A Middle Permian Boreal-Tethyan mixed brachiopod fauna from Yakejima, southern Kitakami Mountains, NE Japan

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Abstract

A collection of brachiopods is described from the Middle Permian Oyakejima Formation of the Yakejima area, southern Kitakami Mountains, northeast Japan. This fauna consists of the following nine species: *Waagenites soochowensis, Transennatia gratiosa, Kochiproductus* sp., *Compressoproductus compressus, Rhynchopora tchernyshae, Stenoscisma margaritovi, Martinia* sp., *Spiriferella* cf. *lita* and *Cleiothyridina subexpansa.* The Yakejima fauna, including a before-described species *Leptodus* sp., is characterized by the mixture of the Boreal-type genera, *Kochiproductus, Stenoscisma* and *Spiriferella*, and the Tethyan-type genera, *Transennatia, Compressoproductus* and *Leptodus*. The occurrence of the Middle Permian Boreal-Tethyan mixed brachiopod fauna from the southern Kitakami Mountains provides evidence that this region was placed on the transitional zone between the Boreal and Tethyan Realms, nearby the Sino-Korean block, in the Middle Permian time.

Key words: Boreal-Tethyan mixed fauna, brachiopods, Permian, southern Kitakami Mountains, Yakejima.

Introduction

The Permian brachiopods described below were collected by the authors in 1989, in the course of regional mapping for the Quadrangle series, scale 1:50,000 "Geology of the Osu district", Geological Survey of Japan (Kamada and Takizawa, 1992), from the Middle Permian Oyakejima Formation in the Yakejima area, southern Kitakami Mountains (South Kitakami Belt), northeast Japan (Fig. 1).

The Yakejima area, consisting of three islets, Hatezaki, Oyakejima and Koyakejima, is

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(Manuscript received 16 September, 1999; accepted 8 November, 1999)

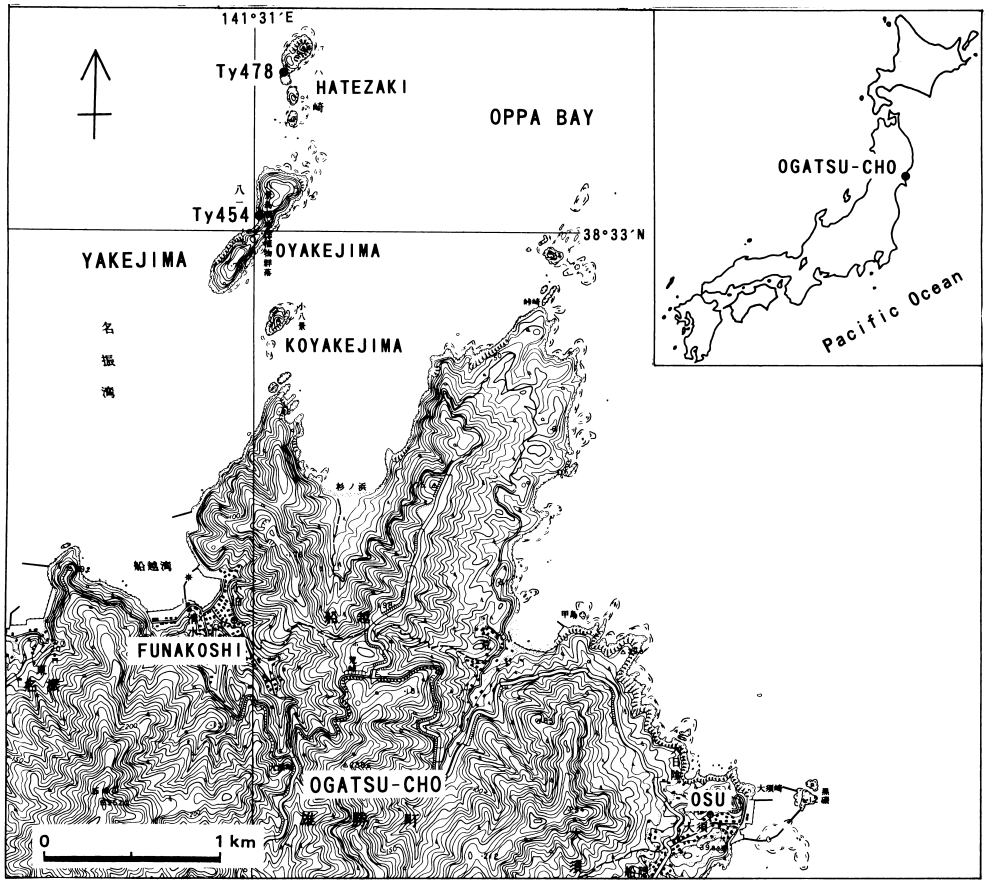


Fig. 1. Map showing the fossil localities (Ty454, Ty478) in the Yakejima area, southern Kitakami Mountains. Using the topographical map of "Osu" scale 1:25,000 published by the Geographical Survey Institution of Japan.

composed of Permian marine continental shelf deposits, the Middle Permian Oyakejima Formation and the Upper Permian Toyoma Formation. The Permian stratigraphy of this area was studied by Inai and Takahashi (1940), Murata and Shimoyama (1979) and Kamada and Takizawa (1992). On the Permian brachiopood fauna of the Yakejima area, only one *Leptodus* species was described by Yabe (1900), although the exact locality were unknown.

The purpose of this paper is to descibe the brachiopods collected from the Yakejima area, and to discuss their palaeobiogeographical significance. The first autohor (J.T.) is responsible for the palaeontology of the brachiopod fauna, and the second and third authors (F.T. and K.K.) are responsible for the stratigraphy of this area. The specimens described below are stored in the Geological Museum, Geological Survey of Japan, Tsukuba.

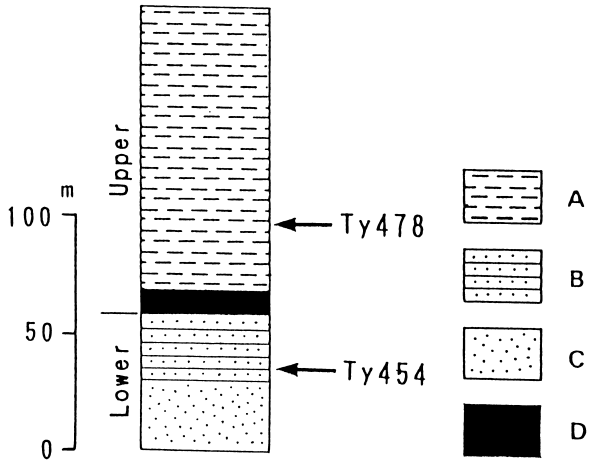


Fig. 2. Columnar section of the Oyakejima Formation in the Yakejima area, showing the stratigraphical positions of the fossil localities (Ty454,Ty478). A: Sandy siltstone or sandy shale, B: Alternation of sandstone and siltstone, C: Sandstone, D: Limestone.

