Orthotetoids from the Lower Permian (Sakmarian) of the Nagaiwa-Sakamotozawa area, South Kitakami Belt, northeast Japan

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Abstract

A lot of brachiopods occur in the basal part of the Sakamotozawa Formation (Sakmarian) in the Nagaiwa-Sakamotozawa area, South Kitakami Belt, northeast Japan. Orthotetoid brachiopods are the most abundant taxa within the Nagaiwa-Sakaotozawa fauna. In this paper, the following five species of the orthotetoid brachiopods are described: *Meekella striatocostata* (Cox), *Meekella nagaiwensis* sp. nov., *Derbyia crassa* (Meek and Hayden), *Derbyia dorsosulcata* Liu and Waterhouse, and *Derbyia sakamotozawensis* sp. nov.

Key words: brachiopod, Lower Permian, Nagaiwa-Sakamotozawa area, orthotetoid, Sakamotozawa Formation, Sakmarian, South Kitakami Belt.

Introduction

Since the pioneering works of Yabe (1900) and Hayasaka (1922), more than 130 species of brachiopods have been described from the Permian rocks of the South Kitakami Belt, northeast Japan. Nakamura (1959, 1960, 1972), Tazawa (1974) and Tazawa and Shintani (2010) described the Early Permian brachiopods of 23 species in 16 genera from the Sakamotozawa Formation in the Yukisawa, Nakadaira, and Kamiyasse areas. However, the whole content of the Early Permian brachiopod fauna is uncertain. Recently, Shintani (2009) reported a brachiopod assemblage with rich faunal diversity consisting of 40 species in 26 genera from the basal part of the Sakamotozawa Formation in the Nagaiwa-Sakamotozawa area, South Kitakami Belt, although most of the species of this fauna remain undescribed. The

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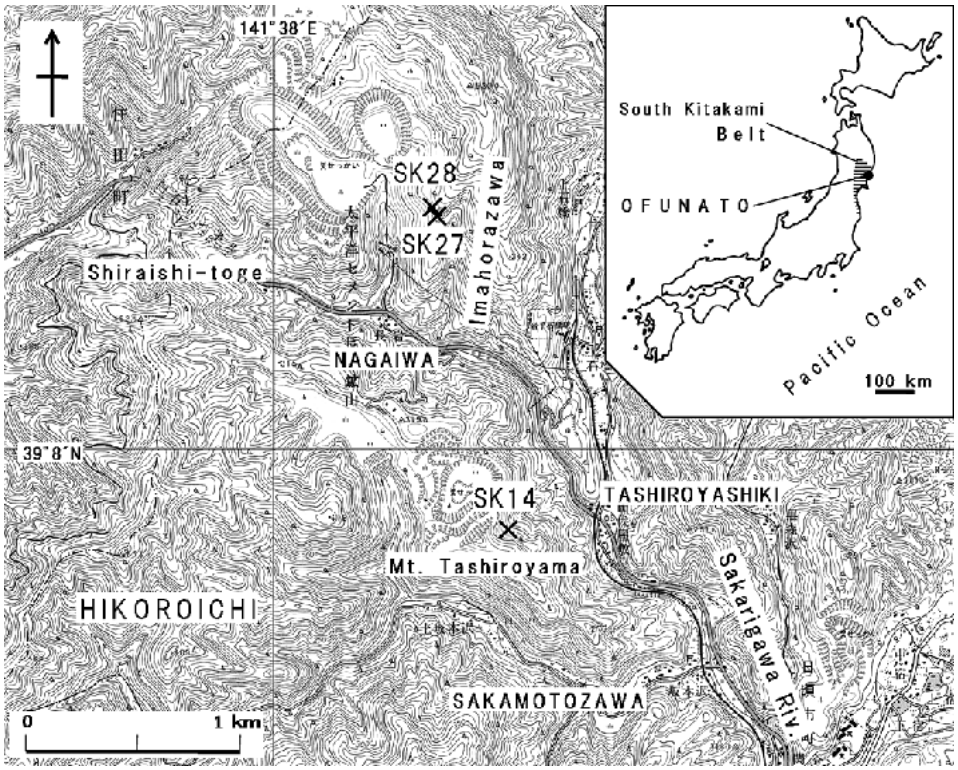


Fig. 1. Index map showing the fossil localities SK14, SK27, and SK28 in the Nagaiwa-Sakamotozawa area (using the topographical map of "Sakari" scale 1:25,000 published by the Geospatial Information Authority of Japan).

age of this fauna has been assigned to the Sakmarian by the fusulinid assemblage (Ueno et al. 2007). Nagaiwa-Sakamotozawa fossil assemblage indicates the comparison between brachiopods and fusulines. Therefore, these brachiopods are important to compare with Permian Boreal and Tethyan brachiopod faunas.

The purpose of this paper is to describe some orthotetoid brachiopods (*Meekella* and *Derbyia*) that represent the most abundant taxa within the Nagaiwa-Sakaotozawa fauna. The brachiopod specimens described in this paper are registered and housed in the Department of Geology, Faculty of Science, Niigata University, Niigata, Japan.

Stratigraphy

The Lower Permian Sakamotozawa Formation, first defined by Onuki, 1937, is typically distributed in the Nagaiwa-Sakamotozawa area, Hikoroichi-cho, Ofunato City, Iwate Prefecture, northeast Japan (Fig. 1). The total thickness of this formation is 685 m. The formation consists

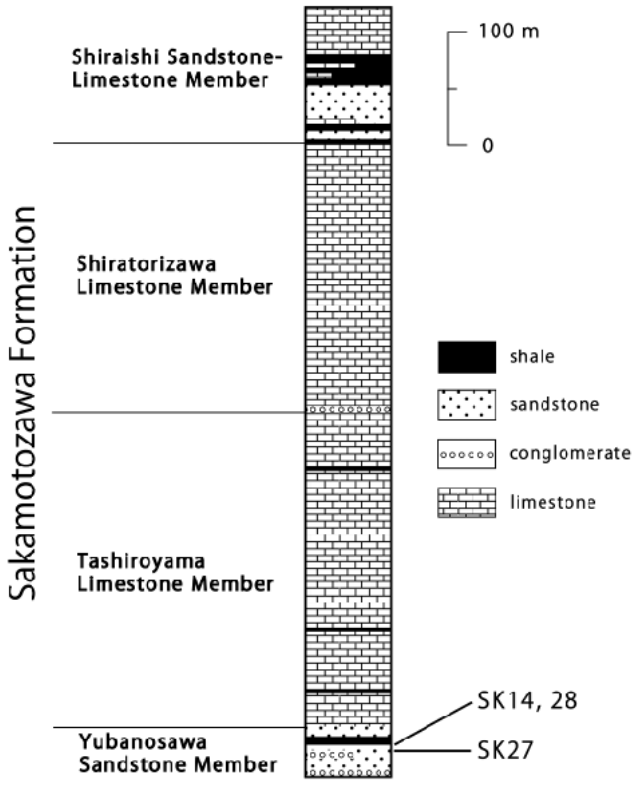


Fig. 2. Generalized columnar section of the Sakamotozawa Formation in the Nagaiwa-Sakamotozawa area, showing the fossil horizons SK14, SK27, and SK28.

