Early Permian (Artinskian) brachiopods from the Ryozensan area, Mino Belt, southwestern Japan

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Abstract

A brachiopod fauna (the Ryozensan fauna), consisting of seven species in six genera, is described from the upper part of the Ryozensan Formation (Artinskian; *Pseudofusulina* Zone) in the Ryozensan area, northern Suzuka Mountains, Mino Belt, southwestern Japan. The brachiopods of the fauna are as follows: *Echinauris* sp., *Meekella* sp., *Enteletes stehlii* Cooper and Grant, *Acosarina rectimarginata* Cooper and Grant, *Acosarina* cf. *dunbari* Cooper and Grant, *Neospirifer* sp. and *Plectelasma* sp. Palaeobiogeographically, the Ryozensan fauna has a close affinity with the lower Permian brachiopod faunas of Kuzu, Kiryu and Hatahoko in the Mino Belt, Japan and West Texas, USA.

Key words: Brachiopoda, Permian, Mino Belt, Ryozensan, Japan.

Introduction

The Ryozensan area in the northern Suzuka Mountains, Mino Belt, southwestern Japan is famous for a Permian large limestone block and its karst topography. The stratigraphy of the Permian rocks in the Ryozensan area has been studied by Miyamura (1973), Miyamura et al. (1976), Harayama et al. (1989), Yamagata (2000) and Sano and Kojima (2000). Consequently, the Permian rocks, named as the Ryozensan Formation, are recognized as an early Permian (Sakmarian–Artinskian) limestone-basalt block (500–600 m thick) in a Jurassic accretionary complex, the Mino Belt. The limestone contains various fossils of marine

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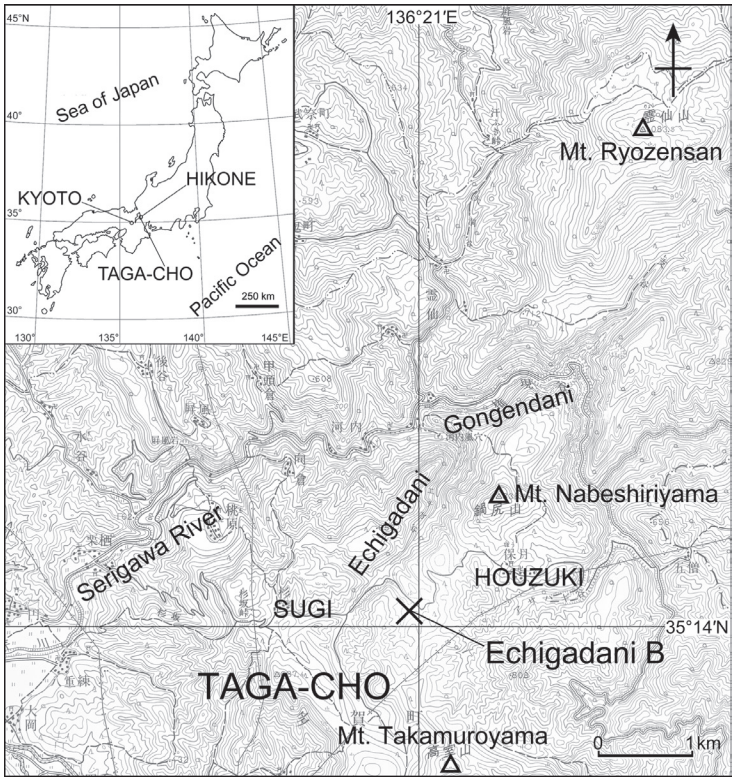

Fig. 1. Map showing the fossil locality Echigadani B in the Ryozensan area, Mino Belt, southwestern Japan (using the topographical map of "East Hikone" scale 1: 50,000 published by the Geospatial Information Authority of Japan).

invertebrates, such as fusulinids, corals, bryozoans, brachiopods, bivalves, gastropods, ammonoids, trilobites and crinoids (Oyagi, 1991). However, palaeontological studies on the fauna are poor. Only some fusulinids (Kobayashi and Furutani, 2009) and one species of trilobite (Kobayashi and Hamada, 1980) have been described until now. In the present paper, we describe a brachiopod fauna, consisting of seven species in six genera, from the upper part of the Ryozensan Formation (*Pseudofusulina* Zone). This is the first systematic study on the brachiopods of the Ryozensan Formation.

