Reconstruction of the Stratigraphy of Cretaceous Systems in Eastern Japan

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Contents

Abstract

Shallow marine to terrestrial Cretaceous systems are sporadically distributed in Japan. The Cretaceous systems in Japan are divided into northeast Japan and southwest Japan by the Tanakura Tectonic Line. The Cretaceous systems in northeast Japan have weak hardening strata and molluscan fauna of high-latitude type. On the other hand, Cretaceous systems in southwest Japan have strong hardening strata and molluscan fauna of low-latitude type (Tashiro, 1985; 1994).

Although these areas are adjacent to each other, they have different characters. Three theories have been proposed to explain this difference, the "sinistral fault movement" theory (Tashiro, 1985; 1993), the "marine current" theory (Matsukawa and Eto, 1987; Matsukawa and Obata, 1993) and the "fluvial infulence" theory (Kozai *et al.*, 2005; 2007).

Present study has sedimentologically investigated the Miyako Group (Iwate Prefecture, Aptian to Albian), the Futaba Group (Fukushima Prefecture, Coniacian to Santonian), the Nakaminato Group (Ibaraki Prefecture, Campanian to Maastrichtian), the Choshi Group (Chiba Prefecture, Barremian to Aptian) and the Sanchu Cretaceous System (Kanto Mountains, Hauterivian to Albian) and obtained mega- and microfossis such as bivalves, ammonoids, beleminites, foraminifers, microenclusters and others. This study revealed sedimentary environments and mixed faunas of these Cretaceous and reconstructed transition of the Cretaceous basin of Japan.

Combined with Matsukawa and Obata (1993) and Iba and Sano (2007), the present study suggests the geohistory of where were investigated in this study as follows; 1) In Hauterivian age, the Sanchu Cretaceous System began to deposit. The lowermost part of Sanchu Cretaceous system is interpreted as the lowstand systems tract (LST) which bears the Northern Tethys fauna and was affected by marine currents from northward. 2) In Barremian age, the Sanchu Cretaceous Systems shifted into highstand systems tracts (HST) and the Choshi Group began to deposit. 3) In Barremian to Albian age, the Sanchu Cretaceous System and Choshi Group were gradually influenced by marine currents from southward. The fossils of the Sanchu Cretaceous System and Choshi Group shifted from the Northern Tethyan fauna to Tethyan fauna. The demise of the high-latitude type from the Sanchu Cretaceous System showed step-wise in several taxa. 4) In Aptian to Albian age, the Miyako Group deposited and was influenced by marine currents from southward. The Miyako Group, which is mainly composed of HST, beared various fossils of the high-latitude type. 5) In Coniacian age, the Futaba Group began to deposit. The lowermost part of the Futaba Group is composed of LST and transgressive systems tract (TST) which bears the Tetyan fauna. 6) In Santonian age, the Futaba Group shifted into HST which bears the North Tethyan fauna. 7) In Campanian to Maastrichtian age, the Nakaminato Group deposited with the eastern extension part of the Izumi Group.

Key words: Cretaceous, paleobiogeography, bivalves, ammonoids, foraminifers, microenclusters

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1. Introduction

Shallow marine to terrestrial Cretaceous systems are sporadically distributed in Japan (Figure 1). The Cretaceous systems in Japan are divided into northeast Japan and southwest Japan by the Tanakura Tectonic Line. The Cretaceous systems in southwest Japan have strong hardening strata and molluscan fauna of low-latitude type (Tashiro, 1985; 1994). On the other hand, the Cretaceous systems in northeast Japan have weak hardening strata and molluscan fauna of high-latitude type (Ando, 2003).

Although these two areas are adjacent to each other, they have different characters. Three theories have been suggested to explain this difference, the "sinistral fault movement" theory (Tashiro, 1985; 1993), the "marine current" theory (Matsukawa and Eto, 1987; Matsukawa and Obata, 1993) and the "fluvial infulence" theory (Kozai *et al*., 2005; 2007). The "sinistral fault movement" theory suggested that the origin of these areas lied 1000 km or more apart and that these areas subsequently having been brought together in their present position by lateral fault (Tashiro, 1985; 1994). The "marine current" theory suggested that the origin of these areas deposited in the present position and these fauna were influenced by transgression and regression of boreal and equatorial currents (Matsukawa and Eto, 1987; Matsukawa and Obata, 1993). The "fluvial infulence" theory suggested that the origin of these areas deposited in the present position and these fauna were influenced by salinity or sediment of fluvial change (Kozai *et al*., 2005; 2007).

It is very important to interpret transition of Cretaceous systems in Japan from the point of geohistory. Although there are some previous studies treating interpretation of Cretaceous in southwest Japan (e.g., Matsukawa and Obata, 1993), little attention has been paid for that in northeast Japan. Therefore, the present study investigates the Miyako Group (Iwate Prefecture), the Futaba Group (Fukushima Prefecture), the Nakaminato Group (Ibaraki Prefecture), the Choshi Group (Chiba Prefecture) and the Sanchu Cretaceous System (Kanto Mountains) and obtained mega- and microfossis (Figure 2). The present study will reveal sedimentary environments and faunas from the results and reconstruct transition of the Cretaceous basin of Japan.

2. Stratigraphy

2.1. Miyako Group

2. 1. 1. Previous works

Since the study of Yaegashi (1900), many paleontologists and geologists have investigated the Miyako Group because of its abundant occurrence of well-preserved marine invertebrate fossils of various taxa. The early stratigraphical and paleontological studies of this Group were reported by Yabe and Otsuki (1902) and Yabe and Yehara (1913).

Straigraphical studies of the Miyako Group have reported by Yabe (1927), Hanai (1950, 1953), Onuki (1956), Hanai *et al.* (1968) and Shimazu (1970). Tanaka (1978) subdivided the Miyako Group into the Raga, Tanohata, Hiraiga, and Aketo Formations in ascending order and suggested contemporaneous relation among the Hiraiga and Sakiyama Formations and *Orbitolina* sandstone. Sato (2001) revised the Orbitolina sandstone to the Hiraname Formation (Table 1).

Ammonoids yield many horizons of the Miyako Group as index fossils. Therefore, ammonid biostratigraphies are significant and have been reported by Shimizu (1931), Hanai *et al.*, (1968), Obata (1967a; b; 1969; 1973; 1975), Obata and Matsukawa (1980), Obata and Futakami (1991; 1992) and Hoffmann *et al.* (2013). These studies reported that age of the Group which is considered to be late Aptian to early Albian. As other index fossils, *Neithea* (Bivalvia; Hanai *et al.*, 1968) and Palynomorph (Umetsu *et al.*, 2003) have been also reported.

Many paleontological researches of the Miyako Group have been published (Jimbo, 1901; Yehara, 1915; 1920; 1923; Yabe and Hanzawa, 1926; Yabe and Toyama, 1928; Nagao, 1934; 1943; Shimakura, 1937; Nisiyama, 1950; Eguchi, 1951; Hanai, 1953; Lowenstam and Epstein, 1954; Kobayashi *et al.*, 1954; Kobayashi and Nakano, 1957; Hayami, 1965a; b; 1966; Ujiie and Kusukawa, 1968; Takahashi, 1971; 1974; Research Group for Mesozoic Fossil Sharks, 1977; Tanaka and Obata, 1982; Kawakami and Tanaka, 1983; Tanaka and Kawakami, 1983; Takeda and Fujiyama, 1983; Kase, 1984; Oji, 1985; Hasegawa *et al.*, 1991; Sato, 2001; Nikaido and Matsuoka, 2004; 2005; Umetsu and Sato, 2007; Ohana, 2008).

Sedimentological researches of the Miyako Group have been reported by Terui (1979), Oji and Hanai (1982), Sano (1991) and Fujino *et al.* (2004; 2006a; b). Hanai *et al.* (1968) and Tanaka (1978) summarized distribution, sedimentary environment, biostratigraphy, age, paleogeography and paleoecology of the Group.

Mochizuki and Ando (2002; 2003) reported 16 sequences from the Group, based on sequence stratigraphical approach for shell beds, paleoecology and taphonomy have increased since 1990's.

Fujino (2003) reported relationship between sedimentary facies and mode of occurrence of molluscan fossils from Tanohata area of the Miyako Group and estimated molluscan habitats.

2. 1. 2. Geological setting

The Lower Cretaceous Miyako Group is exposed sporadically along the Rikuchu coast, which extends for approximately 35 km in Iwate Prefecture, northeast Japan (Figure 3).

The Miyako Group unconformably overlies the Jurassic accretionary complex Masakizawa Formation and Lower Cretaceous Harachiyama Formation at the western area. The eastern area of the Miyako Group is uncertain in the sea.

The total thickness of the Miyako Group is approximately 200 m. Lithofacies of the Group is maily composed of sandstone with silt stone and conglomerate. The generally strata strike NS to N30° E, and dip 20° to 40° E (Figures 4 and 5). The Group bears no geological structure at large scale and strata conformably overlies.

The present study follows stratigraphy in the north area of Sato (2001). In the north area, the Miyako Group is subdivided into the Raga, Tanohata, Hiraiga, and Aketo Formations in ascending order and contemporaneous relation between the Hiraiga and Hiraname Formations (Figures 6 and 7). The Raga Formation is mainly composed of conglomerate. Lower part of the Tanohata Formation is composed of amalgamated hummocky cross stratification (HCS) sandstone with interbedded conglomerate. Upper part of the Tanohata Formation is composed of sandy silt stone including crinoid plates, bivalves such as *Pterotrigonia yokoyamai*, corals. The Hiraiga Formation is composed of alternation amalgamated HCS sandstone and alternation HCS sandstone with sandy silt stone including crinooid plates, bivalves such as *Pterotrigonia hokkaidoana* and ammonoids such as *Valdedorsella* sp. The Hiraname Formation is composed of sandstone with abundant *Orbitolina* (Foraminifera) including bivalves such as *Pterotrigonia hokkaidoana*. The Aketo Formation is mainly composed of alternation HCS sandstone with sandy silt stone including crinoid plates, bivalves such as *Limatula nagaoi* and ammonoids such as *Pseudoleymeriella* sp. (Tables 2 and 3)

The present study follows stratigraphy in the south area of Shimazu *et al.* (1970). In the south area, the Group is subdivided into the Raga, Tanohata, Hiraiga and Sakiyama Formations in ascending order, and the Hideshima Formation (Figures 8 and 9). The Hideshima Formation is inferred to be the uppermost of the Group based on the topographical position of the Formation and geological structure (Shimazu *et al.*, 1970). However, the present study doesn't deal with the Formation for uncertaining relationship among other Formations. The Sakiyama Formation is mainly composed of massive sandy silt stone including ammonoids such as *Aconeceras* sp., bivalves such as *Limatula nagaoi* and gastropods such as *Avellana minima*. (Table 2, 3)

On the basis of the ammonoid biostratigraphy, Formations from the Tanohata to the Aketo is considered to be late Aptian to early Albian in age (Obata, 1974).

2. 1. 3. Lithostratigraphy and geological age

(a) Raga Formation

[Definition]

Yabe and Yehara (1913) defined the Raga conglomerate. Onuki (1956) revised the Raga Formation. The Formation is defined as conglomerate and coarse sandatone which is overlain by fine sandstone of the Tanohata Formation in the present study.

[Type locality]

Hiraiga, Tanohata Village, Shimohei County, Iwate Prefecture (Yabe and Yehara, 1913).

[Stratigraphical correlation]

The Raga Formation clinounconformably overlies the Jurassic accretionary complex Masakizawa Formation and Lower Cretaceous Harachiyama Formation. The Raga Formation is comformably overlain by the Tanohata Formation.

[Distribution]

The Raga Formation distributes in the large area (Kuwagasaki to Takonohama in Miyako City, Taro coast in Moshi Town and Koikorobe to Bentenzaki in Tanohata village).

[Lithofacies]

The Raga Formation is composed of alternation conglomerate and sandstone and subdivided into the basal and main parts. The basal part is composed of massive clast-supported conglomerate (Plate 1-1). Clasts of the conglomerate are poorly sorted, boulder to pebble sized and angular to subangular sandstone, chert and andesite. Matrix of the conglomerate is medium sand. The main part is composed of clast-supported conglomerate with imbrication structure and coarse sandstone (Plate 1-2). Clasts of the conglomerate is well sorted, boulder to granule sized and rounded to subrounded chert, andesite, quartz diorite and sandstone. Matrix of the conglomerate is fine sand.

[Thickness]

General thickness of the Raga Formation is approximately 30 m. Maximum thickness of the Formation is 107 m at Kuwagasaki to Takonohama.

[Fossil]

No fossils are obtained from the Raga Formation in the present study. Nikaido and Matsuoka (2004) reported Jurassic radiorarians from clasts of conglomerate.

[Age]

No index fossils are obtained from the Raga Formation. However, its age is considered to be middle of late Aptian based on the age of the Tanohata Formation.

(b) Tanohata Formation

[Definition]

Hanai (1950) defined the Tanohata conglomeratic subFormation which combined the Moshi sandstone with the Tanohata sandy shale in Yabe and Yehara (1913). Hanai *et al.* (1968) revised the Tanohata Formation. The present study defines the Formation which is amalgamated HCS sandstone and sandy silt stone. They overlies conglomerate of the Raga Formation and is overlain by fine sandstone of the Hiraiga Formation.

[Type Locality]

Hiraiga coast, Tanohata Village, Shimohei County, Iwate Prefectue (Hanai, 1950).

[Stratigraphical correlation]

The Tanohata Formation conformably overlies the Raga Formation and is overlain by the Hiraiga Formation in Tanohata area. In other areas, the Tanohata Formation unconformably overlies the Harachiyama Formation and is conformably overlain the Hiraiga Formation.

[Distribution]

The Tanohata Formation distributes in the large area (Hideshima coast in Miyako City, Taro, Masaki and Moshi coast in Moshi Town and Shimanokoshi to Aketo in Tanohata village).

[Lithofacies]

The Tanohata Formation is mainly composed of amalgumed HCS sandstone in the lower part and massive sandy silt stone in the upper part. Amalgumed HCS sandstone interbeds clast-supported conglomerate (Plate 2-1). Clasts of the conglomerate are poorly sorted, boulder to pebble sized and subrounded coral, andesite, quartz porphyry and chert. Matrix of the conglomerate is coarse to medium sand. The conglomerate is divided into sub-layers by erosional bases. Paleocurrents of sub-layers are truncated each other. The conglomerate bears molluscan fossils and corals. Shell beds and liquefaction structures are frequently born in laminae of the HCS sandstone. Massive sandy silt stone bears calcareous nodules and trace fossils.

[Thickness]

General thickness of the Tanohata Formation is approximately 40 m. Maximum thickness of the Formation is 70 m at Masaki.

[Fossils]

Bivalves such as *Neithea ficalhoi*, *Neohibolites miyakosensis* (Belemnitida), corals and crinoid plates are obtained from HCS sandstone in the present study. From conglomerate, bivalves such as *Pterotrigonia yokoyamai*, gastropods such as *Semisolarium incrassatum* and corals are obtained (Plate 25).

[Age]

Hanai *et al.* (1968) suggests that *Neithea* (Bivalvia) is useful as an index fossil. According to the study, *Neithea* *ficaloi* indicates late Aptian. Therefore, the Tanohata Formation is considered to be late Aptian in age. Obata (1974) reported that the age of the Formation is considered to be middle to late of late Aptian based on ammonoid biostratigraphy.

(c) Hiraiga Formation

[Definition]

Yabe and Yehara (1913) defined the Hiraiga sandstone. Hanai *et al.* (1968) revised the Hiraiga Formation. Shimazu *et al.* (1970) redefined. The present study defines the Formation as amalgamated HCS sandstone (Plate 2-2), alternation HCS sandstone with sandy silt stone and sandy silt stone. These rocks overly thick sandy silt stone of the Raga Formation and are overlain by sandy silt stone of the Sakiyama Formation and *Orbitolina* sandstone of the Hiraname Formation.

[Type locality]

Between the Hiraiga and Raga coast, Tanohata Village, Shimohei County, Iwate Prefecture (Yabe and Yehara, 1913).

[Stratigraphical correlation]

The Hiraiga Formation conformably overlies the Tanohata Formation. The Sakiyama Formation conformably overlies the Hiraiga Formation at Hideshima coast and the Hiraname Formation at Aketo and Raga.

[Distribution]

The Hiraiga Formation distributes in the large area (Hideshima coast in Miyako City, Masaki and Moshi coast in Moshi Town and Koikorobe to Aketo in Tanohata village).

[Lithofacies]

The Hiraiga Formation is composed of fine to medium amalgamated HCS sandstone (Plate 2-2), alternation HCS sandstone of sandy silt stone and massive sandy silt stone (Plate 3-1). Shell beds are frequently born in laminae of the HCS sandstone. Massive sandy silt stone bears trace fossil and autochthonous bivalves.

[Thickness]

General thickness of the Tanohata Formation is more than 40 m. However, upper limit of the Formation is uncertain in the sea excluding Hiraname and Aketo. Maximum thickness of the Formation is 68 m at northern Haipe.

[Fossils]

Ammonoids such as *Valdedorsella* sp., bivalves such as *Pterotrigonia Hokkaidoana*, Gastropods such as *Semisolarium incrassatum*, *Neohibolites miyakoensis* (Belemnitida) and corals are obtained from HCS sandstone in the present study (Plate 26, 27).

[Age]

No index fossils are obtained from the Hiraiga Formation in the present study. Obata (1974) reported that the age of the Formation is considered to be late of late Aptian to late of early Albian based on its ammonoid biostratigraphy.

(d) Hiraname Formation

[Definition]

Yabe and Yehara (1913) defined the *Orbitolina* sandstone. Sato (2001) revised the Hiraname Formation. The present study defines the Formation as sandstone including abundant *Orbitolina* (Foraminifera). It overlies fine sandstone of the Hiraiga Formation.

[Type locality]

Hiraname, Tanohata Village, Shimohei County, Iwate Prefecture (Sato, 2001).

[Stratigraphical correlation]

The Hiraname Formation is contemporaneous relationship with the Hiraiga Formation and comformably overlain by the Aketo Formation.

[Distribution]

The Hiraname Formation distributes from Hiraname to Aketo coast.

[Lithofacies]

The Hiraname Formation is composed of alternation medium to coarse sandstone including abundant *Orbitolina* (Foraminifera) with sandy silt stone (Plate 4-1). The *Orbitolina* sandstone rarely bears bivalves.

[Thickness]

Thickness of the Hiraname Formation is 15 m at Hiraname and 10 m at Aketo, respectively.

[Fossils]

The *Orbitolina* sandstone bears abundant *Orbitolina lenticularis* (Foraminifera) and rarely bivalves such as *Pterotrigonia Hokkaidoana*.

[Age]

Although *Orbitolina lenticularis* is an index fossil for Barremian to Cenomanian (Ujiie and Kusukawa, 1968), the range is too wide for discussion about the stratigraphical position of the Hiraname Formation in the Miyako Group. Age of the Formation is considered to be late Aptian to early Albian by the age of the Hiraiga Formation and the Aketo Formation.

(e) Sakiyama Formation

[Definition]

Shimazu *et al.* (1970) was defined as the Sakiyama Formation. The present study defines the Formation as thick sandy silt stone which overlies fine sandstone of the Hiraiga Formation.

[Type locality]

Hideshima coast, Miyako city, Iwate Prefecture (Shimazu *et al.*, 1970).

[Stratigraphical correlation]

The Sakiyama Formation conformably overlies the Hiraiga Formation. The upper limit of the Sakiyama Formation is uncertain in the sea.

[Distribution]

The Sakiyama Formation distributes from Hideshima coast to Taro.

[Lithofacies]

The Sakiyama Formation is composed of massive sandy silt stone in the lower part and amalgumed HCS sandstone in the upper part (Plate 3-2). The massive sandy silt stone bears calcareous nodules. Abundant fossils are born in host rock and calcareous nodules. Shell beds and tree trunks are frequently born in laminae of the HCS sandstone.

[Thickness]

Thickness of the Sakiyama Formation is more than 15 m at the Hideshima coast. However, upper limit of the Formation is uncertain in the sea.

[Fossils]

The massive sandy silt stone and calcareous nodule bear ammonoids such as *Aconeceras* sp., bivalves such as *Limatula nagaoi*, gastropods such as *Avellana minima* and plants such as *Cladophlebis* sp (Plates 28 and 29).

[Age]

Age of the Sakiyama Formation is considered to be early Albian based on occurrence of ammonoids such as *Pseudoleymeriella hataii*.

(f) Aketo Formation

[Definition]

Yabe and Yehara (1913) defined the Aketo sandstone. Hanai *et al.* (1968) revised the Aketo Formation. The present study defines the Formation as alternation of HCS sandstone and sandy silt stone which overlies amalgumed HCS sandstone of the Hiraiga Formation.

[Type locality]

From Hiraname to Aketo coast, Tanohata Village, Shimohei County, Iwate Prefecture (Hanai *et al.*, 1968).

[Stratigraphical correlation]

The Aketo Formation conformably overlies the Hiraname Formation. The upper limit of the Aketo Formation is uncertain in the sea.

[Distribution]

The Aketo Formation distributes from Hiraname to Aketo coast.

[Lithofacies]

The Aketo Formation is composed of alternation HCS sandstone with sandy silt stone. Shell beds are frequently born in laminae of the HCS sandstone. The sandy silt stone bears calcareous nodules and trace fossils.

[Thickness]

Thickness of the Sakiyama Formation is more than 20 m at the Aketo coast. However, upper limit of the Formation is uncertain in the sea.

[Fossils]

The HCS sandstone bears Ammonoids such as *Pseudoleymeriella* sp., bivalves such as *Limatula nagaoi*, gastropods such as *Tylostoma miyakoense*, *Coenholectypus peridoneus* (Echinoidea), Crinoid plates and shark teeth (Plates 30 and 31).

[Age]

Age of the Sakiyama Formation is considered to be late of early Albian based on occurrence of ammonoids such as *Pseudoleymeriella hataii* (Obata, 1974).

2. 2. Futaba Group

2. 2. 1. Previous works

Many geologists have investigated in the Joban area in the southern Fukushima Prefecture for yielding coal (e. g. Eguchi *et al.*, 1953). Tokunaga (1923a; b) reported Cretacous system from the Futaba area in the northern Joban area. In the study, the Cretaceous was defined as the Futaba Group which was subdivided into the Lower, Middle and Upper Formations in asceding order.

Tokunaga and Shimizu (1926) reported that Late Cretaceous mollusca such as Trigonia and ammonoids and Ichthyosauria were occurred from the Futaba Group. Konno (1938) revised stratigraphy of Tokunaga (1923a) which subdivided into the Ashizawa, Kasamatsu and Tamayama Formations. Saito (1960) subdivided the Ashizawa Formation into the Asamigawa and Obisagawa members (Table 4). Saito (1962) reported mollusca such as bivalves and ammonoids.

Obata (1967c) and Obata and Suzuki (1969) suggested that age of the Futaba Group is considered Coniacian to early Santonian by *Inoceramus* (bivalvia) and ammonoids. Nannoplanktons (Takayama and Obata, 1968) and pollens and spores (Miki, 1970) also suggested the same age of Obata (1967) and Obata and Suzuki (1969).

Ando *et al.* (1995) subdivided into 15 sedimentary facies which is estimated talus, alluvial fan, braided river, meandering river and upper shoreface to inner shelf sediments. The study reported transition of sedimentary environments of the group by sequence stratigraphy.

Kubo *et al.* (2002) subdivided the Tamayama Formation into the Kobisagawa and Irimazawa members (Table 2).

Hirata (2005) reported five molluscan assemblages from the Ashizawa Formation. Sato *et al.* (2006) reported *Futabasaurus suzukii* (Plesiosauroidea) from the Tamayama Formation.

2. 2. 2. Geological setting

The Futaba Group is Late Cretaceous fluvial to shallow-marine sediments narrowly distributed in the Abukuma Belt which is located on north Honshu (Figure 10).

The Futaba Group nonconformably overlies the Early Cretaceous intrusive granitic rocks (126-97.4 Ma; Kubo and Yamamoto, 1990) at the western area. At the southwestern area, the Group contacts with the Permian Takakurayama Group (Yanagisawa, 1967) by fault. At the eastern area, the Futaba Group is clinounconformably overlain by the Paleogene Shiramizu Group. At the northern area, the Futaba Group thins out by erosion of unconformity. At the Southern area, the Futaba Group contacts with Quaternary systems by Futatsuya Fault (Iwao and Matsumoto, 1961).

The total thickness of the Futaba Group is approximately 350 m. Lithofacies of the Group is mainly composed of sandstone, silt stone and conglomerate. The generally strata strike N5° to N25° E, and dip 10° to 20° E in the area (Figures 11 and 12). The Group doesn't have geological structure at large scale and strata overlies conformably or disconformably.

The present study follows the stratigraphy by Kubo *et al.* (2002) which subdivided the Futaba Group into the Asamigawa Member of the Ashizawa Formation, the Obisagawa Member of the Ashizawa Formation, the Kasamatsu Formation, the Kobisagawa Member of the Tamayama Formation and the Irimazawa Formation of the Tamayama Formation in ascending order. The Asamigawa Member is mainly composed of conglomerate. The Obisagawa Member is mainly composed of fine sandstone including molluscan fossils such as *Inoceramus uwajiensis*. The Kasamatsu Formation is mainly composed of upward-fining units of alternation of sandstone and silt stone. The Kobisagawa Member is mainly composed of coarse sandstone. The Irimazawa Member is composed of alternation conglomerate with fine sandstone including bivalves such as *Inoceramus* sp. (Table 5)

On the basis of the Inoceramid biostratigraphy, the Futaba Group is considered to be early Coniacian to early

Santonian in age (Obata and Suzuki, 1969).

2. 2. 3. Lithostratigraphy and geological age

(a) Ashizawa Formation

The Ashizawa Formation was defined by Tokunaga (1923a) as the Lower Formation. Konno (1938) revised the Ashizawa Formation. Saito (1960) subdivided the Formation into the Asamigawa and Obisagawa Members. Although the present study follows the division by Saito (1960), the present study revises boundary of between the members. The type locality is Ashizawa, Obisa-machi, Iwaki City, Fukushima Prefecture (Konno, 1938).

(a-1) Asamigawa Member

[Definition]

The Asamigawa Member was defined by Saito (1960). Saito (1960, 1961) defined the member as all horizons which are interbedded conglomerate. However, Ando *et al.* (1995) defined the member as talus and fullvial sediments before transgressive conglomerate. The present study almost follows division by Ando *et al.* (1995) and defines the members as conglomerate and coarse sandstone which is overlain by marine fine sandstone of the Obisagawa Member.

[Type locality]

Asami River, Hirono Town, Futaba County, Fukushima Prefecture (Saito, 1960).

[Stratigraphical correlation]

The Asaimigawa Member nonconformably overlies the Early Cretaceous intrusive granitic rocks. Because of thining out of the Obisagawa Member, the Asamigawa Member is unconformably overlain by the Shiramizu Group at Osaka, Naraha Town, Futaba County. At other distribution areas, the Asamigawa Member is conformably overlain by the Obisagawa Member.

[Distribution]

The Asamigawa Member distributes narrow area from Osaka, Narahara Town to northeastern Takakurayama.

[Lithofacies]

The Asamigawa Member is composed of alternation of conglomerate and sandstone and subdivided into the basal and main parts. The basal part is composed of massive clast-supported conglomerate (Plate 10-1). Clasts of the conglomerate are well sorted, cobble to pebble and rounded to subrounded granite. Matrix of the conglomerate is fine sand. The main part is composed of clast or matrix-supported conglomerate with imbrication structure and coarse sandstone including gravels. Clasts of the conglomerate is well sorted, and rounded to subrounded granite. Matrix of the conglomerate is fine sand. The main part is recognized upward-fining which transits from the clast-supported to matrix supported conglomerate and increases rate of the coarse sandstone.

[Thickness]

General thickness of the Asamigawa Member is approximately 30 m. Maximum thickness of the Member is 59 m at Asami River and its minimum thickness is 3 m at Obisa River.

[Fossils]

No fossils are obtained from the Asamigawa Member in the present study. Takahashi *et al.* (1999a; b) reported flowers, leaves, spores and pollens of plants.

[Age]

No index fossils are obtained from the Asamigawa Member. However, its age is considered to be early Coniacian on the basis of that of the Obisagawa Member.

(a-2) Obisagawa Member

[Definition]

The Obisagawa Member was defined by Saito (1960). Saito (1960, 1961) defined the member as sandstone which is no iterbedded conglomerate. However, Ando *et al.* (1995) was defined the member as marine sediments with transgressive conglomerate. The present study almost follows division by Ando *et al.* (1995) and defines the members as marine fine sandstone which overlies fullvial sediments of the Asamigawa Member and is overlain quartz-rich sandstone of the Kasamatsu Formation.

[Type locality]

Obisa River, Iwaki City (Saito, 1960).

[Stratigraphical correlation]

The Obisagawa Member contacts with the Takakurayama Group by fault at northeastern Takakurayama. Because of thining out of the Kasamatsu Formation, the Member is unconformably overlain by the Shiramizu Group at Osaka, Naraha Town. At other distribution areas, the member conformably overlies tha Asamigawa Member and is conformably overlain by the Kasamatsu Formation.

[Distribution]

The Obisagawa Member distributes narrow area from Osaka, Narahara Town to northeastern Takakurayama.

[Lithofacies]

The Obisagawa Member is mainly composed of silt stone and fine sandstone, frequently interbedded thin calcareous conglomerate. Shell beds are born in the calcareous conglomerate and obtained bivalves such as *Glycymeris amakusensis* and Gastropods such as *Sargana* sp. (Plate 6-2). The silt stone and fine sandstone are massive and parallel lamination (Plates 7-1, 2 and 8-1). The silt stone and fine sandstone bear calcareous nodules, plant remains and trace fossils. Shell beds are born in the fine sandstone and calcareous nodules and obtained ammonoids such as *Scaphites*? sp., bivalves such as *Inoceramus uwajimensis*, Gastropods such as *Gyrodes* sp. and Shark teeth such as *Cretolamna* sp.

[Thickness]

General thickness of the Obisagawa Member is approximately 70 m. Maximum thickness of the member is 100 m at Obisa River and its minimum thickness is 50 m at Kitaba River.

[Fossils]

The calcareous conglomerate bears bivalves such as *Glycymeris amakusensis* and Gastropods such as *Sargana* sp (Plate 33). The fine sandstone and calcareous nodules bear ammonoids such as *Scaphites*? sp., bivalves such as *Inoceramus uwajimensis*, Gastropods such as *Gyrodes* sp. and Shark teeth such as *Cretolamna* sp. (Plates 34, 35, 36 and 37).

[Age]

Inoceramus uwajimensis is index fossil of middle Coniacian (Toshimitsu *et al*., 1995). Therefore, the Obisagawa member is considered to be middle Coniacian in age. Hirata (2007, MS) reported *I. pedalionoides* from the calcareous conglomerate and suggested that the member is considered to be early Coniacian Age.

(b) Kasamatsu Formation

[Definition]

The Kasamatsu Formation was defined by Konno (1938). The present study defines the Formation as upward-fining units of alternation of quartz-rich sandstone and silt stone which overlies fine sandstone of the Obisagawa Member and is overlain thick sandstone of the Kobisagawa Member.

[Type locality]

Kasamatsu, Iwaki City, Fukushima Prefecture (Konno, 1938).

[Stratigraphical correlation]

Because of thining out of the Kobisagawa Member, the Kasamatsu Formation is unconformably overlain by the Shiramizu Group from Dokameki, Hirono Town, Futaba County to Osaka, Naraha Town. At other distribution areas, the Formation conformably overlies the Obisagawa Member and is conformably overlain the Kobisagawa Member.

[Distribution]

The Kasamatsu Formation distributes narrow area from Osaka, Narahara Town to Tamayama, Iwaki City.

[Lithofacies]

The Kasamatsu Formation is mainly composed of upward-fining units of alternation of quartz-rich sandstone and massive silt stone and intense transition of lithofacies in the Futaba Group (Plate 6-1).

The quartz-rich sandstone is poorly sorted, coarse to fine size, abundant euhedral quartz and poor feldspar. The sandstone includes cross lamination, gravels and load casts. The massive silt stone bears ambers, plant remains and coarse sand size of quartz.

The Kasamatsu Formation is alternation of upward-fining units. The representative unit is composed as follows; 1) The base of unit is rounded conglomerate. 2) Size of clasts of the conglomerate becomes small and ratio of matrix of the conglomerat increases while going upward. 3) The conglomerate is overlain by sandstone. 4) Size of the sandstone transits very coarse including gravel to very fine sandstone. 5) The sandstone is overlain silt stone which is enriched organic matter in uppermost of the unit. 6) Thickness of the unit is several ten centimeters to several meters. The representive unit is rarely recognized, generally lacked some horizons.

[Thickness]

General thickness of the Kasamatsu Formation, which is approximately 75 m, tends to thin at the southern distribution area. Maximum thickness of the Formation is 140 m at Gokurakuzawa.

[Fossils]

The silt stone of the Kasamatsu Formation bears ambers and tree trunks. Takahashi (2005) reported insects and reptiles from the silt stone.

[Age]

No index fossils are obtained from the Kasamatsu Formation. However, its age is considered to be late Coniacian according to the age of the Ashizawa and Tamayama Formation.

(c) Tamayama Formation

The Tamayama Formation was defined by Konno (1938). Ando *et al.* (1995) sudivided the Formation into the lower~middle and upper parts. Kubo *et al.* (2002) defined the lower~middle and upper parts of Ando *et al.* (1995) as the Kobisagawa and Irimazawa Members. The type locality is Tamayama, Iwaki City, Fukushima Prefeture (Konno, 1938).

(c-1) Kobisagawa Member

[Definition]

The Kobisagawa Member was defined by Kubo *et al.* (2005). The present study defines thick sandstone which overlies interbedded silt stone of the Kasamatsu Formation and underlies by conglomerate of the Irimazawa Member.

[Type Locality]

Kobosa River, Iwaki City (Kubo *et al.*, 2002).

[Stratigraphical correlation]

The Kobisagawa Member conformably overlies the Kasamatsu Formation. The Member is conformably overlain by the Irimazawa Member at Irimazawa to Jinba, Iwaki City. Because of thining out of the Irimazawa Member, the Kobisagawa Member is unconformably overlain by the Shiramizu Group at other distribution areas.

[Distribution]

The Kobisagawa Member distributes narrow area from Dokameki, Hirono Town to Tamayama, Iwaki City.

[Lithofacies]

The Kobisagawa Member is mainly composed of thick massive sandstone with interbedded massive silt stone. The sandstone bears gravels, indistinct parallel lamination and cross stratification (Plate 9-1). The silt stone bears abundant organic matter and ambers (Plate 10-2).

[Thickness]

Thickness of the Kobisagawa Member at Obisa river and at Irimazawa River is approximately 135 m and 125 m, respectively.

[Fossils]

The silt stone of the Kobisagawa Member bears ambers and tree trunks. Hashimoto (1991) reported insects and dinosaurs from the silt stone.

[Age]

No index fossils are obtained from the Kobisagawa Member. However, its age is considered to be late Coniacian from that of the Ashizawa Formation and the Kobisagawa Member.

(c-2) Irimazawa Member

[Definition]

The Irimazawa Member is defined by Kubo *et al.* (2002). The present study defines alternation of conglomerate and fine sandstone which overlies thick sandstone of the Kobisagawa Member.

[Type locality]

Lower part of Irimazawa, Iwaki City (Kubo *et al.*, 2002).

[Stratigraphical correlation]

The Irimazawa Member conformably overlies the Kobisagawa Member and unconformably underlies by the Shiramizu Group.

[Distribution]

The Irimazawa Member distributes the small area (Irimazawa to Jinba, Iwaki City).

[Lithofacies]

The Irimazawa Member is composed of alternation of matrix-supported conglomerate and fine sandstone (Plate 8-2). Clasts of the conglomerate is well sorted, pebble, rounded. Matrix of the conglomerate is fine sandstone. The sandstone bears trace fossils, ambers, bivalves such as *Inoceramus* sp. and *Cretolamna* sp. (shark teeth).

[Thickness]

Thickness of the Irimazawa Member is more than 55 m at Obisa River.

[Fossils]

The fine sandstone of the Irimazawa Member bears ambers, bivalves such as *Inoceramus* sp. and *Cretrolamna* sp. of shark teeth (Plate 37).

[Age]

The age of the Irimazawa Formation is considered to be early Santonian based on occurrence of *Inoceramus amakusensis* (Obata and Suzuki, 1969).

2. 3. Nakaminato group

2. 3. 1. Previous works

Ozaki and Saito (1955) reported Cretaceous system from the Nakaminato area with occurrence of heteromorph ammonoids.

The early stratigraphical studies were reported by Ozaki and Saito (1955) and Saito (1958; 1959; 1961; 1962). In these study, the Naka Group is composed of the Oarai and Nakaminato Formations which is subdivided into the Tikko, Hiraiso and Isoai Members in ascending order. Tanaka (1970) revised the Nakaminato Formation as the Nakaminato Group which was subdivided into the Tikko, Hiraiso and Isoai Formation in ascending order (Table 6).

Several studies suggested age of the Nakaminato Group from ammonoids and *Inoceramus* biostratigraphies. Saito (1961; 1962) suggested that age of the Nakaminato Group is considered to be middle Campanian to early Maastrichtian by *Didymoceras awajience* and *Inoceramus* cf. *shikokuense*. Ando (2006) reported *Inoceramus kushiroense* which is considered early Maastrichtian from collection of Saito (1961; 1962).

In respect of sedimentology of the Nakaminato Group, Tanaka (1970), Masuda and Katsura (1978) and

Katsura and Masuda (1978) reported sedimentological structure and considered the Group as submarine fan sediments.

Tanaka (1970; 1986) and Ando (2006) suggested that the Nakaminato Group is an eastern extension of the Izumi Group by stratigraphy, lithofacies and fossils.

2. 3. 2. Geological setting

The Upper Cretacous Nakaminato Group is exposed along the Pacific coast, which extends for approximately 35 km in Ibaraki Prefecture, northeast Japan (Figure 13).

The Nakaminato Group contacts with the Neogene Tonoyama Formation of the Taga Group at southern distribution area, the Isozaki Formation of the Taga Group at northern distribution area and the Taga Group at western distribution area by fault. At eastern distribution area, the Nakaminato Group is uncertain in the sea (Tanaka, 1970).

The total thickness of the Nakaminato Group is more than 1500 m. Lithofacies of the Group is mainly composed of turbidite sandstone with silt stone and conglomerate. The generally strata strike N30° to 75° W and dip 40° E (Figures 14 and 15). The Group bears no geological structure at large scale and strata conformably overlies with the exception of slumping structure.

The present study follows the stratigraphy by Tanaka (1970) which subdivides the Nakaminato Group into the Tikko, Hiraiso and Isoai Formations. However, the Tikko Formation was not recognized. The Hiraiso Formation is mainly composed of lower part of alternation sandstone with silt stone and upper part of CCC turbidites sandstone. The alternation sandstone with silt stone bears calcareous nodules which yield fossils such as *Didymoceras awajiense*. The CCC turbidites sandstone includes ripped-up mud clasts, convolution and climbing ripples. The Isoai Formation is mainly composed of turbidites sandstone which bears trace fossils.

On the basis of the ammonoid and *Inoceramus* biostratigraphies, the Nakaminato Group is considered to be middle Campanian to early Maastrichtian in age (Saito, 1961; 1962).

2. 3. 3. Lithostratigraphy and geological age

(a) Hiraiso Formation

[Definition]

Ozaki and Saito (1955) defined the Hiraiso Member. Tanaka (1970) revised the Hiraiso Formation. The present study defines the Formation as alternation of sandstone and silt stone and CCC turbidites sandstone which is overlain by Bouma sequences of the Isoai Formation.

[Type locality]

Hiraiso, Hitachinaka City, Ibaraki Prefecture (Ozaki and Saito, 1955).

[Stratigraphical correlation]

The Hiraiso Formation conformably overlies the Tikko Formation, and is conformably overlain by the Isoai Formation (Tanaka, 1970). However, the present study doesn't recognize boundary between the Tikko and Isoai Formations.

[Distribution]

The Hiraiso Formation distributes coast of Hiraiso, Hitachinaka City, Ibaraki Prefecture.

[Lithofacies]

The Hiraiso Formation is mainly composed of the lower part of alternation sandstone with silt stone and upper part of CCC turbidites sandstone. The base of lower part is composed of conglomerate with fine sandstone. The main of lower part is composed of 5-10 cm thinly alternation of sandstone and silt stone (Plates 12-2 and 13-1). The silt stone bears calcareous nodules, which includes ammonoids, 5-20 cm in diameter. The sandstone includes liquefaction structures and cross-laminations. The upper part of CCC turbidites sandstone interbeds thin silt stone. The CCC turbidites sandstone is composed of well sorted and medium to coarse sized and includes ripped-up mud clasts, convolution and climbing ripples (Plate 13-2).

[Thickness]

Thickness of the Hiraiso Formation is more than 200 m. However, boundary between the Tikko and Hiraiso Formations is uncertain.

[Fossils]

The calcareous nodules from thin alternation sandstone with silt stone bear *Didymoceras awajiense* and *Diplomoceras*? sp. (Plate 38)

[Age]

The age of the Hiraiso Formation is considered to be middle Campanian by occurrence of *Didymoceras awajiense*.

(b) Isoai Formation

[Definition]

Ozaki and Saito (1955) defined the Isoai Member. Tanaka (1970) reviced the Isoai Formation. The present study defines the Formation as turbidites sandstone which overlies CCC turbidites sandstone of the Hiraiso Formation.

[Type locality]

Isoai, Hitachinaka City, Ibaraki Prefecture (Ozaki and Saito, 1955).

[Stratigraphical correlation]

The Isoai Formation conformably overlies the Hiraiso Formation and underlies by the Isozaki Formation of the Taga Group for fault.

[Distribution]

The Isoai Formation distributes coast of Isoai, Hitachinaka City.

[Lithofacies]

The Isoai Formation is mainly composed of alternation unit of conglomerate, sandstone and silt stone. The representive alternation unit bears Bouma sequence which is composed of massive clast-supported conglomerate with sandstone, parallel-lamination sandstone, current-rippled sandstone, parallel-lamination sandstone and massive silt stone, in ascending order (Plate 11-1). However, the representive alternation unit is rarely recognized, generally lacked some horizons. Clasts of the conglomerate with sandstone are well sorted, pebble to granule sized, subrounded to rounded chert, granite and diorite. Matrix of the conglomerate is medium to coarse sand. The base of the massive clast-supported conglomerate with sandstone bears flute casts and trace fossils. The parallel-lamination sandstone bears dish structure and ripped-up mud clasts.

The Formation includes matrix-supported conglomerate with mudstone matrix (Plate 12-1). Clasts of the conglomerate are composed of alternation sandstone with silt stone. Upper part of the conglomerate bears slumping structures. Although the lower part of the Formation bears abundant conglomerate, the upper part of the Formation bears rarely conglomerate.

[Thickness]

Thickness of the Isoai Formation is more than 310 m. However, the upper limit of the Formation is uncertain.

[Fossils]

No fossils are obtained from the Isoai Formation in the present study. Saito (1961, 1962) and Ando (2006) reported *Inoceramus* cf. *shikokuensis* and *Inoceramus kushiroensis*.

[Age]

The Isoai Formation is considered to be early Maastrichtian in age by *Inoceramus* cf. *shikokuensis* and *Inoceramus kushiroensis* (Saito, 1961; 1962; Ando, 2006).

2. 4. Choshi Group

2. 4. 1. Previous works

Since the study by Ishiwatari (1906), many paleontologists and geologists have investigated the Choshi Group for its abundant occurrence of well-preserved marine invertebrate fossils of various taxa.

The first stratigraphical study of the Choshi Group is Kochibe (1910) which defined the Cretaceous system in the Choshi area as the Choshi Formation. The Formation was subdivided into the six Members by Yehara (1914), the four Members by Yamane (1924) and the four Members by Imazeki (1951). Shikama and Suzuki (1972) revised the Formation as the Choshi Group. Obata *et al.* (1975) subdivided the Group into the Iserogaura, Ashikajima, Kimigahama, Nagasakihana and Toriakeura Formations, in ascending order. Obata *et al.* (1982) subdivided the Group into the Ashikajima Formation, Kimigahama, Inubozaki, Toriakeura and Nagasakihana Formations, in ascending order (Table 7).

Ammonoids yield from many horizons of the Choshi Group as index fossil with the exception of the Nagasakibana Formation. Ammonoid biostratigraphy has been reported by Yehara (1914), Yamane (1924), Shimizu (1926), Shimizu (1931), Obata *et al.* (1975, 1982) and Obata and Matsukawa (2007, 2009a,b). These studies have reported that age of the Group is considered to be from early Barremian to late Aptian. Obata *et al.* (1982) reported late Albian ammonoids as reworking fossils from the base of the Naarai Formation which unconformably overlies the Group.

Many paleontological researches of the Choshi Group have been published topics of their researchers are as follows; foraminifers (Obata *et al.*, 1982), bivalves (Maeda, 1962; Hayami, 1966; Hayami and Oji, 1980), gastropods (Kase, 1984) and plants (Fujimoto, 1933; Nishida, 1959, 1960, 1961a, b, 1962, 1963, 1964, 1965a, b, 1966; Kimura, 1985; Kimura and Ohana, 1985; Kimura *et al.*, 1985; Saiki *et al.*, 1991).

In respect of sedimentology of the Choshi Group, Katsura *et al.* (1984) and Ishigaki and Ito (2000) reported sedimentary facies. Ito and Matsukawa (1997) reported depositional sequences. Hisada and Arai (1995) reported detrital chromian spinels from sandstone of the Group and suggested the Group belongs to the Chichibu Belt.

2. 4. 2. Geological setting

The Lower Cretaceous Choshi Group is exposed along the coast of Choshi Peninsula, which extends 4.5 km in Chiba Prefecture, northeast Japan (Figure 16).

Although the Choshi Group contacts with the Permian Atagoyama Group by fault at northern distribution area, correlation of the Groups is originaly considered to be unconformity (Shikama and Suzuki, 1972). The Choshi Group is unconformably overlain by the Pliocene Naarai Formation at southern distribution area. At eastern area, the Choshi Group is uncertain in the sea.

The total thickness of the Miyako Group is more than 800 m. Lithofacies of the Group is maily composed of sandstone with silt stone and conglomerate. The generally strata strike N40 to N80° W, and dip 20° to 40° S (Figures 17 and 18). The Group bears syncline and anticline with axis of WE direction at Ashikajima and Inubozaki. At Toriakeura to Nagasakihana, the Group bears weak anticline.

The presend study follows the stratigraphy of Obata *et al.* (1982) which is subdivided into the Ashikajima, Kimigahama, Inubozaki, Toriakeura and Nagasakihana Formations, in ascending order. The Ashikajima Formation is composed of conglomerate and coarse hummocky cross-stratification (HCS) sandstone. The Kimigahama Formation is mainly composed of alternation HCS sandstone with silt stone. The sandstone bears bathyal trace fossils. The Inubozaki Formation is mainly composed of amalgumated HCS sandstone and alternation of HCS sandstone and silt stone. The alternation of HCS sandstone and silt stone bears bathyal trace fossils. The Toriakeura Formation is composed of alternation of HCS sandstone, silt stone and massive silt stone. The massive silt stone bears *Portlandia sanchuensis* (Bivalvia). The Nagasakihana Formation is composed of alternation of thickly amalgamated HCS sandstone and thinly silt stone.

On the basis of the ammonoid biostratigraphy, the Choshi Group is considered to be early Barremian to late Albian in age (Obata *et al.*, 1982).

2. 4. 3. Lithostratigraphy and geological age

(a) Ashikajima Formation

[Definition]

Imazeki (1951) defined the Ashikajima sandstone. Obata *et al.* (1982) revised the Ashikajima Formation. The present study defines the Formation as conglomerate and coarse HCS sandstone which overlies alternation of HCS sandstone and silt stone of the Kimigahama Formation.

[Type locality]

Ashikajima, Choshi City, Chiba Prefecture (Imazaki, 1951).

[Stratigraphical correlation]

The Ashikajima Formation contacts with the Permian Atagoyama Group by fault. The Formation is conformably overlain by the Kimigahama Formation.

[Distribution]

The Ashikajima Formation distributes the coast of Kurohae to Ashikajima and western Nagasakibana, Choshi City.

[Lithofacies]

The Ashikajima Formation is composed of the lower part of alternation of clast-supported conglomerate, sandstone and silt stone and the upper part of amalgumed HCS sandstone (Plate 14-1). Clasts of the conglomerate are well-sorted, pebble sized and subrounded to rounded chert and sandstone. The conglomerate includes slumping structures, imbrications and trough cross-stratifications. Matrix of the conglomerate is coarse sand. The silt stone bears abundant organic matter. The amalgumed HCS sandstone is coarse sized.

[Thickness]

Thickness of the Ashikajima Formation is more than 8 m. However, the lower limit of the Formation is uncertain.

[Fossils]

No fossils are obtained from the Ashikajima Formation in the present study. Obata *et al.* (1982) reported ammonoids such as *Barremites* sp., *Hamiticeras* sp. and *Heminautilus tyoshiensis* and *Neohibolites* sp. (Belemnitida).

[Age]

The Ashikajima Formation is considered to be early Barremian in age based on occurrence of ammonoids such as *Barremites* sp., *Hamiticeras* sp. and *Heminautilus tyoshiensis* (Obata *et al.*, 1982).

(b) Kimigahama Formation

[Definition]

Shikama and Suzuki (1972) defined the Kimigahama shale bed. Obata *et al.* (1975) revised the Kimigahama Formation. The present study defines the Formation as alternation of HCS sandstone and silt stone which ovelies amalgumated HCS sandstone of the Ashikajima Formation and is overlain by amalgumed HCS sandstone of the Inubozaki Formation.

[Type locality]

Kimigahama, Choshi City, Chiba Prefecture (Shikama and Suzuki, 1972).

[Stratigraphical correlation]

The Kimigahama Formation conformably overlies the Ashikajima Formation and is conformably overlain the Inubozaki Formation.

[Distribution]

The Kimigahama Formation distributes the coast of Kimigahama to Ashikajima, Choshi City.

[Lithofacies]

The Kimigahama Formation is composed of alternation HCS sandstone with silt stone and interbedded amalgumated HCS sandstone (Plate 14-1). The thickness of the HCS sandstone and silt stone is approximately 10 cm. The HCS sandstone bears generally low-angle cross stratification and parallel lamination units, and rarely rippled cross stratification unit. The HCS sandstone bears bathyal trace fossils such as *Macaronichnus* isp.A, *Macaronichnus* isp.B, *Thalassinoides* isp. and *Zoophycos* isp. The siltstone bears abundant organic matter.

[Thickness]

Thickness of the Kimigahama Formation is approximately 55 m.

[Fossils]

The HCS sandstone bears bathyal trace fossils such as *Macaronichnus* isp.A, *Macaronichnus* isp.B, *Thalassinoides* isp. and *Zoophycos* isp (Plate 39).

[Age]

The Kimigahama Formation is considered to be late Barremian in age based on occurrence of foraminifers such as *Lenticulina heiermanni* and ammonoids such as *Barremites difficilis* (Obata *et al.*, 1982).

(c) Inubozaki Formation

[Definition]

The Inubozaki Formation was defined by Shikama and Suzuki (1972) and revised by Obata *et al.* (1982). The present study defines the Formation as amalgamated HCS sandstone which overlies alternation of HCS sandstone and silt stone of the Kimigahama Formation and which is overlain by alternation of HCS sandstone and silt stone of the Toriakeura Formation.

[Type locality]

Inubozaki, Choshi City, Chiba Prefecture (Shikama and Suzuki, 1972).

[Stratigraphical correlation]

The Inubozaki Formation conformably overlies the Kimigahama Formation and is conformably overlain by the Toriakeura Formation.

[Distribution]

The Inubozaki Formation distributes Inubozaki, Choshi City.

[Lithofacies]

The Inubozaki Formation is composed of amalgamated HCS sandstone and interbedded alternation of HCS sandstone and silt stone. The HCS sandstone includes generally low-angle cross stratification and parallel lamination units, and rarely rippled cross stratification unit (Plate 15-1). The HCS sandstone bears ripped-up mud clasts and bathyal trace fossils such as *Macaronichnus* isp.A, *Macaronichnus* isp.B, *Ophiomorpha* isp., *Arenicolites* isp. and *Thalassinoides* isp.

[Thickness]

Thickness of the Inubozaki Formation is approximately 315 m.

[Fossils]

The HCS sandstone bears bathyal trace fossils such as *Macaronichnus* isp.A, *Macaronichnus* isp.B, *Ophiomorpha* isp., *Arenicolites* isp. and *Thalassinoides* isp. (Plate 39).

[Age]

The Inubozaki Formation is considered to be early Aptian in age based on occurrence of ammonoids such as

Hypophylloceras aff. *onoense* (Obata *et al.*, 1982).

(d) Toriakeura Formation

[Definition]

Shikama and Suzuki (1972) defined the Toriakeura shale bed. Obata *et al.* (1975) revised the Toriakeura Formation. The present study defines the Formation as alternation of HCS sandstone and silt stone and massive silt stone which overlies amalgamated HCS sandstone of the Inubozaki Formation and is overlain by amalgamated HCS sandstone of the Nagasakihana Formation.

[Type locality]

Toriakeura, Choshi City, Chiba Prefecture (Shikama and Suzuki, 1972).

[Stratigraphical correlation]

The Toriakeura Formation conformably overlies the Inubozaki Formation and is conformably overlain by the Nagasakihana Formation.

[Distribution]

The Toriakeura Formation distributes the coast of Toriakeura, Choshi City.

[Lithofacies]

The Toriakeura Formation is composed of the lower part of alternation of HCS sandstone and silt stone and the upper part of massive silt stone. The thickness of alternation HCS sandstone is approximately 10 cm. The HCS sandstone bears generally low-angle cross stratification, parallel lamination and rippled cross stratification units. The HCS sandstone bears *Macaronichnus* isp.A (trace fossils). The Massive silt stone bears calcareous nodules, 1-10 cm in diameter and Articulated bivalves of *Portlandia sachuensis* (Plate 15-2).

[Thickness]

Thickness of the Toriakeura Formation is approximately 10 m.

[Fossils]

The HCS sandstone bears *Macaronichnus* isp.A (trace fossils). The massive silt stone bears articulated bivalves of *Portlandia sachuensis* (Plate 39).

[Age]

The Inubozaki Formation is considered to be end of early to late Aptian in age based on occurrence of foraminifers such as *Hedbergella derlioensis* and ammonoids such as *Cheloniceras* cf. *proteus* (Obata *et al.*, 1982).

(e) Nagasakihana Formation

[Definition]

Imazeki (1951) defined the Nagasakihana sandstone. Obata *et al.* (1975) revised the Nagasakihana Formation. The present study defines the Formation as alternation of thickly amalgamated HCS sandstone and thinly silt stone which overlies massive silt stone of Toriakeura Formation.

[Type locality]

Nagasakihana, Choshi City, Chiba Prefecture (Imazeki, 1951).

[Stratigraphical correlation]

The Nagasakihana Formation conformably overlies the Toriakeura Formation and is unconformavly overlain by the Pliocene Naarai Formation.

[Distribution]

The Nagasakihana Formation distributes the coast of Nagsakibana, Choshi City.

[Lithofacies]

The Nagasakihana Formation is composed of alternation of thickly amalgamated HCS sandstone and thinly silt stone. The HCS sandstone is almost composed of low-angle cross stratification. The HCS sandstone bears mud veins, liquefaction structures and ripped-up mud clasts. The HCS sandstone is very thicker than silt stone.

[Thickness]

Thickness of the Nagasakihana Formation is approximately 45 m.

[Fossils]

No fossils are obtained from the Nagasakihana Formation in the present study.

[Age]

No index fossils are obtained from the Nagasakihana Formation. However, its age is considered to be late Aptian based on the age of the Toriakeura Formation. Obata *et al.* (1982) reported late Albian ammonoids as reworking fossils from the base of the Naarai Formation which unconformably overlies the Nagasakihana Formation.

2. 5. Sanchu Cretaceous System

2. 5. 1. Previous works

Harada (1890) first reported Cretacous system in northeastern Kanto Mountains. Yabe *et al.* (1926) defined as the Sanchu Cretaceous System.

Many stratigraphical studies of the Sanchu Cretaceous system have been suggested by Iwai (1947), Takei (1963, 1985), Takei *et al.* (1977), Matsukawa (1977, 1983), Koizumi (1991) and Ichise (2008) (Table 8). Recently, the stratigraphy of Matsukawa (1983) is generally followed by many studies. According to Matsukawa (1983), the Cretaceous is subdivided into the Shiroi, Ishido, Sebayashi and Sanyama Formations, in ascending order. On the other hand, Ichise (2008) suggested that the Cretaceous is subdivided into the Sanchu and Nanmoku Groups. According to Ichise (2008), the Sanchu Group is subdivided into the Shiroi, Ishido and Sanyama Formations and the Nanmoku Group is subdivided into the Tozawa and Ohnita Formations, in ascending order.

Ammonoids yield from several horizons of the Sanchu Cretaceous System as index fossil. Therefore, several ammonoid biostratigraphies have been suggested by Obata *et al.* (1976; 1984), Matsukawa (1983; 1988), Matsukawa *et al.* (2007), Terabe *et al.* (2007) and Matsukawa and Tomishima (2009). These studies have reported that age of the Sanchu Cretacceous System is considered to be Hauterivian to early Turonian. As other index fossils, corals (Yamagiwa *et al.*, 1998), foraminifers (Kamikawa *et al.*, 1988; Kurihara *et al.*, 1989; Sashida *et al.*, 1992; Matsumaru *et al.*, 2005) and radiolarians (Kawamura and Sashida, 2004) have been reported. Other many paleontological researches of the Choshi Group have been published; plants (Yokoyama, 1895; Kimura and Matsukawa, 1979), bivalves (Yabe *et al.*, 1926; Takei, 1964; Hayami, 1965a; b; 1966; Matsukawa, 1977; 1979; 1983; Tashiro, 1990; Ichise *et al.*, 2002; Ichise, 2008; Terabe and Matsukawa, 2009), gastropods (Kase, 1984), dinosaurs and its foot prints (Matsukawa and Obata, 1985; 1992; Manabe and Hasegawa, 1991; Hasegawa *et al.*, 1999; Molnar *et al.*, 2009), shark teeth (Yabe and Obata, 1930; Takakuwa *et al.*, 2009), crustaceans (Karasawa *et al.*, 2006) and lobsters (Kato and Karasawa, 2006).

In respect of sedimentology of the Sanchu Cretaceous System, several researches have been published; ripple marks (Arai *et al.*, 1958; Takei, 1961), paleocurrents (Saka, 1961; Takei, 1980; Ishii *et al.*, 1991), summary of sedimentary environment (Matsukawa, 1983), sedimentary sequences (Ito and Matsukawa, 1997) and conformity the System with serpentinite (Hirauchi *et al.*, 2006).

Takagi *et al.* (1995) reported that age of granitic clasts from the Sanyama Formation contradict ammonoid biostratigraphy.

2. 5. 2. Geological setting

The Sanchu Cretaceous System is exposed narrow area from Ogano town, Chichibu County, Saitama Prefecture to Saku City, Nagano Prefecture in northeastern Kanto Mountain (Figure 19).

The present study mainly focuces on the Sanchu Cretaceous System in boundary area of Nagano and Gunma Prefectures. The system contacts the Sumaiduku Formation of the Northern Chichibu Belt by fault or unconformity at the northen distribution area. The system is unconformably overlain by the Neogene Uchiyama Formation at the northwestern distribution area. At southern distribution area, the system contacts by fault or unconformably overlies the Otchizawa and Nogurizawa Formations of the Southern Chichibu Belt. Although the system contacts with the Yomopparayama andesite (3.7Ma; Kaneoka *et al.*, 1993) at the Mountain of

Yomoppara, their stratigraphical correlation is uncertain by poor exposition.

The total thickness of the Sanchu Group is approximately 900 m and its of the Nanmoku Group is approximately 90 m. The Sanchu Cretaceous System is mainly composed of sandstone with conglomerate and shale. The generally strata strike N40° to 80° E, and dip 40° to 70° E (Figures 20 and 21). Although the system bears abundant faults and folds, the strara conformably overlies.

Although many stratigraphical researches of the Sanchu Cretaceous system have been published, the present study follows the stratigraphy of Ichise (2008). The study subdivided the system into the Sanchu Group which is subdivided into the Shiroi, Ishido and Sanyama Formations and the Nanmoku Group which is subdivided into the Tozawa and Ohnita Formations, in ascending order.

The Shiroi Formation is mainly composed of coarse sandstone which bears brackish bivalves. The Ishido Formation is mainly composed of shale and sandstone which bear marine molluscans and plants. The Ishido Formation bears limestone. The Sanyama Formation is mainly composed of alternation of sandstone and shale which bears marine molluscans and echinoids. The Tozawa Formation is mainly composed of coarse sandstone. The Ohnita Formation is composed of shale and fine sandstone which bear molluscans (Tables 9 and 10).

On the basis of the ammonoid biostratigraphy, the Sanchu Cretaceous System is considered to be Barremian to Turonian in age (Matsukawa and Tomishima, 2009). However, the age has been disputed (e. g. Sashida *et al.*, 1992).

2. 5. 3. Lithostratigraphy and geological age

2. 5. 3. 1. Sanchu Group

(a) Shiroi Formation

[Definition]

Yabe *et al.* (1926) defined the Shiroi Group. Matsukawa (1983) revised the Shiroi Formation. The present study defines the Formation as upward-fining units which are composed of alternation of conglomerate, sandstone and shale. It is overlain by fine sandstone of the Ishido Formation.

[Type Locality]

Shiroi, Ueno Village, Tano County, Gunma Prefecture (Yabe *et al.*, 1926).

[Stratigraphical correlation]

The Shiroi Formation contacts the Otchizawa Formation of the Southern Chichibu Belt by fault. The Shiroi Formation is conformably overlain by the Ishido Formation.

[Distribution]

The Shiroi Formation sporadically distributes from Shiroi, Ueno Village to Mountain of Yomoppara, Kitaaiki

Village, Minamisaku County, Nagano Prefecture.

[Lithofacies]

The Shiroi Formation is composed of upward-fining units which alternate of clast-supported conglomerate, sandstone and massive shale. Clasts of the conglomerate are well-sorted, boulder to granule sized and subrounded to rounded chert and shale. Matrix of the conglomerate is very coarse to very fine sand. The conglomerate includes up-ward and imbrications (Plate 19-2). The sandstone includes parallel- and trough cross-stratifications. The sandstone bears concentration or scatteration of disarticulated bivalves.

[Thickness]

Thickness of the Shiroi Formation is 100 m at Shiroi, Ueno Village.

[Fossils]

The sandstone bears bivalves of *Hayamina naumanni* (Plate 41).

[Age]

No index fossils are obtained from the Shiroi Formation. However, its age is considered to be Hauterivian based on the age of the Ishido Formation.

(b) Ishido Formation

[Definition]

Yabe *et al.* (1926) defined the Ishido Group. Matsukawa (1983) revised the Ishido Formation. The present study defines fine sandstone and shale which overlies upward-units of the Shiroi Formation and is overlain by alternation of sandstone and shale of the Sanyama Formation.

[Type locality]

Mamonozawa, Kanna Town, Tano County, Gunma Prefecture (Yabe *et al.*, 1926).

[Stratigraphical correlation]

The Ishido Formation conformably overlies the Shiroi Formation or contacts the Otchizawa or Nogurizawa Formation of the Southern Chichibu Belt by fault or unconformity. The Ishido Formation is conformably overlain by the Sanyama Formation.

[Distribution]

The Ishido Formation distributes narrow area from Ogano Town, Chichibu County, Saitama Prefecture to Saku City, Nagano Prefecture.

[Lithofacies]

The Ishido Formation is composed of the base of clast-supported conglomerate and the main part. The Formation bears the base part, in the only case of contaction the Formation with the Southern Chichibu Belt.

Clasts of the conglomerate are well-sorted, boulder to granule sized and subrounded to rounded chert and quartz porphyry. Matrix of the conglomerate is fine sand. The conglomerate includes upward-fining and erosion (Plate 17-2). The fine sandstone includes the parallel stratification and hummocky cross-stratification (HCS) (Plates 20-2, 21-1 and 23-1). The shale bears shell beds of molluscan fossils and calcareous nodules, 5-20 cm in diameter (Plate 22-2). The Formation includes limestone blocks and limestone beds in situ (Plates 18-1 and 19-1). The limestone bears bivalves, corals and microfossils such as foraminifers.

[Thickness]

Maximum thickness of the Ishido Formation is 300 m.

[Fossils]

The shale bears bivalves such as *Scittila dericatostriata* and gastoropods (Plates 42 and 43). The limestone bears bivalves such as *Lithophaga* sp., corals such as *Montivaltia* sp., microenclusters such as *Lithocodium aggregatum*, sponge spiculars, ostracods, foraminifers such as *Globuligerina hoterivica* and radiolarians such as *Archaeodictyomitra* sp. (Plates 44 and 45)

[Age]

The Ishido Formation is considered to be late Hauterivian to late Barremian in age based on ammonoid biostratigraphy (Matsukawa, 1983). On the other hand, Sashida *et al.* (1992) and Matsumaru *et al.* (2005) suggested that the Formation is considered to be late Aptian based on occurrence of foraminifers in the limestone of the Formation.

(c) Sanyama Formation

[Definition]

Takei (1963) defined the Sanyama Formation. Matsukawa (1983) revised. The present study defines the Formation as turbidity alternation of sandstone and shale which overlies fine sandstone and shale of the Ishido Formation.

[Type locality]

Urashima, Ogano Town, Chichibu County, Saitama Prefecture (Takei, 1963).

[Stratigraphical correlation]

The Sanyama Formation conformably overlies the Ishido Formation. The upper limit of the Sanyama Formation contacts the Nanmoku Group or Sumaiduku Formation of the Northern Chichibu Belt by falt or unconformity.

[Distribution]

The Sanyama Formation distributes narrow area from Ogano Town, Chichibu County, Saitama Prefecture to

Saku City, Nagano Prefecture.

[Lithofacies]

The Sanyama Formation is mainly composed of turbidity alternation of sandstone and massive shale (Plates 21-2 and 22-1). The base of the sandstone oftenly includes conglomerate with slumping structure (Plate 18-2). The sandstone shows the Bouma sequence which is composed of massive sandstone, parallel-lamination sandstone, current-rippled sandstone, parallel-lamination sandstone units. However, the sandstone generally includes only the massive sandstone unit. The sandstone bears sole marks and trace fossils. The shale bears molluscan and echinoid fossils. The Formation bears limestone which is embedded shale (Plate 24-1).

[Thickness]

Maximum thickness of the Sanyama Formation is approximately 500 m.

[Fossils]

The shale bears bivalves such as *Portlandia sanchuensis, Neohibolites* sp. (Beleminitida) and Echinoids (Plate 45).

[Age]

The Sanyama Formation is considered to be Turnonian in age based on occurrence of ammonoids such as *Anagaudryceras* cf. *sacya* (Terabe *et al*., 2007).

2. 5. 3. 1. Nanmoku Group

(a) Tozawa Formation

[Definition]

Ichise (2008) defined the Tozawa Formation. The present study defined the Formation as conglomerate and coarse sandstone which is overlained by fine sandstone and shale of the Ohnita Formation.

[Type locality]

Tozawa, Nanmoku Village, Kannra County, Nagano Prefecture (Ichise, 2008).

[Stratigraphical correlation]

The Tozawa Formation contacts the Sumaidukuzawa Formation of the Northern Chichibu Belt by fault. The Tozawa Formation is conformably overlain by Ohnita Foramation.

[Distribution]

The Tozawa Formation distributes Tozawa to Ohnita, Nanmoku Village, Kanra County, Gunma Prefecture.

[Lithofacies]

The Tozawa Formation is composed of clast-supported conglomerate and coarse sandstone (Plate 17-1). Clasts of the conglomerate are medium-sorted, boulder to pebble sized and subangular to subrounded chert and sandstone. Matrix of the conglomerate is coarse sand. The conglomerate bears imbrications. The coarse sandstone bears *Neithea* sp. (Bivalvia).

[Thickness]

Maximum thickness of the Tozawa Formation is approximately 20 m.

[Fossils]

The coarse sandstone bears bivalves of *Neithea* sp. (Plate 47).

[Age]

The Tozawa Formation is considered to be Barremian to Aptian (probably Aptian) in age based on occurrence of *Paracrioceras* cf. *asiaticum* (Ichise, 2008).

(b) Ohnita Formation

[Definition]

Ichise (2008) defined the Ohnita Formation. The present study defines the Formation as alternation of fine sandstone and shale whih overlies coarse sandstone of the Tozawa Formation.

[Type locality]

Ohnita, Nanmoku village, Kanra County, Gunma Prefecture (Ichise, 2008).

[Stratigraphical correlation]

The Ohnita Formation conformably overlies the Tozawa Formation. The Ohnita Formation contacts the Sanyama Formation by fault.

[Distribution]

The Ohnita Formation distributes Tozawa to Ohnita, Nanmoku Village, Kanra County, Gunma Prefectue.

[Lithofacies]

The Ohnita Formation is composed of HCS sandstone and thinly alternation of sandstone and shale. The HCS sandstone is composed of only low-angle cross stratification unit. The HCS sandstone bears bivalves and *Neohibolites* sp. (Belemnitida). The sandstone of alternation includes parallel stratification.

[Thickness]

The maximum thickness of the Ohnita Formation is 70 m.

[Fossils]

The HCS sandstone bears disarticulated bivalves such as *Nipponitrigonia* sp. and beleminite of *Neohibolites* sp. (Plate 48).

[Age]

The Ohnita Formation is considered to be early Albian in age based on occurrence of bivalves such as

Pterotrigonia hokkaidoana (Ichise, 2008).

3. Facies analysis

3. 1. Miyako Group (Figures 22 and 23)

Facies 1. Angular conglomerate (Plate 1-1)

The Facies 1 is composed of clast-supported conglomerate and thinly interbedded coarse sandstone. Clasts of the conglomerate are poorly-sorted, boulder to granule sized and angular to subangular chert and andesite. Matrix of the conglomerate is red silty sand which is inferred to be terrestrial sediments. The facies is discriminated from the Facies 2 by poorly-sorted and angular to subangular clasts and the matrix of red silty sand.

The Facies 1 distributes in the base of the Raga Formation at Haipe. Thickness of the facies is approximately 30 m. The facies is overlain by the Facies 2.

Sedimentary environment of the Facies 1 is inferred to be talus on the basement rocks by limited distribution in the base of the Miyako Group, poorly-sorted and angular to subangular clasts and the matrix of red silty sand.

Facies 2. Alternation of conglomerate and coarse sand (Plate 1-2)

The Facies 2 is composed of alternation of conglomerate and coarse sand. Clasts of the conglomerate are well-sorted, boulder to pebble sized and subrounded to rounded andesite and chert. The conglomerate includes imbrications. The conglomerate is mainly composed of clast-supported. Matrix of the conglomerate is coarse sand. The facies is discriminated from the Facies 1 by well-sorted and subrounded to rounded clasts.

The Facies 2 distributes in the Raga Formation. General thickness of the facies is approximately 10 m. However, maximum thickness of the facies is 107 m from Kuwagasaki to Takonohama. The facies overlies the Facies 1 and is overlain by the Facies 3.

Sedimentary environment of the Facies 2 is inferred to be debris flow in fan delta by well-sorted and subrounded to rounded clasts and drastically changes of thickness.

Facies 3. Amalgamated HCS sandstone (Plate 2-2)

The Facies 3 predominantly distributes in the Miyako Group with the Facies 4. The Facies 3 is composed of amalgamated HCS sandstone. According to Ando (1990), the typical HCS sequence is composed of the low-angle cross stratification (H), parallel stratification (F), rippled cross stratification (X) and bioturbated mud units (Mb). The Facies 3 is composed of amalgamated fine to medium H sandstone. The medium sandstone bears pebble to garanule sized clasts. Shell beds are born in laminae of the sandstone. The sandstone bears trace fossils. The facies is discriminated from the Facies 4 with no the Mb.

The Facies 3 distributes in the Tanohata, Hiraiga and Sakiyama Formations. General thickness of the facies is approximately 10 m. However, maximum thickness of the facies is 61 m at Masaki. The facies alternate with the Facies 4.

Sedimentary environment of the Facies 3 is inferred to be lower shoreface by lacking the Mb which deposits in under mean storm wave base and fair weather water sediments. The facies corresponds to the HCS sandstone (the Hiraiga Formation) of Fujino (2003).

Facies 4. Alternation of HCS sandstone and silt stone (Plate 3-1)

The Facies 4 predominantly distributes in the Miyako Group with the Facies 3. The Facies 4 is composed of alternation of HCS sandstone and silt stone which corresponds to Mb. The HCS sandstone bears H and F sandstone. Because of lacking of the F sandstone, the H sandstone is directly overlain by silt stone in many cases. Shell beds are born in laminae of the sandstone. The facies is discriminated from the Facies 3 by bearing silt stone.

The Facies 4 distributes in the Hiraiga and Aketo Formations. The general thickness of the facies is approximately 10 m. The facies alternate with the Facies 3 and 5.

Sedimentary environment of the Facies 4 is inferred to be inner shelf by including silt stone which deposits under mean storm wave base. The facies corresponds to the alternation of HCS sandstone and silt stone (the Aketo Formation) of Fujino (2003).

Facies 5. *Orbitolina* sandstone (Plate 4-1)

The Facies 5 is composed of *Orbitolina* sandstone. The sandstone is well-sorted and medium to coarse sized. The sandstone bears *Orbitolina* (Formaminifera) and molluscan fossils.

The Facies 5 distributes in the Hiraname Formation at Funaare to Aketo. Thickness of the facies is approximately 40 m. The facies overlies and is overlain by the Facies 4.

