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ARTICLE

SYSTEMATIC DESCRIPTIONS AND PALAEOBIOGEOGRAPHY OF PENNSYLVANIAN (MOSCOVIAN) BRACHIOPODS FROM OMI, CENTRAL JAPAN

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ABSTRACT

This study describes the following 17 species of Pennsylvanian brachiopods in 16 genera from the middle part (*Fusulina–Fusulinella* Zone) of the Omi Limestone in Omi, central Japan: *Isogramma millepunctata*, *Rugoconcha chaoi*, *Sandia brevis*, *Antiquatonia* sp., *Zia novamexicana*, *Echinoconchus punctatus*, *Echinaria* sp., *Karavankina fasciata*, *Buntoxia* sp., *Balakhonia* sp., *Fluctuaria neoundata*, *Costatumulus* sp., *Anthracospirifer newberryi*, *Choristites supramosquensis*, *Neospirifer cameratus*, *N. latus* and *Phricodothyris asiatica*. The Omi fauna indicates a Moscovian age. In terms of palaeobiogeography, the Omi fauna is characterized by a mixture of Boreal, Tethyan and North American elements and belonged to the Akiyoshi–Omi Province, which was situated between the Southern North America Province and the Northern Marginal Tethys Province. The Omi area was a seamount, probably located between the North America block and the North China block in the lower northern latitudes of Panthalassa during the Moscovian.

Key words: Akiyoshi–Omi Province, Brachiopoda, Moscovian, Omi, palaeobiogeography

田沢純一・吉池高行・茨木洋介 (2025)　本州中央部の青海から産出したペンシルバニア亜紀（モスクワ期）腕足類の分類学的記載と古生物地理．福井県立恐竜博物館紀要 24: 15–40.

本州中央部青海の青海石灰岩中部（*Fusulina–Fusulinella* 帯）から産出した 16 属 17 種の腕足類を記載した：*Isogramma millepunctata*, *Rugoconcha chaoi*, *Sandia brevis*, *Antiquatonia* sp., *Zia novamexicana*, *Echinoconchus punctatus*, *Echinaria* sp., *Karavankina fasciata*, *Buntoxia* sp., *Balakhonia* sp., *Fluctuaria neoundata*, *Costatumulus* sp., *Anthracospirifer newberryi*, *Choristites supramosquensis*, *Neospirifer cameratus*, *N. latus*, *Phricodothyris asiatica*. 青海フォーナは，時代的にはモスクワ期のフォーナである．古生物地理学的には北方区，テチス区，北アメリカ区の 3 区の要素が混在するフォーナで，北アメリカ南部地方とテチス北縁地方の中間に位置した秋吉 – 青海地方に属する．モスクワ期に，青海地域は北アメリカと北中国の 2 つの地塊の中間に位置する海山として，パンサラッサの北半球低緯度地域にあったと考えられる．

INTRODUCTION

Hayasaka (1918) reported Carboniferous brachiopods, including *Gigantoproductus* and *Syringothyris*, from limestone at Omi, Itoigawa City, Niigata Prefecture, central Japan. That study was the first report of Carboniferous rocks and fossils in Japan. The Omi Limestone, which is underlain by basaltic rocks, is one of the Akiyoshi-type limestones (i.e., the Omi, Atetsu, Koyama, Hina, Taishaku, Akiyoshi and Hirao limestones). These limestones are Mississippian (Early Carboniferous)–Guadalupian (Middle Permian) in age and occur in the Akiyoshi Belt of the Inner Zone of southwestern Japan (Fig. 1A). The limestone and basalt occur as blocks and are interpreted to have originated as oceanic seamounts with carbonate caps in Panthalassa during the Mississippian. Subsequently, the seamounts were carried northwestward via plate motion at the time of reef development, and were finally accreted to Proto-Japan during the Lopingian (Late Permian; Kanmera et al., 1990). The locations of the Akiyoshi-type seamounts during the Mississippian–Lopingian were unclear because of a paucity of palaeobiogeographical studies on the fossils from the limestone–basalt blocks and surrounding rocks in the Akiyoshi Belt.

In the present study, we describe Pennsylvanian (Late Carboniferous) brachiopods from limestone of the *Fusulina–Fusulinella* Zone at Higashiyama Quarry, northern slope of Mt. Kurohimeyama, Omi, and discuss the age and palaeobiogeography of the brachiopod fauna. J. Tazawa carried out the systematic study of most of the brachiopod species and assessed the palaeobiogeography of the Omi fauna; Y. Ibaraki conducted the systematic study of *Choristites* and

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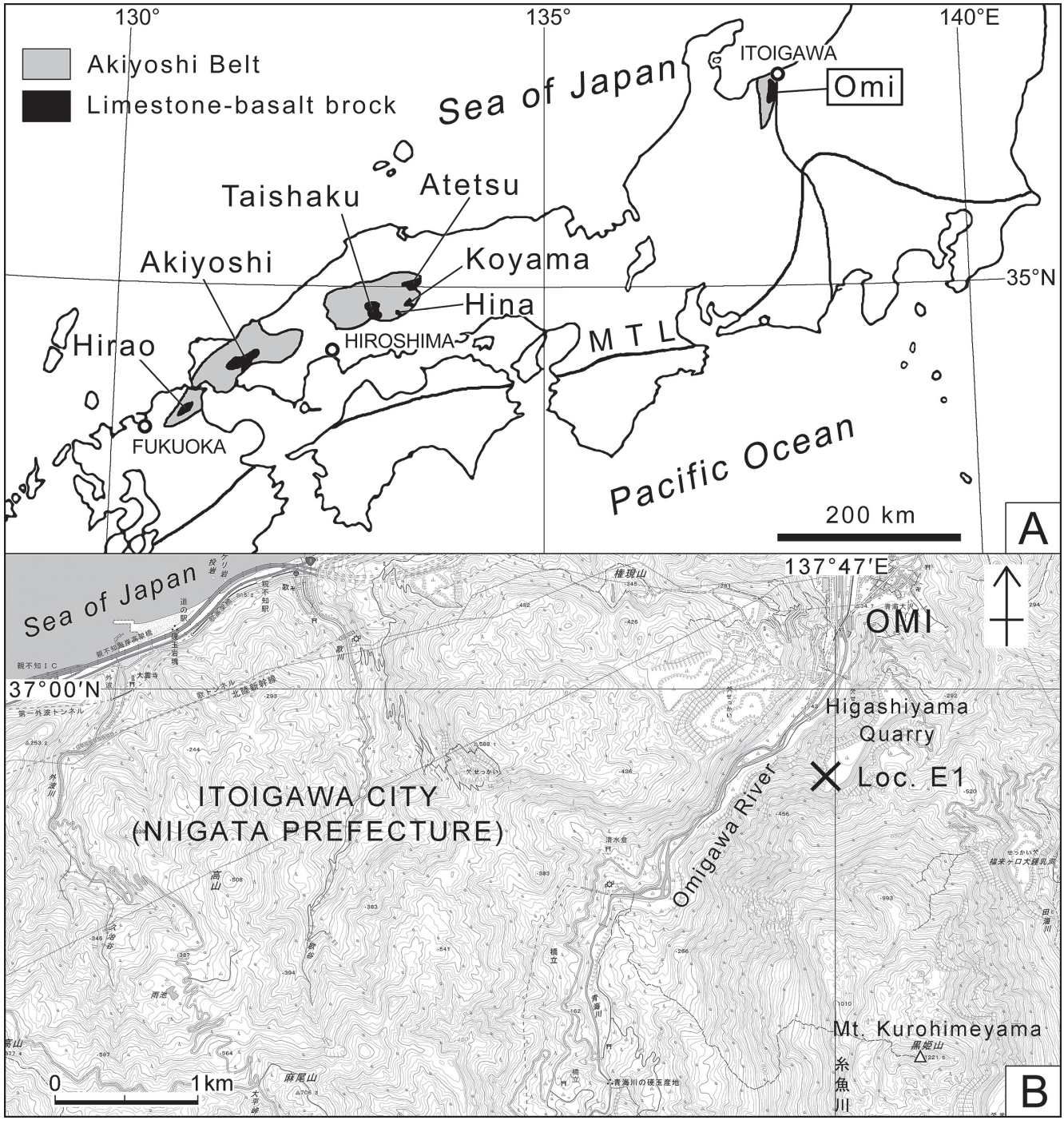

FIGURE 1. Maps showing the location and geology of fossil locality Omi. **A**, Geotectonic map of southwestern Japan, MTL: Median Tectonic Line (base map from Ishida et al., 2013); **B**, topographic map showing the fossil locality E1 in Omi, Itoigawa City, Niigata Prefecture (using the electronic topographical map of the Geospatial Information Authority of Japan).

Phricodothyris. Most of the specimens described herein were collected by T. Yoshiike in 1980–1981, during the course of graduate study at the Institute of Geology and Paleontology, Faculty of Science, Tohoku University, under the supervision of J. Tazawa.

STRATIGRAPHY AND MATERIAL

The stratigraphy of the Omi Limestone was established by Hasegawa et al. (1969) and revised in part by Tazawa et al. (2002) and Takeuchi and Nakazawa (2010). According to Tazawa et al. (2002), the Omi Limestone (about 1,000 m thick) consists of

FIGURE 2. Views of the Omi area. **A**, Northern slope of Mt. Kurohimeyama; **B**, the Higashiyama Quarry in the northern slope of Mt. Kurohimeyama.

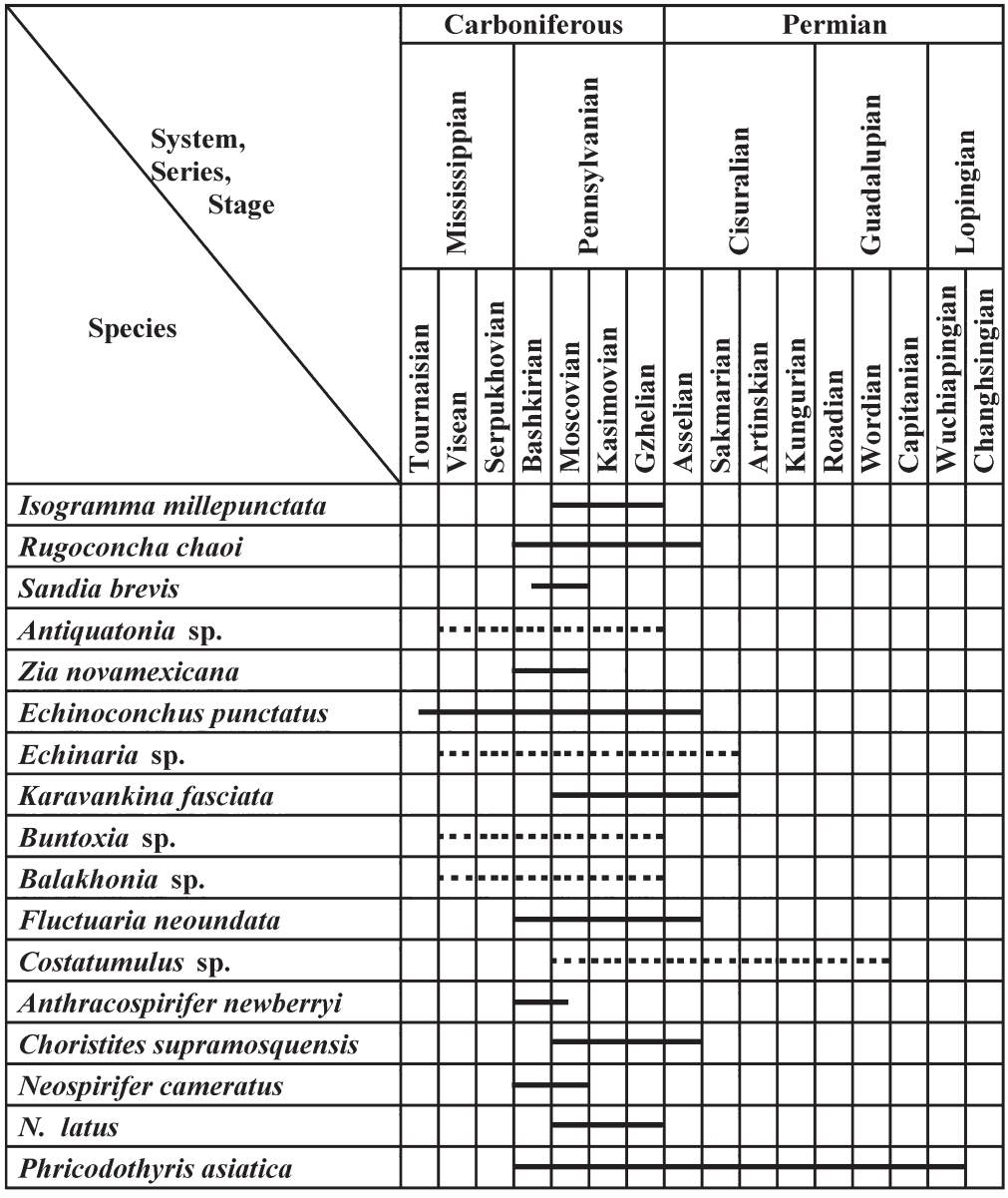

FIGURE 3. Stratigraphic distributions of brachiopod species in the Omi fauna. Broken line shows range of the genus.

basaltic rocks (>15 m thick; upper Visean) in the basal part and overlying thick massive limestones (ca. 1,000 m thick; upper Visean–Capitanian). The thick limestone is subdivided into nine fusulinid zones, as follows (in ascending stratigraphic order): the *Endothyra* Zone (120 m thick, upper Visean), the *Eostafella–Millerella* Zone (200–250 m thick, upper Visean–lower Bashkirian), the *Profusulinella* Zone (90–150 m thick, upper Bashkirian–lowest Moscovian), the *Fusulina–Fusulinella* Zone (120–250 m thick, Moscovian), the *Pseudoschwagerina* Zone (170–250 m thick, Kasimovian–Asselian), the *Pseudofusulina* Zone (180–250 m thick, Sakmarian), the *Parafusulina* Zone (50 m thick, Artinskian), the *Neoschwagerina–Colania* Zone (10+ m thick, Kungurian–Wordian) and the *Lepidolina* Zone (5+ m thick, Capitanian). The huge basalt-limestone block (7.8 km NW-SE, 3.3 km NE-SW) is one of the blocks in the Jurassic accretionary complex in the Omi area (Tazawa et al., 1984; Kawai and Takeuchi, 2001).

