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ARTICLE

EARLY CARBONIFEROUS (MISSISSIPPIAN) BRACHIOPODS FROM THE KARAUMEDATE FORMATION, SOUTH KITAKAMI BELT, JAPAN

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ABSTRACT

We describe early Carboniferous (Mississippian; late Tournaisian and late Visean) brachiopods from the lower part (KU1 Unit) and upper part (KU4 Unit) of the Karaumedate Formation in the Nagasaka area, South Kitakami Belt, northeastern Japan. The Karaumedate fauna consists of 24 species in 21 genera (14 species in 11 genera in the KU1 assemblage from the KU1 Unit, and 10 species in 10 genera in the KU4 assemblage from the KU4 Unit), including a new species (*Martinia georgei* sp. nov). The KU1 assemblage is late Tournaisian in age; therefore, the lower part (KU1 Unit) of the Karaumedate Formation is correlated with the upper Tournaisian. The KU4 assemblage is identified as late Visean; thus, the upper part (KU4 Unit) of the Karaumedate Formation is correlated with the upper Visean. In terms of palaeobiogeography, the KU1 assemblage has close affinity with the early Carboniferous (Mississippian) brachiopod faunas of North America, western Europe, central Russia, Kazakhstan, northwestern China and eastern China, particularly with those of northwestern China (Xinjiang). The KU4 assemblage exhibits close affinity with those of the UK, central Russia, Kazakhstan and northwestern China. The South Kitakami Belt was probably a shallow sea bordering a microcontinent near the North China block in the eastern end of the CAOB (Central Asian Orogenic Belt) during the late Tournaisian and Visean.

Key words: Brachiopoda, early Carboniferous, Karaumedate Formation, Nagasaka, South Kitakami Belt

田沢純一・大澤正博・名倉 弘（2019）南部北上帯の唐梅館層から産出する前期石炭紀（ミシシッピー亜紀）腕足類．福井県立恐竜博物館紀要 18：43–72.

南部北上帯長坂地域に分布する唐梅館層の下部（KU1 ユニット）および 上部（KU4 ユニット）から産出する 21 属 24 種の前期石炭紀腕足類（唐梅館フォーナ）を記載した．これらのなかには 1 種の新種（*Martinia georgei* sp. nov.）が含まれる．KU1 群集（11 属 14 種）は Tournaisian 後期，KU4 群集（10 属 10 種）は Visean 後期を示す．したがって，唐梅館層は Tournaisian 上部～ Visean 上部に対比される．古生物地理学的に，KU1 群集は北アメリカ，西ヨーロッパ，ロシア中央部，カザフスタン，中国西北部および中国東部，とくに中国西北部（新疆）の前期石炭紀腕足類フォーナに類縁がある．また，KU4 群集はイギリス，ロシア中央部，カザフスタンおよび中国西北部の前期石炭紀腕足類フォーナに類縁がある．このことから，前期石炭紀に南部北上帯は中央アジア造山帯の東端，北中国（中朝地塊）の近辺に存在したマイクロコンチネントの縁辺浅海域に位置したと推定される．

INTRODUCTION

Carboniferous rocks are widely distributed in the South Kitakami Belt, northeastern Japan. The Nagasaka area (i.e., Nagasaka, Higashiyama-cho, Ichinoseki City, Iwate Prefecture; Fig. 1) in the western part of the belt is the type locality of the lower Carboniferous (Mississippian) Karaumedate Formation (named by Tachibana, 1952). The stratigraphy of the Karaumedate Formation in the Nagasaka area has been studied by Noda (1934), Tachibana (1952), Onuki (1969), Okami et al. (1973), Minato and Kato (1979), Osawa et al. (1981), Kawamura (1997) and Tajika (1997). However, the age of the formation, except for the upper part which was correlated with the upper Visean on the basis of brachiopods (Tazawa and Osawa, 1979; Tazawa, 1980), is uncertain owing to a paucity of fossil evidence. The lower part of the Karaumedate Formation has been correlated with the lower Tournaisian (Tachibana,

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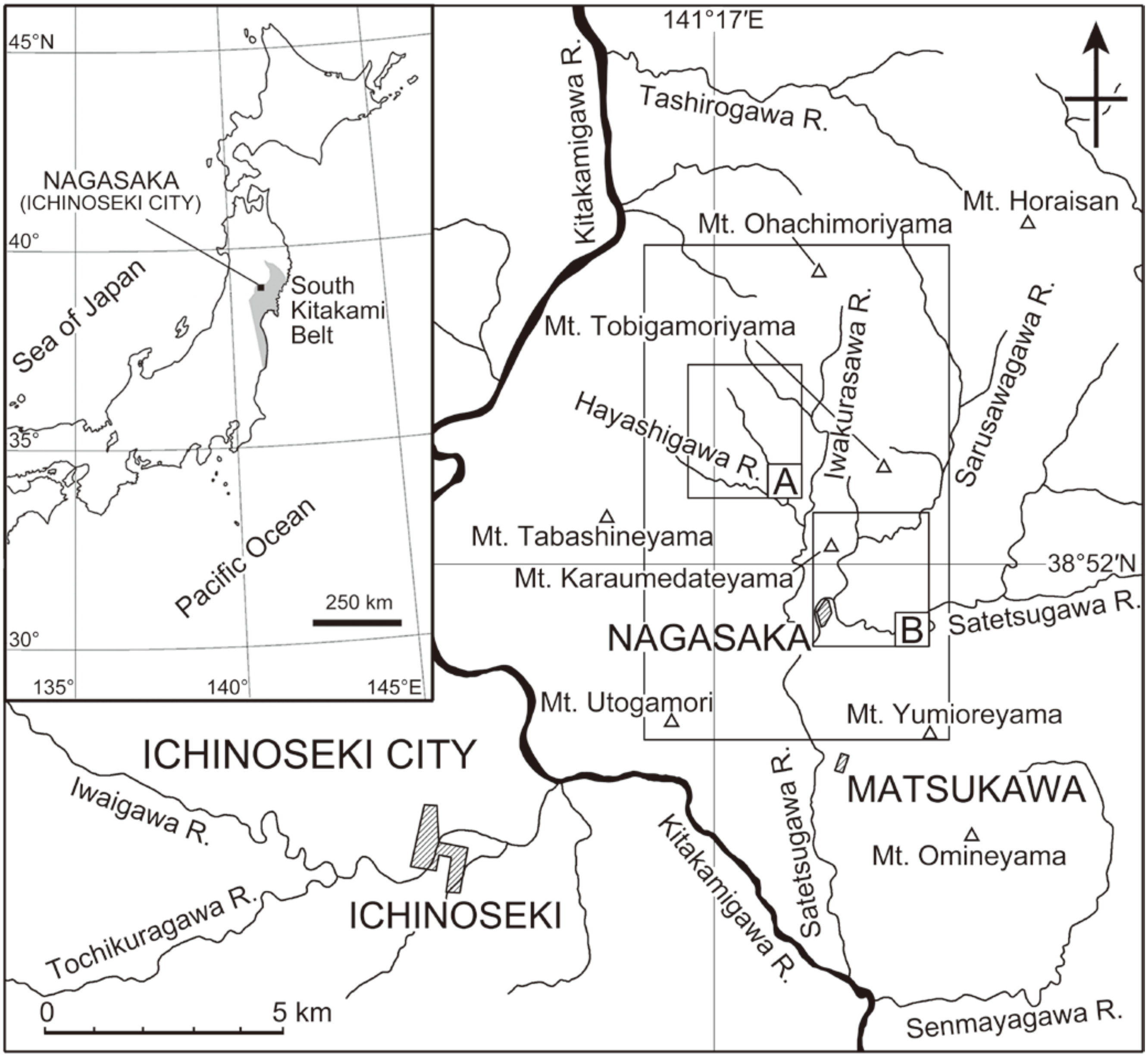

FIGURE 1. Topographic map of Nagasaka area (South Kitakami Belt), enclosed by solid line. Enclosures A and B correspond to Figures 4A and 4B, respectively.

1952; Minato, 1952; Minato and Kato, 1979) based on the following brachiopods, which were described by Tachibana (1956, 1963, 1964, 1969, 1981) and Minato (1952): *Kitakamithyris tyoanjiensis* Minato, *Prospira nodai* (Tachibana), *Globispirifer nagasakaensis* (Tachibana), *Syringothyris karaumedatensis* Tachibana, *S. japonica* Tachibana, *S. sakamotoi* Tachibana and *Nodaea okuboi* Tachibana. However, all the brachiopod species from the lower part of the formation are endemic and not clearly indicate the age of the fossil-bearing horizon; moreover, the exact positions of the fossil horizons and localities are unclear.

In the present study, we describe brachiopods from the lower and upper parts of the Karaumedate Formation in the Nagasaka area, and discuss the age and palaeobiogeography of the faunas. The brachiopod specimens described herein were collected by M. Osawa and H. Nagura in 1978–1979, during the course of graduate study at the Institute of Geology and Paleontology, Faculty of Science, Tohoku University, under the supervision of J. Tazawa. The specimens are now registered and housed in the Tohoku University Museum, Sendai, Japan (prefix IGPS, numbers 96252–96317, 111827–111872 and 112084).

STRATIGRAPHY AND MATERIALS

Carboniferous rocks are exposed in the Nagasaka area, forming a syncline with an axis trending N–S that plunges gently to the south (Fig. 2). The strata are divided lithologically into two formations: the lower, clastic sediment-dominated Karaumedate Formation and the upper, limestone-dominated Takesawa Formation. The Karaumedate Formation consists mainly of sandstone and shale with subordinate tuff and limestone, and has a total thickness of about 400 m. The formation conformably overlies the Upper Devonian–lower Tournaisian Tobigamori Formation (Osawa et al., 1981; Ehiro and Takaizumi, 1992) and in turn is conformably overlain by the upper Visean–upper Carboniferous (Pennsylvanian) Takesawa Formation (Tazawa and Osawa, 1979; Tazawa, 1980).

In this paper, we propose that the Karaumedate Formation be divided into three parts (lower, middle and upper) containing four lithostratigraphic units (the KU1, KU2, KU3 and KU4 units) in the Karaumedate Formation (Fig. 3). The lower part consists of the KU1 Unit (mainly sandstone with subordinate shale, total thickness 159 m); the middle part contains both the KU2 Unit (mainly sandstone, with subordinate shale and tuff, total thickness 100 m) and the KU3 Unit (mainly tuff, with subordinate arenaceous limestone, total thickness 78 m); and the upper part consists of the KU4 Unit (alternating shale and sandstone, with subordinate arenaceous limestone, total thickness 63 m). Brachiopod specimens were collected from 11 localities (NKA4, NKA8, NKA11, OKA4, OKA5, OKA6, OKA9, OKA10, OKA11, OKA15 and OKA17) in the lower part (KU1 Unit), and from one locality (OKA7) in the upper part (KU4 Unit; Fig. 4). The topographic and stratigraphic locations, lithologies and brachiopod species of the 12 fossil localities are shown in Figs. 3–5, and summarized below.

NKA4: 200 m north of the summit of Mt. Karaumedateyama (39°00′ 30″N, 141°15′ 07″E), dark grey medium-grained sandstone, 22 m above the base of the Karaumedate Formation, with *Unispirifer kozuboensis*.

NKA8: Nagasaka Quarry (Nendoyama), Nagasaka (38°59′ 51″N, 141°15′ 08″E), light grey tuffaceous fine-grained sandstone, 22 m above the base of the Karaumedate Formation, with *Rhipidomella kusbassica*, *Globispirifer nagasakaensis* and *Unispirifer kozuboensis*.

NKA11: Minamiiwairi Quarry, Minamiiwairi (39°00′ 25″N, 141°15′ 57″E), grey medium-grained sandstone, 22 m above the base of the Karaumedate Formation, with *Globispirifer nagasakaensis*, *Unispirifer tornacensis* and *Syringothyris japonica*.

OKA4: Roadcut at “Oiwa sen”, along the Takesawagawa River (39°02′ 35″N, 141°13′ 23″E), dark grey medium-grained sandstone, 144 m above the base of the Karaumedate Formation, with *Globispirifer nagasakaensis*.

OKA5: Mouth of the Komekurazawa Valley, a tributary of the Hayashigawa River (39°02′ 38″N, 141°12′ 42″E), dark grey shale, 9 m above the base of the Karaumedate Formation, with *Semiproductus* sp., *Cleiothyridina submabranacea*, *C. harkeri*, *Globispirifer nagasakaensis*, *Prospira nodai*, *Finospirifer shaoyangensis*, *Unispirifer tornacensis*, *Acuminothyris keokuk* and *Syringothyris karaumedatensis*.

OKA6: Mouth of the Komekurazawa Valley, a tributary of the Hayashigawa River (39°02′ 38″N, 141°12′ 45″E), brownish grey tuffaceous fine-grained sandstone, 144 m above the base of the Karaumedate Formation, with *Acuminothyris keokuk*.

OKA7: Eastern slope of the 204 m hill, Jizodo (39°02′ 29″N, 141°13′ 05″E), grey tuffaceous sandy shale, 15 m below the top of the Karaumedate Formation, with *Rugosochonetes extensus*, *Krotovia* sp., *Productus concinnus*, *Karavankina jizodoensis*, *Balakhonia* sp., *Fluctuaria* sp., *Hustedia* sp., *Martinia georgei* sp. nov., *Brachythyrina* sp. and *Phricodothyris* sp.

OKA9: Yoshizawa Valley, a tributary of the Takesawagawa River (39°02′ 47″N, 141°13′ 50″E), greenish grey tuffaceous medium-grained sandstone, 22 m above the base of the Karaumedate Formation, with *Globispirifer nagasakaensis*.

OKA10: Yoshizawa Valley, a tributary of the Takesawagawa River (39°02′ 45″N, 141°13′ 46″E), dark grey shale, 75 m above the base of the Karaumedate Formation, with *Unispirifer tornacensis*.

OKA11: Haginosawa Valley, a tributary of the Takesawagawa River (39°02′ 15″N, 141°14′ 04″E), light grey tuffaceous medium-grained sandstone, 22 m above the base of the Karaumedate Formation, with *Tylothyris* sp.

OKA15: Roadcut at “Takesawa–Natsuyama sen” (39°01′ 59″N, 141°14′ 24″E), light grey tuffaceous fine-grained sandstone, 22 m above the base of the Karaumedate Formation, with *Macropotamorhynchus* sp.

OKA17: Summit of Mt. Takozumoriyama (39°01′ 39″N, 141°14′ 25″E), light grey tuffaceous fine-grained sandstone, 100 m above the base of the Karaumedate Formation, with *Macropotamorhynchus* sp. and *Unispirifer tornacensis*.

KARAUMEDATE FAUNA

The brachiopod fauna (Karaumedate Fauna) described herein consists of 24 species in 21 genera, including a new species (*Martinia georgei* Tazawa, sp. nov.). The list of species is as follows: *Rugosochonetes extensus* (Chao, 1928), *Semiproductus* sp., *Krotovia* sp., *Productus concinnus* Sowerby, 1821, *Karavankina jizodoensis* Tazawa, 1980, *Balakhonia* sp., *Fluctuaria* sp., *Rhipidomella kusbassica* Beznossova in Sarytcheva et al., 1963, *Macropotamorhynchus* sp., *Cleiothyridina submabranacea* (Grabau in Chu, 1933), *C. harkeri* Carter, 1987, *Hustedia* sp., *Martinia georgei* Tazawa, sp. nov., *Globispirifer nagasakaensis* (Tachibana, 1956), *Prospira nodai* (Tachibana, 1956), *Finospirifer shaoyangensis* (Ozaki, 1939), *Unispirifer tornacensis* (de Koninck, 1883), *U. kozuboensis* (Minato, 1952), *Brachythyrina* sp., *Acuminothyris keokuk* Carter, 1990, *Tylothyris* sp., *Phricodothyris* sp., *Syringothyris karaumedatensis* Tachibana, 1969 and *S. japonica* Tachibana, 1969. The Karaumedate fauna contains two assemblages: the KU1 assemblage from the KU1 Unit, and the KU4 assemblage from the KU4 Unit.