Sedimentary environment of the Facies 5 is inferred to be lower shoreface by bearing *Orbitolina* and alternation with the Facies 4. The Facies 5 corresponds to the *Orbitolina* sandstone (the Hiraiga Formation) of Fujino (2003),

Facies 6. Limestone (Plate 5-1)

The Facies 6 is composed of massive limestone. The limestone is bioclasts supported. Matrix of the limestone is well sorted very fine sandstone. The limestone is classified into framestone of Embry and Klovan (1971) by build upped rudists. The limestone bears gastropods.

The Facies 6 distributes in the base of the Tanohata Formation at western Raga. The thickness of the facies is

5 m. The facies directly overlies basement rocks and is overlain by the Facies 3.

Sedimentary environment of the Facies 6 is inferred to be reef sediments of upper shoreface by bearing build upped rudists and matrix of well-sorted very fine sandstone. The facies corresponds to the limestone of Sano (1993).

Facies 7. Tsunami deposits (Plate 2-1)

The Facies 7 is composed of conglomerate and coarse sandstone. Clasts of the conglomerate are poorly-sorted, boulder to pebble sized and subrounded coral, andesite, quartz porphyry and chert. Matrix of the conglomerate is coarse to medium sand. The conglomerate is devided into sub-layers by erosional bases. Paleocurrents of sub-layers are truncated each other. The conglomerate bears broken molluscan fossils and corals.

The Facies 7 distributes in the Tanohata Formation at Koikorobe. Thickness of the facies is 17 m. The facies overlies the Facies 3 and is overlain by the Facies 8.

Sedimentary environment of the Facies 7 is inferred to be tsunami deposits in lower shoreface by bearing broken molluscan fossils, boulder and subrounded corals and truncated paleocurrents of sublayers which include erosional bases. The facies corresponds to the conglomerate (the Tanohata Formation) of Fujino (2003) and Tsunami deposits of the Fujino *et al.* (2006).

Facies 8. Tuff (Plate 4-2)

The Facies 8 is composed of grayish white tuff. The tuff is well-sorted fine sized.

The Facies 8 distributes in the Tanohata Formation at Koikorobe and Funaare. The thickness of the facies is 5 cm. The facies overlies and is overlain by the Facies 3 and 7.

Facies 9. Massive silt stone (Plate 3-2)

The Facies 9 is composed of very well-sorted and massive silt stone. The silt stone bears thinly fine sandstone and boulder to pebble sized calcareous nodules. Shell beds, scalattered and autochthonous occurrence of molluscan fossils are born in the silt stone. The silt stone bears trace fossils and plant remains.

The Facies 9 distributes in the Tanohata, Hiraiga and Sakiyama Formations. Thickness of the facies is approximately 10 m. The facies alternate with the Facies 4.

Sedimentary environment of the Facies 9 is inferred to be inner to outer shelf by poor index structure of wave. The facies corresponds to sandy silt stone of Fujino (2003).

3. 2. Futaba Group (Figures 24 and 25)

Facies 1 Alternation of conglomerate and coarse sandstone (Plate 10-1)

The Facies 1 is composed of clast-supported conglomerate and thinly interbedded coarse sandstone. Clasts of the conglomerate are well-sorted, cobble to pebble sized and subrounded to rounded granite. Matrix of the conglomerate is fine sand. The facies is discriminated from the Facies 3 by bearing no molluscan fossils.

The Facies 1 distibutes in the Asamigawa Member. The facies overlies basement rocks and is overlain by the Facies 3 and 7. General thickness of the facies is several meters. However, the maximum thickness of the facies is 30 m at Asami River.

Sedimentary environment of the Facies 1 is inferred to be debris flow in fan delta by well-sorted and subrounded to rounded clasts, overlying basement rocks and drastically changes of thickness. The facies corresponds to the Facies 2 of Ando *et al.* (1995).

Facies 2. Upward-fining unit (Plate 6-1)

The Facies 2 is composed of upward-fining unit which is alternation pebble sized conglomerate, fine sandstone and silt stone. The sandstone includes cross and parallel laminations. The silt stone bears carbonaceous matter and amber.

The Facies 2 distributes in the Kasamatsu Formation. The facies overlies the Facies 4 and 7 and is overlain the Facies 7. Thickness of the facies is 250 m at Oriki River.

Seidimentary environment of the Facies 2 is inferred to be flood plain or natural leeve by including upward-fining and carbonaceous matter. The facies corresponds to the Facies 5 of Ando *et al.* (1995).

Facies 3. Calcareous conglomerate (Plate 6-2)

The Facies 3 is composed of clast-supported massive and calcareous conglomerate. Clasts of the conglomerate are well-sorted, pebble to granule sized and rounded granite. Matrix of the conglomerate is fine sand. The conglometate bears the *Glycymeris amakusensis*—*Apiotrigonia minor*—*Loxo japonica* assemblage. The assemblage predominantly includes *Glycymeris amakusensis*, *Apiotrigonia minor* and *Loxo japonica*. Bivalves of the assemblage are disarticulated and unbroken. The facies is discriminated from the Facies 1 by bearing molluscan fossils.

The Facies 3 distributes in the base of the Obisagawa Member at Ashizawa and Kayanosawa. The facies overlies the Facies 1 and is overlain by the Facies 4. Thickness of the facies is 10 m at Ashizawa.

Habitats of *Glycymeris amakusensis* and *Loxo japonica* are inferred to be shoreface (Kumagaya and Komatsu, 2004). Tashiro and Matsuda (1983) reported that habitats of *Apiotrigonia minor* inferred to be upper shoreface. Sedimentary environment of the Facies 3 is inffered to be upper shoreface by well-sorted, rounded and calcareous conglomerate which bears the *Glycymeris amakusensis*—*Apiotrigonia minor*—*Loxo japonica* assemblage. The facies corresponds to the Facies 8 of Ando *et al.* (1995).

Facies 4. Silty sandstone (Plates 7-1, 2; 8-1, 2)

The Facies 4 is composed of silty sandstone. The silty sandstone bears parallel stratification, trace fossils and *Inoceramus uwajimensis* — *Myrtea ezoensis*, *Inoceramus uwajimensis* — *Periploma* sp., *Inoceramus uwajimensis*—*Eriphyla higoensis*—*Myrtea ezoensis* and *Inoceramus* sp.—*Glycymeris amakusensis*—*Loxo japonica* assemblages. The facies is discriminated from the Facies 6 by non-carbonaceous sediment and including shallow marine molluscan fossils.

The Facies 4 distributes in the Obisagawa and Irimazawa Member. The facies overlies the Facies 3 and 7 and is overlain by the Facies 1 and 2. General thickness of the Facies 4 is 100 m.

Sedimentary environment of the Facies 4 is inferred to be inner to outer shelf by silty sandstone which bears shallow marine molluscan fossils. The facies corresponds to the Facies 14 of Ando *et al.* (1995).

Facies 5. Tuff (Plate 9-2)

The Facies 5 is composed of grayish white tuff. The tuff is well-sorted fine sized.

The Facies 5 distributes in the Kasamatsu Formation. The facies alternated with the Facies 4 and 7. Thickness of the Facies 5 is 40 cm. The facies corresponds to the Facies 15 of Ando *et al.* (1995).

Facies 6. Carbonaceous silt stone (Plate 10-2)

The Facies 6 is composed of carbonaceous massive well-sorted silt stone. The silt stone bears abundant amber. The facies is discriminated from the Facies 4 by carbonaceous, well-sorted and silt sized.

The Facies 6 distributes in the Kobisagawa Member. The facies alternated with the Facies 7. Thickness of the Facies 6 is 20 m. Sedimentary environment of the Facies 6 is inferred to be flood plain by well-sorted silt stone which bears abundant amber. The facies corresponds to the Facies 6 of Ando *et al.* (1995).

Facies 7. Cross-laminated sandstone (Plate 9-1)

The Facies 10 is composed of well-sorted, medium to coarse sandstone. The sandstone includes cross-stratification. The Facies 7 is discriminated from the Facies 3 by medium to coarse sized and including cross-stratification.

The Facies 7 distributes in the Kobisa

gawa Member. The Facies 7 alternated with the Facies 6. The thickness of the Facies 7 is 120 m.

Sedimentary environment of the Facies 7 is inferred to be braided river by no marine evidence and alternatetion with the Facies 6. The Facies 7 corresponds to the Facies 3 of Ando *et al.* (1995).

3. 3. Nakaminato Group (Figure 26, 27)

Facies 1. Turbidity alternation of conglomerate, sandstone and silt stone (Plate 11-1)

The Facies 1 is composed of turbidity alternation of conglomerate, sandstone and silt stone. The representive alternation unit shows Bouma sequence which is composed of massive clast-supported conglomerate with sandstone, parallel-lamination sandstone, current-rippled sandstone, parallel-lamination sandstone and massive silt stone, in ascending order. However, the representive alternation unit is rarely recognized, generally lacked some horizons. Clasts of the conglomerate with sandstone are well sorted, pebble to granule sized, subrounded to rounded chert, granite and diorite. Matrix of the conglomerate is medium to coarse sand. The base of the massive clast-supported conglomerate with sandstone bears flute casts and trace fossils. The fine to very fine sized parallel-lamination sandstone bears dish structure and ripped-up mud clasts. The silt stone bears calcareous nodules, 5-20 cm in diameter. The facies is discriminated from the Facies 2 and 3 by bearing silt stone and no matrix-supported conglomerate.

The Facies 1 distributes in the lower part of the Hiraiso and lower and upper part of the Isoai Formations. Thickness of the facies is more than 60 m in the lower part of Isoai Formation. The facies alternates with the Facies 2 and 3.

Sedimentary environment of the Facies 1 is inferred to be channel of debris flow in upper submarine fan by representive alternation unit which shows Bouma sequence.

Facies 2. Turbidity sandstone (Plate 11-2)

The Facies 2 is composed of turbidity sandstone. The sandstone incrudes only massive sandstone unit of Bouma sequence. The sandstone is composed of upward fining medium to fine sized sand. The sandstone bears dish structure and erosinal base. The facies is discriminated from the Facies 1 and 6 by including only massive sandstone unit, no cross-stratification and no rippled-up mud clasts.

The Facies distributes in the upper part of the Hiraiso and middle of the Isoai Formations. Thickness of the Facies 2 is more than 40 m in the upper part of the Hiraiso Formation. The facies alternates with the Facies 1, 3, 4 and 6.

Sedimentary environment of the Facies 2 is inferred to be channel of debris flow in upper to middle submarine fan by turbidity sandstone of Bouma sequence.

Facies 3. Turbidity alternation of massive-supported conglomerate, sandstone and silt stone (Plate 12-1)

The Facies 3 is composed of turbidity alternation of massive-supported conglomerate, sandstone and silt stone. The representive alternation unit includes massive-supported conglomerate and Bouma sequence which is composed of massive sandstone, parallel-lamination sandstone, current-rippled sandstone, parallel-lamination sandstone and massive silt stone, in ascending order. However, the representive alternation unit is rarely recognized, generally lacked some horizons. Clasts of the conglomerate are composed of alternation of sandstone and silt stone. Matrix of the conglomerate is mudstone. Upper part of the conglomerate bears slumping structures. The sandstone bears trace fossils which are grazing trace by echinoids. The facies is discriminated from the Facies 1 by bearing matrix-supported conglomerate.

The Facies 3 distributes in the lower part of the Isoai Formation. Thickness of the facies is approximately 15 m. The facies alternates with the Facies 1.

Sedimentary environment of the Facies 3 is inferred to be channel of debris flow in upper submarine fan by representive alternation unit which shows Bouma sequence.

Facies 4. Alternation of sandstone and silt stone (Plate 12-2)

The Facies 4 is composed of alternation of sandstone and silt stone. Although maximum thickness of a bed of alternation is 1 m, it is generally 5-10 cm. The sandstone bears cross stratification. The silt stone bears calcareous nodules, 5-20 cm in diameter. The calcareous nodules bear ammonoids such as *Didymoceras awajiense* and *Diplomoceras*? sp. The alternation bears liquefaction structures and micro faults. The facies is discriminated from the Facies 5 by including sandstone.

The Facies 4 distributes in the Hiraiso Formation. Maximum thickness of the facies is 50 m. The facies alternates the Facies 2, 5 and 6.

Sedimentary environment of the Facies 4 is inferred to be leeve in lower submarine fan by thinly alternation of sandstone and silt stone.

Facies 5. Massive silt stone (Plate 13-1)

The Facies 5 is composed of thickly massive silt stone. The silt stone bears calcareous nodules, 5-20 cm in diameter. The silt stone includes micro faults and rarely sandstone which has thickness of several centimeters. The facies is discriminated from the Facies 4 by thickly silt stone.

The Facies 5 distributes in the Hiraiso and Isoai Formations. Thickness of the facies is approximately 10 m. Although the facies mainly alternates with the Facies 4, the facies rarely alternates with the Facies 2 and 6, too.

Sedimentary environment of the Facies 5 is inferred to be basin-plain in lower submarine fan by thickly silt stone.

Facies 6. CCC turbidity sandstone (Plate 13-2)

The Facies 6 is composed of medium to fine CCC turbidity sandstone. The sandstone repeats beds which have thickness of 1 m. The sandstone rarely bears thinly silt stone. The sandstone includes large sized cross stratification, upward-fining and rippled-up mud clasts. The cross stratification develops into settled direction. Thickness of the sandstone changes along the direction. The facies is discriminated from the Facies 2 by large sized cross stratification and rippled-up mud clasts.

The Facies 6 distributes in the middle of the Hiraiso Formation. Thickness of the facies is approximately 20 m. The facies alternates with the Facies 4 and 5.

Sedimentary facies of the Facies 6 is inferred to be leeved channel in lower submarine fan by including large sized cross stratification and rippled-up mud clasts.

3. 4. Choshi Group (Figures 28 and 29)

Facies 1. Alternation of conglomerate, sandstone and silt stone (Plate 14-1)

The Facies 1 is composed of alternation of clast-supported conglomerate, sandstone and silt stone. Clasts of the conglomerate are well-sorted, pebble sized and subrounded to rounded chert and sandstone. The conglomerate includes slumping structures, imbrications and trough cross-stratifications. Matrix of the conglomerate is coarse sand. The sandstone bears upward-fining. The silt stone bears carbonaceous matter. The facies is discriminated from the Facies 2 by bearing conglomerate.

The Facies 1 distributes the lower part of the Ashikajima Formation. Thickness of the facies is 20 m. The facies overlies by the Facies 3.

Sedimentary environment of the Facies 1 is inferred to be upper shoreface by including well-sorted and rounded conglomerate.

Facies 2. Alternation of HCS sandstone and silt stone (Plate 14-2)

The Facies 2 predominantly distributes in the Choshi Group with the Facies 3. The Facies 2 is composed of Alternation of HCS sandstone and silt stone which corresponds to the Mb. The facies rarely shows all units of HCS sequence. The base of the sandstone frequently includes abundant rippled-up mud clasts, 1-5 cm in diameter. The sandstone bears liquefaction structures. The sandstone bears bathyal trace fossils such as *Macaronichnus* isp.A, *Macaronichnus* isp.B, *Ophiomorpha* isp., *Arenicolites* isp., *Thalassinoides* isp. and *Zoophycos* isp. The facies is discriminated from the Facies 3 by including silt stone

The Facies 2 distributes in the Kimigahama, Inubozaki and Toriakeura Formations. Thickness of the facies is more than 70 m.The facies alternates with the Facies 3 and 4.

Sedimentary environment of the Facies 2 is inferred to be inner shelf by including silt stone which deposits under mean storm wave base.

Facies 3. Amalgamated HCS sandstone (Plate 15-1)

The Facies 3 predominantly distributes in the Choshi Group with the Facies 2. The Facies 3 is composed of amalgamated HCS sandstone. The facies bears no F, X, Mb. So, the facies is composed amalgamated fine to medium H sandstone. The sandstone bears bathyal trace fossils such as *Macaronichnus* isp.B, *Ophiomorpha* isp. and *Arenicolites* isp. The facies is discriminated from the Facies 2 by bearing no the Mb.

The Facies 3 distributes in the Ashikajima, Kimigahama, Inubozaki and Nagasakihana Formations. Thickness of the facies is more than 50 m. The facies alternates with the Facies 2.

Sedimentary environment of the Facies 3 is inferred to be lower shoreface by lacking the Mb which deposits in under mean storm wave base and fair weather water sediments.

Facies 4. Massive silt stone (Plate 15-2)

The Facies 4 is composed of massive silt stone. The silt stone bears articulated bivalves such as *Portlandia sanchuensis* and abundant calcareous nodules, 1-10 cm in diameter.

The Facies 4 distributes in the upper part of the Toriakeura Formation. Thickness of the facies is more than 20 m. The facies overlies the Facies 2 and is overlain by the Facies 3.

Sedimentary environment of the Facies 4 is inferred to be outer shelf by including no sandstone.

Facies 5. Tuff (Plate 16)

The Facies 5 is composed of grayish white tuff. The tuff is well-sorted fine sized.

The Facies 5 distributes in the Inubozaki Formation. Thickness of the facies is approximately 20 cm. The facies alternates with the Facies 2.

3. 5. Sanchu Cretaceous System (Figures 30 and 31)

Facies 1. Angular conglomerate (Plate 17-1)

The Facies 1 is composed of clast-supported angular conglomerate. Clasts of the conglomerate are poorly-sorted, boulder to pebble sized and angular to subangular slate, chert, quartsz porphyry and sandstone. Matrix of the conglomerate is medium to fine sand. The facies is discriminated from the Facies 2 by poorly-sorted, angular to subangular and including boulder sized clasts.

The Facies 1 distributes in the base of the Ishido and Tozawa Formations at limited area. Thickness of the facies is 10 m at Mamonozawa. The facies is overlain by the Facies 2.

Sedimentary environment of the Facies 1 is inferred to be tulaus on the basement rocks by limited distribution of the base of the Miyako Group and poorly-sorted and angular to subangular clasts.

Facies 2. Rounded conglomerate (Plate 17-2)

The Facies 2 is composed of clast-supported rounded conglomerate. Clasts of the conglomerate is well-sorted, pebble to granule sized and subrounded to rounded slate, chert, quartsz porphyry and sandstone. Matrix of the conglomerate is fine sand. The conglomerate includes imbrications and trough cross stratification and upward-fining. The facies is discriminated from the Facies 1 by well-sorted, subrounded to rounded and bearing granule sized and trough cross stratification.

The Facies 2 distributes in the lower part of the Ishido and Tozawa Formations at limited area. Thickness of the facies is 8 m at Mamonozawa. The facies overlies the Facies 1 and is overlain by the Facies 3 and 13.

Sedimentary environment of the Facies 2 is inferred to be fan delta of debris flow by well-sorted and subrounded to rounded clasts, including trough cross stratification and overlying basement rocks.

Facies 3. Autochthonous limestone (Plate 18-1)

The Facies 3 is composed of autochthonous limestone. The limestone is composed of alternation of medium to fine calcareous sandstone and sandy limestone. The calcareous sandstone bears limestone and chert clasts and abundant *Orbitolina* (Foraminifera). The sandy limestone bears chert clasts, peloids, corals and bivalves such as *Rastellum* sp. The Limestone is classified into bioclastic-peloid wackestone by Embry and Klovan (1971). The facies is discriminated from the Facies 5 by successively overlining Formations, including chert clasts and peloids and alternation with calcareous sandstone.

The Facies 3 distributes in the lower part of the Ishido Formation at Otchizawa. Thickness of the facies is approximately 5 m. The facies overlies the Facies 2 and is overlain by the Facies 9.

Sedimentary environment of the Facies 3 is inferred to be high energy reef near land by including chert clasts and peloids and alternation with calcareous sandstone.

Facies 4. Matrix-supported conglomerate (Plate 18-2)

The Facies 4 is composed of matrix-supported matrix conglomerate. Clasts of the conglomerate are poorly-sorted, pebble sized and subrounded to rounded alternation of sandstone and shale. Thickness of the conglomerate radically changes. The conglomerate bears erosional base and slumping structure. The facies is discriminated from the Facies 1 and 2 by matrix-supported and subrounded to rounded clasts.

The Facies 4 distributes in the Sanyama Formation. Thickness of the facies is approximately 40 cm. The facies alternate with the Facies 10.

Sedimentary environment of the Facies 4 is inferred to be channel of debris flow in upper submarine fan by matrix-supported conglomerate and bearing slumping structure.

Facies 5 Limestone block (Plate 19-1)

The Facies 5 is composed of limestone block. The limestone is classified into floatstone and mudstone by Embry and Klovan (1971). The limestone is considered as block by difference of bedding plane from reagional strata. The Floatstone bears corals such as *Montilvanilla* sp., bivalves such as *Lithophaga* sp., spines of echinoids, microenclusters such as *Lithocodium aggregatum*, sponge spiculars, ostracods, foraminifers such as *Globuligerina hoterivica* and radiolarians such as *Archaeodictyomitra* sp. The nuclei of oncoids are corals. The oncoids bears microenclusters. The facies is discriminated from the Facies 3 by occurrence as block and bearing only bioclusts as grains.

The Facies 5 distributes in the Ishido Formation. Thickness of the facies is approximately 20 m. The facies alternates with the Facies 12.

Sedimentary environment of the Facies 5 is inferred to be pacth reef by the characteristics of oncoids and microfacies.

Facies 6. Upward-fining unit (Plate 19-2)

The Facies 6 is composed of upward-fining units which is alternation of clust-supported conglomerate, sandstone and shale. Clasts of the conglomerate are well-sorted, cobble to granule sized and subrounded to rounded sandstone, chert and shale. Matrix of the conglomerate is fine to coarse sand. The conglomerate bears upward-fining and imbrications. The sandstone bears cross and parallel stratification. The shale bears shell beds which are composed of abundant brackish bivalves. The facies is discriminated from the Facies 9 and 10 by upward-fining.

The Facies 6 mainly distributes in the Shiroi Formation. Thickness of the facies is 100 m. The facies overlies basement rocks and is overlain by the Facies 12.

Sedimentary environment of the Facies 6 is inferred to be flood plain or natural leeve near the coast by including upward-fining unit and brackish bivalves.

Facies 7 Carbonaceous shale (Plate 20-1)

The Facies 7 is composed of carbonaceous shale. The shale bears parallel stratification and abundant carbonaceous matter. The consolidation of the shale is low. The facies is discriminated by bearing parallel stratification, carbonaceous matter and low consolidation.

The Facies 7 distributes the Shiroi and Ishido Formation. Maximum thickness of the facies is 5 m. The facies alternates with the Facies 5.

Sedimentary environment of the Facies 7 is inferred to be flood plain by bearing parallel stratification, carbonaceous matter and low consolidation and alternation with the Facies 5.

Facies 8 Amalgamated HCS sandstone (Plate 20-2)

The Facies 8 is composed of amalgamated HCS sandstone. The facies bears no F, X, Mb. Therefore, the facies is composed amalgamated fine to medium H sandstone. Shell beds are born in laminae of the sandstone. The facies is discriminated from the Facies 9 by bearing no the Mb.

The Facies 8 distributes in the Ishido and Ohnita Formations. Maximum thickness of the facies is more than 100 m. The facies alternates with the Facies 9 and 12.

Sedimentary environment of the Facies 8 is inferred to be lower shoreface by lacking the Mb which deposits in under mean storm wave base and fair weather water sediments.

Facies 9. Alternation of HCS sandstone and shale (Plate 21-1)

The Facies 9 is composed of alternation of HCS sandstone and shale which corresponds to Mb. The HCS sandstone bears H and F sandstone. Because of lacking of the F sandstone, the H sandstone is directly overlain by shale in many cases. The shale bears calcareous nodules, 5-15 cm in diameter. Shell beds are born in laminae of the shale. The facies is discriminated from the Facies 8 by bearing shale.

The Facies 9 distributes in the Ishido and Ohnita Formations. Maximum thickness of the facies is 20 m. The facies alternates with the Facies 8, 12 and 14.

Sedimentary environment of the Facies 9 is inferred to be inner shelf by including shale which deposits under mean storm wave base.

Facies 10. Alternation turbidity sandstone and shale (Plate 21-2)

The Facies 10 is composed of turbidity alternation of sandstone and shale. The representive alternation unit shows Bouma sequence which is composed of massive sandstone, parallel-lamination sandstone, current-rippled sandstone, parallel-lamination sandstone and massive shale, in ascending order. However, the representive alternation unit is rarely recognized, generally lacked some horizons. The massive sandstone bears load casts and flute structure. The parallel-lamination, current-rippled and parallel-lamination sandstone is composed of fine to very fine sand. The shale bears disarticulated bivalves, gastropods and echinoids. The facies is discriminated form the Facies 11 by including shale.

The Facies 10 predominately distributes in the Sanyama Formation with the Facies 11. Maximum thickness of the Facies 10 is 200m. The facies alternates with the Facies 9 and 11.

Sedimentary environment of the Facies 10 is inferred to be channel of debris flow in upper submarine fan by represenitive alternation unit which shows Bouma sequence.

Facies 11. Turbidity sandstone (Plate 22-1)

The Facies 11 is composed of turbidity sandstone. The sandstone includes only massive sandstone unit of Bouma sequence. The sandstone is composed of upward fining medium to fine sized sand. The sandstone includes erosional base. The facies is discriminated from the Facies 1, 8 and 13 by including upward-fining and no shale.

The Facies 11 predominantly distributes in the Sanyama Formation with the Facies 10. Maximum thickness of the Facies 11 is 20 m. The facies alternates with the Facies 10 and 12.

Sedsimentary environment of the Facies 11 is inferred to be channel of debris flow in upper to middle submarine fan by turbidity sandstone of Bouma sequence.

Facies 12. Massive shale (Plate 22-2)

The Facies 12 is thickly massive shale. The shale bears calcareous nodules, 5-20 cm in diameter. Shell beds, which are marine bivalves, gastropods, plant fossils are born in the shale. The bivalves are mostly disarticulated. The facies is discriminated from the Facies 7 by massive structure and bearing poorly carbonaceous matter.

The Facies 12 distributes in the Ishido and Sanyama Formations. Maximum thickness of the facies is 100 m. The facies alternates with the Facies 8, 9 and 10.

Sedimentary environment of the Facies 12 is inferred to be inner to outer shelf by including no sandstone.

Facies 13. Cross-laminated sandstone (Plate 23-1)

The Facies 13 is composed of well-sorted and cross-laminated sandstone. The sandstobe includes trough cross-laminated, granule and thinly shale. The facies is discriminated from the Facies 8 and 11 by including trough cross-lamination and no upward-fining structure.

The Facies 13 distributes the lower part of the Ishido Formation. Thickness of the facies is approximately 15

m. The facies overlies the Facies 2 and is overlain by the Facies 8.

Sedimentary environment of the Facies 13 is inferred to be upper shoreface by well-sorted sandstone which including cross-lamination.

Facies 14. Tuff (Plate 23-2)

The Facies 14 is composed of grayish white tuff. The tuff is well-sorted fine sized.

The Facies 14 distributes in the Ishido Formation. Thickness of the facies is approximately 40 cm. The facies alternates with the Facies 9.

Facies 15. Alternation of limestone and shale which bears abundant calcareous nodules (Plate 24-1)

The Facies 15 is composed of alternation of limestone and shale. The limestone, which is composed of only lime mud, is classified into mudstone by Embry and Klovan (1971). The shale bears very abundant calcareous nodules. The shale bears abundant belemnites (Figure 38). The facies is discriminated from the Facies 3, 5 and 12 by bearing very abundant calcareous nodules and no sand sized grains and autochthonous strata.

The Facies 15 distributes in the Sanyama Formation. Maximum thickness of the facies is 2 m. The facies alternates with the Facies 10.

Sedimentary environment of the facies is inferred to be outer shelf by including only shale and mudstone of limestone.

4. Summary of fossils and depositional sequences

4. 1. Miyako Group

4. 1. 1. Ammonids from the Sakiyama Formation

In the present study, many ammonoids were newly obtained from the Sakiyama Formation at Ebisudana (Plate 28). The ammonoids are from calcareous nodules in the sandy mudstone of Facies 9 and the hummocky cross- stratified sandstone of Facies 3 (Figure 32).

Facies 9 contains *Eotetragonites* sp., *Aconeceras* sp., *Valdedorsella getulina*, *Pseudohaploceras* sp., Desmocerataceae gen. et sp. indet., *Ptychoceras* sp., *Pseudoleymeriella hataii*, Douvilleicerataceae gen. et sp. indet., and *Pictetia* sp. Facies 3 rarely contains Desmocerataceae gen. et sp. indet. In the assemblage of Facies 9, *Aconeceras* sp. occurs abundantly. For almost all of the ammonoids, the remaining parts are only fragments of the phragmocone or body chamber, which are associated with relatively small bivalves and plant remains in Facies 9. The preservation of this assemblage suggests that they had similar transport behavior in very weak bottom currents. Similar preservation was reported from the Yezo Group in Hokkaido, northeast Japan (Maeda, 1987).

The stratigraphical position of the Sakiyama Formation in the Miyako Group was discussed by Shimazu *et al.* (1970) and Tanaka (1978). On the basis of sedimentological cyclothemic arrangement, these authors inferred that the Formation is correlated to the upper Hiraiga Formation in the north area.

In the present study, many ammonoids, including important species for comparison with the north area, were obtained from the Sakiyama Formation. The present study compares the newly obtained ammonoids and associated other fossils with the fossils obtained in previous studies.

Firstly, Obata (1974) compiled data on the occurrence of important ammonoids from the Miyako Group. According to Obata (1974), *Valdedorsella getulina* occurs from the Tanohata Formation to the lower part of the Aketo Formation, *Pseudoleymeriella hataii* from the uppermost of the Hiraiga Formation to the Aketo Formation and *Ptychoceras* sp. from the Tanohata Formation to the Aketo Formation. These fossils occur from the uppermost part of the Hiraiga Formation to the lower part of the Aketo Formation.

Secondly, according to Hayami (1966), bivalves from the Sakiyama Formation occur from the upper part of the Hiraiga Formation to the Aketo Formation, with the exception of the following rarely occuring bivalves: *Protocardia hiraigensis*, *Nuclopsis ishidoensis*, *Astarte subsenecta*, *Ludbrookia* cf. *tenuicostata*, and *Mytilus*? sp. Bivalves in the Miyako Group are more important than biostratigraphy for determining the relationship between lithofacies (Hanai *et al.*, 1968). Therefore, the analogous bivalve fauna supports the contention that the lithofacies of the Sakiyama Formation resembles those of the upper part of the Hiraiga Formation to the Aketo Formation.

Finally, *Heteraster hiranamensis* (Echinoid fossil) occurs from the Aketo Formation (Tanaka and Kawakami, 1983). Ehinoids in the Miyako Group are more important than biostratigraphy for determining the relationship between lithofacies (Tanaka and Obata, 1982). The occurrence of *Heteraster hiranamensis* supports the contention that the lithofacies of the Sakiyama Formation resembles those of the Aketo Formation.

The analogous fossil assemblages suggest that the Sakiyama Formation is correlated with the uppermost part of the Hiraiga Formation to the lower part of the Aketo Formation in the north area.

The depositional environments of the Hiraiga Formation and the Aketo Formation are conjectured to be the inner shelf to the lower shoreface (Fujino *et al.*, 2006). These depositional environments are consistent with those of the Sakiyama Formation described in the present study.

The ammonoid species obtained from the Miyako Group (upper Aptian to lower Albian) are the same as or related to those species from the stratotypes of the Cretaceous system in Western Europe, including France and England; the Tethys Sea area, including South Europe, North Africa, and Central Asia; the Indian Ocean, including Madagascar; and the Pacific Ocean side of North America (Hanai *et al.*, 1968).

Aconeceras which is reported from the Miyako Group for the first time in the present paper, has been reported from Europe, Greenland, Algeria, South Africa, Madagascar, Australia (Queensland and Western Australia), Argentina, and Nepal (Wright *et al.*, 1996). *Pseudohaplocras* has been reported from the Sanchu Cretaceous system (Obata *et al.*, 1984) and the Choshi Group (Obata and Matsukawa, 2007) in Japan. Previous studies (e.g. Hanai *et al.*, 1968) suggest that other ammonids from the Miyako Group are also similar to the species from these regions.

Lehman *et al.* (2009) reported Aptian cephalopods from Tunisia, with Deshayesitid—*Pseudohaploceras* cephalopods being dominant in the outer ramp sediments. In the present study, *Pseudohaploceras* was obtained from the Facies 9, which is inferred to be inner shelf sediments. This environment is consistent with the occurrence of *Pseudohaploceras* described by Lehman *et al.* (2009).

4. 1. 2. *Neithea* from the Aketo Formation

Hanai *et al.*, (1968) suggests that *Neithea* (Bivalvia) is useful as index fossil in the Miyako Group. According the study, *N. notabilis* and *N. ficalhoi* are useful as index fossil of late Aptian and *N. nipponica* and *N. aketoensis* are useful as index fossil of early Albian.

N. matsumotoi newly obtained from the Aketo Formation in the present study (Plate 31-9). *N. matsumotoi* is characteristic species from Albian of the Pre-Sotoizumi Group and reported from the Pre-Sotoizumi and Shimanto Groups and the Sanchu Cretaceous system (Tashiro, 2000).

The Aketo Formation is inferred to be late of early Albian in age (Obata, 1974). The age corresponds to age of

N. matsumotoi at other areas.

The occurrence of *N. matsumotoi* supports that the bivalves of the Miyako Group bear common species for contemporaneous Formation in southwest Japan.

4. 1. 3. Boring bivalve from the Tanohata Formation

In the present study, boring bivalve is obtained from the Facies 7 in the Tanohata Formation at Koikorobe, Tanohata Village, Shimohei County, Iwate Prefecture. The bivalve was discovered in a skelton of hexacoral fossil which is born as clasts of conglomerate (Figure 33).

The coral have 3 cm in height and dendroidal compound. The corallum have a simple branching off. The corallites have elliptical cross-section (23×15 mm). Although the interior corallites have been filled up by sandstone, the exterior corallites have been preserved septa. The septa are fine and 44 in number at a half of round. The costae fine, costal tissue rather thin, edges of costae minutely granulated, numbering 10 per 5 mm. The coral is identified as *Dermosmilia miyakoensis* by thinner cotal layers and finer septa.

The corallite of *Dermosmilia miyakoensis* has an elliptical hole (2×3 mm). The cavity of hole has sticky shape and 3 cm in length.

A bivalve is born in the hole. The anterior part of bivalve is in the inner part of the hole. The bivalve is articulated. The bivalve shows the following morphological features: Shell cylindrical, tapering psteriorly, smooth, beaks near anterior end. The bivalve is identified as *Lithopahaga* (*Myapalmula*) sp. Boundary of the bivalve and hole is filled up by sandy silt stone.

L. (*M.*) sp. from the Miyako Group is interpreted as autochthonous boring fossil by mode of occurrence of articulating and beaks position. The mechanism of boring is inferred to be chemical boring by smooth surface of the shell.

Owada (2007) classified Mytilidae into three functional morphologies: mytiliform, modioliform, lithophagiform. *L.* (*M.*) sp. from the Miyako Group is classified into the lithophagiform by the cylindrical shape. The functional morphology supports that the bivalve was adapted to boring habitat.

Kleemann (1990) suggested evolution model of *Lithopahaga* which is divergence to subgenus of *Lithopahaga* and other subgenus in Triassic. *L.* (*M.*) sp. from the Cretaceous Miyako Group suggests that subgenus of *Myapalmula* has appeared since Cretaceous.

Scott (1988) reported that recent specimens of *Lithophaga bisulcata* have different morphologies of shells and holes between living and dead coral borers. According the study, the dead coral borers have narrow shells and no elongated holes. *L.* (*M.*) sp. from the Miyako Group is inferred to be dead coral borer by having narrow shells and no elongated holes.

4. 1. 4. Fossil assemblage

The Miyako Group bears abundant molluscan fossils. Five bivalve fossil assemblages, which correspond to sedimentary facies, are discriminated from the Group by composition of bivalves and mode of occurrence (Figure 34).

The fossil assemblages are represented by multi-species which account for more than 50% of all specimens. The specimens for counting are obtained from 20 cm in thickness at outcrops.

Pterotrigonia yokoyamai—Ostreacea assemblage

The *Pterotrigonia yokoyamai*—Ostreacea assemblage consists mainly of the association of an infaunal suspension feeder, *Pterotrigonia yokoyamai* and an epifaunal suspension feeder, Ostreacea gen. et sp. indet. and asscociated with *Nipponitrigonia* sp., *Lopha nagaoi*, *Pterotrigonia* sp., *Amphidonte subhariotoidea*, *Lithophaga* sp., *Spondylus decorates*, "*Cardita*"(?) sp., Mitilidae? gen. et sp. indet. and *Ceratostreon yabei*. *P. yokoyamai* and Ostreacea (including *Lopha nagaoi*, *Amphidonte subhariotoidea* and *Ceratostreon yabei*) comprise nearly 70% of the total bivalves of the assemblage. Although *Lithophaga* sp. is obtained from coral by autochthonous occurrence, the other bivalves are mostly broken and disarticulated. The Facies 7 in the Tanohata Formation bears the assemblage.

The *Pterotrigonia yokoyamai*—Ostreacea assemblage is inferred to be transported into lower shoreface from upper shoreface by bearing *Pterotrigonia yokoyamai* and *Nipponitrigonia* sp. and consisting broken shells. The assemblage corresponds to the assemblage of Fujino (2003) and Fujino *et al.* (2006) which is characterized by *P. yokoyamai*, *N. kikuchiana*, *Praecaprotina yaegashii*.

Ostreacea assemblage

The Ostreacea assemblage consists mainly of the association of infaunal suspension feeders, such as Ostreacea gen. et sp. indet. and *Amphidonte subhariotoidea* and is associated with *Eriphyla miyakoensis*, *Cucullaea* sp., *Praecaprotina yaegashii*, *Glycymeris densilineata*, *Spondylus decorates*, *Eriphyla pulchella*, *Pterotrigonia hokkaidoana*, "*Cardita*"(?) sp., *Chlamys subacuta*, *Chlamys robinaldina*, Mytilidae? gen. et sp. indet., *Cotinula*? *oshimensis*, *Limatula nagaoi*, Limidae gen. et sp. indet., *Neithea* sp., *Astarte subsenecta* and*Goniomya subarchiaci*. Ostreacea (including *A. subhariotoidea* and *C.* ? *oshimensis*) comprise more than 50% of the total bivalves of the assemblage. The bivalves of the assemblage are mostly disarticulated and unbroken. *Praecaprotina yaegashii* is one of the reef-building bivalves. The Facies 3 in the Hiraiga Foemation bears the assemblage.

The Ostreacea assemblage is inferred to be transported into lower shoreface from upper shoreface by bearing *Praecaprotina yaegashii* and consisting disarticulated shells.

Mesosaccella insignis—*Glycymeris densilineata* assemblage

The *Mesosaccella insignis*—*Glycymeris densilineata* assemblage consists mainly of the association of an infaunal depositional feeders, *Mesosaccella insignis*, and an infaunal suspension feeder, *Glycymeris densilineata*, and is associated with *Eriphyla pulchella, Limatula nagaoi*, *Eriphyla miyakoensis*, *Pterotrigonia hokkaidoana*, *Pterotrigonia pociliformis*, *Cucullaea* sp., *Protocardia hiraigensis*, *Lucinoma*? *kotoi*, *Astarte submalioides*, *Nuclopsis ishidoensis* and *Goniomya* sp. *Mesosaccella insignis* and *Glycymeris densilineata* comprise more than 50% of the total bivalves in the assemblage. Many of the bivalves are disarticulated. In contrast, most *Mesosaccella insignis* specimens are articulated. Almost all of the bivalves are unbroken. The Facies 9 in the Sakiyama Formation bears the assemblage.

The preservation of the *Mesosaccella insignis*—*Glycymeris densilineata* assemblage suggests that bivalves with the exception of *Mesosaccella insignis* were transported into the *Mesosaccella insignis* habitat (inner shelf) from their original habitats (shoreface).

Glycymeris densilineata—*Eriphyla pulchella* assemblage

The *Glycymeris densilineata*—*Eriphyla pulchella* assemblage consists mainly of the association of infaunal suspension feeders, such as *Glycymeris densilineata* and *Eriphyla pulchella* and is associated with *Eriphyla miyakoensis*, *Pterotrigonia hokkaidoana*, *Cucullaea* sp., *Astarte minor, Astarte submalioides*, *Astarte subsenecta*, *Neithea* sp., *Neithea ficalhoi*, *Lucinoma*? *kotoi*, *Anthonya* sp., *Ludbrookia* cf. *tenuicostata, Rastellum* sp., and *Mytilus*? sp. *Glycymeris densilineata* and *Eriphyla pulchella* comprise nearly 60% of the total bivalves in the assemblage. Almost all of the bivalves are disarticulated but are unbroken. The Facies 3 in the Sakiyama Formation bears the assemblage.

The preservation of the *Glycymeris densilineata*—*Eriphyla pulchella* assemblage and the occurrence of a brackish oyster, *Rastellum* sp., suggest that bivalves were transported to the depositional setting of Facies 3 (lower shoreface) from their original habitats. The preservation of the assemblage is similar to that of Type 3 of the molluscan fossil beds of the Hiraiga Formation in the north area (Mochizuki and Ando, 2003).

Limatula nagaoi—*Eriphyla pulchella*—*Anthonya japonica*—*Pterotrigonia hokkaidoana* assemblage

The *Limatula nagaoi*—*Eriphyla pulchella*—*Anthonya japonica*—*Pterotrigonia hokkaidoana* assemblage consists mainly of the association of epifaunal suspension feeders, such as *Limatula nagaoi* and *Anthonya* *japonica* and infaunal suspension feeders, such as *Eriphyla pulchella* and *Pterotrigonia hokkaidoana* and is associated with *Glycymeris densilineata*, *Mesosaccella insignis*, *Eriphyla miyakoensis*, *Astarte submalioides*, *Nipponitrigonia* sp., *Goniomya subarchiaci*, Ostreacea gen. et sp. indet., *Pinna* sp., *Astarte minor*, *Neithea matsumotoi*, *Neithea ficalhoi*, *Neithea nipponica* and *Neithea* sp. *L. nagaoi*, *E. pulchella*, *A. japonica* and *P. hokkaidoana* comprise more than 50% of the total bivalves in the assemblage. The bivalves of the assemblage are mostly disarticulated and unbroken. *Anthonya japonica* has inner shelf of the original habitat. The Facies 4 in the Aketo Formation bears the assemblage.

The habitats of the *Limatula nagaoi*—*Eriphyla pulchella*—*Anthonya japonica*—*Pterotrigonia hokkaidoana* assemblage is inferred to be inner shelf by consisting disarticulated bivalves and their habitats. The assemblage corresponds to the assemblage of Fujino (2003) which is characterized by *E. pulchella* and *P. hokkaidoana.*

4. 1. 5. Depositional sequences

The present study discriminates the 15 Facies and the five assemblages in the Miyako Group. The group is composed of one third-order depositional sequences (DS).

Depositional sequence (The Raga, Tanohata, Hiraiga, Hiraname, Aketo and Sakiyama Formations)

The DS has a lowstand systems tract (LST) as the Raga, Hiraiga and Hiraname Formations and higistand systems tract (HST) as the upper part of the Tanohata, Aketo and Sakiyama Formations. The Raga Formation is composed of the Facies 1 (talus) and 2 (debris flow in fan delta) which unconformably overlie the basement rocks (sequence boundary: SB). The following Tanohata Formation is composed of the Facies 3 (lower shoreface), 4 (inner shelf), 6 (reef sediments in upper shoreface), 7 (tsunami deposits in lower shoreface) and 9 (inner to outer shelf). The Facies 7 in the Tanohata Formation bears the *Pterotrigonia yokoyamai*—Ostreacea assemblage. The bases of the Facies 6 and 7 are interpreted as a ravinement surface (RS). The Facies 6 and 7 are interpreted as the transgressive systems tract (TST). The following HST is composed of the Facies 3, 4 and 9. The following Hiraiga and Hiraname Formations are composed of the Facies 3 (lower shoreface), 4 (inner shelf), 5 (upper shoreface), 8 (tuff) and 9 (inner to outer shelf). The Facies 3 in the Hiraiga Foemation bears the Ostreacea assemblage. The Facies 5 only distributes in the most north area. The Aketo and Sakiyama Formations are composed of the Facies 3 (lower shoreface), 4 (inner shelf) and 9 (inner to outer shelf). In the north area, the Aketo Formation is composed of the Facies 4 which bearing the *Limatula nagaoi*—*Eriphyla pulchella*—*Anthonya japonica*—*Pterotrigonia hokkaidoana* assemblage. On the other hand, the Sakiyama Formation is composed of the Facies 3 and 9 which bearing the *Mesosaccella insignis*—*Glycymeris densilineata* and *Glycymeris densilineata*—*Eriphyla pulchella* assemblages in the south area.

4. 2. Futaba Group

4. 2. 1. Fossil assemblage

The Futaba Group bears abundant molluscan fossils. Five bivalve fossil assemblages, which correspond to sedimentary facies, are discriminated from the Group by composition of bivalves and mode of occurrence (Figure 35)

The fossil assemblages are represented by multi-species which account for more than 50% of all specimens. The specimens for counting are obtained from 20 cm in thickness at outcrops.

Glycymeris amakusensis—*Apiotrigonia minor*—*Loxo japonica* assemblage

The *Glycymeris amakusensis*—*Apiotrigonia minor*—*Loxo japonica* assemblage consists mainly of the association of infaunal suspension feeders, such as *Glycymeris amakusensis*, *Apiotrigonia minor* and *Loxo japonica* and is associated with bivalves such as *Periploma* sp., *Yadia* sp., *Opis* sp., *Cucullaea* sp. and *Isognomon*? sp. and gastropods such as *Sargana* sp. and *Tullitella*? sp. *G. amakusensis* comprise nearly 80% of the total fossils of the assemblage. The bivalves of the assemblage are almost disarticulated and unbroken. Habitats of *G.* and *L. japonica* are inferred to be shoreface (Kumagaya and Komatsu, 2004). Tashiro and Matsuda (1983) reported that habitats of *Apiotrigonia minor* inferred to be upper shoreface. The Facies 3 in the Obisagawa Member bears the assemblage.

The preservation of the *Glycymeris amakusensis*—*Apiotrigonia minor*—*Loxo japonica* assemblage and occurrence of *G. amakusensis*, *A. minor* and *L. japonica* suggest that the habitat of the assemblage is inferred to be upper shoreface. The assemblage corresponds to the First assemblage of Hirata (2005).

Inoceramus uwajimensis—*Myrtea ezoensis* assemblage

The *Inoceramus uwajimensis*—*Myrtea ezoensis* assemblage consists mainly of the association of an epifaunal suspension feeder, *Inoceramus uwajimensis*, and an infaunal suspension feeder, *Myrtea ezoensis* and is associated with gastropods such as *Gyrodes* sp. *Inoceramus uwajimensis* comprises more than 90% of the total fossils of the assemblage. The bivalves of the assemblage are mostly articulated and unbroken. *I. uwajimensis* from the assemblage is characterized by compressed, articulated and large shells and downward to left shell. The characteristics correspond to the Type 1 or 2 from the Yezo Group in classification of *I. uwajimensis* by Hayakawa (1990). Habitats of the Type 1 or 2 of *I. uwajimensis* are inferred to be under mean storm wave base (Hayakawa, 1990). The Facies 4 in the Obisagawa Member bears the assemblage.

The occurrece of the Type 1 or 2 of *Inoceramus uwajimensis* suggests that the habitat of the *Inoceramus* *uwajimensis*—*Myrtea ezoensis* assemblage is inferred to be outer shelf. The assemblage corresponds to the Fourth assemblage of Hirata (2005).

Inoceramus uwajimensis—*Eriphyla higoensis*—*Myrtea ezoensis* assemblage

The *Inoceramus uwajimensis*—*Eriphyla higoensis*—*Myrtea ezoensis* assemblage consists mainly of the association of an epifaunal suspension feeder, *Inoceramus uwajimensis,* and infaunal suspension feeders, *Eriphyla higoensis* and *Myrtea ezoensis* and is associated with bivalves such as *Nanonavis sachalinensis*, *Apiotrigonia minor*, *Glycymeris amakusensis*, *Acila* sp. and Pectenidae gen. et. sp. indet., gastropods such as *Natica* sp., *Gyrodes* sp., *Paladomete* sp. and Caripteraridae gen. sp. indet., ammonoids such as *Scaphites*? sp. and shark teeth such as *Cretolamna* sp. and *Scapanorhynchus* sp. *I. uwajimensis* comprise more than 60% of the total fossils of the assemblage. The bivalves of the assemblage bear disarticulated, articulated and broken shells. *I. uwajimensis* from the assemblage is characterized by uncompressed, bearing disarticulated and broken small shells. The characteristics correspond to the Type 3 from the Yezo Group in classification of *I. uwajimensis* by Hayakawa (1990). Habitats of the Type 3 of *I. uwajimensis* are inferred to be near mean storm wave base (Hayakawa, 1990). Tashiro (1998) reported *E. higoensis*, *M. ezoensis* and *N. sachalinensis* from shallow marine silt stone. The Facies 4 in the Obisagawa Member bears the assemblage.

The occurrence of the Type 3 of *Inoceramus uwajimensis*, *Eriphyla higoensis*, *Myrtea ezoensis* and *Nanonavis sachalinensis* suggest that the habitat of the *Inoceramus uwajimensis*—*Eriphyla higoensis*—*Myrtea ezoensis* assemblage is inferred to be inner shelf. The assemblage corresponds to the Fifth assemblage of Hirata (2005).

Inoceramus uwajimensis—*Periploma* sp. assemblage

The *Inoceramus uwajimensis*—*Periploma* sp. assemblage consists mainly of the association of an epifaunal suspension feeder, *Inoceramus uwajimensis*, and an infaunal suspension feeder, *Peliploma* sp. and is associated with bivalves such as *Glycymeris amakusensis*, *Apiotrigonia minor*, *Parvamussium yubarense*, *Eriphyla higoensis*, *Myrtea ezoensis*, *Acila* sp. and *Leptosolen* sp., gastropods such as *Natica* sp., *Polyptychoceras*? sp. (Ammonoidea) and Isocrinidae gen. et. sp. indet. (Crinoidea). *I. uwajimensis* comprise more than 50% of the total fossils of the assemblage. The bivalves of the assemblage bear disarticulated, articulated and broken shells. *I. uwjimensis* from the assemblage is characterized by uncompressed, bearing disarticulated and broken small shells. The characteristics correspond to the Type 3 from the Yezo Group in classification of *I. uwajimensis* by Hayakawa (1990). Habitats of the Type 3 of *I. uwajimensis* are inferred to be near mean storm wave base (Hayakawa, 1990). Tashiro (1998) reported *E. higoensis*, *M. ezoensis* and *A.* sp. from shallow marine silt stone. The Facies 4 in the Obisagawa Member bears the assemblage.

The occurrence of the Type 3 of *Inoceramus uwajimensis*, *E. higoensis*, *M. ezoensis* and *A.* sp. suggest that the habitat of the *Inoceramus uwajimensis*—*Periploma* sp. assemblage is inferred to be inner shelf. The assemblage corresponds to the Fourth assemblage of Hirata (2005).

Inoceamus sp.—*Glycymeris amakusensis*—*Loxo japonica* assemblage

The *Inoceamus* sp.—*Glycymeris amakusensis*—*Loxo japonica* assemblage consists mainly of the association of an epifaunal suspension feeder, *Inoceramus* sp. and infaunal suspension feeders, *Glycymeris amakusensis* and *Loxo japonica* and is associated with bivalves such as *Nanonavis* sp., *Apiotrigonia minor* and *Ezonuculana matraeformis* and *Cretolamna* sp. (shark teeth). *I.* sp., *G. amakusensis* and *L. japonica* comprise nearly 90% of the total fossils of the assemblage. The bivalves of the assemblage are mostly disarticulated and broken shells. Habitats of *G.* and *L. japonica* are inferred to be shoreface (Kumagaya and Komatsu, 2004). Tashiro (1998) reported *N.* sp. from shallow marine silt stone. The Facies 4 in the Irimazawa Member bears the assemblage.

The preservation of the *Glycymeris amakusensis*—*Apiotrigonia minor*—*Loxo japonica* assemblage suggests that the bivalves of the assemblage is inferred to be transported into inner shelf from their original habitats.

4. 2. 2. *Cucullaea* sp. from the Obisagawa Member

The *Glycymeris amakusensis*—*Apiotrigonia minor*—*Loxo japonica* assemblage in the Facies 3 of the Obisagawa Member bears *Cucullaea* sp. (Plate 32-3). The Northern Tethyan fauna is obtained by the Upper Cretaceous in Japan (Tashiro, 1998). *C.* sp. is a factor of the Tethyan fauna. The occurrence of *C.* sp. suggests that marine currents from south increase in the time which is deposition of the Facies 3.

4. 2. 3. Depositional sequences

The present study discriminates the seven Facies and the five assemblages in the Futaba Group. The group is composed of three DS. Each depositional sequence corresponds to the Ashizawa, Kasamatsu and Tamayama Formations, in ascending order.

First depositional sequence (The Ashizawa Formation)

The first depositional sequence (DS 1) has a LST as the Asamigawa Member. It is composed of the Facies 1 (fan delta) which unconformably overlies the basement rocks (sequence boundary 1: SB 1). The following Obisagawa Member is composed of the Facies 3 (upper shoreface) and 4 (inner to outer shelf). The base of the Facies 3 is interpreted as the ravinment surface (RS 1). The Facies 3 in the member is interpreted as the TST and bears the *Glycymeris amakusensis*—*Apiotrigonia minor*—*Loxo japonica* assemblage. The following HST is composed of the Facies 4. The Facies 4 in the member bears the *Inoceramus uwajimensis*—*Myrtea ezoensis*, the *Inoceramus uwajimensis*—*Periploma* sp. and the *Inoceramus uwajimensis*—*Eriphyla higoensis*—*Myrtea ezoensis* assemblages.

Second depositional sequence (The Kasamatsu Formation)

The second depositional sequence (DS 2) has a LST as the Kasamatsu Formation. The DS 2 conformably (SB 2) overlies the preceding depositional sequence (DS 1) and composed of the Facies 2 (flood plain or natural leeve) and 5.

Third depositional sequence (The Tamayama Formation)

The third depositional sequence (DS 3) has a LST as the Kobisagawa Member. It is composed of the Facies 6 (flood plain) and 7 (braided river). The DS 3 conformably (SB 3) overlies the preceding depositional sequence (DS 2). The following Irimazawa Member is composed of the Facies 4 (inner to outer shelf). The base of the Facies 4 is interpreted as the RS 2 and TST. The Facies 4 is interpreted as the HST. The facies in the member bears the *Inoceamus* sp.—*Glycymeris amakusensis*—*Loxo japonica* assemblage. The upper sequence boundary (SB 4) of DS3 shows the conspicuous clinounconformity between the Futaba Group and the Paleogene Shiramizu Group.

4. 3. Nakaminato Group

4. 3. 1. Ammonoids from the Hiraiso Formation

Didymoceras awajiense and *Diplomoceras*? sp. are obtained from calcareous nodules of the Facies 4 of the Hiraiso Formation in the present study (Plate 38-A). According to Moroizumi (1985), *Didymoceras awajiense* is index fossil of the early of late Campanian in the Seidan Formation of the Izumi Group. However, *Pravitoceras sigmoidale*, which is reported from the upper horizon of *Didymoceras awajiense* in the group, didn't discover from the Nakaminato Group.

The Nakaminato and Izumi Groups have common characteristics which are turbidity lithofacies, weak consolidation and occurrence of *Didymoceras awajiense*. Therefore, the Nakaminato Group is interpreted as the eastern extension part of the Izumi Group.

The Izumi Group is forearc margin sediments controlled by strike-slip faulting. The faulting was suggested that it have an extension trend toward east (Noda and Toshimitsu, 2009). The age of the base of the Nakaminato Group is inferred to be middle Campanian (Saito, 1961, 1962) after the age of the base of the Izumi Group (early Campanian; Moroizumi, 1985). This relation of ages supports that the Nakaminato Group is interpreted as the eastern extension part of the Izumi Group.

4. 3. 2. Radiolarians from siliceous pebbles

The Facies 1 and 3 include conglomerates which are composed of various clasts, such as siliceous pebbles. The siliceous pebbles are composed of white to gray chart and black shale. These pebbles are generally massive, but include bedded rock. Radiolarian fossils are obtained from one horizon in lower part of the Isoai Formation of acid treatmented the pebbles (Figure 36). The specimens are bulk because of small clasts size.

The present paper obtained 12 genera and 16 speicies radiolarian fossils such as *Triassocampe coronata* Bragin, 1991, *Triassocampe deweveri* (Nakaseko and Nishimura, 1979), *Triassocampe* sp., *Triassocampe*? sp., *Pseudodictyomitrella*? sp., *Archaeodictyomitra* sp., *Canoptum*? sp., *Hexalonche*? sp., *Spongostephanidium*? sp., *Annulopoulpus*? sp., *Capnuchosphaera* cf. *deweveri* Kozur and Mostler, 1979, *Betraccium* sp., *Syringocapsa* sp., *Paronaella* sp., *Gongylothorax favosus* Dumitrica, 1970 and Spumellaria? gen. et sp. indet. (Plate 39). In these fossis, following genera and species have been indicated age by Matsuoka and Yao (1986), Pessagno *et al.* (1989), Sugiyama (1997), Hori (1999) and O'Dogherty *et al.* (2009a, b); *Triassocampe coronata* (Triassic Anisian), *Triassocampe deweveri* (Triassic late Anisian to early Ladinian), *Archaeodictyomitra* (Jurassic early Pliensbachian to Cretaceous late Campanian), *Capnuchosphaera* cf. *deweveri* (compared to Triassic early Carnian to early Norian), *Betraccium* (Triassic late Carnian to late Rhaetian), *Paronaella* (Triassic early Rhaetian to Cretaceous late Coniacian) and *Gongylothorax favosus* (Jurassic Bathonian to Tithonian). These ranges indicate various ages which are Middle Triassic to Late Cretaceous.

The Triassic to Jurassic Yamizo Group, which has been interpreted as accretionary complex, is located on west of the Nakaminato Group (e. g. Hori and Sashida, 1998). The age of radiolarians of siliceous pebbles in the Nakaminato Group corresponds with that of the Yamizo Group. However, the assemblage of radiolarians of siliceous pebbles in the Nakaminato Group isn't similar to that of the Yamizo Group. So, it is estimated that these pebbles had been derived from various Mesozoic accretionary complexes (maybe including the Yamizo Group). Tanaka and Kawada (1971) estimated that paleocurrent of the Nakaminato Group is west and volcanic pebbles of the Group are derived from Okunikko Rhyolites or allied volcanics. These volcanics is located as west of the Group. It is estimated that these siliceous pebbles had been derived from various Mesozoic accretionary complexes in western area of the Group by those evidences.

The Nakaminato Group has been located on southern the Tanakura Tectonic Line and Southwestern part of Japan (Ando, 2006). In the Late Cretaceous, the siliceous pebbles of the Nakaminato Group had been derived from various Mesozoic accretionary complexes in western area of the Group which had been uplifted, broken and deformed by the Pro-Tanakura Tectonic Line.

4. 3. 3. Depositional sequence

The present study discriminates the six Facies in the Nakaminato Group. The group is composed of one DS.

Depositional sequence (The Hiraiso and Isoai Formations)

The depositional sequence has a HST as the Hiraiso Formation. It is composed of the Facies 1 (channel of debris flow in upper submarine fan), 2 (channel of debris flow in upper to middle submarine fan), 4 (leeve in lower submarine fan), 5 (basin-plain in lower submarine fan) and 6 (leeved channel in lower submarine fan). The Facies 4 in the Formation bears ammonoids. The following LST consists the Facies 1 (channel of debris flow in upper submarine fan), 2 (channel of debris flow in upper to middle submarine fan), 3 (channel of debris flow in upper submarine fan) and 5 (basin-plain in lower submarine fan) of the Isoai Formation.

4. 4. Choshi Group

4. 4. 1. *Portlandia sanchuensis* from the Toriakeura Formation

Portlandia sanchuensis (bivalvia) is obtained from silt stone of the Facies 4 in the middle of Toriakeura Formation (Plate 39-A). *P. sanchuensis* is interpreted as autochthonous occurrence by articulated and scattered occurence.

Hayami and Oji (1980) reported the Northern Tethyan fauna including *P. sanchuensis* from Kimigahama Formation. Tashiro (1994) reported the Tethyan fauna from the upper of the Toriakeura to Nagasakihana Formation. *P. sanchuensis* from the middle of the Toriakeura Formation suggests that the Formation bears the Northern Tetyan fauna. This suggests that the Northern Tethys fauna change for the Tethyan fauna at the Toriakeura Formation.

4. 4. 2. Depositional sequence

The present study discriminates the five Facies in the Choshi Group. The group is composed of one DS.

Depositional sequence (The Ashikajima, Kimigahama, Inubozaki, Toriakeura, Nagasakihana Formations)

The DS has three LST as the Ashikajima, Inubozaki and Nagasakihana Formations and three HST as the Kimigahama, Toriakeura and Nagasakihana Formations. The first LST is composed of the Ashikajima Formation which consists the Facies 1 (upper shoreface) and 3 (lower shoreface). The Facies 1 unconformity overlies the basement rocks (sequence boundary; SB 1). The following Kimigahama and Inubozaki Formations are composed of the Facies 2 (inner shelf) and 3 (lower shoreface). The following Toriakeura Formation is composed of the Facies 2 (inner shelf) and 4 (outer shelf). The Facies 4 in the Formation bears *Portlandia* *sanchuensis* (bivalvia). The following Nagasakihana Formation is composed of the Facies 3 (lower shoreface). The upper sequence boundary (SB 2) of DS shows the conspicuous clinounconformity between the Choshi Group and the Pliocene Naarai Formation.

4. 5. Sanchu Cretaceous System

4. 5. 1. Limestone from the Ishido Formation

The present study obtained limestones from the Facies 3, 5 and 15 in the Ishido Formation. The limestone of the Facies 5 bears abundant bioclasts. The present study focuses on the limestone.

The limestone is obtained as exotic blocks from shale of the Ishido Formation (Figure 37). The maximum size of the blocks is 10 m in diameter. The blocks irregularly contact with the shale. The shale corresponds to the Facies 12.

The limestone consists of Floatstone and Mudstone of classification by Embry and Klovan (1971). The Floatstone is micrite-matrix supported and bears abundant bioclasts such as corals and spines of echinoid, etc. The Mudstone is micrite-matrix supported and bears few bioclasts.

The Floatsone bears corals such as *Montilvaltia* sp. and *Stylosimilia shirakurai*, spines of echinoid, bivalves such as *Lithophaga* sp. and microfossils. The microfossils bear plamktonic foraminifers such as *Globuligerina hoterivica*, *Hedbergella planispira*, *Globigerinelloides* aff. *blowi*, benthic foraminifers such as *Haplophragmoides* sp., *Pullenia* sp., *Paratrochammides* sp., *Saccamia* sp., *Pseudobolivina* sp., *Tolypammina* sp. and *Bigenerina*? sp., *Archaeodictyomitra* sp. (Radiolaria), Ostracodae gen. et sp. indet. and spicular sponges. The age of the limestone is inferred to be early Aptian by occurrence of *Globu. hoterivica* and *He. Planispira* (Sashida *et al.*, 1992). The present study firstly confirm the age in several blocks. The age contradicts with the age of the Ishido Formation by ammonoids (Hauterivian to Barremian: e.g. Matsukawa, 1983). One of the reasons of the contradiction is inferred to be no integrated mega- and microbiostratigraphy in the Lower Cretaceous at Japan while Toshimitsu *et al.* (1995) suggested integrated biostratigraphy in the Upper Cretaceous.

The Floatstone bears oncoids. The oncoids show the following characters: scattered occurrence, nucleuses are composed of coral, bearing microboring, 3-10 cm sized in diameter, concentric to lobate growth type, porostromate lamination which is alternate of micrite and encrusting organisms. According to relationship characters of oncoid and sedimentary environment by Flügel (2004), the characters and texture of the limestone suggest that sedimentary environment of the limestone is inferred to be patch reef.

The encrusting organisms in oncoids are identified as *Lithocodium aggregatum*, *Koskinobullina socialis* and *Bacinella irregularis*. *L. aggregatum* is a microencruster, characterized by inner cavities an aggregated outer wall with numerous alveoli about 50 μm in diameter. Schmid and Leinfelder (1996) inferred that *L. aggregatum* was a foraminifer with symbiotic algae. *K. socialis* is an enigmatic fossil characterized by spherical to hemispherical vesicles 50-100 µm in diameter. It has a thin, radial-fibrous calcitic outer wall that exhibits regular, fine pores in places. It has been categorized as algae (e.g. Cherchi and Schroeder, 1985) or foraminifers (e. g. Schmid, 1996). *B. irregularis* is an enigmatic microencruster with an irregular micritic meshwork that is assumed to represent a cyanobacterial structure (e. g. Schmid and Leinfelder, 1996). These encrusting organisms correspond to the *Bacinella*—*Lithocodium* association which is reported from the Upper Jurassic in Europe (Leinfelder *et al.*, 1993) and the Upper Jurassic to lowermost Cretaceous Torinosu Group (Shiraishi and Kano, 2004). The finding of the association confirms that the distribution of the European upper Jurassic microencruster association should have been extended as far as Japan since early Aptian, which lies in the Tethyan gateway (Leinfelder *et al.*, 2002).

4. 5. 2. The Tethyan fauna from the Sanchu Cretaceous System

The Northern Tetyan fauna has been reported from the Sanchu Cretaceous System (e.g. Hayami, 1965a, b, 1966). The Tetyan fauna has been also reported from the Cretaceous by Ichise *et al.* (2002), Ichise (2009) and Terabe and Matsuoka (2009). Therefore, the two faunas were known from the Cretaceous. Iba and Sano (2007) suggested the model which was step-wise demise of fauna in Mid-Cretaceous at the Northern Pacific area.

The present study obtained bivalves of the Tetyan fauna from the Ishido Formation on the western part of the Sanchu Cretaceous System (Plate 43). The bivalves include *Scittila dericatostriata* which is reported as one of bivalves of the Tethyan fauna by Terabe and Matsuoka (2009). The Tetyan fauna is reported from the eastern part of the Cretaceous (Ichise *et al.*, 2002; Terabe and Matsuoka, 2009) and the Nanmoku Group in the western part of the Cretaceous (Ichise, 2009). *S. dericatostriata* obtained from the Sanchu Group in the western part of the Cretaceous in the present paper. The bivalve suggests that the habitat of the Tethyan fauna was all area of the Cretaceous.

4. 5. 3. Depositional sequence

The present study discriminate the 15 Facies in the Sanchu Cretaceous system. The Cretaceous is composed of one DS.

Depositional sequence (The Shiroi, Ishido, Sanyama, Tozawa, Ohnita Formations)

The DS has a LST and a HST. The LST is composed of the Shiroi and Ishido and Tozawa Formations. The Shiroi Formation is composed of the Facies 6 (flood plain or natural leeve) and 7 (flood plain). The Facies 6 in the Formation bears bivalves and gastropods. The Facies 6 unconformably overlies the basement rocks (sequence boundary: SB 1). The following Ishido Formation is composed of the Facies 1 (talus), 2 (fan delta), 3 (reef), 5 (reef), 8 (lower shoreface), 9 (inner shelf), 12 (inner shelf), 13 (braided river) and 14 (tuff). The Facies 3, 5, 8, 9 and 12 in the Formation bears bivalves, gastropods, corals, plants and microfossils. The Tozawa Formation, which is contemporaneous relation with the Ishido Formation, is composed of the Facies 1 (talus) and 2 (fan delta). The base of the Facies 2 is interpreted as the RS. The following Sanyama Formation is composed of the Facies 4 (channel in upper submarine fan), 10 (channel in upper submarine fan), 11 (channel in upper to middle submarine fan), 12 (inner shelf) and 15 (outer shelf). The Facies 10 in the Formation bears bivalves, gastropods and echinoids. The Facies 15 in the Formation bears belemnites. The Ohnita Formation, which is contemporaneous relation with the Sanyama Formation, is composed of the Facies 8 (lower shoreface) and 9 (inner shelf). The Facies 8 bears bivalves. The upper sequence boundary (SB 2) of DS shows the conspicuous clinounconformity between the Sanchu Cretaceous System and the Neogene Uchiyama Formation.

5. Sedimentological process of the Cretaceous systems in Japan

5. 1. Tectonic setting of the Cretaceous systems in Japan

Previous studies have suggested two paleobiogeographical regions which are composed of different associations of the low- and high-latitude types.

Tashiro (1994) divided bivalves from the Lower Cretaceous in Japan into the Tethys fauna as the low-latitude type and the Northern Tethys fauna as the high-latitude type. These faunas are composed of common genus. However, they include different species with the exception of cosmopolitan species. The Tethyan fauna distributes in the Southern Chichibu belt. On the other hand, the Northern Tethyan Fauna distributes in the Northern Chichibu and Kurosegawa tectonic Belts which belts distribute in adjacent area each other at present. However, Tashiro (1985; 1994) interpreted that these belts have considerably different latitude by distribution of these faunas and suggested that the reason of their distributions is the offset by the lateral faults of the Kurosegawa Tectonic Belt and Central Tectonic Line. Matsukawa and Obata (1993) divided ammonoids from the Barreminan Formations in Japan into the Tethys fauna as the low-latitude type and the Northwestern European, Borreal and North Pacific founas as the high-latitude type. Although ammonoids of the Northwestern European, Borreal and North Pacific founas of the high-latitude type co-occurs each other, ammonoids of the Tethys fauna as the low-latitude type doesn't co-occcur with the faunas of the high-latitude type. Matsukawa and Obata (1993) suggested that the faunas weren't influenced by lateral faults from the paleomagnetic data of the Monobegawa Group in Shikoku (Maenaka and Sasajima, 1985; Sakai and Maruyama, 1985). The study also suggested that the reason of their distributions was the influence of marine currents. Kozai *et al.* (2005) categorized non-marine bivalves from the Hauterivian Formations in Korea and Japan into the Tatsukawa, Shobu and mixed fauna. The study showed that the Shobu fauna distrtibutes in high-salinity area and the Tastsukawa founa distributes in low-salinity area. Kozai *et al.* (2005; 2007) suggested that the reason of their distributions was difference of salinity, temperature or amount of sediment by paleogeographical settings such as fluvial environments.

In summary, these studies about the Cretceous faunas have different interpretation points their distribution as follows. Tashiro (1985; 1994) suggested that the reason of their distribution is influence in large area and after sedimentation. Matsukawa and Obata (1993) suggested that the reason of their distribution is influence in large area and at a contemporary sedimentation time. Kozai *et al.* (2005; 2007) suggested that the reason of their influence in small area and at a sedimentation time.

The present study obtained many bivalves such as *Neithea matsumotoi* from the Miyako Group, *Cucullaea* sp. from the Futaba Group and *Scittila dericatostriata* from the western part of the Sanchu Group which are characteristic species of the Tethyan fauna and *Portlandia sanchuensis* from the Toriakeura Formation of the

Choshi Group which is chacteristic species of the Northern Tethyan fauna. These bivalves show that the Groups include mixed fauna of the Tethyan and Northern Tethyan faunas.

The present study obtained many ammonoids such as the assemblage from the Sakiyama Formation of the Miyako Group which mainly consists of the Northwestern European fauna with the Tethys fauna of the Choshi Group and the Sanchu Cretaceous System, *Neohibolites* sp. of the belemnite battlefield from the Sanyama Formation which is known from the excluding North Pacific area.

Bacinella—Lithocodium microencruster association from the Sanchu Cretaceous System should have been extended as far as Japan since early Aptian, which lies in the Tethyan gateway.

These fossils show that the mixed faunas of low- and high-latitude types distribute in various taxa, areas and ages. The theory of Tashiro (1985, 1994) inferred to be considerably different latitude, therefore the mixed fauna isn't assumed.

Red beds of Cretacous Systems in Japan are mainly found in the Inner Zone of Southwest Japan. Tashiro (1986) advocated that the displacement in distribution indicates the offset by the lateral faults of the Kurosegawa Tectonic Belt and Central Tectonic Line. However, Conglomerates of the facies 1 in the Miyako Group include matrix of red mud.

Kozai *et al.* (2005, 2007) investigated non-marine bivalves. On the other hand, the present study investigated marine fossils. However, the difference of salinity, temperature or amount of sediment can't be considered as the reason of their marine distributions.

The theory of Matsukawa and Obata (1993) clearly divides ammonoids faunas into the low- and high-latitude types. The present study recognizes the mixed fauna of the low- and high-latitude types from the Miyako Group. However, the fauna is inferred to be boundary between marine currents. Kozai *et al.* (2005) suggested that boundary of the low- and high-latitude types contradict ammonoids and radiolarians (Ishida and Hashimoto, 1991).

Recently, Iba and Sano (2007) suggested the model which is step-wise demise of fauna in Mid-Cretaceous at the Northern Pacific area. The contradiction of the boundary of the low- and high-latitude types among different taxa is interpretated as the influence of the step-wise demise. So, the reason of their distributions is inferred to be the influence of the step-wise demise and the marine currents.

Next, it discusses about sedimentary basins of the Cretaceous systems in the present study. The Cretaceous have basement rocks; the Raga (the Miyako Group), Ashizawa (the Futaba Group), Ashikajima (the Choshi Group) and Shiroi Formations (the Sanchu Cretaceous System). Origins of clasts of these Formations and the Nakaminato Group are considered as the accretional complexes and intrusively granitic rocks of magmatic arc which take continental side. This suggests that the Cretaceous are forearc basin-fill sediments. The ancient forearc basin along the eastern margin of the paleo-Asian continent is called the Yezo forearc basin (e.g. Ando, 2003).

Cretaceous systems in Japan were located at the east of Asian continent. This area was influenced by changing in oceanic plate arrangements. It is generally believed that the change was envisaged by the Izanagi Plate (150-85 Ma) which was subducted obliquely against the trench axis and Kula Plate (85-70 Ma) which was nearly at right angles to the trench (Okada and Sakai, 2000). Okada (1997) suggested that high rates of sedimentation of Cretaceous systems in Japan were occurred by tectonic uplift and highly active magmatism which reflect oceanic plate arrangements.

