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Middle Jurassic radiolarians from chert clasts within conglomerates of the Itsuki Formation of the Itoshiro Subgroup (Tetori Group) in the Taniyamadani Valley, Fukui Prefecture, central Japan

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Abstract

This paper reports Middle Jurassic radiolarians observed in etched surfaces of chert clasts within conglomerates of the Itsuki Formation of the Itoshiro Subgroup (Tetori Group) in the Taniyamadani Valley, Fukui Prefecture, central Japan. This is the first report of Middle Jurassic chert clasts within the Tetori Group. Middle Jurassic cherts were included in late Middle Jurassic and younger accretionary complexes in East Asia on the basis of previous studies. This study indicates that late Middle or younger accretionary complexes had been exposed and denuded in the provenance of the Tetori Group by the depositional time of the Itsuki Formation.

Key words: conglomerate, etched surface, Triassic, Jurassic, radiolaria, conodont, Tetori Group, accretionary complex.

Introduction

The Tetori Group, distributed over the Hokuriku District in Japan, has yielded radiolarian-bearing clasts within conglomerates (e.g., Ito et al., 2012). These clasts were presumably derived from mid-Mesozoic accretionary complexes (ACs) that are widely exposed in East Asia. The initiation of denudation of the mid-Mesozoic ACs in the provenance of the Tetori Group has been discussed on the basis of the age of microfossil-

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bearing clasts. Takeuchi et al. (1991) discovered Triassic and Jurassic radiolarians from clasts within conglomerates of the Akaiwa Subgroup in Toyama Prefecture. They concluded that the mid-Mesozoic ACs were already uplifted and denuded in the late Neocomian (Early Cretaceous). Matsukawa and Takahashi (1999) reported Permian and Triassic radiolarians from chert clasts in the Otaniyama Formation of the Itoshiro Subgroup in Gifu Prefecture. On the basis of the stratigraphic relationship to the ammonoid-bearing Mitarai Formation, the Otaniyama Formation had corresponded to the Upper Jurassic–lowest Cretaceous. They highlighted that the mid-Mesozoic ACs had been exposed earlier than the age presumed by Takeuchi et al. (1991). Sato et al. (2008) discovered Berriasian ammonoids from the Mitarai Formation, indicating that the Otaniyama Formation corresponds to the Lower Cretaceous.

The mid-Mesozoic ACs are characterized by long-term accretions, suggesting that their uplifts and denudations did not occur all at once but in stages. However, few studies have considered the denudational change of the mid-Mesozoic ACs in the provenance of the Tetori Group using microfossils from clasts. We observed microfossils on etched surfaces of siliceous rock clasts in conglomerates of the Itsuki Formation of the Itoshiro Subgroup of the Tetori Group in the Taniyamadani Valley, Fukui Prefecture, central Japan. Some chert clasts yielded Middle Jurassic radiolarians, which were presumably derived from late Middle Jurassic or younger ACs. There are a few reports of Middle Jurassic radiolarians from the clasts within the Tetori Group (Saida, 1987; Ito et al., 2014). However, Saida (1987) extracted Middle Jurassic radiolaria from residues of conglomerate; therefore, the derivation is undetermined. Ito et al. (2014) obtained Middle Jurassic radiolarians from a siliceous mudstone clast within conglomerates of the Mizukamidani Formation in the Itoigawa area, Niigata Prefecture. This study presents the occurrences of Middle Jurassic chert clasts within the Tetori Group for the first time, indicating the denudation of the latest Middle Jurassic or younger ACs in the provenance of the Tetori Group.

Geologic setting

The Kuzuryu area is located in southeastern Fukui Prefecture (Fig. 1). The Tetori Group of this area is composed of three subgroups, Kuzuryu, Itoshiro, and Akaiwa, in the ascending order (Maeda, 1961) (Fig. 2). The Kaizara and Yambarazaka formations yielded Bathonian–Callovian and Oxfordian ammonoids, respectively (Maeda, 1952; Sato and Westermann, 1991; Handa et al., 2014). Tithonian ammonoids occurred in the Kamihambara Formation (Sato and Yamada, 2005). Based on zircon U–Pb dating, the youngest zircon grain from the sandstone of the lower Itsuki Formation has a concordant age of 127.2 ± 2.5 Ma (Kawagoe et al., 2012), which corresponds to the Barremian (126.3–130.8 Ma: Gradstein et al., 2012).

In the route along the Taniyamadani Valley shown in Fig. 1, the Obuchi, Itsuki, and

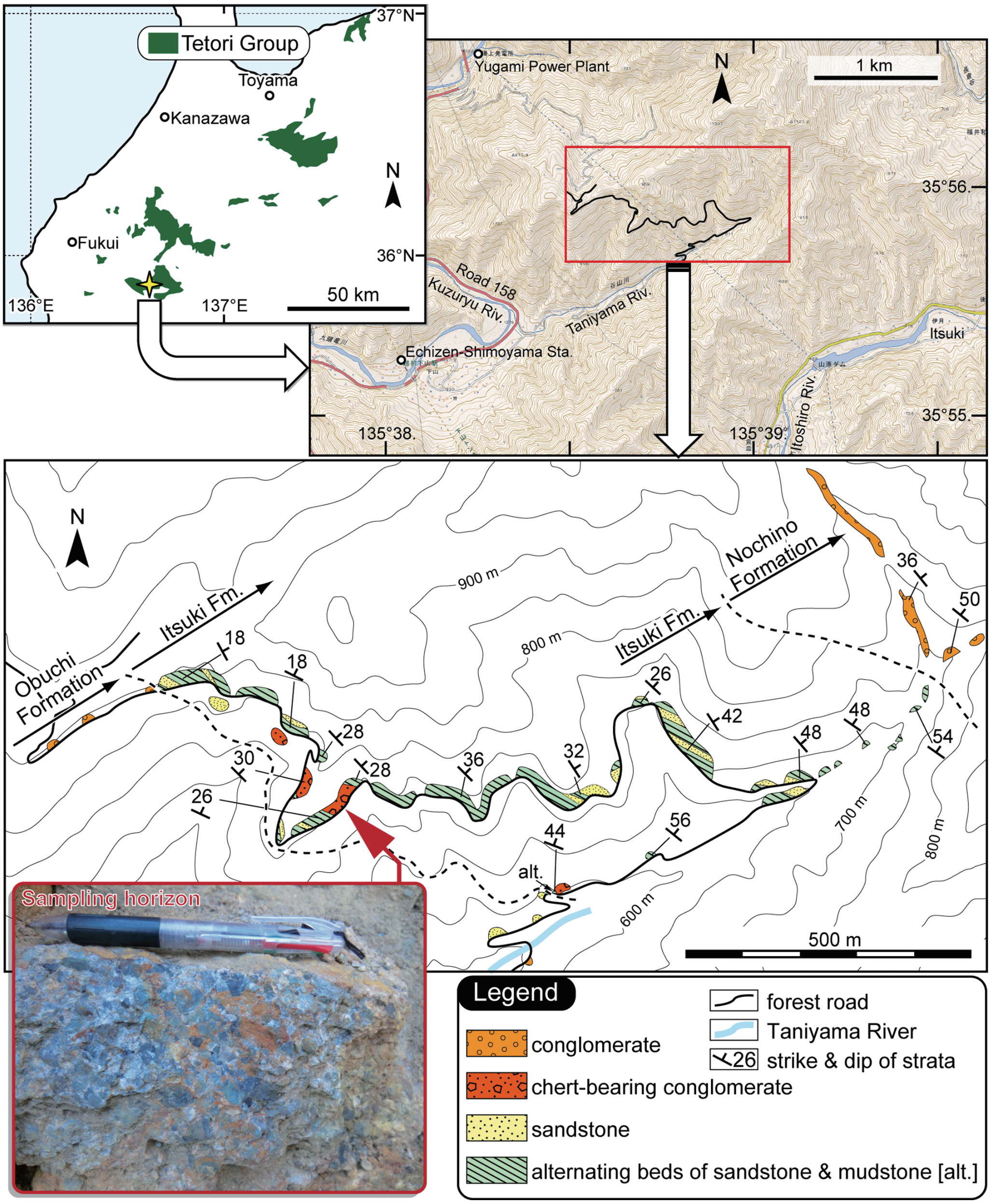

Fig. 1. Index map of the sampling site and a route map through the Taniyamadani Valley, Fukui Prefecture, central Japan. Distributions of the Tetori Group are after Maeda (1961). The map of the Kuzuryu area is modified from topographic map published by Geospatial Information Authority of Japan.

Nochino formations are exposed. These strata strike approximately N40° W and dip approximately 30° NE. A few unmappable small faults and dykes are also present.

The Obuchi Formation in the route is composed mainly of massive conglomerates. The conglomerate is poorly sorted and matrix supported. Clasts are subrounded to rounded and are typically 2–4 cm in diameter. The largest clasts are approximately 10 cm in diameter. The clasts are characterized by noticeable orthoquartzite. Clasts of sandstone and granitic rocks are common, whereas no chert clast is observable. The matrix is bright-gray very-coarse-grained sandstones.

The Itsuki Formation in the route is composed mainly of alternating beds of sandstones and mudstones. Plant and bivalve fossils occur commonly in the alternating beds. Chert-bearing conglomerate layers are present in the lower part of the Itsuki Formation. The conglomerate is well sorted and clast supported. Clasts are subangular to subrounded and are typically 1–2 cm in diameter. The matrix is bright-gray very-coarse-grained sandstone. The clasts are dominantly chert (greenish gray, gray, and black) and minor black siliceous mudstone. There are some quartz pebbles and granules. A few volcanic rock clasts, which seem to be weathered basalt, are present. Meanwhile, some horizons, which are characterized by being matrix supported, include orthoquartzite clasts. Lateral continuity of the conglomerate layers is not distinct. The Obuchi and Nochino formations in the route consist mainly of conglomerates characterized by noticeable orthoquartzite. However, the conglomerates of the Itsuki Formation in the route clearly differ from the conglomerates of these formations in the presence of chert clasts.

The Nochino Formation in the route is composed of conglomerates, which are poorly sorted and clast supported. Most clasts are rounded and are typically 3–5 cm in diameter. The largest clasts exceed 12 cm in diameter. The clasts are characterized by noticeable orthoquartzite. Clasts of granite and andesite are rare. The matrix consists of very coarse sandstone.

Materials and method

We collected conglomerate samples from a horizon of the lower part of a thick conglomerate (ca. 7 m in thickness) at a sampling site in the lower Itsuki Formation (Fig. 1).

The collected samples underwent the following processes for observation of etched surfaces (Fig. 2). The samples were sliced to a chip, a few centimeters on a side, with a rock cutter. About 100 chips were observed using a loupe to identify siliceous and muddy rock clasts. Clasts were found on 37 chips, and these chips were soaked in a solution of approximately 5% hydrofluoric acid (HF) for one day at room temperature. The HF solution was removed, and the etched chips were resoaked in fresh water. The water was then removed, and the etched chips were dried naturally. The etched chips were then observed

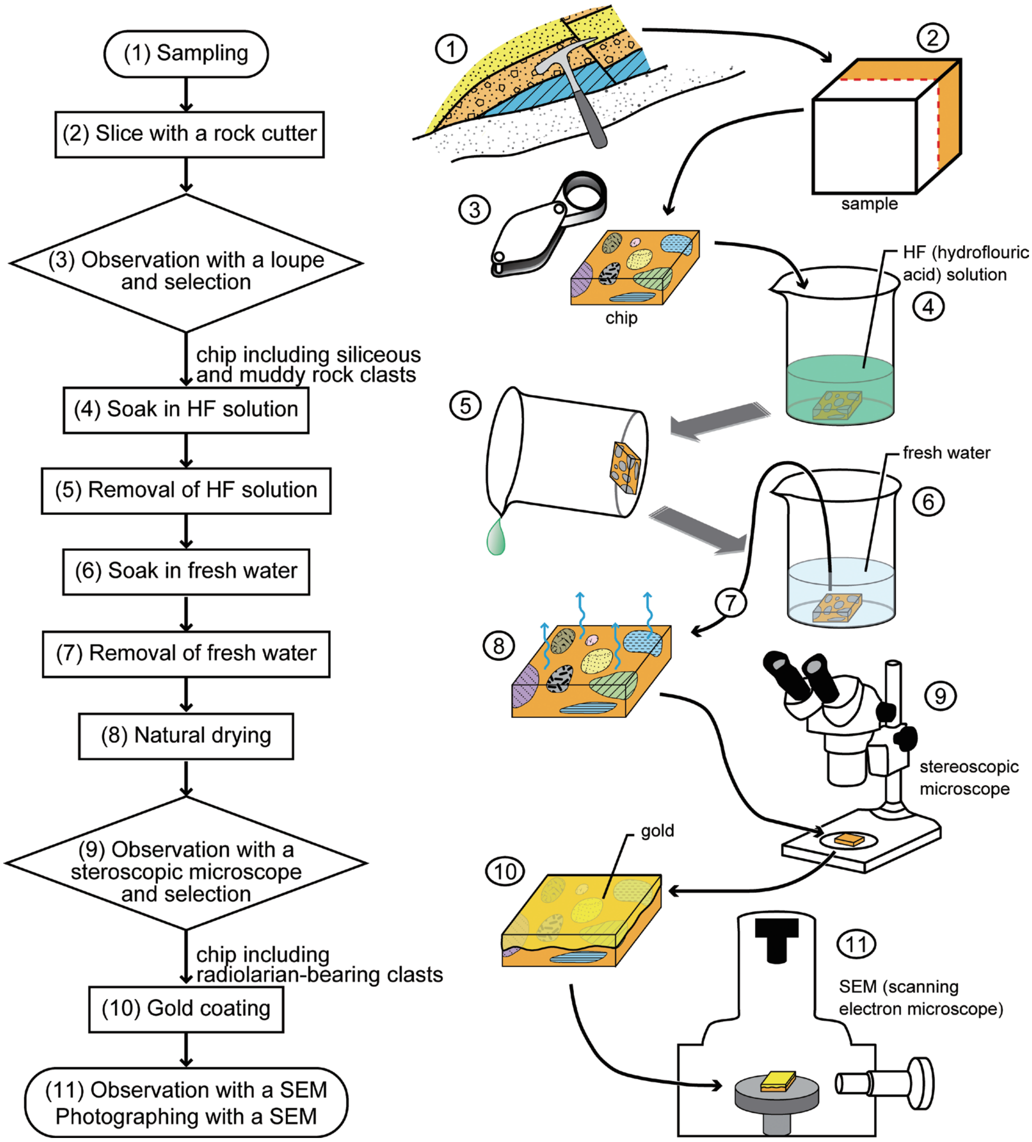

Fig. 2. Flowchart illustrating sample treatment for observation of etched surfaces.

under a stereoscopic microscope. Under the microscope, microfossils were found on the etched surfaces of 15 chips. The surfaces of the etched chips with gold coating were observed and photographed using a scanning electron microscope (SEM).

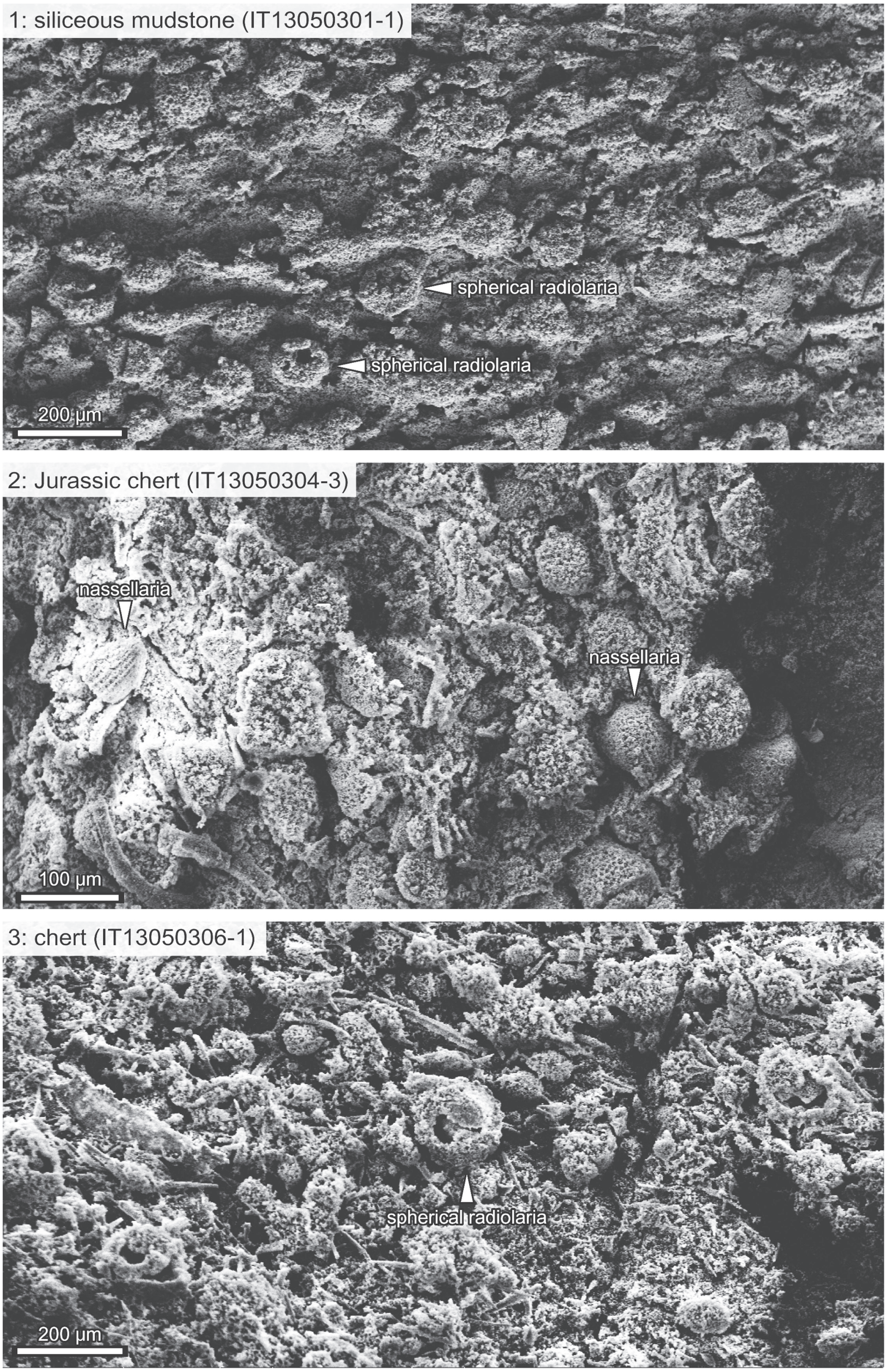

Fig. 3. Photomicrographs of etched surfaces of a siliceous mudstone and chert clasts.

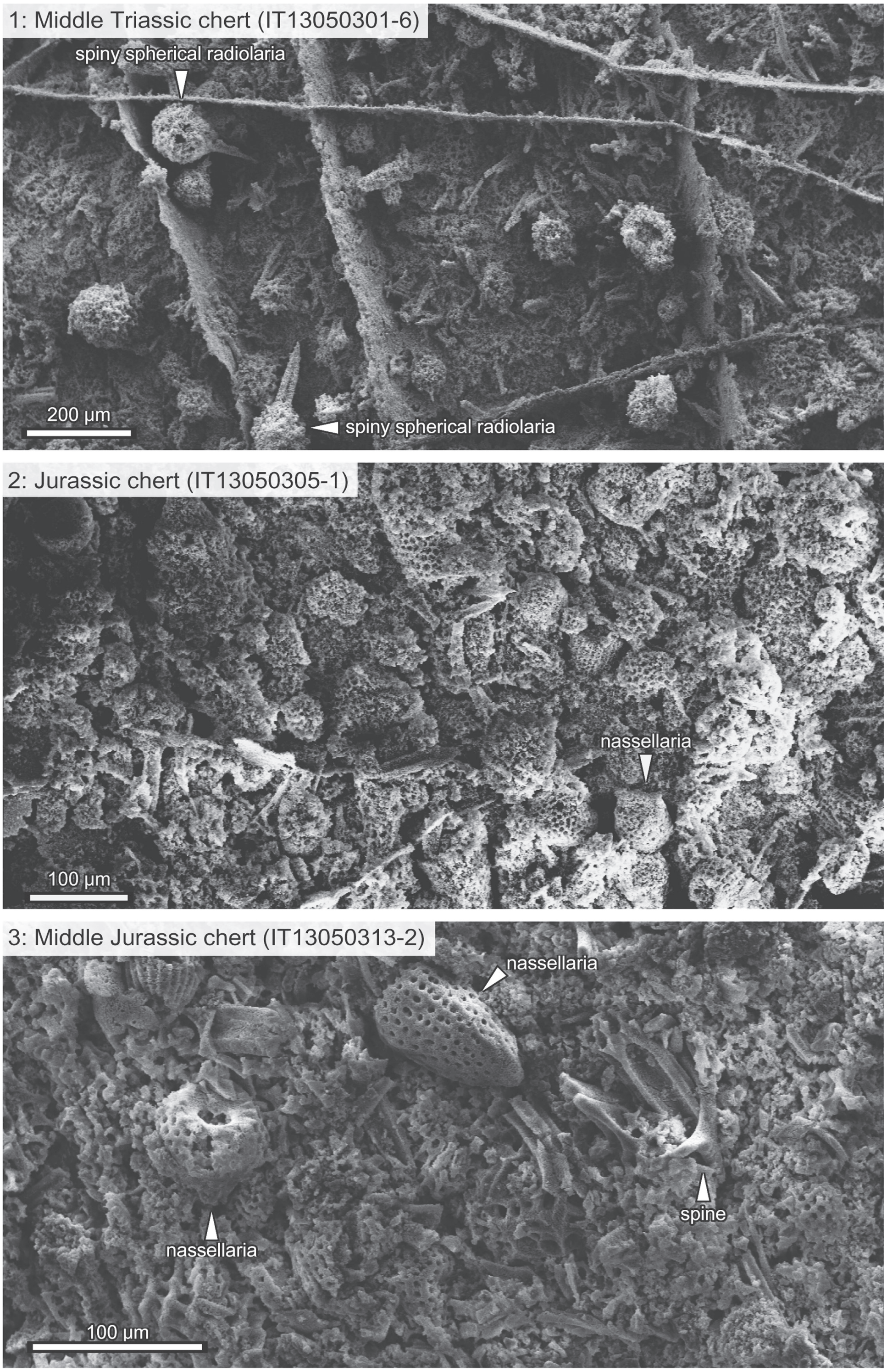

Fig. 4. Photomicrographs of etched surfaces of chert clasts.

Fossil occurrence

The etched surfaces of siliceous mudstone clasts are characterized by dominant mudstone matrices with bioclasts (Fig. 3.1). The bioclasts are scattered on the mudstone matrices and are not sorted. Although some spherical radiolarians and a few spines are present, their preservation is generally poor. In addition, no fossil that proved to be valuable for age assignment was identified in the siliceous mudstone clasts.

The etched surfaces of chert clasts are characterized by dominant bioclasts and by being bioclast supported (Figs. 3.2, 3.3, 4.1–4.3). Bioclasts are composed mainly of spines, spherical radiolarian shells, and nassellarians and these are not sorted. Their components differ by clasts. Figures 3.2 and 4.2 show the dominance of nassellarians; Fig. 3.3 shows dominant spines with minor spherical radiolarian shells; Fig. 4.1 shows the dominance of spines and spiny spherical radiolarian shells, with a few nassellarians; and Fig. 4.3 shows the dominance of nassellarians and spines. Six chert clasts yielded better preserved microfossils (Table 1). SEM images of representative microfossils are shown in Fig. 5.

A chert pebble (IT13050301-6) yielded *Triassocampe* sp. and *Pseudostylosphaera*? sp. These genera occur commonly in the Middle Triassic (e.g., Sugiyama, 1997; O' Dogherty et al., 2009b). Therefore, this chert pebble is probably Middle Triassic.

Neogondolella sp. was obtained from a chert granule (IT13050301-2). In Addition, spines of *Pseudostylosphaera*? sp. occurred in the chert granule. These occurrences indicate the possibility that this chert granule is Triassic.

Hexasaturnalis? sp., *Pantanellium* sp., *Parvicingula*? sp., *Parahsuum* sp., and *Hsuum*? sp. occurred in a chert granule (IT13050304-3). *Pantanellium* sp. and *Parvicingula*? sp. were obtained from a chert granule (IT13050305-1). These genera are common in the Jurassic (e.g., O' Dogherty et al., 2009a), suggesting that these chert granules are Jurassic.

The following radiolarians were extracted from a chert granule (IT13050311-2): *Unuma* sp. cf. *U. typicus* Ichikawa and Yao, *Eucyrtidiellum*? sp., and *Pantanellium* sp. *Unuma typicus* is characterized by 14 to 20 longitudinal plicae and two to four longitudinal rows of small circular pores between adjacent longitudinal plicae. Yao et al. (1982) and Yao (1997) reported that *Unuma typicus* occurs in the *Unuma echinatus* Assemblage-zone or the chronologically equivalent *Striatojaponocapsa plicarum* Zone (JR4: Bajocian–lower Bathonian) of Matsuoka (1995). Consequently, this assemblage can correspond to that of the *S. plicarum* Zone.

