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An early Carboniferous (late Visean) brachiopod fauna from Tairagai in the Yokota area, South Kitakami Belt, Japan

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Abstract. In this paper, a brachiopod fauna (the Tairagai fauna), consisting of 11 species in 11 genera, is described from the uppermost part of the Odaira Formation at Tairagai in the Yokota area, South Kitakami Belt, northeastern Japan. The age of the fauna is identified as the late Visean (early Carboniferous). Palaeobiogeographically, the Tairagai fauna has a close affinity with those of western Europe (the UK, Germany and Belgium), central Russia (southern Urals and Kuznetsk Basin), Kazakhstan, Kyrgyzstan and northwestern China (Xinjiang and Gansu). The South Kitakami region probably was located near the North China block in the late Palaeozoic, and tectonically belongs to the CAOB.

Key words: Brachiopoda, late Visean, Odaira Formation, South Kitakami Belt, Tairagai

Introduction

The Palaeozoic geography and biogeography of the South Kitakami Belt, northeastern Japan, are important for understanding the geotectonic history of the South Kitakami Belt and the Japanese Islands in general. Brachiopods are among the most useful taxa for Palaeozoic biogeographical studies owing to their very abundant fossil records and benthic life style with a short planktonic larval stage.

Three models have been proposed to explain the origin and tectonic development of the South Kitakami Belt: (1) the microcontinent model (Kanmera, 1980; Saito and Hashimoto, 1982; Taira and Tashiro, 1987; Ichikawa, 1990; Ehiro and Kanisawa, 1999; Ehiro, 2001), which states that the South Kitakami Belt is a microcontinent originating from the Pacifica or the Gondwana Palaeocontinent, and was located in the equatorial Panthalassa Ocean during the Carboniferous–Permian; (2) the nappe model (Isozaki and Maruyama, 1991; Isozaki, 1996; Isozaki *et al.*, 2010), which states that the South Kitakami Belt is a nappe derived from the South China (Yangtze) Block, which was located within the Palaeo-Tethys Ocean during the Carboniferous–Permian; and (3) the strike-slip model (Tazawa, 1993, 2000, 2004), which states that the South Kitakami Belt is an early Palaeozoic accretionary belt developed on the northern or eastern margin of the North China (Sino-Korea) Block during the Ordovician–Permian, and was greatly displaced by late Permian to Late Jurassic dextral strike-slip faulting, latest Jurassic to earliest Cretaceous eastward thrusting and Early Cretaceous to Palaeogene sinistral strike-slip faulting.

Brachiopods are extremely common in the early Carboniferous marine fauna of the South Kitakami Belt (southern Kitakami Mountains). Since the pioneering studies of Minato (1951, 1952), 80 species of brachiopod in 49 genera have been described by Tachibana (1956, 1963, 1964, 1969, 1981), Minato and Kato (1977), Tazawa and Katayama (1979), Tazawa (1980, 1981, 1984, 1985, 1989, 1996, 2006), Tazawa and Kurita (1986), Tazawa and Miyake (2002) and Tazawa and Ibaraki (2009). However, there has been a lack of systematic, biostratigraphic and palaeobiogeographic studies on the early Carboniferous brachiopods of the South Kitakami Belt. In terms of biostratigraphy, no brachiopods have been described from the upper part of the Odaira Formation in the Yokota area. In terms of palaeobiogeography, there are only a few studies on the early Carboniferous brachiopods (Minato, 1956; Tazawa, 1996, 2006).

The present paper describes brachiopods of the Tairagai fauna from the uppermost part of the Odaira Formation at Tairagai in the Yokota area, South Kitakami Belt (Figure 1), and discusses the age and palaeobiogeography of the fauna. The brachiopod specimens described herein

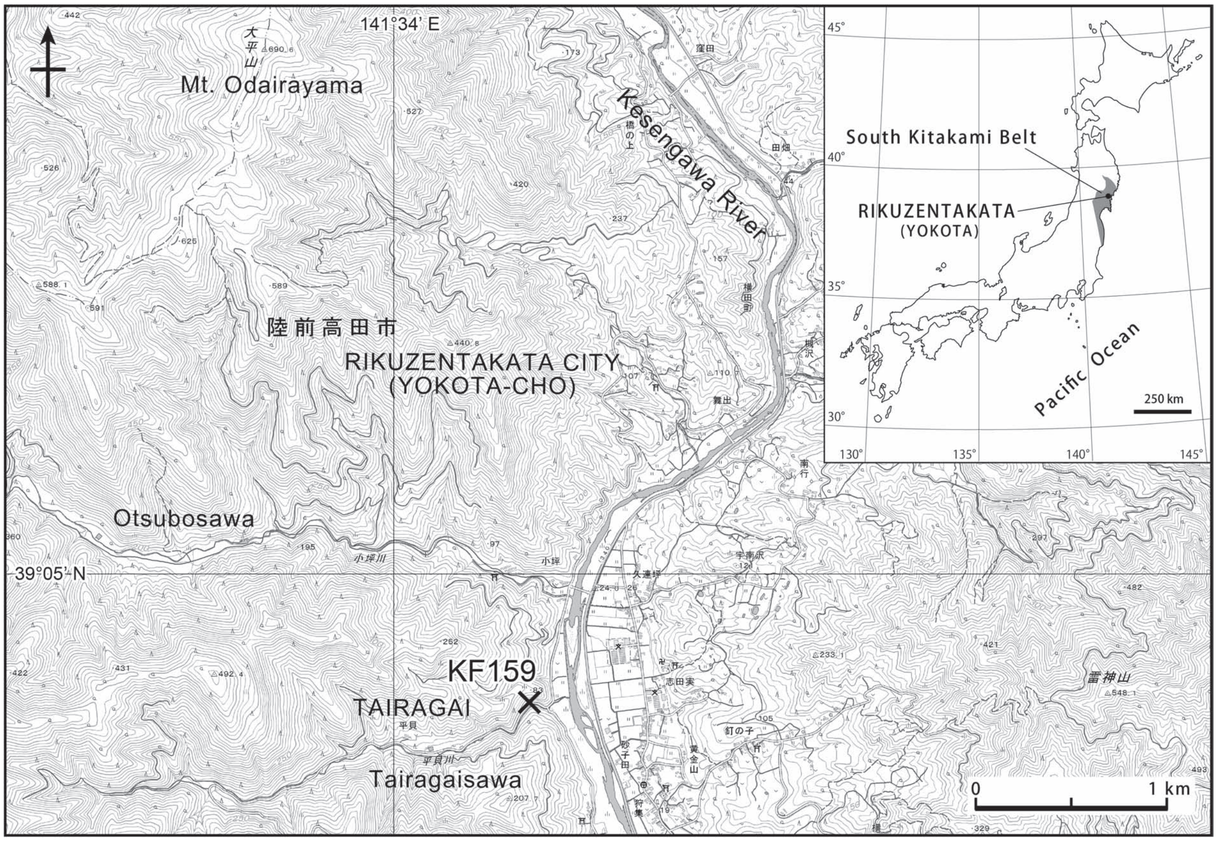

Figure 1. Map showing the fossil locality KF159 at Tairagai in the Yokota area, South Kitakami Belt (using the electronic topographical map of the Geospatial Information Authority of Japan).

are registered and housed in the Department of Geology, Niigata University, Niigata, Japan (prefix NU-B, numbers NU-B2152 to NU-B2172).

Stratigraphy

The Yokota area (Yokota-cho, Rikuzentakata City, Iwate Prefecture) in the South Kitakami Belt is one of the type localities of the lower Carboniferous in Japan. The stratigraphy of the lower Carboniferous rocks of the Yokota area has been studied by Minato (1941), Minato *et al*. (1953), Tazawa and Katayama (1979), Tazawa (1979), Kawamura (1985) and Kawamura *et al*. (1985). Tairagai in the Yokota area is renowned for the stratigraphical studies (Tazawa, 1979; Kawamura *et al.*, 1985) on the boundary between the Odaira Formaton and the conformably overlying Onimaru Formation, which was previously considered by Minato (1941, 1955, 1966) to be a marked angular unconformity.

