

***Spinomarginifera* and *Waagenoconcha* (Productida, Brachiopoda)
from the middle Permian (Wordian–Capitanian)
of the South Kitakami Belt, Japan**

Jun-ichi TAZAWA*

Abstract

This paper describes five species of two productoid brachiopod genera, *Spinomarginifera* and *Waagenoconcha*, from the middle Permian (Wordian–Capitanian) of the Kamiyasse–Imo area, South Kitakami Belt, northeastern Japan. Cooccurrence of a tropical genus *Spinomarginifera* and an antitropical genus *Waagenoconcha* from the middle Permian of the South Kitakami Belt suggests that the South Kitakami region was located in the transitional zone between the Boreal and Tethyan realms, immediately east of North China (Sino-Korea) in the middle Permian.

Key words: Brachiopoda, middle Permian, South Kitakami Belt, *Spinomarginifera*, *Waagenoconcha*.

Introduction

This paper describes five productoid brachiopod species belonging two genera (*Spinomarginifera* and *Waagenoconcha*) from the Kamiyasse Formation (Wordian–Capitanian) of the Kamiyasse–Imo area, South Kitakami Belt, northeastern Japan. The species are as follows: *Spinomarginifera lopingensis* (Kayser, 1883), *Spinomarginifera kueichowensis* Huang, 1932, *Spinomarginifera alpha* Huang, 1932, *Waagenoconcha humboldti* (d’Orbigny, 1842) and *Waagenoconcha irginae* (Stuckenbergh, 1898). Cooccurrence of *Spinomarginifera* and *Waagenoconcha* from the middle Permian of the South Kitakami Belt is strong additional

* Hamaura-cho 1-260-1, Chuo-ku, Niigata 951-8151, Japan
Corresponding author: J. Tazawa,
j1025-tazawa@memoad.jp

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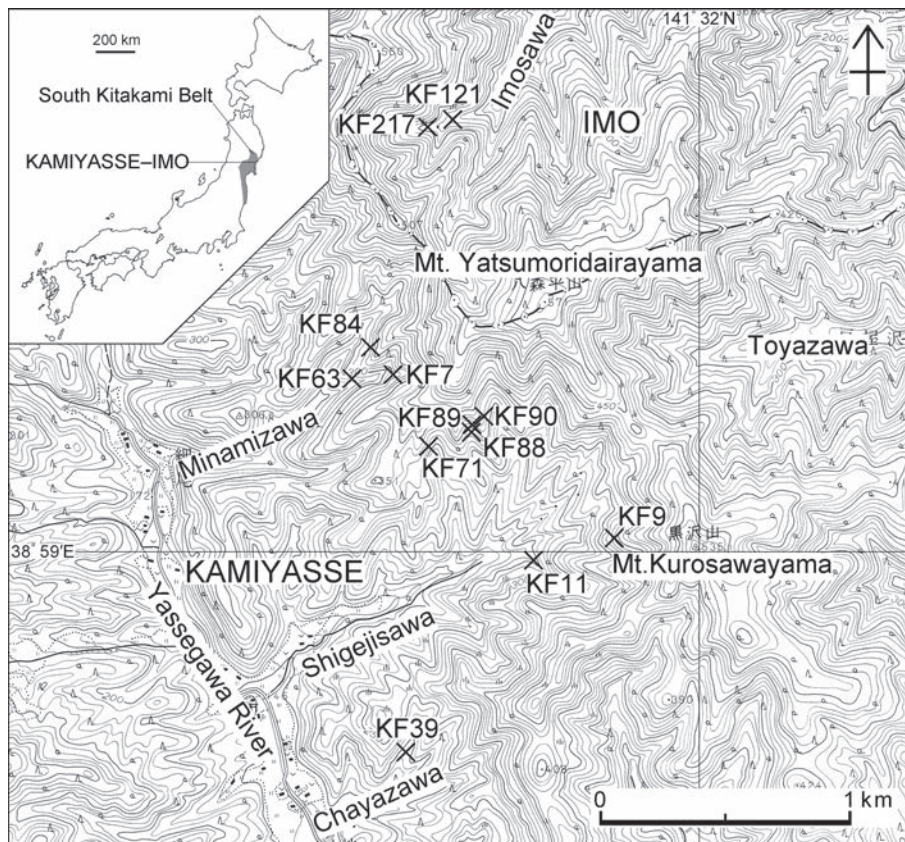


Fig. 1. Map showing the fossil localities KF7, KF9, KF11, KF39, KF63, KF71, KF84, KF88, KF89, KF90, KF121 and KF217 in the Kamiyasase-Imo area, South Kitakami Belt (using the topographic map “Shishiori” scale 1:25,000, published by the Geospatial Information Authority of Japan).

evidence for that the middle Permian brachiopod fauna of the South Kitakami Belt is a mixture of both Boreal and Tethyan elements, and for that the South Kitakami region was placed in the transitional zone between the Boreal and Tethyan realms, immediately east of North China (Sino-Korea) in the middle Permian.

Spinomarginifera was established by Huang (1932) with *Spinomarginifera kueichowensis* Huang, 1932, from the upper Permian (Wuchiapingian) of Guizhou, southwestern China, as type species. The genus is small- to medium-sized productoid, with numerous spine bases on both ventral and dorsal valves and a prominent marginal ridge in dorsal valve, and distributed in the middle to upper Permian (Roadian–Changhsingian) of the Tethyan region, mostly of South China. In Japan four species of the genus have been described from the middle and upper Permian of the South Kitakami Belt, northeastern Japan (Nakamura, 1959; Tazawa, 2012), from the upper Permian of the Maizuru Belt, southwestern Japan (Shimizu, 1961), from the upper Permian of the Kurosegawa Belt, southwestern Japan (Yanagida, 1973), and from the middle Permian of Hitachi (southern extension of the South Kitakami

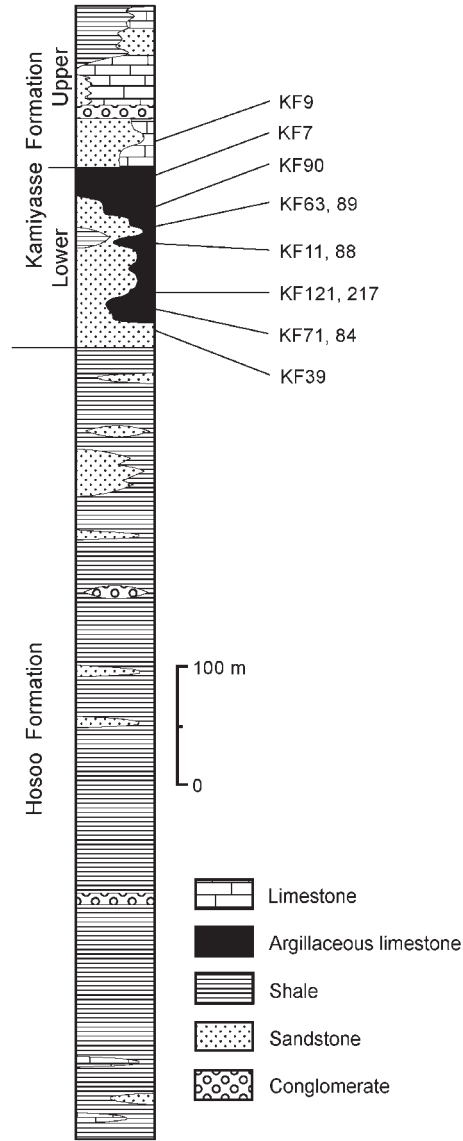


Fig. 2. Generalized columnar section of the middle Permian in the Kamiyasse-Imo area, South Kitakami Belt, showing the fossil horizons KF7, KF9, KF11, KF39, KF63, KF71, KF84, KF88, KF89, KF90, KF121 and KF217 (adapted from Tazawa, 2016).

Belt), central Japan (Tazawa et al., 2014; Tazawa, 2015).

