Anidanthus, *Gypospirifer* and *Alispiriferella* (Brachiopoda) from the Upper Permian Mizukoshi Formation, central Kyushu, SW Japan

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Abstract

A brachiopod fauna, from the Upper Permian (Lopingian) Mizukoshi Formation of the Mizukoshi area, central Kyushu, southwest Japan, is redescribed and biogeographically discussed. The Mizukoshi fauna consists of three brachiopod species, *Anidanthus ussuricus* (Fredericks), *Gypospirifer volatilis* Duan and Li and *Alispiriferella lita* (Fredericks). These species have been reported from the Middle and Upper Permian of northeast Japan (South Kitakami Belt), central Japan (Hida Gaien Belt), Far East Russia (South Primorye), northeast China (Jilin and Heilongjiang) and north China (Inner Mongolia). All the above-cited regions belong to the Boreal-Tethyan transitional zone in eastern Asia. The geographical distribution of the three brachiopod species of the Mizukoshi fauna suggests that the Mizukoshi area is the southwestern extension of the Hida Gaien Belt, and it was located between the Hida Gaien Belt to the north and the South Kitakami Belt to the south in the Late Permian.

Key words: *Alispiriferella*, *Anidanthus*, brachiopod, *Gypospirifer*, Mizukoshi, Upper Permian.

Introduction

Mizukoshi, Kumamoto Prefecture, central Kyushu is one of the famous Permian brachiopod localities in Japan (Fig. 1). Matsumoto and Huzimoto (1939) first recognized Permian rocks containing fusulinoidean fossils in the Mizukoshi area, and named the shale dominant Permian sequence as the Mizukoshi Formation. Afterwards, Yanagida (1958) made a geological map of

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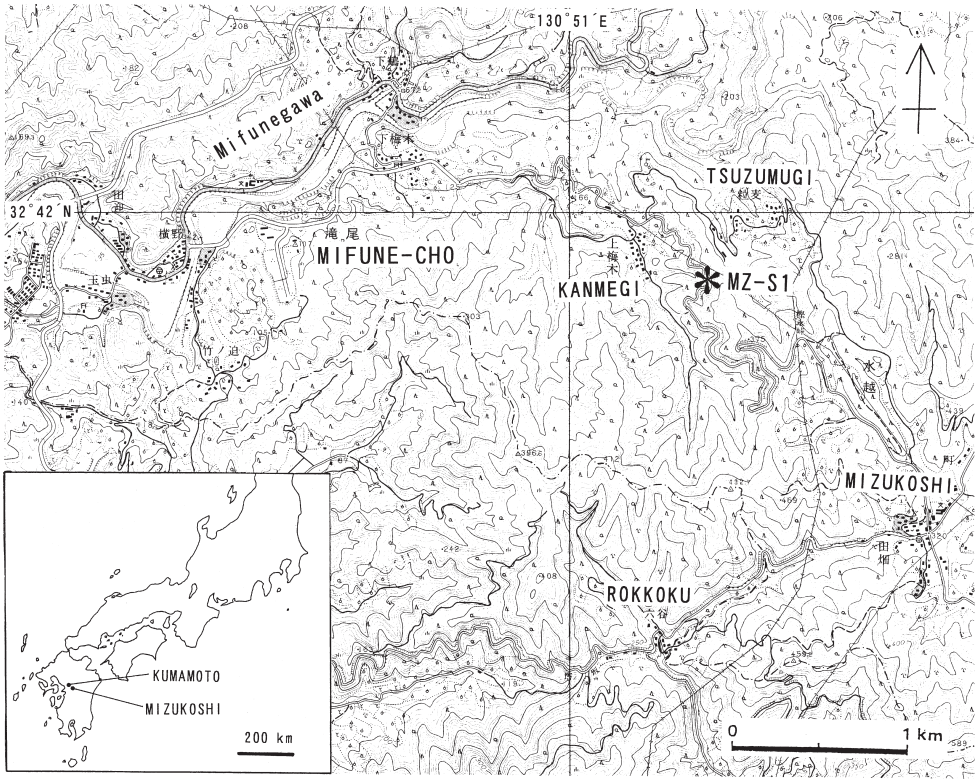


Fig. 1. Map showing the fossil locality MZ-S1 in the Mizukoshi area (using the topographical map of "Mifune" scale 1:25,000 published by the Geographical Survey Institute of Japan).

this area, and assigned a late Middle Permian age for the Mizukoshi Formation based on some fusulinoideans *Lepidolina* species found out from limestone blocks in the upper part of this formation. Moreover, Yanagida (1963) described the following three brachiopod species from shale of the upper part of the Mizukoshi Formation: *Linoproductus* cf. *lineatus* (Waagen), *Neospirifer fasciger* Keyserling and *Spiriferella keilhavii* (von Buch). He considered that the Mizukoshi fauna is most comparable to the Toman fauna described by Noda (1956) from the upper part of the Toman Formation (= Kedao Formation) in the Kaishantun area, eastern Jilin Province, northeast China.