The brachiopods described herein were collected from light grey limestone in the middle part (*Fusulina–Fusulinella* Zone) of the Omi Limestone at Loc. E1 (36°59′ 40″N, 137°46′ 57″E) in Higashiyama Quarry, northern slope of Mt. Kurohimeyama (Figs. 1B, 2). Fossil locality OM-1 of Tazawa et al. (2004) is the same as locality E1 in the present study. The brachiopod specimens are now registered (Prefix FMM; numbers 1320, 6749–6762, 6847–6854 and 6857–6860) and housed in the Fossa Magna Museum, Itoigawa City, Niigata Prefecture, central Japan.

Species \ Region	Japan							USA										Canada	N. Russia								UK											W. Russia		C. Russia				NW China			N. China			NE China	E. China		CS China		SW Chian				
	Akiyoshi Belt																																																											
	1. Omi	2. Miharanoro	3. South Kitakami Belt	4. Peru	5. Bolivia	6. Brazil	7. New Mexico	8. Oklahoma	9. Kansas	10. Nebraska	11. Missouri	12. Illinois	13. Ohio	14. Michigan	15. Ellesmere Island	16. Kolyma	17. Verkhoyansk Range	18. Taimyr Peninsula	19. Northern Urals	20. Pechora Basin	21. Timan	22. Scotland	23. England	24. Wales	25. Ireland	26. Algeria	27. Spain	28. Serbia	29. Belgium	30. Germany	31. Donetz Basin	32. Moscow Basin	33. Southern Urals	34. Kuznetsk Basin	35. Kazakhstan	36. Uzbekistan	37. Kyrgyzstan	38. Xinjiang	39. Qinghai	40. Gansu	41. Inner Mongolia	42. Shanxi	43. Liaoning	44. Zhejiang	45. Hunan	46. Guangxi	47. Guizhou	48. Yunnan	49. Tibet	50. North-central Thailand
Isogramma millepunctata	+									+		+	+																								+		+																			
Rugoconcha chaoi	+																																																									
Sandia brevis	+						+																																																				
Zia novamexicana	+						+																																																				
Echinoconchus punctatus	+	+	+														+	+	+			+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+																			
Karavankina fasciata	+																+															+			+	+	+	+																			
Fluctuaria neoundata	+														+		+		+														+																									
Anthracospirifer newberryi	+						+																																																				
Choristites supramosquensis	+																				+									+	+									+			+													
Neospirifer cameratus	+			+	+	+	+	+		+			+	+																																															
N. latus	+						+		+	+	+					+																																													
Phricodothyris asiatica	+														+	+			+	+	+																		+		+																			

FIGURE 4. Geographic distributions of brachiopod species in the Omi fauna, excluding five uncertain species (*Antiquatonia* sp., *Echinaria* sp., *Buntoxia* sp., *Balakhonia* sp. and *Costatumulus* sp.).

BRACHIOPOD FAUNA

The Omi fauna described herein includes 17 species in 16 genera: *Isogramma millepnctata* (Meek and Worthen, 1870), *Rugoconcha chaoi* (Grabau, 1936), *Sandia brevis* Sutherland and Harlow, 1973, *Antiquatonia* sp., *Zia novamexicana* Sutherland and Harlow, 1973, *Echinoconchus punctatus* (Sowerby, 1822), *Echinaria* sp., *Karavankina fasciata* (Kutorga, 1844), *Buntoxia* sp., *Balakhonia* sp., *Fluctuaria neoundata* Mironova, 1967, *Costatumulus* sp., *Anthracospirifer newberryi* Sutherland and Harlow, 1973, *Choristites supramosquensis* (Nikitin, 1890), *Neospirifer cameratus* (Morton, 1836), *N. latus* Dunbar and Condra, 1932 and *Phricodothyris asiatica* (Chao, 1929). Fourteen species are described for the first time from the Carboniferous of Japan.

AGE AND CORRELATION

The stratigraphic distributions of the brachiopod species are described in the "Systematic descriptions" section of the present paper and summarized in Fig. 3. Of the brachiopod species listed above, *S. brevis*, *Z. novamexicana*, *A. newberryi* and *N. cameratus* have a stratigraphic range of Bashkirian–Moscovian. In contrast, *I. millepunctata* and *N. latus* have a stratigraphic range of Moscovian–Gzhelian; *C. supramosquensis* is known from the Moscovian–Asselian; *K. fasciata* is known from the Moscovian–Sakmarian; and *R. chaoi* and *F. neoundata* are known from the Bashkirian–Asselian. *E. punctatus* and *P. asiatica* are long-ranging species, known from upper Tournaisian to Asselian and from Bashkirian to Wuchiapingian, respectively. At the generic level, *Antiquatonia* is known from the Visean–Gzhelian (Muir-Wood and Cooper, 1960); *Echinaria* from the Visean–Sakmarian (Cooper and Grant, 1975; Tan, 1987; Tazawa and Shintani, 2015; Tazawa, 2017); *Buntoxia* and *Balakhonia* are known from the Visean–Gzhelian (Dunbar and Condra, 1932; Sarytcheva et al., 1963; Sarytheva, 1968; Tazawa, 1980; Brunton et al., 2000); and *Costatumulus* has a range of Moscovian–Wuchiapingian (Abramov, 1970; Shen et al., 2000). To summarize, the fossil horizon of the Omi fauna is identified as Moscovian in age, so the fossil bearing Omi Limestone (*Fusulina–Fusulinella* Zone) is also correlated with the Moscovian.

This conclusion is consistent with biostratigraphical studies on fusulinid foraminifera in the *Fusulinella* Zone of the Omi Limestone (Hasegawa et al., 1969) and on a brachiopod species, *Isogramma millepunctata*, from the same fusulinid zone of the Omi Limestone (Tazawa et al., 2004).

PALAEOBIOGEOGRAPHY

The geographic distributions of the Pennsylvanian brachiopod species of the Omi fauna, excluding five species in open nomenclature (*Antiquatonia* sp., *Echinaria* sp., *Buntoxia* sp., *Balakhonia* sp. and *Costatumulus* sp.), are documented in the "Systematic descriptions" section of the present paper and summarized in Figs. 4 and 5. Of the 12 species of the Omi fauna, five species also occur in southwestern USA (New Mexico); four species also occur in northwestern China (Xinjiang); three species also occur in mid USA (Nevada), northern Russia (Verkhoyansk Range and northern Urals), western Russia (Moscow Basin), central Russia (southern Urals), Uzbekistan (Fergana) and northwestern China (Gansu); and two species are

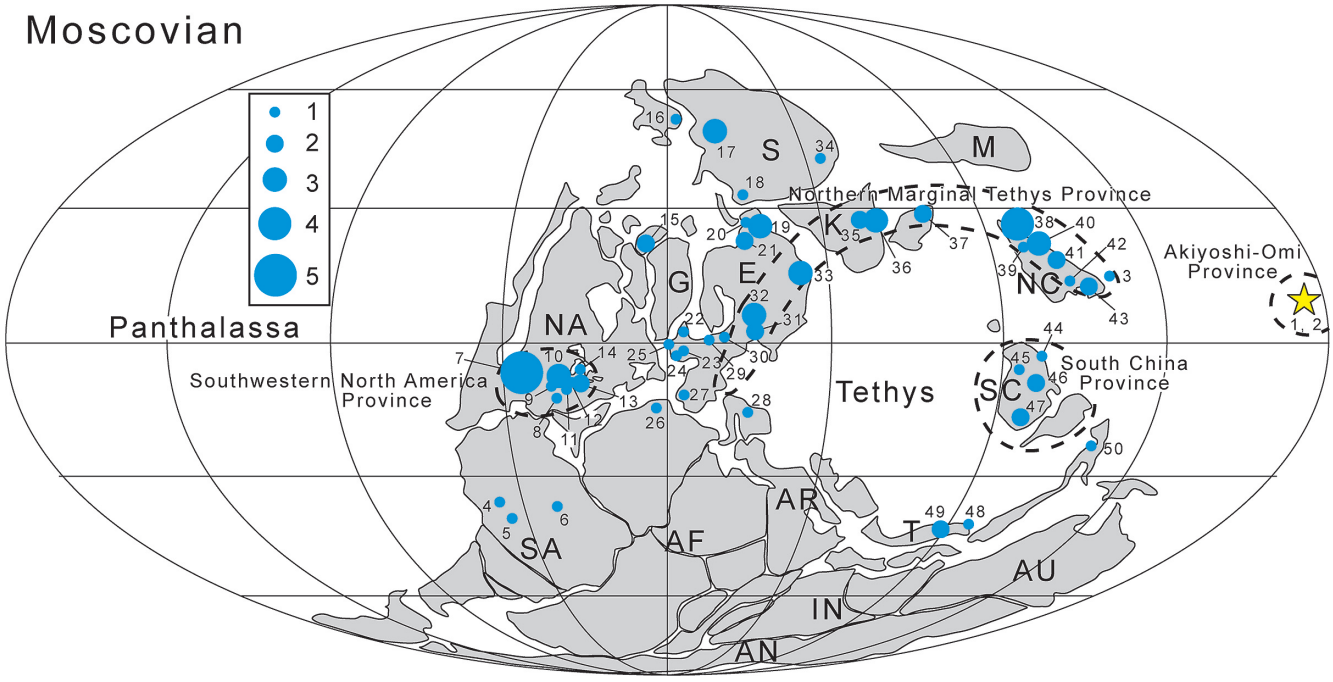

FIGURE 5. Middle Pennsylvanian (Moscovian) reconstruction map of the world (adapted from Scotese, 2004), showing the geographic distributions of brachiopod species in the Omi fauna, excluding five uncertain species (*Antiquatonia* sp., *Echinaria* sp., *Buntoxia* sp., *Balakhonia* sp. and *Costatumulus* sp.). Location numbers are same in Fig. 4, and the numbers appended to the circles in the legend indicate the species numbers, AF: Africa, AN: Antarctica, AR: Arabia, AU: Australia, E: Europe, G: Greenland, IC: Indochina, IN: India, M: Mongolia, NA: North America, NC: North China, SA: South America, SC: South China, T: Tarim.

found in mid USA (Ohio), Arctic Canada (Ellesmere Island), northern Russia (Timan), western Russia (Donetz Basin), Kazakhstan, Kyrgyzstan, northern China (Inner Mongolia), northeastern China (Liaoning), central-southern China (Guangxi), southwestern China (Guizhou) and Tibet. In terms of palaeobiogeography, the Omi fauna is characterized by a mixture of Boreal elements (*I. millepunctata*, *K. fasciata*, *F. neoundata* and *C. supramosquensis*), Tethyan element (*R. chaoi*) and North American elements (*S. brevis*, *Z. novamexicana*, *A. newberyi*, *N. cameratus* and *N. latus*).