Waagenoconcha was established by Chao (1927) with *Productus humboldti* d’Orbigny, 1842, from the lower Permian of Yarbichambi, Bolivia, as type species. The genus is medium- to large-sized productoid, with numerous quincunxially arranged spine bases on both valves, and distributed in the lower Carboniferous (Visean) to upper Permian (Changhsingian), mostly in the lower to middle Permian, of both Boreal and Gondwanan regions. In Japan five species of the genus have been described from the lower Carboniferous of the Akiyoshi Belt, southwestern Japan (Minato and Kato, 1963), from the lower and middle Permian of the South Kitakami Belt, northeastern Japan (Tazawa, 1974;

Tazawa and Ibaraki, 2001; Tazawa and Shintani, 2010, 2014, 2015; Tazawa and Araki, 2016), from the middle Permian of the Hida Gaien Belt, central Japan (Tazawa, 2001), and from the upper Permian of Mizukoshi (southwestern extension of the Hida Gaien Belt), central Kyushu, southwestern Japan (Tazawa, 2008).

The brachiopod specimens described herein were collected by Koji Nakamura and by the present author. The materials are now registered and housed in the Hokkaido University Museum, Sapporo, Japan (with the prefix UHR) and the Department of Geology, Niigata University, Niigata, Japan (with the prefix NU-B).

Stratigraphy

Stratigraphy of the Permian rocks of the Kamiyasse–Imo area has been studied by Shiida (1940), Kambe and Shimazu (1961), Tazawa (1973, 1976), Misaki and Ehiro (2004) and Shiino et al. (2011). The middle Permian rocks in the Kamiyasse–Imo area is subdivided into the lower, Hosoo Formation (400–500 m thick) and the upper, Kamiyasse Formation (150–250 m thick). The lower part of the Kamiyasse Formation consists of sandstone and argillaceous limestone with subordinate shale and conglomerate, and the upper part of the Kamiyasse Formation is composed of sandstone and limestone with subordinate shale and conglomerate. The age of the lower Kamiyasse Formation is assigned to a Wordian based on ammonoids (Ehiro and Misakai, 2005) and brachiopods (Tazawa, 2014), and the upper Kamiyasse Formation is assigned to a Capitanian by fusulinids (Tazawa, 1976; Kobayashi et al., 2009). The brachiopods treated in this study were collected from sandstone and argillaceous limestone of the lower Kamiyasse Formation at eleven sampling localities (KF7, KF11, KF39, KF63, KF71, KF84, KF88, KF89, KF90, KF121 and KF217), and from sandstone of the upper Kamiyasse Formation at one locality (KF9). The fossil localities and horizons are summarized below and indicated in Figs. 1, 2.

KF7: Upper Minamizawa Valley (38° 59' 23" N, 141° 31' 08" E), float of dark grey argillaceous limestone of the lower Kamiyasse Formation, with *Spinomarginifera lopingensis*.

KF9: Upper Shigejisawa Valley (38° 59' 02" N, 141° 31' 44" E), outcrop of greenish grey fine-grained sandstone of the upper Kamiyasse Formation, with *Waagenoconcha irginae*.

KF11: Upper Shigejisawa Valley (38° 58' 59" N, 141° 30' 31" E), outcrop of dark grey argillaceous limestone of the lower Kamiyasse Formation, with *Waagenoconcha irginae*.

KF39: Upper Chayazawa Valley (38° 58' 35" N, 141° 31' 10" E), outcrop of greenish grey fine-grained sandstone of the lower Kamiyasse Formation, with *Waagenoconcha irginae*.

KF63: Upper Minamizawa Valley (38° 59' 22" N, 141° 31' 02" E), float of greenish grey fine-grained sandstone of the lower Kamiyasse Formation, with *Spinomarginifera kueichowensis*.

Stage Species	Permian									
	Gzhelian (Carboniferous)	Asselian	Sakmarian	Artinskian	Kungurian	Roadian	Wordian	Capitanian	Wuchiapingian	Changhsingian
<i>Spinomarginifera lopingensis</i>							■	■	■	■
<i>Spinomarginifera kueichowensis</i>							■	■	■	■
<i>Spinomarginifera alpha</i>							■	■	■	■
<i>Waagenoconcha humboldti</i>	■	■	■	■	■	■	■	■	■	■
<i>Waagenoconcha irginae</i>		■	■	■	■	■	■	■	■	■

Fig. 3. Stratigraphic distribution of *Spinomarginifera lopingensis*, *S. kueichowensis*, *S. alpha*, *Waagenoconcha humboldti* and *W. irginae*.

KF71: Upper Shigejisawa Valley (38° 59' 13" N, 141° 31' 10" E), float of greenish grey fine-grained sandstone of the lower Kamiyasse Formation, with *Spinomarginifera kueichowensis*.

KF84: Upper Minamizawa Valley (38° 59' 26" N, 141° 31' 04" E), float of dark grey argillaceous limestone of the lower Kamiyasse Formation, with *Spinomarginifera kueichowensis*.

KF88: Upper Shigejisawa Valley (38° 59' 15" N, 141° 31' 22" E), float of dark grey argillaceous limestone of the lower Kamiyasse Formation, with *Spinomarginifera kueichowensis*.

KF89: Upper Shigejisawa Valley (38° 59' 16" N, 141° 31' 22" E), float of greenish grey fine-grained sandstone of the lower Kamiyasse Formation, with *Spinomarginifera alpha*.

KF90: Upper Shigejisawa Valley (38° 59' 14" N, 141° 31' 23" E), outcrop of greenish grey fine-grained sandstone of the lower Kamiyasse Formation, with *Spinomarginifera lopingensis*, *Spinomarginifera kueichowensis* and *Spinomarginifera alpha*.

KF121: Upper Imosawa Valley (38° 59' 55" N, 141° 31' 18" E), float of greenish grey fine-grained sandstone of the lower Kamiyasse Formation, with *Waagenoconcha humboldti*.

KF217: Upper Imosawa Valley (38° 59' 55" N, 141° 31' 14" E), outcrop of greenish grey fine-grained sandstone of the lower Kamiyasse Formation, with *Spinomarginifera lopingensis*, *Spinomarginifera kueichowensis*, *Spinomarginifera alpha* and *Waagenoconcha humboldti*.

Palaeobiogeographical importance of *Spinomarginifera* and *Waagenoconcha*

Stratigraphic and geographic distributions of the five species of *Spinomarginifera* and *Waagenoconcha* are summarized as follows and shown in Fig. 3 and Figs. 4, 5, respectively.