In the tectonic setting, according to tectonic types, Cretaceous sedimentary basins in Japan are divided into subduction-related basin, pull-apart basin and continental basins by Okada and Sakai (2000).

Subduction-related basins are subdivided into the trench basin, trench-slope basin and forearc basin, all of which are formed in close relation to subduction of oceanic plates. Because the facies from such basins are difficult to distinguish from each other, they are grouped as trench-forearc basins for convenience. They are represented by the Sorachi Group, the Yezo Super Group of Yezo Arc-Trench System in Hokkaido and the Lower Shimanto Supergroup in Southwest Japan.

In Northeast Japan, Hokkaido Island was separated into two tectonic masses: the Yezo Arc-Trench System to the west and the Okhostsk Paleoland to the east. These two masses were separated by Sorachi Ocean, a part of the Izanagi-Kula Plate, which subducted beneath the two masses. Thus, trench-forearc basins were developed in the Yezo Arc-Trench System, which were deposited by the Yezo Supergroup. According to Ando (2003), the Yezo Arc-Trench basin is subdivided into the Yezo, Kitakami and Joban subbasins. The Kitakami subbasin includes the Miyako Group and the Joban subbasin includes the Futaba Group. Tectonic settings of these Groups coincide with it of the Yezo Supergroup.

In the Outer Zone of Southwest Japan, subduction complex is represented by the Lower Shimanto Supergroup. It shows a large-scale imbricate stacking of strata with their ages younging oceanwards.

In Southwest Japan, pull-apart basins are common in forearc to intra-arc regions. They are generally fault-bounded trough-like depressions arranged in parallel to tectonic lines, and are separately scattered, small, elongated, and filled with clastic sediments of nonmarine, paralic to shallow-sea and deep-sea facies of substantial thickness.

Pull-apart basins are characteristic of forearc and intra-arc regions in the Sanchu and Choshi Groups, Kurosegawa and Axial Belts in Kyushu and along Median Tectonic Line. In general, they show half-graben profiles.

It is worthwhile to point out that the depocenters in these basins shifted gradually eastwards and got yonger in the same direction along the Median Tectonic Line. This diachronism in basin Formation is very similar to the age trend in magmatism in Southwest Japan with a rate of about 1/30 m. y./km (Kinoshita, 1995). This rate is close to that of movements of the Kula Plates (Seno and Maruyama, 1984). Therefore, it is clear that Formation of pull-apart basins and subduction-related magmatisms along the Median Tectonic Line are closely related to each other. At the same time, depocenters of the basins in western Axial Zone migrated northwards, as in the Kurosegawa Belt.

The Nakaminato Group is interpreted as the eastern elongated part of pull-apart basins along the Median Tectonic Line by having common characteristics with the Izumi Group which are turbidity lithofacies, weak consolidation and occurrence of *Didymoceras awajiense*..

Continental basin is characterized mainly by rifting condition. The continental condition of the Japanease Islands was well developed during the latest Late Jurassic to Early Cretaceous time, when the transform continental margin appeared (e. g. Tetori and Kanmon Basins).

Changing of these tectonic setting in Cretaceous Systems in Japan as follows; 1) Through Cretaceous in age, relatively small pull-apart basins occurred in various regions of Southwest Japan. 2) At Albian, pull-apart basins along Median Tectonic Line occurred and started to shift eastwards until Maastrichtian. 3) Subduction complex in Outer Zone of Southwest Japan occurred at Albian to Eocene. 4) At Aptian, the Yezo Arc-Trench System occurred and continued to deposit until Maastrichtian (Figure 39).

5. 2. Fossil faunas and sequence stratigraphies of eastern Japan

On the basis of the theories of Matsukawa and Obata (1993) and Iba and Sano (2007), the present study suggests the following geohistory of dealing with the study (Figure 40). In Hauterivian age, the Sanchu Cretaceous System began to deposit. The lowermost part of Sanchu Cretaceous system is interpreted as the lowstand systems tract (LST) which bears the Northern Tethys fauna and was influenced by marine currents from northward. In Barremian age, the Sanchu Cretaceous Systems shifted into highstand systems tracts (HST) and the Choshi Group began to deposit. In Barremian to Albian age, the Sanchu Cretaceous System and Choshi Group were gradually influenced by marine currents from southward. The fossils of the Sanchu Cretaceous System and Choshi Group shift from the Northern Tethyan to Tethyan fauna. The demise of the high-latitude type from the Sanchu Cretaceous System shows step-wise in several taxa. In Aptian to Albian age, the Miyako Group deposited and was influenced by marine currents from southward. The Miyako Group is mainly composed of HST which bears various fossils of the high-latitude type. In Coniacian age, the Futaba Group began to deposit. The lowermost part of the Futaba Group is composed of LST and transgressive systems tract (TST) which bears the Tetyan fauna. In Santonian age, the Futaba Group shifted into HST which bears the North Tethyan fauna. In Campanian to Maastrichtian age, the Nakaminato Group deposited with the eastern extension part of the Izumi Group. Pebbles in the Nakaminato Group had been derived from various Mesozoic accretionary complexes in western area of the Group.

6. Conclusions

(1) The Miyako Group is subdivided into the nine Facies and recognized the five fossil assemblages. The Futaba Group is subdivided into the ten Facies and the five fossil assemblages. The Nakaminato Group is subdivided into the six Facies. The Choshi Group is subdivided into the four Facies. The Sanchu Cretaceous System is subdivided into the 15 Facies.

(2) The mixed fauna is recognized from the following taxa; Bivalves and ammonoids from the Miyako Group, Bivalves from the Futaba Group, Bivalves from the Choshi Group, Bivalves and belemnites from the Sanchu Cretaceous System.

(3) Distributions of Cretaceous fossils in Japan are explained by combination of marine currents and step-wise demise from distribution of mixed fauna.

(4) The present study suggests the following geohistory of dealing with the study. In Hauterivian age, the Sanchu Cretaceous System began to deposit. The lowermost part of Sanchu Cretaceous system is interpreted as the lowstand systems tract (LST) which was influenced by marine currents from northward. In Barremian age, the Sanchu Cretaceous Systems shifted into highstand systems tracts (HST) and the Choshi Group began to deposit. In Barremian to Albian age, the Sanchu Cretaceous System and Choshi Group were gradually influenced by marine currents from southward. In Aptian to Albian age, the Miyako Group deposited and was influenced by marine currents from southward. The Miyako Group is mainly composed of HST. In Coniacian age, the Futaba Group began to deposit. The lowermost part of the Futaba Group is composed of LST and transgressive systems tract (TST). In Santonian age, the Futaba Group shifted into HST. In Campanian to Maastrichtian age, the Nakaminato Group deposited with the eastern extension part of the Izumi Group.

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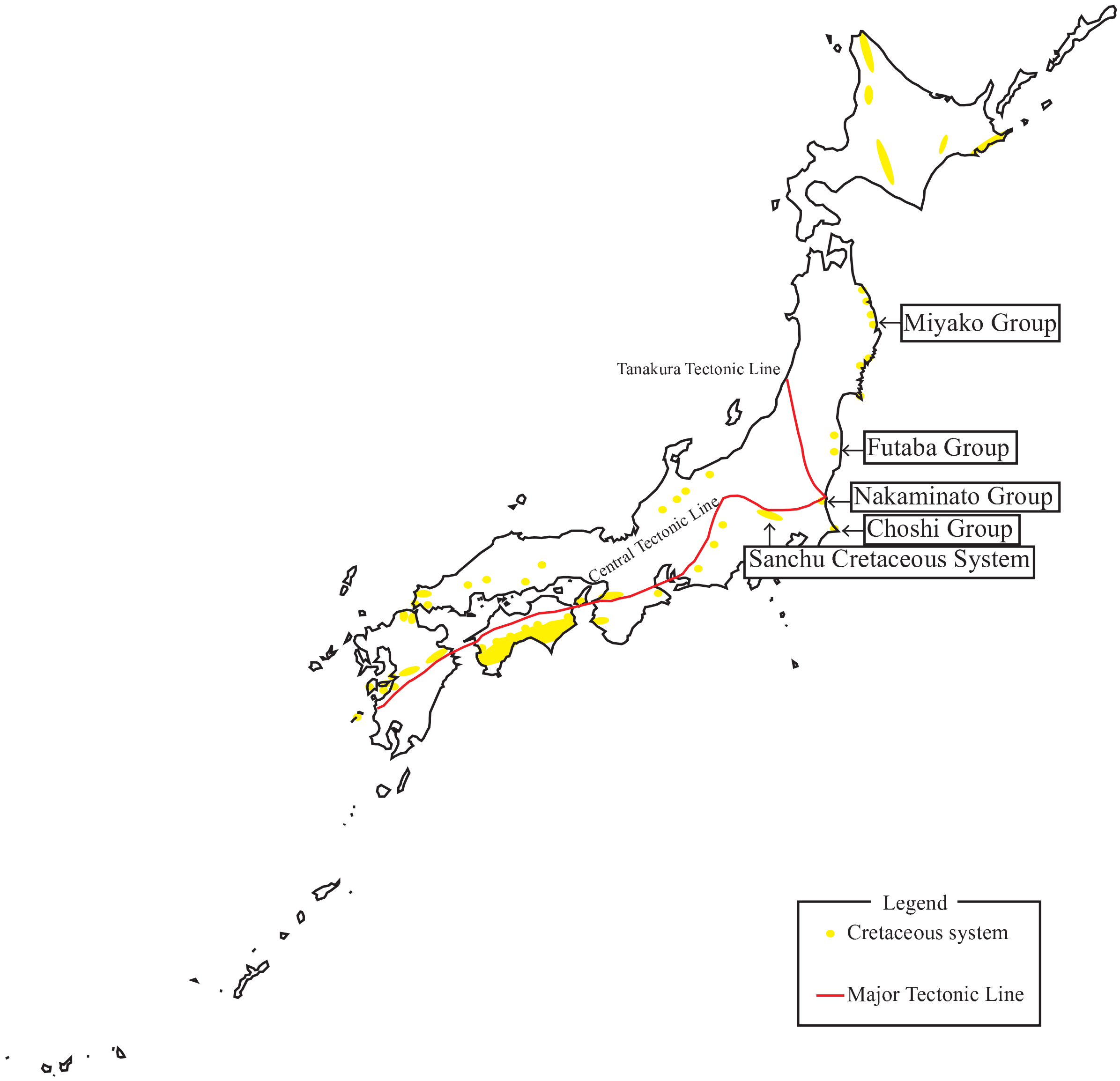


Figure 1. Distribution of shallow marine to terrestrial Cretaceous systems in Japan.

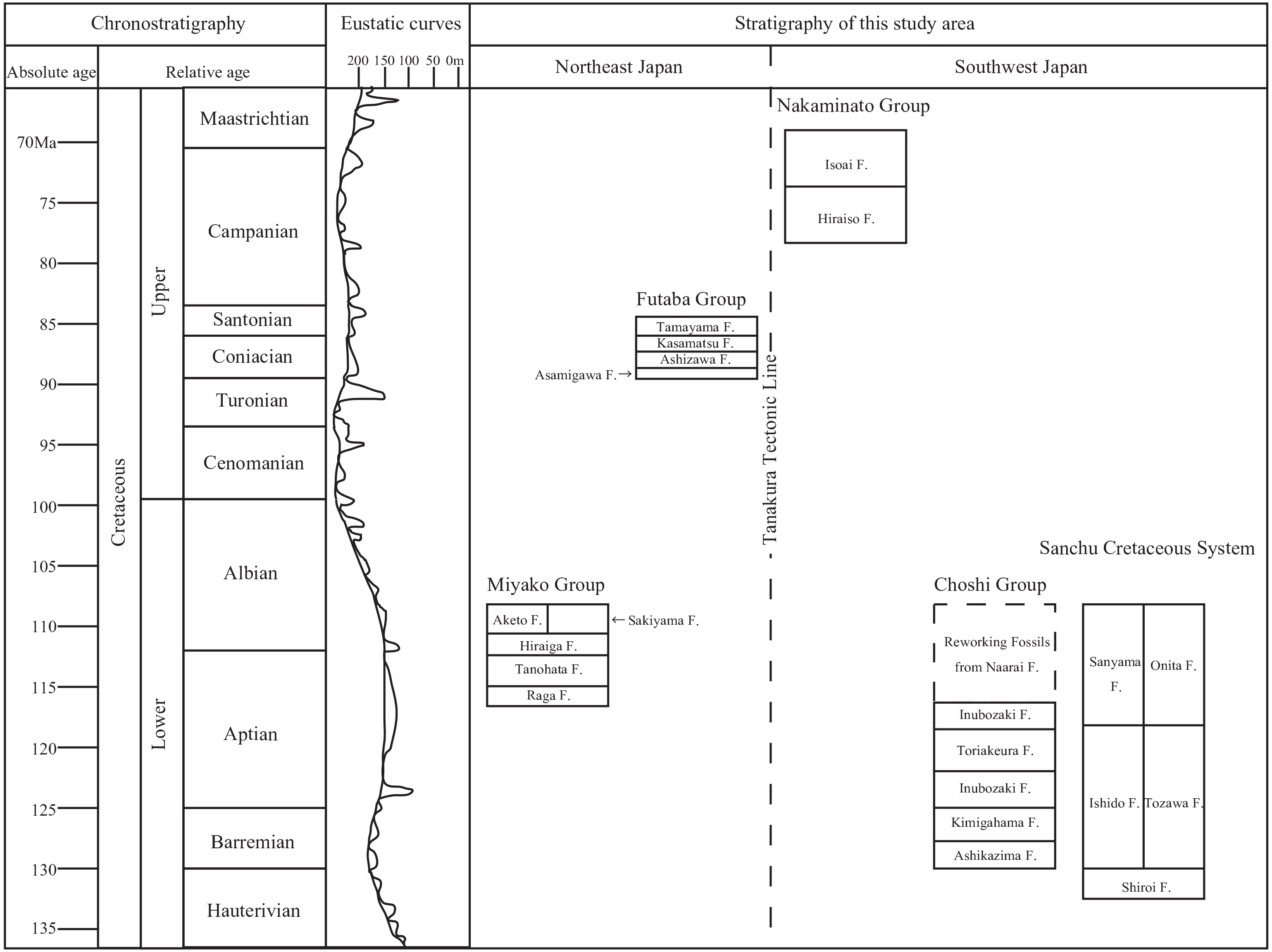


Figure 2. Stratigraphic correlation of Cretaceous systems in the present study.

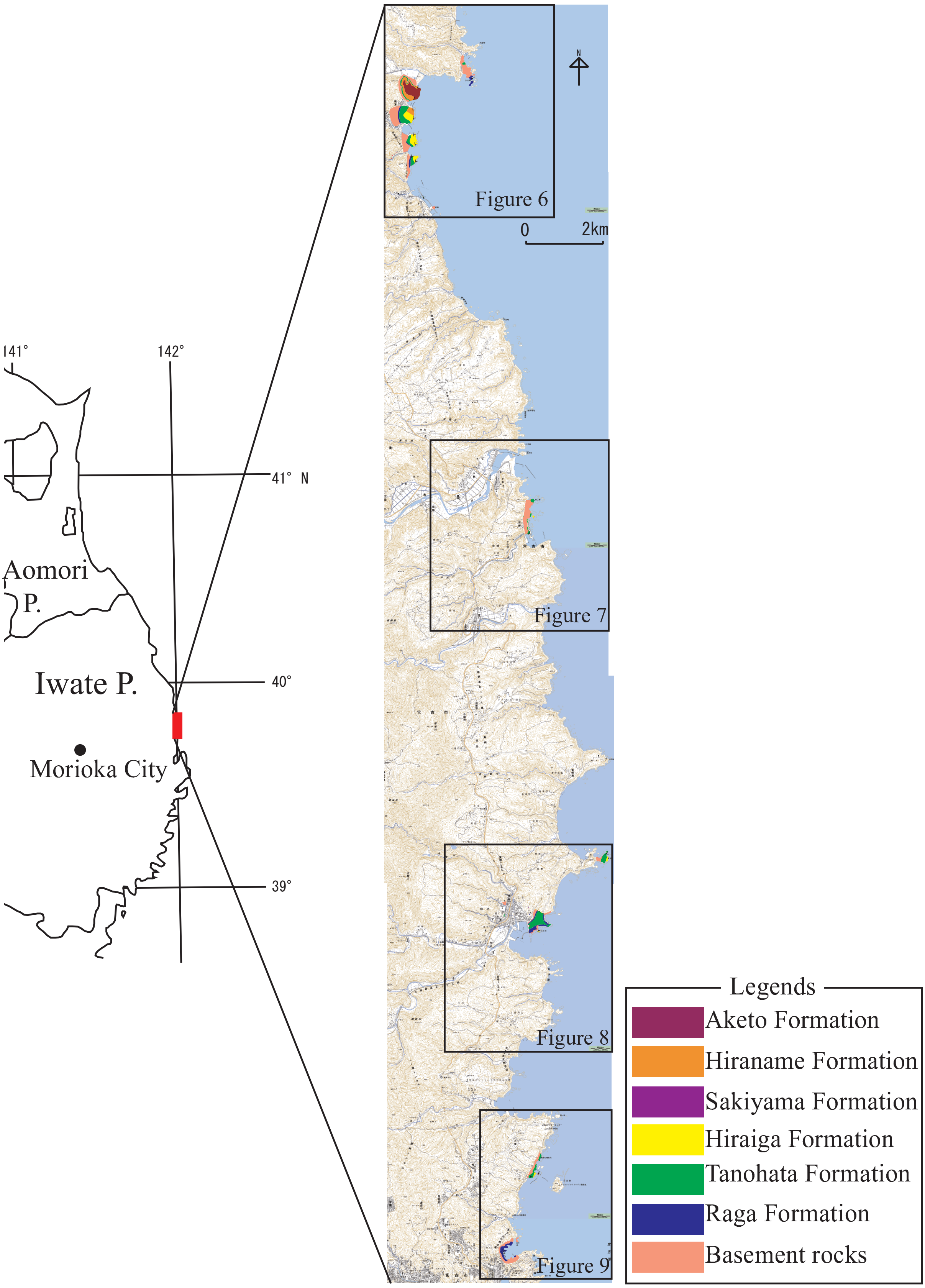


Figure 3. Geological map of the Miyako area.

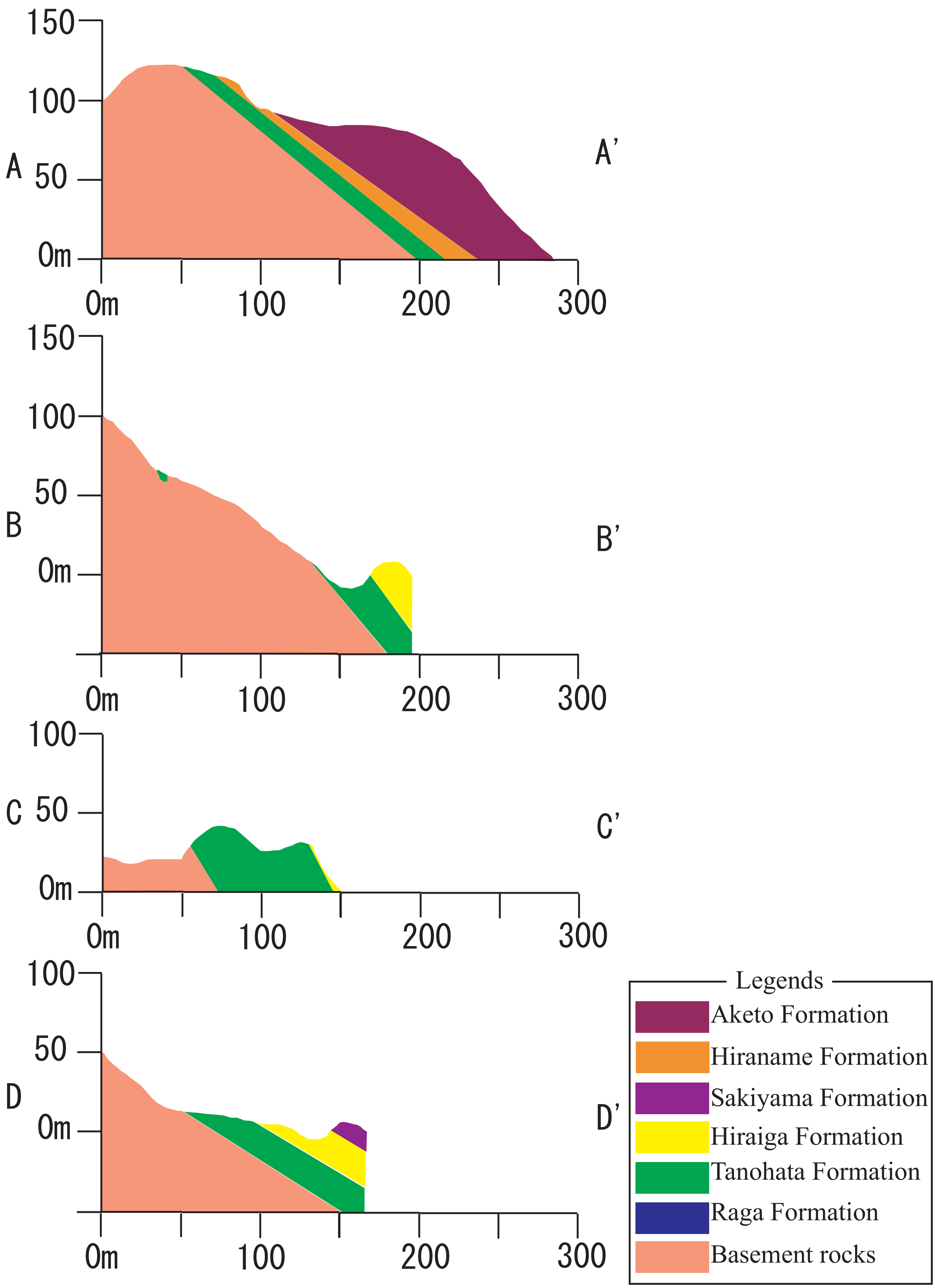


Figure 4. Geological cross-sections of Miyako area.

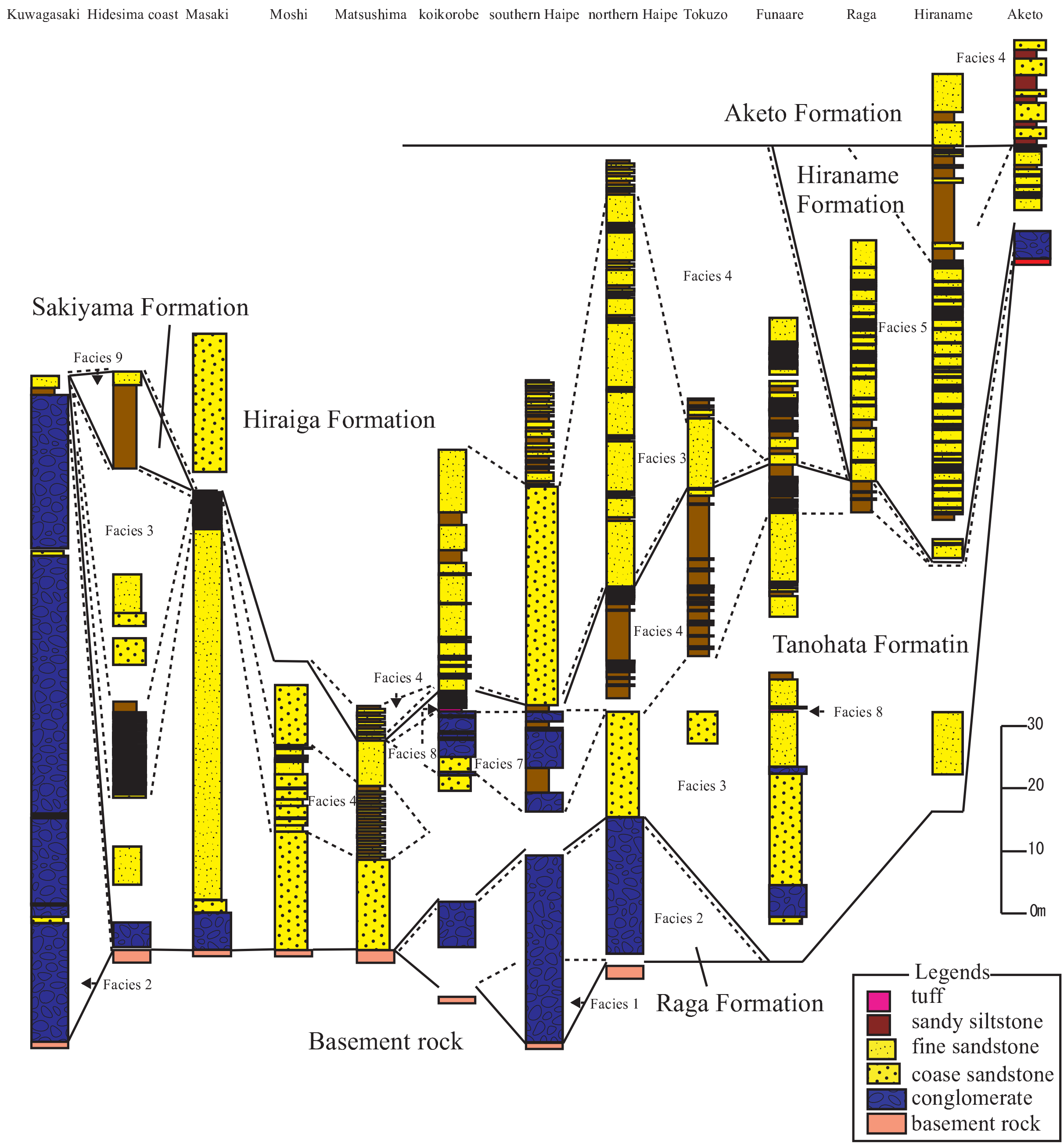


Figure 5. columar sections of the Miyako Group.

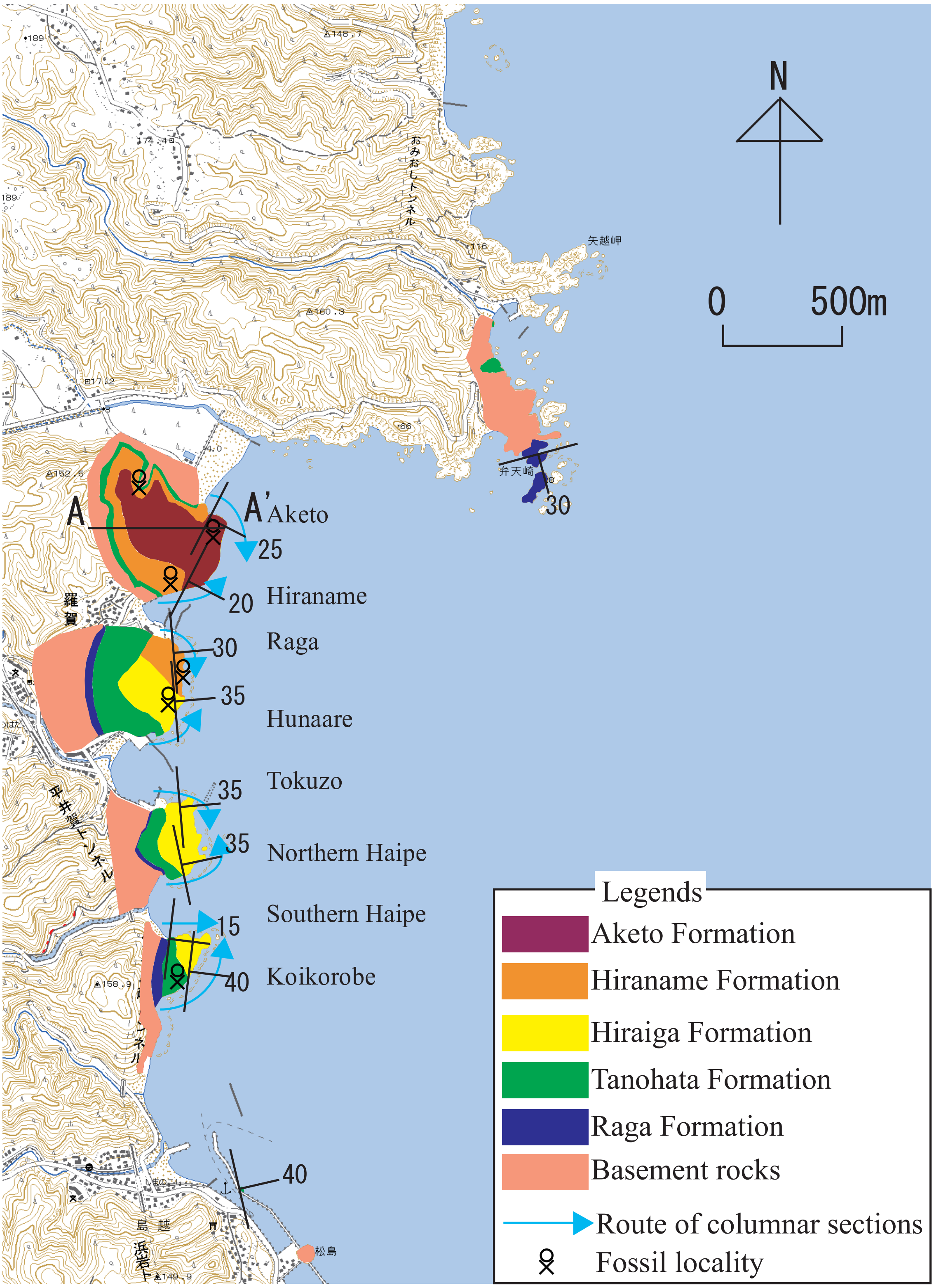


Figure 6. Geological map of Tanohata area.

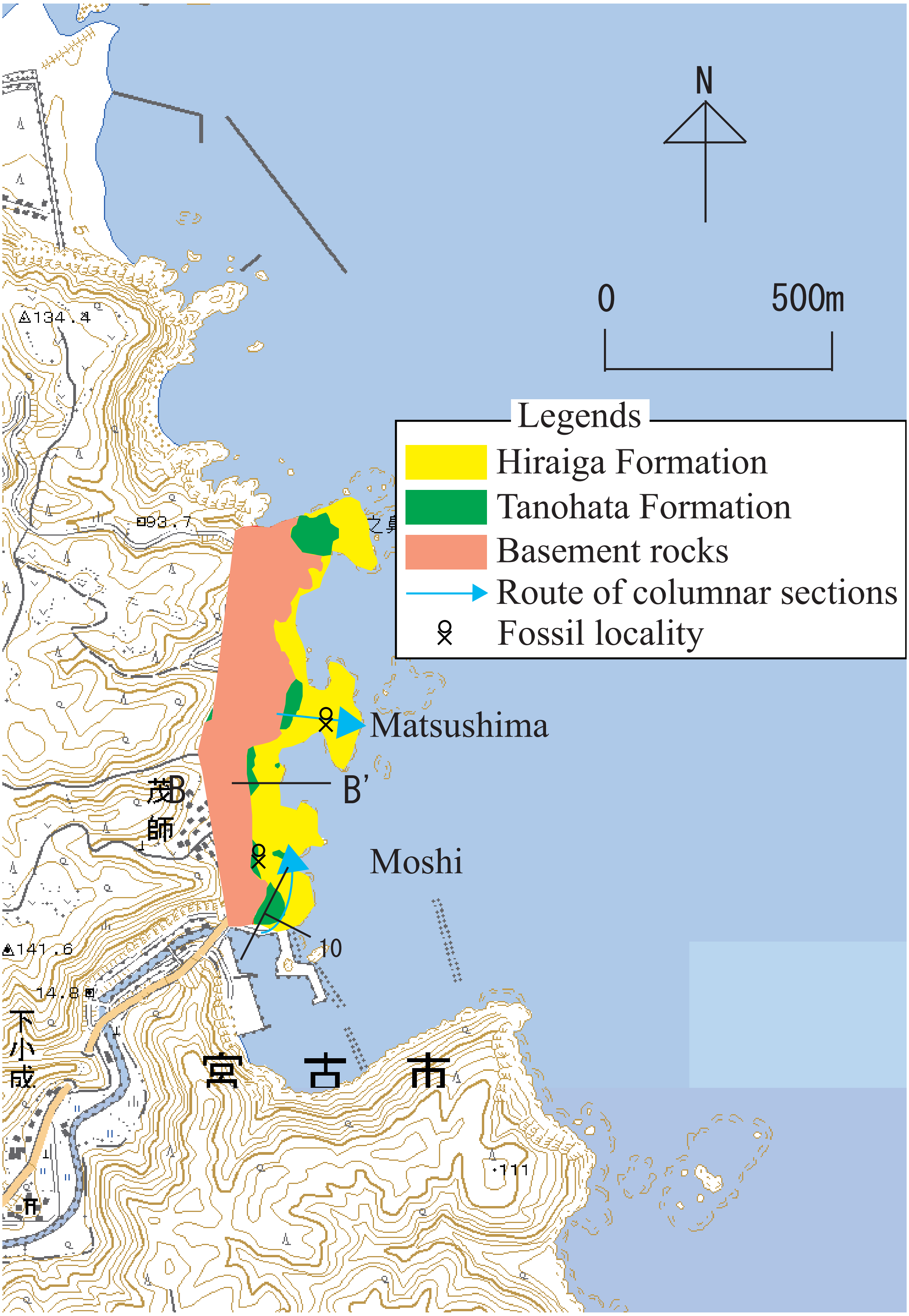


Figure 7. Geological map of Moshi area.

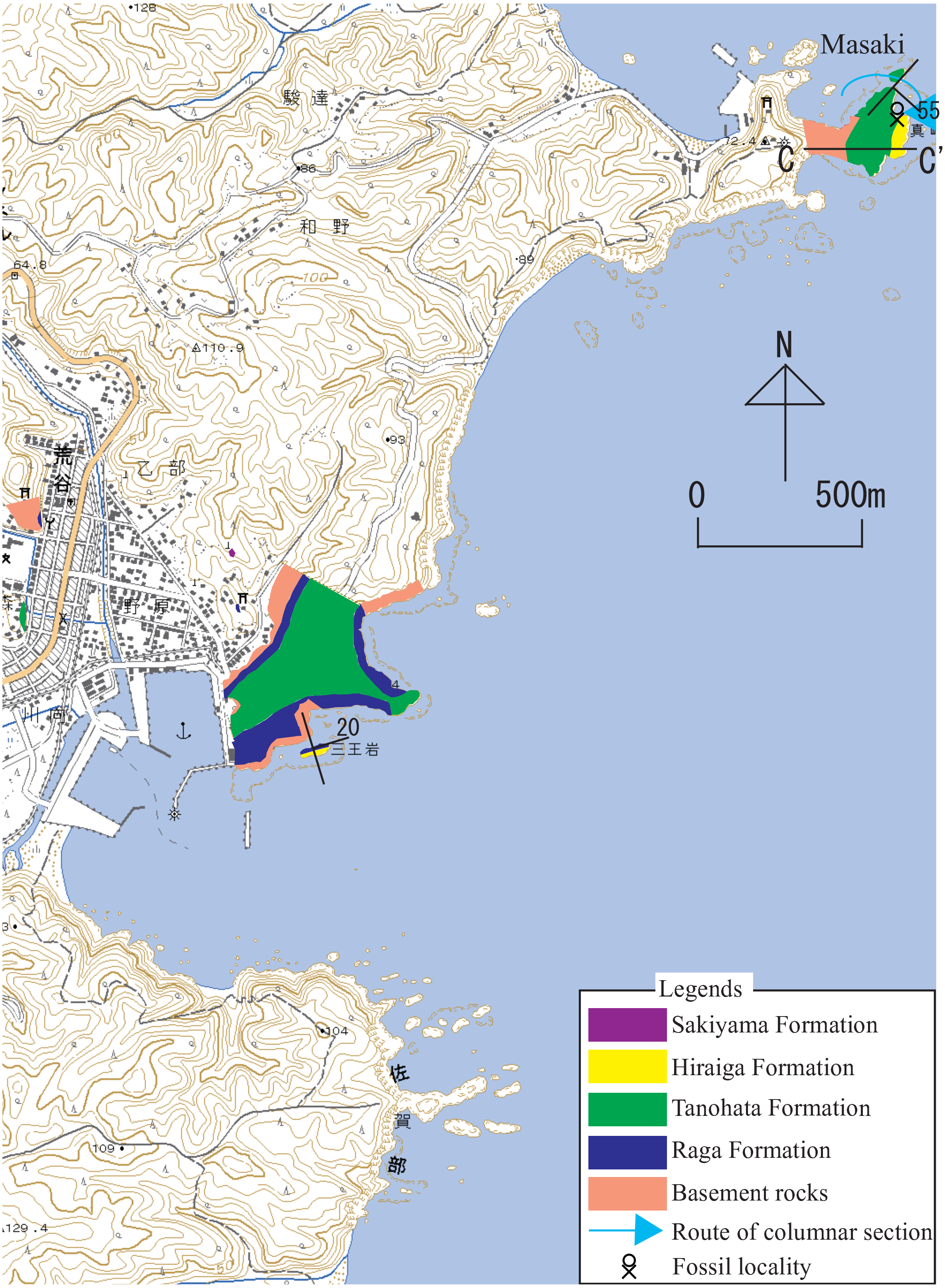


Figure 8. Geological map of Masaki to Taro area.

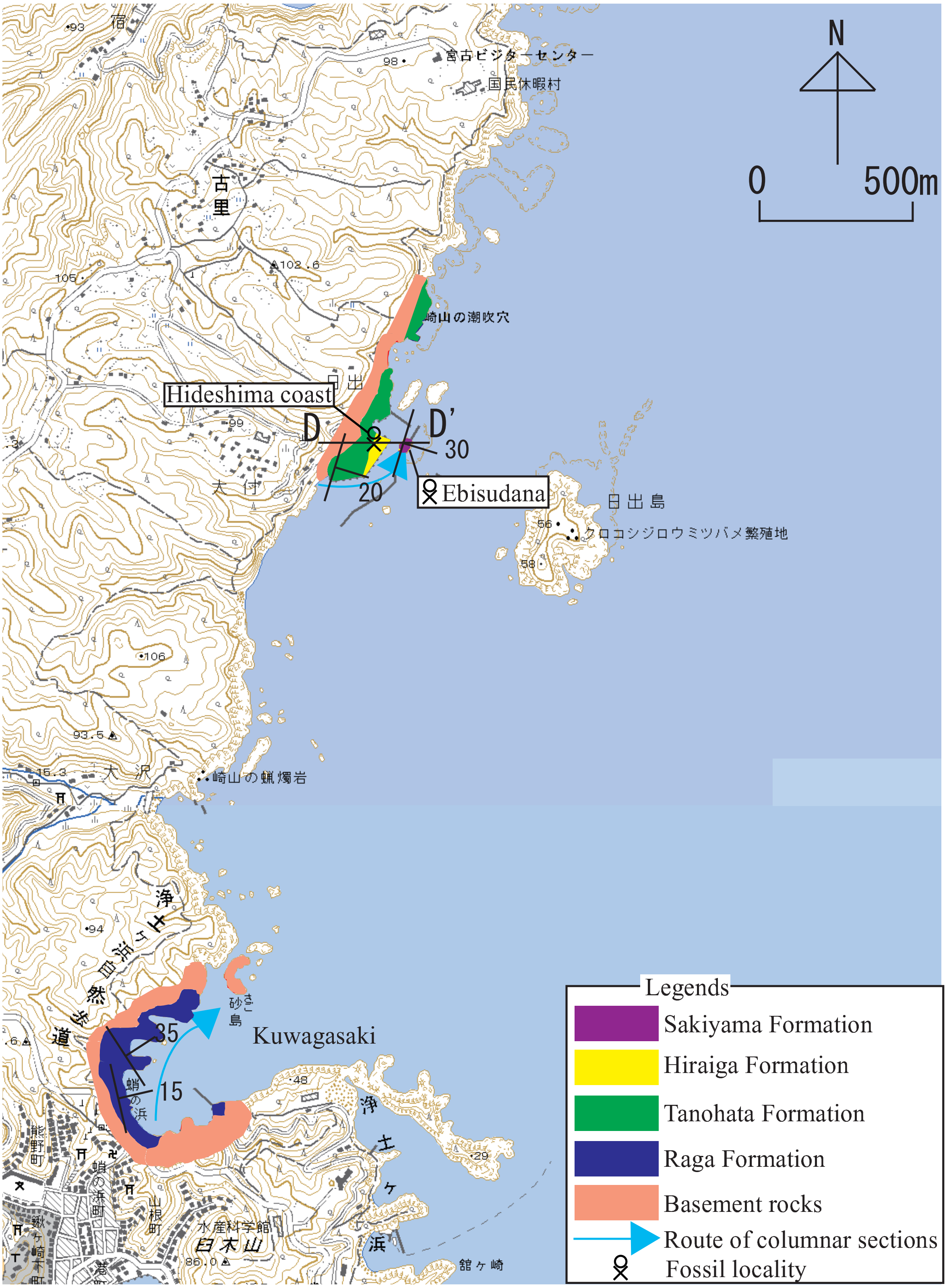


Figure 9. Geological map of Hinodeshima coast to Kuwagasaki area.

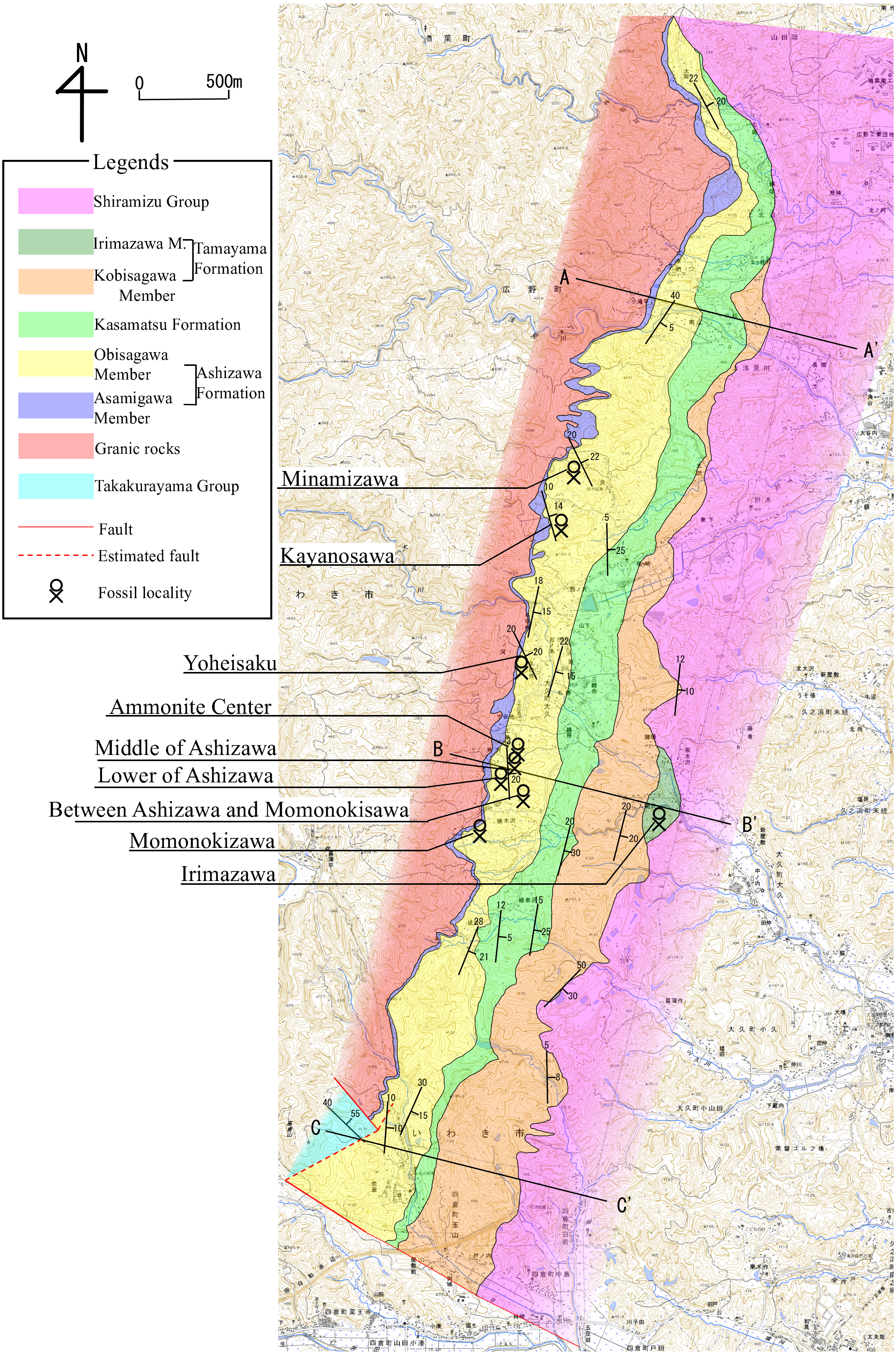


Figure 10. Geological map of the Futaba area.

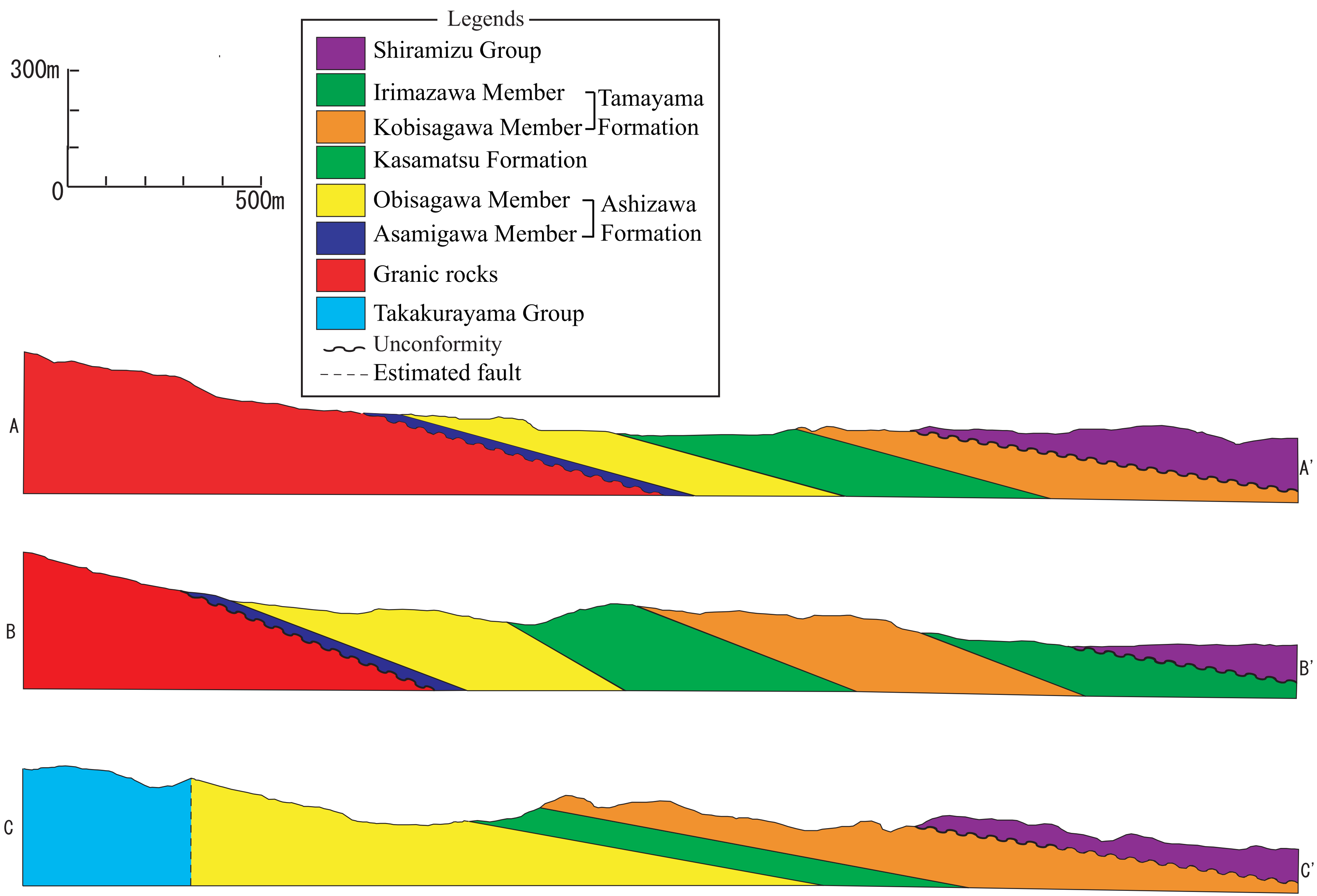


Figure 11. Geological cross-sections of Futaba Area.

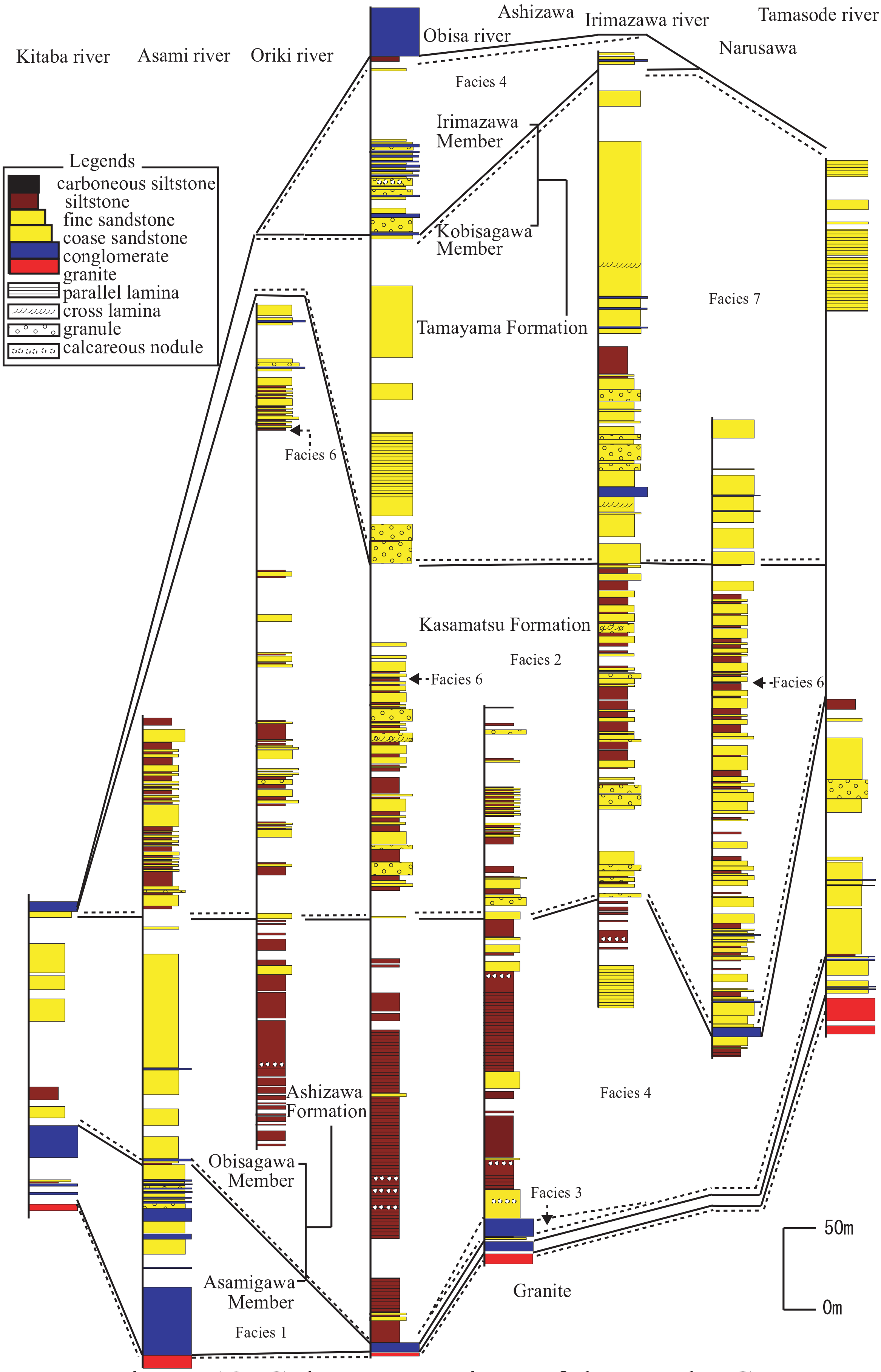


Figure 12. Columnar sections of the Futaba Group.

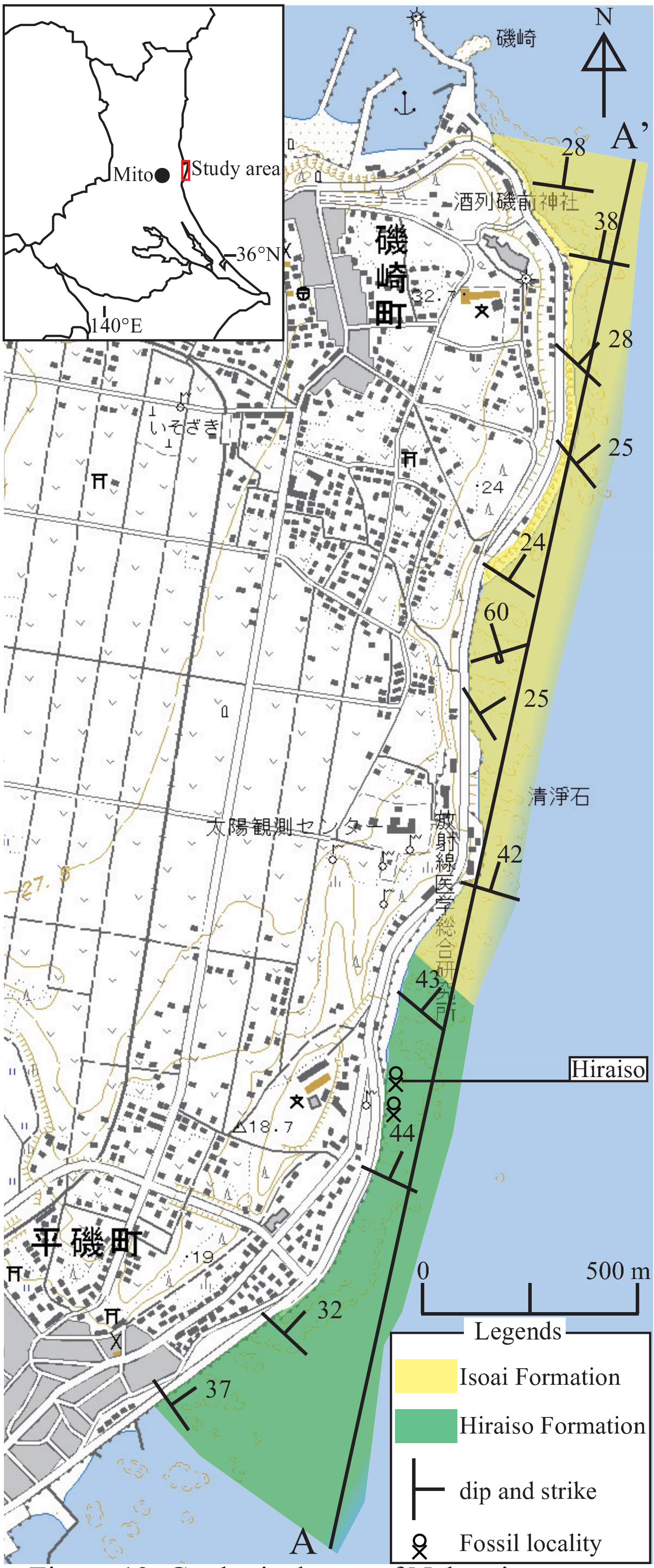


Figure 13. Geological map of Nakaminato area.

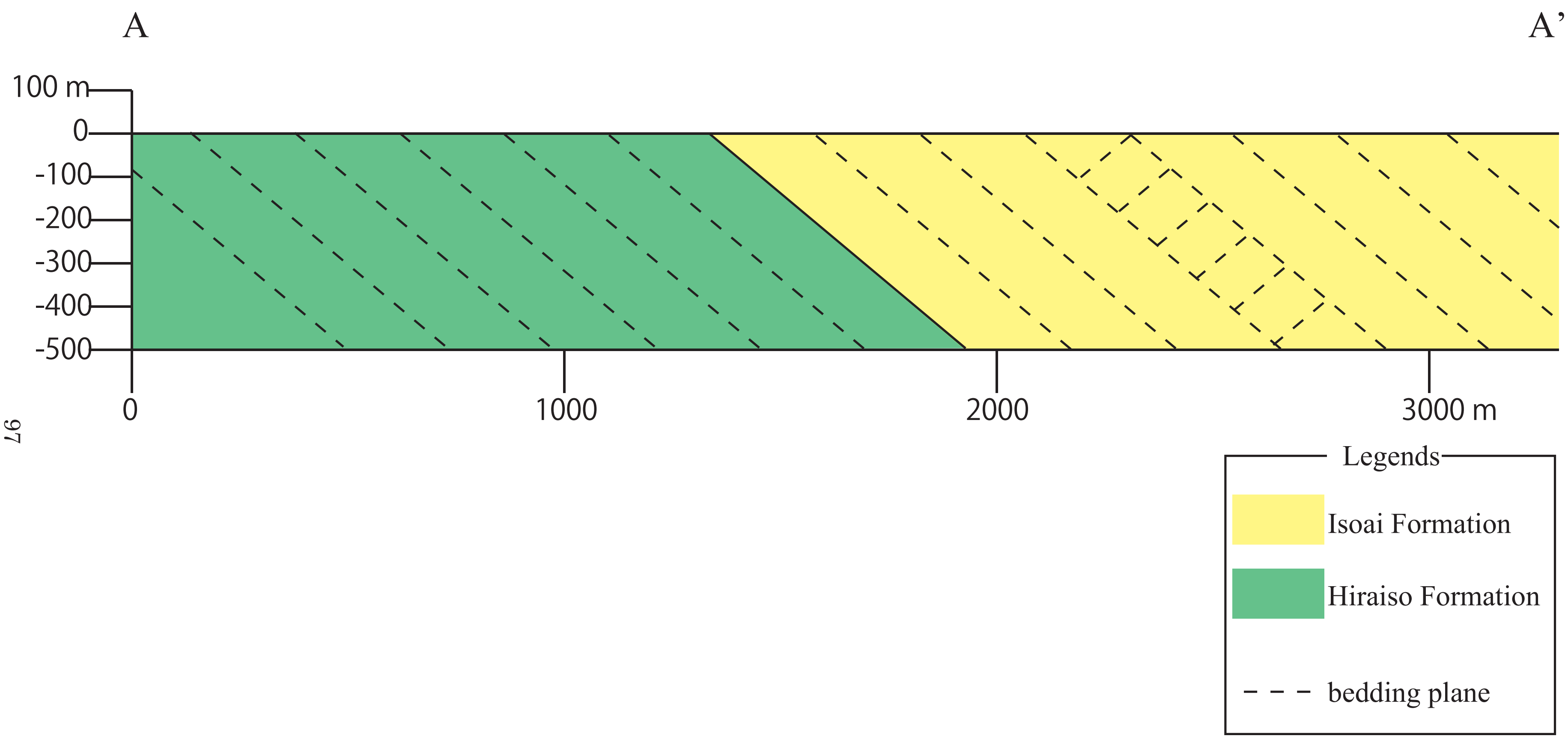


Figure 14. Geological cross-sections of Nakaminato Area.

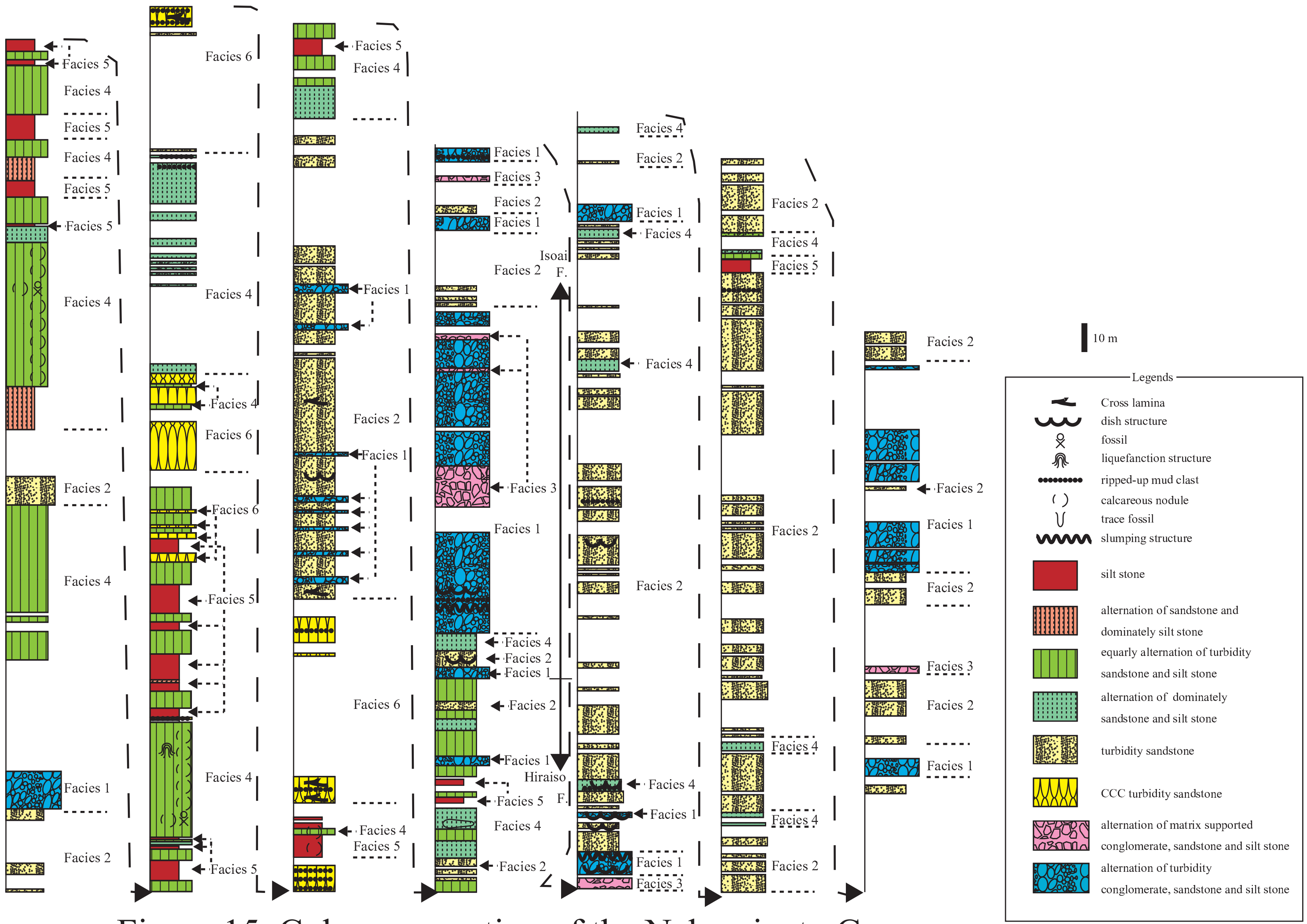


Figure 15. Columnar section of the Nakaminato Group.

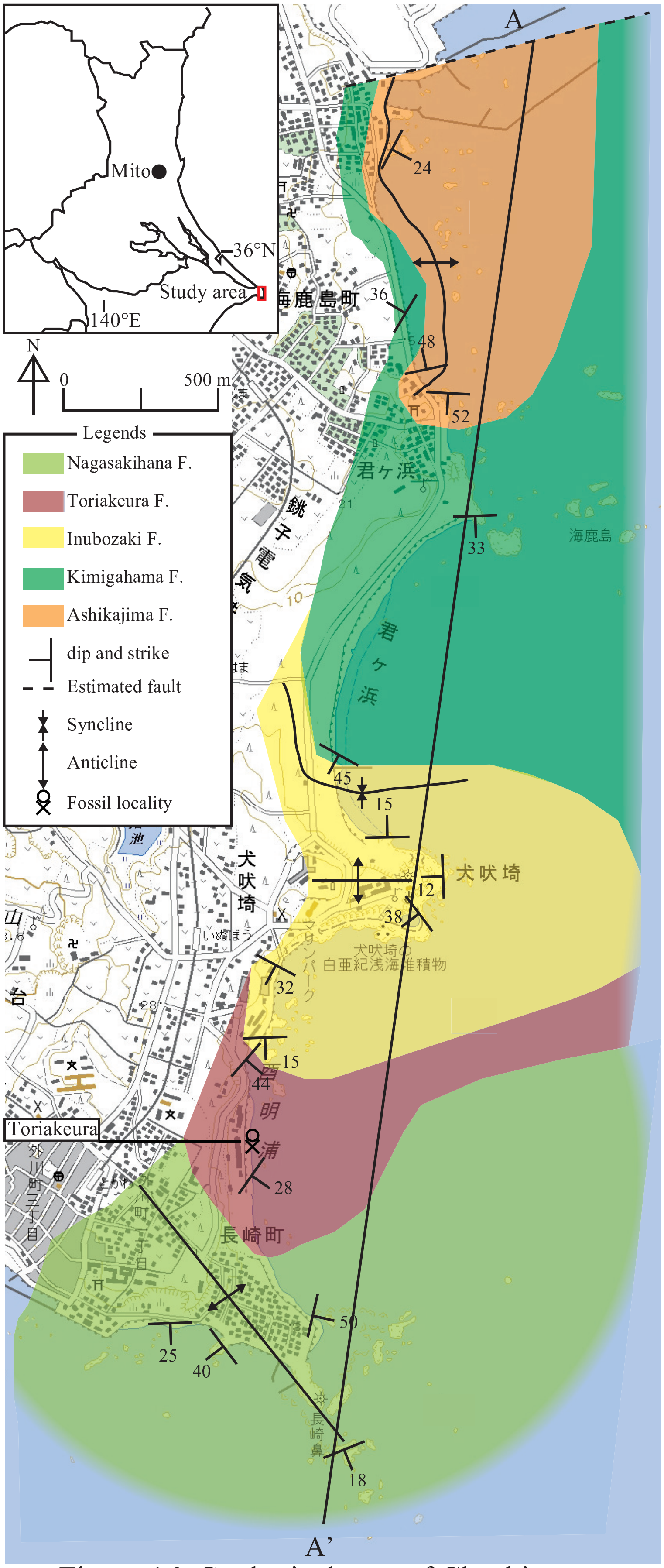


Figure 16. Geological map of Choshi area.

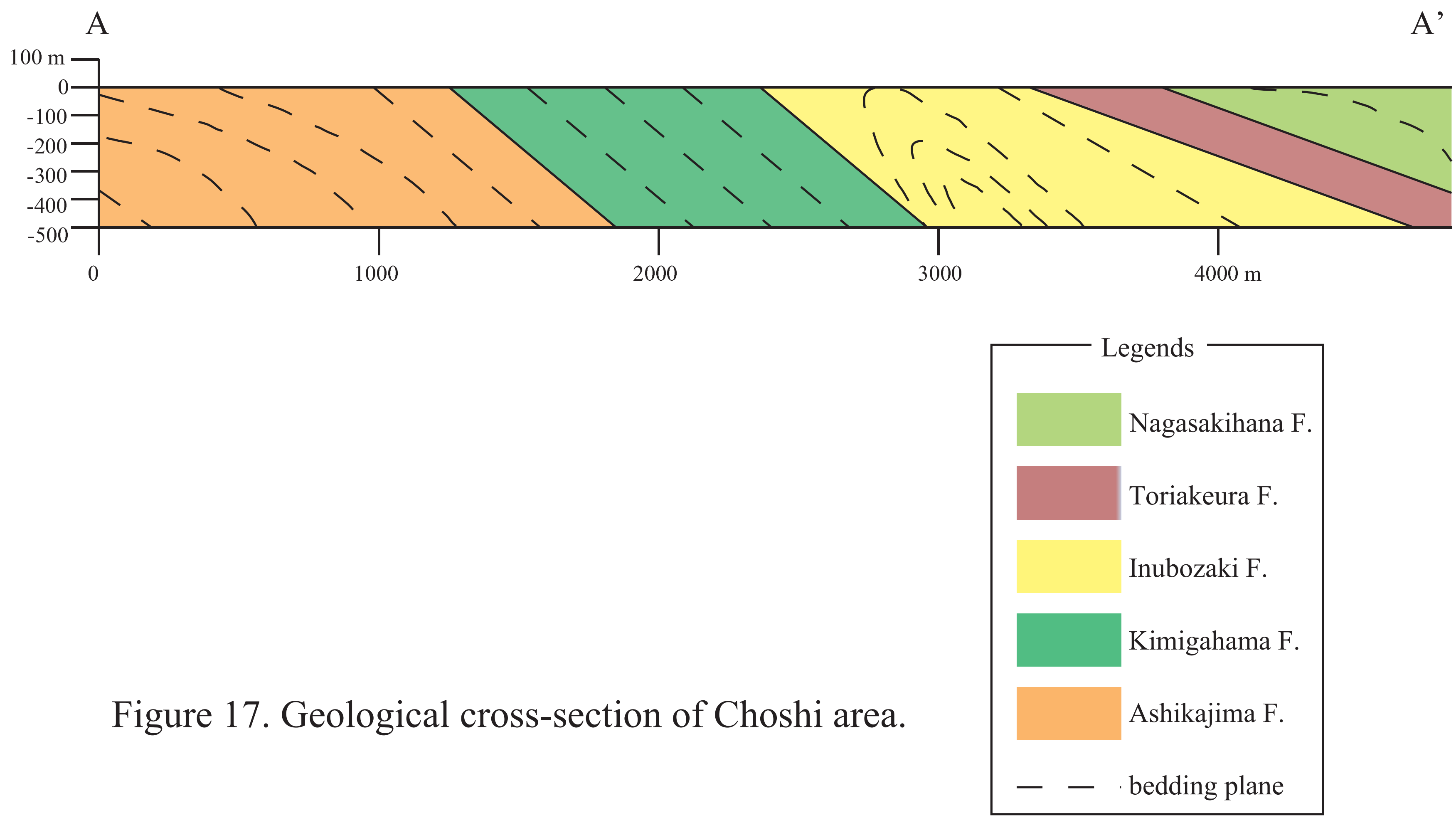


Figure 17. Geological cross-section of Choshi area.

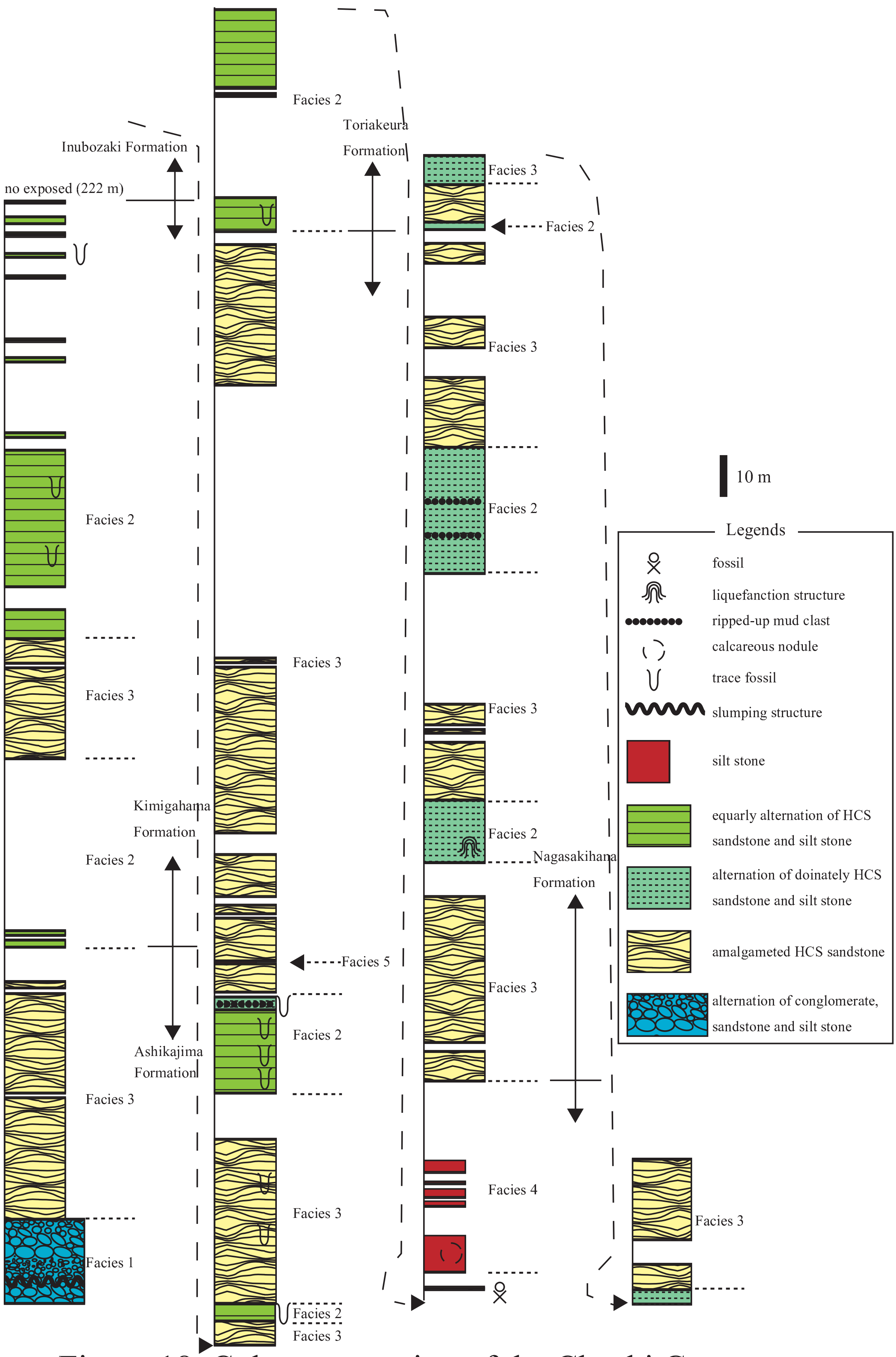


Figure 18. Columnar section of the Choshi Group.

