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Stratigraphy and Geological Development of the Chichibu Terrane in the Kuraoka district, Miyazaki Prefecture, Kyushu.

By

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with 15 tables, 38 Figures and 9 Plates

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ABSTRACT The Chichibu Terrane is divided into the Northern, Middle and Southern Belts. This thesis re-examines the stratigraphy of constituents of the Chichibu Terrane of this study area by investigating lithology, mega- and micro-fossils, and clarifying the geotectonic division, and discusses the tectonic development of the Chichibu Terrane from middle to western Kyushu.

The Northern Belt is composed of the Lower Jurassic olistostrome facies of the Yurugidake and Mamihara Formations. The constituents of the Middle Belt are the pre-Silurian Kuraoka Igneous Rocks, the Silurian to Devonian Gionyama Formation, "green shist formation", the Upper Permian Kagamiyama, Upper Triassic Murono, Lower Jurassic Kanmuridake, Upper Jurassic Oishi Formations and the Cretaceous neritic sediments. The Southern Belt is divided into the northern unit representing the Lower to Upper Jurassic olistostrome facies and the southern unit of Upper Jurassic to Upper Cretaceous by the Shiraiwayama Thrust (Murata, 1981) trending nearly EW. Most of the Kagamiyama Formation, which had been considered to be of Middle Permian (Saito and Kanbe, 1954), is the Late Permian accretionary complex including exotic blocks of green rocks, chert, serpentinite and rare limestone. The high-pressure and low-temperature type metamorphic rocks of jadeite-glaucophene facies are included in some exotic blocks. Considering the radiolarian assemblage, both on northern and southern margins of the previous Kagamiayama Formation are redefined to be the Lower Jurassic olistostrome facies of the Mamihara Formation (newly named) and the Lower Jurassic well-organized Kanmuridake Formation (newly named). Constituents of the Northern Belt are distributed both on northern and southern sides (northern side: the Mamihara Formation, southern side: the Yurugidake Formation) of the Middle Belt (=Kurosegawa Terrane) in the study area, and the main constituents of Kurosegawa Terrane are considered to form a nappes thrust over the Northern Belt. Such distribution and structural relation are also confirmed in the Yatsushiro district (Miyamoto, 1990; and others) that suggests wider distribution from middle to western Kyushu now largely covered by the Aso pyroclastic flow deposits.

The redefined Oishi Formation lies along the southern side of the Gionyama lenticular body which provides exotic blocks of granitic rocks and bluish-green acidic tuff into the apparent lowermost part. The upper part of the formation contains blocks of the Oishi Formation the Upper Permian sandstone, acidic tuff, and the Upper Jurassic sandstone. These exotic blocks are mostly a continental and continental shelf origin with an exception of chert gravels contained within the slump breccia. The Oishi Formation mainly represents a turbidite facies yielding the Early Callovian radiolarian assemblage. Such characteristics of lithofacies indicate that the Oishi Formation was deposited by gravity flow such as turbidity current and subsolifluction down to sedimentary basin during the Late Jurassic, accompanying with breakdown of the Upper Permian and Upper Triassic rocks. The breakdown was most probably caused by thrust movement within the accretionary complex.

On the basis of the fossil evidence and lithofacies, the Cretaceous neritic sediments within the Middle and Northern Belts are divided into the correlatives of the Monobegawa Group in Shikoku (the Hauterivian to Lower Barremian Togawa, Barremian Tsubana, Aptian Kasabe, probably Aptian Gokase and Albian Shibanomoto Formations), the Kubo Formation and unconformably overlying Takahata Formation. The bivalve fauna of Kubo Formation (probably Late Albian) is newly found and is not related to the Lower Cretaceous Monobegawa Group of the Chichibu Terrane. However, it includes common taxa with those of the pre-Sotoizumi and Ryoke types of the Inner Zone-faunas in Southwest Japan. These two formations thrust over the formations (Kagamiyama, Mamihara and Togawa Formations) of the Northern and Middle Belts of the Chichibu Terrane, and judging from the bivalves from Kubo Formations, they are probably nappes from the north.

The southern unit of the Chichibu Terrane distributed in a south area of the Shiroiwayama Thrust mainly consists of sandstone, shale and alternating beds, containing exotic blocks of limestone, chert and green rocks. The pelitic-matrix of this unit yields radiolarian fossils of younger age than early Late Jurassic. The Albian to Cenomanian radiolarian assemblage correlated with the *Holocryptocanium barbui* - *H. geysersense* A-zone (Nakaseko and Nishimura, 1981) or the *H. barbui* A-zone (Yao, 1984) is obtained from siliceous mudstone, suggesting. This unit is comparable with the lowermost to lower Upper Cretaceous Sakaguchi Formation (Nishizono and Murata, 1983) distributed along the southern margin of the Kannose Zone in Yatsushiro district, while the lithofacies and radiolarian age indicate that the formation can also be correlated with the Hinokage Formation (Imai et al., 1971) of the Morozuka Group of the Shimanto Terrane distributed in a south area of the Butsuzo Tectonic Line. The resemblance between these formations across the Butsuzo Tectonic Line reminds to re-examine the location and the significance of the Butsuzo Tectonic Line.

Contents

I. Introduction

Southwest Japan is geologically divided into the Inner Belt (Japan Sea side) and the Outer Belt (Pacific Ocean side) by the Median Tectonic Line. The Outer Belt is subdivided into three terranes from north to south; the Sanbagawa Terrane made up of high-pressure type metamorphic rocks, the Chichibu Terrane, and the Simanto Terrane mainly composed of weakly metamorphosed and non-metamorphic rocks of the Cretaceous to Paleogene. The framework on the geologic structure and development of the Southwest Japan was proposed by Kobayashi (1941). He regarded the rocks of the Southwest Japan except for the Simanto Terrane as a series of sediments deposited in the Chichibu Geosyncline, and expressed the division by the tectonic movement phases. For example, he explained that the northern half of the geosyncline had been uplifted by the Akiyoshi orogenic movement of Permian to Triassic, and the south half had been deformed by the Cretaceous Sakawa orogenic movement. In the geosynclinal orogenism of those days, age determination of rocks was mostly based on the fusulinids, and the Southwest Japan had been considered to be mainly composed of the Upper Paleozoic (Carboniferous-Permian), deposited in a single geosyncline. Therefore, the adjacent strata in the present-days were considered to have been formed in the adjacent locations in terms of paleogeography. Ichikawa et al., (1953, 1956) proposed that the Chichibu Terrane was subdivided into the Northern, Middle and Southern Belts. In the Middle Belt, the Silurian and Devonian rocks together with granitic rocks were considered to have formed the basements of the Chichibu Geosyncline. Ichikawa and his coworkers suggested the uplifting of these older rocks during the Late Palaeozoic to Early Triassic and induced term of the Kurosegawa Terrane for the distributing areas.

By the introducing plate tectonics theory, the model of arc-trench system explaining that the rocks formed in separate areas are now joined together by the plate movement is commonly accepted (Kanmera, 1976, 1980). The total reform in depositional ages of the constituent rocks on the basis of radiolarian fossils since early 1980's largely contributed to the development of this model. Such detailed studies on the radiolarian biostratigraphy in the Southwest Japan have clarified of the wide occurrence of the Mesozoic system within the area which had been considered as the Palaeozoic system (Isozaki et al., 1981; Suyari et al., 1982 and 1983; and others). While, the presence of the Upper Permian within the Middle and Northern Belt of the Chichibu Terrane was confirmed by the recent studies of Ishida (1985 a and b), Isozaki (1986), Yamakita (1986), and others. One of the important works to clarify the tectonic development of a terrane may be to differentiation of the tectonostratigraphic units based on the structural and stratigraphical analyses. The analyses are especially important because a terrane may consist of some tectonicstratigraphic units, in some cases like the Sangun Metamorphic Rocks (Hara et al., 1985). Another essential requirement for such tectonostratigraphic division is the elucidation of the local geology with respect to the detailed field works. Yao (1985) modified and redefined the boundary between the Middle and Northern Belt of the Chichibu Terrane in Shikoku on the basis of the stratigraphic study and the geotectonic division of the pre-Cretaceous. However in Kyushu, such division has not been clarified yet.

In the study area (Kuraoka district, Gokasecho Miyazaki Prefecture, Central Kyushu), the Chichibu Terrane has been studied by several authors. The important works are; a stratigraphy of Kanbe (1957) based on the fusulinids and megafossils, the biostratigraphic study of Silurian to Devonian system (Hamada, 1959), the description of Cretaceous system on the basis of bivalves (Teraoka, 1970) and the examination on the age of siliceous rocks by conodonts (Koike and Murata, 1969; Murata, 1981). However, the general geotectonic division involved and tectonic development with consideration of the ages of acretionary complex have not clarified yet. Since 1986, the author has examined the development of Chichibu Terrane including the Kurosegawa Terrane in Kyushu with his co-llaborators. And the author have already clarified that the Yurugidake Formation previously regarded as the Permian (Kanbe, 1957) of this area was correlated with the Northern Belt of the Chichibu Terrane in Shikoku because of the occurrence of Early Jurassic radiolarians from the pelitic rocks of this formation (Miyamoto et al., 1988; Sogabe et al., 1990; and others). In this thesis, biostratigraphy and geological structure of the constituents of the Chichibu Terrane are re-examined. Then, the author clarifies the geotectonic division of the Chichibu Terrane and discusses the tectonic development of the Chichibu Terrane of middle western Kyushu.

• **Acknowlegement**

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II .Geological outline

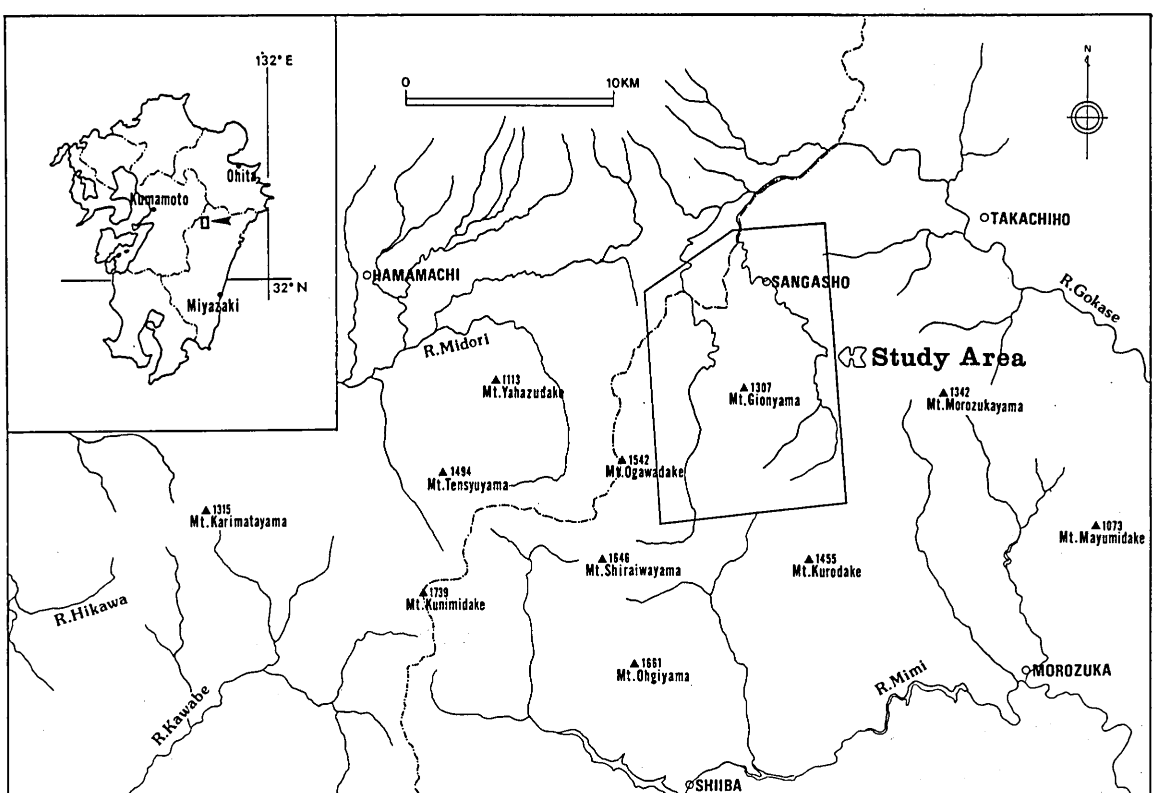
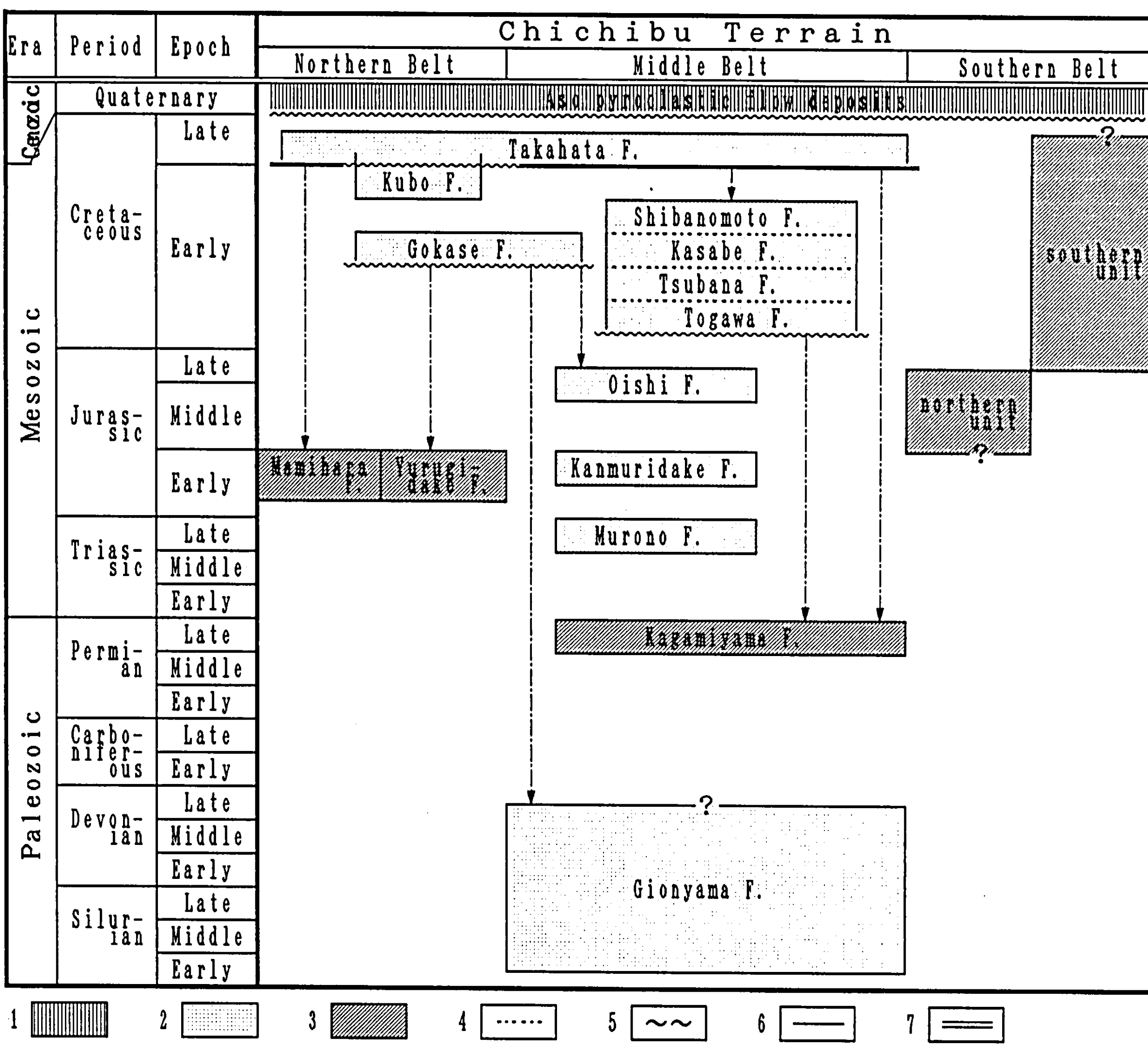


Fig. 1. Index map of the study area.

The study area covers from Gokasecho, Miyazaki Prefecture to Soyohcho, Kumamoto Prefecture in central Kyusyu. The Paleozoic and Mesozoic formations of the Chichibu Terrane expose about 15 km in width between the Usuki Tectonic Line and the Yatsushio Tectonic Line. The Aso volcano is situated about 20 km north–northwest of study area. In this area, the basement rocks of the Chichibu Terrane crop out intermittently, being filled up in the low elevation parts with the Aso volcanic deposits. This area was widely investigated by Saito and Kambe (1954) and Kambe (1957). According to Kambe (1957), the constituents of the Chichibu Terrane namely the Kagamiyama Formation (Middle Permian), the Takahata Formation unknown in age (Upper Mesozoic?), the Shibanomoto Formation (Lower Cretaceous), the Kuraoka Igneous Rocks, the Gionyama Formation (Silurian), the Oishi Formation unknown in age (Upper Permian?), the Yurugidake Formation (middle Lower Permian to Middle Permian) and the Tonegoyama Formation (Upper Jurassic) are distributed from north to south, with zonal arrangement trending in NE-SW direction. Teraoka (1970) re-examined the Chichibu neritic strata on the basis of bivalve fauna and sub-divided into the Togawa, Kasabe, Shibanomoto and Takahata Formations. He regarded the Oishi Formation as the Cretaceous judging from its lithofacies, however Mastumoto and Hirata (1970) assigned this formation the Upper Jurassic system by finding the Late Jurassic ammonite fossils. Most part of the Tonegoyama Formation is assigned to the Upper Triassic, because of the occurrences of the Early Triassic bivalves from limestone blocks to the west of the Tonegoyama (Tamura,1960a) and from the fine-grained pelitic sandstone at the eastern extended area of this formation (Miyazaki Prefectural Government, 1981). Still more, the fine-grained muddy sandstone distributed in the vicinity of Murono to the northeast of the study area was found to yield the Triassic bivales and was newly described as the Upper Triassic Murono Formation (Miyazaki Prefecutural Government, 1981). While, in Kagamiyama and Yurugidake Formations represent olistostrome facies. Many of the Triassic conodonts are obtained from the chert blocks of the Yurugidake Formation, where the Triassic as well as the Middle Permian is found (Koike and Murata, 1969; Murata, 1981). The chert blocks of the Yurugidake Formation yield the Permian to the Triassic radiolarians and its pelitic matrix contains the Late Jurassic ones (Miyamoto et al.,1988; Sogabe et al.,1990), that indicates is an accretionary complex origin corresponding to the Northern Chichibu Terrane in Shikoku. The Early Triassic radiolarian fossils are obtained from the chert blocks in the Kagamiyama Formation. This and the resemblance in lithofacies suggest that the formation, as well as the Yurugidake Formation, is an olistostrome complex forming during the Lower Jurassic. Table 1 shows the stratigraphic division used in this study and Fig. 2 shows the geological map of study area.

Table 1. Stratigraphic division of the Kuraoka district.



1: continental volcanic facies, 2:neritic sedimentary facies, 3:olistostrome facies, 4: conformity, 5: unconformity, 6: fault, 7: thrust

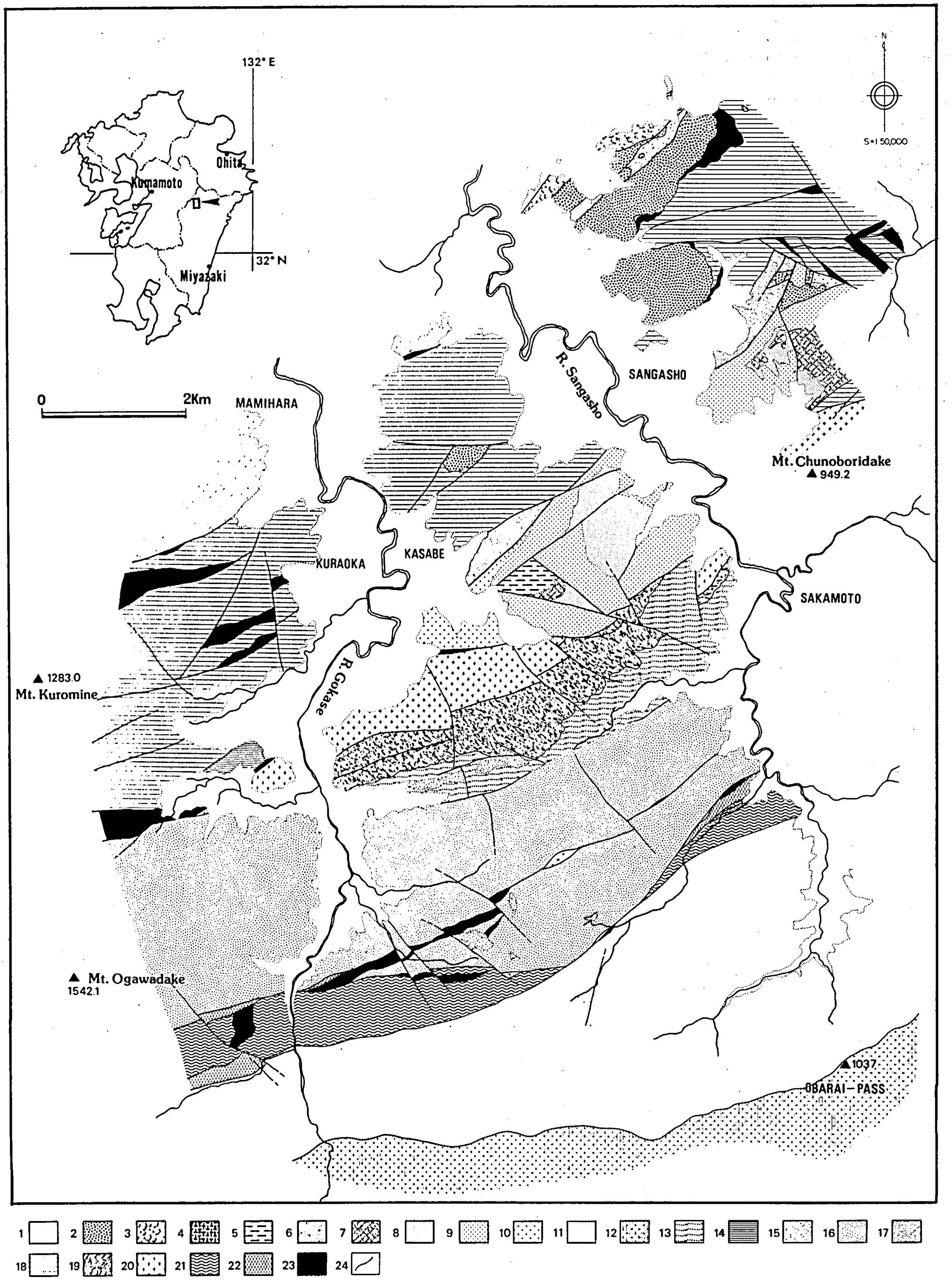


Fig. 2. Geological map of the Kuraoka district.
1:Aso pyroclastic flow deposits, 2:Takahata Formation, 3:Kubo Formation, 4:Shibanomoto Formation, 5:Kasabe Formation, 6:Gokase Formation, 7:Tsubana Formation, 8-10:Togawa Formation (8:upper most member, 9:upper member, 10:lower member), 11:northern unit of the Southern Belt, 12:southern unit of the Southern Belt, 13:Oishi Formation, 14:Kanmuridake Formation, 15:Mamihara Formation, 16:Yurugidake Formation, 17:Murono Formation, 18:Kagamiyama Formation, 19:Gionyama Formation, 20:Kuraoka Igneous Rock, 21:green schist, 22:pelitic schist, 23:serpentinite, 24:fault

The constituents of the Chichibu Terrane in the study area are cut by the fault system with a general trend of NE-SW, and represent zonal arrangement; the Lower Jurassic Mamihara Formation, the Upper Permian Kagamiyama Formation, the Upper Triassic Murono Formation, the Lower Jurassic Kanmuridake Formation, the Kuraoka Igneous Rocks, the Silurian to Devonian Gionyama Formation, the Upper Jurassic Oishi Formation, and the Lower Jurassic Yurugidake Formation from north to south. The strata of the Southern Belt in the Chichibu Terrane occur to the south of the Yurugidake Formation being accompanied green schist formation between them. Cretaceous neritic sediments, Togawa, Tsubana, Kasabe, Gokase, Shibanomoto, Takahata, and Kubo Formations unconformably overlie or thrust over the pre-Cretaceous formations are locally distributed. Among these, underlines show newly named formations, and double underlined ones are redifined geological age and distribution. At the low evevation parts like drainages or foots of the mountains, the Aso pyroclastic flow deposits are widespread, covering the basement rocks as mentioned above.

The Aso pyroclastic flow deposits found in this area mainly consist of intermidiate wellded tuff, accompanied by minor tuff breccia, pumice, volcanic ash and others. Though wellded tuff is strongly consolidated, it is easily weatherd and gray to dark gray. The rock is very heterogeneous and includes a large amount of lapilli and pumice in a matrix of porous tuffaceous sediments. In highly consolidated parts, a remarkable banded structure with the parallel arrangment of lenticulr a obsidian is found. The Aso pyroclastic flow has four main eruption cycles, namely Aao-1,-2,-3,-4, in younging order (Watanabe and Ono, 1969). The ages of eruptions are considered to be Aso-1: 0.3 to 0.35Ma, Aso-2: 0.15Ma, Aso-3: 0.1Ma, Aso-4: 0.04 to 0.08Ma (Yamaguchi, 1986). All of the four eruption products are found in study area, and the Aso-4 has the most extensive distribution.

III. Discription of different geological units

On the basis of the geological structure and lithofacies, the Chichibu Terrane is divided into three belts, namely the Northern, the Middle and the Southern Belts (Ishii et al.,1955). Recently the detailed biostratigraphical studies on radiolarian and other micro fossils have clarified a wide occurrence of the Mesozoic system which had used to be considered as the Upper Palaeozoic (Isozaki et al., 1981; Suyari et al., 1982, 1983; and others). While, recent studies (Ishida, 1985a, b; Isozaki,1986; Yamakita, 1986; and others) have also confirmed that the presence of Upper Palaeozoic system in the Middle or the Northern Chichibu Terrane. The division of the Chichibu Terrane in Shikoku are modified and re-defined by stratigraphic studies and the geotectonic division of pre-Cretaceous system (Yao, 1985). The rocks consisting of three Belts, the Northern, the Middle and the Southern, are shown as follows.

Northern Belt : Lower to Middle Jurassic olistostrome.

Middle Belt : lenticular-bodies of the Kurosegawa Terrane, Crystalline schist, Upper Palaeozoic system, and neritic sediments composed of clastic rocks (Middle to Upper Triassic, Middle to Upper Jurassic and Cretaceous system).

Southern Belt : chert and clastic sediments of Middle Triassic to Early Jurassic age, Lower Jurassic to Lower Cretaceous olistostrome, and strata including by "the Torinosu Limestone" represented by the Torinosu Group.

In this chapter, the detailed description of each Belt is given, in principle, based on the geotectonic division of the Chichibu Terrane proposed by Yao (1985). Fig. 3 and 4 show a lithological map and geological profiles, respectively.

III-1. Northern Belt of the Chichibu Terrane

• Yurugidake Formation

[Previous studies]

The type-locality of the Yurugidake Formation, named by Saito and Kanbe(1954), is located in the vicinity of Mt. Yurugidake to the south of Mt. Gionyama, Gokasecho. Its distribution extends from the southern margin of the Gionyama lenticular-body, known as important development of the Kurosegawa rocks in the Chichibu Terrane, to the Butsuzo Tectonic Line.

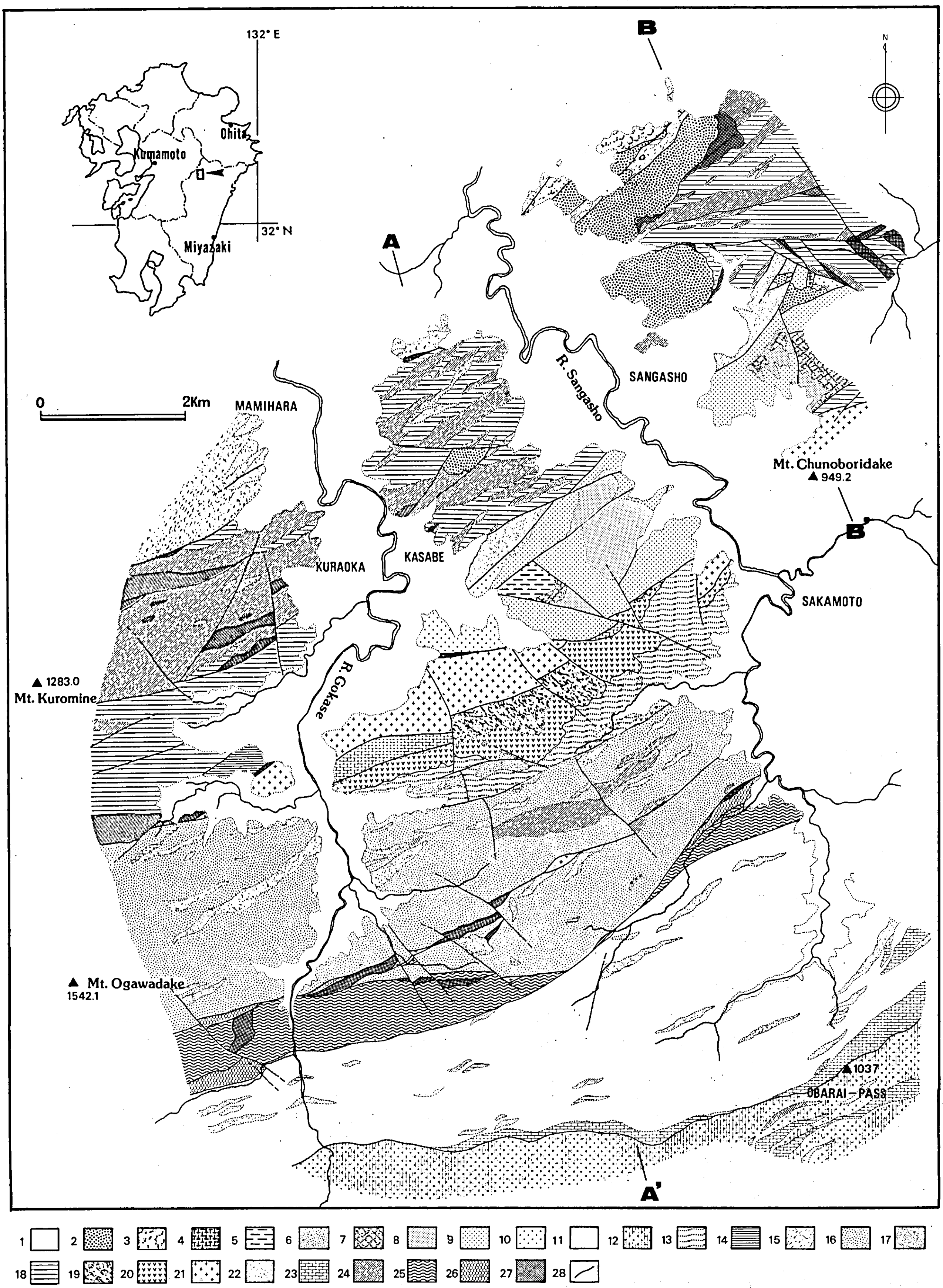


Fig.3. Lithological map of the Kuraoka district.
1:welded tuff, tuff breccia [Aso pyroclastic flow deposits], 2:red conglomerate, sandstone [Takahata F.], 3:sandstone [Kubo F.], 4:black shale [Shibanomoto F.], 5:shale/sandstone/conglomerte alternation [Kasabe F.], 6:conglomerate/sandstone alter. (conglomerate rich)[Gokase F.], 7:shale/sandstone alter. (shale rich)[Tsubana F.], 8:shale/sandstone alter. [upper most member of Togawa F.] , 9:shale/ sandstone/conglomerate alter. [upper member of Togawa F.], 10:red sandstone, red conglomerate [lower member of Togawa F.], 11:pebbly mudstone, sandstone [northern unit of the Southern Belt], 12:pebbly mudstone, sandstone, shale [southern unit of the Southern Belt], 13:sandstone/shale alter. [Oishi F.], 14:sandstone/shale alter. [Kanmuridake F.], 15:pebbly mudstone, sandstone [Mamihara F.] 16:pebbly mudstone,sandstone [Yurugidake F.], 17:sandstone/shale alter. (sandstone rich)[Murono F.], 18:pebbly mudstone, sandstone [Kagamiyama F.], 19:tuffaceous sandstone [Gionyama F.], 20:acidic tuff [Gionyama F.], 21:granitic rock [Kuraoka Igneous Rock], 22:chert, 23: limestone, 24:green rock, 25:green schist, 26:pelitic schist, 27:serpentinite, 28:fault

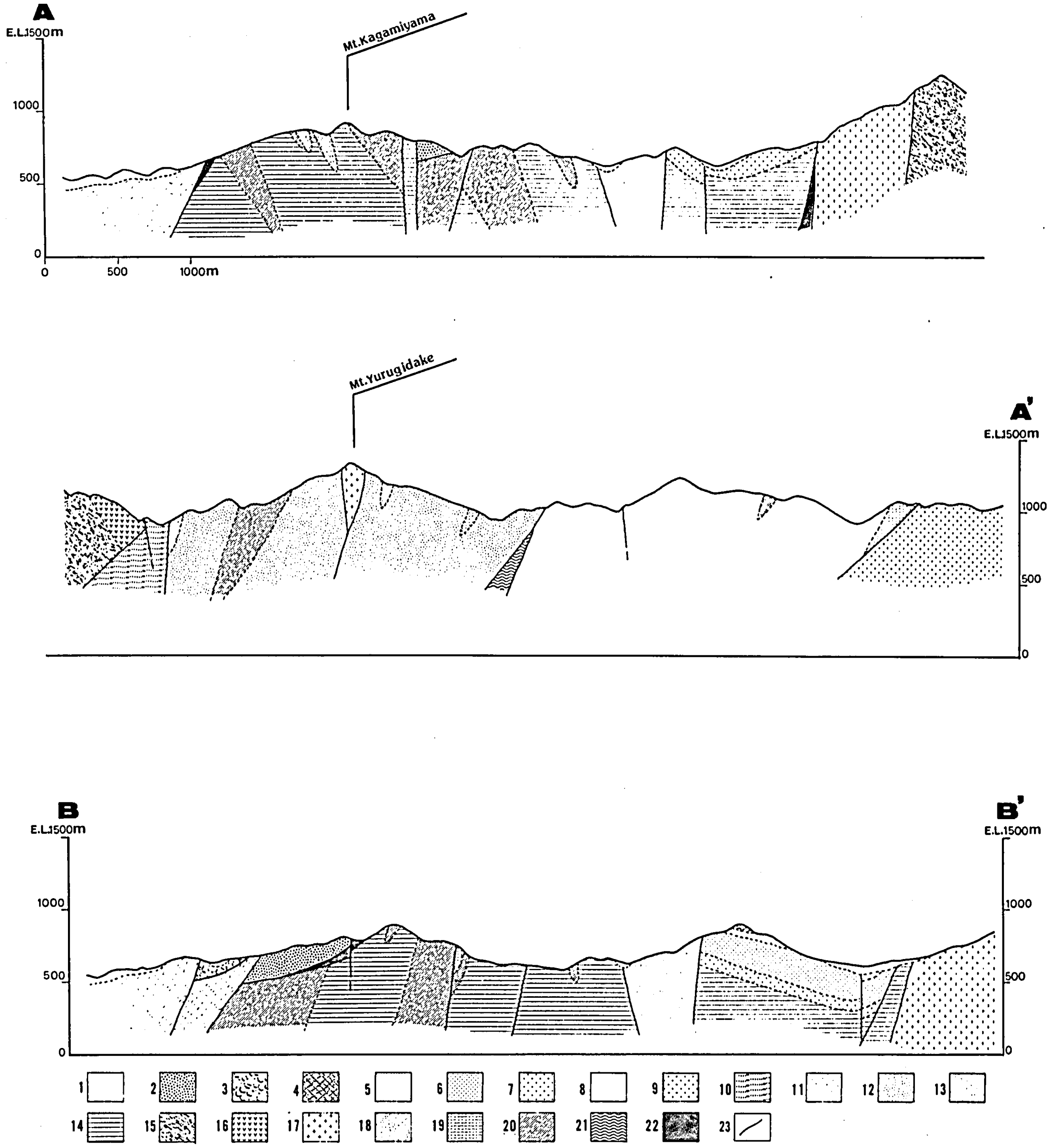


Fig. 4. Geological profiles of the Kuraoka district.
1:Aso pyroclastic flow deposits, 2:Takahata Formation, 3:Kubo Formation, 4:Tsubana Formation, 5-7:Togawa Formation(5:upper most member,6:upper member,7:lower member), 8:northern unit of the Southern Belt, 9:southern unit of the Southern Belt, 10:Oishi Formation, 11:Mamihara Formation, 12:Yurugidake Formation, 13:Murono Formation, 14:Kagamiyama Formation, 15-16:Gionyama Formation (15:sandstone, 16:acidic tuff), 17:Kuraoka Igneous Rock, 18:chert, 19:limestone, 20:green rock, 21:green schist, 22:serpentinite, 23:fault

And it is patchy (northern district of Mt. Cyunoboridake and Mt. Mikatayama) found on the north of the Gionyama lenticular-body. This formation strikes ENE-WSW and is distributed within the Lower Triassic Tonegoyama Formation in a fault contacts (Tamura,1960a; Miyazaki Prefectural Government, 1981). It is composed of sandstone, slate, chert, conglomerate, limestone and schalstein, diabase, and serpentinite intruding along the bedding plane. In the northern and the middle part of this area, it consists mainly of slate and chert. In the southern part, it consists mainly of limestone and schalstein. The limestone of the Yurugidake Formation yields the following fusulinid fossils, *Cancellina, Misellina, Neoschwagerina, Parafusulina, Paraschwagerina, Pseudofusulina, Schwagerina* and *Verbeekina*, and these genera show age ranging from the Early Permian to the Middle Permian. Koike and Murata (1969) and Murata (1981) reported, at the central part of the Yurugidake Formation, the enormous thrust (Shiraiwayama Thrust) with a general trend of EW to NE-SW dipping north. And they named two parts of the Yurugidake Formation separated by this thrust as the Northern Sanbozan Belt and the Southern Sanbozan Belt. They also confirmed the occurrence of the Triassic in addition to the Permian on the basis of biostratigraphy of conodonts fossils from chert and siliceous mudstone of this formation. Miyamoto et al. (1988) and Sogabe et al. (1990) obtained the Middle Permian-Early Triassic and Late Jurassic radiolarian fossils from the chert blocks and the pelitic-matrix at the northern part of the Yurugidake Formation, respectively. We recognized the formation as a accretionary complex corresponding to the Northern Belt of the Chichibu Terrane in Shikoku.

