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

Jun-ichi TAZAWA and Tomohiko SHINTANI

SCIENCE REPORTS OF NIIGATA UNIVERSITY (GEOLOGY)
No. 29 (2014)

Published by
The Department of Geology, Faculty of Science
Niigata University, Niigata, Japan
31 March 2014

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

Jun-ichi TAZAWA* and Tomohiko SHINTANI**

Abstract

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

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

Introduction

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

* Hamaura-cho 1–260–1, Chuo-ku, Niigata 951-8151, Japan
** Dia Consultants, Co., Ltd., Yoshino-cho 2–272–3, Kita-ku, Saitama 331-0811, Japan
(Manuscript received 27 November, 2013; accepted 11 February, 2014)

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

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

Stratigraphy

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

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

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

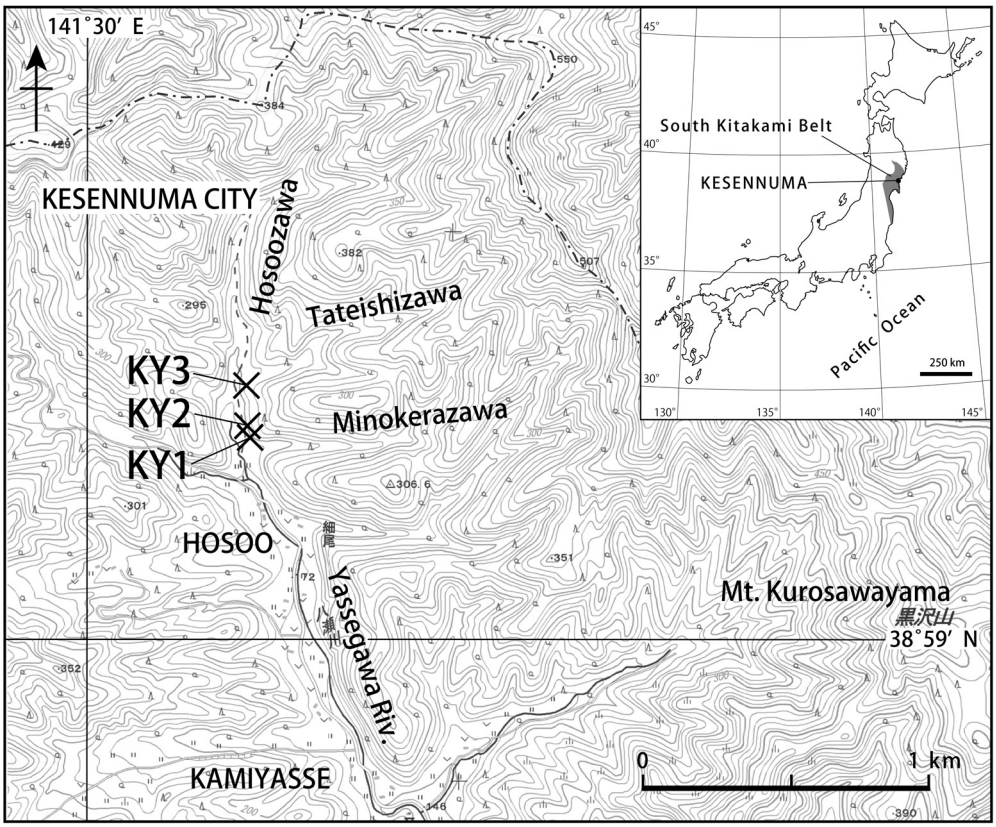


Fig. 1. Index map showing the fossil localities KY1, KY2 and KY3 in the Kamiyasse area, using the topographical map of "Shishiori" scale 1 : 25,000 published by the Geospatial Information Authority of Japan.

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

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

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

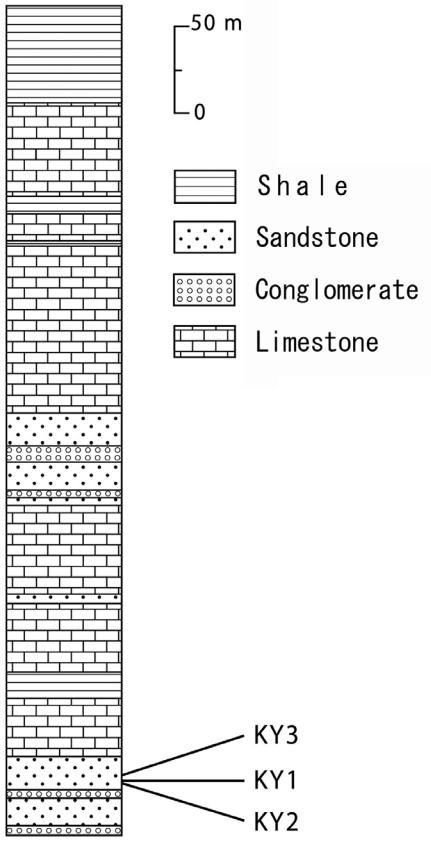


Fig. 2. Generalized columnar section of the Nakadaira Formation in the Kamiyasse area, showing the fossil horizons, KY1, KY2 and KY3.