The lower Carboniferous succession of the Yokota area is divided into four formations, the Shittakazawa, Arisu, Odaira and Onimaru formations, in ascending order (Figure 2). The Odaira Formation (about 550 m thick) consists of basaltic to andesitic tuff and tuff breccia in the lower part, and sandstone with subordinate shale and limestone in the upper part. The brachiopod fossils described herein were collected by the present author from dark grey calcareous shale of the uppermost part of the Odaira Formation, about 20 m below the top of the formation at locality KF159 (39°04′38″N, 141°34′30″E), which is a road cut along the Tairagaisawa Valley, a tributary of the Kesengawa River.

The Tairagai fauna

The brachiopod fauna described herein includes 11 species in 11 genera: *Leptagonia analoga* (Phillips, 1836), *Rugosochonetes extensus* (Chao, 1928), *Marginatia burlingtonensis* (Hall, 1858), *Echinoconchus punctatus* (Sowerby, 1822), *Echinaria* sp., *Pustula pustulosa* (Phillips, 1836), *Schellwienella radialis* (Phillips, 1836), *Cleiothyridina fimbriata* (Phillips, 1836), *Spirifer liangchowensis* Chao, 1929, *Kitakamithyris* sp. and *Pseudosyrinx* sp. Of the brachiopods, 8 species (*Rugosocho-*

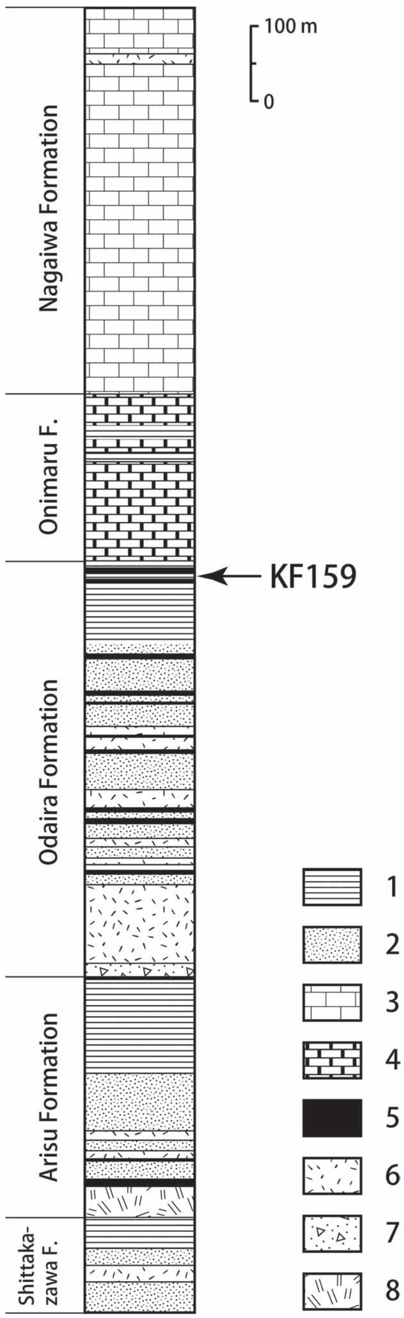

Figure 2. Generalized columnar section of the Carboniferous formations in the Yokota area, showing the fossil horizon KF159 at Tairagai (modified and adapted from Tazawa and Katayama, 1979). 1, shale; 2, sandstone; 3, limestone of the Nagaiwa Formation; 4, limestone of the Onimaru Formation; 5, limestone of the Arisu and Odaira formations; 6, tuff; 7, tuff breccia; 8, lapilli tuff.

netes extensus, *Echinoconchus punctatus*, *Echinaria* sp., *Pustula pustulosa*, *Schellwienella radialis*, *Cleiothyridina fimbriata*, *Spirifer liangchowensis* and *Pseudosyrinx*

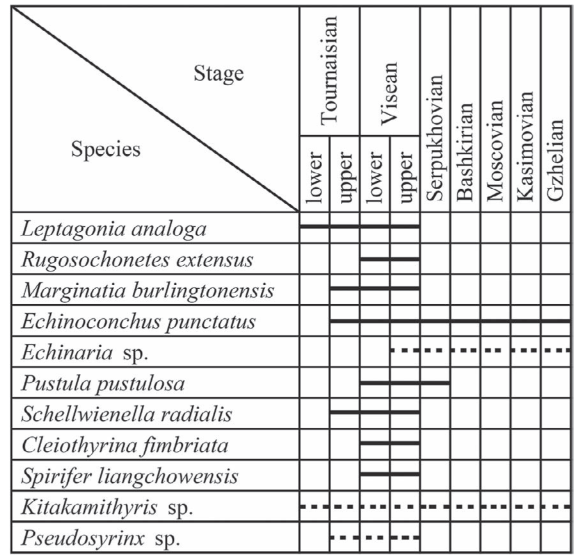

Figure 3. Stratigraphic distribution of brachiopod species of the Tairagai fauna.

sp.) are described for the first time from the Carboniferous of Japan as well as the South Kitakami Belt.

Age

The stratigraphic distribution of the brachiopod species of the Tairagai fauna is summarized in Figure 3.

Of the brachiopods listed above, *Leptagonia analoga* is known from the lower Tournaisian–upper Visean, *Marginatia burlingtonensis* and *Schellwienella radialis* are known from the upper Tournaisian–upper Visean, and *Pustula pustulosa* occurs in the lower Visean–Serpukhovian. Three other species, *Rugosochonetes extensus*, *Cleiothyridina fimbriata* and *Spirifer liangchowensis*, are restricted to the lower–upper Visean. In contrast, *Echinoconchus punctatus* is a long-ranging species known from the upper Tournaisian–Asselian. At the generic level, the genus *Echinaria* has a range from the upper Visean to Sakmarian (Yang *et al*., 1977; Tazawa, 1981; Brunton *et al*., 2000), *Kitakamithyris* is known from the Fammenian to Sakmarian (Pavlova, 1969), and *Pseudosyrinx* is known from the upper Tournaisian to upper Visean (Carter, 2006). In summary, the age of the Tairagai fauna is identified as Visean, probably late Visean.

This conclusion is largely in agreement with that of Kawamura *et al.* (1985), who considered the ages of two fossil horizons in the uppermost part of the Odaira Formation at Tairagai to be as follows. Horizon Tr-I (5 m below KF159), which comprises limestone containing the rugose coral *Sugiyamaella* sp., is correlated with the lower Visean, and horizon Tr-II (2 m above KF159),

Species \ Region	USA							Canada	N. Russia				UK								W. Russia	
	1. Illinois	2. Iowa	3. Missouri	4. Arkansas	5. Oklahoma	6. Utah	7. New Mexico	8. Alberta	9. Verkhoyansk Range	10. Taimyr Peninsula	11. Pechora Basin	12. Northern Urals	13. Scotland	14. England	15. Isle of Man	16. Northern Ireland	17. Germany	18. Belgium	19. Spain	20. Algeria	21. Moscow Basin	22. Donetz Basin
Leptagonia analoga	+	+	+		+	+	+	+	+		+			+	+	+	+	+				+
Rugosochonetes extensus																						
Marginatia burlingtonensis	+	+		+				+														
Echinoconchus punctatus									+	+		+	+	+		+	+		+	+	+	+
Echinaria sp.																						
Pustula pustulosa											+			+		+	+					
Schellwienella radialis													+	+		+	+	+			+	
Cleiothyrina fimbriata														+		+		+				
Spirifer liangchowensis																						
Kitakamithyris sp.																						
Pseudosyrinx sp.																						

Species \ Region			C. Russia						NW China			N. China	NE China	Japan		CS China			SW China	Australia	
	23. Turkey	24. Iran	25. Central Urals	26. Southern Urals	27. Kuznetsk Basin	28. Kazakhstan	29. Uzbekistan	30. Kyrgyzstan	31. Xinjiang	32. Qinghai	33. Gansu	34. Shanxi	35. Liaoning	36. South Kitakami Belt	37. Akiyoshi Belt	38. Hubei	39. Guangdong	40. Guangxi	41. Yunnan	42. W. Australia	43. E. Australia
Leptagonia analoga	+	+		+	+	+			+		+			+		+	+	+	+	+	+
Rugosochonetes extensus											+			+							
Marginatia burlingtonensis	+			+	+	+		+						+	+						
Echinoconchus punctatus				+	+	+	+	+	+	+	+	+	+	+							
Echinaria sp.														+							
Pustula pustulosa			+	+			+	+	+					+							
Schellwienella radialis			+	+					+		+			+							
Cleiothyrina fimbriata														+							
Spirifer liangchowensis											+			+							
Kitakamithyris sp.														+							
Pseudosyrinx sp.														+							

Figure 4. Geographic distribution of brachiopod species of the Tairagai fauna.