From the information provided above, the Moscovian brachiopod fauna of Omi exhibits a close affinity with those of the southwestern to mid USA (i.e., the Southwestern North America Province, equivalent to the northern half of the Southern North America–Northern South America Province of Li et al., 2021), and western Russia, Uzbekistan and northwestern China (i.e., the Northern Marginal Tethys Province, equivalent to the Northern Margin of the Palaeo-Tethys Ocean Province of Li et al., 2021). Of note, the Omi fauna differs from the Moscovian fauna of southern China (i.e., the South China Province of Li et al., 2021). The newly proposed Akiyoshi–Omi Province, which contains the Moscovian brachiopod fauna of the Omi Limestone, was probably located between the Southern North America Province and the Northern Marginal Tethys Province during the Moscovian (Fig. 5). In other words, the Omi area was probably located in Panthalassa at a lower northern latitude and between the North America block and the North China block during the Moscovian.

This conclusion is consistent with a palaeomagnetic study on basaltic rocks in the basal part of the Akiyoshi Limestone (Fujiwara, 1967; summarized by Sasajima, 1991), which concluded that the area was located at 14.3°N in the Early Carboniferous (late Visean). In terms of palaeobiogeography, Tazawa et al. (2004) described the brachiopod species *I. milllepunctata* from the Moscovian limestone of Omi and on that basis inferred the Omi seamount was located at a northern middle latitude (about 20°N) in Panthalassa between Uzbekistan (Fergana)–northwestern China (Xinjiang) and southwestern North America (Nebraska, Illinois and Ohio) during the Moscovian. Tazawa and Ibaraki (2023) described a mixed Boreal–Tethyan–Panthalassan brachiopod fauna from the Asselian limestone of Miharanoro in the Taishaku area, Akiyoshi Belt, southwestern Japan, and concluded that 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.

In contrast, Ehiro and Ozawa (2020) undertook a palaeobiogeographical study of the Miharanoro ammonoid fauna and proposed that the Akiyoshi-type seamounts were located in the equatorial region of Panthalassa (Mid-Panthalassan Realm) in the Asselian. However, the ammonoid fauna consists of four species in open nomenclature (*Agathiceras* sp., *Neoglaphyrites* sp., *Somoholites* sp. and *Eoasianites*? sp.), one taxon indeterminate at both generic and specific levels (Adrianitidae gen. et sp. indet.), and four species that were newly described in that study (*Shumardites umbilicatus*, *Vidrioceras*

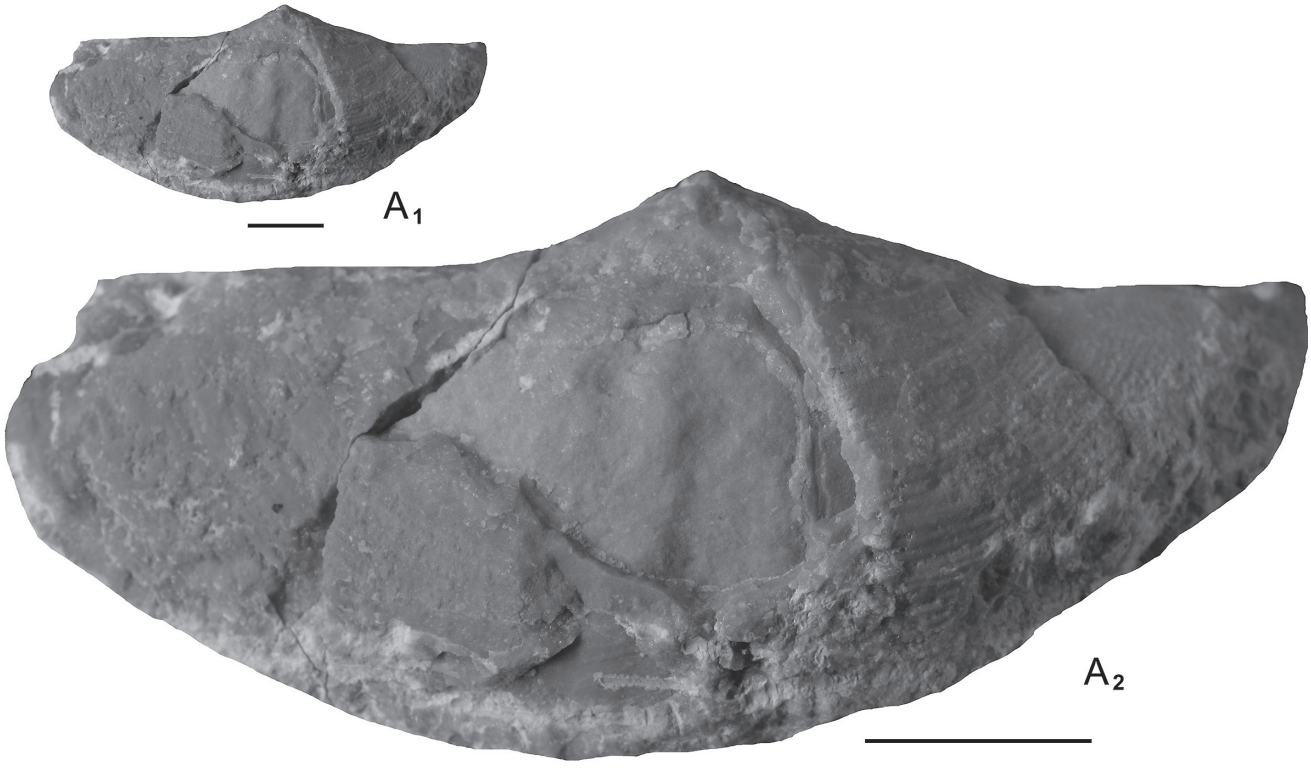

FIGURE 6. **A**, *Isogramma millepunctata* (Meek and Worthen), ventral view (A_1, A_2) of ventral valve, FMM1320. Scale bars are 1 cm.

ellipticum, *Almites hayasakai* and *Boesites biconcavus*); only one species (*Metapronorites timorensis*) was identified with certainty. Moreover, most of the genera of the Miharanoro fauna (*Agathiceras*, *Neoglaphyrites*, *Somoholites*, *Eoasianites* and *Metapronorites*) were cosmopolitan, occurring from the Arctic to equatorial regions (Ehiro and Ozawa, 2020, p. 311–312) and were not restricted to equatorial Panthalassa. Thus, the material seems to be insufficient for the given conclusion.

CONCLUSIONS

This study describes 17 species of Pennsylvanian brachiopods in 16 genera from the middle part (*Fusulina–Fusulinella* Zone) of the Omi Limestone in Omi, central Japan. The species are *Isogramma millepunctata*, *Rugoconcha chaoi*, *Sandia brevis*, *Antiquatonia* sp., *Zia novamexicana*, *Echinoconchus punctatus*, *Echinaria* sp., *Karavankina fasciata*, *Buntoxia* sp., *Balakhonia* sp., *Fluctuaria neoundata*, *Costatumulus* sp., *Anthracospirifer newberryi*, *Choristites supramosquensis*, *Neospirifer cameratus*, *N. latus* and *Phricodothyris asiatica*. The co-occurece of several short-ranging species (*S. brevis*, *Z. novamexicana*, *A. newberryi*, *N. cameratus*, *I. millepunctata* and *N. latus*) indicates a Moscovian age. In terms of palaeobiogeography, the Omi fauna is characterized by a mixture of Boreal elements (*I. millepunctata*, *K. fasciata*, *F. neoundata* and *C. supramosquensis*), Tethyan element (*R. chaoi*) and North American elements (*S. brevis*, *Z. novamexicana*, *A. newberyi*, *N. cameratus* and *N. latus*), and belonged to the Akiyoshi–Omi Province. This province was situated between the Northern Marginal Tethys Province and the Southern North America Province. During the Moscovian the Omi area was a seamount that was probably located between the North America block and the North China block in the lower northern latitudes of Panthalassa.

SYSTEMATIC DESCRIPTIONS

The supra-generic classification used in this paper follows Holmer (2000) for the order Dictyonellida, Waterhouse (2002) for the suborder Productidina, Carter (2006) for the superfamily Spiriferoidea, and Carter and Gourvennec (2006) for the Superfamily Reticularioidea.

Order DICTYONELLIDA Cooper, 1956
Superfamily EICHWALDIOIDEA Schuchert, 1893
Family ISOGRAMMIDAE Schuchert, 1929
Genus *ISOGRAMMA* Meek and Worthen, 1870

Type species.—*Chonetes*? *millepunctatus* Meek and Worthen, 1870.

Isogramma millepnctata (Meek and Worthen, 1870)
(Fig. 6A)

Chonetes? *millepunctatus* Meek and Worthen, 1870, p. 35; Meek and Worthen, 1873, p. 566, pl. 25, fig. 3.
Aulacorhynchus millepunctatus (Meek and Worthen). Morningstar, 1922, p. 180, pl. 7, fig. 12.
Isogramma millepunctata (Meek and Worthen). Dunbar and Condra, 1932, p. 282, pl. 42, figs. 18–21; Volgin, 1957, p. 37, pl. 1, figs. 1–7; Volgin, 1960, p. 41, pl. 2, figs. 3–5; Sturgeon and Hoare, 1968, p. 25, pl. 2, figs. 15, 16; Wang and Yang, 1998, p. 66, pl. 24, fig. 3; Tazawa et al., 2004, p. 20, fig. 4.

Material.—One specimen, a ventral valve, FMM1320.

Remarks.—This specimen was previously described by Tazawa et al. (2004) as *Isogramma millepunctata* (Meek and Worthen, 1870), from the Moscovian limestone at the same locality in the Higashiyama Quarry of Omi. The Omi specimen can be referred to *Isogramma millepunctata* by its medium size (length 27 mm, width about 60 mm), transversely semielliptical outline with nearly straight hinge and external ornament of numerous fine, regular concentric fila (11 in 5 mm at about midvalve). *Isogramma paotechowensis* (Grabau and Chao, in Chao, 1928, p. 33, pl. 1, fig. 27; pl. 4, figs. 1–5) from the Taiyuan Formation of Shanxi, northern China and *Isogramma davidsoni* (Barrois, 1882, p. 326, pl. 16, fig. 6) from the Upper Carboniferous (Pennsylvanian?) of Asturias, northwest Spain are similar to *I. millepunctata* in size and external ornament of ventral valve, but the two species differ from the present species in their less-transverse outline and in having not-straight hinge on ventral valve.

Distribution.—Moscovian–Gzhelian: central Japan (Omi), mid USA (Nebraska, Illinois and Ohio), Uzbekistan (Fergana) and northwestern China (Xinjiang).

Order PRODUCTIDA Sarytcheva and Sokolskaya, 1959
Suborder PRODUCTIDINA Waagen, 1883
Superfamily PRODUCTELLOIDEA Schuchert, 1929
Family OVERTONIIDAE Muir-Wood and Cooper, 1960
Subfamily PLICATIFERINAE Muir-Wood and Cooper, 1960
Genus *RUGOCONCHA* Jin and Sun, 1981

Type species.—*Plicatifera chaoi* Grabau, 1936.

Rugoconcha chaoi (Grabau, 1936)
(Fig. 7A, B)

Plicatifera chaoi Grabau, 1936, p. 171, pl. 6, fig. 9; pl. 8, fig. 2; pl. 14, figs. 21, 22; Jin and Liao, 1974, p. 280, pl. 145, figs. 1, 2; Li et al., 1974, pl. 1, fig. 7; Yang et al., 1977, p. 344, pl. 139, fig. 1; Feng and Jiang, 1978, p. 251, pl. 89, fig. 12; Jin et al., 1985, p. 191, pl. 11, fig. 8.
Rugoconcha chaoi (Grabau). Jin and Sun, 1981, p. 133, pl. 6, fig. 11.

Material.—Two specimens: (1) a dorsal valve, FMM6814; and (2) an external mould of dorsal valve, FMM6815.

Remarks.—These specimens are fragmentarily preserved, but they can be referred to *Rugoconcha chaoi* (Grabau, 1936), originally described by Grabau (1936, p. 171, pl. 6, fig. 9; pl. 8, fig. 2; pl. 14, figs. 21, 22) as *Plicatifera chaoi* Grabau, 1936, from the Kasimovian–Asselian strata of Guangxi and Guizhou, southern China, by the large size (length about 17 mm, width about 34 mm in the larger specimen, FMM6815), transversely subrectangular outline, nearly flat dorsal valve with a low and wide fold, and external ornament of regular, strong rugae (4 in 5 mm at midlength). *Rugoconcha xainzaensis* Yang and Fan (1983, p. 269, pl. 1, figs. 18, 19), from the Sisuo Formation of Xainza, northern Xizang (Tibet) is readily distinguished from *R. chaoi* in its less transverse outline and much smaller size.

Distribution.—Bashkirian–Asselian: central Japan (Omi), northwestern China (Gansu), central-southern China (Guangxi), southwestern China (Guizhou) and Tibet.