Spinomarginifera lopingensis is known from the Wordian to Changhsingian of

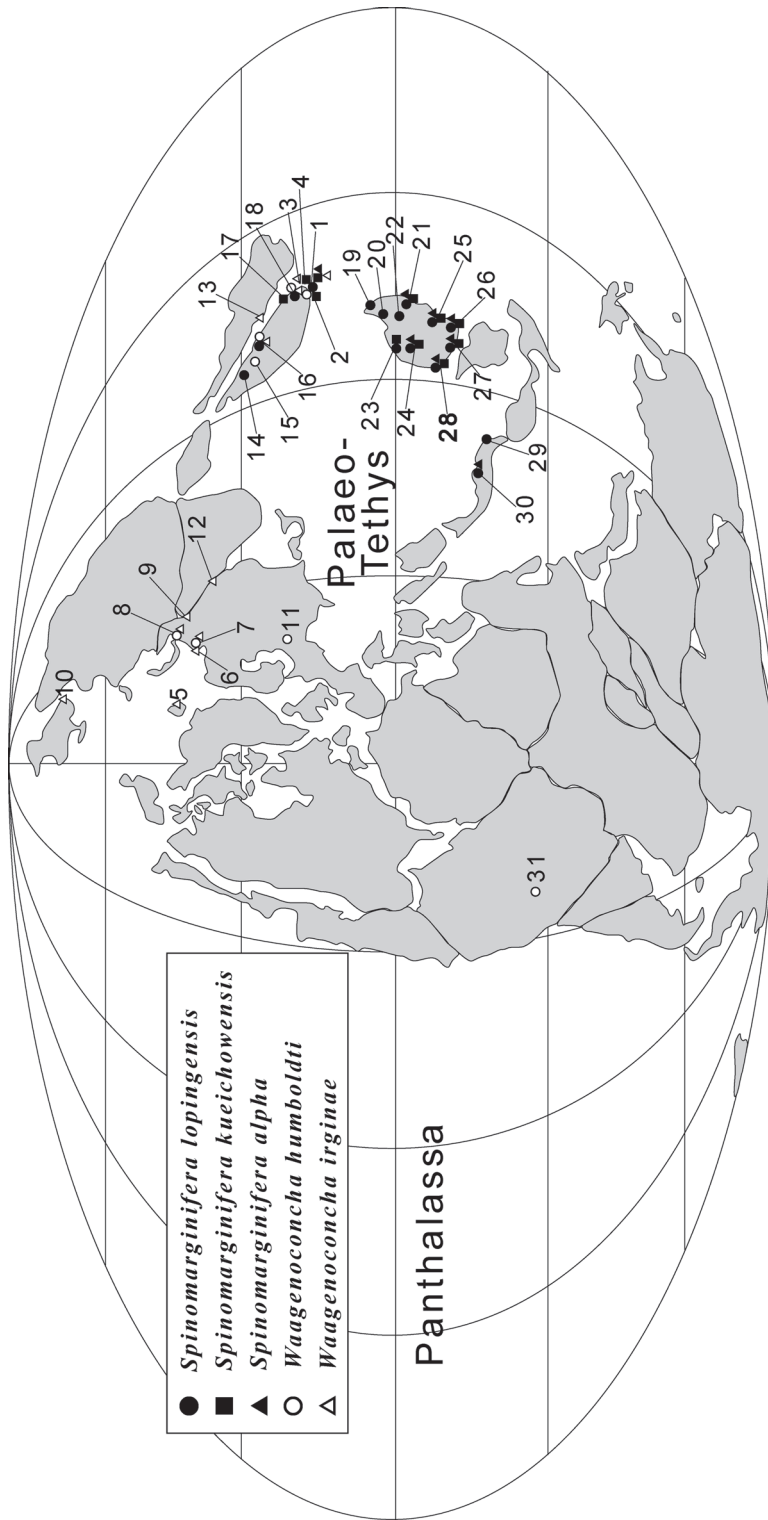


Fig. 5. Middle Permian (Wordian-Capitanian) reconstruction map of the world showing geographic distribution of *Spinomarginifera lopingensis*, *S. kueichowensis*, *S. alpha*, *Waagenoconcha humboldti* and *W. irginae* (adapted from Scotese, 2004). Location numbers are same in Fig. 4.

northwestern China (Qinghai), northern China (Inner Mongolia), eastern Russia (South Primorye), northeastern Japan (South Kitakami Belt), eastern China (Jiangsu, Zhejiang, Anhui and Jiangxi), central-southern China (Hubei, Hunan, Guangdong and Guangxi) and southwestern China (Guizhou, Sichuan, Yunnan and Tibet); *Spinomarginifera kueichowensis* is known from the Wordian to Changhsingian of northeastern China (Jilin), northeastern Japan (South Kitakami Belt), central Japan (Hitachi, southern extension of the South Kitakami Belt), southwestern Japan (Maizuru Belt), eastern China (Zhejiang), central-southern China (Hubei, Hunan, Guangdong and Guangxi) and southwestern China (Guizhou and Sichuan); and *Spinomarginifera alpha* is known from the Wordian to Changhsingian of northeastern Japan (South Kitakami Belt), eastern China (Zhejiang), central-southern China (Hunan, Guangdong and Guangxi) and southwestern China (Guizhou, Sichuan and Tibet).

Waagenoconcha humboldti is known from the Gzhelian to Capitanian of northern Russia (Timan and Pechora Basin), western Russia (Moscow Basin), northwestern China (Gansu), northern China (Inner Mongolia), eastern Russia (South Primorye), northeastern Japan (South Kitakami Belt) and Bolivia; and *Waagenoconcha irginae* is known from the Asselian to Capitanian of Spitsbergen, northern Russia (Pechora Basin, northern Urals and Kolyma), central Russia (southern Urals), southern Mongolia, northern China (Inner Mongolia), eastern Russia (South Primorye), northeastern Japan (South Kitakami Belt) and central Japan (Hida Gaien Belt).

In palaeobiogeographical terms, *Spinomarginifera* is a tropical genus, whereas *Waagenoconcha* is an antitropical genus. Therefore, the middle Permian (Wordian–Capitanian) brachiopod fauna of the Kamiyasse–Imo area is a mixed Boreal–Tethyan fauna. In addition, cooccurrence of both *Spinomarginifera* and *Waagenoconcha* is restricted to the area including northern China (Inner Mongolia), eastern Russia (South Primorye), central Japan (Hida Gaien Belt) and northeastern Japan (South Kitakami Belt), i.e., the northern and eastern margin of North China (Sino-Korea). This conclusion supports the previous opinion of Tazawa (1993, 1998, 2002, 2007) that the South Kitakami region was located in the transitional zone between the Boreal and Tethyan realms, i.e., Inner Mongolian–Japanese Transition Zone of Tazawa (1991) [=Sino-Mongolian–Japanese Province of Shi and Tazawa (2001)].

Systematic descriptions

Order Productida Sarytcheva and Sokolskaya, 1959

Suborder Productidina Waagen, 1883

Superfamily Productoidea Gray, 1840

Superfamily Marginiferoidea Stehli, 1954

Family Costispiniferidae Muir-Wood and Cooper, 1960

Subfamily Spinomarginiferinae Waterhouse, 2002

Genus *Spinomarginifera* Huang, 1932

Type species.—*Spinomarginifera kueichowensis* Huang, 1932.

Spinomarginifera lopingensis (Kayser, 1883)

Fig. 6

Productus nystianus var. *lopingensis* Kayser, 1883, p. 187, pl. 28, figs. 1–5.

Productus (Marginifera) helicus var. Frech, 1911, p. 130, pl. 19, figs. 1–3.

Marginifera lopingensis (Kayser): Chao, 1927, p. 153, pl. 16, figs. 8–12.

Spinomarginifera kueichowensis Huang: Nakamura, 1959, p. 143, pl. 15, fig. 1 only; Minato et al., 1979, pl. 63, fig. 1 only.

Spinomarginifera lopingensis (Kayser): Zhang and Ching, 1961, p. 412, pl. 4, figs. 26–33; Wang et al., 1964, p. 312, pl. 49, figs. 21–23; Yang et al., 1977, p. 349, pl. 139, fig. 5; Tong, 1978, p. 222, pl. 79, fig. 6; Licharew and Kotlyar, 1978, pl. 15, figs. 9, 10; Zhan, 1979, p. 80, pl. 5, figs. 17, 18; Liao, 1980, pl. 5, figs. 35–39; Wang et al., 1982, p. 219, pl. 92, figs. 1, 2; Wang, 1984, p. 187, pl. 80, fig. 16; Yang, 1984, p. 217, pl. 33, fig. 4; Liao, 1987, pl. 5, figs. 5, 7–18; Zeng et al., 1995, pl. 9, fig. 1; Shen et al., 2002, p. 677, figs. 4.32, 4.33, 5.1–5.4; He et al., 2008, p. 812, figs. 4.1–4.10; Li and Shen, 2008, p. 315, figs. 4.17–4.19, 6.1–6.7; Shen and Zhang, 2008, figs. 4.13–4.19; Shen and Shi, 2009, p. 157, figs. 3P–3X; Tazawa, 2012, p. 20, figs. 4.1–4.3.

