

Original Article

Early Permian brachiopods from Kiryu, Ashio Belt, central Japan

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Abstract: This paper describes a brachiopod fauna, consisting of 8 species in 8 genera, from Lower Permian basaltic tuff and limestone in a Jurassic accretionary complex of the Ashio Belt in Kiryu, central Japan. The fauna includes two new species, *Dasysaria japonica* and *Linoproductus ashioensis*, and indicates an Early Permian age (Artinskian-Kungurian or Leonardian). In terms of palaeobiogeography, there is a strong affinity between the Kiryu fauna and the Leonardian West Texas fauna.

Key Words: Ashio Belt, brachiopod, Early Permian, Kiryu, palaeobiogeography

Introduction

Tazawa and Takakuwa (2009) reported two *Eolyttonia* species, *Eolyttonia diabloensis* (Stehli) and *Eolyttonia kiryuensis* Tazawa and Takakuwa, from Lower Permian sandstone (corrected to basaltic tuff in the present paper) in a Jurassic accretionary complex (Kurohone-Kiryu Complex; Kamata, 1996) in the Ashio Belt, from the upper stream of the Iwakayasawa Valley, north of Jarubuchi, Kiryu City, Gunma Prefecture, central Japan (Fig. 1). Their report was the first systematic study of Permian brachiopods from Kiryu, although Koizumi et al. (1998) briefly reported two species of brachiopods, *Eolyttonia* sp. and *Permorthotetes* sp. from the same locality.

The present paper describes new brachiopod specimens, collected from float material of light greenish grey or rarely reddish purple basaltic tuff and dark grey limestone in the upper stream of the Iwakayasawa Valley, and discusses the age and palaeobiogeography of the Kiryu fauna. The junior authors of this study, S. Hayashi, K. Nakamura and M. Shimizu, prepared the material; Y. Takakuwa registered the brachiopod specimens.

The fossils described below are registered with the prefix GMNH-PI and housed in the collections of the Gunma Museum of Natural History in Tomioka City, Gunma Prefecture, Japan.

The Kiryu fauna

The brachiopod fauna described herein includes the following 8 species in 8 genera: *Echinauris lateralis* Muir-Wood and Cooper, 1960, *Dasysaria japonica* sp. nov., *Reticulatia uralica* (Tschernyschew, 1902), *Linoproductus ashioensis* sp. nov., *Eolyttonia kiryuensis* Tazawa and Takakuwa, 2009, *Loxophragmus* sp., *Meekella* sp. and *Orthothetina* sp. Among these species, *L. ashioensis* is the most abundant, accounting for over the half of the material. *E. lateralis*, *D. japonica* and *R. uralica* are common,

and the other species are rare. All specimens were collected from basaltic tuff, although GMNH-PI-3518 (*L. ashioensis*) and GMNH-PI-3534 (*R. uralica*) were collected from limestone.

Among the species and genera of the Kiryu fauna, *E. lateralis* has been reported from the Lower to Middle Permian (Kungurian-Roadian) of West Texas and from Hatahoko in the Mino Belt, central Japan. The genus *Dasysaria* is known only from the Lower Permian (Asselian-Sakmarian) of Texas. *R. uralica* is known from the Upper Carboniferous (Kasimovian-Gzhelian) of northern Russia and North China, and from the Lower Permian (Asselian-Kungurian) of Spitsbergen, northern Russia, Uzbekistan and Arctic Canada. *L. ashioensis* is close to *Linoproductus kaseti* Grant, 1976, from the Lower Permian (Artinskian) of southern Thailand. The genus *Eolyttonia* occurs mainly in the Lower Permian (upper Wolfcampian to upper Leonardian) of West Texas and in the Middle Permian (Wordian) of the transitional zone between the Boreal and Tethyan realms. The genus *Loxophragmus* has been recorded from the Lower Permian (Artinskian-Kungurian) of Southwest China and West Texas, and from the Middle Permian (Wordian) of South China. Both *Meekella* and *Orthothetina* are wide-ranging and cosmopolitan genera, although neither has been reported from the Boreal region.

