Middle Permian brachiopods from Setamai, the type locality of the Kanokura Formation, southern Kitakami Mountains, northeast Japan

Jun-ichi TAZAWA* and Yosuke IBARAKI**

Abstract

A Middle Permian (Kubergandian-Murgabian) brachiopod fauna is described from the type section of the lower Kanokura Formation in the Setamai area, southern Kitakami Mountains, northeast Japan. This fauna contains the following nine species: *Transennatia gratiosa*, *Tyloplecta* cf. *yangzeensis*, *Waagenoconcha* sp., *Linoproductus cora*, *Cancrinella* sp., *Leptodus nobilis*, *Derbyia grandis*, *Derbyia nipponica* and *Spiriferella keilhavii*. The Setamai fauna is characterized by the mixuture of both the Boreal and Tethyan elements.

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

Introduction

The Permian brachiopod specimens described in this paper were collected by the authors and late Prof. M. Minato of Hokkaido University from nine localities in the Kanokurasawa and Kacchizawa valleys in the Setamai area, the type locality of the lower part of the Kanokura Formation, southern Kitakami Mountains, northeast Japan (Figs. 1, 2).

The Middle Permian Kanokura Formation was named by Onuki (1937) as the Kanokura Stage, but Onuki (1956) later changed the name to 'formation' with the outcrops along the Kanokurasawa valley as its type section. The stratigraphy of the Kanokura Formation in the Setamai area was described and discussed in detail by Minato et al. (1954, 1978, 1979), Onuki (1956, 1969), Murata (1964), Saito (1966, 1968) and Choi (1973, 1976). In palaeontology, many species of fusulinaceans (Choi, 1973), corals (Minato, 1955; Minato and Kato, 1965), brachiopods (Hayasaka, 1953; Hayasaka and Minato, 1956; Minato and Nakamura, 1956;

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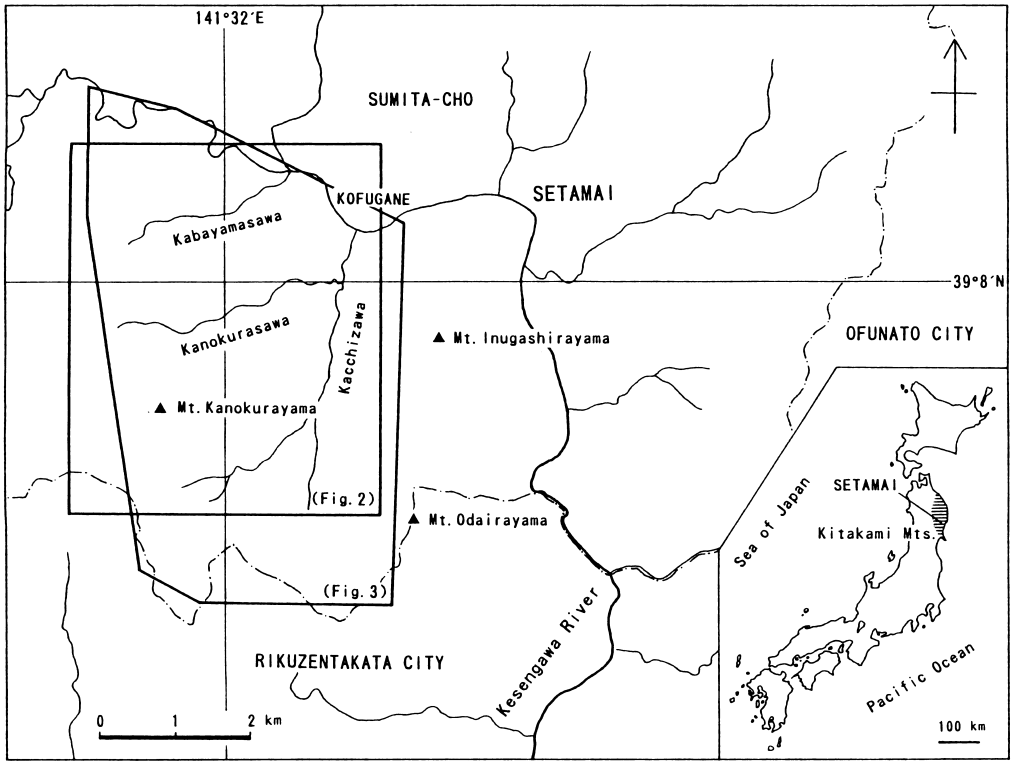

Fig. 1. Index map showing the study area (Figs. 2, 3).

Nakamura et al., 1970) and ammonoids (Hayasaka, 1954) were described from the Kanokura Formation in this area. On brachiopods, the following six species have been hitherto described: *Chonetes* (*Plicochonetes*) *deplanata* (Waagen), *Linoproductus cora* (d'Orbigny) and *Derbyia magnifica* Licharew by Hayasaka and Minato (1956), *Permundaria asiatica* Nakamura, Kato and Choi by Nakamura et al. (1970), *Orthotetes rugosa* Fredericks by Minato and Nakamura (1956), and *Hamletella kitakamiensis* Hayasaka by Hayasaka (1953).

In this paper the brachiopod fauna of the lower Kanokura Formation in the Setamai area is described, and the age and palaeobiogeography of the Setamai fauna are discussed. The first authour (J. T.) is responsible for the systematic descriptions and palaeobiogeography of the fauna, and the second author (Y. I.) is responsible for the field geology. All the specimens are housed in the Department of Geology, Faculty of Science, Niigata University.

Stratigraphy

In the Setamai area marine fossiliferous Permian rocks of continental shelf deposits are well developed, forming a synclinorium trending NNW-SSE and plunging towards the south

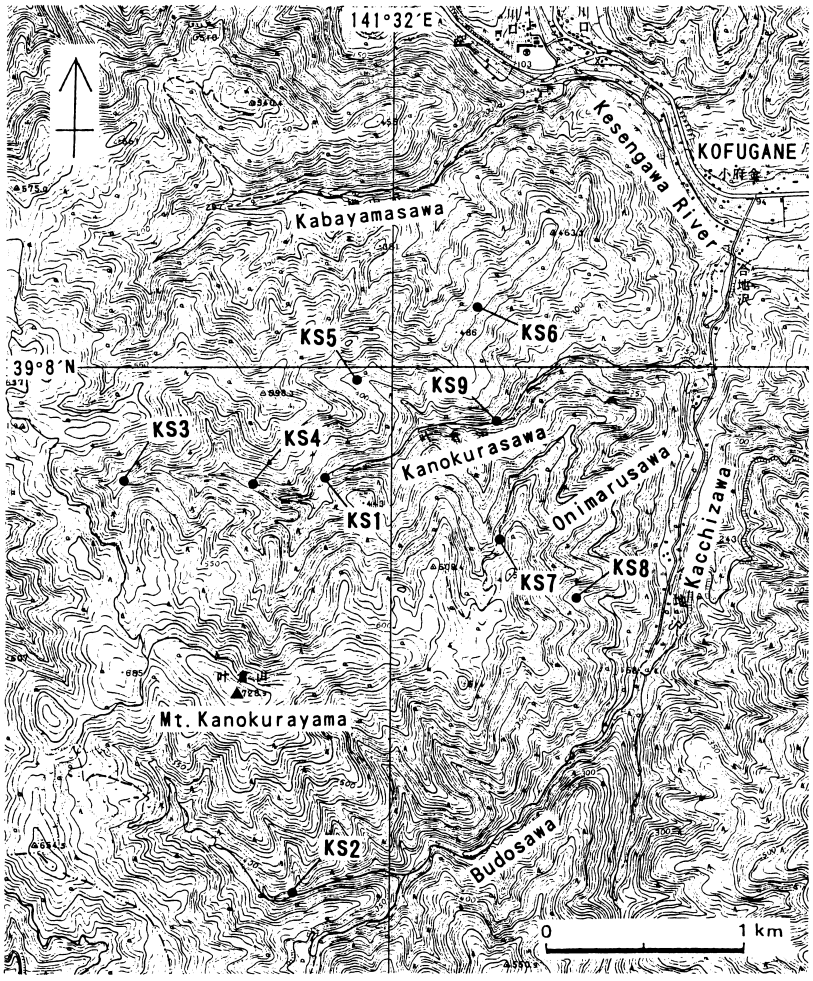

Fig. 2. Index map showing the fossil localities (KS1-9) in the Setamai area. Using the topographical map of "Setamai" scale 1:25,000 published by the Geographical Survey Institution of Japan.

