmatite, 2: two-mica granite, 3: the older granite, 4: the younger granite, 5: metamorphics and Tertiary and Quaternary deposits, 6: sheared zone.



Text-Figure 10 Geologic sketch map of the Koshidai-Takaboyama-Daioh-in structural belt. After Watanabe *et al.* (1978).
1: Tertiary, 2: granitic rocks, 3: tonalite and trondhjemite, 4: "Daiyu-in" type sheared granite, 5: "Gozaisho" metamorphics (including "Hitachi" metamorphics), 6: "Takanuki" metamorphics, 7: high-grade metamorphics uplifting to low-grade metamorphics ("Gozaisho" and "Hitachi") through the tectonic zone, 8: serpentinite ("Madara-ishi"), 9: sheared zone (dotted line: presumably sheared zone). Td: Takanukida, Tk: Tokusa, Tn: Takanuki, Db: Daibara, Kd: Koshidai, G: Gozaisho-yama, Kn: Kadono, A: Asahi-yama, O: Osyo-yama, Nm: Nemuro, Hn: Hanazono, Ty: Tabyuto, Tb: Takabo-yama, Mn: Mizunuma, Is: Isohara, H: Hitachi, D: Daiyu-in, Sw: Suwa mine, Ts: Takasuzu-yama, Tm: Tamadare, Om: Ohmika.

different tectonic control from the formation of the structural belt.

c) The occurrence of almino-silicate porphyroblasts in the Yazukuri schist proves the existence of metasomatic processes during reactivation of the schist.

d) Ore mineralization and related hydrothermal alteration at the Sengosawa can be correlated with that of the Koshidai-Takaboyama-Daioh•in structural belt. However, the area is not comparable in scale and variety of ore mineralization with largely mined areas such as the Hitachi mining district.

The prolongation of both structural belts will be examined. Watanabe *et al.* (1978) have outlined a brief figure of the Koshidai-Takaboyama-Daioh·in structural belt in their paper. According to their map (Fig. 10), the belt starts east of Tamadare-Nishidohira district, around the terminal district of the Abukuma terrain, and extends towards the north *via* Daioh•in, Takaboyama, Koshidai district up to Takanukida village. Further extension of the belt to the north is untraceable due to the interruption of the Ronden granite mass. A notable branched structural belt develops from south of Mt. Takaboyama in a NNW direction running *via* Mizunuma, Nemuro, Daibara and Takanuki and extends further towards the northwest along the southwestern boundary of the Ronden mass. Accordingly, the Uzumine-Sengosawa structural belt seems to connect directly to this branched belt.

Metamorphic rocks mainly composed of amphibole schists intercalated with biotite schists and accompanied by serpentinites are dottedly distributed in the Nakadohri region, Fukushima Prefecture. They have been studied by members of the Nakadohri Collaborating Research Group, and the brief results obtained have been reported at the 85th General Meeting of the Geological Society of Japan (1978). According to them, those interspersed metamorphic rocks and serpentinites, which they have named as the "Nakadohri metamorphic rock belt", can be traced linearly as far as the southwestern periphery of the Fukushima basin from Hiwada village, north of Kohriyama City (Fig. 11). Similar rocks are known to crop out around Kuriko district, in the southwestern part of Yamagata Prefecture. They consider that the Nakadohri metamorphic rock belt continues at least as far as this district, although an exact configuration of the belt cannot be obtained because of the thick covering by Tertiary and Quaternary deposits.

It has been previously mentioned that the extension of the Uzumine-Sengosawa structural belt towards the north can be traced until Akanuma district. The region between Akanuma and Hiwada district is covered with rhyolitic tuff of Tertiary age and no field information concerning the trend of the structural belt has been obtained. However, judging from the trend of the fracture zone and the foliation of the amphibole schists, there is little doubt about the fact that this region must represent a junction zone of the Uzumine-Sengosawa structural belt and the Nakadohri metamorphic rock belt. It is desirable to refer to the three structural belts by a suitable name in the future.

As to the geologic age of formation of the Uzumine-Sengosawa structural belt, no clue has been obtained in this region. However, since Watanabe *et al.* (1978) based on geological evidences from the Hitachi district have concluded that the Koshidai-Takaboyama-Daioh•in

Explanation of Plate 1

Occurrence of the Yazukuri schist.

Fig. 1 Biotite schist with intensely fractured structure. Loc. Sengosawa dam site.