A chert pebble (IT13050313-2) yielded *Stichocapsa japonica* Yao, *Parahsuum*? sp., *Archaeodictyomitra* sp., and *Eucyrtidiellum disparile* (Nagai and Mizutani). Nagai and Mizutani (1990) demonstrated that *E. disparile* occurs mainly in the *Laxtorum*(?) *jurassicum* Zone (JR3: Aalenian) of Matsuoka (1995). *Stichocapsa japonica*, characterized by a flattened-spherical fourth segment with basal flat, occurs commonly in the *Laxtorum*(?) *jurassicum*

Table 1. Microfossil occurrences from clasts within conglomerates of the Itsuki Formation in the study section.

Sample number	IT13050301-2	IT13050301-6	IT13050304-3	IT13050305-1	IT13050311-2	IT13050313-2
Lithology of clast	chert granule	chert pebble	chert granule	chert granule	chert granule	chert pebble
age	Triassic	Middle Triassic	Jurassic	Jurassic	Bajocian–lower Bathonian (JR4)	Aalenian (JR3)
Nassellaria					+	
Closed-end Nassellaria				+	+	+
Archaeodictyomitra sp.						+
Eucyrtidiellum sp.					?	
E. disparile (Nagai & Mizutani)						+
Hexasaturnalis sp.			?			
Hsuum sp.			?			
Pantanellium sp.			+	+	+	
Parahsuum sp.			+			?
Parvincingula sp.			?	?		
Pseudostylosphaera sp.		?				
Spine of *Pseudostylosphaera* sp.	?					
Stichocapsa japonica Yao						+
Triassocampe sp.		+				
Unuma typicus Ichikawa & Yao					cf.	
Neogondolella sp.	+					

and *S. plicarum* zones (JR3 and JR4: Aalenian–lower Bathonian) of Matsuoka (1995). On the basis of these radiolarian occurrences, it is found that this chert pebble probably corresponds to the *Laxtorum*(?) *jurassicum* Zone.

Middle Jurassic chert clasts within the Tetori Group

This study recognizes the Middle Jurassic (Aalenian and Bajocian–lower Bathonian) chert clasts from the Itsuki Formation. The youngest zircon grain from the sandstone of the lower Itsuki Formation has a concordant age of 127.2 ± 2.5 Ma on the basis of a zircon U–Pb dating (Kawagoe et al., 2012). Occurrences of Permian, Triassic, and Early Jurassic radiolarians, derived from clasts within conglomerates of the Tetori Group, have been reported by some researchers (Saida, 1987; Takeuchi et al., 1991; Matsukawa and Takahashi, 1999; Tomita et al., 2007; Ito et al., 2012). However, a few Middle Jurassic radiolarians occurred in clasts within conglomerates of the Tetori Group. Saida (1987) reported *Japonocapsa* sp. cf. *J. fusiformis* (Yao) (described as *Tricolocapsa* (?) cf. *fusiformis* Yao) from the Kamihambara Formation in the Tamodani Valley. *Japonocapsa fusiformis* occurred in the Aalenian–lower Bajocian (Matsuoka, 1995). However, the radiolaria was obtained from residues of conglomerate. Consequently, it is unclear whether the radiolaria was derived

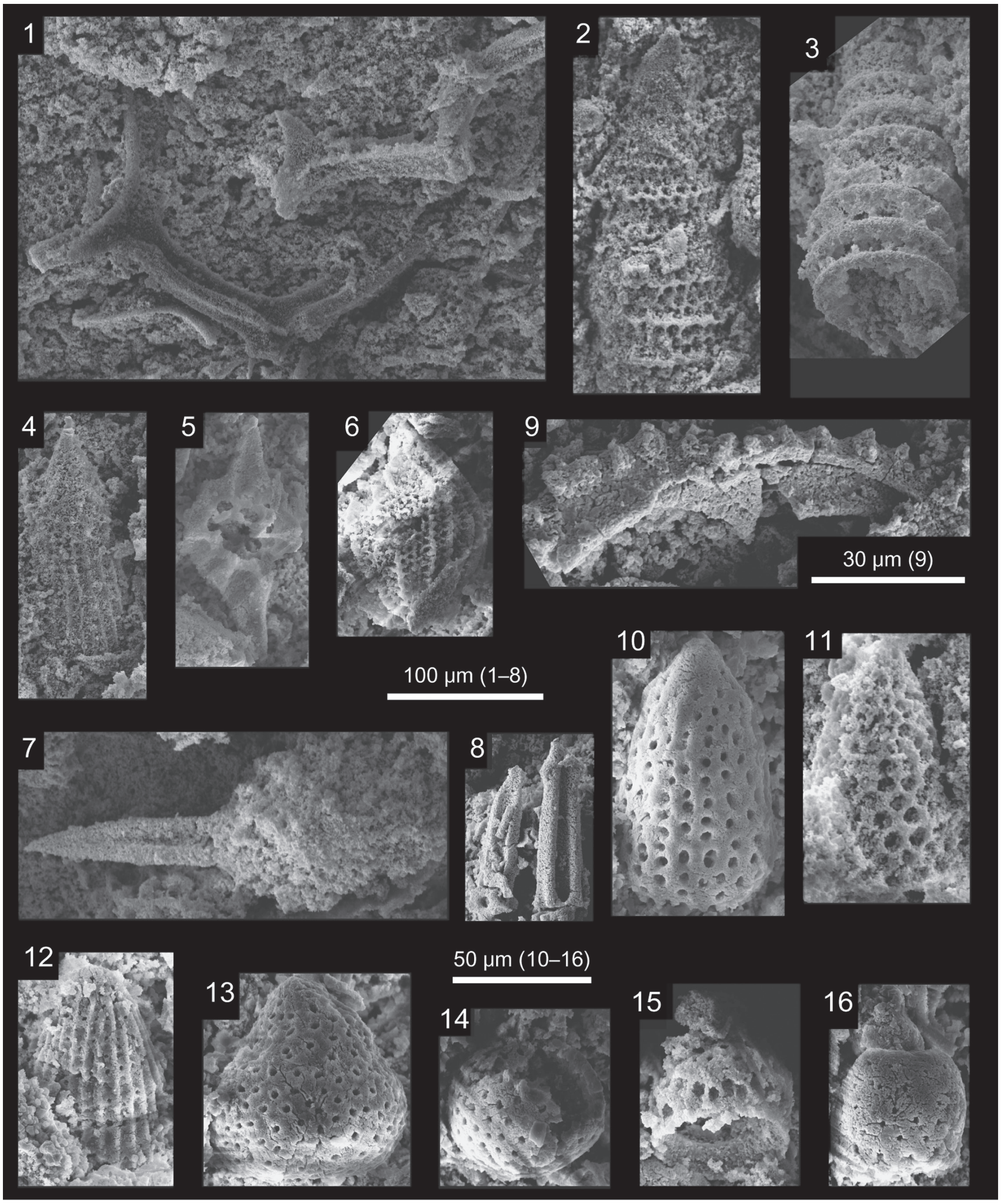

Fig. 5. Photomicrographs of microfossils from chert clasts within conglomerates of the Itsuki Formation in the study section. 1: *Hexasaturnalis*? sp.; 2: *Parvicingula*? sp.; 3: *Triassocampe* sp.; 4: *Parahsuum* sp.; 5: *Pantanellium* sp.; 6: *Unuma* sp. cf. *U. typicus* Ichikawa and Yao; 7: *Pseudostylosphaera*? sp.; 8: spines of *Pseudostylosphaera*? sp.; 9: *Neogondolella* sp.; 10: *Parahsuum*? sp.; 11: *Parvicingula*? sp.; 12: *Archaeodictyomitra* sp.; 13: *Stichocapsa japonica* Yao; 14: Closed-end Nassellaria; 15: *Eucyrtidiellum*? sp.; 16: *Eucyrtidiellum disparile* (Nagai and Mizutani). Sample numbers: 1, 2, 4: IT13050304-3; 3, 7: IT13050301-6; 8, 9: IT13050301-2; 5, 6, 15: IT13050311-2; 10, 12–14, 16: IT13050313-2; 11: IT13050305-1.

from siliceous mudstone or chert clast, or matrix. Ito et al. (2014) reported Middle Jurassic (JR4) radiolarians from conglomerates of the Mizukamidani Formation in the Itoigawa area; however, the radiolarians were derived from a siliceous mudstone clast. This study shows the Middle Jurassic radiolarians from the chert clasts, indicating the first reports of Middle Jurassic chert clasts within the Tetori Group. As shown in Figs. 3 and 4, observations of etched surfaces permit determination of the lithology of the microfossil-bearing clasts. However, this method is not necessarily suitable for detailed identification because a fossil on an etched surface is partially buried. Observations of both etched surfaces and residues are important for the study of microfossil-bearing clasts.

The mid-Mesozoic ACs, widely exposed in East Asia (Kojima and Kametaka, 2000; Wakita and Metcalfe, 2005), are composed mainly of ocean plate deposits and further-overlying terrigenous clastics. These deposits are chert-clastic sequences composed of chert, siliceous mudstone, mudstone, and sandstone (in ascending order). Microfossil dating has clarified the relationships between lithostratigraphy and biostratigraphy of chert-clastic sequences in the mid-Mesozoic ACs (e.g., Nakae, 2000). Middle Jurassic cherts are included in the latest Middle Jurassic and younger ACs, such as the Togano Group (Matsuoka, 1983) and the Tsurugaoka Complex (Nakae, 1990). On the basis of previous studies of the mid-Mesozoic ACs (e.g., Nakae, 2000), it was found that the latest Middle Jurassic AC is younger in the mid-Mesozoic ACs. Consequently, the recognition of Middle Jurassic chert clasts indicates that some younger geological bodies in the mid-Mesozoic ACs had been exposed and denuded in the provenance of the Tetori Group by the depositional time of the Itsuki Formation. In addition, the previous studies of the mid-Mesozoic ACs revealed that the latest Middle Jurassic AC had been structurally located in a lower position in the mid-Mesozoic ACs. This indicates that some geological bodies, which were structurally located in a lower position, had been exposed and denuded by the depositional time. The chert clasts are subangular to subrounded, and lateral continuity of the conglomerate layers is not distinct. These facts suggest that the supply of the chert clast was local.

Further studies based on the aforementioned observational methods will provide information for reconstruction of the denudation history in detail.

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Devonian tabulate corals from pebbles in Mesozoic conglomerate, Kotaki, Niigata Prefecture, central Japan Part 2: Alveolitina

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Abstract

As the second fascicle, this paper describes five species of Devonian alveolitine tabulate corals from limestone pebbles in Mesozoic conglomerate of the Kotaki area, Niigata Prefecture, central Japan. They are *Alveolites* sp. indet., *Crassialveolites niigataensis* Niko, Ibaraki and Tazawa sp. nov., *Squameoalveolites* sp. indet., *Coenites*? sp. indet., *Planocoenites* sp. indet., and *Roseoporella*? sp. indet. A Middle Devonian species, *Crassialveolites tumefactus* Tchi, 1980, from North China is most similar to this new species, but they can separate in growth forms of the coralla and presence or absence of the septal spines. Until now, occurrences of *Crassialveolites* and *Squameoalveolites* have not been known in Japan.

Key words: Devonian, alveolitine tabulae corals, Kotaki area, Mesozoic conglomerate, *Crassialveolites niigataensis* sp. nov.

Introduction

A diverse fauna of Devonian tabulate corals was collected from the Kotaki area of Itoigawa, Niigata Prefecture, central Japan. These coral fossils are preserved in limestone and black shale pebbles in a float block of conglomerate that is derived probably from the Lower Jurassic Kuruma Group. Following Niko et al. (2013), the present second fascicle focuses on the suborder Alveolitina of this material. Five species are described herewith on

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the basis of 39 specimens housed in the Fossa Magna Museum (abbreviation: FMM).

Systematic Paleontology

Subclass Tabulata Milne-Edwards and Haime, 1850
Order Favositida Wedekind, 1937
Suborder Alveolitina Sokolov, 1950
Family Alveolitidae Duncan, 1872
Subfamily Alveolitinae Duncan, 1872
Genus *Alveolites* Lamarck, 1801

Type species.—*Alveolites suborbicularis* Lamarck, 1801.

Alveolites sp. indet.
Figs. 1-1, 2

Material.—FMM5285, 5286.

Description.—Coralla probably massive, alveolitoid. Corallites have fan-shaped to semicircular transverse sections, whose sizes are 0.63–0.86 mm in width and 0.42–0.63 mm in height; form rations (width/height) of corallites range from 1.2 to 1.8. Intercorallite walls uniformly thickened attaining 0.25 mm; mural pores well-developed, situate near corallite angles; septal spines common, high conical; tabulae well-developed, mostly complete. Cylindrical and empty tube (approximately 0.2 mm in diameter) is recognized at corallite angle in a specimen (FMM5285).

Occurrence.—Light gray limestone pebbles.

Discussion.—Only two fragmentary specimens are present. They appear similar to a Givetian (late Middle Devonian) species, *Alveolites maillieuxi* Lecompte (1933, p. 36–38, pl. 3, figs. 2, 3, 3a), described from Ardenne, Belgium. In addition, there is a possibility that they are conspecific with *A.* sp. cf. *A. maillieuxi* of Niko and Senzai (2010, p. 52, 54, figs. 11-1–8) from a float block of tuffaceous shale in the Kuzuryu Lake-Ise River area, Fukui Prefecture. These similarities may suggest age and derivation of pebbles containing *A.* sp. indet.

A tube developed in *Alveolites* sp. indet. was observed in only a single longitudinal thin section. Its morphology is similar to that of a possible parasitic worm, *Chaetosalpinx* Sokolov, 1948.

Genus *Crassialveolites* Sokolov, 1955

Type species.—*Alveolites crassiformis* Sokolov, 1952.

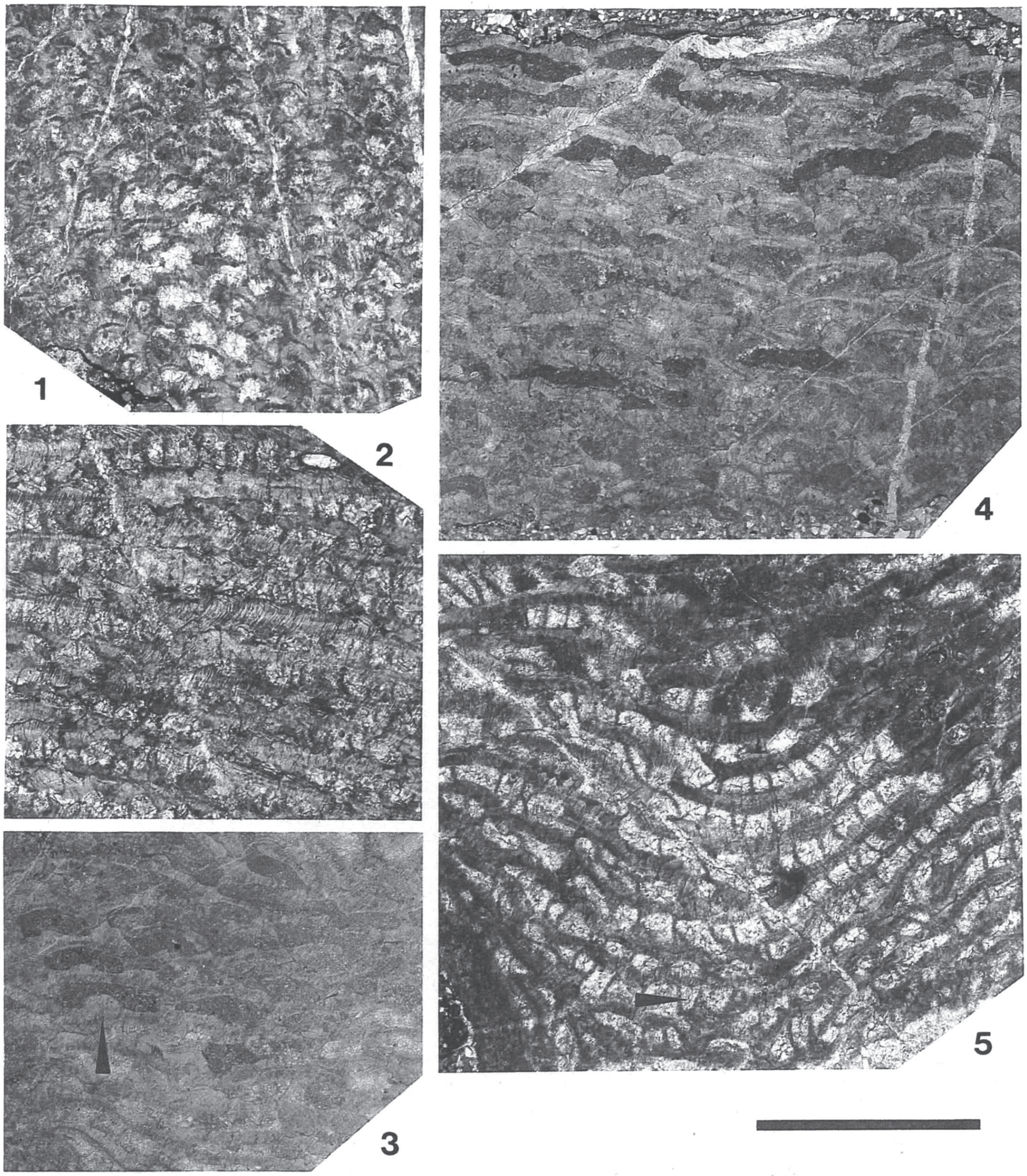
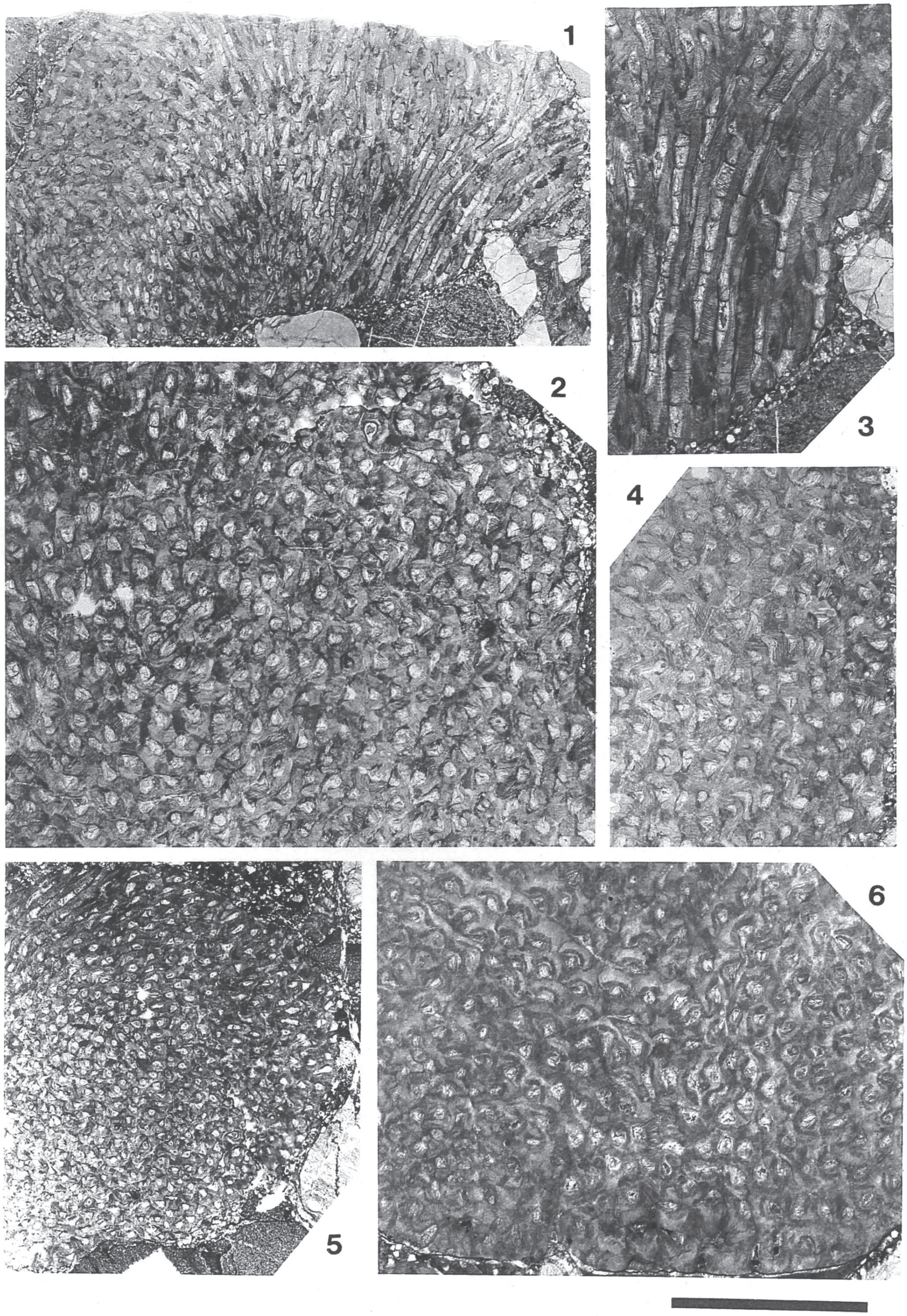


Fig. 1. **1, 2**: *Alveolites* sp. indet., FMM5285, thin sections. **1**, transverse section of corallites; **2**, longitudinal section of corallites, note a tube of possible parasitic worm. **3–5**: *Squameoalveolites* sp. indet., thin sections. **3, 5,** FMM5281; **3**, transverse sections of corallites, arrow indicates squamula; **5**, longitudinal sections of corallites, arrow indicates squamula; **4**, FMM5282, transverse sections of corallites. Scale bar = 3 mm.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Crassialveolites niigataensis sp. nov.
Figs. 2-1–6

Etymology.—The specific name is derived from prefectural name, Niigata, of the type locality.

Material.—Holotype, FMM5293, from which four thin sections were prepared. Three thin sections were studied from a single paratype, FMM5294. In addition, two specimens, FMM5295, 5296, were also examined.

Diagnosis.—Species of *Crassialveolites* with small corallite diameters, approximately 0.40 mm in width and 0.28 mm in height; fan-shaped to semicircular shapes predominate in corallite transverse sections; intercorallite walls attain 0.36 mm in thickness; mural pores well-developed; septal spine absent; tabulae well-developed, complete.

Description.—Coralla massive, alveolitoid; the holotype has nodular growth form and 20 mm in approximate diameter. Corallites subprismatic, more or less inclined; diameters of corallites are very small for the family and small for the genus, 0.38–0.44 mm (0.40 mm mean) in width and 0.25–0.31 mm (0.28 mm mean) in height; transverse sections of corallites are fan-shaped to semicircular, or subpolygonal in rare cases; form rations (width/height) of corallites range from 1.4 to 1.5; increase of corallites is probably lateral; calices deep, open at nearly right angles to corallum surface. Intercorallite walls mostly thick to very thick in comparing with corallite diameters, range from 0.10 to 0.36 mm; constituents of walls are relatively thick median dark layer and stereoplasm; microstructure of stereoplasm is not preserved; tabularia (lumina) narrow with subcircular in usual transverse sections; mural pores well-developed, but not so numerous in comparing the generic type, forming mural tunnels in thickened portions of walls; positions of pores (tunnels) are at corallite angles or on narrow sides of corallite faces; profiles of pores are circular with 0.05–0.10 mm in diameter; septal spine absent; tabulae well-developed, thin and complete; profiles of tabulae are slightly concave to nearly flat; there are 3–7 tabulae in 3 mm of corallite length.

Occurrence.—Gray to milky white limestone pebbles.

Discussion.—Very small diameters of the corallites for the Alveolitidae and the strongly thickened intercorallite walls with the narrowed tabularia of the Kotaki specimens warrant their assignment to *Crassialveolites*. The present discovery represents the first record of the genus in Japan.

In the morphology of the corallites, *Crassialveolites niigataensis* sp. nov. most resembles to *C. tumefactus* Tchi (1980, p. 175, pl. 80, figs. 8, 9a, 9b) from the Middle Devonian of Jilin,

←**Fig. 2.** *Crassialveolites niigataensis* Niko, Ibaraki and Tazawa sp. nov., thin sections. **1–5**, holotype, FMM5293; **1**, longitudinal section of corallum; **2**, **4**, transverse sections of corallites; **3**, longitudinal sections of corallites; **5**, transverse section of corallum; **6**, paratype, FMM5294, transverse sections of corallites. Scale bar = 1.5 mm for Figs. 2-1, 5, = 3 mm for Figs. 2-2–4, 6.

North China. However, the Chinese species differs from *C. niigataensis* in having the tabular corallum and the large septal spines. A Middle Devonian (? to Frasnian, Late Devonian) species, *C. crassus* (Lecompte, 1939, p. 46–48, pl. 8, figs. 1, 1a. 1a, 2) from Europe and the Kuznetsk Basin in southwestern Siberia (Zapalski, 2012) is somewhat similar to the new species, but it differs in having larger diameters of the corallites (0.4–0.6 mm) with subpolygonal profiles in usual transvers sections.

Subfamily Caliaporinae Mironova, 1974

Genus *Squameoalveolites* Mironova, 1969

Type species.—Alveolites fornicatus Schlüter, 1889.

Squameoalveolites sp. indet.

Figs. 1-3–5

Material.—FMM5281–5284.

Description.—Coralla alveolitoid with thick tabular in probable growth form. Corallites reclined, and have laterally elongated subelliptical transverse sections, whose sizes are relatively large, 0.48–1.75 mm in width and 0.25–0.73 mm in height; form rations (width/height) of corallites range from 1.6 to 3.0. Intercorallite walls uniformly thickened attaining 0.29 mm; mural pores well-developed, situate near corallite angles; squamulae common, developed on median flowers of corallites; profiles of squamulae in transverse section of corallites are semielliptical to semicircular; tabulae well-developed, mostly complete.

