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Stratigraphy and Geologic Structure of the Paleozoic Formations in the Upper Kuzuryu River District, Fukui Prefecture, Central Japan

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Introduction

In Central Japan, a remarkable geotectonic belt is found between the Hida metamorphic complex in the north and the non-metamorphosed Paleozoics mainly composed of Permian rocks in the south. The belt called the Hida marginal tectonic belt is characterized by the occurrences of crystalline schists, the Devonian, and Carboniferous formations besides the Permian, and also by the highly complicated geologic structure with many faults and folds and with intrusive rocks such as the granitic rock and serpentinite. As already noted by many geologists, an elucidation of the geology of the belt area seems to make an important contribution to understand the geologic development of the Japanese Islands during the Paleozoic.

The Upper Kuzuryu River district is situated in the eastern part of Fukui Prefecture and its most part belongs geotectonically to the Hida marginal tectonic belt (Fig.1).

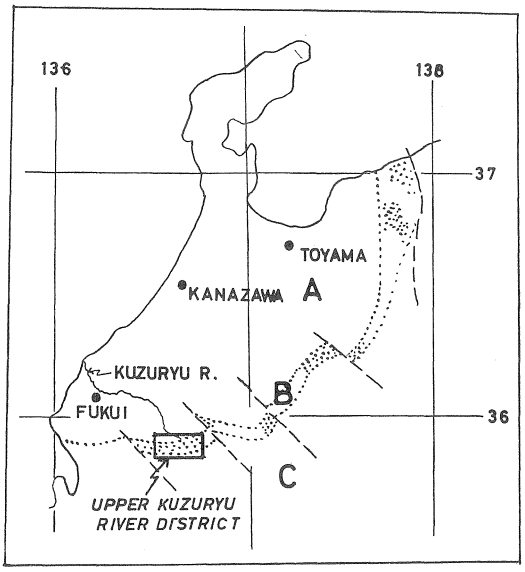

Fig. 1 Map showing the location of the Upper Kuzuryu River district.

A : Hida metamorphic belt
B : Hida marginal tectonic belt
C : Non-metamorphosed Paleozoic belt

The geology of the Upper Kuzuryu River district, where the Mesozoic and Tertiary rocks as well as the Paleozoic ones occur, has been studied by many geologists but the reports published hitherto on the Paleozoic rocks have been rather limited.

The Paleozoic formations in the district were first described by OTSUKI and KIYONO (1919) and later by HORI and HORIUTI (1942), but their details have remained untouched. In 1950, ISHIOKA and KAMEI discovered "Gotlandian fossils"* at Oisedani, which was the first important discovery of biostratigraphical records for the Paleozoics in this district. Subsequently, HAYASAKA and MATSUO (1951) reported the Permian fossils from Oguradani. During 1952-1958, K. OZAKI of Kanazawa University studied the Paleozoic geology of the district together with his students and the present writer and they clarified the outline of stratigraphy and geologic structure of the Paleozoic formations. The result has been briefly summarized in "Geologic studies of the Hida Mountainland" (FUJIMOTO, ed. 1962). Geologic maps and descriptions of the district in whole or part have been given by KOBAYASHI (1954), KAWAI (1956), KAWAI, HIRAYAMA, and YAMADA (1957), and

* Nowadays, the fossils are generally accepted as Devonian in age for Silurian.

MAEDA (1961 a,b). MAEDA (1958 b) also has made a valuable suggestion for the geologic structure of the Paleozoic formations. Recently, important contributions to the study of a conglomerate called Ōtani conglomerate have been added by KANO (1961), YAMAGUCHI and ŌTA (1965), and HASEGAWA (1965). Besides, crystalline schists in the Ise area have been researched by ISHIOKA (1950) and KOBAYASHI (1958).

Notwithstanding their efforts, detailed stratigraphic sequence and geologic structure of the Paleozoic formations have not yet been settled chiefly because of the intense complexity of the geologic structure. Since 1955, the present writer has been working on the geology of the Paleozoics in the district together with several students of Kanazawa University. In this paper he intends to describe the stratigraphic sequence of the Paleozoic formations and to make a few remarks on their geologic structure.

Acknowledgements. The study was started under the leadership of late Professor K. OZAKI of the Kanazawa University. The writer wishes to express his deep appreciation to late Professor OZAKI for his direction and encouragement during the course of the study. The writer also is much indebted to Professor M. MINATO of Hokkaido University for guidance and constant encouragement. His hearty thanks are due to Drs. M. KATO and N. FUJI, Messrs. S. YOSHIDA, M. KONISHI, H. YAMAMOTO, S. TAKAOKA, and H. OKADA, who cooperated with him in field and supplied valuable information.

The writer wishes to express his special acknowledgement to Professor Y. KASENO of Kanazawa University for advice and continuous encouragement. He is also grateful to Dr. K. KONISHI and Professor M. YAMASAKI, both of Kanazawa University, for kind reading the manuscript and to Mr. N. NAKANISHI of same University for identification of igneous rocks.

Outline of Geology of the Upper Kuzuryu River District

In the eastern part of Fukui Prefecture including the Upper Kuzuryu River district, three geotectonic units are distinguished in the pre-Tetori (pre-Middle Jurassic) rocks. These units may correspond, from north to south, to the Hida metamorphic belt, Hida marginal tectonic belt, and non-metamorphosed Paleozoic belt, respectively. In this paper the Paleozoic formations in the Hida marginal tectonic belt of the district will be described.

The generalized geologic map and geologic sections of the surveyed area are given in Fig. 2. The local detailed geologic map of its eastern part is in Fig. 3. The stratigraphic classification of the pre-Tertiary sediments in the mapped area is in descending order as follows:

Cretaceous :	Suhara Formation
Cretaceous-Jurassic :	Tetori Group

Triassic ? :	Ōtani Formation and Motodo Formation
Permian :	Magatoji Formation
	Nojiri Group
	Ōboradani Formation
Carboniferous :	Nagano Formation and probably Fujikuradani Formation
Devonian :	Kamianama Group

In addition to the rocks listed above, in the mapped area are present Ashidani Formation and Ise Crystalline Schists, of which exact stratigraphic positions and ages have not yet been settled, though it may be safely said that they are older in age than the Ōtani Formation.

Besides, the strata assigned to the Paleozoics were mapped in the southwestern corner of the surveyed area. They are a part of the strata distributed extensively to the southward of the mapped area and regarded to be a member of the non-metamorphosed Paleozoic belt.

Pre-Tetori strata. As shown in the geologic map, the pre-Tetori strata are developed mainly and predominantly in a restricted area bounded by two faults, Nagano fault (newly named) and Akiu fault (KOBAYASHI, 1954), both of which have roughly eastward trends. This area may be called, for convenience, Paleozoic terrain though the Mesozoic and younger rocks also occur. However, the occurrences of the Fujikuradani Formation and of part of Ise Crystalline Schists form exceptions, that is, they crop out to the north of the Nagano fault or south of the Akiu fault.