[Distribution]

The Yurugidake Formation is zonally distributed in the center of the study area with a general trend NE-SW, ranging in width from 2 to 3km, between the Gionyama lenticular-body and the Oishi Formation in north, and the green schist formation from Motoyashiki to Ichinose in south. That is equivalent to the distribution of the Yurugidake Formation by Kanbe (1957) except for the part north of the Gionyama lenticular-body (northern area of Mt. Chunoboridake-Mt. Mikatayama) and the south of the green schist formation. After the discrimination from the Yurugidake Formation, the former is now clarified to the Kagamiyama Formation and the latter belong to the Southern Belt of the Chichibu Terrane. In the study area, while the most of which had been considered to be the Tonegoyama Formation is regard to be of the Yurugidake Formation on the basis of lithofacies and radiolarian age.

[lithofacies]

It is the olistostrome sequence which mainly consists of pebbly mudstone and sandstone, and locally intercalate acidic tuff and siliceous mudstone. The rocks included as olistolith are composed of massive to bedded sandstone, chert, green rocks and limestone, in order of their frequency. This formation appears to have a maximum thickness of more than 1500.

Pelitic-matrix of pebbly mudstone looks black to gray, turning to reddish-brown with increase in degree of weathering, and is frequently tuffaceous which often shows bedding in the less pebbly. Blocks of sandstone vary in size from a few centimeters to a few tens meters. They are grayish-green to yellowish-brown and commonly massive, hard and fine to middle grained, but some of them are coarse including chert granule. Blocks of green rocks which mainly consist of basic volcanic rocks like diabase and basalt, ranging in size from several meters to a few hundreds meters, are present. Chert frequently occurs in pebbly mudstone, especially in the north of the distribution, there are many enormous chert blocks reaching a hundred meters. Chert is white, grayish-white, reddish-brown or grayish-black, fine and hard, commonly having remarkable bedding planes. Joints of the chert often have a few centimeters to a few tens centimeters spacing. The chert can be often traced along the strike direction and forms ridges. Limestone, in which crystalline limestone is rarely found, is grayish-white to dark gray, and is commonly massive and hard. It is scattered in this formation, ranging in size from a few meters to a few tens meters.

[Structure]

This formation strikes N60 to 80E and dips 50 to 80N. It strikes nearly E-W at the drainages of the Gokasegawa in the west of study area and about NE-SW at the drainages of the Sangasyogawa, then changing its strike northward in the west. It is bounded by the nearly vertical fault with the Oishi Formation and the Kurosegawa rocks on the north, and by the fault dipping 60 to 80 with green schist formation and the Southern Belt of the Chichibu Terrane on the south. The faults with a general trend parallel to their strike develop, and lenses of granitic rocks and serpentinite are located along them. Some faults making a right angle with the above-mentioned faults are found, and these faults cut the NE-SW faults.

[Occurrence of fossils]

Radiolarian fossils available for age determination are obtained from 16 localities., Loc.YU-1 to YU-16 (show in Fig. 5). Lithofacies of each locality describes as follows ; Locs. YU-1 to YU-5 are chert, Loc. YU-10 is acidic tuff and the rests are shale as the matrix of pebbly mudstone. List of obtained radiolarian fossils from each locality is shown in the Table 2.

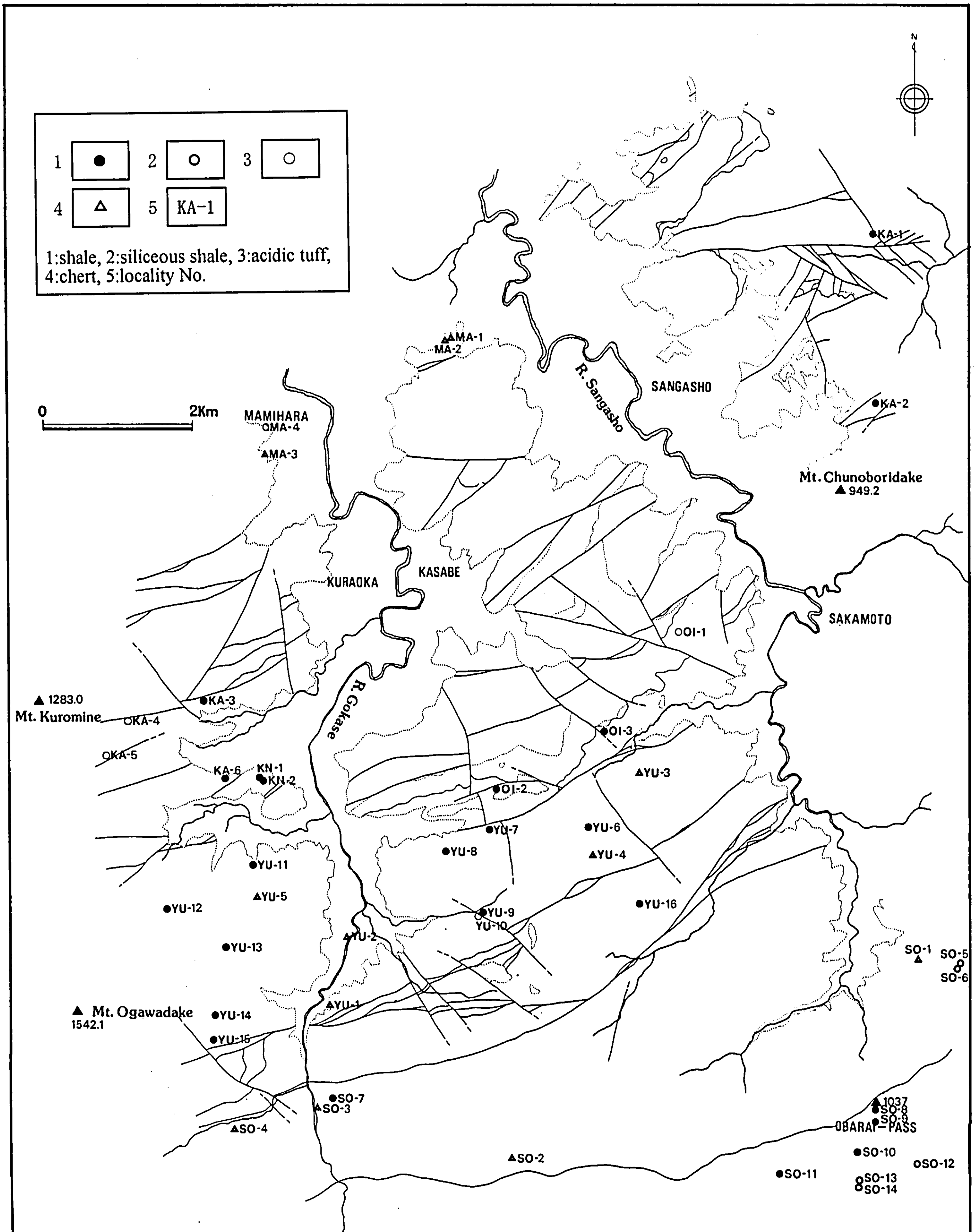


Fig. 5. Localities of radiolarian fossils listed in Table 2,3,4,5,6,12.

Table. 2. List of radiolarian fossils from the Yurugidake Formation.

Species Loc.(YU-)	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
***Follicucullus* sp. cf. *F. dilatatus* RUDENKO**		+														
***Follicucullus* sp. cf. *F. porrectus* RUDENKO**		+														
***Follicucullus scholasticus* ORMISTON and BABCOCK**		+														
***Follicucullus* sp.**		+														
***Pseudoalbaillella* sp. cf. *P. fusiformis* (HOLDWORTH and JONE)**	+															
***Pseudoalbaillella* sp. cf. *P. longtanensis* SHENG and WANG**	+															
***Pseudoalbaillella* sp.**	+															
***Archicapsa pachyderma* TAN SIN HOK**											+					
***Bagotum* sp. cf. *B. erraticum* PESSAGNO and WHALEN**							+									
***Bagotum* sp. aff. *B. maudense* PESSAGNO and WHALEN**							+									
***Bagotum* sp.**							+	+			+					
***Canesium*(?) sp.**				+												
***Canoptum* sp. cf. *C. anulatum* PESSAGNO and POISSON**					+				+							
***Canoptum* sp. aff. *C. artum* YEH**			+													
***Canoptum* sp. aff. *C. laxum* BLOME**						+										
***Canoptum* sp. cf. *C. merum* PESSAGNO and WHALEN**															+	
***Canoptum* sp. aff. *C. poissoni* PESSAGNO**			+													
***Canoptum* sp.**			+		+	+			+		+		+	+	+	
***Canoptum*(?) sp.**			+	+		+	+					+				
***Cyrtocapsa* sp.**								+								
***Droltus hecatensis* PESSAGNO and WHALEN**											+					
***Droltus* sp. cf. *D. hecatensis* PESSAGNO and WHALEN**											+					
***Droltus* sp.**										+						
***Droltus*(?) sp.**							+									
***Dictyomitrella* sp.**					+											
***Latium* sp.**				+												
***Laxtorum*(?) sp.**			+													
***Natoba* sp. cf. *N. minuta* PESSAGNO and POISSON**					+											
***Natoba* sp.**					+											
***Parahsuum ovale* HORI and YAO**								+			+					
***Parahsuum* sp. cf. *P. ovale* HORI and YAO**										+						
***Parahsuum simplum* YAO**							+				+					
***Parahsuum* sp. cf. *P. simplum* YAO**									+							
***Parahsuum* sp. cf. *P. transiens* HORI and YAO**										+						
***Parahsuum* sp.**							+	+	+		+	+				+
***Parahsuum*(?) sp.**							+									
***Parvicingula* sp.**											+					
***Parvicingula*(?) sp.**															+	
***Stichocapsa* sp.**											+					
***Syringocapsa* sp.**								+								
***Xipha* sp.**				+												
***Capnodoce* sp. aff. *C. traversi* PESSAGNO**				+												
***Capnuchosphaera* sp.**				+												
***Ferresium* sp.**															+	
***Ferresium*(?) sp.**														+		
***Gorgansium* sp. aff. *G. crassum* KISHIDA and HISADA**						+										
***Gorgansium* sp. aff. *G. gongyloideum* KISHIDA and HISADA**							+									
***Gorgansium*(?) sp.**							+									
***Homoeparonaella*(?) sp.**						+										
***Kozurastrum* sp.**															+	
***Livarella longus* YOSHIDA**					+											
***Livarella gifuensis* YOSHIDA**					+											
***Livarella* sp.**					+											
***Orbiculiforma* sp.**						+										
***Pantanellium* sp. cf. *P. browni* PESSAGNO and BLOME**															+	
***Pseudoheliodiscus*(?) sp.**			+													
***Sarla* sp. cf. *S. hadrecaera* (DE WEVER)**				+												
***Sarla* sp.**			+	+												

• Mamihara Formation

[Previous studies]

The Mamihara Formation, newly named in this paper, corresponds to the northern margin of the Middle Permian Kagamiyama Formation of Kanbe (1957). Sogabe et al. (1990) have reported occurrence of *Livarella* sp. cf. *L. longus* Yoshida, *Livarella* sp., *Canoptum* sp., and suggest that the Kagamiyama Formation is possibly Jurassic deposits including olistolith of Early Triassic chert.

[Distribution]

This formation is distributed along the northern boundary of the Kagamiyama Formation in Mamihara, Soyocho, Kumamoto Prefecture to Kubo, Gokasecho, Miyazaki Prefecture, northernmost of study area. It crops out in limited areas, because it is overlain by the Aso pyroclastic flow deposits on the northern boundary. According to Tanimoto (1987MS), Early Triassic radiolarian fossils are obtained from the chert blocks of the northern Kagamiyama Formation which lies in the drainages of the Midorikawa to the west of the study area, that suggests that has the large possibility that it belongs to the western extending of this formation.

[lithofacise]

As well as the Yurugidake Formation, this formation shows olistostrome facies mostly composed of pebbly mudstone with minor intercalating of acidic tuff and siliceous mudstone. Olistolith mainly consists of massive to bedded sandstone and chert, including rare green rocks. Olistolith of limestone is not found in the study area. This formation is more than 500m in maximum thickness.

Pelitic-matrix of pebbly mudstone ranges from grayish-black to gray in color, and is often tuffaceous. They have a relatively thick weathered parts subjected to pedogenesis.

Sandstone blocks ranging in size from a few centimeters to a few tens meters are frequently grayish-yellow to yellowish-brown and massive. Green rocks consist of diabasal basic volcanic rocks, forming lenses a few meters in size. Chert appears white to grayish-white or grayish black in color, and as blocks ranging in size a few tens centimeters to a few hundreds meters. They are generally massive with some exceptions of remarkable bedded chert, and there are a lot of chert with many quartz veins.

[Geologic Structure]

This formation trends N40 to 60E and dips 30 to 80N. In the south, it is bounded by a fault partly intercalating and trending N45 to 75E with the Kagamiyama Formation serpentinite along the fault. The field observation follows that the boundary fault dips 60 to 70N. The other faults found in this formation have trends which are nearly parallel to that of the boundary fault.

[Occurrence of fossils]

Radiolarian fossils available for the age determination are obtained from four localities, Locs.MA-1 to MA-4 (shown in Fig. 5). The lithofacies of Locs.MA-1 to MA-3 are chert, and Loc.MA-4 appears tuffaceous shale. The list of radiolarian fossils from each locality is shown in Table 3, and representative radiolarian fossils are figured on Plates 2.

Table. 3. List of the radiolarian fossils from the Mamihara Formation.

Species Loc.(MA-)	1	2	3	4
Archicapsa **sp.**				+
Bagotum **sp.**				+
Canoptum **sp. cf.** ***C.anulatum*** **PESSAGNO and POISSON**			+	
Canoptum **sp.**	+	+	+	
Dictyomitrella **sp.**	+			
Parahsuum ovale **HORI and YAO**				+
Parahsuum **sp.**				+
Tricolocapsa(?) **sp.**				+
Ferresium **sp.**	+			
Higumastra**(?) sp.**	+			
Livarella **sp. cf.** ***L. longus*** **YOSHIDA**		+		
Livarella **sp.**		+		
Mesosatunalis **sp.**				+
Orbiculiforma **sp.**				+

III-2. Middle Belt of the Chichibu Terrane

III-2-1. Kurosegawa rocks

• Kuraoka Igneous Rocks

The Kuraoka Igneous Rocks, named by Kanbe (1957), is typically located in the northern district of Mt. Gionyama, Gokasecho. It is lenticurally distributed on the north of the Silurian to Devonian Gionyama Formation, extending from Mt. Chunoboridake through the border area between Gokasecho and Takachihocaho to Mt. Kanmuridake. According to Kanbe (1957), it consists of granitic rocks of which main components are plagioclase, quartz, K-feldspar, biotite, hornblende and muscovite. Intensely deformed parts come along the faults, and have partly affected by mylonitization. Judged from tectonic position and lithofacies, it have been correlated with the Mitaki igneous rocks of the Kurosegawa Terrane in Shikoku and the Yatsushiro igneous rocks at the drainages of the Kumagawa in Kumamoto Prefecture. Because the Kuraoka Igneous Rocks appears include a xenolith of the Gionyama Formation in an outcrop located south of Mt. Chunoboridake appears to be a xenolith of the Kuraoka Igneous Rocks, it is assumed have intruded after the deposition of the Gionyama Formation (Kanbe, 1957). The Kuraoka Igneous Rocks, however, shear the characteristics of pre-Silurian granitic rocks in the Kurosegawa Terrane (Yoshikura, 1985), and Umeda et al. (1986) has dated the Kuraoka Igneous Rocks in this area to be 450Ma by K-Ar method.

[Distribution]

As stated by Kanbe (1957), it lenticurally lies on the north of the Gionyama Formation ranging from 200 to 1000m wide and is also found in the vicinities of Mt. Chunoboridake and Mt. Kanmuridake. Other occurrences in a small volume within Oishi district southeast to Mt. Gionyama and near the top of Mt. Yurugidake, and intercalation along the fault associated with serpentinite within the Yurugidake Formation.

[lithofacise]

This formation is composed of granitic rocks, ranging from granite to granodiorite. The color is from grayish-white to grayish-green and grain size is medium to coarse. Particularly among small bodies, such as the one near the summit of Mt. Yurugidake, there are many quartz dioritic rocks containing a large quantity of hornblend, and they commonly exhibit green.

[Structure]

For the Gionyama lenticular body distributed in a largest area, both of the northern boundary with the Lower Cretaceous Togawa, the Upper Permian Kagamiyama and the Lower Jurassic Kanmuridake Formation, and the southern boundary of the Gionyama Formation are the high angled faults trending E-W to NE-SW. This lenticular body is subdivided into some fragments by the faults with a general trend NE-SE. On the other hand, the other small bodies except for the ones of Oishi district interbedded along the faults. The body at Oishi district which is 50m in width and 350m in length, appears to be an exotic block included into the Oishi Formation together with the blocks of bluish-green acidic tuff probably originated from the Gionyama Formation.

• Gionyama Formation

[Previous studies]

The Gionyama Formation, named by Saito and Kanbe (1954), is typically located in the vicinity of Mt. Gionyama, Gokasecho. It forms the Gionyama lenticular -body together with the Kuraoka Igneous Rocks. The formation is divided into four members, namely G1 to G4 member, in ascending order. The G1 member, of which lower end is unknown, is mostly composed of sandstone with a thin rhyolitic tuff bed. The G2 member consists of limestone, sandy limestone, sandstone, shale and tuff. Limestone and sandy limestone contain corals, for example *Falsicatenipora shikokuensis*, and co-occurred trilobites fossil such as *Coronocephalus kobayashii*, which indicates that the member is Late Wenlockian in age. The G3 member is made up of reef limestone with abundant corals, stromatoporoids, brachiopods and other fossils which suggests that the member is Early Ludlow in age. The G4 member is mostly composed of acidic tuff and tuffaceous sandstone. The acidic tuff is bluish-green, fairly hard and a key bed of the Gionyama Formation. The lower part of this member chiefly has a conformable relationship with the underlying G3 member. A few sphaeriform radiolarians have been found from this member, but their biostratigraphical significance could not yet be cleared. According to Wakamatsu (1986), however, the G4 member in the Yokokurayama district, Shikoku, yields radiolarian fossils indicating Late Devonian in age. Therefore, it is probable to consider that the Gionyama Formation, at least in part, is Upper Devonian.

[Distribution]

On the south of the Kuraoka Igneous Rocks, the Gionyama Formation in the vicinity of Mt. Gionyama is lenticurally exposed with ENE-WSW trend, ranging from 100 to 1000m in width. Several small outcrops are also found in Oishi district.

[Lithofacies]

The G1 member composed of fine to middle grained sandstone, narrowly crops out in quite poor preservation. The thickness may be about 100m. The G2 member is made up of alternating beds of sandstone and tuffaceous shale (the thickness of each bed is 10 to 20 centimeters), limestone with several shale beds of a few tens centimeters thick, and sandy limestone. This member is about 30m in thickness. G3 member consists of massive limestone which is often turned into breccia with tuffaceous matrix. The maximum thickness is 200 to 250m. G4 member is divided into two units; the upper unit chiefly composed of bluish-green acidic tuff and the lower unit made up of tuffaceous sandstone. They generally have conformable relationship, but interfinger near the boundary between the two units. This member occupies most of the Gionyama Formation, and its maximum thickness may exceeds 1000m.

[Geologic Structure]

The Gionyama Formation strikes N45 to 70E and chiefly dips 50 to 70S, but in the vicinity of boundary faults particularly near the southern thrust fault, dips are extremely variable (some places show the dips of 50 to 60N). Though the boundaries of each member cannot be observed in the field, the distribution of the members indicates that the boundary planes trend N50 to 70E, dip 50 to 60S. This formation is bounded by the high angled fault striking E-W to NE-SW with the Kuraoka Igneous Rocks on the north, and truncated by several faults of nearly right angle to the above mentioned fault. On the south, it thrusts over the Jurassic Oishi Formation by the reverse fault with 35 to 40N dip.

III-2-2. Olistostrome facies

• Kagamiyama Formation

[Previous studies]

The Kagamiyama Formation named by Saito and Kanbe (1954) is distributed along the northern margin of the Kuraoka district, and is typically located in the vicinity of Mt. Kagamiyama, Gokasecho. This formation is largely made up of slate, sandstone, schalstein and chert, frequently intercalating small lenses of limestone, and often contains intrusive diabase and serpentinite (Kanbe, 1957). Fossils available for age determination have not been discovered in this formation. However, Neoschwagerina sp. and Schwagerina sp. found from the limestone lenses indicate that the formation is regarded as a northeastern extension of the Gionyama Formation, Torogu district, Takachihocho, Miyazaki Prefecture. Because of these fusulinids, the formation was inferred to be is Middle Permian in age (Saito et al., 1958).

[Distribution]

The Kagamiyama Formation crops out in a zone from Michinoue, Nagamine, Koga and Kuromine at Gokasecho through Seiwason to Yabecho in Kumamoto Prefecture. This area is almost equivalent to that of Kanbe (1957), except for the distributing area of the Mamihara Formation (newly distinguished in this paper).

[Lithofacies]

This Formation is olistostrome facies chiefly composed of pebbly mudstone, intercalating shale and acidic tuff, and includes exotic blocks of sandstone, chert, green rocks, serpentinite and minor limestone. The formation is similar in lithofacies to the Mamihara and the Yurugidake Formation, however markedly differs from them in contents of a large amount of green rocks. Some of the exotic blocks belong to high pressure -low temperature metamorphic rock type of jadeite-glaucophane facies, which is one of an important lithological features. Though the exact thickness of this formation cannot be cleared owing to the development of fault system, each unit extends to 1000m in maximum thickness. Pelitic matrix of pebbly mudstone is black to dark-gray, and at the Kagamiyama district which is the type-locality of this formation, it is often phyllitic and partly is schistose easily peeling off. Sandstone blocks are gray to grayish-green generally fine and massive without distinct bedding. Chert commonly looks reddish-brown and partly dark-gray to grayish white. It generally has many joints, and is often schistose in some parts. Blocks of sandstone and chert are variable in size, ranging from a few centimeters to a few hundreds meters. Green rocks is a main constituent of exotic blocks in this formation, especially in the western part. They are mainly composed of basic rocks, such as diabase and basalt, and extending in maximum size to a few kilometers. The limestone exposure can be only found in the northeast of study area, as one to the north of the Tsubana tunnel, which is about 50m wide and approximately 200m long. This is crystalline limestone without any fossils. The other exotic blocks which are the high pressure-low temperature type are also frequently contained in this formation. However, these metamorphosed rocks will be stated in chapter III-4.

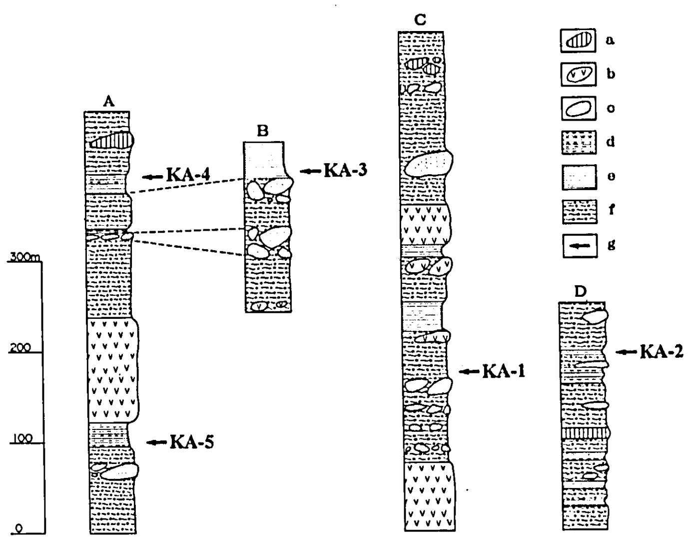


Fig. 6. Generalized lithological columnar sections of the Kagamiyama Formation
(A: Ichinose area, B: Koga area, C: Koshitsugu area, D: Nakamura area), showing the occurrencehorizons of the radiolarian fossils.
a: chert, b: green rocks, c: sandstone, d: acidic tuff, e: shale, f: pebbly mudstone, g: radiolarian occurrences

Table. 4. List of the radiolarian fossils from the Kagamiyama Formation

Species Loc.(KA-)	1	2	3	4	5	6
Albaillella sp. cf. *A. levis* ISHIGA, KITO and IMOTO					+	
Albaillella sp.					+	
Follicucullus sp. cf. *F. charveti* CARIDROIT and DE WEVER				+		
Follicucullus dilatatus RUDENKO					+	
Follicucullus sp. cf. *F. dilatatus* RUDENKO	+		+	+		+
Follicucullus sp. cf. *F. porrectus* RUDENKO	+		+	+		
Follicucullus(?) *scholasticus* ORMISTON and BABCOCK	+					
Follicucullus sp.		+	+	+	+	+
Follicucullus(?) sp.		+				
Entactinosphaera(?) sp.					+	
Latentibifistula sp.			+		+	
Latentibifistula(?) sp.					+	
Nazarovella gracilis DE WEVER and CARIDROIT			+			
Nazarovella sp.					+	

[Geologic Structure]

The Kagamiyama Formation has strikes of N45 to 60E and dips of 60 to 80N or S, which are locally extremely variable. This formation is in a fault contact with the Mamihara Formation on the north, bounded by the fault with the Kuraoka Igneous Rocks, the Murono Formation and the Yurugidake Formation on the south. The formation partly is overlain by Lower Cretaceous system. High angled faults with NE-SW and nearly NW-SE directions develop in the formation. Along these faults serpentinite is often intercalated. The field observation shows that the northern boundary fault with the Mamihara Formation dips 60 to 70N.

[Occurrence of fossils]

The radiolarian fossils which are available for age determination are obtained from six localities shown in Fig. 5, Locs. KA-1 to KA-6. Fig. 6 shows the lithofacies of each locality in this area. Because the development of the high angled fault, prevents precise comparison among the units, no tectonic deformation, such as overturning, was considered for the drawing of the lithological columnar sections. The lithofacies of each locality is as follows; Loc. KA-1 is black shale (matrix of pebbly mudstone), Locs. KA-2, 3 and 6 are shale., Locs. KA-4 and 5 are acidic tuff. Table 4 shows a list of radiolarian fossils from each locality and representative ones are figured on Plate 1.

III-2-3. Neritic sedimentary facies

Neritic sedimentary facies of Kuraoka district is composed of the Triassic (Murono Formation), Jurassic (Kanmuridake and Oishi Formations), and Cretaceous (Togawa, Tsubana, Gokase, Shibanomoto, Kubo, and Takahata Formations). Figs. 7 and 8 show the stratotypes and fossil localities of these formations, and Fig. 9 shows localities analysed on gravel composition.

• Murono Formation

[Previous studies]

The Murono Formation named by Teraoka (1970) is typically located in Murono, Gokasecho. The main components of the formation are thickly alternating beds of sandstone and mudstone, bearing the Late Triassic bivalves, such as *Monotis (Entomonotis) ochotica ochotica, M. (E.) ochotica densistriata.*

[Distribution]

This formation lies in small lenses along the boundary fault between the Cretaceous system and the Permian Kagamiyama Formation to the north of Mt. Gionyama, and is mainly distributed in the area from southwest of Tsubana tunnel to south of Kasabe tunnel.

[Lithofacies]

The Murono Formation consists of thickly alternating beds of sandstone and shale, changing laterally in the east into turbidite appearing an alternation of thin beds of sandstone and mudstone distributed in southwest of Tsubana tunnel (G in Fig. 8). Sandstone is chiefly fine to coarse in grain-size, and much of it appears greenish-gray. This formation is about 350m thick (E in Fig. 10). Fig. 11 shows the route map in south of Kasabe tunnel.

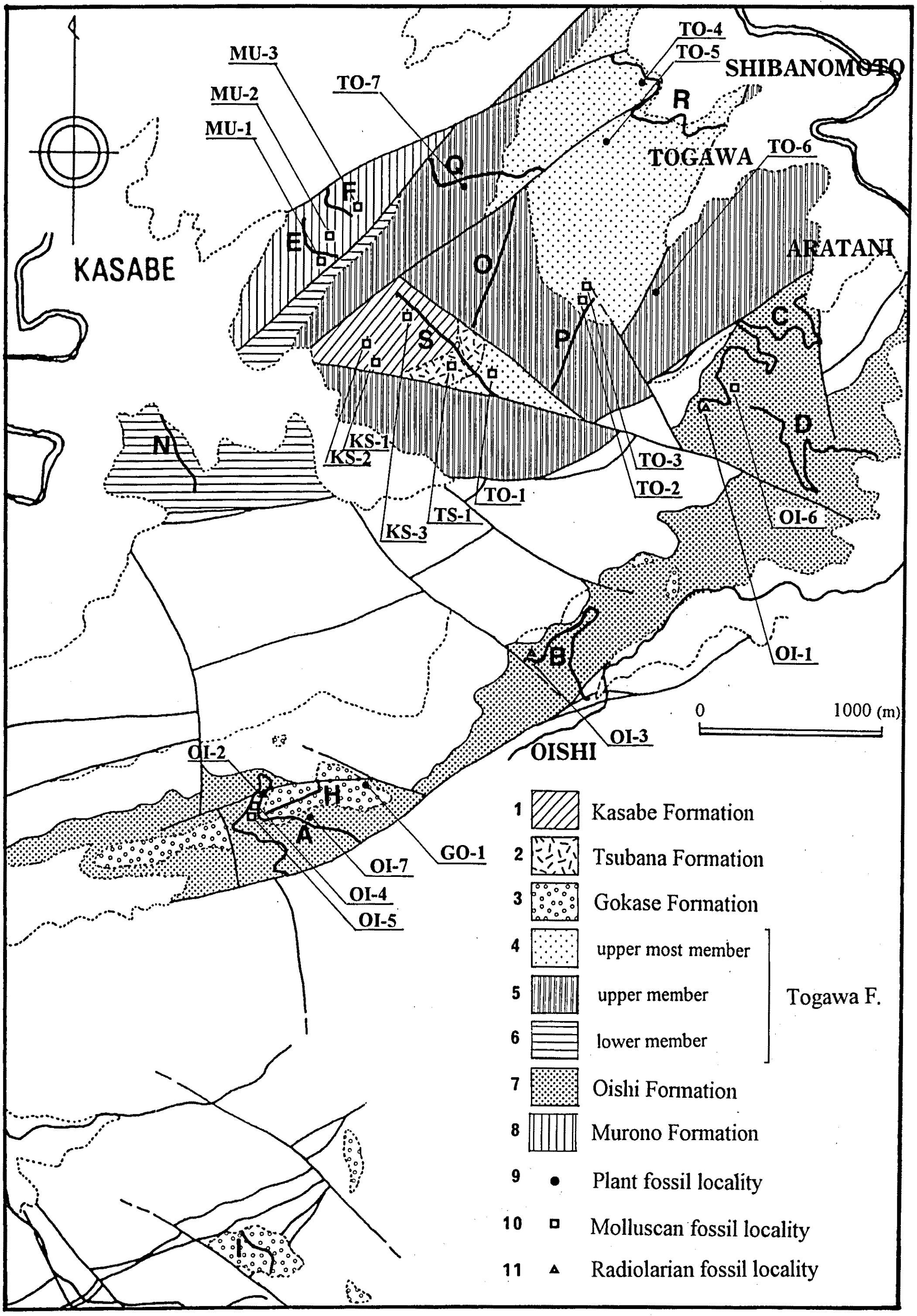


Fig. 7. Map showing the localities of stratotypes and fossils in the Gionyama area.

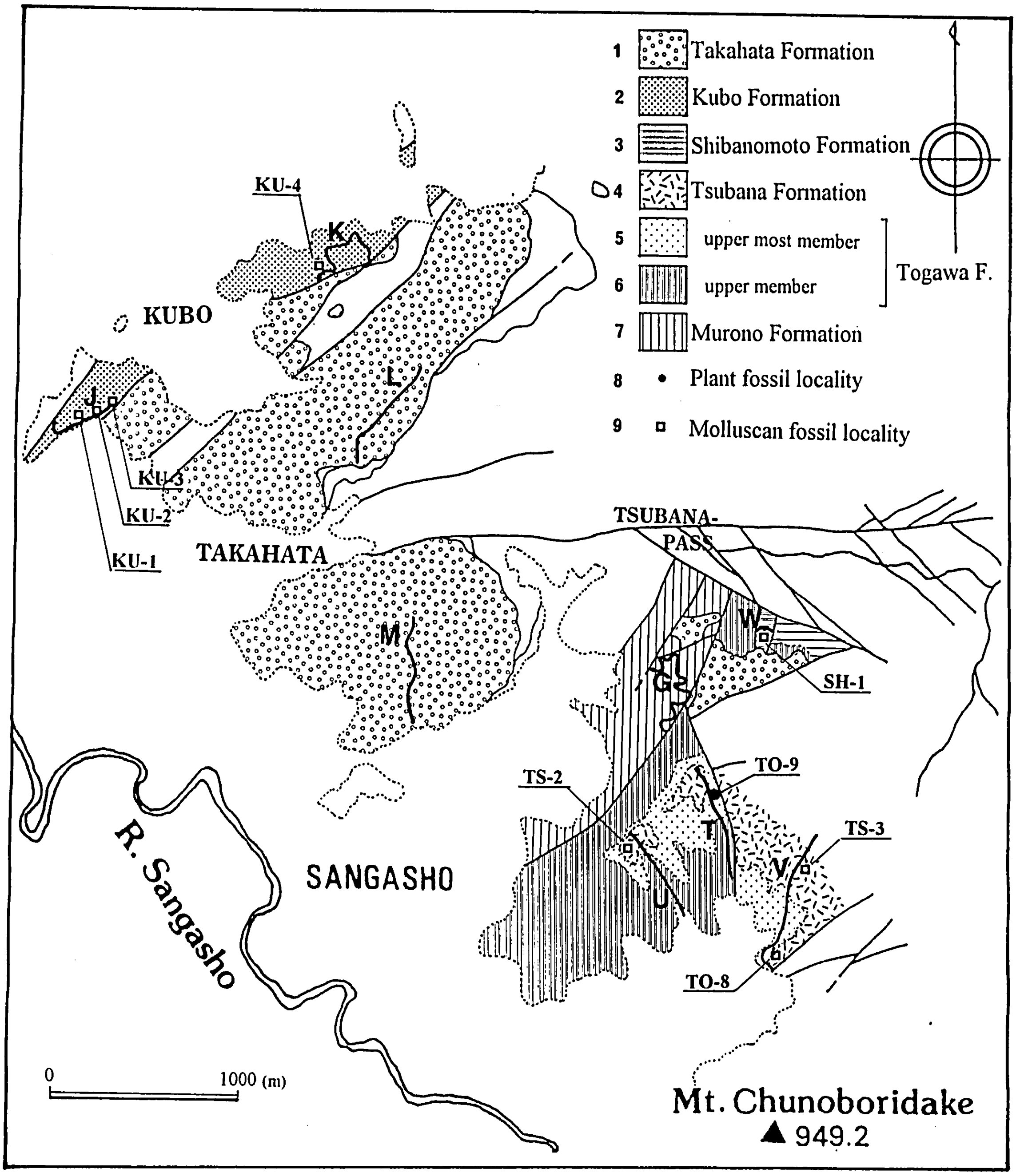


Fig. 8. Map showing the localities of stratotypes and fossils in the Snagasyo area.

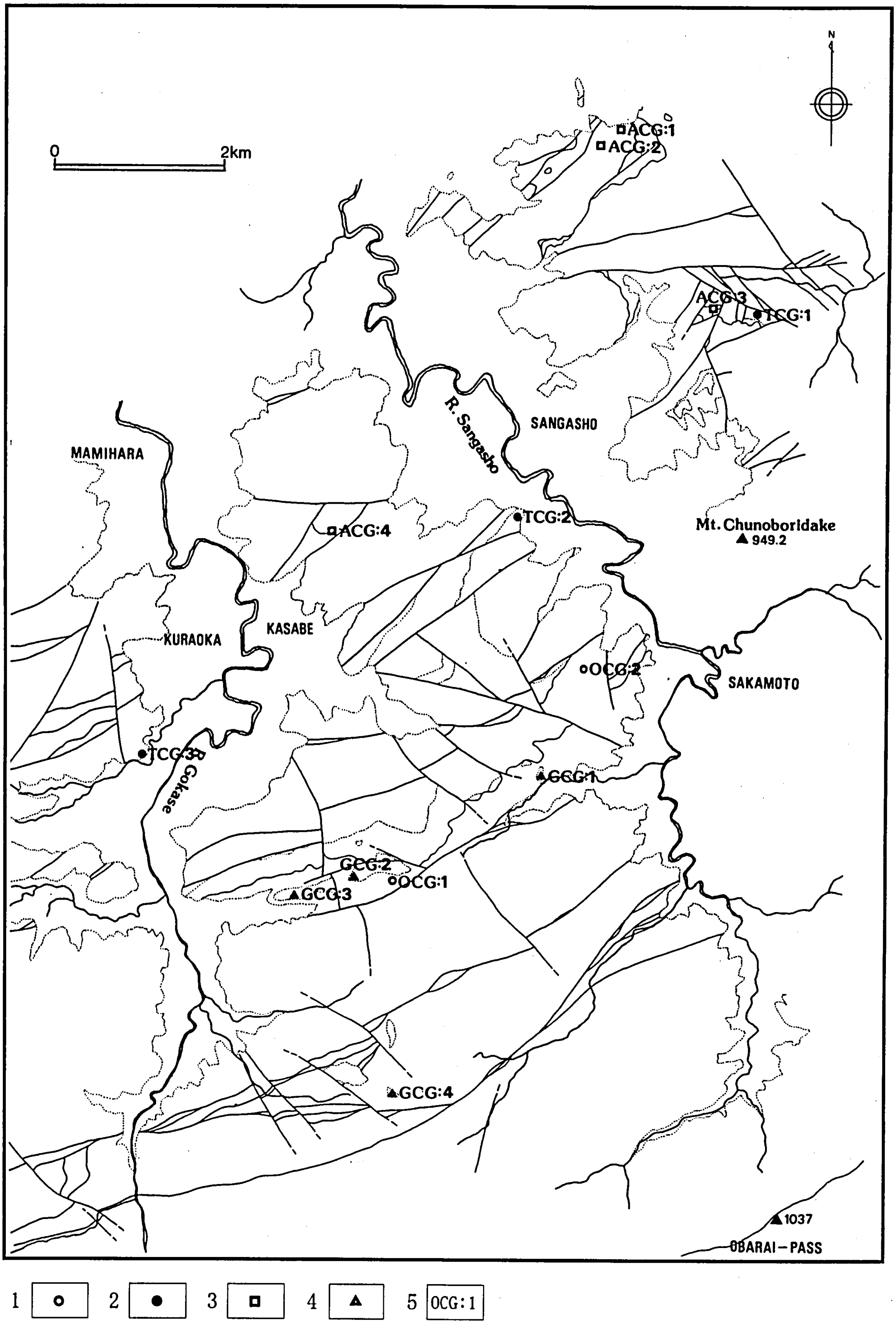


Fig. 9. Sampling localities for gravel composition analysis.
1: Oishi Formation, 2: Togawa Formation, 3: Gokase Formation, 4: Takahata Formation, 5: locality No.