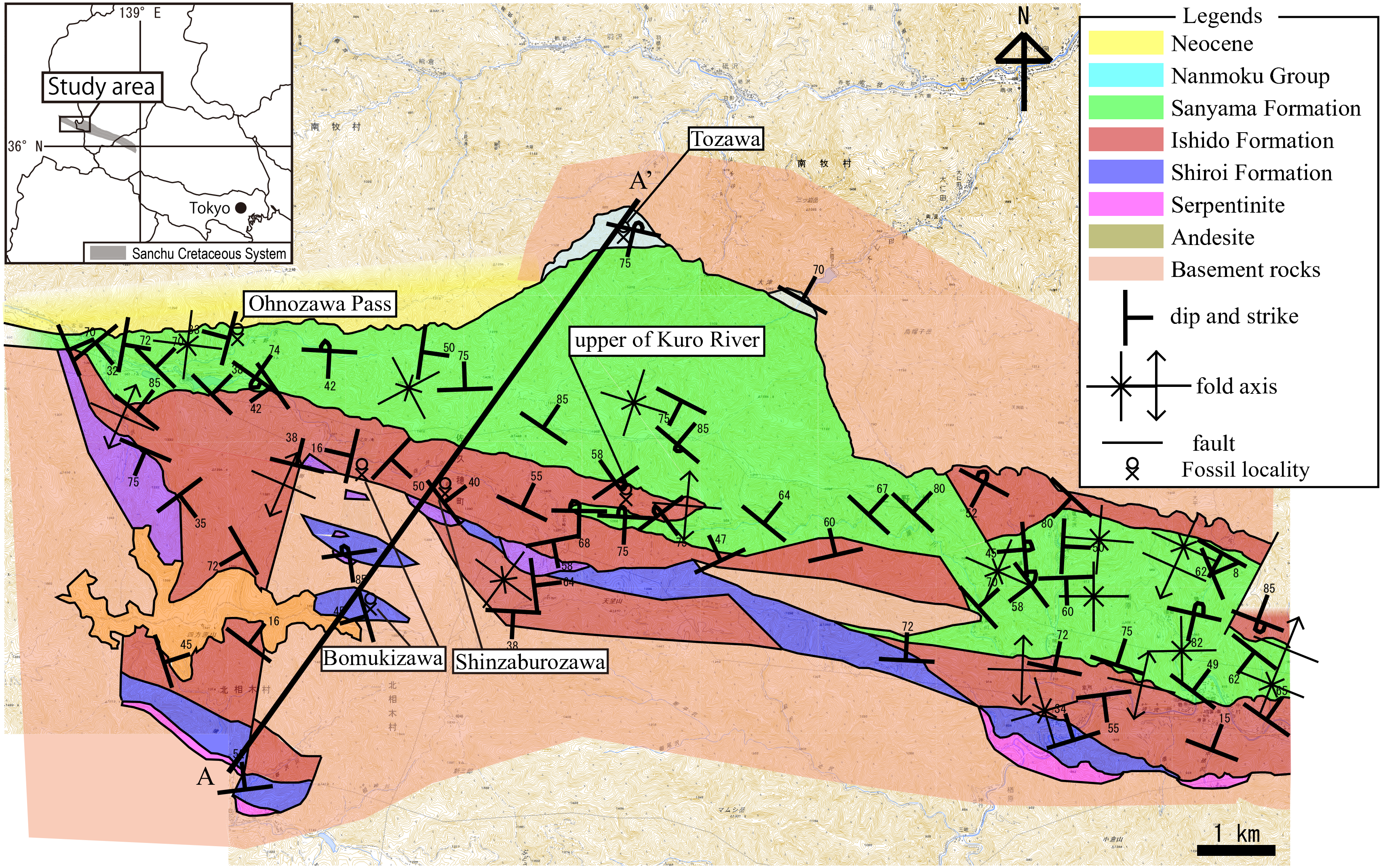


Figure 19. Geological map of northeastern Kanto Mountain area.

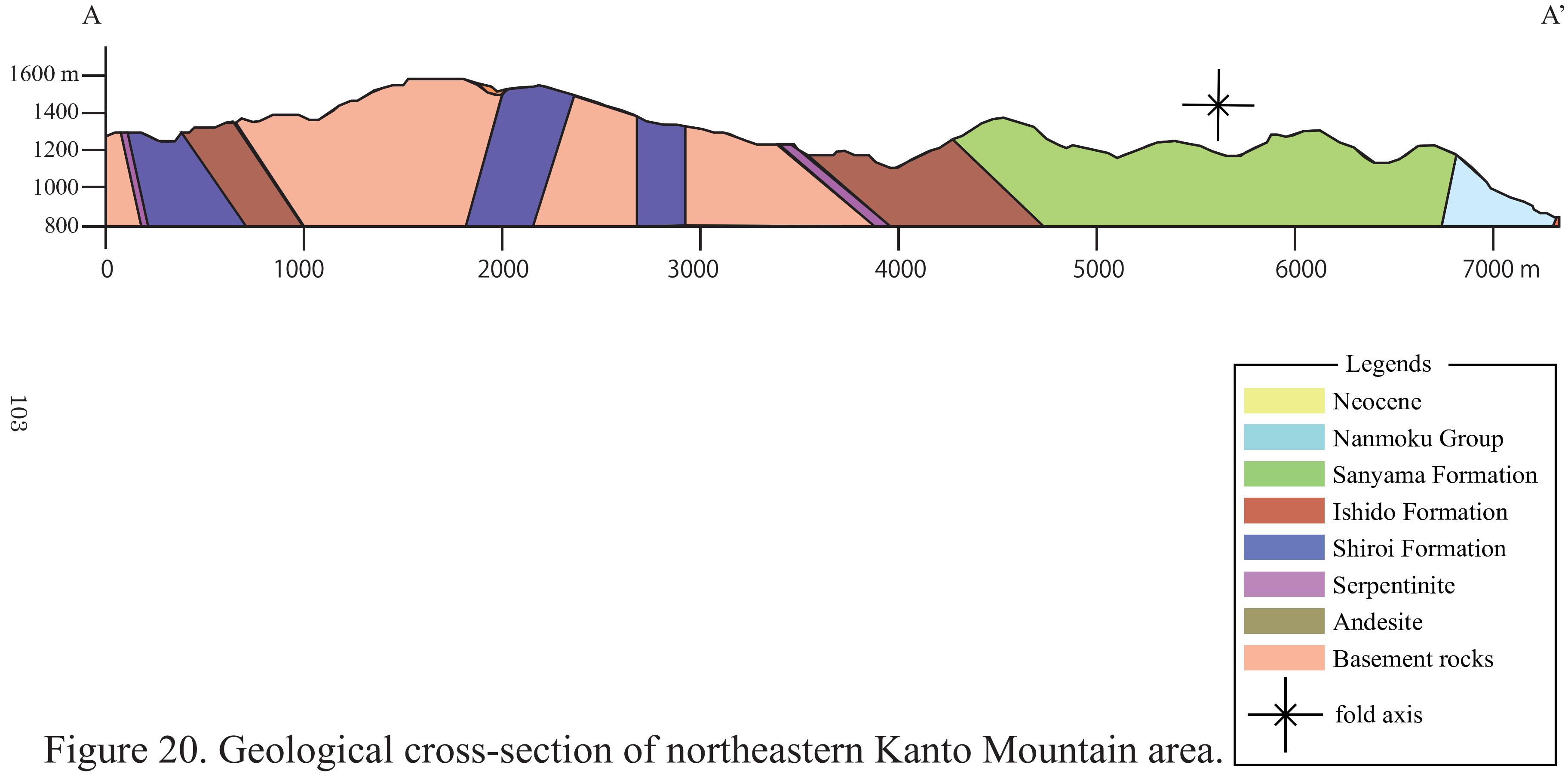


Figure 20. Geological cross-section of northeastern Kanto Mountain area.

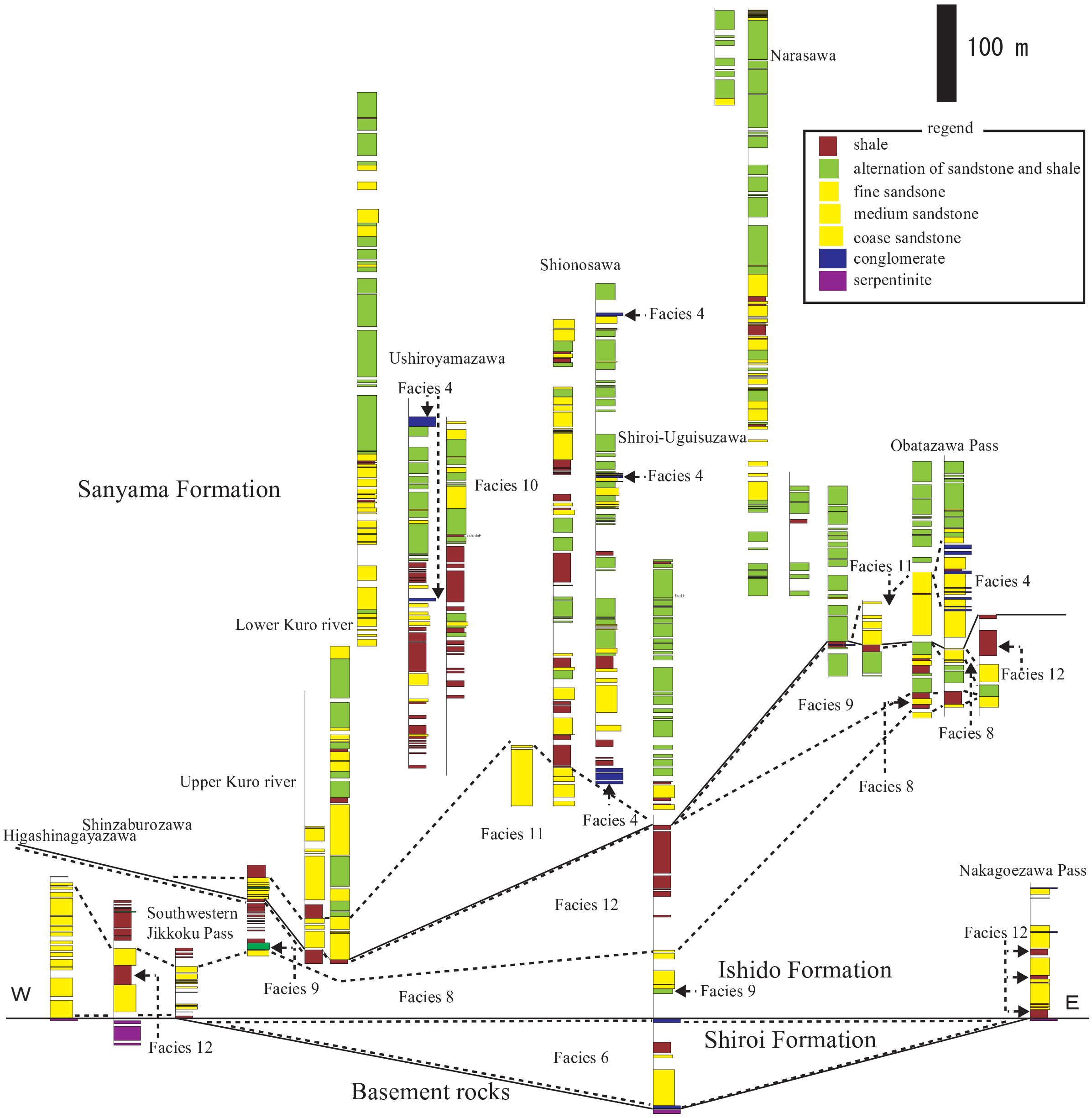


Figure 21. Columnar sections of the Sanchu Group.

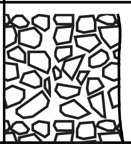
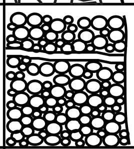
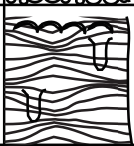
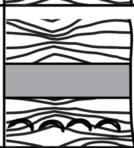
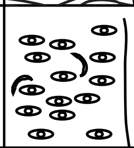
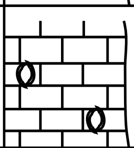
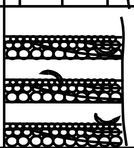
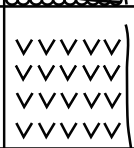
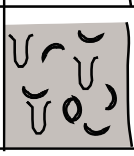
Facies	Column	Descriptions	Fossils	Environments
1		Poorly-sorted, angular to subangular, boulder to cobble, massive conglomerate; red silty sand matrix		Talus
2		Well-sorted, rounded to subrounded, boulder to pebble, massive conglomerate; containing imbrications with coase sandstone		Fan delta
3		Amalgamated, well-sorted, hummocky cross-stratificated fine to medium sandstone; containing disarticulated bivalves and trace fossils	Bivalves Ammonoids Gastropods etc.	Lower shoreface
4		Alternation of well-sorted, hummocky cross-stratificated fine to medium sandstone; containing disarticulated bivalves; and silt stone	Bivalves Ammonoids Gastropods etc.	Inner shelf
5		Well-sorted, medium to coase sandstone containing disarticulated bivalves and abundant *Orbitolina*	*Orbitolina* Bivalves etc.	Lower shoreface
6		Well-sorted, bioclasts-supported, massive limestone; containing build upped rudists	Bivalves Gastropods etc.	reef
7		Alternation of poorly-sorted, subrounded, boulder to pebble conglomerate; devided into sublayers which bear erosional base; and coase sandstone; containing disarticulated bivalves and corals	Corals Bivalves Gastropods etc.	Lower shoreface
8		Well-sorted, grayish white, fine tuff		
9		Very well-sorted, massive silt stone; containing dis- and articulated bivalves, trace fossils and plant remains	Ammonoids Bivalves Gastropods etc.	Inner to outer shelf

Figure 22. Sedimentary facies of the Miyako Group.

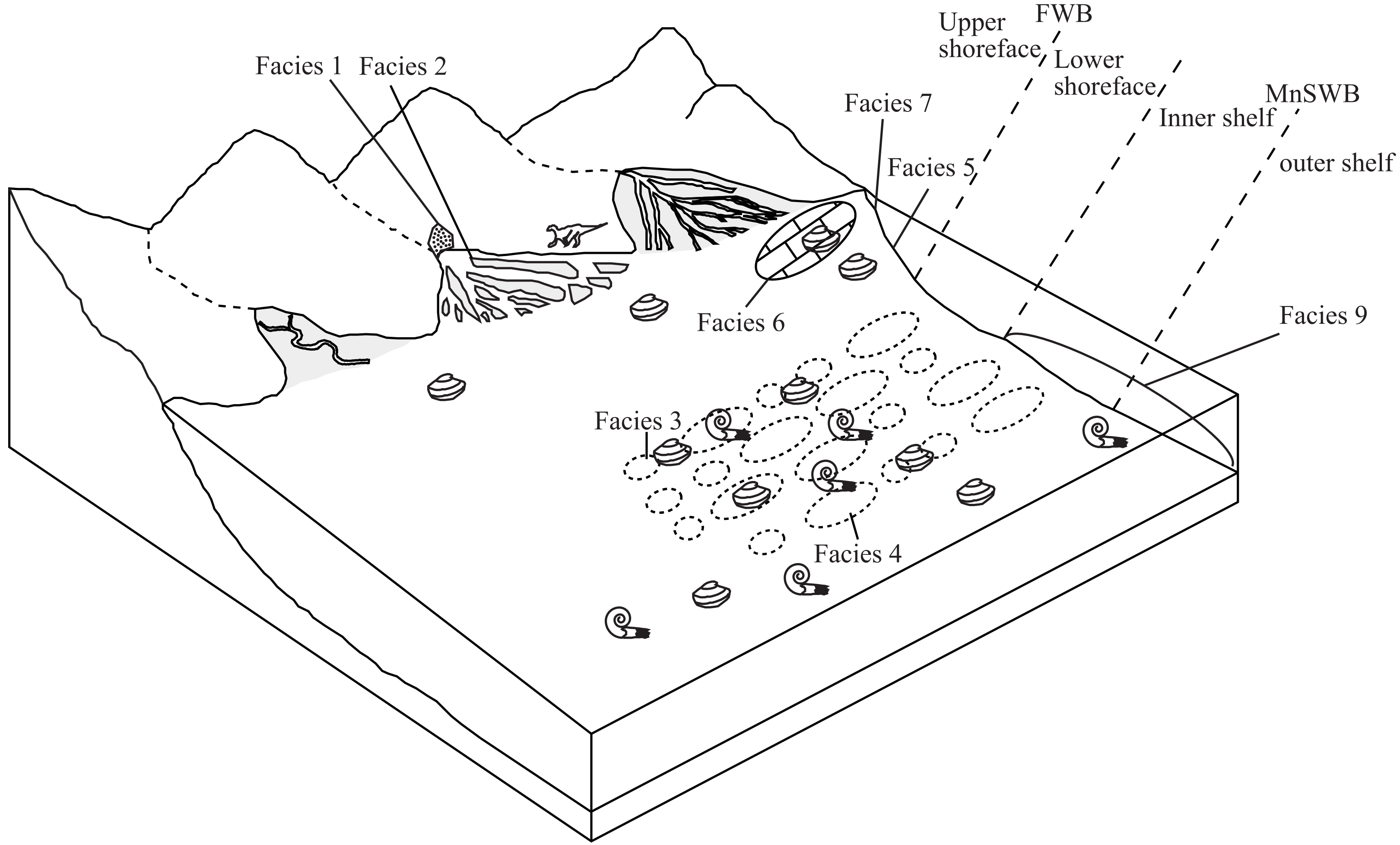


Figure 23. Schematic facies model for the Miyako Group.

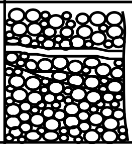
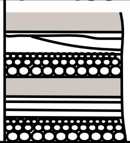
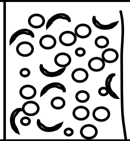
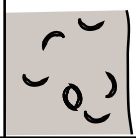
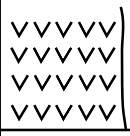
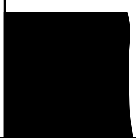
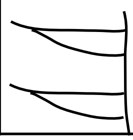
Facies	Column	Descriptions	Fossils	Environments
1		Well-sorted, rounded to subrounded, cobble to pebble, massive or trough cross-stratificated conglomerate with coase sandstone		Fan delta
2		Upward fining unit: alternation of conglomerate, sandstone and silt stone		Flood plain / leeve
3		Well-sorted, rounded to sub rounded, boulder to gravel, massive conglomerate; containing disarticulated bivelves	*Glycymeris amakusrnsis* *Apiotrigonia minor* *Loxo japonica* etc.	Upper shoreface
4		Well-sorted, massive silt stone; containing dis- and articulated bivalves	*Inoceramus uwajimensis* *Inoceramus* sp. etc.	Inner to outer shelf
5		Well-sorted, grayish white, fine tuff		
6		Well-sorted, carbonaceous, massive silt stone; containing amber	Amber	Flood plain
7		Well-sorted, medium to coase, trough cross-stratificated sandstone		Braided river

Figure 24. Sedimentary facies of the Futaba Group.

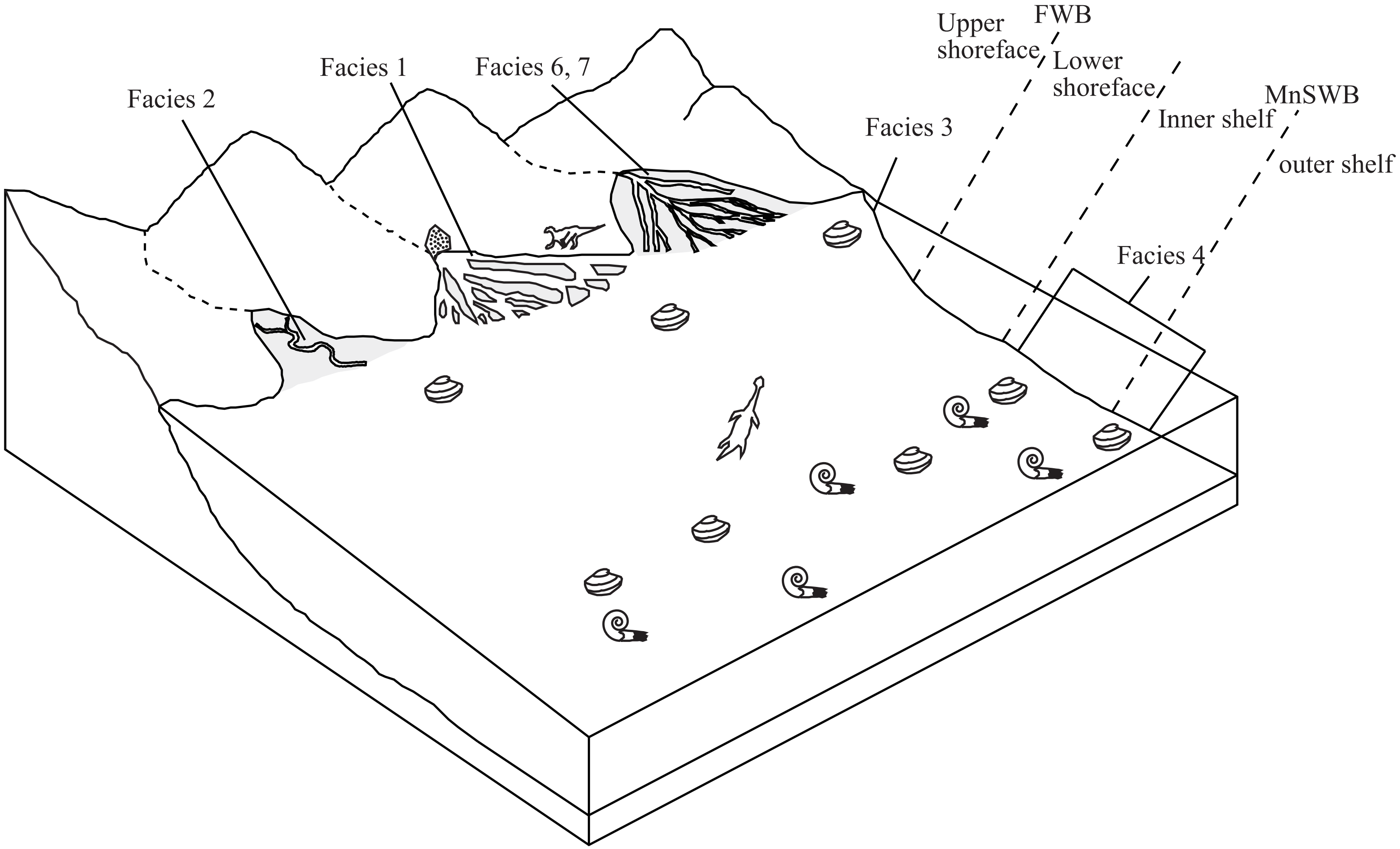


Figure 25. Schematic facies model for the Futaba Group.

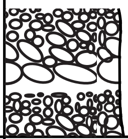
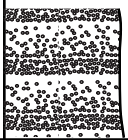
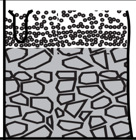
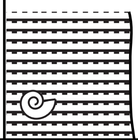
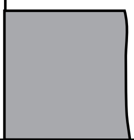
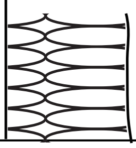
Facies	Column	Descriptions	Fossils	Environments
1		Turbidity alternation of clast-supported massive conglomerate, massive, parallel lamination and current-rippled sandstone and silt stone		channel in upper submarine fan
2		Well-sorted, turbidity medium to fine sandstone; containing dish structure and erosional base		channel in upper to middle submarine fan
3		Alternation of matrix-supported massive conglomerate, massive, parallel lamination and current-rippled turbidity sandstone; containing trace fossils; and silt stone		channel in upper submarine fan
4		Alternation of fine sandstone; containing cross-stratification; and silt stone; containing ammonoids	*Didymoceras awajiense* Notoceratidae gen. et sp. indet.	Leeve in lower submarine fan
5		Well-sorted massive silt stone		Basin-plain in lower submarine fan
6		Well-sorted medium to fine CCC turbidity sandstone; containing large cross-stratification rippled-up mud clasts		Leeved channel in lower submarine fan

Figure 26. Sedimentary facies of the Nakaminato Group.

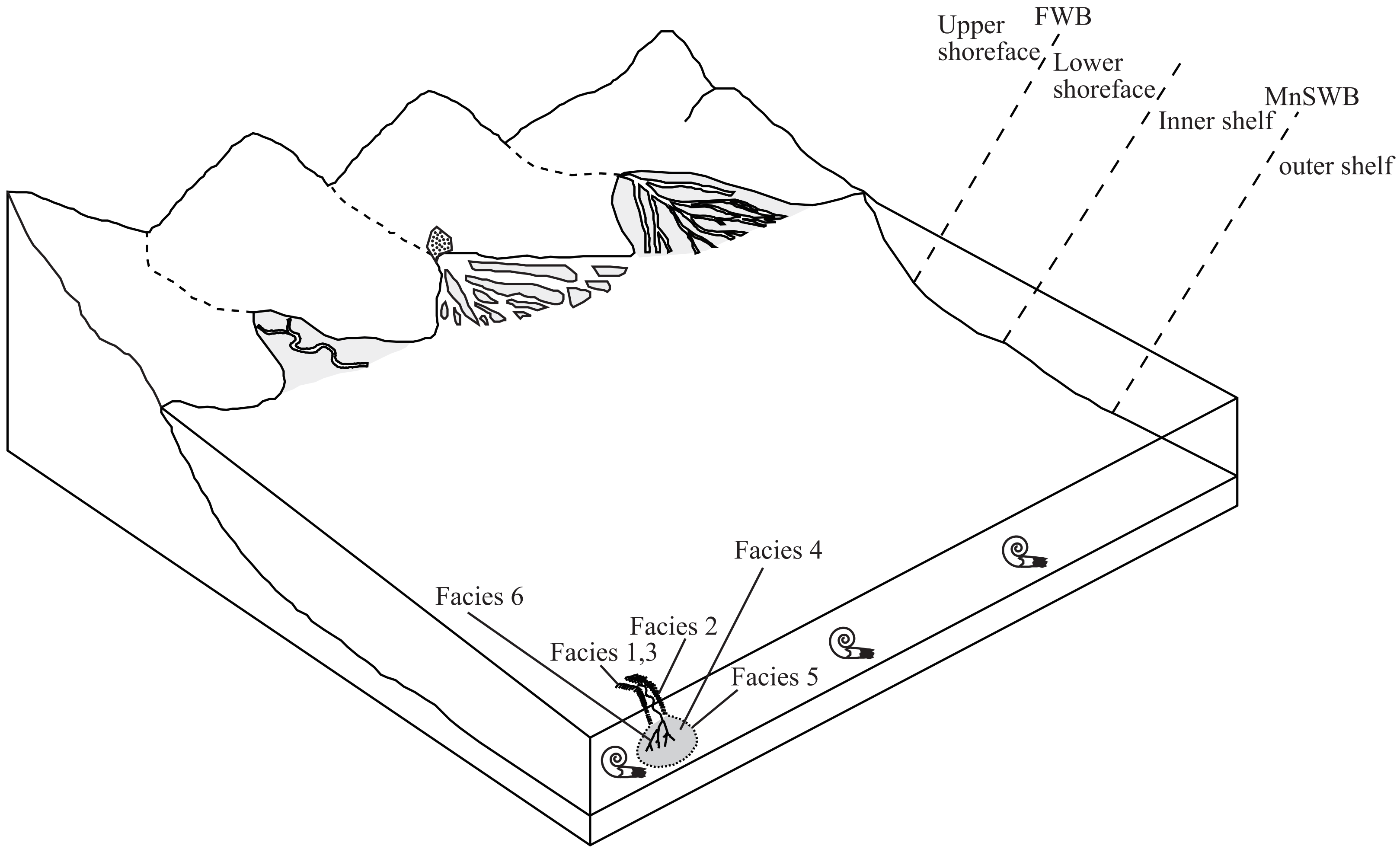


Figure 27. Schematic facies model for the Nakaminato Group.

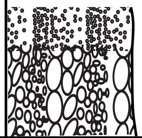
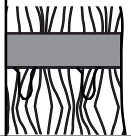
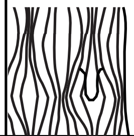
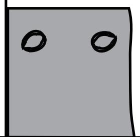
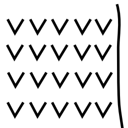
Facies	Column	Descriptions	Fossils	Environments
1		Alternation of clast-supported massive conglomerate; containing slumping structures, imbrications and trough cross-stratifications; massive sandstone and silt stone		Upper shoreface
2		Alternation of well-sorted, hummocky cross-stratificated fine to medium sandstone; containing trace fossils; and silt stone		Inner shelf
3		Amalgamated, well-sorted, hummocky cross-stratificated fine to medium sandstone; containing trace fossils		Lower shoreface
4		Well-sorted, massive silt stone; containing articulated bivalves	*Portlandia sanchuensis*	Outer shelf
5		Well-sorted, grayish white, fine tuff		

Figure 28. Sedimentary facies of the Choshi Group.

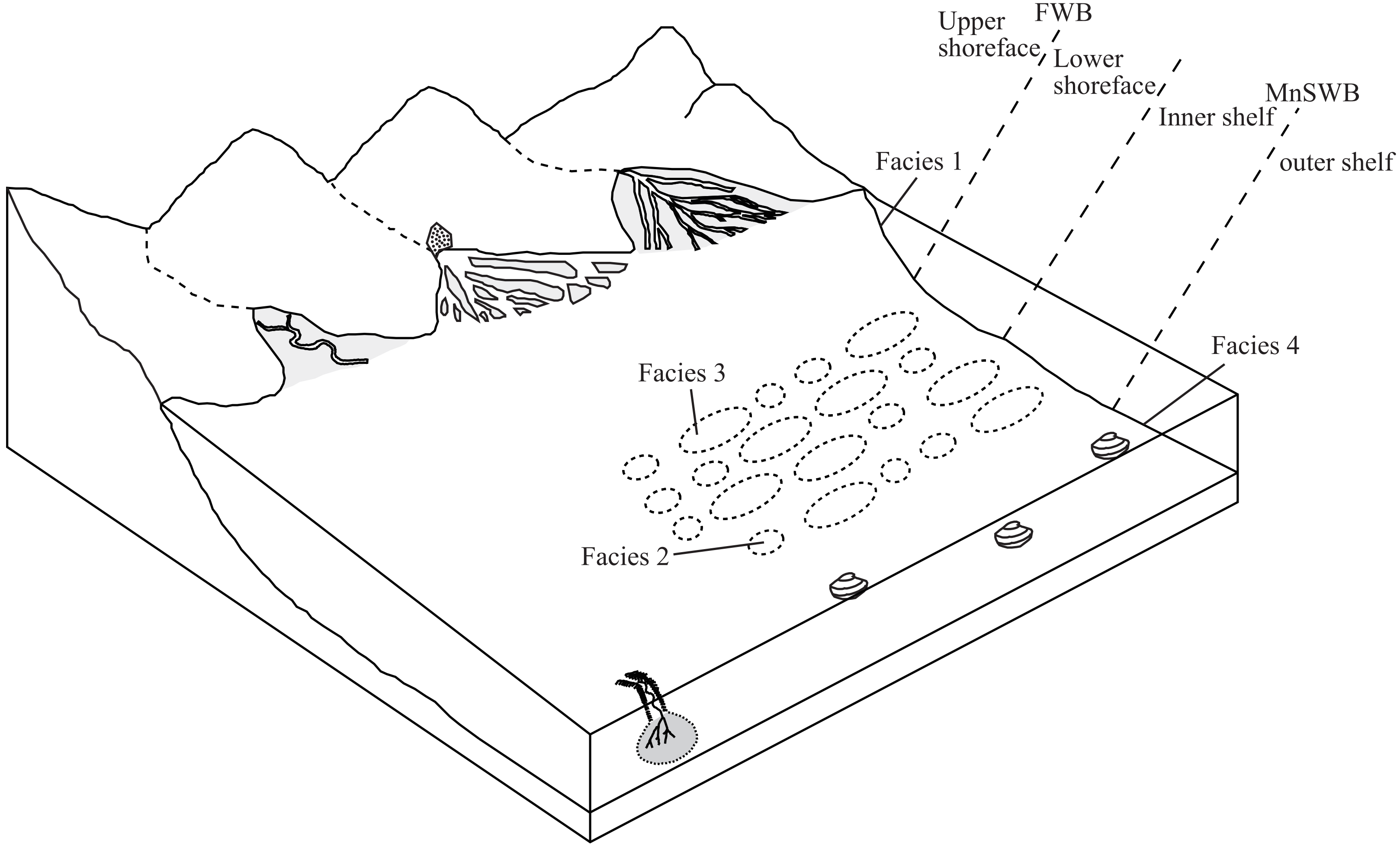


Figure 29. Schematic facies model for the Choshi Group.

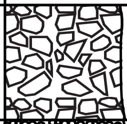
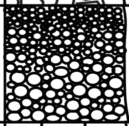
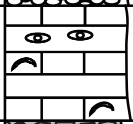
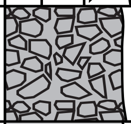
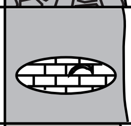
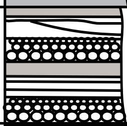
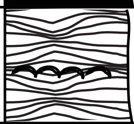
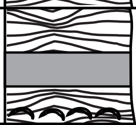
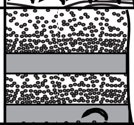
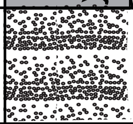
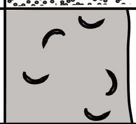
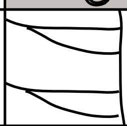
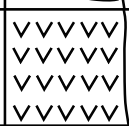
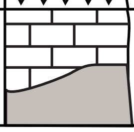
Facies	Column	Descriptions	Fossils	Environments
1		Poorly-sorted, angular to subangular, boulder to pebble, massive conglomerate		Talus
2		Well-sorted, rounded to subrounded, pebble to granule, massive conglomerate; containing imbrications, trough cross-stratifications and upward-fining		Fan delta
3		Alternation of medium to fine sandstone and sandy limestone; containing chert clasts, peloids, corals and disarticulated bivalves	Corals Bivalves etc.	reef
4		Poorly-sorted, subrounded to rounded, pebble, matrix-supported conglomerate; containing erosional base and slumping structure		channel in upper submarine fan
5		Bioclast-supported limestone block; containing oncoids, corals, disarticulated bivalves and microfossils	Corals Bivalves Foraminifers etc.	reef
6		Upward fining unit: alternation of conglomerate, sandstone and shale containing disarticulated bivalves	Bivalves Gastropods	Flood plain / leeve
7		Well-sorted, carbonaceous, massive shale; containing parallel lamination		Flood plain
8		Amalgamated, well-sorted, hummocky cross-stratificated fine to medium sandstone; containing disarticulated bivalves	Bivalves Gastropods	Lower shoreface
9		Alternation of well-sorted, hummocky cross-stratificated fine to medium sandstone; containing disarticulated bivalves; and shale	Bivalves Gastropods	Inner shelf
10		Alternation of well-sorted, turbidity sandstone; containing load casts and flute structures; and shale; containing disarticulated bivalves	Bivalves Gastropods Echinoids	channel in upper submarine fan
11		Well-sorted, turbidity medium to fine sandstone; containing erosional base		channel in upper to middle submarine fan
12		Well-sorted, massive shale; containing disarticulated bivalves	Bivalves Gastropods Plants	Inner shelf
13		Well-sorted, medium to coase, trough cross-stratificated sandstone		Braided river
14		Well-sorted, grayish white, fine tuff		
15		Alternation of limestone and shale; containing belemnites	Beleminites	Outer shelf

Figure 30. Sedimentary facies of the Sanchu Cretaceous System

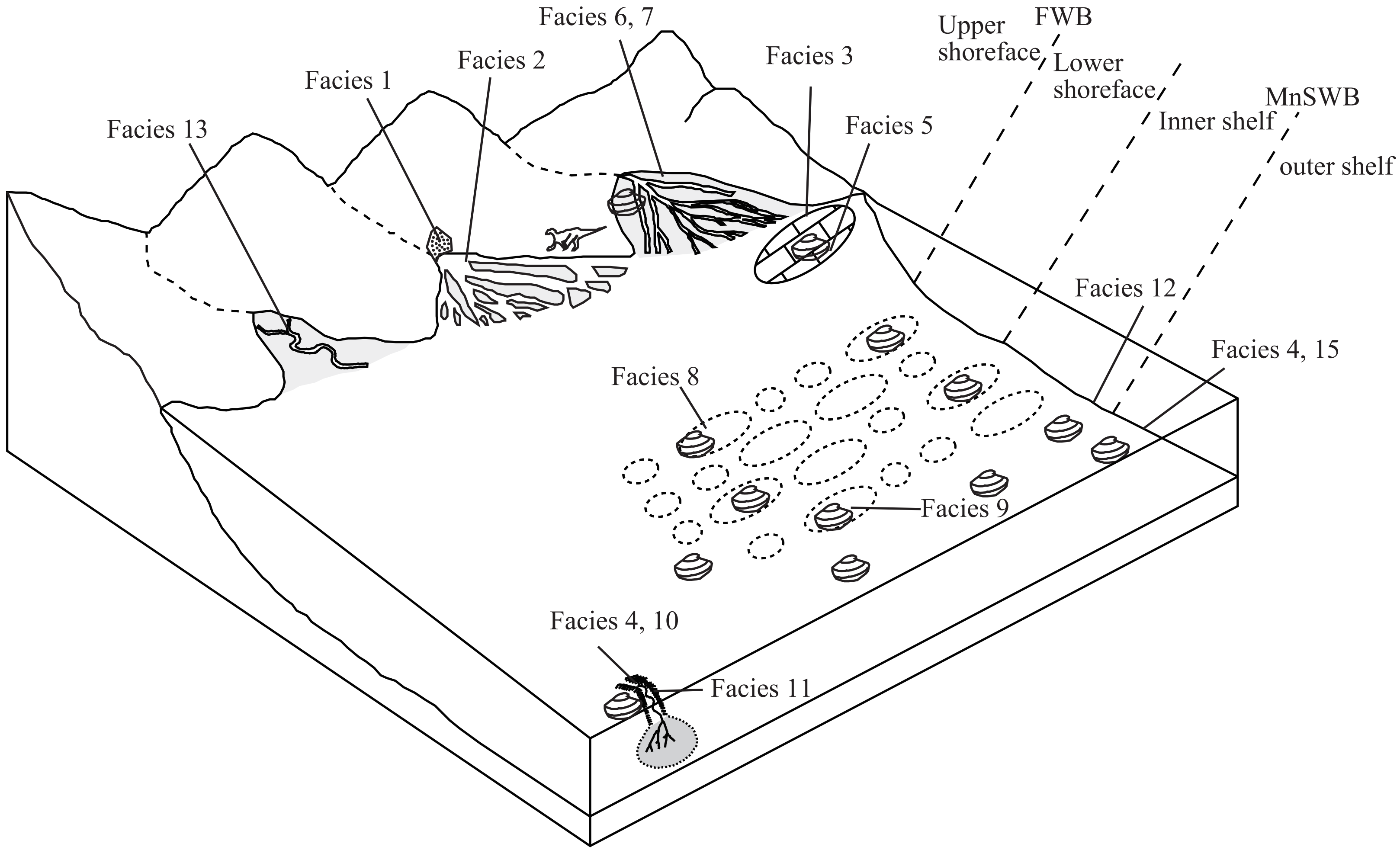


Figure 31. Schematic facies model for the Sanchu Cretaceous System.

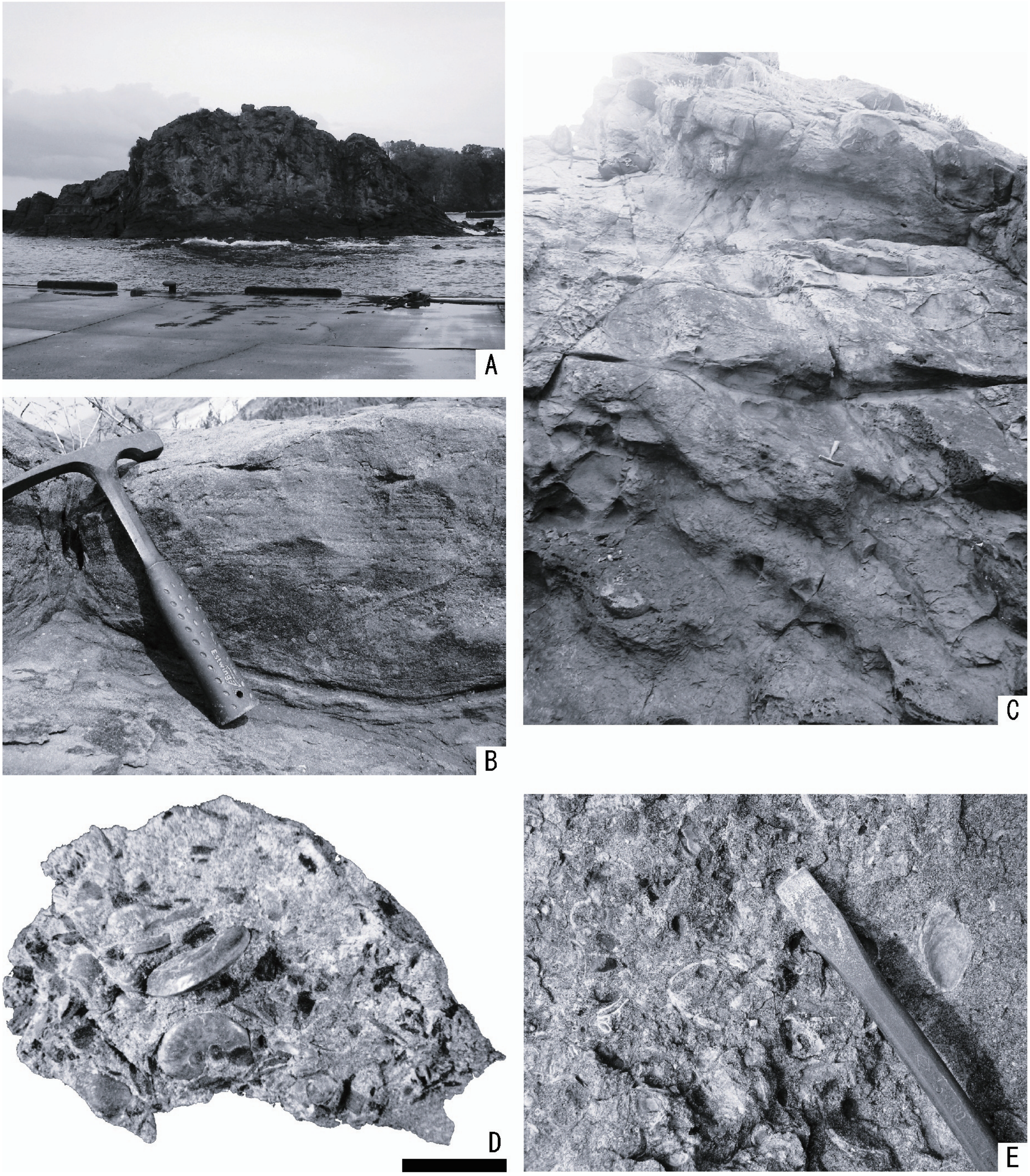


Figure 32. A. Ebisudana from the coast of Hideshima. B. Hummocky cross-stratified sandstone in Facies 2. C. Sandy mudstone (Facies 1) and covering Hummocky cross-stratified sandstone (Facies 2). D. Mode of occurrence of fossils (Facies 1). E. Mode of occurrence of fossils (Facies 2). Scale =hummer in A and B (long=30 cm), bar in D (1 cm), chisel in E (diameter=1 cm).

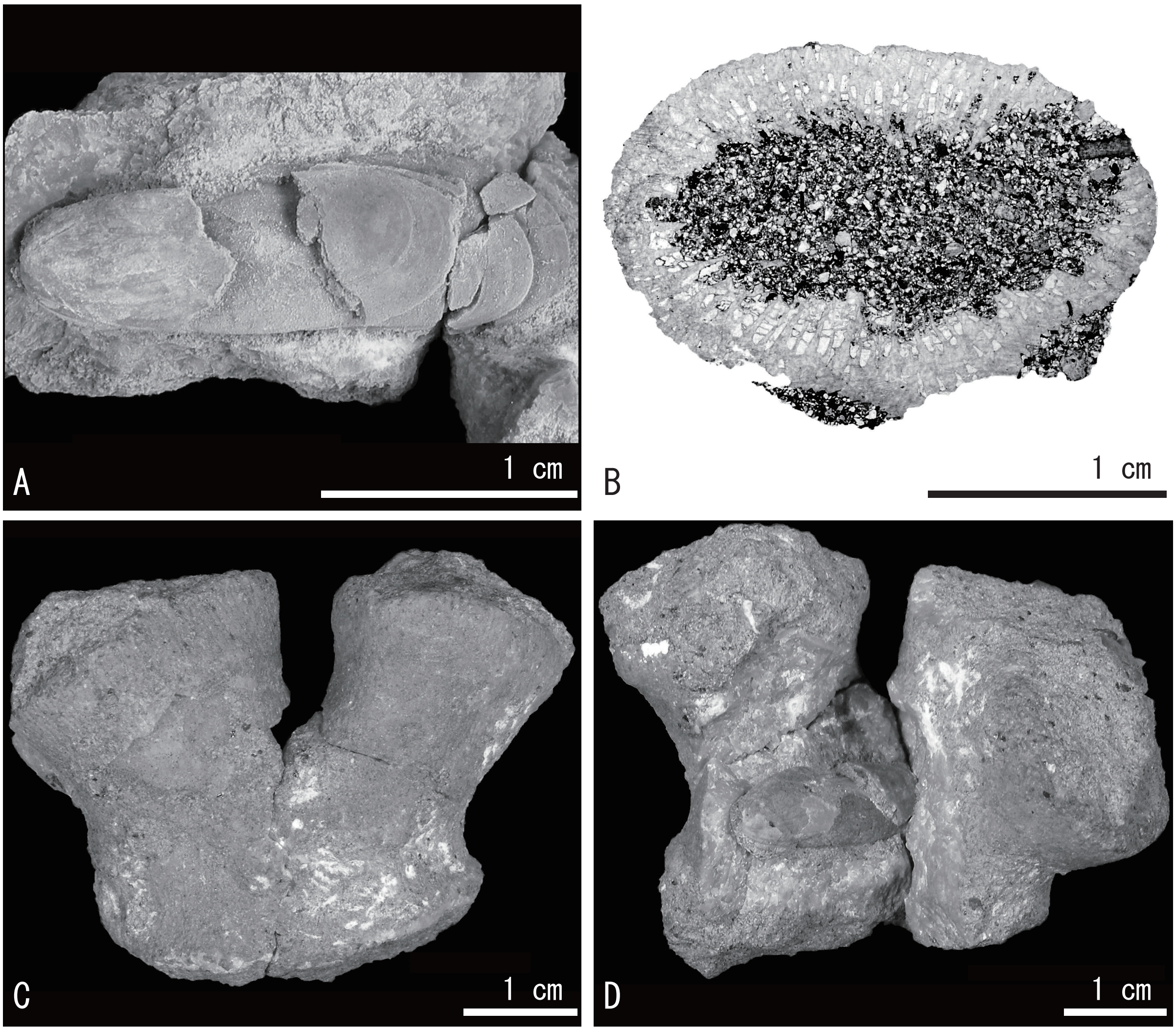


FIgure 33. Boring bivalve from the Tanohata Formation. A. *Lithophaga* (*Myapalmura*) sp. B. Cross section of *Dermosmilia miyakoensis*. C. *Dermosmilia miyakoensis*. D. Mode of occurrence of *Lithophaga* (*Myapalmula*) sp.

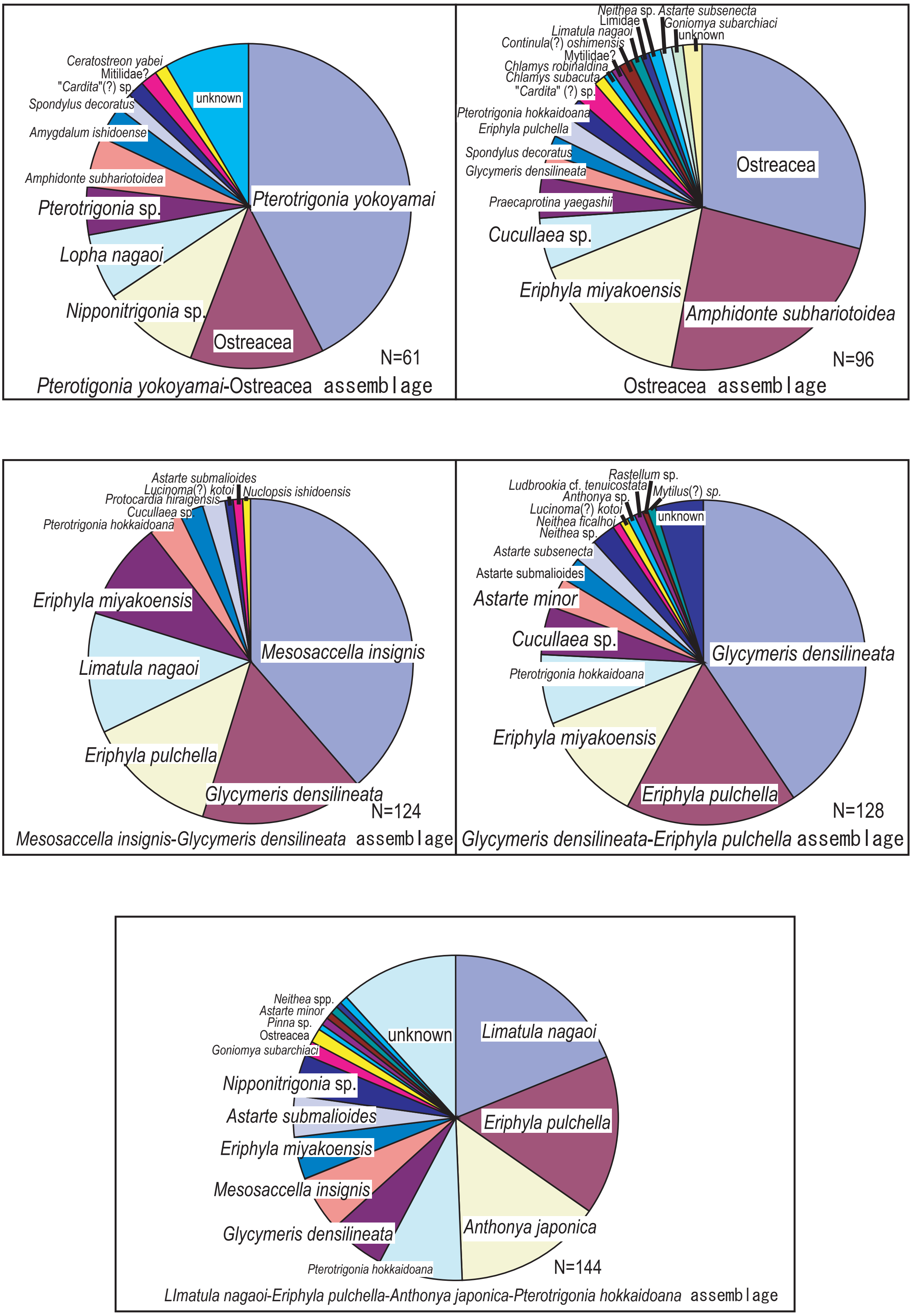
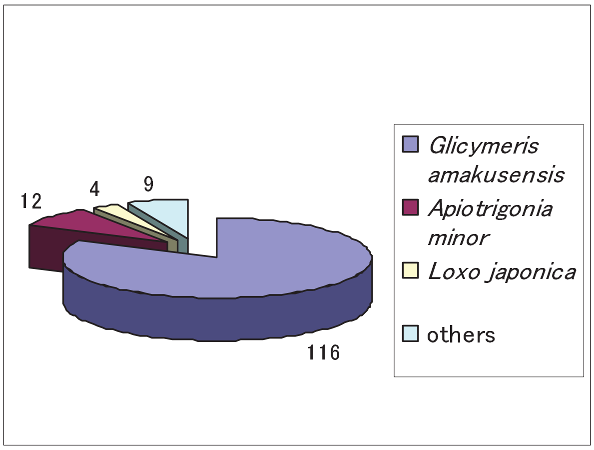
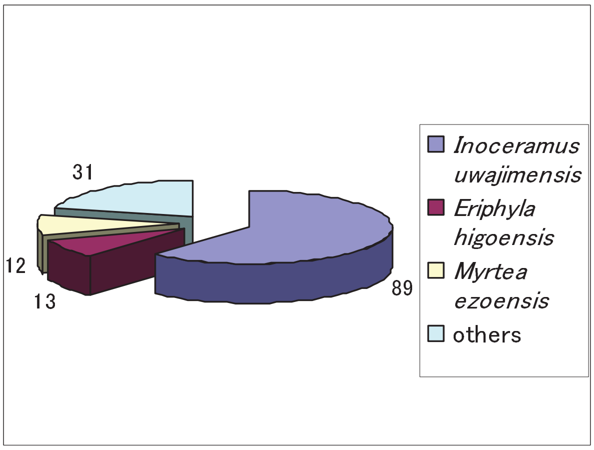


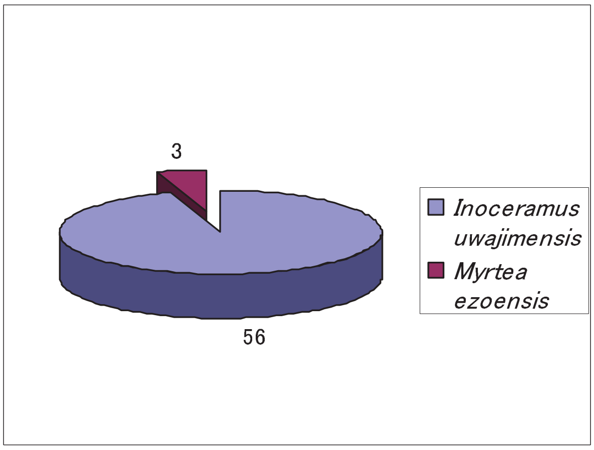
Figure 34. Composition of fossil assemblages of the Miyako Group.



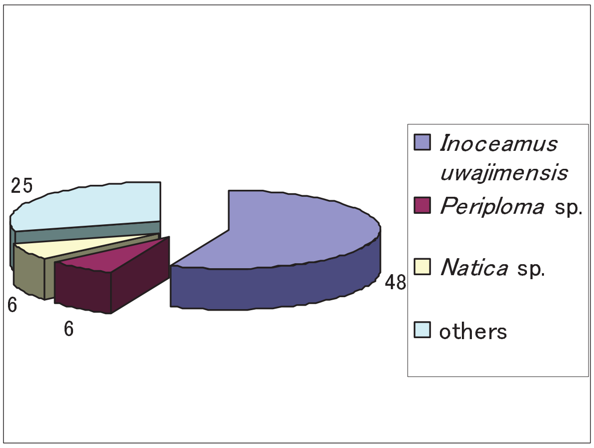
G. amakusensis—A. minor—L. japonica assemblage



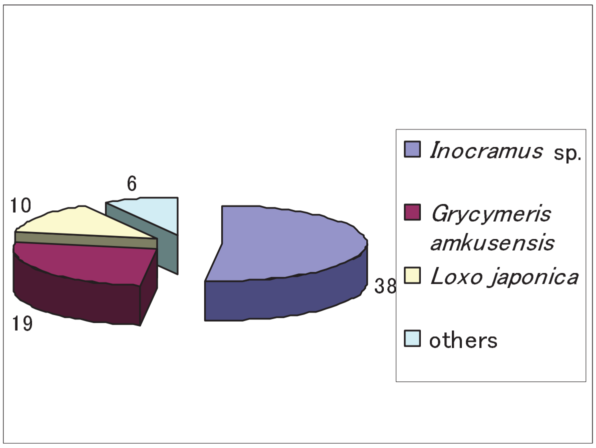
I. uwajimensis—E. higoensis—M. ezoensis assemblage



I.uwajimensis—M.ezoensis assemblage



I. uwajimensis—P. sp. assemblage



I. sp.—*G. amakusensis—L. japonica* assemblage

Figure 35. Composition of fossil assemblages of the Futaba Group.

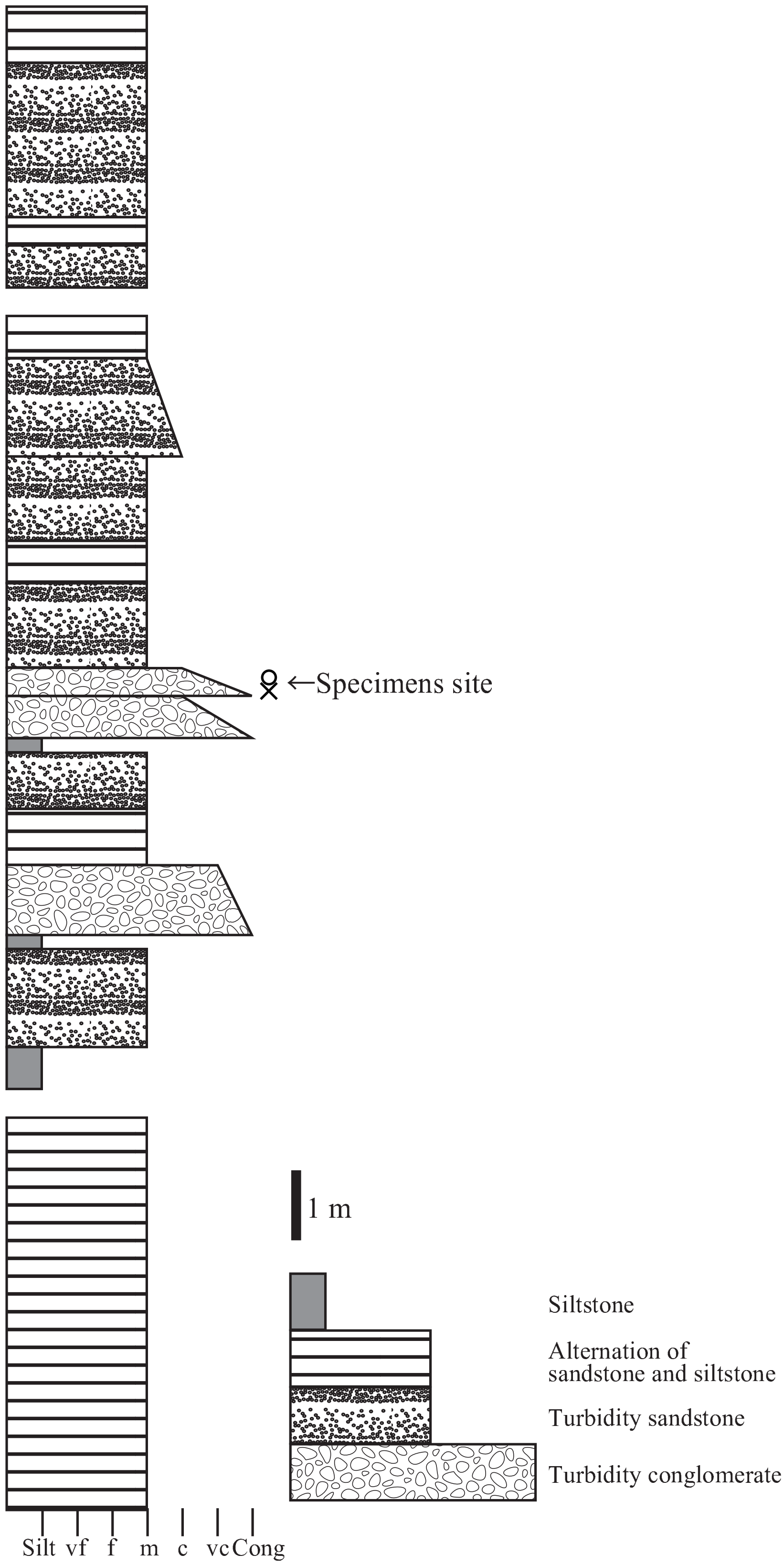


Figure 36. Columnar section of near Radiolarian specimens site.

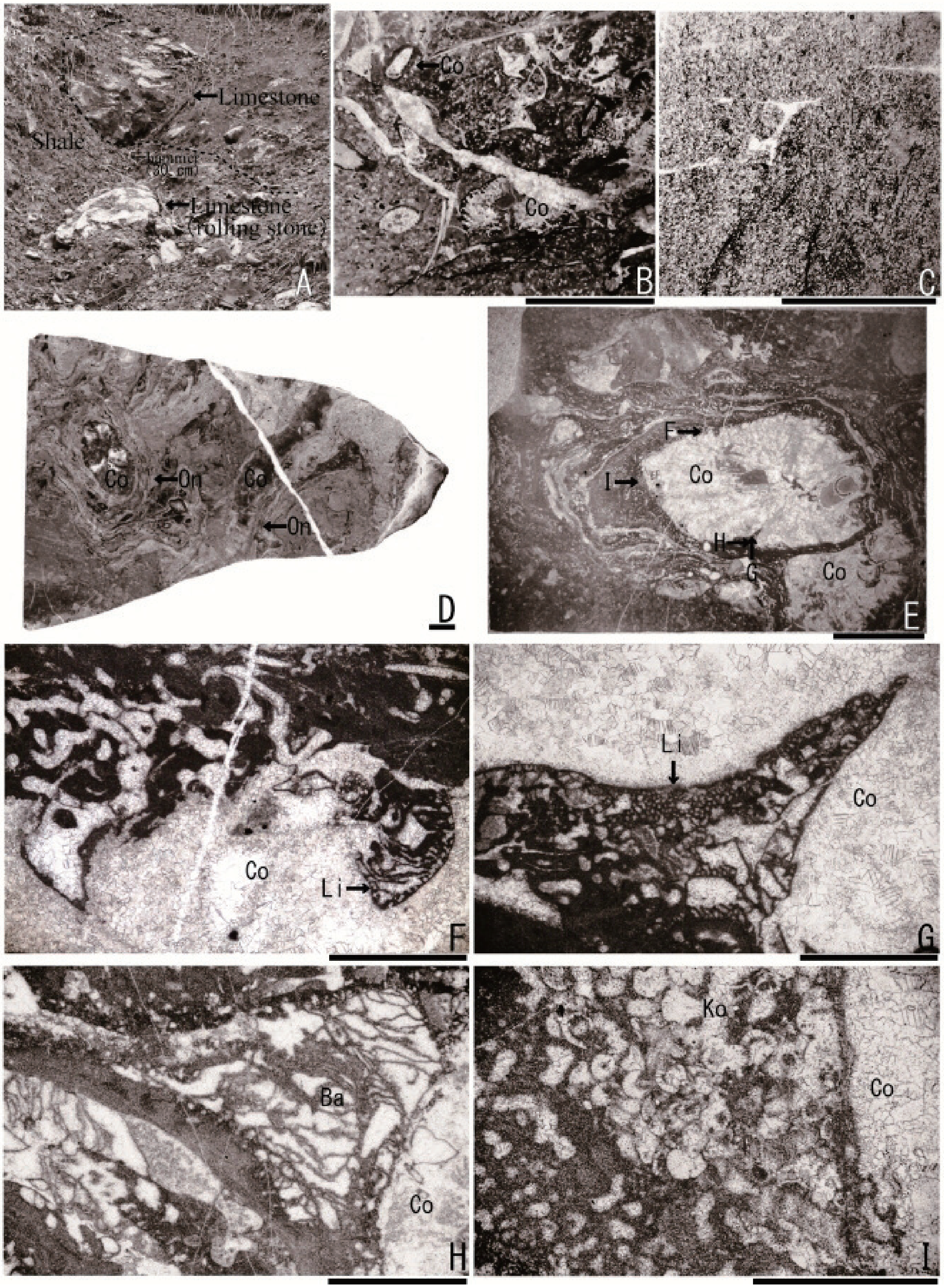


Figure 37. Limestone block from the Ishido Formation. A. Mode of occurrence of limestone block. B. Floatstone.C. Mudstone. D. Mode of occurrence of oncoid. E. Cross section of oncoid. F. Microboring. G. ***Lithocodium aggregatum***. H. ***Bacinella irreguralis***. I. ***Koskinobullina socialis***.

Figure 38. Belemnite battlefield from the Sanyama Formation.

A. Mode of occurrence of belemnite battlefield.

B. *Neohibolites* sp.

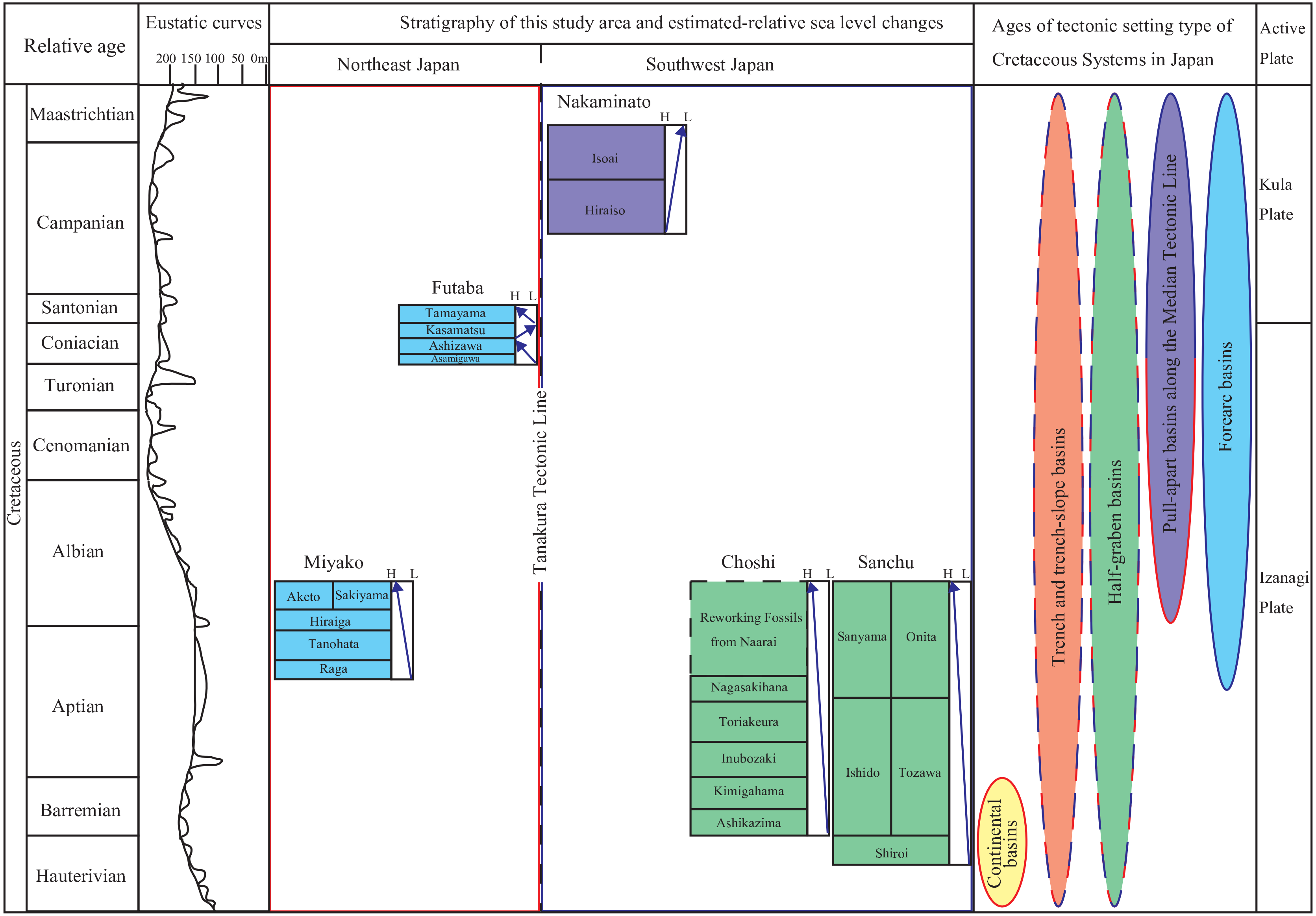


Figure 39. Tectonic setting of this study areas.

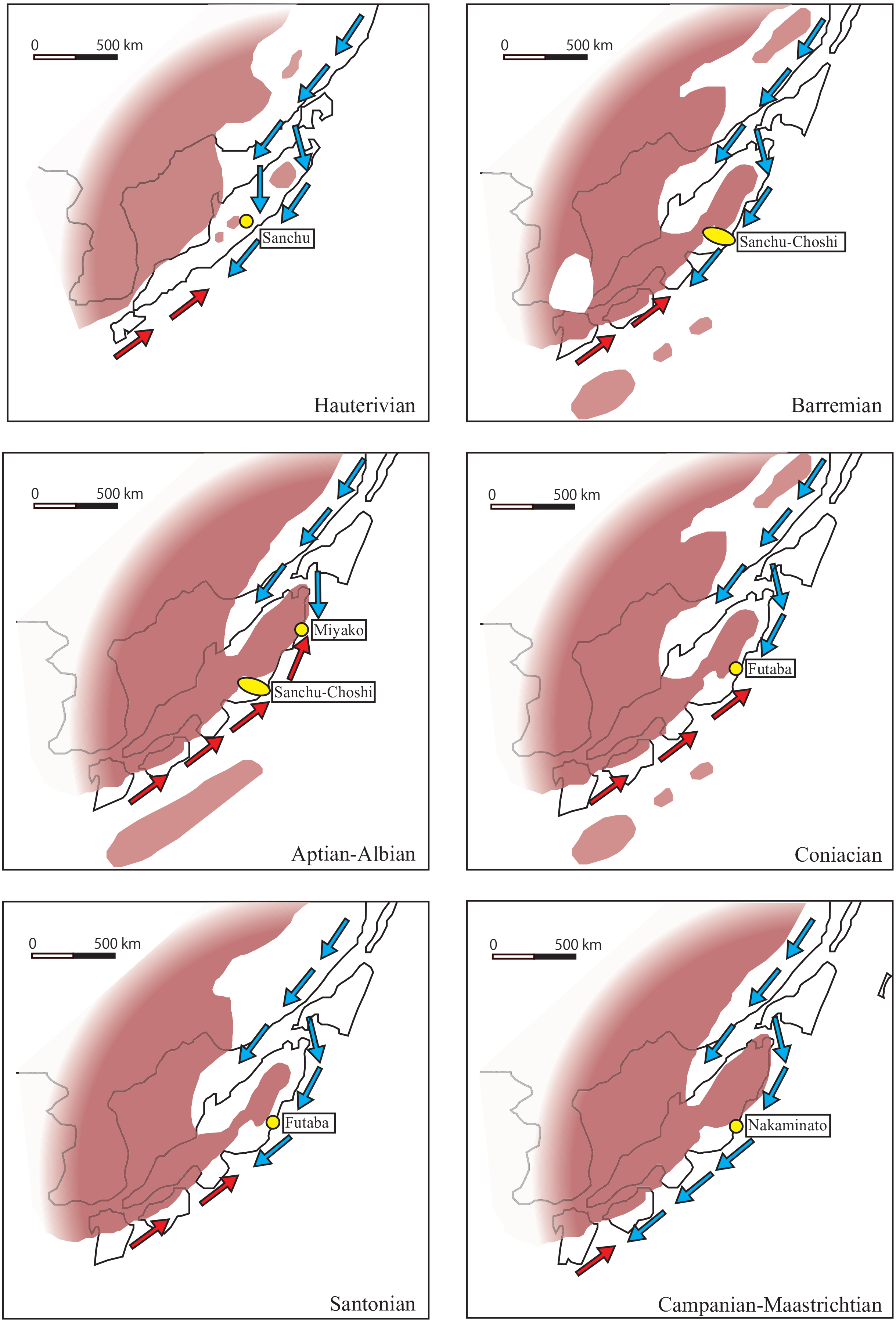


Figure 40. The presumed paleogeography and paleocurrents around Japan.

Table 1. Correlation of stratigraphy of the Miyako Group.

Study / Age	Yabe and Yehara (1913) All area	Hanai **et al**. (1968) North area	Shimazu **et al**. (1970) South area	Obata (1974) North area	Tanaka (1978) All area	Sato (2001) North area	Present study (2011) All area
Cenomanian	Aketo sandstone *Orbitolina* sandstone						
Albian	Hiraiga sandstone	Aketo Formation	Sakiyama Formation	Aketo Formation *Orbitolina* sandstone Hiraiga Formation	Aketo Formation *Orbitolina* sandstone Sakiyama Formation Hiraiga Formation	Aketo Formation Hiraname Formation Hiraiga Formation	Aketo Formation Sakiyama F. Hiraname Formation Hiraiga Formation
Aptian	Tanohata sandy shale Moshi sandstone	Hiraiga Formation Tanohata Formation Raga Formation	Hiraiga Formation Tanohata Formation Raga Formation	Tanohata Formation Raga Formation	Tanohata Formation Raga Formation	Tanohata Formation Raga Formation	Tanohata Formation Raga Formation
Barremian	Raga conglomerate						

Table 2. List of ammonoids from the Miyako Group. Localities are following; 1, 2 are Aketo (Aketo F.), 3, 4, 5 are Ebisudana (Sakiyama F.), 6 is Hideshima (Tanohata F.) and 7 is Funaare (Hiraiga F.).