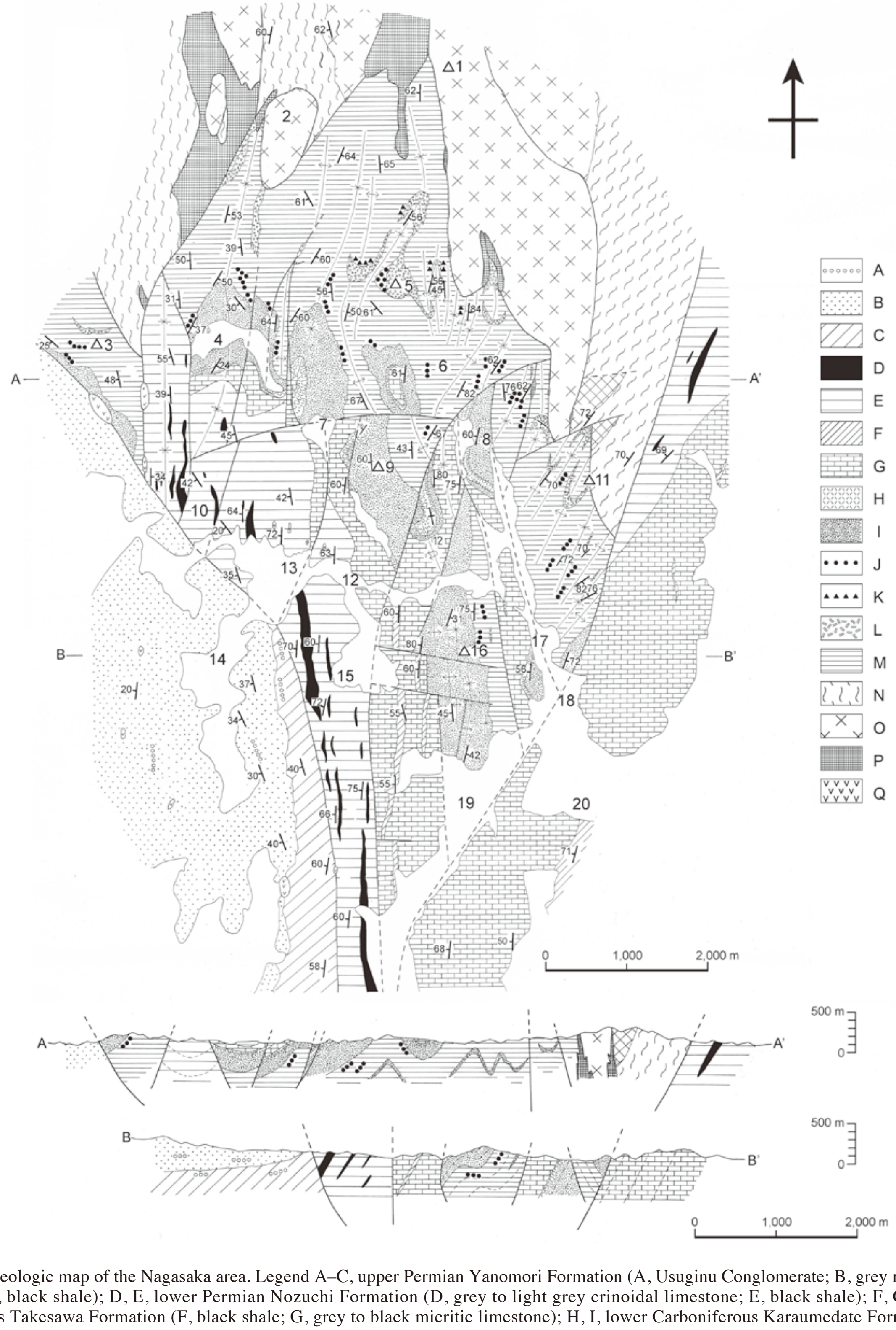

FIGURE 2. Geologic map of the Nagasaka area. Legend A–C, upper Permian Yanomori Formation (A, Usuginu Conglomerate; B, grey medium-grained sandstone; C, black shale); D, E, lower Permian Nozuchi Formation (D, grey to light grey crinoidal limestone; E, black shale); F, G, lower–upper Carboniferous Takesawa Formation (F, black shale; G, grey to black micritic limestone); H, I, lower Carboniferous Karaumedate Formation (H, light green felsic tuff; I, light grey medium-grained sandstone with dark grey shale); J–M, Upper Devonian–lower Carboniferous Tobigamori Formation (J, conglomerate; K, Natsuyama Conglomerate; L, reddish purple shale; M, black shale); N–P, Motai metamorphic rocks (N, phyllite and schist; O, meta gabbro; P, serpentinite); Q, dyke rocks. Location 1, Mt. Ohachimoriyama; 2, Shoboji; 3, Mt. Fujinoneyama; 4, Jizodo; 5, Mt. Natsuyama; 6, Natsuyama; 7, Hirane; 8, Yokosawa; 9, Mt. Takozumoriyama; 10, Kamiagari; 11, Mt. Tobigamoriyama; 12, Ishinomori; 13, Nozuchi; 14, Yanomori; 15, Takagane; 16, Mt. Karaumedateyama: 17, Kitaiwairi; 18, Minamiiwairi; 19, Matsukawa; 20, Nagasaka.

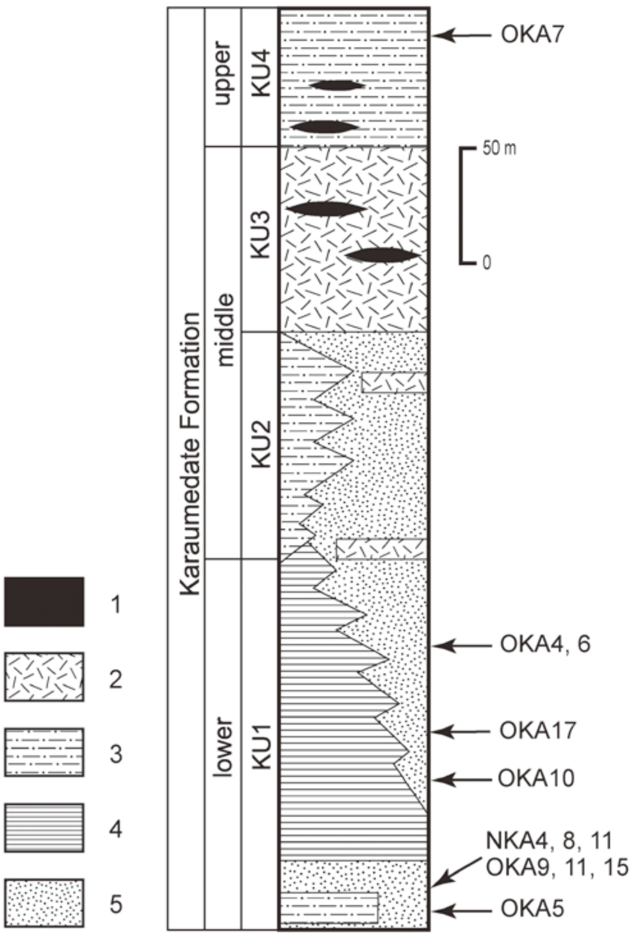

FIGURE 3. Generalized columnar section of the Karaumedate Formation in the Nagasaka area, South Kitakami Belt, showing the fossil horizons NKA4, NKA8, NKA11, OKA4, OKA5, OKA6, OKA7, OKA9, OKA10, OKA11, OKA15 and OKA17. Legend 1, limestone; 2, tuff; 3, alternating shale and sandstone; 4, shale; 5, sandstone.

KU1 assemblage (late Tournaisian)

The KU1 assemblage includes 14 species in 11 genera: *Semiproductus* sp., *Rhipidomella kusbassica*, *Macropotamorhynchus* sp., *Cleiothyridina submabranacea*, *C. harkeri*, *Globispirifer nagasakaensis*, *Prospira nodai*, *Finospirifer shaoyangensis*, *Unispirifer tornacensis*, *U. kozuboensis*, *Acuminothyris keokuk*, *Tylothyris* sp., *Syringothyris karaumedatensis* and *S. japonica*. Of these species, *Globispirifer nagasakaensis* is abundant; *Rhipidomella kusbassica*, *Macropotamorhynchus* sp., *Prospira nodai*, *Unispirifer tornacensis* and *Acuminothyris keokuk* are common; and the others are rare (Fig. 5).

The stratigraphic distributions of the brachiopod species of the KU1 assemblage are summarized in Fig. 6. Of the brachiopods listed above, three species (*Cleiothyridina harkeri*, *Finospirifer shaoyangensis* and *Unispirifer tornacensis*) are known only from the upper Tournaisian, *Rhipidomella kusbassica* has a range of lower Tournaisian to lower Visean, *Cleiothyridina submabranacea* occurs in the Upper Devonian (Famennian) to upper Tournaisian, and two species (*Unispirifer kozuboensis* and *Acuminothyris keokuk*) occur in the upper Tournaisian and lower Visean. At the generic level, *Semiproductus* is known from the Famennian–upper Tournaisian (Abramov, 1970; Brunton et al., 2000); *Macropotamorhynchus* has a range of lower–upper Tournaisian (Carter, 1987, 1999; Savage, 2002); and two genera (*Globispirifer* and *Prospiria*) are known from the lower–upper Tournaisian (Carter and Gourvennec, 2002; Carter, 2006a; this study). The other genera are long-ranging: *Tylothyris* has a range of Givetian–upper Visean (Johnson et al., 2006), and *Syringothyris* has a range of Famennian–Serpukhovian (Carter, 2006b). In summary, the age of the KU1 assemblage is identified as late Tournaisian; thus, the lower part of the Karaumedate Formation (KU1 Unit) is correlated with the upper Tournaisian.

The geographic distributions of the brachiopod species of the KU1 assemblage are summarized in Figs. 7 and 8. Of the 14 species of the KU1 assemblage, three species also occur in northwestern China (Xinjiang); and one species also occur in Canada (Alberta), the USA (Missouri), Belgium, Turkey (Taurus Mountains), central Russia (Kuznetsk Basin), Kazakhstan and eastern China (Jiangsu and Hunan). In summary, the KU1 assemblage has a close affinity with the early Carboniferous (Mississippian) brachiopod faunas of North America, western Europe, central Russia, Kazakhstan, northwestern China and eastern China, particularly with those of northwestern China (Xinjiang). This conclusion is consistent with the results of Tazawa (2018), who reported that the late Tournaisian brachiopod fauna (the HK1 assemblage of the Hikoroichi fauna from Hikoroichi, South Kitakami Belt) has a close affinity with those of North America, western Europe, northern and central Russia, Kazakhstan and northwestern China. The South Kitakami region was probably located near the North China Block during the late Tournaisian.

KU4 assemblage (late Visean)

The KU4 assemblage includes 10 species in 10 genera: *Rugosochonetes extensus*, *Krotovia* sp., *Productus concinnus*, *Karavankina jizodoensis*, *Balakhonia* sp., *Fluctuaria* sp., *Hustedia* sp., *Martinia georgei* sp. nov., *Brachythyrina* sp. and *Phricodothyris* sp. Of these species, *Karavankina jizodoensis* and *Martinia georgei* sp. nov. are abundant; *Productus concinnus*, *Hustedia* sp. and *Brachythyrina* sp. are common; and the other species are rare (Fig. 5).

The stratigraphic distributions of the brachiopod species of the KU4 assemblage are summarized in Fig. 9. Of the brachiopods listed above, *Karavankina jizodoensis* is known from the upper Visean, *Rugosochonetes extensus* from the lower–upper Visean, *Productus concinnus* from the upper Visean–Bashkirian, and *Martinia georgei* sp. nov. from the lower Visean–Bashkirian. At the generic level, *Krotovia* is known from the lower Visean–Bashkirian (Brunton et al., 2000); *Balakhonia* ranges from the upper Visean to the Bashkirian

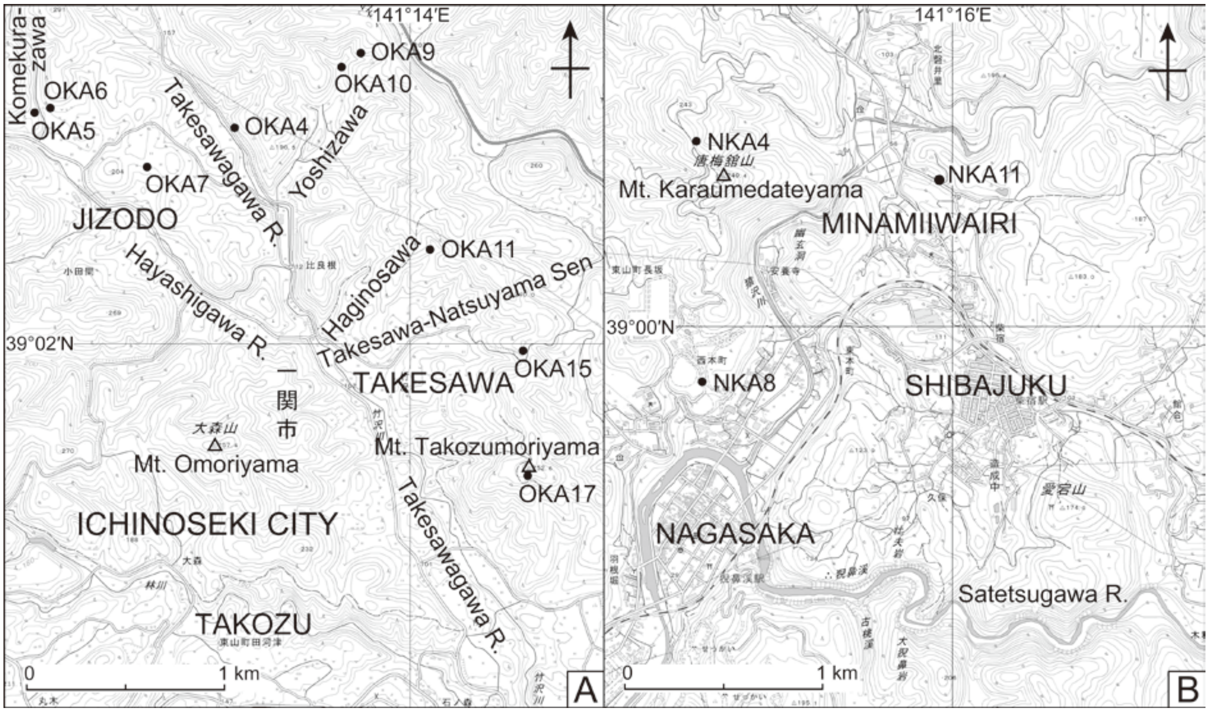

FIGURE 4. Map showing the fossil localities OKA4, OKA5, OKA6, OKA9, OKA10, OKA11, OKA15 and OKA17 in the topographic map **A,** and NKA4, NKA8 and NKA11 in the topographic map **B** (base map is from the electronic topographical map of GSI).

Species \ Lithological units, Localities	KU1											KU4
	OKA5	NKA4	NKA8	NKA11	OKA9	OKA11	OKA15	OKA10	OKA17	OKA4	OKA6	OKA7
Rugosochonetes extensus												R
Semiproductus sp.	R											
Krotovia sp.												R
Productus concinnus												C
Karavankina jizodoensis												A
Balakhonia sp.												R
Fluctuaria sp.												R
Rhipidomella kusbassica			C									
Macropotamorhynchus sp.							C		R			
Cleiothyridina submabranacea	R											
Cleiothyridina harkeri	R											
Hustedia sp.												C
Martinia georgei sp. nov.												A
Globispirifer nagasakaensis	R		R	R	R	R	C			A		
Prospira nodai	C											
Finospirifer shaoyangensis	R											
Unispirifer tornacensis	C				R			R	R			
Unispirifer kozuboensis		R	R									
Brachythyrina sp.												C
Acuminothyris keokuk	C										R	
Tylothyris sp.						R						
Phricodothyris sp.												R
Syringothyris karaumedatensis	R											
Syringothyris japonica				R								

FIGURE 5. Occurrence of brachiopod species from the Karaumedate Formation in the Nagasaka area, South Kitakami Belt. A, abundant; C, common; R, rare.

