The Marginatia-Syringothyris-Rotaia brachiopod assemblage from the Lower Carboniferous of the South Kitakami Belt, northeast Japan, and its palaeobiogeographical implications

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The *Marginatia-Syringothyris-Rotaia* brachiopod assemblage from the Lower Carboniferous of the South Kitakami Belt, northeast Japan, and its palaeobiogeographical implications

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Abstract. Three brachiopod species, *Marginatia burlingtonensis* (Hall), *Syringothyris transversa* Minato and *Rotaia hikoroichiensis* sp. nov., are described from the Lower Carboniferous (Lower Visean) of the Shimoarisu, Yokota and Hikoroichi areas in the South Kitakami Belt (southern Kitakami Mountains), northeast Japan. The *Marginatia-Syringothyris-Rotaia* assemblage from the South Kitakami Belt indicates a palaeobiogeographical similarity between the South Kitakami Belt and the north Xinjiang-Inner Mongolia-Jilin region, i.e., the North China Province of S. Yang (1980) in Early Carboniferous time. Furthermore, the rugose corals *Sugiyamaella*, *Yuanophyllum* and *Kueichouphyllum* from the Lower Carboniferous (Upper Visean) of the South Kitakami Belt are strong evidence of a close connection between this region and the southern part of the North China Province, i.e., the Tianshan-Jilin Province of F. Yang (1994). These palaeobiogeographical data suggest that the South Kitakami region was the eastern extension of the Tianshan-Jilin Province, and located at the continental shelf bordering the eastern margin of North China (Sino-Korea) in the Early Carboniferous.

Key words: brachiopod, Early Carboniferous, *Marginatia-Syringothyris-Rotaia* assemblage, South Kitakami Belt, Tianshan-Jilin Province

Introduction

Palaeozoic geography and biogeography of the South Kitakami Belt, northeast Japan are important and useful for understanding the geotectonic development of the South Kitakami Belt and also the Japanese Islands. Recently the present author proposed the strike-slip model (Tazawa, 2004), which suggested that the South Kitakami Belt is part of the South Kitakami Terrane, the oldest terrane in Japan, and was born at the subduction zone bordering the eastern margin of North China (Sino-Korea) in the Early Ordovician. The palaeoposition of the South Kitakami Belt remained almost unchanged until the Late Permian, although large-scale strike-slip motion occurred afterwards around this area, namely, a dextral strike-slip faulting in the Late Permian to Late Jurassic and a sinistral strike-slip faulting in the Early Cretaceous to Palaeogene. This model is based mainly on the palaeobiogeographical data from the late Palaeozoic (Devonian-Permian) brachiopod faunas of South Kitakami and adjacent regions in East Asia.

Brachiopods are most common in the Early Carboniferous macrofauna of the South Kitakami Belt (southern Kitakami Mountains). Since the pioneering works of Minato (1951, 1952), the brachiopod fauna consisting of 79 species in 47 genera has been described by Tachibana (1956, 1963, 1964, 1969, 1981), Minato and Kato (1977), Tazawa and Katayama (1979), Tazawa (1980, 1981, 1984a, b, 1985, 1989, 1996), Tazawa and Kurita (1986) and Tazawa and Miyake (2002). Many biostratigraphical and tectonic interpretations of the Lower Carboniferous of the South Kitakami region have been made based mainly on these brachiopods (e.g., Minato, 1950a, b, 1955a; Tachibana, 1952; Minato *et al*., 1953, 1979; Tazawa, 1980, 1984b, 1985; Tazawa and Katayama, 1979). However, there are not many detailed palaeobiogeographical studies on the brachiopod faunas, although some articles have been published by Minato (1956), Minato and Kato (1984) and Tazawa (1996, 2002).

The Early Carboniferous (Early Visean) brachio-

pod biogeography of the South Kitakami region was briefly discussed by Tazawa (1996, 2002), in which he concluded that this region was palaeobiogeographically close to the North China Province of S. Yang (1980, 1983), particularly its southern part, i.e., the Tianshan-Jilin Province of F. Yang (1994), and that it was located at the continental shelf bordering the eastern margin of North China in the Early Carboniferous. In this paper the Early Carboniferous brachiopod biogeography of South Kitakami is discussed in comparison with that of China. Three brachiopod species, *Marginatia burlingtonensis* (Hall), *Syringothyris transversa* Minato and *Rotaia hikoroichiensis* sp. nov., all collected from the Lower Visean formations of the southern Kitakami Mountains, are described as the representatives of the index taxa.

All specimens described in this paper are housed in the following institutions as indicated by the prefix to the registered numbers, NU-B: Department of Geology, Niigata University in Niigata; OCM.G.: Ofunato Museum in Ofunato, Iwate Prefecture; UHR: Hokkaido University Museum in Sapporo.

Stratigraphy

The brachiopod specimens described in this paper were collected from nine localities in the Arisu Formation of the Shimoarisu (locality MM1 in Figure 1) and Yokota (localities TK1, KF207, 208 in Figure 1) areas, and the upper part of the lower Hikoroichi Formation of the Hikoroichi area (localities KF171, 172, 174, 182, 202 in Figure 1). The Lower Carboniferous stratigraphy of these areas has been studied by many researchers, in particular, by Takeda (1960) and M. Kawamura (1985a) in the Shimoarisu area; by Minato (1941), Tazawa and Katayama (1979) and M. Kawamura (1985b) in the Yokota area; and by Okubo (1951), T. Kawamura (1983) and Tazawa (1984b) in the Hikoroichi area.