Occurrence.—Light gray to milky white limestone pebbles.

Discussion.—Four specimens examined herein bear the distinctive characteristics of *Squameoalveolites*, such as their relative large corallites with laterally elongated sections and possession of the squamulae. The present discovery from the Kotaki area represents the first record of the genus in Japan.

Family Coenitidae Sardeson, 1896

Genus *Coenites* Eichwald, 1829

Type species.—Coenites juniperinus Eichwald, 1829.

Coenites? sp. indet.

Figs. 3-1–3

Material.—FMM5297–53199.

Description.—Coralla elongate with diameters of 2.6–8.4 mm, cerioid in axial and alveolitoid in peripheral zones. Corallites slender, prismatic to subprismatic; axial corallites

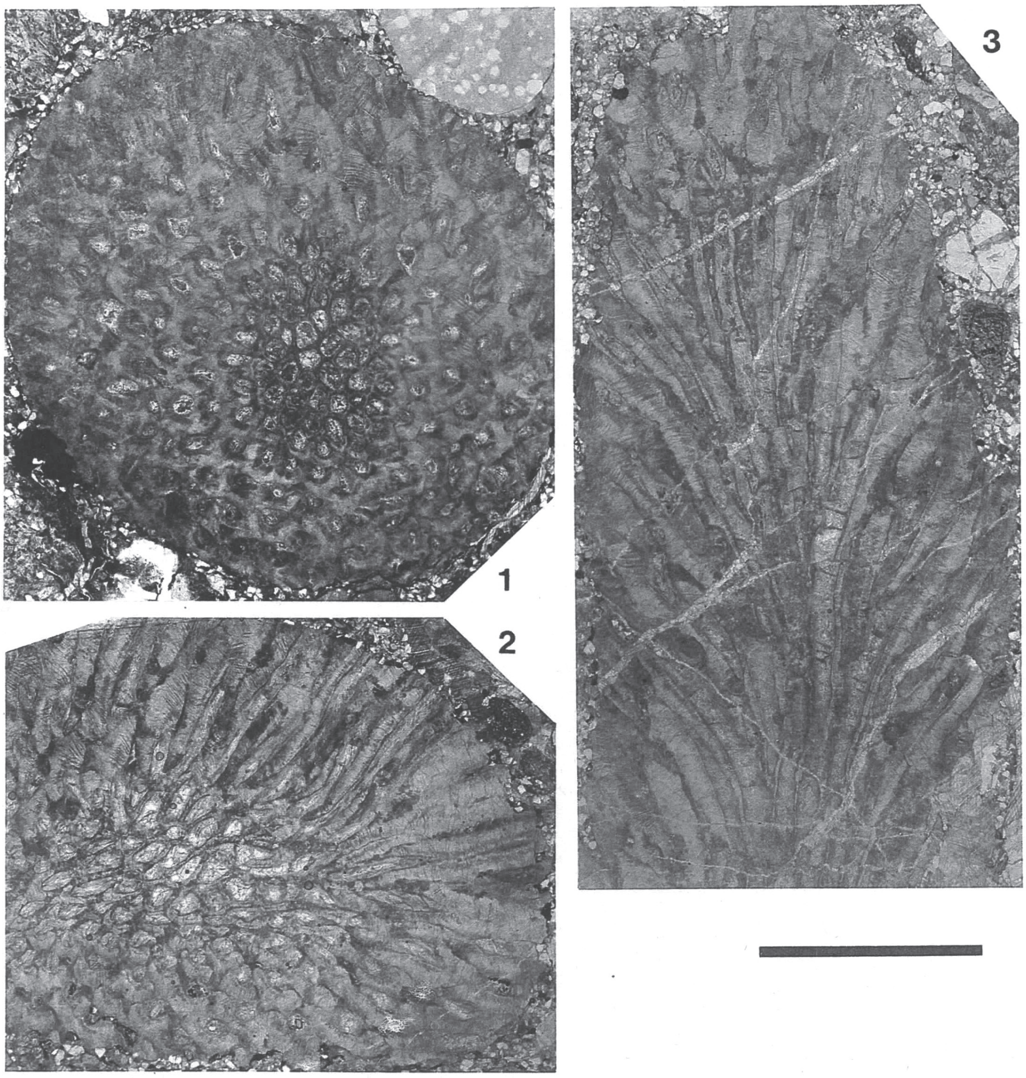

Fig. 3. *Coenites*? sp. indet., thin sections. **1**, **2**, FMM5304; **1**, transverse section of corallum; **2**, oblique section of corallum; **3**; FMM5303, longitudinal section of corallum. Scale bar = 3 mm.

longitudinally directed, having polygonal transverse sections with 4–6 sides and 0.19–0.44 mm in diameter, then they turn outwardly to form peripheral zone where transverse sections of corallites indicate semi-circular to fan-shaped; approximate diameters of peripheral corallites are 0.5–0.7 mm in width and 0.3–0.5 mm in height; form rations (width/height) of corallites range from 1.3 to 2.0; calices very deep, semicircular in transverse sections of usual calical pits. Intercorallite walls relatively thin (0.03–0.08 mm) in axial zone, to thick (up to approximately 0.4 mm) in peripheral one; mural pores well-developed, situate near corallite corners; no septal spine is observed; tabulae sporadic, complete.

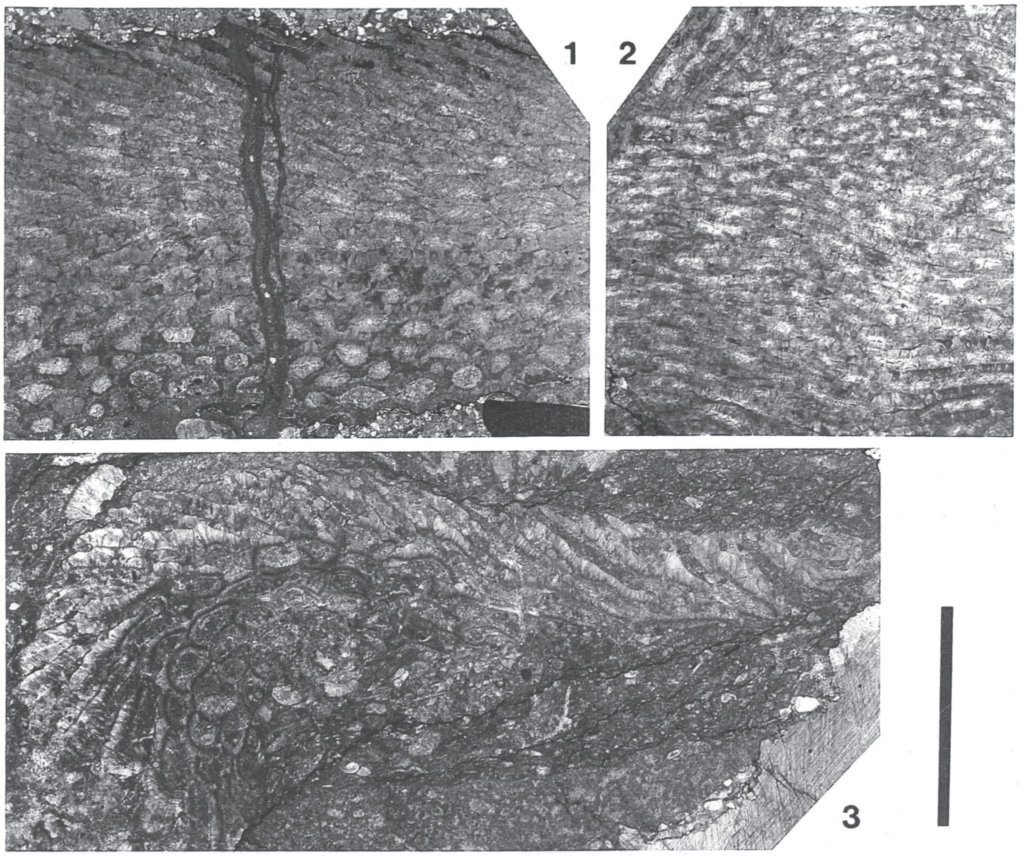

Fig. 4. **1**, **2**: *Roseoporella*? sp. indet., FMM5291, thin sections. **1**, longitudinal section of corallum; **2**, transverse to longitudinal sections of distal corallites. **3**: *Planocoenites* sp. indet., FMM5287, longitudinal thin section of corallum. Scale bar= 3 mm.

Occurrence.—Light gray to milky white limestone pebbles.

Discussion.—All examined specimens from the Kotaki area are small fragments. They are tentatively treated as *Coenites*? sp. inset. The calices of the species differs from typical forms of the genus that is diagnosed by the transversely elongated calical pits.

Genus *Planocoenites* Sokolov, 1952

Type species.—*Coenites orientalis* Eichwald, 1861.

Planocoenites sp. indet.

Fig. 4-3

Material.—FMM5287–5290.

Description.—Coralla encrusting, laminar in growth form, alveolitoid. Corallites reclined, having semicircular to fan-shaped transverse sections; approximate width and height of corallites are 0.4–0.7 mm and 0.2–0.5 mm, respectively; calices oblique, deep. Intercorallite walls of proximal corallites are thin, 0.04–0.06 mm, then they abruptly thickened attaining approximately 0.4 mm in distal corallites; mural pores rare, occur at corallite angles; no septal spine observed; tabulae very rare, complete.

Occurrence.—Dark gray argillaceous limestone to gray limestone pebbles.

Discussion.—Previously three species of *Planocoenites* have been recorded in Japan, namely *P. gifuensis* Niko, 2004, *P. oishinouchiensis* Niko and Adachi, 2002, and *P. ozakii* Niko, 2003. Due to insufficient material from the Kotaki area, detailed comparisons between the present *Planocoenites* sp. indet. and these species are difficult.

Genus *Roseoporella* Spriesterbach, 1934

Type species.—*Roseoporella rhenana* Spriesterbach, 1934.

Remarks.—We follow Zapalski (2012) in considering validity and familial assingment of *Roseoporella*.

Roseoporella? sp. indet.

Figs. 4-1, 2

Material.—FMM5291, 5292.

Description.—Coralla tabular in growth form, alveolitoid. Corallites reclined, subcylindrical; transverse sections of proximal corallites in basal portion of corallum are fan-shaped to elliptical with 0.27–0.88 mm in width and 0.25–0.46 mm in height, then they become strongly elongated elliptical with 0.50–0.71 mm in width and 0.17–0.21 mm in height in more distal ones; form rations (width/height) are 1.1–1.9 in proximal and 3.0–3.4 in distal corallites; calices oblique, deep. Intercorallite walls thin for the family, 0.06–0.17 mm; mural pores rare; no septal spine is observed; tabulae common, complete.

Occurrence.—Milky white limestone pebbles.

Discussion.—Two fragmentary specimens from the Kotaki area indicate strongly elongated transverse sections of the distal corallites and the thin intercorallite walls, whose characters suggest a possible relationship of this species to *Roseoporella* rather than *Planocoenites*.

Acknowledgments

Discovery of Devonian tabulate corals from the Kotaki area was made by Mrs. Kanako

Ito, who allowed us to examine these specimens and donated them to the Fossa Magna Museum. Special thanks are due to her for cooperation. We also thank Dr. Isao Niikawa and Dr. Atsushi Matsuoka for useful comments that considerably improved the manuscript.

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SEM morphological study of the clam shrimp type specimens of *Eosestheria sihetunensis* from the Lower Cretaceous Yixian Formation in western Liaoning, northeastern China

Gang LI*, Atsushi MATSUOKA ** and Helmut WILLEMS ***

Abstract

Morphological reexamination of the type specimems of *Eosestheria sihetunensis* from the Jianshangou beds, the lowest fossil bearing part of the Lower Cretaceous Yixian Formation in Sihetun Village of Beipiao City, western Liaoning Province, northeastern China under a scanning electron microscope (SEM) revealed morphological features on the carapace that had not been recognized previously: growth lines with fine ridges; growth bands near the umbo and in the middle part of the carapace are ornamented with reticulation, within which very fine ridges or cross bars and punta are observed; growth bands in the ventral part of the carapace ornamented with radial lirae, which expand to form triangularly enlarged structure.

Key words: fossil clam shrimps, taxonomy, Lower Cretaceous, Yixian Formation, China.

Introduction

Muroi (1940) established the Yixian Formation in the western part of Yixan County, which is extensively developed in northern Hebei and western Liaoning provinces of China. It is 620–3,695 m thick in western Liaoning (Wang et al., 1989), and consists mainly of volcanic rocks with lacustrine sedimentary intercalations yielding an exceptionally well-preserved Early Cretaceous Jehol Biota (Batten, 1998; Chen and Jin, 1999; Chang et al., 2003; Zhou et al., 2003). The Jehol Biota has become well-known in recent years because its

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beautifully preserved fossils are of evolutionary importance, such as early angiosperms (Sun et al., 1998, 2002), feathered theropod dinosaurs (Chen et al., 1998; Ji et al., 1998), early birds (Hou et al., 1995, 1999; Hou and Chen, 1999) and primitive mammals (Hu et al., 1997; Ji et al., 2002, 2009; Luo et al., 2003, 2007; Li and Luo, 2006).

The Barremian–lower Aptian (Lower Cretaceous) Yixian Formation has been subdivided into four widely recognizable fossil bearing beds within the areas of Yixian County and Beipiao City, western Liaoning Province of northeastern China. The four abundant fossil bearing beds, in ascending order, are called the Jianshangou, Zhuanchengzi, Dakangpu and Jingangshan beds, respectively (Wang et al., 2004; Chen et al., 2005; Wan et al., 2013). Fossil clam shrimps ("Conchostracans", spinicaudatans) are extremely abundant in the formation. They belong to an *Eosestheria* fauna, and are very common and readily found in the lacustrine mudstone and paper shales of the Yixian Formation. This is the reason why fossil clam shrimps were originally used to nominate the Jehol Biota as *Eosestheria middendofii* (clam shrimp)-*Ephemeropsis trisetalis* (insect)-*Lycoptera* (fish) fauna (Chen, 1988, 1999a, 2012). The first taxonomic paper on specimens of the *Eosestheria* fauna recovered from the Turga area, Siberia of Russia was that of Jones (1862) who described *Estheria middendofii* (now *Eosestheria middendofii* (Jones, 1862) Zhang et al., 1976). This was followed by the publications of Chernyshev (1930), Raymond (1946), Kobayashi and Kusumi (1953), Novojilov (1954), Wang (1976, 1980, 1987), Zhang et al. (1976), Niu (1983), Chen and Shen (1985), Chen (1999b), Niu et al. (2003), Li and Batten (2004a) and Shen (2011). Chen (1988) recognized two clam shrimp zones in the Yixian Formation: i.e. the lower *Eosestheria lingyuanensis* Zone in the Jianshangou beds and the upper *E. middendorfii* Zone in the upper part of the Yixian Formation.

The *Eosestheria* fauna, dominated by *Eosestheria* and *Diestheria*, consists of more than 100 species; the majority are 10–20 mm long (i.e. the carapace length). In consideration of the sexual dimorphism and effects of preservation distortion, maybe only 20 or 30 species will be distinguished satisfactorily (Chen et al., 2007). In this sense the *Eosestheria* fauna needs to undergo taxonomic revision. In this paper a re-examination of the type specimen of *Eosestheria sihetunensis* Chen, 1999b under a scanning electron microscope (SEM) revealed some morphological features not previously seen, as recorded below.

Material and method

The type specimens examined are deposited in the collection of the Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences (NIGPCAS). They are all natural carapaces, and were originally collected from the Jianshangou beds of the Lower Cretaceous Yixian Formation in Sihetun Village, Beipiao City of western Liaoning Province.

Most of the previous studies on the palaeotology of fossil clam shrimps have used a light microscope. This means that some potential characters of taxonomic value were difficult to see clearly (Li, 2004; Li and Batten 2004b, 2005; Li et al., 2004, 2006, 2007b, 2009, 2010, 2014; Li and Matsuoka, 2013). Here the authors have relied on examination of specimens using a Leo 1530 VP SEM, and a Zeiss V20 Stereomicroscope.

Systematic palaeontology

The classification of recent spinicaudatans of Martin and Davis (2001) is followed here. Because Cyclestheria Sars, 1887 has been removed from the suborder Spinicaudata Linder, 1945 and is now placed in the suborder Cyclestherida Sars, 1899, which is on an equal footing with the remaining Spinicaudata and Cladocera Latreille, 1829, the Conchostraca Sars, 1867 as a taxonomic unit has been abandoned.

Class: Branchiopoda Latreille, 1817
Subclass: Phyllopoda Preuss, 1951
Order: Diplostraca Gerstaecker, 1866
Suborder: Spinicaudata Linder, 1945
Superfamily: Eosestherioidea Zhang and Chen, in Zhang et al., 1976
Family: Eosestheriidae Zhang and Chen, in Zhang et al., 1976
Genus *Eosestheria* Chen, in Zhang et al., 1976

1976 *Eosestheria* Chen gen. nov., Zhang et al., p. 153.
1976 *Liaoningestheria* Chen gen. nov., Zhang et al., p. 161.
1999 *Eosestheria* Chen, p. 114–115.

Type species. *Eosestheria fuxinensis* Chen, in Zhang et al., 1976.

Occurrence. Lower Cretaceous of northern and northeastern China, southern Mongolia and Transbaikal of Russia.

Diagnosis. Carapace rounded, elliptical or oval in outline, carapace size moderate (carapace length 5–15 mm) or large (>15 mm); growth bands, numerous, even and wide; those near the umbo or in the antero-ventral parts of the carapace are ornamented with medium- (mesh diameter 20–70 μm) or large-sized (mesh diameter 70–200 μm) reticulations (Chen and Shen, 1985), which change gradually to radial lirae on the ventral or in the postero-ventral parts, radial lirae less than 40 within a width of 1 mm; reticulation and radial lirae are irregular (Chen, 1999b).

Discussion. Several fossil clam shrimp genera, except for *Eosestheria*, are characterized by bearing two kinds of ornamentation, i.e. reticulation occurring in the dorsal part, and radial lirae in the ventral part of the carapace, such as *Pseudograpta* Novojilov, 1954, *Yanjiestheria* Chen in Zhang et al., 1976, *Carapacestheria* Shen, 1994. In *Pseudograpta,* the growth lines are more pronounced, the reticulation is coarsely polygonal, and the change from reticulation on the dorsal side to radial lirae on the ventral side is abrupt. In *Yanjiestheria*, the carapace is normally moderate in size, the reticulation is smaller and denser (mesh diameter less than 20 μm), the radial lirae are thinner and more closely spaced (more than 40 within a width of 1 mm) (Li et al., 2007a). In *Carapacestheria*, the carapace is of small or moderate size, and the reticulation is medium-sized (mesh diameter 20–36 μm), radial lirae about 40 within a width of 1 mm. The most distinct character in *Carapacestheria* is that puncta occur within the reticulation and between the radial lirae (Shen, 1994). Although Jones (1862, pl. 4, fig. 19) showed punctate reticulation in *E. middendorfii*, until now no researcher has reported any punctum in *Eosestheria*.

Chen (in Zhang et al., 1976) described *Liaoningestheria* based on the occurrence of reticulation on internal surface of the carapace, but later it was found that this character has no taxonomic importance, so that *Liaoningestheria* was considered as a synonym of *Eosestheria* (Chen and Shen, 1985; Chen, 1999b). There are also some other genera (Chen and Shen, 1985; Chen, 1999) that have also been considered as synonyms of *Eosestheria*, such as *Diformograpta*, Wang, 1976, *Amelestheria* Wang, 1976 and *Dongbeiestheria* Wang, 1980. The further morphological re-studies of the type specimens of these taxa are needed in the future.

Eosestheria sihetunensis (Chen, 1999b) emend.
Figs. 1–2

1999b *Eosestheria sihetunensis* Chen sp. nov., p. 118, pl. 4, figs. 4–7.

Material. Holotype NIGPCAS 131917, a right valve, and NIGPCAS 131916, a left valve, Sihetun, Beipiao City, western Liaoning Province, northeastern China.

Emended diagnosis. Carapace oval in outline; growth lines with fine ridges; growth bands in the dorsal part of the carapace ornamented with medium- or large-sized irregular reticulation with cross bars or fine ridges and puncta in the lumina; those on the ventral part of the carapace ornamented with radial lirae, which on the postero-ventral part of the carapace distribute in the lower half or two-thirds of each growth band and leaving its upper part smooth.

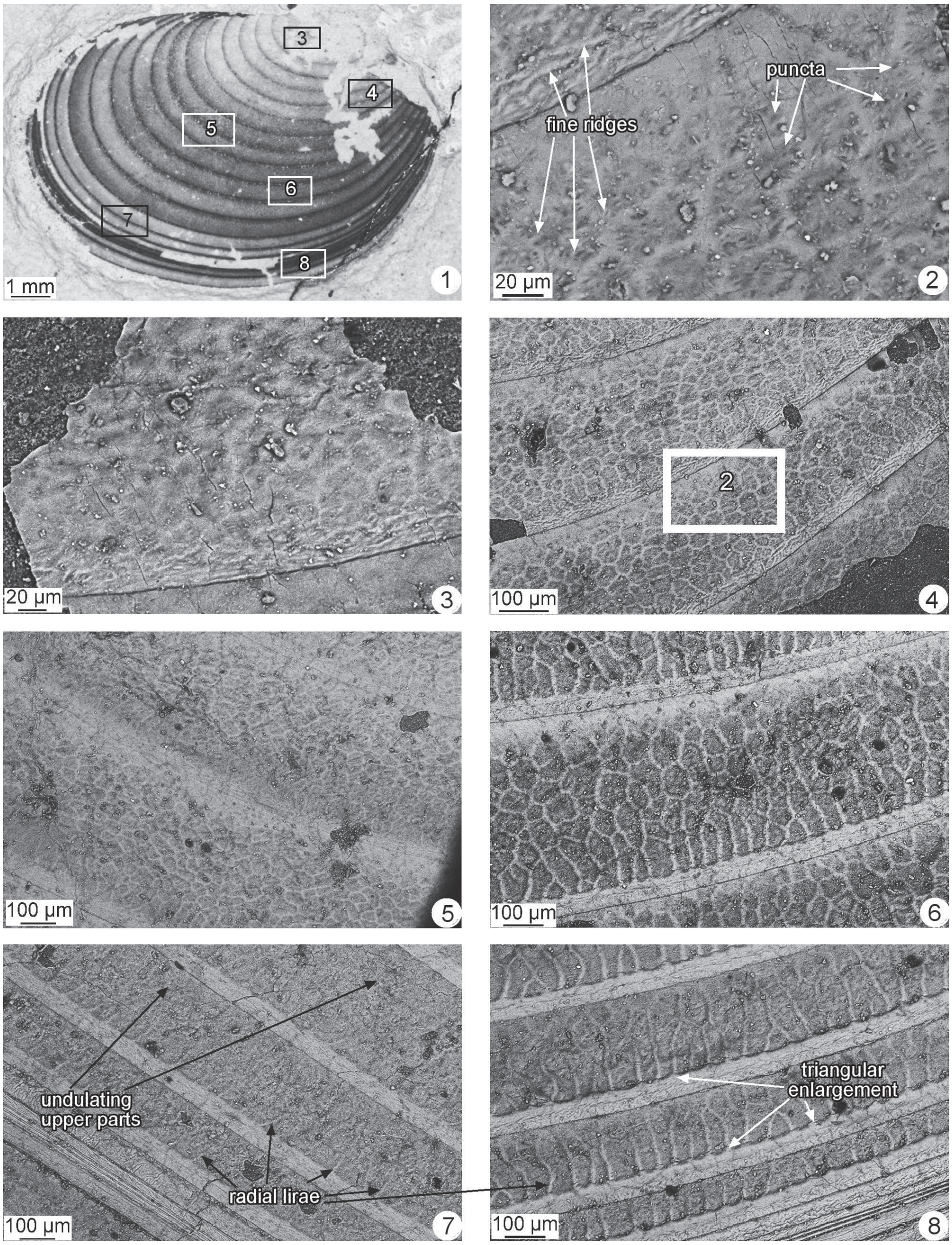

Fig. 1. 1–8, *Eosestheria sihetunensis* (Chen, 1999b) emend., all, except Fig. 1.1 (a light microscopy image), are SEM images of a right valve from the Jianshangou beds of the Lower Cretaceous Yixian Formation, Beipiao City, western Liaoning Province. 1, holotype, NIGPCAS 131917. 2, reticulation on a growth band in the antero-dorssal part of the carapace, showing fine ridges on growth line, fine ridges and puncta within lumina. 3, irregular reticulation on a growth band near the umbo. 4, irregular reticulation on growth bands on the antero-dorsal part of the carapace. 5, irregular reticulation on growth bands in posterior part of the carapace. 6, transition from irregular reticulation to radial lirae on a growth band in the antero-ventral part of the carapace. 7, widely spaced fine radial lirae, occupying the lower half of the growth bands in the postero-ventral part of the carapace. 8, widely spaced radial lirae with triangularly enlarged structure when meeting the growth lines downwards in the antero-ventral part of the carapace.

