

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

Jun-ichi TAZAWA*, Yousuke IBARAKI** and Yukio MIYAKE***

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),

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

** Fossa Magna Museum, Itoigawa 941-0056, Japan

*** Ichinomiya-machi 331-1, Takayama 509-3505, Japan

Corresponding author: J. Tazawa,

j1025-tazawa@memoad.jp

(Manuscript received 31 January, 2022; accepted 25 February, 2022)

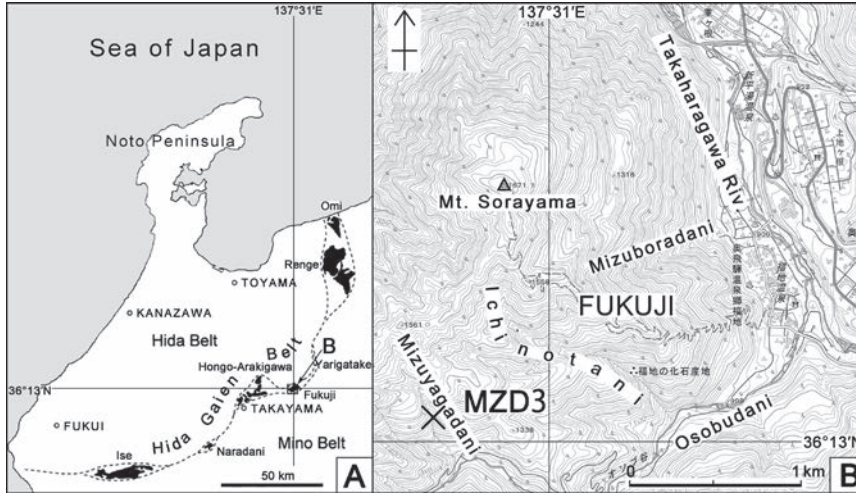


Fig. 1. Maps showing the fossil locality MZD3 in the Fukuji area, Hida Gaien Belt, central Japan: **A**, Geotectonic map of the north-central part of Honshu, showing the distribution of the Hida Gaien Belt (after Tazawa, 2004); **B**, Topographic map showing the fossil locality MZD3 in the Fukuji area (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 Viséan–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

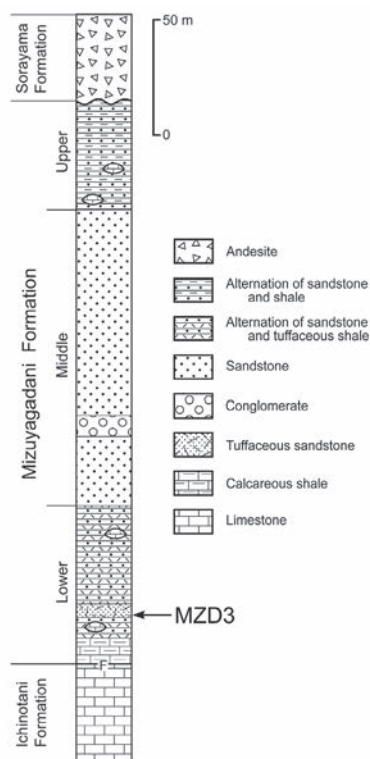


Fig. 2. Generalized columnar section of the Ichinotani, Mizuyagadani and Sorayama formations in the Fukuji area (modified from Niko et al., 1987), showing the fossil horizon of locality MZD3.

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., *Jilimartinia shansiensis* (Chao, 1929) and *Brachythyrina rectangula* (Kutorga, 1844). Among the species, *Brachythyrina rectangula* is abundant, *Kutorginella* sp. and *Jilimartinia shansiensis* are common, and the other species are rare.

System, Series, Stage Species	Carboniferous					Permian						
	Pennsylvanian					Cisuralian			Guadalupian		Lopingian	
	Bashkirian	Moscovian	Kasimovian	Gzhelian	Asselian	Sakmarian	Artinskian	Kungurian	Roadian	Wordian	Capitanian	Wuchiapingian
<i>Krotovia pustulata</i>												
<i>Incisius incisus</i>												
<i>Kutorginella</i> sp.			-----									
<i>Vediproductus punctatiformis</i>												
<i>Linoproductus</i> sp.			-----									
<i>Acosarina dunbari</i>												
<i>Acosarina</i> sp.	-----											
<i>Jilinmartinia shansiensis</i>												
<i>Brachythyryna rectangula</i>												

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 (*Jilinmartinia shansiensis* and *Brachythyryna 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 *Brachythyryna rectangula* from northern and central Russia, Uzbekistan, northwestern, northeastern and southern China, and southern Thailand. At the generic level, *Krotovia*, *Linoproductus* and *Brachythyryna* 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 Gaïen 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 Gaïen 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

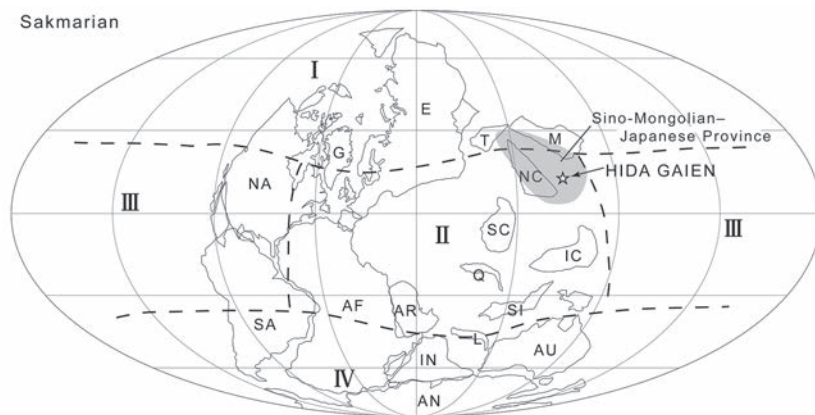


Fig. 4. Early Permian (Sakmarian) reconstruction map of the world, showing palaeoposition of the Hida Gaien area and the Sino-Mongolian-Japanese Province (modified and adapted from Tazawa and Araki, 2017). I, Boreal Realm; II, Tethyan Realm; III, Panthalassan Realm; IV, Gondwanan Realm; AF, Africa; AN, 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; Zavadowsky 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

