

A NEW CONTRIBUTION TO THE STRATIGRAPHY OF THE TETORI GROUP, ADJACENT TO LAKE KUZURYU, FUKUI PREFECTURE, CENTRAL JAPAN

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ABSTRACT

Stratigraphy of the Middle Jurassic to Lower Cretaceous Totori Group which is stratigraphically divided into three subgroups, Kuzuryu, Itoshiro, and Akaiwa, in ascending order, is refined as the result of thorough paleontological and sedimentological analysis, in the area adjacent to Lake Kuzuryu, Fukui Prefecture, Central Japan. The Kuzuryu Subgroup in the study area is subdivided into the Tochimochiyama, Kaizara, and Yambarazaka Formations in ascending order, and the Itoshiro Subgroup is subdivided into the Yambara, Ashidani, Kamihambara, Obuchi, and Itsuki Formations in ascending order. The Akaiwa Subgroup is equivalent to the Nochino Formation.

Within the Itoshiro Subgroup, the neritic Kamihambara Formation hitherto assigned to the upper part of the non-marine Ashidani Formation is established, based on the first find of *Inoceramus* sp. cf. *I. maedae* (a pelecypod). New occurrence of a brackish pelecypod, *Myopholas* sp. cf. *M. semicostata* from the Itsuki Formation suggests the probable reference of the formation to the Hauterivian to Barremian (Early Cretaceous).

Petrographic study of the coarse clastics (grains of sandstone and gravel of conglomerate) of the Itoshiro Subgroup and the overlying Akaiwa Subgroup reveals the upward (temporal) trend in composition of the coarse clastics from the granite-dominant type to the orthoquartzite-dominant one, through the chert-dominant, which implies a dynamic vicissitude of the sedimentary provenance during the deposition of the two subgroups.

Key words: Totori Group, Fukui, Lower Cretaceous, sandstone, conglomerate

藤田将人 (2002) 福井県九頭竜湖周辺に分布する手取層群の層序に関する新知見. 福井県立恐竜博物館紀要 1: 41-53.

福井県九頭竜湖周辺の手取層群の層序の再検討と粗粒碎屑岩類の組成の定量的な解析を行った, その結果, 九頭竜垂層群は下位から上位へ桁餅山層, 貝皿層, 山原坂層に, 石徹白垂層群は山原層, 葦谷層, 上半原層, 大淵層, 伊月層に区分され, 赤岩垂層群は後野層からなる. 石徹白垂層群中に新たにイノセラムス化石を含む海成層を認定し, その地層を上半原層と命名した. さらに伊月層から西南日本外帯の物部川層群の特徴種である *Myopholas* sp. cf. *M. semicostata* を発見し, その堆積年代が白亜紀前期 Hauterivian から Barremian を示す可能性が示唆された. 石徹白垂層群, 赤岩垂層群の砂岩及び礫岩の組成は下位から上位へ花崗岩型, チャート型, オーソコートライト型へと変化し, 後背地の岩質の変遷が伺われる.

INTRODUCTION

The Totori Group is a representative Middle Jurassic to Lower Cretaceous deposit in Central Japan. Besides many pioneering works, the classical studies had been done by Maeda (e.g., 1952a, 1952b, 1955, 1956, 1957a, 1957b, 1957c, 1957d, 1961a,

1961b, 1961c, 1961d). Yamada et al. (1989) suggested lithological changes of the Totori Group in the upper reaches of the Kuzuryu River, and reviewed the stratigraphy. Over a decade, many dinosaur bones and footprints were found from the Totori Group (e.g., Azuma and Takeyama, 1991; Azuma et al., 1992; Azuma and Currie, 2000; Dinosaur Excavation Research Group of Gifu Prefecture, 1994; Hasegawa et al., 1995). In recent years, Fujita et al. (1998) reported the inoceramid fossils from the Lower Cretaceous part of the Totori Group (Itoshiro Subgroup) which was hitherto considered as

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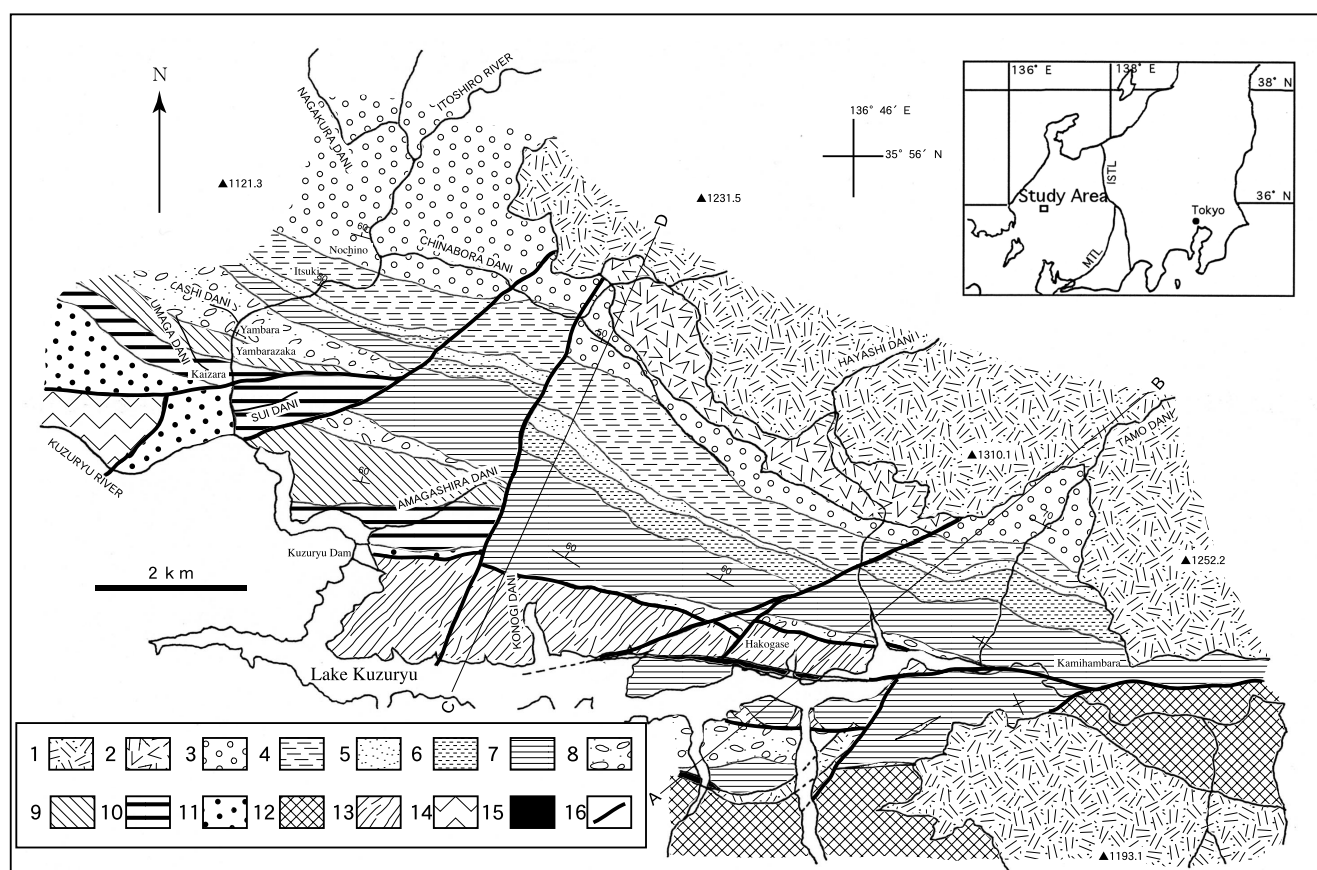


