Early Permian (Kungurian) brachiopods from near the base of the Kanokura Formation in the Nagaiwa–Sakamotozawa area, South Kitakami Belt, Japan

Jun-ichi TAZAWA* and Tomohiko SHINTANI**

Abstract

We describe the Tashiroyama brachiopod fauna, consisting of 11 species in 11 genera, from near the base of the Kanokura Formation in the Nagaiwa–Sakamotozawa area, South Kitakami Belt, northeastern Japan. The fauna is of Kungurian age; thus, the lowest part of the Kanokura Formation is correlated with the Kungurian Stage. Palaeobiogeographically, the Tashiroyama fauna is a mixed Boreal–Tethyan fauna, belonging to the Sino-Mongolian–Japanese Province. Thus, South Kitakami, including the Nagaiwa–Sakamotozawa area, was probably located near and to the east of the North China Block during the Kungurian.

Key words: Brachiopoda, Kanokura Formation, Kungurian, Nagaiwa–Sakamotozawa area, South Kitakami Belt.

Introduction

Permian rocks are widely distributed in the South Kitakami Belt, northeastern Japan. The Nagaiwa–Sakamotozawa area in the eastern part of the belt (i.e., Nagaiwa and Sakamotozawa, Hikoroichi-cho, Ofunato City, Iwate Prefecture; Fig. 1B) contains the type locality of the lower Permian Sakamotozawa Formation (named by Onuki, 1937). In this area, the stratigraphy of the Sakamotozawa Formation was studied by Onuki (1937, 1969), Yamada (1959), Kanmera and Mikami (1965a, 1965b), Minato et al. (1979) and Shintani (2011). Recently Ueno et al. (2007, 2009, 2011) described fusulinids from the Sakamotozawa

* Hamaura-cho 1-260-1, Chuo-ku, Niigata 951-8151, Japan
** Dia Consultants Co. Ltd, Toyotsu-cho 5-3, Suita, Osaka 564-0051, Japan
Corresponding author: J. Tazawa,
j1025-tazawa@memoad.jp
(Manuscript received 29 December, 2020; accepted 1 March, 2021)

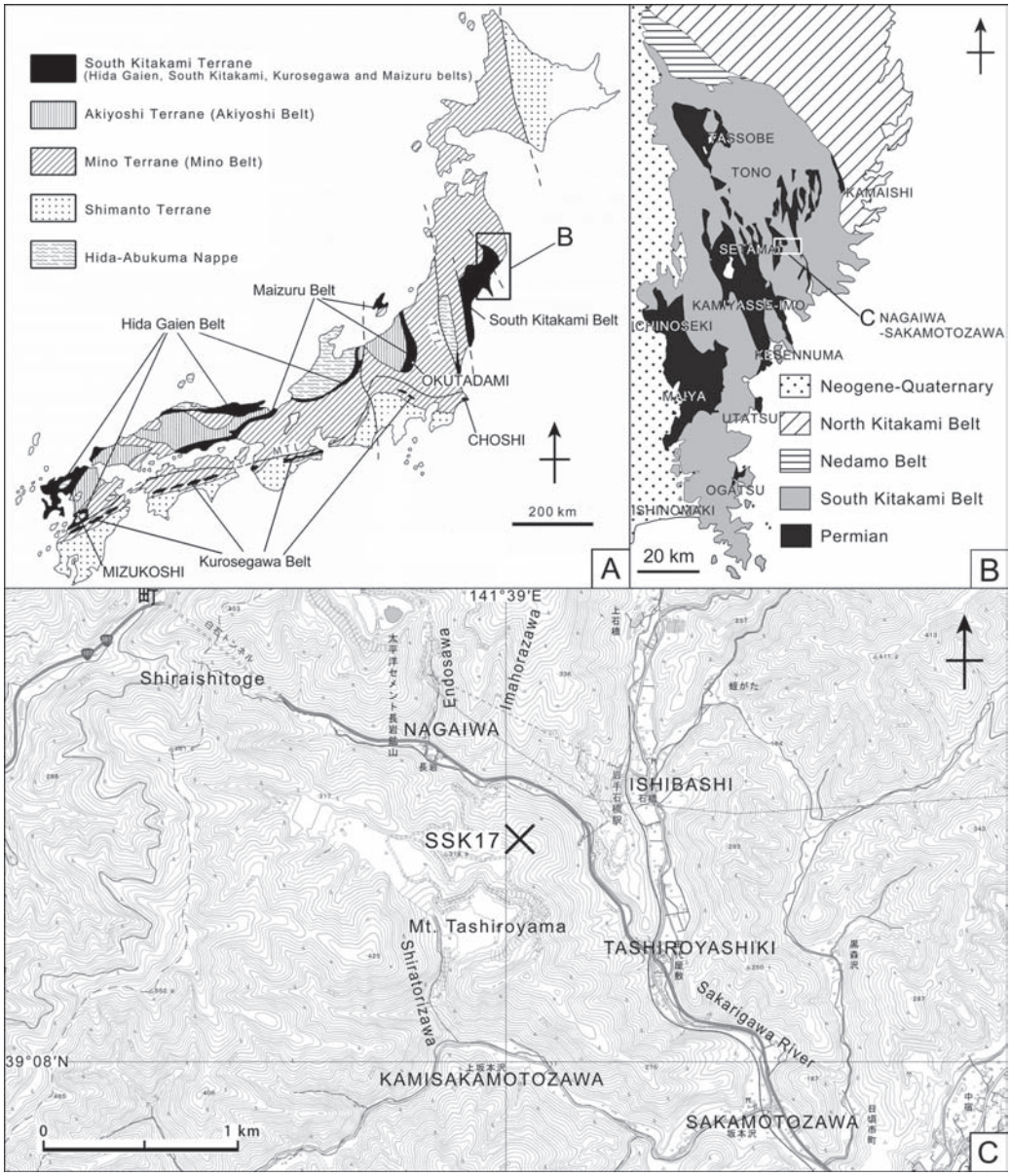

Fig. 1. Maps showing the location and geology of the Nagaiwa–Sakamotozawa area, South Kitakami Belt. (A) Geotectonic map of the Japanese Islands, showing the distribution of the South Kitakami Belt (after Tazawa, 2018); (B) geotectonic map of the northeastern part of Honshu, Japan, showing the distribution of the Permian rocks in the South Kitakami Belt (modified and adapted from Kawamura et al., 2013); and (C) map showing the fossil locality SSK17 at the northern slope of Mt. Tashiroyama in the Nagaiwa–Sakamotozawa area, South Kitakami Belt (using the electronic topographical map of the Geospatial Information Authority of Japan).

Formation, and Tazawa and Shintani (2010, 2015) and Shintani (2011) described brachiopods from the same formation. However, little is known about the stratigraphy, fossil content and age of the overlying Kanokura Formation (named by Onuki, 1937). Kanmera and Mikami

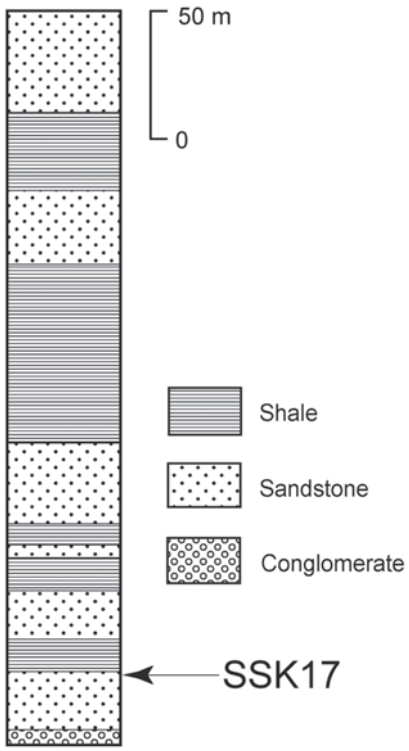

Fig. 2. Generalized columnar section of the Permian Kanokura Formation in the Nagaiwa–Sakamotozawa area, showing the fossil horizon SSK17.