Now it is a problem that the geotectonic position of the Mizukoshi Formation is uncertain. Some authors assigned the Mizukoshi Formation as a member of the Sangun Belt (Taira, 1985; Taira et al., 1989; Isozaki and Maruyama, 1991; Isozaki, 1996) or the Palaeo-Ryoke Belt (Takagi and Shibata, 1996, 2000). On the other hand, Tazawa (1993, 2000a, 2004) considered that the Mizukoshi Formation is the southwestern extension of the Permian of the Hida Gaien Belt, and it belongs to the South Kitakami Terrane which includes the Palaeozoic and Mesozoic rocks of the Hida Gaien, South Kitakami and Kurosegawa Belts.

Recently the junior author (SH) surveyed the Mizukoshi area under the direction of the senior author (JT), and clarified the stratigraphy of the Mizukoshi Formation. The Mizukoshi Formation is composed chiefly of black shale with sandstone and conglomerate intercalations and limestone blocks, about 1,700 m in total thickness (Fig. 2). The black shale is lithologically similar to the shale of the Upper Permian Toyoma Formation of the South Kitakami Belt, northeast Japan, and also to the upper part of the Moribu Formation of the Hida Gaien Belt, central Japan. The conglomerate, developed in the upper part and correlated with the Usuginu-type conglomerate of the South Kitakami Bellt, is 50 cm to 20 m in thickness, and it contains rounded to sub-rounded pebbles and cobbles of granitic rocks and acidic to intermediate volcanic rocks, angular clasts of shale, and irregular-shaped limestone rip-up clasts. The age of the Mizukoshi Formation is considered to be a Late Permian (Lopingian), because of the lithological similarity to the Upper Permian Toyoma Formation with the Usuginu-type conglomerate, 260 Ma K-Ar hornblende age for the granitic clasts of the

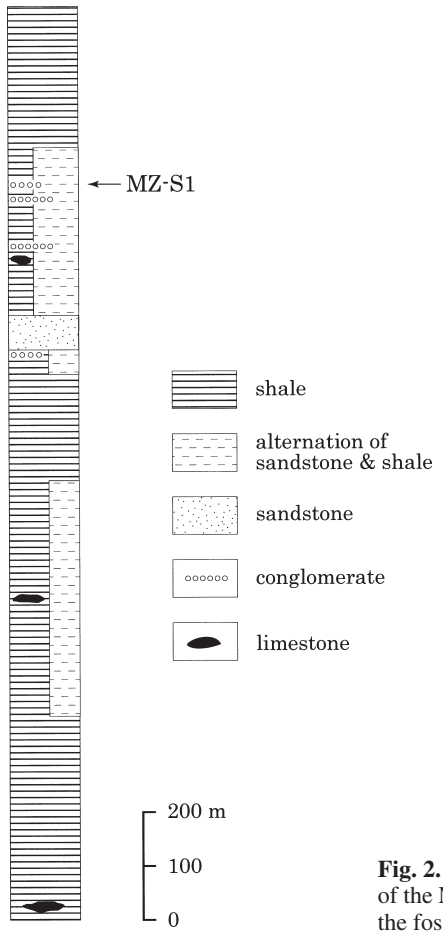


Fig. 2. Generalized columnar section of the Mizukoshi Formation, showing the fossil horizon MZ-S1.

conglomerate (Tobe et al., 2000), and the occurrence of some late Middle to early Late Permian fusulinoideans, such as *Lepidolina shiraiwensis* (Ozawa), *L. kumaensis* Kanmera, *Metadoliolina gravitesta* (Kanmera) and *Codonofusiella* sp. from limestone blocks in the upper part of this formation.