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

The Kamiyasse fauna

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

Age of the fauna

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

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

Palaeobiogeography

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

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

Systematic descriptions

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

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

Echinoconchus? sp.
Figs. 3.1, 3.2

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

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

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

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

Waagenoconcha asiatica Zavodowsky, 1968
Fig. 3.3

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

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

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

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

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

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

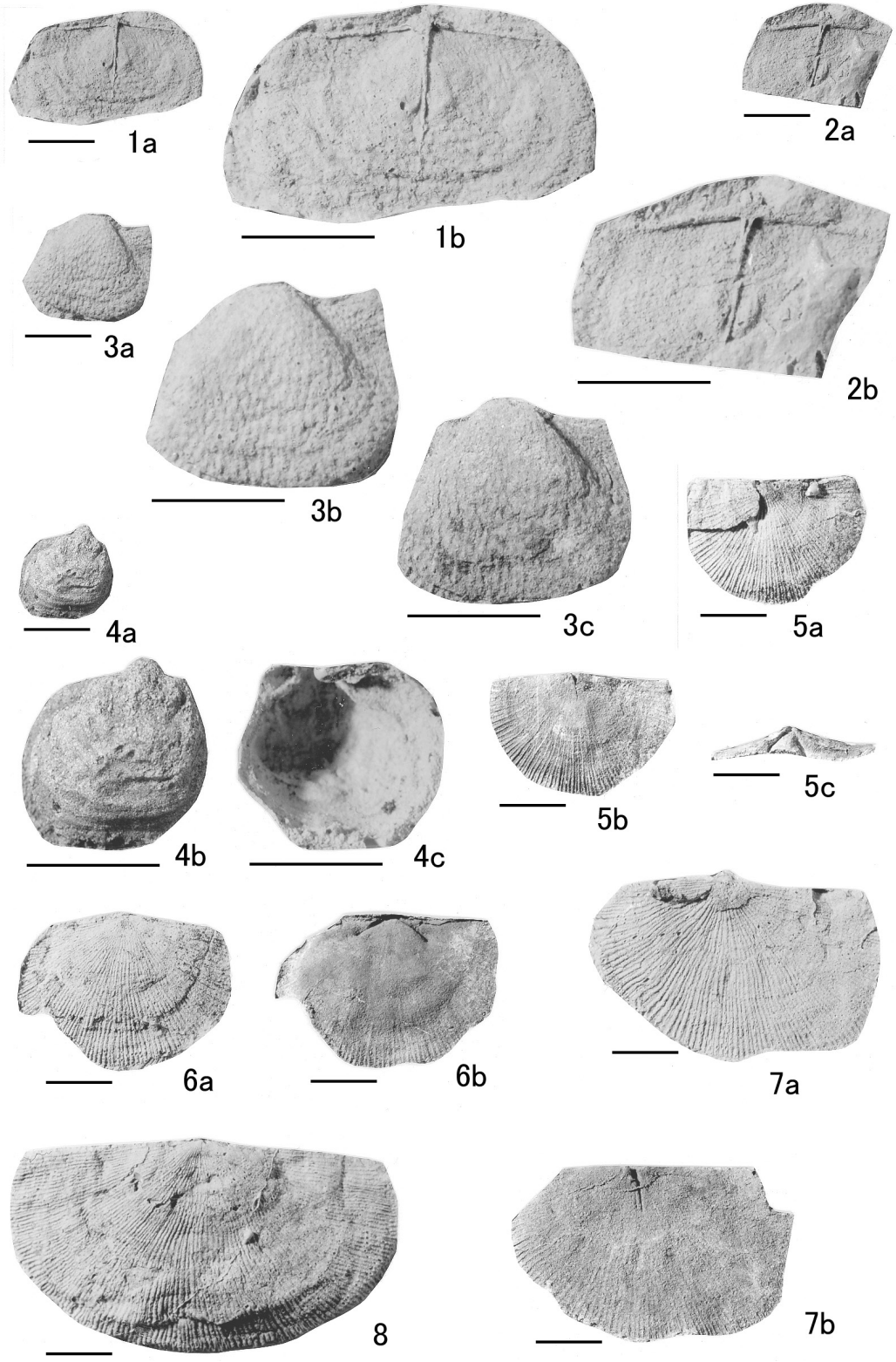
Acritosia sp.
Fig. 3.4

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

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

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

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


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

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

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

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

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

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

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

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

Derbyia dorsosulcata Liu and Waterhouse, 1985
Fig. 3.8

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

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

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

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

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

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

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

Derbyia yukisawensis sp. nov.

Figs 3.7, 4.3

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

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

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

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

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

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

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

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

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

Family Meekellidae Stehli, 1954
Subfamily Meekellinae Stehli, 1954
Genus *Meekella* White and St. John, 1867

