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Redescription of three syringothyridid brachiopod species from the lower Carboniferous of the South Kitakami Belt, Japan

Jun-ichi TAZAWA*

Abstract

In this paper three syringothyridid species, originally described by Minato (1951) from the lower Carboniferous Arisu Formation of the South Kitakami Belt, northeastern Japan, are revised and redescribed based on the type specimens. The species are *Syringothyris texta* (Hall, 1857) (= *Syringothyris transversa* Minato, 1951), *Pseudosyrinx jumonjiensis* (Minato, 1951) (= *Syringothyris jumonjiensis* Minato, 1951) and *Asyrinxia nipponotrigonalis* (Minato, 1951) (= *Fusella nipponotrigonalis* Minato, 1951).

Key words: Brachiopoda, Carboniferous, redescription, South Kitakami Belt, syringothyridid.

Introduction

Syringothyridid brachiopods are antitropical genera distributed mainly in the Boreal and Gondwanan regions in the early Carboniferous. In the lower Carboniferous of the South Kitakami Belt, northeastern Japan, the syringothyridids (*Syringothyris*, *Pseudosyrinx* and *Asyrinxia*) form important stratigraphical marker horizon of the middle part of the Arisu Formation (= D_0 Zone of Minato et al., 1953, 1979). However, the systematics of the syringothyridid species have been insufficient.

In the present study, I redescribe three species of the syringothyridids from the middle part of the Arisu Formation (correlated with the lower Visean, by Tazawa and Iryu, 2018) of the Yokota and Shimoarisu areas in the South Kitakami Belt based on the type specimens,

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which are housed in the Hokkaido University Museum, Sapporo. The species are *Syringothyris transversa* Minato, 1951, *Syringothyris jumonjiensis* Minato, 1951 and *Fusella nipponotrigonalis* Minato, 1951. These species are now revised as *Syringothyris texta* (Hall, 1857), *Pseudosyrinx jumonjiensis* (Minato, 1951) and *Asyrinxia nipponotrigonalis* (Minato, 1951), respectively.

Systematic descriptions

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

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

Syringothyris texta (Hall, 1857)
Fig. 1.1

Spirifer textus Hall, 1857, p. 169.
Syringothyris textus (Hall). Weller, 1914, p. 399, pl. 69, figs. 6–9; pl. 70, figs. 1–4; pl. 71, figs. 1, 2.
Syringothyris transversa Minato, 1951, p. 377, pl. 5, fig. 1; Minato, 1952, p. 167, pl. 11, fig. 5 only; Minato et al., 1979, pl. 21, fig. 11; Tazawa, 2002, fig. 7.6; Tazawa, 2006, p. 134, figs. 7.1, 7.2.

Material.—One specimen from the middle part of the Arisu Formation of Nashirozawa in the Shimoarisu area, internal mould of a conjoined shell, with external mould of the ventral interarea, UHR16925 (holotype).

Description.—Shell large in size for genus, transversely subtriangular in outline, cardinal extremities slightly mucronate; length about 50 mm, width about 84 mm in the holotype (UHR16925). Ventral valve gently convex in lateral profile; interarea moderately high and slightly concave, with a narrow triangular delthyrium, having a delthyrian angle 35°; a syrinx present; sulcus wide and deep. Dorsal valve gently convex in both lateral and anterior profiles; fold wide and high. External surface of both valves ornamented with numerous simple costae on lateral slopes, but nearly smooth on sulcus and fold; costae numbering 3–4 in 10 mm at anterior margin of dorsal valve; microornament of fine concentric growth lines on entire valve. Ventral interior with a pair of strong diverging dental plates and a large rounded and radially striated muscle scars in posterior portion of

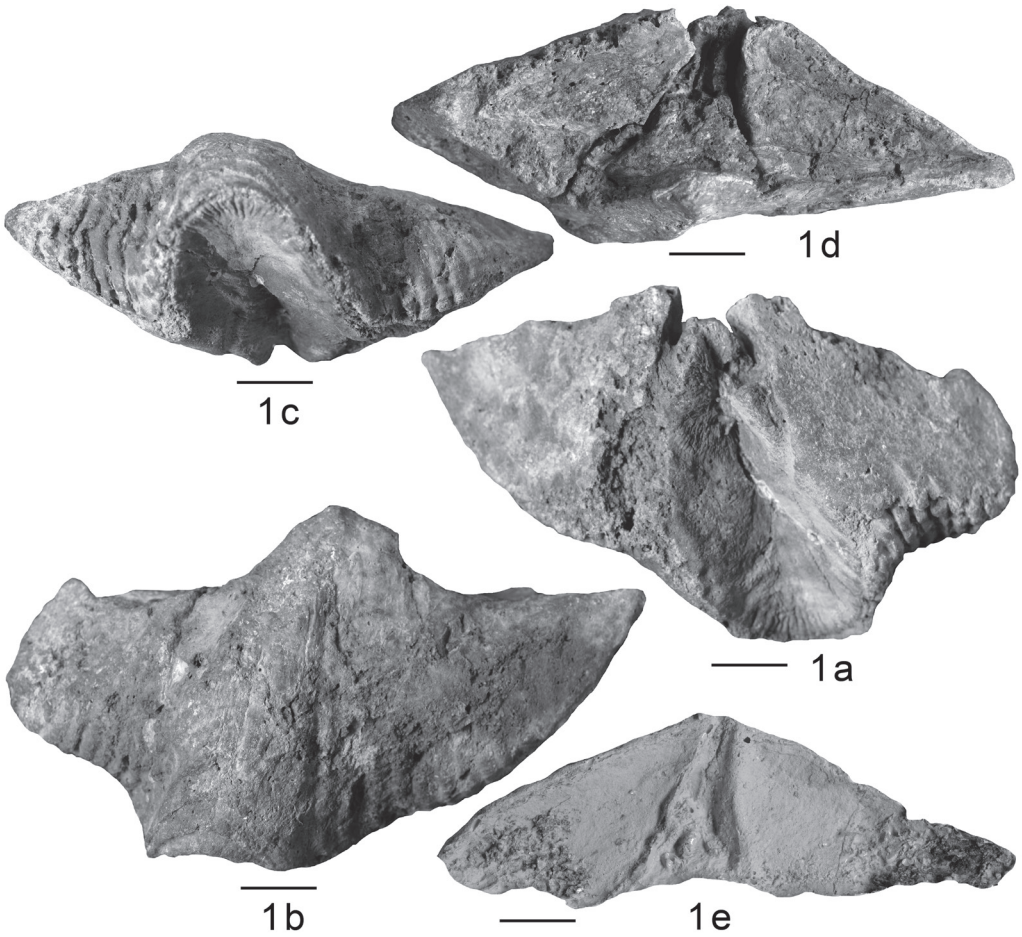

Fig. 1. 1, *Syringothyris texta* (Hall); 1a, 1b, 1c, 1d, ventral, dorsal, anterior and posterior views of internal mould of conjoined shell, UHR16925 (holotype); 1e, external cast of ventral interarea of the conjoined shell. Scale bars represent 1 cm.

valve. Interior of dorsal valve not well preserved.

Remarks.—This specimen was described by Minato (1951, p. 377) as the holotype of *Syringothyris transversa* Minato, 1951. But the Kitakami species is considered to be a junior synonym of *Syringothyris texta* (Hall, 1857), redescribed by Weller (1914, p. 399, pl. 69, figs. 6–9; pl. 70, figs. 1–4; pl. 71, figs. 1, 2) from the Keokuk Limestone of Missouri and the Knobstone Formation of Indiana, in the large, transverse shell and relatively low and slightly concave ventral interarea with a syrinx in the delthyrium. *Syringothyris altaica* Tolmatchoff (1924, p. 162, 555, pl. 8, figs. 9–11; pl. 9, fig. 1), from the upper Tournaisian of the Kuznetsk Basin, central Russia, differs from *S. texta* in having blunt cardinal extremities.

Distribution.—Lower Visean: northeastern Japan (Shimoarisu and Yokota in the South Kitakami Belt) and USA (Missouri and Indiana).

Subfamily Permasyrinxinae Waterhouse, 1986
Genus *Pseudosyrinx* Weller, 1914

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

Pseudosyrinx jumonjiensis (Minato, 1951)
Fig. 2.1

Syringothyris jumonjiensis Minato, 1951, p. 376, pl. 2, fig. 1; Minato et al., 1979, pl. 21, fig. 12.

Material.—One specimen from the middle part of the Arisu Formation of the Shimoarisu area, external mould of a dorsal valve with interarea of the ventral valve, UHR15995 (holotype).

Description.—Shell large in size for genus, transversely rhombus in outline, with mucronate cardinal extremities; length 62 mm, width 97 mm in the holotype (UHR15995). Ventral interarea very high and flat; delthyrium narrow with delthyrial angle about 20°; syrinx absent. Dorsal valve gently convex in both lateral and anterior profiles; fold moderately broad and high, smooth; lateral slopes ornamented with numerous simple rounded costae, numbering 6–7 in 10 mm at anterior margin of valve; microornament consisting of concentric growth lines.

Remarks.—This specimen was described by Minato (1951, p. 376) as the holotype of *Syringothyris jumonjiensis* Minato, 1951. But the genus of the Kitakami species should be replaced to *Pseudosylinx*, for the presence of high, flat ventral interarea and the lacking of syrinx in the delthyrium. The present species most resembles *Pseudosyrinx missouriensis* Weller (1914, p. 406, pl. 65, figs. 5–9; pl. 66, figs. 11–13) from the Burlington Limestone of the Mississippi Valley in general shape, but the American species is smaller in size. *Pseudosyrinx sampsoni* (Weller, 1909, p. 311, pl. 14, fig. 4), from the Fern Glen Formation of Missouri, is also a large-sized *Pseudosyrinx* species, but differs from *P. jumonjiensis* in having fewer and stronger costae on the dorsal valve.

Distribution.—Lower Visean: northeastern Japan (Yokota and Shimoarisu in the South Kitakami Belt).

Genus *Asyrinxia* Campbell, 1957

Type species.—*Spirifera lata* M'Coy, 1847.

Asyrinxia nipponotrigonalis (Minato, 1951)
Figs. 3.1, 3.2

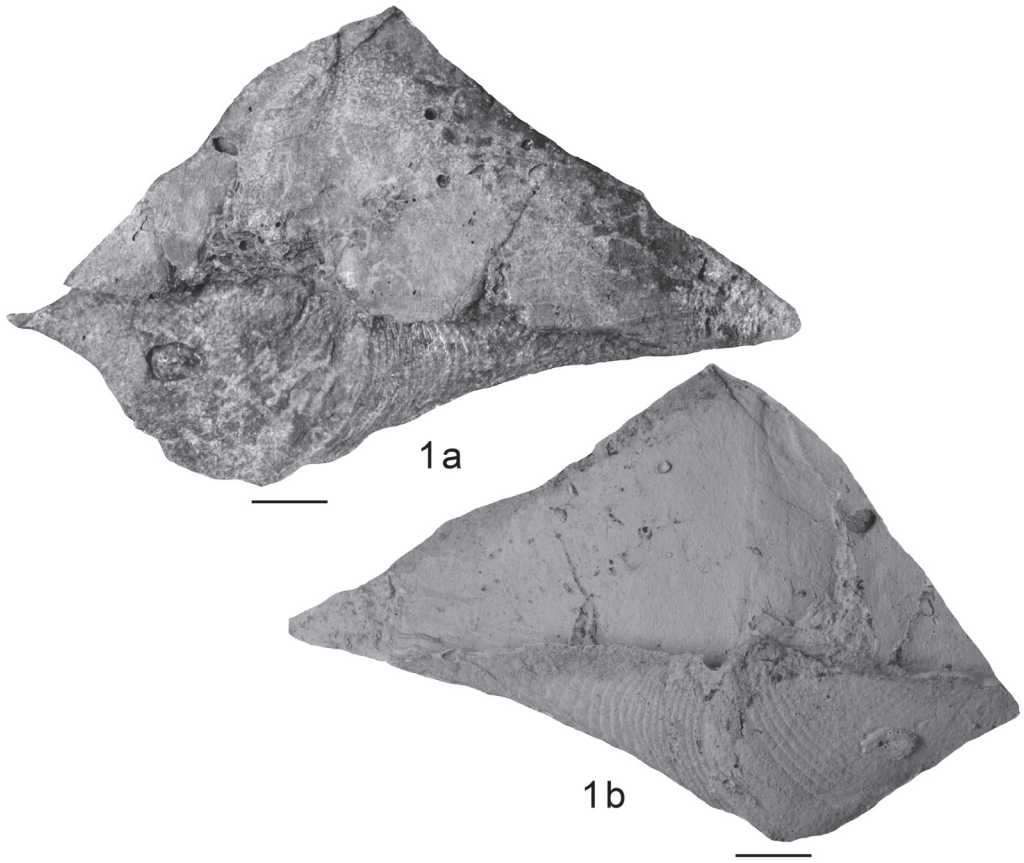

Fig. 2. 1, *Pseudosyrinx jumonjiensis* (Minato); 1a, 1b, external mould and external latex cast of conjoined shell, UHR15995 (holotype). Scale bars represent 1 cm.

Fusella nipponotrigonalis Minato, 1951, p. 372, pl. 2, fig. 5; Minato, 1952, p. 160, pl. 5, fig. 1; pl. 6, fig. 6; pl. 11, fig. 3; Minato et al., 1979, pl. 22, fig. 4.

Fusella nipponotrigonalis var. *minor* Minato, 1952, p. 160, pl. 6, fig. 3.

Asyrinxia sp. Tazawa, 1981, p. 74, pl. 5, fig. 14.

Material.—Two specimens from the middle part of the Arisu Formation of the Otsubosawa Valley, Yokota: (1) internal moulds of a conjoined shell, UHR16018 (holotype); and (2) external and internal moulds of a dorsal valve, UHR16016.

Description.—Shell medium in size for genus, transversely subtrigonal in outline, cardinal extremities slightly mucronate, ventral interarea moderately high and concave, without syrinx; length about 34 mm, width about 98 mm in the holotype (UHR16018). Dorsal valve gently convex in lateral profile; fold broad and moderately high, having no costae; lateral slopes ornamented with numerous simple rounded costae, numbering 4–5 in 10 mm at

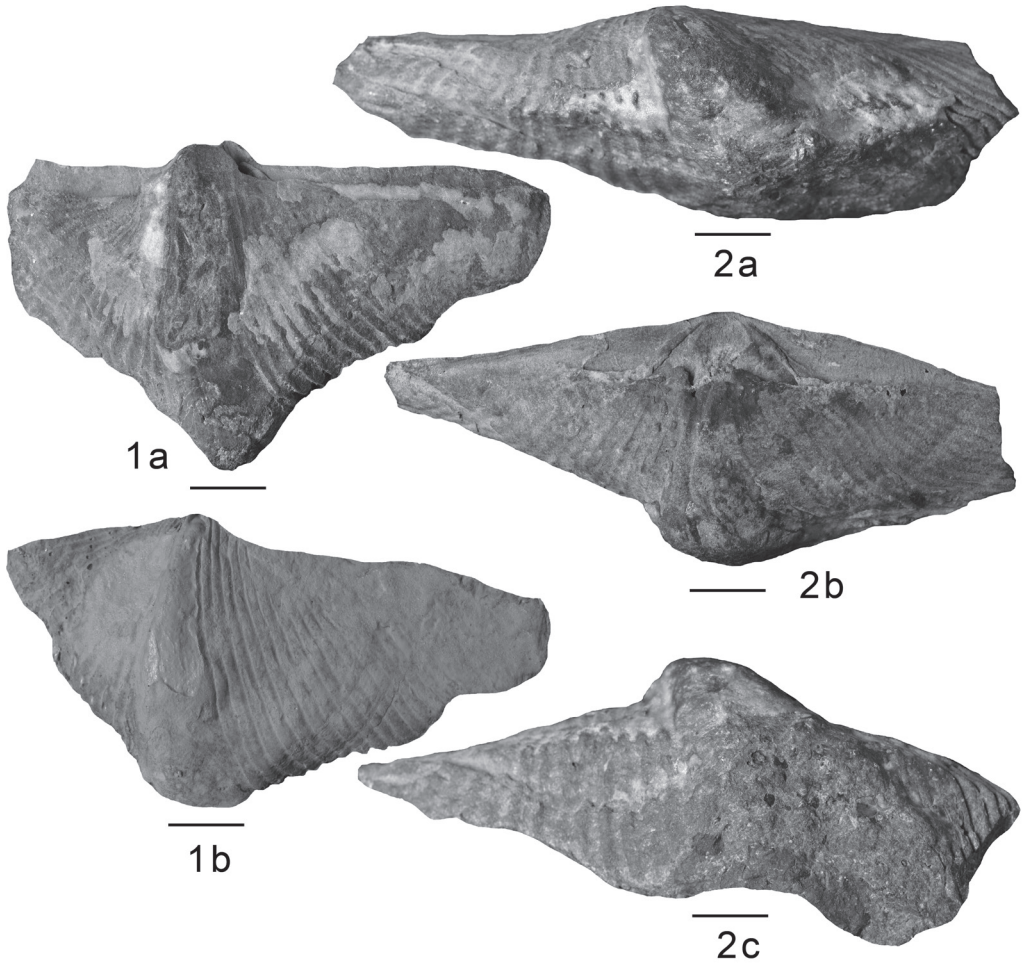

Fig. 3. 1, 2, *Asyrinxia nipponotrigonalis* (Minato); 1a, 1b, internal mould and external latex cast of dorsal valve, UHR16016; 2a, 2b, 2c, dorsal, posterior and anterior views of internal mould of conjoined shell, UHR16018 (holotype). Scale bars represent 1 cm.

anterior margin; microornament of concentric growth lines on entire valve. Internal structures of dorsal valve not well preserved.