[Geologic structure]

This formation trends E-W to WSW and, steeply dips to the north or south. It is bounded by high angled faults with the adjacent formations, and is thrust over by the small lens of the Kubono Formation to the south of Tsubana tunnel.

[Occurrence of fossils]

In this formation, bivalves occur in greenish-gray, medium to coarse-grained sandstone distributed in the south of Kasabe tunnel. Fig. 7 shows three localities (Locs. MU-1 to 3) of the obtained fossils. *Monotis (Entomonotis) ochotica densistriata* (Teller) is found in Locs. MU-1 and 2, and *Monotis (Entomonotis) ochotica ochotica* (Keyserling) occurs in Loc. MU-3.

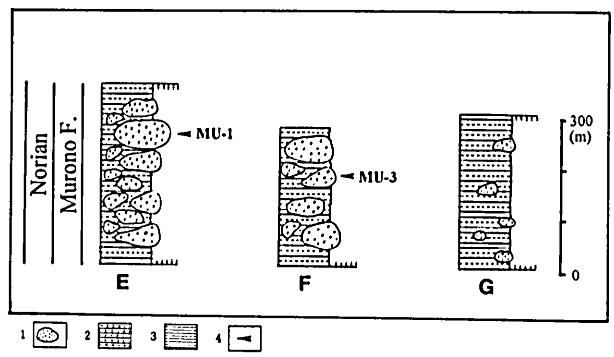


Fig. 10. Stratigraphic columnar section of the Murono Formation, showing the horizons of occurrences of the molluscan fossils.
1: sandstone, 2: alternation of sandstone and shale, 3: shale, 4: molluscan occurrence

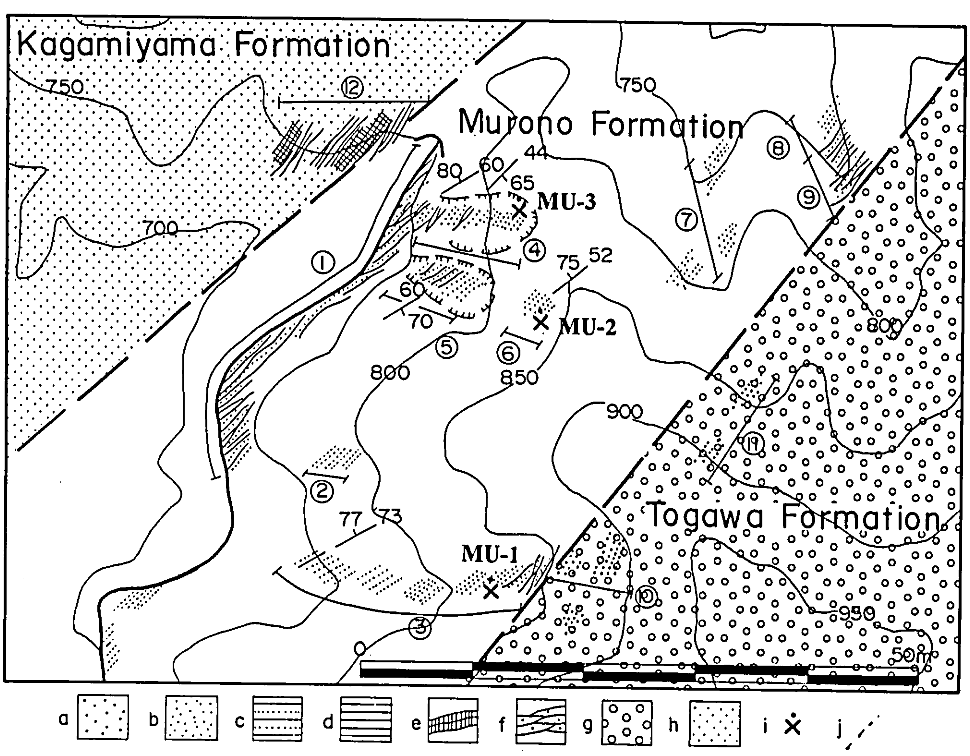


Fig. 11. Route map south of Kasabe tunnel
a: conglomerate, b: sandstone, c: alternation of sandstone and shale, d: shale, e: serpentinite, f: fracture zone, g: Togawa Formation, h: Kagamiyama Formation, i: fossil Loc., j: fault

• Kanmuridake Formation

[Previous studies]

The Kanmuridake Formation, which is newly named in present paper, corresponds to the southern margin of the Middle Permian Kagamiyama Formation defined by Kanbe (1957).

[Distribution]

It lies in a small body extending 300m in N-S and 600m in E-W at the northern side of Mt. Kanmuridake in western study area.

[Lithofacies]

It is composed of sandstone, sandy shale and shale, which frequently form alternating beds. The most of sandstone is solid, massive and grayish-yellow to grayish-green. Its grain size ranges from fine to medium (and fine-grained one is dominant). Shale looks black to gray and is extremely weathered along topographic ridges, and the one alternating with sandstone exhibits distinct bedding. This formation has a more than 150m maximum thickness.

[Geologic Structure]

This formation strikes N50 to 60E and shows monoclinic dipping to north 40 to 50, but the dips along the faults are variable. The northern and southern limits of this formation are the vertical faults trending NE-SW and bounded with the Kagamiyama Formation and the Kuraoka Igneous Rocks, respectively. Serpentinite about 50m wide is intercalated along the southern boundary fault.

[Occurrence of fossils]

Megafossils have not been found from this formation so far. Radiolarian fossils available for age determination were obtained from sandy shale at two localities, Locs. KN-1 and 2 (Fig. 5). The lithological columnar section is shown Fig. 12. The radiolarian species are listed in Table 5, and representative ones are figured on Plate 3.

Table. 5. List of radiolarian fossils from the Kanmuridake Formation.

Species Loc.(KN-)	1	2
***Archicapsa* sp. cf. *A. pachyderma* Tan Sin Hok**	+	
***Bagotum*(?) sp. cf. *B. helmetense* Pessagno and Whalen**	+	
***Bagotum* sp**		+
***Canoptum* sp. cf. *C. merum* Pessagno and Whalen**	+	+
***Canoptum* sp.**	+	+
***Natoba* sp.**		+
***Parvicingula*(?) sp.**	+	
***Stichocapsa* sp.**	+	
***Archaeospongoprunum* sp.**	+	

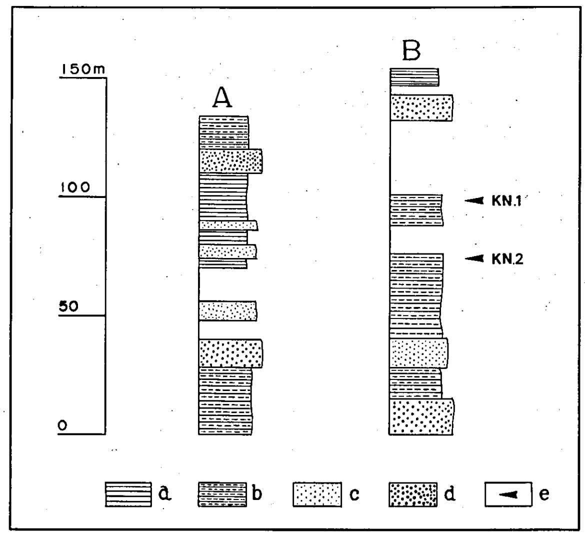


Fig. 12. Generalized lithological columnar sections of the Kanmuridake Formation
(A: western area, B: eastern area), showing the occurrence - horizons of the radiolarian fossils.
a: shale, b: sandy-shale, c: fine sandstone, d: coase sandstone

• Oishi Formation

[Previous studies]

Type locality of the Oishi Formation, named by Saito and Kanbe (1954), is Oishi district, Gokasecho. It is chiefly composed of sandstone and alternating beds of sandstone and mudstone, intercalating thick conglomerate in the middle part. It is unknown in age (Saito and Kanbe, 1954), however, Matsumoto and Hirata (1970) have obtained ammonoids, *Aulaconstephanus* sp., and suggested the possible age of Upper Jurassic. Murata (1992), furthermore, have reported the occurrence of the radiolarians with *Pseudodictyomitra carpatica* in mudstone, suggesting in the age of Kimmeridgian to Tithonian.

[Distribution]

This formation lies from Oishinouchi, Gokasecho through Oishi to east of Sugigagoe, Takachihocho, and the distributing area is 12km in length and 200 to 900m in width.

[Lithofacies]

The formation mainly consists of alternating beds of sandstone and mudstone as turbidite, intercalating thick

-bedded sandstone, shale, and slump breccia. The turbidite contains exotic blocks of sandstone, granite, and acidic tuff, especially in the lower part (near Oishiburaku, B in Fig. 14) includes blocks of the Kuraoka Igneous Rocks and the bluish-green acidic tuff from the Gionyama Formation, ranging in size from a few meters to a hundreds meters. Besides, some of the exotic blocks of sandstone are possibly derived from the Upper Permian Kuma Formation. The detailed description of this sandstone blocks will be given in Chapter IV.

Sandstone, most of which is of greywacke, is greenish-gray to gray, and has a graded bedding. Shale forming turbidite intercalates thin beds of acidic tuff, locally including many fragments of plant fossils (Loc. OH-8). Slump breccia (5 to 10m thick) generally contains sub-rounded to rounded pebble to cobble, representing relatively well-sorting.

Gravel composition (average ratio on the basis of the number) show as follows; chert is 47%, sandstone is 26%, acidic tuff is 13%, and rhyolitic sandstone, green rocks and slate are 4 % (Fig. 14). Its matrix is shale to sandy-shale, and about 550m in a maximum thickness (C in Fig. 14). Figs. 15 and 16 show route maps at Oishigoe and Aratani districts, which are the stratotypes of the Oishi Formation. Saito and Kanbe (1954) have described thick conglomerate middle of this formation (outcrop (3) Fig. 15). However, the trace of conglomerate (outcrop (13) (15)(18)(19), Fig. 15) and the analysis of gravel composition indicate that this conglomerate unconformably covers the Oishi Formation, and that it is distinguished from the Oishi Formation and is newly named the Gokase Formation in this paper.

LOCALITI No.	LITHOLOGY OF GRAVEL (%)							
	GRANITE	RHYOLITE	CHERT	AC-TUFF	SANDSTONE	SHALE	GREEN ROCK	OTHERS
OCG-1	0	6	48	11	21	3	8	3
OCG-2	0	2	45	14	31	5	0	3
AVERAGE	0	4	47	13	26	4	4	3

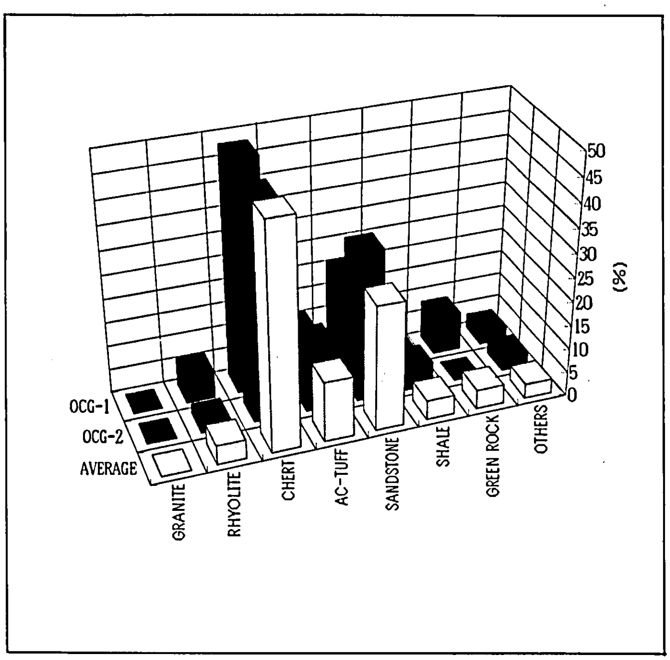


Fig. 13. Gravel composition of the conglomerate in the Oishi Formation.

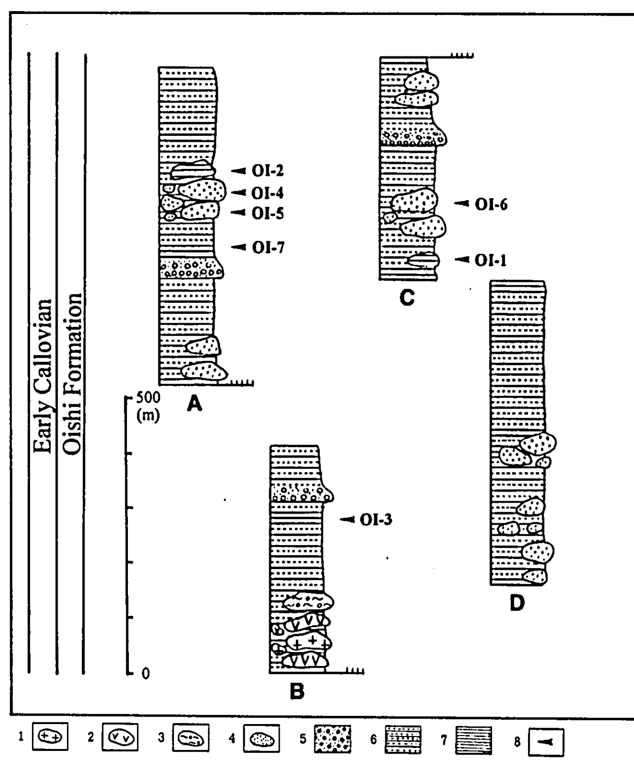


Fig. 14. Stratigraphic columnar section of the Oishi Formation, showing the occurrences and horizons of fossils.
1: granitic rock, 2: acidic tuff, 3: pebbly mudstone, 4: sandstone, 5: conglomerate, 6: alternation of sandstone and shale, 7: shale, 8: fossil occurrence

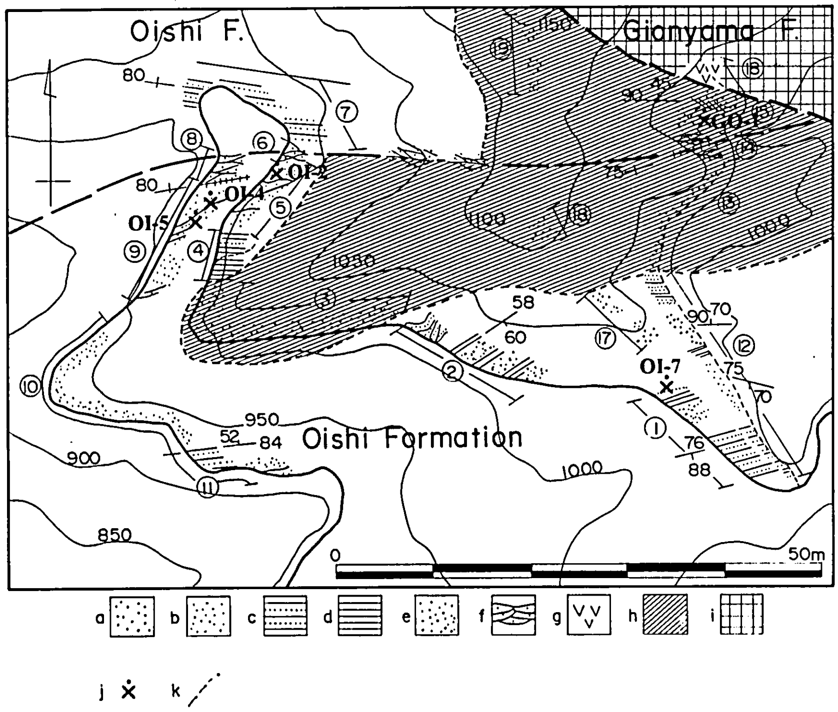


Fig. 15. Route map of Oishigoe district.
a: conglomerate, b: sandstone, c: alternation of sandstone and shale, d: shale, e: slump breccia, f: fracture zone, g: acidic tuff, h: Gionyama Formation, i: Gokase Formation, j: fossil Loc., k: fault

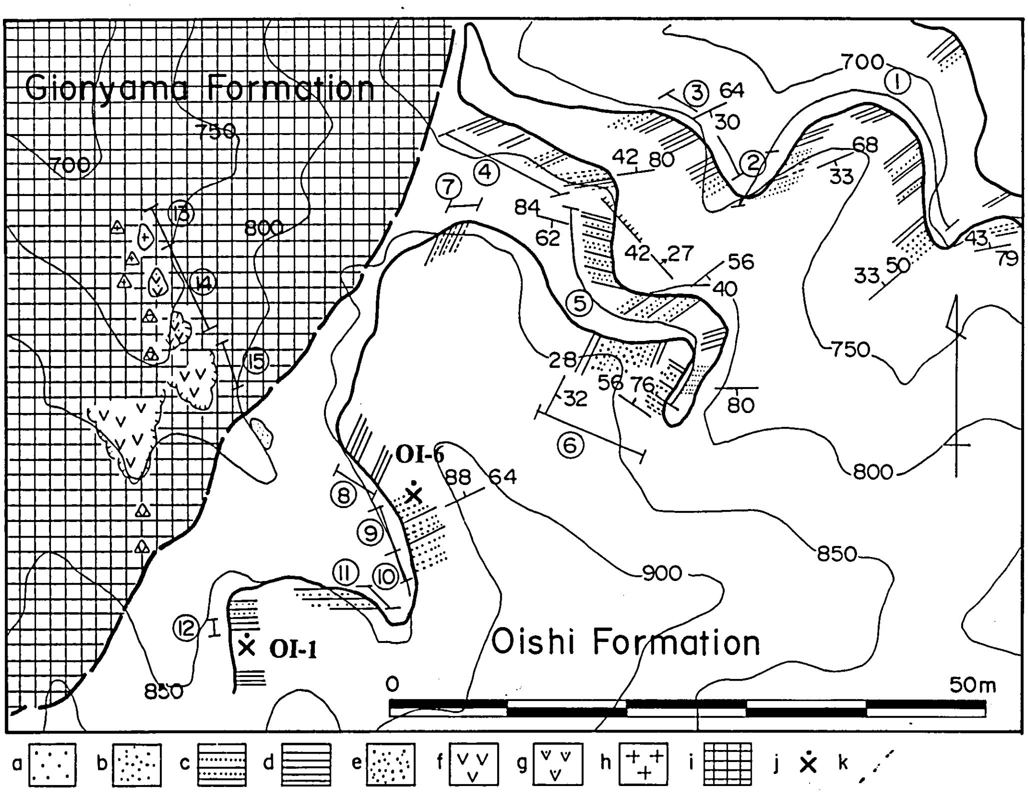


Fig. 16. Route map of Aratani district.
a: conglomerate, b: sandstone, c: alternation of sandstone and shale, d: shale, e: slump breccia, f: acidic tuff, g: rhyolite sandstone, h: granitic rock, i: Gionyama Formation, j: fossil Loc., k: fault

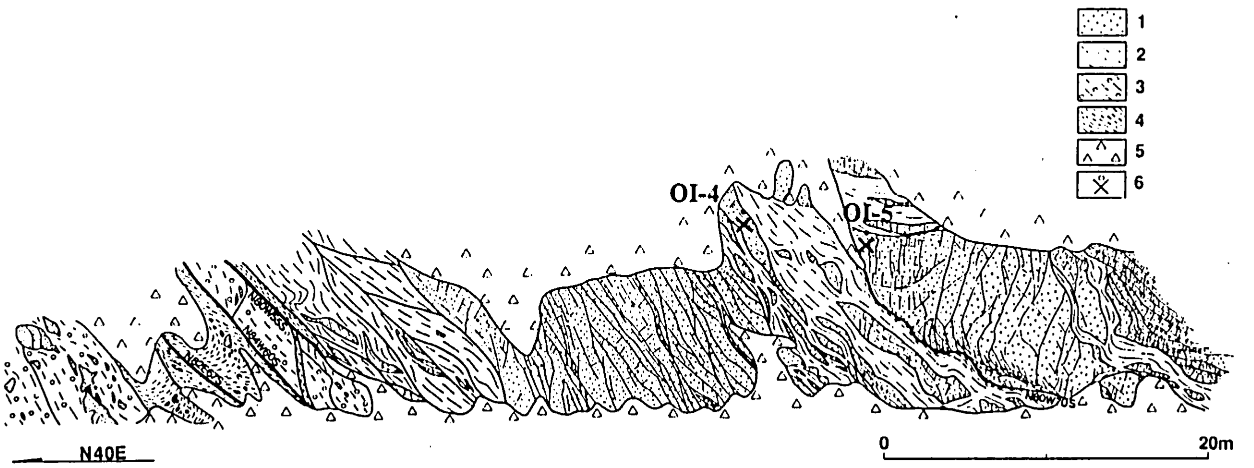


Fig. 17. Outcrop-sketch of the Oishi Formation (near Locs. OI-4 and 5).
1: sandstone, 2: shale, 3: pebbly mudstone, 4: cataclastic mudstone, 5: talus, 6: fossil Loc.

[Geologic structure]

This formation strikes ENE-WSW, and steeply dips to north or south. Turbidite, a main constituent of this formation, is intensely disturbed, and partly overturning (outcrop ② Fig. 15). Although the sandstone of this formation yields molluscan fossils stated, it appears as exotic blocks. Fig.17 shows a sketch of the Oishi Formation exposed Oishigoe district (around Locs. OI-4 and 5). The locality is situated near the NW fault dipping to the south, accompanying with many small faults with dips of 60 to 70S. Sandstone with fossils is included as irregular blocks in shale, and its distribution is tectonically continuous. The formation is bounded by a reverse fault dipping 35 to 40N with the Silurian to Devonian Gionyama Formation on the north, and by a high angled fault trending EW to NE-SW with the Cretaceous Yurugidake Formation on the south. And at the boundary without distribution of the Gionyama Formation, this formation is separated by a high angled fault trending NE-SW with the Cretaceous Togawa Formation. Moreover, the formation is overlain by the Cretaceous Gokase Formation in places.

[Occurrence of fossils]

Molluscan fossils occur from sandstone blocks of this formation at three localities, Locs. OI-4 to 6, as shown in Fig. 7. Gray massive fine sandstone (Loc. OI-4) contains *Tosapecten suzuki* (Kobayashi), *Mytilus (Facimytilus)* sp. cf. *M. (F.) nasai* (Kobayashi and Ichikawa), *Chlamys* sp. cf. *C. moisisovicsi* Kobayashi and Ichikawa, and the one (Loc. OI -5) yields a fragment of an unidentified ammonoid and a coquina of brachiopods. Representative molluscan fossils are figured on Plate 48. Radiolarian fossils available for age determination are found at three localities (Locs. OI-1 to 3) as shown in Fig. 5 and 7. Lithofacies of each locality is as follows; Loc. OI-1 is acidic tuff, and Locs. OI-2 and 3 are black shale. The radiolarian fossils from each locality are listed in Table 6.

Table 6. List of radiolarian fossils from the Oishi Formation.

Species Loc.(OI-)	1	2	3
Follicucullus(?) sp.	+		
Canoptum sp.		+	
Triassocampe sp. cf. *T. nova* YAO		+	
Triassocampe sp.		+	
Archaeodictyomitra sp.			+
Hsuum sp.			+
Tricolocapsa conexa MATSUOKA			+
Tricolocapsa tetragona MATSUOKA			+

• Togawa Formation

[Previous studies]

Cretaceous system at Kuraoka district is mainly distributed with a fault contact in the northern side of the Gionyama lenticular body. Saito and Kanbe (1954) divided into two and named the Shibanomoto and Takahata Formations in ascending order. Teraoka (1970) redefined the Shibanomoto Formation, and subdivided into the Togawa, Kasabe, and Shibanomoto Formations in ascending order, and newly settled the Tabaru Formation upon the Takahata Formation, and the Takayasan Formation as a correlative of the Togawa to Shibanomoto Formation. In this paper, the author have reexamined on the basis of lithofacies, stratigraphy and fossil evidences, and newly subdivides into the Tonegoyama Formation, Kasabe, and Shibanomoto Formations, and settles the Gokase Formation as a correlative of the Kasabe Formation and the Kubo Formation underlain by the Takahata Formation to the north of these formations.

[Distribution]

It widely occurs on northern side of the Gionyama lenticular body, and is found in small body in a fault contacts with the adjacent formations at left bank side of the Gokasegawa, Kuraoka district.

[Lithofacies and geologic structure]

Judging from lithostratigraphy and fossils, this formation is divided into the lower, upper and uppermost members. These members have ENE-WSW axises, forming semi-basin structure with a slightly eastward dipping plunge. The lower member mainly appears in the west, and the upper and uppermost are widely found in the middle to eastern distributing area.

The total thickness of the formation extends to 1350m. Stratigraphic columnar sections of the Togawa, Tsubana, Kasabe, and Shibanomoto Formations in ascending order are shown in Fig. 18.

—**lower member**—

Many of the lower limits of this formation are unknown, overlying by the Aso pyroclastic flow deposits, but the other limits are bounded by faults with basements rock. This member with an about 200m thickness is made up of thickly bedded conglomerate, intercalating thin beds of coarse to medium-grained sandstone and sandy shale, in places. A part of the conglomerate exhibits red in color. Gravel of the conglomerate is relatively well-sorted, subround to round, and cobble to boulder in size. Among the gravel compositions of the Togawa

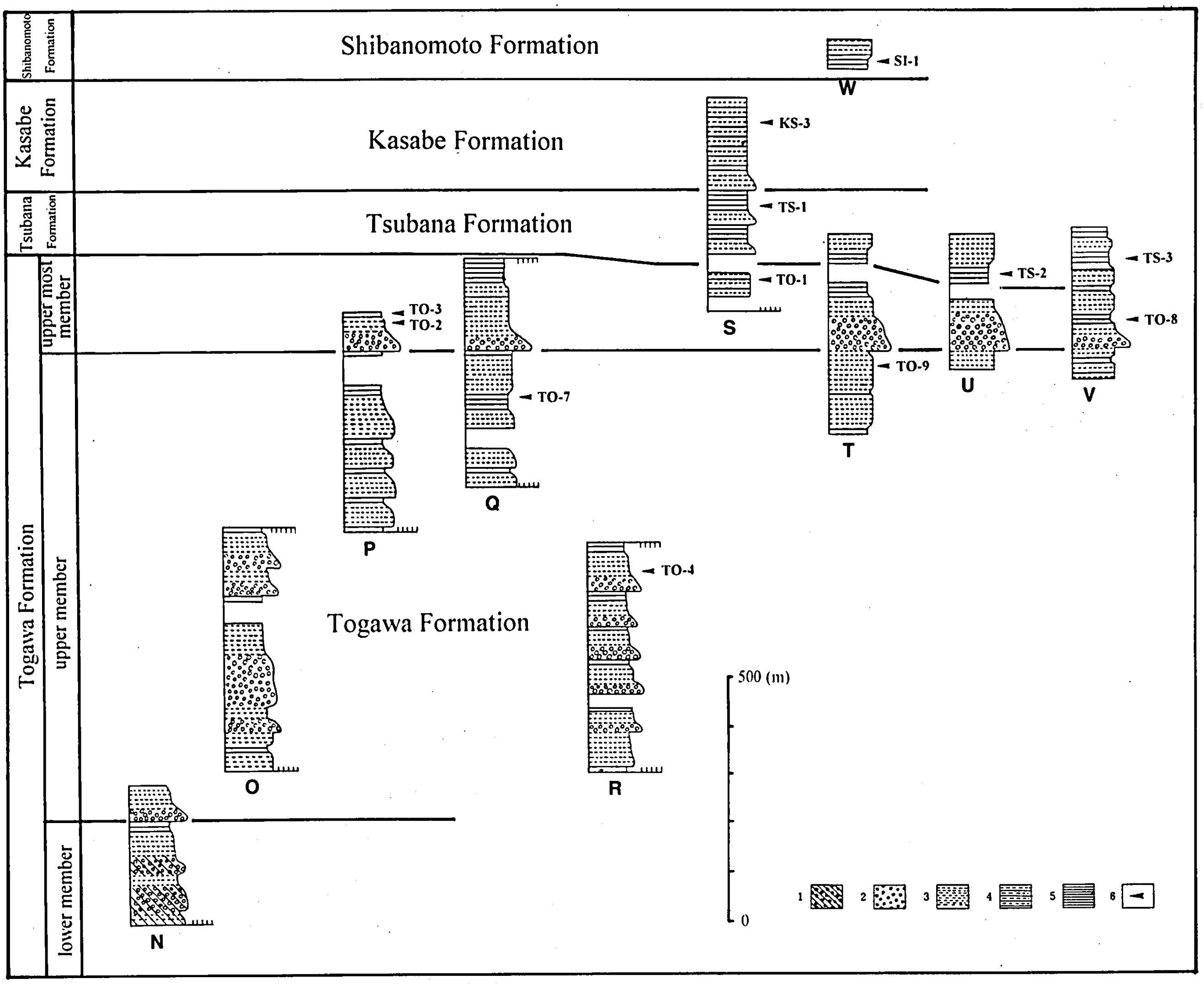


Fig. 18. Stratigraphic columnar sections of the Togawa, Tsubana, Kasabe and Shibanomoto Formations, showing the occurrences and horizons of fossils.

1: red conglomerate, 2: conglomerate, 3: sandstone, 4: alternation of sandstone and shale, 5: shale, 6: fossil occurrence

Formation shown in Fig. 19, data of Locs. TCG-1 and 3 belong to the lower member. Lithology of gravel is chiefly composed of chert (49% at Loc. TCG-1) and sandstone with a maximum gravel size of about 30cm. Intercalated sandstone, which ranges in thickness from a few centimeters to 50 centimeters, laterally decreaces its thickness and changes into sandy shale. As a whole of the lower member, it has a trend to grade upward into sandstone and shale, decreasing size of gravel.

LOCALITI No.	LITHOLOGY OF GRAVEL (%)							
	GRANITE	RHYOLITE	CHERT	AC-TUFF	SANDSTONE	SHALE	GREEN ROCK	OTHERS
TCG-1	0	0	49	4	31	12	2	2
TCG-2	0	0	21	4	68	7	0	0
TCG-3	2	3	25	11	37	7	0	15
AVERAGE	1	1	32	6	45	9	1	6

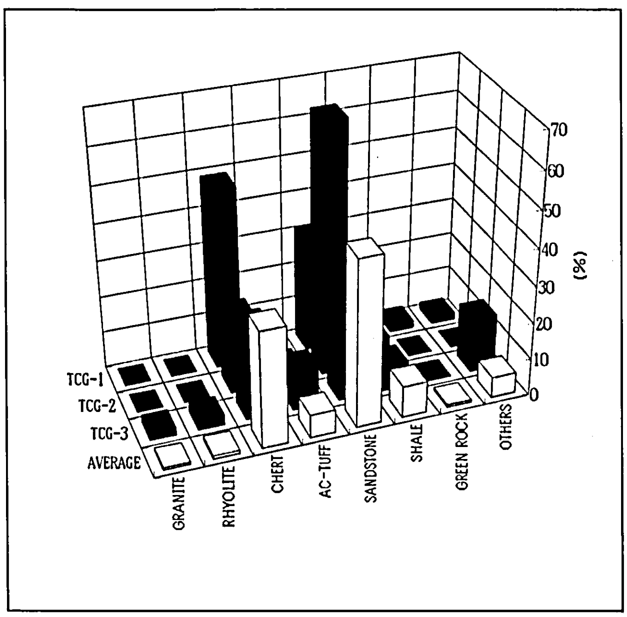


Fig. 19. Gravel composition of the conglomerate in the Togawa Formation.

— **upper member** —

The upper member of about 920m thick, overlain by the uppermost member, is bounded by high angled faults with basements rock, and conformably overlies the lower member. Fig. 20 shows distribution of the upper member at Kasabe district.

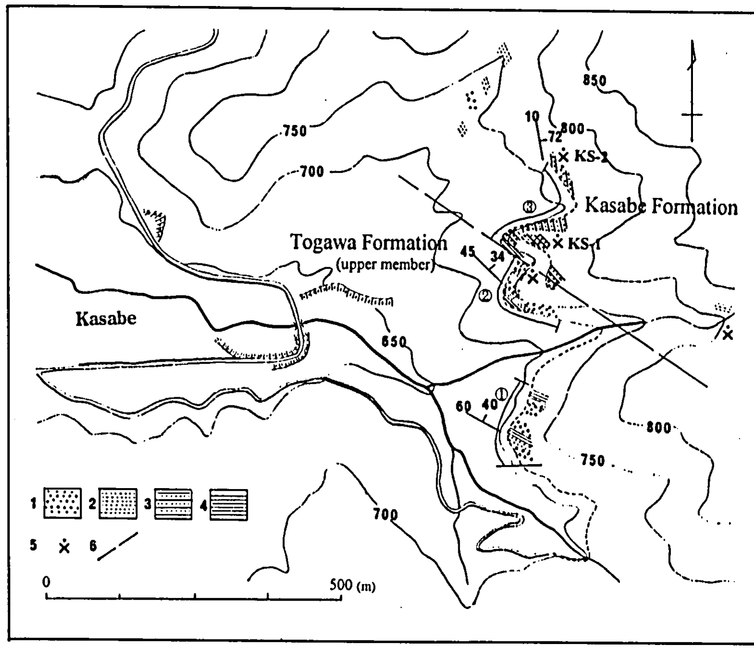


Fig. 20. Route map of Kasabe district.
1: conglomerate, 2: sandstone, 3: alternation of sandstone and shale, 4: shale 5: fossil Loc., 6: fault

This member is formed by cyclothems of conglomerate, sandstone and shale ranging in thickness from 30 to 70m (Outcrops ① and ②, Fig. 20). Gravel is sub-round to round, and granule to pebble in size. Lithology of gravel is overwhelmingly dominated by chert except for minor sandstone.

— **uppermost member** —

The uppermost member with a 230m thickness is conformably overlain by the Tsubana Formation. Conglomerate at basal part of this member is sub-round to round, granule to pebble, and relatively well-sorted. Lithology of gravel is dominated by sandstone and chert (TCG-2, Fig. 19).

[Occurrence of fossils]

In the upper and uppermost of the Togawa Formation, plant fossils such as *Cladophlebis* sp. are found at five localities, Locs. TO-4, 5, 6, 7 and 9 shown in Figs 7 and 8. And molluscan fossils are obtained from four localities (Locs. TO-1,2,3 and 8). Lithology of each locality is shown as follows; Loc. TO-1 is fine sandstone, and Locs. TO-2, 3 and 8 are shale. The list of fossils from each locality is shown in Table 7.

Table 7. List of molluscan fossils from the Togawa Formation.

Species Loc.(TO-)	1	2	3	8
Isodomella shiroiensis (YABE and NAGAO)		+	+	
Tetoria sanchuensis (YABE and NAGAO)	+		+	
Costocyrena otsukai obsoleta TASHIRO	+			
Costocyrena otsukai otsukai (YABE and NAGAO)		+	+	
Hayamina naumanni (NUEMAYR)				+
Hayamina minor TASHIRO and KOZAI		+		
Myopholas sp. cf. *M. semicostata* (AGASSIZ)			+	
Pterinella shinoharai HAYAMI				+
Eonavicula shinanoensis (YABE and NAGAO)			+	
Caestocorbula sp.			+	
Pleuromya (?) sp.			+	
gastropoda gen. et sp. indet A	+			+
gastropoda gen. et sp. indet B	+		+	
gastropoda gen. et sp. indet C	+			

• Tsubana Formation

[Previous studies]

The Tsubana Formation is newly named in this paper, and is a correlative of the Lower Cretaceous Kasabe Formation and a part of the Shibanomoto Formation of Teraoka (1970).

[Distribution]

This formation is distributed in a limited area to 1.2km NNE from the ridge of Mt. Gionyama and also on the southern slope of the ridge about 1km east of Murono to the north of Mt. Chunoboridake.

[Lithofacies]

The formation composed of dark gray shale with thin interbeds of fine grained sandstone in lower part. The upper thick-bedded sandy shale and shale are 120m thick and the lithofacies laterally little changes. The total thickness of this formation is estimated to be about 230m (S.U.V. in Fig. 29).

[Geologic structure]

The formation conformably overlies the Togawa Formation in places. In a small distributing area to the north of Mt. Gionyama (Fig. 7), it is interspread between two faults of NW-SW and WNW-ESE. Here, it nearly strikes NE-SW, and dips N 40 to 50. In a relatively large exposed area to the north of Mt. Chunoboridake (Fig. 8), it forms a syncline with a NE-SW axis plunging N or S with 30 to 60 degree.

[Occurrence of fossils]

Dark gray shale of this formation yields marine molluscan fossils containing pelecypod, gastropods and echinoids from three localities (Locs. TS-1 to 3) shown in Figs. 7 and 8. Table 8 shows the list of important molluscan fossils from each locality.

Table. 8. List of molluscan fossils from the Tsubana Formation.

