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Middle Jurassic radiolarians from a siliceous mudstone clast within conglomerate of the Tetori Group in the Itoigawa area, Niigata Prefecture, central Japan

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and Atsushi MATSUOKA****

Abstract

Well-preserved radiolarians were extracted from a siliceous mudstone pebble within conglomerate of the Mizukamidani Formation of the Tetori Group in the Itoigawa area, Niigata Prefecture, central Japan. These radiolarians correspond to the assemblage of the Middle Jurassic (*Striatojaponocapsa plicarum* Zone (JR4): Bajocian to early Bathonian). Based on general features of an accretionary complex and previous knowledge of the surrounding geological units in East Asia, the Middle Jurassic (JR4) siliceous mudstone was derived from the latest Middle or Late Jurassic accretionary complexes. This result indicates that the latest Middle or Late Jurassic accretionary complexes had been exposed and denudated in the depositional time of the Mizukamidani Formation.

Key words: conglomerate, etched surface, Jurassic radiolaria, Mizukamidani Formation, Tetori Group, accretionary complexes.

Introduction

The Middle Jurassic to Lower Cretaceous Tetori Group is distributed in the Hokuriku District, central Japan (Fig. 1.2). Some radiolarian fossils have occurred from siliceous rock clasts within conglomerates of the Tetori Group (Kojima, 1986; Saida, 1987; Takeuchi et al., 1991; Matsukawa and Takahashi, 1999; Tomita et al., 2007; Ito et al., 2012). Based on these

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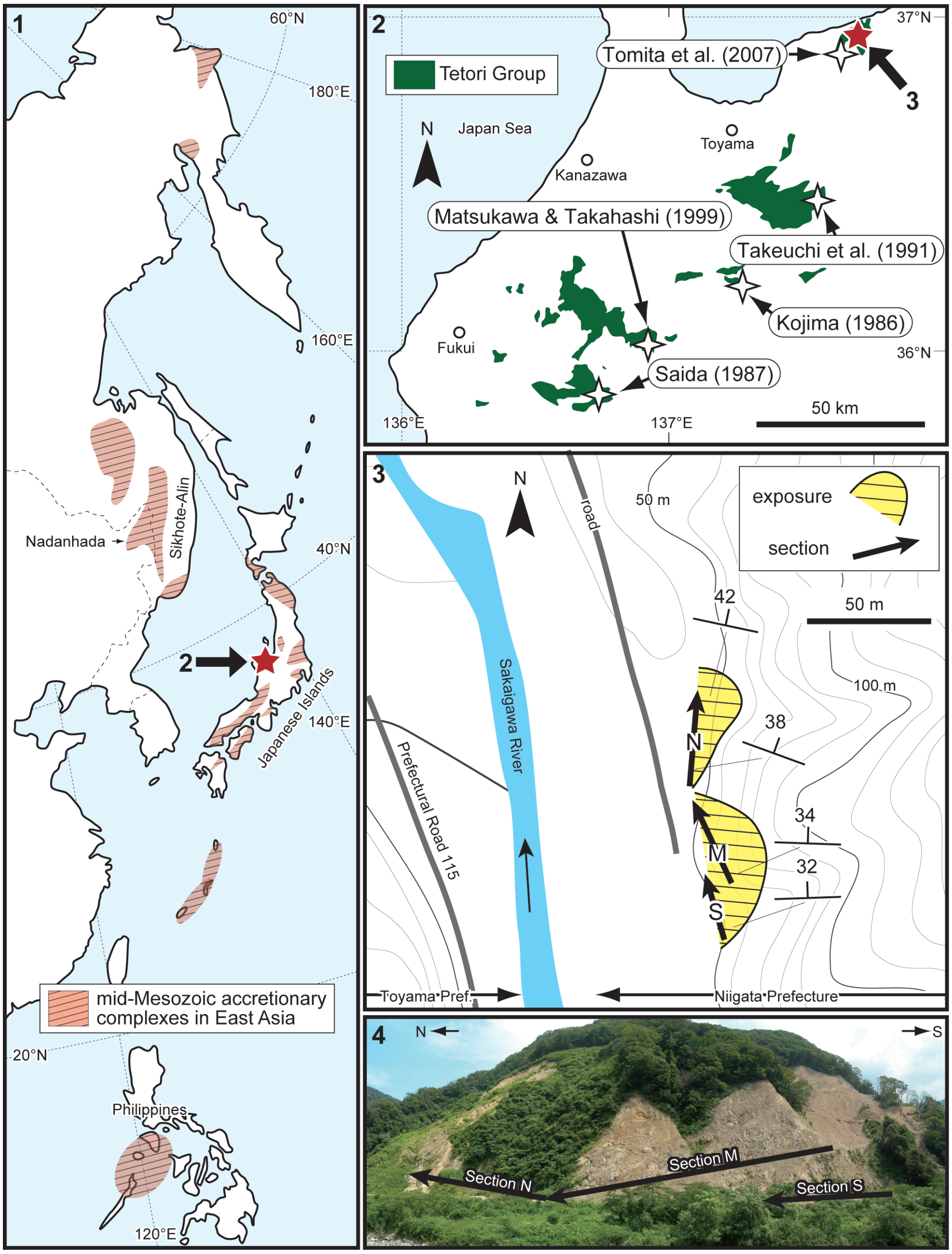

Fig. 1. 1: Distributions of mid-Mesozoic accretionary complexes in East Asia modified from Kojima and Kametaka (2000). 2: Distributions of the Tetori Group (after Maeda, 1961) and radiolarian localities from clasts in previous studies. 3: The studied successions which outcrop along the right bank of the Sakaigawa River. 4: Panoramic view of the study sections from the left bank of the Sakaigawa River.

occurrences, some researchers have discussed the provenances of the Tetori Group. Takeuchi et al. (1991) concluded that the Mino terrane in a broad sense, mid-Mesozoic accretionary complex (AC), was already uplifted and eroded in the late Neocomian (Early Cretaceous) on the basis of the presences of Triassic and Jurassic clasts within conglomerates of the Yakushizawa-migimata Conglomerate Member of the Tetori Group. Matsukawa and Takahashi (1999) found Permian or Triassic chert clasts from the Otaniyama Formation of the Tetori Group in the upper reaches of the Shokawa River. It had been presumed that the Otaniyama Formation corresponds partially to the Upper Jurassic to lowest Cretaceous based on the stratigraphic relationship to the underlying Mitarai Formation, ammonoid-bearing marine deposits. They highlighted the Mino terrane sensu Takeuchi et al. (1991) had been exposed earlier than the age presumed by Takeuchi et al. (1991). However, a Berriasian ammonoid (*Neocosmoceras*) was found from the Mitarai Formation (Sato et al., 2008), indicating that the Otaniyama Formation corresponds to the Lower Cretaceous. In previous studies, valuable radiolarians for detailed age assignments had not occurred from siliceous mudstone clasts of the Tetori Group.

The Itoigawa Mesozoic Research Team has investigated the Mizukamidani Formation of the Tetori Group in the Itoigawa area, Niigata Prefecture, central Japan (Ito et al., 2010, 2012; Sakai et al., 2012, 2013). We obtained Middle Jurassic radiolarian fossils from a siliceous mudstone pebble within conglomerate of the Mizukamidani Formation. In this paper, we report this radiolarian assemblage and speculate the origin of the siliceous mudstone clast.

Geological setting

The Tetori Group is representative sediments from the Middle Jurassic to Early Cretaceous in the Inner Zone of Southwest Japan. The Tetori Group is characterized by marine–terrestrial deposits consisting mainly of clastics and subdivided into the following three subgroups: the Kuzuryu, Itoshiro, and Akaiwa subgroups in ascending order (Maeda, 1961). The Kuzuryu Subgroup consists of marine–brackish strata yielding ammonoids; the Itoshiro Subgroup is composed mainly of brackish–terrestrial strata and characterized by flood plain deposits; the Akaiwa Subgroup consists mainly of brackish–terrestrial strata and is characterized by coarse-grained sandstone formed on braided stream (Isaji, 2010).

The Itoigawa area is located at the west-end of Niigata Prefecture (Fig. 1). The Mesozoic sequences in this area are composed of the Kuruma Group (Lower Jurassic) and the Tetori Group. The Tetori Group in this area consists of the Kurobishiyama Conglomerate, and the Mizukamidani and Shiritakayama formations (e.g., Tomita et al., 2006). The Mizukamidani Formation (Kobayashi et al., 1957) consists mainly of poorly-sorted conglomerates and sandstone. Coaly matters and plant-fossil-fragments occur commonly from the Mizukamidani Formation, while other fossils have barely occurred. Although the Mizukamidani Formation

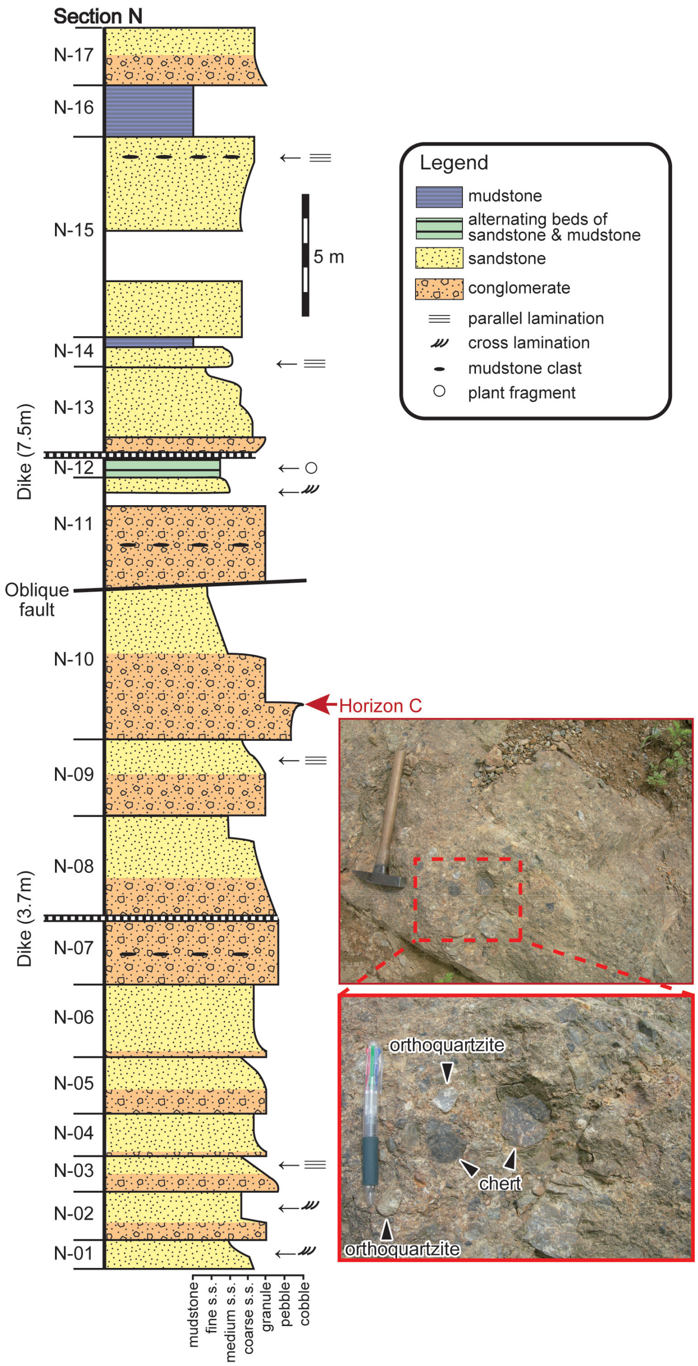

Fig. 2. Stratigraphic column for Section N of the Mizukamidani Formation and the occurrence of conglomerate at Horizon C.

had been formerly considered as the uppermost part of the Kuruma Group (e.g., Kobayashi et al., 1957; Goto, 1983), it has been corresponded to the Akaiwa Subgroup in recent decades (e.g., Takizawa, 1984; Shiraishi 1992; Tomita et al., 2006; Sakai et al., 2012). Based on a zircon U–Pb dating, the youngest zircon grain from the sandstone of the Mizukamidani Formation has the concordant age of 128 Ma (Takeuchi et al., 2013).

The study sections (36°57.556′ N, 137°39.152′ E) outcrop along the right bank of the Sakaigawa River (Figs. 1.3, 1.4). We sectioned three columns, northward-namely S, M, and N (Sakai et al., 2012). These sections are subdivided into 43 subsections. The uppermost part of Section S (S-11 to S-13) and the lowermost part of Section M (M-01 to M-03) are the same horizons. Section M and Section N are successive. These strata approximately strike N80° W and dip 35° N. There are some high-angled oblique faults in the sections. Some bedding faults are recognized in subsection boundaries. The sections are composed mainly of feldspathic-arenite and conglomerates with minor mudstones. The conglomerates are characterized by abundances of chert and orthoquartzite clasts. Fining-upward cycles are repeated in the sections. Coaly matters occur commonly from the sections; plant-fossil-fragments occurred from several horizons; trace fossils are observed. Sakai et al. (2012) reported molluscan fossils from mudstone clasts in the lower S-06 as a first report of mollusks from the Mizukamidani Formation. In this study, we deal with Section N (Fig. 2).

Materials and methods

Ito et al. (2012) collected conglomerate samples from five horizons of Section M and three horizons of Section N. A black siliceous mudstone pebble (IT12050102-1) (Fig. 3.1), dealt in this paper, was collected from Horizon C in Ito et al. (2012). Horizon C is situated in a brown conglomerate layer (3.4 m) in lower N-10 (Fig. 2). Clasts are typically 2 cm in diameter; the largest clasts are approximately 10 cm in diameter. Clasts are sub-rounded to rounded, poorly-sorted, and clast-supported. Chert (black, dark-gray, and gray) and orthoquartzite clasts are dominant; black siliceous mudstone, fine-grained sandstone, and granite clasts are minor; bright-gray very-coarse-grained sandstones are matrices.

The conglomerate sample was cut in hand-size with rock cutter and then soaked in an approximately 5% hydrofluoric acid (HF) solution for one day at room temperature. The HF solution was removed and the etched sample was subsequently refilled with fresh water. The water was removed and the etched sample was dried naturally. Surface of the etched siliceous mudstone without gold coating was photographed with a scanning electron microscope (SEM). A SEM image of the etched surface is shown in Fig. 3.2; SEM images of selected radiolarians are shown in Figs. 3.3–3.12.

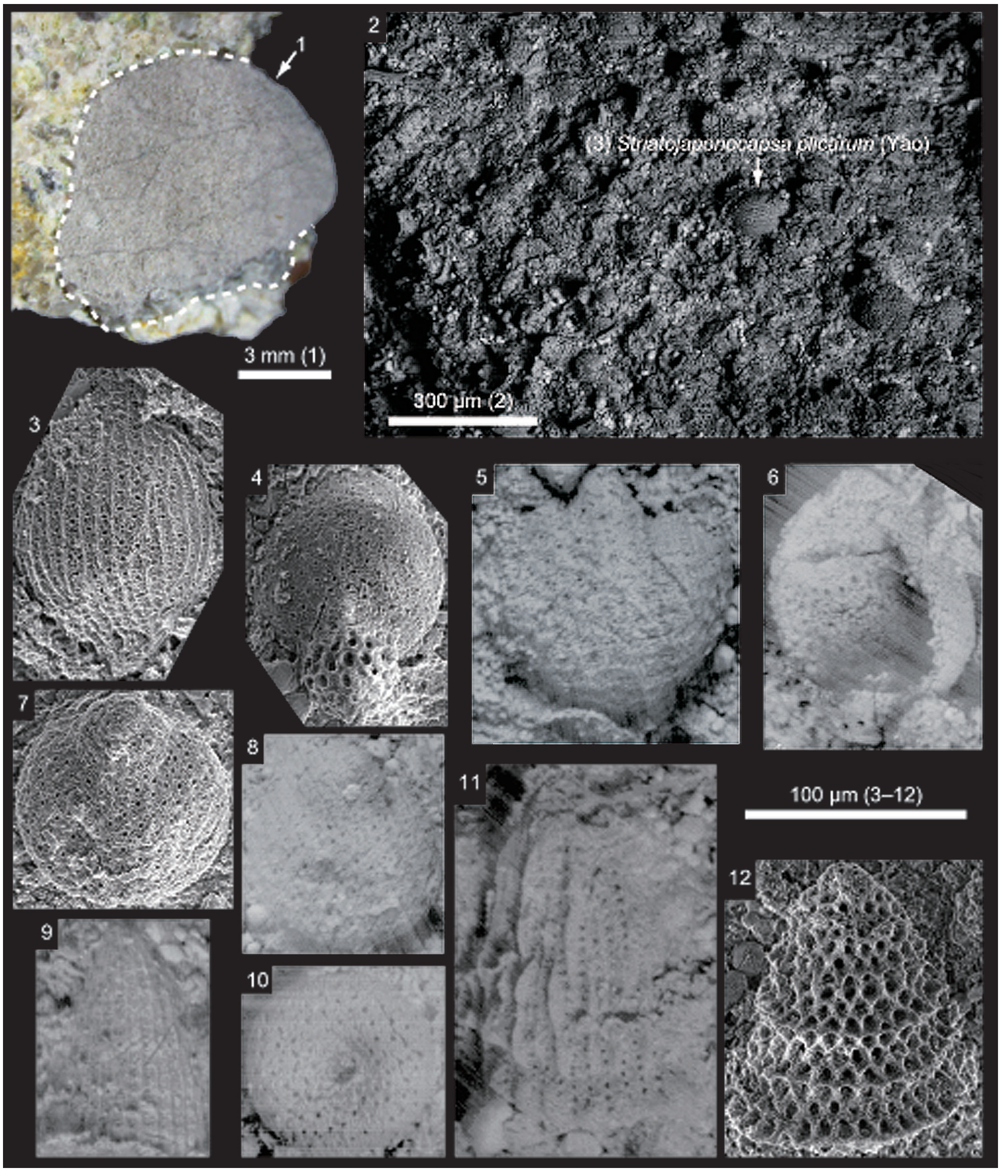

Fig. 3. Photograph of a siliceous mudstone pebble (IT12050102-1) (1), SEM images of enlarged HF-etched surface (2), and radiolarians scattered at the surface (3–12); 3: *Striatojaponocapsa plicarum* (Yao); 4: *Cyrtocapsa mastoidea* Yao; 5–8, 10: closed-end nassellarians; 9: *Archaeodictyomitra* sp.; 11: *Hsuum* sp.; 12: *Parvicingula* sp.