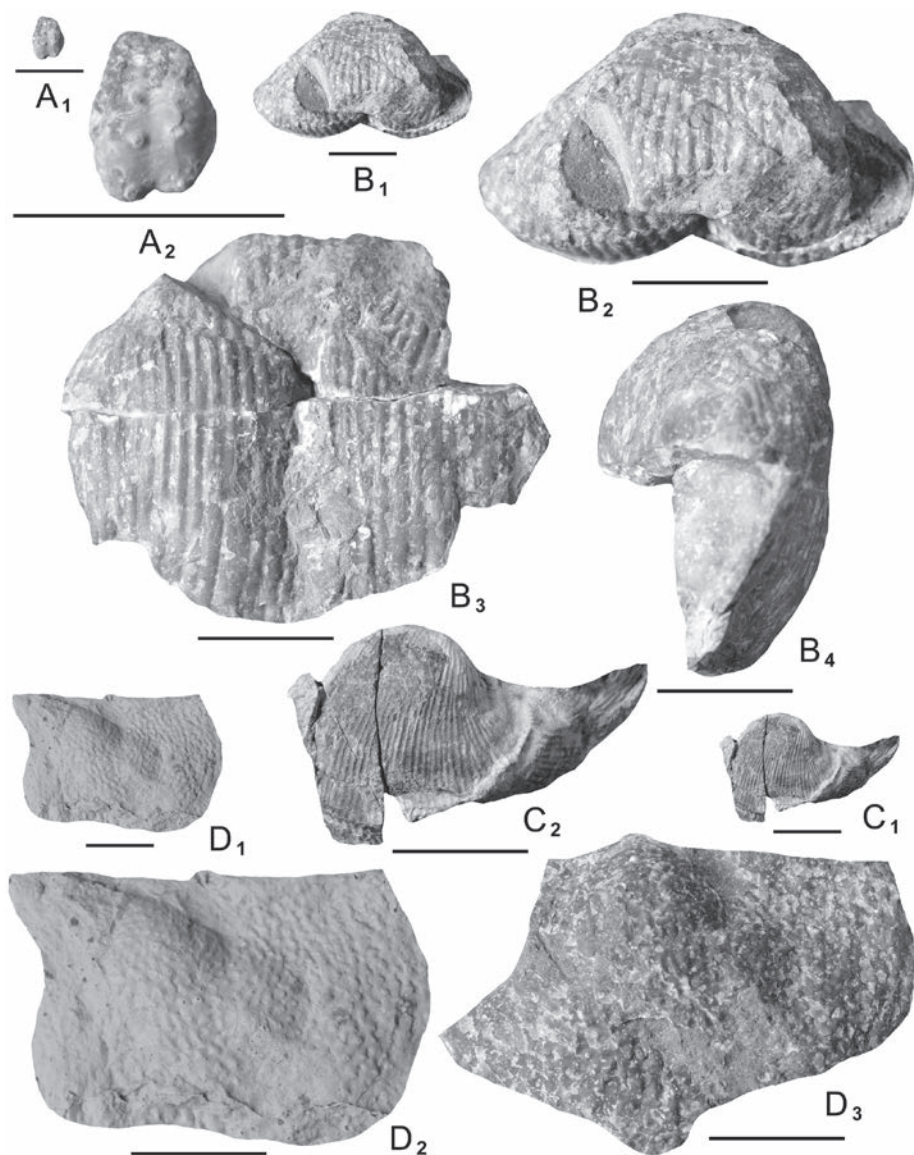


Fig. 5. Brachiopods of the Mizuyagadani fauna (1). **A**, *Incisius incisus* (Schellwien), ventral view (A₁, A₂) of ventral valve, NU-B2351; **B**, *Kutorginella* sp., ventral (B₁, B₂), anterior (B₃) and lateral (B₄) views of ventral valve, NU-B2347; **C**, *Linoproductus* sp., ventral view (C₁, C₂) of ventral valve, NU-B2352; **D**, *Krotovia pustulata* (Keyserling), external latex cast (D₁, D₂) and internal mould (D₃) of ventral valve, 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 Martinioidae 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.