Superfamily MARGINIFEROIDEA Stehli, 1954
Family COSTISPINIFERIDAE Muir-Wood and Cooper, 1960
Subfamily DESMOINESIINAE Waterhouse, 2002
Genus *SANDIA* Sutherland and Harlow, 1973

Type species.—*Sandia brevis* Sutherland and Harlow, 1973.

Sandia brevis Sutherland and Harlow, 1973
(Fig. 7C)

Sandia brevis Sutherland and Harlow, 1973, p. 41, pl. 7, figs. 14–23; pl. 8, figs. 1–3.

Material.—A ventral valve, FMM6829.

Description.—Shell small in size for genus, subquadrate in outline, with greatest width at midlength; length 12 mm, width about 12 mm in the ventral valve specimen (FMM6829). Ventral valve strongly convex in lateral profile; umbo small; ears small, slightly pointed; sulcus faint, shallow on anterior half of valve; lateral slopes steep. External surface of ventral valve ornamented with numerous costellae, regular concentric rugae, and many spines; 7–8 costellae in 5 mm at about midlength; rugae developed on posterior half of valve; spines scattered over entire surface of valve, a row of spines faintly preserved near hinge.

Remarks.—The single ventral valve can be referred to *Sandia brevis* Sutherland and Harlow, 1973, from the Atokan and lower Desmoinesian strata in the southern Sangre de Cristo area, New Mexico, by its small size, subquadrate outline and external ornament of the ventral valve. *Sandia santafeensis* Sutherland and Harlow (1973, p. 44, pl. 8, figs. 4–12), from the Atokan strata of New Mexico, differs from *S. brevis* in its elongate shell outline. *Sandia welleri* (Mather, 1915), redescribed by Sutherland and Harlow (1973, p. 44, pl. 8, figs. 13–17) from the Morrowan strata of Oklahoma and Arkansas, differs from *S. brevis* in its larger size and transverse outline.

Distribution.—Upper Bashkirian–upper Moscovian: central Japan (Omi) and southwestern USA (New Mexico).

Superfamily PRODUCTOIDEA Gray, 1840

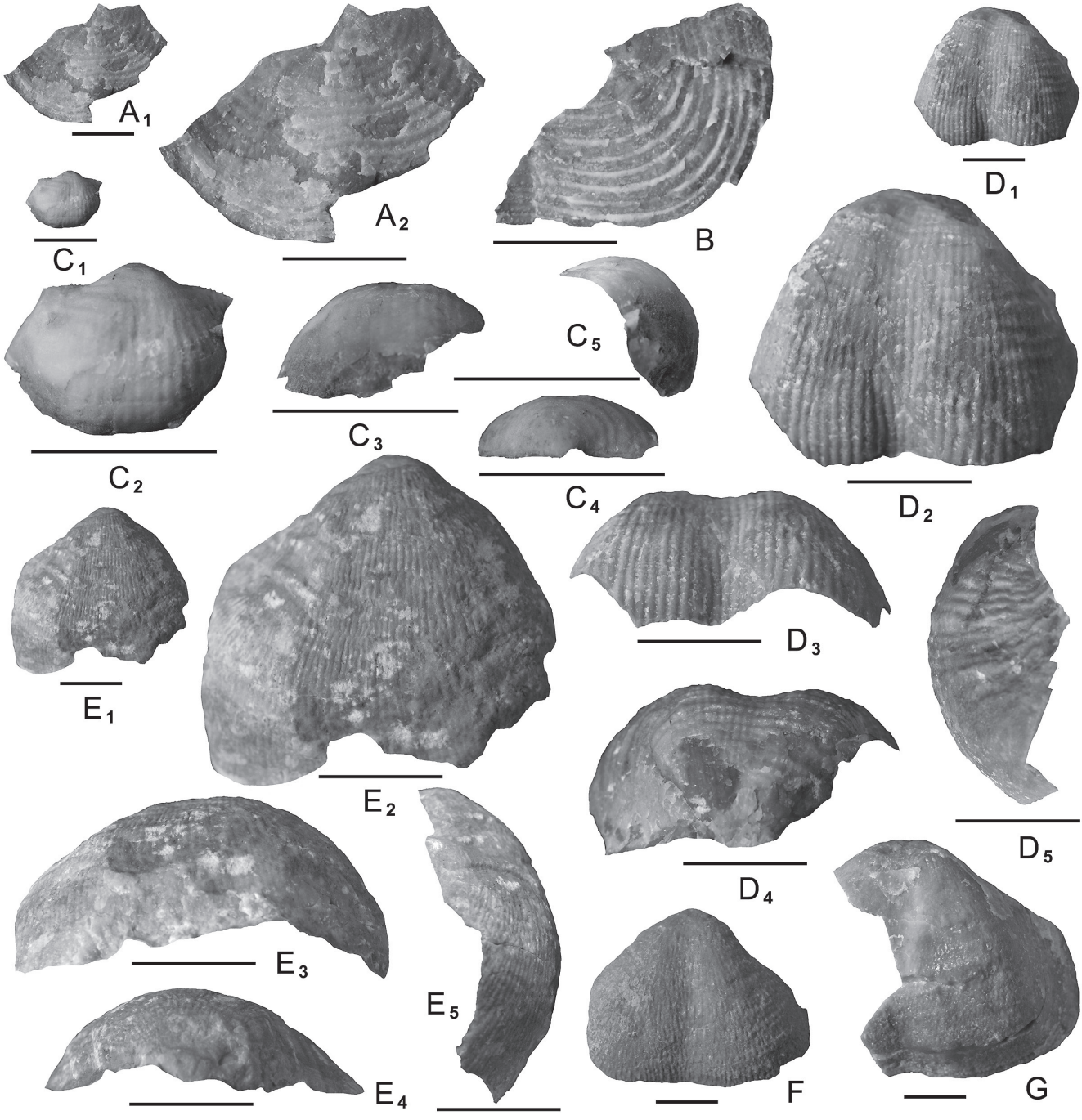

FIGURE 7. **A, B,** *Rugoconcha chaoi* (Grabau); A, dorsal view (A_1, A_2) of dorsal valve, FMM6814; B, dorsal view of external mould of dorsal valve, FMM6815; **C,** *Sandia brevis* Sutherland and Harlow; ventral (C_1, C_2), anterior (C_3), posterior (C_4) and lateral (C_5) views of ventral valve, FMM6829; **D,** *Antiquatonia* sp., ventral (D_1, D_2), anterior (D_3), posterior (D_4) and lateral (D_5) views of ventral valve, FMM6837; **E,** *Zia novamexicana* Sutherland and Harlow, ventral (E_1, E_2), anterior (E_3), posterior (E_4) and lateral (E_5) views of ventral valve, FMM6821: **F, G,** *Echinoconchus punctatus* (Sowerby); F, ventral view of ventral valve, FMM6825: G, ventral view of ventral valve, FMM6826. Scale bars are 1 cm.

Family PRODUCTIDAE Gray, 1840
Subfamily RETARIINAE Muir-Wood and Cooper, 1960
Genus *ANTIQUATONIA* Miloradovich, 1945

Type species.—*Productus antiquatus* Sowerby, 1821.

Antiquatonia sp.
(Fig. 7D)

Material.—A ventral valve, FMM6837.

Remarks.—This specimen is safely assigned to the genus *Antiquatonia* by its small size (length 24 mm, width about 28 mm), subquadrate outline and prominent reticulate ornamentation (5–6 costae in 5 mm at about midlength) on visceral region. The Omi species most resembles *Antiquatonia costellata* Sturgeon and Hoare (1968, p. 48, pl. 11, figs. 22–28), from the lower Desmoinesian strata of Ohio, in its small size and fine costae on ventral valve. The species identification is, however, difficult for the poor material. *Antiquatonia* sp. Yanagida (1965, p. 122, pl. 28, figs. 1, 2, text-fig. 4), from the upper Mississippian limestone of Akiyoshi, southwestern Japan, differs from the Omi species in having finer costae on ventral valve. The type species, *Antiquatonia antiquata* (Sowerby, 1821), redescribed by Muir-Wood (1928, p. 114, pl. 6, fig. 7; pl. 7, figs. 1–4, text-fig. 22) from the D_2 Subzone at Yorkshire and Staffordshire, England, is readily distinguished from the present species in its much larger size.

Family DICTYOCLOSTIDAE Stehli, 1954
Subfamily CALLYTHARRELLINAE Waterhouse, 2002
Genus *ZIA* Sutherland and Harlow, 1973

Type species.—*Zia novamexicana* Sutherland and Harlow, 1973.

Zia novamexicana Sutherland and Harlow, 1973
(Fig. 7E)

Zia novamexicana Sutherland and Harlow, 1973, p. 60, pl. 13, figs. 1–6.

Material.—A ventral valve, FMM6821.

Description.—Shell medium in size, slightly wider subcircular in outline, with maximum width at about midlength; length 28 mm, width about 33 mm. Ventral valve strongly and unevenly convex in lateral profile, with flattened medial region; umbo not well preserved, ears small; sulcus absent; lateral slopes steep. External surface of ventral valve ornamented with numerous fine costellae (9–10 in 5 mm at about midlength), irregular rugae on visceral region (4–5 in 5 mm at about midlength), and comparatively numerous spine bases scattered over valve. Interior of ventral valve not preserved.

Remarks.—This specimen can be referred to *Zia novamexicana* Sutherland and Harlow, 1973, from the lower part of the La Pasada Formation in New Mexico, in its medium size, slightly wider subrcircular outline, strongly convex ventral valve with flattened venter, no sulcus, and external ornament consisting of numerous fine costellae, irregular rugae and comparatively numerous spine bases over the valve. The genus *Zia* consists of only one species, *Zia novamexicana*, from the Morrowan strata in New Mexico.

Distribution.—Lower Bashkirian–Moscovian: central Japan (Omi) and southwestern USA (New Mexico).

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)
(Figs. 7F, G, 8E, 9B)

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; Aksenova in 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 Stojanović-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; Tazawa, 2020, p. 44, fig. 44G, H; Tazawa and Ibaraki, 2023, p. 25, fig. 5C.

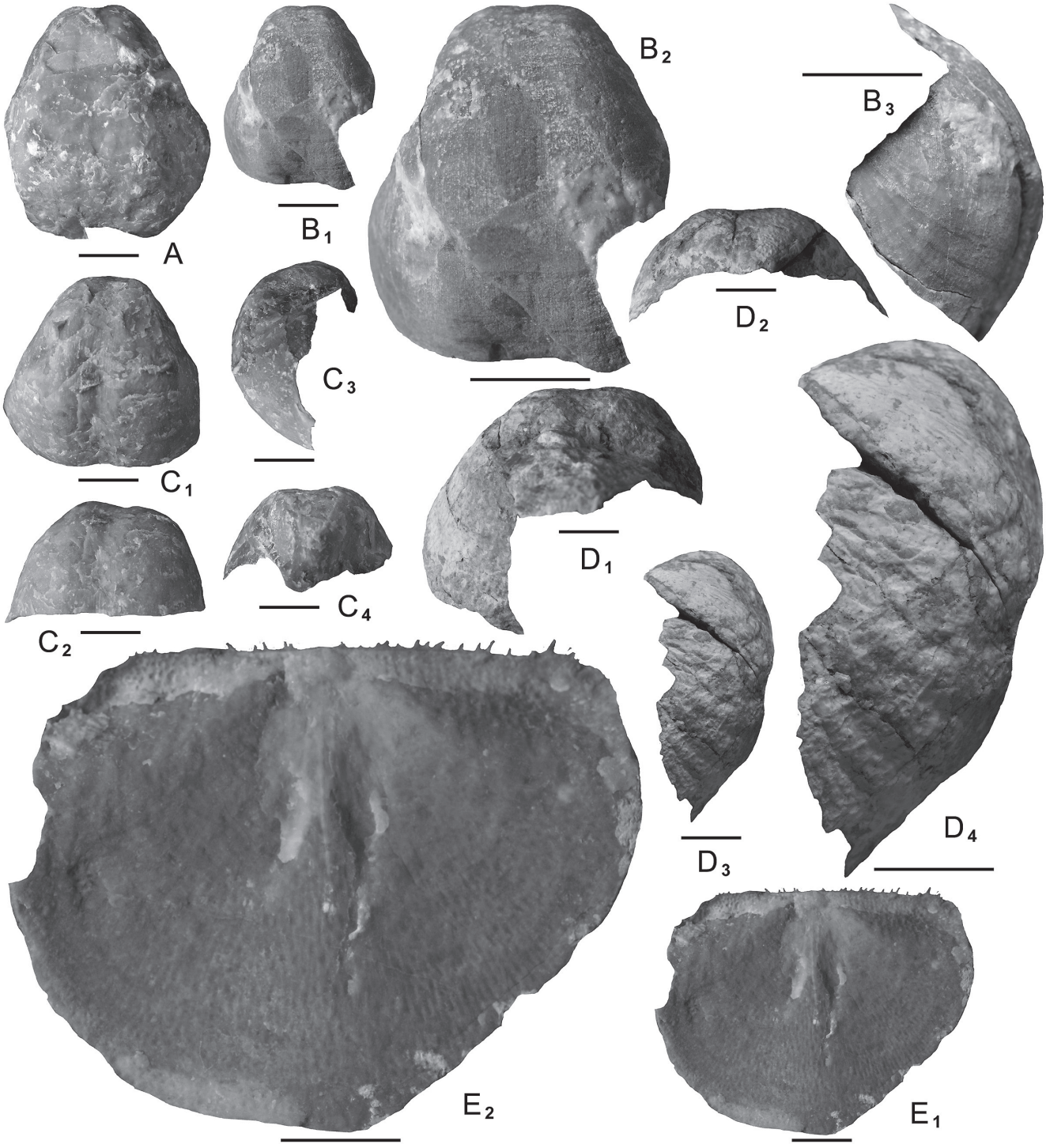

FIGURE 8. **A–C,** *Echinaria* sp.; A, ventral view of ventral valve, FMM6831; B, ventral view (B_1, B_2) of ventral valve, FMM6830; C, ventral (C_1), anterior (C_2), lateral (C_3) and posterior (C_4) views of ventral valve, FMM6833; **D,** *Buntoxia* sp., ventral (D_1), posterior (D_2) and lateral (D_3, D_4) views of ventral valve, FMM6838; **E,** *Echinoconchus punctatus* (Sowerby), dorsal view (E_1, E_2) of abraded dorsal valve, FMM6827. Scale bars are 1 cm.