The Arisu Formation is distributed in the Shimoarisu and Yokota areas. It consists of mafic to intermediate tuff in the lower part and shale and sandstone in the upper part, with thin limestone beds, reaching about 400–700 m in thickness (Figure 2). The Hikoroichi Formation is distributed in the Hikoroichi area and consists mostly of sandstone, with a basal conglomerate and intercalations of shale, felsic to intermediate tuff and limestone, and is 560 m in total thickness. Table 1 indicates the brachiopods, described from the Arisu Formation in the Shimoarisu and Yokota areas and the upper part of the lower Hikoroichi Formation in the Hikoroichi area. The age of both the Arisu Formation and the upper Lower

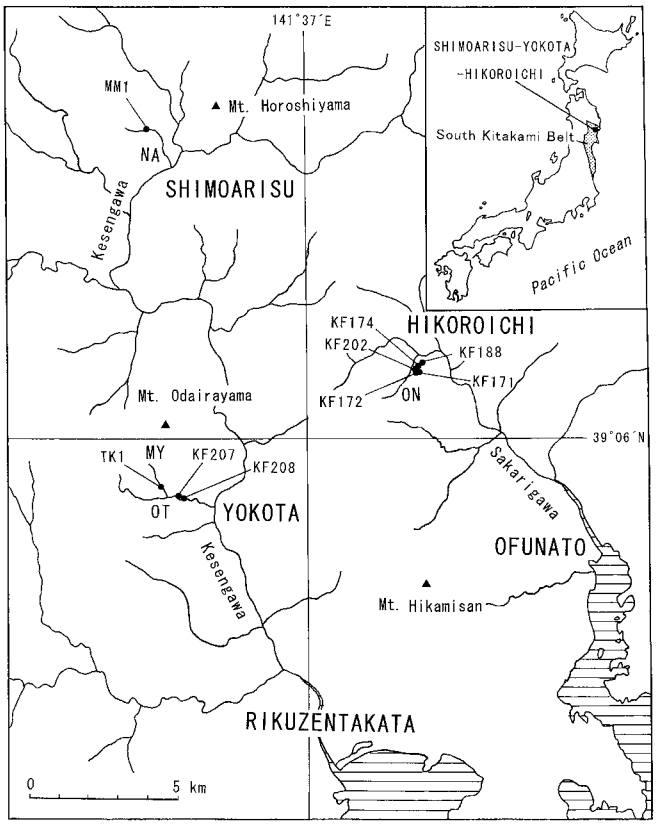

Figure 1. Index map showing the fossil localities in the Shimoarisu, Yokota and Hikoroichi areas. NA, Nashirozawa; ON, Onimarusawa; OT, Otsubosawa.

Hikoroichi Formation are considered to be Early Visean based on corals and brachiopods (T. Kawamura, 1983; Tazawa, 1985).

The stratigraphical and geographical positions of the fossil localities and the brachiopods described here (*Marginatia burlingtonensis*, *Syringothyris transversa* and *Rotaia hikoroichiensis*) are as follows:

MM1: Midstream of Nashirozawa (39°11′43″N, 141°33′24″E) in the Shimoarisu area, green intermediate tuff of the lower Arisu Formation, with *Syringothyris transversa*.

KF171: Hill along the eastern side of Onimarusawa (39°7′14″N, 141°39′35″E) in the Hikoroichi area, black shale of the upper part of the lower Hikoroichi Formation, with *Marginatia burlingtonensis*.

KF172: Hill along the eastern side of Onimarusawa (39°7′15″N, 141°39′29″E) in the Hikoroichi area, black shale of the upper part of the lower Hikoroichi Formation, with *Marginatia burlingtonensis*.

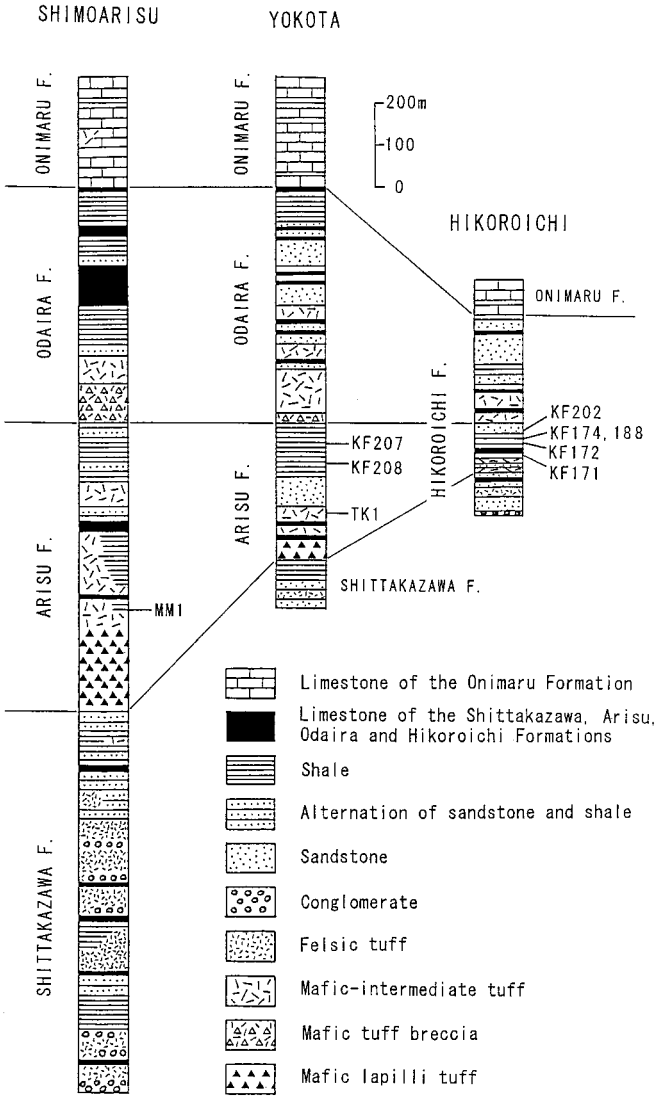

Figure 2. Columnar sections of the Lower Carboniferous of the Shimoarisu, Yokota and Hikoroichi areas, showing the stratigraphical horizons of the fossil localities. Redrawn and adapted from Tazawa and Katayama (1979), Tazawa (1984b) and M. Kawamura (1985a).

KF174: Hill along the eastern side of Onimarusawa (39°7′24″N, 141°39′40″E) in the Hikoroichi area, black shale of the upper part of the lower Hikoroichi Formation, with *Marginatia burlingtonensis*.

KF188: Hill along the eastern side of Onimarusawa (39°7′27″N, 141°39′44″E) in the Hikoroichi area, black shale of the upper part of the lower Hikoroichi Formation, with *Marginatia burlingtonensis*.

KF202: Onimaru quarry (39°7′18″N, 141°39′33″E) in the Hikoroichi area, dark grey calcareous fine-grained sandstone of the upper part of the lower Hikoroichi Formation, with *Marginatia burlingtonensis* and *Rotaia hikoroichiensis*.

KF207: Midstream of Otsubosawa (39°4′57″N, 141°33′59″E) in the Yokota area, black shale of the upper Arisu Formation, with *Marginatia burlingtonensis*.

KF208: Midstream of Otsubosawa (39°4′56″N, 141°34′5″E) in the Yokota area, black shale of the upper Arisu Formation, with *Marginatia burlingtonensis*.