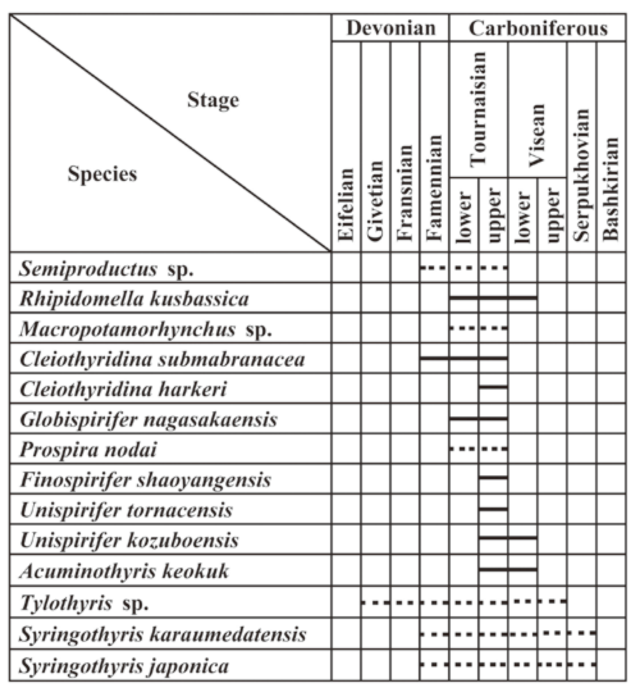

FIGURE 6. Stratigraphic distributions of brachiopod species of the KU1 assemblage in the Karaumedate fauna. Broken line shows range of the genus.

Region / Species	Japan	USA	Canada			C. Russia		NW China	E. China		CS China
	1. South Kitakami Belt	2. Missouri	3. Alberta	4. Belgium	5. Turkey	6. Kuznetsk Basin	7. Kazakhstan	8. Xinjiang	9. Jiangsu	10. Hunan	11. Guangxi
***Semiproductus* sp.**	+										
Rhipidomella kusbassica	+					+	+	+			
***Macropotamorhynchus* sp.**	+										
Cleiothyridina submabranacea	+							+	+		+
Cleiothyridina harkeri	+		+								
Globispirifer nagasakaensis	+										
Prospira nodai	+										
Finospirifer shaoyangensis	+									+	
Unispirifer tornacensis	+			+	+						
Unispirifer kozuboensis	+										
Acuminothyris keokuk	+	+						+			
***Tylothyris* sp.**	+										
Syringothyris karaumedatensis	+										
Syringothyris japonica	+										

FIGURE 7. Geographic distributions of brachiopod species of the KU1 assemblage in the Karaumedate fauna.

(Brunton et al., 2000); and *Fluctuaria* from the lower Visean–Moscovian (Chao, 1927: Winkler Prins, 1968; Brunton et al., 2000). The other three genera (*Hustedia*, *Brachythyrina* and *Phricodothyris*) are long-ranging, from the Mississippian–Lopingian (Alvarez and Rong, 2002; Carter, 2006a; Carter and Gourvennec, 2006). In summary, the age of the KU4 assemblage is identified as late Visean; thus, the upper part of the Karaumedate Formation (KU4 Unit) is correlated with the upper Visean. This conclusion is consistent with those of Tazawa and Osawa (1979) and Tazawa (1980).

The geographic distributions of the brachiopod species of the KU4 assemblage are summarized in Figs. 10 and 11. Among the 10 species of the KU4 assemblage, two species also occur in the UK (Wales), central Russia (southern Urals), Kazakhstan and northwestern China (Xinjiang); and one species also occur in the UK (Scotland, England and northern Ireland), Belgium, Spain, western Russia (Moscow and Donetz basins), central Russia (western Urals), Uzbekistan, Kyrgyzstan, northwestern China (Gansu) and northeastern China (Jilin). In summary, the KU4 assemblage has affinity with the early Carboniferous (Mississippian) brachiopod faunas of the UK, central Russia, Kazakhstan and northwestern China. This conclusion is consistent with those of Tazawa (2017, 2018), who reported that the late Visean brachiopod faunas of Tairagai and Hikoroichi in the South Kitakami Belt have close affinity with those of western Europe, central Russia, Kazakhstan and northwestern China. The South Kitakami region was probably located near the North China block during the late Visean as well.

DISCUSSION: PALAEOPOSITION OF THE SOUTH KITAKAMI BELT IN EARLY CARBONIFERUS

From what has been discussed above, we can conclude that the South Kitakami Belt was probably a shallow sea bordering a microcontinent, which consisted of the Hida–Oki terrane (Suwa, 1990) and the East China Sea region, and located near the North China block in the eastern end of the CAOB during the late Tournaisian and Visean.

Ehiro (2001) and Okawa et al. (2013) considered that the South Kitakami Paleoland (microcontinent) was present at equatorial region near the South China block during Carboniferous on the basis of palaeobiogeography of Carboniferous corals or U-Pb analyses of detrital zircon on the Carboniferous sediments of the South Kitakami Belt. But the early Carboniferous brachiopod faunas of the South Kitakami Belt are quite different from those of the South China block (Figs. 8 and 11).

Isozaki et al. (2014, 2017) proposed the Greater South China (GSC) based mainly on U-Pb analyses of detrital zircon on Palaeozoic sediments of the South Kitakami Belt. According to Isozaki (2017), the GSC consisted of the South China block, SW Japan, NE Japan (including the South Kitakami Belt) and South Primorye in the eastern Russia; and the South Kitakami Belt was located at the northern part of the GSC in Palaeozoic time. However, the GSC can be hardly accepted because the early Carboniferous brachiopod faunas of the South China block differ from those of the South Kitakami Belt (Tazawa, 2006, 2017; Tazawa and Iryu, 2019; Tazawa and Kurita, 2019b; this study).

CONCLUSIONS

In this study, we describe early Carboniferous (Mississippian; late Tournaisian and late Visean) brachiopods from the lower part (KU1 Unit) and upper part (KU4 Unit) of the Karaumedate Formation in the Nagasaka area, South Kitakami Belt, northeastern Japan. The Karaumedate fauna consists of 24 species in 21 genera (14 species in 11 genera in the KU1 assemblage from the KU1 Unit, and 10 species in 10 genera in the KU4 assemblage from the KU4 Unit). The KU1 assemblage is assigned to the late Tournaisian in age; therefore, the lower part (KU1 Unit) of the Karaumedate Formation is correlated with the upper Tournaisian. In terms of palaeobiogeography, the KU1 assemblage has close affinity with those of North America, western Europe, central Russia, Kazakhstan, northwestern China and eastern China, particularly with those of northwestern China (Xinjiang). The age of the KU4 assemblage is identified as late Visean; thus, the upper part of the Karaumedate Formation (KU4 Unit) is correlated with the upper Visean. Palaeobiogeographically, the KU4 assemblage has close affinity

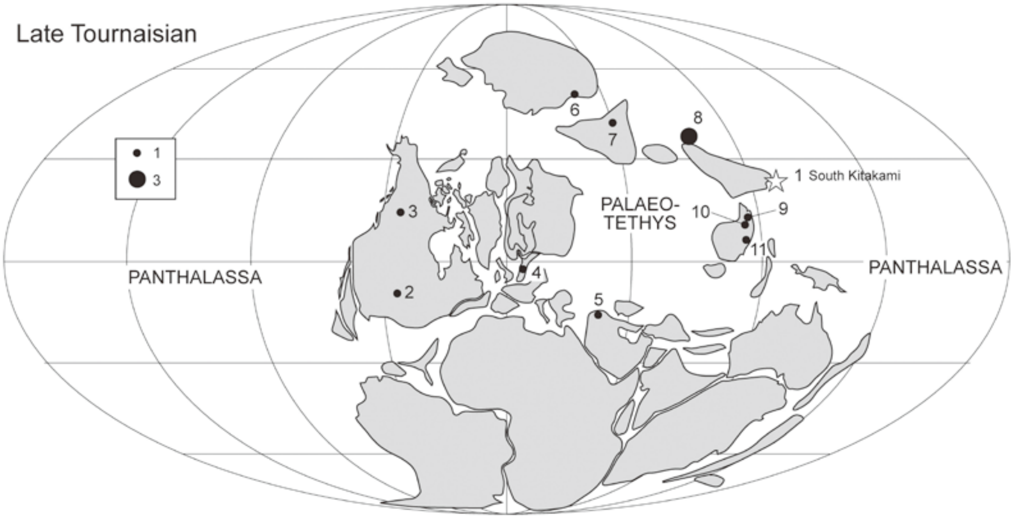

FIGURE 8. Late Tournaisian reconstruction map of the world (base map is from Qiao and Shen, 2014), showing the geographic distributions of brachiopod species of the KU1 assemblage in the Karaumedate fauna. Solid circles indicate numbers of brachiopod species listed in the KU1 assemblage. Station numbers are same as in Fig. 7.

Species \ Stage	Carboniferous								
	Tournaisian		Visean		Serpukhovian	Bashkirian	Moscovian	Kasimovian	Gzhelian
	lower	upper	lower	upper					
Rugosochonetes extensus			—	—					
***Krotovia* sp.**			- -	- -	- -	- -			
Productus concinnus				—	—	—			
Karavankina jizodoensis				—					
***Balakhonia* sp.**				- -	- -	- -			
***Fluctuaria* sp.**			- -	- -	- -	- -	- -		
***Hustedia* sp.**	- -	- -	- -	- -	- -	- -	- -	- -	- -
***Martinia georgi* sp. nov.**			—	—	—	—			
***Brachythyrina* sp.**	- -	- -	- -	- -	- -	- -	- -	- -	- -
***Phricodothyris* sp.**	- -	- -	- -	- -	- -	- -	- -	- -	- -

FIGURE 9. Stratigraphic distributions of brachiopod species of the KU4 assemblage in the Karaumedate fauna. Broken line shows range of the genus.

Species \ Region	Japan	UK						W. Russia		C. Russia					NW China		NE China
	1. South Kitakami Belt	2. Scotland	3. England	4. Wales	5. Northern Ireland	6. Belgium	7. Spain	8. Moscow Basin	9. Donetz Basin	10. Western Urals	11. Southern Urals	12. Kazakhstan	13. Uzbekistan	14. Kyrgyzstan	15. Xinjiang	16. Gansu	17. Jilin
Rugosochonetes extensus	+															+	
***Krotovia* sp.**	+																
Productus concinnus	+	+	+	+	+		+	+			+	+	+	+	+		+
Karavankina jizodoensis	+																
***Balakhonia* sp.**	+																
***Fluctuaria* sp.**	+																
***Hustedia* sp.**	+																
***Martinia georgi* sp. nov.**	+			+		+			+	+	+	+			+		
***Brachythyrina* sp.**	+																
***Phricodothyris* sp.**	+																

FIGURE 10. Geographic distributions of brachiopod species of the KU4 assemblage in the Karaumedate fauna.

with the early Carboniferous (Mississippian) brachiopod faunas of the UK, central Russia, Kazakhstan and northwestern China. The South Kitakami Belt was probably a shallow sea bordering a microcontinent near the North China block in the eastern end of the CAOB during the late Tournaisian and Visean.

SYSTEMATIC DESCRIPTIONS
(by J. Tazawa)

The suprageneric classification given herein mainly follows that of "Treatise on Invertebrate Paleontology, Part H Brachiopoda Revised, Volumes 2–6", edited by Kaesler (2000a, 2000b, 2002, 2006) and Selden (2007), with exception that classification of the suborder Productidina follows Waterhouse (2002).

Order PRODUCTIDA Sarytcheva and Sokolskaya, 1959
Suborder CHONETIDINA Muir-Wood, 1955

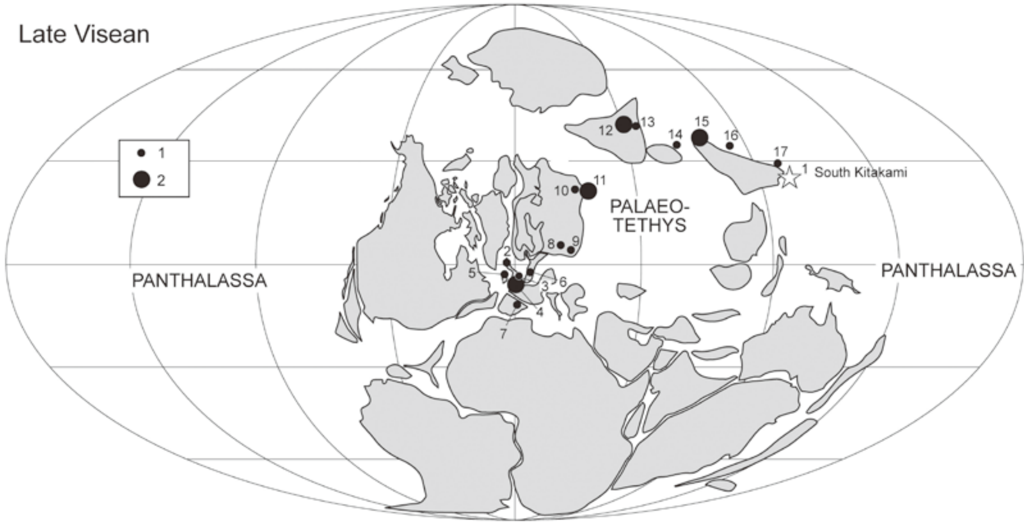

FIGURE 11. Late Visean reconstruction map of the world (base map is from Qiao and Shen, 2014), showing the geographic distributions of brachiopod species of the KU4 assemblage in the Karaumedate fauna. Solid circles indicate numbers of brachiopod species listed in the KU4 assemblage. Station numbers are same as in Fig. 10.

Superfamily CHONETOIDEA Bronn, 1862
Family RUGOSOCHONETIDAE Muir-Wood, 1962
Subfamily RUGOSOCHONETINAE Muir-Wood, 1962
Genus *RUGOSOCHONETES* Sokolskaya, 1950

Type species.—*Orthis hardrensis* Phillips, 1841.

Rugosochonetes extensus (Chao, 1928)
(Fig. 16A)

Chonetes extensa Chao, 1928, p. 9, pl. 1, figs. 7–10; Fang in Yang et al., 1962, p. 39, pl. 12, figs. 1–6; Ding and Qi, 1983, p. 262, pl. 93, fig. 2.
Rugosochonetes sp. Tazawa, 1980, p. 361, pl. 41, fig. 1.
Rugosochonetes extensus (Chao). Tazawa, 2017, p. 334, fig. 6.2.

Material.—One specimen from locality OKA7, internal mould of a ventral valve, IGPS96252.

Remarks.—This specimen was described and figured by Tazawa (1980, p. 361, pl. 41, fig. 1) as *Rugosochonetes* sp. But the Jizodo specimen is referred to *Rugosochonetes extensus* (Chao, 1928), originally described by Chao (1928, p. 9, pl. 1, figs. 7–10) from the Chouniugou Formation of Gausu, northwestern China, by the transverse outline (length 7 mm, width about 22 mm). *Rugosochonetes transversalis* Brunton (1968, p. 65, pl. 9, figs. 16–25), from the Visean of County Fermanagh, northern Ireland, differs from *R. extensus* in having coarser capillae on both ventral and dorsal valves.

Occurrence.—KU4 Unit.

Distribution. — Lower – upper Visean: northeastern Japan (Yokota and Nagasaka in the South Kitakami Belt) and northwestern China (Gansu).

Suborder PRODUCTIDINA Waagen, 1883
Superfamily PRODUCTELLOIDEA Schuchert, 1929
Family PRODUCTELLIDAE Schuchert, 1929
Subfamily SEMIPRODUCTINAE McKellar, 1970
Genus *SEMIPRODUCTUS* Bublichenko, 1956

Type species.—*Semiproductus minax* Bublichenko, 1956.

Semiproductus sp.
(Fig. 12I)

Material.—One specimen from locality OKA5, external and internal moulds of a dorsal valve, IGPS111827.

Remarks.—This specimen is safely assigned to the genus *Semiproductus* by the transverse, medium-sized (length 19 mm, width 33 mm) and strongly geniculated dorsal valve, which is ornamented with numerous fine rugae and quincunxially arranged elongate spine bases on the visceral disc. The Nagasaka species most resembles *Semiproductus irregularicostatus* (Krestovnikov and Karpyshev, 1948), redescribed by Galitskaya (1977, p. 41, pl. 9, figs. 3–7) from the lower Tournaisian of Kyrgyzstan, but differs in having finer rugae on the dorsal valve. The type species, *Semiproductus minax* Bublichenko 1956, redescribed by Grechishnikova (1966, p. 109, pl. 6, figs. 1–6) from the lower Tournaisian of Kazakhstan, differs from the present species in the less transverse outline.

Occurrence.—KU1 Unit.