(Figs. 3, 4). The Permian rocks in the Setamai area are divided into three formations, the Sakamotozawa, Kanokura and Toyoma Formations in ascending order (Fig. 5). The Lower Permian Sakamotozawa Formation is mainly composed of sandstone and conglomerate in the lower part and limestone in the upper part, about 600 m in total thickness. This formation covers the Lower Carboniferous Arisu and Odaira Formations by an angular unconformity (Minato, 1942). The Middle Permian Kanokura Formation consists of sandstone, argillaceous impure limestone and conglomerate in the lower part and limestone in the upper part, about 500 m in total thickness. This formation disconformably overlies the Sakamotozawa Formation (Minato et al., 1954). The Upper Permian Toyoma Formation is mainly made of black shale, with two conglomerate beds, over 500 m in total thickness. This formation conformably overlies

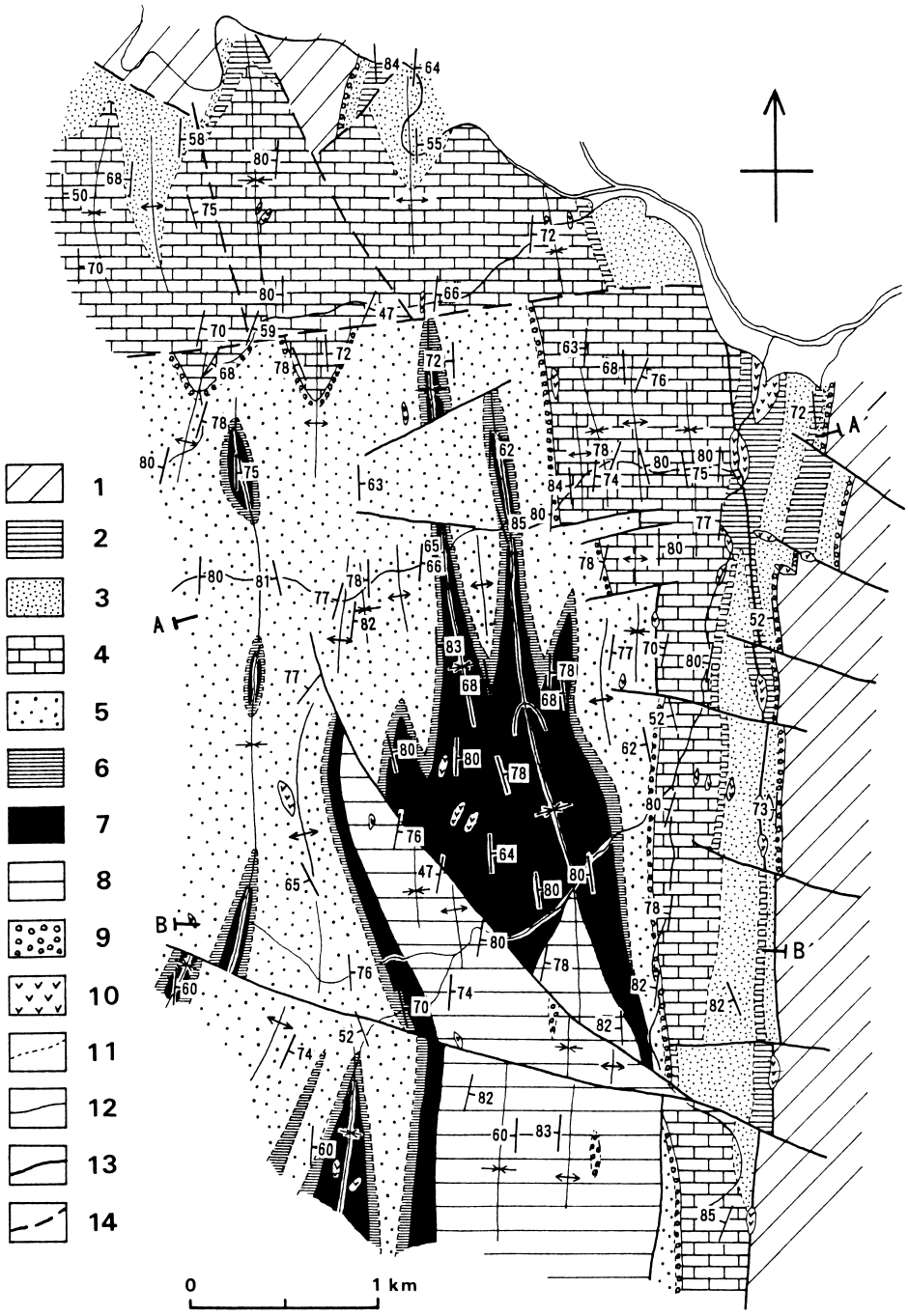

Fig. 3. Geological map of the Setamai area. 1: dyke rocks, 2: conglomerate of the Toyoma, Kanokura and Sakamotozawa Formations, 3: shale of the Toyoma Formation, 4: limestone of the upper Kanokura Formation, 5: argillaceous impure limestone of the lower Kanokura Formation, 6: sandstone of the lower Kanokura Formation, 7: limestone of the Sakamotozawa Formation, 8: shale of the Sakamotozawa Formation, 9: sandstone of the Sakamotozawa Formation, 10: undivided Lower Carboniferous, 11: conformity, 12: unconformity, 13: fault, 14: concealed fault.

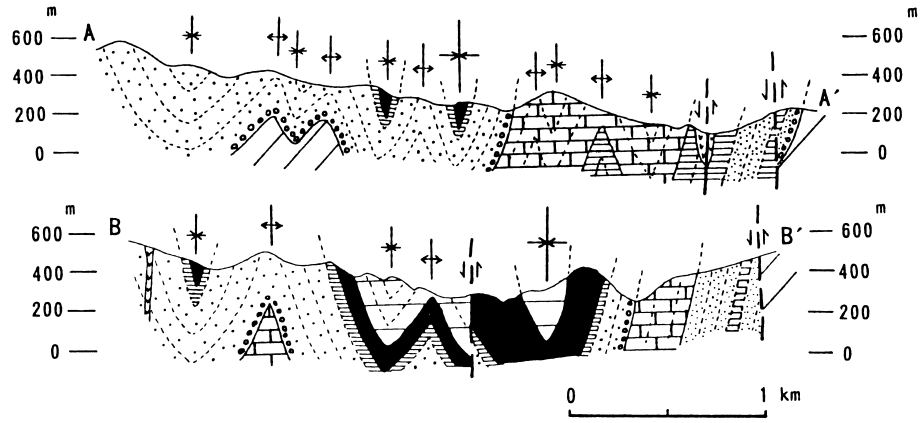

Fig. 4. Cross sections of the Setamai area. Shading as for Fig. 3.

the Kanokura Formation.

The brachiopod fossils treated in this paper were collected from the sandstone, shale and argillaceous impure limestone of the upper part of the lower Kanokura Formation in nine localities (KS1-9). The fossil localities and horizons are shown in Figures 2, 5. A fusulinacean *Monodiexodina matsubaishi* (Fujimoto, 1956) often occurs together with the brachiopods from the sandstone and argillaceous impure limestone of the upper part of the lower Kanokura Formation.