TK1: Myojinsawa (39°5′5″N, 141°33′42″E), a tributary of Otsubosawa in the Yokota area, green intermediate tuff of the lower Arisu Formation, with *Syringothyris transversa*.

Marginatia-Syringothyris-Rotaia assemblage

S. Yang (1980, 1983) was the first to study the Early Carboniferous brachiopod biogeography of China and proposed three provinces, the North China Province, South China Province and Himalayan Province. Afterwards S. Yang *et al.* (1984) refined this provincial classification, and suggested four provinces: the North China, South China, Western China and Himalaya (Gondwana) Provinces (Figure 3). The North China Province occupies the area north of Tarim and Sino-Korea, i.e., the Junggar-Inner Mongolia-Jilin region, and is characterized by the presence of brachiopods *Marginatia*, *Tolmatchoffia*, *Syringothyris* and *Rotaia*. The South China Province occupies the Yangtze and its surrounding areas, and is characterized by brachiopods such as *Yanguania*, *Eochoristites* and *Martiniella*. The Western China Province occupies the vast areas south of Tarim and the regions west of the Yangtze, including north Gansu and north Sichuan, and is characterized by mixed types from the North and South China Provinces. The Himalaya (Gondwana) Province occupies the Himalaya-Tibet region, and contains brachiopods closely related to the Gondwanan fauna, such as *Fusella*, *Ovatia*, *Marginirugus* and *Girtyella*. In the extent of area and faunal composition, the Northern Province of Ching and Liao (1985), the Boreal Realm of S. Yang (1990) and the Tianshan-Hinggan Province of Liao (1995) are almost the same as S. Yang's North China Province.

The Lower Carboniferous brachiopod fauna of the South Kitakami region contains the genera *Marginatia*, *Syringothyris* and *Rotaia*. Figures 6–8 show the specimens of *Marginatia burlingtonensis*, *Syringothyris transversa* and *Rotaia hikoroichiensis* from the Lower

Table 1. Early Carboniferous brachiopods from the Arisu Formation of the Shimoarisu and Yokota areas and the upper Lower Hikoroichi Formation of the Hikoroichi area in the South Kitakami Belt.

Species	Locality			Author
	SHIMOARISU	YOKOTA	HIKOROICHI	
Leptagonia convexa (Weller)	+		+	Minato (1951)
Planoproductus gigantoides Minato	+	+		Minato (1951)
Buxtonia sp.			+	Tazawa (1989)
Marginatia burlingtonensis (Hall)		+	+	Tazawa (1985, 1989, this paper)
Pustula cf. *tenuipustulata* Thomas		+		Minato (1952)
Linoprotonia sp.			+	Tazawa (1984a, 1989)
Orthotetes keokuk (Hall)	+	+		Minato (1952)
Orthotetes sp.		+		Minato (1952)
Derbyia depressa var. *transversa* Minato		+		Minato (1952)
Schizophoria resupinata (Martin)		+		Minato (1952)
Schizophoria pinguis Demanet	+			Tazawa and Kurita (1986)
Lamellosathyris lamellosa (Léveillé)	+	+	+	Minato (1951, 1952), Tazawa (1989)
Cleiothyridina royssii (Léveillé)	+	+		Minato (1951, 1952)
Plicatosyrinx singulare Minato		+		Minato (1952)
Plicatosyrinx? kumanoi Minato		+		Minato (1952)
Syringothyris jumonjiensis Minato	+			Minato (1951)
Syringothyris transversa Minato	+	+		Minato (1951, 1952), Tazawa (this paper)
Syringothyris kitakamiensis Minato		+		Minato (1962)
Syringothyris sp.		+		Minato (1952)
Spirifer ohmoriensis Minato			+	Minato (1952)
Fusella nipponotrigonalis Minato	+	+		Minato (1951, 1952)
Fusella nipponotrigonaris var. *minor* Minato		+		Minato (1952)
Unispirifer kozuboensis (Minato)	+	+		Minato (1952), Tazawa and Kurita (1986)
Unispirifer sp.		+	+	Tazawa (1985, 1989)
Kitakamithyris semicircularis Minato		+	+	Minato (1952)
Rotaia hikoroichiensis Tazawa			+	Tazawa (1996, this paper)

Visean of this region. As mentioned by Tazawa (1996, 2002), it is noteworthy that the Early Visean brachiopod fauna of South Kitakami contains *Marginatia*, *Syringothyris*, and *Rotaia*, which are index genera of the North China Province in that time. Recently Shi *et al.* (2005) described some Early Carboniferous (Late Tournaisian) brachiopod faunas, including all *Marginatia*, *Syringothyris* and *Rotaia*, from the Baoshan block, western Yunnan. But the Lower Carboniferous biota of the western Yunnan area is clearly distinguished from that of South Kitakami by its marine invertebrates and palynomorphs of Gondwanan affinities (Gao, 1998; Wang *et al.*, 2001).

Discussion

The *Marginatia-Syringothyris-Rotaia* assemblage of the Lower Carboniferous of the South Kitakami