Material

The brachiopod specimens were collected by K. Oyagi from grey to dark grey limestone and light brown tuffaceous limestone of the Ryozensan Formation at locality Echigadani B (35° 14′ 05″ N, 136° 20′ 56″ E), upper Echigadani Valley, a tributary of the Serigawa River, 1 km SW of Houzuki, Taga-cho, Inukami-Gun, Shiga Prefecture, southwestern Japan (Fig. 1). The limestone blocks in the Sugi–Houzuki–Takamuroyama area, including the locality

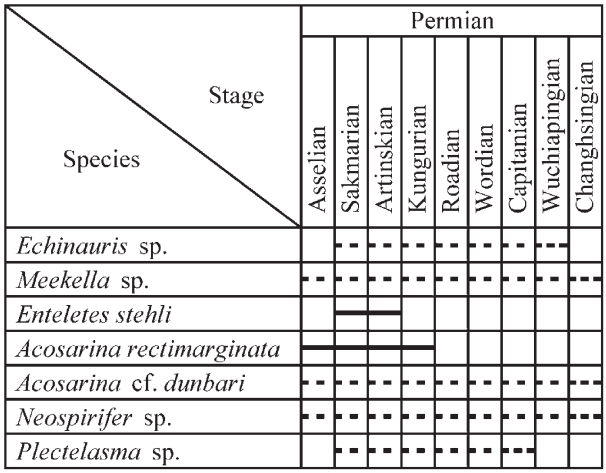

Fig. 2. Stratigraphic distribution of brachiopod species of the Ryozensan fauna. Broken line shows range of the genus.

Echigadani B, belong to the *Pseudofusulina* Zone, which is characterized by the occurrence of *Pseudofusulina vulgaris, P. krotowi, P. norikuraensis* and *P. kraffti* (Miyamura et al., 1976), and is assigned to the Artinskian in age (Sano and Kojima, 2000). The material was studied and described by J. Tazawa; and stored in the Taga Town Museum, Taga-cho, Shiga Prefecture, Japan (prefix TG-Inv, numbers 1064 to 1099).

The Ryozensan fauna

In this study, seven species in six genera are described from the upper part of the Ryozensan Formation of Echigadani, Ryozensan area. The species are as follows: *Echinauris* sp., *Meekella* sp., *Enteletes stehlii* Cooper and Grant, 1976, *Acosarina rectimarginata* Cooper and Grant, 1976, *Acosarina* cf. *dunbari* Cooper and Grant, 1976, *Neospirifer* sp. and *Plectelasma* sp.

Age

The stratigraphic distribution of the brachiopod species of the Ryozensan fauna is summarized in Fig. 2. Of the brachiopods listed above, *Enteletes stehlii* is known from the Sakmarian and Artinskian (Stehli, 1954; Cooper and Grant, 1976), and *Acosarina rectimarginata* from the Asselian to Kungurian (Cooper and Grant, 1976; Shen et al., 2011; Tazawa in Tazawa et al., 2012a). The other five species are uncertain for their species. However, at generic level, *Echinauris* is known from the Sakmarian to Wuchiapingian (Brunton et al., 2000), and *Plectelasma* from the Sakmarian to Capitanian (Cooper and Grant, 1976). Three genera (*Meekella, Acosarina* and *Neospirifer*) are long-ranging: *Meekella* occurs

from the lower Carboniferous–upper Permian (Williams and Brunton, 2000), *Acosarina* from the upper Carboniferous–upper Permian (Harper, 2000), and *Neospirifer* from the lower–upper Permian (Carter, 2006). In summary, the age of the Ryozensan fauna is identified as Sakmarian–Artinskian. This conclusion is consistent with that of Sano and Kojima (2000), who considered the age of the upper part of the Ryozensan Formation to be Artinskian on the basis of the fusulinids listed by Miyamura (1973) and Miyamura et al. (1976).