Stratigraphy

The Oyakejima Formation in the Yakejima area is about 190 m in thickness, and it is divided into two members, the lower sandstone, siltstone and limestone member of 60 m thick, and the upper sandy siltstone or sandy shale member of 130 m thick. Murata and Shimoyama (1979) found a fusulinacean *Lepidolina multiseptata* (Deprat) from light grey limestone of the lowermost part of the upper member. From the lithology and fossils the lower member is correlated with the lower Kanokura Formation (Kattizawa Stage, *Monodiexodina matsubaishi* Zone of Tazawa, 1976), and the upper member is correlated with the upper Kanokura Formation (Iwaizaki Stage, *Lepidolina multiseptata* Zone of Tazawa, 1976), both in the Setamai-Kesennuma area, southern Kitakami Mountains. In the Yakejima area, the Oyakejima Formation is conformably overlain by the Upper Permian Toyoma Formation, which is about 120 m in thickness, and consists mainly of dark grey to black shale with some conglomerate (Usuginu-type conglomerate) intercalations.

The brachiopods occur from two horizons in two localities: (1) the lower horizon, dark grey calcareous fine-grained sandstone bed, located about 20 m below of the base of the limestone at the locality Ty454 in Oyakejima, and (2) the upper horizon, dark grey calcareous siltstone bed, located about 30 m above the top of the limestone at the locality Ty478 in Hatezaki. The geographical and stratigraphical positions of the two localities are shown in Figs. 1, 2.

The Oyakejima fauna

The brachiopods of Yakejima described here, and the number of specimens are shown as follows:

From Ty454 (Lower Oyakejima Formation; Oyakejima)

Compressoproductus compressus (Waagen) 2
Spiriferella cf. *lita* (Fredericks) 2

From Ty478 (Upper Oyakejima Formation; Hatezaki)

Waagenites soochowensis (Chao) 1
Transennatia gratiosa (Waagen) 4
Kochiproductus sp. 1
Rhynchopora tchernyshae Koczyrkevicz 1
Stenoscisma margaritovi (Tschernyschew) 7
Martinia sp. 1
Cleiothyridina subexpansa (Waagen) 2

In generic and specific composition, the Yakejima fauna is most similar to the Middle Permian brachiopod faunas from the Oguradani Formation of the Hida Mountains (Hidagaien Belt), central Japan (Tazawa and Matsumoto, 1998) and from the Barabash and Chandalaz Formations of South Primorye, eastern Russia (Fredericks, 1924, 1925; Licharew and Kotljar, 1978: Koczyrkevicz, 1979a, b).

Among the above-listed species, *Compressoproductus compressus* has been described from the Lower to Upper Permian of Pakistan, south China, east China and northwest China (Waagen, 1884; Reed, 1925; Chao, 1927; Zhang and Ching, 1961; Wang, Y. et al., 1964; Jing and Hu, 1978, Jin et al., 1979; Liu et al., 1982; Wang, G. et al., 1982; Wang, S., 1984; Liang, 1990). *Spiriferella* cf. *lita* is very similar to *Spiriferella lita* which was described from the Middle Permian of South Primorye and Japan (southern Kitakami Mountains) (Fredericks, 1924; Hayasaka, 1925; Tazawa, 1979). *Waagenites soochowensis* has been known from the Middle and Upper Permian of Vietnam, south China and east China (Chao, 1928; Huang, 1932; Chi-Thuan, 1962; Wang, Y. et al., 1964; Yang et al., 1977; Feng and Jiang, 1978; Zhan, 1979; Liao, 1980a, b; Wang, G. et al., 1982; Zhu, 1990; Shi and Shen, 1998). *Transennatia gratiosa* is widely distributed in the Middle and Upper Permian of the Tethyan and its surrounding regions (see Tazawa and Matsumoto, 1998). *Rhynchopora tchernyshae* has been described from the Middle Permian of South Primorye (Koczyrkevicz, 1979a). *Stenoscisma margaritovi* has been known from the Middle Permian of Inner Mongolia, northeast China, South Primorye, central Japan (Hida Mountains) and northeast Japan (southern Kitakami Mountains) (Tschernyschew, 1888; Hayasaka, 1922, 1966; Fredericks, 1924; Lee and Gu,

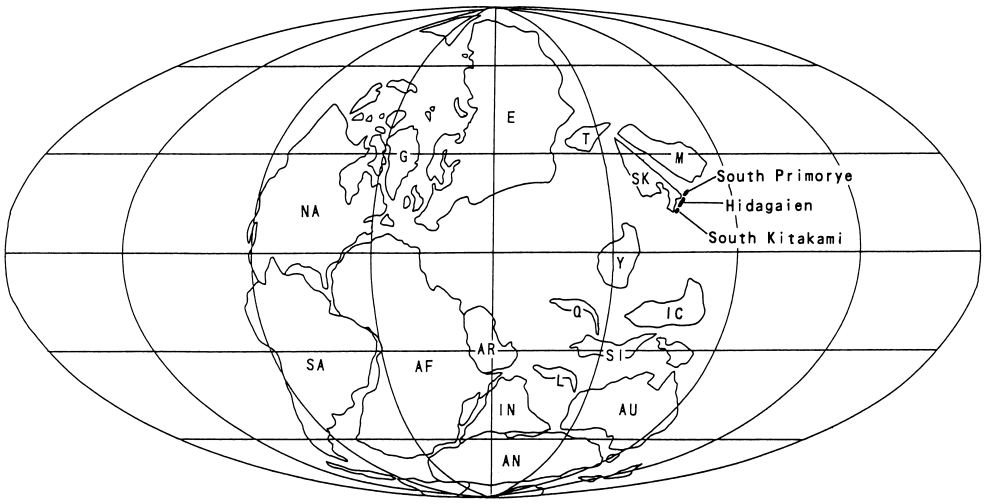


Fig. 3. Geographical reconstruction of the South Kitakami, Hidagaien and South Primorye regions in the Middle Permian time (adapted from Ziegler et al., 1996). Black areas are continental shelf. AF: Africa, AN: Antarctica, AR: Arabia, AU: Australia, E: Eurasia, G: Greenland, IC: Indochina, IN: India, L: Lhasa, M: Mongolia, NA: North America, Q: Quangtang, SA: South America, SI: Sibumasu, SK: Sino-Korea, T: Tarim, Y: Yangtze.

1976; Lee et al., 1980; Tazawa, 1976; Licharew and Kotljar, 1978; Koczyrkevicz, 1979b; Minato et al., 1979; Duan and Li, 1985; Horikoshi et al., 1987; Tazawa and Matsumoto, 1998). *Cleiothyridina subexpansa* has been described from the Middle and Upper Permian of Pakistan, Kashmir, Nepal and Tibet (Waagen, 1883; Diener, 1897, 1915; Waterhouse, 1966; Grunt, 1980; Jin, 1985). Moreover, *Leptodus* sp., described by Yabe (1900, p. 3) as *Lyttonia* cf. *nobilis* Waagen, can be added to the list of the Yakejima fauna. *Leptodus* is a typical Tethyan-type genus (Stehli, 1974; Tazawa, 1991; Shi et al., 1995).