In this paper, we redescribe the Mizukoshi fauna using part of the Yanagida's specimens and materials newly collected by ourselves from the same locality and horizon of the former in the Mizukoshi area. The fossil locality MZ-S1 is placed at a road-cutting of the Root 219 (Yokono-Yabe Line) between Kanmegi and Mizukoshi, and about 500 m SW of Tsuzumugi, Mifune-cho, Kumamoto Prefecture, central Kyushu (see Fig. 1). The fossil horizon is represented by weathered, light brown sandy shale of the upper part of the Mizukoshi Formation, about 330 m below from the top of the formation (see Fig. 2). All the specimens described in this paper are housed in the following institutions as indicated by the prefix to the registered numbers, GK-D: Kyushu University Museum in Fukuoka; NU-B: Department of Geology, Faculty of Science, Niigata University in Niigata.

The Mizukoshi Fauna (MZ-S1)

The brachiopods described by Yanagida (1963) from the locality MZ-S1 as *Linoproductus* cf. *lineatus* (Waagen), *Neospirifer fasciger* Keyserling and *Spiriferella keilhavii* (von Buch) are now redescribed as *Anidanthus ussuricus* (Fredericks), *Gypospirifer volatilis* Duan and Li and *Alispiriferella lita* (Fredericks), respectively. The stratigraphical and geographical distributions of the revised three species are summarised below, and shown in Fig. 3.

Anidanthus ussuricus is distributed in the Middle Permian (Wordian-Capitanian) of north China (Zhesi and Xiujimqinqi, Inner Mongolia), northeast China (Jilin) and eastern Russia (Vladivostok and Nakhodka, South Primorye). Moreover, this species occurs as derived fossils from the Upper Permian (Lopingian) of northeast Japan (Takakurayama in the Abukuma Mountains) and southwest Japan (Mizukoshi, central Kyushu).

Gypospirifer volatilis is distributed in the Middle Permian (Wordian-Capitanian) of north China (Zhesi and Xiujimqinqi) and central Japan (Moribu in the Hida Gaien Belt). Like *A. ussuricus* this species also occurs as derived fossils from the Upper Permian (Lopingian) of northeast Japan (Takakurayama) and southwest Japan (Mizukoshi). Specimens from the Upper Permian Kedao Formation in the Kaishantun area, Jilin Province, northeast China may be also derived (reworked) fossils.

Alispiriferella lita is distributed in the Middle Permian (Wordian-Capitanian) of north China (Zhesi and Xiujimqinqi), northeast China (Heilongjiang), South Primorye (Nakhodka, Artemovka and Vladivostok), central Japan (Moribu) and northeast Japan (Kesennuma, South Kitakami Belt). Besides the above localities, this species occurs as derived fossils from the Upper Permian (Lopingian) of northeast Japan (Ogatsu in the southern Kitakami Mountains) and southwest Japan (Mizukoshi).

Mizukoshi fauna (MZ-S1)	Region											Series/Stage				
	South Kitakami			HG	South Primorye			NE China		Inner Mongolia		Guadalupian			Lopingian	
Revised species	Takakurayama	Ogatsu	Kesennuma	Moribu	Nakhodka	Artemovka	Vladivostok	Jilin	Heilongjiang	Xiujimqinqi	Zhesi	Roadian	Wordian	Capitanian	Wuchiapingian	Changhsingian
Anidanthus ussuricus (Fredericks)	+				+		+	+		+	+		■	■	■	■
Gypospirifer volatilis Duan & Li	+			+				+		+	+		■	■	■	■
Alispiliferella lita (Fredericks)		+	+	+	+	+	+		+	+	+		■	■	■	■

Fig. 3. Geographical and stratigraphical distributions of the three brachiopod species of the Mizukoshi fauna (MZ-S1).

Discussion

The brachiopods from the locality MZ-S1 indicate the Middle Permian (Wordian to Capitanian) age. However, all the brachiopod materials occur as derived fossils (Yanagida, 1958). Furthermore, some late Middle to early Late Permian fusulinoideans, *Lepidolina, Metadoliolina*, *Codonofusiella*, etc., occur as derived fossils from limestone blocks of the upper part of the formation. Consequently, the fossil-bearing horizon (MZ-S1) is not late Middle Permian (Capitanian), but a Late Permian (Lopingian), probably Wuchiapingian in age, although the possibility of a Changhsingian age is undeniable.

The shale of the Mizukoshi Formation is lithologically similar to those of the upper Moribu Formation of the Hida Gaien Belt and the Toyoma Formation of the South Kitakami Belt. The conglomerate is correlated with the Usuginu-type conglomerate, which developed widely in the Upper Permian of the South Kitakami and Kurosegawa Belts, and probably also in the Hida Gaien Belt.

