Brachiopods from the Upper Permian Takakurayama Formation, Abukuma Mountains, northeast Japan

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Abstract

A brachiopod fauna, consisting of 26 species in 20 genera, is described from the Upper Permian (Lopingian) Takakurayama Formation of the Takakurayama area in the Abukuma Mountains, South Kitakami Belt, northeast Japan. This fauna includes two new species, *Chonetinella iwakiensis* and *Chonetinella transversa*. The Takakurayama fauna is a Boreal-Tethyan mixed fauna and allied with the Middle to Late Permian brachiopod faunas of North China (Inner Mongolia), Northeast China (Heilongjiang and Jilin), eastern Russia (South Primorye), northeast Japan (southern Kitakami Mountains in the South Kitakami Belt), central Japan (Moribu in the Hida Gaien Belt) and southwest Japan (Mizukoshi in the Hida Gaien Belt). These regions were probably located within a large continuous sedimentary basin on continental shelf or slope bordering the northern and eastern margins of North China in the Middle to Late Permian.

Key words: Abukuma Mountains, Boreal-Tethyan mixed fauna, Brachiopoda, Takakurayama, Upper Permian.

Introduction

The Takakurayama area, Iwaki City, Fukushima Prefecture in the Abukuma Mountains, South Kitakami Belt, northeast Japan is one of the famous Permian fossil localities in Japan (Fig. 1). On the brachiopods, 21 species have hitherto been described by Yanagisawa (1967) and Nakamura (1972), and 26 species have been listed by Kobiyama (1956) and Koizumi (1979). However, most of the Permian brachiopods from the Takakurayama area need to be revised in light of new taxonomy.

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(Manuscript received 4 January, 2008; accepted 31 January, 2008)

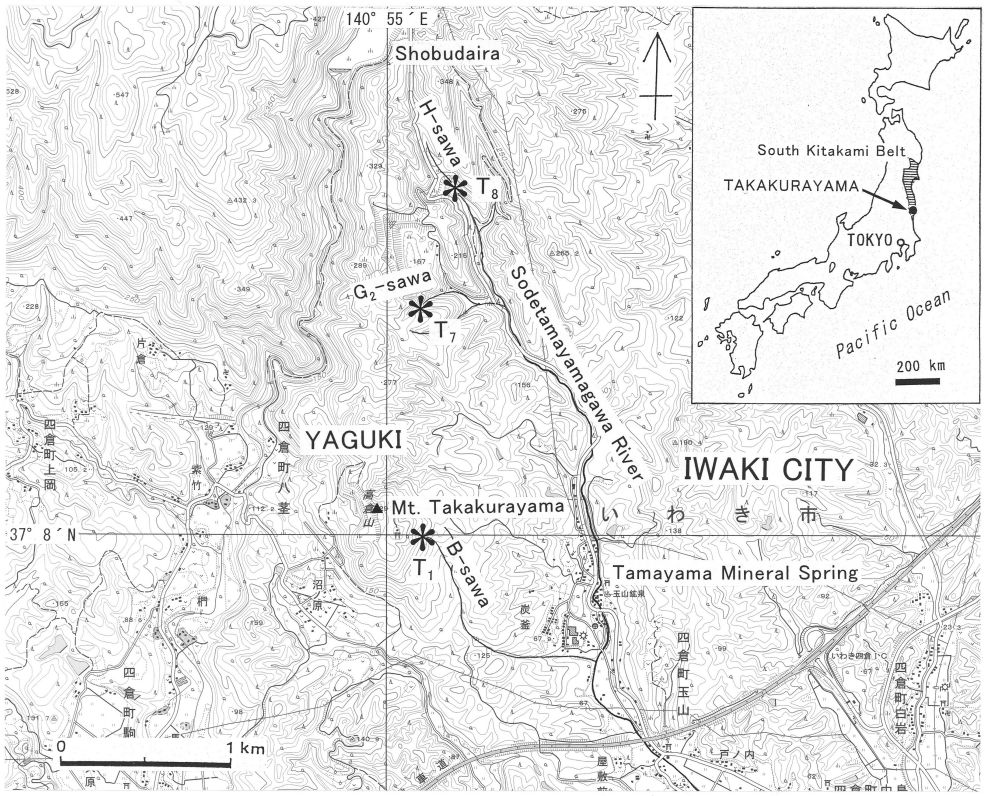


Fig. 1. Index map showing the fossil localities T_1, T_7 and T_8 in the Takakurayama area. Using the topographical map of "Yotsukura" scale 1:25,000 published by the Geographical Survey Institute of Japan.

In the period of 1986-2005, I surveyed in the Takakurayama area and collected a large number of Permian brachiopod fossils with the help of two students (at that time) N. Kaneko and S. Hasegawa; and we clarified the Permian stratigraphy of this area (Tazawa et al., 2005). The brachiopod fossils occur from sandy shale or calcareous shale of three horizons in the lower and upper parts of the Takakurayama Formation. In this paper, the Permian brachiopods of 26 species in 20 genera, including two new species *Chonetinella iwakiensis* and *Chonetinella transversa*, are described.

All of the brachiopod specimens described in this paper are housed in the following institutions, as indicated by the prefixes assigned to the registered specimen numbers: IGPS, Tohoku University Museum in Sendai; NU-B, Department of Geology, Faculty of Science, Niigata University in Niigata.

Stratigraphy

The Takakurayama Formation, named by Onuki (1966), is exposed in the northeastern slope of Mt. Takakurayama, dipping 30-45° W and striking in a general NNE-SSW direction, and occupying the area of about 0.5 km (E-W) × 6 km (N-S). It consists mostly of black shale with subordinate sandstone and conglomerate, more than 805 m in total thickness (Fig. 2). This formation is subdivided into the following three members: the Iriishikura Member, consisting mostly of shale with some sandstone beds, 290 m thick; the Motomura Member, consisting of sandstone and conglomerate with some shale beds, 167 m thick; and the Kashiwadaira Member, consisting mostly of shale with some sandstone and conglomerate beds, 348 m thick, in ascending order. These members are approximately equal to the Iriishikura, Motomura and Kashiwadaira Formations of Yanagisawa and Nemoto (1961), respectively. The brachiopod fossils treated in this paper were collected from sandy shale or calcareous shale of the lower part (Iriishikura Member) and the upper part (Kashiwadaira Member) of the Takakurayama Formation. The locations, horizons and lithology of fossil localities T_1, T_7 and T_8, named by Yanagisawa (1967), are as follows:

T_1: Upperstream of B-sawa (37° 7'59"N, 140° 55'8"E), a tributary of the Sodetamayamagawa River. Dark grey sandy shale of the lower part of the Takakurayama Formation (about 30 m below from the base of the Motomura Member).

T_7: Upperstream of G_2-sawa (37° 8'43"N, 140° 55'8"E), a tributary of the Sodetamayamagawa River. Dark grey sandy shale and calcareous shale of the upper part of the Takakurayama Formation (about 100 m above from the base of the Kashiwadaira Member).

T_8: Midstream of H-sawa (37° 9'5"N, 140° 55'16"E), a tributary of the Sodetamayamagawa River. Dark grey sandy shale of the upper part of the Takakurayama Formation (about 67 m below from the top of the formation).

Lithologically, the black shale of the Takakurayama Formation is similar to that of the Upper Permian Toyoma Formation (Onuki, 1969; Tazawa, 1988) in the southern Kitakami Mountains, and the conglomerate of this formation is correlated with the Usuginu-type conglomerate (Kano, 1971), which is widely distributed in the Upper Permian of Japan.

The Takakurayama fauna

The brachiopod fauna described herein includes the following 26 species assigned to 20 genera (Table 1): *Chonetinella krotovi* (Fredericks, 1925), *Chonetinella iwakiensis* sp. nov., *Chonetinella transversa* sp. nov., *Dyoros* (*Dyoros*) sp., *Haydenella* sp., *Lamnimargus peregrinus* (Fredericks, 1924), *Transennatia gratiosa* (Waagen, 1884), *Costatumulus* cf.

tazawai Shen, Archbold, Shi and Chen, 2000, *Anidanthus ussuricus* (Fredericks, 1924), *Terrekea* sp., *Yakovlevia mammatiformis* (Fredericks, 1926), *Oldhamina* cf. *lianyangensis* Chan (Zhan), 1979, *Derbyia schellwieni* Frech, 1911, *Derbyia*? sp., *Stenoscisma margaritovi* (Tschernyschew, 1888), *Rhynchopora* sp., *Hustedia grandicosta* (Davidson, 1862), *Martinia semiplana* Waagen, 1883, *Martinia lata* Grabau, 1936, *Martinia* sp., *Gypospirifer volatilis* Duan and Li, 1985, *Spiriferella saranae* (de Verneuil, 1845), *Spiriferella*? sp., *Alispiriferella lita* (Fredericks, 1924), *Elivina tibetana* (Diener, 1897) and *Cathayspirina* sp.

Age and Correlation

The Takakurayama fauna contains various brachiopod species of Early Permian (Asselian) to Late Permian (Changhsingian). It is noteworthy that this fauna consists mostly of the Middle Permian (Wordian-Capitanian) species, but it includes some species of Late Permian (Lopingian) elements, such as *Chonetinella transversa* and *Derbyia schellwieni* (see Table 1). Moreover, *Costatumulus* cf. *tazawai* is close to *Costatumulus tazawai* Shen, Archbold, Shi

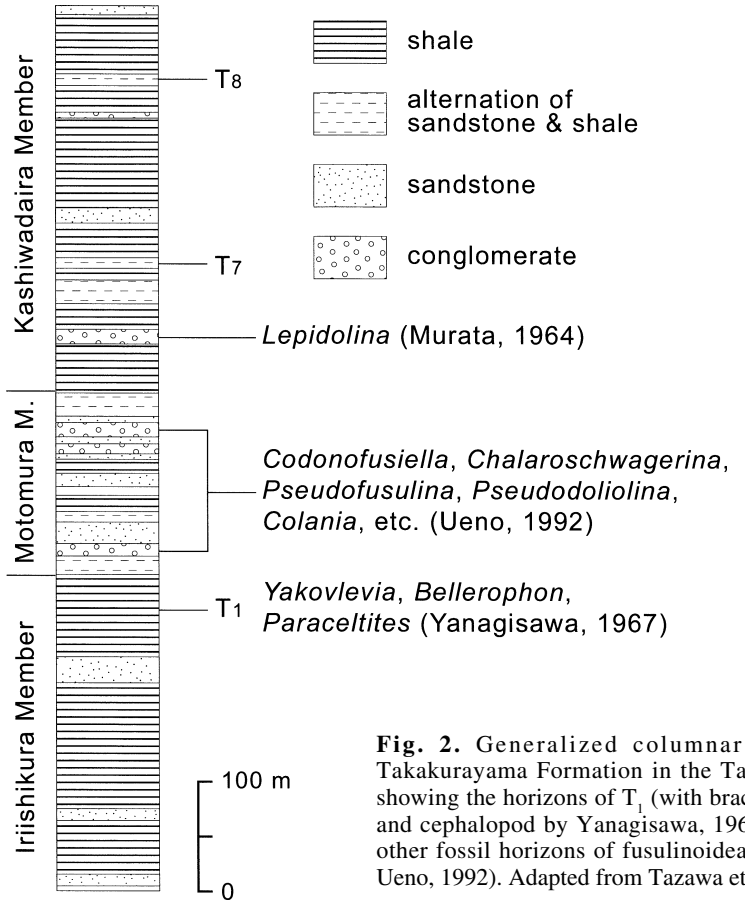


Fig. 2. Generalized columnar section of the Takakurayama Formation in the Takakurayama area, showing the horizons of T_1 (with brachiopod, gastropod and cephalopod by Yanagisawa, 1967), T_7 and T_8, and other fossil horizons of fusulinoideans (Murata, 1964; Ueno, 1992). Adapted from Tazawa et al. (2005).

Table 1. Provincial types, fossil localities (T_1, T_7 and T_8), and geographical and stratigraphical distributions of brachiopods of the Takakurayama fauna. Open circle is the Boreal (bipolar) species, and solid circle is the Tethyan species.

Species \ Region, Stage	Provincial type	Japan								Other regions																				Stage									
		Takakurayama			Hida Gaien Belt (Moribu)	Hida Gaien Belt (Mizukoshi)	South Kitakami Belt	Maizuru Belt	Akiyoshi Belt	Arctic Canada	Spitsbergen	Northern Russia	Eastern Russia	Mongolia	Northwest China	North China	Northeast China	East China	South China	Tibet	Vietnum	Cambodia	Timor	Salt Range	Pamir	Kumaon Himalayas	Asselian	Sakmarian	Artinskian	Kungurian	Roadian	Wordian	Capitanian	Wuchiapingian	Changhsingian
		T_1	T_7	T_8																																		
Chonetinella krotovi (Fredericks)	○		+					+	+				+																									
Chonetinella iwakiensis Tazawa sp. nov.			+																																		
Chonetinella transversa Tazawa sp. nov.		+	+					+																														
Dyoros (*Dyoros*) sp.	○	+	+																																			
Haydenella sp.	●	+																																				
Lamnimargus peregrinus (Fredericks)	○	+	+				+						+			+	+																					
Transennatia gratiosa (Waagen)	●		+		+	+	+						+			+	+	+	+	+	+	+		+		+												
Costatumulus cf. *tazawai* Shen, Archbold, Shi & Chen	○		+																																		
Anidanthus ussuricus (Fredericks)	○		+			+	+						+			+	+																				
Terrakea sp.	○		+				+																															
Yakovlevia mammatiformis (Fredericks)	○	+										+	+	+	+																							
Oldhamina cf. *lianyangensis* Chan	●		+	+																																		
Derbyia schellwieni Frech	●		+																+																			
Derbyia? sp.			+																																			
Stenoscisma margaritovi (Tschernyschew)	○		+		+		+						+			+	+																					
Rhynchopora sp.	○		+																																			
Hustedia grandicosta (Davidson)			+					+							+	+	+		+			+	+	+														
Martinia semiplana Waagen			+				+					+				+	+	+	+					+	+													
Martinia lata Grabau			+	+			+												+																			
Martinia sp.			+																																			
Gypospirifer volatilis Duan & Li	○		+			+										+	+																					
Spiriferella saranae (de Verneuil)	○		+	+	+					+	+	+				+																					
Spiriferella? sp.			+																																			
Alispiriferella lita (Fredericks)	○		+		+	+	+						+			+	+																					
Elivina tibetana (Diener)	○		+			+							+							+			+															
Cathayspirina sp.	●		+																																			

and Chen from the Upper Permian (Wuchiapingian) of southern Xizang (Tibet); and *Oldhamina* cf. *lianyangensis* resembles *Oldhamina lianyangensis* Chan from the Upper Permian (Changhsingian) of Guangdong, South China.

The brachiopod fossils as like as the other animal and plant fossils, such as bivalves, ammonoids, trilobites and land plants, occur as reworked fossils (Tazawa et al., 2005). Therefore, the age of the fossil-bearing beds is a Late Permian (Lopingian), probably a Wuchiapingian age, although the Takakurayama fauna consists mostly of the Middle to Late Permian elements. A gastropod *Bellerophon* from the locality T_1, lower part of the Takakurayama Formation (Yanagisawa, 1967) indicates that this horizon is probably correlated with the *Bellerophon* Zone (Onuki, 1969) of the Upper Permian Toyoma Formation in the southern Kitakami Mountains.

Consequently the age of the whole of the Takakuraya Formation is assigned to be Late Permian (Lopingian), although previous authors considered that the whole Takakurayama Group (=Takakurayama Formation) is correlated with the Lower to Middle Permian (Yanagisawa and Nemoto, 1961), the Middle Permian (Onuki, 1966; Ueno, 1992) and the Lower to Upper Permian (Yanagisawa, 1967).

Palaeobiogeography

The Takakurayama fauna contains many Boreal type (including bipolar or antitropical-type) brachiopods: *Chonetinella krotovi*, *Dyoros* (*Dyoros*) sp., *Lamnimargus peregrinus*, *Costatumulus* cf. *tazawai, Anidanthus ussuricus*, *Terrakea* sp., *Yakovlevia mammatiformis, Stenoscisma margaritovi*, *Rhynchopora* sp., *Gypospirifer volatilis, Spiriferella saranae, Alispiriferella lita* and *Elivina tibetana*. This fauna contains also minor but several Tethyan-type species: *Haydenella* sp., *Transennatia gratiosa*, *Oldhamina* cf. *lianyangensis, Derbyia schellwieni* and *Cathayspirina* sp. In addition to the above species, some cosmopolitan species are present in this fauna: *Hustedia grandicosta, Martinia semiplana* and *Martinia lata.*

To sum up the Takakurayama fauna is a Boreal elements predominant Boreal-Tethyan mixed fauna in the Middle to Late Permian. In generic and specific composition, the Takakurayama fauna is close to the Middle to Late Permian brachiopod faunas of North China (Inner Mongolia), Northeast China (Heilongjiang and Jilin), eastern Russia (South Primorye), northeast Japan (southern Kitakami Mountains in the South Kitakami Belt), central Japan (Moribu in the Hida Gaien Belt) and southwest Japan (Mizukoshi in the Hida Gaien Belt) (see Table 1).

