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THE JOETSU METAMORPHIC BELT AND ITS BEARING ON THE GEOLOGIC STRUCTURE OF THE JAPANESE ISLANDS

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(Abstract)

In the Joetsu region, the small bodies of metamorphic rocks and serpentine are found here and there, and many of them are transformed into hornfels by the contact metamorphism of the Cretaceous to Tertiary granitic rocks. We proved from the field survey that they are polymetamorphic and were schistose rocks prior to the contact metamorphism. On the one hand, crystalline schists are found in the top of Tanigawa-dake and as pebbles of the Jurassic to Miocene conglomerates. They include the glaucophane schist and crystalline schists characteristic for the glaucophanitic metamorphic terrane. From these evidences, the Joetsu region was a regional metamorphic belt of the glaucophanitic type from the Jurassic to the Miocene.

We came to the conclusion that the Joetsu metamorphic belt is the eastern extension of the crystalline schist region surrounding the Hida plateau from the following facts.

1) The Katashina Tectonic Zone of the eastern boundary of the Joetsu metamorphic belt is geologically similar to the Hida Marginal Structural Zone. 2) The metamorphic type of the crystalline schists is common in two regions. 3) The age of metamorphism is same. 4) The non-metamorphic Paleozoic in the outside of the metamorphic belts (the Tanba and the Ashio Belts) is considered to be continual. 5) The geologic history in both regions is very similar.

PREFACE

The Joetsu region is a mountainous land around the boundary of Gunma, Niigata and Fukushima Prefectures. Some of the mountain peaks exceed 2000m in altitude. The region is composed mainly of such basement rocks as the late Paleozoic and Mesozoic sediments as well as the Cretaceous granites and Tertiary quartz diorite. Some Neogene sediments and the Neogene to Quaternary volcanics are also found. These younger rocks are rather extensive in the southern part of this region. The region had long been left unstudied till 1950's when several significant fossils and rocks were discovered, *i. e.* the early Jurassic plant fossils in the Iwamuro district (KIMURA, 1952, 1955), the late Triassic Pelecypod fossils in the upper valley of the Tone river (TOYA, 1954 ; KIZAKI and ARAI, 1955 ; KOBAYASHI, 1955), the so-called Ryoseki-type Cretaceous Pelecypod fossils in the Tokura district(ASANO *et al*., 1957, MS), and the crystalline schists in the Iwamuro district (KIMURA, 1952). These together with the serpentine masses often found in the granite area, aroused our great interests. On the other hand, the geographical location itself of this region also called much attention, because it occupies the southwestern-most part of Northeast Japan. Then it is hoped that the geological study of this area would yield valuable contributions to the problem on the relation between Northeastern

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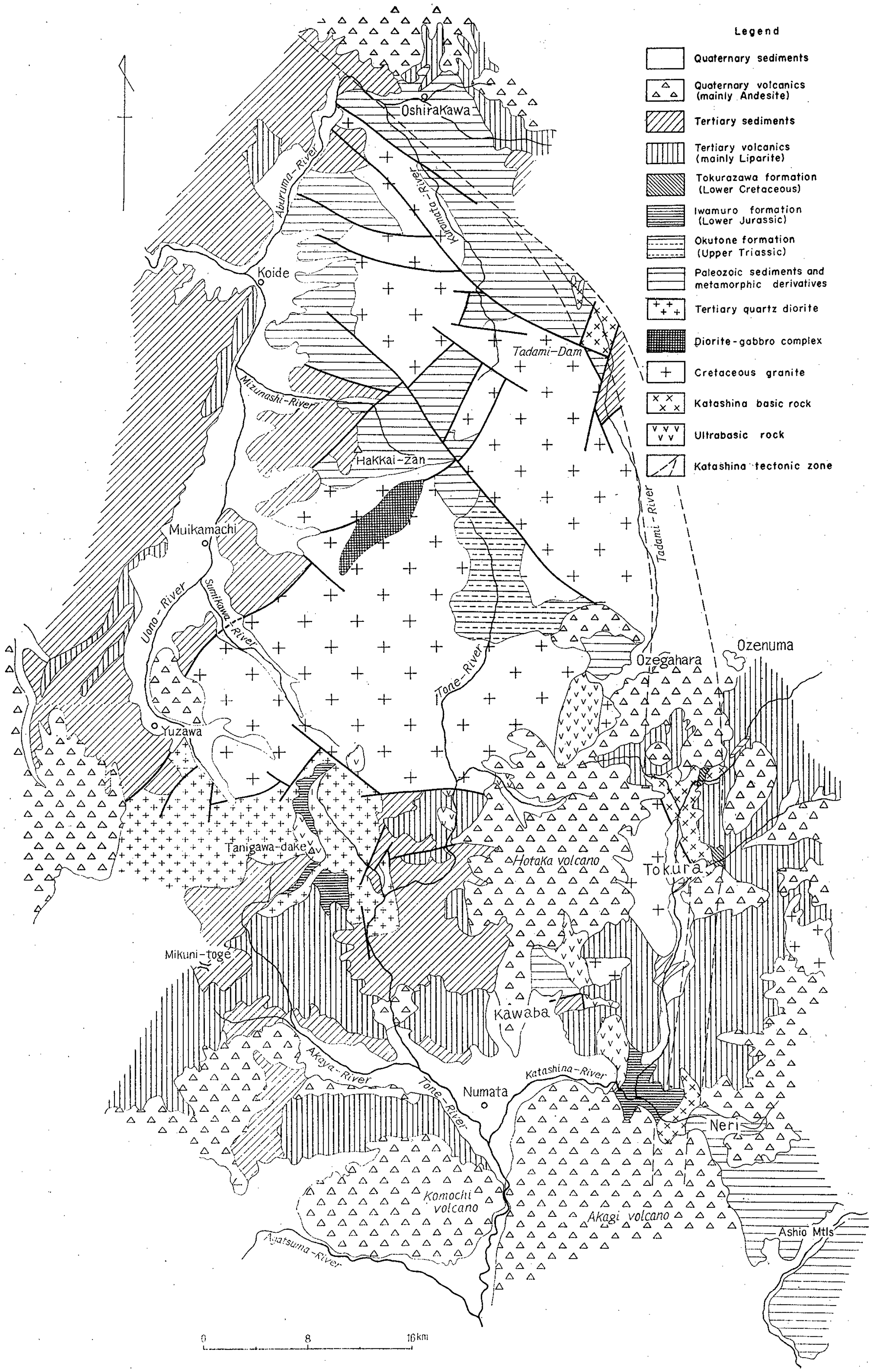

Fig. 1 Compiled geological map of the Joetsu region

and Southwestern Japan.

Such a problem in mind, we engaged in the study of the metamorphic rocks in this region from 1964 to 1966 as one of the themes of Upper Mantle Project in Japan, and then from 1965 to 1967 as one of the themes of the systematic study in „the Historical Development of the Metamorphic Belts in Japan" arranged by the auspices of the Geological Society of Japan. Among the results obtained, the following are essential; 1) there had been in existence a belt of regional metamorphism in this region through the Mesozoic and probably in the Paleogene age, though the belt is now lost by erosion and intrustion of later granites, 2) the metamorphism of this belt was glaucophanitic type, and 3) the belt was bounded in the east by the Katashina Tectonic Zone beyond which the Paleozoic sediments were left unaffected as is seen in the Ashio Mountainland. The vanished metamorphic belt is named the *Joetsu metamorphic belt* after KURODA (1963) who first used the term of the „Joetsu Zone".

OUTLINE OF THE GEOLOGY OF THE JOETSU REGION

A geological map compiled from various sources including the results of our survey is shown in Fig. 1. The area is some 80km long from north to south, and about 40km wide from east to west. In the north as well as in the west, the area is limited by the Aburuma river and the Uono river, the tributaries of the Shinano river, while, in the east, it is limited by the Tadami river and the Katashina river of which the latter is a tributary of the Tone river. The southern limit of the region is roughly given, though somewhat ambiguous, by the lower course of the Katashina river and a valley called the Akaya river. The upstream of the Tone river starts from the triple divide of Gunma, Niigata and Fukushima Prefectures, and flows down to the south in the midst of the southern half of the region, so that the area is divided into the eastern and the western ranges in this part.

Geologically speaking, the region is limited, in the west, by a tectonic line called the *Shibata-Koide Line* (YAMASHITA, 1964) or the Muikamachi Line, beyond which the Neogene and Quaternary sediments of the Niigata oil fields are developed. In the east, it is limited by the *Katashina Tectonic Zone* (YAMASHITA, *et al.*, 1965) which will be described in a later paper. To the east of this zone develops another region of the Ashio Mountainland, where the basement rocks are represented largely by the unmetamorphosed late Paleozoic sediments.

The oldest rocks of the region belong to the so-called Chichibu system or the Chichibu Paleozoic formation. They are found in two areas, one in the north and the other in the southeast. The northern Paleozoics are widely extended and is divided further into the eastern and the western areas by a large batholithic mass of the Cretaceous granite. The eastern subarea is well exposed along the Aburuma river around Oshirakawa and then stretches to the south-southeast along the Kuromata river. It is mainly composed of dark mudstone with some chert and siliceous mudstone. These rocks are generally free from regional metamorphism, but are tightly folded. The lithofacies characterized by chert is similar with that of the Ashio Paleozoics, and, in this sense, is different from that of the Paleozoics in the western subarea.

The Paleozoics of the western subarea is developed along the western margin of this region, and is best exposed in the valley of the Mizunashi river, southeast of Koide. It is generally composed of dark to black mudstones with some intercalations of basic volcanics. Chert and siliceous rocks are absent. Along the Mizunashi river, the rocks in the lower stream are chlorite-muscovite phyllite and garnet-muscovite-chlorite schist, while, in the upper stream, they are changed into compact banded hornfels affected by the Cretaceous granite. To sum up, the Paleozoic sediments in the northern area can be grouped into the eastern and the western parts, both which may be divided by a line coming from the Katashina Tectonic Zone and extending northwest through the lower valley of the Kuromata river. The Paleozoic sediments in the west of this line are changed into crystalline schists, while those in the east are not. Between them the lithofacies is also different, the western being characterized by basic volcanics while the eastern by siliceous rocks.