(1965a) studied the stratigraphy of the Kanokura Formation, but did not report any fossils. Therefore, the age of the Kanokura Formatrion in the Nagaiwa–Sakamotozawa area has been uncertain until now.

In the present study, we describe brachiopods from near the base of the Kanokura Formation on the northern slope of Mt. Tashiroyama in the Nagaiwa–Sakamotozawa area, and discuss the age and palaeobiogegraphy of the fossil fauna. The material was collected by T. Shintani in 2006–2007, in the course of his graduate thesis at the Graduate School of Science and Technology, Niigata University, under the supervision of J. Tazawa. The brachiopod specimens described herein are now registered and housed in the Faculty of Science, Niigata University, Niigata (prefix NU-B, numbers 2280–2306).

Stratigraphy and material

In the Nagaiwa–Sakamotozawa area, the Permian strata form the core of a syncline that trends N–S to NNW–SSE and plunges gently towards the north. In this area, the Kanokura Formation (thickness about 460 m) consists mostly of sandstone and shale, with a thin (1–5 m thick) basal conglomerate (Fig. 2). The brachiopod fossils were collected from greenish

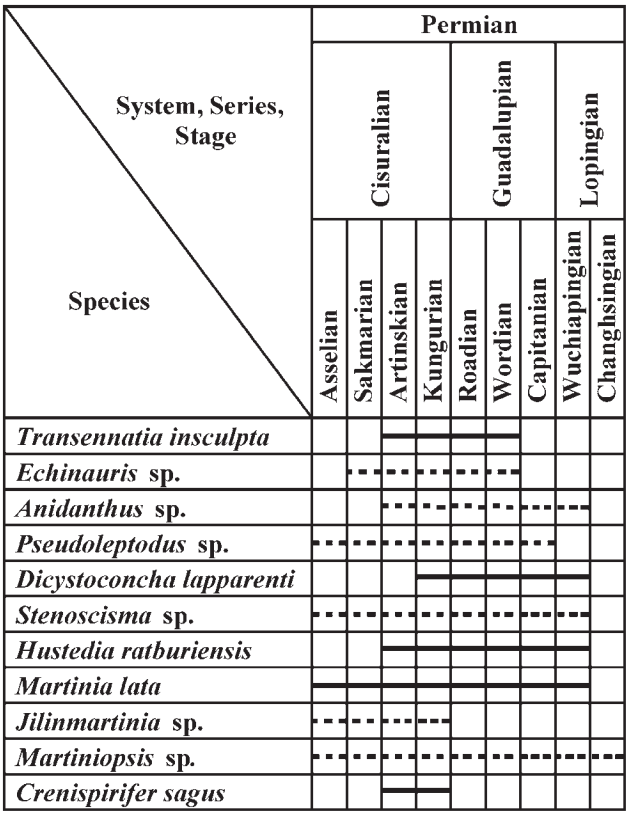

Fig. 3. Stratigraphic distributions of brachiopod species of the Tashiroyama fauna. Broken lines show those of the genera.

grey fine-grained sandstone, 30 m above the base of the Kanokura Formation at locality SSK17 (39°08'36"N, 141°39'04"E; Fig. 1C), 630 m SW of Nagaiwa, northern slope of Mt. Tashiroyama, Kamisakamotozawa, in the Nagaiwa–Sakamotozawa area. The boundary between the Kanokura Formation and the underlying Sakamotozawa Formation is a clinounconformity as reported by Kanmera and Mikami (1965a). Comparing the type section of the Kanokura Formation, described by Tazawa and Ibaraki (2001) in Setamai, about 10 km west of Nagaiwa, the upper part of the formation (consisting mainly of limestone) is lacking in the Nagaiwa–Sakamotozawa area.

The Tashiroyama fauna

The brachiopod fauna described herein includes 11 species in 11 genera: *Transennatia insculpta* (Grant, 1976), *Echinauris* sp., *Anidanthus* sp., *Pseudoleptodus* sp., *Dicystoconcha lapparenti* Termier and Termier in Termier et al., 1974, *Stenoscisma* sp., *Hustedia ratburiensis* Waterhouse and Piyasin, 1970, *Martinia lata* Grabau, 1936, *Jilinmartinia* sp.,

Martiniopsis sp. and *Crenispirifer sagus* Cooper and Grant, 1976b. Of these brachiopods, *Transennatia insculpta* and *Echinauris* sp. are abundant, *Hustedia ratburiensis* and *Martinia lata* are common, and the others are rare.

Age

The stratigraphic distributions of the brachiopod species of the Tashiroyama fauna are summarized in Fig. 3. Of the brachiopod taxa listed above, *Transennatia insculpta* is known from the Artinskian–Wordian (Grant, 1976; Sone in Sone et al., 2003); *Dicystoconcha lapparenti* from the Kungurian–Wuchiapingian (Liang in Wang et al., 1982; Yang, 1984); *Hustedia ratburiensis* from the Artinskian–Wuchiapingian (Archbold, 1999; Tazawa in Tazawa et al., 2015); *Martinia lata* from the Asselian–Wuchiapingian (Grabau, 1936; Tazawa, 2008b); and *Crenispirifer sagus* from the Artinskian–Kungurian (Cooper and Grant, 1976b). At the generic level, *Echinauris* is known from the Sakmarian–Wordian (Brunton et al., 2000); *Anidanthus* from the Artinskian–Wuchiapingian (Brunton et al., 2000); *Pseudoleptodus* from the Asselian–Capitanian (Cooper and Grant, 1974; Grant, 1976); *Stenoscisma* from the lower Carboniferous to the Wuchiapingian (Carlson and Grant, 2002); *Jilinmartinia* from the Moscovian–Kungurian (Pavlova, 1991; Carter and Gourvennec, 2006) and *Martiniopsis* from the upper Carboniferous to the Lopingian (Carter and Gourvennec, 2006). In summary, the Tashiroyama fauna is identified as Kungurian in age; therefore, the lowest part of the Kanokura Formation is correlated with the Kungurian Stage.

Palaeobiogeography

In terms of palaeobiogeography, the Tashiroyama fauna includes both antitropical genera (*Anidanthus* and *Jilinmartinia*) and tropical genera (*Transennatia*, *Echinauris*, *Pseudoleptodus* and *Dicystoconcha*). Therefore, this assemblage represents a mixed Boreal–Tethyan fauna. It is noteworthy that *Jilinmartinia* occurs mostly from northwestern China (Xinjiang) to northeastern China (Jilin). At the species level, *Transennatia insculpta* has been recorded from northwestern China (Xinjiang), southern Thailand and Malaysia; *Dicystoconcha lapparenti* from Afghanistan, northern China (Inner Mongolia), eastern China (Zhejiang) and central-southern China (Hubei and Guangdong); *Hustedia ratburiensis* from central Japan (Hida Gaien Belt), southwestern Japan (Mizukoshi, central Kyushu, western extension of the Hida Gaien Belt), north-central Thailand (Khao Hin King) and southern Thailand (Khao Phrik, Khao Tok Nam and Ko Muk); *Martinia lata* from central-southern China (Guangxi); and *Crenispirifer sagus* from the USA (Texas). To summarize, the Tashiroyama fauna is a mixed Boreal–Tethyan fauna and exhibits affinities with those of northwestern–northeastern China. Thus, the Tashiroyama fauna belonged to the Sino-Mongolian–Japanese Province (of Shi and Tazawa, 2001), which was characterized by the mixture of both Boreal and Tethyan elements and covered the vast area of north and east to the North China Block during the

Permian. South Kitakami, including the Nagaiwa–Sakamotozawa area, was probably located near the North China Block during the Kungurian, in the mid-latitudes of the Northern Hemisphere.