Remarks.—These specimens were described by Minato (1951, p. 372) as the type specimens of *Fusella nipponotrigonalis* Minato, 1951. However, as suggested by Campbell (1957, p. 83–84), the Kitakami species is assigned to the genus *Asyrinxia*, in the large size and in having moderately high, concave ventral interarea, and lacking syrinx. Two syringothyridid species from the lower Carboniferous of the South Kitakami Belt, *Fusella nipponotrigonalis* var. *minor* Minato (1952, p. 160, pl. 6, fig. 3) from the Jumonji and Maide series (middle and upper parts of the Arisu Formation) of the Yokota area and *Asyrinxia* sp. in Tazawa (1981, p. 74, pl. 5, fig. 14) from the Karoyama Formation (upper Visean) of the Nisawa area, are considered to be junior synonyms of the present species. The type species,

Asyrinxia lata (M'Coy, 1857), redescribed by Campbell (1957, p. 81, pl. 16, figs. 1–9) from the middle Visean of Babbinboon, New South Wales, eastern Australia, differs from *A. nipponotrigonalis* by the more transverse outline.

Distribution.—Lower–upper Visean: northeastern Japan (Yokota, Shimoarisu and Nisawa in the South Kitakami Belt).

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I am grateful Yoshitsugu Kobayashi and Hiroki Echizenya (Hokkaido University Museum, Sapporo) for the loan of the type specimens; and Atsushi Matsuoka (Faculty of Science, Niigatra University, Niigata) and an anonymous reviewer for reading the manuscript.

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Middle Permian (Wordian) brachiopod fauna from Matsukawa, South Kitakami Belt, Japan, Part 2

Jun-ichi TAZAWA* and Hideo ARAKI**

Abstract

In this second manuscript in a series, additional brachiopods, consisting of 9 species in 9 genera, are described from the middle Permian (Wordian) Kamiyasse Formation of Matsukawa, South Kitakami Belt, northeastern Japan. The additional species, including one new species, to the Matsukawa fauna are as follows: *Neochonetes* (*Huangichonetes*) *matsukawensis* Tazawa and Araki, sp. nov., *Kunlunia* sp., *Permundaria asiatica* Nakamura, Kato and Choi, *Petasmaia expansa* Cooper and Grant, *Dicystoconcha lapparenti* Termier and Termier, *Meekella nodosa* Nakamura, *Orthothetina* sp., *Stenoscisma margaritovi* (Tschernyschew) and *Martinia* sp.

Key words: Brachiopoda, Matsukawa, middle Permian, Part 2, South Kitakami Belt.

Introduction

In a recent study (Tazawa and Araki, 2017), we described a brachiopod fauna, consisting of 19 species in 18 genera, from the middle Permian (Wordian) Kamiyasse Formation of Matsukawa, Kesennuma City, Miyagi Prefecture (in the South Kitakami Belt), northeastern Japan (Fig. 1). The present paper is a follow-up report on the middle Perman brachiopods of the Matsukawa fauna. In this paper, we describe brachiopods of 9 species in 9 genera from two localities, Anabuchi (AR4) and Omotematsukawa (KZ9). The locations and stratigraphic horizons of the fossil localities are indicated in Fig. 1 and Fig. 2, respectively. All specimens

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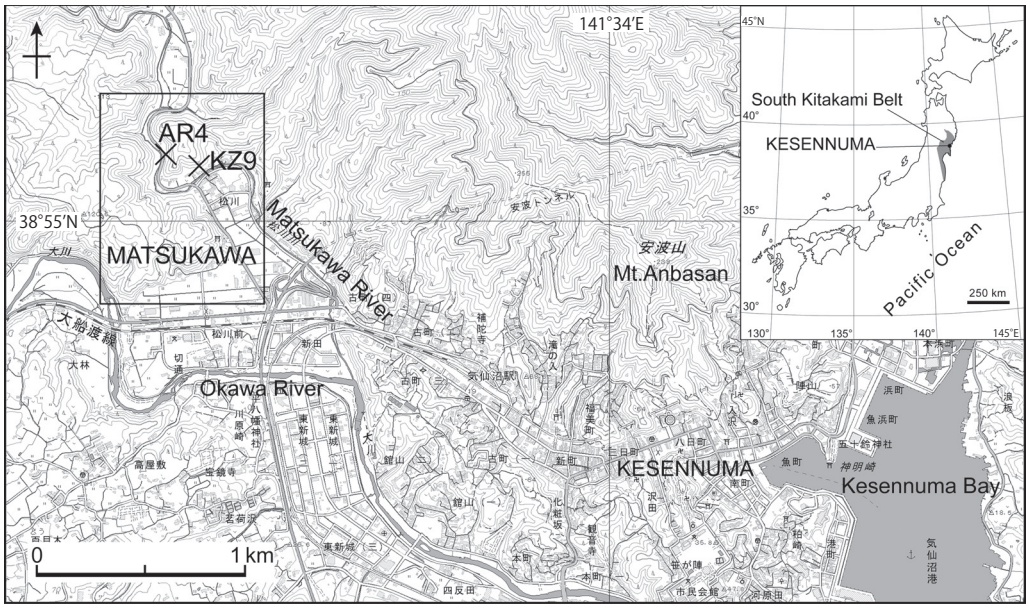

Fig. 1. Map showing the Matsukawa area, South Kitakami Belt and fossil localities AR4 (Anabuchi) and KZ9 (Omotematsukawa) in the area (after Tazawa and Araki, 2017).

were collected by the present author (H. Araki). They are now registered and housed in the Kesennuma Board of Education (tentatively placed in the Old Tsukitate Junior High School) in Kesennuma (prefix KCG, numbers KCG054 to KCG062).

The Matsukawa fauna

In Matsukawa middle Permian (Wordian) brachiopods, consisting of the following 24 species in 23 genera, have been described by Yabe (1900), Hayasaka (1917, 1922, 1925, 1963a, 1963b), Tazawa (1979) and Tazawa and Araki (1984a, 1984b, 1999, 2013, 2017): *Orbiculoidea jangarensis* Ustritsky, *Kitakamichonetes multicapillatus* Afanasjeva and Tazawa, *Capillomesolobus heritschi* Pečar, *Dyoros* (*Dyoros*) sp., *Transennatia gratiosa* (Waagen), *Hexiproductus echidniformis* (Chao), *Urushtenoidea crenulata* (Ding), *Scacchinella gigantea* Schellwien, *Linoproductus hayasakai* Tazawa, *Costatumulus cancriniformis* (Tschernyschew), *Permundaria tenuistriata* Tazawa, *Yakovlevia mammata* (Keyserling), *Y. kaluzinensis* Fredericks, *Productus flemingi* (Sowerby), *Scacchinella gigantea* Schellwien, *Neorichthofenia mabutii* (Tazawa and Araki), *Leptodus nobilis* (Waagen), *Keyserlingina* sp., *Paralyttonia kesennumensis* Tazawa and Araki, *Rhynchonella* (*Uncinulus*) *jabiensis* Waagen, *Martinia* sp., *Alispiriferella lita* (Fredericks), *Licharewia arakii* (Hayasaka) and *Dielasma* sp.

In this study, 9 species in 9 genera, including one new species, are newly described from Matsukawa. The species described herein are as follows: *Neochonetes* (*Huangichonetes*)

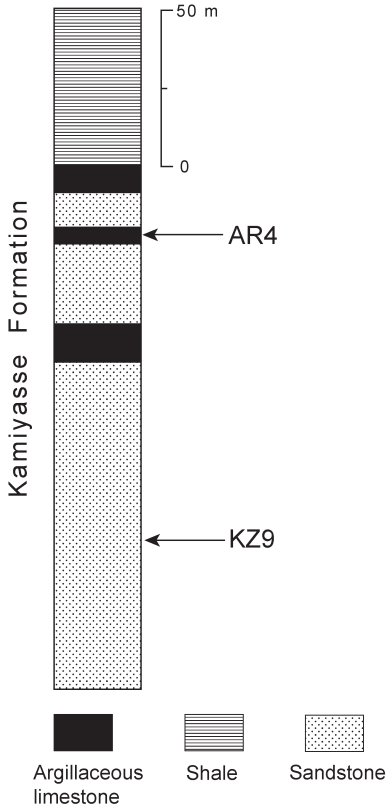

Fig. 2. Generalized columnar section of the lower part of the Kamiyasse Formation in the Matsukawa area, showing the fossil horizons of localities AR4 and KZ9 (after Tazawa and Araki, 2017).

matsukawensis Tazawa and Araki, sp. nov., *Kunlunia* sp., *Permundaria asiatica* Nakamura, Kato and Choi, 1970, *Petasmaia expansa* Cooper and Grant, 1969, *Dicystoconcha lapparenti* Termier and Termier in Termier et al., 1974, *Meekella nodosa* Nakamura, 1972, *Orthothetina* sp., *Stenoscisma margaritovi* (Tschernyschew, 1888) and *Martinia* sp. The total of brachiopods of the Matsukawa fauna, in the present, is 24 species in 23 genera.

On the age of the fauna, *Permundaria asiatica* is restricted to the Wordian; *Petasmaia expansa* is known from the Artinskian–Wordian; two species (*Meekella nodosa* and *Stenoscisma margaritovi*) are known from the Wordian–Wuchiapingian; and *Dicystoconcha lapparenti* is known from the Kungurian–Wuchiapingian (Fig. 3). In summary the Matsukawa fauna is assigned to the Wordian as discussed by Tazawa and Araki (2017). In terms of palaeobiogeography, the Matsukawa fauna is a Tethyan-type dominant Boreal–Tethyan mixed fauna, containing many Tethyan elements, such as *Neochonetes* (*Huangichonetes*), *Permundaria*, *Meekella* and *Orthothetina*, and a few Boreal element, *Kunlunia*. The conclusion is consistent with the previous studies on the middle Permian brachiopod faunas in the South Kitakami Belt (Tazawa et al., 2000; Tazawa and Ibaraki, 2001; Tazawa, 2016; Tazawa and Araki, 2017).

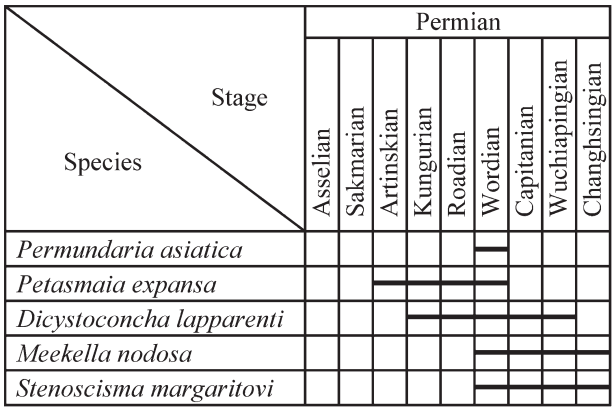

Fig. 3. Stratigraphic distribution of brachiopod species of the Matsukawa fauna, excluding one new species [*Neochonetes* (*Huangichonetes*) *matsukawensis* sp. nov.] and three uncertain species (*Kunlunia* sp., *Orthothetina* sp. and *Martinia* sp.).

Systematic descriptions

Order Productida Sarytcheva and Sokolskaya, 1959

Suborder Chonetidina Muir-Wood, 1995

Superfamily Chonetoidea Bronn, 1862

Family Rugosochonetidae Muir-Wood, 1962

Subfamily Rugosochonetinae Muir-Wood, 1962

Genus *Neochonetes* Muir-Wood, 1962

Subgenus *Huangichonetes* Shen and Archbold, 2002

Type species.—*Chonetes substrophomenoides* Huang, 1932.

Neochonetes (*Huangichonetes*) *matsukawensis* Tazawa and Araki, sp. nov.

Fig. 4.1

Etymology.—Named after the fossil locality, Matsukawa.

Material.—One specimen from locality AR4, external and internal moulds of a ventral valve, KCG061 (holotype).

Diagnosis.—Large, very transverse *Neochonetes* (*Huangichonetes*), with numerous costellae, numbering 56 near anterior margin on ventral valve.

Description.—Shell large in size for genus, transversely trapezoidal in outline; widest at hinge; length 8 mm, width 13 mm in the sole specimen (holotype). Ventral valve strongly convex in lateral profile, most convex at slightly anterior to midlength; umbo small; ears small but prominent; sulcus broad and shallow. External surface of ventral valve

ornamented with numerous costellae, numbering 56 near anterior margin; two or three spine bases preserved on each side of hinge. Ventral interior with a pair of strong teeth and a very short median septum; internal surface of ventral valve radially papillose.

Remarks.—*Neochonetes* (*Huangichonetes*) *matsukawensis* sp. nov. is most similar to the type species, *Neochonetes* (*Hunagichonetes*) *substrophomenoides* (Huang, 1932), redescribed by Shen and Archbold (2002, p. 337, figs. 5E–M), from the Lopingian of Hunan and Guizhou, South China, in shape and external ornament of the ventral valve, but differs from the Chinese species in the larger size and much transverse outline.

Superfamily Productoidea Gray, 1840
Family Dictyoclostidae Stehli, 1954
Subfamily Dictyoclostinae Stehli, 1954
Genus *Kunlunia* Wang in Zhang et al., 1983

Type species.—*Kunlunia aspera* Wang in Zhang et al., 1983.

Kunlunia sp.
Fig. 4.4

Material.—One specimen from locality AR4, external mould of a dorsal valve, KCG059.

Remarks.—This specimen can be assigned to the genus *Kunlunia* in the dictyoclostid shell with large extended ears on the dorsal valve. The Matsukawa species somewhat resembles *Kunlunia grabaui* (Nakamura, 1960), redescribed by Tazawa and Nakamura (2015, p. 162, figs. 5.1–5.3) from the lower part of the Hosoo Formation (Kungurian) of Nakadaira, South Kitakami Belt, in shape and external ornament of the dorsal valve, but differs in the larger size (length 54 mm, width 76 mm in the dorsal valve specimen, KCG059). Specific identification is difficult for the poor material.