To sum up, *Kochiproductus*, *Stenoscisma* and *Spiriferella* are the Boreal-type genera, while *Transennatia*, *Compressoproductus* and *Leptodus* are the Tethyan-type genera. Consequently, the Yakejima fauna is one of the Middle Permian Boreal-Tethyan mixed brachiopod faunas in Japan. It is also suggested that the South Kitakami region was placed on the transitional zone between the Boreal and Tethyan Realms occupying the northeastern area to the Sino-Korean block, i.e., the Inner Mongolian-Japanese Transition Zone of Tazawa (1991, 1999), together with the Hidagaien and South Primorye regions in the Middle Permian time (Fig. 3).

Description of species

Order Chonetida Nalivkin, 1979
Suborder Chonetidina Muir-Wood, 1955
Superfamily Chonetacea Bronn, 1862
Family Rugosochonetidae Muir-Wood, 1962
Subfamily Rugosochonetinae Muir-Wood, 1962
Genus *Waagenites* Paeckelmann, 1930

Waagenites soochowensis (Chao, 1928)
Pl. 1, figs. 1a, 1b.

Chonetes soochowensis Chao, 1928, p. 31, pl. 1, figs. 14-16; Huang, 1932, p. 5, pl. 1, figs. 8, 9; Chi-Thuan, 1962, p. 489, pl. 2, fig. 8; Wang, Y. et al., 1964, p. 241, pl. 37, figs. 20, 21.
Waagenites soochowensis (Chao): Yang et al., 1977, p. 332, pl. 135, fig. 22; Feng and Jiang, 1978, p. 243, pl. 88, fig. 5; Zhan, 1979, p. 72, pl. 11, figs. 7a, b; Liao, 1980a, pl. 2, fig. 7; Liao, 1980b, pl. 5, fig. 4; Wang, G. et al., 1982, p. 197, pl. 91, figs. 3, 4; pl. 95, figs. 7, 8; Zhu, 1990, p. 64, pl. 18, figs. 1, 2; Shi and Shen, 1998, p. 509, fig. 4.6.

Material.—One specimen from Loc. Ty478, a dorsal valve external mould, GSJ F15256.

Remarks.—The single incomplete dorsal valve specimen from Yakejima is transversely trapezoidal in outline, having acute cardinal extremities, with the greatest width at hinge line; length about 7 mm, width about 15 mm. The fold is broad and moderately high. The external surface of the dorsal valve is ornamented by 14 or more simple, flat costellae. This specimen is referred to *Waagenites soochowensis* (Chao, 1928), originally described from the Upper Permian of Jiangsu, east China, in size, shape and external ornament of the dorsal valve.

Waagenites barusiensis (Davidson, 1866), described and figured from the Upper Permian of Kashmir (Davidson, 1866, p. 42, pl. 2, fig. 7; Diener, 1899, p. 49, pl. 6, figs. 4a, b), is also a transverse *Waagenites*, but it differs from the present species in its smaller dimensions and less number of costellae on the ventral valve.

Waagenites deplanata (Waagen, 1884), originally described and figured by Waagen (1884, p. 637, pl. 60, figs, 5, 6) from the Wargal Formation of the Salt Range, is easily distinguished from *W. soochowensis* by its less transverse shell and much stronger costellate ornament. The former has been known also from the Middle Permian Kanokura Formation of the southern Kitakami Mountains (Hayasaka and Minato, 1956, p. 142, pl. 23, fig. 8; Tazawa, 1976, pl. 2, fig. 4).

Distribution.—Middle Permian of Quang Tri, central Vietnam and the southern Kitakami Mountains, northeast Japan. Upper Permian of Son La, northwest Vietnam; Guizhou, Guangdong and Hunan, south China; and Jiangxi, Fujian and Jiangsu, east China.

Order Productida Waagen, 1883
Suborder Productidina Waagen, 1883
Superfamily Productoidea Gray, 1840
Family Productellidae Schuchert in Schuchert and LeVene, 1929
Subfamily Marginiferinae Stehli, 1954
Genus *Transennatia* Waterhouse, 1975

Transennatia gratiosa (Waagen, 1884)
Pl. 1, figs. 3-5.

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

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

Dictyoclostus gratiosus (Waagen): Zhang and Ching, 1961, p. 411, pl. 4, figs. 12-18; Wang, Y. et al., 1964, p. 291, pl. 45, figs. 14-19.

Gratiosina gratiosa (Waagen): Grant, 1976, pl. 33, figs. 19-26; Licharew and Kotljar, 1978, pl. 12, figs. 5, 6; pl. 20, figs. 1a, b; Minato et al., 1979, pl. 61, figs. 11-13.

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

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-d; Ding and Qi, 1983, p. 280, pl. 95, figs. 14a, b.

Transennatia gratiosa (Waagen): Yang, 1984, p. 219, pl. 33, figs. 7a-c; Jin, 1985, pl. 4, figs. 33, 34, 45, 46; Tazawa and Matsumoto, 1998, p. 6, pl. 1, figs. 4-8.

Material.—Four specimens from Loc. Ty478: (1) a conjoined shell internal mould and associated dorsal valve external mould, GSJ F15257; (2) three dorsal valve external moulds, GSJ F15258-15260.

Remarks.—These specimens are referred to *Transennatia gratiosa* (Waagen, 1884), originally described from the Wargal and Chhidru Formations of the Salt Range. The Yakejima specimens are smaller (length 13 mm, width 13 mm in the best preserved specimen, GSJ F15257) than the type specimens from the Salt Range, but comparable with the shells of

T. gratiosa from the Middle Permian of the Hida Mountains, central Japan (Tazawa, 1991; Tazawa and Matsumoto, 1998), the southern Kitakami Mountains, northeast Japan (Hayasaka, 1960; Minato et al., 1979), South Primorye, eastern Russia (Licharew and Kotljar, 1978), and Heilongjiang and Jilin, northeast China (Lee et al., 1980).

Transennatia insculpta (Grant, 1976, p. 135, pl. 32, figs. 1-37; pl. 33, figs. 1-16) from the Rat Buri Limestone of Ko Muk, southern Thailand is also small in size, but differs from *T. gratiosa* in having more transverse shell, with prominent ears and coarser costellae on the ventral valve.

Distribution.—Permian of Tibet and the Karakorum. Middle Permian of the Kumaon Himalayas, Nepal; Cambodge; Vietnam; Timor; Guangxi, south China; Shaanxi, northwest China; Jilin and Heilongjiang, northeast China; South Primorye, eastern Russia; the Hida Mountains, central Japan; and the southern Kitakami Mountains, northeast Japan. Middle and Upper Permian of the Salt Range, Pakistan; and Hubei, south China. Upper Permian of Anhui, Zhejiang and Jiangxi, east China; and Hunan, Sichuan, Guizhou and Guangdong, south China. Upper Permian of Gaqoi, Xizang (Tibet).