Palaeobiogeographically, the Mizukoshi fauna has an close affinity with the Permian brachiopod faunas of northeast Japan (South Kitakami Belt), central Japan (Hida Gien Belt), Far East Russia (South Primorye), northeast China (Jilin and Heilongjiang) and north China (Inner Mongolia). All the regions are included within the Southern Subzone of the Inner Mongolia-Japan Transitional Zone (Tazawa, 1991). This subzone was probably a continental shelf surrounding the north to east boarder of the North China (Sino-Korea) block, which was located in the northern mid-latitude in the Middle to Late Permian.

The above data strongly suggest that the Mizukoshi Formation is the southwestern extension of the Permian rocks of the Hida Gaien Belt, and belongs to the South Kitakami

Terrane as mentioned by Tazawa (1993, 2000a, 2004). The Mizukoshi area was probably located between the Hida Gaien Belt to the north and the South Kitakami Belt to the south in the Late Permian.

Systematic descriptions

Order Productida Sarytcheva and Sokolskaya, 1959
Suborder Productidina Waagen, 1883
Superfamily Linoproductoidea Stehli, 1954
Family Linoproductidae Stehli, 1954
Subfamily Anidanthinae Waterhouse, 1968b
Genus *Anidanthus* Hill, 1950

Type species.—*Linoproductus springsurensis* Booker, 1932, p. 67, pl. 3, figs. 1-6; pl. 4, figs. 1-7.

Anidanthus ussuricus (Fredericks, 1924)
Figs. 4.1-4.7

Productus ussuricus Fredericks, 1924, p. 8, pl. 1, figs. 1-5; Fredericks, 1925, p. 18.
Linoproductus cf. *lineatus* (Waagen): Yanagida, 1963, p. 74, pl. 10, figs. 8-14.
Anidanthus abukumaensis Yanagisawa, 1967, p. 89, pl. 2, fig. 16.
Anidanthus ussuricus (Fredericks): Nakamura, 1972, p. 434, pl. 1, figs. 1a-c; Grigorjeva and Kotlyar, 1977, p. 56, pl. 5, figs. 1-3; text-fig. 34; Licharew and Kotlyar ,1978, pl. 13, figs. 5a-g; Lee et al., 1980, p. 379, pl. 170, figs. 5, 9; Duan and Li, 1985, p. 113, pl. 38, figs. 6-9; Gu, 1992, p. 236, pl. 69, figs. 18, 25; pl. 74, figs. 7, 8; pl.78, figs. 11, 12.
Pseudomarginifera ussuricus (Fredericks): Wang and Zhang, 2003, p. 106, pl. 17, figs. 16-27.

Material.—Seven specimens: (1) internal moulds of two conjoined valves, NU-B732, NU-B733; (2) internal mould of two ventral valves, NU-B734, NU-B735; (3) external moulds of three dorsal valves, NU-B736, NU-B737, NU-B738.

Description.—Shell large for genus, transversely subquadrate in outline; hinge straight, equal to greatest width; length 9 mm, width about 34 mm in the largest ventral valve specimen (NU-B733); length 18 mm, width about 35 mm in the largest dorsal valve specimen (NU-B736). Ventral valve highly convex in both lateral and anterior profiles, with long trail; umbo tapering, pointed and strongly incurved beyond hinge; ears small; sulcus broad and shallow; flanks steep. Dorsal valve slightly concave on venter, strongly geniculated and followed by long trail; ears large, prominent and almost flattened; fold broad and low. External ornament of ventral valve obscure, but numerous capillae faintly observed. Dorsal valve ornamented by strong concentric lamellae and numerous capillae over visceral disc; lamellae only on ears;

numbering 4 lamellae in 5 mm, and 7-8 capillae in 5 mm at about midvalve.

Remarks.—These specimens are poorly preserved and severely deformed but can be referred to *Anidanthus ussuricus* (Fredericks, 1924), originally described from the Chandalaz Formation of the Vladivostok area, South Primorye, Far East Russia by their large size and extremely developed long trail on both valves. The linoproductid shells, described and figured by Yanagida (1963, p. 74, pl. 10, figs. 8-14) as *Linoproductus* cf. *lineatus* (Waagen, 1884) from the same locality and horizon of Mizukoshi, are probably conspecific with the present species, *A. ussuricus* by their strongly convex ventral valves with long trail.

The type species, *Anidanthus springsurensis* (Booker, 1932) from the Cattle Creek Formation of Queensland, eastern Australia, differs from *A. ussuricus* in its much smaller size.