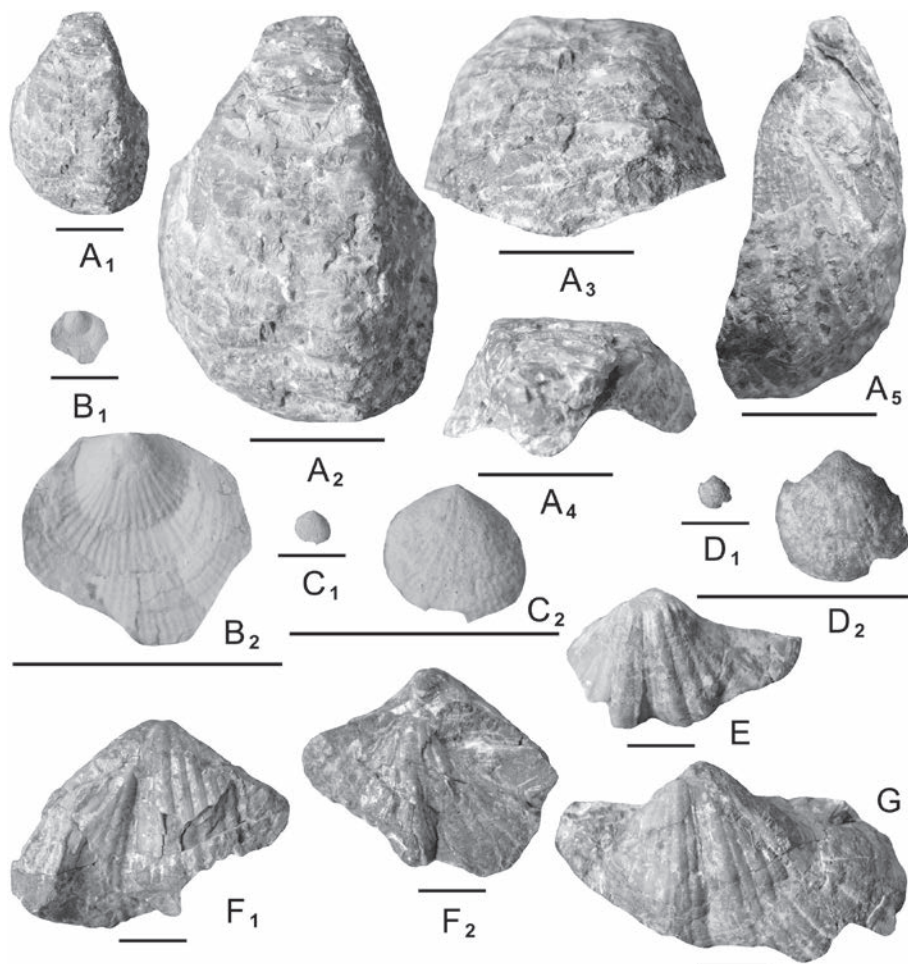


Fig. 6. Brachiopods of the Mizuyagadani fauna (2). **A**, *Vediproductus punctatiformis* (Chao), ventral (A₁, A₂), anterior (A₃), posterior (A₄) and lateral (A₅) views of ventral valve, NU-B2336; **B**, *Acosarina dunbari* Cooper and Grant, external latex cast (B₁, B₂) of ventral valve, NU-B2344; **C**, **D**, *Acosarina* sp.; external latex cast (C₁, C₂) of ventral valve, NU-B2345; internal mould (D₁, D₂) of ventral valve, NU-B2346; **E-G**, *Brachythyrina rectangula* (Kutorga); **E**, ventral view of ventral valve, NU-B2341; ventral (F₁) and dorsal (F₂) views of conjoined shell, NU-B2339; **G**, ventral view of ventral valve, NU-B2340. Scale bars are 1 cm.

Jilinmartinia 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

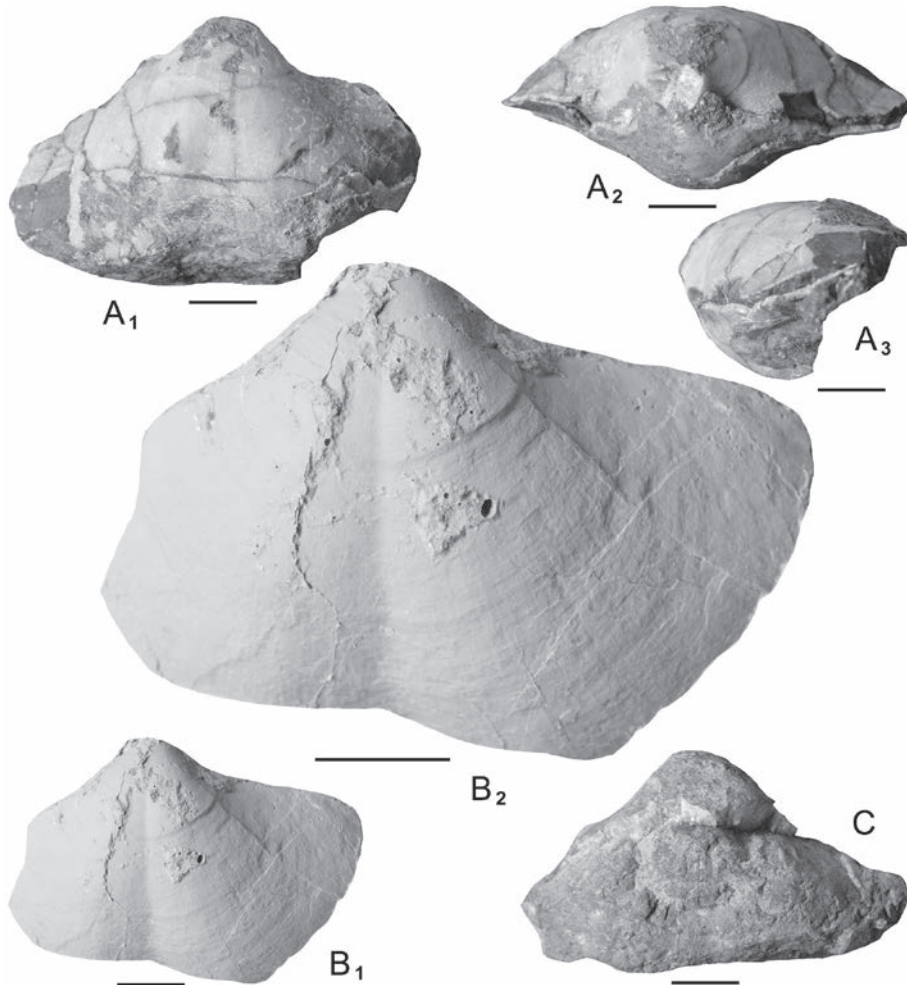


Fig. 7. Brachiopods of the Mizuyagadani fauna (3). **A-C**, *Jilinmartinia shansiensis* (Chao); ventral (**A₁**), posterior (**A₂**) and lateral (**A₃**) views of conjoined shell, NU-B2353; external latex cast (**B₁**, **B₂**) of ventral valve, NU-B2334; **C**, internal mould of ventral valve, NU-B2354. Scale bars are 1 cm.

numerous, simple, strong costae and finely and regularly cancellate microornament. These specimens are referred to *Brachythyryna 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, *Brachythyryna 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. *Brachythyryna* 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 Gaian 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).