The Paleozoic of the southeastern area is found as several isolated patches in and along the Katashina Tectonic Zone. In the Neri district at the northeastern foot of Akagi volcano, the Paleozoics are composed of mudstone and sandstone with subordinate volcanics and limestone. They are found adjacently to the east of the Katashina Tectonics Zone, and are continuous with the Paleozoics of the Ashio Mountainland. From the limestone in this district, KIMURA (1952) found Corals and Fusulinids, but he gave no specific nor generic names of these fossil organisms. Similar rocks are also found along the zone extending to the north, and are regarded as members of the Ashio Paleozoics. Important is the Paleozoic sediments of Mt. Keizuru to the west of Ozegahara Moor. They are represented mostly by hornfels derived from mudstone with intercalating limestone beds. From these limestones FUJIMOTO and KOBAYASHI (1961) found a Fusulinid fauna containing *Lepidolina multiseptata*, *L. Keizurensis*, *Schwagerina incisa* and others. This is the only occurrences of the Paleozoic fossils in the Joetsu region. It suggests, though insufficient for applying to the more extensive area, that the Paleozoic sediments of the Joetsu region belong probably to the Upper Paleozoic. As to the crystalline schists of this region, the first find was made by KIMURA (1952) from the Kawaba area northeast of Numata. He reported the occurrence of biotite schist, green schist, amphibole schist, garnet-titanite schist, diopside-garnet schist, and hornblende-diopside schist, but he did not give any petrographic description. The metamorphic rocks in this area were studied later by HASHIMOTO, after whom the rocks may be products of polymetamorphism, but he could have few data for further discussion (oral communication). In 1958, ARAI and KIZAKI (1958) published a description of the Neogene deposits around Minakami, in which they noticed an occurrence of graphite-quartz schist and green schist as pebbles of the Awazawa conglomerate formation occupying the basal part of the Neogene sequenece. Then, in 1962, MAEDA reported a small mass of crystalline schists on the top of Mt. Tanigawa-dake. The rock types mentioned by him are chlorite-sericite-quartz schist, quartz-sericite-chlorite schist, garnet-sericite-chlorite schist, and diopside-chlorite schist. These were compared by him with those around she Hida gneiss region, and were regarded as belonging to the Sangun metamorphic belt of Southwest Japan. Recently YOSHIMURA and ICHIHASHI (1966) studied the crystalline schist pebbles of the Awazawa conglomerate formation, and indicated the presence of well recrystallized glaucophane schist, garnet-biotite schist, garnet-muscovite schist, and spotted green schist. Another occurrences of crystalline schist have been found through our research from within or at margins of the serpertine masses. Moreover, a lot of schist pebbles have been found from conglomerates of the early Jurassic Iwamuro formation.

Ultrabasic rocks occur in several localities of the southern Joetsu region. They are also contained as pebbles in the Iwamuro formation and its equivalent. The age of their intrusion, therefore, is pre-early Jurassic. But it seems that they have been remobilized through fault movement, and then are in intrusive relation to the lower Jurassic sediments near Mt. Tanigawa-dake. The ultrabasic rocks are almost totally serpentinized, with scarce relics of olivine and orthopyroxene. No clinopyroxene is contained. By the contact effect of either the Cretaceous granite or the Tertiary quartz diorite, the radial aggregate of tremolite is formed.

The late Triassic formations, discovered in 1955, are developed along the uppermost stream of the Tone river, and are composed of mudstones and sandstones with some intraformational conglomerates. Limestones are often intercalated, but are not abundant. These sediments are estimated at about 3000m in thickness, and are folded tightly. Fossils including *Entomonotis ochotica* and *E. zabaicalica* of the Norian age have been discovered from several places of the area.

The early Jurassic Iwamuro formation is best exposed around the junction of the Katashina river and the Neri river at the northern foot of Akagi volcano. It is also very thick, more than 1000m, and folded strongly. The rocks are mainly black mudstones, some of which are sandy. Beds of conglomerate are intercalated in several horizons in which pebbles of ultrabasic rock are found. In spite of the former opinion by KIMURA (1952) that the ultrabasic rocks are intrusive into the Iwamuro, we believe that the Iwamuro is younger. Though we could not observe the very outcrop of the contact, we could find two colossal blocks of special interest in the river bed of the Katashina-gawa just at the boundary of the Iwamuro and the Ultrabasic rocks. Either block is composed of the two parts, of which the one is ultrabasic rock and the other half is conglomerate of the Iwamuro. The pebbles of the conglomerate are composed mostly of ultrabasic rocks with various appearance. In short, the blocks are nothing but large out-door specimens of unconformity between the ultrabasic rocks and the Iwamuro. Plant fossils from the Iwamuro have been described by KIMURA (1959), who compared them with those of the Kuruma group developed at the northeastern extremity of Southwest Japan. The similarity in lithology between the Iwamuro and the Kuruma is also significant, because it shows a close relation between the two areas. A group of hornfelsized mudstones, sandstones and subordinate conglomerates around Mt. Tanigawa-dake, if there is no fossil, may be correlatable to the Iwamuro. Pebbles of metamorphic rocks including crystalline schists are found from the conglomerate beds.

The Pelecypod fossils of the early Cretaceous appearence were discovered first by ASANO *et al.* (1957) near Tokura, but they could not find the sediments *in situ* from which the fossils were derived. The formations yielding these fossils are now found developed in the small gullies and slopes and also in the river bed to the northeast of Tokura (HAYASHI *et al.*, 1965). They are about 260m in thickness, and are composed of sandstones and mudstones. Fossils are abundant in sandy mudstones and most of them are *Corbicula tetoriensis*. In a locality of the river bed, Belemnoid fossils are discovered. These fossils as well as the lithology are all the same as those of the Tetori group widely developed in the Hida region adjacent to the west of the Itoigawa-Shizuoka Tectonic Line. This also shows eloquently the close relationship of this region to the Inner Zone of Southwest Japan.

The Tokurazawa formation is the name given to those sediments that were once called the Tokura formation by MURAYAMA and KAWADA (1956). However the name Tokura had been preoccupied by the Tokura group of KUNO *et al.* (1954) who used the name for the Tertiary volcanic beds near Tokura. The Tokurazawa is intruded by the Katashina basic rocks, but it is really free from contact metamorphism. The Belemnite fossils noticed above are found just between a few centimenters from the contact of the basic rocks. The Katashina basic rocks were called the Tokura basic rocks by MURAYAMA and KAWADA (1956). From the reason mentioned above, we used the new name.

The Katashina basic rocks are confined within the Katashina Tectonic Zone. In other words, they are the characteristic rocks of the Katashina Tectonic Zone, which defines the eastern limit of the Joetsu region. They are generally composed of quartz diorite, but some gabbroic and fine-grained diabasic rocks are accompanied. Characteristically they are sheared and chloritized. As noticed above, the Katashina basic rocks are intrusive into the Tokurazawa formation of the early Cretaceous age. Hence it is apparently younger than the early Cretaceous. It must be noticed, however, that they occupy the boundary zone between the metamorphic and the non-metamorphic parts of the Paleozoic. It suggests that the basic rocks might be intruded along the zone as a result of differentiation of the Paleozoics in earlier ages and might be reactivated in the post-Tokurazawa age. The least effect of metamorphism on the Tokurazawa may be another evidence for reactivation.

The Cretaceous granites are developed extensively in the northern and the central parts of the region. The most representative type, the Sudagai granite (KIZAKI and ARAI, 1955) of the Sudagai dam area, is medium to coarse-grained leucocratic biotite granite, but some granodiorites are also found. In the Kawaba area, the granite mass is intruding into the ultrabasic rocks. Contact metamorphism is remarkable.

Tertiary deposits of both clastic and pyroclastic facies are widespread in the southern parts. Among them the Awazawa formation, the basal conglomerates of the Neogene series, is important, because it contains a large amount of boulders including crystalline schist pebbles that must have been derived from the Joetsu metamorphic rocks. These metamorphic rock pebbles together with those in the lower Jurassics suggest the more extensive distribution of the crystalline schists in earlier ages.

Around Mt. Tanigawa-dake, a mass of quartz diorite with a local gabbroic facies is developed occupying a fairly large area. It is considered, like the quartz diorite of Mt. Tanzawa, to be of the Miocene age. Another quartz diorite mass with a gabbroic facies is found in the south of Mt. Hakkaizan amidst of the area of the Cretaceous granite. The rocks, in this case, are crushed and mineralized along the crushed zones forming the ore deposits of copper, lead, and zinc ores. Though the rocks are apparently different from those of the Mt. Tanigawa-dake, they are probably of the Miocene age.

The Quaternary volcanics occupy a fairly large area in the east-central and southern parts. Volcano Hotaka and volcanoes around Ozegahara Moor lie in the east-central part, while Akagi and Komochi volcanoes do in the south. These volcanoes, with lavas and pyroclastics of andesitic composition, preserve fairly well the original topography, and thier ejectamenta cover all the rocks from the Paleozoic to the Tertiary.

DISTRIBUTION AND MODE OF OCCURRENCE OF METAMORPHIC ROCKS IN THE JOETSU REGION

In the Joetsu region, metamorphic rocks occur sporadically in small areas and all are transformed into hornfels by the contact effect of the Cretaceous granite, with one exception at the top of Tanigawa-dake. On the other hand, crystalline schists occur in abundance as pebbles of the lower Jurassic to the Miocene conglomerates. The distribution and the mode of occurrence of these metamorphic rocks will be described, as follows.

1. The Top of Mt. Tanigawa-dake (Fig. 2)

At the top of Mt. Tanigawa-dake occur coarse-grained crystalline schists as roof pendant on a serpentine mass. Also the same schists occur in one of the northern peaks of Mt. Tanigawa-dake and in the northern ridge of Mt. Ichinokura-dake. The serpentine body distributing from Mt. Tanigawa-dake to Mt. Ichinokura-dake is, in turn, a roof pendant on the Tertiary granitic and quartz-dioritic mass of this district and is subjected with contact effect by the latter. But as the body is large, the central part of the body is not so recrystallized as high as forming tremolite. So the crystalline schists also preserve its original feature.

The rocks are green and black schists. The former is the so-called spotted schist with many albite prophyroblasts. Some of them are conspicuously schistose and the others are rather massive. Both types of green rock are garnet-amphibolite with or without epidote. The black schists are garnet-muscovite schists, some of which contain epidote and/or hornblende pool.

In two occurrences north of Mt. Tanigawa-dake, the rocks consist of green schists of rather massive type.