Order Spiriferida Waagen, 1883
Suborder Spiriferidina Waagen, 1883
Superfamily Spiriferoidea King, 1846
Family Trigonotretidae Schuchert, 1893
Subfamily Neospiriferinae Waterhouse, 1968a
Genus *Gypospirifer* Cooper and Grant, 1976

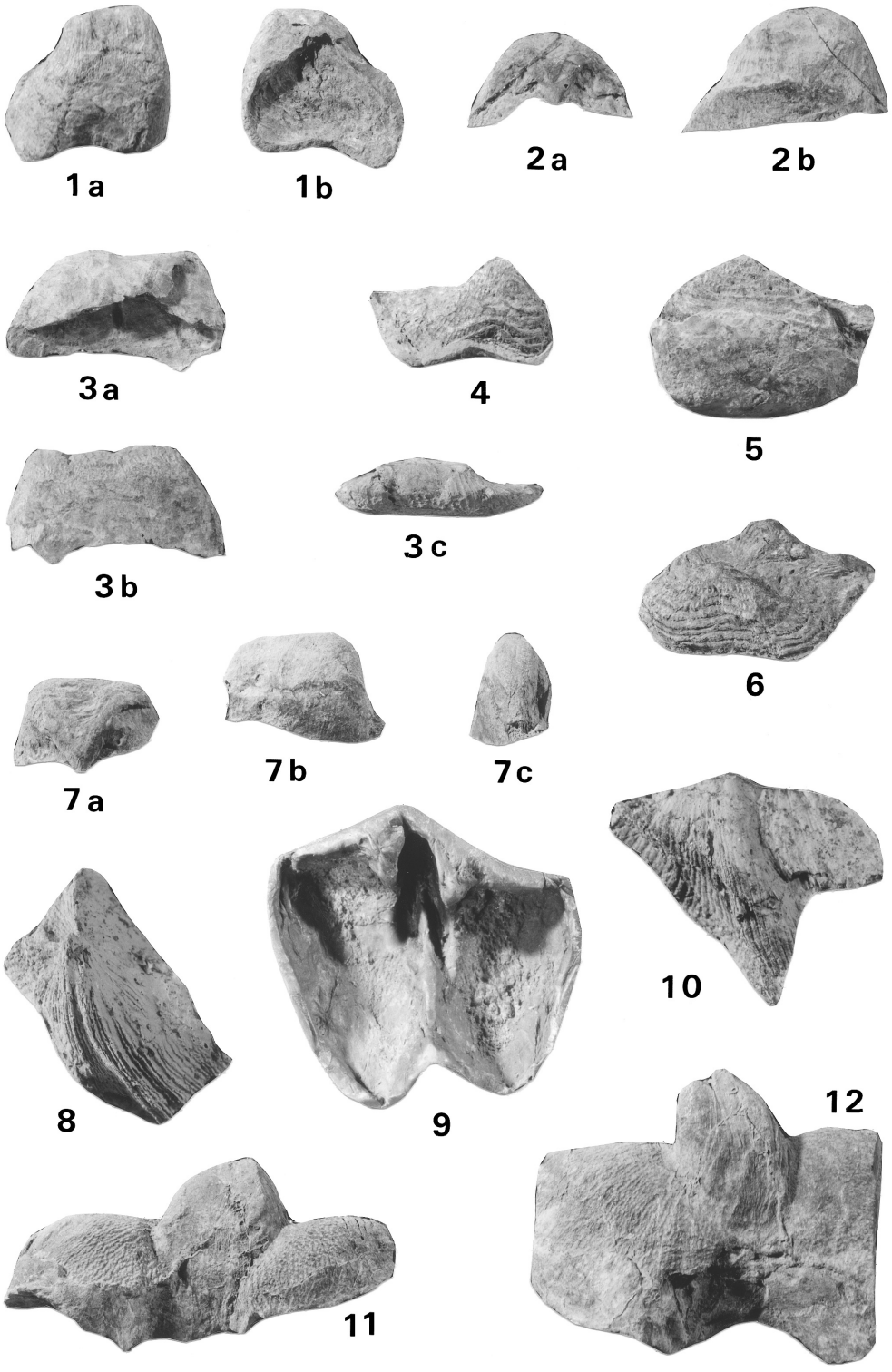
Type species.—*Gypospirifer nelsoni* Cooper and Grant, 1976, p. 2214, pl. 591, figs. 6-9.