In summary, the age of the Kiryu fauna is Early Permian (Artinskian-Kungurian or Leonardian), which is consistent with Kobayashi and Hamada (1984), Koizumi et al. (1988) and Igo et al. (2000), who considered the age of the fossil horizon as Leonardian or Artinskian-Kungurian based on the occurrence of trilobite *Pseudophillipsia* (*Pseudophillipsia*) species and the rugose coral *Yatsengia kuzuensis* from the Iwakayasawa and Yonesawa valleys, north of Jarubuchi, Kiryu. In terms of palaeobiogeography, the Kiryu fauna is close to the Early Permian (Leonardian) West Texas fauna, described by Stehli (1954), Muir-Wood and Cooper (1960) and Cooper and Grant (1969, 1974, 1975), with

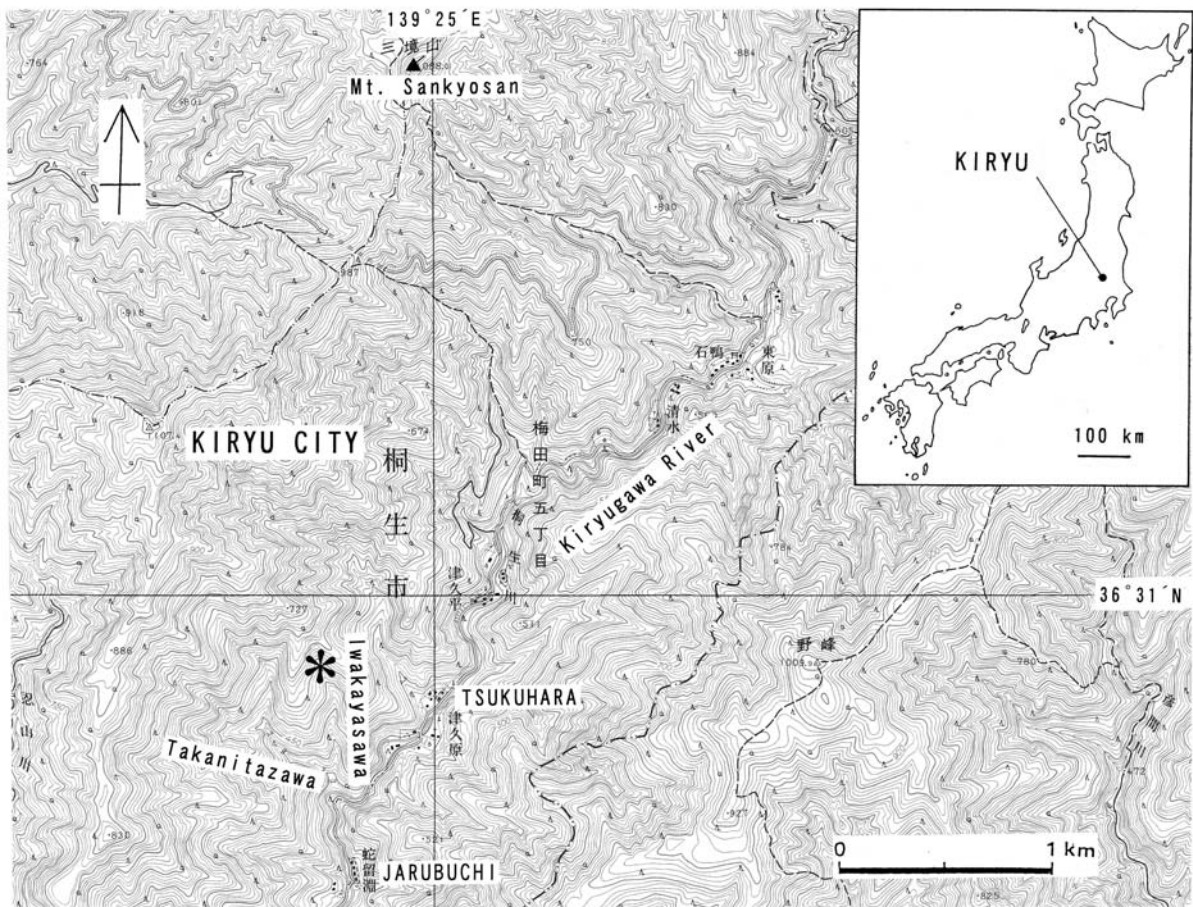


Figure 1 Index map showing the fossil locality (asterisk), using the topographical map of “So-on” scale 1 : 25,000 published by the Geospatial Authority of Japan.

predominant tropical elements. It is presumed that the Ashio Belt including the Kiryu area was located in the equatorial region, close to the North American Continent, in the Early Permian.

Systematic descriptions

(by J. Tazawa)

Order Productida Sarytcheva and Sokolskaya, 1959

Suborder Productidina Waagen, 1883

Superfamily Productoidea Gray, 1840

Family Productellidae Schuchert, 1929

Subfamily Overtoniinae Muir-Wood and Cooper, 1960

Tribe Costispiniferini Muir-Wood and Cooper, 1960

Genus *Echinauris* Muir-Wood and Cooper, 1960

Type species.—*Echinauris lateralis* Muir-Wood and Cooper, 1960.