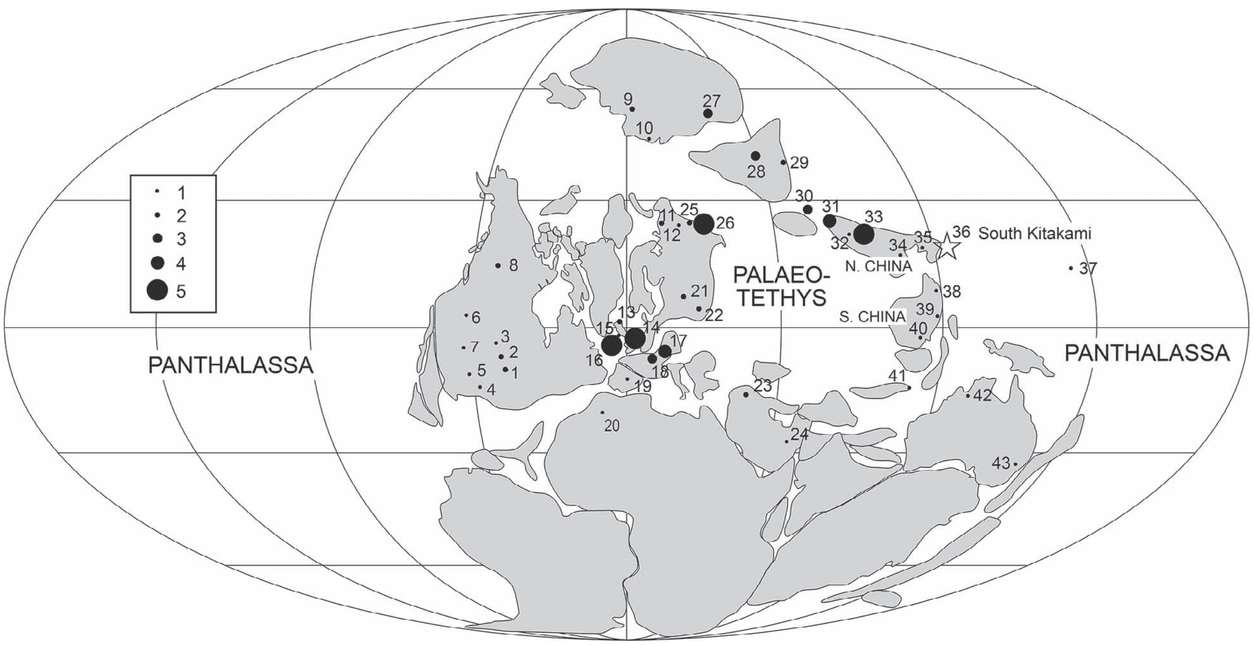

Figure 5. Early Carboniferous (Visean) reconstruction map of the world (adapted from Scotese, 2004), showing the geographic distribution of brachiopod species of the Tairagai fauna excluding the three uncertain species (*Echinaria* sp., *Kitakamithyris* sp. and *Pseudosyrinx* sp). Solid circles indicate numbers of brachiopod species listed in the Tairagai fauna. Station numbers are same as in Figure 4.

which comprises limestone containing the rugose corals *Siphonophyllia* sp., *Sugiyamaella* sp., *Kueichouphyllum heishihkuanensis*, *Yuanophyllum kansuense*, "*Lophophyllum*" sp. and "*Caninia*" sp., is correlated with the upper Visean. The age of the brachiopod-bearing horizon KF159, which occurs between Tr-1 and Tr-2, is now considered to be late Visean based on the brachiopods of the Tairagai fauna.

Palaeobiogeography

The geographic distributions of the brachiopod species of the Tairagai fauna are summarized in Figures 4 and 5.

Of the 11 species of the Tairagai fauna, five species also occur in the UK (England and northern Ireland), central Russia (southern Urals) and northwestern China (Gansu); four species also occur in Germany and northwestern China (Xinjiang); and three species are also present in Belgium, central Russia (Kuznetsk Basin), Kazakhstan and Kyrgyzstan. From the palaeobiogeographical data, the Tairagai fauna apparently possesses a close affinity with those of western Europe, central Russia, Kazakhstan, Kyrgyzstan, Xinjiang and Gansu. It is noteworthy that northern Xinjiang and northern Gansu belong to the North China Province of Yang (1980) [= Tianshan–Hinggan Province of Liao (1995)], and eastern Kazakhstan and Kyrgyzstan are the western extension of the province. In other words, this fauna has a close affinity with those of the Central Asian Orogenic Belt (CAOB) including the northern regions outside of North China (Sino-Korea), and is different from those of South China (Yangtze).

This conclusion is consistent with that of Tazawa (2006), who reported that South Kitakami is probably the eastern extension of the Tianshan–Jilin Province of Yang (1994) [= the southern part of the North China Province of Yang (1980)] based on the co-occurrence of brachiopods (*Marginatia*, *Syringothyris and Rotaia*) and rugose corals (*Sugiyamaella*, *Yuanophyllum* and *Kueichouphyllum*) from the lower Carboniferous (lower Visean) of the South Kitakami Belt. In addition to the above, Kobayashi and Hamada (1980) and Kobayashi (1989) reported that the early Carboniferous trilobite fauna of the South Kitakami Belt is in close affinity with those of the Mongolian Geosyncline (Xinjiang, Kazakhstan and Kyrgyzstan) and North America.

Systematic descriptions

Order Strophomenida Öpik, 1934
Superfamily Strophomenoidea King, 1846
Family Rafinesquinidae Schuchert, 1893
Subfamily Leptaeninae Hall and Clarke, 1894
Genus ***Leptagonia*** M'Coy, 1844

Type species.—*Producta analoga* Phillips, 1836.

Leptagonia analoga (Phillips, 1836)

Figure 6.1

Producta analoga Phillips, 1836, p. 116, pl. 7, fig. 10.
Strophomena rhomboidalis var. *analoga* Phillips. Davidson, 1861, p. 119, pl. 28, figs. 1–6, 9–13; Etheridge, 1872, p. 333, pl. 18, fig. 1.
Leptaena analoga (Phillips). Weller, 1914, p. 49, pl. 2, figs. 1–10; Frech, 1916, p. 237, pl. 2, figs. 2, 3d; Girty, 1920, pl. 54, fig. 3; Tolmatchoff, 1924, p. 209, pl. 13, fig. 8; Girty, 1927, pl. 22, figs. 6–8; Demanet, 1934, p. 61, pl. 5, figs. 1–14, text-figs. 1–14; Branson, 1938, p. 24, pl. 5, fig. 31; Minato, 1951, p. 361, pl. 3, fig. 1; Nelson, 1961, pl. 4, fig. 26; Sokolskaya in Sarytcheva *et al.*, 1963, p. 80, pl. 4, figs. 9–14.
Leptaena rhomboidalis Wilckens. Sommer, 1909, p. 626, pl. 29, fig. 14.
Leptagonia cf. *analoga* (Phillips). Cvancara, 1958, p. 860, pl. 110, figs. 6–13, text-figs. 3, 4.
Leptaenella analoga (Phillips). Yang, 1964, p. 61, pl. 1, fig. 5; Gretchischnikova, 1966, p. 94, pl. 1, figs. 19, 20; pl. 2, figs. 1–6; Abramov, 1970, p. 108, pl. 1, figs. 11, 12; Aisenverg and Poletaev, 1971, pl. 60, figs. 2, 3; Nalivkin and Fotieva, 1973, p. 20, pl. 1, figs. 9–13.
Leptagonia analoga (Phillips). Brunton, 1968, p. 29, pl. 3, figs. 26–31; pl. 4, figs. 1–9, text-figs. 6–17; Gaetani, 1968, p. 688, pl. 47, fig. 3; Thomas, 1971, p. 30, pl. 18, figs. 1–8, text-fig. 11; Bublitschenko, 1971, p. 37, pl. 3, figs. 1–5; Brand, 1972, p. 59, pl. 8, figs. 1–6, text-figs. 1a, 3; Kalashnikov, 1974, p. 23, pl. 3, fig. 5; Litvinovich *et al.*, 1975, p. 53, pl. 16, fig. 11; Bublitschenko, 1976, p. 22, pl. 1, fig. 10; Yang *et al.*, 1977, p. 316, pl. 131, fig. 2; Minato *et al.*, 1979, pl. 15, fig. 2; Nalivkin, 1979, p. 18, pl. 3, figs. 1–3, 5, 6; Ding and Qi, 1983, p. 251, pl. 89, figs. 9, 10, 12; Zhang *et al.*, 1983, p. 271, pl. 107, fig. 13; pl. 106, fig. 3; Tazawa *et al.*, 1984, p. 350, pl. 67, figs. 2–4; Yang, 1984, p. 205, pl. 29, fig. 11; Xu and Yao, 1988, p. 274, pl. 67, figs. 4, 6–10; Carter, 1999, p. 96, fig. 1A–E; Shi *et al.*, 2005, p. 39, fig. 3A, E.