2. The Kanosawa-iri valley (Fig. 2)

The valley east of the Minakami station is called the Kanosawa-iri. Along the boundary fault between quartz diorite and liparite or the Awazawa formation, a serpentine body exposes extending to the northern ridge though its further extension is unknown. This serpentine mass accompanies schistose hornfels, in which folded structure is conspicous. On the other hand, a lot of autochthonous debris of schistose hornfels are found on a summit, south of the Tone river and east of Kochi. The serpentine-hornfels complex of Kanosawa-iri, therefore, may extend northward, though covered by liparite and the Awazawa formation.

Moreover, in the liparite area east of the Kanosawa-iri serpentine body, a boring core sample of talc schist free from contact effect is brought from the depth of 130 to 140m (INOUE, Y. oral communication). These facts, therefore, suggest that the schistose hornfels is polymetamorphic and the contact effect is limited only near quartz diorite. Under both the Awazawa formation and the liparite, crystalline schists may widely distribute.

3. The Kawaba area (Fig. 3)

In the Kawaba area, the serpentine-hornfels complex composes the mountain area between the Usune and the Sakuragawa rivers. In the Akakura-dani east of the area, granite exposes widely and the metamorphic grade due to contact effect becomes higher towards the east. The original rocks of the metamorphic rocks are mainly schalstein, with intercalations of pelitic

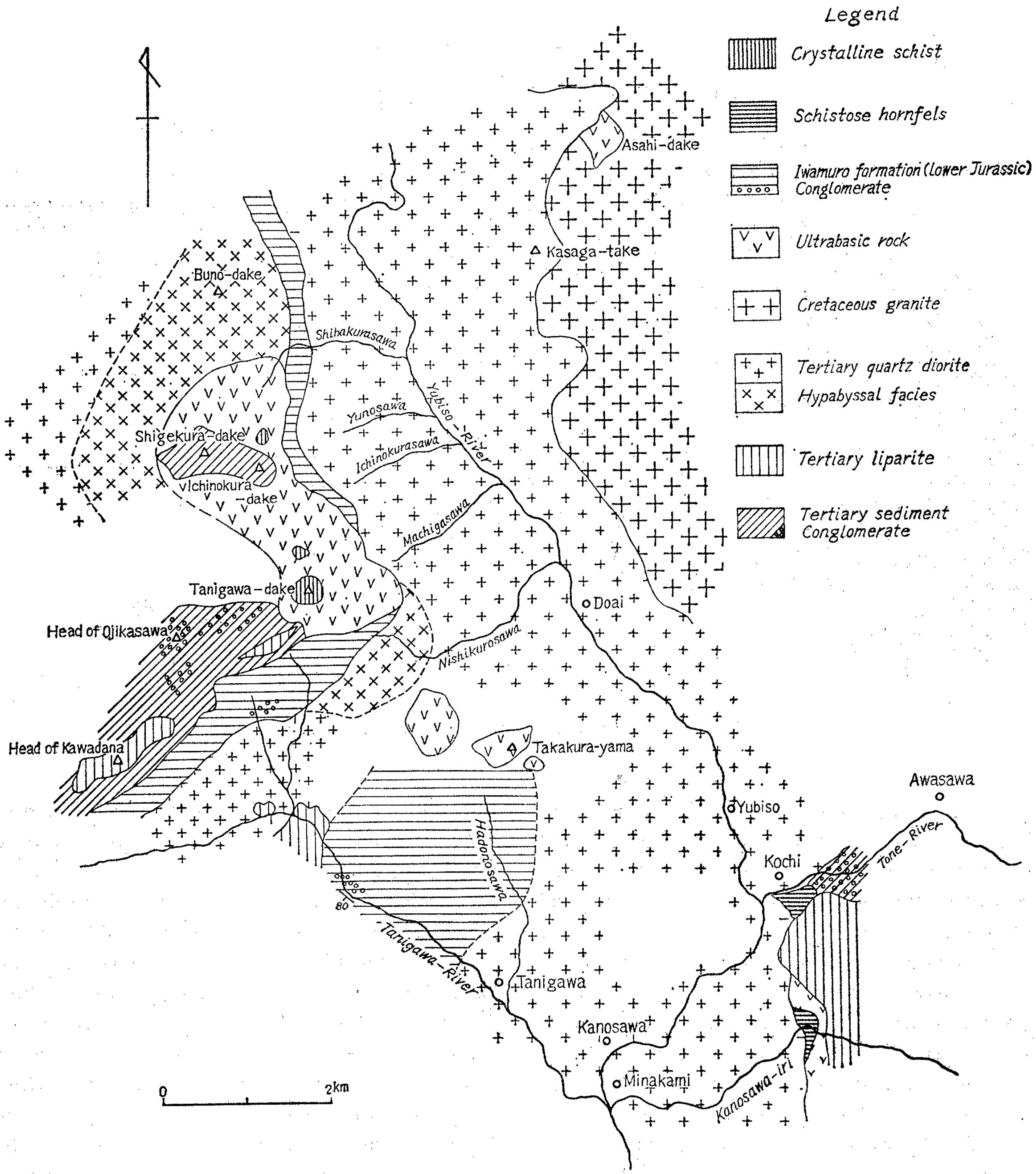

Fig. 2 Geological map of Tanigawa-dake and adjacent area

and psammitic sediments. KIMURA (1952) interpreted the pelitic and psammitic metamorphic rocks as the metamorphic facies of the Iwamuro formation and the basic metamorphic rocks as basic igneous rocks, while we consider them to be the Paleozoic schalstein-clastic complex, with one doubtful exception near Taro. The metamorphic rocks of this area were studied by KOBAYASHI (1966, MS) as a graduate thesis of Gunma University. We shall describe the rocks after her (Fig. 3).

In the eastern part of the area, recrystallization is complete and the rocks are altered into compact hornfels with schistosity or conspicuous banded

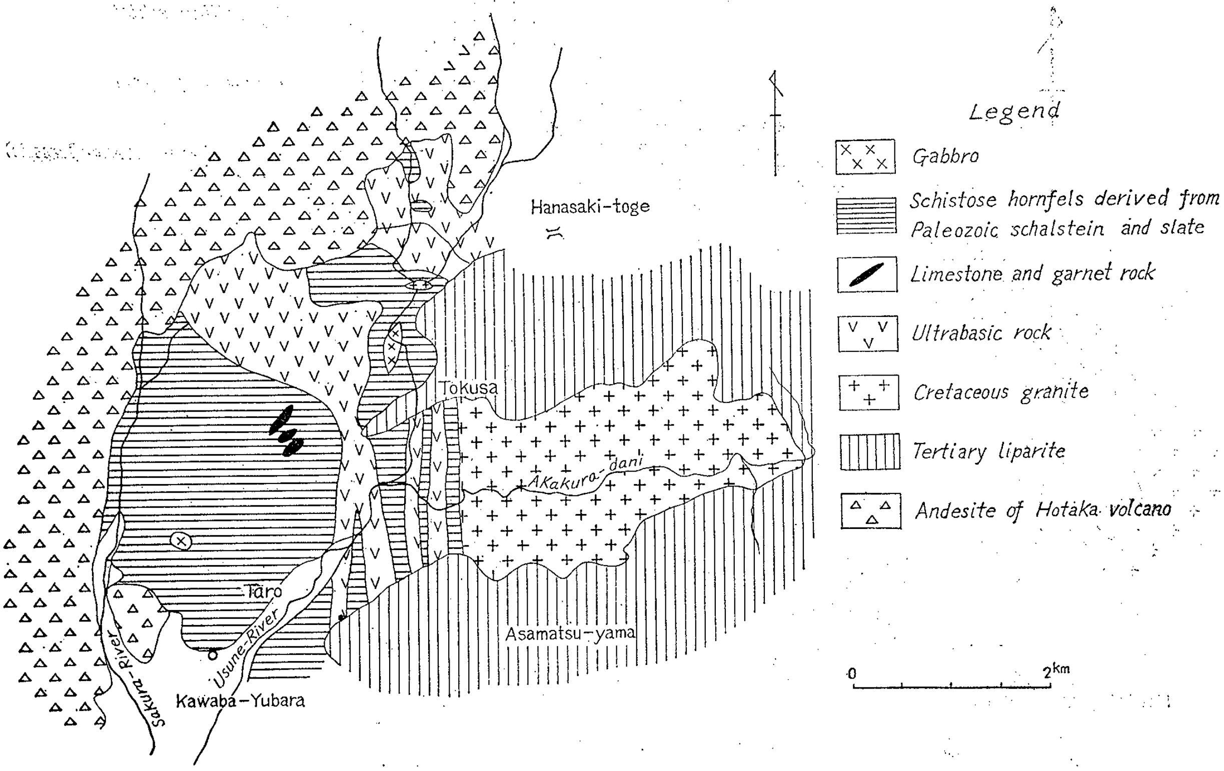

Fig. 3 Geological map of the Kawaba area

structure. Purely pelitic rocks are biotite hornfels with both schistosity and conspicuous white and dark banded structure. The white band is composed of quartz and plagioclase and the dark band of biotite. The former is coarser than the latter. Pelitic hornfels has rarely sillimanite or garnet. These accessories occur in the dark band. Sillimanite-bearing rock has no muscovite. Garnet occurs as streak of fine granules. Generally pelitic rocks form intimate banding with basic rocks. Such rocks are hornblende-biotite-hornfels. Biotite is always yellowish brown. Basic rocks are mainly amphibolite. Near the contact with granite in the Akakura-dani, amphibolite is coarse-grained and has rarely large porphyroblast of plagioclase but it becomes finer rapidly to the west. The fine rocks are frequently epidote-amphibolite and they are generally schistose. Hornblende of the amphibolite is grass-green or greenish brown, and on the other hand, in the epidote-amphibolite it is yellowish green or bluish green.

In the central part of the area, pelitic rocks are biotite hornfels and chlorite-biotite hornfels with conspicuous schistosity. Biotite is dusty aggregate. Also in the uppermost of the Usune river, the rocks are fine-grained chlorite-biotite and chlorite-actinolite hornfelses. The former shows conspicuous banding with coarser white band. Biotite is dusty aggregate. In the southern and the western parts of the area, the metamorphic grade becomes lowest. Pelitic rocks are black phyllite, sometimes with dusty biotite. Basic rocks are schalstein, frequently containing fibrous actinolite. It is noted that, even in this part, the pelitic rocks show often banded structure but they have no fissility. Probably, they have suffered slight contact metamorphism, by which dusty biotite and fibrous actinolite were formed. It is of special notice that basic rocks in this zone frequently show basaltic relict texture, even in the rocks with actinolite.