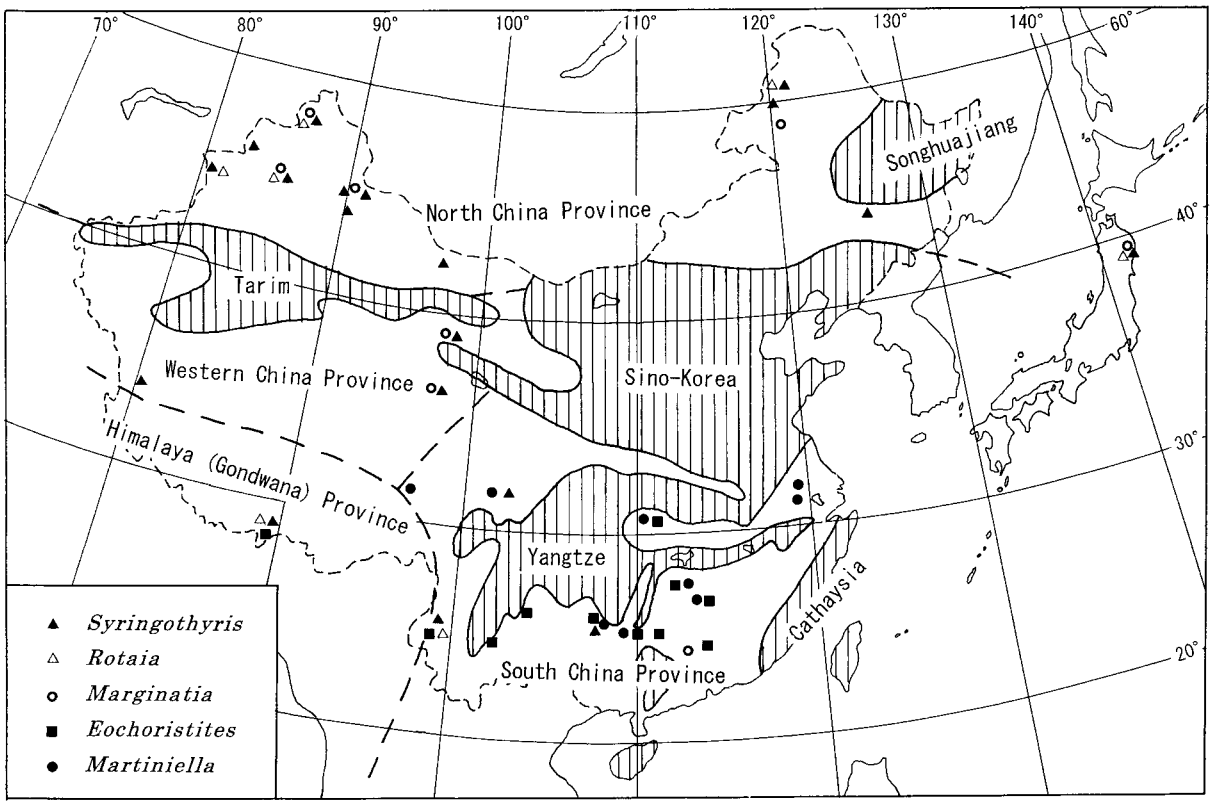

Figure 3. Early Carboniferous brachiopod biogeography of China and adjacent regions, including Japan (South Kitakami), showing the geographical distribution of the index genera. Lined areas were land. Redrawn and adapted from S. Yang (1983) and S. Yang *et al.* (1984).

region indicates clearly that the Early Carboniferous (Early Visean) brachiopod fauna of this region demonstrates a close relationship to that of the North China Province. According to F. Yang (1994), S. Yang's North China Province is further subdivided into two provinces, the Tianshan-Jilin Province in the south and the Junggar-Xingan Province in the north (Figure 4). The Tianshan-Jilin Province is differentiated from the Junggar-Xingan Province by the presence of some rugose corals, such as *Sugiyamaella*, *Yuanophyllum* and *Kueichouphyllum*. The coral assemblage is very similar to the Early Carboniferous (Late Visean) coral fauna of South Kitakami (Minato, 1955b; Minato *et al*., 1979). Based on the brachiopod and coral faunas, South Kitakami is considered to be the eastern extension of the Tianshan-Jilin Province of F. Yang (1994) in the Early Carboniferous. This suggests that the South Kitakami region was located at the eastern margin of North China (Sino-Korea) in the Early Carboniferous (Late Visean) (Figure 5).

Concerning the Early Carboniferous biogeography of Japan (South Kitakami), Minato (1956) mentioned faunal affinities of Japan with northeast China and eastern Australia, although no specific data was indicated. In this time, he emphasized the dissimilarities between the faunas of South Kitakami and southern China. S. Yang (1980) also mentioned that the Early Carboniferous brachiopod faunas of the North China Province were closely related to the contemporaneous brachiopod faunas of northern Russia and North America. In addition, Minato and Kato (1984) suggested that certain Tournaisian fossils of South Kitakami showed an intimate relationship with the faunas of northern China, Russia and North America. These opinions are in agreement with the conclusion of this study, especially the close affinity between South Kitakami and northern China. However, Kato (1990) and Kawamura *et al.* (1999) suggested that Early Carboniferous South Kitakami coral faunas have a close affinity to those of Australia and South China. Further investigation on the faunal relationship between South Kitakami and the other regions, such as Russia, North America, Australia and South China, is called for.