Material.—One specimen, external mould of a ventral valve, NU-B2154.

Remarks.—This specimen is referred to *Leptagonia analoga* (Phillips, 1836), redescribed by Brunton (1968, p. 29, pl. 3, figs. 26–31; pl. 4, figs. 1–9, text-figs. 6–17) on the type specimens from the Visean of England and northern Ireland, in the transversely trapezoidal and flattened ventral valve, ornamented with numerous fine costellae (numbering 13–15 in 5 mm at about midlength) and regularly but slightly flexuous concentric rugae. The Tairagai specimen, being smaller in size (length 23 mm, width about 34 mm) than the type specimens, may be a juvenile shell.

Distribution.—Lower Tournaisian–upper Visean: USA (Illinois, Iowa, Missouri, Oklahoma, Utah and New Mexico), western Canada (Alberta), northern Russia (Verkhoyansk Range and Pechora Basin), UK (England, lsle of Man and northern Ireland), Germany, Belgium, western Russia (Donetz Basin), Turkey (Taurus Mountains), Iran (Elburz Range), central Russia (southern Urals and Kuznetsk Basin), Kazakhstan, northwestern China (Xinjiang and Gansu), northeastern Japan (South Kitakami Belt), central-southern China (Hubei, Guangdong and Guangxi), southwestern China (Yunnan), western Australia (Bonaparte Gulf Basin) and eastern Australia (Queensland and New South Wales).

Order Productida Sarytcheva and Sokolskaya, 1959
Suborder Chonetidina Muir-Wood, 1955
Superfamily Chonetoidea Bronn, 1862
Family Rugosochonetidae Muir-Wood, 1962
Subfamily Rugosochonetinae Muir-Wood, 1962
Genus ***Rugosochonetes*** Sokolskaya, 1950

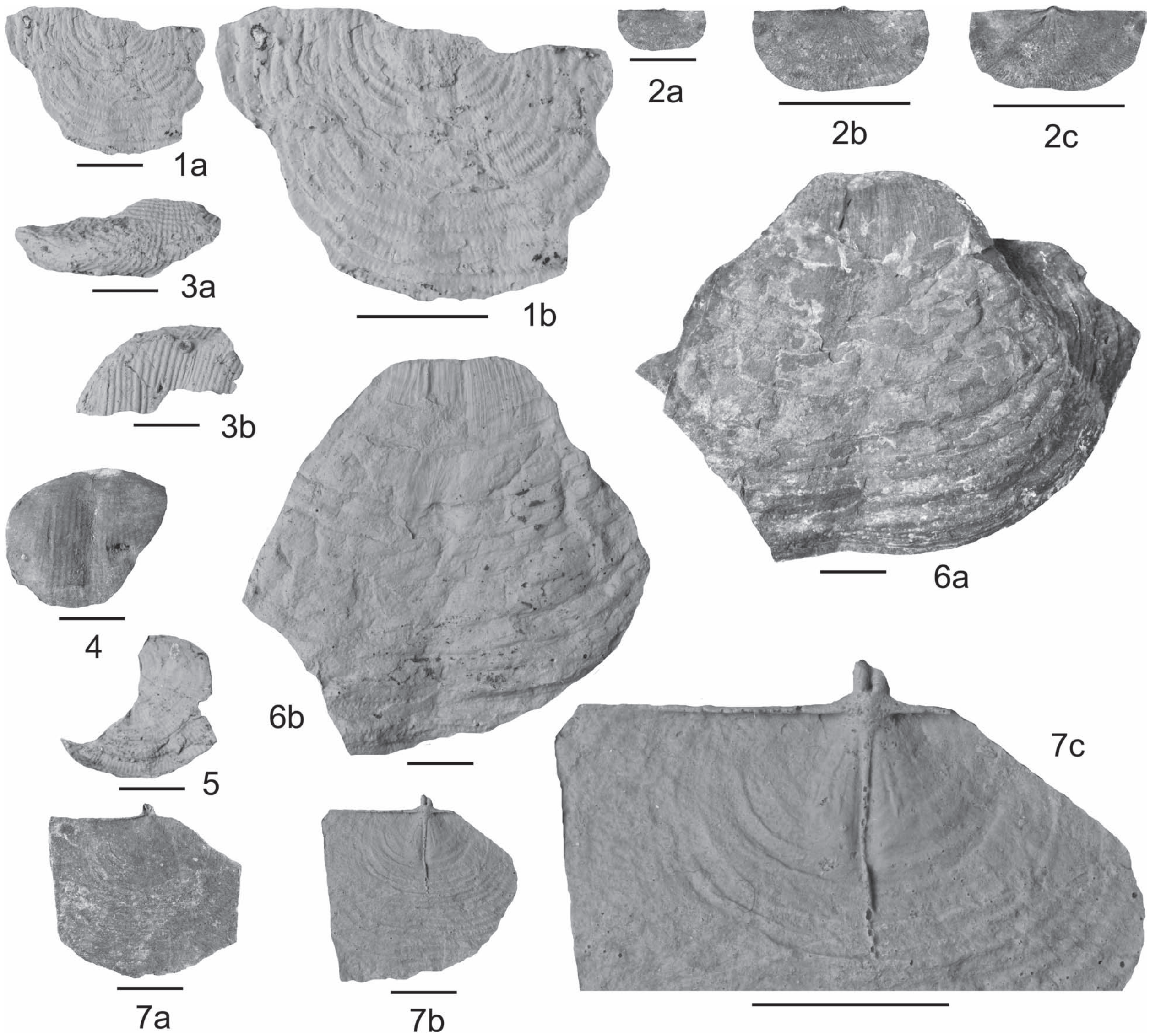

Figure 6. **1,** *Leptagonia analoga* (Phillips); 1a, b, external latex cast of ventral valve, NU-B2154; **2,** *Rugosochonetes extensus* (Chao); 2a–c, external mould and internal mould of dorsal valve, NU-B2172; **3–5,** *Marginatia burlingtonensis* (Hall); 3a, b, ventral and anterior views of external latex cast of ventral valve, NU-B2160; 4, anterior view of internal mould of ventral valve, NU-B2161; 5, external latex cast of dorsal valve, NU-B2162; **6, 7,** *Echinoconchus punctatus* (Sowerby); 6a, b, internal mould and external latex cast of ventral valve, NU-B2155; 7a–c, external mould and internal latex cast of dorsal valve, NU-B2156. Scale bars represent 1 cm.

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

Rugosochonetes extensus (Chao, 1928)

Figure 6.2

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.

Material.—One specimen, external and internal moulds of a dorsal valve, NU-B2172.

Remarks.—This specimen can be referred to *Rugosochonetes extensus* (Chao, 1928), from the Chouniugou Formation of Gansu, northwestern China, by the transverse outline (length 7 mm, width 14 mm), acute cardinal extremities and external ornament of numerous fine capillae (numbering 8 in 2 mm at about midlength). *Rugosochonetes* sp., described by Tazawa (1980, p. 361, pl. 41, fig. 1) from the upper part of the Karaumedate Formation in the Nagasaka area, South Kitakami Belt, is conspecific with the present species. *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.