FIGURE 1. Geological map of the upper Kuzuryu district. 1: Late Cretaceous acid igneous rocks, 2: Hayashidani Andesite, 3: Nochino Formation (Akaiwa Subgroup), 4-8: Itoshiro Subgroup (4: Itsuki Formation, 5: Obuchi Formation, 6: Kamihambara Formation, 7: Ashidani Formation, 8: Yambara Formation), 9-11: Kuzuryu Subgroup (9: Yambarazaka Formation, 10: Kaizara Formation, 11: Tochimochiyama Formation), 12: Samondake Unit, 13: Circum-Hida rocks, 14: Hida metamorphic rocks, 15: serpentinite, 16: fault.

nonmarine deposits (ML-16 in Fig. 4).

Abundant orthoquartzite gravels were reported in the Tetori Group in the Shokawa district (Kumon and Kano, 1991). On the other hand, chert clasts which were derived from the Jurassic accretionary complex were obtained from the Tetori Group (Saida, 1987; Takeuchi et al., 1991). Only few quantitative attempts have so far been made at composition of clastics of the Tetori Group in the study area.

The purpose of this paper is to reexamine of the stratigraphy of the Tetori Group with reference to the temporal change of the composition of clastics, adjacent to Lake Kuzuryu, Fukui Prefecture.

GEOLOGICAL SETTING

The study area belongs geotectonically to the Hida Terrane, Circum-Hida Terrane and Mino Terrane. It extends about 15km from east to west and approximately 10km from south to north

(Figs. 1 and 2).

The basement rocks are represented by metamorphic rocks and Paleozoic to early Mesozoic granitic rocks, and serpentinite. Metamorphic rocks of the Hida Terrane, which are distributed in the western part of the study area, consist of biotite-hornblende gneiss and crystalline limestone (Kawai et al., 1957). The Circum-Hida rocks around the Lake Kuzuryu, consist mainly of crystalline schist, phyllites, siliceous shale, greenstone, limestone, sandstone and conglomerate.

The Middle Jurassic to Early Cretaceous Tetori Group is composed of sandstone, conglomerate and shale (Fig. 3). It rests unconformably on the Circum-Hida rocks in part, while for the most parts is in a fault contact with them and overlain by the Hayashidani Andesite (Yamada et al., 1982) or Late Cretaceous acid igneous rocks. The K-Ar age of the Hayashidani Andesite indicates 99.7 ± 5.0 Ma (Tanase et al., 1994). The Tetori Group on the south of the Lake Kuzuryu, is in fault contact with the Middle Jurassic Samondake Unit of the Mino Terrane (Fig. 1).

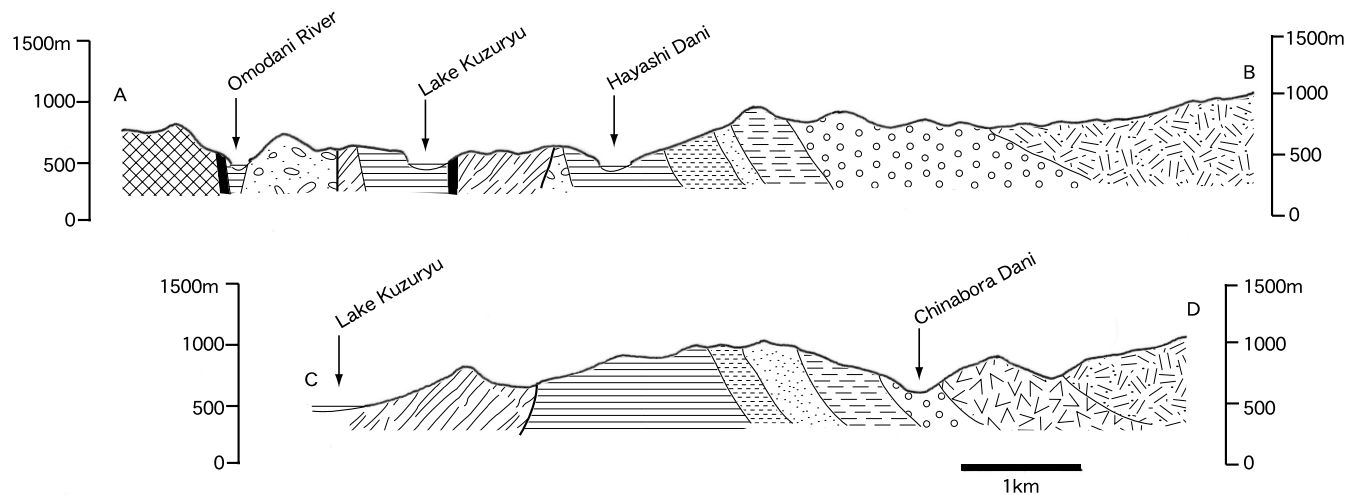


FIGURE 2. Geological profiles of the study area. See the legend of Fig. 1.