The Setamai fauna

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

Transennatia gratiosa (Waagen, 1884) 5
Tyloplecta cf. *yangzeensis* (Chao, 1927) 1
Waagenoconcha sp. 1
Linoproductus cora (d'Orbigny, 1842) 26
Cancrinella sp. 1
Leptodus nobilis (Waagen, 1883) 7
Derbyia grandis Waagen, 1884 2
Derbyia nipponica Nakamura, 1972 5
Spiriferella keilhavii (von Buch, 1846) 20

Among these species, *Waagenoconcha* sp., *Cancrinella* sp., *Derbyia grandis* and

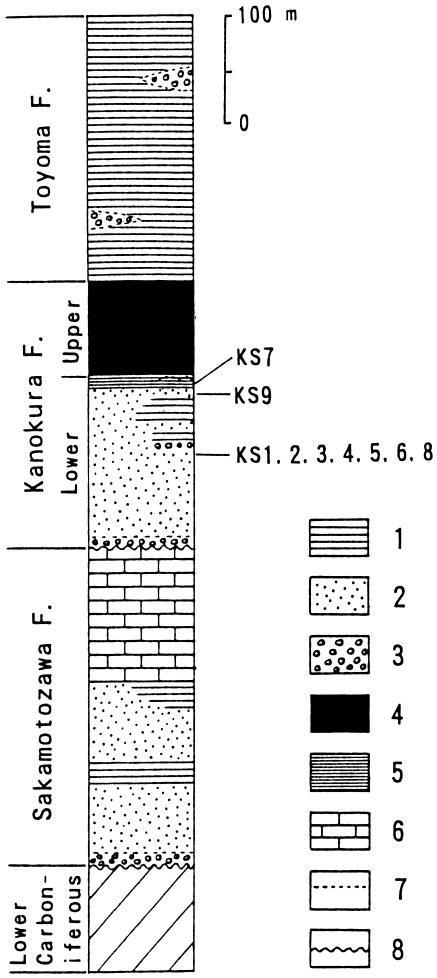

Fig. 5. Columnar section of the Permian rocks in the Setamai area, showing the stratigraphic positions of the fossil localities (KS1-9). 1: shale, 2: sandstone, 3: conglomerate, 4: limestone of the upper Kanokura Formation, 5: argillaceous impure limestone of the lower Kanokura Formation, 6: limestone of the Sakamotozawa Formation, 7: conformity, 8: unconformity.

Spiriferella keilhavii are the Boreal or antitropical elements. On the other hand, *Transennatia gratiosa*, *Tyloplecta* cf. *yangzeensis* and *Leptodus nobilis* are the Tethyan elements. *Linoproductus cora* is a cosmopolitan species; and *Derbyia nipponica* is an endemic form. The Setamai fauna is certainly a Boreal-Tethyan mixed brachiopod fauna.

The age of the Setamai fauna is roughly assigned to the Middle Permian (Kungurian-lower Kazanian) by the occurrence of *Spiriferella keilhavii* (Waterhouse et al., 1978). The fossil-bearing sandstone and argillaceous impure limestone often contains a fusulinacean *Monodiexodina matsubaishi*, an index fossil of the lower Kanokura Formation (*Monodiexodina matsubaishi* Zone, Tazawa, 1976). The lower Kanokura Formation is correlated with the Middle Permian

(Ufimian-Kazanian) (Minato et al., 1978, 1979). From the above fossil evidence and stratigraphical position, we conclude that the upper part of the lower Kanokura Formation in the Setamai area can be correlated with the Middle Permian (Kubergandian-Murgabian).

Consequently, the Setamai fauna is a Middle Permian (Kubergandian-Murgabian) Boreal-Tethyan mixed brachiopod fauna in the southern Kitakami Mountains. This conclusion supports the Tazawa's opinion (Tazawa, 1991, 1998, 1999a, b) that the South Kitakami region was placed on the transitional zone between the Boreal and Tethyan Realms occupying the eastern sea of the Sino-Korean block, i.e., the Inner Mongolian-Japanese Transition Zone of Tazawa (1991) in the Middle Permian time.

Description of species

Order Productida Sarytcheva and Sokolskaya, 1959
Suborder Productidina Waagen, 1883
Superfamily Productoidea Gray, 1840
Family Productellidae Schuchert, 1929
Subfamily Marginiferinae Stehli, 1954
Tribe Paucispiniferini Muir-Wood and Cooper, 1960
Genus *Transennatia* Waterhouse, 1975

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

Productus gratiosus Waagen, 1884, p. 691, pl. 72, figs. 3-7; Rothpletz,1892, p. 76, pl. 10, figs. 15-15c; Diener,1897, p. 23, pl. 3, figs. 3-7; 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 (Jin), 1961, p. 411, pl. 4, figs. 12-18; Wang et al., 1964, p. 291, pl. 45, figs. 14-19.

Gratiosina gratiosa (Waagen): Grant, 1976, pl. 33, figs. 19-26; Licharew and Kotlyar, 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; 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, 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; Tazawa et al., 2000, p. 7, pl. 1, figs. 3-5.

Material.—Five specimens, from localities KS2, KS9: (1) external moulds of two ventral valves, NU-B302, 303; (2) internal moulds of two ventral valves, NU-B304, 305; (3) external mould of a dorsal valve, NU-B306.

Remarks.—These specimens are referred to *Transennatia gratiosa* (Waagen, 1884), originally described from the Wargal and Chhidru Formations of the Salt Range, on the basis of their small shells, strongly convex ventral valve and reticulate ornament on the disks of both valves. The Setamai specimens are smaller (length 12 mm, width 13 mm in the largest specimen, NU-B305) than the Salt Range specimens, but similar to the shells of *T. gratiosa* from the Middle Permian of the Hida Gaien Belt, central Japan (Tazawa, 1991; Tazawa and Matsumoto, 1998), the South Kitakami Belt, northeast Japan (Hayasaka, 1960; Minato et al., 1979; Tazawa et al., 2000), South Primorye, eastern Russia (Licharew and Kotlyar, 1978) and Heilongjiang and Jilin, northeast China (Lee et al., 1980).

Distribution.—Middle to Upper Permian: Salt Range, Himalayas (Gaqoi), Kumaon Himalayas, Cambodia, Vietnam, Timor, south China (Guangxi, Guangdong, Guizhou, Hunan, Sichuan and Hubei), northwest China (Shaanxi), east China (Jiangxi, Zhejiang and Anhui), northeast China (Jilin and Heilongjiang), eastern Russia (South Primorye) and Japan (Hida Gaien and South Kitakami Belts).

Family Productidae Gray, 1840
Subfamily Leioproductinae Muir-Wood and Cooper, 1960
Tribe Tyloplectini Termier and Termier, 1970
Genus *Tyloplecta* Muir-Wood and Cooper, 1960

Tyloplecta cf. *yangtzeensis* (Chao, 1927)
Pl. 1, fig. 5.

Compare.—

Productus yangtzeensis Chao, 1927, p. 50, pl. 5, figs. 1-3; pl. 8, fig. 9.

Productus (Dictyoclostus) yangtzeensis Chao: Huang, 1932, p. 26, pl.1, figs. 1a-c.

Tyloplecta yangtzeensis (Chao): Schréter, 1963, p. 124, pl. 6, figs. 1-7; Nakamura et al., 1981, p. 44, pl. 1, figs. 1-3; pl. 3, figs. 1, 2.

Material.—One specimen, from locality KS8, external mould of a dorsal valve and associated internal mould of a part of the dorsal valve, NU-B335.

Remarks.—This specimen is safely assigned to the genus *Tyloplecta* by its large (length 48 mm, width about 52 mm), subquadrate dorsal valve with large ears, reticulate ornament on the posterior portion and a strong trilobate cardinal process. The Setamai specimen most resembles *T. yangtzeensis* (Chao, 1927), originally described from the Upper Permian of south and east China, in size, shape and external ornament of the dorsal valve. But the poor preservation of the present material makes accurate comparison difficult.

Tyloplecta is a typical Tethyan-type genus and occurs mainly from the Lower to Middle Permian of south China.

Superfamily Echinoconchoidea Stehli, 1954
Family Echinoconchidae Stehli, 1954
Subfamily Juresaniinae Muir-Wood and Cooper, 1960
Tribe Waagenoconchini Muir-Wood and Cooper, 1960
Genus *Waagenoconcha* Chao, 1927

Waagenoconcha sp.
Pl. 1, fig. 4.

Material.—One specimen, from locality KS9, external mould of a dorsal valve and associated internal mould of a part of the dorsal valve, NU-B336.

Remarks.—The single incomplete dorsal valve specimen from Setamai is transverse subquadrate in outline, slightly concave, with low median fold, and strongly geniculated, length about 29 mm, width about 42 mm. The external surface of the dorsal valve is ornamented by numerous quincuncially arranged spine bases and a few weak concentric rugae. Only a strong trilobed cardinal process is observed as the dorsal valve internal structure. This specimen is safely assigned to the genus *Waagenoconcha* by its size, shape and external ornament of the dorsal valve, although the specific identification is difficult.