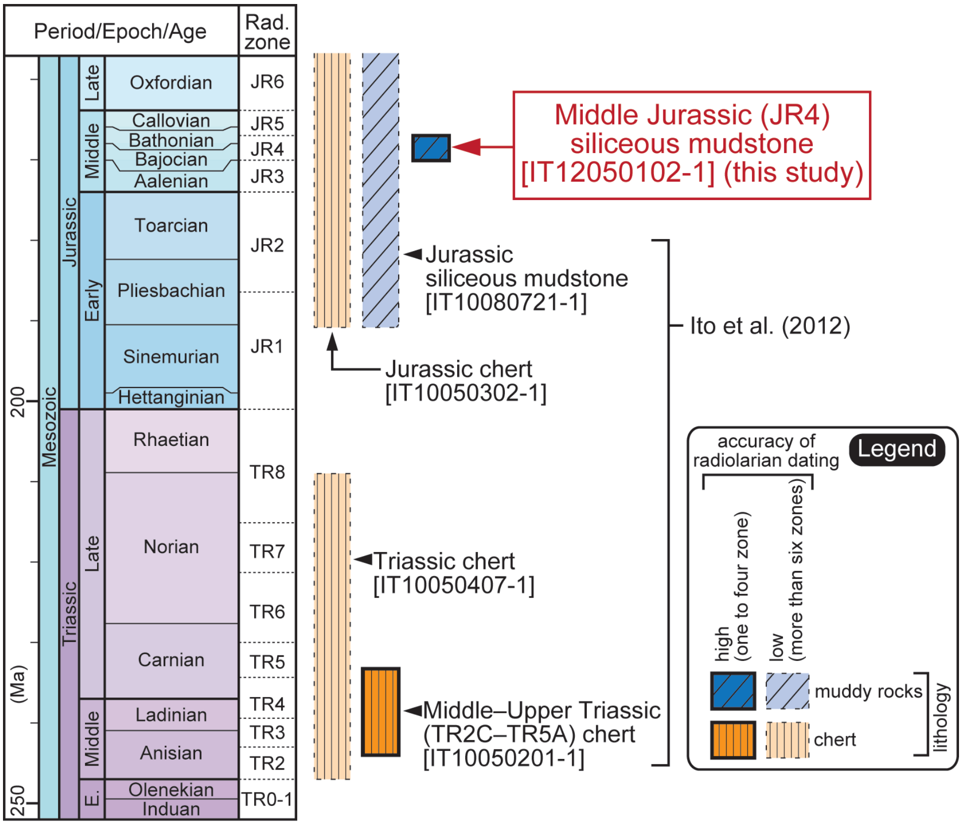

Fig. 4. Relations between the lithology of radiolarian-bearing clasts and their age assignments within conglomerates in the Mizukamidani Formation. Radiolarian zones and their age assignments are after Sugiyama (1997) and Matsuoka (1995).

Radiolarian occurrence

An etched surface of the siliceous mudstone pebble (IT12050102-1) is characterized by dominance of closed-end and multi-segmented nassellarians, and being slightly-matrix-supported (Fig. 3.2). The bioclasts are distributed uniformly in the surface. The preferred orientation of bioclasts is not observed.

The following radiolarians occurred from the siliceous mudstone pebble: *Striatojaponocapsa plicarum* (Yao) (Fig. 3.3), *Cyrtocapsa mastoidea* Yao (Fig. 3.4), closed-end nassellarians (Figs. 3.5–3.8, 3.10), *Archaeodictyomitra* sp. (Fig. 3.9), *Hsuum* sp. (Fig. 3.11), and *Parvicingula* sp. (Fig. 3.12).

Striatojaponocapsa is a key genus of Middle Jurassic and its lineage has been investigated in detail (e.g., Matsuoka, 1983, 1986, 1988; O'Dogherty et al., 2005; Hatakeda et al., 2007). *Striatojaponocapsa plicarum* is a diagnostic species of the *Striatojaponocapsa plicarum* Zone (JR4) of Matsuoka (1995) and occurs from the *S. plicarum* and *Striatojaponocapsa conexa* zones (JR4 and JR5). *Striatojaponocapsa plicarum* evolved from the *Stichocapsa tegiminis* Yao group (Matsuoka and Yao, 1986; Matsuoka, 1995). The first evolutionary appearance of *S. plicarum* defines the base of the JR4 Zone. The occurrence of *Cyrtocapsa mastoidea* is limited to only the JR4 Zone (Matsuoka, 1983, 1995). Therefore, the siliceous mudstone pebble corresponds to the JR4 Zone (Bajocian to lower Bathonian).

Discussion

This study recognized the Middle Jurassic (JR4) siliceous mudstone clast from the study section, in addition to the Middle to Upper Triassic (TR2C to TR5A zones of Sugiyama, 1997: middle Anisian to middle Carnian) chert, Jurassic chert, Triassic chert, and Jurassic siliceous mudstone clasts of Ito et al. (2012). Based on the previous knowledge of the surrounding geological units in East Asia, these clasts are probably derived from the mid-Mesozoic ACs. Figure 4 shows relations between the lithology of the radiolarian-bearing clasts and their age assignments. The mid-Mesozoic ACs are widely distributed in southwest Japan (Kojima and Kametaka, 2000; Nakae, 2000) and other countries in East Asia (e.g., Russian, China, and the Philippines) (Wakita and Metcalfe, 2005) (Fig. 1.1). Middle Jurassic (JR4) siliceous mudstones have occurred from some geologic bodies of the mid-Mesozoic ACs, such as the Kamiaso Complex of the Mino terrane (Matsuoka, 1988), the Togano Unit of the Southern Chichibu terrane (Matsuoka, 1983), the Otori Formation of the North Kitakami terrane (Suzuki et al., 2007), the Khabarovsk Complex in Russian (Kojima et al., 1991), and the Northern Busuanga Belt in the Philippines (Zamoras and Matsuoka, 2001). Based on the general feature of an AC and the previous occurrences as mentioned above, the Middle Jurassic (JR4) siliceous mudstone clast was derived from the latest Middle or Late Jurassic ACs. In other words, the middle Middle Jurassic and older ACs should not include Middle Jurassic (JR4) siliceous mudstones. Hence the siliceous mudstone clast from this study should not be originated from the middle Middle Jurassic and older ACs but some of the latest Middle or Late Jurassic ACs such as the above geological bodies or corresponding ones.

Although some researchers have reported radiolarian occurrences from clasts within the Tetori Group, there has no occurrence of valuable Mesozoic radiolarians for age assignment from siliceous mudstone clasts. The result of this study, the first report of Middle Jurassic siliceous mudstone clast, indicates that the latest Middle or Late Jurassic accretionary complexes had been exposed and denudated in the depositional time of the Mizukamidani Formation.

Acknowledgements

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Early Permian (Sakmarian) brachiopods from Kamiyasse, South Kitakami Belt, northeast Japan

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Abstract

An early Permian (Sakmarian) brachiopod fauna, consisting of 20 species in 14 genera, is described from the basal part of the Nakadaira Formation in the Kamiyasse area, South Kitakami Belt, northeast Japan. The new species described here are *Derbyia yukisawensis* Tazawa and Shintani, *Nipponirhynchia kamiyassensis* Tazawa and Shintani, *Spiriferellina nanbuensis* Tazawa and Shintani and *Crenispirifer nakamurai* Tazawa and Shintani. The Kamiyasse fauna is a mixed Boreal–Tethyan fauna, and has some affinities with the early Permian brachiopod faunas of northern Russia (Kolyma, Pechora and the northern Urals), northwest China (Xinjiang) and north China (Inner Mongolia). Palaeobiogeographical data for the Kamiyasse fauna suggest that during the Sakmarian the South Kitakami region was probably located at mid-latitudes in the Northern Hemisphere, immediately east of North China (Sino-Korea).

Key words: Brachiopoda, Kamiyasse, mixed Boreal–Tethyan fauna, Sakmarian, South Kitakami Belt.

Introduction

Permian brachiopod faunas of the South Kitakami Belt, northeast Japan are important and useful in understanding the Permian palaeogeography and palaeobiogeography of both this region and the Japanese Islands. Compared with those of the middle and late Permian, however, the early Permian brachiopods of the South Kitakami Belt have been poorly

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documented. Brachiopods from the basal part of the Sakamotozawa Formation (Sakmarian) of the Sakamotozawa area and its equivalents are particularly scarce; only the following 12 species have been described previously: *Orthotetes* cf. *callytharrensis* (Thomas), *Streptorhynchus* sp., *Derbyia* sp. B and *Magniderbyia* sp. (= *Derbyia dorsosulcata* Liu and Waterhouse) by Nakamura (1972); *Waagenoconcha asiatica* Zavodowsky by Tazawa (1974); *Waagenoconcha humboldti* (d'Orbigny), *Scacchinella* sp. and *Rhynchopora* sp. by Tazawa and Shintani (2010); and *Meekella striatocostata* (Cox), *Meekella nagaiwensis* Shintani, *Derbyia dorsosulcata* and *Derbyia sakamotozawensis* Shintani by Shintani (2011).

The present study describes the brachiopod species from the basal part of the Nakadaira Formation in the Kamiyasse area, South Kitakami Belt (Fig. 1), based on specimens housed at Hokkaido University and new material collected by the junior author (T. S.) of this paper. The age and palaeobiogeography of the Kamiyasse fauna are also discussed. The specimens described herein are registered and housed in the Hokkaido University Museum in Sapporo (prefix UHR) and the Department of Geology, Faculty of Science, Niigata University in Niigata (prefix NU-B), Japan.

Stratigraphy

The Permian stratigraphy of the Kamiyasse area was first studied by Shiida (1940), who divided the Permian into two formations, the lower, Kamiyasse Formation and the upper, Futatsumori Formation. Subsequently Kambe and Shimazu (1961) and Tazawa (1973, 1976) reclassified the Permian into the following three series (in ascending order): the Sakamotozawa, Kanokura and Toyoma, following the stratigraphy of the Permian type section in the Setamai area defined by Minato et al. (1954). Recently, Misaki and Ehiro (2004) classified the Permian into the following four formations (in ascending order): the Nakadaira, Hosoo, Kamiyasse and Kurosawa, producing a stratigraphy very different from previous studies. In the present study, we follow basically the four-fold division, although the boundary between the Nakadaira and the Hosoo formations is placed at different horizon from that of Misaki and Ehiro (2004).

The Nakadaira Formation in the Kamiyasse area consists mostly of limestone, with associated shale, sandstone and conglomerate, and has an estimated total thickness of 479 m (Fig. 2). The brachiopod specimens were collected from sandstones in the basal part of the Nakadaira Formation, exposed at three localities, KY1, KY2 and KY3. The lithological, topographical and stratigraphical details of the fossil localities are as follows (see also Figs. 1, 2).

KY1: Light grey–brown, medium to coarse-grained sandstone, 31 m above the base of the Nakadaira Formation, exposed at a road-cutting along the Hosoozawa Valley, 91 m NE of

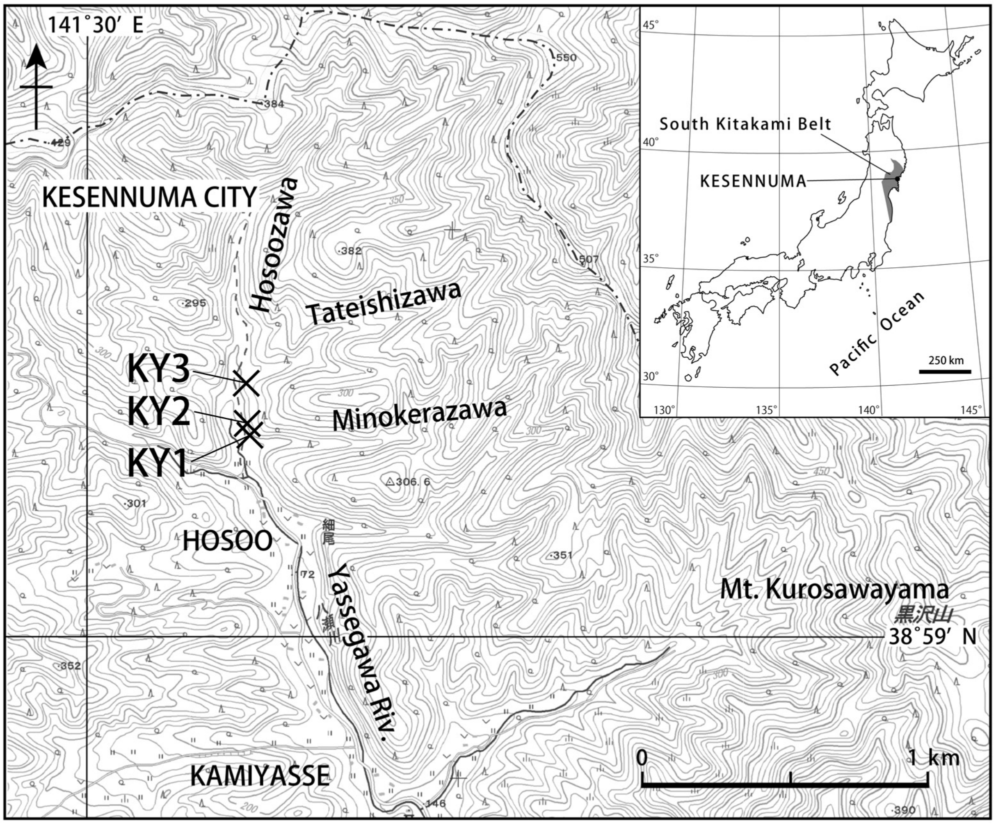


Fig. 1. Index map showing the fossil localities KY1, KY2 and KY3 in the Kamiyasse area, using the topographical map of "Shishiori" scale 1 : 25,000 published by the Geospatial Information Authority of Japan.

the junction of the Hosoozawa and Minokerazawa valleys (Lat. 38°59′ 23″ N, Long. 141°30′ 45″ E), containing *Echinoconchus*? sp., *Waagenoconcha asiatica*, *Derbyia buchi* (d'Orbigny), *Derbyia yukisawensis* Tazawa and Shintani, *Orthothetina curvata* Ustritsky, *Orthothetina* sp. and *Hustedia indica* (Waagen). The fusulinid foraminifers described by Ueno et al. (2011) were also collected from this locality.

KY2: Light greenish grey–light brown, medium-grained sandstone, 30 m above the base of the Nakadaira Formation, exposed at a road-cutting along the Hosoozawa Valley, 36 m N of KY1, containing *Nipponirhynchia kamiyassensis* Tazawa and Shintani, *Uncinunellina* cf. *wangenheimi* (Pander), *Uncinunellina* sp., *Callispirina* sp. and *Crenispirifer nakamurai* Tazawa and Shintani.

KY3: Light grey–light brown, fine to medium-grained sandstone, 33 m above the base of the Nakadaira Formation, exposed on the western slope, about 40 m SE of the junction of the Hosoozawa and Tateishizawa valleys (Lat. 38°59′ 28″ N, Long. 141°30′ 23″ E), containing *Echinoconchus*? sp., *Acritosia* sp., *Derbyia dorsosulcata, Derbyia yukisawensis, Meekella*

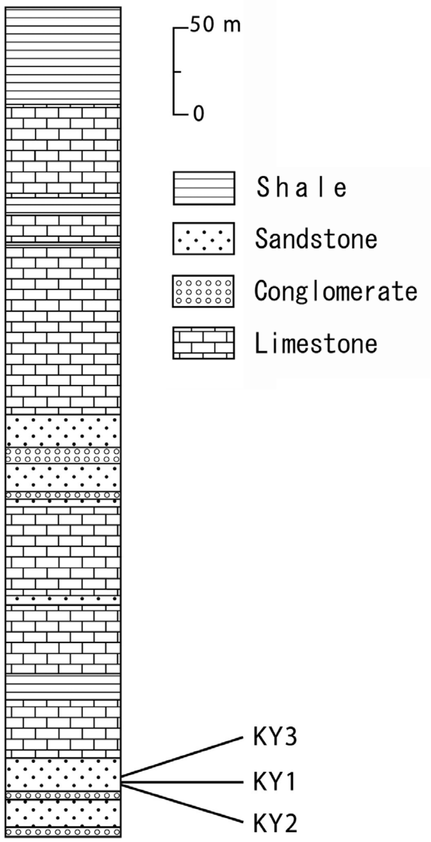


Fig. 2. Generalized columnar section of the Nakadaira Formation in the Kamiyasse area, showing the fossil horizons, KY1, KY2 and KY3.

uralica Tschernyschew, *Meekella* sp., *Orthothetina curvata, Uncinunellina* sp., *Cleiothyridina* sp., *Hustedia indica, Martiniopsis* sp., *Spiriferellina nanbuensis* Tazawa and Shintani, *Spiriferellina* sp. and *Crenispirifer nakamurai*.

The Kamiyasse fauna

The brachiopod fauna described herein includes the following 20 species, belonging to 14 genera: *Echinoconchus*? sp., *Waagenoconcha asiatica* Zavodowsky, 1968, *Acritosia* sp., *Derbyia buchi* (d'Orbigny, 1842), *Derbyia dorsosulcata* Liu and Waterhouse, 1985, *Derbyia yukisawensis* Tazawa and Shintani, sp. nov., *Meekella uralica* Tschernyschew, 1902, *Meekella* sp., *Orthothetina curvata* Ustritsky, 1960, *Orthothetina* sp., *Nipponirhynchia kamiyassensis* Tazawa and Shintani, sp nov., *Uncinunellina* cf. *wangenheimi* (Pander in Müller, 1862), *Uncinunellina* sp., *Cleiothyridina* sp., *Hustedia indica* (Waagen, 1883), *Martiniopsis* sp., *Spiriferellina nanbuensis* Tazawa and Shintani, sp. nov., *Spiriferellina* sp., *Callispirina* sp. and *Crenispirifer nakamurai* Tazawa and Shintani, sp. nov.