Palaeobiogeography

In terms of palaeobiogeography, *Enteletes stehlii* is found from the Sakmarian–Kungurian of southwestern Japan (Hachiman in the Mino Belt) and West Texas, USA (see the distribution of this species in the chapter "Systematic descriptions"). *Acosarina rectimarginata* is found from the Asselian–Kungurian of central Japan (Kuzu and Hatahoko in the Mino Belt) and West Texas. *Echinauris* sp. resembles *Echinauris lateralis,* which is found from the Kungurian–Wordian of central Japan (Kiryu and Kuzu in the Mino Belt) and West Texas. *Meekella* sp. resembles *Meekella bisculpta,* from the Artinskian of Ko Muk, southern Thailand. *Acosarina* cf. *dunbari* resembles *Acosarina dunbari,* from the lower Wolfcampian of Nebraska, USA. *Neospirifer* sp. resembles *Neospirifer placidus,* from the lower Wolfcampian of West Texas. *Plectelasma* sp. resembles *Plectelasma kingi*, from the Wolfcampian of West Texas. Consequently, the Ryozensan fauna has a close affinity with the lower Permian brachiopod faunas of Kuzu, Kiryu and Hatahoko in the Mino Belt, Japan and West Texas, USA. This conclusion is consistent with those of Tazawa and Shen (1997), Shen et al. (2011) and Tazawa et al. (1998, 2013, 2016), who reported that the Permian brachiopod faunas of the Mino Belt are tropical faunas of the equatorial Panthalassa, not far from North America (West Texas).

Systematic descriptions

Order Productida Sarytcheva and Sokolskaya, 1959
Suborder Productidina Waagen, 1883
Superfamily Marginiferoidea Stehli, 1954
Family Costispiniferidae Muir-Wood and Cooper, 1960
Subfamily Costispiniferinae Muir-Wood and Cooper, 1960
Genus *Echinauris* Muir-Wood and Cooper, 1960