mainly of limestone, along with shale, sandstone, and conglomerate in the basal and uppermost parts. The Sakamotozawa Formation is subdivided into the Yubanosawa Sandstone Member (45 m thick), the Tashiroyama Limestone Member (280 m), the Shiratorizawa Limestone Member (240 m), and the Shiraishi Sandstone-Limestone Member (120 m), in ascending stratigraphic order (Fig. 2). These four members were named by Ueno et al. (2007). This subdivision corresponds to the Sa, Sb, Sc, and Sd members of Mikami (1965), and Kanmera and Mikami (1965), respectively. Brachiopods were collected from two horizons at three localities (SK14, SK27, SK28) in the Yubanosawa Sandstone Member. The lithology, stratigraphy, and topography of these localities are outlined below.

SK14: The rocks at this locality, cropping out 160 m northeast of Mt. Tashiroyama (Lat. 39°8'15" N, Long. 141°39'12"E), consists of grey to light-brown medium-grained sandstone and light-grey coarse-grained sandstone. The fossil-bearing horizon is located 28 m above the base of the Sakamotozawa Formation.

SK27: The brachiopods-bearing strata are composed of dark-grey to grey sandy shale and grey fine-grained sandstone. This locality exposed in the upstream of Imahorazawa, approximately 690 m north-northeast of the junction between the Sakarigawa River and

Imahorazawa (Lat. 39°9'9" N, Long. 141°38'56"E). Brachiopods occur 20 m above the base of the Sakamotozawa Formation.

SK28: The fossil-bearing rocks consist of grey to light-brown medium grained sandstone and light-grey coarse-grained sandstone. The strata exposed approximately 720 m north of the junction between the Sakarigawa River and Imahorazawa (Lat. 39°9'11" N, Long. 141°38'54"E). This horizon is located 28 m above the base of the Sakamotozawa Formation. The rocks and fossil assemblage of SK28 are similar to SK14. SK28 is considered to be almost the same horizon as SK14.

Ueno et al. (2007) described five fusulinid species (*Schubertella* sp., *Quasifusulina*? sp., *Rugosofusulina* sp., *Eoparafuslina* aff. *perplexa* (Grozdilova and Lebedeva), and *Nipponitella explicata* Hanzawa from SK27, and concluded that the basal part of the Sakamotozawa Formation is correlated with the Sakmarian. Tazawa and Shintani (2010) described two Boreal-type species (*Waagenoconcha humboldti* (d'Orbigny) and *Rhynchopora* sp.) and a Tethyan-type species (*Scacchinella* sp.) within the Nagaiwa-Sakamotozawa fauna. The authors concluded that this fauna was a Boreal-Tethyan mixed fauna in the Early Permian.

Orthotetoids within the Nagaiwa-Sakamotozawa fauna

The numbers and localities of the orthotetoid brachiopods described herein are as follows:

Meekella striatocostata (Cox, 1857) 4 (SK14, SK27, SK28)
Meekella nagaiwensis sp. nov. 5 (SK14, SK27, SK28)
Derbyia crassa (Meek and Hayden, 1858) 40 (SK14, SK28)
Derbyia dorsosulcata Liu and Waterhouse, 1985 ..... 12 (SK14, SK28)
Derbyia sakamotozawensis sp. nov. 7 (SK14)

Among these species, *M. striatocostata* is common in the Sakamotozawa Formation. This cosmopolitan species occurs in the Upper Carboniferous to Lower Permian of the United States, the Lower Permian of northern Russia, and the Lower to Middle Permian of northeast Japan.

M. nagaiwensis, which is common in the Sakamotozawa Formation, is similar to *M. kueichowensis* Huang described from the Upper Permian of South China.

D. crassa, which is very abundant in the Sakamotozawa Formation, is a cosmopolitan species that occurs in the Upper Carboniferous of the United States, Italy, and North China, as well as in the Lower Permian of northern Russia and northeast Japan.

D. dorsosulcata is abundant in the Sakamotozawa Formation. This species was originally described from the Middle Permian of North China.

The new species *D. sakamotozawensis* is common in the Sakamotozawa Formation. This

species is similar to *D. grandis* Waagen which is an antitropical brachiopod previously reported from the Lower-Upper Permian of Arctic Canada, Spitsbergen, northern Russia, Pakistan (Salt Range), southeast Pamir, Timor, Southwest China, East China, North China, Northeast China, eastern Russia, and northeast Japan.

Systematic descriptions

The supra-generic classification used in this paper follows Williams et al. (2000).

Order Orthotetida Waagen, 1884
Suborder Orthotetidina Waagen, 1884
Superfamily Orthotetoidea Waagen, 1884
Family Meekellidae Stehli, 1954
Subfamily Meekellinae Stehli, 1954
Genus *Meekella* White and St. Jhon, 1867