Species Loc.(TS-)	1	2	3
Nanonavis yokoyamai (YABE and NAGAO)	+	+	
Periploma (?) *monobeensis* TASHIRO and KOZAI		+	
Pholadomya sp.	+		
Shasticrioceras sp.	+		
Heteraster sp.			+
gastropod gen. et sp. indet D	+	+	

• Kasabe Formation

[Previous studies]

The Kasabe Formation, named by Teraoka (1970), is typically located in Kasabe district, Gokasecho, that is in the middle of the distributing area of the Shibanomoto Formation of Saito and Kanbe (1954). It is composed of thick conglomerate in the lower part. And in the upper part, it consists of sandstone, shale and alternating beds, partly containing conglomerate. This formation is corresponded to the Hachiryuzan Formation of Yatsushiro district because of the common occurrence of marine bivalves and gastropods in the upper shale.

[Distribution]

The formation crops out in a very limited area near the ridge about 1.5km north-northeast of Mt. Gionyama.

[Lithofacies]

This formation is characterized by regularly alternating thin beds of sandstone and shale (outcrop ③ and Fig. 20). Each of the sandstone layers in the alternating beds ranges in thickness from a few centimeters to 30cm, showing a graded bedding and parallel lamination. Small-scale slump structure are observed at several horizons. The maximum thickness of this formation is more than 200m (S in Fig. 18).

[Geologic structure]

This formation conformably overlies the Tsubana Formation. The formation as well as the subordinating Tsubana Formation, have a NE-SW axis, and forms a small semi-basin plunging to NW. It is bounded by faults trending NW-SE and WNW-ESE with the adjoining Togawa Formation.

[Occurrence of fossils]

Sandstone of this formation bears well-preserved bivalves and gastropods from three localities (Locs. KS-1 to 3) shown in Figs. 7 and 20. Important molluscan fossils from each locality are listed in Table 9.

Table 9. List of molluscan fossils fromthe Kasabe Formation.

Species Loc.(KS-)	1	2	3
Nuculopsis (Palaeonucula) ishidoensis (YABE and NAGAO)	+		
Mesosaccella (?) sanchuensis (YABE and NAGAO)	+		+
Acesta kasabensis TASHIRO and TANAKA	+		
Gervillia (Gervillia) forbesiana d' ORBIGNY	+	+	
Gervillaria haradae (YOKOYAMA)	+		+
Pterotrigonia pocillformis (YOKOYAMA)	+	+	+
Myrtea (?) *monobeana* TASHIRO and KOZAI	+		
Granocardium ishidoense (YABE and NAGAO)	+		
Astarte (Astarte) subsenecta (YABE and NAGAO)	+	+	+
Astarte (Nicaniella) costata YABE and NAGAO	+		
Yabea densecrenulata TASHIRO and KOZAI	+		
Agapella hyugaensis TASHIRO and TANAKA	+		
Venilicardia japonica TASHIRO and TANAKA	+		
Goshoraia minor TASHIRO and KOZAI	+		
Linearia sp.	+		
Rasatrix (Vectorbis) japonica TASHIRO and KOZAI		+	
Costocyrena minima OHTA	+		
Caestcorbula monobensis (KOZAI)	+		
gastropoda gen. et sp. indet E	+		
gastropoda gen. et sp. indet F	+		
gastropoda gen. et sp. indet G	+		

• Gokase Formation

[Previous studies]

The Gokase Formation, named in this paper, corresponds to thick conglomerate in the middle part of the Oishi Formation of Saito and Kanbe (1954).

[Distribution]

This formation is distributed in an area about 800m south of Mt. Gionyama, in Oishi district east of Mt. Gionyama; and also in small area near the ridge about 1.5km southwest of Mt. Yurugidake(Fig. 7).

[Lithofacies]

The formation mainly consists of conglomerate grading into sandstone and shale (Fig. 21). Poor-sorted gravel ranges from pebble to boulder (including a granite 50cm in maximum size) in size. 54% of the gravel is originated from the Kurosegawa Rocks 54% in average (granitic rocks, 20%; acidic tuff, 23%; rhyolitic sandstone, 11%) and among other 45%; chert, 26%; green rocks, 2%; shale, 1% (Fig. 22). Sandstone ranging in thickness a few centimeters to meters laterally changes into sandy shale. The formation appears to be about 220m thick (K in Fig. 21).

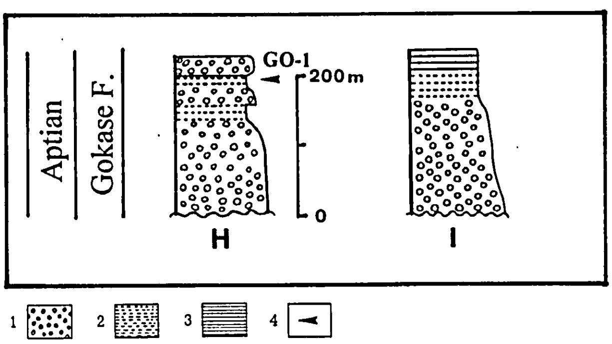


Fig. 21. Stratigraphic columnar section of the Gokase Formation, showing the occurrences and horizons of fossils.
1: conglomerate, 2: sandstone, 3: shale, 4: plant fossil occurrence

[Geologic structure]

This formation overlies the Gionyama, Yurugidake and Oishi Formation in an angular unconformity. Strikes and dips are N15E 29E at some measurable points but unknown in detail.

[Occurrence of fossils]

Cladophlebis sp. is found in bluish-gray fine sandstone (Loc. GO-1) shown in Fig. 7.

LOCALITI No.	LITHOLOGY OF GRAVEL (%)							
	GRANITE	RHYOLITE	CHERT	AC-TUFF	SANDSTONE	SHALE	GREEN ROCK	OTHERS
GCG-1	8	0	31	41	17	0	2	1
GCG-2	18	13	30	32	4	0	0	3
GCG-3	30	22	16	11	17	0	0	4
GCG-4	24	8	28	7	22	3	4	4
AVERAGE	20	11	26	23	15	1	2	3

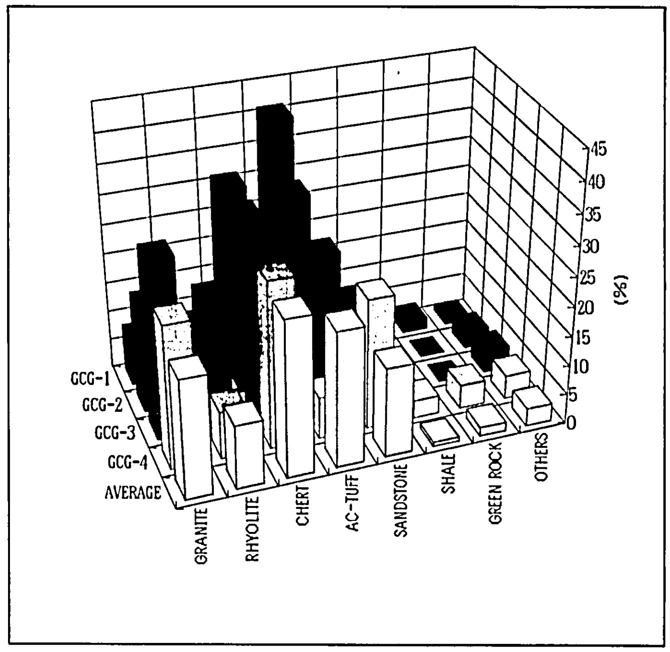


Fig. 22. Gravel composition of the conglomerate of the Gokase Formation.

• Shibanomoto Formation

[Previous studies]

The Shibanomoto Formation, which is named by Saito and Kanbe (1954) and redefined by Teraoka (1970), is typically located in Shibanomoto, Gokasecho. It is mainly composed of thick beds of sandstone and conglomerate with shale in a lower part. The upper shale yields marine bivalves and gastropods, correlated with the Hinagu Formation (Matsumoto and Kanmera, 1949) at Yatsushiro district.

[Distribution]

This formation is only distributed in a area about 600m southeast of Tsubana-Pass, and cut by the faults with a trend of NE-SW at the eastern and the western boundaries.

[Lithofacies]

The formation is mainly composed of dark-gray sandy shale and shale, containing shale rich alternating beds in upper part. (W in Fig. 18). The formation is about 70m thick. Fig. 23 shows a route map south of Tsubana-Pass.

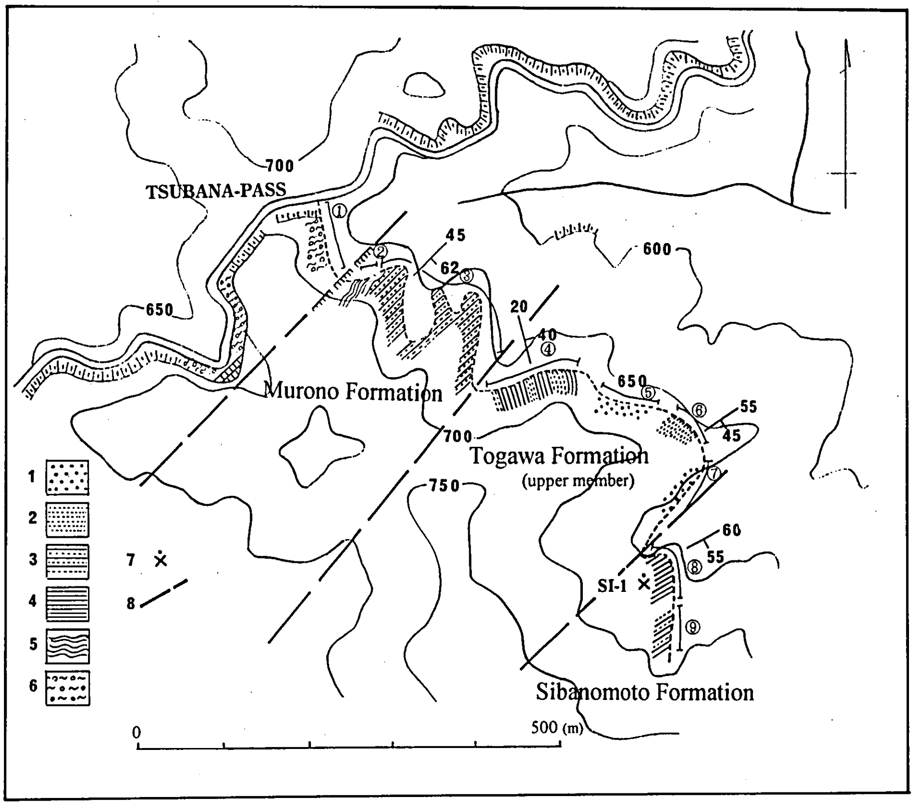


Fig. 23. Route map of southern area of Tsubana-Pass.
1: conglomerate, 2: sandstone, 3: alternation of sandstone and shale, 4: shale, 5: fracture zone, 6: pebbly mudstone, 7: fossil Loc., 8: fault

[Geologic structure]

The formation is in a fault (trending NE-SW) contact with the upper and lower members of Tonegoyama Formation on the eastern and western boundaries, respectively. The strikes and dips are N60E 55S.

[Occurrence of fossils]

This formation yields marine bivalves of *Bakevellia (Neolakevellia) pseudorostrata* from shale (Loc. SH-1) shown in Figs. 8. and 23.

• Kubo Formation

[Previous studies]

The Kubo Formation, named in present paper, corresponds to the greenish-gray sandstone strata of the Takahata Formation proposed by Saito and Kanbe (1954). It yields *Pterotrigonia* sp. *Astarte* sp. Teraoka (1970) correlated it with the Yatsushiro Formation at Yatsushiro district, judging from the lithofacies and fossils.

[Distribution]

The formation is lenticurally distributed in a small area, interspaced the faults with NE-SW trends north of Takahata Formation described bellow.

[Lithofacies]

The formation is chiefly composed of gray to greenish-gray and medium to coarse-grained massive sandstone, laterally changing into much pebbly lithology in northeast. It is more than 200m thick (K in Fig. 24). Fig. 25 shows the route map of Kubo district.

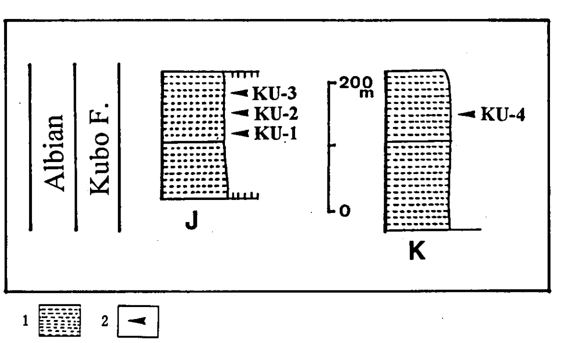


Fig. 24. Stratigraphic columnar sections of the Kubo Formation, showing the occurrences and horizons of fossils.
1: sandstone, 2: fossil occurrence

[Geologic structure]

The formation is in a fault (trending NE-SW) contacts with the Mamihara and Takahata Formation on the north and south, respectively. At topographic highs within the distributing area, the Takahata Formation unconformably overlies this formation. This formation strikes N20 to 40E and dips 55 to 70S.

[Occurrence of fossils]

The formation contains molluscan fossils from massive sandstone at four localities (Loc. KU-1 to 4) show in Figs. 8 and 25. These fossils form a bivalve assemblage which has not been found before. The list of important molluscan fossils is shown in Table 10, and representative ones are figured on Plate 7 to 9.

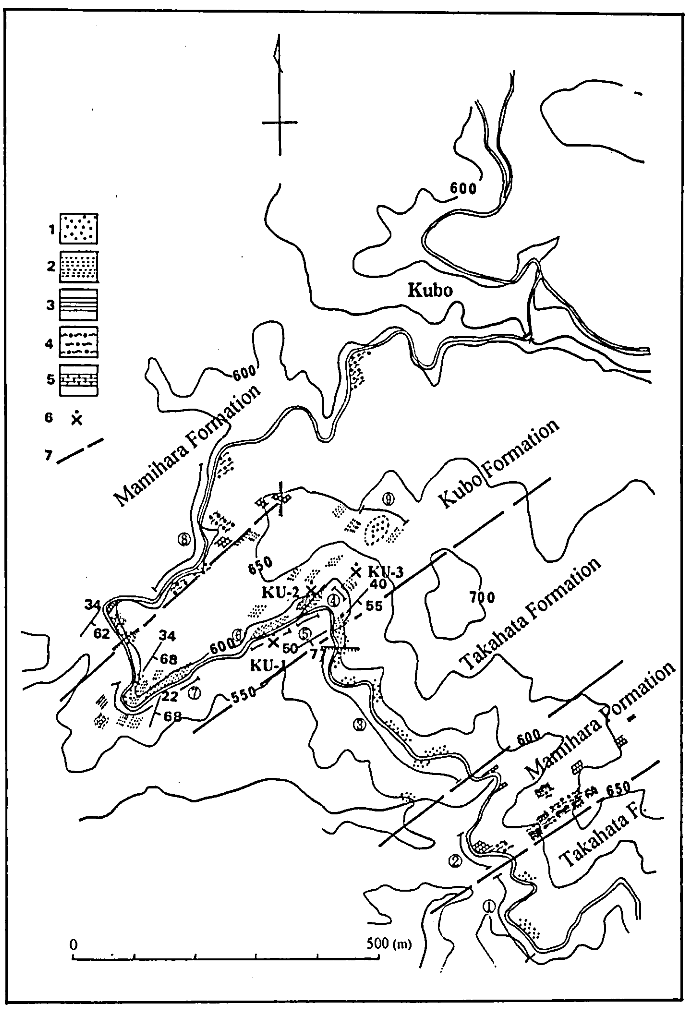


Fig. 25. Route map of Kubo district.
1: conglomerate, 2: sandstone, 3: shale, 4: pebbly mudstone, 5: chert, 6: fossil Loc., 7: fault

Table 10. List of molluscan fossils from Kubo Formation.

Species Loc.(KU-)	1	2	3	4
Nanonavis takahatensis TASHIRO and TANAKA	+		+	
Cucullaea (Idonearca) sp. cf. *C. (I.) amaxensis* MATSUMOTO	+			
Modiolus tamurai TASHIRO and TANAKA			+	
Gervillaria miyakoensis (NAGAO)			+	
Phelopteria sp. aff. *P. electa* TAMURA			+	
Entolium ikedai TASHIRO				+
Placnopsisi sp.			+	
Amphidonte (Amphidonte) subhariotoidea (NAGAO)			+	
Rastellum (Arctostrea) sp. aff. *R. (A.) carinatum* (LAMARCK)				+
Pterotorigonia (Pterotorigonia) takahatensis TASHIRO and TANAKA	+	+	+	+
Globocardium sphaeroideum (FORBES)				+
Astarte (Astarte) yatushiroensis TASHIRO and TANAKA	+		+	
Astarte (Nicaniella) makibaensis TASHIRO and KOZAI	+			
Bungoella sp.			+	
Anthonya sp. aff. *A. mifunensis* TAMURA			+	
Rasatrix (Vectorbis) miyazakiensis TASHIRO and TANAKA	+		+	
Caestcorbula sp.			+	
Periplomya sp.			+	

• Takahata Formation

[Previous studies]

The Takahata Formation named by Saito and Kanbe (1954) is typically located in Takahata, Gokasecho. It consists of red conglomerate. It was correlated with the Yatsushiro Formation at Yatsushiro district on the basis of the lithofacies (Teraoka, 1970).

[Distribution]

The formation is widely distributed in a area on the northern and southern sides of Takahata bounded by faults, and also lies in a small area at the southern slope of Mt. Kagamiyama.

[Lithofacies]

The formation is made up of poorly-sorted red conglomerate, ranging in size from pebble to boulder (50cm in a maximum size). As shown in Fig. 27, gravel is dominated by green rocks (64%), and other important constituents are chert (21%) , sandstone (10%). It appears to be about 350m in a maximum thickness. (L in Fig. 26).

[Geologic structure]

It appears to overlie the Kubo, Kagamiyama and Murono Formations, the lower and upper member of the Togawa Formation and the Sibanomoto Formation. The relationship with each formation is not unconformable. The basement of conglomerate is conformably distributed with contours, and many low angled faults develop there. Serpentinites are often intercalated in a low angle along the subordinating formation.

LOCALITI No.	LITHOLOGY OF GRAVEL (%)							
	GRANITE	RHYOLITE	CHERT	AC-TUFF	SANDSTONE	SHALE	GREEN ROCK	OTHERS
ACG-1	0	0	19	0	3	0	78	0
ACG-2	2	0	16	8	0	0	74	0
ACG-3	0	0	32	0	15	1	49	3
ACG-4	3	0	15	0	21	6	55	0
AVERAGE	1	0	21	2	10	2	64	1

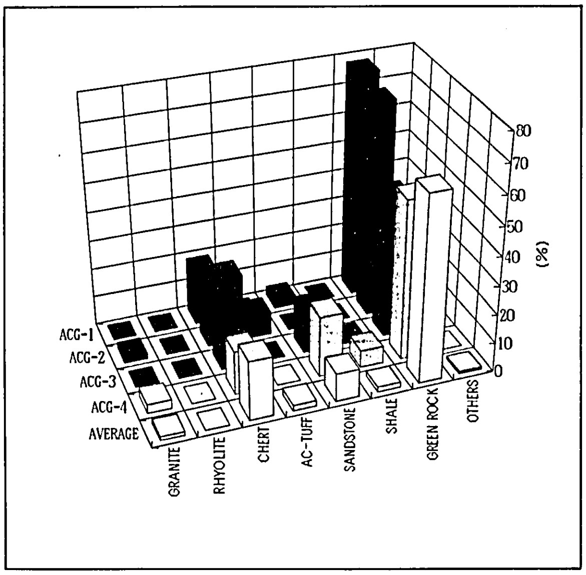


Fig. 27. Gravel composition of the conglomerate in the Takabata Formation.

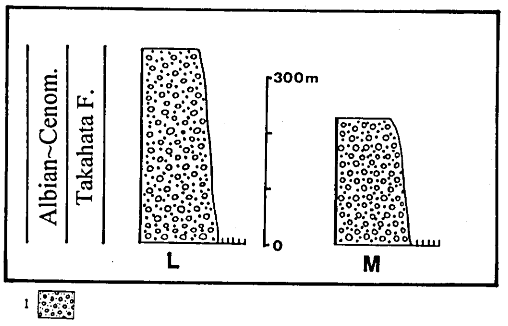


Fig. 26. Stratigraphic columnar sections of the Kubo Formation.
1: red conglomerate

III-3. Southern Belt of the Chichibu Terrane

[Previous studies]

Since the work by Kanbe (1957), the rocks in the southern most part of study area has been considered to be a part of the Yurugidake Formation. However, Sogabe et al. (1990) suggests the possibility that the area south of green schist is a member of the Southern Belt in the Chichibu Terrane, because the green schist distributed in southern study area is equivalent to the Haki Green Schist (Karakida et al., 1977) which divides the Chichibu Terrane in Yatsushiro district into the Northern-Middle and the Southern Belts. In this paper, the Southern Belt of the Chichibu Terrane is newly distinguished on the basis of its paleontology and lithology different from the Yurugidake Formation. This belt is divided into the northern and the southern units by the Shiraiwayama thrust (Murata, 1981) trending EWE to NE.

- **Northern unit**

[Distribution]

It is distributed in a zone from the south to Motoyashiki, through Nakazaki and Obara to Naratsu, trending EW to NE-SW. It is about 1.5km wide at the draniages of the Gokasegawa in the west of study area, becomes wider to east, and gets approximately 3.5km wide at the drainages of the Sangashogawa.

[Lithofacies]

It shows olistostrome facies mainly composed of pebbly mudstone, yet frequently intercalating sandstone, shale and alternating beds. Olistolith is made up of massive to bedded sandstone, limestone, chert and green rocks. Among these rocks, limestone is mainly found in the northern area, green rocks is minor, and shale comparatively lies in masses at the central distributing part to the south of Mt. Yurugidake. It consists of bedding black partly phyllitic shale. Limestone blocks range in length from a few meters to a few kilometers, and especially the one occurred along the Shiraiwayama thrust can be traced more than 2km. The other limestone blocks are in small size and, are scattered. This limestone is rarely crystallized and often yields fossils like fusulinids. Chert blocks with a maximum length of a few hundreds meters are distributed in lenses parallel to the strike. Most of chert is grayish-white to bluish-white, solid and fine, and has remarkable bedding. Green rocks composed of basic volcanic rocks are very small both in volume and scale, and are not in such a large scale one in the Yurugidake Formation (a few hundreds meters in length) contained in the Yurugidake Formation.

[Structure]

Strike and dip of this unit are E-W to N45E and 60 to 80N. It strikes about E-W in the east and nearly NE-SW to the north of Obarai-Pass, varying its strike northward, in the west. On the north, this unit is bounded by the fault, which trends E-W to N45E and dips 60 to 70N, with green schist and the Yurugidake Formation. On the south, it is demarcated from the southern unit by the Shiraiwayama thrust fault. According to Murata (1981), the thrust runs from Iiboshi-Pass through Obarai-Pass and Takaragi to Mt. Shiraiwayama. Its strike and dip are N70E,36N in the western part to the south of Motoyashiki, are N81E45N in the central part to the north of Takaragi, and are N34E,27N at Iiboshi-pass district in the eastern part.

[Occurrence of fossils]

Foraminiferal fossils occur in the limestone from the localities shown in Fig. 28, Locs. SO-15 to SO-20, and are listed in Table 11. Radiolarian fossils available for age determination were obtained from seven localities, Locs. SO-1 to SO-7, as shown in Fig. 5. Lithofacies of each locality is shown as follows; Locs. SO-1 to 4 are chert, Locs. SO-5 and 6 are siliceous shale and Loc. SO-7 is black shale. A list of radiolarian fossils from each locality is shown in Table 12, and representative ones are figured in Plate 4.

Table 11. List of foraminiferal fossils from the Northern Unit of the Southern Belt.

Species Loc.(SO-)	15	16	17	18	19	20
Cancellina sp.			+		+	
Colania sp.	+	+	+			+
Neoschwagerina ex gr. *craticufera*		+				
Neoschwagerina sp.		+				+
Yabeina sp.	+			+	+	+
Schwagerinid		+			+	
Agathammina sp.		+				
Clibrogenerina sp.						+
Climacammina sp.						+
Globivalvulina sp.		+	+			+
Hemigordius sp.	+		+	+	+	+
Kahlerina sp.			+		+	+
Lunucammina sp.			+			
Pachyphloia sp.					+	+
Palaeotextularia sp.		+				

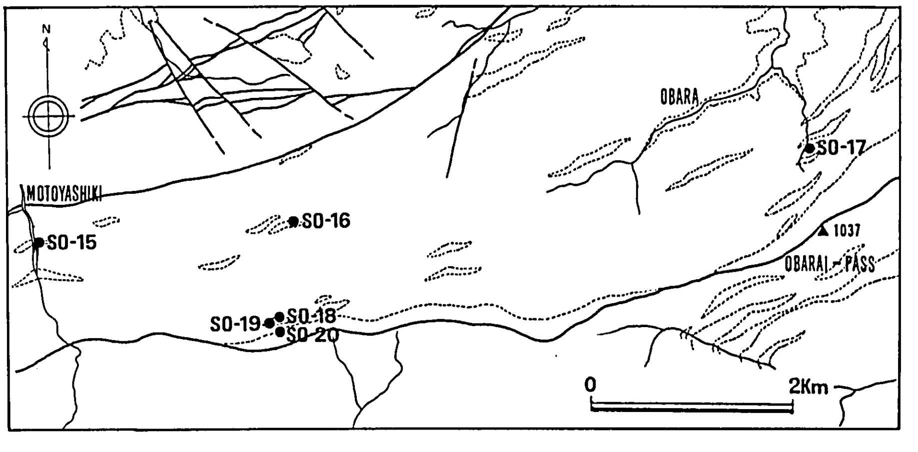


Fig. 28. Localities of foraminiferal fossils list in Table. 11.

Table 12. List of radiolarian fossils from the Southern Belt of the Chichibu Terrane.

Species Loc.(SO-)	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Canoptum rugosum PESSAGNO and WHALEN							+							
Canoptum sp.			+				+							
Corum sp.			+											
Dictyomitrella sp.		+												
Syringocapsa batodes DE WEVER				+										
Triassocampe nova YAO				+										
Triassocampe sp.	+			+										
Triassocampe(?) sp.			+											
Xipha sp. cf. X. *striata* BLOME				+										
Capnodoce sp.			+	+										
Capnuchosphaera theloides DE WEVER				+										
Eptingium sp.		+												
Pseudostylosphaera japonica (NAKASEKO and NISHIMURA)	+													
Pseudostylosphaera sp.	+													
Archaeodictyomitra(?) *amabilis* AITA					+									
Archaeodictyomitra gifuensis TAKEMURA						+								
Archaeodictyomitra pseudoscalaris (TAN SIN HOK)													+	
Archaeodictyomitra sp.					+	+		+	+	+	+	+	+	+
Bagotum erraticum PESSAGNO and WHALEN							+							
Bagotum sp.							+							
Cinguloturris sp.						+								
Dictyomitra sp.												+		
Hemicryptocapsa sp.								+				+	+	
Hsuum sp.					+	+								
Katroma elliptica KISHIDA and HISADA							+							
Katroma triangularis KISHIDA and HISADA							+							
Katroma sp.							+							
Mirifusus guadalupensis PESSAGNO						+								
Mirifusus mediodilatatus (RUST)														+
Mirifusus(?) sp.														+
Parahsuum sp.						+	+						+	
Parvicingula boessi (PARONA)													+	+
Parvicingula mashitaensis MIZUTANI								+						+
Patellula planoconvexa PESSAGNO													+	+
Pseudodictyomitra sp.								+	+		+		+	+
Pseudoeucyrtis sp.						+								
Solenotryma(?) *ichikawai* MATSUOKA and YAO													+	
Solenotryma sp.														+
Stichocapsa japonica YAO					+									
Stichocapsa sp. aff. *S. tegiminis* YAO							+							
Stichocapsa sp. cf. *S. clava* YAO														+
Stichocapsa sp.					+									
Stylocapsa lacrimalis MATSUOKA										+				
Stylocapsa(?) *spiralis* MATSUOKA										+				
Tricolocapsa sp. cf. *T. conexa* MATSUOKA										+				
Tricolocapsa plicarum YAO					+	+								
Tricolocapsa tetragona MATSUOKA					+									
Tricolocapsa sp.					+	+				+	+			
Triversus sp. cf. *T. mashitaensis* MIZUTANI						+								
Triversus sp.						+								
Zhamoidellum sp.									+	+	+			+
Williriedellum sp.						+					+			
Xitus sp.												+		+
Archaeospongoprunum sp.					+	+						+		
Pantanellium sp.							+							
Amphipyndax sp.												+		
Diacanthocapsa sp.												+		
Holocryptocanium barbui DUMITRICA												+		
Mita(?) sp.												+		
Praeconocaryomma sp.												+		
Protunuma sp.												+		
Pseudodictyomitra lodogaensis PESSAGNO												+		
Pseudodictyomitra pentacolaensis PESSAGNO												+		
Pseudodictyomitra vestalensis PESSAGNO												+		
Sethocapsa cetia FOREMAN												+		
Sethocapsa sp.												+		
Stichomitra(?) sp.												+		
Thanarla praeveneta PESSAGNO												+		
Thanarla sp.												+		
Orbiculiforma maxima PESSAGNO												+		

[Loc.SO-1～7:northern unit, Loc.SO-8～14:southern unit]

laws: lawsonite, pump: pumpellyite, glauco: glaucophaen, act: actinolite, chl: chlorite, Na-amph: Na-amphibole, ep: epidote, mus: muscovite, calc: calcite, preh: prehnite, stilp: stilpnomelane. Albite and quartz appear in the all associations.

• Southern unit

[Distribution]

It is located in the southern end of the study area, on the south of the Shiraiwayama thrust fault. The northern margin of the southern unit is distributed in the study area. According to Kanbe (1957) and Murata (1981), southern limit extends Shiibason and Morozukason, Miyazaki Prefecture, and is bounded by the Butsuzo Tectonic Line, with the Shimanto Terrane.

[Lithofacies]

This unit distributed in the study area consists of shale, sandstone, limestone, chert and green rocks. Sandstone and shale are frequently alternated. Exotic blocks of limestone, chert, and green rocks are quite continuous to the strike direction. The matrix mudstone of exotic blocks is less pebbly. The thickness is unknown. Shale is well-bedded and locally siliceous. Sandstone, most of which is fine to medium grained, looks greenish-gray to dark-gray. Graded bedding directing to the north are often found in the alternating beds of sandstone and shale.

[Geologic Structure]

Relatively uniform strikes and dips, which rarely varies, of the southern unit in the study area are N50 to 70E and 40 to 70N, respectively. These strikes are nearly parallel to those of the northern unit in the eastern study area (Obarai-Pass district), however, in the west (to the south of Motoyashiki), it is large diagonal. Because the strike of the Butsuzo Tectonic Line and this unit are almost parallel in this area, the distance between the Shiraiwayama thrust and the Butsuzo Tectonic Line (= width of this area) is about 1.2km in the east and approximately 6km to the south of Motoyashiki, getting wider to the west (Murata, 1981).

[Occurrence of fossils]

Radiolarian fossils available for age determination were obtained from seven localities, Locs. SO-8 to SO-14, as shown in Fig. 5. Lithofacies of each locality is shown as Locs. SO-8 to 11 are black shale and the rests are siliceous shale. Radiolarian species are listed in Table 12, and representative ones are figured on Plate 5.

III-4. Metamorphic rocks

Metamorphic rocks in the study area are distributed with two modes of occurrence-mode (Fig. 29). One is a regional metamorphosed formation occupying the southern part of the area, which mostly consists of the crystalline schists of basic volcanic origin. Therefore, this type is here called as the "Green schist Formation". Another is exposed as exotic blocks in pebbly mudstone of the Kagamiyama Formation, in which the northern part of the study area.

• "Green schist Formation"

The constituent rocks crop out along the boundary between the Middle and the Southern Belt of the Chichibu Terrane. The thickness is extremely variable and attains a maximum of about 700m at the east of Motoyashiki. It trends EW to N60E and dips 60 to 80N. This formation is always in a fault contact with adjoining formations. In the case when the fault contact is associated with serpentinite, fault clays are usually found along the boundary. Besides, serpentinite in some places intrudes in this formation as veinlets, showing such structures to suggest a shear movement as foliation and slickenside. Main constituent rocks of the formation are mafic green schist, and weakly metamorphosed basalt and gabbro. In the formation, siliceous and pelitic schists are sometimes associated but their exposures are confined to the small-scaled ones. Representative mineral assemblages are as follows:

(1)lawsonite + actinolite + epidote + chlorite + albite + quartz

(2)Na-amphibole + garnet + stilpnomelane + albite + quartz

(3)Na-amphibole + pumpellyite + actinolite + epidote + albite + quartz

(4)Na-amphibole + actinolite + epidote + chlorite + calcite + albite + quartz

(5)Na-amphibole + epidote + chlorite + albite + quartz

(6)actinolite + epidote + chlorite + albite + quartz

(7)actinolite + epidote + muscovite + albite + quartz

(8)prehnite + zoisite + clinozoisite + chlorite + albite + quartz

As shown in Fig. 30 , Na-amphiboles show a wide range in composition such as glaucophane, ferro-glaucophane, crossite and riebeckite. Judged from the mineralogical characteristics, it is inferred that the formation has been affected by the regional metamorphism of the prehnite-pumpellyite facies to glaucophane schist facies.

Considering the lithology and metamorphic mineral assemblages, the formation probably corresponds to the Haki Green Schist (Oshima, 1979 etc.), which is distributed to the south of Yatsushiro, Kumamoto Prefecture (Table 13). Mylonitic granite, garnet-amphibolite and amphibolite sporadically occur in the formation. They could undergo the regional metamorphism affecting this formation, but a definite conclusion must be preserved owing to the lack of detailed petrological investigation.

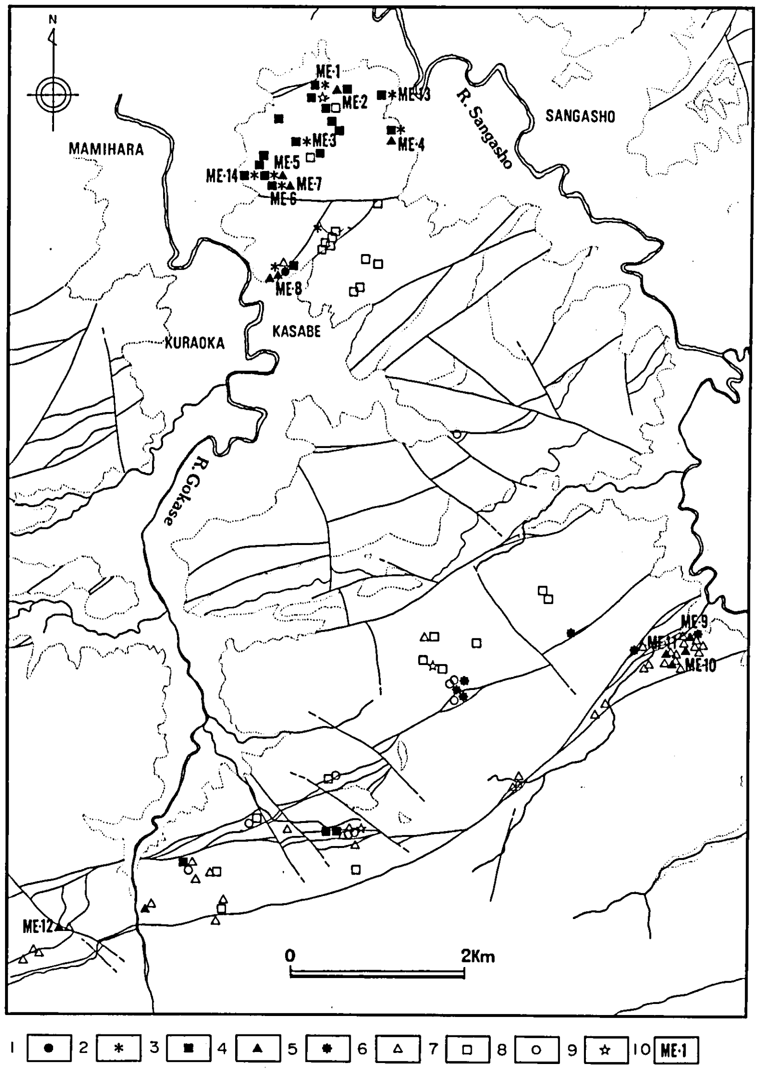
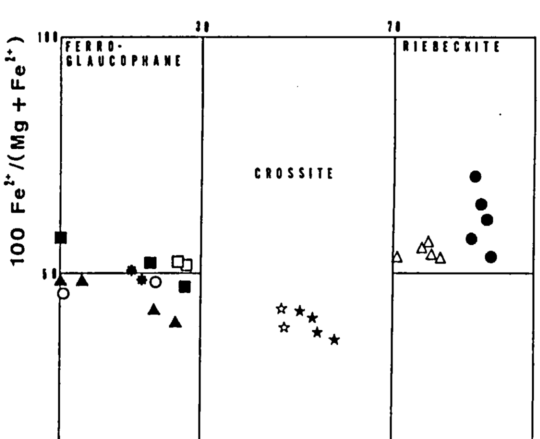


Fig. 29. Localities of metamorphic minerals. Metamorphic rocks in study area are distributed showing two types of mode of occurrence
1: jadeite, 2: aegirine-augite, 3: lawsonite, 4: alkali-amphibole, 5: garnet, 6: actinolite, 7: pumpellyite, 8: prehnite, 9: zoisite, 10: sample No.



Kagamiyama F. (sample No.), ●: (ME-5), ▲: (ME-4), ■: (ME-7), ★: (ME-8), ✱: (ME-2)
"Green schist F."(sample No.), ○: (ME-12), △: (ME-9), □: (ME-10), ☆: (ME-11)

Fig. 30. Diagram showing the variation of Na-amphibole in exotic blocks in the Kagamiyama Formation and "Green schist Formation".