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

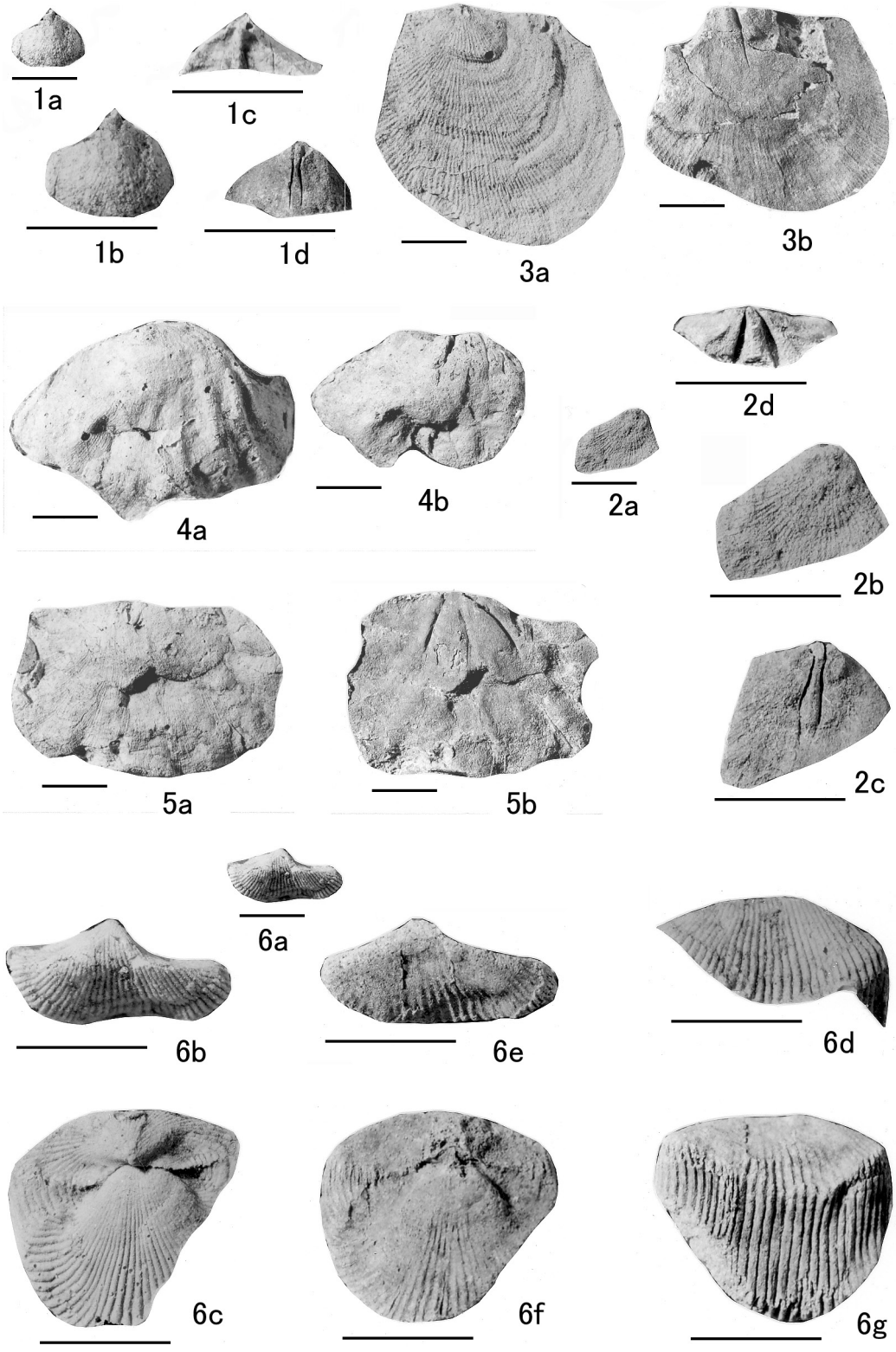
Meekella uralica Tschernyschew, 1902
Fig. 4.5

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

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

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

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


1a
1c
1b
1d
3a
3b
4a
4b
2d
2a
2b
5a
5b
2c
6a
6b
6e
6d
6c
6f
6g

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

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

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

Meekella sp.
Fig. 4.4

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

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

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

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

Genus *Orthothetina* Schellwien, 1900

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

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

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

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

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

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

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

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

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

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

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

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

Orthothetina sp.
Fig. 5.2

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

Description.—Shell medium size for genus, transversely subelliptical in outline; hinge shorter than greatest width at about midlength; length about 27 mm, width about 36 mm, hinge width about 27 mm in the sole ventral valve specimen (NU-B1533). Ventral valve moderately convex in lateral profile with flattened venter, no sulcus. External surface of

ventral valve ornamented by numerous fine costellae, numbering 9–11 in 5 mm at about midlength; some concentric rugae irregularly developed in anterior half of valve. Interior of ventral valve with a pair of long, thin, subparallel dental plates, slightly diverging anteriorly and extending for about one-third of valve length.

