Early Permian (Sakmarian) brachiopod fauna with *Jilinmartinia shansiensis* from Fukuji, Hida Gaien Belt, central Japan

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Abstract

An early Permian brachiopod fauna consisting of nine species in eight genera with *Jilinmartinia shansiensis* is described from the basal part of the Mizuyagadani Formation, Fukuji in the Hida Gaien Belt, central Japan. The brachiopod fauna (Mizuyagadani fauna) is assigned to the Sakmarian. In terms of palaeobiogeography, the fauna is a mixed Boreal–Tethyan fauna, and has affinity with those of northwestern China (Xinjiang and Gansu) and northern China (Shanxi). Thus, the Mizuyagadani fauna probably belonged to the Sino-Mongolian–Japanese Province, and the Hida Gaien region, including Fukuji, was probably located near and to the northeast of the North China Block during the Sakmarian.

Key words: Brachiopoda, Hida Gaien Belt, *Jilinmartinia*, mixed Boreal–Tethyan fauna, Sakmarian.

Introduction

Jilinmartinia shansiensis (Chao, 1929) is type species of the spiriferid brachiopod genus *Jilinmartinia* Lee and Gu, 1980. This species is known to be from the Moscovian–Asselian of northwestern China (Xinjiang and Gansu) and northern China (Shanxi), outside of central Japan (Fukuji in the Hida Gaien Belt). In the present paper, we describe a brachiopod fauna (Mizuyagadani Fauna), with *J. shansiensis*, from the basal part of the Mizuyagadani Formation (named by Igo, 1956), Fukuji, Gifu Prefecture, Hida Gaien Belt, central Japan (Fig. 1),

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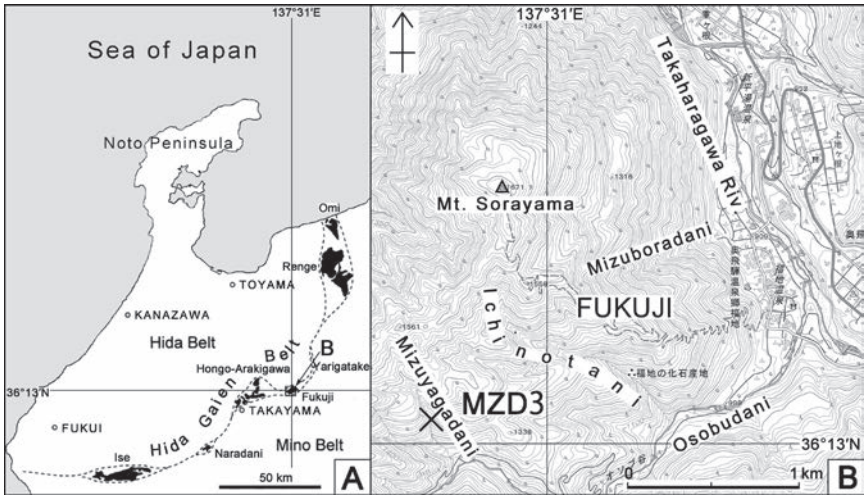

Fig. 1. Maps showing the fossil localiy MZD3 in the Fukuji area, Hida Gaien Belt, central Japan; **A,** Geotectonic map of the north-central part of Honshu, showing the distribution of the Hida Gaien Belt (after Tazawa, 2004); **B,** Topographic map showing the fossil locality MZD3 in the Fukuji area (using the topographical map "Yakedake" 1:25,000 published by the Geospatial Information Authority of Japan).

and discuss the age and palaeobiogeography of the fauna. In a previous study, Kamei (1952) reported the following brachiopods from the same locality of Fukuji: *Marginifera* sp., *Pustula* (*Echinoconchus*) sp., *Spirifer* sp., *Spirifer* (*Spiriferella*) cf. *salteri* Tchernyschew, *Squamulalia asiatica* Chao and *Dielasma* sp. The brachiopod specimens, however, remained undescribed.

In the present study, J. T. initiated the study and was primarily responsible for the taxonomic aspects. Y. I. and Y. M. studied the stratigraphy and collected the brachiopod fossil specimens.

Stratigraphy and material

The stratigraphy of the Mizuyagadani Formation in the Fukuji area has been studied by Kamei (1952), Igo (1956), Niikawa (1980), Niko et al. (1987), Harayama (1990), Tsukada et al. (1999) and Kurihara and Kametaka (2008). According to unpublished data of the present author (Y. I.), the Mizuyagadani Formation is subdivided into the lower part (alternating tuffaceous sandstone and tuffaceous shale, with some lenticular limestone blocks, 68 m thick), middle part (massive sandstone, with a conglomerate bed, 127 m thick) and upper part (alternating sandstone and shale, with some lenticular limestone blocks, 47 m thick), with a total thickness of 242 m (Fig. 2). The Mizuyagadani Formation is in fault contact with the underlying Ichinotani Formation (upper Visean–Uralian; Niikawa, 1980), and is in turn unconformably overlain by the Sorayama Formation (Middle Permian; Tsukada et al., 1999).

The brachiopod specimens were collected from greenish grey tuffaceous, partly

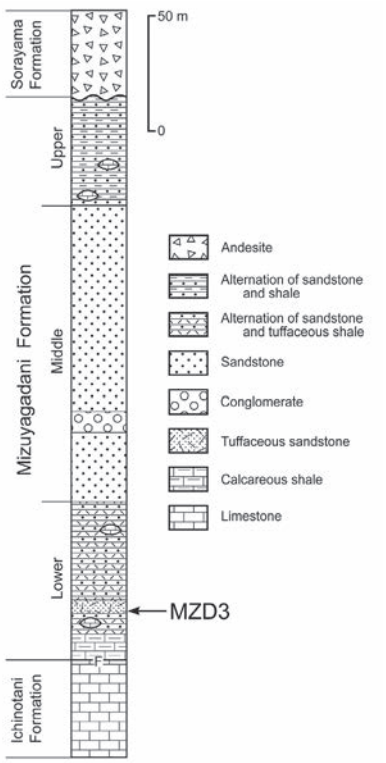

Fig. 2. Generalized columnar section of the Ichinotani, Mizuyagadani and Sorayama formations in the Fukuji area (modified from Niko et al., 1987), showing the fossil horizon of locality MZD3.

