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Late Permian (Changhsingian) brachiopod fauna from Nabekoshiyama in the Kesennuma area, South Kitakami Belt, northeast Japan

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Abstract

A Late Permian (Changhsingian) brachiopod fauna, consisting of 25 species in 19 genera, is described from the upper Toyoma Formation of Nabekoshiyama in the Kesennuma area, South Kitakami Belt, northeast Japan. New species described here are *Terrakea nabekoshiyamensis* and *Orthothrix sudoi*. The Nabekoshiyama fauna is a mixed Boreal–Tethyan fauna and is allied with the Late Permian brachiopod fauna of South Primorye, eastern Russia.

Key words: Brachiopoda, Changhsingian, mixed Boreal–Tethyan fauna, Nabekoshiyama, South Kitakami Belt.

Introduction

Tazawa (1975) described the following foraminifer and brachiopod species from limestone and sandstone in the upper part of the Toyoma Formation around Mt. Nabekoshiyama in the Kesennuma area, South Kitakami Belt, northeast Japan (Fig. 1): (foraminifers) *Colaniella parva* (Colani), *Paracolaniella leei* Wang and *Lantschichites* sp.; (brachiopods) *Orthothrix* cf. *excavata* (Geinitz), *Tschernyschewia typica* Stoyanow, *Megousia nakamurai* Tazawa, *Paramarginifera japonica* Tazawa and *Eolyttonia* cf. *nakazawai* Shimizu. This was the first record of uppermost Permian (Changhsingian) fossils in Japan. More recently, Kobayashi (2002) re-examined the Changhsingian foraminifers of Mt. Nabekoshiyama, and described *Colaniella parva* (Colani), *Nanlingella* cf. *meridionalis* Rui and Sheng and *Palaeofusulina* sp., among others, from lenticular limestones of the upper Toyoma Formation; however, many brachiopod species in these rocks have yet to be described.

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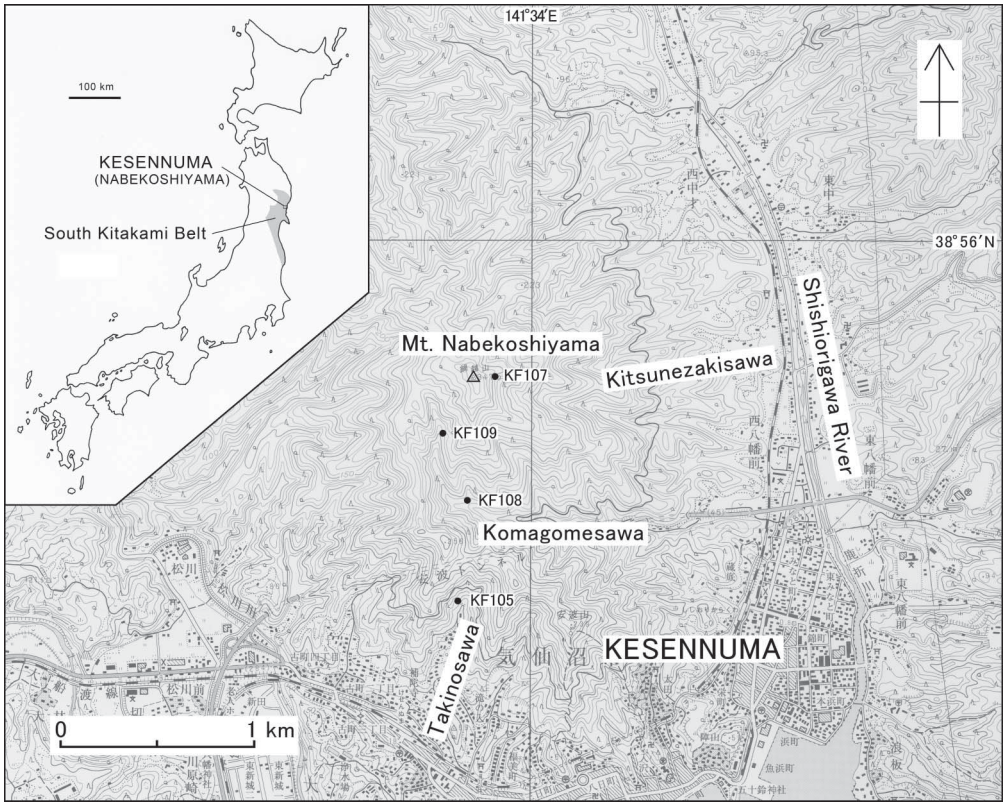


Fig. 1. Index map showing the fossil localities of Nabekoshiyama in the Kesennuma area, South Kitakami Belt, using the topographical maps of "Shishiori" and "Kesennuma", scale 1:25,000 published by the Geospatial Authority of Japan.

The present study describes the brachiopod species from the upper Toyoma Formation of Nabekoshiyama, based on specimens housed at Hokkaido University and new material collected by the present author and by a student of Niigata University. The age and palaeobiogeography of the Nabekoshiyama fauna are also discussed.

The specimens described herein are registered and housed in the Hokkaido University Museum, Sapporo (with prefix UHR) and the Department of Geology, Faculty of Science, Niigata University, Niigata (with prefix NU-B).

Stratigraphy

According to Tazawa (1975), the upper part of the Toyoma Formation in Nabekoshiyama is composed mainly of sandstone and black shale with intercalated conglomerate and limestone (total thickness, 525 m+; Fig. 2). The lower part of the Toyoma Formation consists of black shale (thickness, 700 m+). The brachiopods occur from sandstone at four localities in Nabekoshiyama, Kesennuma City, Miyagi Prefecture, northeast Japan. The topography, horizon, lithology and brachiopod occurrence of the fossil localities KF105, KF107, KF108 and KF109 are as follows (see also Figs. 1, 2).

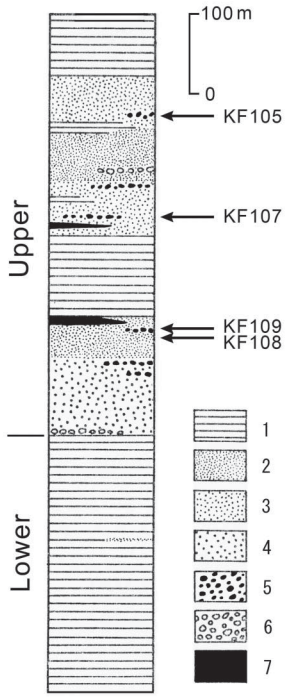


Fig. 2. Generalized columnar section of the Toyoma Formation in Nabekoshiyama, showing the fossil horizons, 1: shale, 2: fine-grained sandstone, 3: medium-grained sandstone, 4: coarse-grained sandstone, 5: granule conglomerate, 6: pebble conglomerate, 7: limestone. Modified and adapted from Tazawa (1975).

KF105 (Loc. 6 of Tazawa, 1975): light brown granule to very coarse-grained sandstone, 394 m above the base of the upper part of the formation, in the upper Takinosawa Valley (38°54′47″ N, 141°33′43″ E), with *Orthothrix sudoi*.

KF107 (Loc. 2 of Tazawa, 1975): light brown granule to very coarse-grained sandstone, 269 m above the base of the upper part of the formation, at 125 m ESE of the summit of Mt. Nabekoshiyama, in the upper Kitsunezakisawa Valley (38°55′53″ N, 141°33′51″ E), with *Lamnimargus japonicus*, *Megousia nakamurai*, *Orthothrix sudoi*, *Edriosteges* sp., *Hustedia indica* and *Martinia* sp.

KF108 (Loc. 5 of Tazawa, 1975): grey medium-grained sandstone, 119 m above the base of the upper part of the formation, in the middle Komagomesawa Valley (38°55′15″ N, 141°33′45″ E), with all species excluding *Edriosteges* sp., *Oldhamina squamosa* and *Martinia* sp.

KF109 (Loc. 4 of Tazawa, 1975): grey fine-grained sandstone, 131 m above the base of the upper part of the formation, in the upper Komagomesawa Valley (38°55′27″ N, 141°33′37″ E), with *Megousia nakamurai*, *Eolyttonia tenuis* and *Oldhamina squamosa*.

The Nabekoshiyama fauna

The brachiopods (25 species, 19 genera) from Nabekoshiyama described in the present report, along with the number of specimens, are as follows:

Neochonetes sp.	3
Spinomarginifera lopingensis (Kayser, 1883)	6
Lamnimargus peregrinus (Fredericks, 1924)	3
Lamnimargus japonicus (Tazawa, 1975)	17
Linoproductus sp.	1
Megousia auriculata Muir-Wood and Cooper, 1960	5
Megousia nakamurai Tazawa, 1975	15
Terrakea nabekoshiyamensis sp. nov.	2
Orthothrix sudoi sp. nov.	10
Edriosteges sp.	1
Tschernyschewia typica Stoyanow, 1910	9
Eolyttonia tenuis (Waagen, 1883)	8
Eolyttonia mira (Fredericks, 1916)	3
Oldhamina squamosa Huang, 1932	1
Oldhamina anshunensis Huang, 1932	5
Oldhamina kitakamiensis Tazawa, 1982	1
Derbyia sp.	1
Enteletes sp.	1
Peltichia cf. *transversa* (Huang, 1933)	1
Orthotichia sp.	1
Hustedia indica (Waagen, 1883)	2
Hustedia minuta Tazawa in Tazawa and Miyake, 2011	14
Martinia sp.	2
Choristitella wynnei (Waagen, 1883)	1
Spiriferellina cristata (Schlotheim, 1816)	3

Age and correlations

In previous works in the present area, Tazawa (1975) described the foraminifer *Colaniella parva* from lenticular limestone in the upper Toyoma Formation in the Nabekoshiyama area. Kobayashi (2002) described *Colaniella parva*, *Nanlingella* cf. *meridionalis* and *Palaeofusulina* sp. from the same limestone. These foraminifers indicate a Changhsingian age; consequently, the upper part of the Toyoma Formation, bearing brachiopod fossils is correlated with the uppermost Permian (Changhsingian) of South China.