Table 13. Comparison of the metamorphic rocks in "Green schist Formation" with the Haki green schist

"Green schist F."		Haki green schist
green schist garnet amphibolite amphibolite pelitic schist gabbro basalt	rock type	green schist pelitic schist siliceous schist
1) laws + act + ep + chl 2) Na-amph + garnet + stilp 3) Na-amph + pump + act + ep 4) Na-amph + act + ep + chl + calc 5) Na-amph + ep + chl 6) act + ep + chl 7) act + ep + mus 8) preh + zoisite + clinozoisite + chl	metamorphic mineral association	1) laws + act + glauco + chl 2) laws + pump + act + glauco + chl 3) laws + ep + glauco + chl 4) laws + ep + act + glauco + chl 5) laws + ep + act + chl 6) pump + glauco + chl 7) pump + act + glauco + chl 8) pump + act + chl 9) pump + ep + act + glauco + chl 10) ep + act + glauco + chl 11) act + glauco + chl 12) pump + ep + act + chl 13) ep + act + chl (Ohshima , 1979)

laws: lawsonite, pump: pumpellyite, glauc: glaucophaen, ep: epidote, chl: chlorite, mus: muscovite, alb: albite, Na-amph: Na-amphibole, ac: aegirine-augite, jd: jadeite, stil: stilpnomelane, chlm: chloromelanite, q: quartz .

• Exotic blocks in the Kagamiyama Formation

In the Kagamiyama Formation, various kinds of pebbles are found. They are essentially characterized by the association of high pressure-low temperature type metamorphic minerals. It has been reported that exotic blocks equivalent to the Kurosegawa rocks are occasionally intermingled in mudstone of the Northern and Middle Belt of the Chichibu Terrane (Tominaga et al., 1979, 1981; Tsukuda, 1980). Miyamoto et al. (1983) has described a lawsonite-bearing metamorphic pebble in mudstone of the Yatsushiro district, Kumamoto Prefecture. Maruyama et al. (1978) have found 208-240 Ma high pressure-low temperature schist blocks from serpentinite near Kochi, Shikoku. They are characterized by the association of jadeite + quartz, and are inferred to undergo three metamorphic events, which are older than the Sanbagawa metamorphism. In the study area, pebbles are composed of pelitic schist, blue schist, amphibolite, basalt and dolerite. Representative metamorphic mineral associations in the pebbles are as follows:

(1)jadeite + lawsonite + Na-amphibole + albite + quartz
(2)aegirine-augite + lawsonite + Na-amphibole + albite + quartz
(3)aegirine-augite + lawsonite + albite + quartz
(4)Na-amphibole + stilpnomelane + albite + quartz
(5)lawsonite + zoisite + quartz
(6)aegirine + chlorite + albite + quarries
(7)lawsonite + pumpellyite + albite + quartz
(8)lawsonite + muscovite + albite + quartz
(9)pumpellyite + chlorite + albite

Na-pyroxene has a wide range in composition from jadeite to aegirine (Fig. 31), that many reflect the difference in bulk chemistry of the original rocks Chemical composition of Na-amphiboles suggests that they are classified into glaucophane, ferro-glaucophane, crossite and riebeckite (Fig. 30). It is concluded that the metamorphic facies suggested by the pebbles are from the prehnite-pumpellyite through the lawsonite-albite-chlorite to the blue schist facies.

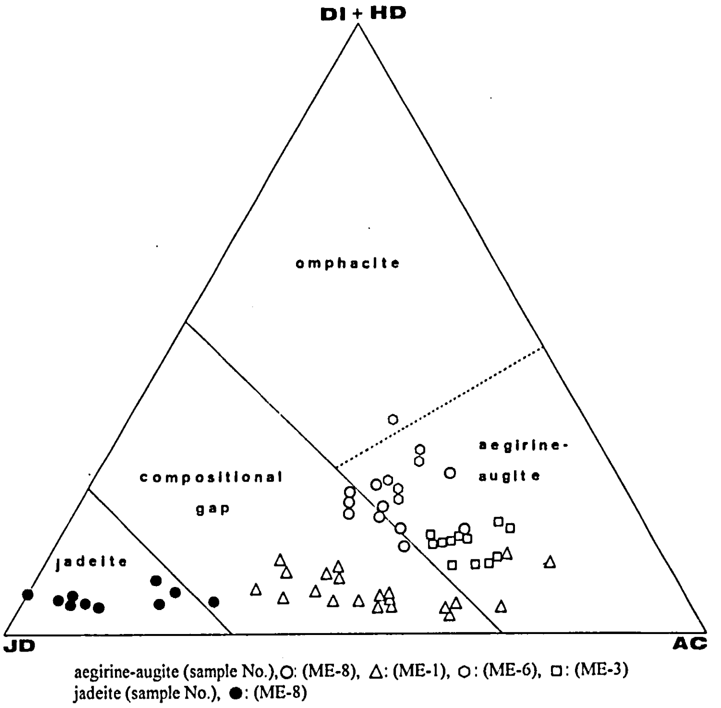


Fig. 31. Diagram showing the variation of pyroxenes in exotic blocks in the Kagamiyama Formation. The end-member components are jadeite (JD), acmite (AC), and diopside + hedenbergite (DI + HD).

Metamorphic grade of the matrix of pebbly mudstone is as low as yielding the association of pumpellyite+chlorite and muscovite + chlorite. Therefore, it is inferred that the pebbles had been derived from some high pressure-low temperature metamorphic terrain into mudstone matrix and after that the pebbly mudstone as a whole were affected by low-grade regional metamorphism. Judged from the lithology and critical mineral associations, the pebbles have a possibility to be correlative with the blocks reported by Maruyama et al. (1978), (Table 14). The latter, however, are found only in serpentinite and the former in mudstone. It appears that the Kagamiyama Formation had been formed during the Late Permian, which suggests their metamorphosed ages are different to each other. Further investigation, especially on the view point of geochronology, is necessary for the pebbles of study area.

Table 14. Comparison of the metamorphic blocks in the Kagamiyama Formation with those in the Ino Formation

Kagamiyama F.		Ino F.
olistolith	mode of occurrence	xenolith
pelitic schist basalt dolerite amphibolite blue schist	rock type	green schist amphibolite pillow lava block lava hyaloclastite chert
1) jd + laws + Na-amph + alb + q 2) ac + laws + Na-amph + alb + q 3) ac + laws + alb + q 4) Na-amph + stil + alb + q 5) laws + zoisite + q 6) ac + chl + alb +q 7) laws + pump + alb +q 8) laws + mus + alb +q 9) pump + chl + alb	metamorphic mineral association	1) laws + glauc + stil + jd + ac + alb + q 2) laws + pump + jd + ac + aib 3) laws + pump + glauc + ac + alb + q 4) laws + pump + glauc + jd + ac + salite + chl + alb +q 5) laws + pump + crossite + ep + alb + q 6)laws + pump + chlm + chl + alb + q 7) laws + pump + glauc + alb + q 8) laws + glauc + stil + alb +q 9) laws + pump + glauc + chlm + microcline + alb +q 10) laws + glauc + alb 11) laws + pump + glauc + alb 12) laws + pump + glauc + ac + alb 13) laws + glauc + ac + alb 14) pump + chl + alb

laws: lawsonite, pump: pumpellyite, glauc: glaucophaen, ep: epidote, chl: chlorite, mus: muscovite, alb: albite, Na-amph: Na-amphibole, ac: aegirine-augite, jd: jadeite, stil: stilpnomelane, chlm: chloromelanete, q: quatz.

IV. Discussion on age and correlation

The paleontological studies in the Kuraoka district have been published by many authors; for instance, Saito and Kanbe (1954), Tamura (1960a), Teraoka (1970), Ando (1987), Tashiro et al. (1991, 1992, 1993), Sogabe et al. (1995MS), on marine and non-marine bivalves; Matsumoto and Hirata (1970) on ammonoids; Koike and Murata (1979), Murata (1981) on conodonts; Sogabe et al. (1990, 1994, 1995MS) on radiolarians. I have also collected many molluscan and radiolarian fossils etc. from more than 50 localities of at least in 15 stratigraphic horizons. In this chapter, the geological ages of the olistostrome facies (Yurugidake, Mamihara and Kagamiyama Formations, and northern and southern units in the Southern Belt of the Chichibu Terrane) and the neritic sedimentary facies (Murono, Kanmuridake, Oishi, Togawa, Tsubana, Kasabe, Gokase, Shibanomoto, Kubo and Takahata Formations) in the Kuraoka district are discussed on the basis of radiolarian fossils, bivalves and ammonoids, and the correlation among various areas within the Outer Zone of the Southwest Japan is attempted. For the correlation, not only the fossil evidences but also the lithofacies, sedimentary structure, tectonic location, and others characteristics were taken into account.

IV-1. Olistostrome facies

• Yurugidake Formation

Radiolarian fossils obtained from the chert blocks (Locs. YU-1 to 5) of the Yurugidake Formation indicates Middle and Late Permian, and Late Triassic to early Early Jurassic in age. Among these, the radiolarian assemblage characterized by *Psuedoalbaillella* sp. cf. *fusiformis* (Holdworth and Jone), *P.* sp. cf. *longtanensis* Sheng and Wang from Loc. YU-1 is correlated with the *Pseudoalbaillella* sp. C A-zone of Ishiga (1986) and is assigned to the early Middle Permian. The radiolarian assemblage from Loc. YU-2 is characterized by *Follicucullus* sp. cf. *F.dilatatus* Rudenko, *F.* sp. cf. *F. porrectus* Rudenco, *F. scholasticus* Ormiston and Babcock, and others. This assemblage, which corresponds to the *Follicucullus scholasticus* A-zone of Ishiga (1986) or the *Follicucullus charveti* - *F. porrectus* A-zone, is assigned to the early Late Permian. On the other hand, radiolarian fossils from Loc. YU-4, such as *Capnodoce* sp. aff. *C. traversi* Pessagno, *Sarla* sp. cf. *S. hadrecaena* (De Wever), *Capuuchoshaera* sp., *Canesium* (?) sp., *Latium* sp., *Xipa* sp., are characteristic species of the *Capnodoce* A-zone (Blome, 1984), which range in age from Upper Carnian to Middle Norian. The radiolarian assemblage from Loc. YU-5 characterized by *Livarella longus* Yoshida, *Livarella gifuensis* Yoshida, *Livarella* sp., *Natoba* sp. cf. *N. minuta* Pessagno and Poisson, *Canoptum* sp. cf. *C. anulatum* Pessagno and Poisson, *Dictyomitrella* sp. and others, may indicate the early Early Jurassic.

Murata (1981) have reported the occurrence of foraminifers containing *Misellina* sp. aff. *M. claudiae* in a limestone block near Mt. Yurugidake, that indicates the Early Permian.

While, radiolarian fossils obtained from pelitic matrix (Locs. YU-6 to 15) are all assigned to Early Jurassic in age. Among these, The radiolarian assemblage occurring in Loc. YU-7 is characterized by *Bagotum* sp. cf. *B. erraticum* Pessagno and Whalen, *B.* sp. aff. *B. maudense* Pessagno and Whalen, *Parahsuum simplum* Yao, *Gorgansium* sp. aff. *G. gongyloideum* Kishida and Hisada, *Canoptum* (?) sp., *Parahsuum* sp. and others. These species typically occur in the lower to middle part of the *Parahsuum simplum* A-zone (Yao,1982), and according to Yao (1990), this A-zone ranges in age from Hettangian to Pliensbachian. The radiolarian assemblage from Loc. YU-10 is characterized by *Parahsuum* sp. cf. *P. ovale* Hori and Yao, *P.* sp. cf. *P. transiens* Hori and Yao, *Droltus* sp. and others. *Parahsuum ovale* and *P. transiens* were originally described from Lower Jurassic chert in the Inuyama area, Central Japan (Hori and Yao, 1988). According to Hori (1990), the occurrence of *Parahsuum ovale* and *Parahsuum transiens* are confirmed to be from the Hettangian to Pliensbachian and to be from the Toarcian to Aalenian, respectively. Co-occurrence of these two species clarified the age assemblage from the Pliensbachian to Toarcian. The radiolarian assemblage from Loc. YU-11 is characterized by *Archicapsa pachderma* Tan Sin Hok, *Parahsuum* sp. cf. *P. ovale* Hori and Yao, *P. simplum* Yao, *Parvieingula* sp., and others. The first appearance of *Archicapsa pachderma* is the boundary between the Pliensbachian and Toarcian (Matusoka and Yao, 1986). These fossils are correlated with the *Parahsuum* (?) *grande* A-zone of Yao (1982) indicating the Toarcian (Yao, 1990).

As indicated by these radiolarian ages, the Yurugidake Formation is the Lower Jurassic olistostrome sediment including the blocks of Lower Permian limestone and Middle Permian to Lowermost Jurassic chert. This formation, judging from age, lithofacies and tectonic location, corresponds to the Lower Jurassic Hashirimizu Formation (Matsumoto and Kanmera, 1952; Miyamoto and Kuwazuru, 1993b) distributed in Yatsusiro district, Kumamoto Prefecture to the west of the study area. The Hashirimizu Formation is chiefly composed of sandstone with thin intercalations of black shale and pebbly mudstone, including exotic blocks of chert, green rocks and limestone (Miyamoto and Kuwazuru, 1993b). Limestone blocks yield fusulinids, such as *Neoschwagerina margaritae*, *Neoschwagerina craticurifera*, *Verbeekina Velbeeki* and *Schwagerina* sp., indicating the Middle Permian (Mastumoto and Kanmera, 1952). Miyamoto and Kuwazuru (1993b) have reported the presence of the radiolarian assemblage characterized by *Bagotum erraticum* Pessagno, *B. maudense* Pessagno and Whalen, *B. pseudoerraticum* Kishida and Hisada, *Canoptum* sp. cf. *C. anulatum* Pessagno and Poisson, *C.* sp. cf. *C. rugosum* Pessagno and Poisson, *Gigi elliptica* (Kishida and Hisada), *Parahsuum simplum* Yao, *P. ovale* Hori and Yao, *Pantanellum* sp. cf. *P. inornatum* Pessagno and Poisson, and others, from the mudstone in the Hashirimizu Formation. And it suggests in age from Sinemurian to Pliensbachian, correlated with the middle to upper part of the *Parahsuum simplum* A-zone of Yao (1982).

A part from the southern slop of Mt. Yurugidake to the Tonegogawa, belonging to the Yurugidake Formation in this paper, had been considered to be a member of the Tonegoyama Formation (Saito and Kanbe, 1954). The route map of this area is shown in Fig. 32.

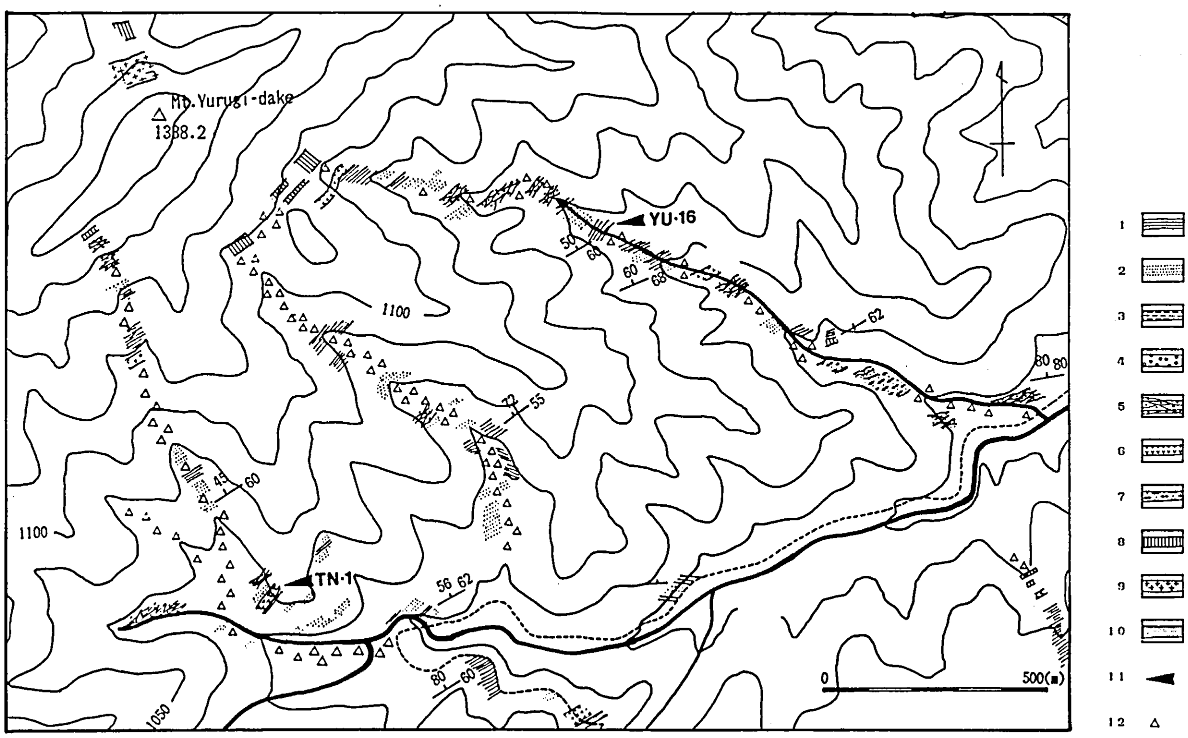


Fig. 32. Route map of the south of Mt. Yurugidake
1:shale, 2:sandstone, 3:marlstone, 4:conglomerate, 5:pebbly mudstone, 6:green rock, 7:green schist, 8:chert, 9:granitic rock, 10:serpentinite, 11:fossil Loc., 12:float

The Tonegoyama Formation consisting of sandstone and slate is characterized by intercalating beds of thin conglomerate and marlstone and by the lack of chert (Kanbe, 1957). Kanbe (1957) obtained ammonites from the black slate on the northern side of limestone exposed at Mt. Tonegoyama district to the eastern study area, and suggest the Tonegoyama Formation to be Lower Jurassic system. Tamura (1960a), however, found *Oxytoma multistriatum, Tosapecten suzukii, Frenguelliella (Kumatrigonia) tanouresis* in marlstone as shown in Fig.32 , Loc. TN-1, and suggests that the most of the Tonegoyama Formation is Upper Triassic system. Moreover, *Pleeuromya* sp. and *Monotis ochotica* were obtained from the sandstone-and mudstone-floats of this formation to the east of the study area, which indicates that the upper member of Tonegoyama Formation in the Late Carnian to the Late Norian (Murata, 1981). However as shown in Fig. 32, the formation distributed on the southern slope of Mt. Yurugidake contains much of green rocks, chert, pebbly mudstone. These lithological components are quite similar to those of the Yurugidake Formation distributed to the north of Mt. Yurugidake, although the sandstone and mudstone beds of the Tonegoyama Formation are slightly thicker than those of the Yurugidake Formation. The black shale from Loc. YU-16, beside, yields radiolarian fossils (*Parahsuum* sp.) suggesting Early Jurassic. In the study area, thus, Upper Triassic system does not have enough volume to be regarded as a formation, and a large part which had been considered the Tonegoyama Formation should be probably included in the Lower Jurassic Yurugidake Formation. The relationship between the Yurugidake Formation and The Triassic marlstone and its accompanying strata does not clear owing to poor outcrops. However, a rich occurrence of pebbly mudstone around the Triassic marlstone suggests that greenrocks and chert have been possibly included as exotic blocks. The conglomerate containing much gravel of granitic rock and acidic tuff, was previously regarded as the Tonegoyama Formation, and is distinguished from the Yurugidake Formation, but is newly described as the Gokase Formation.

• Mamihara Formation

The presence of *Livarella* sp. cf. *L. longus* Yoshida, *Livarella* sp., *Ferresium* sp., *Higmastra* (?) sp., *Canoptum* sp. cf. *C. anulatum* Pessagno and Poisson, *Canoptum* sp. and *Dictyomitrella* sp. in the chert blocks (Locs. MA-1 to MA-3) of the Mamihara Formation indicates the age of Late Triassic to early Early Jurassic.

While, only one locality (Loc. MA-4) from pelitic matrix, tuffaceous shale bears radiolarians, such as *Archicapsa* sp., *Bagotum* sp., *Mesosatunalis* sp., *Orbiculiforma* sp., *Tricolocapsa* (?) sp., *Parahsuum ovale* Hori and Yao, and *Parahsuum* sp. Among these, *Parahsuum ovale* was described as *Parahsuum* (?) sp. C (Yao, 1982), according to Hori and Yao (1988) and Hori (1990), this species is known to occur only in *Parahsuum simplum* A-zone. It is difficult to determine the age owing to rare contents of reliable fossils, but these radiolarian fossils are considered to be of Early Jurassic in age.

The Mamihara Formation is correlated with the Shimodake Formation (Kanmera, 1952; Miyamoto, 1990) occuring in Yatsushiro district. According to Miyamoto (1990), the Shimodake Formation represents olistostrome facies mainly composed of pebbly mudstone containing olistoliths of sandstone, chert, and minor green rocks and limestone. And the formation is distributed in a fault contact with the northern Tobiishi Group (Kanmera, 1952) on the north of the Upper Permian Miyama Formation (Miyamoto, 1985). The Permian, Late Triassic and Early Jurassic radiolarian fossils are obtained from the chert blocks of the Shimodake Formation, and the pelitic matrix yields such radiolarians as *Pantanellium* sp. cf. *P. inornatum* Pessagno and Poisson, *Pantanellium* sp. aff. *P. danaense* Pessagno and Blome, *Bagotum* sp. cf. *B. pseudeoerraticum* Kishida and Hisada, *Bagotum* sp. aff. *B.erraticum* Pessagno and Blome, and others, suggesting Early Jurassic in age.

• Kagamiyama Formation

The Late Permian radiolarians are found in acidic tuff, shale and black mudstone considered as a matrix of pebbly mudstone. Among the radiolarian fossils shown in Table 4, *Albaillella levis* was originally described from chert of the Ikuridani Group, Shiga Prefecture (Ishiga et al.,1982) and was found in the pelitic rocks of the Upper Permian Miyama Formation, Yatsushirogun, Kumamoto Prefecture (Miyamoto et al., 1985). *Follicucullus charveti* was originally described from mudstone of the Tatsuno Group, Hyogo Prefecture (Caridroit and De Wever, 1984), and later it was found in mudstone of the Upper Permian Kuma Formation of the Chichibu Terrane in Kyushu (Miyamoto et al., 1985; Ishiga and Miyamoto, 1986). *Follicucullus dilatatus* reported the occurrence from Upper Permian system in Primorje (SE Siberia) and in Sosio Balley (Italy). *Follicucullus porrectus* is regarded as a synonym of *F. scholasticus* morphotype II described by Ishiga (1984) (Kozur, 1993). The descriptions on morphotypes of *F. scholasticus* (morphotypes I and II) were given by Ishiga and Imoto (1980) and Ishiga (1984, 1985). *Follicucullus scholasticus* was originally described from the Guadalupian Lamar Limestone (Ormiston and Babcock, 1979) and has been reported from Upper Permian units of many localities in Japan. *Nazarovella gracilis* was originally described from the Upper Permian of the Kamigori Zone mentioned above (De Wever and Caridroit, 1984).

As stated, the radiolarian fossils obtained from the Kagamiyama Formation have been found in other Permian stratigraphic units. The radiolarian assemblages from Locs. KA-1, 3 and 4, corresponding to the *Follicucullus charveti* - *F.porrectus* A-zone of Kozur (1993), suggest early Late Permian in age. Occurrence of *Albaillella* sp. cf. *A. Levis* found at Loc. KA-5 is assigned near the boundary between *Neoalbaillella optima* A-zone and *Neoalbaillella ornithormis* A-zone, and it appears slightly younger than the other localities.

The Kagamiyama Formation, re-defined in this investigation, is considered to be an accretionary complex formed during Late Permian. Judging from the age, lithofacies, and tectonic location, it is correlated with the Upper Permian Miyama Formation distributed at Yatsushiro district, Kumamoto Prefecture to the east of the study area. According to Miyamoto et al. (1985), the Miyama Formation shows olistostrome facies, including plenty of Early to Middle exotic blocks of chert, green rocks, sandstone and serpentinite. The Late Permian radiolarians, such as *Albaillella levis* Ishiga, Kito and Imoto, *Follicuculus scholasticus* Ormiston and Babcock and *Neoalbaillella* sp. were obtained from black shale of this formation. And high pressure metamorphosed rocks containing lawsonite were also found as the exotic blocks (Miyamoto et al., 1983).

• Northern unit of the Southern Belt

The radiolarian fossils obtained from chert blocks (Locs. SO-1 to 4) of the northern unit is assigned to the Middle to Late Triassic. Among these, the radiolarian assemblage from Loc. SO-4 is characterized by *Capnuchosphaera theloides* De Wever, *Syringocapsa batodes* De Wever, *Triassocampe nova* Yao, *T.* sp. *Xipha* sp. cf. *X. striata* Blome, and others. These fossils are correlated with the upper part of the *Triassocampe nova* A-zone (Yao et al., 1982), suggesting Early Norian in age. Murata (1981), beside, has obtained the Late Scythian to Norian conodont fossils from chert of five localities in this area.

From limestone blocks (Locs. SO-15 to 20), the Middle Permian foraminiferal fossils, such as *Yabeina* sp., *Neoschwagerina* ex. gr. *craticufera*, *N.* sp., *Colania* sp., *Cancellina* sp., Schwagerinid, *Pachyphloia* sp., *Lunucammina* sp., *Paleotextularia* sp., *Climacammina* sp., *Globivalvulina* sp., *Kahlerina* sp., *Hemigordius* sp., *Agathammina* sp., have been obtained.

On the other hand, radiolarians (Locs. SO-5 to 7) occur in pelitic matrix indicate in age Early Jurassic to Late Jurassic. One of the radiolarian assemblages (Loc. SO-7) is characterized by *Canoptum rugosum* Pessagno and Whalen, *Bagotum erraticum* Pessagno and Whalen, *Katroma elliptica* Kishida and Hisada, *K. triangularis* Kishida and Hisada, *Parahsuum* sp., *Stichocapsa* sp. aff. *S. tegiminis* Yao, *Pantanellium* sp., and others. The co-occurrence of *Canoptum, Katroma* and *Bagotum* suggesting Early Jurassic is correlated with the part of *Parahsuum simplum* A-zone (Yao, 1982) and, indicates the Sinemurian to Pliensbachian. The radiolarian assemblage characterized by *Tricolocapsa plicarum* Yao, *T. tetragona* Matsuoka, *T.* sp, *Stichocapsa japonica* Yao, *Archaeodictyomitra* (?) *amabilis* Aita, *Hsuum* sp., and others, occurs in acidic tuff (Loc. SO-5). *Tricolocapsa plicarum* is a representative species of the *Tricolocapsa plicarum* Zone (Matsuoka and Yao, 1986), and *T. tetragona* is a characteristic species of *T. conex* Zone (Matsuoka and Yao, 1986). However because of the lack of *T. conex*, it is may assigned to the uppermost part of the *T. plicarum* Zone (Matsuoka and Yao, 1986) , suggesting the middle Middle Jurassic (probably Bathonian). The radiolarian assemblage from acidic tuff (Loc. SO-5) is characterized by *Archaeodictyomitra gifuensis* Takemura, *Parahsuum* sp., *Cinguloturris* sp., *Pseudoeucyrts* sp., *Mirifusus guadalupensis* Pessagno, *Parvicingula* sp. cf. *P. mashitaensis* Mizutani, *Tricolocapsa plicarum* Yao, *T.* sp., and others. Occurrence of *Tricolocapsa plicarum* ranges up to the upper part of the *Stylocapsa* (?) *spiralis* Zone of the Oxfordian (Matsuoka and Yao, 1986). *Mirifusus guadalupensis* was originally described from the Lower Tithonian of the California Coast Ranges by Pessagno (1977) and is a representative species of the *Mirifusus guadalupensis* A-zone of the Oxfordian (Kishida and Hisada, 1986). And these radiolarian fossils are probably assigned to the lower to middle Late Jurassic.

On the basis of the above-mentioned radiolarian datings, the northern unit is the Lower to Upper Jurassic olistostrome sediments, including exotic blocks of the Middle Permian limestone and Middle to Upper Triassic chert. Most of stratigraphic studies on the southern unit of the Chichibu Terrane in Kyushu have done in Yatsushiro and Usuki area. The southern unit distributed in Yatsushiro district is divided into four, namely the Yonaku, Yoshio, Amatsuki and Konose Zones from north to south, by the lithostratigraphic classification (Matsuoka et al., 1962; Matsumoto and Kanmera, 1964). The southern unit is demarcated on the north from the Northern and the Middle Belts (Hashirimizu Zone) in the Chichibu Terrane by the Haki Tectonic Line (Karakida et al., 1977) and is brought into the contact with the Shimanto Terrane on the south by the Osakama Tectonic Line (Kanmera, 1950). Recently on the basis of radiolarian records, biostratigraphy of the southern unit in this area has been reviewed by Nishizono and Murata (1983), and Sato and et al. (1986). As a result from those, it is re-divided into the Yonaku, Yoshio, Ebirase, Konose and Sakaguchi Formations from north to south (Murata, 1992). The Yonaku, Yoshio and Konose Formations represent pelagic sedimentary facies and the Ebirase and Sakaguchi Formations are neritic ones. According to Murata (1992), the Yonaku Formation mainly consists of pebbly mudstone including exotic blocks of chert, acidic tuff and siliceous shale, and olistolith of various litologys such as limestone, basic volcanics, pyroclastic rocks, calcareous sandstone, sandstone and chert. Radiolarian age of each lithofacies shows as follows; chert is the Late Triassic to Early Jurassic and the subordinating pebbly mudstone is the Middle Triassic. While, the Yoshio Formation on the south of the Yonaku Formation is made up of quite thick chert (lower member) grading upward into siliceous shale (upper member). The upper member mainly includes olistoliths composed of massive sandstone, limestone and basic pyroclastic rocks. Radiolarian ages are as followings; bedded chert of the lower member is the Early Triassic to early Early Jurassic and the siliceous shale of the upper member is the middle Early Jurassic. The Ebira Formation is lentically distributed in the middle of the Yoshio Formation and chiefly consists of alternating beds of sandstone and mudstone, intercalating acidic tuff, siliceous mudstone and chert. The formation includes exotic blocks of thick massive sandstone, chert, limestone and shale with the Middle to late Late Jurassic radiolarian fossils.

Considering of the correlation based on the lithological similarities between the green schist on the north of the northern unit and the Haki Green Schist (Matsumoto and Kanmera,1964) along the Haki Tectonic Line, the northern unit probably corresponds to the Yonaku Formation although the radiolarian age of the northern unit is clearly younger than that of the Yonaku Formation. The southern unit only extends about 5km in N-S at this district, while it covers approximately 13km at Yatsushiro district. This is mostly caused by the bending of the Butsuzo Tectonic Line. Moreover, the Northern and the Middle Belts (= Kurosegawa Terrane) in the Chichibu Terrane may thrust over larger at this district than at Yatsushiro district, that causes the lack of the middle Triassic to lowermost Jurassic Yonaku Formation. This idea suggests the northern unit is probably correlated with the Lower Triassic to lower Middle Jurassic Yoshio Formation or a part of the Ebira Formation intercalated within the Yoshio Formation in a fault contacts.

• Southern unit of the Southern Belt

The small occurrence of the southern unit is found in the southern end of the study area, south of the Shiroiwayama Thrust. The Late Jurassic to Middle Cretaceous radiolarian assemblages occur in pelitic rocks (Locs. SO-8 to 14) of the southern unit in the south of Obarai-Pass. Among these, the radiolarian assemblage obtained from Loc. SO-10 is characterized by *Stylocapsa* (?) *spiralis* Matsuoka, *S. lacrimalis* Matsuoka, *Tricolocapsa* sp. cf. *T. conexa* Matsuoka, *T.* sp., *Archaeodictyomitra* sp. These species are assigned to the *Stylocapsa* (?) *spiralis* Zone (Matsuoka and Yao, 1986), indicating early Late Jurassic (Oxfordian) in age (Yao, 1990). From Loc. SO-14, beside, the radiolarian assemblage characterized by *Mirifusus mediodilatatus* (Rust), *Parvicingula mashitaensis* Mizutani, *P. boesii* (Parona), *Stichocapsa* sp. cf. *S. clava* (Parona), *Patellula planoconvexa* (Pessagno), and others are obtained. The assemblages is late Late Jurassic to early Early Cretaceous in age, corresponding to the *Dictyomitra* sp. B – *Dictyomitra* sp. A A-zone of Yao (1984), or *Mirifusus mediodilatatus* – *Pseudodictyomitra* cf. *carpatica* A-zone which was defined at Yatsushiro area in the northern unit of the Chichibu Terrane by Nishizono and Murata (1983).

On the other hand, the radiolarian assemblage characterized by *Holocryptocanium barbui* Pessagno, *Pseudodictyomitra lodogaensis* Pessagno, *P. pentacolaensis* Pessagno, *P. vestalensis* Pessagno, *Sethocapsa cetia* Foreman, *Thanarla praeveneta* Pessagno, *Orbiculiforma maxima* Pessagno, *Archaeodictyomitra* sp. *Archaeospongoprunum* sp., and others, is found in siliceous shale (Loc. SO-12). *Holocryptocanium barbui* is a representative species of the *Holocryptocanium barbui* - *H. geysersense* A-zone of Nakaseko and Nishimura (1981) or the *H. barbui* A-zone of Yao (1984). According to Yao (1984), *Pseudodictyomitra lodogaensis* is known to occur only in the *H. barbui* A-zone and occurrence of *Thanarla praeveneta* is limited in age from Albian to Coniacian (Suyari, 1986). The other co-occurring species are also often found in Middle Cretaceous system and the radiolarian assemblage from Loc. SO-12 is correlated with the *H. barbui-H. geysersense* A-zone of Nakaseko and Nishimura (1981) or the *H. barbui* A-zone of Yao (1984), suggesting the Albian to Cenomanian (Nakaseko and Nishimura, 1981). The ages of exotic blocks of chert and limestone, indicating the ages stated above, were closely examined by means of conodont fossils (Murata, 1981). Murata (1981) obtained *Neogondolella* sp., *Hindeodella* sp., *Anchignathodus* sp. from the chert at Kunimi district to the southwest of the study area and *Neospathodus homeri, Neogondolella bulgarica, N. foliata, N. polygnathiformis, Epigondoella bidentata, Misikella hernsteini* from chert to the south of Kunimi-Pass, and suggests that each the two cherts range in age from Middle to Upper Permian, and from upper Lower Triassic to middle Upper Triassic, respectively. And in spite of rare occurrence of fossils in the limestone south of the Shiroiwayama Thrust, *Epigondolrlla primitia* suggesting the Upper Triassic was found in the limestone along on the north side of the Butsuzo Tectonic Line.

On the basis of the study on micro fossil biostratigraphy and lithology, Murata (1981) regarded the fundamental structure in this area, in which rocks and strata are divided into fragments by north dipping thrust faults (between the Shiroiwayama Thrust and Butsuzo Tectonic Line) as a shingle block structure. In this area, not having the younging polarity to the south (continental side), it have formed not by the accretion accompanying the subduction of plate at the trench of the continental side, but by the enormous sedimentation of geosyncline deposits with lateral change of lithofacies, and by the following tectonic movement closely associated with formation of the Butsuzo Tectonic Line. Although this investigation only covers northern end of this area (between the Shiroiwayama Thrust and Butsuzo Tectonic Line), in the south of the Obarai-Pass (show in Fig. 33), the uppermost Jurassic lowermost Cretaceous (Locs. SO-8.9), Upper Jurassic (Locs. SO-10.11), Middle Cretaceous (Loc. SO-12), uppermost Jurassic to lowermost Cretaceous members (Locs. SO-13.14) are seemed to expose with a few hundreds meters width from north to south in an apparent decreasing order. These facts are in accordance with the presence of the shingle block structure although any fault−exposures have not been identified yet. However, considering the existence of Upper Cretaceous strata, it is doubtful that the activity of the Sanbosan Geosyncline continued until the Upper Cretaceous, and it is more likely that the Permian and the Triassic cherts and some limestones were taken in the southern unit as exotic blocks before the formation of shingle block structure.