calcareous, fine-grained sandstone in alternating tuffaceous sandstone and tuffaceous shale, the basal part (about 20 m above from the base) of the Mizuyagadani Formation at locality MZD3 (36° 13 ' 5"N, 137° 30'35"E), lower Mizuyagadani Valley. The alternation of tuffaceous sandstone and tuffaceous shale is fossiliferous, and contains various kind of invertebrate fossils such as smaller foraminifers (Okimura et al., 1984), radiolarians (Niko et al., 1987; Kurihara and Kametaka, 2008), rugose corals (Igo, 1959), tabulate corals (Niko, 2001, 2011), brachiopods (Kamei, 1952; this study) and nautiloids (Okimura et al., 1984). The brachiopod specimens described below are registered and housed in the Faculty of Science, Niigata University, Niigata (prefix NU-B, numbers 2333–2362).

The Mizuyagadani fauna

The Mizuyagadani fauna includes nine species in eight genera: *Krotovia pustulata* (Keyserling, 1853), *Incisius incisus* (Schellwien, 1900), *Kutorginella* sp., *Vediproductus punctatiformis* (Chao, 1927), *Linoproductus* sp., *Acosarina dunbari* Cooper and Grant, 1976, *Acosarina* sp., *Jilinmartinia shansiensis* (Chao, 1929) and *Brachythyrina rectangula* (Kutorga, 1844). Among the species, *Brachythyrina rectangul*a is abundant, *Kutorginella* sp. and *Jilinmartinia shansiensis* are common, and the other species are rare.

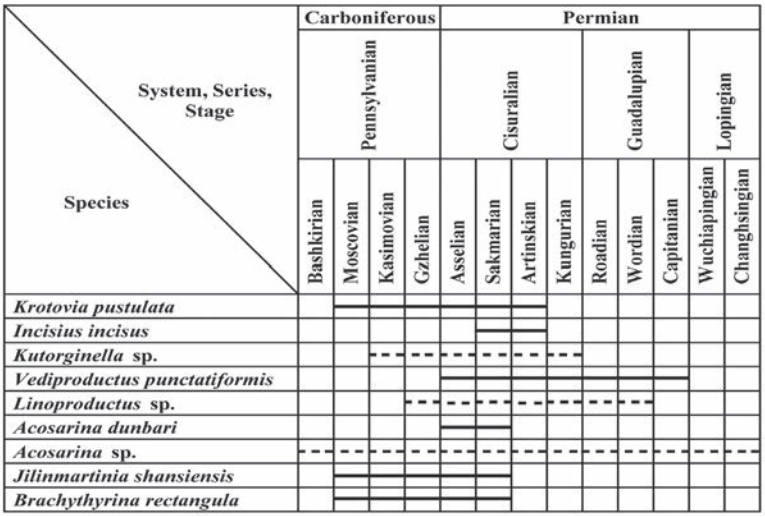

Fig. 3. Stratigraphic distributions of brachiopod species of the MD3 and ICT1 assemblages in the Mizuyagadani fauna. Broken lines show ranges of the genera.

Age

The stratigraphic distributions of the brachiopod species of the Mizuyagadani fauna are described in the section 'Systematic descriptions' and summarized in Fig. 3. Of the brachiopod taxa listed above, *Krotovia pustulata* is known to be from the Moscovian–Artinskian, *Incisius incisus* is known to be from the Sakmarian–Artinskian, *Vediproductus punctatiformis* occurs from the Asselian–Capitanian, *Acosarina dunbari* occurs from the Asselian–Sakmarian, and the other two species (*Jilinmartnia shansiensis* and *Brachythyrina rectangula*) occur from the Moscovian–Sakmarian. At the generic level, *Kutorginella* occurs from the Kasimovian–Kungurian (Brunton et al., 2000), *Linoproductus* from the Gzhelian–Wordian (Brunton et al., 2000), and *Acosarina* from the Bashkirian–Changhsingian (Williams and Harper, 2000). In summary, the Mizuyagadani fauna is identified as the Sakmarian, meaning that the basal part of the Mizuyagadani Formation is correlated with the Sakmarian.

Palaeobiogeography

The geographic distributions of the brachiopod species of the Mizuyagadani fauna are described in the section 'Systematic descriptions'. Palaeobiogeographically, *Krotovia pustulosa* is known to be from the USA, Canada, Russia, Kazakhstan and China; *Incisius incisus* is known to be from Slovenia and southern Thailand; *Vediproductus punctatiformis* is known to be from northeastern Japan (South Kitakami Belt) and both northern and southern China; *Acosarina dunbari* from only the USA (Nebraska); *Jilinmartinia shansiensis* from northwestern and northern China; and *Brachythyrina rectangula* from northern and central Russia, Uzbekistan, northwestern, northeastern and southern China, and southern Thailand. At the generic level, *Krotovia*, *Linoproductus* and *Brachythyrina* are cosmopolitan

genera (Muir-Wood and Cooper, 1960; Brunton *et al*., 2000; Carter, 2006); *Kutorginella* is also a cosmopolitan genus, but occurs commonly from the Boreal region (Bamber and Waterhouse, 1971; Kalashnikov, 1980, 1993; Sarytcheva, 1977); and both *Vediproductus* and *Acosarina* are Tethyan or Panthalassan genera inhabit in mostly the equatorial region (Brunton et al., 2000; Harper, 2000). In contrast, *Jilinmartinia* is a Boreal genus, that was recorded in arctic Canada (Carter and Poletaev, 1998), northern Russia (Kalashnikov, 1980) western Russia (Licharew, 1939), central Russia (Tschernyschew, 1902), Uzbekistan (Volgin, 1960), southern Mongolia (Pavlova, 1991) and northwestern–northeastern China (Chao, 1929; Lee and Gu, 1980; Wang and Yang, 1998). It is noteworthy that *Jilinmartinia shansiensis* is known to be from only northwestern China (Xinjiang and Gansu) and northern China (Shanxi), outside of central Japan (Fukuji in the Hida Gaien Belt). In summary, the Mizuyagadani fauna is a mixed Boreal–Tethyan fauna, and possesses affinity with those of northwestern and northern China.