In the Paleozoic terrain the Permian Nojiri Group occupies the widest exposure extending from east to west, and nextly followed by Motodo Formation with moderate distribution. The Ashidani Formation composed of phyllitic rocks and Ise Crystalline Schists are found respectively in the northeastern and the southeastern part of the Paleozoic terrain. The Kamianama, Nagano, and Ōboradani Formations are distributed sporadically within two narrow zones, one of which, named Ōtani disturbed zone tentatively, extends eastwards from near Nagano to Kamihanbara, and the other, Tomedōro disturbed zone, does northeastwards from Ise pass to Tomedōro. The Ōtani Formation also occurs mostly in these zones. Furthermore, it is noted that serpentinite is found principally along the zones. Each of the above pre-Tetori strata dips steeply in general and is bounded on its circumference by faults in most places.

Tetori Group and younger rocks. The Tetori Group ranging from Middle Jurassic to Lower Cretaceous is developed extensively in the outside of the Paleozoic terrain except a few sporadic exposures.

Details on the stratigraphy and geologic structure of the group have been reported by KAWAI (1956), KAWAI, HIRAYAMA, and YAMADA (1957), and MAEDA (1957 a,b, 1961 a,b). Further, the geotectonic development of the district through the

later Mesozoic time has been discussed in detail by KAWAI (1956) and MAEDA (1961b).

According to them, the Tetori Group in the outside of the Paleozoic terrain is mainly composed of conglomerate, sandstone, and shale, and strongly folded. Its maximum thickness seems to exceed 1500m. The lower part of the group (Kuzuryu Subgroup) is of marine origin, and middle and upper parts (Itoshiro and Akaiwa Subgroup, respectively) are of non-marine. The group in the outside of the terrain covers with angular-unconformity the Paleozoic Fujikuradani Formation (WAKABAYASHI and SATO, 1966), but is separated by faults, the Nagano and Akiu faults, from the older rocks exposed in the Paleozoic terrain.

The Tetori Group in the Paleozoic terrain has the same lithology as that of the outside of the terrain and crops out in several narrow areas as inserts by faulting or as erosional remnants underlain unconformably by the older rocks. Its original thickness may be thinner than that in the outside of the terrain.

The Upper Cretaceous Suhara Formation is composed of conglomerate, sandstone, shale, and acidic tuff, and occurs narrowly in the western part of the Paleozoic terrain. Rocks nearly equivalent in age to the Suhara Formation are widely distributed close to the southeast of the surveyed area. These rocks and Suhara Formation have received apparently no effect of folding, which differs from the case of the Tetori Group. They overlie unconformably Paleozoic rocks as well as the Tetori Group.

Tertiary volcanic rocks such as andestie and rhyolite occur in the west part of the mapped area and rest with unconformity on the older rocks.

Intrusive rocks. Relatively large bodies of the intrusive rocks in the surveyed area are of granodiorite, metadiorite, and serpentinite.

The granodiorite bodies are found in the western part of the area. The rocks intrude into the Permian Nojiri Group and seem to be in fault contact with the Triassic? Motodo Formation at present. Its relation to the Tetori Group has not been ascertained. According to T. NOZAWA (oral communication), the granodiorite resembles in lithology some type of Funatsu granodiorite of pre-Tetori age in Hida Mountainland.

Two bodies of metadiorite varying in composition from diorite to gabbro are present in the southeastern corner of mapped area and have penetrated into the Ise Crystalline Schists and the Tetori Group.

The serpentinite* bodies occur principally along the Tomedōro disturbed zone. Their intrusion probably took place in the latest Permian or early Mesozoic time, but some of them might be re-moved later along the Akiu fault.

Smaller masses of dyke rocks are found in many places. Although acidic rocks such as quartz porphyry are found occasionally, many of them are of basic to

* 'Silica-carbonate rock' is included under the name of serpentinite in this paper, because it is considered to be a product of the alteration of serpentinite.

intermediate in composition. The intrusion of these rocks must have occurred in various stages but its discrimination has not yet been succeeded.

Paleozoic Formations and Metamorphic Rocks

Devonian System

Kamianama Group

The Kamianama Group, which is the oldest fossil-bearing formation in the Upper Kuzuryu River district, is distributed sporadically in two narrow zones, namely the Ōtani and the Tomedōro disturbed zone, and its contact to the surrounding younger sediments is in fault everywhere. The group crops out at Shibasudani, Akubaradani, Ōboradani, and Iyamadani in the Ōtani disturbed zone, and in the area extending from Ise pass to Kamiise in the Tomedōro disturbed zone. The maximum width of the exposure is 250m at Shibasudani and the minimum 20m at Akubaradani.

The group at Kamiise, the type locality of the group, consists of dark grey or black limestone estimated at several ten meters in maximum thickness. Locally the limestone is white and recrystallized. Rather excellent section of the group is measured at Ōboradani, where the group strikes N. 60~70°W. and dips 30~70°S. The section is as below in descending order:

	Thickness
—— Fault ——	
Sandstone, fine- to medium-grained, siliceous, poorly exposed.	20m
Limestone, dark grey, massive, fossiliferous.	30m
Slate and sandstone, gradually transitional or bedded; sandstone, fine- to coarse-grained.	25m
Sandstone, coarse-grained to conglomeratic, intercalated with irregular shaped thin shale, reddish brown, transitional from the overlying bed.	25m
—— Fault —— Total	100m

In other places the group appears to consist of limestone, slate, and sandstone, and to be accompanied with less amount of tuffaceous rocks in one place. Their detailed sections, however, have not been obtained because of ill exposure of rocks except limestones resistive to weathering. As a whole the group is marked with the dominance of limestone.

The marine fauna such as corals, stromatoporoids, and brachiopods are contained in the limestone of the group in many places. A fossil list (Table 1) is prepared from the unpublished data by K. OZAKI and M. KATO in addition to those by ISHIOKA and KAMEI (1950), OZAKI (1956, 1957), KAWAI, HIRAYAMA, and YAMADA (1957), MAEDA (1958.b), and HAMADA (1959).

Table 1. List of fossils from the Kamianama Group.

Specific name	Localities		
	1	2	3
Entelophyllum articulatum (EHRENBERG)	×		×
Tryplasma sp.	×	×	×
Cyathophyllum sp.	×		
Cystiphyllum sp.			×
Oborophyllum oboroensis OZAKI		×	×
O. katoi OZAKI		×	×
Favosites hidensis KAMEI	×		×
F. cfr. *baculoides* (BARRANDE)	×		
F. forbesi takarensis KAMEI	×		
F. cfr. *asper* D' ORBIGNY		×	×
F. spp.	×	×	×
Parafavosites fukujiensis KAMEI	×		
Heliolites bohemicus WENTZEL	×		
H. sp.	×	×	×
Coenites sp.	×	×	×
Clathrodictyon onukii SUGIYAMA	×		×
C. sp.		×	×
Clavidictyon sp.		×	×
Amphipora cylindrica SUGIYAMA		×	
A. sp.	×	×	×
Actinostroma sp.	×	×	
Atrypa cfr. *reticularis* (LINNÉ)	×		

Locality 1 : Kamiise, 2 : Shibasudani, 3 : Ōboradani

The Kamianama Group has been generally correlated by many geologists with the Fukuji Formation in the Hida Mountainland and they both were first assigned to Silurian in age. Lately, the age of the Fukuji Formation, at least of its principal part, was revised to Lower Devonian by HAMADA (1959) or Middle Devonian by KAMEI (1961). At the same time it was suggested by them again that the group may be nearly equivalent to the Fukuji Formation. In accordance with HAMADA's or KAMEI's view, the age of the Kamianama Group is now regarded as Early and Middle Devonian or Middle Devonian, but a more detailed paleontological study on the group is necessary in the future.