This age determination is supported by the occurrence of *Spinomarginifera lopingensis*, *Lamnimargus peregrinus*, *Lamnimargus japonicus*, *Tschernyschewia typica*, *Oldhamina squamosa*, *Oldhamina anshunensis* and *Oldhamina kitakamiensis*. However, the Nabekoshiyama fauna includes some Middle Permian and lower Upper Permian elements, such as *Eolyttonia mira*, *Hustedia indica*, *Choristitella wynnei* and *Spiriferellina cristata*.

This mixing of Middle and Upper Permian elements indicates that the sandstone-conglomerate-limestone in black shale represents turbidites deposited during Changhsingian time. Kobayashi (2002) also reported reworked fossils in the Nabekoshiyama fauna.

Palaeobiogeography

Tazawa and Miyake (2011) described a mixed Boreal–Tethyann fauna from the Upper Permian (Changhsingian) of Maeda in the Ofunato area, South Kitakami Belt, northeast Japan. The Boreal elements include *Lamnimargus*, *Attenuatella* and *Choristitella*, and the Tethyan elements include *Tethyochonetes*, *Richthofenia* and *Geyerella*. Similarly, the Nabekoshiyama fauna contains both Boreal elements (*Lamnimargus*, *Megousia*, *Terrakea*, *Orthothrix*, *Choristitella wynnei* and *Spiriferellina cristata*) and Tethyan genera (*Tschernyschewia*, *Eolyttonia*, *Oldhamina*, *Enteletes*, *Peltichia* and *Orthotichia*). Consequently, the Nabekoshiyama fauna is a mixed Boreal–Tethyan fauna of the latest Permian (Changhsingian), although Kobayashi (2002) concluded that the Nabekoshiyama foraminifer fauna is solely Tethyan.

In Changhsingian time, the South Kitakami region (Nabekoshiyama and Maeda areas) was probably located in the mid-latitude of the Northern Hemisphere; i.e., Inner Mongolia–Japan Transitional Zone (Tazawa, 1991), a transitional zone between the Boreal and Tethyan realms, close to South Primorye, eastern Russia. This interpretation supports a previous reconstruction of Changhsingian palaeobiogeography (Shen et al., 2000) in which the Boreal–Tethyan transitional zone was still present during the latest Permian.

Systematic descriptions

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 *Neochonetes* Muir-Wood, 1962

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

Neochonetes sp.
Figs. 3.1–3.3

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

Remarks.—The specimens from Nabekoshiyama are assigned to the genus *Neochonetes*, on account of their medium size for the Permian chonetoids (length 8 mm, width about 13 mm in the best preserved specimen, NU-B1654), transversely subquadrate outline, moderately developed ventral sulcus and ventral interior with strong median septum. *Neochonetes* sp., described by Tazawa (1979, p. 25, pl. 4, fig. 1) from the Middle Permian Kanokura Formation of Matsukawa, South Kitakami Belt is clearly distinguished from the Nabekoshiyama species by its much larger size and more acute cardinal extremities.

Suborder Productidina Waagen, 1883
Superfamily Productoidea Gray, 1840
Family Productellidae Schuchert, 1929
Subfamily Margiferinae Stehli, 1954
Tribe Margiferini Stehli, 1954
Genus *Spinomarginifera* Huang, 1932

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

Spinomarginifera lopingensis (Kayser, 1883)
Figs. 4.1–4.3

Productus nystianus var. *lopingensis* Kayser, 1883, p. 187, pl. 28, figs. 1–5.
Productus (*Marginifera*) *helicus* Abich var. Frech, 1911, p. 130, pl. 19, figs. 1–3.
Marginifera lopingensis (Kayser): Chao, 1927, p. 153, pl. 16, figs. 8–12.
Spinomarginifera lopingensis (Kayser): Zhang and Ching, 1961, p. 412, pl. 4, figs. 26–33; 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; Yang, 1984, p. 217, pl. 33, fig. 4; Wang, 1984, p. 187, pl. 80, fig. 16; 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; Chen et al., 2005, p. 354, fig. 7H; He et al., 2008, p. 812, figs. 4.1–4.10; Li and Shen, 2008, p. 315, figs. 4.17–4.19, 6.1–6.7; Shen and Zhang, 2008, figs. 4.13–4.19; Shen and Shi, 2009, p. 157, figs. 3P–3X.
Spinomarginifera lopingensis (Chao): Jin et al., 1985, 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.

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; (3) internal moulds of two dorsal valves, NU-B1573, 1574.

Description.—Shell medium size for genus, transversely trapezoidal in outline, with greatest width at hinge; length about 15 mm, width about 19 mm in the best preserved ventral valve specimen (NU-B1569); length 16 mm, width about 22 mm in the largest dorsal valve specimen (NU-B1573). Ventral valve strongly and unevenly convex in lateral profile, most convex at umbonal region, gently convex on visceral disc, strongly geniculated at anterior margin of visceral disc, and followed by long trail; umbo rounded, incurved beyond hinge; ears moderately large; no sulcus; lateral slopes steep. Dorsal valve almost flat on visceral disc, strongly geniculated at anterolateral margins, and followed by short trail. External surface of dorsal valve ornamented with numerous fine spine bases and fine concentric rugae on visceral disc, numerous prominent costae on trail. Dorsal valve interior with a long median septum extending half shell length; pear-shaped adductor scars on both sides of median septum; lateral ridges slightly diverging towards anterior; marginal ridge strongly developed around the margin of visceral disc.

Remarks.—These specimens are referred to *Spinomarginifera lopingensis* (Kayser, 1883), originally described from the Upper Permian of Loping, Jiangxi Province, South China, by their medium size of the shell, and in having prominent costae on the dorsal trail.

Spinomarginifera kueichowensis Huang (1932, p. 56, pl. 5, figs. 1–11), from the Upper Permian (Wuchiapingian) of Guizhou, South China, differs from *S. lopingensis* in its larger dimensions and in lacking radial costae on both ventral and dorsal valves.

Spinomarginifera nipponica Shimizu (1961b, p. 244, pl. 8, figs. 1–20; pl. 9, figs. 14–16), from the Upper Permian (Changhsingian) Gujo Formation of the Maizuru Belt, southwest Japan, differs from the present species in having a shallow sulcus and less strong geniculation on the ventral valve.

Distribution.—Middle Permian (Wordian–Capitanian) of eastern Russia (South Primorye) and South China (Guangxi); Upper Permian (Wuchiapingian) of Northwest China (Qinghai), South China (Anhui, Zhejiang, Hubei, Hunan, Guangdong, Guizhou, Sichuan and Yunnan); Upper Permian (Lopingian) of South China (Jiangsu, Hubei, Jiangxi, Guangxi, Sichuan and Xizang); Upper Permian (Changhsingian) of South China (Sichuan) and northeast Japan (Nabekoshiyama in the South Kitakami Belt).

Tribe Paucispiniferini Muir-Wood and Cooper, 1960
Genus *Lamnimargus* Waterhouse, 1975