Acknowledgements

We sincerely thank Atsushi Matsuoka (Faculty of Science, Niigata University, Niigata) and an anonymous reviewer for their valuable comments and suggestions on the manuscript.

References

- Alexandrov, V. A. and Einor, O. L., 1979, Brachiopoda. In Einor, O. L., ed., *Atlas of the Middle–Upper Carboniferous Fauna and Flora of Bashkiria*. Nedra, Moskva, 55–97 (in Russian).
- Bamber, E. W. and Waterhouse, J. B., 1971, Carboniferous and Permian stratigraphy and paleontology, northern Yukon Territory, Canada. *Bull. Can. Petr. Geol.*, **19**, 29–250.
- Brunton, C. H. C., Lazarev, S. S., Grant, R. E. and Jin, Y.-G., 2000, Productidina. In Kaesler, R. L., ed., *Treatise on Invertebrate Paleontology, Part H Brachiopoda Revised, Volume 3: Linguliformea, Craniiformea, and Rhynchonelliformea (Part)*. Geol. Soc. Amer., Boulder and Univ. Kansas, Lawrence, 424–609.
- Campi, M. J., Shi, G. R. and Leman, M. S., 2005, Guadalupian (Middle Permian) brachiopods from Sungai Toh, a *Leptodus* Shale locality in the Central Belt of Peninsular Malaysia. *Palaeontographica, Abt. A*, **273**, 97–160.
- Carter, J. L., 2006, Spiriferoidea. In Kaesler, R. L., ed., *Treatise on Invertebrate Paleontology, Part H Brachiopoda Revised, Volume 5: Rhynchonelliformea (Part)*. Geol. Soc. Amer., Boulder and Univ. Kansas, Lawrence, 1769–1811.
- Carter, J. L. and Poletaev, V. I., 1998, Atokan (late Bashkirian or early Moscovian) brachiopods from the Hare Fiord Formation of Ellesmere Island, Canadian Arctic Archipelago. *Ann. Carnegie Mus.*, **67**, 105–180.
- Chang, M.-L., 1987, Fossil Brachiopoda from Chihsia Formation, Anqing, Anhui. *Acta Palaeont. Sin.*, **26**, 753–766 (in Chinese).
- Chao, Y.-T., 1927, Productidae of China, Part 1. Producti. *Palaeont. Sin., Ser. B*, **5**, fasc. 2, 1–244.
- Chao, Y.-T., 1928, Productidae of China, Part 2. Chonetinae, Productinae and Richthofeninae. *Palaeont. Sin., Ser. B*, **5**, fasc. 3, 1–103.
- Chao, Y.-T., 1929, Carboniferous and Permian spiriferids of China. *Palaeont. Sin., Ser. B*, **11**, 1–133.
- Cooper, G. A., 1957, Permian brachiopods from central Oregon. *Smithson. Miscel. Col.*, **134**, 1–79.
- 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., 1975, Permian brachiopods of West Texas, 3. *Smithson. Contr. Paleobiol.*, no. 19, 795–1922.
- Cooper, G. A. and Grant, R. E., 1976, Permian brachiopods of West Texas, 5. *Smithson. Contr. Paleobiol.*, no. 24, 2609–3160.
- Ding, P.-Z. and Qi, W.-T., 1983, Phylum Brachiopoda (Carboniferous and Permian). In Xian Institute of Geology and Mineral Resources, ed., *Palaeontological Atlas of Northwest China; Shaanxi, Gansu and Ningxia Volume, Part 2. Upper Palaeozoic*. Geol. Publ. House, Beijing, 244–425 (in Chinese).
- Feng, R.-L. and Jiang, Z.-L., 1978, Phylum Brachiopoda. In Working Group of Stratigraphy and Palaeontology of Guizhou Province, ed., *Palaeontological Atlas of Southwestern China, Guizhou Volume 2*. Geol. Publ. House, Beijing, 231–304 (in Chinese).
- Fredericks, G., 1928, Contribution to the classification of the genus *Productus* Sow. *Izv. Geol. Kom.*, **46**, 773–792 (in Russian).