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

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

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

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

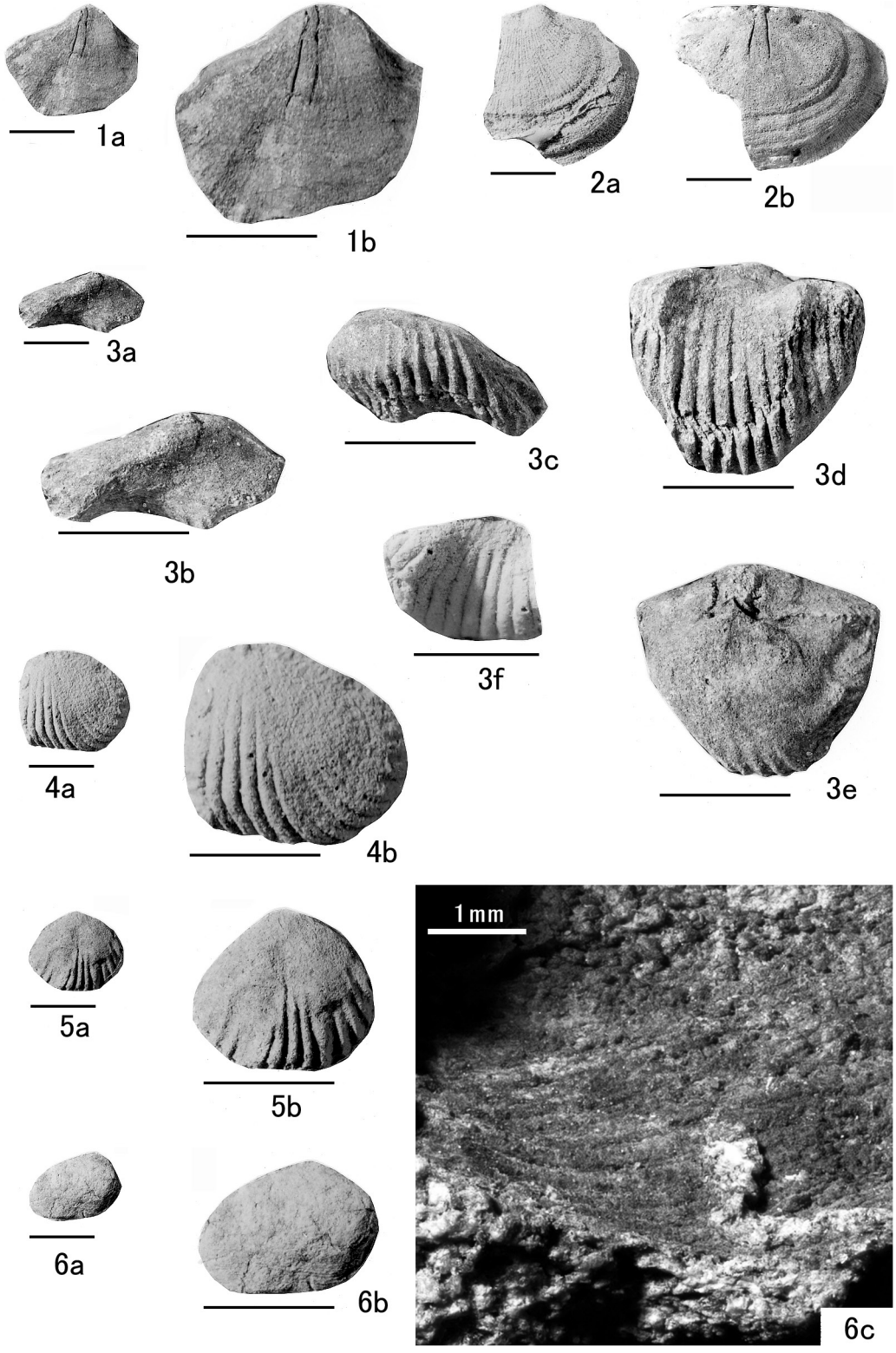
Nipponirhynchia kamiyassensis sp. nov.
Fig. 4.6

Etymology.—Named after the fossil locality, Kamiyasse.