From the above descriptions, the original rocks of the hornfelses in the Kawaba area are considered to have been schistose or banded black phyllite and less phyllitic schalstein, and to have been almost devoid of metamorphic new minerals.

In the central part of the area, a few beds of limestone are intercalated in the basic metamorphic rocks. Some of them are now metamorphosed into monomineralic andradite rocks which have been interpreted as a kind of skarn due to contact metamorphism of granite after HASHIMOTO (1960).

4. The Mizunashi River (Fig. 4)

Metamorphic rocks expose well along the Mizunashi river. Due to granitic intrusion in the upper stream area of the river, metamorphic grade becomes higher towards the upper stream. Metamorphic rocks show remarkable banded structure, and schistosity is also conspicuous in the western part where the rocks are black schists megascopically. Under the microscope, the rocks contain dusty biotite and sometimes much garnet. Then the rocks are chlorite-muscovite-phyllite and garnet-muscovite-chorite schist. In the upper stream, schalstein is frequently intercalated. Therein pelitic metamorphic rocks are biotite hornfels and basic metamorphic rocks are hornblende hornfels. Not only high grade but also low grade pelitic metamorphic rocks show remarkable banding which consists of quartzo-feldspathic white band and graphite-biotite rich dark band. The former is always coarser than the latter.

These metamorphic rocks are polymetamorphic. This is clearly evidenced from the fact that the fault clay cutting the banding has been completely recrystallized into biotite hornfels (Pl. 4). From this point of view, the original schists may be represented by the rocks of the lowest metamorphic grade, that is, chlorite-biotite phyllite and chlorite-garnet-muscovite-biotite schist in the westernmost part of the area.

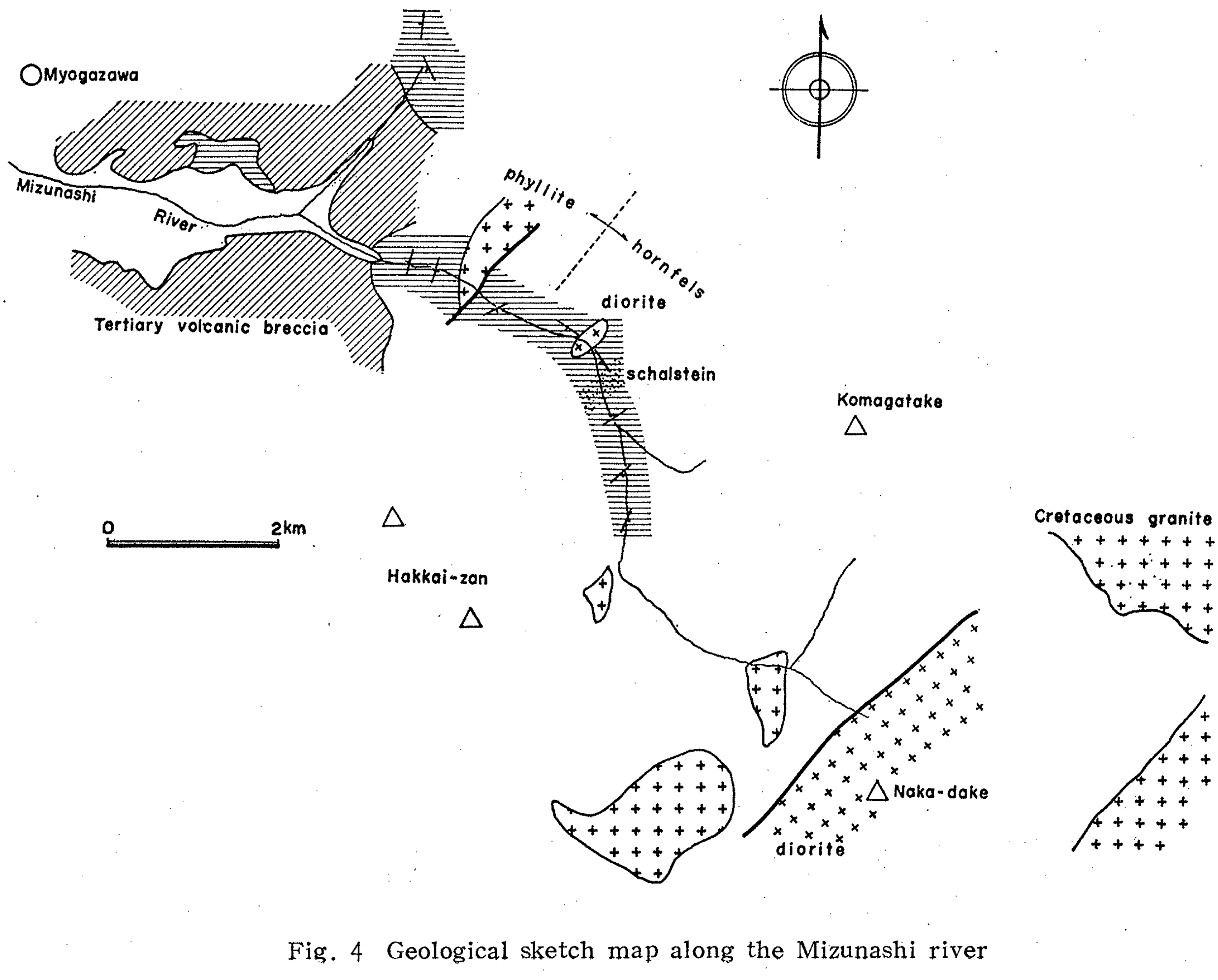

Fig. 4 Geological sketch map along the Mizunashi river

5. Other Occurrences of Hornfels

Besides the above occurrences, hornfels is found as recent river pebbles at many localities, *e.g.* near Yunokoya and in both western and eastern foots of Mt. Shibutsu-san (Heigen-zawa, the Katashina river, north of Hatomachi-toge *etc.*). All of these are located near the serpentine bodies. Probably, the other serpentine bodies of the Joetsu region may accompany such hornfels more or less. These hornfelses are always consisting of banded rocks and are undoubtedly polymetamorphic in nature, like the hornfels mentioned in the foregoing sections.

6. Allochthonous Occurrences of Crystalline Schists (Fig. 5)

As already mentioned, crystalline schists occur as pebbles in the Miocene basal conglomerate, the Awazawa formation, and in the intraformational conglomerate of the lower Jurassic Iwamuro formation. The Awazawa formation distributes widely in the area around the Fujiwara dam and an equivalent conglomerate bed also occurs in the western ridge of Tanigawa-dake. On the other hand, the interaformational conglomerate of the Iwamuro formation containing crystalline schist has been found only along the Tanigawa river. The samples of crystalline schist of the Awazawa formation were collected from Okurazawa and from the Shikama river. On the contary, the samples of crystalline schists of the conglomerates near Tanigawa-dake was collected from the river pebbles of the Tanigawa river. Then the distinction whether it is derived from the Mesozoic or the Tertiary was practically impossible.

The schist pebbles collected from the Tanigawa

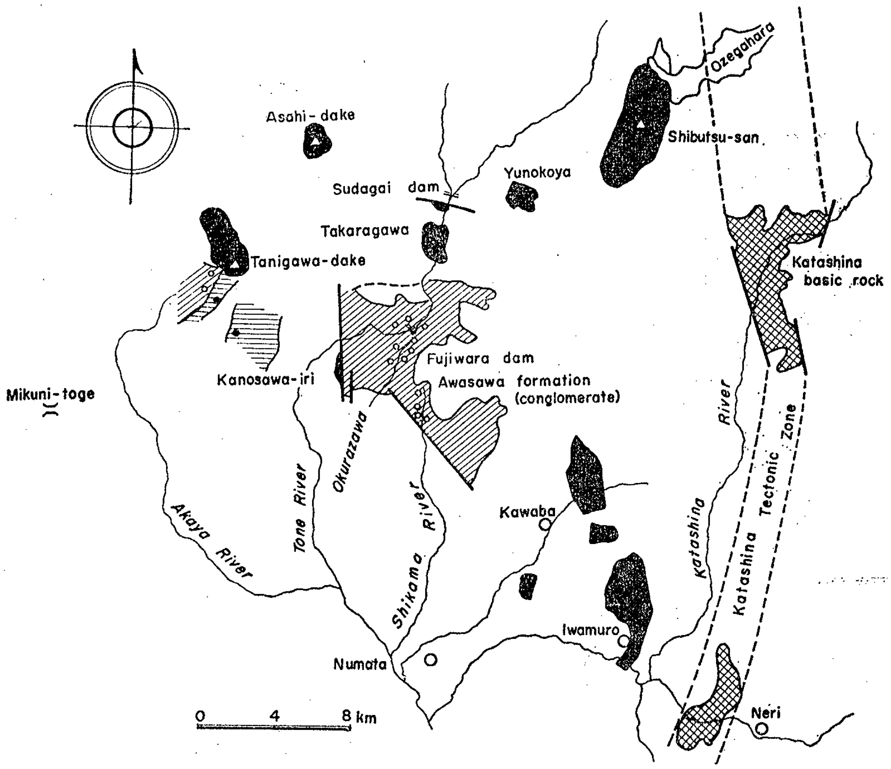

Fig. 5 Distribution of the sediments containing the pebbles of crystalline schist

Oblique hatch ; Miocene sediments
Horizontal hatch ; Mesozoic sediments
Open circle ; sampling localities (Miocene)
Solid circle ; sampling localities (Mesozoic)
Black area ; serpentine
Dashed line ; the Katashina Tectonic Zone
Crossed hatch ; the Katashina basic rock

river are coarse-grained rocks megascopically resembling the crystalline schists of Mt. Tanigawa-dake. Garnet is very common in both basic and pelitic rocks. Basic schist is garnet amphibolite with accessory epidote and pelitic rock is garnet-muscovite schist. Besides, quartz schist is rarely found. Glaucophane-bearing schist is not found.