- Fredericks, G., 1929, Fauna of the Kyn Limestone of the Urals. *Izv. Geol. Kom.*, **48**, 369–413 (in Russian).
- Garanj, I. M., Guseva, S. N., Devingtal, V. V., Donakova, L. M., Enokyan, N. V., Kalashnikov, N. V., Lapina, N. N., Mikhaylova, E. N., Nalivkin, D. V., Semichatova, S. V., Stepanov, D. I., Stepanova, G. A., Shestakova, M. F. and Einor, O. L., 1975, Brachiopoda. In Stepanov, D. L., Krylova, A. K., Grozdnilova, L. P., Pozner, V. M. and Sultanaev, A. A., eds., *Palaeontological Atlas of the Carboniferous Deposits of the Urals*. Nedra, Leningrad, 154–203 (in Russian).
- Gobbett, D. J., 1963, Carboniferous and Permian brachiopods of Svalbard. *Norsk Polarinst. Skrift*, **127**, 1–201.
- Grabau, A. W., 1936, Early Permian fossils of China, Part 2. Fauna of the Maping Limestone of Kwangsi and Kweichow. *Palaeontol. Sin., Ser. B*, **8**, fasc. 4, 1–441.
- Grant, R. E., 1976, Permian brachiopods from southern Thailand. *Jour. Paleont.*, **56**, sup. no. 3, 1–269.
- Gray, J. E., 1840, *Synopsis of the Contents of the British Museum, 42nd Edition*. British Mus., London, 370 p.
- Gu, F., 1992, Carboniferous and Permian Brachiopoda. In Jilin Institute of Geology and Mineral Resources, ed., *Paleontological Atlas of Jilin*. Jilin Sci. Tech. Publ. House, Changchun, 210–255 (in Chinese).
- Harayama, S., 1990, *Geology of the Kamikochi District, with Geological Sheet Map at 1: 50,000*. Geol. Surv. Japan, Tsukuba, 175 p. (in Japanese).
- Harper, D. A. T., 2000, Dalmanellidina. In Kaesler, R. L., ed., *Treatise on Invertebrate Paleontology, Part H Brachiopoda Revised, Vol. 3: Linguliformea, Craniiformea, and Rhynchonelliformea (Part)*. Geol. Soc. Amer., Boulder and Univ. Kansas, Lawrence, 782–844.
- Igo, H., 1956, On the Carboniferous and Permian of the Fukuji district, Hida Massif, with special reference to the fusulinid zones of the Ichinotani Group. *Jour. Geol. Soc. Japan*, **62**, 217–240 (in Japanese).
- Igo, H., 1959, Note on some Permian corals from Fukuji, Hida Massif, central Japan. *Trans. Proc. Palaeont. Soc. Japan, N. S.*, no. 34, 79–85.
- Ivanova, E. A., 1951, New data on productid systematics (genus *Kutorginella*). *Compt. Rendu. Acad. Sci. USSR*, **77**, 329–331 (in Russian).
- Jin, Y.-G. and Liao, Z.-T., 1974, Descriptions of Fossils; Carboniferous Brachiopoda. In Nanjing Inst. Geol. Palaeont., Chin. Acad. Sci., ed., *Handbook of Stratigraphy and Palaeontology in Southwest China*. Sci. Press, Beijing, 308–313 (in Chinese).
- Kalashnikov, N. V., 1980, *Brachiopods of the Upper Palaeozoic of European Siberia, USSR*. Nauka, Leningrad, 132 p. (in Russian).
- Kalashnikov, N. V., 1986, Systematic descriptions; Brachiopoda. In Gorsky, V. P. and Kalmykova, M. A., eds., *Atlas of Characteristic Permian Fauna and Flora of the Russian Platform*. VSEGEI, Nedra, Leningrad, 89–94 (in Russian).
- Kalashnikov, N. V., 1993, *Permian Brachiopods of European Northern Russia*. Nauka, Sanct-Peterburg, 114 p. (in Russian).
- Kamei, T., 1952, The stratigraphy of the Palaeozoic rocks of the Fukuji district, southern part of Hida Mountainland. *Jour. Fac. Liber. Arts, Shinshu Univ., Ser. 1*, no. 2, 43–74.
- Keyserling, A., 1853, Sur les fossiles du calcaire carbonifère de Sterlitamak (Russie). *Bull. Soc. Géol. France, 2e Ser.*, **10**, 242–254.
- King, W., 1846, Remarks on certain genera belonging to the class Palliobranchiata. *Ann. Mag. Nat. Hist., London, Ser. 1*, **18**, 26–42, 83–94.
- Kuang, G.-D., Li, J.-X., Zhong, K., Su, Y.-B. and Tao, Y.-B., 1999, *Stratigraphy of Guangxi, China, Part 2. Carboniferous of Guangxi*. China Univ. Geosci. Wuhan, 258 p. (in Chinese).
- Kurihara, T. and Kametaka, M., 2008, Radiolaria-dated Lower Permian clastic-rock sequence in the Fukuji area of the Hida-gaien terrane, central Japan, and its inter-terrane correlation across Southwest Japan. *Island Arc*, **17**, 521–545.
- Kutorga, S. S., 1844, Zweiter Beitrag zur Paleontologie Russlands. *Russ.-Kaiser. Min. Gesel. St. Petersburg, Verhandl., 1844*, 62–104.
- Lee, L. and Duan, C.-H., 1985, Phylum Brachiopoda. In Tianjin Institute of Geology and Mineral Resources, ed., *Palaeontological Atlas of North China, 1. Palaeozoic Volume*. Geol. Publ. House, Beijing, 209–260 (in Chinese).
- Lee, L. and Gu, F., 1976, Carboniferous and Permian Brachiopoda. In Geological Bureau of Nei Mongol and Geological Institute of Northeast China, eds., *Palaeontological Atlas of Northeast China, Nei Mongol, Part*

