# A mixed Boreal–Tethyan–Panthalassan brachiopod fauna from the lower Permian (Asselian) of Miharanoro, Akiyoshi Belt, southwestern Japan

Jun-ichi TAZAWA* and Yousuke IBARAKI**

**Abstract**

In this paper a brachiopod fauna (the Miharanoro fauna), consisting of 11 species in 9 genera, is described from the lower Permian limestone (Uyamano Formation) of Miharanoro in the Taishaku area, Akiyoshi Belt, southwestern Japan. The age of the Miharanoro fauna is identified as the Asselian (early Permian, Cisuralian). In terms of palaeobiogeography, the Miharanoro fauna is a mixed Boreal–Tethyan–Panthalassan fauna, and exhibits an affinity with the lower Permian fauna of Texas. Thus, the seamounts of the Akiyoshi Belt, including Taishaku, were probably located between the Sino-Mongolian–Japanese Province and North America (Texas) in Panthalassa during the Asselian.

*Key words*: Akiyoshi-type seamount, Asselian, Brachiopoda, Miharanoro, palaeobiogeography.

## Introduction

The Akiyoshi Belt, southwestern Japan consists of a Permian accretionary complex, which is composed of lower Carboniferous–middle Permian limestone–basalt blocks (including the Omi, Atetsu, Taishaku, Akiyoshi and Hirao blocks; Fig. 1A) with contemporaneous cherts and upper Permian clastic rocks. The limestone–basalt blocks were seamounts with carbonate caps in Panthalassa during the early Carboniferous–middle Permian; they accreted to Proto-Japan during the late Permian (Kanmera et al., 1990; Isozaki, 1997). The locations of the seamounts during the early Carboniferous–middle Permian are, however, unclear because of a paucity of palaeobiogeographical studies on the

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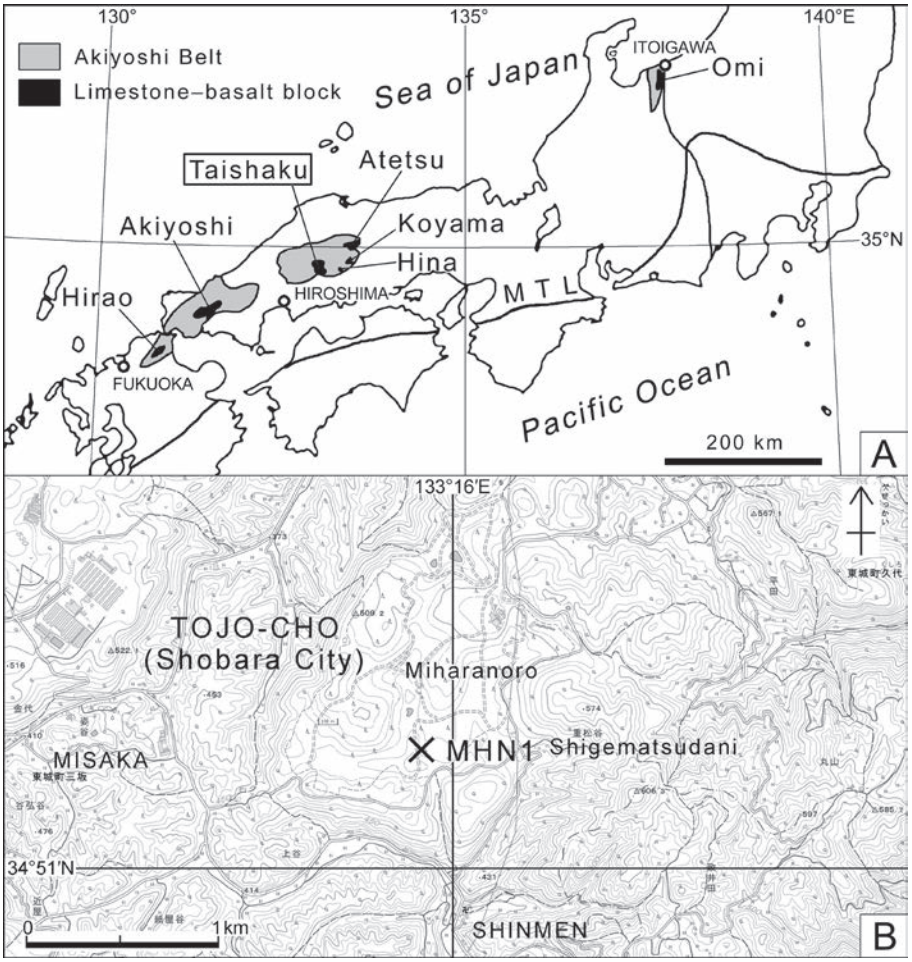


**Fig. 1.** Maps showing the location and geology of fossil locality Miharanoro in the Taishaku area of the Akiyoshi Belt, southwestern Japan; **A**, geotectonic map of the southwestern Japan, MTL: Median Tectonic Line (based on Ishida et al., 2013); **B**, topographic map showing the fossil locality MHN1 in Miharanoro, Tojo-cho, Shobara City, Hiroshima Prefecture (using the electronic topographical map of the Geospatial Information Authority of Japan).

fossil biota from the limestone–basalt blocks and the surrounding clastic rocks in the Akiyoshi Belt.

The present study describes an early Permian brachiopod fauna (the Miharanoro fauna), consisting of 11 species in 9 genera from a limestone block at Miharanoro in the Taishaku area, Akiyoshi Belt, and discuss the age and palaeobiogeography of the fauna. In this study, Y. Ibaraki studied systematics in part (*Choristites*); and J. Tazawa studied systematics for the most part of the brachiopod species and palaeobiogeography of the Miharanoro fauna.

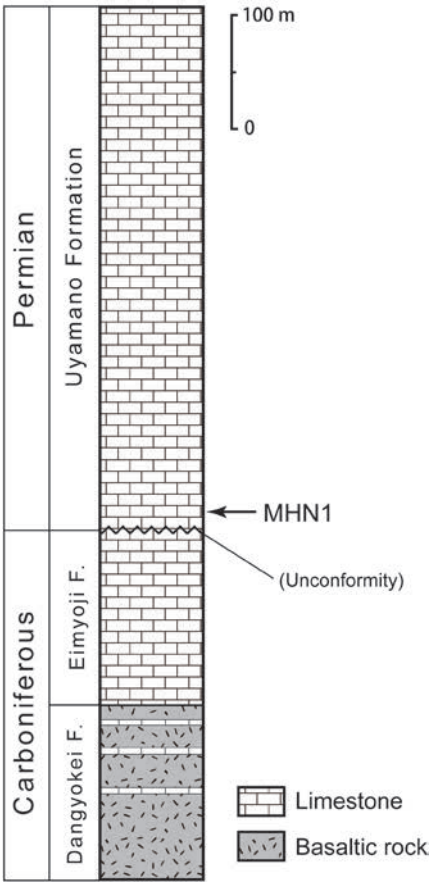


**Fig. 2.** Generalized columnar section of the limestone-basalt complex of the Taishaku area, Akiyochi Belt (compiled from Hase et al., 1974 and Ehiro and Ozawa, 2020).

## Stratigraphy and material

The stratigraphy of the Carboniferous–Permian rocks of the Taishaku area, including Miharanoro, was studied and summarized by Hase et al. (1974). According to that study, the limestone–basalt block in the Taishaku area is divided into three formations, which are, in ascending stratigraphic order, the Dangyokei Formation (lower Carboniferous basaltic rocks, more than 150 m thick), the Eimyoji Formation (upper Carboniferous limestones, approximately 150 m thick), and the Uyamano Formation (lower–middle Permian limestones, 400–500 m thick). The brachiopod specimens, considered in the present study were collected by Isao Nishikawa in the 1950s and 1960s from light grey limestone of the lower part of the Uyamano Formation at locality MHN1 (34°51′20″N, 133°15′54″E, which is the same as locality 1 of Ehiro et al., 2014, fig. 1B), Miharanoro (i.e., Miharanoro, Tojo-cho, Shobara City, Hiroshima Prefecture) in the Taishaku area, Akiyoshi Belt, southwestern Japan (Figs. 1B and 2).

