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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<sub>1</sub> 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<sub>1</sub>) 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

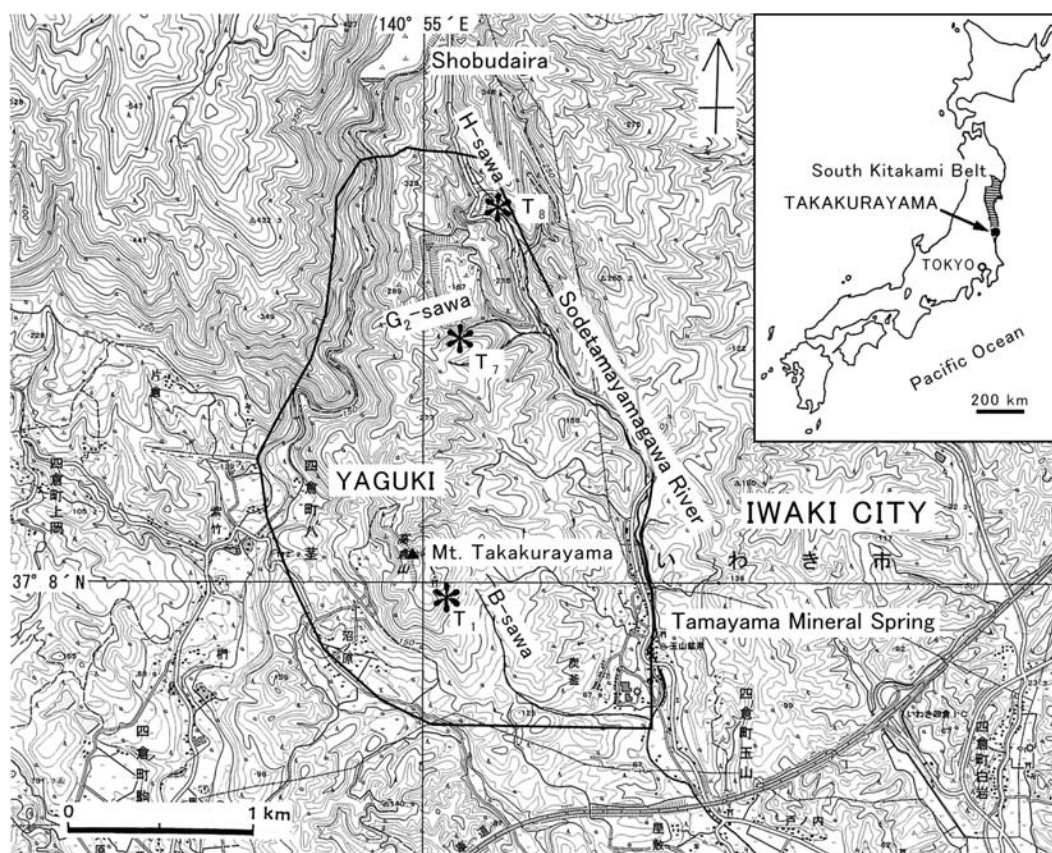
## Introduction

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<sub>1</sub>, 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<sub>1</sub> 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<sup>2</sup> 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 rathburiensis* Waterhouse and Piyasin, 1970, *Neospirifer* sp., *Gypospirifer kobyamai* 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