Fossils	Locality					
	1	2	3	4	5	6	7
Eotetragonites sp.			●				
Aconeceras sp.			●		●		
Valdedorsella getulina							●
Pseudohaploceras sp.	●	●			●		
Desmocerataceae gen. indet.			●	●			
Ptychoceras sp.			●				
Hamites sp.	●	●					
Pseudoleymeriella hataii	●		●				
Douvilleicerataceae gen. indet.			●		●		
Ammonoidea gen. indet.						●	

Table 3. List of bivalves from the Miyako Group. Localities are following; 1, 2 are Aketo (Aketo F.), 3 is Koikorobe (Tanohata F.), 4, 5, 6 are Ebisudana (Sakiyama F.) and 7 is Hideshima (Tanohata F.).

fossils	Locality						
	1	2	3	4	5	6	7
Nuclopsis ishidoensis				●			
Mesosaccella insignis	●	●		●		●	
Cucullaea sp.				●	●		●
Glycymeris densilineata	●	●		●	●	●	●
Mytilus(?) sp.					●		
Amygdalum ishidoense			●				
Mytilidae? gen. Indet.			●				●
Pinna sp.	●						
Neithea ficalhoi		●			●		
Neithea matsumotoi		●					
Neithea nipponica	●						
Neithea sp.		●			●		●
Chlamys robinaldia							●
Chlamys subacuta							●
Spondylus decoratus			●				●
Limatula nagaoi	●	●		●			●
Limidae gen. indet.							●
Catinula(?) *oshimensis*							●
Amphidonte subhariotoidea			●				●
Ceratostreon yabei			●				
Lopha nagaoi			●				
Rastellum sp.					●		
Ostreacea gen. indet.	●		●				●
Nipponitrigonia sp.	●	●	●				
Pterotrigonia hokkaidoana	●	●		●	●	●	●
Pterotrigonia yokoyamai			●				
Pterotrigonia sp.			●				
Lucinoma(?) *kotoi*				●	●		
Cardita(?) sp.			●				●
Ludbrookia cf. *tenuicostata*					●		
Astarte subsenecta					●		●
Astarte minor		●			●	●	
Astarte submalioides	●	●		●	●		
Anthonya japonica	●	●					
Anthonya sp.					●		
Eriphyla miyakoensis	●	●		●	●	●	●
Eriphyla pulchela	●	●		●	●	●	●
Protocardia hiraigensis				●			
Goniomya subarchiaci	●					●	●
Praecaprotina yaegashii							●

Table 4. Correlation of staratigraphy of the Futaba Group

<table>
<tr><th colspan="3">Study / Age</th><th>Tokunaga (1923a,b)</th><th>Konno (1938)</th><th colspan="2">Saito (1960)</th><th>Obata and Suzuki (1969)</th><th colspan="2">Kubo et al. (2002)</th><th colspan="2">The present study (2011)</th></tr>
<tr><td rowspan="10">Cretaceous</td><td rowspan="3">Cenomanian</td><td>late</td><td rowspan="3">Upper Formation</td><td rowspan="3">Tamayama Formation</td><td colspan="2" rowspan="3"></td><td rowspan="5"></td><td colspan="2" rowspan="5"></td><td colspan="2" rowspan="5"></td></tr>
<tr><td>middle</td></tr>
<tr><td>early</td></tr>
<tr><td rowspan="3">Santonian</td><td>late</td><td rowspan="3">Middle Formation</td><td rowspan="3">Kasamatsu Formation</td><td colspan="2">Tamayama Formation</td></tr>
<tr><td>middle</td><td colspan="2" rowspan="2">Kasamatsu Formation</td></tr>
<tr><td>early</td><td rowspan="5">Futaba Group</td><td rowspan="2">Tamayama Formation</td><td>Irimazawa Member</td><td rowspan="2">Tamayama Formation</td><td>Irimazawa Member</td></tr>
<tr><td rowspan="4">Coniacian</td><td rowspan="2">late</td><td rowspan="4">Lower Formation</td><td rowspan="4">Ashizawa Formation</td><td rowspan="4">Ashizawa F.</td><td rowspan="2">Obisagawa Member</td><td>Kobisagawa M.</td><td>Kobisagawa M.</td></tr>
<tr><td colspan="2">Kasamatsu F.</td><td colspan="2">Kasamatsu F.</td></tr>
<tr><td>middle</td><td rowspan="2">Asamigawa Member</td><td rowspan="2">Ashizawa F.</td><td>Obisagawa Member</td><td rowspan="2">Ashizawa F.</td><td>Obisagawa Member</td></tr>
<tr><td>early</td><td>Asamigawa Member</td><td>Asamigawa Member</td></tr>
</table>

Table 5. List of fossils from the Futaba Group. Localities are following; 1is upper of Ashizawa, 2 is Kayanosawa, 3 is Minamisawa, 4 is Momonokizawa, 5 is between Ashizawa and Momonokizawa, 6 is lower part of middle of Ashizawa, 7 is upper part of middle of Ashizawa, 8 is Ammonite Center, 9 is Yoheisaku and 10 is Irimazawa. 1to 9 belong to Obisagawa M. 10 belongs to Irimazawa M.

Fossils	Locality									
	1	2	3	4	5	6	7	8	9	10
Ezonuculana mactraeformis										●
Inoceramus uwajimensis			●		●	●	●	●	●	
Inoceramus sp.										●
Glycymeris amakusensis	●	●	●	●				●	●	●
Apiotrigonia minor		●					●	●	●	●
Opis sp.		●								
Loxo japonica		●						●		●
Clisocolus sp.								●		
Eriphyra higoensis				●			●	●	●	
Nanonavis sachalinensis							●	●		
Nanonavis sp.										●
Acila sp.							●	●	●	
Myrtea ezoensis					●	●		●	●	
Yadia sp.	●									
Parvamussium yubarense									●	
Costocynera cf. *matsumotoi*							●			
Periploma sp.				●					●	
Leptosolen sp.									●	
Isognomn? sp.		●								
Cucullaea sp.		●								
Crassostrea ? sp.								●		
Pectenidae gen. et. sp. indet.								●		
Sargana sp.		●								
Gyrodes sp.					●			●		
Natica sp.								●	●	
Paladmete sp.								●		
Tullitella? sp.		●								
Carypteraeidae gen. et. sp. indet.								●		
Scaphites ? sp.							●	●		
Polyptychoceras ? sp.									●	
Cretolamna sp.								●		●
Scapanorhynchus sp.								●		
Isocrinidae gen. et. sp. indet.									●	

Table 6. Correlation of stratigraphy of the Nakaminato Group.

Age			Ozaki and Saito (1955)	Tanaka (1970)	Ando (2006)	Present study (2011)
Upper Cretaceous	Maastrichtian	Upper				
		Middle				
		Lower	Naka Group: Nakaminato Formation: Isoai Member	Nakaminato Group: Isoai Formation	Nakaminato Group: Isoai Formation	Nakaminato Group: Isoai Formation
	Campanian	Upper				
		Middle	Hiraiso Member	Hiraiso Formation	Hiraiso Formation	Hiraiso Formation ? Chikko Formation ?
		Lower	Chikko Member			
	Santonian	Upper	Oarai Formation	? Chikko Formation ?		
		Middle				
		Lower				
	Coniacian	Upper				
		Middle				
		Lower				

Table 7. Correlation of stratigraphy of the Choshi Group.

Age			Kochibe (1910)	Imazeki (1951)	Shikama and Suzuki (1972)	Obata *et al.* (1982)	Present study (2011)
Cretaceous	Cenomanian	Late	Choshi Formation		Nagasaki F.		
		Middle					
		Early		Choshi Formation: Nagasaki sandstone	Choshi Group: Nagasakihana ss. b.		
	Albian	Late		Inubozaki alternation	Inubo F.: Toriake sh. b.; Inubo ss. b.		
		Middle					
		Early					
	Aptian	Late				Choshi Group: Nagasakihana F.; Toriakeura F.	Choshi Group: Nagasakihana F.; Toriakeura F.
		Early			Ashikajima F.: Kimigahama sh. b.; Ashikajima ss. b.; Ashikajima cg. b.	Inubozaki F.	Inubozaki F.
	Barremian	Late		Ashikajima sandstone		Kimigahama F.	Kimigahama F.
		Early				Ashikajima F.	Ashikajima F.
	Hauterivian	Late		Kurobai conglomerate			
		Early			Kurobai F.: Iseji sh. b.; Kurobai cg. b.		

Table 8. Correlation of Stratigraphy of the Sanchu Cretaceous System.

Age			Yabe *et al.* (1926)	Matsukawa (1983)	Terabe *et al.* (2007)	Ichise (2008)			Present study (2011)		
Cretaceous	Turonian	Late									
		Middle									
		Early			Sanyama Formation						
	Cenomanian	Late			Sanyama Formation						
		Middle			Sanyama Formation						
		Early		Sanyama Formation	Sanyama Formation						
	Albian	Late		Sanyama Formation	Sanyama Formation	Sanchu Group	Sanyama F.		Sanchu Group	Sanyama F.	
		Middle		Sanyama Formation	Sanyama Formation	Sanchu Group	Sanyama F.		Sanchu Group	Sanyama F.	
		Early		Sanyama Formation	Sanyama Formation	Sanchu Group	Sanyama F.	Nanmoku Group: Ohnita F.	Sanchu Group	Sanyama F.	Nanmoku Group: Ohnita F.
	Aptian	Late	Kawarazawa Group	Sanyama Formation / Sebayashi Formation	Sanyama Formation	Sanchu Group	Sanyama F.	Nanmoku Group: Tozawa F.	Sanchu Group	Sanyama F.	Nanmoku Group: Tozawa
		Early	Kawarazawa Group	Sebayashi Formation	Sanyama Formation	Sanchu Group	Ishido F.	Nanmoku Group: Tozawa F.	Sanchu Group	Ishido F.	Nanmoku Group: Tozawa
	Barremian	Late	Ishido Group	Sebayashi Formation	Sebayashi Formation	Sanchu Group	Ishido F.		Sanchu Group	Ishido F.	
		Early	Ishido Group	Ishido Formation	Ishido Formation	Sanchu Group	Ishido F.		Sanchu Group	Ishido F.	
	Hauterivian	Late	Shiroi Group ? Ohnosawa Group	Ishido Formation / Shiroi Formation	Ishido Formation / Shiroi Formation	Sanchu Group	Shiroi F.		Sanchu Group	Shiroi F.	
		Early	Ohnosawa Group ? Miyakozawa Group			Sanchu Group	Shiroi F.		Sanchu Group	Shiroi F.	

Table 9. List of megafossils from the Sanchu Cretaceous System. Localities are following; 1 is Bonukizawa (Shiroi F.), 2 is Mamonozawa River (Ishido F.), 3 is Bonukizawa (Ishido F.), 4 is Shinzaburozawa (Ishido F.), 5 is Ohnozawa Pass (Sanyama F.), 6 is Susuki River (Sanyama F.), 7 is Tozawa (Tozawa F.) and 8 is Tozawa (Ohnita F.).

Fossils								
	1	2	3	4	5	6	7	8
Portlandia sanchuensis					●			
Cucullaea sp.			●					
Myrtea sp.								●
Nipponitrigonia sp.								●
Neithea sp.							●	
Hayamina naumanni	●	●						
Hayamina minor		●						
Tetoria sanchuensis								
Costcynera matsumotoi		●	●					
Costcynera otsukai			●					
Scittilla dericatostriata			●					
Astarte costata								●
Astarte yatsushiroensis								●
Corbula sp.					●			
Yabea? sp.								●
Pachytraga japonica		●	●					
Protocardia sp.			●					
Protocardia? sp.			●					
Lithophaga sp.				●				
Bivalvia gen. et sp. indet.					●			
Cassiope ogaii		●						
Gastropoda gen. et sp. indet.		●	●		●			
Neohibolites sp.						●		●
Echinoidea gen. sp. indet.					●			

Table 10. List of microfossils from limestones of the Ishido Formation. Localities are following; 1 is Shinzaburozawa and 2 is upper part of Kuro River.

Fossils	Locality 1	Locality 2
Globigerinelloides aff. *blowi*	●	●
Hedbergella planispira	●	●
Globuligerina hoterivica		●
Haplophragmoides sp.	●	●
Haplophragmoides ? sp.		●
Pullenia sp.	●	
Saccamia sp.		●
Paratrochammides sp.		●
Pseudobolivina sp.	●	●
Tolypammina sp.	●	
Bigenerina? sp.	●	
Foraminifera gen. indet.	●	●
sponge spicular (four axies type)	●	
sponge spicular (one axies type)	●	
Archaeodictyomitra sp.		●
Ostracoda gen. indet.	●	

Plates

Explanation of Plate 1

Figure 1. Angular conglomerate in the Raga Formation exposed at coast of Raga, Tanohata Village, Shimohei County, Iwate Prefecture.

Figure 2. Rounded conglomerate in the Raga Formation exposed at coast of Kuwagasaki, Miyako City, Iwate Prefecture.

Plate 1

1.

2.

Explanation of Plate 2

Figure 1. Tsunami deposits in the Tanohata Formation exposed at coast of Koikorobe, Tanohata Village, Shimohei County, Iwate Prefecture.

Figure 2. Amalgamated hummocky cross-stratification sandstone in the Hiraiga Formation exposed at coast of Hiraiga, Tanohata Village, Shimohei County, Iwate Prefecture.

Plate 2

1.

2.

Explanation of Plate 3

Figure 1. Alternation of hummocky cross-stratification sandstone and silt stone in the Hiraiga Formation exposed at coast of Hiraiga, Tanohata Village, Shimohei County, Iwate Prefecture.

Figure 2. Massive sandy silt stone in the Sakiyama Formation exposed at Ebisudana, Miyako City, Iwate Prefecture.

Plate 3

1.

2.

Explanation of Plate 4

Figure 1. *Orbitolina* sandstone in the Hiraname Formation exposed at Hiraname, Tanohata Village, Shimohei County, Iwate Prefecture.

Figure 2. Tuff in the Tanohata Formation exposed at Koikorobe, Tanohata Village, Shimohei County, Iwate Prefecture.

Plate 4

1.

2.

Explanation of Plate 5

Figure 1. Limestone from the Tanohata Formation exposed at Raga, Tanohata Village, Shimohei County, Iwate Prefecture.

Plate 5

1.

Explanation of Plate 6

Figure 1. Upward fining unit of alternation of sandstone and silt stone in the Kasamatsu Formation exposed at Oriki River, Hirono Town, Futaba County, Fukushima Prefecture.

Figure 2. Calcareous conglomerate in the Obisagawa Member at Kayanosawa, Hirono Town, Futaba County, Fukushima Prefecture.

Plate 6

1.

2.

Explanation of Plate 7

Figure 1. Parallel stratificated, massive silt stone in the Obisagawa Member exposed at Ashizawa, Iwaki City, Fukushima Prefecture.

Figure 2. Moderately-sorted, massive sandstone in the Obisagawa Member exposed at Ammonite Center, Iwaki City, Fukushima Prefecture.

Plate 7

1.

2.

Explanation of Plate 8

Figure 1. Very well-sorted, silt stone from the Obisagawa Member exposed at Yoheisaku, Iwaki City, Fukushima Prefecture.

Figure 2. Well-sorted, massive sandstone from the Irimazawa Member exposed at Irimazawa, Iwaki City, Fukushima Prefecture.

Plate 8

1.

2.

Explanation of Plate 9

Figure 1. Cross-laminated sandstone from the Kobisagawa Member exposed at Suetsugi, Iwaki City, Fukushima Prefecture.

Figure 2. Tuff from the Kasamatsu Formation exposed at Momonokizawa, Iwaki City, Fukushima Prefecture.

Plate 9

1.

2.

Explanation of Plate 10

Figure 1. Rounded conglomerate from the Asamigawa Member exposed at Asami River, Hirono Town, Futaba County, Fukushima Prefecture.

Figure 2. Carbonaceous silt stone from the Kobisagawa Member exposed at Kobisa, Iwaki City, Fukushima Prefecture.

Plate 10

1.

2.

Explanation of Plate 11

Figure 1. Alternation of clast-supported conglomerate, sandstone and silt stone from the Isoai Formation exposed at Coast of Hiraiso, Hitachinaka City, Ibaraki Prefecture.

Figure 2. Turbidity sandstone from the Isoai Formation exposed at Coast of Isoai, Hitachinaka City, Ibaraki Prefecture.

Plate 11

1.

2.

Explanation of Plate 12

Figure 1. Alternation of matrix-supported conglomerate, sandstone and silt stone from the Isoai Formation exposed at Coast of Hiraiso, Hitachinaka City, Ibaraki Prefecture.

Figure 2. Alternation of sandstone and silt stone from the Hiraiso Formation exposed at Coast of Hiraiso, Hitachinaka City, Ibaraki Prefecture.

Plate12

1.

2.

Explanation of Plate 13

Figure 1. Massive silt stone from the Hiraiso Formation exposed at Coast of Hiraiso, Hitachinaka City, Ibaraki Prefecture.

Figure 2. CCC turbidity sandstone from the Isoai Formation exposed at Coast of Hiraiso, Hitachinaka City, Ibaraki Prefecture.

Plate 13

1.

2.

Explanation of Plate 14

Figure 1. Rounded conglomerate from the Ashikajima Formation exposed at Coast of Kurohae, Choshi City, Chiba Prefecture.

Figure 2. Alteranation of hummocky cross-stratification sandstone and silt stone from the Kimigahama Formation at Coast of Kimigahama, Choshi City, Chiba Prefecture.

Plate 14

1.

2.

Explanation of Plate 15

Figure 1. Amalgamated hummocky cross-stratificated sandstone from Inubozaki Formation exposed at Coast of Inubozaki, Choshi City, Chiba Prefecture.

Figure 2. Massive silt stone from the Toriakeura Formation exposed at Coast of Toriakeura, Choshi City, Chiba Prefecture.

Plate 15

1.

2.

Explanation of Plate 16

Tuff from the Inubozaki Formation exposed at Coast of Inubozaki, Choshi City, Chiba Prefecture.

Plate 16

Explanation of Plate 17

Figure 1. Angular conglomerate from the Tozawa Formation exposed at Tozawa, Kitaaiki Village, Minamisaku County, Nagano Prefecture.

Figure 2. Rounded conglomerate from the Ishido Formation exposed at Mamonozawa River, Ueno Village, Tano County, Gunma Prefecture.

Plate 17

1.

2.

Explanation of Plate 18

Figure 1. Alternation of limestone and calcareous sandstone from the Ishido Formation exposed at Otchizawa, Ueno Village, Tano County, Gunma Prefecture.

Figure 2. Matrix-supported conglomerate from the Sanyama Formation exposed at Shionosawa, Ueno Village, Tano County, Gunma Prefecture.

Plate 18

1.

2.

Explanation of Plate 19

Figure 1. Limestone block from the Ishido Formation exposed at Jikkoku Pass, Sakuho Town, Minamisaku County, Nagano Prefecture.

Figure 2. Upward fining conglomerate from the Shiroi Formation exposed at Shiroi, Ueno Village, Tano County, Gunma Prefecture.

Plate 19

1.

2.

Explanation of Plate 20

Figure 1. Cabonaceous shale from the Ishido Formation exposed at Ohnozawa Pass, Saku City, Nagano Prefecture.

Figure 2. Amalgamated hummocky cross-stratification sandstone from the Ishido Formation at Mamozawa, Ueno Village, Tano County, Nagano Prefecture.

Plate 20

1.

2.

Explanation of Plate 21

Figure 1. Alternation of hummocky sandstone and shale from the Ishido Formation exposed at Shiroi, Ueno Village, Tano County, Gunma Prefecture.

Figure 2. Alternation of turbidity sandstone and shale from the Sanyama Formation exposed at Mamonozawa River, Ueno Village, Tano County, Gunma Prefecture.

Plate 21

1.

2.

Explanation of Plate 22

Figure 1. Turbidity sandstone from the Sanyama Formation exposed at Mamonozawa River, Ueno Village, Tano County, Gunma Prefecture.

Figure 2. Massive shale from the Ishido Formation exposed at Nukui River, Sakuho Town, Minamisaku County, Nagano Prefecture.

Plate 22

1.

2.

Explanation of Plate 23

Figure 1. Cross laminated sandstone from the Ishodo Formation exposed at Mamonozawa River, Ueno Village, Tano County, Gunma Prefecture.

Figure 2. Tuff from the Ishido Formation exposed at Shiroi, Ueno Village, Tano County, Gunma Prfecture.

Plate 23

1.

2.

Explanation of Plate 24

Figure 1. Alternation of limestone and shale from the Sanyama Formation exposed at Hikage, Ogano Town, Chichibu County, Saitama Prefecture.

Plate 24

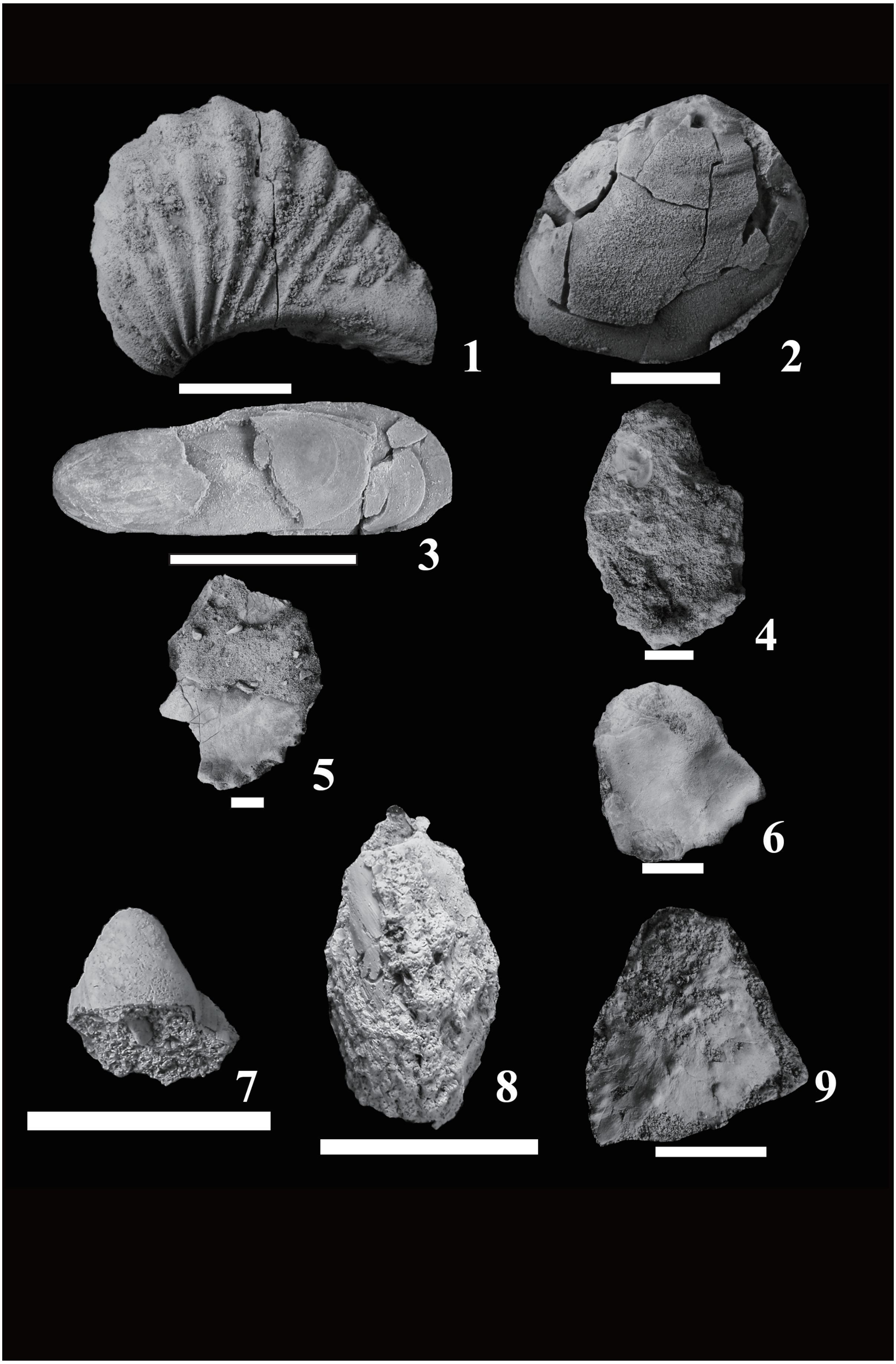
1.

Explanation of Plate 25

Fossils from the Tanohata Formation exposed at coast of Koikorobe, Tanohata Village, Shimohei County, Iwate Prefecture. All scale bars are 1 cm.

1. *Pterotrigonia yokoyamai*
2. *Nipponitrigonia* sp.
3. *Lithophaga* sp.
4. *Lopha nagaoi*
5. *Ceratostreon yabei*
6. *Amphidonte subhariotoidea*
7. Mytilidae? gen. et sp. indet.
8. "*Cardita*"? sp.
9. *Spondylus decorates*

Plate 25

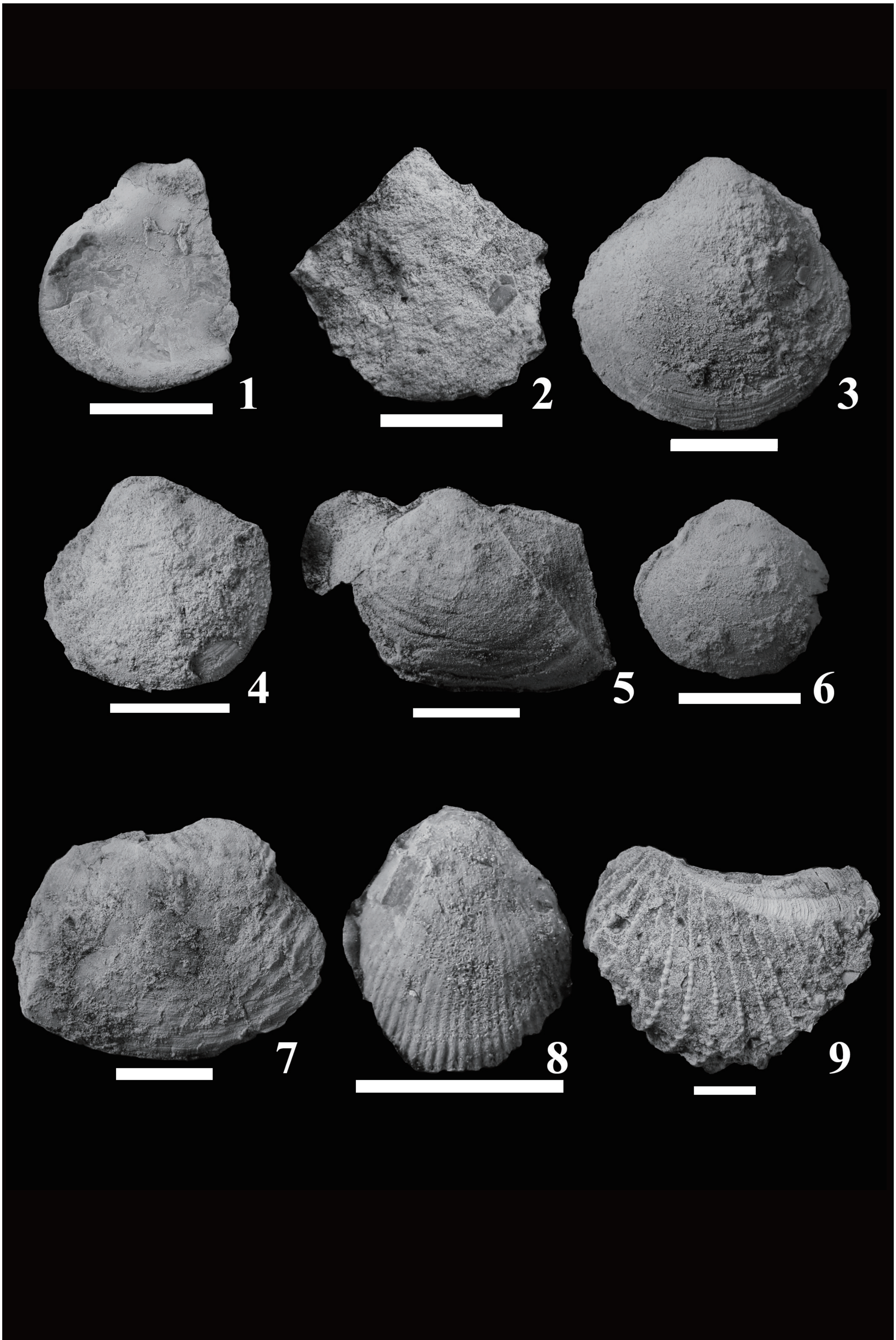


Explanation of Plate 26

Fossils from the Hiraiga Formation exposed at Hideshima coast, Miyako City, Iwate Prefecture. All scale bars are 1 cm.

1. *Amphidonte subhariotoidea*
2. *Catinula*? *oshimensis*
3. *Eripyla miyakoensis*
4. *Eriphyla pulchella*
5. *Nanonavis sachalinensis*
6. *Glycymeris densilineata*
7. *Goniomya subarchiai*
8. *Limatula nagaoi*
9. *Pterotrigonia hokkaidoana*

Plate 26

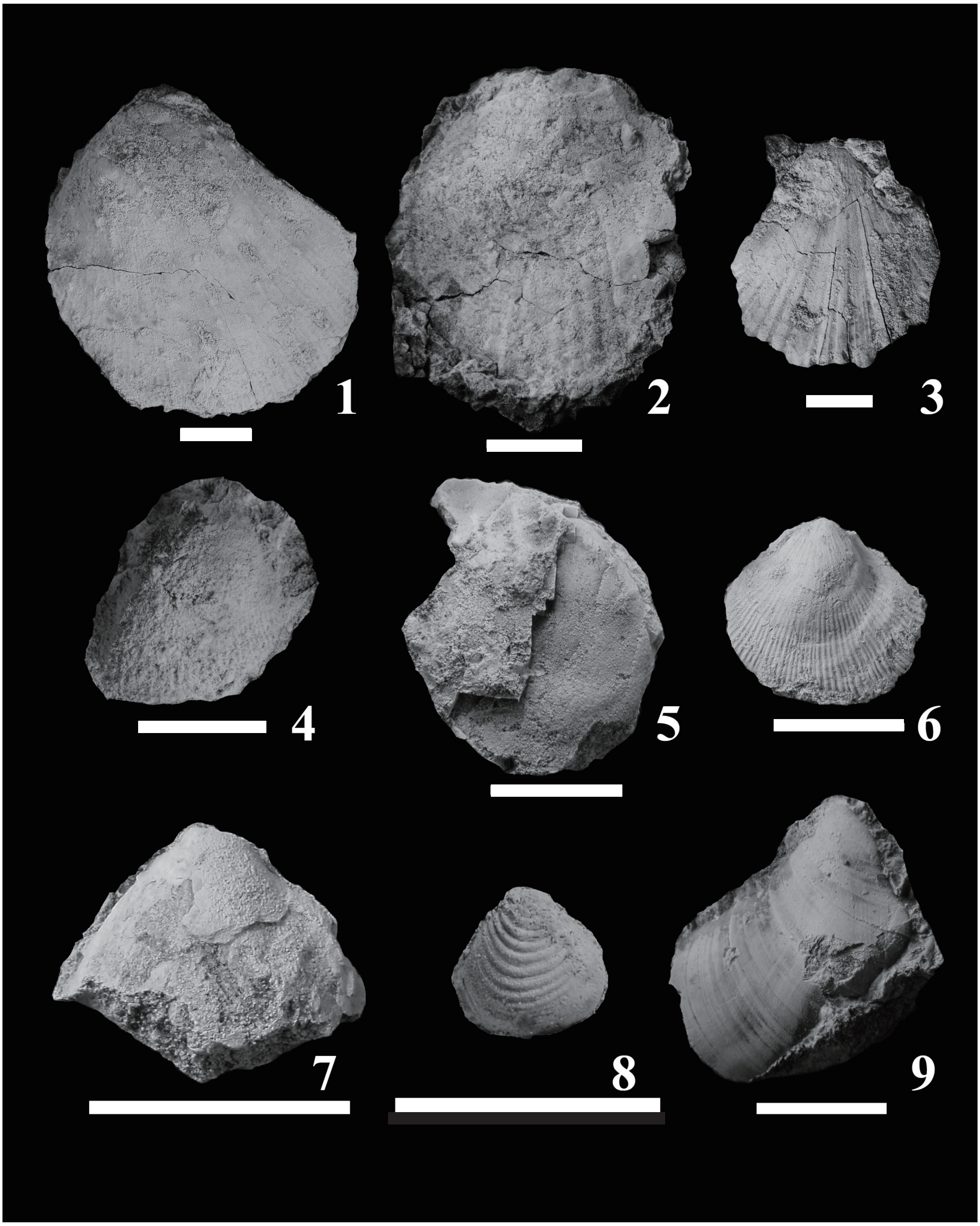


Explanation of Plate 27

Fossils from the Hiraiga Formation exposed at Hideshima coast, Miyako City, Iwate Prefecture. All scale bars are 1 cm.

1. *Spondylus decoratus*
2. *Chlamys subacuta*
3. *Neithea* sp.
4. "*Cardita*"? sp.
5. *Chlamys robinaldia*
6. Limidae gen. et sp. indet.
7. Mytilidae? gen. et sp. indet.
8. *Astarte subsenecta*
9. *Praecaprotina yaegashii*

Plate 27



Explanation of Plate 28

Ammonoids from the Sakiyama Formation exposed at Ebisudana, Miyako City, Iwate Prefecture. All scale bars are 1 cm.

1. *Aconeceras* sp.

2. *Pseudoleymeriella hatai*

3. *Valdedorsella getulina*

4. Desmocerataceae gen. et sp. indet.

5. *Eotetragonites* sp.

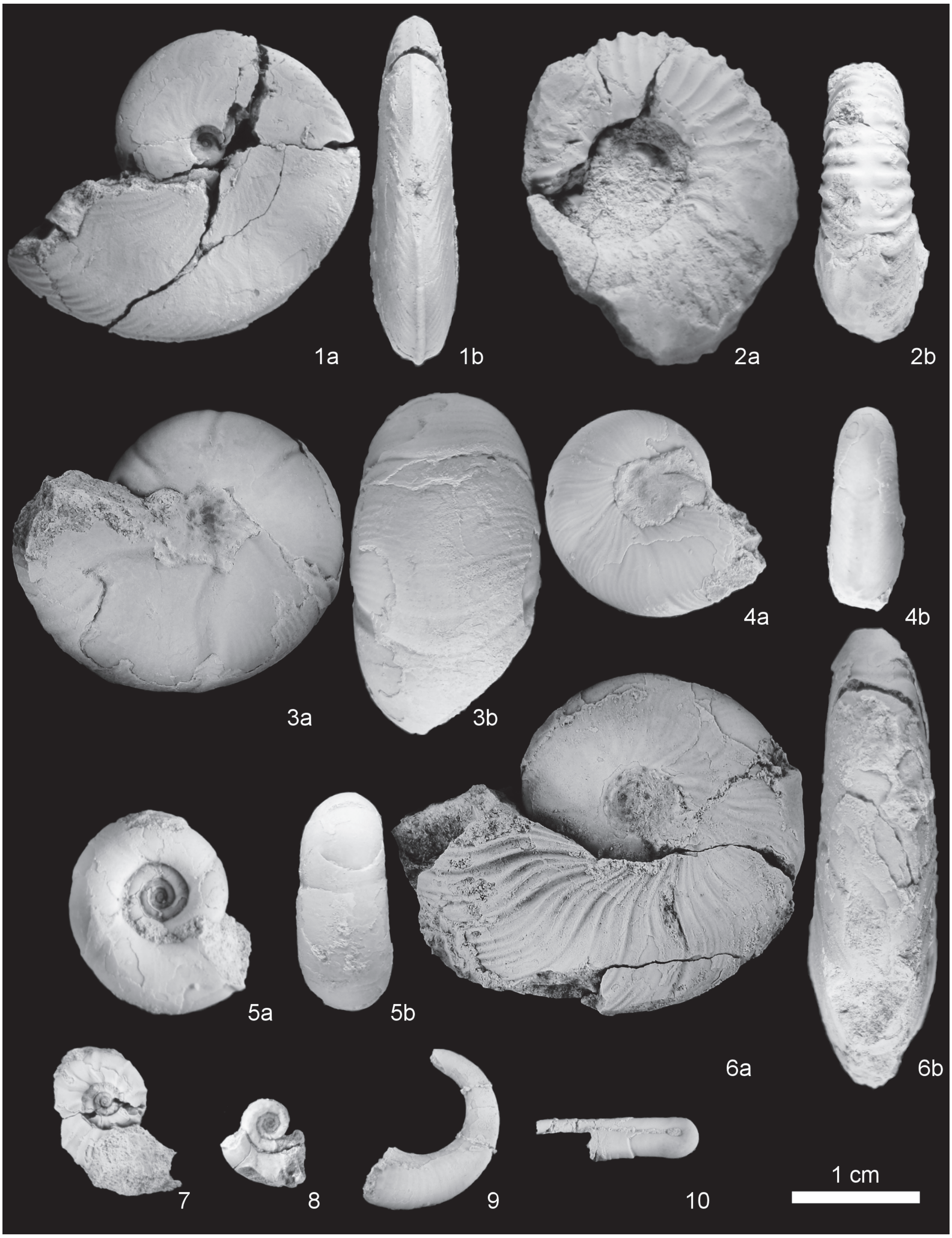
6. *Pseudohaploceras* sp.

7, 8. Douvilleicerataceae gen. et sp. indet.

9. Ancylocerataceae gen. et sp. indet.

10. *Ptychoceras* sp.

Plate 28

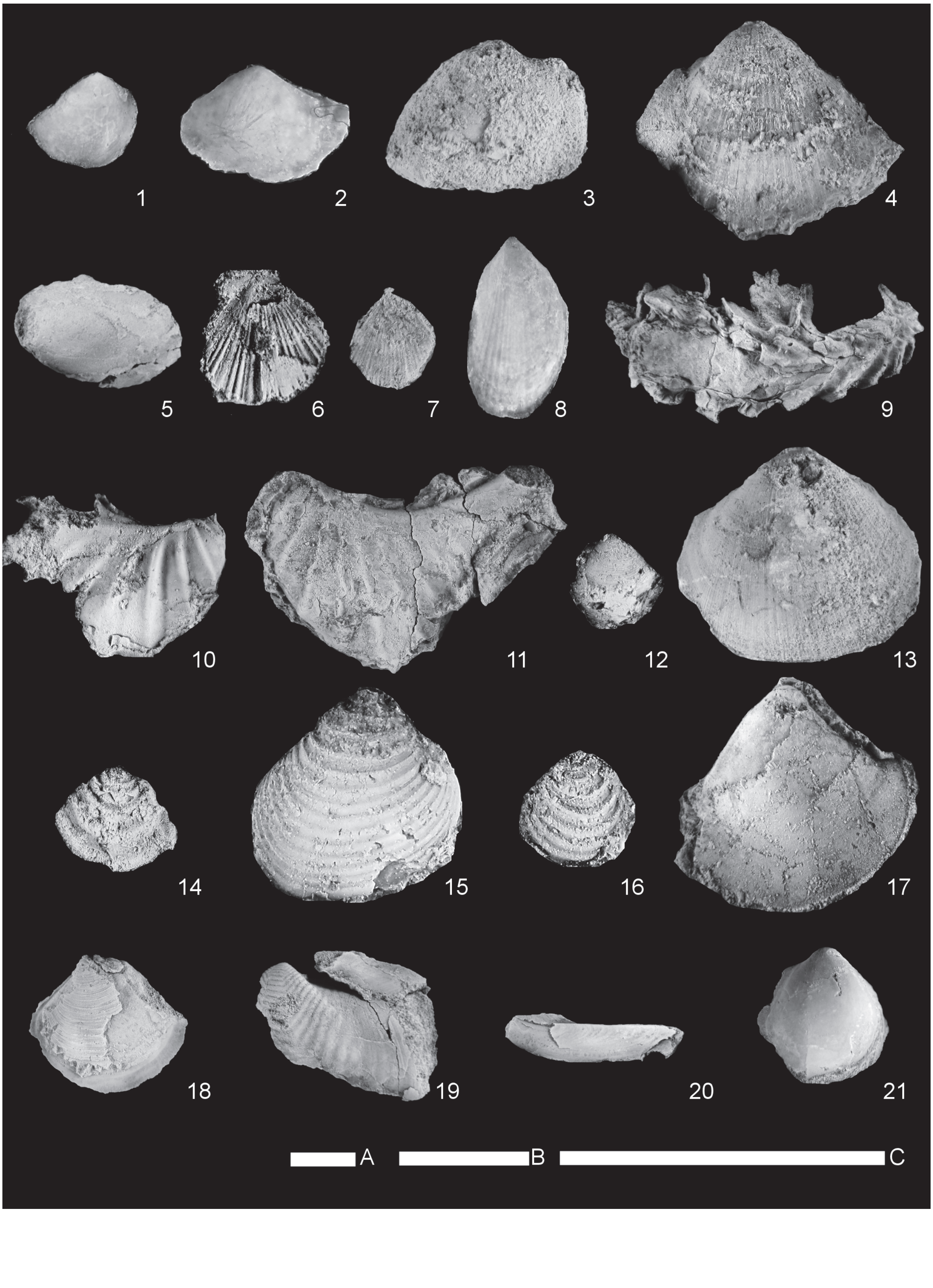


Explanation of Plate 29

Bivalves from the Sakiyama Formation exposed at Ebisudana, Miyako City, Iwate Prefecture. The scale bar of A is applied to 5, 9, 11, 18, 19 and 21. The scale bar of B is applied to 1, 3, 4, 6-8, 10, 12-14, 17 and 20. The scale bar of C is applied to the others. All scale bars are 1 cm.

1. *Nuclopsis ishidoensis*
2. *Mesosaccella insignis*
3. *Cucullaea* sp.
4. *Glycymeris densilineata*
5. *Mytilus*? sp.
6. *Neithea ficalhoi*
7. *Neithea* sp.
8. *Limatula nagaoi*
9. *Rastellum* sp.
10. *Pterotrigonia pociliformis*
11. *Pterotrigonia hokkaidoana*
12. *Lucinoma*? *kotoi*
13. *Ludbrookia* cf. *tenuicostata*
14. *Astarte subsenecta*
15. *Astarte submalioides*
16. *Astarte minor*
17. *Eriphyla miyakoensis*
18. *Eriphyla pulchella*
19. *Goniomya* sp.
20. *Anthonya* sp.
21. *Protocardia hiraigensis*

Plate 29

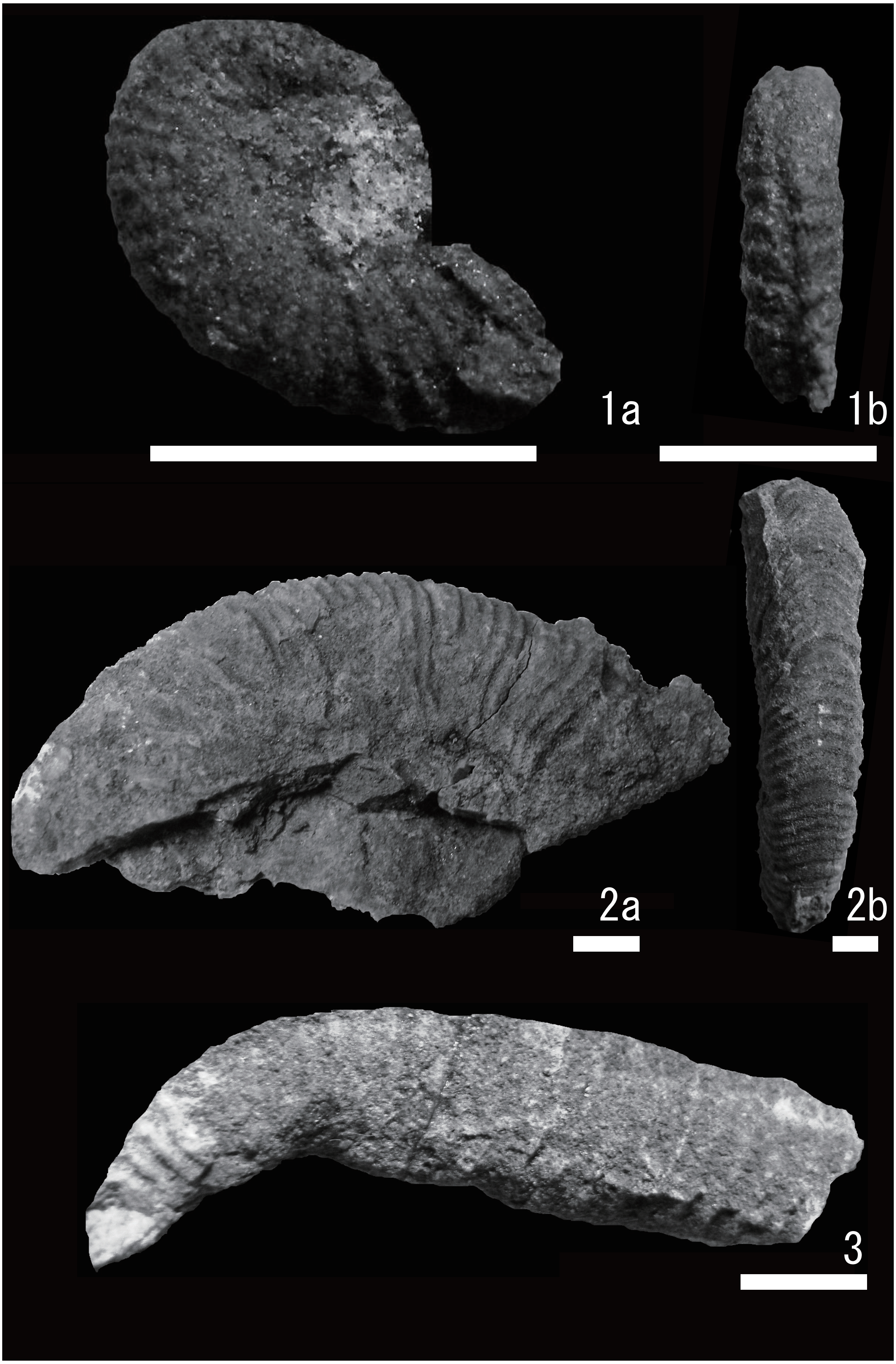


Explanation of Plate 30

Ammonoids from the Aketo Formation exposed at coast of Aketo, Tanohata Village, Shimohei County, Iwate Prefecture. All scale bars are 1 cm.

1. *Pseudoleymeriella* sp.
2. *Pseudohaploceras* sp.
3. *Hamites* sp.

Plate 30

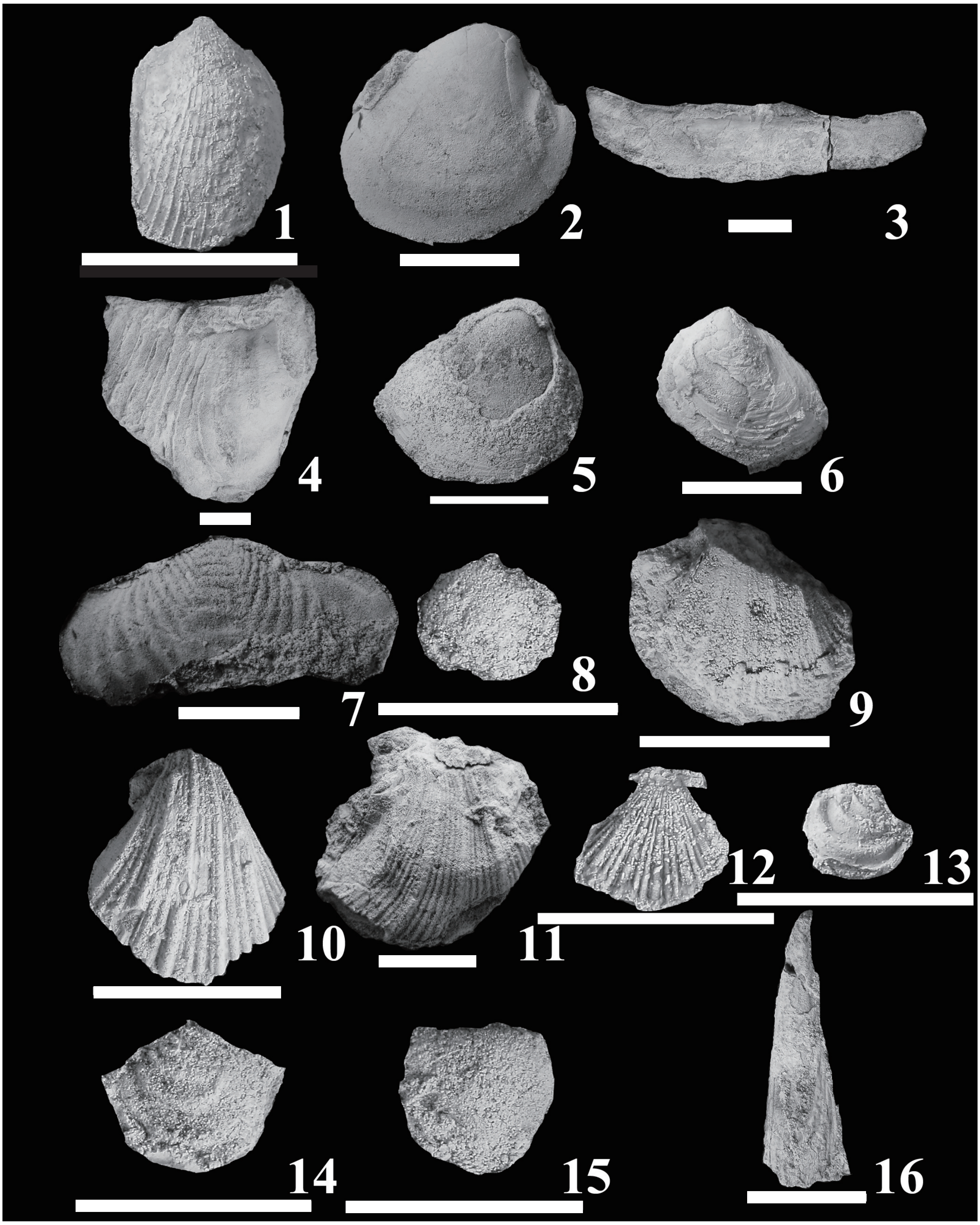


Explanation of Plate 31

Bivalves from the Aketo Formation exposed at coast of Aketo, Tanohata Village, Shimohei County, Iwate Prefecture. All scale bars are 1 cm.

1. *Limatula nagaoi*
2. *Eriphyla miyakoensis*
3. *Anthonya japonica*
4. *Pterotrigonia hokkaidoana*
5. *Eriphyla pulchella*
6. *Nipponitrigonia* sp.
7. *Goniomya subarchiai*
8. *Glycymeris densilineata*
9. *Neithea matsumotoi*
10. *Neithea ficalhoi*
11. *Neithea nipponica*
12. *Neithea* sp.
13. *Astarte minor*
14. *Astarte submalioides*
15. *Mesosaccella insignis*
16. *Pinna* sp.

Plate 31

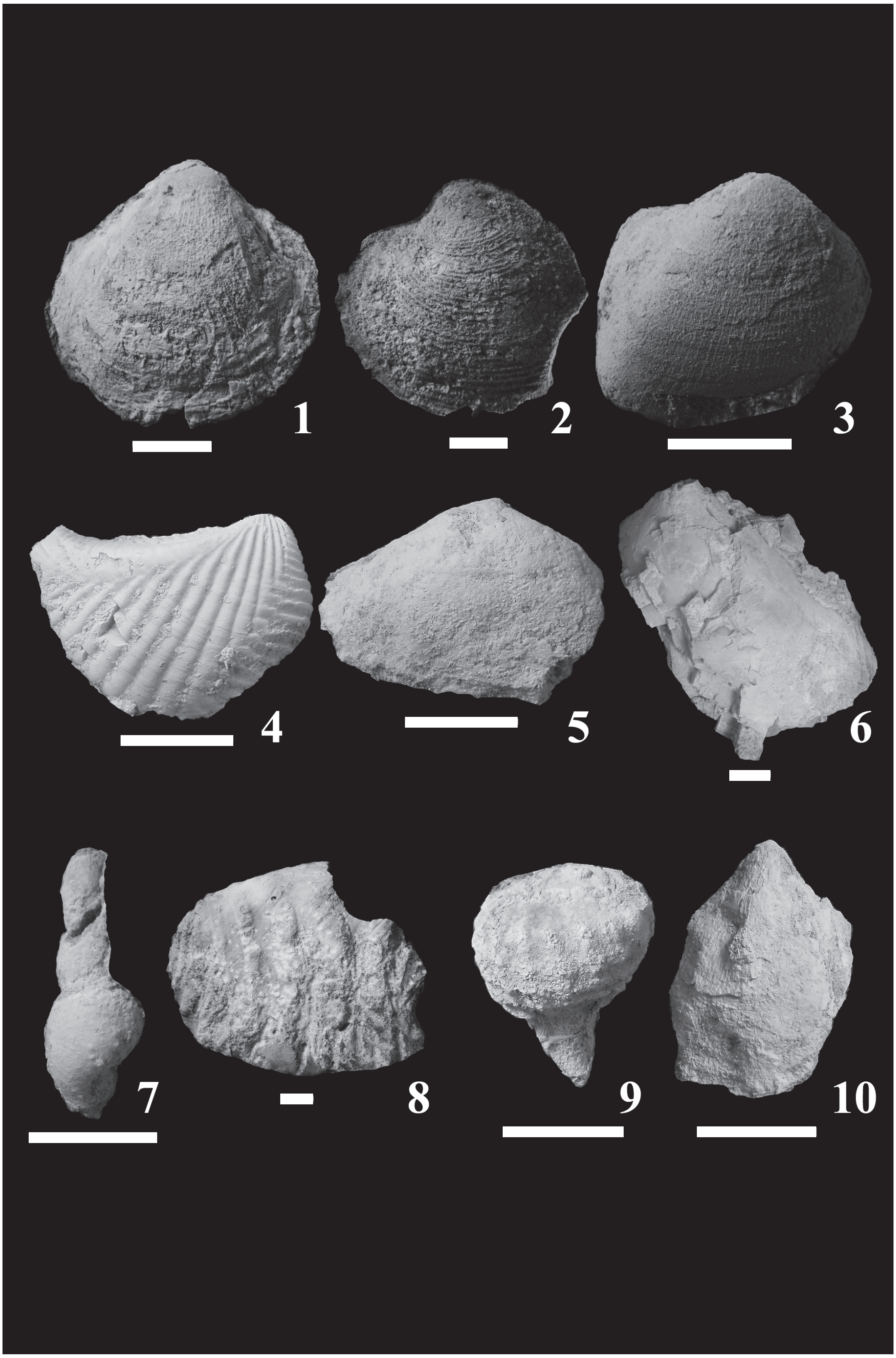


Explanation of Plate 32

Fossils from the Facies 3 of the Obisagawa Memember. All scale bars are 1 cm.

1. *Glycymeris amakusnsis* from Kayanosawa, Hirono Town, Futaba County, Fukushima Prefecture.
2. *Loxo japponica* from Kayanosawa, Hirono Town, Futaba County, Fukushima Prefecture.
3. *Cucullaea* sp. from Kayanosawa, Hirono Town, Futaba County, Fukushima Prefecture.
4. *Apiotrigonia minor* from Kayanosawa, Hirono Town, Futaba County, Fukushima Prefecture.
5. *Periploma* sp. from Kayanosawa, Hirono Town, Futaba County, Fukushima Prefecture.
6. *Isognomon*? sp. from Kayanosawa, Hirono Town, Futaba County, Fukushima Prefecture.
7. *Turritella*? sp. from Kayanosawa, Hirono Town, Futaba County, Fukushima Prefecture.
8. *Yadia* sp. from Lower of Ashizawa, Iwaki City, Fukushima Prefecture.
9. *Sargana* sp. from Kayanosawa, Hirono Town, Futaba County, Fukushima Prefecture.
10. *Opis* sp. from Kayanosawa, Hirono Town, Futaba County, Fukushima Prefecture.

Plate 32

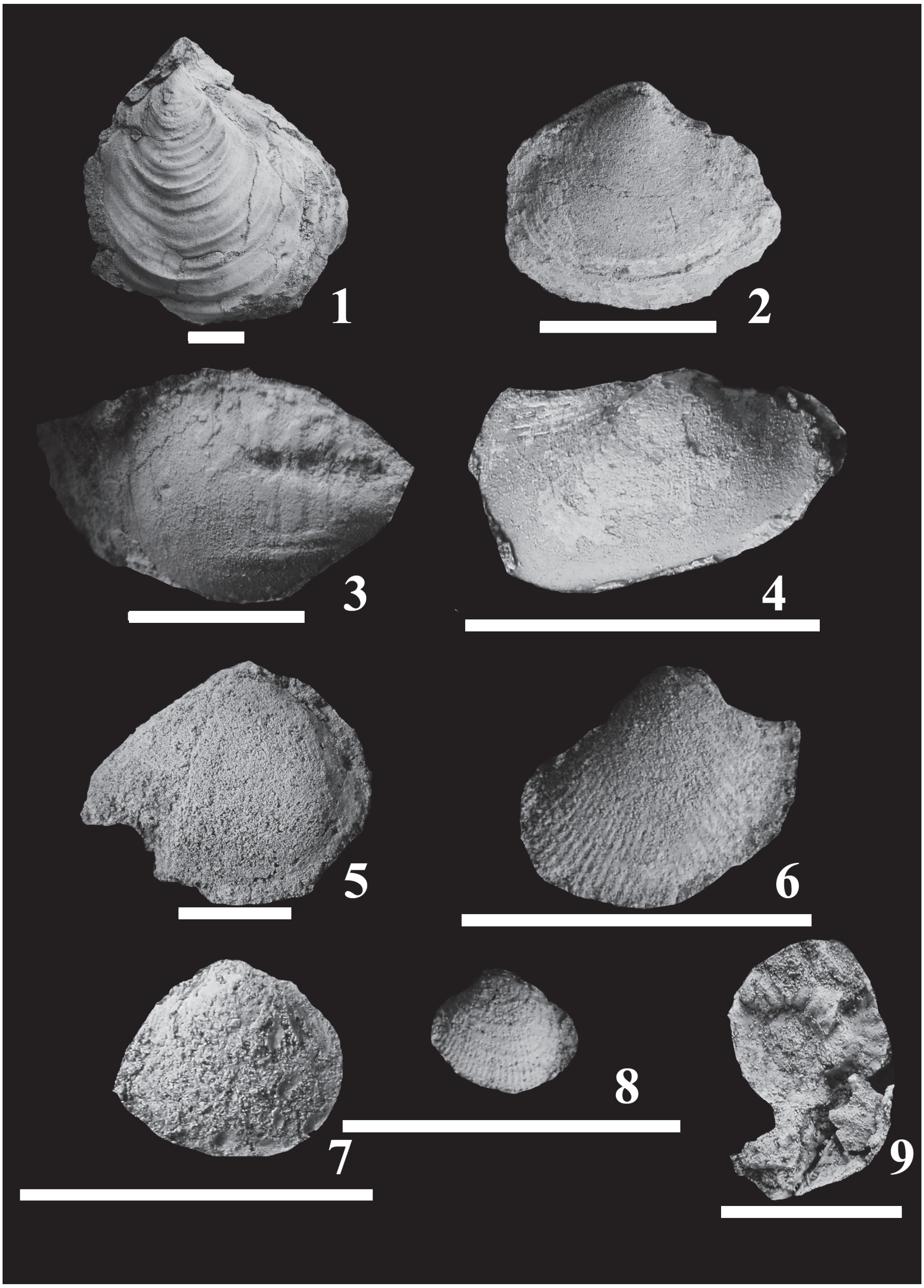


Explanation Plate 33

Fossils from the Facies 4 of the Obisagawa Member. All scale bars are 1 cm.

1. *Inoceramus uwajimensis* from middle of Ashizawa, Iwaki City, Fukushima Prefecture.
2. *Myrtea ezoensis* from middle of Ashizawa, Iwaki City, Fukushima Prefecture.
3. *Apiotrigonia minor* from middle of Ashizawa, Iwaki City, Fukushima Prefecture.
4. *Nanonavis sachalinensis* from middle of Ashizawa, Iwaki City, Fukushima Prefecture.
5. *Glycymeris amakusensis* from Minamisawa, Hirono Town, Futaba County, Fukushima Prefecture.
6. *Acila* sp. from middle of Ashizawa, Iwaki City, Fukushima Prefecture.
7. *Myrtea ezoensis* from Momonokizawa, Iwaki City, Fukushima Prefecture.
8. *Costocynera* cf. *matsumotoi* from middle of Ashizawa, Iwaki City, Fukushima Prefecture.
9. *Scaphites*? sp from middle of Ashizawa, Iwaki City, Fukushima Prefecture.

Plate 33

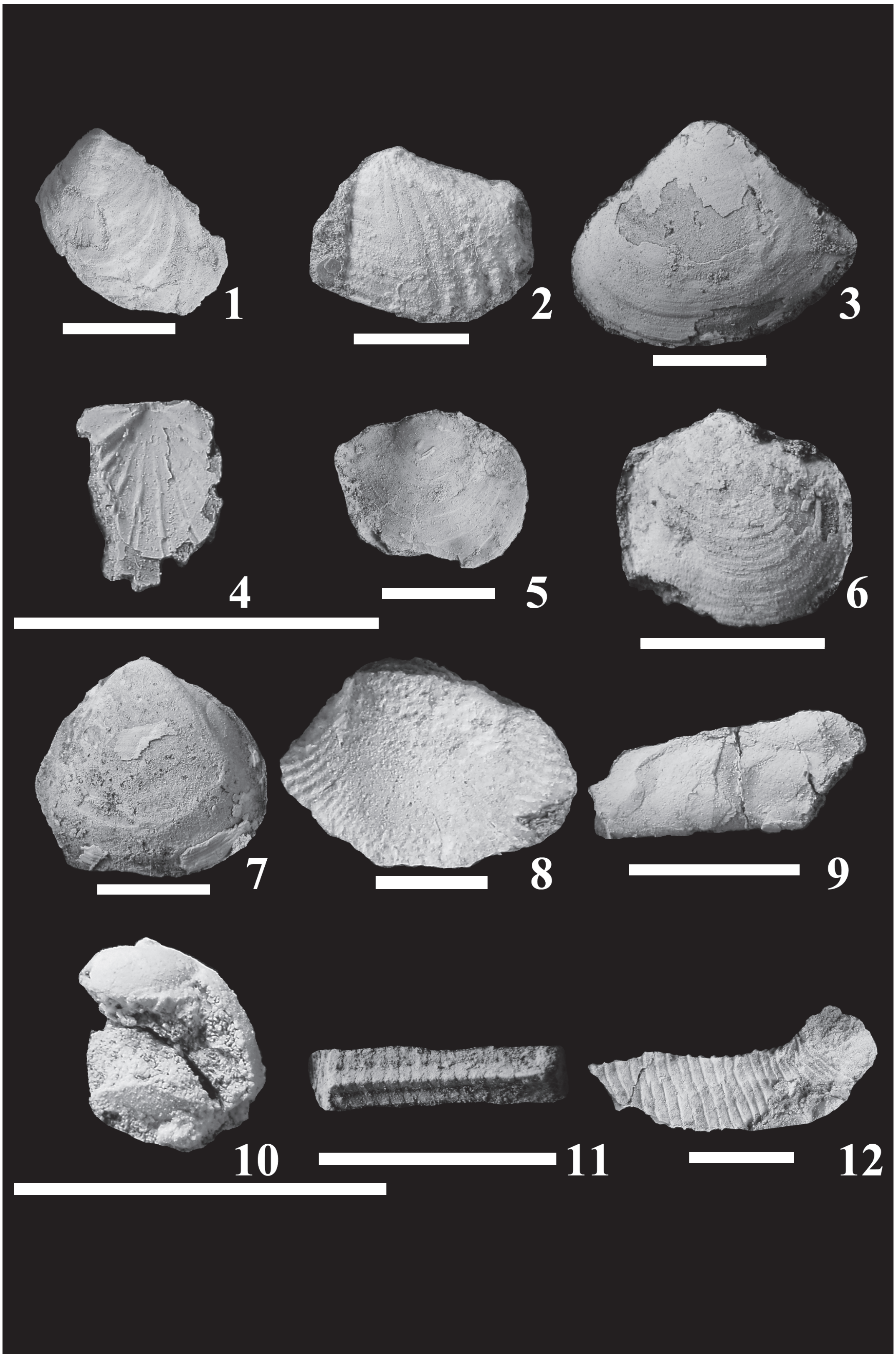


Explanation of Plate 34

Fossils from the Facies 5 of the Obisagawa Member. All scale bars are 1 cm.

1. *Inoceramus uwajimensis* from Yoheisaku, Iwaki City, Fukushima Prefecture.
2. *Apiotrigonia minor* from Yoheisaku, Iwaki City, Fukushima Prefecture.
3. *Periploma* sp. from Yoheisaku, Iwaki City, Fukushima Prefecture.
4. *Parvamussium yubarense* from Yoheisaku, Iwaki City, Fukushima Prefecture.
5. *Eriphyra higoensis* from Yoheisaku, Iwaki City, Fukushima Prefecture.
6. *Myrtea ezoensis* from Yoheisaku, Iwaki City, Fukushima Prefecture.
7. *Glycymeris amakusensis* from Yoheisaku, Iwaki City, Fukushima Prefecture.
8. *Acila* sp. from Yoheisaku, Iwaki City, Fukushima Prefecture.
9. *Leptosolen* sp. from Yoheisaku, Iwaki City, Fukushima Prefecture.
10. Isocrinidae gen. et. sp. indet. from Yoheisaku, Iwaki City, Fukushima Prefecture.
11. *Natica* sp. from Yoheisaku, Iwaki City, Fukushima Prefecture.
12. *Polyptychoceras*? sp. from Yoheisaku, Iwaki City, Fukushima Prefecture.

Plate 34

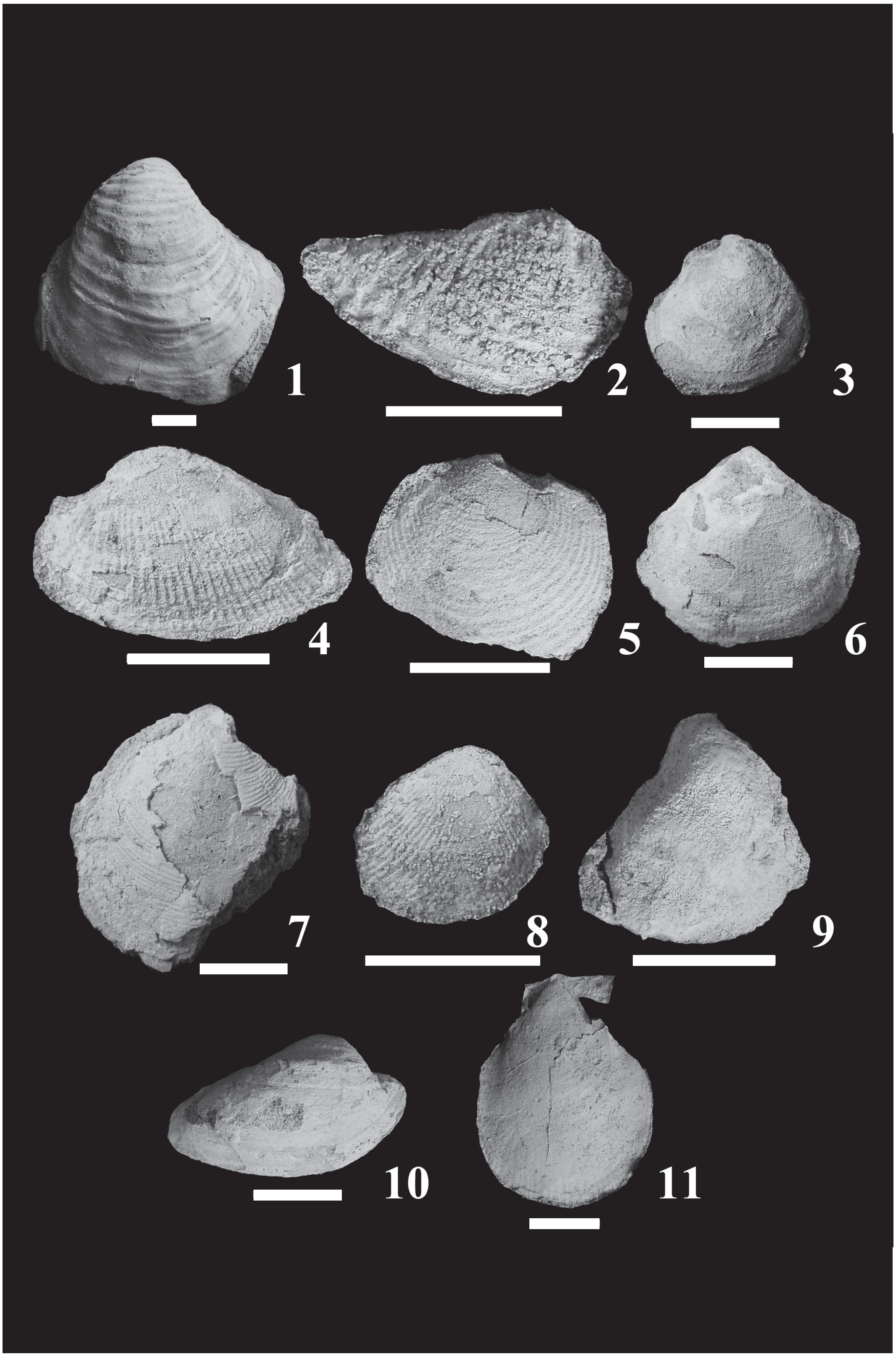


Explanation of Plate 35

Bivalves from the Facies 6 of the Obisagawa Member. All scale bars are 1 cm.

1. *Inoceramus uwajimensis* from Ammonite Center, Iwaki City, Fukushima Prefecture.
2. *Apiotrigonia minor* from Ammonite Center, Iwaki City, Fukushima Prefecture.
3. *Eriphyra higoensis* from Ammonite Center, Iwaki City, Fukushima Prefecture.
4. *Nanonavis sachalinensis* from Ammonite Center, Iwaki City, Fukushima Prefecture.
5. *Myrtea ezoensis* from Ammonite Center, Iwaki City, Fukushima Prefecture.
6. *Glycymeris amakusensis* from Ammonite Center, Iwaki City, Fukushima Prefecture.
7. *Loxo japonica* from Ammonite Center, Iwaki City, Fukushima Prefecture.
8. *Acila* sp. from Ammonite Center, Iwaki City, Fukushima Prefecture.
9. *Crassostrea*? sp. from Ammonite Center, Iwaki City, Fukushima Prefecture.
10. *Clisocolus* sp. from Ammonite Center, Iwaki City, Fukushima Prefecture.
11. Internal mold of Pectenidae gen. et. sp. indet. from Ammonite Center, Iwaki City, Fukushima Prefecture.

Plate 35

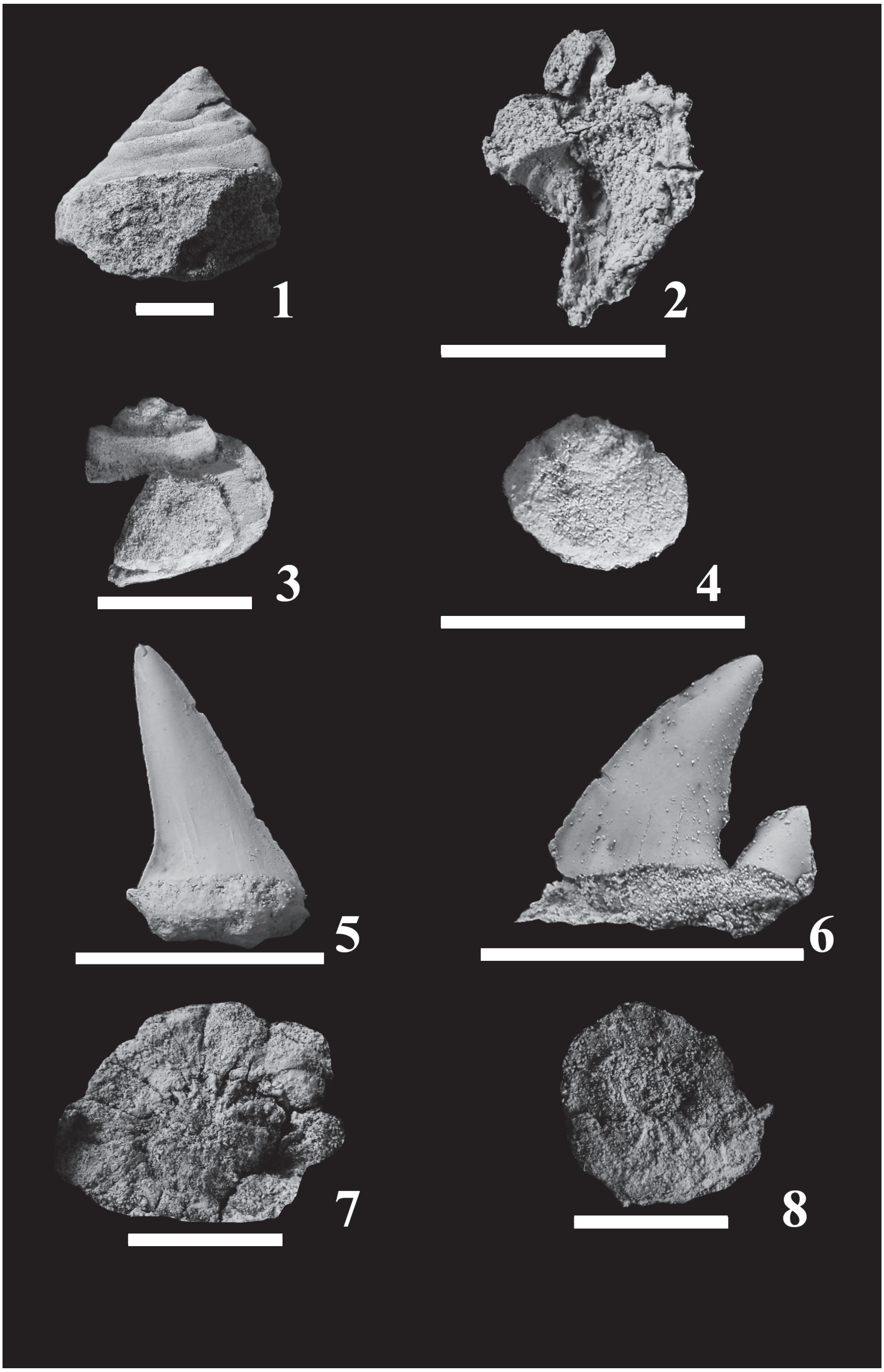


Explanation of Plate 36

Fossils from the Facies 6 of the Obisagawa Member. All scale bars are 1 cm.