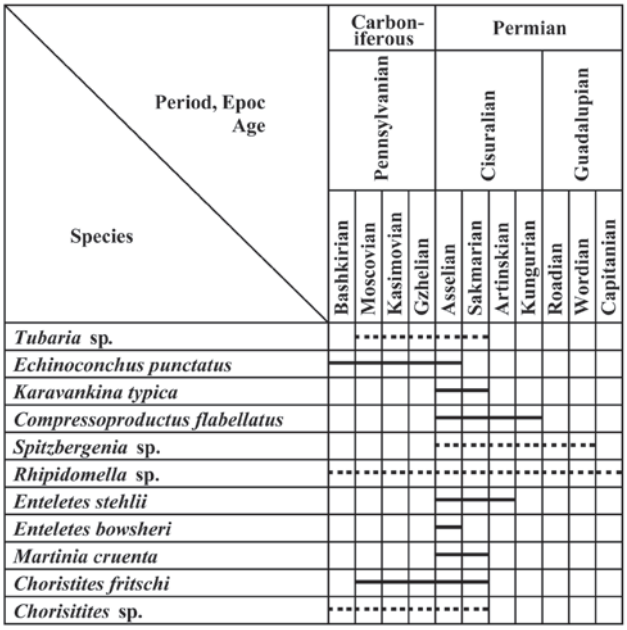


**Fig. 3.** Stratigraphic distributions of brachiopod species of the Miharanoro fauna. Broken lines show those of the genera.

The Nishikawa brachiopod collection was initially studied by Hayasaka and Kato (1966) and subsequently by Nakamura and Nishikawa (1979): Hayasaka and Kato (1966) described a brachiopod species *Enteletes gibbosus* Chronic; and Nakamura and Nishikawa (1979) found a Boreal brachiopod genus *Spitzbergenia* (species uncertain) in the collection, and briefly noted palaeobiogeographical significance of the genus. Subsequently, most of the Nishikawa collection, excluding the specimens described by Hayasaka and Kato (1966) as *Enteletes gibbosus*, was made available to the senior author (J. T.) by Koji Nakamura. The brachiopod specimens studied in the present work are now registered (prefix FMM, numbers 6323–6376) and housed in the Fossa Magna Museum, Itoigawa City, Niigata Prefecture, Japan.

## Miharanoro fauna

The brachiopod fauna (Miharanoro fauna) described herein consists of 11 species in 9 genera. The list of species is as follows: *Tubaria* sp., *Echinoconchus punctatus* (Sowerby), *Karavankina typica* Ramovš, *Compressoproductus flabellatus* Cooper and Grant, *Spitzbergenia* sp., *Rhipidomella* sp., *Enteletes stehlii* Cooper and Grant, *E. bowsheri* Cooper and Grant, *Martinia cruenta* Cooper and Grant, *Choristites fritschi* (Schellwien) and *Choristites* sp. Of these species, *Enteletes stehlii*, *Martinia cruenta* and *Choristites fritschi* are abundant; *Enteletes bowsheri* and *Choristites* sp. are common; and the other species are rare in the Miharanoro fauna.

**Age**

The stratigrapic distributions of the brachiopod species of the Miharanoro fauna are described in the section "Systematic descriptions" and summarized in Fig. 3. Of the brachiopod taxa listed above, *Enteletes bowsheri* is known only from the Asselian. *Echinoconchus punctatus* is known from the upper Tournaisian–Asselian and *Choristites fritschi* is known from the Moscovian–Sakmarian. In contrast, *Compressoproductus flabellatus* occurs from the Asselian–Kungurian, two species (*Karavankina typica* and *Martinia cruenta*) have a stratigraphic range of Asselian–Sakmarian, and *Enteletes stehlii* occurs from the Asselian–Artinskian. At the generic level, *Tubaria* is known from the Moscovian–Sakmarian (Sarytcheva, 1977; Kalashnikov, 1993) and *Spitzbergenia* ranges from the Asselian–Wordian (Grigorjeva et al., 1977; Klets, 2005; this study). Two of the genera (*Rhipidomella* and *Choristites*) have long stratigraphic ranges: *Rhipidomella* has a range of middle Devonian (Eifelian) to upper Permian (Tatarian; Harper, 2000); and *Choristites* is known from the lower Carboniferous (Mississippian)–lower Permian (Cisuralian; Carter, 2006).

In summary, the age of the Miharanoro fauna is identified as Asselian; thus, the lower part of the Uyamano Formation in Miharanoro is correlated with the Asselian. This conclusion is consistent with previous studies (Ehiro et al., 2014; Ehiro and Ozawa, 2020) on the fusulinoid–ammonoid fauna from the lower part of the Uyamano Formation of Miharanoro.

**Palaeobiogeography**

The geographic distributions of the brachiopod species of the Miharanoro fauna are described in the "Systematic descriptions" section. *Echinoconchus punctatus* is known from northeastern Japan (South Kitakami Belt), northern Russia (Verkhoyansk Range, Taimyr Peninsula and northern Urals), the UK (Scotland, England and Wales), Germany, Belgium, Spain, western Russia (Moscow Basin), central Russia (southern Urals), Kyrgyzstan, northwestern China (Xinjiang and Qinghai), northern China (Shanxi) and northeastern China (Liaoning). *Karavankina typica* is known from Slovenia. Four species (*Compressoproductus flabellatus*, *Enteletes stehlii*, *E. bowsheri* and *Martinia cruenta*) are known from the USA (Texas). *Choristites fritschi* is known from Spain, Slovenia, Austria, Kazakhstan, Uzbekistan and eastern China (Shandong). At the generic level, *Tubaria* is known from northern Russia (northern Urals, Pay-Khoy and Timan), Svalbard (Spitsbergen), western Russia (Moscow Basin and Donetz Basin), central Russia (southern Urals) and Uzbekistan (Muir-Wood and Cooper, 1960; Kalashnikov, 1993). *Spitzbergenia* is known from Arctic Canada (northern Yukon Territory), northern Russia (Verkhoyansk Range, Kolyma–Omolon Massif, Kanin Peninsula, northern Russian Platform and Novaya Zemlya), Svalbard (Spitsbergen and Northeast Island), Greenland and southern Mongolia (Grigorjeva et al., 1977; Brunton et al., 2000). *Rhipidomella* and *Martinia* are cosmopolitan (Harper, 2000; Carter and Gourvennec,

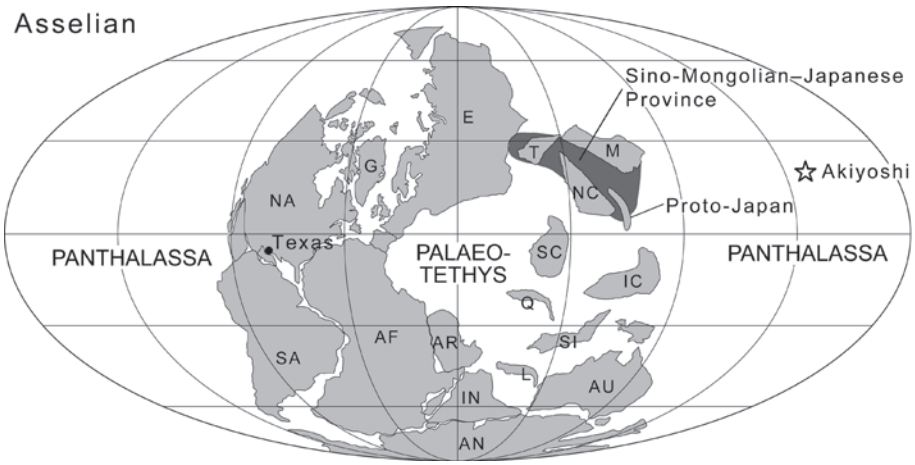


**Fig. 4.** Early Permian (Asselian) reconstruction map of the world (adapted from Ziegler et al., 1997), showing the location of the Aiyoshi-type seamounts (asterisk). AF: Africa, AN: Antarctica, AR: Arabia, AU: Australia, E: Eurasia; G: Greenland, IC: Indochina, IN: India, L: Lhasa, M: Mongolia, NA: North America, NC: North China, Q: Qangtang, SA: South America, SC: South China, SI: Sibumasu, T: Tarim.