Discussion and conclusion

From what has been discussed above, we can conclude that the age of the basal part of the Mizuyagadani Formation is Sakmarian on the basis of the Mizuyagadani fauna. This conclusion is consistent with that of Igo (1959) based on rugose corals (*Sochkineophyllum japonicum* Igo, *S. pauciseptatum* Igo, *Amandophyllum* sp., *Iranophyllum tunicatum* Igo, *Wentzelella osobudaniensis* Igo and *Lonsdaleiastraea*? sp.) and that of Niko et al. (1987) based on radiolarians [*Pseudoalbaillella lomentaria* Ishiga and Imoto, *P. longicornis* Ishiga and Imoto and *P. sakmarensis* (Kozur)]. On the other hand, Kurihara and Kametaka (2008) considered that the age of the basal part (at ich-07072, Kurihara and Kametaka, 2008) of the Mizuyagadani Formation to be identified as Asselian–Sakmarian on the basis of a radiolarian fauna, including *Pseudoalbaillella u-forma* Holdsworth and Jones, *P. chilensis* Ling and Forsythe, *P. elegans* Ishiga and Imoto, *P. simplex* Ishiga and Imoto, *P. lomentaria* Ishiga and Imoto and *P. sakmarensis* (Kozur).

In terms of palaeobiogeography, the Mizuyagadani fauna is a mixed Boreal–Tethyan fauna. Moreover, the fauna includes *Jilinmartinia shansiensis*, which is known from northwestern China (Xinjiang and Gansu), northern China (Shanxi) and central Japan (Fukuji in the Hida Gaien Belt). Thus, the Mizuyagadani fauna probably belonged to the Sino-Mongolian–Japanese Province (established by Shi and Tazawa, 2001; refigured by Tazawa and Araki, 2017, fig. 5; Fig. 4), which was characterized by a mixture of Boreal and Tethyan brachiopods, and covered a broad area of north to the North China Block in the Permian. This conclusion is consistent with that of Niko (2011), in which a tabulate coral, *Sinkiangopora kanumai* Niko, is described from the basal part of the Mizuyagadani Formation in the same fossil locality. According to Niko (2011), *Sinkiangopora* is known to be from Xizang (Tibet), northwestern China (Xinjiang), northeastern China (Heilongjiang and

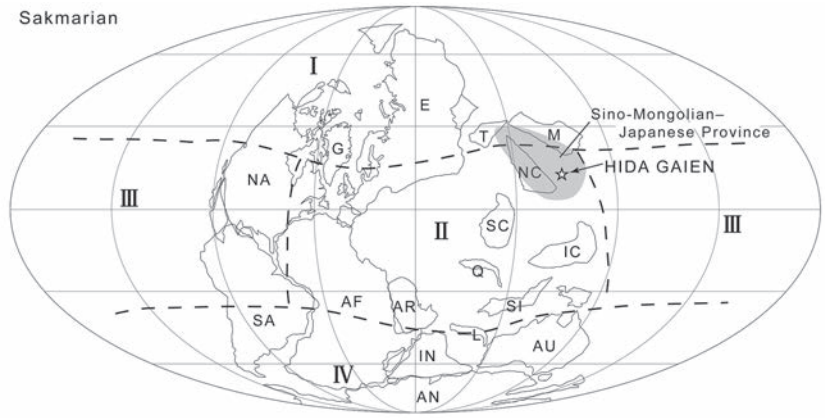

Fig. 4. Early Permian (Sakmarian) reconstruction map of the word, showing palaeoposition of the Hida Gaien area and the Sino-Mongolian–Japanese Province (modified and adapted from Tazawa and Araki, 2017). Ⅰ, Boreal Realm; Ⅱ, Tethyan Realm; Ⅲ, Panthalassan Realm; Ⅳ, Gondwanan Realm; AF, Africa; AN, Antarctica; AR, Arabia; AU, Australia; E, Eurasia; G, Greenland; IC, Indochina; IN, India; L, Lhasa; M, Mongolia; NA, North America; NC, North China; Q, Qiangtang; SA, South America; SC, South China; SI, Sibumasu; T, Tarim.

Jilin), central Japan (Omi in the Akiyoshi Belt) and southwestern Japan (Akiyoshi in the Akiyoshi Belt), all located in the anti-tropical region during the Permian.

Systematic descriptions

(by J. Tazawa)

Order Productida Sarytcheva and Sokolskaya, 1959
Suborder Productidina Waagen, 1883
Superfamily Productelloidea Schuchert, 1929
Family Avoniidae Sarytcheva in Sarytcheva et al., 1960
Subfamily Tubersulculinae Waterhouse, 1971
Genus *Krotovia* Fredericks, 1928

Type species.—*Productus spinulosus* Sowerby, 1814.

Krotovia pustulata (Keyserling, 1853)
Fig. 5D

Productus pustulatus Keyserling, 1853, p. 247; Tschernyschew, 1902, p. 271, 617, pl. 30, figs. 1, 2; pl. 53, fig. 6 only.