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

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

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


1a
1b
2a
2b
3a
3b
3c
3d
3e
3f
4a
4b
5a
5b
6a
6b
1 mm
6c

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

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

Subfamily Uncinunellininae Savage, 1996
Genus *Uncinunellina* Grabau, 1932

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

Uncinunellina cf. *wangenheimi* (Pander in Müller, 1862)
Fig. 5.3

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

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

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

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

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

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

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

Uncinunellina sp.
Figs. 5.4, 5.5

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

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

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

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

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

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

Cleiothyridina sp.
Figs. 5.6, 6.1

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

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

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

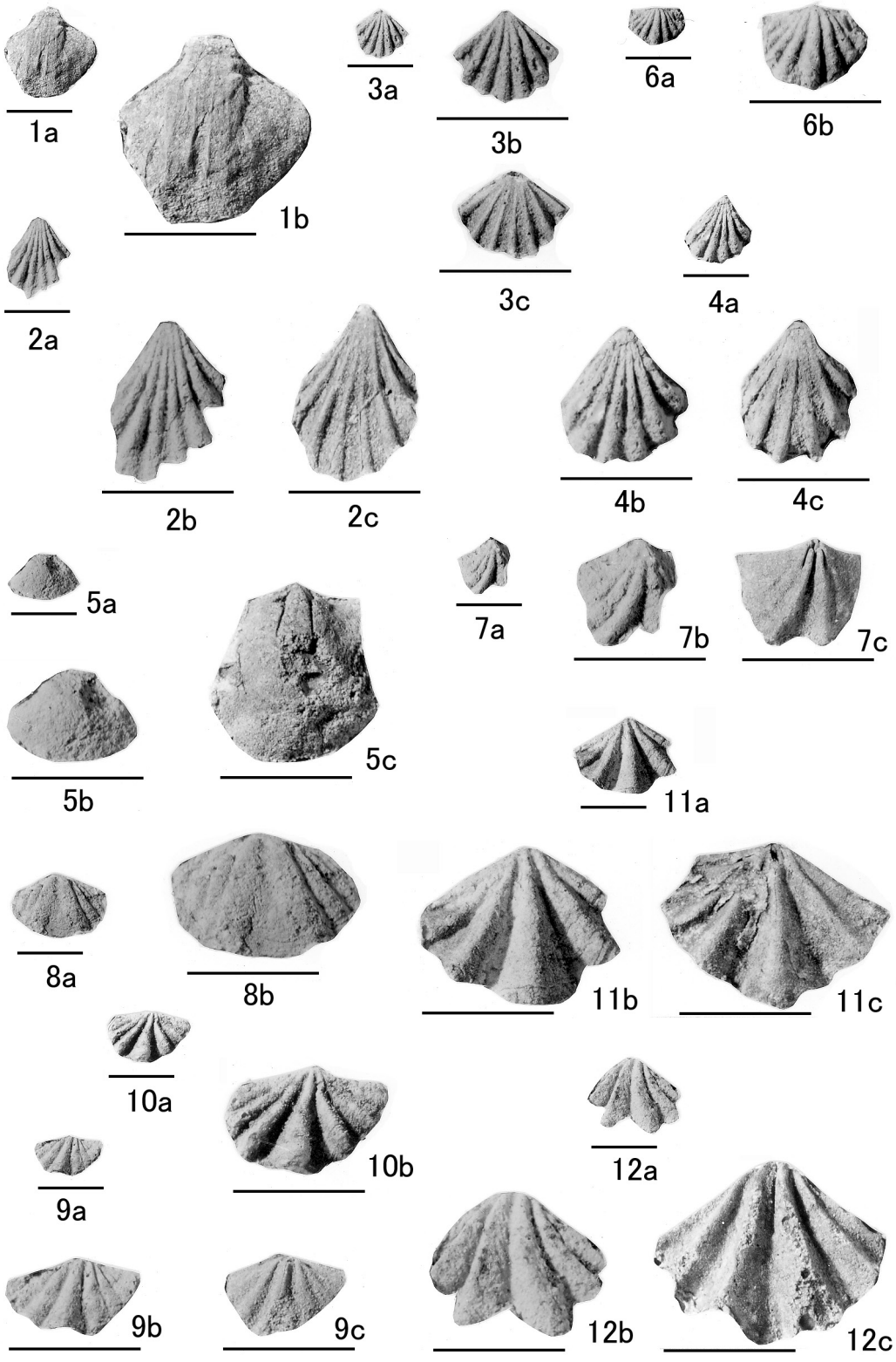
Type species.—*Terebratula mormoni* Marcou, 1858.

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

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

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

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


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

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

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

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

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

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

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

Martiniopsis sp.
Fig. 6.5

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

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

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

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

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

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

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

Spiriferellina nanbuensis sp. nov.
Figs. 6.6, 6.7

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

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

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

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

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

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

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

Spiriferellina sp.
Figs. 6.8, 6.9

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

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

Genus *Callispirina* Cooper and Muir-Wood, 1951

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

Callispirina sp.
Fig. 6.10

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

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

pustules over the valve.

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

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

Family Spiriferellinidae Ivanova, 1972

Genus *Crenispirifer* Stehli, 1954

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

Crenispirifer nakamurai sp. nov.

Figs. 6.11, 6.12

Etymology.—Named for Professor Koji Nakamura.

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

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

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

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

An average-sized species, *Crenispirifer angulatus* (King, 1931, p. 122, pl. 42, figs. 12, 13),

from the Hess and Leonard formations of west Texas, differs from the Kamiyasse species in its more transverse shell and in having larger number of costae on the both valves.

Acknowledgements

Sincere thanks are due to Naotomo Kaneko (Geological Museum, Geological Survey of Japan, AIST, Tsukuba) for his help in drawing figures; Atsushi Matsuoka (Department of Geology, Niigata University, Niigata) for his critical review of the manuscript by which this paper is greatly improved.

References

Alvarez, F., Rong, J. Y. and Boucot, A. J., 1998, The classification of athyridid brachiopods. *Jour. Paleont.,* **72**, 827–855.

Boucot, A. J., Johnson, J. G. and Staton, R. D., 1964, On some atrypoid, retzioidea, and athyridoid Brachiopoda. *Jour. Paleont.,* **38**, 805–822.

Buckman, S. S., 1906, Brachiopod nomenclature: *Epithyris, Hypothyris, Cleiothyris* Phillips, 1841. *Ann. Magaz. Nat. Hist., Ser. 7,* **18**, 321–327.

Campbell, K. S. W., 1959, The type species of three Upper Palaeozoic punctate spiriferoids. *Palaeontology*, **1**, 351–363.

Chao, Y. T., 1927, Productidae of China, Part 1; Producti. *Palaeont. Sinica, Ser. B,* **5**, 1–244.

Chen, Z. Q. and Shi, G. R., 2006, Artinskian–Kungurian (Early Permian) brachiopod faunas from the Tarim Basin, Northwest China, Part 2: Paleobiogeography and systematics of Orthotetida, Orthida, Spiriferida, Spiriferinida, Rhynchonellida, Athyridida and Terebratulida. *Palaeontographica, Abt. A,* **275**, 1–53.

Chronic, J., 1953, Part 2. Invertebrate paleontology (excepting fusulinids and corals). *In* Newell, N. D., Chronic, J. and Roberts, T. G., *Upper Paleozoic of Peru*, Geol. Soc. Amer., Memoir 58, Geol. Soc. Amer., New York, 43–165.