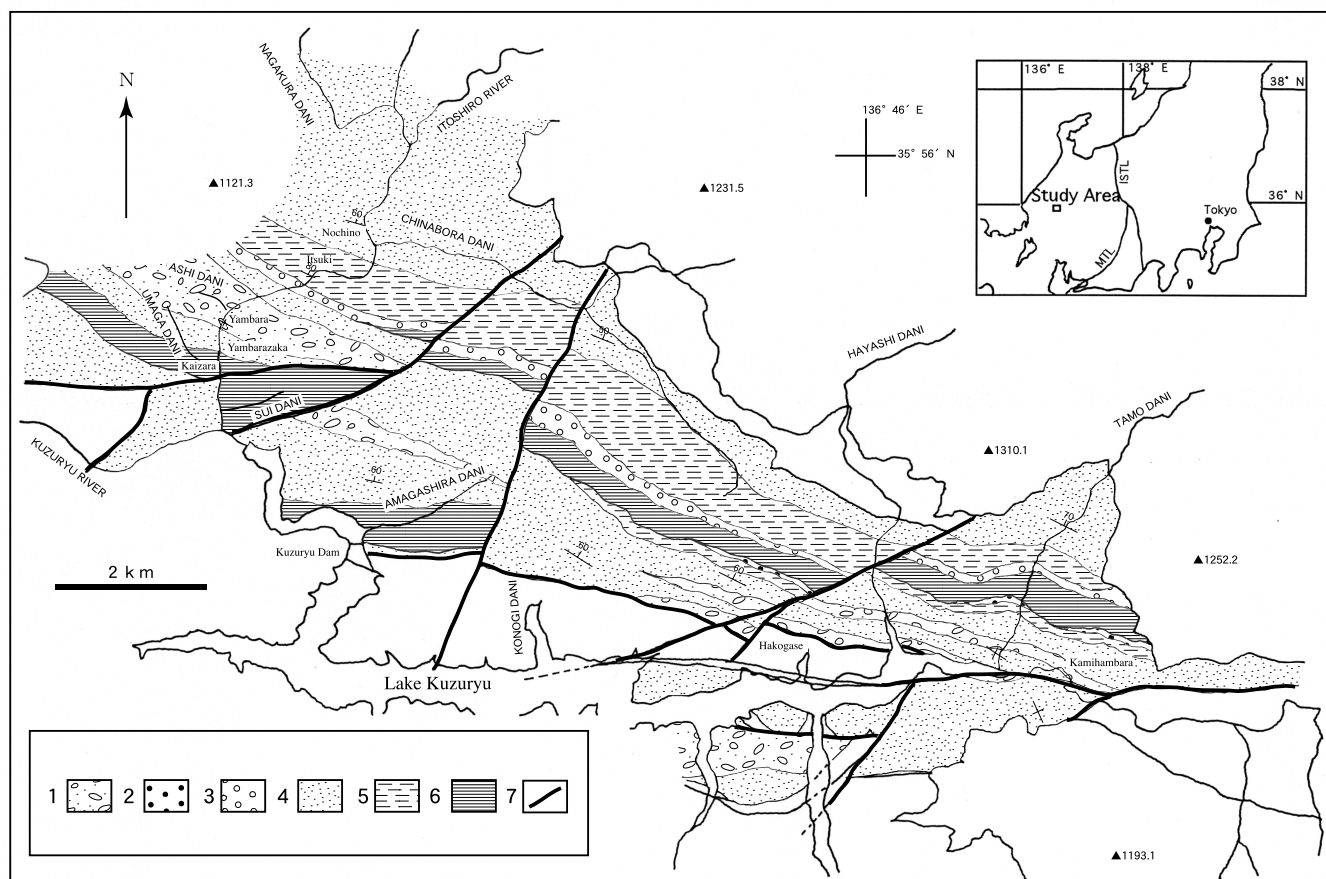



FIGURE 3. Lithological map of the upper Kuzuryu district. 1: conglomerate (granite gravel rich), 2: conglomerate (chert gravel rich), 3: sandstone intercalating conglomerate, 4: sandstone, 5: alternation of sandstone and shale (sandstone rich), 6: alternation of sandstone and shale (shale rich), 7: fault.

TABLE 1. Comparison of the stratigraphic divisions of the Tetori Group in the study area.

	Maeda (1952) Maeda (1957)	Yamada et. al. (1989)	This Study	Age		
Akaiwa Subgroup	Chinaboradani Formation	Akaiwa Subgroup	Nochino Formation	?		
	Nochino Formation					
Itoshiro Subgroup	Itsuki Formation	Upper Formation	Itsuki Formation	Hauterivian to Barremian	Early	Cretaceous
	Obuchi Formation		Obuchi Formation			
	Ashidani Formation	Lower Formation	Kamihambara Formation	?		
			Ashidani Formation			
	Yambara Formation		 Yambara Formation			
Kuzuryu Subgroup	Yambarazaka Formation	Upper Formation	Yambarazaka Formation	Oxfordian	Late	
	Kaizara Formation	Middle Formation	Kaizara Formation	Callovian	Middle	
	Tochimochiyama Formation	Lower Formation	Tochimochiyama Formation	?		

The Tetori Group on the north of the Lake Kuzuryu strikes NW and dips north, and the beds are right-side-up, while the beds of the Tetori Group on the south of the Lake Kuzuryu are right-side-up and dip southwards, with a general trend of NW-SE. Intrusion of serpentinite and acid igneous rocks are observed at the boundaries between the Tetori Group and the Circum-Hida rocks or the Samondake Unit.

LITHOSTRATIGRAPHIC DIVISION

The Tetori Group is generally divided into the Kuzuryu, Itoshiro and Akaiwa Subgroups in ascending order (Maeda, 1961d), as follows.

Kuzuryu Subgroup

The Kuzuryu Subgroup is subdivided into the Tochimochiyama Formation, the Kaizara Formation, and the Yambarazaka Formation in ascending order (Table 1).

1. Tochimochiyama Formation

Designation: After Oishi (1933).

Type locality: The type locality is from the Ooi-dani to the Hora-dani, Kaizara, Izumi Village.

Thickness: 500m.

Distribution and structure: The formation is distributed in the western part of the study area and is in faulted contact with the Hida metamorphic rocks and Circum-Hida rocks. The general trend is nearly NW-SE and dips south or north steeply. The formation is overturned in the Amagashira-dani.

Lithology and fossils: This formation is made up mainly of sandstone and pebbly sandstone with intercalations of shale. Normal graded bedding is commonly observed. Pebbly

sandstone includes clasts up to 1 cm, passing upward into medium-grained sandstone. Parallel lamination is well developed in the shale which is eroded by sandstone or pebbly sandstone. Belemnites were once discovered in the formation (Maeda, 1952b).

2. Kaizara Formation

Designation: After Maeda (1952b).

Type locality: Hora-dani, Kaizara, Izumi Village.

Thickness: 250m.

Distribution and structure: The formation is distributed in the western part of the study area and conformably overlies on the Tochimochiyama Formation. The formation strikes approximately EW dipping to the south or north steeply.

Lithology and fossils: The formation is composed mainly of dark gray shale with intercalations of fine- to coarse-grained sandstone. Parallel and convolute laminations are developed in the shale. This formation yields abundant marine fossils such as ammonites, belemnites, and pelecypods (Maeda, 1961d). Maeda (1961d) regarded the Kaizara Formation as Callovian in age judging from the ammonites.

3. Yambarazaka Formation

Designation: After Maeda (1952b).

Type locality: Yambarazaka along the Itoshiro River.

Thickness: 200m.

Distribution and structure: The formation is distributed in the western part of the study area and conformably overlies the Kaizara Formation. The general trend is roughly NW-SE and dips to the north steeply.

Lithology and fossils: The formation consists of alternating beds of sandstone and siltstone. The sandstone beds are several tens centimeters to several meters in thickness. The sandstone is fine to very coarse grained and often shows trough or planar cross-bedding. Normal graded bedding is commonly observed in the pebbly sandstone (including shale clasts up to 50 cm) passing upward into medium or coarse-grained sandstone. The base of sandstone bed is erosional surface. Thickness of the siltstone is about several centimeters. Parallel lamination is dominant in the siltstone, with subordinate current ripple lamination. The medium-grained sandstone and siltstone are occasionally carbonaceous. Marine faunas such as belemnites, brachiopoda, ammonites, and pelecypods are obtained in this formation. The ammonites suggest Oxfordian in age (Maeda, 1952b).