Spinomarginifera lopingensis (Chao): Jin et al., 1985, p. 194, pl. 9, figs. 3–9; Jin, 1985, pl. 7, figs. 5, 16, 18, 20.

Spinomarginifera lopingensis Huang: Liao and Xu, 2002, pl. 1, figs. 28–33.

Spinomarginifera huangi Wang and Zhang, 2003, p. 73, pl. 21, fig. 12 only.

Material.—Six specimens from localities KF7, KF90 and KF217: (1) external and internal moulds of two conjoined shells, UHR12642, 30077; (2) internal moulds of two conjoined shells, with external moulds of the ventral valves, NU-B2021, 2022; and (3) external moulds of two dorsal valves, NU-B2023, 2024.

Description.—Shell medium in size for genus, transversely subquadrate in outline, with greatest width at hinge; length about 19 mm, width about 32 mm in the best preserved specimen (UHR12642). Ventral valve strongly and unevenly convex in lateral profile, most convex at umbonal region, gently convex on visceral disc, strongly geniculated at anterior margin of visceral disc, and followed by long trail; umbo rounded, incurved beyond hinge; ears moderately large; sulcus broad and shallow; lateral slopes steep. Dorsal valve almost flat on visceral disc, strongly geniculated at anterolateral margins, and followed by short trail. External surface of ventral valve ornamented with numerous fine spine bases and fine

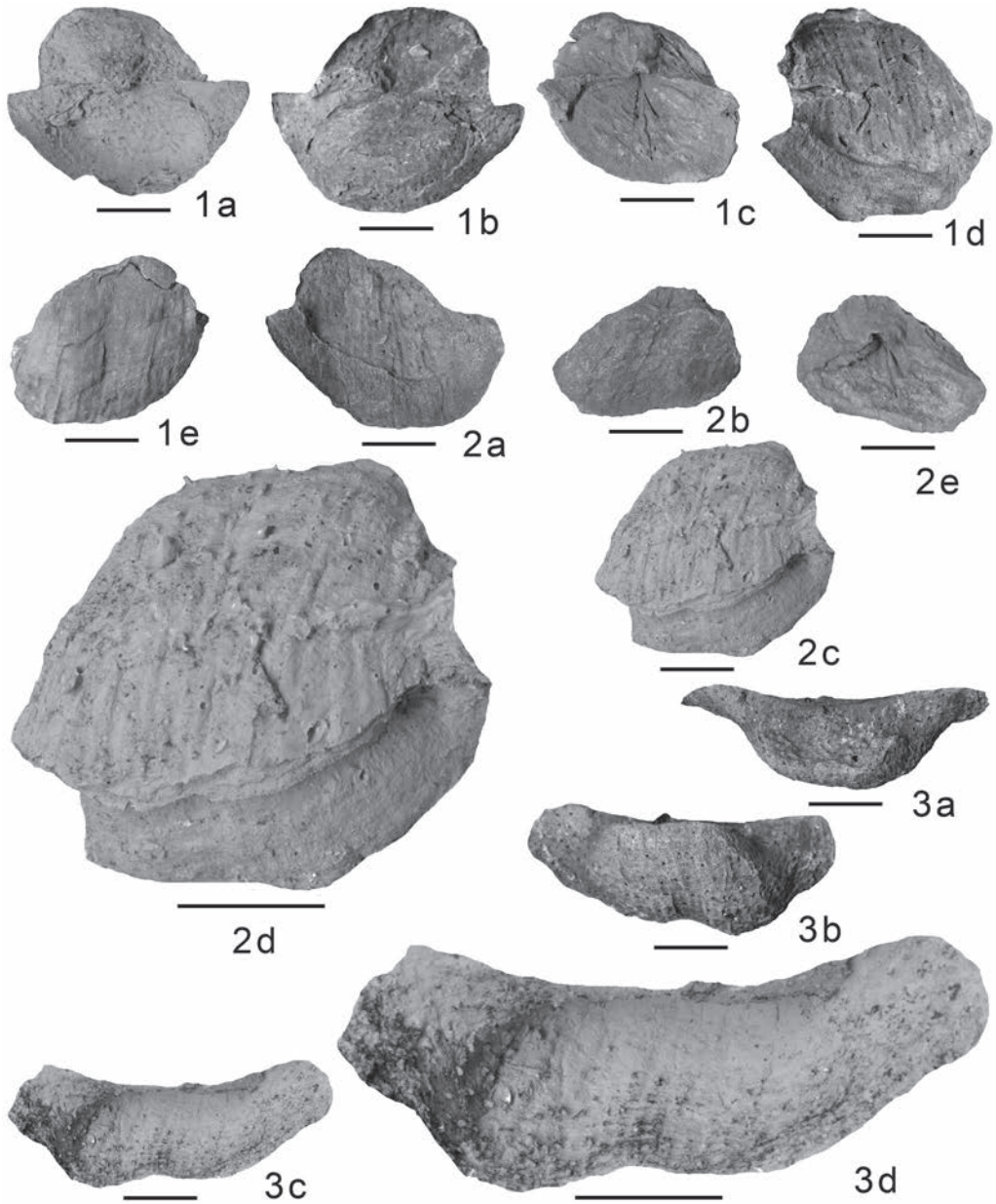


Fig. 6. 1-3, *Spinomarginifera lopingensis* (Kayser): 1, dorsal views of external latex cast (1a), external mould (1b) and internal mould (1c), and ventral views of external mould (1d) and internal mould (1e) of conjoined shell, UHR12642; 2, ventral views of external mould (2a), internal mould (2b) and external latex cast (2c, 2d), and dorsal view of internal mould (2e) of conjoined shell, NU-B2021; 3, dorsal view (3a) and anterior view (3b) of external mould, and external latex cast (3c, 3d) of dorsal valve, NU-B2023. Scale bars represent 1 cm.

concentric rugae on visceral disc, and numerous prominent costae on trail. External ornament of dorsal valve same as opposite valve. Dorsal interior with a small bilobate cardinal process, a long median septum extending to half shell length, and pear-shaped adductor scars on both sides of median septum; lateral ridges slightly diverging towards anterior; marginal ridge strongly developed around visceral disc; brachial ridges occurring anteriorly.

Remarks.—These specimens are referred to *Spinomarginifera lopingensis* (Kayser, 1883), originally described from the upper Permian of Loping, Jiangxi Province, southwestern China, by their medium size and in having prominent costae on the trails of both valves. *Spinomarginifera kueichowensis* Huang (1932, p. 56, pl. 5, figs. 1–11), from the upper Permian (Wuchiapingian) of Guizhou, southwestern China, differs from *S. lopingensis* in lacking radial costae on both ventral and dorsal valves.

Distribution.—Wordian–Changhsingian: northeastern Japan (Kamiyasse–Imo and Nabekoshiyama in the South Kitakami Belt), northwestern China (Qinghai), northern China (Inner Mongolia), eastern Russia (South Primorye), eastern China (Jiangsu, Anhui, Zhejiang and Jiangxi), central-southern China (Hubei, Hunan, Guangdong and Guangxi) and southwestern China (Guizhou, Sichuan and Yunnan) and Tibet.

Spinomarginifera kueichowensis Huang, 1932

Fig. 7

Spinomarginifera kueichowensis Huang, 1932, p. 56, pl. 5, figs. 1–11; Nakamura, 1959, p. 143, pl. 15, figs. 2–4 only; Muir-Wood and Cooper, 1960, p. 65, figs. 15–22, 24; Wang et al., 1964, p. 316, pl. 51, figs. 9–11; Jin et al., 1974, p. 312, pl. 164, fig. 13; Tazawa, 1976, pl. 2, fig. 1; Feng and Jiang, 1978, p. 252, pl. 89, figs. 5, 6; Minato et al., 1979, pl. 63, fig. 2 only; Zhan, 1979, p. 80, pl. 11, figs. 14–17, 20; Liao, 1980, pl. 4, fig. 29; Liu et al., 1982, p. 184, pl. 131, figs. 8–10; Wang, 1984, p. 187, pl. 74, fig. 16; pl. 76, fig. 3; Zeng et al., 1995, pl. 5, fig. 10; Tazawa, 2002, fig. 10.11; Chen in Chen et al., 2006, p. 314, fig. 8, table 2; Shen and Shi, 2009, p. 158, figs. 3DD, 3EE, 4I; Tazawa et al., 2014, p. 381, fig. 2.10; Tazawa, 2015, p. 67, fig. 6.10.