Cooper, G. A. and Grant, R. E., 1969, New Permian brachiopods from West Texas. *Smithson. Contr. Paleobiol.,* no. 1, 1–20.

Cooper, G. A. and Grant, R. E., 1974–1976, Permian brachiopods of West Texas, 2, 3, 5. *Smithson. Contr. Paleobiol.,* no. 15, 233–794 (1974), no. 19, 715–1921 (1975), no. 24, 2609–3159 (1976).

Cooper, G. A. and Muir-Wood, H. M., 1951, Brachiopod homonyms. *Jour. Wash. Acad. Sci.,* **41**, 195–196.

Cox, E. T., 1857, A description of some of the most characteristic shells of the principal coal seams in the western basin of Kentucky. *Geol. Surv. Ken., Rep.,* **3**, 557–576.

Dagys, A. S., 1972, Morfologiia i systematika Mezozoiskikh Retsiodnykh brakhiopod. *Tr. Inst. Geol. Geofiz., Siber. Otdel., Akad. Nauk SSSR,* **112**, 94–105 (in Russian).

Davidson, T., 1881, On genera and species of spiral-bearing Brachiopoda from specimens developed by Rev. Norman Glass: with notes on the results obtained by Mr. George Maw from extensive washing of the Wenlock and Ludlow shales of Shropshire. *Geol. Magaz., N. S.,* **8**, 1–13.

Ding, P. and Qi, W., 1983, Carboniferous and Permian Brachiopoda. *In* Xian Institute of Geology and Mineral Resources, ed., *Palaeontological Atlas of Northwest China; Shaanxi, Gansu and Ninxia Volume, Part 2. Upper Palaeozoic,* Geol. Pub. House, Beijing, 244–425 (in Chinese).

Eichwald, C. E., 1840, *O Siluriyskoy Systeme Plastov v Estlyandii*. St. Petersburg, 210p (in Russian).

Fredericks, G., 1924, Paleontologitcheskie ztoudy, 2: O verkhne kamennougolnykh spiriferidakh Ourala. *Izvest. Geol. Kom.*, **38**, 295–324 (in Russian).

Girty, G. H., 1908, *The Guadalupian Fauna*. US Geol. Surv., Prof. Pap., **58**, Gov. Print. Office, Wash., 627p.

Grabau, A. W., 1932, Studies for students, Series 1. Palaeontology, The Brachiopoda Part 3. *Sci. Quat. Nat. Univ. Peking,* **3**, 75–112.

Grabau, A. W., 1936, Early Permian fossils of China, Pt. 2. Fauna of the Maping Limestone of Kwangsii and Kweichow. *Palaeont. Sinica, Ser. B,* **8**, 1–441.

Grunt, T. A., 1986, *Systema Brakhiopod Otryada Atiridida*. Tr. Paleont. Inst., Akad. Nauk SSSR, **215**, Nauka, Moskva, 200p (in Russian).

Hall, J. and Clarke, J. M., 1893, *An Introduction to the Study of the Genera of Palaeozoic Brachiopoda*. Palaeont. New York, **8**, Charles van Benthuysen and Sons, Albany, 317p.

Huang, T. K., 1933, Late Permian Brachiopoda of Southwestern China, Part 2. *Palaeont. Sinica, Ser. B*, **9**, 1–172.

Ivanova, E. A., 1972, Osnovnye zakonomernosti evolyutsii Spiriferid (Brachiopoda). *Paleont. Zhur., 1972,* no. 3, 28–42 (in Russian).

Jin, Y. and Fang, R., 1985, Early Permian brachiopods from the Kuangshan Formation in Luliang County, Yunnan with notes on paleogeography of South China during the Liangshanian Stage. *Acta Palaeont. Sinica,* **24**, 216–228 (in Chinese).

Kalashnikov, N. V., 1980, *Brakhiopody Verkhnego Paleozoya Evropeyskogo Severa SSSR*. Nauka, Leningrad, 134p (in Russian).

Kambe, N. and Shimazu, M., 1961, *Explanatory Text of the Geological Map of Japan, "Kesennuma" Scale 1:50,000*. Geol. Surv. Japan, Kawasaki, 73p (in Japanese).

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. *Univ. Texas Bull.*, no. 3042, 1–245.

Kozlowski, R., 1914, Les brachiopods du Carbonifère supérieur de Bolivie. *Ann. Paléont.,* **9**, 1–97.

Kuhn, O., 1949, *Lehrbuch der Paläozoologie*. E. Schweizerbart. Verlagsbuchhandl., Stuttgart, 326p.

Licharew, B. K., 1939, Klass Brakhiopody. *In* Gorsky, I. I., ed., *Atlas Rukovodyaschikh Form Iskopaemykh Faun SSSR,* TSNIGRI, Leningrad, 79–113 (in Russian).

Licharew, B. K., 1956, Nadsemeistvo Rhynchonellacea Gray, 1848. *In* Kiparisova, L. D., Markowskii, B. P. and Radchenko, G. P., eds., Materialy po paleontologii, novye semeistva i rody. *VSEGEI, Mater. (Paleont.)*, **12**, 56–61 (in Russian).

Liu, F. and Waterhouse, J. B., 1985, Permian strata and brachiopods from Xiujimqinqi region of Neimongol (Inner Mongolia) Autonomous Region, China. *Pap. Dept. Geol., Univ. Qd.,* **11**, 1–44.