Carboniferous System

Nagano Formation

The Middle Carboniferous deposit, named Nagano Formation by YAMADA, OZAKI, KATO, YOSHIDA, and KONISHI (1958), occurs discontinuously in the same zones as the Kamianama Group: it is at Konogidani, Iyamadani, and two localities in the vicinity of Ashidani in the Ōtani disturbed zone and at Ise pass, Kamiise (MAEDA, 1958a),

and upper reach of Hamidani in the Tomedōro disturbed zone. Its type locality is in the eastern part of Ashidani on the south of Nagano. The formation is overlain unconformably by the Ōtani Formation at Ise pass and possibly at Ashidani, but is in fault contact with the surrounding rocks in other places. The formation attains the widest distribution at the western part of Ashidani, where the thickness reaches up to about 100m, the maximum value for the mapped area. The attitude of the formation is variable in places.

The formation is mainly composed of limestone. The limestone is light to dark grey, and mostly massive and partly bedded; oolitic texture is common. A red and green shale of 2~3 m thick and a small amount of volcanic materials are intercalated in the limestone at Ashidani.

The limestone attributed to the Nagano Formation is all fossiliferous. The fusulinids obtained from the limestone are listed in Table 2.

Table 2. List of fusulinids from the Nagano Formation.

Specific name	Localities		
	1	2	3
Fusulinella biconica HAYASAKA			×
F. hanzawai IGO	×		×
F. cfr. *pseudobocki* LEE et CHEN	×		×
F. simplicata TORIYAMA		×	
F. spp.	×	×	×
Fusulina ozakii YAMADA (MS)	×	×	×
F. cfr. *schellwieni* (STAFF)			×
F. quasicylindrica megaspherica SHENG		×	
F. spp.		×	×
Profusulinella cfr. *rhomboides* (LEE et CHEN)		×	
Pseudowedekindellina ? sp.		×	
Fusiella typica LEE et CHEN		×	
F. paradoxa LEE et CHEN			×
F. spp.		×	×
Eoschubertella lata (LEE et CHEN)		×	×
E. lata elliptica (SHENG)		×	
E. obscura (LEE et CHEN)	×	×	×
E. elongata (SHENG)			×
Ozawainella sp.		×	×
Millerella cfr. *minuta* SHENG		×	

Locality 1 : Ise pass, 2 : Ashidani, 3 : Iyamadani.

On the basis of the fusulinids listed above, the age of the Nagano Formation is assigned to the Middle Carboniferous as a whole. Strictly speaking, however, the precise age of each limestone body belonging to the formation may vary slightly from place to place. That is, the rocks containing such fusulinids as *Fusulinella hanzawai* IGO, *F. biconica* HAYASAKA, and *F.* cfr. *pseudobocki* LEE et CHEN at Iyamadeni and

Ise pass may be equivalent in age to that of *Fusulinella biconica* zone (TORIYAMA, 1954), perhaps of its upper part, of Akiyoshi Plateau in western Honshu, where the Middle Carboniferous rocks is typically developed and establishment of faunal zones is made by many paleontologists. On the other hand, the formation in the type locality which yields *Profusulinella* cfr. *rhomboides* (LEE et CHEN) coexisting with *Pseudowedekindellina?* sp. and *Fusulinella simplicata* TORIYAMA in addition to various species of *Fusulinella* and *Fusulina*, seems to range from the upper part of *Profusulinella beppensis* zone to *Fusulinella biconica* zone of Akiyoshi Plateau. But the detailed stratigraphic relationship between the horizons containing the above each species is not ascertained, because in this place the only small outcrops are dotted on the slopes under heavy vegetation. As a result, the whole Nagano Formation may be correlative with upper half of *Profusulinella beppensis* zone and *Fusulinella biconica* zone of Akiyoshi Plateau.

Fujikuradani Formation

The Fujikuradani Formation, designated by KAWAI (1956), is typically found at Nakatatsu Mine area in central part of the district. Lately, the detailed study, especially of its geologic structure, has been reported by WAKABAYASHI and SATO (1966).

According to them, the formation extending eastwards is cut out by faults on both the north* and the south side except for several places, where the formation is overlain with angular-unconformity by the Tetori Group. It is composed of limestone with many thin shale layers and black slate, and intensely folded. Some of the limestones have been suffered recrystallization and skarnization which are closely related to injection of quartz porphyry in post-Tetori time. Because of complex folding and faulting the actual thickness is not measured; however, it may be at least a few hundred meters.

Only a species of coral, *Diphyphyllum* sp., besides crinoid stems has been obtained by the writer from the formation at Dosaiyama westward of the Nakatatsu Mine. Its exact specific name can not been determined for its ill preservation; it is said, however, by M. KATO (personal communication) that the species may be allied to that of Nagaiwan series in the Kitakami Massif, northeast Honshu. If it is tenable, the Fujikuradani Formation may be, at least partly, assigned to lower Middle Carboniferous, not Permian suggested by KAWAI *et al.* (1957). Now the writer is inclined to consider that the duration of the formation may possibly exceed beyond that of the Nagano Formation at both upper and lower limits.

Permian System

Ōboradani Formation

* The fault bounding on the north side is well known under the name of Ōno fault.

The formation, first named by YAMADA, OZAKI, KATO, YOSHIDA, and KONISHI (1958), is only found in the Ōtani disturbed zone and its outcrops are at Ōboradani and Akubaradani, the exposures being 200 m long and 50 m wide, and 50 m long and 20m wide, respectively. Although no direct observation is made for poor exposures, the contact between the formation and the surrounding rocks is presumed to be fault.

The formation consists exclusively of medium to dark grey, massive limestone. A small amount of limestone conglomerate is present in the marginal parts of the limestone mass at Akubaradani.

Rather abundant remains of foraminifers are contained in the formation. Among them the following fusulinids have been identified;

Quasifusulina longissima (MÖLLER)
Pseudoschwagerina morikawai IGO
Triticites spp.
Pseudofusulina ? sp.
Schubertella sp.

This fauna shows a strongly close similarity to that reported by IGO (1957) from the *Pseudoschwagerina morikawai* zone of Fukuji in the Hida Mountainland. According to him, the zone which is characterized by *Quasifusulina longissima* (MÖLLER), *Rugosofusulina alpina*(SCHELLWIEN), *Triticites* cfr. *kagaharensis* FUJIMOTO, and *Triticites* spp. besides *Pseudoschwagerina morikawai* IGO is equivalent to the lower half of the *Pseudoschwagerina* zone (TORIYAMA, 1954) of Akiyoshi plateau, and may be correlated with the Sakmarian series or Wolfcampian series, especially their lower parts. Thus, the Ōboradani Formation correlated with the *Pseudoschwagerina morikawai* zone of Fukuji may be considered to be the earlist Permian in age.