1. *Palaeozoic Volume*. Geol. Publ. House, Beijing, 228–306 (in Chinese).
- Lee, L. and Gu, F., 1980, Late Carboniferous brachiopods from Yanji of Jilin, NE China. *Acta Palaeont. Sin.*, **19**, 483–491 (in Chinese).
- Lee, L., Gu, F. and Su, Y.-Z., 1980, Carboniferous and Permian Brachiopoda. In Shenyang Institute of Geology and Mineral Resources, ed., *Palaeontological Atlas of Northeast China, Part 1 Palaeozoic Volume*. Geol. Publ. House, Beijing, 327–428 (in Chinese).
- Legrand-Blain, M., 1985, A new genus of Carboniferous spiriferid brachiopod from Scotland. *Palaeontology*, **28**, 567–575.
- Liang, W.-P., 1990, *Lengwu Formation of Permian and its Brachiopod Fauna in Zhejiang Province*. Geol. Publ. House, Beijing, 522 p. (in Chinese).
- Liao, Z.-T. and Meng, F.-Y., 1986, Late Chanxingian brachiopods from Huatang of Chen Xian County, southern Hunan. *Mem. Nanjing Inst. Geol. Palaeont., Acad. Sin.*, no. 22, 73–94 (in Chinese).
- Licharew, B., 1939, Class Brachiopoda. In Gorsky, I., ed., *The Atlas of the Leading Forms of the Fossil Faunas of USSR*. Gonti, Leningrad, 99–113 (in Russian).
- Minato, M., Hunahashi, M., Watanabe, J. and Kato, M., 1979, *Variscan Geohistory of Northern Japan: The Abean Orogeny*. Tokai Univ. Press, Tokyo, 427 p.
- Mironova, M. G., 1967, *Late Carboniferous Brachiopods from Bashkirii*. Leningrad Univ., Leningrad, 63 p. (in Russian).
- Moore, R. C., 1952, Brachiopoda. In Moore, R. C., Lalicker, C. G. and Fischer, A. G., eds., *Invertebrate Fossils*. McGraw-Hill, New York, 197–267.
- Muir-Wood, H. M. and Cooper, G. A., 1960, Morphology, classification and life habits of the Productoidea (Brachiopoda). *Geol. Soc. Amer. Mem.*, **81**, 1–447.
- Nelzina, R. E., 1965, *Contributions to the Geology and Useful Minerals of Northwestern RSFSR, 4. Brachiopods and Pelecypods of Middle and Upper Carboniferous of Prionezhya*. Nedra, Leningrad, 118 p. (in Russian).
- Niikawa, I., 1980, Geology and biostratigraphy of the Fukuji district, Gifu Prefecture, central Japan. *Jour. Geol. Soc. Japan*, **86**, 25–36 (in Japanese).
- Niko, S., 2001, Sakmarian (Early Permian) tabulate corals from the Mizuyagadani Formation, Gifu Prefecture. *Bull. Nat. Sci. Mus., Tokyo, Ser. C*, **27**, 25–32.
- Niko, S., 2011, *Sinkiangopora kanumai*, a new tabulate coral species from the Permian Mizuyagadani Formation, Gifu Prefecture, Japan. *Bull. Nat. Sci. Mus., Ser. C*, **37**, 43–46.
- Niko, S., Yamakita, S., Otoh, S., Yanai, S. and Hamada, T., 1987, Permian radiolarians from the Mizuyagadani Formation in Fukuji area, Hida Marginal Belt and their significance. *Jour. Geol. Soc. Japan*, **93**, 431–433 (in Japanese).
- Okimura, Y., Niko, S. and Nishida, T., 1984, Discovery of michelinoceratine nautiloids (Orthocerida) and calcareous imperforate foraminiferal assemblage from the Permian Mizuyagadani Formation of Fukuji district, Hida Marginal Belt. *Jour. Geol. Soc. Japan*, **90**, 211–214 (in Japanese).
- d'Orbigny, A., 1842, Voyages dans l'Amérique Méridionale. *Pitois-Lebrault*, **3**, 50–56.
- Pavlova, E. E., 1991, Systematical part; Family Spiriferidae. In Tatarinov, L. P., Luvsandansan, B., Afanasjeva, G. A., Barsbold, R., Morozova, I. P., Novitskaja, L. I., Rasnitsyn, A. P., Reschetov, V. Yu., Posanov, A. Yu., Sysoev, V. A. and Trofimov, B. A., eds., *Permian Invertebrates of Southern Mongolia*. Nauka, Moskva, 124–138 (in Russian).
- Prokofiev, V. A., 1975, *Upper Carboniferous Brachiopods from Samarskoy Luki*. Tr. VNIGNI, **162**, Nedra, Moskva, 144 p. (in Russian).
- Sarytcheva, T. G., 1965, Order Productida. In Ruzhentsev, V. E. and Sarytcheva, T. G. eds., The development and change of marine organisms at the Palaeozoic–Mesozoic boundary, *Tr. Paleont. Inst., Akad. Nauk SSSR*, **108**, 209–232 (in Russian).
- Sarytcheva, T. G., ed., 1968, Upper Palaeozoic brachiopods of eastern Kazakhstan. *Tr. Paleont. Inst., Akad. Nauk USSR*, **121**, 1–212 (in Russian).
- Sarytcheva, T. G., 1977, Systematic descriptions; Family Retariidae. In Sarytcheva, T. G. ed., Late Paleozoic productids of Siberia and Arctic Russia, *Tr. Paleont. Inst., Akad. Nauk SSSR*, **161**, 65–79 (in Russian).
- Sarytcheva, T. G., Likharev, B. K. and Sokolskaya, A. N., 1960, Order Productida. In Sarytcheva, T. G., asst. ed., *Bryozoa, Brachiopoda with Phoronida*. In Orlov, Ya. A., ed., *Principles of Paleontology, Vol. 7*, Akad.