This conclusion supports the Permian reconstruction by Tazawa (2000, 2007), in which the South Kitakami region was located at the eastern margin of North China (Sino-Korea) in the middle latitude area of the Northern Hemisphere. Furthermore, the Permian reconstruction is very evidence for the strike-slip model proposed by Tazawa (1993, 2004), which describes that the South Kitakami region including the Takakurayama area was located at the eastern margin of North China in the Ordovician to Late Jurassic, and it moved to the north about

1,500-2,000 km by sinistral strike-slip faulting along the Tanakura-Median Tectonic Line in the Early Cretaceous to Palaeogene time.

Systematic descriptions

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

Chonetinella krotovi (Fredericks, 1925)
Figs. 3.1a-3.7

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, figs. 2.10a, 2.10b.

Material.—Twenty-two specimens, from locality T_7: (1) internal and external moulds of two ventral valves, NU-B1122 (holotype), 1123; (2) external casts of two ventral valves, NU-B1124, 1125; (3) internal moulds of six ventral valves, IGPS86645, NU-B1126-1130; (4) external and internal moulds of a dorsal valve, NU-B1131; (5) external moulds of seven dorsal valves, NU-B1132-1138; (5) internal moulds of four dorsal valves, NU-B1139-1142.

Description.— Shell small for genus, length and width about equal, subquadrate in outline, with greatest width at hinge; length 6 mm, width 8 mm in the holotype (NU-B1122); length 7 mm, width about 8 mm in the largest ventral valve specimen (NU-B1126). Ventral valve strongly convex in both lateral and anterior profiles; umbo small, incurved; ears large, trigonal shape, well defined and slightly convex; sulcus deep, narrow, bordered by a pair of high and slightly diverging lateral ridges which broaden anteriorly. External surface of ventral valve ornamented by numerous capillae on whole of valve but obscure on posterior half of ears; capillae numbering 8-9 in 2 mm at anterior margin. Dorsal valve with distinct fold corresponding to ventral sulcus; surface ornament consisting of numerous capillae, numbering 8-9 in 2 mm at anterior margin.

Internally, ventral valve having laterally elongated teeth; short and low median septum. Dorsal valve having small bilobed cardinal process with relatively large alveolus. Endospines in radial rows on both valves.

Remarks.— These specimens are referred to *Chonetinella krotovi* (Fredericks, 1925, p. 6,

pl. 1, figs. 54-57) from the Middle Permian Chandalaz Formation of the Vladivostok area, South Primorye, eastern Russia, in size and shape of the shell and in having highly developed ridges bordering the ventral sulcus.

Chonetinella granti Waterhouse 1981 (=*Chonetinella* sp. Grant, 1976, p. 79, pl. 17, figs. 23-28), from the Rat Buri Limestone of Khao Chang, southern Thailand, is close to *Chonetinella krotovi*, but it differs from the latter by its less acute cardinal extremities and much lower ridges bordering the ventral sulcus.

One of the Takakurayama specimens (IGPS86645) was described by Yanagisawa (1967) as *Chonetes uralicus* Moeller [=*Chonetinella uralica* (Moeller)], but the Russian species is larger and much transverse species (see Tschernyschew, 1902, pl. 63, figs. 4, 6).

Shells of *Chonetes substrophomenoides* forma A, described by Shimizu (1961) from the Upper Permian Maizuru Group of the Maizuru Belt, southwest Japan, and *Waagenites* aff. *striata* Liao, figured by Yanagida (1996) from the Upper Permian Tsunemori Formation of the Akiyoshi Belt, southwest Japan, are referred to *Chonetinella krotovi* by their size, outline and surface ornament of both valves.

Distribution.—Middle Permian (Wordian-Capitanian) of eastern Russia (South Primorye); Upper Permian (Lopingian) of northeast Japan (Takakurayama in the South Kitakami Belt) and southwest Japan (Kawahigashi in the Maizuru Belt and Tsunemori in the Akiyoshi Belt).

Chonetinella iwakiensis sp. nov.
Figs. 3.8a-3.14

Etymology.—Fossil locality Iwaki City, Fukushima Prefecture.

Chonetes blanfordi lata Hayasaka: Yanagisawa, 1967, p. 85, pl. 1, figs. 3, 17.

Material.—Eleven specimens, from locality T_7: (1) external and internal moulds of a ventral valve, NU-B1143 (holotype); (2) external moulds of two ventral valves, NU-B1144, 1145; (3) internal moulds of eight ventral valves, IGPS86644A, 86644C, NU-B1146-1151.

Diagnosis.—Large, transverse *Chonetinella*, with moderately convex ventral valve having shallow and narrow sulcus, and ornamented by numerous capillae, numbering 7-8 in 2 mm near anterior margin.

Description.—Shell large for genus, transversely subrectangular in outline, with greatest width near hinge; length about 10 mm, width about 17 mm in the holotype (NU-B1143). Ventral valve moderately convex in lateral profile; umbo small, blunt, overhanging hingeline a little; ears large, slightly convex; sulcus shallow and narrow in most of specimens, but obscure in some specimens. External surface of ventral valve ornamented by numerous capillae, numbering 7-8 in 2 mm near anterior margin; hinge spines distinct, curved. Interior

of ventral valve with short median septum posteriorly. Other internal structures not preserved.

Remarks.—The specimens from Takakurayama somewhat resemble *Chonetinella uralica* (Moeller) from the Lower Permian of the Urals in outline of the ventral valves, but the Russian species is larger in size and having more distinct ventral sulcus (see Tschernyschew, 1902, pl. 63, figs. 4, 6).

Chonetinella andamanensis Waterhouse (1981, p. 65, pl. 2, figs. 18, 19; pl. 3, figs. 1-18), from the Lower Permian (upper Sakmarian) of Ko Yao Noi, southern Thailand, is also a large transverse species, but it differs from *Chonetinella iwakiensis* sp. nov. in having deeper and broader ventral sulcus.

Some of the Takakurayama specimens (IGPS86644A, 86644C) were described by Yanagisawa (1967) as *Chonetes blanfordi lata* Hayasaka. However, *Chonetes blanfordi* Reed var. *lata* Hayasaka (1925, p. 92, pl. 5, figs. 3, 4) from the Middle Permian Kanokura Formation of the Imo area, South Kitakami Belt is clearly distinguished from the present new species by its much larger size.

Distribution.—Upper Permian (Lopingian) of northeast Japan (Takakurayama in the South Kitakami Belt).

Chonetinella transversa sp. nov.
Figs. 3.15-3.17

Etymology.—Latin, *transverse*, transversely.

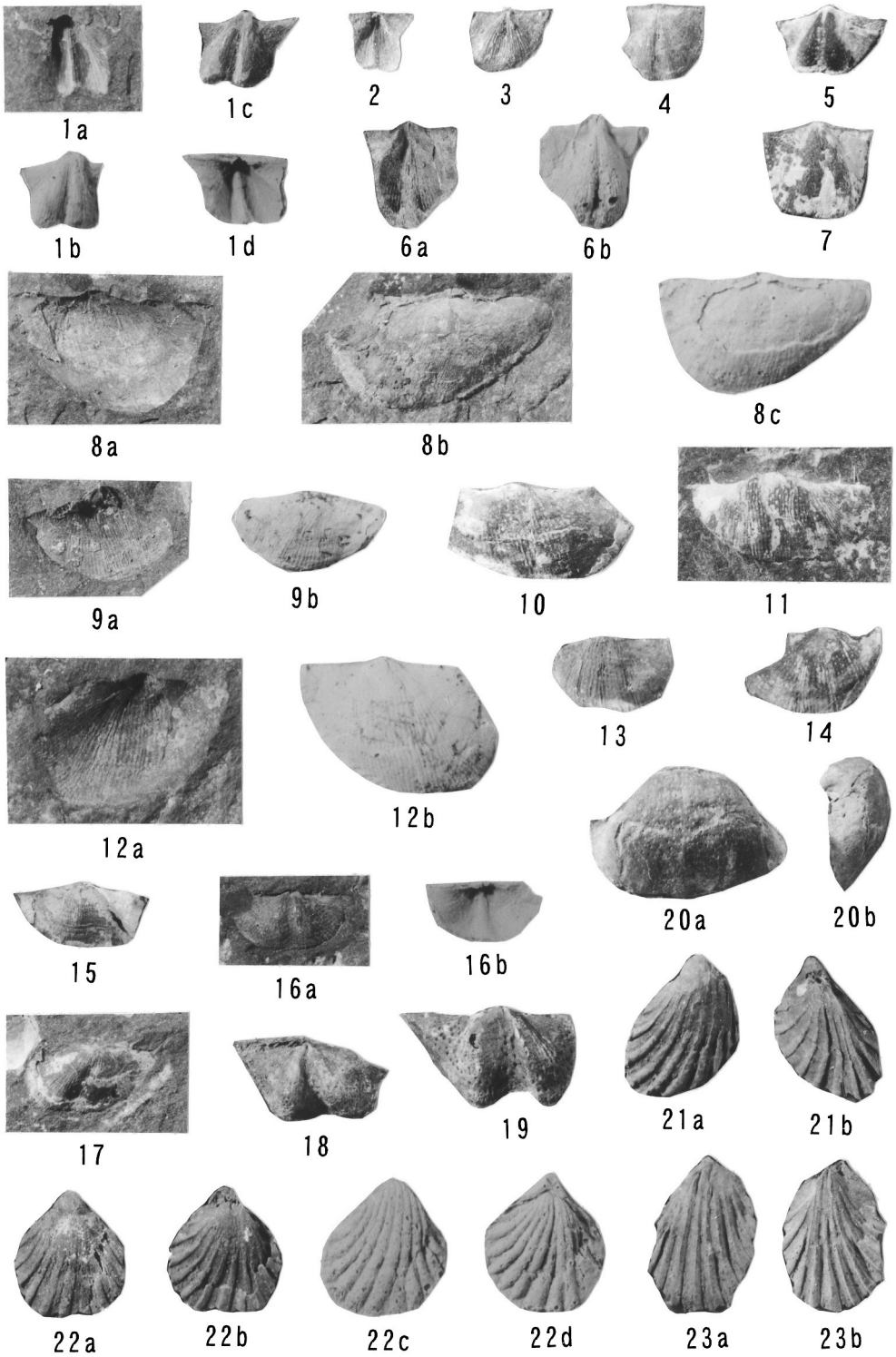
Chonetina substrophomenoides forma B Shimizu, 1961, p. 317, pl. 16, figs. 15-19.

Material.—Seven specimens, from localities T_1, T_7, internal moulds of seven ventral valves, NU-B1152 (holotype, from locality T_7) -1158.

Diagnosis.—Medium, transverse *Chonetinella*, with deep, broad ventral sulcus, ornament of numerous capillae and weak growth lines.

Description.—Shell medium size for genus, transversely subrectangular in outline, widest at hinge; length about 5 mm, width about 10 mm in the holotype (NU-B1152). Ventral valve highly elevated in visceral area; ears large, trigonal, nearly flat; sulcus deep, broaden anteriorly. External ornament consisting of numerous capillae and weak growth lines, although they are not clearly preserved. Interior of ventral valve with thick and short median septum; endospines numerous, arranging in radial rows.

Remarks.—These specimens are safely assigned to the genus *Chonetinella* by their small, highly convex ventral valve with deep sulcus and strong median septum. The Takakurayama species is named here as *Chonetinella transversa* sp. nov. The new species is readily distinguished from the above-described species, *Chonetinella iwakiensis* sp. nov., by its deeper and broader ventral sulcus and more acute cardinal extremities.


1a
1c
2
3
4
5
1b
1d
6a
6b
7
8a
8b
8c
9a
9b
10
11
12a
12b
13
14
15
16a
16b
20a
20b
17
18
19
21a
21b
22a
22b
22c
22d
23a
23b

The shells, described by Shimizu (1961) as *Chonetina substrophomenoides* forma B Shimizu, 1961 from the Upper Permian (Changhsingian) Maizuru Group of the Maizuru Belt, southwest Japan are referred to *Chonetinella transversa* sp. nov. in the similarity of size and shape of the ventral valve.

Chonetinella substrophomenoides (Huang, 1932, p. 3, pl. 1, figs. 3-7) from the Upper Permian (Changhsingian) of Guizhou, south China differs from the present new species by its less transverse shell.

Distribution.—Upper Permian (Lopingian) of northeast Japan (Takakurayama in the South Kitakami Belt) and southwest Japan (Kawahigashi in the Maizuru Belt).

Subfamily Svalbardiinae Archbold, 1982
Genus *Dyoros* Stehli, 1954
Subgenus *Dyoros* (*Dyoros*) Stehli, 1954

Dyoros (*Dyoros*) sp.
Figs. 3.18, 3.19

Material.—Three specimens, from localities T_1 and T_7, internal moulds of three ventral valves, NU-B1119-1121.

Remarks.—The ventral valve specimens from Takakurayama are safely assigned to the subgenus *Dyoros* (*Dyoros*) by their transverse shells (length about 7 mm, width about 14 mm in the larger specimen, NU-B1120), wide hinge, large, angular ears, deep sulcus and visceral region fringed by strong spines on anterolateral side. These specimens are closely similar to *Dyoros* aff. *transversus* Cooper and Grant, described by Kalashnikov (1993, p. 28, pl. 10, figs. 8, 9) from the Lower Permian (Artinskian) of Pai-Khoi, northern Russia in size and outline of the ventral valve. The present specimens are, however, too imperfect for comparison.

⬅ **Fig. 3. 1a-7:** *Chonetinella krotovi* (Fredericks), 1a, 1b, 1c, 1d: external mould, external latex cast, internal mould and internal latex cast of ventral valve, NU-B1122, 2: internal mould of dorsal valve, NU-B1141, 3: external mould of dorsal valve, NU-B1132, 4: external mould of dorsal valve, NU-B1136, 5: internal mould of ventral valve, IGPS86645, 6a, 6b: internal mould and internal latex cast of dorsal valve, NU-B1140, 7: external cast of ventral valve, NU-B1124. **8a-14:** *Chonetinella iwakiensis* sp. nov., 8a, 8b, 8c: external mould, internal mould and external latex cast of ventral valve, NU-B1143 (holotype), 9a, 9b: external mould and external latex cast of ventral valve, NU-B1145, 10: internal mould of ventral valve, NU-B1147, 11: internal mould of ventral valve, IGPS86644C, 12a, 12b: external mould and external latex cast of ventral valve, NU-B1144, 13: internal mould of ventral valve, NU-B1148, 14: internal mould of ventral valve, IGPS86644A. **15-17:** *Chonetinella transversa* sp. nov., 15: internal mould of ventral valve, NU-B1156, 16a, 16b: internal mould and internal latex cast of ventral valve, NU-B1158, 17: internal mould of ventral valve, NU-B1152 (holotype). **18, 19:** *Dyoros* (*Dyoros*) sp., 18: internal moud of ventral valve, NU-B1119, 19: internal mould of ventral valve, NU-B1120. **20a, 20b:** *Haydenella* sp., ventral and lateral views of internal mould of ventral valve, NU-B1077. **21a-23b:** *Hustedia grandicosta* (Davidson), 21a, 21b: ventral and dorsal views of internal mould of conjoined valve, NU-B1092, 22a, 22b, 22c, 22d: ventral and dorsal views of internal mould of conjoined valve, external latex cast of ventral valve and external latex cast of dorsal valve, NU-B1087. (All × 2).

Dyoros (*Dyoros*) *transversus* Cooper and Grant (1975, p. 1239, pl. 486, figs. 28-67; pl. 487, figs. 1-17; pl. 501, figs. 1-4) from the Upper Leonardian of West Texas is also similar in outline, but the American species is much larger in size.

Suborder Productidina Waagen, 1883
Superfamily Productoidea Gray, 1840
Family Productellidae Schuchert, 1929
Subfamily Productininae Muir-Wood and Cooper, 1960
Tribe Chonetellini Licharew in Sarytcheva, Licharew and Sokolskaya, 1960
Genus *Haydenella* Reed, 1944

Haydenella sp.
Figs. 3.20a, 3.20b

Mateial.—One specimen, from locality T_1, internal mould of a ventral valve, NU-B1077.