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

Suborder Productidina Waagen, 1883
Superfamily Productoidea Gray, 1840
Family Buxtoniidae Muir-Wood and Cooper, 1960
Subfamily Marginatiinae Waterhouse, 2002
Genus ***Marginatia*** Muir-Wood and Cooper, 1960

Type species.—*Productus fernglenensis* Weller, 1909.

Marginatia burlingtonensis (Hall, 1858)

Figures 6.3–6.5

Productus flemingi var. *burlingtonensis* Hall, 1858, p. 598, pl. 12, fig. 3.
Productus burlingtonensis Hall. Weller, 1914, p. 104, pl. 9, figs. 1–10; Frech, 1916, p. 239, pl. 6, fig. 1; Tolmatchoff, 1924, p. 237, 575, pl. 14, figs. 8–11; Girty, 1929, p. 85, pl. 9, figs. 20–24.
Productus (*Productus*) *burlingtonensis* Hall. Nalivkin, 1937, p. 66, pl. 7, figs. 7–11.
Productus sp. Minato, 1951, p. 366, pl. 1, fig. 4.
Productus (*Dictyoclostus*s) *burlingtonensis* Hall. Simorin, 1956, p. 136, pl. 9, figs. 1–3.
Marginatia burlingtonensis (Hall). Sarytcheva in Sarytcheva *et al*., 1963, p. 191, pl. 28, figs. 5–8, text-figs. 81, 82; Grechishnikova, 1966, p. 116, pl. 8, figs. 11–13; Litvinovich *et al*., 1969, p. 213, pl. 35, figs. 2–4; Nalivkin and Fotieva, 1973, p. 39, pl. 8, fig. 1; Bublitschenko, 1976, p. 50, pl. 2, fig. 12; pl. 4, fig. 6; pl. 5, figs. 4–6; pl. 6, fig. 9; Galitskaya, 1977, p. 83, pl. 22, figs. 6–10; Nalivkin, 1979, p. 94, pl. 32, figs. 1–10; pl. 34, figs. 3, 4; Jin, 1985, p. 77, pl. 1, figs. 20–22; Carter, 1987, p. 39, pl. 9, figs. 1–8; Shi *et al*., 2005, p. 44, fig. 5D, I–K, M; Tazawa, 2006, p. 132, figs. 6.1–6.8.
Dictyoclostus sp. Hase and Yokoyama, 1975, pl. 18, fig. 1.
Marginatia sp. Tazawa, 1985, p. 459, figs. 2.3–2.7; Tazawa, 1989, p. 60, pl. 1, fig. 1; Tazawa, 2002, figs. 7.1, 7.2.

Material.—Three specimens: (1) external mould of a ventral valve, NU-B2160; (2) internal mould of a ventral valve, NU-B2161; and (3) external mould of a dorsal valve, NU-B2162.

Remarks.—These specimens are fragmentarily preserved, but can be referred to *Marginatia burlingtonensis* (Hall, 1858), from the Burlington Limestone of Illinois and Iowa, by their medium size (length about 20 mm, width about 46 mm in the best preserved ventral valve, NU-B2160), strongly geniculated ventral valve, reticulate ornament on visceral discs of both valves, and two symmetrically arranged strong halteroid spines on ventral trail. The Tairagai specimens resemble well the shells of *Marginatia burlingtonensis*, described by Tazawa (2006, p. 132, figs. 6.1–6.8) from the Hikoroichi and Arisu formations of the South Kitakami Belt, in size and external ornament of the ventral valve. The type species, *Marginatia fernglenensis* (Weller) (Weller, 1909, p. 299, pl. 12, figs. 14–17, as *Productus fernglenensis*) from the Fern Glen Formation of Missouri, differs from *M. burlingtonensis* in having a shallower ventral sulcus.

Distribution.—Upper Tournaisian–upper Visean: USA (Illinois, Iowa and Arkansas), western Canada (Alberta), Turkey (Taurus Mountains), central Russia (southern Urals and Kuznetsk Basin), Kazakhstan, Kyrgyzstan, northeastern Japan (South Kitakami Belt) and southwestern Japan (Hina, in the Akiyoshi Belt).

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)

Figures 6.6, 6.7

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; Pareyn, 1961, p. 197, pl. 23, figs. 1–4; Ding in Yang *et al*., 1962, p. 51, pl. 19, figs. 1–4; Yang, 1964, p. 81, pl. 4, figs. 5, 6, 9, 10, text-fig. 7; Abramov, 1965, p. 38, pl. 3, fig. 2; Litvinovich *et al.*, 1969, p. 164, pl. 9, figs. 5, 6; pl. 10, fig. 1; Abramov, 1970, p. 117, pl. 9, fig. 4; Alexandrow and Solomina, 1973, p. 93, pl. 22, figs. 1–3; Volgin and Kushnar, 1975, p. 46, pl. 4, fig. 1; Donakova, 1978, p. 208, pl. 1, figs. 5, 6; Nalivkin, 1979, p. 78, pl. 24, figs. 8, 9; Zhang *et al*., 1983, p. 288, pl. 127, fig. 111; 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) em. 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.
Echinoconchus (*Echinoconchus*) *punctatus* (Sowerby). Galitzkaja, 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 *et al*., 1980, p. 363, pl. 147, figs. 1, 2.

Material.—Two specimens: (1) external and internal moulds of a ventral valve, NU-B2155; and (2) external and internal moulds of a dorsal valve, NU-B2156.

Description.—Shell large in size for genus, slightly transverse subcircular in outline, hinge shorter than greatest width at about midlength; length about 62 mm, width about 82 mm in the larger specimen (NU-B2155). Ventral valve moderately and unevenly convex in lateral profile, strongly convex in both umbonal and anterior regions, but gently convex in visceral region; sulcus narrow and shallow. Dorsal valve nearly flat in visceral disc. External surface of both valves ornamented with regular concentric bands bearing numerous fine spine bases; bands broad in ventral valve but narrow in dorsal valve, numbering 2–3 and 9–10 in 10 mm on ventral and dorsal valves, respectively; spine bases somewhat quincunxially arranged on each band. Ventral interior with narrow, elongated, smooth adductor scars between broad, radiating diductor scars. Dorsal interior with prominent, internally bilobed cardinal process with narrow median sulcus; a pair of straight lateral ridges along hinge; a thin, long median septum extending to half of visceral disc; and adductor scars smooth, elongate, and slightly diverging anteriorly.

Remarks.—These specimens are 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 Visean of the UK (Scotland and England) and Belgium, by their large size, regular broad bands on the ventral valve, prominent bilobate cardinal process and elongate smooth adductor scars in the dorsal valve. The smaller dorsal specimen may be a young shell. *Anomites punctatus* described by Martin (1809), was selected as the type species of *Echinoconchus* by Weller (1914, p. 138); however, it was, along with the other names introduced by Martin in his works of 1793 and 1809, declared nomenclatorially invalid in 1948 by the International Commission on Zoological Nomenclature by reason of being non-binomial. Twelve of Martin's "*Anomites*" were referred to subsequent authors, in the case of *punctatus* to Sowerby, 1822 (Muir-Wood and Cooper, 1960, p. 243). *Echinoconchus aohanensis* Lee, Gu and Su (1980, p. 363, pl. 147, figs. 1, 2), from the middle Carboniferous of Liaoning, northeastern China, is regarded as a junior synonym of the present species. *Echinoconchus alternatus* (Norwood and Pratten, 1855), redescribed by Weller (1914, p. 138, pl. 17, figs. 1–7), from the Osagean and Meramecian of the Mississippi Valley, USA, differs from *E. punctatus* in having a longer hinge.

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

Genus ***Echinaria*** Muir-Wood and Cooper, 1960

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

Echinaria sp.

Figure 7.2

Material.—One specimen, external and internal moulds of a dorsal valve, NU-B2157.

Remarks.—The single dorsal valve specimen from Tairagai is safely assigned to the genus *Echinaria* by its external ornament consisting of closely spaced regular bands with numerous spine bases of two series, a larger posterior one and a smaller anterior one and elongate adductor scars, posterior one dendritic and anterior one smooth.. The Kitakami species is large in size (length more than 60 mm, width more than 55 mm), and closely resembles two species, *Echinaria semipunctata* (Shepard, 1838), redescribed by Dunbar and Condra (1932, p. 205, pl. 24, fig. 6; pl. 25, figs. 1–3) from the Upper Pennsylvanian of Nebraska, and *Echinaria rara* (Nasikanova in Sarytcheva, 1968, p. 91, pl. 6, figs. 11–16, text-figs. 33–35) from the Bashkirian of eastern Kazakhstan in size and shape of the dorsal valve, although accurate comparison is difficult owing to ill preservation of the present material. *Echinaria minatoi* Tazawa (1981, p. 54, pl. 4, figs. 3–11), from the lower part of the Nagaiwa Formation (upper Visean–Serpukhovian) of the Hikoroichi area, South Kitakami Belt, is readily distinguished from the Tairagai species by its much smaller dimensions.