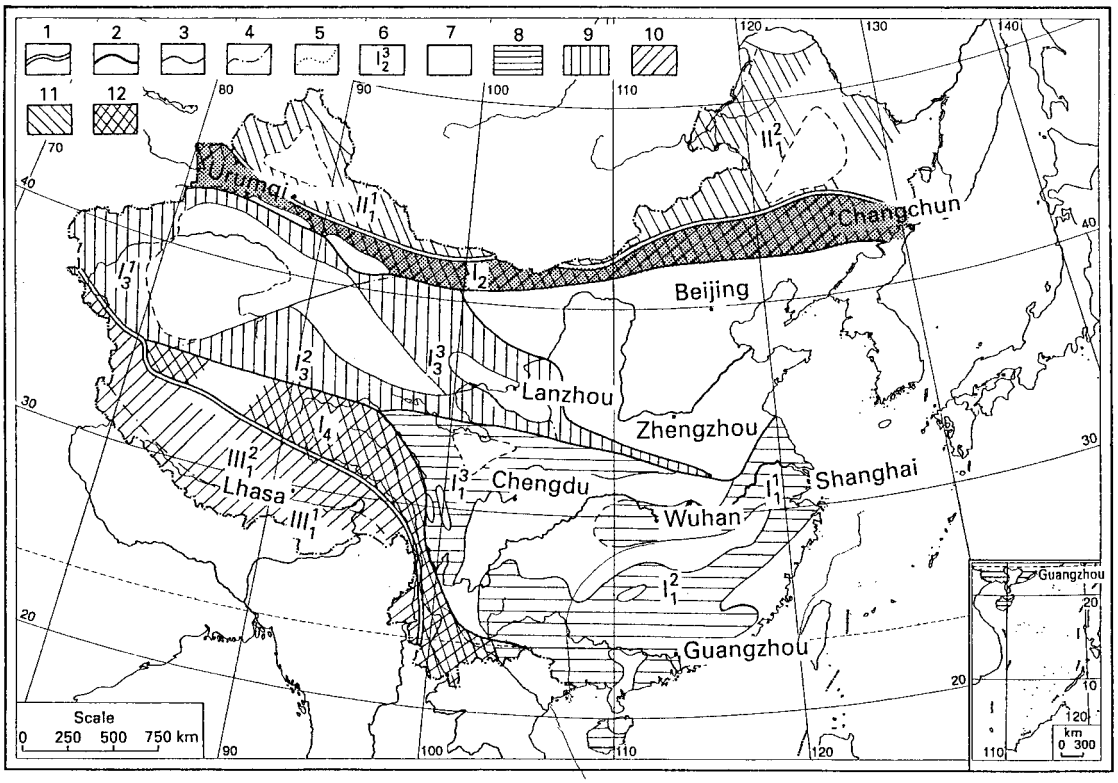

Figure 4. Early Carboniferous biogeography of China, showing especially the Tianshan-Jilin Province (I_2). 1, boundary of realms; 2, boundary of regions; 3, boundary of provinces; 4, boundary of biomes; 5, boundary of communities; 6, roman numeral = realm mark, subscript numeral = province mark, superscript numeral = biome mark; 7, oldland; 8–12, marine and paralic regions; 8, South China; 9, North China; 10, Gondwana; 11, Junggar-Xingan; 12, transitional; I, Palaeo-Tethyan Realm, Cathaysian Region; I_1, South China Province; I_{1^1}, Jiangsu-Zhejiang-Anhui Biome; I_{1^2}, Hunan-Guizhou-Guangxi Biome; I_{1^3}, Qinling-Longmenshan Biome; I_2, Tianshan-Jilin Province; I_3, Tarim-Qilian Province; I_{3^1}, Tarim Basin Margin Biome; I_{3^2}, Qaidam Biome; I_{3^3}:,Qilian Biome; I_4, Northern Tibet-Western Yunnan Province; II, Boreal Realm, Central Asia-Mongolia Region; II_1, Junggar-Xingan Province; II_{1^1}, Junggar-Altay Biome; II_{1^2}, Xingan Biome; III, Gondwana Realm; III_1, Himalaya-Gangdise-Nianqingtanggula Province; III_{1^1}, Himalaya Biome; III_{1^2}, Gangdise-Nianqingtanggula Biome. Adapted from F. Yang (1994).

Systematic descriptions

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

Type species.—*Productus fernglenensis* Weller, 1909

Marginatia burlingtonensis (Hall, 1858)

Figures 6.1–6.8

Productus flemingi var. *burlingtonensis* Hall, 1858, p. 598, pl. 12, figs. 3a–g.
Productus burlingtonensis Hall. Weller, 1914, p. 104, pl. 9, figs. 1–10.
Productus (*Productus*) *burlingtonensis* Hall. Nalivkin, 1937, p. 66, pl. 7, figs. 7–11.
Productus sp. Minato, 1951, p. 366, pl. 1, figs. 4a, b.
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; Bublitschenko, 1976, p. 50, pl. 2, figs. 12a, b, v; pl. 4, figs. 6a, b, v; pl. 5, figs. 4–6; pl. 6, figs. 9a, b; Galitskaya, 1977, p. 83, pl. 22, figs. 6–10; Nalivkin, 1979, p. 94, pl. 32, figs. 1–10; pl. 34, figs. 3, 4; Carter, 1987, p. 39, pl. 9, figs. 1–8; Shi *et al*., 2005, p. 44, figs. 5D, I–K, M.
Marginatia sp. Tazawa, 1985, p. 459, figs. 2.3–7; Tazawa, 1989, p. 60, pl. 1, figs. 1a, b; Tazawa, 2002, figs. 7.1, 2.

Material.—Twenty-two specimens, from the hill along the eastern side of Onimarusawa and the Onimaru quarry, Hikoroichi (localities KF171, 172, 174, 188, 202), and midstream of Otsubosawa, Yokota (localities KF207, 208): (1) external and internal moulds of a conjoined valve, NU-B629; (2) external and internal moulds of two ventral valves, NU-B630, 631: (3) external moulds of a ventral valve, NU-B632:

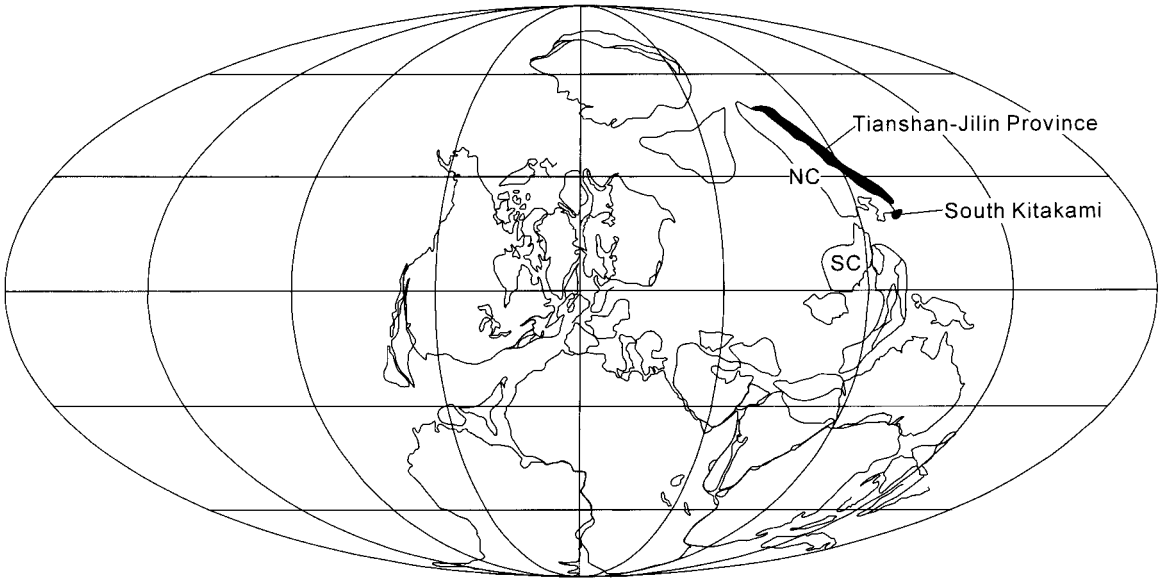

Figure 5. Early Carboniferous reconstruction map of the world, showing especially the Tianshan-Jilin Province (continental shelf) and the South Kitakami region (continental shelf). NC: North China, SC: South China. Redrawn and adapted from Scotese (1997).