Superfamily Linoproductoidea Stehli, 1954
Family Kansuellidae Muir-Wood and Cooper, 1960
Subfamily Auriculispininae Waterhouse in Waterhouse and Briggs, 1986
Genus *Permundaria* Nakamura, Kato and Choi, 1970

Type species.—*Permundaria asiatica* Nakamura, Kato and Choi, 1970.

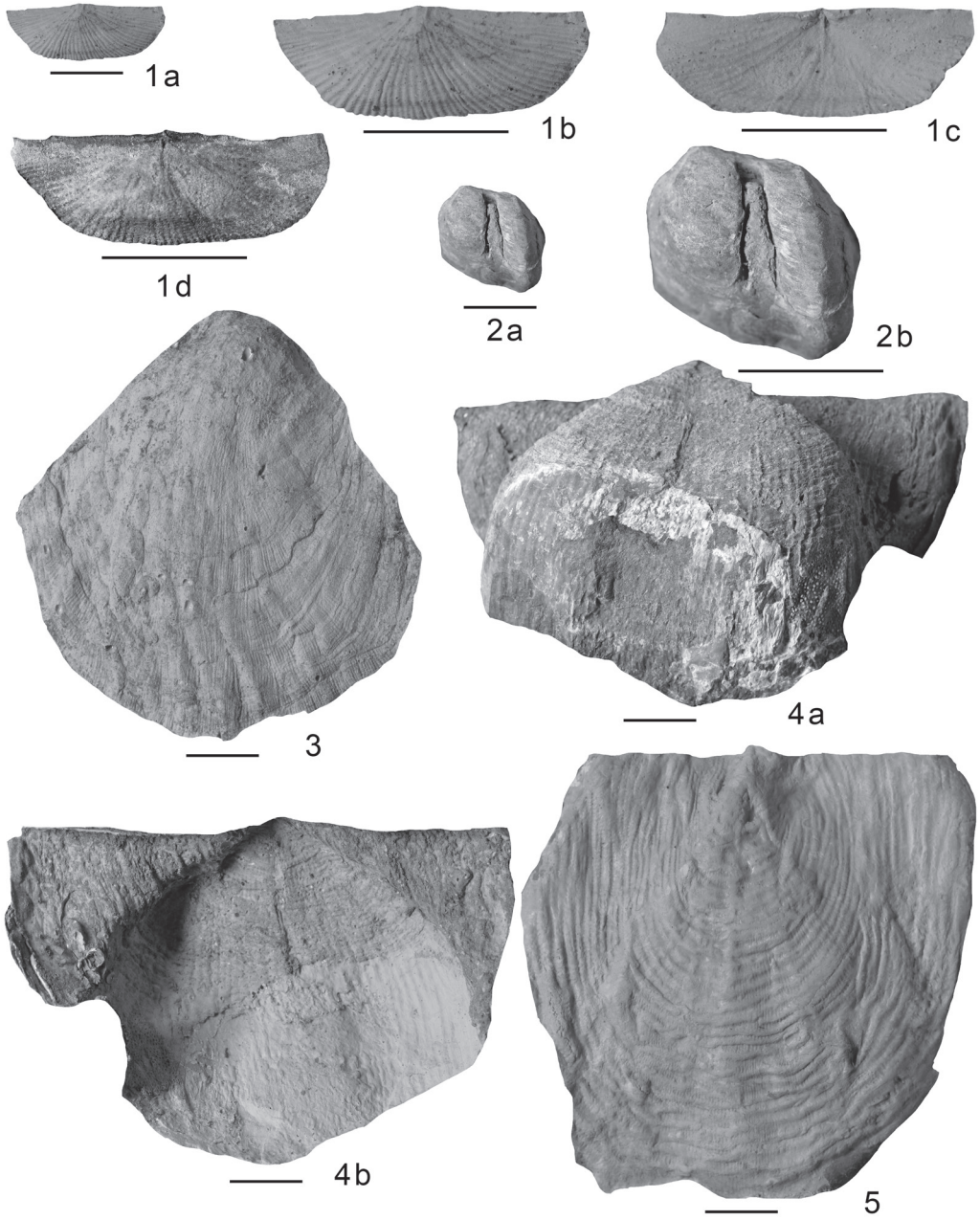

Fig. 4. 1, *Neochonetes* (*Huangichonetes*) *matsukawensis* sp. nov.; 1a–d, external latex cast, internal latex cast and internal mould of ventral valve, KCG061 (holotype). **2,** *Dicystoconcha lapparenti* Termier and Termier; 2a, b, internal mould of ventral valve, KCG058. **3,** *Meekella nodosa* Nakamura, external latex cast of ventral valve, KCG060. **4,** *Kunlunia* sp.; 4a, b, external mould and external latex cast of dorsal valve, KCG059. **5,** *Permundaria asiatica* Nakamura, Kato and Choi, external latex cast of ventral valve, KCG054. Scale bars represent 1 cm.

Permundaria asiatica Nakamura, Kato and Choi, 1970
Fig. 4.5

Striatifera? sp. Hayasaka and Minato, 1956, p. 144, pl. 23, figs. 6, 7.
Permundaria asiatica Nakamura, Kato and Choi, 1970, p. 296, pl. 2, figs. 1, 2; Tazawa, 1974, p. 315, pl. 43, figs. 3, 4; Tazawa, 1976, pl. 2, fig. 7; Minato et al., 1979, pl. 62, figs. 12, 13; Tazawa, 2001, p. 296, figs. 7.17–7.19.

Material.—One specimen from locality AR4, external mould of a ventral valve, KCG054.

Remarks.—This specimen is referred to *Permundaria asiatica* Nakamura, Kato and Choi, 1970, in the large, subquadrate and flattened ventral valve (length more than 65 mm, width more than 64 mm), ornamented with numerous fine costellae (numbering 5 in 2 mm at about midlength) and numerous regular but slightly undulate concentric rugae. As noted by Nakamura et al. (1970, p. 297), *Striatifera*? sp. Hayasaka and Minato, 1956, from the lower part of the Kanokura Series (= Kamiyase Formation) of Imo, South Kitakami Belt, is a synonym of the present species. *Permundaria tenuistriata* Tazawa (1974, p. 317, pl. 43, figs. 1, 2), from the lower Kamiyasse Formation of Kamiyasse, South Kitakami Belt, is distinguished from *P. asiatica* in having finer capillae on both ventral and dorsal valves.

Distribution.—Wordian: northeastern Japan (South Kitakami Belt) and central Japan (Hida Gaien Belt).

Suborder Lyttoniidina Williams, Harper and Grant, 2000
Superfamily Lyttonioidea Waagen, 1883
Family Lyttoniidae Waagen, 1883
Subfamily Lyttoniinae Waagen, 1883
Genus *Petasmaia* Cooper and Grant, 1969

Type species.—*Petasmaia expansa* Cooper and Grant, 1969.

Petasmaia expansa Cooper and Grant, 1969
Figs. 5, 6.4

Petasmaia expansa Cooper and Grant, 1969, p. 10, pl. 2, figs. 15–18; Cooper and Grant, 1974, p. 430, pl. 163, figs. 1–8; pl. 164, figs. 1–16; pl. 165, figs. 1–23; pl. 169, figs. 11–16; Tazawa and Ono, 2013, p. 51, figs. 2, 3; Tazawa et al., 2016, p. 374, fig. 7.6.

Material.—One specimen from locality KZ9, internal mould of a ventral valve, KCG055.

Description.—Shell medium in size for genus, transversely wider elliptical in outline, with

Fig. 5. *Petasmaia expansa* Cooper and Grant, longitudinal section of internal latex cast of ventral valve, KCG055, showing lateral septa, A: anterior, P: posterior.

greatest width at midlength; length about 45 mm, width about 58 mm. Ventral valve almost flat in both lateral and anterior profiles. Interior of ventral valve with numerous regularly and symmetrically arranged thin lateral septa on both sides of a low thin median septum; lateral septa with sharp crests and broad interspaces, being gently convex anteriorly and inclined, dipping posteriorly at low angle to valve surface in lateral profile, numbering 11 pairs of lateral septa.

Remarks.—This specimen is referred to *Petasmaia expansa* Cooper and Grant, 1969, from the Cathedral Mountain Formation (Leonardian) of the Glass Mountains, West Texas, USA, on account of the transversely wider ventral valve and the regularly arranged thin lateral septa, being gently convex anteriorly and inclined posteriorly. The Matsukawa specimen, smaller than the type specimens of West Texas, may be a young individual. *Petasmaia ehiroi* Tazawa and Miyake (2011, p. 8, figs. 3.10, 3.11, 4), from the Toyoma Formation of Maeda, South Kitakami Belt, differs from *P. expansa* in having lateral septa with narrower interspaces.

Distribution.—Artinskian–Wordian: northeastern Japan (Setamai and Kamiyasse–Imo in the South Kitakami Belt), southwestern Japan (Akasaka in the Mino Belt) and western USA (West Texas).

Superfamily Permianelloidea He and Zhu, 1979

Family Permianellidae He and Zhu, 1979

Genus *Dicystoconcha* Termier and Termier in Termier et al., 1974

Type species.—*Dicystoconcha lapparenti* Termier and Termier in Termier et al., 1974.

Dicystoconcha lapparenti Termier and Termier in Termier et al., 1974

Fig. 4.2

Dicystoconcha lapparenti Termier and Termier in Termier et al., 1974, p. 123, pl. 22, figs. 1, 2; text-fig. 22; Wang and Jin, 1991, p. 495, pl. 1, figs. 1–9; pl. 3, figs. 1–7; Shen and Tazawa, 2014, p. 248, figs. 3.1–3.5; Tazawa et al., 2014, p. 383, fig. 2.6; Tazawa, 2015, p. 73, fig. 6.6.

Dipunctella contracta Liang in Wang et al., 1982, p. 229, pl. 102, fig. 3.

Guangjiayanella guangjiayanensis Yang, 1984, p. 212, pl. 31, figs. 11–16; text-fig. 5.9.
Guangdongina xiamaoensis Mou and Liu, 1989, p. 458, pl. 1, figs. 1–9; pl. 2, figs. 1–7; text-fig. 5.
Guangdongina leguminiformis Mou and Liu, 1989, p. 458, pl. 3, figs. 4–8.
Guangdongina perforatus Mou and Liu, 1989, p. 459, pl. 2, fig. 8; pl. 3, figs. 1–3.
Guangdongina sp. Mou and Liu, 1989, p. 459, pl. 2, fig. 9.
Paritisteges latesulcata Liang, 1990, p. 380, pl. 42, figs. 1, 2.
Febulasteges planata Liang, 1990, p. 381, pl. 42, figs. 3, 4.

Material.—One specimen from locality AR4, internal mould of ventral valve, KCG058.

Remarks.—This specimen is referred to *Dicystoconcha lapparenti* Termier and Termier in Termier et al., 1974, from the lower Murgabian of Wardak, central Afganistan, in the small, ovate, strongly convex and bilobate ventral valve (length about 15 mm, width 14 mm). Shen and Tazawa (2014, p. 248) treated the following six forms from the Permian of South China as the junior synonyms of *Dicystoconcha lapparenti*: *Guangjiayanella guangjiayanensis* Yang, 1984, *Guangdongina xiamaoensis* Mou and Liu, 1989, *Guangdongina leguminiformis* Mou and Liu, 1989, *Guangdongina perforatus* Mou and Liu, 1989, *Guangdongina* sp. Mou and Liu, 1989, and *Fabulasteges planata* Liang, 1990. Moreover, *Paritisteges latesulcata* Liang, 1990, from the lower Lengwu Formation of Lengwu, Zhejiang, eastern China, is also considered to be a junior synonym of the present species.

Distribution.—Kungurian–Wuchiapingian: northeastern Japan (Kamiyasse–Imo in the South Kitakami Belt), central Japan (Hitachi), Afganistan, northern China (Inner Mongolia), eastern China (Zhejiang) and central-southern China (Hubei and Guangdong).

Order Orthotetida Waagen, 1884
Suborder Orthotetidina Waagen, 1884
Superfamily Orthotetoidea Waagen, 1884
Family Meekellidae Stehli, 1954
Subfamily Meekellinae Stehli, 1954
Genus *Meekella* White and St. John, 1867

Type species.—*Plicatula striatocostata* Cox, 1857.

Meekella nodosa Nakamura, 1972
Fig. 4.3

Meekella sp. Huang, 1933, p. 31, pl. 4, figs. 8, 9.
Meekella nodosa Nakamura, 1972, p. 388, pl. 6, figs. 3, 4; Minato et al., 1979, pl. 59, fig. 8.

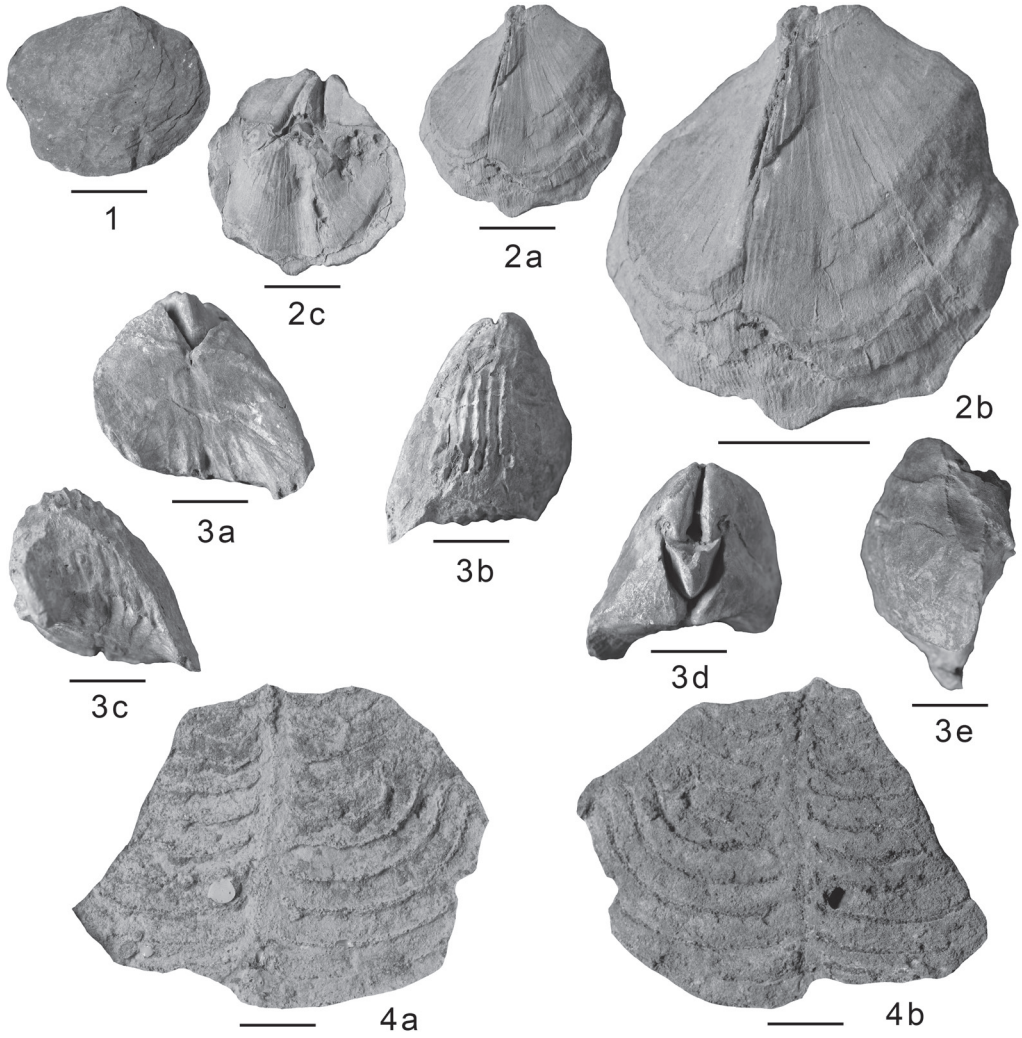

Fig. 6. 1, *Martinia* sp., internal mould of ventral valve, KCG062. **2,** *Orthothetina* sp.; 2a–c, internal latex casts of ventral and dorsal valves, KCG057. **3,** *Stenoscisma margaritovi* (Tschernyschew), 3a–e, ventral, dorsal, anterior, posterior and lateral views of internal mould of conjoined shell, KCG056. **4,** *Petasmaia expansa* Cooper and Grant, 4a, b, internal latex cast and internal mould of ventral valve, KCG055. Scale bars represent 1 cm.