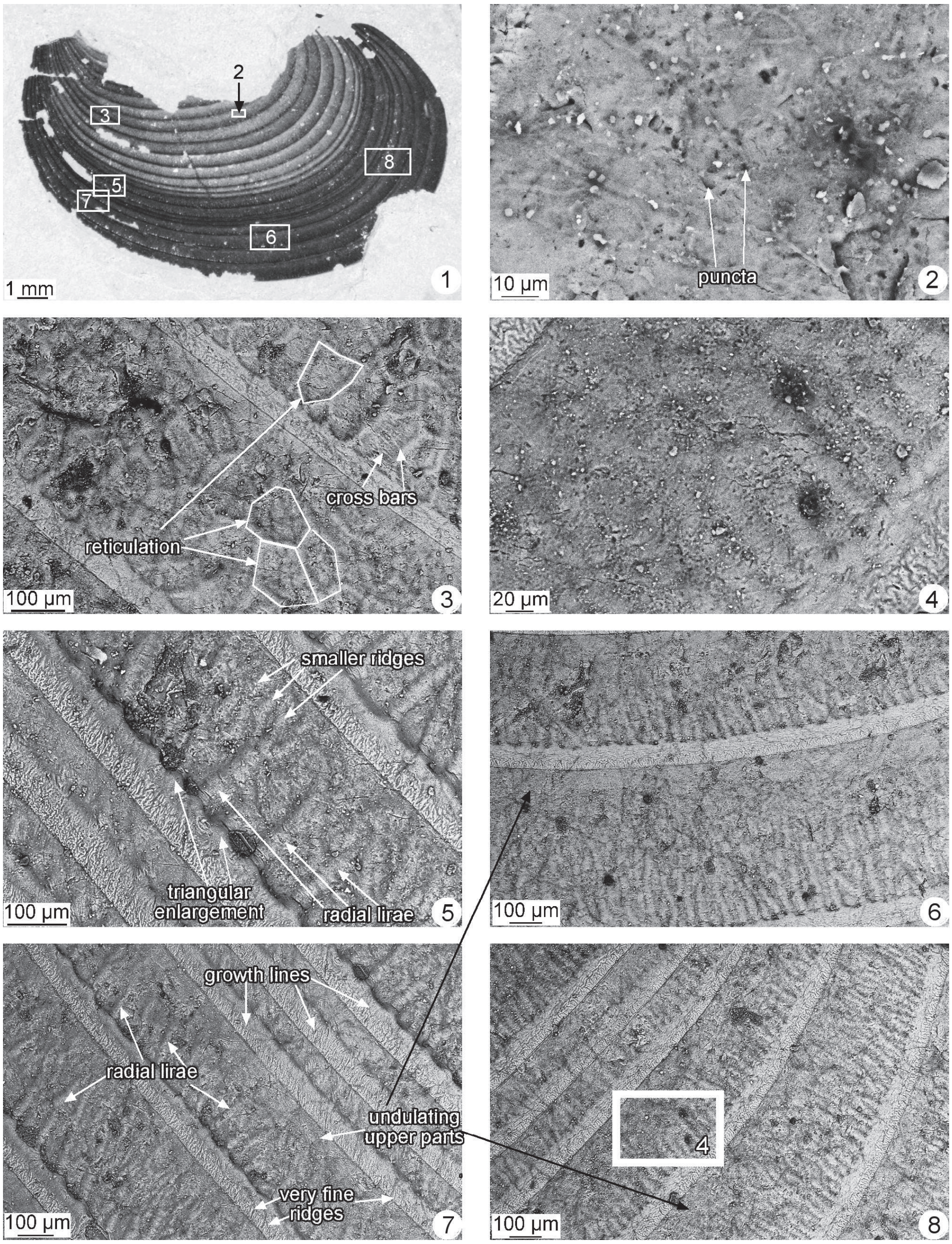

Fig. 2. 1–8, *Eosestheria sihetunensis* (Chen, 1999b) emend., all, except Fig. 2.1 (a light microscopy image), are SEM images of a left valve from the Jianshangou beds of the Lower Cretaceous Yixian Formation in Sihutun Village, Beipiao City, western Liaoning Province. 1, NIGPCAS 131916. 2, punctate ornamentation on a growth band on the dorsal part of the carapace. 3, irregular reticulation on growth bands in anterior part of the carapace. 4, 8, densely spaced radial lirae on growth bands in the postero-ventral part of the carapace. 5, 7, widely spaced radial lirae on growth bands in antero-ventral part of the carapace. 6, densely spaced fine radial lirae on growth bands in the ventral part of the carapace.

Dimensions of the type specimens. In order: specimen no.; number of growth lines; length of carapace (mm); heigh of carapace (mm): NIGPCAS 131916; >21; 14.6; 9.0; NIGPCAS 131917; >20; 10.6; 7.0.

Description. Carapace is of moderate size (10–15 mm long, 7–9 mm high), which is oval in outline with a higher posterior height; umbo small, located at the anterior one-fourth of the long and straight dorsal margin; growth lines 20–25, even and wide, ornamented with very find ridges (Fig. 1.2); growth bands in the umbonal area ornamented with irregular polygonal medium-sized reticulation (Fig. 1.3), which become larger in the middle part of the carapace (Fig. 1.4), with fine ridges and puncta (Fig. 1.2) and cross bars (Fig. 2.3); reticulation gradually change into radial lirae in the lower part of the carapace (Figs. 1.6, 1.8, 2.5, 2.8). The transition from reticulation to radial lirae could be seen in one growth band, on which the upper part is ornamented with reticulation, and the lower part with radial lirae (Fig. 1.6). Radial lirae are widely spaced in the antero-ventral part of the carapace (Figs. 1.8, 2.5, 2.7), but become thinner (Fig. 1.7) or densely spaced (Fig. 2.8), and only occupy the lower half or two-thirds of each band in the postero-ventral part (Figs. 1.7, 2.8). Radial lirae change to triangularly enlarged structure when they meet the growth line downwards in the antero-ventral part of the carapace (Figs. 1.8, 2.5), and some radial lirae branch into secondary ridges upwards (Fig. 2.5).

Discussion. Chen (1999b) designated the specimen NIGPCAS 131917 (Fig. 1) as the holotype of *E. sihetunensis* in the explanation of pl. 4, fig. 5, but the image of the specimen of NIGPCAS 131916 (Fig. 2) was showed. Here we still follow the original designation of NIGPCAS 131917 as the holotype. According to the new SEM images of the two specimens, the holotype has well developed reticulation ornamentation, while the specimen labeled as NIGPCAS 131916 has limited reticulation ornamentation, maybe this is caused by the damage of its dorsal part.

E. sihetunensis is similar to *E. ovata* (Chen, in Zhang et al., 1976) in carapace outline, but differs in having smaller carapace dimensions, and the radial lirae occupy the lower part of each growth band in the postero-ventral part of the carapace. In addition, the fine ridges or cross bars and puncta within the reticulation is very special, having not been reported in *Eosestheria* until now. Although Jones (1862) showed punctate reticulation, this ornamentation has not been confirmed before. Although *Carapacestheria* (Shen, 1994) has punctate reticulation, it differs by having smaller mesh diameter (20–36 μm).

In *Eosestheriopsis* Shen and Chen, 1982, a row of tubercles occurs along the lower margin of each growth band in the middle and ventral parts of the carapace. In the present species, the radial lirae expand to form a triangularly enlarged structure when they meet the growth lines downwards, but it differs by not forming tubercles. Further morphological study on the taxa of *Eosestheria* and *Eosestheriopsis* is needed to confirm the basic difference between the two genera.

Acknowledgments

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Early Permian (Sakmarian) brachiopods from the Nagaiwa–Sakamotozawa area, South Kitakami Belt, northeastern Japan, Part 3: Productidina

Jun-ichi TAZAWA* and Tomohiko SHINTANI**

Abstract

In this third manuscript in a series, the following 10 species of productid brachiopods (suborder Productidina), including one new species, are described from the lowest part of the Sakamotozawa Formation (Sakmarian) in the Nagaiwa–Sakamotozawa area, South Kitakami Belt, northeastern Japan: *Echinauris opuntia* (Waagen), *Reticulatia* cf. *donetziana* (Licharew), *Echinaria* sp., *Juresania* sp., *Waagenoconcha humboldti* (d'Orbigny), *Edriosteges* cf. *multispinosus* Muir-Wood and Cooper, *Linoproductus simensis* (Tschernyschew), *Auriculispina kanmerai* Tazawa and Shintani, sp. nov., *Terrakea* sp. and *Cyclacantharia* sp. The Nagaiwa–Sakamotozawa fauna is a mixed Boreal–Tethyan fauna, with a predominance of Boreal elements.

Key words: early Permian, mixed Boreal–Tethyan fauna, Nagaiwa–Sakamotozawa area, productid brachiopods, South Kitakami Belt.

Introduction

Tazawa and Shintani (2010) and Shintani (2011) described an early Permian (Sakmarian) brachiopod fauna from the lowest part of the Sakamotozawa Formation in the type locality, the Nagaiwa–Sakamotozawa area, South Kitakami Belt, northeastern Japan. Tazawa and Shintani (2010) described three species: *Waagenoconcha humboldti, Scacchinella* sp. and *Rhynchopora* sp.; and Shintani (2011) described five orthotetoid species: *Meekella striatocostata, M. nagaiwensis, Derbyia crassa, D. dorsosulcata* and *D. sakamotozawensis.*

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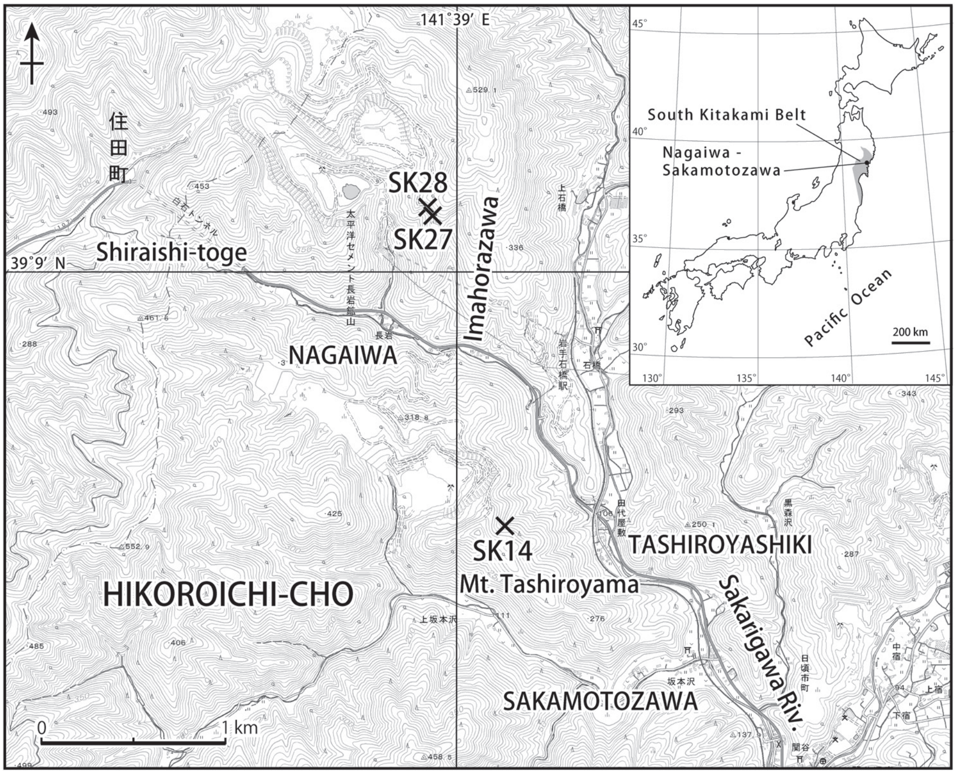

Fig. 1. Map showing the fossil localities, SK14, SK27 and SK28 in the Nagaiwa–Sakamotozawa area, using the topographic map of "Sakari" scale 1 : 25,000, published by the Geospatial Information Authority of Japan.

Thus, the present paper is the third report on the Nagaiwa–Sakamotozawa fauna.

This paper describes 10 species of productid brachiopods (suborder Productidina, Waagen, 1883), including one new species: *Echinauris opuntia* (Waagen, 1884), *Reticulatia* cf. *donetziana* (Licharew, 1938), *Echinaria* sp., *Juresania* sp., *Waagenoconcha humboldti* (d'Orbigny, 1842), *Edriosteges* cf. *multispinosus* Muir-Wood and Cooper, 1960, *Linoproductus simensis* (Tschernyschew, 1902), *Auriculispina kanmerai* Tazawa and Shintani, sp. nov., *Terrakea* sp. and *Cyclacantharia* sp. The geographic locations and stratigraphical horizons of the three fossil localities (SK14, SK27 and SK28), at which these species were found, are explained in detail by Shintani (2011, p. 75–76), and indicated in Figs. 1 and 2, respectively.

Among the productid species listed above, *Juresania* sp., *Waagenoconcha humboldti, Auriculispina kanmerai* and *Terrakea* sp. are Boreal (antitropical) elements, whereas *Echinauris opuntia* and *Cyclacantharia* sp. are Tethyan (tropical) elements. Therefore, the early Permian (Sakmarian) productid brachiopod fauna from the Nagaiwa–Sakamotozawa area is regarded as a mixed Boreal–Tethyan fauna with a predominance of Boreal elements.

The specimens described here were prepared by the second author (T. Shintani), and

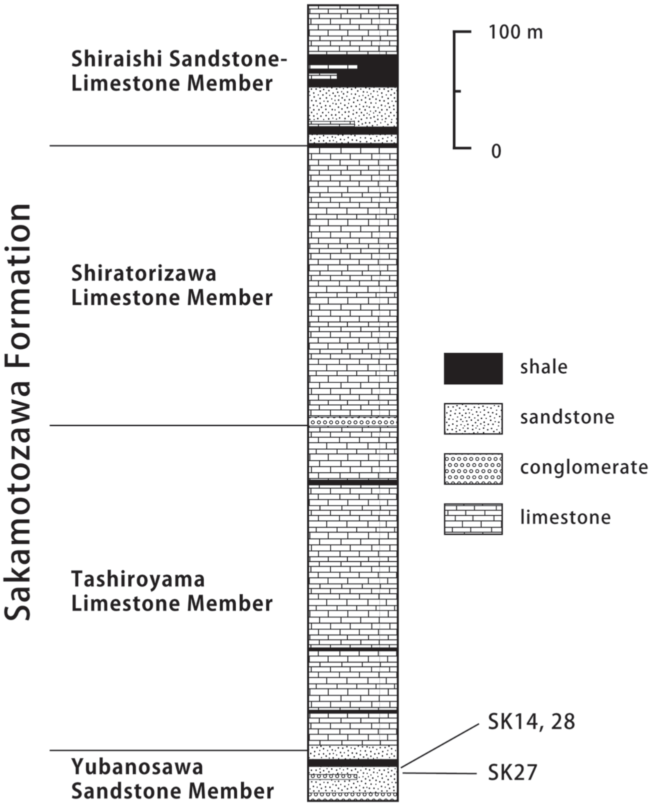

Fig. 2. Generalized columnar section of the Sakamotozawa Formation in the Nagaiwa–Sakamotozawa area, showing the fossil horizons, SK14, SK27 and SK28 (after Shintani, 2011).

are now registered and housed in the Department of Geology, Niigata University, Niigata, Japan, under the prefix NU-B.

Systematic descriptions

Order Productida Sarytcheva and Sokolskaya, 1959
Suborder Productidina Waagen, 1883
Superfamily Marginiferoidea Stehli, 1954
Family Costispiniferidae Muir-Wood and Cooper, 1960
Subfamily Costispiniferinae Muir-Wood and Cooper, 1960
Genus *Echinauris* Muir-Wood and Cooper, 1960

Type species.—*Echinauris lateralis* Muir-Wood and Cooper, 1960.

Echinauris opuntia (Waagen, 1884)
Fig. 3.5

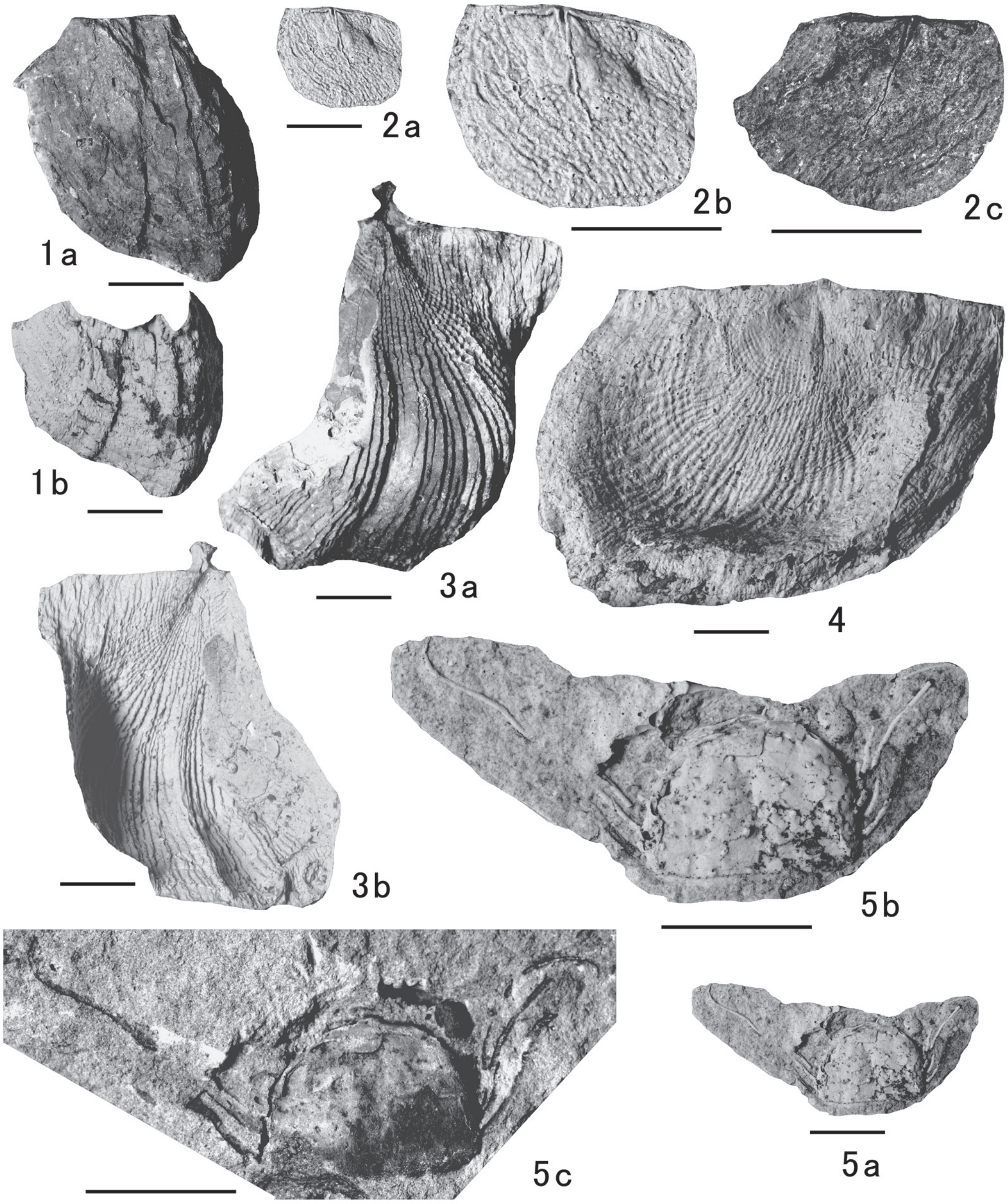

Fig. 3. 1. *Echinaria* sp., 1a, 1b, internal mould and external latex cast of ventral valve, NU-B1899; **2,** *Juresania* sp., 2a, 2b, 2c, internal latex cast and internal mould of dorsal valve, NU-B1900; **3, 4,** *Reticulatia* cf. *donetziana* (Licharew); 3a, 3b, internal mould and external latex cast of dorsal valve, NU-B1873; 4. external latex cast of dorsal valve, NU-B1874; **5,** *Echinauris opuntia* (Waagen); 5a, 5b, 5c, external latex cast and internal mould of ventral valve, NU-B1867. Scale bars represent 1 cm.

Productus opuntia Waagen, 1884, p. 707, pl. 79, figs. 1, 2.

Echinauris opuntia (Waagen): Grant, 1968, p. 27, pl. 8, figs. 1–8; pl. 9, figs. 1–8; Licharew and Kotlyar, 1978, pl. 20, fig. 14; Shen et al., 2000, p. 742, figs. 10.24–10.32; Shen and Shi, 2009, p. 158, figs. 3Y–3CC.

Material.—One specimen from locality SK27, external and internal moulds of a ventral valve, NU-B1867.

Remarks.—This specimen can be referred to *Echinauris opuntia* (Waagen, 1884), redescribed by Grant (1968, p. 27, pl. 8, figs. 1–8; pl. 9, figs. 1–8), from the Wargal Formation of the Salt Range, Pakistan, by its small, slightly transverse, rounded subtriangular ventral valve (length 11 mm, width 14 mm), with numerous long, thin spines on the lateral slopes. The type species, *Echinauris lateralis* Muir-Wood and Cooper (1960, p. 222, pl. 68, figs. 1–13), from the Word Formation of the Glass Mountains, western Texas, differs from the present species in the larger size and in having stronger and thicker spines on the ventral valve.

Distribution.—Sakmarian–Changhsingian: eastern Russia (South Primorye), northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt), central-southern China (Guangxi), southwestern China (Xizang) and Pakistan (Salt Range).

Superfamily Productoidea Gray, 1840

Family Dictyoclostidae Stehli, 1954

Subfamily Dictyoclostinae Stehli, 1954

Genus *Reticulatia* Muir-Wood and Cooper, 1960

Type species.—*Productus huecoensis* King, 1931.

Reticulatia cf. *donetziana* (Licharew, 1938)

Figs. 3.3, 3.4

Cf. *Productus donetzianus* Licharew, 1938, p. 78, pl. 1, fig. 5; Licharew, 1939, p. 91, pl. 20, figs. 5, 6.

Material.—Two specimens from locality SK27: (1) external and internal moulds of a dorsal valve, NU-B1873; (3) external mould of a dorsal valve, NU-B1874.

Description.—Shell medium in size for genus, transversely subrectangular in outline, with greatest width at hinge; length about 38 mm, width about 55 mm in the larger dorsal valve specimen (NU-B1874). Dorsal valve slightly concave, with broad and flattened visceral disc, strongly geniculated at anterior margin, and followed by a long trail with bordering reflexed flange, 8–9 mm length; ears large, slightly concave; fold low and narrow in trail.

External surface of dorsal valve ornamented by numerous costae and concentric rugae on visceral disc, costae only in trail; costae strong and round with narrow interspaces, becoming finer and more numerous in trail, and numbering 4–5 in 5 mm at midlength; rugae regularly developed, numbering 7–8 in 5 mm at midlength. Interior of dorsal valve with a large trilobed cardinal process. Other internal structures obscure.

Remarks.—These specimens resemble *Reticulatia donetziana* (Licharew, 1938), from the Upper Carboniferous (Kasimovian) of the Donetz Basin, western Russia, in having a peculiar bordering flange at antero-lateral margins of the dorsal valve. The same ringlike structure has been described and figured by Sutton (1942, p. 464, pl. 71, figs. 12, 13) in the specimens of *Reticulatia americana* (Dunbar and Condra, 1932) from the Pennsylvanian of Illinois, USA. The Kitakami species more like the Russian species than the American species in size, shape and external ornament of the dorsal valve.

Superfamily Echinoconchoidea Stehli, 1954

Family Echinoconchidae Stehli, 1954

Subfamily Echinoconchinae Stehli, 1954

Tribe Echinoconchini Stehli, 1954

Genus *Echinaria* Muir-Wood and Cooper, 1960

Type species.—*Productus semipunctatus* Shepard, 1838.

Echinaria sp.

Fig. 3.1

Material.—One specimen from locality SK27, external and internal moulds of a ventral valve, NU-B1899.

Remarks.—This specimen is a fragment of dorsal valve, lacking the posterior portion, but it is safely assigned to the genus *Echinaria* by its large, elongate ventral valve (length more than 37 mm, width about 28 mm), with narrow and moderately deep sulcus, and ornamented by numerous broad concentric lamellae, with 3–4 rows of spine bases on each lamella. The species identification is, however, difficult owing to the poorly preserved specimen.

Subfamily Juresaniinae Muir-Wood and Cooper, 1960

Tribe Juresaniini Muir-Wood and Cooper, 1960

Genus *Juresania* Fredericks, 1928

Type species.—*Productus juresanensis* Tschernyschew, 1902.

Juresania sp.
Fig. 3.2

Material.—One specimen from locality SK27, internal mould of a dorsal valve, NU-B1900.

Remarks.—This specimen can be assigned to the genus *Juresania* by its small-sized (length 24 mm+, width 27 mm) dorsal valve, with flat visceral disc, covered internally by numerous concentrically arranged endospines, and in having a long, thin breviseptum and short converging buttress plates enclosing end of breviseptum and the more posterior antron. The Kitakami species somewhat resembles *Juresania juresanensis* (Tschernyschew, 1902, p. 276, 620, pl. 29, figs. 1, 2; pl. 47, figs. 1, 2; pl. 53, fig. 4), from the Cora Limestone of Timan, northern Russia and from the *Schwagerina* Limestone (Sakmarian) of the Urals, central Russia, in size and shape of the dorsal valve, but accurate comparison is difficult due to the poorly preserved specimen.