Spinomarginifera nipponica Shimizu, 1961, p. 244, pl. 8, figs. 1–20; pl. 9, figs. 14–16.

Spinomarginifera cf. *kueichowensis* Huang: Lee et al., 1980, p. 357, pl. 165, fig. 11; pl. 166, fig. 25; Gu, 1992, p. 224, pl. 69, fig. 6.

Material.—Twelve specimens from localities KF63, KF71, KF84, KF88, KF90 and KF217: (1) external and internal moulds of a conjoined shell, NU-B2017; (2) internal moulds of two conjoined shells, with external mould of the ventral valves, UHR12584, 30074; (3) external and internal moulds of four dorsal valves, NU-B2018, 2019, 2020, UHR30071; and (4) external moulds of five dorsal valves, UHR11554, 12368, 30068, 30080, 30082.

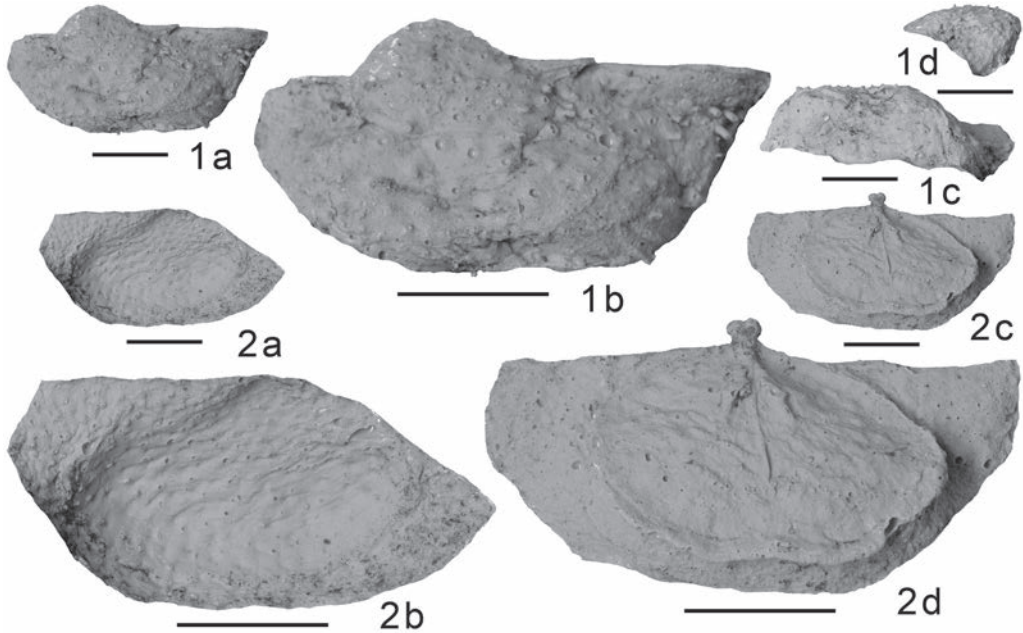


Fig. 7. 1, 2, *Spinomarginifera kueichowensis* Huang: 1, ventral view (1a, 1b), anterior view (1c) and lateral view (1d) of ventral valve, UHR30074; 2, external latex cast (2a, 2b) and internal latex cast (2c, 2d) of dorsal valve, UHR30071. Scale bars represent 1 cm.

Description.—Shell medium in size for genus, transversely subquadrate in outline, with greatest width at hinge; length 18 mm, width about 38 mm in the largest specimen (UHR30074). Ventral valve strongly and unevenly convex in lateral profile, most convex at umbonal region, gently geniculated, and followed by long trail; umbo slightly incurved beyond hingeline; ears large, triangular, slightly convex; sulcus wide and shallow; lateral slopes steep. Dorsal valve flattened on visceral disc, strongly geniculated, and followed by long trail; no fold. External surface of ventral valve ornamented with weak, irregular concentric rugae and numerous spines; spine bases quincunxially arranged on visceral region, and crowded on ears. External ornament of dorsal valve same as ventral valve, but spine bases smaller and not crowded on ears. Dorsal interior with a short bilobate cardinal process, a long median septum extending to two-thirds length of visceral disc, a pair of lateral ridges diverging from hinge, curving inside ears and connected to marginal ridges developed around anterolateral margins of visceral disc; brachial ridges well preserved in some specimens; anterior adductor scars smooth, pear-shaped, diverging and elevated, but posterior adductor scars smaller and not elevated.

Remarks.—These specimens are referred to *Spinomarginifera kueichowensis* Huang, 1932, from the upper Permian (Wuchiapingian) of Guizhou, southwestern China, in their medium size, transverse outline, numerous spine bases on the ventral valve and strongly

developed marginal ridge in the dorsal valve. *Spinomarginifera nipponica* Shimizu, 1961, from the Gujo Formation of Kawahigashi in the Maizuru Belt, southwestern Japan, is regarded as a junior synonym of the present species. The preceding species, *Spinomarginifera lopingensis* (Kayser, 1883), is distinguished from *S. kueichowensis* in having costae on the trails of both valves. *Spinomarginifera alpha* Huang, 1932, originally described by Huang (1932, p. 60, pl. 5, figs. 12, 13) as *Spinomarginifera kueichowensis* mut. *a* from the upper Permian of Guizhou, southwestern China, differs from the present species in its larger size and in having coarser and sparser spine bases on the ventral valve.

Distribution.—Wordian–Changhsingian: northeastern Japan (Kamiyasse–Imo in the South Kitakami Belt), central Japan (Hitachi), southwestern Japan (Kawahigashi in the Maizuru Belt), northeastern China (Jilin), eastern China (Zhejiang), central-southern China (Hubei, Hunan, Guangdong and Guangxi) and south-western China (Guizhou and Sichuan).

Spinomarginifera alpha Huang, 1932

Fig. 8

Spinomarginifera kueichowensis mut. *a* Huang, 1932, p. 60, pl. 5, figs. 12, 13; Wang et al., 1964, p. 316, pl. 49, figs. 31–33; Jin et al., 1974, p. 313, pl. 164, figs. 11, 12; Yang et al., 1977, p. 349, pl. 139, fig. 9.

Spinomarginifera huangi Nakamura, 1959, p. 145, pl. 15, figs. 5–7; Minato et al., 1979, pl. 63, figs. 3–5.

Spinomarginifera alpha Huang: Liao, 1980, p. 259, pl. 5, figs. 44–47; Zhao et al., 1981, pl. 8, figs. 28, 29; Wang et al., 1982, p. 219, pl. 96, fig. 26; Shen et al., 2003, p. 231, pl. 1, figs. 6–9; Chen et al., 2005, p. 355, figs. 10C, 10D.

Material.—Six specimens from localities KF89, KF90 and KF217: (1) internal mould of a conjoined shell, with external mould of the ventral valve, NU-B2025; (2) internal moulds of two conjoined shells, with external moulds of the dorsal valves, NU-B2026, UHR12370; (3) external moulds of a conjoined shell, UHR30086; (4) external and internal moulds of a dorsal valve, UHR12371; and (5) external mould of a dorsal valve, UHR12369.