Itoshiro Subgroup

Itoshiro Subgroup is subdivided into the Yambara, Ashidani, Kamihambara, Obuchi, and the Itsuki Formations in ascending order (Table 1).

1. Yambara Formation

Designation: After Maeda (1952b). This formation corresponds to the lowest part of the Lower Formation of Yamada et al. (1989).

Type locality: Yambara along the Itoshiro River.

Thickness: 20-200m.

Distribution and structure: This formation is distributed along the Itoshiro River and around the Lake Kuzuryu. Although, this formation disappear laterally at the Konogi-dani. This formation overlies the Kuzuryu Subgroup unconformably in the study area. This formation strikes NW and dips 60° to 90° in the north of the Lake Kuzuryu and strikes NW and dips south steeply in the south of it.

Lithology and fossils: This formation is composed mainly of conglomerate and coarse-grained sandstone. Diameter of gravels in the conglomerate ranges from 1 to 100 centimeters. Lithology of gravel is chiefly composed of granitic rocks, sandstone, shale, and limestone. *Inoceramus* is collected from reworked shale gravel which attributed to the Kaizara Formation (Maeda, 1952b). *Vaugonia yambarensis* (Trigonian) was obtained from conglomeratic sandstone (Kobayashi, 1956).

2. Ashidani Formation

Designation: The Ashidani Formation is redefined in this paper, and corresponds to the lower part of the Ashidani Formation of Maeda (1957d).

Type locality: Valley of the Itoshiro River.

Thickness: 600m.

Distribution and structure: The formation is widely distributed in the south and north of the Lake Kuzuryu. The formation, distributed in the eastern part of study area, is in faulted contact with the Samondake Unit. This formation strikes NW and dips 40° to 90° in the north of the Lake Kuzuryu and strikes NW and dips south steeply in the south of it.

Lithology and fossils: This formation is mainly composed of alternating beds of sandstone and shale with intercalations of conglomerate and coal seam. Sandstone is chiefly fine to coarse in grain-size, and much of it appears light gray or greenish gray. Thickness of the coal seams range from 5 to 30 centimeters. Plant fossils are obtained from siltstone and shale in the Konogi-dani and on the north of the Hakogase tunnel (Fig. 4, Table 2). Brackish molluscan fossil, *Myrene* (*Mesocorbicula*) sp. cf. *M. (M) tetoriensis*, is obtained from the shale and siltstone (ML-15: Fig. 4, Table 3).

3. Kamihambara Formation

Designation: The Kamihambara Formation is newly defined in this paper, and corresponds to the upper part of the Ashidani Formation of Maeda (1957d).

Type locality: Kamihambara, Izumi Village.

Thickness: 200m.

Distribution and structure: The formation is distributed in the eastern and central parts of the study area. The formation is well exposed in the Tamo-dani, a path of the Kamihambara and Hayashidani. This formation overlies the Ashidani Formation with erosional surface, and the bed strikes NW and dips 40° to 90° north.

Lithology and fossils: The basal part of this formation consists

of ill-sorted conglomerate whose thickness ranges from 3 to 8 meters. The conglomerate which includes sometimes shell fragments mainly consists of chert and granite clasts. The succeeding main part is made up almost of dark gray shale rich alternating beds of sandstone and shale, which yields marine fossils such as *Inoceramus* sp. cf. *I. maedae* and brachiopods (Fujita et al., 1998). The locality is shown as ML-16 in Fig. 4. Sandstone is chiefly fine- to coarse- grained and contains rip up clasts. Many sole marks and wood fossils are recognized on the underside of bed of sandstone. This is newly discovered neritic formation of the Itoshiro Subgroup in the study area.

4. Obuchi Formation

Designation: After Maeda (1957d).

Type locality: Valley of the Itoshiro River.

Thickness: 250m.

Distribution and structure : This formation is distributed from the Kamihambara to the Itoshiro River with a general trend WNW-ESE and the bed strikes NW and dips 50° to 80°. There are good exposures of this formation along the Tamo-dani and the Kamihambara. This formation overlies the Kamihambara Formation conformably.

Lithology and fossils: This formation is composed mainly of conglomerate and sandstone, which frequently form alternating beds. The conglomerate is well sorted and clast-supported. Diameter of gravels of the conglomerate is up to 1 centimeter. Lithology of the gravels is chiefly composed of chert, siliceous shale, shale, and granitic rocks. Some gravels of chert and siliceous shale yield radiolarian fossils. The most of the sandstone are massive, well-sorted and grayish yellow to light gray in color. Its grain size ranges from medium- to very coarse-grained.

5. Itsuki Formation

Designation: After Oishi (1933).

Type locality: Itsuki along the Itoshiro River, Izumi Village.

Thickness: 500m.

Distribution and structure : This formation is distributed from the Tamo-dani to the Itoshiro River with a general trend WNW-ESE and strikes NW and dips 50° to 80°N. The formation is well exposed in the Tamo-dani, a path of the Hayashidani, and the Nochino along the Itoshiro River. This formation overlies the Obuchi Formation conformably.

Lithology and fossils: This formation mainly consists of alternating beds of sandstone and shale with intercalation of coal seams. Each of the sandstone layers in the alternating beds range from a few centimeters to several meters in thickness. Thickness of a bed of dark gray shale, which is often carbonaceous or calcareous, ranges from 5 centimeters to several tens centimeters. Thickness of the coal seams are several tens centimeters. Abundant brackish molluscan fossils such as *Myrene* (*Mesocorbicula*) *tetoriensis*, *Crassostrea* sp., *Tetoria* sp., and *Melanoides* sp. are obtained from the sandstone and shale. *Myopholas* sp. cf. *M. semicostata* is

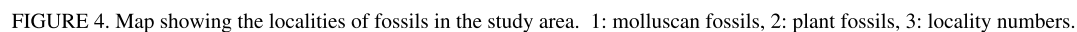


TABLE 3. List of molluscan fossils from the Tetori Group in the study area.