2006). *Choristites* is known from Eurasia (Carter, 2006), mostly from Russia and northern China (Chao, 1929; Ivanov and Ivanova, 1937; Barchatova, 1970; He et al., 1995).

In summary, the Miharanoro fauna is a mixed Boreal–Tethyan–Panthalassan fauna, consisting of Boreal elements (*Tubaria* sp. and *Spitzbergenia* sp.), Tethyan elements (*Karavankina typica* and *Choristites fritschi*) and Panthalassan elements (*Compressoprodutus flabellatus*, *Enteletes stehlii*, *E. bowsheri* and *Martinia cruenta*). It is noteworthy that four species (*Compressoprodutus flabellatus*, *Enteletes stehlii*, *E. bowsheri* and *Martinia cruenta*) also occur in Texas. Moreover, mixed Boreal–Tethyan fauna occur in the Sino-Mongolian–Japanese Province (Shi and Tazawa, 2001) [=Inner Mongolian–Japanese Transition Zone (Tazawa, 1991); Northern Transitional Zone (Shi et al., 1995)], which occupied a vast area of the North China Block and the surrounding area. From the above data, it is concluded that the Akiyoshi-type seamounts, including the Taishaku (Miharanoro) one, were probably located between the Sino-Mongolian–Japanese Province and North America (Texas) in Panthalassa during the Asselian (Fig. 4).

In contrast, Ehiro and Ozawa (2020) proposed another hypothesis on the basis of a palaeobiogeographical study of the Miharanoro ammonoid fauna: the Akiyoshi-type seamounts were located in the equatorial region of Panthalassa (Mid-Panthalassan Realm) in the early Permian (Asselian). However, the ammonoid fauna consists of four indeterminate species, one taxon indeterminate at both generic and specific levels, and four new species; only one species (*Metapronorites timorensis*) was identified with certainty. Moreover, most of the genera of the Miharanoro fauna (*Agathiceras*, *Neoglaphyrites*, *Somoholites*, *Eoasianites*

and *Metapronorites*) are cosmopolitan, occurring from the arctic to the equatorial regions and not restricted to the equatorial Panthalassa (Ehiro and Ozawa, 2020, p. 311–312). The material seems to be insufficient for the given conclusion.

## Conclusion

The Miharanoro brachiopod fauna from the lower part of the Uyamano Formation of Miharanoro consists of 11 species in 9 genera: *Tubaria* sp., *Echinoconchus punctatus*, *Karavankina typica*, *Compressoproductus flabellatus*, *Spitzbergenia* sp., *Rhipidomella* sp., *Enteletes stehlii*, *E. bowsheri*, *Martinia cruenta*, *Choristites fritschi* and *Choristites* sp. The age of the Miharanoro fauna is identified as Asselian (early Permian, Cisuralian); thus, the lower part of the Uyamano Formation in Miharanoro is correlated with the Asselian. Palaeobiogeographically, the Miharanoro fauna is a mixed Boreal–Tethyan–Panthalassan fauna, and has an affinity with the lower Permian fauna of Texas. Thus, the Akiyoshi-type seamounts, including the Miharanoro (Taishaku) one, were probably located between the Sino-Mongolian–Japanese Province and North America (Texas) in Panthalassa during the Asselian.

## Systematic descriptions

Order Productida Sarytcheva and Sokolskaya, 1959
Suborder Productidina Waagen, 1883
Superfamily Productoidea Gray, 1840
Family Productidae Gray, 1840
Subfamily Retariinae Muir-Wood and Cooper, 1960
Genus *Tubaria* Muir-Wood and Cooper, 1960

*Type species.*—*Productus genuinus* Kutorga, 1844.

*Tubaria* sp.
Fig. 5A, B

*Material.*—Two specimens: (1) a ventral valve, FMM6323; and (2) a dorsal valve, FMM6324.

*Remarks.*—These specimens are fragmentarily preserved, but can be assigned to the genus *Tubaria* Muir-Wood and Cooper, 1960 by medium-size and transverse outline of the shell (length about 18 mm without tube-like anterior extension, width about 34 mm in the ventral valve specimen, FMM6323) and in havng an extended tubelike anterior margin. The