On the other hand, chlorite-epidote-glaucophane schist is rather common in Okurazawa, while garnet-bearing schist is not uncommon. The crystalline schists of Okurazawa contain only rarely hornblende but commonly chlorite. In these respects, they are different from the crystalline schists near Tanigawa-dake. The rocks are garnet-muscovite-chlorite schist and chlorite-muscovite schist in pelitic rocks and chlorite-epidote-actinolite schist and rarely garnet-epidote-hornblende schist in basic rocks.

The schist pebbles in the Shikama river are rich in phyllite with „sericitic" white mica. But the rocks containig well recrystallized white mica are not uncommn. The rock types, therefore, are chlorite-sericite phyllite and chlorite-muscovite schist.

Chlorite-muscovite-garnet schist and chlorite-epidote schist are rare.

From the distribution of the schist pebbles in conglomerates of the southern Joetsu region, it is evident that, from the west to the east, the rocks of lower metamorphic grade become more and more plentiful.

Another allochthonous occurrence of cystalline schists is known from tuff breccia in the immediate lower stream of the Sudagai dam. They are mainly chlorite-carbonate schist and frequently carbonate schist consisting almost completely of carbonate. Besides these, schistose serpentine is contained.

7. The Hypothesis of the Joetsu Metamorphic Belt

On the foregoing pages, the distribution of the metamorphic rocks in the Joetsu region was outlined. The metamorphic rocks of autochthonous occurrence are now polymetamorphosed into hornfels by the thermal effect of either Cretaceous or Tertiary granitic rock. Judging from the rocks of the lowest metamorphic grade of the Mizunashi river and the Kawaba area, however, the original rocks prior to the contact metamorphism are considered to have been phyllite and chlorite-garnet schist. These area are situated in the eastern part of the Joetsu region. On the contrary, the distribution of the schist pebbles in the lower Jurassic and the Miocene conglomerates suggests that the metamorphic grade in the source land of the pebbles become higher from the east to the west. Moreover the autochthonous crystalline schists of the highest metamorphic grade occur on the top of Tanigawa-dake.

From these facts, the regional metamorphic belt is considered to have been exposed in this region through the lower Jurassic to the early Miocene age. The metamorphism was a type accompanying the glaucophane schist facies in the medium grade of metamorphism. Its metamorphic grade was higher in the west and lower in the east. We propose the Joetsu metamorphic belt for this lost metamorphic belt.

PETROLOGY OF THE CRYSTALLINE SCHISTS OF THE JOETSU METAMORPHIC BELT*

1. Petrography

As already mentioned, in the Joetsu metamorphic belt the metamorphic grade is considered to become lower from the west to the east. But, the authochthonous occurrences of the schists are confined in those areas as the top of Tanigawa-dake, the lower area of the Mizunashi river, and the westernmost part of the Kawaba area among which the rocks of the latter two suffer slightly contact metamorphism. Accordingly the zonal structure of the belt can hardly be reconstructed. Judging from the mineral assemblage as well as the grade of recrystallization (grain-size) of the rocks, however, the metamorphic rocks of the lower area of the Mizunashi river and the western part of the Kawaba area are considered to represent the lowest grade of the regional metamorphism in the Joetsu metamorphic belt.

On the other hand, the essentially unmetamorphosed rocks occur as pebbles of the Awazawa formation in the drainage of the Shikama river. They are slate to the naked eye. Frequently, they show microfolding and, under the micro-

* In this paper, the contact metamorphism is not treatized,

scope, schistose texture is obvious. Mineral assemblage is graphite-kaoline-chlorite-sericite-carbonate-quartz. Chlorite is colorless or yellowish and is different from that of usually green color, occurring in the schists.

These rocks are devoid of recrystallization but the tectonic movement accompanying the regional metamorphism is considered to have taken part in the formation of their structure and texture. The rocks of the western and the southern parts of the Kawaba area may belong to this grade of metamorphism.

The metamorphic rocks corresponding to chlorite-muscovite phyllite and garnet-muscovite-chlorite schist in the lower area of the Mizunashi river are found abundantly as pebbles of the Awazawa formation occurring along Shikama river and Okurazawa. Mineral assemblages of pelitic rocks are as follows ;

graphite-garnet-muscovite-chlorite-albite-quartz

graphite-muscovite-chlorite-albite-quartz.

Accessory minerals are apatite, carbonate, titanite, and blue tourmaline. Some rocks are rich in albite and the others are poor. In the former assemblage, albite grows large with minute inclusions and frequently bends conformably to the folding of the rocks. Garnet is very fine granule and generally small in amount. On the contrary, chlorite and muscovite grow to large flakes.

Mineral assemblages of basic rocks are as follows ;

epidote-chlorite-albite-quartz

epidote-chlorite-muscovite-albite-quartz

garnet-epidote-chlorite-muscovite-albite-quartz

actinolite-epidote-chlorite-albite.

Accessory minerals are apatite, titanite, blue tourmaline, and opaque minerals. The basic rocks are generally devoid of carbonate. Albite forms porphyroblasts with many inclusions, though they are not detectable with the naked eye. In the rocks with conspicuous schistosity, albite-porphyroblast bends conformably to the schistosity, as in the pelitic rocks.

The pebbles from Okurazawa contain many glaucophane-schists. These glaucophane schists belong probably to the same grade of metamorphism as the above schists, Glaucophane schists and actinolite schists occuring in thin bands or intermingling irregularly are also known from the Sanbagawa belt in Shikoku and from the Omi schist region. The glaucophane schist has mineral assemblage of chlorite-glaucophane-epidote-albite-quartz. Some rocks contain a small amount of muscovite which forms always thin seams together with epidote and chlorite. Muscovite scatters by no means evenly throughout the rock. Frequently large crystal of calcite is contained in vein associating chlorite. Accessory minerals are titanite and opaque mineral. The glaucophane schists contains much quartz, whereas the actionolite schists does almost no quartz. A sample of glaucophane schist contains a small amount of actionolite. Glaucophane is somewhat paler blue in tint. In this rock-type, actinolite occurs intimately with albite vein ; for example, glaucophane crystal ramifies into slender branches toward the contact with albite vein and then penetrates into the vein as actinolite. This mode

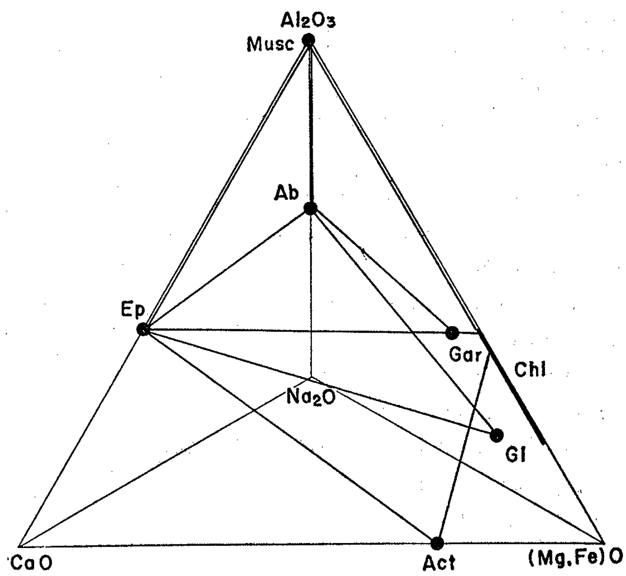

Fig. 6 Mineral assemblages of the glaucophane schist facies

of occurrence of actinolite is probably related in genesis with the fact that actinolite does not coexist with quartz. The glaucophane schist is very rich in epidote. The mineral assemblages in this grade of metamorphism are shown in Fig. 6.

The crystalline schists from the top of Mt. Tanigawa-dake are considered to represent the highest grade of the Joetsu metamorphic belt. The rocks corresponding in grade to these schists occur as pebbles of the Mesozoic and the Tertiary sediments around Mt. Tanigawa-dake and of the Awazawa formation in Okurazawa. In the pelitic metamorphic rocks, mineral assemblages do not change but the occurrence of garnet becomes more common and the schists of Mt. Tanigawa-dake contain the mineral without exception. In the basic metamorphic rocks, actinolite and glaucophane disappear and hornblende appers in stead of the formers. Also the occurrence of garnet becomes more common and the representative rock type is garnet-hornblende-epidote-chlorite-albite-quartz schist.

Garnet grows to large porphyroblast in both pelitic and basic rocks. It includes graphite in the pelitic rocks and many minute granules of epidote in honeycomb fashion. Albite porphyroblast in the basic rocks is rarely detectable even with the naked eye. Albite and quartz are generally contained in both basic and pelitic rocks. However, the basic rocks contain much more albite than quartz and sometimes they have no quartz. On the contrary, the pelitic rocks contain much more quartz than albite. Accessory minerals are titanite and rarely blue tourmaline in the pelitic rocks. Mineral assemblages of this metamorphic grade are shown in Fig. 7.

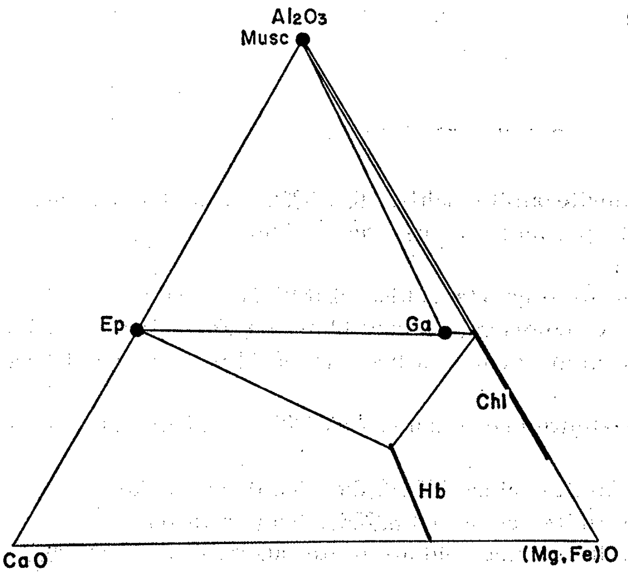

Fig. 7 Mineral assemblages of the epidote amphibolite facies.

As rare rock-types, there are pebbles of quartz schist and metagabbro. Quartz schist contains a small amount of epidote, muscovite, and chlorite. Metagabbro is coarse-grained and consists mainly of altered plagioclase, pale brown hornblende, and epidote with a small amount of muscovite.