Age of the fauna

Of the taxa identified in the Kamiyasse fauna, *Waagenoconcha asiatica* is known from the lower Permian (Asselian) of northern Russia (Kolyma). *Derbyia buchi* is known from the lower Permian (Asselian–Kungurian) of North America (Texas) and South America (Peru and Bolivia). *Derbyia dorsosulcata* is known from the lower Permian (Sakmarian) of northeast Japan (Sakamotozawa and Yukisawa areas, South Kitakami Belt) and from the middle Permian (Wordian) of north China (Inner Mongolia). *Meekella uralica* is known from the upper Carboniferous (Kasimovian) to lower Permian (Asselian) of northern Russia (Pechora Basin and the northern Urals) and northwest China (Xinjiang). *Orthothetina curvata* is known from the upper Carboniferous (Kasimovian) to lower Permian (Kungurian) of northwest China (Xinjiang) and southwest China (Yunnan). *Hustedia indica* is a long ranging species, known from the lower Permian (Asselian) to upper Permian (Changhsingian) of northern Russia (Urals), northwest China (Gansu) and Pakistan (Salt Range). *Acritosia* is abundant in the lower Permian (Wolfcampian, correlated with the Asselian–Sakmarian) of North America (Texas). Outside the South Kitakami Belt, *Nipponirhynchia* is known only from the lower Permian (Sakmarian) of Kawai, Hiroshima Prefecture, southwest Japan.

In summary, the age of the Kamiyasse fauna is assigned to the early Permian (Asselian–Sakmarian, probably Sakmarian), which is consistent with the findings of Ueno et al. (2011), who considered the age to be Sakmarian based on the occurrence of the fusulinid foraminifers *Dutkevitchia*? *hindukushiensis* (Leven), *Pseudofusulina* cf. *callosa* (Rauser-Chernousova), *Pseudochusenella* ex gr. *cushmani* (Chen), *Nipponitella* sp., *Eoparafusulina* sp. and others.

Palaeobiogeography

Of the brachiopods listed above, *Waagenoconcha* is a bipolar-type (antitropical) genus, and *Meekella uralica* and *Derbyia dorsosulcata* are Boreal-type species. Conversely, *Acritosia* and *Orthothetina* are Tethyan (tropical) genera. Consequently, the Kamiyasse fauna is a mixed Boreal–Tethyan fauna. In terms of generic and specific composition, the Kamiyasse fauna is endemic, although it has some affinities with the early Permian brachiopod faunas of northern Russia (Kolyma, Pechora and the northern Urals), northwest China (Xinjiang) and north China (Inner Mongolia).

The palaeobiogeographical data suggest that the South Kitakami region, including the Kamiyasse area, was probably located at mid-latitudes in the Northern Hemisphere, immediately east of North China (Sino-Korea), within the Inner Mongolia–Japan Transitional Zone (Tazawa, 1991, 2007) (=Northern Transitional Zone of Shi et al., 1995; Sino-Mongolian–Japanese Province of Shi and Tazawa, 2001), in the Sakmarian.

Systematic descriptions

Order Productida Sarytcheva and Sokolskaya, 1959
Suborder Productidina Waagen, 1883
Superfamily Echinoconchoidea Stehli, 1954
Family Echinoconchidae Stehli, 1954
Subfamily Echinoconchinae Stehli, 1954
Tribe Echinoconchini Stehli, 1954
Genus *Echinoconchus* Weller, 1914

Type species. —*Anomites punctatus* Martin, 1809.

Echinoconchus? sp.
Figs. 3.1, 3.2

Material.—Two specimens from localities KY1 and KY3, external and internal moulds of two dorsal valves, NU-B1513, 1514.

Remarks.—These specimens are probably assigned to the genus *Echinoconchus* by their flat, transversely subquadrate dorsal valve (length about 17 mm, width about 27 mm in the better preserved specimen, NU-B1513), ornamented by prominent concentric rugae and numerous spine bases, and in having internal structures consisting of a cardinal process, trilobed externally and bilobed internally and a thin, long median septum with a distinct alveolus. The generic and specific identifications are difficult for the poorly preserved specimens.

Family Waagenoconchidae Muir-Wood and Cooper, 1960
Subfamily Waagenoconchinae Muir-Wood and Cooper, 1960
Tribe Waagenoconchini Muir-Wood and Cooper, 1960
Genus *Waagenoconcha* Chao, 1927

Type species.—*Productus humboldti* d'Orbigny, 1842.

Waagenoconcha asiatica Zavodowsky, 1968
Fig. 3.3

Waagenoconcha asiatica Zavodowsky, 1968, p. 92, pl. 33, fig. 5; Zavodowsky and Stepanov, 1970, p. 89, pl. 3, figs. 1, 2; Tazawa, 1974, p. 123, pl. 1, fig. 1; pl. 4, fig. 5; Minato et al., 1979, pl. 45, fig. 1.

Material.—One specimen from locality KY1, external and internal moulds of a ventral valve, UHR19848.

Remarks.—The single ventral valve specimen from Kamiyasse was previously described by Tazawa (1974, p. 123) as *Waagenoconcha asiatica* Zavodowsky, 1968. In the present paper we follow the identification and the description. Shells of *Waagenoconcha humboldti* (d'Orbigny, 1842), described by Tazawa and Shintani (2010, p. 56, figs. 4.1–4.5) from the basal part of the Sakamotozawa Formation in the Sakamotozawa area, South Kitakami Belt, are clearly distinguished from the Kamiyasse specimen by their larger dimensions and stronger concentric rugae on the ventral valve.

Distribution.—Asselian–Sakmarian: northern Russia (Kolyma) and northeast Japan (Kamiyasse in the South Kitakami Belt).

Superfamily Richthofenioidea Waagen, 1885
Family Teguliferinidae Muir-Wood and Cooper, 1960
Subfamily Teguliferininae Muir-Wood and Cooper, 1960
Genus *Acritosia* Cooper and Grant, 1969

Type species.—*Acritosia magna* Cooper and Grant, 1969.

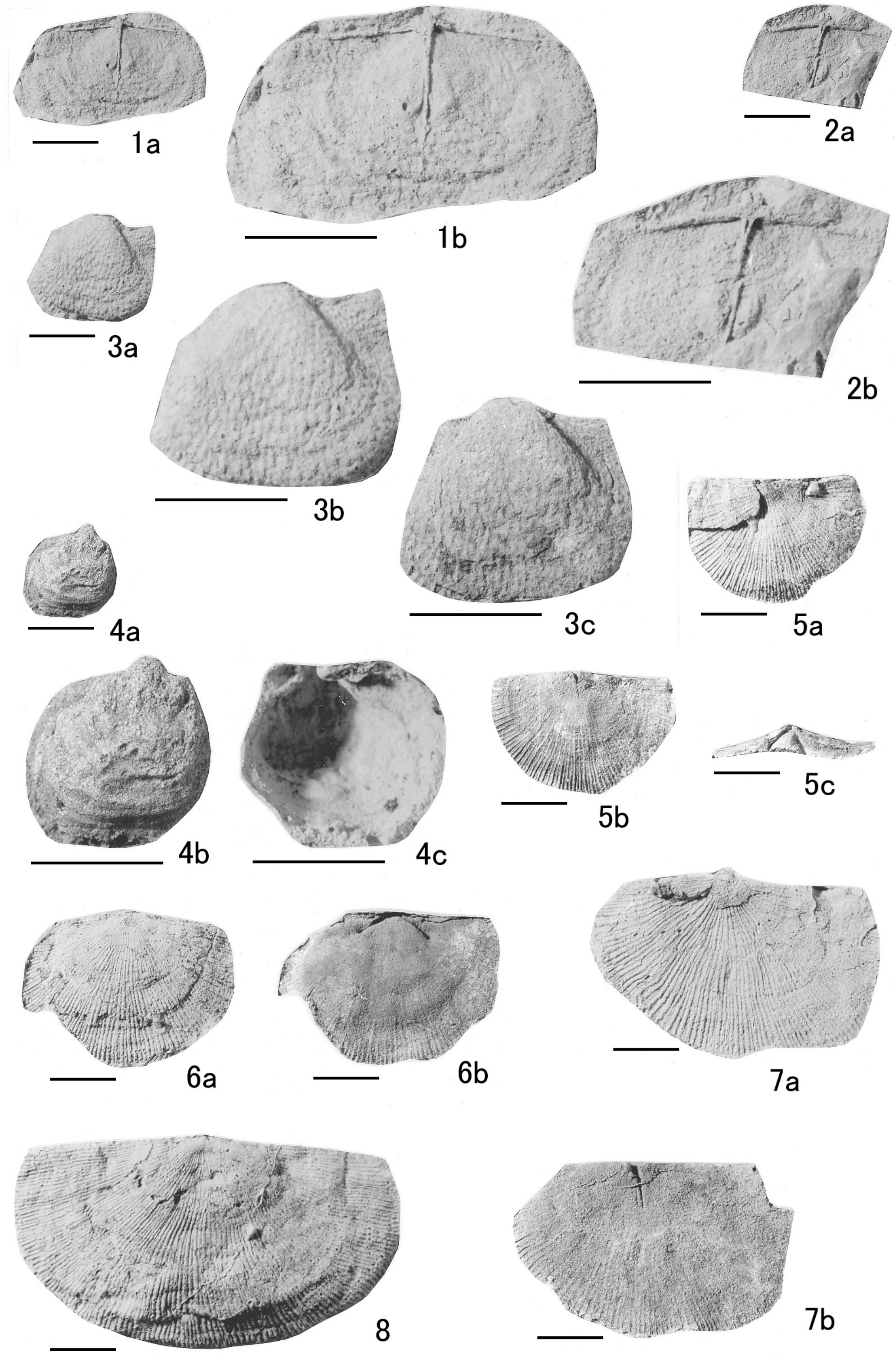
Acritosia sp.
Fig. 3.4

Material.—One specimen from locality KY3, internal mould of a ventral valve, NU-B1562.

Remarks.—This specimen is safely assigned to the genus *Acritosia* by its low, conical ventral valve (length 15 mm, width 17 mm, height about 11 mm), without median septum. The Kamiyasse species resembles *Acritosia silicica* Cooper and Grant (1975, p. 819, pl. 200, figs. 1–29; pl. 309, figs. 1–5), from the Hueco Formation (Wolfcampian) of west Texas, in its average-sized, slightly oblique cone-shaped ventral valve. However, accurate comparison is difficult because information on the external character of the ventral valve is lacking.

Order Orthotetida Waagen, 1884
Suborder Orthotetidina Waagen, 1884
Superfamily Orthotetoidea Waagen, 1884
Family Derbyiidae Stehli, 1954
Genus *Derbyia* Waagen, 1884

Type species.—*Derbyia regularis* Waagen, 1884.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3a
3b
3c
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4b
4c
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5c
6a
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7a
7b
8

Derbyia buchi (d'Orbigny, 1842)
Figs 3.5, 3.6

Orthis buchi d'Orbigny, 1842, p. 49.
Derbyia buchi (d'Orbigny): Kozlowski, 1914, p. 57, pl. 8, figs. 1–6; Chronic, 1953, p. 75, pl. 12, figs. 19–21; King, 1931, p. 58, pl. 8, figs. 4–6.

Material.—Two specimens from locality KY1: (1) external and internal moulds of a ventral valve, NU-B1540; (2) external and internal moulds of a dorsal valve, NU-B1541.

Description.—Shell small for genus, transverselly subrectangular in outline, hinge slightly shorter than greatest width at about midlength; length 19 mm, width 28 mm in the smaller ventral valve specimen (NU-B1540); length 24 mm, width 36 mm in the larger dorsal valve specimen (NU-B1541). Ventral valve inflated at umbo, flat to very slightly concave or slightly convex on antero-lateral slopes; umbo small, suberect. Dorsal valve very slightly convex in both lateral and anterior profiles. External surface of both valves ornamented by numerous, closely spaced, rounded costellae and some irregular, strong rugae; costellae often intercalated, numbering 10–11 in 5 mm at about midlength of both ventral and dorsal valves. Internally, ventral valve having a short, high median septum, extending for one-third length of valve. Dorsal valve having a pair of strong, widely diverging crural plates.

Remarks.—These specimens can be referred to *Derbyia buchi* (d'Orbigny, 1842), from the lower Permian Copacabana Group of Bolivia, by their small size, flattened shell with narrow corpus, and numerous, fine, often intercalated costellae on both valves.

Derbyia buchi is very similar to *Derbyia regularis* Waagen (1884, p. 594, pl. 53, figs. 1, 2, 4), from the Amb and Wargal formations of the Salt Range, in general shape, but it differs from the Salt Range species in its much smaller size and finer costellae on the both valves.

Distribution.— Asselian–Kungurian: northeast Japan (Kamiyasse in the South Kitakami Belt), North America (west Texas) and South America (Peru and Bolivia).

Derbyia dorsosulcata Liu and Waterhouse, 1985
Fig. 3.8

←**Fig. 3. 1, 2,** *Echinoconchus*? sp.; 1a, 1b, internal latex cast of dorsal valve, NU-B1513; 2a, 2b, internal latex cast of dorsal valve, NU-B1514. **3,** *Waagenoconcha asiatica* Zavodowsky; 3a, 3b, 3c, external latex cast and internal mould of ventral valve, UHR19848. **4**, *Acritosia* sp.; 4a, 4b, 4c, internal mould and internal latex cast of ventral valve, NU-B1562. **5, 6**, *Derbyia buchi* (d'Orbigny); 5a, 5b, 5c, external latex cast, and ventral and posterior views of internal mould of ventral valve, NU-B1540; 6a, 6b, external latex cast and internal mould of dorsal valve, NU-B1541. **7**, *Derbyia yukisawensis* Tazawa and Shintani, sp. nov.; 7a, 7b, external latex cast and internal mould of ventral valve, NU-B1543 (holotype). **8**, *Derbyia dorsosulcata* Liu and Waterhouse, external latex cast of dorsal valve, NU-B1542. Scale bars represent 1 cm.

Magniderbyia sp. Nakamura, 1972, p. 403, pl. 9, fig. 2.

Derbyia dorsosulcata Liu and Waterhouse, 1985, p. 11, pl. 1, figs. 1, 7, 8, 10; Wang and Zhang, 2003, p. 121, pl. 25, figs. 1, 2; pl. 26, figs. 2–6; Shintani, 2011, p. 84, figs. 5.4–5.6, 6.1–6.4.

Material.—One specimen from locality KY3, external mould of a dorsal valve, NU-B1542.

Remarks.—The single specimen from Kamiyasse resembles well the dorsal valve specimen (NU-B1268) of *Derbyia dorsosulcata* Liu and Waterhouse, 1985, figured by Shintani (2011, figs. 5.4–5.6, 6.1–6.4) from the basal part of the Sakamotozawa Formation in the Sakamotozawa area, South Kitakami Belt, in its large, transverse dorsal valve (length 34 mm, width 59 mm), with a shallow sulcus and the external ornament of numerous, fine costellae, numbering 7–8 in 5 mm at about midlength.

Comparison with the other *Derbyia* species is fully discussed by Shintani (2011, p. 86).

Distribution.— Sakmarian–Wordian: north China (Inner Mongolia) and northeast Japan (Sakamotozawa and Kamiyasse in the South Kitakami Belt).

Derbyia yukisawensis sp. nov.
Figs 3.7, 4.3

Derbyia sp. B Nakamura, 1972, p. 401, pl. 8, figs. 1, 7.

Etymology.—Named after the old locality, Yukisawa, Yahagi-cho, Rikuzentakata City, Iwate Prefecture, northeast Japan.

Material.—Four specimens from localities KY1 and KY3: (1) external and internal moulds of three ventral valves, NU-B1543 (holotype), 1544, 1545; (2) external mould of a ventral valve, NU-B1546.

Diagnosis.—Medium to large *Derbyia,* with wide hinge nearly equal to greatest width of shell, and radial costellae with a density of 8–10 in 5 mm at midlength of ventral valve.

Description.—Shell medium to large size for genus, transversely semicircular in outline, with straight hinge nearly equal to greatest width of shell; length 31 mm, width 47 mm, hinge width 42 mm in the holotype (NU-B1543). Ventral valve nearly flat with small, slightly inflated umbo. External surface of ventral valve ornamented by numerous fine costellae and some strong rugae; costellae numbering 8–10 in 5 mm at about midlength. Ventral interior with a strong median septum, extending for about a quarter of the length of the valve.

Remarks.—These specimens are identical with *Derbyia* sp. B, described by Nakamura (1972, p. 401) from the basal part of the Sakamotozawa Formation of Yukisawa in the Yahagi area, South Kitakami Belt. This species is here redescribed as a new species, *Derbyia yukisawensis* Tazawa and Shintani, sp. nov., on the material from the same horizon of

Kamiyasse. *Derbyia yukisawensis* resembles well *Derbyia regularis* Waagen, 1884 in outline of shell, but it differs from the Salt Range species in its smaller size and finer costellae on the ventral valve.

Derbyia sakamotozawensis Shintani (2011, p. 86, fig. 7), from the basal part of the Sakamotozawa Formation of the Sakamotozawa area, South Kitakami Belt, is readily distinguished from the present new species by its large flabellate muscle scar in the ventral valve.

Distribution.— Sakmarian: northeast Japan (Yahagi and Kamiyasse in the South Kitakami Belt).

Family Meekellidae Stehli, 1954

Subfamily Meekellinae Stehli, 1954

Genus *Meekella* White and St. John, 1867

Type species.—*Plicatula striatocostata* Cox, 1857.

