Late Carboniferous (Moscovian) choristitid brachiopods from Nagaiwa in the South Kitakami Belt, NE Japan

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Abstract

This study describes the following four choristitid brachiopod species from the Upper Carboniferous (Moscovian) Nagaiwa Formation of Nagaiwa, South Kitakami Belt, northeast Japan: *Choristites mosquensis* Fischer de Waldheim, *Choristites jigulensis* (Stuckenberg), *Parachoristites nagaiwensis* sp. nov., and *Parachoristites* sp. The occurrence of these brachiopods suggests that the South Kitakami region was part of the continental shelf bordering the eastern margin of North China (Sino-Korea) during the Late Carboniferous. This finding supports the strike-slip model, one of three models proposed to explain the Pre-Neogene tectonics of Japan.

Key words: brachiopod, *Choristites*, Moscovian, Nagaiwa Formation, *Parachoristites*, South Kitakami Belt.

Introduction

The Late Palaeozoic geography of the South Kitakami Belt represents a key to the Palaeozoic-Mesozoic tectonic development of the Japanese Islands. At present, three models have been proposed for the Pre-Neogene tectonics of Japan: (1) the microcontinent model (Kanmera, 1980; Taira, 1985; Ichikawa, 1990); (2) the nappe model (Isozaki and Maruyama, 1991; Isozaki, 1996); and (3) the strike-slip model (Tazawa, 1993, 2004). Tazawa (2002) proposed that the South Kitakami region was part of the continental shelf bordering the eastern margin of North China (Sino-Korea) during the Middle Devonian, Early Carboniferous, and

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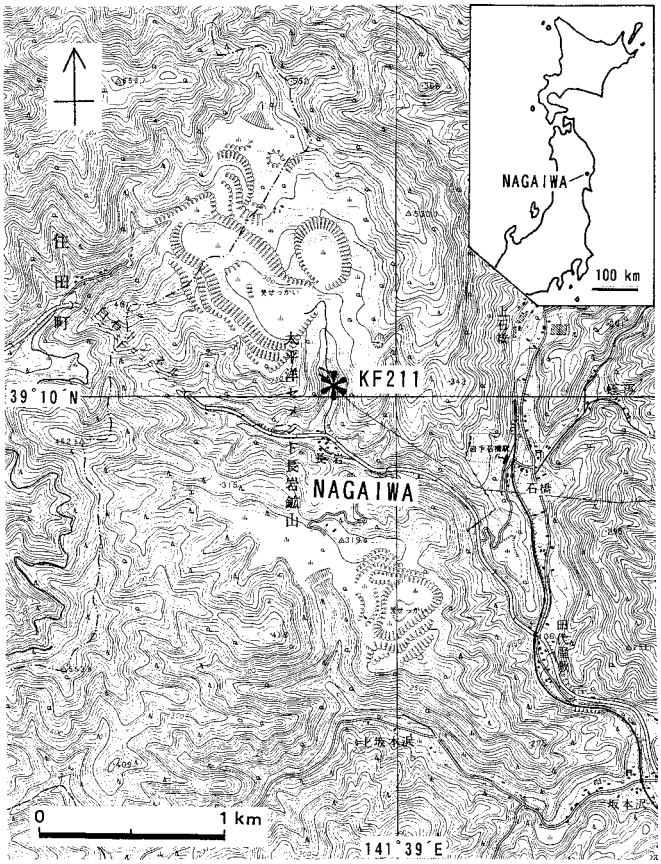

Fig. 1. Index map showing the fossil locality KF211 in the Nagaiwa area, South Kitakami Belt, northeast Japan.

Middle Permian, based on the brachiopod-derived palaeobiogeography of South Kitakami and adjacent regions in East Asia. This reconstruction is consistent with the requirements of the strike-slip model; however, there exists a lack of Late Carboniferous data regarding the palaeogeography of the South Kitakami Belt.

In this study four choristitid brachiopod species useful for reconstructions of Late Carboniferous biogeography and geography are described from the Upper Carboniferous (Moscovian) Nagaiwa Formation of Nagaiwa, the type area of the formation. The Late Carboniferous palaeogeography of the South Kitakami Belt is discussed with reference to the analysed choristitids. The brachiopod specimens are housed in the Department of Geology, Faculty of Science, Niigata University, Niigata, Japan.

Stratigraphy

The material was collected by the present author from pebbly limestone in the upper part of the Nagaiwa Formation, at a road-cutting at the entrance to a limestone quarry in Nagaiwa

(locality KF211; 39°9'0"N, 141°38'43"E), Hikoroichi-cho, Ofunato City, Iwate Prefecture, eastern part of the South Kitakami Belt, northeast Japan (Fig. 1). The fossil-bearing pebbly limestone belongs to the *Parastaffella* cf. *vlerki* Subzone (upper part of the Zone of *Profusulinella*) of Kobayashi (1973a, b), and is correlated with the lower Moscovian.

