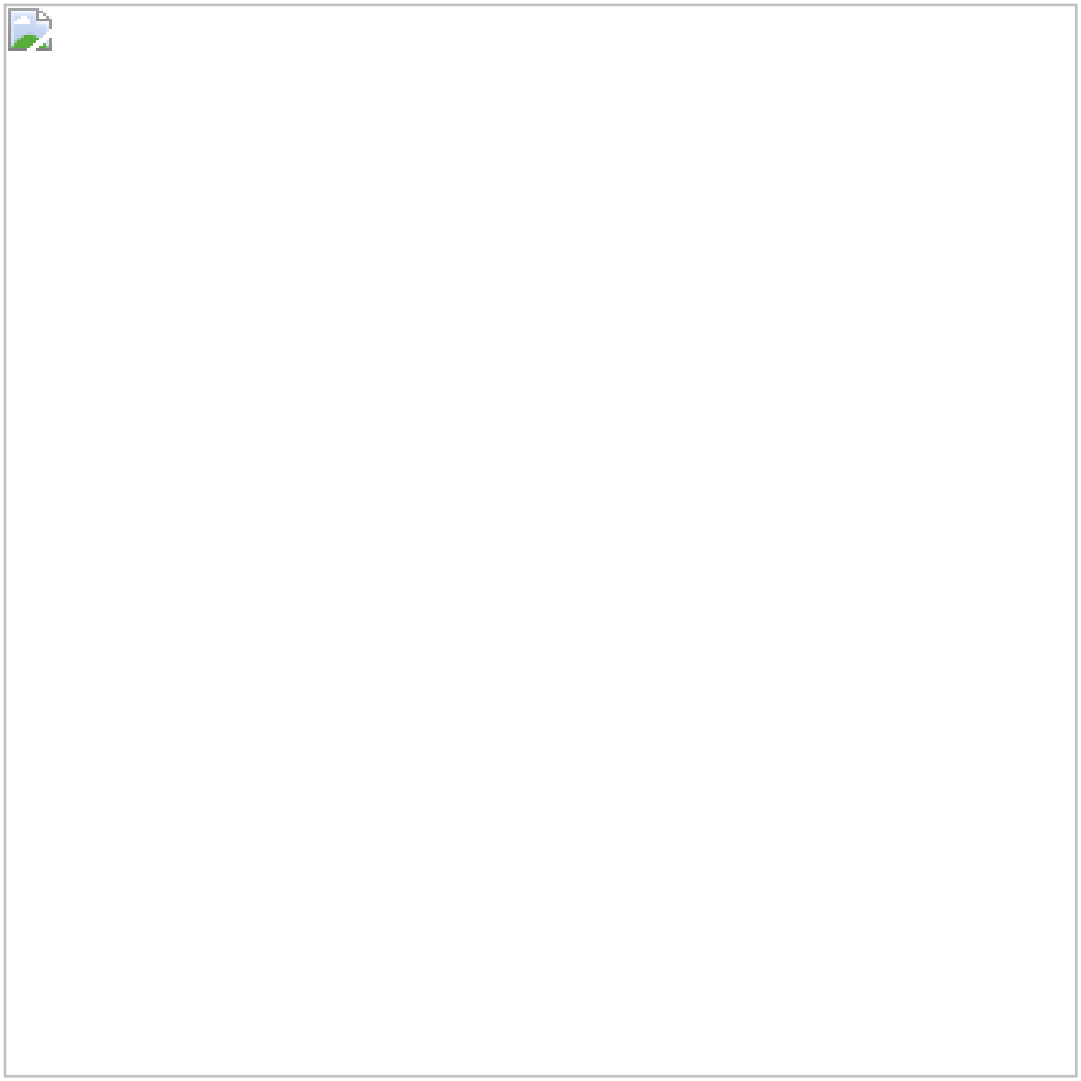

Late Permian (Wuchiapingian) Brachiopod Fauna from the Lower Takakurayama Formation, Abukuma Mountains, Northeastern Japan

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Late Permian (Wuchiapingian) brachiopod fauna from the lower Takakurayama Formation, Abukuma Mountains, northeastern Japan

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Abstract. **This study describes a brachiopod fauna, consisting of 15 species in 15 genera, from the lower part of the Takakurayama Formation at the locality T_1 in the Takakurayama area, Abukuma Mountains, South Kitakami Belt, northeastern Japan. The fauna is considered to be late Permian (Wuchiapingian) in age based on the occurrence of *Haydenella wenganensis*, *Costatumulus tazawai* and *Pterospirifer alatus*. In terms of palaeobiogeography, the Takakurayama (T_1) fauna is a mixed Boreal–Tethyan fauna with *Chonetinella*, *Lamnimargus*, *Megousia*, *Costatumulus*, *Yakovlevia*, *Neospirifer*, *Gypospirifer*, *Alispiriferella* and *Pterospirifer* as the Boreal (anti-tropical) elements, and *Haydenella*, *Transennatia* and *Echinauris* as the Tethyan (tropical) elements. The fauna is allied with the middle–late Permian brachiopod fauna of South Primorye, Far Eastern Russia.**

Key words: **Brachiopoda, mixed Boreal–Tethyan fauna, South Kitakami Belt, Takakurayama Formation, Wuchiapingian**

Introduction

The Takakurayama area in the Abukuma Mountains, South Kitakami Belt, northeastern Japan (Figure 1) is a renowned Permian fossil locality in Japan. Many fossils of marine invertebrates and land plants have been previously described from the Permian Takakurayama Formation, including foraminifers (Ueno, 1992), brachiopods (Yanagisawa, 1967; Nakamura, 1972; Tazawa, 1999b, 2008b), pelecypods (Yanagisawa, 1967; Nakazawa and Newell, 1968), cephalopods (Hayasaka, 1957, 1965; Yanagisawa, 1967; Tazawa *et al.*, 2005; Ehiro, 2008; Fujikawa and Suzuki, 2011), trilobites (Yanagisawa, 1958, 1967; Endo and Matsumoto, 1962; Koizumi, 1972, 1974; Kobayashi and Hamada, 1984) and plants (Asama, 1974).

However, there is little agreement on the age of the Takakurayama Formation, especially of the lower part, owing to a lack of systematic studies of the fossils. Until now, only six brachiopod species (Yanagisawa, 1967; Tazawa, 1999b; Tazawa, 2008b) and four ammonoid species (Fujikawa and Suzuki, 2011) have been described from locality T_1, a single fossil locality of the lower part of the Takakurayama Formation (= Iriishikura Formation of Yanagisawa and Nemoto, 1961). The lower part of the formation has variously been assigned to the lower Permian (Sakmarian–Kungurian) by Yanagisawa (1967) and Nakazawa and Newell (1968), the middle Permian (Wordian) by Ehiro and Okami (1989) and the upper Permian (Wuchiapingian) by Tazawa (2008b).

The present study describes the brachiopod species from the lower part of the Takakurayama Formation at the locality T_1 in the B-sawa Valley (named by Yanagisawa and Nemoto, 1961), a tributary of the Sodetamayamagawa River, in the Takakurayama area, and discusses the age and palaeobiogeography of the brachiopod fauna. In this study, C. Suzuki prepared the brachiopod specimens; N. Kaneko and S. Hasegawa studied the stratigraphy of the Takakurayama Formation; and J. Tazawa studied the systematics of the brachiopods. The specimens described herein are registered and housed in the Geological Museum, Geological Survey of Japan, AIST, Tsukuba with prefix GSJ F.

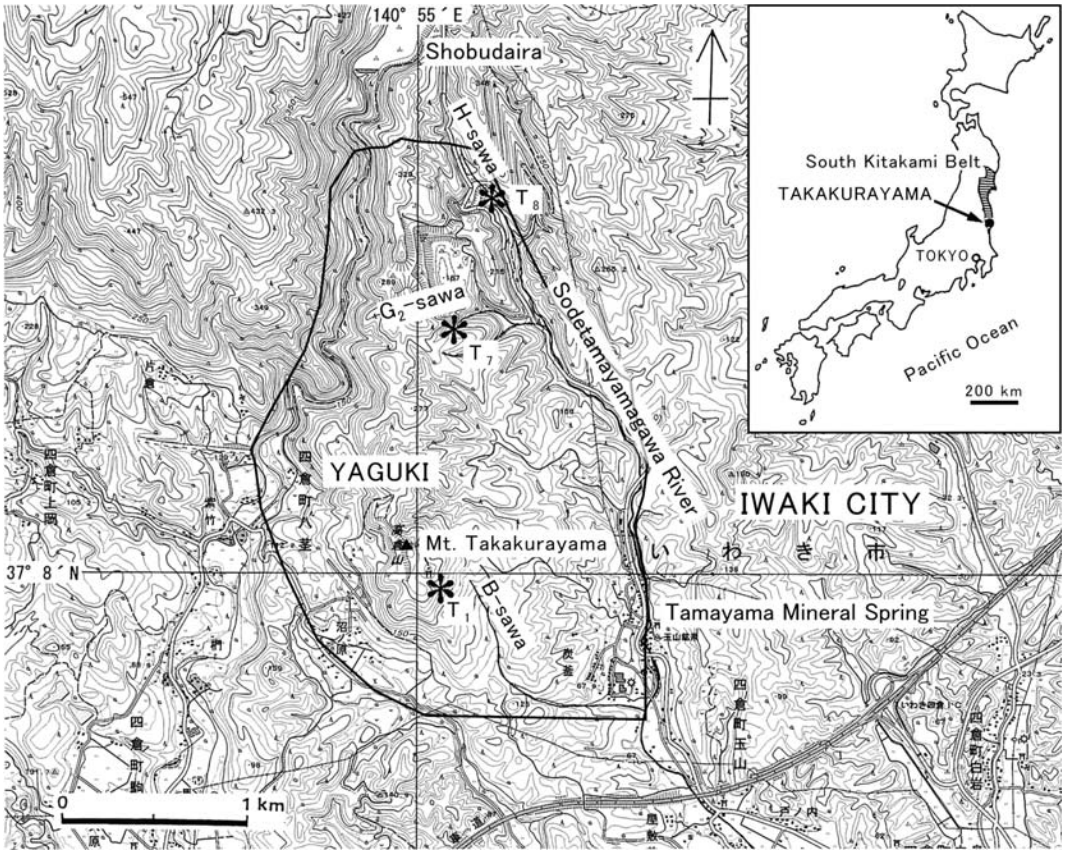

Figure 1. Map showing the surveyed area, enclosed by solid line, and fossil localities T_1, T_7 and T_8 in the Takakurayama area (using the topographical map "Yotsukura" scale 1:25,000 published by the Geospatial Information Authority of Japan).

Stratigraphy

The Takakurayama Formation (named by Onuki, 1966) is distributed on an area of about 3 km^2 on the northeastern slope of Mt. Takakurayama, with a general NNE-SSW strike and dip of 30°–58° toward the WNW (Figure 2). The formation consists mainly of black shale with subordinate sandstone and conglomerate, and exceeds 805 m in total thickness (Figure 3). The black shale of the Takakurayama Formation is lithologically similar to that of the upper Permian Toyoma Formation (Onuki, 1969) in the southern Kitakami Mountains, northeastern Japan, and the conglomerate is correlated with the Usuginu-type conglomerate (Kano, 1971), which is widely distributed in the upper Permian of Japan.

The fossil locality T_1 (Figures 1, 3) occurs in the upper stream of B-sawa Valley (lat. 37°7′57″N, long. 140°55′8″E), where there occurs alternation of dark grey, fine-grained sandstone and dark grey shale in the lower part of the Takakurayama Formation, about 255 m above its base.

Brachiopod fauna from the lower Takakurayama Formation

The brachiopod fauna from the locality T_1 consists of the following 15 species in 15 genera: *Chonetinella krotovi* (Fredericks, 1925), *Rugoconcha* sp., *Haydenella wenganensis* (Huang, 1932), *Transennatia gratiosa* (Waagen, 1884), *Lamnimargus peregrinus* (Fredericks, 1924b), *Echinauris* sp., *Megousia auriculata* Muir-Wood and Cooper, 1960, *Costatumulus tazawai* Shen, Archbold, Shi and Chen, 2000, *Yakovlevia mammatiformis* (Fredericks, 1926), *Hustedia ratburiensis* Waterhouse and Piyasin, 1970, *Neospirifer* sp., *Gypospirifer kobiyamai* Tazawa and Araki, 2013, *Alispiriferella* sp., *Pterospirifer alatus* (von Schlotheim, 1813) and *Dielasma* sp.