Fig. 2 Andalusite porphyroblastic biotite schist. Loc. Sengosawa dam site.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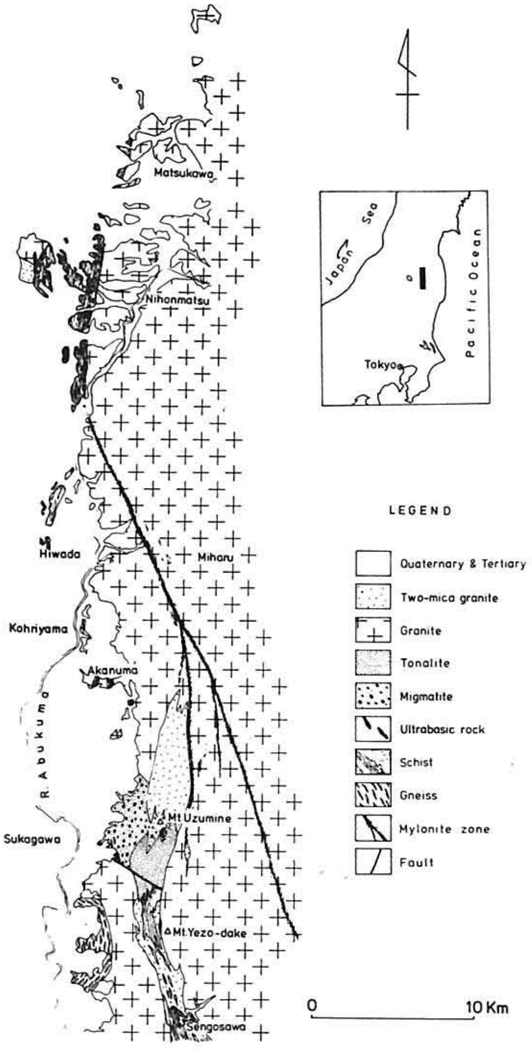


Text-Figure 11 Geologic sketch map of the Nakadohri and Uzumine-Sengosawa districts. The map is compiled based on the map given by the Nakadohri Collaborating Research Group and the present study.

Explanation of Plate 2

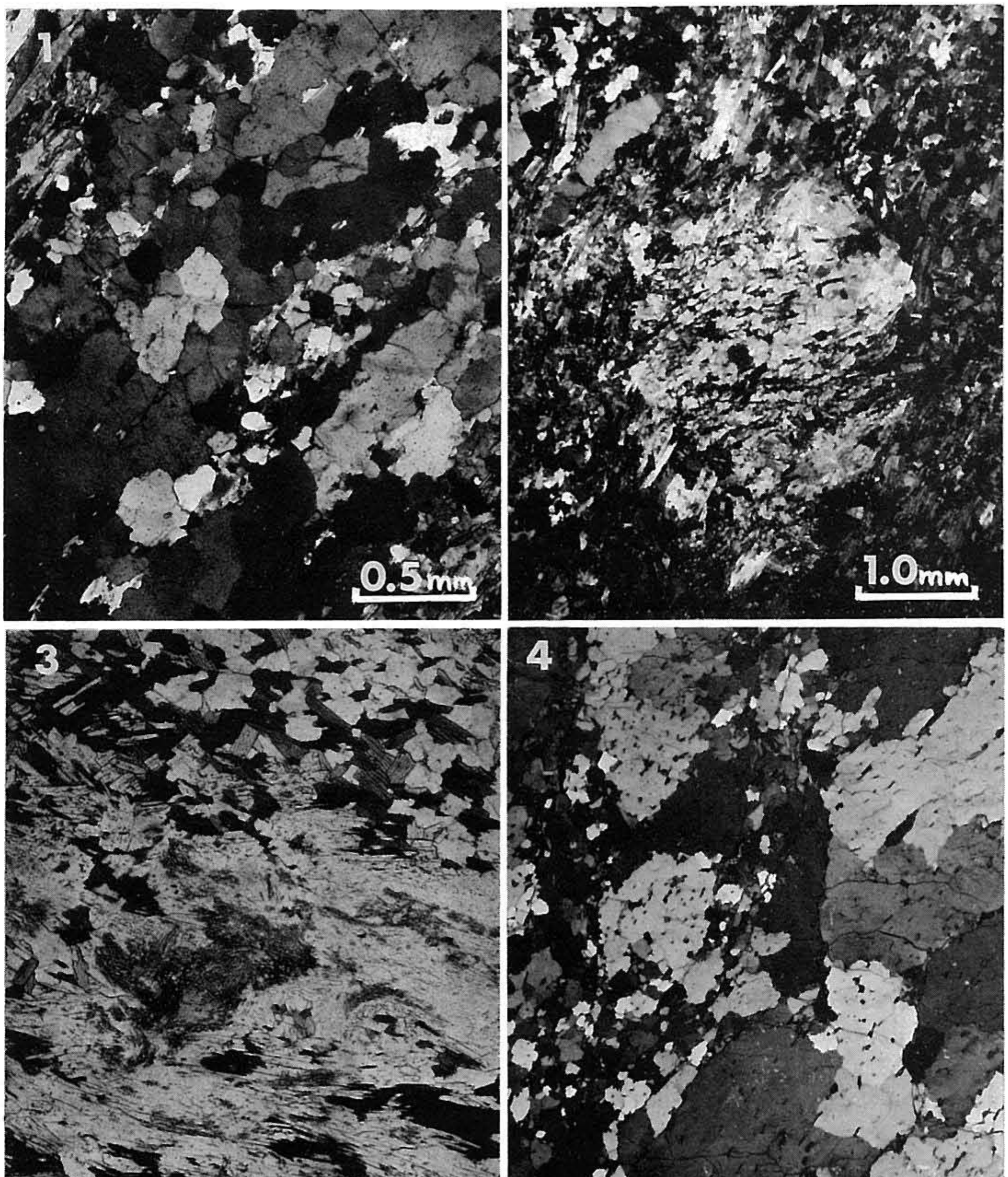
Photomicrographs of the metamorphic rocks.