Family AVONIIDAE Sarytcheva, 1960
Subfamily TUBERSULCULINAE Waterhouse, 1971
Genus *KROTOVIA* Fredericks, 1928

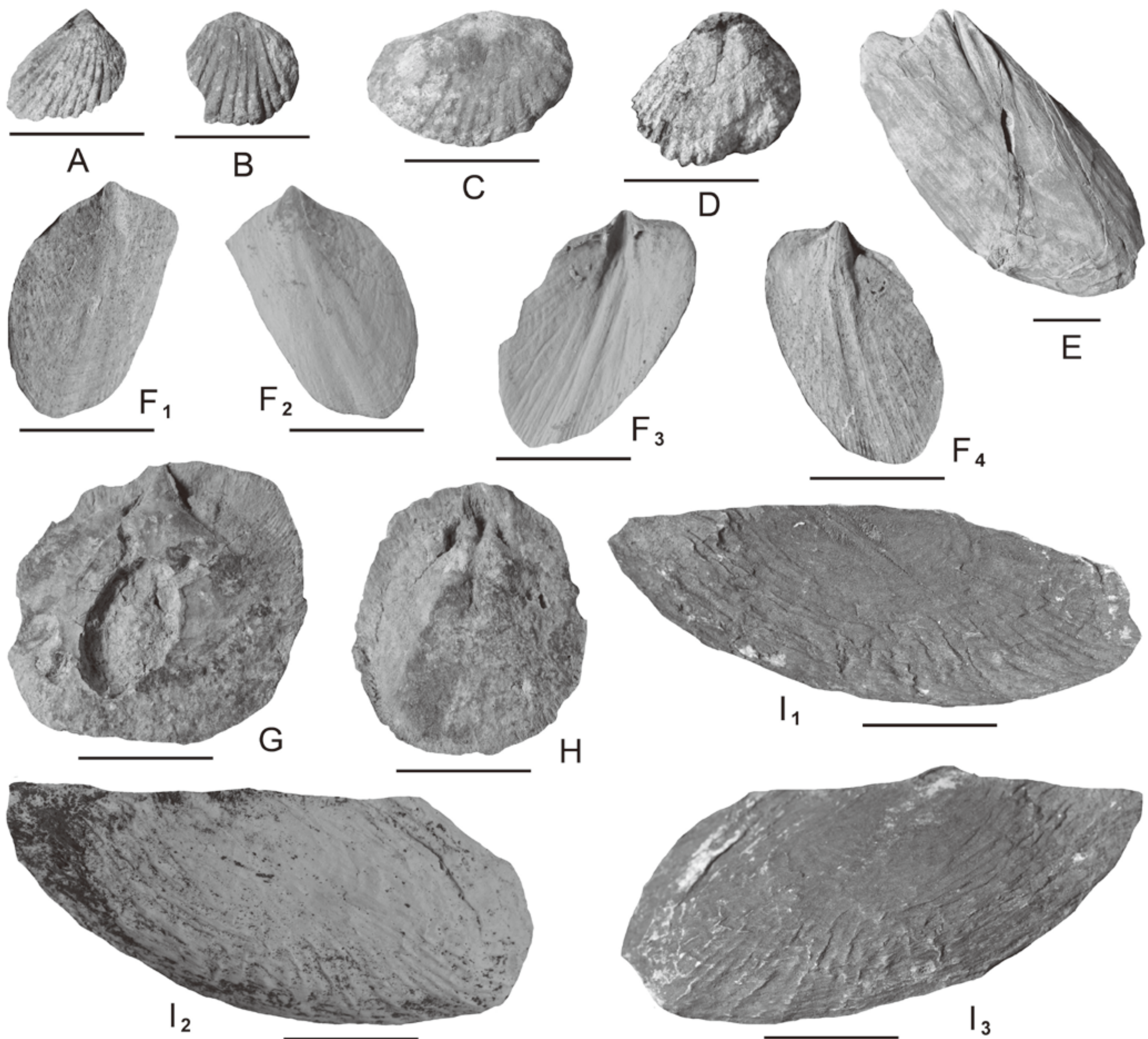

FIGURE 12. Brachiopods of the KU1 assemblage (1). **A–D,** *Macropotamorhynchus* sp., internal mould of dorsal valve, (A) IGPS111833, (B) IGPS111834, (C) IGPS111832, (D) IGPS111835; **E,** *Cleiothyridina harkeri* Carter, internal mould of ventral valve, IGPS111838; **F,** *Cleiothyridina submabranacea* (Grabau), external mould (F1), external latex cast (F2), internal latex cast (F3) and internal mould (F4) of ventral valve, IGPS111837; **G, H,** *Rhipidomella kusbassica* Beznossova; G, internal mould of ventral valve, IGPS111829; H, internal mould of dorsal valve, IGPS111831; **I,** *Semiproductus* sp., internal mould (I1), external latex cast (I2) and external mould (I3) of dorsal valve, IGPS111827. Scale bars are 1 cm.

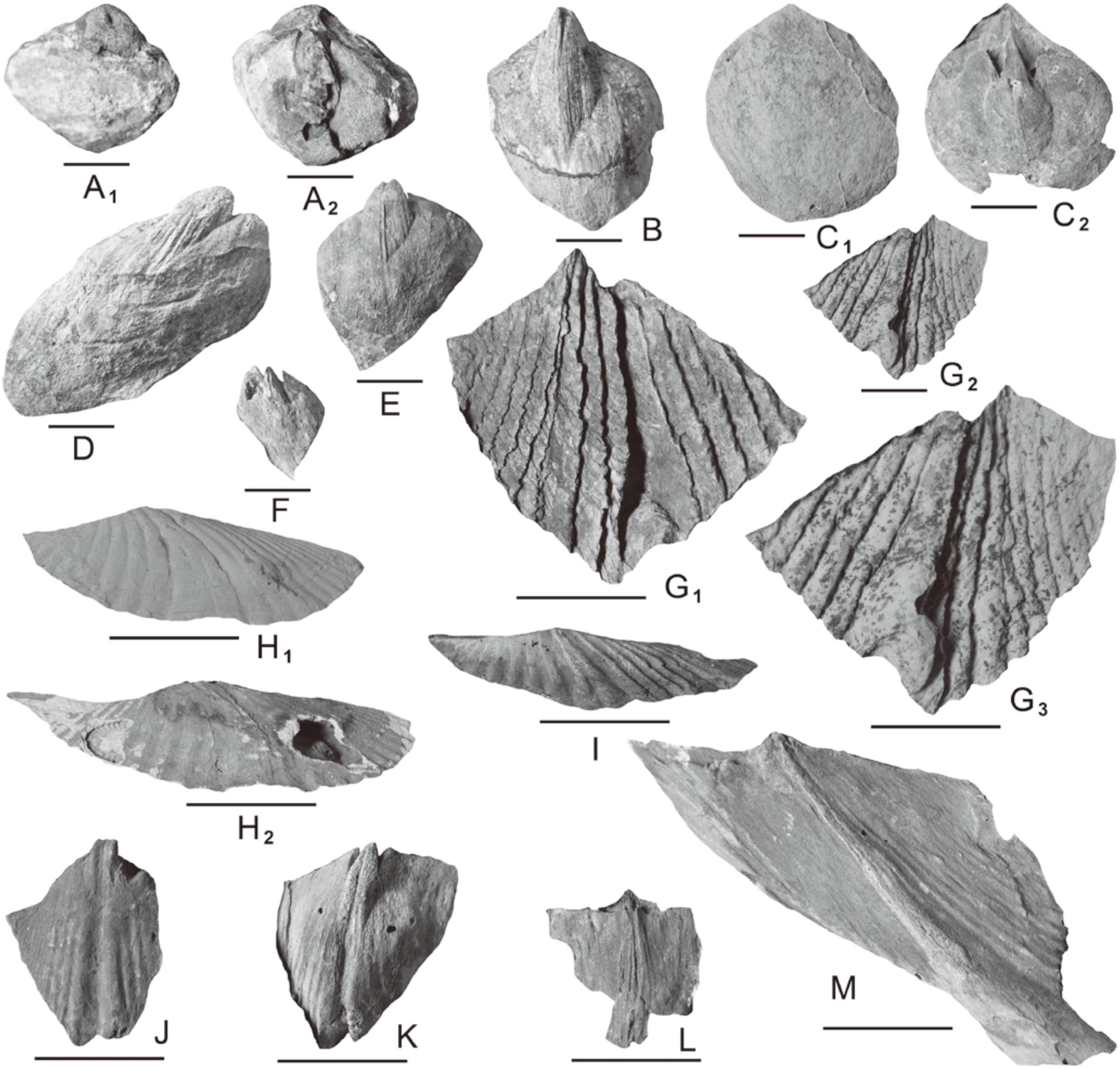

FIGURE 13. Brachiopods of the KU1 assemblage (2). **A**–**F**, *Globispirifer nagasakaensis* (Tachibana); A, ventral (A_1) and dorsal (A_2) views of internal mould of conjoined shell, IGPS111839; B, internal mould of ventral valve, IGPS111841; C, external latex cast (C_1) and internal mould (C_2) of ventral valve, IGPS111840; D, internal mould of ventral valve, IGPS111843; E, internal mould of ventral valve, IGPS111842; F, internal mould of dorsal valve, IGPS111850; **G,** *Tylothyris* sp., external latex cast (G_1) and external mould (G_2, G_3) of dorsal valve, IGPS111869; **H, I,** *Acuminothyris keokuk* Carter; H, external latex cast (H_1) and internal mould (H_2) of dorsal valve, IGPS111865; I, internal mould of dorsal valve, IGPS111868; **J**–**L,** *Prospira nodai* (Tachibana); J, internal mould of ventral valve, IGPS111853, K, internal mould of ventral valve, IGPS111854; L, internal mould of dorsal valve, IGPS111855; **M,** *Finospirifer shaoyangensis* (Ozaki), internal mould of dorsal valve, IGPS111856. Scale bars are 1 cm.

Type species.—*Productus spinulosus* Sowerby, 1814.

Krotovia sp.
(Fig. 16B)

Krotovia sp. Tazawa, 1980, p. 361, pl. 41, fig. 2.

Material.—One specimen from locality OKA7, external mould of a dorsal valve, IGPS96253.

Remarks.—This specimen was previously described and figured by Tazawa (1980, p. 361, pl. 41, fig. 2) as *Krotovia* sp. The dorsal valve is small in size, transverse subrectangular in outline, and slightly concave, measuring length 9 mm, width about 18 mm, and ornamented with numerous small spine bases and weak growth lines; numbering 6–7 spine bases in 5 mm width at midlength of the valve. The Jizodo specimen can be safely assigned to the genus *Krotovia* by its small size, numerous spine bases and weak growth lines on the dorsal valve, but the specific identification is difficult owing to ill preservation of the specimen.

Occurrence.—KU4 Unit.

Superfamily PRODUCTOIDEA Gray, 1840
Family PRODUCTIDAE Gray, 1840
Subfamily PRODUCTINAE Gray, 1840
Genus *PRODUCTUS* Sowerby, 1814

Type species.—*Anomites productus* Martin, 1809.

Productus concinnus Sowerby, 1821
(Fig. 16C–E)

Productus concinnus Sowerby, 1821, p. 16, pl. 318, fig. 1; Muir-Wood, 1928, p. 49, pl. 1, figs. 7–10, text-fig. 12; Yanishewsky, 1918, p. 32, pl. 5, figs. 3, 12–14; Sarytcheva in Sarytcheva and Sokolskaya, 1952, p. 134, pl. 37, fig. 184; Litvinovich in Litvinovich et al., 1969, p. 203, pl. 28, figs. 4, 8, 10; Yang, 1964, p. 94, pl. 9, figs. 2–5; text-fig. 9; Galitskaya, 1977, p. 54, pl. 14, figs. 1–8; Alexandrow and Solomina, 1973, p. 95, pl. 23, figs. 3, 4; pl. 24, fig. 7; Martinez Chacon, 1979, p. 173, pl. 16, fig. 17; pl. 17, figs. 1–10; Tyulyandina, 1974, p. 41, pl. 1, figs. 10, 11; pl. 2, figs. 1–5, 7, 8; Gu, 1992, p. 226, pl. 64, figs. 6, 8, 16, 17, 35.
Productus semireticulatus var. *concinna* Sowerby. Davidson, 1861, p. 149, pl. 43, figs. 9, 10.
Productus concinnus mut. D_2 Sibly, 1906, p. 372, pl. 32, fig. 3.
Productus cf. *concinnus* Sowerby. Tazawa, 1980, p. 362, pl. 41, figs. 3–6.

Material.—Four specimens from locality OKA7: (1) external and internal moulds of a ventral valve, IGPS96254; (2) internal mould of a ventral valve, IGPS96255; and (3) external moulds of two dorsal valves, IGPS96256, 96257.

Remarks.—These specimens, previously described by Tazawa (1980, p. 362, pl. 41, figs. 3–6) as *Productus* cf. *concinnus* Sowerby, 1814, are referred to *Productus concinnus* Sowerby, 1814, redescribed by Muir-Wood (1928, p. 49, pl. 1, figs. 7–10, text-fig. 12) from the upper Visean of the UK (England and Scotland), in general shape and external ornament of both ventral and dorsal valves, particularly in having relatively large ears and a median fold on front of ventral trail. The type species, *Productus productus* (Martin, 1809), refigured by Muir-Wood and Cooper (1960, pl. 72, figs. 7–12, 15) from the Visean of the UK (England and Isle of Man), is distinguished from the present species by its larger dimensions and in having smaller ears and a long, laterally spreading ventral trail.

Occurrence.—KU4 Unit.

Distribution.—Upper Visean–Bashkirian: northeastern Japan (Nagasaka in the South Kitakami Belt), UK (Scotland, England, Wales and northern Ireland), Spain (Cantabrian Mountains), western Russia (Moscow Basin), central Russia (southern Urals), Kazakhstan, Uzbekistan (Fergana), Kyrgyzstan (Tienshan), northwestern China (Xinjiang) and northeastern China (Jilin).

Superfamily ECHINOCONCHOIDEA Stehli, 1954
Family ECHINOCONCHIDAE Stehli, 1954
Subfamily ECHINOCONCHINAE Stehli, 1954
Genus *KARAVANKINA* Ramov□ 1969

Type species.—*Karavankina typica* Ramov□ 1969.

Karavankina jizodoensis Tazawa, 1980
(Figs. 17A, 18A–D)

Karavankina jizodoensis Tazawa, 1980, p. 362, pl. 41, figs. 8–16; pl. 42, fig. 14, text-fig. 2.
Karavankina sp. Tazawa, 1984, p. 306, pl. 61, fig. 2.

Material.—Eighteen specimens from locality OKA7: (1) external and internal moulds of a conjoined shell, IGPS96258 (holotype); (2) internal mould of a conjoined shell, with external mould of the dorsal valve, IGPS96263; (3) internal mould of a conjoined shell, IGPS96264; (4) external and internal moulds of two ventral valves, IGPS96259, 96260; (5) internal moulds of two ventral valves, IGPS96261, 96262; (6) external and internal moulds of two dorsal valves, IGPS96265, 96266; (7) external moulds of four dorsal valves, IGPS96267–96270; (8) internal moulds of three dorsal valves, IGPS96271–96273; and (9) external moulds of two valve fragments, IGPS96274, 96275.

