

LATE PERMIAN (CHANGHSINGIAN) BRACHIOPODS FROM THE TOYOMA FORMATION, SOUTH KITAKAMI BELT, JAPAN

Jun-ichi TAZAWA

Hamaura-cho 1-260-1, Chuo-ku, Niigata 951-8151, Japan

ABSTRACT

This study describes 35 species of late Permian (Changhsingian) brachiopods in 28 genera (including one new species, *Edriosteges kotlyari* sp. nov.) from the upper part of the Toyoma Formation in the eastern (Maeda area) and central (Kanayashiki and Nabekoshiyama areas) parts of the South Kitakami Belt (southern Kitakami Mountains), northeastern Japan. Based mainly on brachiopod biostratigraphy, the upper part of the Toyoma Formation is correlated with the Changhsingian. In terms of palaeobiogeography, the Changhsingian brachiopod assemblage is a mixed Boreal–Tethyan fauna, and has a close affinity with that of the Maizuru Belt, southwestern Japan. Thus, during the latest Permian, the South Kitakami region was a part of the Sino-Mongolian–Japanese Province located between the Boreal and Tethyan realms in the middle latitudes of the Northern Hemisphere. This region was probably a deep sea bordering a microcontinent (the Proto-Japan Block), which was located east of the North China Block at the eastern end of the Central Asian Orogenic Belt during the Changhsingian.

Key words: Brachiopoda, Changhsingian, late Permian, South Kitakami Belt, Toyoma Formation

田沢純一 (2024) 南部北上帯の登米層から産出するペルム紀後期 (長興期) 腕足類. 福井県立恐竜博物館紀要 23: 9–61.

南部北上帯 (南部北上山地) 東部の前田地域および中部の^{かなやしき}金屋敷・^{なべこしやま}鍋越山地域に分布する^{とよま}登米層上部から産出する 28 属 35 種 (1 新種 *Edriosteges kotlyari* sp. nov. を含む) のペルム紀後期 (長興期, Changhsingian) 腕足類を記載した. 主にこれらの腕足類により, 生層序学的に, 登米層上部は最上部ペルム系 Changhsingian に対比される. 古生物地理学的には, 南部北上地域の Changhsingian フォーナはボレアル型–テチス型混合フォーナで, 西南日本 (舞鶴帯) のフォーナに類似する. 南部北上地域は, 後期ペルム紀 (Changhsingian) に北半球中緯度付近にあったボレアル区とテチス区の境界に位置したシノモンゴル–日本区に属し, おそらく中央アジア造山帯の東端, 北中国地塊の東方に存在した原日本地塊の縁辺深海域であったと推定される.

INTRODUCTION

This paper is the sixth and final contribution in a series on the early Carboniferous (Tournaisian) to late Permian (Changhsingian) brachiopods of the South Kitakami Belt, northeastern Japan. In the first of the series (Tazawa, 2018b), I described the Tournaisian and Visean brachiopods from the Hikoroichi Formation of the Hikoroichi area, eastern part of the belt. The second contribution (Tazawa et al., 2019) addressed the Tournaisian and Visean brachiopods from the Karaumedate Formation in the Nagasaka area, western part of the belt. The third of the series (Tazawa, 2020) considered the Tournaisian and Visean brachiopods from the Shittakazawa, Arisu and Odaira Formations in the central part of the belt (Shimoarisu, Yokota, Yahagi, Nisawa, Okuhinotsuchi and Shizu areas). The

fourth contribution (Tazawa and Shintani, 2022) addressed the Sakmarian and Kungurian brachiopods from the Nagaiwa–Sakamotozawa area, eastern part of the belt, and the fifth of the series (Tazawa and Ibaraki, 2023) was concerned with the Roadian–Capitanian, mostly Wordian brachiopods from the central part of the belt (Setamai, Kamiyasse–Imo and Matsukawa areas). In the present study, the last of the series, I describe the latest Permian (Changhsingian) brachiopods from the Toyoma Formation in the eastern (Maeda area) and central (Kanayashiki and Nabekoshiyama areas) parts of the South Kitakami Belt.

Upper Permian marine sedimentary rocks are widely distributed in the central to southwestern parts of the South Kitakami Belt. The upper Permian succession of the South Kitakami Belt consists mostly of black shale, often associated with thick sandstone and conglomerate. The upper Permian deposits are considered to be deep-sea (bathyal zone) sediments with slump deposits (Kamada, 1990, 1998). Fossils are scarcer than in the other Carboniferous and Permian formations of the

Received May 30, 2024. Accepted September 22, 2024.

E-mail: j1025-tazawa@memoad.jp

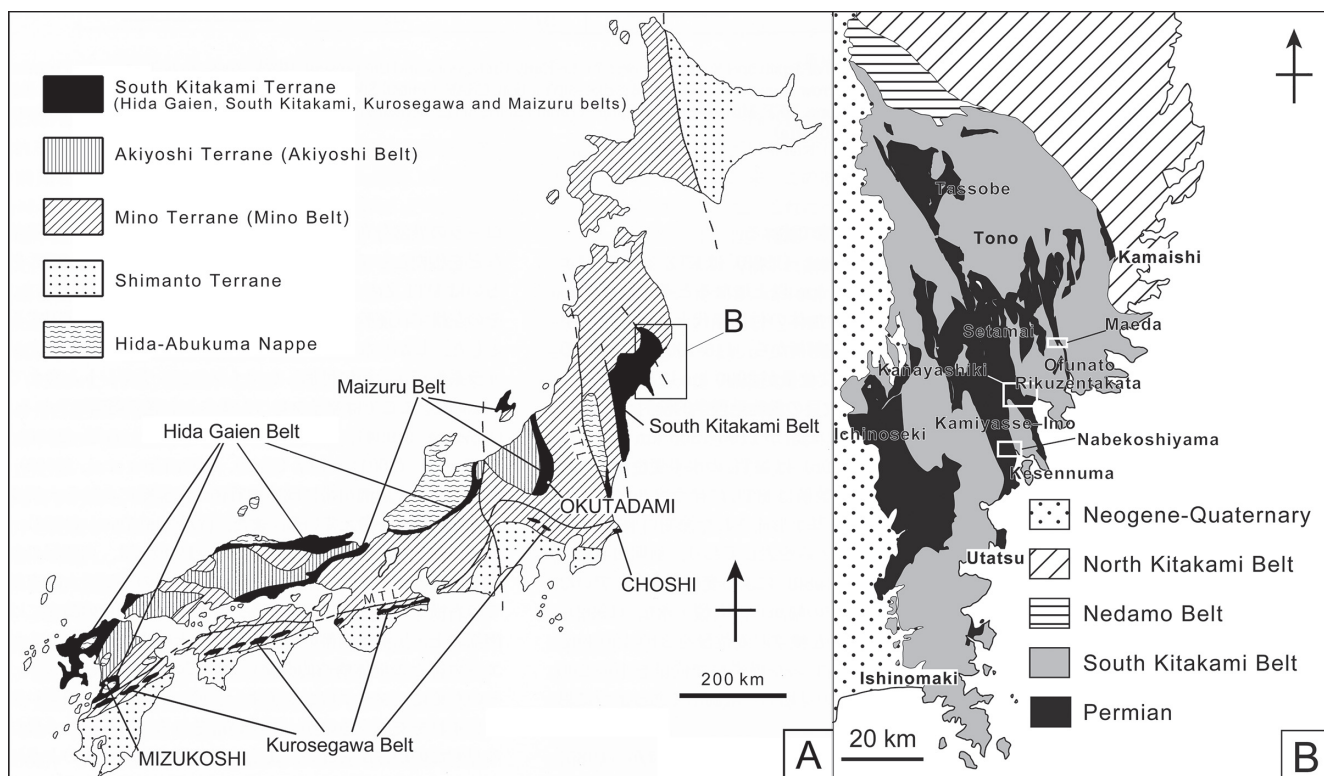


FIGURE 1. Maps showing the location and geology of the Maeda, Kanayashiki and Nabekoshiyama areas, South Kitakami Belt, northeastern Japan. **A**, Geotectonic map of the Japanese Islands, showing the distribution of the South Kitakami Belt (based on Tazawa, 2018a); **B**, geotectonic map of the northeastern Honshu, Japan, showing the distribution of the Permian rocks in the South Kitakami Belt (based on Kawamura et al., 2013).

South Kitakami Belt. In this paper, I describe brachiopods from the upper part of the Toyoma Formation (Onuki, 1956, 1969) in the Maeda area (in Ikawa-cho, Ofunato City, Iwate Prefecture), the Kanayashiki area (in Yahagi-cho, Rikuzentakata City, Iwate Prefecture) and the Nabekoshiyama area (in Kesennuma City, Miyagi Prefecture) (Figs. 1–3), and discuss the age and palaeobiogeography of the brachiopod faunas. I collected most of the brachiopod specimens described in this paper at Nabekoshiyama in 1972–1974, during the course of graduate studies at Hokkaido University under the supervision of M. Minato. Other specimens from Maeda and Nabekoshiyama were collected by Y. Miyake and H. Araki.

PREVIOUS WORK

Stratigraphy

Previous studies on the stratigraphy of the upper Permian rocks in the Maeda area are summarized in Fig. 4. Until now, no detailed geological map of the Maeda area has been published; thus, the stratigraphy of the upper Permian rocks in the area has not been established. In early studies, the upper Permian rocks of the area were considered to be lower to middle Permian, and were named the Maiya Group (Yabe and Sugiyama, 1937), “the Lower–Middle Permian” (Onuki, 1956), and the Kanokura Series (Minato et al., 1979). Ehiro (1996) first recognized

the uppermost Permian (Changhsingian) in the Maeda area based on two ammonoid species, *Paratirolites compressus* and *Paratirolites* sp., although the fossil-bearing shale was not named. Subsequently, Tazawa (2008a) and Tazawa and Miyake (2011) named the uppermost Permian rocks the upper Toyoma Formation based on lithology and the presence of several brachiopod species, including *Tethyochonetes* sp. (= *Fusichonetes* sp.), *Lamnimargus peregrinus*, and *Choristitella wynnei*.

Previous studies on the stratigraphy of the upper Permian rocks in the Kanayashiki area are summarized in Fig. 5. Initially, the black shale-dominated formation overlying the middle Permian succession in Kanayashiki was named the Futatsumori Formation by Shiida (1940). Subsequently, Onuki (1956) named the same unit the Kowaragi Formation. This scheme was employed by Ehiro (1974, 1977), although he proposed the name “Kanayashiki Sandstone Member” for a thick sandstone with conglomerate in the upper part of the formation. Murata and Shimoyama (1979) considered that the Kanayashiki Sandstone Member is the northwestern extension of the lower part of the Toyoma Formation of Kowaragi in the Karakuwa area, based on mollusc fossils (*Euphemitopsis kitakamiensis*, *Astartella toyomensis* and *Pseudopermophorus uedai*). However, Tazawa (1982) correlated the formation with thick sandstone of the Toyoma Formation (Changhsingian) in Nabekoshiyama, based on lithology and the occurrence of the brachiopod *Oldhamina kitakamiensis*, which resembles the Changhsingian *Oldhamina*



FIGURE 2. Views of the Nabekoshiyama area. **A**, Eastern slope of the Mt. Nabekoshiyama; **B**, upper stream of the Komagomesawa Valley.



FIGURE 3. **A**, Outcrop of black shale in the upper part of the Toyoma Formation at the middle stream of the Komagomesawa Valley; **B**, outcrop of calcareous sandstone in the upper part of the Toyoma Formation at the upper stream of the Komagomesawa Valley.

			Yabe and Sugiyama (1937)	Onuki (1956)	Minato et al. (1979)	Ehiro (1996)	Tazawa (2008a)	Tazawa and Miyake (2011)	Tazawa (This study)
Permian	Lopingian	Changhsingian				"Uppermost Permian"	Toyoma Formation (Upper)	Toyoma Formation (Upper)	Toyoma Formation (Upper)
		Wuchiapingian							
	Guadalupian		Maiya Group	"Lower-Middle Permian"	Kanokura Series				
Cisuralian									

FIGURE 4. Comparison of stratigraphic schemes proposed for the upper Permian formations in the Maeda area, South Kitakami Belt.

			Shiida (1940)	Onuki (1956)	Ehiro (1974)	Murata and Shimoyama (1979)	Tazawa (1982)	Tazawa (This study)
Upper Permian (Lopingian)	Changhsingian						KSM Toyoma Formation (Lower)	KSM Toyoma Formation (Lower)
	Wuchiapingian	Futatsumori Formation	Kowaragi Formation	KSM Kowaragi Formation	KSM Toyoma Formation (Lower)			

FIGURE 5. Comparison of stratigraphic schemes proposed for the upper Permian formations in the Kanayashiki area, South Kitakami Belt. KSM: Kanayashiki Sandstone Member.

FIGURE 6. Comparison of stratigraphic schemes proposed for the upper Permian formations in the Nabekoshiyama area, South Kitakami Belt. NSM: Nabekoshiyama Sandstone Member.

Palaeontology

There have been few studies on the invertebrate fossils, with the exception of the brachiopods, from the upper part of the Toyoma Formation in Maeda, Kanayashiki and Nabekoshiyama. Until now only a few species of the foraminifers, pelecypods and ammonoids have been described: *Colaniella parva*, *Paracolaniella leei*, *Nanlingella* cf. *meridionalis* and *Palaeofusulina* sp. from Nabekoshiyama (Tazawa, 1975; Kobayashi, 2002); *Girtypecten* cf. *beipeiensis* and *Etheripecten*? sp. from Maeda (Nakazawa, 1998) and *Actinodontophora katsurensis* from Nabekoshiyama (Nakazawa and Newell, 1968); and *Paratirolites compressus* and *Paratirolites* sp. from Maeda (Ehiro, 1996). In contrast, taxonomic studies on the brachiopods are plentiful. Tazawa (2008a) and Tazawa and Miyake (2011) described the following 15 species in 14 genera from Maeda: *Tethyochonetes* sp., *Lammimargus peregrinus*, *Compressopproductus* cf. *mytiloides*, *Richthofenia* sp., *Petasmaia ehroi*, *Derbyia* sp., *Geyerella ofunatoensis*, *Geyerella* sp., *Tropidelasma* sp., *Enteleles andrewsi*, *Orthotichia* sp., *Hustedia minuta*, *Attenuatella* sp., *Choristitella wynnei* and *Callispirina* sp. Tazawa (1982) described one species, *Oldhamina kitakamiensis*, from Kanayashiki. Tazawa (1975, 2012) and Tazawa and Araki (2014) described 28 species in 21 genera from Nabekoshiyama: *Neochonetes* sp.,

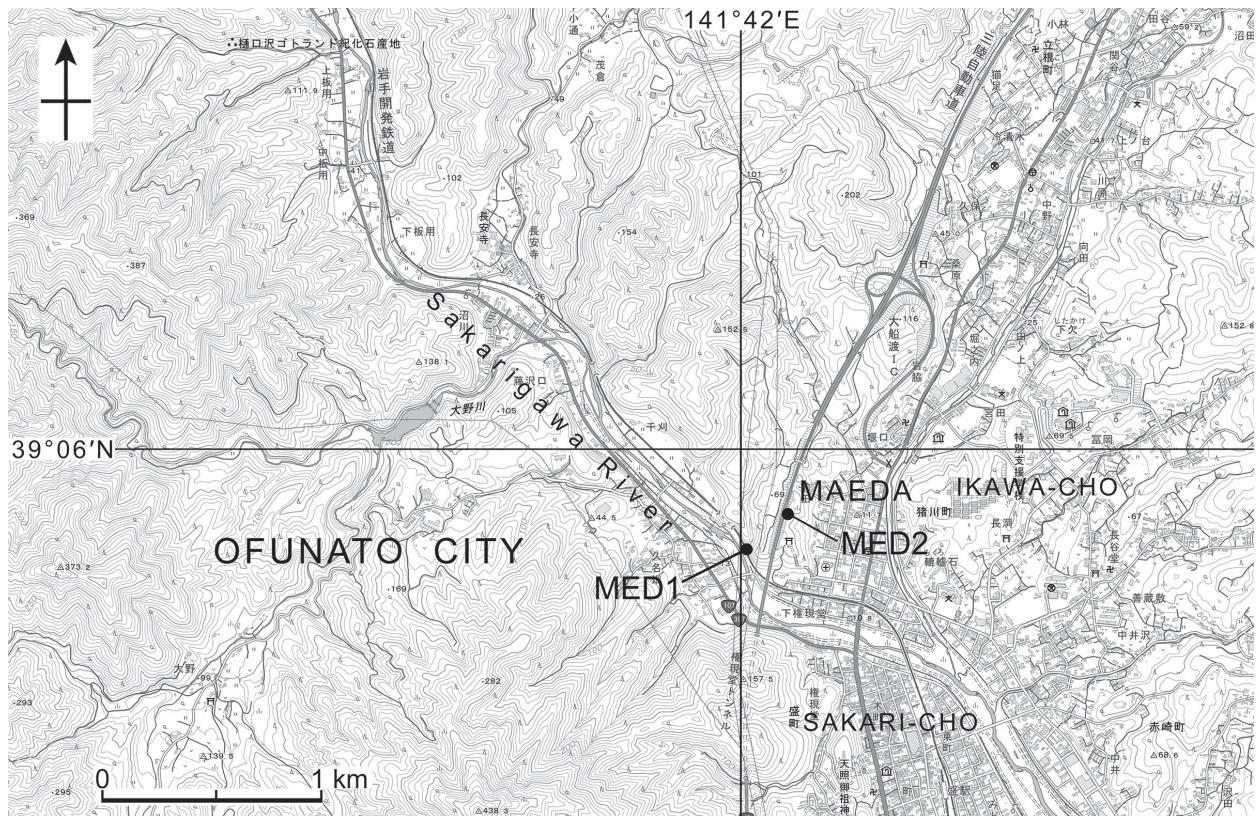


FIGURE 7. Map showing the fossil localities MED1 and MED2 in the Maeda area (using the electronic topographical map of GSI).

Spinomarginifera lopingensis, *Lamnimargus peregrinus*, *L. japonicus*, *Linoproductus* sp., *Megousia auriculata*, *M. nakamurai*, *Terrakea nabekoshiyamensis*, *Orthothrix sudoi*, *Edriosteges* sp. A, *Tschernyschewia typica*, *Eolyttonia tenuis*, *E. mira*, *Oldhamina squamosa*, *O. anshunensis*, *O. kitakamiensis*, *O. ehiro*, *Derbyia* sp., *Meekella* sp., *Enteles* sp., *Peltichia* cf. *transversa*, *Orthotichia* sp., *Hustedia indica*, *H. minuta*, *Attenuatella bandoi*, *Martinia* sp., *Choristitella wynnei* and *Spiriferellina cristata*.

In terms of biostratigraphy, Tazawa (1975) first recognized the Changhsingian age of the upper part of the Toyoma Formation in Nabekoshiyama based on foraminifers (*Colaniella parva* and *Paracolaniella leei*) and brachiopods (*Paramarginifera japonica* and *Eolyttonia* cf. *nakazawai*). Ishii et al. (1975) also documented upper Permian foraminifers (*Colaniella minima*, *Palaeofusulina* sp. and other taxa) from Nabekoshiyama, but these specimens were not described. In Kanayashiki, Tazawa (1982) assigned the upper part of the Toyoma Formation to the Changhsingian based on the sole brachiopod species, *Oldhamina kitakamiensis*. In Maeda, Ehiro (1996) found Changhsingian ammonoids (*Palatirolites compressus* and *Paratirolites* sp.), and Nakazawa (1998) described Changhsingian pelecypods (*Girtypecten* cf. *beipeiensis* and *Etheripecten*? sp.). Subsequently, Kobayashi (2002) described the Changhsingian foraminifers *Colaniella parva* and *Palaeofusulina* sp., *Paracolaniella leei*, *Nanlingella* cf. *meridionalis* and *Palaeofusulina* sp. from

Nabekoshiyama. Tazawa and Miyake (2011) described the Changhsingian brachiopods from Maeda, and Tazawa (2012) described those from Nabekoshiyama.

In terms of palaeobiogeography, Nakazawa (1988) reported that the Changhsingian pelecypods (*Girtypecten* cf. *beipeiensis* and *Etheripecten*? sp.) from Maeda showed an affinity with the bivalve fauna of South China. Kobayashi (2002) proposed that the Nabekoshiyama foraminifer fauna, consisting of *Colaniella parva*, *Nanlingella* cf. *meridionalis* and *Palaeofusulina* sp., belonged to the Tethyan Province, and was allied to the late Permian faunas known from the Maizuru and Kurosegawa belts of southwestern Japan, South China and Southeast Asia. In contrast, Tazawa (2008a) considered that the brachiopod genus *Lamnimargus* from the upper Toyoma Formation of Maeda was an anti-tropical genus distributed in the middle-latitude areas of both Northern and Southern Hemispheres, meaning that the South Kitakami region, including Maeda, was located in the mid-latitude area of the Northern Hemisphere, probably near eastern Russia (South Primorye), northeastern China and northern China (Inner Mongolia). Subsequently, Tazawa and Miyake (2011) proposed the Maeda brachiopod fauna was a mixed Boreal and Tethyan fauna, and that the area was located near North China during the late Permian. Tazawa (2012) proposed that the Nabekoshiyama brachiopod fauna was a mixed Boreal and Tethyan fauna, and was allied with the late Permian fauna of South Primorye, eastern Russia.



FIGURE 8. Map showing the fossil locality KNY1 in the Kanayashiki area (using the electronic topographical map of GSI).

STRATIGRAPHY

Upper Permian rocks of the Toyoma Formation are exposed in the Maeda, Kanayashiki and Nabekoshiyama areas, forming three subparallel synclines that trend NNW–SSE and plunge gently towards the south (Fig. 1; Minato et al., 1979, fig. 2k-1). The upper Permian successions of these areas consist mostly of black shale with subordinate sandstone, conglomerate and limestone. In two areas (Kanayashiki and Nabekoshiyama), thick sandstones are developed.

Maeda

The upper Permian succession of the Maeda area composed mainly of black to dark grey shale, with subordinate sandy shale, sandstone and conglomerate (Ehiro, 1996). The total thickness is unknown. These strata strike NNW–SSE to NW–SE and dip 40–80°W. Brachiopod fossils were collected from dark grey sandy shale at two localities MED1 and MED2 (Fig. 7). Tazawa (2008a) regarded the shale-dominated beds as the upper part of the Toyoma Formation on the basis of lithology and fossil content; i.e., the Changhsingian ammonoids and pelecypods described by Ehiro (1996) and Nakazawa (1998), respectively.

Kanayashiki

The upper Permian of the Kanayashiki area (Fig. 8) is more than 1,000 m thick, and consists mostly of alternating black shale and dark grey sandstone, with a comparatively thick sandstone and conglomerate unit (the Kanayashiki Sandstone Member) in the upper part (Fig. 9; Ehiro, 1974). A single specimen of the brachiopod *Oldhamina kitakamiensis* was collected from calcareous shale float at locality KNY1, and was probably derived from the Kanayashiki Sandstone Member (exact horizon is unknown).

Nabekoshiyama

The upper Permian Toyoma Formation is exposed in the Nabekoshiyama area, forming the core of a syncline that trends NW–SE and plunges SE (Figs. 10, 11). According to Tazawa (1975), the upper Permian rocks in the Nabekoshiyama area are mostly composed of black shale and sandstone with subordinate conglomerate and limestone, with a total thickness of more than 700 m. The lower part consists of black shale that is more than 330 m thick. The upper part is subdivided into two parts: the lower interval contains mostly sandstone with subordinate black

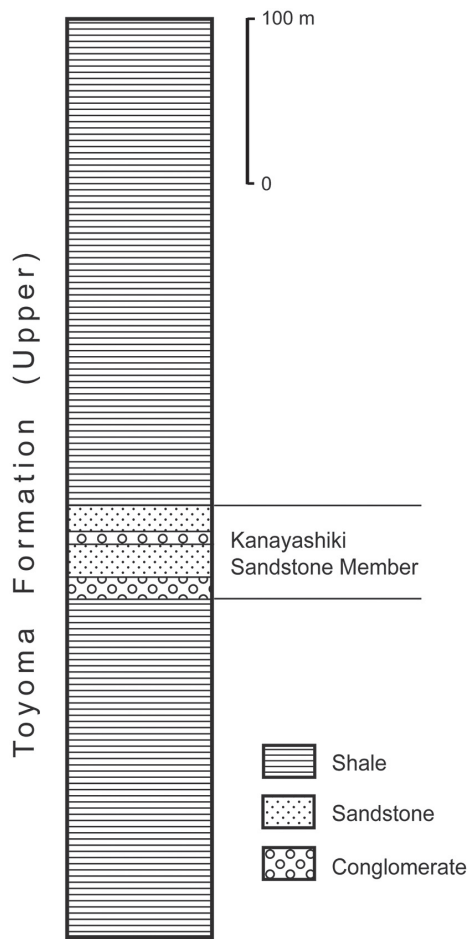


FIGURE 9. Generalized columnar section of the upper part of the Toyoma Formation in the Kanayashiki area (modified from Ehira, 1974).

shale and intercalations of conglomerate, shale and limestone, and is 450 m thick; the upper interval consists of black shale that is more than 80 m thick (Fig. 12). Fossil foraminifers and brachiopods occur in the sandstone and limestone of the upper part of the Toyoma Formation. The brachiopods of the Nabekoshiyama area were collected from seven localities (AR6, AR7, KF105, KF107, KF 108, KF109 and KZ2) in the sandstone of the upper part of the Toyoma Formation. In this paper I propose the name “Nabekoshiyama Sandstone Member” for the thick sandstone-dominated sequence in the upper part of the Toyoma Formation in the Nabekoshiyama area.

MATERIALS AND FOSSIL LOCALITIES

The brachiopod specimens described herein were collected from 10 localities (stations) in the Maeda, Kanayashiki and Nabekoshiyama areas of the South Kitakami Belt. The materials were collected by H. Araki, Y. Miyake and the present author. The topographic and stratigraphic locations, lithologies and brachiopod species from the 10 fossil localities are indicated in Figs. 7–10, 12, 13, and summarized below. These specimens are

PROPOSAL FOR STRATIGRAPHIC UNIT

Nabekoshiyama Sandstone Member

Type locality: Komagomesawa Valley, south of Mt. Nabekoshiyama, Kesennuma, Miyagi Prefecture, northeastern Japan. Distribution: Around Mt. Nabekoshiyama, Kesennuma, Miyagi Prefecture, northeastern Japan. Thickness: 450 m thick. Lithology: Sandstone with intercalations of conglomerate, shale and limestone. Fossils occur from sandstone (brachiopods) and limestone (foraminifers). The stratigraphic succession of the Nabekoshiyama Sandstone Member in ascending order is as follows: sandstone with intercalations of limestone and conglomerate (150 m thick), dark-grey to black shale (100 m thick), and sandstone with intercalations of limestone, shale and conglomerate (200 m thick). Fossils: Foraminifers (*Colaniella parva*, *Palaeofusulina* sp., etc.) and brachiopods (*Lamnimargus peregrinus*, *L. japonicus*, *Spinomarginifera lopingensis*, *Edriosteges kotlyari* sp. nov., *Tschernyschewia typica*, *Megousia auriculata*, *M. nakamurai*, *Eolytonia tenuis*, *E. mira*, *Oldhamina squamosa*, *O. anshunensis*, *Peltichia transversa*, *Orthotichia dorashamensis*, *Attenuatella bandoi*, *Choristitella wynnei*, *Spiriferellina cristata*, etc.). Stratigraphic relationship: Conformably overlies black shale of the lower part of the Toyoma Formation, and is in turn conformably overlain by black shale of the upper part of the Toyoma Formation. References: Kobayashi, F. 2002. Lithology and foraminiferal fauna of allochthonous limestones (Changhsingian) in the upper part of the Toyoma Formation in the South Kitakami Belt, northeast Japan. *Paleont. Res.* 6: 331–342; Tazawa, J. 1975. Uppermost Permian fossils from the Southern Kitakami Mountains, northeast Japan. *Jour. Geol. Soc. Japan.* 81: 629–640; Tazawa, J. 2012. Late Permian (Changhsingian) brachiopod fauna from Nabekoshiyama in the Kesennuma area, South Kitakami Belt, northeast Japan. *Sci. Rep. Niigata Univ. (Geol.)* 27: 15–50.

now registered and stored in the Department of Geology, Niigata University, Niigata (NU-B prefix); the Hokkaido University Museum, Sapporo (UHR prefix); the Tohoku University Museum, Sendai (IGPS prefix); and the Kesennuma Board of Education, Kesennuma, Miyagi Prefecture (KCG prefix).

AR6: Nabekoshiyama area (38°55′ 29″N, 141°34′ 00″E), upper Kitsunezakisawa Valley, grey to light brown coarse-grained sandstone, 435 m above the base of the Nabekoshiyama Sandstone Member in the upper part of the Toyoma Formation, with *Petasmaia ehroi*.

AR7: Nabekoshiyama area (38°54′ 58″N, 141°33′ 50″E), upper Takinosawa Valley, dark grey to black shale, 447 m above the base of the Nabekoshiyama Sandstone Member in the upper part of the Toyoma Formation, with *Attenuatella bandoi*.

KF105 (Loc. 6 of Tazawa, 1975): Nabekoshiyama area (38°54′ 58″N, 141°33′ 42″E), upper Takinosawa Valley, light brown granule to very coarse-grained sandstone, 394 m above the base of the Nabekoshiyama Sandstone Member in the upper part of the Toyoma Formation, with *Orthothrix sudoi*.

KF107 (Loc. 2 of Tazawa, 1975): Nabekoshiyama area (38°55′

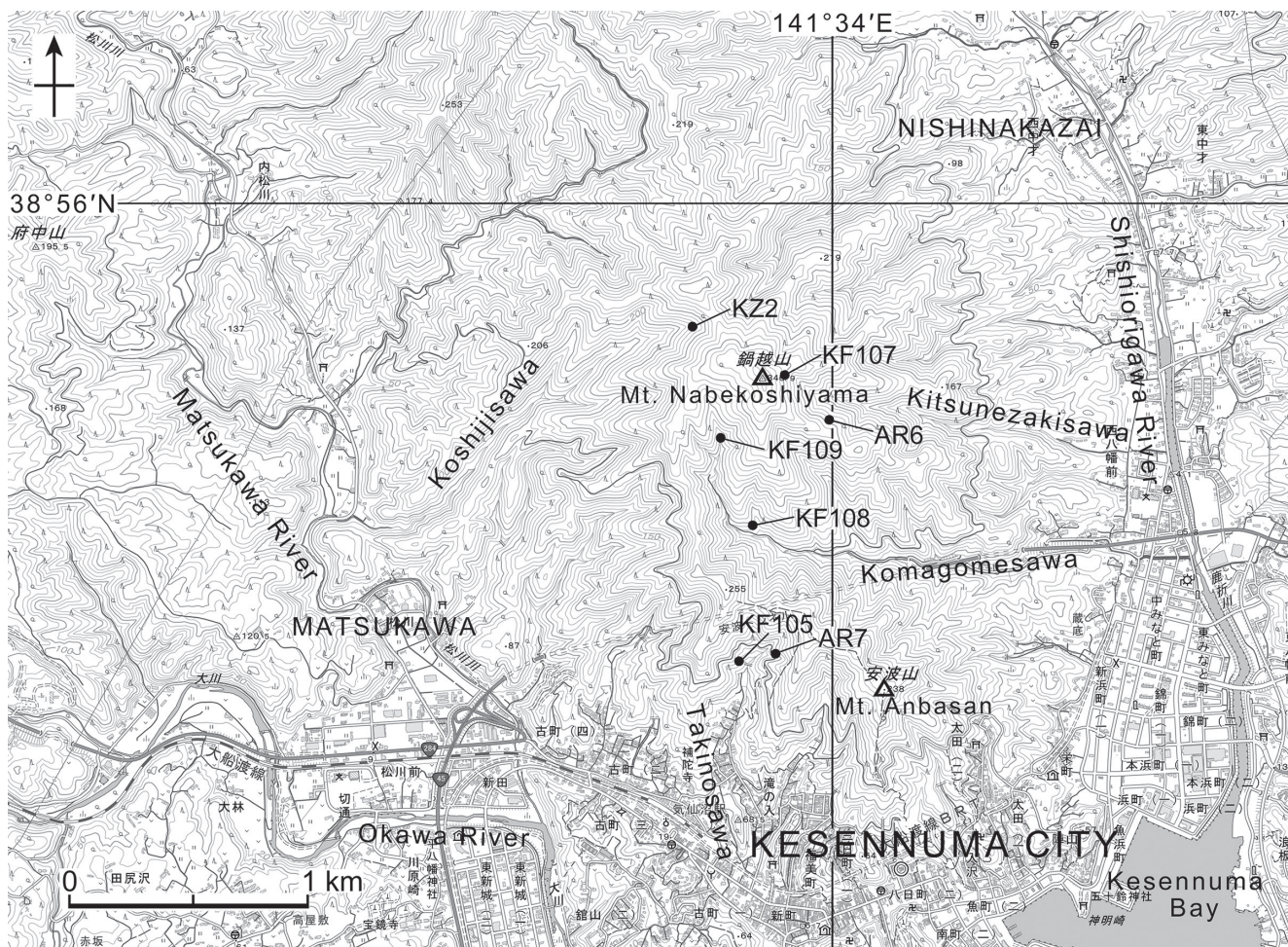


FIGURE 10. Map showing the fossil localities AR6, AR7, KF107, KF108, KF109 and KZ2 in the Nabekoshiyama area (using the electronic topographical map of GSI).

36°N, 141°33' 51"E), upper Kitsunezakisawa Valley, 125 m ESE of the summit of Mt. Nabekoshiyama, light brown granule to very coarse-grained sandstone, 265 m above the base of the Nabekoshiyama Sandstone Member in the upper part of the Toyoma Formation, with *Lammimargus japonicus*, *Edriosteges kotlyari* sp. nov., *Megousia auriculata*, *M. nakamurai*, *Orthothrix sudoi*, *Hustedia indica* and *Martinia* sp.

KF108 (Loc. 5 of Tazawa, 1975): Nabekoshiyama area (38°55' 16"N, 141°33' 46"E), middle Komagomesawa Valley, grey medium-grained sandstone, 124 m above the base of the Nabekoshiyama Sandstone Member in the upper part of the Toyoma Formation, with *Neochonetes* sp., *Lammimargus peregrinus*, *L. japonicus*, *Spinomarginifera lopingensis*, *Tschernyschewia typica*, *Linoproductus* sp., *Megousia auriculata*, *M. nakamurai*, *Terrakea nabekoshiyamensis*, *Orthothrix sudoi*, *Eolyttonia tenuis*, *E. mira*, *Oldhamina squamosa*, *O. anshunensis*, *O. kitakamiensis*, *Petasmaia ehiroi*, *Derbyia* sp., *Enteletes andrewsi*, *Peltichia transversa*, *Orthotichia dorashamensis*, *Hustedia indica*, *H. minuta*,

Choristitella wynnei and *Spiriferellina cristata*.