Material.—One specimen from locality KZ9, external mould of a ventral valve, KCG060.

Remarks.—This specimen can be referred to *Meekella nodosa* Nakamura, 1972, from the lower Kanokura Series (= lower Kamiyasse Formation) of Kamiyasse, South Kitakami Belt, by its large size (length 58 mm, width 56 mm) and the characteristic external ornament of the ventral valve, nodose appearance represented by numerous radial costae and costellae crossed by numerous concentric rugae. As noted by Nakamura (1972, p. 389), *Meekella* sp. Huang, 1933, from the Wuchiapingian of Guizhou, southwestern China, is a synonym of the present species. *Meekella irregularis* Schellwien, 1900 (p. 20, pl. 2, figs. 8, 9), from the

Trogkofel Limestone of the Karavanke Mountains, Slovenia, also has nodose ornament on the ventral valve, but the Karavanke species differs from *M. nodosa* in its much elongate outline.

Distribution.—Wordian–Wuchiapingian: northeastern Japan (Kamiyasse and Matsukawa in the South Kitakami Belt) and southwestern China (Guizhou).

Genus *Orthothetina* Schellwien, 1900

Type species.—*Orthothetes persicus* Schuchert in Schuchert and LeVene, 1929.

Orthothetina sp.
Fig. 6.2

Material.—One specimen from locality AR4, internal mould of a conjoined shell, KCG057.

Remarks.—This specimen is safely assigned to the genus *Orthothetina* by its Orthothetid-formed shell and in having a pair of long, thin and subparallel dental plates in the ventral valve. The Matsukawa species resembles the specimens, described by Nakamura (1972, p. 300, pl. 2, figs. 2–5) as *Orthothetina kayseri* (Jäkel) from the lower Kanokura Series (= Kamiyasse Formation) of Imo, South Kitakami Belt, in size and shape of the shell, particularly in having a broad and deep sulcus in the dorsal valve. But accurate comparison is difficult because lacking information on the external ornament of both valves.

Order Rhynchonellida Kuhn, 1949
Superfamily Stenoscismatoidea Oehlert, 1887
Family Stenoscismatidae Oehlert, 1887
Subfamily Stenoscismatinae Oehlert, 1887
Genus *Stenoscisma* Conrad, 1839

Type species.—*Terebratula schlottheimii* von Buch, 1834

Stenoscisma margaritovi (Tschernyschew, 1888)
Fig. 6.3

Camarophoria margaritovi Tschernyschew, 1888, p. 355, figs. 1–3; Fredericks, 1924, p. 48, pl. 1, figs. 32–42; text-fig. 4.

Camarophoria humbletonensis Howse: Hayasaka, 1922, p. 62, pl. 8, figs. 10–12; pl. 10, fig. 9; Hayasaka, 1966, p. 1226, text-figs. 6–8.

Stenoscisma humbletonensis (Howse): Tazawa, 1976, pl. 2, figs. 9, 10; Minato et al., 1979, pl. 66, figs. 6–8.

Stenoscisma gigantea (Diener): Lee and Gu, 1976, p. 272, pl. 176, fig. 3; pl. 177, fig. 18; Lee et al., 1980, p. 395, pl. 173, figs. 6, 8.

Stenoscisma margaritovi (Tschernyschew): Licharew and Kotlyar, 1978, pl. 17, fig. 7; Koczyrkevicz, 1979, p. 50, pl. 11, figs. 5, 6; Duan and Li, 1985, p. 120, pl. 43, figs. 5–8; Tazawa and Matsumoto, 1998, p. 9, pl. 2, figs. 1–5; Tazawa et al., 2000, p. 10, pl. 1, figs. 7–11; Tazawa, 2001, p. 298, figs. 8.1–8.4; Tazawa, 2002, fig. 10.5; Wang and Zhang, 2003, p. 130, pl. 33, figs. 6, 7, 12–16; pl. 50, fig. 19; Tazawa and Chen, 2006, p. 333, figs. 5.7, 5.8.

Stenoscisma gigantea elongatum Lee and Su in Lee et al., 1980, p. 395, pl. 173, figs. 1, 2.

Stenoscisma purdoni (Davidson): Lee et al., 1980, p. 395, pl. 173, figs. 4, 5, 7.

Material.—One specimen from locality AR4, internal mould of a conjoined shell, KCG056.

Remarks.—This specimen is poorly preserved, but can be referred to *Stenoscisma margaritovi* (Tschernyschew, 1888), from the middle Permian of Vladivostok, eastern Russia, on account of the large, slightly elongate shell with strong and relatively large number of costae on both ventral sulcus and dorsal fold (numbering 5 on the dorsal fold).

Distribution.—Wordian–Wuchiapingian: northeastern Japan (Kamiyasse, Matsukawa, Ogatsu and Takakurayama in the South Kitakami Belt), central Japan (Moribu and Oguradani in the Hida Gaien Belt); northern China (Inner Mongolia), northeastern China (Heilongjiang and Jilin) and eastern Russia (South Primorye).

Order Spiriferida Waagen, 1883
Suborder Spiriferidina Waagen, 1883
Superfamily Martinioidea Waagen, 1883
Family Martiniidae Waagen, 1883
Subfamily Martiniinae Waagen, 1883
Genus *Martinia* M'Coy, 1844

Type species.—*Spirifer glaber* Sowerby, 1820.

Martinia sp.
Fig. 6.1

Material.—One specimen from locality AR4, internal mould of a ventral valve, KCG062.

Remarks.—This specimen is safely assigned to the genus *Martinia* by its medium (length 23 mm, width 29 mm), subcircular and gently convex ventral valve, with several radial vascular markings. But specific identification is difficult owing to ill preservation of the present material.

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Lithostratigraphy of the Miocene Iwaine Formation in the Yatsuo area, central Japan

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Abstract

We examined the Miocene Iwaine Formation formed in the margin of the Eurasian continent during the Japan Sea opening, of the Yatsuo Group in the Yatsuo area located in Toyama Prefecture, central Japan, on the basis of lithology and stratigraphy. The Iwaine Formation is composed mainly of monomictic autobreccia, polymictic volcanic breccia, pumice tuff and coherent andesites, with clastic rocks whose clasts were derived from the Iwaine Formation, in stratigraphically ascending order. Lithostratigraphy of the Iwaine Formation in the Yatsuo area will be of great significance to reveal the characteristics of volcanism during the Japan Sea opening.

Key words: Miocene, Iwaine Formation, Japan Sea opening, Yatsuo Group, lithostratigraphy.

Introduction

The Japan Sea opening which is the formation of a back-arc basin in the margin of the Eurasian continent is the most significant event in the Neogene of Japan (e.g., Yoshida, 2009). Kano et al. (2007) suggested that the earliest stage of the Japan Sea opening had already initiated in latest Eocene. The Japan arc was then separated from the continent due to rapid spreading of the Japan Sea in 20–15 Ma (substage IA; Nakajima et al., 2015), and deposits during this stage are widely distributed in the Neogene strata (Fig. 1). Toyama Prefecture is

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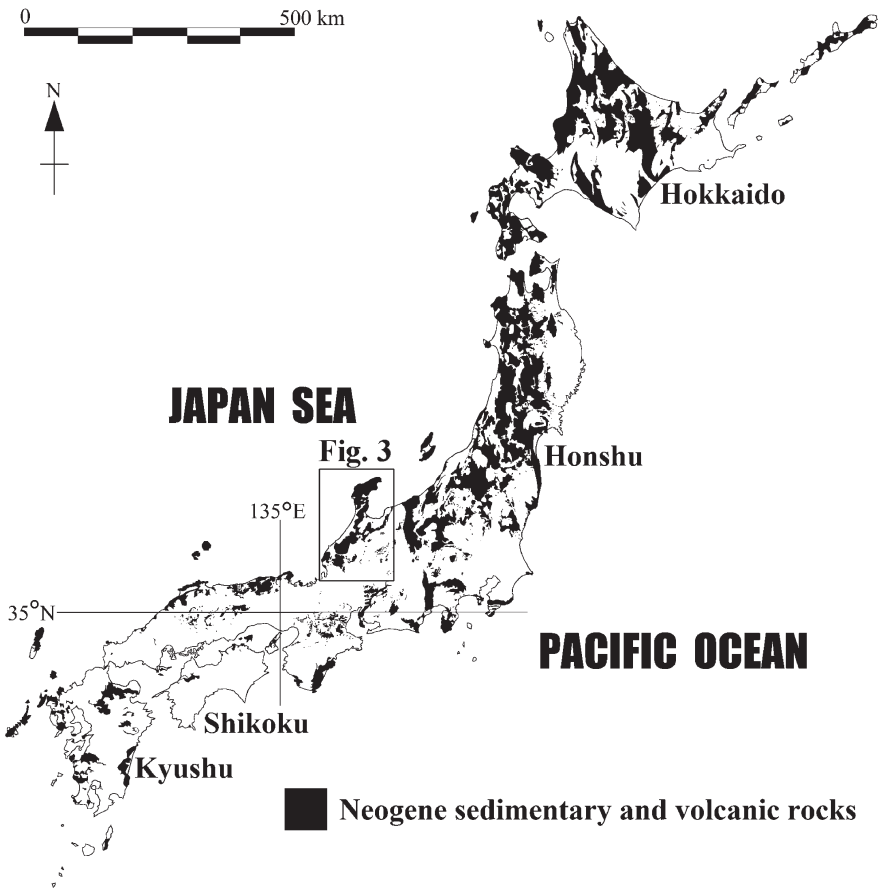


Fig. 1. Map showing the distribution of Neogene sedimentary and volcanic rocks in Japan. Modified from Seamless digital geological map of Japan 1: 200000, Geological Survey of Japan.

one of the most suitable places to study the Japan Sea opening, because the strata formed during this period are well preserved without large deformation.

In Toyama Prefecture, there are two successions that were formed during the Japan Sea opening: the upper Oligocene stratum (Tori Conglomerate and Usunaka Moonstone Rhyolite) and the lower to middle Miocene Yatsuo Group (Fig. 2). The Tori Conglomerate and the Usunaka Moonstone Rhyolite were formed in the early stage of the opening on the margin of the continent. Since sedimentary environment of the lower to middle Miocene Yatsuo Group changed gradually from non-marine or shallow marine to deep sea (Hayakawa and Takemura, 1987), it is expected to reflect the deepening of the Japan Sea.

The Iwaine Formation of the Yatsuo Group and equivalent beds, widely distributed in the Hokuriku Region, central Japan (Fig. 3), are composed mainly of andesites which erupted in the margin of the Eurasian continent in Early Miocene (Takahashi and Shuto, 1999). Petrological studies of the Iwaine Formation have been conducted by Ishiwatari and

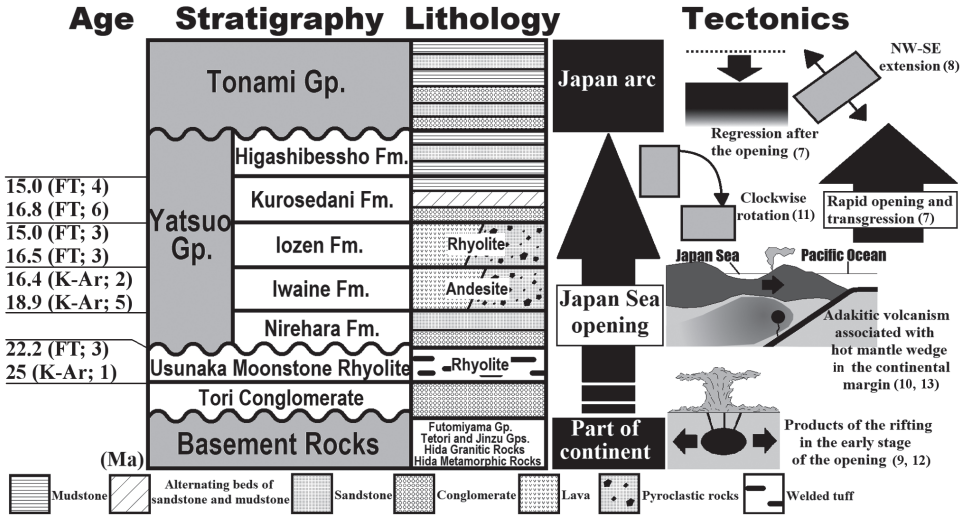


Fig. 2. Stratigraphy of strata associated with the Japan Sea opening in Toyama Prefecture (after Sudo (1979), and Hayakawa and Takemura (1987)). The youngest and oldest ages are showed as age data of each formation (1, Ueda and Aoki, 1970; 2, Shibata, 1973; 3, Ganzawa, 1983; 4, Nakajima and Mizushima, 1984; 5, Japan National Oil Corporation, 1985; 6, Hayakawa and Danhara, 1986). The tectonic interpretations associated with the Japan Sea opening are based on Hayakawa and Takemura (1987; 7), Fournier et al. (1994; 8), Ishida et al. (1998; 9), Takahashi and Shuto (1999; 10), Tamaki et al. (2006; 11), Ayalew and Ishiwatari (2011; 12), Sato et al. (2013; 13). K–Ar: K–Ar age. FT: zircon fission track age. Gp.: Group. Fm.: Formation.

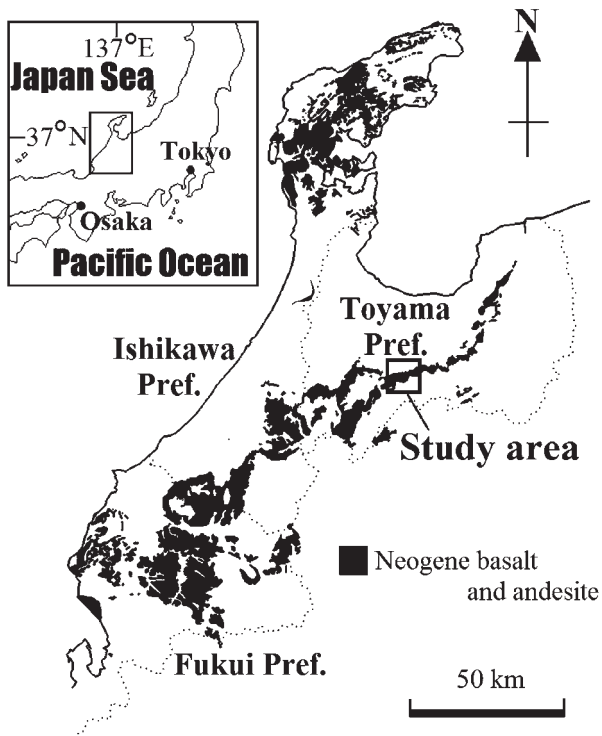


Fig. 3. Index map showing the distribution of Neogene basalts and andesites in Hokuriku Region (modified from Seamless digital geological map of Japan 1: 200,000, Geological Survey of Japan) and the study area. Pref.: Prefecture.