Nojiri Group

The name Nojiri Group was first given by HAYASAKA and MATSUO (1951) to the Permian rocks in the eastern part of the mapped area. Now the rocks assigned to the Nojiri Group are exposed in four areas: the principal one including the type area is in the eastern to central part, another is in the northeastern part, and the other two are in the western corner of the surveyed area.

The group is divided into two formations, Oguradani and Konogidani formations, which are in a conformable contact. The chronological order between the two formations, however, is yet unsettled because of the steepness in the bedding of the group, and of lack of informations to determine original top-and-bottom relations. In this paper the Konogidani Formation is tentatively regarded to overlie the Oguradani, according to the apparent order of succession at present.

The Nojiri Group in the principal area seems to take an isoclinal fold on a large scale, of which axial plane steeply dipping southward may be situated in the nearly median part of the Oguradani Formation in its eastern part. The probable existence of the fold is supported by the general correspondence in lithology between the sequences

of the both sides of the assumed axial plane, and also by the occurrence of several isoclinal folds of minor scale in the Oguradani Formation.

Oguradani Formation. The Oguradani Formation, which was first called Oguradani Subgroup by OZAKI, YAMADA, and KATO (1954), has its type locality at Oguradani in Nojiri. The formation in the principal area is mainly composed of slate, sandstone, and their alternation, and accompanied with limestone layers. The type section at Oguradani, where the thickness of the formation is about 400m, shows that sandstone is rather dominant in lower one-third and slate is highly abundant in upper two-thirds. The slate is black or pale green and partly phyllitic. The sandstone is pale bluish green, dark grey, or yellowish brown, and fine- to coarse-grained. The limestone layers are intercalated at two horizons but not continuous in either cases. The one, less than 20m in thickness, is at some 100m below the top of the formation; it is bluish grey or dark grey, massive commonly and laminated in somewhat sandy part, and contains a small amount of organic remains such as crinoid stems. The other layer, several ten meters in maximum thickness, is at top of the formation, and developed well in the western part; it is bluish grey or dark grey, massive or bedded, and apparently unfossiliferous.

In the western corner of the mapped area, one of the formation attributed probably to the Oguradani Formation is the Kumokawa Formation (KOBAYASHI, 1954). The formation exposed to the west of Nakajima consists of black shale, fine-grained sandstone, and limestone. The shale is rather dominant, mostly slaty. No clear section is measured because of ill exposure in addition to structural complication of the formation; the thickness of the formation may attain at least a few hundred meters. The other formation in this corner assigned to the Oguradani Formation crops out in a narrow belt of about 200m wide to the north of Suhara, where it is composed of black phyllitic slate highly folded. This formation is considered to be direct extension of that in the principal area, though both are now separated by the outliers of younger rocks.

The base of the Oguradani Formation is exposed nowhere because it is concealed in depth even along the axis of the anticline or otherwise displaced by faults. The formation is succeeded conformably by the Konogidani Formation.

Konogidani Formation. The Konogidani Formation, first designated Konogidani schalstein member by OZAKI, YAMADA, and KATO (1954), corresponds to Tomedōro schalstein member (KAWAI, 1956) in the eastern part of the mapped area and to the most part of Akiu Formation (KOBAYASHI, 1954) in the central and western areas.

The formation is distributed in a wide area extending from the east to the center of the mapped area, and here the formation dips steeply to the south in general. It also develops in a narrow strip in the northwestern area, where the formation

appears to take a synclinal structure, the axis of which plunges eastward.

The Konogidani Formation is composed principally of greenstone intercalated with a small amount of slate, and accompanied with limestone. No detailed section has been measured, but its thickness may be over 500m in the east and more than 1000m in the center of the mapped area. The greenstone is generally altered; its color is usually dark green but partly reddish purple. Although the petrographic study has not been carried out in detail, it is interpreted that the greenstone was originally andesite, diabase, andesitic or basaltic tuffs and tuff-breccias. Of these rocks the lateral change in thickness is considerable. Schistosity is recognizable in some of the tuff. The limestone is mostly bluish grey. It occurs at various horizons and shows a variable thickness in places; it is well developed in the western area rather than in the eastern area. In the former area the thickness of a limestone bed is estimated to reach to a hundred meters, while in the latter area less than a few ten meters. The slate is black; its maximum thickness is about 30m but it alternates finely with tuff in many cases.

The apparent top of the succession of the Konogidani Formation is in fault everywhere except for a place at the south of Ōtani, where the formation is overlain unconformably by the Ōtani Formation.

Both the Oguradani and the Konogidani Formation contain marine organic remains in the layers of limestone or limy slate.

The Oguradani Formation yields rather abundant fossils at two localities, though most of them are compressed and deformed. The one is at Oguradani, the type locality of the formation, where the limy slate part inserted in a limestone contains brachiopods, bryozoans, ammonites, and others. According to HAYASAKA and MATSUO (1951) and HAYASAKA and OZAKI (1955), they are *Lyttonia richthofeni* KAYSER, *Camarophoria humbletonensis* HOWSE, cfr. *Schellwienella regina* GRABAU, *Productus flemingii* (SOW.), *Derbya* sp., *Enteletes* cfr. *acuteplicata* WAAGEN, *Paraceltites* cfr. *elegans* GIRTY, *Foordiceras whynneiforme* HAYASAKA and OZAKI, *Luciella planoconvex* GRABAU, and others. In addition, a fusulinid, *Monodiexodina* sp. is found. As already stated by them, the horizon containing the above fauna is correlative with the lower Kanokura series in the Kitakami Massif, northeast Japan, which may be attributable to lower Middle Permian. The other locality is to the west of Nakajima, where the fauna such as *Streptorhynchus* sp., *Camarotoechia* sp., *Echinoconchus* sp., *Spirifer* cfr. *octoplicata* SOWERBY, and others has been collected from the limy slate (KOBAYASHI, 1954). Besides, *Monodiexodina* sp. has been rarely found in some limestones.

The Konogidani Formation yields merely crinoid stems in limestones but some limestone breccias comprise *Rugosofusulina alpina* (SCHELLWIEN).

Thus, although the Konogidani Formation yields no index fossils, the Nojiri Group as a whole may be referred to Middle Permian in age.

Magatoji Formation

The term Magatoji Formation (KAWAI, 1956) has been applied to a member composed of black shale, sandstone, fossiliferous limestone, chert, and greenstone in a narrow zone on the south of Kamiise, where the formation occurs inserted between the surrounding Tetori Group by faultings.

The succession of the formation is not clear at present owing to the poor exposure. Moreover, there is a doubt whether all of the rocks so far assigned to the formation should be included in the same stratigraphic unit. The narrow zone in which the Magatoji Formation crops out may be a striking fault zone, and so the formation may possibly be composite composed of rocks of different units which have been taken in the fault zone. This possibility is suggested by the fact that rocks in the formation have been crushed more or less in several places. Accordingly, in this paper the name Magatoji Formation is applied to the rocks of age represented by that of fossiliferous limestone, whose age is late Middle or early Late Permian judging from the occurrence of such fusulinids as *Yabeina katoi* (OZAWA), *Y. globosa* (YABE), *Neoschwagerina minoensis* DEPRAT em. OZAWA, and others (KAMEI, YOSHIDA, and MAEDA, 1959).