Family Productidae Gray, 1840
Subfamily Buxtoniinae Muir-Wood and Cooper, 1960
Genus *Kochiproductus* Dunbar, 1955

Kochiproductus sp.
Pl. 1, figs. 13a-13c.

Material.—One specimen from Loc. Ty478, a conjoined shell external cast and associated dorsal valve external mould, GSJ F15261.

Remarks.—The single specimen from Yakejima is fragmentary. However, this specimen is safely assigned to the genus *Kochiproductus* by its large size (length over 45 mm, width about 48 mm), broad and shallow ventral sulcus, narrow and low dorsal fold, moderately strong geniculation at anterior margin of dorsal visceral disc, and external ornament of fine costae, strong, rather regular rugae and numerous, very fine concentric lirae on both valves.

This specimen is smaller than the mature shells of any other *Kochiproductus* species, e.g., *K. porrectus* (Kutorga, 1844), *K. flexicostatus* Dunbar, 1955 and *K. peruvianus* (d'Orbigny, 1842). *Kochiproductus tianchiensis* Wang and Yang (1998, p. 80, pl. 6, figs. 11, 13), from the Upper Carboniferous of central Xinjiang, north China, is also a small-sized species, but the accurate comparison is difficult for the poorly preserved specimen.

Superfamily Linoproductoidea Stehli, 1954
Family Monticuliferidae Muir-Wood and Cooper, 1960
Subfamily Compressoproductinae Jing and Hu, 1978

Genus *Compressoproductus* Sarytcheva in Sarytcheva et al., 1960

Compressoproductus compressus (Waagen, 1884)
Pl. 1, figs. 2a, 2b.

Productus compressus Waagen, 1884, p. 710, pl. 81, figs. 1, 2; Reed, 1925, p. 25, pl. 5, figs. 3, 3a.
Striatifera compressa (Waagen): Chao, 1927, p. 99, pl. 11, figs. 4a, b.
Compressoproductus compressa (Waagen): Zhang and Ching, 1961, p. 409, pl. 3, figs. 15-17; Wang, G. et al., 1982, p. 225, pl. 86, fig. 17; pl. 93, figs. 15, 16.
Compressoproductus compressus (Waagen): Wang, Y. et al., 1964, p. 334, pl. 53, fig. 11; Jing and Hu, 1978, p. 115, pl. 2, figs. 30, 31; Jin et al., 1979, p. 94, pl. 27, fig. 17; Liu et al., 1982, p. 188, pl. 136, fig. 10; Wang, S., 1984, p. 196, pl. 81, figs. 5, 6; Liang, 1990, p. 209, pl. 34, fig. 4.

Material.—Two specimens from Loc. Ty454, two dorsal valve external moulds, GSJ F15262, 15263.

Remarks.—The dorsal valves from Yakejima are elongate subtrigonal in outline and unevenly concave in both lateral and anterior profiles, with flattened venter and steep anterolateral slopes. The greatest width occur slightly anterior to the midvalve; length 31 mm, width 18 mm in the better preserved specimen (GSJ F15262). The external surface of the valve is ornamented by irregular concentric rugae and numerous capillae. These specimens are referred to *Compressoproductus compressus* (Waagen, 1884), originally described from the Wargal and Chhidru Formations of the Salt Range, in view of their size, outline and surface ornament of the dorsal valve.

Compressoproductus mongolicus (Diener, 1897, p. 28, pl. 4, figs. 8-10) from the Middle Permian of Chitichun No. 1, Kumaon Himalayas differs from *C. compressus* in having coarser capillae on both ventral and dorsal valves.

Compressoproductus sp. described and figured by Tazawa and Shen (1997, p. 6, pl. 1, figs. 5a, b) from the Middle Permian of Hiyomo, Mino Belt, central Japan is easily distinguished from the present species by its much smaller size.

Distribution.— Lower Permian of Chitral, Pakistan. Middle Permian of Qinghai, northwest China; Hubei and Hunan, south China; Zhejiang, east China; and the southern Kitakami Mountains, northeast Japan. Middle and Upper Permian of the Salt Range, Pakistan. Upper Permian of Anhui and Jiangxi, east China.

Order Rhynchonellida Kühn, 1949
Superfamily Rhynchoporoidea Muir-Wood, 1955
Family Rhynchoporidae Muir-Wood, 1955
Genus *Rhynchopora* King, 1865

Rhynchopora tchernyshae Koczyrkevicz, 1979
Pl. 1, figs. 6a-6d.

Rhynchopora tchernyshae Koczyrkevicz, 1979a, p. 47, pl. 11, figs. 1-4.

Material.—One specimen from Loc. Ty478, a dorsl valve external mould and associated conjoined shell internal mould, GSJ F15264.

Description.—Shell medium size for genus, pentagonal in outline, with greatest width slightly anterior to midvalve; length 13 mm, width 11 mm in the sole specimen. Ventral valve gently convex in lateral profile. Umbo narrow. Sulcus broad and shallow, originating at midvalve. Dorsal valve gently convex in lateral profile. Fold broad and low. External surface of both valves ornamented by numerous costae; 4 in ventral sulcus, 5 on each lateral flank of ventral valve; 5 on fold, 5-6 on each flank of dorsal valve. Internal structures of both valves obscure in the present specimen.

Remarks.—This specimen can be referred to *Rhynchopora tchernyshae* Koczyrkevicz, 1979, originally described from the lower Barabash Formation (*Monodiexodina sutschanika* Zone) of South Primorye, by its size, outline of the shell, and the number of costae on the both valves.

Rhynchopora variabilis Stuckenberg, 1898 is also a medium-sized *Rhynchopora*, but it differs from *R. tchernyshae* in its subelliptical shell with stronger and fewer costae on the both valves (see Tschernyschew, 1902, pl. 21, figs. 16, 17; Biernat and Birkenmajer, 1981, pl. 7, figs. 1-11; pl. 8, figs. 1-7).

Distribution.—Middle Permian of South Primorye, eastern Russia; and the southern Kitakami Mountains, northeast Japan.

Superfamily Stenoscismatoidea Oehlert, 1887
Family Stenoscismatidae Oehlert, 1887
Subfamily Stenoscismatinae Oehlert, 1887
Genus *Stenoscisma* Conrad, 1839

Stenoscisma margaritovi (Tschernyschew, 1888)
Pl. 1, figs. 7-11.

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. 9, 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 Kotljar, 1978, pl. 17, figs. 7a, b; Koczyrkevicz, 1979b, 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.

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

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

Stenoscisma sp. Horikoshi et al., 1987, p. 142; Kamada and Takizawa, 1992, table 1.

Material.—Seven specimens from Loc. Ty478: (1) a ventral valve external mould and associated conjoined shell internal mould, GSJ F15265; (2) a ventral valve external and internal moulds, GSJ F15266; (3) a dorsal valve external mould and associated conjoined shell internal mould, GSJ F15267; (4) three conjoined shell internal moulds, GSJ F15268-15270; (5) a ventral valve internal mould, GSJ F15271.