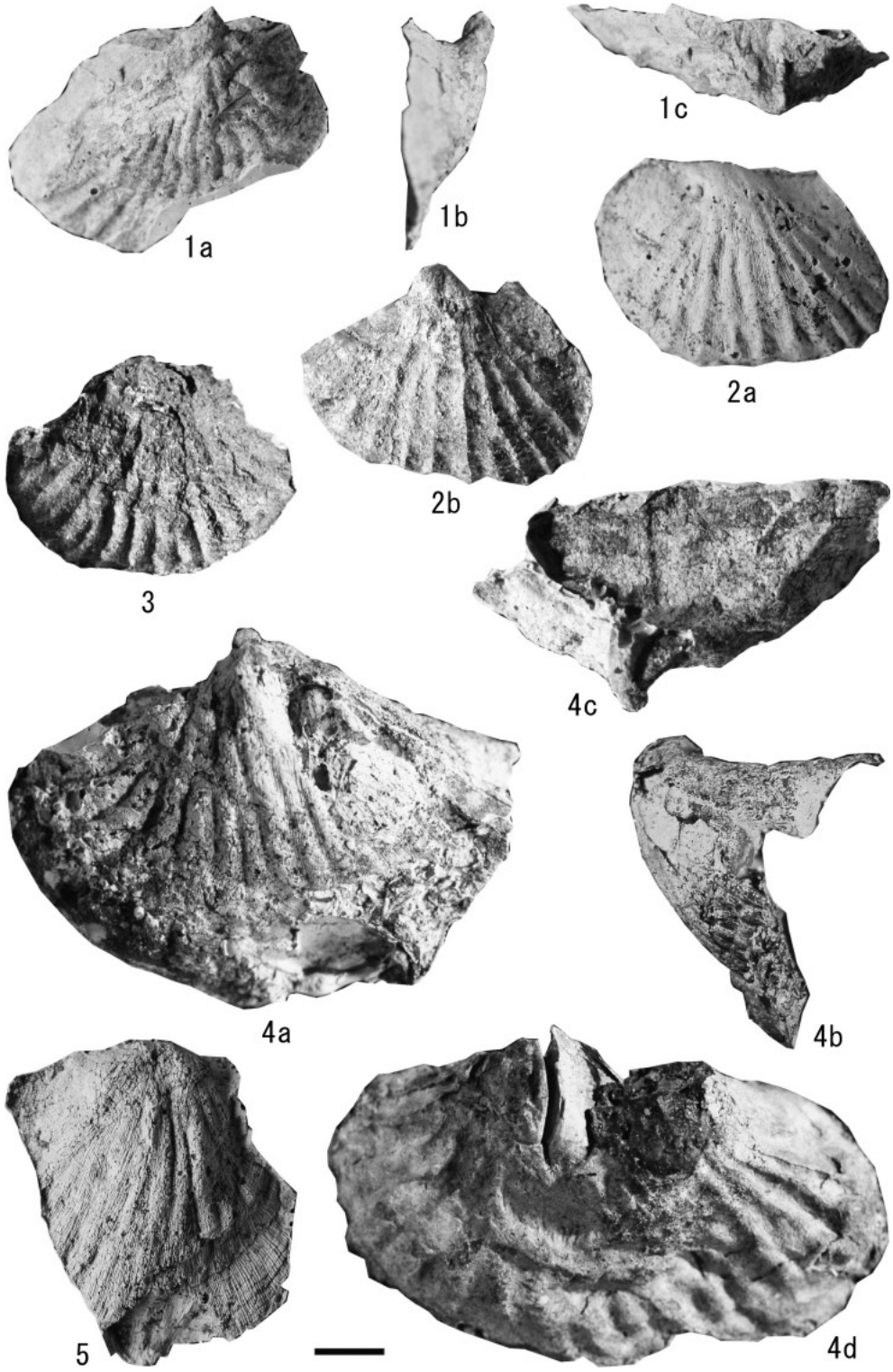
Type species.—*Meekella striatocostata* (Cox, 1857).

Meekella striatocostata (Cox, 1857)
Figs. 3.1a-3.3

Plicatula striatocostata Cox, 1857, p. 568, pl. 8, fig. 7.
Meekella striatocostata? (Cox): Kayser, 1883, p. 178, pl. 23, fig. 8.
Meekella striatocostata (Cox): Girty, 1909, p. 54, pl. 6, fig. 6; Mansuy, 1913, p. 51, pl. 4, fig. 13; King, 1931, p. 56, pl. 7, fig. 9; Dunbar and Condra, 1932, p. 125, pl. 16, figs. 1-10; pl. 17, figs. 3a-3c; Hayasaka, 1937, p. 263, text-figs. 1, 2; Elias, 1957, p. 493, pl. 52, fig. 5; Hayasaka, 1963, p. 753, fig. 5; Sturgeon and Hoare, 1968, p. 24, pl. 2, figs. 1-3; West, 1977, p. 741, text-fig. 3; Jin et al., 1979, p. 78, pl. 22, figs. 1-3; Li et al., 1986, p. 218, pl. 1, fig. 6.
Meekella cf. *striatocostata* (Cox): Nakamura, 1972, p. 385, pl. 5, figs. 1a, 1b.
Meekella cf. *striatocostata* (Cox): Sutherland and Harlow, 1973, p. 20, pl. 1, fig. 18.

Material.—Four specimens from localities SK14, SK27, and SK28: (1) external mould of a ventral valve, NU-B1212; (2) external and internal moulds of two dorsal valves, NU-B1213, 1214; (3) internal mould of a dorsal valve, NU-B1215.

Description.—Shell medium to moderately large for genus, transversely subelliptical in outline; hinge straight, equal to about three-fifths of greatest width at midvalve; length 35 mm, width 63 mm in the ventral valve specimen (NU-B1212); length 29 mm, width 42 mm in the best-preserved, average-sized dorsal valve specimen (NU-B1213). Ventral valve strongly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convex in lateral profile; sulcus absent; interarea moderately high and apsacline; umbonal angle about 100°. Dorsal valve moderately convex, most gibbous at midvalve. External surface of both valves ornamented with numerous fine radial costellae and regular rounded plicae; costellae increasing in number by intercalation, converging toward crest of plicae, and numbering 15-17 in 5 mm at midvalve; costae arising gradually near umbonal area, increasing in number by intercalation, and numbering 8-14 in 5 mm.

Remarks.—These specimens are referred to *Meekella striatocostata* (Cox, 1857), described from the Moscovian-Kasimovian of Kentucky, the United States, on account of size, shape, and external ornament of both valves, especially in its trigonal shaped ventral valve.

Meekella skenoides Girty (1908, p. 206, pl. 30, figs. 8,9), from the Delaware Mountain Formation of West Texas, is similar in size and trigonal outline. However, *M. skenoides* has a more strongly convex ventral valve and more angulated plicae.

Meekella eximia (Eichwald, 1840, p. 157, pl. 17, figs. 4-8), from the Kasimovian of Kasimov, western Russia, is similar in size and external ornament, but differs from the present species in having a less convex ventral valve and flat interarea.