Description.—Shell large in size for genus, transversely trapezoidal in outline, with greatest width at hinge; length 29 mm, width 35 mm in the best preserved ventral valve specimen (UHR30086); length 30 mm, width 36 mm in the best preserved dorsal valve specimen (UHR12371). Ventral valve strongly and unevenly convex in lateral profile, with strongly incurved umbo and wide and flattened visceral disc, geniculated and followed by long trail; ears large, triangular and slightly convex; sulcus narrow, deep, originating just anterior to umbo and extending to anterior margin of valve; lateral slopes steep. Dorsal valve with wide, flat visceral disc, strongly geniculated at anterior margin, and followed by

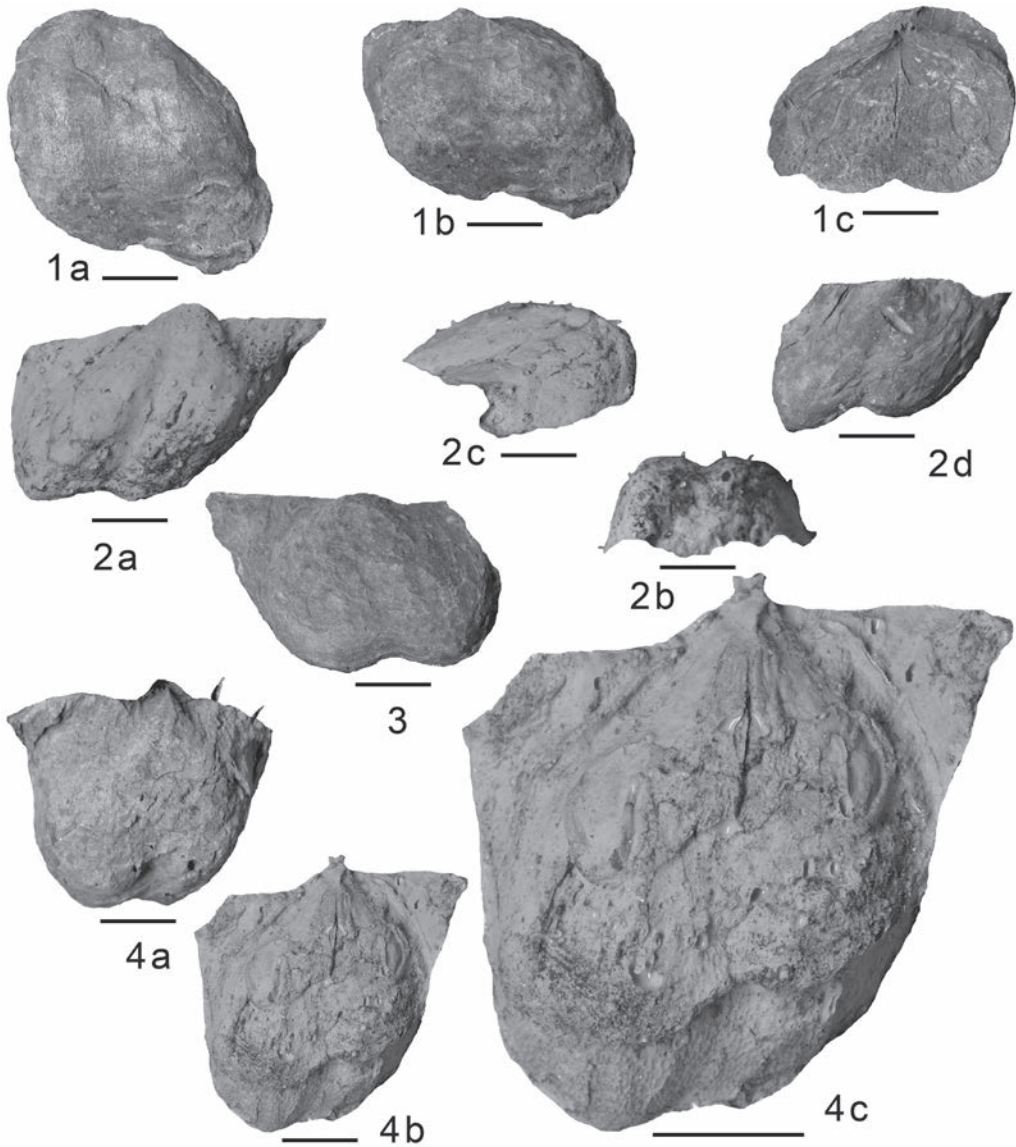


Fig. 8. 1-4, *Spinomarginifera alpha* Huang: 1, ventral view of internal mould (1a), and ventral view (1b) and dorsal view (1c) of internal mould of conjoined shell, NU-B2026; 2, ventral view (2a), anterior view (2b) and lateral view (2c) of external latex cast, and ventral view of external mould (2d) of conjoined shell, UHR30086; 3, external mould of dorsal valve, UHR12369; 4, external mould (4a) and internal latex cast (4b, 4c) of dorsal valve, UHR12371. Scale bars represent 1 cm.

long trail; fold narrow and low on trail. External surface of ventral valve ornamented with numerous coarse spine bases and some irregular rugae. Dorsal valve ornament same as the opposite valve. Dorsal interior with a short bilobate cardinal process, a thin, short median septum and prominent marginal ridge; a pair of brachial ridges developed on both sides of

median septum anteriorly.

Remarks.—The specimens from the Kamiyasse–Imo area are referred to *Spinomarginifera alpha* Huang, 1932, originally described by Huang (1932, p. 60, pl. 5, figs. 12, 13) as *Spinomarginifera kueichowensis* mut. *a* from the upper Permian (Lopingian) of Guizhou, southwestern China, in their large size, coarse, widely-spaced spine bases on the both ventral and dorsal valves. *Spinomarginifera huangi* Nakamura (1959, p. 145, pl. 15, figs. 5–7), from the lower Kanokura Series (=lower Kamiyasse Formation) of the South Kitakami Belt, is regarded as a junior synonym of the present species. The preceding species, *Spinomarginifera kueichowensis* Huang, 1932, is distinguished from the present species by its smaller size, much transverse outline and more numerous and finer spine bases on the both ventral and dorsal valves.

Distribution.—Wordian–Changhsingian: northeastern Japan (Kamiyasse–Imo in the South Kitakami Belt), eastern China (Zhejiang), central-southern China (Hunan, Guangdong and Guangxi) and southwestern China (Guizhou, Sichuan and Tibet).

Superfamily Echinoconchoidea Stehli, 1954

Family Waagenoconchidae Muir-Wood and Cooper, 1960

Subfamily Waagenoconchinae Muir-Wood and Cooper, 1960

Genus *Waagenoconcha* Chao, 1927

Type species.—*Productus humboldti* d'Orbigny, 1842.

Waagenoconcha humboldti (d'Orbigny, 1842)

Fig. 9

Productus humboldti d'Orbigny, 1842, p. 54, pl. 5, figs. 4–7; Tschernyschew, 1902, p. 275, 620, pl. 53, figs. 1–3; Kozłowski, 1914, p. 40, pl. 7, figs. 7–9; Fredericks, 1925, p. 19, pl. 2, fig. 84.

Waagenoconcha humboldti (d'Orbigny): Chao, 1927, p. 86, pl. 15, figs. 2, 3; Sarytcheva and Sokolskaya, 1952, p. 98, pl. 15, fig. 109; Chronic, 1953, p. 86, pl. 15, figs. 4–7; Muir-Wood and Cooper, 1960, pl. 89, figs. 6–10; Samtleben, 1971, p. 60, pl. 2, figs. 17–19; Ifanova, 1972, p. 102, pl. 3, figs. 11–13; Tazawa, 1974, p. 125, pl. 1, figs. 2, 3; pl. 2, fig. 1; pl. 4, fig. 6; Ding and Qi, 1983, p. 283, pl. 96, fig. 9; Duan and Li, 1985, p. 108, pl. 35, figs. 2, 3; Wang and Zhang, 2003, p. 94, pl. 9, figs. 5–7; pl. 15, figs. 8–10; Tazawa and Shintani, 2010, p. 56, figs. 4.1–4.5; Tazawa and Shintani, 2015, p. 45, fig. 4.1.