Age unknown

Ise Crystalline Schists

The crystalline schists are exposed as three patches in the east of the mapped area : the principal one, nearly 3 square kilometers wide, is in the upper part of the Ise River, another is immediately south of the principal area, and the other is in the lower part of the Nigure River.

According to MANABE (1965, MS), the rocks are of low-grade metamorphic facies, and composed of green schists derived from basic volcanic materials and of black schists derived from pelitic sediments. Major constituent minerals of the green schists are actinolite, clinozoisite, chlorite, and albite. Glaucophane schist is present at Nigure (KAWAI, HIRAYAMA, and YAMADA, 1957). The black schists are composed chiefly of quartz, albite, chlorite, sericite, garnet, stilpnomelane, and graphite, accompanied with biotite locally. Their schistosity is generally distinct except some places. Its general trends are shown in the geologic map.

The schists are overlain unconformably by the Tetori Group and are in fault contact with the Paleozoic rocks. Although they are probably older than the Ōtani Formation, their exact stratigraphic positon has not been ascertained.

Ashidani Formation

The Ashidani Formation underlies an area extending eastward from the south of Nagano to the north of Ōtani in the northeastern part of mapped area. Its type locality is in Ashidani to the south of Nagano. Although minor isoclinal folds are observed in places, the formation shows attitudes curving gently from N. 60~70°E. in

strike and 40~50°S. in dip in the west, E~W. and 60~70°S. in the center, to N.70~90°W. and 70~80°S. or more in the east.

The formation is composed mostly of black and green phyllites and schistose sandstone, and divided into three members. The lower one (more than 180m thick) consists of black phyllite, schistose sandstone, and less amount of green phyllite. The schistose sandstone is green or reddish purple, coarse- to medium-grained, and consists of such minerals as quartz, feldspar, sericite, chlorite, and calcite. A schistose conglomerate holding stretched pebbles locally occurs. The middle member (300m thick) consists of black phyllite intercalated with a thin white tuffaceous sandstone. Banded limestone layers less than 20m thick are occasionally interlayered in the uppermost part of the member. It is possible that parts of the lower and middle members may be interfingered each other. The upper member (more than 120m thick) is represented by green phyllite with the subordinate amount of black phyllite. Some of the green phyllite may be tuff in origin.

The Ashidani Formation, first named Ashidani Group by KATO (1954, MS) and later emended by KAWAI (1956), has been considered generally to be Middle Carboniferous in age because a *Fusulinella*-bearing limestone has been included as a member of the formation. The limestone, however, which is in the type section of the Nagano Formation in this paper, is separated from the phyllite of the Ashidani Formation by faults. Accordingly, the phyllite and limestone under consideration should be now distinguished as the different stratigraphic units.

The formation is bounded by faults on its upper and lower limits and yields no fossils. Consequently, its stratigraphic position as well as age has been unsettled yet. It is probably said, however, that the age of the formation is prior to the deposition of the Ōtani Formation (Triassic?) which contains pebbles such as green and black phyllites perhaps derived from the Ashidani Formation or its allies. Also, it may be suggested that the formation shows a certain similarity in lithology and metamorphic grade to the Kiyomi Group in the vicinity of Naradani, Gifu Prefecture, which is a member belonging to the Hida marginal tectonic belt and is Late? Devonian in age.

Short notes on the Ōtani and the Motodo Formation

Both the Ōtani and Motodo Formations are mainly composed of conglomerate containing the pebbles of various kinds and times, and regarded to be perhaps Triassic age in this paper. Some geologists, however, have held different views on their ages and stratigraphic positions. As to the Ōtani Formation, YAMAGUCHI and ŌTA (1965) have considered that the formation is intraformational conglomerate and correlative with the *Yabeina* zone of Late Permian or possibly a younger age. The present writer would suggest briefly on the stratigraphic setting of these two formations, especially of the Ōtani Formation, with their description in this chapter. Detailed discussion on this subject will be dealt with in another paper.

Ōtani Formation. The formation, first designated by OZAKI, YAMADA, and KATO (1954) under the name of Ōtani conglomerate member, has its type locality to the north of Ōtani. Its distribution is nearly restricted in the Ōtani and Tomedōro disturbed zones except a few exposures. The dip of the formation is thought to be rather steep in general, though it is not always measured well.

The formation consists of conglomerate with a few sandstone layers, and reaches a maximum of 200m in thickness. The conglomerate is massive generally, and reddish brown, reddish purple or green. The pebbles are rounded as a whole, and poorly sorted; its maximum diameter exceeds 50cm. The rock types contained are granite, diorite, gabbro, serpentinite, andesite, basalt, quartz porphyry, black and green phyllites, sandstone, slate, siliceous rocks, and limestone. The limestone pebbles bear fossils of various times. They are *Favosites* sp., *Heliolites* sp., *Orthis* sp., *Rhynchonella* sp., *Eoschubertella* cfr. *obscura* (LEE and CHEN), *Fusiella* sp., *Fusulinella* sp., *Triticites* spp., *Pseudofusulina* sp., *Parafusulina* sp., *Lepidolina kumaensis* KANMERA, and others. The matrix of the conglomerate is sandstone with calcareous, or green or red argillaceous cement. According to KANO (1961), it has been pointed out that the conglomerate is characterized by the abundance of less durable materials and consequently by the highly immature property.

The Ōtani Formation is in fault contact with the surrounding rocks at present except a few places where the formation rests unconformably on the older rocks.

Motodo Formation. The formation was named by KOBAYASHI (1954) from the exposures along the Sasao River. It is extensively developed in an area extending from the north of Suhara through the south of Nakatatsu Mine to Nojiri. The Nojiri conglomerate member (OZAKI, YAMADA, and KATO, 1954) is included in the Motodo Formation at present. The formation strikes roughly eastward, and dips 70~90°S. along the Kumo River, 30~40°S. in type area and central part, and 50~80°S. in the eastern part of the mapped area. The Konogidani conglomerate bed (KAWAI, 1956) (not Konogidani Formation in this paper) which is exposed along the northern boundary of the Paleozoic terrain in the eastern part of the surveyed area, is assigned to the Motodo Formation. The other narrow outcrop of the formation occurs to the south of Suhara.

The formation consists principally of conglomerate and sandstone with a small amount of shale. Tuff-breccia occurs in the upper part of the section. These rocks are red, reddish purple, and occasionally green. The pebbles of the conglomerate are rounded or subrounded and range from cobble to granule. The rock types found are granite, diorite, quartz porphyry, porphyrite, andesite, sandstone, chert, limestone, black and green phyllite, gneiss, chloritoid-bearing argillaceous hornfels (ARITA, YAMADA, FUJI, and YAMAMOTO, 1957). According to KOBAYASHI (1954) and KONISHI, MIURA, and ŌMURA (1966), limestone pebbles yields several organic remains such as *Lepidolina toriyamai* KANMERA, *Yabeina* sp., *Schwagerina* sp. and others. *Fusulinella* sp.

also occurs in the pebble. Except those in the pebbles, no fossils are found in the formation.