Description.—Shell small for genus, transverse subelliptical in outline, widest at hinge; length about 10 mm, width about 15 mm. 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 evenly convex in anterior profile, with nearly flattened venter and steeply inclined lateral slopes; umbo small, tapering and scarcely projecting over hinge; ears small. External surface of ventral valve nearly smooth, faintly costellate; a row of spine bases at base of ears; numerous fine pits scattered over anterior two-thirds of valve. Internal structures of ventral valve are obscure in the present material.

Remarks.—The single ventral valve specimen from Takakurayama may be a new species of *Haydenella*. This specimen most resembles the shell, described as *Linoproductus kiangsiensis* (Kayser) by Shimizu (1961, p. 326, pl. 15, figs. 16, 17) from the Upper Permian Maizuru Group in the Maizuru Belt, southwest Japan in size and outline of the ventral valve. But the poor preservation of the present material makes accurate comparison difficult.

The type species, *Haydenella kiangsiensis* (Kayser, 1883, p. 185, pl. 26, figs. 6-11) from the Upper Permian of Loping, Jiangxi, South China differs from the Takakurayama species in its larger dimensions.

Haydenella minuta Sarytcheva (in Ruzhentsev and Sarytcheva, 1965, p. 228, pl. 38, figs. 10a-11b) from the Dzulfian and Induan Stages of Transcaucasia differs from the present species by its much smaller and longer shell.

Subfamily Marginiferinae Stehli, 1954
Tribe Paucispiniferini Muir-Wood and Cooper, 1960
Genus *Lamnimargus* Waterhouse, 1975

Lamnimargus peregrinus (Fredericks, 1924)
Figs. 4.2a-4.4

Paramarginifera peregrina Fredericks, 1924, p. 24, pl. 1, figs. 7, 8; Fredericks, 1925, p. 12, pl. 1, figs. 41-44.
Dictyoproductus zesiensis Lee and Gu, 1976, p. 256, pl. 167, figs. 5, 6: pl. 170, figs. 1a, 1b.
Probolionia caucasica peregrina (Fredericks): Licharew and Kotlyar, 1978, pl. 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 in Kotlyar and Zakharov, 1989, pl. 23, figs. 9a, 9b.
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, 2008b, p. 7, figs. 3A-3T.

Material.—Three specimens, from localities T_1, T_7: (1) external and internal moulds of a ventral valve, NU-B1191; (2) internal mould of a ventral valve, NU-B1192; (3) external mould of a dorsal valve, IGPS86643.

Description.—Shell medium size for genus, transversely trapezoidal in outline, with greatest width at hinge; length about 16 mm, width about 27 mm in the best preserved specimen (NU-B1191). Ventral valve gently convex on visceral disc, strongly geniculated and followed by two long trails; umbo small, pointed and slightly incurved; ears large, prominent and slightly convex; sulcus deep, broad, originating a little below umbo and extending to anterior margin. External surface of ventral valve ornamented with numerous costellae and strong concentric rugae on both visceral disc and ears, but costellae only on trail; costellae numbering 7 in 5 mm at midvalve. Large spine bases poorly preserved; one row near base of ears, one pair on anterior portion of visceral disc. Interior of ventral valve, with a faint marginal ridge on anterolateral margins of visceral disc. Other internal structures not observed.

Remarks.—These specimens are poorly preserved, but they can be referred to *Lamnimargus peregrinus* (Fredericks, 1924), originally described from the Middle Permian Chandalaz Formation of the Vladivostok area, South Primorye, eastern Russia, by their size, shape and external ornament of the ventral valve, in particular, the relatively strong reticulate ornament on the visceral disc.

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

Lamnimargus japonicus (Tazawa, 1975, p. 636, pl. 2, figs. 3-6; pl. 3, figs. 1-4) from the Upper Permian (Changhsingian) of the Nabekoshiyama area, South Kitakami Belt, northeast Japan differs from the present species by its smaller size and finer reticulate ornament on the ventral valve.

Distribution.—Middle Permian (Wordian-Capitanian) of North China (Inner Mongolia), Northeast China (Heilongjiang), eastern Russia (South Primorye); Upper Permian (Lopingian) of eastern Russia (South Primorye) and northeast Japan (Ofunato and Takakurayama in the South Kitakami Belt).

Genus *Transennatia* Waterhouse, 1975

Transennatia gratiosa (Waagen, 1884)
Figs. 4.1

Productus gratiosus Waagen, 1884, p. 691, pl. 72, figs. 3-7; Rothpletz, 1892, p. 76, pl. 10, figs. 15, 15a-15c; Diener, 1897, p. 23, pl. 3, figs. 3-7; Mansuy, 1913, p. 115, pl. 13, figs. 1a, 1b; Broili, 1916, p. 12, pl. 116, figs. 4, 5, 7-13; Colani, 1919, p. 10, pl. 1, figs. 2a-2c; 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, figs. 14a, 14b; Hayasaka, 1960, p. 49, pl. 1, fig. 8.

Marginifera gratiosa (Waagen): Reed, 1944, p. 98, pl. 19, figs. 6-7a.

Dictyoclostus gratiosus (Waagen): Zhang and Ching (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, figs. 1a, 1b; Minato et al., 1979, pl. 61, figs. 11-13.

Asioproductus gratiosus (Waagen): Yang et al., 1977, p. 350, pl. 140, figs. 5a-5c; Feng and Jiang, 1978, p. 254, pl. 90, figs. 1a-2; Tong, 1978, p. 228, pl. 80, figs. 7a, 7b; Lee et al., 1980, p. 373, pl. 164, figs. 14a-14c; pl. 166, figs. 5-6b.

Asioproductus bellus Chan (Zhan), 1979, p. 85, pl. 6, figs. 7-13; pl. 9, figs. 8-10; text-fig. 18.

Gratiosina sp. Minato et al., 1979, pl. 61, fig. 14; Tazawa, 1991, p. 215.

Transennatia gratiosus (Waagen): Liu et al., 1982, p. 185, pl. 132, figs. 9a-9d; Wang et al., 1982, p. 214, pl. 92, figs. 6-8; pl. 102, figs. 4-9; Ding and Qi, 1983, p. 280, pl. 95, figs. 14a, 14b.

Transennatia gratiosa (Waagen): Yang, 1984, p. 219, pl. 33, figs. 7a-7c; 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 and Ibaraki, 2001, p. 7, pl. 1, figs. 1-3; Tazawa, 2001, p. 289, figs. 6.1-6.7; Shen et al., 2002, p. 676, figs. 4.27-4.31; Tazawa, 2002, fig. 10.2; Tazawa, 2008c, p. 43, figs. 6.6a-6.7b.

Mateial.—One specimen, from locality T_7, external cast of a ventral valve, NU-B1076.

Remarks.—The single specimen from Takakurayama can be referred to *Transennatia gratiosa* (Waagen, 1884) by its transversely subquadrate, strongly convex, small-sized ventral valve (length 11 mm, width 18 mm), with distinct and pointed ears, and fine, reticulate ornament on venter. This specimen is smaller than the type specimens from the Wargal and Chhidru

Formations of the Salt Range (Waagen, 1884, pl. 72, figs. 3-7), but it is similar in size to the relatively smaller specimens of *T. gratiosa*, from the Middle Permian of the South Kitakami Belt, northeast Japan (Hayasaka, 1960; Tazawa et al., 2000; Tazawa and Ibaraki, 2001), the Hida Gaien Belt, central Japan (Tazawa and Matsumoto, 1998; Tazawa, 2001), South Primorye, eastern Russia (Licharew and Kotlyar, 1978) and Northeast China (Lee et al., 1980).

Distribution.—Middle Permian (Wordian-Capitanian) of North China (Shaanxi), Northeast China (Heilongjiang and Jilin), eastern Russia (South Primorye), central Japan (Moribu and Oguradani in the Hida Gaien Belt), South China (Guangxi) and Cambodia (Sisophon); Middle Permian (Wordian) to Upper Permian (Changhsingian) of northeast Japan (Setamai, Kamiyasse-Imo and Ogatsu in the South Kitakami Belt), South China (Hubei) and Pakistan (Salt Range); Upper Permian (Lopingian) of northeast Japan (Takakurayama in the South Kitakami Belt), East China (Anhui and Zhejiang), South China (Jiangxi, Hunan, Guangdong, Guizhou, Sichuan and Yunnan), Southwest China (Tibet), Nepal (Kumaon Himalayas) and Vietnam (Quang Tri).

Superfamily Linoproductoidea Stehli, 1954
Family Linoproductidae Stehli, 1954
Subfamily Linoproductinae Stehli, 1954
Genus *Costatumulus* Waterhouse, 1983

Costatumulus cf. *tazawai* Shen, Archbold, Shi and Chen, 2000
Fig. 4.5

Compare.—
Costatumulus tazawai Shen, Archbold, Shi and Chen, 2000, p. 743, figs. 12.1-12.8, 12.11-12.14.

Material.—One specimen, from locality T_7, external mould of a dorsal valve, NU-B1187.

Remarks.—The single dorsal valve specimen is small in size (length 19 mm, width about 16 mm), slightly concave and strongly geniculated; external ornament consisting of numerous fine costellae (13-14 in 5 mm at midvalve), strong and slightly undulated concentric rugae and numerous quincuncially arranged elongate dimples. The Takakurayama specimen somewhat resembles the shells of *Costatumulus tazawai* Shen, Archbold, Shi and Chen, 2000, described from the Upper Permian (Wuchiapingian) Selong Group of southern Xizang (Tibet), in size, shape and surface ornament of the dorsal valve. But the accurate comparison is difficult for lacking information of the ventral valve.

The type species *Costatumulus tumida* (Waterhouse, 1983) from the Lower Permian (Artinskian) Tiverton Formation of the Bowen Basin, eastern Australia differs from *C. tazawai* by its much larger size and the lower and weak concentric rugae on the dorsal valve.

Subfamily Anidanthinae Waterhouse, 1968b
Genus *Anidanthus* Hill, 1950

Anidanthus ussuricus (Fredericks, 1924)
Figs. 4.6-4.11

Productus ussuricus Fredericks, 1924, p. 8, pl. 1, figs. 1-5; Fredericks, 1925, p. 18.
Linoproductus cf. *lineatus* (Waagen): Yanagida, 1963, p. 74, pl. 10, figs. 8-14.
Productus cora d'Orbigny: Yanagisawa, 1967, p. 87, pl. 1, fig. 4.
Anidanthus abukumaensis Yanagisawa, 1967, p. 89, pl. 2, fig. 16.
Anidanthus ussuricus (Fredericks): Nakamura, 1972, p. 434, pl. 1, figs. 1a-1c; Grigorjeva and Kotlyar, 1977, p. 56, pl. 5, figs. 1-3; text-fig. 34; Licharew and Kotlyar, 1978, pl. 13, figs. 5a-5g; Lee et al., 1980, p. 379, pl. 170, figs. 5, 9; Duan and Li, 1985, p. 113, pl. 38, figs. 6-9; Gu, 1992, p. 236, pl. 69, figs. 18, 25; pl. 78, figs. 11, 12; pl. 74, figs. 7, 8. Tazawa and Hasegawa, 2007, p. 6, figs. 4.1-4.7; Tazawa, 2008c, p. 46, figs. 7.1a-7.5.
Megousia koizumii Nakamura, 1972, p. 438, pl. 2, figs. 1, 4, 5; Tazawa and Gunji, 1982, p. 69, pl. 4, figs. 2a, 2b.
Pseudomarginifera ussuricus (Fredericks): Wang and Zhang, 2003, p. 106, pl. 17, figs. 16-27.

Material.—Eight specimens, from locality T_7, external moulds of eight dorsal valves, IGPS86640, 86641, NU-B1080-1085.

Description.—Shell large for genus, transversely subquadrate in outline; hinge straight, equal to greatest width; length about 15 mm, width about 34 mm in the largest dorsal valve specimen (NU-B1082). Dorsal valve slightly concave on venter, strongly geniculated and followed by long trail; ears large, prominent and almost flattened; fold absent. External surface of dorsal valve ornamented by strong concentric lamellae and numerous costellae over visceral disc, some costellae on ears; costellae numbering 8 in 5 mm at midvalve, 11-12 in 5 mm on trail.

Remarks.—These specimens are referred to *Anidanthus ussuricus* (Fredericks, 1924) from the Middle Permian Chandalaz Formation of the Vladivostok area, South Primorye, on account of size, shape and external ornament of the dorsal valves, in particular, their strong geniculation and having long trail covered by numerous fine costellae.

Yanagisawa (1967) described two productoid shells from the same locality of Takakurayama as *Productus cora* d'Orbigny [=*Linoproductus cora* (d'Orbigny, 1842)] and *Anidanthus abukumaensis* Yanagisawa, 1967, but all the specimens can be referred to *A. ussuricus.*

Distribution.—Middle Permian (Wordian-Capitanian) of North China (Zhesi and Xiujimqinqi, Inner Mongolia), Northeast China (Jilin) and eastern Russia (Vladivostok and Nakhodka, South Primorye); Upper Permian (Lopingian) of northeast Japan (Soma and

Takakurayama in the South Kitakami Belt) and southwest Japan (Mizukoshi in the Hida Gaien Belt).

Subfamily Paucispinauriinae Waterhouse, 1986
Genus *Terrakea* Booker, 1930

Terrakea sp.
Figs. 4.12a, 4.12b

Terrakea sp. A Tazawa, 2008a, p. 63, figs. 2A-2L.

Material.—Two specimens, from locality T_7: (1) external and internal moulds of a ventral valve, NU-B1188; (2) internal mould of a conjoined valve, NU-B1189.

Remarks.—These specimens are not well preserved, but can be safely assigned to the genus *Terrakea* on the basis of its size, shape and external ornament of the ventral valve. The Takakurayama species is close to and identical with *Terrakea* sp. A, described by Tazawa (2008a, p. 63, figs. 2A-2L) from the lower Kanokura Formation of the South Kitakami Belt, northeast Japan in the small (length about 18 mm, width more than 20 mm in the larger specimen, NU-B1188), strongly convex ventral valve, and the external ornament consisting of numerous costellae (7-8 in 5 mm at the midvalve) and elongate spine bases.

Distribution.—Middle Permian (Wordian) of northeast Japan (Kamiyasse-Imo in the South Kitakami Belt); Upper Permian (Lopingian) of northeast Japan (Takakurayama in the South Kitakami Belt).

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

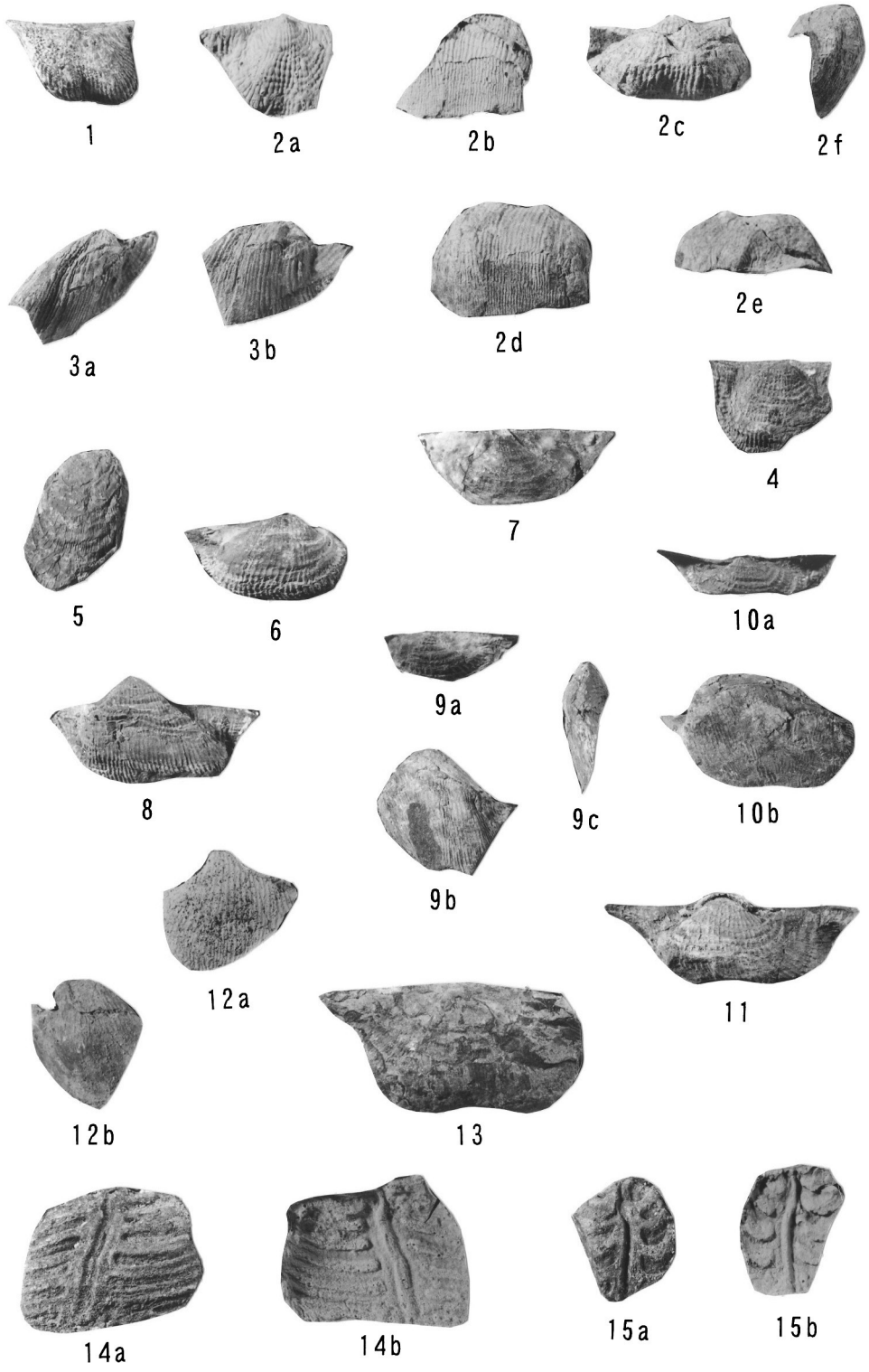
Yakovlevia mammatiformis (Fredericks, 1926)
Fig. 4.13

Productus mammatiformis Fredericks, 1926, p. 87, pl. 3, figs. 4-6.