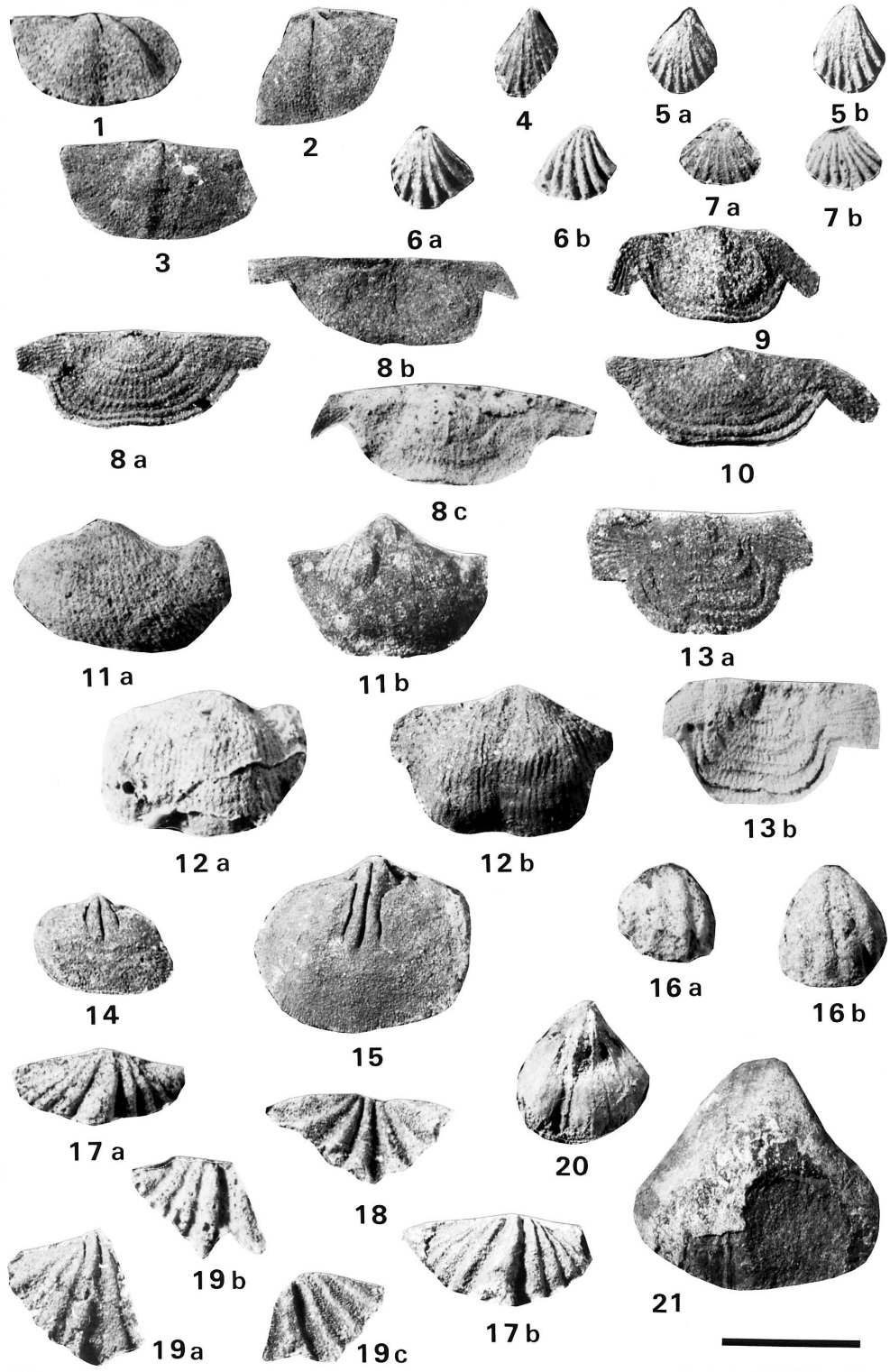
Type species.—*Marginifera himalayensis* Diener, 1899.

Lamnimargus peregrinus (Fredericks, 1924)
Figs. 4.4, 4.5

Paramarginifera peregrina Fredericks, 1924, p. 24, pl. 1, figs. 7, 8; Fredericks, 1925, p. 12, pl. 1, figs. 41–44.
Dictyoclostus 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: Duan and Li, 1985, p. 112, pl. 42, figs. 1–7; Lee et al., 1980, p. 356, pl. 166, figs. 18, 28.
Lamnimargus himalayensis (Diener): Kotlyar, 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, figs. 3A–3T; Tazawa, 2008b, p. 25, figs. 4.2–4.4; Tazawa in Tazawa and Miyake, 2011, p. 4, figs. 3.1–3.3.

Material.—Three specimens from locality KF108: (1) external and internal moulds of a dorsal valve, NU-B1588: (2) external moulds of two dorsal valves, NU-B1589, 1590.

Remarks.—These specimens are poorly preserved, but can be referred to *Lamnimargus peregrinus* (Fredericks, 1924), originally described by Fredericks (1924, p. 24) from the Middle Permian Chandalaz Formation of South Primorye, eastern Russia, in its transverse outline, small to medium size (length about 16 mm, width about 27 mm in the best preserved dorsal valve specimen, NU-B1588) and strong reticulate ornament (7–8 rugae in


1
2
4
5 a
5 b
3
6 a
6 b
7 a
7 b
8 b
9
8 a
8 c
10
11 a
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12 a
12 b
13 b
14
15
16 a
16 b
17 a
18
20
19 b
21
19 a
19 c
17 b

5 mm, 8–9 costellate in 5 mm at midlength) on the dorsal valve.

Lamnimargus japonicus (Tazawa, 1975, p. 636, pl. 2, figs. 3–6; pl. 3, figs. 1–4), from the Upper Permian (Changhsingian) of Nabekoshiyama in the South Kitakami Belt, differs from the present species in its smaller size and finer reticulate ornament on visceral disc of the dorsal valve.

Distribution.—Middle Permian (Wordian–Capitanian) of North China (Inner Mongolia), Northeast China (Heilongjiang), eastern Russia (South Primorye); Upper Permian (Wuchiapingian) of eastern Russia (South Primorye); Upper Permian (Changhsingian) of northeast Japan (Maeda and Nabekoshiyama in the South Kitakami Belt).

Lamnimargus japonicus (Tazawa, 1975)
Figs. 4.6–4.12

Productus (*Dictyoclostus*) *gratiosus* Waagen: Shimizu, 1961a, p. 323, pl. 15, figs. 19–21.
Productus (*Dictyoclostus*) sp. Shimizu, 1961a, 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.
Kozlowskia sp. Yanagida, 1996, fig. 2.12.
Lamnimargus japonicus (Tazawa): Tazawa, 2006a, p. 10, figs. 3A–3E; Tazawa, 2006b, p. 511, figs. 2, 3; Tazawa, 2009, p. 70, figs. 4.3–4.6; Tazawa et al., 2009, fig. 3.7.

Material.—Seventeen specimens from localities KF107, 108: (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 seven ventral valves, UHR19879–19884, 19886; (4) external and internal moulds of two dorsal valves, NU-B1593, 1594; (5) external moulds of six dorsal valves, UHR19874, 19875 (holotype), 19876–19878, NU-B1595.

← **Fig. 3.** 1–3: *Neochonetes* sp., internal moulds of ventral valves, 1: NU-B1654, 2: NU-B1656, 3: NU-B1655. 4–7: *Hustedia minuta* Tazawa in Tazawa and Miyake, 4: internal mould of ventral valve, NU-B1621, 5a, 5b: dorsal and ventral views of internal mould of conjoined shell, NU-B1615, 6a, 6b: internal mould and external latex cast of dorsal valve, NU-B1625, 7a, 7b: internal mould and external latex cast of dorsal valve, NU-B1624. 8–10: *Megousia auriculata* Muir-Wood and Cooper, 8a, 8b, 8c: external mould, internal mould and internal latex cast of dorsal valve, NU-B1605, 9: external mould of dorsal valve, UHR19531, 10: external mould of dorsal valve, NU-B1606. 11–13: *Megousis nakamurai* Tazawa, 11a, 11b: external latex cast and internal mould of ventral valve, UHR19885, 12a, 12b: external latex cast and internal mould of ventral valve, NU-B1596, 13a, 13b: external mould and external latex cast of dorsal valve, UHR19873 (holotype). 14: *Orthotichia* sp., internal mould of ventral valve, NU-B1643. 15: *Enteletes* sp., internal mould of ventral valve, NU-B1631. 16: *Hustedia indica* (Waagen), 16a, 16b: external latex cast and internal mould of ventral valve, NU-B1629. 17–19: *Spiriferellina cristata* (Schlotheim), 17a, 17b: external latex cast and internal mould of dorsal valve, NU-B1612, 18: external mould of dorsal valve, NU-B1613, 19a, 19b, 19c: internal mould, external latex cast and external mould of ventral valve, NU-B1611. 20, 21: *Martinia* sp., 20: internal mould of ventral valve, NU-B1610, 21: external natural cast of ventral valve, NU-B1609. Scale bar represents 1 cm.

Description.—Shell medium size for genus, transversely subrectangular in outline, widest at hinge; 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). Ventral valve highly convex in lateral profile; umbo small, pointed and slightly protruding beyond hinge line; sulcus narrow and deep; lateral slopes steep. Dorsal valve deeply and unevenly concave in lateral profile, with nearly flat visceral disc, strongly geniculated at anterior margin of visceral disc, and followed by long trail; fold narrow and low throughout length of valve; ears large, prominent, obscurely demarcated from visceral disc, tapering, and cylindrically enrolled near the extremities. External surface of ventral valve invisible, but two large spine bases are rarely preserved on ventral internal mould (UHR19884); 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. Ventral valve interior with large, flabellate and striated diductor scars, and elongate oval, non-dendritic adductor scars; marginal ridge developed on anterior margin of visceral disc. Dorsal valve interior with small, sessile bilobate cardinal process; median septum thin, extending to about half length of visceral disc; adductor scars smooth, elongate oval; brachial ridges clearly visible; marginal ridge distinctly developed.

Remarks.—Most of the Nabekoshiyama specimens were described by Tazawa (1975, p. 636) as *Paramarginifera japonica* Tazawa, 1975. Afterwards the generic name of the present species were changed to *Lamnimargus* Waterhouse, 1975 (Tazawa, 2006a, b, 2009; Tazawa et al., 2009).

The type species, *Lamnimargus himalayensis* Diener (1899, p. 39, pl. 2, figs. 1–7; pl. 6, figs. 1, 2), from the Upper Permian Kuling Shales of the Punjab Himalayas, Kashmir, differs from *L. japonicus* in its larger size and coarser reticulate ornament on both ventral and dorsal valves.

Distribution.—Upper Permian (Changhsingian) of northeast Japan (Nabekoshiyama in the South Kitakami Belt) and southwest Japan (Kawahigashi in the Maizuru Belt and Tsunemori in the Akiyoshi Belt).

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. 4.15

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

Remarks.—This specimen is safely assigned to the genus *Linoproductus* by its medium size (length 23 mm, width 25 mm), flatly concave dorsal valve, ornamented with numerous costellae (11–12 in 5 mm at about midlength) and irregular strong rugae, and 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 because of lacking the ventral valve.