Conclusions

In this study, an early Permian brachiopod fauna (Tashiroyama fauna), consisting of 11 species in 11 genera, is described from near the base of the Kanokura Formation in the Nagaiwa–Sakamotozawa area, South Kitakami Belt, northeastern Japan. The Tashiroyama fauna indicates a Kungurian age. Thus, the lowest part of the Kanokura Formation is correlated with the Kungurian. In terms of palaeobiogeography, the Tashiroyama fauna is a mixed Boreal–Tethyan brachiopod fauna, and has a close affinity with the early Permian brachiopod faunas of northwestern–northeastern China. Thus, the Tashiroyama fauna belonged to the Sino-Mongolian–Japanese Province; and South Kitakami, including the Nagaiwa–Sakamotozawa area, was probably located near and to the east of the North China Block during the Kungurian.

Systematic descriptions

Order Productida Sarytcheva and Sokolskaya, 1959
Suborder Productidina Waagen, 1883
Superfamily Marginiferoidea Stehli, 1954
Family Marginiferidae Stehli, 1954
Subfamily Marginiferinae Stehli, 1954
Genus *Transennatia* Waterhouse, 1975

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

Transennatia insculpta (Grant, 1976)
Fig. 4A–C

Gratiosina insculpta Grant, 1976, p. 135, pl. 32, figs. 1–37; pl. 33, figs. 1–16.
Transennatia cf. *insculpta* (Grant). Sone in Sone et al., 2003, p. 528, figs. 7, 8c.
Transennatia insculpta (Grant). Chen, 2004, p. 14, pl. 2, figs. 5–12.

Material.—Six specimens: (1) external and internal moulds of a ventral valve, NU-B2281; (2) external mould of a ventral valve, NU-B2282; (3) external and internal moulds of two dorsal valves, NU-B2283, 2284; (4) external mould of a dorsal valve, NU-B2285; and (5)

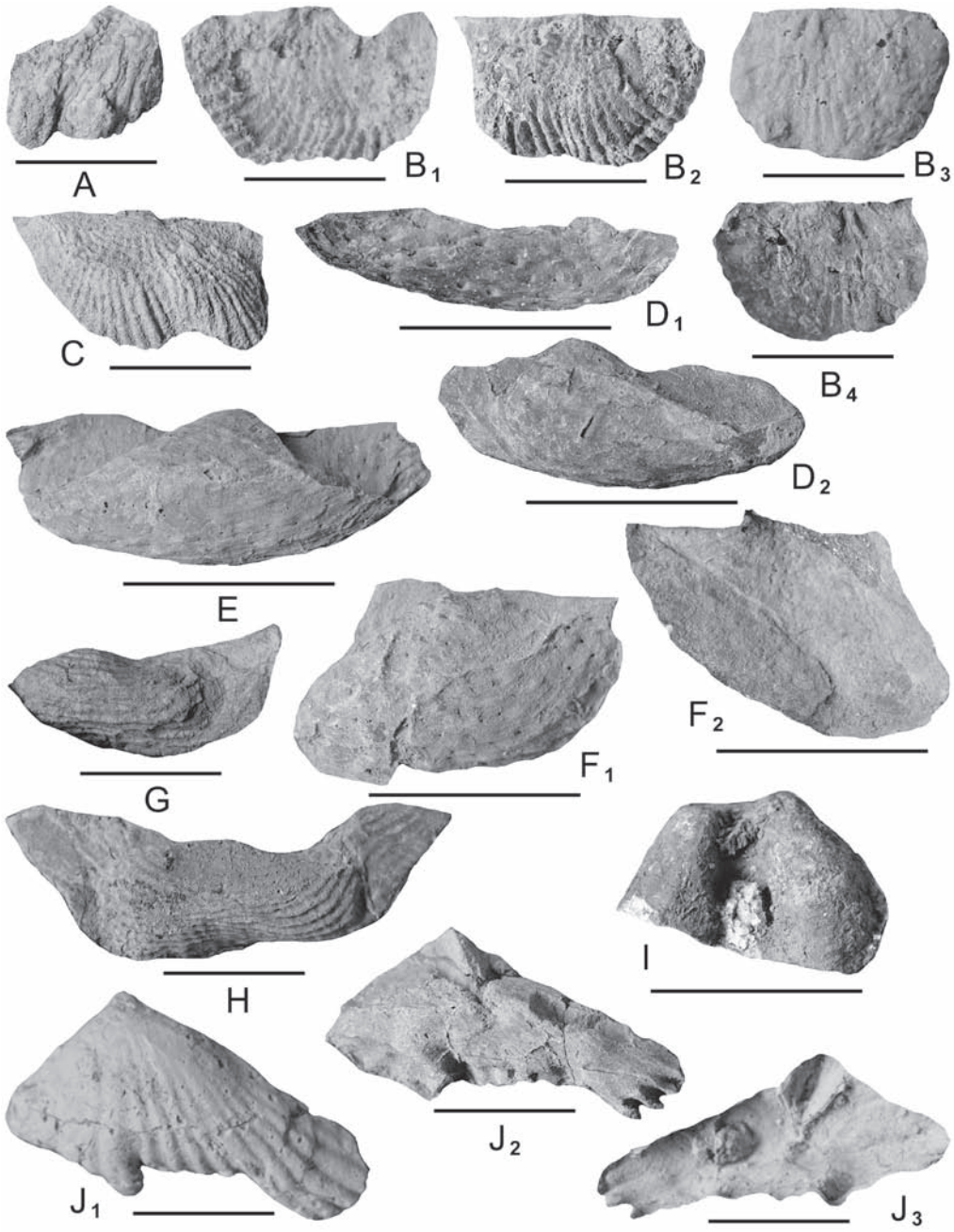

Fig. 4. Brachiopods of the Tashiroyama fauna (1). **A–C**, *Transennatia insculpta* (Grant); A, external latex cast of ventral valve, NU-B2282; external latex cast (B_1), external mould (B_2) and internal latex cast (B_3) of dorsal valve, NU-B2283; C, external mould of dorsal valve, NU-B2284; **D–F**, *Echinauris* sp., external mould (D_1) and internal mould (D_2) of ventral valve, NU-B2287; E, external mould of dorsal valve, NU-B2292; external mould (F_1) and internal mould (F_2) of dorsal valve, NU-B2289; **G**, **H**, *Anidanthus* sp., G, external mould of dorsal valve, NU-B2301; H, external mould of dorsal valve, NU-B2302; **I**, *Dicystoconcha lapparenti* Ternier and Termier; internal mould of ventral valve, NU-B2280; **J**, *Stenoscisma* sp.; external latex cast (J_1), internal mould (J_2) and internal latex cast (J_3) of ventral valve, NU-B2306. Scale bars are 1 cm.

internal mould of a conjoined shell, NU-B2286.

Remarks.—These specimens are referred to *Transennatia insculpta* (Grant, 1976), originally described by Grant (1976, p. 135, pl. 32, figs. 1–37; pl. 33, figs. 1–16) as *Gratiosina insculpta* Grant, 1976, from the Ratburi Formation of Ko Muk, southern Thailand, in the small and transverse shell (length 12 mm, width 19 mm in the best preserved dorsal valve specimen, NU-B2283) and the coarse reticulate ornament on the visceral discs of both ventral and dorsal valves. The type species, *Transennatia gratiosa* (Waagen, 1884, p. 691, pl. 72, figs. 3–7), from the Wargal and Chhidru formations of the Salt Range, Pakistan, differs from *T. insculpta* in the larger size and in having finer reticulate ornament on the discs of both valves.

Distribution.—Artinskian–Wordian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt), northwestern China (Xinjiang), southern Thailand (Ko Muk) and Malaysia.

Family Costispiniferidae Muir-Wood and Cooper, 1960
Subfamily Costispiniferinae Muir-Wood and Cooper, 1960
Genus *Echinauris* Muir-Wood and Cooper, 1960

Type species.—*Echinauris lateralis* Muir-Wood and Cooper, 1960.

Echinauris sp.
Fig. 4D–F

Material.—Six specimens: (1) external and internal moulds of two ventral valves, NU-B2287, 2288; (2) external and internal moulds of two dorsal valves, NU-B2289, 2290; and (3) external moulds of two dorsal valves, NU-B2291, 2292.