Krotovia pustulata (Keyserling). Chao, 1928, p. 52, pl. 5, figs. 18–20; Grabau, 1936, p. 150, pl. 14, fig. 4; Cooper, 1957, p. 33, pl. 8A, figs. 1–5; Muir-Wood and Cooper, 1960, pl. 50, figs. 6–9; Mironova, 1967, p. 14, pl. 1, figs. 16, 17; Sarytcheva, 1968, p. 79, pl. 5, fig. 9; Zavodowsky and Stepanov,

1970, p. 81, pl. 12, fig. 4; pl. 26, fig. 10 only; Waterhouse in Bamber and Waterhouse, 1971, pl. 15, fig. 21; pl. 16, fig. 2; Jin and Liao, 1974, p. 280, pl. 147, fig. 8; Lee and Gu, 1976, p. 241, pl. 134, fig. 3; pl. 140, fig. 12; Yang et al., 1977, p. 343, pl. 138, fig. 9; Feng and Jiang, 1978, p. 250, pl. 89, fig. 14; Alexandrov and Einor, 1979, p. 61, pl. 23, fig. 3; Kalashnikov, 1980, p. 41, pl. 8, figs. 6–9; Lee et al., 1980, p. 351, pl. 146, fig. 3; Zhang et al., 1983, p. 290, pl. 109, fig. 8; pl. 126, fig. 7; pl. 127, fig. 12; Kalashnikov, 1986, pl. 111, fig. 1; Shi and Waterhouse, 1996, p. 57, pl. 4, figs. 21–23; Wang and Yang, 1998, p. 68, pl. 3, figs. 14–17; Kuang et al., 1999, pl. 16, fig. 25.

Productus (*Avonia*) *pustulatus* Keyserling. Stepanov, 1948, p. 28, pl. 5, fig. 6.

Krotovia? *pustulata* (Keyserling). Sarytcheva in Sarytcheva and Sokolskaya, 1952, p. 93, pl. 14, fig. 100.

Avonia pustulata (Keyserling). Ustritsky and Tschernjak, 1963, p. 74, pl. 4, figs. 5, 6; Garanj et al., 1975, p. 161, pl. 64, fig. 9.

Material.—Two specimens: (1) external and internal moulds of a ventral valve, NU-B2337; and (2) internal mould of a ventral valve, NU-B2338.

Remarks.—The specimens available are referred to *Krotovia pustulata* (Keyserling, 1853), redescribed by Tschernyschew (1902, p. 271, 617, pl. 30, figs. 1, 2; pl. 53, fig. 5) from the Sakmarian of Ufa, southern Urals, in the relatively large, transverse and gently convex ventral valve (length about 24 mm, width about 38 mm in the better preserved specimen, NU-B2337), which is ornamented with numerous large, quincunxially arranged spine bases over the valve. *Krotovia jizodoensis* Tazawa (1980, p. 361, pl. 41, fig. 2), from the upper part of the Karaumedate Formation (upper Visean) of the Nagasaka area, South Kitakami Belt, northeastern Japan, differs from *K. pustulata* in much smaller size. The type species, *Krotovia spinulosa* (Sowerby, 1814), refigured by Muir-Wood and Cooper (1960, pl. 50, figs. 1–5) from the Visean of Cumberland, England, differs from the present species in much smaller size and less transverse outline.

Distribution.—Moscovian–Artinskian: central Japan (Fukuji in the Hida Gaien Belt), USA (Oregon), northern Canada (Yukon Territory), northern Russia (Kolyma Massif, Taimyr Peninsula and northern Urals), western Russia (Moscow Basin), central Russia (southern Urals), Kazakhstan, northwestern China (Xinjiang), northern China (Inner Mongolia), northeastern China (Liaoning), central-southern China (Guangxi) and southwestern China (Guizhou).

Superfamily Marginiferoidea Stehli, 1954
Family Marginiferidae Stehli, 1954
Subfamily Scapharininae Cooper and Grant, 1975
Genus *Incisius* Grant, 1976

Type species.—*Productus incisus* Schellwien, 1900.

Incisius incisus (Schellwien, 1900)
Fig. 5A

Productus incisus Schellwien, 1900, p. 54, pl. 8, figs. 3–5.
Incisius concisus Grant, 1976, p. 105, pl. 23, figs. 1–43; text-figs. 12, 13.

Material.—One specimen, a ventral valve, NU-B2351.

Remarks.—This specimen is referred to *Incisius incisus* (Schellwien, 1900, p. 54, pl. 8, figs. 3–5), from the Trogkofel Formation (Sakmarian) of Slovenia, in the small, slightly elongate and strongly convex ventral valve (length about 6 mm, width about 5 mm), which is narrow, widening anteriorly, having a deep sulcus, and ornamented with a row of large spine bases on each flank. *Incisius concisus* Grant (1976, p. 105, pl. 23, figs. 1–43, text-figs. 12, 13), from the Ratburi Formation of Ko Muk, southern Thailand, is deemed to be a junior synonym of *Incisius incisus*. *Incisus huatangensis* Liao and Meng (1986, p. 77, pl. 2, fig. 1), from the Changhsingian of Hunan, central-southern China, differs from *I. incisus* in much larger size.

Distribution.—Sakmarian–Artinskian: central Japan (Fukuji in the Hida Gaien Belt), Slovenia and southern Thailand (Ko Muk).

Superfamily Productoidea Gray, 1840
Family Productidae Gray, 1840
Subfamily Retariinae Muir-Wood and Cooper, 1960
Genus *Kutorginella* Ivanova, 1951

Type species.—*Kutorginella mosquensis* Ivanova, 1951.

Kutorginella sp.
Fig. 5B

Material.—Four specimens, incomplete four ventral valves, NU-B2347–2350.

Remarks.—These specimens can be assigned to the genus *Kutorginella* on account of the strongly convex ventral valve with faintly reticulate visceral disc and costate long trail, both of which having a broad and moderately deep sulcus. The Fukuji species resembles *Kutorginella yohi* (Chao, 1928, p. 60, pl. 5, figs. 13–17), from the Maping Formation of Guizhou, southwestern China, in size (length about 20 mm, width about 36 mm in the best preserved specimen, NU-B2347), shape and external ornament of the ventral valve, particularly in having relatively coarse costae (9–10 in 10 mm at midlength) on the trail. But accurate comparison is difficult for the poorly preserved specimens.