Ohama (1997), Takahashi and Shuto (1999), Tsuchihashi and Ishiwatari (2006), Ishiwatari et al. (2007), Sato et al. (2013), and Watanabe and Takahashi (2017). Most petrological studies concluded that the Iwaine Formation was formed by volcanic activities associated with hot mantle wedge in the margin of the Eurasian continent, in a subduction zone setting. However, this state differed from the present subduction and volcanic activities in the Japan arc. Although many researchers have referred to lithology and stratigraphy of the Iwaine Formation (e.g., Tsuda, 1953, 1955; Sakamoto and Nozawa, 1960; Hayakawa and Takemura, 1987), detailed studies on the lithostratigraphy of the Iwaine Formation are still not enough. Geology, including lithology and stratigraphy, should be as significant as petrology to reveal the characteristics of volcanism of the Iwaine Formation. Therefore, we examined lithology and stratigraphy of the Iwaine Formation in the Yatsuo area (Fig. 3), and accordingly we report the results of our field research and figure out some unsolved issues on stratigraphy of the Iwaine Formation.

Regional geology in the Yatsuo area

The stratigraphic division of the Neogene in the Yatsuo area was first founded by Makiyama (1930), and many other researchers have revised it (e.g., Imamura, 1936, 1937; Fujita and Nakagawa, 1948; Tsuda and Chiji, 1950; Tsuda, 1953; Nakaseko, 1953, 1954; Sakamoto et al., 1959; Sakamoto and Nozawa, 1960; Hayakawa and Takemura, 1987). Hayakawa and Takemura (1987) showed a stratigraphic division based on the correlation of key tuff beds and detailed columnar sections of the Miocene in the Yatsuo area. We think that their stratigraphic division is reasonable because they associated lithostratigraphy of Neogene strata in the Yatsuo area with the Japan Sea opening, and hence follow it in our study. However, type localities of some formations have already sunk into rivers due to construction of dams.

Mesozoic basement rocks are distributed in the southern part of the target area, and the Miocene Yatsuo Group overlies them (Fig. 4); the Miocene Yatsuo Group is composed of the Nirehara, Iwaine, Iozen, Kurosedani and Higashibessho formations, in stratigraphically ascending order (Fig. 5). The Yatsuo Group strikes ENE–WSW and dips 10–40° N (Fig. 4).

1. Basement rocks

The basement rocks of the Miocene in the Yatsuo area consist of the Hida Granitic Rocks (Kano, 1990), the Tetori and Jinzu groups (Matsukawa et al., 2014). The granite in this area is weathered and appears to be pale pink, consisting of potassium feldspar, plagioclase, quartz, biotite, and opaque minerals. The Tetori and Jinzu groups are in fault contact with the Hida Granitic Rocks (e.g., Sakamoto and Nozawa, 1960). The Tetori Group in the study area consists of upper Oxfordian marine sandstone and mudstone, whereas the Jinzu Group consists of Lower Cretaceous non-marine sandstone and mudstone (Matsukawa et al., 2014).

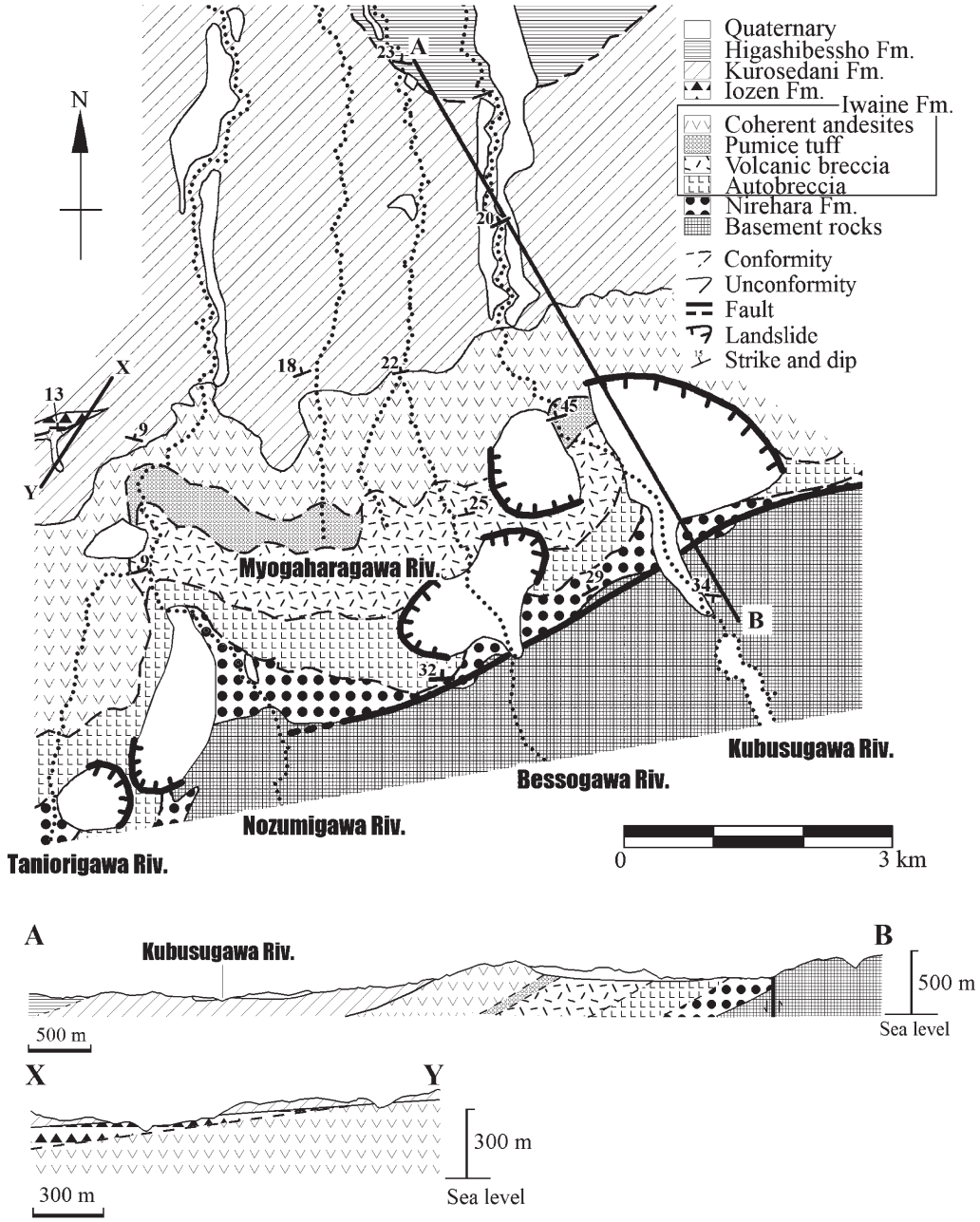


Fig. 4. Geological map and two cross sections of the Yatsuo area. Fm.: Formation.

2. Nirehara Formation

Name Named by Tsuda and Chiji (1950).

Type locality The bank of the Jinzugawa River in Nirehara, Toyama City, Toyama Prefecture (Hayakawa and Takemura, 1987).

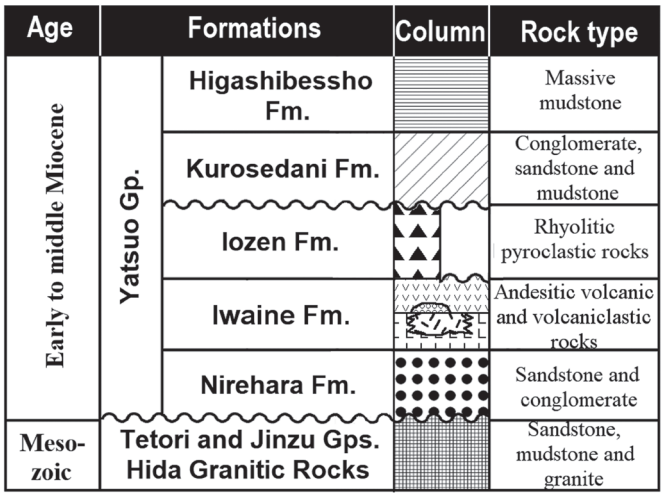


Fig. 5. Stratigraphy of the study area. The division of basement rocks is after Kano (1990) and Matsukawa et al. (2014). Gp.: Group. Fm.: Formation.

Distribution The Nirehara Formation is distributed narrowly between Taniori and Kiridani, southern part of the study area (Fig. 4).

Thickness 100–250 m.

Stratigraphic relationship The Nirehara Formation is in unconformable or fault contact with the basement rocks in the study area (Fig. 4).

Lithology The lower part of the Nirehara Formation is composed mainly of matrix-supported conglomerate containing rounded pebbles of granites and chert (approximately 10 cm in diameter). The conglomerate rarely shows imbricate structure and includes lenticular sandstone and mudstone. The upper part is composed of massive (rarely showing cross bedding) arkose sandstone and mudstone.

Fossil Tsuda (1953), Sakamoto and Nozawa (1960), and Hayakawa and Takemura (1987) reported unidentifiable fragments of plant fossils. Kashiwagi (2012) reported radiolarian fossils from chert gravels in the formation and concluded that the chert gravels were originated from the chert in the Tamba–Mino Belt or the chert gravels in the conglomerate beds of the Tetori Group.

3. Iwaine Formation

Name Named by Imamura (1937).

Type locality The bank of the Jinzu River in Iwaine, Toyama City, Toyama Prefecture (Hayakawa and Takemura, 1987).

Distribution The Iwaine Formation is distributed widely between Nunotani and Mt. Otakayama, the southern part of the study area (Fig. 4).

Thickness 600–1450 m.

Stratigraphic relationship The Iwaine Formation conformably covers the Nirehara Formation (Fig. 5).

Lithology The Iwaine Formation consists of coherent andesites, volcaniclastic and clastic rocks. Volcaniclastic and clastic rocks are predominant in the lower part of the formation, whereas coherent andesites are predominant in the upper part. Coherent andesites are generally massive but partly has joints. Thin beds of volcaniclastic or clastic rocks are intercalated often between coherent andesites. Volcaniclastic rocks in the Iwaine Formation are composed mainly of autobreccia, volcanic breccia and pumice tuff showing pale to dark green color.

Fossil Tsuda (1953) reported unidentifiable fragments of plant fossils. Sakamoto and Nozawa (1960) reported molluscan (e.g., *Soletollina* sp., *Calyptrea* sp. and *Nassarius* sp.) and plant (*Fagus antipofi*) fossils from mudstone in the formation. In this study, a gastropod molluscan shell of *Cerithideopsilla* sp. was found from siltstone in the upper part of the formation (Fig. 7).

Age K–Ar and FT (fission track) ages have been reported by Shibata (1973; K–Ar age; 13.6 ± 0.7, 15.9 ± 0.9, 16.0 ± 0.9 Ma), Japan National Oil Corporation (1985; K–Ar age; 15.8 ± 1.1, 18.9 ± 0.9 Ma), Kaneko (2001; K–Ar age; 16.3 ± 0.9, 16.5 ± 0.9 Ma), and Itoh and Watanabe (2006; FT age; 17.2 ± 0.9 Ma). Recently, Nakajima et al. (2015) reported the weighted average of ^{238}U–^{206}Pb ages of 17.6 ± 0.3 Ma from zircons in the welded tuff of the Iwaine Formation in the Kubusugawa basin.

4. Iozen Formation

Name Named by Fujita and Nakagawa (1948).

Type locality Mt. Iozen on the boundary between Nanto City, Toyama Prefecture and Kanazawa City, Ishikawa Prefecture (Hayakawa and Takemura, 1987).

Distribution The Iozen Formation is distributed narrowly around Yomedani, the westernmost part of the study area (Fig. 4).

Thickness Less than 50 m in this area.

Stratigraphic relationship The Iozen Formation conformably covers the Iwaine Formation (Fig. 5).

Lithology The Iozen Formation in the study area is composed of rhyolitic pumice tuff and lapilli tuff. The Iozen Formation can be distinguished from the Iwaine Formation by presence of rhyolitic rocks.

Age K–Ar and FT ages have been reported by Shibata (1973; K–Ar age; 14.1 ± 1.2 Ma), Ganzawa (1983; FT age; 15.0 ± 2.1, 16.5 ± 1.4 Ma) and Kaneko (2001; K–Ar age; 14.3 ± 0.3, 14.4 ± 0.3 Ma).

5. Kurosedani Formation

Name Named by Tsuda and Chiji (1950).

Type locality Area between Kakehata and Do, Toyama City, Toyama Prefecture (Hayakawa and Takemura, 1987).

Distribution The Kurosedani Formation is distributed widely between Do and Yomedani, the northern part of the study area (Fig. 4).

Thickness More than 900 m.

Stratigraphic relationship The Kurosedani Formation unconformably covers the Iozen and Iwaine formations (Fig. 5).

Lithology The lower part of the formation consists mainly of irregularly alternating beds of conglomerate, sandstone, and mudstone, whereas the upper part consists mainly of mudstone and alternating beds of sandstone and mudstone. Conglomerate contains rounded to sub-rounded pebbles of andesite. The lithofacies of the Kurosedani Formation changes gradually into the Higashibessho Formation.

Fossil The Kurosedani Formation is a Miocene fossiliferous formation in Japan. Various bivalve and gastropod fossils have been found including *Anadara kakehataensis, Cerithideopsilla* n. sp., *Vicarya yokoyamai*, and *Vicaryella ishiiana* var. (Tsuda, 1953, 1959). Tsuda (1953) also reported fossils of plants, Echinodermata, Crustacea, coral and shark teeth from the formation.

Age K–Ar and FT ages have been reported by Hayakawa (1983; FT age; 16.0 ± 2.4 Ma), Nakajima and Mizushima (1984; FT age; 15.0 ± 1.0 Ma), Hayakawa and Danhara (1986; FT age;16.8 ± 0.9 Ma), Kaneko (2001; K–Ar age;13.8 ± 0.4, 14.0 ± 0.4 Ma) from tuffs of the Kurosedani Formation. Yamada et al. (1998), Kaneko (2001), and Itoh and Watanabe (2006) reported 15.3–12.2 Ma of K–Ar and FT ages from volcanic rocks in the Fukuhira Formation, which is heterotopic with the Kurosedani Formation in the eastern part of Toyama Prefecture.

6. Higashibessho Formation

Name Named by Fujita and Nakagawa (1948).

Type locality Higashibessho, Tonami City, Toyama Prefecture (Hayakawa and Takemura, 1987).

Distribution The Higashibessho Formation is distributed around Kashio, the northern part of the study area (Fig. 4).

Thickness More than 500 m.

Stratigraphic relationship The Higashibessho Formation conformably covers the Kurosedani Formation in the study area (Fig. 5) and is unconformably covered by the Upper Miocene Otogawa Formation, the Tonami Group outside the study area (Hayakawa and Takemura, 1987).

Lithology The Higashibessho Formation is composed mainly of massive mudstone showing dark gray color. Thin conglomerate beds (2–10 cm thick) are intercalated in the formation and often include allochthonous bivalve and gastropod fossils.

Fossil The Higashibessho Formation abundantly yields fossils of mollusk, foraminifer, radiolarian and diatom (Hayakawa and Takemura, 1987).

Lithostratigraphy of the Iwaine Formation

We obtained columnar sections along fifteen routes in the Iwaine Formation (Fig. 6). We classify volcaniclastic rocks after the definition of Fisher (1961, 1966). Following the lithology and stratigraphy, the distribution of lithofacies can be classified into four parts (Fig. 7).

Monomictic variegated autobreccia (Fig. 8a), whose clasts are composed completely of amphibole-bearing andesite (Fig. 8b), without matrix occupies the lowest part of the Iwaine Formation (Fig. 7), and its maximum thickness reaches approximately 250 m. Coherent amphibole-bearing andesite sometimes occurs with the autobreccia.

Matrix supported volcanic breccia (Fig. 8c and d) composed of poorly sorted polymictic andesitic clasts overlie the autobreccia in many routes (Fig. 7). Generally, the volcanic breccia shows massive or reverse-grading structures (Fig. 8d). Its thickness indicates greatly lateral change. Clasts in the volcanic breccia consist of sub-angular to sub-rounded gravels (mainly 30–50 cm; maximum 100 cm in diameter) of various andesites. Conglomerate, sandstone and mudstone whose andesitic clasts derived from the Iwaine Formation overlie thickly the volcanic breccia in Routes 7 and 13 (Fig. 8e).