Distribution.—Upper Carboniferous (Bashkirian-Kasimovian) of the United States (Colorado, Iowa, Kansas, Missouri, Nebraska, New Mexico, Ohio, and Oklahoma); Lower Permian (Asselian) of northern Russia (northern Urals); Lower Permian (Sakmarian-Artinskian) of the United States (Texas); Lower Permian (Sakmarian) to Middle Permian (Roadian) of northeast Japan (South Kitakami Belt).

Meekella nagaiwensis sp. nov.
Figs. 3.4a-3.5, 4.1a-4.3

Etymology.—Named after the fossil locality, Nagaiwa.

Material.—Five specimens, from localities SK14, SK27, and SK28: (1) external and internal moulds of a ventral valves, NU-B1216 (holotype); (2) external and internal moulds of two dorsal valves, NU-B1217, 1218; (3) external mould of a dorsal valve, NU-B1219; (4) internal mould of a dorsal valves, NU-B1220.

Diagnosis.—Large, transverse *Meekella*, having a strongly convex ventral valve and a slightly convex to nearly flat dorsal valve, with numerous irregular plicae on both valves.

Description.—Shell large for genus, transversely subcircular in outline; hinge shorter than greatest width, the latter occurring at midvalve; length 58 mm, width 82 mm in the best-preserved, average-sized ventral valve specimen (NU-B1216); length 48 mm, width 66 mm in

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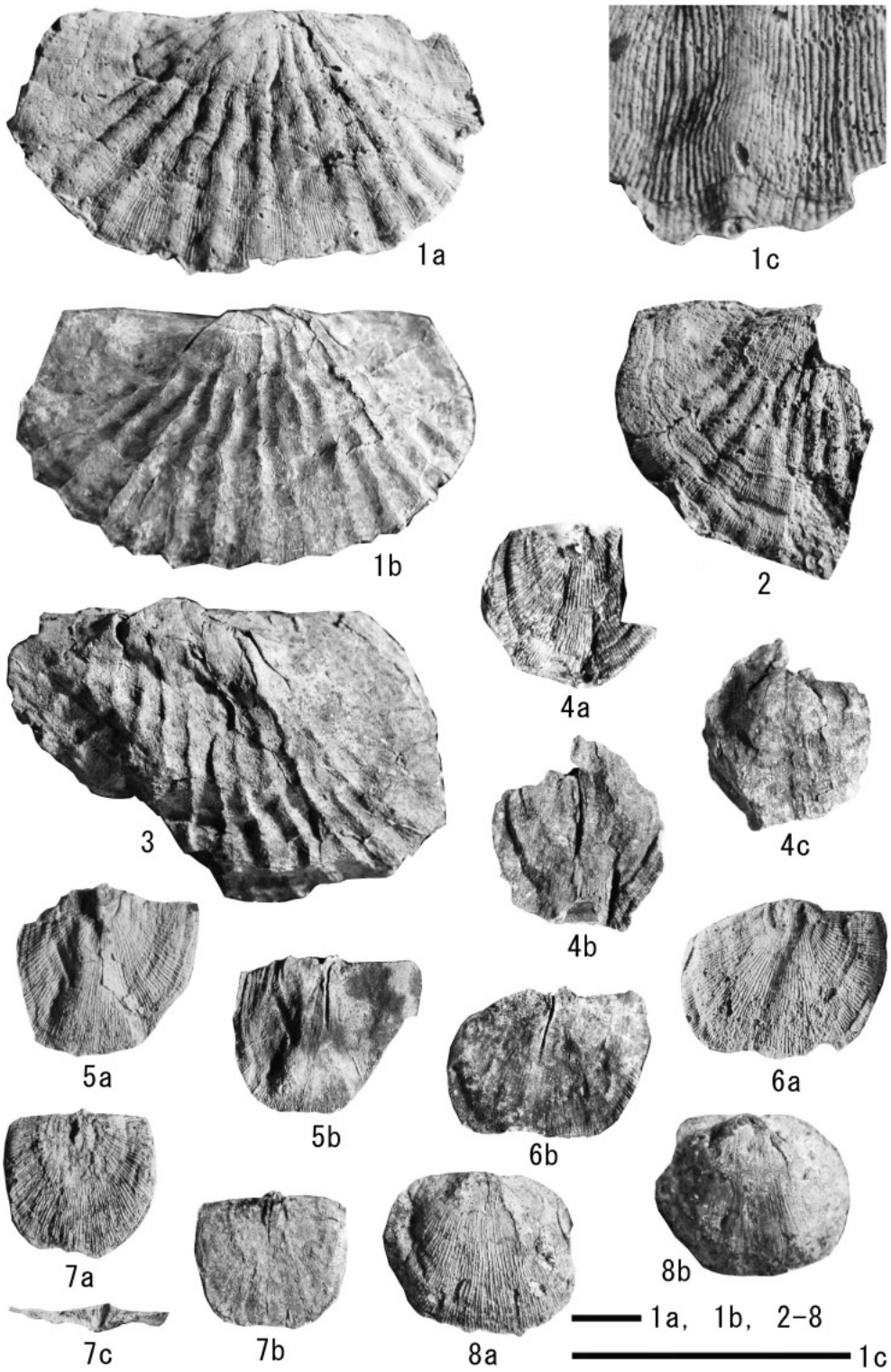
⬅ **Fig. 3. 1a-3.** *Meekella striatocostata* (Cox), 1a, 1b, 1c: ventral, lateral and posterior views of external latex cast of ventral valve, NU-B1212, 2a, 2b: external latex cast and internal mould of dorsal valve, NU-B1213, 3: internal mould of dorsal valve, NU-B1215, **4.** *Meekella nagaiwensis* sp. nov., 4a, 4b, 4c, 4d: ventral, lateral and posterior views of external latex cast, and internal mould of ventral valve, NU-B1216 (holotype), 5: external latex cast of dorsal valve, NU-B1219. Scale bar represents 1 cm.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the average-sized dorsal valve specimen (NU-B1217).