Meekella uralica Tschernyschew, 1902

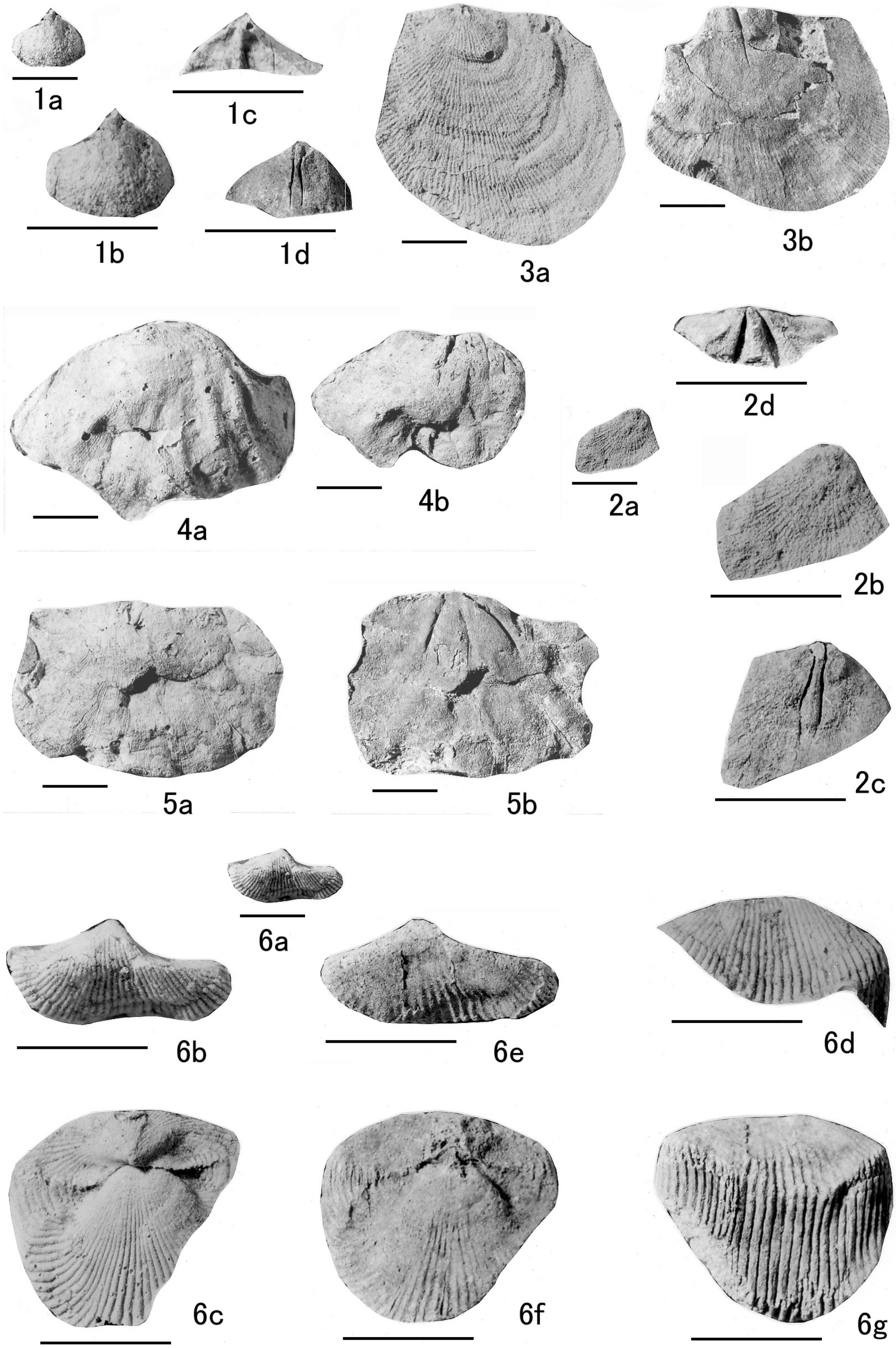
Fig. 4.5

Meekella uralica Tschernyschew, 1902, p. 215, 583, pl. 51, figs. 1, 2; Licharew, 1939, p. 82, pl. 17, fig. 3; Kalashnikov, 1980, p. 27, pl. 1, figs. 10–12; Zhang et al., 1983, p. 278, pl. 125, fig. 13; Wang, 1995, pl. 1, fig. 11; Wang and Yang, 1998, p. 62, pl. 1, figs. 1, 3 only.

Material.—One specimen from locality KY3, external and internal moulds of a dorsal valve, NU-B1539.

Description.—Shell average size for genus; length about 33 mm, width 44 mm in the sole dorsal valve specimen (NU-B1539). Dorsal valve flatly convex in lateral profile, and transversely subrectangular in outline; hinge slightly shorter than greatest width at about midlength; length about 32 mm, width about 45 mm. External surface of dorsal valve ornamented by numerous fine costellae and several broad, rounded costae; costellae numbering 13–15 in 5 mm at about midlength; costae occurring only at anterior half of valve, and having narrow interspaces. Some weak concentric rugae developed near anterior margin of valve. Interior of dorsal valve with a pair of strong, diverging crural plates enclosing adductor scars and a low, short median septum.

Remarks.—Although the dorsal valve is severely crushed, the single specimen from Kamiyasse can be referred to *Meekella uralica* Tschernyschew, 1902, from the lower Permian (Asselian) of the northern Urals, by its medium-sized, transverse dorsal valve and the external ornament consisting of numerous fine costellae and strong costae, in particular,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5a
5b
2c
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6b
6e
6d
6c
6f
6g

the closely arranged, broad, rounded costae on the anterior half of the valve.

Meekella magnifica Cooper and Grant (1974, p. 365, pl. 100, figs. 1–33; pl. 116, figs. 9–18), from the Wolfcampian of west Texas, is similar in having non-costated youthful stage, but it differs from *M. uralica* in its large size and irregular costae on the both ventral and dorsal valves.

Distribution.— Kasimovian–Sakmarian: northern Russia (Pechora Basin and northern Urals), northwest China (Xinjian) and northeast Japan (Kamiyasse in the South Kitakami Belt).

Meekella sp.

Fig. 4.4

Material.—Two specimens from locality KY3: (1) external and internal moulds of a dorsal valve, NU-B1537; (2) external mould of a dorsal valve, NU-B1538.

Remarks.—These specimens are safely assigned to the genus *Meekella* by their dorsal valves, ornamented by numerous fine costellae (15–16 in 5 mm at midlength) and strong, subangular costae (2–3 in 10 mm at anterior margin of valve) with relatively wide intercostal troughs, and having internally a pair of strong, widely diverging crural plates.

The Kamiyasse species resembles well *Meekella eximia* (Eichwald, 1840), redescribed by Zavodowsky and Stepanov (1970, p. 72, pl. 42, figs. 3–5) and by Kalashnikov (1980, p. 26, pl. 1, fig. 9) on the material from the lower Permian (Kungurian) of the Omolon Massif, and from the upper Carboniferous (Moscovian–Gzhelian) of Novaya Zemlya and the Pechora Basin, northern Russia, respectively, in size, shape and external ornament of the dorsal valve. But specific identification is difficult owing to the poor preservation of the present material.

The type species, *Meekella striatocostata* (Cox, 1857, p. 568, pl. 8, fig. 7), from the Pennsylvanian of Kentucky, is readily distinguished from the present species by the broad, rounded costae with narrower interspaces on the dorsal valve.

Genus *Orthothetina* Schellwien, 1900

Type species.—*Orthothetes persicus* Schuchert in Schuchert and Le Vene, 1929.

←**Fig. 4. 1, 2,** *Orthothetina curvata* Ustritsky; 1a, 1b, 1c, 1d, ventral and posterior views of external latex cast, and internal mould of ventral valve, NU-B1534; 2a, 2b, 2c, 2d, external latex cast, and ventral and posterior views of internal mould of ventral valve, NU-B1535. **3**, *Derbyia yukisawensis* Tazawa and Shintani, sp. nov.; 3a, 3b, external latex cast and internal mould of ventral valve, NU-B1544. **4**, *Meekella* sp.; 4a, 4b, external latex cast and internal mould of dorsal valve, NU-B1537. **5**, *Meekella uralica* Tschernyschew; 5a, 5b, external latex cast and internal mould of dorsal valve, NU-B1539. **6,** *Nipponirhynchia kamiyassensis* Tazawa and Shintani, sp. nov.; 6a, 6b, 6c, 6d, ventral, posterior and anterior views of external latex cast of conjoined shell; 6e, 6f, 6g, ventral, posterior and anterior views of internal mould of conjoined shell, NU-B1509 (holotype). Scale bars represent 1 cm.

Orthothetina curvata Ustritsky, 1960
Figs. 4.1, 4.2, 5.1

Orthotetina curvata Ustritsky, 1960, p. 16, pl. 1, figs. 6–11; Zhang et al., 1983, p. 277, pl. 125, figs. 9, 10; Jin and Fang, 1985, pl. 1, figs. 24–31; Wang, 1995, pl. 1, fig. 8; Wang and Yang, 1998, p. 64, pl. 2, fig. 6.

Orthotetina sp. B Nakamura, 1972, p. 383, pl. 4, figs. 8–10.

Meekella mexicana Girty: Nakamura, 1972, p. 390, pl. 5, figs. 3, 4; Minato et al., 1979, pl. 46, figs. 5, 6.

Orthothetina sp. Minato et al., 1979, pl. 46, figs. 3, 4.

Orthothetina curvata Ustritsky: Chen and Shi, 2006, p. 9, pl. 1, figs. 11, 12, 22; pl. 3, figs. 5, 6 only.

Material.—Three specimens from localities KY1 and KY3: (1) external and internal moulds of two ventral valves, NU-B1534, 1535; (2) internal mould of a ventral valve, NU-B1536.

Remarks.—The specimens from Kamiyasse are referred to *Orthothetina curvata* Ustritsky, 1960, originally described from the lower Permian (Sakmarian–Artinskian) of the western Kunlun Mountains, northwest China, by their small, elongate suboval-shaped ventral valves, with flattened venter, slightly elevated umbonal region, and high, triangular interarea. Numerous, fine costellae on the ventral valve are numbering 13–15 in 5 mm near the anterior margin of the valve.

Three orthotetid species, *Orthotetina* sp. B Nakamura, 1972, *Meekella mexicana* Girty by Nakamura (1972) and Minato et al. (1979), and *Orthothetina* sp. Minato et al., 1979, from the upper part of the Nakadaira Formation of Nakadaira, South Kitakami Belt, are synomyms of the present species.

Distribution.— Kasimovian–Kungurian: northwest China (south Xinjiang), northeast Japan (Kamiyasse and Nakadaira in the South Kitakami Belt) and southwest China (Yunnan).

Orthothetina sp.
Fig. 5.2

Material.—One specimen from locality KY1, external and internal moulds of ventral valve, NU-B1533.

Description.—Shell medium size for genus, transversely subelliptical in outline; hinge shorter than greatest width at about midlength; length about 27 mm, width about 36 mm, hinge width about 27 mm in the sole ventral valve specimen (NU-B1533). Ventral valve moderately convex in lateral profile with flattened venter, no sulcus. External surface of ventral valve ornamented by numerous fine costellae, numbering 9–11 in 5 mm at about midlength; some concentric rugae irregularly developed in anterior half of valve. Interior of ventral valve with a pair of long, thin, subparallel dental plates, slightly diverging anteriorly and extending for about one-third of valve length.

Remarks.—This specimen is characterized by its transverse and moderately convex ventral valve. The Kamiyasse species most resembles *Orthothetina* sp. A, described by Nakamura (1972, p. 382, pl. 4, figs. 3–7) from the lower Kamiyasse Formation of Imo in the South Kitakami Belt, in size and shape of the ventral valve, but differs from the Nakamura's species in having finer costellae on the ventral valve.

Orthothetina ruchae Yanagida and Nakornsri (1999, p. 116, pl. 27, figs. 9, 11), from the middle to upper Permian Tak Fa Formation of Khao Hin Kling, north-central Thailand, is also a medium-sized, transverse *Orthothetina*, but it differs from the Kamiyasse species in its much shorter hinge and more numerous costellae on the ventral valve.

Order Rhynchonellida Kuhn, 1949
Superfamily Wellerelloidea Licharew, 1956
Family Wellerellidae Licharew, 1956
Subfamily Nipponirhynchiinae Savage, 1996
Genus *Nipponirhynchia* Yanagida and Nishikawa, 1984

Type species.—*Nipponirhynchia shutoi* Yanagida and Nishikawa, 1984.

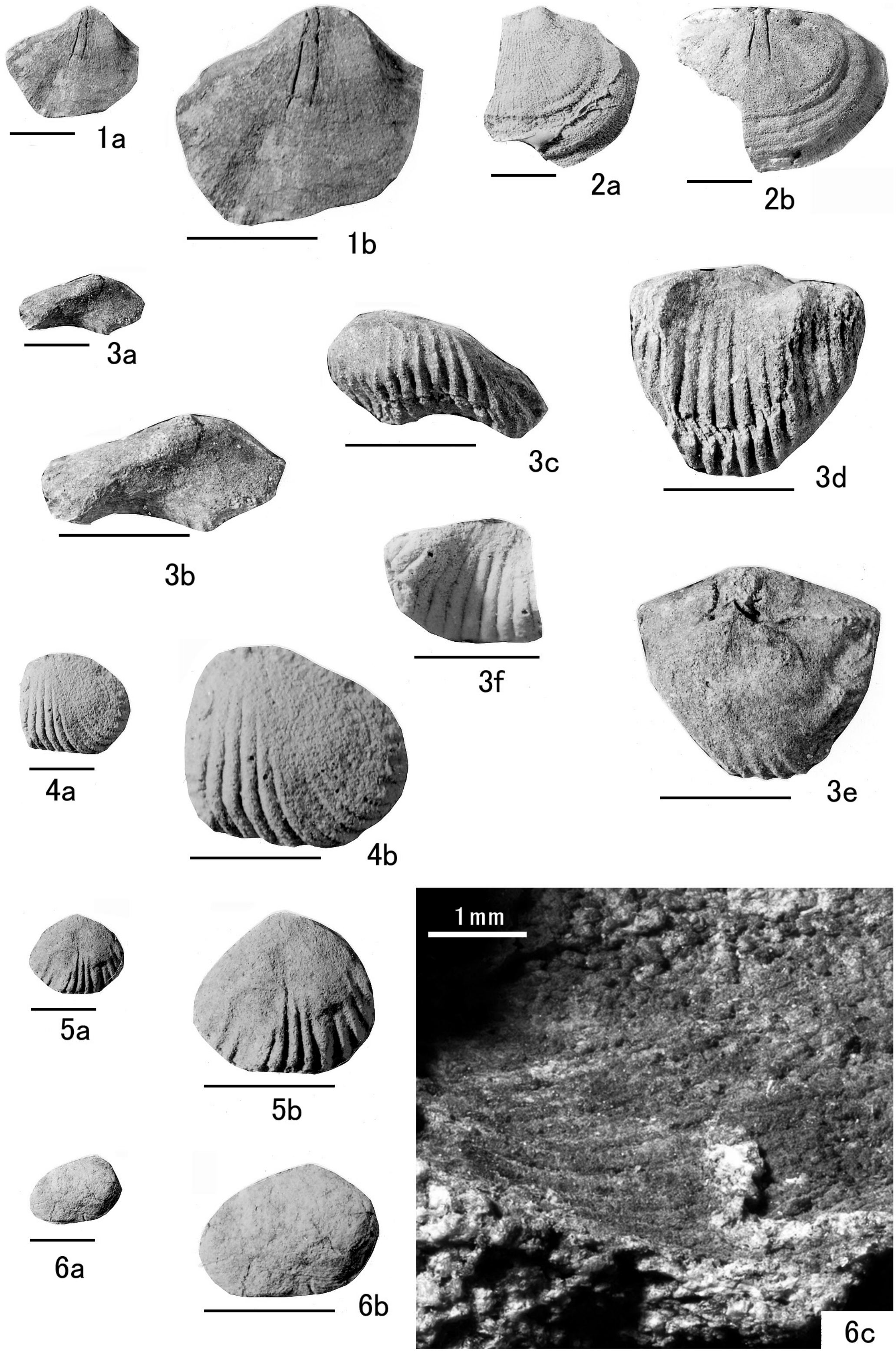
Nipponirhynchia kamiyassensis sp. nov.
Fig. 4.6

Etymology.—Named after the fossil locality, Kamiyasse.

Material.—One specimen from locality KY2, external and internal moulds of a conjoined shell, NU-B1509 (holotype).

Diagnosis.—Small, transverse *Nipponirhynchia,* with numerous, fine, simple but occasionally bifurcated costae on both valves.

Description.—Shell small for genus, transversely subpentagonal in outline, with greatest width at about midlength; length about 9 mm, width about 18 mm in the holotype (NU-B1509). Ventral valve nearly flat in venter, strongly geniculated near anterior margin, and followed by a long tongue; beak small, pointed; sulcus shallow and broad. Dorsal valve moderately convex in umbonal region, nearly flat in visceral disc, strongly geniculated near anterior margin, and followed by long lateral wings. External surface of both valves ornamented by numerous, simple but occasionally bifurcated costae, with narrow and deep interspaces; costae numbering 42 on ventral valve. Marginal spines developed along antero-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6c

lateral margins of both valves. Interior of ventral valve with thin, short dental plates. Other internal structures not well preserved.

Remarks.—Nipponirhynchia kamiyassensis Tazawa and Shintani, sp. nov. somewhat resembles *Nipponirhynchia shutoi* Yanagida and Nishikawa (1984, p. 163, pl. 16, figs. 1–4), from the lower Permian (Sakmarian) Kawai Limestone of Kogoro in the Kawai area, Hiroshima Prefecture, southwest Japan, in general shape of the shell, but it differs from the type species in its smaller size, and in having finer and occasionally bifurcated costae on both ventral and dorsal valves.

Subfamily Uncinunellininae Savage, 1996

Genus *Uncinunellina* Grabau, 1932

Type species.—Uncinulus theobaldi Waagen, 1883.

Uncinunellina cf. *wangenheimi* (Pander in Müller, 1862)

Fig. 5.3

Cf. *Uncinulus wangenheimi* Pander: Tschernyschew, 1902, p. 72, 487, pl. 44, figs. 3–5; pl. 46, figs. 15–17; pl. 50, fig. 11.

Material.—One specimen from locality KY2, external and internal moulds of a conjoined shell, NU-B1510.

Description.—Shell medium size for genus, transversely subpentagonal in outline, with greatest width at about midlength; length about 10 mm, width about 19 mm in the single specimen (NU-B1510). Both valves strongly convex with dorsal valve much more convex than ventral valve, strongly geniculated, and having deep ventral sulcus and high dorsal fold; anterior commissure strongly uniplicate. External surface of both valves ornamented by simple, rounded costae, numbering 9 on ventral sulcus. Marginal spines distinct near anterior commissure.

Remarks.—The single conjoined shell specimen from Kamiyasse resembles well the shells of *Uncinunellina wangenheimi* (Pander in Müller, 1862), redescribed by Tschernyschew (1902) from the lower Permian Schwagerina Limestone of the Urals, in size,

←**Fig. 5. 1,** *Orthothetina curvata* Ustritsky; 1a, 1b, internal mould of ventral valve, NU-B1536. **2**, *Orthothetina* sp.; 2a, 2b, external latex cast and internal mould of ventral valve, NU-B1533. **3**, *Uncinunellina* cf. *wangenheimi* (Pander); 3a, 3b, 3c, 3d, 3e, ventral, dorsal, anterior and posterior views of internal mould of conjoined shell, NU-B1510; 3f, ventral view of external latex cast of conjoined shell, NU-B1510. **4, 5**, *Uncinunellina* sp.; 4a, 4b, external latex cast of dorsal valve, NU-B1511; 5a, 5b, internal mould of dorsal valve, NU-B1512. **6**, *Cleiothyridina* sp., 6a, 6b, 6c, external latex cast and a part of external mould of dorsal valve, NU-B1516. Scale bars represent 1 cm.

shape and external ornament of both valves. We could not refer the original description of this species, because of lacking the Müller's paper. Therefore, the Kamiyasse specimen is tentatively described as *Uncinunellina* cf. *wangenheimi* (Pander in Müller, 1862) in the present paper.