Superfamily Echinoconchoidea Stehli, 1954
Family Echinoconchidae Stehli, 1954
Subfamily Juresaniinae Muir-Wood and Cooper, 1960
Genus *Vediproductus* Sarytcheva in Sarytcheva and Sokolskaya, 1965

Type species.—*Vediproductus vediensis* Sarytcheva, 1965.

Vediproductus punctatiformis (Chao, 1927)
Fig. 6A

Echinoconchus punctatiformis Chao, 1927, p. 72, pl. 6, figs. 9–12; Yang et al., 1962, p. 52, pl. 20, figs. 1–3; Zhan and Lee, 1962, p. 477, pl. 2, fig. 9.
Bathymyonia punctatiformis (Chao). Feng and Jiang, 1978, p. 256, pl. 90, fig. 10.
Echinoconchus cf. *fasciatus* (Kutorga). Minato et al., 1979, pl. 65, figs. 5–7.
Vediproductus punctatiformis (Chao). Yang et al., 1977, p. 356, pl. 141, fig. 6; Tong, 1978, p. 225, pl. 79, fig. 16; Wang et al., 1982, p. 208, pl. 80, figs. 10, 11; pl. 84, fig. 4; Ding and Qi, 1983, p. 282, pl. 96, fig. 3; Wang, 1984, p. 190, pl. 76, fig. 7; Chang, 1987, p. 759, pl. 2, fig. 4; Liang, 1990, p. 187, pl. 27, fig. 5; Wang, 1995, pl. 1, fig. 20; Wang and Yang, 1998, p. 81, pl. 5, figs. 14–15, 18; Shiino, 2009, p. 255, fig. 4A–H; Tazawa, 2016, p. 19, figs. 7.1–7.5.

Material.—One specimen, a ventral valve, NU-B2336.

Description.—Shell medium in size for genus, elongate oval in outline, hinge slightly shorter than greatest width, which placed at slightly anterior to midlength; length 30 mm, width 23 mm in the sole ventral valve specimen (NU-B2336). Ventral valve strongly and unevenly convex in lateral profile, most convex at umbonal region, slightly convex at venter, roundly geniculated, and followed by a long trail; umbo small, incurved and followed by narrow, strongly convex umbonal slope; ears small; sulcus originating slightly anterior to umbo, narrow and shallow; venter broad, nearly flattened with steep lateral slopes in anterior profile. External surface of ventral valve ornamented with numerous, strong and regular concentric bands (4 in 10 mm at about midlength) with rows of spine bases on each front; spine bases consisting of larger elongate spines and more numerous smaller spines.

Remarks.—This specimen is referred to *Vediproductus punctatiformis* (Chao, 1927, p. 72, pl. 6, figs. 9–12), from the Ksiaokiang Limestone (lower Maokouan) of Jiangxi, eastern China, in the medium-sized, elongate oval and strongly convex ventral valve, ornamented with numerous regular spinose bands. Shen et al. (2002, p. 673) regarded the type species, *Vediproductus vediensis* Sarytcheva (1965, p. 221, pl. 35, figs. 1–3, text-fig. 33), from the Gnishik Horizon of Transcaucasus, as a junior synonym of *V. punctatiformis*. But the former differs from the latter in less convex and transversely wider ventral valve and broader