In some routes, poorly sorted massive pumice tuff (Fig. 8f) overlies the clastic rocks or the polymictic volcanic breccia (Fig. 7). The pumice tuff is composed of lithic clasts of andesites and pumice (approximately 5 cm in diameter), with tuffaceous matrix. The pumice

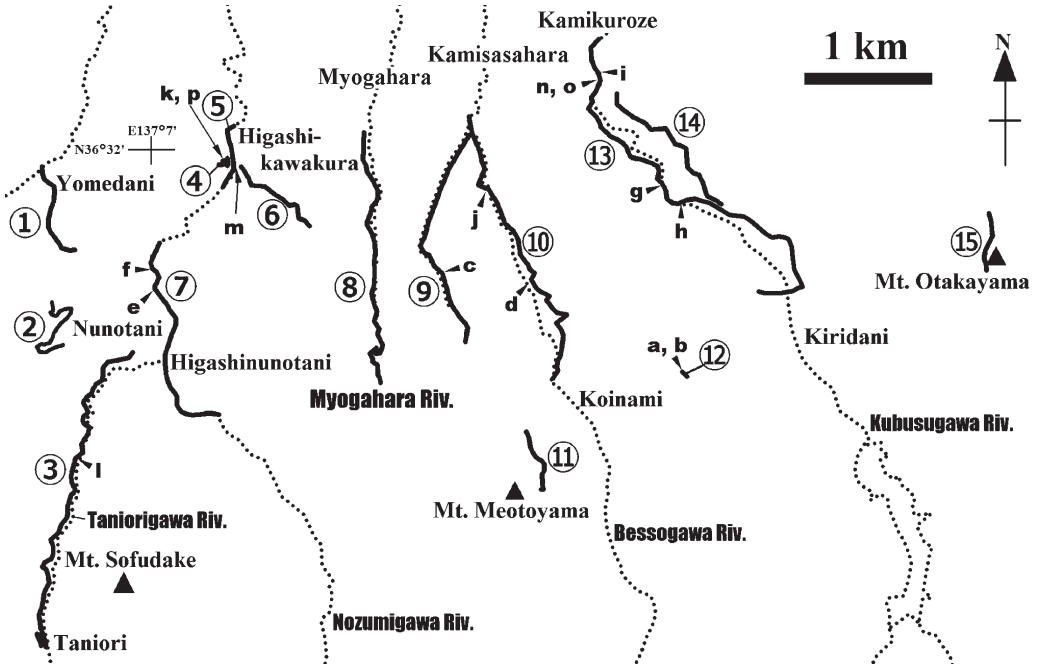


Fig. 6. Map showing place-names and routes along which columnar sections were obtained. Alphabets (a–p) with arrows indicate sampling points and locality of outcrops in Fig. 8. Riv.: River.

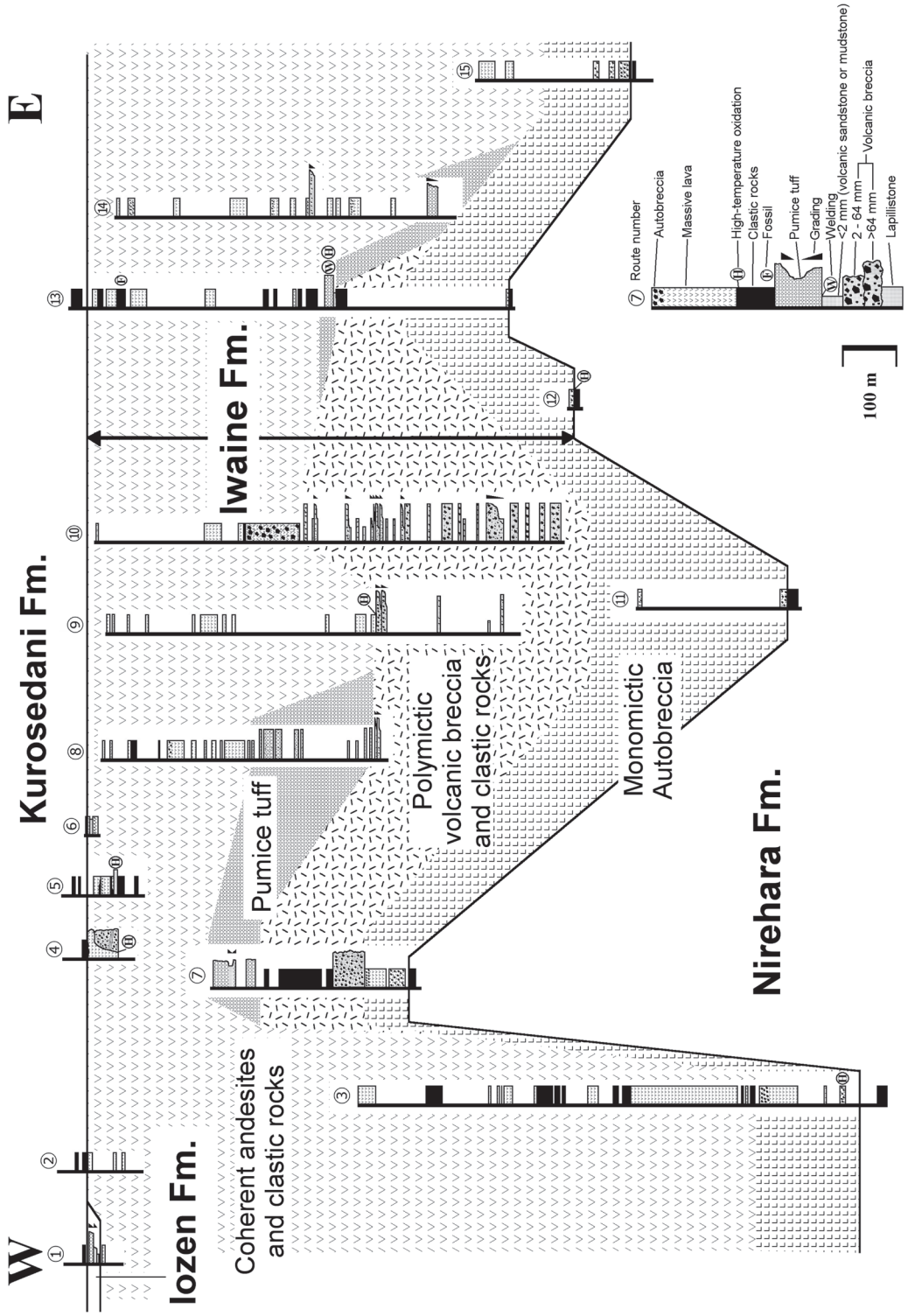


Fig. 7. Correlated columnar sections of the Iwaine Formation, the Yatsuo area and simplified distribution of rock types. Routes are shown in Fig. 6. Fm.: Formation.

tuff is partly welded in Route 13 (Fig. 8g and h). The content of lithic clasts and pumice changes with stratigraphic horizons and routes. In Route 8, the pumice tuff includes a lot of lithic clasts instead of pumice, while the pumice tuff in other routes includes much pumice rather than lithic clasts.

Coherent andesites (Fig. 8i–l) overlie thickly the pumice tuff or breccia (autobreccia and volcanic breccia) of the lower part. Pyroxene phenocrysts (two pyroxene, clinopyroxene or orthopyroxene; Fig. 8j) occur in coherent andesites of the upper part of the Iwaine Formation. Coherent andesites imply often columnar or platy joints (Fig. 8k). Coherent andesites change gradually to homogeneous autobreccia upward, which comprises reddish-brown colored angular blocks or vesicular scoriaceous clasts (Fig. 8l). Clastic rocks and polymictic volcanic breccia showing various lithofacies are intercalated usually between coherent andesites. A bed (10 m in thick) of very well sorted monomictic lapillistone occur in Route 5 (Fig. 8m). A gastropod molluscan shell of *Cerithideopsilla* sp. (Fig. 8n) was found from clastic rocks (Fig. 8o) of the uppermost Iwaine Formation, Route 13 in this study. The locality is probably the same as the locality where Sakamoto and Nozawa (1960) found some fossils including *Cerithidea miofluviatilis*. An outcrop, where a dike intrudes in volcanic breccia and partly shows red color, is exposed in Route 4 (Fig. 8p). The dike changes to effusive coherent andesite in the outcrop. Massive aphyric andesite is distributed successively in the top of the Iwaine Formation.

Implication

The Yatsuo Group is associated with the Japan Sea opening (Hayakawa and Takemura, 1987; Kaneko, 2001). Therefore, many experts have studied stratigraphy especially in the Yatsuo area, the central part of Toyama Prefecture, as already mentioned in the introduction. Following the stratigraphy in the Yatsuo area, some ones have studied in the eastern part (e.g., Nozawa and Sakamoto, 1960; Sumi and Nozawa, 1973; Kaneko, 2001) and the western part (e.g., Inoue et al., 1964; Sudo, 1979; Ganzawa, 1983) of Toyama Prefecture. Unfortunately, some formations which are not observed in the Yatsuo area occur in these areas (e.g., Fukuhira Formation in the eastern part; Tori Conglomerate and Usunaka Moonstone Rhyolite in the western part). In addition, the Neogene strata in some areas have been classified according to the division of the Hokuriku Group (Sakamoto et al., 1959), which had been widely accepted by geologists studying the Neogene in the Hokuriku Region until Hayakawa and Takemura (1987) proposed the division of the Yatsuo Group. As a result, the division and stratigraphy of the Yatsuo Group is waiting to be solved.

Sumi and Nozawa (1973) classified the Iwaine Formation in the Uozu area into three members. Although Kaneko (2001) correlated the Iwaine Formation in the Uozu area to the upper Iozen Formation, it includes both of andesites and rhyolites (Kaneko, 2001). Since the

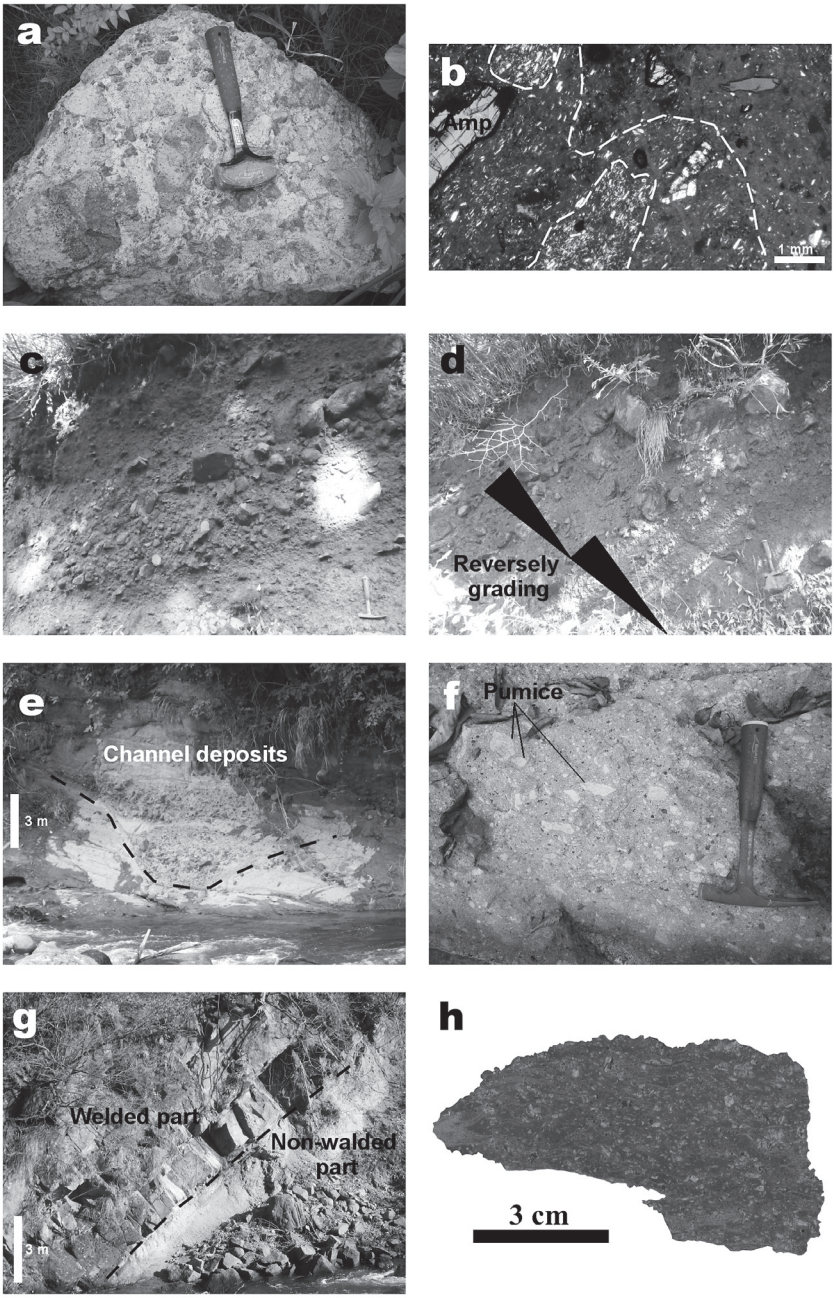
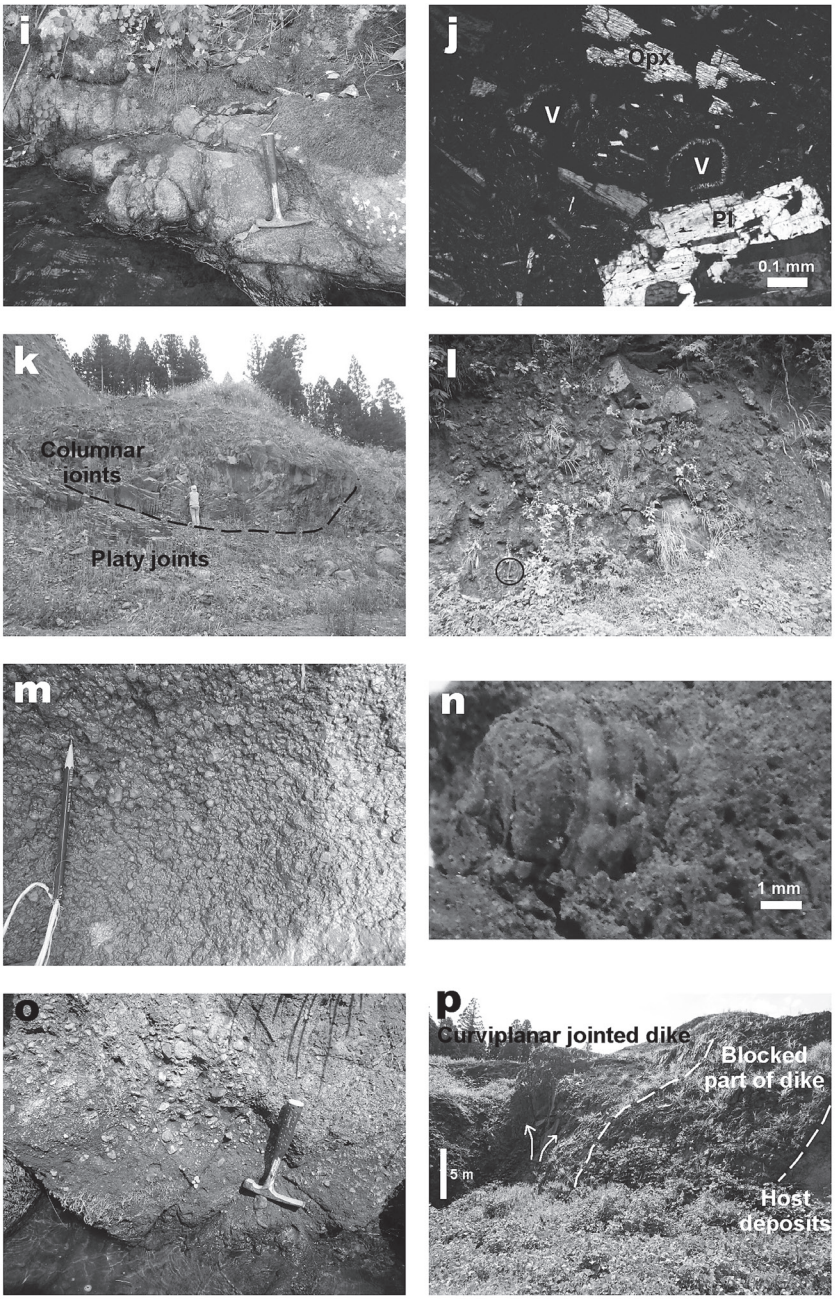