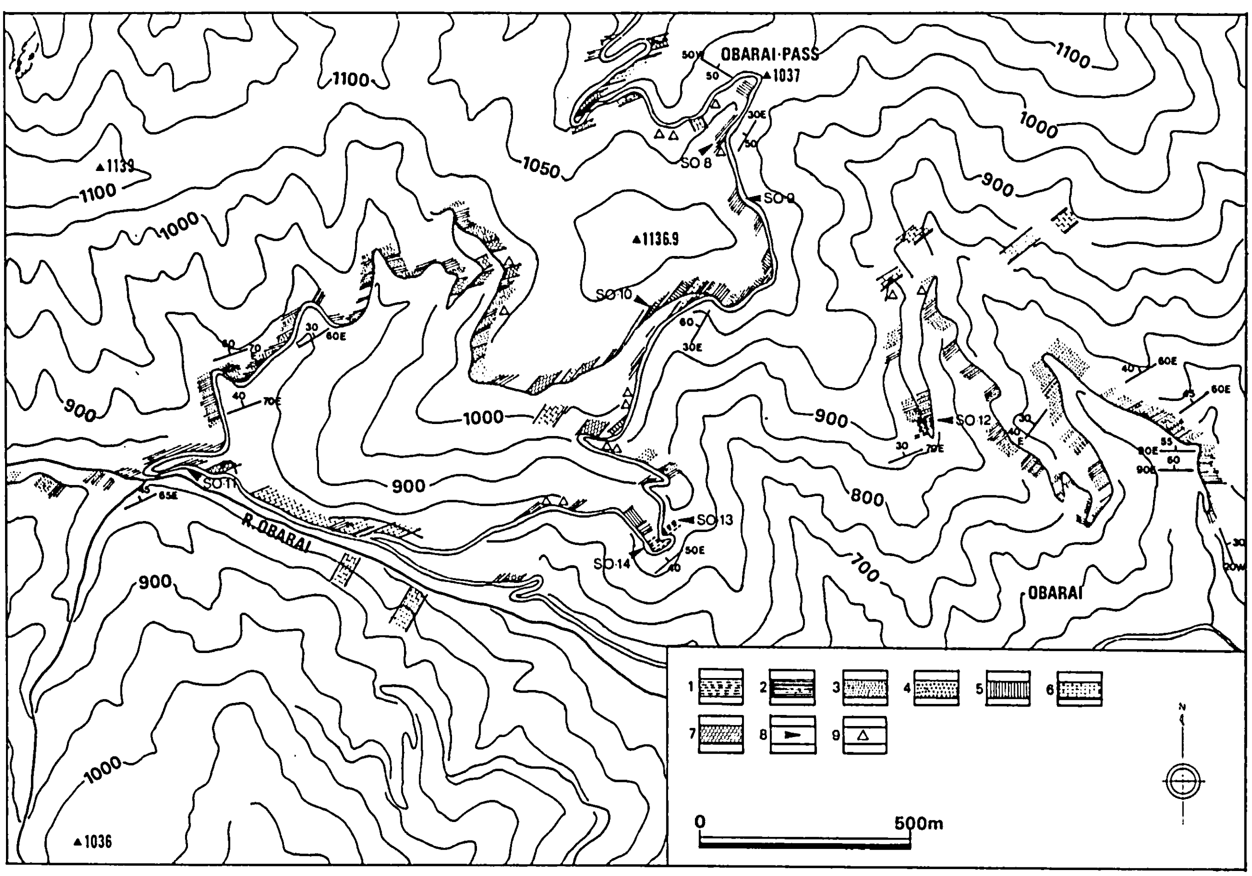


Fig. 33. Route map south of the Obarai-Pass.
1: siliceous shale, 2: shale, 3: sandstone, 4: conglomerate, 5: chert, 6: limestone, 7: green rock, 8: fossil Loc., 9: float

On the basis of above-mentioned discussions, a part of the southern unit is regarded as an equivalence of the Sakaguchi Formation (Nishizono and Murata, 1983) distributed in the southern margin of the Chichibu Terrane at Yatsushiro district. According to Nishizono and Murata (1983), the Sakaguchi Formation, which is situated in the southern margin of the Konose Zone, is almost equivalent to the Osakama Formation described by Kanmera and Furukawa (1964). It mainly consists of black to gray shale, which alternates with bedded chert and pale-green acidic tuff a few meters thick at the lower member and with fine-grained sandstone less than several tens centimeters at the upper member. At the lowermost member, beside, various rock masses, such as brecciated limestone, basic volcanic rocks, pyroclastic rocks, micritic limestone and massive sandstone, are contained as olistolith. Exotic chert blocks yield the Late Jurassic radiolarian assemblages, where as acidic tuff and shale bear the early Early to early Late Cretaceous ones. While, the district south of the Butsuzo Tectonic Line to the south of the study area is occupied by the Hinokage Formation (Imai et al., 1971) of the Morozuka Group in the Shimanto Terrane. Hinokage Formation is chiefly composed of alternating beds with various thickness dominated by turbidite-sandstone. (Sakai and Kanmera, 1981). The radiolarian assemblage characterized by *Holocryptocanium burbai, H. geysersensis, H. japonicum, Thanarla pulchra, Pseudodictyomitra pseudomacrocephara, Novixitus weyli,* and others are found in the thin acidic tuff intercalated within the middle member of Hinokage Formation (Sakai, 1985; and others). This is correlated with the *H. barbui - H. geysersense* A-zone of Nakaseko and Nishimura (1981), ranging in age from Albian to Cenomanian. This age is equal to the one of the southern unit (Loc. SO-12), and lithofacies is also resemble the alternating beds of sandstone and mudstone distributed around Loc. SO-12 (show Fig. 33). Thus, it is possible that a part of southern unit is correlated with the formation which develops within the Shimanto Terrane. In this case, because the geological sequences which share the same ages and similar lithofacies are distributed on the both northern and southern side of the Butsuzo Tectonic Line, it needs to reconsider the location of the Butsuzo Tectonic Line itself and its geotectonic significance.

IV-2. Neritic sedimentary facies

• Murono Formation

The Murono Formation yields *Monotis (Entomonotis) ochotica densistriata* (Teller) and *Monotis (Entomonotis) ochotica ochotica* (Keyserling) from greenish-gray medium sandstone (Locs. MU-1 to 3). Age and classification of *Monotis* are unified by Ando (1987). According to this, *Monotis ochotica densistriata* and *Monotis ochotica ochotica* is probably assigned to Norian. *Monotis* beds in Kyushu are follows; the Washidani Formation in Oita Prefecture with contents of *Monotis scutiformis, M. ochotica densistriata, M. ochotica ochotica* (Ando et al., 1987), the Tonegoyama Formation in Miyazaki Prefecture with contents of *M. ochotica* (Murata, 1981), at Arase Dam with *M. ochotica densistriata* and *M. ochotica ochotica* (Tamura, 1965), at Misaka district with *M. ochotica densistriata, M. ochotica ochotica, M. ochotica eurachis* (Kanmera, 1951), in Miyamadani district with M. ochotica densistriata, *M. ochotica ochotica, M. mabara* (Ando, 1987) and the Takagouchi Formation with a content of *M.* sp. cf. *M. typica* (Tamura and Murakami, 1985).

• Kanmuridake Formation

Sandy shale of the Kanmuridake Formation yields the Early Jurassic radiolarians at two localities (Locs. KN-1 and 2).

Radiolarian assemblage is characterized by *Archicapsa* sp. cf. *A. pachyderma* Tan Sin Hok, *Bagotum* (?) sp. cf. *B. helmetense* Pessagno and Poisson, *Canoptum* sp. cf. *C. merum* Pessagno and Whalen, *C.* sp., *Natoba* sp., *Parvicingula* (?) sp., *Stichocapsa* sp. and others, suggesting Early Jurassic. Among these, *Archicapsa pachyderma* is a characteristic species of the *Parahsuum* (?) *grande* A-zone (Yao, 1982; Matsuoka et al., 1994), of which first appearance is about the boundary between the Pliensbachian and the Toarcian (Yao, 1990). Consequently, the Kanmuridake Formation may have been accumulated during late Early Jurassic time (possibly Toarcian). The Kanmuridake Formation exhibits a well-organized stratification without exotic blocks such as chert, and different from Lower Jurassic olistostrome formation in lithofacies, such as the Yurugidake and Mamihara Formation. The Yurugidake Formation lies to the south of this formation, intercalating the Gionyama lenticular body, and the Mamihara Formation occurs to the north of it, intercalating the Upper Permian Kagamiyama Formation. In the Kurosegawa Terrane (Middle Belt of the Chichibu Terrane) in Kyushu, the Lower Jurassic neritic sediments which can be correlated with this formation is only the Nishinoiwa Formation (Miyamoto and Kuwazuru, 1993a) distributed in Yatsushiro district, Kumamoto Prefecture. According to Miyamoto and Kuwazuru (1993a), the Nishinoiwa Formation is made up of sandstone and shale, intercalating thin acidic tuff layer in places, and extends 1200m in thickness. Shale and acidic tuff contain the Early to Middle Jurassic well-preserved radiolarian fossils. The Nishinoiwa Formation is in a fault contacts at the both northern and southern boundaries with the Upper Permian Miyama Formation (equivalence of the Kagamiyama Formation) and the Lower Jurassic Hashirimizu Formation (equivalence of the Yurugidake Formation), respectively. Because this geological locatin is comparable to that of the Kanmuridake Formation in this study area, the Kanmuridake Formation is assumed to be the eastern extend of the Nishinoiwa Formation at Yatsushiro district. The occurrence of the Lower Jurassic neritic sediments distributed in the Kurosegawa Terrane such as the Nishinoiwa Formation (Lower to Middle Jurassic) and the Kanmuridake Formation had not been discovered in Kyushu. However in Shikoku, earlier reports of the middle to lower Jurassic neritic formations are the Nakanose Formation (possibly lowermost Jurassic) (Hada and Kurimoto, 1990) at Niyodomura district, Kochi Prefecture and the equivalents and the Keta Formation (the Middle Jurassic, Bajocian to Bathonian) (Matsuoka, 1985) at Sasagawa district, Kochi Prefecture and the equivalents. However, the ages of each formation more or less differ from those of the Nishinoiwa and Kagamiyama Formations, therefore, the exact correlation is still doubtful.

• Oishi Formation

Bivalves fossil available for age determination are obtained from gray, massive and fine grained sandstone (Locs. OI-4 to 6). From Locs. 4 and 5, *Tosapecten suzukii suzukii* (Kobayashi), *Mytilus (Falcimytilus)* sp. cf. *M.(F) nasai* Kobayashi and Ichikawa and *Chiamys* sp. cf. *C. mojsisovicsi* Kobayashi and Ichikawa are identified. These fossils are equal to those from the Upper Triassic Kouchigadani Group. In Kyushu, *Tosapecten suzukii* has reported form the Tanoura Formation (Matsumoto and Kanmera, 1964) and Takagouchi Formation (Tamura and Murakami, 1985) in Kumamoto Prefecture, the Tonegoyama Formation (Tamura, 1960a) in Miyazaki Prefecture, and the Kashimine Formation (Tanaka, 1989) in Oita Prefecture, most of which co-occur with *Halobia.* The age of the Kouchigadani Group and the correlatives are not determined precisely because of poor occurrence of ammonoids. However on the basis of the studies on ammonoids of the Kouchigadani Group in Shikoku (Bando, 1964), the *Halobia-Tosapecten* bed have contained *Paratrachyceras* n. sp., suggesting Middle Carnian.

Fine sandstone (Loc. OI-6) bears *Monotis (Entomonotis) ochotica ochotica* (Keyserling), indicating around the Norian (Ando, 1987).

Three radiolarian fossil assemblages having different ages are found in shale and acidic tuff of the Oishi Formation at three localities (Locs. OI-1 to 3). Acidic tuff (Loc. OI-1) yields poorly-preserved *Follicucullus* (?) sp., indicating Late Permian. Shale (Loc. OI-2) bears *Triasocampe* sp. cf. *T. nova* Yao, *T.* sp., *Canoptum* sp., among these, *Triasocampe nova,* which is a representative species of the *Triasocampe nova* A-zone, is originally described by Yao (1982) from chert at Inuyama district, Central Japan. *Triasocampe nova* occurs only the *Triasocampe nova* A-zone (Yao, 1982), ranging in age from Carnian to middle Norian (Yao, 1990). On the other hand, *Archaeodictyomitra* sp., *Hsuum* sp., *Tricolocapsa conexa* Matsuoka, *Tricolocapsa tetragona* Matsuoka are found in the shale (Loc. OI-3). Among these, *Tricolocapsa conexa* and *T. tetragona* are originally described from siliceous rocks at Sakawa and adjacent areas, Shikoku (Matsuoka, 1983). These species are characteristic species of the *T. conexa* Zone (Matsuoka and Yao, 1986), suggesting Late Bathonian to Early Oxfordian (Yao, 1990). Moreover, the occurrence of *T. tetragona* is limited in the middle part of the *T. conexa* Zone (Matsuoka,1983), therefore shale (Loc. OI-3) indicates Early Callovian.

As mentioned above, the Upper Triassic sandstone and mudstone and the Upper Permian acidic tuff are incorporated into the Upper Jurassic Oishi Formation representing turbidite facies. Among these, the possible sources of the Upper Permian sedimentary rocks are as follows; the Kuma (Kanmera, 1953), Kozaki (Kanmera, 1953), Miyama (Miyamoto, 1985), Kamoshishigawa (Tanimoto and Miyamoto, 1986) and Kagamiyama Formations (Saito and Kanbe, 1954; present paper) in Kurosegawa Terrane, western to middle Kyushu. The Kuma and Kozaki Formations mainly consist of sandstone, shale and alternating beds with well-organized stratification and intercalating conglomerate and limestone, but lacks chert and green rocks. While, the Miyama, Kamoshishigawa and Kagamiyama Formations are contemporaneous with the above-mentioned two formations, and show olistostrome facies which contains a large quantity of exotic blocks of chert and green rocks. Isozaki (1986) suggests that well-organized formation in Chichibu Terrane, such as the Kuma and Kozaki Formations, were accumulated in a fore-arc basin or at a basin upper of a trench-inner slope, which correspond to the stage of plate-subduction into the Kurosegawa micro-continent during Late Permian. He also regards the Shingai Formation (Isozaki, 1985) representing nearly contemporaneous olistostrome facies as deposits at convergent zone. The Shingai Formation can be correlated with the Miyama, Kamoshishigawa and Kagamiyama Formations in Kyushu. The differences between the two sedimentary environments provide a key to consider of the sedimentary place of the Oishi Formation itself, containing blocks originated from the Shinkai Formation. Recently, Miyamoto and his co-workers have directed their attention to elements of detrital garnets contained in sandstone of western Kyushu and examined the source of the Mesozoic and Palaeozoic sediments in the Chichibu Terrane. They (Miyamoto et al., 1992; Miyamoto and Kuwazuru, 1993a, 1994) have investigated the chemical composition of garnets in Upper Permian to Upper Cretaceous sandstone. The followings are the results.

1) In the Upper Permian well-organized formation (Kuma and Kozaki Formation) of the Kurosegawa Terrane, the majority of detrital garnets (Kuma Formation: 88%, Kozaki Formation: 95%) in sandstone consists of Ca-rich garnets containing more than 90 mol.% in grossular + andradite content. On the other hand, the detrital garnets in sandstone from the contemporaneous Miyama and Kamoshishigawa Formations of olistostrome facies are not Ca-rich garnet, and most of them are rich almandine content.
2) Detrital garnets in sandstone from the Mesozoic well-organized stratigraphic units (Upper Triassic system, Lower to Middle Jurassic Nishinoiwa Formation, Middle to Upper Jurassic system) on the south of Kuma Formation at Yatsushiro district are chiefly composed of almandine, Mg-rich almandine, spessartine, and rare grandite.

Thus, there are significant differences in chemical composition between the detrital garnets of the sandstone from Upper Permian well-organized formations and those from the olistostrome facies. On the basis of this result, for the type route near the locality, Loc. OI-1, which yields the Late Permian radiolarian fossils of Oishi Formation, the compositions of detrital garnets in sandstone are primarily reported. Fig. 34 shows lithofacies and sampling localities of the type route. On the fraction in this figure, a denominator shows total grains of detrital garnets, and a numerator is the number of included Ca-rich garnets, which contains more than 90mol.% in grossular + andradite content.

229 grains of detrital garnets, of 11 samples of sandstone collected from the Oishi Formation, Aratani district, have been analyzed by EPMA, using 8 elements (Si, Ti, Al, Fe, Mn, Mg, Ca and Cr).The chemical composition of garnets are plotted on two types of ternary diagrams (Fig. 35). As shown in (grossular + andradite) - (spessartine) - (pyrope + almandine) diagram, about 67% garnets (154/229) belong to Ca-rich type (containing more than 80 mol.% in grandite content). Fig. 36 represents the frequency distribution of grossular content for these Ca-rich garnets. And most of the remaining garnets are of pyralspite (almandine) type (containing less than 43 mol.% pyrope content).

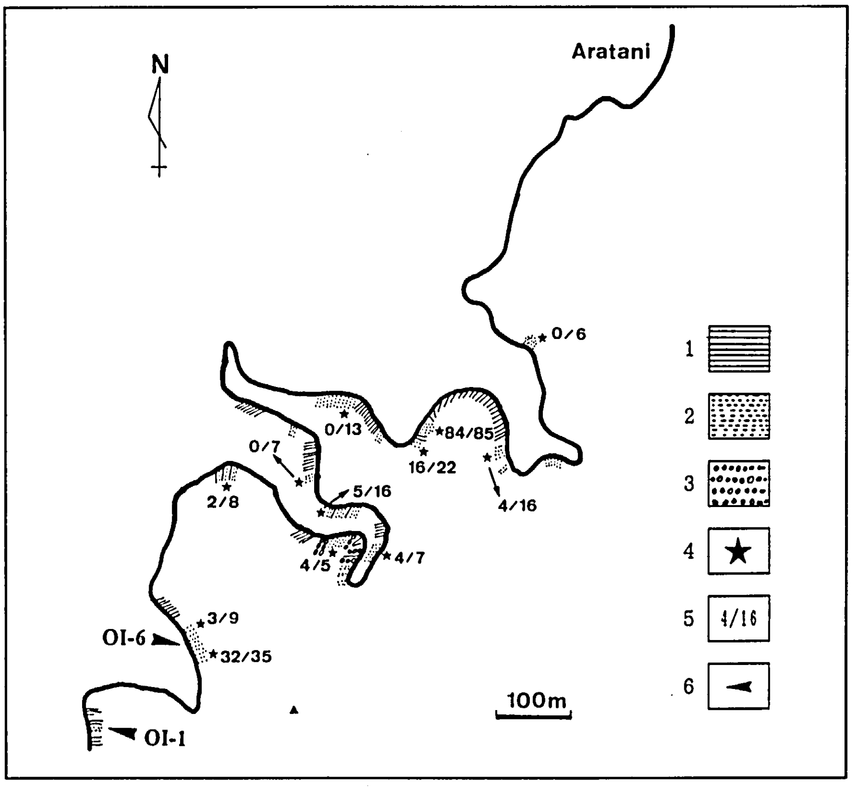


Fig. 34. Map showing localities of the examined sandstone and lithofacies from the Oishi Formation in the Aratani district.
1: shale, 2: sandstone, 3: conglomerate, 4: sample Loc., 5: Ca-rich garnet content, 6: fossil Loc.

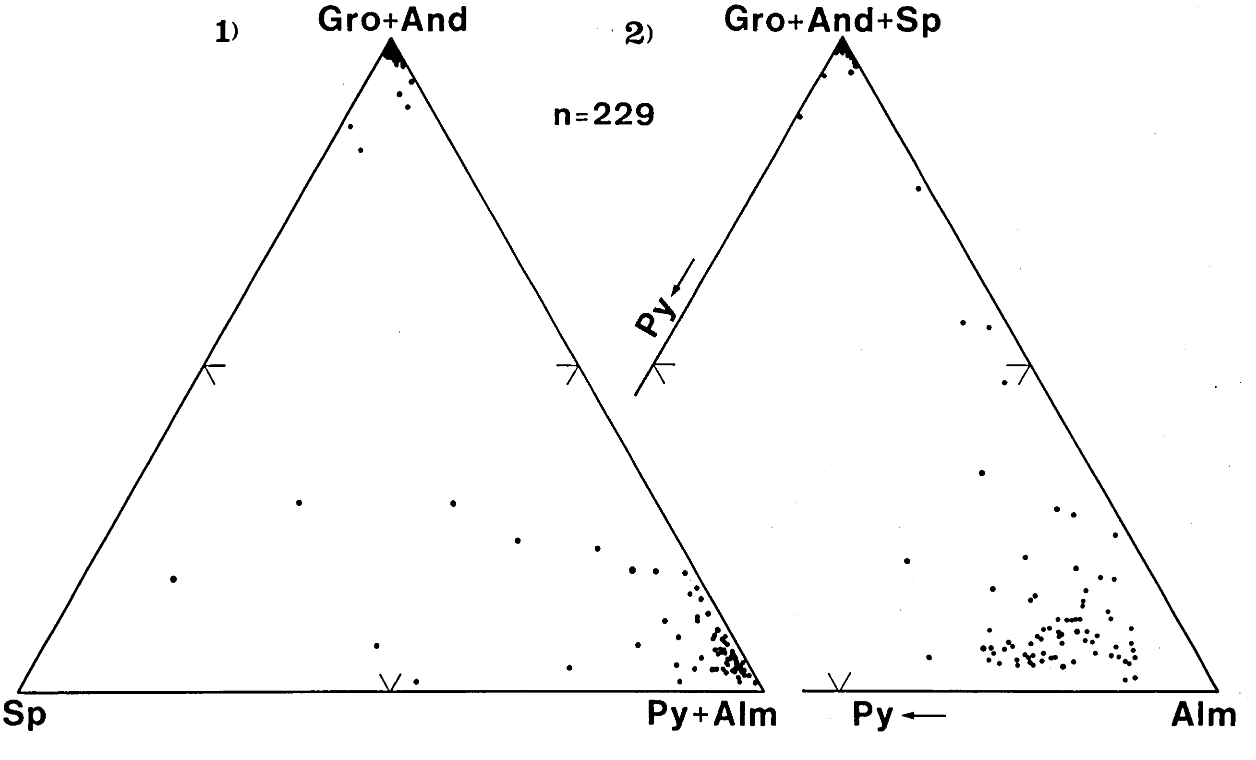


Fig. 35. Plots of chemical composition of detrital garnets in sandstone from the Oishi Formation in the Aratani district. Py: Pyrope, Alm: Almandine, Sp: Spessartine, Gro: Grossular, And: Andradite.

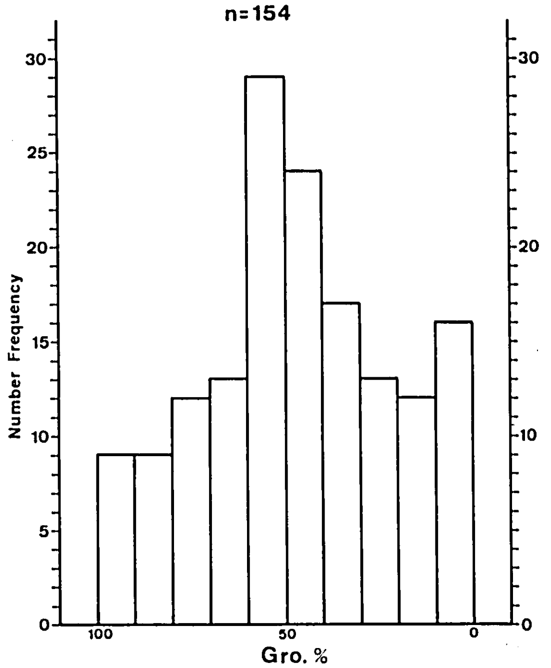


Fig. 36. Frequency (%) distribution with respect to grossular content (mol%) in Ca-rich garnets in sandstone from the Oishi Formation.

It should be noted here that content of Ca-rich garnet form each sampling point is variable. In a sample, Ca-rich garnet occupies about 99% (84/85), while, three samples (among 11 samples) have no Ca-rich garnets (Fig. 34). This suggests that the Oishi Formation contains sandstone blocks ranging in age from Upper Permian to Upper Triassic. With considering primary reports obtained from detrital garnets of Oishi Formation with the results. (Miyamoto et al., 1992; Miyamoto and Kuwazuru, 1993a, 1994), at least some of the Permian sandstones and mudstones are consider to be derived from the neritic well-organized stratigraphic units of Kuma Formation type which have been accumulated in a fore-arc basin or a basin upper inner slope of trench. The rocks of which main component is Ca-rich garnet are generally originated from contact or thermally metamorphosed impure calcareous sediments, particularly metasomatic skarn deposits. However, this does not suggest the direct hinterlands of the Oishi Formation. Thus, on sedimentary environment of the Oishi Formation, it may result from flowing of gravity gliding such as turbidity current and subsolifluction down to sedimentary basin or ocean floor during Late Jurassic, accompanying with mixing with Upper Permian or Upper Triassic rocks. It have not reported that the occurrence of sediments with sedimentary features like the Oishi Formation in Southwest Japan so far. The Sakamoto Formation distributed along the Kumagawa, Kumamoto Prefecture (Omachi, 1938; Tamura, 1960b) and the Shinkai Formation Miecho, Oita Prefecture (Fujii, 1954) are known as the Upper Jurassic neritic sedimentary facies of the Kurosegawa Terrane on Kyushu. However, lithofacies of them differ from that of Oishi Formation in containing limestone correlated with the Torinosu Group in Shikoku.

• Togawa Formation

The Togawa Formation is characterized by the frequent occurrence of red-colored rocks, and contains non-marine and marine molluscans listed in Table 7. The age of the formation is not determined precisely, because no leading fossil has been obtained. It is, however, probably referable to the Hauterivian to Lower Barremian, judging from the following line.

1) The non-marine bivalves fauna of the Togawa Formation is closely similar to the Ryoseki Fauna widely distributed in Lower Cretaceous of the Outer Zone of Southwest Japan. The uppermost member contains a few marine bivalve such as *Pterinella shinoharai*, *Eonavicula shinanoensis*. These marine bivalves have been known to occur from the Monobe Formation of Shikoku, which is characterized by the occurrence of *Crioceratites* and other ammonoids of Lower Barremian.
2) The Tsubana Formation, characterized by the occurrence of the Barremian ammonoids, conformably covers the top of the Togawa Formation.

From the fossil-contents and the stratigraphic position, the formation in question is comparable to the Shiroi Formation of Sanchu area (Matsukawa, 1977, 1979, 1983), the Yuasa Formation of the Aritagawa area (Hirayama and Tanaka, 1956), Tatsukawa Formation of the Katsuuragawa area (Nakai, 1968), Ryoseki Formation of the Monobegawa area (Tashiro et al., 1980) and Koshigoe Formation of the Haidateyama area (Tanaka, 1989).

• Tsubana Formation

This formation is characterized by the occurrence of shallow marine fossils, such as pelecypods, gastropods and echinoids. In addition, ammonoids e.g. *Shasticrioceras* sp. is obtained from the upper part (Loc. TS-1). *Shasticrioceras*, which indicates Barremian in age, has been recorded from the Lower Horsettown Group in California (Anderson, 1938). In Japan, it occurs from the Ishido Formation of the Sanchu area (Matsukawa, 1983), the Idaira Formation near Lake Hamana (Hayashi et al., 1981), the Arida Formation of the Aridagawa area (Obata and Ogawa, 1976), the Monobe Formation of the Monobegawa area (Tashiro et al., 1980) and the Osaka Formation of Haidateyama area (Tanaka, 1989).

The bivalve fauna of the Tsubana Formation is closely similar to that of the Haidateyama Formation, and is comparable with the faunas of the Monobe and Ishido Formations.

From the evidence of fossils mentioned above, the Tsubana Formation undoubtedly assigned to Barremian.

• Kasabe Formation

The Kasabe Formation contains abundant bivalve shells, together with gastropods. They listed in Table 9. Among the identified species, *Myrtea* (?) *monobeana*, *Astarte (Astarte) subsenecta*, *Astarte (Nicaniella) costata*, *Yabea densecrenulata*, *Goshoraia minor* are common or diagnostic. The bivalve fauna from the Kasabe Formation resembles the faunas of the lower part of the Hibihara Formation (Aptian) of the Monobegawa area (Tashiro et al., 1980), the Kimigahama Formation (Aptian) of the Choshi area (Hayami and Oji, 1980) and the Miyaji Formation of the Yatsushiro area, containing the Aptian genera and species such as *Goshoraia minor, Astarte (Nicaniella) costata, Yabea* sp. From the evidence of fossils mentioned above, the Kasabe Formation can safely be assigned to Aptian.

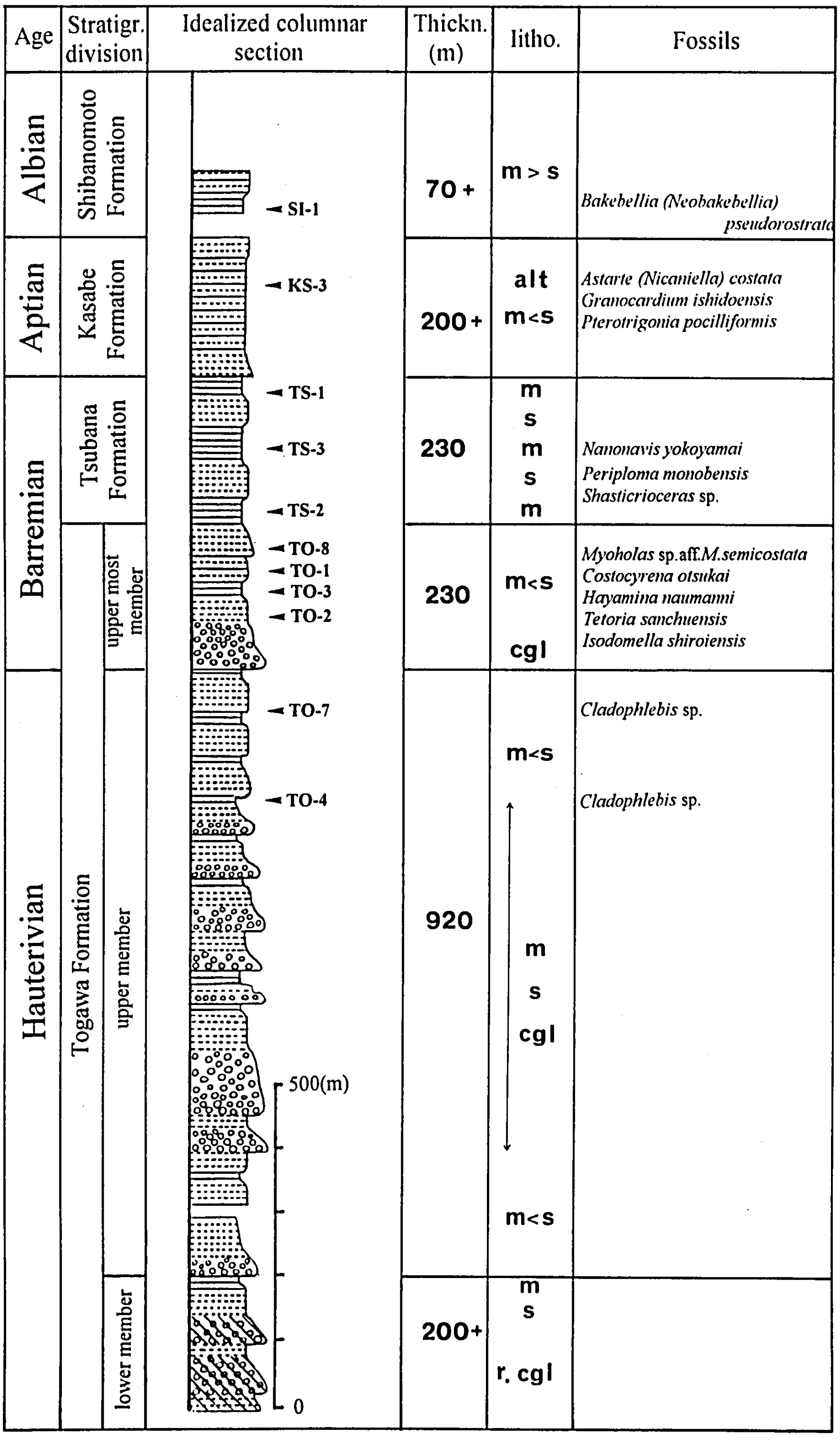


Fig. 37. Total lithological columnar sections of the correlatives of the Monobegawa Group (Togawa, Tsubana, Kasabe, and Shibanomoto Formations).

• Gokase Formation

Although there is no reliable fossil, the Gokase formation may roughly be correlated to Aptian or thereabout, judging from the following lines.

1) The Gokase Formation, about 220m thick, is mainly composed of thickly bedded conglomerate with occasional intercalations of thin layers of coarse-grained sandstone, and unconformably overlies the Oishi Formation.
2) The most striking feature of the conglomerate contains the boulder of granitic rocks.

Plenty of granitic rocks are found in Cretaceous sediments in the Outer Zone in Southwest Japan, for example conglomerate in the lower member of the Hibihara Formation in Shikoku (Tanaka et al., 1984; Tashiro, 1993) and of the Hinagu Formation in Kumamoto Prefecture (Tashiro and Ikeda, 1989). They indicate Aptian in age, therefore, this conglomerate has probably formed during the Aptian.

• Shibanomoto Formation

The Shibanomoto Formation is characterized by the occurrence of bivalves such as *Bakevellia (Neobakevellia) pseudorostrate* (Nagao) and others. Although the bivalve fossils are very rare in the occurrence from the Shibanomoto Formation, a fragmemtal inoceramid specimen which was not able to determine the specific taxa, was collected by the author. This bivalve has been recorded from the Albian strata of Japan, e.g. the upper part of the Hibihara Formation of the Monobegawa area (Tashiro and Kozai, 1984) and the Tomochi Formation of the Yatsushiro area (Hayami, 1975).

• Kubo Formation

The Kubo Formation contains abundant bivalve shells listed in Table 10. The bivalves have already been described by Tashiro et al. (1992). The representative species are *Cucullaea (Idonearca)* sp. cf. *C. (I.) amaxensis, Modiolus tamurai, Phelopteria* sp. aff. *P. electa, Entolium ikedai, Amphidonte (Amphidonte) subhariotoidea, Pterotrigonia (Pterotrigonia) takahatensis, Astarte (Astarte) yatsushiroensis, Astarte (Nicaniella) makibaensis, Bungoella* sp., *Anthonya* sp. aff. *A. mifunensis.*

Cucullaea (Idonearca) sp. cf. *C. (I.) amaxensis* Matsumoto is smaller in size than the type specimen of *Cucullaea amaxensis* Matsumoto (1938) from the Goshonoura Group in central Kyushu (Uppermost Albian to lowermost Cenomanian), the other diagnostic features of this specimen are nearly identical with those of the type specimen described by Matsumoto (1938).

Modiolus tamurai Tashiro and Tanaka is safely identified to *Modiolus* sp. from the Middle Cenomanian Mifune Group in central Kyushu, described by Tamura (1976) with the same species, judging from in each conspecific features, e. g., the smooth surface, the subterminal and less prominent umbo, the depressed escutcheonal area, the shallow radial sulcus on disk and the elongated outline.

Phelopteria sp. aff. *P. electa* Tamura resembles *Phelopteria electa* Tamura (1997), from the Middle Cenomanian Mifune Group of central Kyushu, in its outline of valve and ligamental and dental structures of the hinge. This is, however, characterized by smaller size of the valve and the thinner test. It is possible that this specimen is an immature or of *P. electa.*

Entolium ikedai Tashiro is undoubtedly conspecific with *Entolium ikedai* Tashiro (1990), from the Kesado Formation of the Pre-Sotoizumi Group in central Kyushu, judging from its rounded outline of the valve, and delicate but distinct and numerous concentric ribs on the disk.

Amphidonte (Amphidonte) subhariotoidea Nagao seems that the occurrence of this species are restricted from the distributions of the Miyako Group (Aptian to Albian), the Nankai Group (Aptian), the Pre-Sotoizumi Group (Barremian to Aptian) and Doganaro Formation (Barremian to Aptian) of the Shimanto Belt.

Pterotrigonia (Pterotrigonia) Takahatensis Tashiro and Tanaka resembles *Pterotrigonia* (s. l.) *obsoleta* (Nakano, 1958) from the Goshonoura Group (Part of the uppermost Albian) of the central Kyushu, in its crescent outline, number of costae on the disk, and arrangement of the costellae on the escutcheon.

Astarte (Astarte) yatsushiroensis Tashiro and Tanaka is discriminated *A. (A.) subsenecta* by its more numerous crenulations of inner margin and subtrigonal outline, and weaker and less numerous external concentric ribs. Like this species, occurred from the Yatsushiro Formation, had been listed as *A. (A.) subsenecta* Yabe and Nagao by some authors (e.g., Hayami, 1965; Matsumoto, 1954; Tashiro and Ikeda, 1989).

Astarte (Nicaniella) makibaensis Tashiro and Kozai is somewhat larger in size than *A. (N.) makibaensis* Tashiro and Kozai (1988) from the Nankai Group in Shikoku. This is, however, undoubtedly conspecific with *A. (N.) makibaensis,* with another features which were described in detail by Tashiro and Kozai (1988).

Bungoella sp. very resembles to *Bungoella yabeaformis* Tashiro and Matsuda (1985), from the Upper Albian Sukubo Formation (Tanaka, 1989) of central Kyushu, in its subtrigonal outline, smooth external surface and strong inflation of the valve, and its prosogyrate prominent umbo.

Anthonya sp. aff. *A. mifunensis* Tamura closely resemble to *Anthonya mifunensis* Tamura (1977), from the Middle Cenomanian Mifune Group in central Kyushu, in having its concentric or horizontal ribs which were located partially on the anteriormarginal part of the disk.

From the evidence of fossils mentioned above, the Kubo Formation is roughly correlative with Upper Albian or thereabout. The Kubo fauna contains some elements of both the Pre-Sotoizumi-type and Ryouke-type faunas of the Inner Zone of Southwest Japan Fauna.

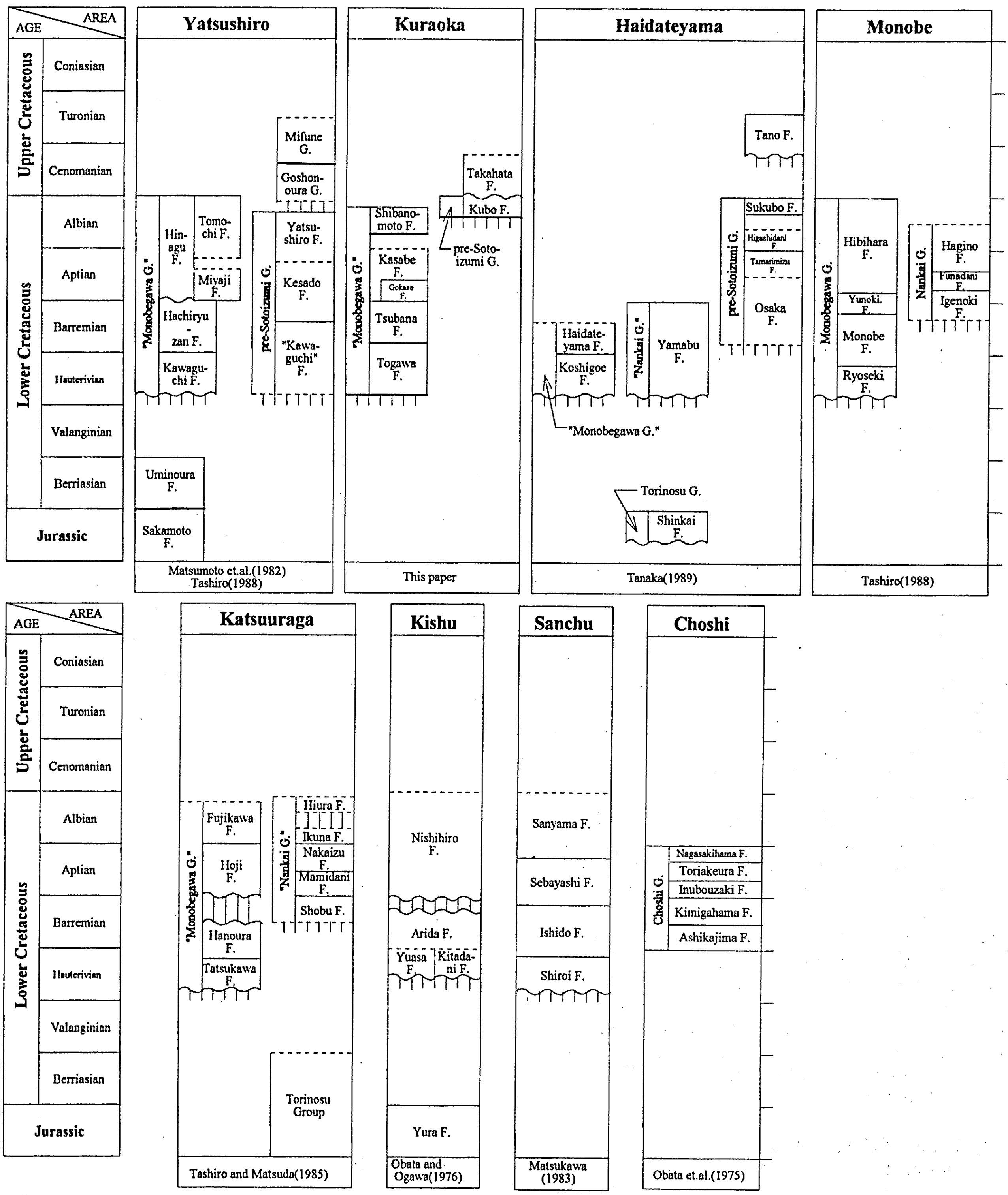
• Takahata Formation

Although there is no reliable fossil, the Takahata Formation is probably referable to Upper Albian to Lower Cenomanian, judging from the following lines.