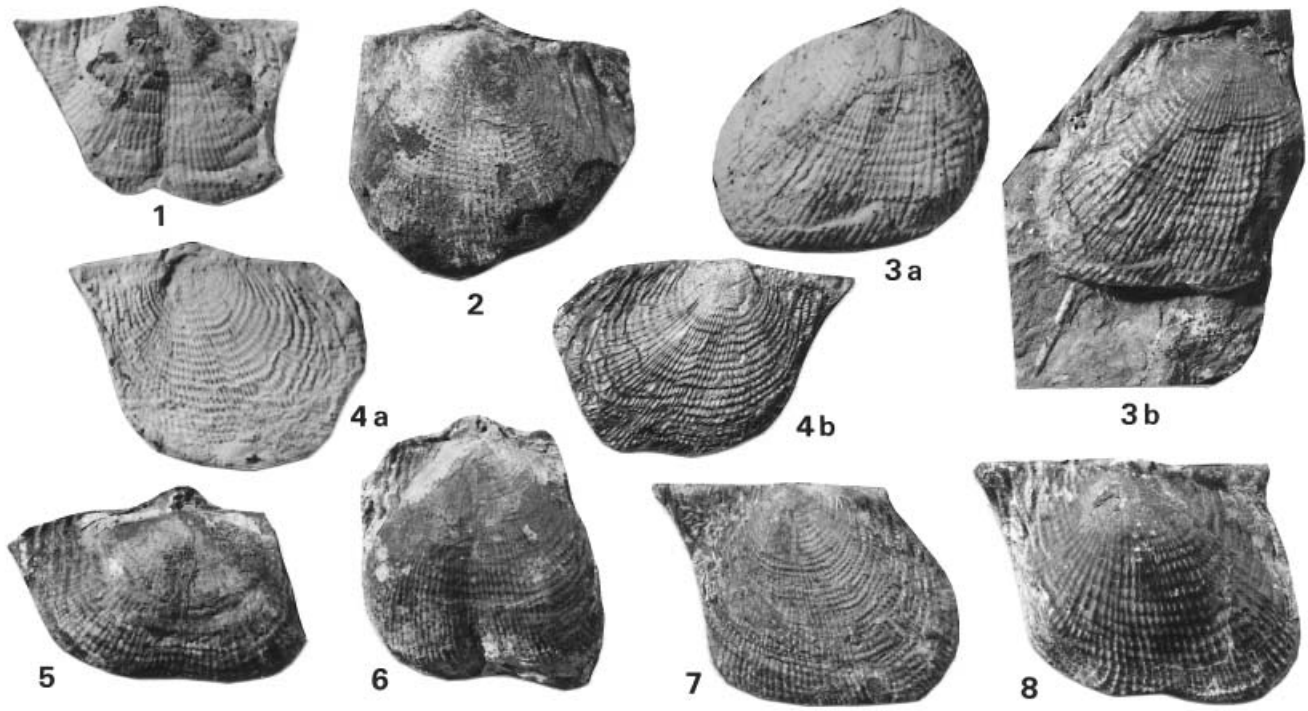

Figure 6. *Marginatia burlingtonensis* (Hall, 1858), from the Lower Carboniferous of the South Kitakami Belt (natural size). **1.** external latex cast of a ventral valve, NU-B629. **2.** external mould of a dorsal valve, NU-B642. **3a, 3b.** internal latex cast and external mould of a dorsal valve, NU-B633. **4a, 4b.** external latex cast and external mould of a dorsal valve, NU-B643. **5.** external mould of a dorsal valve, NU-B648. **6.** external mould of a dorsal valve, NU-B645. **7.** external mould of a dorsal valve, NU-B634. **8.** external mould of a dorsal valve, NU-B640.

(4) external and internal moulds of seven dorsal valves, NU-B633-639; (5) external moulds of eleven dorsal valves, NU-B640-650.

Description.—Shell medium to large for genus, transversely subrectangular in outline, with greatest width at hinge; length 28 mm, width about 49 mm in the best preserved specimen (NU-B629); length 36 mm, width about 55 mm in the largest dorsal valve specimen (NU-B641).

Ventral valve gently convex on venter, strongly geniculated and followed by long trail; umbo small, pointed and protruding a little beyond hinge line; ears rather small, pointed, often mucronate and well demarcated from venter; lateral slopes steep; sulcus shallow on both venter and trail; trail about 26 mm long so far as it is preserved. External ornament of ventral valve consisting of concentric rugae and costae on venter, costae only on trail; rugae strong, regular, having a density of 4 in 5 mm near anterior margin of venter; costae rounded, often intercalated, having a density of 5–6 in 5 mm near anterior margin of venter. A few long and straight halteroid spines scattered on trail. Other spines or spine bases not observed. Dorsal valve nearly flat on venter, geniculated to form short trail and having low fold over venter and trail. External ornament similar to that of the opposite valve; rugae having a density of 4 in 5 mm at midventer; costae having a density of 6–7 in 5 mm at midventer. Spines or spine bases absent.

Internally, ventral valve having a pair of large, fan-shaped and striated diductor scars in posterior half of valve. Dorsal valve having a thin median septum, extending to half length of valve; buttress plates parallel, about 5 mm long, situated on either side of median septum near posterior margin; lateral ridges short, diverging slightly from hinge line; adductor scars subtrigonal in shape, smooth or faintly dendritic, placed just anterior to buttress plates. Other internal structures not observed in the present specimens.

Remarks.—The Kitakami specimens are referred to *Marginatia burlingtonensis* (Hall, 1858), originally described by Hall (1858) from the Burlington Limestone of Iowa and Illinois, U.S.A., as they are identical in size and shape of the shells, and in particular, the strongly convex ventral valve and pointed, often mucronate ears.

Marginatia patersonensis Roberts (1965, p. 63, pl. 10, figs. 1–5; 1976, p. 67, pl. 12, figs. 1–10) from the lower and upper Visean of Trevallyn, New South Wales, Australia, somewhat resembles *M. burlingtonensis* in size and outline, but the former differs from the latter in having finer costae and a larger number of spines on the ventral valve.

Marginatia toriyamai Yanagida (1973, p. 41, pl. 1, figs. 1–5; pl. 2, figs. 1–9; text-figs. 6–8) from the Lower Carboniferous (probably Visean) of Akiyoshi, southwest Japan is easily distinguished from *M. burlingtonensis* by its smaller size and finer costellate ornament.

Productus sp. of Minato (1951, p. 366, pl. 1, figs. 4a, 4b) from the Arisu and Odaira Formations of the southern Kitakami Mountains is a probable synonym of the present species because of their close similarities in size, shape and external ornament of the ventral valve.

Distribution.—Upper Tournaisian to Lower Visean of Russia (Urals and Kuznetsk Basin), east Kazakhstan, northern Kirgiz and southwest China (Yunnan). Lower Visean of Japan (southern Kitakami Mountains). Osagean of U.S.A. (Mississippi Valley) and Canada (western Alberta).