Echinauris lateralis Muir-Wood and Cooper, 1960

Fig. 2.1

Avonia subhorrida King, 1931, p. 84, pl. 20, figs. 10, 11.

Echinauris lateralis Muir-Wood and Cooper, 1960, p. 222, pl.

68, figs. 1-13; Cooper and Grant, 1975, p. 1011, pl. 333, figs. 1-34; pl. 334, figs. 1-33; pl. 335, figs. 36-51; pl. 468, figs. 5-9; Shen et al., 2011, p. 557, figs. 3.3-3.6, 3.10-3.21.

Material.—Four specimens: (1) external and internal moulds of a ventral valve, GMNH-PI-3526; (2) external mould of a ventral valve, GMNH-PI-3527; (3) external mould of two dorsal valves, GMNH-PI-3528, 3529.

Description.—Shell medium size for genus, slightly transverse subcircular in outline, with greatest width at slightly anterior to midlength; length 13 mm, width 14 mm in the largest ventral valve specimen (GMNH-PI-3527). Ventral valve strongly and unevenly convex in lateral profile, most convex at umbonal region; umbo small, incurved and overhanging hinge line a little; ears small; no sulcus; lateral slopes steep. Dorsal valve strongly and almost evenly concave, with maximum concavity near midlength; no fold. External surface of ventral valve ornamented with numerous stout spines; long, nearly straight spines extending laterally. External surface of dorsal valve ornamented with numerous fine spine bases, but no rugae or costae. Internal structure of ventral valve not well preserved and obscure.

Remarks.—These specimens can be referred to *Echinauris lateralis* Muir-Wood and Cooper, 1960, from the Road Canyon and Word formations (upper Leonardian-lower Guadalupian) of West Texas, by their size, outline and external ornament, particularly,

by the long, nearly straight halteroid spines on lateral slopes.

Echinauris opuntia (Waagen, 1884, p. 707, pl. 79, figs. 1, 2), from the Wargal Formation of the Salt Range, Pakistan, is distinguished from *E. lateralis* by its larger and slightly longer shell.

Distribution.—Lower Permian (Artinskian-Kungurian) of central Japan (Hatahoko in the Mino Belt and Kiryu in the Ashio Belt); Lower to Middle Permian (Kungurian-Roadian) of the United States (West Texas).

Family Productidae Gray, 1840
Subfamily Dictyoclostinae Stehli, 1954
Genus *Dasysaria* Cooper and Grant, 1969

Type species.—*Dasysaria undata* Cooper and Grant, 1969.

Dasysaria japonica sp. nov.
Figs. 2.2, 2.3

Etymology.—Named after the fossil locality, Japan.

Material.—Three specimens: (1) external mould of a conjoined shell, GMNH-PI-3537 (holotype); (2) an abraded conjoined shell, GMNH-PI-3538; (3) external mould of a ventral valve, GMNH-PI-3539.

Diagnosis.—Large, transversally wider *Dasysaria* with large ears and fine costae on both valves.

Description.—Shell large size for genus, transversely subrectangular in outline, widest at hinge; length about 40 mm, width about 60 mm in the better preserved ventral valve specimen (GMNH-PI-3538); length about 22 mm, width about 65 mm in the dorsal valve of the holotype (GMNH-PI-3537). Ventral valve strongly and unevenly convex in lateral profile, most convex at umbonal half; umbo small, blunt; ears moderately large, flattened and extended laterally; sulcus broad and shallow, originating at about mid of visceral disc; lateral slopes steep; trail not well preserved. Dorsal valve flatly concave on visceral disc, strongly geniculated and followed by a long trail; ears large, extended; no fold. External surface of ventral valve ornamented with numerous fine costae and closely spaced somewhat wavy rugae on visceral disc, and numerous large spine bases on ears; costae numbering 13-14 in 10 mm at mid of visceral disc. Dorsal valve with somewhat irregular reticulate ornament on visceral disc and multicostate ornament on trail, but spines or spine bases lacking completely; costae numbering 13-14 in 10 mm at mid of visceral disc, 11-12 in 10 mm at mid of trail. Ventral valve interior with fairly large, flabellate and striated diductor scars and a pair of elongate, dendritic adductor scars.