Ventral valve strongly convex; interarea high, moderately transverse and slightly concave; umbonal angle about 105°; sulcus absent. Dorsal valve slightly convex to nearly flat, and most gibbous at umbonal region. External surface of both valves ornamented with numerous fine radial costellae and numerous rounded plicae; costellae increasing by intercalation, showing tendency to converge toward crest of plicae, numbering 14-16 in 5 mm at midvalve; plicae arising near umbo, extending to margins with increasing size, numbering 16-18 in 5 mm at midvalve.

Internally, ventral valve having thick, subparallel dental plates; dental plates extending about one-third of valve length and diverging anteriorly.

Remarks.—*Meekella nagaiwensis* sp. nov. most resembles *Meekella kueichowensis* Huang (1933, p. 27, pl. 3, figs. 19-21; pl. 4, figs. 1-4) from the Lungtan Formation of Guizhou, South China in size and outline of the shell. However, the Kitakami species differs from the Chinese species in having irregular plicae and thicker dental plates on the ventral valve.

Meekella grandis King (1931, p. 54, pl. 6, figs. 5-7), described from the Leonard Formation of West Texas, is similar to the present species in size and longitudinal profile, but it differs from the latter in having a less transverse shell and coarser plicae.

Meekella langdaiensis Liao (1980, p. 255, pl. 3, figs. 20-23), from the Upper Permian (Lopingian) of western Guizhou, South China, is easily distinguished from the present species by its less transverse shell and more strongly convex dorsal valve.

Family Derbyiidae, Stehli, 1954
Genus *Derbyia* Waagen, 1884

Type species.—*Derbyia regularis* Waagen, 1884.

Derbyia crassa (Meek and Hayden, 1858)
Figs. 4.4a-4.8b, 5.1a-5.3

Orthisina crassa Meek and Hayden, 1858, p. 261.
Derbyia crassa (Meek and Hayden). Tschernyschew, 1902, p. 209, pl. 26, figs. 1, 2; Girty,

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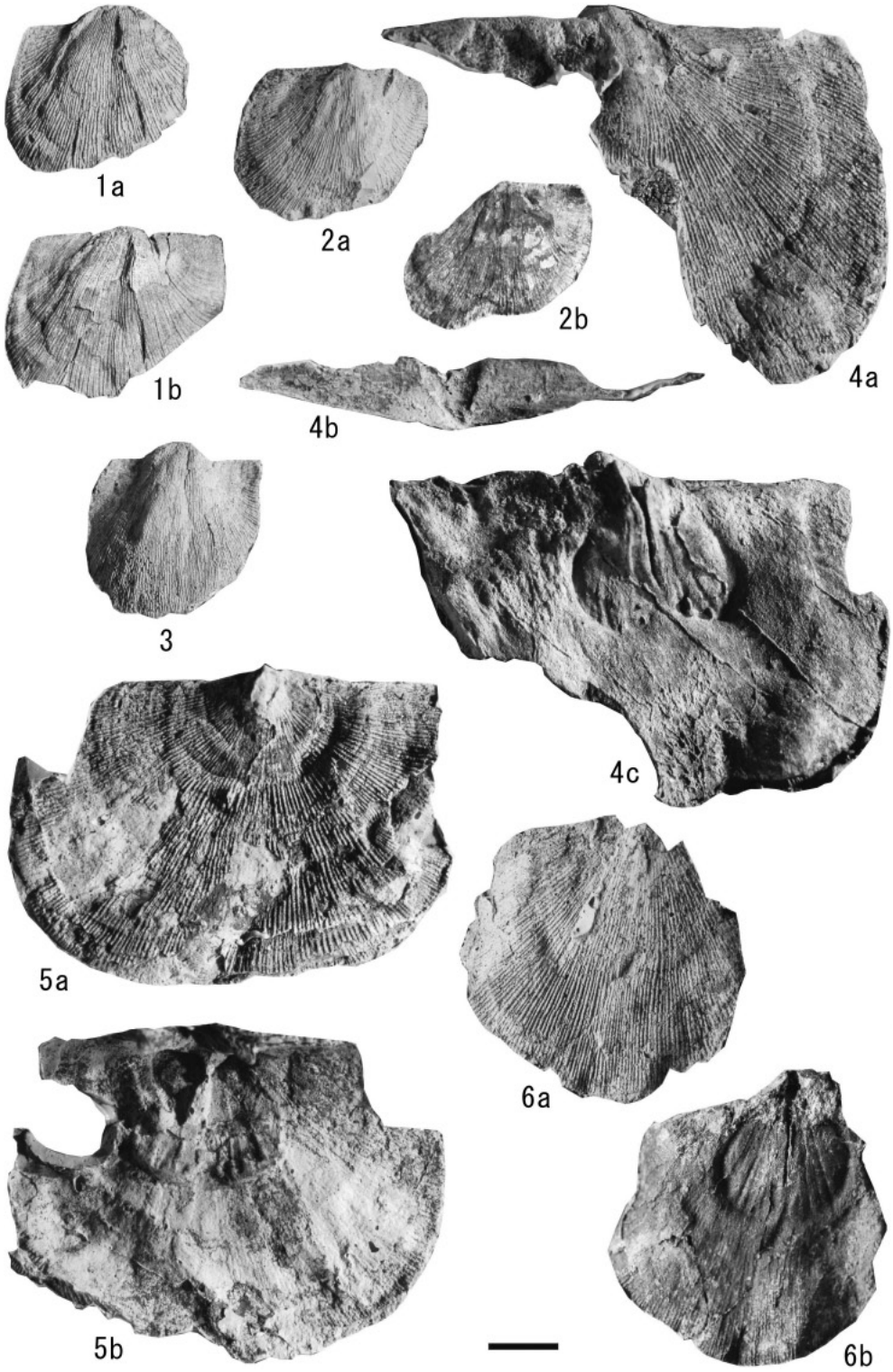
⬅ **Fig. 4. 1a-3.** *Meekella nagaiwensis* sp. nov., 1a, 1b, 1c: external latex cast, internal mould and external ornament of dorsal valve, NU-B1217, 2: external latex cast of dorsal valve, NU-B1218, 3: internal mould of dorsal valve, NU-B1220, **4a-8b.** *Derbyia crassa* (Meek and Hayden), 4a, 4b, 4c: external latex cast of ventral valve, and ventral and dorsal views of a conjoined valve, NU-B1221, 5a, 5b: external latex cast and internal mould of ventral valve, NU-B1223, 6a, 6b: external latex cast and internal mould of ventral valve, NU-B1225, 7a, 7b, 7c: ventral and posterior views of external latex cast, and internal mould of ventral valve, NU-B1226, 8a, 8b: external latex cast and internal mould of dorsal valve, NU-B1232. Scale bars represent 1 cm.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1915, p. 54, pl. 7, figs. 1a-1c; Kelly, 1930, p. 138, pl. 11, fig. 4; Sayre, 1930, p. 93, pl. 4, figs. 3-5; Dunbar and Condra, 1932, p. 79, pl. 3, figs. 1-12; text-fig. 3; Stepanov, 1948, p. 12, pl. 1, figs. 5, 6; Hoare and Burgess, 1960, p. 711, pl. 91, fig. 8; Hoare, 1961, p. 27, pl. 1, figs. 17-23; Sturgeon and Hoare, 1968, p. 26, pl. 3, figs. 1-4; Sutherland and Harlow, 1973, p. 21, pl. 2, figs. 8-12; Brew and Beus, 1976, p. 894, pl. 1, figs. 14-18; Alexandrov and Einor, 1979, p. 56, pl. 22, figs. 7a, 7b; Liu, 1992, p. 251, pl. 1, figs. 5-9, 11-12; Fan and He, 1999, p. 105, pl. 3, figs. 8-10, 12.