KF109 (Loc. 4 of Tazawa, 1975): Nabekoshiyama area (38°55' 28"N, 141°33' 40"E), upper Komagomesawa Valley, grey calcareous medium-grained sandstone, 135 m above the base of the Nabekoshiyama Sandstone Member in the upper part of the Toyoma Formation, with *Megousia nakamurai*, *Eolyttonia tenuis*, *E. mira*, *Oldhamina squamosa*, *O. anshunensis* and *Petasmaia ehiroi*.

KNY1: Kanayashiki area (39°01' 03"N, 141°34' 13"E), lower Komasunaizawa Valley, float, grey coarse-grained sandstone of the Kanayashiki Sandstone Member in the upper part of the Toyoma Formation, with *Oldhamina kitakamiensis*.

KZ2: Nabekoshiyama area (38°55' 43"N, 141°33' 35"E), upper Koshijisawa Valley, grey fine-grained sandstone, 14 m above the base of the Nabekoshiyama Sandstone Member in the upper part of the Toyoma Formation, with *Edriosteges kotlyari* sp. nov., *Meekella* sp. and *Orthotichia* sp.

MED1 (Loc. A of Ehiro, 1996): Maeda area (39°05' 45"N, 141°42' 02"E), railroad-cut at 200 m NW from junction of railroad (Iwate Kaihatsu Tetsudo) and road (Sanriku

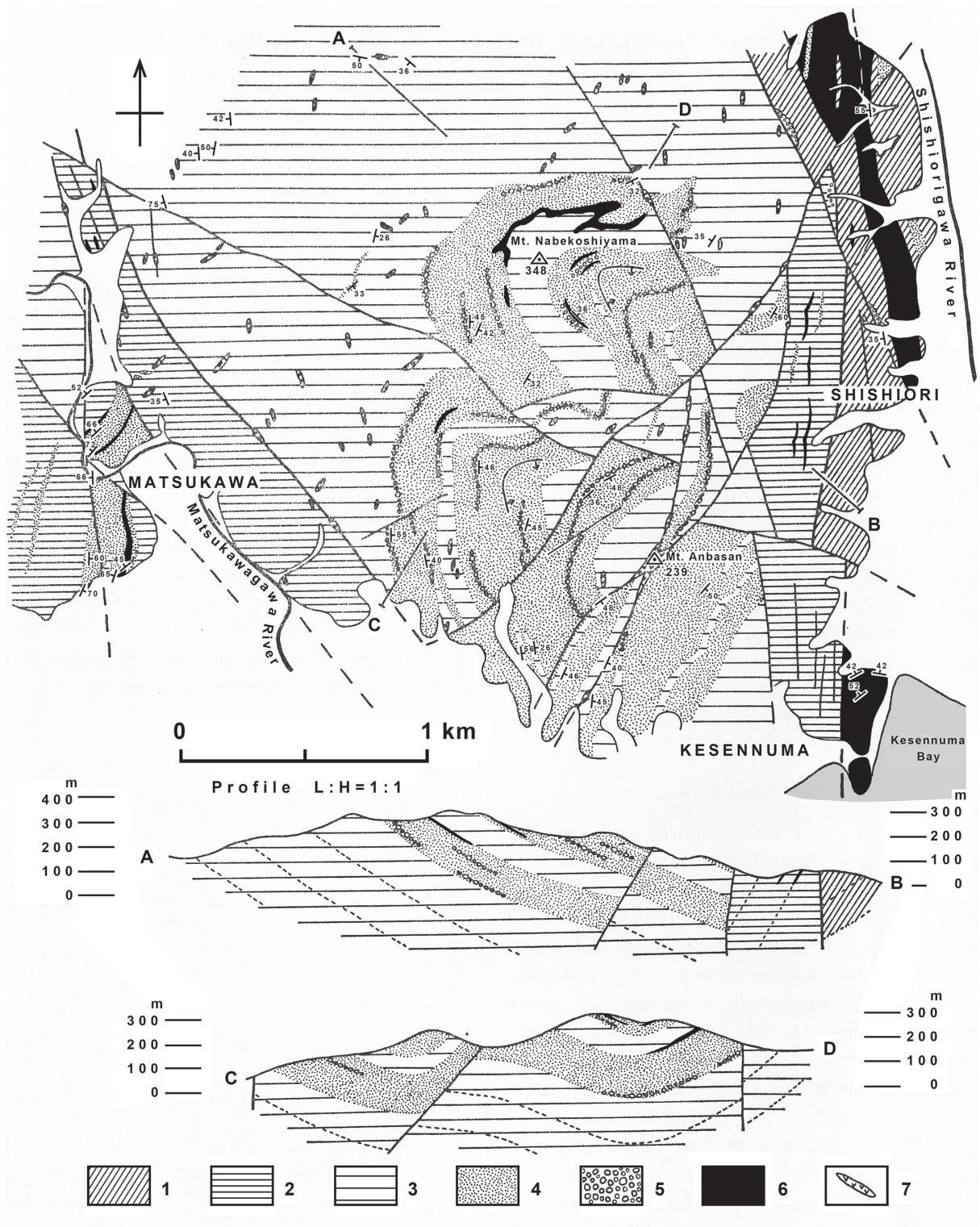


FIGURE 11. Geologic map of the Nabekoshiyama area (after Tazawa, 1975). Legend 1, Shale of the Sakamotozawa Formation; 2, Shale of the Kamiyasse Formation; 3, Shale of the Toyoma Formation; 4, Sandstone; 5, Conglomerate; 6, Limestone; 7, Dyke rock.

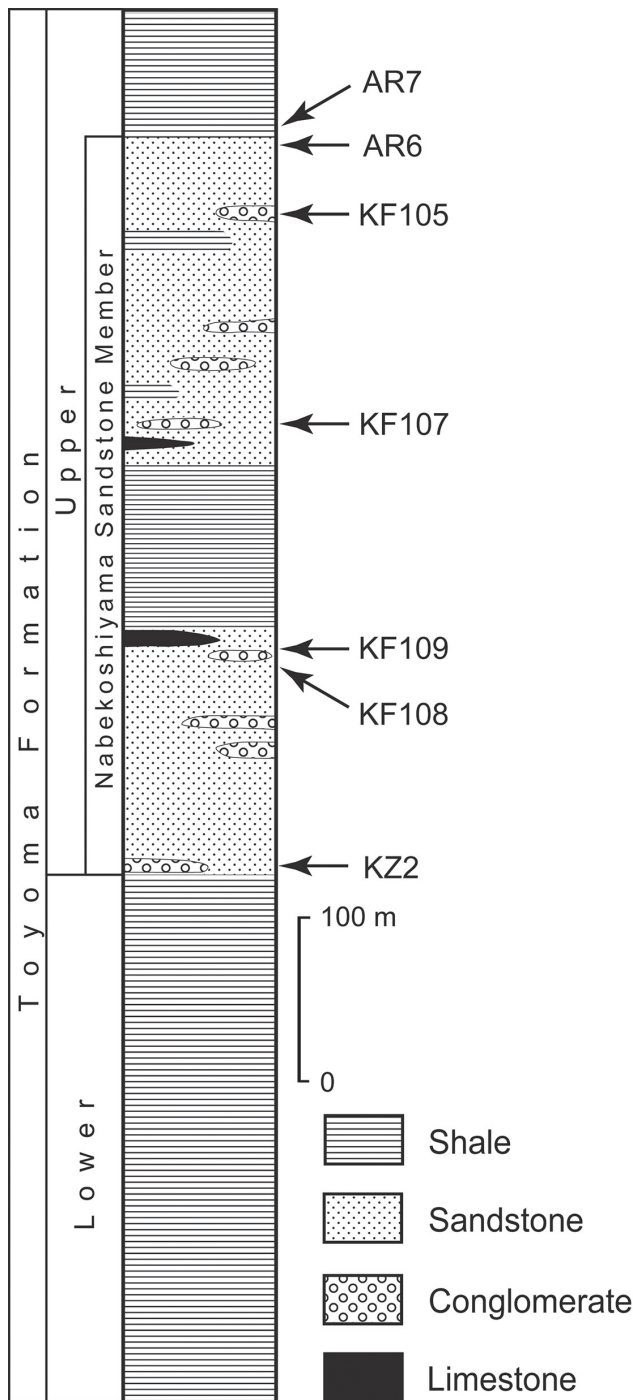


FIGURE 12. Generalized columnar section of the Toyoma Formation in the Nabekoshiyama area, showing the fossil horizons KZ2, KF108, KF109, KF107, KF105, AR6 and AR7 (modified and adapted from Tazawa, 1975).

Jidoshado), upper part of the Toyoma Formation, with *Lamnimargus peregrinus*.

MED2 (Loc. B of Ehiro, 1996): Maeda area (39°05' 50" N, 141°42' 09" E), roadcut at 300 m NNE from junction of railroad (Iwate Kaihatsu Tetsudo) and road (Sanriku

Jidoshado), upper part of the Toyoma Formation, with *Fusichonetes* sp., *Lamnimargus peregrinus*, *Compressoproductus* cf. *mytiloides*, *Richthofenia* sp., *Petasmaia ehiro*, *Geyerella ofunatoensis*, *Tropidelasma* sp., *Enteleter andrewsi*, *Orthotichia dorashamensis*, *Hustedia minuta*, *Choristitella wynnei* and *Callispirina* sp.

BRACHIOPOD FAUNA

The brachiopods described herein are the following 35 species in 28 genera: *Fusichonetes* sp., *Neochonetes* sp., *Lamnimargus peregrinus* (Fredericks, 1924a), *L. japonicus* (Tazawa, 1975), *Spinomarginifera lopingensis* (Kayser, 1883), *Edriosteges kotlyari* sp. nov., *Tschernyschewia typica* Stoyanow, 1910, *Linoproductus* sp., *Megousia auriculata* Muir-Wood and Cooper, 1960, *M. nakamurai* Tazawa, 1975, *Compressoproductus* cf. *mytiloides* (Waagen, 1884), *Terrakea nabekoshiyamensis* Tazawa, 2012, *Orthothrix sudo* Tazawa, 2012, *Richthofenia* sp., *Eolyttonia tenuis* (Waagen, 1883), *E. mira* (Fredericks, 1916), *Oldhamina squamosa* Huang, 1932, *O. anshunensis* Huang, 1932, *O. kitakamiensis* Tazawa, 1982, *Petasmaia ehiro* Tazawa in Tazawa and Miyake, 2011, *Derbyia* sp., *Meekella* sp., *Geyerella ofunatoensis* Tazawa in Tazawa and Miyake, 2011, *Tropidelasma* sp., *Enteretes andrewsi* Grabau, 1931, *Peltichia transversa* (Huang, 1933), *Orthotichia dorashamensis* Sokolskaya, 1965, *Orthotichia* sp., *Hustedia indica* (Waagen, 1883), *H. minuta* Tazawa in Tazawa and Miyake, 2011, *Attenuatella bandoi* Tazawa, 1987, *Martinia* sp., *Choristitella wynnei* (Waagen, 1883), *Callispirina* sp. and *Spiriferellina cristata* (von Schlotheim, 1816).

The brachiopods listed above is classified into two faunas (Maeda and Nabekoshiyama faunas) and sole species *Oldhamina kitakamiensis* from Kanayashiki.

Maeda fauna

The Maeda fauna, from the upper part of the Toyoma Formation in Maeda (localities MED1 and MED2), includes 12 species in 12 genera. The species are *Fusichonetes* sp., *Lamnimargus peregrinus*, *Compressoproductus* cf. *mytiloides*, *Richthofenia* sp., *Petasmaia ehiro*, *Geyerella ofunatoensis*, *Tropidelasma* sp., *Enteleter andrewsi*, *Orthotichia dorashamensis*, *Hustedia minuta*, *Choristitella wynnei* and *Callispirina* sp. Of these species, *Lamnimargus peregrinus*, *Geyerella ofunatoensis* and *Enteleter andrewsi* are abundant; *Richthofenia* sp., *Tropidelasma* sp., *Hustedia minuta* and *Callispirina* sp. are common; and the other species are rare (Fig. 13).

Nabekoshiyama fauna

The Nabekoshiyama fauna, from the upper part of the Toyoma Formation in Nabekoshiyama (localities KZ2, KF108, KF109, KF107, KF105, AR6 and AR7), includes 29 species in 22 genera. The species are *Neochonetes* sp., *Lamnimargus peregrinus*, *L.*

Species \ locality	Maeda		Kanayashiki	Nabekoshiyama						
	MED1	MED2	KNY1	KZ2	KF108	KF109	KF107	KF105	AR6	AR7
<i>Fusichonetes</i> sp.		R								
<i>Neochonetes</i> sp.					C					
<i>Lamnimargus peregrinus</i>	C	A			C					
<i>L. japonicus</i>					A		A			
<i>Spinomarginifera lopingensis</i>					A					
<i>Edriosteges kotlyari</i> sp. nov.				R			R			
<i>Tschernyschewia typica</i>					A					
<i>Linoproductus</i> sp.					R					
<i>Megousia auriculata</i>					C		R			
<i>M. nakamurai</i>					A	R	R			
<i>Compressoproductus</i> cf. <i>mytiloides</i>		R								
<i>Terrakea nabekoshiyamensis</i>					R					
<i>Orthothrix sudoi</i>					A		R	R		
<i>Richthofenia</i> sp.		C								
<i>Eolyttonia tenuis</i>					A	R				
<i>E. mira</i>					R	R				
<i>Oldhamina squamosa</i>					R	R				
<i>O. anshunensis</i>					R	R				
<i>O. kitakamiensis</i>			R		R					
<i>Petasmaia ehiroii</i>		R							R	
<i>Derbyia</i> sp.					R					
<i>Meekella</i> sp.				R						
<i>Geyerella ofunatoensis</i>		A								
<i>Tropidelasma</i> sp.		C								
<i>Enteleles andrewsi</i>		A			R					
<i>Peltichia transversa</i>					R					
<i>Orthotichia dorashamensis</i>		R			R					
<i>Orthotichia</i> sp.				R						
<i>Hustedia indica</i>					R		R			
<i>H. minuta</i>		C			A					
<i>Attenuatella bandoi</i>										R
<i>Martinia</i> sp.							R			
<i>Choristitella wynnei</i>		R			R					
<i>Callispirina</i> sp.		C								
<i>Spiriferellina cristata</i>					C					

FIGURE 13. Occurrence of brachiopod species from the upper part of the Toyoma Formation in the Maeda, Kanayashiki and Nabekoshiyama areas, South Kitakami Belt. A: abundant, C: common, R: rare.

japonicus, *Spinomarginifera lopingensis*, *Edriosteges kotlyari* sp. nov., *Tschernyschewia typica*, *Linoproductus* sp., *Megousia auriculata*, *M. nakamurai*, *Terrakea nabekoshiyamensis*, *Orthothrix sudoi*, *Eolyttonia tenuis*, *E. mira*, *Oldhamina squamosa*, *O. anshunensis*, *O. kitakamiensis*, *Petasmaia ehiroii*, *Derbyia* sp., *Meekella* sp., *Enteleles andrewsi*, *Peltichia transversa*, *Orthotichia dorashamensis*, *Orthotichia* sp., *Hustedia indica*, *H. minuta*, *Attenuatella bandoi*, *Martinia* sp., *Choristitella wynnei* and *Spiriferellina cristata*. Of these

species, *Lamnimargus japonicus*, *Spinomarginifera lopingensis*, *Tschernyschewia typica*, *Megousia nakamurai*, *Orthothrix sudoi*, *Eolyttonia tenuis* and *Hustedia minuta* are abundant; *Neochonetes* sp., *Lamnimargus peregrinus*, *Megousia auriculata* and *Spiriferellina cristata* are common; and the other species are rare (Fig. 13).

AGE AND CORRELATION

System, Series, Stage	Permian							
	Cisuralian				Guadalupian		Lopingian	
	Asselian	Sakmarian	Artinskian	Kungurian	Roadian	Wordian	Capitanian	Wuchiapingian Changhsingian
<i>Fusichonetes</i> sp.								
<i>Lamnimargus peregrinus</i>								
<i>Compressoproductus</i> cf. <i>mytiloides</i>								
<i>Richthofenia</i> sp.								
<i>Petasmaia ehiro</i>								
<i>Geyerella ofunatoensis</i>								
<i>Tropidelasma</i> sp.								
<i>Enteleles andrewsi</i>								
<i>Orthotichia dorashamensis</i>								
<i>Hustedia minuta</i>								
<i>Choristitella wynnei</i>								
<i>Callispirina</i> sp.								

FIGURE 14. Stratigraphic distributions of the brachiopod species in the Maeda fauna. Broken line shows range of the genus.

Upper part of the Toyoma Formation

Maeda

The stratigraphic distributions of the brachiopod species of the Maeda fauna are described in the “Systematic descriptions” section of the present paper, and summarized in Fig. 14. Of the brachiopods listed above, four species (*Petasmaia ehiro*, *Geyerella ofunatoensis*, *Orthotichia dorashamensis* and *Hustedia minuta*) are known only from the Changhsingian; *Choristitella wynnei* is known from the Capitanian–Changhsingian; *Lamnimargus peregrinus* from the Wordian–Changhsingian; and *Enteleles andrewsi* from the Roadian–Changhsingian. At the generic level, *Fusichonetes* has a stratigraphic range of Changhsingian to lowest Triassic (Shen et al., 2017). In summary, the age of the Maeda fauna is identified as Changhsingian; thus, the upper part of the Toyoma Formation in Maeda is correlated with the Changhsingian. This conclusion is consistent with those of previous studies (Ehiro, 1996; Nakazawa, 1998), in which the upper Permian successions at Maeda was assigned to the Changhsingian based on ammonoids (*Paratirolites compressus* and *Paratirolites* sp.; Ehiro, 1996) and pelecypods (*Girtypecten* cf. *beipeiensis* and *Etheripecten*? sp.; Nakazawa, 1998).

Kanayashiki

One brachiopod species, *Oldhamina kitakamiensis*, occurs in the upper part of the Toyoma Formation (Kanayashiki Sandstone Member) in Kanayashiki. This species closely

System, Series, Stage	Permian							
	Cisuralian				Guadalupian		Lopingian	
	Asselian	Sakmarian	Artinskian	Kungurian	Roadian	Wordian	Capitanian	Wuchiapingian Changhsingian
<i>Neochonetes</i> sp.								
<i>Lamnimargus peregrinus</i>								
<i>L. japonicus</i>								
<i>Spinomarginifera lopingensis</i>								
<i>Edriostege kotlyari</i> sp. nov.								
<i>Tschernyschewia typica</i>								
<i>Linoproductus</i> sp.								
<i>Megousis auriculata</i>								
<i>M. nakamurai</i>								
<i>Terrakea nabekoshiyamensis</i>								
<i>Orthothrix sudo</i>								
<i>Eolytonia tenuis</i>								
<i>E. mira</i>								
<i>Oldhamina squamosa</i>								
<i>O. anshunensis</i>								
<i>O. kitakamiensis</i>								
<i>Petasmaia ehiro</i>								
<i>Derbyia</i> sp.								
<i>Meekella</i> sp.								
<i>Enteleles andrewsi</i>								
<i>Peltichia transversa</i>								
<i>Orthotichia dorashamensis</i>								
<i>Orthotichia</i> sp.								
<i>Hustedia indica</i>								
<i>H. minuta</i>								
<i>Attenuatella bandoi</i>								
<i>Martinia</i> sp.								
<i>Choristitella wynnei</i>								
<i>Spiriferellina cristata</i>								

FIGURE 15. Stratigraphic distributions of the brachiopod species in the Nabekoshiyama fauna. Broken line shows range of the genus.

resembles *Oldhamina anshunensis*, from the Changhsingian of Guizhou, southwestern China, and also occurs in the upper part of the Toyoma Formation (Nabekoshiyama Sandstone Member) in Nabekoshiyama. Thus, the age of the *Oldhamina*-bearing formation is identified as Changhsingian. This conclusion is consistent with previous work (Tazawa, 1982), in which the upper part of the Toyoma Formation in Kanayashiki was correlated with the upper part of the Toyoma Formation (identified as Changhsingian by Tazawa, 1975) in Nabekoshiyama on the basis of lithology and brachiopod fossils.

Nabekoshiyama

The stratigraphic distributions of the brachiopod species of the Nabekoshiyama fauna are described in the “Systematic

Species \ Region																		
	Japan								E. China				CS China		SW China		Iran	
	1. South Kitakami Belt	2. Maizuru Belt	3. Kurosegawa Belt	4. Akiyoshi Belt	5. Hungary	6. Slovenia	7. Serbia	8. Zhejiang	9. Fujian	10. Hubei	11. Hunan	12. Guangdong	13. Guangxi	14. Guizhou	15. Sichuan	16. Transcaucasia	17. Julfa	18. Northern Thailand
<i>Lamnimargus peregrinus</i>	+																	
<i>L. japonicus</i>	+	+		+														
<i>Spinomarginifera lopingensis</i>	+									+			+		+			
<i>Edriosteges kotlyari</i> sp. nov.	+																	
<i>Tschernyschewia typica</i>	+					+	+											
<i>Megousia auriculata</i>	+																	
<i>M. nakamurai</i>	+																	
<i>Compressoproductus</i> cf. <i>mytiloides</i>	+																	
<i>Terrakea nabekoshiyamensis</i>	+																	
<i>Orthothrix sudoi</i>	+																	
<i>Eolyttonia tenuis</i>	+	+	+									+		+	+			
<i>E. mira</i>	+																	
<i>Oldhamina squamosa</i>	+							+	+			+	+	+	+			+
<i>O. anshunensis</i>	+													+	+			
<i>O. kitakamiensis</i>	+																	
<i>Petasmaia ehiroï</i>	+																	
<i>Geyerella ofunatoensis</i>	+																	
<i>Enteleles andrewsi</i>	+																	
<i>Peltichia transversa</i>	+							+			+		+	+	+			
<i>Orthotichia dorashamensis</i>	+															+	+	
<i>Hustedia indica</i>	+	+																
<i>H. minuta</i>	+																	
<i>Attenuatella bandoi</i>	+																	
<i>Choristitella wynnei</i>	+																	
<i>Spiriferellina cristata</i>	+				+													

FIGURE 16. Geographic distributions of brachiopod species of the Maeda and Nabekoshiyama faunas with *Oldhamina kitakamiensis* from Kanayashiki.

descriptions” section of the present paper, and summarized in Fig. 15. Of the brachiopod species listed above, nine species (*Lamnimargus japonicus*, *Megousia nakamurai*, *Terrakea nabekoshiyamensis*, *Orthothrix sudoi*, *Oldhamina squamosa*, *O. kitakamiensis*, *Petasmaia ehiroï*, *Orthotichia dorashamensis* and *Hustedia minuta*) are known only from the Changhsingian; five species (*Edriosteges kotlyari* sp. nov., *Tschernyschewia typica*, *Oldhamina anshunensis*, *Peltichia transversa* and *Attenuatella bandoi*) are known from the Wuchiapingian–Changhsingian; *Choristitella wynnei* is known from the Capitanian–Changhsingian; and three species (*Lamnimargus peregrinus*, *Spinomarginifera lopingensis* and *Eolyttonia mira*)

are known from the Wordian–Changhsingian. In summary, the Nabekoshiyama fauna is identified as Changhsingian in age. Thus, the upper part of the Toyoma Formation (including the Nabekoshiyama Sandstone Member) is correlated with the Changhsingian. This conclusion is consistent with those of previous studies (Tazawa, 1975, 2012; Kobayashi, 2002), in which the age of the upper part of the Toyoma Formation in Nabekoshiyama was identified as Changhsingian based on both foraminifers (*Colaniella parva* and *Palaeofusulina* sp.) and brachiopods (*Lamnimargus peregrinus*, *L. japonicus*, *Spinomarginifera lopingensis*, *Tschernyschewia typica*, *Oldhamina squamosa*, *O. anshunensis* and *O. kitakamiensis*).

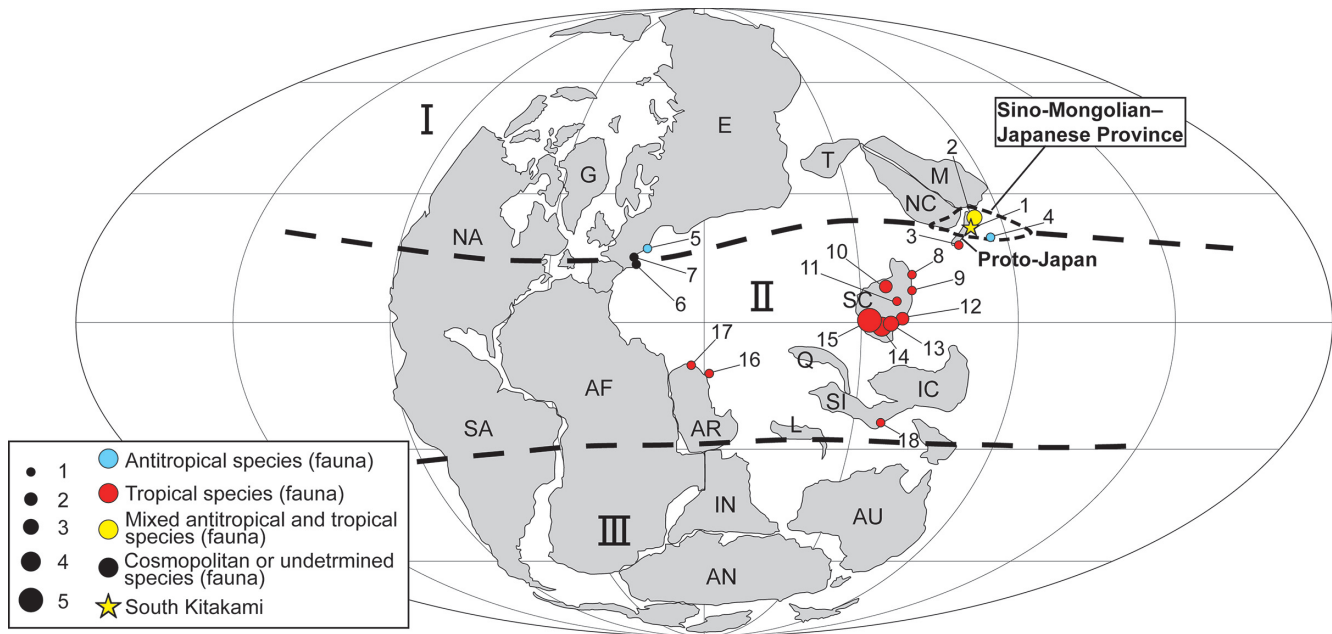


FIGURE 17. Late Permian (Changhsingian) reconstruction map of the world (adapted from Ziegler et al., 1997), showing the geographic distribution of brachiopod species in the Maeda and Nabekoshiyama faunas (excluding 10 uncertain species) with *Oldhamina kitakamiensis* from Kanayashiki. Location numbers are same in Figure 16, and the numbers appended to the circles in the legend indicate the species numbers, AF: Africa, AN: Antarctica, AR: Arabia, AU: Australia, E: Eurasia, G: Greenland, IC: Indochina, IN: India, L: Lhasa, M: Mongolia, NA: North America, NC: North China, Q: Qiangtang, SA: South America, SC: South China, SI: Sibumasu, T: Tarim.; I: Boreal Realm, II: Tethyan Realm, III: Gondwanan Realm.

PALAEOBIOGEOGRAPHY

The geographic distributions of the Changhsingian brachiopod species of the Maeda and Nabekoshiyama faunas and the Kanayashiki species (*Oldhamina kitakamiensis*) are documented in the “Systematic descriptions” section and are summarized in Figs. 16 and 17. Of the 25 species (excluding 10 uncertain species) of Changhsingian brachiopods, five species also occur in southwestern China (Sichuan); four species also occur in southwestern China (Guizhou); three species are found in southwestern Japan (Maizuru Belt) and central-southern China (Guangxi); and two species are found in central-southern China (Hubei and Guangdong). Furthermore, the Changhsingian brachiopod faunas of the South Kitakami and Maizuru belts include both antitropical (*Lamnimargus* and *Megousia*) and tropical (*Spinomarginifera*, *Eolyttonia*, *Oldhamina* and *Peltichia*) genera; in contrast, the Changhsingian brachiopod faunas of central-southern China (Hubei, Guangdong and Guangxi) and southwestern China (Guizhou and Sichuan) include tropical genera (*Spinomarginifera*, *Eolyttonia*, *Oldhamina* and *Peltichia*), but lack antitropical genera (such as *Lamnimargus* and *Megousia*). To summarise, the Changhsingian fauna of the South Kitakami Belt is a mixed Boreal–Tethyan fauna, and exhibits affinities with that of southwestern Japan (Maizuru Belt). This conclusion is consistent with the previous works on the Changhsingian brachiopod faunas of Maeda (Tazawa and Miyake, 2011) and Nabekoshiyama (Tazawa, 2012) in the South Kitakami Belt and Kawahigashi (Tazawa, 2006a, b) in the Maizuru Belt.

From the information provided above, I conclude that the Changhsingian brachiopod fauna of the South Kitakami Belt is characterised by a mixture of Boreal and Tethyan elements, and belonged to the Sino-Mongolian–Japanese Province (Shi and Tazawa, 2001) located between the Boreal and Tethyan realms in the mid-latitudes of the Northern Hemisphere (Fig. 17). The South Kitakami region was probably east of the North China Block as a remnant of the Sino-Mongolian–Japanese Province during the Changhsingian (Fig. 17). This conclusion is consistent with earlier studies of the Changhsingian brachiopod biogeography of eastern Asia (Tazawa and Miyake, 2011; Tazawa, 2012) and globally (Shen et al., 2000).

CONCLUSIONS

In this study, late Permian (Changhsingian) brachiopods are described from the upper part of the Toyoma Formation in the eastern (Maeda) and central (Kanayashiki and Nabekoshiyama) parts of the South Kitakami Belt (southern Kitakami Belt), northeastern Japan. A total of 35 species in 28 genera are described, of which one species (*Edriosteges kotlyari* sp. nov.) is new. In terms of biostratigraphy, the upper part of the Toyoma Formation in the Maeda, Nabekoshiyama and Kanayashiki areas is correlated with the Changhsingian. Palaeobiogeographically, the Changhsingian brachiopod fauna, including the Maeda and Nabekoshiyama faunas and the Kanayashiki species (*Oldhamina kitakamiensis*), is a mixed Boreal–Tethyan fauna and exhibits affinities with that of the Maizuru Belt, southwestern Japan. Thus, the South Kitakami region belonged to the Sino-

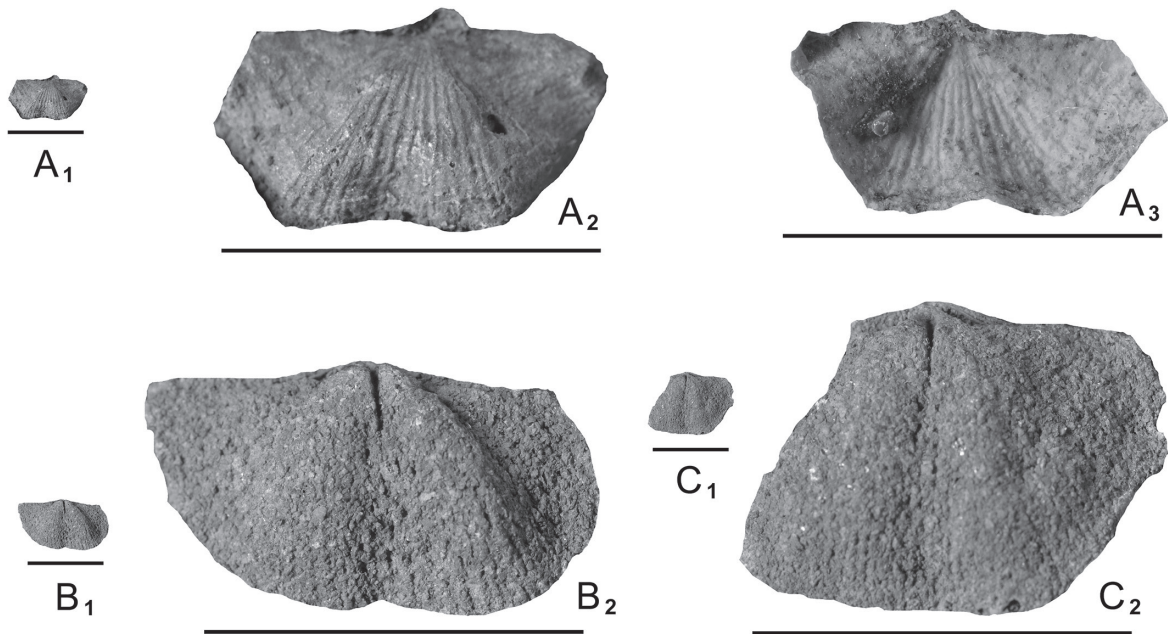


FIGURE 18. **A**, *Fusichonetes* sp., external mould (A₁, A₂) and external latex cast (A₃) of dorsal valve, NU-B1479; **B**, **C**, *Neochonetes* sp., **B**, internal mould (B₁, B₂) of ventral valve, NU-B1654; **C**, internal mould (C₁, C₂) of ventral valve, NU-B1656. Scale bars are 1 cm.

Mongolian–Japanese Province (Shi and Tazawa, 2001) between the Boreal and Tethyan realms in the Northern Hemisphere. This region was probably a deep sea bordering a microcontinent (the Proto-Japan Block), which was located near and east of the North China Block at the eastern end of the Central Asian Orogenic Belt during the Changhsingian.

SYSTEMATIC DESCRIPTIONS

The suprageneric classification given herein mainly follows that of “Treatise on Invertebrate Paleontology, Part H Brachiopoda Revised, Volumes 2–6”, edited by Kaesler (2000a, 2000b, 2002, 2006) and Selden (2007), with exception that classification of suborder Productidina follows Waterhouse (2002).

Order PRODUCTIDA Sarytcheva and Sokolskaya, 1959
 Suborder CHONETIDINA Muir-Wood, 1955
 Superfamily CHONETOIDEA Bronn, 1862
 Family RUGOSOCHONETIDAE Muir-Wood, 1962
 Subfamily RUGOSOCHONETINAE Muir-Wood, 1962
 Genus *FUSICHONETES* Liao in Zhao et al., 1981

Type species.—*Plicochonetes nayongensis* Liao, 1980.

Fusichonetes sp.
 (Fig. 18A)

Tethyochonetes sp. Tazawa in Tazawa and Miyake, 2011, p. 4, fig. 2.1.

Material.—One specimen from locality MED2, external mould of a dorsal valve, NU-B1479.