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 humboldti (d'Orbigny, 1842)
Fig. 4.1

Productus humboldti d'Orbigny, 1842, p. 54, pl. 5, figs. 4–7; Tschernyschew, 1902, p. 275, 620, pl. 53, figs. 1–3; Kozlowski, 1914, p. 40, pl. 7, figs. 7–9; Fredericks, 1925, p. 19, pl. 2, fig. 84.

Waagenoconcha humboldti (d'Orbigny): Chao, 1927, p. 86, pl. 15, figs. 2, 3; Sarytcheva and Sokolskaya, 1952, p. 98, pl. 15, fig. 109; Chronic, 1953, p. 86, pl. 15, figs. 4–7; Muir-Wood and Cooper, 1960, p. 252, pl. 89, figs. 6–10; Samtleben, 1971, p. 60, pl. 2, figs. 17–19; Ifanova, 1972, p. 102, pl. 3, figs. 11–13; Tazawa, 1974, p. 125, pl. 1, figs. 2, 3; pl. 2, fig. 1; pl. 4, fig. 6; Duan and Li, 1985, p. 108, pl. 35, figs. 2, 3; Wang and Zhang, 2003, p. 94, pl. 9, figs. 5–7; pl. 15, figs. 8–10; Tazawa and Shintani, 2010, p. 56, figs. 4, 5.

Material.—One specimen from locality SK27, external mould of a dorsal valve, NU-B1872.

Remarks.—The material available is a dorsal valve specimen, transversely subrectangular in outline (length 19 mm, width 38 mm), with hinge slightly shorter than the maximum width; almost flat visceral disc, strongly geniculated at anterior margin, and followed by a short trail; external surface of the ventral valve is ornamented by numerous

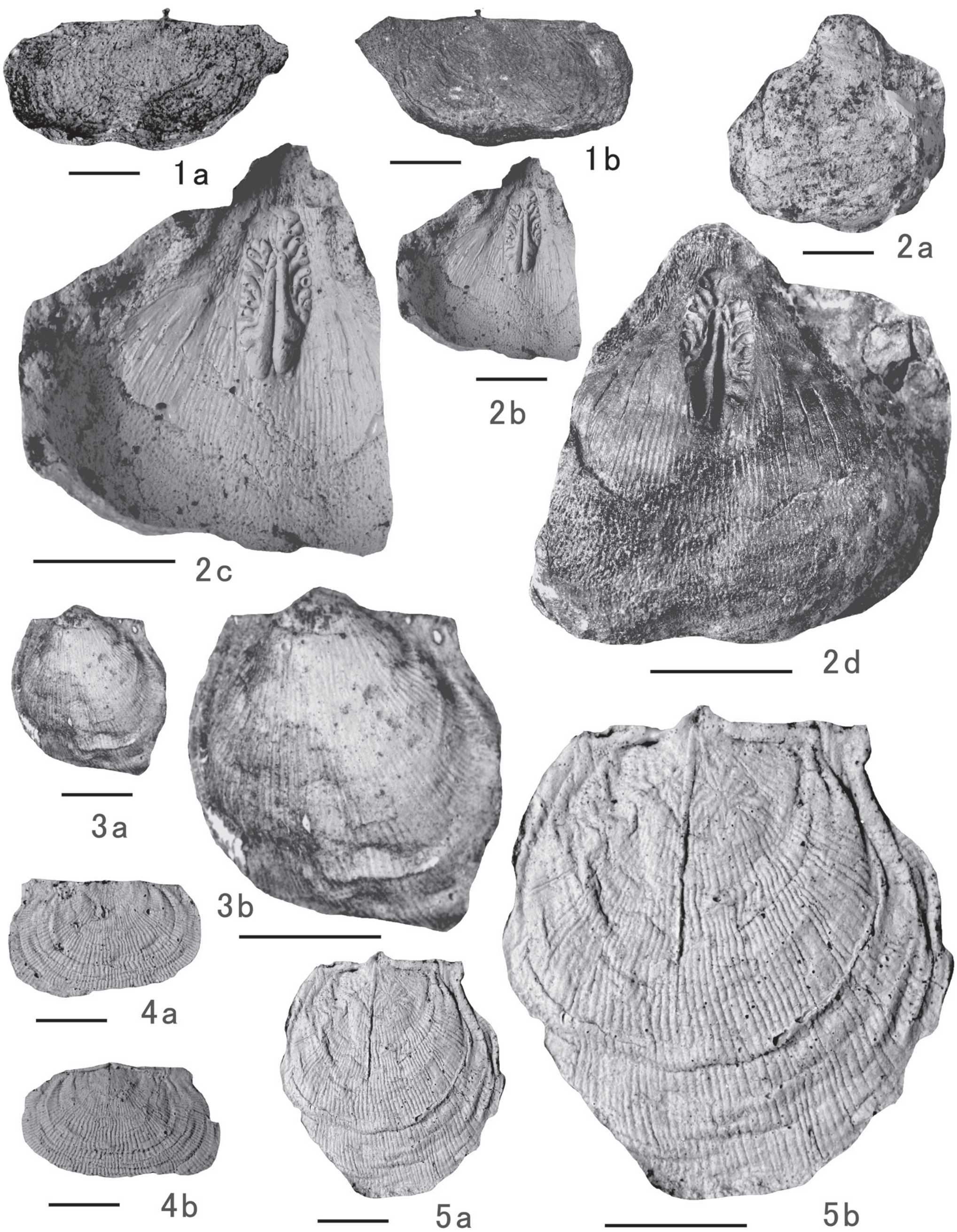

Fig. 4. 1, *Waagenoconcha humboldti* (d'Orbigny); 1a, 1b, external latex cast and external mould of dorsal valve, NU-B1872; **2,** *Edriosteges* cf. *multispinosus* Muir-Wood and Cooper; 2a, 2b, 2c, 2d, external latex cast, internal latex cast and internal mould of ventral valve, NU-B1868; **3–5,** *Linoproductus simensis* (Tschernyschew); 3a, 3b, external latex cast of ventral valve, NU-B1875; 4a, 4b, external latex cast and internal latex cast of dorsal valve, NU-B1879; 5a, 5b, internal latex cast of dorsal valve, NU-B1881. Scale bars represent 1 cm.

fine quincuncially arranged spine bases and several strong concentric rugae.

This specimen can be referred to *Waagenoconcha humboldti* (d'Orbigny, 1842), originally described from the Lower Permian (Asselian) of Yarbichambi, Bolivia, in size, shape and external ornament of the dorsal valve. Recently Tazawa and Shintani (2010) described *W. humboldti* from the basal part of the Sakamotozawa Formation at the locality SK27 in the Nagaiwa–Sakamotozawa area, South Kitakami Belt. The present specimen resembles well the previously described specimens from the Nagaiwa–Sakamotozawa area. Comparison with other *Waagenoconcha* species has been fully discussed by Tazawa and Shintani (2010, p. 57).

Distribution.—Gzhelian–Capitanian: western Russia (Moscow Basin), northern Russia (Timan, Pechora Basin and northern Urals), northern China (Inner Mongolia), eastern Russia (South Primorye), northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt) and Bolivia.

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 cf. *multispinosus* Muir-Wood and Cooper, 1960

Fig. 4.2

Cf. *Edriosteges multispinosus* Muir-Wood and Cooper, 1960, p. 104, pl. 17, figs. 1–10.

Material.—Two specimens from locality SK28: (1) external and internal moulds of a ventral valve, NU-B1868; (2) internal mould of a ventral valve, NU-B1869.

Description.—Shell medium in size for genus, equidimensional subquadrate in outline, widest at anterior one-third; length 33 mm, width about 34 mm in the larger specimen (NU-B1868). Ventral valve strongly convex medianly, flattened toward umbo, and with shallow sulcus on trail. External surface of ventral valve ornamented by numerous fine spines and obscure concentric lamellae; strong spines in group on ears and lateral slopes. Interior of ventral valve with narrow dendritic posterior and lobate anterior adductor scars, set on low median ridge; diductor scars large, broad, and longitudinally striated.

Remarks.—The Sakamotozawa species resembles well the type species, *Edriosteges multispinosus* Muir-Wood and Cooper, 1960, from the upper Leonard Formation of western Texas, in size and outline of the ventral valve, but accurate comparison is difficult owing to lack of the opposite valve.

Edriosteges sp. A, described by Tazawa and Araki (2014, p. 47, fig. 3.5) from the Upper Permian Nabekoshiyama Formation of Nabekoshiyama in the Kesennuma area, South Kitakami Belt, differs from the present species in the subtriangular outline of the ventral valve.

Superfamily Linoproductoidea Stehli, 1954
Family Linoproductidae Stehli, 1954
Subfamily Linoproductinae Stehli, 1954
Tribe Linoproductini Stehli, 1954
Genus *Linoproductus* Chao, 1927

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

Linoproductus simensis (Tschernyschew, 1902)
Figs. 4.3–4.5

Productus simensis Tschernyschew, 1902, p. 286, 626, pl. 35, fig. 7; pl. 55, figs. 2–5.
Linoproductus simensis (Tschernyschew): Volgin, 1960, p. 72, pl. 8, fig. 1; Zhao, 1965, p. 425, pl. 1, figs. 6, 7; Bamber and Waterhouse, 1971, pl. 16, figs. 8, 11; Sergunkova and Zhizhilo, 1975, p. 62, pl. 9, figs. 9, 10; pl. 10, figs. 8, 9; Lee and Gu, 1976, p. 258, pl. 139, figs. 9–12; Kalashnikov, 1980, p. 47, pl. 10, figs. 8, 9 only; Lee et al., 1980, p. 376, pl. 152, fig. 11; Tazawa et al., 2001, p. 38, figs. 2D–2J.
Linoproductus neimongolensis Lee and Gu, 1976, p. 258, pl. 178, figs. 1–10.

Material.—Seven specimens from locality SK27: (1) external and internal moulds of two ventral valves, NU-B1875, 1876; (2) external and internal moulds of three dorsal valves, NU-B1877–1879; (3) external mould of a dorsal valve, NU-B1880; (4) internal mould of a dorsal valve, NU-B1881.

Description.—Shell small in size for genus, slightly elongated oval in outline, hinge slightly shorter than greatest width at midlength; ears small, well demarcated from visceral region; cardinal extremities obtuse, angular; length 37 mm, width 35 mm in the largest dorsal valve specimen (NU-B1881); length 25 mm, width 23 mm in best preserved ventral valve specimen (NU-B1875). Ventral valve strongly and unevenly convex in lateral profile, most convex at umbonal region, not geniculated; sulcus absent. Dorsal valve slightly concave in both lateral and anterior profiles, with almost flat visceral disc; no fold. External surface of ventral valve ornamented by numerous costellae and some rugae; costellae numbering 11–12 in 5 mm at midlength; rugae developed on ears and lateral slopes; some spine bases on ears. External ornament of dorsal valve like those of ventral valve, but rugae more irregularly developed on the visceral disc. Interior of dorsal valve with a long median septum extending to midlength of the valve; a pair of strong but short lateral ridges, and large dendritic adductor scars.

Remarks.—These specimens are referred to *Linoproductus simensis* (Tschernyschew, 1902), from the *Schwagerina* Limestone (Sakmarian) of the Urals, in size, shape and external ornament of the ventral valve. *Linoproductus neimongolensis* Lee and Gu, 1976, from the Lower Permian of the Dongujimqinqi area, Inner Mongolia, is a junior synonym of *L. simensis*. Shells described by Chao (1927, p. 137, pl. 14, figs. 6–8) as *Linoproductus simensis* (Tschernyschew), from the Visean of Guizhou, southwestern China, differs from *L. simensis* in having stronger and fewer costellae (9–10 in 5 mm).

Linoproductus hayasakai Tazawa (1979, p. 26, pl. 4, figs. 5–11), from the lower Kamiyasse Formation (Wordian) of Wayama in the Kesennuma area, South Kitakami Belt, differs from *L. simensis* in its larger, transverse shell and in having stronger costellae (7–9 in 5 mm) on the ventral valve.

Distribution.—Kasimovian–Roadian: northern Russia (northern and southern Urals), Uzbekistan (Fergana), northern China (Inner Mongolia), northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt) and northern Canada (Yukon Territory).

Family Kansuellidae Muir-Wood and Cooper, 1960

Subfamily Auriculispininae Waterhouse, 1986

Tribe Auriculispinini Waterhouse, 1986

Genus *Auriculispina* Waterhouse, 1975

Type species.—*Cancrinella levis* Maxwell, 1964.

Auriculispina kanmerai sp. nov.

Figs. 5.1–5.3

Etymology.—Named for late Professor Kametoshi Kanmera.

Material.—Twelve specimens from locality SK27: (1) external and internal moulds of five ventral valves, NU-B1882 (holotype), NU-B1883–1886; (2) internal moulds of three ventral valves, NU-B1887–1889; (3) external and internal moulds of two dorsal valves, NU-B1890, 1891; (4) internal mould of two dorsal valves, NU-B1892, 1893.

Diagnosis.—Small-sized *Auriculispina*, ornamented with 7–8 capillae per 2 mm in ventral valve.

Description.—Shell small in size for genus, transversely subquadrate in outline, with greatest width at about midlength; length 7 mm, width about 9 mm in the holotype (NU-

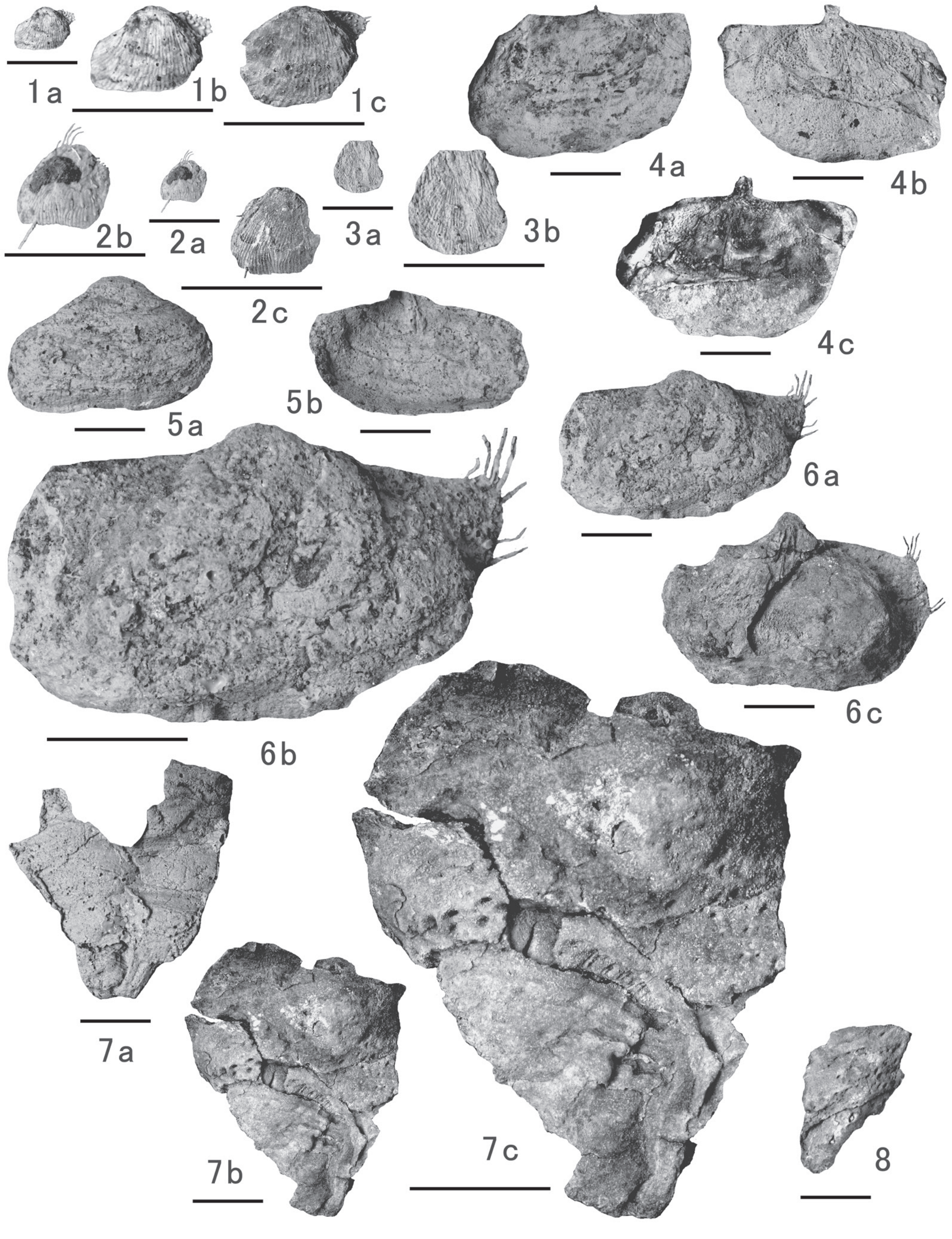

Fig. 5. 1–3, *Auriculispina kanmerai* Tazawa and Shintani, sp. nov.; 1a, 1b, 1c, external latex cast and internal mould of ventral valve, NU-B1882 (holotype); 2a, 2b, 2c, external latex cast and internal mould of ventral valve, NU-B1884; 3a, 3b, internal latex cast of dorsal valve, NU-B1893; **4–6,** *Terrakea* sp.: 4a, 4b, 4c, external latex cast, internal latex cast and internal mould of dorsal valve, NU-B1897; 5a, 5b, external latex cast and internal latex cast of ventral valve, NU-B1894; 6a, 6b, 6c, external latex cast and internal mould of ventral valve, NU-B1895; **7, 8,** *Cyclacantharia* sp.; 7a, 7b, 7c, external latex cast and internal mould of ventral valve, NU-B1870; 8, internal mould of ventral valve, NU-B1871. Scale bars represent 1 cm.

B1882). Ventral valve gently convex; ears moderate size, gently convex; no sulcus. Dorsal valve slightly concave; no fold. External surface of ventral valve ornamented by numerous fine capillae, some weak rugae and numerous spines; capillae often irregular and flexuous, numbering 7–8 in 2 mm at midlength; rugae developed near anterior margin; spine bases cluster on ears and scattered over valve. Dorsal valve capillate, without spines or spine bases. Internal structures of both valves not well preserved.

Remarks.—*Auriculispina kanmerai* Tazawa and Shintani, sp. nov. most resembles *Auriculispina capillata* (Waterhouse, 1988, p. 156, fig. 8), from the Grant Formation (Asselian–Sakmarian) of the Canning Basin, western Australia, in size and shape of the shell, but the present new species differs from the Australian species in having finer capillae on the ventral valve.

The type species, *Auriculispina levis* (Maxwell, 1964, p. 34, pl. 6, figs. 15–18), from the Upper Carboniferous and the Lower Permian (Sakmarian) of the Yarrol Basin, eastern Australia, is readily distinguished from *A. kanmerai* by the larger and more transverse shell and in having coarser capillae on the ventral valve.

Subfamily Paucispinauriinae Waterhouse, 1986

Tribe Paucispinauriini Waterhouse, 1986

Genus *Terrakea* Booker, 1930

Type species.—*Productus brachythaerus* Morris in de Strezelecki, 1845.

Terrakea sp.

Figs. 5.4–5.6

Material.—Five specimens from localities SK28 and SK14: (1) external and internal moulds of two ventral valves, NU-B1894, 1895; (2) internal mould of a ventral valve, NU-B1896; (3) external and internal moulds of two dorsal valves, NU-B1897, 1898.

Description.—Shell large in size for genus, transversely subrectangular in outline, with greatest width at midlength; length 28 mm, width 38 mm in the largest specimen (NU-B1895). Ventral valve strongly and unevenly convex in lateral profile, most convex at umbonal region, flattened in visceral disc, geniculated and followed by a short trail; ears small, slightly convex; sulcus very shallow if it is present; lateral slopes steep. Dorsal valve moderately concave, with broad, flat visceral disc, geniculated, and followed by a short trail. External surface of ventral valve ornamented by numerous rugae and fine spine bases; spine bases clustered on ears and scattered on visceral region. External ornament of dorsal valve similar to the opposite valve, but spine bases are finer than those of the ventral valve. Ventral interior with broad, longitudinally striated diductor scars and elongate oval, finely dendritic adductor scars. Dorsal interior with a long median septum and short, slightly diverging lateral ridges. Adductor muscle scars large, finely dendritic.

Remarks.—These specimens can be assigned to the genus *Terrakea* by their size, shape and external ornament of both ventral and dorsal valves. The Sakamotozawa species somewhat resembles the type species, *Terrakea brachythaera* (Morris in de Strezelecki, 1845), redescribed and refigured by Briggs (1998, p. 176, figs. 87A–87I), from the Broughton Formation of the Sydney Basin, eastern Australia, in outer configuration, but accurate comparison is difficult due to the ill-preserved specimens.

Terrakea nabekoshiyamensis Tazawa (2012, p. 26, figs. 4.13, 4.14), from the Nabekoshiyama Formation of Nabekoshiyama in the Kesennuma area, South Kitakami Belt, is a transverse species, but it differs from the present species by the much smaller dimensions.

Superfamily Richthofenioidea Waagen, 1885
Family Teguliferinidae Muir-Wood and Cooper, 1960
Subfamily Cyclacanthariinae Cooper and Grant, 1975
Genus *Cyclacantharia* Cooper and Grant, 1969

Type species.—*Cyclacantharia kingorum* Cooper and Grant, 1969.

Cyclacantharia sp.
Figs. 5.7, 5.8

Material.—Two specimens from locality SK14: (1) external and internal moulds of a ventral valve, NU-B1870; (2) internal mould of a ventral valve, NU-B1871.

Remarks.—These specimens are safely assigned to the genus *Cyclacantharia* by their highly cone-shaped ventral valve (height about 40 mm in the larger specimen, NU-B1870), without a median septum and with numerous strong spine bases all around the inside of the cup aperture. The Kitakami species resembles the type species, *Cyclacantharia kingorum* Cooper and Grant (1969, p. 7, pl. 5, figs. 13–16) from the Word Formation of western Texas, in size and shape of the ventral valve. However, accurate comparison is difficult because of ill preservation of the present material.

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Systematics and palaeobiogeograpy of Permian brachiopods from Pliocene conglomerate of Hitachi, central Japan

Jun-ichi TAZAWA*

Abstract

This paper describes a Permian brachiopod fauna (Ishinazaka fauna) from shale and argillaceous limestone boulders in the basal conglomerate of the Pliocene Kume Formation of Hitachi, central Japan, and reexamines the age and palaeobiogeography of the fauna. The results, which are the same as our previous opinions, are as follows: 1) the Ishinazaka fauna, consisting of 17 species in 16 genera, resembles the middle Permian brachiopod fauna of the South Kitakami Belt in species composition, and indicates a middle Permian (Wordian) in age; 2) the Ishinazaka fauna is a mixed Boreal–Tethyan fauna in the Sino-Mongolian–Japanese Province; and 3) the Hitachi area was probably part of the continental shelf bordering the eastern margin of North China during the Wordian.

Key words: Ayukawa Formation, brachiopod, Hitachi Palaeozoic rocks, Ishinazaka fauna, Permian.

Introduction

The Hitachi Palaeozoic rocks (=Hitachi metamorphic rocks, Watanabe, 1920–1921; Kuroda, 1959; Tagiri, 1971), which contain the oldest rocks in Japan, are important for understanding the origin and geotectonic development of the Japanese Islands. Tagiri et al. (2011) proposed that the Hitachi Palaeozoic rocks originated from sediments of a Cambrian–Permian magmatic arc in the marginal area of North China (Sino-Korea), based on SHRIMP zircon dating and chemical analysis of the rocks. However, the origin of the Hitachi

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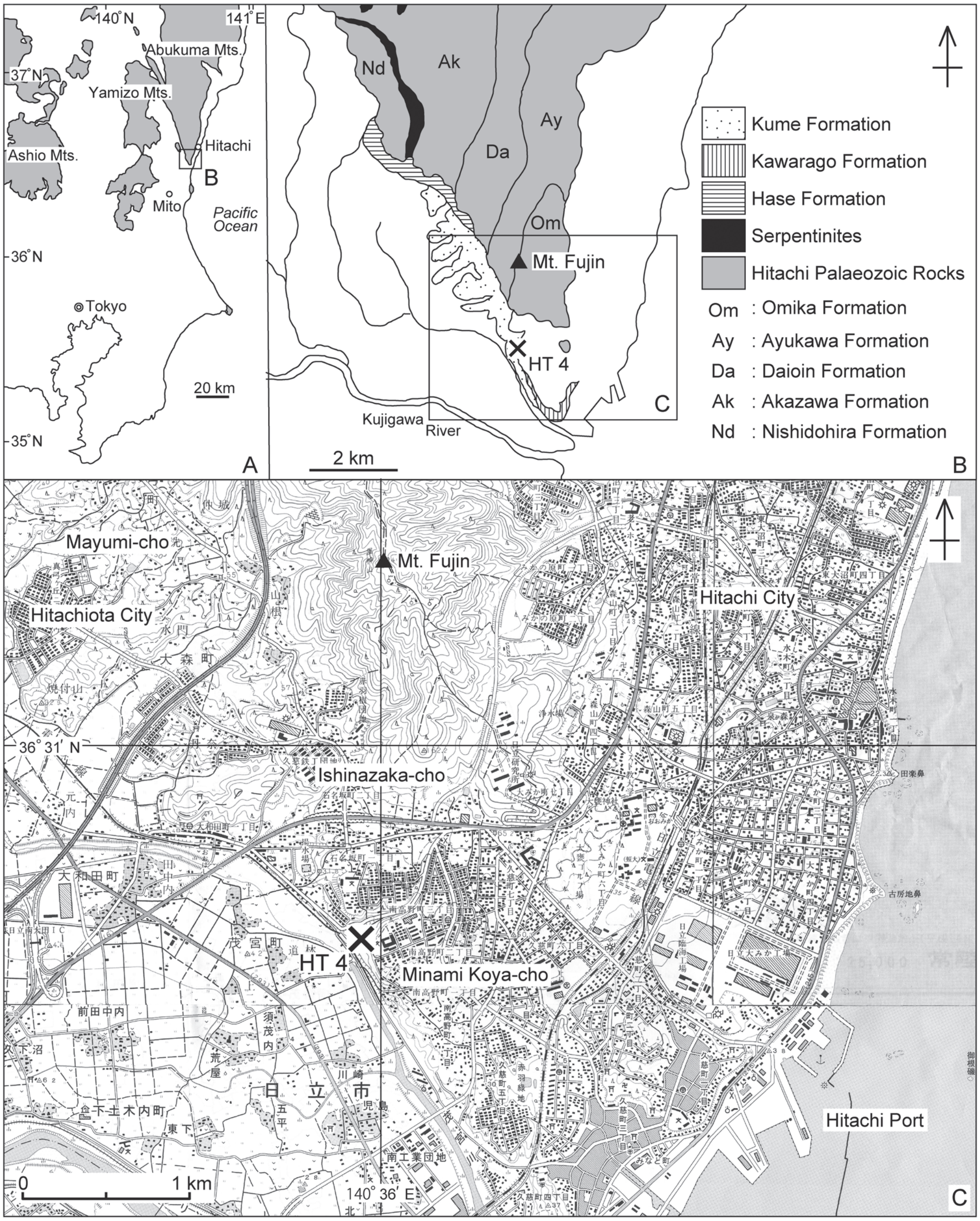


Fig. 1. Maps showing the location and geology of the Hitachi area, including the locations of fossil locality (HT4). (A) Distribution of pre-Neogene rocks in the eastern Kanto region (based on Takeuchi, 2008). (B) Geologic map of the Hitachi area (based on Tagiri et al., 2011). (C) Topographic map of the Hitachi area. Using 1 : 25,000 scale topographic maps of "Hitachi-Ota", "Hitachi-Kuji" and "Southern Hitachi", published by the Geospatial Information Authority of Japan (after Tazawa et al., 2014).