Shells described and figured by Grabau (1936, p. 175, pl. 18, figs. 1, 2) as *Uncinunellina wangenheimi* (Pander), from the upper Carboniferous Maping Limestone of Guizhou, southwest China, differs from the present species in their less transverse and rounded outline.

Uncinunellina sp.
Figs. 5.4, 5.5

Material.—Two specimens from locality KY2 and KY3, (1) external and internal moulds of a dorsal valve, NU-B1511; (2) internal mould of a dorsal valve, NU-B1512.

Description.—Shell medium size for genus, equidimensional, subtriangular to subpentagonal in outline, with greatest width at about midlength; length 16 mm, width about 16 mm in the larger dorsal valve specimen (NU-B1511). Dorsal valve almost flat on visceral disc, strongly geniculated near anterior margin; fold broad and high. External ornament of dorsal valve consisting of numerous, simple, rounded costae, numbering 6 on fold, and 7–8 on lateral wings. Marginal spines observed as thin furrows on the top of costae near anterior margin of dorsal fold.

Remarks.—These specimens most resemble *Uncinunellina jabiensis* (Waagen, 1883, p. 427, pl. 34, fig. 2), from the Wargal and Chhidru formations of the Salt Range, in size, shape and external ornament of the dorsal valve. However, exact comparison with the Pakistani specimen is difficult owing to lacking the ventral valve in the present material.

The type species, *Uncinunellina theobaldi* Waagen (1883, p. 425, pl. 34, fig. 1), from the Wargal Formation of the Salt Range, differs from the Kamiyasse species in its transverse outline, and in having more numerous, finer costae on the both ventral and dorsal valves.

Order Athyridida Boucot, Johnson and Staton, 1964
Suborder Athyrididina Boucot, Johnson and Staton, 1964
Superfamily Athyridoidea Davidson, 1881
Family Athyrididae Davidson, 1881
Subfamily Cleiothyridininae Alvarez, Rong and Boucot, 1998
Genus *Cleiothyridina* Buckman, 1906

Type species.—*Atrypa pectinifera* Sowerby, 1840.

Cleiothyridina sp.
Figs. 5.6, 6.1

Material.—Two specimens from locality KY3: (1) external and internal moulds of a ventral valve, NU-B1515; (2) external and internal moulds of a dorsal valve, NU-B1516.

Remarks.—The specimens from Kamiyasse exhibit the characteristic slightly transverse, elliptical outline (length about 14 mm, width about 20 mm in the ventral valve specimen, NU-B1515) and numerous concentric growth lamellae on both valves of the genus *Cleiothyridina*. While our specimens are inadequate for specific identification, they are similar to *Cleiothyridina capillata* (Waagen, 1883, p. 479, pl. 39, figs. 6–9; pl. 40, figs. 1–5; pl. 42, figs. 1–5), from the Wargal and Chhidru formations of the Salt Range, in their size, shape and surface ornament of the shell, in particular, the small, slightly sulcate shell and very dense, narrow growth lamellae on the both valves.

Suborder Retziidina Boucot, Johnson and Staton, 1964
Superfamily Retzioidea Waagen, 1883
Family Neoretziidae Dagys, 1972
Subfamily Hustediinae Grunt, 1986
Genus *Hustedia* Hall and Clarke, 1893

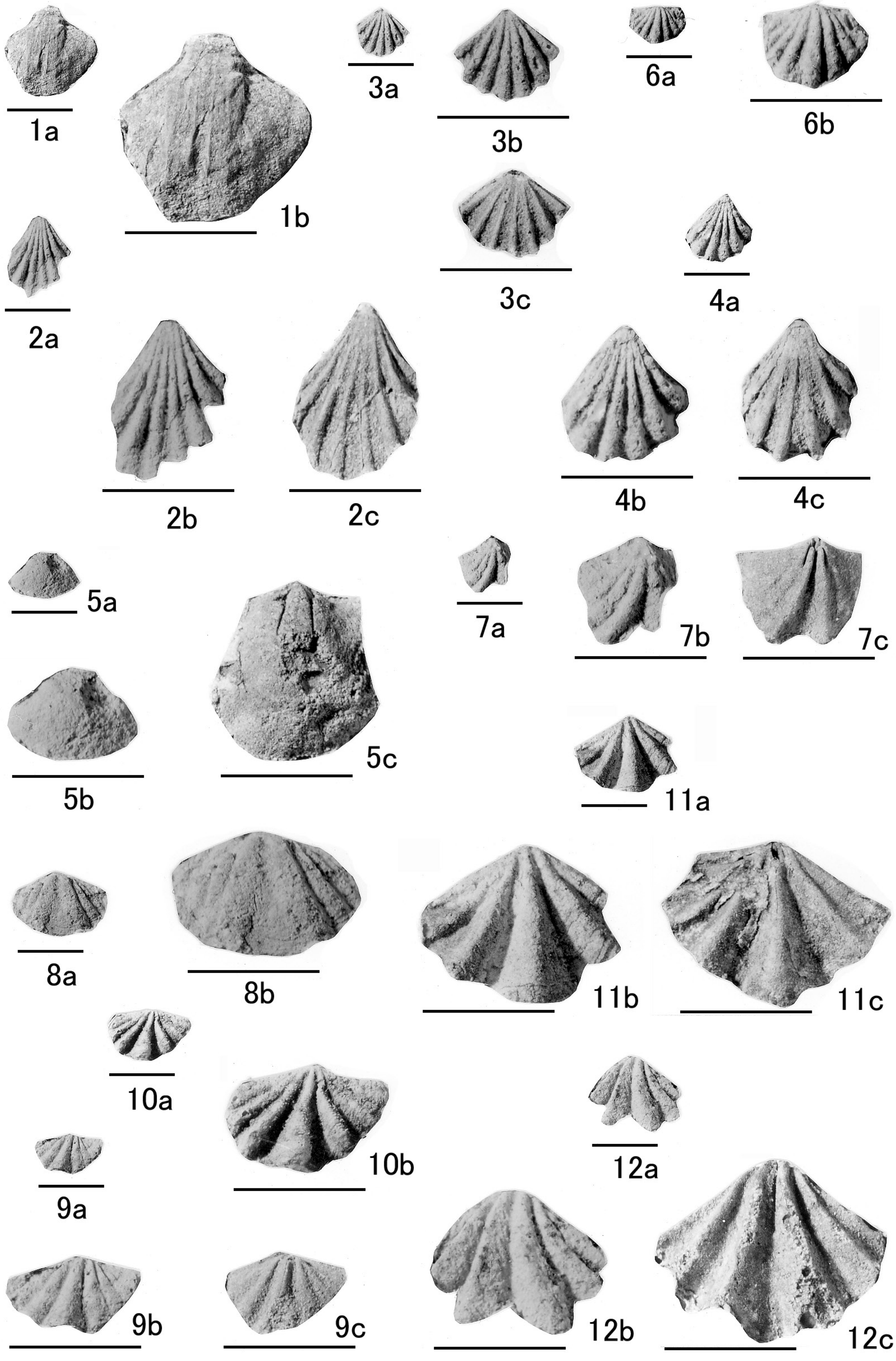
Type species.—*Terebratula mormoni* Marcou, 1858.

Hustedia indica (Waagen, 1883)
Figs. 6.2–6.4

Eumetria indica Waagen, 1883, p. 493, pl. 35, figs. 1, 2.
Hustedia indica (Waagen): Tschernyschew, 1902, p. 109, pl. 47, fig. 12; Ding and Qi, 1983, p. 359, pl. 120, fig. 5.

Material.—Fifteen specimens from localities KY1 and KY3: (1) external and internal moulds of five ventral valves, NU-B1547–1551; (2) external moulds of two ventral valves, NU-B1552, 1553; (3) external and internal moulds of six dorsal valves, NU-B1554–1559; (4) external moulds of two dorsal valves, NU-B1560, 1561.

Description.—Shell medium size for genus, elongate suboval in outline, with greatest width slightly anterior to midlength; length 14 mm, width 9 mm in the largest specimen (NU-B1547). Ventral valve moderately and unevenly convex in lateral profile, strongly convex in both posterior and anterior regions, but flattened in visceral region, no sulcus. Dorsal valve also moderately and unevenly convex in lateral profile, no fold. External


1a
1b
3a
3b
3c
6a
6b
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4a
2b
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4b
4c
5a
5b
5c
7a
7b
7c
11a
8a
8b
11b
11c
10a
10b
12a
9a
9b
9c
12b
12c

surface of both valves ornamented by simple, strong, rounded costae with wide intercostal spaces; outer costae often curved towards postero-lateral margins; costae numbering 8 on ventral valve, 9 on dorsal valve.

Remarks.—These specimens are referred to *Hustedia indica* (Waagen, 1883), originally described from the Amb and Wargal formations of the Salt Range, on account of size, shape and external ornament of both valves. The Kamiyasse specimens are very similar to the shells of *H. indica,* figured by Tschernyschew (1902, pl. 47, fig. 12) from the Schwagerina Limestone (Asselian) of the Urals.

Hustedia ratburiensis Waterhouse and Piyasin (1970, p. 138, pl. 23, figs. 15–30), from the middle Permian (Kazanian) of Khao Phrik, southern Thailand, is close to *H. indica* in general appearance, but it has more numerous costae on the both ventral and dorsal valves.

Distribution.— Asselian–Wuchiapingian: northern Russia (Urals), northwest China (Gansu), northeast Japan (Kamiyasse in the South Kitakami Belt) and Pakistan (Salt Range).

Order Spiriferida Waagen, 1883
Suborder Spiriferidina Waagen, 1883
Superfamily Martinioidea Waagen, 1883
Family Ingelarellidae Campbell, 1959
Subfamily Ingelarellinae Campbell, 1959
Genus *Martiniopsis* Waagen, 1883

Type species.—*Martiniopsis inflata* Waagen, 1883.

Martiniopsis sp.
Fig. 6.5

Material.—Two specimens from locality KY3, external and internal moulds of two dorsal valves, NU-B1522, 1523.

Remarks.—These specimens are fragmentarily preserved, but safely assigned to the

←**Fig. 6. 1,** *Cleiothyridina* sp., 1a, 1b, internal mould of ventral valve, NU-B1515. **2-4,** *Hustedia indica* (Waagen); 2a, 2b, 2c, external latex cast and internal mould of ventral valve, NU-B1547; 3a, 3b, 3c, external latex cast and internal mould of dorsal valve, NU-B1554; 4a, 4b, 4c, external latex cast and internal mould of ventral valve, NU-B1549. **5,** *Martiniopsis* sp.; 5a, 5b, 5c, external latex cast and internal mould of dorsal valve, NU-B1522. **6, 7,** *Spiriferellina nanbuensis* Tazawa and Shintani, sp. nov.; 6a, 6b, external latex cast of dorsal valve, NU-B1530; 7a, 7b, 7c, external latex cast and internal mould of ventral valve, NU-B1525 (holotype). **8, 9,** *Spiriferellina* sp.; 8a, 8b, external latex cast of ventral valve, NU-B1531; 9a, 9b, 9c, external latex cast and internal mould of dorsal valve, NU-B1532. **10,** *Callispirina* sp.; 10a, 10b, external latex cast of dorsal valve, NU-B1517. **11, 12,** *Crenispirifer nakamurai* Tazawa and Shintani, sp. nov.; 11a, 11b, 11c, external latex cast and internal mould of dorsal valve, NU-B1521; 12a, 12b, 12c, external latex cast and internal mould of ventral valve, NU-B1519 (holotype). Scale bars represent 1 cm.

genus *Martiniopsis* by their small, oval-shaped dorsal valve, with a pair of thin, long adminicular converging anteriorly and longitudinally striated small muscle area between adminicula. The Kitakami species somewhat resembles *Martiniopsis uralica* Tschernyschew (1902, p. 170, 555, pl. 18, figs. 6–10; pl. 20, figs. 7–8), from the lower Permian of the Urals, in size and outline of the dorsal valve. But accurate comparison is difficult for the fragmentary specimens.

Martiniopsis sp. Tazawa (2001, p. 301, figs. 8.8, 8.9), from the lower Moribu Formation of Moribu, Hida Gaien Belt, central Japan, differs from the present species in its larger, transverse shell.

Order Spiriferinida Ivanova, 1972
Suborder Spiriferinidina Ivanova, 1972
Superfamily Pennospiriferinoidea Dagys, 1972
Family Paraspiriferinidae Cooper and Grant, 1976
Genus *Spiriferellina* Fredericks, 1924

Type species.—*Terebratulites cristatus* Schlotheim, 1816.

Spiriferellina nanbuensis sp. nov.
Figs. 6.6, 6.7

Etymology.—Named after the old name of northeast Japan, Nanbu, including the South Kitakami region.

Material.—Seven specimens from locality KY3: (1) external and internal moulds of a conjoined shell, NU-B1524; (2) external and internal moulds of four ventral valves, NU-B1525 (holotype), 1526–1528; (3) external and internal moulds of a dorsal valve, NU-B1529; (4) internal mould of a dorsal valve, NU-B1530.

Diagnosis.—Small, nearly equidimensional to slightly transverse *Spiriferellina,* with 3–4 costae on each lateral flank of both valves.

Description.—Shell small, slightly wider than long, widest at hinge, not alate; length 8 mm, width 9 mm in the holotype (NU-B1525). Ventral valve moderately convex in lateral profile; sulcus deep and broad, with flattened bottom; costae strong and rounded, numbering 3–4 on each lateral flank. Dorsal valve flatly convex in lateral profile, fold strong; costae with rounded crests, numbering 4 on each lateral flank of valve. External surface of both valves ornamented by some irregular concentric growth lamellae and numerous fine pustules. Ventral interior with a pair of dental plates and a long median septum, attained nearly half of valve length. Dorsal interior with a pair of strong crural plates and a small knob-like cardinal process.

Remarks.—*Spiriferellina nanbuensis* Tazawa and Shintani, sp. nov. most resembles *Spiriferellina hilli* (Girty, 1908), redescribed by Cooper and Grant (1976, p. 2703, pl. 704, figs. 18–25; pl. 709, figs. 18–71), from the Word Formation of west Texas, in size and shape of the shell, but it differs from the Texan species in having fewer costae on the both vaves, and lacking median ridge in the ventral sulcus.

Spiriferellina adunctata Waterhouse and Piyasin (1970, p. 149, pl. 26, figs. 19–22; pl. 27, figs. 1–15; pl. 28, figs. 1–10; pl. 29, figs. 1–5; text-figs. 15, 16, 18, 21), from the middle Permian (Wordian) of Khao Phrik, southern Thailand, differs from *S. nanbuensis* sp. nov. in its more transverse shell with rounded cardinal extremities.

The type species, *Spiriferellina cristata* (Schlotheim, 1816), redescribed and illustrated by Campbell (1959, p. 358, pl. 59, figs. 1–9; pl. 60, fig. 3; text-fig. 5) on the syntype and lectotype from the Zechstein of Thuringia, Germany, is clearly distinguished from the Kitakami species by its much transverse shell.

Spiriferellina sp.
Figs. 6.8, 6.9

Material.—Two specimens from locality KY3: (1) external mould of a ventral valve, NU-B1531; (2) external and internal moulds of a dorsal valve, NU-B1532.

Remarks.—These specimens are average-sized, transverse *Spiriferellina,* with 3–4 strong, rounded costae on each flank of the both valves. The Kamiyasse species resembles *Spiriferellina cristata* (Schlotheim, 1816) in size, shape and external ornament of the shell, especially their transverse outline and broad ventral sulcus with flattened bottom. The present material is, however, too imperfect for comparison.

Genus *Callispirina* Cooper and Muir-Wood, 1951

Type species.—*Spiriferina ornata* Waagen, 1883.

Callispirina sp.
Fig. 6.10

Material.—Two specimens from locality KY2, external and internal moulds of two dorsal valves, NU-B1517, 1518.

Remarks.—These specimens are safely assigned to the genus *Callispirina* by their small, transversely subelliptical dorsal valve (length 11 mm, width 13 mm in the larger specimen, NU-B1517), having high, broad fold and strong, angular 3 costae on each lateral flank, and ornamented by regularly and closely spaced, imbricate growth lamellae and numerous fine pustules over the valve.

The Kamiyasse species most resembles *Callispirina rotunda* Cooper and Grant (1976, p. 2743, pl. 705, figs. 66–82), from the Bell Canyon Formation (upper Guadalupian) of west Texas, in size and shape of the dorsal valve, but it differs from the Texan species in having fewer costae on each side of the fold.

Callispirina sp., described by Tazawa in Tazawa and Miyake (2011, p. 17, figs. 2.3, 2.4) from the upper Permian (Changhsingian) of Maeda in the Ofunato area, South Kitakami Belt, is distinguished from the present species by its smaller size.

Family Spiriferellinidae Ivanova, 1972

Genus *Crenispirifer* Stehli, 1954

Type species.—*Spiriferelina angulata* King, 1931.

Crenispirifer nakamurai sp. nov.

Figs. 6.11, 6.12

Etymology.—Named for Professor Koji Nakamura.

Material.—Three specimens from localities KY2 and KY3: (1) external and internal moulds of two ventral valves, NU-B1519 (holotype), 1520; (2) external and internal moulds of a dorsal valve, NU-B1521.

Diagnosis.—Average-sized, slightly transverse *Crenispirifer,* with 3 strong, subangular costae on each lateral flank of both valves.

Description.—Shell medium size for genus, transversely subelliptical in outline; cardinal extremities rounded; hinge slightly shorter than greatest width at about midlength; length 12 mm, width 16 mm in the holotype (NU-B1519); length 13 mm, width 18 mm in the larger dorsal valve specimen (NU-B1521). Ventral valve slightly convex in lateral profile; sulcus deep and wide, with V-shaped bottom; costae strong, simple and subangular, numbering 3 on each lateral flank of valve. Dorsal valve slightly convex, with high, broad fold and 3 strong, subangular costae on each lateral flank. External surface of both valves ornamented by irregular growth lamellae and numerous, fine, quincunxially arranged pustules. Ventral interior with high median septum and a pair of short, subparallel dental plates. Dorsal interior with longitudinally striated cardinal process. No other internal structures observed.