Waagenoconcha is a common antitropical genus in the Permian time (Tazawa, 1974, 1991; Shi et al., 1995).

Superfamily Linoproductoidea Stehli, 1954
Family Linoproductidae Stehli, 1954
Subfamily Linoproductinae Stehli, 1954
Genus *Linoproductus Chao, 1927*

Linoproductus cora (d'Orbigny, 1842)
Pl. 1, figs. 11-13; Pl. 2, figs. 1-8.

Productus cora, d'Orbigny, 1842, p. 55, pl. 5, figs. 8-10; Waagen, 1884, p. 677, pl. 66, fig. 3; pl. 67, figs. 1, 2; Schellwien, 1900, p. 41, pl. 7, figs. 15-17; Tschernyschew, 1902, p. 279, 621, pl. 33, figs. 2, 3: pl. 35, figs. 1a-c; pl. 54, figs. 1-5; text-figs. 69-71; Kozlowsky, 1914, p. 48, pl. 4, figs. 19a, b; pl. 5, fig. 5; pl. 6, figs. 1-10; Hayasaka, 1925, p. 94, pl. 5, figs. 7-9; Licharew, 1939, p. 88, pl. 19, figs. 5-7.

Productus (*Productus*) *cora* d'Orbigny: Licharew, 1937, p. 29, 101, pl. 6, figs. 1, 2.

Linoproductus cora (d'Orbigny): Chao, 1927, pars, p. 132, pl. 14, figs. 1a, b only; Ivanov, 1935, p. 105, pl. 5, fig. 4; Grabau, 1936, p. 123, pl. 12, figs. 7-9; Sarytcheva and Sokolskaya, 1952, p. 115, pl. 20, fig. 147; Chronic, 1953, p. 88, pl. 7, figs. 7-9; Hayasaka and Minato, 1956, p. 145, pl. 23, figs. 9, 10; Muir-Wood and Cooper, 1960, pl. 111, figs. 3-6; Zavodowsky et al., 1970, p. 94, pl. 5, fig. 3; pl. 36, fig. 2; pl. 62, figs. 10, 11; Samtleben, 1971, p. 80, pl. 7, figs. 2-5; text-fig. 13; Prokofiev, 1975, p. 32, pl. 4, figs. 1-2; Lee and Gu, 1976, p. 258, pl. 167, figs. 11, 12; Tazawa, 1976, pl. 2, fig. 11; Minato et al., 1979, pl. 62, figs. 1, 2; Lee et al., 1980, p. 376, pl. 152, figs. 6-8; pl. 169, fig. 10; Wang et al., 1982, p. 221, pl. 90, figs. 2, 4; Wang, 1984, p. 192, pl. 78, figs. 4a, b; Kalashnikov, 1986, pl. 119, fig. 1; Zhu, 1990, p. 77, pl. 15, figs. 21-24; Wang and Yang, 1998, p. 99, pl. 15, figs. 8-13.

Linoproductus hayasakai Tazawa, 1979, p. 26, pl. 4, figs. 5-11.

Linoproductus sp. Minato et al., 1979, pl. 62, figs. 3, 4.

Material.—Twenty-six specimens, from localities KS1, KS3, KS4: (1) external and internal moulds of four ventral valves, NU-B337-340; (2) internal moulds of nineteen ventral valves, NU-B341-359; (3) external moulds of three dorsal valves, NU-B360-362.

Description.—Shell large for genus, transverse subcircular in outline, widest at hinge; length about 56 mm, width about 80 mm in the largest specimen (NU-B341); length about 36 mm, width about 46 mm in the best preserved specimen (NU-B351). Ventral valve strongly convex in lateral profile, most convex at just posterior to midvalve and slightly convex to nearly flat on anterior half of valve, not geniculated. Anterior profile of the valve unevenly convex, with flattened venter and steeply inclined lateral slopes. Sulcus absent. Umbo small. Ears large, flattened, with blunt, angular extremities. Dorsal valve slightly concave on visceral disk, no fold. Trail not preserved. External surface of both valves ornamented by numerous, fine costellae and several strong rugae; costellae rather regularly developed, numbering 16-18 in 10 mm at midvalve; rugae occuring on ears of ventral valve and on whole surface of dorsal valve.

Internal structures of ventral valve are obscure in the present material.

Remarks.—These specimens are referred to *Linoproductus cora* (d'Orbigny, 1842), originally described from the Lower Permian of Apillapampa, Bolivia, in the trans-

verse shell outline and no ventral sulcus. The Setamai specimens have no spine bases on the ventral valves.

Linoproductus hayasakai Tazawa (1979, p. 26, pl. 4, figs. 5-11) and *Linoproductus* sp. (Minato et al., 1979, pl. 62, figs. 3, 4) from the lower Kanokura Formation of the southern Kitakami Mountains, also lack spine bases on the ventral valves, and they seem to be conspecific with *L. cora*.

Distribution.—Middle Carboniferous to Middle Permian: Peru, Bolivia (Apillapampa), western Russia (Moscow Basin), Urals, northern Russia (Timan), northeastern Russia (Kolyma), Carnic Alps, Caucasus, Uzbekistan (Fergana), Salt Range, south China (Guizhou and Hubei), east China (Fujian), northwest China (Gansu and Xinjiang), north China (Inner Mongolia), northeast China (Heilongjiang) and Japan (South Kitakami Belt).

Subfamily Grandaurispininae Lazarev, 1986
Genus *Cancrinella* Fredericks, 1928

Cancrinella sp.
Pl. 1, figs. 6a, b.

Material.—One specimen, from locality KS9, external mould of a ventral valve, NU-B307.

Remarks.—The single specimen from the Kanokurasawa valley is strongly deformed, but is safely assigned to the genus *Cancrinella* by its small size (length 17 mm, width 12 mm) and numerous elongate spine bases on the ventral valve. This specimen most resembles *Cancrinella kozlowskiana* (Fredericks, 1925, p. 18, pl. 1, figs. 36-40; pl. 2, figs. 86, 87) from the Middle Permian of Cape Kalouzin, South Primorye in size and external ornament. However, accurate comparison is dificult for the poorly preserved specimen.

Suborder Lyttoniidina Williams, Harper and Grant, 2000
Superfamily Lyttonioidea Waagen, 1883
Family Lyttoniidae Waagen, 1883
Sufamily Lyttoniinae Waagen, 1883
Genus *Leptodus* Kayser, 1883

Leptodus nobilis (Waagen, 1883)
Pl. 1, figs. 7-10.

Lyttonia nobilis Waagen, 1883, p. 398, pl. 29, figs.1-3; pl. 30, figs. 1, 2, 5, 6, 8, 10, 11; Diener, 1897, p. 37, pl. 1, figs. 5-7; Noetling, 1904, p. 112, text-figs. 4-7; Noetling, 1905, p. 140, pl. 17, figs. 1, 2; pl. 18, figs. 1-11; text-fig. 2; Mansuy, 1913, p. 123, pl. 13, fig. 10; Mansuy, 1914, p. 32, pl. 6, figs. 7a-d; pl. 7, figs. 1a-e; Diener, 1915, p. 99, pl. 10, fig. 15;

Albrecht, 1924, p. 289, figs. 1a, b; Grabau, 1931, pars, p. 285, pl. 28, figs. 4, 5 only; Huang, 1932, p. 89, pl. 7, figs. 9, 10; pl. 8, figs. 8, 9; pl. 9, figs. 1-8; text-figs. 8-11; Simic, 1933, p. 49, pl. 4, fig. 1.

Lyttonia tenuis Waagen, 1883, p. 401, pl. 30, figs. 3, 4, 7, 9.

Lyttonia sp. Yabe, 1900, p. 2, text-figs. 1, 2.

Lyttonia richthofeni (Kayser): Frech, 1911, pars, p. 135, pl. 20, figs. 2a, b only; Hayasaka, 1917, p. 43, pl. 18, figs. 1-8; Hayasaka, 1922a, p. 62, pl. 11, figs. 1-6; Hayasaka, 1922b, p. 103, pl. 4, figs. 12, 13; Licharew, 1932b, p. 56, 86, pl. 1, figs. 1-16; pl. 2, figs. 1, 2, 5, 7, 10, 12; pl. 3, figs. 2-7; pl. 4, figs. 1-17; pl. 5, figs. 1-4, 6; Mashiko, 1934, p. 182, text-fig.