Derbyia crassa var. *texana* Dunbar and Condra, 1932, p. 84, pl. 4, figs. 2-11; Hoare, 1961, p. 29, pl. 1, fig. 24.

Material.—Forty specimens from localities SK14 and SK28: (1) external and internal moulds of two conjoined valves, NU-B1221, 1222; (2) external and internal moulds of seven ventral valves, NU-B1223-1229; (3) internal moulds of two ventral valves, NU-B1230, 1231; (4) external and internal moulds of twenty dorsal valves, NU-B1232-1251; (5) external moulds of two dorsal valves, NU-B1252, 1253; (6) internal moulds of seven dorsal valves, NU-B1254-1260.

Description.—Shell small for genus, subquadrate in outline; hinge slightly shorter than greatest width at about midvalve; length 24 mm, width 26 mm in the best-preserved, average-sized ventral valve specimen (NU-B1221); length 22 mm, width 26 mm in the average-sized dorsal valve specimen (NU-B1232).

Ventral valve slightly concave to nearly flat, interarea low; pseudodeltidium moderately vaulted and medium-sized, forming an angle of approximately 44˚; umbonal angle 135˚. External surface of ventral valve ornamented by numerous fine regular costellae and rugae; costellae increasing by intercalation, having narrow interspaces and numbering 25-28 in 10 mm at midvalve; rugae numbering 3-5. Dorsal valve slightly more convex than ventral valve and externally covered by fine regular costellae.

Internally, ventral valve having thin median septum extending to about two-fifths of valve length; dorsal valve having divergent crural plates.

Remarks.—The obtained specimens are referred to *Derbyia crassa* (Meek and Hayden, 1858, p. 261), originally described from the Kasimovian of east Kansas, on account of their medium size, subquadrate outline, low interarea, and external ornamentation consisting of numerous fine costellae.

Derbyia waageni Schellwien (1892, p. 32, pl. 6, figs. 4, 5; pl. 7, figs. 7-10), described from

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⬅ **Fig. 5. 1a-3.** *Derbyia crassa* (Meek and Hayden), 1a, 1b: external latex cast and internal mould of dorsal valve, NU-B1239, 2a, 2b: external latex cast and internal mould of dorsal valve, NU-B1240, 3: external latex cast of dorsal valve, NU-B1252, **4a-6b.** *Derbyia dorsosulcata* Liu and Waterhouse, 4a, 4b, 4c: ventral and posterior views of an external latex cast, and internal mould of ventral valve, NU-B1261, 5a, 5b: external latex cast and internal mould of ventral valve, NU-B1262, 6a, 6b: external latex cast and internal mould of ventral valve NU-B1264. Scale bar represents 1 cm.

the Krone Formation of north Italy, is similar to the present species in size, outline, and external ornament, but differs in having a less convex dorsal valve.

Derbyia bonita Sutherland and Harlow (1973, p. 20, pl. 2, figs. 4-7), from the Bashkirian to the Moscovian of northern New Mexico, United States, is similar to this species in outline and external ornament, but differs from *D. crassa* in its smaller size and having a shorter median septum.

Distribution.—Upper Carboniferous (Moscovian-Kasimovian) of the United States (Arizona, Colorado, Idaho, Kansas, Michigan, Missouri, Nebraska, New Mexico, Ohio, Oklahoma, Texas and Wyoming), Italy (eastern Alps), North China (Hebei); Lower Permian (Asselian) of northern Russia (northern Urals); Lower Permian (Sakmarian) of northeast Japan (South Kitakami Belt).