Remarks.—*Dasysaria japonica* sp. nov. most resembles *Dasysaria welleri* (King, 1938), from the upper Wolfcampian of Putnam, north-central Texas, in size and shape of the shell, but it differs from the Texan species in having a broad and shallow sulcus on the ventral valve and finer costae on the both ventral and dorsal valves.

The type species, *Dasysaria undata* Cooper and Grant (1969, p. 9, pl. 5, figs. 32-34), from the Hueco Formation of West Texas, is distinguished from *D. japonica* by its less transverse shell, smaller ears, and coarser costae on the both valves.

Dasysaria wolfcampensis (King, 1931, p. 74, pl. 16, figs. 1-5), from the Wolfcampian of West Texas, is readily distinguished

from the present new species by its smaller and narrower shell, and coarser costae on the both valves.

Genus *Reticulatia* Muir-Wood and Cooper, 1960

Type species.—*Productus huecoensis* King, 1931.

Reticulatia uralica (Tschernyschew, 1902)
Figs. 2.4, 2.5, 3.11

Productus uralicus Tschernyschew, 1902, p. 259, 612, pl. 32, fig. 1; pl. 33, fig. 1; pl. 62, fig. 1; Chao, 1927, p. 40, pl. 1, figs. 5-9; Frebold, 1937, p. 15, pl. 7, figs. 1, 4; pl. 8, figs. 1, 2.

Productus moelleri var. *uralicus* Tschernyschew: Fredericks, 1915, p. 44, pl. 1, fig. 12; pl. 2, figs. 1, 2.

Dictyoclostus uralicus (Tschernyschew): Volgin, 1960, p. 91, pl. 11, fig. 3.

Costiferina cf. *uralica* (Tschernyschew): Gobbett, 1963, p. 94, pl. 9, fig. 7.

Reticulatia cf. *uralica* (Tschernyschew): Bamber and Waterhouse, 1971, pl. 13, fig. 4.

Reticulatia sp. 1 Cooper and Grant, 1975, p. 1089, pl. 393, figs. 1-10.

Reticulatia uralica (Tschernyschew): Alexandrov and Einor, 1979, p. 66, pl. 25, fig. 2; pl. 26, fig. 1; Kalashnikov, 1986, pl. 115, fig. 1; Kalashnikov, 1993, p. 57, pl. 21, figs. 2, 3; Shi and Waterhouse, 1996, p. 85, pl. 11, fig. 11; pl. 12, figs. 1-11; pl. 13, figs. 1, 2; pl. 32, fig. 1.

Material.—Six specimens: (1) external moulds of two ventral valves, GMNH-PI-3531, 3532; (2) external moulds of four dorsal valves, GMNH-PI-3533-3536.

Description.—Shell large size for genus, transversely rectangular in outline, hinge forming widest part; length about 65 mm, width about 127 mm in the largest dorsal valve specimen (GMNH-PI-3533). Ventral valve strongly and unevenly convex in lateral profile, with long trail; umbo small, tapering and slightly overhanging hinge line; sulcus narrow and deep on anterior half of visceral disc and trail. Dorsal valve nearly flat on visceral disc, strongly geniculated, and followed by a short trail; no fold; ears large, triangular and flatly concave. External surface of ventral valve ornamented with numerous regular rugae and costae on visceral disc, and costae only on trail; numbering 7 costae in 10 mm at mid of trail. External ornament of dorsal valve similar to the opposite valve; reticulate on both visceral disc and ears, and costate on trail.

Remarks.—These specimens are not well preserved, but can be referred to *Reticulatia uralica* (Tschernyschew, 1902), from the Lower Permian of the Urals, by their large size, narrow and deep sulcus, and thick, strong costae on the ventral valve. *Reticulatia* sp. 1, described by Cooper and Grant (1975) from the Neal Ranch Formation (lower Wolfcampian) of West Texas is probably conspecific with the present species.

Reticulatia robusta Cooper and Grant (1975, p. 1088, pl. 386, fig. 1; pl. 392, figs. 1-6), from the Wolfcampian and lower Leonardian of West Texas, is also a large-sized species with coarse costae on the ventral valve, but the Texan species is distinguished from *R. uralica* by its shallower sulcus and coarser