1) The Takahata Formation unconformably overlies the Kubo Formation, the latter of which is characterized by the occurrence of Late Albian bivalves.
2) The formation is comparable with the Upper Cenomanian Tano Formation of the Haidateyama area (Teraoka, 1970), the Cenomanian to Turonian Mifune and middle Albian to middle Cenomanian

Goshonoura Formations of the Yatsushiro area (Matsumoto, 1938; Tamura, 1976) from its lithofacies represented by thick-bedded red conglomerate with occasional intercalation of thin layers of coarse to medium grained sandstone.

Table 15. Correlation of the lower Cretaceous strata in the Outer Zone of the Southwest Japan.



V. Geological development

Since the concept of geosynclinal orogenesis after Kobayashi (1941), the tectonic development of the Chichibu Terrane including the Kurosegawa Terrane had been discussed on the basis of the Chichibu (Kobayashi, 1941) and Honshu (Yamashita et al., 1957) geosyncline for a long time. However, the following opinions based on plate tectonics and detailed biostratigraphic studies of microfossils have been developed later. One is that the northward movement of the Kurosegawa micro-continent result in collision and accretion with east margin of the Asia (Kanmera, 1980; Ichikawa, 1982; Maruyama et al., 1984; and others.), followed by the tectonic breakup and deplacement by lateral fault (Taira et al., 1981). And another is that the Kurosegawa lenticular rocks are the south extended tectonic outliers of the pre-Jurassic system containing the Sangun metamorphic rocks (Isozaki and Itadani, 1991; and others.). From these recent studies, formation of constituents of the Chichibu Terrane distributed in middle to western Kyushu will be examined in this chapter.

V-1. Upper Permian stage

During the Early Permian, the oceanic plate dipped to the south along the northern margin of the Kurosegawa micro-continent (Isozaki, 1986; Tominaga, 1987; Kanmera et al., 1992), and the Upper Permian accretionary complex such as the Kagamiyama, Miyama and Kamoshishigawa Formation were formed along the convergent zone. Some of the accreted materials undergone by a subduction-associated metamorphism before the Middle Permian may have been already uplifted near the surface, providing metamorphic rocks contained in the Kagamiyama and Miyama Formations as exotic blocks. The well-organized Kuma and Kosaki Formations have been accumulated as contemporaneous heterotopic facies in the fore-arc basin along the northern margin of the Kurosegawa micro-continent or the basin at the upper trench-inner slope. Because the Kozaki Formation is unconformably overlain by the Upper Triassic continental shelf sediments (Kanmera, 1961) in Yatsushiro district, these neritic formations may have been uplifted and exposed before Late Triassic at least. Deferences in chemical composition of the detrital garnets of these two contemporaneous sedimentary facies indicate the different hinterlands. This indicates the gap in age between sandstone blocks of the Upper Permian accretionary complex and the Upper Permian well-organized strata. During this gap, metamorphosed impure calcareous sediments particularly metasomatic skarn deposits, which are probably sources of Ca-rich garnet in well-organized strata seems to have uplifted and exposed for erosion. On the other hand, the oceanic plate subducting along the Yangtze craton to the north of the Kurosegawa micro-continent, forming accretionry complexs such as the Sangun-Chugoku Terrane (Kanmera and Nishi, 1983; and others).

V-2. Upper Triassic stage

In this stage, neritic continental shelf facies such as the Murono Formation have been accumulated in shallow sea around the Kurosegawa micro-continent. During the deposition of the Triassic sediment, the above-mentioned Upper Permian formations uplifted and eroded, as indicated by partly unconformable contact with the Triassic neritic sedimentary facies.

V-3. Lower to Middle Jurassic stage

In this stage, the constituents of the Northern Belt of the Chichibu Terrane (Mamihara and Yurugidake Formations) have been formed. These formations represent olistostrome facies as an accretionary complex. The constituents of the Northern Belt of the Chichibu Terrane appear on both northern and southern sides of the Kurosegawa Terrane (north: Shimodake Formation, south: Hashirimizu Formation) at Yatsushiro district, Kyushu (Miyamoto, 1990). The same constitutional arrangement of the terrane is also found in this area. Accordingly, it suggests that this structure probably develops in a vast area from western to middle Kyushu. The nappes of the Kurosegawa Rocks clearly thrust over at some areas such as Kyushu (Sonoda and Hara, 1984), southern Kishu (Maejima, 1978) and the Kanto Ridge (Tokuda, 1986). From these facts, it is easy to understand the concept that the Kurosegawa Rocks have thrust over the Jurassic accretionary complex formed at the convergent zone of the southern margin of the Kurosegawa micro-continent by the successive tectonic movement, rather than the one of contemporaneous subduction forming accretionary complexes at the northern and the southern sides of the Kurosegawa micro-continent. Along the northern margin of the Kurosegawa micro-continent, ceasing of the subduction forming the Upper Permian accretionary complex such as the Miyama and Kagamiyama Formations and the successive collapse of fore-arc basin resulted in the deposition of the Lower Jurassic Kanmuridake and Nishinoiwa Formations distributed in a very limited area in the Middle Belt of the Chichibu Terrane. While, the formation of the Southern Belt of the Chichibu Terrane started since Early Jurassic. The Nankai Group (Tashiro, 1985a) of the Lower Cretaceous neritic sedimentary facies, closely resembles to the Upper Jurassic to Lower Cretaceous Torinosu Group occuring within the Southern Belt. The bivalves fauna of the Nankai Group belongs to the Tethyan fauna in warm water (Tashiro, 1993; and others) and differs from the bivalve fauna (Ryoseki fauna) of the Lower Cretaceous Monobegawa Group (Tashiro, 1985b) unconformably overlying the Northern and Middle Belts of the Chichibu Terrane. Although the Torinosu and Nankai Groups are not found in the study area, most of them are regarded as autochthonous sedimentary formations overlying the Southern Belt of the Chichibu Terrane (Tamura and Murakami, 1987; Tashiro and Katto, 1986; and others). The differences in these faunas suggests the different location of their basements, the Northern-Middle and Southern Belts of the Chichibu Terrane at least until the Early Cretaceous. Considering the development of reefal limestone represented by the Torinosu Group, and the bivalve faunas of the Nankai Group, a part of the Southern Belt is assumed to be formed to the south of the initial location of the Northern-Middle Belts.

V-4. Upper Jurassic stage

This stage is represented by the deposition of the

Upper Jurassic Oishi Formation. As stated above, development of the fault system with a NE-SW trend disturbs construction of the exact stratigraphy of the Oishi Formation. However, this formation apperas to contains exotic blocks of granitic rocks and acidic tuff originated from the Kurosegawa rocks in the lowermost part, and of the Upper Permian sandstone and acidic tuff and the Upper Triassic sandstone with various ages in the upper part. These exotic blocks are all derived from the Kurosegawa micro-continent and the surrounding area, not from an oceanic origin except for chert gravel of slump breccia. Most of the Oishi Formation shows turbidite of alternating beds of sandstone and mudstone, containing the Early Callovian radiolarian fossils in shale. Further sedimentological investigations are necessary for understanding of sedimentary condition of the Oishi Formation with unique lithofacies. From Late Jurassic to early Early Cretaceous time, the Kurosegawa micro-continent and accompanying sedimentary facies collided and accreted to the Sino-Korean craton (Kanmera et al., 1992; Ozaki et al., 1985; Taira et al., 1983; and others). And this collision followed violent thrust movement of accretionary complex, forming nappes in Southwest Japan (Ozawa et al., 1985; and others). From the lithofacies and age, the Oishi Formation is probably the material broken down to the front margin of the thrust sheets of these accretionary complex (containing associated with the thrust movement that the Middle Belt (=Kurosegawa Terrane) thrust over the Northern Belt of the Chichibu Terrane in western and middle Kyushu). The correlatives of the Oishi Formation have not found from outside of the study area so for. One of the reasons is the larger occurrence and less erosion of the Kurosegawa Terrane in middle and western Kyushu than in any other region. Besides some Monotis beds in Kyushu are probably mixed into turbidite of alternating beds of sandstone and mudstone in blocks, and it needs total examination by using radiolarian fossils from the pelitic -matrix. On the other hand, the accretion of the Southern Belt of the Chichibu Terrane continued and the formation of the Torinosu Group started.

V-5. Lower Cretaceous stage

This stage is characterized by the Lower Cretaceous neritic sedimentary facies of the Togawa, Tsubana, Kasabe and Shibanomoto Formations which are the correlatives of the Monobegawa Group. Distribution of paleocurrents and gravel size may suggest that the sediments provided from the west (Tashiro, 1985; Tanaka, 1989). With respect to gravel composition of each horizon, increase in gravel content across Aptian suggests that a part of the Kurosegawa Terrane which collided during these phenomena emerged and began to be eroded. The southward drainage developed in a part of the uplifted Kurosegawa Terrane, formed the Gokase Formation unconformably overlying the Oishi and Yurugidake Formations, and others. On the Southern Belt of the Chichibu Terrane, the Nankai Group, contemporaneous heterotopic facies of the Monobegawa Group, was formed during the plate subduction forming the Northern Belt of the Shimanto Terrane.

V-6. Upper Cretaceous stage

This stage is characterized by the disappearance of basins of the Monobegawa Group and the accumulation of the Upper Cretaceous Onogawa Group of the Inner Zone. In the Ryoke Terrane, the Upper Cretaceous neritic sedimentary facies represented by the Onogawa Group began to be accumulated in the fore-arc basin along the Median Tectonic Line and followed by the Izumi Group with a eastward movement of the sedimentary site (Taira et al., 1981; and others). From the fossil evidence of the Kubo Formation and the unconformably overlying Takahata Formation, they are not considered to be involved in the Lower Cretaceous Monobegawa Group of the Chichibu Terrane, but are the basements of the Upper Cretaceous Goshonoura Group of the Ryoke Terrane and the Onogawa Group or underlain by the pre-Sotoizumi Group (Tashiro, 1993). Moreover, in considering the distribution, the Kubo and Takahata Formations which now occur south of the Median Tectonic Line is regarded as a nappes of the Ryoke Terrane. One possible reason of the formation of the nappes from the north is the reduction of the front-arc involved in the opening of the Japan Sea after the Mesozoic (Takeshita, 1991). The Southern Belt of the Chichibu Terrane have relatively moved northwards to the present location where the Monobegawa Group meets Nankai Group by the lateral movement owing to the slanting plate-subduction.

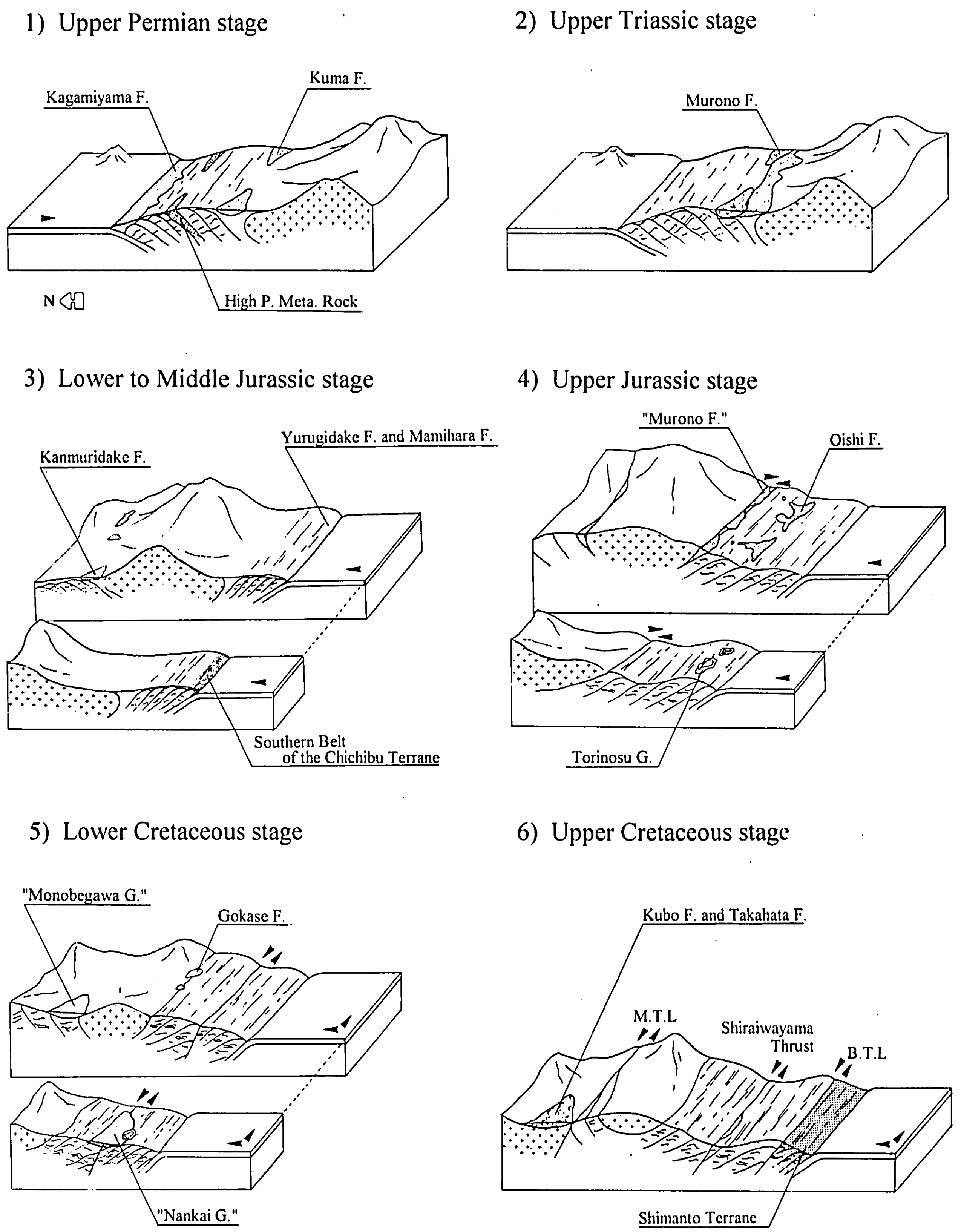


Fig. 38 Schematic paleogeographical profiles across the Chichibu Terrane in Central Kyushu. (not to scale)

VI. Summary and conclusion

1) The Chichibu Terrane distributed in Kuraoka district, Miyazaki Prefecture, Central Kyushu is subdivided into three, namely the Northern, Middle and Southern Belts. The components of the Northern Belt are the Yurugidake and Mamihara (newly named) Formation. The Middle Belt consists of the Kuraoka Igneous Rocks, the Silurian to Devonian Gionyama, "Green Shist", Kagamiyama (redefined), Upper Triassic Murono, Kanmuridake (newly named) and Oishi (redefined) Formations and the Cretaceous neritic sedimentary formations. The Southern Belt is subdivided into the northern and southern units.

2) The Yurugidake Formation is the Lower Jurassic olistostrome formation containing exotic blocks of the Lower Permian limestone and the Middle Permian to Lowermost Jurassic chert, and is correlated with the Lower Jurassic Hashirimizu Formation (Matsumoto and Kanmera, 1952; Miyamoto and Kuwazuru,1993b) distributed in the western study area, Yatsushiro district, Kumamoto Prefecture.

3) The Mamihara Formation is assigned to the northern margin of the Kagamiyama Formation (Saito and Kanbe, 1954) which had been considered to be the Middle Permian. It is an olistostrome formation, which mainly consists of pebbly mudstone with exotic blocks of massive to bedded sandstone, chert and poor green rocks, containing the Late Triassic to early Early Jurassic radiolarian fossils in chert blocks. The radiolarians such as *Archicapsa* sp., *Bagotum* sp., *Mesosatunalis* sp., *Orbiculiforma* sp., *Tricolocapsa* (?) sp., *Parahsuum ovale* Hori and Yao, *Parahsuum* sp., and others are obtained from the pelitic-matrix, and suggest Early Jurassic. The Mamihara Formation is correlated with the Shimodake Formation in Yatsushiro district (Kanmera, 1952; Miyamoto, 1990).

4) The redefined Kagamiyama Formation is regarded as an accretionary complex of the Late Permian. It represents an olistostrome facies mainly composed of pebbly mudstone, intercalating shale and acidic tuff, and contains exotic blocks of sandstone, chert, green rocks, serpentinite and rare limestone. Some of the exotic blocks are undergone by high pressure-low temperature metamorphism of jadeite-glaucophane facies, and the metamorphic blocks is a character of lithofacies. The pelitic-matrix yields radiolarian fossils correlated with the *Follicucullus charveti-F. porrectus* A-zone (Kozur, 1993) such as *F. charveti Caridroit, F. dilatatus* Rudenko, *F. porrectus* Rudenko, *F. scholasticus* Ormiston and Babcock and *Nazarovella gracilis* De Wever and Caridroit, indicating early Late Permian.

5) Judging from the age, lithofacies, and the tectonic position, the Kagamiyama Formation is clearly correlated with the Upper Permian Miyama Formation (Miyamoto, 1985) in Yatsushiro district and the Late Permian accretionary complex widely occurs within the Middle Belt of the Chichibu Terrane in western to middle Kyushu (Miyama Formation, Kamoshishigawa Formation (Tanimoto and Miyamoto, 1986) and Kagamiyama Formation).

6) Distribution of the Kanmuridake Formation is restricted in a small area within the southern end of that of the previous definition (Saito and Kanbe, 1954). It is an well-organized formation composed of alternating beds of sandstone and mudstone without exotic blocks of chert. The radiolarian assemblage characterized by *Archicapsa* sp. cf. *A. pachyderma* Tan Sin Hok, *Bagotum* (?) sp. cf. *B. helmetense* Pessagno and Poisson, *Canoptum* sp. cf. *C. merum* Pessagno and Whalen, *Natoba* sp., *Parvicingula* (?) sp., and others is obtained from sandy shale. These fossils are correlated with the *Parahsuum* (?) *grande* A-zone (Yao, 1982; Matsuoka et al., 1994), indicateing the late Early Jurassic (probably Toarcian). The Kanmuridake Formation is considered to be the east extend of the Lower to Middle Jurassic Nishinoiwa Formation (Miyamoto and Kuwazuru, 1993a) in Yatsushiro district.

7) The redefined Oishi Formation lies along the southern margin of the Gionyama lenticular body. The apparent lowermost part of this Formation contains exotic blocks of granitic rocks and bluish-green acidic tuff, derived from the Gionyama lenticular body, and the upper part contains the Upper Permian sandstone and acidic tuff with *Follicuculus* (?) sp. and the Upper Triassic sandstone with *Tosapecten suzukii suzukii* (Kobayashi), *Mytilus* (Falcimytilus) sp. cf . *M. (F.) nasai* Kobayashi and Ichikawa, *Chiamys* sp. cf. *C. mojsisovicsi* Kobayashi and Ichikawa and *Monotis (Entomonotis) ochotica ochotica* (Keyserling), suggesting various ages. These exotic blocks are originated from the continent and surrounding facies, and have no rocks from the ocean floor with exception of chert in slump breccia. Most of the Oishi Formation represents a turbidite facies of alternating beds of sandstone and shale. And the shale bears radiolarians such as *Archaeodictyomitra* sp., *Hsuum* sp., *Tricolocapsa conexa* Matsuoka, *T. tetragona* Matsuoka, suggesting Early Callovian.

8) On sedimentary environment of the Oishi Formation with unique lithofacies, it may result from gravity flow such as turbidity current and subsolifluction down to sedimentary basin or ocean floor during the Late Jurassic, accompanying with mixing with the Upper Permian or Upper Triassic rocks. Such sedimentary facies was caused by the material broken down to the front margin at the time of thrust movement of accretionary complex. Correlatives of Oishi Formation have not been found from outside of this study area so far. Possible reasons are the larger occurrence and less erosion of the Kurosegawa Terrane in middle and western Kyushu than in any other regions. Some Monotis beds in Kyushu are probably mixed into turbidite of alternating beds of sandstone and mudstone in blocks, and the age of the pelitic-matrix need total examination by using radiolarian.

9) The Upper Permian Kagamiyama Formation lies on north of the Mesozoic and Paraeozoic terrigenous clastic formations such as the Gionyama Formation, and these all the formations are the components of the Middle Belt of the Chichibu Terrane. The Lower Jurassic olistostrome formations are distributed in the areas both on the south and north of these components (northern side: the Mamihara Formation, southern side: the Yurugidake Formation). From the lithofacies and the ages, the formations are assigned to the Northern Belt of the Chichibu Terrane. In the Yatsushiro district, the distribution of the Northern Belt on the northern and southern sides of the Middle Belt (= Kurosegawa Terrane) indicates that the most of the Kurosegawa Terrane thrusts

over the Northern Belt, forming nappes (Miyamoto, 1990 and others), and this is in accordance with the result in this area. This also explains the wide occurrence of above mentioned geotectonic structure from middle to western Kyushu, although it is often covered with the Aso pyroclastic flow deposits.

10) The Cretaceous neritic sedimentary formations in Kuraoka district are divided into the Togawa (redefined), Tsubana (newly named) Kasabe (redefined), Gokase (newly named), Shibanomoto (redefined), Kubo (newly named) and Takahata (redefined) Formations.

11) The Togawa, Tsubana, Kasabe and Shibanomoto Formations, which are successive sedimentary formations from the Hauterivian to Albian, are correlated with the Monobegawa Group in Shikoku by the occurrences of marine and nonmarine molluscan fossils, and lithofacies. These formation, most of which shows an semi-basin structure with a ENE-WNW axis and a eastward plunging, are distributed in the northern side of the Gionyama lenticular body.

12) The Gokase Formation corresponds to the thick conglomerate in the middle of the Oishi Formation of Saito and Kanbe (1954). This formation is scattered south of the Gionyama lenticular body, unconformably overlying the Upper Jurassic Oishi and Lower Cretaceous Yurugidake Formations, and others. With respect to gravel composition and distribution, it may be assigned to around Aptian, although there is no fossils evidence available for the exact age determination.

13) The Kubo and Takahata Formations are generally distributed in north area of the other Cretaceous neritic sedimentary formations, and the Takahata Formation composed of thick red conglomerate unconformably overlies the Kubo Formation. The Kubo Formation yields bivalves such as *Cucullaea (Idonearca)* sp. cf. *C. (I.) amaxensis, Modiolus tamurai, Phelopteria* sp. aff. *P. electa, Entolium ikedai, Amphidonte (Amphidonte) subhariotoidea, Pterotrigonia (Pterotrigonia) takahatensis, Astarte (Astarte) yatushiroensis, Astarte (Nicaniella) makibaensis, Bungoella* sp., and *Anthonya* sp. aff. *A. mifunensis,* suggesting around Late Albian. These fossils are the bivalve fauna which has not found before and are not related to the Lower Cretaceous Monobegawa Group of the Chichibu Terrane, having character of the pre-Sotoizumi and Ryoke types of the Inner Zone-faunas in Southwest Japan.

14) The Kubo and Takahata Formations thrust over the formations (Kagamiyama, Mamihara and Togawa Formations) of the Northern and Middle Belts of the Chichibu Terrane, and judging from the bivalves from Kubo Formations, they are probably nappes from the Inner Zone side.

15) The Southern Belt of the Chichibu Terrane widely lies in the southern study area, and is subdivided into the northern and southern units by the Shiroiwayama thrust (Murata, 1981) with a general trend of EW. The northern unit represents an olistostrome facies chiefly composed of pebbly mudstone, containing exotic blocks of chert with the Middle to Upper Triassic radiolarians and limestone with the Middle Permian foraminiferas. Moreover, the Lower to Upper Jurassic radiolarian fossils are obtained from pelitic-matrix. This unit is possibly correlated with some of the Lower Triassic to middle Lower Jurassic Yoshio Formation (Kanmera, 1950; Murata, 1992) or the Middle to uppermost Jurassic Ebirase Formation (Kanmera, 1950; Murata, 1992) included within the Yoshio Formation in lens.

16) The southern unit mainly consists of sandstone, shale and alternating beds, containing exotic blocks of limestone, chert and green rocks. The radiolarian fossils younger than the early Late Jurassic are obtained from pelitic-matrix. The radiolarian assemblage correlated with the *Holocryptocanium barbui-H. geysersense* A-zone (Nakaseko and Nishimura, 1981) or *H. barbui* A-zone (Yao, 1984) are found in siliceous rocks, indicating Albian to Cenomanian. This unit is comparable with the lowermost to lower Upper Cretaceous Sakaguchi Formation (Nishizono and Murata, 1983) distributed along the southern margin of the Southern Belt of the Chichibu Terrane in Yatsushiro district, while judging from lithofacies and radiolarian age, it also can be correlated with the Hinokage Formation (Imai et al., 1971) of the Morozuka Group of the Shimanto Terrane distributed in an area south of the Butsuzo Tectonic Line, that need to re-examine the location and the significance of the Butsuzo Tectonic Line.

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* in Japanese with English abstract
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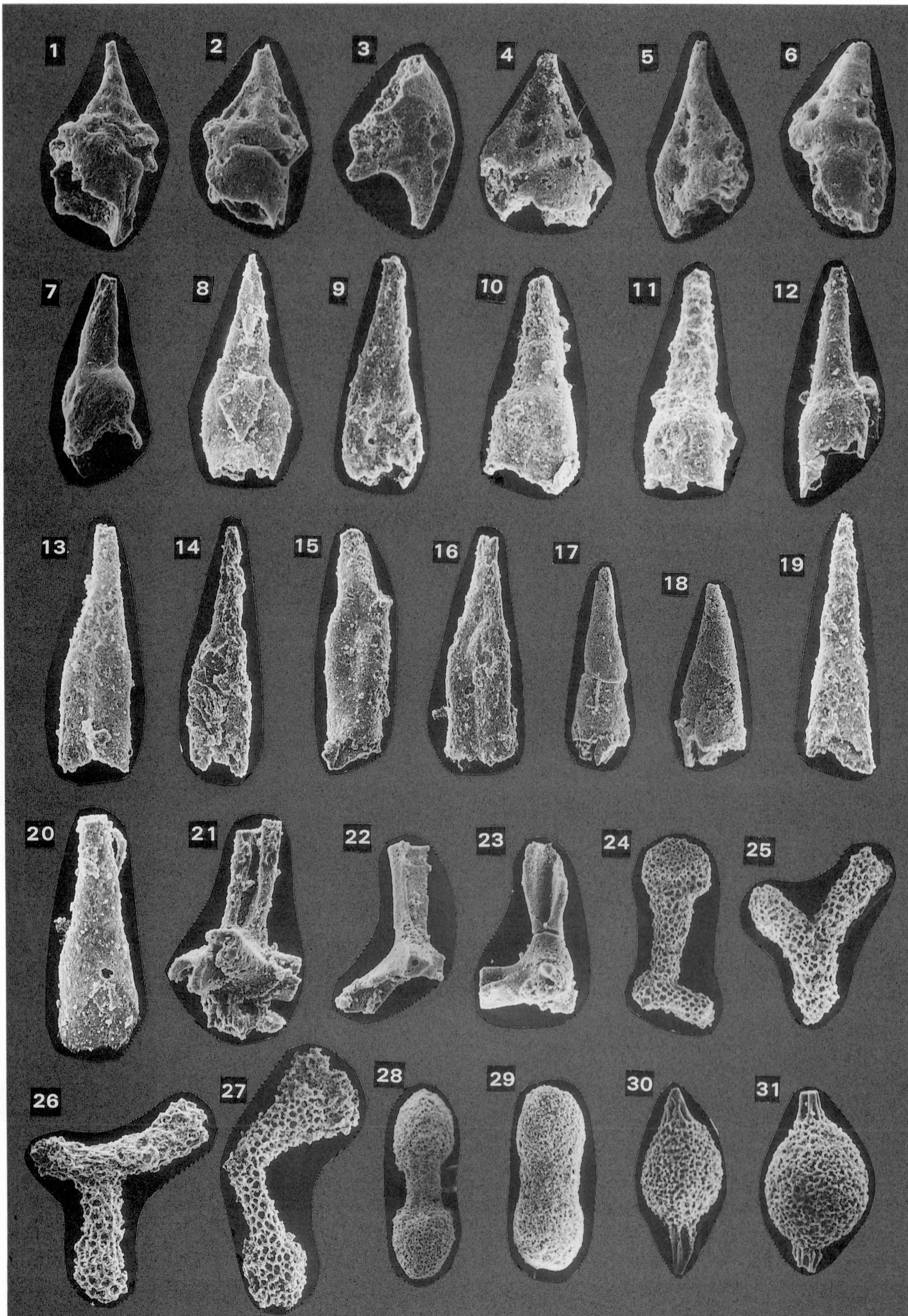
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Explanation of Plate 1

All figures are scanning electron micrographs of radiolarians from the Kagamiyama Formation.

Figs. 1-4. *Albaillella* sp. cf. A. levis Ishiga, Kito and Imoto
1. x280, Loc. KA-5; 2. x280, Loc. KA-5; 3. x260, Loc. KA-5; 4. x325, Loc. KA-5

Figs. 5-6. *Albaillella* sp.
5. x325, Loc. KA-5 ; 6. x319, Loc. KA-5

Fig. 7. Follicucullus dilatatus Rudenko
x182, Loc. KA-5

Figs. 8-11. *Follicucullus* sp. cf. *F. dilatatus* Rudenko
8. x195, Loc. KA-3; 9. x234, Loc. KA-3; 10. x260, Loc. KA-3; 11. x273, Loc.KA-3

Figs. 12-16. *Follicucullus* sp. cf. *F. porrectus* Rudenko
12. x195, Loc. KA-3; 13. x189, Loc. KA-3; 14. x163, Loc. KA-3; 15. x195, Loc. KA-3; 16. x143, Loc. KA-3

Figs. 17-20. *Follicucullus* sp
17. x208, Loc. KA-5; 18. x280, Loc. KA-5; 19. x182, Loc. KA-3; 20. x260, Loc. KA-3

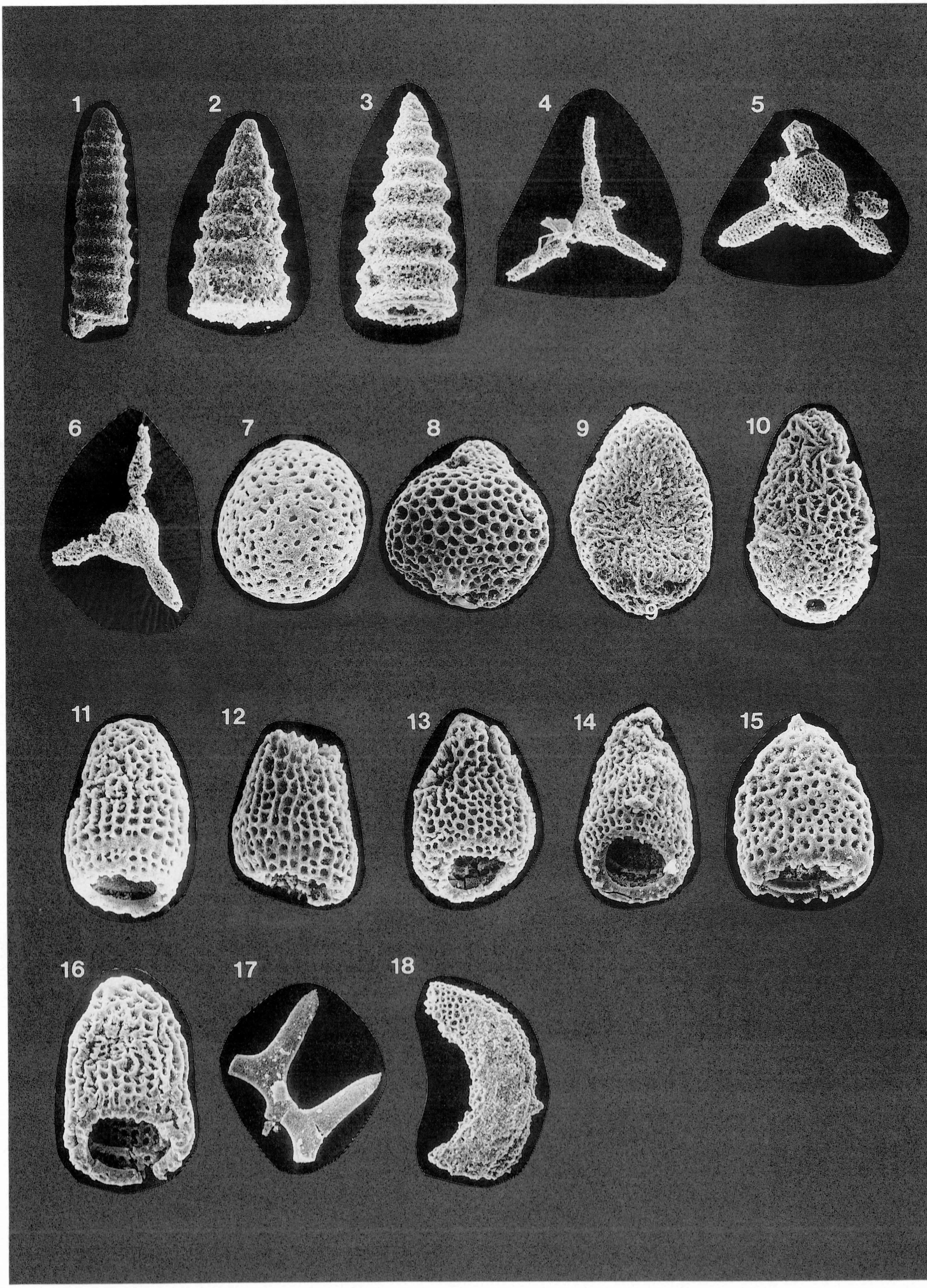
Fig. 21. *Nazarovella gracilis* De Wever and Caridroit
x280, Loc. KA-3

Figs. 22-23. *Nazarovella* sp.
22. x221, Loc. KA-5; 23. x306, Loc. KA-5

Figs. 24-27. *Latentibifisutula* sp.
24. x130, Loc. KA-5; 25. x182, Loc. KA-5; 26. x182, Loc. KA-3; 27. x163, Loc. KA-3

Figs. 28-29. *Latentibifisutula* (?) sp.
28. x163, Loc. KA-5; 29. x176, Loc. KA-5

Figs. 30-31. *Entactinosphaera* (?) sp.
30. x228, Loc. KA-5; 31. x260, Loc. KA-5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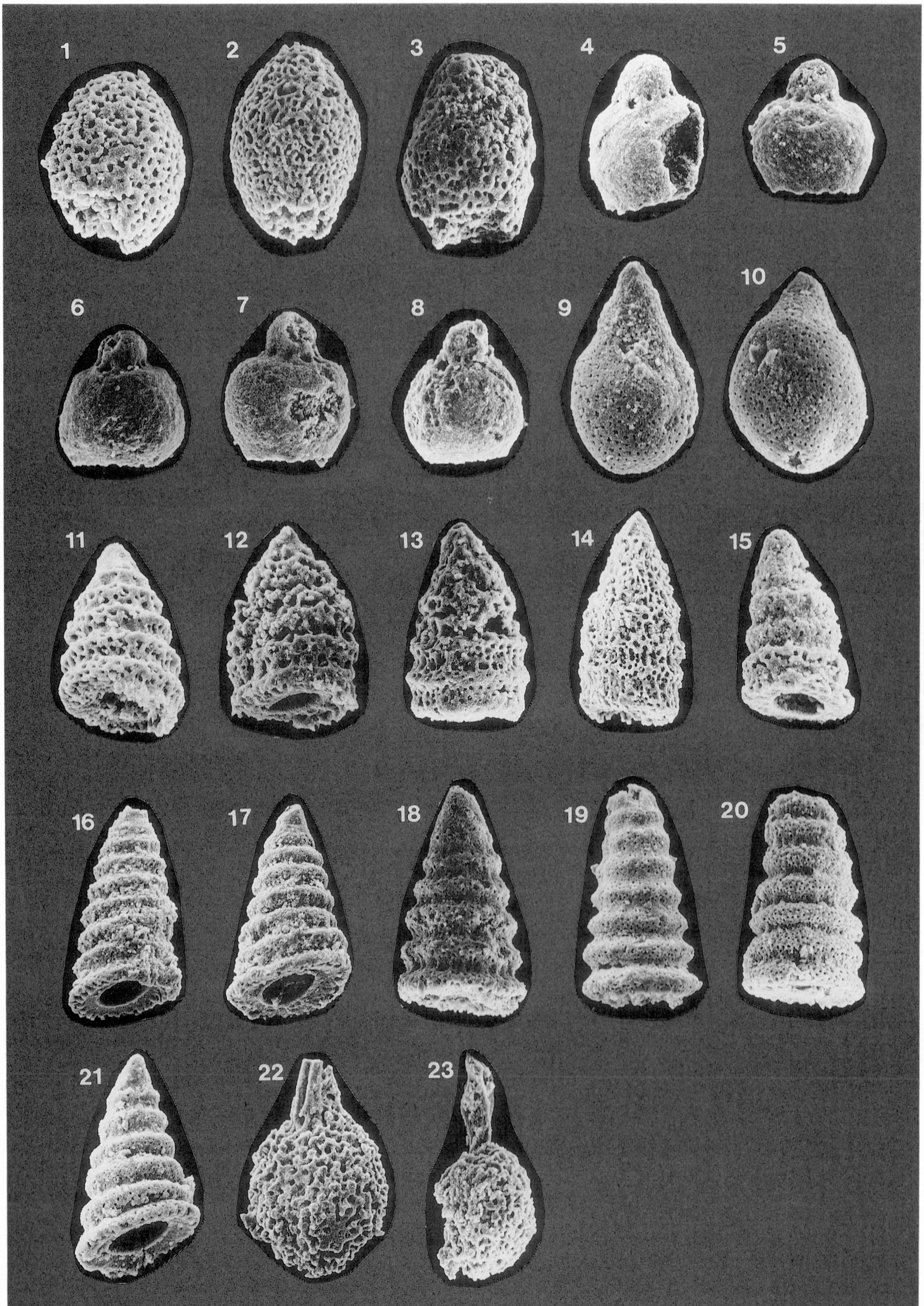
Explanation of Plate 2

All figures are scanning electron micrographs of radiolarians from the Mamihara Formation.