1. Calypteraeidae gen. et. sp. indet. from Ammonite Center, Iwaki City, Fukushima Prefecture.
2. *Paladmete* sp. from Ammonite Center, Iwaki City, Fukushima Prefecture.
3. *Gyrodes* sp. from Ammonite Center, Iwaki City, Fukushima Prefecture.
4. *Natica* sp. from Ammonite Center, Iwaki City, Fukushima Prefecture.
5. *Scapanorhynchus* sp. from Ammonite Center, Iwaki City, Fukushima Prefecture.
6. *Cretolamna* sp. from Ammonite Center, Iwaki City, Fukushima Prefecture.
7. Pines from Ammonite Center, Iwaki City, Fukushima Prefecture.
8. *Scaphites*? sp. from Ammonite Center, Iwaki City, Fukushima Prefecture.

Plate 36

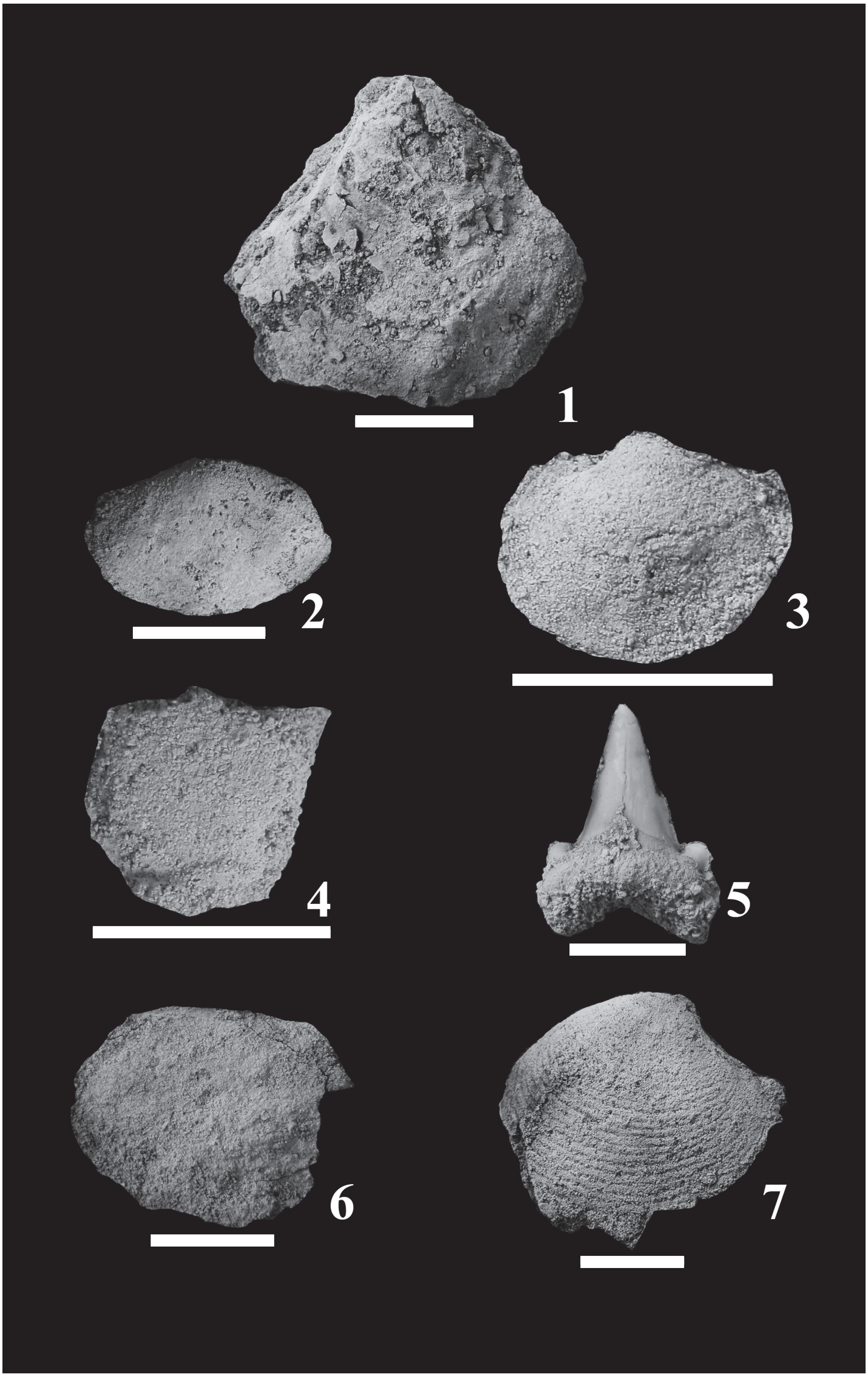


Explanation of Plate 37

Fossils from the Facies 7 of the Irimazawa Member. All scale bars are 1 cm.

1. *Inoceramus* sp. from Irimazawa, Iwaki City, Fukushima Prefecture.
2. *Ezonuculana mactraeformis* from Irimazawa, Iwaki City, Fukushima Prefecture.
3. *Glycymeis amakusensis* from Irimazawa, Iwaki City, Fukushima Prefecture.
4. *Nanonavis sachalinensis*. from Irimazawa, Iwaki City, Fukushima Prefecture.
5. *Cretolamna* sp. from Irimazawa, Iwaki City, Fukushima Prefecture.
6. *Apiotrigonia minor* from Irimazawa, Iwaki City, Fukushima Prefecture.
7. *Loxo japonica* from Irimazawa, Iwaki City, Fukushima Prefecture.

Plate 37



Explanation of Plate 38

Figure A. Ammonoids from the Hiraiso Formation exposed at Coast of Hiraiso, Hitachinaka City, Ibaraki Prefecture. A scale bar is 1 cm.

1. *Didymoceras awajiense*
2. *Diplomoceras* ? sp.

Figure B. Trace fossils from the Isoai Formation exposed at Coast of Hiraiso, Hitachinaka City, Ibaraki Prefecture.

Plate 38

A

B

Explanation of Plate 39

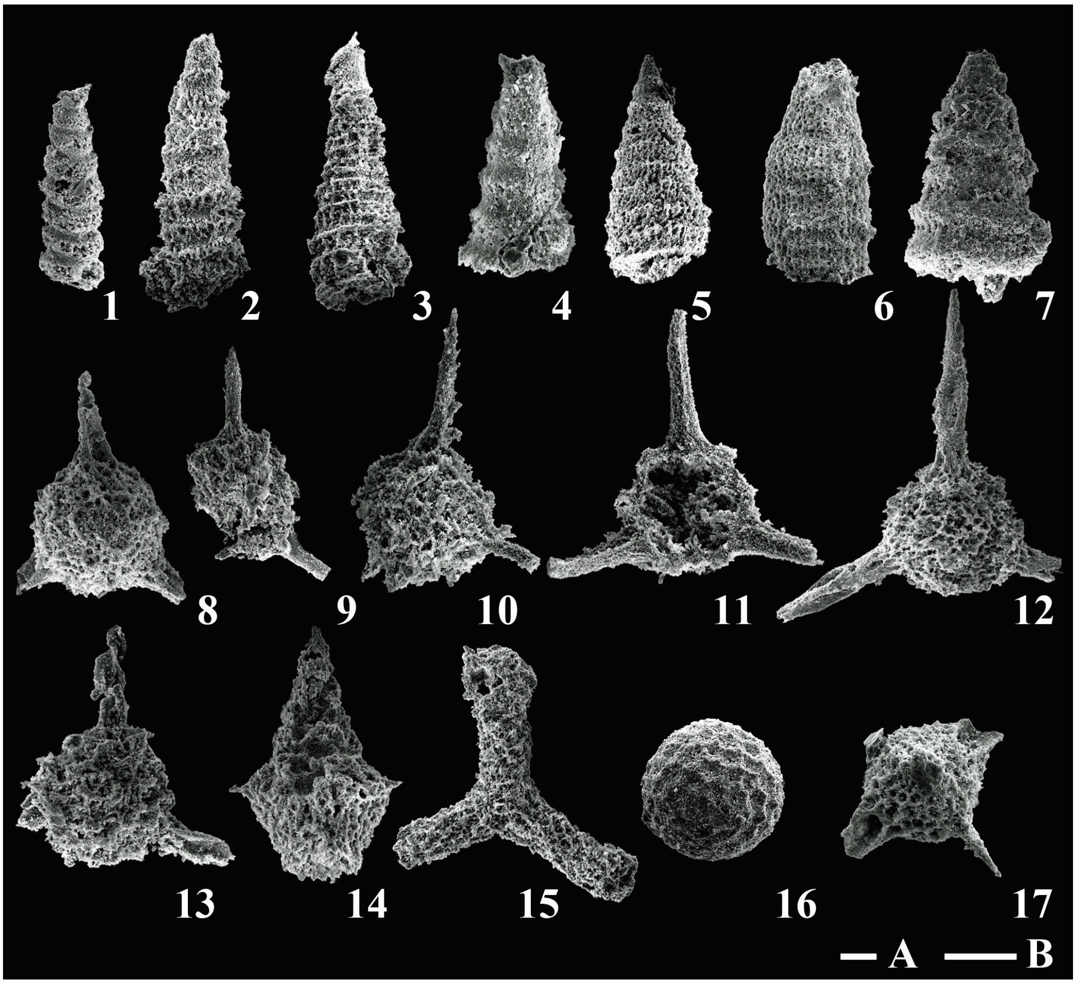
Radioralians from the clasts of the conglomerate in the Isoai Formation of the Nakaminato Group. All specimens are obtained from coast of Hiraiso, Hitachinaka City, Ibaraki Prefecture. Both scale bars are 50 µm. The scale bar A is applied to 1-3, 5, 6, 9 and11-15. The scale bar B is applied to 4, 7, 8, 10, 16 and 17.

1. *Triassocampe coronata* Bragin, 1991
2. *Triassocampe deweveri* (Nakaseko and Nishimura, 1979)
3. *Triassocampe* sp.
4. *Triassocampe*? sp.
5. *Pseudodictyomitrella*? sp.
6. *Archaeodictyomitra* sp.
7. *Canoptum*? sp.
8. *Hexalonche*? sp.

9, 10. *Spongostephanidium*? sp.

11. *Annulopoulpus*? sp.
12. *Capnuchosphaera* cf. *deweveri* Kozur and Mostler, 1979
13. *Betraccium* sp.
14. *Syringocapsa* sp.
15. *Paronaella* sp.
16. *Gongylothorax favosus* Dumitrica, 1970
17. Spumellaria? gen. et sp. indet.

Plate 39



Explanation of Plate 40

Figure A-1, 2. *Portlandia sanchuesnsis* from the Toriakeura Formation exposed at Coast of Toriakeura, Choshi City, Chiba Prefecture.

Figure B. *Macharonichnus* isp. A from the Kimigahama Formation exposed at Coast of Kimigahama, Choshi City, Chiba Prefecture.

Figure C. *Macharonichnus* isp. B from the Kimigahama Formation exposed at Coast of Kimigahama, Choshi City, Chiba Prefecture.

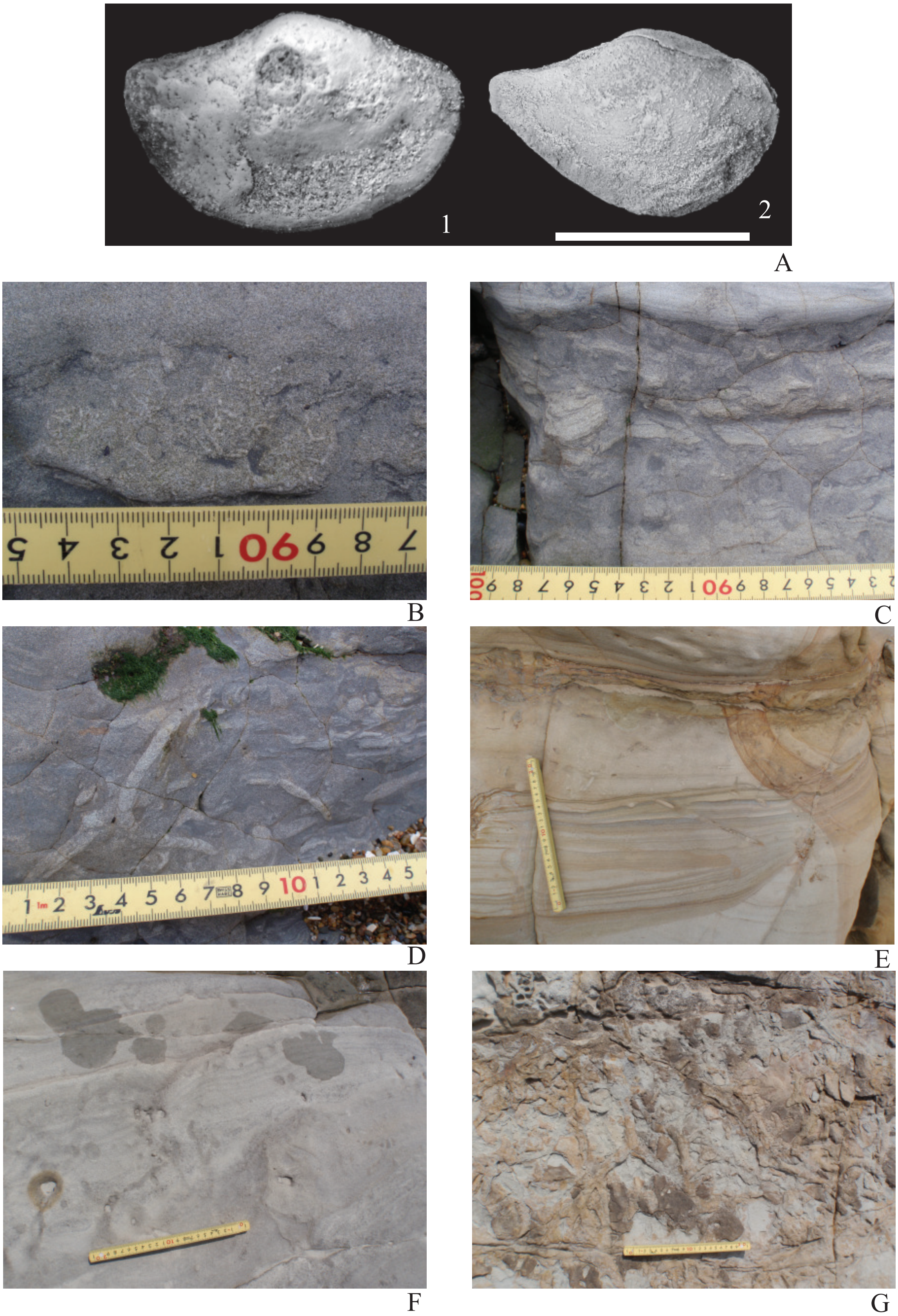
Figure D. *Zoophycos* isp. from the Kimigahama Formation exposed at Coast of Kimigahama, Choshi City, Chiba Prefecture.

Figure E. *Ophiomorpha* isp. from the Inubozaki Formation exposed at Coast of Inubozaki, Choshi City, Chiba Prefecture.

Figure F. *Arenicolites* isp. from the Inubozaki Formation exposed at Coast of Inubozaki, Choshi City, Chiba Prefecture.

Figure G. *Tharassinoides* isp. from the Inubozaki Formation exposed at Coast of Inubozaki, Choshi City, Chiba Prefecture.

Plate 40



Explanation of Plate 41

Fossils from the Shiroi Formation exposed at Bomukizawa, Sakuho Town, Minamisaku County, Nagano Prefecture. A scale bar is 1 cm.

1. External cast of *Hayamina naumanni*.
2. Internal cast of *Hayamina naumanni*.

Plate 41

Explanation of Plate 42

Fossils from the Ishido Formation exposed at Mamonozawa River, Ueno Village, Tano County, Gunma Prefecture. The scale bar A is applied to 1. The scale bar B is applied to 2 and 3. The scale bar C is applied to 4 to 8. All scale bars are 1 cm.

1.External cast of *Hayamina naumanni*

2, 3. *Cassiope* (*Cassiopella*) *ogaii*

4. Internal cast of *Costocynera matsumotoi*

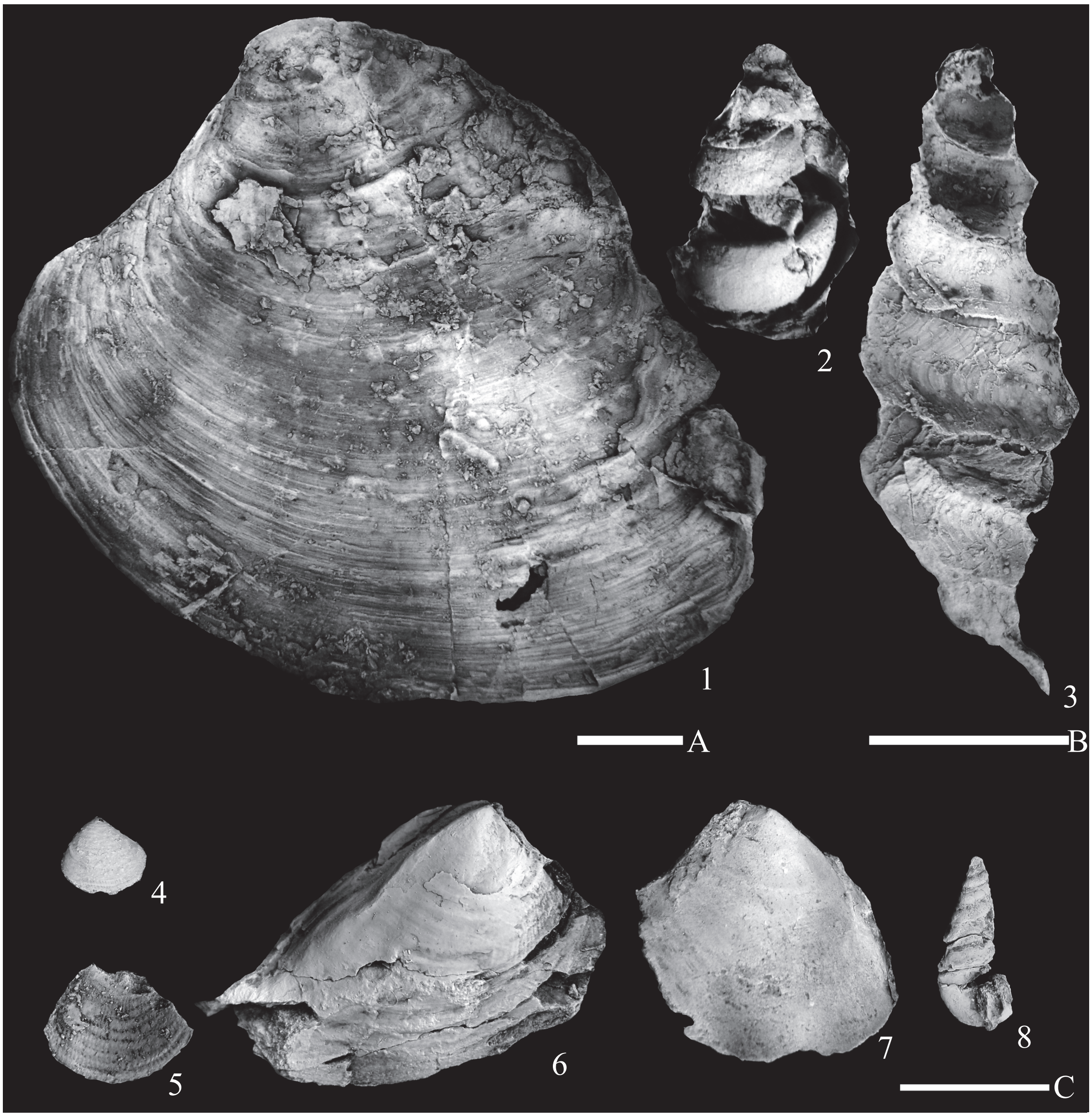
5. External cast of *Costocynera matsumotoi*

6. *Hayamina minor*

7. *Pachytraga japonica*

8. Gastropoda gen. et sp. indet.

Plate 42

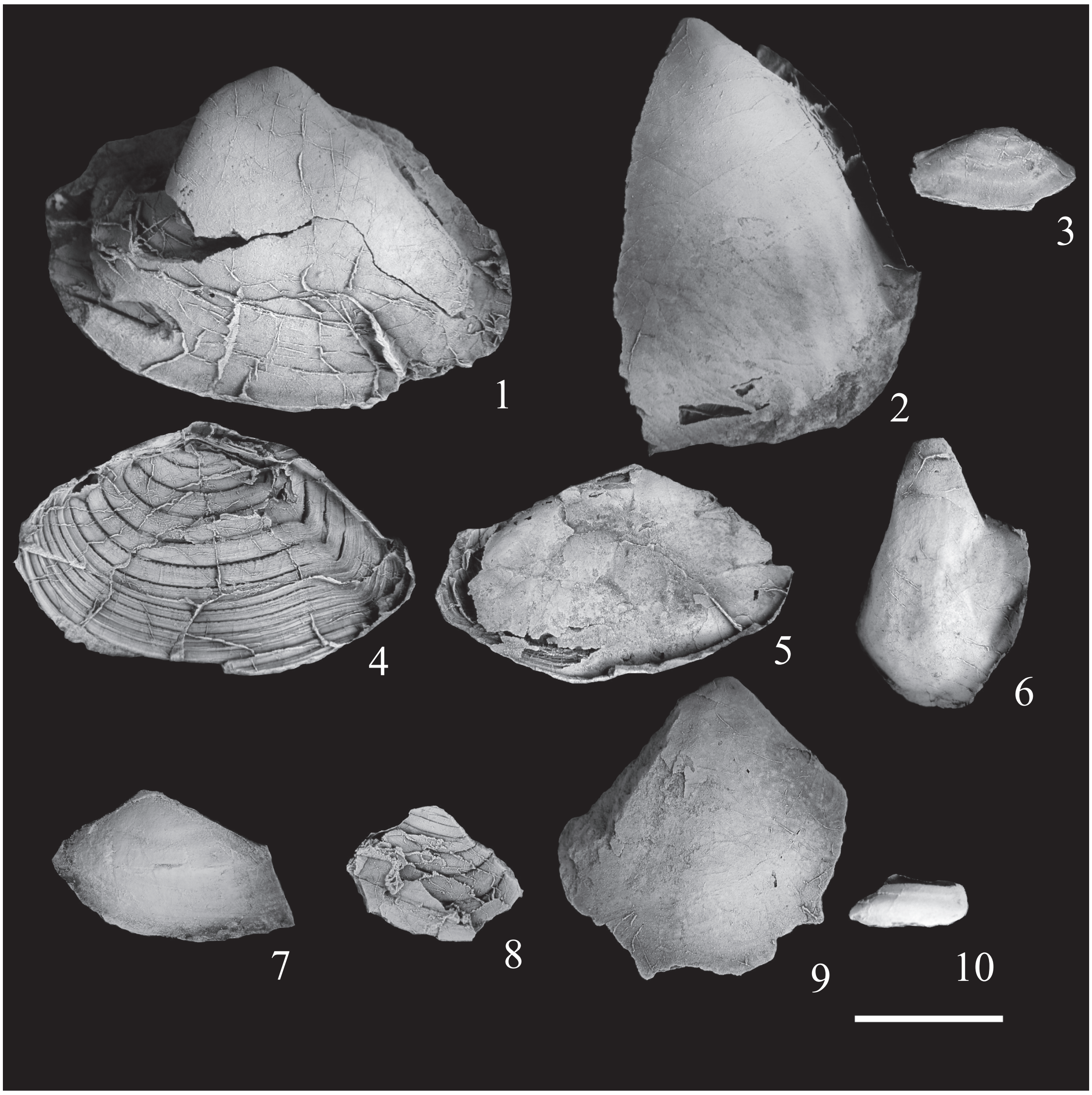


Explanation of Plate 43

Fossils from the Ishido Formation exposed at Bomukizawa, Sakuho Town, Minamisaku County, Nagano Prefecture. A scale bar is 1 cm.

1. *Cucullaea* sp.
2. *Protocardia* sp.
3. *Scittila dericatostriata*
4. External cast of *Costocynera otsukai*
5. Internal cast of *Costocynera otsukai*
6. *Protocardia* ? sp.
7. External cast of *Costocynera matsumotoi*
8. Internal cast of *Costocynera matsumotoi*
9. *Pachytraga japonica*
10. Gastropoda gen. et sp. indet.

Plate 43



Explanation of Plate 44

Formaminifers from the Facies 5 of the Ishido Formation. 5-7, 9, 11, 19 and 24 are obtained from upper of Kuro River, Ueno Village, Tano County, Gunma Prefecture. The others are obtained from Shinzaburozawa, Sakuho Town, Minamisaku County, Nagano Prefecture. All scale bars are 100 μm. The scale bar A is applied to 24.The scale bar B is applied to 18-20 and 22. The scale bar C is applied to 11. The scale bar D is applied to 9 and 23. The scale bar E is applied to 8 and 21. The scale bar F is applied to 1-3, 5, 6, 10, 12, 13 and 16. The scale bar G is applied to 4, 7, 14, 15 and 17.

1-3. *Globigerinelloides* aff. *blowi*

4-6. *Hedbergella planispira*

7. *Globuligerina hoterivica*

8-10. *Haplophragmoides* sp.

11. *Haplophragmoides* ? sp.

12, 13. *Pullenia* sp.

14, 16, 17. *Saccamia* sp.

15. *Paratrochammides* sp.

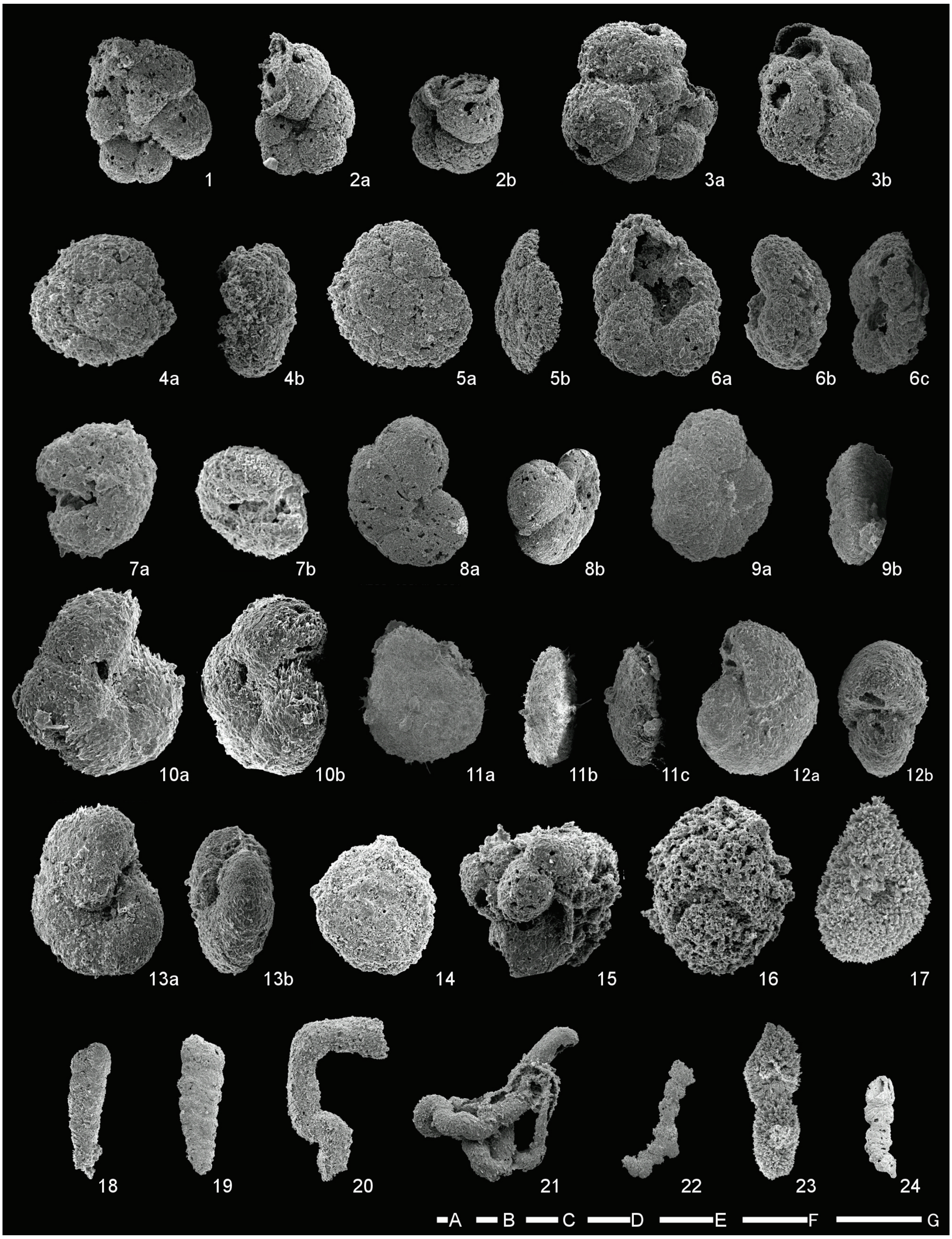
23, 24. Foraminifera gen. et sp. indet.

18, 19. *Pseudobolivina* sp.

20, 21. *Tolypammina* sp.

22. *Bigenerina* ? sp.

Plate 44



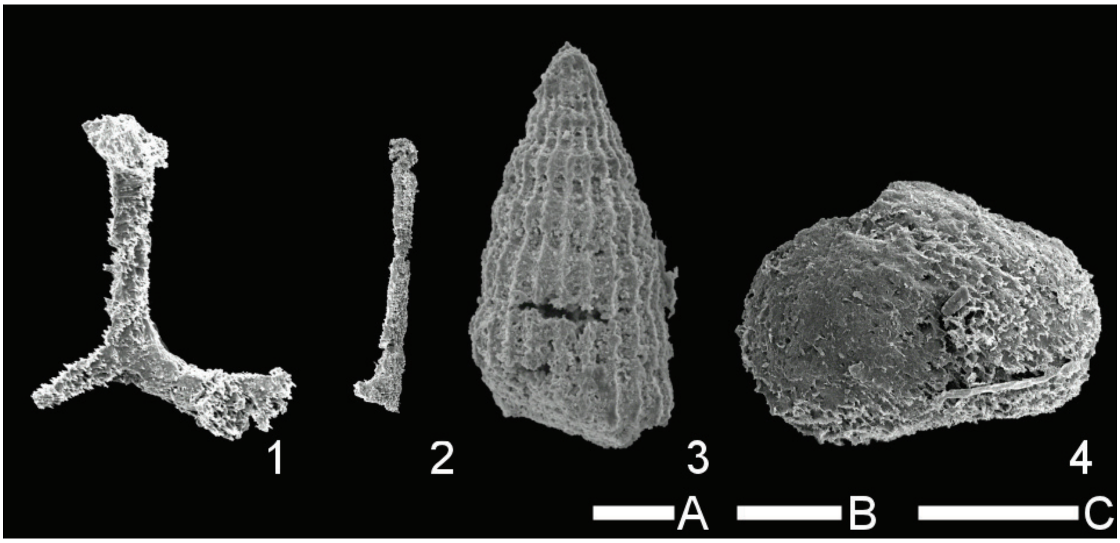
1
2a
2b
3a
3b
4a
4b
5a
5b
6a
6b
6c
7a
7b
8a
8b
9a
9b
10a
10b
11a
11b
11c
12a
12b
13a
13b
14
15
16
17
18
19
20
21
22
23
24
A
B
C
D
E
F
G

Explanation of Plate 45

Microfossils from the Facies 5 of the Ishido Formation. 3 is obtained from upper of Kuro River, Ueno Village, Tano County, Gunma Prefecture. The others are obtained from Shinzaburozawa, Sakuho Town, Minamisaku County, Nagano Prefecture. All scale bars are 100 μm. The scale bar A is applied to 2. The scale bar B is applied to 4. The scale bar C is applied to 1 and 3.

1. Sponge spicular (four axes type)
2. Sponge spicular (one axis type)
3. *Archaeodictyomitra* sp.
4. Ostracoda gen. et sp. indet.

Plate 45



Explanation of Plate 46

Fossils from the Sanyama Formation exposed at Ohnozawa Pass, Saku City, Nagano Prefeture. All scale bars are 1 cm. The scale bar A is applied to 1 and 2. The scale bar B is applied to 3-8.

1, 2. Echinoidea gen. et sp. indet. (counter parts)

3. Internal cast of *Portlandia sanchuensis*

4. External cast of *Portlandia sanchuensis*

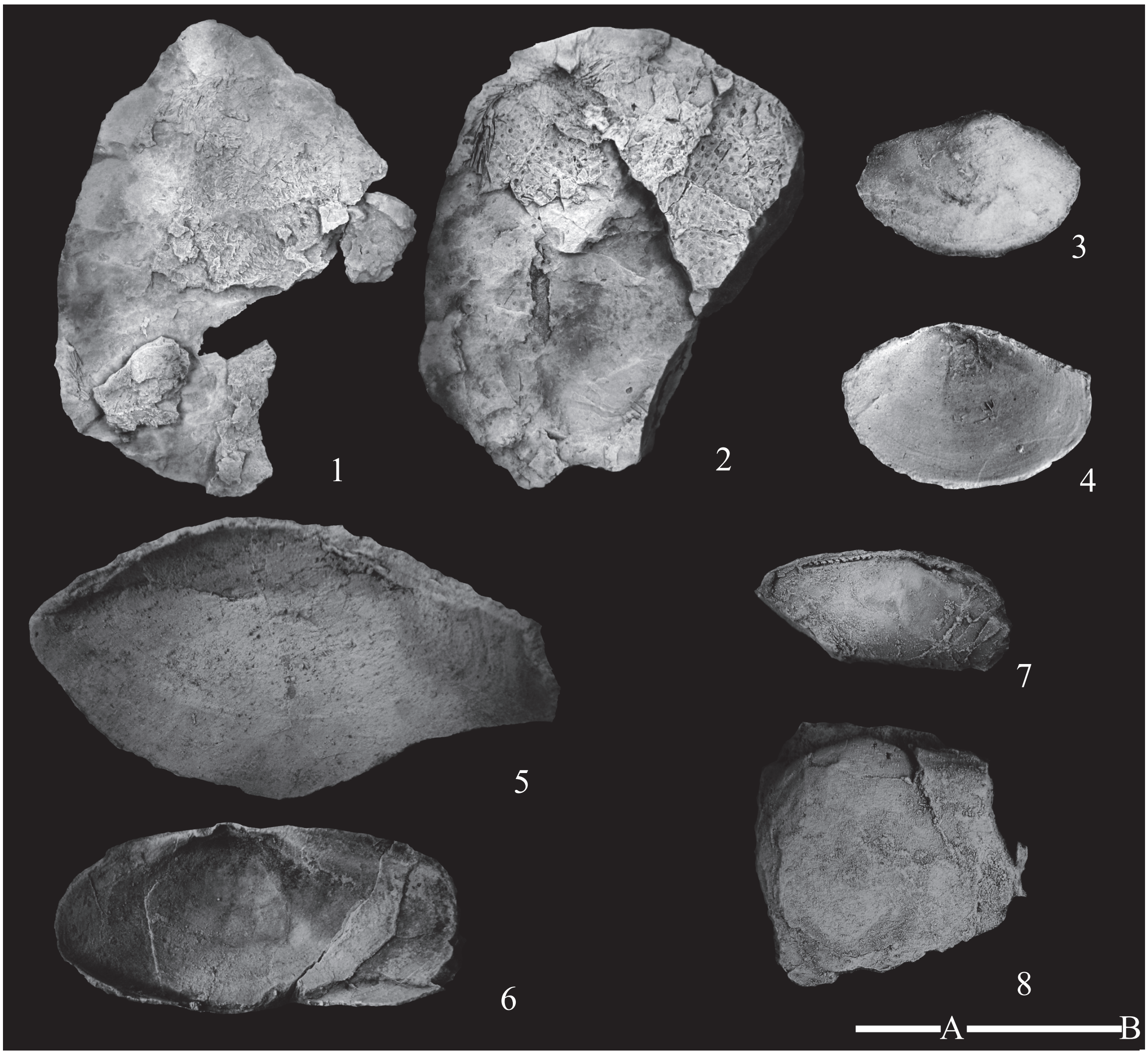
5. External cast of Bivalvia gen. et sp. indet.

6. External cast of *Corbula* sp.

7. External cast of *Portlandia sanchuensis*

8. Internal cast of *Tetoria sanchuensis*

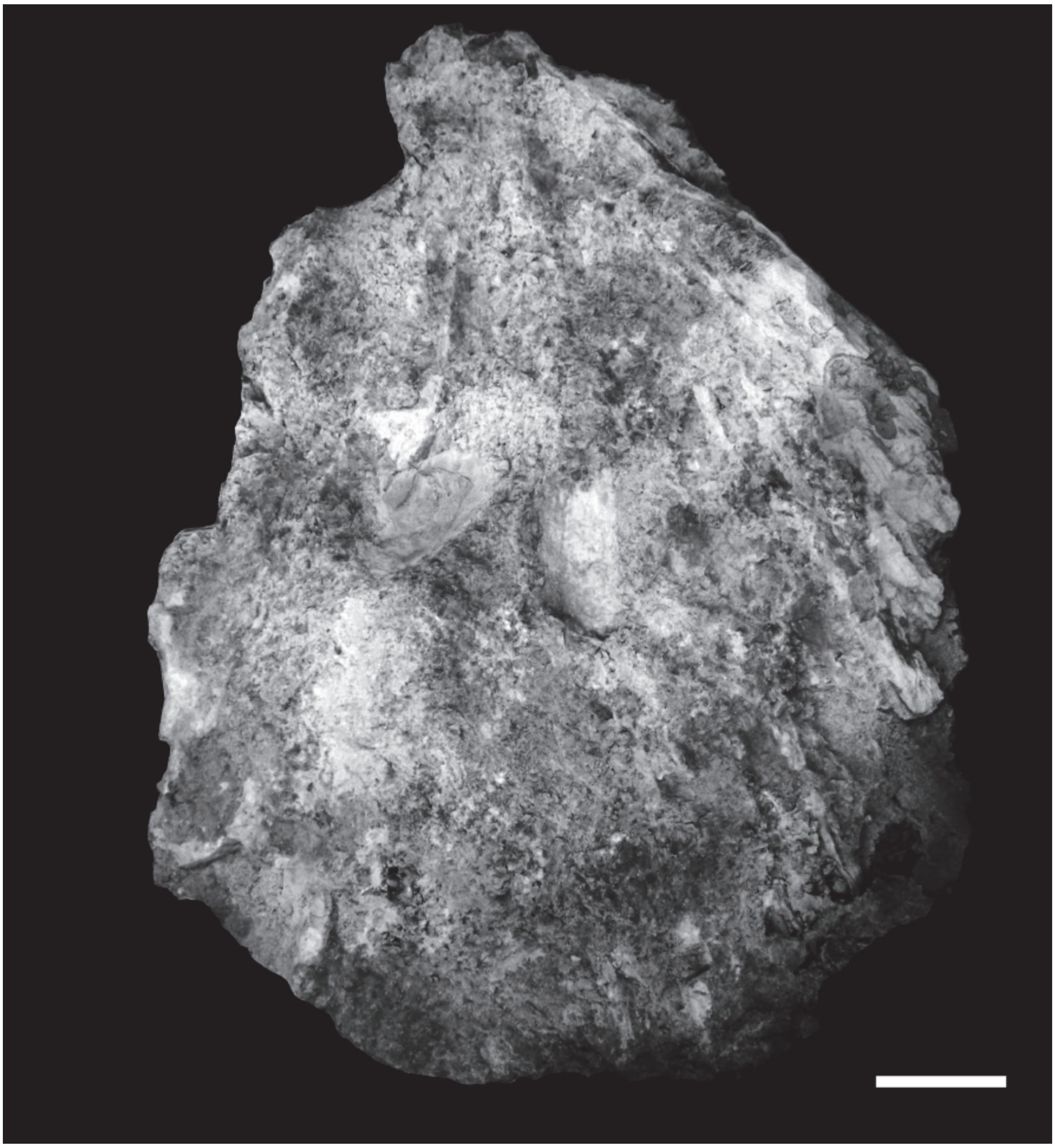
Plate 46



Explanation of Plate 47

Neithea sp. from the Tozawa Formation exposed at Tozawa, Nanmoku Village, Kanra County, Gunma Prefecture. A scale bar is 1 cm.

Plate 47



Explanation of Plate 48

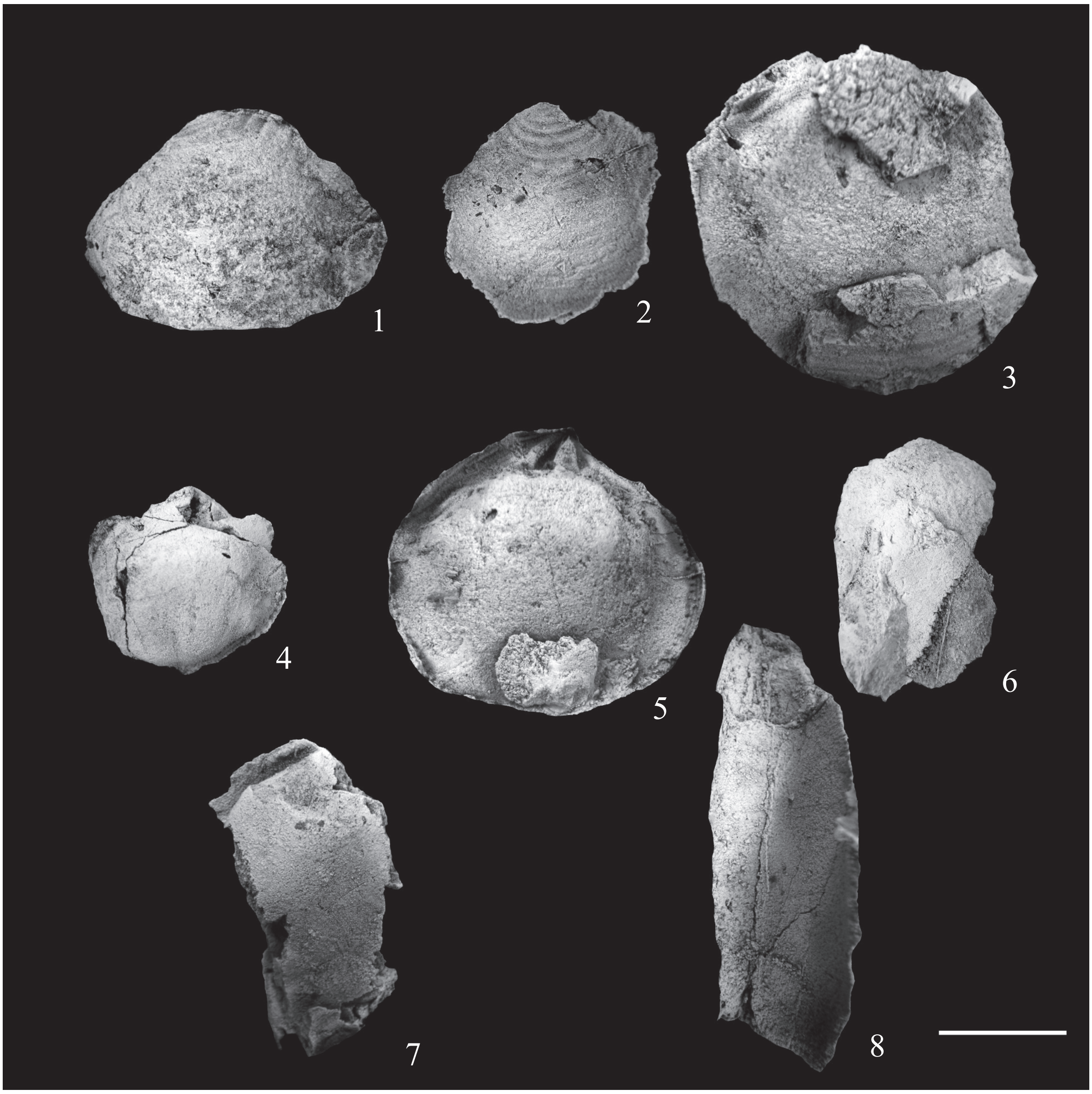
Fossils from the Ohnita Formation exposed at Tozawa, Nanmoku Village, Kanra County, Gunma Prefecture. A scale bar is 1 cm.

1. Internal cast of *Nipponitrigonia* sp.
2. External cast of *Nipponitrigonia* sp.
3. *Myrtea* sp.
4. Internal cast of *Astarte costata*
5. Internal cast of *Astarte yatsushiroensis*

6, 7. Internal cast of *Yabea*? sp.

8. *Neohibolites* sp.

Plate 48



Appendix

1. List of identified fossils

In the present study, the age assignments and depositional environments of the sedimentary rocks depend on previously several papers (e. g. Sashida *et al.*, 1992; Hayami, 1965a; b; 1966; Obata, 1974). For use of these schemes, the accurate identification of morphotypes of fossils is very important. Following is a list of identified species and interminable species with abbreviations of aff. or cf. illustrated in plates 25 to 47..

Order Foraminiferida d'Orbigny, 1826

Foraminifera gen. et sp. indet.

Plates 44-23; 24

Material.—Two specimens from the Ishido Formation of the Sanchu Cretaceous System.

Description.—Test free, elongate, uniserial, wall agglutinated, fine, smooth; cylindal chamber; axies slightly bent; aperture small at end of cylindal chamber.

Remarks.—The specimens are similar to Textulariina. However, to identify species from the speciemens is difficult because of poorly-preservation.

Occurrence.—The present specimens are obtained from upper of Kuro River, Ueno Village, Tano County, Gunma Prefecture and Shinzaburozawa, Sakuho Town, Minamisaku County, Nagano Prefecture.

Suborder Textulariina Delage and Herouard, 1896

Superfamily Ammodiscacea Reuss, 1862

Family Saccamminidae Brady, 1884

Subfamily Saccammininae Brady, 1884

Genus ***Saccammina*** Sars, 1869

Type species.—*Saccammina sphaerica* Brady, 1871

Saccamina **sp.**

Plates 44-14; 16; 17

Material.—Three specimens from the Ishido Formation of the Sanchu Cretaceous System.

Description.—Test free, simple globular chamber, spherical, oval or pyriform, wall agglutinated, fine, smooth; aperture very small, at tapered end of chamber; no distinct neck, but gradually contracted toward apertural end.

Remarks.—The present specimens are similar to *Saccamina atlantica* (Cushman, 1944) and *Saccamina* *spaerica* Sars, 1872 reported from abundant recent and fossil specimens (e. g. Vázquez Riveiros and Patterson, 2008). However, the present speciemens have more finely agglutinated wall than *S. atlantica* and smaller aperture than *S. spaerica*.

Occurrence.—The speciemens are obtained from Shinzaburozawa, Sakuho Town, Minamisaku County, Nagano Prefecture.

Family Ammodiscidae Reuss, 1862

Subfamily Tolypammininae Cushman, 1928

Genus ***Tolypammina*** Rhumbler, 1895

Type species.—*Hypermmina vagans* Brady, 1879

***Tolypammina* sp.**

Plates 44-20; 21

Material.—Two specimens from the Ishido Formation of the Sanchu Cretaceous System.

Description.—Test long, irregularly bent and undivided tubular, wall agglutinated, fine, smooth; aperture rather large, at open end of tubular chamber.

Remarks.—The present specimens are identified the genus of *Tolypammina* by long, irregularly bent and undivided tubular chamber. However, to identify species from the speciemens is difficult because of fragmentary materials.

Occurrence.—The speciemens are obtained from Shinzaburozawa, Sakuho Town, Minamisaku County, Nagano Prefecture.

Superfamily Lituolacea Blainville, 1825

Family Textulariidae Ehrenberg, 1838b

Subfamily Textulariinae Ehrenberg, 1838b

Genus ***Bigenerina*** d'Orbigny, 1826

Type species.—*Bigenerina nodosaria* Cushman, 1911

***Bigenerina*? sp.**

Plate 44-22

Material.—One specimen from the Ishido Formation of the Sanchu Cretaceous System.

Description.—Test free, elongate, bent between early biserial and later uniserial parts; 5 chambers, gradually increasing in size at early biserial part; 4 chambers, almost equal in size at later uniserial part, aperture very small at end of later uniserial part.

Remarks.—The present specimen has characters of the genus of *Bigenerina*, such as having early biserial and later uniserial parts. However, the present specimen has bent between early biserial and later uniserial parts, which is different character from the genus of *Bigenerina*.

Occurrence.—The speciemen is obtained from Shinzaburozawa, Sakuho Town, Minamisaku County, Nagano Prefecture.

Subfamily Pseudobolvininae Wiesner, 1931

Genus ***Pseudobolivina*** Wiesner, 1931

Type species.—*Bolivina punctata* d'Orbigny var. *arenacea* Heron-Allen and Earland, 1922

***Pseudobolivina* sp.**

Plates 44-18; 19

Material.—Two specimens from the Ishido Formation of the Sanchu Cretaceous System.

Description.—Test free, biserial chamber, tending to become uniserial, wedge-shaped, axis slightly twisted; aperture circular, at the terminal chamber.

Remarks.—The present specimens are resembles *Pseudobolivina variabilis* Vasieck, 1947 reported from ODP Leg 171B in the Southeast France Basin (Erbacher *et al.*, 1999). However, the present specimens have more elongated test more than *P. variabilis*.

Occurrence.—The present specimens are obtained from upper of Kuro River, Ueno Village, Tano County, Gunma Prefecture and Shinzaburozawa, Sakuho Town, Minamisaku County, Nagano Prefecture.

Suborder Globigerinina Delage and Hérouard, 1896

Superfamily Rotaliporacea Sigal, 1958

Family Hedbergellidae Loeblich and Tappan, 1961

Subfamily Hedbergellinae Loeblich and Tappan, 1961

Genus ***Hedbergella*** Brönnimann and Brown, 1958

Type species.—*Anomalina lorneiana* d'Orbigny var. *trocoidea* Gandolfi, 1942

Hedbergella planispira (Tappan, 1940)

Plates 44-4-6

Globigerina planispira Tappan, 1940, p.122, pl.19, fig. 12

Hedbergella planispira (Tappan). Loeblich and Tappan, 1961, p. 276, pl. 5, figs. 4-11; Pflaumann and Krasheninnikov, 1977, p. 547, pl. 2, figs. 1-5, pl. 3, fig. 3; Gradstein, 1978, p. 673, pl. 11, figs. 14-16; Caron, 1978, p. 658, pl. 1, figs. 1, 2; pl. 7, figs. 7, 8; Miles and Orr, 1980, p. 799, pl. 3, figs. 1-4; Leckie, 1984, p. 599, pl.

9, figs. 6-7; Nishi *et al.*, 1989, p. 6, 7, figs. 3-4a-4c; Sashida *et al.*, 1992, p. 276, figs. 3-1a-2c; Neagu, p. 317, 2005, pl. 1, figs. 13-21; Patterson *et al.*, 2010, p. 21, figs. 8-29-30.

Material.—Three specimens from the Ishido Formation of the Sanchu Cretaceous System.

Description.—Test free, trochospiral, biconvex, umbilicate, periphery rounded; globular or ovate, 5 chambers at the last whorl; depressed suture; smooth surface; interiomarginal aperture.

Remarks.—Although the present speciemens are very poorly preserved, they have the characteristic feature of this species in size and number of chambers in the last whorl.

Occurrence.—Common in the present planktonic assemblage..

Family Favusellidae Longoria, 1974

Genus ***Globuligerina*** Bignot and Guyader, 1971

Type species.—*Globigerina oxfordiana* Grigelis, 1958

Globuligerina hoterivica

Plate 44-7

Globigerina hoterivica Subbotina, 1953, p. 50, pl. 1, figs. 1a-c.

Globigerina kugleri Bolli, 1959, p. 270, pl. 23, figs. 3a-c.

"*Globigerina*" *hoterivica* Subbotina. Gradstein, 1978, p. 672, pl. 9, figs. 9-15.

Hedbergella hoterivica (Subbotina). Butt, 1979, pl. 3, figs. 1-7, pl. 4, figs. 1-4.

Globuligerina hoterivica (Subbotina). Caron, 1985, p. 57, figs. 25-1-3; Sashida *et al.*, 1992, p. 276, figs. 3-3a-4.

Material.—One specimen from the Ishido Formation of the Sanchu Cretaceous System.

Description.—Test free, high trochospiral globular forms, biconvex, periphery rounded; subglobular, four chambers at the last whorl; depressed suture.

Remarks.—Although the present speciemen is very poorly preserved, that has the characteristic feature of this species in size and number of chambers in the last whorl.

Occurrence.—Rare in the present planktonic assemblage.

Superfamily Planomalinacea Bolli, Loeblich and Tappan, 1957

Family Globigerinelloides Longoria, 1974

Subfamily Globigerinelloidinae Longoria, 1974

Genus ***Globigerinelloides*** Cushman and Ten Dam, 1948

Type species.—*Globigerinelloides algerianus* Cushman and Ten Dam, 1948

Globigerinelloides **aff.** ***blowi***

Plates 44-1-3

Compared with:

Planomalina blowi Bolli, 1959, p. 260, pl. 20, figs. 2, 3.

Globigerinelloides blowi (Bolli). Gradstein, 1978, p. 672, pl. 9, figs. 5-8; Caron, 1978, p. 658, pl. 6, figs. 11, 12; Butt, 1979, pl. 3, figs. 14-17.

Globigerinelloides blowi s. l. (Bolli). Leckie, 1984, p. 593, pl. 1, figs. 4-8.

Material.—Three specimens from the Ishido Formation of the Sanchu Cretaceous System.

Description.—Test free, medium trochospiral forms, umbilicate, periphery rounded; subglobular, increasing moderately in size, 5 chambers at the last whorl; moderately depressed suture; smooth surface.

Remarks.—This well-known and short ranging (early to late Aptian) species is characterized by having spherical to subspherical chambers which increase fairly rapidly in size. The present specimens are similar to the previously reported figures of *Globigerinelloides blowi* in general appearance. The present paper tentatively refers those to *G. blowi* because of limited number of poorly-preserved specimens.

Occurrence.—Rare in the present planktonic assemblage.

Superfamily Lituolacea de Blainville, 1825

Family Haplophragmoididae Maync, 1952

Genus ***Haplophragmoides*** Cushman, 1910

Type species.—*Nonionina canariensis* d'Orbigny, 1839

***Haplophragmoides* sp.**

Plates 44-8-10

Material.—Three specimens from the Ishido Formation of the Sanchu Cretaceous System.

Description.—Test free, planispiral forms, shallow and wide umbilicate, periphery rounded; trapezoidal, increasing moderately in size, 5 chambers at the last whorl; slightly concave suture; smooth surface; low, broadly, oval aperture at base of last chamber.

Remarks.—The present specimens are similar to *Haplophragmoides* sp. B by Sashida *et al.* (1992). However, those include speciemens which have narrow chambers.

Occurrence.—The present specimens are obtained from upper of Kuro River, Ueno Village, Tano County, Gunma Prefecture and Shinzaburozawa, Sakuho Town, Minamisaku County, Nagano Prefecture.

***Haplophragmoides*? sp.**

Plate 44-11

Material.—One specimen from the Ishido Formation of the Sanchu Cretaceous System.

Description.—Test free, planispiral forms, shallow and narrow umbilicate, periphery rounded; trapezoidal, increasing moderately in size, 5 chambers at the last whorl; depressed suture; small aperture.

Remarks.—Although the present specimen has similar characters of *Haplophragmoides* sp., that has numerous spines. The present paper tentatively refers to genus of *Haplophragmoides*.

Occurrence.—The present specimen is obtained from upper of Kuro River, Ueno Village, Tano County, Gunma Prefecture.

Family Lituolidae de Blainville, 1825

Genus ***Paratrochamminoides*** Soliman, 1972

Type species.—*Trochamminoides korosmezoensis* Majzon, 1943

***Paratrochamminoides* sp.**

Plate 44-15

Material.—One specimen from the Ishido Formation of the Sanchu Cretaceous System.

Description.—Test free, low, coiling and irregularly trocoidal; bead-shaped, 6 chambers at the last whorl; slightly depressed suture; smooth surface.

Remarks.—The present specimen is identified the genus of *Paratrochamminoides* by low, coiling and irregularly trocoidal forms. However, to identify species from the speciemen is difficult because of poorly-preserved for determination of precise coiling pattern.

Occurrence.—Rare in the present benthic assemblage.

Superfamily Cassidulinacea d'Orbigny, 1839

Family Nonionidae Schultze, 1854

Genus ***Pullenia*** Carpenter, Parker and Jones, 1862

Type species.—*Nonionina bulloides*, d'Orbigny, 1846

***Pullenia* sp.**

Plates 44-12; 13

Material.—Two specimens from the Ishido Formation of the Sanchu Cretaceous System.

Description.—Test free, planispiral, convolute, deep and narrow umbilicate, peripherary rounded; trapezoidal, increasing moderately in size, 6 chambers at the last whorl; radial suture, aperture a narrow crescentic interiomarginal slit at last chamber.

Remarks.—The present specimens are similar to *Pullenia cretacea* Cushman reported from DSDP Leg 78 in the western Central Atlantic Ocean (Hemleben and Troester, 1983). However, the latter has a more inflated oval test in axial profile than that of the former.

Occurrence.—Common in the present benthic assemblage.

Phylum Radiozoa Müller, 1858

Class Polycystinea Ehrenberg, 1838a

Suborder Spumellaria Ehrenberg, 1875

Spumellaria? gen. et sp. indet.

Plate 39-17

Material.—One specimen from siliceous pebbles in the Isoai Formation of the Nakaminato Group.

Description.—Skelton spherical; polygonal meshwork surface; four radial spines.

Remarks.—The described specimen is similar to the suborder of Spumellaria. However, to identify of the genus is difficult by poor-preservation.

Occurrence.—The present specimen is obtained from siliceous pebbles in the Isoai Formation of the Nakaminato Group.

Family Williriedellidae Dumitrica, 1970

Genus ***Gongylothorax*** Foreman, 1968

Type species.—*Dicolocapsa verbeeki* Tan, 1927

Gongylothorax favosus Dumitrica, 1970

Plate 39-16

Gongylothorax favosus, Dumitrica, 1970, p. 56, pl. 1, figs. 1, 2; Hori, 1999, p. 74, figs. 6-10.

Material.—One specimen from siliceous pebbles in the Isoai Formation of the Nakaminato Group.

Description.—Skelton spherical; polygonal pore frames with a small pore.

Remarks.—The described specimen is identified as *Gongylothorax favosus* by spherical outline and polygonal pore frames.

Occurrence.—The present species has been yielded from Bathonian to Tithonian (Jurassic).

Family Actinommidae Haeckel, 1862

Genus ***Hexalonche*** Haeckel, 1881

Type species.—*Hexalonche pythagoraea* Haeckel, 1881

***Hexalonche*? sp.**

Plate 39-8

Material.—One specimen from siliceous pebbles in the Isoai Formation of the Nakaminato Group.

Description.—Skelton spherical; smooth surface; three radial spines.

Remarks.—The described specimen is similar to the genus of *Hexalonche*. However, to identify of the genus is difficult by poor-preservation.

Occurrence.—The present specimen is obtained from siliceous pebbles in the Isoai Formation of the Nakaminato Group.

Family Eptingiidae Dumitrica, 1978

Genus ***Spongostephanidium*** Dumitrica, 1978

Type species.—*Spongostephanidium spongiosum* Dumitrica, 1978

***Spongostephanidium*? sp.**

Plates 39-9; 10

Material.—Two specimens from siliceous pebbles in the Isoai Formation of the Nakaminato Group.

Description.—Skelton spherical; spongy meshed surface; three radial spines.

Remarks.—The described specimens are similar to the genus of *Spongostephanidium*. However, to identify of the genus is difficult by poor-preservation.

Occurrence.—The present specimens are obtained from siliceous pebbles in the Isoai Formation of the Nakaminato Group.

Family Poulpidae de Wever, 1981

Genus ***Annulopoulpus*** Kozur and Mostler, 1981

Type species.—*Annulopoulpus* costatus Kozur and Mostler, 1981

***Annulopoulpus*? sp.**

Plate 39-11

Material.—One specimens from siliceous pebbles in the Isoai Formation of the Nakaminato Group.

Description.—Skelton spherical; maybe four radial spines.

Remarks.—The described specimen is similar to the genus of *Annulopoulpus*. However, to identify of the genus is difficult by poor-preservation.

Occurrence.—The present specimen is obtained from siliceous pebbles in the Isoai Formation of the Nakaminato Group.

Family Capnuchosphaeridae de Wever, 1979

Genus ***Capnuchosphaera*** de Wever, 1979

Type species.—Capnuchosphaera triassica de Wever, 1979

Capnuchosphaera* cf. *deweveri Kozur and Mostler, 1979

Plate 39-12

Compared with:

Capnuchosphaera deweveri, Kozur and Mostler, 1979, p. 75-76, pl. 10, figs. 4-7, pl. 12, fig. 1.

Material.—One specimens from siliceous pebbles in the Isoai Formation of the Nakaminato Group.

Description.—Skelton spherical; tetragonal to pentagonal pore frames with subcircular to circular pores; three radial spines very long and triradiate in axitial section.

Remarks.—The described specimen is compared with *Capnuchosphaera deweveri* by tetragonal to pentagonal pore frames with subcircular to circular pores and radial long spines.

Occurrence.—The compared species has been yielded from lower Carnian to lower Norian (Triassic).

Family Pantanelliidae Pessagno, 1977

Genus ***Betraccium*** Pessagno, 1979

Type species.—*Betraccium smithi* Pessagno, 1979

***Betraccium* sp.**

Plate 39-13

Material.—One specimen from siliceous pebbles in the Isoai Formation of the Nakaminato Group.

Description.—Skelton subspherical; coase polygonal meshwork surface; polygonal pore flames; three radial spines wide and twisted.

Remarks.—The described specimen is identified the genus of *Betraccium* by coase meshwork and twisted and wide radial spines. However, to identify of the species is difficult because of poorly-preservation.

Occurrence.—The present species has been yielded from upper Carnian to upper Rhaetian (Triassic).

Family Spongodiscidae Haeckel, 1862

Genus ***Paronaella*** Pessagno, 1971

Type species.—Paronaella solanoensis Pessagno, 1971

***Paronaella* sp.**

Plate 39-15

Materilal.—One speciemen from siliceous pebbles in the Isoai Formation of the Nakaminato Group.

Description.—Skelton lacking rays with brachiopyle; rays nearly equal length; meshwork sublinear; irreguraly polygonal pores.

Remarks.—The described specimen is identified as the genus of *paronaella* by the outline.

Occurrence.—The present genus has been yielded from lower Rhaetian (Triassic) to upper Coniacian (Cretaceous).

Family Syringocapsidae Pessagno, 1977

Genus ***Syringocapsa*** Neviani, 1900

Type species.—*Theosyringium robustum* Vinassa, 1901

***Syringocapsa* sp.**

Plate 39-14

Material.—One specimen from siliceous pebbles in the Isoai Formation of the Nakaminato Group.

Description.—Skelton spindle; proximal segments conical; end segment inflated and cylindrical with weak two spines; pore small and rounded.

Remarks.—The described specimen is identified as the genus of *Syringocapsa* by the outline.

Occurrence.—The present specimen is obtained from siliceous pebbles in the Isoai Formation of the Nakaminato Group.

Order Nassellariina Ehrenberg, 1875

Family Triassocampidae Kozur and Mostler, 1981

Genus ***Triassocampe*** Dumitrica, Kozur and Mostler, 1980

Type species.—*Triassocampe scalaris* Dumitrica, Kozur and Mostler, 1980

***Triassocampe* sp.**

Plate 39-3

Material.—One specimen from siliceous pebbles in the Isoai Formation of the Nakaminato Group.

Description.—Skelton thorax and rounded subsequent segments; sharp circumferential ridges; small pores arranged.

Remarks.—The described specimen is identified the genus of *Triassocampe* by the outline. However, to identify of the species is difficult because of poorly-preservation.

Occurrence.—The present specimen is obtained from siliceous pebbles in the Isoai Formation of the Nakaminato Group.

***Triassocampe*? sp.**

Plate 39-4

Material.—One specimen from siliceous pebbles in the Isoai Formation of the Nakaminato Group.

Description.—Skelton thorax and rounded subsequent segments; circumferential ridges well developed; very small pores arranged.

Remarks.—The described specimen is similar to the genus of *Triassocampe*. However, to identify of the genus is difficult by poor-preservation.

Occurrence.—The present specimen is obtained from siliceous pebbles in the Isoai Formation of the Nakaminato Group.

Triassocampe deweveri (Nakaseko and Nishiura, 1979)

Plate 39-2

Dictyomitrella deweveri, Nakaseko and Nishiura, 1979, p. 77, pl. 10, figs. 8, 9.

Triassocampe deweveri, Sugiyama, 1997, p. 188, fig. 27-8; Hori and Sashida, 1998, figs. 8-9, 11.

Material.—One specimen from siliceous pebbles in the Isoai Formation of the Nakaminato Group.

Description.—Skelton thorax and rounded subsequent segments; circumferential ridges well developed; irregular pores arranged.

Remarks.—The described specimen is identified as *Triassocampe deweveri* by well developed circumferential ridges.

Occurrence.—The present species has been yielded from upper Anisian to lower Ladinian (Triassic).

Triassocampe coronata Bragin, 1991

Plate 39-1

Triassocampe coronata, Bragin, 1991, p. 99, pl. 1, fig. 15; Sugiyama, 1992, figs. 11-5, 6.

Material.—One specimen from siliceous pebbles in the Isoai Formation of the Nakaminato Group.

Description.—Skelton thorax and rounded subsequent segments; well-developed sharp circumferential ridges; one row of large pores arranged.

Remarks.—The described specimen is identified as *Triassocampe coronata* by well-developed sharp circumferential ridges and large pores.

Occurrence.—The present species has been yielded from Anisian (Triassic).

Family Archaeodictyomitridae Pessagno, 1976

Genus ***Archaeodictyomitra*** Pessagno, 1976

Type species.—Archaeodictyomitra squinaboli Pessagno, 1976

***Archaeodictyomitra* sp.**

Plate 39-6, 45-3

Material.—Two specimens from siliceous pebbles in the Isoai Formation of the Nakaminato Group and the Ishido Formation of the Sanchu Cretaceous System.

Description.—Skeleton subconical, elongate; slight constrictions, increasing moderately in size towards apical region, 9 costae; pores rounded.

Remarks.—The described specimens are identified the genus of *Archaeodictyomitra* by subconical and elongated skeleton. However, to identify species from the speciemen is difficult because of poorly-preservation.

Occurrence.—The present species has been yielded from lower Pliensbachian (Jurassic) to upper Campanian (Cretaceous).

Family Xitidae Pessagno, 1977

Genus ***Pseudodictyomitrella*** Grill and Kozur 1986

Type species.—Pseudodictyomitrella spinosa Grill and Kozur, 1986

***Pseudodictyomitrella*? sp.**

Plate 39-5

Material.—One specimen from siliceous pebbles in the Isoai Formation of the Nakaminato Group.

Description.—Skeleton conical; very slight constrictions, increasing moderately in size towards apical region; pores arranged.

Remarks.—The described specimen is identified the genus of *Pseudodictyomitrella* by conical outline. However, to identify species from the speciemen is difficult because of poorly-preservation.

Occurrence.—The present specimen is obtained from siliceous pebbles in the Isoai Formation of the Nakaminato Group.

Family Canoptidae Pessagno, 1979

Genus ***Canoptum*** Pessagno, 1979

Type species.—Canoptum poissoni Pessagno, 1979

***Canoptum*? sp.**

Plate 39-7

Material.—One specimen from siliceous pebbles in the Isoai Formation of the Nakaminato Group.

Description.—Skeleton spindle; developed circumferential ridges, increasing moderately in size towards apical region; pores very small.

Remarks.—The described specimen is similar to the genus of *Canoptum*. However, to identify of the genus is difficult by poor-preservation.

Occurrence.—The present specimen is obtained from siliceous pebbles in the Isoai Formation of the Nakaminato Group.

Family Williridellidae Dumitrica, 1970

Genus ***Praezhamoidellum*** Kozur, 1984

Type species.—*Praezhamoidellum yaoi* Kozur, 1984

***Praezhamoidellum*? sp.**

Plate 39-18

Material.—One specimen from siliceous pebbles in the Isoai Formation of the Nakaminato Group.

Description.—Skelton tricyrtid; less costated; polygonal pores.

Remarks.—The described specimen is similar to the genus of *Praezhamoidellum* for the outline. However, to identify of the genus is difficult by poor-preservation.

Occurrence.—The described specimen is obtained from siliceous pebbles in the Isoai Formation of the Nakaminato Group.

Family Canoptidae Pessagno, 1979 in Pessagno *et al.* (1979)

Genus ***Cinguloturris*** Dumitrica, 1982 in Dumitrica and Mello (1982)

Type species.—*Cinguloturris carpatica* Dumitrica, 1982 in Dumitrica and Mello (1982)

Cinguloturris carpatica Dumitrica, 1982

Plate 39-7

Cinguloturris carpatica Dumitrica, 1982 (Dumitrica and Mello, 1982), p. 23, pl. 4, figs. 7-11; Hori, 1999, p. 91, fig. 9-1.

Material.—One specimen from siliceous pebbles in the Isoai Formation of the Nakaminato Group.

Description.—Skeleton spindle shape; less costated; thickened a-segments; spongy meshwork well developed.

Remarks.—The described specimen is identified as *Cinguloturris carpatica* by less costated and thickened a-segments.

Occurrence.—The present species has been yielded from Callovian to Tithonian.

Phylum Porifera Grant, 1836

Class Hexactinellida Schmidt, 1870

Sponge spicular (four axes type)

Plate 45-1

Material.—One specimen from Shinzaburozawa.

Descriptions.—Spicular small, four axis, posterior end is broader than central part.

Remarks.—The present specimen is discriminated from one axis type by four axis.

Occurrence.—The described specien is obtained from Shinzaburozawa.

Sponge spicular (one axis type)

Plate 45-2

Material.—One specimen from Shinzaburozawa.

Descriptions.—Spicular small, one axis, diameter is fairly constant.

Remarks.—The present specimen is discriminated from four axis type by one axis.

Occurrence.—The described specien is obtained from Shinzaburozawa.

Class Gastropoda Cuvier, 1797

Gastropoda gen. et sp. indet.

Plate 43-10

Material.—One specimen from Bomukizawa, Sakuho Town, Minamisaku County, Nagano Prefecture.

Descriptions.—Shell small, turreted-conical, six whorled, elongate, slender, sculptured with spiral ribs, growth lines curved, aperture round.

Measurements.—H=11.7 mm of the present specimen and L=5.2 mm.

Remarks.—To identify of species is difficult because of poor preservation and small in siza.

Occurrence.—The described specimen is obtained from Bomukizawa, Sakuho Town, Minamisaku County, Nagano Prefecture.

Family Calyptraeidea Lamarck, 1809

Calyptraeidea gen. et. sp. indet.

Plate 36-1

Material.—One specimen from Ammonite Center, Iwaki City, Fukushima Prefecture.

Descriptions.—Shell medium in size, cap-shaped, bilaterally symmetrical, but more or less irregular in outline; inner surface smooth.

Measurements.—H=18.3 mm of the present specimen and D=24.6 mm.

Remarks.—The present specimen is identified as Calyptraeidea of the family by cap-shaped. However, to identify of the genus is difficult because of inner mold.

Occurence.—The described specimen is obtained from Ammonite Center, Iwaki City, Fukushima Prefecture.

Superfamily Cerithiacea Ferussac, 1819

Family Cassiopidae Kollmann, 1979

Genus ***Cassiope*** Coquand, 1865

Type species.—*Cassiope kefersteini* Goldfuss, 1844

Cassiope* (*Cassiopella*) *ogaii Kase, 1984

Plates 42-2; 3

Cassiope ogaii Kase, 1984, p. 117, pl. 18, fig. 1-10, 19.

Material.—One specimen from Mamonozawa River, Ueno Village, Tano County, Gunma Prefecture.

Descriptions.—Shell medium in size, turreted, anomphalous and elongate cerithiform in outline with height slightly smaller than twice of width; height of spire smaller than a half of shell height; whorls at least six in number and isometrically expanded; early whorls cyrtoconoid; spire whorls angularly convex, separated by impressed suture with inclined narrow ramp; body whorl higher than wide, slightly discoidal, abruptly constricted anteriorly and possesses slightly convex base without any peripheral angulation; outer lip weakly prosocline, somewhat thin and angularly concave with a notch placed at basal periphery; parietal lip thickened by callus and straight; columellar lip also thickened by callus, slightly inclined to shell axis; surface ornamented by fine and regularly spaced spiral lirae.

Measurements.—H=29.0 mm of the present specimen and D=7.9 mm.

Remarks.—The present specimen is identified as *Cassiope ogaii* by larger size and a thicker inner lip and columella.

Occurrence.—Occurrence from the Sanchu Cretaceous System and Ofunato Group.

Superfamily Cerithioidea Fleming, 1822

Family Turritellidae Lamarck, 1799

Subfamily Turritellinae Lamarck, 1799

Genus ***Turritella*** Lamarck, 1799

Type species.—*Turbo terebra* Linné, 1758

***Turritella*? sp.**

Plate 32-7

Material.—One specimen from Kayanosawa, Hirono Town, Futaba County, Fukushima Prefecture.

Descriptions.—Shell small and thin, turreted-conical, more than three whorled, elongate, slender, sculptured with spiral ribs, growth lines curved, aperture round and entire, sinuous and prosocline at suture, columella smooth and concave.

Measurements.—H=20.9+ mm of the present specimen and D=7.8 mm.

Remarks.—The present specimen resembles *Turritella* of the genus by turrited-conical form.