Fig. 8. Photographs of outcrops, a float, a hand specimen and thin sections (Pl: plagioclase, Opx: orthopyroxene, V: vesicle, Amp: amphibole). Localities of outcrops and sampling points are shown in Fig. 6. **a,** a float of monomictic autobreccia. **b,** a thin section of monomictic autobreccia. Broken lines indicate boundaries, which are unclear, of clasts. **c,** a cross section of polymictic volcanic breccia showing massive structure. Hammer for scale. **d,** a cross section of reverse-graded polymictic volcanic breccia. Hammer for scale. **e,** a cross section of clastic rocks whose all clasts are derived from the Iwaine Formation. **f,** a cross section of massive pumice tuff. **g,** a cross section of the contact between welded and non-welded parts of pumice tuff. **h,** a hand specimen of welded tuff. **i,** a cross section of massive coherent andesite. **j,** a thin



section of orthopyroxene-bearing andesite. **k,** a cross section of aphyric andesite showing columnar and platy joints. Parson for scale. **l,** a cross section of polymictic autobreccia consisting of andesitic coherent blocks. It would be clinker (flow breccia). Hammer (circle) for scale. **m,** a cross section of very well-sorted monomictic lapillistone. **n,** a photograph of a gastropod mollusk of *Cerithideopsilla* sp. obtained from clastic rocks (o), the uppermost Iwaine Formation. **o,** a cross section of fossiliferous clastic rocks, where a gastropod mollusk of *Cerithideopsilla* sp. was found (n). **p,** a cross section of a dike intruding host deposits (volcaniclastic rocks). The host deposits adjacent to the dike show red color by high-temperature oxidation.

Iwaine and Iozen formations comprise of andesites and rhyolites (e.g., Hayakawa and Takemura, 1987) respectively, it is difficult to judge which is correct. Nevertheless, Ganzawa (1983) and Takahashi and Shuto (1999) reported that amphibole-bearing andesites occur in the lowest part of the Iwaine Formation and that pyroxene-bearing andesites overlie them. The lithostratigraphy of the Iwaine Formation in the study area is consistent with their reports.

The stratigraphic division of volcanic rocks in the Yatsuo Group is very important to reveal the temporal change of characteristics of volcanism during the Japan Sea opening. Accordingly, lithostratigraphic evidence reported by this study will be significant to solve such issues. What we need to do is establishing formative history of the Iwaine Formation based on facies analysis, which is necessary to propose the stratigraphic division of this formation.

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*The title was translated by the authors.

Report of the 15th meeting of the International Association of Radiolarists (InterRad XV), 20 October – 1 November, 2017, Niigata, Japan

Atsushi MATSUOKA* and organizing committee of the InterRad XV

Abstract

The InterRad XV was organized in Japan from 20 October to 1 November 2017, co-hosted by the International Association of Radiolarists, the Geological Society of Japan, the Palaeontological Society of Japan, the Society of Science on Form, Japan, and the Geological Survey of Japan, AIST. A total of 187 participants from 16 countries attended the meeting. The scientific sessions were held during 23–27 October at Niigata University, which was regarded as an activity of a joint seminar in the bilateral programs between Japan (Japan Society of Promotion of Sciences; JSPS) and China (National Natural Science Foundation of China; NSFC). An Abstract Volume including 128 papers presented in the oral and poster sessions was printed as Volume 40 of "Radiolaria" (ISSN: 0297–5270), the formal newsletter of InterRad. Outreach programs were also included in the InterRad XV. Pre-, mid-, and post-conference excursions were carried out and an excursion guide was published in a volume of Science Reports of Niigata University (Geology) (ISSN: 1349–1237), No. 32 (Supplement), which is available at the Niigata University Academic Repository (Nuar). The proceedings of the InterRad XV will be published as special issues of Island Arc, Paleontological Research, Revue de Micropaléontologie, and Bulletin of the Geological Survey of Japan.

Key words: InterRad, radiolaria, joint seminar, JSPS–NSFC bilateral program, outreach, proceedings.

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Introduction

InterRad is the International Association of Radiolarists. It is a non-profit organization that promotes research on all aspects of radiolarian-related fields including biology, ecology, taxonomy, evolution, biogeography, biostratigraphy and so on. Meetings of InterRad (including former Eurorad) have been held every three years regularly since 1970. The 15th meeting of InterRad (InterRad XV) was organized from 20 October to 1 November 2017 in Japan. The scientific sessions were held during 23–27 October, 2017 at Niigata University. InterRad meeting returned to Japan after 23 years since the 7th meeting was held in October, 1994 in Osaka.

The InterRad XV aimed at having an opportunity to exchange idea for understanding all aspects of radiolarian-related topics beyond the radiolarian society. The organizing committee has strongly encouraged the involvement of non radiolarists including scientists of various research fields, science communicators such as geoparks, artists, and members of the general public who are interested in radiolarians. In order to achieve this goal, the committee organized interdisciplinary symposia in the scientific sessions, set up various outreach programs, and created new products in collaboration with artists for outreach purposes.

This report summarizes the organization of the InterRad XV in Niigata 2017, the scientific sessions, excursions, and outreach activities. Reports on the InterRad XV in Niigata 2017 have already been published in Abstracts of Society of Science on Form, Japan (Matsuoka, 2017) and in "News" of the Geological Society of Japan (Fujii, 2018; Nakagawa et al., 2018). A short summary of the meeting was also reported in Volume 41 of "Radiolaria", the official newsletter of InterRad (Matsuoka, 2018a). Additional reports will be presented in "Fossils" of the Palaeontological Society of Japan (Ichinohe and Yamashita, 2018) and in the Journal of Geography of the Tokyo Geographical Society (Matsuoka, 2018b).

Organization of InterRad XV in Niigata 2017

The InterRad XV in Niigata 2017 was planned and conducted by the following committees and was co-hosted by the International Association of Radiolarists, the Geological Society of Japan, the Palaeontological Society of Japan, the Society of Science on Form, Japan, and the Geological Survey of Japan, AIST.

Organizing Committee of InterRad XV in Niigata 2017:
Honorary Chairperson: Akira YAO (Osaka City University)
Chairperson: Atsushi MATSUOKA (Niigata University)
Main Secretary: Noritoshi SUZUKI (Tohoku University)

Sub Secretary: Takuya ITAKI (Geological Survey of Japan) and Tsuyoshi ITO (Geological Survey of Japan)

Treasurer: Toshiyuki KURIHARA (Niigata University)

Executive Members: Satoshi NAKAE (Geological Survey of Japan), Yukihisa NISHIZONO (West Japan Engineering Consultants Inc.), Yoshihito KAMATA (Tsukuba University), and Takashi YOSHINO (Toyo University)

Webmaster: Takashi YOSHINO

Publication Planners:

Co-chief: Atsushi MATSUOKA, Noritoshi SUZUKI, and Takuya ITAKI

Editorial Members: Katsuo SASHIDA, U. Kagan TEKIN, Keisuke ISHIDA (Island Arc), Atsushi TAKEMURA (Paleontological Research), Satoshi NAKAE (Bulletin of the Geological Survey of Japan), and Taniel DANELIAN (Revue de Micropaléontologie)

Excursion Coordinator: Tsuyoshi ITO

Excursion Leaders:

Pre-meeting Excursions

Excursion A (Boso–Bandai) [cancelled]: Isao MOTOYAMA, Takuya ITAKI, Shin'ichi KAMIKURI, Yojiro TAKETANI, and Makoto OKADA

Excursion B (Inuyama): Tetsuji ONOUE, Rie S. HORI, and Satoru KOJIMA

Mid-day Excursions

Excursion C (Itoigawa): Tsuyoshi ITO, Yousuke IBARAKI, and Atsushi MATSUOKA

Excursion D (Tainai): Isao MOTOYAMA, Toshiyuki KURIHARA, and Takuya ITAKI

Post-meeting Excursion

Excursion E (Okinawa): Atsushi MATSUOKA, Tsuyoshi ITO, Noritoshi SUZUKI, Katsunori KIMOTO, Akihiro TUJI, Xin LI, and Ryo ICHINOHE

Scientific Committee:

Atsushi MATSUOKA, Takuya ITAKI, Yoshiaki AITA, Peter O.BAUMGARTNER, Marco CHIARI, Taniel DANELIAN, Špela GORIČAN, Weihong HE, Rie S. HORI, Richard W. JORDAN, Yoshihito KAMATA, Katsunori KIMOTO, Kiyoko KUWAHARA, Gang LI, Hui LUO, Fabrice NOT, Luis O'DOGHERTY, Yusuke OKAZAKI, John ROGERS, Yuta SHIINO, Satoshi TAKAHASHI, U. Kagan TEKIN, and Yuki TOKUDA

Corporate Backers:

Niigata University; Faculty of Science, Niigata University; Graduate School of Science and Technology, Niigata University; Research Center of Science on Form, Niigata University;

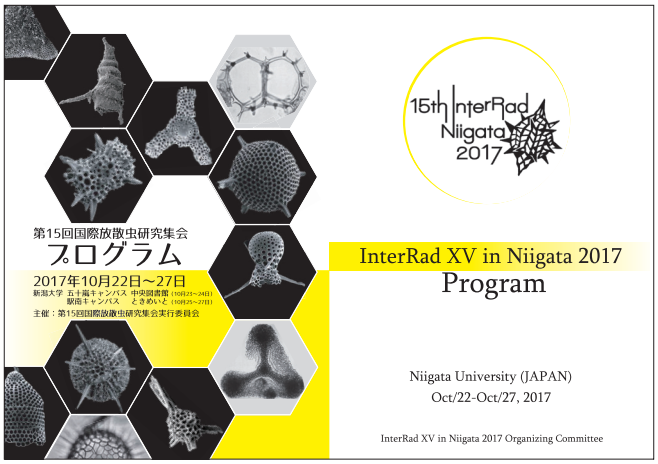

Fig. 1. Program Booklet for InterRad XV in Niigata 2017.

Sesoko Station, the Tropical Biosphere Research Center, the University of the Ryukyus; Japanese Geopark Network; Itoigawa UNESCO Global Geopark; Bandaisan Geopark; RC GEAR; Image Mission Inc.; JUNKUDO Bookstore Niigata; The Niigata Nippo; The Asahi Shimbun Company (朝日新聞新潟総局); The Yomiuri Shimbun (読売新聞新潟支局); The Mainichi Newspapers (毎日新聞新潟支局); NHK (Japan Broadcasting Corporation); Broadcasting System of Niigata Inc.; NST; Television Niigata Network Co. Ltd.; The Niigata Television Network 21, Inc.; FM-NIIGATA Co. Ltd.

Outline of InterRad XV in Niigata 2017

A total of 187 participants, including 46 scientists from abroad, attended the meeting from 16 countries; Australia, China, France, Germany, Indonesia, Italy, Japan, Korea, Mongolia, the Philippines, Russia, Slovenia, Spain, Switzerland, Turkey, and the United States of America. A 14-page Program Booklet (Fig. 1) describes all of the activities held in Niigata. The scientific sessions were held on 23–24 October at the Ikarashi Campus of Niigata University and on 26–27 October at the "Eki-nan" Campus TOKIMATE of Niigata University. The scientific sessions with mid-day excursions were regarded as an activity of a joint seminar in the bilateral programs between Japan (Japan Society of Promotion of Sciences; JSPS) and China (National Natural Science Foundation of China; NSFC). An abstract Volume (Fig. 2A) including 128 papers presented in the oral and poster sessions was printed as Volume 40 of "Radiolaria" (ISSN: 0297–5270) (Ito et al. (eds.), 2017), the formal newsletter of InterRad. Outreach programs were performed on 22 and 25 October. The Icebreaker Party, Welcome Party, and Farewell Party were held in the evenings of 22, 23 and 27 October, respectively.

Two pre-conference excursions were planned; Boso–Bandai (Excursion A, Motoyama et

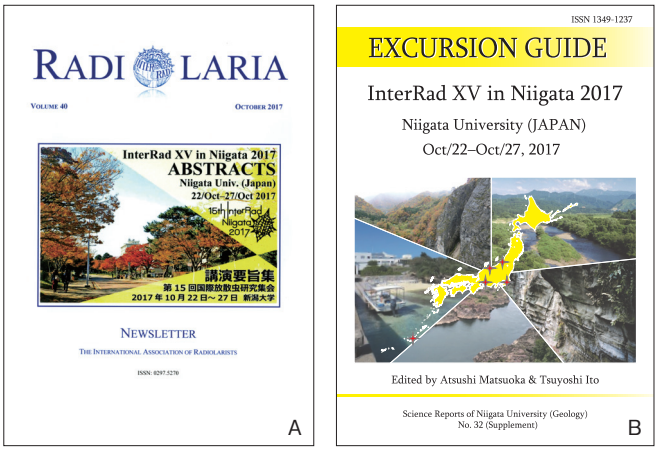

Fig. 2. Cover pages of Abstract Volume (A) and Excursion Guide (B) of InterRad XV in Niigata 2017.

al., 2017a) and Inuyama (Excursion B, Onoue et al., 2017), but only Excursion B was carried out. On 25 October, two mid-day excursions were held: Itoigawa (Excursion C, Ito et al., 2017) and Tainai (Excursion D, Motoyama et al., 2017b). After all activities in Niigata, a post-conference excursion was carried out in Okinawa (Excursion E, Ito and Matsuoka, 2017; Matsuoka et al., 2017). An excursion guide (Fig. 2B) was published in a volume of Science Reports of Niigata University (Geology) (ISSN: 1349–1237), No. 32 (Supplement), which is available at the Niigata University Academic Repository (Nuar).

Scientific sessions

The scientific sessions were held on 23–24 October in the Central Library in the Ikarashi Campus, Niigata University (Fig. 3) and on 26–27 October in the "Eki-nan" Campus TOKIMATE of Niigata University (Fig. 4).

1. Opening Ceremony

The Opening Ceremony was performed in the morning of 23 October at the Library Hall in the Central Library of Niigata University in a windy condition due to an unseasonable typhoon. It started with an opening address by MATSUOKA, A. (Chairperson of InterRad XV) and was followed by two welcome addresses by Sugata TAKAHASHI (President of Niigata University) and YAO, A. (Honorary Chairperson of InterRad XV) who was the chairperson of the InterRad VII in 1994. Group photographs (Fig. 3A) were taken inside of the Library Hall because of stormy weather.

2. Oral and poster presentations

A total number of 128 papers were presented in the oral and poster sessions during the

Fig. 3. Science sessions on 23–24 October in the Central Library of Niigata University (Ikarashi Campus). **A.** Group photograph in the Library Hall, **B.** Oral session in the Library Hall, **C.** Poster presentation in the Library Gallery, **D.** Poster presentation with hands-on exhibit, **E.** Display booth in the Exhibition Space.