Fig. 1 The brickwork texture of quartz in the biotite schist of the Yazukuri schist (crossed nicols). Sengosawa dam site (sp. 78Se-8A-3).

Fig. 2 Andalusite porphyroblast in the biotite schist of the Yazukuri schist (crossed nicols). Loc. Sengosawa dam site (sp. 78Se-8).

Fig. 3 Fibrolite-muscovite clot in the biotite schist of the Yazukuri schist (open nicol). Loc. Sengosawa dam site (sp. 78Se-D7).

Fig. 4 Quartzose gneiss in the Gampohji gneiss (crossed nicols). Loc. Kodaka, Tamagawa-mura (sp. A-509).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structural belt would be a movement related to the Indosinian Orogeny, the writers assume a similar relationship for the Uzumine-Sengosawa structural belt.

Conclusion

1) The presence of a structural belt can be revealed in the Uzumine-Sengosawa region and the name of Uzumine-Sengosawa structural belt is proposed for it.
2) The structural belt extends in a N-S direction from the Sengosawa district to the Uzumine district where it branches into two directions; one extends to the Akanuma district with a NNW-SSE trend the other reaches up to Miharu Town with a N-S direction.
3) Plutonic activity took place repeatedly in this belt, the formation of the Uzumine migmatite represents the first event being followed by the intrusion of the Kami-oyamada tonalite. Intrusion of two-mica granites also took place in large scale. Besides them, several intrusive bodies of serpentinites of various sizes are found.
4) The belt divides two series of metamorphic rocks which were formed in different stages; the Takanuki metamorphic rocks and the Gozaisho metamorphic rocks.
5) Besement rocks or uplifted bodies of basement rocks as for example the Yazukuri schist and xenoblocks of gneiss in the older granite, plus the metamorphic rocks of younger age, *i.e.* the Gozaisho schists are involved in this structural belt.
6) Metasomatic reaction took place on the uplifted bodies leading to formation of alumino-silicate porphyroblasts such as kyanite (?), sillimanite, andalusite etc., together with some amount of tectonic deformation.
7) Indications of ore mineralization and related hydrothermal alteration are detected in several localities.
8) The Uzumine-Sengosawa structural belt has an equivalent geological significance as compared with the Koshidai-Takaboyama-Daioh•in structural belt.
9) The Uzumine-Sengosawa structural belt is together with the Koshidai- Takaboyama-Daioh•in structural belt and the Nakadohri metamorphic rock belt – part of a major structural belt which longitudinally divides the Abukuma terrain.

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Explanation of Plate 3
Occurrence of the Uzumine migmatite.
Fig. 1 Plagioclase porphyroblastic biotite gneiss. Loc. Ogura, Sukagawa City.
Fig. 2 Tonalitic neosome and palaeosome materials. Loc. The Uzumine country club, Sukagawa City.