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 u. Furrer, Zürich, 144p.

Martin, W., 1809, *Petrificata Derbiensia; or Figures and Descriptions of Petrefactions Collected in Derbyshire*. D. Lyon, Wigan, 28p.

Minato, M., Hashimoto, S., Suyama, K., Takeda, Y., Suzuki, Y., Kimura, S., Yamada, K., Kakimi, T., Ichikawa, T. and Suetomi, H., 1954, Zur Biostratigraphie der permischen Formation des Setamai-Geländes im Süd-Kitakami Gebirge. *Jour. Geol. Soc. Japan,* **60**, 378–387 (in Japanese).

Minato, M., Hunahashi, M., Watanabe, J. and Kato, M., 1979, *Variscan Geohistory of Northern Japan: The Abean Orogeny*. Tokai Univ. Press, Tokyo, 427p.

Misaki, A. and Ehiro, M., 2004, Stratigraphy and geologic age of the Middle Permian in the Kamiyasse–Imo district, Southern Kitakami Massif, Northeast Japan. *Jour. Geol. Soc. Japan*, **110**, 129–145 (in Japanese).

Muir-Wood, H. M. and Cooper, G. A., 1960, *Morphology, Classification and Life Hibits of the Productoidea (Brachiopoda)*. Geol. Soc. Amer., Memoir 81, Geol. Soc. Amer., New York, 447p.

Müller, F., 1862, Geologicheskie i paleontologicheskie zametki ob osadkakh gornoizvestkovoy formatsii otklonov khrebta Uralskogo. *Gorniy Zhur.*, **4**, 43–51, 163–208 (in Russian).

Nakamura, K., 1972, Permian Davidsoniacea from the southern Kitakami Mountains, Japan. *Jour. Fac. Sci., Hokkaido Univ., Ser. 4*, **15**, 361–426.

d'Orbigny, A., 1842, *Voyage dans l'Amérique Méridionale Géologie, Paléontologie; Foraminifères, Vol. 3,* Pitois-Levrault, Paris, 50–56.

Sarytcheva, T. G. and Sokolskaya, A. N., 1959, O klassifikatsin lozhnoporistykh brakhiopod. *Doklady, Akad. Nauk SSSR,* **125**, 181–184 (in Russian).

Savage, N. M., 1996, Classification of Paleozoic rhynchonellid brachiopods. *In* Copper, P. and Jin, J., eds., *Brachiopods,* A. A. Balkema, Rotterdam, 249–260.

Schellwien, E., 1900, Beiträge zur Systematik der Strophomeniden des oberen Palaeozoicum. *Neues Jahrb. Min. Geol. Palaeont.,* **1**, 1–15.

Schlotheim, F. F., 1816, Beitrage zur Naturgeschichte der Versteinerungen in geognostischer Hinsicht. *Denks. Bayer. Acad. Wissenschaft.,* **6**, 13–36.

Schuchert, C. and Le Vene, C. M., 1929, Brachiopoda (generum et genotyporum index et bibliographia). *In* Pompeckj, J. F., ed., *Fossilium Catalogus, Vol. 1. Animalia, Pars 42,* W. Junk, Berlin, 140p.

Shi, G. R., Archbold, N. W. and Zhan, L.-P., 1995, Distribution and characteristics of mixed (transitional) mid-Permian (Late Artinskian–Ufimian) marine faunas in Asia and their palaeogeographical implications. *Palaeogeogr. Palaeoclimatol. Palaeoecol.,* **114**, 241–271.

Shi, G. R. and Tazawa, J., 2001, *Rhynchopora* and *Blasispirifer* (Brachiopoda) from the Middle Permian of the Hida Gaien Belt, central Japan, and their paleobiogeographical significance. *Jour. Geol. Soc. Japan,* **107**, 755–761.

Shiida, I., 1940, On the geology of the vicinity of Kesennuma City, Miyagi Prefecture. *Contr. Inst. Geol. Paleont., Tohoku Univ.,* no. 33, 1–72 (in Japanese).

Shintani, T., 2011, Orthotetoids from the Lower Permian (Sakmarian) of the Nagaiwa–Sakamotozawa area, South Kitakami Belt, northeast Japan. *Sci. Rep. Niigata Univ. (Geol.),* no. 26, 73–90.

Sowerby, J. de C., 1840–1846, *The Mineral Conchology of Great Britain, Vol. 7*. Published by the author, London, 80p.

Stehli, F. G., 1954, Lower Leonardian Brachiopoda of the Sierra Diablo. *Bull. Amer. Mus. Nat.*

Hist., **105**, 263–358.

Tazawa, J., 1973, Geology of the Kamiyasse area, southern Kitakami Mountains. *Jour. Geol. Soc. Japan,* **79**, 677–686 (in Japanese).

Tazawa, J., 1974, *Waagenoconcha* (Brachiopoda) from the Permian of the southern Kitakami Mountains, northeast Japan. *Jour. Fac. Sci., Hokkaido Univ., Ser. 4,* **16**, 121–143.

Tazawa, J., 1976. The Permian of Kesennuma, Kitakami Mountains: A preliminary report. *Earth Sci. (Chikyu Kagaku),* **30**, 175–185.