Muirwoodia mammatiformis (Fredericks): Solomina, 1960, pl. 12, figs. 7, 8; Kulikov, 1974, p. 89, pl. 3, figs. 6a-6v.

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., figs. 14a-14v; Zavodowsky and Stepanov in Zavodowsky et al., 1970, p. 114, pl. 35, figs. 8-10; Ifanova, 1972, p. 119, pl. 6, figs. 15a-16; pl. 7, figs. 1a-2; Kalashnikov, 1983, p. 210, pl. 49, figs. 5, 6, 9; Kalashnikov, 1986, pl. 116, fig. 1; Manankov in Tatarinov et al., 1991, p. 107, pl. 26, figs. 1-3; Kalashnikov, 1993, p. 61, pl. 16, figs. 1-4; Tazawa, 1999, p. 92, fig. 3.6.

Linoproductus cf. *mammatus* (Keyserling): Yanagisawa, 1967, p. 88, pl. 2, fig. 7.


1
2a
2b
2c
2f
3a
3b
2d
2e
4
7
5
6
10a
9a
8
9c
10b
9b
12a
11
12b
13
14a
14b
15a
15b

Material.—One specimen, locality T_1, external mould of a dorsal valve, IGPS86649.

Remarks.—This specimen was first described by Yanagisawa (1967, p. 88, pl. 2, fig. 7) as *Linoproductus* cf. *mammatus* (Keyserling, 1846), and subsequently redescribed by Tazawa (1999, p. 92, fig. 3.6) as *Yakovlevia mammatiformis* (Fredericks, 1926).

Distribution.—Lower Permian (Sakmarian) to Middle Permian (Wordian) of northern Russia (Novaya Zemlya, Pechora Basin, Pai Khoi, northern Urals and Omolon Massif), southern Mongolia, Northwest China (Gansu) and eastern Russia (South Primorye); Upper Permian (Lopingian) of northeast Japan (Takakurayama in the South Kitakami Belt).

Suborder Lyttoniidina Williams, Harper and Grant, 2000
Superfamily Lyttonioidea Waagen, 1883
Family Lyttoniidae Waagen, 1883
Subfamily Lyttoniinae Waagen, 1883
Genus *Oldhamina* Waagen, 1883

Oldhamina cf. *lianyangensis* Chan (Zhan), 1979
Figs. 4.14a-4.15b

Lyttonia richthofeni Kayser em. Hayasaka: Yanagisawa, 1967, p. 89, pl. 2, fig. 1.

Compare.—
Oldhamina lianyangensis Chan (Zhan), 1979, p. 92, pl. 12, figs. 11, 12; Xu, 1987, p. 228, pl. 13, fig. 20; pl. 14, fig. 1.

Material.—Two specimens, from localities T_7, T_8, internal moulds of two ventral valves, IGPS86648, NU-B1079.

Description.—Shell small size for genus; length about 27 mm, width about 29 mm in the larger specimen (IGPS86648); length about 20 mm, width about 16 mm in the smaller specimen

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⬅ **Fig. 4. 1:** *Transennatia gratiosa* (Waagen), external cast of ventral valve, NU-B1076. **2a-4:** *Lamnimargus peregrinus* (Fredericks), 2a, 2b, 2c, 2d, 2e, 2f: ventral and anterior views of external latex cast of ventral valve, and ventral, anterior, posterior and lateral views of internal mould of ventral valve, NU-B1191, 3a, 3b: ventral and anterior views of internal mould of ventral valve, NU-B1192, 4: external mould of dorsal valve, IGPS86643. **5:** *Costatumulus* cf. *tazawai* Shen, Archbold, Shi and Chen, external mould of dorsal valve, NU-B1187. **6-11:** *Anidanthus ussuricus* (Fredericks), 6: external mould of dorsal valve, IGPS86640, 7: external mould of dorsal valve, IGPS86641, 8: external mould of dorsal valve, NU-B1085, 9a, 9b, 9c: dorsal, anterior and lateral views of external mould of dorsal valve, NU-B1081, 10a, 10b: dorsal and anterior views of external mould of dorsal valve, NU-B1080, 11: external mould of dorsal valve, NU-B1082. **12a, 12b:** *Terrakea* sp., external latex cast and internal mould of ventral valve, NU-B1188. **13:** *Yakovlevia mammatiformis* (Fredericks), external mould of dorsal valve, IGPS86649. **14a-15b:** *Oldhamina* cf. *lianyangensis* Chan, 14a, 14b: internal mould and internal latex cast of ventral valve, IGPS86648, 15a, 15b: internal mould and internal latex cast of ventral valve, NU-B1079. (All × 1).

(NU-B1079). Ventral valve slightly convex in lateral and anterior profiles. Internally ventral valve having a thick median septum and 4-7 symmetrically arranged lateral septa on each side of median septum; lateral septa sharp, inclined anteriorly, and slightly arcuate toward anterior.

Remarks.—These specimens are safely assigned to the genus *Oldhamina* by their sharp and forward-dipping lateral septa. The Takakurayama specimens well resemble *Oldhamina lianyangensis* Chan (Zhan), 1979, originally described from the Upper Permian (Changhsingian) of Guangdong, South China, in their slightly convex ventral valves with nearly straight, symmetrically arranged lateral septa.

Order Orthotetida Waagen, 1884
Suborder Orthotetidina Waagen, 1884
Superfamily Orthotetoidea Waagen, 1884
Family Derbyiidae Stehli, 1954
Genus *Derbyia* Waagen, 1884

Derbyia schellwieni Frech, 1911
Figs. 5.16a-5.16d

Derbyia schellwieni Frech, 1911, p. 125, pl. 18, figs. 3a-3d; Yang et al., 1977, p. 325, pl. 134, figs. 5a, 5b; Liu et al., 1982, p. 176, pl. 128, figs. 7a, 7b.
Derbyia cf. *crassa* (Meek and Hayden): Yanagisawa, 1967, p. 85, pl. 3, figs. 5, 8.

Material.—One specimen, from locality T_7, external and internal moulds of a ventral valve, IGPS86650.

Description.—Shell medium size for genus, transversely subrectangular in outline; length 29 mm, width more than 33 mm in the sole specimen (IGPS86650). Ventral valve nearly flat, slightly concave and having a low fold posteriorly; external surface with parvicostellate ornament on whole of valve; costellae numbering 11-15 in 10 mm near anterolateral margins; concentric rugae few and irregular. Interior of ventral valve with a strong, short median septum, extending to one fourth of valve length. Other internal structures not observed.

Remarks.—This specimen can be referred to *Derbyia schellwieni* Frech, 1911, from the Upper Permian (Lopingian) of Loping, Jiangxi Province, South China, in its medium-sized transverse shell and fine parvicostellate ornament of the ventral valve.

The present specimen from Takakurayam was first described by Yanagisawa (1967, p. 85) as *Derbyia* cf. *crassa* (Meek and Hayden), although *Derbyia crassa* (Meek and Hayden) from the Pennsylvanian of Kansas differs from the Takakurayama species by its much smaller size (see Dunbar and Condra, 1932, pl. 3, figs. 1-12; Sutherland and Harlow, 1973, pl. 2, figs. 8-12).

Distribution.—Upper Permian (Wuchiapingian) of South China (Hunan); Upper Permian (Lopingian) of northeast Japan (Takakurayama in the South Kitakami Belt) and South China (Jiangxi).

Derbyia? sp.
Figs. 5.15a, 5.15b

Productus cf. *sinensis* (sic) Tschernyschew: Yanagisawa, 1967, p. 87, pl. 2, fig. 6.

Material.—One specimen, from locality T_7, internal mould of a dorsal valve, IGPS86651.

Remarks.—The single dorsal valve specimen from Takakurayama was described by Yanagisawa (1967, p. 87) as *Productus* cf. *sinensis* (sic) Tschernyschew [=*Productus* cf. *simensis* Tschernyschew, 1902]. However, the dorsal valve has a large cardinal process fused with strong socket ridges, which is a characteristic internal structure of the superfamily Orthotetoidea Waagen, 1884. The Takakurayama specimen may be a species assigned to the genus *Derbyia* Waagen, 1884, although the specific identification is difficult because of ill-preservation of the present material.

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

Stenoscisma margaritovi (Tschernyschew, 1888)
Fig. 5.1

Camarophoria margaritovi Tschernyschew, 1888, p. 355, figs. 1-3; Fredericks, 1924, p. 48, pl. 1, figs. 32-42; text-fig. 4.

Camarophoria humbletonensis Howse: Hayasaka, 1922, p. 62, pl. 8, figs. 10-12; pl. 10, fig. 9; Hayasaka, 1966, p. 1226, text-figs. 6-8.

Stenoscisma humbletonensis (Howse): Tazawa, 1976, pl. 2, figs. 9, 10; Minato et al., 1979, pl. 66, figs. 6-8.

Stenoscisma gigantea (Diener): Lee and Gu, 1976, p. 272, pl. 176, fig. 3; pl. 177, fig. 18; Lee et al., 1980, p. 395, pl. 173, figs. 6, 8.

Stenoscisma margaritovi (Tschernyschew): Licharew and Kotlyar, 1978, pl. 17, figs. 7a, 7b; Koczyrkevicz, 1979, p. 50, pl. 11, figs. 5, 6; Duan and Li, 1985, p. 120, pl. 43, figs. 5-8; Tazawa and Matsumoto, 1998, p. 9, pl. 2, figs. 1-5; Tazawa et al., 2000, p. 10, pl. 1, figs. 7-11; Tazawa, 2001, p. 298, figs. 8.1a-8.4; Tazawa, 2002, fig. 10.5; Wang and Zhang, 2003, p. 130, pl. 33, figs. 6-7, 12-16; pl. 50, fig. 19; Tazawa and Chen, 2006, p. 333, figs. 5.7, 5.8.

Stenoscisma gigantea elongatum Lee, Gu and Su, 1980, p. 395, pl. 173, figs. 1, 2.

Stenoscisma purdoni (Davidson): Lee et al., 1980, p. 395, pl. 173, figs. 4, 5, 7.

Material.—One specimen, from locality T_7, internal mould of a dorsal valve, NU-B1078.

Remarks.—The single specimen from Takakurayama is poorly preserved, but it is safely assigned to the genus *Stenoscisma* by its rhynchonelliform dorsal valve with a spoon-shaped camarophorium supported by short and high median septum. It can be referred to *Stenoscisma margaritovi* (Tschernyschew, 1888), from the Middle Permian of Vladivostok, eastern Russia, on the basis of its medium-sized, transverse dorsal valve (length about 15 mm, width about 23 mm), with strong costae, numbering 6 on fold and 5 on each flank.

Distribution.—Middle Permian (Wordian-Capitanian) of North China (Inner Mongolia), Northeast China (Heilongjiang and Jilin), eastern Russia (South Primorye) and Japan (South Kitakami and Hida Gaien Belts); Upper Permian (Lopingian) of northeast Japan (Ogatsu and Takakurayama in the South Kitakami Belt).

Superfamily Rhynchoporoidea Muir-Wood, 1955
Family Rhynchoporidae Muir-Wood, 1955
Subfamily Rhynchoporinae Muir-Wood, 1955
Genus *Rhynchopora* King, 1865

Rhynchopora sp.
Figs. 5.2a, 5.2b

Material.—One specimen, from locality T_7, internal mould of a conjoined valve, NU-B1086.

Remarks.—This specimen is safely assigned to the genus *Rhynchopora* by its small, transversely subpentagonal shell (length about 10 mm, width about 14 mm), distinct ventral sulcus and dorsal fold, and numerous simple costae on both valves, numbering 4 on fold and 5 on each flank of the dorsal valve. The Takakurayama specimen somewhat resembles *Rhynchopora tchernyshae* Koczyrkevicz (1979, p. 47, pl. 11, figs. 1-4), from the Middle Permian Barabash Formation of the Barabash area, South Primorye, in size and outline of the shell, but it differs from the Russian species by fewer costae on the dorsal valve.

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

Hustedia grandicosta (Davidson, 1862)
Figs. 3.21a-3.23b

Retzia radialis var. *grandicosta* Davidson, 1862, p. 28, pl. 1, figs. 5a, 5b; Broili, 1916, p. 51, pl. 124, figs. 14-22 only.

Eumetria grandicosta (Davidson): Waagen, 1883, p. 491, pl. 34, figs. 6-12.

Hustedia grandicosta (Davidson): Grabau, 1931, p. 121, pl. 5, figs. 6a-6d; Grabau, 1934, p. 105, pl. 7, figs. 5a-5c; Shimizu, 1961, p. 328, pl. 16, figs. 39-42; Lee and Gu, 1976, p. 275, pl. 160, fig. 17; Koizumi, 1979, pl. 1, fig. 7; Lee et al., 1980, p. 398, pl. 173, figs. 16, 17; Liu et al., 1982, p. 199, pl. 144, figs. 6a-6d; Wang, 1995, pl. 3, figs. 3a-3c; Wang and Yang, 1998, p. 108, pl. 17, figs. 15a, 15b; Wang and Zhang, 2003, p. 141, pl. 34, figs. 2-8.

Hustedia radialis var. *grandicosta* (Davidson): Chi-Thuan, 1961, p. 300, pl. 4, figs. 1a-2.

Material.—Thirty-one specimens, from locality T_7: (1) external and internal moulds of a conjoined valve, NU-B1087; (2) internal mould of a conjoined valve with external mould of the dorsal valve, NU-B1088; (3) internal moulds of sixteen conjoined valves, NU-B1089-1104; (4) external moulds of two ventral valves, NU-B1105, 1106; (5) internal moulds of three ventral valves, NU-B1107-1109; (6) external and internal moulds of two dorsal valves, NU-B1110, 1111; (7) internal moulds of seven dorsal valves, NU-B1112-1118.