- Nauk, SSSR, Moskva, 221–238 (in Russian).
- Sarytcheva, T. G. and Sokolskaya, A. N., 1952, Descriptions of the Paleozoic brachiopods of the Moscow Basin. *Tr. Paleont. Inst., Akad. Nauk SSSR*, **38**, 1–307 (in Russian).
- Sarytcheva, T. G. and Sokolskaya, A. N., 1959, On the classification of pseudopunctate brachiopods. *Dokl. Akad. Nauk, SSSR*, **125**, 181–184 (in Russian).
- Sarytcheva, T. G. and Sokolskaya, A. N., 1965, Order Productida. In Ruzhentcev, V. E. and Sarytcheva, T. G., eds., The development and change of marine organisms at the Palaeozoic–Mesozoic boundary. *Tr. Paleont. Inst., Akad. Nauk SSSR*, **108**, 209–232 (in Russian).
- Schellwien, E., 1900, Die Fauna der Trogkofelschichten in den Karnischen Alpen und den Karawanken, 1 Theil. Die Brachiopoden. *Abhandl. K. K. Geol. Reichsanst.*, **16**, 1–122.
- Schuchert, C., 1929, Classification of brachiopod genera, fossil and recent. In Pompeckj, J. F., ed., *Fossilium Catalogus, Vol. I*, W. Junk, Berlin, 10–25.
- Schuchert, C. and Cooper, G. A., 1932, Brachiopod genera of the suborders Orthoidea and Pentamerioidea. *Mem. Peabody Mus. Nat. Hist.*, **4**, 1–270.
- Schuchert, C. and LeVene, C. M., 1929, Brachiopoda (generum et genotyporum index et bibliographia). In Pompeckj, J. F., ed., *Fossilium Catalogus, Vol. I. Animalia, Pars 42*, W. Junk, Berlin, 140 p.
- Sergunkova, O. I. and Zhizhilo, O. R., 1975, Middle to Upper Carboniferous and Lower Permian brachiopods from Fergana. In Khodanovich, R. L., ed., *Upper Paleozoic Biostratigraphy of Southern Fergana*. Fan., Tashkent, 54–77 (in Russian).
- Shen, S.-Z., Jin, Y.-G., Zhang, Y. and Weldon, E. A., 2017, Permian brachiopod genera on type species of China. In Rong, J.-Y., Jin, Y.-G., Shen, S.-Z. and Zhan, R.-B., eds., *Phanerozoic Brachiopod Genera of China, Vol. 2*. Sci. Press, Beijing, 651–881.
- Shen, S.-Z., Shi, G. R. and Fang, Z.-J., 2002, Permian brachiopods from the Baoshan and Simao blocks in western Yunnan, China. *Jour. Asian Earth Sci.*, **20**, 665–682.
- 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.
- Shi, G. R. and Waterhouse, J. B., 1996, Lower Permian brachiopods and molluscs from the upper Jungle Creek Formation, northern Yukon Territory, Canada. *Geol. Surv. Can. Bull.*, **424**, 1–241.
- Shiino, Y., 2009, Middle Permian echinoconchide brachiopod *Vediproductus* in the Kamiyasse area, southern Kitakami Mountains, northeast Japan. *Paleont. Res.*, **13**, 251–258.
- Sowerby, J., 1812–1815, *The Mineral Conchology of Great Britain, Vol. I*, Published by the author, London, 234 p.
- Stehli, F. G., 1954, Lower Leonardian Brachiopoda of the Sierra Diablo. *Bull. Amer. Mus. Nat. Hist.*, **105**, 262–358.
- Stepanov, D. L., 1948, Upper Carboniferous brachiopods of Bashkirii. *Tr. VNIGRI, N. S.*, **22**, 1–64 (In Russian).
- Tazawa, J., 1980, Viséan brachiopods from the Karaumedate Formation, Southern Kitakami Mountains. *Trans. Proc. Palaeont. Soc. Japan, N. S.*, no. 119, 359–370.
- Tazawa, J., 2004, Palaeozoic and Mesozoic tectonics of the Hida Gaien Belt, central Japan: Overview. *Jour. Geol. Soc. Japan*, **110**, 567–579 (in Japanese).
- Tazawa, J., 2016, Middle Permian (Wordian) mixed Boreal–Tethyan brachiopod fauna from Kamiyasse–Imo, South Kitakami Belt, Japan. *Sci. Rep. Niigata Univ. (Geol.)*, no. 31, 7–43.
- Tazawa, J. and Araki, H., 2017, Middle Permian (Wordian) mixed Boreal–Tethyan brachiopod fauna from Matsukawa, South Kitakami Belt, Japan. *Paleont. Res.*, **21**, 265–287.
- Tazawa, J. and Nakamura, K., 2015, Early Permian (Kungurian) brachiopods from Nakadaira, South Kitakami Belt, northeastern Japan. *Paleont. Res.*, **19**, 156–177.
- Tazawa, J. and Oyagi, K., 2019, Early Permian (Artinskian) brachiopods from the Ryozensan area, Mino Belt, southwestern Japan. *Sci. Rep. Niigata Univ. (Geol.)*, no. 34, 27–38.
- Tong, Z.-X., 1978, Phylum Brachiopoda (Carboniferous–Permian Part). In Geological Institute of Southwest China, ed., *Palaeontological Atlas of Southwestern China, Sichuan Province, Volume 2*, Geol. Publ. House, Beijing, 210–267 (in Chinese).
- Tschernyschew, Th., 1902, Die obercarbonischen Brachiopoden des Ural und des Timan. *Tr. Geol. Kom.*, **16**,