Palaeozoic rocks is still uncertain. For instance, Isozaki et al. (2010) assigned the Hitachi Palaeozoic rocks to the eastern extension of the Dabie–Sulu UHP metamorphic rocks in the collisional suture between North China and South China (Yangtze).

Recently, Tazawa et al. (2014) found a Permian brachiopod fauna (Ishinazaka fauna) from shale and argillaceous limestone boulders in the basal conglomerate of the Pliocene Kume Formation of Hitachi, central Japan, and stated as follows: 1) the fossil-bearing boulders are probably derived from the Permian Ayukawa Formation belonging to the Hitachi Palaeozoic rocks; 2) the Ishinazaka fauna, which contains 17 species in 16 genera, resembles the middle Permian brachiopod fauna of the South Kitakami Belt in terms of species composition, and indicates a middle Permian (Wordian) in age; 3) the Ishinazaka fauna is a mixed Boreal–Tethyan fauna in the Sino-Mongolian–Japanese Province; 4) the Ayukawa Formation is correlated with the lower to upper Permian of the southern Kitakami Mountains, northeastern Japan; and 5) the Hitachi area was probably located in the continental shelf bordered the eastern margin of North China during the Wordian.

This paper describes the Ishinazaka fauna on the material reported by Tazawa et al. (2014), and reexamines the age and biogeography of the fauna. The results are the same as those in Tazawa et al. (2014). The brachiopod specimens described below are registered with the prefix KFM and housed in the Kuzu Fossil Museum in Kuzu, Sano City, Tochigi Prefecture, Japan.

Geological setting

According to Tazawa et al. (2014), the brachiopod specimens of this study were collected from shale and argillaceous limestone boulders from the basal conglomerate of the Pliocence Kume Formation (Suzuki and Omori, 1953; Ozaki and Saito, 1954), which crops out at locality HT4 (36° 30′ 24″ N, 140° 35′ 53″ E). This locality is a cutting at the western border of the Sakamoto Elementary School, Minamikoya-cho, Hitachi City, Ibaraki Prefecture, central Japan (Figs. 1–3). The fossil-bearing boulders are black shale and dark grey argillaceous limestone of 0.3 to 1.5 m in diameter, and contain fossils of brachiopods, bryozoans, crinoids, fusulinids, bivalves, gastropods and trilobites. The Pliocence Kume Formation is distributed in the southwestern side of the Hitachi Palaeozoic rocks (Fig. 1B). Therefore, the fossil-bearing boulders are considered to have been derived from the Hitachi Palaeozoic rocks, probably from the Permian Ayukawa Formation, which consists of weakly metamorphosed or non-metamorphosed tuffaceous shale and sandstone, associated with minor limestone and conglomerate (Tagiri and Hiroi, 2008), and contains an early Permian fusulinid, "*Pseudofusulina*" *vulgaris,* reported by Sugiyama (1972) from a lenticular limestone block. The fossil-bearing shale and argillaceous limestone boulders are similar in lithology to those of the Ayukawa Formation, and also to those of the lower Kanokura Series (Minato et al.,

Fig. 2. Outcrop of the basal conglomerate of the Kume Formation in the fossil locality HT4, cutting at the western border of the Sakamoto Elementary School, Minamikoya-cho, Hitachi City, Ibaraki Prefecture.

1979), including the lower Kanokura Formation (Tazawa and Ibaraki, 2001) and lower Kamiyasse Formation (Misaki and Ehiro, 2004) of the South Kitakami Belt, northeastern Japan.

The Ishinazaka fauna

The brachiopods of the Ishinazaka fauna contains the following 17 species in 16 genera: *Isogramma heritschi* Nakamura, 1970, *Kitakamichonetes multicapillatus* Afanasjeva and Tazawa, 2007, *Transennatia gratiosa* (Waagen, 1884), *Spinomarginifera kueichowensis* Huang, 1932, *Bathymyonia ussurica* Kotlyar in Licharew and Kotlyar, 1978, *Bathymyonia neimongolica* (Wang and Zhang, 2003), *Urushtenoidea chaoi* (Jin, 1963), *Linoproductus* sp., *Permianella typica* He and Zhu, 1979, *Dicystoconcha lapparenti* Termier and Termier in Termier et al., 1974, *Schuchertella debaisiensis* Wang and Zhang, 2003, *Uncinunellina timorensis* (Beyrich, 1865), *Cleiothyridina* sp., *Martinia* sp., *Spiriferella* sp., *Spiriferellina fredericksi* Tazawa, 2014 and *Whitspakia* sp.

Representative specimens from the Ishinazaka fauna are shown in Figs. 6–8, and the

Fig. 3. Close view of the outcrop of the basal conglomerate of the Kume Formation in the fossil locality HT4.

geographical and stratigraphical distributions of the brachiopod species in the fauna, excluding 5 uncertain species, are summarized in Fig. 4.

Age and correlation

As shown in Fig. 4, *Isogramma heritschi* and *Spiriferellina fredericksi* are known from the Wordian; *Bathymyonia ussurica* and *B. neimongolica* are known from the Wordian–Capitanian; *Kitakamichonetes multicapillatus*, *Spinomarginifera kueichowensis* and *Permianella typica* are known from the Wordian–Wuchiapingian; and *Transennatia gratiosa* is known from the Wordian–Changhsingian. On the other hand, *Urushtenoidea chaoi* is known from the Roadian–Capitnian; *Dicystoconcha lapparenti* is known from the Kungurian–Wuchiapingian; and *Schuchertella debaisiensis* is known from the Kungurian–Wordian. *Uncinunellina timorensis* is a long-ranging species, known from the Asselian–Changhsingian.

In summary, the Ishinazaka fauna is identified as Wordian, which is younger than the early Permian age determined from the fusulinid species, "*Pseudofusulina*" *vulgaris* by Sugiyama (1972). The Ishinazaka fauna is determined to have been derived from the upper horizon rather than the fusulinid-bearing limestone bed of the Ayukawa Formation.

Species \ Region, Stage	Japan: Abukuma Belt	Japan: South Kitakami Belt		Japan: Hida Gaien B.																Permian								
	Hitachi	S. Kitakami Mts.	Abukuma Mts.	Moribu, Oguradani	Mizukoshi	Northwestern China	Northern China	Northeastern China	Eastern Russia	Eastern China	Central–Southern China	Southwestern China	Vietnam	Cambodia	Malaysia	Indonesia (Timor)	Nepal (Kumaon Himalayas)	Pakistan (Salt Range)	Afghanistan	Greece (Hydra Island)	Asselian	Sakmarian	Artinskian	Kungurian	Roadian	Wordian	Capitanian	Wuchiapingian	Changhsingian
Isogramma heritschi	+	+																								—			
Kitakamichonetes multicapillatus	+	+			+																					—	—	—	
Transennatia gratiosa	+	+	+	+	+	+		+	+	+	+	+	+	+	+		+	+		+						—	—	—	—
Spinomarginifera kueichowensis	+	+								+	+	+	+													—	—	—	
Bathymyonia ussurica	+						+		+																	—	—		
Bathymyonia neimongolica	+	+					+																			—	—		
Urushtenoidea chaoi	+									+		+		+	+										—	—	—		
Permianella typica	+	+			+					+		+			+											—	—	—	
Dicystoconcha lapparenti	+	+					+			+	+								+					—	—	—	—	—	
Schuchertella debaisiensis	+						+																	—	—	—			
Uncinunellina timorensis	+					+				+	+	+				+		+			—	—	—	—	—	—	—	—	—
Spiriferellina fredericksi	+	+							+																	—			

Fig. 4. Geographic and stratigraphic distributions of brachiopod species of the Ishinazaka fauna, excluding 5 uncertain species (modified from Tazawa et al., 2014).

Palaeobiogeography

Of the 17 species of the Ishinazaka fauna, 8 species also occur in the southern Kitakami Mountains (South Kitakami Belt), and 5 are known from eastern China and southwestern China, The Wordian fauna of the South Kitakami Belt shows particularly strong affinity with the Ishinazaka fauna. In palaeobiogeographical terms, *Bathymyonia* and *Spiriferella* are Boreal (antitropical)-type genera, whereas *Isogramma, Transennatia, Spinomarginifera, Permianella, Dicystoconcha* and *Urushtenoidea* are Tethyan (tropical)-type genera. Moreover, *Schuchertella debaisiensis* and *Spiriferellina fredericksi* are probably antitropical elements. Therefore, the Ishinazaka fauna is a mixed Boreal–Tethyan fauna dominated by Tethyan elements.

The present results indicate that during the middle Permian (Wordian) the Hitachi area was located slightly south to the South Kitakami area and also in a transitional zone between the Boreal and Tethyan realms, the Sino-Mongolian–Japanese Province (Shi and Tazawa, 2001, Shen et al., 2009) (Fig. 5). This province is equivalent to the Inner Mongolia–Japan Transitional Zone of Tazawa (1991, 2007), developed along the northern and eastern margins of North China. The Ayukawa Formation probably represents the southern extension of the Permian deposits of the South Kitakami Belt.

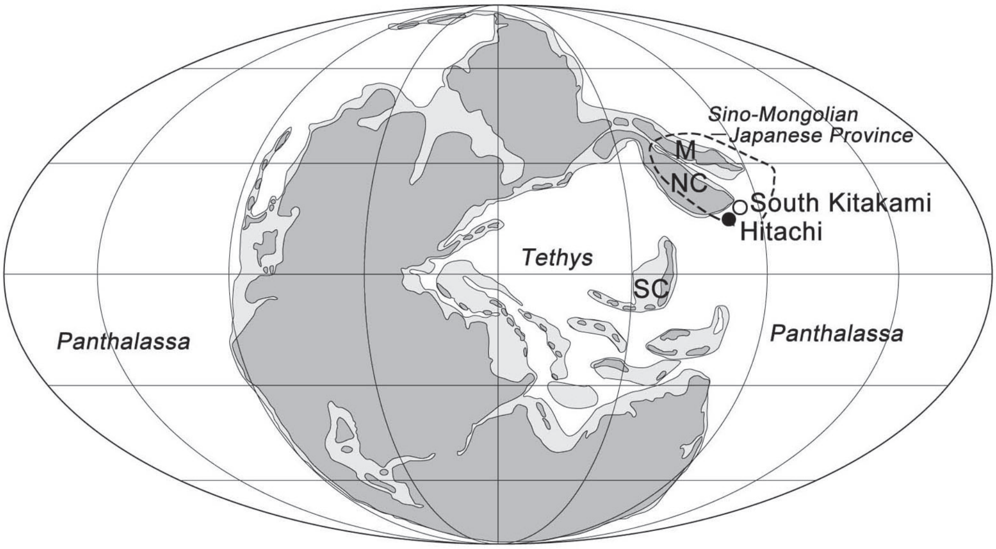


Fig. 5. Simplified middle Permian (Wordian) world map showing the Sino-Mongolian–Japanese Province and palaeoposition of both South Kitakami and Hitachi, using base map of Shen et al. (2009). M: Mongolia, NC: North China, SC: South China (after Tazawa et al., 2014).

Systematic descriptions

Order Dictyonellida Cooper, 1956
Superfamiy Eichwaldioidea Schuchert, 1893
Family Isogrammidae Schuchert, 1929
Genus *Isogramma* Meek and Worthen, 1870

Type species.—*Chonetes*? *millepunctatus* Meek and Worthen, 1870.

Isogramma heritschi Nakamura, 1970
Fig. 6.4

Isogramma heritschi Nakamura, 1970, p. 308, pl. 4, figs. 3–7; Minato et al., 1979, pl. 57, figs. 2–4, 6; Tazawa et al., 2014, p. 378, fig. 2.4.

Material.—One specimen, internal mould of a dorsal valve, KFM1872.

Remarks.—This specimen can be referred to *Isogramma heritschi* Nakamura, 1970, from the lower Kamiyasse Formation of the Kamiyasse–Imo area, South Kitakami Belt, northeastern Japan, by its medium-sized, flat, semicircular dorsal valve (length about 20 mm, width about 30 mm), and the external ornament consisting of numerous very fine concentric growth lines and stronger concentric rugae; numbering 10–11 growth lines in 1 mm, 2–3 rugae in 5 mm at about midlength. *Isogramma paotechowensis* (Grabau and Chao in Chao, 1928, p. 33, pl. 1, fig. 27; pl. 4, figs. 1–5), from the Taiyuan Formation of Shanxi, northern China, is readily distinguished from *I. heritschi* by its larger dimensions and in having coarser growth lines in the dorsal valve.

Distribution.—Wordian: northeastern Japan (Kamiyasse–Imo in the South Kitakami Belt).

Order Productida Sarytcheva and Sokolskaya, 1959
Suborder Chonetidina Muir-Wood, 1955
Superfamily Chonetoidea Bronn, 1862
Family Rugosochonetidae Muir-Wood, 1962
Subfamily Chalimochonetinae Afanasjeva, 1988
Genus *Kitakamichonetes* Afanasjeva and Tazawa, 2007

Type species.—*Kitakamichonetes multicapillatus* Afanasjeva and Tazawa, 2007.

Kitakamichonetes multicapillatus Afanasjeva and Tazawa, 2007
Fig. 6.1

Kitakamichonetes multicapillatus Afanasjeva and Tazawa, 2007, p. 73, pl. 11, figs. 1–12; Tazawa, 2008b, p. 42, figs. 6.3, 6.4; Tazawa et al., 2014, p. 378, fig. 2.1.

Material.—One specimen, internal mould of a ventral valve, KFM1890.

Remarks.—The single imperfect specimen from Hitachi is referred to *Kitakamichonetes multicapillatus* Afanasjeva and Tazawa, 2007, from the lower Kamiyasse Formation of the Kamiyasse–Imo area, South Kitakami Belt, by its large chonetid shell (length more than 19 mm, width more than 22 mm), numerous costellae (numbering 9 in 2 mm near anterior valve margin) and long median septum in the ventral valve.

Distribution.—Wordian–Wuchiapingian: northeastern Japan (Kamiyasse–Imo in the South Kitakami Belt), central Japan (Hitachi) and southwestern Japan (Mizukoshi in central Kyushu, western extension of the Hida Gaien Belt).

Suborder Productidina Waagen, 1884
Superfamily Marginiferoidea Stehli, 1954
Family Marginiferidae Stehli, 1954
Subfamily Marginiferinae Stehli, 1954
Genus *Transennatia* Waterhouse, 1975

Type species.—*Productus gratiosus* Waagen, 1884.

Transennatia gratiosa (Waagen, 1884)
Figs. 6.2, 6.3

Productus gratiosus Waagen, 1884, p. 691, pl. 72, figs. 3–7; Diener, 1897, p. 23, pl. 3, figs. 3–7; Mansuy, 1913, p. 115, pl. 13, fig. 1; Colani, 1919, p. 10, pl. 1, fig. 2; Chao, 1927, p. 44, pl. 4, figs. 6–10; Chi-Thuan, 1962, p. 491, pl. 2, figs. 5–7.

Productus (*Dictyoclostus*) *gratiosus* Waagen: Huang, 1933, p. 88, pl. 11, fig. 14; Hayasaka, 1960, p. 49, pl. 1, fig. 8.

Marginifera gratiosa (Waagen): Reed, 1944, p. 98, pl. 19, figs. 6, 7.

Dictyoclostus gratiosus (Waagen): Zhang and Ching (Jin), 1961, p. 411, pl. 4, figs. 12–18; Wang et al., 1964, p. 291, pl. 45, figs. 14–19; Leman, 1994, pl. 1, figs. 11–13.

Gratiosina gratiosa (Waagen): Grant, 1976, pl. 33, figs. 19–26; Licharew and Kotlyar, 1978, pl. 12, figs. 5, 6; pl. 20, fig. 1; Minato et al., 1979, pl. 61, figs. 11–13.

Asioproductus gratiosus (Waagen): Yang et al., 1977, p. 350, pl. 140, fig. 5; Feng and Jiang, 1978, p. 254, pl. 90, figs. 1, 2; Tong, 1978, p. 228, pl. 80, fig. 7; Lee et al., 1980, p. 373, pl. 164, fig. 14; pl. 166, figs. 5, 6.

Gratiosina sp. Minato et al., 1979, pl. 61, fig. 14.

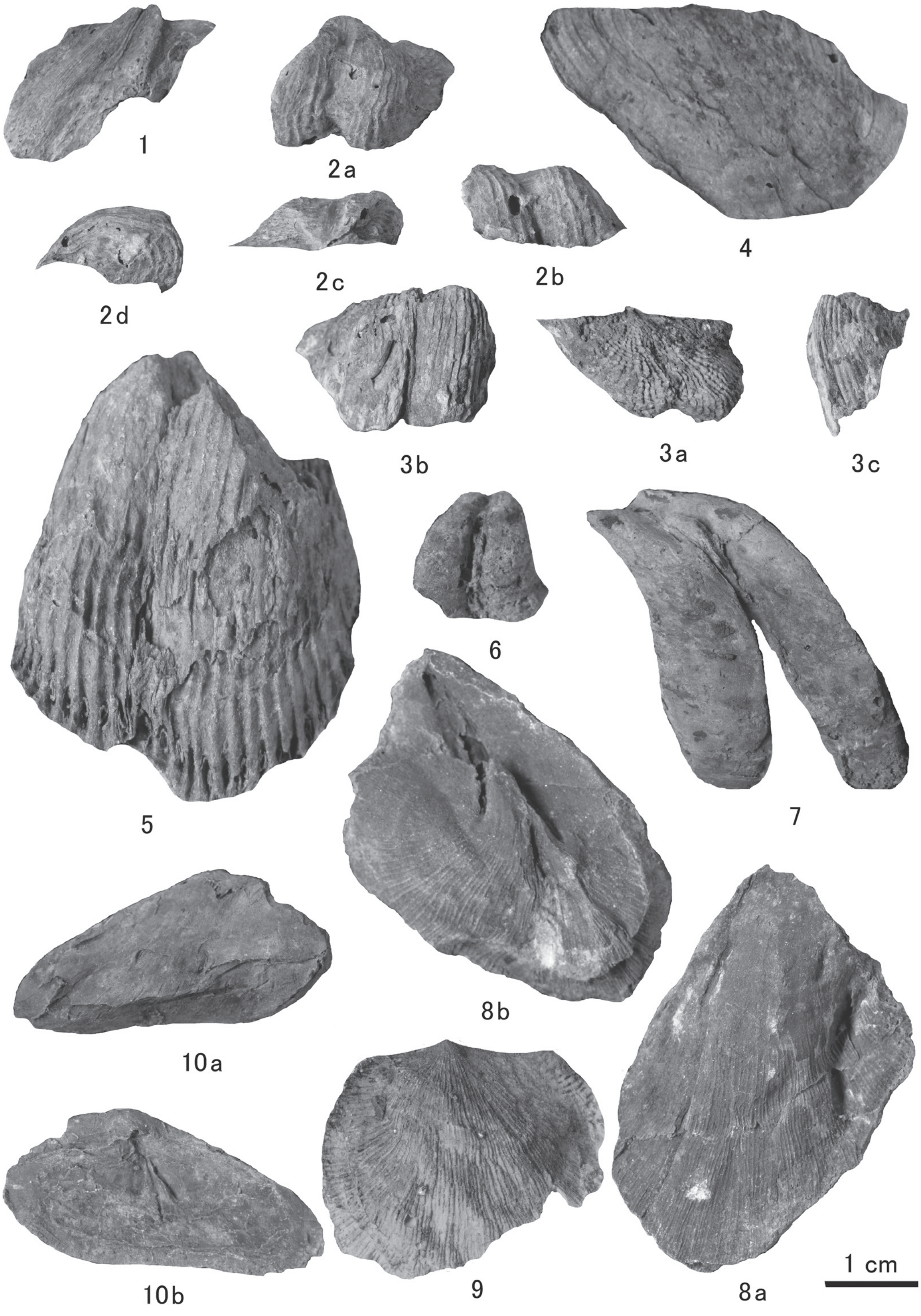
Dictyoclostus minor Lee and Gu in Lee et al., 1980, p. 372, pl. 166, figs. 1–4.

Transennatia gratiosus (Waagen): Wang et al., 1982, p. 214, pl. 92, figs. 6–8; pl. 102, figs. 4–9; Liu et al., 1982, p. 185, pl. 132, fig. 9; Ding and Qi, 1983, p. 280, pl. 95, fig. 14; Zeng et al., 1995, pl. 5, figs. 14, 15.

Transennatia gratiosa (Waagen): Yang, 1984, p. 219, pl. 33, fig. 7; Jin, 1985, pl. 4, figs. 33, 34, 45, 46; Tazawa and Matsumoto, 1998, p. 6, pl. 1, figs. 4–8; Tazawa et al., 2000, p. 7, pl. 1, figs. 3–5; Tazawa, 2001, p. 289, figs. 6.1–6.7; Tazawa and Ibaraki, 2001, p. 7, pl. 1, figs. 1–3; Shen et al., 2002, p. 676, figs. 4.27–4.31; Tazawa, 2002, fig. 10.2; Chen et al., 2005, p. 354, figs. 10E–10H, 11; Tazawa, 2008a, p. 26, fig. 4.1; Tazawa, 2008b, p. 43, figs. 6.6, 6.7; Shen and Zhang, 2008, figs. 4.20–4.22; Shen and Clapham, 2009, p. 718, pl. 1, figs. 13–22; Shen and Shi, 2009, p. 157, figs. 3K–3O; Tazawa et al., 2014, p. 378, figs. 2.2, 2.3.

Material.—Fifteen specimens: (1) internal moulds of three ventral valves, KFM1873–1875; (2) external moulds of twelve dorsal valves, KFM1876–1887.

Remarks.—These specimens are referred to *Transennatia gratiosa* (Waagen, 1884), originally described from the Wargal and Chhidru formations of the Salt Range, Pakistan, on the basis of their small size (length 13 mm, width 17 mm in the largest specimen, KFM1874), strongly convex ventral valve, strongly geniculated dorsal valve and sharply reticulate ornament on the visceral discs of both valves, although the Hitachi specimens are smaller in


1
2a
2b
2c
2d
3a
3b
3c
4
5
6
7
8a
8b
9
10a
10b
1 cm

size than the Salt Range specimens. *Dictyoclostus minor* Lee and Gu (in Lee et al., 1980), from the Miaoling Formation of Jilin, northeastern China, is probably a junior synonym of the present species.

Distribution.—Wordian–Changhsingian: northern China (Shaanxi), northeastern China (Heilongjiang and Jilin), eastern Russia (South Primorye), northeastern Japan (Setamai, Kamiyasse–Imo, Kesennuma, Ogatsu and Takakurayama in the South Kitakami Belt), central Japan (Moribu and Oguradani in the Hida Gaien Belt and Hitachi), southwestern Japan (Mizukoshi in central Kyushu), eastern China (Zhejiang, Anhui and Jiangxi), central-southern China (Hubei, Hunan, Guangdong and Guangxi), southwestern China (Guizhou, Sichuan, Yunnan and Xizang), Vietnam, Cambodia (Sisophon), Malaysia, Nepal (Kumaon Himalayas), Pakistan (Salt Range) and Greece (Hydra Island).