Remarks.—*Crenispirifer nakamurai* Tazawa and Shintani, sp. nov. most resembles the type species, *Crenispirifer alpheus* (Huang, 1933, p. 59, pl. 9, figs. 2, 3), from the Lopingian of Guizhou, southwest China, in shell outline and number of costae on the both ventral and dorsal valves, but it differs from the Chinese species in its much larger size.

An average-sized species, *Crenispirifer angulatus* (King, 1931, p. 122, pl. 42, figs. 12, 13), from the Hess and Leonard formations of west Texas, differs from the Kamiyasse species in its more transverse shell and in having larger number of costae on the both valves.

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Additional brachiopod species from the upper Permian (Changhsingian) of Nabekoshiyama in the Kesennuma area, South Kitakami Belt, northeast Japan

Jun-ichi TAZAWA* and Hideo ARAKI**

Abstract

Four brachiopod spesies, *Edriosteges* sp. A, *Oldhamina ehiroi* (Tazawa in Tazawa and Miyake, 2011), *Meekella* sp. and *Attenuatella bandoi* Tazawa, 1987 are described as additional species of the Nabekoshiyama fauna from the Nabekoshiyama Formation (Changhsingian) of Nabekoshiyama in the Kesennuma area, South Kitakami Belt, northeastern Japan. Among the newly described species, *Attenuatella bandoi* is an antitropical element, and *Oldhamina ehiroi* and *Meekella* sp. are tropical elements. Therefore, the additional brachiopods indicate that the Nabekoshiyama fauna is a mixed Boreal–Tethyan fauna in the Changhsingian.

Key words: brachiopod, Changhsingian, mixed Boreal–Tethyan fauna, Nabekoshiyama, palaeobiogeography.

Introduction

This paper is the third report for Changhsingian brachiopod fauna of Nabekoshiyama (around Mt. Nabekoshiyama), Kesennuma area (Fig. 1), southern Kitakami Mountains (South Kitakami Belt), northeastern Japan. The present paper describes four species newly found from the Nabekoshiyama Formation in Nabekoshiyama: *Edriosteges* sp. A, *Oldhamina ehiroi* (Tazawa in Tazawa and Miyake, 2011), *Meekella* sp. and *Attenuatella bandoi* Tazawa, 1987. The brachiopod specimens described herein were prepared by the second author (H.A.); and they are now registered and housed in the Kesennuma Board of Education, Kesennuma City, Miyagi Prefecture.

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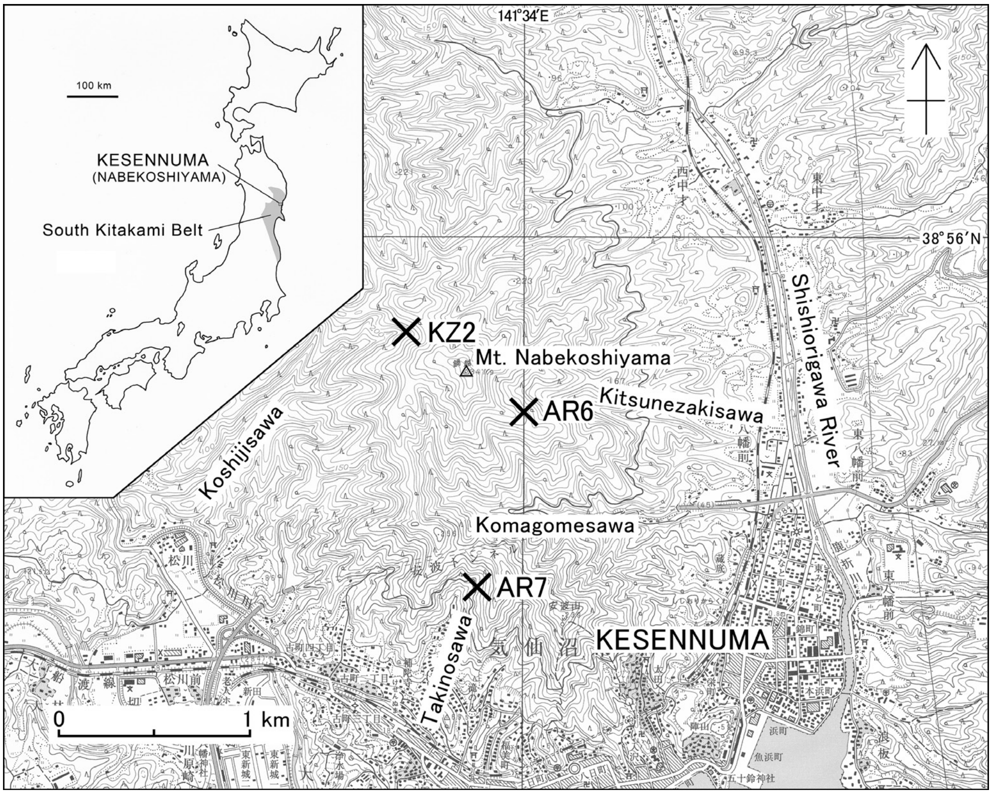

Fig. 1. Map showing the fossil localities AR6, AR7 and KZ2 in Nabekoshiyama, Kesennuma area, South Kitakami Belt, using the topographical maps of "Shishiori" and "Kesennuma", scale 1 : 25,000 published by the Geospatial Information Authority of Japan.

Stratigraphy

The Permian of Nabekoshiyama in the Kesennuma area is divided into two formations, the lower, Kurosawa Formation (named by Misaki and Ehiro, 2004; equivalent to the lower Toyoma Series of Tazawa, 1975, and to the lower Toyoma Formation of Kobayashi, 2002) and the upper, Nabekoshiyama Formation (named by Ehiro, 1974, revised by Tazawa, 1975; equivalent to the upper Toyoma Series of Tazawa, 1975, and to the upper Toyoma Formation of Kobayashi, 2002) (Fig. 2). According to Tazawa (1975), the Nabekoshiyama Formation is composed mainly of sandstone and shale with intercalated conglomerate and limestone, 525 m+ in total thickness. The brachiopods, treated in this paper, were collected by Hideo Araki and the late Hitoshi Koizumi from sandstone and shale at three fossil localities, AR6, AR7 and KZ2 (see Figs. 1, 2).

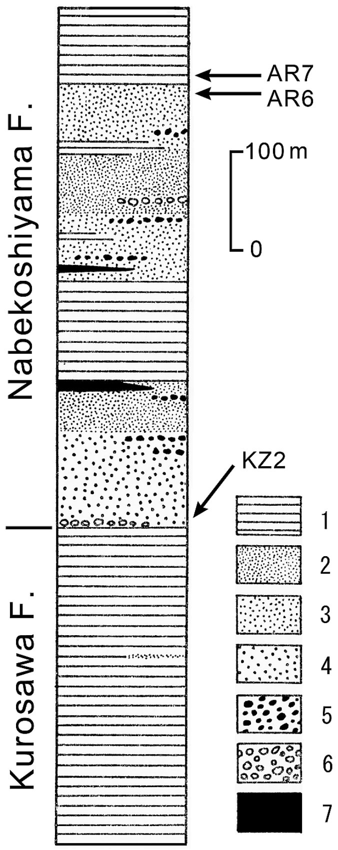

Fig. 2. Generalized columnar section of the upper Permian of Nabekoshiyama, showing the fossil horizons AR6, AR7 and KZ2. Legend 1: shale, 2: fine-grained sandstone, 3: medium-grained sandstone, 4: coarse-grained sandstone, 5: granule conglomerate, 6: pebble conglomerate, 7: limestone. Modified and adapted from Tazawa (1975).

AR6 (38°55′29″N, 141°34′00″E): grey to light brown coarse-grained sandstone, 438 m above the base of the Nabekoshiyama Formation, in the upper Kitsunezakisawa Valley, with *Oldhamina ehiroi*.

AR7 (38°54′58″N, 141°33′50″E): dark grey to black shale, 438 m above the base of the Nabekoshiyama Formation, in the upper Takinosawa Valley, with *Attenuatella bandoi*.

KZ2 (38°55′43″N, 141°33′34″E): grey fine-grained sandstone, 14 m above the base of the Nabekoshiyama Formation, in the upper Koshijisawa Valley, with *Edriosteges* sp. A and *Meekella* sp.

The Nabekoshiyama fauna

The Nabekoshiyama fauna has been described by Tazawa (1975, 2012) and contains the following 25 species in 19 genera: *Neochonetes* sp., *Spinomarginifera lopingensis* (Kayser, 1883), *Lamnimargus peregrinus* (Fredericks, 1924), *Lamnimargus japonicus* (Tazawa, 1975), *Linoproductus* sp., *Megousia auriculata* Muir-Wood and Cooper, 1960, *Megousia nakamurai*

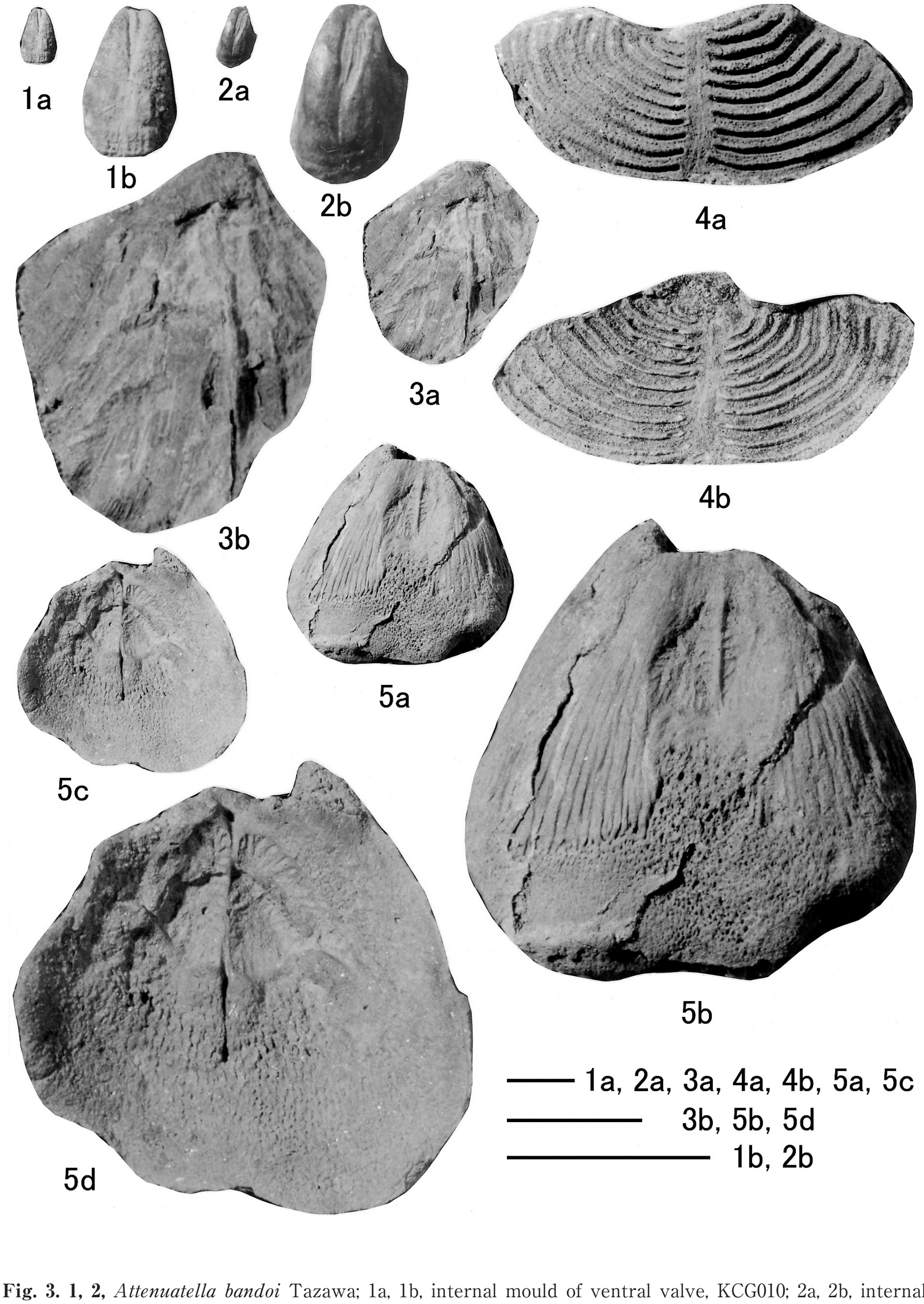

Fig. 3. 1, 2, *Attenuatella bandoi* Tazawa; 1a, 1b, internal mould of ventral valve, KCG010; 2a, 2b, internal mould of ventral valve, KCG009. **3**, *Meekella* sp.; 3a, 3b, internal mould of ventral valve, KCG012. **4**, *Oldhamina ehiroi* (Tazawa); 4a, 4b, internal mould and internal latex cast of ventral valve, KCG005. **5**, *Edriosteges* sp. A; 5a, 5b, internal mould of ventral valve; 5c, 5d, internal mould of dorsal valve, KCG013. Scale bars represent 1 cm.

Tazawa, 1975, *Terrakea nabekoshiyamensis* Tazawa, 2012, *Orthothrix sudoi* Tazawa, 2012, *Edriosteges* sp., *Tschernyschewia typica* Stoyanow, 1910, *Eolyttonia tenuis* (Waagen, 1883), *Eolyttonia mira* (Fredericks, 1916), *Oldhamina squamosa* Huang, 1932, *Oldhamina anshunensis* Huang, 1932, *Oldhamina kitakamiensis* Tazawa, 1982, *Derbyia* sp., *Enteletes* sp., *Peltichia* cf. *transversa* (Huang, 1933), *Orthotichia* sp., *Hustedia indica* (Waagen, 1883), *Hustedia minuta* Tazawa in Tazawa and Miyake, 2011, *Martinia* sp., *Choristitella wynnei* (Waagen, 1883) and *Spiriferellina cristata* (Schlotheim, 1816). The Nabekoshiyama fauna is a mixed Boreal–Tethyan fauna in the latest Permian (Changhsingian) (Tazawa, 2012).

In the present paper, four brachiopod spesies, *Edriosteges* sp. A, *Oldhamina ehiroi* (Tazawa in Tazawa and Miyake, 2011), *Meekella* sp. and *Attenuatella bandoi* Tazawa, 1987 are described as additional species of the Nabekoshiyama fauna. Among the newly described species, *Attenuatella bandoi* is an antitropical element (Tazawa, 1987, 2011), and *Oldhamina ehiroi* and *Meekella* sp. are tropical elements (Tazawa, 2002, 2012; Tazawa and Miyake, 2011). Therefore, the additional brachiopods also indicate that the Nabekoshiyama fauna is a mixed Boreal–Tethyan fauna in the uppermost Permian (Changhsingian) of the South Kitakami Belt, northeastern Japan.

Systematic descriptions

Order Productida Sarytcheva and Sokolskaya, 1959
Suborder Productidina Waagen, 1883
Superfamily Aulostegoidea Muir-Wood and Cooper, 1960
Family Echinostegidae Muir-Wood and Cooper, 1960
Subfamily Echinosteginae Muir-Wood and Cooper, 1960
Genus *Edriosteges* Muir-Wood and Cooper, 1960

Type species.—*Edriosteges multispinosus* Muir-Wood and Cooper, 1960.

Edriosteges sp. A
Fig. 3.5

Edriosteges sp. Tazawa, 2012, p. 29, fig. 2.20.

Material.—One specimen from locality KZ2, internal mould of a conjoined shell, KCG013.

Remarks.—This specimen is safely assigned to the genus *Edriosteges* by its medium sized (length about 35 mm, width about 35 mm), slightly concavo-convex shell, with narrow and shallow ventral sulcus anteriorly, and strongly dendritic adductor scars in both ventral and dorsal valves. The Nabekoshiyama species, tentatively named as *Edriosteges* sp. A,

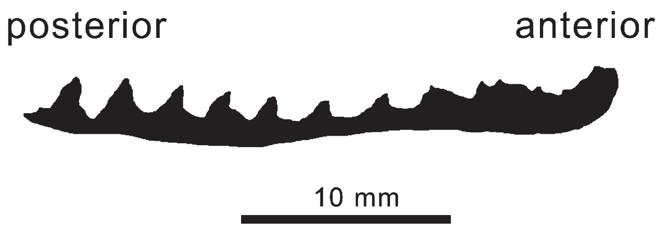

Fig. 4. Longitudinal section of ventral internal latex cast of *Oldhamina ehiroi* (Tazawa), from the Nabekoshiyama Formation of Nabekoshiyama, KCG005, showing acute crests of lateral septa.

may be a new species of *Edriosteges*, together with the ventral valve specimen of *Edriosteges* sp. Tazawa, 2012, from the middle Nabekoshiyama Formation at locality KF107, east of the summit of Mt. Nabekoshiyama.

An *Edriosteges* shell, figured by Kotlyar (1989, pl. 23, fig. 15) as *Edriosteges poyangensis* (Kayer, 1883) from the Nakhodka Reef (Wuchiapingian) of South Primorye, eastern Russia is like to the Nabekoshiyama species in size and outline, and probably identical with the latter.

Distribution.—Changhsingian: northeastern Japan (Kesennuma in the South Kitakami Belt).

Suborder Lyttoniidina Williams, Harper and Grant, 2000

Superfamily Lyttonioidea Waagen, 1883

Family Lyttoniidae Waagen, 1883

Subfamily Lyttoniinae Waagen, 1883

Genus *Oldhamina* Waagen, 1883

Type species.—*Bellerophon decipiens* de Koninck, 1863.

Oldhamina ehiroi (Tazawa in Tazawa and Miyake, 2011)

Figs. 3.4, 4

Petasmaia ehiroi Tazawa in Tazawa and Miyake, 2011, p. 8, figs. 3.10, 3.11, 4.

Material.—One specimen from locality AR6, internal mould of a ventral valve, KCG005.

Remarks.—The single specimen from Nabekoshiyama is referred to *Oldhamina ehiroi* (Tazawa in Tazawa and Miyake, 2011), from the upper Toyoma Formation of Maeda in the Ofunato area, South Kitakami Belt, by its strongly arcuate, thin and closely arranged lateral septa, with acute crests (see Fig. 4), in the ventral valve.