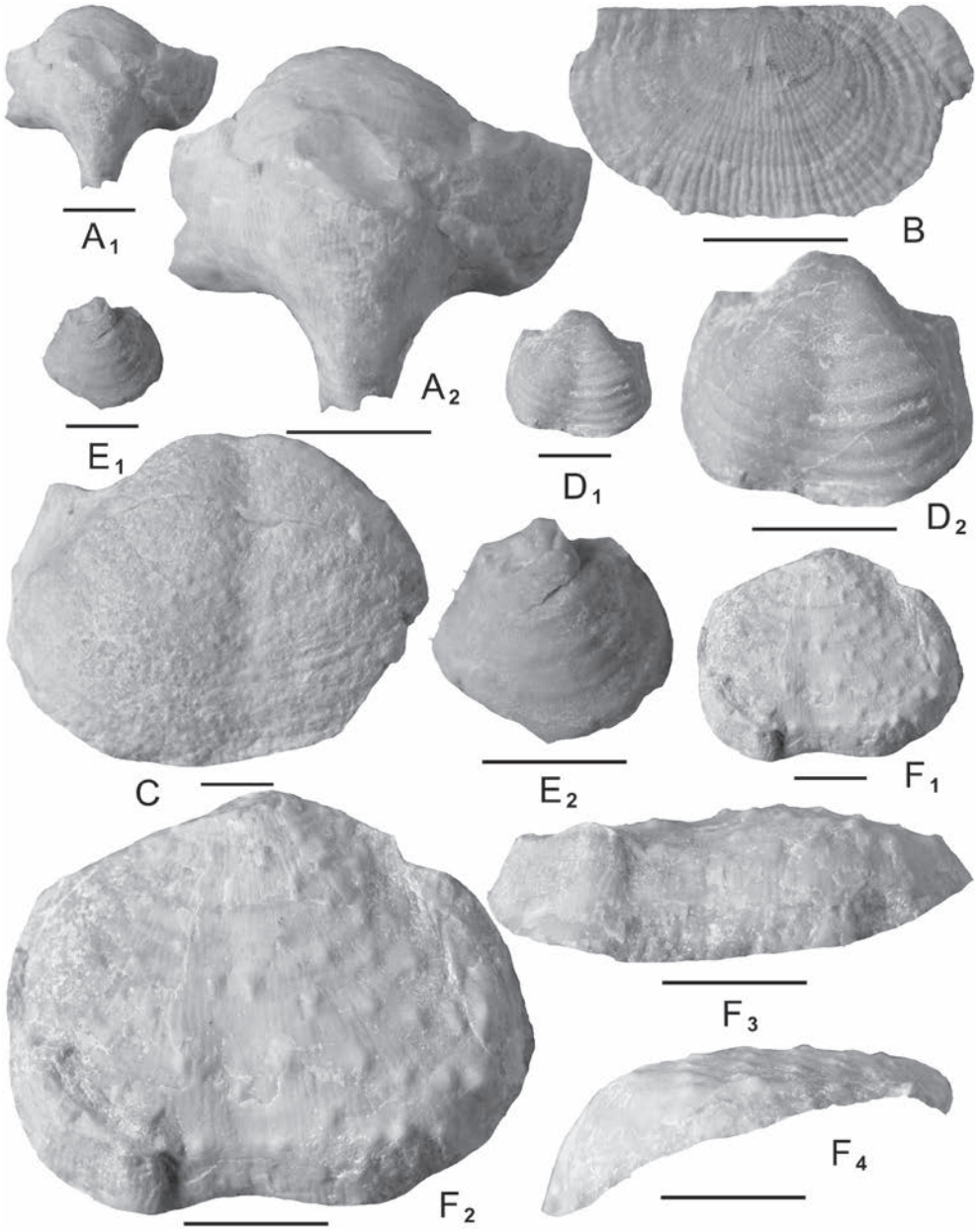


**Fig. 5. A, B,** *Tubaria* sp.; $A_1$, $A_2$, ventral view of ventral valve, FMM6323; B, dorsal view of dorsal valve, FMM6324; **C,** *Echinoconchus punctatus* (Sowerby), ventral view of ventral valve, FMM6330; **D,** *Karavankina typica* Ramovš, ventral view ($D_1$, $D_2$) of ventral valve, FMM6328; **E,** *Compressoproductus flabelatus* Cooper and Grant, ventral view ($E_1$, $E_2$) of ventral valve, FMM6329; **F,** *Spitzbergenia* sp., ventral ($F_1$, $F_2$), anterior ($F_3$) and lateral ($F_4$) views of ventral valve, FMM6350. Scale bars are 1 cm.

Miharanoro specimens resemble externally the type species, *Tubaria genuina* (Kutorga, 1844), redescribed by Sarytcheva (1971, p. 42, pl. 5, figs. 4–7; pl. 6, figs. 1–4, text-figs. 3–7) from the Asselian–Sakmarian of the southern Urals, central Russia, but the latter is larger in size. Accurate comparison is difficult owing to ill preservation of the Miharanoro specimens.

Superfamily Echinoconchoidea Stehli, 1954
Family Echinoconchidae Stehli, 1954
Subfamily Echinoconchinae Stehli, 1954
Genus *Echinoconchus* Weller, 1914

*Type species.*—*Productus punctatus* Sowerby, 1822.

*Echinoconchus punctatus* (Sowerby, 1822)
Fig. 5C

*Productus punctatus* Martin. Sowerby, 1822, p. 22, pl. 323, lower right figure; Davidson, 1861, p. 172, pl. 44, figs. 9–11, 16, 17.

*Pustula punctata* (Martin). Thomas, 1914, p. 303, pl. 17, figs. 16–19, text-fig. 11; Tolmatchoff, 1924, p. 256, 584, pl. 16, fig. 9; Rotai, 1931, p. 58, pl. 4, figs. 1, 11.

*Productus* (*Pustula*) *punctatus* Martin. Yanishevsky, 1918, p. 47, pl. 3, figs. 7, 9.

*Echinoconchus punctatus* (Martin). Chao, 1927, p. 67, pl. 6, figs. 7, 8, 15, 16; Sarytcheva in Sarytcheva and Sokolskaya, 1952, p. 103, pl. 18, fig. 120; Dedok and Tschernjak, 1960, p. 53, pl. 1, fig. 6; Ding in Yang et al., 1962, p. 51, pl. 19, figs. 1–4; Yang, 1964, p. 81, pl. 4, figs. 5, 6, 9, 10, text-fig. 7; Abramov, 1965, p. 38, pl. 3, fig. 2; Litvinovich et al., 1969, p. 164, pl. 9, figs. 5, 6; pl. 10, fig. 1; Abramov, 1970, p. 117, pl. 9, fig. 4; Alexandrow and Solomina, 1973, p. 93, pl. 22, figs. 1–3; Volgin and Kushnar, 1975, p. 46, pl. 4, fig. 1; Donakova, 1978, p. 208, pl. 1, figs. 5, 6; Nalivkin, 1979, p. 78, pl. 24, figs. 8, 9; Zhang et al., 1983, p. 288, pl. 127, fig. 11; pl. 128, fig. 2; Jin et al., 1985, p. 192, pl. 9, figs. 11, 12; Zhan and Wu, 1987, p. 207, pl. 48, fig. 38; Archbold and Stojamović-Kuzenko, 1995, pl. 62, fig. 10; Wang and Yang, 1998, p. 77, pl. 9, figs. 17, 18.

*Productus* (*Echinoconchus*) *punctatus* (Martin) emend. Thomas. Paeckelmann, 1931, p. 152, pl. 15, figs. 7–10.

*Productus* (*Echinoconchus*) *punctatus* (Martin). Nalivkin, 1937, p. 64, pl. 9, fig. 5.

*Echinoconchus punctatus* (Sowerby). Muir-Wood, 1951, p. 102, pl. 4, fig. 2; Muir-Wood and Cooper, 1960, pl. 66, figs. 1, 2; pl. 82, figs. 8–10; pl. 83, figs. 1–4; pl. 88, fig. 11; pl. 125, fig. 5; Winkler Prins, 1968, p. 89, pl. 3, figs. 12–14; Nalivkin and Fotieva, 1973, p. 35, pl. 6, fig. 8; Kalashnikov, 1974, p. 48, pl. 9, figs. 1–3; Martinez Chacon and Legrand-Blain, 1992, p. 110,

pl. 3, figs. 15–18; Tazawa, 2017, p. 335, figs. 6.6, 6.7; Tazawa, 2018, p. 46, fig. 23G, H.

*Productus-Echinoconchus-punctatus* Martin. Pareyn, 1961, p. 197, pl. 23, figs. 1–4.

*Productus* (*Echinoconchus*) *punctatus* (Sowerby). Galitskaya, 1977, p. 62, pl. 16, figs. 1–5; pl. 18, fig. 1, text-fig. 7; Kalashnikov, 1980, p. 34, pl. 5, fig. 1.

*Echinoconchus aohanensis* Lee and Gu in Lee et al., 1980, p. 363, pl. 147, figs. 1, 2.

*Material*.—One specimen, a ventral valve, FMM6330.

*Remarks*.—This specimen can be referred to *Echinoconchus punctatus* (Sowerby, 1822), redescribed by Muir-Wood (1951, p. 102, pl. 4, fig. 2) and refigured by Muir-Wood and Cooper (1960, pl. 66, figs. 1, 2; pl. 82, figs. 8–10; pl. 83, figs. 1–4; pl. 88, fig. 11; pl. 125, fig. 5) from the upper Visean of England, in large size (length about 46 mm, width about 62 mm) and external ornament of the ventral valve consisting of regular strong concentric bands with rows of numerous slightly elongate spine bases. *Echinoconchus aohanensis* Lee and Gu (in Lee et al., 1980, p. 363, pl. 147, figs. 1, 2), from the lower Pennsylvanian of Liaoning, northeastern China, is deemed to be a junior synonym of *E. punctatus*. *Echinoconchus alternatus* (Norwood and Pratten, 1855), redescribed by Weller (1914, p. 138, pl. 17, figs. 1–7) from the Osagean of the Mississippi Valley, differs from *E. punctatus* in less transverse outline and in having broader concentric bands in the ventral valve. *Echinoconchus postpunctatus* Stepanov (in Mironova, 1967, p. 11, pl. 1, fig. 11), from the upper Carboniferous Kirovsky Horizon of the Urals, differs from *E. punctatus* in more elongate outline.