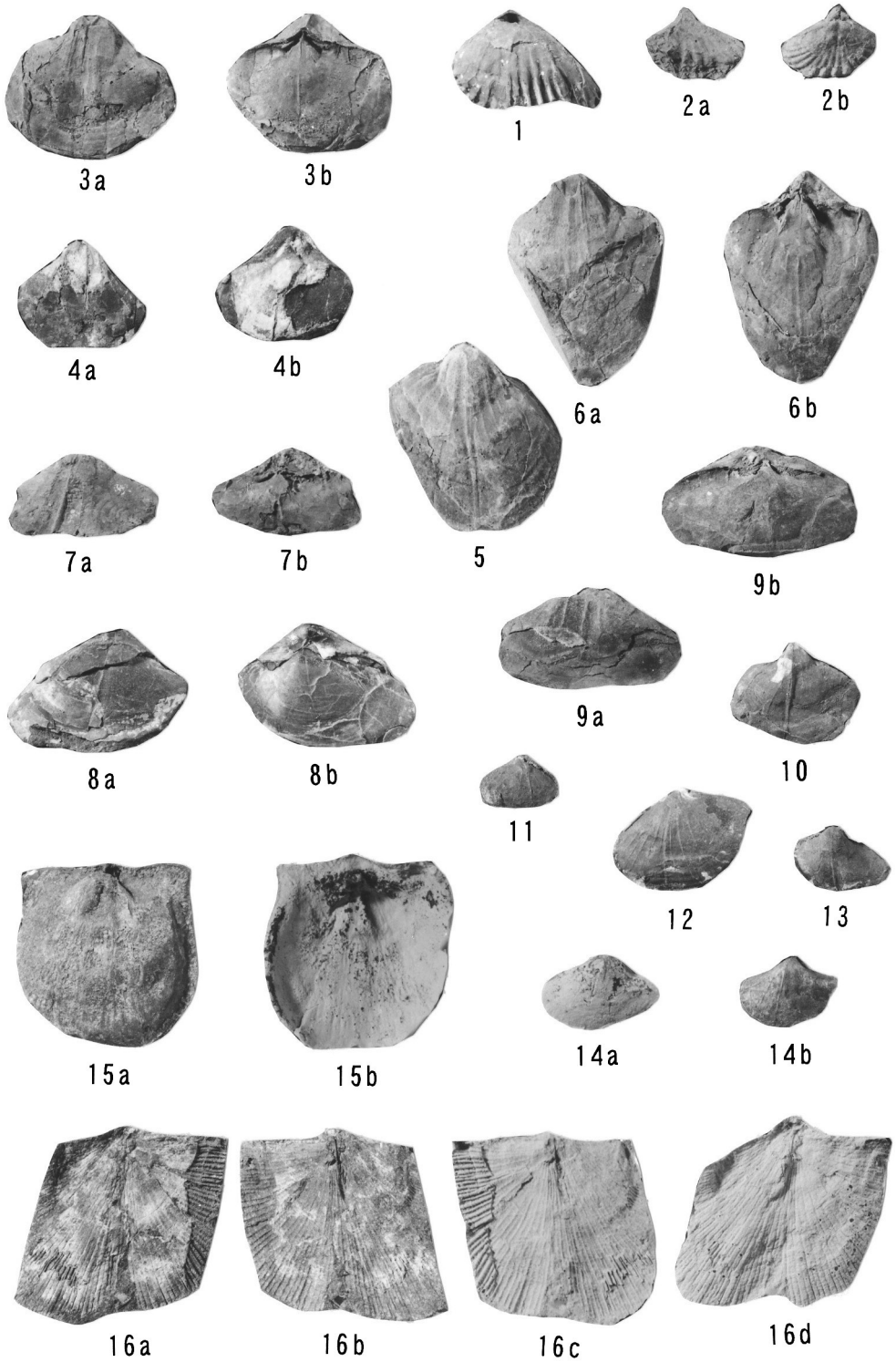
Description—Shell medium size for genus, suboval in outline, with greatest width slightly anterior to midvalve; length 10 mm, width 9 mm in the largest and best preserved specimen (NU-B1087). Ventral valve moderately convex in both lateral and anterior profiles, without sulcus. External surface of ventral valve ornamented with strong, simple and rounded costae, numbering 11-14; intercostal spaces narrow. Dorsal valve moderately convex in both profiles, without fold, and ornamented with 11-13 strong, rounded costae. Interior of dorsal valve with short, high median septum. Other internal structures of both valves obscure in the present specimens.

Remarks.—The Takakurayama specimens can be referred to *Hustedia grandicosta* (Davidson, 1862), originally described by Davidson (1862) and redescribed by Waagen (1883) from the Middle and Upper Permian (Amb, Wargal and Chhidru Formations) of the Salt Range, by their size, shape and external ornament of both valves.

Hustedia orbicostata Xu and Grant (1994, p. 60, figs. 49, 50) from the Changhsingian of Sichuan and Zhejiang, South China somewhat resembles *H. grandicosta*, but the former differs from the latter in its smaller size and fewer costae on both valves.

Hustedia remota (Eichwald, 1860) is clearly distinguished from *H. grandicosta* in having wider and flat-bottomed intercostal spaces on both valves (see Tschernyschew, 1902, pl. 47, figs. 8-11; Huang, 1933, p. 81).

Distribution.—Lower Permian (Asselian-Kungurian) of Northwest China (Xinjiang), North China (Inner Mongolia), Salt Range and Timor; Middle Permian (Roadian-Capitanian) of North China (Inner Mongolia), Northeast China (Heilongjiang), Salt Range and Cambodia; Upper Permian (Lopingian) of northeast Japan (Takakurayama in the South Kitakami Belt), southwest Japan (Kawahigashi in the Maizuru Belt), South China (Hunan and Guizhou) and Salt Range.


3a
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15a
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14b
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16b
16c
16d

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

Martinia semiplana Waagen, 1883
Figs. 5.3a-5.4b

Martinia semiplana Waagen, 1883, p. 536, pl. 43, figs. 4a-4e; Tschernyschew, 1902, p. 182, 565, pl. 60, figs. 15-17; Tschernyschew, 1914, p. 23, 57, pl. 10, figs. 5, 6; Grabau, 1936, p. 237, pl. 24, figs. 1-4; Hayasaka and Minato, 1956, p. 146, pl. 23, fig. 2; Zhang and Ching, 1961, p. 406, pl. 2, figs. 16-19; Zeng, 1990, p. 228, pl. 7, figs. 6, 7; pl. 8, figs. 11a-11d; Fan and He, 1999, p. 149, pl. 36, figs. 3a-3d.

Material.—Three specimens, from locality T_7: (1) external and internal moulds of a conjoined valve, NU-B1169; (2) internal moulds of two conjoined valves, NU-B1170, 1171.

Description.—Shell medium size for genus, subcircular in outline, gently biconvex, lacking ventral sulcus and dorsal fold, surface of both valves smooth; length 20 mm, width 18 mm in the best preserved specimen (NU-B1169); length about 20 mm, width about 23 mm in the largest specimen (NU-B1171). Internally, both valves having distinct vascular impressions.

Remarks.—These specimens are referred to *Martinia semiplana* Waagen, 1883, from the Middle to Upper Permian (Capitanian-Wuchiapingian) Wargal Formation of the Salt Range, by their size, shape and outline of the shells and having no sulcus and fold.

Martinia orbiculata Gemmellaro is similar in size and outline of the shell, but it differs from *M. semiplana* in its strongly convex ventral valve (see Tschernyschew, 1902, pl. 17, figs. 1c, 3c).

⬅ **Fig. 5. 1:** *Stenoscisma margaritovi* (Tschernyschew), internal mould of dorsal valve, NU-B1078. **2a, 2b:** *Rhynchopora* sp., ventral and dorsal views of internal mould of conjoined valve, NU-B1086. **3a-4b:** *Martinia semiplana* Waagen, 3a, 3b: ventral and dorsal views of internal mould of conjoined valve, NU-B1171, 4a, 4b: ventral and dorsal views of internal mould of conjoined valve, NU-B1170. **5-6b:** *Martinia* sp., 5: internal mould of ventral valve, NU-B1173, 6a, 6b: ventral and dorsal views of internal mould of conjoined valve, NU-B1172. **7a-14b:** *Martinia lata* Grabau, 7a, 7b: ventral and dorsal views of internal mould of conjoined valve, NU-B1161, 8a, 8b: ventral and dorsal views of internal mould of conjoined valve, NU-B1160, 9a, 9b: ventral and dorsal views of internal mould of conjoined valve, NU-B1159, 10: internal mould of ventral valve, NU-B1164, 11: internal mould of ventral valve, NU-B1168, 12: internal mould of ventral valve, NU-B1166, 13: internal mould of ventral valve, NU-B1167, 14a, 14b: external latex cast and internal mould of ventral valve, NU-B1162. **15a, 15b:** *Derbyia*? sp., internal mould and internal latex cast of dorsal valve, IGPS86651. **16a, 16b, 16c, 16d:** *Derbyia schellwieni* Frech, external mould, internal mould, external latex cast and internal latex cast of ventral valve, IGPS86650. (All × 1).

Distribution.—Upper Carboniferous of North China (Inner Mongolia) and South China (Guizhou); Lower Permian of northern Urals, northern Pamir, North China (Shanxi) and Northeast China (Liaoning); Middle Permian (Wordian) of northeast Japan (Kamiyasse-Imo in the South Kitakami Belt); Middle to Upper Permian (Capitanian-Wuchiapingian) of Salt Range; Upper Permian (Lopingian) of northeast Japan (Takakurayama in the South Kitakami Belt) and East China (Anhui).

Martinia lata Grabau, 1936
Figs. 5.7a-5.14b

Martinia semiplana var. *lata* Grabau, 1936, p. 239, pl. 21, figs. 1-3; Hayasaka and Minato, 1956, p. 146, pl. 23, fig. 3.

Material.—Ten specimens, from localities T_7, T_8: (1) internal moulds of three conjoined valves, NU-B1159-1161; (2) external and internal moulds of a ventral valve, NU-B1162; (3) external mould of a ventral valve, NU-B1163; (4) internal moulds of five ventral valves, NU-B1164-1168.

Remarks.—These specimens are referred to *Martinia lata* Grabau, 1936, originally described as *Martinia semiplana* var. *lata* Grabau from the Lower Permian Maping Formation of Guangxi, South China, by their medium-sized, transversely subelliptical shell (length 18 mm, width 26 mm in the best preserved specimen, NU-B1160) with no sulcus and fold. This species was also described by Hayasaka and Minato (1956) from the Middle Permian (Wordian) lower Kanokura Formation of the South Kitakami Belt, northeast Japan.

Martinia semiplana Waagen, 1883, the preceding species, is clearly distinguished from *M. lata* by its less transverse shell.

Distribution.—Lower Permian (Asselian-Artinskian) of South China (Guangxi); Middle Permian (Wordian) of northeast Japan (Kamiyasse-Imo in the South Kitakami Belt); Upper Permian (Lopingian) of northeast Japan (Takakurayama in the South Kitakami Belt).

Martinia sp.
Figs. 5.5-5.6b

Martinia rhomboidaris Grabau: Koizumi, 1979, pl. 1, fig. 9.

Material.—Three specimens, from locality T_7: (1) external mould of a ventral valve, with internal mould of a conjoined valve, NU-B1172; (2) internal moulds of two ventral valves, NU-B1173 (holotype), 1174.

Remarks.—These specimens are safely assigned to the genus *Martinia* by their longer ellipsoidal outline (length about 30 mm, width about 25 mm in the largest specimen, NU-

B1173) and some radial vascular scars on the ventral valves. The Takakurayama specimens may be a new species of *Martinia*, although the preservation of them are not adequate for establishing the new species. The single shell, figured by Koizumi (1979, pl. 1, fig. 9) as *Martinia rhomboidaris* Grabau, 1931 from the same locality of the Takakurayama area, is deemed conspecific with the present species.

Martinia uralica Tschernyschew (1902, p. 183, 566, pl. 18, figs. 1-4) from the Lower Permian of the Urals is somewhat like to the present species in size, shape of the ventral valve. But the accurate comparison is difficult for poorly preserved specimens.

Superfamily Spiriferoidea King, 1846
Family Trigonotretidae Schuchert, 1893
Subfamily Neospiriferinae Waterhouse, 1968a
Genus *Gypospirifer* Cooper and Grant, 1976

Gypospirifer volatilis Duan and Li, 1985
Fig. 6.17

Spirifer cf. *moosakhailensis* Davidson: Noda, 1956, p. 17, pl. 6, fig. 10 only.
Spirifer fasciger var. *simplex* Grabau: Kobiyama, 1956, fig. 4.
Neospirifer fasciger (Keyserling): Yanagida, 1963, p. 71, pl. 8, figs. 1-3; Koizumi, 1979, pl. 1, fig. 16.
Neospirifer cf. *fasciger* (Keyserling): Yanagisawa, 1967, p. 90, pl. 2, fig. 18.
Neospirifer moosakhailensis (Davidson): Lee and Gu, 1976, p. 286, pl. 175, figs. 1-3 only.
Gypospirifer volatilis Duan and Li, 1985, p. 127, 207, pl. 48, figs. 1-2; pl. 49, figs. 1-2c; Tazawa, 2001, p. 302, figs. 8.23-8.26; Tazawa and Chen, 2006, p. 335, figs. 6.5-6.7; Tazawa and Hasegawa, 2007, p. 7, figs. 4.8-4.12, 5.1, 5.2; Tazawa, 2008c, p. 54, figs. 9.3-9.7.
Neospirifer volatilis (Duan and Li): Wang and Zhang, 2003, p. 146, pl. 38, figs. 1-8.

Material.—One specimen, from locality T_7, external cast of a ventral valve, IGPS86653.

Description.—Shell medium size for genus, transversely semielliptical in outline, with greatest width at hinge, length about 35 mm, width about 72 mm in the sole ventral valve specimen (IGPS86653). Ventral valve gently convex in lateral and anterior profiles, most convex at umbonal region; umbo slightly extended and strongly incurved; sulcus deep and rapidly widening anteriorly, with U-shaped bottom. External surface of ventral valve ornamented by numerous fine costae and concentric ornament of some strong rugae and numerous fine growth lines; costae subridged, often bifurcated, numbering 10-11 in 10 mm at about midvalve.

Remarks.—This specimen is referred to *Gypospirifer volatilis* Duan and Li, 1985, from the Middle Permian Zhesi (Jisu) Formation of Zhesi, Inner Mongolia, on account of size, shape

and external ornament of ventral valve.

Yanagisawa (1967) described the Takakurayama specimen as *Neospirifer* cf. *fasciger* (Keyserling, 1846), but *Neospirifer fasciger*, the type species of the genus *Neospirifer* Fredericks, 1924 is much smaller in size and having conspicuous fasciculate ornament on both valves.

Distribution.—Middle Permian (Roadian-Capitanian) of North China (Zhesi and Xiujimqinqi, Inner Mongolia), Northeast China (Heilongjiang) and central Japan (Moribu in the Hida Gaien Belt); Upper Permian (Lopingian) of Northeast China (Jilin), northeast Japan (Takakurayama in the South Kitakami Belt) and southwest Japan (Mizukoshi in the Hida Gaien Belt).

Family Spiriferellidae Waterhouse, 1968a
Genus *Spiriferella* Tschernyschew, 1902

Spiriferella saranae (de Verneuil, 1845)
Figs. 6.1-6.4

Spirifer saranae de Verneuil, 1845, p. 169, pl. 6, figs. 15a, 15b.
Spiriferina (*Spiriferella*) *saranae* de Verneuil: Tschernyschew, 1902, p. 121, 522, pl. 12, figs. 4a, 4b; pl. 40, fig. 7; text-figs. 41-46.
Spiriferella saranae (de Verneuil): Grabau, 1931, p. 155, pl. 22, figs. 4a, 4b; text-fig. 43; Yanagisawa, 1967, p. 91, pl. 2, fig. 10 only; Harker, 1960, p. 71, pl. 22, figs. 1-8; pl. 23, figs. 3, 4, 8; Nelson and Johnson, 1968, p. 729, pl. 93, figs. 1-10; pl. 96, fig. 9; test-figs. 4f, 5a, 13f; Ifanova, 1972, p. 135, pl. 11, figs. 3a, 3b; Waterhouse and Waddington, 1982, p. 17, pl. 4, figs. 1-11; text-figs. 14, 16a, 16c; Nakamura et al., 1992, pl. 4, figs. 2, 5; Shi and Waterhouse, 1996, p. 132, pl. 24, figs. 21-32; pl. 25, figs. 1-5.
Spirifer (*Spiriferella*) *saranae* de Verneuil: Licharew and Einor, 1939, p. 133, 216, pl. 22, fig. 1.
Spiriferella cf. *saranae* (de Verneuil): Yanagisawa, 1967, p. 92, pl. 2, fig. 19.

Material.—Four specimens, from localities T_7, T_8: (1) external cast of a conjoined valve, NU-B1175; (2) external casts of three ventral valves, IGPS86638, 86654B, NU-B1176.

Remarks.—These specimens are poorly preserved, but can be referred to *Spiriferella saranae* (de Verneuil, 1845) from the Lower Permian (Artinskian) of the Urals by their longer ventral valve (length about 28 mm, width about 22 mm in the best preserved specimen, IGPS86638; length more than 42 mm, width more than 39 mm in the largest specimen, IGPS86654B), with deep V-shaped sulcus bearing two or three pairs of faint sulcal costae and strong simple costae on lateral flanks.

Spiriferella persaranae Grabau (1931, p. 156, pl. 19, figs. 4a, 4b; text-fig. 61), from the Middle Permian Zhesi (Jisu) Formation of Zhesi, Inner Mongolia, is distinguished from *S.*

saranae by its smaller dimensions and deeper sulcus with smooth V-shaped bottom on the ventral valve.

Distribution.—Lower Permian (Asselian-Kungurian) of northern Russia (northern Urals, Timan, Pechora Basin and Novaya Zemlya), Arctic Canada (northern Yukon Territory and Devon Island); Middle Permian (Wordian-Capitanian) of Spitsbergen and North China (Inner Mongolia); Upper Permian (Lopingian) of northeast Japan (Takakurayama in the South Kitakami Belt).