Subfamily Anidanthinae Waterhouse, 1968
Genus *Megousia* Muir-Wood and Cooper, 1960

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

Megousia auriculata Muir-Wood and Cooper, 1960
Figs. 3.8–3.10

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

Material.—Five specimens from localities KF107, 108: (1) external and internal moulds of two dorsal valves, NU-B1604, 1605; (2) external moulds of three dorsal valves, UHR19531, NU-B1606, 1607.

Remarks.—The material from Nabekoshiyama lacks ventral valve specimen. However, the Nabekoshiyama specimens can be referred to *Megousia auriculata* Muir-Wood and Cooper, 1960, originally described from the Word Formation of the Glass Mountains, West Texas, by their small, transverse dorsal valves (length 8 mm, width 20 mm in the largest specimen, NU-B1606) with long, slender, 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, northeast Japan, is assigned to the present species by its small size and extremely long, slender ears.

Distribution.—Lower to Middle Permian (Artinskian–Wordian) of the United States (West Texas); Upper Permian (Lopingian) of northeast Japan (Takakurayama in the South Kitakami Belt); Upper Permian (Changhsingian) of northeast Japan (Nabekoshiyama in the South Kitakami Belt).

Megousia nakamurai Tazawa, 1975
Figs. 3.11–3.13

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.

Material.—Fifteen specimens from localities KF107, 108, 109: (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; (3) external moulds of two dorsal valves, UHR19809, 19873 (holotype).

Description.—Shell small size for genus, transversely subrectangular in outline, widest at hinge; length 11 mm, width 18 mm in the largest ventral valve specimen (NU-B1596); length 10 mm, width 17 mm in the holotype (UHR19873). Ventral valve strongly and unevenly convex in lateral profile, greatest curvature in umbonal region; anterior profile forming broad, high, steep-sided dome; umbo small, pointed, but not overhanging hinge line; ears not well preserved, probably large; sulcus broad and shallow, originating at about midlength of valve. Dorsal valve deeply concave, with flat, broad ears; fold absent or very low near anterior margin of valve. External surface of ventral valve weakly reticulate on visceral disc, and costellate on trail; costellae numbering 10–11 in 5 mm at about midlength of valve. External ornament of dorsal valve consisting of strong concentric lamellae and fine numerous costellae on visceral disc, but costellae only on ears; numbering 5 lamellae in 5 mm, and 12–13 costellae in 5 mm at about midlength of valve. Interiorly, ventral valve having a pair of small, elongate adductor scars and large, striated diductor scars. Dorsal valve having small, massive, trilobate cardinal process and thin, short median septum; brachial ridges obscure.

Remarks.—*Megousia nakamurai* is distinguished from the type species, *Megousia auriculata* Muir-Wood and Cooper, 1960, originally described from the Middle Permian (Wordian) of West Texas, by its less transverse shell, broader ears and finer costellae on both ventral and dorsal valves.

Megousia solita Waterhouse (1968, 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 dorsal valve.

Megousia definita Cooper and Grant (1975, p. 1194, pl. 449, figs. 1–46), from the Middle Permian (Wordian) of West Texas, is similar in general shape, but much larger in size.

Distribution.—Upper Permian (Changhsingian) of northeast Japan (Nabekoshiyama in the South Kitakami Belt).

Subfamily Paucispinauriinae Waterhouse, 1986
Genus *Terrakea* Booker, 1930

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

Terrakea nabekoshiyamensis sp. nov.
Figs. 4.13, 4.14

Etymology.—Named after the fossil locality, Nabekoshiyama.

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

Diagnosis.—Small, transverse *Terrakea*, widest at hinge, and having strongly convex ventral valve.

Description.—Shell small size for genus, transversely subrectangular in outline, with greatest width at hinge; length 19 mm, width 28 mm in the holotype (NU-B1632). Ventral valve strongly convex, rounded geniculate, and followed by long trail; umbo large, tapering, strongly incurved; ears small, triangular and clearly demarcated from visceral portion; sulcus broad and shallow; lateral slopes steep. External surface of ventral valve ornamented with less prominent costellae and numerous quincuncially arranged elongate spines on both venter and trail; rounded spines crowded on ears.

Remarks.—*Terrakea nabekoshiyamensis* sp. nov. 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 japonica (Tazawa, 2008d, p. 336, fig. 3), from the lower Kanokura Formation of the Imo area, South Kitakami Belt, northeast Japan, is clearly distinguished from *T. nabekoshiyamensis* by its less transverse outline and more numerous, strong costellae on the ventral valve.

Terrakea yanagidai Tazawa (2008c, p. 47, figs. 7.9–7.13), from the Upper Permian (Lopingian) of Mizukoshi, central Kyushu, southwest Japan, differs from the present species in having numerous fine, but more distinct costellae on the ventral valve.

Suborder Strophalosiidina Shuchert, 1913
Superfamily Strophalosioidea Schuchert, 1913
Family Strophalosiidae Schuchert, 1913
Subfamily Dasyalosiinae Brunton, 1966
Genus *Orthothrix* Geinitz, 1847

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

Orthothrix sudoi sp. nov.
Figs. 4.16–4.19

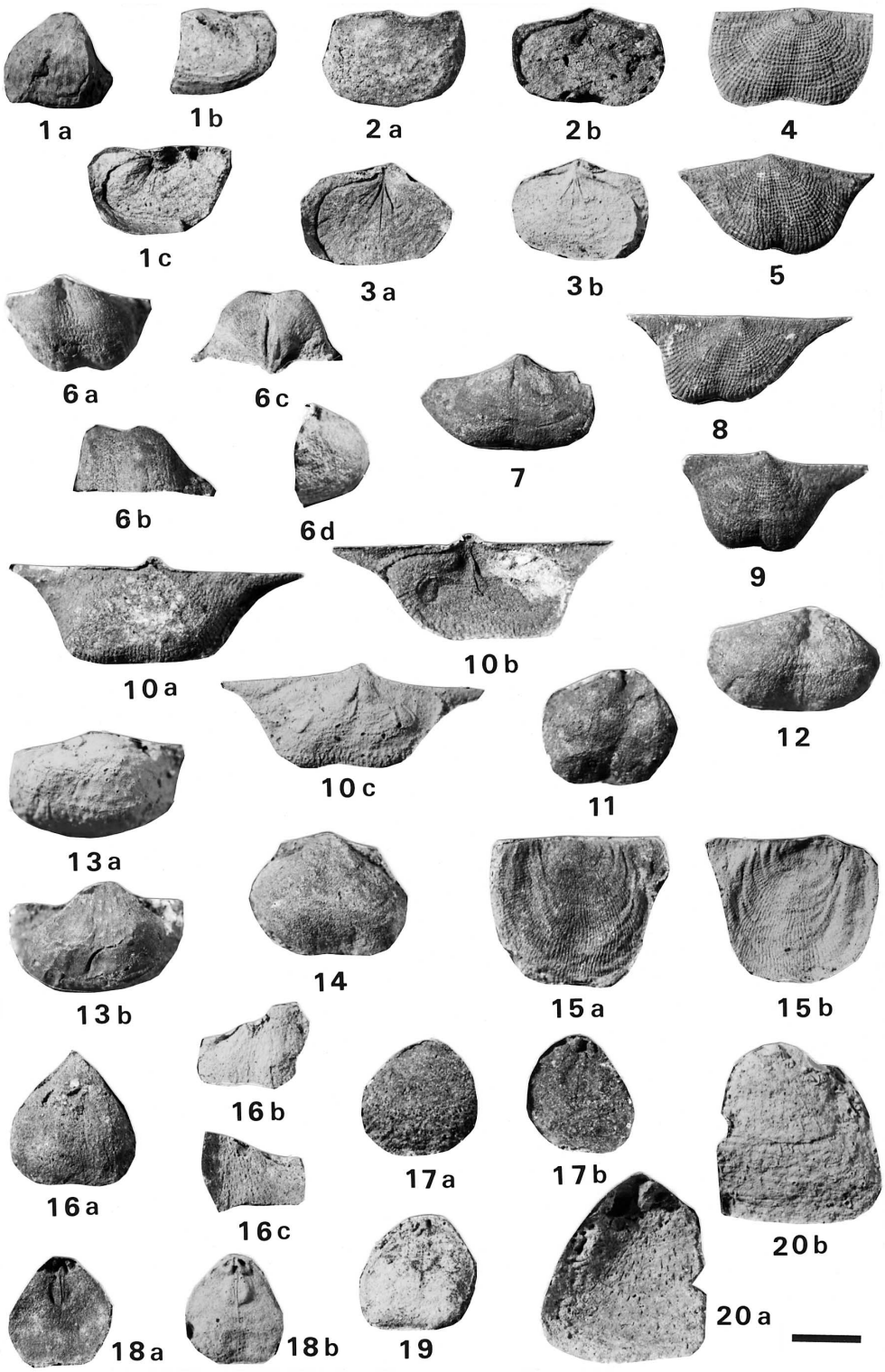
Orthothrix cf. *excavata* (Geinitz): Tazawa, 1975, p. 633, pl. 2, fig. 1; Minato et al., 1979, pl. 71, fig. 1.

Etymology.—Named for Mr. Fumio Sudo who surveyed the Nabekoshiyama area for his graduation thesis of the Department of Geology and Mineralogy, Hokkaido University.