Gypospirifer volatilis Duan and Li, 1985
Figs. 4.8-4.12, 5.1, 5.2

Spirifer cf. *moosakhailensis* Davidson: Noda, 1956, p. 17, pl. 4, figs. 9, 10.
Neospirifer fasciger (Keyserling): Yanagida, 1963, p. 71, pl. 8, figs. 1-7; pl. 9, figs. 1-3.
Neospirifer cf. *fasciger* (Keyserling): Yanagisawa, 1967, p. 90, pl. 2, fig. 18.
Neospirifer moosakhailensis (Davidson): Lee and Gu, 1976, p. 286, pl. 175, figs. 1-3 only.
Gypospirifer volatilis Duan and Li, 1985, p. 127, 207, pl. 48, figs. 1-2; pl. 49, figs. 1-2; Tazawa, 2001, p. 302, figs. 8.23-8.26.
Gypospirifer sp. Tazawa, 2000b, figs. 3.12, 3.13.
Neospirifer volatilis (Duan and Li): Wang and Zhang, 2003, p. 146, pl. 38, figs. 1-8.

Material.—Sixteen specimens: (1) external moulds of two conjoined valves, GK-D31003, GK-D31008; (2) external moulds of a ventral valve, NU-B723; (3) internal moulds of ten ventral valves, GK-D31001, GK-D31002, NU-B724, NU-B725, NU-B726, NU-B727, NU-B728, NU-B729, NU-B730, NU-B731; (4) external moulds of three dorsal valves, GK-D31004, GK-D31005, GK-D31009.

Description.—Shell medium to large for genus, transversely semielliptical in outline, with greatest width at hinge, and slightly alate; length about 50 mm, width more than 70 mm in the


1a
1b
2a
2b
3a
4
5
3b
3c
6
7a
7b
7c
8
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11
12

largest specimen (NU-B726); length about 38 mm, width about 60 mm in the best preserved specimen (GK-D31005). Ventral valve gently convex in lateral and anterior profiles, most convex at umbonal region; umbo slightly extended and strongly incurved; interarea moderately high, broad and gently concave; sulcus deep, narrow, and rapidly widening anteriorly, with U-shaped bottom. External surface of ventral valve ornamented by numerous costae and very fine growth lines; costae subridged, added by bifurcation, and weakly fasciculated, numbering 10-12 in 10 mm at about midvalve. Dorsal valve gently convex in both profiles, having a high and narrow fold. External ornament of dorsal valve similar to that of opposite valve. Ventral valve interior with a pair of thick, short dental plates and a deeply impressed muscle field.

Remarks.—The Mizukoshi specimens are not so well preserved but they can be identified with *Gypospirifer volatilis* Duan and Li, 1985, originally described from the Middle Permian Zhesi (Jisu) Formation of the Zhesi area, Inner Mongolia, by their size, outline and surface ornament of shells, especially the deep ventral sulcus and high dorsal fold. Tazawa (2001, p. 302) has discussed this species and its comparison with related forms.

A single ventral specimen, described and figured by Yanagisawa (1967, p. 90, pl. 2, fig. 18) as *Neospirifer* cf. *fasciger* (Keyserling) from the Kashiwadaira Formation (= upper Takakurayama Formation) of the Takakurayama area, Abukuma Mountains, northeast Japan, is referred to *Gypospirifer volatilis* in its large size and having a fold rapidly widening anteriorly.

Family Spiriferellidae Waterhouse, 1968a

Genus *Alispiriferella* Waterhouse and Waddington, 1982

Type species.—*Spirifer* (*Spiriferella*) *keilhavii* (von Buch) var. *ordinaria* Einor, in Licharew and Einor, 1939, p. 140, pl. 23, figs. 6, 7; pl. 24, figs. 1a-d.