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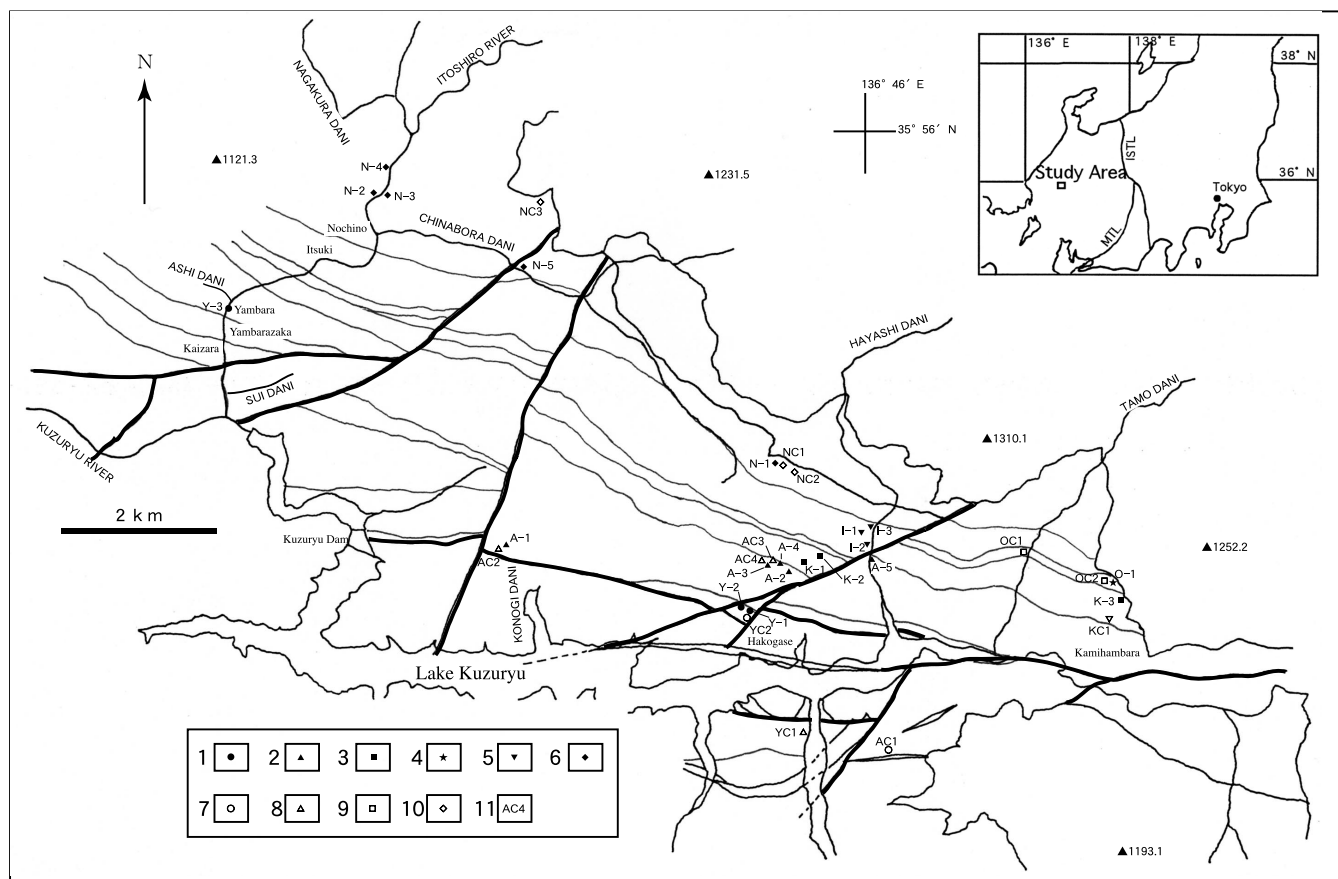


FIGURE 5. Map showing the sampling localities of sandstone and conglomerate specimens in the study area. 1-6: sandstone specimens, 7-10: conglomerate specimens, 11: sampling number.

collected from a float, which is characteristic species of Monobegawa Group. The locality is shown as ML-12 in Fig. 4. Molluscan fossils occur as disarticulated or articulated valves. Plant fossils (Pteropsida, Coniferales) and abundant rootlets occur in the sandstone and shale, too. Charophytes are obtained from the carbonaceous siltstone. Dinosaur and bird footprints (Azuma et al., 1992) and tyrannosaurid tooth (Manabe, 1999) are discovered from this formation.

Akaiwa Subgroup

Akaiwa Subgroup in the study area is composed of the Nochino Formation (Table 1).

1. Nochino Formation

Designation: This formation is introduced by Maeda (1957d) at first, but it is redefined in this paper. This corresponds to the Nochino Formation and the Chinaboradani Formation of Maeda (1957d).

Type locality: Nochino along the Itoshiro River.

Thickness: 800m.

Distribution and structure: This formation crops out in the Tamo-dani, Chinabara-dani, and the Nochino along the Itoshiro River. It conformably overlies the Itsuki Formation and strikes NW and dips 60° to 80°N. This formation is overlain by the Hayashidani andesite and the Late Cretaceous acid igneous rocks.

Lithology and fossils: This formation is composed mainly of thick-bedded sandstone and siltstone with intercalation of conglomerate. The conglomerate is matrix-supported and its gravel size is up to 20 centimeters. Coal seams whose thickness ranges from 10 to 30 centimeters are occasionally intercalated in this formation. The sandstone is medium- to very coarse-grained in size. The sandstone contains abundant shale clasts at the basal part and often shows trough cross bedding. Wood fossils and plant fragments occur in the sandstone. Rootlets are recognized in the siltstone. Dinosaur footprints are found on the underside of a bed of sandstone at the Nagakura-dani (Azuma et al., 1992).