*Distribution*.—Lower Carboniferous (upper Tournaisian)–lower Permian (Asselian): southwestern Japan (Miharanoro in the Akiyoshi Belt), northeastern Japan (Hikoroichi and Yokota in the South Kitakami Belt), northern Russia (Verkhoyansk Range, Taimyr Peninsula and northern Urals), the UK (Scotland, England and Wales), Germany, Belgium, Spain, western Russia (Moscow Basin), central Russia (southern Urals), Kyrgyzstan, northwestern China (Xinjiang and Qinghai), northern China (Shanxi) and northeastern China (Liaoning).

## Genus *Karavankina* Ramovš, 1969

*Type species*.—*Karavankina typica* Ramovš, 1969.

### *Karavankina typica* Ramovš, 1969

Fig. 5D

*Karavankina typica* Ramovš, 1969, p. 254, 262, pl. 1, figs. 1–4.

*Material*.—One specimen, a ventral valve, FMM6328.

*Remarks*.—This specimen can be referred to *Karavankina typica* Ramovš, 1969, from the

Trogkofel Limestone of the Carnian Alps, Slovenia, by its small, strongly convex ventral valve (length 17 mm, width 19 mm) and in having regular concentric rugae with numerous very fine spine bases on the ventral valve. *Karavankina schellwieni* Ramovš (1969, p. 257, 264, pl. 2, figs. 1–4), from the same horizon and the same locality of Slovenia differs from *K. typica* in having no sulcus on the ventral valve.

*Distribution*.—Asselian–Sakmarian: southwestern Japan (Miharanoro in the Akiyoshi Belt) and Slovenia.

Superfamily Linoproductoidea Stehli, 1954
Family Linoproductidae Stehli, 1954
Subfamily Striatiferinae Muir-Wood and Cooper, 1960
Genus *Compressoproductus* Sarytcheva in Sarytcheva et al., 1960

*Type species*.—*Productus compressus* Waagen, 1884.

*Compressoproductus flabellatus* Cooper and Grant, 1975
Fig. 5E

*Compressoproductus flabellatus* Cooper and Grant, 1975, p. 1206, pl. 456, figs. 22–50; pl. 461, figs. 1–66; pl. 464, figs. 24–26.

*Material*.—One specimen, a ventral valve, FMM6329.

*Remarks*.—This specimen can be referred to *Compressoproductus flabellatus* Cooper and Grant, 1975, from the Cathedral Mountain Formation of Texas, in its small, roundly and transversely elliptical ventral valve (length 17 mm, width 18 mm) and in having numerous fine capillae (numbering 5 in 1 mm at about midlength) and somewhat irregular rugae on the ventral valve. *Compressoproductus parvus* Cooper and Grant (1975, p. 1207, pl. 459, figs. 9–31), from the Skinner Ranch Formation of Texas, differs from *E. flabellatus* in its elongate oval outline and in having more irregular rugae on the ventral valve. *Compressoproductus mongolicus* (Diener, 1897, p. 28, pl. 4, figs. 8–10), from the Capitanian–Wuchiapingian limestones of Chitichun in the Himalayas, is readily distinguished from *E. flabellatus* in having coarser capillae on the ventral valve.

*Distribution*.—Asselian–Kungurian: southwestern Japan (Miharanoro in the Akiyoshi Belt) and the USA (Texas).

Family Kansuellidae Muir-Wood and Cooper, 1960
Subfamily Auriculispininae Waterhouse, 1986
Genus *Spitzbergenia* Kotlyar in Grigorjeva et al., 1977

*Type species*.—*Productus loveni* Wiman, 1914.

*Spitzbergenia* sp.
Fig. 5F

*Spitzbergenia* sp. Nakamura and Nishikawa, 1979, p. 165.

*Material*.—One specimen, a ventral valve, FMM6350.

Remarks.—This specimen is readily assigned to the genus *Spitzbergenia* Kotlyar in Grigorjeva et al., 1977 by numerous large, prominent spine bases and numerous fine costellae on flattened visceral disc of the ventral valve. The Miharanoro species resembles the type species, *Spitzbergenia loveni* (Wiman, 1914), originally described by Wiman (1914, p. 72, pl. 17, figs. 12–18) from the Spirifer Limestone of Spitsbergen, Svalbard and redescribed by Grigorjeva et al. (1977, p. 156, pl. 25, figs. 5–9, text-fig. 87) from the Selandersk Formation of Severo-Vostoknaya Zemlya (Nordaustlandet), Svalbard, in being relatively large size (length about 34 mm, width about 41 mm) and wider subrectangular outline of the ventral valve. But accurate comparison is difficult on the poorly preserved specimen. *Spitzbergenia gracilis* Kotlyar (in Grigorjeva et al., 1977, p. 157, pl. 25, fig. 10; pl. 26, figs. 1–5, text-fig. 88), from the Selandersk Formation of Severo-Vostoknaya Zemlya, differs from the present species in its smaller size and in having finer spines on the ventral valve.

Order Orthida Schuchert and Cooper, 1932
Suborder Dalmanellidina Moore, 1952
Superfamily Dalmanelloidea Schuchert, 1913
Family Rhipidomellidae Schuchert, 1913
Subfamily Rhipidomellinae Shuchert, 1913
Genus *Rhipidomella* Oehlert, 1890

*Type species*.—*Terebratula michelini* Léveillé, 1835.