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.—Five specimens: (1) external mould and cast of a ventral valve, FMM6823: (2) three ventral valves, FMM6824–6826; and (2) a dorsal valve, FMM6827.

Description.—Shell medium in size for genus, transversely subcircular in outline, hinge slightly shorter than greatest width at midlength; length 31 mm, width about 38 mm in the best-preserved ventral valve specimen (FMM6825); length 43 mm, width 53 mm in the sole dorsal valve specimen (FMM6827). Ventral valve moderately and unevenly convex in lateral profile, most convex at umbonal region; umbo rounded, massive and incurved; ears small; sulcus wide and shallow, lateral slopes gently convex and spreading. Dorsal valve slightly concave, nearly flat; fold low and narrow; trail not preserved. External surface of both valves ornamented with regular, strong concentric bands and numerous elongate spine bases; 3–4 bands in 10 mm on ventral valve. Interior of dorsal valve with a long median septum extending to about a half of length of valve and a pair of muscle scars; adductor scars smooth, elongate.

Remarks.—These specimens can be referred to *Echinoconchus punctatus* (Sowerby, 1822), 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 strata of England, in size, outline and external ornament of both ventral and dorsal valves, and internal structure of dorsal valve. *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 beds of the Mississippi Valley, differs from *E. punctatus* in its less transverse outline and in having broader concentric bands on 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 its more elongate outline.

Distribution.—Upper Tournaisian – Asselian: central Japan (Omi), southwestern Japan (Miharanoro), northeastern Japan (South Kitakami Belt), northern Russia (Verkhoyansk Range, Taimyr Peninsula and northern Urals), UK (Scotland, England and Wales), Ireland, Algeria, Spain, Serbia, Belgium, Germany, western Russia (Donetz and Moscow basins), central Russia (southern Urals and Kuznetsk Basin), Kazakhstan, Uzbekistan (Fergana), Kyrgyzstan, northwestern China (Xinjiang, Qinghai and Gansu), northern China (Shanxi), northeastern China (Liaoning) and Tibet.

Genus *ECHINARIA* Muir-Wood and Cooper, 1960

Type species.—*Productus semipunctatus* Shepard, 1838.

Echinaria sp.
(Fig. 8A–C)

Material.—Seven specimens, abraded seven ventral valves, FMM6830–6836.

Remarks.—These specimens can be assigned to the genus *Echinaria* by the medium-sized, elongate oval-shaped shell (length 40 mm, width 34 mm in the largest ventral valve specimen (FMM6831) and external ornament of ventral valve consisting of regular bands bearing numerous fine spines. The Omi species resembles *Echinaria moorei* (Dunbar and Condra, 1932, p. 209, pl. 24, figs. 1–5), from the Missourian beds of Nebraska and Kansas, in size and outline of ventral valve. However, the poorly preserved specimens cannot allow specific assignment. The type species, *Echinaria semipunctata* (Shepard, 1838), refigured by Muir-Wood and Cooper, (1960, pl. 85, figs. 1–5; pl. 86, figs. 1–9, except 5) from the Pennsylvanian of Indiana, Illinois, Kansas and Texas, differs from the Omi species in its much larger size.

Genus *KARAVANKINA* Ramovš, 1969

Type species.—*Karavankina typica* Ramovš, 1969

Karavankina fasciata (Kutorga, 1844)
(Fig. 9A)

Productus fasciatus Kutorga, 1844, p. 100, pl. 10, fig. 4; Tschernyschew, 1914, p. 31, 63, pl. 8, figs. 7, 8; Keidel, 1906, p. 368, pl. 12, fig. 3.
Echinoconchus fasciatus (Kutorga). Ivanov, 1935, p. 102, pl. 2, figs. 8–10; Wang and Yang, 1998, p. 78, pl. 5, figs. 1–8, 12, 13.
Echinoconchus (*Karavankina*) *fasciatus* (Kutorga). Sarytcheva in Sarytcheva, 1968, p. 95, pl. 7, figs. 1–8, text-figs. 36–38; Kalashnikov, 1980, p. 34, pl. 7, fig. 5.

Material.—One specimen, a ventral valve, FMM6822.

Remarks.—This specimen can be referred to *Karavankina fasciata* (Kutorga, 1844), redescribed by Sarytcheva (in Sarytcheva, 1968, p. 95, pl. 7, figs. 1–8, text-figs. 36–38) from the upper Moscovian–lower Kasimovian strata in eastern Kazakhstan, by its small, slightly elongate and strongly convex ventral valve (length 17 mm, width 15 mm), with shallow sulcus, and external ornament consisting of strong concentric bands with wide spine-free regions and numerous fine spine bases. *Karavankina* sp., described by Tazawa and Hasegawa (1994, p. 494, fig. 3) from the Arakigawa Formation at Moribu, Hida Gaien Belt, central Japan, differs from the present species in its wider and larger shell. The type species, *Karavankina typica* Ramovš (1969, p 254, 262, pl. 1, figs. 1–4), from the Trogkofel Limestone of the Carnic Alps, Slovenia, differs from the Omi

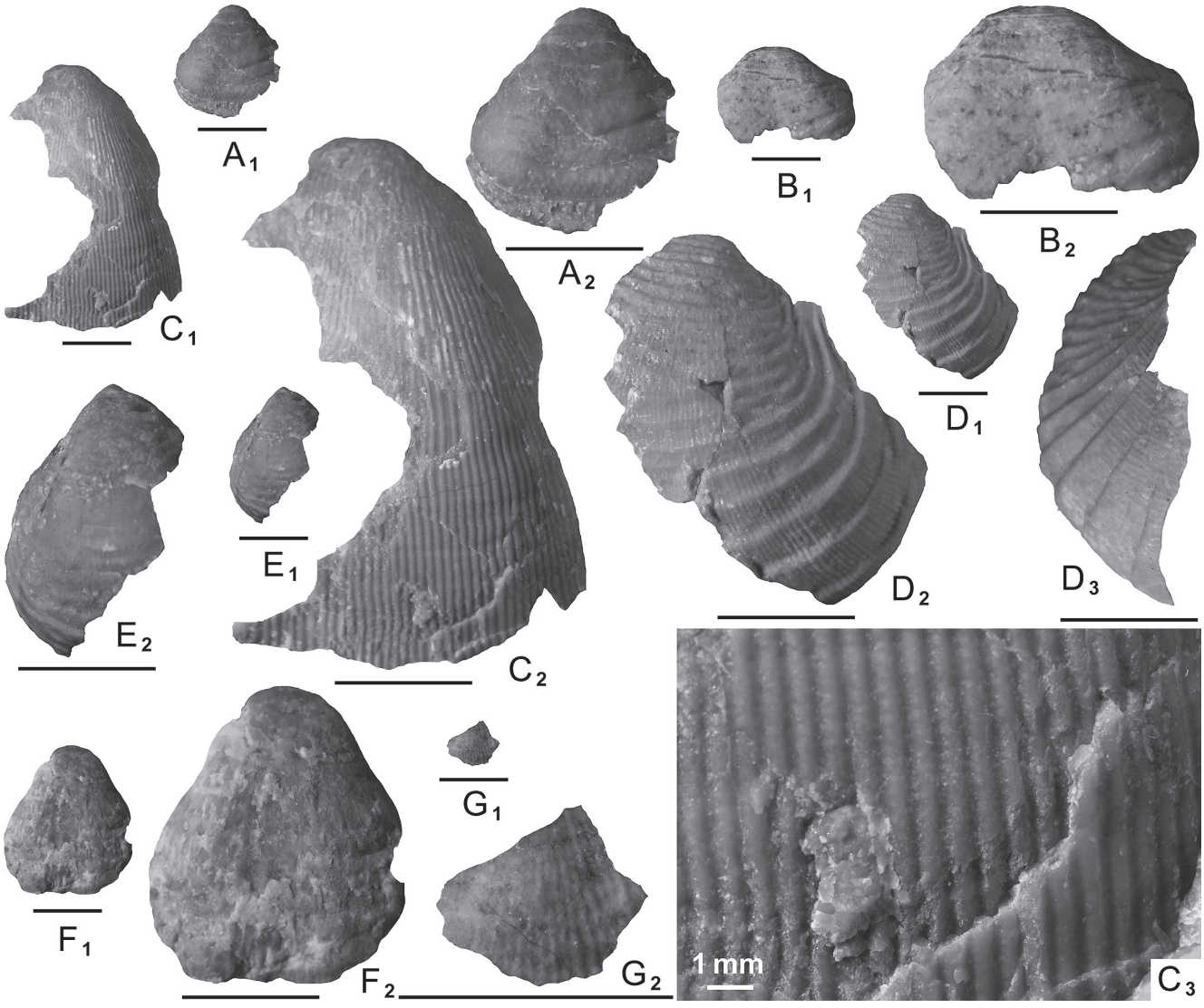

FIGURE 9. **A,** *Karavankina fasciata* (Kutorga), ventral view (A_1, A_2) of ventral valve, FMM6822; **B,** *Echinoconchus punctatus* (Sowerby), ventral view (B_1, B_2) of external cast of ventral valve, FMM6823; **C,** *Balakhonia* sp., ventral view (C_1, C_2) and enlarged external ornament, showing fine concentric growth lines interrupting costellae (C_3) of ventral valve, FMM6828; **D, E,** *Fluctuaria neoundata* Mironova; D, ventral (D_1, D_2) and lateral (D_3) views of ventral valve, FMM6816; E, ventral view (E_1, E_2) of ventral valve, FMM6818; **F, G,** *Costatumulus* sp.; F, ventral view (F_1, F_2) of ventral valve, FMM6819; G, ventral view (G_1, G_2) of ventral valve fragment, FMM6820. Scale bars are 1 cm.

species in its wider outline.

Distribution.—Moscovian–Sakmarian: central Japan (Omi), northern Russia (Verkhoyansk Range), western Russia (Moscow Basin), Kazakhsan, Uzbekistan (Fergana), Kyrgyzstan (southern Tian Shan) and northwestern China (Xinjiang).

Subfamily JURESANIINAE Muir-Wood and Cooper, 1960
Genus *BUNTOXIA* Lazarev, 1986

Type species.—*Buxtonia scabricula* var. *mosquensis* Ivanov, 1935.

Buntoxia sp.
(Fig. 8D)

Material.—One specimen, a ventral valve, FMM6838.

Remarks.—This specimen is severely broken. However, it can be assigned to the genus *Buntoxia* by the large, elongate and strongly convex ventral valve (length about 50 mm, width about 45 mm), ornamented with concentric bands and numerous spine-bases on bands; bands developed anteriorly but lacking in posterior region of the valve. The Omi species most resembles the type species, *Buntoxia mosquensis* (Ivanov, 1935), refigured by Sarytcheva in Sarytcheva and Sokolskaya (1952, p. 101, pl. 16, fig. 115) from the Serpukovian–Kasimovian strata in the Moscow Basin. But accurate comparison is difficult owing to ill preservation of the present material.