Remarks.—The specimens from Jizodo, previously described by Tazawa (1980, p. 362, pl. 41, figs. 8–16; pl. 42, fig. 14, text-fig. 2.) as *Karavankina jizodoensis* Tazawa, 1980, are characterized by the large, transverse shells. *Karavankina* sp. Tazawa (1984, p. 306, pl. 61, fig. 2), from the upper part of the Hikoroichi Formation of Hikoroichi, South Kitakami Belt, is considered to be a synonym of the present species. *Karavankina dobsinensis* (Rakusz, 1932, p. 55, pl. 2, figs. 21, 22; pl. 3, fig. 2), from the Moscovian of Hungary, resembles *K. jizodoensis* in size and shape of the ventral valve, but it differs from the

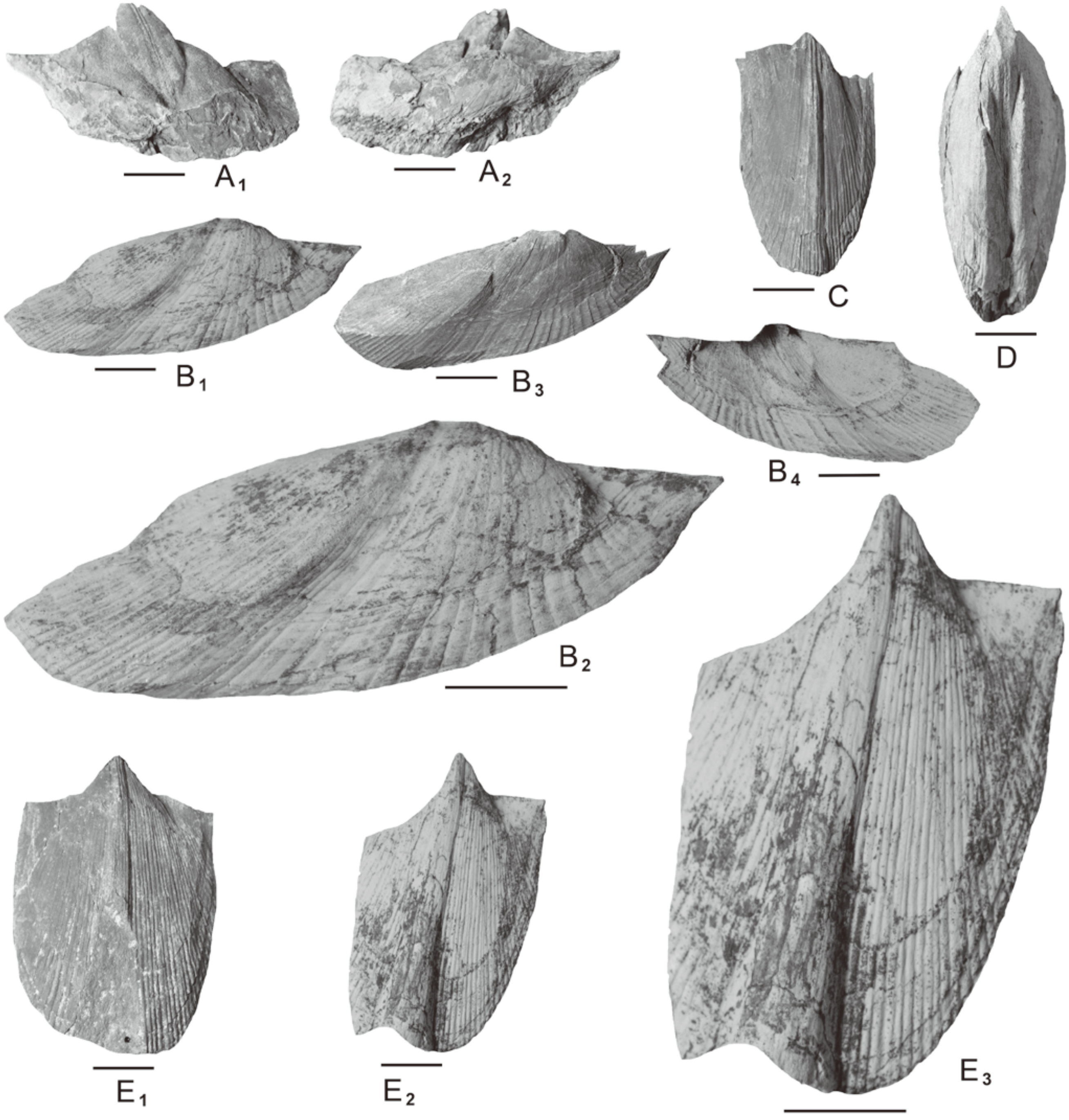

FIGURE 14. Brachiopods of the KU1 assemblage (3). **A–E,** *Unispirifer tornacensis* de Koninck; A, ventral (A_1) and dorsal (A_2) views of internal mould of conjoined shell, IGPS111857; B, external latex cast (B_1, B_2), internal mould (B_3) and internal latex cast (B_4) of ventral valve, IGPS111858; C, internal mould of dorsal valve, IGPS111862; D, internal mould of ventral valve, IGPS111859; E, internal mould (E_1) and external latex cast (E_2, E_3) of dorsal valve, IGPS111861. Scale bars are 1 cm.

Kitakami species in having more numerous narrower concentric lamellae on the ventral valve. *Karavankina* sp. described by Tazawa and Hasegawa (1994, p. 494, fig. 3) from the upper part of the Arakigawa Formation of Moribu, Hida Gaien Belt, central Japan, differs from *K. jizodoensis* in the less transverse shell.

Occurrence.— KU4 Unit.

Distribution.—Upper Visean: northeastern Japan (Hikoroichi and Nagasaka in the South Kitakami Belt).

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. 16G)

Balakhonia sp. Tazawa, 1980, p. 364, pl. 41, fig. 7.

Material.—One specimen from locality OKA7, external mould of a dorsal valve, IGPS96276.

Remarks.—This specimen was described by Tazawa (1980, p. 364, pl. 41, fig. 7) as *Balakhonia* sp. from the upper Visean of Jizodo in the Nagasaka area, South Kitakami Belt, on the basis of the transverse dorsal valve with wide hinge and the external ornament consisting of numerous costellae, some irregular rugae and very fine concentric growth lines. The Jizodo specimen most resembles the shells of *Balakhonia silimica* (Semichatova, 1964), redescribed by Sarytcheva (1968, p. 149, pl. 21, figs. 2–7; pl. 22, figs. 1–3, text-fig. 66) from the upper Carboniferous–lower Permian of eastern Kazakhstan, in the small-sized, transverse dorsal valve. *Balakhonia peregrina* Taboada (1997, p. 229, pl. 1, figs. 1–12), from the Pituil Formation (Westphalian) of San Juan, northwestern Argentina, is also a small-sized species, but differs from the Jizodo species in having less transverse dorsal valve. The type species, *Balakhonia ostrogensis* Sarytcheva (in Sarytcheva et al., 1963, p. 233, pl. 38, figs. 1–3, text-figs. 103, 104), from the Serpukhovian of the Kuznetsk Basin, central Russia, is clearly distinguished from the present species by its larger size and longer outline.

Occurrence.—KU4 Unit.

Genus *FLUCTUARIA* Muir-Wood and Cooper, 1960

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

Fluctuaria sp.
(Fig. 16F)

Material.—One specimen from locality OKA7, external and internal moulds of a ventral valve, IGPS112084.

Remarks.—This specimen is poorly preserved but can be assigned to the genus *Fluctuaria* by the external ornament of the ventral valve, consisting of closely spaced flexuous concentric rugae and numerous fine capillae, numbering 4 rugae in 5 mm, and 6–7 capillae in 2 mm at midlength of the valve. The Jizodo species resembles the type species, *Fluctuaria undata* (Defrance, 1826), refigured by Muir-Wood and Cooper (1960, pl. 115, figs. 11–20) from the Visean of Belgium and the UK (Isle of Man), in general shape and external ornament of the ventral valve. But accurate comparison is difficult for the fragmentarily preserved specimen.

Occurrence.—KU4 Unit.

Order ORTHIDA Schuchert and Cooper, 1932
Suborder DALMANELLIDINA Moore, 1952
Superfamily DALMANELLOIDEA Schuchert, 1913b
Family RHIPIDOMELLIDAE Schuchert, 1913b
Subfamily RHIPIDOMELLINAE Schuchert, 1913b
Genus *RHIPIDOMELLA* Oehlert, 1890

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

Rhipidomella kusbassica Beznossova in Sarytcheva et al., 1963
(Fig. 12G, H)

Rhipidomella michelini (non Léveillé). Tolmatchoff, 1924, p. 212, 569, pl. 13, fig. 4; Nalivkin, 1937, p. 36, pl. 3, figs. 6, 7.
Rhipidomela kusbassica Beznossoba in Sarytcheva et al., 1963, p. 74, pl. 2, figs. 9–11; Grechishnicova, 1966, p. 91, pl. 1, figs. 5–10; Zhang et al., 1983, p. 264, pl. 106, fig. 9; Tazawa and Kurita, 2019a, p. 221, fig. 4A.

Material.—Four specimens from locality NKA8: (1) internal mould of a ventral valve, IGPS111828; and (2) internal moulds of three dorsal valves, IGPS111829–111831.

Remarks.—These specimens are poorly preserved, but can be referred to *Rhipidomella kusbassica* Beznossova in Sarytcheva et al. (1963, p. 74, pl. 2, figs. 9–11) from the lower Tournaisian–lower Visean of the Kuznetsk Basin, central Russia, by the small, slightly elongate subcircular dorsal valve with a relatively wide hinge (length 21 mm, width 18 mm, hinge width 15 mm in the best preserved dorsal valve specimen, IGPS111831), and the interior with strong brachiophores diverging anteriorly. *Rhipidomella altaica* Tolmatchoff (1924, p. 213, 569, pl. 13, figs. 5–7, 9, 10), from the Tournaisian of the Kuznetsk Basin, also has a wide hinge, but differs from *R. kusbassica* in being more transverse outline and in having slightly shorter hinge. The type species, *Rhipidomella michelini* (Léveillé), redescribed by Brunton (1968, p. 17, pl. 3, figs. 1–25, text-fig. 5) from the Visean of Fermanagh, northern Ireland, is readily distinguished from *R. kusbassica* in the subtrigonal shell with a much shorter hinge.

Occurrence.—KU1 Unit.

Distribution. —Lower Tournaisian–lower Visean: northeastern Japan (Okuhinotsuchi and Nagasaka in the South

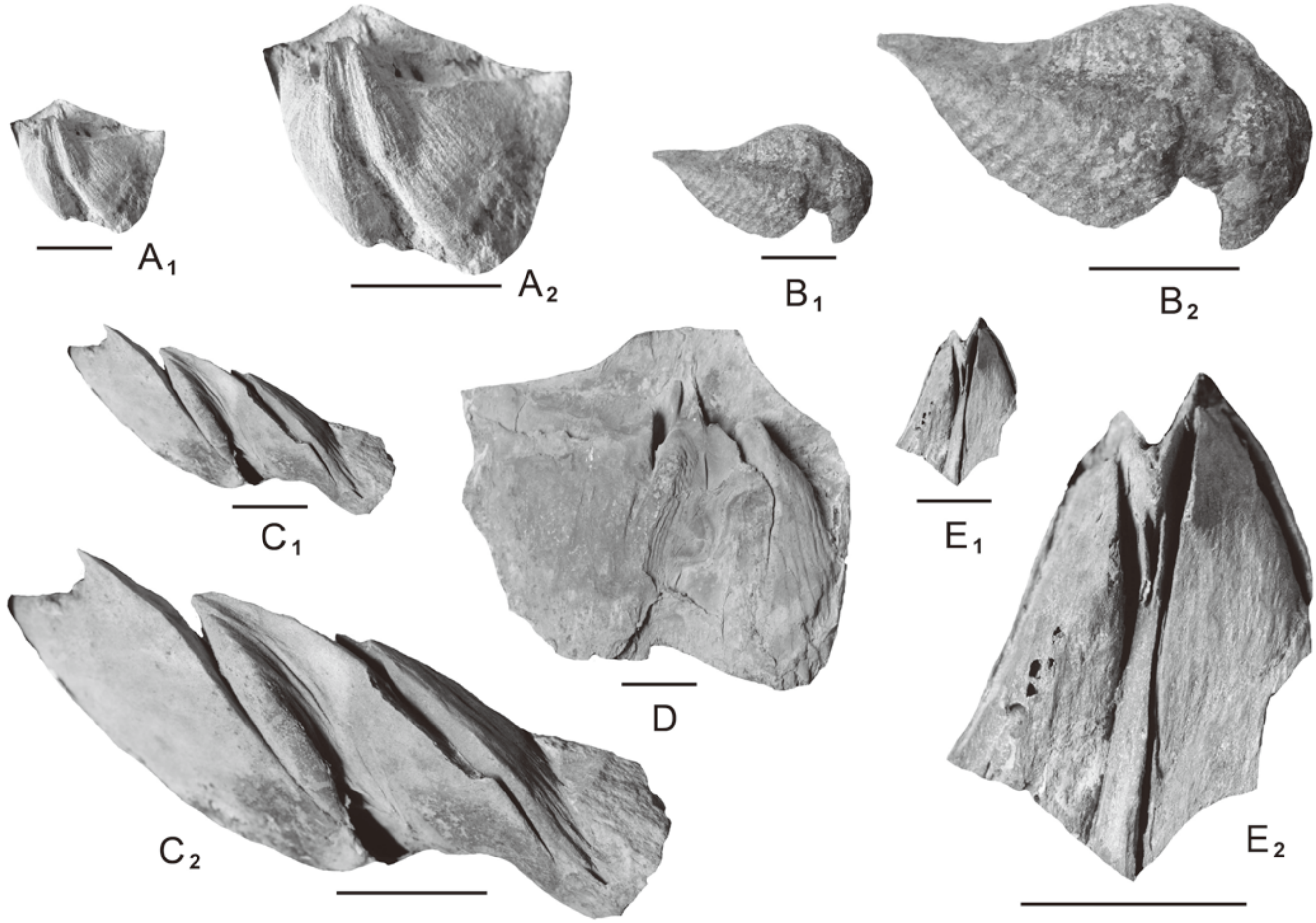

FIGURE 15. Brachiopods of the KU1 assemblage (4). **A, B,** *Unispirifer kozuboensis* (Minato); A, internal mould (A1, A2) of ventral valve, IGPS111864; B, internal mould (B1, B2) of ventral valve, IGPS111863; **C, D,** *Syringothyris japonica* Tachibana; C, internal mould (C1, C2) of ventral valve, IGPS111872; D, internal mould of ventral valve, IGPS111871; **E,** *Syringothyris karaumedatensis* Tachibana, posterior view of internal mould of ventral valve (E1, E2), IGPS111870. Scale bars are 1 cm.

Kitakami Belt), central Russia (Kuznetsk Basin), Kazakhstan and northwestern China (Xinjiang).

Order RHYNCHONELLIDA Kuhn, 1949
Superfamily RHYNCHOTREMATOIDEA Schuchert, 1913a
Family TRIGONIRHYCHIIDAE Schmidt, 1965
Subfamily TRIGONIRHYNCHIINAE Schmidt, 1965
Genus *MACROPOTAMORHYNCHUS* Sartenaer, 1970

Type species.—*Camarotoechia mitcheldeanensis* Vaughan, 1905.

Macropotamorhynchus sp.
(Fig. 12A–D)

Material.—Five specimens from localities OKA15 and OKA17: (1) external and internal moulds of a dorsal valve, IGPS111832; and (2) internal moulds of four dorsal valves, IGPS111833–111836.

Description.—Shell medium in size for genus, outline variable, ranging from longitudinally subtrigonal to transversely subpentagonal, with greatest width at slightly anterior to midlength; length 10 mm, width 14 mm in the largest dorsal valve specimen (IGPS111832); length 9 mm, width 8 mm in the smallest dorsal valve specimen (IGPS111833). Dorsal valve strongly and unevenly convex in lateral profile, slightly flattened medially; fold broad and low. External surface of dorsal valve ornamented with numerous radial costae, numbering 4–6 on each lateral slope, and 4–5 in fold. Dorsal interior with a long median septum, extending to about midlength.

Remarks.—These specimens are lacking the ventral valve, but can be assigned to the genus *Macropotamorhynchus* by their small size, subtrigonal to subpentagonal outline, and the dorsal valve with a weak fold. The Nagasaka species most resembles *Macropotamorhynchus curiosus* Carter (1987, p. 45, pl. 16, figs. 1–48, text-figs. 9, 10), from the middle part of the Banff

Formation (*Calvustrigis rutherfordi* Zone) of western Alberta, Canada, in variable shape of the dorsal valve. But accurate comparison is difficult for the poorly preserved material. The type species, *Macropotamorhynchus micheldeanensis* (Vaughan, 1905, p. 302, pl. 26, fig. 7, text-fig. 6), from the lower Tournaisian of Gloucestershire, England, differs from the present species in the smaller size and more transverse outline.

Occurrence.—KU1 Unit.

Order ATHYRIDIDA Boucot, Johnson and Staton, 1964
Suborder ATHYRIDIDINA Boucot, Johnson and Staton, 1964
Superfamily ATHYRIDOIDEA Davidson, 1881
Family ATHYRIDIDAE Davidson, 1881
Subfamily CLEIOTHYRIDININAE Alvarez, Rong and Boucot, 1998
Genus *CLEIOTHYRIDINA* Buckman, 1906

Type species.—*Atrypa pectinifera* Sowerby, 1840.

Cleiothyridina submabranacea (Grabau in Chu, 1933)
(Fig. 12F)

Athyris submabranacea Grabau in Chu, 1933, p. 53, pl. 5, figs. 8–13.
Cleiothyridina submabranacea (Grabau). Chen and Archbold, 2000, p. 191, figs. 5.27–5.28; Xu and Yao, 1988, p. 284, pl. 72, fig. 3; pl. 73, fig. 1.

Material.—One specimen from locality OKA5, external and internal moulds of a ventral valve, IGPS111837.