Waagenoconcha imperfecta Prendergast: Tazawa, 1974, p. 127, pl. 2, fig. 6 only.

Material.—Eight specimens from localities KF121 and KF217: (1) internal mould of a conjoined shell, UHR19819; (2) external and internal moulds of two ventral valves,

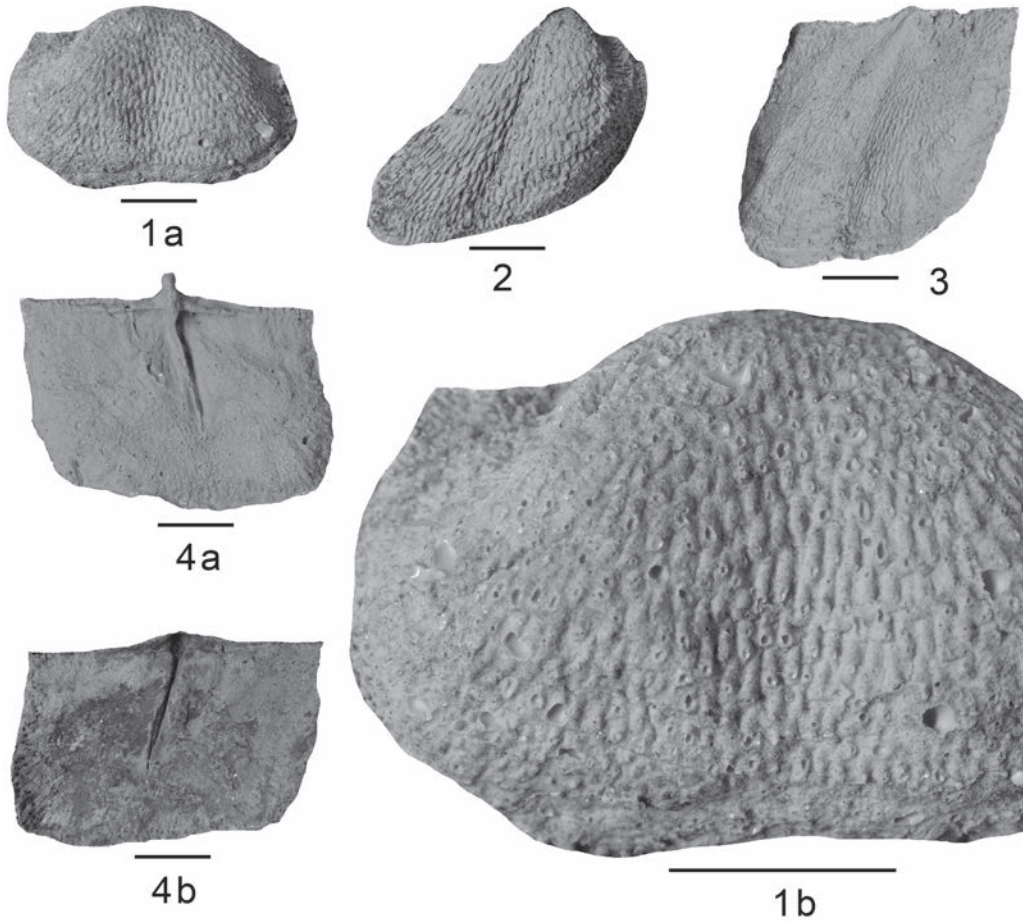


Fig. 9. 1–4, *Waagenoconcha humboldti* (d’Orbigny): 1, external latex cast (1a, 1b) of ventral valve, UHR12596; 2, external latex cast of ventral valve, UHR19847; 3, external latex cast of dorsal valve, UHR19846; 4, internal latex cast (4a) and internal mould (4b) of dorsal valve, UHR19842. Scale bars represent 1 cm.

UHR12133, 19847; (3) external moulds of two ventral valves, UHR12595, 12596; (4) external mould of a dorsal valve, UHR19846; and (5) internal moulds of two dorsal valves, UHR19842, 19843.

Description.—Shell medium in size for genus, transversely subrectangular in outline; hinge slightly narrower than maximum width at midlength; length about 33 mm, width about 45 mm in the largest specimen (UHR12596). Ventral valve moderately convex in lateral profile; umbo tapering, strongly incurved beyond hinge line; ears small, triangular in shape, obscurely demarcated from visceral region; sulcus broad and shallow; lateral slopes rounded. Dorsal valve with large, flat to slightly concave visceral disc, geniculated at anterior margin, and followed by short trail; fold broad and low, occurring just anterior to umbonal depression and extending to anterior margin. External surface of ventral valve

ornamented with some strong concentric rugae and numerous, elongate, and quincunxially arranged spine bases (tubercles); numbering 4–5 spine bases in 5 mm width at midlength. External ornament of dorsal valve similar to that of opposite valve, but rugae more regularly and closely spaced, and spine bases finer. Ventral valve interior with large, longitudinally striated diductor scars. Dorsal interior with trilobed cardinal process followed by thick, long median septum, extending to nearly two-thirds length of valve; adductor scars dendritic.

Remarks.—These specimens are referred to *Waagenoconcha humboldti* (d’Orbigny, 1842), originally described from the lower Permian (Asselian) of Yarbichambi, Bolivia, on account of size, shape and external ornament of both valves, particularly, in having elongate, rather coarse spine bases and strong rugae on the ventral valve. *Waagenoconcha abichi* (Waagen, 1884, p. 697, pl. 74, figs. 1–7), from the Wargal and Chhidru formations of the Salt Range, Pakistan, is also a medium-sized species, but the Pakistani species differs from *W. humboldti* in having coarser and sparser spine bases on the ventral valve.

Distribution.—Gzhelian–Capitanian: northeastern Japan (Nagaiwa–Sakamotozawa and Kamiyasse–Imo in the South Kitakami Belt), northern Russia (Timan and Pechora Basin), western Russia (Moscow Basin), northwestern China (Gansu), northern China (Inner Mongolia), eastern Russia (South Primorye) and Bolivia.

Waagenoconcha irginae (Stuckenberg, 1898)

Fig. 10

Productus irginae Stuckenberg, 1898, p. 220, pl. 2, fig. 16; Tschernyschew, 1902, p. 273, 618, pl. 30, figs. 3, 4; pl. 52, figs. 1–4; Miloradovich, 1935, p. 67, 133, pl. 5, figs. 1, 2.

Productus cf. *humboldti irginae* Stuckenberg; Fredericks, 1925, p. 19, pl. 4, fig. 117.

Waagenoconcha humboldti var. *irginae* (Stuckenberg); Solomina, 1960, p. 31, pl. 2, figs. 1–4.

Waagenoconcha irginae (Stuckenberg): Muir-Wood and Cooper, 1960, pl. 89, figs. 15, 16; Gobbett, 1963, p. 76, pl. 5, fig. 7; pl. 6, figs. 1–5; Zavodowsky and Stepanov, 1970, p. 89, pl. 3, figs. 3, 4; Ifanova, 1972, p. 103, pl. 3, figs. 14–16; Lee and Gu, 1976, p. 252, pl. 155, figs. 3, 4; pl. 170, fig. 3; Kalashnikov, 1986, pl. 118, figs. 2, 3; Kalashnikov, 1993, p. 70, pl. 36, figs. 3–5; Tazawa and Araki, 2016, p. 157, figs. 4.1–4.6.

Waagenoconcha imperfecta Prendergast: Tazawa, 1974, p. 127, pl. 1, figs. 4–6; pl. 2, figs. 2–7; pl. 3, figs. 1–3; pl. 4, figs. 1–4, 7 (excluding pl. 2, fig. 6; pl. 3, fig. 2); Tazawa, 1976, pl. 2, fig. 6; Minato et al., 1979, pl. 65, figs. 1, 2; Manankov, 1991, p. 112, pl. 23, figs. 4–7; Tazawa, 2002, figs. 10.12; Tazawa, 2007, fig. 4.12.