The stratigraphy of the Nagaiwa Formation in the Nagaiwa area has been studied by Yamada (1958), Kobayashi (1973a, b), Musashino (1973), and Kato et al. (1979). The Nagaiwa Formation consists mostly of limestone, with subordinate felsic tuff, sandstone, and conglomerate, and has an estimated total thickness of 460-700 m. The age of the Nagaiwa Formation is assigned to the early Bashkirian-early Moscovian based on fusulinids (Kobayashi, 1973a, b), or to the middle Serpukhovian-early Moscovian based on conodonts (Kato et al., 1979).

Choristitid fauna at Nagaiwa

1. Species and distribution

The choristitid fauna from Nagaiwa consists of the following four species: *Choristites mosquensis* Fischer de Waldheim, 1825, *Choristites jigulensis* (Stuckenberg, 1905), *Parachoristites nagaiwensis* sp. nov., and *Parachoristites* sp., of which *Parachoristites nagaiwensis* is most abundant. The stratigraphical and geographical distributions of these species are summarized below, and the geographical distribution is shown in Fig. 2.

Choristites mosquensis is distributed in the Upper Carboniferous (Moscovian-Kasimovian) of Russia (Novaya Zemlya, Timan, Onega, Moscow Basin, Donetz Basin, southern Urals), Uzbekistan (southern Fergana), China (Xinjiang, Gansu, Inner Mongolia, Liaoning, and Hebei), and Japan (South Kitakami). *Choristites jigulensis* is distributed in the Upper Carboniferous (Moscovian-Gzhelian) of Russia (Timan, Moscow Basin, and southern Urals), China (Xinjiang, Inner Mongolia, Liaoning, and Shanxi), and Japan (South Kitakami). The genus *Parachoristites* consists of 15 species from the Upper Carboniferous (Bashkirian and Moscovian) and lowest Permian (Asselian) of Novaya Zemlya, Timan, Taymyr, northern and southern Urals, eastern Kazakhstan, and southern Fergana (see Poletaev, 1986).

2. Palaeogeographical implication

All the species of the choristitid fauna from Nagaiwa are Boreal-type, found in the Upper Carboniferous and lowermost Permian of northern and western Russia, northern China and northeast Japan. It is noteworthy that the choristitid species are absent from South China (Yangze), but are common in northern and eastern areas of North China. Therefore, South Kitakami was probably located at the eastern margin of North China during the Late Carboniferous (Moscovian). This conclusion is consistent with the findings of Tazawa (2002), who proposed that during the Middle Devonian, Early Carboniferous, and Middle Permian, South Kitakami was part of the continental shelf bordering the eastern margin of North China.

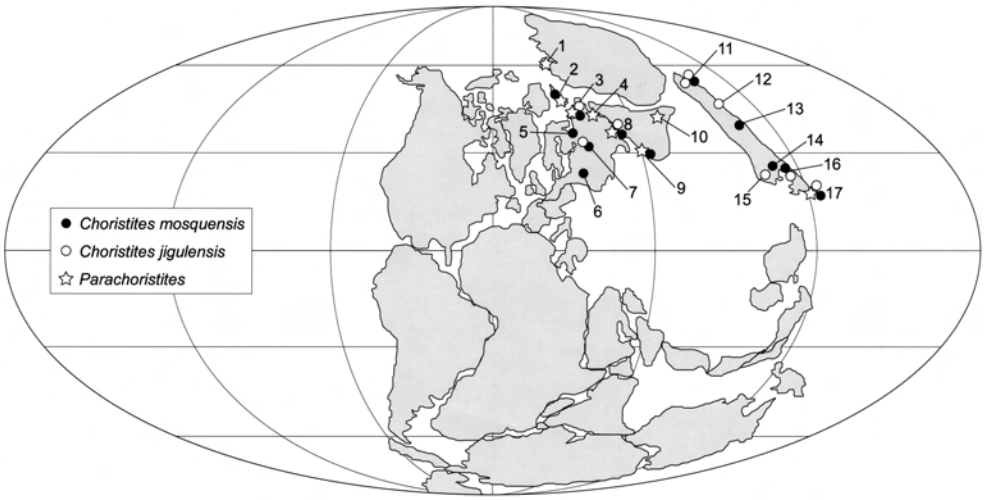

Fig. 2. Geographical distribution of *Choristites mosquensis, Choristites jigulensis*, and all species assigned to the genus *Parachoristites* in the Late Carboniferous (Bashkirian) to the earliest Permian (Asselian), 1: Taymyr, 2: Novaya Zemlya, 3: Timan, 4: northern Urals, 5: Onega, 6: Donetz Basin, 7: Moscow Basin; 8: southern Urals, 9: southern Fergana, 10: eastern Kazakhstan, 11: Xinjiang, 12: western Inner Mongolia, 13: Gansu, 14: Hebei, 15: Shanxi, 16: Liaoning, 17: South Kitakami.