Remarks.—This specimen can be referred to *Cleiothyridina submabranacea* (Grabau in Chu, 1933), described by Grabau (in Chu, 1933, p. 53, pl. 5, figs. 8–13) from the Jinling Formation of Jiangsu, eastern China, by the small, elongate pentagonal ventral valve (length 19 mm, width 12 mm), with a narrow and shallow sulcus, and ornamented by very dense concentric growth lamellae with numerous spines. *Cleiothyridina tenuilineata* (Rowley, 1900), redescribed by Carter (1967, p. 344, pl. 16, figs. 8–14, text-fig. 21) from the Chappel Limestone of central Texas, differs from *C. submabranacea* by the more transverse outline.

Occurrence.—KU1 Unit.

Distribution.—Upper Devonian (Famennian)–upper Tournaisian: northeastern Japan (Nagasaka in the South Kitakami Belt), northwestern China (Xinjiang), eastern China (Jiangsu) and central-southern China (Guangxi).

Cleiothyridina harkeri Carter, 1987
(Fig. 12E)

Cleiothyridina harkeri Carter, 1987, p. 60, pl. 19, figs. 2–27.

Material.—One specimen from locality OKA5, internal mould of a ventral valve, IGPS111838.

Remarks.—This specimen is referred to *Cleiothyridina harkeri* Carter, 1987, described by Carter (1987, p. 60, pl. 19, figs. 2–27) from the upper part of the Banff Formation (*Stegacanthia* cf. *bowsheri*–*Marginatia fernglenensis* Zone) of Alberta, western Canada, by the large size (length about 44 mm, width about 47 mm), transverse subelliptical outline, faintly preserved very dense growth lamellae on the ventral valve and very shallow ventral sulcus. Both species, *Cleiothyridina glabristria* (Phillips, 1836), redescribed by Brunton (1980, p. 229, fig. 25) from the lower Carboniferous of Yorkshire, England and *Cleiothyridina obmaxima* (McChesney, 1861), redescribed by Weller (1914, p. 475, pl. 79, figs. 1–11) from the Kinderhookian and Osagean of the Mississipi Valley, USA, are also large-sized *Cleiothyridina* species, but these species differ from *C. harkeri* in having well developed fold and sulcus.

Occurrence.—KU1 Unit.

Distribution.—Upper Tournaisian: northeastern Japan (Nagasaka in the South Kitakami Belt) and western Canada (Alberta).

Suborder RETZIIDINA Boucot, Johnson and Staton, 1964
Superfamily RETZIOIDEA Waagen, 1883
Family NEORETZIIDAE Dagys, 1972
Subfamily HUSTEDIINAE Grunt, 1986
Genus *HUSTEDIA* Hall and Clarke, 1893

Type species.—*Terebratula mormoni* Marcou, 1858.

Hustedia sp.
(Fig. 19A–D)

Yanishewskiella? sp. Tazawa, 1980, p. 364, pl. 42, figs. 1–4.

Material.—Four specimens from locality OKA7: (1) external and internal moulds of a ventral valve, IGPS96277; (2) external mould of a ventral valve, IGPS96278; and (3) external moulds of two dorsal valves, IGPS96279, 96280.

Remarks.—These specimens were described as *Yanishewskiella*? sp. by Tazawa (1980, p. 364, pl. 42, figs. 1–4). The Jizodo species is now redescribed as *Hustedia* sp. The present species somewhat resembles *Hustedia ratburiensis* Waterhouse and Piyasin (1970, p. 138, pl. 23, figs. 15–30), from the middle Permian (Wordian) of Khao Phrik, southern Thailand, in size (length 12 mm, width 8 mm in the larger dorsal valve specimen, IGPS96279) and external ornament (consisting of simple, rounded costae and numerous fine concentric lamellae) of both valves, but differs from the Thailand species in being subtrigonal outline and in having fewer costae on the both ventral and dorsal valves. *Hustedia remota* (Eichwald), redescribed by Tschernyschew (1902, p. 107, pl. 47, figs. 8–11), from the lower Permian (*Schwagerina* Limestone) of Ufa, southern Urals, is distinguished from the present species by having more numerous costae in the both valves.

Occurrence.—KU4 Unit.

Order SPIRIFERIDA Waagen, 1883
Suborder SPIRIFERIDINA Waagen, 1883

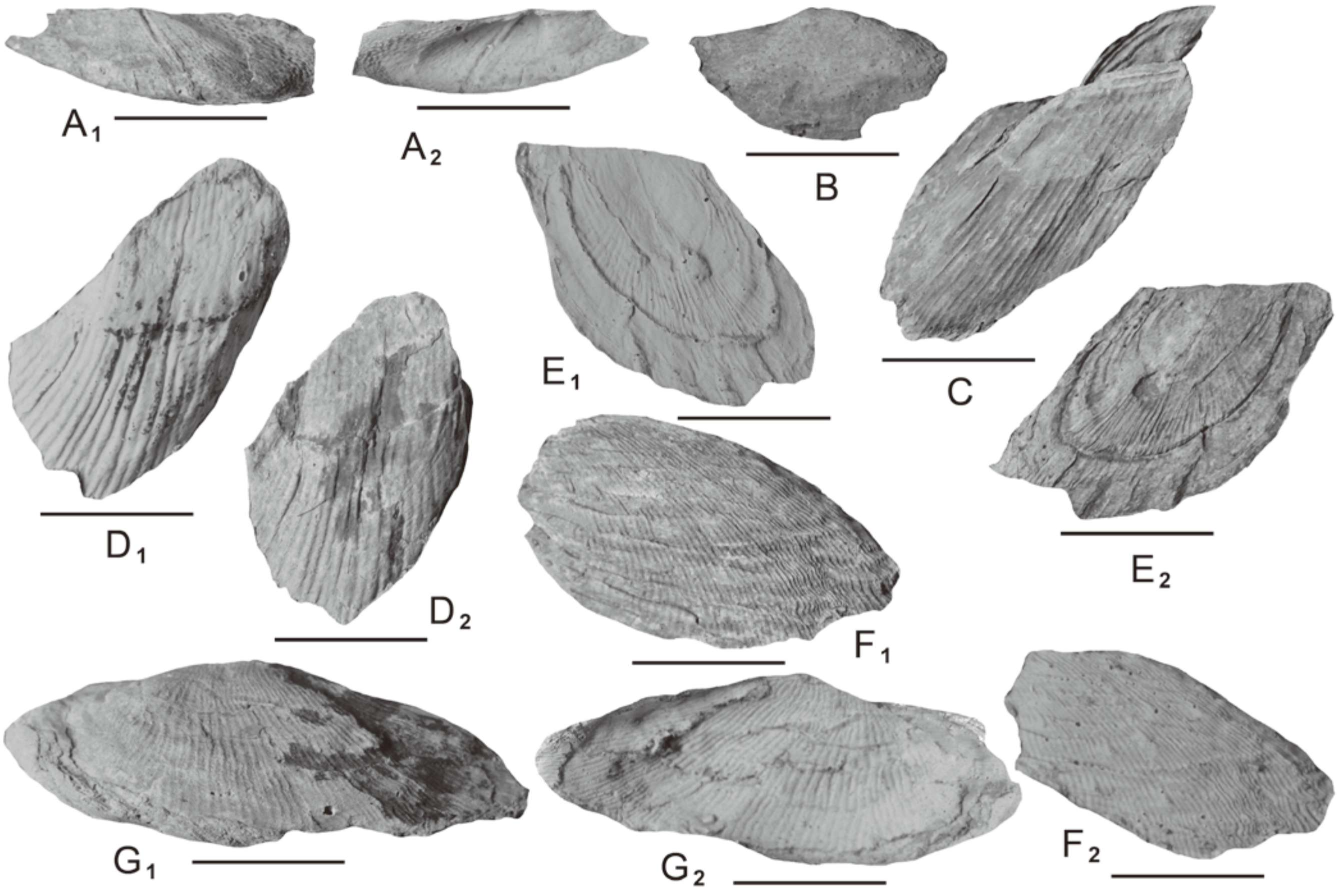

FIGURE 16. Brachiopods of the KU4 assemblage (1). **A,** *Rugosochonetes* sp., internal mould (A_1) and internal latex cast (A_2) of ventral valve, IGPS96252; **B,** *Krotovia* sp., external mould of dorsal valve, IGPS96253; **C–E,** *Productus concinnus* Sowerby; C, internal mould of ventral valve, IGPS96255; D, external latex cast (D_1) and internal mould (D_2) of ventral valve, IGPS96254; E, external latex cast (E_1) and external mould (E_2) of dorsal valve, IGPS96257; **F,** *Fluctuaria* sp., internal mould (F_1) and external latex cast (F_2) of ventral valve, IGPS112084; **G,** *Balakhonia* sp., external mould (G_1) and external latex cast (G_2) of dorsal valve, IGPS96276. Scale bars are 1 cm.

Superfamily MARTINIOIDEA Waagen, 1883
Family MARTINIIDAE Waagen, 1883
Subfamily MARTINIINAE Waagen, 1883
Genus *MARTINIA* M'Coy, 1844

Type species.—*Spirifer glaber* Sowerby, 1820

Martinia georgei Tazawa, sp. nov.
(Fig. 19E–J)

Martinia aff. *glabra* (Martin). George, 1927, p. 112, text-figs. 3–11; Demanet, 1938, p. 103, pl. 9, figs. 24–29.
Spirifer (*Martinia*) *glaber* Martin. Einor, 1936, p. 40, pl. 7, figs. 4, 5.
Martinia glabra (Martin). Yang, 1964, p. 141, pl. 21, figs. 3, 4, text-fig. 32A; Litvinovich in Litvinovich et al., 1969, p. 275, pl. 68, fig. 1; Donakova, 1983, pl. 3, fig. 8.
Martinia glabra (non Sowerby). Poletaev, 1975, p. 43, pl. 9, figs. 1, 2; Chen and Shi, 2003, p. 168, pl. 11, figs. 1–8, 12–17, 37, 39.
Martinia sp. Tazawa and Osawa, 1979, p. 775, text-fig. 2.
Martinia aff. *glabra* (Sowerby). Tazawa, 1980, p. 366, pl. 42, figs. 6–11; Tazawa, 1981, p. 74, pl. 5, figs. 9–13; Tazawa et al., 1981, pl. 1, figs. 1–3.

Etymology.—Named for Thomas N. George, who first recognized the present species from the upper Visean of the South Wales.

Material.—Thirty-three specimens from locality OKA7: (1) internal moulds of three conjoined shells, with external moulds of the ventral valves, IGPS96285–96287; (2) internal moulds of three conjoined shells, with external moulds of the dorsal valves, IGPS96288–96290; (3) external and internal moulds of a ventral valve, IGPS96291; (4) internal moulds of four conjoined shells, IGPS96292, 96293, 96294 (holotype), 96295; and (5) internal moulds of twenty-two ventral valves, IGPS96296–96317.

Diagnosis.—Medium-sized *Martinia*, having very short hinge, well rounded cardinal extremities, broad and shallow

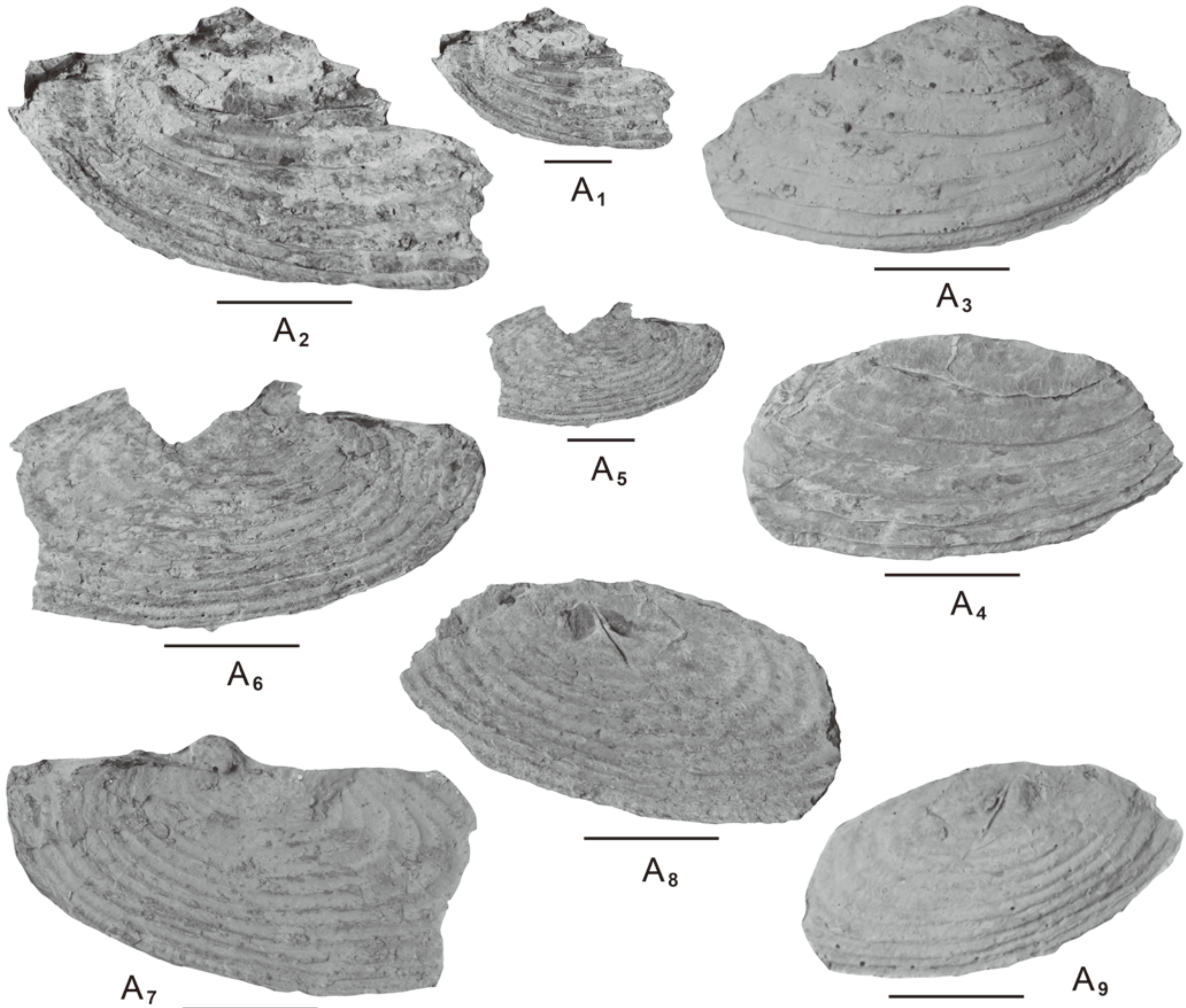

FIGURE 17. Brachiopods of the KU4 assemblage (2). **A,** *Karavankina jizodoensis* Tazawa, external mould (A1, A2), external latex cast (A3), internal mould (A4) of ventral valve, and external mould (A5, A6), external latex cast (A7), internal mould (A8) and internal latex cast (A9) of dorsal valve, IGPS96258. Scale bars are 1 cm.

ventral sulcus and broad and low dorsal fold, and 7–13 radial vascular markings in ventral valve.

Description.—Shell medium in size for genus, transversely subelliptical in outline; cardinal extremities well rounded; hinge straight, much less than greatest width at slightly anterior to midlength; length 23 mm, width 51 mm in the largest specimen (IGPS96291); length about 21 mm, width about 30 mm in the holotype (IGPS96294). Ventral valve gently convex except for umbo in lateral profile; sulcus broad and shallow, originating at slightly posterior to midlength and extending to anterior valve margin. Dorsal valve slightly convex on posterior portion, but almost flattened anterolaterally; fold broad and low on anterior half of valve. External surface of both valves entirely smooth. Ventral interior with a muscle scar and 7–13 vascular markings; muscle scar small, rhomboidal and placed at slightly below umbo; vascular markings radially branching out from base of muscular scar and extending to two-thirds length of valve. Dorsal interior with a pair of elongate muscle scars; vascular markings not observed.

Remarks.—These specimens were figured or described by Tazawa and Osawa (1979, p. 775, text-fig. 2) and Tazawa (1980, p. 366, pl. 42, figs. 6–11) as *Martinia* sp. and *Martinia* aff. *glabra* (Sowerby, 1820), respectively. But the Jizodo specimens referred to *Martinia* aff. *glabra* (Martin, 1809), described by George (1927, p. 112, text-figs. 3–11) from the upper Visean of Wales. In this paper the senior author (Tazawa) redescribes the Jizodo species as a new species, *Martinia georgei* Tazawa, sp. nov. *Martinia glabra* (Sowerby, 1820), redescribed by Muir-Wood (1951, p. 109, pl. 3, fig. 2), from the upper Visean of Derbyshire, England, differs from the present new species in the much larger dimensions.