The geographical and stratigraphical distributions of the brachiopod species of the Takakurayama (T_1) fauna

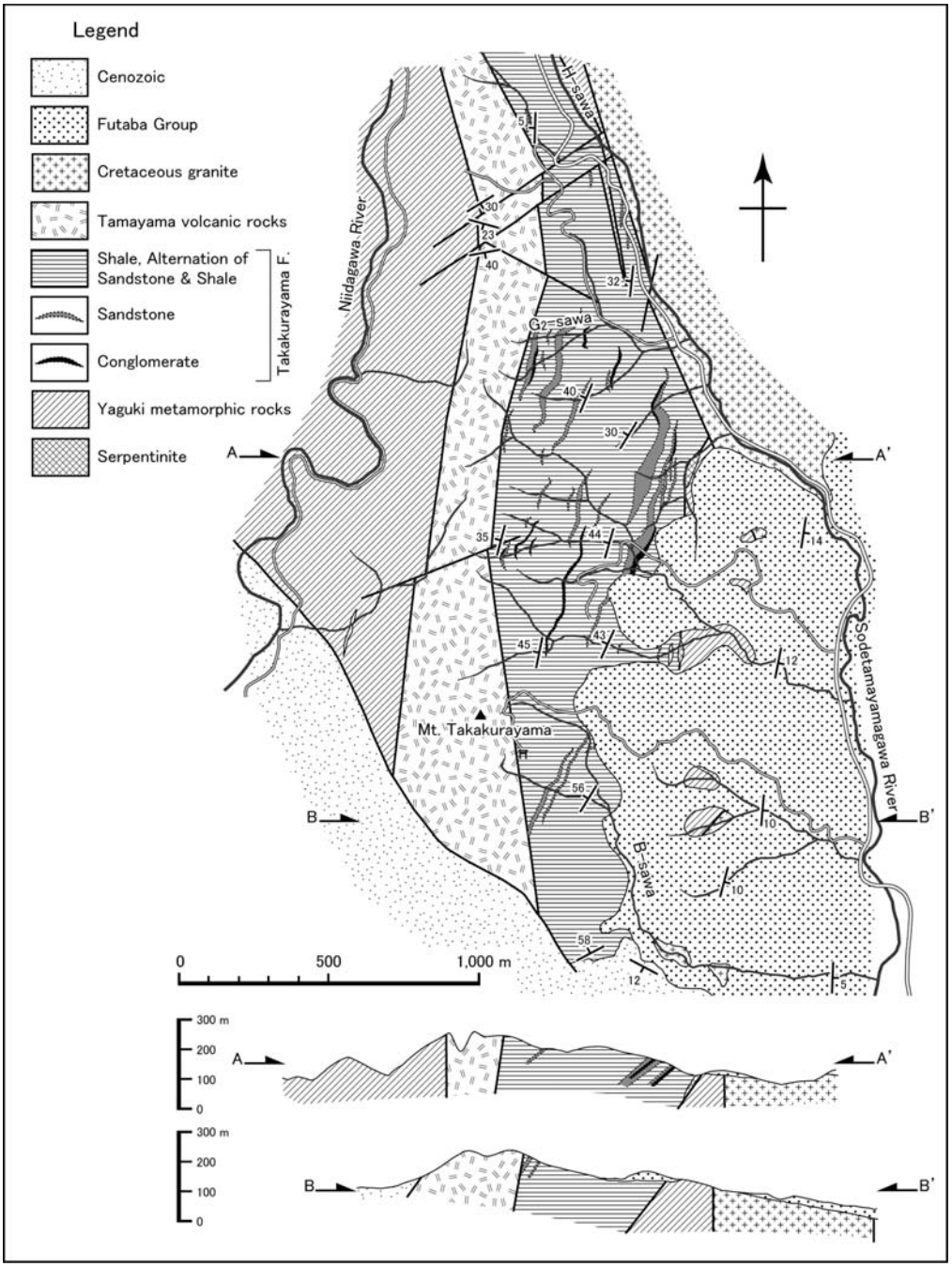

Figure 2. Geological map of the Takakurayama area.

are summarized in Figure 4. It is noteworthy that 6 species (*Chonetinella krotovi*, *Haydenella wenganensis*, *Transennatia gratiosa*, *Lamnimargus peregrinus*, *Costatumulus tazawai* and *Gypospirifer kobiyamai*) also occur in the upper part of the Takakurayama Formation at the localities T_7 and T_8 (Figures 1, 3, 4).

Age and correlation

Chonetinella krotovi, *Transennatia gratiosa* and *Lamnimargus peregrinus* are known from the Wordian–Changhsingian; *Haydenella wenganensis* is known from the Wuchiapingian–Changhsingian; *Gypospirifer kobiyamai* is known from the Wordian–Wuchiapingian; and

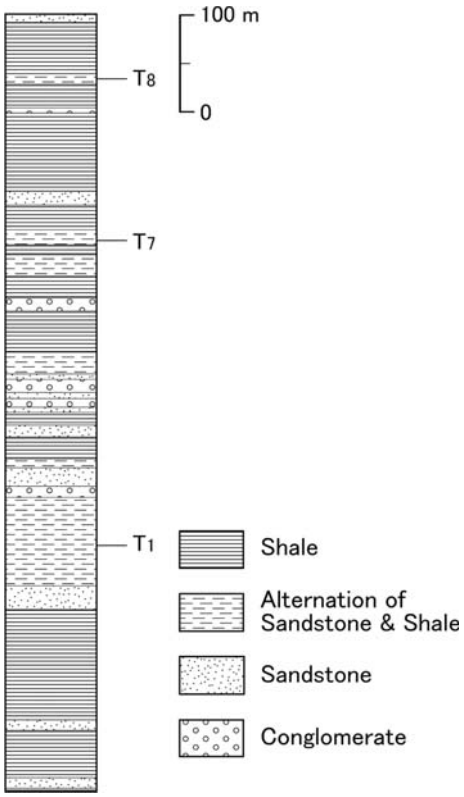

Figure 3. Generalized columnar section of the Takakurayama Formation in the Takakurayama area, showing the fossil horizons of T_1, T_7, T_8.

Pterospirifer alatus is known from the Capitanian–Wuchiapingian. *Costatumulus tazawai* is restricted to the Wuchiapingian. *Megousia auriculata*, *Yakovlevia mammatiformis* and *Hustedia ratburiensis* are long-ranging species.

In summary, the age of the Takakurayama (T_1) fauna is considered to be Capitanian–Wuchiapingian, most probably Wuchiapingian. The brachiopods from the upper part of the Takakurayama Formation at localities T_7 and T_8 indicate a Wuchiapingian–Changhsingian age, probably Wuchiapingian (Tazawa, 2008b). Therefore, the whole of the Takakurayama Formation is assigned to the upper Permian (Wuchiapingian), and is correlated with the lower part of the Toyoma Formation, including the Usuginu-type conglomerate, in the southern Kitakami Mountains, northeastern Japan.

Sedimentary environment of the Daido Formation (equivalent of the Toyoma Formation) and the Usuginu Conglomerate is considered to be a deep-water turbidite basin (Yoshida and Machiyama, 1997, 1998). The early Permian (Sakmarian–Artinskian) ammonoids (*Thalassoceras*? sp., *Agathiceras* sp., *Paragastrioceras*? sp. and *Artinskia* sp.), described by Fujikawa and Suzuki (2011) from the locality T_1, are poorly preserved and may have been reworked into these late Permian (Wuchiapingian) turbidites, as was stated by the authors (p. 64), "we cannot say for certain whether these fossils are reworked or not".

Palaeobiogeography

The Takakurayama (T_1) fauna includes the Boreal (anti-tropical) elements *Chonetinella krotovi*, *Lamnimargus peregrinus*, *Megousia auriculata*, *Costatumulus tazawai*, *Yakovlevia mammatiformis*, *Neospirifer* sp., *Gypospirifer kobiyamai*, *Alispiriferella* sp. and *Pterospirifer alatus*, and also the Tethyan (tropical) elements *Haydenella wenganensis*, *Transennatia gratiosa* and *Echinauris* sp. Consequently, the fauna is a mixed Boreal–Tethyan fauna, with a predominance of Boreal elements. In terms of the specific composition, the Takakurayama (T_1) fauna is closest to the middle–upper Permian brachiopod fauna of South Primorye, Far Eastern Russia (Fredericks, 1924b, 1925; Licharew and Kotlyar, 1978; Kotlyar, 1989). The following five species are common to both faunas: *Chonetinella krotovi*, *Transennatia gratiosa*, *Lamnimargus peregrinus*, *Yakovlevia mammatiformis* and *Gypospirifer kobiyamai*.

These data suggest that in the late Permian (Wuchiapingian) the South Kitakami region, including the Takakurayama area, was located in the mid-latitudes of the Northern Hemisphere, the Inner Mongolia–Japan Transitional Zone (Tazawa, 1991, 1998, 2007) and/or the Sino-Mongolian–Japanese Province (Shi and Tazawa, 2001; Shi, 2006; Shen *et al.*, 2009), a transitional zone between the Boreal and Tethyan realms in East Asia, and close to South Primorye. This conclusion is in agreement with Tazawa's (2008c, 2011, 2012) late Permian reconstruction of Proto-Japan (i.e., the Hida Gaien, South Kitakami and Kurosegawa belts).

Systematic descriptions

(by J. Tazawa)

Order Productida Sarytcheva and Sokolskaya, 1959
Suborder Chonetidina Muir-Wood, 1955
Superfamily Chonetoidea Bronn, 1862
Family Rugosochonetidae Muir-Wood, 1962
Subfamily Rugosochonetinae Muir-Wood, 1962
Genus ***Chonetinella*** Ramsbottom, 1952

Type species.—*Chonetes flemingi* Norwood and Pratten, 1855

Chonetinella krotovi (Fredericks, 1925)

Figure 5.1

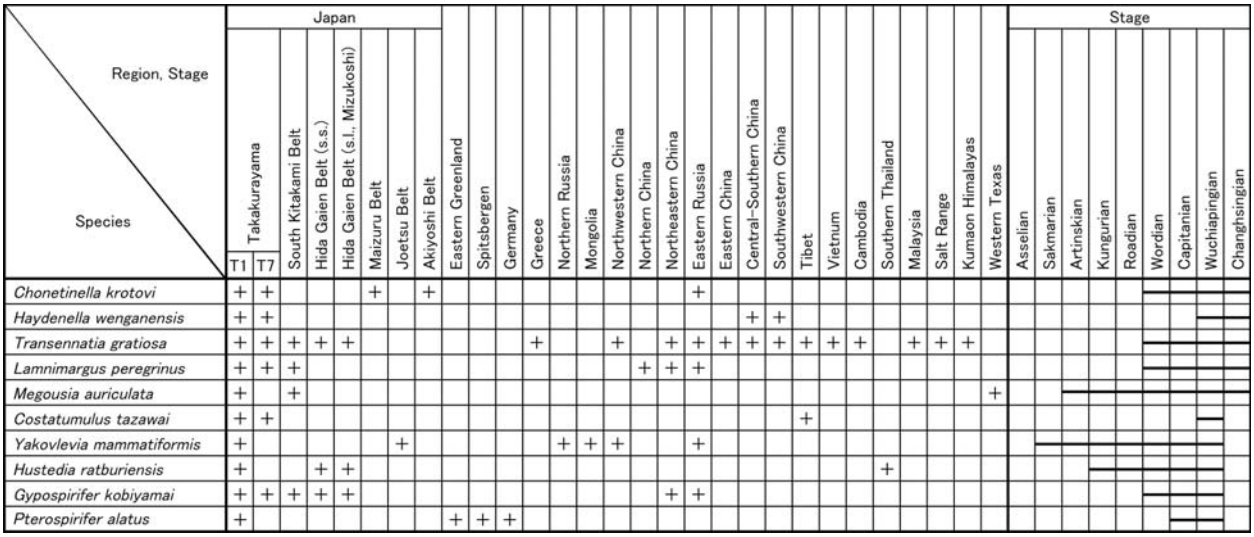

Figure 4. Geographical and stratigraphical distributions of brachiopod species of the Takakurayama (T_1) fauna, excluding five species uncertain.

Chonetes (*Chonetina*) *krotovi* Fredericks, 1925, p. 6, pl. 1, figs. 54–57.
Chonetina substrophomenoides forma A Shimizu, 1961, p. 317, pl. 16, figs. 11–14.
Chonetes uralicus Moeller. Yanagisawa, 1967, p. 86, pl. 1, fig. 11.
Waagenites aff. *striata* Liao. Yanagida, 1996, fig. 2.10.
Chonetinella krotovi (Fredericks). Tazawa, 2008b, p. 19, figs. 3.1–3.7; Tazawa, 2009, p. 69, fig. 4.1.

Material.—One specimen, a ventral valve, GSJ F18045.

Remarks.—The single ventral valve specimen from Takakurayama is small in size (length 6 mm, width 7 mm), slightly transverse, subquadrate in outline, strongly convex in lateral profile, and having a deep and narrow sulcus bordered by a pair of high, broad lateral ridges. External surface of the ventral valve is ornamented by numerous capillae on the whole valve except for the posterior half of the ears. The specimen is referred to *Chonetinella krotovi* (Fredericks, 1925), from the Chandalaz Formation of South Primorye, Russian Far East, in size and shape of the ventral valve and in having a deep and narrow sulcus bordered by a pair of high, broad ridges.

Distribution.—Wordian–Changhsingian: Far Eastern Russia (South Primorye), northeastern Japan (Takakurayama in the South Kitakami Belt) and southwestern Japan (Kawahigashi in the Maizuru Belt and Tsunemori in the Akiyoshi Belt).

Suborder Productidina Waagen, 1883
Superfamily Productelloidea Schuchert, 1929
Family Overtoniidae Muir-Wood and Cooper, 1960
Subfamily Plicatiferinae Muir-Wood and Cooper, 1960
Tribe Plicatiferini Muir-Wood and Cooper, 1960
Genus ***Rugoconcha*** Jin and Sun, 1981

Type species.—*Plicatifera chaoi* Grabau, 1936.

Rugoconcha sp.

Figure 5.2

Material.—One specimen, external mould of a dorsal valve, GSJ F18046.

Description.—Shell small size for genus, transversely subrectangular in outline, with greatest width slightly anterior to hinge; length about 16 mm, width about 18 mm in the single dorsal valve specimen (GSJ F18046). Dorsal valve gently convex, nearly flat on visceral disc, not geniculated; ears large, not clearly demarcated from visceral region; no fold. External surface of dorsal valve ornamented by numerous, strong, subangular and somewhat irregular concentric rugae on whole valve, numbering 3–4 rugae in 3 mm at about midlength; interspaces of rugae broad, with rounded bottom; no spines on valve entirely.