Remarks.—These specimens are safely assigned to the genus *Echinauris* Muir-Wood and Cooper, 1960 by the small, elongate shell (length 11 mm, width 15 mm in the best preserved dorsal valve specimen, NU-B2289), and the external ornaments of numerous stout spine bases on the ventral valve and numerous dimples and fine growth lines on the dorsal valve. The Tashiroyama species is most like *Echinauris crassa* Cooper and Grant (1975, p. 1006, pl. 327, figs. 1–36), from the Leonardian of Texas, the USA, in the transverse outline and in having large ears, but differs from the latter in being wider and larger. *Echinauris interrupta* Cooper and Grant (1975, p. 1006, pl. 328, figs. 1–33), from the Wolfcampian of Texas, differs from the present species in the larger size and in having finer spine bases on the ventral valve. The type species, *Echinauris lateralis* Muir-Wood and Cooper (1960, p. 222, pl. 68, figs. 1–13), from the Word Formation of Texas, is readily distinguished from the present species in the less transverse outline and in having smaller ears. The Tashiroyama species may be a new species of *Echinauris*, although the specimens are poorly preserved.

Superfamily Linoproductoidea Stehli, 1954
Family Linoproductidae Stehli, 1954
Subfamily Anidanthinae Waterhouse, 1968
Genus *Anidanthus* Booker, 1932

Type species.—*Linoproductus springsurensis* Booker, 1932.

Anidanthus sp.
Fig. 4G, H

Material.—Two specimens, external moulds of two dorsal valves, NU-B2301, 2302.

Remarks.—These specimens are safely assigned to the genus *Anidanthus* Booker, 1932 on the basis of lamellose rugae on the visceral disc of the dorsal valve and large, prominent ears with rugae on the valve. *Anidanthus boikowi* (Stepanov, 1946), redescribed by Grigorjeva and Kotlyar (in Sartytcheva, 1977, p. 57, pl. 5, figs. 4–13), from the lower Permian of the Verkhoyansk Range, northern Russia, somewhat resembles the Kitakami species in having large ears but differs in the larger and less transverse dorsal valve. The type species, *Anidanthus springsurensis* (Booker, 1932, p. 67, pl. 3, figs. 1–6; pl. 4, figs. 1–7), from the lower Bowen Series of Queensland, eastern Australia, differs from the present species in being less transverse outline. The Kitakami species is probably a new species, although the material is poorly preserved and not adequate for the establishment.

Suborder Lyttoniidina Williams, Harper and Grant, 2000
Superfamily Lyttonioidea Waagen, 1883
Family Lyttoniidae Waagen, 1883
Subfamily Poikilosakinae Williams, 1953
Genus *Pseudoleptodus* Stehli, 1956

Type species.—*Pseudoleptodus getawayensis* Stehli, 1956.

Pseudoleptodus sp.
Fig. 5A, B

Material.—Two specimens: (1) external and internal moulds of a ventral valve, NU-B2299; and (2) internal mould of a ventral valve, NU-B2300.

Remarks.—The specimens from Mt. Tashiroyama are represented by two incomplete ventral valves lacking the half of lateral sides. They can be assigned to the genus *Pseudoleptodus* Stehli, 1956 in having regularly arranged, low and wide lateral septa, with

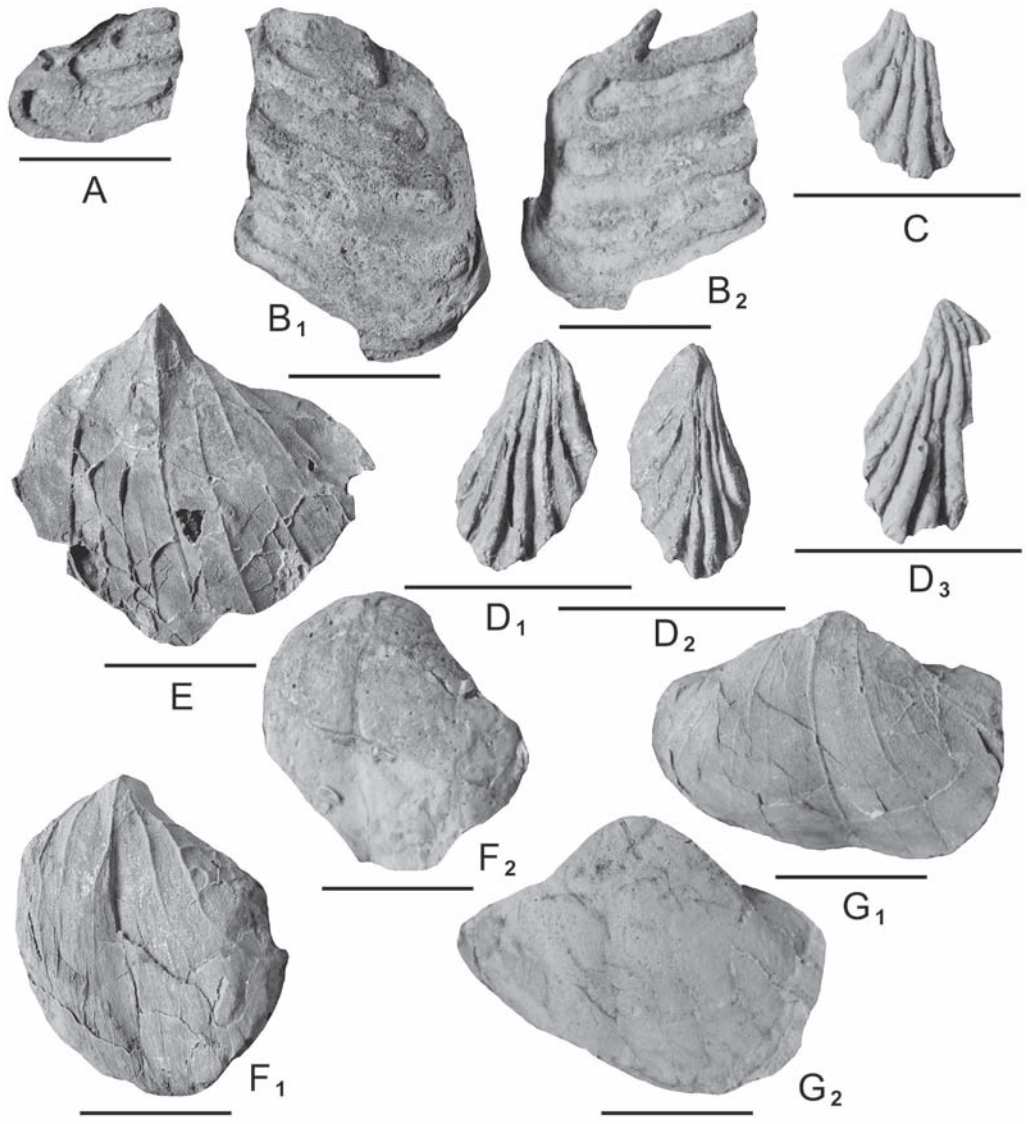

Fig. 5. Brachiopods of the Tashiroyama fauna (2). **A**, **B**, *Pseudoleptodus* sp.; A, internal mould of ventral valve, NU-B2300; internal mould (B_1) and internal latex cast (B_2) of ventral valve, NU-B2299; **C**, **D**, *Hustedia ratburiensis* Waterhouse and Piyasin; C, external latex cast of dorsal valve, NU-B2304; ventral internal mould (D_1), dorsal internal mould (D_2) and dorsal external latex cast (D_3) of conjoined shell, NU-B2303; **E–G**, *Martinia lata* Grabau; E, internal mould of ventral valve, NU-B2295; internal mould (F_1) and external latex cast (F_2) of ventral valve, NU-B2296; internal mould (G_1) and external latex cast (G_2) of ventral valve, NU-B2294; Scale bars are 1 cm.

flattened top. The Kitakami species is probably an advanced-form of the genus, and somewhat resembles *Pseudoleptodus getawayensis* Stehli (1956), redescribed by Cooper and Grant (1974, p. 395, pl. 130, figs. 18–34) from the Cherry Canyon Formation of the Guadalupe

Mountains, Texas, in size and shape of the shell. But the Texan species differs from the Kitakami species in having lateral septa extending anteriorly at steeper angle to the median septum.