*Rhipidomella* sp.
Fig. 6A

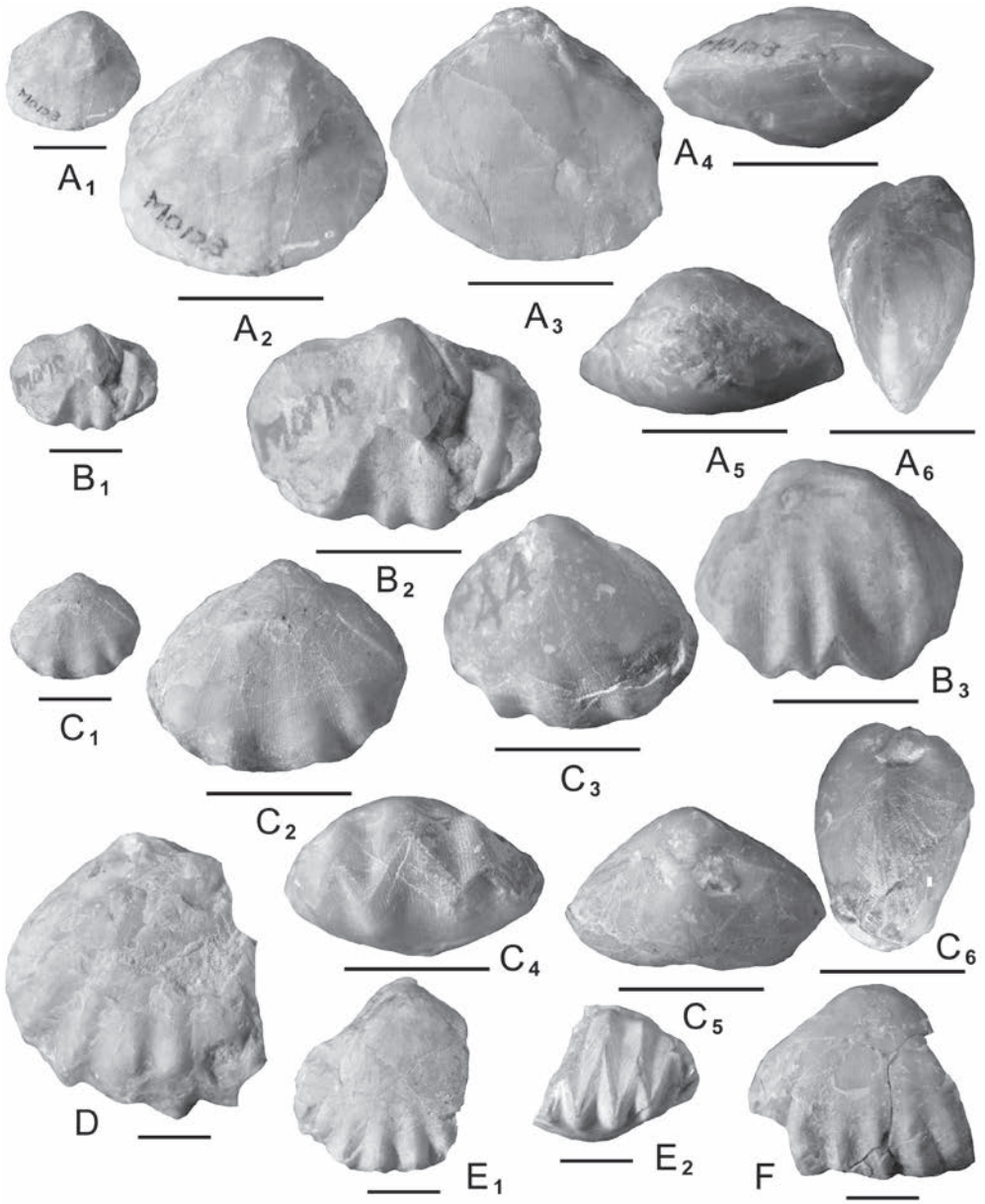


**Fig. 6. A,** *Rhipidomella* sp., ventral ($A_1$, $A_2$), dorsal ($A_3$), anterior ($A_4$), posterior ($A_5$) and lateral ($A_6$) views of conjoined shell, FMM6376; **B, C,** *Enteretes stehlii* Cooper and Grant; B, ventral ($B_1$, $B_2$) and dorsal ($B_3$) view of conjoined shell, FMM6339; C, ventral ($C_1$, $C_2$), dorsal ($C_3$), anterior ($C_4$), posterior ($C_5$) and lateral ($C_6$) views of conjoined shell, FMM6345; **D–F,** *Enteletes bowsheri* Cooper and Grant; D, dorsal view of conjoined shell, FMM6334; E, ventral ($E_1$) and anterior ($E_2$) views of conjoined shell, FMM6336; F, ventral view of conjoined shell, FMM6338. Scale bars are 1 cm.

*Material*.—One specimen, a conjoined shell, FMM6376.

*Remarks*.—This specimen can be assigned to the genus *Rhipidomella* Oehlert, 1890 on account of its small size (length 17 mm, width 19 mm), subcircular outline with short hinge, moderately biconvex profile with rectimarginate anterior margin and in having external ornaments consisting of numerous fine costellae (numbering 10–11 in 2 mm at about midlength of ventral valve) and irregular growth lines. *Rhipidomella hessensis* King (1931, p. 43, pl. 1, figs. 2–4), from the Hess Formation of the Glass Mountains, Texas, is also a large-sized *Rhipidomella* species, but the Texan species differs from the Miharanoro species in having more numerous tubercles on the both valves. *Rhipidomella corallina* (Waagen, 1884, p. 572, pl. 56, fig. 1), from the Wargal Formation of the Salt Range, Pakistan, differs from the present species in much larger size. The Miharanoro species may be a new species of *Rhipidomella*, but the poor material precludes that determination.

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, 1976b
Fig. 6B, C

*Enteletes stehlii* Cooper and Grant, 1976b, p. 2639, pl. 688, figs. 1–51.

*Material*.—Eleven conjoined-valve specimens, FMM6339–6349.

*Remarks*.—These specimens are safely assigned to the genus *Enteletes* Fischer de Waldheim, 1825 by strongly biconvex shell and external ornament consisting of angular to subangular simple costae and numerous fine capillae. The Miharanoro species can be referred to *Enteletes stehlii* Cooper and Grant, 1976b, from the Skinner Ranch and Bone Spring formations of Texas, by its small, transverse and relatively low shell (length about 15 mm, width about 21 mm, thickness about 13 mm in the largest specimen, FMM6339). *Enteletes wolfcampensis* King, 1931, redescribed by Cooper and Grant (1976b, p. 2642, pl. 684, figs. 21–33; pl. 687, figs. 1–56) from the lower Wolfcampian of Texas, is also a small-sized *Enteletes* species, but differs from *E. stehlii* in being subequal and rotund outline. Hayasaka and Kato (1966, p. 281, pl. 34, figs. 1–4; pl. 35, figs. 1–4. text-figs. 1, 2) described *Enteletes gibbosus* Chronic, 1953 from the same locality of Miharanoro, southwestern Japan.

*Distribution*.—Asselian–Artinskian: southwestern Japan (Miharanoro in the Akiyoshi Belt) and the USA (Texas).

*Enteletes bowsheri* Cooper and Grant, 1976b
Fig. 6D–F

*Enteletes bowsheri* Cooper and Grant, 1976b, p. 2629, pl. 693, figs. 27–36.

*Material*.—Five specimens: (1) three conjoined shells, FMM6334–6336; and (2) two ventral valves, FMM6337, 6338.

*Remarks*.—These specimens are safely assigned to the genus *Enteletes* Fischer de Waldheim, 1825 by highly biconvex shell with external ornament consisting of strong simple costae and numerous fine capillae. The Miharanoro species can be referred to *Enteletes bowsheri* Cooper and Grant,1976b, from the Bursum Formation of Texas, by large, roundly elliptical shell (length about 37 mm, width about 50 mm in the largest specimen, FMM6334), with strong rounded costae which occur only anterior half of the both valves. This species is readily distinguished from the preceding species, *E. stehli* by its more strongly biconvex and globose outline. *Enteletes subcircularis* Cooper and Grant (1976b, p. 2640, pl. 675, figs. 36–39; pl. 676, figs. 1–30; pl. 685, figs. 1–27), from the Skinner Ranch, Hess and Bone Spring formations of Texas, is also a large-sized *Enteletes* species, but differs from the present species in having strong subangular costae extending to umbonal region. *Enteletes acutiplicatus* Hayasaka, 1932, redescribed by Hayasaka (1933, p. 23, pl. 8, fig. 19) from the Nabeyama Limestone of Nabeyama, Kuzu area in the Mino Belt, central Japan, is clearly distinguished from the Minaranoro species in having a few, very acute costae on the dorsal valve.

*Distribution*.—Asselian: southwestern Japan (Miharanoro in the Akiyoshi Belt) and the USA (Texas).

Order Spiriferida Waagen, 1883
Suborder Spiriferidina Waagen, 1883
Superfamily Martinioidea Waagen, 1883
Family Martiniidae Waagen, 1883
Subfamily Martiniinae Waagen, 1883
Genus *Martinia* M'Coy, 1844

*Type species*.—*Spirifer glaber* Sowerby, 1820.

*Martinia cruenta* Cooper and Grant, 1976a
Figs. 7A, B

*Martinia cruenta* Cooper and Grant, 1976a, p. 2266, pl. 644, figs. 54–57.