Remarks.—The material available is lacking the ventral valve, but is safely assigned to the genus *Rugoconcha* by its size, shape and external ornament of the dorsal valve. The Takakurayama specimen resembles the type species, *Rugoconcha chaoi* (Grabau, 1936, p. 171, pl. 6, fig. 9; pl. 8, fig. 2; pl. 14, figs. 21, 22), from the Maping Limestone of Guangxi, central-southern China and Guizhou, southwestern China, but the Chinese species is somewhat

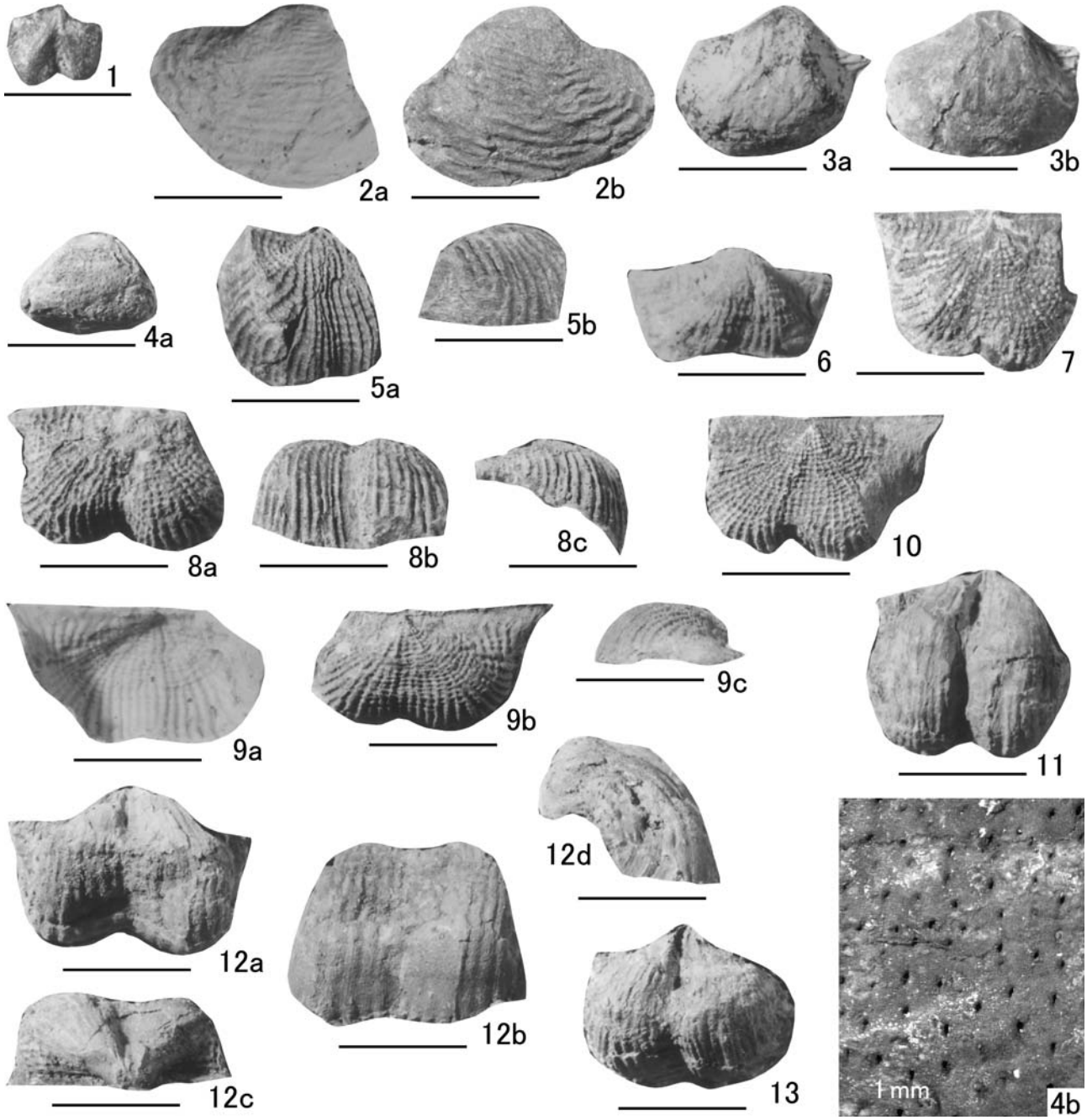

Figure 5. **1,** *Chonetinella krotovi* (Fredericks), ventral view of ventral valve, GSJ F18045; **2,** *Rugoconcha* sp.; 2a, 2b, dorsal view of external latex cast and external mould of dorsal valve, GSJ F18046; **3, 4,** *Haydenella wenganensis* (Huang); 3a, 3b, ventral view of external latex cast and internal mould of ventral valve, GSJ F18047; 4a, 4b, ventral view of internal mould of ventral valve and pseudopunctae on the surface of the specimen, GSJ F18048; **5–10,** *Transennatia gratiosa* (Waagen); 5a, 5b, dorsal and lateral views of external mould of dorsal valve, GSJ F18051; 6, ventral view of external latex cast of ventral valve, GSJ F18052; 7, dorsal view of external mould of dorsal valve, GSJ F18063; 8a, 8b, 8c, dorsal, anterior and lateral views of external mould of dorsal valve, GSJ F18056; 9a, 9b, 9c, dorsal view of external latex cast of dorsal valve, and dorsal and lateral views of external mould of dorsal valve, GSJ F18058; 10, dorsal view of external mould of dorsal valve, GSJ F18064; **11–13,** *Lamnimargus peregrinus* (Fredericks); 11, ventral view of internal mould of ventral valve, GSJ F18076; 12a, 12b, 12c, 12d, ventral, anterior, posterior and lateral views of internal mould of ventral valve, GSJ F18067; 13, ventral view of internal mould of ventral valve, GSJ F18071. Scale bars represent 1 cm.

larger in size.

Rugoconcha xainzaensis Yang and Fan (1983, p. 269, pl. 1, figs. 18, 19), from the upper Carboniferous Susuo Formation of Xainza, northern Xizang (Tibet), differs from the present species in its much smaller size.

Family Productinidae Muir-Wood and Cooper, 1960
Subfamily Chonetellinae Licharew in Sarytcheva *et al*., 1960
Genus ***Haydenella*** Reed, 1944

Type species.—*Productus kiangsiensis* Kayser, 1883.

Haydenella wenganensis (Huang, 1932)

Figures 5.3, 5.4

Linoproductus kiangsiensis var. *wenganensis* Huang, 1932, p. 49, pl. 3, figs. 16–18.
Haydenella kiangsiensis wenganensis (Huang). Zhan, 1979, p. 81, pl. 5, figs. 1, 2.
Haydenella wenganensis (Huang). Liao, 1980, pl. 6, figs. 32, 33; Zeng *et al.*, 1995, pl. 5, fig. 5.
Haydenella sp. Tazawa, 2008b, p. 24, fig. 3.20.

Material.—Four specimens: (1) external and internal moulds of a ventral valve, GSJ F18047; (2) internal moulds of three ventral valves, GSJ F18048–18050.

Description.—Shell small size for genus, transverse subelliptical in outline, with greatest width at hinge; length 12 mm, width 15 mm in the best preserved specimen (GSJ F18047). Ventral valve strongly and unevenly convex in lateral profile, most convex at umbonal region, slightly convex on anterior half of valve, not geniculated; strongly and unevenly convex in anterior profile, with nearly flat venter and steeply inclined lateral slopes; umbo small, tapering and scarcely projecting over hinge; ears small, slightly convex; no sulcus. External surface of ventral valve nearly smooth, faintly costellate; a row of spine bases at base of ears; numerous, very fine tubercles (pseudopunctae) scattered on decorticated surface of valve (Figure 5.4b). Internal structures of ventral valve obscure.

Remarks.—These specimens are referred to *Haydenella wenganensis* (Huang, 1932), originally described as *Linoproductus kiangsiensis* var. *wenganensis* Huang, 1932 from the upper Permian of Guizhou, southwestern China, in size, shape and external ornament of the ventral valves. The Takakurayama specimens resemble well the shells of *H. wenganensis*, described or figured by Zhan (1979), Liao (1980) and Zeng *et al*. (1995) from the Wuchiapingian–Changhsingian of Guangdong, Guizhou and Sichuan, respectively.

Haydenella minuta Sarytcheva (in Sarytcheva and Sokolskaya, 1965, p. 228, pl. 38, figs. 10, 14), from the Dzulfian and Induan stages of Armenia is similar in size, but the Armenian species differs from *H. wenganensis* in having stronger costae on the ventral valve.

The single ventral valve specimen, described by Shimizu (1961, p. 326, pl. 15, figs. 16, 17) as *Linoproductus kiangsiensis* (Kayser, 1883) from the upper Permian Maizuru Group of Kawahigashi, Maizuru Belt, southwestern Japan, is also a small-sized *Haydenella* species, but it differs from *H. wenganensis* in having numerous fine costae on the ventral valve.

Distribution.—Wuchiapingian–Changhsingian: northeastern Japan (Takakurayama in the South Kitakami Belt), central-southern China (Guangdong) and southwestern China (Guizhou and Sichuan).

Superfamily Marginiferoidea Stehli, 1954
Family Marginiferidae Stehli, 1954
Subfamily Marginiferinae Stehli, 1954
Genus ***Transennatia*** Waterhouse, 1975

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

Transennatia gratiosa (Waagen, 1884)

Figures 5.5–5.10

Productus gratiosus Waagen, 1884, p. 691, pl. 72, figs. 3–7; Diener, 1897, p. 23, pl. 3, figs. 3–7; Mansuy, 1913, p. 115, pl. 13, fig. 1; Colani, 1919, p. 10, pl. 1, fig. 2; Chao, 1927, p. 44, pl. 4, figs. 6–10; Chi-Thuan, 1962, p. 491, pl. 2, figs. 5–7.
Productus (*Dictyoclostus*) *gratiosus* Waagen. Huang, 1933, p. 88, pl. 11, fig. 14; Hayasaka, 1960, p. 49, pl. 1, fig. 8.
Marginifera gratiosa (Waagen). Reed, 1944, p. 98, pl. 19, figs. 6, 7.
Dictyoclostus gratiosus (Waagen). Zhang and Jin, 1961, p. 411, pl. 4, figs. 12–18; Wang *et al*., 1964, p. 291, pl. 45, figs. 14–19; Leman, 1994, pl. 1, figs. 11–13.
Gratiosina gratiosa (Waagen). Grant, 1976, pl. 33, figs. 19–26; Licharew and Kotlyar, 1978, pl. 12, figs. 5, 6; pl. 20, fig. 1; Minato *et al.*, 1979, pl. 61, figs. 11–13.
Asioproductus gratiosus (Waagen). Yang *et al*., 1977, p. 350, pl. 140, fig. 5; Feng and Jiang, 1978, p. 254, pl. 90, figs. 1, 2; Tong, 1978, p. 228, pl. 80, fig. 7; Lee *et al.*, 1980, p. 373, pl. 164, fig. 14; pl. 166, figs. 5, 6.
Gratiosina sp., Minato *et al*., 1979, pl. 61, fig. 14.
Dictyoclostus minor Lee and Gu in Lee *et al*., 1980, p. 372, pl. 166, figs. 1–4.
Transennatia gratiosus (Waagen). Wang *et al*., 1982, p. 214, pl. 92, figs. 6–8; pl. 102, figs. 4–9; Liu *et al*., 1982, p. 185, pl. 132, fig. 9; Ding and Qi, 1983, p. 280, pl. 95, fig. 14; Zeng *et al.*, 1995, pl. 5, figs. 14, 15.
Transennatia gratiosa (Waagen). Yang, 1984, p. 219, pl. 33, fig. 7; Jin, 1985, pl. 4, figs. 33, 34, 45, 46; Tazawa and Matsumoto, 1998, p. 6, pl. 1, figs. 4–8; Tazawa *et al.*, 2000, p. 7, pl. 1, figs. 3–5; Tazawa, 2001, p. 289, figs. 6.1–6.7; Tazawa and Ibaraki, 2001, p. 7, pl. 1, figs. 1–3; Shen *et al*., 2002, p. 676, figs. 4.27–4.31; Tazawa, 2002, fig. 10.2; Chen *et al*., 2005, p. 354, figs. 10E–10H, 11; Tazawa, 2008b, p. 26, fig. 4.1; Tazawa, 2008c, p. 43, figs. 6.6, 6.7; Shen and Zhang, 2008, figs. 4.20–4.22; Shen and Clapham, 2009, p. 718, pl. 1, figs. 13–22; Shen and Shi, 2009, p. 157, figs. 3K–3O.

Material.—Sixteen specimens: (1) external mould of a ventral valve, GSJ F18052; (2) internal moulds of two ventral valves, GSJ F18053, 18054; (3) external moulds of thirteen dorsal valves, GSJ F18051, 18055–18066.

Description.—Shell small size for genus, transversely subquadrate in outline, with greatest width at hinge; length 13 mm, width about 20 mm in the largest dorsal valve specimen (GSJ F18066). Ventral valve strongly and unevenly convex in lateral profile, most convex at umbonal region, strongly geniculated and followed by long trail; umbo small, slightly incurved; ears small, pointed; sulcus narrow and deep; lateral slopes steep. Dorsal valve nearly flat on visceral disc, strongly geniculated and followed by long trail; fold invisible on visceral disc, but highly developed on trail. External surface of both valves reticulate on visceral disc and costate on trail; costae converging into ventral sulcus and dorsal fold anteriorly; numbering 7 costae in 5 mm at midlength of dorsal valve; spines or spine bases absent. Ventral interior with small, elongate, highly raised adductor scars and large, flabellate, longitudinally striated diductor scars in posterior portion of valve. Dorsal interior not observed.

Remarks.—These specimens are referred to *Transennatia gratiosa* (Waagen, 1884), originally described from the Wargal and Chhidru formations of the Salt Range, in their small size, strongly convex ventral valve and sharply reticulate ornament on the visceral disc of both valves, although the Takakurayama specimens are smaller in size than the type specimens from the Salt Range (Waagen, 1884, pl. 72, figs. 3–7).

Transennatia insculpta (Grant, 1976, p. 135, pl. 32, figs. 1–37; pl. 33, figs. 1–36), from the Ratburi Limestone of Ko Muk, southern Thailand, is also a small-sized *Transennatia* species, but it differs from *T. gratiosa* in its more transverse outline, more prominent ears and coarser costae on the ventral valve.

Distribution.—Wordian–Changhsingian: northwestern China (Shaanxi), northeastern China (Heilongjiang and Jilin), Russian Far East (South Primorye), northeastern Japan (Setamai, Kamiyasse, Kesennuma, Ogatsu and Takakurayama in the South Kitakami Belt), central Japan (Moribu and Oguradani in the Hida Gaien Belt), southwestern Japan (Mizukoshi in Kyushu Island, western extension of the Hida Gaien Belt), eastern China (Zhejiang, Anhui and Jiangxi), central-southern China (Hubei, Hunan, Guangdong and Guangxi), southwestern China (Guizhou, Sichuan and Yunnan), Tibet (Xizang), Vietnam, Cambodia (Sisophon), Malaysia, Nepal (Kumaon Himalayas), Pakistan (Salt Range) and Greece (Hydra Island).