Family Waagenoconchidae Muir-Wood and Cooper, 1960
Subfamily Pustulinae Waterhouse, 1981
Genus ***Pustula*** Thomas, 1914

Type species.—*Producta pustulosa* Phillips, 1836.

Pustula pustulosa (Phillips, 1836)

Figures 7.3, 7.4

Producta pustulosa Phillps, 1836, p. 216, pl. 7, fig. 15.
Productus pustulosus Phillips. Krenkel, 1913, p. 18, 43, pl. 1, fig. 7.
Pustula pustulosa (Phillips). Thomas, 1914, p. 261, pl. 17, figs. 24–28; pl. 18, fig. 1; Muir-Wood and Cooper, 1960, pl. 59, fig. 4; pl. 84,

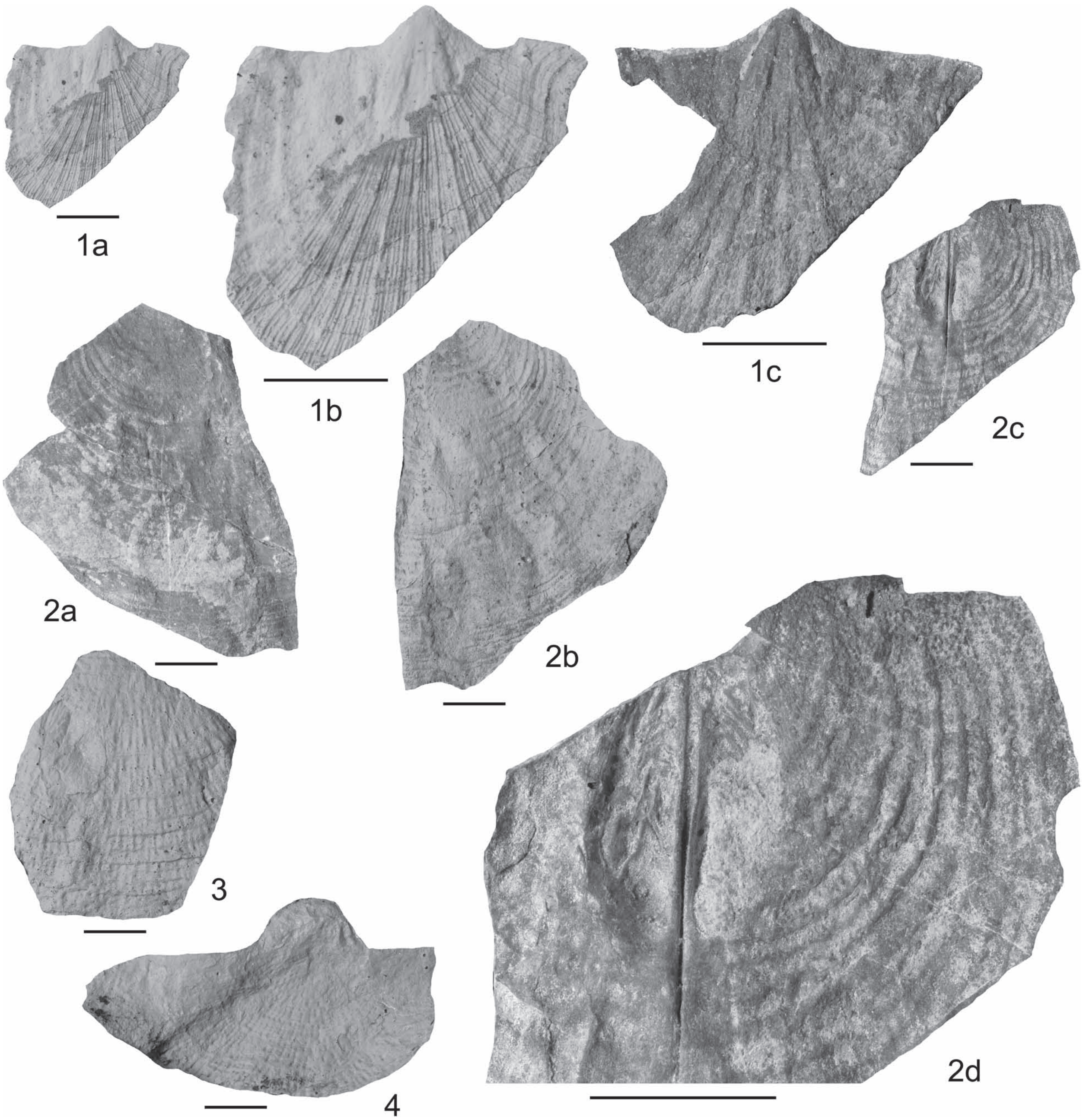

Figure 7. **1,** *Schellwienella radialis* (Phillips); 1a–c, external latex cast and internal mould of ventral valve, NU-B2152; **2,** *Echinaria* sp.; 2a–d, external mould, external latex cast, and internal mould of dorsal valve, NU-B2157; **3, 4,** *Pustula pustulosa* (Phillips); 3, external latex cast of ventral valve, NU-B2158; 4, external latex cast of dorsal valve, NU-B2159. Scale bars represent 1 cm.

figs. 1–7; pl. 85, figs. 6–10; Nalivkin and Fotieva, 1973, p. 36, pl. 6, figs. 11–13; Kalashnikov, 1974, p. 51, pl. 10, figs. 6–9; pl. 11, figs. 1, 2; pl. 13, figs. 4, 5; pl. 30, fig. 6; Garanj *et al*., 1975, p. 163, pl. 65, figs. 3, 4; Volgin and Kushnar, 1975, p. 45, pl. 3, figs. 10–12; Galitskaya, 1977, p. 67, pl. 19, figs. 1–5; pl. 20, fig. 1; Zhang *et al*., 1983, p. 289, pl. 109, fig. 4.

Productus (*Pustula*) *pustulosus* Phillips emend. Thomas. Paeckelmann, 1931, p. 138, pl. 13, figs. 2, 3.

Pustula cf. *pustulosa* (Phillips). Mori and Tazawa, 1980, text-fig. 3.2; Tazawa, 1984, p. 306, pl. 61, fig. 8.

Material.—Two specimens: (1) external and internal moulds of a ventral valve, NU-B2158; and (2) external and internal moulds of a dorsal valve, NU-B2159.

Remarks.—The fragmentary specimens from Tairagai can be referred to *Pustula pustulosa* (Phillips, 1836), redescribed by Thomas (1914, p. 261, pl. 17, figs. 24–28; pl. 18, fig. 1) from the upper Visean of England, by the large size (length more than 47 mm, width more than 42 mm in the ventral valve specimen, NU-B2158), subrectangular outline, well developed ventral sulcus and dorsal fold, and external ornament of both valves consisting of regular concentric bands and numerous, quincunxially arranged elongate spine bases. *Pustula* cf. *pustulosa* (Phillips, 1836), figured by Mori and Tazawa (1980, text-fig. 3.2) and subsequently described by Tazawa (1984, p. 306, pl. 61, fig. 8) from the upper part of the Hikoroichi Formation of the Hikoroichi area, South Kitakami Belt, is regarded as a synonym of the present species. *Pustula tenuipustulosa* Thomas (1914, p. 288, pl. 20, figs. 10, 11, text-fig. 7) differs from *P. pustulosa* in having smaller spine bases and less-marked bands.

Distribution.—Lower Visean–Serpukhovian: northern Russia (Pechora Basin), UK (England and northern Ireland), Germany, central Russia (central and southern Urals), Uzbekistan (Fergana), Kyrgyzstan, northwestern China (Xinjiang) and northeastern Japan (South Kitakami Belt).