Waagenoconcha sp. Tazawa and Ibaraki, 2001, p. 9, pl. 1, fig. 4.

Waagenoconcha cf. *imperfecta* Prendergast: Tazawa, 2001, p. 293, fig. 7.24.

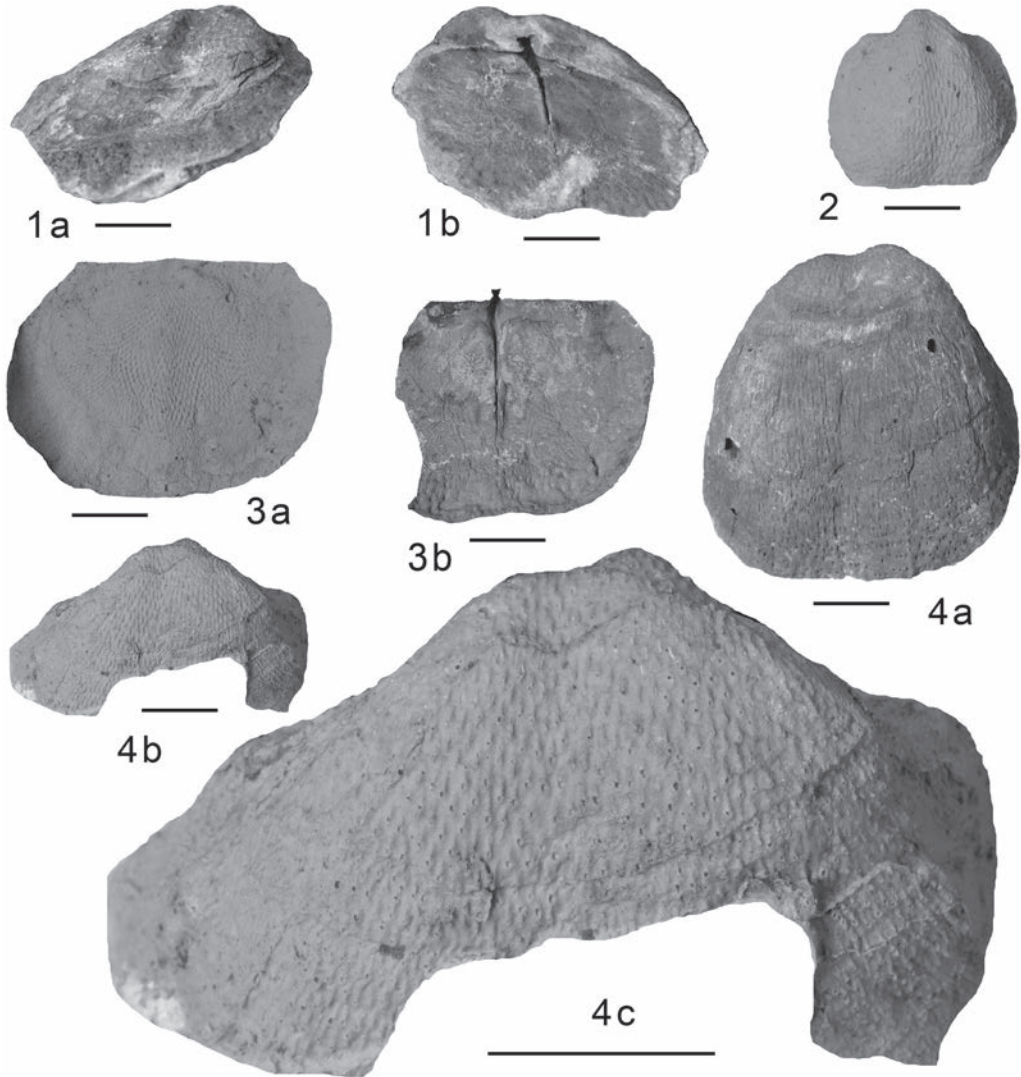


Fig. 10. 1–4, *Waagenoconcha irginae* (Stuckenberg): 1, ventral view (1a) and dorsal view (1b) of internal mould of conjoined shell, KCG028; 2, external latex cast of ventral valve, UHR19838; 3, external latex cast (3a) and internal mould (3b) of dorsal valve, UHR19826; 4, internal mould (4a) and external latex cast (4b, 4c) of ventral valve, UHR19818. Scale bars represent 1 cm.

Material.—Twenty-nine specimens from localities KF9, KF11 and KF39: (1) external and internal moulds of two conjoined shells, UHR19823, 19841; (2) internal moulds of three conjoined shells, with external moulds of the dorsal valves, UHR19816, 19817, 19827; (3) internal moulds of two conjoined shells, UHR19834, 19839; (4) external and internal moulds of six ventral valves, UHR19812, 19818, 19822, 19828, 19838, 19840; (5) external mould of a ventral valve, UHR19823; (6) internal moulds of six ventral valves, NU-B1659, UHR19815,

19825, 19830, 19832, 19835; (7) external and internal moulds of eight dorsal valves, UHR19814, 19821, 19824, 19826, 19829, 19831, 19836, 19837; and (8) external mould of a dorsal valve, UHR19820.

Description.—Shell medium in size for genus, equidimensional to slightly longer subrectangular in outline, with greatest width at about two-thirds length from umbo; length 44 mm, width 43 mm in the largest specimen (UHR19818); length 34 mm, width 34 mm in the average-sized specimen (UHR19835); length 10 mm, width 12 mm in the smallest specimen (UHR19816). Ventral valve moderately convex in lateral profile, most convex at umbo, not geniculated; ears small; sulcus narrow and moderately deep, commencing at umbo and extending to anterior margin; lateral slopes steep. Dorsal valve nearly flat on visceral disc, strongly geniculated, and followed by short trail; fold narrow and low on anterior half of valve. External surface of ventral valve ornamented with several irregular concentric rugae and numerous spine bases; spine bases fine, elongate, quincunxially arranged, and smaller in size anteriorly, numbering 8–9 in 5 mm width at midlength. External ornament of dorsal valve same as that of opposite valve, although spine bases being finer in dorsal valve. Ventral interior with large, longitudinally striated diductor scars and small, elongate dendritic adductor scars; coarse irregular pustules occurring around anterior margin. Dorsal interior with moderately large, trifid cardinal process bearing a groove on ventral face; median septum thin and long, extending to half or more length of valve; lateral ridges short and straight; adductor scars large and dendritic in anterior ones and small, elongate and smooth in posterior ones; numerous pustules becoming coarser anteriorly.

Remarks.—The specimens available are referred to *Waagenoconcha irginae* (Stuckenberg, 1898), redescribed and refigured by Tschernyschew (1902, p. 273, 618, pl. 30, figs. 3, 4; pl. 52, figs. 1–4) from the lower Permian (*Cora-Schwagerina* horizons) of Ufa, central Russia, in size, shape and external ornament of both valves, in particular, fine quincunxially arranged spine bases becoming finer anteriorly. Tazawa (1974) described most of the Kitakami specimens as *Waagenoconcha imperfecta* Prendergast, 1935. But the Australian species differs from *W. irginae* in its much larger size (see Archbold, 1993, p. 20, figs. 11–13) and in having finer spine bases on the ventral valve. The type species, *Waagenoconcha humboldti* (d'Orbigny, 1842), is distinguished from *W. irginae* by the coarser spine bases on the ventral valve.

Distribution.—Asselian–Capitanian: northeastern Japan (Setamai and Kamiyasse–Imo in the South Kitakami Belt), central Japan (Moribu in the Hida Gaien Belt), Spitsbergen, northern Russia (Kanin Peninsula, Timan, Pechora Basin, northern Urals and Kolyma), central Russia (southern Urals), southern Mongolia, northern China (Inner Mongolia) and eastern Russia (South Primorye).

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