- 1-749 (in Russian).
- Tsukada, K., Takahashi, Y. and Ozawa, T., 1999, Stratigraphic relationship between the Mizuyagadani and Sorayama formations, and age of the Sorayama Formation, in the Hida-gaien Tectonic Zone, Kamitakara Village, Gifu Prefecture, central Japan. *Jour. Geol. Soc. Japan*, **105**, 496-507 (in Japanese).
- Ustritsky, V. I. and Tschernjak, G. E., 1963, Biostratigraphy and brachiopods of the Upper Palaeozoic of Taimyr. *Tr. NIIGA*, **134**, 1-139 (in Russian).
- Volgin, V. I., 1960, *Upper Carboniferous and Lower Permian Brachiopods from Southern Fergana*. Izd. Leningradskogo Univ., Leningrad, 203 p. (in Russian).
- de Verneuil, E., 1845, Paléontologie, mollusques, brachiopodes. In Murchison, R. I., de Verneuil, E. and Keyserling, A., eds., *Géologie de la Russie d'Europe et des Montagnes de l'Oural, Système Jurassique: Mollusques, Lamellibranches ou Acéphales, Vol. 2, Pt. 3.*, John Murray, London, 17-395.
- Waagen, W., 1883-1884, Salt Range fossils, Vol. 1, Pt. 4, *Productus*-Limestone fossils, Brachiopoda. *Palaeont. Ind., Ser. 13*, fasc. 2, 391-546 (1883), fasc. 3 and 4, 547-728 (1884).
- Wang, C.-W., 1995, Brachiopod fauna from Kangkelin Formation in Akesu, Xinjiang Autonomous Region. *Jour. Changchun Univ., Earth Sci.*, **25**, 15-23 (in Chinese).
- Wang, C.-W. and Yang, S.-P., 1998, *Late Carboniferous-Early Permian Brachiopods of Central Xinjiang and their Biostratigraphical Studies*. Geol. Publ. House, Beijing, 156 p. (in Chinese).
- Wang, G.-P., Liu, Q.-Z., Jin, Y.-G., Hu, S.-Z., Liang, W.-P. and Liao, Z.-T., 1982, Phylum Brachiopoda. In Nanjing Institute of Geology and Mineral Resources, ed., *Paleontological Atlas of East China, Vol. 2. Late Paleozoic*. Geol. Publ. House, Beijing, 186-256 (in Chinese).
- Wang, S.-M., 1984, Phylum Brachiopoda. In Regional Geological Surveying Team of Hubei, ed., *The Palaeontological Atlas of Hubei Province*, Hubei Sci. Tech. Press, Wuhan, 128-236 (in Chinese).
- Wang, Y., Jin, Y.-G. and Fang, D.-W., 1964, *Brachiopod Fossils from China, Vols. 1-2*, Sci. Press, Beijing, 777 p. (in Chinese).
- Waterhouse, J. B., 1968, The classification and descriptions of Permian Spiriferida (Brachiopoda) from New Zealand. *Palaeontographica, Abt. A*, **129**, 1-94.
- Waterhouse, J. B., 1971: Appendix 2. Systematic descriptions of new brachiopod species and genera. In Bamber, E. W. and Waterhouse, J. B., eds., Carboniferous and Permian stratigraphy and paleontology, northern Yukon Territory, Canada. *Bull. Can. Petr. Geol.*, **19**, 205-224.
- Waterhouse, J. B., Pitakpaivan, K. and Mantajit, N., 1981, *Early Permian Brachiopods from Ko Yao Noi and near Krabi, Southern Thailand*. Thai Geol. Surv. Mem., Vol. 4, Bangkok, 213 p.
- Williams, A. and Harper, D. A. T., 2000, Orthida. In Kaesler, R. L., ed., *Treatise on Invertebrate Paleontology, Part H. Brachiopoda Revised, Vol. 3. Linguliformea, Craniiformea, and Rhynchonelliformea (Part)*. Geol. Soc. Amer., Boulder and Univ. Kansas, Lawrence, 714-846.
- Yang, D.-L., Ni, S.-Z., Chang, M.-L. and Zhao, R.-X., 1977, Phylum Brachiopoda. In Geological Institute of Hubei et al., eds., *Palaeontological Atlas of South-Central China, Part 2. Late Palaeozoic Volume*. Geol. Publ. House, Beijing, 303-470 (in Chinese).
- Yang, T.-Y., 1948, Permo-Carboniferous brachiopods of Shihchientan Formation, Shihchientan, northeastern Sinkiang. *Sci. Rep. Nat. Tsing Hua Univ., Ser. C*, **1**, 196-214.
- Yang, Z.-Y., Ting (Ding), P.-Z., Yin, H.-F., Zhang, S.-X. and Fang, J.-S., 1962, Carboniferous, Permian and Triassic brachiopod faunas from the Chilianshan region. In Institute of Geology and Palaeontology, Geological Institute, Academia Sinica and Beijing University of Geology, eds., *Monograph on Geology of the Chilianshan Mountains, Volume 4, Part 4*. Sci. Press, Beijing, 1-129 (in Chinese).
- Zavodowsky, V. M. and Stepanov, D. L., 1970, Phylum Brachiopoda. In Kulikov, M. V., ed., *Field Atlas of Permian Fauna and Flora of the Northeastern USSR*. Magadanskoe Kniz. Izd., Magadan, 70-182 (in Russian).
- Zhan, L. and Lee, L., 1962, Early Permian Maokouan brachiopods from the eastern Qinling Mountains. *Acta Palaeont. Sin.*, **10**, 472-493 (in Chinese).
- Zhang, C., Zhang, S.-Z., Zhang, Z.-X. and Wang, Z., 1983, Phylum Brachiopoda. In Regional Geological Surveying Team of Xinjiang, Institute of Geoscience of Xinjiang and Geological Surveying Group of Petroleum Bureau of Xinjiang, eds., *Palaeontological Atlas of Northwest China; Xinjiang Autonomous Region, Part 2. Late Palaeozoic Volume*, Geol. Publ. House, Beijing, 262-286 (in Chinese).