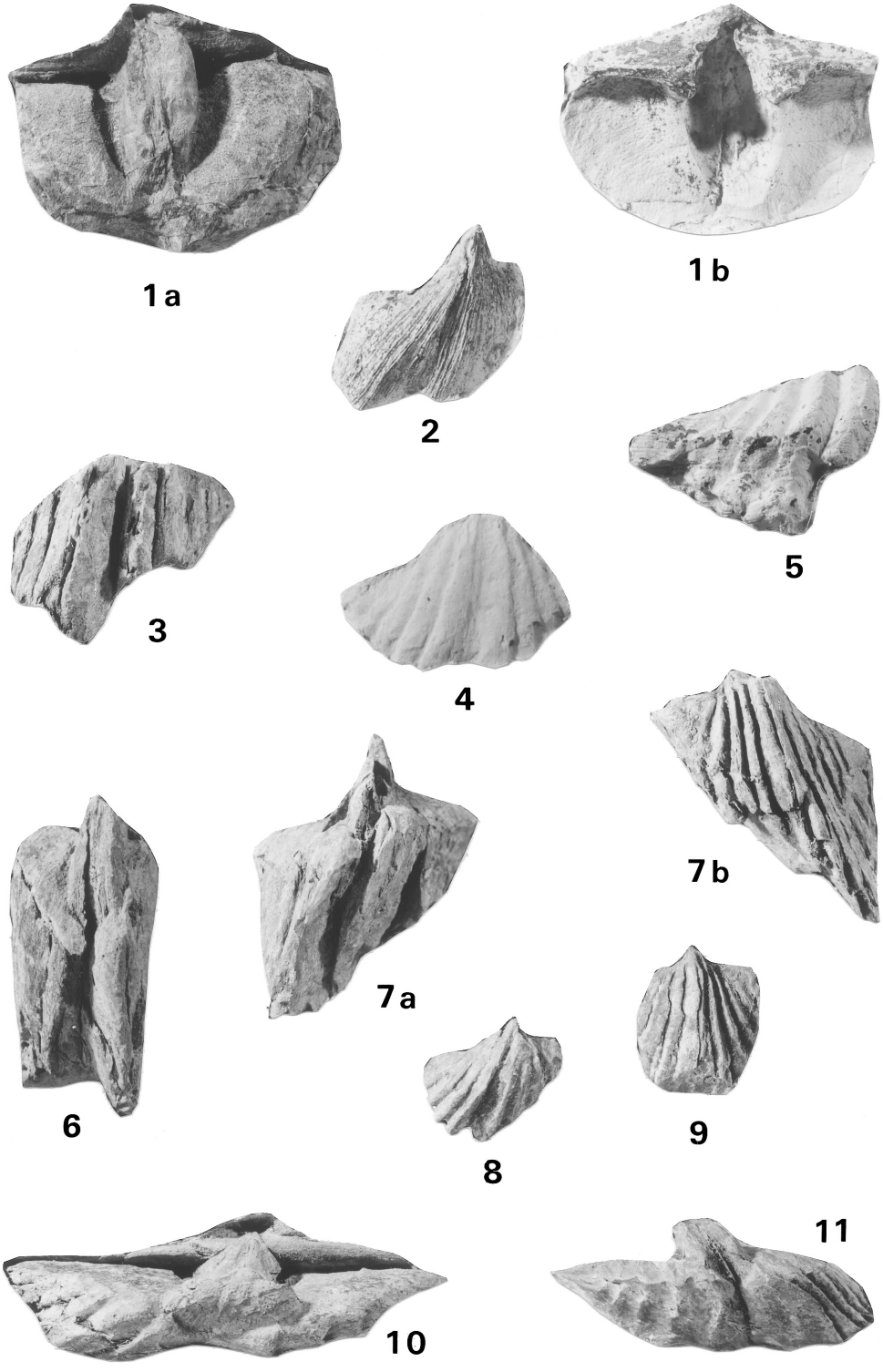
Alispiriferella lita (Fredericks, 1924)

Figs. 5.3-5.11

Spiriferella saranae mut. *lita* Fredericks, 1924, p. 36, pl. 1, figs. 16-27; text-figs. 2a, b.

Spirifer cf. *saranae* mut. *lita* Fredericks: Hayasaka, 1925, p. 98, pl. 5, fig. 14.

⬅ **Fig. 4.** Permian brachiopods of the Mizukoshi fauna (MZ-S1), from the upper Mizukoshi Formation in the Mizukoshi area. **1-7:** *Anidanthus ussuricus* (Fredericks), 1a, 1b: anterior and posterior views of internal mould of a conjoined valve, NU-B732, 2a, 2b: posterior and anterior views of internal mould of a conjoined valve, NU-B733, 3a, 3b, 3c: posterior, anterior and ventral views of internal mould of a ventral valve, NU-B734, 4: dorsal view of external mould of a dorsal valve, NU-B737, 5: posterior view of external mould of a dorsal valve, NU-B738, 6: dorsal view of external mould of a dorsal valve, NU-B736, 7a, 7b, 7c: posterior, anterior and lateral views of internal mould of a ventral valve, NU-B735, **8-12:** *Gypospirifer volatilis* Duan and Li, 8: external latex cast of a ventral valve, GK-D31003, 9: internal latex cast of a ventral valve, GK-D31002, 10: external latex cast of a dorsal valve, GK-D31005, 11: ventral view of internal mould of a ventral valve, NU-B727, 12: ventral view of internal mould of a ventral valve, NU-B726. (All figures are in natural size).