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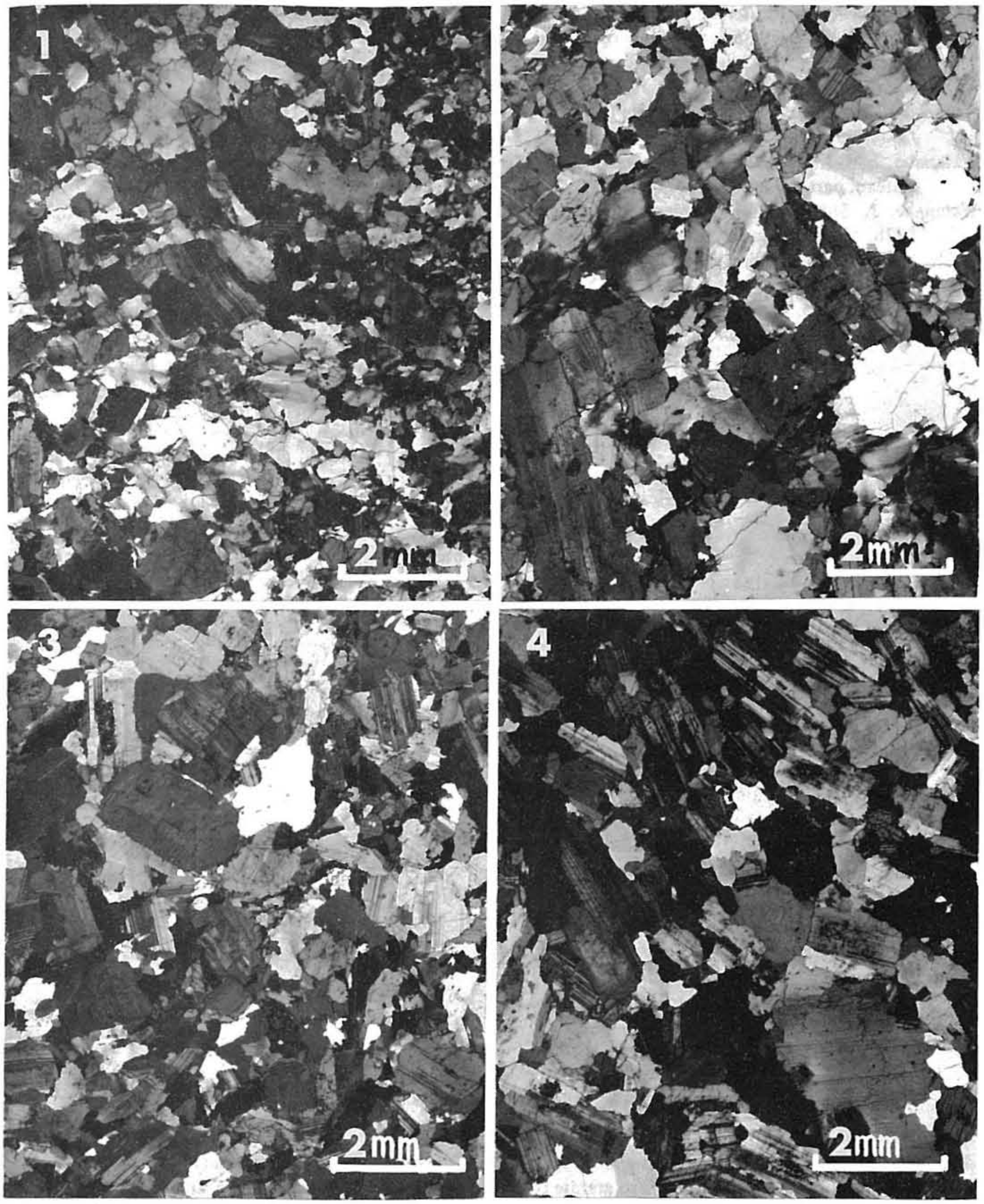
Explanation of Plate 4

Fig. 1 Photomicrograph of the Uzumine migmatite (crossed nicols). Loc. Ogura, Sukagawa City (sp. A-369-b).

Fig. 2 Photomicrograph of plagioclase porphyroblastic biotite gneiss in the Uzumine migmatite (crossed nicols). Loc. Ogura, Sukagawa City (sp. A-369-a).

Fig. 3 Photomicrograph of the Kami-oyamada tonalite (crossed nicols). Loc. Yamagoya, Sukagawa City (sp. A-1052).