Lyttonia cf. *tenuis* Waagen: Mansuy, 1912, p. 19, pl. 4, fig. 4; pl. 5, figs. 1a-e; Huang, 1936, p. 493, pl. 1, fig. 6.

Oldhamina (*Lyttonia*) *richthofeni* var. *nobilis* Waagen: Fredericks, 1916, p. 76, pl. 4, fig. 2; text-fig.22.

Lyttonia (*Leptodus*) *richthofeni* Kayser: Hamlet, 1928, p. 31, pl. 6, figs. 1-4.

Lyttonia cf. *richthofeni* (Kayser): Huang, 1932, p. 87, pl. 8, figs. 4a, b.

Lyttonia richthofeni Kayser forma *nobilis* Waagen: Licharew, 1932a, p. 69, 96, pl. 2, figs. 13, 14; pl. 5, figs. 1-4, 6; text-fig. 3.

Leptodus nobilis (Waagen): Wanner and Sieverts, 1935, p. 249, pl. 9, figs. 27, 28; text-figs. 16-18; Ramovs, 1958, p. 497, pl. 2, fig. 3; pl. 10, fig. 3; Termier and Termier, 1960, p. 241, pl. 3, figs. 1-10; Chi-Thuan, 1961, p. 274, pl. 1, figs. 1a, b; Schréter, 1963, pl. 3, figs. 5-8; Sarytcheva, 1964, p. 65, pl. 7, figs. 5-8; text-fig. 1; Ruzhentsev and Sarytcheva, 1965, pl. 39, figs. 6-8; Cooper and Grant, 1974, pl. 191, figs. 8, 9; Grant, 1976, pl. 43, figs. 18, 19; Lee and Gu, 1976, p. 267, pl. 162, figs. 1, 2; Tazawa, 1976, pl. 2, fig. 8; Yang et al., 1977, p. 371, pl. 147, fig. 5; Feng and Jiang, 1978, p. 269, pl. 100, fig. 2; Licharew and Kotlyar, 1978, pl. 14, figs. 13-15; Jin et al., 1979, p. 82, pl. 23, fig. 15; Minato et al., 1979, pl. 66, figs. 1, 4, 5; Zhan, 1979, p. 93, pl. 9, fig. 12; Lee et al., 1980, p. 389, pl. 172, figs. 15, 16; Wang et al., 1982, p. 229, pl. 95, fig. 20; Zhan and Wu, 1982, pl. 4, fig. 4; Zhang et al., 1983, p. 297, pl. 102, figs. 7, 8; Yang, 1984, p. 226, pl. 35, fig. 12; Gu and Zhu, 1985, pl. 1, figs. 31, 33, 34; Liao and Meng, 1986, p. 81, pl. 2, figs. 24, 25; Sremac, 1986, p. 30, pl. 10, figs. 1-2; Tazawa, 1987, text-fig. 1.11; Kotlyar, in Kotlyar and Zakharov, 1989, pl. 20, fig. 6; pl. 23, fig. 12; Liang, 1990, p. 225, pl. 40, figs. 1, 5; Fang and Fan, 1994, p. 83, pl. 23, figs. 1-3; pl. 30, fig. 5; Tazawa and Matsumoto, 1998, p. 7, pl. 2, figs. 7-12; Tazawa et al., 1998, p. 241, figs. 2.1, 2.2, 4; Kato et al., 1999, p. 47, figs. 4a, b.

Lyttonia cf. *nobilis* Waagen: Huang, 1936, p. 493, pl. 1, fig. 5.

Leptodus cf. *nobilis* (Waagen): Thomas, 1957, p. 177, pl. 20, figs. 1-6.

Leptodus richthofeni Kayser: Shimizu, 1961, pl. 18, figs. 14, 15; Schréter, 1963, p. 106, pl. 3, fig. 4; Sarytcheva, 1964, p. 65, pl. 7, figs. 2-4; Yang et al., 1977, p. 372, pl. 147, fig. 10; Yang, 1984, p. 226, pl. 35, fig. 11; Duan and Li, 1985, p. 119, pl. 35, figs. 17-19.

Leptodus ivanovi Fredericks: Minato et al., 1979, pl. 66, fig. 3.

Leptodus sp. Minato et al., 1979, pl. 66, fig. 2; Tazawa, 1987, text-fig. 1.10; Yanagida, 1996, fig. 2.14.

Leptodus tenuis (Waagen): Wang et al., 1982, p. 229, pl. 86, fig. 14; pl. 88, fig. 6; pl. 100, fig. 7; Duan and Li, 1985, p. 119, pl. 35, figs. 14-16; Liang, 1990, p. 226, pl. 40, fig. 9; Zhu, 1990, p. 79, pl. 18, figs. 19-21; Fang and Fan, 1994, p. 83, pl. 23, figs. 4-5; pl. 30, fig. 6.

Gubleria sp. Zhu, 1990, p. 80, pl. 16, fig. 24.

Material.—Seven specimens, from localities KS1, KS7, internal moulds of seven ventral valves, NU-B308-314.

Remarks.—These specimens are referred to *Leptodus nobilis* (Waagen, 1883), originally described from the Wargal and Chhidru Formations of the Salt Range, by their flat ventral valve with thick lateral ridges and nearly straight lateral lobes. The Setamai specimens are smaller than the type specimens. The dimensions of the best preserved specimen (NU-B308) with 18 lateral lobes are: length 34 mm, width 38 mm.

Leptodus richthofeni Kayser, 1883, originally described and figured by Kayser (1883, p. 161, pl. 21, figs. 9-11) from the Upper Permian of Jiangxi (Loping), South China and refigured by Cooper and Grant (1974, pl. 191, figs. 11-13), is easily distinguished from the present species by its more convex ventral valve with sharp lateral ridges and thick and strongly arched lateral lobes.

Distribution.—Lower Permian (Sakmarian) to Upper Permian (Dorashamian): southern Europe (Hungary, Croatia and Serbia), Transcaucasia, Pamir, Kashmir, Salt Range, Kumaon Himalayas, Tibet (Xizang), southern Thailand, Cambodia, Laos, Vietnam, Timor, northern Australia (Northern Territory), south China (Yunnan, Sichuan, Guizhou, Guangxi, Guangdong, Hunan and Hubei), east China (Jiangxi, Fujian, Zhejiang and Anhui), northwest China (Shaanxi, Gansu and Qinghai), north China (Inner Mongolia), northeast China (Heilongjiang and Jilin), eastern Russia (South Primorye) and Japan (South Kitakami, Hida Gaien, Maizuru, Mino and Akiyoshi Belts).

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

Derbyia grandis Waagen, 1884
Pl. 2, figs. 9a, b; Pl. 3, figs. 3a-c.

Derbyia grandis Waagen, 1884, p. 597, pl. 51, figs. 1-1c; pl. 52, figs.1, 3: pl. 53, figs. 3, 5; Tschernyschew, 1902, p. 207, 580, pl. 24, figs. 1, 2; pl. 26, figs. 5a, b; text-figs. 59, 60;

Broili, 1916, p. 7, pl. 115, fig. 9; Frebold, 1950, p. 41, pl. 1, figs. 5, 5a; Grunt and Dmitriev, 1973, p. 84, pl. 3, figs. 1-4; Manankov, 1973, pl. 8, figs. 4, 5; Kulikov, 1974, p. 82, pl. 1, figs. 6a, b, v; Lee and Gu, 1976, p. 236, pl. 161, fig. 12; Licharew and Kotlyar, 1978, pl. 12, fig. 1; Lee et al., 1980, p. 336, pl. 159, fig. 13; Kalashnikov, 1986, pl. 114, fig. 1; Nakamura et al., 1992, pl. 1, fig. 1; Kalashnikov, 1993, p. 23, pl. 6, figs. 1, 2; pl. 7, fig. 7; Fang and Fan, 1994, p. 73, pl. 27, figs. 5-8; pl. 28, figs. 1, 2.

Derbyia cf. *grandis* Waagen: Frech, 1911, p. 125, pl.18, figs. 4a-d; Stepanov, 1937, p. 110, 174, pl. 1, fig. 5; Harker, 1960, p. 52, pl. 16, figs. 9, 10; Bamber and Waterhouse, 1971, pl. 18, fig. 1; Manankov, 1979, p. 57, pl. 4, fig. 1; text-fig. 25.