2. Mineralogy

As mentioned in the foregoing section, the crystalline schist of the Joetsu region are considered to be the product of the glaucophanitic metamorphism. This is justified in this section from the view-point of amphibole-and garnet-mineralogy.

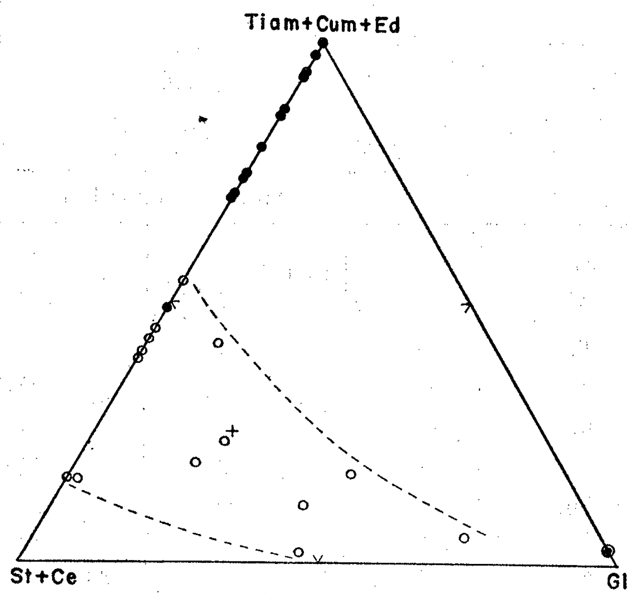

Fig. 8 Substitution relation in calciferous amphiboles.

Solid circle: calciferous amphiboles of metamorphic rocks of the higher temperature and lower pressure type, from HAYAMA (1964b) and SHIDO (1958).

Open circle: calciferous amphiboles of metamorphic rocks of the glaucophanitic type, from BANNO (1964). One exception in the former type, plotted in the field of the glaucophanitic type, is due to the richness in tschermakite molecule.

Cross: Joetsu hornblende.

Double circle: Joetsu glaucophane.

a) Calciferous amphibole

Calciferous amphibole was separated from a

Table 1 Chemical analyses of minerals

	1	2	3	4	5*	6*	7*	8*
SiO_2	48.38	55.88	38.00	38.25				
Al_2O_3	9.27	8.10	20.62	20.14	22.3	26.1	25.5	31.7
TiO_2	0.55	0.48	0.19	0.58				
Fe_2O_3	3.50	8.32	6.03	2.65	3.1	3.6	4.2	0.1
FeO	12.60	7.91	22.44	24.03	18.4	20.6	21.3	22.6
MnO	0.26	0.16	1.79	1.89	0.3	1.0	1.3	7.8
MgO	11.58	9.92	1.77	2.04	1.3	1.4	2.0	1.2
CaO	10.79	2.51	8.49	9.00	7.0	9.3	8.4	1.4
Na_2O	1.46	5.39	0.35	0.21				
K_2O	0.27	0.08	0.01	0.01				
P_2O_5	0.04	0.03	<0.01	<0.01				
C	0.04	—	0.13	0.18				
H_2O-	0.14	0.16	0.12	0.34				
H_2O+	1.02	0.80	0.06	0.61				
total	99.90	99.74	100.01	99.94				

Atomic proportion

	1		2		3		4	
Si	7.00	8.00	7.74	8.00	3.00		3.04	
Al	1.58 {1.00, 0.58}		1.32 {0.26, 1.06}		1.92	2.00	1.89	2.00
Ti	6	5.07	5	4.97	1		3	
Fe^{+3}	38		87		0.36 {0.07, 0.29}		0.16 {0.08, 0.08}	
Fe^{+2}	1.52		92		1.48	2.87	1.60	2.85
Mn	3		2		12		13	
Mg	2.50		2.05		21		24	
Ca	1.68	2.14	37	1.83	72		77	
Na	41		1.44		5		3	
K	5		2					
H_2O	98		74					

Analyst, K. MAEDA
* by electron probe microanalyser (analyst, K. UGAI and Y. SHIMAZAKI)

1 hornblende from garnet-hornblende-epidote-chlorite-albite schist (65080205), calculated based on O=23. $\beta=1.654-1.655$ for minimum of n_2 and maximum of n_1, respectively. $2V_x=73°$. X=pale yellow, Y=grass green and Z=pale bluish green

2 glaucophane from chlorite-epidote-glaucophane-albite-quartz schist (65080513b), calculated based on O=23. $\beta=1.655$. $2V_x=36°$. b=Z, $c\wedge Y=7°$. X=colorless, Y=sky blue and Z=magenta purple.

3 garnet from graphite-garnet-muscovite-chlorite-albite-quartz schist (65080511c), calculated based on O=12

4 garnet from graphite-garnet-muscovite-chlorite-albite-quartz schist (66082001), calculated based on O=12

5 garnet from chlorite-garnet-epidote-hornblende-albite schist (65080205), Tanigawa-dake

6 garnet from chlorite-garnet-epidote-hornblende-albite schist (65080206), Tanigawa-dake

7 garnet from hornblende-bearing chlorite-muscovite-garnet-epidote-albite-quartz-schist (66082003), Tanigawa-dake

8 garnet from chlorite-garnet-muscovite-biotite-albite-quartz schist (66092514), on the lower stream of the Mizunashi river

garnet-hornblende-epidote-chlorite-albite schist at the top of Tanigawa-dake and chemically analysed (Table 1, no.1). This is common hornblende. The chemical formulas of various members of calciferous amphibole are well expressed by the following seven types of substitution. Starting from the tremolite formula, according to SHIDO (1958), they are titano-amphibole-substitution (Ti, Al_2 — Mg, Si_2), cummingtonite-substitution (Mg—Ca), calcium-edenite-substitution (Ca, Al_2—Si_2), soda tremolite-substitution (Na_2 — Ca), edenite-substitution (Na, Al — Si), glaucophane-substitution (Na, Al — Ca, Mg), and tschermakite-substitution (Al_2 — Mg, Si). Among these, titanoamphibole-, cummingtonite-, and edenite-substitutions, are empirically conspicuous in calciferous amphiboles of the metamorphic rocks of the higher temperature and lower pressure type. On the contrary, in metamorphic calciferous amphiboles of the glaucophanitic metamorphism, glaucophane-and soda tremolite-substitutions are conspicuous. The calicium edenite-substitution may be characteristic for hornblende of lower grades of the former type of metamorphism. These relation is well shown in Fig. 8.

The Joetsu hornblende is moderate in the glaucophane- and soda tremolite-substitutions and nothing in the calcium edenite-substitution. This character is typical for hornblende in the glaucophanitic metamorphism.

b) Glaucophane

Alkali amphiboles in the Joetsu metamorphic belt are purplish blue variety and the analysed sample is subglaucophane, according to the Miyashiro's classification (MIYASHIRO, 1957), that is, $Fe^{+2}/(Fe^{+2}+Mg) = 0.31$ and $Fe^{+3}/(Fe^{+3}+Al^{VI}) = 0.45$.

c) Garnet

Garnet is the commonest rock-forming mineral in the Joetsu metamorphic rocks. It occurs in the pelitic rocks from the lowest to the highest metamorphic grades, but in the basic rocks it does not occur in lower grade. Their chemical compositions are shown in Table 1 and 2. They are rich in almandine and grandite molecules and poor in spessartine molecule. This chemical character may be proper to the garnet in the glaucophanitic metamorphism, as shown in Fig. 9. With some exceptions, the garnet in the glaucophanitic metamorphism is rich in grandite

Table 2 Molecular proportion of garnet

No.	3	4	5	6	7	8
almandine	61.8	58.0	70.5	65.5	66.8	69.4
pyrope	7.3	8.7	4.0	3.7	4.9	2.8
spessartine	4.2	4.7	1.0	3.3	4.0	23.8
grossular	22.6	22.9	8.5	12.3	6.1	3.2
andradite	4.0	5.5	16.4	15.2	18.2	0.8

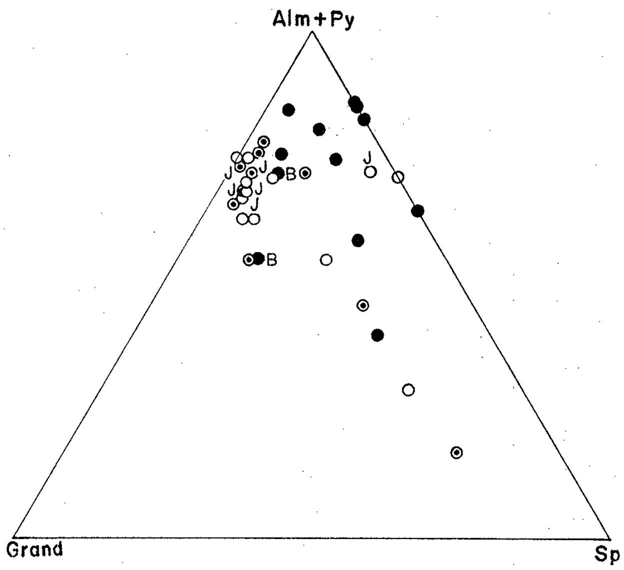

Fig.9 Comparison of chemical compositions of garnets between the glaucophanitic and the non-glaucophanitic metamorphism.
Solid circle; non-glaucophanitic metamorphism (suffix B; basic rocks), from MIYASHIRO (1953), HAYAMA (1964), GOLDSCHMIDT (1920), WISEMAN (1934), PHILLIPS (1930), and BILLINGS (1937).
Open and double circle; glaucophanitic metamorphism (open; pelitic rock, double; basic rock), from BANNO (1964), and IWASAKI (1963).
Suffix J; Joetsu garnet.

molecule, regardless the calcium-content in its host rock. On the other hand, garnet in the nonglaucophanitic metamorphism may depend largely on the bulk chemical composition of its host rock: that is, it is poor in grandite molecule in pelitic rock and rich in basic rock. One of the Joetsu garnets in the lowest metamorphic grade is exceptionally poor in grandite molecule and rather rich in spessartine molecule. This garnet is may be the contact product of later granite.