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

Echinauris sp.
Fig. 3A

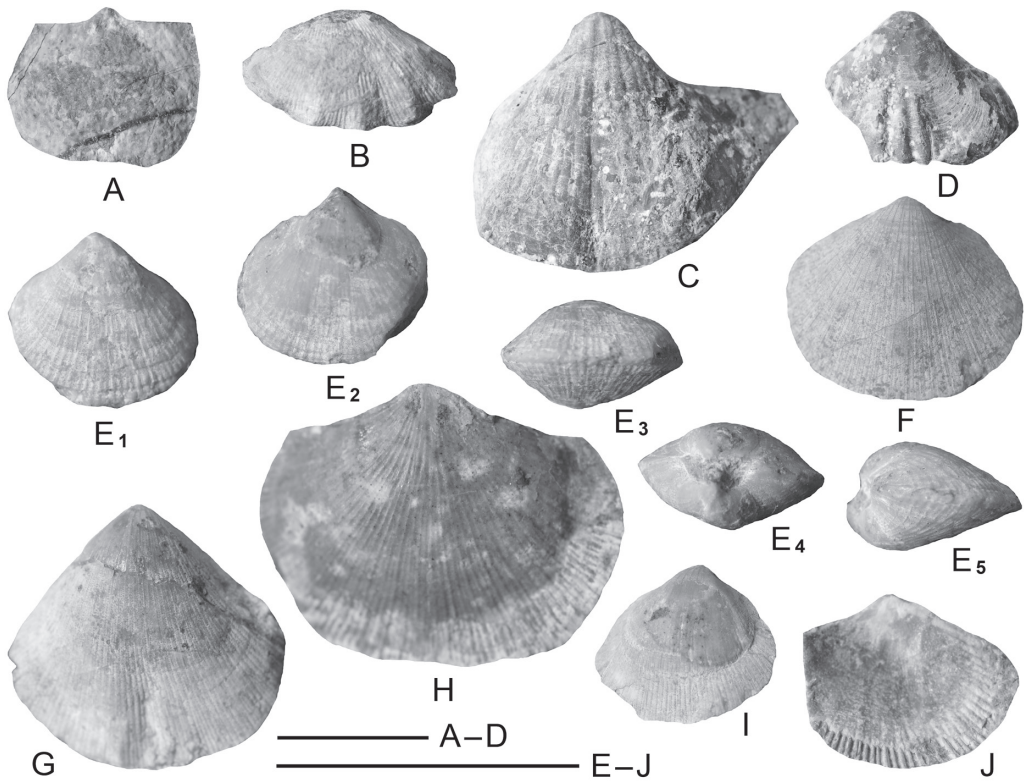

Fig. 3. Brachiopods of the Ryozensan fauna (1). **A,** *Echinauris* sp., external mould of dorsal valve, TG-Inv1057; **B,** *Meekella* sp., dorsal valve, TG-Inv1093; **C,** *Neospirifer* sp., ventral valve, TG-Inv1100; **D,** *Plectelasma* sp., dorsal valve, TG-Inv1101; **E, F,** *Acosarina rectimarginata* Cooper and Grant; E, ventral (E_1), dorsal (E_2), anterior (E_3), posterior (E_4) and lateral (E_5) views of conjoined shell, TG-Inv1090; F, dorsal valve, TG-Inv1095; **G–J,** *Acosarina* cf. *dunbari* Cooper and Grant, G, ventral valve, TG-Inv1085; H, dorsal valve, TG-Inv1088; I, ventral valve, TG-Inv1086; J, interior of dorsal valve, TG-Inv1092. Scale bars are 1 cm.

Material.—One specimen, external mould of a dorsal valve, TG-Inv1057.

Remarks.—This specimen can be assigned to the genus *Echinauris* by the small, transverse and gently concave dorsal valve (length 11 mm, width 13 mm), ornamented with numerous large, round dimples over the valve. The Ryozensan species resembles the type species, *Echinauris lateralis* Muir-Wood and Cooper (1960, p. 222, pl. 68, figs. 1–13) from the Road Canyon and Word formations of West Texas, in size, shape and external ornament of the dorsal valve. This species was described also from the lower Permian of Kuzu and Kiryu in the Ashio Mountains, central Japan (Tazawa in Tazawa et al., 2012a, b). But the poor preservation of the present material makes accurate comparison difficult.