Remarks.—This specimen was previously described by Tazawa (in Tazawa and Miyake, 2011, p. 4, fig. 2) as *Tethyochonetes* sp. from the upper part of the Toyoma Formation in Maeda. According to Wu et al. (2017) and Shen et al. (2017), the genus *Tethyochonetes* Chen et al., 2000 is a junior synonym of the genus *Fusichonetes* Liao in Zhao et al., 1981. The Maeda species can be assigned to the genus *Fusichonetes* by its small size (length about 6 mm, width about 12 mm in the sole specimen, NU-B1479), transversely subquadrate outline, and in having numerous simple, round costellae (8–9 in 3 mm at midvalve) on the dorsal valve. This species superficially resembles *Fusispirifer soochowensis* (Chao, 1928, p. 31, pl. 1, figs. 14–16), from the Lungtan Formation (Wuchiapingian) of Jiangsu, eastern China and Guizhou, southwestern China in its transversely subquadrate outline and in having large ears. But specific identification is difficult for the poor material.

Occurrence.—Upper part of the Toyoma Formation in Maeda (locality MED2).

Distribution.—Changhsingian (Maeda in the South Kitakami Belt).

Genus *NEOCHONETES* Muir-Wood, 1962

Type species.—*Chonetes dominus* King, 1938.

Neochonetes sp.
 (Fig. 18B, C)

Neochonetes sp. Tazawa, 2012, p. 19, fig. 3.1–3.3.

Material.—Three specimens from locality KF108, internal moulds of three ventral valves, NU-B1654–1656.

Remarks.—These specimens were previously described by Tazawa (2012, p. 19, fig. 3.1–3.3) as *Neochonetes* sp. from the upper part of the Toyoma Formation in Nabekoshiyama. The Nabekoshiyama species can be assigned to the genus *Neochonetes* Muir-Wood, 1962 on account of medium size for the Permian chonetoids (length 8 mm, width about 13 mm in the best-preserved specimen, NU-B1654), transversely subquadrate outline and the ventral valve with a moderately developed sulcus and a strong median septum. However, specific identification is difficult for the poorly preserved specimens.

Occurrence.—Upper part of the Toyoma Formation in Nabekoshiyama (locality KF108).

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

Suborder PRODUCTIDINA Waagen, 1883

Superfamily MARGINIFEROIDEA Stehli, 1954

Family PAUCISPINIFERIDAE Muir-Wood and Cooper, 1960

Subfamily PAUCISPINIFERINAE Muir-Wood and Cooper, 1960

Genus *LAMNIMARGUS* Waterhouse, 1975

Type species.—*Marginifera himalayensis* Diener, 1899.

Lamnimargus peregrinus (Fredericks, 1924a)
(Fig. 19A–E)

Paramarginifera peregrina Fredericks, 1924a, p. 24, pl. 1, figs. 7, 8; Fredericks, 1925, p. 12, pl. 1, figs. 41–44.

Dictyoproductus zesiensis Lee and Gu, 1976, p. 256, pl. 167, figs. 5, 6; pl. 170, fig. 1.

Probolionia caucasica peregrina (Fredericks). Licharew and Kotlyar, 1978, p. 12, figs. 13, 14.

Paramarginifera? *peregrina* Fredericks. Lee et al., 1980, p. 356, pl. 166, figs. 18, 28; Duan and Li, 1985, p. 112, pl. 42, figs. 1–7;

Lamnimargus himalayensis (Diener). Kotlyar in Kotlyar and Zakharov, 1989, pl. 23, fig. 9.

Lamnimargus peregrina (Fredericks). Wang and Zhang, 2003, p. 73, pl. 14, figs. 3, 8, 9; pl. 15, fig. 11; pl. 21, figs. 14–16, 22–24.

Lamnimargus peregrinus (Fredericks). Tazawa, 2008a, p. 7, fig. 3A–T; Tazawa, 2008b, p. 25, fig. 4.2–4.4; Tazawa in Tazawa and Miyake, 2011, p. 4, fig. 3.1–3.3; Tazawa, 2012, p. 21, fig. 4.4, 4.5.

Material.—Twenty-two specimens from localities KF108, MED1 and MED2: (1) external and internal moulds of two conjoined shells, NU-B1063, 1064; (2) internal mould of a conjoined shell with external mould of the ventral valve, NU-B1065; (3) internal mould of a conjoined shell with external

mould of the dorsal valve, NU-B1066; (4) external and internal moulds of a ventral valve, NU-B1067; (5) external cast of a ventral valve, NU-B1494; (6) internal moulds of six ventral valves, NU-B1068, 1069, 1495–1498; (7) external and internal moulds of a dorsal valve, NU-B1588; (8) external cast of a dorsal valve, NU-B1499; and (9) external moulds of eight dorsal valves, NU-B1070–1075, 1589, 1590.

Remarks.—Most of the specimens were previously described by Tazawa (2008a, p. 7, fig. 3A–T; 2012, p. 21, fig. 4.4, 4.5) as *Lamnimargus peregrinus* (Fredericks, 1924a) from the upper part of the Toyoma Formation in Maeda and Nabekoshiyama. The species from both Maeda and Nabekoshiyama can be referred to *Lamnimargus peregrinus* (Fredericks, 1924a), originally described by Fredericks (1924a, p. 24, pl. 1, figs. 7, 8) from the Chandalar Formation of South Primorye, eastern Russia, in its medium to large size (length about 23 mm, width about 40 mm in the largest specimen, NU-B1063), transversely trapezoidal to subrectangular outline, and external ornament of ventral valve, consisting of regular numerous costae on visceral disc, rugae only on ears and costae only on trail (costae numbering 8–9 in 5 mm at midlength), a row of spine bases on base of ears and a pair of strong spine bases on trail. The type species, *Lamnimargus himalayensis* (Diener, 1899, p. 39, pl. 2, figs. 1–7; pl. 6, figs. 1, 2), from the Kuling Shales (Wuchiapingian–Changhsingian) of the Panjab Himalayas, differs from the present species in having coarser costellae on both ventral and dorsal valves and much larger, prominent and convex ears on ventral valve.

Occurrence.—Upper part of the Toyoma Formation in Maeda (localities MED1 and MED2) and Nabekoshiyama (locality KF108).

Distribution.—Wordian–Wuchiapingian: northern China (Inner Mongolia), northeastern China (Heilongjiang) and eastern Russia (South Primorye); and Changhsingian: northeastern Japan (Maeda and Nabekoshiyama in the South Kitakami Belt).

Lamnimargus japonicus (Tazawa, 1975)
(Fig. 20A–E)

Productus (*Dictyoclostus*) *gratiosus* Waagen. Shimizu, 1961, p. 323, pl. 15, figs. 19–21.

Productus (*Dictyoclostus*) sp. Shimizu, 1961, p. 325, pl. 15, figs. 13–15.

Paramarginifera japonica Tazawa, 1975, p. 636, pl. 2, figs. 3–6; pl. 3, figs. 1–4; Tazawa, 1976, pl. 3, figs. 10, 15; Minato et al., 1979, pl. 71, figs. 3–6; pl. 72, figs. 1–4.

Kozłowska sp. Yanagida, 1996, fig. 2.12.

Lamnimargus japonicus (Tazawa). Tazawa, 2006a, p. 10, fig. 3A–E; Tazawa, 2006b, p. 511, figs. 2, 3; Tazawa, 2009, p. 70, fig. 4.3–4.6; Tazawa et al., 2009, fig. 3.7; Tazawa, 2012, p. 23, fig. 4.6–4.12.

Material.—Seventeen specimens from localities KF107 and KF108: (1) internal mould of a conjoined shell with external mould of the dorsal valve, NU-B1591; (2) external and internal moulds of a ventral valve, NU-B1592; (3) internal moulds of

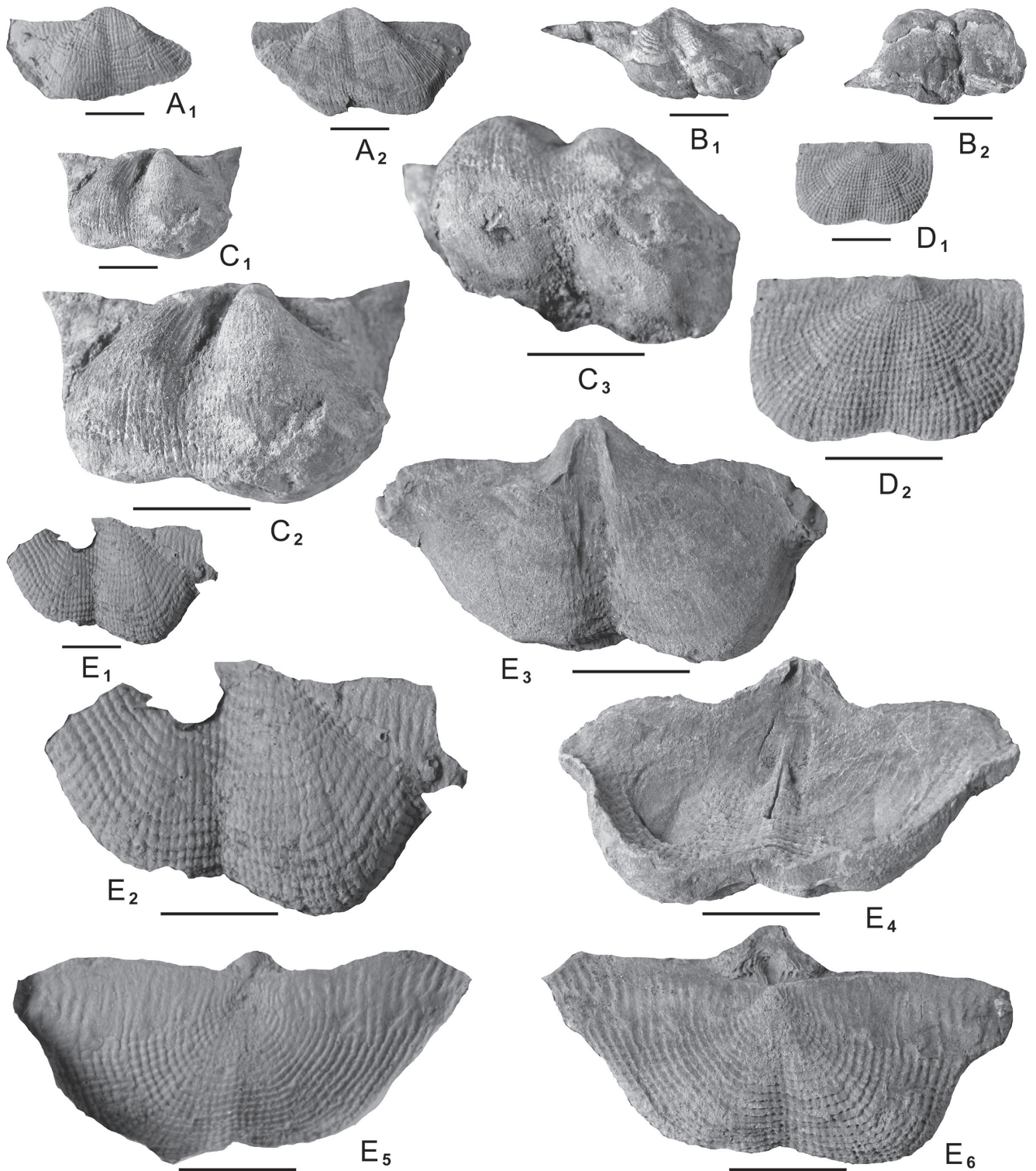


FIGURE 19. A–E, *Lamnimargus peregrinus* (Fredericks); A, external latex cast (A₁) and internal mould (A₂) of ventral valve, NU-B1967; B, ventral (B₁) and anterior (B₂) views of external latex cast of ventral valve, NU-B1494; C, ventral (C₁, C₂) and anterior (C₃) views of internal mould of ventral valve, NU-B1495; D, external mould (D₁, D₂) of dorsal valve, NU-B1588; E, ventral external latex cast (E₁, E₂), ventral internal mould (E₃), dorsal internal mould (E₄), dorsal external latex cast (E₅) and dorsal internal mould (E₆) of conjoined shell, NU-B1063. Scale bars are 1 cm.

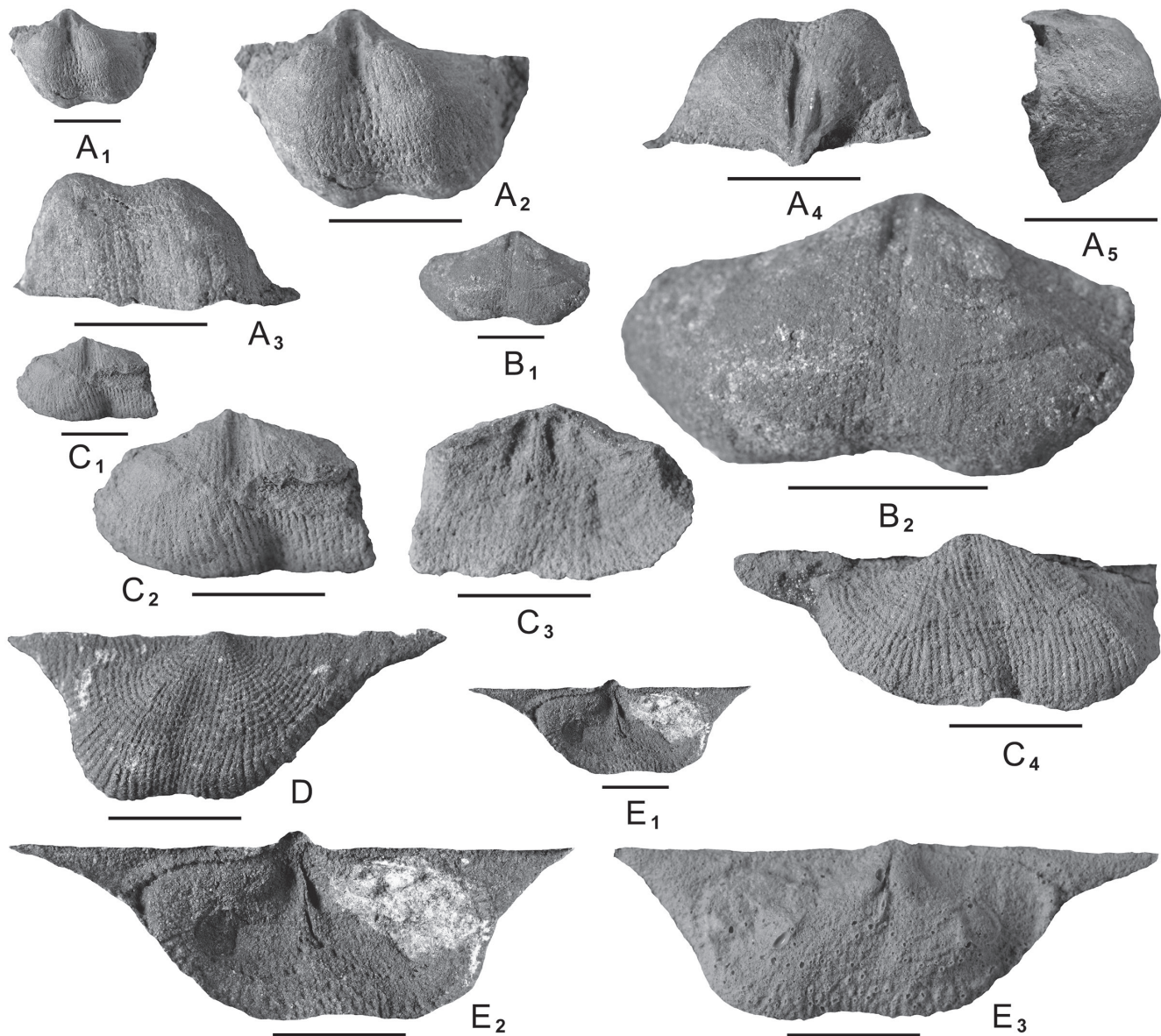


FIGURE 20. A–E, *Lamnimargus japonicus* (Tazawa); A, ventral (A₁, A₂), anterior (A₃), posterior (A₄) and lateral (A₅) views of internal mould of ventral valve, UHR19880; B, internal mould (B₁, B₂) of ventral valve, UNR19886; C, ventral internal mould (C₁, C₂), dorsal internal mould (C₃) and dorsal external mould (C₄) of conjoined shell, NU-B1591; D, external mould of dorsal valve, UHR19875 (holotype); E, internal mould (E₁, E₂) and internal latex cast (E₃) of dorsal valve, NU-B1593. Scale bars are 1 cm.

seven ventral valves, UHR19879–19884, 19886; (4) external and internal moulds of two dorsal valves, NU-B1593, 1594; and (5) external moulds of six dorsal valves, NU-B1595, UHR19874, 19875 (holotype), 19876–19878.

Remarks.—Most of the Nabekoshiyama specimens were previously described by Tazawa (1975, p. 636, pl. 2, figs. 3–6; pl. 3, figs. 1–4) as *Paramarginifera japonica* Tazawa, 1975. Subsequently, the generic name was changed to *Lamnimargus* Waterhouse, 1975 by Tazawa (2006a, p. 10). *Lamnimargus japonicus* is medium in size for genus (length 16 mm, width 24 mm in the best-preserved ventral valve specimen, UHR19880;

length 16 mm, width 43 mm in the largest dorsal valve specimen, NU-B1593), transversely subrectangular in outline, and widest at hinge. External surface of ventral valve invisible, but two large spine bases are rarely preserved on trail; dorsal valve finely reticulate on visceral disc and costellate on trail; numbering 8–9 rugae in 5 mm, and 10–11 costellae in 5 mm at midlength. The preceding species, *Lamnimargus peregrinus* (Fredericks, 1924a), differs from *L. japonicus* in its larger size and in having coarser costellae on the ventral valve.

Occurrence.—Upper part of the Toyoma Formation in Nabekoshiyama (localities KF107 and KF108).

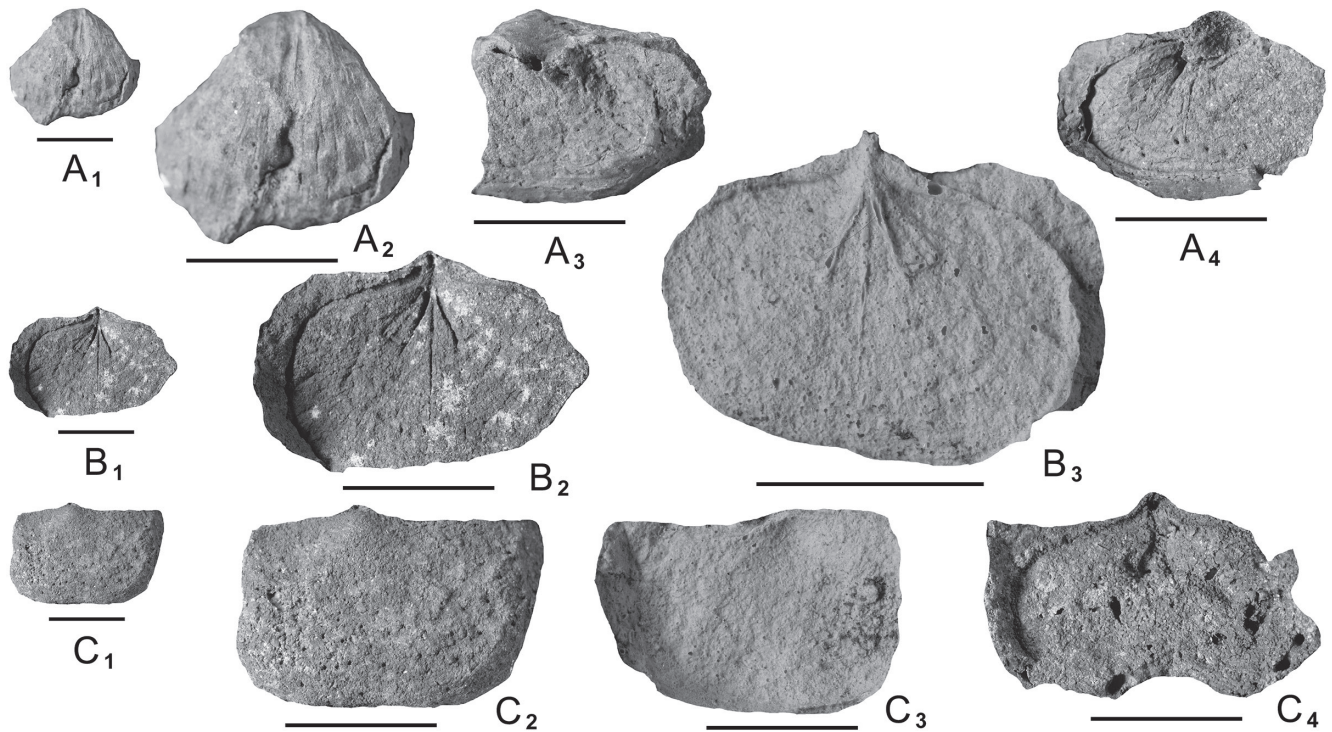


FIGURE 21. A–C, *Spinomarginifera lopingensis* (Kayser); A, ventral internal mould (A₁, A₂), dorsal external latex cast (A₃) and dorsal internal mould (A₄) of conjoined shell, NU-B1569; B, internal mould (B₁, B₂) and internal latex cast (B₃) of dorsal valve, NU-B1573; C, external mould (C₁, C₂), external latex cast (C₃) and internal mould (C₄) of dorsal valve, NU-B1570. Scale bars are 1 cm.

Distribution.—Changhsingian: northeastern Japan (Nabekoshiyama in the South Kitakami Belt) and southwestern Japan (Oe-cho in the Maizuru Belt and Tsunemori in the Akiyoshi Belt).

Family COSTISPINIFERIDAE Muir-Wood and Cooper, 1960
Subfamily SPINOMARGINIFERINAE Waterhouse, 2002
Genus *SPINOMARGINIFERA* Huang, 1932

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

Spinomarginifera lopingensis (Kayser, 1883)
(Fig. 21A–C)

Productus nystianus var. *lopingensis* Kayser, 1883, p. 187, pl. 28, figs. 1–5.

Productus (Marginifera) helicus var. Frech, 1911, p. 130, pl. 19, figs. 1–3.

Marginifera lopingensis (Kayser). Chao, 1927, p. 153, pl. 16, figs. 8–12.

Spinomarginifera kueichowensis Huang. Nakamura, 1959, p. 143, pl. 15, fig. 1 only; Minato et al., 1979, pl. 63, fig. 1 only.

Spinomarginifera lopingensis (Kayser). Zhang and Ching (Jin), 1961, p. 412, pl. 4, figs. 26–33; Wang et al., 1964, p. 312, pl. 49, figs. 21–23; Yang et al., 1977, p. 349, pl. 139, fig. 5;

Tong, 1978, p. 222, pl. 79, fig. 6; Licharew and Kotlyar, 1978, pl. 15, figs. 9, 10; Zhan, 1979, p. 80, pl. 5, figs. 17, 18; Liao, 1980, pl. 5, figs. 35–39; Wang et al., 1982, p. 219, pl. 92, figs. 1, 2; Wang, 1984, p. 187, pl. 80, fig. 16; Yang, 1984, p. 217, pl. 33, fig. 4; Liao, 1987, pl. 5, figs. 5, 7–18; Zeng et al., 1995, pl. 9, fig. 1; Shen et al., 2002, p. 677, figs. 4.32, 4.33, 5.1–5.4; He et al., 2008, p. 812, fig. 4.1–4.10; Li and Shen, 2008, p. 315, figs. 4.17–4.19, 6.1–6.7; Shen and Zhang, 2008, fig. 4.13–4.19; Shen and Shi, 2009, p. 157, fig. 3P–X; Tazawa, 2012, p. 20, fig. 4.1–4.3; Tazawa, 2017, p. 41, fig. 6.1–6.3; Tazawa, 2023, p. 45, fig. 25A, B.

Spinomarginifera lopingensis (Chao). Jin et al., 1985, p. 194, pl. 9, figs. 3–9; Jin, 1985, pl. 7, figs. 5, 16, 18, 20.

Spinomarginifera lopingensis Huang. Liao and Xu, 2002, pl. 1, figs. 28–33.

Spinomarginifera huangi Wang and Zhang, 2003, p. 73, pl. 21, fig. 12 only.

Material.—Six specimens from locality KF108: (1) internal mould of a ventral valve, with external and internal moulds of a dorsal valve, NU-B1569; (2) external and internal moulds of three dorsal valves, NU-B1570–1572; and (3) internal moulds of two dorsal valves, NU-B1573, 1574.

Remarks.—These specimens were previously described by Tazawa (2012, p. 20, fig. 4.1–4.3) as *Spinomarginifera lopingensis* (Kayser, 1883). The specimens from Nabekoshiyama

can be referred to *Spinomarginifera lopingensis* (Kayser, 1883), originally described from the upper Permian of Loping, Jiangxi Province, eastern China, in medium size (length 15 mm, width 19 mm in a ventral valve specimen, NU-B1569; length 16 mm, width 22 mm in the largest dorsal valve specimen, NU-B1573) and in having prominent costae on dorsal trail. *Spinomarginifera kueichowensis* Huang (1932, p. 56, pl. 5, figs. 1–11), from the upper Permian (Wuchiapingian) of Guizhou, southwestern China, differs from *S. lopingensis* in its larger dimensions and in lacking radial costae on both ventral and dorsal valves. *Spinomarginifera nipponica* Shimizu (1961, p. 244, pl. 8, figs. 1–20; pl. 9, figs. 14–16), from the Gujo Formation (Changhsingian) of the Maizuru Belt, southwestern Japan, differs from the present species in having a shallow sulcus and less strong geniculation on the ventral valve.

Occurrence.—Upper part of the Toyoma Formation in Nabekoshiyama (locality KF108).

Distribution.—Wordian–Wuchiapingian: northeastern Japan (Kamiyasse–Imo in the South Kitakami Belt), northwestern China (Qinghai), northern China (Inner Mongolia), eastern Russia (South Primorye), eastern China (Jiangsu, Zhejiang and Jiangxi), central-southern China (Hubei, Hunan, Guangdong and Guangxi), southwestern China (Guizhou and Yunnan) and northwestern China (Tibet); and Changhsingian: northeastern Japan (Nabekoshiyama in the South Kitakami Belt), central-southern China (Hubei and Guangxi) and southwestern China (Sichuan).

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 kotlyari sp. nov.
(Fig. 22A, B)

Edriosteges poyangensis (Kayser). Kotlyar in Kotlyar and Zakharov, 1989, pl. 23, fig. 15.
Edriosteges sp. Tazawa, 2012, p. 29, fig. 4.20.
Edriosteges sp. A Tazawa and Araki, 2014, p. 47, fig. 3.5.

Etymology.—Named for Galina V. Kotlyar, who first recognized the present species from the upper Permian (Wuchiapingian) of South Primorye, eastern Russia.

Material.—Two specimens from localities KF107 and KZ2: (1) external mould of a ventral valve, UHR11374; and (2) internal mould of a conjoined shell, KCG13 (holotype).

Diagnosis.—Medium-sized, slightly longer subpentagonal-shaped *Edriosteges*, with relatively short hinge.

Description.—Shell medium in size for genus (length 35 mm, width 35 mm in the larger specimen, holotype, KCG13; length

29 mm, width 32 mm in the smaller ventral valve specimen, UHR11374), slightly longer subpentagonal in outline, hinge shorter than greatest width at near anterior margin. Ventral valve moderately and unevenly convex in lateral profile, slightly convex on posterior portion and most convex at two-thirds length from umbo; sulcus wide and shallow on anterior one-third of valve; ears small, triangular. Dorsal valve slightly concave in both lateral and anterior profiles. External surface of ventral valve except for ears ornamented with numerous quincuncially-arranged elongate spines and irregular, weak concentric lamellae. Internally, both ventral and dorsal valves having strongly dendritic adductor scars.

Remarks.—These specimens were previously described by Tazawa (2012, p. 29, fig. 4.20) and Tazawa and Araki (2014, p. 47, fig. 3.5) as *Edriosteges* sp. and *Edriosteges* sp. A, respectively, from the upper part of the Toyoma Formation in Nabekoshiyama. The Nabekoshiyama species resembles the shell, figured by Kotlyar (in Kotlyar and Zakharov, 1989, pl. 23, fig. 5) as *Edriosteges poyangensis* (Kayser, 1883) from the Nakhodka Reef (Wuchiapingian) of South Primorye, eastern Russia, in medium size and slightly longer subpentagonal outline and in having relatively short hinge. In the present study, the Kitakami and Russian species are described as a new species, *Edriosteges kotlyari* sp. nov. *Edriosteges poyangensis* (Kayser, 1883, p. 190, pl. 28, figs. 8–10), from the upper Permian of Loping, Jiangxi Province, eastern China, differs from the present new species in its smaller size and transverse outline. The type species, *Edriosteges multispinosus* Muir-Wood and Cooper (1960, p. 104, pl. 17, figs. 1–10), from the upper Leonardian of the Glass Mountains, Texas, differs from *Edriosteges kotlyari* sp. nov. in its larger dimensions, subquadrate outline, with long hinge which nearly equal to the greatest width of shell.

Occurrence.—Upper part of the Toyoma Formation in Nabekoshiyama (localities KF107 and KZ2).

Distribution.—Wuchiapingian: eastern Russia (South Primorye); and Changhsingian: northeastern Japan (Nabekoshiyama in the South Kitakami Belt).

Nomenclatural acts.—This published work and the nomenclatural acts it contains have been registered in ZooBank. The LSIDs are CF95C89F-084A-46E2-A73B-87395F7AC0A9 for this publication, 5096D266-1A08-43D1-99C3-2455AF649442 for the genus *Edriosteges*, and 12B9486D-22CC-444B-9019-240D58340FAD for the new species *E. kotlyari*.

Family TSCHERNYSCHEWIIDAE Muir-Wood and Cooper, 1960
Genus *TSCHERNYSCHEWIA* Stoyanow, 1910

Type species.—*Tschernyschewia typica* Stoyanow, 1910.

Tschernyschewia typica Stoyanow, 1910
(Fig. 23A–C)

Productus scabriculus Martin. Abich, 1878, p. 33, pl. 5, fig. 3.

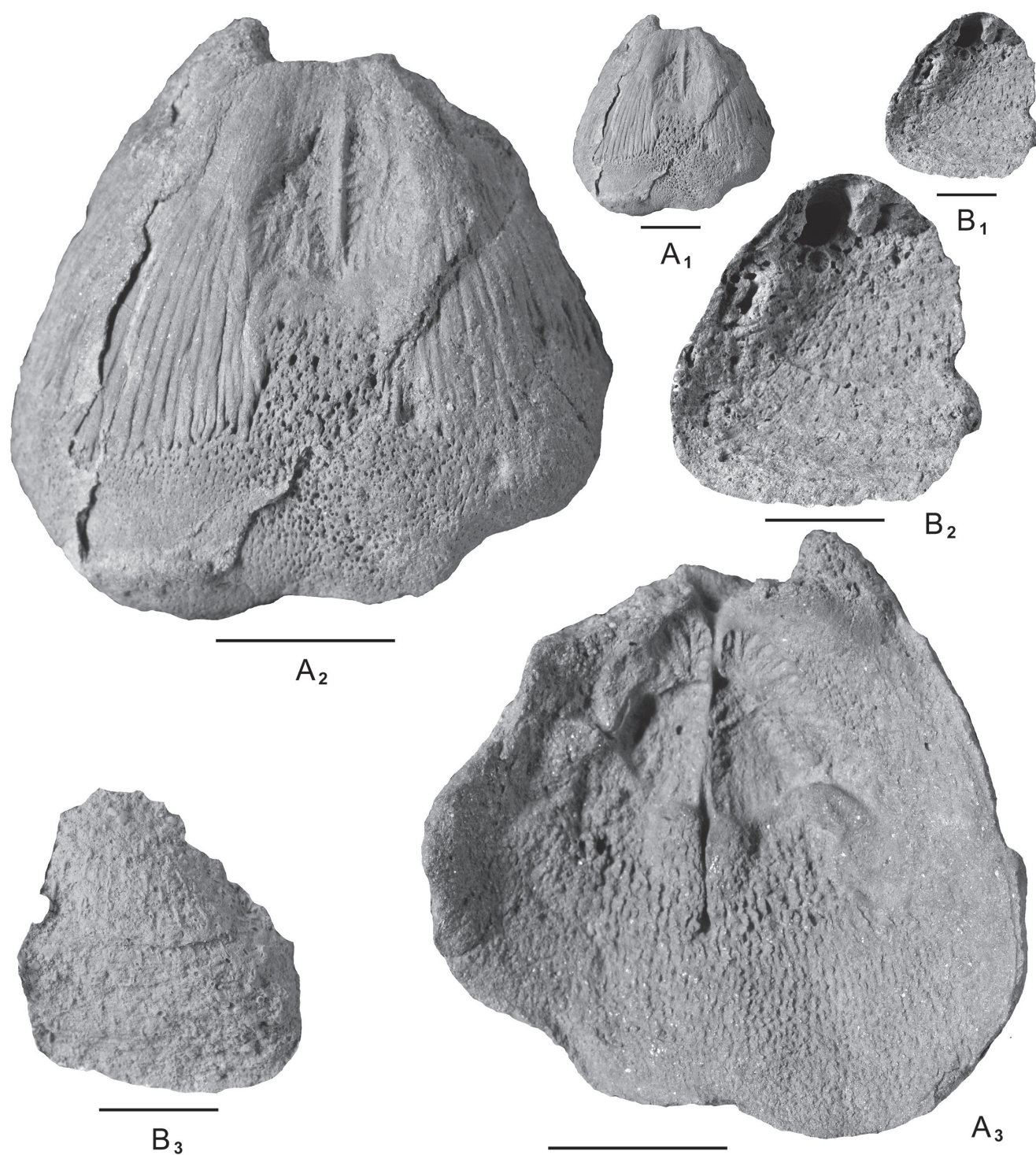


FIGURE 22. **A, B**, *Edriosteges kotlyari* sp. nov.; A, ventral internal mould (A₁, A₂) and dorsal internal mould (A₃) of conjoined shell, KCG13 (holotype); B, external mould (B₁, B₂) and external latex cast (B₃) of ventral valve, UHR11374. Scale bars are 1 cm.