Occurrence.—The described specimen is obtained from Kayanosawa, Hirono Town, Futaba County, Fukushima Prefecture.

Superfamily Naticoidea Guilding, 1834

Family Naticidae Guilding, 1834

Genus ***Natica*** Scopoli, 1777

Type species.—*Natica vitellus* Linné, 1758

***Natica* sp.**

Plates 34-11; 36-4

Material.—Two specimens from Ammonite Center and Yoheisaku, Iwaki City, Fukushima Prefecture.

Descriptions.—Shell small, semicircular oval, three whorled, weakly flattened, smooth surface, sinuous sinuous and prosocline at suture, columella smooth and concave.

Measurements.—H=3.3 mm of the present specimen from Ammonite Center and D=4.8 mm and H=4.8 mm of the present specimen from Yoheisaku and D=5.7 mm.

Remarks.—The present specimens are identified as *Natica* of the genus by weakly impressed shell.

Occurrence.—The described specimens are obtained from Ammonite Center and Yoheisaku, Iwaki City, Fukushima Prefecture.

Genus ***Gyrodes*** Conrad, 1860

Type species.—*Rapa supraplicata* Conrad, 1858

***Gyrodes* sp.**

Plate 36-3

Material.—One specimen from Ammonite Center, Iwaki City, Fukushima Prefecture.

Descriptions.—Shell small, three whorled, whorls flattened, subsuturally and crenate, umbilicus, margined by noncrenate carination in early stages that rounds off in late growth stages, sculptured with spiral ribs.

Measurements.—H=7.1 mm of the present specimen and D=11.0 mm.

Remarks.—The present specimen is identified as *Gyrodes* of the genus by flattened shell.

Occurrence.—The described specimen is obtained from Ammonite Center, Iwaki City, Fukushima Prefecture.

Superfamily Cancellarioides Gray, 1853

Family Paradmetidae Stephenson, 1941

Genus ***Paladmete*** Gardner, 1916

Type species.—*Trichotropis cancellaria* Conrad, 1858

***Paladmete* sp.**

Plate 36-2

Material.—One specimen from Ammonite Center, Iwaki City, Fukushima Prefecture.

Descriptions.—Shell small, thin; three whorled; spire somewhat more than half total shell high, sculpture reticulate varice common, aperture holostomonous.

Measurements.—H=13.8 mm of the present specimen and D=10.0 mm.

Remarks.—The present specimen is identified as *Paladmete* of the genus by the aperture and sculpture form.

Occurence.—The described specimen is obtained from Ammonite Center, Iwaki City, Fukushima Prefecture.

Superfamily Muricoidea de Costa, 1776

Family Muricidae de Costa, 1776

Genus ***Sargana*** Stephenson, 1923

Type species.—*Rapana stantoni* Weller, 1907

***Sargana* sp.**

Plate 32-9

Material.—One specimen from Kayanosawa, Hirono Town, Futaba County, Fukushima Prefecture.

Descriptions.—Shell small, subpyriform, vertically corrugated imbillcus; the spire depressed, the suture ill defined; the anterior portion of the shell rather abruptly contracted from the body, shell moderately thick, surface of outer whorl sculptured with strong revolving ribs separated by somewhat wider rounded furrows.

Measurements.—H=15.8 mm of the present specimen and D=13.5 mm.

Remarks.—The present specimen is identified as *Sargana* of the genus by subpyriform and strong revolving ribs.

Occurrence.—The described specimen is obtained from Kayanosawa, Hirono Town, Futaba County, Fukushima Prefecture.

Class Bivalvia Linné, 1758

Bivalvia gen. et sp. indet.

Plate 46-5

Material.—One specimen from Ohnozawa Pass, Saku City, Nagano Prefeture.

Descriptions.—Shell medium in size, well inflated, elongately ovate; umbo not prominent, subcentral; anterior dorsal margin semi-curcular, gradually changing into broadly arched ventral margin; posterior margin well rounded; surface ornamented by only concentric lines.

Measurements.—L=30.6 mm of the present specimen, H=16.6 mm, T=3.8 mm and 1.84.

Remarks.—To identify of the family for the present specimen is difficult because of poor presevation of external cast.

Occurrence.—The described specimen is obtained from Ohnozawa Pass, Saku City, Nagano Prefeture.

Subclass Palaeotaxodonta Korobkov, 1954

Order Nuculoida Dall, 1889

Superfamily Nuculacea Gray, 1824

Family Nuculidae Gray, 1824

Genus ***Nuculopsis*** Girty, 1911

Type species.—*Nucula ventricosa* Hall, 1858

Nuculopsis ishidoensis (Yabe and Nagao, 1926)

Plate 29-1

Nucula ishidoensis Yabe and Nagao. Yabe, Nagao and Shimizu, 1926, p. 41, pl. 13, fig. 46. 47.

Nuclopsis ishidoensis. Hayami, 1965a, p. 234.

Material.—One specimen from Ebisudana, Miyako City, Iwate Prefecture.

Descriptions.—Shell small, obliquely truncated behind, relatively short, convex; posterior part short; postero-dorsal margin deeply excavated beneath umbo, the cardinal slightly arcuated, the anterior narrowly rounded, and the ventral broadly curved, passing with an abrupt curvature into the posterior. Umbo subterminal, not prominent.

Measurements.—L=7.8 mm of the present specimen, H=7.0 mm and L/H=1.11.

Remarks.—The present specimen is internal cast. However, that is identifined *Nuculopsis ishidoensis* by size and outline of shell.

Occurrence.—Occurrence from the Monobe Group.

Genus ***Acila*** Adams and Adams, 1858

Type species.—*Nucula divaricata* Hinds, 1843

***Acila* sp.**

Plates 33-6; 34-8; 35-8

Material.—Three specimens from the middle of Ashizawa, Ammonite center and Yoheisaku, Iwaki City, Fukushima Prefecture..

Descriptions.—Shell small, very inequilateral, anterior side about twice posterior; anterior end rounded and posterior obliquely truncated; rather slightly convex; anterior margin slightly arcuate; ventral margin evenly convex, antero-ventral margin rounded, postero-ventral margin subangulated; beak relatively prominant, convex, opisthogyrous; lunule very narrow, bordered by sharp ridge, smooth except for numerous fine growth lines; escutceon deeply depressed, broad and circumscribed by a ridge; area elongate-ovate, composed of two parts, upper convex and ornamented with radial ribs and lower concave and smooth.

Surface of shell ornamented with round-topped diverging ribs; primary bifurcation line situated anteriorly on shell; ribs on anterior half side about equal to posterior one; interspaces more or less narrower than ribs; test not so thick.

Measurements.—L=6.2 mm of the present specimen from the middle of Ashizawa, H=4.8 mm, T=0.7 mm and L/H=1.29, L=10.9 mm of the present specimen from Ammonite center, H=9.0 mm, T=2.1 mm and L/H=1.21 and L=12.1 mm of the present specimen from Yoheisaku, H=10.0 mm, T=2.4 mm and L/H=1.21.

Remarks.—The present specimens resemble *Acila hokkaidoensis*. However, to identify of the species is difficult by poorly preservation.

Occurrence.—The described specimens are obtained from the middle of Ashizawa, Ammonite center and Yoheisaku, Iwaki City, Fukushima Prefecture.

Superfamily Nuculanacea Adams and Adams, 1858

Family Nuculanidae Adams and Adams, 1858

Genus ***Ezonuculana*** Nagao, 1938

Type species.—*Jupiteria mactraeformis* Nagao, 1932

Ezonuculana mactraeformis (Nagao, 1932)

Plate 37-2

Nuculana mactraesormis Nagao, 1932, p. 30, pl. 5, figs. 4-6, 8, 9, 16.

Nuculana (*Ezonuculana*) *mactraeformis* Nagao, 1938, p. 122, pl. 14, figs. 4-8.

Jupiteria (*Ezonuculana*) *mactraeformis* (Nagao), Ichikawa and Maeda, 1958, p. 87, pl. 5, figs 1-3.

Nuculana (*Ezonuculana*) *mactraeformis* (Nagao), Saito, 1962, p. 60, pl. 1, fig. 13.

Material.—One specimen from Irimazawa, Iwaki City, Fukushima Prefecture.

Description.—Shell small, well inflated, elongately ovate; umbo prominent, orthogyrous, subcentral; anterior dorsal margin semi-curcular, gradually changing into broadly arched ventral margin; posterior margin well rounded; escutcheon narrow, fairly depressed, nearly smooth, separeted from posterior area by a dorsal carina which is bluntly angulated and moderately concave.

Measurements.—L=14.9 mm of one of the present specimens, H=10.1 mm, T=1.5 mm and L/H=1.48.

Remarks.—The present specimen is identified as *Ezonuculana mactraeformis* by less elongate in outline.

Occurrence.—Occurrence from the Upper Ezo, Kuji, Futaba, Uwajima, Sotoizumi, Ohnogawa and Himenoura Groups and Sawamari Formation.

Genus ***Portlandia*** Mörch, 1857

Type species.—*Arca arctdca* Gray, 1847

Portlandia sanchuesnsis (Yabe and Nagao, 1926)

Plate 39A-1; 2; 46-3; 4; 7

Nuculana sanchuensis Yabe and Nagao, Yabe, Nagao and Shimizu, 1926, p. 42, pl. 12, figs. 21-23; Hayami, 1965a, p. 235.

Material.—Five specimens from Toriakeura, Choshi City, Chiba Prefecture and Ohnozawa Pass, Saku City, Nagano Prefeture..

Description.—Shell small, elongate ovate, inequilateral, moderately inflated; test comparatively thin ; antero-dorsal margin nearly straight, gradually bending down to rounded anterior margin; postero-dorsal margin long and broadly concave, somewhat abruptly turned to posterior margin at rostrated posterior end; ventral margin smoothly arcuate; umbo broad, not prominent, orthogyrous, situated a little anteriorly from mid-length; escutcheon not clearly demarcated; surface of middle portion of valve ornamented by numerous delicate concentric striae, which are abruptly effaced toward anterior and posterior sides; anterior and posterior areas quite smooth except for growth-lines, occupying nearly the same width as median ornamented area.

Measurements.—L=14.9 mm of the present specimen from Toriakeura, H=9.5 mm, 2T=6.8 mm and L/H=2.29, L=11.4 mm of one of the present specimen from Ohnozawa Pass, H=7.2 mm, T=2.0 mm and L/H=1.58 and L=12.1 mm of one of the other specimen from Ohnozawa Pass (counter parts), H=8.5 mm, T=1.0 mm and L/H=1.42 and L=15.5 mm of another specimen from Ohnozawa Pass and T=2.7 mm.

Remarks.—The present specimens are identified as *Portlandia sanchuensis* by outline and ornamention and distinguishable from other species of *Portlandia* by the concentric striae restricted to the middle portion of valves.

Occurrence.—Occurrence from the Monobe and Nankai Groups.

Genus ***Mesosaccella*** Chavan, 1946

Type species.—*Nucula forsteri* Müller, 1847

Mesosaccella insignis Nagao, 1934

Plate 29-2

Nuculana insignis Nagao, 1934, p. 189, pl. 29, figs. 10-12.

Mesosaccella insignis (Nagao), Hayami, 1965a, p. 189, pl. 27, fig. 1.

Material.—Two specimens from Ebisudana, Miyako City, Iwate Prefecture.

Description.—Shell very small, elongated, *Saccella*-like in outline, tapering gradually to the posterior end, pointed at the extremity; test moderately thick, translucent; antero-dorsal margin smoothly arcuate, while postero-dorsal margin is concave; ventral margin broadly arcuate; umbo not prominent, placed a little posteriorly from mid-point of length; escutcheon not clearly defined but distinctly excavated; surface marked with 20 or more regular subconcentric grooves which are much narrower than their flat interspaces and become somewhat weaker on anterior and posterior peripheral parts; two or three grooves cut obliquely by postero-ventral margin.

Measurements.—L=5.6 mm of one of the present specimens, H=3.6 mm, T=1.0 mm and L/H=1.56. L=4.1mm of another specimen, H=2.5 mm, T=0.8 mm and L/H=1.64.

Remarks.—The present specimens are identified the genus of *Mesosaccella* by those of outline. *Mesosaccella perdita* (Conrad, 1852) which was reported from France (Chavan, 1947) and Cameroun (Dartevelle and Freneix, 1957) resembles the present specimens, however that species is obviously larger than the present specimens.

Occurrence.—Occurrence from the Miyako and Monobegawa Groups.

Subclass Pteriomorphia Beurlen, 1944

Order Arcoida Stoliczka, 1871

Superfamily Arcacea Lamarck, 1809

Family Parallelodontidae Dall, 1898

Subfamily Parallelodontinae Dall, 1898

Genus ***Nanonavis*** Stewart, 1930

Type species.—*Arca carinata* Sowerby, 1813

Nanonavis sachalinensis (Schmidt, 1873)

Plates 26-5; 33-4; 34-8; 37-4

Cucullaea sachalinensis Schmidt, 1873, p. 24, pl. 5, fig. 5, pl. 8, figs. 6, 7.

Cucullaea cf. *sachalinensis* Schmidt, Yokoyama, 1890, p. 176, pl. 18, fig. 8.

Grammatodon sachalinensis (Schmidt), Yabe, 1927, pl. 7, fig. 3; Nagao, 1932, p. 31, pl. 6, figs. 1-5; Amano, 1957a, p. 56, pl. 2, figs. 9-11.

Parallelodon (*Nanonavis*) *sachalinensis* (Schmidt), Nagao and Otatume, 1938, p. 38, pl. 2, fig. 2.

Nanonavis sachalinensis (Schmidt), Saito, 1962, p. 61, pl. 1, fig. 16; Matsumoto, Hayami and Asano, 1963, p. 29, pl. 44, fig. 8.

Material.—Four specimens from the middle of Ashizawa, Ammonite center and Irimazawa, Iwaki City, Fukushima Prefecture and coast of Hideshima, Miyako City, Iwate Prefecture.

Description.—Shell small, tranversely elongate; rather convex especially near beak; very inequilateral, anterior side much shorter than posterior; dorsal margin long, straight, ventral subparallel of slightly oblique to hinge margin; anterior margin oblique backward, bearing a subpointed and more or less produced antero-dorsal end between it and dorsal margin: posterior part of shell attenuate, postero-dorsal area more or less excaavated; beak broad, prominent, convex and prosogyrous; ligamental area narrow, elongate, with numerous crowded and fine ligamental grooves; hinge narrow, with two or three anterior teeth and four posterior, beside numerous short, slightly divergent upward of posterior teeth, three dorsal long and one ventral short, subparallel to hinge margin.

Ornamentation consisting of numerous concentric lines and radial ribs; ribs on posterior area smaller and more crowded than in middle on shell; radial ribs on right valve more numerous, rather broader, and more crowded.

Measurements.—L=9.0 mm of the present specimen from the middle of Ashizawa, H=4.5 mm, T=1.6 mm and L/H=2.0, L=19.9 mm of the present specimen from Ammonite Center, H=14.2 mm, T=4.4 mm and L/H=1.40, H=7.2 mm of the present specimen from Irimazawa and T=1.2 mm and L=8.6 mm of the present specimen from coast of Hideshima, H=7.2 mm, T=3.0 mm and L/H=1.19.

Remarks.—The present specimens are smaller than *Nanonavis sachalinensis* from Hokkaido and Saghalien. However, those are identified as the present species by the outline and radial ribs.

Occurrence.—Occurrence from the Upper Ezo, Kuji, Futaba, Uwajima, Ohnogawa and Himenoura Groups and Sawamawari Formation.

Family Cucullaeidae Stewart, 1930

Genus ***Cucullaea*** Lamarck, 1801

Type species.—*Cucullaea auriculifera* Lamarck, 1801

Cucullaea **sp.**

Plates 29-3; 32-3; 43-1

Material.—Four specimens from Bomukizawa, Sakuho Town, Minamisaku County, Nagano Prefecture, Kayanosawa, Hirono Town, Futaba County, Fukushima Prefecture, and Ebisudana, Miyako City, Iwate Prefecture.

Description.—Shell is small, inequilateral, obliquely trapezoidal, well inflated, much longer than high; test thick; hinge-line moderate in length, occupying about two-thirds of shell-length; anterior margin forming an obtuse angle with hinge, smoothly arcuate; posterior margin long, nearly straight in dorsal half, forming an obtuse angle of about 120 degrees with hinge axis; ventral margin nearly slightly convex; posterior carina sharp, persistent from umbo to postero-ventral extremity; postero-dorsal area, which is clearly defined by carina, fairly wide, occupying about a third of whole surface, divided subequally into two faintly concave areas by a weak median carina.

Measurements.—L=25.4 mm of the present specimen from Bomukizawa, H=17.4 mm, T=7.9 mm and L/H=1.46, L=19.0 mm of the present specimen from Kayanosawa, H=18.4 mm, T=7.3 mm and L/H=1.03. L=15.3 mm of the present specimen from Ebisudana, H=11.7+ mm, T=9.5 mm and L/H=1.31-, and L=25.6 mm of another specimen from Ebisudana, H=15.8 mm, T=9.1 mm and L/H=1.62.

Remarks.—The present specimens are similar *Cucullaea acuticarinata*. However, to identify species for specimens is difficult because of poorly-preservation.

Occurrence.—The described specimens are obtained from Bomukizawa, Sakuho Town, Minamisaku County, Nagano Prefecture, Kayanosawa, Hirono Town, Futaba County, Fukushima Prefecture, Ebisudana, Miyako City, Iwate Prefecture.

Family Glycymerididae Newton, 1922

Genus *Glycymeris* da Costa, 1778

Type species.—*Glycymeris densilineata* Nagao, 1934

Glycymeris amakusensis Nagao, 1930

Plates 32-1; 33-5; 34-7; 35-6; 37-3

Glycymeris amakusensis Nagao, 1930, p. 15, pl. 2, figs. 4-7.

Material.—Five specimens from the middle of Ashizawa, Ammonite Center, Yoheisaku, Iwaki City, Fukushima Prefecture, Kayanosawa, Hirono Town, Futaba County, Fukushima Prefecture and Irimazawa, Iwaki City, Fukushima Prefecture.

Description.—Shell small, well inflated, more or less inequilaeral, prosocline; umbo prominent, placed mid pointed of length; ventral margin with coase internal crenulations; ligament area of moderate width, slightly concave, marked with a few chevrons; hinge slightly asymmetrical; surface nearly smooth except for rounded and low radial ribs and grooves in which there are numerous fine radial striae.

Measurements.—L=16.7 mm of the present specimen from the middle of Ashizawa, H=16.7 mm, T=4.4 mm and L/H=1.00, L=25.5 mm of the present specimen from Ammonite Center, H=22.4 mm, T=7.2 mm and L/H=1.14, L=17.7 mm of the present specimen from Yoheisaku, H=17.5 mm, T=5.9 mm and L/H=1.01, L=33.8 mm of the present specimen from Kayanosawa, H=33.0 mm, T=7.0 mm and L/H=1.02 and L=9.3 mm of the present specimen from Irimazawa, H=8.6 mm, T=1.3 mm and L/H=1.08.

Remarks.—The present specimens are identified as *Glycymeris amakusensis* by rounded and low ribs.

Occurrence.—Occurrence from the Himenoura, Ohnogawa, Uwajima, Sotoizumi and Futaba Groups.

Glycymeris densilineata Nagao, 1934

Plates 26-6; 29-4; 31-8

Glycymeris densilineata Nagao, 1934, p. 195, pl. 32, figs. 8, 9.

Glycymeris (*Hanaia*) *densilineata* Nagao, Hayami, 1965a, p. 251, pl. 29, figs.1-15; Tashiro, 1971, p. 234, text-fig. 5c, pl. 28, figs. 22, 23.

Material.—Six specimens from Ebisudana, coast of Hideshima, Miyako City, Iwate Prefecture and Aketo, Tanohata Village, Shimohei County, Iwate Prefecture.

Description.—Shell small, well inflated, more or less inequilateral, prosocline; umbo prominent, placed mid pointed of length; ventral margin with coarse internal crenulations; ligament area of moderate width, slightly concave, marked with a few chevrons; hinge slightly asymmetrical; surface nearly smooth except for rounded radial ribs and grooves in which there are numerous fine radial striae.

Measurements.—L=17.0 mm of one of the present specimen from Ebisudana, H=14.7 mm, T=17.8 mm and

L/H=1.16, L=5.1 mm of another specimen from Ebisudana, H=4.5 mm, T=1.0 mm and L/H=1.13, L=10.8 mm of the present specimen from Aketo, H=9.5 mm, T=4.0 mm and L/H=1.14, L=14.7 mm of the other present specimen from Aketo, H=13.0 mm, T=3.7 mm and L/H=1.13 and L=4.8 mm of another specimen from Aketo, H=4.5 mm, T=0.8 mm and L/H=1.07.

Remarks.—The present specimens are identified as *Glycymeris densilineata* by the outline.

Occurrence.—Occurrence from the Miyako and Sotoizumi Groups.

Order Mytiloida Férussac, 1822

Superfamily Mytilacea Rafinesque, 1815

Family Mitilidae Rafinesque, 1815

Mytilidae? gen. et sp. indet.

Plates 25-7; 27-7

Material.—Two specimens from coast of Hideshima, Miyako City, Iwate Prefecture and Koikorobe, Tanohata Village, Shimohei County, Iwate Prefecture.

Description.—Shell small, concave, equilateral; umbo prominent; test thin; anterior and posterior margins straight; the apical angle is about 80 degrees.

Measurements.—L=10.9 mm of the present specimen from coast of Hideshima and T=3.5 mm and L=7.0 mm of the present specimen from Koikorobe and T=4.3 mm.

Remarks.—The present specimen resembles Mytilidae of the family by the outline. However, to identify of the genus is difficult because of poor preservation.

Occurrence.—The described specimens are obtained from coast of Hideshima, Miyako City, Iwate Prefecture and Koikorobe, Tanohata Village, Shimohei County, Iwate Prefecture.

Subfamily Mytilinae Rafinesque, 1815

Genus ***Mytilus*** Linné, 1758

Type species.—Mytilus edulis Linné, 1758

***Mytilus*? sp.**

Plate 29-5

Material.—One specimen from Ebisudana, Miyako City, Iwate Prefecture.

Desciption.—The shell small, very obliquely elongated with nearly straight anterior and posterior margins which are subparallel to each other. The estimated apical angle is about 20 degrees, although the umbo is lacked in the specimen.

Measurements.—L=25.4 mm of the present specimen, H=15.0 mm, T=6.7 mm and L/H=1.69.

Remarks.—The present specimen resembles the genus of *Mytilus* which has elongated outline. However, to identify genus for specimens is difficult because of poorly-preservation.

Occurrence.—The described specimen is obtained from Ebisudana, Miyako City, Iwate Prefecture.

Subfamily Lithophaginae Adams and Adams, 1857

Genus ***Lithophaga*** Röding, 1798

Type species.—*Mytilus lithophagus* Linné, 1780

***Lithophaga* sp.**

Plate 25-3

Material.—One specimen from Koikorobe, Tanohata Village, Shimohei County, Iwate Prefecture.

Description.—Shell small, elongated, cylindrical, concave, equivalve; lithophagiform; test moderately thick; umbo not prominent, placed near the anterior end; posterior margin rounded; surface ornamented with only concentric lines.

Measurements.—L=21.7 mm of the present specimen, H=7.65 mm, T=5.25 mm and L/H=2.84.

Remarks.—The present specimen is identified as *Lithophaga* of the genus by lithophagiform. However, to identify of species is difficult because of only one specimen.

Occurrence.—The described specimen is obtained from Koikorobe, Tanohata Village, Shimohei County, Iwate Prefecture.

Superfamily Pinnacea Leach, 1819

Family Pinnidae Leach, 1819

Genus ***Pinna*** Linné, 1758

Type species.—*Pinna rudis* Linné, 1758

***Pinna* sp.**

Plate 31-16

Material.—One specimen from Aketo, Tanohata Village, Shimohei County, Iwate Prefecture.

Description.—Shell small, straight, elongated, acutely trigonal in lateral view, subrhomboidal in transverse section, well inflated; posterior margin angular; surface divided into two planes by a sharp median carina; dorsal slope nearly flat, provided with several equidistant, moderately strong, radial ribs, interspaces of which are roundly concave and much narrower than the ribs; concentric lamellae weak.

Measurements.—L=21.0 mm of the present specimen, H=7.5 mm, T=3.3 mm and L/H=2.80.

Remarks.—The present specimen similars *Pinna robinaldina* d'Orbigny, 1858. However, the present specimen is discriminated from the species by fairly narrow interspaces.

Occurrence.—The described specimen is obtained from Aketo, Tanohata Village, Shimohei County, Iwate Prefecture.

Order Pterioida Newell, 1965

Suborder Pteriina Newell, 1965

Superfamily Ambonychiacea Miller, 1877

Family Isognomonidae Woodring, 1925

Genus ***Isognomon*** Lightfoot, 1786

Type species.—*Isognomon lignea* Lightfoot, 1786

***Isognomon*? sp.**

Plate 32-6

Material.—One specimen from Kayanosawa, Hirono Town, Futaba County, Fukushima Prefecture.

Description.—Shell medium in size, subtrapezoidal, prosocline, nearly as long as high; right valve linguiform, weakly inflated, not carinate; test thick; umbo terminal, prosogyrous, not rising above dorsal margin; byssal gape probably narrow; dorsal margin moderately long, forming an angle of about 70 degrees with anterior margin; posterior margin slightly concave, forming a postero-dorsal angle of about 100 degrees with hinge; anterior wing absent; posterior area much flattened but not clearly alate; surface marked with several widely spaced irregular concentric lamellae besides closely spaced growth-lines.

Measurements.—L=71.8+ mm of the present specimen, H=65.7 mm and T=10.3 mm.

Remarks.—The present specimen resembles *Isognomon* of the genus by linguiform. However, to identify of species is difficult because of absent teeth structure.

Occurrence.—The described specimen is obtained from Kayanosawa, Hirono Town, Futaba County, Fukushima Prefecture.

Family Inoceramidae Giebel, 1852

Genus ***Inoceramus*** Sowerby, 1814

Type species.—*Inoceramus cuvieri* Sowerby, 1814

***Inoceramus* sp.**

Plate 37-1

Material.—One specimen from Irimazawa, Iwaki City, Fukushima Prefecture.

Description.—Shell small, inequilateral; moderately convex from anterior to posterior and also along growth axis; umbo small, terminal; beak angle about 90 degrees; fan-shaped; surface ornamentation: major concentric ribs commonly predominant, variable in density, crowded or broadening with growth, often irregular in shape, sharply acute-topped to blunt.

Measurements.—L=30.7 mm of the present specimen, H=27.3 mm, T=9.1 mm and L/H=1.12.

Remarks.—The present specimen resembles *Inoceramus amakusensis* Nagao and Matsumoto, 1940 which has fairly broad beak angle. However, to identify of species is difficult by poorly preservation.

Occurrence.—The described specimen is obtained from Irimazawa, Iwaki City, Fukushima Prefecture.

Inoceramus uwajimensis Yehara, 1924

Plates 33-1; 34-1; 35-1

Inoceramus uwajimensis Yehara, 1924, p. 36, pl. 3, figs. 1, 2, pl. 4, fig. 2: Nagao and Matsumoto, 1939, p. 286, pl. 34, figs. 1, 3, 4, 6, pl. 35, figs. 1-3; Matsumoto, 1959, pl. 11, fig. c; Saito, 1962, p. 65, pl. 1, figs. 14, 17; Noda, 1969, pl. 1, fig. 5; Noda, 1971, p. 26, pl. 2, fig. 4; Kanie, 1972, p. 21, pl. 3, figs. 4, 5.

Inoceramus cf. *uwajimensis* Yehara, Takai and Matumoto, 1961, p. 273, pl. 11, figs. 2-4; Noda, 1971, p. 27, pl. 2, figs. 6, 7.

Inoceramus uwajimensis var. yeharai Nagao and Matsumoto, 1939, p. 287, pl. 34, figs. 2, 5; Noda, 1969, p. 26, pl. 2, fig. 4.

Material.—Three specimens from the middle of Ashizawa, Ammonite center and Yoheisaku, Iwaki City, Fukushima Prefecture.

Description.—Shell small to medium sized, slightly inequivalve, inequilateral; moderately and uniformly convex from anterior to posterior and also along growth axis; umbo small, terminal, and slightly projected over hinge line: posterior wing-like area variable in shape and extent; beak angle variable, about 70 to 90 degrees; general outline highly variable: oval, fan-shaped, pentagonal and elongate ellipse; surface ornamentation: major concentric ribs commonly predominant, variable in density, crowded or broadening with growth, often irregular in shape, sharply acute-topped to blunt: minor riblets generally hardly perceptible, but distinct near the umbo.

Measurements.—L=46.3 mm of the present specimen from the middle of Ashizawa, H=51.5 mm, 2T=14 mm and L/H=0.90, L=51.2 mm of the present specimen from Ammonite Center, H=49.6 mm, 2T=31.8 mm and L/H=1.03 and L=17.9 m of the present specimen from Yoheisaku, H=17.0 mm, T=4.1 mm and L/H=1.05.

Remarks.—The present specimens are identified as *Inoceramus uwajimensis* by small umbo and fairly sharp beak angle. Noda and Matsumoto (1998) described several variation of *Inoceramus uwajimensis*. The variation types have a tendency to be obtained from different lithofacies, each other (Hayakawa, 1995). These tendency indicates possibility that the present species includes several species. However, to distinguish species is difficult by only simple characters. So, the present paper deals with the present species as only one species.

Occurrence.—Occurrence from the Uwajima, Fuaba, Upper Ezo, Ohnogawa, Taisho and Sotoizumi Groups.

Superfamily Pectinacea Rafinesque, 1815

Family Pectinidae Rafinesque, 1815

Pectenidae gen. et. sp. indet.

Plate 35-11

Material.—One specimen from Ammonite Center, Iwaki City, Fukushima Prefecture.

Description.—Shell moderate in size, subequilateral, relatively narrow, much higher than long; much compressed; antero-dorsal margin nearly straight: apical angle about 40 degrees; finely radial riblets slightly sinuous on ventral region; anterior byssal auricle proportionally large, with a deep byssal notch, marked with well-defined growth-lamellae but almost lacking radial ornament, connected with main body by a narrow fasciole area.

Measurements.—L=23.7 mm of the present specimen, H=32.1 mm, T=3.9 mm and L/H=0.74.

Remarks.—The present specimen resembles *Chlamys* of the genus by the outline. However, to identify of the genus is difficult because of poor preservation.

Occurrence.—The described specimen is obtained from Ammonite Center, Iwaki City, Fukushima Prefecture.

Subfamily Pectininae Rafinesque, 1815

Genus ***Neithea*** Drouet, 1825

Type species.—*Pecten versicostatus* Lamarck, 1819

***Neithea* sp. A**

Plates 27-3; 29-7

Material.—Two specimens from Ebisudana and coast of Hideshima, Miyako City, Iwate Prefecture.

Description.—Shell small to medium sized; test fairly thick; subequilateral, polygonally ovate. Left valve higher than long or high as same as long, very weakly inflated, anterior and posterior margins straight; apical angle about 65 to 75 degrees; primary ribs four to six in number, roof-shaped in transverse section, prominent, interspaces of primary ribs flattened at bottoms, bearing three-five weak secondary riblets, which are of rather unequal prominence, nearly as wide as their interspaces; auricles small, subequal.

Measurements.—L=6.2 mm of the present specimen from Ebisudana, H=7.0 mm, T=0.7 mm and L/H=0.89 and L=29.4 mm of the present specimen from coast of Hideshima, H=29.4 mm, T=2.3 mm and L/H=1.0.

Remarks.—The present specimens are identified as *Neithea* of genus by prominentally primary ribs. However, to identify of species is difficult because of left and poorly-preserved specimens.

Occurrence.—The described specimens are obtained from Ebisudana and coast of Hideshima, Miyako City, Iwate Prefecture.

***Neithea* sp. B**

Plate 47

Material.—One specimen from Tozawa in the Tozawa Formation, Nanmoku Village, Kanra County, Gunma Prefecture.

Description.—Shell large in size; test thick; subequilateral, polygonally ovate; right valve higher than long, weakly inflated; antero-dorsal and postero-dorsal margin nearly straight; apical angle about 70 degrees whrn viewed perpendicularly to valve margin; seven primary ribs frequently accompanied by weak subordinate riblets on their anterior and posterior slopes; both lateral areas typically smooth; auricles small, suequal.

Measurements.—L=69.0 mm of the present specimen, H=87.2 mm, T=7.7 mm and L/H=0.79.

*Remark*s.—The present specimen is identified as *Neithea* of genus by prominentally primary ribs. However, to identify of species is difficult because of poorly-preserved specimens.

Occurrence.—The described specimen is obtained from Tozawa in the Tozawa Formation, Nanmoku Village, Kanra County, Gunma Prefecture.

Neithea ficalhoi (Choffat, 1888)

Plates 29-6; 31-10

Pecten morrisi Pictet and Renevier, Nagao, 1934, p. 206, pl. 26, figs. 2-6.

Neithea ficalhoi (Choffat), Hayami, 1965a, p. 302, text-fig. 4, pl. 42, figs. 5-16.

Neithea alpine (d'Orbigny), Dhondt, 1973, p. 15.

Material.—Two specimens from Ebisudana, Miyako City, Iwate Prefecture and Aketo, Tanohata Village, Shimohei County, Iwate Prefecture.

Description.—Shell small; test fairy thick. Right valve higher than long, strongly inflated, with a prominently projecting, strongly incurved umbo, provided with two constant stout secondary ribs in each interspace; antero-dorsal and postero-doesal margin nearly straight; apical angle about 70 degrees when viewed perpendicularly to valve margin; six primary ribs frequently accompanied by weak subordinate riblets on their anterior and posterior slopes; both lateral areas typically smooth; auricles small, subequal.

Mesurements.—L=11.2 mm of the present specimen from Ebisudana, H=12.0 mm, T=5.3 mm and L/H=0.93 and L=10.2 mm of the present specimen from Aketo, H=10.2 mm, T=0.3 mm and L/H=1.0.

Remarks.—Hayami (1965a) defined *Neithea ficalhoi* which has regular ornamation. The present specimen have same ornamation pattern.

Occurrence.—Occurrence from the Monobegawa and Miyako Groups.

Neithea matsumotoi Hayami, 1965a

Plate 31-9

Neithea matsumotoi Hayami, 1965a, p. 297, text fig. 4, pl. 41, figs. 1-7.

Material.—One specimen from Aketo, Tanohata Village, Shimohei County, Iwate Prefecture.

Description.—Shell small, plano-convex, subequilateral, polygonally ovate. Right valve higher than long to a varying extent, well inflated; anterior and posterior margins slightly concave when viewed perpendicularly to valve margin; ventral margin frilled, corresponding to radial ribs of two orders; apical angle about 75 degrees; primary ribs six in number, roof-shaped in transverse section, very prominent, giving rise to digitations of ventral margin, slightly curved outwards; ribs distinctly plicated; interspaces of primary ribs flattened at bottoms, bearing three-five weak secondary riblets, which are of rather unequal prominence, nearly as wide as their interspaces.

Measurements.—L=10.0 mm of the present specimen and T=4.2 mm.

Remarks.—The present specimen resembles *Neithea matsumotoi* and *Neithea atava*. However, *Neithea atava* have narrower ribs. *Neithea matsumotoi* has common characters with the present specimen.

Occurrence.—Occurrence from the Senizumi and Shinjogawa Groups.

Neithea nipponica Hayami, 1965a

Plate 31-11

Pecten sp., Nagao, 1934, p. 209, pl. 29, figs. 8, 9.

Neitha nipponica Hayami, 1965a, p. 296, text-fig. 4, pl. 40, figs. 1-6, pl. 52, figs. 1, 2.

Neithea quinquecostata (Sowerby), Dhondt, 1973, p.32.

Material.—One specimen from Aketo, Tanohata Village, Shimohei County, Iwate Prefecture.

Description.—Shell small, plano-convex, polygonally ovate in outline, subequilateral, slightly higher than long; test moderately thick. Right valve strongly inflated; antero-dorsal margins long, broadly concave, forming an apical angle of about 80 degrees; ventral margin distinctly concave between primary ribs; each interval between primary ribs slightly concave, provided with four regular secondary riblets which are subequal to their interspaces in breadth; both lateral areas marked with a number of still finer riblets; concentric lines comparatively weak.

Measurements.—L=19.2 mm of the present specimen, H=17.5 mm, T=7.1 mm and L/H=1.10

Remarks.—The present specimen is identified *Neithea nipponica* by fine primary and secondary ribs and low height of shell.

Occurrence.—Occurrence from the Miyako Group.

Subfamily Chlamydinae Korobkov, 1960

Genus ***Chlamys*** Röding, 1798

Type species.—*Chlamys cinnabarina* Röding, 1798

Chlamys robinaldia (d'Orbigny, 1847)

Plate 27-5

Chlamys robinaldia (d'Orbigny), Hayami, 1965a, p. 310, pl. 44, figs. 5-7.

Material.—One specimen from coast of Hideshima.

Description.—Shell small, slightly inequilateral, slightly prosocline, relatively narrow, much higher than long; much compressed. Right valve very weakly convex; antero-dorsal margin nearly straight; apical angle about 80 degrees; finely radial riblets slightly sinuous on ventral region, somewhat scaly at intersections with concentric lines which are more or less regularly spaced; anterior byssal auricle proportionally large, with a deep byssal notch, marked with well-defined growth-lamellae but almost lacking radial ornament, connected with main body by a narrow fasciole area.

Measurements.—L=16.7 mm of the present specimen, H=18.6 mm, T=7.0 mm and L/H=0.90

Remarks.—The present specimen is identified *Chlamys robinaldia* which has narrow outline, large auricle, small apical angle and numerous radial riblets.

Occurrence.—Occurrence from the Miyako Group.

Chlamys subacuta (Lamarck, 1819)

Plate 27-2

Chlamys cf. *subacuta* (Lamarck), Hayami, 1965a, p. 312, pl. 45, fig.1.

Material.—One specimen from coast of Hideshima, Miyako City, Iwate Prefecture.

Description.—Shell medium-sized, slightly opisthocline, higher than long; test moderate in thickness; antero-dorsal margin of valve slightly concave, postero-dorsal one nearly straight; surface ornamented with about 23 roof-shaped, scaly and prominent ribs which become somewhat weaker on the posterior part and are slightly curved forwards on the anterior part; radials neither bifurcated nor intercalated.

Measurements.—H=29.3 mm of the present specimen and T=2.6 mm.

Remarks.—The present specimen is identified *Chlamys subacuta* by characteristic roof-shaped radial ribs.

Occurrence.—Occurrence from the Miyako Group.

Family Propeamussiidae Abbott, 1954

Genus ***Parvamussium*** Sacco, 1897

Type species.—*Parvamussium duodecimlamellatum* Bronn, 1831

Parvamussium yubarense (Yabe and Nagao, 1928)

Plate 34-4

Pecten cowperi var. *yubarensis* Yabe and Nagao, 1928, p. 88, pl. 16, figs. 17-19; Nagao, 1932, p. 38, pl. 6, figs. 7, 8, 12, 13; Nagao, 1938, p. 129, pl. 16, fig. 3.

Material.—One specimen from Yoheisaku, Iwaki City, Fukushima Prefecture.

Description.—Shell very small, equilateral, circular, rather inflated, high and long equal in size; test thin; anterior auricle larger than posterior; apical angle about 95 degrees; posterior margin fairly straight and ventral margin rounded; hinge line straight; nine internal primary ribs.

Measurements.—L=4.9 mm of the present specimen, H=4.9 mm, T=0.5 mm and L/H=1.00.

Remarks.—The present specimen is identified as *Parvamussium yubarense* by nine internal primary ribs.

Occurrence.—Occurrence from the Himenoura, Upper Ezo, Futaba, Ohnogawa, Goshonoura, Izumi, Shinjogawa and Sotoizumi Groups.

Family Spondylidae Gray, 1826

Genus ***Spondylus*** Linné, 1758

Type species.—*Spondylus gaederopus* Linné, 1758

Spondylus decoratus Nagao, 1934

Plates 25-9; 27-1

Spondylus decorates Nagao, 1934, p. 210, pl. 27, figs. 2, 5-7; Hayami, 1965a, p. 324, pl. 47, figs. 4-9, pl. 52, fig. 6.

Spondylus aff. *decorates* Nagao, 1934, p. 211, pl. 27, fig. 8.

Material.—Two specimens from coast of Hideshima and Koikorobe.

Description.—Shell medium sized, suboval, slightly inequilateral, slightly prosocline; test of moderate thickness, not porous. Left valve moderately inflated, slightly higher than long, comparatively regular in outline; postero-dorsal margin straight, much longer than antero-dorsal; umbo pointed, rising a little above dorsal margin; apical angle about 90 degrees; surface marked with numerous radial ribs of two orders of prominence; primary ribs about seven in number, not much broader than secondaries but prominent in middle ventral part, roof-shaped in transverse section, provided with a few irregularly disposed short spines; secondary ribs about seven in number in each interspace between primaries, not bifurcate, without spines.

Measurements.—L=41.2 mm of the present specimen from coast of Hideshima, H=44.7 mm, T=8.6 mm and L/H=0.92 and L=15.0 mm of the present specimen from Koikorobe, H=18.6 mm, T=2.5 mm and L/H=0.81.

Remarks.—The present specimens are identified *Spondylus decoratus* by the outline and developed spines.

Occurrence.—Occurrence from the Miyako Group.

Superfamily Limacea Rafinesque, 1815

Family Limidae Rafinesque, 1815

Limidae gen. et sp. indet.

Plate 27-6

Material.—One specimen from coast of Hideshima, Miyako City, Iwate Prefecture.

Description.—Shell small, trapezoidal, fairly inequilateral, longer than high; fan-shaped; umbo prominent, placed att about three-fifths of shell-length from the anterior end; strongly convex near the umbo and moderately inflated near the ventral margin; surface ornamented with fine ribs.

Measurements.—L=14.3 mm of the present specimen, H=13.8 mm, T=5.8 mm and L/H=1.04.

Remarks.—The present specimen resembles Limidae of the family by the outline. However, the convexity pattern of the present specimen is discriminated from all genus of Limidae.

Occurrence.—The described specimen is obtained from coast of Hideshima, Miyako City, Iwate Prefecture.

Genus ***Limatula*** Wood, 1839

Type species.—*Pecten subauriculatus* Montagu, 1808

Limatula nagaoi Hayami, 1965a

Plates 26-8; 29-8; 31-1

Lima ishidoensis Yabe and Nagao, Nagao, 1934, p. 213, pl. 27, figs. 9, 10.

Limatula nagaoi Hayami, 1965a, p. 333, pl. 49, figs. 1-4, Shikama and Suzuki, 1972, pl. 5, fig.4

Material.—Three specimens from Ebisudana, coast of Hideshima, Miyako City, Iwate Prefecture and Aketo, Tanohata Village, Shimohei County, Iwate Prefecture.

Description.—Shell small, narrow, elongate-oval, nearly acline, slightly inequilateral with the posterior margin more rounded than the anterior; height about twice the length; shell-convexity strong; test thin; no anterior umbonal ridge; umbo comparatively narrow, slightly rising above dorsal margin, placed submesially; auricles subequal, obtusely truncated, illdemarcated from main body; median ridge observable only near umbo; central-ventral area evenly inflated; ornamentation consisting of 15-17 fine simple radial riblets which are confined to the median part of surface; anterior and posterior unornamented areas subequal in breadth; riblets roof-shaped in transverse section, densely spaced near centre, becoming somewhat weaker and more sparse towards anterior and posterior areas; growth-lines very weak.

Measurements.—L=13.1 mm of the present specimen from Ebisudana, H=7.6 mm, T=4.2 mm and L/H=1.72, L=11.7 mm of the present specimen from coast of Hideshima, H=8.0 mm, T=4.0 mm and L/H=1.46 and L=9.9 mm of the present specimen from Aketo, H=8.2 mm, T=2.4 mm and L/H=1.21.

Remarks.—The present specimens are similar *Limatula nagaoi* and *Limatula ishidoensis*. However, *Limatula ishidoensis* has more equilateral outline and more distinctly concave anterior and posterior and posterior margins of auricles than the present specimens. The present specimens are identified as *Limatula nagaoi* by outline.

Occurrence.—Occurrence from the Miyako and Monobegawa Groups.

Suborder Ostreina Férussac, 1822

Superfamily Ostreacea Rafinesque, 1815

Family Ostreidae Rafinesque, 1815

Subfamily Gryphaeinae Vyalov, 1936

Genus ***Catinula*** Rollier, 1911

Type species.—*Ostrea knorri* Voltz, 1828

Catinula? oshimensis Hayami, 1965a

Plate 26-2

Gryphaea oshimensis Hayami, 1965a, p. 348, pl. 51, figs. 3-7, pl. 52, fig. 9; Hatai, Kotaka and Noda, 1969, p. 32, pl. 1, fig. 10.

Material.—One specimen from coast of Hideshima, Miyako City, Iwate Prefecture.

Description.—Shell small, subequilateral, subovate, much higher than long; test of moderate thickness. Left valve moderately inflated; antero- and postero-dorsal margins slightly concave; anterior and posterior areas not much flattened, not auriculated; not posterior sulcus; surface fairly smooth.

Measurements.—H=34.5 mm of the present specimen and T=5.9 mm.

Remarks.—The present specimen is identified as *Gryphaea oshimensis* which was described in Hayami (1965a) by the outline. However, the present species similars *Continila* of the genus which has no prominent concentric lines.

Occurrence.—Occurrence from the Oshima and Miyako Groups.

Subfamily Exogyrinae Vyalov, 1936

Genus ***Amphidonte*** Fischer de Waldheim, 1829

Type species.—*Amphidonta humboldti* Fischer de Waldheim, 1829

Amphidonte subhariotoidea (Nagao, 1934)

Plate 26-1

Exogyra subhaliotoidea Nagao, 1934, p. 203, pl. 30, figs. 1-4.

Amphidonte subhariotoidea (Nagao), Hayami, 1965a, p. 343, pl. 50, figs. 6-9, pl. 51, figs. 1-2; Hayami and Karasawa, 1967, p. 78, pl. 9, fig. 5; Shikama and Suzuki, 1972, pl. 5, figs. 10-14.

Material.—Two specimens from coast of Hideshima, Miyako City, Iwate Prefecture and Koikorobe, Tanohata Village, Shimohei County, Iwate Prefecture.

Description.—Shell medium-sized, inequilateral, *Haliotis*-like in outline, much higher than long; test fairly thick, neither plicated nor radially ribbed. Right valve also *Haliotis*-like but more weakly inflated and even slightly concave in posterior area; anterior margin raised to form a rounded rim, posterior margin nearly flat; umbo strongly coiled, operculiform; ligament area close to and elongated along dorsal margin, very narrow, only slightly concave, provided with a conical tooth-like projection; exterior of anterior rim marked with numerous subvertical striae.

Measurements.—H=18.7 mm of the present specimen from coast of Hideshima and T=4.3 mm and H=25.3 mm of the present specimen from Koikorobe and T=4.6 mm.

Remarks.—The present specimen similar *Amphidonte humboldti* and *Amphidonte subhariotoidea*. However, the present specimen is identified as *Amphidonte subhariotoides* which is discriminated from *Amphidonte humboldti* by broader attachment area.

Occurrence.—Occurrence from the Miyako, Nankai and Shinjogawa Groups.

Genus ***Ceratostreon*** Bayle, 1878

Type species.—*Ostrea matheroniana* d'Orbigny, 1848

Ceratostreon yabei (Nagao, 1934)

Plate 25-5

Exogyra yabei Nagao, 1934, p. 202, pl. 25, fig. 7, pl. 26, fig. 1, pl. 27, fig. 1, pl. 28, figs. 1, 2, pl. 29, figs. 1, 14.

Amphidonte (*Ceratostreon*) *yabei* (Nagao), Hayami, 1965a, p. 345, pl. 49, fig. 12, pl. 50, figs. 3-5; Shikama and Suzuki, 1972, pl. 5, fig. 9.

Material.—One specimen from Koikorobe, Tanohata Village, Shimohei County, Iwate Prefecture.

Description.—Shell fairly large, inequilateral, subovate in outline, not much elongated, curved posteriorly, higher than long; test fairly thick; left valve moderately inflated; radial plications obscurely impressed on attachment area but very conspicuous and angular on anterior slope, which is nearly perpendicular to commissure plane; attachment area very wide; valve margin finely crenulated internally.

Measurements.—L=37.0 mm of the present specimen and T=13.0 mm.

Remarks.—The present specimen is identified as *Ceratostreon yabei* by the outline and valve margin.

Occurrence.—Occurrence from the Miyako Group.

Subfamily Lophinae Vyalov, 1936

Genus ***Lopha*** Röding, 1798

Type species.—*Mytilus cristagalli* Linne, 1758

Lopha nagaoi Hayami, 1965a

Plate 25-4

Lopha nagaoi Hayami, 1965a, p. 338, pl. 49, figs. 8-11, pl. 50, figs. 1, 2; Shikama and Suzuki, 1972, pl. 5, fig. 8.

Material.—One specimen from Koikorobe, Tanohata Village, Shimohei County, Iwate Prefecture.

Description.—Shell medium in size, subovate, not much elongated, higher than long; test fairly thick; right valve weakly convex; umbo much depressed; ligament area very thin; surface ornamented with fine radial plications; a median parting may present; wide attachment area; valve margin strongly plicated.

Measurements.—L=28.7 mm of the present specimen, H=45.4 mm, T=12.9 mm and L/H=0.63.

Remarks.—The present specimen is identified as *Lopha nagaoi* as the elongated outline and wide attachment area.

Occurrence.—Occurrence from the Miyako and Choshi Groups.

Genus ***Rastellum*** Faujas-Saint-Fond, 1799

Type species.—*Ostrea macroptera* Sowerby, 1824

***Rastellum* sp.**

Plate 29-9

Material.—One specimen from Ebisudana, Miyako City, Iwate Prefecture.

Description.—Shell medium in size, weakly inequilateral, elongated, much longer than high; test fairly thick; storongly convex; umbo much depressed; surface ornamented with strong and fine radial plications.

Measurements.—L=43.1 mm of the present specimen, H=20.9 mm, T=9.6 mm and L/H=2.06.

Remarks.—The present specimen is identified as *Rastellum* of the genus by strong and fine rdial plications. However, to identify of species is difficult because of only one specimen.

Occurrence.—The described specimen is obtained from Ebisudana, Miyako City, Iwate Prefecture.

Subfamily Ostreinae Rafinesque, 1815

Genus ***Crassostrea*** Sacco, 1897

Type species.—Ostrea virginica (Gmelin, 1791)

***Crassostrea*? sp.**

Plate 35-9

Material.—One specimen from Ammonite Center, Iwaki City, Fukushima Prefecture.

Description.—Shell small, elongate, higher than long; outline slightly curved; shell gradually broader toward the ventral margin; test thin; surface smooth except for sparsely spaced growth-lines which are partly scaly; lacks radial ribs or plications; posterior sulcus absent.

Measurements.—L=13.9 mm of the present specimen, H=14.9 mm, T-=5.4 mm and L/H=0.92.

Remarks.—The present specimen resembles *Crassostrea* of the genus by the outline. However, to identify of the genus is difficult because of poor preservation.

Occurrence.—The described specimen is obtained from Ammonite Center, Iwaki City, Fukushima Prefecture.

Subclass Palaeoheterodonta Newell, 1965

Order Trigonioida Dall, 1889

Superfamily Trigoniacea Lamarck, 1819

Family Trigoniidae Lamarck, 1819

Genus ***Nipponitrigonia*** Cox, 1952

Type species.—Trigonia kikuchiana Yokoyama, 1891

***Nipponitrigonia* sp.**

Plates 25-2; 31-6; 48-1; 2

Material.—Four specimen from Tozawa in Ohnita Formation, Nanmoku Village, Kanra County, Gunma Prefecture, Koikorobe, Tanohata Village, Shimohei County, Iwate Prefecture and Aketo, Tanohata Village, Shimohei County, Iwate Prefecture.

Description.—Shell small to medium in size, trapezoidal, inequilateral, long as same size as high, strongly convex from umbo to venter and from anterior to posterior; test fairly thick; antero-ventral margin short and nearly straight or slightly concave, transmitting gradually into broadly arched venter; siphonal well rounded and sometimes angulated at junction with dorsal or ventral margin; dorsal long and nearly straight or slightly convex; umbo rather small; beak prosogyrous, located at about two-fifths from front; marginal carina distinct near the umbo, but rounded off later; disk ornamented with about 5 concentric ridges and grooves near the umbo, but smoothed later; area fairly broad, slightly concave, provided with some concentric sculptures which are direct continuations from those on the disk; escutcheon ill-defined.

Measurements.—L=19.6 mm of from the present specimen from Tozawa, H=18.9 mm, T=4.4 mm and L/H=1.04, L=18.9 mm of the present specimen from Koikorobe, H=17.0 mm, T=5.4 mm and L/H=1.11, L=14.0 mm of one of the present specimen from Aketo, H=13.8 mm, T=4.1 mm and L/H=1.01 and L=23.5 mm of another specimen from Aketo, H=23.1 mm, T=6.7 mm and L/H=1.02.

Remarks.—The present specimens resemble *Nipponitrigonia tahiroi* Matsuda, 1989ms by concentric ridge and convexity. However, to identify of species is difficult because of less description of the present species by publishment in journal.

Occurrence.—The described specimens are obtained from Tozawa in Ohnita Formation, Nanmoku Village, Kanra County, Gunma Prefecture, Koikorobe, Tanohata Village, Shimohei County, Iwate Prefecture and Aketo, Tanohata Village, Shimohei County, Iwate Prefecture..

Subfamily Prosogyrotrigoniinae Kobayashi, 1954

Genus ***Apiotrigonia*** Cox, 1952

Type species.—*Trigonia sulcataria* Lamarck, 1819

Apiotrigonia minor (Yabe and Nagao, 1925)

Plates 32-4; 33-3; 34-2; 35-2

Trigonia cf. *subovalis* Jimbo, Yehara, 1915, p. 42, pl. 1, figs. 14-17; Hayasaka, 1921, p. 4, pl. 1, fig. 2; Yehara, 1923a, p. 8, pl. 6, figs. 1-5.

Trigonia subovalis Jimbo, Yehara, 1923b, p. 78, pl. 11, figs. 4-8.

Trigonia subovalis var. *minor* Yabe and Nagao, 1925, p. 116; Yabe, 1927, pl. 7, fig. 4; Nagao and Otatume, 1938, p. 42, pl. 1, figs. 7-9.

Apiotrigonia subovalis minor (Yabe and Nagao), Kobayashi, 1954, p.77.

Apiotrigonia minor (Yabe and Nagao), Nakano, 1957, p. 110, pl. 8, figs. 1-4; Saito, 1962, p. 63, pl. 1, figs. 8, 9; Maeda and Kawabe, 1967, p. 423, pl. 1, fig. 10.

Apiotrigonia ashizawaensis Saito, 1962, p. 64, pl. 1, fig. 6.

Apiotrigonia futabaensis Maeda and Kawabe, 1967, p. 421, pl. 1, figs. 5, 6.

Apiotrigonia hironoensis Maeda and Kawabe, 1967, p. 422, pl. 1, figs. 7-9.

Apiotrigonia orikiensis Maeda and Kawabe, 1967, p. 423, pl. 1, figs. 1-4.

Material.—Four specimens from the middle of Ashizawa, Ammonite center, Yoheisaku, Iwaki City, Fukushima Prefecture and Kayanosawa, Hirono Town, Futaba County, Fukushima Prefecture.

Description.—Shell small, pyriform to trigonal-ovate, inequilateral, moderately inflated; anterior margin rounded, passing gradually into broadly arcuated ventral margin; dorsal long and slightly concave; siphonal narrowly rounded: beak small, somewhat prominent, opisthogyrous, pointed at about a third to a fourth from front; flank with two series of plain costae, except for umbonal region with four five concentrics; anterior series composed of about 17 costae, first subconcentric and letter horizonal and occasionally slight flexed near anterior margin; posterior series consists of about 15 radial or subvertical costae, broadened and gradually obscured ventrally; anterior half of radial costae confluent with some costae of anteries series; posterior ones extended to ventral margin; marginal, median and escutcheon carinae effaced except near beak; area narrow, sculptured with several transverse costae in early stage, but rapidly broadened and gradually smoothened; median furrow shallow; escutcheon broad, depressed, with about 20 plain costellae, sometimes bifurcating at first subconcentric and gradually become oblique. ante-cardinal depression well developed and shallow.

Measurements.—L=14.7 mm of the present specimen from the middle of Ashizawa, H=11.1 mm, T=1.1 mm and L/H=1.32, L=15.2 mm of the present specimen from Ammonite Center, H=10.3 mm, T=2.3 mm and L/H=1.48, H=12.4 mm of the present specimen from Yoheisaku and T=3.6 mm and L=23.6 mm of the present specimen from Kayanosawa, H=18.8 mm, T=7.0 mm and L/H=1.26.

Remarks.—The described specimens are identified as *Apiotrigonia minor* by cross costae.

Occurrence.—Occurrence from the Futaba, Uwajima, Himenoura and Upper Ezo Groups.

Subfamily Myophorellinae Bayle, 1878

Genus ***Yaadia*** Crickmay, 1930

Type species.—*Yaadia lewisagassizi* Crickmay, 1930

***Yaadia* sp.**

Plate 32-8

Material.—One specimen from lower of Ashizawa, Hirono Town, Futaba County, Fukushima Prefecture.

Description.—Shell large, ovately quadrate, very inequilateral, anterior side being much shorter than the posterior and abruptly truncated at end; lower border long and broadly arched; postero-dorsal long and nearly straight; umbo subanterior, obtuse, not much elevated nor conspicuously recurved; area narrow, slightly convex, bounded by a smooth carina on each side, distinctly marked with rough lines of growth; escutcheon elongated narrow and flattened, bounded on each side by a rather obtuse edge lined with tubercles; the remaining portion of the surface is provided with oblique, straight or slightly curved row of irregurarly formed tubercles, which are large, though not prominent, closely arranged and rather unequal in size.

Measurements.—L=82.4+ mm of the present specimens, H=64.1 mm and T=28.6 mm.

Remarks.—The present specimen is identified as *Yaadia* of the genus by the large size and ornamention.

Occurrence.—The described specimen is obtained from the lower of Ashizawa, Hirono Town, Futaba County, Fukushima Prefecture.

Subfamily Pterotrigoniinae van Hoepen, 1929

Genus ***Pterotrigonia*** van Hoepen, 1929

Type species.—*Pterotrigonia crista* van Hoepen, 1929

Pterotrigonia pociliformis Yokoyama, 1891

Plate 29-10

Trigonia pociliformis Yokoyama, 1891, p. 361, pl. 40, figs. 1-3; Yehara, 1923b, p. 71, pl. 9, figs. 8-10, pl. 10, figs. 4-6; Yabe, Nagao and Shimizu, 1926, p. 45; Yabe, 1927, pl. 4, fig. 3.

Pterotrigonia pociliformis (Yokoyama), Kobayashi, 1954, p. 77; Kobayashi and Nakano, 1957, p. 227, pl. 16, figs. 1-3; Kobayashi and Nakano, 1958, p. 147, pl. 11, fig. 12; Matoba, 1964, pl. 37, figs. 6, 7; Maeda and Kitamura, 1964, p. 52, pl. 1, figs. 1-12; Maeda and Kawabe, 1967, p. 91, pl. 1, figs. 1-3.

Pterotrigonia pociliformis var. *yamanokamiensis* Kobayashi and Nakano, 1957, p. 229, pl. 16, figs. 8-10.

Material.—One specimen from Ebisudana, Miyako City, Iwate Prefecture.

Description.—Shell small, lunate, elongated backward, moderately inflated; anterior margin rounded, gently passing into gently arcuate ventral and somewhat sinuated before reaching the end; siphonal margin rounded; dorsal long and concave; umbo narrow, prominent, opisthogyrous, placed at about a fourth from the anterior end; carinae absent except near the umbo; area narrow, with several transverse costae in early stages, abruptly broadened and effaced; median furrow distinct; escutcheon depressed, broad, provided with about finely tuberculate costellae; costae on disk narrow, prominent, tubercuate; their interval of moderate breadth; umbonal region provided with about 2 concentric costae; next 7 straight and diagonal; last 8 slender, straight, subvertical and gradually becoming oblique backwards.

Measurements.—L=38.4 mm of the present specimens, H=30.1 mm, T=12.5 mm and L/H=1.28

Remarks.—The present specimen is identified as *Pterotrigonia pociliformis* by area form and fine ribs.

Occurrence.—Occurrence from the Monobegawa and Lower Ezo Groups.

Pterotrigonia hokkaidoana Yehara, 1915

Plate 26-10

Trigonia hokkaidoana Yehara, 1915, p. 39, pl. 1, figs. 1-8; Yehara 1923a, p. 5, pl. 7, figs. 3-5; Yehara 1923b, p. 70, pl. 11, figs. 9, 10, pl. 12, fig. 5; Yabe, 1927, pl. 4, fig. 6; Nagao, 1934, p. 205.

Trigonia kotoi Yehara, 1915, p. 40, pl. 1, fig. 10; Yehara, 1923b, p. 73, pl. 9, fig. 7; Nagao, 1934, p. 206.

Trigonia pociliformis var. *sachalinensis* Yabe and Nagao, 1925, p. 118, pl. 28, figs. 5, 6.

Pterotrigonia hokkaidoana (Yehara), Kobayashi, 1954, p. 76; Kobayashi and Nakano, 1957, p. 229, pl. 16, fig. 4; Kobayashi and Nakano, 1958, p. 148, pl. 11, figs. 9-11: Matoba, 1964, p. 259, pl. 37, figs. 4, 5; Hayami and Kawasawa, 1967, p. 79, pl. 9, figs. 6-9; Hayami and Nakano, 1968, p. 200, figs. 2-6; Hatai, Kotaka and Noda, 1969, p. 32, pl. 1, figs. 1, 11.

Pterotrigonia kotoi (Yehara), Kobayashi, 1954, p. 77.

Pterotrigonia pociliformis sachalinensis (Yabe and Nagao), Kobayashi, 1954, p. 77.

Pterotrigonia cf. *hokkaidoana* (Yehara), Matoba, 1964, p. 259, pl. 37, figs. 1-3.

Material.—Four specimens from Ebisudana, coast of Hideshima, Miyako City, Iwate Prefecture and Aketo, Tanohata Village, Shimohei County, Iwate Prefecture.

Description.—Shell medium in size, subtrigonal, inequilateral, inflated anteriorly, a little broader than high; anterior margin rounded, passing gradually into broadly arched ventral; dorsal margin long and concave; siphonal rounded; umbo small, promimnent; beak opisthogyrous, pointed at a third to a fourth from the anterior end; carinae obscure except near umbo; area narrow, provided with some 8 tranverse costae in juvenalium, but soon broadened and effaced; median furrow fairly deep and distinct; escutcheon broad, depressed, with about 15 tuberculate transverse costellae; disk with widely spaced numerous tuberculate diagonal costae; 2 to 3 near umbo concentric; next 7 on the most inflated part straight and oblique; last 9 nearly straight, first oblique anteriorly and later oblique posteriorly.

Measurements.—L=21.1 mm of the present specimen from Ebisudana, H=17.1 mm, T=8.2 mm and

L/H=1.23, L=13.4 mm of another specimen from Ebisudana, H=9.0 mm, T=4.9 mm and L/H=1.49, L=44.8 mm of the present specimen from coast of Hideshima, H=31.9 mm, T=13.1 mm and L/H=1.40 and H=40.8 mm of the present specimen from Aketo and T=15.2 mm.

Remarks.—The present specimens are identified as *Pterotrigonia hokkaidoana* by fine ribs.

Occurrence.—Occurrence from the Miyako, Sensotoizumi and Shinjogawa Groups.

Pterotrigonia yokoyamai Yehara, 1915

Plate 25-1

Trigonia yokoyamai Yehara, 1915, p. 41, pl. 2, figs. 15-17; Nagao, 1934, p. 205.

Pterotrigonia yokoyamai (Yehara), Kobayashi, 1954, p.77.

Material.—One specimen from Koikorobe, Tanohata Village, Shimohei County, Iwate Prefecture.

Description.—Shell small, subtrigonal, inequilateral, inflated anteriorly, longer than high; anterior margin rounded, passing gradually into broadly arched ventral; dorsal margin long and concave; siphonal rounded; umbo small, fairly promimnent; beak opisthogyrous, pointed at a fifths from the anterior end; area narrow; median furrow fairly deep and distinct; escutcheon broad, depressed, with about 12 tuberculate transverse costellae; disk with widely spaced several tuberculate diagonal costae; 1 to 2 near umbo concentric; next 6 on the most inflated part straight and oblique; last 6 nearly straight, first oblique anteriorly and later oblique posteriorly.

Measurements.—L=31.8 mm of the present specimen, H=27.5 mm, T=11.0 mm and L/H=1.16.

Remarks.—The present specimen is identified as *Pterotrigonia yokoyamai* by the coarse ribs.

Occurrence.—Occurrence from the Miyako and Nankai Groups.

Subclass Heterodonta Neumayr, 1884

Order Veneroida Adams and Adams, 1856

Superfamily Lucinacea Fleming, 1828

Family Lucinidae Fleming, 1828

Subfamily Myrteinae Chavan, 1969

Genus ***Myrtea*** Turton, 1822

Type species.—*Venus spinifera* Montagu, 1803

Myrtea **sp.**

Plate 48-3

Material.—One specimen from Tozawa in Ohnita Formation, Nanmoku Village, Kanra County, Gunma

Prefecture.

Description.—Shell small, somewhat pentagonally ovate in outline, slightly higher than long, subequilateral, convex from beak toward ventral margin, compressed and sttenuated both anterioly and posteriorly; antero-dorsal margin nearly horizonal, slightly excavated beneath beak; postero-dorsal margin straight, inclined backward and downward; ventral margin broadly and evenly curved, passing gradually into anterior one which is arcuate and rounded along margin; posterior end vertically truncated by a straight and rather long margin which forms an obtuse angle with ventral: beak small, subcentral, not prominent, with a rounded posterior umbonal angle running from it to postero-central end, surface behind this angle compressed and flattened; anterior umbonal angle not well defined, antero-dorsal area broadened by a distinct groove which originates from beak and runs to antero-dorsal end; lunule small, very short, deep, bounded by sharp ridges: test relatively thin; surface ornamented by concentric lines.

Measurements.—L=16.9 mm of the present specimen, H=18.0 mm, T=4.3 mm and L/H=0.94.

Remarks.—The present specimen resembles *Myrtea ezoensis*, but is discriminated by low L/H ratio and convex shell.

Occurrence.—The described specimen is obtained from Tozawa in Ohnita Formation, Nanmoku Village, Kanra County, Gunma Prefecture.

Myrtea ezoensis (Nagao, 1938)

Plate 33-2

Lucina cf. *fallax* Forbes, Yokoyama, 1890, p. 176, pl. 18, fig. 9.

Lucina (*Myrtea*) *ezoensis* Nagao, 1938, p. 136, pl. 16, figs. 4-6; Matsumoto, Hayami and Asano, 1963, p. 29, pl. 44, fig. 9.

Lucinoma ezoensis (Nagano), Saito, 1962, p. 70, pl. 2, figs. 6, 11.

Material.—Three specimens from the middle of Ashizawa, Ammonite center and Yoheisaku, Iwaki City, Fukushima Prefecture.

Descriptions.—Shell rather small, somewhat pentagonally ovate in outline, slightly longer than high, subequilateral, moderately convex from beak toward ventral margin, compressed and attenuated both anteriorly and posteriorly; antero-dorsal margin nearly horizonal, slightly excavated beneath beak; postero-dorsal margin straight, inclined backward and downward; ventral margin broadly and evenly curved, passing gradually into anterior one which is arcuate and rounded along margin; posterior end vertically truncated by a straight and rather long margin which forms an obtuse angle with ventral: beak small, subcentral, not prominent, with a rounded posterior umbonal angle running from it to postero-central end, surface behind this angle compressed and flattened; anterior umbonal angle not well defined, antero-dorsal area broadened by a distinct groove which originates from beak and runs to antero-dorsal end; lunule small, very short, deep, bounded by sharp ridges: ligamental groove deeply depressed; escutcheon well defined; test relatively thin.

Surface with numerous, prominent and widely spaced concentric lamellae and flat interspaces in alternation, latter having a few fine concentric lines. These lamellae prolonged on ridges at anterior margin of escutcheon and also near antero-dorsal margin; lamellae and lines distinctly wavy on crossing groove near anterior margin.

Measurements.—L=15.9 mm of the present specimen from the middle of Ashizawa, H=13.0 mm, 2T=3.9 mm and L/H=1.22, L=16.5 mm of the present specimen from Ammonite Center and T=2.7 mm and L=8.9 mm of the present specimen from Yoheisaku, H=8.8 mm, T=2.1 mm and L/H=1.01.

Remarks.—The present specimens are identified as *Myrtea ezoensis* by outline and concentric lines.

Occurrence.—Occurrence from the Himenoura, Upper Ezo, Futaba and Uwajima Groups.

Genus ***Lucinoma*** Dall, 1901

Type species.—*Lucina filosa* Stimpson, 1851

Lucinoma*? *kotoi (Nagao, 1934)

Plate29-12

Lucina kotoi Nagao, 1934, p. 226, pl. 29, figs. 5, 6.

Lucinoma? *kotoi* (Nagao), Hayami, 1965b, p. 113, pl. 15, figs. 4-6.

Material.—One specimen from Ebisudana, Miyako City, Iwate Prefecture.

Description.—Shell small, slightly inequilateral, orbicularly ovate, longer than high, weakly inflated, not carinated; test thin; antero-dorsal margin slightly concave in front of the umbo, whereas postero-dorsal margin is broadly arcuate and passes gradually into the postero-dorsal margin; umbo slightly prosogyrous, placed slightly anteriorly from the mid-point of length, scarcely rising above the dorsal margin; lunule probably small, circumscribed by a sharp ridge; escutcheon distinct; surface marked with numerous narrow concentric lamellae, which are somewhat irregular in interval and prominence but usually much narrower than their interspaces.

Measurements.—L=6.0 mm of the present specimen, H=5.9 mm, T=1.3 mm and L/H=1.02.

Remarks.—The present specimen is identified as *Lucinoma*? *kotoi* by the ovate outline and numerous concentric lines.

Occurrence.—Occurrence from the Miyako Group.

Family Mactromyidae Cox, 1929

Genus ***Clisocolus*** Gabb, 1869

Type species.—*Loripes dubia* Gabb, 1864

***Clisocolus* sp.**

Plate 35-10

Material.—One specimen from Ammonite center, Iwaki City, Fukushima Prefecture.

Description.—Shell small, subovate, strongly inflated; umbo pointed but not so prominent for genus, situated at about the mid-length of the valve, slightly prosogyrate; anterior dorsal margin weakly convex, but narrowly concave near the umbo; posterior dorsal margin nearly straight; both lateral margins convex, passing gradually to well rounded ventral margin; weak posterior carina perceptible near the umbo, but not discernible on the major part; surface of the valve nearly smooth except for very weakly marked growth lines; lunular area narrowly depressed but not separated from the disk.

Measurements.—L=27.7 mm of the present specimen, H=16.7 mm, T=10.5 mm and L/H=1.63.

Remarks.—The present specimen is identified as *Clisocolus* of the genus by strongly inflated outline. However, to identify of species is difficult because of poorly preservation.

Occurrence.—The described specimen is obtained from Ammonite center, Iwaki City, Fukushima Prefecture.

Superfamily Carditacea Fleming, 1820

Family Carditidae Fleming, 1828

Subfamily Carditinae Fleming, 1828

Genus ***Cardita*** Bruguière, 1792

Type species.—*Cardita variegata* Bruguière, 1792

"*Cardita*"? sp.

Plate 25-8, 27-4

Material.—Two specimens from coast of Hideshima, Miyako City, Iwate Prefecture and Koikorobe, Tanohata Village, Shimohei County, Iwate Prefecture.

Descriptions.—Shell small, inequilateral, much higher than long; umbo prosogyrous, not prominent, placed at about one-third of shell-length from the anterior end; antero- and postero-dorsal margin a little concave; radial ornamentation with weak granules.

Measurements.—L=17.2 mm of the present specimen of coast of Hideshima, H=16.5 mm, T=5.5 mm and L/H=1.04 and L=7.3 mm of the present specimen from Koikorobe, H=12.8 mm, T=4.4 mm and L/H=0.57.

Remarks.—The outline and ornamentation remind those of some species of the Carditidae, although the generic reference cannot be decided at present.

Occurrence.—The described specimens are obtained from coast of Hideshima, Miyako City, Iwate Prefecture and Koikorobe, Tanohata Village, Shimohei County, Iwate Prefecture..

Subfamily Venericardinae Chavan, 1969

Genus ***Ludbrookia*** Chavan, 1951

Type species.—*Cardita dupiniana* d'Orbigny, 1843

Ludbrookia* cf. *tenuicostata (Sowerby, 1836)

Plate 29-13

Pseudocardia cf. *tenuicostata* (Sowerby), Hayami, 1965b, p. 77, pl. 7, figs. 1-3; Shikama and Suzuki, 1972, pl. 6, fig. 2.

Material.—One specimen from Ebisudana, Miyako City, Iwate Prefecture.

Description.—Shell small, subquadrate in outline, highly inequilateral, much longer than high, moderately inflated but somewhat flattened in the postero-dorsal peripheral area; antero-dorsal margin short, straight; postero-dorsal margin much longer, nearly straight, forming an angle of approximately 100 degrees with the antero-sorsal margin; posterior margin subvertical, weakly convex; ventral margin well rounded, defined from the antero-dorsal and posterior margins respectively by strong curvature; umbo prosogyrous, placed anteriorly, slightly rising above the dorsal margin; a blunt rounded carina extends diagonally from the umbo to the postero-ventral corner; lunule hemispherical, fairly deep, nearly smooth; escutcheon delimited by a sharp ridge, elongated along the postero-dorsal margin; surface ornamented with about 50 radial ribs which are somewhat irregular in prominence but much narrower than their interspaces and become finer towards the posterior area; numerous concentric lines cross radials, forming small scales at the intersections; ventral margin crenulated internally in accordance with the external radials.