Superfamily LINOPRODUCTOIDEA Stehli, 1954
Family LINOPRODUCTIDAE Stehli, 1954
Subfamily LINOPRODUCTINAE Stehli, 1954
Genus *BALAKHONIA* Sarytcheva in Sarytcheva et al., 1963

Type species.—*Balakhonia ostrogensis* Sarytcheva in Sarytcheva et al., 1963.

Balakhonia sp.
(Fig. 9C)

Material.—One specimen, a ventral valve, FMM6828.

Remarks.—This specimen can be assigned to the genus *Balakhonia* on the basis of external ornament of the ventral valve consisting of numerous costellae, some irregular rugae and very fine concentric growth lines interrupting costellae. The Omi species most resembles *Balakhonia ostrogensis* Sarytcheva (in Sarytcheva et al., 1963, p. 233, pl. 38, figs. 1–3, text-figs. 103, 104), from the Serpukhovian strata of the Kuznetsk Basin, central Russia, in its medium size and elongate outline (length about 40 mm, width about 37 mm). *Balakhonia* sp. Tazawa (1980, p. 364, pl. 41, fig. 7), from the uppermost Karaumedate Formation (upper Visean) at Nagasaka, South Kitakami Belt, northeastern Japan, differs from the present species in its much smaller size and transverse outline.

Genus *FLUCTUARIA* Muir-Wood and Cooper, 1960

Type species.—*Productus undatus* Defrance, 1826.

Fluctuaria neoundata Mironova, 1967
(Fig. 9D, E)

Fluctuaria neoundata Mironova, 1967, p. 21, pl. 2, figs, 7, 8; Alexandrov and Einor, 1979, p. 63, pl. 24, fig. 4; Kalashnikov, 1980, p. 49, pl. 7, figs. 1, 2; Abramov and Grigorjeva, 1983, p. 89, pl. 9, figs. 1–4.
Fluctuaria cf. *undata* (Defrance). Carter and Poletaev, 1998, p. 136, figs. 7.19–7.22.

Material.—Three ventral valves, FMM6816–6818.

Description.—Shell medium in size for genus, transversely subovate in outline; with greatest width slightly anterior to midlength; length about 29 mm, width about 32 mm in the largest specimen (FMM6816). Ventral valve strongly and almost evenly convex in lateral profile; ears small; sulcus absent. External surface of ventral valve ornamented with strong, somewhat undulate rugae and numerous fine capillae, which counted 11–12 in 5 mm at about midlength of valve; spines not observed.

Remarks.—The specimens from Omi can be referred to *Fluctuaria neoundata* Mironova (1967, p. 21, pl. 2, figs. 7, 8) from the Bashkirian beds in Bashkir, southern Urals, by the medium size, transversely subovate outline and external ornament consisting of strong, somewhat undulate rugae and numerous fine capillae over the ventral valve. *Fluctuaria undata* (Defrance, 1826), refigured by Muir-Wood and Cooper (1960, pl. 115, figs. 11–20) from the Visean beds in Belgium and Isle of Man, differs from *F. neoundata* in its elongate outline. *Fluctuaria* cf. *undata* (Defrance), described by Carter and Poletaev (1998, p. 13, fig. 7.19–7.22), from the Hare Fiord Formation (upper Bashkirian or lower Moscovian) of Ellesmere Island, Canadian Arctic Archipelago, may be conspecific with *F. neoundata*.

Distribution.—Bashkirian–Asselian: central Japan (Omi), Arctic Canada (Ellesmere Island), northern Russia (Verkhoyansk Range and northern Urals) and central Russia (southern Urals).

Family KANSUELLIDAE Muir-Wood and Cooper, 1960
Subfamily AURICULISPININAE Waterhouse in Waterhouse and Briggs, 1986
Genus *COSTATUMULUS* Waterhouse, 1983

Type species.—*Auriculispina tumida* Waterhouse in Waterhouse, Briggs and Parfrey, 1983.

Costatumulus sp.
(Fig. 9F, G)

Material.—Two specimens: (1) a ventral valve, FMM6819; and (2) a fragment of ventral valve, FMM6820.

Remarks.—These specimens can be assigned to the genus *Costatumulus* by the small-sized ventral valve (length 21 mm, width about 20 mm in the better-preserved specimen, FMM6819) and external ornament consisting of narrow rugae, fine costellae and quincunxially arranged spines over the ventral valve. The Omi species somewhat resembles *Costatumulus polliciformis* (Waterhouse, 1978, p. 76, pl. 11, figs. 9–12), from the lower Changhsingian beds in northwestern Nepal, in its elongate outline, but accurate comparison is difficult owing to ill preservation of the present material.

Order SPIRIFERIDA Waagen, 1883
Suborder SPIRIFERIDINA Waagen, 1883
Superfamily SPIRIFEROIDEA King, 1846
Family SPIRIFERIDAE King, 1846
Subfamily SERGOSPIRIFERINAE Carter in Carter et al. 1994
Genus *ANTHRACOSPIRIFER* Lane, 1963

Type species.—*Anthracospirifer birdspringensis* Lane, 1963.

Anthracospirifer newberryi Sutherand and Harlow, 1973
(Fig. 13A)

Anthracospirifer newberryi Sutherland and Harlow, 1973, p. 78, pl. 16, figs. 1–4.

Material.—One specimen, a dorsal valve, FMM6852.

Remarks.—The single dorsal valve specimen can be referred to *Anthracospirifer newberryi* Sutherland and Harlow, 1973,

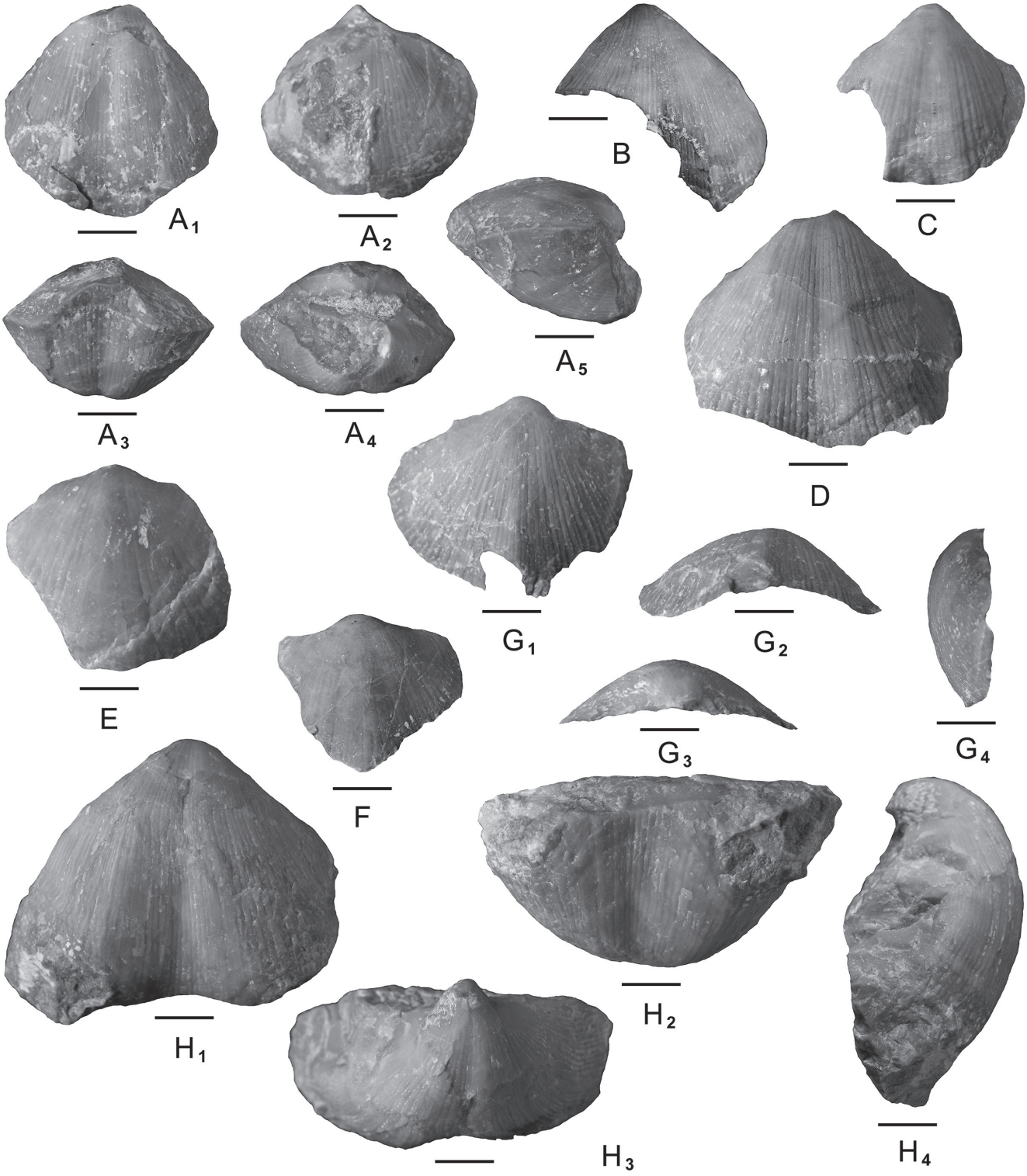

FIGURE 10. *Choristites supramosquensis* (Nikitin), **A,** ventral (A_1), dorsal (A_2), anterior (A_3), posterior (A_4) and lateral (A_5) views of conjoined shell, FMM6749; **B,** ventral valve, FMM6758; **C,** ventral valve, FMM6754; **D,** ventral valve, FMM6756; **E,** dorsal valve, FMM6760; **F,** dorsal valve, FMM6761; **G,** dorsal (G_1), anterior (G_2), posterior (G_3) and lateral (G_4) views of dorsal valve, FMM6762; **H,** ventral (H_1), anterior (H_2), posterior (H_3) and lateral (H_4) views of ventral valve, FMM6755. Scale bars are 1 cm.

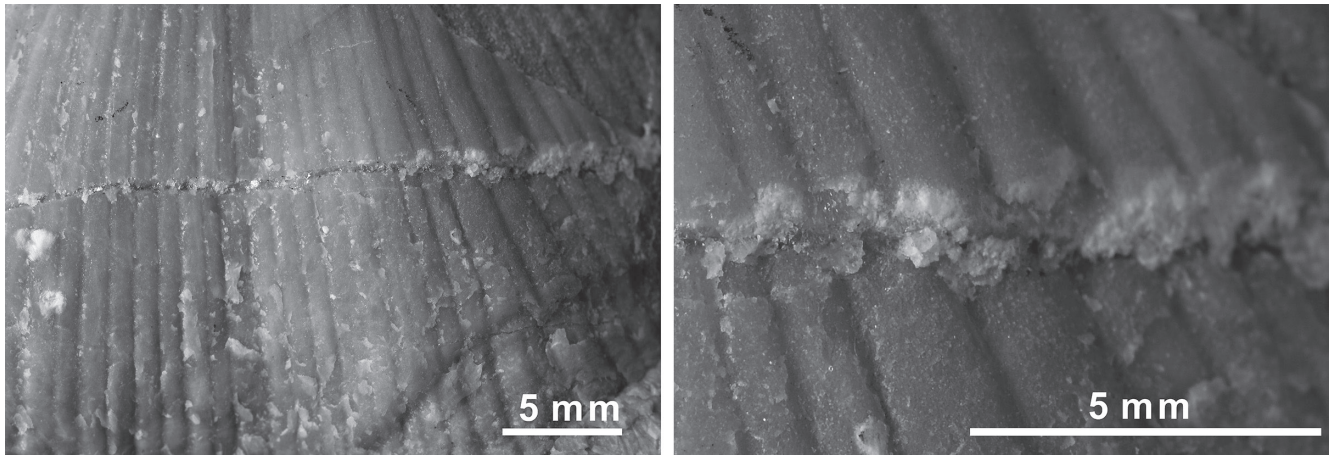

FIGURE 11. Enlarged external ornament of a ventral valve (FMM6756), *Choristites supramosquensis* (Nikitin) from Omi. showing flattened costae with narrow interspaces.