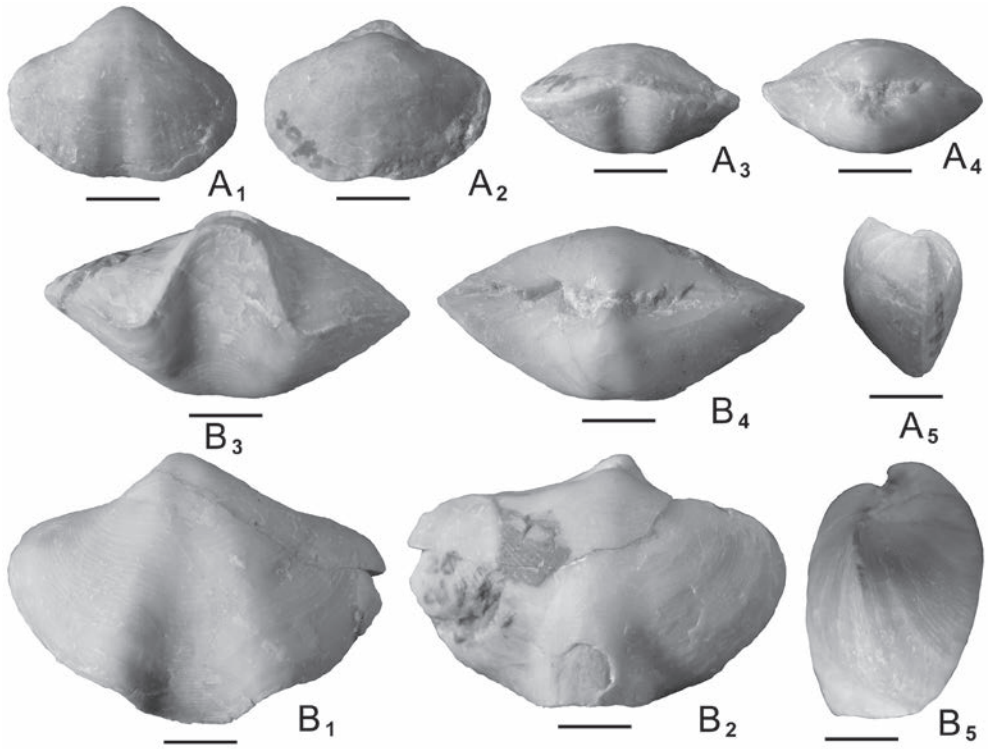


**Fig. 7. A, B,** *Martinia cruenta* Cooper and Grant; A, ventral ($A_1$), dorsal ($A_2$), anterior ($A_3$), posterior ($A_4$) and lateral ($A_5$) views of conjoined shell, FMM6374; B, ventral ($B_1$), dorsal ($B_2$), anterior ($B_3$), posterior ($B_4$) and lateral ($B_5$) views of conjoined sell, FMM6364. Scale bars are 1 cm.

*Material*.—Fifteen conjoined-valve specimens, FMM6361–6375.

*Description*.—Shell large in size for genus, transversely subrectangular in outline, with greatest width at midlength; cardinal extremities rounded: hinge wide, about two-thirds maximum width; length 47 mm, width 64 mm in the largest specimen (FMM6361); length 32 mm, width 53 mm in the best-preserved specimen (FMM6364). Ventral valve moderately convex in lateral profile, most convex in umbonal region; umbo small, strongly incurved; sulcus with U-shaped bottom, originating just posterior to midlength, shallow to moderately deep throughout its length, except for strongly depressed near anterior margin. Dorsal valve gently convex in lateral profile; fold originating just posterior to midlength, low to moderately high except for strongly elevated near anterior margin. External surface of both valves smooth except for very fine growth lines.

*Remarks*.—These specimens can be referred to *Martinia cruenta* Cooper and Grant, 1976a, from the Wolfcampian (Hess Formation?) of Texas, by being large, transverse outline and in having wide hinge and well developed sulcus-fold. *Martinia nipponica* Yanagida and Nishikawa (1984, p. 178, pl. 18, figs. 3, 4), from the Kawai Limestone (Asselian) of Kawai in the Akiyoshi Belt, southwestern Japan, has also conspicuous sulcus-fold, but differs from the

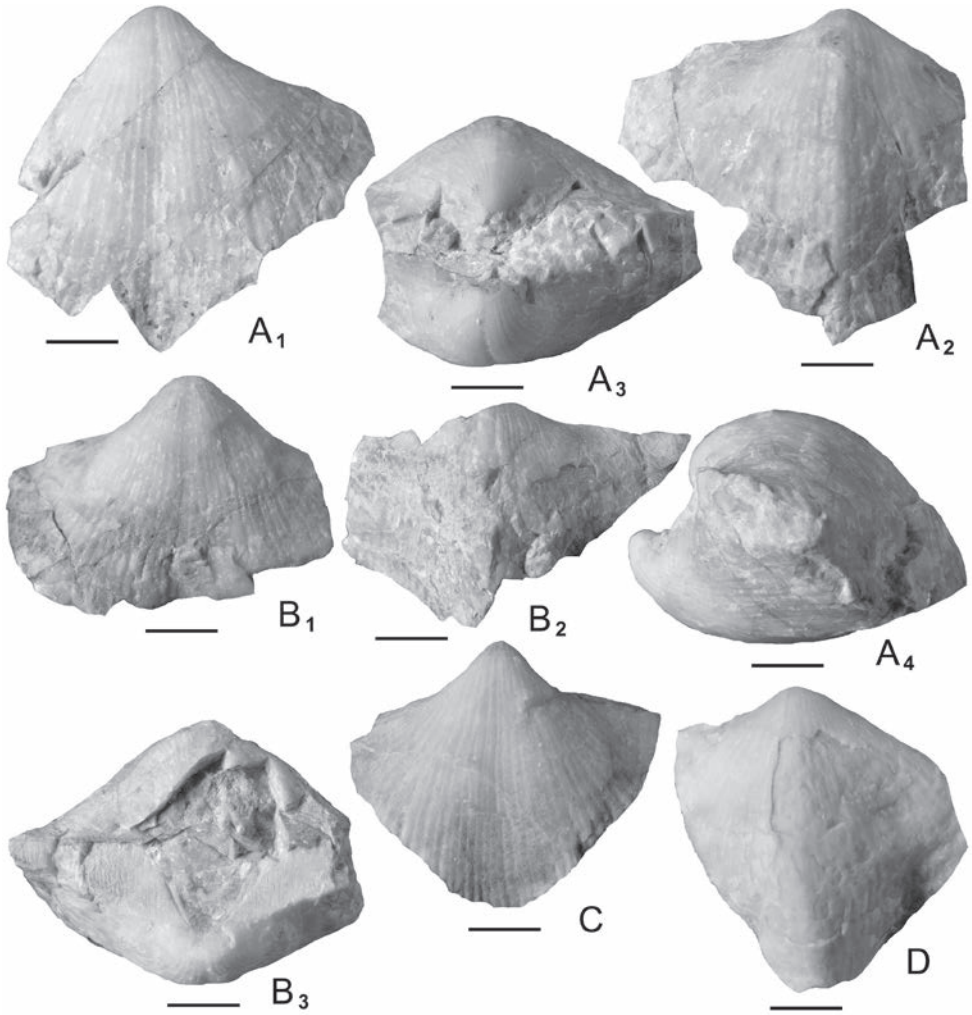


**Fig. 8. A–D,** *Choristites fritschi* (Schellwien); A, ventral ($A_1$), dorsal ($A_2$), posterior ($A_3$) and lateral ($A_4$) views of conjoined shell, FMM6351; B, ventral ($B_1$), dorsal ($B_2$) and posterior ($B_3$) views of conjoined shell, FMM6355; C, ventral view of ventral valve, FMM6354; D, dorsal view of dorsal valve, FMM6352. Scale bars are 1 cm.

present species in much smaller size and in having weak costae on each side of the dorsal fold.

*Distribution*.—Asselian–Sakmarian: southwestern Japan (Miharanoro in the Akiyoshi Belt) and the USA (Texas).