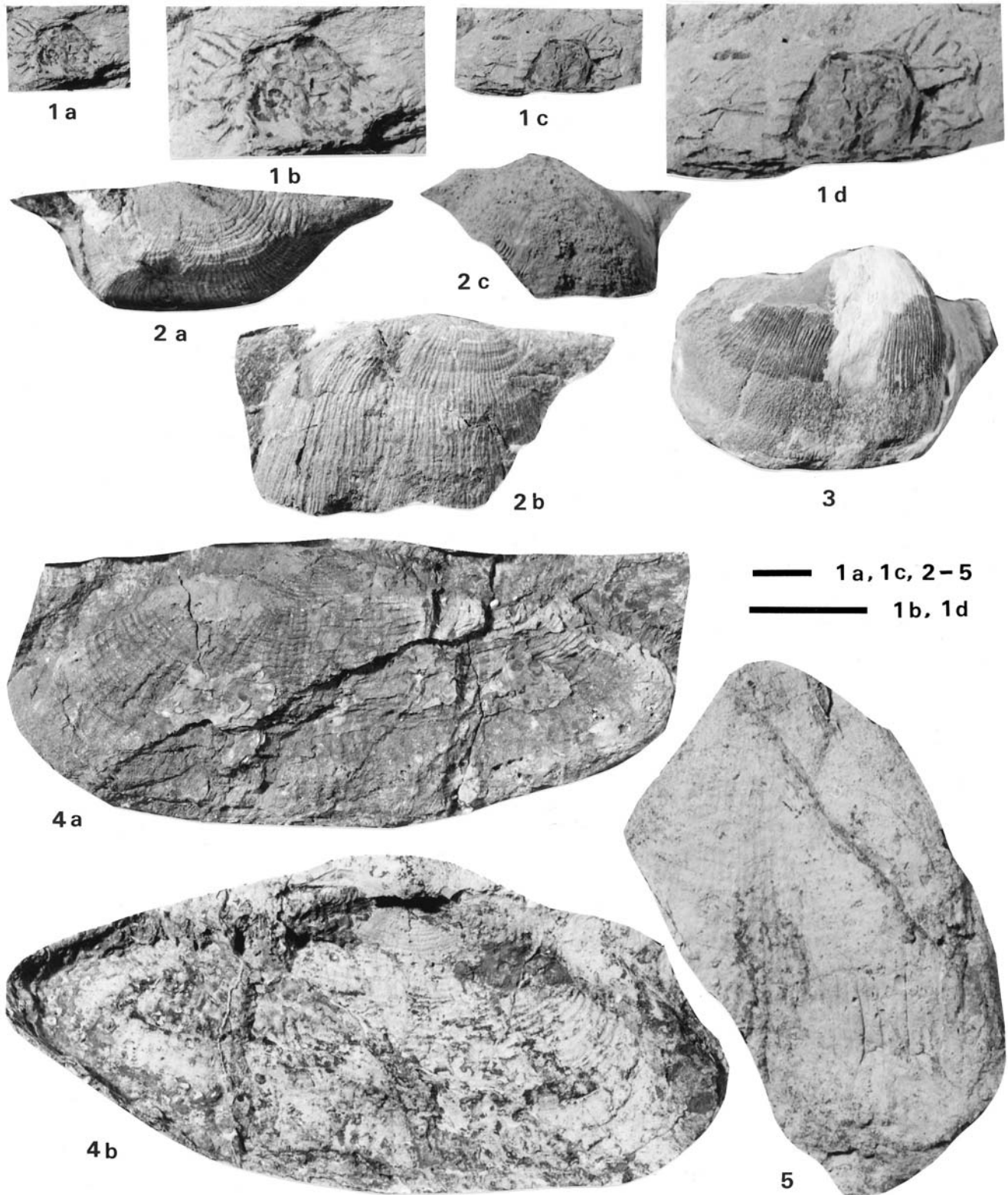


Figure 2 1: *Echinauris lateralis* Muir-Wood and Cooper, 1a, 1b: external mould of ventral valve, GMNH-PI-3526. 2, 3: *Dasysaria japonica* sp. nov., 2a, 2b, 2c: dorsal and anterior views of external mould of dorsal valve, and external latex cast of ventral valve, GMNH-PI-3537 (holotype), 3: abraded ventral valve, GMNH-PI-3538. 4, 5: *Reticulatia uralica* (Tschernyschew), 4a, 4b: external mould and external latex cast of dorsal valve, GMNH-PI-3533, 5: external latex cast of ventral valve, GMNH-PI-3531. Scale bars represent 1 cm.

costae on the ventral valve

The type species, *Reticulatia huecoensis* (King, 1931, p. 68, pl. 11, figs. 7, 8), from the Wolfcampian of West Texas, is readily distinguished from the present species by its smaller size, shallower sulcus and finer costae on the ventral valve.