Material.—Ten specimens from localities KF105, 107, 108: (1) external and internal moulds of three ventral valves, NU-B1645 (holotype), 1646, 1647; (2) internal moulds of two ventral valves, NU-B1648, 1649; (3) external and internal moulds of five dorsal valves, UHR30105, NU-B1650–1653.

Diagnosis.—Large-sized *Orthothrix*, with narrow and shallow sulcus in ventral valve, and large sockets and prominent adductor scars in dorsal valve.

Description.—Shell large size for genus, elongate subtrigonal to subcircular in outline; hinge straight, nearly one-half maximum shell width occurring at two-thirds length of shell; length 21 mm, width 19 mm in the holotype (NU-B1645); length 19 mm, width 18 mm in the best preserved dorsal valve specimen (UHR30105). Ventral valve gently convex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16b
17a
17b
16a
16c
20b
18a
18b
19
20a

in lateral profile; umbo small; sulcus narrow and shallow; interarea low; cicatrix of attachment invisible. Dorsal valve almost flattened in both profiles, rather steeply concave at antero-lateral margins. External surface of both valves ornamented with numerous fine spines; larger recumbent spines, numbering 7–8 per 5 mm at about midlength, on ventral valve, and smaller erect spines, numbering 9–11 per 5 mm width at about midlength, on dorsal valve; some delicate concentric lamellae on anterior portion of dorsal valve. Dorsal interior with a pair of deep sockets enclosed by anterior ridge; cardinal process small; median septum extending about midlength; adductor scars prominent, elevated from floor; marginal ridges developed posteriorly. Ventral interior poorly preserved.

Remarks.—One of the specimens from Nabekoshiyama, external and internal moulds of a dorsal valve (UHR30105), was described by Tazawa (1975, p. 633) as *Orthothrix* cf. *excavata* (Geinitz, 1842). Now I describe it as a new species *Orthothrix sudoi* sp. nov.

The Nabekoshiyama species is readily distinguished from 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, by means of its larger size and shallower ventral sulcus.

Superfamily Aulostegoidea Muir-Wood and Cooper, 1960
Family Aulostegidae Muir-Wood and Cooper, 1960
Subfamily Echinosteginae Muir-Wood and Cooper, 1960
Genus *Edriosteges* Muir-Wood and Cooper, 1960

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

Edriosteges sp.
Fig. 4.20

← **Fig. 4.** 1–3: *Spinomarginifera lopingensis* (Kayser), 1a, 1b, 1c: internal mould of ventral valve, external mould of dorsal valve and internal mould of dorsal valve, NU-B1569, 2a, 2b: external mould and internal mould of dorsal valve, NU-B1570, 3a, 3b: internal mould and internal latex cast of dorsal valve, NU-B1573. 4, 5: *Lamnimargus peregrinus* (Fredericks), 4: external mould of dorsal valve, NU-B1588, 5: external mould of dorsal valve, NU-B1589. 6–12: *Lamnimargus japonicus* (Tazawa), 6a, 6b, 6c, 6d: ventral, anterior, posterior and lateral views of internal mould of ventral valve, UHR19880, 7: internal mould of ventral valve, UHR19886, 8: external mould of dorsal valve, NU-B1595, 9: external mould of dorsal valve, UHR19875 (holotype), 10a, 10b, 10c: external mould, internal mould and internal latex cast of dorsal valve, NU-B1593, 11: internal mould of ventral valve, UHR19884, 12: internal mould of ventral valve, UHR19883. 13, 14: *Terrakea nabekoshiyamensis* sp. nov., 13a, 13b: external latex cast and internal mould of ventral valve, NU-B1632 (holotype), 14: internal mould of ventral valve, NU-B1633. 15: *Linoproductus* sp., 15a, 15b: external mould and external latex cast of dorsal valve, NU-B1644. 16–19: *Orthothrix sudoi* sp. nov., 16a, 16b, 16c: internal mould, external latex cast and external mould of ventral valve, NU-B1645 (holotype), 17a, 17b: external mould and internal mould of dorsal valve, UHR30105, 18a, 18b: internal mould and internal latex cast of dorsal valve, NU-B1651, 19: internal latex cast of dorsal valve, NU-B1652. 20: *Edriosteges* sp., 20a, 20b: external mould and external latex cast of ventral valve, UHR11374. Scale bar represents 1 cm.

Material.—One specimen from locality KF107, external mould of a ventral valve, UHR11374.

Description.—Shell medium size for genus, transversely subpentagonal in outline, with greatest width near anterior margin; length 29 mm, width about 32 mm. 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. External surface of ventral valve except for ears ornamented with numerous quincuncially arranged elongate spines and irregular, weak concentric lamellae; ears having a cluster of rounded spine bases.

Remarks.—This specimen can be assigned to the genus *Edriosteges* by its size, shape and external ornament of the ventral valve. The Nabekoshiyama specimen most resembles shell figured by Kotlyar (1989, pl. 23, fig. 5) as *Edriosteges poyangensis* (Kayser, 1883), from the Upper Permian Lyudyanza Formation of the Nakhodka area, South Primorye, eastern Russia.

The type species, *Edriosteges multispinosus* Muir-Wood and Cooper (1960, p. 104, pl. 17, figs. 1–10), from the upper Leonard Formation of the Glass Mountains, West Texas, is also like to the present species in general shape and external ornament of the ventral valve. But accurate comparison is difficult for the poorly preserved specimen.

Family Tschernyschewiidae Muir-Wood and Cooper, 1960
Genus *Tschernyschewia* Stoyanow, 1910

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

Tschernyschewia typica Stoyanow, 1910
Figs. 7.1–7.3

Productus scabriculus Martin: Abich, 1878, p. 33, pl. 5, fig. 3.
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; Ramovs, 1958, p. 524, pl. 9, figs. 3, 4; Muir-Wood and Cooper, 1960, pl. 126, 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.

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

Remarks.—The Nabekoshiyama specimens lack the ventral valves, but they can be referred to *Tschernyschewia typica* Stoyanow, 1910, from the Upper Permian (Dzulfian) of Armenia, by their subcircular, almost flattened, medium-sized dorsal valves (length 23 mm, width about 32 mm in the largest specimen, NU-B1642), 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 Upper

Permian (Lopingian) of Loping, Jiangxi Province, South China, is clearly distinguished from *Tschernyschewia typica* by its elongate shell outline and much longer hinge.

Distribution.—Upper Permian (Lopingian) of western Servia, Armenia, Iran (Julfa) and northeast Japan (Nabekoshiyama 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, 1924

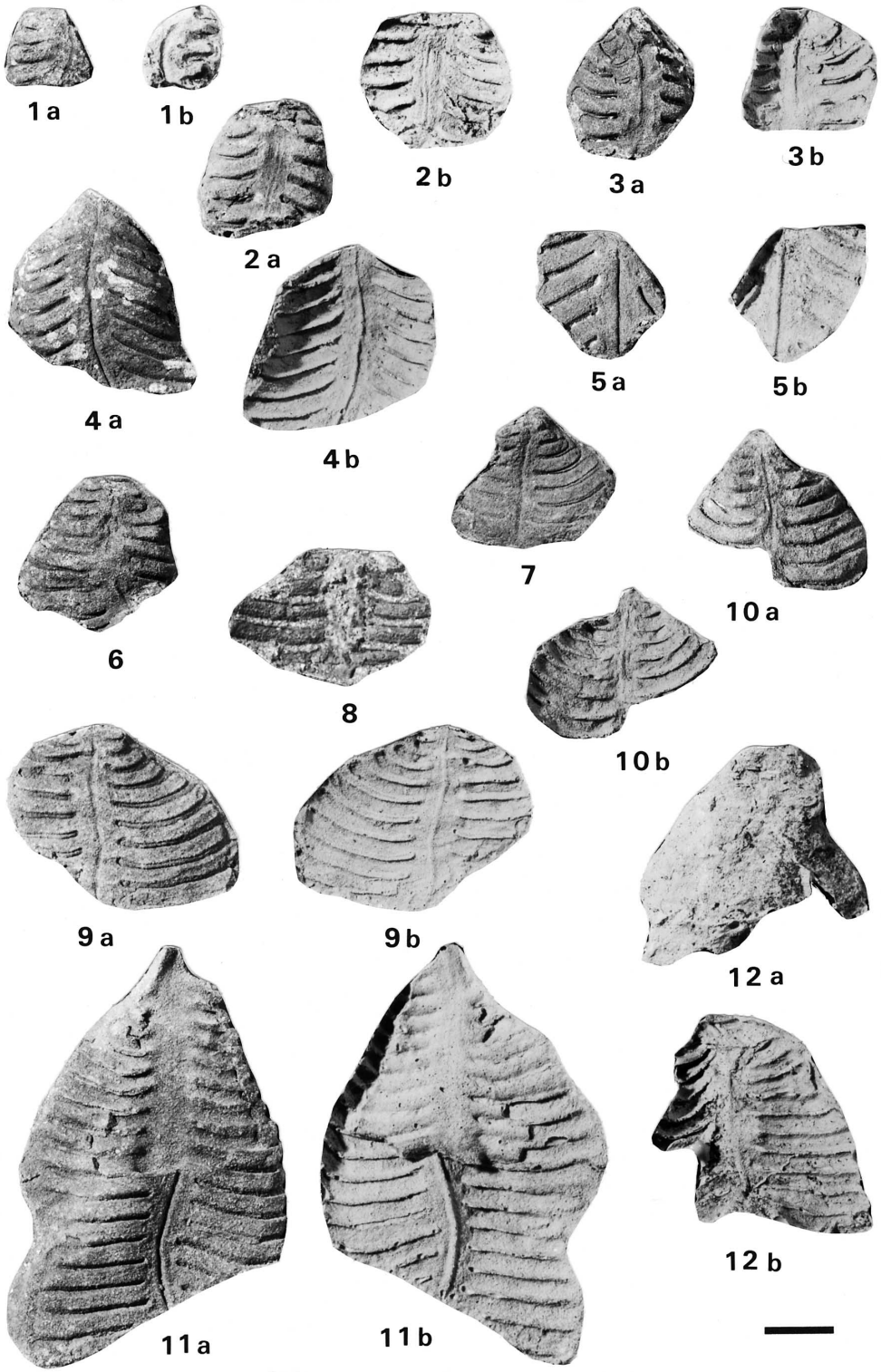
Type species.—*Oldhamina* (*Lyttonia*) *mira* Fredericks, 1916.