Family Paucispiniferidae Muir-Wood and Cooper, 1960

Subfamily Paucispiniferinae Muir-Wood and Cooper, 1960

Tribe Paucispiniferini Muir-Wood and Cooper, 1960

Genus ***Lamnimargus*** Waterhouse, 1975

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

Lamnimargus peregrinus (Fredericks, 1924b)

Figures 5.11–5.13

Paramarginifera peregrina Fredericks, 1924b, p. 24, pl. 1, figs. 7, 8; Fredericks, 1925, p. 12, pl. 1, figs. 41–44.

Dictyoclostus zesiensis Lee and Gu, 1976, p. 256, pl. 167, figs. 5, 6; pl. 170, fig. 1.

Probolionia caucasica peregrina (Fredericks). Licharew and Kotlyar, 1978, p. 12, figs. 13, 14.

Paramarginifera? *peregrina* Fredericks. Duan and Li, 1985, p. 112, pl. 42, figs. 1–7; Lee *et al*., 1980, p. 356, pl. 166, figs. 18, 28.

Lamnimargus himalayensis (Diener). Kotlyar, 1989, pl. 23, fig. 9.

Lamnimargus peregrina (Fredericks). Wang and Zhang, 2003, p. 73, pl. 14, figs. 3, 8, 9; pl. 15, fig. 11; pl. 21, figs. 14–16, 22–24.

Lamnimargus peregrinus (Fredericks). Tazawa, 2008a, p. 7, figs. 3, 4; Tazawa, 2008b, p. 25, figs. 4.2–4.4; Tazawa in Tazawa and Miyake, 2011, p. 4, figs. 3.1–3.3; Tazawa, 2012, p. 21, figs. 4.4, 4.5.

Material.—Eleven specimens: (1) internal moulds of three ventral valves, with fragments of external moulds of the valves, GSJ F18067–18069; (2) an abraded ventral valve, GSJ F18070; (3) internal moulds of seven ventral valves, GSJ F18071–18077.

Description.—Shell medium size for genus; length 15 mm, width 18 mm in corpus of the largest specimen (GSJ F18067). Ventral valve strongly and unevenly convex in lateral profile, most convex at umbonal slope, bluntly geniculated and followed by long trail; sulcus narrow and deep, originating near umbo and extending to anterior margin; lateral slopes steep. External surface of ventral valve ornamented by numerous costae, numbering 3 in 2 mm at midlength of trail; a row of fine spines along hinge. Ventral interior with a pair of elongate, highly raised, smooth adductor scars and impressed, wide, oval and striated diductor scars; marginal ridge developed at anterior portion.

Remarks.—The material available is fragmentarily preserved internal moulds of ventral valves, lacking ears. However, the Takakurayama specimens are referred to *Lamnimargus peregrinus* (Fredericks, 1924b), from the Chandalaz Formation of the Vladivostok area, South Primorye, Russian Far East, by their size, shape, and external ornamentation of the ventral valve. The Takakurayama specimens resemble well the specimens of *L. peregrinus* described and figured by Tazawa (2008a, p. 7, figs. 3, 4) from the upper Toyoma Forma-

tion of Maeda, Ofunato area, South Kitakami Belt.

The type species, *Lamnimargus himalayensis* (Diener, 1899, p. 39, pl. 2, figs. 1–7; pl. 6, figs. 1, 2), from the Kuling Shales of the Punjab Himalayas, Kashmir, is distinguished from *L. peregrinus* by its much larger, prominent ears and coarser costellae on the ventral valve.

Distribution.—Wordian–Changhsingian: northern China (Inner Mongolia), northeastern China (Heilongjiang), Far Eastern Russia (South Primorye) and northeastern Japan (Ofunato, Kesennuma and Takakurayama in the South Kitakami Belt).

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.

Figure 6.1

Material.—Two specimens: (1) external mould of a ventral valve, GSJ F18078; (2) external mould of a dorsal valve, GSJ F18079.

Description.—Shell small size for genus, transversely subcircular in outline, with greatest width at midlength; length 11 mm, width 13 mm in the ventral valve specimen (GSJ F18078). Ventral valve strongly and unevenly convex in lateral profile, maximum curvature in posterior third, not geniculated; anterior profile domed, with steep sides; umbonal region broadly swollen; ears small; sulcus wide and shallow in anterior slope. Dorsal valve evenly and moderately concave; ears small, flattened; fold absent. External surface of ventral valve ornamented by very fine growth lines and numerous stout spines, scattered over venter, numbering 2–3 in 3 mm width at about midlength of valve. External ornament of dorsal valve similar to the opposite valve. Internal structure of both ventral and dorsal valves not preserved.

Remarks.—This specimen is safely assigned to the genus *Echinauris* by its small size, subcircular outline, and numerous stout spines on the ventral valve. The Takakurayama specimen resembles *Echinauris irregularis* Cooper and Grant (1975, p. 1008, pl. 329, figs. 1–24; pl. 330, figs. 1–43; pl. 331, figs. 1–34; pl. 332, figs. 25–32), from the upper Wolfcampian and Leonardian of western Texas, but differs from the latter in having no interrupted costae 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 the Glass Mountains, western Texas, is distinguished from the Takakurayama species by its larger and elongate oval shell.

Echinauris opuntia (Waagen, 1884, p. 707, pl. 79, figs. 1, 2), from the Wargal Formation of the Salt Range, is distinguished from the present species by its slightly elongate outline and less stout spines on the ventral valve.

Superfamily Linoproductoidea Stehli, 1954
Family Linoproductidae Stehli, 1954
Subfamily Anidanthinae Waterhouse, 1968b
Genus ***Megousia*** Muir-Wood and Cooper, 1960

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

Megousia auriculata Muir-Wood and Cooper, 1960

Figure 6.2

Linoproductus waagenites Girty. King, 1931, p. 77, pl. 17, figs. 11–15 only.

Megousia auriculata Muir-Wood and Cooper, 1960, p. 310, pl. 113, figs. 1–11; Ferguson, 1969, pl. 1, figs. 5–11; Nakamura, 1972, p. 436, pl. 2, fig. 3; Cooper and Grant, 1975, p. 1192, pl. 450, figs. 1–48; pl. 451, figs. 1–49; pl. 452, figs. 19–28; pl. 453, figs. 13–24; pl. 463, figs. 5–8; pl. 467, figs. 9–13; Tazawa, 2012, p. 25, figs. 3.8–3.10.

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

Material.—Two specimens: (1) internal mould of a conjoined shell, with external mould of the ventral valve, GSJ F18080; (2) internal mould of a ventral valve, GSJ F18081.

Description.—Shell medium size for genus, transversely wider subcylindrical in outline, with greatest width at hinge; length 11 mm, width about 24 mm in the better preserved specimen (GSJ F18080). Ventral valve strongly convex in lateral profile; umbo narrowly swollen; ears large, prominent; lateral slopes steep. Dorsal valve moderately convex in lateral profile, strongly geniculated and followed by short trail; ears long, slender; fold broad and low on trail. External surface of dorsal valve ornamented by strong, irregular concentric lamellae and numerous fine costellae, numbering 8–9 in 5 mm at midlength; ears also ornamented with radial costellae. Ventral interior with a pair of small, triangular adductor scars and large, flabellate diductor scars. Dorsal interior with a small, short-shafted and trilobed cardinal process, and strong, short median septum.

Remarks.—The Takakurayama specimens can be referred to *Megousia auriculata* Muir-Wood and Cooper, 1960, originally described from the Word Formation of the Glass Mountains, western Texas, by their small, very transverse shell and in having radially ribbing, slender

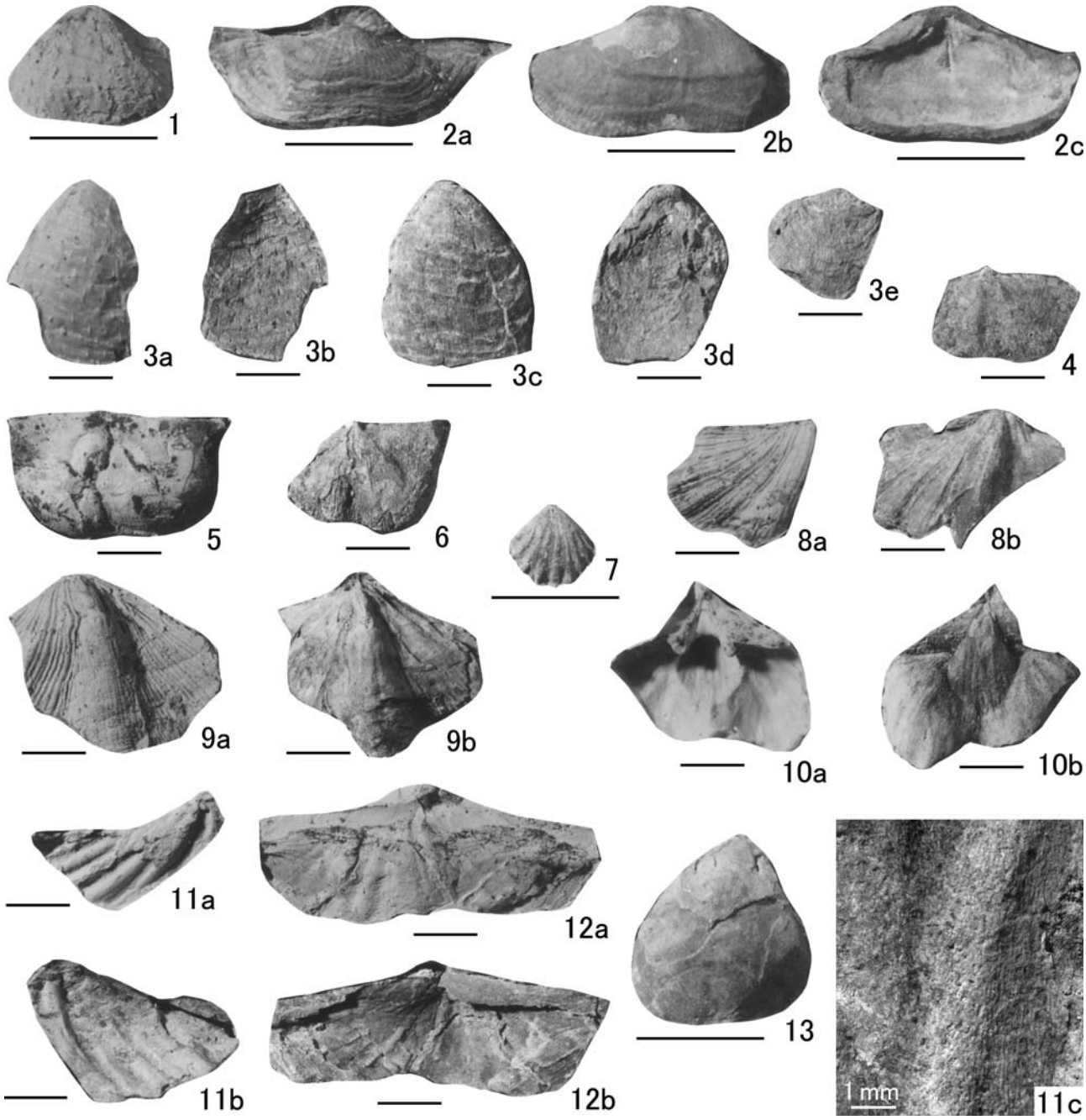

Figure 6. **1,** *Echinauris* sp., ventral view of external latex cast of ventral valve, GSJ F18078; **2,** *Megousia auriculata* Muir-Wood and Cooper; 2a, 2b, 2c, dorsal view of external mould of dorsal valve, and ventral and dorsal views of internal mould of conjoined shell, GSJ F18080; **3,** *Costatumulus tazawai* Shen, Archbold, Shi and Chen; 3a, 3b, 3c, 3d, 3e, ventral views of external latex cast and internal mould of ventral valve, ventral and dorsal views of internal mould of conjoined shell, and dorsal view of external mould of dorsal valve, GSJ F18082; **4–6,** *Yakovlevia mammatiformis* (Fredericks); 4, dorsal view of external mould of dorsal valve, GSJ F18088; 5, external latex cast of ventral valve, GSJ F18086; 6, ventral view of internal mould of ventral valve, GSJ F18087; **7,** *Hustedia ratburiensis* Waterhouse and Piyasin, dorsal view of internal mould of dorsal valve, GSJ F18090; **8,** *Neospirifer* sp.; 8a, 8b, dorsal views of external latex cast and internal mould of dorsal valve, GSJ F18091; **9,** *Gypospirifer kobiyamai* Tazawa and Araki; 9a, 9b, dorsal views of external latex cast and internal mould of dorsal valve, GSJ F18092; **10,** *Alispiriferella* sp.; 10a, 10b, ventral views of internal latex cast and internal mould of ventral valve, GSJ F18094; **11, 12,** *Pterospirifer alatus* (von Schlotheim); 11a, 11b, 11c, ventral view of external latex cast of ventral valve, internal mould of ventral valve, and microornamentation of ventral valve, GSJ F18095; 12a, 12b, dorsal view of external latex cast and external mould of dorsal valve, GSJ F18096; **13,** *Dielasma* sp., 13, ventral view of internal mould of ventral valve, GSJ F18097. Scale bars represent 1 cm.

ears on the dorsal valve.

Megousia nakamurai Tazawa (1975, p. 635, pl. 3, figs. 5, 6), from the upper Toyoma Formation of Nabekoshiyama, Kesennuma area, South Kitakami Belt, is readily distinguished from *M. auriculata* by its less transverse outline, much broader ears and finer costellae on the dorsal valve.

Distribution.—Artinskian–Changhsingian: northeastern Japan (Kesennuma and Takakurayama in the South Kitakami Belt) and the United States (western Texas).