Order Spiriferida Waagen, 1883
Suborder Spiriferinidina Ivanova, 1972
Superfamily Syringothyridoidea Fredericks, 1926
Family Syringothyrididae Fredericks, 1926
Subfamily Syringothyridinae Fredericks, 1926
Genus ***Syringothyris*** Winchell, 1863

Type species.—*Spirifer carteri* Hall, 1857

Syringothyris transversa Minato, 1951

Figures 7.1a–7.2b

Syringothyris transversa Minato, 1951, p. 377, pl. 5, figs. 1a–f; Minato, 1952, *pars*, p. 167, pl. 11, figs. 5a, b only; Minato *et al*., 1979, pl. 21, figs. 11a–c; Tazawa, 2002, figs. 7.6a, b.

Material.—Two specimens, from midstream of Nashirozawa, Jumonji, Shimoarisu (locality MM1), and Myojinsawa, a tributary of Otsubosawa, Yokota (locality TK1): (1) internal mould of a conjoined valve with external mould of the ventral interarea, UHR16925 (holotype); (2) internal mould of a conjoined valve, NU-B651.

Remarks.—The holotype, from the upper Arisu Formation (AR3) in Nashirozawa, Jumonji, has been fully described by Minato (1951, p. 377). Another specimen (NU-B651), collected from float in Myojinsawa, a tributary of Otsubosawa, Yokota, is identical with *Syringothyris transversa* in its size, shape and external ornament of the shell, although this specimen is heavily abraded.

Syringothyris textus (Hall), described and figured by Weller (1914, p. 399, pl. 69, figs. 6–9; pl. 70, figs. 1–4; pl. 71, figs. 1–2), from the Keokuk Limestone and the Knobstone Formation of the Mississippi Valley Basin, is like *S. transversa* in the size, shape and external

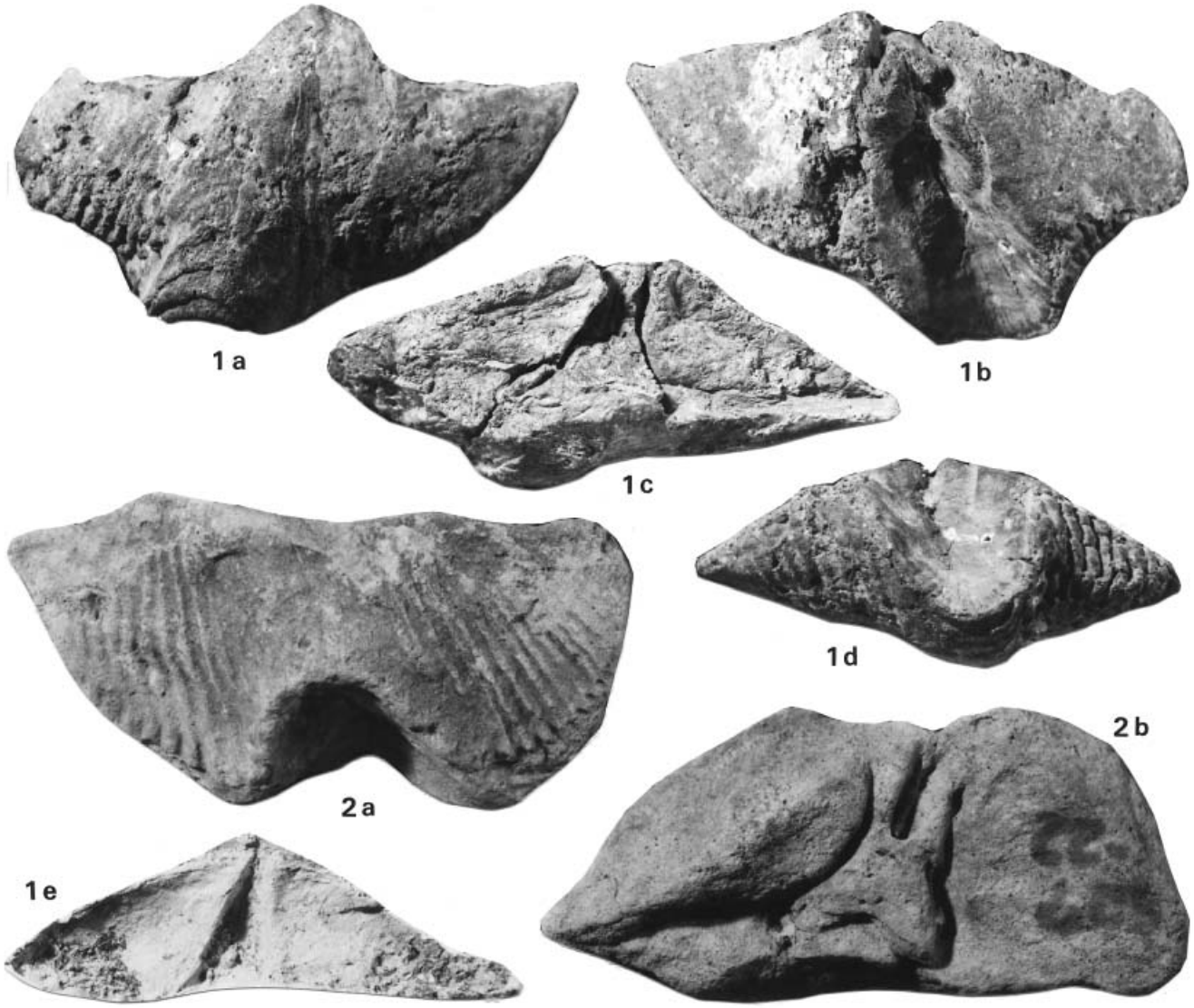

Figure 7. *Syringothyris transversa* Minato, 1951, from the Lower Carboniferous of the South Kitakami Belt (natural size). **1a, 1b, 1c, 1d, 1e.** dorsal, ventral, posterior and anterior views of internal mould of a conjoined valve, and external latex cast of the ventral internal area, UHR16925. **2a, 2b.** dorsal and posterior views of abraded internal mould of a dorsal valve, NU-B651.

ornament. However, comparison of these species is difficult owing to the bad preservation of the Kitakami specimens.

Distribution.—Lower Visean of Japan (southern Kitakami Mountains).