Distribution.—Upper Carboniferous (Kasimovian-Gzelian) of northern Russia (Bashkiria in the southern Urals) and North China (Shanxi); Lower Permian (Asselian-Kungurian) of Spitsbergen, northern Russia (northern Urals, Pai Khoi), Uzbekistan (southern Fergana), central Japan (Kiryu in the Ashio Belt) and Arctic Canada (northern Yukon Territory).

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

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

***Linoproductus ashioensis* sp. nov.**

Figs. 3.1-3.7

Etymology.—Named after the fossil locality, Ashio Belt.

Material.—Twenty-two specimens: (1) six conjoined shells, GMNH-PI-3504 (holotype), 3505-3509; (2) external and internal moulds of a ventral valve, GMNH-PI-3510; (3) six ventral valves, GMNH-PI-3511-3516; (4) external and internal moulds of a dorsal valve, GMNH-PI-3517; (5) eight dorsal valves, GMNH-PI-3518-3525.

Diagnosis.—Average-sized, subquadrate *Linoproductus*, with numerous costellae numbering 9-10 in 5 mm at midlength of ventral valve.

Description.—Shell medium size for genus, subquadrate in outline, with greatest width at slightly anterior to midlength; hinge equal to or slightly shorter than greatest width; length 30 mm, width 28 mm in the holotype (GMNH-PI-3504); length 34 mm, width 36 mm in the largest ventral valve specimen (GMNH-PI-3513). Ventral valve strongly and unevenly convex in lateral profile, most convex at umbonal region; umbo small, incurved; ears large, flat; sulcus broad and shallow; lateral slopes steep. Dorsal valve strongly and unevenly concave in lateral profile; visceral disc gently concave, strongly geniculated at anterior margin, and followed by long trail; fold broad and low at anterior half of visceral disc. External surface of ventral valve ornamented with few, strong rugae and numerous fine costellae; spine bases not observed; rugae developed on lateral and anterior slopes; costellae numbering 9-10 in 5 mm at about midlength. Dorsal valve strongly reticulate on visceral disc and costellate on trail, no spine bases.

Remarks.—*Linoproductus ashioensis* sp. nov. is most like *Linoproductus kaseti* Grant (1976, p. 154, pl. 41, figs. 8-28), from the Lower Permian (Artinskian) Rat Buri Limestone of Phangnga, southern Thailand, in size and outline of the shell, but differs in having finer costellae.

Linoproductus simensis (Tschernyschew, 1902, p. 286, 626, pl. 35, fig. 7, pl. 55, figs. 2-5), from the Lower Permian of the Ural Mountains, differs from the Kiryu species in having no ventral sulcus.

Linoproductus undatus Cooper and Grant (1975, p. 1149,

pl. 433, figs. 27-43), from the Hess Formation (Wolfcampian) of West Texas, somewhat resembles in shape of the shell, but differs from the present new species in having a row of stout halteroid spines along the posterior margin of the shell.

Suborder Lytoniida Williams, Harper and Grant, 2000
Superfamily Lytonioidea Waagen, 1883
Family Lytoniidae Waagen, 1883
Subfamily Lytoniinae Waagen, 1883
Genus *Eolytonia* Fredericks, 1924

Type species.—*Oldhamina* (*Lyttonia*) *mira* Fredericks, 1916.

***Eolytonia kiryuensis* Tazawa and Takakuwa, 2009**
Fig. 3.8

Eolytonia kiryuensis Tazawa and Takakuwa, 2009, p. 31, figs. 2B, 3.3-3.5.

Material.—One specimen, internal mould of a ventral valve, GMNH-PI-3530.

Remarks.—The ventral valve specimen from Kiryu is flat in lateral profile, medium size (width about 34 mm, length about 32 mm), and having symmetrically arranged, slightly arched lateral septa with flat crests (solidiseptate) in the posterior region and deeply concave crests (angustilobate) in the anterior region, numbering 12 on both sides of strong median septum. This specimen can be referred to *Eolytonia kiryuensis* Tazawa and Takakuwa, 2009, from the same locality of Kiryu by its strong median septum and lateral septa with flat crests in the posterior region and deeply grooved crests in the anterior region.

Eolytonia diabloensis (Stehli, 1954), redescribed by Cooper and Grant (1974, p. 420, pl. 140, figs. 1-25; pl. 162, figs. 11-18) from the upper Wolfcampian and the lower Leonardian of West Texas, differs from *E. kiryuensis* in having thin, anteriorly separated median septum and somewhat irregular, deeply grooved lateral septa in the ventral valve.

Genus *Loxophragmus* Cooper and Grant, 1974

Type species.—*Loxophragmus ellipticus* Cooper and Grant, 1974.