Fig. 4 Photomicrograph of the Ishikawa granite (crossed nicols). Loc. Bobata, Ishikawa Town (sp. 74050114).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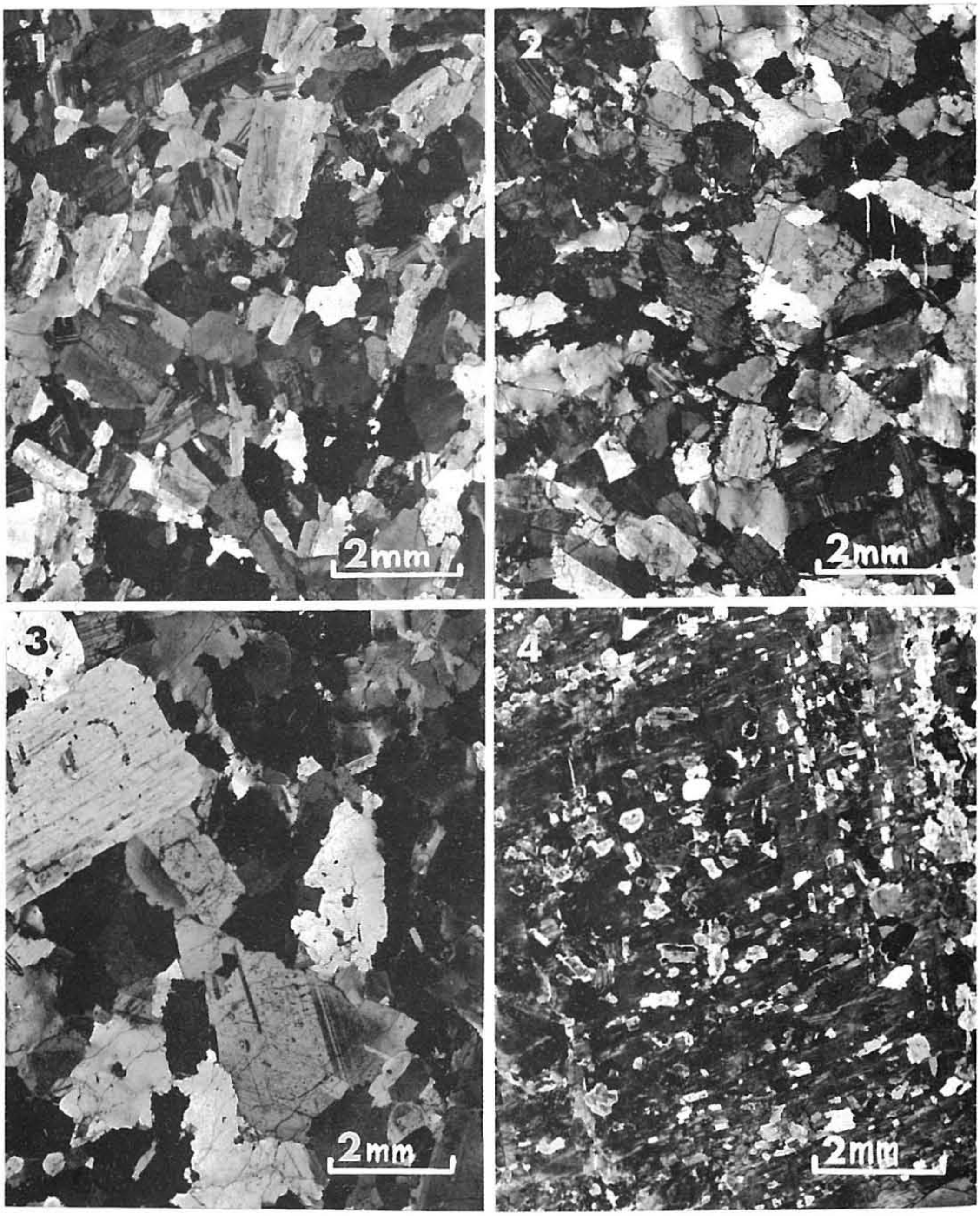
Explanation of Plate 5

Fig. 1 Photomicrograph of the older granite (crossed nicols). Loc. Taki, Miharu Town (sp. A-655).

Fig. 2 Photomicrograph of the Miharu granite (crossed nicols). Loc. Yogiashi, Miharu Town (sp. A-639).

Fig. 3 Photomicrograph of the Ronden granite (crossed nicols). Loc. south of Mt. Yezo-dake, Sukagawa City (sp. A-1010).

Fig. 4 Photomicrograph of potash feldspar porphyroblast in the two-mica granite (crossed nicols). Loc. north of Mt. Uzumine (sp. 362-b).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