Order Rhynchonellida Kuhn, 1949
Superfamily Rhynchotetradoidea Licharew in Rzhonsnitskaya, 1956
Family Tetracameridae Licharew in Rzhonsnitskaya, 1956
Genus ***Rotaia*** Rzhonsnitskaya, 1959

Type species.—*Rhynchonella subtrigona* Meek and Worthen, 1860

Rotaia hikoroichiensis sp. nov.

Figures 8.1a–8.3c

Rotaia sp. Tazawa, 1996, p. 8, figs. 4a, b; Tazawa, 2002, figs. 7.3–5.

Material.—Three specimens, from the Onimaru quarry, Hikoroichi (locality KF202): (1) one conjoined valve, OCM.G.881; (2) external and internal moulds of two ventral valves, OCM.G.732, NU-B49.

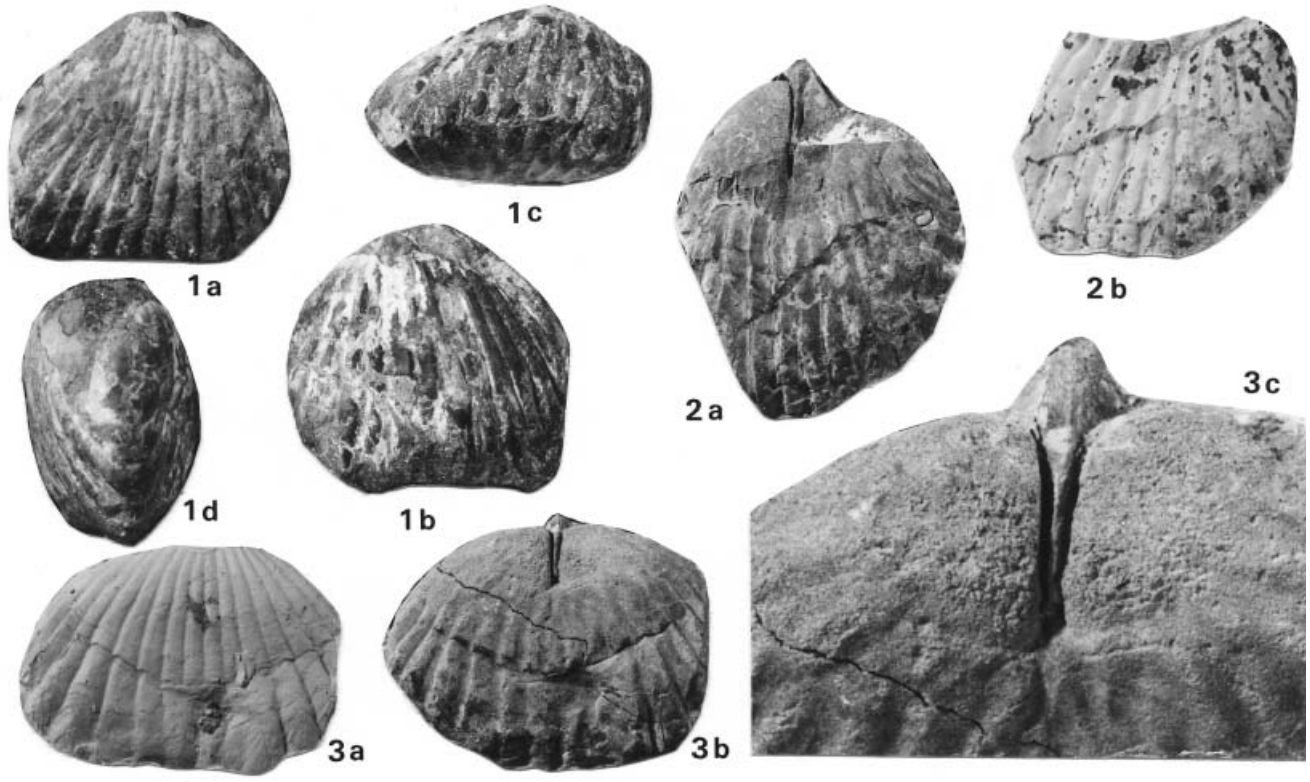

Figure 8. *Rotaia hikoroichiensis* sp. nov., from the Lower Carboniferous of the South Kitakami Belt (natural size unless otherwise specified). **1a, 1b, 1c, 1d.** ventral, dorsal, anterior and lateral views of a conjoined valve, OCM.G.881. **2a, 2b.** internal mould and external latex cast of a ventral valve, NU-B49. **3a, 3b, 3c.** external latex cast and internal mould of a ventral valve (3c ×3), OCM.G.732.

Diagnosis.—Large, transverse *Rotaia*, with ill-defined sulcus and fold, ornamented by coarse costae on both valves.

Description.—Shell large size for genus, transversely subpentagonal in outline, with greatest width slightly anterior to midvalve; length 36 mm, width 40 mm in the best preserved but smaller specimen (OCM.G.881); length about 37 mm, width about 44 mm in the larger ventral valve specimen (OCM.G.732). Ventral valve moderately convex near umbo, becoming slightly convex to flat anteriorly. Sulcus shallow, wide and ill-defined. Dorsal valve more strongly convex than opposite valve, having a low, wide and ill-defined fold. External ornament of both valves consisting of broad and rounded costae, numbering 15–17 on the whole ventral or dorsal valve, 6 costae in sulcus, and 5 costae on fold. Interior of ventral valve with a small, elongate spondylium, extending to one-third the length of the valve.

Remarks.—*Rotaia hikoroichiensis* sp. nov. is distinguished from *Rotaia subtrigona* (Meek and Worthen, 1860) by its larger, more transverse shell, and by having an ill-defined sulcus and fold and coarser costae on both valves. The large, longer ventral valve specimen (NU-B49) is severely deformed, and the original outline is not preserved.

Rotaia kusbassi (Rotai, 1938) from the Serpukhovian of the Kuznetsk Basin is distinguished from *R. hikoroichiensis* by its strongly inflated dorsal valve and more fine and many costae on both valves (*see* Sarytcheva *et al*., 1963, pl. 41, figs. 12–15).

Rotaia dowhatensis (Diener, 1915), originally described as *Camarophoria dowhatensis* by Diener (1915, p. 45, pl. 5, figs. 1–4) from the Fenestella Series (Visean) of Kashmir, is distinguished from the present species by its finer and more numerous costae in the ventral sulcus.

Rotaia sp. of Shi *et al*. (2005, p. 72, figs. 19F–J, 20) from the Upper Tournaisian of west Yunnan, China differs from the Kitakami species in having a deeper ventral sulcus.

Distribution.—Lower Visean of Japan (southern Kitakami Mountains).

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