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. 3B

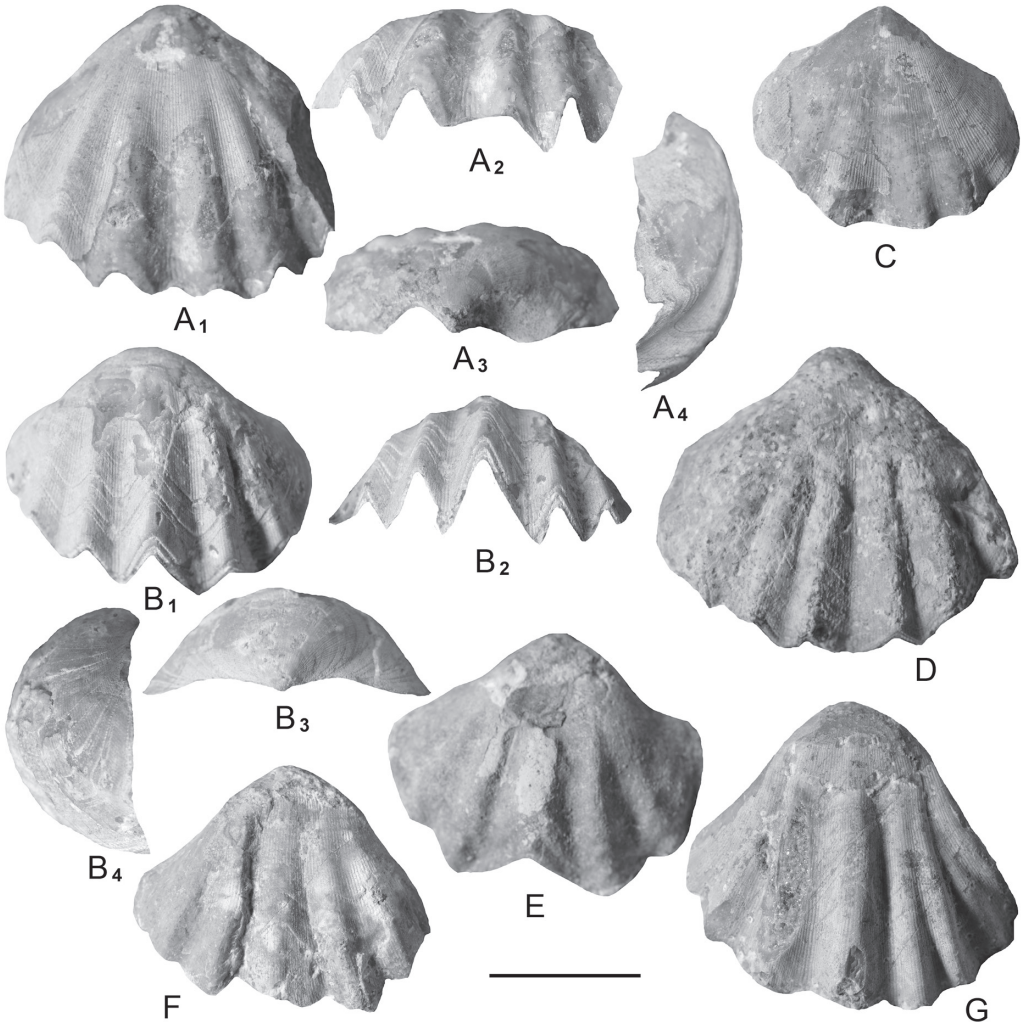

Fig. 4. Brachiopods of the Ryozensan fauna (2). **A–G,** *Enteletes stehlii* Cooper and Grant; A, ventral (A_1), anterior (A_2), posterior (A_3) and lateral (A_4) views of ventral valve, TG-Inv1070; B, dorsal (B_1), anterior (B_2), posterior (B_3) and lateral (B_4) views of dorsal valve, TG-Inv1064; C, ventral valve, TG-Inv1066; D, ventral valve, TG-Inv1061; E, dorsal valve, TG-Inv1062; F, dorsal valve, TG-Inv1059; G, dorsal valve, TG-Inv1060. Scale bar is 1 cm.

Material.—One specimen, a dorsal valve, TG-Inv1093.

Remarks.—This specimen is safely assigned to the genus *Meekella* by the external ornament, consisting of costae and costellae (numbering 4 costae in 10 mm, 3–4 costellae in 1 mm near the anterior margin). The Ryozensan species is small in size for the genus (length 9 mm, width 15 mm in the dorsal valve), and is characterized by the low rounded costae occurring near the anterior margin of the valve. The most comparable species, *Meekella bisculpta* Grant (1976, p. 58, pl. 10, figs. 1–35), from the Ratburi Limestone of Ko Muk, southern Thailand, differs from the present species in having more numerous costae with finer costellae on the dorsal valve.

Order Orthida Schuchert and Cooper, 1932
Suborder Dalmanellidina Moore, 1952
Superfamily Enteletoidea Waagen, 1884
Family Enteletidae Waagen, 1884
Genus *Enteletes* Fischer de Waldheim, 1825

Type species.—*Enteletes glabra* Fischer de Waldheim, 1830.

Enteletes stehlii Cooper and Grant, 1976
Figs. 4A–G

Enteletes dumblei Girty. Stehli, 1954, p. 295, pl. 17, figs. 13–18.
Enteletes stehlii Cooper and Grant, 1976, p. 2639, pl. 688, figs. 1–51.

Material.—Twenty specimens: (1) external and internal moulds of a ventral valve, TG-Inv1065; (2) twelve ventral valves, TG-Inv1061, 1063, 1066, 1070, 1097, 1098, 1099, 1102, 1103, 1104, 1105, 1106; and (3) seven dorsal valves, TG-Inv1058, 1059, 1060, 1062, 1064, 1067, 1068.