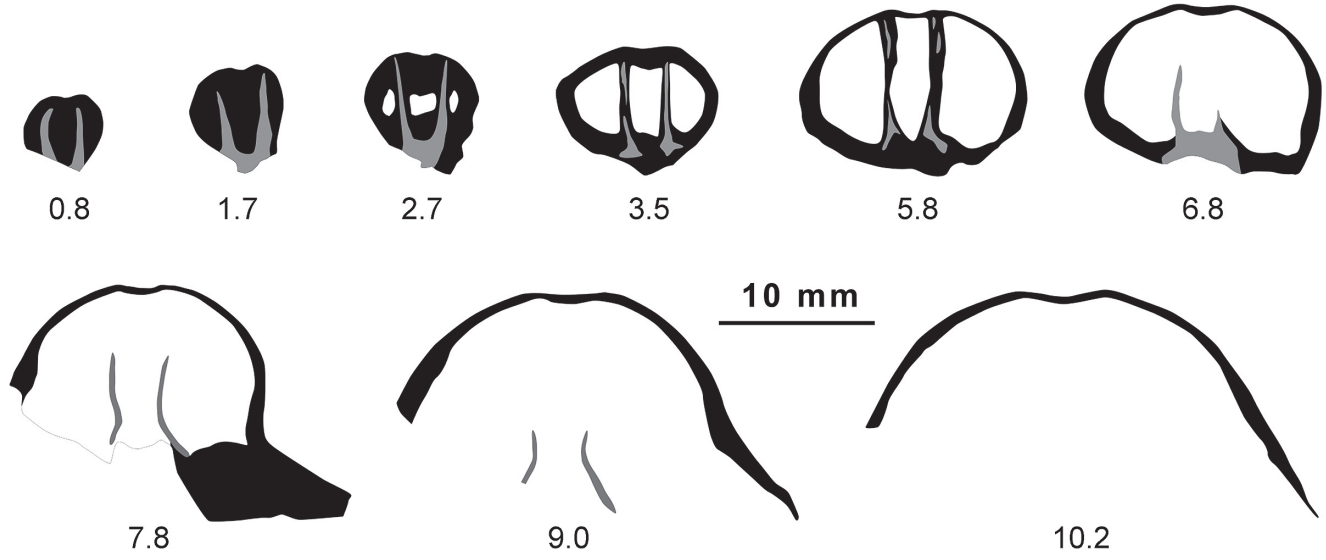

FIGURE 12. Transverse serial sections of a ventral valve (FMM6758), *Choristites supramosquensis* (Nikitin) from Omi. Numbers at bottom of each section indicate distance (mm) from ventral beak.

from the Morrowan and the lower Atokan strata in the southern Sangre de Cristo Mountains, New Mexico, by its medium size (length 18 mm, width 31 mm in the sole dorsal valve specimen, FMM6852), transverse but not mucronate in outline and external ornament consisting of low and rounded costae (7 on fold, and more than 11 on each lateral slope; 4 in 5 mm at middle of lateral slope) and numerous fine concentric lamellae. *Anthracospirifer curvilateralis* Easton, 1962, described by Easton (1962, p. 68, pl. 9, figs. 14–19) as *Spirifer curvilateralis* Easton, 1962, from the Mississippian or Pennsylvanian beds of central Montana, differs from the Omi specimen in its less transverse outline. The type species, *Anthracospirifer birdspringensis* Lane, 1963, from the lower Bird Spring Formation (Morrowan) of Clark County, southern Nevada, differs from the Omi specimen in its smaller size, less transverse outline, and in having rounded cardinal extremities.

Distribution.—Bashkirian–lower Moscovian: central Japan (Omi) and southwestern USA (New Mexico).

Family CHORISTITIDAE Waterhouse, 1968
Subfamily CHORISTITINAE Waterhouse, 1968
Genus *CHORISTITES* Fischer de Waldheim, 1825

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

Choristites supramosquensis (Nikitin, 1890)
(Figs. 10–12)

Spirifer supramosquensis Nikitin, 1890, p. 66, pl. 3, figs. 1–3; Hayasaka, 1922, p. 126, pl. 6, fig. 14.
Spirifer duplicicostus Phillips. Hayasaka, 1924, p. 44, pl. 6, figs. 7–9.

Choristites supramosquensis (Nikitin). Ivanov and Ivanova, 1937, p. 143, 194, pl. 14, figs. 1, 2; pl. 22, figs. 3–5, text-figs. 43, 44. Sokolskaya in Sarytcheva and Sokolskaya, 1952, p. 207, pl. 62, fig. 346; Zeng, 1990, p. 225, pl. 6, fig. 7.

Choristites supramosquensis var. *magna* Ivanov and Ivanova, 1937, p. 148, 195, pl. 14, fig. 3; pl, 23, fig. 1, text-fig. 45; Sokolskaya in Sarytcheva and Sokolskaya, 1952, p. 208, pl. 62, fig. 347.

Spirifer (*Choristites*) *supramosquensis* Nikitin. Likharew, 1939, p. 105, pl. 25, figs. 6, 7.

Material.—Fourteen specimens: (1) one conjoined shell, FMM6749; (2) ten ventral valves, FMM6750–6759 and (3) three dorsal valves, FMM6760–6762.

Description.—Shell medium in size for genus, slightly transverse, nearly equidimensional suboval in outline, with rounded cardinal extremities; hinge slightly shorter than greatest width at midlength; length 47 mm, width 54 mm in the largest specimen (FMM6755); length 32 mm, width 33 mm in a small specimen (FMM6754). Ventral valve moderately and unevenly convex in lateral profile, most convex in umbonal region; sulcus narrow and shallow in posterior half, but wide and moderately deep anteriorly. Dorsal valve gently convex in lateral profile; fold low and not clearly defined. External surface of both valves ornamented with numerous costae over the valves; costae thick and flattened, with narrow interspaces, often bifurcated or trifurcated, numbering 7–9 costae per 10 mm on midlength of ventral lateral flanks; 8–9 costae in 10 mm on midlength of dorsal lateral flanks. Ventral valve interior with a pair of long and parallel dental plates.

Remarks.— These specimens can be referred to *Choristites supramosquensis* (Nikitin, 1890), originally described by Nikitin (1890, p. 66, pl. 3, figs. 1–3) from the Upper Carboniferous in the Moscow Basin, by the medium size and suboval outline with rounded cardinal extremities, and in having external ornament of both valves consisting of numerous thick, flattened, often bifurcated or trifurcated costae, and a pair of long and parallel dental plates in the ventral valve. The specimens, described by Hayasaka (1924) as *Spirifer duplicicostus* Phillips from Omi, can be identified with *Choristites supramosquensis* in size, outline and external ornament of both ventral and dorsal valves. *Choristites supramosquensis* var. *magna* Ivanov and Ivanova (1937, p. 148, 195, pl. 14, fig. 3; pl. 23, fig. 1, text-fig. 45), from the Gzhelian of the Moscow Basin, is regarded to be conspecific with *C. supramosquensis*. *Choristites* sp., described by Tazawa and Ibaraki (2023, p. 36, fig. 10A–C) from the Asselian limestone of Miharanoro in the Taishaku area, southwestern Japan, differs from *C. supramosquensis* in its much larger size and widely transverse outline. The type species, *Choristites mosquensis* Fischer de Waldheim, 1825, redescribed by Ivanov and Ivanova (1937, p. 93, 191, pl. 6, figs. 1–4; pl. 20, figs. 2–4), from the upper Moscovian in the Moscow Basin, is most similar to *C. supramosquensis* in size and outline of the shell and in having rounded cardinal extremities, but differs in having finer costae on the both ventral and dorsal valves.

Distribution.—Moscovian–Asselian: central Japan (Omi), northern Russia (Timan), western Russia (Donetz Basin and Moscow Basin), northern China (Inner Mongolia) and northeastern China (Liaoning).

Family TRIGONOTRETIDAE Schuchert, 1893
Subfamily NEOSPIRIFERINAE Waterhouse, 1968
Genus *NEOSPIFER* Fredericks, 1924

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

Neospirifer cameratus (Morton, 1836)
(Fig. 13B, C)

Spirifer cameratus Morton, 1836, p. 150, pl. 2, fig. 3; Kozlowski, 1914, p. 70, pl. 5, figs. 6–11; Girty, 1915, p. 87, pl. 11, fig. 4; Kelly, 1930, p. 147, pl. 11, fig. 17.

Spirifer (*Neospirifer*) *cameratus* (Morton), Dresser, 1954, p. 119, pl. 5, fig. 11; pl. 7, figs. 7–11.

Neospirifer cameratus (Morton). Dunbar and Condra, 1932, p. 334, pl. 39, figs. 4, 6–9; Chronic, 1953, p. 59, pl. 7, figs. 1–3; Sutherland and Harlow, 1973, p. 72, pl. 15, figs. 5–8; Chen et al., 2004, p. 461, fig. 9A, D.

Material.—Two specimens, two dorsal valves, FMM6853, 6854.

Remarks.—The dorsal valve specimens from Omi can be referred to *Neospirifer cameratus* (Morton, 1836), originally described from the Desmoinesian strata of Ohio, in the middle size, transverse outline (length 18 mm, width 35 mm in the wider specimen, FMM6854; length 20 mm, width 30 mm in the less transverse specimen, FMM6853), and in having numerous fine (5–6 in 5 mm at middle of lateral slope), weakly fasciculate costae on lateral slope of the dorsal valve. *Neospirifer goreii* (Mather, 1915), redescribed by Spencer (1967, p. 32, figs. 7.2, 22) from the Cherokee Group (upper Desmoinesian) of Kansas, differs from *N. cameratus* in having numerous and finer costae on lateral slopes of both valves. *Neospirifer fasciger* (Keyserling, 1846), redescribed by Tschernyschew (1902, p. 141, 532, pl. 38, figs. 3, 4; pl. 49, fig. 1) from the Lower Permian (*Schwagerina* Horizon) of Timan, northern Russia, differs from *N. cameratus* in its less transverse outline and in having strongly fasciculate bundled costae on the both valves.

Distribution.—Bashkirian–Moscovian; central Japan (Omi), Peru, Bolivia, Brazil, southwestern USA (New Mexico), mid USA (Oklahoma and Nebraska) and northeastern USA (Ohio and Michigan).

Neospirifer latus Dunbar and Condra, 1932
(Fig. 13D–G)

Neospirifer latus Dunbar and Condra, 1932, p. 336, pl. 40, figs. 1–5.

Neospirifer latus latus Dunbar and Condra. Spencer, 1967, p. 26, figs. 18, 19.

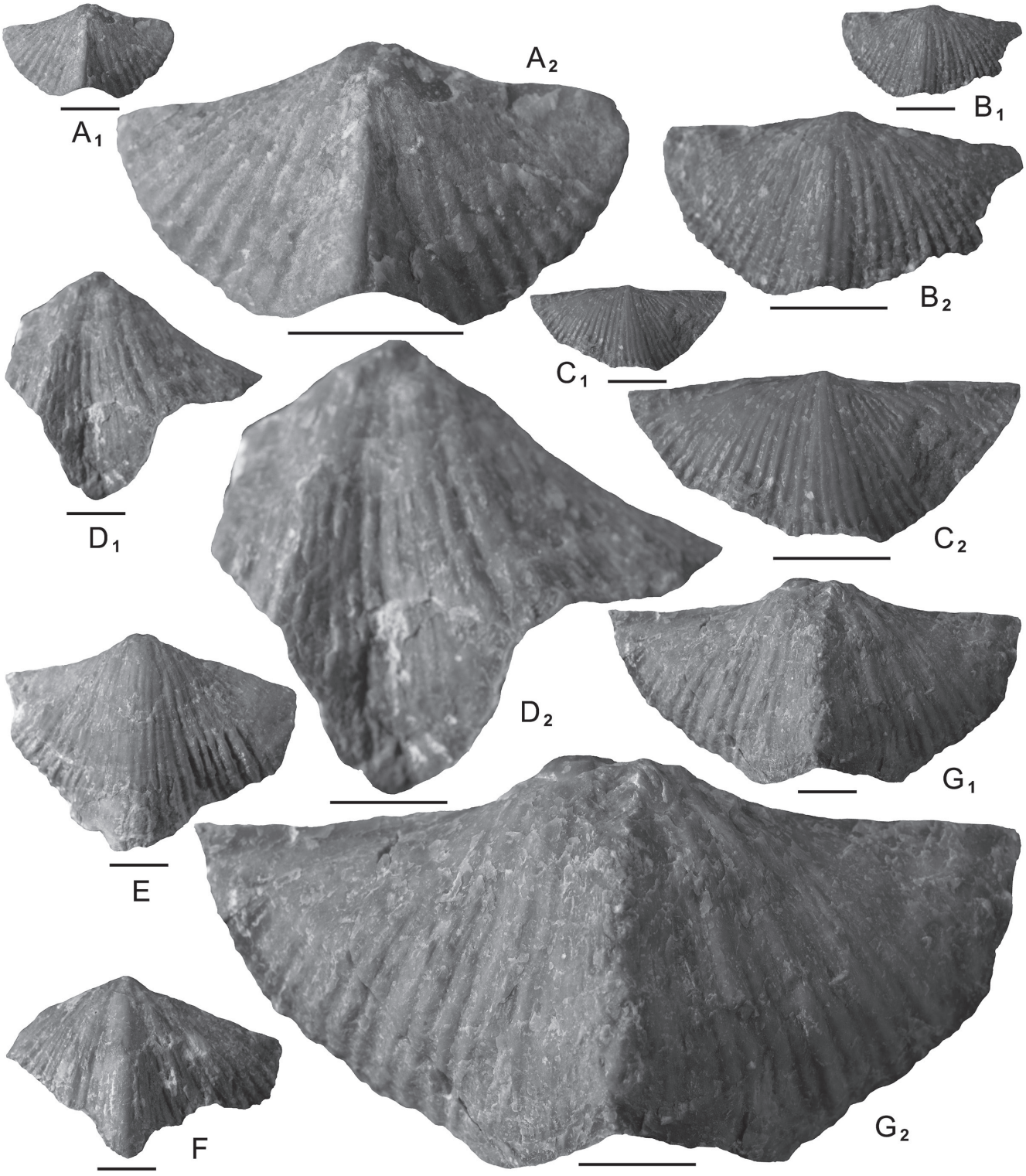

FIGURE 13. **A,** *Anthracospirifer newberryi* Sutherland and Harlow, dorsal view (A_1, A_2) of dorsal valve, FMM6852; **B, C,** *Neospirifer cameratus* (Morton); B, dorsal view (B_1, B_2) of dorsal valve, FMM6853; C, dorsal view (C_1, C_2) of dorsal valve, FMM6854; **D–G,** *Neospirifer latus* Dunbar and Condra; D, ventral view (D_1, D_2) of ventral valve, FMM6847; E, dorsal view of dorsal valve, FMM6850: F, dorsal view of dorsal valve, FMM6849; G, dorsal view (G_1, G_2) of dorsal valve, FMM6848. Scale bars are 1 cm.