Discussion

The strike-slip model proposed to explain the Pre-Neogene tectonics of Japan requires the geographical arrangement of the Hida Gaien, South Kitakami, and Kurosegawa belts from north to south along the eastern margin of North China prior to the Cretaceous, pre-dating the large-scale sinistral strike-slip movement that occurred from the early Cretaceous to Palaeogene. The occurrence of Boreal-type choristitid brachiopods from the Upper Carboniferous of the South Kitakami Belt is consistent with the palaeogeographical requirements of the strike-slip model.

The microcontinent model is based on the assumption that the South Kitakami Microcontinent was located within an equatorial (or slightly south of the equator) region of Panthalassa during the Carboniferous and Permian. For example, Ehiro and Kanisawa (1999, fig. 4) presented a Late Carboniferous geographical reconstruction in which South Kitakami was located at low latitudes in the Southern Hemispere, close to Indochina and South China. The nappe model postulates that the South Kitakami Belt is a nappe derived from South China (Isozaki and Maruyama, 1991, fig. 9; Isozaki, 1996, fig. 13); therefore the model requires similar litho- and biofacies in the Palaeozoic sequences of the South Kitakami Belt and South China.

However, the choristitids described from the Upper Carboniferous Nagaiwa Formation of Nagaiwa, South Kitakami Belt, have not been reported from Indochina or South China. The Late Carboniferous reconstructions of South Kitakami according to the microcontinent and nappe models are therefore inconsistent with palaeobiogeographical data based on Late Carboniferous choristitid brachiopods.

Systematic descriptions

The supra-generic classification used in this paper follows Carter et al. (2006).

Order Spiriferida Waagen, 1883
Suborder Spiriferidina Waagen, 1883
Superfamily Spiriferoidea King, 1846
Family Choristitidae Waterhouse, 1968
Subfamily Choristitinae Waterhouse, 1968
Genus *Choristites* Fischer de Waldheim, 1825

Type species.—*Choristites mosquensis* Fischer de Waldheim, 1825.

Yatsengina Semichatova, 1936, p. 216.
Betachoristites Gatinaud, 1949, p. 492.

Diagnosis.—Shell medium to large in size; outline subobate, often nearly equidimensional; ventral valve strongly inflated; umbonal region strongly incurved; hinge line usually shorter than maximum width; fold and sulcus well developed; entire surface of both valves ornamented with numerous flattened simple or bifurcating costae with narrow interspaces; ventral interior with long, slender, nearly parallel dental adminicula.

Remarks.—The name *Choristites* was proposed by Fischer de Waldheim (1825) for *Choristites mosquensis* Fischer de Waldheim, 1825 and *Choristites sowerby* Fischer de Waldheim, 1825, from the Upper Carboniferous of the Moscow Basin. Buckman (1908, p. 30) designated *C. mosquensis* as the type species, and gave a diagnosis of the genus as follows, “narrow; short hinge-line; fine ribs medianly and laterally; large dental plates”. The distinctive apical structure of ventral valve has been found that it is important for the classification of the choristitid spiriferids by some Russian students (e.g., Fredericks, 1919; Ivanov, 1925; Ivanov and Ivanova, 1937; Poletaev, 1986). Poletaev (1986) distinguished two types of apical structures, the choristitid type and the munellid type. The genus *Choristites* is characterized by having the choristitid-type apical structure, in which the adminiculae are almost mutually parallel, close together, and four or five times as long as the delthyrial ridge.