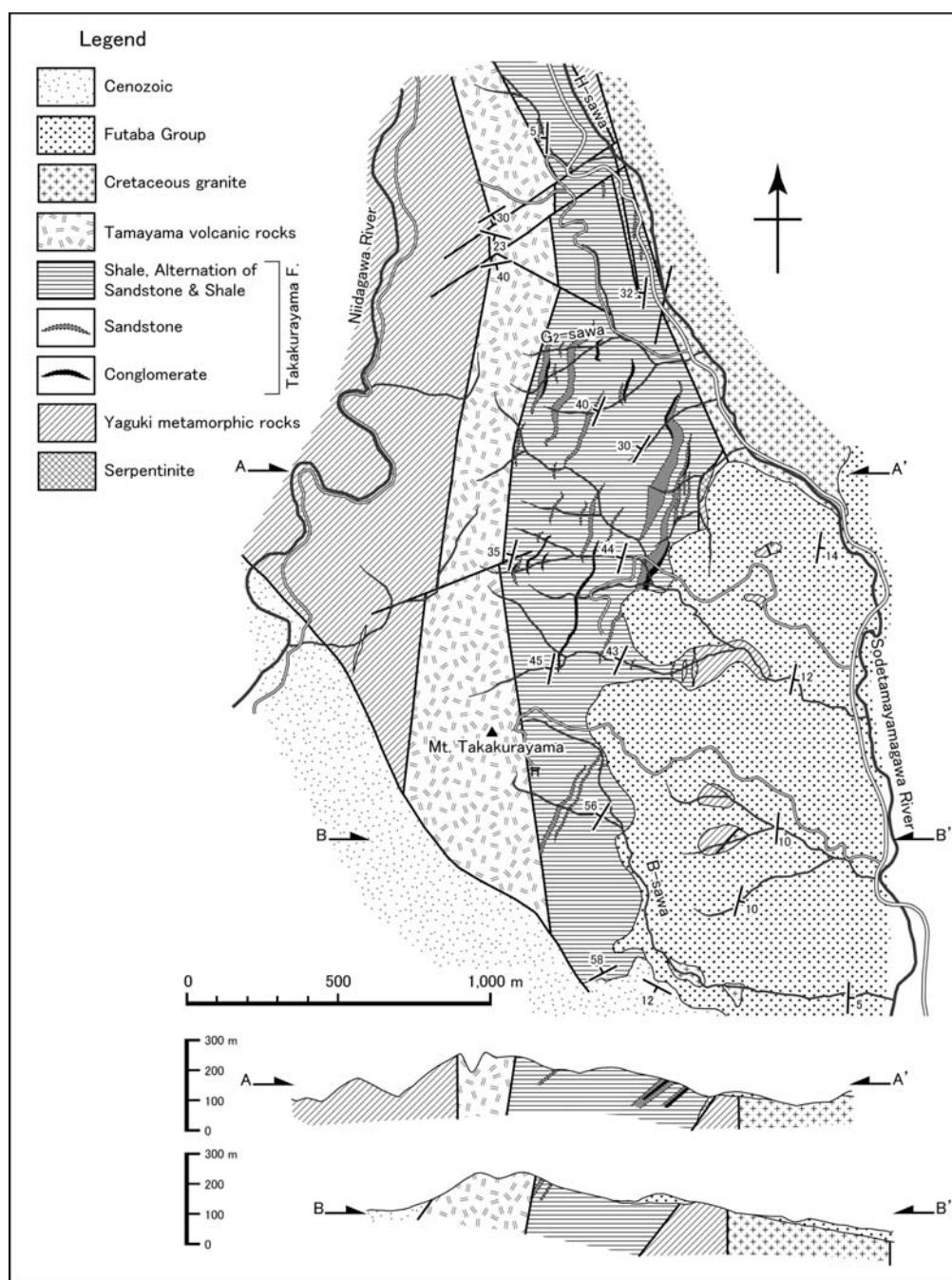
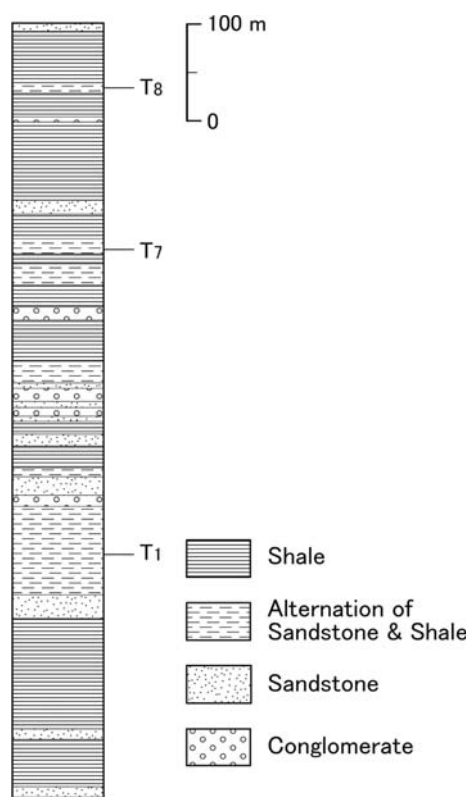