Occurrence.—KU4 Unit.

Distribution.— Lower Visean–Bashkirian: northeastern Japan (Nisawa and Nagasaka in the South Kitakami Belt), UK (Wales), Belgium, western Russia (Donetz Basin), central Russia (western Urals and southern Urals), Kazakhstan and northwestern China (Xinjiang).

Subfamily EOMARTINIOPSINAE Carter in Carter et al., 1994

Genus *GLOBISPIRIFER* Tachibana, 1964

Type species.—*Spirifer* (*Martiniopsis*?) *nagasakaensis* Tachibana, 1956.

Globispirifer nagasakaensis (Tachibana, 1956)

(Fig. 13A–F)

Spirifer (*Martiniopsis*?) *nagasakaensis* Tachibana, 1956, p. 13, pl. 1, figs. 15–20.

Globispirifer nagasakaensis (Tachibana). Tachibana, 1964, p. 37; Chen and Tazawa, 2007, p. 38, figs. 2, 3; Tazawa and Taira, 2012, p. 141, fig. 3.

Material.—Fourteen specimens from localities NKA8, NKA11, OKA4, OKA5, OKA9, OKA11 and OKA15: (1) internal mould of a conjoined shell, with external mould of the ventral valve, IGPS111839; (2) external and internal moulds of a ventral valve, IGPS111840; (3) internal moulds of seven ventral valves, IGPS111841–111847; and (4) internal moulds of five dorsal valves, IGPS111848–111852.

Remarks.—These specimens are referred to *Globispirifer nagasakaensis* (Tachibana, 1956), redescribed by Chen and Tazawa (2007) from the lower part of the Karaumedate Formation in the Nagasaka area, South Kitakami Belt, in the biconvex shell with elongate oval to subcircular outline (length about 47 mm, width about 38 mm in the largest specimen, IGPS111843; length 26 mm, width 31 mm in the best preserved specimen, IGPS111839), and smooth external surface of ventral valve. Internally, both valves having well-developed, blade-like and slightly diverging adminicula extending forward about one-third length of the valves. *G. nagasakaensis* is the most abundant brachiopod species in the Karaumedate fauna. The genus *Globispirifer* consists of the type species only.

Occurrence.—KU1 Unit.

Distribution.—Tournaisian: northeastern Japan (Nagasaka and Soma in the South Kitakami Belt).

Superfamily SPIRIFEROIDEA King, 1846

Family SPIRIFERIDAE King, 1846

Subfamily PROSPIRINAE Carter, 1974

Genus *PROSPIRA* Maxwell, 1954

Type species.—*Prospira typa* Maxwell, 1954.

Prospira nodai (Tachibana, 1956)

(Fig. 13J–L)

Spirifer nodai Tachibana, 1956, p. 11, pl. 1, figs. 1—14.

Prospira nodai (Tachibana). Tachibana, 1969, p. 19.

Material.—Three specimens from locality OKA5: (1) internal moulds of two ventral valves, IGPS111853, 111854; and (2) internal mould of a dorsal valve, IGPS111855.

Remarks.—These specimens are referred to *Prospira nodai* (Tachibana, 1956), originally described by Tachibana (1956, p. 11, pl. 1, figs. 1–14) as *Spirifer nodai* Tachibana, 1956, from the lower part of the Karaumedate Formation in the Nagasaka area, South Kitakami Belt, in being small size (length about 18 mm, width more than 15 mm in the largest specimen, IGPS111853) and the presence of four costae in the dorsal fold. The Nagasaka species most resembles the type species, *Prospira typa* (Maxwell, 1954, p.35, pl. 4, figs. 6–8), from the upper Tournaisian–lower Visean of the Yarrol Basin, eastern Australia, in size and outline of the shell, but accurate comparison is difficult for the poor preservation of the present material. Tachibana (1956, p. 12) noted that the Nagasaka species closely resembles *Prospiria lousianensis* (Rowley, 1900), redescribed by Weller (1914, p. 322, pl. 40, figs. 1–23) from the upper Kinderhookian and the lower Osagean of the Mississippi Valley, but the American species is much smaller in size.

Occurrence.—KU1 Unit.

Genus *FINOSPIRIFER* Yin, 1981

Type species.—*Finospirifer taotangensis* Yin, 1981.

Finospirifer shaoyangensis (Ozaki, 1939)

(Fig. 13M)

Spirifer shaoyangensis Ozaki, 1939, p. 257, pl. 41, fig. 1.

Finospirifer shaoyangensis (Ozaki). Yin, 1981, p. 238, pl. 1, figs. 5, 10, 14; Tan, 1986, p. 439, pl. 3, figs. 1–3; Tan, 1987, p. 130, pl. 19, figs. 25–27; Shi, 1988, pl. 2, figs. 6, 11.

Material.—One specimen from locality OKA5, internal mould of a dorsal valve, IGPS111856.

Remarks.—This specimen is poorly preserved, but can be referred to *Finospirifer shaoyangensis* (Ozaki, 1939, p. 257, pl. 41, fig. 1), from the Mengongao Formation of Hunan, eastern China, by the relatively small (length 34 mm, width more than 30 mm), subtrigonal dorsal valve, with high and prominent fold and numerous simple costae (numbering 5 costae in 5 mm at

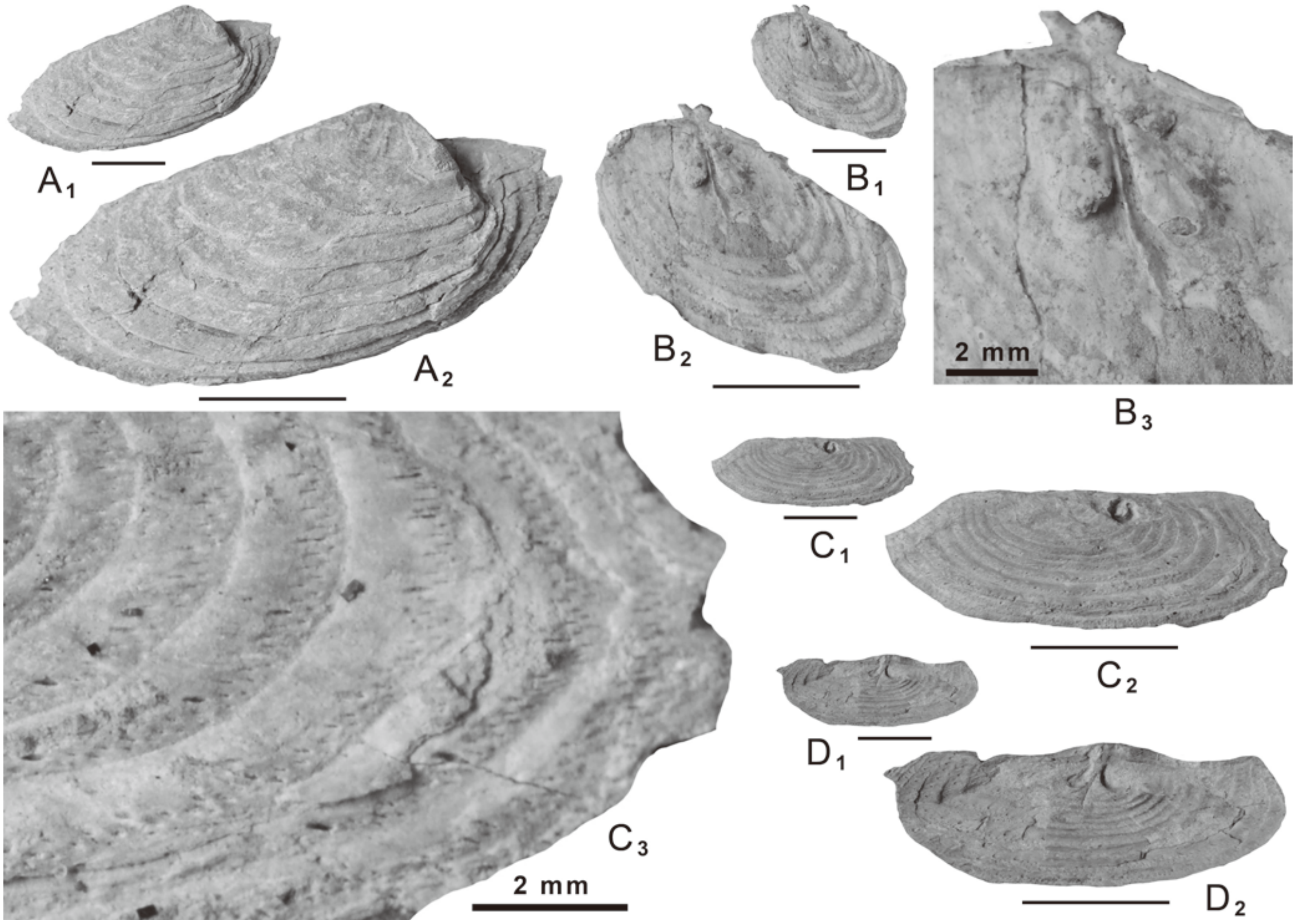

FIGURE 18. Brachiopods of the KU4 assemblage (3). **A–D,** *Karavankina jizodoensis* Tazawa; A, internal mould (A1, A2) of ventral valve, IGPS96261; B, internal latex cast of dorsal valve (B1, B2) and the posterior portion, showing cardinal process, lateral ridges, buttress plates and median septum (B3), IGPS96264; C, external mould of dorsal valve (C1, C2) and the enlarged portion, showing elongate spine bases (C3), IGPS96265; D, internal mould (D1, D2) of dorsal valve, IGPS96205. Scale bars are 1 cm, except for B3 and C3.

anterior margin) on the lateral slopes. The type species, *Finospirifer taotangensis* Yin (1981, p. 237, pl. 1, figs. 1–4), from the Mengongao Formation at Xikuangshan of Xinhua, Hunan Province, central-southern China differs from *F. shaoyangensis* in the larger size and in having fewer and stronger costae on lateral slope of the dorsal valve.

Occurrence.—KU1 Unit.

Distribution.—Upper Tournaisian: northeastern Japan (Nagasaka in the South Kitakami Belt) and eastern China (Hunan).

Genus *UNISPIRIFER* Campbell, 1957

Type species.—*Spirifera striatoconvoluta* Dun and Benson, 1920.

Unispirifer tornacensis (de Koninck, 1883)
(Fig. 14A–E)

Spirifer tornacensis de Koninck, 1883, p. 373, pl. 13, figs. 1–9: Frech, 1916, p. 230, pl. 2, fig. 1.

Unispirifer tornacensis (de Koninck). Campbell, 1957, p. 67.

Atylephorus tornacensis (de Koninck). Sartenaer and Plodowski, 1996, p. 60, pl. 1, figs. 1–10; pl. 2, figs. 11–19; pl. 3, figs. 27–41; pl. 4, figs. 42–58; pl. 5, figs. 60–73.

Unispirifer (*Atylephorus*) *tornacensis* (de Koninck). Shi et al., 2005, p. 57.

Material.—Six specimens from localities NKA11, OKA5, OKA10 and OKA17: (1) internal mould of a conjoined shell, IGPS111857; (2) external and internal moulds of a ventral valve, IGPS111858; (3) internal moulds of two ventral valves, IGPS111859, 111860; (4) external and internal moulds of a dorsal valve, IGPS111861; and (5) internal mould of a dorsal valve, IGPS111862.

Description.—Shell large in size for genus, transversely

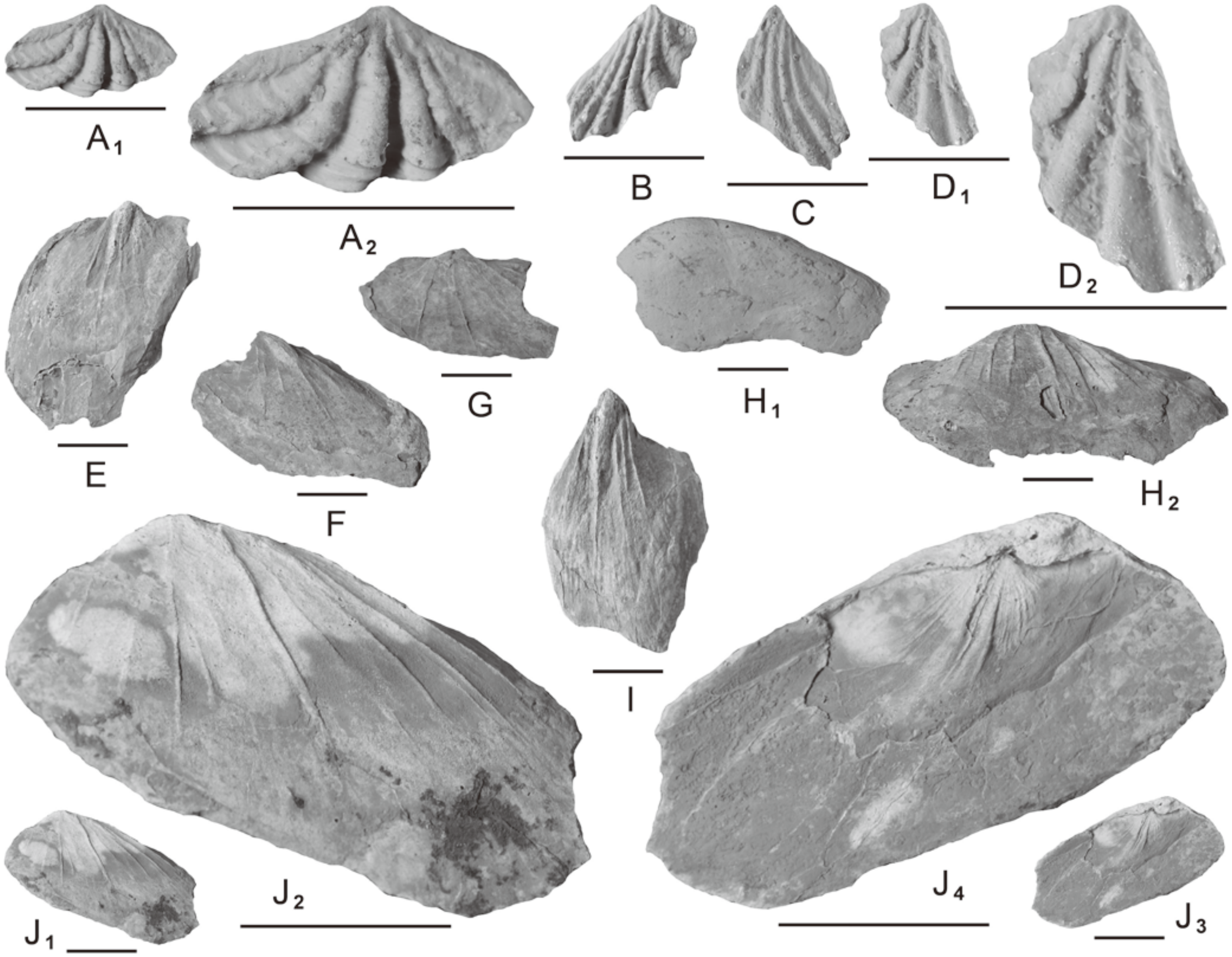

FIGURE 19. Brachiopods of the KU4 assemblage (4). **A–D,** *Hustedia* sp.; A, external latex cast (A_1, A_2) of ventral valve, IGPS96277; B, external latex cast of ventral valve, IGPS96278; C, external latex cast of dorsal valve, IGPS96279; D, external latex cast (D_1, D_2) of dorsal valve, IGPS96280; **E–J,** *Martinia georgei* Tazawa, sp. nov.; E, internal mould of ventral valve, IGPS96315; F, internal mould of ventral valve, IGPS96313; G, internal mould of ventral valve, IGPS96296; H, external latex cast (H_1) and internal mould (H_2) of ventral valve, IGPS96291; I, internal mould of ventral valve, IGPS96307; J, internal mould of ventral valve (J_1, J_2) and internal mould of dorsal valve (J_3, J_4), IGPS96294 (holotype). Scale bars are 1 cm.

subrectangular in outline, cardinal extremities mucronate, with greatest width at hinge; length about 22 mm, width about 55 mm in the largest ventral valve specimen (IGPS111858). Ventral valve moderately and unevenly convex in lateral profile, most convex at umbonal region; sulcus narrow and shallow, not clearly demarcated from lateral slopes. Dorsal valve gently convex in both lateral and anterior profiles; fold narrow and moderately high. External surface of both valves ornamented with numerous flatly rounded costae with narrow intercostal grooves and some irregular concentric rugae on whole of valves; numbering 6–7 costae in 10 mm at anterior margin of ventral lateral slopes; number of costae on sulcus and fold being between 6–12. Micro-ornament consisting of closely spaced growth lines and fine radial capillae. Ventral interior with short, stout and diverging dental plates; muscle field elongate subelliptical in outline, bilobate posteriorly, and moderately impressed. Internal structures of dorsal valve not well preserved.