Family Kansuellidae Mur-Wood and Cooper, 1960
Subfamily Auriculispininae Waterhouse, 1986
Tribe Auriculispinini Waterhouse, 1986
Genus ***Costatumulus*** Waterhouse, 1983

Type species.—*Auriculispina tumida* Waterhouse in Waterhouse *et al*., 1983.

Costatumulus tazawai Shen, Archbold, Shi and Chen, 2000

Figure 6.3

Costatumulus tazawai Shen, Archbold, Shi and Chen, 2000, p. 743, figs. 12.1–8, 11–14.
Costatumulus cf. *tazawai* Shen, Archbold, Shi and Chen. Tazawa, 2008b, p. 27, fig. 4.5.

Material.—Four specimens: (1) external moulds of a conjoined shell, with internal mould of the dorsal valve, GSJ F18082; (2) external moulds of three dorsal valves, GSJ F18083–18085.

Description.—Shell medium size for genus, suboval in outline; length more than 29 mm, width more than 22 mm in the largest specimen (GSJ F18082); length about 12 mm, width about 20 mm in the best preserved dorsal valve specimen. Ventral valve gently convex in lateral profile, with maximum convexity at umbonal slope; ears not preserved; no sulcus. Dorsal valve slightly concave in lateral profile, weakly geniculated and followed by short trail; no fold. External surface of ventral valve ornamented by strong, irregular concentric rugae, numerous, fine costellae and numerous, fine, recumbent spines on whole venter of valve; numbering 12–13 costellae in 5 mm at midlength. External surface of dorsal valve also ornamented by numerous strong rugae, fine costellae and several dimples, but no spines.

Remarks.—The specimens from Takakurayama are incompletely preserved and lacking most of the ears, but they can be referred to *Costatumulus tazawai* Shen, Archbold, Shi and Chen, 2000, from the middle part of the Selong Group of Selong, southern Xizang (Tibet), southwestern China, by their concavo-convex shell, with relatively coarse rugae and fine costellae on both ventral and dorsal valves. *Costatumulus* cf. *tazawai*, described by Tazawa (2008b), from the upper part of the Takakurayama Formation in the Takakurayama area, may be conspecific with the present species.

Costatumulus polliciformis (Waterhouse, 1978, p. 76, pl. 11, figs. 9–12), from the lower Senja Formation of northwest Nepal, differs from *C. tazawai* in having less strong rugae and coarser costellae on the ventral valve.

The type species, *Costatumulus tumida* (Waterhouse in Waterhouse *et al*., 1983, p. 133, pl. 3, figs. 2–4, 6–7), from the Tiverton Formation of northern Bowen Basin, eastern Australia, is readily distinguished from *C. tazawai* by its less strong rugae on the ventral valve.

Distribution.—Wuchiapingian: northeastern Japan (Takakurayama in the South Kitakami Belt) and Xizang (Tibet).

Family Yakovleviidae Waterhouse, 1975
Genus ***Yakovlevia*** Fredericks, 1925

Type species.—*Yakovlevia kaluzinensis* Fredericks, 1925.

Yakovlevia mammatiformis (Fredericks, 1926)

Figures 6.4–6.6

Productus mammatiformis Fredericks, 1926, p. 87, pl. 3, figs. 4–6.
Muirwoodia mammatiformis (Fredericks). Solomina, 1960, p. 65, pl. 12, figs. 7, 8; Kulikov, 1974, p. 89, pl. 3, fig. 6.
Yakovlevia mammatiformis (Fredericks). Kotlyar, 1961, text-figs. 7, 8; Ustritsky, 1963, p. 12, pl. 2, figs. 6–8; pl. 3, figs. 1–3; Mironova, 1964, p. 97, pl., fig. 14; Zavodowsky and Stepanov, 1970, p. 114, pl. 35, figs. 8–10; Ifanova, 1972, p. 119, pl. 6, figs. 15, 16; pl. 7, figs. 1, 2; Kalashnikov, 1983, p. 210, pl. 49, figs. 5, 6, 9; Manankov, 1991, p. 107, pl. 26, figs. 1–3; Kalashnikov, 1993, p. 61, pl. 16, figs. 1–4; Tazawa, 1999a, fig. 2.3; Tazawa, 1999b, p. 92, fig. 3.6; Klets *et al*., 2001, pl. 2, fig. 9; Klets, 2005, pl. 32, fig. 9; Tazawa, 2008b, p. 29, fig. 4.13; Tazawa, 2011, p. 175, fig. 4.8.
Linoproductus cf. *mammatus* (Keyserling). Yanagisawa, 1967, p. 88, pl. 2, fig. 7.
Yakovlevia sp. Tazawa and Niigata Pre-Tertiary Research Group, 1999, fig. 12 only.

Material.—Four specimens: (1) external mould of a ventral valve, GSJ F18086; (2) internal mould of a ventral valve, GSJ F18087; (3) external and internal moulds of a dorsal valve, GSJ F18088; (4) external mould of a dorsal valve, GSJ F18089.

Description.—Shell medium size for genus, transversely subrectangular in outline, with greatest width at hinge; length about 20 mm, width more than 36 mm in the largest ventral valve specimen (GSJ F18086). Ventral valve gently convex on visceral disc, strongly geniculated and followed by long trail; umbo small; sulcus narrow and moderately deep; lateral slopes steep. Dorsal

valve almost flat on visceral disc, strongly geniculated and followed by long trail. External surface of both valves ornamented by numerous fine costellae; numbering 10–11 costellae in 5 mm at midlength of ventral valve; 12–13 costellae in 5 mm at midlength of dorsal valve; a thick halteroid spine on lateral slope of ventral valve. Ventral interior with a pair of small, elongate adductor scars and large flabellate diductor scars, encircled by a ridge posterolaterally.

Remarks.—These specimens can be referred to *Yakovlevia mammatiformis* (Fredericks, 1926), from the lower Permian (Artinskian) of the Pechora Basin, northern Russia, in size, shape and external ornament of the ventral valve.

Yakovlevia transversa (Cooper, 1957, p. 39, pl. 5, figs. 1–13), from the Coyote Butte Formation of central Oregon, resembles *Y. mammatiformis* in general appearance, but the former is distinguished from the latter by its smaller dimensions, more strongly developed fold commencing a little below the umbo, and coarser costellae on both the ventral and dorsal valves.

Yakovlevia mammata (Keyserling, 1846, p. 206, pl. 4, fig. 5), from the lower Permian (possibly Sakmarian) of the Pechora Basin, differs from *Y. mammatiformis* in its smaller size, less transverse outline, and external ornament consisting of more numerous, finer costellae.

Distribution.—Sakmarian–Wuchiapingian: Russian Arctic and Far North (Novaya Zemlya, Pechora Basin, Pai Khoi, northern Urals, Verkhoyansk and Omolon Massif), southern Mongolia, northwestern China (Gansu), Russian Far East (South Primorye), northeastern Japan (Takakurayama in the South Kitakami Belt) and central Japan (Okutadami in the Joetsu Belt).

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

Figure 6.7

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; Archbold, 1999, figs. 5E–5H; Yanagida and Nakornsri, 1999, p. 118, pl. 32, figs. 11–16; Tazawa, 2001, p. 299, fig. 8.6; Tazawa, 2008c, p. 53, figs. 8.2–8.6.
Hustedia thailandica Waterhouse and Piyasin, 1970, text-figs. 12, 13.
Hustedia nakornsrii Yanagida, 1970, p. 79, pl. 14, fig. 9.

Material.—One specimen, internal mould of a dorsal valve, GSJ F18090.

Remarks.—The single dorsal valve specimen from Takakurayama can be referred to *Hustedia ratburiensis* Waterhouse and Piyasin, 1970, from the Ratburi Limestone of Khao Phrik, southern Thailand, by its small size (length 7 mm, width 7 mm), subcircular outline, and nine strong costae on the dorsal valve.

Hustedia grandicosta (Davidson, 1862), redescribed by Waagen (1883, p. 491, pl. 34, figs. 6–12), from the Amb, Wargal and Chhidru formations of the Salt Range, differs from *H. ratburiensis* in having more numerous, fine costae on the dorsal valve.

Hustedia minuta Tazawa and Miyake (2011, p. 15, figs. 2.5, 2.6), from the upper Toyoma Formation of Maeda, in the Ofunato area, South Kitakami Belt, is distinguished from the present species by its smaller size and in having more numerous costae on the dorsal valve.

Distribution.—Kungurian–Wuchiapingian: northeastern Japan (Takakurayama in the South Kitakami Belt), central Japan (Moribu in the Hida Gaien Belt), southwestern Japan (Mizukoshi, central Kyushu) and southern Thailand (Khao Phrik, Khao Nong Ta On and Khao Hin King).

Order Spiriferida Waagen, 1883
Suborder Spiriferidina Waagen, 1883
Superfamily Spiriferoidea King, 1846
Family Trigonotretidae Schuchert, 1893
Subfamily Neospiriferinae Waterhouse, 1968a
Genus ***Neospirifer*** Fredericks, 1924a

Type species.—*Spirifer fasciger* Keyserling, 1846.

Neospirifer sp.

Figure. 6.8

Material.—One specimen, external and internal moulds of a dorsal valve, GSJ F18091.

Remarks.—This specimen is safely assigned to the genus *Neospirifer* by its transverse, medium-sized dorsal valve (length about 25 mm, width about 40 mm), with high, broad fold and ornamented by numerous fasciculate costae and very fine concentric growth lamellae. The Takakurayama species resembles the type species, *Neospirifer fasciger* (Keyserling, 1846), from the lower Permian of Timan, northern Russia in size and shape of the dorsal valve, but accurate comparison is difficult because of the former's ill preserved cardinal extremities. *N. fasciger* is characterized by its rounded cardinal extremities (Poletaev, 1997, pl. 4, figs. 2–7).

Genus ***Gypospirifer*** Cooper and Grant, 1976

Type species.—*Gypospirifer nelsoni* Cooper and Grant, 1976.

Gypospirifer kobiyamai Tazawa and Araki, 2013

Figure 6.9

Spirifer fasciger var. *simplex* Grabau. Kobiyama, 1956, fig. 4.
Neospirifer fasciger (Keyserling). Hayasaka, 1960, p. 42, pl. 2, figs. 1, 2 only; Yanagida, 1963, p. 71, pl. 8, figs. 3, 6; pl. 9, fig. 3 only; Koizumi, 1979, pl. 1, fig. 16 only.
Neospirifer aff. *cameratus* Morton. Yanagisawa, 1967, p. 91, pl. 2, fig. 11.
Neospirifer striato-paradoxus (Toula). Licharew and Kotlyar, 1978, pl. 18, fig. 1; Lee *et al*., 1980, p. 412, pl. 177, figs. 3, 6, 9.
Gypospirifer volatilis Duan and Li. Tazawa, 2001, p. 302, figs. 8.23–8.26; Tazawa and Hasegawa, 2007, p. 7, figs. 4.8–4.12, 5.1, 5.2; Tazawa, 2008b, p. 39, fig. 6.17; Tazawa, 2008c, p. 54, figs. 9.3–9.7.
Gypospirifer kobiyamai Tazawa and Araki, 2013, p. 7, figs. 2.3, 2.4.

Material.—Two specimens, external and internal moulds of two dorsal valves, GSJ F18092, 18093.

Remarks.—The specimens from Takakurayama are fragmentarily preserved, but they can be referred to *Gypospirifer kobiyamai* Tazawa and Araki, 2013, from the lower Kamiyasse Formation of Kamiyasse, South Kitakami Belt, northeastern Japan, by their large size (length more than 40 mm, width more than 65 mm in the larger specimen, GSJ F18093), narrow and high dorsal fold, and numerous fine, often bifurcated and weakly fasciculated costae (numbering 10–12 in 10 mm at mid-length) on the dorsal valve.

Gypospirifer volatilis Duan and Li (1985, p. 127, 207, pl. 48, figs. 1, 2; pl. 49, figs. 1, 2), from the Zhesi (Jisu) Formation of Zhesi, Inner Mongolia, northern China, differs from *G. kobiyamai* in having a much broader and higher fold on the dorsal valve.

Gypospirifer gryphus Cooper and Grant (1976, p. 2211, pl. 591, figs. 1–5), from the Graham Formation of western Texas, differs from *G. kobiyamai* in its more transverse outline.

Distribution.—Wordian–Wuchiapingian: northeastern China (Heilongjiang), Far Eastern Russia (South Primorye), northeastern Japan (Kesennuma and Takakurayama in the South Kitakami Belt), central Japan (Moribu in the Hida Gaien Belt) and southwestern Japan (Mizukoshi, central Kyushu, western extension of the Hida Gaien Belt).

Family Spiriferellidae Waterhouse, 1968a
Genus ***Alispiriferella*** Waterhouse and Waddington, 1982

Type species.—*Spirifer* (*Spiriferella*) *keilhavii* (von Buch) var. *ordinaria* Einor in Licharew and Einor, 1939.

Alispiriferella sp.

Figure 6.10

Material.—One specimen, internal mould of a ventral valve, with external mould of the ventral interarea, GSJ F18094.

Remarks.—The material available is lacking external ornament of the ventral valve, but it resembles well the specimens of *Alispiriferella lita* (Fredericks, 1924b), described and figured by Tazawa (2008c, p. 55, figs. 9.8–9.14) from the Mizukoshi Formation of Mizukoshi, central Kyushu, southwestern Japan. It is characterized by its large, transverse shell (length more than 30 mm, width more than 35 mm) and in having a pair of high dental plates and a deeply impressed heart-shaped muscle field in the ventral valve. The Takakurayama specimen may be an *Alispiriferella* species, although specific identification is difficult.

Superfamily Paeckelmanelloidea Ivanova, 1972
Family Strophopleuridae Carter, 1974
Subfamily Pterospiriferinae Waterhouse, 1975
Genus ***Pterospirifer*** Dunbar, 1955

Type species.—*Spirifer alatus* von Schlotheim, 1813.