Description.—Shell large for genus, elongate subtrigonal in outline, with greatest width at two thirds length of shell; length 32 mm, width 24 mm in the best preserved, average-sized specimen (GSJ F15265).

Ventral valve gently convex in lateral profile, strongly convex at umbonal region and slightly convex to nearly flat on anterior half of valve. Umbo small and incurved. Sulcus broad and shallow. External surface of ventral valve ornamented by strong, rounded costae, numbering 7 on sulcus and 6-7 on each lateral flank. Dorsal valve gently convex in both lateral and anterior profiles, with a broad, low fold. External surface ornament of dorsal valve same as the opposite valve.

Internal structure of both valves are obscure in the present material.

Comparison.—These specimens are referred to *Stenoscisma margaritovi* (Tschernyschew, 1888), originally described from the Middle Permian of the Vladivostok area, South Primorye, on account of their elongate subtrigonal outline, shallow ventral sulcus and low dorsal fold, and relatively large number of costae on both valves.

Stenoscisma gigantea (Diener, 1897, p. 72, pl. 12, figs. 5, 7, 10), from the Middle Permian of Chitichun No. 1 in the Kumaon Himalayas is also a large *Stenoscisma* species, but the Himalayan species differs from the present species in its more transverse shell.

Stenoscisma humbletonensis (Howse, 1848) has numerous rounded costae on the both valves, but it differs from *S. margaritovi* in having a narrower and deeper ventral sulcus and a higher dorsal fold. The shells which was described or figured as *S. humbletonensis* from the lower Kanokura Formation of the southern Kitakami Mountains (Hayasaka, 1922, 1966; Tazawa, 1976; Minato et al., 1979) are referred to the present species.

Distribution.—Middle Permian of Jisu, Inner Mongolia; Jilin and Heilongjiang, northeast China; South Primorye, eastern Russia; the Hida Mountains, central Japan; and the southern

Kitakami Mountains, northeast Japan.

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 sp.
Pl. 1, fig. 12.

Material.—One specimen from Loc. Ty478, a dorsl valve internal mould, with the posterior portion of ventral valve attached, GSJ F15272.

Remarks.—The shell is subpentagonal in outline, slightly longer than wide, length about 23 mm, width about 18 mm. The dorsal valve is gently convex in both lateral and anterior profiles, with a broad and low fold. The external surface of the dorsal valve is ornamented with several concentric growth lamellae. The internal structure of the dorsal valve is obscure, except for a pair of narrow, slightly depressed adductor scars on the posterior portion of the valve.

In size and outline, this specimen resembles *Martinia elongata* Waagen (1883, p. 532, pl. 43, figs. 5a-e, 7a-d) from the Wargal Formation of the Salt Range, and *Martinia longa* Tschernyschew (1902, p. 185, 567, pl. 18, figs. 5a-d; pl. 40, figs. 9a-d) from the Lower Permian of the Urals. But the preservation of the present specimen is inadequate for definite comparison.

Superfamily Spiriferoidea King, 1846
Family Spiriferellidae Waterhouse, 1968
Subfamily Spiriferellinae Waterhouse, 1968
Genus *Spiriferella* Tschernyschew, 1902

Spiriferella cf. *lita* (Fredericks, 1924)
Pl. 1, figs. 16, 17.

Compare.—
Spirifer saranae mut. *lita* Fredericks, 1924, p. 36, pl. 1, figs. 16-27; Hayasaka, 1925, p. 98, pl. 5, fig. 14.
Spiriferella lita (Fredericks): Tazawa, 1979, p. 28, pl. 4, figs. 12-13; pl. 5, figs. 1-4, 6.

Material.—Two specimens from Loc. Ty454, (1) a ventral valve external mould, GSJ F15273; (2) a dorsal valve external mould, GSJ F15274.

Remarks.—These specimens are strongly distorted and fragmentary, but safely assigned to the genus *Spiriferella* on the basis of their size and shape of the ventral and dorsal valves, and strong, simple costae on lateral slopes of both valves.

The Yakejima specimens most resemble *Spiriferella lita* (Fredericks, 1924), originally described from the Middle Permian of South Primorye and subsequently recorded from the Middle Permian of the southern Kitakami Mountains, northeast Japan (Hayasaka, 1925; Tazawa, 1979), in having a deep, smooth-bottomed sulcus on the ventral valve, and a high fold with median groove on the dorsal valve. But the poor preservation of the present material makes accurate comparison difficult.

Order Atrypida Rzhonsnitskaya, 1960
Suborder Athyrididina Boucot, Johnson and Staton, 1964
Superfamily Athyridoidea M'Coy, 1844
Family Athyrididae M'Coy, 1844
Subfamily Athyridinae M'Coy, 1844
Genus *Cleiothyridina* Buckman, 1906

Cleiothyridina subexpansa (Waagen, 1883).
Pl. 1, figs. 14, 15.

Athyris subexpansa Waagen, 1883, p. 478, pl. 39, figs. 1-5; Diener, 1897, p. 61, pl. 10, figs. 4a- d.
Spirigera subexpansa (Waagen): Diener, 1915, p. 94, pl. 10, figs. 4a-d.
Athyris (Cleiothyridina) subexpansa Waagen: Reed, 1925, p. 53, pl. 7, figs. 4, 4a.
Cleiothyridina subexpansa (Waagen): Waterhouse, 1966, p. 62, pl. 8, fig. 3; pl. 10, fig. 3; Grunt, 1980, p. 86, pl. 14, figs. 5, 6; pl. 15, figs. 3, 4; text-fig. 43; Jin, 1985, pl. 4, figs. 18-21.

Material.—Two specimens from Loc. Ty478: (1) a ventral valve external mould and associated conjoined shell internal mould, GSJ F15275; (2) a conjoined shell external cast, GSJ F15276.

Description.—Shell medium size for genus, little inflated and transversely elliptical in outline, with greatest width at midvalve; length 19 mm, width 30 mm in the larger and better preserved specimen (GSJ F15276).

Ventral valve slightly convex in both lateral and anterior profiles. Sulcus wide and very shallow on anterior half of pedicle valve. External surface of ventral valve ornamented by strong concentric lamellae, which projecting anteriorly as flat spines, with a density of 5-6 lamellae per 5 mm, 15-17 spines per 5 mm near valve margins. Dorsal valve also slightly

convex in lateral and anterior profiles. Fold absent.

Internal structures of both valves are obscure, except for a thin and low median septum extending to posterior one-third valve length in dorsal valve.

Remarks.—These specimens are referred to *Cleiothyridina subexpansa* (Waagen, 1883), originally described from the Wargal and Chhidru Formations of the Salt Range, on the basis of their medium-sized, transversely elliptical shells, with a shallow ventral sulcus but without a dorsal fold.

Cleiothyridina royssiana (Keyserling, 1846, p. 237) from the Permian of Pechora Basin is also a transverse *Cleiothyridina* species, but it differs from *C. subexpansa* in having a deeper ventral sulcus and a rather high dorsal fold (see Gobbett, 1963, pl. 21, figs. 13-16; pl. 22, figs. 1, 2; Kulikov, 1974, pl. 2, figs. 9-11).