Description.—Shell medium in size for genus, roundly elliptical in outline, slightly wider than long, with greatest width at midlength; length 21 mm, width 25 mm in the largest specimen (TG-Inv1061). Ventral valve moderately and unevenly convex in lateral profile, strongly convex umbonal region and somewhat flattened venter; sulcus narrow and shallow. Dorsal valve strongly convex in lateral profile; fold narrow and low. External surface of both valves ornamented with costae and capillae; costae strong and rounded, numbering usually 3, rarely 4 on each side of sulcus and fold; 3–4 capillae in 1 mm at anterior margin of ventral valve. Internal structures of both valves not observed.

Remarks.—These specimens are referred to *Enteletes stehlii* Cooper and Grant (1976, p. 2639, pl. 688, figs. 1–51), from the Skinner Ranch and Bone Spring formations of West Texas, on account of the average-sized, slightly transverse and moderately biconvex shell,

ornamented with 3–4 costae on each side of ventral costae and dorsal fold. *Enteletes gibbosus* Chronic (1953, p. 92, pl. 16, figs. 9–14), from the Copacabana Group (Wolfcampian) of southern Peru, differs from *E. stehlii* in having globose shell and ventral sulcus with V-shaped bottom and dorsal sulcus with sharp crest. *Enteletes costellatus* Cooper and Grant (1976, p. 2629, pl. 686, figs. 1–10), from the Hueco Formation of West Texas, differs from *E. stehlii* in having fewer and lower costae that originate just posterior to midlength of valve.

Distribution.—Sakmarian–Artinskian: southwestern Japan (Ryozensan in the Mino Belt) and western USA (Texas).

Family Schizophoriidae Schuchert and LeVene, 1929
Genus *Acosarina* Cooper and Grant, 1969

Type species.—*Acosarina dorsisulcata* Cooper and Grant, 1969.

Acosarina rectimarginata Cooper and Grant, 1976
Fig. 3E, F

Acosarina rectimarginata Cooper and Grant, 1976, p. 2624, pl. 674, figs. 1–46; Shen et al., 2011, p. 564, figs. 6.1–6.18; Tazawa in Tazawa et al., 2012b, p. 63, fig. 4.5.

Material.—Six specimens: (1) a conjoined shell, TG-Inv1090; (2) four ventral valves, TG-Inv1073, 1074, 1076, 1082 and (3) a dorsal valve, TG-Inv1095.

Description.—Shell small to medium in size for genus, transversely subelliptical in outline, with greatest width at midlength; hinge rather wide; sides rounded; anterior commissure rectimarginate; length 6 mm, width 7 mm in the best preserved specimen (TG-Inv1090); length 7 mm width 8 mm in the largest dorsal valve specimen (TG-Inv1095). Ventral valve moderately and unevenly convex in lateral profile, most convex in umbonal region; sulcus absent. Dorsal valve moderately convex in lateral profile, slightly more convex than ventral valve; fold absent. External surface of both valves ornamented with numerous rounded costellae and a few strong concentric lamellae; costellae numbering 4–5 in 1 mm anterior to midlength of ventral valve.

Remarks.—These specimens are referred to *Acosarina rectimarginata* Cooper and Grant (1976, p. 2624, pl. 674, figs. 1–46), from the Neal Ranch Formation (lower Wolfcampian) of West Texas, by size, shape and external ornament of both ventral and dorsal valves, particularly by the rectimarginate anterior commissure. The type species, *Acosarina dorsisulcata* Cooper and Grant, 1969, redescribed by Cooper and Grant (1976, p, 2621, pl. 667, figs. 1–26; pl. 673, figs. 1–6) from the upper Wolfcampian–lower Leonardian of West Texas, is readily distinguished from *A. rectimarginata* in having a median sulcus on the dorsal valve.

Distribution.—Asselian–Kungurian: central Japan (Kuzu and Hatahoko in the Mino Belt), southwestern Japan (Ryozensan in the Mino Belt) and USA (West Texas).

Acosarina cf. *dunbari* Cooper and Grant, 1976
Figs. 3G–J

cf. *Acosarina dunbari* Cooper and Grant, 1976, p. 2622, pl. 670, figs. 1–8.