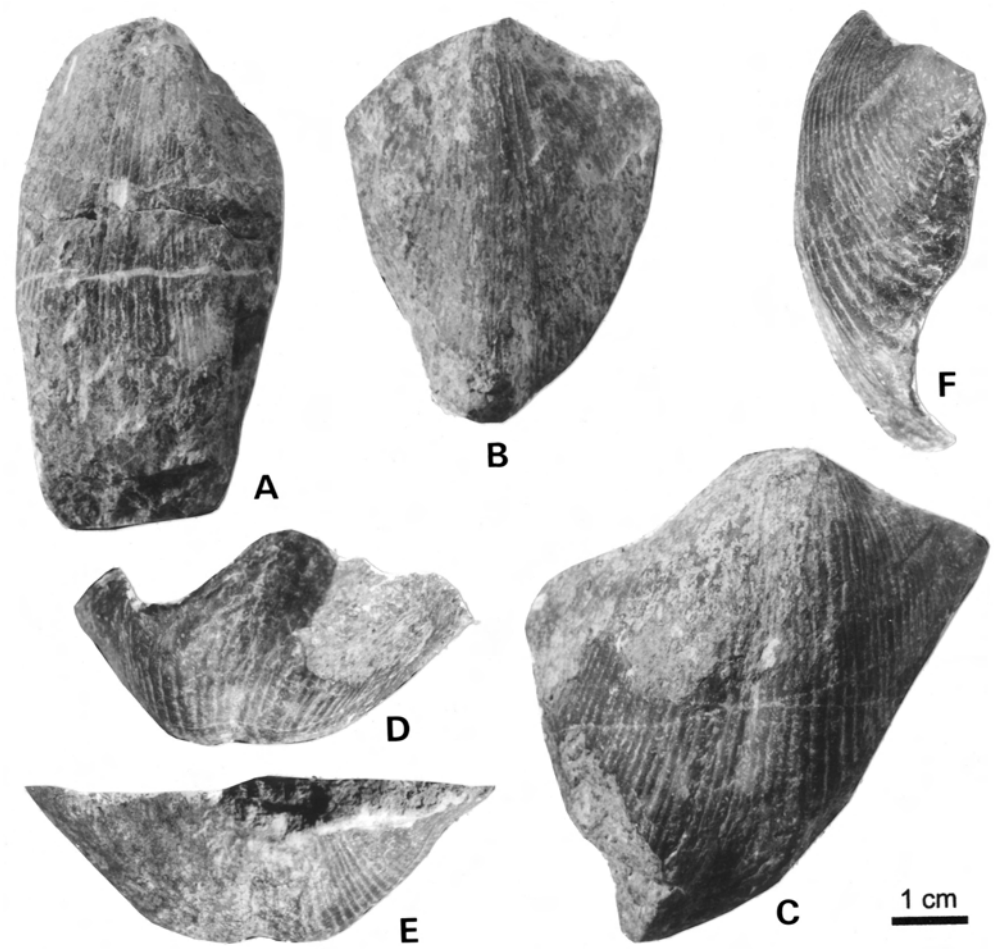

Fig. 3. Choristitid brachiopods from the Nagaiwa Formation of the Nagaiwa area. **A, B:** *Choristites mosquensis* Fischer de Waldheim, A: venral valve, NU-B1197, B: dorsal valve, NU-B1198, **C-E:** *Choristites jigulensis* (Stuckenberg), ventral, anterior, posterior, and lateral views of ventral valve, NU-B1202.

Choristites mosquensis Fischer de Waldheim, 1825
Figs. 3A, B, 4

Choristites mosquensis Fischer de Waldheim, 1825, p. 7, figs. 4, 8; Chao, 1925, p. 232, pl. 2, fig. 2 only; Fredericks, 1926, p. 255, pl. 1, figs. 1-4, 13, 24; pl. 2, figs. 1, 2, 14, 16, 27; Chao, 1929, p. 15, pl. 2, figs. 9, 10; text-figs. 3, 4; Lebedew, 1929, p. 242, pl. 8, figs. 1-5; Ivanov and Ivanova, 1937, p. 93, 191, pl. 6, figs. 1-4; pl. 20, figs. 2-4; Sarytcheva and

Sokolskaya, 1952, p. 204, pl. 59, fig. 332; Lapina, 1957, p. 101, pl. 21, figs. 1, 2; Nelzina, 1965, p. 50, pl. 6, figs. 3, 5; Tyulyandina, 1974, p. 52, pl. 6, fig. 6; Stepanov et al., 1975, p. 197, pl. 90, figs. 5a-c; Lee and Gu, 1976, p. 289, pl. 131, figs. 13a-d; Lee et al., 1980, p. 415, pl. 156, fig. 17; Zhang et al., 1983, p. 352, pl. 141, figs. 1a-c; Tazawa, 2010, figs. 2.1, 2.2.

Spirifer mosquensis (Fischer de Waldheim): Lebedew, 1929, p. 242, pl. 8, figs. 1-5.

Spirifer (*Choristites*) *mosquensis* (Fischer de Waldheim): Ozaki, 1931, p. 31, pl. 1, figs. 7-10; Licharew, 1939, p. 104, pl. 25, figs. 3a-c; Rotai, 1951, p. 78, pl. 15, figs. 6, 7; pl. 16, fig. 3; pl. 24, figs. 9, 10.

Material.—Two specimens: (1) an incomplete ventral valve, NU-B1197; (2) an incomplete dorsal valve, NU-B1198.