Figure 2. Geological map of the Takakurayama area.

are summarized in Figure 4. It is noteworthy that 6 species (*Chonetinella krotovi*, *Haydenella wenganensis*, *Transennatia gratiosa*, *Lamnimargus peregrinus*, *Costatumulus tazawai* and *Gypospirifer kobyamai*) also occur in the upper part of the Takakurayama Formation at the localities T<sub>7</sub> and T<sub>8</sub> (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 kobyamai* 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<sub>1</sub>, T<sub>7</sub>, T<sub>8</sub>.

*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<sub>1</sub>) fauna is considered to be Capitanian–Wuchiapingian, most probably Wuchiapingian. The brachiopods from the upper part of the Takakurayama Formation at localities T<sub>7</sub> and T<sub>8</sub> 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<sub>1</sub>, 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<sub>1</sub>) fauna includes the Boreal (anti-tropical) elements *Chonetinella krotovi*, *Lamnimargus peregrinus*, *Megousia auriculata*, *Costatumulus tazawai*, *Yakovlevia mammatiformis*, *Neospirifer* sp., *Gypospirifer kobyamai*, *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<sub>1</sub>) 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 kobyamai*.

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 Gaian, 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

[illegible]

*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.

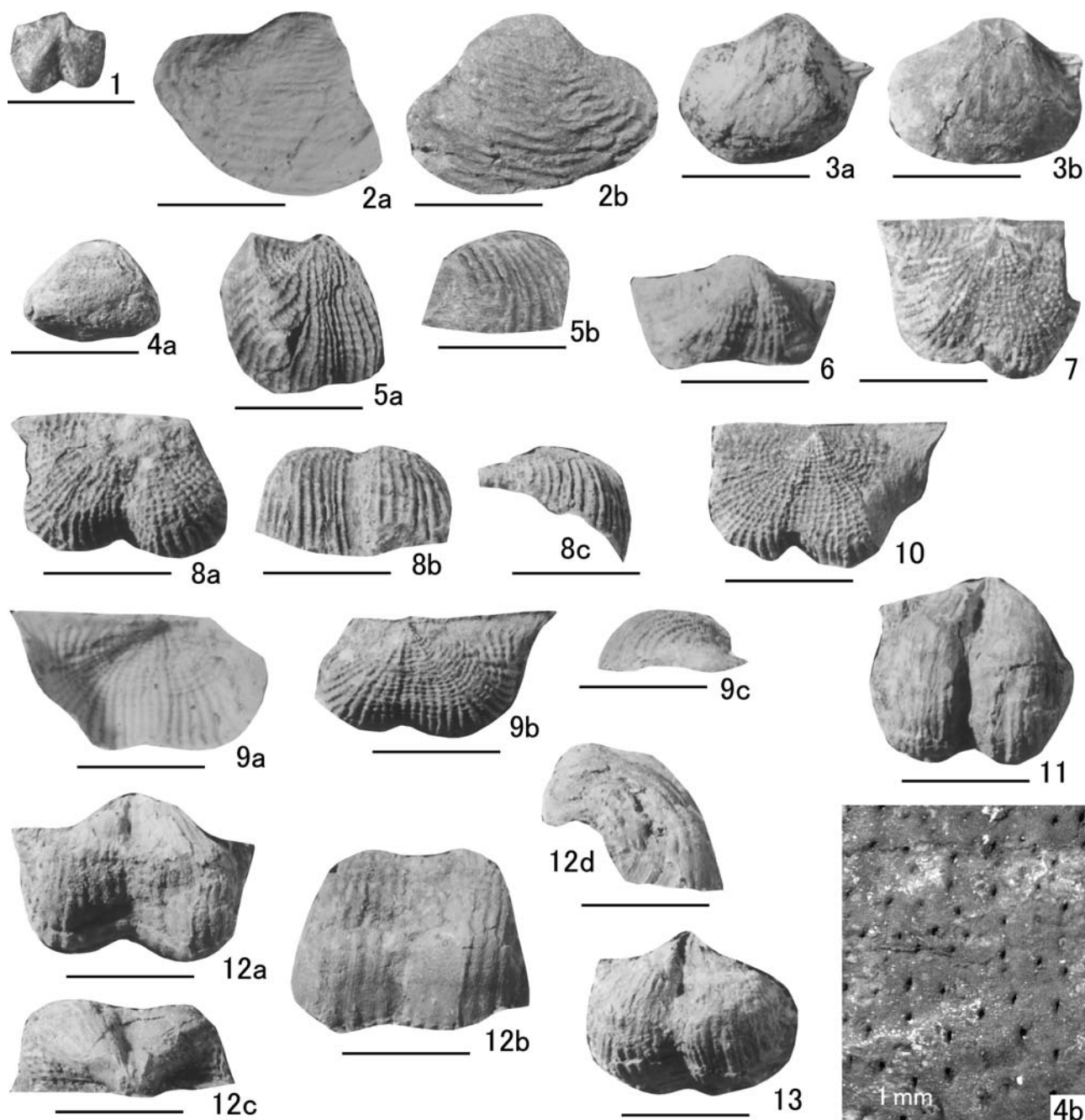
*Remarks.*—The single ventral valve specimen from Takakurayama is small in size (length 6 mm, width 7 mm), slightly transverse, subquadrate in outline, strongly convex in lateral profile, and having a deep and narrow sulcus bordered by a pair of high, broad lateral ridges. External surface of the ventral 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.