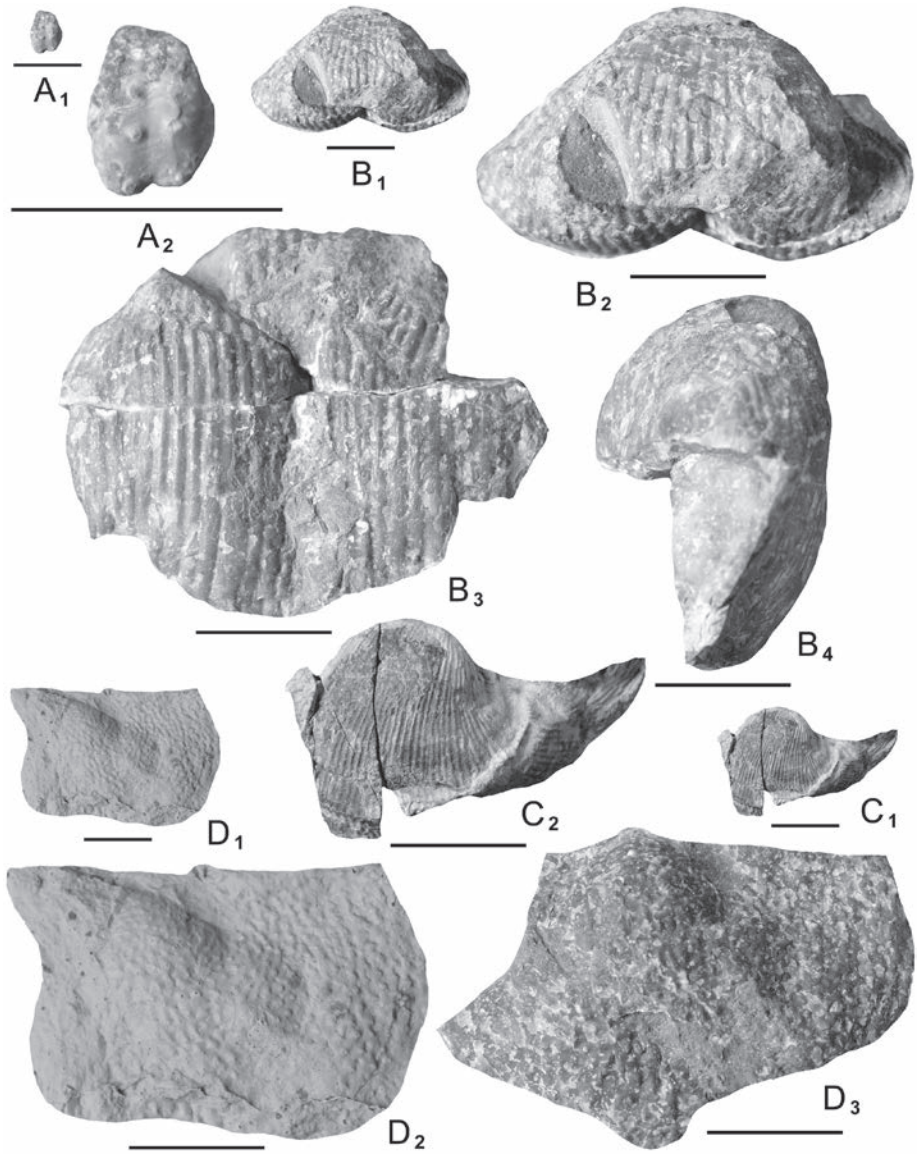

Fig. 5. Brachiopods of the Mizuyagadani fauna (1). **A,** *Incisius incisus* (Schellwien), ventral view (A_1, A_2) of ventral valve, NU-B2351; **B,** *Kutorginella* sp., ventral (B_1, B_2), anterior (B_3) and lateral (B_4) views of ventral valve, NU-B2347; **C,** *Linoproductus* sp., ventral view (C_1, C_2) of ventral valve, NU-B2352; **D,** *Krotovia pustulata* (Keyserling), external latex cast (D_1, D_2) and internal mould (D_3) of ventral vave, NU-B2337. Scale bars are 1 cm.

concentric bands on the valve. Shells described by Campi et al. (2005, p. 115, pl. 2, figs. B–C, E, H–P. text-figs. 6, 7) as *Vediproductus punctatiformis* (Chao) from the Capitanian–Wuchiapingian of Pahang, Malaysia, are deemed to be *V. vediensis*.

Distribution.—Asselian–Capitanian: northeastern Japan (Kamiyasse–Imo in the South Kitakami Belt), central Japan (Fukuji in the Hida Gaien Belt), northwestern China (Xinjiang,

Qinghai and Gansu), eastern China (Anhui, Zhejiang and Jiangxi), central southern China (Hubei) and southwestern China (Guizhou and Sichuan).

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. 5C

Material.—One specimen, an incomplete ventral valve, NU-B2352.

Remarks.—The single incomplete ventral valve specimen from Fukuji can be assigned to the genus *Linoproductus* on account of its medium size (length more than 17 mm, width about 35 mm), subcircular outline with the widest part at hinge, and external ornament consisting of numerous costellae (10–11 in 5 mm at 10 mm anterior to umbo) over the ventral valve. However, specific identification is difficult for the poorly preserved specimen.

Order Orthida Schuchert and Cooper, 1932
Suborder Dalmanellidina Moore, 1952
Superfamily Enteletoidea Waagen, 1884
Family Schizophoriidae Schuchert and LeVene, 1929
Genus *Acosarina* Cooper and Grant, 1969

Type species.—*Acosarina dorsisulcata* Cooper and Grant, 1969.

Acosarina dunbari Cooper and Grant, 1976
Fig. 6B

Acosarina dunbari Cooper and Grant, 1976, p. 2622, pl. 670, figs. 1–8.

Material.—One specimen, external mould of a ventral valve, NU-B2344.

Remarks.—This specimen is referred to *Acosarina dunbari* Cooper and Grant (1976, p. 2622, pl. 670, figs. 1–8), from the Foraker Limestone (lower Wolfcampian) of Nebraska, the USA, in the small and slightly transverse ventral valve (length 8 mm, width 10 mm), which is strongly convex at posterior half but flattened anteriorly, and ornamented with several

strong concentric lamellae besides numerous fine costellae (numbering 3 in 1 mm at about midlength of the valve). *Acosarina* cf. *dunbari* Cooper and Grant, described by Tazawa and Oyagi (2019, p. 35, figs. 3G–J) from the upper part of the Ryozensan Formation of Ryozensan, Mino Belt, southwestern Japan, differs from the present species in being slightly larger in size and in having finer costellae on the ventral valve.

Distribution.—Asselian–Sakmarian: central Japan (Fukuji in the Hida Gaien Belt) and USA (Nebraska).

Acosarina sp.
Fig. 6C, D

Material.—Three specimens: (1) a ventral valve, NU-B2359; (2) external mould of a ventral valve, NU-B2345; and (3) internal mould of a ventral valve, NU-B2346.

Remarks.—These specimens can be assigned to the genus *Acosarina* by the small, subcircular and moderately convex ventral valve (length 5 mm, width 6 mm in the largest specimen, NU-B2345), having no sulcus, and ornamented with numerous costellae (3 in 1 mm at midlength). The Fukuji species somewhat resembles *Acosarina rectimarginata* Cooper and Grant (1976, p. 2624, pl. 674, figs. 1–46), from the Neal Ranch Formation (lower Wolfcampian) of the Glass Mountains, Texas, in the small size and rectimarginate anterior commissure, but differs from the Texan species in having coarser costellae on the ventral valve. Specific identification is difficult for the poorly preserved specimens.

Order Spiriferida Waagen, 1883
Suborder Spiriferidina Waagen, 1883
Superfamily Martinioidea Waagen, 1883
Family Martiniidae Waagen, 1883
Subfamily Martiniinae Waagen, 1883
Genus *Jilinmartinia* Lee and Gu, 1980

Type species.—*Brachythyris shansiensis* Chao, 1929.

Jilinmartinia shansiensis (Chao, 1929)
Fig. 7A–C

Brachythyris shansiensis Chao, 1929, p. 55, pl. 9, figs. 1–3.
Martinia shansiensis (Chao). Yang, 1948, p. 207, pl. 2, figs. 19, 20; Zhang et al., 1983, p. 371, pl. 144, fig. 5.
"*Martinia*" *shansiensis* (Chao). Wang et al., 1964, p. 564, pl. 109, fig. 28.