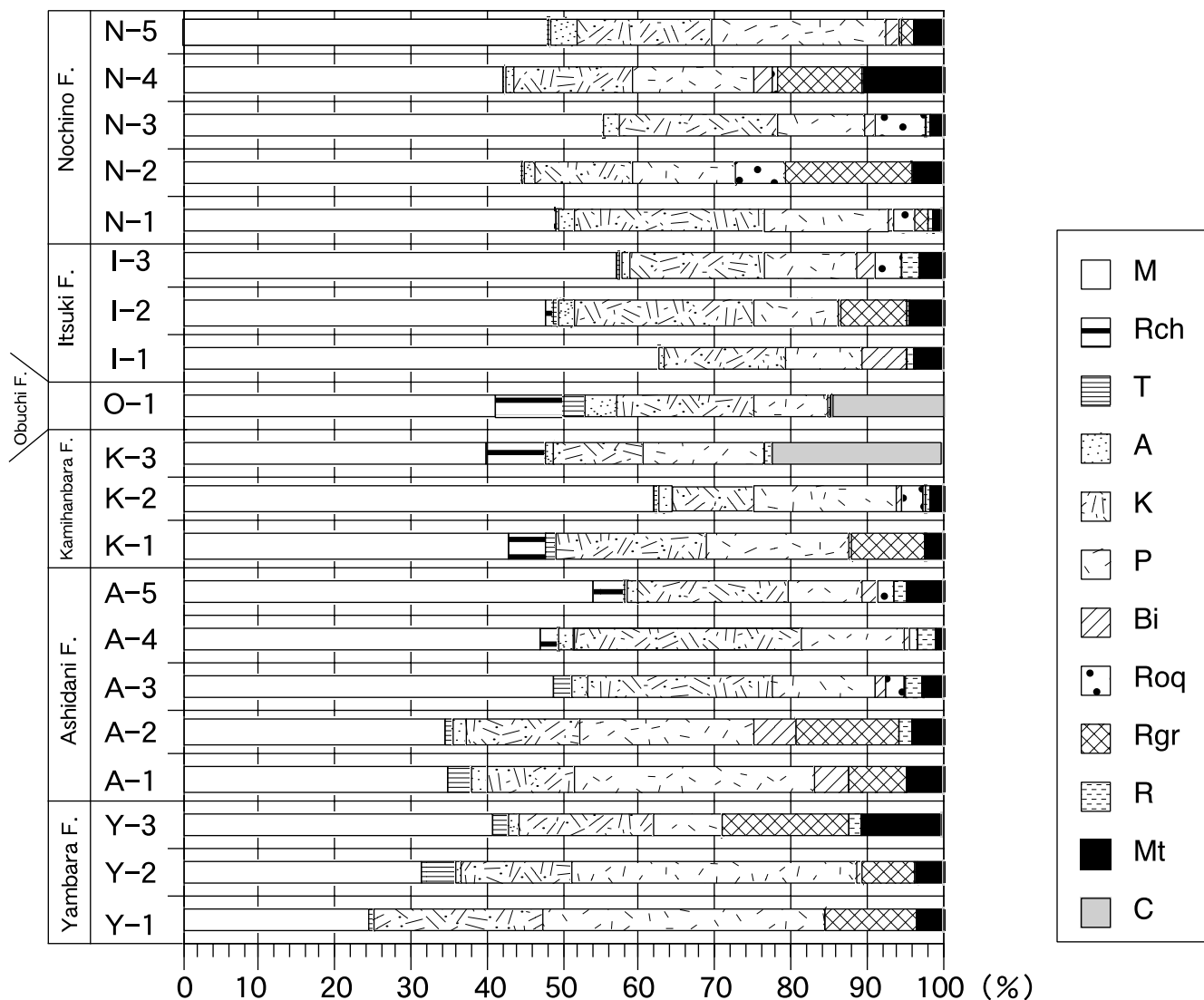


FIGURE 6. Composition of sandstones of the Tetori Group. M: monocrystalline quartz, Rch: chert, T: quartz tectonite, A: aggregate quartz, K: potash feldspar, P: plagioclase, Bi: biotite, Roq: orthoquartzite, Rgr: granitic rocks, R: others of rock fragments, Mt: matrix, C: cements.

FRAMEWORK COMPOSITION OF COARSE CLASTICS

Composition of sandstone

In this study, samples for examination were collected from massive and medium to coarse grained sandstone. The samples are 15 specimens from the Itoshiro Subgroup and 5 specimens from the Akaiwa Subgroup. The localities of the examined sandstones are shown in Fig. 5. The modal composition was obtained by the traditional point-counting 500 points per thin section under the microscope (Fig. 6). I could not obtain the information on the Kuzuryu Subgroup because of the limited number of the samples.

The major constituents of sandstone are classified into

monocrystalline quartz, polycrystalline quartz, potash feldspar, plagioclase, rock fragments, matrix, and cements. The monocrystalline quartz grain, which often shows undulatory extinction, is commonly subangular to subrounded, but it is occasionally rounded. Polycrystalline quartz is divided into two types, quartz tectonite (T) and aggregate quartz (A). Quartz tectonite has sutured intercrystal boundaries and elongated quartz crystals showing planar fabric corresponds to quartz-mica tectonite by Graham et al. (1976). Aggregate quartz showing intergrown crystalline quartz without referred elongation of crystals. Potash feldspar sometimes shows microcline structure or perthite structure. Plagioclase often indicates twinning and is replaced by selicite in part.

Rock fragments are subdivided into Rgr (granitic rocks), Roq

(orthoquartzite and quartzite), Rch (chert) and R (the others). Roq is an assemblage of well-rounded quartz grains, which sometimes show overgrowths of secondary quartz. Rch is microcrystalline or cryptocrystalline quartz aggregate, which often contains radiolarian tests. R consists of shale, metamorphic rocks, volcanic rocks and sandstone. All of the analyzed sandstones belong to arenite (matrix content is less than 15%).

The characters of the sandstone composition of each formation are given below.

Yambara Formation

The Yambara Formation (Y-1, 2, 3) is rich in feldspar (Fig. 6). Granitic rock fragments are commonly contained in the formation. The sandstones are poorly sorted and include large (up to 1cm) subangular crystals of feldspar.

Ashidani Formation

The lower part of the Ashidani Formation (A-1) is rich in feldspar such like the Yambara Formation. The upper part of the formation (A-3, 4, 5) increase the amount of monocrystalline quartz. Chert fragments (Rch) are included in the A-4 and 5.

Kamihambara Formation

The sandstones of the Kamihambara Formation are rich in monocrystalline quartz and feldspar. The sandstone of K-3 includes relatively many calcite cements (more than 20%). Chert fragments are contained in K-1 and K-3.

Obuchi Formation

The sandstone of the Obuchi Formation is also dominant in monocrystalline quartz and feldspar. The ratio of chert fragments to the all constituents is about 10 percents, which is the highest content in the all specimens from the Tetori Group in the study area. Calcite cements content is relatively higher than other formations except for K-3. Argillaceous matrix is almost absent.

Itsuki Formation

The sandstone of the Itsuki Formation is also dominant in monocrystalline quartz and feldspar. The ratio of monocrystalline and polycrystalline quartz to the all constituents is over 50 percents.

Nochino Formation (Akaiwa Subgroup)

The sandstone of the Nochino Formation is occupied by quartz and feldspar dominantly. Granitic rocks and orthoquartzite are found out in rock fragments. Many well rounded grains of monocrystalline quartz are recognized in the sandstone.

Composition of gravel in conglomerate

Conglomerate compositions are examined at 12 localities of the Tetori Group (Fig. 5): 2 localities in the Yambara Formation, 4 localities in the Ashidani Formation, 1 locality in the Kamihambara Formation, 2 localities in the Obuchi Formation, and 3 localities in the Nochino Formation. They were collected 50 gravels in order of size at each locality. Lithology of gravel

is identified usually by naked eyes, but in case of being difficult to judge, identification was carried out under a microscope. Composition of gravel in conglomerate of the Tetori Group is shown in Fig. 7.

Yambara Formation

The conglomerate of the Yambara Formation contains predominantly subrounded to rounded pebbles and cobbles of granitic rocks (Fig. 7). Especially, muscovite granite is predominant. Two cobbles of pelitic gneiss (sillimanite-cordierite gneiss and sillimanite biotite gneiss) were found in YC-2. Arkosic sandstone gravels (16%), which would be reworked from the Kuzuryu Subgroup, are collected at the YC-2.

Ashidani Formation

The lower part of the Ashidani Formation (AC-1, 2) is composed mainly of granitic gravels. The conglomerates of the upper part of the formation (AC-3, 4) include both orthoquartzite and chert gravels, although those of the lower part of the formation (AC-1, 2) do not include them.