The Motodo Formation is cut out by faults on its upper and lower limits, and the thickness is estimated at up to 800m. The detailed stratigraphic and sedimentological studies have been carried out by KONISHI and ŌMURA and a part of the results has been published (KONISHI, MIURA and ŌMURA, 1966 and ŌMURA, 1967).

The Ōtani Formation was considered by many geologists including the writer that it was a basal member of the Nojiri Group and its present exposure pattern on the north and south of the Nojiri Group were resulted from an isoclinal synclinal folding. Lately, however, fusulinids such as *Lepidolina kumaensis* KANMERA denoted Late Permian age were discovered from the limestone pebbles of the formation by YAMAGUCHI and ŌTA (1965)*. Therefore, the former view on the age and stratigraphic position of the formation must be revised.

As previously mentioned, YAMAGUCHI and ŌTA have suggested that the Ōtani Formation is intraformational conglomerate bed in volcanic sediments** and correlated with *Yabeina* zone of Late Permian or a younger age. The Ōtani Formation, however, rests indeed unconformably not only on the Konogidani Formation (at the south of Ōtani) but also on the Nagano Formation (at Ise pass and possibly at Ashidani). Furthermore, the formation contains abundant pebbles derived probably from the rocks of various times, of which allies are exposed in the surveyed area at present. Hence, the writer has the view that the Ōtani Formation originally may have covered with a remarkable clino-unconformity rocks older than the Magatoji Formation. In other words, the deposition of the Ōtani Formation was preceded by the folding of the Nojiri Group (and Magatoji Formation).

On the other hand, the stratigraphic relationship between the Ōtani Formation and the Tetori Group has not been ascertained. It seems, however, that the former is older than the latter, judging from the distributional and structural pattern and lithology of the Ōtani Formation. Thus, the Ōtani Formation may be roughly assigned to Triassic age.

There are two different views on the age of the Motodo Formation, Cretaceous time (KOBAYASHI, 1954, KAWAI, HIRAYAMA, and YAMADA, 1957) and pre-Tetori (TSUKANO and MIURA, 1959, KONISHI, MIURA, and ŌMURA, 1966). Although this subject is not treated here, the writer considers its age as pre-Tetori time (Triassic). The Motodo Formation is perhaps nearly correlative to the Ōtani Formation or slightly younger.

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* Now *Lepidolina kumaensis* KANMERA has been found from pebbles of the conglomerate belonging to the Tomedōro disturbed zone at Tomedōro and to the Ōtani disturbed zone at Akubaradani by YAMAGUCHI and ŌTA (1965), and OMURA and the present writer, respectively.

** The volcanic sediments are members of the Konogidani Formation in the present writer's view.

Remarks on the Geologic Structure of the Paleozoic Formations

As mentioned previously, the Paleozoic terrain, where the pre-Tetori rocks are mainly and predominantly developed, is bounded on its north and south limits by the Nagano and Akiu faults, respectively. The Nagano fault extends from the west of Nakajima to Kamihanbara or more eastward through the south of Nakatatsu and Nagano, and dips vertically or steeply southward. The Akiu fault dipping vertically or steeply northward is traced from the south of Suhara through Ise pass to Hakogase, where it seems to join the Nagano fault. The bodies of the Fujikuradani Formation and crystalline schists in the outside of the Paleozoic terrain also are bounded on their circumferences by vertical or high-angle thrust faults. These pre-Tetori rocks of the inside and outside of the Paleozoic terrain are thought to have been brought up from depth into the overlaying Tetori Group during Late Mesozoic time.

A different view on the structural relationship between the pre-Tetori rocks and Tetori Group has been maintained by KAWAI (1956, 1959). According to him, the pre-Tetori rocks (including the Motodo Formation*) in the Hida marginal tectonic belt of the Upper Kuzuryu River district has formed the Decken structure on the Tetori Group by the Nagano and Akiu faults.

Although objections against KAWAI's view have been taken by TSUKANO and MIURA (1959) and MAEDA (1961 b), the writer also has suggested on the basis of his field survey that a limestone mass belonging to the Fujikuradani Formation at the south slope of Mount Dōsaiyama is originally covered by the Tetori Group and not Klippe (ARITA, YAMADA, FUJI, and YAMAMOTO, 1957, MS). Later, an outcrop showing the unconformable contact between the limestone and Tetori Group was found at this place by K. WAKABAYASHI (personal communication) and MAEDA (1961). It is the limestone mass that has been mapped to be Klippe by KAWAI (1956). The unconformity between the Fujikuradani Formation and Tetori Group has been ascertained at Nakatatsu Mine, too (WAKABAYASHI and SATO, 1966). Furthermore, as pointed out by MAEDA (1961 b), some outliers of the Tetori Group in the Paleozoic terrain are erosional remnants underlain unconformably by the Paleozoic formations or crystalline schists. These facts show evidently that KAWAI's view is unacceptable to be appropriate.

Zonal arrangement of the Paleozoic formations. Concerning the Paleozoic formations, the Paleozoic terrain can be divided structurally into three zones separated from one another by two disturbed zones, the Ōtani and Tomedōro disturbed zones. These three zones, here named Ashidani, Nojiri, and Ise zones from the north to south, wave gently and take eastward trends as a whole. Their arrangements are shown in Fig. 4.

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* KAWAI (1956) has been considered the Motodo Formation to be Cretaceous in age.

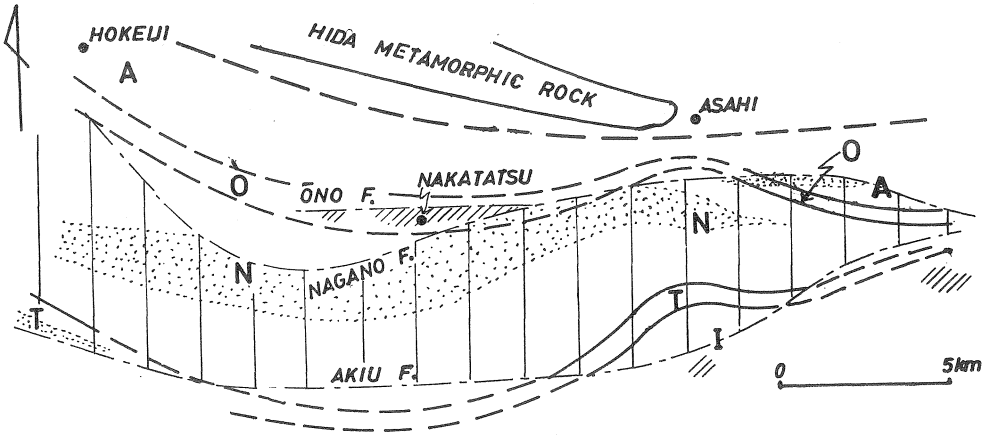

Fig. 4. Schematic structural division of the Paleozoic formations in the Upper Kuzuryu River district.
A : Ashidani zone N : Nojiri zone I : Ise zone O : Ōtani disturbed zone
T : Tomedōro disturbed zone
Vertical lined area shows the Paleozoic terrain.
Oblique lined area shows the exposures of the pre-Tetori rocks in the outside of the Paleozoic terrain.
Dotted area shows exposures of the Motodo Formation.
Broken lines indicate roughly presumed subsurface elongation.