Material.—Five specimens: (1) two ventral valves, TG-Inv1085, 1086; (2) two dorsal valves, TG-Inv1088, 1096; and (3) interior of a dorsal valve. TG-Inv1092.

Remarks.—These specimens can be assigned to the genus *Acosarina* by their small, transversely semioval and strongly biconvex shells (length 11 mm, width 13 mm in the largest specimen, TG-Inv1088) with rectimarginate anterior commissure and external ornaments consisting of numerous costellae (numbering 4–6 in 1 mm at near anterior margin) and a few concentric lamellae. The Ryozensan species resembles *Acosarina dunbari* Cooper and Grant (1976, p. 2622, pl. 670, figs. 1–8) from the Foraker Limestone (lower Wolfcampian) of Nebraska, USA, but differs from the American species in having finer costellae. The present species may be a new species, but the material is not adequate for establishing a new species.

Order Spiriferida Waagen, 1883
Suborder Spiriferidina Waagen, 1883
Superfamily Spiriferoidea King, 1846
Family Trigonotretidae Schuchert, 1893
Subfamily Neospiriferinae Waterhouse, 1968
Genus *Neospirifer* Fredericks, 1924

Type species.—*Spirifer fasciger* Keyserling, 1846.

Neospirifer sp.
Fig. 3C

Material.—One specimen, a ventral valve, TG-Inv1100.

Remarks.—This specimen is safely assigned to the genus *Neospirifer* by the transverse outline (length 17 mm, width about 30 mm), the greatest width at hinge and numerous sparsely bundled, rounded costae on the lateral slopes of the ventral valve. The Ryozensan species somewhat resembles *Neospirifer placidus* Cooper and Grant (1976, p. 2188, pl. 609, figs. 1–29), from the Neal Ranch Formation (lower Wolfcampian) of the Glass Mountains,

West Texas, in the small to medium size, and in having sparsely bundled costae on the ventral valve. However, specific identification is difficult for the poorly preserved specimen.

Order Terebratulida Waagen, 1883
Suborder Terebratulidina Waagen, 1883
Superfamily Dielasmatoidea Schuchert, 1913
Family Dielasmatidae Schuchert, 1913
Subfamily Dielasmatinae Schuchert, 1913
Genus *Plectelasma* Cooper and Grant, 1969

Type species.—*Plectelasma kingi* Cooper and Grant, 1969.

Plectelasma sp.
Fig. 3D

Material.—One specimen, a dorsal valve, TG-Inv1101.

Remarks.—This specimen is safely assigned to the genus *Plectelasma* by the small size (length 16 mm, width 14 mm) and the plicated anterior margin of the dorsal valve. The Ryozensan species most resembles the type species, *Plectelasma kingi* Cooper and Grant, 1969, redescribed by Cooper and Grant (1976, p. 2904, pl. 755, figs. 53–80; pl. 778, figs. 18–23) from the Wolfcampian of the Glass Mountains, West Texas, but less elongate in outline.

Conclusions

In this study, brachiopods of seven species in six genera are described from the upper part of the Ryozensan Formation (Artinskian; *Pseudofusulina* Zone) at locality Echigadani B in the Ryozensan area, northern Suzuka Mountains, Mino Belt, southwestern Japan. The species are as follows: *Echinauris* sp., *Meekella* sp., *Enteletes stehlii* Cooper and Grant, *Acosarina rectimarginata* Cooper and Grant, *Acosarina* cf. *dunbari* Cooper and Grant, *Neospirifer* sp. and *Plectelasma* sp. The age of the Ryozensan fauna is identified as a Sakmarian–Artinskian, which is approximately consistent with that of Sano and Kojima (2000), an Artinskian, on the basis of fusulinids. In terms of palaeobiogeography, the Ryozensan fauna has a close affinity with those of Kuzu, Kiryu and Hatahoko in the Mino Belt, Japan and West Texas, USA. This conclusion is consistent with those of Tazawa and Shen (1997), Shen et al. (2011) and Tazawa et al. (1998, 2013, 2016), who reported that the Permian brachiopod faunas of the Mino Belt are tropical faunas of the equatorial Panthalassa, not far from North America (West Texas).

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