Oldhamina transversa Jin and Ye (in Jin et al., 1979, p. 82, pl. 23, figs. 18, 19), from the Uli Group (Lopingian) of Qinghai, northwestern China, is most closest to *O. ehiroi* in having strongly arcuate lateral septa in the ventral valve, but the Chinese species differs from the latter in its larger size and the lateral septa with broader interspaces.

Distribution.—Changhsingian: northeastern Japan (Ofunato and Kesennuma in the South Kitakami Belt).

Order Orthotetida Waagen, 1884
Suborder Orthotetidina Waagen, 1884
Superfamily Orthotetoidea Waagen, 1884
Family Meekellidae Stehli, 1954
Subfamily Meekellinae Stehli, 1954
Genus *Meekella* White and St. John, 1867

Type species.—*Plicatula striatocostata* Cox, 1857.

Meekella sp.
Fig. 3.3

Material.—One specimen from locality KZ2, internal mould of a ventral valve, KCG012.

Remarks.—The single ventral valve specimen from Kesennuma is small to medium in size (length more than 33 mm, width about 31 mm), subcircular in outline, and slightly convex in both anterior and lateral profiles. External surface of the ventral valve is ornamented by strong costae and numerous capillae; costae numbering 6 on one side of lateral slope. The Kesennuma species most resembles *Meekella deltoides* Liao (1980, p. 256, pl. 3, figs. 1–4), from the Longtanian of Guizhou, southwestern China, in size and shape of the ventral valve, but accurate comparison is difficult for the poorly preserved specimen.

Order Spiriferida Waagen, 1883
Suborder Spiriferidina Waagen, 1883
Superfamily Ambocoelioidea George, 1931
Family Ambocoeliidae George, 1931
Subfamily Ambocoeliinae George, 1931
Genus *Attenuatella* Stehli, 1954

Type species.—*Attenuatella texana* Stehli, 1954.

Attenuatella bandoi Tazawa, 1987
Figs. 3.1, 3.2

Attenuatella bandoi Tazawa, 1987, p. 281, figs. 3, 4; Tazawa, 2011, p. 177, figs. 5.1–5.3.
Attenuatella sp. Tazawa and Niigata Pre-Tertiary Research Group, 1999, figs. 2.6–2.9; Tazawa, 2001, figs. 38.2F–38.2H

Material.—Two specimens from locality AR7, internal moulds of two ventral valves, KCG009 and KCG010.

Remarks.—These specimens are referred to *Attenuatella bandoi* Tazawa, 1987, from the lower Toyoma Formation of Ishihama in the Utatsu area, South Kitakami Belt, northeastern Japan by their relatively large size for the genus (length 10 mm, width 6 mm in the larger specimen, KCG009) and in having long and broad adductor scars in the ventral valve.

Attenuatella incurvata Waterhouse (1964, p. 108, pl. 20, figs. 1–12; pl. 21, figs. 1–9; text-figs. 47–52), from the middle Permian (Kungurian–Kazanian) of New Zealand, differs from *A. bandoi* in its wider shell outline.

Attenuatella mengi He, Shi, Feng and Peng (2007, p. 276, figs. 5A–P, 6A–H), from the upper Permian (Changhsingian) of Guangxi, central-southern China, is distinguished from the present species by its less elongate outline and shorter adductor scars in the ventral valve.

Distribution.—Wuchiapingian–Changhsingian: northeastern Japan (Kesennuma and Utatsu in the South Kitakami Belt) and central Japan (Okutadami in the Joetsu Belt).

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Devonian tabulate corals from pebbles in Mesozoic conglomerate, Kotaki, Niigata Prefecture, central Japan Part 1: Favositina

Shuji NIKO*, Yousuke IBARAKI** and Jun-ichi TAZAWA***

Abstract

A float block of Mesozoic conglomerate, probably derived from the Lower Jurassic Kuruma Group, containing Devonian tabulate corals was collected in the Kotaki area, Itoigawa, Niigata Prefecture, central Japan. As the first fascicle of our study concerning this material, the present paper focuses on taxa of the suborder Favositina. They consist of *Favosites*? sp. indet., *Pachyfavosites* sp. indet. 1, *P*. sp. indet. 2, *Plicatomurus*? sp. indet., *Thamnopora itoae* Niko, Ibaraki and Tazawa sp. nov. and *Thamnoptychia mana* Niko and Senzai, 2010 from milky white to gray limestone pebbles and *Hillaepora* sp. indet., from black shale pebble. A Givetian (late Middle Devonian) species, *Thamnopora nicholsoni* (Frech, 1885), shows close resemblance with the new species, but differs by having larger mean diameters of the distal corallites and the fewer tabulae. *Thamnoptychia mana* indicates a Givetian age. Reliable stratigraphic distribution of the genus *Hillaepora* is restricted within the Lower Devonian.

Key words: Devonian, favositine tabulae corals, Kotaki area, Mesozoic conglomerate, *Thamnopora itoae* sp. nov.

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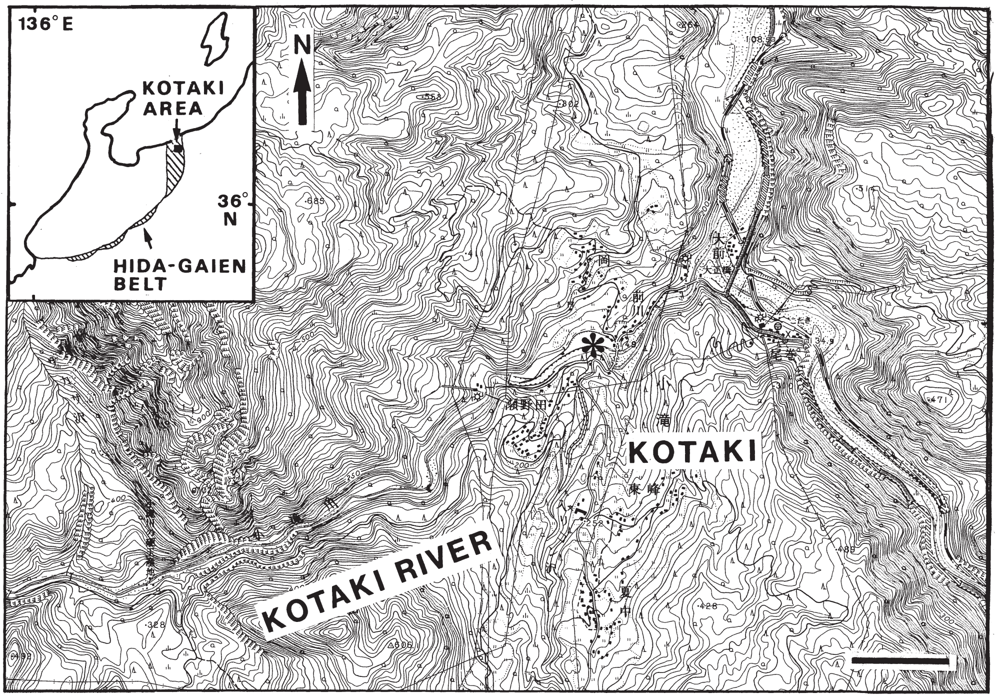


Fig. 1. Index map showing the fossil locality (asterisk) in the Kotaki area, Niigata Prefecture. Used topographic map is "Kotaki" scale 1:25,000 published by the Geospatial Information Authority of Japan. Scale bar = 500 m.

Introduction

A diverse fauna of Devonian tabulate corals was recovered from limestone and shale pebbles in a float block of conglomerate that was collected at the riverbed of the Kotaki River in the Kotaki area, Itoigawa, Niigata Prefecture, central Japan (Fig. 1). This discovery made by Mrs. Kanako Ito is noteworthy because the Middle Palaeozoic strata in the eastern part of the Hida-Gaien Belt including the Kotaki area had been subjected to erosion and disappeared at the present time. This paper represents the first fascicle of our long termed project concerning the new material, the objectives of which works are: to clear the whole aspect of this tabulate coral fauna; to determine the precise age for each species; and to discuss faunal implications. Herewith, seven species of favositines are described or documented on the basis of 43 specimens. Their repository is the Fossa Magna Museum (abbreviation: FMM).

The conglomerate has sandy matrix (Fig. 2) and consists of subrounded to rounded pebbles, whose constituents are basic to intermediate volcanic rocks (abundant), chert (abundant), limestone (common), shale (common) and sandstone (relatively rare). There can be no doubt that the conglomerate was derived from the Mesozoic strata. Judging from its sedimentary facies and geology of the upriver district of the collecting site, furthermore, the most probable origin is the Lower Jurassic Kuruma Group (Kobayashi et al., 1957; Nagamori et al., 2010).

Systematic Paleontology

Subclass Tabulata Milne-Edwards and Haime, 1850

Order Favositida Wedekind, 1937

Suborder Favositina Wedekind, 1937

Superfamily Favositoidea Dana, 1846

Family Favositidae Dana, 1846

Subfamily Favositinae Dana, 1846

Genus *Favosites* Lamarck, 1816

Type species.—Favosites gothlandicus Lamarck, 1816.

Favosites? sp. indet.

Fig. 3-1

Material.—FMM2108.

Description.—Corallum cerioid consists of prismatic corallites that have transverse sections of 3–8 sides in immature portions and indistinct 8–11 sides in mature ones; corallite diameters range from 0.4 to 2.1 mm; transverse sections of tabularia (lumina) are polygonal;. Intercorallite walls thin, approximately 0.19 mm; mural pores occur on corallite faces; septal spines long, needle-like; tabulae probably complete.

Occurrence.—Milky white limestone pebble.

Discussion.—A single fragmentary specimen is present. Although information of longitudinal sections of its corallites is lacking, this species is assigned questionably to *Favosites* because the thin intercorallite walls with the mid-wall pores and the long septal spines were found. These characters would distinguish it from the comparable genera, such as *Mesofavosites* Sokolov, 1951, *Pachyfavosites* Sokolov, 1952, and *Squameofavosites* Chernyshev, 1941.

Subfamily Pachyfavositinae Mironova, 1965

Genus *Pachyfavosites* Sokolov, 1952

Type species.—Calamopora polymorpha var. *tuberosa* Goldfuss, 1826.

Pachyfavosites sp. indet. 1

Figs. 3-4, 5

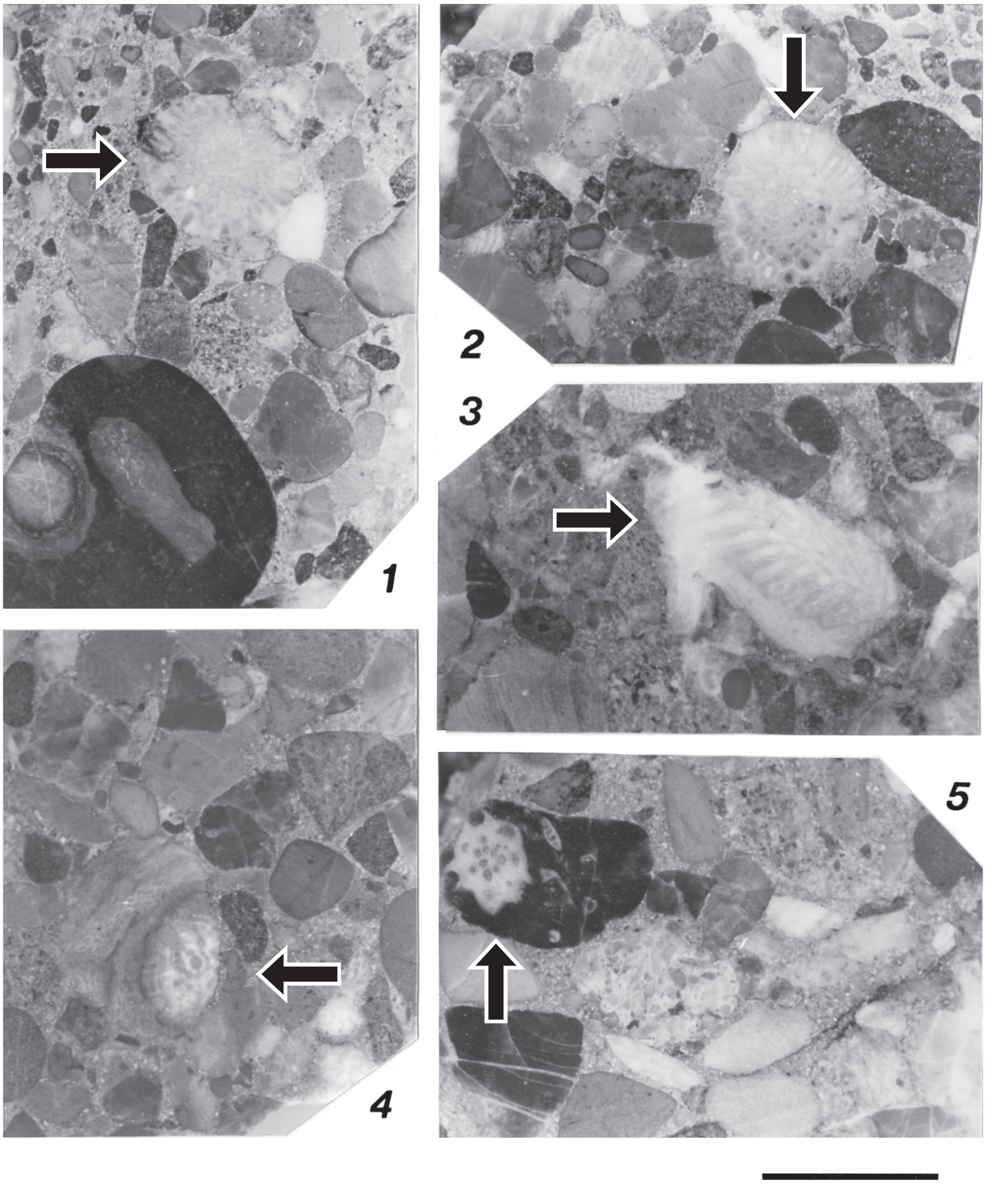


Fig. 2. Polished sections of conglomerate slabs showing mode of occurrence of Devonian fossils. **1**: Isolated branch of *Thamnopora itoae* Niko, Ibaraki and Tazawa sp. nov. (holotype, FMM2072, arrow) from limestone pebble and black shale pebble containing stromatoporoids. **2**: Isolated branch of *T. itoae* (paratype, FMM 2068, arrow) from limestone pebble. **3**: *Thamnopora itoae* (paratype, FMM2073, arrow) in milky white limestone pebble. **4**: *Thamnoptychia mana* Niko and Senzai (2010; FMM2097, arrow) in gray limestone pebble. **5**: *Hillaepora* sp. indet. (FMM2100, arrow) in black shale pebble. Scale bar = 10 mm for Figs. 2-1, 2; = 9 mm for Fig. 2-3; = 7 mm for Figs. 2-4, 5.

Material.—FMM2104, 2105.

Description.—Coralla massive with approximately 9 mm in maximum observable diameter, cerioid. Corallites prismatic, 5–8 sided in transverse section; their diameters 0.4–1.0 mm. Intercorallite walls thickened by stereoplasm, attaining 0.48 mm; transverse sections of tabularia (lumina) are rounded polygonal; mural pores common, occur on corallite faces; diameters of pores are large in comparing with corallite size, 0.15 mm in typical one; apparent septal spine is not detected; tabulae rare, complete.

Occurrence.—Gray limestone pebbles.

Discussion.—The thickened intercorallite walls, rounded polygonal profiles of the lumina, the relatively large diameters of the mural pores of this species are consistent with the morphology of *Pachyfavosites*.

Pachyfavosites sp. indet. 2

Fig. 3-6

Material.—FMM2106, 2107.

Description.—Coralla probably massive, cerioid. Corallites prismatic, 4–8 sided in transverse section; diameters of corallites 0.3–1.2 mm. Intercorallite walls thickened by stereoplasm, attaining 0.42 mm; transverse sections of tabularia (lumina) are rounded polygonal; no apparent mural pore and septal spine are detected; tabulae well-developed, complete or dissepiment-like in rare cases.

Occurrence.—Gray limestone pebbles.

Discussion.—The second species also has comparable morphology with *Pachyfavosites*. However, information of its mural pores is lacking, so the generic assignment is tentative. *Pachyfavosites* sp. indet. 2 differs from *P*. sp. indet. 1 by the well-developed tabulae.

Genus *Plicatomurus* Chang, 1959

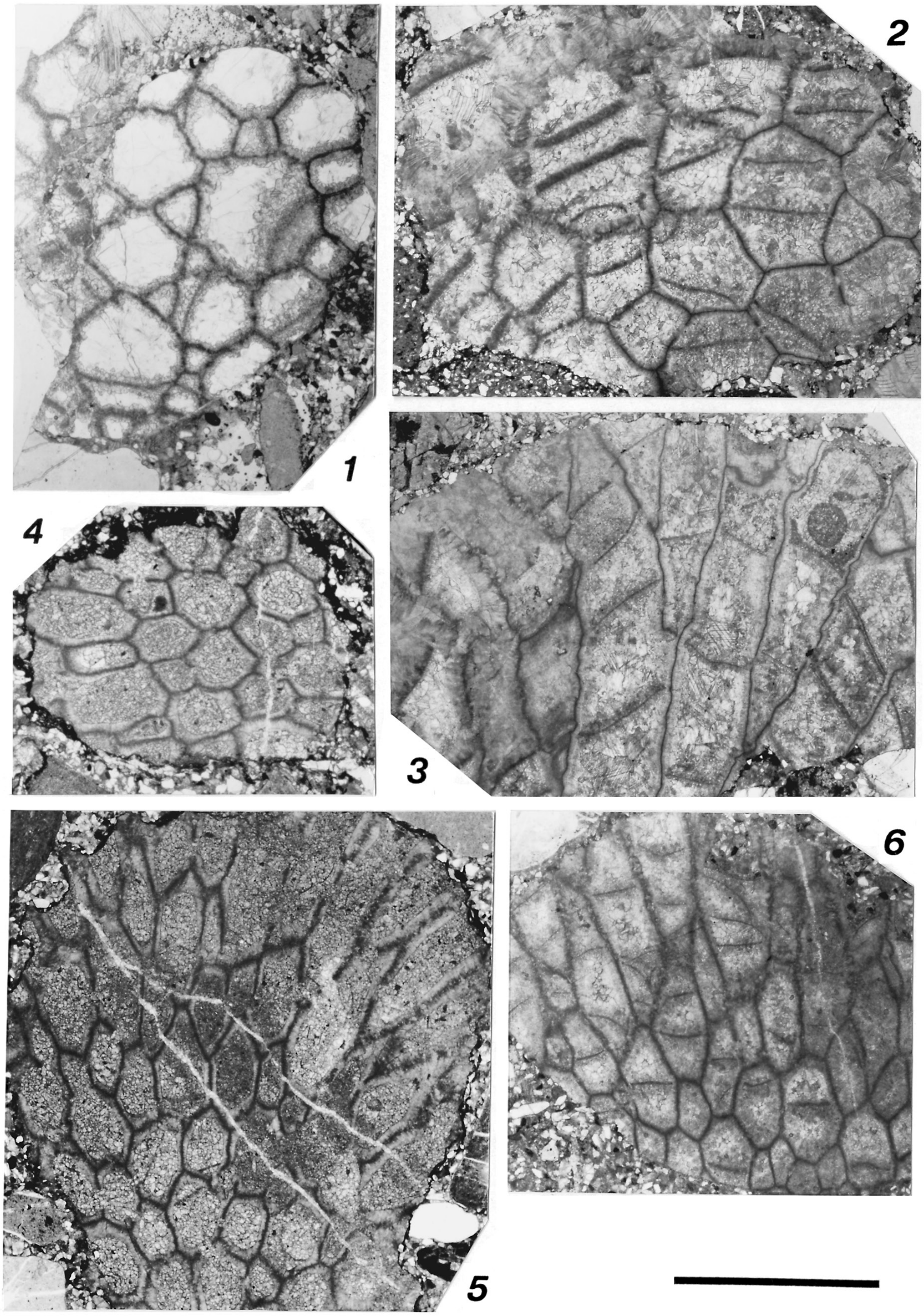
Type species.—*Plicatomurus solidus* Chang, 1959.