Description.—Shell medium size for genus, longitudinally elongate oval in outline, with greatest width at about midvalve; length 61 mm, width 36 mm in the ventral valve specimen (NU-B1197). Ventral valve moderately convex in lateral profile, with maximum convexity at umbonal region; hinge line long and straight, but slightly shorter than maximum width of valve; sulcus shallow and narrow; lateral slopes steep. Dorsal valve gently convex in lateral profile; fold high and narrow. External surface of both valves ornamented with numerous costae; costae often bifurcate in sulcus and fold, numbering 10-11 in 10 mm at mid-length of ventral lateral slopes. Ventral valve interior having a pair of long, slender, nearly parallel dental adminicula with developed thick secondary prismatic shell layer.

Remarks.—The Nagaiwa specimens are referred to *Choristites mosquensis* Fischer de Waldheim, 1825 by their longitudinally ovate shell outline, shallow and narrow ventral sulcus, and fine costae on both ventral and dorsal valves.

Choristites sowerbyi Fischer de Waldheim, 1825, from the Upper Carboniferous (Moscovian and Kasimovian) of the Moscow Basin, is also a medium-sized *Choristites* species, but it differs from *Choristites mosquensis* by its wider shell (see Ivanov and Ivanova, 1937, pl. 8, figs. 1-6).

Distribution.—Upper Carboniferous (Moscovian-Kasimovian): Russia (Novaya Zemlya, Timan, Onega, Moscow Basin, Donetz Basin, southern Urals), Uzbekistan (southern Fergana), China (Xinjiang, Gansu, Inner Mongolia, Liaoning, and Hebei), and Japan (South Kitakami).

Choristites jigulensis (Stuckenberg, 1905)

Figs. 3C-F

Spirifer jigulensis Stuckenberg, 1905, p. 49, pl. 6, figs. 4-6; pl. 8, fig. 1; Hayasaka, 1922, p. 122, pl. 6, figs. 5-8.

Spirifer (*Choristites*) *jigulensis* (Stuckenberg): Ozaki, 1931, p. 33, pl. 1, figs. 11-14; pl. 2, figs. 1-4; Stepanov, 1948, p. 41, pl. 8, figs. 1-5; pl. 9, figs. 1a-2.

Choristites jigulensis (Stuckenberg): Ivanov and Ivanova, 1937, p. 134, 193, pl. 11, figs. 1-5;

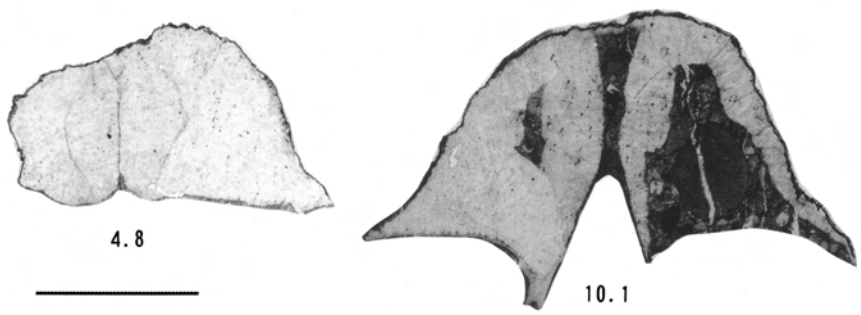

Fig. 4. Transverse serial sections of *Choristites mosquensis* Fischer de Waldheim, ventral valve, NU-B1197. Numbers refer to distance in mm from ventral beak. Scale bar represents 10 mm.

pl. 12, figs. 1a, b; pl. 21, figs. 4, 5; text-figs. 40a, b; Ustritsky, 1960, p. 70, pl. 19, figs. 4, 5; Barchatova, 1970, p. 170, pl. 17, figs. 4a, b; pl. 18, figs. 1a-2b; Lee and Gu, 1976, p. 290, pl. 146, figs. 4a-c; He et al., 1995, pl. 63, fig. 4; pl. 65, figs. 5a-e; Wang and Yang, 1998, p. 119, pl. 20, figs. 8-10; Fan and He, 1999, p. 137, pl. 26, figs. 3, 4; pl. 27, figs. 2a-e; Tazawa, 2010, fig. 2.3.

Material.—An incomplete ventral valve, NU-B1202.

Description.—Shell large for genus, subquadrate in outline, with greatest width at hinge; length about 70 mm, width about 64 mm in the larger ventral valve specimen (NU-B1202). Ventral valve moderately convex in lateral profile; umbo large, strongly incurved and overhanging hinge line; ears large, trigonal in shape, slightly convex; cardinal extremities acute; sulcus broad and deep; lateral slopes gently convex. External surface of ventral valve ornamented with numerous thick costae and some irregular concentric rugae; costae numbering 6-7 in 10 mm at mid-length of lateral slopes.