Kamihambara Formation

The basal part of the Kamihambara Formation consists of matrix-supported conglomerate whose thickness ranges from 2 to 8 meters. The conglomerate of this formation is composed mainly of subrounded to rounded pebbles of chert (52%) and contains pebbles of granitic rock (40%), vein quartz (4%), and shale (4%).

Obuchi Formation

This formation intercalates several beds of conglomerate which are commonly clast-supported and well-sorted. The conglomerates contain predominantly subrounded to rounded pebbles of chert (about 80 %). Radiolarian fossils are observed in the chert clasts under a microscope. Minor components of the conglomerate are crystalline schist, shale, and vein quartz.

Nochino Formation (Akaiwa Subgroup)

The conglomerates of the Nochino Formation contain predominantly subrounded to rounded pebbles and cobbles of orthoquartzite and granitic rocks. Minor components of the conglomerates are mylonite, sandstone, gneiss, vein quartz, chert, and crystalline schist. The gravels of orthoquartzite are pink, reddish purple, gray, white, and bluish gray in color. Granite gravels are composed mainly of fine-grained granite and gneissose granite, which sometimes contain zircon and feldspar with antiperthitic structure. Potash feldspar in the granite gravel shows microcline structure and looks fresh in appearance. Sandstone gravel is feldspathic arenite. Secondary growth of quartz grains is observable in orthoquartzite gravels.

DISCUSSION

Stratigraphy and fossils of the Tetori Group

The Itoshiro Subgroup covers unconformably the Kuzuryu Subgroup because of developing of basal conglomerate

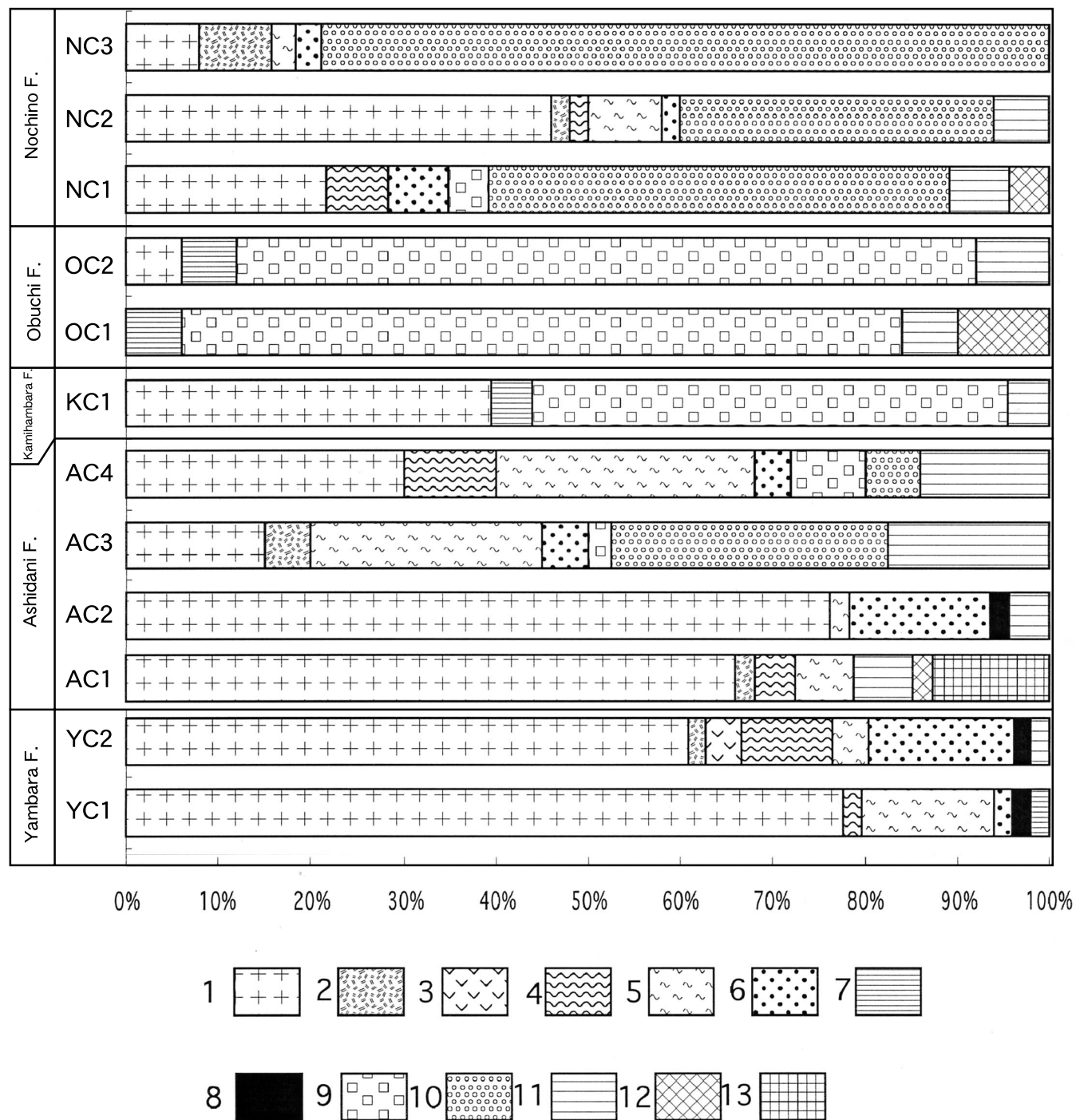


FIGURE 7. Gravel composition of the conglomerates of the Tetori Group in the study area. 1: granite, 2: rhyolite, 3: andesite, 4: gneiss, 5: mylonite, 6: sandstone, 7: mudstone (shale), 8: siliceous shale, 9: chert, 10: orthoquartzite and quartzite, 11: vein quartz, 12: crystalline schist, 13: hornfels.

(Yambara Formation). Maeda (1952b) reported the distinct erosional surface between the Yambarazaka Formation and Yambara Formation at the Umagadani on the north of the Kaizara. Sandstone gravels in the Yambara Formation, which

are probably derived from the Kuzuryu Subgroup, also suggest the unconformity. The Kuzuryu Subgroup is not distributed at the central and eastern part of the study area, and it suggests that the Kuzuryu Subgroup was eroded before the accumulation of

the Itoshiro Subgroup.

Yamada et al. (1989) correlated a formation, which is narrowly exposed at the Hayashi-dani, being faulted against the basement rocks on the south side with the Upper Formation of the Kuzuryu Subgroup. The formation is regarded as the Yambara and Ashidani Formation (Itoshiro Subgroup) in this paper. The reasons are given below (1) The Upper Formation of the Kuzuryu Subgroup (Yambarazaka Formation) is neritic facies which yields ammonoid, belemnite, trigonians (Maeda, 1952b; Kobayashi, 1957). However, well preserved plant fossils, which do not indicate marine environment, are obtained from the formation at P-1 and P-2 (Fig. 4). (2) The formation has almost same geological structure with the Itoshiro Subgroup, nevertheless the relationship between the Kuzuryu Subgroup and Itoshiro Subgroup is angular unconformity at the valley of the Itoshiro River (Maeda, 1952b).