Derbyia dorsosulcata Liu and Waterhouse, 1985
Figs. 5.4a-5.6b, 6.1-6.4

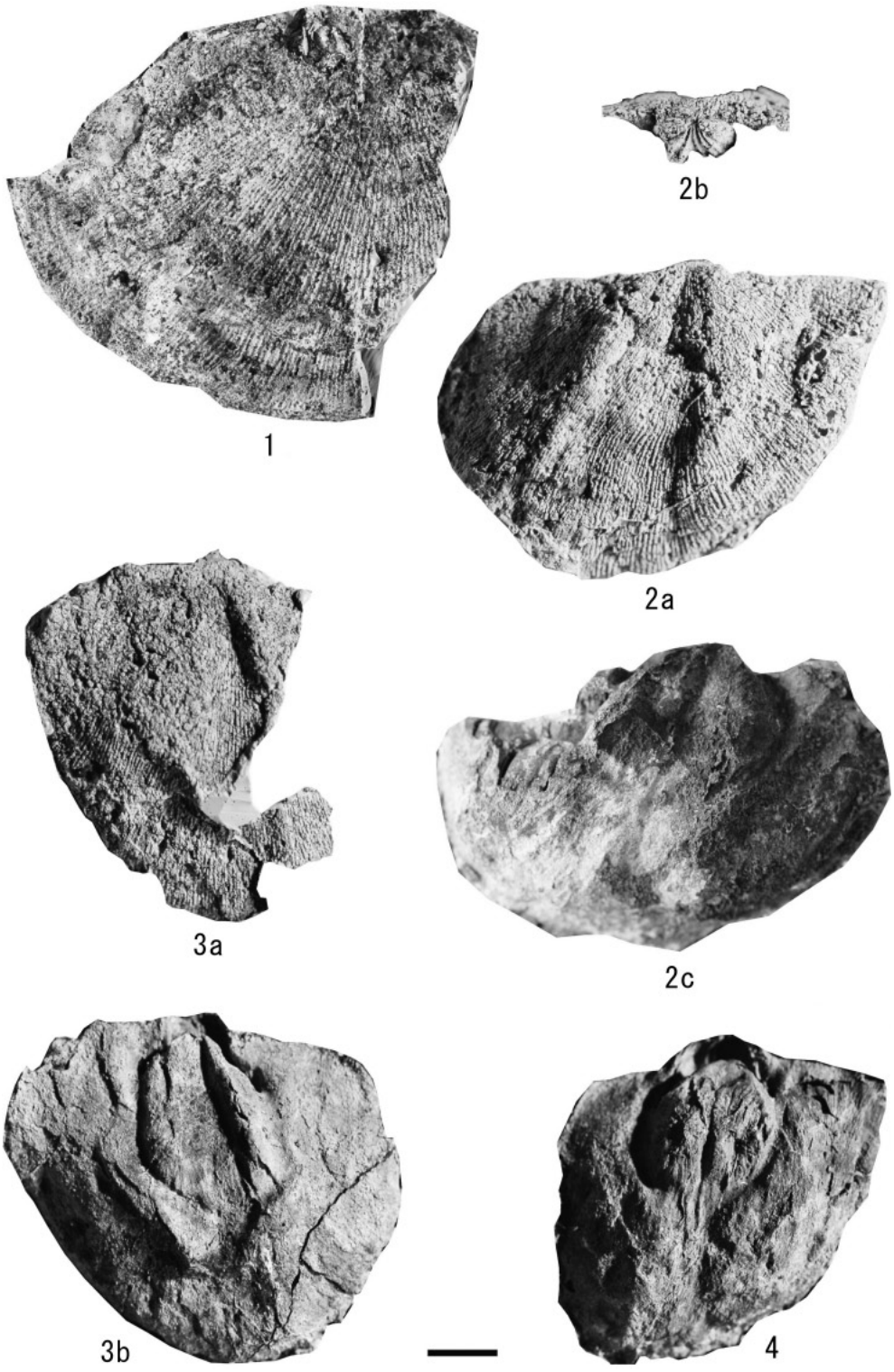
Magniderbyia sp. Nakamura, 1972, p. 403, pl. 9, figs. 2a, 2b.
Derbyia dorsosulcata Liu and Waterhouse, 1985, p. 11, pl. 1, figs. 1, 7, 8, 10; Wang and Zhang, 2003, p. 121, pl. 25, figs. 1, 2; pl. 26, figs. 2-6.

Material.—Twelve specimens collected from locality SK14 and SK28: (1) external and internal moulds of four ventral valves, NU-B1261-1264; (2) external moulds of a ventral valve, NU-B1265; (3) internal moulds of two ventral valves, NU-B1266, 1267; (4) external and internal moulds of four dorsal valves, NU-B1268-1271; (5) internal mould of a dorsal valve, NU-B1272.

Description.—Shell large for genus, transversely subrectangular in outline; greatest width near hinge; length 44 mm, width 64mm in the best-preserved, average-sized ventral valve specimen (NU-B1261); length 42 mm, width about 62 mm in the average-sized ventral valve specimen (NU-B1268).

Ventral valve slightly convex to nearly flat and ornamented with numerous fine regular costellae and a few rugae; costellae increasing by intercalation, having broad interspaces and numbering 16-18 in 10 mm at midvalve; interarea low and transverse; pseudodeltidium strongly vaulted, medium-sized and forming an angle of approximately 54°; umbonal angle 150°; beak pointed. Dorsal valve strongly convex with moderately deep sulcus and having numerous costellae.

➡ **Fig. 6. 1-4.** *Derbyia dorsosulcata* Liu and Waterhouse, 1: external latex cast of ventral valve, NU-B1265, 2a, 2b, 2c: dorsal and posterior views of external latex cast, and internal mould of dorsal valve, NU-B1268, 3a, 3b: external latex cast and internal mould of dorsal valve, NU-B1269, 4: internal mould of dorsal valve, NU-B1272. Scale bar represents 1 cm.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Internally, ventral valve having strong, high median septum and large flabellate muscle scar; median septum extending about two-fifths of valve length; muscle scar deeply impressed and surrounded by raised ridges. Dorsal valve having bilobed cardinal process.

Remarks.—The described specimens can be referred to *Derbyia dorsosulcata* Liu and Waterhouse (1985, p. 11, pl. 1, figs. 1, 7, 8, 10), from the lower Zhesi Formation of Xiujimqinqi, Inner Mongolia, on account of their large subrectangular shells, low transverse triangular interarea and moderately deep dorsal sulcus, external ornament consisting of a few rugae and numerous costellae with broad interspaces, and large muscle scars.

Magniderbyia sp., described by Nakamura (1972, p. 403, pl. 9, figs. 2a, 2b.) from the lower Sakamotozawa Formation of Yukisawa in the Yahagi area, South Kitakami Belt, is referred to *D. dorsosulcata*, based on the size and outline of shell, numerous costellae with broad interspaces, and flabellate ventral muscle scar.

Derbyia grandis Waagen (1884, p. 597, pl. 51, figs. 1a-c; pl. 52, figs. 1, 3; pl. 53, figs. 3, 5), described from the Wargal and Chhidru Formations of the Salt Range, resembles the present species in size, outline, and muscle scar of ventral valve. However, *D. grandis* differs from *D. dorsosulcata* in having a more convex profile and coarser costellae on the ventral valve.

Derbyia hemisphaerica Waagen (1884, p. 604, pl. 54, figs. 1-3), from the Chhidru Formation of the Salt Range, is similar to *D. dorsosulcata* in size and slightly convex to flat ventral valve, but differs from the present speces in having a higher interarea.

Distribution.—Lower Permian (Sakmarian) of northeast Japan (South Kitakami Belt); Middle Permian (Wordian) of North China (Inner Mongolia).

Derbyia sakamotozawensis sp. nov.
Figs. 7.1a-7.4

Etymology.—Named after the fossil locality, Sakamotozawa.