Family Costispiniferidae Muir-Wood and Cooper, 1960
Subfamily Spinomarginiferinae Waterhouse, 2002
Genus *Spinomarginifera* Huang, 1932

Type species.—*Spinomarginifera kueichowensis* Huang, 1932.

Spinomarginifera kueichowensis Huang, 1932
Fig. 6.10

Spinomarginifera kueichowensis Huang, 1932, p. 56, pl. 5, figs. 1–11; Nakamura, 1959, p. 143, pl. 15, figs. 1–4; Chi-Thuan, 1962, p. 493, pl. 2, fig. 1; Jin et al., 1974, p. 312, pl. 164, fig. 13; Tazawa, 1976, pl. 2, fig. 1; Yang et al., 1977, p. 349, pl. 139, fig. 11; Feng and Jiang, 1978, p. 252, pl. 89, figs. 5, 6; Tong, 1978, p. 222, pl. 79, fig. 5; Zhan, 1979, p. 80, pl. 11, figs. 14–17, 20; Liu et al., 1982, p. 184, pl. 131, figs. 8–10; Wang et al., 1982, p. 219, pl. 92, fig. 3; Wang, 1984, p. 187, pl. 74, fig. 16; pl. 76, fig. 3; Zeng et al., 1995, pl. 5, fig. 10; Chen in Chen et al., 2006, p. 314, fig. 8; Shen and Shi, 2009, p. 158, figs. 3DD, 3EE, 4I; Tazawa et al., 2014, p. 381, fig. 2.10.

← **Fig. 6.** Representatives of the Ishinazaka fauna (1). 1, *Kitakamichonetes multicapillatus* Afanasjeva and Tazawa, internal mould of ventral valve, KFM1890. 2, 3, *Transennatia gratiosa* (Waagen); 2a, 2b, 2c, 2d, ventral, anterior, posterior and lateral views of internal mould of ventral valve, KFM1874; 3a, 3b, 3c, dorsal, anterior and lateral views of internal mould of dorsal valve, KFM1883. 4, *Isogramma heritschi* Nakamura, internal mould of dorsal valve, KFM1872. 5, *Urushtenoidea chaoi* (Jin), internal mould of ventral valve, KFM1888. 6, *Dicystoconcha lapparenti* Termier and Termier, internal mould of ventral valve, KFM1868. 7, *Permianella typica* He and Zhu, internal mould of ventral valve, KFM1863. 8, 9, *Schuchertella debaisiensis* Wang and Zhang; 8a, 8b, ventral and dorsal views of internal mould of conjoined shell, KFM1939; 9, latex cast of external mould of dorsal valve, KFM1943. 10, *Spinomarginifera kueichowensis* Huang; 10a, 10b, ventral and dorsal views of internal mould of conjoined shell, KFM1870 (after Tazawa et al., 2014).

Material.—Two specimens, internal moulds of two conjoined shells, KFM1870, 1871.

Remarks.—These specimens are poorly preserved, but can be referred to *Spinomarginifera kueichowensis* Huang, 1932, from the Wuchiapingian of Guizhou, southwestern China, by their transverse outline (length 14 mm, width 30 mm in the larger specimen, KFM1870), strongly geniculated ventral valve, and slightly concave visceral disc of dorsal valve, with a thin, long median septum and diverging elongate adductor scars. The Hitachi specimens most resemble the shells of *S. kueichowensis*, described and figured by Nakamura (1959, p. 143, pl. 15, figs. 1–4) from the lower Kamiyasse Formation of the Kamiyasse–Imo area, South Kitakami Belt.

Distribution.—Wordian–Wuchiapingian: northeastern Japan (Kamiyasse–Imo in the South Kitakami Belt), central Japan (Hitachi), eastern China (Jhejiang and Jiangxi), central-southern China (Hubei, Hunan, Guangdong and Guangxi), southwestern China (Guizhou and Sichuan) and Vietnam (Quang Tri).

Superfamily Echinoconchoidea Stehli, 1954

Family Echinoconchidae Stehli, 1954

Subfamily Juresaniinae Muir-Wood and Cooper, 1960

Tribe Bathymyoniini Lazarev, 1990

Genus *Bathymyonia* Muir-Wood and Cooper, 1960

Type species.—*Productus nevadensis* Meek, 1877.

Bathymyonia ussurica Kotlyar in Licharew and Kotlyar, 1978

Figs. 7.3–7.5

Bathymyonia ussurica Kotlyar in Licharew and Kotlyar, 1978, p. 67, pl. 16, figs. 2, 3; Tazawa et al., 2014, p. 381, figs. 3.3–3.5.

Waagenoconcha xiujumqinqiensis Lee, Gu and Li, 1982, p. 117, pl. 2, figs. 1, 2.

Waagenoconcha noda-lineata Lee, Gu and Li, 1983, p. 72, pl. 3, fig. 11.

Waagenoconcha xiuqiensis Lee, Gu and Li, 1983, pl. 1, figs. 14, 17; pl. 3, figs. 1, 4.

Waagenoconcha (*Yazengoconcha*) *xiujumqinqiensis* (Lee, Gu and Li): Wang and Zhang, 2003, p. 98, pl. 10, figs. 1–9; pl. 11, figs. 1–3; pl. 12, figs. 3, 6; pl. 15, figs. 1–3.

Material.—Five specimens: (1) internal moulds of three conjoined shells, KFM1897–1899; (2) external moulds of two dorsal valves, KFM1900, 1901.

Description.—Shell medium in size for genus, transversely subquadrate in outline, hinge shorter than greatest width at slightly anterior to midlength; length about 58 mm, width about 71 mm in the largest specimen (KFM1897). Ventral valve strongly and unevenly convex in lateral profile, most convex at umbonal region, gently convex on visceral disc, moderately geniculated at anterior margin and followed by long trail; sulcus wide and shallow; lateral slopes steep. Dorsal valve with flatly concave visceral disc, geniculated and followed by short trail; fold narrow and low. External ornament of dorsal valve consisting of numerous quincuncially arranged spine bases and irregular concentric rugae; the latter occurring near anterior valve margin. Ventral interior with large flabellate and longitudinally striated diductor scars, and small, elongate and dendritic adductor scars. Dorsal interior with large cardinal process supported by short, strong lateral ridges; median septum long, extending two-thirds valve length; adductor scars large, strongly dendritic.

Remarks.—These specimens can be referred to *Bathymyonia ussurica* Kotlyar in Licharew and Kotlyar, 1978, from the upper Barabashevka Formation of South Primorye, eastern Russia, by their transverse outline and very short hinge of the shells. Some *Bathymyonia* species, described or figured from the Zhesi Formation of the Ujimqinqi area, Inner Mongolia, as *Waagenoconcha xiujumqinqiensis* Lee, Gu and Li, 1982, *Waagenoconcha noda-lineata* Lee, Gu and Li, 1983, and *Waagenoconcha xiuqiensis* Lee, Gu and Li, 1983, are junior synonym of *Bathymyonia ussurica*. *Bathymyonia neimongolica* (Wang and Zhang, 2003), originally described from the Zhesi Formation of the Xiujimqinqi area, Inner Mongolia, is readily distinguished from the present species by its much elongate outline.

Distribution.—Wordian–Capitanian: northern China (Inner Mongolia), eastern Russia (South Primorye) and central Japan (Hitachi).

Bathymyonia neimongolica (Wang and Zhang, 2003)
Figs. 7.1, 7.2

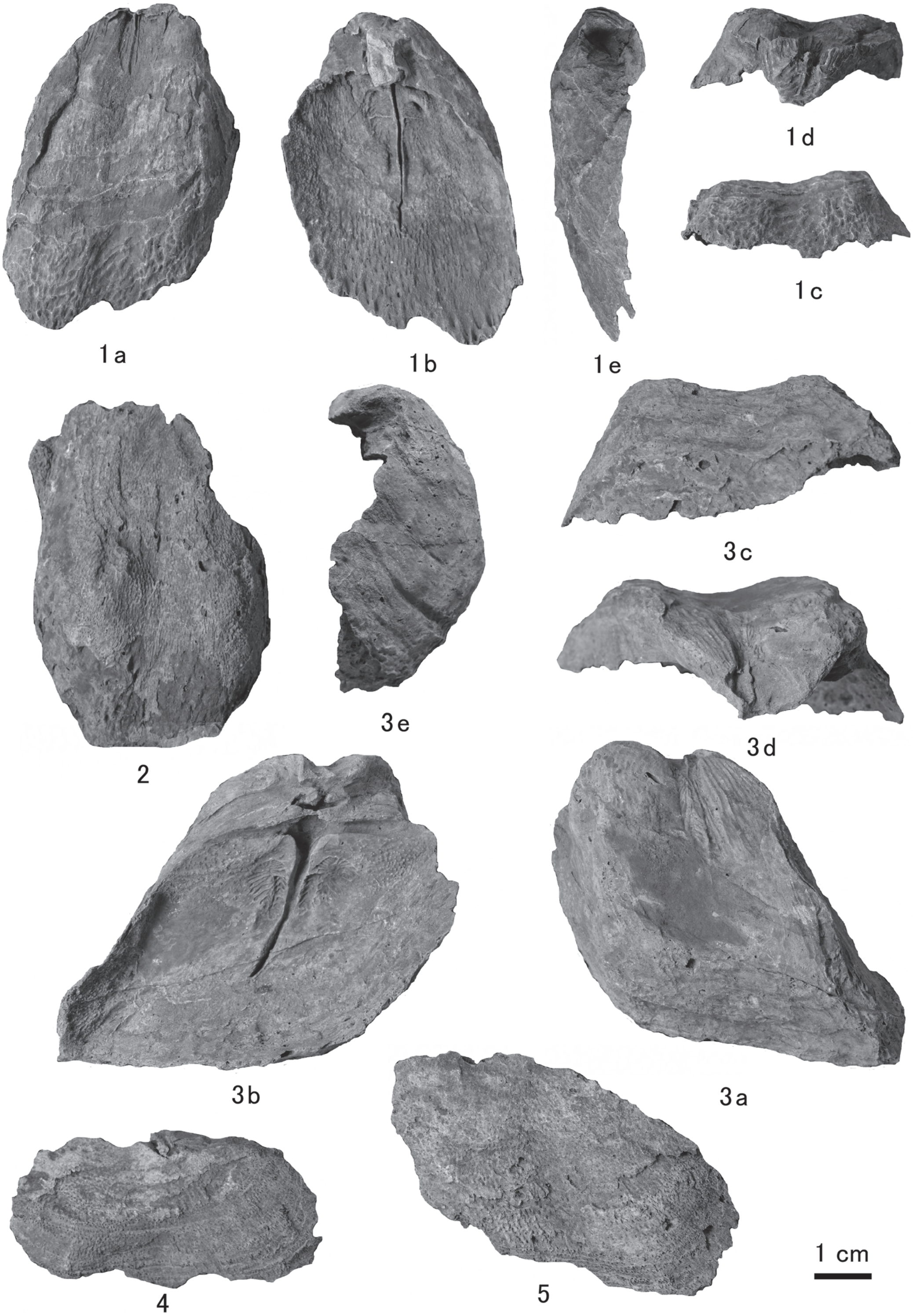
Waagenoconcha imperfecta Prendergast: Tazawa, 1974, p. 127, pl. 3, fig. 2 only; Shiino and Suzuki, 2007, figs. 3–6.

Waagenoconcha (*Yazengoconcha*) *neimongolica* Wang and Zhang, 2003, p. 97, pl. 8, figs. 1–8; pl. 9, figs. 1–4; pl. 14, figs. 4–7.

Bathymyonia neimongolica (Wang and Zhang, 2003): Tazawa, 2014, p. 17, figs. 3.1–3.4; Tazawa et al., 2014, p. 381, figs. 3.1, 3.2.

Material.—Six specimens: (1) internal moulds of five conjoined shells, KFM1891–1895; (2) external mould of a dorsal valve, KFM1896.

Description.—Shell medium in size for genus, elongate subrectangular in outline, with greatest width slightly anterior to midlength; length about 70 mm, width about 35 mm in the largest specimen (KFM1895). Ventral valve strongly and unevenly convex in both lateral and anterior profiles; umbo large, strongly incurved; visceral disc gently convex, moderately geniculated and followed by long trail; sulcus narrow and deep; lateral slopes steep. Dorsal


1a
1b
1e
1d
1c
2
3e
3c
3d
3b
3a
4
5
1 cm

valve gently concave in visceral disc, geniculated at anterior margin and followed by short trail; fold narrow and low on whole valve. External surface of dorsal valve ornamented by numerous elongate and quincuncially arranged spine bases and irregularly developed concentric rugae. Ventral interior with large, flabellate and longitudinally striated diductor scars, and elongate, dendritic adductor scars set on elevated ridges. Dorsal interior with massive cardinal process, supported by short, broad lateral ridges; median septum long, extending two-thirds valve length; adductor scars strongly dendritic.

Remarks.—These specimens are referred to *Bathymyonia neimongolica* (Wang and Zhang, 2003), from the Zhesi Formation of Inner Mongolia, on account of the elongate subrectangular outline, gently convex visceral region and steep lateral slopes of the ventral valve, and in having enormously large cardinal process and short, broad lateral ridges in the dorsal valve. The type species, *Bathymyonia nevadensis* (Meek, 1877), from the Phosphoria Formaion of Wyoming, Utah and Nevada, USA, is distinguished from *B. neimongolica* by its smaller, less elongate and more evenly convex ventral valve.

Distribution.—Wordian–Capitanian: northern China (Inner Mongolia), northeastern Japan (Kamiyasse–Imo in the South Kitakami Belt) and central Japan (Hitachi).

Superfamily Aulostegoidea Muir-Wood and Cooper, 1960

Family Echinostegidae Muir-Wood and Cooper, 1960

Subfamily Chonosteginae Muir-Wood and Cooper, 1960

Genus *Urushtenoidea* Jin and Hu, 1978

Type species.—*Urushtenia chaoi* Jin, 1963.

Urushtenoidea chaoi (Jin, 1963)

Fig. 6.5

Urushtenia chaoi Jin, 1963, p. 15, 28, pl. 1, figs. 1–4, 9–12; pl. 2, figs. 7, 8, 13–17.

Urushtenoidea chaoi (Jin): Jin and Hu, 1978, p. 116, pl. 2, fig. 10; Tong, 1978, p. 218, pl. 78, fig. 18; Nakamura, 1979, p. 230, pl. 2, fig. 4; Hu, 1983, pl. 3, fig. 6; Zeng, 1992, pl. 1, figs. 9–11; Sone et al., 2001, p. 184, figs. 5.7–5.14, 5.16–5.18; Tazawa et al., 2014, p. 383, fig. 2.5.

Material.—One specimen, internal mould of a ventral valve, KFM1888.

← **Fig. 7.** Representatives of the Ishinazaka fana (2). 1, 2, *Bathymyonia neimongolica* (Wang and Zhang); 1a, 1b, 1c, 1d, 1e, ventral, dorsal, anterior, posterior and lateral views of internal mould of conjoined shell, KFM1893; 2, external mould of dorsal valve, KFM1896. 3–5, *Bathymyonia ussurica* Kotlyar; 3a, 3b, 3c, 3d, 3e, ventral, dorsal, anterior, posterior and lateral views of internal mould of conjoined shell, KFM1897; 4, external mould of dorsal valve, KFM1901; 5, external mould of dorsal valve, KFM1900 (after Tazawa et al., 2014).

Remarks.—This specimen can be identified with *Urushtenoidea chaoi* (Jin, 1963), from the upper Chihsian to the lower Maokouan of Anhui and Jiangxi, eastern China, by its small size (length 20 mm, width 15 mm), strongly convex and geniculate ventral valve with a narrow and deep sulcus, and the external ornament consisting of strong costae on trail, numbering 14 on each lateral slope and 8 in sulcus.

Distribution.—Roadian–Capitanian: central Japan (Hitachi), eastern China (Jiansu, Anhui and Jiangxi), southwestern China (Sichuan), Cambodia and Malaysia.

Superfamily Linoproductoidea Stehli, 1954
Family Linoproductidae Stehli, 1954
Subfamily Linoproductinae Stehli, 1954
Genus *Linoproductus* Chao, 1927

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

Linoproductus sp.
Fig. 8.6

Linoproductus sp. Tazawa et al., 2014, p. 383, fig. 4.6.

Material.—One specimen, internal mould of a ventral valve, KFM1869.

Remarks.—The single ventral valve specimen from Hitachi is medium in size, and elongate oval in outline, with the greatest width at about two-thirds length from umbo; length 47 mm, width 30 mm. External surface of ventral valve is ornamented by numerous fine costellae and some strong concentric rugae, which occurring near anterior margin of the valve. This specimen is safely assigned to the genus *Linoproductus* Stehli, 1954, by its size, outline and external ornament of the ventral valve. But the specific identification is difficult owing to ill preservation of the present material.

Suborder Lyttoniidina Williams, Harper and Grant, 2000
Superfamily Permianelloidea He and Zhu, 1979
Family Permianellidae He and Zhu, 1979
Genus *Permianella* He and Zhu, 1979

Type species.—*Permianella typica* He and Zhu, 1979.

Permianella typica He and Zhu, 1979
Fig. 6.7

Permianella typica He and Zhu, 1979, p. 132, 137, pl. 1, fig. 1; pl. 2, figs. 1–3; pl. 3, figs. 1–3; Wang and Jin, 1991, p. 496, pl. 2, figs. 1–3; Zeng et al., 1995; pl. 21, fig. 16; Shen and Tazawa, 1997, p. 288, figs. 2–4, 5.1–5.14; Campi et al., 2005, p. 127, pl. 4, figs. I, J; Tazawa, 2008b, p. 50, fig. 8.1; Tazawa et al., 2014, p. 383, fig. 2.7.

Permianella sp. He and Zhu, 1979, p. 133, 139, pl. 1, figs. 2, 3.

Material.—Five specimens, internal moulds of five ventral valves, KFM1863–1867.

Remarks.—These specimens are referred to *Permianella typica* He and Zhu, 1979, originally described from the Longtan Formation of Jiangxi, eastern China and Sichuan, southwestern China, by their unique elongate bilobate shells (length 35 mm, width 18 mm in the largest specimen, KFM1863), with narrow ventral sulcus and deep incision. *Permianella* sp. He and Zhu, 1979, from the Longtan Formation of Jiangsu, eastern China, is similar in size and shape of the shell, and can be referred to *P. typica*.

Distribution.—Wordian–Wuchiapingian: northeastern Japan (Kamiyasse–Imo in the South Kitakami Belt), central Japan (Hitachi), southwestern Japan (Mizukoshi in central Kyushu), eastern China (Zhejiang and Jiangxi), southwestern China (Sichuan) and Malaysia (Pahang).

Genus *Dicystoconcha* Termier and Termier in Termier et al., 1974

Type species.—*Dicystoconcha lapparenti* Termier and Termier in Termier et al., 1974.

Dicystoconcha lapparenti Termier and Termier in Termier et al., 1974

Fig. 6.6

Dicystoconcha lapparenti Termier and Termier in Termier et al., 1974, p. 123, pl. 22, figs. 1, 2; text-fig. 22; Wang and Jin, 1991, p. 495, pl. 1, figs. 1–9; pl. 3, figs. 1–7; Shen and Tazawa, 2014, p. 248, figs. 3.1–3.5; Tazawa et al., 2014, p. 383, fig. 2.6.

Dipunctella contracta Liang in Wang et al., 1982, p. 229, pl. 102, fig. 3.

Guangjiayanella guangjiayanensis Yang, 1984, p. 212, pl. 31, figs. 11–16; text-fig. 5.9.

Guangdongina xiamaoensis Mou and Liu, 1989, p. 458, pl. 1, figs. 1–9; pl. 2, figs. 1–7; text-fig. 5.

Guangdongina leguminiformis Mou and Liu, 1989, p. 458, pl. 3, figs. 4–8.

Guangdongina perforatus Mou and Liu, 1989, p. 459, pl. 2, fig. 8; pl. 3, figs. 1–3.

Guangdongina sp. Mou and Liu, 1989, p. 459, pl. 2, fig. 9.

Paritisteges latesulcata Liang, 1990, p. 380, pl. 42, figs. 1, 2.

Fabulasteges planata Liang, 1990, p. 381, pl. 42, figs. 3, 4.

Material.—One specimen, internal mould of a ventral valve, KFM1868.

Remarks.—This specimen is referred to *Dicystoconcha lapparenti* Termier and Termier in Termier et al., 1974, from the lower Murgabian of Wardak, central Afghanistan, in its small, ovate and bilobate ventral valve (length 13 mm, width 12 mm), with shallow incision and a distinct central platform.

Distribution.—Kungurian–Wuchiapingian: Afghanistan, northern China (Inner Mongolia), northeastern Japan (Kamiyasse–Imo in the South Kitakami Belt), central Japan (Hitachi), eastern China (Zhejiang) and central-southern China (Hubei and Guangdong).

Order Orthotetida Waagen, 1884
Suborder Orthotetidina Waagen, 1884
Superfamily Orthotetoidea Waagen, 1884
Family Schuchertellidae Williams, 1953
Subfamily Schuchertellinae Williams, 1953
Genus *Schuchertella* Girty, 1904

Type species.—*Streptorhynchus lens* White, 1862.

Schuchertella debaisiensis Wang and Zhang, 2003
Figs. 6.8, 6.9

Schuchertella debaisiensis Wang and Zhang, 2003, p. 122, pl. 27, figs. 1–9: pl. 29, figs. 1, 2; Tazawa et al., 2014, p. 383, figs. 2.8, 2.9.

Material.—Seven specimens: (1) internal moulds of two conjoined shells, KFM1939, 1940; (2) external and internal moulds of a dorsal valve, KFM1941; (3) external moulds of two dorsal valves, KFM1942, 1943; (5) internal moulds of two dorsal valves, KFM1944, 1945.

Description.—Shell medium in size for genus, transversely elliptical in outline, with greatest width slightly anterior to hinge; length about 33 mm, width about 35 mm in the largest specimen (KFM1939). Ventral valve gently convex in both anterior and lateral profiles; umbo narrow, slightly projected; interarea moderately high, triangular; ears small, nearly flat; sulcus absent. Dorasl valve slightly convex, without fold. External surface of dorsal valve ornamented by numerous costellae and some irregular concentric rugae; costellae often intercalated, numbering 5–6 in 2 mm at about midlength. Dorsal interior with a pair of diverging socket ridges; adductor scars impressed and subdivided by a low myophragm.

Remarks.—These specimens are referred to *Schuchertella debaisiensis* Wang and Zhang, 2003, from the Dashizai and Zhesi (Jisu) formations of Inner Mongolia, by size, shape and external ornament of the dorsal valves, in particular, by the slightly convex profile. *Schuchertella semiplana* (Waagen, 1884, p. 608, pl. 55, figs. 1, 2), from the Chhidru Formation of the Salt Range, differs from the present species in having flat dorsal valve.

Distribution.—Kungurian–Wordian: northern China (Inner Mongolia) and central Japan (Hitachi).

Order Rhynchonellida Kuhn, 1949

Superfamily Wellerelloidea Licharew, 1956

Family Wellerellidae Licharew, 1956

Subfamily Uncinunellininae Savage, 1996

Genus *Uncinunellina* Grabau, 1932

Type species.—*Uncinulus theobaldi* Waagen, 1883.

Uncinunellina timorensis (Beyrich, 1865)

Fig. 8.1

Rhynchonella timorensis Beyrich, 1865, p. 72, pl. 1, fig. 10.

Uncinulus theobaldi Waagen, 1883, p. 425, pl. 34, fig. 1.

Rhynchonella (*Uncinulus*) *timorensis* Beyrich: Rothpletz, 1892, p. 84, pl. 10, fig. 6; Hamlet, 1928, p. 62, pl. 10, figs. 3–7.