Derbyia aff. *grandis* Waagen: Gobbett, 1963, p. 54, pl. 2, figs. 1, 2.

Material.—Two specimens, from localities KS1, KS9, external and internal moulds of two ventral valves, NU-B363, 364.

Description.—Shell large for genus, transverse outline; length about 63 mm, width 115 mm+ in the better preserved specimen (NU-B363). Ventral valve slightly concave to nearly flat in both profiles, ornamented by numerous costellae and several strong, irregular rugae. Costellae thin, with broad interspaces, and increasing by intercalation; numbering 10-11 in 10 mm at midvalve.

Ventral valve interior with strong, high median septum and large flabellate muscle scar. Median septum extending about one-third valve length. Muscle scar deeply impressed and surrounded by raised ridges.

Remarks.—These specimens can be referred to *Derbyia grandis* Waagen, 1884, originally described from the Wargal and Chhidru Formations of the Salt Range, on account of their large, transverse shells, and the external ornament of the ventral valves consisting of strong, irregular rugae and numerous costellae with broad interspaces. The type specimens from Salt Range differ from the present material in having more strongly convex ventral valve. The Setamai specimens closely resemble the shells, described as *Derbyia* cf. *grandis*, from the Assistance Formation of Devon Island (Harker, 1960, p. 52, pl. 16, figs. 9, 10) and from the Kapp Starostin Formation of Spitsbergen (Gobbett, 1963, p. 54, pl. 2, figs. 1, 2), in their slightly concave to nearly flattened ventral valve.

Distribution.—Lower to Upper Permian, mostly Lower and Middle Permian: Arctic Canada (northern Yukon Territory and Devon Island), northeast Grenland, Spitsbergen, northern Russia (Timan, northern Urals and Kolyma-Omolon region), Salt Range, southeast Pamir, Timor, southwest China (Yunnan), east China (Jiangsu), north China (Inner Mongolia), northeast China (Jilin), eastern Russia (South Primorye) and Japan (South Kitakami Belt).

Derbyia nipponica Nakamura, 1972

Pl. 3, figs. 1, 2, 4.

Derbyia magnifica Licharew: Hayasaka and Minato, 1956, p. 141, pl. 23, figs. 1a-c; Hayasaka, 1960, p. 45, pl. 2, figs. 5, 6.

Derbyia nipponica Nakamura, 1972, p. 399, pl. 7, figs. 1, 4-9; Minato et al., 1979, pl. 60, figs. 1-4.

Material.—Five specimens, from localities KS1, KS9: (1) external and internal moulds of three ventral valves, NU-B365-367; (2) internal mould of a ventral valve, NU-B368; (3) internal mould of a dorsal valve, NU-B369.

Description.—Shell medium to large for genus, transversely subelliptical in outline; greatest width near midvalve; length 41 mm, width 49 mm in the best preserved ventral valve specimen (NU-B365); length 51 mm, width about 73 mm in the largest dorsal valve specimen (NU-B369).

Ventral valve slightly convex to nearly flat, ornamented by numerous fine costellae and 3-5 irregular, strong rugae. Costellae regularly developed, increasing by intercalation, and having narrow interspaces; numbering 19-20 in 10 mm at midvalve. Dorsal valve slightly but more strongly convex than ventral valve. External ornament obscure in the present material.

Internally, ventral valve having thin, long median septum, extending near midvalve. Dorsal valve having high cardinal process and divergent, strong crural plates.

Remarks.—The Setamai specimens are referred to *Derbyia nipponica* Nakamura, 1972, originally described as *Derbyia magnifica* Licharew, 1932, by Hayasaka and Minato (1956, p. 141, pl. 23, figs. 1a-c) from the lower Kanokura Formation in the Imo and Setamai areas, southern Kitakami Mountains, and redescribed as *D. nipponica* by Nakamura (1972, p. 399, pl. 7, figs. 1, 4-9) on new materials from the Imo area, one of the type localities. *D. nipponica* is characterized by its weakly biconvex and transverse shell, short hinge, and regularly developed, fine costellae with narrow interspaces.

Derbyia magnifica Licharew, 1932, originally described as *Derbya magna* Licharew (1932a, p. 18, 40, pl. 1, figs. 1, 2, 6, 7, 13; pl. 2, figs.1a-c; pl. 3, figs. 1a, b) from the Lower Permian of northern Caucasus, differs from *D. nipponica* in having long hinge marking the greatest width, ventral fold and dorsal sulcus.

Derbyia regularis Waagen (1884, p. 594, pl. 53, figs. 1, 2, 4) from the Amb and Wargal Formations of the Salt Range is also medium to large, transverse Derbyia, but it differs from the present species in having more less dense costellae.

Distribution.—Middle Permian of Japan (South Kitakami Belt).

Order Spiriferida Waagen,1883

Suborder Spiriferidina Waagen, 1883

Superfamily Spiriferoidea King, 1846

Family Spiriferellidae Waterhouse, 1968

Subfamily Spiriferellinae Waterhouse, 1968

Genus *Spiriferella* Tschernyschew, 1902

Spiriferella keilhavii (von Buch, 1846)
Pl. 4, figs. 1-10.

Spirifer keilhavii von Buch, 1846, p. 74, figs. 2a, b.
Spiriferina keilhavii (von Buch): Wiman, 1914, pl. 2, figs. 25-30; pl. 3, fig. 1.
Spiriferina draschei (Toula): Wiman, 1914, p. 38, pl. 3, fig. 2 only.
Spiriferella keilhavii (von Buch): Frebold, 1931, p. 28, pl. 5, figs. 7-9; Grabau, 1931, p. 164, pl. 20, figs. 9a-c; pl. 21, figs. 1-5; Frebold, 1937, p. 46, pl. 11, fig. 9; Stepanov, 1937, p. 143, 179, pl. 7, figs. 8-11; Dunbar, 1955, p. 139, pl. 25, figs. 1-9; pl. 26, figs. 1-11; pl. 27, figs. 1-14; Harker, 1960, p. 72, pl. 22, figs. 9-11; pl. 23, figs. 1, 2; Gobbett, 1963, p. 152, pl. 20, figs. 8-10; Yanagida, 1963, pl. 9, figs. 4-9; pl. 10, figs. 1-7; Nelson and Johnson, 1968, p. 736, pl. 96, figs. 7, 8, 12; text-figs. 3e, 8a, 9, 13b; Koizumi, 1979, pl. 1, figs. 10, 11 only; Minato et al., 1979, pl. 67, figs. 1-3; Lee et al., 1980, p. 418, pl. 178, fig. 8; Tazawa and Gunji, 1982, p. 70, pl. 4, figs. 4-7; Waterhouse and Waddington, 1982, p. 28, pl. 6, figs. 3-14; text-figs. 16e, g, h, i, 19; not pl. 4, fig. 15; Lee et al., 1985, p. 122, pl. 2, figs. 1a, b, 5, 8; Tazawa et al., 1999, p. 160, fig. 2.2-5; Tazawa, 1999a, p. 5, pl. 1, figs. 2-6.
Spiriferella parryana (Toula): Frebold, 1937, p. 45, pl. 11, fig. 6.
Spiriferella aff. *keilhavii* (von Buch): Bamber and Waterhouse, 1971, pl. 20, fig. 7.

Material.—Twenty specimens, from locality KS9: (1) external and internal moulds of two ventral valves, NU-B315, 316; (2) external moulds of two ventral valves, NU-B317, 318; (3) external mould of a dorsal valve and internal mould of the conjoined valve, NU-B319; (4) external and internal moulds of a dorsal valve, NU-B320; (5) external moulds of four dorsal valves, NU-B321-324; (6) internal mould of a conjoined valve, NU-B325; (7) internal moulds of six ventral valves, NU-B326-331; (8) internal moulds of three dorsal valves, NU-B332-334.