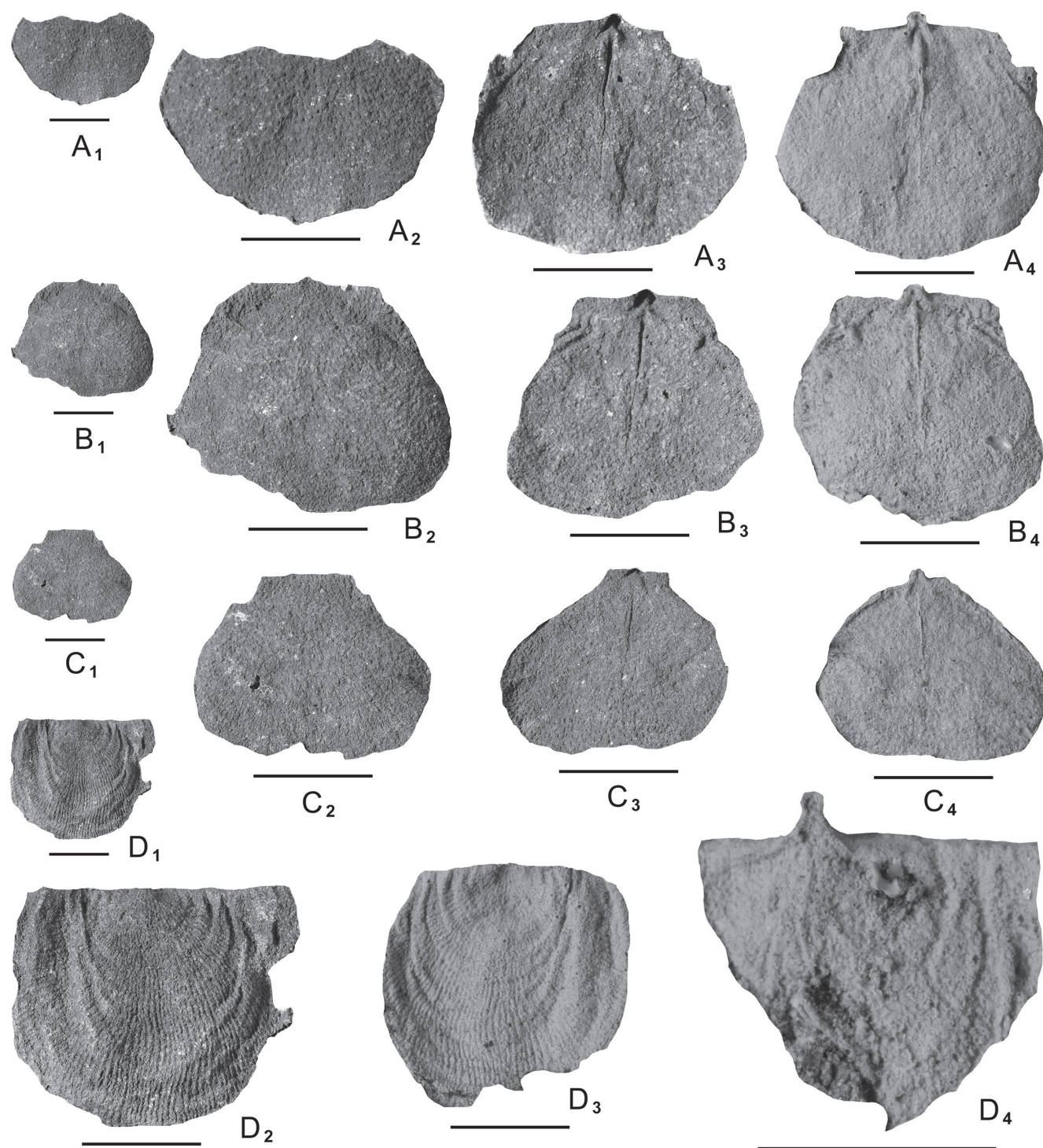


FIGURE 23. A–C, *Tschernyschewia typica* Stoyanow; A, external latex cast (A₁, A₂), internal mould (A₃) and internal latex cast (A₄) of dorsal valve, UHR30106; B, external mould (B₁, B₂), internal mould (B₃) and internal latex cast (B₄) of dorsal valve, NU-B1634; C, external mould (C₁, C₂), internal mould (C₃) and internal latex cast (C₄) of dorsal valve, NU-B1637; D, *Linoproductus* sp., external mould (D₁, D₂), external latex cast (D₃) and internal latex cast (D₄) of dorsal valve, NU-B1644. Scale bars are 1 cm.

Tschernyschewia typica Stoyanow, 1910, p. 853; Stoyanow, 1916, p. 33, 77, pl. 1, figs. 1–5; pl. 2, figs. 1–12; pl. 4, fig. 1; Simić, 1933, p. 38, 95, pl. 1, figs. 15–18; Muir-Wood and Cooper, 1960, pl. 25, figs. 1–9; Sarytcheva, 1965, pl. 33, figs. 8, 9; Stepanov et al., 1969, p. 28, pl. 4, fig. 5; Termier and Termier, 1970, p. 453, text-fig. 7; Tazawa, 1975, p. 634, pl. 2, fig. 2; Tazawa, 1976, pl. 3, fig. 11; Minato et al., 1979, pl. 71, fig. 2; Tazawa, 2012, p. 30, fig. 7.1–7.3.

Tschernyschewia typica typica Stoyanow. Ramovs, 1958, p. 524, pl. 9, figs. 3, 4.

Material.—Ten specimens from locality KF108: (1) external and internal moulds of six dorsal valves, NU-B1634–1638, UHR30106; (2) external moulds of three dorsal valves, NU-B1639–1641; and (3) internal mould of a dorsal valve, NU-B1642.

Remarks.—These specimens were previously described by Tazawa (1975, p. 634, pl. 2, fig. 2; Tazawa, 2012, p. 30, fig. 7.1–7.3) as *Tschernyschewia typica* Stoyanow, 1910 from the upper part of the Toyoma Formation in Nabekoshiyama. The Nabekoshiyama species lacks the ventral valve, but it can be referred to *Tschernyschewia typica* Stoyanow, 1910, originally described from the upper Permian (Dzulfian) of Armenia, by its subcircular, almost flattened, and medium-sized dorsal valve (length 18 mm, width 29 mm in the largest specimen, NU-B1635), ornamented with numerous small spine bases, and internally having a prominent bilobate cardinal process, supported by a strong median septum and diverging short lateral ridges. *Tschernyschewia sinensis* Chao (1928, p. 76, pl. 3, figs. 20–23), from the Lopingian of Loping in Jiangxi, central-southern China, is clearly distinguished from *T. typica* by its elongate shell and much longer hinge.

Occurrence.—Upper part of the Toyoma Formation in Nabekoshiyama (locality KF108).

Distribution.—Wuchiapingian: Transcaucasia (Armenia) and Iran (Julfa); and Changhsingian: northeastern Japan (Nabekoshiyama in the South Kitakami Belt), Slovenia and Serbia.

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. 23D)

Linoproductus sp. Tazawa, 2012, p. 24, fig. 4.15.

Material.—One specimen from locality KF108, external and internal moulds of a dorsal valve, NU-B1644.

Remarks.—This specimen was previously described by Tazawa (2012, p. 24, fig. 4.15) as *Linoproductus* sp. from the

upper part of the Toyoma Formation in Nabekoshiyama. The single dorsal valve specimen is safely assigned to the genus *Linoproductus* Chao, 1927 by its medium size (length 23 mm, width 25 mm), flatly concave dorsal valve, external ornament consisting of numerous costellae (11–12 in 5 mm at about midlength) and irregular strong rugae, and in having a thin median septum and a sessile trilobate cardinal process supported by slightly diverging lateral ridges in the dorsal valve. Specific identification is, however, difficult for the poorly preserved specimen lacking the ventral valve.

Occurrence.—Upper part of the Toyoma Formation in Nabekoshiyama (locality KF108).

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

Subfamily ANIDANTHINAE Waterhouse, 1968b

Genus *MEGOUSIA* Muir-Wood and Cooper, 1960

Type species.—*Megousia auriculata* Muir-Wood and Cooper, 1960.

Megousia auriculata Muir-Wood and Cooper, 1960

(Fig. 24A–D)

Linoproductus waagenites Girty: King, 1931, p. 77, pl. 17, figs. 11–15 only.

Megousia auriculata Muir-Wood and Cooper, 1960, p. 310, pl. 113, figs. 1–11; Ferguson, 1969, pl. 1, figs. 5–11; Nakamura, 1972, p. 436, pl. 2, fig. 3; Cooper and Grant, 1975, p. 1192, pl. 450, figs. 1–48; pl. 451, figs. 1–49; pl. 452, figs. 19–28; pl. 453, figs. 13–24; pl. 463, figs. 5–8; pl. 467, figs. 9–13; Tazawa, 2012, p. 25, fig. 3.8–3.10.

Megousia cf. *auriculata* Nakamura, 1972, p. 437, pl. 2, fig. 2.

Material.—Five specimens from localities KF107 and KF108: (1) external and internal moulds of two dorsal valves, NU-B1604, 1605; and (2) external moulds of three dorsal valves, UHR19531, NU-B1606, 1607.

Remarks.—These specimens were described by Tazawa (2012, p. 25, fig. 3.8–3.10) as *Megousia auriculata* Muir-Wood and Cooper, 1960 from the upper part of the Toyoma Formation in Nabekoshiyama. The Nabekoshiyama species can be referred to *Megousia auriculata* Muir-Wood and Cooper (1960, p. 310, pl. 113, figs. 1–11), from the Word Formation of the Glass Mountains, Texas, by its small and transverse dorsal valve (length 8 mm, width 20 mm in the largest specimen, NU-B1606) with long, slender and curved winglike ears and external ornament consisting of strong concentric lamellae and fine numerous costellae (numbering 6–7 lamellae in 5 mm, 10–11 costellae in 5 mm at about midlength) on visceral disc but costellae only on ears. The single dorsal valve specimen, described by Nakamura (1972, p. 437, pl. 2, fig. 2) as *Megousia* cf. *auriculata* Muir-Wood and Cooper, 1960, from the upper Permian (Lopingian) of Takakurayama in the Abukuma Mountains, northeastern Japan, is assigned to the present species by its small size and extremely

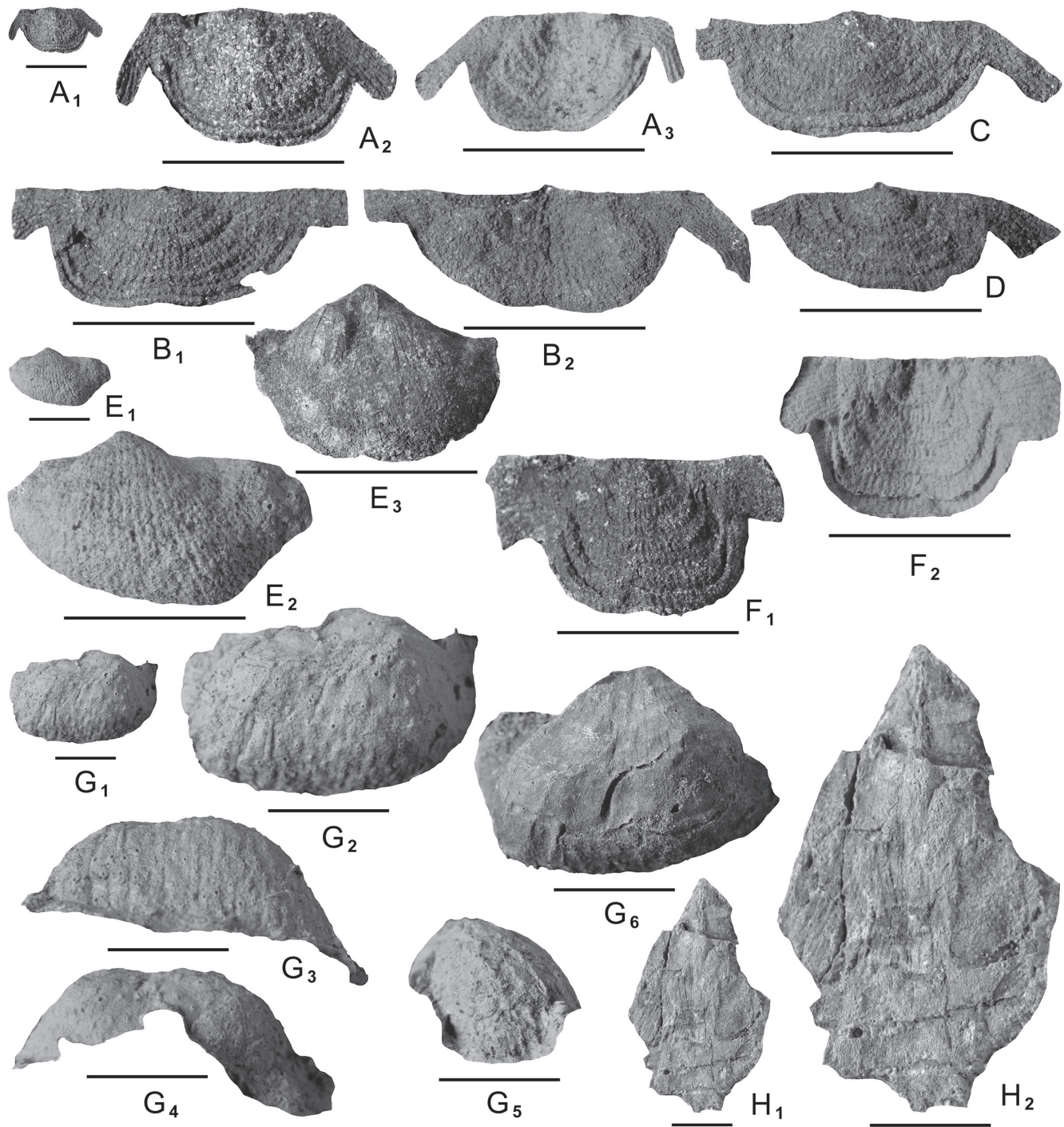


FIGURE 24. A–D, *Megousia auriculata* Muir-Wood and Cooper; A, external mould (A₁, A₂) and external latex cast (A₃) of dorsal valve, UHR19531; B, external mould (B₁) and internal mould (B₂) of dorsal valve, NU-B1605; C, external mould of dorsal valve, NU-B1606; D, external mould of dorsal valve, NU-B1607; E, F, *Megousia nakamurai* Tazawa; E, external latex cast (E₁, E₂) and internal mould (E₃) of ventral valve, UHR19885; F, external mould (F₁) and external latex cast (F₂) of dorsal valve, UHR19873 (holotype); G, *Terrakea nabekoshiyamensis* Tazawa, ventral (G₁, G₂), anterior (G₃), posterior (G₄) and lateral (G₅) views of external latex cast of ventral valve, NU-B1632 (holotype); H, *Compressoproductus* cf. *mytiloides* (Waagen), internal mould (H₁, H₂) of ventral valve, NU-B1508. Scale bars are 1 cm.

long, slender ears.

Occurrence.— Upper part of the Toyoma Formation in Nabekoshiyama (localities KF107 and KF108).

Distribution.— Artinskian–Wuchiapingian: northeastern Japan (Takakurayama in the South Kitakami Belt) and the USA (Texas); and Changhsingian: northeastern Japan (Nabekoshiyama in the South Kitakami Belt).

Megousia nakamurai Tazawa, 1975
(Fig. 24E, F)

Megousia nakamurai Tazawa, 1975, p. 635, pl. 3, figs. 5, 6; Tazawa, 1976, pl. 3, fig. 14; Minato et al., 1979, pl. 72, figs. 5, 6; Tazawa, 2006b, fig. 3F; Tazawa, 2012, p. 25, fig. 3.11–3.13.

Material.—Fifteen specimens from localities KF107, KF108 and KF109: (1) external and internal moulds of four ventral valves, UHR19885, NU-B1596–1598; (2) internal moulds of nine ventral valves, UHR30100–30103, NU-B1599–1603; and (3) external moulds of two dorsal valves, UHR19809, 19873 (holotype).

Remarks.—These specimens were previously described by Tazawa (1975, p. 635, pl. 3, figs. 5, 6; Tazawa, 2012, p. 25, fig. 3.11–3.13) as *Megousia nakamurai* Tazawa, 1975 from the upper part of the Toyoma Formation in Nabekoshiyama. *Megousia nakamurai* is distinguished from the type species, *Megousia auriculata* Muir-Wood and Cooper, 1960 by its less transverse shell (length 10 mm, width 17 mm in the holotype, UHR19873), broader ears and finer costellae (10–11 in 5 mm at about midlength) on both ventral and dorsal valves. *Megousia solita* Waterhouse (1968b, p. 1172, pl. 154, figs. 1–6, 8–10), from the Ulladulla Formation (Kungurian) of New South Wales, eastern Australia, differs from *M. nakamurai* by its deeper ventral sulcus, distinct dorsal fold, and irregular concentric lamellae on the dorsal valve. *Megousia definita* Cooper and Grant (1975, p. 1194, pl. 449, figs. 1–46), from the Middle Permian (Wordian) of Texas, is similar in general shape, but much larger in size.

Occurrence.— Upper part of the Toyoma Formation in Nabekoshiyama (localities KF107, KF108 and KF109).

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

Subfamily STRIATIFERINAE Muir-Wood and Cooper, 1960
Genus COMPRESOPRODUCTUS Sarytcheva in Sarytcheva et al., 1960

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

Compressoproductus cf. *mytiloides* (Waagen, 1884)
(Fig. 24H)

Compressoproductus cf. *mytiloides* (Waagen). Tazawa in Tazawa and Miyake, 2011, p. 7, fig. 3.4.

Material.—One specimen from locality MED2, internal

mould of a ventral valve, with internal mould of posterior region of the dorsal valve, NU-B1508.

Remarks.—The single specimen from Maeda was previously described by Tazawa (in Tazawa and Miyake, 2011, p. 7, fig. 3.4) as *Compressoproductus* cf. *mytiloides* (Waagen, 1884). This specimen most resembles *Compressoproductus mytiloides* (Waagen, 1884, p. 711, pl. 80, fig. 4a–d), from the Chhidru Formation of the Salt Range, Pakistan, in size and shape of the ventral valve, and in having somewhat irregular concentric rugae with broad interspaces. However, accurate comparison is difficult for the poorly preserved specimen. *Compressoproductus fenshujiangensis* Liang (1990, p. 210, pl. 34, figs. 6–8), from the upper Lengwu Formation (Wuchiapingian) of Lengwu in Zhejiang, eastern China, differs from the present species in its much larger dimensions. The type species, *Compressoproductus compressus* Waagen (1884, p. 710, pl. 81, figs. 1, 2), from the Chhidru Formation of the Salt Range, differs from the Kitakami species by its more strongly inflated ventral valve and in having concentric rugae with narrower interspaces on the valve.

Occurrence.—Upper part of the Toyoma Formation in Maeda (locality MED2).

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

Family KANSUELLIDAE Muir-Wood and Cooper, 1960
Subfamily PAUCISPINAURIINAE Waterhouse, 1986
Genus TERRAKEA Booker, 1930

Type species.—*Productus brachythaerus* Morris, 1845.

Terrakea nabekoshiyamensis Tazawa, 2012
(Fig. 24G)

Terrakea nabekoshiyamensis Tazawa, 2012, p. 26, fig. 4.13, 4.14.

Material.—Two specimens from locality KF108: (1) external and internal moulds of a ventral valve, NU-B1632 (holotype); and (2) internal mould of a ventral valve, NU-B1633.

Remarks.—These specimens were previously described by Tazawa (2012, p. 26, fig. 4.13, 4.14) as *Terrakea nabekoshiyamensis* Tazawa, 2012 from the upper part of the Toyoma Formation in Nabekoshiyama. *Terrakea nabekoshiyamensis* somewhat resembles the type species, *Terrakea brachythaera* (Morris, 1845), from the middle Permian (Wordian) of the Bowen–Sydney Basin, eastern Australia, in general shape, but the Australian species is much larger in size. *Terrakea yanagidai* Tazawa (2008c, p. 47, fig. 7.9–7.13), from the upper Permian (Lopingian) of Mizukoshi, central Kyushu, southwestern Japan, differs from the present species in having numerous fine, but more distinct costellae on the ventral valve.

Occurrence.—Upper part of the Toyoma Formation in Nabekoshiyama (locality KF108).

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

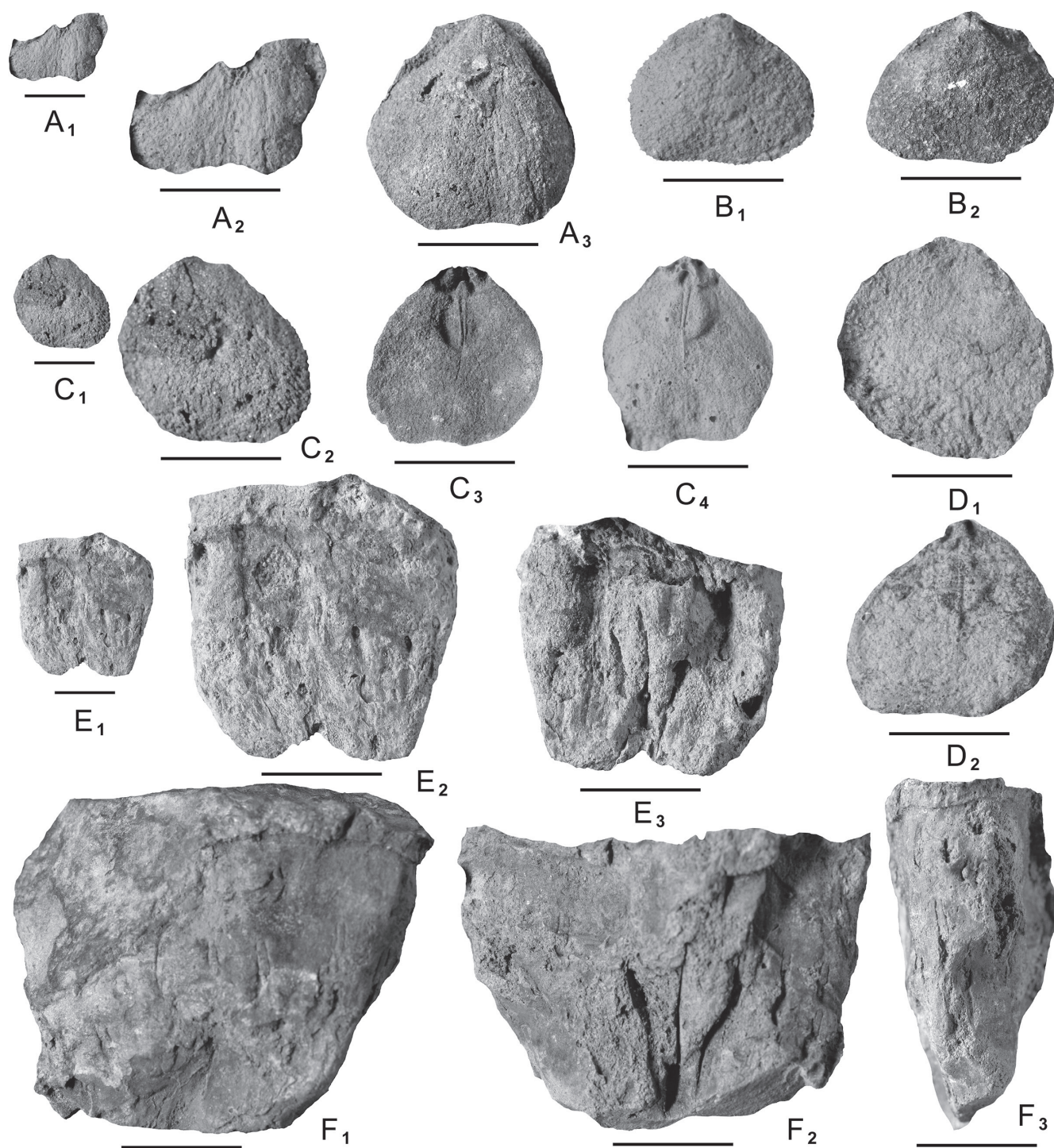


FIGURE 25. **A–D**, *Orthothrix sudoi* Tazawa; **A**, external latex cast (A₁, A₂) and internal mould (A₃) of ventral valve, NU-B1645 (holotype); **B**, external latex cast (B₁) and internal mould (B₂) of ventral valve, NU-B1647; **C**, external mould (C₁, C₂), internal mould (C₃) and internal latex cast (C₄) of dorsal valve, NU-B1651; **D**, external latex cast (D₁) and internal latex cast (D₂) of dorsal valve, UHR30105; **E, F**, *Richthofenia* sp.; **E**, anterior (E₁, E₂) and posterior (E₃) views of internal mould of ventral valve, NU-B1471; **F**, anterior (F₁), posterior (F₂) and lateral (F₃) views of internal mould of ventral valve, NU-B1470. Scale bars are 1 cm.

Suborder STROPHALOSIIDINA Waterhouse, 1975
 Superfamily STROPHALOSIOIDEA Schuchert, 1913
 Family STROPHALOSIIDAE Schuchert, 1913
 Subfamily ECHINALOSIINAE Waterhouse, 2001
 Genus *ORTHOTHRIX* Geinitz, 1847

Type species.—*Orthis excavata* Geinitz, 1842.

Orthothrix sudoi Tazawa, 2012
 (Fig. 25A–D)

Orthothrix cf. *excavata* (Geinitz). Tazawa, 1975, p. 633, pl. 2, fig. 1; Minato et al., 1979, pl. 71, fig. 1.

Orthothrix sudoi Tazawa, 2012, p. 27, fig. 4.16–4.19.

Material.—Ten specimens from localities KF105, KF107 and KF108: (1) external and internal moulds of three ventral valves, NU-B1645 (holotype), 1646, 1647; (2) internal moulds of two ventral valves, NU-B1648, 1649; and (3) external and internal moulds of five dorsal valves, UHR30105, NU-B1650–1653.

Remarks.—These specimens were previously described by Tazawa (2012, p. 27, fig. 4.16–4.19) as *Orthothrix sudoi* Tazawa, 2012 from the upper part of the Toyoma Formation in Nabekoshiyama. *Orthothrix sudoi* is large in size for the genus (length 21 mm, width 19 mm in the holotype, NU-B1645) and having a narrow and shallow sulcus in ventral valve, and a pair of large sockets and prominent adductor scars in dorsal valve. The type species, *Orthothrix excavata* (Geinitz, 1842), refigured by Muir-Wood and Cooper (1960, pl. 7, figs. 7–16), from the middle Zechstein of Thuringia, Germany, differs from the Kitakami species by its smaller size and broader outline and in having deeper ventral sulcus.

Occurrence.—Upper part of the Toyoma Formation in Nabekoshiyama (localities KF105, KF107 and KF108).

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

Superfamily RICHTHOFENIOIDEA Waagen, 1885
 Family RICHTHOFENIIDAE Waagen, 1885
 Genus *RICHTHOFENIA* Kayser, 1881

Type species.—*Anomia lawrenciana* de Koninck, 1863.

Richthofenia sp.
 (Fig. 25E, F)

Richthofenia sp. Tazawa in Tazawa and Miyake, 2011, p. 8, fig. 3.5, 3.6.

Material.—Three specimens from locality MED2: (1) external and internal moulds of a ventral valve, NU-B1469; and (2) internal moulds of two ventral valves, NU-B1470, 1471.

Remarks.—These specimens were described by Tazawa (in Tazawa and Miyake, 2011, p. 8, fig. 3.5, 3.6) as *Richthofenia* sp. from the upper part of the Toyoma Formation in Maeda.

The Maeda species is safely assigned to the genus *Richthofenia* Kayser, 1881 by its deep, conical-shaped ventral valve (length about 15 mm, width about 38 mm, height about 24 mm in the largest specimen, NU-B1470), elongate trigonal interarea with distinct pseudodeltidium, and external ornament of the ventral valve consisting of strong concentric rugae and numerous fine capillae. The Maeda species most resembles *Richthofenia lawrenciana* (de Koninck, 1863, p. 6, pl. 4, figs. 7–9), from the Wargal Formation of the Salt Range, in size and shape of the ventral valve. But accurate comparison is difficult for the poorly preserved specimens.

Occurrence.—Upper part of the Toyoma Formation in Maeda (locality MED2).

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

Suborder LYTTONIIDINA Williams, Harper and Grant, 2000
 Superfamily LYTTONIOIDEA Waagen, 1883
 Family LYTTONIIDAE Waagen, 1883
 Subfamily LYTTONIINAE Waagen, 1883
 Genus *EOLYTTONIA* Fredericks, 1924a

Type species.—*Oldhamina* (*Lyttonia*) *mira* Fredericks, 1916.

Eolyttonia tenuis (Waagen, 1883)
 (Figs. 26C–F, 29A)

Lyttonia tenuis Waagen, 1883, p. 401, pl. 30, figs. 3, 4, 7, 9; Huang, 1932, p. 95, pl. 9, figs. 9–11.

Oldhamina (*Lyttonia*) var. *ivanovi* Fredericks, 1916, p. 78, pl. 2, fig. 7 only.

Eolyttonia tenuis (Waagen). Fredericks, 1925, p. 15, pl. 3, figs. 105–107; Tazawa, 2012, p. 31, figs. 5.6–5.9, 6A, 7.9, 7.10.

Leptodus tenuis (Waagen). Yang et al., 1962, p. 90, pl. 37, fig. 5; Zhan, 1979, p. 94, pl. 9, fig. 24; pl. 12, fig. 14; pl. 13, figs. 15, 18; Wang et al., 1982, p. 229, pl. 86, fig. 14; pl. 88, fig. 6; pl. 100, fig. 7; Fang, 1983, p. 101, pl. 5, figs. 2, 3; Yang, 1984, p. 226, pl. 35, fig. 13; Liang, 1990, p. 226, pl. 40, fig. 9; Zhu, 1990, p. 79, pl. 18, figs. 19–21; Fang and Fan, 1994, p. 83, pl. 23, figs. 4, 5; pl. 30, fig. 6; Zeng et al., 1995, pl. 11, fig. 4; Campi et al., 2002, fig. 6J; Campi et al., 2005, p. 126, pl. 4, figs. C, F; Tazawa and Hirota, 2012, p. 226, fig. 2A, B.

Leptodus cf. *tenuis* (Waagen). Kindle, 1926, p. 110, fig. 1; Chi-Thuan, 1962, p. 489, pl. 1, figs. 2, 3; pl. 2, fig. 3.

Eolyttonia nakazawai Shimizu, 1961, p. 330, pl. 15, fig. 22.

Eolyttonia cf. *nakazawai* Shimizu. Tazawa, 1975, p. 637, pl. 3, fig. 8 only; Tazawa, 1976, pl. 3, fig. 13 only; Minato et al., 1979, pl. 72, fig. 8 only.

Material.—Eight specimens from localities KF108 and KF109: (1) external and internal moulds of four ventral valves, NU-B1580–1583; (2) internal moulds of three ventral valves, UHR30104, NU-B1584, 1585; and (3) internal mould of a dorsal valve (internal plate), UHR30110.

Remarks.—These specimens were previously described by

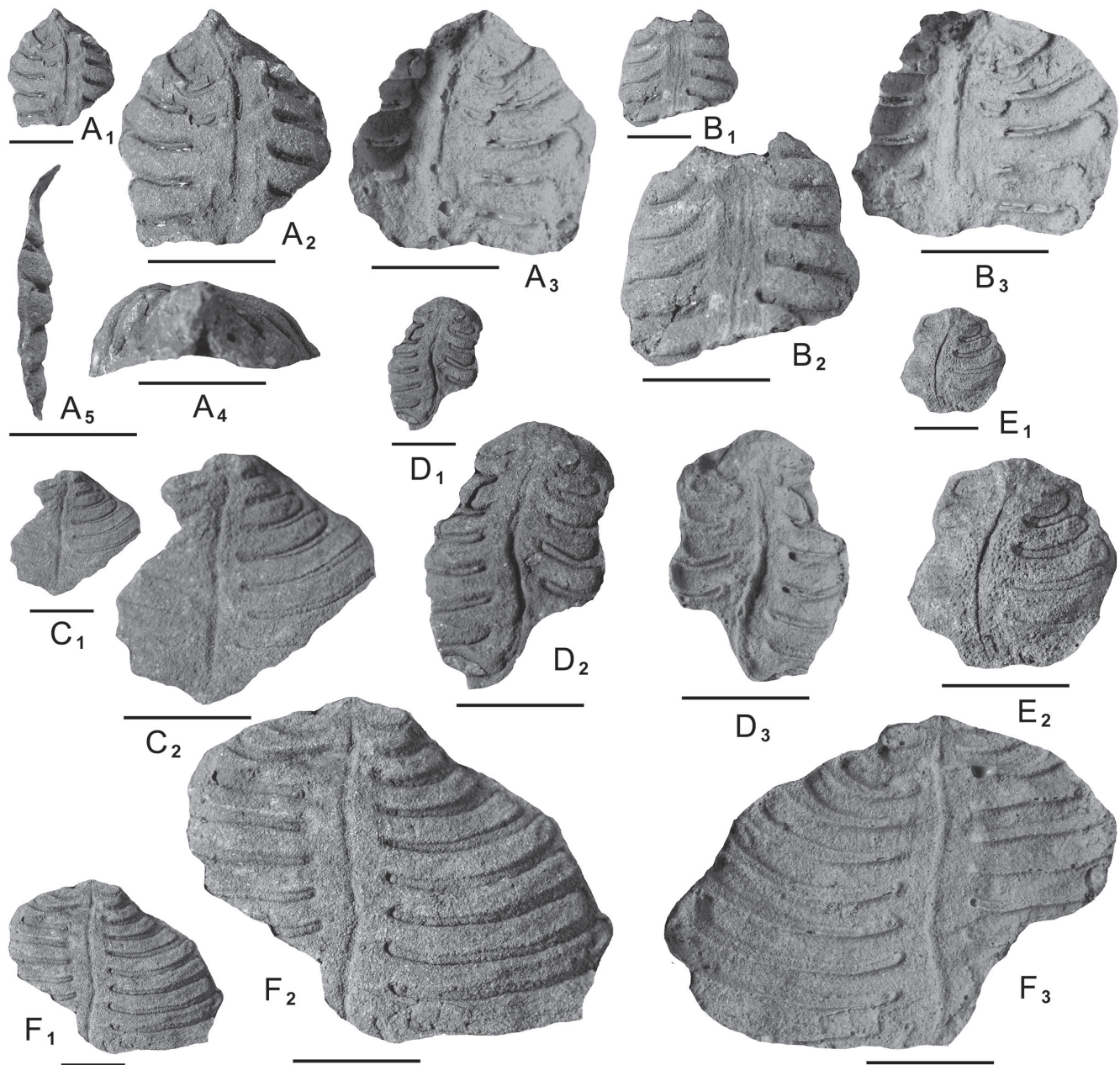


FIGURE 26. **A, B**, *Eolyttonia mira* (Fredericks): A, ventral internal mould (A₁, A₂), ventral internal latex cast (A₃), posterior (A₄) and lateral (A₅) views of internal mould of ventral valve, NU-B1587; B, internal mould (B₁, B₂) and internal latex cast (B₃) of ventral valve, NU-B1586; **C–F**, *Eolyttonia tenuis* (Waagen): C, internal mould (C₁, C₂) of ventral valve, NU-B1581; D, internal mould (D₁, D₂) and internal latex cast (D₃) of ventral valve, NU-B1584; E, internal mould (E₁, E₂) of ventral valve, NU-B1585; F, internal mould (F₁, F₂) and internal latex cast (F₃) of ventral valve, NU-B1580. Scale bars are 1 cm.