1a
1b
2
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7a
7b
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Spiriferella cf. *saranae* mut. *lita* Fredericks: Nonaka, 1944, p. 86, pl. 7, figs. 12-14.
Spiriferella keilhavii (von Buch): Yanagida, 1963, p. 72, pl. 9, figs. 4-9; pl. 10, figs. 1-7.
Timaniella harkeri Waterhouse: Licharew and Kotlyar, 1978, pl. 18, figs. 2, 3.
Spiriferella grandis Kotlyar, in Licharew and Kotlyar, 1978, p. 73, pl. 18, figs. 7, 8.
Spiriferella lita (Fredericks): Tazawa, 1979, p. 28, pl. 4, figs. 12, 13; pl. 5, figs. 1-4, 6; Tazawa, 2001, p. 302, figs. 8.19-8.22; Tazawa and Chen, 2006, p. 336, fig. 6.4.
Spiriferella cf. *lita* (Fredericks): Tazawa et al., 2000, p. 12, pl. 1, figs. 16, 17.
Alispiriferella ordinaria (Einor, in Licharew and Einor): Tazawa, 2001, p. 302, figs. 8.14a-8.14c.
Alispiriferella japonica Tazawa, 2001, p. 303, figs. 8.15-8.18.
Alispiriferella neimongolensis Wang and Zhang, 2003, p. 154, pl. 46, figs. 9-18; pl. 50, figs. 5, 9.

Material.—Nineteen specimens: (1) external and internal moulds of a conjoined valve, NU-B711; (2) external and internal moulds of a ventral valve, NU-B712; (3) external moulds of five ventral valves, GK-D31013, GK-D31014, GK-D31017, GK-D31022, GK-D31023; (4) internal moulds of eleven ventral valves, GK-D31011, GK-D31021; NU-B713, NU-B714, NU-B715, NU-B716, NU-B717, NU-B718, NU-B719, NU-B720, NU-B721; (4) internal mould of a dorsal valve, NU-B722.

Description.—Shell large for genus, transversely trapezoidal in outline; hinge straight, equal to widest part; length about 27 mm, width about 70 mm in the largest specimen (NU-B713). Ventral valve moderately convex in lateral profile, with maximum convexity at umbonal slope; interarea moderately high, broad and gently concave, with large delthyrium; sulcus deep, wide and having smooth V-shaped bottom; 5-6 pairs of strong, simple, broad and rounded costae on each side of sulcus. Dorsal valve moderately convex in both lateral and anterior profiles; fold high, wide and having a median groove; 5 pairs of simple or bifurcated costae on each side of fold. Internally, ventral valve having a pair of high dental plates and a deeply impressed heart-shaped muscle field.

Remarks.— These specimens are referred to *Alispiriferella lita* (Fredericks, 1924), originally described from the Middle Permian of Ussuri, eastern Russia, by their large, transverse shells, ventral sulcus with smooth V-shaped bottom and strong, simple and rounded costae on the ventral valves.

The type species, *Alispiriferella ordinaria* (Einor, in Licharew and Einor, 1939) from the

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⬅ **Fig. 5.** Permian brachiopods of the Mizukoshi fauna (MZ-S1), from the upper Mizukoshi Formation in the Mizukoshi area. **1, 2:** *Gypospirifer volatilis* Duan and Li, 1a, 1b: internal mould and latex cast of a ventral valve, NU-B724, 2: external latex cast of a ventral valve, NU-B723, **3-11:** *Alispiriferella lita* (Fredericks), 3: ventral view of internal mould of a ventral valve, NU-B717, 4: external latex cast of a ventral valve, GK-D31023, 5: external latex cast of a ventral valve, GK-D31017, 6: ventral view of internal mould of a ventral valve, NU-B715, 7a, 7b: ventral and dorsal views of internal mould of a conjoined valve, NU-B711, 8: ventral view of internal mould of a ventral valve, NU-B718, 9: dorsal view of internal mould of a dorsal valve, NU-B722, 10: ventral view of internal mould of a ventral valve, NU-B713, 11: ventral view of internal mould of a ventral valve, NU-B714. (All figures are in natural size).

Lower Permian of Novaya Zemlya is clearly distinguished from *A. lita* by its smaller and less transverse shell with ventral sulcus bearing two prominent sulcal costae and more often fasciculate costae on both ventral and dorsal valves.

The smaller specimens, described by Tazawa (2001) as *A. ordinaria* and *Alispiriferella japonica* Tazawa, 2001, from the Middle Permian of Moribu, central Japan are seemed to be young shells of *A. lita,* in having smooth-bottomed ventral sulcus.

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