The Kamihambara Formation should be neritic strata because of yielding marine fossils (*Inoceramus* sp. cf. *I. maedae*). Goto (2001) reported an Early Cretaceous (late Hauterivian to early Barremian) ammonoid fossil in a float which would be derived from the Itoshiro Subgroup in Ohno City, Fukui Prefecture. The beds including the ammonoid fossil might be correlated with the Kamihambara Formation. He also mentioned about the conglomerates including abundant chert and siliceous shale clasts near the locality bearing the ammonoid. It is likely that the conglomerates correspond with the basal conglomerate of the Kamihambara Formation or the Obuchi Formation because of analogy of the lithofacies. Belemnite fossils discovered from the coarse grained sandstone in the lower part of the Otaniyama Formation of the Itoshiro Subgroup at the Shokawa, Gifu Prefecture (Kumon and Umezawa, 2001). Although it is possible that the Otaniyama Formation is correlated with the Kamihambara Formation, it needs further consideration.

The Itsuki Formation yields a brackish molluscan fossil which is available for age. *Myopholas* sp. cf. *M. semicostata* (AGASSIZ) is newly discovered from the Tetori Group. This fossil occurred in the Ryoseki Formation of the Monobegawa Group and the Togawa Formation that correlated the Ryoseki Formation in the Outer Zone of the Southwest Japan (Tashiro, 1993; Tashiro et al., 1993). The age of the Ryoseki Formation is interpreted as from late Hauterivian to Barremian on the grounds that the Ryoseki Formation is conformably overlain by the Monobe Formation which yields ammonites indicating Barremian (Tashiro, 1993). Therefore, the age of the Itsuki Formation seems to be Hauterivian to Barremian (Early Cretaceous), which is in accordance with the age of the ammonoid fossil from the Ohno City.

Lithological change of the composition of clastics of the Tetori Group and their provenances

The lithological vicissitude of the clasts is recognized in the Tetori Group. The composition of the coarse clasts changes

from the granite-dominant type to the orthoquartzite-dominant type through the chert-dominant type in ascending order. It indicates that provenance of the Tetori Group changed temporally.

The conglomerate of the Yambara Formation contains predominantly subrounded to rounded pebbles and cobbles of granitic rock whose plagioclase sometimes shows antiperthite structure. The antiperthitic structure is commonly recognized in the Funatsu granite (Suzuki and Osakabe, 1982). Fujita et al. (1995) reported gravels of sillimanite-cordierite gneiss which include garnet from the locality AC2 of the Yambara Formation. Tsujimori (1995) reported that a staurolite-bearing sillimanite schist cobble from a boulder probably derived from the Yambara Formation at Yambara. He suggested that a medium-P/T type metamorphic belt analogous to the present Unazuki metamorphic belt was exposed in the source area of the Tetori Group. The granitic and metamorphic clasts imply that the provenances of the Tetori Group are the Hida Terrane, Funatsu granite, and medium-P/T type metamorphic belt (Unazuki metamorphic belt?). Maeda (1961a) reported that spilite gravels, which are derived from Paleozoic strata, are included in the Kuzuryu Subgroup. The Tetori Group rests unconformably on the Circum-Hida rocks in part at the study area. The Circum-Hida Terrane was also distributed as hinterland of it.

Chert clasts are found in the upper part of the Ashidani Formation, Kamihambara Formation, and Obuchi Formation. Saida (1987) reported Triassic and Jurassic radiolarian fossils from chert and siliceous shale gravels of the Kamihambara Formation. In outside of the study area, Kumon and Kano (1991) reported conglomerates including abundant chert gravels of the Otaniyama Formation in the Shokawa area. Radiolarian bearing pebbles of the Akaiwa Subgroup in the upper reaches of the Kurobegawa River were interpreted to have been derived from the Jurassic accretionary complex of the Tamba, Mino, Ashio, Nandanhada or Sikhote-Alin terrane (Takeuchi et al., 1991). The Jurassic accretionary complex would be exposed widely as hinterland of the Itoshiro and Akaiwa Subgroups.

The orthoquartzite clasts are represented by the Nochino Formation. This facts indicate that provenance consisting of orthoquartzite was distributed at that time. The upward increase of the ratio of orthoquartzite clasts is recognized in the Tetori Group of the study area and other areas (Kumon and Kano, 1991). This increase tendency of orthoquartzite clasts might be caused by change direction of rivers or the beds of orthoquartzite are gradually exposed by erosion. There are no strata of orthoquartzite in Japan, although orthoquartzitic sandstone are commonly found in the upper Precambrian formations in East Asia; the Sinian System of China and the Shogen (Sangweon) System of North Korea (Shibata, 1979). The orthoquartzite clasts of the Tetori Group might be derived from such places.

The mineralogical maturity (quartz and chert fragment / feldspar and other lithic fragments) of sandstones of the Itoshiro

Subgroup increase in ascending order (Fig. 6), which indicates that the sediments of the upper part of the Itoshiro Subgroup are more affected by weathering than the lower part. High ratio of calcite cements with almost absent of argillaceous matrix of the Obuchi Formation indicates sedimentation under strong current energy such as wave.

CONCLUSIONS

- 1) The Tetori Group is divided into the Kuzuryu, Itoshiro and Akaiwa Subgroups in ascending order. The Kuzuryu Subgroup is composed of the Tochimochiyama, Kaizara, and Yambarazaka Formations. The Itoshiro Subgroup, which covers the Kuzuryu Subgroup unconformably, is classified into the Yambara, Ashidani, Kamihambara, Obuchi, and Itsuki Formations in ascending order. The Akaiwa Subgroup consists of the Nochino Formation.
- 2) The Kamihambara Formation is the first designated neritic strata of the Itoshiro Subgroup in the study area.
- 3) It seems that *Myopholas* sp. cf. *M. semicostata* from the Itsuki Formation suggests Hauterivian to Barremian in age.
- 4) The lithological vicissitude of the clasts is recognized in the Tetori Group, which changes from the granite-dominant to the orthoquartzite-dominant type through the chert-dominant type in ascending order.

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- * : in Japanese with English abstract
** : in Japanese

<地名>

Akaiwa	赤岩	Ooi-dani	大井谷	Itsuki	伊月
Kuzuryu	九頭竜	Hayashi-dan	林谷	Yambara	山原
Amagashira-dani	天頭谷	Sui-dani	スイ谷	Izumi	和泉
Nochino	後野	Hora-dani	ホラ谷	Yambarazaka	山原坂
Ashidani	葦谷	Tamo-dani	田茂谷	Kaizara	貝皿
Obuchi	大淵	Itoshiro	石徹白	Umaga-dani	馬ガ谷
Hakogase	箱ヶ瀬	Tochimochiyama	栃餅山	Kamihambara	上半原