Tazawa (2012, p. 31, figs. 5.6–5.9, 6A, 7.9, 7.10) as *Eolyttonia tenuis* (Waagen, 1883) from the upper part of the Toyoma Formation in Nabekoshiyama. The Nabekoshiyama species can be referred to *Eolyttonia tenuis* (Waagen, 1883), originally described by Waagen (1883, p. 401, pl. 30, figs. 3, 4, 7, 9) from the Wargal Formation of the Salt Range, Pakistan, by its medium-sized (length 30 mm, width 33 mm in the largest specimen, NU-B1580; length 19 mm, width 14 mm in a young specimen, NU-B1584), flatly convex ventral valve and more

than 9 grooved (angustilobate) lateral septa on each side of the valve, numbering 7–8 in 20 mm. *Lyttonia tenuis* is now assessed as an *Eolyttonia* species, in having lateral septa with concave crests in the ventral valve, as noted by Fredericks (1925, p. 15). It is highly probable that *Eolyttonia nakazawai* Shimizu (1961, p. 330, pl. 15, fig. 22), from the upper Permian (Changhsingian) of Yakuno in the Maizuru Belt, southwestern Japan, may be an immature shell of *Eolyttonia tenuis*. The type species, *Eolyttonia mira* (Fredericks, 1916, p. 74, pl. 2, figs. 8, 9; pl. 4, fig. 1), from

the middle Permian (Wordian–Capitanian) of South Primorye, eastern Russia, differs from *E. tenuis* in its smaller and more inflated ventral valve.

Occurrence.—Upper part of the Toyoma Formation in Nabekoshiyama (localities KF108 and KF109).

Distribution.—Kungurian–Wuchiapingian: Canada (British Columbia), northwestern China (Qinghai), eastern Russia (South Primorye), eastern China (Anhui, Zhejiang and Fujian), central-southern China (Hubei and Guangdong), southwestern China (Yunnan), Vietnam, Malaysia and Pakistan (Salt Range); and Changhsingian: northeastern Japan (Nabekoshiyama in the South Kitakami Belt), southwestern Japan (Yakuno in the Maizuru Belt; Sakawa in the Kurosegawa Belt), central-southern China (Guangdong) and southwestern China (Guizhou and Sichuan).

Eolyttonia mira (Fredericks, 1916)
(Figs. 26A, B, 29B)

Oldhamina (*Lyttonia*) *mira* Fredericks, 1916, p. 74, pl. 2, figs. 8, 9; pl. 4, fig. 1.

Eolyttonia mira (Fredericks). Fredericks, 1925, p. 12, pl. 3, figs. 98–102; text-fig. 11; Tazawa, 2012, p. 33, figs. 5.1–5.3, 6B.

Eolyttonia cf. *nakazawai* Shimizu. Tazawa, 1975, p. 637, pl. 3, fig. 7 only; Minato et al., 1979, pl. 72, fig. 7 only; Tazawa, 2006b, fig. 3H.

Material.—Three specimens from localities KF108 and KF109, internal moulds of three ventral valves, UHR30111, NU-B1586, 1587.

Remarks.—These specimens were previously described by Tazawa (2012, p. 33, figs. 5.1–5.3, 6B) as *Eolyttonia mira* (Fredericks, 1916) from the upper part of the Toyoma Formation in Nabekoshiyama. The Nabekoshiyama species can be identified with *Eolyttonia mira* (Fredericks, 1916), from the Chandalaz Formation (Wordian–Capitanian) of Cape Kalouzin, Vladivostok, eastern Russia, in its small size (length 23 mm, width 20 mm in the largest specimen, NU-B1586), strongly convex ventral valve and symmetrically arranged, grooved lateral septa. The preceding species, *Eolyttonia tenuis* (Waagen, 1883), is distinguished from *Eolyttonia mira* by its larger and less convex ventral valve.

Occurrence.—Upper part of the Toyoma Formation in Nabekoshiyama (localities KF108 and KF109).

Distribution.—Wordian–Capitanian: eastern Russia (South Primorye); and Changhsingian: northeastern Japan (Nabekoshiyama in the South Kitakami Belt).

Genus *OLDHAMINA* Waagen, 1883

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

Oldhamina squamosa Huang, 1932
(Figs. 27A, 29C)

Oldhamina squamosa Huang, 1932, p. 74, pl. 6, figs. 1–5; pl.

7, fig. 11; Yang et al., 1977, p. 370, pl. 147, fig. 3; Feng and Jiang, 1978, p. 270, pl. 100, fig. 6; Liao, 1979, pl. 1, fig. 29; Zhan, 1979, p. 91, pl. 9, fig. 18; pl. 12, fig. 13; Liao, 1980, pl. 5, fig. 48; Wang et al., 1982, p. 230, pl. 95, fig. 19; Waterhouse, 1983, p. 130, pl. 5, figs. 1–10; Liao, 1987, p. 106, pl. 3, figs. 25, 26; Zhu, 1990, p. 79, pl. 18, figs. 24, 25; Zeng et al., 1995, pl. 11, fig. 10; Tazawa, 2012, p. 34, figs. 5.4, 6C.

Eolyttonia cf. *nakazawai* Shimizu. Tazawa, 1975, p. 637, pl. 3, fig. 9 only; Minato et al., 1979, pl. 72, fig. 9 only.

Material.—Two specimens from localities KF108 and KF109: (1) external and internal moulds of a ventral valve, NU-B1576; and (2) internal mould of a ventral valve, UHR30109.

Remarks.—One of the specimens was previously described by Tazawa (2012, p. 34, figs. 5.4, 6C) as *Oldhamina squamosa* Huang, 1932 from the upper part of the Toyoma Formation in Nabekoshiyama. The Nabekoshiyama species can be referred to *Oldhamina squamosa* Huang, 1932, originally described from the upper Permian (Changhsingian) of Guizhou and Sichuan, southwestern China, by its moderately convex ventral valve, and sharp lateral septa (anguliseptate) inclined towards the anterior margin of the valve. The type species, *Oldhamina decipiens* (de Koninck, 1863, p. 8, pl. 3, fig. 1), from the Productus Limestone of the Salt Range, differs from *Oldhamina squamosa* in its more inflated ventral valve and in having smaller number of lateral septa in the ventral valve.

Occurrence.—Upper part of the Toyoma Formation in Nabekoshiyama (localities KF108 and KF109).

Distribution.—Changhsingian: northeastern Japan (Nabekoshiyama in the South Kitakami Belt), eastern China (Fujian), central-southern China (Hubei, Guangdong and Guangxi), southwestern China (Guizhou and Sichuan) and northern Thailand (Huai Tak).

Oldhamina anshunensis Huang, 1932
(Figs. 27B–D, 29D)

Oldhamina squamosa var. *anshunensis* Huang, 1932, p. 77, pl. 6, figs. 6, 7; pl. 7, figs. 1–4; Zhang and Ching (Jin), 1961, p. 409, pl. 3, figs. 18–20; Liu et al., 1982, p. 190, pl. 136, fig. 13; Wang et al., 1982, p. 230, pl. 91, fig. 18.

Eolyttonia cf. *nakazawai* Shimizu. Tazawa, 1975, p. 637, pl. 3, fig. 10, 11 only; Tazawa, 1976, pl. 3, fig. 12 only; Minato et al., 1979, pl. 72, figs. 10, 11 only.

Oldhamina anshunensis Huang. Feng and Jiang, 1978, p. 271, pl. 101, fig. 23; Liao, 1980, pl. 5, fig. 49; Ding and Qi, 1983, p. 297, pl. 102, figs. 5, 6; Yanagida et al., 1993, p. 3, pl. 1, figs. 7, 10.

Oldhamina squamosa anshunensis Huang. Zhan, 1979, p. 91, pl. 7, fig. 9.

Material.—Four specimens from localities KF108 and KF109: (1) internal mould of a ventral valve with external mould of the dorsal valve, UHR30107; (2) external and internal moulds of a ventral valve, UHR30108; and (3) internal moulds of two ventral valves, NU-B1577, 1578.

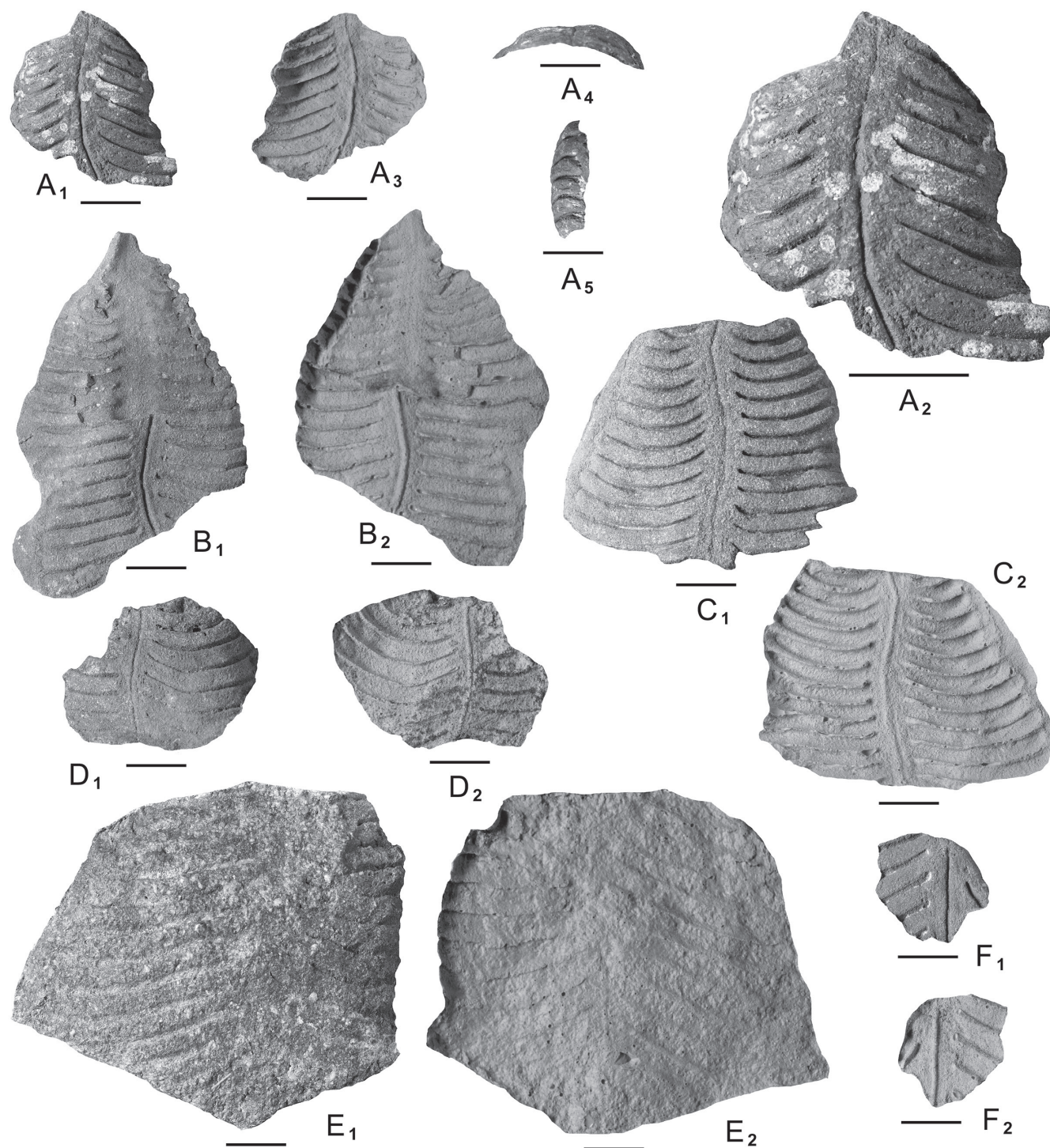


FIGURE 27. **A**, *Oldhamina squamosa* Huang, internal mould (A₁, A₂), internal latex cast (A₃), posterior (A₄) and lateral (A₅) views of internal mould of ventral valve, UHR30109; **B–D**, *Oldhamina anshunensis* Huang; **B**, internal mould (B₁) and internal latex cast (B₂) of ventral valve, UHR30107; **C**, internal mould (C₁) and internal latex cast (C₂) of ventral valve, UHR30108; **D**, internal mould (D₁) and internal latex cast (D₂) of ventral valve, NU-B1577; **E, F**, *Oldhamina kitakamiensis* Tazawa; **E**, internal mould (E₁) and external mould (E₂) of ventral valve, IGPS97715 (holotype); **F**, internal mould (F₁) and internal latex cast (F₂) of ventral valve, NU-B1579. Scale bars are 1 cm.

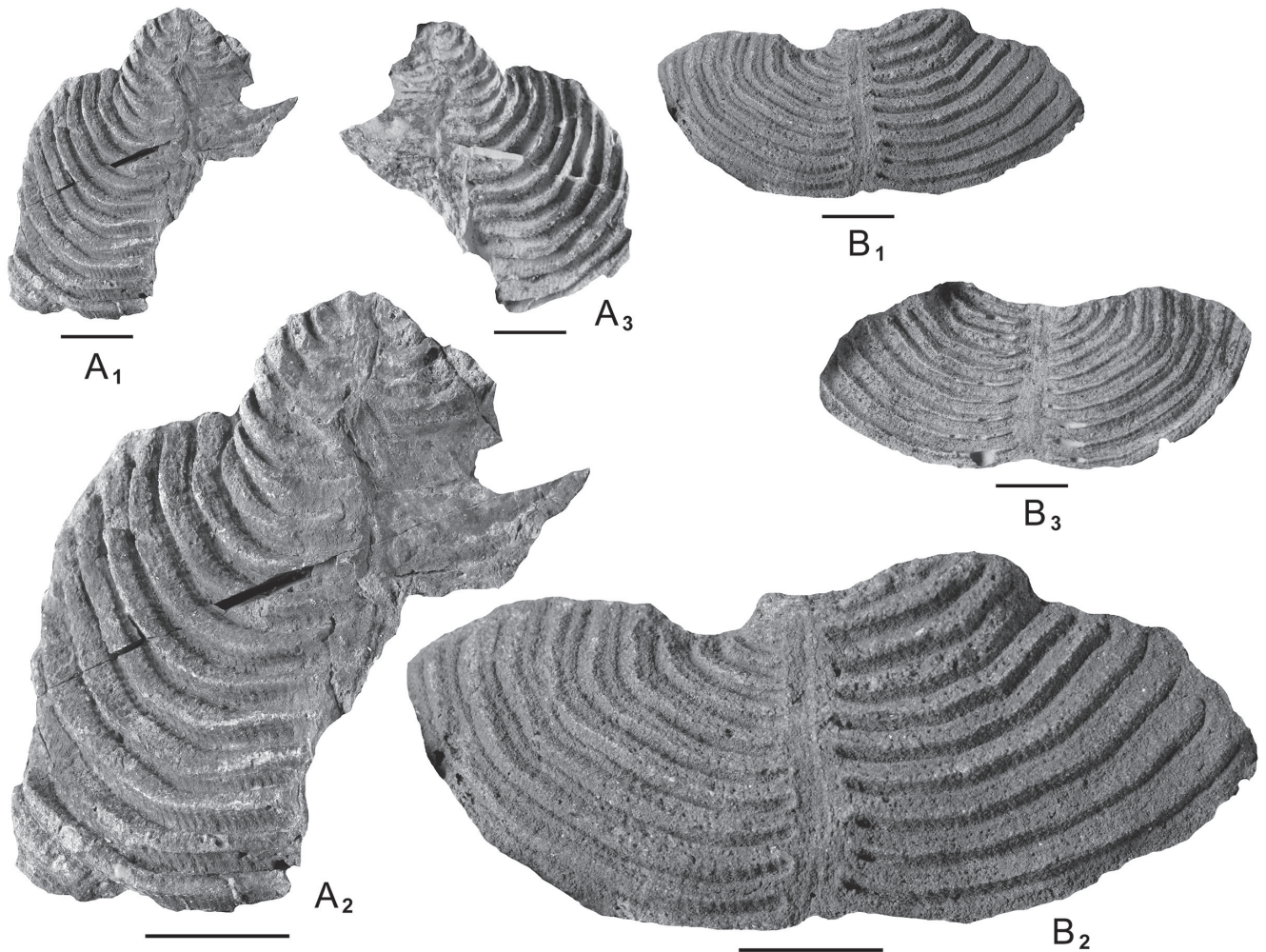


FIGURE 28. **A, B.** *Petasmaia ehiro* Tazawa; A, internal mould (A₁, A₂) and internal latex cast (A₃) of ventral valve, NU-B1476 (holotype); B, internal mould (B₁, B₂) and internal latex cast (B₃) of ventral valve, KCG5. Scale bars are 1 cm.

Remarks.—Two of the Nabekoshiyama specimens (UHR30107, 30108) were misidentified and described by Tazawa (1975, p. 637) as *Eolyttonia* cf. *nakazawai* Shimizu, 1961. The Nabekoshiyama species including the above two specimens can be referred to *Oldhamina anshunensis* Huang, 1932, originally described by Huang (1932, p. 77, pl. 6, figs. 6, 7; pl. 7, figs. 1–4) as *Oldhamina squamosa* var. *anshunensis* Huang, 1932, from the Changhsingian of Guizhou, southwestern China, by its medium to large size (length about 62 mm, width 42 mm in the largest specimen, UHR30107), flatly convex ventral valve and weakly arched lateral septa (mostly anguliseptate, with some solidiseptate). The preceding species, *Oldhamina squamosa* Huang, 1932, is readily distinguished from *O. anshunensis* by its more strongly inflated ventral valve, and in having lateral septa strongly inclined toward the front.

Occurrence.—Upper part of the Toyoma Formation in Nabekoshiyama (localities KF108 and KF109).

Distribution.—Wuchiapingian: southwestern Japan (Yachiyo in the Maizuru Belt), northwestern China (Shaanxi),

eastern China (Anhui), central-southern China (Hunan) and southwestern China (Guizhou); and Changhsingian: northeastern Japan (Nabekoshiyama in the South Kitakami Belt) and southwestern China (Guizhou and Sichuan).

Oldhamina kitakamiensis Tazawa, 1982
(Figs. 27E, F, 29E)

Oldhamina kitakamiensis Tazawa, 1982, p. 448, pl. 69, figs. 1–6, text-fig. 2; Tazawa, 2012, p. 36, figs. 5.5, 6E.

Material.—Two specimens from localities KF108 and KNY1: (1) internal cast and mould of a ventral valve, IGPS97715 (holotype); and (2) internal mould of a ventral valve, NU-B1579.

Remarks.—The specimen from Kanayashiki was previously described by Tazawa (1982, p. 448, pl. 69, figs. 1–6; text-fig. 2) as the holotype of *Oldhamina kitakamiensis* Tazawa, 1982. The specimen from Nabekoshiyama was also previously described by Tazawa (2012, p. 36, figs. 5.5, 6E) as *Oldhamina*

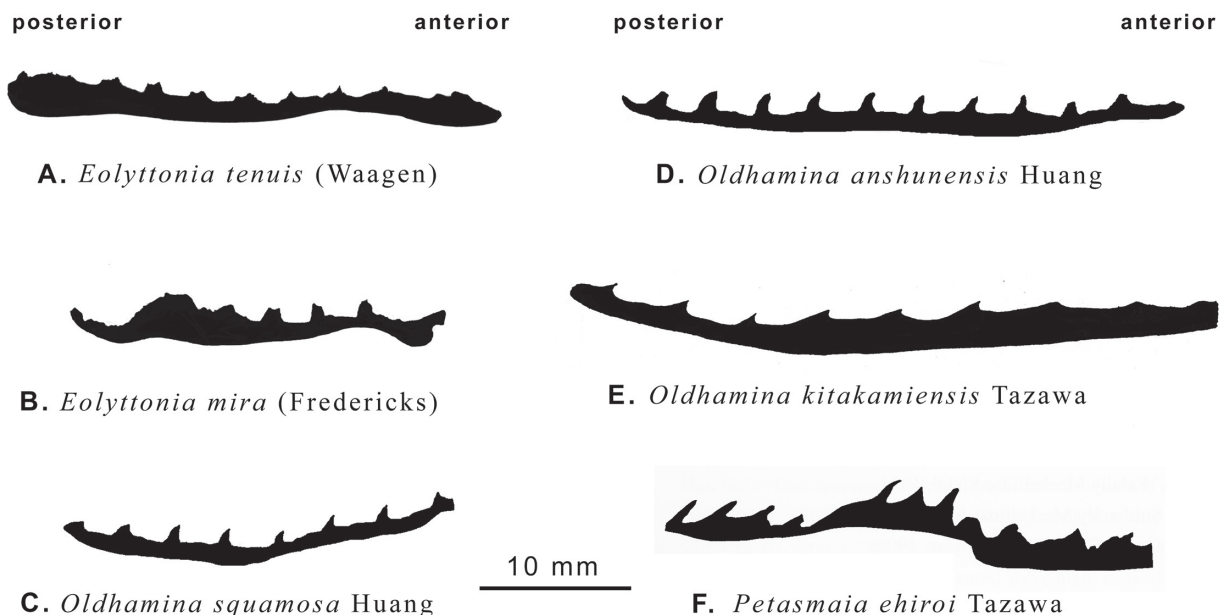


FIGURE 29. Longitudinal section of internal latex cast of ventral valve, showing lateral septa. **A**, *Eolyttonia tenuis* (Waagen), NU-B1580; **B**, *Eolyttonia mira* (Fredericks), NU-B1587; **C**, *Oldhamina squamosa* Huang, UHR30109; **D**, *Oldhamina anshunensis* Huang, UHR30108; **E**, *Oldhamina kitakamiensis* Tazawa, IGPS97715 (holotype); **F**, *Petasmaia ehiroï* Tazawa, NU-B1477.

kitakamiensis Tazawa, 1982. These specimens are referred to *Oldhamina kitakamiensis* by their almost flat ventral valve, and thin widely spaced lateral septa (numbering 5 septa in 20 mm), which having acute crests, dipping to the front at angles 40–50° and strongly inclined anteriorly. *Oldhamina kitakamiensis* most resembles *Oldhamina squamosa* Huang, 1932, from the Changhsingian beds of Guizhou and Sichuan, southwestern China, in having anteriorly inclined lateral septa, but differs from the Chinese species in its less inflated ventral valve. The type species, *Oldhamina decipiens* (de Koninck, 1863), redescribed by Waagen (1883, p. 406, pl. 31, figs. 1–9) from the Wargal and Chhidru Formations of the Salt Range, has also anteriorly inclined lateral septa, but differs in its strongly inflated ventral valve.

Occurrence.—Upper part of the Toyoma Formation in Kanayashiki (locality KNY1) and Nabekoshiyama (locality KF109).

Distribution.—Changhsingian: northeastern Japan (Nabekoshiyama and Kanayashiki in the South Kitakami Belt).

Genus *PETASMAIA* Cooper and Grant, 1969

Type species.—*Petasmaia expansa* Cooper and Grant, 1969.

Petasmaia ehiroï Tazawa in Tazawa and Miyake, 2011
(Figs. 28A, B, 29F)

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

Oldhamina ehiroï (Tazawa). Tazawa and Araki, 2014, p. 48, figs. 3.4, 4.

Material.—Three specimens from localities AR6 and MED2: (1) external and internal moulds of two ventral valves, NU-B1476 (holotype), 1477; and (2) internal mould of a ventral valve, KCG5.

Remarks.—The two specimens (NU-B1476, 1477) from the upper part of the Toyoma Formation in Maeda were previously described by Tazawa (in Tazawa and Miyake, 2011, p. 8, figs. 3.10–3.11, 4) as *Petasmaia ehiroï* Tazawa in Tazawa and Miyake, 2011; and one specimen (KCG5) from the upper part of the Toyoma Formation in Nabekoshiyama was described by Tazawa and Araki (2014, p. 48, figs. 3.4, 4) as *Oldhamina ehiroï* (Tazawa in Tazawa and Miyake, 2011). These specimens can be referred to *Petasmaia ehiroï* Tazawa in Tazawa and Miyake, 2011, in medium size for the genus (length 52 mm, width 50 mm in the holotype, NU-B1476) and in having regularly and symmetrically arranged, strongly arcuate lateral septa with acute crests (anguliseptate). The type species, *Petasmaia expansa* Cooper and Grant (1969, p. 10, pl. 2, figs. 1–16; Cooper and Grant, 1974, p. 430, pl. 163, figs. 1–8; pl. 164, figs. 1–16; pl. 165, figs. 11–16), from the Cathedral Mountain Formation (Leonardian) of the Glass Mountains, Texas, differs from *Petasmaia ehiroï* in having lateral septa with broader interspaces.

Occurrence.—Upper part of the Toyoma Formation in Maeda (locality MED2) and Nabekoshiyama (locality AR6).

Distribution.—Changhsingian: northeastern Japan (Maeda and Nabekoshiyama in the South Kitakami Belt).

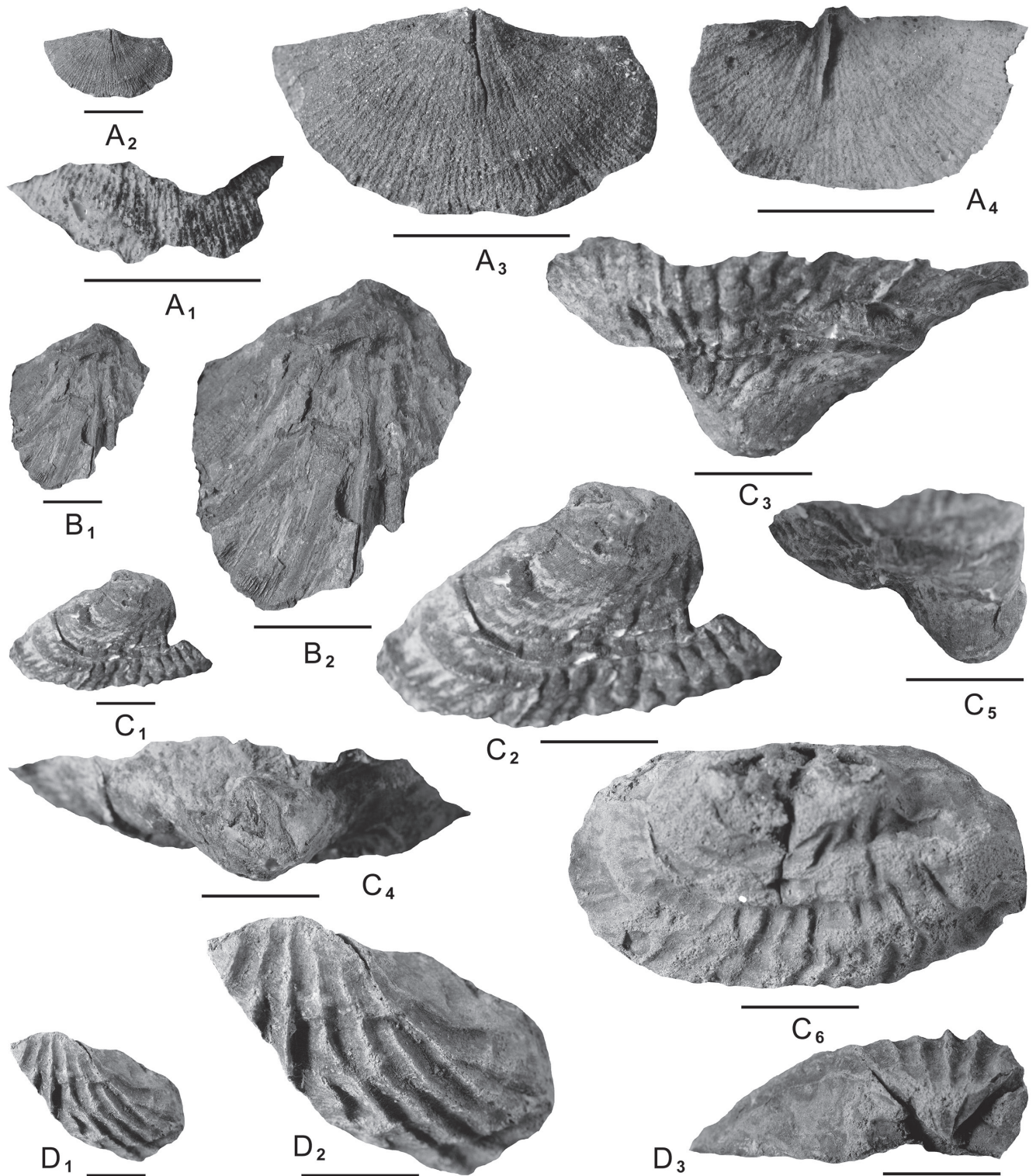


FIGURE 30. **A**, *Derbyia* sp., external latex cast (A₁), internal mould (A₂, A₃) and internal latex cast (A₄) of ventral valve, NU-B1614; **B**, *Meekella* sp., internal mould (B₁, B₂) of ventral valve, KCG12; **C**, **D**, *Geyerella ofunatoensis* Tazawa; **C**, ventral (C₁, C₂), anterior (C₃), posterior (C₄) and lateral (C₅) views of external latex cast, and internal mould (C₆) of ventral valve, NU-B 1487 (holotype); **D**, dorsal (D₁, D₂) and posterior (D₃) views of internal mould of dorsal valve, NU-B1491. Scale bars are 1 cm.

Order ORTHOTETIDA Waagen, 1884
 Suborder ORTHOTETIDINA Waagen, 1884
 Superfamily ORTHOTETOIDEA Waagen, 1884
 Family DERBYIIDAE Stehli, 1954
 Genus *DERBYIA* Waagen, 1884

Type species.—*Derbyia regularis* Waagen, 1884.

Derbyia sp.
 (Fig. 30A)

Derbyia sp. Tazawa, 2012, p. 37, fig. 7.4.

Material.—One specimen from locality KF108, external and internal moulds of a ventral valve, NU-B1614.

Remarks.—The single ventral valve specimen was previously described by Tazawa (2012, p. 37, fig. 7.4) as *Derbyia* sp. from the upper part of the Toyoma Formation in Nabekoshiyama. The Nabekoshiyama species is safely assigned to the genus *Derbyia* Waagen, 1884 by its flatly convex ventral valve, ornamented with numerous costellae (11–12 in 5 mm near the anterior margin) and in having a strong, short median septum in the ventral valve. This species most resembles *Derbyia nigpi* Chen and Liao (2007, p. 992, fig. 7), from the upper Changhsing Formation of Dongluo, Guangxi Province, central-southern China, in size, outline and external ornament of the ventral valve. But accurate comparison is difficult for the poorly preserved specimen. *Derbyia schellwieni* Frech (1911, p. 125, pl. 18, fig. 3), from the Lopingian of Loping, Jiangxi Province, eastern China, differs from the Nabekoshiyama species in its less transverse outline and in having coarser costellae on the ventral valve.

Occurrence.—Upper part of the Toyoma Formation in Nabekoshiyama (locality KF108).

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

Family MEEKELLIDAE Stehli, 1954
 Subfamily MEEKELLINAE Stehli, 1954
 Genus *MEEKELLA* White and St. John, 1867

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

Meekella sp.
 (Fig. 30B)

Meekella sp. Tazawa and Araki, 2014, p. 49, fig. 3.3.

Material.—One specimen from locality KZ2, internal mould of a ventral valve, KCG12.

Remarks.—This specimen was previously described by Tazawa and Araki (2014, p. 49, fig. 3.3) as *Meekella* sp. from the upper part of the Toyoma Formation in Nabekoshiyama. The single ventral valve specimen from Nabekoshiyama is small to medium in size (length more than 33 mm, width about

31 mm), subcircular in outline, and slightly convex in both anterior and lateral profiles. External surface of the ventral valve is ornamented with strong costae and numerous capillae; costae numbering seven on one side of lateral slopes. The Nabekoshiyama species most resembles *Meekella deltoidea* Liao (1980, p. 256, pl. 3, figs. 1–4), from the Longtanian of Guizhou, southwestern China, in size and shape of the ventral valve, but accurate comparison is difficult for the poorly preserved specimen.

Occurrence.—Upper part of the Toyoma Formation in Nabekoshiyama (locality KZ2).

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

Genus *GEYERELLA* Schellwien, 1900a

Type species.—*Geyerella gemmellaroi* Schellwien, 1900a.

Geyerella ofunatoensis Tazawa in Tazawa and Miyake, 2011
 (Figs. 30C, D, 31A)

Geyerella ofunatoensis Tazawa in Tazawa and Miyake, 2011, p. 10, fig. 5.1–5.6.

Geyerella sp. Tazawa in Tazawa and Miyake, 2011, p. 10, fig. 5.7.

Material.—Nine specimens from locality MED2: (1) external cast of a ventral valve, NU-B1486; (2) external and internal moulds of two ventral valves, NU-B1478, 1487 (holotype); (3) external cast of a dorsal valve, NU-B1488; and (4) internal moulds of five dorsal valves, NU-B1489–1493.

Remarks.—Most of the specimens except for a smaller one (NU-B1478) were previously described by Tazawa (in Tazawa and Miyake, 2011, p. 10, fig. 5.1–5.6) as *Geyerella ofunatoensis* Tazawa in Tazawa and Miyake, 2011 from the upper part of the Toyoma Formation in Maeda. *Geyerella ofunatoensis* is an average-sized (length 29 mm, width 43 mm, height about 15 mm, hinge width 28 mm in the holotype, NU-B1487), shallow cone-shaped *Geyerella*, with irregular strong rugae besides numerous costae and costellae on ventral valve. The Maeda species most resembles *Geyerella mongolica* Grabau (1931, p. 267, pl. 26, fig. 1, text-fig. 67A–C), from the Zhesi (Jisu) Formation in Zhesi, Inner Mongolia, northern China, by its irregular strong concentric rugae on the both ventral and dorsal valves, but it differs from the latter in having more numerous, finer costae on the both valves. *Geyerella gemmellaroi* Schellwien (1900a, p. 13, pl. 1, fig. 7a, 7b) from the Permian of Sosio, differs from *G. ofunatoensis* in lacking concentric rugae on the ventral valve. *Geyerella* sp. Tazawa (in Tazawa and Miyake, 2011, p. 10, fig. 5.7) from the same locality in Maeda may be a young individual of *Geyerella ofunatoensis*.

Occurrence.—Upper part of the Toyoma Formation in Maeda (locality MED2).