Fig. 1. *Canoptum* **sp. cf.** *C. anulatum* **Pessagno and Poisso**
x228, Loc. MA-3
Figs. 2-3. *Canoptum* **sp.**
2. x325, Loc. MA-2; 3. x293, Loc. MA-2
Fig. 4. *Livarella* **sp. cf.** *L. longus* **Yoshida**
x169, Loc. MA-2
Figs. 5-6. *Livarella* **sp.**
5. x195, Loc. MA-2; 6. x228, Loc. MA-2
Fig. 7. *Archicapsa* **sp.**
x221, Loc. MA-4
Fig. 8. *Tricolocapsa* **(?) sp.**
x215, Loc. MA-4
Figs. 9-10. *Bagotum* **sp.**
9. x260, Loc. MA-4; 10. x293, Loc. MA-4
Fig. 11. *Parahsuum ovale* **Hori and Yao**
x336, Loc. MA-4
Figs. 12-16. *Parahsuum* **sp.**
12. x377, Loc. MA-4; 13. x345, Loc. MA-4; 14. x312, Loc. MA-4; 15. x423, Loc. MA-4; 16. x312, Loc. MA-4
Fig. 17. *Mesosatunalis* **sp.**
x293, Loc. MA-4
Fig. 18. *Orbiculiforma* **sp.**
x163, Loc. MA-4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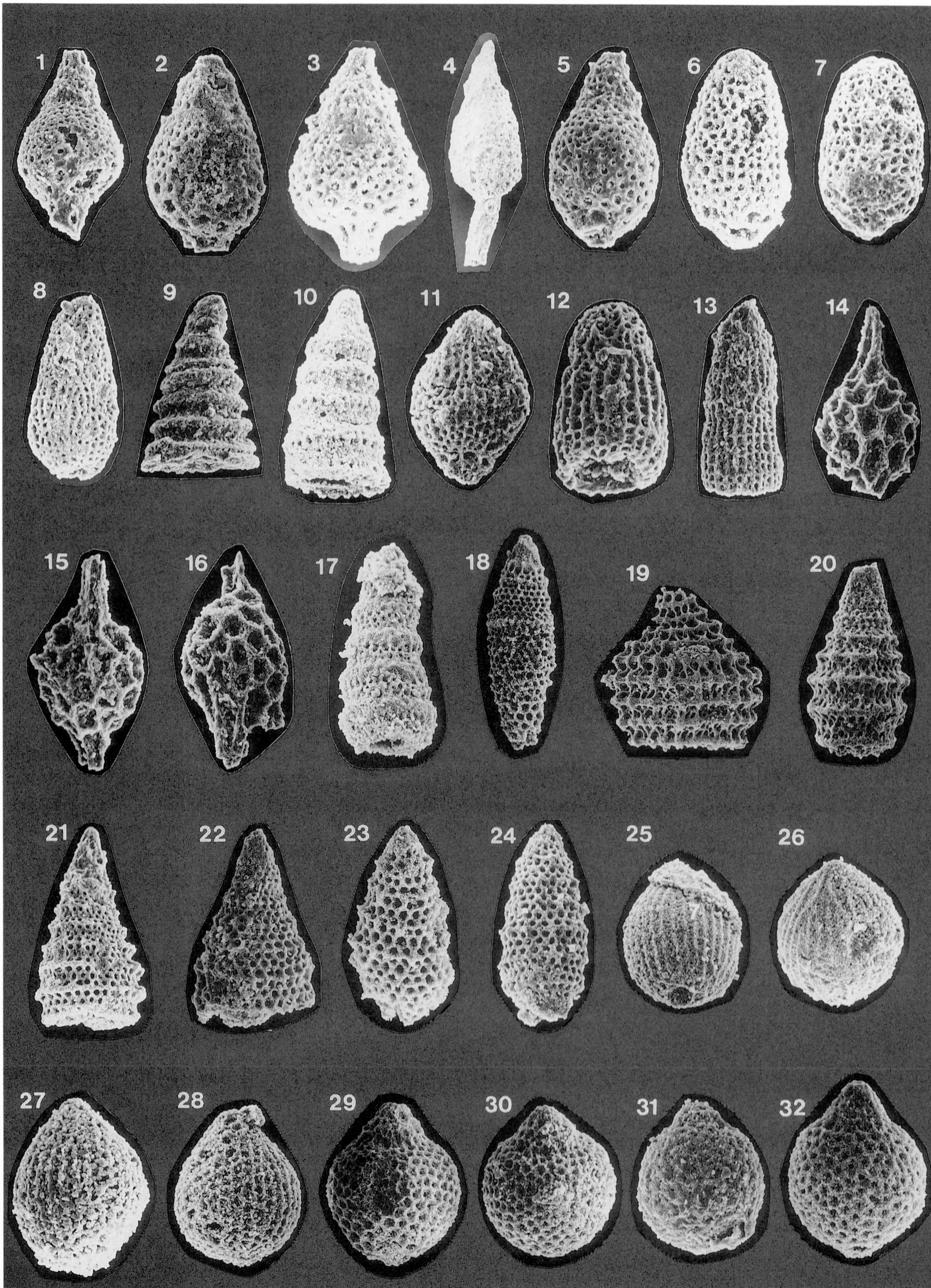
Explanation of Plate 3

All figures are scanning electron micrographs of radiolarians from the Kanmuridake Formation.

Fig. 1. *Archicapsa* **sp. cf.** *A. pachyderm* **Tan Sin Hok**
x423, Loc. KN-1
Fig. 2. *Bagotum* **(?) sp. cf.** *B. helmetense* **Pessagno and Whalen**
x358, Loc. KN-1
Fig. 3. *Bagotum* **sp.**
B-11, x390, Loc. KN-2
Figs. 4-8. *Natoba* **sp.**
4. x416, Loc. KN-2; 5. x416, Loc. KN-2; 6. x416, Loc. KN-2; 7. x423, Loc. KN-2; 8. x423, Loc. KN-2
Figs. 9-10. *Stichocapsa* **sp.**
9. x338, Loc. KN-1; 10. x364, Loc. KN-1
Figs. 11-13. *Parvicingula* **(?) sp.**
11. x416, Loc. KN-1; 12. x416, Loc. KN-1; 13. x429, Loc. KN-1
Fig. 14. *Parahsuum* **sp.**
x325, Loc. KN-1
Figs. 15-18. *Canoptum* **sp. cf.** *C. merum* **Pessagno and Whalen**
15. x416, Loc. KN-1; 16. x280, Loc. KN-1; 17. x332, Loc. KN-1; 18. x429, Loc. KN-2
Figs. 19-21. *Canoptum* **sp.**
19. x325, Loc. KN-1; 20. x338, Loc. KN-1; 21. x390, Loc. KN-1
Figs. 22-23. *Archaeospongoprunum* **sp.**
22. x254, Loc. KN-1; 23. x293, Loc. KN-1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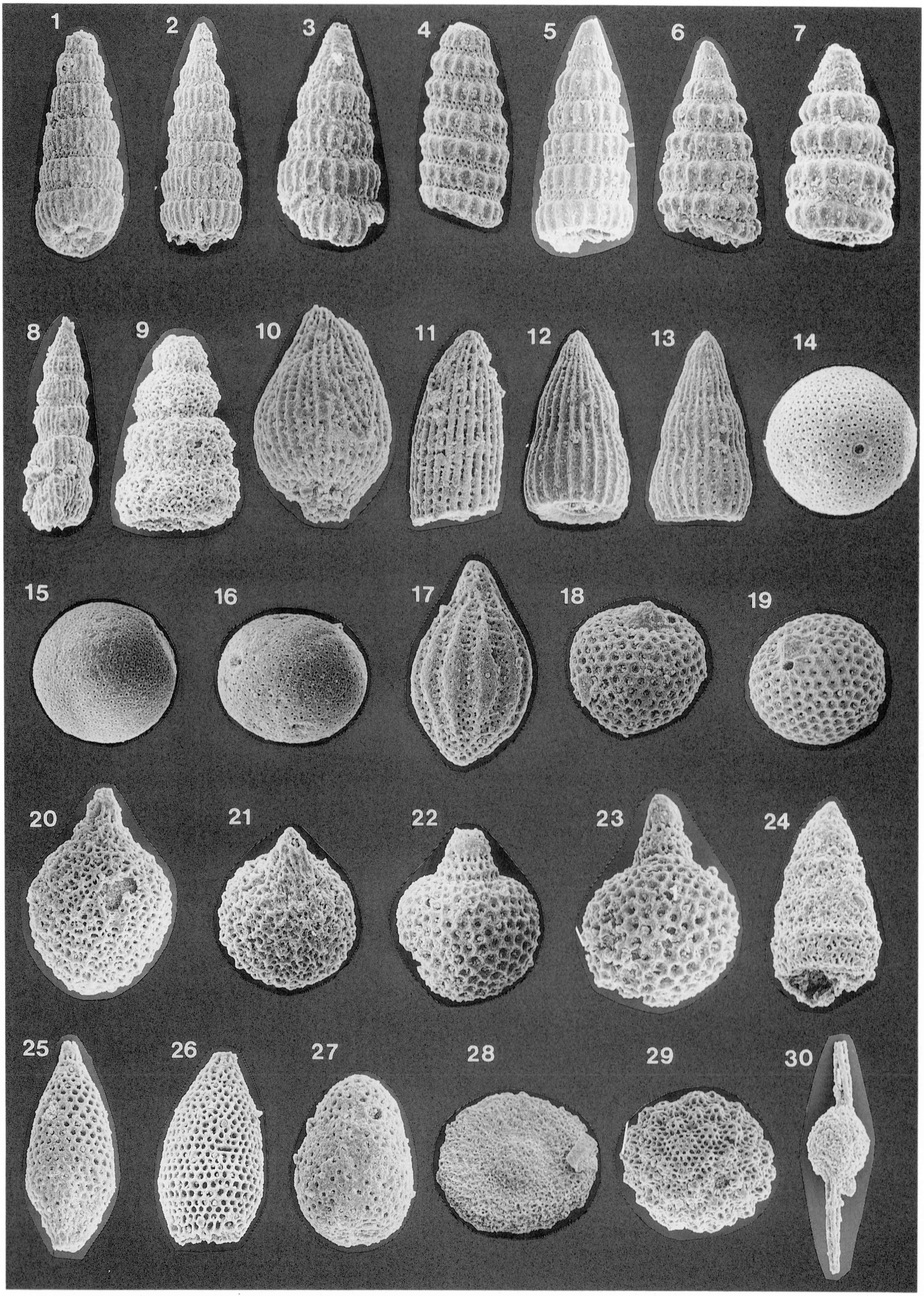
Explanation of Plate 4

All figures are scanning electron micrographs of radiolarians from Southern Belt of the Chichibu Terrane.

Fig. 1. *Katroma elliptica* **Kishida and Hisada**
x293, Loc. SO-7
Fig. 2. *Katroma* **sp. cf.** *K. elliptica* **Kishida and Hisada**
x358, Loc. SO-7
Fig. 3. *Katroma triangularis* **Kishida and Hisada**
x390, Loc. SO-7
Fig. 4. *Katroma* **sp.**
x228, Loc. SO-7
Fig. 5. *Katroma* **(?) sp.**
x358, Loc. SO-7
Fig. 6. *Bagotum erraticum* **Pessagno and Whalen**
x163, Loc. SO-7
Figs. 7-8. *Bagotum* **sp.**
7. x293, Loc. SO-7; 8. x260, Loc. SO-7
Fig. 9. *Canoptum rugosum* **Pessagno and Whalen**
x293, Loc. SO-7
Fig. 10. *Canoptum* **sp.**
x325, Loc. SO-7
Fig. 11. *Stichocapsa* **sp. aff.** *S.* **tegiminis Yao**
x325, Loc. SO-7
Figs. 12-13. *Parahsuum* **sp.**
12. x358, Loc. SO-7; 13. x260, Loc. SO-7
Figs. 14-16. *Pantanellium* **sp.**
14. x293, Loc. SO-7; 15. x325, Loc. SO-7; 16. x325, Loc. SO-7
Fig. 17. *Cinguloturris* **sp.**
x325, Loc. SO-6
Fig. 18. *Pseudoeucyrtis* **sp.**
x228, Loc. SO-6
Fig. 19. *Mirifusus guadalupensis* **Pessagno**
x163, Loc. SO-6
Fig. 20. *Parvicingula* **sp. cf.** *P. mashitaensis* **Mizutani**
x228, Loc. SO-6
Figs. 21-24. *Triversus* **sp.**
21. x228, Loc. SO-6; 22. x260, Loc. SO-6; 23. x325, Loc. SO-6; 24. x293, Loc. SO-6
Figs. 25-28. *Tricolocapsa plicarum* **Yao**
25. x293, Loc. SO-6; 26. x293, Loc. SO-6; 27. x325, Loc. SO-6; 28. x325, Loc. SO-6
Figs. 29-32. *Tricolocapsa* **sp.**
29. x260, Loc. SO-6; 30. x260, Loc. SO-6; 31. x358, Loc. SO-6; 32. x358, Loc. SO-6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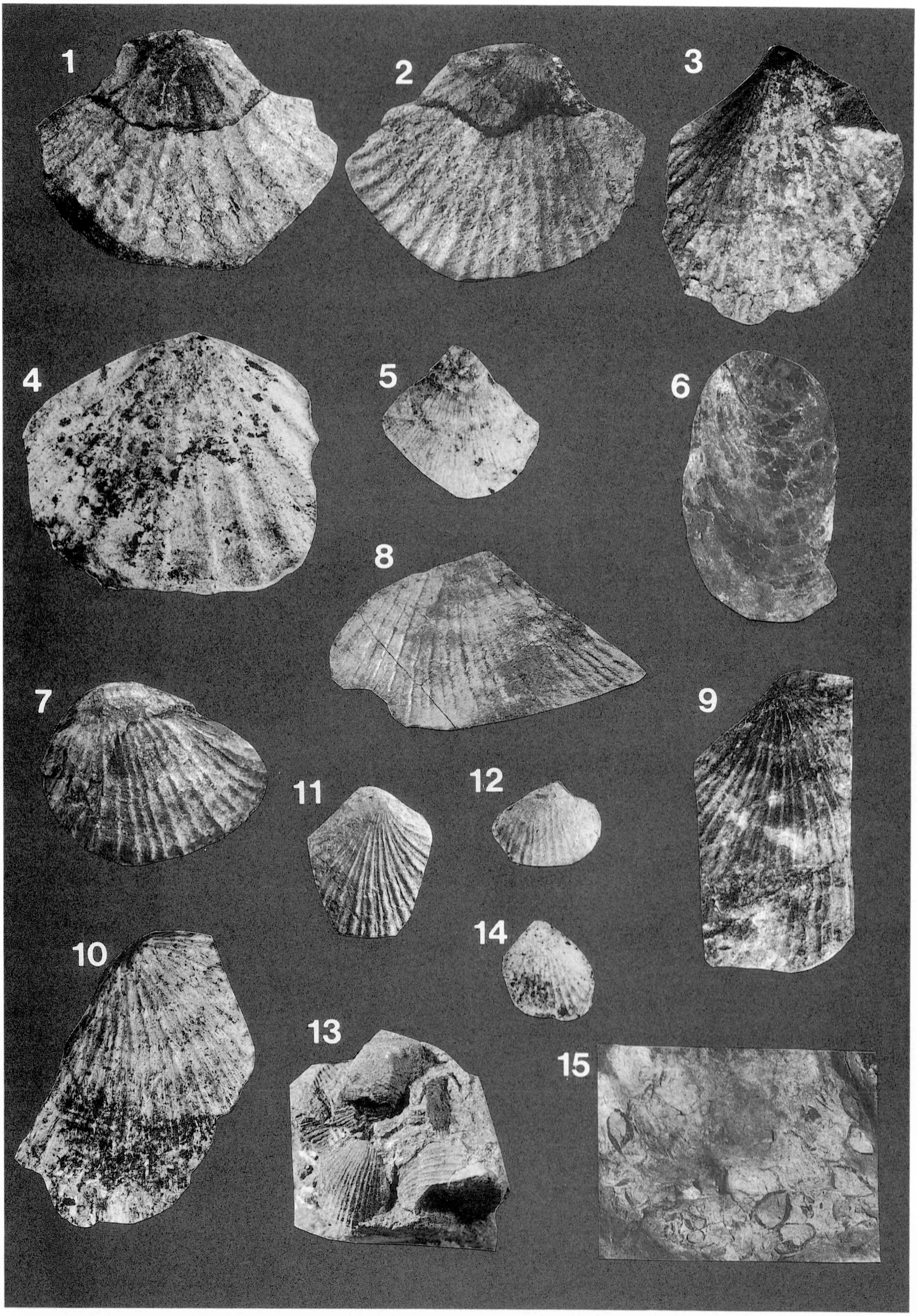
Explanation of Plate 5

All figures are scanning electron micrographs of radiolarians from Southern Belt of the Chichibu Terrane.

Figs. 1-2. *Pseudodictyomitra lodogaensis* **Pessagno**
1. x260, Loc. SO-12; 2. x211, Loc. SO-12
Fig. 3. *Psuedodictyomitra pentacolaensis* **Pessagno**
x261, Loc. SO-12
Figs. 4-7. *Psuedodictyomitra* **sp. cf.** *P. pentacolaensis* **Pessagno**
4. x182, Loc. SO-12; 5. x195, Loc. SO-12; 6. x195, Loc. SO-12; 7. x247, Loc. SO-12
Fig. 8. *Psuedodictyomitra vestalensis* **Pessagno**
x211, Loc. SO-12
Fig. 9. *Stichomitra* **(?) sp.**
x195, Loc. SO-12
Fig. 10. *Archaeodictyomitra* **(?) sp.**
x324, Loc. SO-12
Fig. 11. *Mita* **(?) sp.**
x293, Loc. SO-12
Figs. 12-15. *Thanarla praeveneta* **Pessagno**
12. x260, Loc. SO-12; 13. x293, Loc. SO-12; 14. x326, Loc. SO-12; 15. x280, Loc. SO-12
Figs. 16-18. *Holocryptocanium barbui* **Dumitrica**
16. x228, Loc. SO-12; 17. x195, Loc. SO-12; 18. x247, Loc. SO-12
Fig. 19. *Protunuma* **sp.**
x293, Loc. SO-12
Figs. 20-21. *Hemicryptocapsa* **sp.**
20. x267, Loc. SO-12; 21. x228, Loc. SO-12
Figs. 22-23. *Sethocapsa cetia* **Foreman**
22. x244, Loc. SO-12; 23. x248, Loc. SO-12
Figs. 24-25. *Sethocapsa* **sp.**
24. x260, Loc. SO-12; 25. x280, Loc. SO-12
Fig. 26. *Xitus* **sp.**
x215, Loc. SO-12
Figs. 27-28. *Amphipyndax* **sp.**
27. x228, Loc. SO-12; 28. x228, Loc. SO-12
Fig. 29. *Diacanthocapsa* **sp.**
x325, Loc. SO-12
Fig. 30. *Orbiculiforma maxima* **Pessagno**
x144, Loc. SO-12
Fig. 31. *Praeconocaryomma* **sp.**
x163, Loc. SO-12
Fig. 32. *Archaeospongoprunum* **sp.**
x182, Loc. SO-12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Explanation of Plate 6

All figures are molluscan fossils from the Murono and Oishi Formations.

Figs. 1-4. *Tosapecten suzukii suzukii* **(Kobayashi)**
1. Internal mould of left valve, x1.4, Loc.OI-4; 2. Internal mould of right valve, x1.2, Loc.OI-4; 3. Internal mould of right valve, x1.4, Loc.OI-4; 4. Rubber external cast of left valve, x1.5, Loc.OI-4

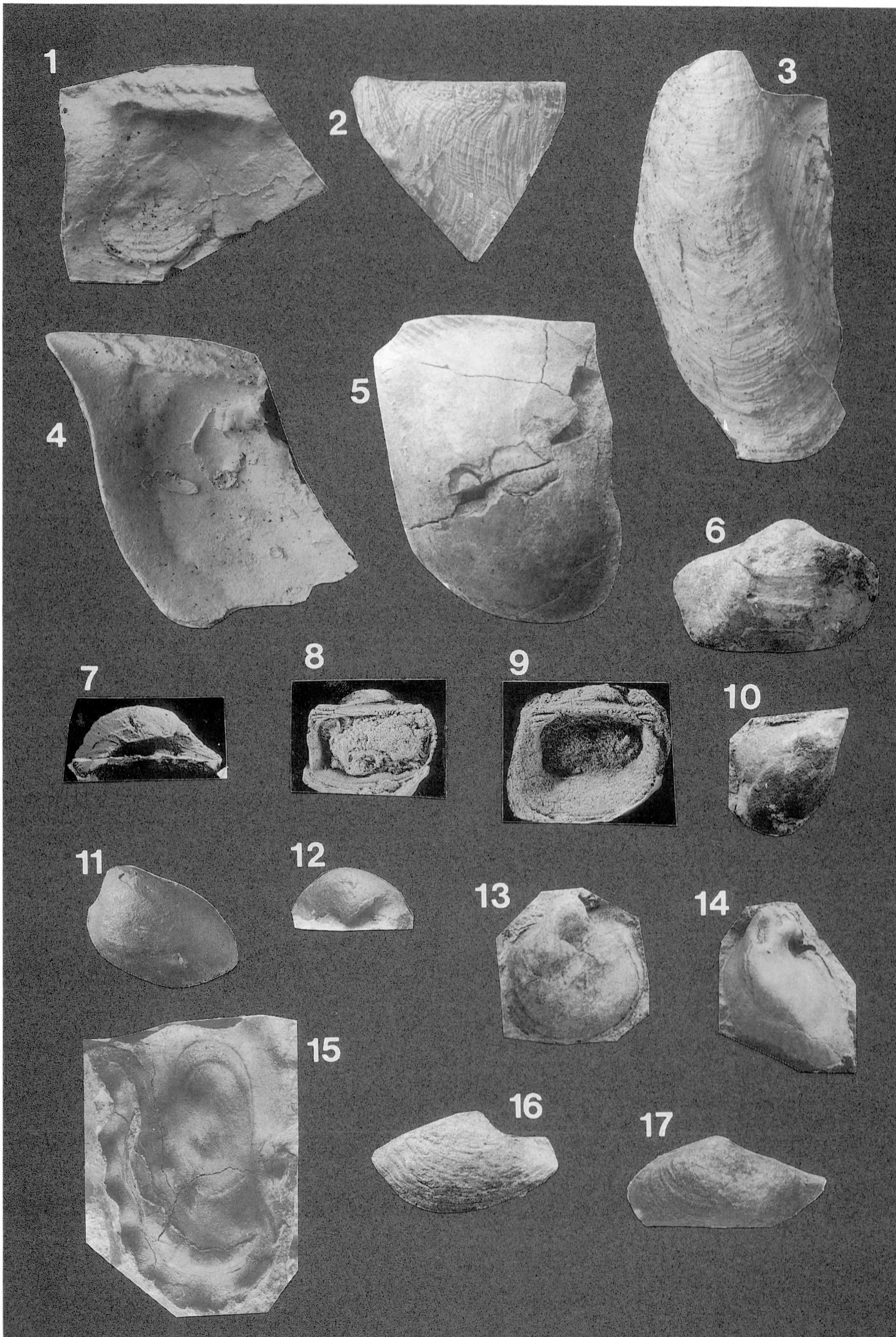
Fig. 5. *Chlamys* sp. cf. *C. mojsiscovicsi* **Kobayashi** and **Ichikawa**
Rubber external cast of right valve, x1.5, Loc.OI-5

Fig. 6. *Mytilus (Falcimytilus)* sp. cf. *M. (F.) nasai* **Kobayashi** and **Ichikawa**
External cast of right valve, x1.2, Loc.OI-5

Figs. 7-11. *Monotis ochotica ochotica* **(Keyserling)**
7. Internal mould of left valve, x1.3, Loc.MU-3; 8. Internal mould of left valve, x1.1, Loc.OI-5; 9. Internal mould of right valve, x1.1, Loc.OI-5; 10. Internal mould of right valve, x1.0, Loc.OI-5; 11. Internal mould of right valve, x1.2, Loc.MU-3

Figs. 12-14. *Monotis ochotica densistriata* **(Teller)**
12. Internal mould of left valve, x1.5, Loc.MU-2; 13. Internal mould of right valve, x1.1, Loc.MU-1; 14. Rubber external cast of left valve, x1.3, Loc.MU-1

Fig. 15. Brachiopoda gen. et. sp. indet.
Crowded occurrence on a slab with Brachiopoda, siliceous sandstone, x0.5, Loc.OI-5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Explanation of Plate 7

All figures are molluscan fossils from the Kubo Formation.

Figs. 1-5. *Gervillaria miyakoensis* **(Nagao)**
1. Rubber internal cast of right valve, x1.2, Loc.KU-3; 2. Rubber external cast of left valve, x1.2, Loc.KU-3; 3. Rubber external cast of left valve, x1.2, Loc.KU-3; 4. Rubber internal cast of right valve, x1.2, Loc.KU-3; 5. Internal mould of right valve, x1.2, Loc.KU-3

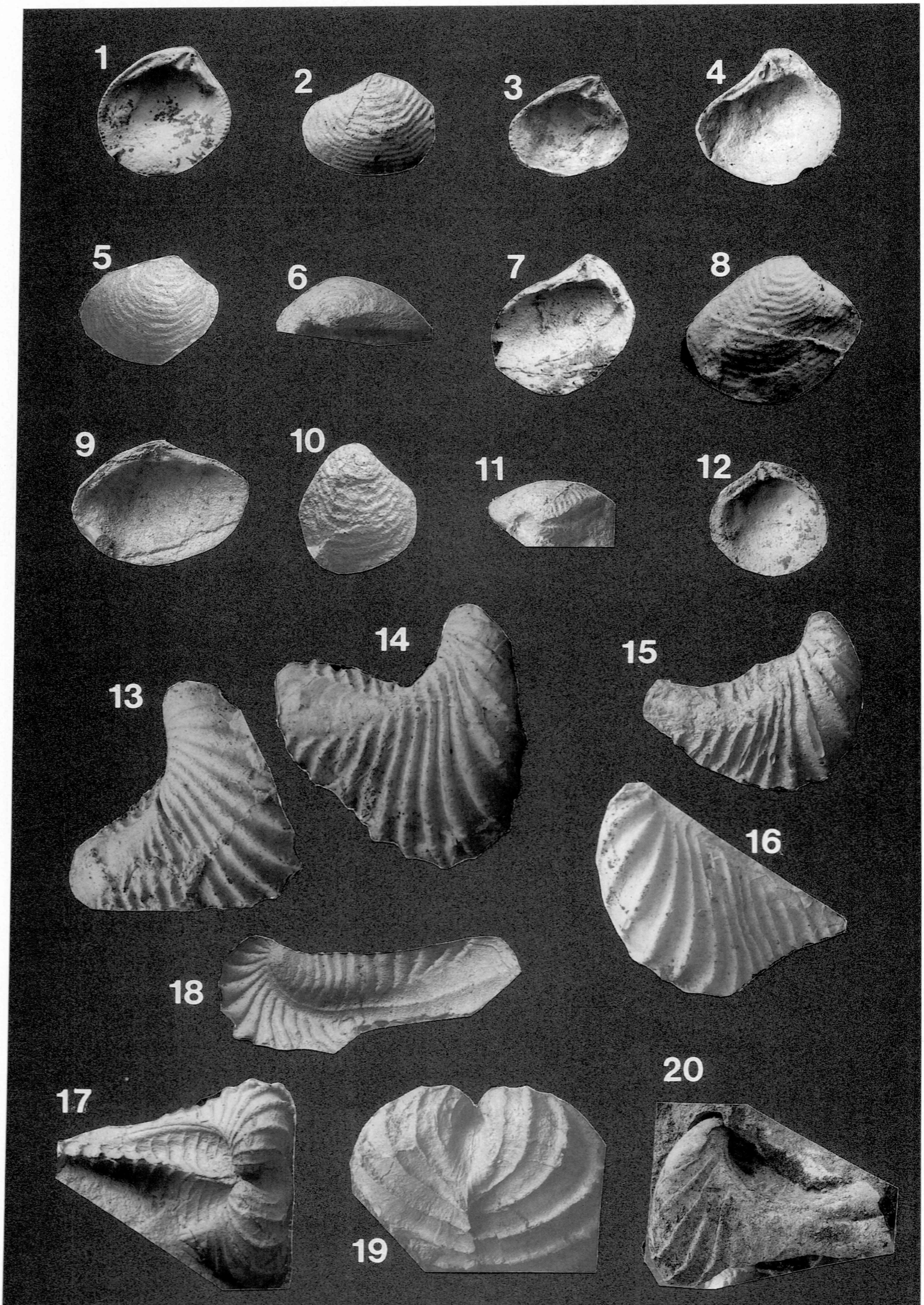
Figs. 6-9. *Nanonavis takahatensis* **Tashiro** and **Tanaka**
6. Rubber external cast of right valve, x1.2, Loc.KU-1; 7. Rubber external cast of left valve, x1.2, Loc.KU-1; 8. Rubber internal cast of left valve, x1.2, Loc.KU-1; 9. Rubber internal cast of left valve, x1.2, Loc.KU-1

Fig. 10. *Phelopteria* sp. aff. *P. electa* **Tanura**
Internal mould of right valve, x1.4, Loc.KU-3

Figs. 11-12. *Bungoella* sp.
11. Internal mould of left valve, x1.4, KU-3; 12. Internal mould of left valve, x1.2, KU-3

Figs. 13-15. *Amphidonte (Amphidonte) subhaliotoidea* **(Nagao)**
13. Internal mould of left valve, x1.4, Loc.KU-3; 14. Internal mould of left valve, x1.4, Loc.KU-3; 15. Rubber internal cast of left valve, x1.4, Loc.KU-3

Figs. 16-17. *Periplomya* sp.
16. Rubber external cast of left valve, x1.2, Loc.KU-3; 17. External cast of left valve, x1.2, KU-3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Explanation of Plate 8

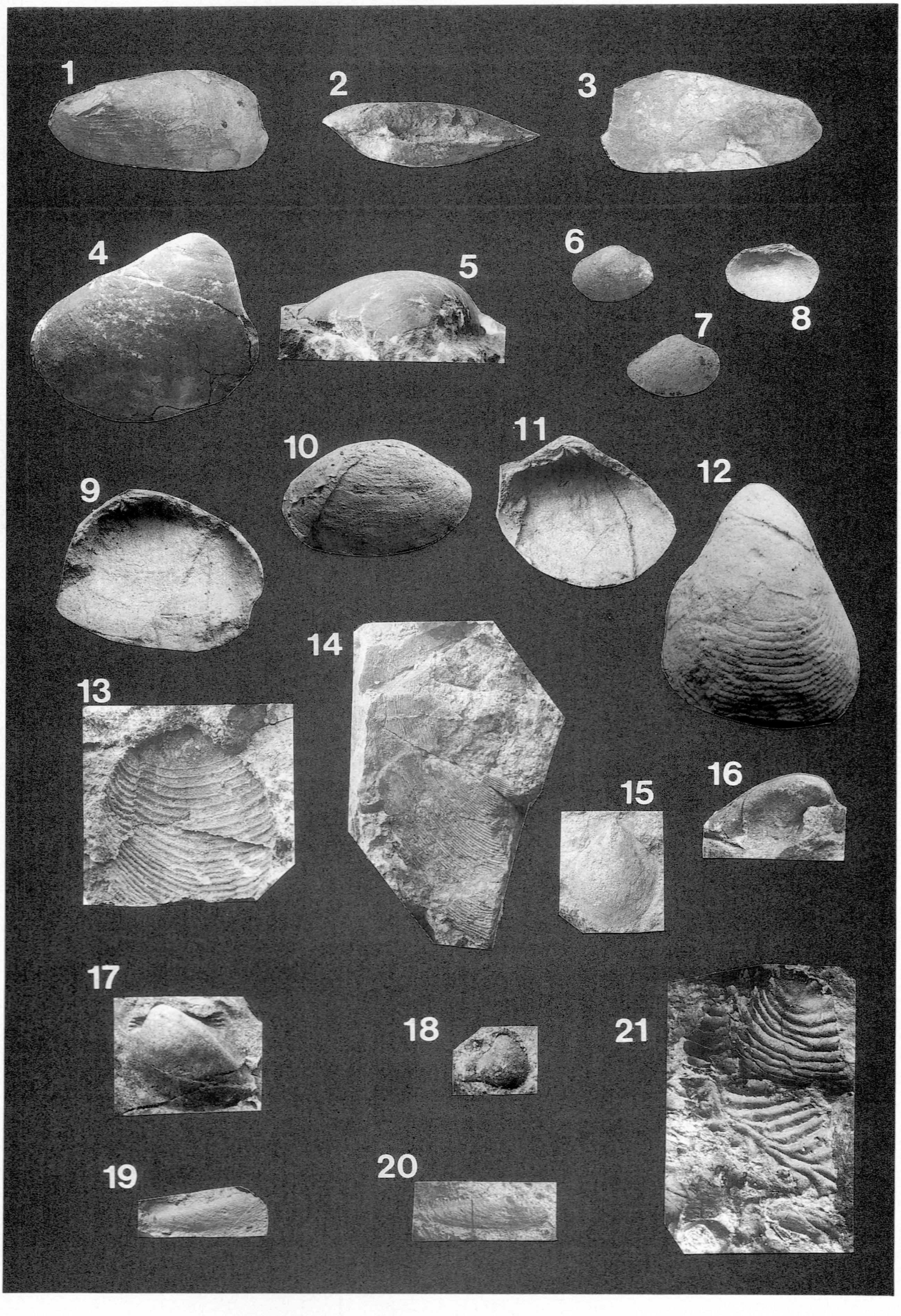
All figures are molluscan fossils from the Kubo Formation.

Figs. 1-7. *Astarte (Astarte) yatsushiroensis* **Tashiro** and **Tanaka**
1. Rubber internal cast of left valve, x1.8, Loc.KU-3; 2. Rubber external cast of left valve, x1.8, Loc.KU-3; 3. Rubber internal cast of left valve, x1.8, Loc.KU-3; 4. Rubber internal cast of right valve, x1.8, Loc.KU-1; 5. Rubber external cast of right valve, x1.8, Loc.KU-3; 6. Rubber external cast of right valve, x1.8, Loc.KU-3; 7. Rubber internal cast of right valve, x1.8, Loc.KU-1

Figs. 8-9. *Astarte (Nicaniella) makibaensis* **Tashiro** and **Kozai**
8. Rubber external cast of right valve, x1.8, Loc.KU-1; 9. Rubber internal cast of left valve, x1.8, Loc.KU1

Figs. 10-12. *Astarte (Astarte) yatsushiroensis* **Tashiro** and **Tanaka**
10. Rubber external cast of right valve, x1.8, Loc.KU-1; 11. Rubber external cast of right valve, x1.8, Loc.KU-1; 12. Rubber internal cast of right valve, x1.8, Loc.KU-3

Figs. 13-20. *Pterotrigonia (Pterotrigonia) takahatensis* **Tashiro** and **Tanaka**
13. Rubber external cast of right valve, x1.2, Loc.KU-1; 14. Rubber external cast of right valve, x1.2, Loc.KU-1; 15. Rubber external cast of right valve, x1.2, Loc.KU-2; 16. Rubber external cast of left valve, x1.2, Loc.KU-2; 17. Rubber external cast of conjoined valves, x1.2, KU-3; 18. Rubber external cast of left valve, x1.2, Loc.KU-3; 19. Rubber external cast of conjoined valves, x1.2, KU-1; 20. Internal mould of left valve, x1.2, Loc.KU3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Explanation of Plate 9

All figures are molluscan fossils from the Kubo Formation.

Figs. 1-3. *Modiolus tamurai* **Tashiro** and **Tanaka**
1. Left valve, x1.2, Loc.KU-3; 2. Conjoined valves, x1.2, Loc.KU-3; 3. Right valve, x1.2, Loc.KU-3

Figs. 4-5. *Bungoella* sp.
4. Right valve, x1.2, Loc.KU-3; 5. Right valve, x1.2, Loc.KU-3

Figs. 6-11. *Rasatrix (Vectorbis) miyazakiensis* **Tashiro** and **Tanaka**
6. Internal mould of right valve, x1.2, Loc.KU-3; 7. Internal mould of right valve, x1.2, Loc.KU-3; 8. Rubber internal cast of left valve, x1.2, Loc.KU-3; 9. Rubber internal cast of right valve, x1.2, Loc.KU-1; 10. Rubber external cast of right valve, x1.2, Loc.KU-3; 11. Rubber internal cast of right valve, x1.2, Loc.KU-3

Figs. 2-13. *Globocardium sphaeroidium* **(Forbes)**
12. Rubber external cast of left valve, x1.2, Loc.KU-4; 13. External mould of left -valve, x1.2, Loc.KU-4

Figs. 14-15. *Entolium ikedai* **Tashiro**
14. External mould of right valve, x1.2, Loc.KU-4; 15. Internal mould of right valve, x1.2, Loc.KU-4

Figs. 16-17. *Cucullaea (Idonearca)* sp. cf. *C. (I.) amaxensis* **Matsumoto**
16. Internal mould of left valve, x1.2, Loc.KU-1; 17. Internal mould of left valve, x1.2, Loc.KU-1

Fig. 18. *Caestocorbula* sp.
Internal mould of right valve, x2.4, Loc.KU-3

Figs. 19-20. *Anthonya* sp. aff. *A. mifunensis* **Tamura**
19. Rubber external cast of left valve, x1.4, KU-3; 20. Internal mould of left valve, x1.4, Loc.KU-3

Fig. 21. *Rastellium (Arctostrea)* sp. aff. *R. (A.) carinatum* **(Lamarck)**
21. Rubber external cast of left valve, x1.2, Loc.KU-4