Superfamily Permianelloidea He and Zhu, 1979
Family Permianellidae He and Zhu, 1979
Genus *Dicystoconcha* Termier and Termier in Termier et al., 1974

Type species.—*Dicystoconcha lapparenti* Termier and Termier in Termier et al., 1974.

Dicystoconcha lapparenti Termier and Termier in Termier et al., 1974
Fig. 4I

Dicystoconcha lapparenti Termier and Termier in Termier et al., 1974, p. 123, pl. 22, figs. 1, 2, text-fig. 22; Wang and Jin, 1991, p. 495, pl. 1, figs. 1–9; pl. 3, figs. 1–7; Shen and Tazawa, 2014, p. 248, figs. 3.1–3.5; Tazawa et al., 2014, p. 383, fig. 2.6; Tazawa, 2015, p. 73, fig. 6.6; Tazawa and Araki, 2018, p. 16, fig. 4.2.
Dipunctella contricta Liang in Wang et al., 1982, p. 229, pl. 102, fig. 3.
Guangjiayanella guangjiayanensis Yang, 1984, p. 212, pl. 31, figs. 11–16, text-fig. 5.9.
Guangdongina xiamaoensis Mou and Liu, 1989, p. 458, pl. 1, figs. 1–9; pl. 2, figs. 1–7, text-fig. 5.
Guangdongina leguminiformis Mou and Liu, 1989, p. 458, pl. 3, figs. 4–6.
Guangdongina perforates Mou and Liu, 1989, p. 459, pl. 2, fig. 8; pl. 3, figs. 1–3.
Guangdongina sp. Mou and Liu, 1989, p. 459, pl. 2, fig. 9.
Peritisteges latesulcata Liang, 1990, p. 380, pl. 42, figs. 1, 2.
Fabulasteges planata Liang, 1990, p. 381, pl. 42, figs. 3, 4.

Material.—One specimen, internal mould of a ventral valve, NU-B2280.

Remarks.—The single specimen from Mt. Tashiroyama is referred to *Dicystoconcha lapparenti* Termier and Termier (in Termier et al., 1974, p. 123, pl. 22, figs. 1, 2, text-fig. 22), from the lower Murgabian of Wardak, central Afghanistan, in the small, ovate and bilobate ventral valve (length more than 11 mm, width about 13 mm), with shallow incision and a distinct central platform. As discussed by Shen and Tazawa (2014, p. 248), the following six species from the Kungurian–Capitanian of South China are junior synonyms of *Dicystoconcha lapparenti*: *Guangjiayanella guangjiayanensis* Yang, 1984, *Guangdongina xiamaoensis* Mou and Liu, 1989, *G. leguminiformis* Mou and Liu, 1989, *G. perforatus* Mou and Liu, 1989, *Guangdongina* sp. Mou and Liu, 1989 and *Fabulasteges planata* Liang, 1990. Moreover, *Paritisteges latesulcata* Liang (1990, p. 380, pl. 42, figs. 1, 2), from the Wordian of Zhejiang, eastern China, is also considered to be a junior synonym of the present species.

Distribution.—Kungurian–Wuchiapingian: northeastern Japan (Nagaiwa–Sakamotozawa, Kamiyasse–Imo and Hitachi in the South Kitakami Belt), Afghanistan, northern China (Inner Mongolia), eastern China (Zhejiang) and central-southern China (Hubei and Guangdong).

Order Rhynchonellida Kuhn, 1949
Superfamily Stenoscismatoidea Oehlert, 1887
Family Stenoscismatidae Oehlert, 1887
Subfamily Stenoscismatinae Oehlert, 1887
Genus *Stenoscisma* Conrad, 1839

Type species.—*Terebratula schlottheimii* von Buch, 1834.

Stenoscisma sp.
Fig. 4J

Material.—One specimen, external and internal moulds of a ventral valve, NU-B2306.

Remarks.—This specimen is safely assigned to the genus *Stenoscisma* Conrad, 1839 by the rhynchonellid-formed shell, with a spondylium in the ventral valve. The Kitakami species is medium in size (length 15 mm, width 27 mm), transversely subtrigonal in shape, and external surface of the ventral valve is ornamented with strong costae, numbering 4 on sulcus and 5 on each flank. *Stenoscisma hueconianum* (Girty, 1929), redescribed by Cooper and Grant (1976a, p. 2096, pl. 563, figs. 1–54), from the upper Wolfcampian of Texas, resembles the Kitakami species in shape and external ornament of the ventral valve, but differs from the latter in the much smaller size. *Stenoscisma mutabilis* (Tschernyschew, 1902, p. 81, 491, pl. 22, fig. 18; pl. 23, fig. 10; pl. 45, figs. 1–15; pl. 46, fig. 14), from the *Schwagerina* Horizon of the Urals and Timan, resembles the Kitakami species in size, shape and external ornament of the ventral valve, particularly in the medium-sized, transversely subtrigonal specimen (illustrated by Tschernyschew, 1902, pl. 45, fig. 14). However, an accurate comparison is difficult for this poorly preserved specimen.

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

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

Hustedia ratburiensis Waterhouse and Piyasin, 1970
Fig. 5C, D

Hustedia ratburiensis Waterhouse and Piyasin, 1970, p. 138, pl. 23, figs. 15–30; Grant, 1976, p. 241, pl. 66, figs. 1–69: pl. 67, figs. 51–58; Yanagida and Nakornsri, 1999, p. 118, pl. 32, figs. 11–16; Archbold, 1999, figs. 5E–H; Tazawa, 2001, p. 299, fig. 8.6; Tazawa, 2008a, p. 53, figs. 8.2–8.6; Tazawa in Tazawa et al., 2015, p. 44, fig. 6.7; Tazawa and Nakamura, 2015, p. 169, figs. 7.1–7.7.
Hustedia nakornsrii Yanagida, 1970, p. 79, pl. 14, fig. 9.

Material.—Three specimens: (1) internal mould of a conjoined shell, with external mould of the dorsal valve, NU-B2303; (2) external mould of a dorsal valve, NU-B2304; and (3) internal mould of a dorsal valve, NU-B2305.

Remarks.—These specimens are referred to *Hustedia ratburiensis* Waterhouse and Piyasin (1970, p. 138, pl. 23, figs. 15–30), from the Wordian of Khao Phrik, southern Thailand, by the medium size (length 11 mm, width 7 mm in the best preserved specimen, NU-B2303) and in having rounded costae which occur three close-set medianly and four pairs laterally on the dorsal valve. *Hustedia nakornsrii* Yanagida (1970, p. 79, pl. 14, fig. 9), from the Ratburi Formation of Khao Phrik, is deemed to be conspecific with the present species. *Hustedia indica* (Waagen, 1883, p. 493, pl. 35, figs. 1, 2), from the Wargal Formation of the Salt Range, differs from *H. ratburiensis* in having fewer and broader costae on both valves.

Distribution.—Artinskian–Wuchiapingian: northeastern Japan (Nagaiwa–Sakamotozawa, Nakadaira and Takakurayama in the South Kitakami Belt), central Japan (Moribu in the Hida Gaien Belt), southwestern Japan (Mizukoshi, central Kyushu, western extension of the Hida Gaien Belt), north-central Thailand (Khao Hin King) and southern Thailand (Khao Phrik, Khao Tok Nam and Ko Muk).

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

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

Martinia lata Grabau, 1936
Fig. 5E–G

Martinia semiplana var. *lata* Grabau, 1936, p. 239, pl. 21, figs. 1–3; Hayasaka and Minato, 1956, p. 146, pl. 23, fig. 3.
Martinia lata Grabau. Tazawa, 2008b, p. 38, figs. 5.7–5.14.