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

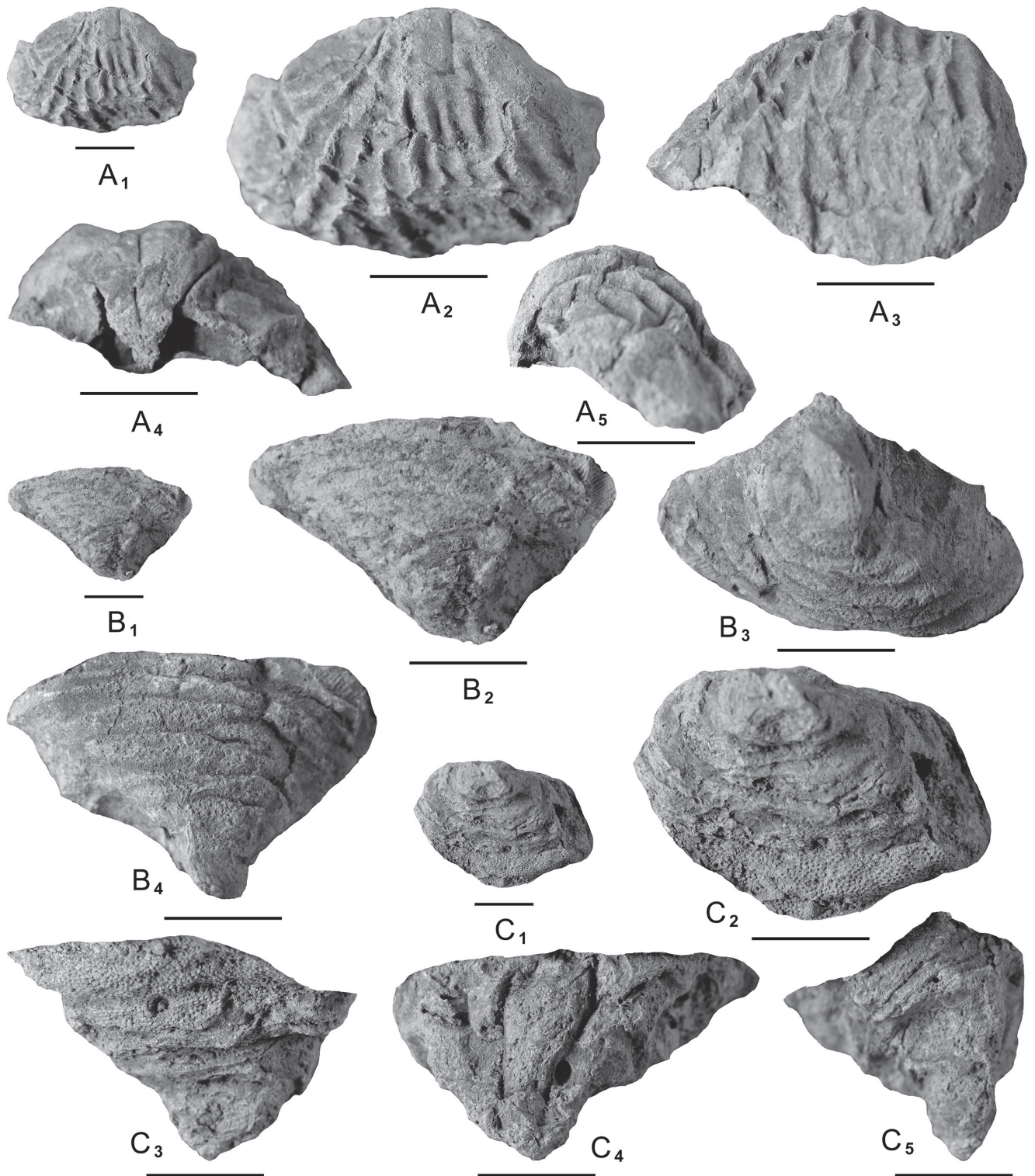


FIGURE 31. **A**, *Geyerella ofunatoensis* Tazawa, dorsal (A₁, A₂), anterior (A₃), posterior (A₄) and lateral (A₅) views of internal mould of dorsal valve, NU-B1492; **B**, *Tropidelasma* sp.; B, anterior (B₁, B₂) and ventral (B₃) views of external latex cast, and anterior view (B₄) of external mould of ventral valve, NU-B1480; **C**, ventral (C₁, C₂), anterior (C₃), posterior (C₄) and lateral (C₅) views of internal mould of ventral valve, NU-B1481. Scale bars are 1 cm.

Family SCHUCHERTELLIDAE Williams, 1953
 Subfamily STREPTORHYNCHINAE Stehli, 1954
 Genus *TROPIDELASMA* Cooper and Grant, 1969

Type species.—*Tropidelasma culmenatum* Cooper and Grant, 1969.

Tropidelasma sp.
 (Fig. 31B, C)

Tropidelasma sp. Tazawa in Tazawa and Miyake, 2011, p. 11, fig. 5.8, 5.9.

Material.—Three specimens from locality MED2: (1) external and internal moulds of a ventral valve, NU-B1480; and (2) internal moulds of two ventral valves, NU-B1481, 1482.

Remarks.—These specimens were previously described by Tazawa (in Tazawa and Miyake, 2011, p. 11, fig. 5.8, 5.9) as *Tropidelasma* sp. from the upper part of the Toyoma Formation in Maeda. The Maeda species can be assigned to the genus *Tropidelasma* Cooper and Grant, 1969 by its deep, slightly bent, cone-shaped ventral valve, with long interarea and external ornamentation consisting of strong rugae and fine numerous capillae. However, specific identification is difficult owing to ill preservation of the present material. *Tropidelasma anthicum* Cooper and Grant (1974, p. 335, pl. 59, figs. 1–36; pl. 60, figs. 1–39), from the Word Formation of Texas, differs from the Kitakami species in its smaller size. *Tropidelasma yamasugensis* Tazawa in Tazawa et al. (2010, p. 39, fig. 3.2), from the Nabeyama Formation (Murgabian or Wordian) of Yamasuge in the Kuzu area, central Japan, differs from the present species in its more numerous and less strong rugae on the ventral valve.

Occurrence.—Upper part of the Toyoma Formation in Maeda (locality MED2).

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

Order ORTHIDA Schuchert and Cooper, 1932
 Suborder DALMANELLIDINA Moore, 1952
 Superfamily ENTELETOIDEA Waagen, 1884
 Family ENTELETIDAE Waagen, 1884
 Genus *ENTELETES* Fischer de Waldheim, 1825

Type species.—*Enteleles glabra* Fischer de Waldmeim, 1830.

Enteleles andrewsi Grabau, 1931
 (Fig. 32A–C)

Enteleles andrewsi Grabau, 1931, p. 222, pl. 10, figs. 2–5; pl. 11, figs. 1, 2; Jin, 1985, pl. 6, figs. 9–11; Duan and Li, 1985, p. 99, pl. 33, figs. 1–7; Wang and Zhang, 2003, p. 127, pl. 30, figs. 1–15; pl. 50, figs. 3, 8; Tazawa in Tazawa and Miyake, 2011, p. 13, fig. 3.7–3.9.

Enteleles obesa Grabau, 1931, p. 229, pl. 9, fig. 7.7; pl. 12, figs. 2–4; Duan and Li, 1985, p. 100, pl. 34, figs. 1–5.

Enteleles obesus Grabau. Licharew and Kotlyar, 1978, pl. 19, fig. 3.3.

Enteleles sp. Tazawa, 2012, p. 37, fig. 3.15.

Material.—Six specimens from localities MED2 and KF108: (1) external and internal moulds of a ventral valve, NU-B1631; (2) internal moulds of two ventral valves, NU-B1502, 1503; (3) external casts of two dorsal valves, NU-B1504, 1505; and (4) internal mould of a dorsal valve, NU-B1506.

Remarks.—These specimens were previously described by Tazawa (in Tazawa and Miyake, 2011, p. 13, fig. 3.7–3.9) as *Enteleles andrewsi* Grabau, 1931 from the upper part of the Toyoma Formation in Maeda, and by Tazawa (2012, p. 37, fig. 3.15) as *Enteleles* sp. from the upper part of the Toyoma Formation in Nabekoshiyama. The Maeda species can be referred to *Enteleles andrewsi* Grabau, 1931, from the Jisu Honguer Limestone (= Yiheusu Formation, Duan and Li, 1985) of Inner Mongolia, northern China, in its small, elongate shell (length 21 mm, width 18 mm in the best-preserved dorsal valve specimen, NU-B1504), and in having external ornament consisting of some strong subangular costae and numerous capillae. The Nabekoshiyama species is also referred to *Enteleles andrewsi* Grabau, 1931, by its small size and elongate outline. *Enteleles gibbosus* Chronic (1953, p. 92, pl. 16, figs. 9–14), from the Copacabana Group of Peru, differs from *Enteleles andrewsi* in its rounded shell and in having more weak costae on the both ventral and dorsal valves.

Occurrence.—Upper part of the Toyoma Formation in Maeda (locality MED2) and Nabekoshiyama (locality KF108).

Distribution.—Roadian–Capitanian: northwestern China (Qinghai), northern China (Inner Mongolia) and eastern Russia (South Primorye); and Changhsingian: northeastern Japan (Maeda and Nabekoshiyama in the South Kitakami Belt).

Genus *PELTICHIA* Jin and Liao in Jin and Sun, 1981

Type species.—*Parenteleles sinensis zigzag* Huang, 1933.

Peltichia transversa (Huang, 1933)
 (Fig. 33D)

Parenteleles sinensis mut. *transversus* Huang, 1933, p. 14, pl. 2, figs. 8–10.

Enteletina sinensis mut. *transversus* (Huang). Wang et al., 1964, p. 152, pl. 20, figs. 4–7; Feng and Jiang, 1978, p. 234, pl. 85, fig. 17.

Enteletina sinensis (Huang). Feng and Jiang, 1978, p. 234, pl. 85, fig. 16 only.

Enteleles sinensis (Huang). Jin et al., 1979, p. 74, pl. 36, figs. 31–34.

Enteletina transversa (Huang). Liao, 1980, p. 253, pl. 1, figs. 49–52.

Peltichia transversa (Huang). Shen and He, 1994, pl. 1, figs. 29–34; Shen and Shi, 2007, p. 45, pl. 17, figs. 13–30.

Peltichia schizoides Xu and Grant, 1994, p. 21, fig. 9.1–9.10.

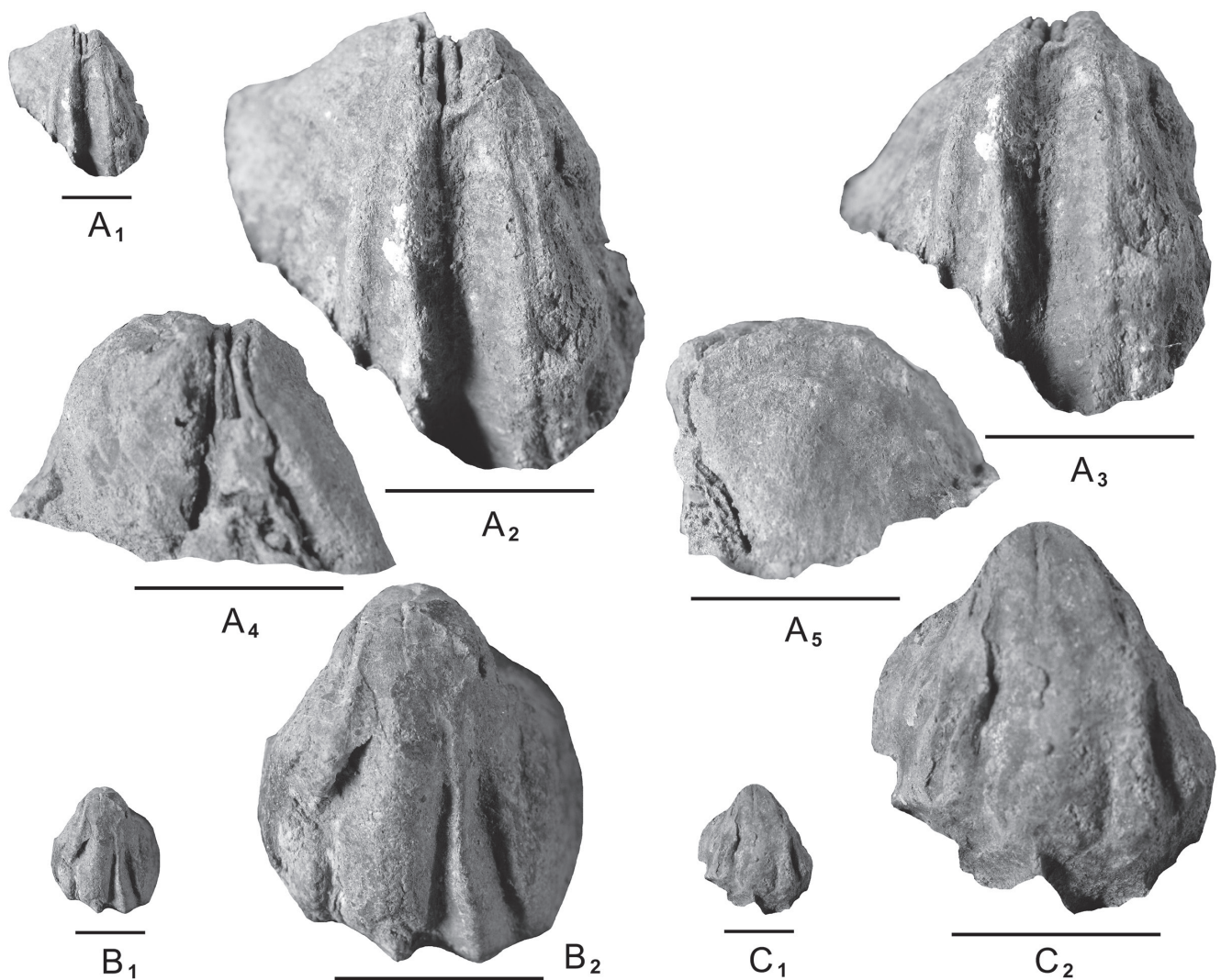


FIGURE 32. A–C, *Enteleles andrewsi* Grabau; A, ventral (A₁, A₂), anterior (A₃), posterior (A₄) and lateral (A₅) views of internal mould of ventral valve, NU-B1502; B, external latex cast (B₁, B₂) of dorsal valve, NU-B1504; C, internal mould (C₁, C₂) of dorsal valve, NU-B1606. Scale bars are 1 cm.

Peltichia transversus (Huang). Xu and Grant, 1994, fig. 9.17, 9.18, 9.21, 9.22, 9.24; Shen et al., 1999, p. 58, figs. 6.8, 8.8–8.12, 10.11–10.25, 10.30.

Peltichia sinensis transversa (Huang). Zeng et al., 1995, pl. 2, fig. 1.

Peltichia sinensis (Huang). Zeng et al., 1995, pl. 2, fig. 4; pl. 3, figs. 1, 2.

Peltichia cf. *transversa* (Huang). Tazawa, 2012, p. 39, fig. 7.5.

Material.—One specimen from locality KF108, internal mould of a dorsal valve, NU-B1608.

Remarks.—This specimen was previously described by Tazawa (2012, p. 39, fig. 7.5) as *Peltichia* cf. *transversa* (Huang, 1933) from the upper part of the Toyoma Formation in Nabekoshiyama. The single dorsal valve specimen from Nabekoshiyama is small to medium in size (length about 32 mm, width about 42 mm), transversely elliptical in outline, and

having a pair of strong brachioophore supporting plates, diverging anteriorly, a low and short median ridge and an elevated adductor platform. The Nabekoshiyama species can be referred to *Peltichia transversa* (Huang, 1933), originally described by Huang (1933, p. 14, pl. 2, figs. 8–10) as *Parenteleles sinensis* mut. *transversa* Huang, 1933 from the coal-bearing formation (Wuchiapingian) in Guizhou, southwestern China, in its small size and transverse outline. *Peltichia akasakensis* (Ozawa, 1927), redescribed by Shen et al. (1999, p. 53, figs. 6.1–6.5, 6.9–6.12, 7) from the lower part (*Parafusulina* Zone) of the Akasaka Limestone of Akasaka, Mino Belt, central Japan, differs from *P. transversa* in its much larger size and more elongate outline. The type species, *Peltichia zigzag* (Huang, 1933, p. 13, pl. 2, fig. 7), from the Lungtan Formation in Guizhou, differs from *P. transversa* in having strong paraplicate anterior commissure.

Occurrence.—Upper part of the Toyoma Formation in Nabekoshiyama (locality KF108).

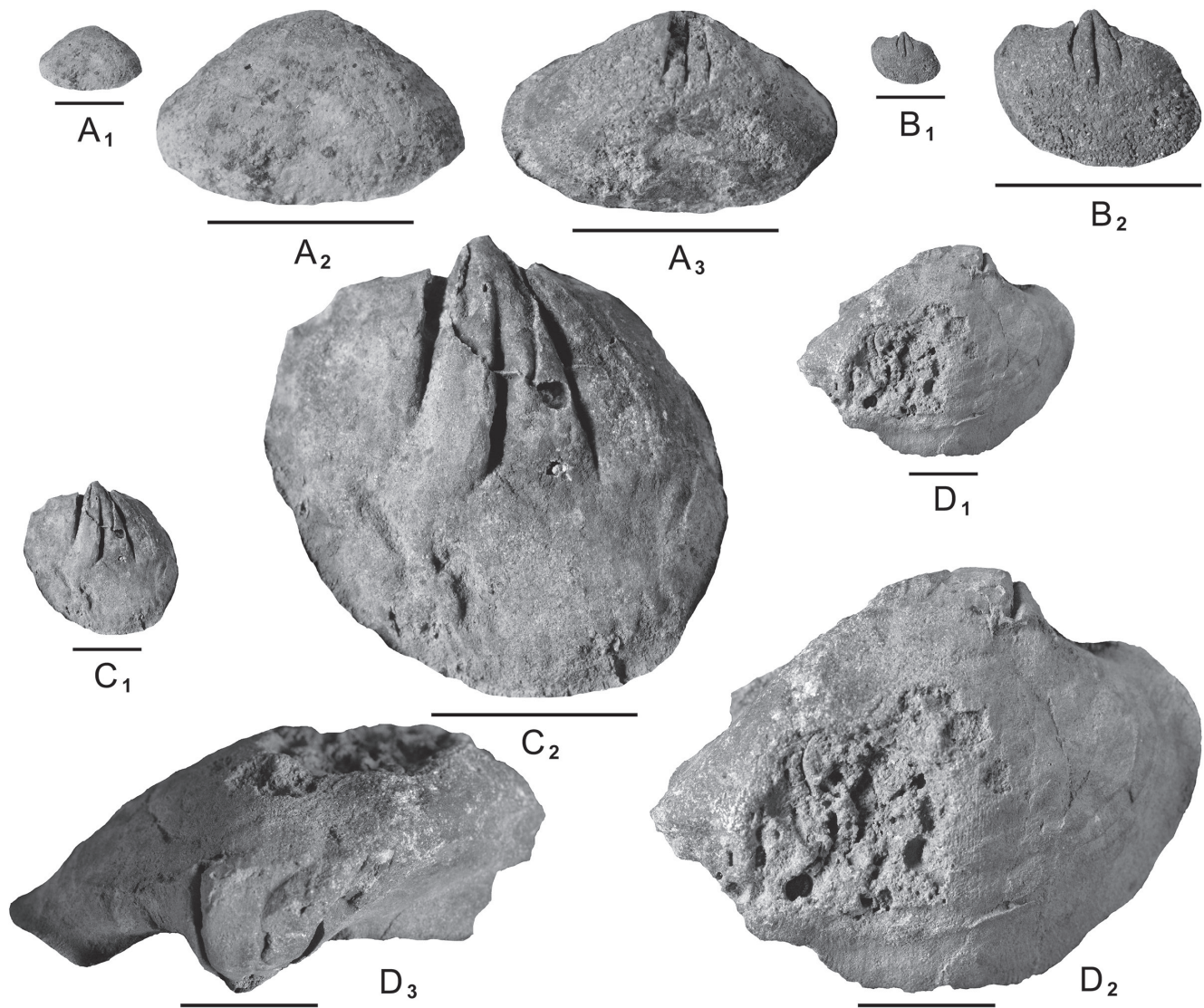


FIGURE 33. **A, B**, *Orthotichia dorashamiensis* Sokolskaya; **A**, external latex cast (A₁, A₂) and internal mould (A₃) of ventral valve, NU-B1500; **B**, internal mould (B₁, B₂) of ventral valve, NU-B1643; **C**, *Orthotichia* sp., internal mould (C₁, C₂) of ventral valve, KCG11; **D**, *Peltichia transversa* (Huang), ventral (D₁, D₂) and posterior (D₃) views of internal mould of ventral valve, NU-B1608. Scale bars are 1 cm.

Distribution.—Wuchiapingian: northwestern China (Qinghai), southwestern China (Guizhou) and northwestern China (Qinghai); Changhsingian: northeastern Japan (Nabekoshiyama in the South Kitakami Belt), eastern China (Zhejiang), central-southern China (Hunan and Guangxi) and southwestern China (Guizhou and Sichuan).

Family SCHIZOPHORIIDAE Schuchert and LeVene, 1929
Genus *ORTHOTICHIA* Hall and Clarke, 1892

Type species.—*Orthis? morganiana* Derby, 1874.

Orthotichia dorashamensis Sokolskaya, 1965
(Fig. 33A, B)

Orthotichia dorashamensis Sokolskaya, 1965, p. 200, pl. 29, fig. 6, text-fig. 24; Fantini Sestini and Glaes, 1966, p. 899, pl. 63, fig. 4.

Orthotichia sp. Tazawa in Tazawa and Miyake, 2011, p. 14, fig. 2; Tazawa, 2012, p. 40, fig. 3.14.

Material.—Two specimens from localities KF108 and MED2: (1) external and internal moulds of a ventral valve, NU-B1500; and (2) internal mould of a ventral valve, NU-B1643.

Remarks.—These specimens were previously described by Tazawa (in Tazawa and Miyake, 2011, p. 14, fig. 2; Tazawa, 2012, p. 40, fig. 3.14) as *Orthotichia* sp. from the upper part of the Toyoma Formation in Maeda and Nabekoshiyama. The Kitakami species can be identified with *Orthotichia dorashamiensis* Sokolskaya (1965, p. 200, pl. 29, fig. 6, text-

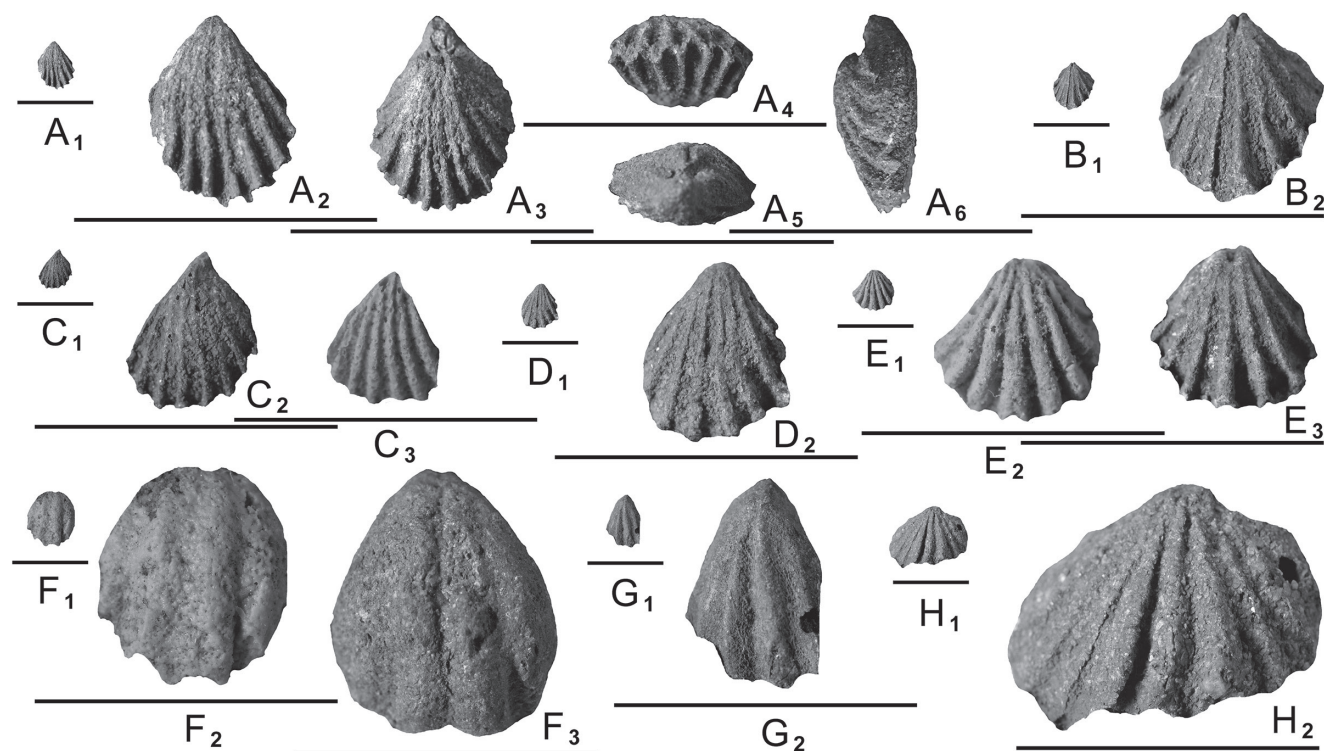


FIGURE 34. **A–E**, *Hustedia minuta* Tazawa; **A**, ventral (**A**₁, **A**₂), dorsal (**A**₃), anterior (**A**₄), posterior (**A**₅) and lateral (**A**₆) views of internal mould of conjoined shell, NU-B1615; **B**, internal mould (**B**₁, **B**₂) of dorsal valve, NU-B1627; **C**, internal mould (**C**₁, **C**₂) and external latex cast (**C**₃) of ventral valve, NU-B1619; **D**, internal mould (**D**₁, **D**₂) of ventral valve, NU-B1620; **E**, external latex cast (**E**₁, **E**₂) and internal mould (**E**₃) of dorsal valve, NU-B1625; **F–H**, *Hustedia indica* (Waagen); **F**, external latex cast (**F**₁, **F**₂) and internal mould (**F**₃) of ventral valve, NU-B1629; **G**, internal mould (**G**₁, **G**₂) of ventral valve, NU-B1630; **H**, internal mould (**H**₁, **H**₂) of dorsal valve, NU-B2593. Scale bars are 1 cm.

fig. 24), from the Dorashamian (Changhsingian) in Dhulfa, Transcaucasia, in its small size and transversely subelliptical outline (length 10 mm, width 18 mm in the larger specimen, NU-B1500; length 7 mm, width 11 mm in the smaller specimen, NU-B1643). *Orthotichia newelli* Cooper and Grant (1976, p. 2619, pl. 475, figs. 16–20; pl. 663, figs. 1–10; pl. 671, figs. 20–31), from the Wolfcampian in Texas, differs from *Orthotichia dorashamensis* in its larger size and less transverse outline of the ventral valve. The type species, *Orthotichia morganiana* (Derby, 1874), is readily distinguished from the present species by its much larger size and less transverse outline.

Occurrence.—Upper part of the Toyoma Formation in Maeda (locality MED2) and Nabekoshiyama (KF108).

Distribution.—Changhsingian: northeastern Japan (Maeda and Nabekoshiyama in the South Kitakami Belt), Transcaucasia (Dzhulfa) and northern Iran (central Elburz).

Orthotichia sp.
(Fig. 33C)

Material.—One specimen from locality KZ2, internal mould of a ventral valve, KCG11.

Remarks.—The single ventral valve specimen from Nabekoshiyama can be assigned to the genus *Orthotichia* Hall and Clarke, 1892 in its medium size, subrounded outline (length

about 25 mm, width about 25 mm), and in having internal structures consisting of a pair of strong dental plates and a long median septum in the ventral valve. The Nabekoshiyama species resembles *Orthotichia morganiana* (Derby, 1874), redescribed by Shi and Waterhouse (1996, p. 44, pl. 1, figs. 2–18), from the upper Jungle Creek Formation (Sakmarian–Artinskian) in northern Yukon Territory, in size and outline of the ventral valve, but accurate comparison is difficult for the poor material. The preceding species, *Orthotichia darashamiensis* Sokolskaya (1965), is readily distinguished from the present species in its much smaller size and more transverse outline.

Occurrence.—Upper part of the Toyoma Formation in Nabekoshiyama (locality KZ2).

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

Order ATHYRIDIDA Boucot, Johnson and Staton, 1964
Suborder RETZIIDINA Boucot, Johnson and Staton, 1964
Superfamily RETZIOIDEA Waagen, 1883
Family NEORETZIIDAE Dagys, 1972
Subfamily HUSTEDIINAE Grunt, 1986
Genus *HUSTEDIA* Hall and Clarke, 1893

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

Hustedia indica (Waagen, 1883)
(Fig. 34A–E)

Eumetria indica Waagen, 1883, p. 493, pl. 35, figs. 1, 2.

Hustedia indica (Waagen). Tschernyschew, 1902, p. 109, pl. 47, fig. 12; Huang, 1933, p. 78, pl. 11, fig. 3; Shimizu, 1961, p. 329, pl. 16, figs. 43–45; Liao, 1980, pl. 9, figs. 22–25; Ding and Qi, 1983, p. 359, pl. 120, fig. 5; Yang, 1984, p. 231, pl. 37, fig. 8; Tazawa, 2012, p. 40, fig. 3.16; Tazawa and Shintani, 2014, p. 31, fig. 6.2–6.4.

Retzia (*Hustedia*) *indica* (Waagen). Broili, 1916, p. 54, pl. 125, figs. 4–6.

Material.—Two specimens from localities KF107 and 108, external and internal moulds of two ventral valves, NU-B1629, 1630.

Remarks.—The specimens from Nabekoshiyama were previously described by Tazawa (2012, p. 40, fig. 3.16) as *Hustedia indica* (Waagen, 1883) on account of medium-sized, slightly elongate shell (length 9 mm, width 7 mm in the better preserved ventral valve specimen, NU-B1629) and external ornament consisting of 7–8 strong, rounded costae on the ventral valve. *Hustedia remota* (von Eichwald, 1860), redescribed by Tschernyschew (1902, p. 107, pl. 47, figs. 8–11) from the Schwagerina Limestone of Ufa, southern Urals, differs from *Hustedia indica* in having wider and flat-bottomed intercostal spaces on both ventral and dorsal valves.

Occurrence.—Upper part of the Toyoma Formation in Nabekoshiyama (localities KF107 and KF108).

Distribution.—Asselian–Wuchiapingian: northeastern Japan (Kamiyasse–Imo in the South Kitakami Belt), central Russia (southern Urals), northwestern China (Gansu), central-southern China (Hubei), southwestern China (Guizhou), Indonesia (Timor) and Pakistan (Salt Range); and Changhsingian: northeastern Japan (Nabekoshiyama in the South Kitakami Belt) and southwestern Japan (Yakuno in the Maizuru Belt).

Hustedia minuta Tazawa in Tazawa and Miyake, 2011
(Fig. 34F–H)

Hustedia minuta Tazawa in Tazawa and Miyake, 2011, p. 15, fig. 2.5, 2.6; Tazawa, 2012, p. 41, fig. 3.4–3.7.

Material.—Seventeen specimens from localities KF108 and MED2: (1) internal mould of a conjoined shell, with external mould of the ventral valve, NU-B1615; (2) internal moulds of three conjoined shells, NU-B1616–1618; (3) external and internal moulds of a ventral valve, NU-B1619; (4) external cast of a ventral valve, NU-B1472 (holotype); (5) internal moulds of five ventral valves, NU-B1620–1623; (6) external and internal moulds of two dorsal valves, NU-B1473, 1624, 1625; and (7) internal moulds of four dorsal valves, NU-B1474, 1626–1628.

Remarks.—These specimens were previously described by Tazawa (in Tazawa and Miyake, 2011, p. 15, fig. 2.5, 2.6) and Tazawa (2012, p. 41, fig. 3.4–3.7) as *Hustedia minuta* Tazawa

in Tazawa and Miyake, 2011 from the upper part of the Toyoma Formation in both Maeda and Nabekoshiyama. *Hustedia minuta* is small in size for genus (length about 5 mm, width about 4 mm in the holotype, NU-B1472) and having 12 rounded costae with broad and flat intercostal furrows on ventral valve. *Hustedia episkopiensis* Shen and Clapham (2009, p. 728, pl. 4, figs. 17–24), from the upper Permian (Wuchiapingian) of Hydra Island, Greece, is also a small-sized species, but the Greek species differs from *Hustedia minuta* in having more numerous costae, with narrower intercostal spaces. The preceding species, *Hustedia indica* (Waagen, 1883), differs from *H. minuta* in its larger and more elongate shell and in having fewer costae on the ventral valve.

Occurrence.—Upper part of the Toyoma Formation in Maeda (locality MED2) and Nabekoshiyama (locality KF108).

Distribution.—Changhsingian: northeastern Japan (Maeda and Nabekoshiyama in the South Kitakami Belt).

Order SPIRIFERIDA Waagen, 1883
Suborder SPIRIFERIDINA Waagen, 1883
Superfamily AMBOCOELIOIDEA George, 1931
Family AMBOCOELIIDAE George, 1931
Subfamily AMBOCOELIINAE George, 1931
Genus *ATTENUATELLA* Stehli, 1954

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

Attenuatella bandoi Tazawa, 1987
(Fig. 35A, B)

Attenuatella bandoi Tazawa, 1987, p. 281, figs. 3.1–3.11, 4; Tazawa, 2011, p. 177, fig. 5.1–5.3; Tazawa and Araki, 2014, p. 50, fig. 3.1, 3.2.

Attenuatella sp. Tazawa and Niigata Pre-Tertiary Research Group, 1999, fig. 2.6–2.9; Tazawa, 2001, fig. 38.2F–H.

Material.—Two specimens from locality AR7, internal moulds of two ventral valves, KCG9, 10.