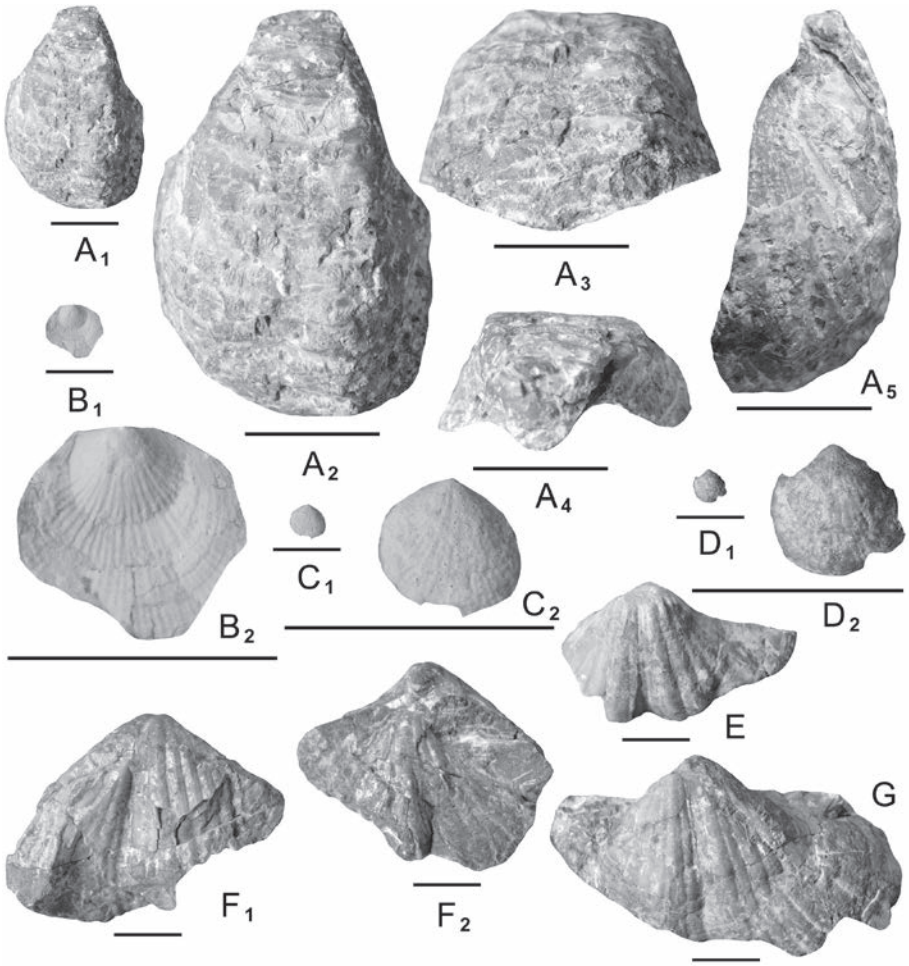

Fig. 6. Brachiopods of the Mizuyagadani fauna (2). **A,** *Vediproductus punctatiformis* (Chao), ventral (A_1, A_2), anterior (A_3), posterior (A_4) and lateral (A_5) views of ventral valve, NU-B2336; **B,** *Acosarina dunbari* Cooper and Grant, external latex cast (B_1, B_2) of ventral valve, NU-B2344; **C, D,** *Acosarina* sp.; external latex cast (C_1, C_2) of ventral valve, NU-B2345; internal mould (D_1, D_2) of ventral valve, NU-B2346; **E–G,** *Brachythyrina rectangula* (Kutorga); E, ventral view of ventral valve, NU-B2341; ventral (F_1) and dorsal (F_2) views of conjoined shell, NU-B2339; G, ventral view of ventral valve, NU-B2340. Scale bars are 1 cm.

Jilinomartinia shansiensis (Chao). Lee and Duan, 1985, p. 258, pl. 79, fig. 6; Wang and Yang, 1998, p. 129, pl. 22, figs. 20–22.

Jilinmartinia shansiensis (Chao). Shen et al., 2017, pl. P28, figs. 16–18.

Material.—Five specimens: (1) external and internal moulds of a ventral valve, NU-B2333; (2) ventral valve, NU-B2353; (3) external mould of a ventral valve, NU-B2334; and (4) internal moulds of two ventral valves, NU-B2335, 2354.

Description.—Shell medium in size for genus, transversely subelliptical in outline; hinge slightly shorter than maximum width at about midlength; cardinal extremities rounded; length

36 mm, width about 57 mm in the largest specimen (NU-B2334). Ventral valve strongly and unevenly convex in lateral profile, most convex at umbonal region; sulcus broad and shallow. External surface of ventral valve nearly smooth, except for faint concentric growth lines over valve. Internal structures of ventral valve not well preserved, except for a large muscle scar.

Remarks.—These specimens are referred to *Jilinmartinia shansiensis* (Chao, 1929), originally described by Chao (1929, p. 55, pl. 9, figs. 1–3) as *Brachythyris shansiensis* Chao, 1929, from the Lichiachuan Formation of Gansu, northwestern China and from the Miaokou Formation of Shanxi, northern China, in the large, transverse ventral valve which is ornamented with faint concentric growth lines. *Jilinmartinia sokolovi* (Tschernyschew, 1902, p. 166, pl. 8, fig. 3; pl. 39, fig. 4), from the Asselian of the Urals, central Russia, differs from *J. shansiensis* by its larger dimensions and in having ventral sulcus with a low median fold.

Distribution.—Moscovian–Sakmarian: central Japan (Fukuji in the Hida Gaien Belt), northwestern China (Xinjiang and Gansu) and northern China (Shanxi).