Pterospirifer alatus (von Schlotheim, 1813)

Figures 6.11, 6.12

Spirifer alatus von Schlotheim, 1813, p. 87, pl. 16, figs. 1–7.
Pterospirifer alatus (von Schlotheim). Dunbar, 1955, p. 129, pl. 22, figs. 19–25; Ivanova, 1981, p. 33, pl. 1, figs. 1–3; pl. 2, fig. 1; text-figs. 1, 2b, 4a, 5, 10; Nakamura *et al*., 1992, pl. 5, figs. 1–3.

Material.—Two specimens: (1) external mould of a ventral valve, GSJ F18095; (2) external mould of a dorsal valve, GSJ F18096.

Remarks.—The Takakurayama specimens are fragmentarily preserved, but they can be referred to *Pterospirifer alatus* (von Schlotheim, 1813), from the lower Zechstein of Germany, in their large, transverse shells (length about 25 mm, width more than 57 mm in the better preserved dorsal valve specimen, GSJ F18096), with strongly alate cardinal extremities, broad, moderately high and smooth dorsal fold, numerous simple costae and microornament consisting of numerous very fine capillae and growth lamellae (Figure 6.11c) on both the ventral and dorsal valves.

Pterospirifer terechovi Zavodowsky (1968, p. 150, pl. 43, fig. 1), from the lower Permian of Kolyma, northeastern Russia, differs from *P. alatus* in its much larger size.

Distribution.—Capitanian–Wuchiapingian: eastern Greenland, Spitsbergen, Germany and northeastern Japan (Takakurayama in the South Kitakami Belt).

Order Terebratulida Waagen, 1883
Suborder Terebratulidina Waagen, 1883
Superfamily Dielasmatoidea Schuchert, 1913
Family Dielasmatidae Schuchert, 1913
Subfamily Dielasmatinae Schuchert, 1913
Genus ***Dielasma*** King, 1859

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

Dielasma sp.

Figure 6.13

Material.—Two specimens, internal moulds of two ventral valves, GSJ F18097, 18098.

Remarks.—These specimens are safely assigned to the genus *Dielasma* by their medium size (length 17 mm, width 14 mm in the better preserved specimen, GSJ F18097), elongate, subpentagonal outline of the shell and gently convex dorsal valve with a shallow sulcus and a pair of strong dental plates. The Takakurayama species resembles well and may be identical with *Dielasma* sp., described by Tazawa (2008c, p. 57, figs. 9.15–9.18) from the upper part of the Mizukoshi Formation of Mizukoshi, central Kyushu, southwest Japan, in size and outline of the dorsal valve, but accurate comparison is difficult because of the poor preservation of the present material.

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References

Archbold, N. W., 1999: Additional records of Permian brachiopods from near Rat Buri, Thailand. *Proceedings of the Royal Society of Victoria*, vol. 111, p. 71–86.

Asama, K., 1974: Permian plants from Takakurayama, Japan. *Bulletin of the National Science Museum, Tokyo*, vol. 17, p. 239–252.

Boucot, A. J., Johnson, J. G. and Staton, R. D., 1964: On some atrypoid, retzioid, and athyridoid Brachiopoda. *Journal of Paleontology*, vol. 38, p. 805–822.

Bronn, H. G., 1862: *Die Klassen und Ordnungen der Weichthiere, Wissenschaftlich Dargestellt in Wort und Bild, 3. Bd. 1. Abtheilung, Kopflose Thiere (Malacozoa Acephala)*, 518 p. C. F. Winter'sche Verlagshandlung, Leipzig and Heidelberg.

Carter, J. L., 1974: New genera of spiriferid and brachythyrid brachiopods. *Journal of Paleontology*, vol. 48, p. 674–696.

Chao, Y. T., 1927: Productidae of China, Part 1. Producti. *Palaeontologia Sinica, Series B*, vol. 5, p. 1–244.

Chen, Z.-Q., Campi, M., Shi, G. R. and Kaiho, K., 2005: Post-extinction brachiopod faunas from the Late Permian Wuchiapingian coal series of South China. *Acta Palaeontologica Polonica*, vol. 50, p. 343–363.

Chi-Thuan, T. T., 1962: Les brachiopodes permiens de Cam-Lo (Province de Quang-Tri). *Annales de la Faculté des Sciences, Université de Saigon*, 1962, p. 485–498.

Colani, M. M., 1919: Sur quelques fossiles ouralo-permiens de Hongay. *Bulletin du Service Géologique de l'Indochine*, vol. 6, p. 1–27.

Cooper, G. A., 1957: Permian brachiopods from central Oregon. *Smithsonian Miscellaneous Collections*, vol. 134, p. 1–79.

Cooper, G. A. and Grant, R. E., 1975: Permian brachiopods of West Texas, 3. *Smithsonian Contributions to Paleobiology*, no. 19, p. 795–1921.

Cooper, G. A. and Grant, R. E., 1976: Permian brachiopods of West Texas, 4. *Smithsonian Contributions to Paleobiology*, no. 21, p. 1923–2607.

Dagys, A. S., 1972: Morfologiya i sistema mezozoyskikh rettsioidnykh brakhiopod (Morphology and systematics of Mesozoic retzioid brachiopods). *Akademiya Nauk SSSR, Sibirskoye Otdeleniye, Trudy Instituta Geologii i Geofiziki*, vol. 112, p. 94–105. (*in Russian; original title translated*)

Davidson, T., 1862: On some Carboniferous Brachiopoda, collected in India by A. Fleming, M. D., and W. Purdon, Esq., F. G. S. *Quarterly Journal of the Geological Society of London*, vol. 18, p. 25–35.

Diener, C., 1897: The Permocarboniferous fauna of Chitichun, No. 1. *Palaeontologia Indica, Series 15*, vol. 1, p. 1–105.

Diener, C., 1899: Anthracolithic fossils of Kashmir and Spiti. *Palaeontologia Indica, Series 15*, vol. 1, p. 1–95.

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

Duan, C. and Li, W., 1985: Description of fossils, (4) Phylum Brachiopoda. *In*, Ding, Y., Xia, G., Duan, C., Li, W., Liu, X. and Liang, Z., Study on the Early Permian stratigraphy and fauna in Zhesi district, Nei Mongol Zizhiqu (Inner Mongolia). *Bulletin of the Tianjin Institute of Geology and Mineral Resources*, no. 10, p. 99–145, 199–214. (*in Chinese with English abstract*)

Dunbar, C. O., 1955: Permian brachiopod faunas of Central East Greenland. *Meddelelser om Grønland*, vol. 110, p. 1–169.

Ehiro, M., 2008: Two genera of Popanoceratidae (Permian Ammonoidea) from the South Kitakami Belt, northeast Japan, with a note on the age of the Takakurayama Formation in the Abukuma Massif. *Bulletin of the Tohoku University Museum*, no. 8, p. 1–8.

Ehiro, M. and Okami, K., 1989: Permian; Yaguki area. *In*, Editorial Committee of Tohoku, Part 2 of Regional Geology of Japan *ed*., *Regional Geology of Japan, Part 2 Tohoku*, p. 58–60. Kyoritsu Shuppan, Tokyo. (*in Japanese; original title translated*)

Endo, R. and Matsumoto, E., 1962: Permo–Carboniferous trilobites from Japan. *Science Reports of Saitama University, Series B*, vol. 4, p. 149–172.

Feng, R. and Jiang, Z., 1978: Phylum Brachiopoda. *In*, Geological and Palaeontological Team of Guizhou *ed*., *Palaeontological Atlas of Southwest China; Guizhou, Part 2. Carboniferous to Quaternary Volume*, p. 231–305. Geological Publishing House, Beijing. (*in Chinese; original title translated*)

Ferguson, L., 1969: Possible brood pouches and sexual dimorphism in the productid brachiopod *Megousia* Muir-Wood and Cooper. *In*, Westermann, G. E. G. *ed.*, *Sexual Dimorphism in Fossil Metazoa and Taxonomic Implications*, p. 37–50. E. Schweizerbart'sche Verlagsbuchhandlung, Stuttgart.

Fredericks, G., 1924a: Paleontologicheskie ztoudy, 2. O verkhnekamennougolnykh spiriferidakh Urala (Paleontological studies, 2. On Upper Carboniferous spiriferids from the Urals). *Izvestiya Geologicheskogo Komiteta*, vol. 38, p. 295–324. (*in Russian; original title translated*)

Fredericks, G., 1924b: Ussuriyskiy verkhniy paleozoy, 1. Brachiopoda (Upper Paleozoic of the Ussuriland, 1. Brachiopoda). *Materialy po Geologii i Poleznym Iskopaemym Dalnego Vostoka*, no. 28, p. 1–52. (*in Russian with English abstract*)

Fredericks, G., 1925: Ussuriyskiy verkhniy paleozoy, 2. Permskie brakhiopody s mysa Kaluzina (Upper Palaeozoicum of Oussouriland, 2. Permian Brachiopoda of Cape Kalouzin). *Materialy po Geologii i Poleznym Iskopaemym Dal'nego Vostoka*, no. 40, p. 1–28. (*in Russian with English title*)

Fredericks, G., 1926: Materialy k faune peschano-glinistoy tolschi s r. Kezhim-Terovey (Materials for the study of the fauna from sandstone- argillite sequence in the Kejim-Terovey River). *Izvestiya Geologicheskogo Komiteta*, vol. 45, p. 81–91. (*in Russian; original title translated*)

Fujikawa, M. and Suzuki, C., 2011: Early Permian ammonoids from the Takakurayama area, Abukuma Mountains, northeast Japan. *Science Reports of Niigata University (Geology)*, no. 26, p. 61–72.

Grabau, A. W., 1936: Early Permian fossils of China, Part 2. Fauna of the Maping Limestone of Kwangsi and Kweichow. *Palaeontologia Sinica, Series B*, vol. 8, p. 1–441.

Grant, R. E., 1976: Permian brachiopods from southern Thailand. *Paleontological Society Memoir*, no. 9, p. 1–269.

Grunt, T. A., 1986: Sistema brakhiopod otryada Atiridida (Classification of brachiopods of the order Athyridida). *Akademiya Nauk SSSR, Trudy Paleontologicheskogo Instituta*, vol. 215, p. 1–200. (*in Russian; original title translated*)

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

Hayasaka, I., 1957: Two Permian nautiloids from Takakura-yama near Yotsukura-machi, Fukushima Prefecture (Abukuma Plateau region), Japan. *Science Reports of the Yokohama National University, Section 2*, no. 6, p. 21–30.

Hayasaka, I., 1960: On the occurrence of *Neospirifer fasciger* (Keyserling) in Japan, and a note on some associate Permian brachiopods from around Kesen-numa City, northeast Japan. *In*, Shimane University *ed.*, *Collection of Essays in Commemoration of the Tenth Anniversary (1959) of Shimane University (Natural Science)*, p. 34–57. Shimane University, Matsue.

Hayasaka, I., 1965: Some cephalopods in the Permian faunule of Takakura-yama, Fukushima Prefecture, Japan (with a note on the geology of the district, by Ichiro Yanagisawa and Mamoru Nemoto). *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 57, p. 8–27.

Huang, T. K., 1932: Late Permian Brachiopoda of southwestern China, *Palaeontologia Sinica, Series B*, vol. 9, fasc. 1, p. 139.

Huang, T. K., 1933: Late Permian Brachiopoda of southwestern China, Pt. 2. *Palaeontologia Sinica, Series B*, fasc. 2, vol. 9, p. 1–131.

Ifanova, V. V., 1972: Permian brachiopods of the Pechora basin. *In*, Ifanova, V. V. and Semenova, E. G., *Middle Carboniferous and Permian brachiopodsfrom east and north of the European part of the USSR*, p. 72–161. Nauka, Moskva. (*in Russian with English title*)

Ivanova, E. A., 1972: Osnovnye zakonomernosti evolyutsii spiriferid (Brachiopoda) [Main features of spiriferid evolution (Brachiopoda)]. *Paleontologicheskiy Zhurnal*, 1972, no. 3, p. 28–42. (*in Russian; original title translated*)

Ivanova, E. A., 1981: *Morfologiya i Razvitie Brakhiopod (Nadsemeystvo Paeckelmanellacea) [Morphology and Development of Brachiopods (Superfamily Paeckelmannellacea)]*, 55 p. Nauka, Moskva. (*in Russian; original title translated*)

Jin, Y., 1985: Permian Brachiopoda and palaeogeography of the Qinghai–Xizang (Tibet) Plateau. *Palaeontologia Cathayana*, no. 2, p. 19–71.

Jin, Y. and Sun, D., 1981: Palaeozoic brachiopods from Xizang. *In*, Nanjing Institute of Geology and Palaeontology *ed.*, *Palaeontology of Xizang, Book 3, The Series of the Scientific Expedition to the Qinghai–Xizang Plateau*, p. 127–171. Science Press, Beijing. (*in Chinese with English abstract*)

Kalashnikov, N. V., 1983: Brakhiopody. *In*, Meyen, S. V. *ed*., *Paleontologicheskiy Atlas Permskikh Otlozheniy Pechorskogo Ugol'nogo Basseyna (Palaeontological Atlas of the Permian Deposits of the Pechora Coal Basin)*, p. 203–211. Nauka, Leningrad. (*in Russian; original title translated*)

Kalashnikov, N. V., 1993: *Brakhiopody Permi Evropeyskogo Severa Rossii*, 113 p. Nauka, Sankt-Peterburg. (*in Russian; original title translated*)

Kano, H., 1971: Studies on the Usuginu conglomerates in the Kitakami Mountains—Studies on the granite-bearing conglomerates in Japan, no. 22—. *Journal of the Geological Society of Japan*, vol. 77, p. 415–440. (*in Japanese with English abstract*)

Kayser, E., 1883: Obercarbonische Fauna von Lo-ping. *In*, von Richthofen, F. F. *ed.*, *China, Bd. 4*, p. 160–208. Dietrich Reimer, Berlin.

Keyserling, A., 1846: Geognostische Beobachtungen, 1. Paläontologische Bemerkungen. *In*, von Krusenstern, P. and Keyserling, A. *eds*., *Wissenschaftliche Beobachtungen auf einer Reise in das Petschora-Land im Jahre 1843*, p. 151–406. Carl Kray, St. Petersburg.

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. *University of Texas Bulletin*, no. 3042, p. 1–245.