Remarks.—These specimens were previously described by Tazawa and Araki (2014, p. 50, fig. 3.1, 3.2) as *Attenuatella bandoi* Tazawa, 1987 from the upper part of the Toyoma Formation in Nabekoshiyama. The Nabekoshiyama species can be referred to *Attenuatella bandoi* Tazawa, 1987, from the lower part of the Toyoma Formation in Ishihama, Utatsu area, South Kitakami Belt, by its relatively large size for genus (length 10 mm, width 6 mm in the larger specimen, KCG9), elongate outline, and in having long and broad adductor scars in the ventral valve. *Attenuatella incurvata* Waterhouse (1964, p. 108, pl. 20, figs. 1–12, pl. 21, figs. 1–9, text-figs. 47–52), from the Kungurian–Kazanian beds of New Zealand, differs from *A. bandoi* in its slightly smaller and less elongate shell, and in having more dense spine bases on both ventral and dorsal valves. *Attenuatella mengi* He, Shi, Feng and Peng (2007, p. 276, figs. 5A–P, 6A–H), from the Talung Formation (Changhsingian) of Guangxi, central-southern China, differs from *A. bandoi* in its

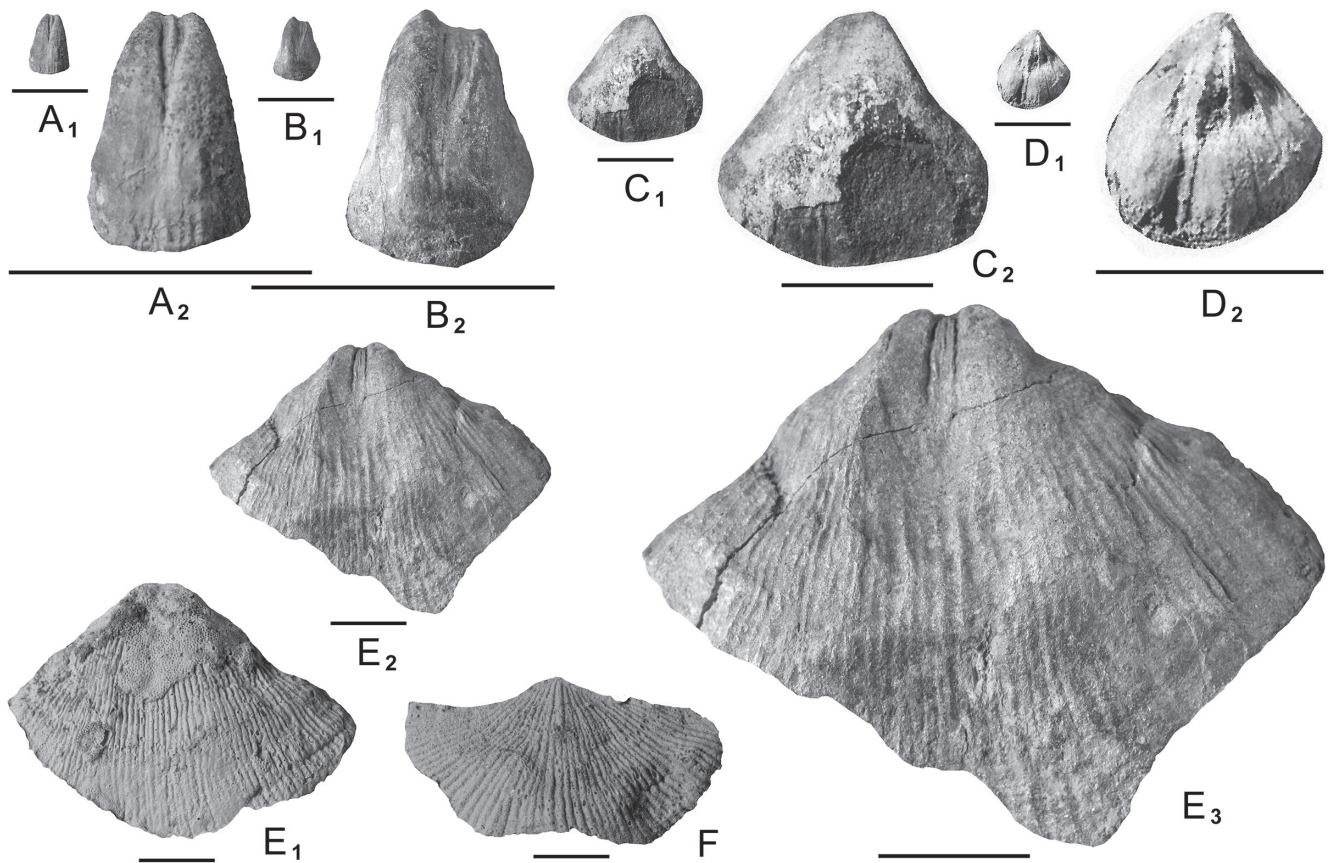


FIGURE 35. **A, B**, *Attenuatella bandoi* Tazawa; **A**, internal mould (**A**₁, **A**₂) of ventral valve, KCG10; **B**, internal mould (**B**₁, **B**₂) of ventral valve, KCG9; **C**, **D**, *Martinia* sp.; **C**, external natural cast of ventral valve, NU-B1609; **D**, internal mould (**D**₁, **D**₂) of ventral valve, NU-B1610; **E, F**, *Choristitella wynnei* (Waagen); **E**, external latex cast (**E**₁) and internal mould (**E**₂, **E**₃) of ventral valve, NU-B1501; **F**, external latex cast of dorsal valve, NU-B1575. Scale bars are 1 cm.

less elongate outline and shorter adductor scars in the ventral valve. The type species, *Attenuatella texana* Stehli (1954, p. 343, pl. 25, figs. 31–33), from the Bone Spring Formation (Leonardian) in the Sierra Diablo, western Texas, differs from the Kitakami species in its much smaller size.

Occurrence.—Upper part of the Toyoma Formation in Nabekoshiyama (locality AR7).

Distribution.—Wuchiapingian: northeastern Japan (Ishihama in the South Kitakami Belt) and central Japan (Okutadami in the Maizuru Belt); and Changhsingian: northeastern Japan (Nabekoshiyama in the South Kitakami Belt).

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. 35C, D)

Martinia sp. Tazawa, 2012, p. 41, fig. 3.20, 3.21.

Material.—Two specimens from locality KF107: external cast of a ventral valve, NU-B1609; and (2) internal mould of a ventral valve, NU-B1610.

Remarks.—These specimens were previously described by Tazawa (2012, p. 41, fig. 3.20, 3.21) as *Martinia* sp. from the upper part of the Toyoma Formation in Nabekoshiyama. The Nabekoshiyama species is safely assigned to the genus *Martinia* M'Coy, 1844 by its small size (length about 18 mm, width about 19 mm in the larger specimen, NU-B1609), subcircular outline, and in having several distinct radial vascular markings in posterior portion of the ventral valve. However, specific determination is difficult for the poorly preserved specimens.

Occurrence.—Upper part of the Toyoma Formation in Nabekoshiyama (locality KF107).

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

Superfamily SPIRIFEROIDEA King, 1846

Family CHORISTITIDAE Waterhouse, 1968a

Subfamily CHORISTITINAE Waterhouse, 1968a

Genus *CHORISTITELLA* Ivanov and Ivanova, 1937

Type species.—*Choristites podolskensis* Ivanov and Ivanova, 1937.

Choristitella wynnei (Waagen, 1883)
(Fig. 35E, F)

Spirifer wynnei Waagen, 1883, p. 517, pl. 44, figs. 6–7; Licharew and Kotlyar, 1978, pl. 21, fig. 14.

Choristitella wynnei (Waagen). Kotlyar in Kotlyar and Zakharov, 1989, pl. 24, figs. 4, 5; Tazawa in Tazawa and Miyake, 2011, fig. 5.10; Tazawa, 2012, p. 42, fig. 7.6.

Material.—Two specimens from localities KF108 and MED2: (1) external and internal moulds of a ventral valve, NU-B1501; and (2) external mould of a dorsal valve, NU-B1575.

Remarks.—These specimens were previously described by Tazawa (in Tazawa and Miyake, 2011, fig. 5.10) and Tazawa (2012, p. 42, fig. 7.6) as *Choristitella wynnei* (Waagen, 1883) from the upper part of the Toyoma Formation in both Maeda and Nabekoshiyama. The single ventral valve specimen from Maeda can be referred to *Choristitella wynnei* (Waagen, 1883), originally described from the Wargal Formation of the Salt Range, Pakistan, by its large, transverse ventral valve (length about 35 mm, width about 50 mm) and external ornament, consisting of numerous costae with a density of 5–6 in 5 mm at about the midvalve. The dorsal valve specimen from Nabekoshiyama is also referred to *Choristitella wynnei* by its large, transverse dorsal valve (length more than 45 mm, width about 30 mm), with low and broad fold and external ornament consisting of numerous fine costae, numbering 5–6 in 5 mm at about midvalve. The type species, *Choristitella podolskensis* (Ivanov and Ivanova, 1937, p. 170, 196, pl. 15, figs. 2–5; pl. 23, figs. 3–4, text-fig. 55) from the upper Moscovian of the Moscow Basin, western Russia, differs from *Choristitella wynnei* in its smaller size, less transverse outline, and in having deeper and narrower sulcus on the ventral valve.

Occurrence.—Upper part of the Toyoma Formation in Maeda (locality MED2) and Nabekoshiyama (locality KF108).

Distribution.—Capitanian–Wuchiapingian: eastern Russia (South Primorye) and Pakistan (Salt Range); and Changhsingian: northeastern Japan (Maeda and Nabekoshiyama in the South Kitakami Belt).

Order SPIRIFERINIDA Ivanova, 1972
Suborder SPIRIFERINIDINA Ivanova, 1972
Superfamily PENNOSPIRIFERINOIDEA Dagys, 1972
Family PARASPIRIFERINIDAE Cooper and Grant, 1976
Genus *CALLISPIRINA* Cooper and Muir-Wood, 1951

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

Callispirina sp.
(Fig. 36A, B)

Callispirina sp. Tazawa in Tazawa and Miyake, 2011, p. 17, fig. 2.3, 2.4.

Material.—Three specimens from locality MED2: (1) external moulds of two ventral valves, NU-B1483, 1484; and (2) internal mould of a ventral valve, NU-B1485.

Remarks.—These specimens were previously described by Tazawa (in Tazawa and Miyake, 2011, p. 17, fig. 2.3, 2.4) as *Callispirina* sp. from the upper part of the Toyoma Formation in Maeda. The Maeda species can be safely assigned to the genus *Callispirina* Cooper and Muir-Wood, 1951 by its small, nearly equidimensional shell (length about 9 mm, width about 11 mm in the better preserved ventral valve specimen, NU-B1483), externally, having a deep sulcus with V-shaped bottom in ventral valve, three simple, strong and angular costae on each side of the sulcus and numerous, closely spaced growth lines over the ventral valve, and internally, having a thin but high median septum, extending for midlength of the valve. The type species, *Callispirina ornata* (Waagen, 1883, p. 505, pl. 50, figs. 1, 2), from the Chhidru Formation of the Salt Range, differs from the present species in its much larger size. *Callispirina austrina* Grant (1976, p. 231, pl. 63, figs. 1–37), from the Rat Buri Limestone of Ko Muk, southern Thailand, is similar in size, but the Thai species has more numerous, less angular costae in the ventral valve. *Callispirina? rotundella* Xu and Grant (1994, p. 47, fig. 36.24–36.30), from the Changhsingian of Zhejiang and Sichuan, eastern China is also a small-sized *Callispirina* species, but the Chinese species differs from the Kitakami species in having more numerous costae on the ventral valve.

Occurrence.—Upper part of the Toyoma Formation in Maeda (locality MED2).

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

Family SPIRIFERELLINIDAE Ivanova, 1972
Genus *SPIRIFERELLINA* Fredericks, 1924b

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

Spiriferellina cristata (von Schlotheim, 1816)
(Fig. 36C–E)

Terebratulites cristatus von Schlotheim, 1816, p. 28, pl. 1, fig. 3.
Spirifer cristatus (von Schlotheim). de Koninck, 1843, p. 240, pl. 15, fig. 5.

Spiriferina cristata (von Schlotheim). Tschernyschew, 1902, p. 115, 517, pl. 37, figs. 1, 2; Ozaki, 1931, p. 172, pl. 15, fig. 14; Malzahn, 1937, p. 40, pl. 3, figs. 26, 27.

Spiriferellina cristata (von Schlotheim). Heritsche, 1935, p. 364, pl. 2, fig. 22; Heritsche, 1938, p. 133, pl. 7, figs. 15–19; Campbell, 1959, p. 358, pl. 59, figs. 1–9; pl. 60, fig. 3, text-fig. 5; Schröter, 1963, p. 144, pl. 8, figs. 11–14; Alexandrov and Einor, 1979, p. 91, pl. 38, figs. 2, 3; Lee et al., 1980, p. 422, pl. 179, figs. 3, 6–8; Kalashnikov, 1998, p. 75, pl. 30, fig. 3; pl. 32, figs. 1, 2; Wang and Yang, 1998, p. 125, pl. 22, figs.

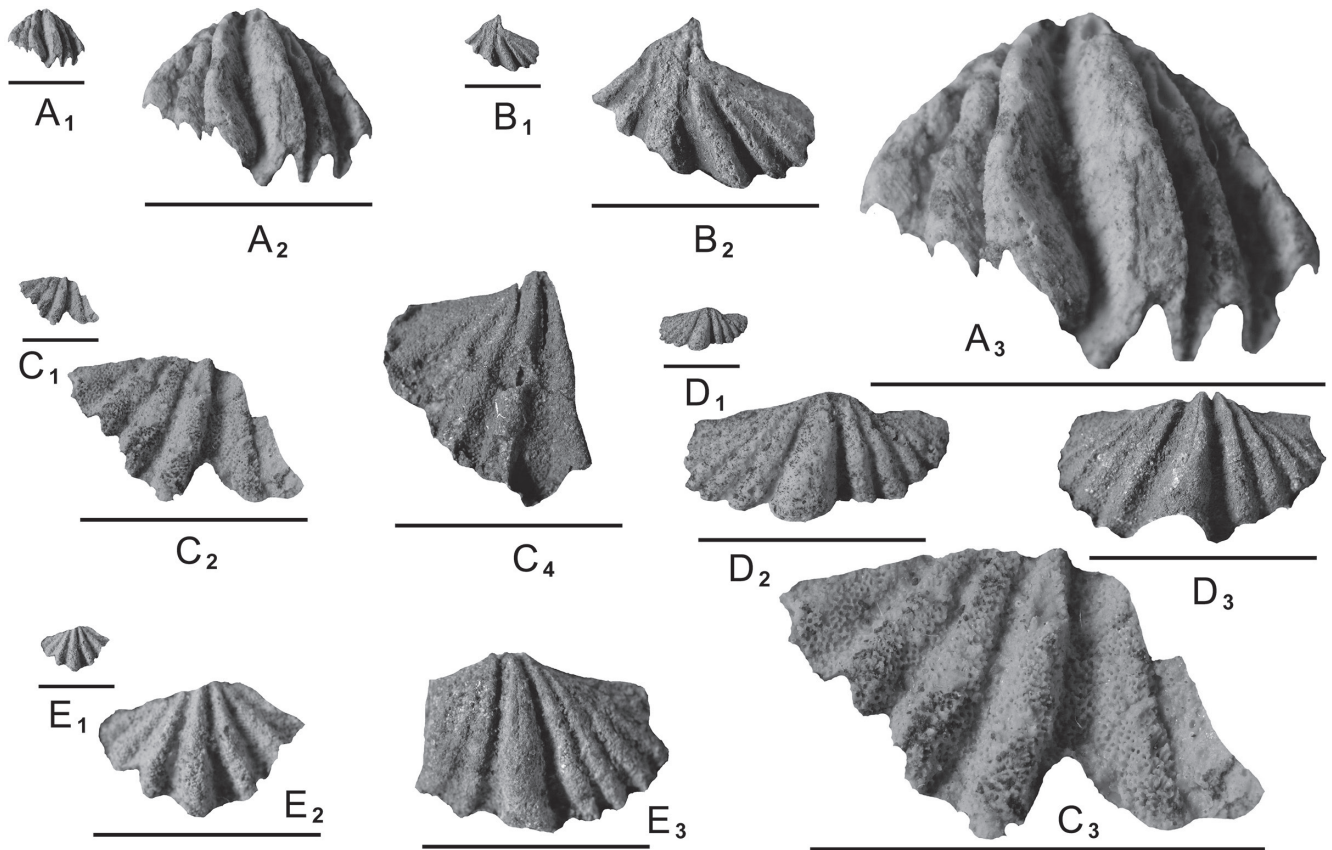


FIGURE 36. **A, B**, *Callispirina* sp.: A, external latex cast (A₁, A₂, A₃) of ventral valve, NU-B1483; B, internal mould (B₁, B₂) of ventral valve, NU-B1485; **C–E**, *Spiriferellina cristata* (von Schlotheim); C, external latex cast (C₁, C₂) of ventral valve, NU-B1611; D, external latex cast (D₁, D₂) and internal mould (D₃) of dorsal valve, N-B1612; E, external latex cast (E₁, E₂) and internal mould (E₃) of dorsal valve, NU-B1613. Scale bars are 1 cm.

9, 13, 14; Fan and He, 1999, p. 146, pl. 33, figs. 11–20; Wang and Zhang, 2003, p. 168, pl. 34, figs. 12–16; pl. 50, figs. 14, 16; Tazawa, 2012, p. 42, fig. 3.17–3.19; Tazawa and Shintani, 2022, p. 46, fig. 29C–F.

Spiriferina cristata (von Schlotheim). von Malzahn, 1937, p. 40, pl. 3, figs. 26, 27.

Punctospirifer cristata (von Schlotheim). Dunbar, 1955, p. 149, pl. 29, figs. 13–20.

Material.—Three specimens from locality KF108: (1) external and internal moulds of a ventral valve, NU-B1611; and (2) external and internal moulds of two dorsal valves, NU-B1612, 1613.

Remarks.—These specimens were previously described by Tazawa (2012, p. 42, fig. 3.17–3.19) as *Spiriferellina cristata* (von Schlotheim, 1816) from the upper part of the Toyoma Formation in Nabekoshiyama. The Nabekoshiyama species can be referred to *Spiriferellina cristata* (von Schlotheim, 1816), redescribed by Campbell (1959, p. 358, pl. 59, figs. 1–9; pl. 60, fig. 3, text-fig. 5) from the Zechstein of Thuringia, Germany, in its small, transverse shell (length 6 mm, width 12 mm in the best-preserved dorsal valve specimen, NU-B1612) and in having 4–5 pairs of rounded costae on both ventral and dorsal valves.

The shells, described and figured by Hayasaka (1922, p. 66, pl. 9, figs. 5–9; Hayasaka, 1960, p. 53, pl. 1, fig. 10) as *Spiriferina cristata* (von Schlotheim, 1816) from the middle Permian (Wordian) of the South Kitakami Belt, northeastern Japan were recently redescribed by Tazawa (2014, p. 19, fig. 3.5–3.7) as *Spiriferellina fredericki* Tazawa, 2014.

Occurrence.—Upper part of the Toyoma Formation in Nabekoshiyama (locality KF108).

Distribution.—Kasimovian–Changhsingian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt), northern Russia (Timan and northern Urals), Greenland, Germany, Austria (Carnic Alps), central Russia (southern Urals), northwestern China (Xinjiang), northern China (Inner Mongolia and Shanxi) and northeastern China (Heilongjiang); and Changhsingian: northeastern Japan (Nabekoshiyama in the South Kitakami Belt) and Hungary (Bukk Mountains).

ACKNOWLEDGEMENTS

I sincerely thank Kenshiro Ogasawara (Professor Emeritus of the University of Tsukuba, Tsukuba), Toru Sekiya (Fukui Prefectural Dinosaur Museum, Katsuyama) and Soichiro Kawabe (Fukui Prefectural University, Eiheiji-cho) for editing

the manuscript; Shuzhong Shen (Nanjing University, Nanjing) and an anonymous reviewer for their constructive comments and suggestions; Hiroki Echizenya (Hokkaido University Museum, Sapporo) and Jun Nemoto (Tohoku University Museum, Sendai) for loan of the type specimens; Yousuke Ibaraki (Fossa Magna Museum, Itoigawa) for his help in drawing the figures; Yukio Miyake (Takayama, Gifu Prefecture) and Hideo Araki (Kesennuma, Miyagi Prefecture) for providing part of the brachiopod specimens.

REFERENCES

- Abich, O. W. H. 1878. Geologische Forschungen in den Kaukasischen Ländern, Teil 1. Eine Bergkalkfauna aus der Araxesenge bei Djoulfa in Armenien, Vol. 7. In commission bei A. Hölder, Wien, 126 pp.
- Alexandrov, V. A., and O. L. Einor. 1979. Descriptions of Fauna and Flora: Brachiopoda; pp. 55–76 in O. L. Einor (ed.), Atlas of the Middle–Upper Carboniferous Fauna and Flora of Bashkiria. Nedra, Moskva.***
- Booker, F. W. 1930. A review of some of the Permo-Carboniferous Productidae of New South Wales, with a tentative reclassification. Royal Society of New South Wales, Journal and Proceedings (Sydney) 64: 65–77.
- Boucot, A. J., J. G. Johnson and R. D. Staton. 1964. On some atrypoid, retzioid, and athyridoid Brachiopoda. Journal of Paleontology 38: 805–822.
- Broili, F. 1916. Die permischen Brachiopoden von Timor; pp. 1–104 in J. Wanner (ed.), Palaeontologie von Timor, No. 7, Pt. 12. E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.
- Bronn, H. G. 1862. Die Klassen und Ordnungen der Weichthiere (Malacozoa), Vol. 3. C. F. Winter'sche Verlagshandlung, Leipzig and Heidelberg, 518 pp.
- Campbell, K. S. W. 1959. The type species of three Upper Palaeozoic punctate spiriferids. Palaeontology 1: 351–363.
- Campi, M. J., G. R. Shi and M. S. Leman. 2002. The *Leptodus* Shales of central Peninsular Malaysia: distribution, age and palaeobiogeographical affinities. Journal of Asian Earth Sciences 20: 703–717.
- Campi, M. J., G. R. Shi and M. S. Leman. 2005. Guadalupian (Middle Permian) brachiopods from Sungai Toh, a *Leptodus* Shale locality in the Central Belt of Peninsular Malaysia. Palaeontographica, Abhandlung A 273: 97–160.
- Chao, Y. T. 1927. Productidae of China, Part 1: Producti. Palaeontologia Sinica, Series B 5 (2): 1–244.
- Chao, Y. T. 1928. Productidae of China, Part 2. Chonetinae, Productinae and Richthofeninae. Palaeontologia Sinica, Series B 5: 1–103.
- Chen, Z.-Q., and Z.-T. Liao. 2007. Last orthotetid brachiopods from the uppermost Permian of South China. Journal of Paleontology 81: 986–997.
- Chen, Z.-Q., G. R. Shi, S.-Z. Shen and N. W. Archbold. 2000. *Tethyochonetes* gen. nov. (Chonetida, Brachiopoda) from the Lopingian (late Permian) of China. Proceedings of the Royal Society of Victoria 112: 1–15.
- Chronic, J. 1953. Part 2. Invertebrate paleontology (excepting fusulinids and corals); pp. 43–165 in N. D. Newell, J. Chronic and T. G. Roberts, Upper Paleozoic of Peru. Geological Society of America, Memoir 58.
- Chi-Thuan, T. T. 1962. Les brachiopods permien de Cam-lo (Province de Quang-Tri). Annales de la Faculté des Sciences, Université de Saigon 1962: 485–498.
- Cooper, G. A., and R. E. Grant. 1969. New Permian brachiopods from West Texas. Smithsonian Contributions to Paleobiology 1: 1–20.
- Cooper, G. A., and R. E. Grant. 1974. Permian brachiopods of West Texas, 2. Smithsonian Contributions to Paleobiology 15: 233–794.
- Cooper, G. A., and R. E. Grant. 1975. Permian brachiopods of West Texas, 3. Smithsonian Contributions to Paleobiology 19: 795–1922.
- Cooper, G. A., and R. E. Grant. 1976. Permian brachiopods of West Texas, 5. Smithsonian Contributions to Paleobiology 24: 2609–3159.
- Cooper, G. A., and H. M. Muir-Wood. 1951. Brachiopod homonyms. Journal of the Washington Academy of Sciences 41: 195–196.
- Cox, T. 1857. A description of some of the most characteristic shells of the principal coal seams in the western basin of Kentucky. Geological Survey of Kentucky Report 3: 557–576.
- Dagys, A. S. 1972. Morphology and systematics of Mesozoic retzioid brachiopods. Trudy Sibirskoe Otdelenie, Institut Geologii i Geofiziki 112: 94–105.***
- Derby, O. A. 1874. On the Carboniferous Brachiopoda of Itaituba, Rio Tapajos, Province of Para, Brazil. Cornell University Scientific Bulletin, Series 2 1: 1–63.
- Diener, C. 1899. Himalayan fossils, Volume 1, Part 2. Anthracolithic fossils of Kashmir and Spiti. Palaeontologia Indica, Series 15 1 (2): 1–95.
- Ding, P.-Z. and W.-T. Qi, 1983. Phylum Brachiopoda (Carboniferous–Permian); pp. 244–425 in Xian Institute of Geology and Mineral Resources (ed.), Palaeontological Atlas of Northwest China; Shaanxi, Gansu and Ningxia Volume, Part 2. Upper Palaeozoic. Geological Publishing House, Beijing.**
- Duan, C.-H., and W.-G. Li. 1985. Descriptions of fossils, 4. Phylum Brachiopoda; pp. 99–145 in Ding, Y.-J., G.-Y. Xia, C.-H. Duan, W.-G. Li, X.-L. Liu and Z.-F. Liang, Study on the early Permian stratigraphy and fauna in Zhesi district, Nei Mongol Zizhiqu (Inner Mongolia). Bulletin of the Tianjin Institute of Geology and Mineral Resources, Chinese Academy of Geological Sciences 10. **
- Dunbar, C. O. 1955. Permian brachiopod faunas of central East Grønland. Meddelelser om Grønland 110: 1–169.
- Ehiro, M. 1974. Geological and structural studies of the area along the Hizume–Kesennuma Tectonic Line, in southern Kitakami Massif. Journal of the Geological Society of Japan 80: 457–474.*
- Ehiro, M. 1977. The Hizume–Kesennuma Fault—With special reference to its character and significance on the geologic

- development—. Contributions from the Institute of Geology and Paleontology, Tohoku University 77: 1–37.*
- Ehiro, M. 1996. Latest Permian ammonoid *Paratirolites* from the Ofunato district, Southern Kitakami Massif, Northeast Japan. Transactions and Proceedings of the Palaeontological Society of Japan, New Series 184: 592–596.
- von Eichwald, E. 1860. Lethaea Rossica ou Paléontologie de la Russie décrite et figurée. Permian volume, Ancienne Periode. E. Schweizerbart, Stuttgart, 1635 pp.
- Fan, B.-H., and X.-L. He. 1999. Research on Brachiopod Fauna and Stratigraphy of the Late Paleozoic in North China Platform. China University of Mining and Technology Press, Xuzhou, 179 pp.**
- Fang, R.-S. 1983. The Early Permian Brachiopoda from Xiaoxinzhai of Gengma Yunnan and its geological significance; pp. 93–119 in CGQXP Editorial Committee, Ministry of Geology and Mineral Resources, People's Republic of China (eds.), Contribution to the geology of the Qinghai–Xizang (Tibet) Plateau, Vol. 11. Geological Publishing House, Beijing.**
- Fang, R.-S., and J.-C. Fan. 1994. Middle to Upper Carboniferous–Early Permian Gondwana Facies and Paleontology in Western Yunnan. Yunnan Science and Technology Press, Kunming, 121 pp.**
- Fantini Sestini, N., and Glaus, M. 1966. Brachiopods from the Upper Permian Nesen Formation (North Iran). Rivista Italiana di Paleontologia e Stratigrafia 72: 887–930.
- Feng, R.-L., and Z.-L. Jiang, 1978. Phylum Brachiopoda; pp. 231–305 in Geological and Palaeontological Team of Guizhou (ed.), Palaeontological Atlas of Southwest China, Guizhou, Part 2. Carboniferous to Quaternary. Geological Publishing House, Beijing.**
- Ferguson, L., 1969, Possible brood pouches and sexual dimorphism in the productid brachiopod *Megousia* Muir-Wood and Cooper; pp. 37–51 in G. E. G. Westermann (ed.), Sexual dimorphism in fossil Metazoa and taxonomic implications. E. Schweizerbart'sche Verlagsbuchhandlung (Nägele und Obermiller), Stuttgart.
- Fischer de Waldheim, G. 1825. Notice sur la Choristite. Programme d'invitation à la Société Impériale des Naturalistes de Moscow, Moscow, 12 pp.
- Frech, F. 1911. Die Dyas; pp. 103–202 in F. von Richthofen (ed.), China, Fünfter Band. Dietrich Reimer, Berlin.
- Fredericks, G. 1916. The palaeontological notes, 2. On some Upper Palaeozoic Brachiopoda of Eurasia. Trudy Geologicheskago Komiteta, Novaya Seriya 156: 1–87***
- Fredericks, G. 1924a. Upper Paleozoic of the Ussuriland, 1: Brachiopoda. Materialy po Geologii i Poleznyim Iskopaemym Dalnego Vostoka 28: 1–53.***
- Fredericks, G. 1924b. Paleontological studies, 2: On Upper Carboniferous spiriferids from the Urals. Izvestiya Geologicheskogo Komiteta 38: 295–324.***
- Fredericks, G. 1925. Upper Palaeozoicum of Oussouriland, 2. Permian Brachiopoda of Cape Kalouzin. Materialy po Geologii i Poleznyim Iskolaemym Dalnego Vostoka 40: 1–30.***
- Geinitz, H. B. 1842. Ueber einige Petrefacten des Zechsteins und Muschelkalks. Neues Jahrbuch für Mineralogie, Geognosie, Geologie, und Petrefakten-Kunde 1842: 576–579.
- Geinitz, H. B. 1847. *Orthothrix* Geinitz. Société Imperiale des Naturalistes de Moscou, Bulletin 20: 84–86.
- George, T. N. 1931. *Ambocoelia* Hall and certain similar British Spiriferidae. Quarterly Journal of the Geological Society of London 87: 30–61.
- Grabau, A. W. 1931. The Permian of Mongolia: A Report of the Permian Fauna of the Jisu Honguer Limestone of Mongolia and its Relations to the Permian of Other Parts of the World. Natural History of Central Asia, Vol. 4. American Museum of Natural History, New York, 665 pp.
- Grant, R. E. 1976. Permian brachiopods from southern Thailand. Journal of Paleontology 50: 1–269.
- Grunt, T. A. 1986. Classification of brachiopods of the order Athyridida. Trudy Paleontologicheskogo Instituta, Akademiya Nauk SSSR 215: 1–200.***
- Hall, J., and J. M. Clarke. 1892. An Introduction to the Study of the Genera of Palaeozoic Brachiopoda, Natural History of New York, Palaeontology, Vol. 8, Part 1. New York Geological Survey, Charles van Benthuysen and Sons, Albany, 367 pp.
- Hayasaka, I. 1922. Some Permian brachiopods from the Kitakami Mountains. Japanese Journal of Geology and Geography 1: 51–70.
- Hayasaka, I. 1960. On the occurrence of *Neospirifer fasciger* (Keyserling) in Japan, and a note on some associate Permian brachiopods from around Kesen-numa City, northeast Japan; pp. 34–57 in Shimane University (ed.) Collection of Essays in Commemoration of the Tenth Anniversary (1959) of Shimane University (Natural Science). Shimane University, Matsue.
- He, W.-H., G. R. Shi, J.-J. Bu and Z.-J. Niu. 2008. A new brachiopod fauna from the Early to Middle Permian of southern Qinghai Province, Northwest China. Journal of Paleontology 82: 811–822.
- He, W.-H., G. R. Shi, Q.-L. Feng and Y.-Q. Peng. 2007. Discovery of late Changhsingian (latest Permian) brachiopod *Attenuatella* species from South China. Alcheringa 31: 274–284.
- Heritsche, F. 1935. Neue Versteinerungen aus den Nassfeldschichten der Karnischen Alpen. Sitzungsberichten der Akademie der Wissenschaften in Wien, Mathematisch-Naturwissenschaftlichen Klasse, Abteilung 1 144: 349–375.
- Heritsche, F. 1938. Die stratigraphische Stellung des Trogkofelkalkes. Neues Jahrbuch für Mineralogie, Geologie und Paläontologie, Abteilung B 79: 63–186.
- Huang, T.-K. 1932. Late Permian Brachiopoda of southwestern China. Palaeontologia Sinica, Series B 9 (1): 1–139.
- Huang, T.-K. 1933. Late Permian Brachiopoda of southwestern China, Part 2. Palaeontologia Sinica, Series B 9 (2): 1–172.
- Ishii, K., Y. Okimura and K. Nakazawa. 1975. On the genus *Colaniella* and its biostratigraphic significance. Journal of Geosciences, Osaka City University 19: 107–138.
- Ivanov, A. P., and E. A. Ivanova. 1937. Brachiopoda of the