Spiriferella? sp.
Fig. 6.5

Neospirifer cf. *fasciger* (Keyserling): Yanagisawa, 1967, p. 90, pl. 2, fig. 18.

Material.—One specimen, from locality T_7, internal mould of a ventral valve, IGPS86637A.

Remarks.—The single ventral valve specimen from Takakurayama was described by Yanagisawa (1967) as *Neospirifer* cf. *fasciger* (Keyserling, 1846), but it differs from *N. fasciger* in having strong simple costae on the flanks. The Takakurayama specimen is seemed to be a species of *Spiriferella* Tschernyschew, 1902 or *Alispiriferella* Waterhouse and Waddington 1982, on the basis of its medium size (length about 19 mm, width about 20 mm), strong simple costae numbering four on each lateral flank and deeply impressed heart-shaped muscle field. However, accurate comparison is difficult due to the lack of clear external information in the present specimen.

Genus *Alispiriferella* Waterhouse and Waddington, 1982

Alispiriferella lita (Fredericks, 1924)
Figs. 6.6, 6.7

Spiriferella saranae mut. *lita* Fredericks, 1924, p. 36, pl. 1, figs. 16-27; text-figs. 2a, 2b.
Spirifer cf. *saranae* mut. *lita* Fredericks: Hayasaka, 1925, p. 98, pl. 5, fig. 14.
Spiriferella cf. *saranae* mut. *lita* Fredericks: Nonaka, 1944, p. 86, pl. 7, figs. 12-14.
Spiriferella keilhavii (von Buch): Yanagida, 1963, p. 72, pl. 9, figs. 4-9; pl. 10, figs. 1-7.
Alispirifer aff. *laminosus transversa* Maxwell: Yanagisawa, 1967, p. 90, pl. 2, fig. 3.
Cancellospirifer? *maxwelli* Campbell: Yanagisawa, 1967, p. 92, pl. 3, fig. 16.
Timaniella harkeri Waterhouse: Licharew and Kotlyar, 1978, pl. 18, figs. 2, 3.
Spiriferella grandis Kotlyar in Licharew and Kotlyar, 1978, p. 73, pl. 18, figs. 7, 8.
Spiriferella lita (Fredericks): Tazawa, 1979, p. 28, pl. 4, figs. 12a-13b; pl. 5, figs. 1-4, 6; Tazawa, 2001, p. 302, figs. 8.19-8.22; Tazawa and Chen, 2006, p. 336, fig. 6.4.

Spiriferella cf. *lita* (Fredericks): Tazawa *et al.*, 2000, p. 12, pl. 1, figs. 16, 17.
Alispiriferella ordinaria (Einor in Licharew and Einor): Tazawa, 2001, p. 302, figs. 8.14a-8.14c.
Alispiriferella japonica Tazawa, 2001, p. 303, figs. 8.15-8.18.
Alispiriferella neimongolensis Wang and Zhang, 2003, p. 154, pl. 46, figs. 9-18; pl. 50, figs. 5, 9.
Alispiriferella lita (Fredericks): Tazawa and Hasegawa, 2007, p. 9, figs. 5.3-5.11; Tazawa, 2008c, p. 55, figs. 9.8a-9.14.

Material.—Two specimens, from locality T_7: (1) external and internal moulds of a ventral valve, IGPS86642; (2) internal mould of a ventral valve, IGPS86652.

Remarks.—The two ventral valve specimens, collected by Yanagisawa from the locality T_7, are available. Yanagisawa (1967) described the larger specimen (IGPS86652) as *Alispirifer* aff. *laminosus transversa* Maxwell, 1964, and the smaller specimen (IGPS86642) as *Cancellospirifer*? *maxwelli* Campbell, 1953. But these specimens can be referred to *Alispiriferella lita* (Fredericks, 1924), from the Middle Permian Chandalaz Formation of South Primorye, eastern Russia, by their transversely but not mucronate shell (length about 20 mm, width about 40 mm in the larger specimen), with strong simple costae. The Takakurayama specimens seemed to be young shells. *A. lita* is a Middle Permian (Wordian-Capitanian) species, but in Japan it often occurs from the Upper Permian (Lopingian) beds as reworked fossils (Tazawa et al., 2000; Tazawa and Hasegawa, 2007; Tazawa, 2008c).

The type species, *Alispiriferella ordinaria* (Einor in Licharew and Einor, 1939) is clearly distinguished from *A. lita* by its smaller and less transverse shell with ventral sulcus bearing two prominent sulcal costae and more often fasciculate costae on both ventral and dorsal valves.

Distribution.—Middle Permian (Wordian-Capitanian) of North China (Zhesi and Xiujimqinqi, Inner Mongolia), Northeast China (Heilongjiang), eastern Russia (South Primorye), northeast Japan (Kesennuma in the South Kitakami Belt), central Japan (Moribu in the Hida Gaien Belt); Upper Permian (Lopingian) of northeast Japan (Ogatsu and Takakurayama in the South Kitakami Belt) and southwest Japan (Mizukoshi in the Hida Gaien Belt).

Genus *Elivina* Fredericks, 1924

Elivina tibetana (Diener, 1897)
Figs. 6.8a-6.16

Spirifer tibetanus Diener, 1897, p. 45, pl. 6, figs. 1-7; Hamlet, 1928, p. 37, pl. 7, figs. 1, 2.
Spiriferina cristata Schellwien (sic): Yanagisawa, 1967, p. 92, pl. 1, fig. 12; pl. 3, fig. 6.
Hustedia cf. *remota* (Eichwald): Yanagisawa, 1967, table 2.
Spiriferella tibetana (Diener): Licharew and Kotlyar, 1978, pl. 18, figs. 4, 5.

Elivina tibetana (Diener): Shen et al., 2003, p. 244, pl. 4, figs. 7-10.
Elivina sp. Tazawa, 2008c, p. 57, figs. 9.1a-9.2b.

Material.—Thirteen specimens, from locality T_7: (1) external and internal mouds of a conjoined valve, NU-B1177; (2) external cast of a conjoined valve with external mould of the dorsal valve, NU-B1178; (3) internal mould of a conjoined valve with external mould of the dorsal valve, NU-B1179; (4) external casts of two conjoined valves, NU-B1180, 1181; (5) external and internal moulds of a ventral valve, NU-B1182; (6) external cast of a ventral valve, NU-B1183; (7) external casts of five dorsal valves, IGPS86639A, 86639B, 86655, NU-B1184, 1185; (8) internal mould of a dorsal valve, NU-B1186.

Description.—Shell medium size for genus, elongate oval in outline, cardinal extremities rounded, hinge narrow, with greatest width at about midvalve; length 22 mm, width 18 mm in the largest ventral valve specimen (NU-B1182); length 17 mm, width 28 mm in the largest dorsal valve specimen (IGPS86639A).

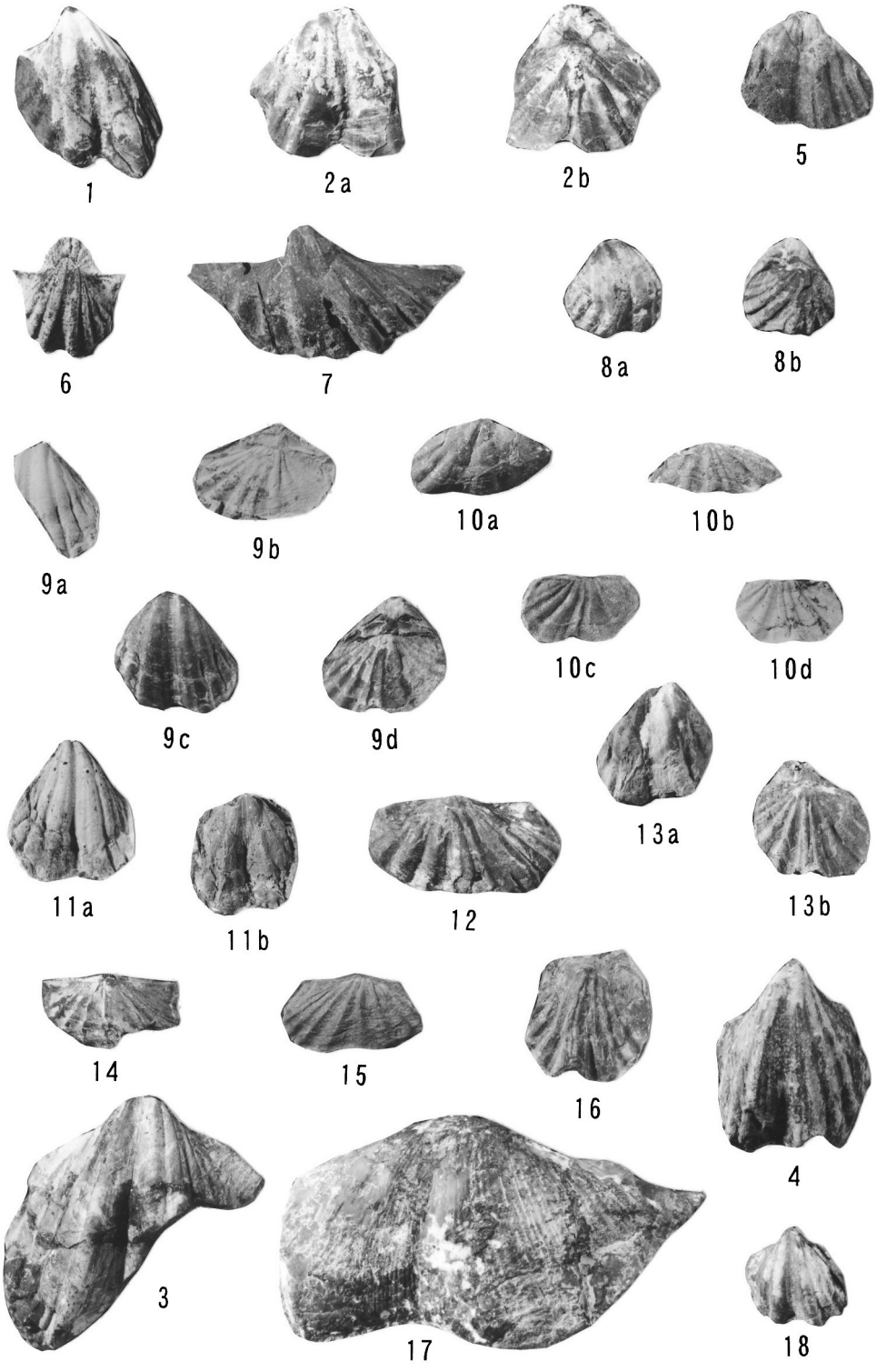
Ventral valve strongly and unevenly convex in lateral profile, most convex at umbonal region; umbo prominent, pointed, strongly incurved, and overhanging hinge line; interarea highly triangular, concave, bisected by relatively narrow delthyrium; sulcus deep and broad, originating from beak, U-shaped in cross section, having one or two pairs of faint sulcal costae, but no median costa. Dorsal valve transversely subelliptical in outline, moderately convex in lateral profile; interarea low but distinct; fold low, widening anteriorly, with two or three costae. External ornament consisting of strong simple costae, radial capillae and fine growth lamellae; costae rounded, numbering 3-4 on each flank.

Internally, ventral valve having short dental plates; dorsal valve with relatively large longitudinally striated ctenophoridium; median septum thin, short. Other internal features not observed.

Remarks.—These specimens are referred to *Elivina tibetana* (Diener, 1897) from the Middle Permian (Capitanian) limestone block of Chichichun, southern Tibet by their size, outline and surface ornament of shells, especially the elongate ventral valve with simple rounded costae on the flanks. Yanagisawa (1967) described or listed a part of the Takakurayama specimens as *Spiriferina cristata* Schellwien (sic) [=*Spiriferellina cristata* (Schlotheim, 1816)] and *Hustedia* cf. *remota* (Eichwald, 1860), but both *Spiriferellina cristata* and *Hustedia remota* are quite differ from *Elivina* species in its size, outline and external ornament of the shell. *Elivina* sp. (Tazawa, 2008c, p. 57, figs. 9.1a-9.2b) from the Upper Permian Mizukoshi Formation of Mizukoshi, southwest Japan can be referred to *E. tibetana,* although it is small in size.

Elivina sinensis Liu and Waterhouse (1985, p. 34, pl. 9, figs. 1-4, 6, 7; pl. 10, figs. 1, 4, 5, 7, 9) from the Zhesi Formation of Xiujimqinqi, Inner Mongolia differs from *E. tibetana* in its triangular outline and stronger simple costae on both valves.

Elivina hoskingae Archbold and Thomas (1985, p. 44, figs. 3A-3Y) from the Lower Permian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of the Perth and Carnarvon Basins, western Australia is also a medium-sized, elongate species, but the Australian species is clearly distinguished from *E. tibetana* by its ventral sulcus bearing distinct median costa.

Distribution.—Middle Permian (Capitanian) of southern Tibet (Chitichun) and western Timor; Upper Permian (Wuchiapingian) of southern Tibet (Zhongbei in the Indus-Tsangpo Suture Zone) and eastern Russia (West Primorye); Upper Permian (Lopingian) of northeast Japan (Takakurayama in the South Kitakami Belt).

Superfamily Brachythyridoidea Fredericks, 1924
Family Brachythyrididae Fredericks, 1924
Genus *Cathayspirina* Liang, 1990

Cathayspirina sp.
Fig. 6.18

Material.—One specimen, from locality T_7, external cast of a ventral valve, NU-B1190.

Remarks.—This specimen is safely assigned to the genus *Cathayspirina* by its small, equidimensional ventral valve (length 14 mm, width 15 mm), deep and broad sulcus without sulcal costae, and simple rounded costae (numbering 3 on each flank) with relatively broad, rounded interspaces.

The Takakurayama specimen most resembles *Cathayspirina* aff. *fenshuijiangensis* Liang, 1990, figured by Yanagida (1996, figs. 2.1a-2.1c) from the Upper Permian (Lopingian) Tsunemori Formation of Tsunemori in the Akiyoshi Belt, southwest Japan, in its large size.

Cathayspirina fenshuijiangensis Liang (1990, p. 340, pl. 54, figs. 1-28) from the Upper Permian (Wuchiapingian) of Zhejiang, east China differs from the present species in its smaller size.

⬅ **Fig. 6. 1-4:** *Spiriferella saranae* (de Verneuil), 1: external cast of ventral valve, NU-B1176, 2a, 2b: ventral and dorsal views of external cast of conjoined valve, NU-B1175, 3: external cast of ventral valve, IGPS86654B, 4: external cast of ventral valve, IGPS86638. **5:** *Spiriferella*? sp., internal mould of ventral valve, IGPS86637A. **6, 7:** *Alispiriferella lita* (Fredericks), 6: external latex cast of ventral valve, IGPS86642, 7: internal mould of ventral valve, IGPS86652. **8a-16:** *Elivina tibetana* (Diener), 8a, 8b: ventral and dorsal views of external cast of conjoined valve, NU-B1178, 9a, 9b, 9c, 9d: ventral and dorsal views of external latex cast, and ventral and dorsal views of internal mould of conjoined valve, NU-B1177, 10a, 10b, 10c, 10d: ventral and dorsal views of internal mould of conjoined valve, and external mould and external latex cast of dorsal valve, NU-B1179, 11a, 11b: external latex cast and internal mould of ventral valve, NU-B1182, 12: external cast of dorsal valve, IGPS86639A, 13a, 13b: ventral and dorsal views of external cast of conjoined valve, NU-B1181, 14: external cast of dorsal valve, NU-B1184, 15: internal mould of dorsal valve, NU-B1186, 16: external cast of dorsal valve, IGPS86655. **17:** *Gypospirifer volatilis* Duan and Li, external cast of ventral valve, IGPS86653. **18:** *Cathayspirina* sp., external cast of ventral valve, NU-B1190. (All × 1).

Acknowledgements

I would like to thank Naotomo Kaneko (Geological Survey of Japan, AIST) and Satoshi Hasegawa (Kyushu Regional Office, Yachiyo Engineering Co., Ltd.) for help of field work in the Takakurayama area; Toshiyuki Kurihara (Department of Geology, Niigata University) for help of drawing pictures; Alexander M. Popov (Far East Geological Institute, Russian Academy of Sciences, Vladivostok) for sending some Russian literatures; Atsushi Matsuoka (Department of Geology, Niigata University) for critical reading of the manuscript.

References

Archbold, N.W., 1982, Classification and evolution of the brachiopod family Rugosochonetidae Muir-Wood 1962. *Proc. Roy. Soc. Vict.*, **94**, 1-9.

Archbold, N.W. and Thomas, G.A., 1985, Permian Spiriferellinae (Brachiopoda) from Western Australia. *Alcheringa*, **9**, 35-48.

Booker, F.W., 1930, A review of some of the Permo-Carboniferous Productidae of New South Wales, with a tentative reclassification. *Jour. Roy. Soc. N. S. W.*, **64**, 65-77.