***Loxophragmus* sp.**
Fig. 3.9

Material.—One specimen, imperfect internal mould of a ventral valve, GMNH-PI-3503.

Remarks.—This specimen is a fragmentarily preserved, but it is safely assigned to the genus *Loxophragmus* by its crenulated, slanting lateral septa in the ventral valve. The Kiryu species may be a new species, characterized by its large size (length more than 34 mm, width more than 40 mm). All of the previously known species, *Loxophragmus ellipticus* Cooper and Grant, 1974 from the Lower Permian (Leonardian) of West Texas, *Loxophragmus kuzishanensis* (Liang in Wang et al., 1982) from the Middle Permian (Wordian) of Zhejiang, South China, and *Loxophragmus* sp. Shen, Shi and Fang, 2002 from the Lower Permian (Artinskian-Kungurian) of Yunnan, Southwest China, are much smaller than the Kiryu species.

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. John, 1867

Type species.—*Plicatula striatocostata* Cox, 1857.

Meekella sp.
 Fig. 3.12

Material.—One specimen, fragmentarily preserved external and internal moulds of a ventral valve, GMNH-PI-3502.

Remarks.—This specimen is safely assigned to the genus *Meekella* by its external ornament of the ventral valve consisting of several costae and numerous fine costellae. Within the group,