Fig. 4. Science sessions on 26–27 October in TOKIMATE of Niigata University "Eki-nan" Campus. **A.** Entrance of TOKIMATE, **B.** Oral session in the Lecture Room, **C.** Poster presentation in the Meeting Room A.

scientific sessions at Niigata University. Abstract Volume of InterRad XV with 324 pages (Fig. 2A) was printed as Volume 40 of "Radiolaria", formal newsletter of InterRad, which is available at the InterRad XV web page as well. A 14-page Program Booklet (Fig. 1) was prepared for all of the activities held in Niigata. Digital data of the printed material are included in a DVD which was delivered to all participants as one of conference material.

The first two days (23–24 Oct.) were devoted to special symposium composed of five oral sessions, namely Paleoceanography of Tethys and Panthalassa (Chairs: TAKAHASHI, S. and BAUMGARTNER, P. O.), Cenozoic Paleoceanography in Marginal Seas (Chairs: ITAKI, T., OKAZAKI, Y., and JORDAN, R. W.), Biology and Paleobiology of Shelled Protista (Chairs: KIMOTO, K. and NOT, F.), An Interface between Function and Evolution (Chairs: TOKUDA, Y. and SHIINO, Y.), and Jurassic–Cretaceous Boundary (Chairs: MATSUOKA, A. and LI, G.). All of these sessions were organized in an interdisciplinary manner. Specialists from a wide range of research fields including micropaleontology, oceanography, tectonics, molecular biology, science on form, etc. attended the sessions. Poster sessions of these topics were also held in the Library Gallery. The Geological Survey of Japan, Itoigawa UNESCO Global Geopark, RC GEAR, and Image Mission Inc. set up a booth and displayed their products or work in the exhibition space next to the Library Hall.

The last two days (26–27 Oct.) were assigned to general symposia consisting of eight oral sessions, namely Insightful Studies for Radiolarians (Chairs: AITA, Y. and ROGERS, J.), Biosiliceous Records (Chairs: ROGERS, J. and AITA, Y.), Modern Oceanography (Chairs: Hori, R. S. and KUWAHARA, K.), Paleobiogeography (Chairs: KUWAHARA, K. and HORI, R. S.), Evolution and Diversity (Chairs: HE, W. H. and CHIARI, M.), Biostratigraphy (Chairs: CHIARI, M. and HE, W. H.), Tibetan Tectonics (Chairs: DANELIAN, T. and LUO, H.), and European Tectonics (Chairs: LUO, H. and DANELIAN, T.). The oral sessions were held in the Lecture Room of TOKIMATE. The poster sessions of these topics were also held in the Multi-purpose Space and Meeting Room A in TOKIMATE. The Geological Survey of Japan and RC GEAR displayed their products in the Multi-purpose Space. The participants enjoyed the exhibition "World of Radiolaria" displayed as an activity of the Niigata University WeeK. Paleozoic, Mesozoic, and Cenozoic–Recent Working Group meetings were also organized in TOKIMATE. At the end of the meeting on 27 October, a business meeting and the Closing Ceremony were performed at TOKIMATE. During the business meeting, it was decided that the 16th InterRad meeting will be held in Ljubljana, Slovenia in September, 2020 and the next InterRad President would be GORIČAN, Š.

Icebreaker Party, Welcome Party and Farewell Party

1. Icebreaker Party

The Icebreaker Party was held at Art Hotel Niigata Station in the evening of 22 October just after the talk show "What's Rad??" performed in Café Space in JUNKDO Bookstore Niigata, basement floor of the same building of Art Hotel Niigata Station. The participants enjoyed a good time at a buffet party.

2. Welcome Party

In the evening of 23 October, the Welcome Party was held at ANA Crown Hotel Niigata (Fig. 5A). The party started with a welcome address by MATSUOKA, A., followed by a "Kagami-Biraki", a "sake" barrel opening ceremony (Fig. 5B) and toast proposed by Yuichiro TANAKA, representative of the Geological Survey of Japan, AIST. Participants enjoyed performance of dance and music by Niigata "Geigi" women (Fig. 5D) and by a Japanese drum team (Fig. 5E). Speeches by representative of the co-host organizations were as follows: Yoshio WATANABE, President of the Geological Society of Japan; Makoto MANABE, President of the Palaeontological Society of Japan; Kiyoshi MIYAMOTO, President of Science on Form, Japan.

3. Farewell Party

The Farewell Party was performed at Art Hotel Niigata Station in the evening of 27

Fig. 5. Welcome Party at ANA Crown Hotel Niigata. **A.** Sit-down dinner in Room Fuyo, **B.** "Kagami-Biraki", "sake" barrel opening ceremony, **C.** "Choco", small cup for "sake" rice wine, with logo of InterRad XV in Niigata 2017, **D.** Dance and music by Niigata "Geigi" women, **E.** Performance by a Japanese drum team.

October. Winners of the Best Oral and Poster Presentation Award for Young Scientists in InterRad XV were introduced and the awarding ceremony was also held during the Farewell Party (Fig. 6). The winners' names in bold and the titles of their presentation are as follows.

Best Oral Presentation Award for Young Scientists:

Miguel M. SANDIN, Loic PILLET, Tristan BIARD, Camille POIRIER, Florence LE GALL, Estelle BIGEARD, Sarah ROMAC, Sebastien COLIN, Charles BACHY, Lucie BITNER, Taniel DANELIAN, Noritoshi SUZUKI, and Fabrice NOT: Time calibrated morpho-molecular classification of Polycystine Nassellaria (Radiolaria)

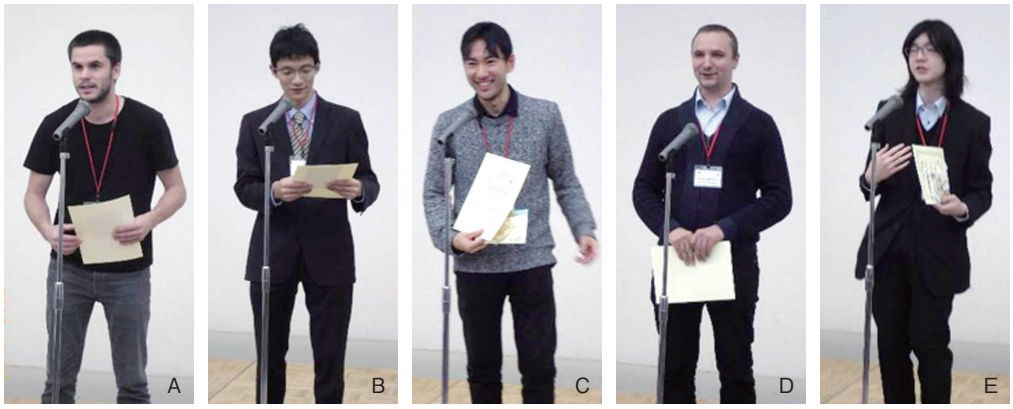

Fig. 6. Winners of Best Oral and Poster Presentation Awards for Young Scientists at Farewell Party. **A.** Miguel M. SANDIN, **B.** Shun MUTO, **C.** Yasuhide NAKAMURA, **D.** Maximilien BOLE, **E.** Kento NIIMURA.

Shun MUTO, Satoshi TAKAHASHI and Satoshi YAMAKITA: Three episodes of black claystone deposition in the pelagic Panthalassa during the Early Triassic

Best Poster Presentation Award for Young Scientists:

Yasuhide NAKAMURA, Rei SOMIYA, Akihiro TUJI, Dhugal J. LINDSAY, Hiroaki OHFUJI, and Rie S. HORI: Cell division of phaeodarians —the first step to clarify the life cycle—

Maximilien BOLE, Peter O. BAUMGARTNER, Rie HORI, and Masayuki IKEDA: Secular variations of oxygen and silicon isotopes in Mesozoic radiolarites from Panthalassa and Tethys —proxies for paleo temperature and paleo productivity

Kento NIIMURA, Yoshiaki AITA, Sakurako SUZUKI, Kako MASHIKO, Yoshino ISHIZAKI, and Naoko KISHIMOTO: Detailed internal structures of Middle Triassic *Glomeropyle galagala*? and unnamed *Glomeropyle* sp. with the use of X-ray micro-CT

Outreach activities

1. Outreach Programs

The InterRad XV in Niigata 2017 started with two outreach programs entitled "Let's make friends with plankton" at TOKIMATE, a satellite (Eki-nan) campus of Niigata University during 14:00–15:00 on 22 October and "What's rad??" at Café Space in JUNKDO Bookstore Niigata during 15:30–17:00 on the same day (Fig. 7).

The former was one of the Niigata University WeeK activities, which included an exhibition called "World of Radiolaria" in the Multi-purpose Space of TOKIMATE from 15 October to 27 October (Fig. 7A). The participants took delight in microscope observations of plankton with living radiolarians obtained from the Japan Sea off Sado Island by a staff in the Sado Marine Station belonging to Faculty of Science, Niigata University.

Fig. 7. Outreach activities during InterRad XV. **A.** Hands-on display "Let's make friends with plankton" and exhibition "World of Radiolaria" in the Multi-purpose Space of TOKIMATE, **B.** Talk show "What's rad??" at Café Space in JUNKDO Bookstore Niigata, **C.** International Communication Program in the Multi-purpose Space of TOKIMATE, **D.** Outreach items displayed in exhibition "World of Radiolaria".

The talk show "What's rad??" was performed by MATSUOKA, A. as a scientist and Hayato YOKOYAMA as an artist (Fig. 7B). This scientist–artist collaboration was assigned to the 101th performance of Science Café Niigata. Some of the participants in the show joined the Icebreaker Party held at Art Hotel Niigata Station and had an opportunity to talk with radiolarian specialists from all over the world.

2. International Communication Program

In the evening of 25 October, an International Communication Program was held in the Multi-purpose Space of TOKIMATE (Fig. 7C). BAUMGARTNER, P. O., Professor of the University of Lausanne in Switzerland, made a one-hour lecture on Mesozoic radiolarians and ocean circulation not only for scientists but also for radiolarian-loving persons with an English–Japanese consecutive interpretation by MATSUOKA, A. As many as 50 people attended the lecture.

3. Outreach items

The logo of the 15th InterRad in Niigata 2017 was a result of collaborative work with an

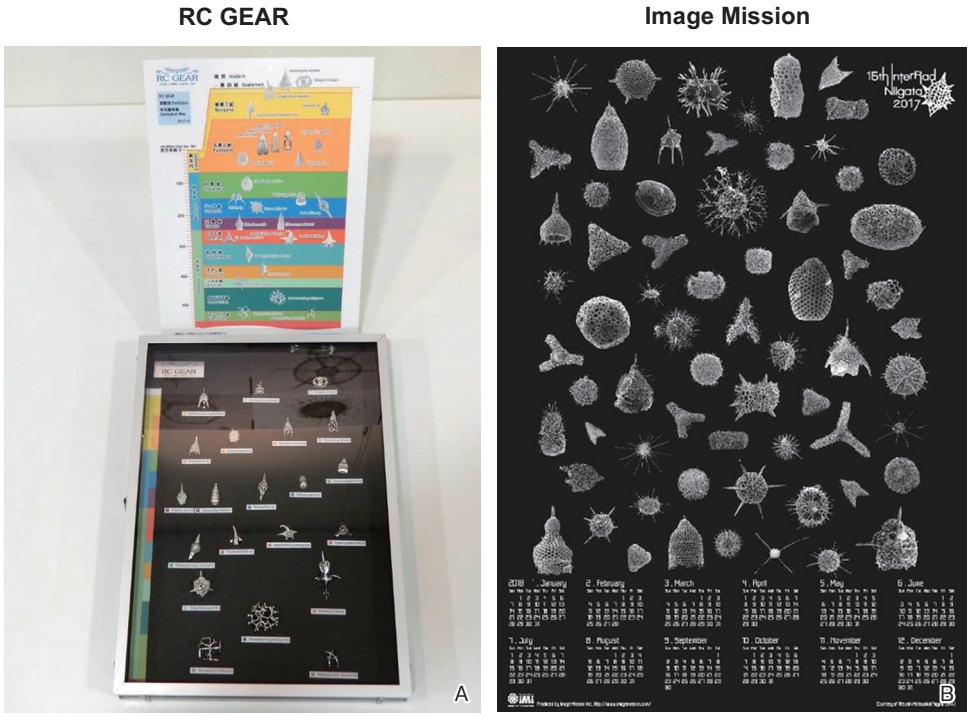

Fig. 8. Silver figures of radiolarians produced by RC GEAR **(A)** and 2018 radiolarian calendar made by Image Mission Inc **(B)**.

artist (Kazuyuki MORIA). The logo was used for publicity activities, official documents, Abstract Volume, Program Booklet, and even for the design of *choko* small cups for sake (Japanese rice wine) (Fig. 5C). Silver figures of radiolarian skeletons ranging in age from the Cambrian to Quaternary (Fig. 8A), which were results of joint work between an artist (YOKOYAMA, H.) and radiolarian specialists, were an official commemorative gift for each participant. On the occasion of the InterRad XV, several outreach items were newly produced. Photomicrographic images or designs of radiolarian skeletons were used for calendars, playing cards, T-shirt prints and so on (Fig. 7D). A radiolarian calendar for the year of 2018 was made by Image Mission Inc. (Fig. 8B) and was sold at JUNKDO Bookstore Niigata, National Science Museum in Tokyo, Osaka Museum of Natural History, and others.

Excursions

A total of five excursions (A to E), two pre-conference, two mid-day, and one post-conference excursions, were planned (Fig. 9). Four of them, except Excursion A (Boso–Bandai), were implemented with some modifications due to weather conditions. An excursion guide (Fig. 2B) was published in a volume of Science Reports of Niigata University

Fig. 9. Excursion locations and group photograph of each excursion. **A.** Location map of Excursions, **B.** Kiso River bank in Excursion B, **C.** Fossa Magna Museum in Excursion C, **D.** Shimizu-en in Excursion D, **E.** Sesoko Marine Station in Excursion E.

(Geology) (ISSN: 1349–1237), No. 32 (Supplement), which is available at the Niigata University Academic Repository (Nuar). Highlights of each excursion were introduced by the editors (Matsuoka and Ito, 2017). The location map in the excursion guide and group photograph of each excursion are shown in Fig. 9.

1. Pre-conference excursion

Pre-conference Excursion B (Inuyama) with 19 participants started from Unuma near Nagoya on 20 October, visited several localities of Triassic–Jurassic chert sequences in the Mino and Hida areas, central Japan (Fig. 9B), and finished at Niigata Station in the afternoon of 22 October. Fujii (2018) and Nakagawa et al. (2018) reported their experience during the excursion. Detailed descriptions of all the stops are given in Onoue et al. (2017).

2. Mid-day excursions

In the mid-day of the meeting on 25 October, two mid-day excursions were carried out in the Itoigawa UNESCO Global Geopark (24 participants) and the Tainai area with a "sake" winery visit in Shibata (20 participants). Details of Excursions C (Itoigawa) and D (Tainai) are described in Ito et al. (2017) and Motoyama et al. (2017b), respectively.

3. Post-meeting excursion

In the morning of 28 October, the participants of the post-conference excursion (Excursion E) headed to Tokyo together with another unseasonable typhoon. After an unplanned overnight in Tokyo, the 22 participants flew to Okinawa, observed living radiolarians and enjoyed the Okinawa Churaumi Aquarium and the Nakijin Castle Ruins — a UNESCO World Heritage site. Detailed descriptions of procedures in living radiolarian research and the excursion sites are given in Matsuoka et al. (2017) and Ito and Matsuoka (2017).

All the activities of the InterRad XV ended successfully at Naha Airport in Okinawa on 1 November.

Proceedings

The proceedings of the InterRad XV will be published as special issues of Island Arc (SASHIDA, K., TEKIN, U. K., and ISHIDA, K.), Paleontological Research (TAKEMURA, A.), Revue de Micropaléontologie (DANELIAN, T.), and Bulletin of the Geological Survey of Japan (NAKAE, S.). Editors of each special issue are indicated in parentheses. MATSUOKA, A., SUZUKI, N., and ITAKI, T. act as publication planners.

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