Remarks.—The single ventral valve specimen from Nagaiwa can be identified with *Choristites jigulensis* (Stuckenberg, 1905), originally described from the Upper Carboniferous of the Samara River region, east of Moscow, western Russia, by its size, outline and surface ornament of the ventral valve, especially the large ears and deep sulcus. *C. jigulensis* is safely assigned to the genus *Choristites* in having parallel ventral adminicula (see Ivanov and Ivanova, 1937, pl. 21, figs. 4, 5; text-fig. 40b).

Choristites shantungensis (Ozaki, 1931, p. 53, pl. 4, figs. 4, 5, 12) from the Upper Carboniferous of Shandong, North China somewhat resembles *C. jigulensis* in shape and outline of the shell, but Chinese species differs from the latter by its smaller size and much stronger, thick costae on the ventral valve.

Choristites fritschi (Schellwien, 1892, p. 43, pl. 5, figs. 4-8) from the Upper Carboniferous of the Carnic Alps, Austria is also a large-sized choristitid, but the Carnic Alps species differs

from *C. jigulensis* by its more transverse shell and finer costae on the ventral valve.

Distribution.—Upper Carboniferous (Moscovian-Gzhelian): Russia (Timan, Moscow Basin, and southern Urals), China (Xinjiang, Inner Mongolia, Liaoning, and Shanxi), and Japan (South Kitakami).

Genus *Parachoristites* Barchatova, 1968

Type species.—*Parachoristites volongaensis* Barchatova, 1968.

Diagnosis.—Shell small to large in size; outline variable, often transversely subtrapezoidal or subovate; entire surface of both valves multicostate, costae on lateral slopes flattened, simple or bifurcating with narrow interspaces; ventral interior with a pair of long dental adminicula, diverging anteriorly and to the valve floor.

Remarks.—Poletaev (1986) described and figured the apical structure of the genus *Parachoristites* Barchatova, 1968 on the basis of the topotype specimens. At that time, she selected the following 15 species, assigned to this genus, among large groups of choristitid spiriferids: (1) *Parachoristites volongaensis* Barchatova, 1968; (2) *Parachoristites carus* Barchatova, 1968; (3) *Parachoristites falcatus* Barchatova, 1970; (4) *Spirifer* (*Choristites*) *anikeevi* Einor, 1939; (5) *Choristites taimyricus* Tschernjak in Ustritsky and Tschernjak, 1963; (6) *Spirifer piassinaensis* Tschernjak in Ustritsky and Tschernjak, 1963; (7) *Spirifer* (*Choristites*) *fritschi* var. *arctica* Einor, 1939; (8) *Spirifer pseudoholtedali* Einor in Licharew and Einor, 1939; (9) *Spirifer* (*Choristites*) *barenzi* Einor in Licharew and Einor, 1939; (10) *Choristites fritschi ferganicus* Licharew, 1943; (11) *Choristites husanicus* Volgin, 1960; (12) *Choristites praejigulensis* Einor, 1979; (13) *Spirifer* cf. *fritschi*, sensu Tschernyschew, 1902; (14) *Purdonella* (?) *tschernyschewi* Kalashnikov, 1980; (15) (?) *Choristites fritschi* (non Schellwien, 1892, sensu Besnossova, 1968).

Parachoristites nagaiwensis sp. nov.

Figs. 5A-G, 6

Parachoristites sp. A Tazawa, 2010, fig. 2.3.

Etymology.—Named after the fossil locality, Nagaiwa.

Material.—Eight specimens: (1) five incomplete ventral valves, NU-B1203 (holotype), NU-B1204-1207; (2) three incomplete dorsal valves, NU-B1208-1210.

Diagnosis.—Large, transverse *Parachoristites*, ornamented with numerous, thick, flattened costae numbering 6-7 in 10 mm on ventral lateral slopes.

Description.—Shell large for genus, transversely subelliptical in outline, with greatest width at hinge; length about 45 mm, width about 61 mm in the holotype (NU-B1203); length