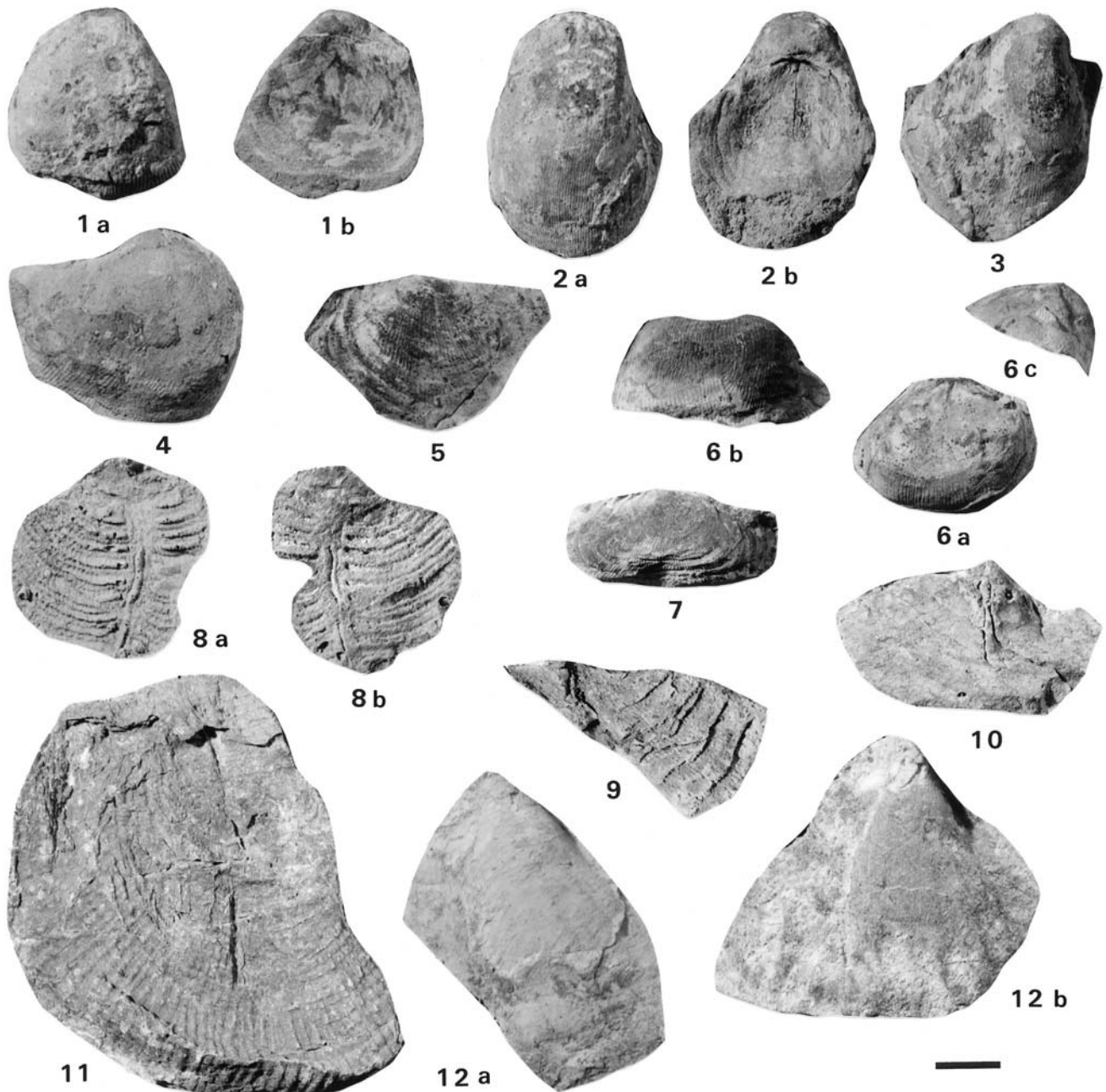


Figure 3 1-7: *Linoproductus ashioensis* sp. nov., 1a, 1b: ventral and dorsal views of conjoined shell, GMNH-PI-3504 (holotype), 2a, 2b: ventral and dorsal views of conjoined shell, GMNH-PI-3505, 3: internal mould of ventral valve, GMNH-PI-3510, 4: ventral valve, GMNH-PI-3513, 5: dorsal valve, GMNH-PI-3523, 6a, 6b, 6c: dorsal, anterior and lateral views of dorsal valve, GMNH-PI-3520, 7: dorsal valve, GMNH-PI-3519. 8: *Eolyttonia kiryuensis* Tazawa and Takakuwa, 8a, 8b: internal latex cast and internal mould of ventral valve, GMNH-PI-3530. 9: *Loxophragmus* sp., internal mould of ventral valve, GMNH-PI-3503. 10: *Orthothetina* sp., internal mould of ventral valve, GMNH-PI-3501. 11: *Reticulatia uralica* (Tschernyschew), external mould of dorsal valve, GMNH-PI-3534. 12: *Meekella* sp., 12a, 12b: external latex cast and internal mould of ventral valve, GMNH-PI-3502. Scale bar represents 1 cm.

the Kiryu species is closely allied to *Meekella gigantea* Hayasaka, 1932, originally described briefly by Hayasaka (1932, p. 551, pl. 5, fig. 1), and subsequently described in detail by Hayasaka (1933, p. 26, pl. 6, fig. 2; pls. 9, 10, 11; pl. 12, fig. 1; text-fig. 4) from the Lower Permian Nabeyama Formation of Nabeyama in the Kuzu area, Ashio Belt, central Japan, by its large, transverse (length about 46 mm, width about 64 mm) and gently convex, rather low ventral valve.

Meekella magnifica Cooper and Grant (1974, p. 365, pl. 100, figs. 1-33; pl. 116, figs. 9-18), from the Gaptank, Neal Ranch and Lenox Hills formations (lower Leonardian) of West Texas, is also a large-sized species, but the Texan species differs from the Kiryu species by its high, conical ventral valve.

Genus *Orthothenina* Schellwien, 1900

Type species.—*Orthothenes persicus* Schuchert in Schuchert and Le Vene, 1929.

Orthothenina sp.

Fig. 3.10

Material.—One specimen, internal mould of a ventral valve, GMNH-PI-3501.

Remarks.—This specimen is not well preserved, but can be assigned to the genus *Orthothenina* by its long, thin, subparallel dental plates and lacking any traces of strong costae on the ventral valve. The Kiryu species is a medium-sized *Orthothenina*, but specific identification is difficult in the poorly preserved specimen.

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足尾帯桐生から産出した前期ペルム紀腕足類

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要旨: 足尾帯桐生地域 (群馬県桐生市蛇留淵^{じゃるぶち}北方, 岩萱沢^{いわかやさわ}上流) に分布するジュラ紀付加体中の玄武岩質凝灰岩および石灰岩のブロックから産出した腕足類を記載する. この腕足類フォーナは次の8属8種からなる: *Echinauris lateralis* Muir-Wood and Cooper, *Dasysaria japonica* sp. nov., *Reticulatia uralica* (Tschernyschew), *Linoproductus ashioensis* sp. nov., *Eolyttonia kiryuensis* Tazawa and Takakuwa, *Loxophragmus* sp., *Meekella* sp., *Orthothenina* sp. 桐生フォーナは, 時代的には前期ペルム紀 (Artinskian-KungurianまたはLeonardian) を示し, 古生物地理学的にはアメリカ合衆国テキサス西部の前期ペルム紀 (Leonardian) 腕足類フォーナとの強い類縁性を示す.

キーワード: 足尾帯, 腕足類, 前期ペルム紀, 桐生, 古生物地理