Order Orthotetida Waagen, 1884
Suborder Orthotetidina Waagen, 1884
Superfamily Orthotetoidea Waagen, 1884
Family Pulsiidae Cooper and Grant, 1974
Genus ***Schellwienella*** Thomas, 1910

Type species.—*Spirifera crenistria* Phillips, 1836.

Schellwienella radialis (Phillips, 1836)

Figure 7.1

Spirifera radialis Phillips, 1836, p. 220, pl. 11, fig. 5.
Streptorhynchus crenistria var. *radialis* (Phillips). Davidson, 1861, p. 129, pl. 25, figs. 16–18.
Schuchertella radialis (Phillips). Paeckelmann, 1930, p. 199, pl. 11, figs. 5, 6; pl. 12, figs. 1, 2; pl. 14, fig. 10; Sokolskaya in Sarytcheva and Sokolskaya, 1952, p. 43, pl. 4, fig. 29; Yang, 1964, p. 63, pl. 2, fig. 1; Zhang *et al*., 1983, p. 275, pl. 106, fig. 8.
Schellwienella aspis mut. *radialiformis* Demanet, 1934, p. 85, pl. 7, figs. 6–12.
Schuchertella aff. *radialis* (Phillips). Zhang in Yang *et al*., 1962, p. 23, pl. 2, fig. 1.
Schellwienella radialis (Phillips). Brunton, 1968, p. 42, pl. 6, figs. 13–24, text-figs. 27–35; Nalivkin, 1979, p. 21, pl. 4, fig. 4.

Material.—One specimen, external and internal moulds of a ventral valve, NU-B2152.

Remarks.—This specimen is poorly preserved but can be referred to *Schellwienella radialis* (Phillips, 1836), redescribed by Brunton (1968, p. 42, pl. 6, figs. 13–24, text-figs. 27–35) on the type specimens from the upper Visean of Fermanagh, northern Ireland, by its medium-sized (length about 32 mm, width about 33 mm), flattened ventral valve, with strong divergent dental plates, and the parvicostellate ornament with concentric growth lines forming serrations along crests of the costellae. *Schellwienella radialis* is distinguished from other species of the genus *Schellwienella* by the strong parvicostellate ornament. *Schellwienella izirii* Minato (1951, p. 363, pl. 5, fig. 3), from the Hikoroichi Series (= Karoyama Formation of Tazawa *et al*., 1981) of Okuhinotsuchi, South Kitakami Belt, is not assigned to the genus *Schellwienella* by the presence of a median septum in the ventral valve. The Okuhinotsuchi species is identical with *Schizophoria resupinata* (Martin, 1809) on account of its size, shape, external ornament and internal structure of the ventral valve.

Distribution.—Upper Tournaisian–upper Visean: UK (Scotland, England and northern Ireland), Germany, Belgium, western Russia (Moscow Basin), central Russia (central and southern Urals), northwestern China (Xinjiang and Gansu) and northeastern Japan (South Kitakami Belt).

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 fimbriata (Phillips, 1836)

Figure 8.8

Spirifer fimbriata Phillips, 1836, p. 220.
Terebratula plano-sulcata (Phillips). de Koninck, 1843, p. 301, pl. 21, fig. 1e, f only.
Athyris roysii Léveillé. Davidson, 1861, p. 84, pl. 18, figs. 8–11 only.
Cleiothyridina fimbriata (Phillips). Brunton and Champion, 1974, p. 829, pl. 109, figs. 22, 23; Brunton, 1980, p. 227, figs. 19–22; Brunton, 1984, p. 53, figs. 53–66.

Material.—Two specimens, external moulds of two dorsal valves, NU-B2164, 2165.

Remarks.—The specimens from Tairagai are safely assigned to the genus *Cleiothyridina* by their transversely elliptical outline (length 21 mm, width 28 mm in the better preserved specimen, NU-B2164), moderately convex in lateral profile, and external ornament consisting of dense, narrow growth lamellae, the free edges of which are fringed with numerous flattened spines. The Tairagai species can be referred to *Cleiothyridina fim-*

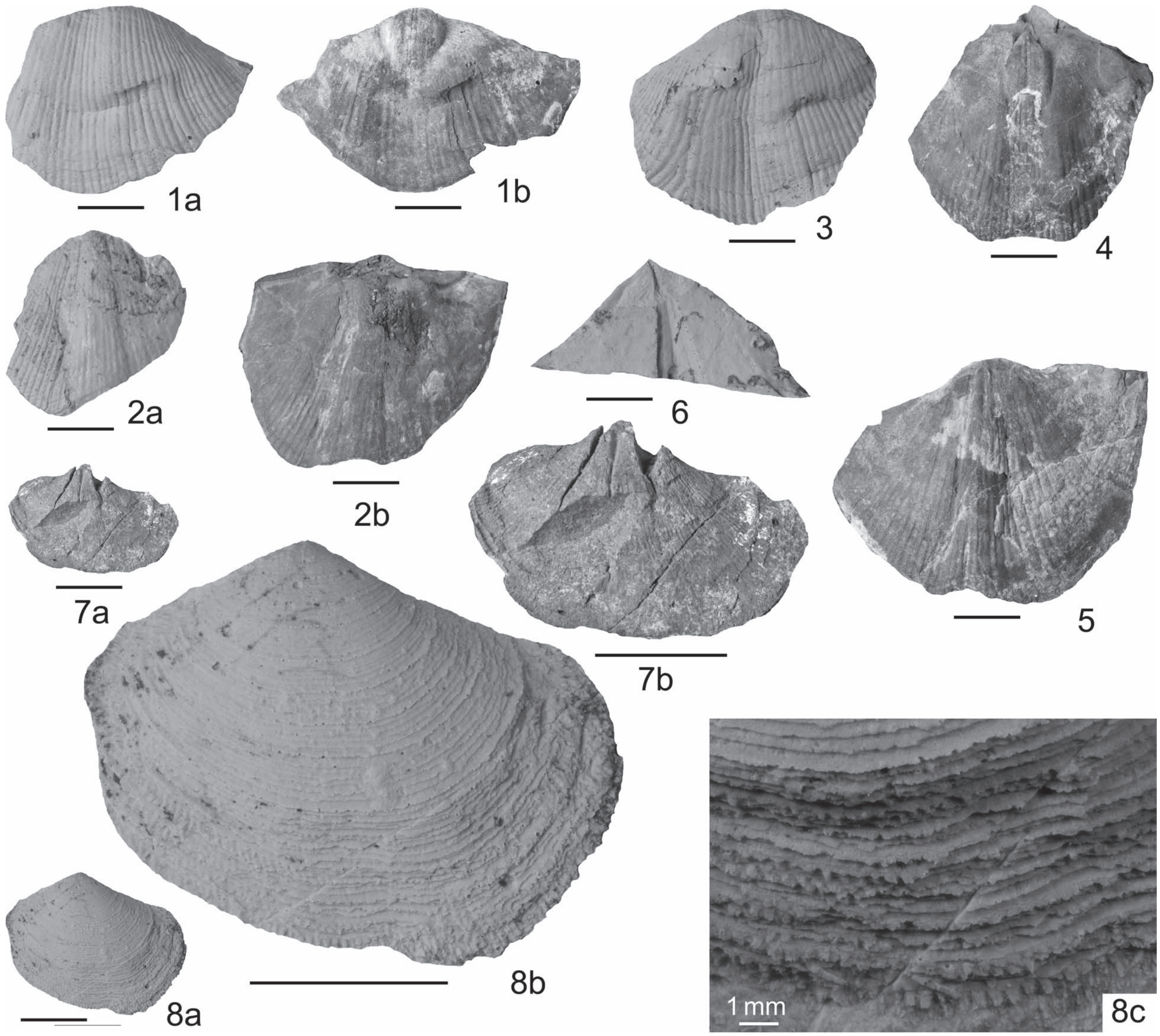

Figure 8. **1–5,** *Spirifer liangchowensis* Chao; 1a, b, external latex cast and internal mould of ventral valve, NU-B2166; 2a, b, external latex cast and internal mould of dorsal valve, NU-B2170; 3, external latex cast of ventral valve, NU-B2167; 4, internal mould of ventral valve, NU-B2168; 5, internal mould of dorsal valve, NU-B2171; **6,** *Pseudosyrinx* sp., external latex cast of ventral interarea, NU-B2163; **7,** *Kitakamithyris* sp.; 7a, b, internal mould of ventral valve, NU-B2153; **8,** *Cleiothyridina fimbriata* (Phillips); 8a–c, external latex cast and enlarged microornamentation of dorsal valve, NU-B2164. Scale bars represent 1 cm, except for 8c.

briata (Phillips, 1836), redescribed by Brunton (1980, p. 227, figs. 19–22), from the upper Visean of County Fermanagh, northern Ireland, by the absence of a dorsal fold and the external ornament of concentric lamellae with spine-like frilly outgrowths. *Cleiothyridina deroissyi* (Léveillé, 1835), from the lower Carboniferous (Tournaisian?) of the Tournai area, Belgium, is readily distinguished from *C. fimbriata* by the presence of a distinct ventral sulcus and a dorsal fold.