Material.—Seven specimens, from locality SK14: (1) external and internal moulds of four ventral valves, NU-B1273 (holotype), 1274-1276; (2) internal moulds of two ventral valves, NU-B1277, 1278; (3) internal mould of a dorsal valve, NU-B1279.

Diagnosis.—Large, semicircular *Derbyia*, with fine, numerous costellae on both valves, numbering 17-20 in 10 mm at about midvalve, having large ventral muscle scar.

Description.—Shell moderately large for genus, semicircular in outline; greatest width at just anterior to hinge; beak pointed; length 49 mm, width 61 mm in the best-preserved, average sized ventral valve specimen (NU-B1273).

Ventral valve slightly convex to nearly flat, ornamented with numerous regular fine costellae; costellae increasing by intercalation, having slightly narrow interspaces and numbering 17-20 in 10 mm at midvalve; interarea moderately high and transverse; pseudodeltidium strongly vaulted, medium-sized and forming an angle of approximately 40°; umbonal angle about 130°.

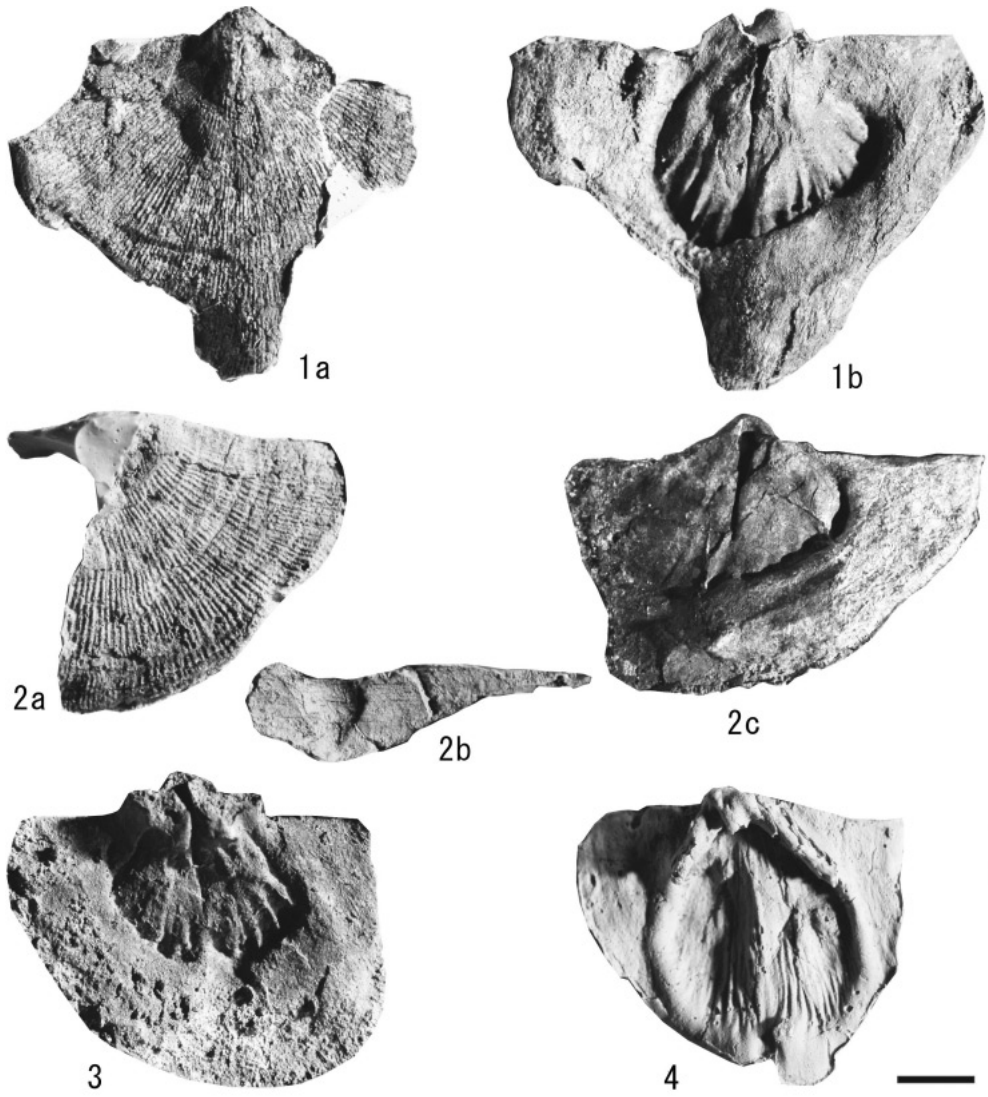

Fig. 7. 1a-4. *Derbyia sakamotozawensis* sp. nov., 1a, 1b: external latex cast and internal mould of ventral valve, NU-B1273 (holotype), 2a, 2b, 2c: ventral and posterior views of external latex cast, and internal mould of ventral valve, NU-B1274, 3: internal mould of ventral valve, NU-B1277, 4: internal latex cast of dorsal valve, NU-B1279. Scale bar represents 1 cm.

Internally, ventral valve having thick median septum and large flabellate muscle scar; median septum extending about two-thirds of valve length; muscle scar extremely large, oval and surrounded by raised ridges. Dorsal valve having large oval muscle scar and bilobed cardinal process.

Remarks.—*Derbyia sakamotozawensis* sp. nov. is distinguished from the type species,

Derbyia regularis Waagen (1884, p. 594, pl. 53, figs. 1, 2, 4) from the Amb and Wargal Formations of the Salt Range by its semicircular outline, smaller shell, and larger ventral muscle scar.

Derbyia grandis Waagen (1884, p. 597, pl. 51, figs. 1a-c; pl. 52, figs. 1, 3; pl. 53, figs. 3, 5), described from the Wargal and Chhidru Formations of the Salt Range, is similar to *D. sakamotozawensis*, but differs from the latter in its larger size and coarser costellae on both valves.

The above-described species, *Derbyia dorsosulcata* Liu and Waterhouse, differs from the present species in its subrectangular outline and smaller ventral muscle scar.

Derbyia wabaunsensis Dunbar and Condra (1932, p. 95, pl. 7, figs. 1-6), from the Wabaunsee Group of Nebraska, is similar to the present species in size and shape of the shell, but it differs from the Kitakami species in having strongly concave ventral valve and smaller ventral muscle scar.

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