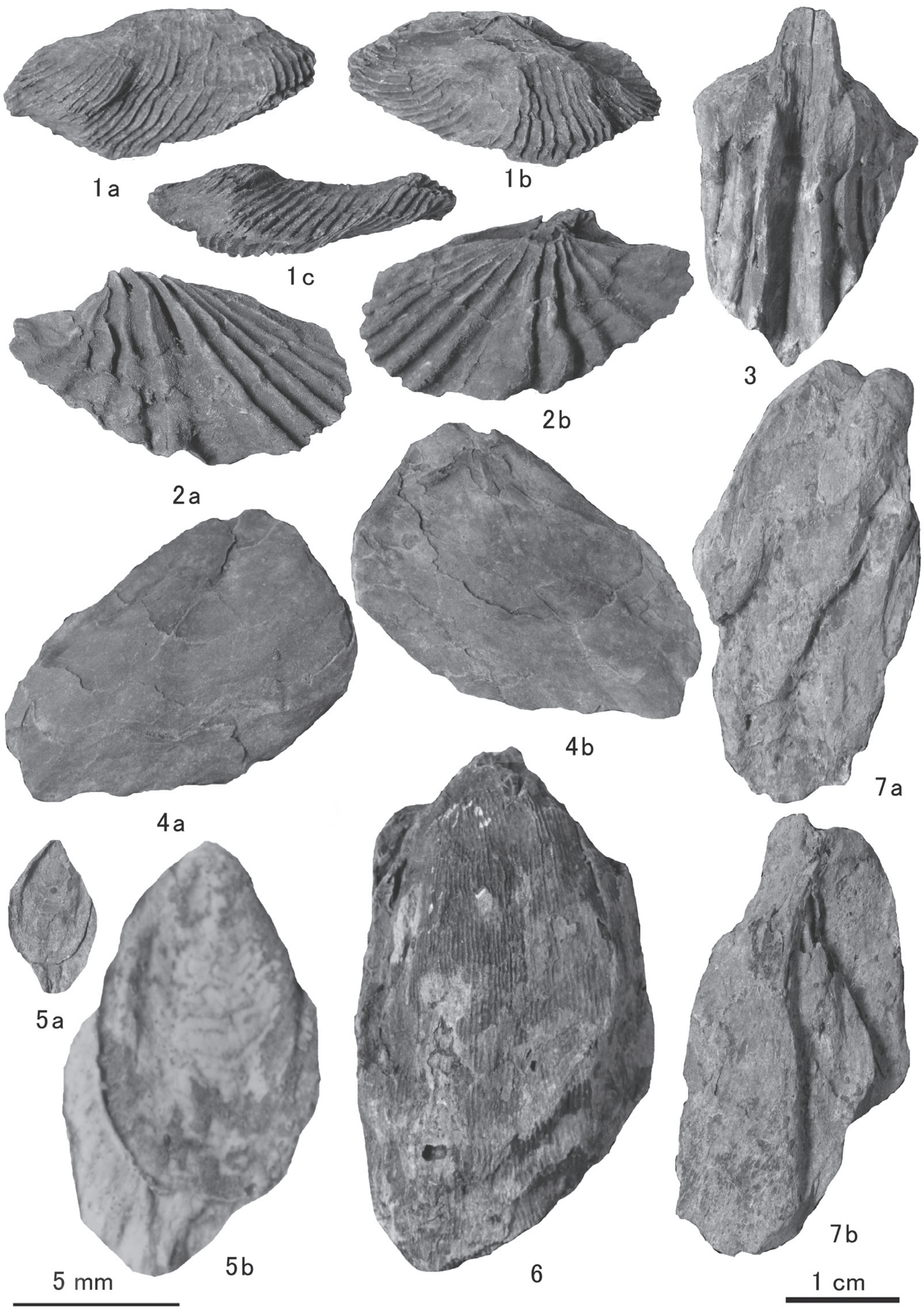
Uncinulus timorensis Beyrich: Diener, 1897, p. 69, pl. 10, figs. 7–10.

Uncinunellina timorensis (Beyrich): Zhang and Ching (Jin), 1961, p. 404, pl. 1, figs. 9–16; Yang et al., 1977, p. 378, pl. 150, fig. 2; Jin et al., 1979, p. 100, pl. 30, figs. 21–27; Zhan, 1979, p. 95, pl. 8, fig. 9; pl. 10, fig. 4; Liu et al., 1982, p. 192, pl. 138, fig. 11; Wang et al., 1982, p. 233, pl. 84, fig. 3; pl. 93, fig. 5; Xu, 1987, p. 230, pl. 14, figs. 7–9; pl. 15, figs. 1–3; Zeng et al., 1995, pl. 12, figs. 9, 10; Shen and Shi, 2007, p. 46, pl. 17, figs. 31–42; text-fig. 11; Tazawa et al., 2014, p. 385, fig. 4.1.

Uncinunellina theobaldi (Waagen): Grant, 1976, pl. 48, figs. 1–9; Yang et al., 1977, p. 378, pl. 150, fig. 5; Zeng et al., 1995, pl. 12, fig. 11; Chen, 2004, p. 55, pl. 11, figs. 30–33.

Material.—Twenty-five specimens: (1) internal moulds of twenty-one conjoined shells, KFM1911–1931; (2) external moulds of two ventral valves, KFM1932, 1933; (2) external moulds of two dorsal valves, KFM1934, 1935.

Description.—Shell medium in size for genus, transversely pentagonal to elliptical in outline; widest at midlength; length 14 mm, width 27 mm in the largest specimen (KFM1911). Ventral valve gently convex in visceral region, strongly geniculated, and followed by long trail (tongue); umbo small, pointed; sulcus wide and deep, with flat to slightly round bottom; lateral flanks gently convex. Dorsal valve moderately convex, strongly geniculated at anterior margin, and followed by short trail; fold wide and high; flanks gently convex.


1a
1b
1c
2a
2b
3
4a
4b
5a
5b
6
7a
7b
5 mm
1 cm

External surface of both valves ornamented by numerous costae, numbering 8–11 in sulcus and 9–11 on each flank; costae flattened anteriorly and faintly grooved medianly as traces of very fine spines of the opposite valve. Internal structures of both valves not well preserved.

Remarks.—These specimens are referred to *Uncinunellina timorensis* (Beyrich, 1865), from the upper Permian (Wuchiapingian?) of western Timor, by their size, shape and external ornament of the shells. *Uncinunellina theobaldi* (Waagen, 1883), from the Wargal Formation of the Salt Range, is a junior synonym of the present species (Diener, 1897, p. 69). *Uncinunellina multicostifera* Xu and Grant (1994, p. 35, figs. 21, 22.1–22.27), from the Changhsingian of Zhejiang (eastern China), Hubei (central-southern China) and Sichuan (southwestern Chia), is distinguished from *U. theobaldi* by its more numerous costae on both ventral and dorsal valves.

Distribution.—Asselian–Changhsingian; northwestern China (Xinjiang and Qinghai), central Japan (Hitachi), eastern China (Anhui and Jiangxi), cntral-southern China (Hubei, Hunan and Guangdong), southwestern China (Guizhou, Sichuan and Xizang), Pakistan (Salt Range) and Indonesia (Timor).

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.
Fig. 8.5

Cleiothyridina sp. Tazawa et al., 2014, p. 385, fig. 4.5.

Material.—Two specimens: (1) external mould of a ventral valve, KFM1946, (2) internal

← **Fig. 8.** Representatives of the Ishinazaka fana (3). 1, *Uncinunellina timorensis* (Beyrich); 1a, 1b, 1c, ventral, dorsal and anterior views of internal mould of conjoined shell, KFM1911. 2, *Spiriferellina fredericksi* Tazawa; 2a, 2b, ventral and dorsal views of internal mould of conjoined shell, KFM1904. 3, *Spiriferella* sp., internal mould of ventral valve, KFM1889. 4, *Martinia* sp.; 4a, 4b, ventral and dorsal views of internal mould of conjoined shell, KFM1936. 5, *Cleiothyridina* sp.; 5a, 5b, external mould and external latex cast of ventral valve, KFM1946. 6, *Linoproductus* sp., internal mould of ventral valve, KFM1869. 7, *Whitspakia* sp.; 7a, 7b, ventral and dorsal views of internal mould of conjoined shell, KFM1902. The scale bar (1 cm) is applied to all figures except for 5b; and the another scale bar (5 mm) is applied to fig. 5b only (after Tazawa et al., 2014).

mould of a dorsal valve, KFM1947.

Remarks.—These specimens are safely assigned to the genus *Cleiothyridina* by the small, longitudinally ovate shell (length 12 mm, width 9 mm in the ventral valve specimen, KFM1946), and the external ornament consisting of numerous concentric lamellae, projecting anteriorly as long flat spines. The Hitachi species most resembles *Cleiothyridina aculeata* Fang (in Fang and Fan, 1994, p. 85, pl. 23, figs. 6–7; pl. 30, fig. 11; pl. 31, figs. 1, 2), from the lower Permian (Sakmarian–Artinskian) of western Yunnan, southwestern China, in its small size and flattened ventral valve, although accurate comparison is difficult owing to ill preservation of the present material.

Order Spiriferida Waagen, 1883
Suborder Spiriferidina Waagen, 1883
Superfamily Martinioidea Waagen, 1883
Family Martiniidae Waagen, 1883
Subfamily Martiniinae Waagen, 1883
Genus *Martinia* M'Coy, 1844

Type species.—*Spirifer glaber* Sowerby, 1820.

Martinia sp.
Fig. 8.4

Martinia sp. Tazawa et al., 2014, p. 385, fig. 4.4.

Material.—Three specimens: (1) internal moulds of two conjoined shells, KFM1936, 1937; (2) internal mould of a ventral valve, KFM1938.

Remarks.—These specimens are safely assigned to the genus *Martinia* by their subcircular, gently convex shells, with distinct vascular impressions in both ventral and dorsal valves. The Hitachi specimens resemble *Martinia semiplana* Waagen (1883, p. 536, pl. 43, fig. 4), from the Wargal Formation of the Salt Range, in size and shape of the shell. However, accurate comparison is difficult because of lacking the external information in the present specimens.

Superfamily Spiriferoidea King, 1846
Family Spiriferellidae Waterhouse, 1968
Genus *Spiriferella* Tschernyschew, 1902

Type species.—*Spirifer saranae* de Verneuil, 1845.

Spiriferella sp.
Fig. 8.3

Spiriferella sp. Tazawa et al., 2014, p. 385, fig. 4.3.

Material.—One specimen, internal mould of a ventral valve, KFM1889.

Remarks.—The single specimen from Hitachi is safely assigned to the genus *Spiriferella* by its medium-sized, longer shell (length about 35 mm, width about 22 mm), with 3–4 simple coarse costae on each side of the ventral valve, and in having a deeply impressed, heart-shaped muscle field. However the specific identification is difficult owing to ill state of preservation of the present material.

Order Spiriferinida Ivanova, 1972
Suborder Spiriferinidina Ivanova, 1972
Superfamily Pennospiriferinoidea Dagys, 1972
Family Spiriferellinidae Ivanova, 1972
Genus *Spiriferellina* Fredericks, 1924a

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

Spiriferellina fredericksi Tazawa, 2014
Fig. 8.2

Spiriferina cristata (Schellwien): Hayasaka, 1922, p. 66, pl. 9, figs. 5–9.
Spiriferina cristata (von Schlotheim): Hayasaka, 1960, p. 53, pl. 1, fig. 10.
Spiriferellina cristata biplicata (Davidson): Fredericks, 1924b, p. 35, pl. 1, fig. 15.
Spiriferellina cristata (Schlotheim): Tazawa, 1976, pl. 2, fig. 3; Minato et al., 1979, pl. 67, figs. 4, 5.
Spiriferellina fredericksi Tazawa, 2014, p. 19, figs. 3.5–3.7; Tazawa et al., 2014, p. 385, fig. 4.2.

Material.—Eight specimens: (1) internal mould of a conjoined shell, with external mould of the dorsal valve, KFM1903; (2) internal mould of a conjoined shell, KFM1904; (3) a ventral valve, KFM1905; (4) external mould of a ventral valve, KFM1906; (5) internal mould of two ventral valves, KFM1907, 1908; (6) external mould of a dorsal valve, KFM1909; (7) internal mould of a dorsal valve, KFM1910.

Description.—Shell large in size for genus, transversely subelliptical in outline; widest at or near hinge; cardinal extremities acute; length about 21 mm, width about 44 mm in the best preserved specimen (KFM1903). Ventral valve moderately convex in lateral profile, most convex in umbonal region, somewhat flattened in visceral region; interarea broadly triangular; sulcus broad and deep, with flattened bottom. Dorsal valve slightly convex in lateral profile, but nearly flat in anterior profie, except for broad and high fold. External surface of both valves ornamented by strong, simple, rounded costae, numbering 5–6 pairs in both valves; growth laminae irregularly developed, more densely in anterior region; numerous very fine pustules on whole surface of both valves. Ventral interior with a pair of short adminicula, slightly divergent; median septum high and long, extending to midlength of valve. Other internal structures of both valves are not well preserved.

Remarks.—These species are referred to *Spiriferellina fredericksi* Tazawa, 2014, from the lower Kamiyasse Formation of the South Kitakami Belt, by their large size, transverse outline and in having rather numerous costae on both ventral and dorsal valves. This species is distinguished from *Spiriferellina cristata* (von Schlotheim, 1816) by its larger size, transverse outline and in having more numerous costae on both ventral and dorsal valves. *Spiriferellina sonorensis* Cooper (1953, p. 69, pl. 21C, figs. 13–27; pl. 22D, figs. 26–29), from the Monos Formation (Kungurian) of El Antimonio, Mexico, is also a large, transverse species of *Spiriferellina*, but the Mexican species differs from *S. fredericksi* in having strongly mucronate cardinal extremities.

Distribution.—Wordian: eastern Russia (South Primorye), northeastern Japan (Kamiyasse–Imo in the South Kitakami Belt) and central Japan (Hitachi).

Order Terebratulida Waagen, 1883
Suborder Terebratulidina Waagen, 1883
Superfamily Dielasmatoidea Schuchert, 1913
Family Dielasmatidae Schuchert, 1913
Subfamily Dielasmatinae Schuchert, 1913
Genus *Whitspakia* Stehli, 1964

Type species.—*Dielasma biplex* Waagen, 1882.

Whitspakia sp.
Fig. 8.7

Whitspakia sp. Tazawa et al., 2014, p. 385, fig. 4.7.

Material.—One specimen, internal mould of a conjoined shell, KFM1902.

Remarks.—This specimen can be assigned to the genus *Whitspakia* by its elongate subpentagonal shell (length about 41 mm, width about 21 mm), having an acute, strongly incurved ventral umbo, shallow ventral sulcus with median costa and low dorsal fold. The

Hitachi species resembles *Dielasma* sp. Tazawa (1979, p. 30, pl. 5, fig. 5), from the lower Kamiyasse Formation of Matsukawa in the Kesennuma area, South Kitakami Belt, in having a prominent fold in the dorsal valve. But accurate comparison is difficult for the poorly preserved specimen.

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Report of the 2nd International Symposium on Earth History of Asia, 31 October – 3 November, 2014, Niigata, Japan

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Abstract

The 2nd International Symposium on Earth History of Asia was organized at Niigata, Japan, from 31 October to 3 November, 2014. The scientific session was held in Niigata University (Ikarashi Campus) on 31 October and 1 November, where a total of 126 scientists including 27 oversea ones from China, Korea, Taiwan, and India participated. The scientific session included 5 keynote talks, 9 invited talks, 13 oral presentations and 31 poster presentations. The program and abstracts of the scientific session was published in a supplement volume of Science Reports of Niigata University (Geology). The symposium also included a two-day field excursion in the Itoigawa Global Geopark. Activities of the excursion were, visits to three geosites, a tour of the Itoigawa City Museum of History and Folklore and a panel discussion at the Itoigawa City Hall. Sixty-one participants including earth scientists and local geopark mentors and tour guides joined the panel discussion. This symposium was conducted as part of the Niigata University Good Practice (GP) Program entitled "Formation of research and education hub for field geology in Asia-Oceania region" by the Faculty of Science from 2012 to 2014 fiscal years.

Key words: Earth History of Asia, partner institutions, Double Degree Program, Itoigawa Global Geopark, Niigata University Good Practice Program.

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Introduction

The 1st International Symposium on Earth History of Asia was held in October, 2009 at Niigata University, Japan. The symposium was a milestone for initiating collaboration in research and education between Niigata University and partner institutions. Since then, collaborative research and student exchange have been increasing continuously. As part of the Global Circus Program performed by the Graduate School of Science and Technology, a special educational program termed "Double Degree Program" (DDP) was started in 2009, through which the participating students can matriculate at both Niigata University and the partner institutions. They are eligible to obtain "the double-degree", receiving a separate degree from each university or institution. To date, three graduate students in the field of earth sciences from Niigata University have been sent to partner institutions in China and one student has been received from Taiwan.

The 2nd International Symposium on Earth History of Asia was held at Niigata University in Niigata, Japan, from 31 October to 3 November, 2014. The symposium aimed at having an opportunity to exchange idea for understanding the evolutionary history of geo-sphere and bio-sphere of the earth, especially in the Asian regions. Another objective of this symposium was to enhance partnerships among cooperative organizations, especially DDP partners. Participating institutions were China University of Geosciences (Beijing), China University of Geosciences (Wuhan), Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, National Cheng Kung University (Taiwan), Pukyong National University (Korea), and Indian Institute of Science. During the symposium, we visited the Itoigawa Global Geopark and had an outreach session on geopark activities. Participating graduate students from each institution had an occasion to present their research achievements either in oral or poster presentation session and to participate in further discussion sessions and various exchange opportunities with undergraduate and graduate students from Niigata University and other international partner institutions. We believe that this was a great chance to foster and expand international academic networks among faculty members and students in order to make advancements in research and education.

This symposium is one of activities in the Niigata University Good Practice (GP) Program entitled "Formation of research and education hub for field geology in Asia-Oceania region" which has been performed by the Faculty of Science from 2012 to 2014 fiscal years. Undergraduate students of the Faculty of Science who participated in the entire activities of the symposium obtained a credit of "Overseas training course". This report summarizes the organization of the symposium, the scientific session in Niigata University and the excursion in the Itoigawa Global Geopark.

Organization of the symposium

The symposium was planned and performed by the following committees.

Organizing Committee:
Prof. Atsushi MATSUOKA, Niigata University (Chairperson)
Prof. Eiichi TAKAZAWA, Niigata University
Prof. M. SATISH-KUMAR, Niigata University
Associate Prof. Toshiyuki KURIHARA, Niigata University

Program Committee:
Prof. M. SATISH-KUMAR, Niigata University
Prof. Xiaoqiao WAN, China University of Geosciences, Beijing
Prof. Qinglai FENG, China University of Geosciences, Wuhan
Prof. Yongdong WANG, Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences
Prof. Huai-Jen YANG, National Cheng Kung University
Prof. Tae-Seob KANG, Pukyong National University

Advisory Committee:
Prof. Hisaaki KUDO, Niigata University
Prof. Shouting ZHANG, China University of Geosciences, Beijing
Prof. Changqian MA, China University of Geosciences, Wuhan
Prof. Qun YANG, Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences
Prof. Gwo Giun LEE, National Cheng Kung University
Prof. Heon-Tae KIM, Pukyong National University

Supporting organizations for the international symposium were the Graduate School of Science and Technology, Niigata University; Faculty of Science, Niigata University; Research Centre for Earth and Environmental Sciences, Niigata University; Research Center of Science on Form, Niigata University; Itoigawa Geopark Council; Japanese Geoparks Network.

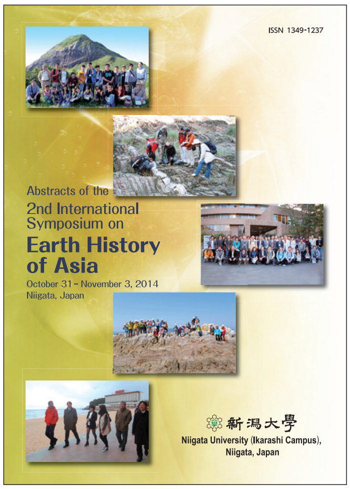

Fig. 1. Cover page of Abstracts of the 2nd International Symposium on Earth History of Asia.

Scientific session in Niigata University

The scientific session of Earth History of Asia was held on 31 October at the University Library Hall and on 1 November at a lecture room of the Graduate School of Science and Technology, Niigata University (Ikarashi Campus). The session was composed of oral and poster presentations. Posters were displayed during these two days. A total of 126 participants, including 27 from overseas partner institutions joined the session. The program and abstracts of the scientific session are presented in a supplement volume of Science Reports of Niigata University (Geology) (Organizing Committee of EHA-II, 2014). The cover page is shown in Fig. 1.

On 31 October, the session started with a welcome speech by Prof. Hisaaki KUDO, Dean of the Graduate School of Science and Technology, Niigata University, followed by an opening address by Prof. Atsushi MATSUOKA, Vice Dean of the Graduate School of Science and Technology, Niigata University. A group photo was taken at the University Library Hall after the opening session (Fig. 2). Five keynote lectures were presented by Prof. Xiaoqiao WAN (China University of Geosciences, Beijing), Prof. Yongdong WANG (Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences), Prof. Tae-Seob KANG (Pukyong National University), Prof. Yueh Jen LAI (National Cheng Kung University), and Prof. Hiroshi FUKUOKA (Niigata University). A Conference Banquet was

Fig. 2. Group photograph of the participants in the scientific session of the 2nd International Symposium on Earth History of Asia held at the University Library Hall, Niigata University (Ikarashi campus).

held at Hotel Nikko Niigata. The banquet started with a welcome address by Prof. Takuji OHYAMA, Dean of Institute of Natural Science and Technology, Niigata University, and the participants enjoyed traditional Japanese delicacies.

On 1 November, nine invited talks and 13 oral presentations were performed in the morning and afternoon sessions, respectively. The invited talks were presented by delegates from Indian Institute of Science (Bengaluru), China University of Geosciences (Beijing), Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences, National Cheng Kung University (Taiwan), Ibaraki University, Hokkaido University, University of Toyama and Niigata University. A total of 31 posters were presented in the entrance hall of the Graduate School of Science and Technology. A lunch-on meeting of faculty members was organized and various issues on research, education and future collaboration were discussed. After the full-day symposium, a Conference Reception was held at Niigata University Cafeteria. Winners of excellent oral and poster presentation prizes were announced during the reception (Fig. 3). The excellent oral prize was awarded to Liqin LI of Nanjing Institute of Geology and Palaeontology for her talk entitled "Late Triassic palaeoclimate and palaeoecosystem variations inferred by palynological record in the northeastern Sichuan Basin, China". The excellent poster prize was awarded to Aya KUBOTA of Hokkaido University for her poster entitled "Micro-organisms in amber from the Aptian (Cretaceous) of Yezo Group, northern Japan".

Fig. 3. Winners of excellent oral and poster presentation prizes, Liqin LI (A) and Aya KUBOTA (B).

Excursion in Itoigawa Global Geopark

After the scientific session held in Niigata University, a two-day field excursion in the Itoigawa Global Geopark was organized. Activities of the excursion included visits to three geosites in the Itoigawa Global Geopark, a tour of the Itoigawa City Museum of History and Folklore and a panel discussion at the Itoigawa City Hall.

A tour bus started from Niigata City in the morning of 2 November, heading to Itoigawa. After 2 and half hours of drive, 34 participants arrived at the Kotakigawa Jade Gorge Geosite (Fig. 4A). They examined the complex geology composed of Paleozoic–Mesozoic rocks and enjoyed traditional local lunch (Fig. 4B) prepared by Kotaki residents. In the afternoon, the participants continued field observations along the Kotakigawa River. After the first day's excursion, the participants stayed at two different places; the faculty members stayed at Hotel White Cliff and the student participants at the Seminar House of Omi Junior High School.

In the morning of 3 November, the two groups joined at the Fossa Magna Park in the Itoigawa–Shizuoka Tectonic Line and Salt Trail (North) Geosite and walked around the park (Fig. 4C). The highlight of the geosite was to examine an outcrop of the Itoigwa–Shizuoka Tectonic Line. The next site was the Omi Coast Geosite where the participants tried to collect jade pebbles. No one was successful in finding a jade, but all could enjoy big waves of the sea (Fig. 4D). After the outdoor activities, they moved to the city center and visited the Itoigwa City Museum of History and Folklore.

In the afternoon, an outreach session composed of lectures and a panel discussion was held at the Itoigawa City Hall. Sixty-one participants including earth scientists and local geopark mentors and guides joined the event (Fig. 4E). The session started with an opening address by Dr. Ko TAKENOUCHI of the Fossa Magna Museum in Itoigawa City and was followed by a welcome speech by Mr. Toru YONEDA, Mayor of Itoigawa City. Two lectures introduced geoparks: Charms of Itoigawa Global Geopark by Mr. Theodore BROWN, Itoigawa Geopark Council; Charms of Tateyama–Kurobe Geopark by Dr. Utako UCHIKOSHIYAMA, Uozu Buried Forest Museum in Uozu City, Toyama Prefecture. The aims of the panel discussion were to establish partnership between local communities and earth scientists from neighboring Asian countries and to exchange idea for improving outreach activities through direct communications between them. The panel discussion was facilitated by Prof. Atsushi MATSUOKA (Niigata University) with a contribution of Mr. Theodore BROWN, Dr. Utako UCHIKOSHIYAMA, Prof. Tae-Seob KANG (Pukyong National University), Prof. Huai-Jen YANG (National Cheng Kung University), Prof. Yongdong WANG (Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences), Prof. Xiaoqiao WAN (China University of Geosciences, Beijing), and Dr. Tsuyoshi ITO (China

Fig. 4. Field excursion and panel discussion in the Itoigawa Global Geopark. A. Group photograph at the Kotakigawa Jade Gorge Geosite, B. Traditional lunch prepared by Kotaki residents, C. Field observation at the Fossa Magna Park (Itoigawa–Shizuoka Tectonic Line), D. Jade collection at the Omi Coast Geosite, E. Group photograph of the participants in the outreach session and panel discussion at the Itoigawa City Hall.

University of Geosciences, Wuhan). A closing address was given by Mr. Haruhisa TAMURA, Director of the Fossa Magna Museum. Mr. Theodore BROWN acted as an interpreter throughout the session.

The Itoigawa excursion was planned and guided by Yousuke IBARAKI, Ko TAKENOUCHI (Fossa Magna Museum, Itoigawa), Tsuyoshi ITO (China University of Geosciences, Wuhan), Toshiro TAKAHASHI and Atsushi MATSUOKA (Niigata University).

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We express our thanks to all the participants for making this international symposium a success. Our thanks go to Mr. Toru YONEDA, Mayor of Itoigawa City, for his participation in the outreach event at the Itoigawa City Hall. We are very grateful to the Secretariats of the Itoigawa Geopark Council and the Tateyama–Kurobe Geopark Council for their collaboration. We thank Ms. Haruka OHKOUCHI of the incorporated non-profit organization GeoProject Niigata for assisting the symposium. This symposium was financially supported by Niigata Prefecture and Niigata Visitors & Convention Bureau.

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