The Ashidani zone is characterized by low-grade metamorphic rocks such as black and green phyllites, and schistose sandstone, of which the distributional trends are harmonized with that of the zone itself. Although the rocks belonging to this zone in the mapped area are only exposed in the northeastern part of the Paleozoic terrain, crystalline schists (sericite-albite-quartz schist and others) at Hokeiji (MAEDA, 1959) situated to the northwestern part of the surveyed area are possibly attributed in this zone.

The Nojiri zone is broadest one and occupied by non-metamorphosed Permian Nojiri Group, which strikes in harmony with general trend of the zone and is strongly folded.

The Ise zone is composed of Ise Crystalline Schists which expose in Ise area, at the south of Shimoise, and along the Nigure River. The latter two localities are situated outside the Paleozoic terrain. As noted by KOBAYASHI (1958), the schistosity trend of the rocks in the Ise area are oblique to the arrangement of the zones.

The Ōtani and Tomedōro disturbed zones which separate the Nojiri zone from the northern Ashidani and from the southern Ise, respectively, are characterized by the several steep faults and sporadic occurrences of the pre-Nojiri formations such as the Kamianama, Nagano, and Ōboradani Formations. The probable location of the Tomedōro disturbed zone in the western part of the Paleozoic terrain was traced, judging from the trend pattern of the northern Nojiri Group and the presence of the serpentinite group rock (silica-carbonate rock) at the south of Suhara which occurs

exclusively along the Tomedōro disturbed zone in the eastern part of the mapped area. The western extension of the Ōtani disturbed zone is not always obvious at present, but it may be possibly traced to the Nakatatsu Mine area occupied by the Middle Carboniferous Fujikuradani Formation. The distributional pattern of the Fujikuradani Formation extending eastward straight is due to cutting out by nearly vertical eastward faults on its north and south sides. According to WAKABAYASHI and SATO (1966), the formation is intensely folded and main plunge of the folds dips steeply. Its structural trend curves moderately and is similar to that of the Paleozoic rocks in the Paleozoic terrain.

The remarkable structural contrast between the Paleozoic formations and the Tetori Group has been pointed out by MAEDA (1961b) and WAKABAYSHI and SATO (1966). According to them, the fold and the other principal structure of the Paleozoic formations had been made up before the Tetori Group was deposited. Further, it seems to the present writer that the zonal structure as well as fold of the Paleozoic formations was fundamentally accomplished before the deposition of the Ōtani (and Motodo) Formation. This conclusion follows from the existence of the pre-Ōtani unconformity which is a striking clino-unconformity as mentioned in the foregoing chapter.

The conclusion is supplemented by a following consideration on the mode of occurrence of the Motodo Formation which is probably correlative with the Ōtani Formation.

The principal part of the Motodo Formation is distributed from the western end to the eastern part of the Paleozoic terrain. Its distributional pattern crosses obviously that of the Paleozoic formations, especially in the western part, though at first sight both the distributional pattern seem to be similar, especially in the eastern part. Also, the distributional pattern of the Motodo Formation occurring along the Nagano fault in the northeastern part of the Paleozoic terrain is distinctly oblique to the zonal trend of the Paleozoic formations. Besides, it is noteworthy that the Motodo Formation has hardly received the effect of the strong folding and only tilted. These facts are probably taken to show that the Motodo Formation is a deposit after the zonal arrangement as well as fold of the Paleozoic formations was formed. The age of the disturbance of the Paleozoic formations is probably latest Permian or early Triassic.

The structural feature of the Paleozoic formations has been modified by the crustal movements in later, especially in Late Mesozoic time, in which the Tetori Group was intensely folded and the Nagano and Akiu faults were formed. During such crustal movements, part of the Ōtani Formation covering unconformably the Paleozoic formations was taken in the pre-existing narrow disturbed zones such as the Ōtani and Tomedōro, which might be moved again more or less in such a case. The mode of occurrence of the Ōtani Formation at present is interpreted as thus.

Summary and Conclusion

1. The Paleozoic formations in the Upper Kuzuryu River district is classified into following stratigraphic units: Early to Middle (or Middle) Devonian--Kamianama Group, Middle Carboniferous--Nagano and Fujikuradani Formations, Lowest Permian--Ōboradani Formation, Middle Permian--Nojiri Group, and Late Permian--Magatoji Formation. Besides, there are two low-grade metamorphic rocks, Ise Crystalline Schists and Ashidani Formation as for pre-Mesozoic rocks. Among them, the Nagano and Ōboradani Formations are newly designated in this paper. While, the age of the Fujikuradani Formation which was suggested to be probably Permian is revised to Middle Carboniferous, and also the misjudgement on the age of the Ashidani Formation assigned usually to Middle Carboniferous is pointed out.

The Paleozoic formations including metamorphic rocks in this district are in fault contact with one another, and original stratigraphic relationships among them have not yet been ascertained.

2. The lithologic contrast between the Middle Permian rocks and the lowest Permian and Middle Carboniferous rocks is distinct: the former is represented by thick, predominant volcanic materials, while the latter is by rather thin limestone.

3. As already stated by S. MAEDA, the present writer also believes that the Paleozoic formations under consideration are not Klippe on the Mesozoic Tetori Group but were brought up from depth into the overlaying Tetori Group during Late Mesozoic time.

4. The terrain occupied by the Paleozoic formations is divided structurally into three zones separated from one another by two narrow disturbed zones (Fig. 4). These three zones take eastward trend as a whole. This zonal structure as well as fold of the Paleozoic formations is thought to have been essentially accomplished in latest Permian or Early Triassic age.

5. The Ōtani and Motodo Formations rested originally with remarkable clino-unconformity on the Paleozoic formations. They are deposits after the zonal arrangement of the Paleozoic formations was formed, and are perhaps attributed to pre-Tetori (pre-Middle Jurassic) time.