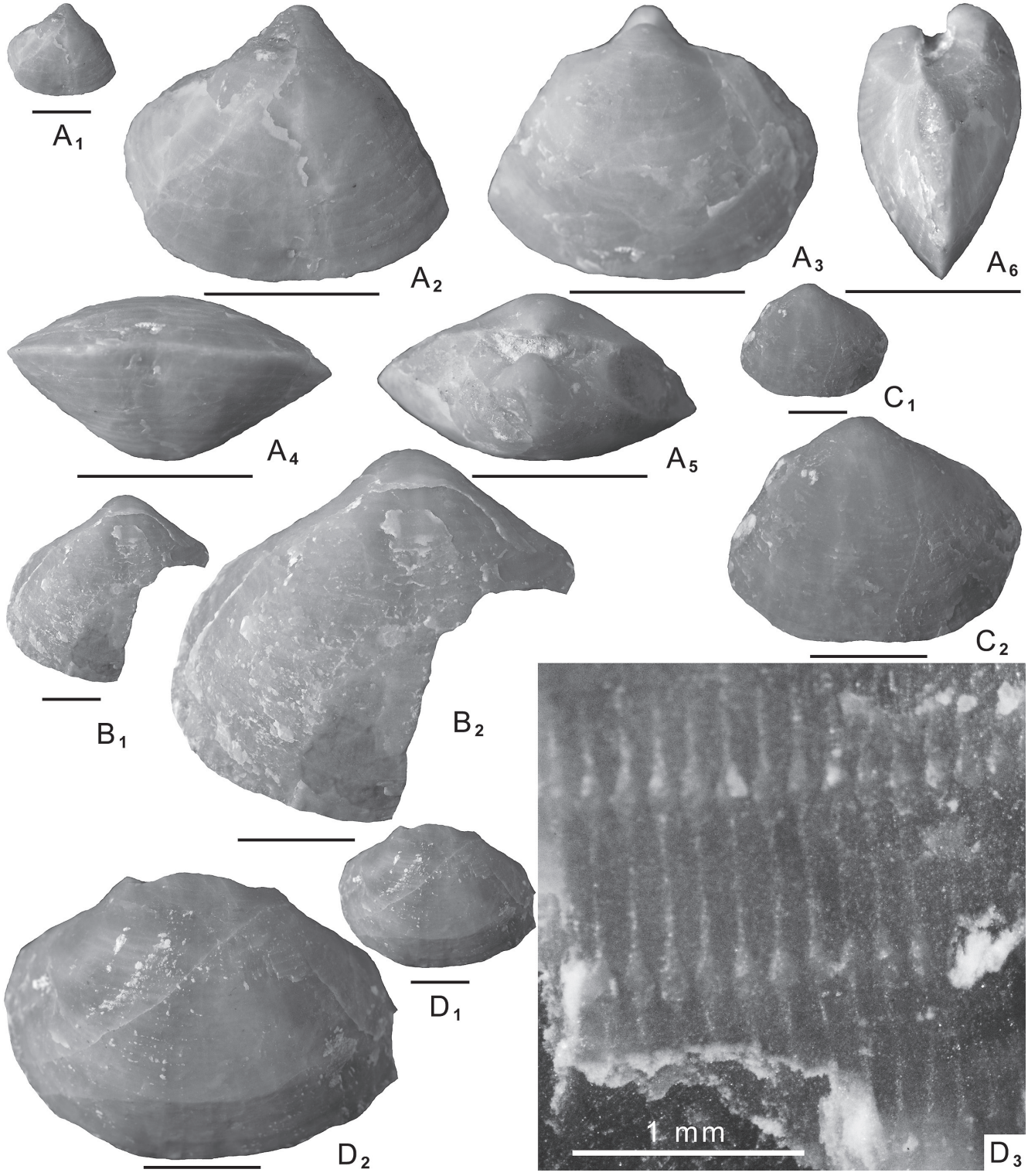

FIGURE 14. *Phricodothyris asiatica* (Chao), **A,** ventral (A_1, A_2), dorsal (A_3), anterior (A_4), posterior (A_5) and lateral (A_6) views of conjoined shell, FMM6857; **B,** ventral view (B_1, B_2) of ventral valve, FMM6859; **C,** dorsal view (C_1, C_2) of dorsal valve, FMM6860; **D,** ventral view (D_1, D_2) and enlarged external ornament of ventral valve (D_3). Scale bars are 1 cm, except for D_3.

Neospirifer alatus Dunbar and Condra. Sutherland and Harlow, 1973, p. 75, pl. 17, figs. 1–5.

Material.—Five specimens: (1) a ventral valve, FMM6847, and (2) four dorsal valves, FMM6848–6851.

Description.—Shell large in size for genus, transversely subtriangular in outline, with blunt, acute cardinal extremities; hinge nearly equal to greatest width; length 44 mm, width 75 mm in the largest dorsal valve specimen (FMM6848). Ventral valve moderately convex in lateral profile; sulcus broad and moderately deep. Dorsal valve slightly and unevenly convex in lateral profile, most convex in umbonal region; fold broad and low. External surface of both valves ornamented with numerous coarse, fasciculate costae on lateral slopes of both valves, numbering 4–5 in 10 mm at middle of dorsal valve.

Remarks.—These specimens can be referred to *Neospirifer latus* Dunbar and Condra, 1932, from the Missourian strata of Nebraska and Missouri, in their large size, very transverse outline, and coarse bundling costae. The neospiriferid species, described by Sutherland and Harlow (1973, p. 75, pl. 17, figs. 1–5) as *Neospirifer alatus* Dunbar and Condra, 1932 from the Missourian beds of New Mexico, seems to be conspecific with the present species. *Neospirifer latus lateralis* Spencer (1967, p. 28, fig. 7.4) from the Missourian beds of Kansas differs from *N. latus* in its acute cardinal extremities. *Neospirifer moosakhailensis* (Davidson, 1862), redescribed by Waagen (1883, p. 512, pl. 45, figs. 1–6) as *Spirifer musakheylensis* Davidson, 1862 from the Amb, Wargal and Chhidru Formations of the Salt Range, Pakistan, is also large and transverse *Neospirifer* species, but it differs from *N. latus* in having coarser costae on the both ventral and dorsal valves. The preceding species, *Neospirifer cameratus* (Morton, 1836) is clearly distinguished from the present species in its smaller size and weakly fasciculate costae on the dorsal valve.

Distribution.—Moscovian–Gzhelian: central Japan (Omi), southwestern USA (New Mexico) and mid USA (Kansas, Nebraska and Missouri).

Suborder DELTHYRIDINA Ivanova, 1972
Superfamily RETICULARIOIDEA Waagen, 1883
Family ELYTHIDAE Fredericks, 1924
Subfamily PHRICODOTHYRIDINAE Caster, 1939
Genus *PHRICODOTHYRIS* George, 1932

Type species.—*Phricodothyris lucerna* George, 1932.

Phricodothyris asiatica (Chao, 1929)
(Fig. 14A–D)

Reticularia lineata Martin. Tschernyschew, 1902, p. 193, 574, pl. 20, figs. 9–13.
Squamularia asiatica Chao, 1929, p. 91, pl. 11, figs. 12–14.
Phricodothyris asiatica (Chao). Ustritsky, 1963, p. 32, pl. 10, fig. 3; Yanagida, 1967, p. 75, pl. 14, figs. 1, 2, 5, 7, text-fig. 11; Zavodovsky and Stepanov, 1970, p. 172, pl. 39, figs. 6–8; Ifanova, 1972, p. 141, pl. 13, figs. 5–10; Yang et al., 1977, p. 450, pl. 179, fig. 5; Liang, 1990, p. 285, pl. 62, figs. 1–10; pl. 63, figs. 6–11; pl. 65, fig. 18, text-fig. 38; Zeng, 1990, p. 227, pl. 7, fig. 11; Carter and Poletaev, 1998, p. 172, figs. 27.19–27.32; Wang and Yang, 1998, p. 127, pl. 23, figs. 5, 6, 9; Shi and Shen, 2001, p. 254, pl. 2, figs. 10, 14–17.

Material.—Four specimens: (1) one conjoined shell, FMM6857; (2) two ventral valves, FMM6858, 6859; and (3) one dorsal valve, FMM6860.

Description.—Shell medium in size for genus, subcircular to suboval, slightly transverse in outline, ventribiconvex; cardinal extremities rounded; hinge much shorter than maximum width at midlength; both dorsal fold and ventral sulcus absent; length 36 mm, width about 40 mm in the largest specimen (FMM6859); length 16 mm, width 19 mm in the smallest specimen (FMM6857). External surface of both valves ornamented with regular concentric lamellae, with numerous closely set, slender, longitudinal double-barrelled spinules; 5–6 lamellae in 5 mm on ventral valve, and 7 lamellae in 5 mm on dorsal valve; and 6 spinules in 1 mm.

Remarks.—These specimens can be referred to *Phricodothyris asiatica* (Chao, 1929), originally described by Chao (1929, p. 91) as *Squamularia asiatica* Chao, 1929, from the lower Permian of Guizhou, southwestern China in size and outline of shell and external ornaments of both valves consisting of regular concentric lamellae with numerous, closely set, longitudinal double-barrelled spinules. *Phricodothyris echinata* (Chao, 1929, p. 86, pl. 8, figs. 17–19), from the Penchi and Taiyuan Series of Shanxi and Gansu, northern China, differs from *P. asiatica* in its slightly longer outline and in having larger and less-tightly arranged spinules. *Phricodothyris perplex* (McChesney, 1860), redescribed by Dunbar and Condra (1932, p. 313, pl. 42, figs. 5–8) from the Pennsylvanian of Nebraska, differs from *P. asiatica* in having two-type pustules, larger one and smaller one. The type species, *Phricodothyris lucerna* George (1932, p. 546, pl. 35, fig. 2), from the upper Visean of Lowick, Northumberland, England, differs from the present species in having finer concentric lamellae (numbering 16 in a length of 10 mm).

Distribution.—Bashkirian–Wuchiapingian: central Japan (Omi), Arctic Canada (Ellesmere Island), northern Russia (Kolyma, northern Urals, Pechora Basin and Timan), central Russia (southern Urals), northwestern China (Xinjiang and Gansu), northern China (Inner Mongolia), eastern China (Zhejiang), central-southern China (Hunan and Guangxi), southwestern China (Guizhou and Yunnan) and north-central Thailand (Thun Nam Maholan).

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* in Japanese
** in Chinese
*** in Russian

＜　地名・地層名　＞

Akiyoshi……秋吉
Akiyoshi Belt……秋吉帯
Atetsu……阿哲
Higashiyama Quarry……東山採石場
Hina……日南
Hirao……平尾
Itoigawa……糸魚川
Karaumedate Formation……唐梅館層
Koyama (Ko-yama)……高山
Miharanoro……三原野呂
Mt. Kurohimeyama……黒姫山
Nagasaka……長坂
Niigata……新潟
Omi……青海
Omigawa River……青海川
South Kitakami Belt……南部北上帯
Taishaku……帝釈