Remarks.—These specimens are referred to *Unispirifer tornacensis* (de Koninck, 1883), redescribed by Sartenaer and Plodowski (1996, p. 60, pl. 1, figs. 1–10; pl. 2, figs. 11–19; pl. 3, figs. 27–41; pl. 4, figs. 42–58; pl. 5, figs. 60–73) as *Atylephorus tornacensis* (de Koninck, 1883) on the type specimens from the upper Tournaisian of Tournai, Belgium, in the large, transverse shell, with mucronate cardinal extremities and shallow ventral sulcus, and ornamented with numerous flattened costae, irregularly spaced concentric rugae, and micro-ornament

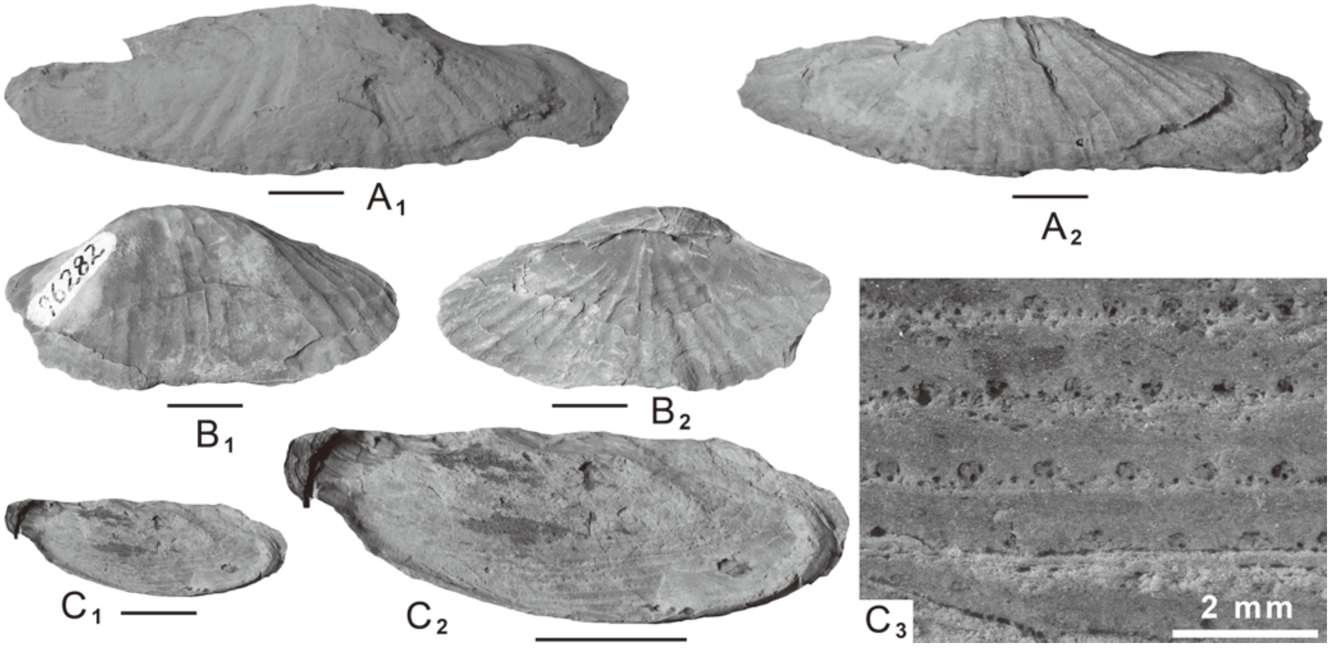

FIGURE 20. Brachiopods of the KU4 assemblage (5). **A, B,** *Brachythyrina* sp.; A, external latex cast (A_1) and internal mould (A_2) of ventral valve, IGPS96281; B, internal mould of ventral valve (B_1) and internal mould of dorsal valve (B_2), IGPS96282; **C,** *Phricodothyris* sp., external mould of dorsal valve (C_1, C_2) and the enlarged portion, showing concentrically arranged biramous spine bases and interspinous pustules (C_3), IGPS96284. Scale bars are 1 cm, except for C_3.

consisting of very fine growth lines and capillae. *U. tornacensis* was assigned to the genus *Atylephorus* by Sartenaer and Plodowski (1996, p. 60), or to the subgenus *Unispirifer* (*Atylephorus*) by Shi et al. (2005, p. 57). However, I consider that this species belongs to the genus *Unispirifer*, following Carter (2006a, p. 1777). The type species, *Unispirifer striatoconvolutus* (Dun and Benson, 1920, p. 350, pl. 20, figs. 7, 8), from the Lower Burindi Group of Babbinboon, New South Wales, eastern Australia, is readily distinguished from *U. tornacensis* by the much transverse outline.

Occurrence.—KU1 Unit.

Distribution.—Upper Tournaisian: northeastern Japan (Nagasaka in the South Kitakami Belt), Belgium and Turkey (Taurus Mountains).

Unispirifer kozuboensis (Minato, 1952)
(Fig. 15A, B)

Spirifer kozuboensis Minato, 1952, p. 155, pl. 5, fig. 7; Minato et al., 1979, pl. 18, fig. 5.

Unispirifer kozuboensis (Minato). Tazawa and Kurita, 1986, p. 167, fig. 2.1; Tazawa, 2018, p. 66, fig. 28A–E; Tazawa and Kurita, 2019a, p. 223, fig. 4G, H.

Material.—Two specimens from localities NKA4 and NKA8, internal moulds of two ventral valves, IGPS111863, 111864.

Remarks.—These specimens are referred to *Unispirifer kozuboensis* (Minato, 1952), originally described by Minato (1952, p. 155, pl. 5, fig. 7) from the D_0 Zone of the Arisu Series (= middle part of the Arisu Formation) of Kozubo (Otsubo), Yokota area, South Kitakami Belt, in the medium size (length about 18 mm, width about 45 mm in the larger specimen, IGPS111863) and in having acute cardinal extremities. The preceding species, *Unispirifer tornacensis* (de Koninck, 1883) differs from *U. kozuboensis* in the much larger dimensions.

Occurrence.—KU1 Unit.

Distribution.—Upper Tournaisian–lower Visean: northeastern Japan (Hikoroichi, Yokota, Okuhinotsuchi and Nagasaka in the South Kitakami Belt).

Family CHORISTITIDAE Waterhouse, 1968
Subfamily ANGIOSPIRIFERINAE Legrand-Blain, 1985
Genus *BRACHYTHYRINA* Fredericks, 1929

Type species.—*Spirifer strangwaysi* de Verneuil, 1845.

Brachythyrina sp.
(Fig. 20A, B)

Brachythyris cf. *elliptica* Roberts. Tazawa, 1980, p. 365, pl. 42, figs. 12, 13.

Material.—Three specimens from locality OKA7: (1) internal moulds of a conjoined shell, IGPS96282; (2) extermal and internal moulds of a ventral valve, IGPS96281; and (3) internal mould of a ventral valve, IGPS96283.

Remarks.—These specimens were described by Tazawa (1980, p. 365, pl. 42, figs. 12, 13) as *Brachythyris* cf. *eliptica* Roberts, 1963. But the Jizodo species is assigned to the genus *Brachythyrina* in having ventral sulcus with four or five simple costae. This species most resembles *Brachythyrina rectangula* (Kutorga, 1844), redescribed and refigured by Tschernyschew (1902, p. 158, 545, pl. 8, fig. 1; pl. 41, figs. 1–5) from the lower Permian (Sakmarian) of the Urals, by the large size and the transverse outline. However, accurate comparison with the Russian species is difficult owing to ill preservation of the present material.

Occurrence.—KU4 Unit.

Superfamily PAECKERMANELLOIDEA Ivanova, 1972
Family STROPHOPLEURIDAE Carter, 1974
Subfamily STROPHOPLEURINAE Carter, 1974
Genus *ACUMINOTHYRIS* Roberts, 1963

Type species.—*Acminothyris triangularis* Roberts, 1963.

Acuminothyris keokuk Carter, 1990
(Fig. 13H, I)

Acuminothyris keokuk Carter, 1990, p. 236, figs. 8.1–8.9; Chen and Archbold, 2000, p. 193, figs. 5.1–5.4; Tazawa, 2018, p. 70, figs. 19D–F.

Material.—Four specimens from localities OKA5 and OKA6: (1) external and internal moulds of a dorsal valve, IGPS111865; (2) external mould of a dorsal valve, IGPS111866; and (3) internal moulds of two dorsal valves, IGPS111867, 111868.

Remarks.—These specimens are referred to *Acuminothyris keokuk* Carter (1990, p. 236, figs. 8.1–8.9), from the upper part of the Keokuk Limestone of Missouri, USA in the small size (length 11 mm, width about 32 mm in the larger dorsal valve specimen, IGPS111865), very transverse outline, and the external ornament consisting of numerous simple rounded costae and fine concentric lamellae (numbering 12 costae on each flank). The type species, *Acuminothyris triangularis* Roberts (1963, p. 15, pl. 5, figs. 1–8, text-figs. 7, 8), from the upper Tournaisian of New South Wales, eastern Australia, differs from *A. keokuk* in the much transverse outline.

Occurrence.—KU1 Unit.

Distribution.—Upper Tournaisian–lower Visean: northeastern Japan (Hikoroichi and Nagasaka in the South Kitakami Belt), USA (Missouri) and northwestern China (Xinjiang).

Suborder DELTHYRIDINA Ivanova, 1972
Superfamily DELTHYRIDOIDEA Phillips, 1841
Family MUCROSPIRIFERIDAE Boucot, 1959
Subfamily TYLOTHYRIDINAE Carter, 1972
Genus *TYLOTHYRIS* North, 1920

Type species.—*Cyrtia laminosa* M'Coy, 1844.

Tylothyris sp.
(Fig. 13G)

Material.—One specimen from locality OKA11, external mould of a dorsal valve, IGPS111869.

Remarks.—This specimen is readily assigned to the genus *Tylothyris* by the medium size (length about 23 mm, width more than 29 mm) and the external ornament consisting of numerous simple costae (numbering 10 or more in each lateral frank) and imbricate growth lamellae. The Nagasaka species resembles well the type species, *Tylothyris laminosa* (M'Coy, 1844), redescribed by Brunton (1984, p. 77, figs. 108–109) from the upper Visean of Conty Fermanach, northern Ireland, in size, shape and external ornament of the dorsal valve. But accurate comparison is difficult for the ill-preserved specimen.

Occurrence.—KU1 Unit.

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

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

Phricodothyris sp.
(Fig. 20C)

Phricodothyris sp. Tazawa, 1980, p. 365, pl. 42, fig. 5.

Material.—One specimen from locality OKA7, external mould of a dorsal valve, IGPS96284.

Remarks.—The sole specimen from Jizodo was described by Tazawa (1980, p. 365, pl. 42, fig. 5) as *Phricodothyris* sp. This specimen is a medium-sized, transverse *Phricodothyris* species (length 13 mm, width 37 mm), with micro-ornament consisting of numerous concentrically arranged biramous spine bases and interspinous pustules, numbering 18–20 spine bases in 10 mm, and three interspinous pustules between two spine bases. The Jizodo species somewhat resembles *Phricodothyris tripustulosa* Demanet (1938, p. 95, pl. 9, figs. 11 15, text-fig. 29), from the upper Visean of Belgium, in size and micro-ornament. But the Belgian spesies differs from the present species in the less transverse shell and denser spine bases.

Occurrence.—KU4 Unit.

Order SPIRIFERINIDA Ivanova, 1972
Suborder SPIRIFERINIDINA Ivanova, 1972
Superfamily SYRINGOTHYRIDOIDEA Fredericks, 1926
Family SYRINGOTHYRIDIDAE Fredericks, 1926
Subfamily SYRINGOTHYRIDINAE Fredericks, 1926
Genus *SYRINGOTHYRIS* Winchell, 1863

Type species.—*Syringothyris typa* Winchell, 1863.

Syringothyris karaumedatensis Tachibana, 1969
(Fig. 15E)

Syringothyris karaumedatensis Tachibana, 1969, p. 20, pl. 1, figs. 1–8; pl. 2, figs. 1–6.

Material.—One specimen from locality OKA5, internal mould of a ventral valve (posterior portion), IGPS111870.

Remarks.—This specimen is poorly preserved, but can be referred to *Syringothyris karaumedatensis* Tachibana, 1969 (p. 20, pl. 1, figs. 1–8; pl. 2, figs. 1–6) from the lower part of the Karaumedate Formation in the Nagasaka area (exact horizon and locality are unclear), by the relatively small-sized ventral valve, with a high, flattened ventral interarea which is slightly concave near the apex. The present species resembles the shells of *Syringothyris carteri* Hall, described by Tolmatchoff (1924, p. 156, 554, pl. 7, figs. 34–36; pl. 8, figs. 1, 2) from the Tournaisian of the Kuznetsk Basin, central Russia, in the small size and the high, slightly incurved ventral interarea. However, accurate comparison is difficult for the poorly preserved material.

Occurrence.—KU1 Unit.

Syringothyris japonica Tachibana, 1969
(Fig. 15C, D)

Syringothyris cf. *randalli* Simpson. Tachibana, 1963, p. 53, fig. 1.
Syringothyris japonica Tachibana, 1969, p. 22, pl. 3, figs. 1–5; pl. 4, figs. 1–8; pl. 5, figs. 1–7; pl. 6, figs. 1–4; text-fig. 1.

Material.—Two specimens from locality NKA11, internal moulds of two ventral valves, IGPS111871, 111872.

Remarks.—These specimens are fragmentarily preserved, but can be referred to *Syringothyris japonica* Tachibana, 1969 (p. 22, pl. 3, figs. 1–5; pl. 4, figs. 1–8; pl. 5, figs. 1–7; pl. 6, figs. 1–4; text-fig. 1) from the lower part of the Karaumedate Formation of the Nagasaka area (exact horizon and locality are unclear), by their large size (length more than 36 mm, width more than 53 mm in the larger specimen, IGPS111871) and the low, slightly concave ventral interarea. As suggested by Tachibana (1963, p. 24), *S. japonica* superficially resembles *Syringothyris randelli* Simpson, 1890, redescribed by Sass (1960, p. 355, pl. 35, figs. 1–11) from the lower Corny Sandstone of Pennsylvania. But accurate comparison is difficult for the poorly preserved material. The preceding species, *Syringothyris karaumedatensis* Tachibana, 1969, differs from the present species in the smaller size, less transverse outline and in having higher and flattened ventral interarea.

Occurrence.—KU1 Unit.

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

< 地名・地層名 >

Arisu Formation	有住層
Haginosawa	萩ノ沢
Hayashigawa River	林川
Higashiyama-cho	東山町
Hikoroichi Formation	日頃市層
Hirane	比良根
Ichinoseki	一関
Ishinomori	石ノ森
Jizodo	地蔵堂
Kamiagari	紙生里
Karaumedate Formation	唐梅館層
Kitaiwairi	北磐井里
Komekurazawa	米倉沢
Matsukawa	松川
Minamiiwairi	南磐井里
Motai metamorphic rocks	母体変成岩類
Mt. Fujinoneyama	富士の根山
Mt. Ohachimoriyama	大鉢森山
Mt. Takozumoriyama	田河津森山
Nagasaka	長坂
Natsuyama Conglomerate	夏山礫岩
Nisawa	荷沢
Nozuchi Formation	野土層
Oiwa sen	大岩線
Okuhinotsuchi	奥火の土
Otsubo	小坪
Shoboji	正法寺
Takesawa Formation	竹沢層
Takesawa-Natsuyama sen	竹沢–夏山線
Tobigamori Formation	鳶ヶ森層
Usuginu Conglomerate	薄衣礫岩
Yanomori Formation	矢ノ森層
Yokosawa	横沢
Yoshizawa	ヨシ沢