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(E) : in English ; (J+E) : in Japanese with English abstract ; (J) : in Japanese

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Appendix : *Alphabetical List of Place Names*

Akiu	秋生
Akubaradani	悪原谷
Ashidani	芦谷
Dosaiyama	道斉山
Fujikuradani	藤倉谷
Hamidani	羽見谷
Ise	伊勢
Kamianama	上穴馬
Konogidani	此木谷
Kumokawa	雲川
Nakatatsu	中竜
Nagano	長野
Nojiri	野尻
Ōboradani	大洞谷
Oguradani	小椋谷
Oisedani	大伊勢谷
Ōtani	大谷
Ōno (fault)	大納
Sasaogawa	笹生川
Shibasudani	司馬巣谷
Suhara	巣原
Tomedōro	米俵

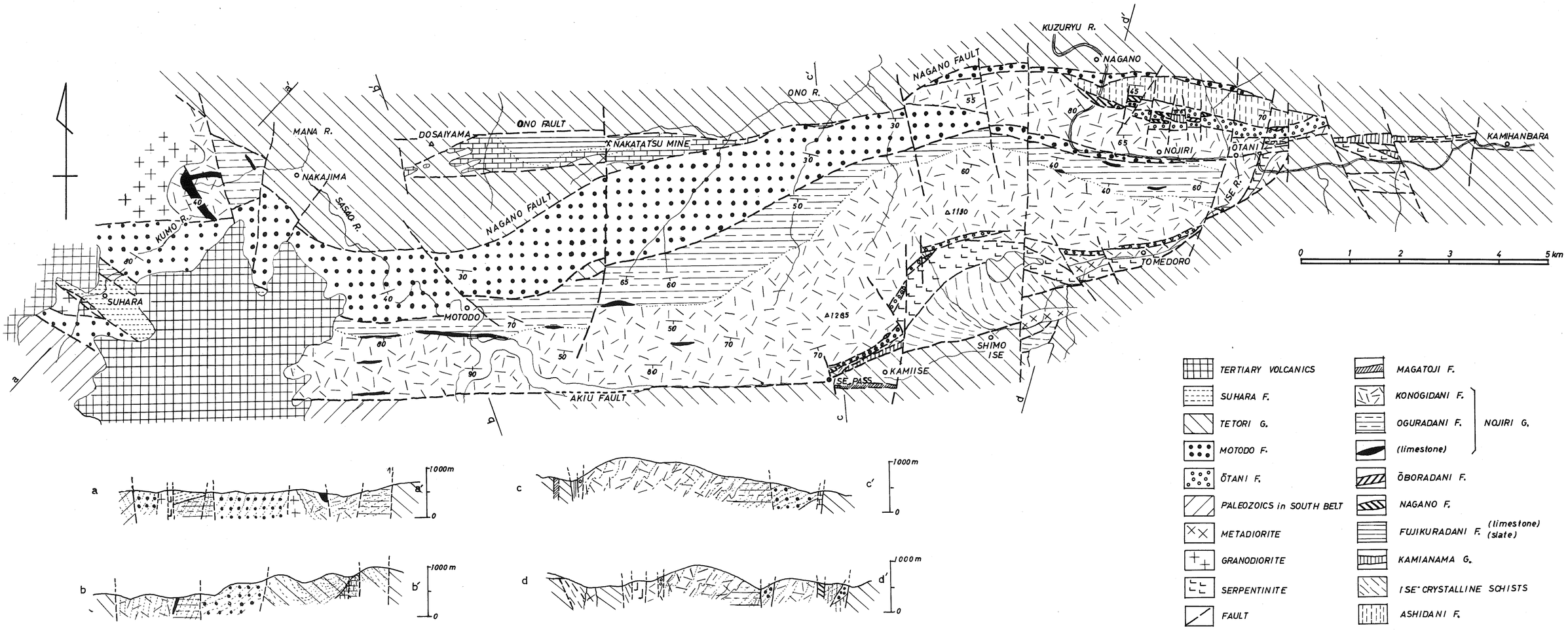

Fig. 2. Generalized geologic map and cross-sections of the Upper Kuzuryu River district (compiled by YAMADA).

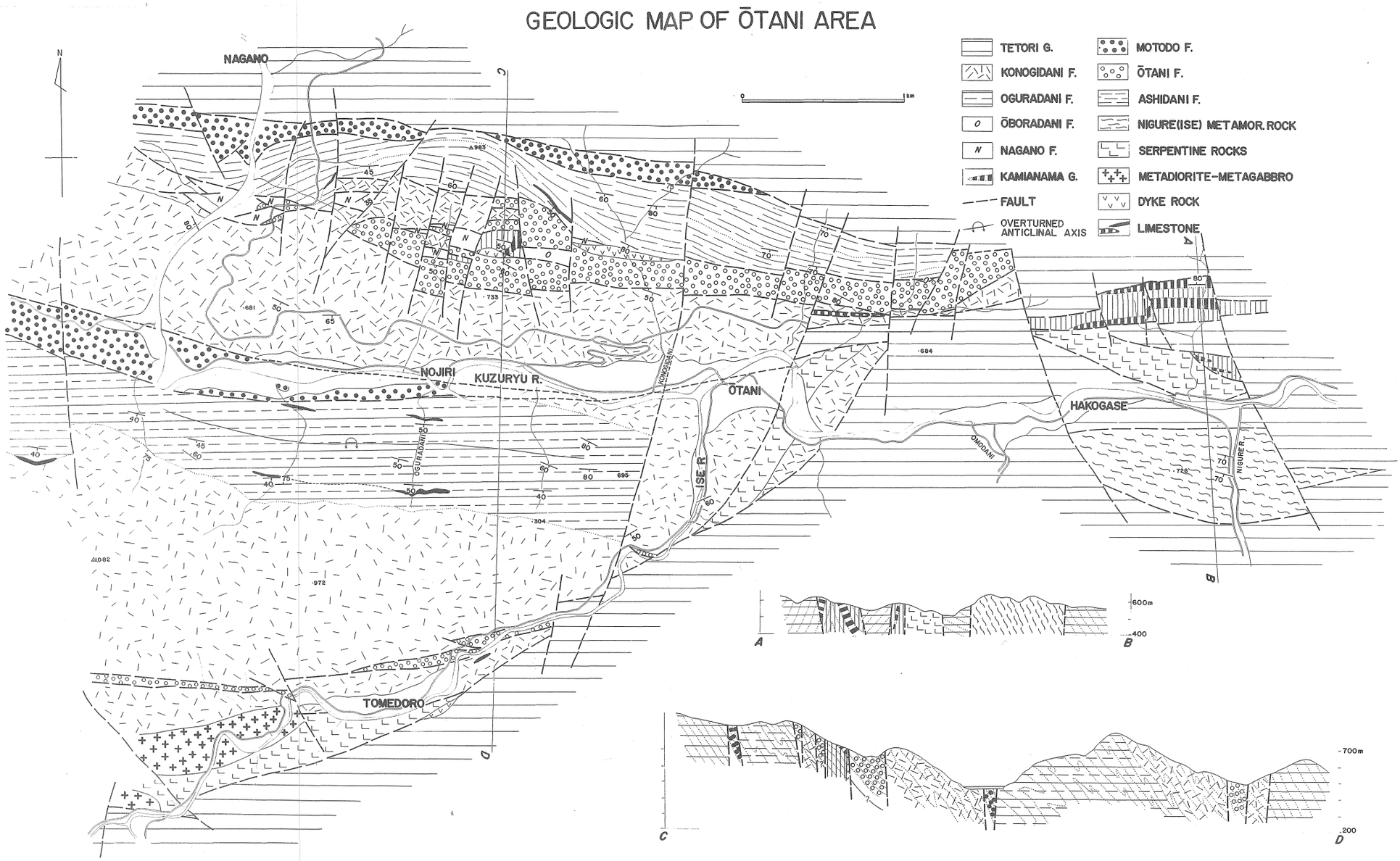

Fig. 3. Geologic map and cross-sections of the Ōtani area. (compiled by YAMADA)