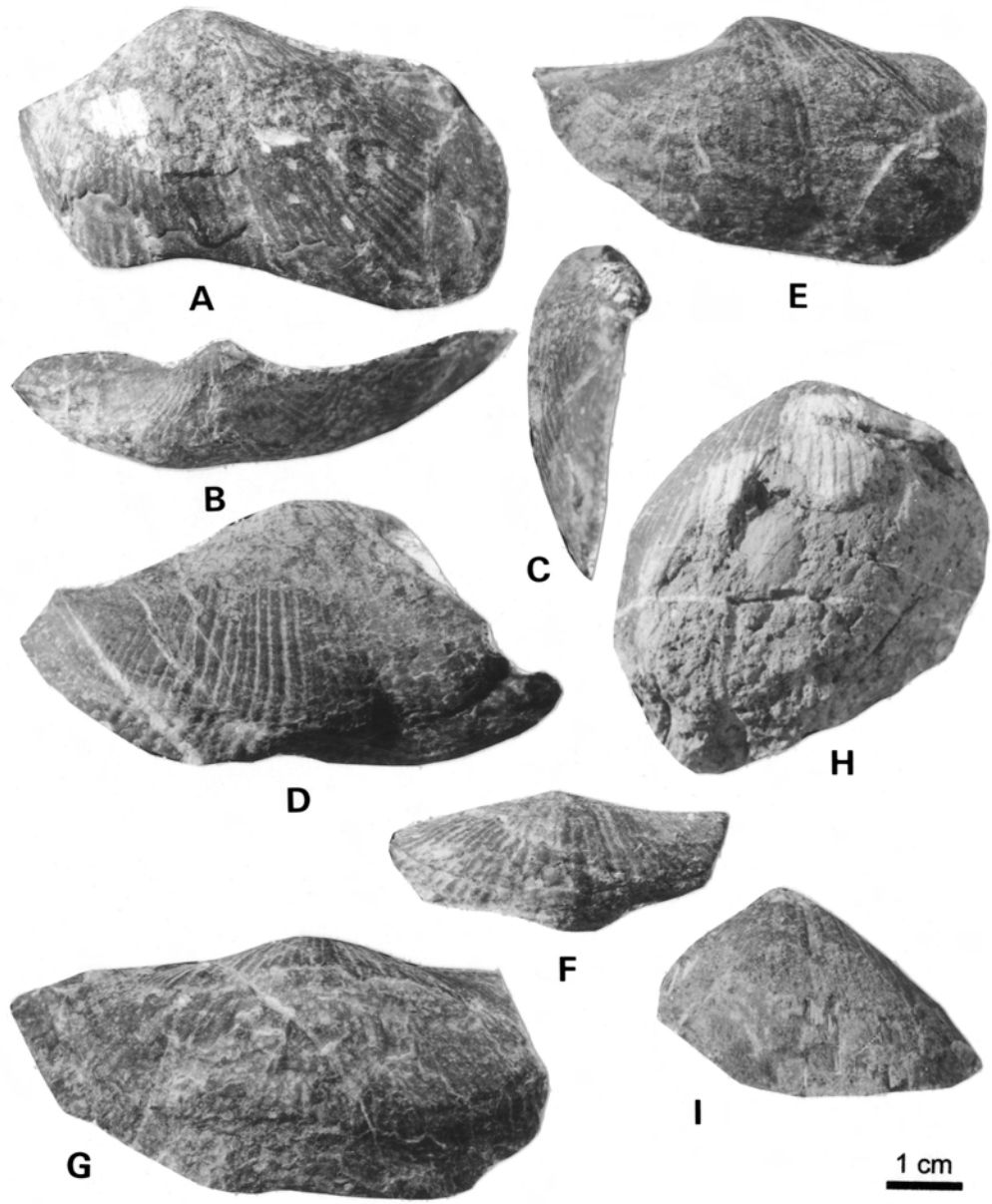

Fig. 5. Choristitid brachiopods from the Nagaiwa Formation of the Nagaiwa area. **A-G:** *Parachoristites nagaiwensis* sp. nov., A-C: ventral, posterior, and lateral views of ventral valve, NU-B1203 (holotype), D: ventral valve, NU-B1204, E: ventral valve, NU-B1205, F: dorsal valve, NU-B1209, G: dorsal valve, NU-B1208, **H, I:** *Parachoristites* sp. H: ventral valve, NU-B1199, I: ventral valve, NU-B1200.

38 mm, width about 76 mm in the largest ventral valve specimen (NU-B1204). Ventral valve moderately and unevenly convex in lateral profile, with maximum convexity at umbonal region; hinge line long and straight; umbo small, strongly incurved; ears large, prominent; cardinal extremities blunt, acute; sulcus broad and shallow; lateral slopes gently convex. Dorsal valve gently convex, except for strongly convex umbonal region, in lateral profile; fold broad and low; lateral slopes slightly convex. External surface of both valves ornamented with numerous thick, flattened costae; costae often bifurcate, numbering 6-7 in 10 mm at mid-length of ventral lateral slopes. Ventral valve interior with a pair of dental adminicula diverging anteriorly and towards valve floor.

Remarks.—Parachoristites nagaiwensis sp. nov. most resembles the type species *Parachoristites volongaensis* Barchatova in Markovsky (1968, p. 165, pl. 47, figs. 1a-2) from the Bashkirian of northern Timan in size, shape and external ornament of the shell, but it differs from the Russian species in having less prominent umbo in the ventral valve.