Material.—Three specimens, external and internal moulds of three ventral valves, NU-B2294–2296.

Remarks.—These specimens are referred to *Martinia lata* Grabau, 1936, originally described by Grabau (1936, p. 239, pl. 21, figs. 1–3) as *Martinia semiplana* Waagen var. *lata* Grabau, 1936, from the Maping Formation of Guangxi, central-southern China, by the medium-sized, transversely subelliptical shell (length 17 mm, width 24 mm in the best preserved specimen, NU-B2294) and in having a shallow ventral sulcus. *Martinia semiplana* Waagen (1883, p. 536, pl. 43, fig. 4), from the Wargal Formation of the Salt Range, differs from *M. lata* in the smaller size and less transverse outline.

Distribution.—Asselian–Wuchiapingian: northeastern Japan (Nagaiwa–Sakamotozawa, Kamiyasse–Imo and Takakurayama in the South Kitakami Belt) and central-southern China (Guangxi).

Genus *Jilinmartinia* Lee and Gu, 1980

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

Jilinmartinia sp.
Fig. 6C

Material.—One specimen, external and internal moulds of a conjoined shell, NU-B2293.

Remarks.—The single specimen from Mt. Tashiroyama is safely assigned to the genus *Jilinmartinia* Lee and Gu, 1980 by the large size (length about 33 mm, width about 85 mm), wider subcircular outline, moderately developed sulcus, external ornament consisting of fine concentric growth lines, and some radial vascular markings in the ventral valve. The Kitakami species resembles the type species, *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 (Asselian) of Gansu, northwestern China, in size and shape of the shell and external ornament of the ventral valve. But the Chinese species differs from the present species in the less transverse outline and in having narrower and deeper sulcus on the ventral valve. *Jilinmartinia sokolovi* (Tschernyschew, 1902, p. 166, pl. 8, fig. 3; pl. 39, fig.

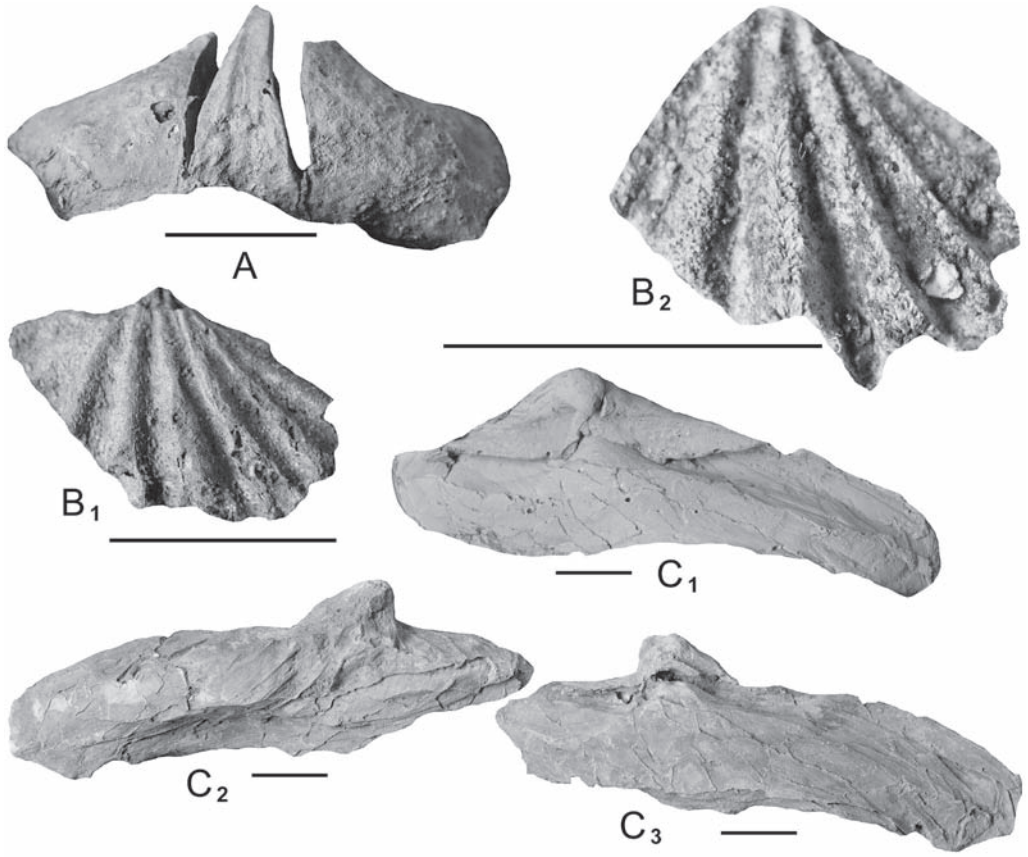

Fig. 6. Brachiopods of the Tashiroyama fauna (3). **A**, *Martiniopsis* sp., internal mould of ventral valve, NU-B2297; **B**, *Crenispirifer sagus* Cooper and Grant; internal mould (B_1) and external latex cast (B_2) of dorsal valve, NU-B2298; **C**, *Jilinmartinia* sp.; dorsal external latex cast (C_1), ventral internal mould (C_2) and dorsal internal mould (C_3) of conjoined shell, NU-B2293. Scale bars are 1 cm.

4), from the Asselian of the Urals, is also a transverse *Jilinmartinia* species, but the Russian species differs from the Kitakami species in having two costae in the ventral sulcus.

Family Ingelarellidae Campbell, 1959
Subfamily Ingelarellinae Campbell, 1959
Genus *Martiniopsis* Waagen, 1883

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

Martiniopsis sp.
Fig. 6A

Material.—One specimen, external and internal moulds of a ventral valve, NU-B2297.

Remarks.—The single ventral valve specimen from Mt. Tashiroyama can be assigned to the genus *Martiniopsis* Waagen, 1883 by the long, slender subparallel dental adminicula in the ventral valve and in having no impressions of costae on the valve. The Kitakami species closely resembles *Martiniopsis inflata* Waagen (1883, p. 525, pl. 41, figs. 7, 8, text-fig. 9), from the Chhidru Formation of the Salt Range, in the medium size (length more than 17 mm, width about 35 mm) and transverse outline. *Martiniopsis cathaysiensis* Grabau (1936, p. 242, pl. 21, figs. 7, 8; pl. 24, fig. 9), from the Maping Limestone of Guangxi, central-southern China and Guizhou, southwestern China, is also transversely wider in outline but much smaller in size. An accurate comparison is difficult for this poorly preserved specimen.

Order Spiriferinida Ivanova, 1972
Suborder Spiriferinidina Ivanova, 1972
Superfamily Pennospiriferinoidea Dagys, 1972
Family Spiriferellinidae Ivanova, 1972
Genus *Crenispirifer* Stehli, 1954

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

Crenispirifer sagus Cooper and Grant, 1976b
Fig. 6B

Crenispirifer sagus Cooper and Grant, 1976b, p. 2715, pl. 718, figs. 1–15.

Material.—One specimen, external and internal moulds of a dorsal valve, NU-B2298.

Remarks.—This specimen is referred to *Crenispirifer sagus* Cooper and Grant (1976b, p. 2715, pl. 718, figs. 1–15), from the Bone Spring Formation (lower Leonardian) of Texas, by the medium size (length about 10 mm, width about 16 mm in the single dorsal valve) and in having rather numerous costae (numbering 4 on each lateral slope of the dorsal valve) and external surface of the valve ornamented with numerous very fine pustules. *Crenispirifer nakamurai* Tazawa and Shintani (2014, p. 36, figs. 6.11, 6.12), from the Nakadaira Formation (Sakmarian) of Kamiyasse, South Kitakami Belt, differs from *C. sagus* in having more stout costae on the dorsal valve. *Crenispirifer alpheus* (Huang, 1933, p. 59, pl. 9, figs. 2, 3), from the Lopingian of Guizhou, southwestern China, differs from the present species in being smaller size. The type species, *Crenispirifer angulatus* (King, 1931), redescribed by Cooper and Grant (1976b, p. 2710, pl. 716, figs. 1–70; pl. 717, figs. 23–43; pl. 719, figs. 41–47), from the Bone Spring, Skinner Ranch and Gibolo formations of Texas, differs from *C. sagus* in the larger size and in having larger number of costae on the dorsal valve.