Measurements.—L=16.7 mm of the present specimens, H=14.8 mm, 2T=10.5 mm and L/H=1.13.

Remarks.—The present specimen is identified as *Pseudocardita* cf. *tenuicosta* which was described by Hayami (1965b). But the present species is classified into *Ludbrookia* of the genus by fairly deep lunule.

Occurrence.—Occurrence from the Miyako and Choshi Groups.

Superfamily Crassatellacea Férussac, 1822

Family Astartidae d'Orbigny, 1844

Subfamily Astartinae d'Orbigny, 1844

Genus ***Astarte*** Sowerby, 1816

Type species.—Astarte lurida Sowerby, 1816

Astarte subsenecta Yabe and Nagao, 1926

Plate 27-8

Astarte subsencta Yabe and Nagao, Yabe, Nagao and Shimizu, 1926, p. 47, pl. 13, figs. 14-16, pl. 14, fig. 11; Hayami, 1965b, p. 81, pl. 7, figs. 10-18, pl. 14, figs. 1-5; Shikama and Suzuki, pl. 6, fig. 4.

Material.—Two specimens from Ebisudana and coast of Hideshima, Miyako City, Iwate Prefecture.

Description.—Shell very small, inequilateral, subovate, moderately inflated, more or less longer than high; antero-dorsal margin nearly straight; postero-dorsal margin much much longer than the antero-dorsal, arcuate; posterior margin truncated subvertically, defined from the postero-dorsal and ventral margins by obtuse angles; posterior area delimited from the disk by an obsucure carina; umbo prosogyrous, not very prominent, placed at about one-third of shell-length from the anterior end, broad, scarcely rising above the dorsal margin; lunule narrow but fairly deep; escutcheon narrow, weakly delimited by a ridge; umbonal cavity very shallow; surface marked wholly with numerous fine concentric lines of growth; a few broad concentric ribs distributed on the umbonal and middle surface, becoming much weaker towards the ventral margin.

Measurements.—L=6.4 mm of the present specimen from Ebisudana, H=5.8 mm, T=1.6 mm and L/H=1.10 and L=4.7 mm of the present specimen from coast of Hideshima, H=4.4 mm, T=0.8 mm and L/H=1.07.

Remarks.—The present specimens are identified *Astarte subsenecta* by not prominent umbo and fine concentric lines.

Occurrence.—Occurrence from the Monobegawa Groups.

Astarte yatsushiroensis Tashiro, 1992ms

Plate 48-5

Astarte yatsushiroensis Tashiro, 1992ms, p. 186, pl. 52, figs. 8, 9.

Material.—One specimen from Tozawa in the Ohnita Formation, Nanmoku Village, Kanra County, Gunma Prefecture.

Description.—Shell small, inequilateral, subovate, moderately inflated, more or less longer than high; antero-dorsal margin nearly straight; postero-dorsal margin much much longer than the antero-dorsal, arcuate; posterior margin truncated subvertically, defined from the postero-dorsal and ventral margins by obtuse angles; posterior area delimited from the disk by an obsucure carina; umbo prosogyrous, not very prominent, placed at about one-third of shell-length from the anterior end, broad, scarcely rising above the dorsal margin; lunule narrow but fairly deep; escutcheon narrow, weakly delimited by a ridge; umbonal cavity very shallow; surface marked wholly with numerous very fine concentric lines of growth; a few broad concentric ribs distributed on the umbonal and middle surface, becoming much weaker towards the ventral margin.

Measurements.—L=21.0 mm of the present specimens, H=20.0 mm, T=3.8 mm and L/H=1.05.

Remarks.—The present specimen resembles *Astarte subsencta*, but is discriminated by very fine concentric lines and identified as *Astarte costata*.

Occurrence.—Occurrence from the Sensotoizumi and Nankai Groups.

Astarte costata Yabe and Nagao, 1926

Plate 48-4

Astarte subsencta var. costata Yabe and Nagao, Yabe, Nagao and Shimizu, 1926, p. 48, pl. 14, fig. 10.

Astarte costata Yabe and Nagao, Hayami, 1965b, p. 85, pl. 8, figs. 1, 2; Shikama and Suzuki, 1972, pl. 6, fig. 5.

Material.—One specimen from Tozawa in the Ohnita Formation, Nanmoku Village, Kanra County, Gunma Prefecture.

Description.—Shell small, not strongly inflated, polygonally ovate, longer than high; antero-dorsal margin moderate in length slightly concave in front of umbo; postero-dorsal margin much longer than the antero-dorsal a little convex; posterior margin subvertically truncated, clearly discriminated, forming obtuse angles with the postero-dorsal and ventral margins; umbo prosogyrous, rather narrow, slightly rising above the dorsal margin, situated at about two-fifths of shell-length from the anterior extremity; a weak rounded carina extends from the umbo to the postero-ventral periphery, delimiting clearly a broad posterior area; lunule narrowly elongate, compressed, delimited by a sharp ridge.

Measurements.—L=15.0 mm of the present specimens, H=13.8 mm, T=5.1 mm and L/H=1.09.

Remarks.—The present specimen is identified as *Astarte costata* by the outline.

Occurrence.—Occurrence from the Monobegawa Group.

Astarte minor Nagao, 1934

Plate 29-16

Astarte minor Nagao, 1934, p. 220, pl. 28, figs. 5-10; Hayami, 1965b, p. 91, pl. 8, figs. 19-22.

Material.—One specimen from Ebisudana, Miyako City, Iwate Prefecture.

Description.—Shell very small; suboval in outline, subequilateral, nearly as high as long, not carinated, strongly inflated; antero-dorsal margin a little concave, while postero-dorsal margin is slightly convex; anterior, ventral and posterior margins well rounded without any angulation; umbo very prominent above dorsal margin, contigunous, incurved, very slightly prosogyrous, placed nearly at the mid-point of length; surface ornamented with 8 strong, highly elevated, from the umbo to the ventral margin.

Measurements.—L=3.5 mm of the present specimens, H=3.5 mm, T=0.8 mm and L/H=1.0.

Remarks.—The present specimen is identified as *Astarte minor* by small size and concentric sculpture and discriminated from Astarte submalioides by far storonger convexity, less inequilateral outline, more strongly convex postero-dorsal margin and more prominent umbo.

Occurrence.—Occurrence from the Miyako Group.

Astarte submalioides Nagao, 1934

Plates 29-15; 31-14.

Astarte submalioides Nagao, 1934, p. 219, pl. 27, figs. 3, 4; Hayami, 1965b, p. 88, pl. 8, figs. 12-18.

Astarte semicostata Nagao, 1934, p. 221, pl. 25, fig. 2.

Material.—Four specimens from Ebisudana, Miyako City, Iwate Prefecture and Aketo, Tanohata Village, Shimohei County, Iwate Prefecture.

Description.—Shell very small, inequilateral, subquadrate, slightly longer than high, weakly inflated; test thick; antero-dorsal margin a little concave in front of umbo to form a narrow lunule; postero-dorsal margin much longer than the anterior-dorsal, nearly straight, forming an angle of about 110 degrees with the posterior margin; carina absent, but the posterior and ventral margins obscurely delimited from each other by a strong curvature; umbo a little prosogyrous, scarcely rising above the dorsal margin, placed at about two-fifth of shell-length from the anterior extremity; escutcheon narrow, clearly delimited by a very sharp ridge; surface decorated with strong concentric ribs, which are seven to nine in number.

Measurements.—L=5.8 mm of one of the present specimen from Ebisudana, H=4.8 mm, T=1.2 mm and L/H=1.21, H=5.7 mm of another specimen from Ebisudana and T=1.5 mm, L=8.2 mm of one of the present specimen from Aketo, H=7.4 mm, T=1.8 mm and L/H=1.11 and L=7.0 mm of another specimen from Aketo, H=5.2 mm, T=0.9 mm and L/H=1.35.

Remarks.—The present specimens are identified as *Astarte submalioides* by highly raised concentric sculpture.

Occurrence.—Occurrence from the Miyako Group.

Genus ***Yabea*** Hayami, 1965b

Type species.—*Astarte shinanoensis* Yabe and Nagao, 1926

***Yabea*? sp.**

Plates 48-6; 7

Material.—One specimen from Tozawa in the Ohnita Formation, Nanmoku Village, Kanra County, Gunma Prefecture.

Description.—Shell small, inequilateral outline, strong shell convex, subterminal and extremely prosogyrous umbo, deeply excavated pre-umbonal margin and fine ventral crenulations; surface smooth.

Measurements.—H=16.5 mm of the present specimen and T=4.7 mm.

Remarks.—The present specimen resembles *Yabea* of the genus by the outline. However, to identify of the genus is difficult because of poorly preservation.

Occurrence.—The described specimen is obtained from Tozawa in the Ohnita Formation, Nanmoku Village, Kanra County, Gunma Prefecture.

Subfamily Eriphylinae Chavan, 1952

Genus ***Eriphyla*** Gabb, 1864

Type species.—*Eriphyla umbonata* Gabb, 1864

Eripyla miyakoensis (Nagao, 1927)

Plates 26-3; 29-17; 31-2

Astarte miyakoensis Nagao, in Yabe, 1927, pl. 4, fig. 5; Nagao, 1934, p. 218, pl. 30, fig. 8, pl. 32, figs. 1, 3-5.

Eriphyla miyakoensis (Nagao), Hayami, 1965b, p. 101, pl. 10, figs. 1-8, pl. 11, figs. 1-8.

Material.—Five specimens from Ebisudana, coast of Hideshima, Miyako City, Iwate Prefecture and Aketo, Tanohata Village, Shimohei County, Iwate Prefecture.

Descriptions.—Shell small, suborbicular in outline, nearly as long as high, moderately inflated, never carinated; test thick and solid; antero-dorsal margin comparatively long, weakly concave in front of umbo, passing gradually into the ventral margin without any angulation; postero-dorsal margin moderate in length, broadly convex, gradually bent down towards the posterior margin; posterior margin not clearly discriminated; ventral margin broadly arcuate; umbo prosogyrous, overhanging lunule, prominent above dorsal margin, placed at about two-fifth of shell-length from the anterior end; escutcheon delimited by a weak ridge, narrow, nearly vertical; lunule moderate in width, profound, circumscribed by a blunt ridge; surface quite smooth except for numerous faint concentric lines of growth; ligament external; umbonal cavity fairly deep.

Measurements.—L=19.4 mm of one of the present specimen from Ebisudana, H=18.5 mm, T=3.0 mm and L/H=1.05, L=9.2 mm of another specimen from Ebisudana, H=9.0 mm, T=4.4 mm and L/H=1.02, L=24.5 mm of the present specimen from coast of Hideshima, H=23.6 mm, T=7.2 mm and L/H=1.04, L=19.4 mm of one of the present specimen from Aketo, H=19.8 mm, T=5.3 mm and L/H=0.98 and L=17.0 mm of another specimen from Aketo, H=15.8 mm, T=5.5 mm, L/H=1.08.

Remarks.—The present specimens are identified as *Eriphyla miyakoensis* by the outline and umbo position.

Occurrence.—Occurrence from the Miyako Group.

Eriphyla pulchella Hayami, 1965b

Plates 26-4; 29-18; 31-5

Eriphyla pulchella Hayami, 1965b, p. 98, pl. 9, figs. 6-12, pl. 14, fig. 6.

Material.—Seven specimens from Ebisudana, coast of Hideshima, Miyako City, Iwate Prefecture and Aketo, Tanohata Village, Shimohei County, Iwate Prefecture.

Description.—Shell small, suborbicular but invariably longer than high, strongly inflated; test moderate in thickness; antero-dorsal margin broadly concave, while postero-dorsal margin is nearly straight; posterior margin not clearly delimited, passing gradually into the postero-dorsal and vertical margins; umbo comparatively narrow, prominent above the dorsal margin, prosogyrous, placed at about three-sevenths of shell length from the anterior end; lunule narrow, moderately deep, obscurely demarcated; escutcheon narrow, delimited by a sharp ridge; surface ornamented with densely spaced regular concentric lines; vertical margin apparently smooth without crenulations; hinge plate moderate in breadth; umbo cavity deep.

Measurements.—L=22.9 mm of one of the present specimen from Ebisudana, H=20.6 mm, 2T=8.9 mm and L/H=1.11, L=10.4 mm of the other present specimen from Ebisudana, H=10.0 mm, T=2.1 mm and L/H=1.04, L=8.7 mm of another specimen from Ebisudana, H=7.7 mm, T=3.0 mm and L/H=1.13, L=21.0 mm of the present specimen from coast of Hideshima, H=19.8 mm, T=4.8 mm, L/H=1.06, L=7.8 mm of one of the present specimen from Aketo, H=6.6 mm, T=2.5 mm and L/H=1.18, L=21.4 mm of the other present specimen from Aketo, H=20.0 mm, T=5.5 mm and L/H=1.07 and L=10.7 mm of another specimen from Aketo, H=9.0 mm, T=4.0 mm and L/H=1.19.

Remarks.—The present specimens are identified as *Eriphyra pulchella* by the outline and umbo position and discriminated from *Eriphyla miyakoensis*. Because the umbo is placed a little more centrally, the average ratio of length/height distinctly larger, the lunule much shallower and concentric lines are more regular and more conspicuous than *Eriphyla miyakoensis*.

Occurrence.—Occurrence from the Miyako Group.

Eriphyra higoensis Tashiro, 1976

Plates 34-5; 35-3

Lucina sp. Nagao, 1930, p. 20, 21, pl. 11, fig. 10.

Eriphyla higoensis Tashiro, 1976, p. 64, pl. 8, figs. 6-12.

Material.—Two specimens from Ammonite center and Yoheisaku, Iwaki City, Fukushima Prefecture.

Description.—Shell small, subcircular, moderately inflated; umbo small, located at sbout a fourth of valve length from front; anterior dorsal margin slightly concave; posterior dorsal margin gently convex; anterior to ventral margin semicircular; posterior margin moderately arched; lunule narrow, depressed; escutcheon indistinct; surface ornamented with irregular fine concentric growth lines; adductor scars weakly impressed; pallial sinus deep for *Eriphyla*; inner margin smooth.

Measuremrnts.—L=17.1 mm of the present specimen from Ammonite Center, H=14.8 mm, 2T=7.7 mm and L/H=1.16 and L=15.6 mm of the present specimen from Yoheisaku, H=14.0 mm, T=2.3 mm and L/H=1.11.

Remarks.—The present specimens are identified as Eriphyla higoensis by the high L/H.

Occurrence.—Occurrence from the Himenoura Group.

Subfamily Opinae Chavan, 1952

Genus ***Opis*** Defrance, 1825

Type species.—*Trigonia cardissoides* Lamarck, 1819

***Opis* sp.**

Plate 32-10

Material.—One specimen from Kayanosawa, Hirono Town, Futaba County, Fukushima Prefecture.

Description.—Shell small, subquadrilateral, much higher than long, inequilateral, greatly inflated, but with flattened sides; anterior margin rounded; posterior margin truncated, slightly concave, forming an angle with gently curved ventral margin and also with postero-dorsal margin; beak prominent, slender, greatly incurved, almost touching in young; a prominent carina extends from beak to postero-ventral angle, cutting off an area which is divided into two parts by a prominent but rounded carina which ends at postero-dorsal angle; outer part only of area is seem in a side view, and is concave; inner part depressed and its dorsal portion is flattened and resembles a lunule; lunule very large, cordate, flattened.

Measurements.—L=12.9 mm of the present specimen, H=14.5 mm, T=2.6 mm and L/H=0.89.

Remarks.—The present specimen is identified as *Opis* of the genus by outline. However, to identify of the species is difficult because of poorly preservation.

Occurrence.—The described specimen is obtained from Kayanosawa, Hirono Town, Futaba County, Fukushima Prefecture.

Family Crassatellidae Férussac, 1822

Subfamily Crassatellinae Férussac, 1822

Genus ***Anthonya*** Gabb, 1864

Type species.—*Anthonya cultriformis* Gabb, 1864

Anthonya **sp.**

Plate 29-10

Material.—One specimen from Ebisudana, Miyako City, Iwate Prefecture.

Description.—Shell small, elongate-trigonal, highly inequilateral, gradually tapering towards the posterior end, much longer than high, nearly flat; test moderate in thickness; antero-dorsal margin very long, nearly straight or broadly concave,; a blunt carina extends from the umbo to the postero-ventral angle, defining a narrow and slightly concave postero-dorsal area from the disk; surface ornamented with regularly spaced concentric ribs which are somewhat broader than their interspaces and strengthened on the anterior and postero-dorsal areas; ribs and interspaces marked with faint growth-lines.

Measurements.—H=8.6 mm of the present specimen and T=1.3 mm.

Remarks.—The present specimen similars *Anthonya subcantiana* Nagao, 1934 which has elongate-trigonal shell. However, to identify of the species is difficult because of lacking umbo.

Occurrence.—The described specimen is obtained from Ebisudana, Miyako City, Iwate Prefecture.

Anthonya japonica Matsumoto, 1938

Plate 31-3

Anthonya japonica Matsumoto, 1938, p. 16, text-figs. 6, 7; Tamura and Packard, 1972, p. 27, text-fig. 3, pl. 1, figs. 9-11.

Anthonya ensiformis Nagao, 1938, p. 135, pl. 15, figs. 4-8, p. 142.

Material.—One specimen from Aketo, Tanohata Village, Shimohei County, Iwate Prefecture.

Description.—Shell medium sized, elongate-trigonal, highly inequilateral, gradually tapering towards the posterior end, much longer than high, nearly flat; test moderate in thickness; antero-dorsal margin very long, nearly straight or broadly concave, forming an umbonal angle of about 30 degrees with the antero-dorsal; posterior margin subvertically truncated; umbo orthigyrous, pointed but not rising above the dorsasl margin, placed very anteriorly but not terminal; a blunt carina extends from the umbo to the postero-ventral angle, defining a narrow and slightly concave postero-dorsal area from the disk; escutcheon very narrow; lunule not impressed; surface smooth.

Measurements.—L=52.8 mm of the present specimen H=11.6 mm, T=3.0 mm and L/H=4.55.

Remarks.—The present specimen is identified as *Anthonya japonica* by elongate trigonal shell and discriminated from *Anthonya subcantiana* by the high L/H ratio and smooth surface.

Occurrence.—Occurrence from the Goshonoura and Mikasa Groups.

Superfamily Cardiacea Lamarck, 1809

Family Cardiidae Lamarck, 1809

Subfamily Protocardiinae Keen, 1951

Genus ***Protocardia*** von Beyrich, 1845

Type species.—*Cardium sphaeroideum* Forbes, 1845

***Protocardia* sp.**

Plate 43-2

Material.—One specimen from Bomukizawa, Sakuho Town, Minamisaku County, Nagano Prefecture.

Description.—Shell medium in size, suborbicular in outline, faintly carinated, strongly inflated; test thin; umbo prominent, highly protruded above the dorsal margin; posterior area obscurely delimited from the disk, very slightly concave; radial ribs on internal surface.

Measurements.—H=22.2 mm of the present specimen and T=7.0 mm.

Remarks.—The present specimen is identified as *Protocardia* of the genus by strong shell convexity and outline. However, to identify of species is difficult because of poorly preservation.

Occurrence.—The described specimen is obtained from Bomukizawa, Sakuho Town, Minamisaku County, Nagano Prefecture.

***Protocardia*? sp.**

Plate 43-6

Material.—One specimen from Bomukizawa, Sakuho Town, Minamisaku County, Nagano Prefecture.

Descriptions.— Shell small, suborbicular in outline, faintly carinated, strongly inflated; test thin; umbo prominent, highly protruded above the dorsal margin; posterior area obscurely delimited from the disk, very slightly concave; internal surface smooth.

Measurements.—L=11.3 mm of the present specimen, H=14.8 mm, T=5.4 mm and L/H=0.76.

Remarks.—The present specimen resembles *Protocardia* of the genus by the outline. However, to identify as *Protocardia* is difficult because of internal surface smooth.

Occurrence.—The described specimen is obtained from Bomukizawa, Sakuho Town, Minamisaku County, Nagano Prefecture.

Protocardia hiraigensis Hayami, 1965b

Plate 29-21

Cardium sp. Nagao, 1934, p. 228, pl. 29, fig. 15.

Protocardia hiraigaensis Hayami, 1965b, p. 119, pl. 15, figs. 8-10.

Material.—One specimen from Ebisudana, Miyako City, Iwate Prefecture.

Description.—Shell small, slightly inequilateral, suborbicular in outline, faintly carinated, nearly as long as high, strongly inflated; test thin; posterior margin obliquely truncated; umbo prominent, highly protruded above the dorsal margin, placed slightly anteriorly from the mid-point of length; posterior area obscurely delimited from the disk, very slightly concave.

Measurements.—L=10.1 mm of the present specimen, H=9.4 mm, T=3.5 mm and L/H=1.07.

Remarks.—The present specimen is identified as *Protocardia hiraigensis* by strong shell convexity and outline.

Occurrence.—Occurrence from the Miyako Group.

Superfamily Solenacea Lamarck, 1809

Family Cultellidae Davies, 1935

Genus ***Leptosolen*** Conrad, 1865

Type species.—Siliquaria biplicata Conrad, 1858

***Leptosolen* sp.**

Plate 34-9

Material.—One specimen from Yoheisaku, Iwaki City, Fukushima Prefecture.

Description.—Shell small, thin, a little inflated, the maximum convexity along the longitudinal line near the dorsal margin; very elongate posteriorly, syncylindrical in outline, the dorsal and the ventral margin approximately parallel; ventral margin nearly straight, but slightly convex ventrally; a broad, very low radial swell from the umbo to the antero-ventral extremity; umbo small, low, not projecting; surface of the shell smooth, with fine concentric growth-lines and a broad shallow radial sulcus.

Measurements.—H=6.6 mm of the present specimen and T=2.2 mm.

Remarks.—The present specimen resembles *Leptosolen* sp. of Tashiro and Kozai (1988) by the outline and a broad shallow sulcus.

Occurrence.—The described specimen is obtained from Yoheisaku, Iwaki City, Fukushima Prefecture.

Superfamily Tellinacea de Blainville, 1814

Family Icanotiidae Casey, 1961

Genus ***Scittila*** Casey, 1961

Type species.—*Scittila nasuta* Casey, 1961

Scittila dericatostriata Tashiro and Kozai, 1988

Plate 43-3

Scittila dericatostriata Tashiro and Kozai, 1988, p. 63, plate 3, figs. 17, 18.

Material.—One specimen from Bomukizawa, Sakuho Town, Minamisaku County, Nagano Prefecture.

Description.—Shell elongate ovate, very longer than high, weakly inflated; test very thin; umbosmall, a little prominent, orthogyrous, located at nearly central of valve; anterior dorsal margin nearly straight but a little concave near umbo; posterior dorsal margin very weakly convex; anterior margin narrowly rounded; posterior margin weakly arched, obliquely truncated from posterior dorsal margin; ventral margin nearly horizontal, but weakly concave or shallowly undulated on nearly central part of the margin; posterior carina distinctly angulated, extends nearly straight from umbo to postero-ventral corner; posterior area divided by a very weak median groove; internal surface ornamented by numerous miserable threads which are directed transversely from dorsal margin to ventral margin.

Measurements.—L=12.5 mm of the present specimen, H=8.8 mm, T=3.3 mm and L/H=1.42.

Remarks.—The present specimen is identified as *Scittila dericatostriata* by elongated shell and numerous threads.

Occurrence.—Occurrence from the Nankai Group.

Superfamily Arcticacea Newton, 1891

Family Neomiodontidae Casey, 1955

Subfamily Eomiodontinae Hayami, 1965b

Genus ***Costocynera*** Hayami, 1965b

Type species.—*Costocynera matsumotoi* Hayami, 1965b

Costocynera matsumotoi Hayami, 1965b

Plates 43-7; 8

Costocynera matsumotoi, Hayami, 1965b, p. 133, pl. 18, figs. 2-12.

Material.—One specimen from Bomukizawa, Sakuho Town, Minamisaku County, Nagano Prefecture.

Description.—Shell small, trigonally cuneiform and Anomalodiscus-like in outline, much longer than high, moderately inflated; test fairly thick; umbo prominent, slightly incurved, prosogyrous, placed at about one-third od shell-length from the anterior end; antero-dorsal margin slightly concave in front of umbo, smoothly sloping down into the anterior margin; postero-dorsal margin gently convex, much longer than the antero-dorsal; posterior margin poorly delimited from the postero-dorsal and ventral ones; ventral margin commonly slightly concave in the posterior part but gently arcuate in the anterior part; a blunt carina runs from the umbonal region to the postero-ventral corner, defining a postero-dorsal slope; lunule wide but comparatively shallow, nearly smooth, circumscribed by a shallow furrow; surface ornamented with more than 60 radial riblets in addition to many irregular erect concentric lamellae; radials much weakened on the concentric ribs and ventral peripheral area, but apparently continous; both elements of ornamentation somewhat effaced on the postero-dorsal slope behind the carina.

Measurements.—L=6.2 mm of the present specimen, H=5.4 mm, T=0.7 mm and L/H=1.14.

Remarks.—The present specimen is identified as *Costocynera matsumotoi* by outline and ornamentation.

Occurrence.—Occurrence from the Sensotoizumi Group.

Costocynera* cf. *matsumotoi Hayami, 1965b

Plate 33-8

Material.—One specimen from the middle of Ashizawa, Iwaki City, Fukushima Prefecture.

Description.—Shell very small, trigonally cuneiform and Anomalodiscus-like in outline, much longer than high, moderately inflated; test fairly thick; umbo prominent, slightly incurved, prosogyrous, placed at about one-third od shell-length from the anterior end; antero-dorsal margin slightly concave in front of umbo, smoothly sloping down into the anterior margin; postero-dorsal margin gently convex, much longer than the antero-dorsal; posterior margin poorly delimited from the postero-dorsal and ventral ones; ventral margin commonly slightly concave in the posterior part but gently arcuate in the anterior part; a blunt carina runs from the umbonal region to the postero-ventral corner, defining a postero-dorsal slope; lunule wide but comparatively shallow, nearly smooth, circumscribed by a shallow furrow; surface ornamented with more than 60 radial riblets in addition to many irregular erect concentric lamellae; radials much weakened on the concentric ribs and ventral peripheral area, but apparently continous; both elements of ornamentation somewhat effaced on the postero-dorsal slope behind the carina.

Measurements.—L=3.1 mm of the present specimen, H=3.0 mm, T=0.5 mm and L/H=1.03.

Remarks.—The present specimen resembles *Costocynera matsumotoi* because of outline and ornamentation and is discriminated by small size.

Occurrence.—The described specimen is obtained from the middle of Ashizawa, Iwaki City, Fukushima Prefecture.

Costocynera otsukai Yabe and Nagao, 1926

Plate 43-4, 5

Cynera otsukai Yabe and Nagao, Yabe, Nagao and Shimizu, 1926, p. 50, pl. 2, figs. 20-24.

Costocynera otsukai (Yabe and Nagao), Ohta, 1973, p. 256, pl. 3, figs. 1-11.

Costocynera crenatus Ohta, 1973, p. 258, pl. 3, fig. 12.

Material.—Two specimens from Bomukizawa, Sakuho Town, Minamisaku County, Nagano Prefecture.

Description.—Shell small, equivalve, compressed, trapezoidal, very inequilateral, anterior side being about one-third of the length of the valve; much longer than high; antero-dorsal margin almost straight, slightly concave beneath umbo, the postero-dorsal long, also straight and nearly as oblique as the antero-dorsal; anterior end rounded and posterior truncated vertically; ventral margin broadly convex, though usually sinuated near its posterior end and sometimes being nearly straight in its posterior half; umbo small, pointed, lying at about one-third of the length of the valve from the anterior end, with a rounded but distinct carina extending from it to the postero-ventral end and limiting a flattened posterior area; lunule lanceolate, and escutcheon narrow, elongate, both being deep and borderd by a sharp ridge; inner margin smooth; pallial sinus simple.

Surface ornamented with distant, regular, narrow, elevated, somewhat crenulated concentric ribs, separated by broad, flat interspaces with a number of crowded, very fine, concentric lines which are prominent on the umbonal carina and the posterior area; lunule and escutcheon smooth except for fine concentric lines; hinge-plate narrow, with three cardinal teeth in each valve, of which the left posterior and right anterior are very small; as well as a very elongated anterior and a posterior lateral teeth.

Measurements.—L=22.9 mm of the present specimen from Bomukizawa and counter parts, H=14.1 mm, T=1.2 mm and L/H=1.62.

Remarks.—The described specimens are identified as *Costocynera otsukai* by posterior truncated vertically and simple ornamentation.

Occurrence.—Occurrence from the Monobegawa Group.

Superfamily Corbiculacea Gray, 1847

Family Corbiculidae Gray, 1847

Genus ***Hayamina*** Ohta, 1982

Type species.—*Cynera naumanni* Neumayr, 1890

Hayamina naumanni (Neumayr, 1890)

Plates 41-1; 2; 42-1

Cynera naumanni Neumayr, Naumann and Neumayr, 1890, p. 33, pl. 4, figs. 3, 4; Yabe, Nagao and Shimizu, 1926, p. 49, pl. 12, figs. 6, 17, 18, pl. 14, fig. 15, 23, 24, 26, 29, 31; Yabe, 1927, pl. 3, fig. 5.

Cynera lithocardium Neumayr, Naumann and Neumayr, 1890, p. 34, pl. 4, fig. 1.

Cynera grravida Neumayr, Naumann and Neumayr, 1890, p. 34, pl. 4, fig. 2.

Polymesoda naumanni (Neumayr), Suzuki and Oyama, 1943, p. 139, 146.

"*Cynera*" *naumanni* Neumayr, Hayami, Matsumoto and Asano, 1963, p. 34, pl. 52, figs. 1-4.

Protocyprina naumanni (Neumayr), Hayami and Nakai, 1965, p. 117. text-fig. 3, pl. 13, figs. 1-3, pl. 14, figs. 1-8; Hayami, 1975, p. 139.

Neumayria naumanni (Neumayr), Ohta, 1981, p. 444.

Hayamina naumanni (Neumayr), Ohta, 1982, p. 444; Tashiro and Ohnishi, 1985, text-figs. 4, 8, pl. 1, figs. 6-8; Tashiro and Kozai, 1989, p. 128, plate 4, figs. 14, 15.

Material.—Three specimens from Bomikuzawa, Sakuho Town, Minamisaku County, Nagano Prefecture and Mamonozawa River, Ueno Village, Tano County, Gunma Prefecture.

Description.—Shell large, ovate, longer than high, weakly inflated; umbo not prominent, placed at about two-fifths from anterior end of the valve, weakly prosogyrate; anterior dorsal margin fairly short, weakly concave; posterior dorsal margin longer than anterior one, slightly convex; anterior margin well rounded, gradually changing into broadly arched ventral margin; posterior margin rounded, posterior carina weak but distinctly angulated near the umbo; escutcheon narrow, deeply depressed, indistinctly demarcated from the posterior area by an obtuse ridge: lunular area deeply depressed but not separated from the disk by distinct carina or line; disk broad, strongly inflated; surface ornamented with numerous frilled concentric ribs.

Measurements.—L=63.0 mm of the present specimen from Bomukizawa, H=63.8 mm, T=11.1 mm and L/H=0.99 and L=73.7 mm of the present specimen from Mamonozawa River, H=66.6 mm, T=6.9 mm and L/H=1.11.

Remarks.—The present specimens are identified as *Hayamina naumanni* by large size, not prominent umbo and frilled concentric ribs.

Occurrence.—Occurrence from the Monobegawa Group.

Hayamina minor Tashiro and Kozai, 1989

Plate 42-6

Hayamina minor Tashiro and Kozai, 1989, p. 132, text-figs 6A, B, plate 5 figs. 1-10.

Material.—One specimen from Mamonozawa River, Ueno Village, Tano County, Gunma Prefecture.

Description.—Shell small, ovate, slightly longer than high, strongly inflated; umbo well prominent, placed at about a fourth from anterior end of the valve, strongly prosogyrate; anterior dorsal margin short, weakly concave; posterior dorsal margin longer than anterior one, slightly convex; anterior margin well rounded, gradually changing into broadly arched ventral margin; posterior margin nearly straight, truncated obliquely from the dorsal margin; posterior carina weak but distinctly angulated near the umbo; escutcheon narrow, deeply depressed, indistinctly demarcated from the posterior area by an obtuse ridge; lunular area deeply depressed but not separated from the disk by distinct carina or line; disk broad, strongly inflated; surface ornamented with numerous irregular concentric ribs.

Measurements.—L=20.8 mm of the present specimens, H=17.2 mm, T=4.7 mm and 1.21.

Remarks.—The present specimen is identified as *Hayamina minor* by small size, prominet umbo and smooth surface.

Occurrence.—Occurrence from the Monobegawa Group.

Genus ***Tetoria*** Kobayashi and Suzuki, 1937

Type species.—*Batissa yokoyamai* Kobayashi and Suzuki, 1937

Tetoria sanchuensis (Yabe and Nagao, 1926)

Plate 46-8

Corbicula sanchuensis Yabe and Nagao, Yabe, Nagao and Shimizu, 1926, p. 53, pl. 12, fig. 8, pl. 13, figs. 8-10, 17.

Polymesoda sanchuensis (Yabe and Nagao), Suzuki and Oyama, 1943, p. 141, 146; Maeda, 1959, p. 159, pl. 17, figs. 12-16.

Tetoria sanchuensis (Yabe and Nagao), Ota, 1965, pl. 13, fig. 14.

Material.—One specimen from Ohnozawa Pass, Saku City, Nagano Prefeture..

Description.—Shell small, trigonally ovate, moderately inequilateral; very convex; umbo very convex, prominent, much curved inwards and forwards; lunule deep, broad; pallial sinus deep, acute, ascending.

Measurements.—H=12.4 mm of the present specimens and T=2.6 mm.

Remarks.—The present specimen is identified as *Tetoria sanchuensis* by the outline.

Occurrence.—Occurrence from the Monobegawa Group.

Superfamily Veneracea Rafinesque, 1815

Family Veneridae Rafinesque, 1815

Subfamily Pitarinae Stewart, 1930

Genus ***Loxo*** Dailay and Popenoe, 1966

Type species.—*Loxo decore* Dailay and Popenoe, 1966

Loxo japponica (Amano), 1957

Plates 32-2; 35-7; 37-7.

Callista japonica Amano, 1957, p.59, pl. 1, figs. 15-18.

Trigonocallista ornata Ichikawa and Maeda, 1963, p. 126-127, pl. 11, figs. 5, 6.

Loxo japonica (Amano), Tashiro, 1976, p. 69, pl. 11, figs. 7-17.

Material.—Three specimens from Ammonite Center, Iwaki City, Fukushima Prefecture, Kayanosawa, Hirono Town, Futaba County, Fukushima Prefecture and Irimazawa, Iwaki City, Fukushima Prefecture.

Description.—Shell medium in size, round to elliptical; inequilateral, anterior side being very short; moderately convex; umbo more or less prominent and pointed, curved anteriorly; the antero-dorsal margin concave; postero-dorsal long and slightly convex; ventral margin broadly arched; anterior part produced with rounded margin; posterior margin short, rounded or a little truncated.

In the right valve, the anterior and median cardinal teeth oblique anteriorly, the socket between the two slender and not communicates with the anterior lateral socket; the posterior cardinal long, oblique and slightly bifid, embracing triangular, large socket with the median cardinal.

In the left valve, the anterior cardinal tooth nearly vertical or slightly oblique anteriorly; posterior cardinal tooth a very oblique, long, slender and not bifid; anterior lateral tooth, very oblique, elongated, ridge-like and not rugose but smooth; surface ornamented with coasely arranged, sharp, concentric ribs alternating with broader grooves than ribs.

Measurements.—H=28.6 mm of the present specimen from Ammonite Center and 2T=9.4 mm, L=37.6 mm of the present specimen from Kayanosawa, H=37.0 mm, T=8.7 mm and L/H=1.02 and 24.8 mm of the present specimen from Irimazawa, H=23.6 mm, T=7.4 mm and L/H=1.05.

Remarks.—The present specimens are identified as *Loxo japonica* by concave and coasely concentric ribs.

Occurrence.—Occurrence from the Himenoura, Izumi and Uwajima Groups.

Order Myoida Stoliczka, 1870

Suborder Myina Stoliczka, 1870

Superfamily Myacea Lamarck, 1809

Family Corbulidae Lamarck, 1818

Subfamily Corbulinae Lamarck, 1818

Genus ***Corbula*** Bruguière, 1797

Type species.—*Corbula sulcata* Lamarck, 1801

***Corbula* sp.**

Plate 46-6

Material.—One specimen from Ohnozawa Pass, Saku City, Nagano Prefeture..

Description.—Shell small, trigonally ovate, well inflated, longer than high; umbo moderately large, a little anteriorly subcentral; anterior dorsal margin weakly concave; posterior dorsal margin nearly straight; anterior and posterior margin rounded; posterior margin more rounded than anterior margin; ventral margin broadly arched; apical angle about 120 degrees; surface smooth except for fine irregular growth lines.

Measurements.—L=23.5 mm of the present specimen, H=11.0 mm, T=1.9 mm and L/H=2.14.

Remarks.—The present specimen is identified as *Corbula* of the genus by the outline.

Occurrence.—The described specimen is obtained from Ohnozawa Pass, Saku City, Nagano Prefeture.

Order Hippuritoidea Newell, 1965

Superfamily Hippuritacea Gray, 1848

Family Caprotinidae Gray, 1848

Genus ***Praecaprotina*** Yabe and Nagao, 1926

Type species.—*Horiopleura yaegashii* Yehara, 1920

Praecaprotina yaegashii (Yehara, 1920)

Plate 27-9

Horiopleura yaegashii Yehara, 1920, p.41, pl. 1, figs. 1-3, pl. 2, figs. 1-3.

Praecaprotina yaegashii (Yehara, 1920), Yabe and Nagao, 1926, p. 21, pl. 7, figs. 1-10; Nagao, 1934, p. 226; Saito, 1964, p. 320, pl. 47, figs. 10-12.

Material.—One specimen from coast of Hideshima, Miyako City, Iwate Prefecture.

Description.—Shell small; test moderately thick; upper valve convex, beak broad, incurved toward the hinge margin of the lower valve; ligament situated posteriorly close to the beak short and prominent.

Measurements.—H=14.4 mm of the present specimen and T=2.4 mm.

Remarks.—The present specimen is identified as *Praecaprotina yaegashii* by the outline.

Occurrence.—Occurrence from the Miyako and Lower Ezo Groups.

Genus ***Pachytraga*** Paquier, 1900

Type species.—*Sphaerulites paradoxa* Pictet and Campiche, 1869

Pachytraga japonica Okubo and Matsukawa, 1959

Plate 43-9

Pachytraga japonica Okubo and Matsukawa, 1959, p. 2, text-figs. 1-7.

Material.—One specimen from Mamonozawa River, Sakuho Town, Minamisaku County, Nagano Prefecture.

Description.—Shell small; test thin; surface generately smooth with weakly concentric lines; umbo small, moderately produced; anterior and posterior margin is slightly convex.

Measurements.— L=17.5 mm of the present specimen, H=16.8 mm, T=5.4 mm and L/H=1.04.

Remarks.—The present specimen is identified as *Pachytraga japonica* by the outline.

Occurrence.—Occurrence from the Sensotoizumi and Shinjogawa Groups.

Genus ***Goniomya*** Agassiz, 1841

Type species.—*Mya angulifera* Soweby, 1819

***Goniomya* sp.**

Plate 29-19

Material.—One specimen from Ebisudana, Miyako City, Iwate Prefecture.

Descriptions.—Shell medium sized, fairly inequilateral, elongate-elliptical, transversely elongated, moderately inflated; test very thin, translucent; antero-dorsal margin obliquely truncated; umbo fairly prominent, orthogyrous, incurved, a little rising above the dorsal margin, placed at about one-third of shell-length from the anterior end; a weak carina extending from the umbo to the postero-ventral corner, defining obscurely a slightly concave and somewhat flattened postero-dorsal area; surface ornamented with characteristic U-shaped ribs of *Goniomya*-type, which are distributed on a triangular area covering the umbonal and central surface; umbonal angle of the triangle about 100 degrees, divided into three parts of about 40, 25 and 35 degrees from the anterior side; ribs of the anterior part about 14-16 in number, prosocline, prominent; ribs of the median part similar in number but more or less weakened towards the venter, nearly horizontal, forming an obtuse angle of about 140 degrees with the anterior set just below the umbo; three sets of ribs generally continuous but sometimes median set truncated by posterior set; ribs never scribe Vs even in the adult stage.

Measurements.—H=22.8 mm of the present specimen and T=6.8 mm.

Remarks.—The present specimen is identified as *Goniomya* of the genus by chraracteristic ornamentation. However, to identify of the species is difficult because of the fragment specimen.

Occurrence.—The described specimen is obtained from Ebisudana, Miyako City, Iwate Prefecture.

Goniomya subarchiai Nagao, 1934

Plates 26-7; 31-7

Goniomya subarchiai Nagao, 1934, p. 215, pl. 29, figs. 2, 3; Hayami, 1966, p. 163, pl. 25, figs. 1-13

Materials.—Two specimens from coast of Hideshima, Miyako City, Iwate Prefecture and Aketo, Tanohata

Village, Shimohei County, Iwate Prefecture.

Description.—Shell medium sized, fairly inequilateral, elongate-elliptical, transversely elongated, moderately inflated; length smaller than twice the height; test very thin, translucent; antero-dorsal margin obliquely truncated; postero-dorsal margin slightly concave behind the umbo, much longer than the antero-dorsal; siphonal margin well delimited, forming an obtuse angle with the postero-dorsal margin; ventral margin broadly arcuate; umbo fairly prominent, orthogyrous, incurved, a little rising above the dorsal margin, placed at about one-third of shell-length from the anterior end; a weak carina extending from the umbo to the postero-ventral corner, defining obscurely a slightly concave and somewhat flattened postero-dorsal area; a pair of prominent ridges run subparallel to the antero- and postero-dorsal margins, delimting narrow crescentic areas corresponding to the lunule and escutcheon; surface ornamented with characteristic U-shaped ribs of *Goniomya*-type, which are distributed on a triangular area covering the umbonal and central surface; umbonal angle of the triangle about 100 degrees, divided into three parts of about 40, 25 and 35 degrees from the anterior side; ribs of the anterior part about 14-16 in number, prosocline, prominent; ribs of the median part similar in number but more or less weakened towards the venter, nearly horizontal, forming an obtuse angle of about 140 degrees with the anterior set just below the umbo; ribs of the posterior part broad, smaller in number, opisthocline, meeting median horizontal ribs with obtuse angle of about 115 degrees; three sets of ribs generally continuous but sometimes median set truncated by posterior set; ribs never scribe Vs even in the adult stage; anterior, posterior and ventral areas of the shell nearly smooth except for faint growth-lines and many fine radial threads composed of numerous microscopic serial punctures.

Measurements.—L=29.4 mm of the present specimen from coast of Hideshima, H=24.2 mm, 2T=11.6 mm and L/H=1.21 and L=25.8 mm of the present specimen from Aketo and T=4.8 mm.

Remarks.—The present specimens are identified as G*oniomya subarchiaci* by outline and pattern of ribs and discriminated from *Goniomya nonvscripta* Tamura, 1959 by narrow ortamented area.

Occurrence.—Occurrence from the Miyako Group.

Superfamily Pandoracea Rafinesque, 1815

Family Laternulidae Hedley, 1918

Genus ***Periplomya*** Conrad, 1870

Type species.—*Periploma applicata* Conrad, 1858

***Periplomya* sp.**

Plates 32-5; 34-3

Material.—Two specimens from Yoheisaku, Iwaki City, Fukushima Prefecture and Kayanosawa, Hirono

Town, Futaba County, Fukushima Prefecture.

Description.—Shell small, elongately ovate, concave; eakly inflated; umbo small. Located at about two of third of valve length from posterior end of valve; anterior dorsal margin long, weakly arched; posterior dorsal margin short, slightly concave; apical angle about 100 degrees; anterior margin well rounded; ventral margin nearly straight; posterior margin more rounded than anterior margin; posterior ridge weakly elevated; surface ornamented with fine and irregular growth striae; chondrophore sall, nearly vertical.

Measurements.—L=20.9 mm of the present specimen from Yoheisaku, H=17.1 mm, T=2.6 mm and L/H=1.22 and L=23.2 mm of the present specimen from Kayanosawa, H=15.0 mm, T=5.5 mm and L/H=1.55.

Remarks.—The present specimens are identified genus of *Periplomya* by elongate outline. However, to identify of species is difficult by poorly preservation.

Occurrence.—The described specimens are obtained from Yoheisaku, Iwaki City, Fukushima Prefecture and Kayanosawa, Hirono Town, Futaba County, Fukushima Prefectur.

Class Cephalopoda Cuvier, 1797

Subclass Ammonoidea Zittel, 1884

Superfamily Lytocerataceae Neumayr, 1875

Family Tetragonitidae Hyatt, 1900

Subfamily Gaudryceratinae Spath, 1927

Genus ***Eotetragonites*** Breistroffer, 1947

Type species.—*Eotetragonites raspaili* Breistroffer, 1947

***Eotetragonites* sp.**

Plate 28-5

Material.—One specimen from Ebisudana, Miyako City, Iwate Prefecture.

Description.—The specimen is very small. The outer whorls have nearly flattened parallel flanks, while the inner whorls have rather inflated curvature of the flanks. The umbilical shoulder of the whorl is subangular and the umbilical wall is perpendicular and subrounded. The venter is widely arched and the ventro-lateral shoulder is somewhat rounded. The cross section of the outer whorls is nearly square, but that of the inner whorls is reniform as the whorl-height is smaller than breadth.

The shell surface is almost smooth except numerous striae which show a gentle forward curvature on the flanks and widely arched on the venter. There are several prorsiradiate constrictions which start from the umbilical seam. They are fairly distinct on the flanks and cross on the venter, being widely convex.

The suture line is rather complicated. E is deep and rather narrow breadth. The saddle between E and L is irregularly and widely divided.

Measurements.—Taken at D=15.6 mm of the present specimen, U=5.8 mm, H= 5.3 mm, W=6.4 mm, U/D=0.37, W/H=1.21

Remarcks.—The present specimen resembles *Eotetragonites aketoensis* Obata and Futakami in the morphologic features. However, the specimen has only several constrictions by maybe young stage. So, the present study doesn't identify species level.

Occurrence.—The described specimen is obtained from Loc. 2 of the Facies 1 at Ebisudana, the Sakiyama Formation.

Superfamily Haplocerataceae Zittel, 1884

Family Oppeliidae Douvillé, 1890

Subfamily Aconeceratinae Spath, 1922

Genus ***Aconeceras*** Hyatt, 1903

Type species.—*Ammonites nisus* Orbigny, 1842

***Aconeceras* sp.**

Plate 28-1

Material.—Three specimens from Ebisudana, Miyako City, Iwate Prefecture.

Description.—The speciemens are small. The whorl is much depressed with the maximum breadth at the mid-flank. The inner whorl is moderately overlapped by the outer whorl, with nearly a half involution. The umbilicus is narrow and fairly deep, with a subrounded umbilical shoulder. The venter is fairly rounded with one rectiradiated keel at outer whorl. There are ribs which are fine, falcoid and projected on the vemter. The ribs of outer whorl are much stronger than those of outer whorl.

The suture line is rather simple and consists of E, L and U. E is deep and rather narrow breadth. L is narrower than but nearly as deep as E, and is tripartite at the base. U is shallower than L. The first lateral saddle between E and L is tall, massive, asymmetric in outline, divided with a small lobule at the top. The saddle between L and U is the tallest.

Measurements.—Taken at D=27.5 mm of one of the present specimens, U=2.9 mm, H=15.1 mm, W=6.5 mm, U/D=0.11, W/H=0.43 and D=16.0 mm of one of the other present specimen, U=2.5 mm, H=8.0 mm, W=4.4 mm, U/D=0.16, W/H=0.55 and D=12.2 mm of another present specimen.

Remarcks.—The present specimens resemble *A. nisus* (Orbigny), the type species of the genus, from the

Upper Aptian of France, in the compressed shell, sides more or less flat, keel low and ribs appearing late in ontogeny. The present specimens are distinguished, however, from the species in that these have keels with no finely denticulation and fairly strong ribs.

Occurrence.—The described specimens are obtained from Loc. 1 and 2 of the Facies 1 at Ebisudana, the Sakiyama Formation.

Superfamily Desmocerataceae Zittel, 1895

Family Desmoceratidae Zittel, 1895

Desmoceratidae gen. et sp. indet.

Plate 28-4

Material.—Three specimens from Ebisudana, Miyako City, Iwate Prefecture.

Description.—The speciemens are very small. The whorl is much depressed. The venter is fairly rounded. The umbilicus is fairly deep and narrow, with a subrounded umbilical shoulder. There are at least four weak constrictions which are concave and prorsiradiate in the lateral area and bent forward on the venter. There are lirae on the venter between the constrictions. The lirae are less projected than the constrictions.

Measurements.—Taken at D=15.3 mm of one of the present specimens, U=2.6 mm, H=6.9 mm, W=5.6 mm, U/D=0.17, W/H=0.81 and D=9.8 mm of one of the other present specimen, U=2.2 mm, H=4.2 mm, W=3.7 mm, U/D=0.22, W/H=0.88 and D=15.0 mm of another specimen, U=3.1 mm, H=7.3 mm, W=5.2 mm, U/D=0.21, W/H=0.71.

Remarcks.—To identify genus for the specimens is difficult because of young stage.

Occurrence.—The described specimens are obtained from Loc. 2 of the Facies 1 and Loc. 3 of the Facies 2 at Ebisudana, the Sakiyama Formation.

Subfamily Puzosiinae Spath, 1922

Genus ***Valdedorsella*** Breistroffer, 1947

Type species.—*Desmoceras akuschaense* Anthula, 1899 (designated by Breistroffer, 1947)

Valdedorsella getulina (Coquand, 1880)

Plate 28-3

Ammonites getulinus Coquand, 1880, p. 18, pl. 2.

Puzosia getulina (Coquand). Pervinquière, 1907, p.151, pl. 6, fig. 16.

Valdedorsella cf. *getulina* (Coquand). Breistroffer, 1947, p. 19, listed.

Valdedorsella getulina (Coquand). Colignon, 1962, p. 33, fig. 977.

Material.—Three specimens from Ebisudana, Miyako City, Iwate Prefecture.

Description.—The speciemens are very small. The whorl is much depressed. The venter is broadly rounded. The umbilicus is deep and fairly narrow, with a subrounded umbilical shoulder. There are at least 8 strong constrictions which are prorsiradiate in the lateral area and bent forward on the venter. Each constriction is posteriorly bordered by a rounded rib which is low on the flanks and fairly prominent on the venter. There are lirae on the venter between the constrictions. The lirae are less projected than the constrictions. In the younger part the suture is almost smooth.

The suture line is rather simple. The first and the second saddles are rather slender, bifid, and are slightly asymmetric. L is asymmetrically trifid and as large as E. The auxiliary elements descend fairly rapidly to the umbilicus.

Measurements.—Taken at D=24.5 mm of one of the present specimens, U=5.3 mm, H=11.0 mm, W=15.6 mm, U/D=0.21, W/H=1.42 and at D=13.0 mm of one of the other present specimen, U=3.0 mm, H= 6.2 mm, W=8.6 mm, U/D=0.23, W/H=1.39 and D=10.9 mm of another present specimen, U=2.2 mm, H=4.0 mm, W=5.4 mm, U/D=0.20, W/H=1.35.

Remarcks.—Obata (1967a) suggested that there are only minor differences in the outline of the cross section and the width of umbilicus in proportion to diameter among the specimens of *V. getulina* from North Africa, Majorca, Madagascar and Japan. The present specimens show similar morphologic characters. So, the present specimens identified as the species.

Occurrence.—Occurrence from the Miyako Group, North Africa, Majorca and Madagascar.

Genus ***Pseudohaploceras*** Hyatt, 1900

Type species.—*Ammonites liptoviensis* Zeuschner, 1856

***Pseudohaploceras* sp.**

Plates 28-6, 30-2

Material.—Two specimens from Ebisudana, Miyako City and Akeo, Tanohata Village, Shimohei County, Iwate Prefecture.

Description.—The specimen is small. The whorl is compressed. The venter is narrowly rounded. The umbilicus is narrow, with a subrounded umbilical shoulder. There are ribs fine, slightly sinuous. The inner whorl has smooth surface.

Measurements.—Taken at D=31.9 mm of the present specimen from Ebisudana, U=4.4 mm, H=15.2 mm, W=9.5 mm, U/D=0.14, W/H=0.63.

Remarcks.—Recently, Bogdanova and Hoedemaeker (2004) described eight species of *Pseudohaploceras* from the Lower Cretaceous of Colombia. Obata and Matsukawa (2007) reported *Pseudohaploceras* sp. from the Choshi Group, Japan. The present specimen is discriminated from these species by fine ribs and no constrictions.

Occurrence.—The described specimens are obtained from Loc. 1 of the Facies 1 at Ebisudana, the Sakiyama Formation.

Superfamily Ancylocerataceae Gill, 1871

Family Ptychoceratidae Gill, 1871

Genus ***Ptychoceras*** Orbigny, 1842

Type species.—*Ptychoceras emericianum* Diener, 1925

***Ptychocera* sp.**

Plate 28-10

Material.—Two specimens from Ebisudana, Miyako City, Iwate Prefecture.

Description.—The specimens are very small. The whorls are tightly folded ptychocones with at least three and smooth adpressed shafts. There is at least one prorsiradiate constriction. The cross section of the whorl approximately circular excepts where shafts are in contact.

The suture line is rather simple. E is deep and rather narrow. The first saddle between E and L is broad. L is shallower than E. The second saddle is tall as same as the first saddle.

Measurements.—Taken at L=12.8 mm of one of the present specimen, H=2.5 mm, W=2.2 mm, W/H=0.88 and H=5.8 mm of another specimen, W=6.0 mm, W/H=1.03.

Remarcks.—To identify species for the specimens is difficult because of young stage.

Occurrence.—The described specimen is obtained from Loc. 2 of the Facies 1 at Ebisudana, the Sakiyama Formation.

Family Hamitidae Gill, 1871

Genus ***Hamites*** Parkinson, 1811

Type species.—*Hamites attenuatus* Sowerby, 1814

***Hamites* sp.**

Plate 30-3

Material.—One specimen from Akeo, Tanohata Village, Shimohei County, Iwate Prefecture.

Descriptions.—The specimen is medium in size. The whorls are U-shaped, well separated and subparallel.

The cross section of the whorl fairly depressed. The ribs are rectiradiate, fine and dense to coarse and distant.

Remarks.—The described specimen is identified as *Hamites* of the genus by U-shaped whorls. However, to identify of the species is difficult because of fragment.

Occurrence.—The described specimen is obtained from Aketo.

Genus ***Pictetia*** Uhlig, 1883

Type species.—*Crioceras astierianus* d'Orbigny, 1842

***Pictetia* sp.**

Plate 28-9

Material.—One specimen from Ebisudana, Miyako City, Iwate Prefecture.

Description.—The specimen is very small. The whorl is loosely coiled. The shell surface is almost smooth except numerous striae which show a gentle forward concave on the flanks. The cross section of the whorl is circular.

Measurements.—Taken at D=12.9 mm of the present specimen, H=4.7 mm, W=4.1 mm, W/H=0.87.

Remarcks.—To identify genus for the specimens is difficult because of young stage.

Occurrence.—The described specimen is obtained from Loc. 2 of the Facies 1 at Ebisudana, the Sakiyama Formation.

Family Nostoceratidae Hyatt, 1894

Genus ***Diplomoceras*** Hyatt, 1900

Type species.—*Baculites cylindracea* Defrance, 1816 (designation by Hyatt, 1900)

***Diplomoceras*? sp.**

Plate 38A-2

Material.—One specimen from coast of Hiraiso, Hitachinaka City, Ibaraki Prefecture.

Descriptions.—The specimen is large. The whorl is nearly straight. The shell surface is numerous, irregularly branching and looped ribs with 2 rows of ventral tubercles. The cross section of the whorl is approximately circular.

Remarks.—The present specimen resembles body chamber of the genus of *Diplomoceras* by the outline and ribs. However, to identify of the genus is difficult because of fragment.

Occurrence.—The described specimen is obtained from coast of Hiraiso, Hitachinaka City, Ibaraki Prefecture.

Genus ***Didymoceras*** Hyatt, 1894

Type species.—Ancyloceras? nebrascense Meek and Hayden, 1857

Didymoceras awajiense Yabe, 1902

Plate 38A-1

Material.—One specimen from coast of Hiraiso, Hitachinaka City, Ibaraki Prefecture.

Descriptions.—The specimen are large. The whorl is loosely and irregularly coiled at first, even hamitoid and then helicoid with whorls just. The shell surface is numerous, irregularly branching and looped ribs with 2 rows of ventral tubercles. The cross section of the whorl is approximately circular.

Remarks.—The present specimen is identified as *Didymoceras awajiense* by the hamitoid and helicoid whorls.

Occurrence.—Occurrence from the Izumi and Nakaminato Groups.

Family Diplomoceratidae Spath, 1926

Subfamily Polyptychoceratinae Matsumoto, 1938

Genus ***Polyptychoceras*** Yabe, 1927

Type species.—Ptychoeras pseudogaultinum Yokoyama, 1890

***Polyptychoceras*? sp.**

Plate 34-12

Material.—One specimen from Yoheisaku, Iwaki City, Fukushima Prefecture.

Description.—The specimen is small. The whorls are tightly folded ptychocones with at least two and adpressed shafts. There are numerous finely prorsiradiate ribs. The cross section of the whorl is depressed by secondary deformation, however originally cross section is approximately circular.

Measurements.—Taken at L=31.9 mm of the present specimen, H/2=8.65 mm.

Remarcks.—The present specimen has similar characters of the genus of *Polyptychoceras*. However, to identify genus for the specimens is difficult because of fragments.

Occurrence.—The described specimen is obtained from Yoheisaku, Iwaki City, Fukushima Prefecture.

Superfamily Scaphitaceae Gill, 1871

Family Scaphitidae Gill, 1871

Subfamily Scaphitinae Gill, 1871

Genus ***Scaphites*** Parkinson, 1811

Type species.—*Scaphites equalis* Sowerby, 1813

***Scaphites*? sp.**

Plates 33-9; 36-8

Material.—Two specimen from the middle of Ashizawa and Ammonite Center, Iwaki City, Fukushima Prefecture.

Description.—The specimen is very small. The inner whorl is moderately overlapped by the outer whorl in the early stage. The whorl is fairly compressed. Width of umbilicus is fairly narrow. Umbilical wall is low and steeply inclined. The ribs are convex and rectiradiate.

Measurements.—Taken at D=11.6 mm of the present specimen from middle of Ashizawa, U=3.3 mm, H=4.55 mm, W=2.5 mm, U/D=0.28, W/H=0.55.

Remarcks.—The present specimen has similar characters of the genus of *Scaphites*. However, to identify genus for the specimens is difficult because of young stage.

Occurrence.—The described specimen is obtained from the middle of Ashizawa, Iwaki City, Fukushima Prefecture.

Superfamily Douvilleicerataceae Parona and Bonarelli, 1897

Family Douvilleiceratidae Parona and Bonarelli, 1897

Douvilleiceratidae gen. et sp. indet.

Plates 28-7; 8

Material.—Two specimens from Ebisudana, Miyako City, Iwate Prefecture.

Description.—The specimens are very small. The inner whorl is moderately overlapped by the outer whorl, with nearly a half involution. The whorl is fairly compressed. The whorl is narrower than broad, with the maximum breadth at the mid-flank. It has a rounded venter. Width of umbilicus is fairly narrow. Umbilical wall is low and steeply inclined. The ribs are almost rectiradiate and rursiradiate.

The suture line is rather simple and consists of E, L and U. E is deep and rather narrow breadth. L is narrower than but nearly as deep as E. U is shallower than L.

Measurements.—Taken at D=9.7 mm of the present specimen, U=3.2 mm, H=3.2 mm, W=5.0 mm, U/D=0.33, W/H=1.56 and D=7.9 mm of another specimen, U=3.7 mm, H=2.9 mm, W=5.1 mm, U/D=0.47, W/H=1.76.

Remarcks.—To identify genus for the specimens is difficult because of young stage.

Occurrence.—The described specimen is obtained from Loc. 2 of the Facies 1 at Ebisudana, the Sakiyama Formation.

Family Trochleiceratidae Breistroffer, 1951

Genus ***Pseudoleymeriella*** Casey, 1957

Type species.—*Hoplites haidaquensis* Whiteaves, 1893 (designated by Casey, 1957)

Pseudoleymeriella hataii Obata, 1973

Plate 28-2

Pseudoleymeriella hataii Obata, 1973, p. 310, pl. 34, figs. 1, 2, 4, 5, 7, 8.

Material.—Three specimens from Ebisudana, Miyako City, Iwate Prefecture.

Description.—The speciemens are very small. The inner whorl is moderately overlapped by the outer whorl, with nearly a half involution. The whorl is nearly as high as broad, with the maximum breadth at the mid-flank. It has a rounded venter and gently inflated flanks. Width of umbilicus is fairly narrow. Umbilical wall is low and steeply inclined.

The ribs are almost rectiradiate and slightly projected forward on the venter, forming an obtuse arch, but are interrupted by a shallow sulcus on the mid-venter; they consist of single primary ribs and inserted sencondary ribs, being about thirty in number per whorl. The primary ribs start from the umbilical shoulder, slightly concave or almost rectiradiate on the flank, but gently projected on the ventro-lateral area. Between the two primary ribs thereare a few inserted ribs, which are nearly equal to the former in strength at the ventro-lateral area. Peripheral tubercles on both sides of a median ventral groove are in a corresponding position. At the ventro-lateral shoulder below one-third of the height small tubercles occur occasionally.

The suture line is rather simple and consists of E, L and U. E is deep and rather narrow breadth. L is broader than but nearly as deep as E, and is tripartite at the base. U is shallower than L. The first lateral saddle between E and L is the tallest, massive, asymmetric in outline, with a steeper ventral slope, divided with a small lobule at the top. The saddle between L and U is small.

Measurements.—Taken at D=20.4 mm of one of the present specimens, U=6.9 mm, H=7.2 mm, W=7.4 mm, U/D=0.34, W/H=1.03 and D=8.0 mm of one of the other present specimen, U=2.4 mm, H=3.5 mm, W=3.7 mm, U/D=0.30, W/H=1.06 and D=13.0 mm of another present specimen, U=3.4 mm, H=5.1 mm, W=6.2 mm, U/D=0.26, W/H=1.22.

Remarcks.—The present specimens have following features; small shell, numerous ribs, some lateral tubercles. The features correspond to *P. hataii*.

Occurrence.—Occurrence from the Miyako Group.

***Pseudoleymeriella* sp.**

Plate 30-1

Material.—One specimen from Aketo, Tanohata Village, Shimohei County, Iwate Prefecture.

Description.—The speciemens are very small. The inner whorl is moderately overlapped by the outer whorl, with nearly a half involution. The whorl is nearly as high as broad, with the maximum breadth at the mid-flank. It has a rounded venter and gently inflated flanks. Width of umbilicus is fairly narrow. Umbilical wall is low and steeply inclined.

The ribs are almost rectiradiate and slightly projected forward on the venter, forming an obtuse arch, but are interrupted by a shallow sulcus on the mid-venter; they consist of only fine primary ribs. The primary ribs start from the umbilical shoulder, slightly concave or almost rectiradiate on the flank, but gently projected on the ventro-lateral area.

Remarks.—The present specimen resembles *Pseudoleymeriella hiranamensis* by lacking of secondary ribs and peripheral tubercles. However, to identify of the species is difficult because of younger stage.

Occurrence.—The described specimen is obtained from Aketo, Tanohata Village, Shimohei County, Iwate Prefecture.

Order Belemnitida Zittel, 1895

Suborder Belemnopseina Jeletzky, 1965

Family Belemnopeidae Naef, 1922

Genus ***Neohibolites*** Stolley, 1911

Type species.—*Belemnites semicanaliculatus* Blainville, 1827

***Neohibolites* sp.**

Plate 48-8

Material.—One specimen from Susuki River, Chichibu County, Saitama Prefecture.

Description.—Rostrum pinkish grey, medium in size, moderately elongate; estimated length of the rostrum about 6 times as long as the maximum dorso-ventral diameter. The maximum transverse diameter found in the middle to fairly lower part of the stem region, and thenceforth the rostrum taperss gradually toward the posterior end. Apical angle of the rostrum acute, measuring about 15 degrees. Axis and apex of the rostrum central. Rostrum nearly circular in tranverse section. Surface smooth.

Measurements.—L= 50.0 mm of the present specimen and D=8 mm.

Remarks.—The specimens resembles *Neohibolites miyakoensis* Hanai, 1953 which is reported from the Miyako Group in size and position of the maximum transverse diameter. However, the specimens are descriminated from *N. miyakoensis* by sharply apical angle of the rostrum acute.

Occurrence.—The described specimens are obtained from Susuki River, Chichibu County, Saitama Prefecture.

Phylum Arthropoda Latreille, 1829

Subphylum Crustacea Brünnich, 1772

Class Maxillopoda Dahl, 1956

Subclass Ostracoda Latreille, 1806

Ostracoda gen. et sp. indet.

Plate 45-4

Material.—One specimen from Shinzaburozawa, Sakuho Town, Minamisaku County, Nagano Prefecture.

Description.—Valve medium in size, more broadly rounded in the front than at the caudal side, ventral side curved, dorsal side straight, sloping downwards towards the caudinal side; valve surface smooth.

Remarks.—To identify of the family is difficult because of only left valve and outer side.

Occurrence.—The described specimen is obtained from Shinzaburozawa, Sakuho Town, Minamisaku County, Nagano Prefecture.

Phylum Echinodermata Klein, 1734

Class Crinoidea Miller, 1821

Subclass Articulata Zittel, 1879

Order Isocrinida Sieverts-Doreck, 1952

Family Isocrinidae Gislen, 1924

Isocrinidae gen. et. sp. indet.

Plate 34-10

Material.—One specimen from Yoheisaku Iwaki City, Fukushima Prefecture.

Description.—The specimen is fragment which is composed by only short stem. Column fairly constant at 5 mm in diameter. Columnar is pentagonal and no internodals.

Remarks.—The present specimens are identified the Family of Isocrinidae by pentagonal columnar. However, to identify species for the genus is difficult because of fragment specimen.

Occurrence.—The described specimens are obtained from Yoheisaku Iwaki City, Fukushima Prefecture.

Class Echinoidea Leske, 1778

Echinoidea gen. et sp. indet.

Plate 46-1, 2

Material.—One specimen from Ohnozawa Pass, Saku City, Nagano Prefeture.

Description.—Test large, ovate in outline, somewhat heart-shaped, slightly emarginate in front, longer than wide, widest somewhat in front of the midpoint, more or less contracted behind, relatively low; frontal ambulacrum rather short, narrow, shallowly sunken throughout its length, subpetagoloid.

Measurements.—L=51.4 mm of the present specimen and H=40.7 mm.

Remarks.—The present specimen resembles *Heteraster* of the genus by the outline. However, to identify of the genus is difficult by poor preservation.

Occurrence.—The described specimen is obtained from Ohnozawa Pass, Saku City, Nagano Prefeture.

Class Chondrichthyes Huxley, 1880

Subclass Elasmobranchii Bonaparte, 1838

Superorder Galeomorphii Compagno, 1973

Order Lamniformes Berg, 1958

Family Mitsukurinidae Jordan, 1898

Genus ***Scapanorhynchus*** Woodward, 1889

Type species.—Rbinognathus lewisii Davis, 1890

***Scapanorhynchus* sp.**

Plate 36-5

Material.—One specimen from Ammonite Center, Iwaki City, Fukushima Prefecture.

Description.—The specimen is medium sized. The crown has a slender, straight cusp with a strongly convex lingulal face bearing numerous well marked folds, parallel near the base. The specimen is thin with smooth enameloid with one pairs of sharp lateral cusplets.

Remarks.—The present specimens are identified the genus of *Scapanorhynchus* by slender form. However, to identify species for the specimens is difficult because of few specimens.

Occurrence.—The described specimens are obtained from Ammonite Center, Iwaki City, Fukushima Prefecture.

Family Cretoxyrhinidae Glückman, 1958

Genus ***Cretolamna*** Glückman, 1958

Type species.—Lamna appendiculata Agassiz, 1843

Cretolamna sp.

Plate 36-6, 37-5

Material.—Two specimens from Ammonite Center, Iwaki City, Fukushima Prefecture.

Descriptions.—The specimens are medium sized with a triangular crown that is rather broad at its base, and three pairs of well developed lateral cusplets. The crown is thin with smooth enameloid. The root lacks a groove and generally has a well marked lingual protuberance; the root lobes are short, elongated in lateral teeth. The marginal edges of the root are often straight in lateral teeth and the basal edge is medially concave.

Remarks.—The present specimens are identified the genus of *Cretolamna* by triangular crown. However, However, to identify species for the specimens is difficult because of few specimens.

Occurrence.—The described specimens are obtained from Ammonite Center, Iwaki City, Fukushima Prefecture and Ebisudana, Miyako City, Iwate Prefecture.

Pines

Plate 36-7

Material.—One specimen from Ammonite Center, Iwaki City, Fukushima Prefecture.

Descriptions.—Specimen small, subovate, center column is ovate, septum are 14 in number.

Measurements.—D=13.8 mm of the present specimens

Remarks.—The present specimen resembles pinecone. However, to identify of the species is difficult because of poor preservation.

Occurrence.—The described specimen is obtained from Ammonite Center, Iwaki City, Fukushima Prefecture.

Trace fossils

Plate 38-B

Material.—One specimen from coast of Hiraiso.

Description.—Very large, multiple and flexibled burrowing systems distinctly lined with aggultinated pelletoidal sediments; branches Y-shaped, typically enlarged at point of bifurcation; well developed lamina; burrow dimensions vary with a given system.

Remarks.—The present specimen resembles burrowing of echinoid.

Occurrence.—The described specimen is yielded from Hiraiso, Hitachinaka City, Ibaraki Prefecture.

Genus ***Macaronichnus*** Clifton and Thompson, 1978

Type species.—*Macaronichnus segregatis* Clifton and Thompson, 1978

***Macaronichnus* isp. A**

Plate 40-B

Material.—One specimen from coast of Kimigahama, Choshi City, Chiba Prefecture.

Description.—Small, simple and flexibled burrowing systems distinctly lined with aggultinated pelletoidal sediments; no branch; burrows is preserved as pelletal structure exteriorly.

Remarks.—The present specimen is identified as *Macaronichnus* of the ichnogenus by flexibled burrows and discriminated from *Macaronichnus* isp. B by small in size.

Occurrence.—The described specimen is yielded from coast of Kimigahama, Choshi City, Chiba Prefecture.

***Macaronichnus* isp. B**

Plate 40-C

Material.—One specimen from coast of Inubozaki.

Description.—Large, simple and flexibled burrowing systems distinctly lined with aggultinated pelletoidal sediments; no branch; burrows is preserved as pelletal structure exteriorly.

Remarks.—The present specimen is identified as *Macaronichnus* of the ichnogenus by flexibled burrows and discriminated from *Macaronichnus* isp. A by large in size.

Occurrence.—The described specimen is yielded from coast of Kimigahama, Choshi City, Chiba Prefecture.

Genus ***Ophiomorpha*** Lundren, 1891

Type species.—*Ophiomorpha nodosa* Lundren, 1891

***Ophiomorpha* isp.**

Plate 40-E

Material.—One specimen from coast of Inubozaki, Choshi City, Chiba Prefecture.

Description.—Simple to complicated burrowing systems distinctly lined with aggultinated pelletoidal sediments; downward branching morphological system is well characterized; pelletal walls is altered to ironoxide smooth lining; burrows is preserved as pelletal structure exteriorly.

Remarks.—The present specimen is identified as *Ophiomorpha* of the ichnogenus by simple burrow and pelletal.

Occurrence.—The described specimen is yielded from coast of Inubozaki, Choshi City, Chiba Prefecture.

Genus ***Arenicolites*** Salter, 1857

Type species.—*Arenicola carbonaria* Binney, 1852

***Arenicolites* isp.**

Plate 40-F

Material.—One specimen from coast of Inubozaki, Choshi City, Chiba Prefecture.

Description.—Simple and small burrowing systems with smooth-walled; unbranched, subhorizontal U-shaped burrows with parallel longitudinal striae all of approximately even depth.

Remarks.—The present specimen is identified as *Arenicolites* of the ichonogenus by small and U-shaped burrows.

Occurrence.—The described specimen is yielded from coast of Inubozaki, Choshi City, Chiba Prefecture.

Genus ***Thalassinoides*** Ehrenberg, 1944

Type species.—*Thalassinoides callainassae* Ehrenberg, 1944

***Thalassinoides* isp.**

Plate 40-G

Material.—One specimen from coast of Inubozaki, Choshi City, Chiba Prefecture.

Description.—Large burrow system consisting of smooth-walled, essentially cylindrical componants is characterized; branches Y- to T- shaped, typically enlarged at point of bifurcation; burrow dimensions vary with a given system.

Remarks.—The present specimen is identified as *Tharassinoides* of ichogenus by branches Y- to T-shaped.

Occurrence.—The described specimen is yielded from coast of Inubozaki, Choshi City, Chiba Prefecture.

Genus ***Zoophycos*** Massalongo, 1885

Type species.—*Zoophycos caputmedusae* Massalongo, 1855

***Zoophycos* isp.**

Plate 40-D

Material.—One specimen from coast of Kimigahama, Choshi City, Chiba Prefecture.

Description.—Small and simple burrow systems with well developed lamina; no branch; pelletal walls is altered to ironoxide smooth lining; burrows is preserved as pelletal structure exteriorly.

Remarks.—The present specimen is identified as *Zoophycos* of the ichnogenus by no branch and well developed lamina.

Occurrence.—The described specimen is yielded from coast of Kimigahama, Choshi City, Chiba Prefecture.

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