Cleiothyridina gerardi (Diener, 1899, p. 56, pl. 6, figs. 12-14.) from the Middle Permian Kuling Shale of Spiti differs from *C. subexpansa* in its larger dimensions.

Distribution.—Middle Permian of Chitral, Pakistan; and Chitichun No. 1, Kumaon Himalayas. Middle and Upper Permian of the Salt Range. Upper Permian of Kashmir; Dolpo , west Nepal; and Gaqoi, Xizang (Tibet).

Acknowledgements

We thank Dr. Isao Niikawa of the Department of Geology, Niigata University, who kindly read the manuscript; Dr. Seiichi Toshimitsu of the Geological Museum, Geological Survey of Japan, Tsukuba, who help the register of the brachiopod specimens described in this paper.

References

Biernat, G. and Birkenmajer, K., 1981, Permian brachiopods from the base of the Kapp Starostin Formation at Palakkfjellet, Spitsbergen. *Studia Geol. Polonica*, **73**, 7-24.

Boucot, A.J., Johnson, J.G. and Staton, R.D., 1964, On some atrypoid, retzioid, and athyridoid Brachiopoda. *Jour. Paleontology*, **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), 3.* Leipzig and Heidelberg, 518 p.

Buckman, S.S., 1906, Brachiopod homoeomorphy: *Pygope, Antinomia, Pygites. Quart. Jour., Geol. Soc. London*, **62**, 433-455.

Chao, Y.T., 1927, Productidae of China, Pt. 1, Producti. *Palaeont. Sinica, Ser. B*, **5**, fasc. 2, 1-244.

Chao, Y.T., 1928, Productidae of China, Pt. 2, Chonetinae, Productinae and Richthofeninae. *Palaeont. Sinica, Ser. B*, **5**, fasc. 3, 1-103.

Chi-Thuan, T., 1962, Les brachiopodes de Cam-Lo (Province de Quang-Tri). *Ann. Fac. Sci. 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. *New York State Geol. Surv., 3rd Ann. Rept.*, 57-66.

Davidson, T., 1866, Notes on the Carboniferous Brachiopoda collected by Captain Godwin-Austen in the valley of Kashmere. *Quart. Jour., Geol. Soc. London*, **22**, 39-45.

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

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

Diener, C., 1915, The Anthracolithic faunae of Kashmir, Kanaur and Spiti. *Palaeont. Indica, N. S.*, **5**, 1-135.

Ding, P. and Qi, W., 1983, Phylum Brachiopoda. *In* Xian Institute of Geology and Mineral Resources, ed., *Palaeontological atlas of northwest China; Shaanxi, Gansu and Ningxia volume, Pt. 2, Upper Palaeozoic*, Geol. Pub. House, Beijing, 244-425. (In Chinese).

Duan, C. and Li, W., 1985, Descriptions of fossils; Phylum Brachiopoda. *In* Ding, Y., Xia, G., Duan, C. and Li, W., Study on the Early Permian stratigraphy and fauna in Zhesi district, Nei Mongol Zizhiqu (Inner Mongolia). *Bull. Tianjin Inst. Geol. Min. Res., Chinese Acad. Geol. Sci.*, no. 10, 99-145, 199-214. (In Chinese).

Dunbar, C.O., 1955, Permian brachiopod faunas of central East Greenland. *Meddel. Grønland*, **110**, 1-169.

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).

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).

Gobbett, D.J., 1963, Carboniferous and Permian brachiopods of Svalbard. *Norsk Polarinst. Skrift.*, no. 127, 1-201.

Grant, R.E., 1976, Permian brachiopods from southern Thailand. *Jour. Paleontology*, **50**, 1-269.

Gray, J.E., 1840, *Synopsis of the contents of the British Museum, 42nd edit.* London, 370 p.

Grunt, T.A., 1980, Atirididy Russkoy Platformy. *Tr. Paleont. Inst.*, **182**, 1-163. (In Russian).

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.

Horikoshi, E., Tazawa, J., Naito, N. and Kaneda, J., 1987, Permian brachiopods from Moribu, north of Takayama City, Hida Mountains, central Japan. *Jour. Geol. Soc. Japan*, **93**, 141-143. (In Japanese).

Howse, R., 1848, A catalogue of the fossils of the Permian System of the countries of Northumberland and Durham. *Trans. Tyneside Nat. Field Club*, 219-264.

Huang, T.K., 1932, Late Permian Brachiopoda of southwestern China. *Palaeont. Sinica, Ser. B*, **9**, fasc. 1, 1-138.

Huang, T.K., 1933, Late Permian Brachiopoda of southwestern China, Pt. 2. *Palaeont. Sinica,*

Ser. B, **9**, fasc. 2, 1-172.

Inai, Y. and Takahashi, T., 1940, The geology of the southernmost area of the Kitakami Mountainland. *Contr. Inst. Geol. Paleont., Tohoku Univ.*, no. 34, 1-40. (In Japanese).

Jin, Y., 1985, Permian Brachiopoda and paleogeography of the Qinghai-Xizang (Tibet) Plateau. *Palaeont. Cathayana*, no. 2, 19-71.

Jin, Y., Ye, S., Yu, H. and Sun, D., 1979, Phylum Brachiopoda. In Nanjing Institute of Geology and Palaeontology and Qinghai Institute of Geological Sciences, eds., *Palaeontologicaal atlas of northwest China; Qinghai, Pt. 1*, Geol. Pub. House, Beijing, 60-217. (In Chinese).

Jing, Y. and Hu, S., 1978, Brachiopods of the Kuhfeng Formation in south Anhui and Nanking Hills. *Acta Palaeont. Sinica*, **17**, 101-127. (In Chinese).

Kamada, K. and Takizawa, F., 1992, *Quadrangle series, scale 1:50,000 "Geology of the Osu district"*. Geol. Surv. Japan, Tsukuba, 69 p. (In Japanese).

Keyserling, A.G., 1846, *Wissenschaftliche Beobachtungen auf einer Reise in das Petchora-Land, im Jahre 1843; Mollusca, Brachiopoda.* Carl Kray, St. Petersburg, 195-243.

King,W., 1846, Remarks on certain genera belonging to the class Palliobranchiata. *Ann. Mag. Nat. Hist.*, **18**, 26-42.

King, W., 1865, Remarks of the history of two specimens of *Rhynchopora geinitziana* de Verneuil, from near the River Oukhla, Province of Archangel. *Ann. Mag. Nat. Hist., Ser. 3*, **16**, 124-128.

Koczyrkevicz, B.V., 1979a, Novye permskie *Rhynchopora* (Brachiopoda) Yuzhnogo Primorya i nekotorye voprosy ikh morfologii. *In* Petrashevskaya, V.T., ed., *Iskopaemye Bespozvonochnye Dalnego Vostoka (Dannye po novym nakhodkam)*, DVNTS AN SSSR, Vladivostok, 41-49. (In Russian).