King, W., 1846: Remarks on certain genera belonging to the class Palliobranchiata. *Annals and Magazine of Natural History, Series 1*, vol. 18, p. 26–42 and p. 83–94.

King, W., 1859: On *Gwynia*, *Dielasma*, and *Macandrevia*, three new genera of Palliobranchiata Mollusca, one of which has been dredged in the Strangford Lough. *Proceedings of Dublin University, Zoological and Botanical Association*, vol. 1, p. 256–262.

Klets, A. G., 2005: *Upper Paleozoic of Marginal Seas of Angarida*, 239 p. Akademicheskoe Izdatelstvo "Geo", Novosibirsk. (*in Russian with English abstract*)

Klets, A. G., Budnikov, I. V., Kutygin, R. V. and Grinenko, V. S., 2001: The reference section of the Lower–Upper Permian boundary beds in the Verkhoyansk region and its correlation. *Stratigraphy and Geological Correlation*, vol. 9, p. 247–262.

Kobayashi, T. and Hamada, T., 1984: Permian trilobites of Japan in comparison with Asian, Pacific and other faunas. *Palaeontological Society of Japan, Special Papers*, no. 26, p. 1–92.

Kobiyama, M., 1956: On the age of the Takakurayama Formation. *Bulletin of the Taira Chigaku Dokokai*, no. 3, p. 7–10. (*in Japanese; original title translated*)

Koizumi, H., 1972: New genera of trilobite family Phillipsidae from the Takakurayama Group (Permian), Abukuma Massif in Japan.

Earth Science (Chikyu Kagaku), vol. 26, p. 19–25. (*in Japanese with English abstract*)

Koizumi, H., 1974: New genera of trilobite from the Takakurayama Group. *Bulletin of the Taira Chigaku Dokokai*, no. 12, p. 12–14. (*in Japanese; original title translated*)

Koizumi, H., 1979: Permian brachiopods from Takakura-yama Formation and its geological age, N. E. Japan. *Bulletin of the Taira Chigaku Dokokai, Special Volume*, p. 1–3. (*in Japanese with English title*)

Kotlyar, G. V., 1961: Rod *Yakovlevia* Fredericks (Genus *Yakovlevia* Fredericks). *Doklady Akademii Nauk SSSR*, vol. 140, p. 459–461. (*in Russian; original title translated*)

Kotlyar, G. V., 1989: Paleontological description: Brachiopods. *In*, Kotlyar, G. V. and Zakharov, Yu. D. *eds*., *Evolution of the Latest Permian Biota: Midian Regional Stage in the USSR*, p. 117–125. Nauka, Leningrad. (*in Russian with English abstract*)

Kulikov, M. V., 1974: Brakhiopody kungurskogo yarusa Urala *(Algae, Brachiopods and Miospores from the Permian Deposits of the Western Urals)*. *In*, Papulov, G. N. and Chuvashov, B. I. *eds*., *Vodorosli Brakhiopody i Miospory iz Permskikh Otlozheniy Zapadnogo Urala*, p. 77–123. Uralskiy Nauchyy Tsentr Akademii Nauk SSSR, Sverdlovsk. (*in Russian; original title translated*)

Lee, L. and Gu, F., 1976: Carboniferous and Permian Brachiopoda. *In*, Geological Bureau of Nei Mongol and Geological Institute of Northeast Chia *eds*., *Palaeontological Atlas of Northeast China; Nei Mongol, Part 1. Palaeozoic Volume*, p. 228–306. Geological Publishing House, Beijing. (*in Chinese; original title translated*)

Lee, L., Gu, F. and Su, Y., 1980: Carboniferous and Permian Brachiopoda. *In*, Shenyang Institute of Geology and Mineral Resources *ed*., *Palaeontological Atlas of Northeast China, Part 1. Palaeozoic Volume*, p. 327–428. Geological Publishing House, Beijing. (*in Chinese with English title*)

Leman, M. S., 1994: The significance of Upper Permian brachiopods from Merapoh area, northwest Pahang. *Geological Society of Malaysia, Bulletin*, vol. 35, p. 113–121.

Liao, Z.-T., 1980: Upper Permian brachiopods from western Guizhou. *In*, Nanjing Institute of Geology and Palaeontology *ed*., *Stratigraphy and Palaeontology of the Upper Permian Coal-bearing Formation in Western Guizhou and Eastern Yunnan*, p. 241–277. Science Press, Beijing. (*in Chinese; original title translated*)

Licharew, B. K. and Einor, O. L., 1939: Paleontologiya Sovetskoy Arktiki Vipusk 4 (Palaeontology of the Soviet Arctic, Part 4). *Trudy Arkticheskogo Nauchno-Issledovatelskogo Instituta*, vol. 127, p. 1–245. (*in Russian with English abstract*)

Licharew, B. K. and Kotlyar, G. V., 1978: Permskie brakhiopody Yuzhnogo Primorya. *In*, Popeko, L. I. *ed*., *Verkhniy Paleozoy Severo-Vostochnoy Azii (Upper Palaeozoic of Northeast Asia)*, p. 63–75. Dal'nevostochnyy Nauchnyy Tsentr Akademii Nauk SSSR (DVNTS AN SSSR), Vladivostok. (*in Russian; original title translated*)

Liu, Z., Tan, Z. and Ding, Y., 1982: Phylum Brachiopoda. *In*, Geological Bureau of Hunan *ed*., *Palaeontological Atlas of Hunan*, p. 172–216. Geological Publishing House, Beijing. (*in Chinese with English abstract*)

Manankov, I. N., 1991: Systematical part: Family Yakovleviidae. *In*, Tatarinov, L. P., Luvsandansan, B., Afanasjeva, G. A., Barsbold, R., Morozova, I. P., Novitskaya, L. I., Rasnitsyn, A. P., Reschetov, V. Yu., Posanov, A. Yu., Sysoev, V. A. and Trofimov, B. A. *eds*., *Permian Invertebrates of Southern Mongolia*, p. 106–108. Nauka, Moskva. (*in Russian with English abstract*)

Mansuy, H., 1913: Faunes des Calcaires à *Productus* de l'Indochine, *Première* Série. *Mémoires du Service Géologique de l'Indochine*, vol. 2, p. 1–133.

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*, 144 p. Zürcher und Furrer, Zürich.

Minato, M., Hunahashi, M., Watanabe, J. and Kato, M., 1979: *Variscan Geohistory of Northern Japan: The Abean Orogeny*, 207 p. Tokai University Press, Tokyo.

Mironova, M. G., 1964: K poznaniyu rannepermskikh brakhiopod Pechorskogo basseyna (Early Permian brachiopods of the Pechora Basin). *Voprosy Paleontogii*, vol. 4, p. 85–99. (*in Russian; original title translated*)

Muir-Wood, H. M., 1955: *A History of the Classification of the Phylum Brachiopoda*, 124 p. British Museum (Natural History), London.

Muir-Wood, H. M., 1962: *On the Morphology and Classification of the Brachiopod Suborder Chonetoidea*, 132 p. British Museum (Natural History), London.

Muir-Wood, H. M. and Cooper, G. A., 1960: *Morphology, Classification and Life Habits of the Productoidea (Brachiopoda). Geological Society of America Memoir*, 81, 447 p. Geological Society of America, New York.

Nakamura, K., 1972: *Anidanthus* and *Megousia* (Brachiopoda) from the Permian of Japan and Cambodia. *Journal of the Faculty of Science, Hokkaido University, Series 4*, vol. 15, p. 427–445.

Nakamura, K., Tazawa, J. and Kumon, F., 1992: Permian brachiopods of the Kapp Starostin Formation, West Spitsbergen. *In*, Nakamura, K. *ed*., *Investigations on the Upper Carboniferous–Upper Permian Succession of West Spitsbergen 1989–1991*, p. 77–95. Publication of Hokkaido University, Sapporo.

Nakazawa, K. and Newell, N. D., 1968: Permian bivalves of Japan. *Memoirs of the Faculty of Science, Kyoto University, Series B*, vol. 35, p. 1–108.

Norwood, J. G. and Pratten, H., 1855: Notice of the genus *Chonetes*, as found in the Western states and territories with descriptions of eleven new species. *Philadelphia Academy of Natural Sciences Journal, New Series*, vol. 3, p. 23–32.

Onuki, Y., 1966: Stratigraphy and structural geology of the Palaeozoic formations in the Yaguki and Takakurayama districts, Abukuma Massif, Fukushima Prefecture, Japan. *Professor Susumu Matsushita Memorial Volume*, p. 41–52. (*in Japanese with English abstract*)

Onuki, Y., 1969: Geology of the Kitakami Massif, northeast Japan. *Contributions from the Institute of Geology and Palaeontology, Tohoku University*, no. 69, p. 1–239. (*in Japanese with English abstract*)

Poletaev, V. I., 1997: The revision of genus *Neospirifer* Fredericks, 1924 and new genus *Lutuginia* of subfamily Neospiriferinae. *Paleontologicheskiy Zhurnal*, 1997, no. 3, p. 54–63. (*in Russian with English abstract*)

Ramsbottom, W. H. C., 1952: The fauna of the Cefn Coed marine band in the Coal Measures at Aberbaiden, near Tondu, Glamorgan. *Bulletin of the Great Britain Geological Survey, Palaeontology*, vol. 4, p. 8–32.

Reed, F. R. C., 1944: Brachiopoda and Mollusca from the *Productus* Limestones of the Salt Range. *Palaeontologia Indica, New Series*, vol. 23, p. 1–678.

Sarytcheva, T. G., Licharew, B. K. and Sokolskaya, A. N., 1960: Otryad Productida. *In*, Sarytcheva, T. G. *ed*., *Osnovy Paleontologii, Volume 7. Mshanki, Brakhiopody, Pripozhenie—Foronidy (Basic Palaeontology, Volume 7. Bryozoa, Brachiopoda, with Phoronida)*, p. 221–238, Akademiya Nauk SSSR, Moskva. (*in Russian; original title translated*)

Sarytcheva, T. G. and Sokolskaya, A. N., 1959: O klassifikatsii lozhnoporistykh brakhiopod (On the classification of pseudopunctate

brachiopods). *Doklady, Akademii Nauk SSSR*, vol. 125, p. 181–184. (*in Russian; original title translated*)

Sarytcheva, T. G. and Sokolskaya, A. N., 1965: Otryad Productida. *In*, Ruzhentsev, V. E. and Sarytcheva, T. G. *eds*., *Razvitie i Smena Morskikh Organizmov na Rubezhe Paleozoya i Mezozoya (The Development and Change of Marine Organisms at the Palaeozoic–Mesozoic Boundary)*, p. 209–232. Trudy Paleontologicheskogo Instituta Akademii Nauk SSSR, vol. 108, Nauka, Moskva. (*in Russian; original title translated*)

Schlotheim, E. F. von, 1813: Beiträge zur Naturgeschichte der Versteinerungen in geognostischer Hinsicht. *In*, Leonhard, C. C. *ed*., *Taschenbuch für die Gesammte Mineralogie mit Hinsicht auf die Neuesten Entdeckungen*, 7. Jahrg., 1. Abth., p. 1–134. Hermannsche Buchhandlung, Frankfurt am Main.

Schlotheim, E. F. von, 1816: Beitrage zur Naturgeschichte der Versteinerungen in geognostischer Hinsicht. *Denkschriften der Bayerischen Academie der Wissenschaften*, vol. 6, p. 13–36.

Schuchert, C., 1893: Classification of the Brachiopoda. *American Geologist*, vol. 11, p. 141–167.

Schuchert, C., 1913: Class 2. Brachiopoda. *In*, Zittel, K. A. von, *Textbook of Palaeontology, Volume 1, Part 1, 2nd Edition*, p. 355–420. Macmillan, London.

Schuchert, C., 1929: Cassification of brachiopod genera, fossil and recent. *In*, Schuchert, C. and Le Vene, C. M., *Animalia Pars 42, Fossilium Catalogus, Volume 1*, p. 10–25. W. Junk, Berlin.

Shen, S.-Z., Archbold, N. W., Shi, G. R. and Chen, Z.-Q., 2000: Permian brachiopods from the Selong Xishan section, Xizang (Tibet), China, Part 1: Stratigraphy, Strophomenida, Productida and Rhynchonellida. *Geobios*, vol. 33, p. 725–752.

Shen, S.-Z. and Clapham. M. E., 2009: Wuchiapingian (Lopingian. Late Permian) brachiopods from the Episkopi Formation of Hydra Island, Greece. *Palaeontology*, vol. 52, p. 713–743.

Shen, S.-Z. and Shi, G. R., 2009: Latest Guadalupian brachiopods from the Guadalupian/Lopingian boundary GSSP section at Penglaitan in Labin, Guangxi, South China and implications for the timing of the pre-Lopingian crisis. *Palaeoworld*, vol. 18, p. 152–161.

Shen, S.-Z., Shi, G. R. and Fang, Z., 2002: Permian brachiopods from Baoshan and Simao blocks in western Yunnan, China. *Journal of Asian Earth Sciences*, vol. 20, p. 665–682.

Shen, S.-Z., Xie, J.-F., Zhang, H. and Shi, G. R., 2009: Roadian–Wordian (Guadalupian, Middle Permian) global palaeobiogeography of brachiopods. *Global and Planetary Change*, vol. 65, p. 166–181.

Shen, S.-Z. and Zhang, Y.-C., 2008: Earliest Wuchiapingian (Lopingian, Late Permian) brachiopods in southern Hunan, South China: Implications for the pre-Lopingian crisis and onset of Lopingian recovery/radiation. *Journal of Paleontology*, vol. 82, p. 924–937.

Shi, G. R., 2006: The marine Permian of East and Northeast Asia: an overview of biostratigraphy, palaeobiogeography and palaeogeographical implications. *Journal of Asian Earth Sciences*, vol. 26, p. 175–206.

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. *Journal of the Geological Society of Japan*, vol. 107, p. 755–761.

Shimizu, D., 1961: Brachiopod fossils from the Perman Maizuru Group. *Memoirs of the College of Science, University of Kyoto, Series B*, vol. 27, p. 309–351.