Distribution.—Artinskian–Kungurian: northeastern Japan (Nagaiwa–Sakamotozawa in the South Kitakami Belt) and USA (Texas).

Acknowledgements

We sincerely thank Atsushi Matsuoka (Faculty of Science, Niigata University) and an anonymous reviewer for their critical readings of the manuscript; and Yousuke Ibaraki (Fossa Magna Museum, Itoigawa) for his help in drawing figures.

References

Archbold, N. W., 1999, Additional records of Permian brachiopods from near Rat Buri, Thailand. *Proc. Roy. Soc. Vict.*, **111**, 71–86.

Booker, F. W., 1932, A new species of *Productus* from the lower Bowen Series—Queensland. *Proc. Roy. Soc. Qld.*, **43**, 66–72.

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

von Buch, L., 1834, Über Terebrateln, mit einem Versuch sie zu klassifizieren und zu beschreiben. *Phys. Abh. König. Akad. Wis., 1833*, 1–124.

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.

Campbell, K. S. W., 1959, The *Martiniopsis*-like spiriferids of the Queensland Permian. *Palaeontology*, **1**, 333–350.

Carlson, S. J. and Grant, R. E., 2002, Stenoscismatoidea. *In* Kaesler, R. L., ed., *Treatise on Invertebrate Paleontology, Part H Brachiopoda Revised, Volume 4: Rhynchonelliformea (Part)*. Geol. Soc. Amer., Boulder and Univ. Kansas, Lawrence, 1218–1230.

Carter, J. L. and Gourvennec, R., 2006, Martinioidea. *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, 1747–1768.

Chao, Y.-T., 1929, Carboniferous and Permian spiriferids of China. *Palaeont. Sin., Ser. B*, **11**, 1–133.

Chen, Z.-Q., 2004, Lower Permian reef-dwelling brachiopod faunas from the Tarim Basin, Northwest China: biostratigraphy, palaeoecology and biogeography. *Palaeontogr., Abt. A*, **272**, 1–96.

Conrad, T. A., 1839, Descriptions of new species of organic remains. Second annual report on the Palaeontological Department of the Society. *New York State Geol. Surv., Sec. Ann. Rep.*, 57–66.

Cooper, G. A. and Grant, R. E., 1974, Permian brachiopods of West Texas, 2. *Smithson. Contr. Paleobiol.*, no. 15, 233–793.

Cooper, G. A. and Grant, R. E., 1975, Permian brachiopods of West Texas, 3. *Smithson. Contr. Paleobiol.*, no. 19, 795–1921.

Cooper, G. A. and Grant, R. E., 1976a, Permian brachiopods of West Texas, 4. *Smithson. Contr. Paleobiol.*, no. 21, 1923–2607.

Cooper, G. A. and Grant, R. E., 1976b, Permian brachiopods of West Texas, 5. *Smithson. Contr. Paleobiol.*, no. 24, 2609–3159.

Dagys, A. S., 1972, Morphology and systematics of Mesozoic retzioid brachiopods. *Tr. Inst. Geol. Geofiz., Akad. Nauk SSSR, Siber. Otd.*, **112**, 94–105 (in Russian).

Girty, G. H., 1929, New Carboniferous invertebrates 2. *Jour. Wash. Acad. Sci.*, **19**, 406–415.

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

Grant, R. E., 1976, Permian brachiopods from southern Thailand. *Jour. Paleont.*, **50** (supp., no. 3), 1–269.

Grunt, T. A., 1986, Classification of brachiopods of the order Athyridida. *Tr. Paleont. Inst., Akad. Nauk SSSR*, **215**, 1–200 (in Russian).

Hall, J. and Clarke, J. M., 1893, *An Introduction to the Study of the Genera of Palaeozoic Brachiopoda, Palaeontology of New York, Volume 8, Part 2*. Charles van Benthuysen and Sons, Albany. 317 p.

Hayasaka, I. and Minato, M., 1956. Some brachiopods from the lower Kanokura Series of the Kitakami Mountains, Japan. *Trans. Proc. Palaeont. Soc. Japan, N. S.*, no. 21, 141–147.

He, X.-L. and Zhu, M.-L., 1979, A new form of brachiopods and its systematical classification. *Jour. Chin. Inst. Min. Tech.*, no. 4, 131–140 (in Chinese).

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

Ivanova, E. A., 1972, Main features of spiriferid evolution (Brachiopoda). *Paleont. Zhur.*, no. 1972-3, 28–42 (in Russian).

Kanmera, K. and Mikami, T., 1965a, Succession and sedimentary features of the Lower Permian Sakamotozawa Formation. *Mem. Fac. Sci., Kyushu Univ., Ser. D*, **16**, 265–274.

Kanmera, K. and Mikami, T., 1965b, Fusuline zonation of the Lower Permian Sakamotozawa Series. *Mem. Fac. Sci., Kyushu Univ., Ser. D*, **16**, 275–320.

Kawamura, T., Uchino, T., Kawamura, M., Yoshida, K., Nakagawa, M. and Nagata, H., 2013, *Geology of Hayachine San District; Quadrangle Series, 1:50,000. Geological Survey of Japan, AIST*. Maeda Insatsu, Tsukuba. 101 p. (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.

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

Lee, L. and Gu, F., 1980, Late Carboniferous brachiopods from Yanji of Jilin, NE China. *Acta Palaeont. Sin.*, **19**, 483–492 (in Chinese).

Liang, W.-P., 1990, *Lengwu Formation of Permian and its Brachiopod Fauna in Zhejiang Province*. Geol. Mem., Ser. 2, No. 10, Geol. Publ. House, Beijing, 522 p. (in Chinese).

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*. Zürcher und Furrer, Zürich, 144 p.

M'Coy, F., 1844, *A Synopsis of the Characters of the Carboniferous Limestone Fossils of Ireland*. Williams and Norgate, London, 207 p.

Minato, M., Nakamura, K., Choi, D. R. and Kato, M., 1979, Chapter 2k2. The Sakamotozawa Series. *In* Minato, M., Hunahashi, M., Watanabe, J. and Kato, M. eds., *Variscan Geohistory of Northern Japan: The Abean Orogeny*. Tokai Univ. Press, Tokyo, 174–176.

Mou, C.-J. and Liu, C.-L., 1989, A new type of brachiopods—*Guangdongina* and its ecological environment. *Acta Palaeont. Sin.*, **28**, 455–462 (in Chinese).

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

Oehlert, D. P., 1887, Appendice sur les brachiopodes. *In* Fischer, P., *Manuel de Conchyliologie et de Paléontologie conchyliologique ou Histoire naturelle des Mollusques vivants et fossils, Vol. 4, Part 11*, Lib. F. Savy, Paris, 1189–1334.

Onuki, Y., 1937, On the Palaeozoic formation near Sakamotozawa, Kitakami Mountainland. *Jour. Geol. Soc. Japan*, **44**, 168–186 (in Japanese).

Onuki, Y., 1969, Geology of the Kitakami Massif, Northeast Japan. *Contr. Inst. Paleont., Tohoku Univ.*, no. 69, 1–239 (in Japanese).

Pavlova, E. E., 1991, Systematical part; Family Spiriferidae. *In* Tatarinov, L. P., Luvsandansan, B., Afanasjeva, G. A., Barsbold, R., Morosova, 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. The Joint Soviet–Mongolian Paleontological Expedition, Transactions, Volume 40*, Nauka, Moskva, 124–138 (in Russian).