Koczyrkevicz, B.V., 1979b, Permskie stenostsizmatsei (Brachiopoda) Yuzhnogo Primorya. *In* Petrashevskaya, V.T., ed., *Iskopaemye Bespozvonochnye Dalnego Vostoka (Dannye po novym nakhodkam)*, DVNTS AN SSSR, Vladivostok, 50-59. (In Russian).

Kulikov, M.V., 1974, O rasselenii i usloviyakh obitaniya fauny v severnoy chasti Kazanskogo Morya. *Tr. VSEGEI*, **182**, 138-153. (In Russian).

Kutorga, S., 1844, *Zweiter Beitrag zur Paläontologie Russlands*. Verh., Russ. Kais. Min. Ges., St. Petersburg, 62-104.

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

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).

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

Liao, Z., 1980a, Brachiopod assemblages from the Upper Permian and Permian-Triassic boundary beds, south China. *Can. Jour. Earth Sci.*, **17**, 289-295.

Liao, Z., 1980b, Upper Permian brachiopods from western Guizhou. *In* Nanjing Institute of Geology and Palaeontology, ed., *Stratigraphy and palaeontology of Upper permian coal-bearing formation in western Guizhou and eastern Yunnan*, Sci. Press, Beijing, 241-277. (In Chinese).

Licharew, B.K. and Kotljar, G.V., 1978, Permskie brakhiopody Yuzhnogo Primorya. *In* Popeko, L.I., ed., *Verkhniy Paleozoy Severo-Vostochnoy Azii*, Dalnevostoch. Nauch. Chentr, Akad. Nauk SSSR, Vladivostok, 63-75. (In Russian).

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.

M'Coy, F., 1844, *A synopsis of the characters of the Carboniferous limestone fossils of Ireland.* The University Press, Dublin, 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.

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. and Shimoyama, S., 1979, Stratigraphy near the Permian-Triassic boundary and the pre-Triassic unconformity in the Kitakami Massif, northeast Japan. *Kumamoto Jour. Sci. Geol.*, **11**, 11-31. (In Japanese).

Nalivkin, D.V., 1979, *Brakhiopody turneiskogo yarusa Urala.* Nauka, Leningrad, 248 p. (In Russian).

Oehlert, D.P., 1887, *Manuel de conchyliologie et de paléontologie conchyliologique, ou Histoire naturelle des mollusques vivants et fossiles, Pt. 11.* Savy, Paris, 1189-1334.

Orbigny, A. d', 1842, *Voyages dans l'Amérique méridionale; Pitois-Levrault et cie, vol. 3, Paléontologie.* Paris, 50-56.

Paeckelmann,W., 1930, Die Brachiopoden des deutschen Unterkarbons, 1 Teil: Die Orthiden, Strophomeniden und Choneten des Mittleren und Oberen Unterkarbons. *Abh. Preuss. Geol. Landesanst., N. F.*, **122**, 143-326.

Reed, F.R.C., 1925, Upper Carboniferous fossils from Chitral and the Pamirs. *Palaeont. Indica, N. S.*, **6**, 1-154.

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.

Rudwick, M.J.S. and Cowen, R., 1967, The functional morphology of some aberrant strophomenide brachiopods from the Permian of Sicily. *Boll. Soc. Paleont. Italiana*, **6**, 113-176.

Rzhonsnitskaya, M.A., 1960, Otryad Atrypida. *In* Sarytcheva, T.G., ed., *Osnovy paleontologii; Mshanki, Brakhiopody, Prilozhenis: Foronidy.* Akad. Nauk SSSR, Moskva, 257-264. (In Russian).

Sarytcheva, T.G., Licharew, B.K. and Sokolskaja, A.N., 1960, Otryad Productida. *In* Sarytcheva, T.G., ed., *Osnovy paleontologii; Mshanki, Brakhiopody, Prilozhenis: Foronidy*, Akad. Nauk SSSR, Moskva, 221-238. (In Russian).

Schuchert, C. and LeVene, C.M., 1929, *Brachiopoda (Generum et genotyporum index et bibliographia): Fossilium catalogus, 1, Animalia.* W. Junk, Berlin, 140 p.

Shi, G.R., Archbold, N.W. and Zhan, L., 1995, Distribution and characteristics of mixed (transitional) mid-Permian (Late Artinskian-Ufimian) marine faunas in Asia and their palaeogeographical implications. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, **114**, 241-271.

Shi, G.R. and Shen, S., 1998, A Changhsingian (Late Permian) brachiopod fauna from Son La, northwest Vietnam. *Jour. Asian Earth Sci.*, **16**, 501-511.

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

Stehli, F.G., 1974, Permian brachiopods. *In* Hallam, A., ed., *Atlas of palaeobiogeography*, Elsevier, Amsterdam, 143-149.

Stuckenberg, A., 1898, Allgemeine geologische Karte von Russland. *Com. Géol. St. Petersbourg, Mém.*, **16**, 1-362.

Tazawa, J., 1976, The Permian of Kesennuma, Kitakami Mountains: A preliminary report. *Earth Science (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, 23-34.

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

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

Tazawa, J. and Shen, S., 1997, Middle Permian brachiopods from Hiyomo, Mino Belt, central Japan: Their provincial relationships with North America. *Sci. Rep., Niigata Univ., Ser. E*, no. 12, 1-17.

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, F., 1888, Zametka o kamennougolnoy kollektsii iz okrestnoitey Vladivostoka. *Izv. Geol. Kom.*, **7**, 353-359. (In Russian).

Tschernyschew, F., 1902, Verkhnekamennougolnyya brakhiopody Urala i Timana. *Tr. Geol. Kom.*, **16**, 1-749. (In Russian).

Waagen, W., 1883, Productus-Limestone fossils. *Palaeont. Indica, Ser. 13*, **1**, 391-546.

Waagen,W., 1884, Productus-Limestone fossils. *Palaeont. Indica, Ser. 13*, **1**, 611-728.

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, 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, S., 1984, Phylum Brachiopoda. *In* Regional Geological Surveying Team of Hubei, ed., *The palaeontological atlas of Hubei Province*, Hubei Sci. Tech. Press, Wuhan, 128-235. (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., 1966, Lower Carboniferous and Upper Permian brachiopods from Nepal. *Jahr. Geol. Bundesanst.*, **12**, 5-99.

Waterhouse, J.B., 1968, The classification and descriptions of Permian Spiriferida (Brachiopoda) from New Zealand. *Palaeontographica, Abt. A*, **129**, 1-94.

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

Yabe, H., 1900, The brachiopod *Lyttonia* from Rikuzen Province. *Jour. Geol. Soc. Tokyo*, **7**, 1-4.

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 Sciences et al., eds., *Palaeontological atlas of mid-south China, Pt. 2, Late Palaeozoic volume*, Geol. Pub. House, Beijing, 303-470. (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 Jingxian, Anhui Province. *Acta Palaeont. Sinica*, **9**, 401-417. (In Chinese).