3. Petrochemistry

The chemical compostions of the main rock-types in the Joetsu metamorphic belt are shown in Table 3. Pelitic rock is rather similar to the Paleozoic slates of the Kiso Mountainland (KATADA *et al.*, 1963), but the Joetsu rock is considerably higher in Na_2O and CaO and slightly higher in MgO than the latter. On the other hand, compared to the pelitic schists of the Sanbagawa metamorphic belt (BANNO, 1964), the Joetsu rock is distinctly lower in SiO_2 and richer in CaO and MgO. Na_2O content of the Sanbagawa rocks is very variable and, therefore, it is not said that the Joetsu rock is always richer in Na_2O. Compared to the Sanbagawa basic schist, the Joetsu ones are lower in Na_2O in average, espeically in glaucophane schists. But, on the whole, both are very similar to each other.

Table 3 Chemical composition of metamorphic rocks

	1	2	3	4
SiO_2	64.68	47.83	49.40	46.90
Al_2O_3	16.55	14.36	14.56	16.42
TiO_2	0.48	1.83	1.39	1.45
Fe_2O_3	1.02	4.03	3.01	10.40
FeO	3.66	8.94	9.64	2.80
MnO	0.07	0.20	0.27	0.23
MgO	3.35	7.44	7.60	3.78
CaO	2.23	9.52	8.14	14.73
Na_2O	3.38	2.67	2.69	1.75
K_2O	1.84	0.81	1.00	0.10
P_2O_5	0.14	0.18	0.10	0.13
C	0.17	—	—	—
H_2O+	2.08	1.86	1.88	1.00
H_2O-	0.26	0.30	0.32	0.16
total	99.91	99.97	100.00	99.85

1 graphite-garnet-muscovite-chlorite-albite quartz schist (66082001) from the top of Tanigawa-dake
2 garnet-hornblende-epidote-chlorite-albite schist (65080205) from the top of Tanigawa-dake
3 garnet-hornblende-epidote-chlorite-albite schist (65080206) from the top of Tanigawa-dake
4 chlorite-epidote-glaucophane-albite-quartz schist (65080513b) from the pebbles of the Awasawa formation in Okurazawa

SEKI (1958) found that some glaucophane-bearing schists have statistically larger amounts of FeO and Na_2O than glaucophane-free schists. The high oxidation ratio in glaucophane-schist is also valid in the Joetsu rock, whereas the high content of Na_2O is not so. Na_2O content is significantly lower than the associated glaucophane-free schists.

4. Metamorphic facies

From the above descriptions, the crystalline schists of the Joetsu region are undoubtedly the product of the glaucophanitic metamorphism. Moreover, the garnet-albite-epidote amphibolite represents the epidote amphibolite facies. According to BANNO (1964), the rocks of the epidote-amphibolite facies of the Sanbagawa metamorphic belt in Shikoku contain biotite, but the Joetsu rocks by no means contain the mineral. Therefore, the Joetsu epidote-amphibolite is considered to represent the lower grade of the epidote-amphibolite facies.

It is sure that the glaucophane-bearing schists represent the glaucophane schist facies. However, in the Joetsu region, there is no rock containing pumpellyite and lawsonite. Therefore, the Joetsu glaucophane schist represents the higher grade of the glaucophane schist facies.

On the other hand, the rocks of the lowest metamorphic grade, *e. g.* chlorite-muscovite-garnet schist from the Mizunashi valley, are questionable about their metamorphic facies. They do not contain pumpellyite and lawsonite. This may be due to any slight effect of the contact modification, by which pumpellyite and lowsonite, if present may have disappeared. If it is so, the facies series of the Joetsu metamorphic rocks ranges from the higher grade of the glaucophane schist facies to the epidote-amphibolite facies.

5. Serpentine

We made no detailed examination on serpentine widely exposed in the Joetsu region, but AOKI,

Table 4 Composition of olivine by X-ray diffraction*

No.	2θ	d	Fo %	Note
65052205	32.30	2.7715	91.6	orthopyroxene
65052206	32.30	2.7715	91.6	
65052207a	32.32	2.7699	94.0	
65052207b	32.31	2.7707	92.8	
65052208	32.28	2.7732	89.0	olivine abundant
65052209a	32.32	2.7699	94.0	
65052209b	32.31	2.7707	92.8	olivine abundant
65052301	32.29	2.7723	90.4	
65052302	32.28	2.7732	89.0	chromite
65052307	32.29	2.7723	90.4	orthopyr. 2V(+)=74,
65052308	32.29	2.7723	90.4	
65052309a	32.29	2.7723	90.4	
65052313	32.29	2.7723	90.4	olivine abundant
65070208YH	32.31	2.7707	92.8	olivine abundant
65070209YH	32.31	2.7707	92.8	
65070101	32.31	2.7707	92.8	
65070102	32.31	2.7707	92.8	
65070109	32.31	2.7707	92.8	
65112006	32.30	2.7715	91.6	orthopyr.; oliv. abundant
65112009	32.31	2.7707	92.8	
65112101	32.29	2.7723	90.4	orthopyr. 2V(+)=72; olivine abundant
65112603	32.33	2.7690	95.0	olivine abundant
65112601	32.33	2.7690	95.0	
65112610a	32.33	2.7690	95.0	olivine abundant
65112703	32.29	2.7723	90.4	orthopyr.
65112707	32.30	2.7715	91.6	

* sample powder was heated at 650°C for 30 minutes (determined by K. AOKI)

a member of our group, determined the chemical compositions of relic olivine. The result is shown in Table 4. All of them range 90 to 95% in forsterite molecule. The relic minerals are olivine, orthopyroxene, and chromite. There is no clinopyroxene. The original ultrabasic rocks are considered to have been largely dunite with subordinate amount of harzburgite.

GEOLOGIC SITUATION OF THE JOETSU METAMORPHIC BELT IN THE JAPANESE ISLANDS

As is well known, the parallel arrangement of the Sanbagawa, Chichibu, and Shimanto Belts are quite evident in the Outer Zone of Southwest Japan. Toward the east, it is traced across the Fossa Magna into the Kanto Mountainland, which is isolated in the midst of the Cainozoic terrain of central Japan. Beyond this the eastern extension of these belts are hidden beneath the younger deposits of the Kanto Structural Basin. In the Inner Zone of Southwest Japan, the Sangun Belt of metamorphic rocks occupies the western half while the Tanba Belt of non-metamorphic Paleozoic rocks is developed in the eastern half. The former can be followed, though intermittently, along the northern margin of the Tanba Belt and terminates in the Omi district. This zone is known

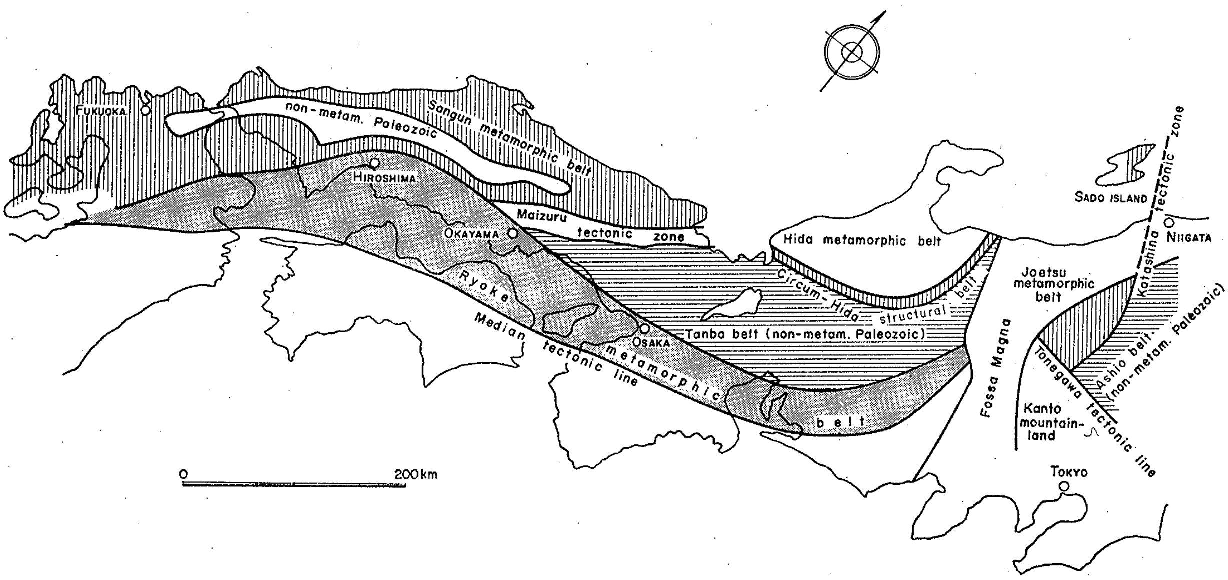

Fig. 10 Zonal structure in the inner zone of Southwestern Japan and its relation to the Joetsu metamorphic belt.
The extension of the Joetsu metamorphic belt to the Sado island is due to H. HATTORI (1966)

under the name of the Hida Marginal Structural Zone. The crystalline schists are of glaucophanitic type (BANNO, 1958, SEKI, 1959, ITO, 1960), and resemble those of the Joetsu region. It shows, together with the similarities between the lower Jurassic and Cretaceous deposits on both sides of the Fossa Magna, that the Joetsu metamorphic belt is an eastern extension of the Sangun Belt. The additional considerations are summarized as follows.

1. The Katashina Tectonic Zone

In the eastern margin of the Joetsu region, there runs the Katashina Tectonic Zone, and it is very similar to the Hida Marginal Structural Zone. As the details of the Katashina Tectonic Zone will be described in a separate paper, their essentials will be next pointed out in connection with the Hida Marginal Structural Zone.

The Katashina Tectonic Zone is a boundary between the Joetsu metamorphic belt and the Ashio Belt of the unmetamorphosed Paleozoic formation. The zone is characterized by the existence of the Tokurazawa formation (the Tetori series), the Iwamuro formation (the Kuruma series), and the Katashina basic rocks, the last of which are intruding into the former two formations. Similarly, the Hida Marginal Structural Zone is situated along the northern margin of the Tanba Belt of the unmetamorphosed Paleozoic formation, and is characterized by the Tetori and the Kuruma formations and also by the basic rocks, which are intrusive into the Tetori formation (KAWAI, *et al.*, 1957). There are, however, slight differences between the two tectonic zones as follows ; first, in the Hida district, the Tetori and the Kuruma formations are not confined within the Hida Marginal Structural Zone but exposed widely over the Hida metamorphic belt. Secondly, the Hida Marginal Structural Zone itself is the metamorphic belt, characterized by glaucophanitic metamorphism. Thirdly, in the Hida Marginal Structural Zone, there are exposed sporadically the sediments of the Devonian to lower Carboniferous age, which have not been found in the Katashina Tectonic Zone.