Eolyttonia tenuis (Waagen, 1883)
Figs. 5.6–5.9, 6A, 7.9, 7.10

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.
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.
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 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, 109: (1) external and internal moulds of four ventral valves, NU-B1580–1583; (2) internal moulds of three ventral valves, UHR30104, NU-B1584, 1585; (3) internal mould of a dorsal valve (internal plate), UHR30110.

Description.—Shell medium size for genus, slightly transverse to elongate spatulate in outline, with greatest width near anterior margin; length 30 mm, width 33 mm in the largest specimen (NU-B1580); length 19 mm, width 14 mm in a young specimen (NU-B1584). Ventral valve almost flat, slightly convex in lateral and anterior profiles. External surface of ventral valve flexuous corresponding to the internal lobes. Interior of ventral valve with a rather thick median septum and more than 9 lateral septa on each side of valve, numbering 7–8 in 20 mm; lateral septa regularly and symmetrically arranged, slightly arched towards front; crests of septa deeply concave (angustilobate). Internal plate of dorsal valve, with broad nearly straight, and regularly and symmetrically arranged lateral lobes, ornamented with numerous pustules.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12b

Remarks.—These specimens can be referred to *Eolyttonia tenuis* (Waagen, 1883), originally described by Waagen (1883, p. 401) as *Lyttonia tenuis* Waagen, 1883, from the Wargal Formation of the Salt Range, Pakistan, by its medium-sized, flatly convex ventral valve and the grooved lateral septa. *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 the holotype of *Eolyttonia nakazawai* Shimizu (1961a, p. 330, pl. 15, fig. 22), from the Upper Permian (Changhsingian) of Takauchi in the Maizuru Belt, southwest Japan, is 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.

Distribution.—Lower Permian (Kungurian) of Southwest China (Yunnan); Middle Permian (Roadian-Capitanian) of eastern Russia (South Primorye) and South China (Anhui, Zhejiang and Fujian); Middle Permian (Capitanian) and Upper Permian (Wuchiapingian) of Northwest China (Qinghai), South China (Hubei), Southwest China (Yunnan), Vietnam (Camlo), Malaysia (Sungai Toh), Pakistan (Salt Range) and Canada (British Columbia); Upper Permian (Changhsingian) of South China (Guangdong, Guizhou and Sichuan) and northeast Japan (Nabekoshiyama in the South Kitakami Belt).

Eolyttonia mira (Fredericks, 1916)
Figs. 5.1–5.3, 6B

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. 1I.
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, 109, internal moulds of three ventral valves, UHR30111, NU-B1586, 1587.

Description.—Shell small size for genus, slightly elongate oval in outline; length 23 mm, width 20 mm in the largest specimen (NU-B1586). Ventral valve nearly flat in lateral profile, but strongly convex in anterior profile. Internally, ventral valve having a thick, low median septum and regularly and symmetrically arranged, grooved lateral septa; lateral septa straight or slightly arched towards front of valve, numbering 6 in 20 mm.

← **Fig. 5.** 1–3: *Eolyttonia mira* (Fredericks), 1a, 1b: internal mould and internal latex cast of ventral valve, UHR30111, 2a, 2b: internal mould and internal latex cast of ventral valve, NU-B1586, 3a, 3b: internal mould and internal latex cast of ventral valve, NU-B1587. 4: *Oldhamina squamosa* Huang, 4a, 4b: internal mould and internal latex cast of ventral valve, UHR30109. 5: *Oldhamina kitakamiensis* Tazawa, 5a, 5b: internal mould and internal latex cast of ventral valve, NU-B1579. 6–9: *Eolyttonia tenuis* (Waagen), 6: internal mould of ventral valve, UHR30104, 7: internal mould of ventral valve, NU-B1581, 8: internal mould of dorsal valve, UHR30110, 9a, 9b: internal mould and internal latex cast of ventral valve, NU-B1580. 10–12: *Oldhamina anshunensis* Huang, 10a, 10b: internal mould and internal latex cast of ventral valve, NU-B1578, 11a, 11b: internal mould and internal latex cast of ventral valve, UHR30107, 12a, 12b: external latex cast and internal latex cast of ventral valve, NU-B1576. Scale bar represents 1 cm.

Remarks.—These specimens can be identified with *Eolyttonia mira* (Fredericks, 1916), from the Chandalaz Formation (Wordian–Capitanian) of Cape Kalouzin, Vladivostok, eastern Russia, in its small size, strongly convex ventral valve and lateral septa with convex crests.

The above-described species, *Eolyttonia tenuis* (Waagen, 1883), is distinguished from the present species by its larger size and less convex ventral valve.

Distribution.—Middle Permian (Wordian–Capitanian) of eastern Russia (South Primorye); Upper Permian (Changhsingian) of northeast Japan (Nabekoshiyama in the South Kitakami Belt).

Genus *Oldhamina* Waagen, 1883

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

Oldhamina squamosa Huang, 1932
Figs. 5.4, 6C

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.

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

Material.—One specimen from locality KF109, internal mould of a ventral valve, UHR30109.

Description.—Shell small size for genus, longer than wide; length about 34 mm, width about 28 mm. Ventral valve almost flat in lateral profile, but moderately convex in anterior profile. Ventral interior with a thin median septum and numerous symmetrically arranged lateral septa; lateral septa sharp (anguliseptate), inclined towards anterior margin of valve, and dipping to the front at angles 67–71° in lateral profile, numbering 7 septa in 20 mm, and totally 10 pairs of septa in the single ventral valve specimen.

Remarks.—This specimen was previously described by Tazawa (1975, p. 637) as *Eolyttonia* cf. *nakazawai* Shimizu, 1961a. However, the specimen can be identified with *Oldhamina squamosa* Huang, 1932, from the Upper Permian (Changhsingian) of Guizhou and Sichuan, South China, by its moderately convex ventral valve and the sharp lateral septa, 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 *O. squamosa* in its more inflated ventral valve and the smaller number of lateral septa in the ventral valve.

Distribution.—Upper Permian (Lopingian) of South China (Hubei); Upper Permian (Changhsingian) of South China (Fujian, Guangdong, Guangxi, Guizhou and Sichuan),

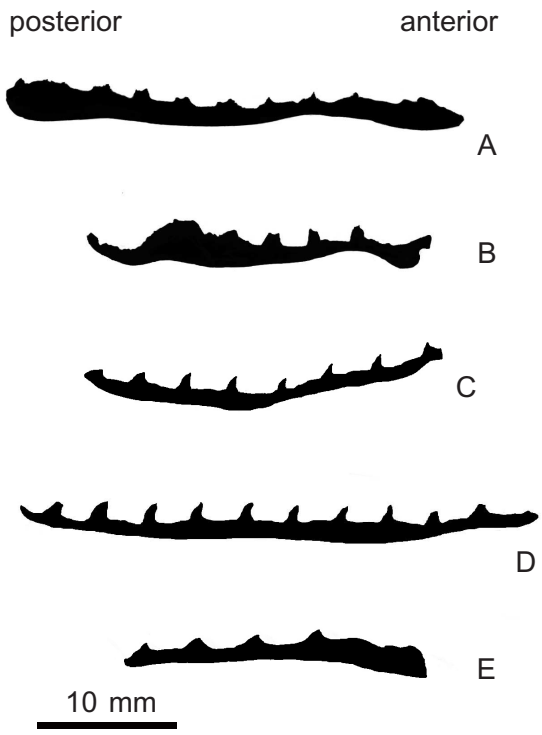


Fig. 6. Longitudinal section of ventral internal latex cast of lyttoniid species, showing crests of lateral septa. A: *Eolyttonia tenuis* (Waagen), NU-B1580, B: *Eolyttonia mira* (Fredericks), NU-B1587, C: *Oldhamina squamosa* Huang, UHR30109, D: *Oldhamina anshunensis* Huang, UHR30108, E: *Oldhamina kitakamiensis* Tazawa, NU-B1579.

northern Thailand (Huai Tak) and northeast Japan (Nabekoshiyama in the South Kitakami Belt).

Oldhamina anshunensis Huang, 1932
Figs. 5.10–5.12, 6D, 7.7, 7.8

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, figs. 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, pl. 7, fig. 9.

Material.—Five specimens from locality KF108: (1) internal mould of a ventral valve with external mould of the dorsal valve, UHR30107; (2) external and internal moulds of two ventral valves, UHR30108, NU-B1576; (3) internal moulds of two ventral valves, NU-B1577, 1578.