Distribution.—Lower–upper Visean: UK (England and northern Ireland), Belgium and northeastern Japan (South Kitakami Belt).

Order Spiriferida Waagen, 1883
Suborder Spiriferidina Waagen, 1883
Superfamily Spiriferoidea King, 1846
Family Spiriferidae King, 1846
Subfamily Spiriferinae King, 1846
Genus ***Spirifer*** Sowerby, 1816

Type species.—*Conchyliolithus* (*Anomia*) *striatus* Martin, 1793.

Spirifer liangchowensis Chao, 1929

Figures 8.1–8.5

Spirifer liangchowensis Chao, 1929, p. 6, pl. 1, figs. 1–7, text-fig. 1; Yang in Yang *et al.*, 1962, p. 99, pl. 39, fig. 1.
Neospirifer liangchowensis (Chao, 1929): Wang *et al.*, 1964, p. 508, pl. 89, figs. 14–16; Ding and Qi, 1983, p. 401, pl. 135, fig. 5.

Material.—Six specimens: (1) external and internal moulds of a ventral valve, NU-B2166; (2) external mould of a ventral valve, NU-B2167; (3) internal moulds of two ventral valves, NU-B2168, 2169; (4) external and internal moulds of a dorsal valve, NU-B2170; and (5) internal mould of a dorsal valve, NU-B2171.

Description.—Shell medium in size for genus, slightly transverse, subrectangular in outline, widest at hinge; cardinal extremities blunt, angular, not mucronate; length 39 mm, width about 50 mm in the largest dorsal valve specimen (NU-B2171). Ventral valve strongly and unevenly convex in lateral profile, most convex in umbonal region; sulcus narrow and deep, not clearly demarcated from lateral slopes. Dorsal valve less inflated than ventral valve, moderately convex in umbonal region and flanks, flattened near cardinal extremities; fold narrow and high, defined by fold-bounding grooves. External surface of both valves ornamented with numerous, fine, rounded and bifurcating costae, irregular concentric rugae, and very fine numerous growth lines; costae numbering 4–5 in 5 mm at midlength of ventral flanks. Ventral interior with short, moderately stout and slightly divergent dental adminicula; muscle field elongate subelliptical, moderately impressed; other details not observed. Internal structures of dorsal valve not well preserved in the present material.

Remarks.—These specimens are referred to *Spirifer liangchowensis* Chao, 1929, from the Chouniugou Formation of Gansu, northwestern China, on account of the middle-sized, less transverse shell, with deep ventral sulcus and high dorsal fold. *Spirifer karagai* (Litvinovich, 1962, p. 273, pl. 33, fig. 2), from the upper Visean of central Kazakhstan, resembles *S. liangchouensis* in size and outline of the shell, but differs from the latter in having a shallower ventral sulcus and a lower dorsal fold. *Spirifer gregeri* Weller (1914, p. 359, pl. 55, figs. 1–8), from the lower Burlington Limestone of the Mississippi Valley, differs from *S. liangchowensis* in its longer shell with a shorter hinge. The type species, *Spirifer striata* (Martin, 1793), from the lower Carboniferous (Visean?) of Derbyshire, England, is readily distinguished from the present species by its much larger size, transverse outline, and more acute cardinal extremities.

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

Suborder Delthyridina Ivanova, 1972
Superfamily Reticularioidea Waagen, 1883
Family Elythidae Fredericks, 1924
Subfamily Elythinae Fredericks, 1924
Genus ***Kitakamithyris*** Minato, 1951

Type species.—*Torynifer* (*Kitakamithyris*) *tyoanjiensis* Minato, 1951.

Kitakamithyris sp.

Figure 8.7

Kitakamithyris sp. Tazawa, 1979, p. 11, fig. 11.4.

Material.—One specimen, internal mould of a ventral valve, NU-B2153.

Remarks.—This specimen is fragmentarily preserved, but can be assigned to the genus *Kitakamithyris* by its medium-sized (length about 18 mm, width about 32 mm), subelliptical and gently convex ventral valve, with numerous radiating grooves on the internal surface, and the presence of a long median septum and a pair of divergent adminicula. The Tairagai species resembles *Kitakamithyris hikoroitiensis* Minato (1951, p. 375, pl. 1, fig. 1) and its junior synonym, *Kitakamithyris semicircularis* Minato (1952, p. 171, pl. 7, fig. 6; pl. 8, fig. 5; pl. 10, fig. 3), from the Hikoroichi Series (= Hikoroichi Formation) of the South Kitakami Belt, in size, shape and internal characters of the ventral valve. Accurate comparison is, however, difficult for the poorly preserved material.

Order Spiriferinida Ivanova, 1972
Suborder Spiriferinidina Ivanova, 1972
Superfamily Syringothyridoidea Fredericks, 1926
Family Syringothyrididae Fredericks, 1926
Subfamily Permasyrinxinae Waterhouse, 1986
Genus ***Pseudosyrinx*** Weller, 1914

Type species.—*Pseudosyrinx missouriensis* Weller, 1914.

Pseudosyrinx sp.

Figure 8.6

Material.—One specimen, external mould of ventral interarea, NU-B2163.

Remarks.—The single specimen from Tairagai preserves only the interarea of the ventral valve. The ventral interarea is high, flat, and triangular in outline, measuring 21 mm or more in height, 45 mm in width; delthyrium is narrowly triangular, and covered by concave delthyrial plate except for the anterior portion. Syrinx is not observed. This specimen can be assigned to the genus

Pseudosyrinx Weller, 1914 in having a high interarea with narrowly triangular delthyrium and the absence of a syrinx. The Tairagai species somewhat resembles the type species, *Pseudosyrinx missouriensis* Weller (1914, p. 65, figs. 5–9; pl. 66, figs. 11–13), from the Burlington Limestone of the Mississippi Valley, by the high interarea with narrowly triangular delthyrium in the ventral valve, but accurate comparison is difficult in the fragmentary specimen.

Conclusions

In this study, brachiopods of 11 species in 11 genera are described from the uppermost part of the Odaira Formation at Tairagai in the South Kitakami Belt. The species are as follows: *Leptagonia analoga*, *Rugosochonetes extensus*, *Marginatia burlingtonensis*, *Echinoconchus punctatus*, *Echinaria* sp., *Pustula pustulosa*, *Schellwienella radialis*, *Cleiothyridina fimbriata*, *Spirifer liangchowensis*, *Kitakamithyris* sp. and *Pseudosyrinx* sp.

A late Visean age is assigned to the Tairagai fauna. Therefore, the age of the uppermost part of the Odaira Formation is late Visean; and the Odaira Formation is overlain conformably by the upper Visean Onimaru Formation. The Abean Orogeny (Minato, 1966; Minato *et al*., 1979), which is based mainly on some unconformities including the pre-Onimaru unconformity in the Palaeozoic succession of the South Kitakami Belt, is not present as noted by the previous authors (e.g. Tazawa and Katayama, 1979; Tazawa, 1980, 1984; Kawamura, 1983; Tazawa *et al*., 1984; Kawamura, 1985).

The Tairagai fauna possesses a close affinity with those of western Europe, central Russia, Kazakhstan, Kyrgyzstan, Xinjiang and Gansu. In other words, this fauna has a close affinity with those of the CAOB, and is quite different from those of South China. The South Kitakami region was probably located near North China in the late Palaeozoic, and tectonically belongs to the CAOB. Among the tectonic models of Japan, the strike-slip model is accepted, but both the microcontinent model and the nappe model are not accepted in the late Palaeozoic biogeography of East Asia.

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