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

Broili, F., 1916, Die permischen Brachiopoden von Timor. *Paläont. Timor*, **7**, 1-104.

Bronn, H.G., 1862, *Die Klassen und Ordnungen der Weichthiere (Malacozoa), vol. 3, no. 1.* C.F. Winter'sche Verlagshandlung, Leipzig u. Heidelberg, 518 p.

Campbell, K.S.W., 1953, The fauna of the Permo-Carboniferous Ingelara beds of Queensland. *Univ. Qd. Pap., Dept. Geol.*, **4**, 1-43.

Chao, Y.T., 1927, Productidae of China, pt. 1. Producti. *Palaeont. Sinica, Ser. B*, **5**, 1-244.

Chi-Thuan, T.T., 1961, Les brachiopodes permiens du Phnom-Tup (Sisophon-Cambodge). *Ann. Fac. Sci., Univ. Saigon, 1961*, 267-308.

Chi-Thuan, T.T., 1962, Les brachiopodes de Cam-Lo (Province de Quang-Tri). *Ann. Fac. Sci., Univ. Saigon, 1962*, 485-498.

Colani, M.M., 1919, Sur quelques fossiles Ouralo-Permiens de Hongay. *Bull. Serv. Géol. L'Indochine*, **6**, 1-27.

Conrad, T.A., 1839, Descriptions of new species of organic remains. *Second Ann. Rep., Palaeont. Dep. Surv., New York State Geol. Surv.*, 57-66.

Cooper, G.A. and Grant, R.E., 1975, Permian brachiopods of West Texas, 3. *Smithson. Contr. Paleobiol.*, no. 19, 795-1298 (text), 1300-1921 (plates).

Cooper, G.A. and Grant, R.E., 1976, Permian brachiopods of West Texas, 4. *Smithson. Contr. Paleobiol.,* no. 21, 1923-2285 (text), 2288-2607 (plates).

Dagys, A.S., 1972, Morfologiia i systematika Mesozoiskikh Retsiodnykh brakhipod. *Tr. Sibir. Otdel. Inst. Geol. Geofiz*., **112**, 94-105. (in Russian)

Davidson, T., 1862, On some Carboniferous Brachiopoda, collected in India by A. Fleming, M.D., and W. Purdon, Esq., F.G.S. *Quart. Jour. Geol. Soc. Landon*, **18**, 25-35.

Diener, C., 1897, Himalayan fossils, vol. 1, pt. 3. The Permocarboniferous fauna of Chitichun, No. 1. *Palaeont. Indica, Ser. 15,* **1**, pt. 3, 1-105.

Diener, C., 1899, Anthracolithic fossils of Kashmir and Spiti. *Palaeont. Indica, Ser. 15*, **1**, pt. 2, 1-95.

Ding, P. and Qi, W., 1983, Phylum Brachiopoda. *In* Xian Institute of Geology and Mineral Resources, ed., *Palaeontological atlas of Northeast China; Shaanxi, Gansu and Ningxia*

volume, pt. 2. Upper palaeozoic, Geol. Pub. House, Beijing, 244-425. (in Chinese)
Duan, C. and Li, W., 1985, 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). *Bull. Tianjin Inst. Geol. Min. Res.*, no. 10, 99-145, 199-214. (in Chinese)
Dunbar, C.O. and Condra, G.E., 1932, Brachiopoda of the Pennsylvanian System in Nebraska. *Nebraska Geol. Surv., Bull.*, **5**, 1-377.
Eichwald, E. von, 1860, *Lethaea Rossica, ou Paléontologie de la Russie décrite et figuére, Permian volume, Ancienne Peride.* E. Schweizerbart, Stuttgart, 1635 p.
Fan, B. and He, X., 1999, *Research on brachiopod fauna and stratigraphy of the Late Paleozoic in North China Platform.* China Univ. Min. Tech. Press, Xuizhou, 179 p. (in Chinese)
Feng, R. and Jiang, Z., 1978, Phylum Brachiopoda. *In* Geological and Palaeontological Team of Guizhou, ed., *Palaeontological atlas of Southwest China; Guizhou, pt. 2. Carboniferous to Quaternary*. Geol. Pub. House, Beijing, 231-305. (in Chinese)
Frech, F., 1911, Die Dyas. *In* Richthofen, F. von, ed., *China, Fünfter Band*, Dietrich Reimer, Berlin, 103-137.
Fredericks, G., 1924, Ussuriyskiy verkhniy paleozoy, 1. Brachiopoda. *Mater. Geol. Polezn. Iskopaem. Dalnego Vostoka,* no. 28, 1-52. (in Russian)
Fredericks, G., 1925, Ussuriyskiy verkhniy paleozoy, 2. Permskie brakhiopody s mysa Kaluzina. *Mater. Geol. Polezn. Iskopaem. Dalnego Vostoka,* no. 40, 1-28. (in Russian)
Fredericks, G., 1926, Materialy k faune peschano-glinistoy tolschi s r. Kezhim-Terovey. *Izv. Geol. Kom.*, **45**, 81-95. (in Russian)
Grabau, A.W., 1931, The Permian of Mongolia. *In* Reeds, C.A., ed., *Natural history of Central Asia, vol. 4*, Amer. Mus. Nat. Hist., New York, 665 p.
Grabau, A.W., 1934, Early Permian fossils of China, pt. 1. Early Permian brachiopods, pelecypods and gastropods of Kueichow. *Palaeont. Sinica, Ser. B,* **8**, fasc. 3, 1-214.
Grabau, A.W., 1936, Early Permian fossils of China, pt. 2. Fauna of the Maping Limestone of Kwangsi and Kweichou. *Palaeont. Sinica, Ser. B,* **8**, fasc. 4, 1-441.
Grant, R.E., 1976, Permian brachiopods from southern Thailand. *Paleont. Soc. Mem.*, **9**, 1-269.
Gray, J.E., 1840, *Synopsis of the contents of the British Museum, 42nd edition.* Brit. Mus., London, 370 p.
Grigorjeva, A.D. and Kotlyar, G.V., 1977, Semeystvo Anidantidae. *In* Sarytcheva, T.G., ed., Pozdnepaleozoyskie produktidy Sibiri i Arktiki. *Tr. Paleont. Inst., Akad. Nauk SSSR*, **161**, 1-220. (in Russian)
Grunt, T.A., 1986, Sistema brakhiopod otriada atiridida. *Tr. Paleont. Inst.*, **215**, 1-200. (in Russian)
Gu, F., 1992, Carboniferous and Permian Brachiopoda. *In* Jilin Institute of Geology and Mineral Resources, ed., *Palaeontological atlas of Jilin,* Jilin Sci. Tech. Pub. House, Changhchun, 210-255. (in Chinese)
Hall, J. and Clarke, J.M., 1893, An introduction to the study of the genera of Palaeozoic Brachiopoda. *Palaeont. New York*, **8**, pt. 2, 1-317.
Hamlet, B., 1928, Permische Brachiopoden, Lamellibranchiaten und Gastropoden von Timor. *Jaar. Mijnw. Ned.-Indie,* **56**, 1-115.
Harker, P., 1960, Corals, brachiopods and mollusks of Grinnell Peninsula. *In* Harker, P. and Thorsteinsson, R., Permian rocks and faunas of Grinnell Peninsula, Arctic Archipelago. *Geol. Surv. Canada, Mem.*, **309**, 39-79.
Hayasaka, I., 1922, Some Permian brachiopods from the Kitakami Mountains. *Japan. Jour. Geol. Geogr.*, **1**, 51-70.
Hayasaka, I., 1925, On some brachiopods from the Lyttonia horizon of the Kitakami Mountains.

Japan. Jour. Geol. Geogr., **4**, 89-103.
Hayasaka, I., 1960, On the occurrence of *Neospirifer fasciger* (Keyserling) in Japan, and a note on some associate Permian brachiopods from around Kesennuma City, northeast Japan. *Coll. Essays Comm. 10th Anniv. Shimane Univ.*, 34-57.
Hayasaka, I., 1966, Some Permian fossils from southern Kitakami, 6. Three brachiopods. *Proc. Japan Acad.*, **42**, 1223-1228.
Hayasaka, I. and Minato, M., 1956, Some brachiopods from the lower Kanokura Series of the Kitakami Mountains, Japan. *Trans. Proc. Palaeont. Soc. Japan, N. S.*, no. 21, 141-147.
Hill, D., 1950, The Productinae of the Artinskian Cracow Fauna of Queensland. *Pap. Dept. Geol. Univ. Qd.*, **3**, 1-36.
Huang, T.K., 1932, late Permian Brachiopoda of southwestern China, pt. 1. Productidae and Lyttonidae. *Palaeont. Sinica, Ser. B*, **9**, fasc. 1, 1-139.
Huang, T.K., 1933, Late Permian Brachiopoda of southwestern China, pt. 2. *Palaeont. Sinica, Ser. B*, **9**, fasc. 2, 1-172.
Ifanova, V.V., 1972, Permskie brakhiopody Pechorskogo basseyna. *In* Ifanova, V.V. and Semenova, E.G., *Srednekamennougolnye i permskie brakhiopody vostoka i severa evropeyskoy chasti SSSR*, Nauka, Moskva, 72-161. (in Russian)
Jin, Y., 1985, Permian Brachiopoda and paleogeography of the Qinghai-Xizang (Tibet) Plateau. *Palaeont. Cathayana*, no. 2, 19-71.
Kalashnikov, N.V., 1983, Brakhiopody. *In* Meyen, S.V., ed., *Paleontologicheskiy atlas permskikh otlozheniy Pechorskogo ugolnogo basseyna,* Nauka Leningrad, 45-59. (in Russian)
Kalashnikov, N.V., 1986, Brakhiopody. *In* Gorskii, V.P. and Kalmykova, M.A., eds., Atlas kharakternykh kompleksov permskoi fauny i flory Urala: Russkoi platformy *Tr. VSEGEI*, **331**, 29-30, 89-94. (in Russian)
Kalashnikov, N.V., 1993, *Brakhiopody permi Evropeyskogo Severa Rossii.* Nauka, Sankt-Peterburg, 113 p. (in Russian)
Kano, H., 1971, Studies on the Usuginu conglomerates in the Kitakami Mountains. *Jour. Geol. Soc. Japan*, **77**, 415-440. (in Japanese)
Kayser, E., 1883, Obercarbonische Fauna von Lo-Ping. *In* Richthofen, F. von, ed., *China, Vierter Band*, Dietrich Reimer, Berlin, 160-208.
Keyserling, A., 1846, Geognostische Beobachtungen, 1. Palaeontologische Bemerkungen. *In* Krusenstern, P. von and Keyseling, A., eds., *Wissenschaftlic Beobachtungen auf einer Reise in das Petschora-Land im Jahre 1843*, Carl Kray, St. Petersburg, 151-336.
King, W., 1846, Remarks on certain genera bearing to the class Palliobranchiata. *Ann. Mag. Nat. Hist., Ser. 1*, **18**, 26-42.
King, W., 1865, Remarks of the history of two species of *Rhynchopora geinitziana* de Verneuil, from near the River Oukhla, Province of Archangel. *Ann. Mag. Nat. Hist., Ser. 3*, **16**, 124-128.
Kobiyama, M., 1956, On the age of the Takakurayama Formation. *Bull. Taira Chigaku Dokokai*, no. 3, 7-10. (in Japanese)
Koczyrkevicz, B.V., 1979, Permskie stenostsizmatatsei (Brachiopoda) Yuzhnogo Primorya. *In* Petraschevskaya, V.T., ed., *Iskopaemie bespozvonochnie Dalnego Vostoka*, DVNTS AN SSSR, Vladivostok, 50-59. (in Russian)
Koizumi, H., 1979, Permian brachiopods from Takakurayama Formation and its geological age, N. E. Japan. *Bull. Taira Chigaku Dokokai, Spec. vol.*, 1-3. (in Japanese)
Kotlyar, G.V., 1961, Rod *Yakovlevia* Fredericks. *Doklady, Akad. Nauk SSSR*, **140**, 459-461. (in Russian)
Kotlyar, G.V. and Zakharov, Yu.D., 1989, *Pozdnepermskiy etap evolyutsii organicheskogo mira: Midiyskiy yarus SSSR,* Nauka, Leningrad, 182 p. (in Russian)
Kuhn, O., 1949, *Lehrbuch der Paläozoologie*. E. Schweizerbart, Stuttgart, 326 p.

Kulikov, M.V., 1974, Brakhiopody kungurskogo yarusa Urala. *Tr. Inst. Geol. Geokhim*., **109,** 77-123. (in Russian)

Lee, L. and Gu, F., 1976, Carboniferous and Permian Brachiopoda. *In* Geological Bureau of Nei Mongol and Geological Institute of Northeast China, eds., *Palaeontological atlas of Northeast China; Nei Mongol, pt. 1. Palaeozoic volume*, Geol. Pub. House, Beijing, 228-306. (in Chinese)

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, pt. 1. Palaeozoic volume*, Geol. Pub. House, Beijing, 327-428. (in Chinese)

Leman, M.S., 1994, The significance of Upper Permian brachiopods from Merapoh area, northwest Pahang. *Geol. Soc. Malaysia, Bull.*, **35**, 113-121.

Liang, W., 1990, Lengwu Formation of Permian and its brachiopod fauna in Zhejiang Province. *P. R. China, Minist. Geol. Min. Res., Geol. Mem., Ser. 2*, no. 10, 1-522. (in Chinese)

Licharew, B.K. and Einor, O.L., 1939, Materialy k poznaniyu verkhnepaleozoyskikh faun Novoy Zemli Brachiopoda. *Tr. Arkt. Nauch-Issle. Inst*., **127**, 1-245. (in Russian)

Licharew, B.K. and Kotlyar, G.V., 1978, Permskie brakhiopody Yuzhnogo Primorya. *In* Popeko, L.I., ed., *Verkhniy Paleozoy Severo-Vostochnoy Azii*, DVNTS AN SSSR, Vladivostok, 63-75. (in Russian)

Liu, F. and Waterhouse, J.B., 1985, Permian strata and brachiopods from Xiujimqinqi region of Neimongol (Inner Mongolia) Autonomous Region, China. *Pap. Dep. Geol. Univ. Qd*., **11**, 1-44.

Liu, Z., Tan, Z. and Ding, Y., 1982, Phylum Brachiopoda. *In* Geological Bureau of Hunan, ed., *The palaeontological atlas of Hunan*, Geol. Pub. House, Beijing, 172-216. (in Chinese)

Mansuy, H., 1913, Faunes des calcaires a productus de l'Indochine, Premiere serie. *Mém. Serv. Géol. L'Indochine*, **2**, 1-132.

Maxwell, W.G.H., 1964, The geology of the Yarrol region, pt. 1. Biostratigraphy. *Univ. Qd. Pap., Dept. Geol*., **5**, 3-79.

M'Coy, F., 1844, *A synopsis of the characters of the Carboniferous Limestone fossils of Ireland.* Williams and Norgate, London, 207 p.

Minato, M., Hunahashi, M., Watanabe, J. and Kato, M., 1979, *Variscan geohistory of northern Japan: The Abean Orogeny*. Tokai Univ. Press, Tokyo, 427 p.

Mironova, M.G., 1964, K poznaniyu rannepermskikh brakhiopod Pechorskogo basseyna. *Voprosy Paleontologii,* **4**, 85-99. (in Russian)

Muir-Wood, H. M., 1955, *A history of the classification of the Phylum Brachiopoda*. Brit. Mus. (Nat. Hist.), London, 124 p.

Muir-Wood, H.M., 1962, *On the morphology and classification of the brachiopod suborder Chonetoidea*. Brit. Mus. (Nat. Hist.), London, 132 p.

Muir-Wood, H.M. and Cooper, G.A., 1960, Morphology, classification and life habits of the Productoidea (Brachiopoda). *Geol. Soc. Amer., Mem*., **81**, 1-135.

Murata, M., 1964, Geological age of the Kanokura Formation in the southern part of the Kitakami Massif, Northeast Japan. *Saito Ho-on Kai Mus. Res. Bull.*, no. 33, 17-29.

Nakamura, K., 1972, *Anidanthus* and *Megousia* (Brachiopoda) from the Permian of Japan and Cambodia. *Jour. Fac. Sci., Hokkaido Univ., Ser. 4*, **15**, 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*, Publ. Hokkaido Univ., Sapporo, 77-95.

Nelson, S.J. and Johnson, C.E., 1968, Permo-Pennsylvanian brachythyrid and horridonid brachiopods from the Yukon Territory, Canada. *Jour. Paleont.*, **42**, 715-746.