Superfamily Spiriferoidea King, 1846

Family Choristitidae Waterhouse, 1968

Subfamily Choristitinae Waterhouse, 1968

Genus *Choristites* Fischer de Waldhaim, 1825

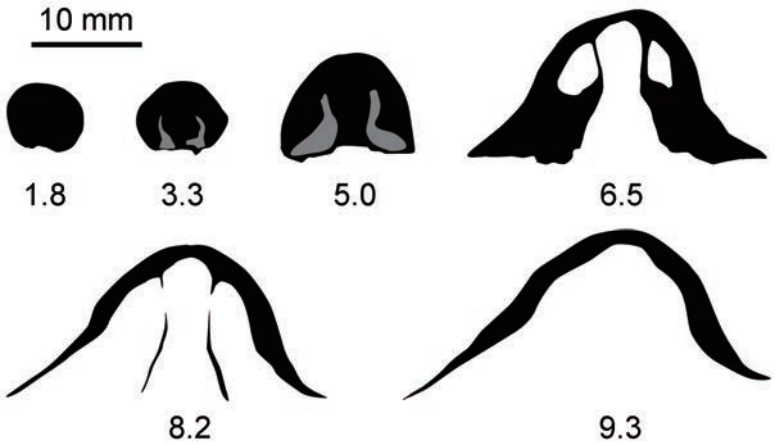


**Fig. 9.** Serial sections of ventral valve, *Choristites fritschi* (Schellwien), FMM6366. Numbers are distance (mm) from posterior end of ventral beak.

*Type species.*—*Choristites mosquensis* Buckman, 1908.

*Choristites fritschi* (Schellwien, 1892)
Figs. 8A–D, 9

*Spirifer fritschi* Schellwien, 1892, p. 43, pl. 5, figs. 4–8; Schellwien, 1900, p. 71, pl. 10, figs. 7–10; Tschernyschew, 1914, p. 21, pl. 5, fig. 4; Heritsch, 1931, p. 25, pl. 2, figs. 67–74.
*Spirifer* (*Choristites*) *fritschi* Schellwien. Ozaki, 1931, p. 38, pl. 2, fig. 6.
*Spirifer* (*Munella*?) *fritschi* Schellwien. Metz, 1936, p. 173, pl. 6, figs. 9, 10.
*Choristites fritschi* (Schellwien). Gauri, 1965, p. 45, pl. 7, figs. 1, 2, text-fig. 16; Besnossova, 1968, p. 182, pl. 28, figs. 1–5; Winkler Prins, 1970, p. 540, pl. 38. fig. 1.

*Material.*—Ten specimens: (1) two conjoined shells, FMM6351, 6352; and (2) eight ventral valves, FMM6353–6360.

*Descriptions.*—Shell medium to large in size for genus, transversely subsemicircular in outline, hinge equal to or slightly shorter than greatest width; length about 50 mm, width more than 60 mm in the largest specimen (FMM6351); length 36 mm, width 45 mm in the best preserved and average-sized specimen (FMM6354). Ventral valve moderately and unevenly convex in lateral profile, with maximum convexity at umbonal region; beak pointed and incurved; cardinal extremities blunt, angular; sulcus originating at beak, broad and shallow, and ornamented with 14–17 costae in anterior part of sulcus. Dorsal valve less convex than opposite valve; fold narrow and moderately high. External surface of both valves ornamented with numerous rounded costae, mostly irregularly bifurcated, numbering

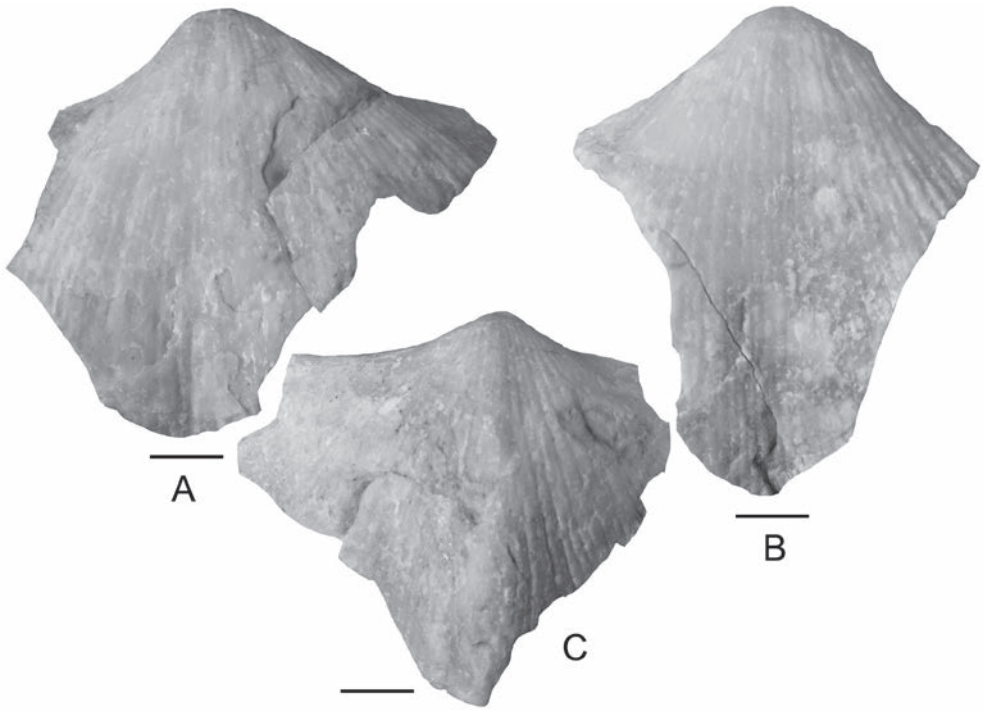


**Fig. 10. A–C,** *Choristites* sp.; A, ventral view of ventral valve, FMM6326; B, ventral view of ventral valve, FMM6325; C, dorsal view of dorsal valve, FMM6327. Scale bars are 1 cm.

6–7 costae in 10 mm at about midlength of ventral valve. Interior of ventral valve with a pair of long, subparallel dental adminicula. Interior of dorsal valve not well preserved.

*Remarks.*—These specimens can be referred to *Choristites fritschi* (Schellwien, 1892), from the upper Carboniferous of the Carnian Alps, in large size, transverse outline and in having numerous rather fine, bifurcated costae on the both ventral and dorsal valves. *Choristites wangchchueni* Chao (1929, p. 45, pl. 3, fig. 1; pl. 6, fig. 7), from the Penchi Formation of Shanxi, northern China, is also a transverse subsemicircular *Choristites* species, but differs from *C. fritschi* in much smaller size and in having more numerous, finer costae on the both valves. *Choristites jigulensis* (Stuckenberg, 1905), redescribed by Sokolskaya (in Sarytcheva and Sokolskaya, 1952, p. 206, pl. 61, fig. 342) from the Moscovian–Gzhelian of the Moscow Basin, western Russia, differs from *C. fritschi* in having thicker costae on the both valves. The type species, *Choristites mosquensis* Buckman, 1908, redescribed by Sokolskaya (in Sarytcheva and Sokolskaya, 1952, p. 204, pl. 59, fig. 332), from the Moscovian–Kasimovian of the Moscow Basin, is readily distinguished from the present species by its longer outline.

*Distribution.*—Moscovian–Sakmarian: southwestern Japan (Miharanoro in the Akiyoshi

Belt), Spain, Slovenia, Austria, Kazakhstan, Uzbekistan (Fergana) and eastern China (Shandong).

*Choristites* sp.
Fig. 10A–C

*Material*.—Three specimens: (1) two ventral valves, FMM6325, 6326; and (2) a dorsal valve, FMM6327.

*Remarks*.—These specimens can be assigned to the genus *Choristites* Fischer de Waldhaim, 1825, in having numerous simple, flat and thick costae on both valves. The Miharanoro species resembles *Choristites jigulensis* (Stuckenberg, 1905), redescribed by Barchatova (1970, p. 170, pl. 17, fig. 4; pl. 18, figs. 1, 2) from the Timansky Horizon (Orenburgian) of Timan, northern Russia, by its large size (length 72 mm, width more than 75 mm in the larger ventral valve specimen, FMM6325; length 54 mm, width more than 72 mm in the dorsal valve specimen, FMM6327), well developed sulcus-fold, and in having numerous thick costae (numbering 5–6 in 10 mm at about midlength of ventral valve) over the both valves. But accurate comparison is difficult for the ill preserved specimens.

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