Zhu, T., 1990, *The Permian coal-bearing strata and palaeobiocoenosis of Fusian*. Geol. Pub. House, Beijing, 127 p. (In Chinese).

Ziegler, A.M., Hulver, M.L. and Rowley, D.B., 1996, Permian world topography and climate. *In* Martini, I.P., ed., *Late glacial and postglacial environmental changes—Quaternary, Carboniferous-Permian and Proterozoic*, Oxford Univ. Press, New York, 1-37.

Explanation of Plate 1

(Natural size unless otherwise indicated)

Figs. 1a, 1b. *Waagenites soochowensis* Chao

Ventral view of an external mould of a dorsal valve, GSJ F15256. Fig. 1a is ×2.

Figs. 2a, 2b. *Compressoproductus compressus* (Waagen)

Ventral and lateral views of an external mould of a dorsal valve, GSJ F15262.

Figs. 3-5. *Transennatia gratiosa* (Waagen)

3a, 3b, 3c. Ventral, anterior and dorsal views of an internal mould of a conjoined shell; 3d. Ventral view of an external mould of a dorsal valve, GSJ F 15257; 4. Ventral view of an external mould of a dorsal valve, GSJ F15258; 5. Ventral view of an external mould of a dorsal valve, GSJ F15260.

Figs. 6a-6d. *Rhynchopora tschernyshae* Koczyrkevicz

6a, 6b, 6c. Ventral and dorsal views of an internal mould of a conjoined shell; 6d. Dorsal view of a latex cast of a dorsal valve, GSJ F15264. Figs. 6b-6d are ×2.

Figs. 7-11. *Stenoscisma margaritovi* (Tschernyschew)

7a. Ventral view of a latex cast of a ventral valve; 7b, 7c. Ventral and dorsal views of an internal mould of a conjoined shell, GSJ F15265; 8a, 8b. Ventral and dorsal views of an internal mould of a conjoined shell, GSJ F15267; 9a, 9b. Ventral and dorsal views of an internal mould of a conjoined shell, GSJ F15268; 10a, 10b. Ventral and dorsal views of an internal mould of a conjoined shell, GSJ F15269; 11a, 11b. Ventral view of a latex cast and an internal mould of a ventral valve, GSJ F15266.

Fig. 12. *Martinia* sp.

Dorsal view of an internal mould of a dorsal valve, GSJ F15272.

Figs. 13a-13c. *Kochiproductus* sp.

13a, 13b. Ventral and dorsal views of an external cast of a conjoined shell; 13c. Ventral view of an external mould of a dorsal valve, GSJ F15261.

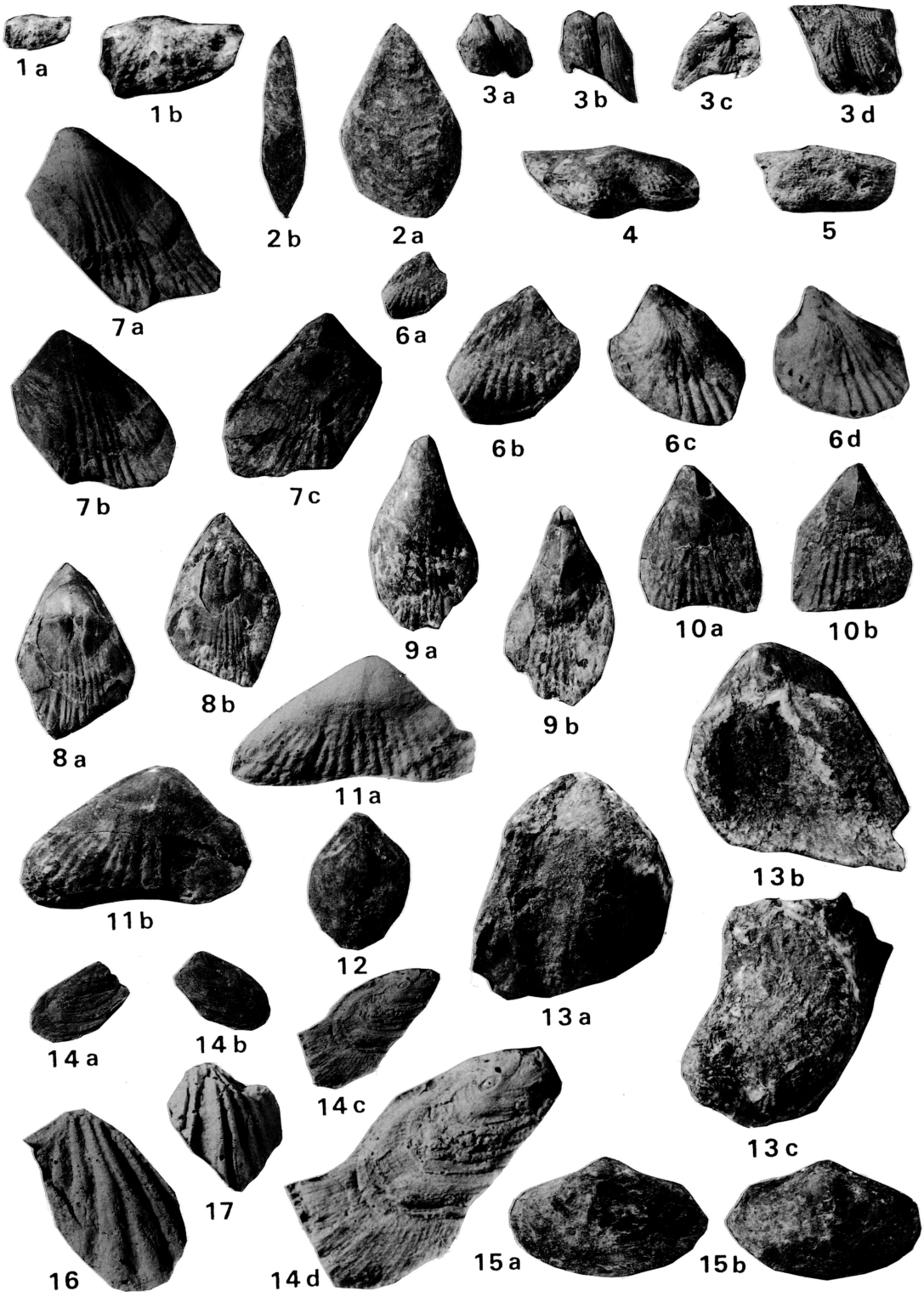
Figs. 14, 15. *Cleiothyridina subexpansa* (Waagen)

14a, 14b. Ventral and dorsal views of an internal mould of a conjoined shell; 14c, 14d. Ventral view of a latex cast of a ventral valve, GSJ F15275; 15a, 15b. Ventral and dorsal views of an external cast of a conjoined shell, GSJ F15276. Figs. 14d is ×2.

Figs. 16, 17. *Spiriferella* cf. *lita* (Fredericks)

16. Dorsal view of a latex cast of a dorsal valve, GSJ F15274; 17. Ventral view of a latex cast of a ventral valve, GSJ F15273.

Plate 1


1a
1b
2b
2a
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15b