Noda, M., 1956, Stratigraphical and palaeontological studies of the Toman Formation in the

Kaishantun and Kamisanbo districts. *Rep. Earth Sci., Dept. Gen. Educ., Kyushu Univ*., no. 2, 1-22.

Nonaka, J., 1944, Some Permian brachiopods from Inner Mongolia. *Japan. Jour. Geol. Geogr.*, **19**, 83-87.

Oehlert, D.P., 1887, Appendice sur les brachiopods. *In* Fischer, P., *Manuel de Conchyliologie et de Paléontologie conchyliologique ou Histoire naturelle des Mollusques vivants et fossiles, vol. 4, pt. 11*. Librairie F. Savy, Paris, 1189-1334.

Onuki, Y., 1966, Stratigraphy and structural geology of the Paleozoic Formations in the Yaguki and Takakurayama districts, Abukuma Massif, Fukushima Prefecture, Japan. *Prof. S. Matsushita Mem. Vol*., 41-32. (in Japanese)

Onuki, Y., 1969, Geology of the Kitakami Massif, northeast Japan. *Contr., Inst. Geol. Pal., Tohoku Univ.*, no. 69, 1-239. (in Japanese)

Orbigny, A. d', 1842, *Voyages dans l'Amérique Méridionale*, Pitois-Levrault, Paris, 50-56.

Ramsbottom, W.H.C., 1952, The fauna of the Cefn Coed marine band in the Coal Measures at Aberbaiden, near Tondu, Glamorgan. *Bull. Great Brit. Geol. Surv., Palaeont*., **4**., 8-32.

Reed, F.R.C., 1944, Brachiopoda and Mollusca from the Productus Limestone of the Salt Range. *Palaeont. Indica, N. S*., **23**, 1-596.

Rothpletz, A., 1892, Die Perm-, Trias- und Jura-Formation auf Timor und Rotti im indischen Archipel. *Palaeontographica*, **39**, 57-106.

Ruzhentsev, V.E. and Sarytcheva, T.G., 1965, Razvitie i smena morskikh organizmov na rubezhe Paleozoya i Mesozoya. *Tr. Paleont. Inst*., **108**, 1-431. (in Russian)

Sarytcheva, T.G., Licharew, B.K. and Sokolskaya, A.N., 1960, Otriad Productida. *In* Orlov, Yu.A., ed., *Osnovy paleontologii; Mshanki, Brakhiopody, Prilozhenie: Foronidy*, Akad. Nauk SSSR, Moskva, 221-238. (in Russian)

Sarytcheva, T.G. and Sokolskaya, A.N., 1959, O klassifikatsin lozhnoporistykh brakhiopod. *Doklady, Akad. Nauk SSSR*, **125**, 181-184. (in Russian)

Schlotheim, E.F. von, 1816, Beiträge zur Naturgeschichte der Versteinerungen in geognostischer Hinsicht. *Denkschrift. Wiss. München, Math.-Phys. Klasse*, **6**, 13-36.

Schuchert, C., 1893, Classification of the Brachiopoda. *Amer. Geologist*, **11**, 141-167.

Schuchert, C., 1929, Classification of brachiopod genera, fossil and recent. *In* Pompeckj, J.F., ed., *Fossilium catalogus, vol. 1. Animalia*, W. Junk, Berlin, 10-25.

Shen, S.Z., Shi, G.R. and Archbold, N.W., 2003, A Wuchiapingian (Late Permian) brachiopod fauna from an exotic block in the Indus-Tsangpo suture zone, southern Tibet, and its palaeobiogeographical and tectonic implications. *Palaeontology*, **46**, 225-256.

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*, **33**, 725-752.

Shen, S.Z., Shi, G.R. and Fong, Z., 2002, Permian brachiopods from Baoshan and Simao blocks in western Yunnan, China. *Jour. Asian Earth Sci*., **20**, 665-682.

Shi, G.R. and Waterhouse, J.B., 1996, Lower Permian brachiopods and molluscs from the upper Jungle Creek Formation, northern Yukon Territory, Canada. *Geol. Surv. Canada, Bull*., **424**, 1-241.

Shimizu, D., 1961, Brachiopod fossils from the Permian Maizuru Group. *Mem. Coll. Sci., Univ. Kyoto, Ser. B*, **27**, 309-351.

Solomina, P.V., 1960, Nekotorye permskie brakhiopody Pay-Khoya. *Sbor. Stat. Paleont. Biostratigr.*, **9**, 24-73. (in Russian)

Stehli, F.G., 1954, Lower Leonardian Brachiopoda of the Sierra Diablo. *Bull. Amer. Mus. Nat. Hist.*, **105**, 263-358.

Sutherland, P.K. and Harlow, F.H., 1973, Pennsylvanian brachiopods and biostratigraphy in southern Sargre de Cristo Mountains, New Mexico. *New Mexico Bur. Mines Min. Res., Mem*., **27**, 1-173.

Tatarinov, L.P., Luvsandansan, B., Afanasjeva, G.A., Barshold, R., Morozova, I.P., Novitskaja, L.I., Rasnitasyn, A.P., Reschetov, V.Yu., Posanov, A.Yu., Sysoev, V.A. and Trofimov, B.A., 1991, *Permskie bespozvonochnye Yuzhnoy Mongolii*, Nauka, Moskva, 91-173. (in Russian)

Tazawa, J., 1975, Uppermost Permian fossils from the southern Kitakami Mountains, northeast Japan. *Jour. Geol. Soc. Japan*, **81**, 629-640.

Tazawa, J., 1976, The Permian of Kesennuma, Kitakami Mountains: A preliminary report. *Earth Sci. (Chikyu Kagaku)*, **30**, 175-185.

Tazawa, J., 1979, Middle Permian brachiopods from Matsukawa, Kesennuma region, southern Kitakami Mountains. *Saito Ho-on Kai Mus., Nat. Hist., Res. Bull*., no. 47, 23-35.

Tazawa, J., 1988, Palaeozoic-Mesozoic stratigraphy and tectonics of the Kitakami Mountains, northeast Japan. *Earth Sci. (Chikyu Kagaku)*, **42**, 165-178. (in Japanese)

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*, Matsuya Insatsu, Osaka, 213-230.

Tazawa, J., 1993, Pre-Neogene tectonics of the Japanese Islands from the viewpoint of palaeobiogeography. *Jour. Geol. Soc. Japan*, **99**, 525-543. (in Japanese)

Tazawa, J., 1999, Boreal-type brachiopod *Yakovlevia* from the Middle Permian of Japan. *Paleont. Res*., **3**, 88-94.

Tazawa, J., 2000, Permian brachiopod faunas and pre-Neogene tectonics in the Inner Side of Southwest Japan. *Monograph (Chidanken Senpo)*, no. 49, 5-22. (in Japanese)

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

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

Tazawa, J., 2004, The strike-slip model: A synthesis on the origin and tectonic evolution of the Japanese Islands. *Jour. Geol. Soc. Japan*, **110**, 503-517. (in Japanese)

Tazawa, J., 2007, Middle Permian brachiopod faunas of Japan and their significance for understanding the Paleozoic-Mesozoic tectonics of the Japanese Islands. In Wong, Th.E., ed., *Proceedings of the XVth International Congress on Carboniferous and Permian Stratigraphy*, Roy. Netherlands Acad. Arts Sci., Amsterdam, 565-573.

Tazawa, J., 2008a, Permian bipolar-type brachiopod genus *Terrakea* from the South Kitakami and Hida Gaien belts, Japan: Palaeobiogeographical implications. *Earth Sci. (Chikyu Kagaku)*, **62**, 63-67. (in Japanese)

Tazawa, J., 2008b, *Lamnimargus* (Productida, Brachiopoda) from the Upper Permian of Ofunato in the South Kitakami Belt, NE Japan, and its palaeobiogeographical significance. *Sci. Rep., Niigata Univ. (Geol.*), no. 23, 1-11.

Tazawa, J., 2008c, Permian brachiopods from the Mizukoshi Formation, central Kyushu, SW Japan: Systematics, palaeobiogeography and tectonic implications. *Paleont. Res*., **12**, 37-61. (in press)

Tazawa, J. and Chen, Z.Q., 2006, Middle Permian brachiopods from the Tumenling Formation in the Wuchang area, southern Heilongjiang, NE China, and their palaeobiogeographical implications. *Jour. Asian Earth Sci.*, **26**, 327-338.

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. *Sci. Rep., Niigata Univ. (Geol.)*, no. 20, 15-27.

Tazawa, J. and Gunji, Y., 1982, Middle Permian brachiopods from the Oashi Formation, Abukuma Mountains, northeast Japan. *Saito Ho-on Kai Mus. Nat. Hist., Res. Bull.*, no. 50, 67-74.

Tazawa, J. and Hasegawa, S., 2007, *Anidanthus, Gypospirifer* and *Alispiriferella*

(Brachiopoda) from the Upper Permian Mizukoshi Formation, central Kyushu, SW Japan. *Sci. Rep., Niigata Univ. (Geol.)*, no. 22, 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. *Sci. Rep., Niigata Univ., Ser. E*, no. 16, 1-33.

Tazawa, J. and Matsumoto, T., 1998, Middle Permian brachiopods from the Oguradani Formation, Ise district, Hida Gaien Belt, central Japan. S*ci. Rep., Niigata Univ., Ser. E*, no. 13, 1-19.

Tazawa, J., Takizawa, F. and Kamada, K., 2000, A Middle Permian Boreal-Tethyan mixed brachiopod fauna from Yakejima, southern Kitakami Mountains, NE Japan. *Sci. Rep., Niigata Univ., Ser. E*, no. 15, 1-21.

Tong, Z., 1978, Phylum Brachiopoda; Carboniferous and Permian. *In* Geological Institute of Southwest China, ed., *Palaeontological atlas of Southwest China; Sichuan, pt. 2. Carboniferous to Mesozoic*, Geol. Pub. House, Beijing, 210-267. (in Chinese)

Tschernyschew, Th., 1888, Zametka o kamennougolnoy kollektsii iz okrestnostey Vladivostoka. *Izv. Geol. Kom.*, **7**, 353-359. (in Russian)

Tschernyschew, Th., 1902, Verkhnekamennougolnye brakhiopody Urala i Timana. *Tr. Geol. Kom.*, **16,** 1-749. (in Russian)

Tschernyschew, Th., 1914, Fauna verkhnepaleozoyskikh otlozheniy Darvaza. *Tr. Geol. Kom., N. S.*, **104**, 1-66. (in Russian)

Ueno, K., 1992, Permian foraminifers from the Takakurayama Group of the southern Abukuma Mountains, northeast Japan. *Trans. Proc. Palaeont. Soc. Japan, N. S.*, no. 168, 1265-1295.

Ustritsky, V.I., 1963, *Permian stratigraphy and fauna of the Beishan area, western Gansu*. China Indust. Press, Beijing, 73 p. (in Chinese)

Verneuil, E. de, 1845, Paléontologie, Mollusques, Brachiopodes. *In* Murchison, R.I., Verneuil, E. de and Keyserling, A. de, *Géologie de la Russie d'Europe et des Montagnes de l'Oural*, John Murray, London and Bertrand, Paris, 37-294.

Waagen, W., 1883, Salt Range fossils, 1. Productus-Limestone fossils: Brachiopoda. *Palaeont. Indica, Ser. 13*, **1**, pt. 4, fasc. 2, 391-546.

Waagen, W., 1884, Salt Range fossils, 1. Productus-Limestone fossils: Brachiopoda. *Palaeont. Indica, Ser. 13*, **1**, pt. 4, fasc. 4, 611-728.

Wang, C., 1995, Brachiopod fauna from Kangkelin Formation in Akesu, Xinjiang Autonomous Region. *Jour Changchun Univ. Earth Sci.,* **25**, 15-23. (in Chinese)

Wang, C. and Yang, S., 1998, *Late Carboniferous-Early Permian brachiopods of central Xinjiang and their biostratigraphical studies*. Geol. Pub. House, Beijing, 156 p. (in Chinese)

Wang, C. and Zhang, S., 2003, *Zhesi brachiopod fauna.* Geol. Pub. House, Beijing, 210 p. (in Chinese)

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*, Geol. Pub. House, Beijing, 186-256. (in Chinese)

Wang, Y., Jin, Y. and Fang, D., 1964, *Brachiopod fossils of China, pt. 1*. Sci. Press, Beijing, 354 p. (in Chinese)

Waterhouse, J.B., 1968a, The classification and descriptions of Permian Spiriferida (Brachiopoda) from New Zealand. *Palaeontographica, Abt. A*, **129**, 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. *Jour. Paleont.*, **42**, 1171-1185.

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

Waterhouse, J.B., 1981, *Early Permian brachiopod from Ko Yao Noi and near Krabi, southern Thailand*. Geol. Surv. Mem. 4, Geol. Surv., Dept. Min. Res., Bangkok, 213 p.

Waterhouse, J.B., 1983, New Permian invertebrate genera from the East Australian segment of Gondwana. *Bull. Ind. Geol. Assoc*., **16**, 153-158.

Waterhouse, J.B., 1986, Late Palaeozoic Scyphozoa and Brachiopoda (Inarticulata, Strophomenida, Productida and Rhynchonellida) from the southeast Bowen Basin, Australia. *Palaeontographica, Abt. 1*, **193**, 1-76.

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 Archpelago. *Geol. Surv. Canada, Bull*., **289**, 1-73.

Williams, A., Harper, A.T. and Grant, R.E., 2000, Lyttoniidina. *In* Williams, S.A., Brunton, C.H.C. and Carlson, S.J. et al., *Treatise on invertebrate paleontology, part H. Brachiopoda Revised, vol. 3. Linguliformea, Craniiformea, and Rhynchonelliformea (part),* Geol. Soc. Amer., Boulder and Univ. Kansas, Lawrence, 619-642.

Xu, G., 1987, Systematic descriptions: Brachiopoda. *In* Yang, Z. et al., Permian-Triassic boundary stratigraphy and fauna of South China, *P. R. China, Minist. Geol. Min. Res., Geol. Mem., Ser. 2*, no. 6, 215-235, 317-326. (in Chinese)

Xu, G. and Grant, R.E., 1994, Brachiopods near the Permian-Triassic boundary in South China. *Smithson. Contr. Palaeobiol.*, no. 76, 1-68.

Yanagida, J., 1963, Brachiopods from the Upper Permian Mizukoshi Formation, central Kyushu. *Mem. Fac. Sci., Kyushu Univ., Ser. D*, **14**, 69-78.

Yanagida, J., 1996, Permian brachiopods from the Tsunemori Formation, SW Japan, and their paleobiogeographic implication. *In* Copper, P. and Jin, J., eds., *Brachiopods*, A.A. Balkema, Rotterdam, 313-315.

Yanagisawa, I., 1967, Geology and paleontology of the Takakurayama-Yaguki area, Yotsukura-cho, Fukushima Prefecture. *Sci. Rep., Tohoku Univ., 2nd ser.,* **39**, 63-112.

Yanagisawa, I. and Nemoto, M., 1961, On the Paleozoic formations of the Takakura-Yama district, Abukuma Mountainland. *Jour. Geol. Soc. Japan*, **67**, 274-283. (in Japanese)

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

Yang, D., Ni, S., Chang, M. and Zhao, R., 1977, Phylum Brachiopoda. *In* Hubei Institute of Geological Science et al., eds., *Palaeontological atlas of Mid-South China, pt. 2. Late Palaeozoic volume*, Geol. Pub. House, Beijing, 303-470. (in Chinese)

Zavodovsky, V.M., Stepanov, D.L., Balashova, E.A., Eltysheva, R.S., Lobanova, O.V., Lyutkevich, E.M., Miklukho-Maklay, A.D., Nekoroshev, V.P., Popov, Yu.N., Radchenko, G.P. and Sokolov, B.S., 1970, *Polevoy atlas permskoy fauny i flory Severo-Vostoka SSSR*, Magadanskoe Kniz. Isd., Magadan, 407 p. (in Russian)

Zeng, Y., 1990, Systematic description to the different kinds of fossils, 3. Description of brachiopods. *In* He, X., Zhang, Y., Zhu, M., Zhang, G., Zhuang, S., Zeng, Y. and Song, P., *Research on the Late Paleozoic coal-bearing stratigraphy and biota in Jungar, Nei Mongol (Inner Mongolia)*. China Univ. Min. Tech. Press, Xuzhou, 205-238. (in Chinese)

Zhan, L., 1979, Descriptions of fossils; Brachiopoda. *In* Hou, H., Zhan, L., Chen, B. et al., *The coal-bearing strata and fossils of Late Permian from Guangtung*, Geol. Pub. House, Beijing, 61-100. (in Chinese)

Zhang, Y. and Ching, Y., 1961, An Upper Permian brachiopod fauna from Jiangxian, Anhui Province. *Acta Palaeont. Sinica,* **9**, 401-417. (in Chinese)