- Middle and Upper Carboniferous of the Moscow Basin (*Neospirifer*, *Choristites*). Trudy Paleontologicheskogo Instituta, Akademiya Nauk SSSR 6: 1–215.***
- Ivanova, E. A. 1972. Main features of spiriferid evolution (Brachiopoda). Paleontologicheskii Zhurnal, 1972 3: 28–42.***
- Jin, Y.-G. 1985. Permian Brachiopoda and palaeogeography of the Qinghai–Xizang (Tibet) Plateau. Palaeontologia Cathayana 2: 19–71.
- Jin, Y.-G., and D.-L. Sun. 1981. Palaeozoic brachiopods from Xizang (Tibet); pp. 127–176 in Nanjing Institute of Geology and Palaeontology, Academia Sinica (ed.), Palaeontology of Xizang, Book 3. The series of the Scientific Expedition to the Qinghai–Xizang Plateau, Science Press, Beijing.**
- Jin, Y.-G., Y. Wang, D.-L. Sun and Q. Shi. 1985. Late Paleozoic and Triassic brachiopods from the East of the Qinghai–Xizang Plateau; pp. 182–237 in Regional Geological Surveying Team of Sichuan Province and Nanjing Institute of Geology and Palaeontology, Academia Sinica (eds.), Stratigraphy and Palaeontology in W. Sichuan and E. Xizang, China, Part 3. Sichuan Science and Technology Publishing House, Chengdu.**
- Jin, Y.-G., S.-L. Ye, H.-K. Xu and D.-L. Sun. 1979. Phylum Brachiopoda; pp. 60–217 in Nanjing Institute of Geology and Palaeontology and Qinghai Institute of Geological Sciences (eds.), Palaeontological Atlas of Northwest China; Qinghai, Part 1. Geological Publishing House, Beijing.**
- Kaesler, R. L. (ed.). 2000a. Treatise on Invertebrate Paleontology, Part H Brachiopoda Revised, Volume 2: Linguliformea, Craniiformea, and Rhynchonelliformea (Part). Geological Society of America, Boulder and University of Kansas, Lawrence. 423 pp. (1–423).
- Kaesler, R. L. (ed.). 2000b. Treatise on Invertebrate Paleontology, Part H Brachiopoda Revised, Volume 3: Linguliformea, Craniiformea, and Rhynchonelliformea (Part). Geological Society of America, Boulder and University of Kansas, Lawrence. 496 pp. (424–919).
- Kaesler, R. L. (ed.). 2002. Treatise on Invertebrate Paleontology, Part H Brachiopoda Revised, Volume 4: Rhynchonelliformea (Part). Geological Society of America, Boulder and University of Kansas, Lawrence. 768 pp. (921–1688).
- Kaesler, R. L. (ed.). 2006. Treatise on Invertebrate Paleontology, Part H Brachiopoda Revised, Volume 5: Rhynchonelliformea (Part). Geological Society of America, Boulder and University of Kansas, Lawrence. 632 pp. (1689–2320).
- Kalashnikov, N. V. 1998. Permian Spiriferids from the North of European Russia. GEOS, Moskva, 138 pp.***
- Kamada, K. 1990. Upper Permian to Middle Triassic sedimentation and its tectonic implication in the Southern Kitakami Belt, Japan: Preliminary report. Saito Ho-on Kai Special Publication 3, 423–432.
- Kamada, K. 1998. Upper Permian channel-slope deposits of the Toyoma Formation in the Tsuya area in the Southern Kitakami Belt, Northeast Japan. Earth Science (Chikyu Kagaku) 52: 453–463.
- Kambe, N., and M. Shimazu. 1961. Explanatory Text of the Geologic Map of Japan, Scale 1: 50,000, Kesenuma. Geological Survey of Japan, Kawasaki, 73 pp.*
- Kayser, E. 1881. Mittheilungen über die Fauna des chinesischen Kohlenkalks von Lo-Ping. Zeitschrift der Deutschen Geologischen Gesellschaft 33: 351–352.
- Kayser, E. 1883. Obercarbonische Fauna von Lo-ping; pp. 160–208 in F. von Richthofen (ed.), China, Vierter Band. Palaeontologischen Theil. D. Reimer, Berlin.
- Kindle, E. M. 1926. The occurrence of the genus *Leptodus* in the Anthracolithic fauna of British Columbia. Transactions of the Royal Society of Canada, Section 4 20: 109–111.
- King, R. E. 1931. The geology of the Glass Mountains, Texas, Part 2. Faunal summary and correlation of the Permian formations with description of Brachiopoda. University of Texas Bulletin 3042: 1–245.
- King, R. H. 1938. New Chonetidae and Productidae from Pennsylvanian and Permian strata of north central Texas. Journal of Paleontology 12: 257–279.
- King, W. 1846. Remarks on certain genera belonging to the class Palliobranchiata. Annals and Magazine of Natural History, London 18: 26–42 and 83–94.
- Kobayashi, F. 2002. Lithology and foraminiferal fauna of allochthonous limestones (Changhsingian) in the upper part of the Toyoma Formation in the South Kitakami Belt, Northeast Japan. Paleontological Research 6: 331–342.
- de Koninck, L. G. 1841–1844. Description des animaux fossiles qui se trouvent dans le terrain Carbonifère de Belgique. H. Dessain, Liège, 650 pp.
- de Koninck, L. G. 1863. Mémoire sur les fossiles paléozoïques recueillis dans l'Inde par M. le Docteur Fleming. H. Dessain, Liege, 44 pp.
- Kotlyar, G. V., and Yu. D. Zakharov (eds.). 1989. Evolution of the Latest Permian Biota; Midian Regional Stage in the USSR. Nauka, Leningrad, 182 pp.***
- Lee, L., and F. Gu, 1976. Carboniferous and Permian Brachiopoda; pp. 228–306 in Geological Bureau of Nei Mongol and Geological Institute of Northeast China (eds.), Palaeontological Atlas of Northeast China; Nei Mongol, Part 1. Palaeozoic Volume. Geological Publishing House, Beijing.**
- Lee, L., F. Gu and Y.-Z. Su. 1980. Carboniferous and Permian Brachiopoda; pp. 327–428 in Shenyang Institute of Geology and Mineral Resources (ed.), Paleontological Atlas of Northeast China (1) Paleozoic Volume. Geological Publishing House, Beijing.**
- Li, W.-Z., and S.-Z. Shen. 2008. Lopingian (late Permian) brachiopods around the Wuchiapingian–Changhsingian boundary at the Meishan Section C and D, Changxing, South China. Geobios 41: 307–320.
- Liang, W.-P. 1990. Lengwu Formation of Permian and its Brachiopod Fauna in Zhejiang Province. Geological Memoir 10, Ministry of Geology and Mineral Resources, People's Republic of China, Geological Publishing House, Beijing, 522 pp.**
- Liao, Z.-T. 1979. Brachiopod assemblage zone of Changhsing

- Stage and brachiopods from Permo-Triassic boundary beds in China. *Acta Stratigraphica Sinica* 3: 200–207.**
- Liao, Z.-T. 1980. Upper Permian brachiopods from western Guizhou; pp. 241–277 in *Nanjing Institute of Geology and Palaeontology, Chinese Academy of Sciences (ed.), Stratigraphy and Palaeontology of Upper Permian Coal-bearing Formations in Western Guizhou and Eastern Yunnan, China*. Science Press, Beijing.**
- Liao, Z.-T. 1987. Paleocological characters and stratigraphic significance of silicified brachiopods of the Upper Permian from Heshan, Laibin, Guangxi; pp. 81–125 in *Nanjing Institute of Geology and Palaeontology, Academia Sinica (ed.), Stratigraphy and Palaeontology of Systematic Boundaries in China: Permian–Triassic Boundary (1)*. Nanjing University Press, Nanjing.**
- Liao, Z.-T., and J.-T. Xu, 2002. Late Permian brachiopods from the lower part of the Wuli Group, southwestern Qinghai and the geographic distribution of *Waagenites*. *Acta Palaeontologica Sinica* 41: 130–136.**
- Licharew, B. K., and G. V. Kotlyar. 1978. Permian brachiopods from South Primorye; pp. 63–75 in L. I. Popeko (ed.), *Upper Palaeozoic of northeastern Asia*. Akademiya Nauk SSSR, Dalnevostochny Nauchny Tsentr, Institut Tektoniki i Geofiziki, Vladibostok.***
- Liu, Z.-H., Z.-X. Tan and Y.-L. Ding. 1982. Phylum Brachiopoda; pp. 172–216 in *Geological Bureau of Hunan (ed.), The Palaeontological Atlas of Hunan*. Geological Publishing House, Beijing.**
- von Malzahn, E. 1937. Die deutschen Zechsteinbrachiopoden mit besonderer Berücksichtigung der stammesgeschichtlichen Beziehungen von *Productus horridus* Sowerby zu *Productus timanicus* Stuckenbergh. *Preussischen Geologischen Landesanstalt, Neue Folge* 185: 1–77.
- Marcou, J. 1858. *Geology of North America, with Two Reports on the Prairies of Arkansas and Texas, the Rocky Mountains of New Mexico and the Sierra Nevada of California*. Züricher and Furrer, Zürich, 144 pp.
- M'Coy, F. 1844. A Synopsis of the Characters of the Carboniferous Limestone of Ireland. Williams and Norgate, London, 207 pp.
- Minato, M., M. Hunahashi, J. Watanabe and M. Kato (eds.). 1979. *Variscan Geohistory of Northern Japan: Abean Orogeny*. Tokai University Press, Tokyo, 427 pp.
- Moore, R. C. 1952. Brachiopoda; pp. 197–267 in R. C. Moore, C. G. Lalicker and A. G. Fischer, *Invertebrate Fossils*. McGraw-Hill, New York.
- Morris, J. 1845. Descriptions of fossils, Mollusca; pp. 270–291 in P. E. Strzelecki, *Physical Description of New South Wales and Van Dremen's Land*. Longman, London.
- Muir-Wood, H. M. 1955. A History of the Classification of the Phylum Brachiopoda. British Museum (Natural History), London, 124 pp.
- Muir-Wood, H. M. 1962. On the Morphology and Classification of the Brachiopod Suborder Chonetoida. British Museum (Natural History), London, 132 pp.
- Muir-Wood, H. M., and G. A. Cooper. 1960. Morphology, classification and life habits of the Productoida (Brachiopoda). Geological Society of America, Memoir 81: 1–447.
- Murata, M., and S. Shimoyama. 1979. Stratigraphy near the Permian–Triassic boundary and the pre-Triassic unconformity in the Kitakami Massif, northeast Japan. *Kumamoto Journal of Science (Geology)* 11, 11–31.*
- Nakamura, K. 1959. *Spinomarginifera* found in Japanese Permian. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series* 35: 143–146.
- Nakamura, K., 1972. *Anidanthus* and *Megousia* (Brachiopoda) from the Permian of Japan and Cambodia. *Journal of the Faculty of Science, Hokkaido University, Series 4* 15: 427–445.
- Nakazawa, K. 1998. Uppermost Permian bivalve fossils from the Southern Kitakami Mountains. *Earth Science (Chikyu Kagaku)* 52: 51–54.*
- Nakazawa, K., and N. D. Newell. 1968. Permian bivalves of Japan. *Memoirs of the Faculty of Science, Kyoto University, Series B* 35: 1–108.
- Onuki, Y. 1956. Geology of the Kitakami Massif; pp. 1–189 in *Iwate Prefecture (ed.), Explanation Text of Iwate Prefecture*. Sasaki Shuppan, Sendai.*
- Onuki, Y. 1969. Geology of the Kitakami Massif, Northeast Japan. *Contributions from the Institute of Geology and Paleontology, Tohoku University* 69: 1–239.*
- d'Orbigny, A. 1842. Voyage dans l'Amérique Méridionale. Géologie, Paléontologie; Foraminifères 3: 50–56.
- Ozaki, K. 1931. Upper Carboniferous brachiopods from North China. *Bulletin of the Shanghai Science Institute* 1: 1–205.
- Ozawa, Y., 1927. Stratigraphical studies of the Fusulina Limestone of Akasaka, Province of Mino. *Journal of the Faculty of Science, Imperial University of Tokyo, Series 2* 2: 121–164.
- Ramovs, A. 1958. Razvoj zgorniega perma v Loških in Polhograjskih hribih. Razprave, Slovenska Akademija Znanosti in Umetnosti 4: 451–622.
- Sarytcheva, T. G. 1965. Otriad Productida. in Ruzhentsev, V. E. and Sarytcheva, T. G., eds., *The development and change of marine organisms at the Palaeozoic–Mesozoic boundary*. Trudy. Paleontologicheskii. institut., Akademiia. Nauk SSSR 108: 209–232.***
- Sarytcheva, T. G., B. K. Licharev and A. N. Sokolskaya. 1960. Order Productida; pp. 221–238 in Yu. A. Orlov (ed.), *Osnovy Paleologii*, Vol. 7. Academia Nauk SSSR, Moscow.***
- Sarytcheva, T. G., and A. N. Sokolskaya. 1959. On the classification of pseudopunctate brachiopods. *Doklady, Akademii Nauk SSSR* 125: 181–184.***
- Schellwien, E. 1900a. Beiträge zur Systematik der Strophomeniden des Oberen Palaeozoicum. *Neues Jahrbuch für Mineralogie, Geologie und Palaeontologie* 1: 1–15.
- von Schlotheim, E. F. 1816. Beiträge zur Naturgeschichte der Versteinerungen in geognostischer Hinsicht. *Akademi Wissenschaften München Mathematische-Physike Klasse*

- Denkschriften 6: 13–36.
- Schréter, Z. 1963. A Bükkhegység felső-permi brachiopodai. *Geologica Hungarica, Series Palaeontologica* 28: 1–181.
- Schuchert, C. 1913. Class Brachiopoda; pp. 290–449 in C. Schuchert, C. K., Swartz, T. P. Maynard and R. B. Rowe, The Lower Devonian Deposits of Maryland. Maryland Geological Survey, Baltimore.
- Schuchert, C., and G. A. Cooper. 1932. Brachiopod genera of the suborder Orthoidea and Pentameroidea. *Memoirs of the Peabody Museum of Natural History* 4: 1–270.
- Schuchert, C., and C. M. LeVene. 1929. Brachiopoda (generum et genotyporum index et bibliographia); 140 pp. in J. E. Pompeckj (ed.), *Fossilium Catalogus*, Vol. 1. Animaria, Pars 42, W. Junk, Berlin.
- Selden, P. A. (ed.). 2007. *Treatise on Invertebrate Paleontology, Part H Brachiopoda Revised, Volume 6: Supplement*. Geological Society of America, Boulder and University of Kansas, Lawrence, 906 pp. (2321–3226).
- Shen, S.-Z., N. W. Archbold and G. R. Shi. 2000. Changhsingian (Late Permian) brachiopod palaeobiogeography. *Historical Biology* 15: 121–134.
- Shen, S.-Z., and M. Clapham. 2009. Wuchiapingian (Lopingian, Late Permian) brachiopods from the Episkopi Formation of Hydra Island, Greece. *Palaeontology* 52: 713–743.
- Shen, S.-Z., and X.-L. He. 1994. Changhsingian brachiopod fauna from Guiding, Guizhou. *Acta Palaeontologica Sinica* 33: 440–454.**
- Shen, S.-Z., Y.-G. Jin, Y. Zhang and A. W. Weldon. 2017. Permian brachiopod genera on type species of China; pp. 651–881 in J.-Y. Rong, Y.-G. Jin, S.-Z. Shen and R.-B. Zhan (eds.), *Phanerozoic Brachiopod Genera of China*. Science Press, Beijing.
- Shen, S.-Z., and G. R. Shi. 2007. Lopingian (Late Permian) brachiopods from South China, Part 1: Orthotetida, Orthida and Rhynchonellida. *Bulletin of the Tohoku University Museum* 6: 1–102.
- Shen S.-Z., and G. R. Shi. 2009. Latest Guadalupian brachiopods from the Guadalupian/Lopingian boundary GSSP section at Penglaitan in Laibin, Guangxi, South China and implications for the timing of the pre-Lopingian crisis. *Palaeoworld* 18: 152–161.
- Shen, S.-Z., G. R. Shi and Z.-J. Fang. 2002. Permian brachiopods from the Baoshan and Simao Blocks in western Yunnan, China. *Journal of Asian Earth Sciences* 20: 665–682.
- Shen, S.-Z., J. Tazawa and G. R. Shi. 1999. *Peltichia* Jin and Liao, 1981 (Enteletidae, Brachiopoda) from Asia: Taxonomy, biostratigraphy, and paleobiogeography. *Journal of Paleontology* 73: 49–62.
- Shen, S.-Z., and Y.-C. Zhang. 2008. Earliest Wuchiapingian (Lopingian, Late Permian) brachiopods in southern Hunan, South China: Implications for the pre-Lopingian crisis and onset of Lopingian recovery/radiation. *Journal of Paleontology* 82: 924–937.
- Shi, G. R., and J. Tazawa, 2001. *Rhynchopora* and *Blasispirifer* (Brachiopoda) from the Middle Permian of the Hida Gaien Belt, central Japan, and their paleobiogeographical significance. *Journal of the Geological Society of Japan* 107: 755–761.
- Shi, G. R., and J. B. Waterhouse. 1996. Lower Permian brachiopods and molluscs from the upper Jungle Creek Formation, northern Yukon Territory, Canada. *Geological Survey of Canada Bulletin* 424: 1–241.
- Shiida, I. 1940. Geology of the Paleozoic–Mesozoic rocks near Kesennuma, Miyagi Prefecture, northeastern Japan. *Contributions from the Institute of Geology and Paleontology, Tohoku Imperial University* 33: 1–72.*
- Shimizu, D. 1961. Brachiopod fossils from the Permian Maizuru Group. *Memoirs of the College of Science, University of Kyoto, Series B* 27: 309–351.
- Simič, V. 1933. Das oberperm in Westserbien. *Rasprave Geološkog Instituta Karlj, Jugoslavije, Sveska* 1 1: 1–130.
- Sokolskaya, A. N. 1965. Descriptive part; Phylum Brachiopoda, Order Orthida; pp. 198–203 in V. E. Ruzhentsev, and T. G. Sarytcheva (eds.), *The development and change of marine organisms at the Palaeozoic–Mesozoic boundary*. *Trudy Paleontologicheskogo Instituta, Akademiya Nauk SSSR* 108.***
- Sowerby, J. 1818–1822. *The Mineral Conchology of Great Britain*, Vol. 3. W. Arding, London, 184 pp.
- Stehli, F. G. 1954. Lower Leonardian Brachiopoda of the Sierra Diablo. *Bulletin of the American Museum of Natural History* 105: 257–358.
- Stepanov, D. L., F. Golschani and J. Stöcklin. 1969. Upper Permian and Permian–Triassic boundary in North Iran. *Geological Survey of Iran, Papers* 12: 1–72.
- Stoyanow, A. A. 1910. On a new genus of Brachiopoda. *Bulletin de l'Académie Impériale des Sciences de St. Pétersbourg, Series* 6 4: 853–855.***
- Stoyanow, A. A., 1916, On some Permian Brachiopoda of Armenia. *Trudy Geologicheskago Komiteta, Novaya Seriya* 111: 1–92.***
- Tazawa, J. 1975. Uppermost Permian fossils from the southern Kitakami Mountains, northeast Japan. *Journal of the Geological Society of Japan* 81: 629–640.
- Tazawa, J. 1976. The Permian of Kesennuma, Kitakami Mountains: A Preliminary report. *Earth Science (Chikyu Kagaku)* 30: 175–185.
- Tazawa, J. 1978. Palaeozoic formations of the Kitakami Mountains, (1) Permian of Kesennuma. *Chishitsu News* 291: 10–17.*
- Tazawa, J. 1982. *Oldhamina* from the Upper Permian of the Kitakami Mountains, Japan and its Tethyan province distribution. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series* 128: 445–451.
- Tazawa, J. 1987. *Attenuatella* (Brachiopoda) from the Upper Permian of northeast Japan and its bipolar distribution. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series* 148: 276–284.
- Tazawa, J. 2001. A Permian Boreal brachiopod fauna from Okutadami, central Japan, and its tectonic implication; pp.

- 373–383 in C. H. C. Brunton, L. R. M. Cocks and S. Long (eds.), *Brachiopods Past and Present. The Systematics Association Special Volume Series 63*, Taylor and Francis, London.
- Tazawa, J. 2006a. *Lamnimargus*, *Megousia* and *Eolyttonia* (Productida, Brachiopoda) from the Upper Permian (Changhsingian) of the Kawahigashi area, Maizuru Belt, southwest Japan, and their palaeobiogeographical significance. *Science Reports of Niigata University (Geology)* 21: 1–18.
- Tazawa, J. 2006b. Late Permian Boreal–Tethyan mixed brachiopod fauna from the Maizuru Belt, southwest Japan: Fossil evidence for the tectono-sedimentological setting of the Maizuru Group. *Journal of the Geological Society of Japan* 112: 510–518.*
- Tazawa, J. 2008a. *Lamnimargus* (Productida, Brachiopoda) from the Upper Permian of Ofunato in the South Kitakami Belt, NE Japan, and its palaeobiogeographical significance. *Science Reports of Niigata University (Geology)* 23: 1–11.
- Tazawa, J. 2008b. Brachiopods from the Upper Permian Takakurayama Formation, Abukuma Mountains, northeast Japan. *Science Reports of Niigata University (Geology)* 23: 13–53.
- Tazawa, J. 2008c. Permian brachiopods from the Mizukoshi Formation, central Kyushu, SW Japan: Systematics, palaeobiogeography and tectonic implications. *Paleontological Research* 12: 37–61.
- Tazawa, J. 2009. Brachiopods from the Upper Permian Tsunemori Formation of the Akiyoshi area, southwest Japan, and their tectonic implications. *Paleontological Research* 13: 65–78.
- Tazawa, J. 2011. Late Permian (Wuchiapingian) brachiopod fauna from Okutadami, central Japan: Systematics, palaeobiogeography and tectonic implications. *Paleontological Research* 15: 168–180.
- Tazawa, J. 2012. Late Permian (Changhsingian) brachiopod fauna from Nabekoshiyama in the Kesennuma area, South Kitakami Belt, northeast Japan. *Science Reports of Niigata University (Geology)* 27: 15–50.
- Tazawa, J. 2014. Antitropical brachiopods from the middle Permian (Wordian) of the southern Kitakami Mountains, northeast Japan. *Earth Science (Chikyu Kagaku)* 68: 15–22.
- Tazawa, J. 2017. *Spinomarginifera* and *Waagenoconcha* (Productida, Brachiopoda) from the middle Permian (Wordian–Capitanian) of the South Kitakami Belt, Japan. *Science Reports of Niigata University (Geology)* 32: 33–56.
- Tazawa, J. 2018a. Palaeobiogeographical studies on the Palaeozoic brachiopods of Japan, and their tectonic significance: A review. *Journal of the Geological Society of Japan* 124: 655–673.*
- Tazawa, J. 2018b. Early Carboniferous (Mississippian) brachiopods from the Hikoroichi Formation, South Kitakami Belt, Japan. *Memoir of the Fukui Prefectural Dinosaur Museum* 17: 27–87.
- Tazawa, J. 2020. Early Carboniferous (Mississippian) brachiopods from the Shittakazawa, Arisu and Odaira Formations, South Kitakami Belt, Japan. *Memoir of the Fukui Prefectural Dinosaur Museum* 19: 11–88.
- Tazawa, J., and H. Araki. 2014. Additional brachiopod species from the Upper Permian (Changhsingian) of Nabekoshiyama in the Kesennuma area, South Kitakami Belt, northeast Japan. *Science Reports of Niigata University (Geology)* 29: 43–52.
- Tazawa, J., M. Fujikawa and Y. Ota. 2009. Permian brachiopods from the Tsunemori Formation of the Akiyoshi area, southwest Japan: Fossil evidence for the accretion site of the Akiyoshi Belt. *Journal of the Geological Society of Japan* 115: 168–176.*
- Tazawa, J., and T. Hirota. 2012. Permian brachiopod *Eolyttonia* from the Katsura Sandstone in the Sakawa area, Kochi Prefecture, southwest Japan. *Earth Science (Chikyu Kagaku)* 66: 225–228.*
- Tazawa, J., and Y. Ibaraki. 2023. Middle Permian (Guadalupian) brachiopods from Setamai, Kamiyasse–Imo and Matsukawa in the South Kitakami Belt, Japan. *Memoir of the Fukui Prefectural Dinosaur Museum* 22: 13–141.
- Tazawa, J., and Y. Miyake. 2011. Late Permian (Changhsingian) brachiopod fauna from Maeda in the Ofunato area, South Kitakami Belt, NE Japan. *Science Reports of Niigata University (Geology)* 26: 1–22.
- Tazawa, J., and Niigata Pre-Tertiary Research Group. 1999. Permian brachiopods from Okutadami area, near the boundary between Niigata and Fukushima Prefectures, central Japan, and their tectonic implications. *Journal of the Geological Society of Japan* 105: 729–732.*
- Tazawa, J., Y. Okumura and H. Kojima. 2010. Middle Permian brachiopods from Yamasuge in the Kuzu area, Ashio Mountains, central Japan. *Science Reports of Niigata University (Geology)* 25: 35–49.
- Tazawa, J., M. Osawa and H. Nagura. 2019. Early Carboniferous (Mississippian) brachiopods from the Karaumedate Formation, South Kitakami Belt, Japan. *Memoir of the Fukui Prefectural Dinosaur Museum* 18: 43–72.
- Tazawa, J., and T. Shintani. 2014. Early Permian (Sakmarian) brachiopods from Kamiyasse, South Kitakami Belt, northeast Japan. *Science Reports of Niigata University (Geology)* 29: 13–41.
- Tazawa, J., and T. Shintani. 2022. Early Permian (Cisuralian) brachiopods from Nagaiwa–Sakamotozawa, South Kitakami Belt, Japan. *Memoir of the Fukui Prefectural Dinosaur Museum* 21: 1–58.
- Termier, H., and G. Termier. 1970. Les Productoidés du Djoufien (Permien supérieur) dans la Téthys orientale: essai sur l'agonie d'un phylum. *Société Géologique du Nord, Annales* 90: 443–461.
- Tong, Z.-X. 1978. Phylum Brachiopoda (Carboniferous–Permian Part); pp. 210–267 in *Geological Institute of Southwest China (ed.), Palaeontological Atlas of Southwestern China, Sichuan Province, Volume 2*. Geological Publishing House, Beijing.**
- Tschernyschew, Th. 1902. Die obercarbonischen Brachiopoden des Ural und des Timan. *Mémoires du Comité Géologique* 16: 1–749.***

- Waagen, W. 1883–1885. Salt Range fossils, 1. Productus-Limestone fossils: Brachiopoda. *Palaeontologia Indica*, Series 13 1: 391–546 (1883), 547–728 (1884) and 729–770 (1885).
- Wang, C.-W., and S.-P. Yang. 1998. Late Carboniferous–Early Permian Brachiopods of Central Xinjiang and their Biostratigraphical Studies. Geological Publishing House, Beijing, 156 pp.**
- Wang, C.-W., and S.-M. Zhang. 2003. Zhesi Brachiopod Fauna. Geological Publishing House, Beijing, 210 pp.**
- Wang, G.-P., Q.-Z. Liu, Y.-G. Jin, S.-Z. Hu, W.-P. Liang and Z.-T. Liao. 1982. Phylum Brachiopoda; pp. 186–256 in Nanjing Institute of Geology and Mineral Resources (ed.), *Palaeontological Atlas of East China, Part 1. Late Palaeozoic Volume*. Geological Publishing House, Beijing.**
- Wang, S.-M. 1984. Phylum Brachiopoda; pp. 128–236 in Regional Geological Surveying Team of Hubei (ed.), *The Palaeontological Atlas of Hubei Province*. Hubei Science and Technology Press, Wuhan.**
- Wang, Y., Y.-G. Jin and D. Fang (eds.). 1964. Brachiopod Fossils of China, Part 1. Science Press, Beijing, 354 pp.**
- Waterhouse, J. B. 1964. Permian brachiopods of New Zealand. *New Zealand Geological Survey, Palaeontological Bulletin* 35: 1–287.
- Waterhouse, J. B. 1968a. The classification and descriptions of Permian Spiriferida (Brachiopoda) from New Zealand. *Palaeontographica, Abteilung A* 129: 1–94.
- Waterhouse, J. B. 1968b. New species of *Megousia* Muir-Wood and Cooper and allied new genus from the Permian of Australia and North America. *Journal of Paleontology* 42: 1171–1185.
- Waterhouse, J. B. 1975. New Permian and Triassic brachiopod taxa. *Papers of the Department of Geology, University of Queensland* 7: 1–23.
- Waterhouse, J. B. 1983. A Late Permian lytoniid fauna from northwest Thailand. *University of Queensland, Department of Geology, Papers* 10: 111–153.
- Waterhouse, J. B. 1986. Late Palaeozoic Scyphozoa and Brachiopoda (Inarticulata, Strophomenida, Productida and Rhynchonellida) from the southeast Bowen Basin, Australia. *Palaeontographica, Abteilung A* 193: 1–76.
- Waterhouse, J. B. 2001. Late Paleozoic Brachiopoda and Mollusca, chiefly from Wairaki Downs, New Zealand, with notes on Scyphozoa and Triassic ammonoids and new classifications of Linoproductoidea (Brachiopoda) and Pectinida (Bivalvia). *Earthwise* 3: 1–195.
- Waterhouse, J. B. 2002. Classification within Productidina and Strophalosiidina (Brachiopoda). *Earthwise* 5: 1–60.
- White, C. A., and O. St. John. 1867. Descriptions of new sub-Carboniferous coal-measure fossils, collected upon the geological survey of Iowa, together with a notice of new generic characters involved in two species of Brachiopoda. *Chicago Academy of Sciences Transactions* 1: 115–127.
- Williams, A. 1953. The classification of the strophomenoid brachiopods. *Washington Academy of Sciences Journal* 43: 1–13.
- Williams, A., D. A. T. Harper and R. E. Grant. 2000. Lytoniidina; pp. 619–642 in R. L. Kaesler (ed.), *Treatise on Invertebrate Paleontology, Part H Brachiopoda Revised, Volume 3: Linguliformea, Craniiformea, and Rhynchonelliformea (Part)*. Geological Society of America, Boulder and University of Kansas, Lawrence.
- Wu, H.-T., G. R. Shi and W.-H. He. 2017. A quantitative taxonomic review of *Fusichonetes* and *Tethyochonetes* (Chonetidina, Brachiopoda). *Journal of Paleontology* 91: 1296–1305.
- Xu, G.-R., and R. E. Grant. 1994. Brachiopods near the Permian–Triassic boundary in South China. *Smithsonian Contributions to Paleobiology* 76: 1–68.
- Yabe, H., and T. Sugiyama. 1937. Preliminary report on the fossiliferous Gotlandian and Devonian deposits newly discovered in the Kitakami Mountainland. *Proceedings of the Imperial Academy of Tokyo* 13: 417–420.
- Yanagida, J. 1996. Permian brachiopods from the Tsunemori Formation, SW Japan, and their palaeobiogeographic implication; pp. 313–315 in P. Copper and J. Jin (eds.), *Brachiopods*. A. A. Balkema, Rotterdam.
- Yanagida, J., S. Imamura and M. Kawai. 1993. Reexamination of the brachiopod fauna from the Permian Karita Formation, Southwest Japan. *Memoirs of the Faculty of Science, Kyushu University, Series D* 28: 1–21.
- Yang, D.-L. 1984. Systematic description of Palaeontology: Brachiopoda; pp. 203–239, 330–333 and 387–396 in Yichan Institute of Geology and Mineral Resources (ed.), *Biostratigraphy of the Yangtze Gorge Area (3) Late Palaeozoic Era*. Geological Publishing House, Beijing.**
- Yang, D.-L., S.-Z. Ni, M.-L. Chang and R.-X. Zhao. 1977. Phylum Brachiopoda; pp. 303–470 in Geological Institute of Hubei et al. (eds.), *Palaeontological Atlas of South-Central China, Part 2. Late Palaeozoic Volume*. Geological Publishing House, Beijing.**
- Yang, Z.-Y., P.-Z. Ting (Ding), H.-F. Yin, S.-X. Zhang and J.-S. Fang. 1962. Carboniferous, Permian and Triassic brachiopod faunas from the Chilianshan region; pp. 1–129 in Institute of Geology and Paleontology, Geological Institute, Academia Sinica and Beijing University of Geology (eds.), *Monograph on Geology of the Chilianshan Mountains, Vol. 4, Pt. 4*. Science Press, Beijing.**
- Yoshida, K., G. Kawakami and M. Kawamura. 1995. Heavy mineral-concentrated sandstones in the uppermost Permian and the lowest Triassic of the South Kitakami Terrane. *Journal of the Geological Society of Japan* 101: 279–294.*
- Zeng, Y., X.-L. He and M.-L. Zhu. 1995. Permian Brachiopods and Community Succession in the Huayin Mountains, Sichuan. China University of Mining and Technology Press, Xuzhou, 187 pp.**
- Zhan, L.-P. 1979. Descriptions of fossils, (2) Brachiopoda; pp. 61–100 in H.-F. Hou, L.-P. Zhan, B.-W. Chen et al. (eds.), *The Coal-bearing Strata and Fossils of Late Permian from Guangtung*. Geological Publishing House, Beijing.**
- Zhang, Y., and Y.-G. Jin (Ching). 1961. An Upper Permian

- brachiopod fauna from Jiangxian, Anhui Province. *Acta Palaeontologica Sinica* 9: 401–417.**
- Zhao, J.-K., J.-Z. Sheng, Z.-Q. Yao, X.-L. Liang, C.-Z. Chen, L. Rui and Z.-T. Liao. 1981. The Changhsingian and Permian–Triassic boundary of South China. *Bulletin of the Nanjing Institute of Geology and Palaeontology, Academia Sinica* 2: 58–85.
- Zhu, T. 1990. The Permian Coal-bearing Strata and Palaeobiocoenosis of Fusian. Geological Publishing House, Beijing. 127 pp.**

- Ziegler, A. M., M. L. Hulver and D. B. Rowley. 1997. Permian world topography and climate; pp. 111–146 in I. P. Martin (ed.), *Late Glacial and Postglacial Environmental Changes—Quaternary, Carboniferous–Permian and Proterozoic*. Oxford University Press, New York.

* in Japanese

** in Chinese

*** in Russian

< 地名・地層名 >

Abukuma Mountains 阿武隈山地
 Akasaka Limestone 赤坂石灰岩
 Akiyoshi Belt 秋吉帯
 Anbasan 安波山
 Arisu Formation 有住層
 Choshi 銚子
 Futatsumori Formation ニッ森層
 Gujo Formation 公庄層
 Hida–Abukuma Nappe ... 飛騨–阿武隈ナップ
 Hida Gaien Belt 飛騨外縁帯
 Hikoroichi Formation 日頃市層
 Hirota Bay 広田湾
 Ichinoseki 一関
 Ikawa-cho 猪川町
 Ishihama 石浜
 Ishinomaki 石巻
 Kamaishi 釜石
 Komasunaizawa 小柅内沢
 Kamiyasse Formation 上八瀬層
 Kamiyasse–Imo 上八瀬–飯森
 Kanayashiki 金屋敷
 Kanokura Series 叶倉統
 Karakuwa 唐桑
 Karaumedate Formation 唐梅館層
 Kawahigashi 河東
 Kesennuma City 気仙沼市

Kitsunozakisawa 狐崎沢
 Komagomesawa 駒米沢
 Koshijisawa 越路沢
 Kowaragi Formation 小原木層
 Kurosegawa Belt 黒瀬川帯
 Kuzu 葛生
 Maeda 前田
 Maiya Group 米谷層群
 Maizuru Belt 舞鶴帯
 Matsukawa 松川
 Matsukurayama 松倉山
 Median Tectonic Line 中央構造線
 Mino Belt 美濃帯
 Mizukoshi 水越
 Nabekoshiyama 鍋越山
 Nabeyama Formation 鍋山層
 Nagaiwa–Sakamotozawa ... 長岩–坂本沢
 Nagasaka 長坂
 Nedamo Belt 根田茂帯
 Nisawa 荷沢
 Nishinakazai 西中才
 Odaira Formation 大平層
 Oe-cho 大江町
 Ofunato City 大船渡市
 Okawa River 大川
 Okutadami 奥只見

Okuhinotsuchi 奥火の土
 Rikuzentakata City 陸前高田市
 Sakari-machi 盛町
 Sakawa 佐川
 Setamai 世田米
 Shimanto Terrane 四万十テレーン
 Shimoarisu 下有住
 Shishiorigawa River 鹿折川
 Shittakazawa Formation 尻高沢層
 Shizu 清水
 South Kitakami Belt 南部北上帯
 Takakurayama 高倉山
 Takinosawa 滝ノ沢
 Tassobe 達曽部
 Tono 遠野
 Toyoma Formation 登米層
 Tsunemori 常森
 Utatsu 歌津
 Yachiyo 八千代
 Yahagi-cho 矢作町
 Yakuno 夜久野
 Yamasuge 山菅
 Yokota 横田
 Yokoteyama 横手山