Description.—Shell medium size for genus, elongate subtrigonal in outline; length about 62 mm, width 42 mm in the largest specimen (UHR30107). Ventral valve slightly convex in both lateral and anterior profiles, except for strongly convex apical region. External surface of ventral valve smooth, but faintly flexuous corresponding to the internal lateral lobes. Ventral interior with numerous, regularly and symmetrically disposed lateral septa on both sides of thin median septum; lateral septa thin, with acute crests (mostly anguliseptate, but solidiseptate in some septa), nearly straight to slightly arched towards anterior margin of valve, and dipping to the front at angles 68–73° in lateral profile, numbering 6–7 septa in 20 mm, and totally 19 pairs of septa in the largest specimen. Dorsal interior with a flat, broad median plate and numerous symmetrically disposed, slightly convex lateral plates.

Remarks.—Two of the Nabekoshiyama specimens (UHR30107, 30108) were misidentified and described by Tazawa (1975, p. 637) as *Eolyttonia* cf. *nakazawai* Shimizu, 1961a. However the shells including the two specimens are referred to *Oldhamina anshunensis* Huang, 1932, originally described as *Oldhamina squamosa* var. *anshunensis* Huang, 1932, from the Upper Permian (Changhsingian) of Guizhou, South China, by their medium size, flatly convex ventral valve and weakly arched lateral septa.

Oldhamina squamosa Huang (1932, p. 74, pl. 6, figs. 1–5; pl. 7, fig. 11), from the Upper Permian (Changhsingian) of Guizhou, South China, is distinguished from *O. anshunensis* by its more strongly inflated ventral valve and the ventral lateral septa strongly inclined toward the front.

Distribution.—Upper Permian (Wuchiapingian) of South China (Anhui and Guangdong) and southwest Japan (Yachiyo in the Maizuru Belt); Upper Permian (Lopingian) of South China (Shaanxi, Hunan and Guizhou); Upper Permian (Changhsingian) of northeast Japan (Nabekoshiyama in the South Kitakami Belt).

Oldhamina kitakamiensis Tazawa, 1982
Figs. 5.5, 6E

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

Material.—One specimen from locality KF108, internal mould of a ventral valve, NU-B1579.

Remarks.—This specimen is represented by a fragment of internal mould of ventral valve. In spite of ill preservation, the Nabekoshiyama specimen can be reffered to *Oldhamina kitakamiensis* Tazawa, 1982, described from the Upper Permian (Changhsingian) of Kanayashiki in the Yahagi area, South Kitakami Belt, northeast Japan, by its almost flat ventral valve, and the thin, widely spaced lateral septa (numbering 5 septa in 20 mm) which strongly inclined (at angles 40–48°) towards the front. Comparison between the present species and the other *Oldhamina* species is fully discussed by Tazawa (1982, p. 448).

Distribution.—Upper Permian (Changhsingian) of northeast Japan (Kanayashiki and

Nabekoshiyama in the South Kitakami Belt).

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. 7.4

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

Remarks.—The single specimen from Nabekoshiyama is safely assigned to the genus *Derbyia* by its flatly convex ventral valve, ornamented with numerous costellae (11–12 in 5 mm near the anterior margin), and the strong, short median septum in the valve. This specimen most resembles *Derbyia nigpi* Chen and Liao (2007, p. 992, fig. 7), from the upper Changhsing Formation of Dongluo, southern Guangxi, South China, in size, outline and external ornament of the ventral valve. But accurate comparison is difficult for the poorly preserved specimen.

Derbyia sp. Tazawa in Tazawa and Miyake (2011, p. 9, fig. 2.7), from the upper Toyoma Formation (Changhsingian) of Maeda, Ofunato area, South Kitakami Belt, differs from the present species in its finer costellae on the dorsal valve.

Derbyia schellwieni Frech (1911, p. 125, pl. 18, fig. 3), from the Upper Permian (Lopingian) of Loping, Jiangxi Province, South China, differs from the Nabekoshiyama species in its less transverse outline and coarser costellae on the ventral valve.

Order Orthida Schuchert and Cooper, 1932
Suborder Dalmanellidina Moore, 1952
Superfamily Enteletoidea Waagen, 1884
Family Enteletidae Waagen, 1884

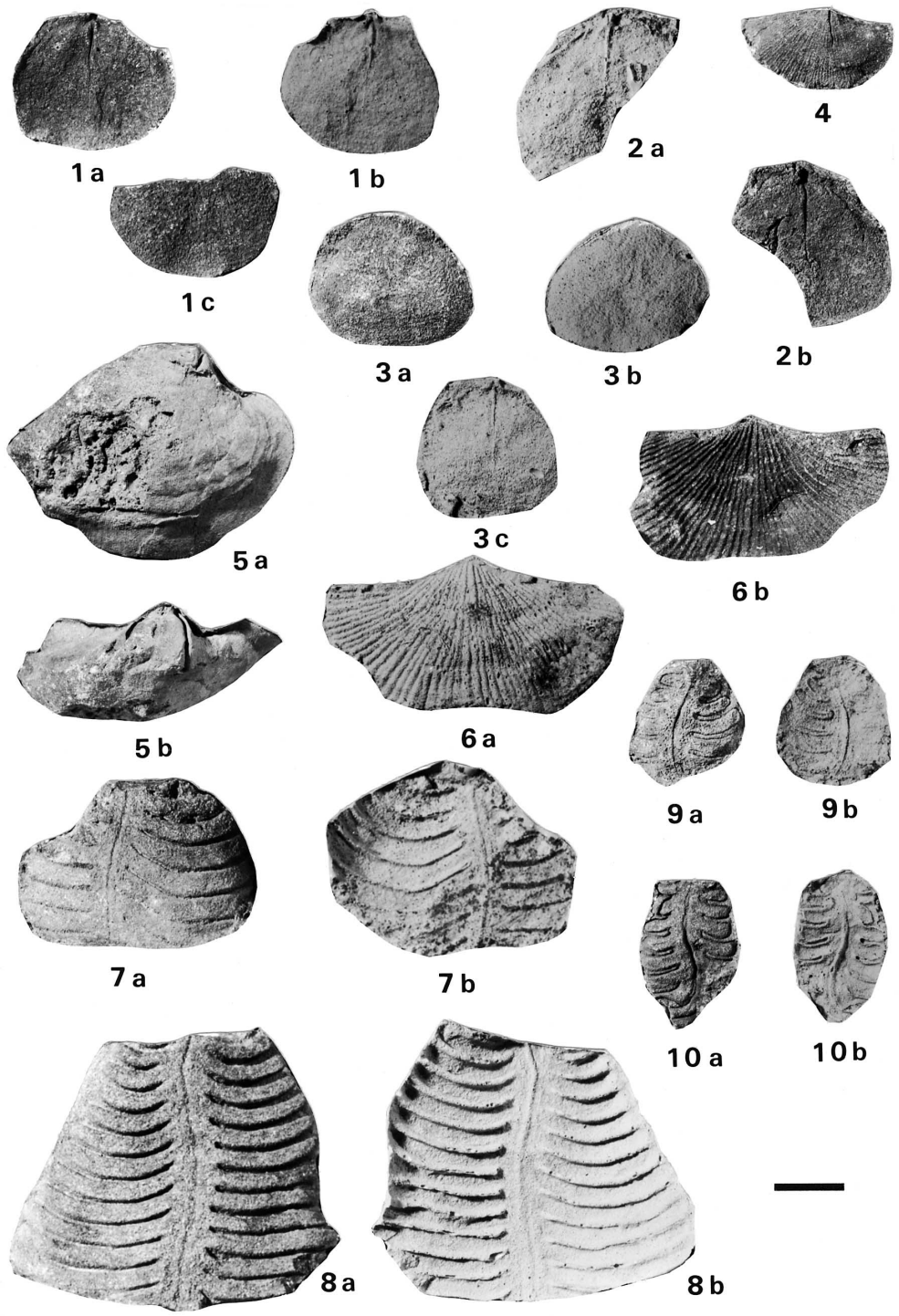
Genus *Enteletes* Fischer de Waldheim, 1825

Type species.—*Enteletes glabra* Fischer de Waldheim, 1830.

Enteletes sp.
Fig. 3.15

Material.—One specimen from locality KF108, external and internal moulds of a ventral valve, NU-B1631.

Remarks.—This specimen is safely assigned to the genus *Enteletes* by its small, subcircular ventral valve (length about 14 mm, width about 16 mm), ornamented with


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

numerous very fine costellae and having a pair of strong teeth and long, subparallel dental plates sloping anteriorly and a high median septum in the posterior portion of the valve. But specific identification is difficult for the poorly preserved specimen.

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

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

Peltichia cf. *transversa* (Huang, 1933)
Fig. 7.5

Compare.—
Parenteretes sinensis mut. *transversus* Huang, 1933, p. 14, pl. 2, figs. 8–10.
Peltichia transversus (Huang): Shen et al., 1999, p. 58, figs. 6.8, 8.8–8.12, 10.11–10.25, 10.30.

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

Remarks.—The single dorsal valve specimen from Nabekoshiyama is medium size for genus (length about 32 mm, width about 42 mm), transversely elliptical in outline, and having a pair of strong brachiophore supporting plates, diverging anteriorly, a low and short median ridge, and an elevated adductor platform. In size, shape and internal structure of the dorsal valve, the Nabekoshiyama specimen most resembles *Peltichia transversa* (Huang, 1933), from the Changhsing Formation of Guizhou, South China. Accurate comparison is, however, difficult due to the ill preservation of the present material.