2. The similarity between the Tanba and the Ashio Belts

In the outer side of the Hida Marginal Structural Zone, there develops the Tanba Belt of the unmetamorphosed Paleozoic sediments, while in the outer side of the Katashina Tectonic Zone, there is the Ashio Belt of the unmetamorphosed Paleozoic sediments. The sediments of both regions are characterized by the common occurrence of chert. Especially, in the east of the Kuromata river, which is located in the eastern boundary of the Joetsu metamorphic belt in its northernmost part, the Paleozoic sediments contain the so-called Aka-shiro Keiseki (a sort of chert), which also chracterizes the Paleozoic sediments of the Tanba Belt. These facts suggest that the Ashio Belt is the extension of the Tanba Belt in Northeast Japan.

3. Geologic history

The geologic history of the Hida Marginal Structural Belt including its northern area is very similar to that of the Joetsu region. In the Joetsu region, the sedimentary basins of the Mesozoic era were formed over and over again. They are shown by the Okutone formation in the Trassic, by the Iwamuro formation in the Jurassic, and by the Tokurazawa formation in the Cretaceous. Similarly in the Hida region, the transgressions occurred repeatedly, as represented by the Kuruma and the Tetori formations. From the end of the Cretaceous to the Paleogene, active acid magmatism occurred in both regions, and then, in the Miocene, large sedimentary basins were formed. By the late Cretaceous granite the crystalline schists of the Hida Marginal Structural Belt as well as of the Joetu metamorphic belt were polymetamorphosed and transformed largely into hornfels. In the Paleogene, the Oamamiyama rhyolites and Futomiyama rhyolites were extruded in the Hida region, and also in the adjacent area of the Katashina Tectonic Zone the silimar activity of rhyolite seems to have occurred (KAWADA, oral communication).

4. Age of the metamorphism

As mentioned already, the Joetsu metamorphic belt supplied pebbles for the Jurassic Iwamuro formation, while serpentine is covered unconformably by the latter. Therefore, the age of the metamorphism is surely pre-Jurassic. Moreover, in Keizuru-yama to the north of Ozegahara Moor, the unmetamorphosed uppermost Permian sediment containing *Lepidolina* and *Schwagerina* has been found (FUJIMOTO, *et al.*, 1961). Although these fossils are only found in pebbles in river bed, this fact suggests that the metamorphism is probably pre-uppemost Permian in age.

On the other hand, the age of the metamorphism in the Hida Marginal Structural Belt is unknown. But, as mentioned already, it is considered to be the same as the age of the metamorphism in the Sangun metamorphic belt, which is pre-middle Triassic.

Acknowledgements

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上越変成帯とその日本列島地質構造への意義

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要　　旨

上越地方には，変成岩および蛇紋岩の小岩体が各地に散在するが，その多くは，もと片状岩類だったものが白亜紀ないし第三紀の花崗岩の接触変成作用によってホルンヘルス化した複変成岩である．いっぽう，谷川岳頂上のルーフペンダント，およびジュラ系（岩室層）ないし第三系（粟沢層）の礫岩に見出される結晶片岩礫には，藍閃片岩または藍閃片岩相地域に特徴的な変成岩が認められる．これらによって，上越地方には，少くもジュラ紀から中新世にかけて，藍閃石型広域変成帯が実在したと推定され，現在はほとんど失なわれているが，これを上越変成帯と名付けた．

さらに次の理由から，上越変成帯を，飛騨高原をとりまく結晶片岩帯の東方の延長と考えた．1) 上越変成帯の東縁をなす片品構造帯は種々の点から飛騨外縁構造帯に類似する，2) 結晶片岩の変成様式が両地域で共通する，3) 変成作用の時期が同じ，4) 両変成帯の外側に分布する非変成古生層（丹波帯と足尾帯）は連続している，5) 両地域の地史がよく似ている．

本文・図中の地名(ABC順)

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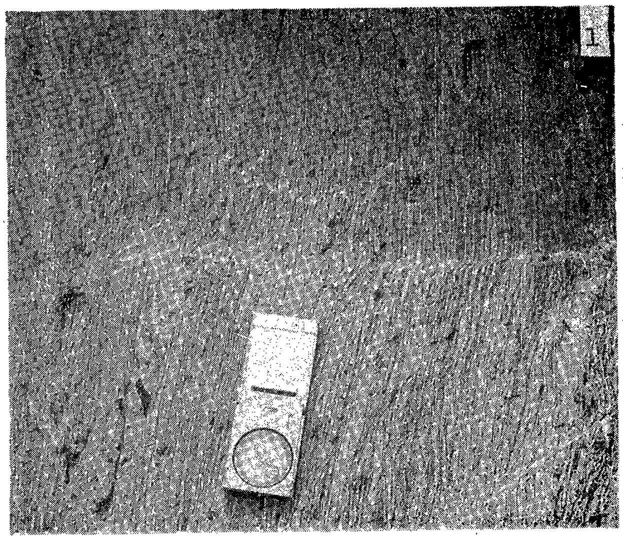
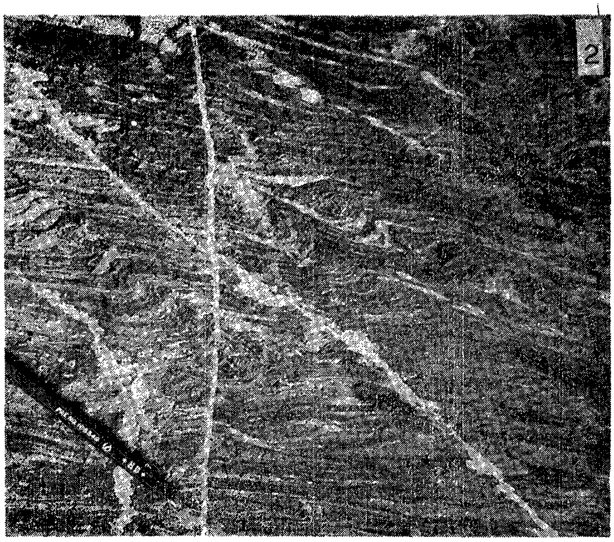
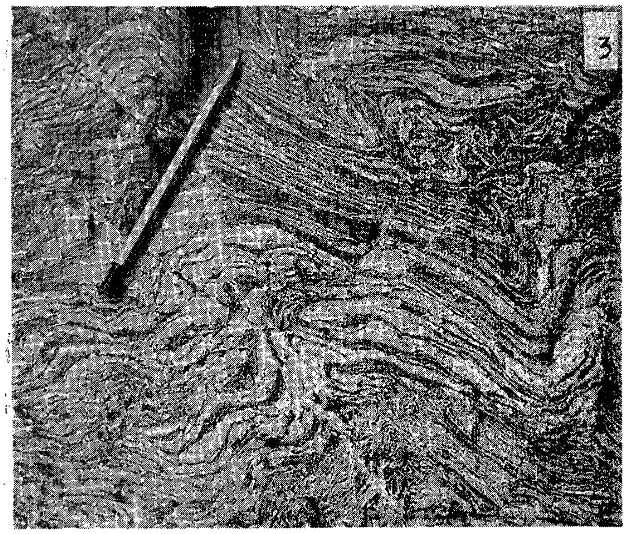
討　　論

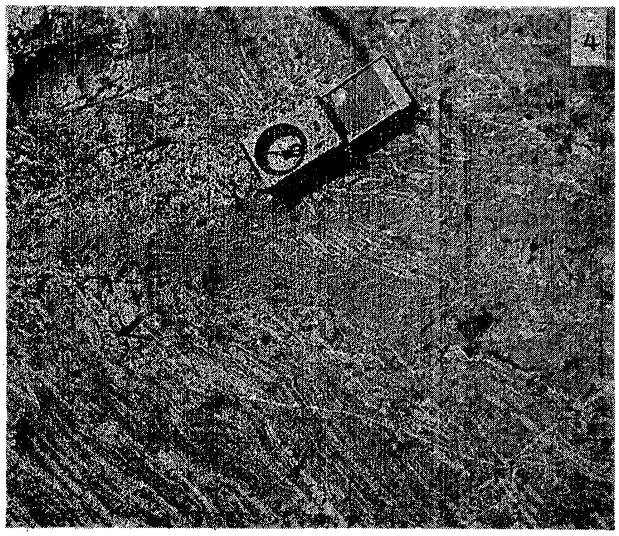
島津光夫(新潟大) 上越変成帯の北方延長の問題であるが, この点で関係があるとおもわれる資料に, 佐渡の古生層を貫ぬく変輝緑岩〜変はんれい岩, 新潟油田新第三系の重鉱物がある. 後者については西山および中央油帯の椎谷層砂岩 (鈴木・吉村, 1966) および東山油帯の椎谷・西山層砂岩 (佐々木・牛島, 1968) 中の藍閃石・ざくろ石・緑れん石などを重視したい. これらの研究および新潟油田堆積盆地の状況からすると, „まぼろし"の変成帯は, 谷川・片品川地域から水無川地域をへて, 三条・弥彦隆起帯, さらに佐渡につらなる延長が考えられる. また古生層の層相からは, 端山も指摘したように, 上越変成帯の東側に丹波帯, 足尾帯と配列し, ひだ外縁帯の延長と考えることに同感. とくに, 丹波帯と考えられる部分に, いわゆる赤白珪石の産出があることに注目したい.

佐藤信次(東京教育大)
関東山地には三波川帯はあるが, 領家帯およびそれに伴なう花こう岩が発見されていない. また上越変成帯をひだ外縁帯に対比するならば, ひだ片麻岩帯に相当するものがどこかにないか？ 昔からいわれている日本国片麻岩はどうであろうか？ こういう問題を含め, 失われた変成帯とか, 埋没した変成帯とかいうが, 日本の変成帯では地表調査だけでなく, 今後はボーリングを加える必要を痛感している.









1 low-grade schist thermally metamorphosed slightly. Loc. Mizunashi river

2 & 3 banded hornfels thermally metamorphosed, Loc. Mizunashi river

4 fault breccia thermally metamorphosed. Loc. Mizunashi river

5 thermally metamorphosed diabase dike. Loc. Mizunashi river