Plicatomurus? sp. indet.

Figs. 3-2, 3

Material.—FMM2101–2103.

Description.—Coralla, massive, cerioid composed by prismatic corallites; transverse section of corallites possesses 3–8 sides and has approximately 0.8–2.5 mm in diameter. Intercorallite walls wavy and thickened to form distinct peripheral stereozone; mural pores well-developed, occur on corallite faces; apparent septal spine is not detected; tabulae well-developed, complete; distal tabulae thickened.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Occurrence.—Milky white to gray limestone pebbles.

Discussion.—The presence of the stereozone in the peripheral corallum and wavy nature of the intercorallite walls are features of *Plicatomurus*. However, the examined specimens are too poor in preservation to confident generic assignment.

Superfamily Pachyporoidea Gerth, 1921

Family Pachyporidae Gerth, 1921

Genus *Hillaepora* Mironova, 1960

Type species.—*Hillaepora spica* Mironova, 1960.

Hillaepora sp. indet.

Figs. 2-5; 5-5

Material.—FMM2100.

Description.—Examined specimen is represented by a fragmentary branch that has 3.3–4.5 mm in diameter. Except for free and cylindrical calical rims, corallites are prismatic having indistinct triangular transverse sections in axial zone or sub-prismatic having sub-trapezoidal to fan-shaped sections in peripheral zone of branch; diameters of corallites 0.3–1.3 mm. Intercorallite walls thickened by stereoplasm, attaining approximately 0.63 mm; mural pores well-developed, occur on corallite faces, and have 0.13–0.63 mm in diameter; apparent septal spine is not detected; tabulae probably rare, complete.

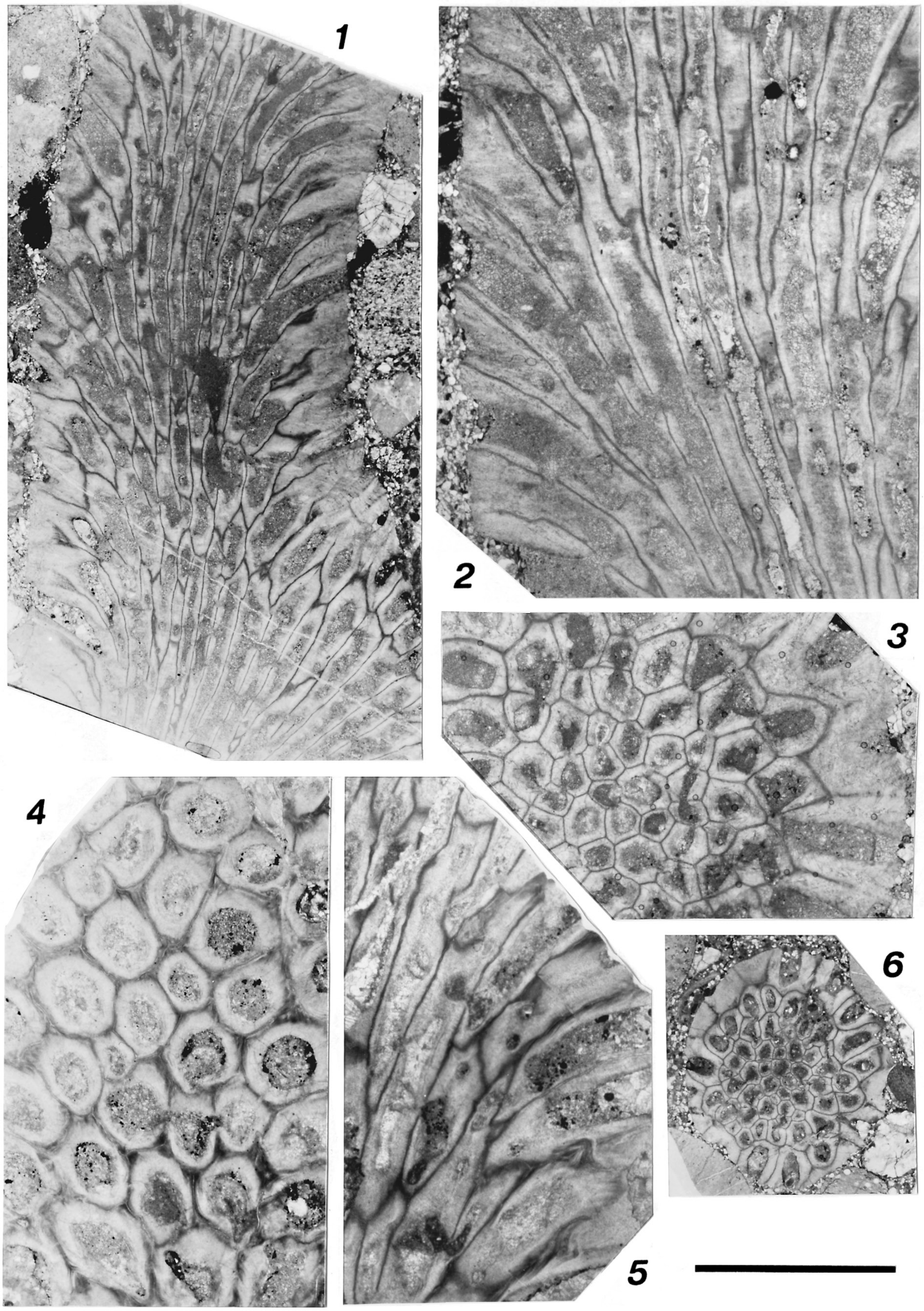
Occurrence.—Black shale pebble.

Discussion.—The observable features of this distinctive specimen seem to conform to the diagnosis of *Hillaepora*. Its reliable stratigraphic distribution is restricted within the Lower Devonian (Hill, 1981). Previously, *Hillaepora* sp. cf. *H. altaica* Dubatolov *in* Dubatolov and Spasskiy (1964) from the Takaharagawa Member of the Fukuji Formation in Gifu Prefecture (Niko, 2005, p. 13, 14, 16, figs. 2-1–7) was an only representative of the genus in Japan. The present specimen differs from the Fukuji species by having triangular transverse sections of the corallites in the axial zone of the branches, but information about longitudinal section of the corallites is necessary to advocate a new species.

Genus *Thamnopora* Steininger, 1831

Type species.—*Thamnopora madreporacea* Steininger, 1831.

←**Fig. 3. 1:** *Favosites*? sp. indet., FMM2108, transverse thin section of corallum. **2, 3:** *Plicatomurus*? sp. indet., thin sections. **2**, FMM2101, transvers section of corallum; **3**, FMM2103, longitudinal section of corallum. **4**, **5**: *Pachyfavosites* sp. indet. 1, FMM2104, thin oblique sections of corallum. **6**: *Pachyfavosites* sp. indet. 2, FMM2106, thin oblique section of corallum. Scale bar = 3 mm.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Thamnopora itoae sp. nov.

Figs. 2-1–3; 4-1–6

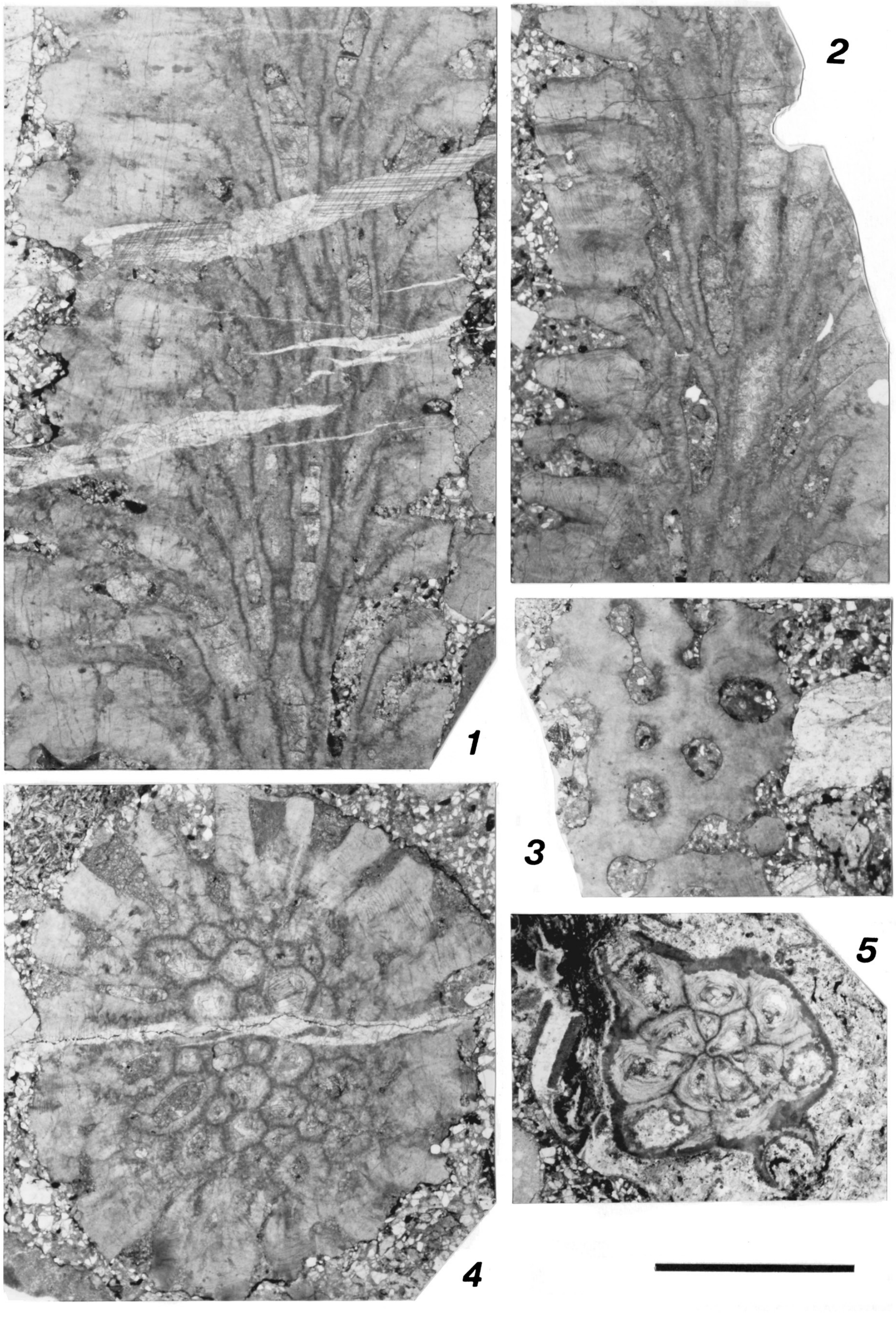
Etymology.—The specific name honors Mrs. Kanako Ito, who collected the examined block of conglomerate including all specimens of this new species.

Material.—Holotype, FMM2072, from which five thin and one polished sections were prepared. Thirteen thin and five polished sectiones were studied from the seven paratypes, FMM2066, 2068, 2069, 2071, 2073, 2077, 2078. In addition, eight fragmentary specimens, FMM2067, 2074–2076, 2079–2082, were also examined.

Diagnosis.—Species of *Thamnopora* with 6.6–10.8 mm in usual diameter of branches, 73–97 in number of corallites in transverse section of branches, and approximately 1.4 mm in distal corallite diameter; thickness of intercorallite walls attains 0.86 mm in peripheral zone of branches; mural pore abundant, elliptical; robust septal spines well developed in peripheral zone; tabulae relatively rare.

Description.—Coralla ramose with cylindrical branches, cerioid; branching probably common, bifurcate; usual diameters of branches are 6.6–10.8 mm; total corallum diameter and growth form unknown. Corallites prismatic, 4–7 sided; there are 73–97 corallites in transverse section of branches; each corallite consists of narrowly divergent proximal portion and outwardly curved distal one; these proximal and distal portions respectively form axial and peripheral zones of branches; ratios of axial zone width per branch diameter are approximately 0.5–0.7; diameters of corallites range from 0.4 to 1.7 mm, with 1.4 mm mean in distal corallites; tabularia (lumina) indicate rounded polygonal transverse sections, and shift to very deep calical pits; calices have obliquely upwards to nearly perpendicular direction with 44°–83° in angle to branch axis; lateral increases of new corallites commonly occur in axial zone. Intercorallite walls uniformly thickened in axial zone, 0.15–0.59 mm, then their thickness gradually increases attaining 0.86 mm in peripheral zone and form distinct stereozone; constituents of walls are median dark line and stereoplasm; microstructure of the latter layer is rect-radiate fibers; in addition, lamellar wall structure is developed in peripheral stereozone; mural pores abundant forming a single row on each corallite face, and longitudinally elongated elliptical profiles with somewhat variable in size; typical pores have 0.15 × 0.21, 0.17 × 0.36, 0.23 × 0.38 mm in diameter; septal spines common in axial zone and well developed in peripheral one, robust and low to high conical having 0.06–0.19 mm in length of protrude portions into tabularia; tabulae relatively rare, complete, concave proximally, nearly flat, or slightly oblique.

←**Fig. 4.** *Thamnopora itoae* Niko, Ibaraki and Tazawa sp. nov., thin sections. **1–3**: Holotype, FMM2072. **1**, longitudinal section of branch; **2**, longitudinal sections of distal corallites; **3**, transverse section of branch. **4**, **5**: Paratype, FMM2071. **4**, transvers sections of distal corallites; **5**, oblique sections of distal corallites. **6**: Paratype, FMM2069, transverse section of branch. Scale bar = 1.5 mm for Figs. 4-1, 6, = 3 mm for Figs. 4-2–5.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Occurrence.—Milky white to gray limestone pebbles.

Discussion.—Due to its morphologies of the branches and the intercorallite walls, *Thamnopora itoae* sp. nov. most closely resembles a Givetian (late Middle Devonian) species, *T. nicholsoni* (Frech, 1885, p. 104, 105), known from Germany, Novaya Zemlya, Ukraine, Morocco, Siberia, South China, and the Kuzuryu Lake–Ise River area, Fukui Prefecture (Niko and Senzai, 2011, p. 31, 33, 34, figs. 2-1–8). However, *T. nicholsoni* differs from this new species by larger mean diameters of the distal corallites (1.9 mm) and the fewer tabulae.

Thamnopora itoae is also similar to *T. siavis* Dubatolov *in* Dubatolov et al. (1959, p. 22, 23, pl. 7, figs. 2a–e) from the Middle Devonian of Da Xinggan Ling (the Greater Khingan), Northeast China and *T. incerta* Regnéll (1941, p. 36–40, pl. 8, figs. 4a, b, 5, 6; pl. 9, figs. 1a, b, 2a, b, 3a–e, 4, 5) from the lower Devonian of Tarim, but the former species has larger diameters of the usual branches (15 mm) than the new species and the latter one is diagnosed by the lacking of the septal spine. Previously known other species of the genus from Japan, such as *T. hayasakai* Niko (2005, p. 22, 24, 26, figs. 6-1–9; Niko and Senzai, 2010, p. 49, 50, figs. 8-3, 4; Ibaraki and Niko, 2012, p. 107, 109, figs. 3-6–8), *T. senzaii* Niko (2003, p. 10, 12, figs. 2-1–9; 4-6–8; Niko and Adachi, 2004, p. 48, figs. 1-4, 7), *T. suberidaniensis* Niko (2003, p. 12, 15, 17, figs. 3-1–8), are readily differentiated from *T. itoae* by their smaller diameters of the branches.

Genus *Thamnoptychia* Hall, 1876

Type species.—*Striatopora* (*Thamnoptychia*) *limbata* Eaton, 1832.

Thamnoptychia mana Niko and Senzai, 2010

Figs. 2-4; 5-1–4

Thamnoptychia mana Niko and Senzai, 2010, p. 50, 52, figs. 10-1–8.

Material.—FMM2070, 2083–2099.

Occurrence.—Milky white to gray limestone pebbles.

Discussion.—The present material is conspecific with *Thamnoptychia mana*, whose types were recovered from float block of tuffaceous shale in the Kuzuryu Lake–Ise River area, Fukui Prefecture. Niko and Senzai (2011) regarded its age as the Givetian. *Thamnoptychia mana* differs from another species from Japan, *T. yanagidai* Niko (2010, p. 13, 14, pl. 2, figs. 1–6), by having the narrower peripheral stereozone in the branches.

←**Fig. 5. 1–4:** *Thamnoptychia mana* Niko and Senzai, 2010, thin sections. **1**, FMM2090, longitudinal section of branch; **2**, **3**, FMM2088, **2**, longitudinal section of branch, **3**, transverse sections of distal corallites; **4**, FMM2096, transverse section of branch. **5**: *Hillaepora* sp. indet., FMM2100, thin transverse section of branch. Scale bar = 3 mm.

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