Suborder Productidina Waagen, 1883  
Superfamily Productelloidea Schuchert, 1929  
Family Overtoniidae Muir-Wood and Cooper, 1960

*Rugoconcha* sp.

*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, south-western 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: north-eastern Japan (Takakurayama in the South Kitakami Belt), central-southern China (Guangdong) and south-western China (Guizhou and Sichuan).

Superfamily Marginiferoidea Stehli, 1954

Family Marginiferidae Stehli, 1954

Subfamily Marginiferinae Stehli, 1954

Genus *Transennatia* Waterhouse, 1975

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

*Transennatia graciola* (Waagen, 1884)

Figures 5.5–5.10

*Productus graciosus* 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) graciosus* Waagen. Huang, 1933, p. 88, pl. 11, fig. 14; Hayasaka, 1960, p. 49, pl. 1, fig. 8.

*Marginifera graciola* (Waagen). Reed, 1944, p. 98, pl. 19, figs. 6, 7.

*Dictyoclostus graciosus* (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 graciola* (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.

*Asiopproductus graciosus* (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 graciosus* (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 graciola* (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 dis-

tinguished 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.

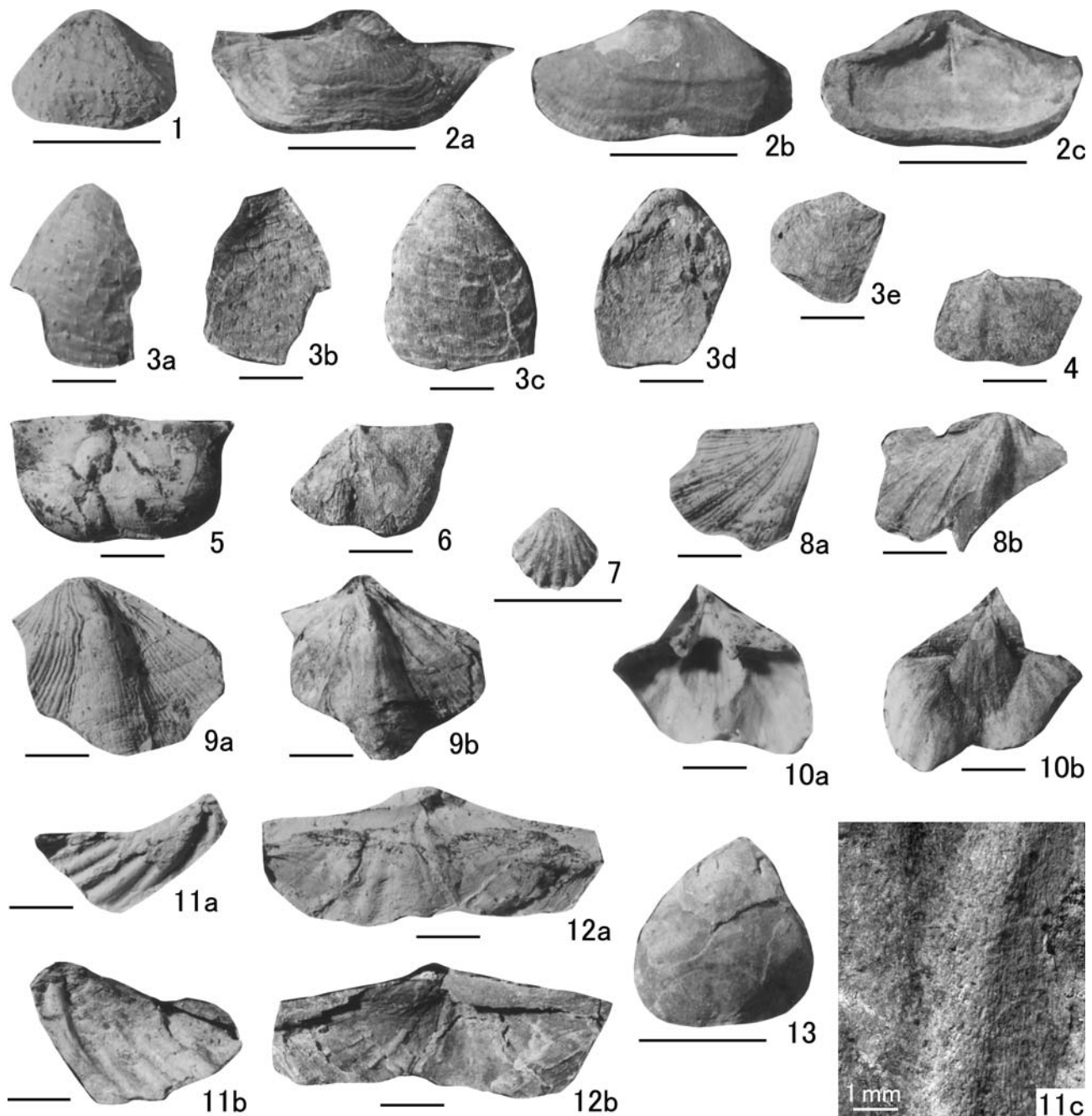
*Megousia auriculata* Muir-Wood and Cooper, 1960, p. 310, pl. 113, figs. 1–11; Ferguson, 1969, pl. 1, figs. 5–11; Nakamura, 1972, p. 436, pl. 2, fig. 3; Cooper and Grant, 1975, p. 1192, pl. 450, figs. 1–48; pl. 451, figs. 1–49; pl. 452, figs. 19–28; pl. 453, figs. 13–24; pl. 463, figs. 5–8; pl. 467, 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, *Costatumulius 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 kobyamai* 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 Kansuelliidae 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 kobyamai* Tazawa and Araki, 2013**

Figure 6.9

- Spirifer fasciger* var. *simplex* Grabau. Kobyama, 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 kobyamai* 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 kobyamai* 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. kobyamai* 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. kobyamai* 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 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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