Parachoristites praejigulensis (Einor in Alexandrov and Einor, 1979, p. 80, pl. 32, figs. 1, 2) from the Moscovian of the southern Urals is also a large, transverse species of *Parachoristites,* but it differs from the present new species in its less transverse shell outline, and in having more thick costae on the ventral valve.

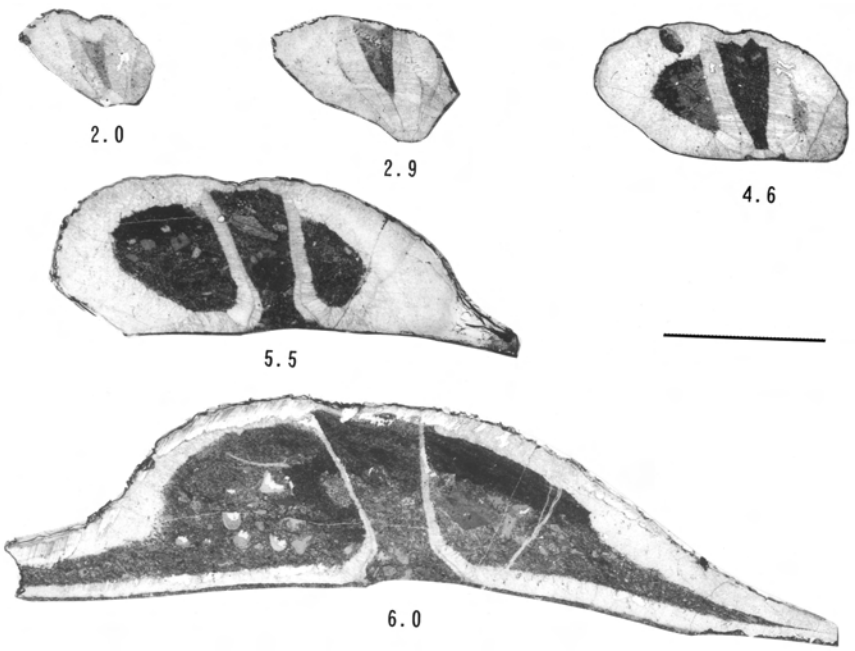

Fig. 6. Transverse serial sections of *Parachoristites nagaiwensis* sp. nov., ventral valve, NU-B1205. Numbers refer to distance in mm from ventral beak. Scale bar represents 10 mm.

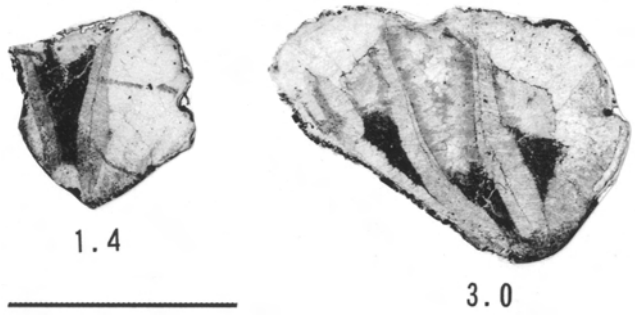

Fig. 7. Transverse serial sections of *Parachoristites* sp., ventral valve, NU-B1200. Numbers refer to distance in mm from ventral beak. Scale bar represents 10 mm.

Parachoristites sp.
Figs. 5H, I, 7

Parachoristites sp. B Tazawa, 2010, fig. 2.4.

Material.—Three incomplete ventral valves, NU-B1199-1201.

Description.—Shell medium size for genus, subcircular in outline, with greatest width at about mid-length; length about 50 mm, width about 45 mm in the largest ventral valve specimen (NU-B1199). Ventral valve moderately convex in lateral profile, most convex in umbonal region; umbo small, strongly incurved; ears small; sulcus shallow and narrow; lateral slopes weakly convex. External ornament of ventral valve consisting of numerous bifurcating costae, numbering 8-9 in 10 mm at about mid-length of lateral slopes. Ventral valve interior with a pair of diverging dental adminicula; secondary prismatic layer relatively thin and less developed.

Remarks.—These specimens are safely assigned to the genus *Parachoristites* by their less alate shell outline, and in having a pair of rather long dental adminicula, diverging to the valve floor in the ventral valve. The Nagaiwa species superficially resembles *Parachoristits taimyrensis* (Tschernjak in Ustritskiy and Tschernjak, 1963, p. 110, pl. 37, figs. 6a-7v) from the Bashkirian (?) of Taymyr in general shape of the ventral valve, but it differs from the Russian species in its larger size and in having a shallower ventral sulcus.

The type species, *Parachoristites volongaensis* is clearly distinguished from the present species by its much larger and transverse shell.

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