Description.—Shell large for genus, slightly transverse subquadrate in outline, with greatest width at or near hinge; length more than 29 mm, width about 63 mm in the largest specimen (NU-B317); length 29 mm, width about 30 mm in the best preserved ventral valve specimen (NU-B318). Ventral valve gently convex in lateral profile, with maximum convexity at umbonal slope. Beak and interarea not well preserved. Sulcus wide and deep, with U-shaped cross-section and two minor costae on each side of inner slopes. External surface of ventral valve ornamented by 10-12 strong costae and numerous very fine concentric lirae; costae broad, rounded, and projecting fascicles of 2-3. Dorsal valve slightly convex in lateral profile. Fold wide and low, with a deep median groove commencing at hinge. External ornament of dorsal valve same as ventral valve.

Internally, ventral valve having a deeply impressed, large, heart-shaped muscle field and a pair of strong dental plates; adductors long and narrow; diductors wide and weakly striated longitudinally. Dorsal valve having a small, striated cardinal process. Other internal structures

Remarks.—These specimens are referred to *Spiriferella keilhavii* (von Buch, 1846), originally described from the Middle Permian of Mt. Misery, Bear Island, by their transverse shell, weakly fasciculated costae on both valves and broad, low fold with a deep median groove.

Spiriferella lita Fredericks, 1924, from the Chandalaz Formation of South Primorye (Fredericks, 1924, p. 36, pl. 1, figs. 16-27, text-fig. 2) differs from *S. keilhavii* in having strong and simple costae on the ventral valve.

Spiriferella loveni (Diener, 1903), redescribed and refigured by Waterhouse and Waddington (1982, p. 22, pl. 5, figs. 2-17; pl. 6, figs. 1, 2; text-figs. 16b, d, f, 17, 18) on the specimens from the Middle Permian of the Canadian Arctic region, is distinguished from *S. keilhavii* by its high, distinct dorsal fold with a broad, deep median groove.

Distribution.—Middle Permian (Bolorian-Midian): Arctic Canada (Yukon Territory, Devon Island and Ellesmere Island), Greenland, Svalbard (Spitsbergen and Bear Island), north China (Inner Mongolia), northeast China (Heilongjiang) and Japan (South Kitakami and Hida Gaien Belts).

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Explanation of Plates

(All figures are in natural size)

Plate 1

Figs. 1-3. *Transennatia gratiosa* (Waagen)
1. Internal mould of a ventral valve, NU-B305; 2. External latex cast of a ventral valve, NU-B302; 3. Anterior view of an internal mould of a ventral valve, NU-B304.

Fig. 4. *Waagenoconcha* sp.
External mould of a dorsal valve, NU-B336.

Fig. 5. *Tyloplecta* cf. *yangzeensis* (Chao)
External mould of a dorsal valve, NU-B335.

Figs. 6a, b. *Cancrinella* sp.
External mould and external latex cast of a ventral valve, NU-B307.

Figs. 7-10. *Leptodus nobilis* (Waagen)
Internal moulds of four ventral valves, 7. NU-B308; 8. NU-B309; 9. NU-B313; 10. NU-B314.

Figs. 11-13. *Linoproductus cora* (d'Orbigny)
11a, b. External latex cast and internal mould of a ventral valve, NU-B337;12, 13. Internal moulds of two ventral valves, 12. NU-B357; 13. NU-B341.

Plate 1

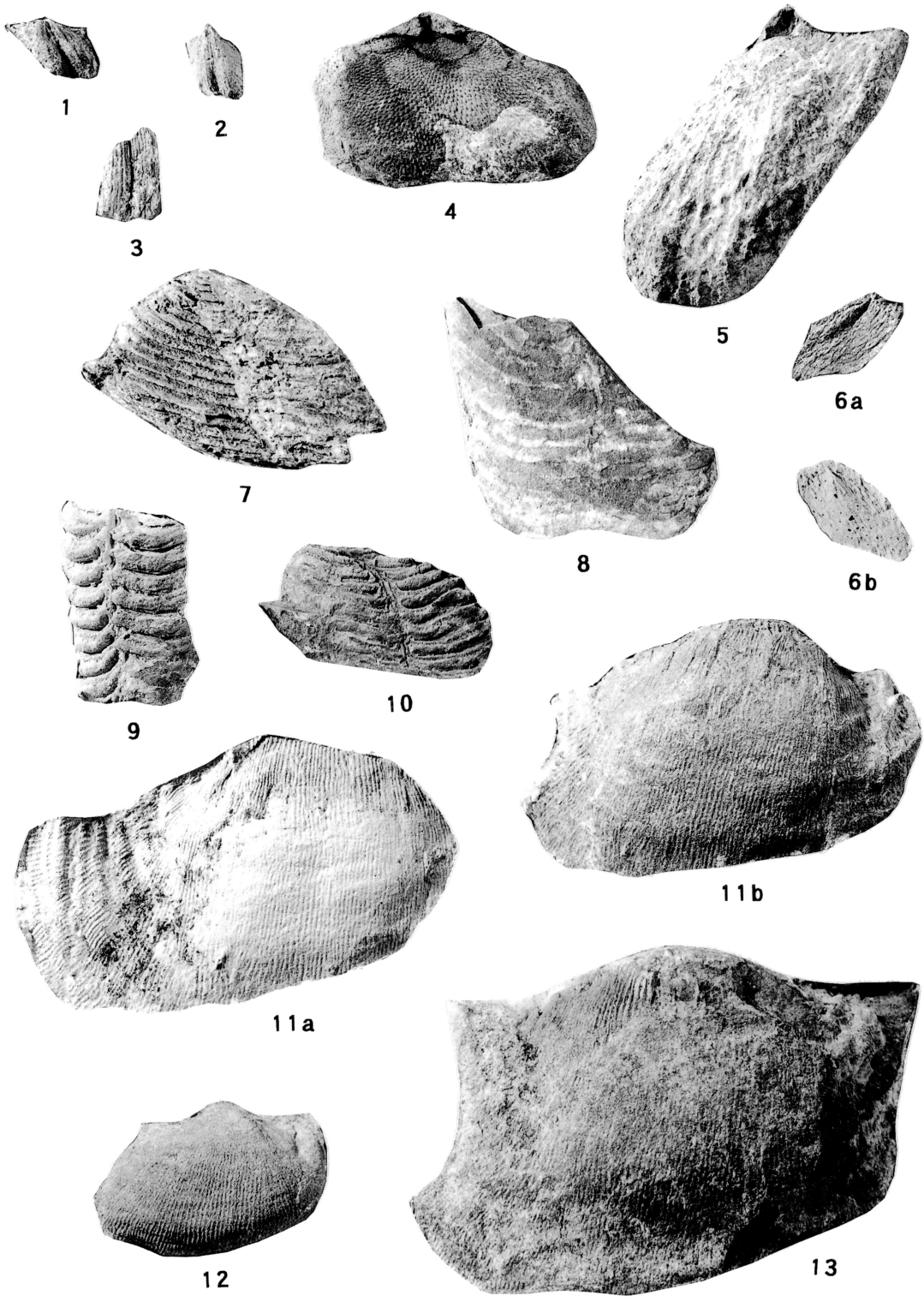

Plate 2

Figs. 1-8. *Linoproductus cora* (d'Orbigny)

1a, b, c, d. Ventral, posterior, anterior and lateral views of an internal mould of a ventral valve, NU-B344; 2, 3. External latex casts of two dorsal valves, 2. NU-B361; 3. NU-B362; 4-6. Internal moulds of three ventral valves, 4. NU-B351; 5. NU-B352; 6. NU-B350; 7. External latex cast of a ventral valve, NU-B340; 8. External mould of a dorsal valve, NU-B360.

Figs. 9a, b. *Derbyia grandis* Waagen

External latex cast and internal mould of a ventral valve, NU-B364.