Solomina, R. V., 1960: Nekotorye permskie brakhiopody Pay-Khoya (Some Permian brachiopods of Pai-Khoi). *Sbornik Statey po Paleontologii i Biostratigrafii*, no. 19, p. 24–73. (*in Russian; original title translated*)

Stehli, F. G., 1954: Lower Leonardian Brachiopoda of the Sierra Diablo. *Bulletin of the American Museum of Natural History*, vol. 105, p. 262–358.

Tazawa, J., 1975: Uppermost Permian fossils from the southern Kitakami Mountains, northeast Japan. *Journal of the Geological Society of Japan*, vol. 81, p. 629–640.

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

Tazawa, J., 1998: Pre-Neogene tectonic divisions and Middle Permian brachiopod faunal provinces of Japan. *Proceedings of the Royal Society of Victoria*, vol. 110, p. 281–288.

Tazawa, J., 1999a: Occurrence of the Boreal-type brachiopod *Yakovlevia* from the Middle Permian of the Hida Gaien and South Kitakami belts, Japan and its tectonic implications. *Journal of the Geological Society of Japan*, vol. 105, p. 227–230. (*in Japanese with English abstract*)

Tazawa, J., 1999b: Boreal-type brachiopod *Yakovlevia* from the Middle Permian of Japan. *Paleontological Research*, vol. 3, p. 88–94.

Tazawa, J., 2001: Middle Permian brachiopods from the Moribu area, Hida Gaien Belt, central Japan. *Paleontological Research*, vol. 5, p. 283–310.

Tazawa, J., 2002: Late Paleozoic brachiopod faunas of the South Kitakami Belt, northeast Japan, and their paleobiogeographic and tectonic implications. *Island Arc*, vol. 11, p. 287–301.

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

Tazawa, J., 2008a: *Lamnimargus* (Productida, Brachiopoda) from the Upper Permian of Ofunato in the South Kitakami Belt, NE Japan, and its palaeobiogeographical significance. *Science Reports of Niigata University (Geology)*, no. 23, p. 1–11.

Tazawa, J., 2008b: Brachiopods from the Upper Permian Takakurayama Formation, Abukuma Mountains, northeast Japan. *Science Reports of Niigata University (Geology)*, no. 23, p. 13–53.

Tazawa. J., 2008c: Permian brachiopods from the Mizukoshi Formation, central Kyushu, SW Japan: Systematics, palaeobiogeography and tectonic implications. *Paleontological Research*, vol. 12, p. 37–61.

Tazawa, J., 2009: Brachiopods from the Upper Permian Tsunemori Formation of the Akiyoshi area, southwest Japan, and their tectonic implications. *Paleontological Research*, vol. 13, p. 65–78.

Tazawa, J., 2011: Late Permian (Wuchiapingian) brachiopod fauna from Okutadami, central Japan: Systematics, palaeobiogeography and tectonic implications. *Paleontological Research*, vol. 15, p. 168–180.

Tazawa, J., 2012: Late Permian (Changhsingian) brachiopod fauna from Nabekoshiyama in the Kesennuma area, South Kitakami Belt, northeast Japan. *Science Reports of Niigata University (Geology)*, no. 27, p. 15–50.

Tazawa, J. and Araki, H., 2013: Four brachiopod species newly described from the Middle Permian of Kesennuma, South Kitakami Belt, northeast Japan. *Science Reports of Niigata University (Geology)*, no. 28, p. 1–14.

Tazawa, J., Fujikawa, M., Zakharov, Yu, D. and Hasegawa, S., 2005: Middle Permian ammonoids from the Takakurayama area, Abukuma Mountains, northeast Japan and their stratigraphical significance. *Science Reports of Niigata University (Geology)*, no.

20, p. 15–27.
Tazawa, J. and Hasegawa, S., 2007: *Anidanthus*, *Gypospirifer* and *Alispiriferella* (Brachiopoda) from the Upper Permian Mizukoshi Formation, central Kyushu, SW Japan. *Science Reports of Niigata University (Geology)*, no. 22, p. 1–14.
Tazawa, J. and Ibaraki, Y., 2001: Middle Permian brachiopods from Setamai, the type locality of the Kanokura Formation, southern Kitakami Mountains, northeast Japan. *Science Reports of Niigata University, Series E*, no. 16, p. 1–33.
Tazawa, J. and Matsumoto, T., 1998: Middle Permian brachiopods from the Oguradani Formation, Ise district, Hida Gaien Belt, central Japan. *Science Reports of Niigata University, Series E*, no. 13, p. 1–19.
Tazawa, J. and Miyake, Y., 2011: Late Permian (Changhsingian) brachiopod fauna from Maeda in the Ofunato area, South Kitakami Belt, NE Japan. *Science Reports of Niigata University (Geology)*, no. 26, p. 1–22.
Tazawa, J. and Niigata Pre-Tertiary Research Group, 1999: Permian brachiopods from the Okutadami area, near the boundary between Niigata and Fukushima Prefectures, central Japan and their tectonic implications. *Journal of the Geological Society of Japan*, vol. 105, p. 729–732. (*in Japanese with English abstract*)
Tazawa, J., Takizawa, F. and Kamada, K., 2000: A Middle Permian Boreal-Tethyan mixed brachiopod fauna from Yakejima, southern Kitakami Mountains, NE Japan. *Science Reports of Niigata University, Series E*, no. 15, p. 1–21.
Tong, Z., 1978: Carboniferous and Permian Brachiopoda. *In*, Geological Institute of Southwest China *ed*., *Palaeontological Atlas of Southwest China; Sichuan*, *Part 2. Carboniferous to Mesozoic*, p. 210–267. Geological Publishing House, Beijing. (*in Chinese; original title translated*)
Ueno, K., 1992: Permian foraminifers from the Takakurayama Group of the southern Abukuma Mountains, northeast Japan. *Transactions and Proceedings of the Palaeontological Society of Japan, New Series*, no. 168, p. 1265–1295.
Ustritsky, V. I., 1963: Description of the fauna; Phylum Brachiopoda and Mollusca. *In*, Ustritsky, V. I. *et al*., *Permian Stratigraphy and Fauna of the Beishan Area, Western Gansu (Permian Stratigraphy and Fauna of the Beishan Area, Western Gansu)*, p. 6–36. China Industry Press, Beijing. (*in Chinese; original title translated*)
Waagen, W., 1883–1884: Salt Range fossils, 1. *Productus*-Limestone fossils: Brachiopoda. *Palaeontologia Indica*, *Series 13*, vol. 1, p. 391–546 (1883) and p. 547–728 (1884).
Wang, C. and Zhang, S., 2003: *Zhesi Brachiopod Fauna*, 210 p. Geological Publishing House, Beijing. (*in Chinese; original title translated*)
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. Late Palaeozoic Volume*, p. 186–256, Geological Publishing House, Beijing. (*in Chinese*)
Wang, Y., Jin, Y. and Fang, D., 1964: *Brachiopod Fossils of China, Vols. 1 and 2*, p. 1–354 and p. 355–777. Science Press, Beijing. (*in Chinese; original title translated*)
Waterhouse, J. B., 1968a: The classification and descriptions of Permian Spiriferida (Brachiopoda) from New Zealand. *Palaeontographica*, *Abteilung A*, vol. 129, p. 1–94.
Waterhouse, J. B., 1968b: New species of *Megousia* Muir-Wood and Cooper and allied new genus from the Permian of Australia and North America. *Journal of Paleontology*, vol. 42, p. 1171–1185.
Waterhouse, J. B., 1975: New Permian and Triassic brachiopod taxa. *University of Queensland Papers, Department of Geology*, vol. 7, p. 1–23.
Waterhouse, J. B., 1978: Permian Brachiopoda and Mollusca from north-west Nepal. *Palaeontographica*, *Abteilung A*, vol. 160, p. 1–175.
Waterhouse, J. B., 1983: New Permian invertebrate genera from the east Australian segment of Gondwana. *Bulletin of the Indian Geologists Association*, vol. 16, p. 153–158.
Waterhouse, J. B., 1986: Late Palaeozoic Scyphozoa and Brachiopoda (Inarticulata, Strophomenida, Productida and Rhynchonellida) from the southeast Bowen Basin, Australia. *Palaeontographica*, *Abteilung A*, vol. 193, p. 1–76.
Waterhouse, J. B., Briggs, D. J. C. and Parfrey, S. M., 1983: Major faunal assemblages in the Early Permian Tiverton Formation near Homevale Homestead, northern Bowen Basin, Queensland. *In*, Foster, C. *ed*., *Permian Geology of Queensland*, p. 121–138. Geological Society of Australia, Queensland Division, Brisbane.
Waterhouse, J. B. and Piyasin, S., 1970: Mid-Permian brachiopods from Khao Phrik, Thailand. *Palaeontographica*, *Abteilung A*, vol. 135, p. 83–197.
Waterhouse, J. B. and Waddington, J., 1982: *Systematic descriptions, paleoecology and correlations of the Late Paleozoic subfamily Spiriferellinae (Brachiopoda) from the Yukon Territory and the Canadian Arctic Archipelago*, 73 p. Geological Survey of Canada, Bulletin 289, Minister of Supply and Services Canada, Ottawa.
Yanagida, J., 1963: Brachiopods from the Upper Permian Mizukoshi Formation, central Kyushu. *Memoirs of the Faculty of Science, Kyushu University, Series D*, vol. 14, p. 69–78.
Yanagida, J., 1970: Permian brachiopods from Khao Phrik, near Rat Buri, Thailand. *Geology and Palaeontology of Southwest Asia*, vol. 8, p. 69–96.
Yanagida, J., 1996: Permian brachiopods from the Tsunemori Formation, SW Japan, and their paleobiogeographic implication. *In*, Copper, P. and Jin, J. *eds*., *Brachiopods*, p. 313–315. A. A. Balkema, Rotterdam.
Yanagida, J. and Nakornsri, N., 1999: Permian brachiopods from Khao Hin Kling area near Phetchabun, north-central Thailand. *Bulletin of the Kitakyushu Museum of Natural History*, no. 18, p. 105–136.
Yanagisawa, I., 1958: On a discovery of trilobite (Permian) from the Takakurayama Group, Abukuma Mountainland. *Journal of the Geological Society of Japan*, vol. 64, 207 p. (*in Japanese with English abstract*)
Yanagisawa, I., 1967: Geology and paleontology of the Takakurayama–Yaguki area, Yotsukura-cho, Fukushima Prefecture. *Science Reports of the Tohoku University, 2nd Series*, vol. 39, p. 63–112.
Yanagisawa, I. and Nemoto, M., 1961: On the Paleozoic formations of the Takakura-yama district, Abukuma Mountainland. *Journal of the Geological Society of Japan*, vol. 67, p. 274–283. (*in Japanese with English abstract*)
Yang, D., 1984: Systematic descriptions of palaeontology: Brachiopoda. *In*, Yichang Institute of Geology and Mineral Resources *ed*., *Biostratigraphy of the Yangtze Gorge Area, (3) Late Palaeozoic Era*, p. 203–239, p. 330–333 and p. 387–396. Geological Publishing House, Beijing. (*in Chinese with English abstract*)
Yang, D., Ni, S., Chang, M. and Zhao, R., 1977: Phylum Brachiopoda. *In*, Geological Institute of Hubei *et al*., *eds*., *Palaeontological Atlas of South–Central China, Part 2. Late Palaeozoic Volume*, p. 303–470. Geological Publishing House, Beijing. (*in Chinese; original title translated*)
Yang, S. and Fan, Y., 1983: Carboniferous brachiopods from Xizang (Tibet) and their faunal provinces. *In*, CGQXP Editorial Committee, Ministry of Geology and Mineral Resources, PPC *ed*., *Contribution to the Geology of the Qinghai–Xizang (Tibet) Plateau*,

Volume 11, p. 265–289. Geological Publishing House, Beijing. (*in Chinese with English abstract*)

Yoshida, K. and Machiyama, H., 1997: The sedimentary environment of the Permian Daido Formation in the South Kitakami Terrane, northeast Japan. *In*, Kawamura, M., Oka, T. and Kondo, T. *eds*., *Commemorative Volume for Professor Makoto Kato*, p. 261–273. Nakanishi Insatsu, Sapporo. (*in Japanese with English abstract*)

Yoshida, K. and Machiyama, H., 1998: Middle Permian coarse clastics in the western marginal area of the South Kitakami Terrane, northeast Japan. *Journal of the Geological Society of Japan*, vol. 104, p. 71–89. (*in Japanese with English abstract*)

Zavodowsky, V. M., 1968: Otryad Spiriferida, nadsemeystvo Spiriferacea. *In*, Markovsky, B. L. *ed*., *Novye Vidy Drevnikh Rasteniy i Bespozvochnykh SSSR, Vypusk 2 (New Species of Ancient Plants and Invertebrates of the USSR)*, p. 149–160. Nedra, Moskva. (*in Russian; original title translated*)

Zavodowsky, V. M. and Stepanov, D. L., 1970: Opisanie vidov; Tip Brachiopoda, klass Articulata. *In*, Kulikov, M. V. ed., *Polevoy Atlas Permskoy Fauny i Flory Severo-Vostoka SSSR (Field Atlas of the Permian Fauna and Flora of the Northeastern USSR)*, p. 72–182. Magadanskoe Knizhnoe Izdatelstvo, Magadan. (*in Russian; original title translated*)

Zeng, Y., He, X. and Zhu, M., 1995: *Permian Brachiopods and Community Succession in the Huayin Mountains, Sichuan*, 187 p., China University of Mining and Technology Press, Xuzhou. (*in Chinese with English abstract*)

Zhan, L.-P., 1979: Descriptions of fossils; Brachiopoda. *In*, Hou, H.-F., Zhan, L.-P., Chen, B.-W. and others, *The Coal-bearing Strata and Fossils of Late Permian from Guangtung*, p. 61–100. Geological Publishing House, Beijing. (*in Chinese with English title*)

Zhang, Y. and Jin, Y., 1961: An Upper Permian Brachiopoda fauna from Jiangxian. Anhui Province. *Acta Palaeontologica Sinica*, vol. 9, p. 401–417. (*in Chinese with English abstract*)