Superfamily Spiriferoidea King, 1846
Family Choristitidae Waterhouse, 1968
Subfamily Angiospiriferinae Legrand-Blain, 1985
Genus *Brachythyrina* Fredericks, 1929

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

Brachythyrina rectangula (Kutorga, 1844)
Fig. 6E–G

Spirifer rectangulus Kutorga, 1844, p. 90, pl. 9, fig. 5; Tschernyschew, 1902, p. 158, 545, pl. 8, fig. 1; pl. 41, figs. 1–5; Waterhouse et al., 1981, p. 96, pl. 21, figs. 1–14; pl. 22, figs. 1–8; pl. 23, fig. 1.
Brachythyrina rectangula (Kutorga). Chao, 1929, p. 60, pl. 8, fig. 3; Nelzina, 1965, p. 67, pl. 10, figs. 1, 5; Sergunkova and Zhizhilo, 1975, p. 75, pl. 16, fig. 2; Prokofiev, 1975, p. 101, pl. 21, fig. 1; Yang et al., 1977, p. 439, pl. 175, fig. 1; Lee and Gu, 1980, p. 488, pl. 1, fig. 16; Lee et al., 1980, p. 408, pl. 154, fig. 9; Gu, 1992, p. 248, pl. 79, figs. 21, 23; Wang, 1995, pl. 3, fig. 12; Wang and Yang, 1998, p. 116, pl. 18, figs. 7, 9, 17; Kuang et al., 1999, pl. 18, fig. 7.
Spirifer (*Brachythyrina*) *rectangulus* Kutorga. Grabau, 1936, p. 208, pl. 20, fig. 7.

Material.—Five specimens: (1) internal mould of a conjoined shell, with external mould of the ventral valve, NU-B2339; and (2) external and internal moulds of four ventral valves, NU-B2340–2343.

Remarks.—The specimens from Fukuji are represented by large, transverse ventral valves (length 35 mm, width 53 mm in the largest specimen, NU-B2340), ornamented with

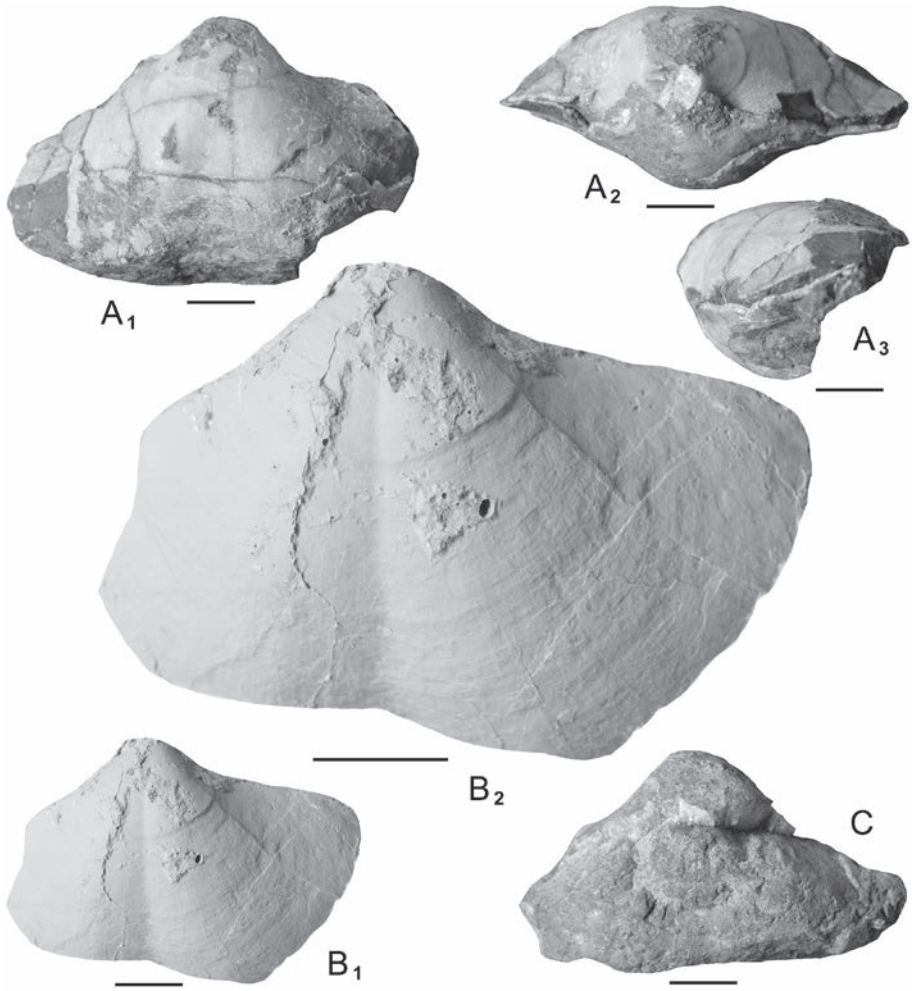

Fig. 7. Brachiopods of the Mizuyagadani fauna (3). **A–C,** *Jilinmartinia shansiensis* (Chao); ventral (A_1), posterior (A_2) and lateral (A_3) views of conjoined shell, NU-B2353; external latex cast (B_1, B_2) of ventral valve, NU-B2334; C, internal mould of ventral valve, NU-B2354. Scale bars are 1 cm.

numerous, simple, strong costae and finely and regularly cancellate microornament. These specimens are referred to *Brachythyrina rectangula* (Kutorga, 1844), redescribed by Tschernyschew (1902, p. 158, 545, pl. 8, fig. 1; pl. 41, figs. 1–5), from the Sakmarian of the Urals, on account of size, shape and external ornament of the ventral valve. The type species, *Brachythyrina strangwaysi* (de Verneuil, 1845), redescribed by Sokolskaya (in Sarytcheva and Sokolskaya, 1952, p. 189, pl. 53, fig. 305) from the Moscovian–Gzhelian of the Moscow Basin, differs from *B. rectangula* in the much smaller size. *Brachythyrina* cf. *arctica* Gobbett, 1963, described by Tazawa and Nakamura (2015, p. 172, figs. 9.6, 9.7) from the Hosoo Formation (Kungurian) of Nakadaira, South Kitakami Belt, northeastern Japan, is readily distinguished from the present species by the smaller and less transverse ventral valve.

Distribution.—Moscovian–Sakmarian: central Japan (Fukuji in the Hida Gaien Belt), northern Russia (Onega), central Russia (western and southern Urals), Uzbekistan (Fergana), northwestern China (Xinjiang), northeastern China (Jilin), central-southern China (Guangxi), southwestern China (Guizhou) and southern Thailand (Ko Yao Noi).

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