Tazawa, J., 1991, Middle Permian brachiopod biogeography of Japan and adjacent regions in East Asia. *In* Ishii, K., Liu, X., Ichikawa, K. and Huang, B., eds., *Pre-Jurassic Geology of Inner Mongolia, China: Report of China–Japan Cooperate Research Group, 1987–1989,* Matsuya Insatsu, Osaka, 213–230.

Tazawa, J., 2001, Middle Permian brachiopods from the Moribu area, Hida Gaien Belt, central Japan. *Paleont. Res.*, **5**, 283–310.

Tazawa, J., 2007, Middle Permian brachiopod faunas of Japan and their significance for understanding the Paleozoic–Mesozoic tectonics of the Japanese Islands. *In* Wong, Th. E., ed., *Proceedings of the 15th International Congress on Carboniferous and Permian Stratigraphy. Utrecht, the Netherlands, 10–16 August 2003,* Roy. Neth. Acad. Arts Sci., Amsterdam, 565–573.

Tazawa, J. and Miyake, Y., 2011, Late Permian (Changhsingian) brachiopod fauna from Maeda in the Ofunato area, South Kitakami Belt, NE Japan. *Sci. Rep. Niigata Univ. (Geol.),* no. 26, 1–22.

Tazawa, J. and Shintani, T., 2010, A Lower Permian mixed Boreal–Tethyan brachiopod fauna from the Nagaiwa–Sakamotozawa area, South Kitakami Belt, NE Japan. *Sci. Rep. Niigata Univ. (Geol.),* no. 25, 51–62.

Tschernyschew, Th., 1902, Verkhnekamennougolnye brakhiopody Urala i Timana. *Tr. Geol. Kom.,* **16**, 1–749 (in Russian).

Ueno, K., Shintani, T. and Tazawa, J., 2011, A fusuline fauna from the basal part of the Sakamotozawa Formation in the Kamiyasse area, South Kitakami Belt, Northeast Japan. *Sci. Rep. Niigata Univ. (Geol.),* no. 26, 23–41.

Ustritsky, V. I., 1960, Carboniferous and Permian strata and faunas of the western Kunlun Mountains. *Mem. Geol. Inst., Ministr. Geol. Min., P. R. China, Ser. B,* **5**, 1–132 (in Chinese).

Waagen, W., 1883–1885, Salt Range fossils, Vol. 1, Part 4. Productus-Limestone fossils, Brachiopoda. *Palaeont. Indica, Ser. 13,* **1**, pt. 4, fasc. 2, 391–546 (1883), fasc. 3, 4, 547–728 (1884), fasc. 5, 729–770 (1885).

Wang, C., 1995, Brachiopod fauna from Kangkelin Formation in Akesu, Xinjiang Autonomous Region. *Jour. Changchun Univ. Earth Sci.,* **25**, 15–23 (in Chinese).

Wang, C. and Yang, S., 1998, *Late Carboniferous–Early Permian Brachiopods of Central Xinjiang, and Their Biostratigraphical Studies*. Geol. Pub. House, Beijing, 156p (in Chinese).

Wang, C. and Zhang, S., 2003, *Zhesi Brachiopod Fauna*. Geol. Pub. House, Beijing, 210p (in Chinese).

Waterhouse, J. B. and Piyasin, S., 1970, Mid-Permian brachiopods from Khao Phrik, Thailand. *Palaeontographica, Abt. A,* **135,** 83–197.

Weller, S., 1914, *The Mississippian Brachiopoda of the Mississippi Valley Basin*. Illinois State Geol. Surv., Monograph 1, Illinois State Geol. Surv., Urbana, 508p.

White, C. A. and St. John, O., 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 Acad. Sci. Trans.*, **18**, 281–283.

Yanagida, J. and Nakornsri, N., 1999, Permian brachiopods from the Khao Hin Kling area near Phetchabun, north-central Thailand. *Bull. Kitakyushu Mus. Nat. Hist.*, **18**, 105–136.

Yanagida, J. and Nishikawa, I., 1984, Early Permian brachiopods from the Kawai Limestone, Hiroshima Prefecture, Southwest Japan. *Mem. Fac. Sci., Kyushu Univ., Ser. D*, **25**, 159–197.

Zavodowsky, V. M., 1968, Novye vidy, permskikh produktatsiy Severo-Vostoka SSSR. *In* Markovsky, B. P., ed., *Novye Vidy Drevnikh Rasteniy i Bespoznochnykh SSSR, Part 2,* Nedra Moskva, 92–97 (in Russian).

Zavodowsky, V. M. and Stepanov, D. L., 1970, Tip Brachiopoda. *In* Kulikov, M. V., ed., *Polevoy Atlas Permskoy Fauny i Flory Severo-Vostoka SSSR,* Magadanskoe Knizhnee Izdatelstvo, Magadan, 70–182 (in Russian).

Zhang, C., Zhang, F., Zhang, Z. and Wang, Z., 1983, Phyllum Brachiopoda. *In* Regional Geological Survey Team of Xinjiang, Institute of Geoscience of Xinjiang, and Geological Survey Group of Petroleum Bureau of Xinjiang, eds., *Palaeontological Atlas of Northwest China; Xinjiang Autonomous Region, Part 2. Late Palaeozoic,* Geol. Pub. House, Beijing, 262–386 (in Chinese).