Sarytcheva, T. G., ed., 1977, Late Palaeozoic productids of Siberia and Arctic Russia. *Tr. Paleont. Inst., Akad. Nauk SSSR*, **161**, 1–220 (in Russian).

Sarytcheva, T. G. and Sokolskaya, A. N., 1959, On the classification of pseudopunctate brachiopods. *Doklady, Akad. Nauk SSSR*, **125**, 181–184 (in Russian).

Shen, S.-Z. and Tazawa, J., 2014, *Pararigbyella* and *Dicystoconcha* (Lyttoniidina, Brachiopoda) from the middle Permian (Wordian) of Japan. *Paleont. Res.*, **18**, 245–249.

Shi, G. R. and Tazawa, J., 2001, *Rhnchopora* 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.

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.

Sone, M., Metcalfe, I. and Leman, M. J., 2003, Palaeobiogeographic implications of Middle Permian brachiopods from Johore (Peninsular Malaysia). *Geol. Mag.*, **140**, 523–538.

Sowerby, J., 1818–1821, *The Mineral Conchology of Great Britain, Volume 3*. W. Ardling, London, 184 p.

Stehli, F. G., 1954, Lower Leonardian Brachiopoda of the Sierra Diablo. *Bull. Amer. Mus. Nat. Hist.*, **105**, 262–358.

Stehli, F. G., 1956, Notes on oldhaminid brachiopods. *Jour. Paleont.*, **30**, 305–313.

Stepanov, D. L., 1946, Upper Paleozoic brachiopods from Aldan Basin (Yakutsk, USSR). *Vest. Leningrad. Gosudarstv. Univ.*, no. 93, 196–222 (in Russian).

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

Tazawa, J., 2008a, Permian brachiopods from the Mizukoshi Formation, central Kyushu, SW Japan: Systematics, palaeobiogeography and tectonic implications. *Paleont. Res.*, **12**, 37–61.

Tazawa, J., 2008b, Brachiopods from the Upper Permian Takakurayama Formation, Abukuma Mountains, northeast Japan. *Sci. Rep., Niigata Univ. (Geol.)*, no. 23, 13–53.

Tazawa, J., 2015, Systematics and palaeobiogeography of Permian brachiopods from Pliocene conglomerate of Hitachi, central Japan. *Sci. Rep., Niigata Univ. (Geol.)*, no. 30, 57–88.

Tazawa, J., 2018, Palaeobiogeographical studies on the Palaeozoic brachiopods of Japan, and their tectonic significance: A review. *Jour. Geol. Soc. Japan*, **124**, 655–673 (in Japanese).

Tazawa, J. and Araki, H., 2018, Middle Permian (Wordian) brachiopod fauna from Matsukawa, South Kitakami Belt, Japan, Part 2. *Sci, Rep., Niigata Univ, (Geol.)*, no. 33, 9–24.

Tazawa, J. and Ibaraki, Y., 2001, Middle Permian brachiopods from Setamai, the type locality of the Kanokura Formation, southern Kitakami Mountains, northeast Japan. *Sci. Rep., Niigata Univ. (Geol.)*, no. 16, 1–33.

Tazawa, J., Kaneko, N., Suzuki, C. and Hasagawa, S., 2015, Late Permian (Wuchiapingian) brachiopod fauna from the lower Takakurayama Formation, Abukuma Mountains, northeastern Japan. *Paleont. Res.*, **19**, 33–51.

Tazawa, J., Kikuchi, Y., Nikaido, A., Adachi, S. and Okumura, Y., 2014, Permian brachiopods from boulders in the Pliocence basal conglomerate of Hitachi, central Japan. *Jour. Geol. Soc. Japan*, **120**, 377–391 (in Japanese).

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 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.

Tazawa, J. and Shintani, T., 2014, Early Permian (Sakmarian) brachiopods from Kamiyasse, South Kitakami Belt, northeast Japan. *Sci. Rep., Niigata Univ. (Geol.)*, no. 29, 13–41.

Tazawa, J. and Shintani, T., 2015, Early Permian (Sakmarian) brachiopods from the Nagaiwa–Sakamotozawa area, South Kitakami Belt, northeastern Japan, Part 3: Productidina. *Sci. Rep., Niigata Univ. (Geol.)*, no. 30, 39–55.

Termier, G., Termier, H., de Lapparent, A. F. and Marin, P., 1974, Monographie du Permo–Carbonifère de Wardak (Afghanistan central). *Doc. Lab. Géol. Fac. Sci. Lyon, Hors Ser.*, **2**, 1–167.

Tscernyschew, Th., 1902, Die obercarbonischen Brachiopoden des Ural und des Timan. *Tr. Geol. Kom.*, **16**, 1–749 (in Russian).

Ueno, K., Shintani, T. and Tazawa, J., 2009, Fusuline foraminifera from the upper part of the Sakamotozawa Formation, South Kitakami Belt, Northeast Japan. *Sci. Rep., Niigata Univ. (Geol.)*, no. 24, 27–61.

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.

Ueno, K., Tazawa, J. and Shintani, T., 2007, Fusuline foraminifera from the basal part of the Sakamotozawa Formation, South Kitakami Belt, Northeast Japan. *Sci. Rep., Niigata Univ. (Geol.)*, no. 22, 15–33.

Waagen, W., 1883–1884, Salt Range fossils, Vol. 1, Part 4. *Productus* Limestone fossils, Brachiopoda. *Palaeont. Ind., Ser. 13*, fasc. 2, 391–546 (1883), fasc. 3, 547–610 (1884) and fasc. 4, 611–728 (1884).

Wang, G., Liu, Q., Jin, Y., Hu, S., Liang, W. and Liao, Z., 1982, Phylum Brachiopoda. *In* Nanjing Institute of Geology and Mineral Resources, *ed., Palaeontological Atlas of East China, Part 2. Volume of Late Palaeozoic*. Geol. Publ. House, Beijing, 186–256 (in Chinese).

Wang, H.-Y. and Jin, Y.-G., 1991, On permianellids (Brachiopoda). *Acta Palaeont. Sin.*, **30**, 481–501 (in Chinese).

Waterhouse, J. B., 1968, Classification and descriptions of Permian Spiriferida (Brachiopoda) from New Zealand. *Palaeontogr., Abt. A*, **129**, 1–94.

Waterhouse, J. B., 1975, New Permian and Triassic brachiopod taxa. *Univ. Qd. Pap., Dept. Geol.*, **7**, 1–23.

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

Williams, A., 1953, The classification of the strophomenoid brachiopods. *Wash. Acad. Sci. Jour.*, **43,** 1–13.

Williams, A., Harper, D. A. and Grant, R. E., 2000: Lyttoniidina. *In* Kaesler, R., *ed., Treatise on Invertebrate Paleontology, Part H Brachiopoda Revised, Volume 3: Linguliformea, Craniiformea, and Rhynchonelliformea (Part)*, Geol. Soc. Amer., Boulder and Univ. Kansas, Lawrence, 619–642.

Yanagida, J., 1970, Permian brachiopods from Khao Phrik, near Rat Buri, Thailand. *Geol. Palaeont. SE Asia*, **8**, 69–96.

Yamada, Y., 1959, On the unconformity of the post-Nagaiwa—pre-Sakamotozawa epoch in the Hikoroichi district. *Jour. Geol. Soc. Japan*, **65**, 713–724 (in Japanese).

Yanagida, J. and Nakornsri, N., 1999, Permian brachiopods from the Khao Hin Kling area near Phetchabun, north-central Thailand. *Bull. Kitakyushu Mus. Nat. Hist.*, no. 18, 105–136.

Yang, D., 1984, Systematic description of palaeontology; Brachiopoda. *In* Yichang Institute of Geology and Mineral Resources, *ed., Biostratigraphy of the Yangtze Gorge Area, (3) Late Palaeozoic Era*, Geol. Publ. House, Beijing. 203–239, 330–333 and 387–396 (in Chinese).