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 the present species in its much larger size and more elongate outline.

Family Schizophoriidae Schuchert and LeVene, 1929
Genus *Orthotichia* Hall and Clarke, 1892.

← **Fig. 7.** 1–3: *Tschernyschewia typica* Stoyanow, 1a, 1b, 1c: internal mould, internal latex cast and external mould of dorsal valve, UHR30106, 2a, 2b: internal latex cast and internal mould of dorsal valve, NU-B1638, 3a, 3b, 3c: external mould, external latex cast and internal latex cast of dorsal valve, NU-B1634. 4: *Derbyia* sp., internal mould of ventral valve, NU-B1614. 5: *Peltichia* cf. *transversa* (Huang), 5a, 5b: dorsal and posterior views of internal mould of dorsal valve, NU-B1608. 6: *Choristitella wynnei* (Waagen), 6a, 6b: external latex cast and external mould of dorsal valve, NU-B1575. 7, 8: *Oldhamina anshunensis* Huang, 7a, 7b: internal mould and internal latex cast of ventral valve, NU-B1577, 8a, 8b: internal mould and internal latex cast of ventral valve, UHR30108. 9, 10: *Eolyttonia tenuis* (Waagen), 9a, 9b: internal mould and internal latex cast of ventral valve, NU-B1585, 10a, 10b: internal mould and internal latex cast of ventral valve, NU-B1584. Scale bar represents 1 cm.

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

Orthotichia sp.
Fig. 3.14

Material.—One specimen from locality KF108, internal mould of a ventral valve, NU-B1643.

Remarks.—This specimen can be assigned to the genus *Orthotichia* by its small, transversely subelliptical shell (length 7 mm, width 11 mm), having a pair of strong, subpararell dental plates and a long median septum extending slightly anterior to the ends of the dental plates. The Nabekoshiyama specimen may be a small-sized *Orthotichia*, although specific identification is difficult.

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. 3.16

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; Ding and Qi, 1983, p. 359, pl. 120, fig. 5; Yang, 1984, p. 231, pl. 37, fig. 8.
Retzia (*Hustedia*) *indica* (Waagen): Broili, 1916, p. 54, pl. 125, figs. 4–6.

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

Remarks.—The specimens from Nabekoshiyama are referred to *Hustedia indica* (Waagen, 1883), originally described as *Eumetria indica* Waagen from the Amb and Wargal formations of the Salt Range, Pakistan, by their medium-sized, slightly elongate shell (length 9 mm, width 7 mm in the better preserved ventral valve specimen, NU-B1629) with 7–8 strong, rounded costae on the ventral valve.

Hustedia remota (von Eichwald, 1860) is distinguished from *H. indica* in having wider and flat-bottomed intercostal spaces on both ventral and dorsal valves (see Tschernyschew, 1902, pl. 47, figs. 8–11).

Distribution.—Lower Permian (Asselian) of central Russia (Urals); Middle Permian (Kungurian–Wordian) of North China (Gansu); Middle Permian (Roadian) to Upper Permian (Wuchiapingian) of Pakistan (Salt Range); Upper Permian (Wuchiapingian) of South China (Hubei and Guizhou) and Indonesia (Timor); Upper Permian (Changhsingian)

of northeast Japan (Nabekoshiyama in the South Kitakami Belt).

Hustedia minuta Tazawa in Tazawa and Miyake, 2011
Figs. 3.4–3.7

Hustedia minuta Tazawa in Tazawa and Miyake, 2011, p. 15, figs. 2.5, 2.6.

Material.—Fourteen specimens from locality KF108: (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) internal moulds of four ventral valves, NU-B1620–1623; (5) external and internal moulds of two dorsal valves, NU-B1624, 1625; (6) internal moulds of three dorsal valves, NU-B1626–1628.

Description.—Shell small size for genus, slightly longer than wide; length 7 mm, width 5 mm in the largest specimen (NU-B1615). Ventral valve moderately convex in lateral profile, having no sulcus. Dorsal valve gently convex, without fold. External surface of both valves ornamented with rounded costae; numbering 10 in ventral valve, 11 in dorsal valve; intercostal spaces with flattened bottom. Dorsal valve interior with strong but short median septum. Other internal structure of both ventral and dorsal valves obscure.

Remarks.—These specimens are referred to *Hustedia minuta* Tazawa in Tazawa and Miyake, 2011, from the Upper Permian (Changhsingian) of Maeda in the Ofunato area, South Kitakami Belt, by their small size and rather numerous costae and intercostal spaces with flattened bottom.

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 it differs from *H. minuta* in having more numerous costae, with narrower intercostal spaces.

Distribution.—Upper Permian (Changhsingian) of northeast Japan (Maeda and Nabekoshiyama, both in the South Kitakami Belt).

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

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

Martinia sp.
Figs. 3.20, 3.21

Material.—Two specimens from locality KF107: (1) external cast of a ventral valve, NU-B1609: (2) internal mould of a ventral valve, NU-B1610.

Remarks.—These specimens are safely assigned to the genus *Martinia* by their small (length about 18 mm, width about 19 mm in the larger specimen, NU-B1609), subcircular

ventral valves, with several radial vascular markings. But accurate comparison is difficult for the poorly preserved specimens.

Superfamily Spiriferoidea King, 1846
Family Choristitidae Waterhouse, 1968
Subfamily Choristitinae Waterhouse, 1968
Genus *Choristitella* Ivanov and Ivanova, 1937

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

Choristitella wynnei (Waagen, 1883)
Fig. 7.6

Spirifer wynnei Waagen, 1883, p. 517, pl. 44, figs. 6, 7; Licharew and Kotlyar, 1978, pl. 21, fig. 14.
Choristitella wynnei (Waagen): Kotlyar, 1989, pl. 24, figs. 4, 5; Tazawa in Tazawa and Miyake, 2011, p. 16, fig. 5.10.

Material.—One specimen from locality KF108, external mould of a dorsal valve, NU-B1575.

Remarks.—This specimen can be identified with *Choristitella wynnei* (Waagen, 1883), originally described from the Wargal Formation of the Salt Range, by its large, transverse dorsal valve (length more than 45 mm, width about 30 mm), with a low and broad fold, and external ornament consisting of numerous fine costae numbering 5–6 in 5 mm at about midlength of the valve. A spiriferid species described by Ozaki (1931, p. 35, pl. 3, fig. 1) as *Spirifer* (*Choristites*) *wynnei* Waagen, 1883, from the Upper Carboniferous of Shanxi, North China, differs from the present species in having coarser costae on the dorsal valve.

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, differs from *C. wynnei* in its smaller size and less transverse outline.

Distribution.—Middle Permian (Capitanian) to Upper Permian (Wuchiapingian) of the Salt Range, Pakistan; Upper Permian (Wuchiapingian) of South Primorye, eastern Russia; Upper Permian (Changhsingian) of the South Kitakami Belt, northeast Japan.

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

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

Spiriferellina cristata (von Schlotheim, 1816)
Figs. 3.17–3.19

Terebratulites cristatus von Schlotheim, 1816, p. 28, pl. 1, fig. 3.
Spiriferellina cristata (von Schlotheim): Schréter, 1963, p. 144, pl. 8, figs. 11–14; Campbell, 1959, pl. 59, figs. 1–9; pl. 60, fig. 3; text-fig. 5.
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; (2) external and internal moulds of two dorsal valves, NU-B1612, 1613.

Description.—Shell medium size for genus, transversely subelliptical in outline, widest near hinge; length about 11 mm, width about 18 mm in the largest ventral valve specimen (NU-B1611); length 6 mm, width 12 mm in the best preserved dorsal valve specimen (NU-B1612). Ventral valve moderately and unevenly convex in lateral profile, most convex in umbonal region; sulcus broad and deep, with flat bottom. Dorsal valve moderately and unevenly convex in lateral profile; fold broad and high. External surface of both ventral and dorsal valves ornamented with strong, rounded costae, numbering 5 pairs in dorsal valve; micro-ornament of very numerous fine pustules on whole surface of both valves. Interior of ventral valve with strong but short median septum. Other internal structures obscure.

Remarks.—These specimens are referred to *Spiriferellina cristata* (von Schlotheim, 1816), redescribed and refigured by Campbell (1959, p. 358, pl. 59, figs. 1–9; pl. 60, fig. 3) on the syntype and lectotype specimens from the Zechstein of Thuringia, Germany, in their small, transverse shells, and 4–5 pairs of rounded costae on both ventral and dorsal valves.

The shells, described and figured as *Spiriferina cristata* (von Schlotheim, 1816) from the Middle Permian (Wordian) of the South Kitakami Belt, northeast Japan (Hayasaka, 1922, p. 66, pl. 9, figs. 5–9; Hayasaka, 1960, p. 53, pl. 1, fig. 10) are larger than the type specimens of Germany; and they may be a different species.

Distribution.—Middle Permian (Capitanian) of East Greenland; Middle Permian (Capitanian) to Upper Permian (Wuchiapingian) of Germany (Thuringia); Upper Permian (Wuchiapingian) of Hungary (Bukk Mountains); Upper Permian (Changhsingian) of northeast Japan (Nabekoshiyama in the South Kitakami Belt).

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