Plate 2

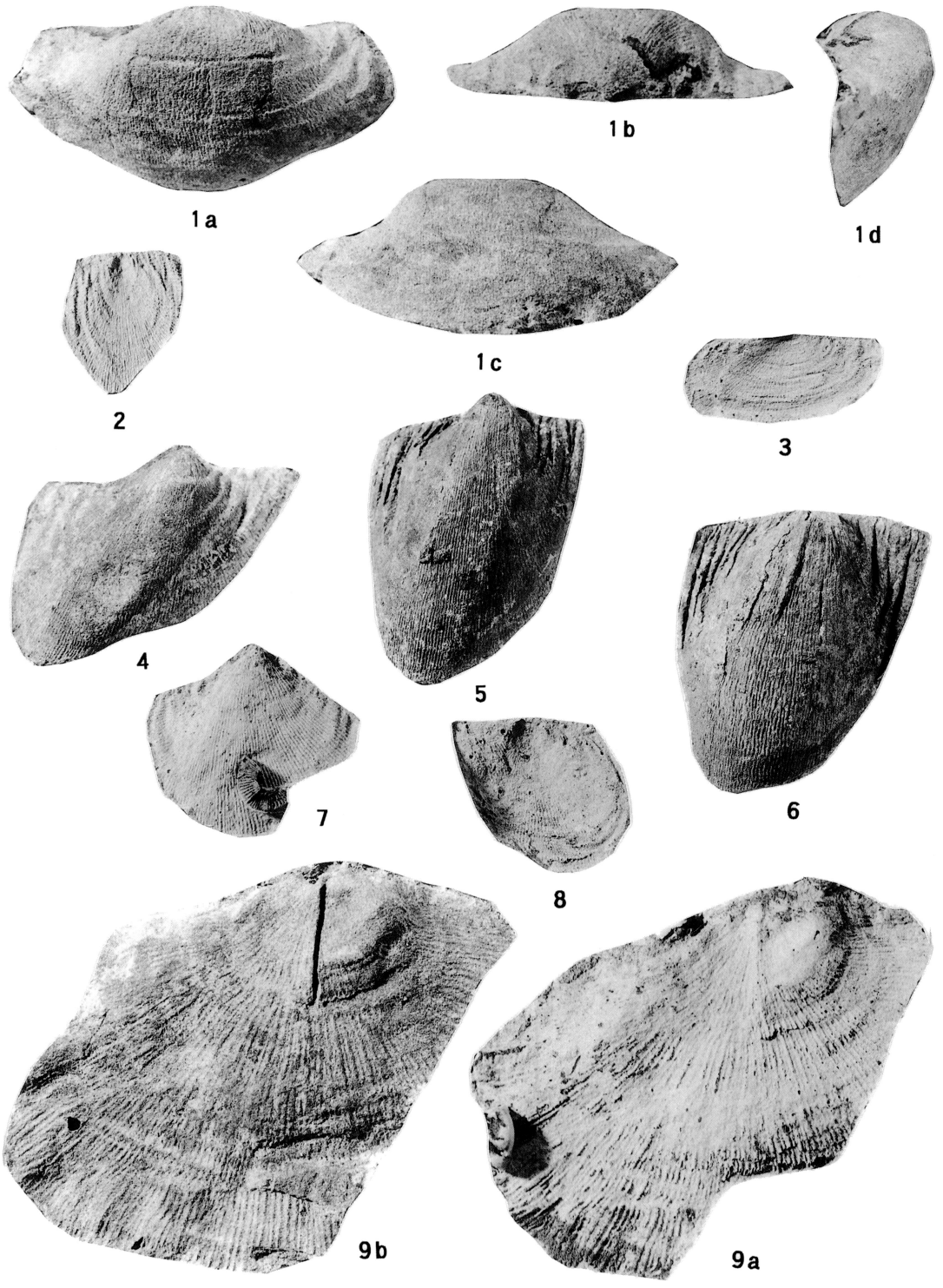

Plate 3

Figs. 1, 2, 4. *Derbyia nipponica* Nakamura

1a, b. External latex cast and internal mould of a ventral valve, NU-B365; 2. Internal mould of a tral valve, NU-B367.4. Internal mould of a ventral valve, NU-B367.

Figs. 3a-c. *Derbyia grandis* Waagen

External latex cast, internal mould and internal latex cast of a ventral valve, NU-B363.

Plate 3

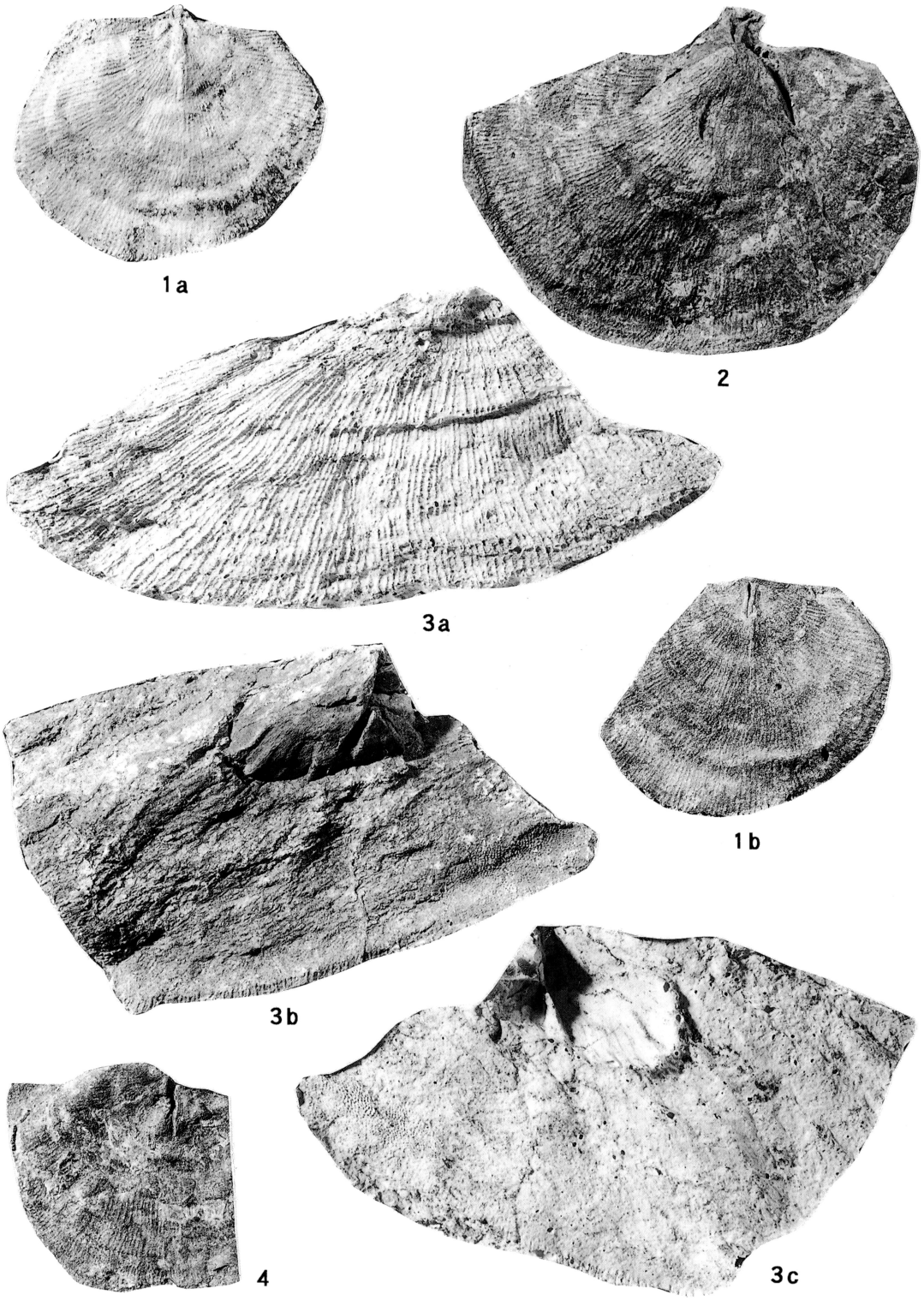

Plate 4

Figs. 1-10. *Spiriferella keilhavii* (von Buch)

1a, b. Ventral and dorsal views of internal mould of a conjoined valve, NU-B325; 2. External latex cast of a ventral valve, NU-B317; 3. External latex cast of a dorsal valve, NU-B321; 4. External latex cast of a ventral valve, NU-B318; 5a, b. Internal mould and internal latex cast of a dorsal valve, NU-B332; 6. Internal mould of a ventral valve, NU-B326; 7a, b. External latex cast and internal mould of a ventral valve, NU-B315; 8a, b. Internal mould and internal latex cast of a ventral valve, NU-B329; 9a, b. Internal mould and internal latex cast of a dorsal valve, NU-B334; 10a, b. Internal mould and internal latex cast of a ventral valve, NU-B327.

Plate 4