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Paleogeographical and paleoenvironmental significance of ostracodes from the Pennsylvanian Nagaiwa Formation, northeast Japan

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Abstract.—The Early Pennsylvanian Nagaiwa Formation contains fossils such as corals, fusulinids, and ostracodes, and its age and depositional environments have been determined by fusulinids and sedimentology. In this study, I describe the ostracode assemblages from the Nagaiwa Formation. Moreover, I provide a reconstruction of the paleogeography of northeastern Japan during the Early Pennsylvanian by comparing this ostracode assemblage with assemblages from other regions during the same period. Thirty ostracode species, including 12 genera, have been identified, most of which are endemic species and 10 of which are new: *Jordanites michinokuensis* n. sp., *Thuringobolbina ikeyai* n. sp., *Aechmina iwatensis* n. sp., *Pseudobythocypris asiatica* n. sp., *P. zipangu* n. sp., *P. siveteri* n. sp., *Platyrhomboides tohokuensis* n. sp., *P. japonica* n. sp., *Healdia ofunatensis* n. sp., and *H. rikutyuensis* n. sp. Two of these species are also found in central Japan. The ostracodes from the Nagaiwa Formation are unique when compared with any other similarly aged assemblages.

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Introduction

Several attempts have been made to reconstruct the paleogeographic position of Japan in the Paleozoic. Tazawa (2004) mentioned that Japan originated in a subduction zone of the eastern margin of North China during the Early Ordovician, and the position did not change until the late Permian–Late Jurassic. On the other hand, Ehiro (2001) considered Japan as located near South China from the early Paleozoic to the middle Permian or Mesozoic as a "microcontinent." Isozaki et al. (2010) applied age estimation methods using detrital zircons in Paleozoic sedimentary rocks from Japan, compared various zircon ages from adjacent areas and considered the paleogeographic position of Japan. The typical peaks of zircon ages from the Paleozoic of Japan indicate that it originated as arcs outboard from South China (Isozaki et al., 2011). With further data from zircon ages, Isozaki et al. (2014) proposed "Greater South China," which expands from the South China craton to the South Kitakami belt of Japan, via the East China Sea. He also explained that the similarity of brachiopod assemblages between Japan and Northeast China can be explained by the northward extension of Greater South China where Northeast Japan is located (Isozaki, 2019). Recently, Wakita et al. (2021) collected detrital zircon ages and examined igneous rocks in the West Pacific region. They concluded that Japan initially was situated on the continental margin of Gondwana during the early–middle Paleozoic; then, with the break-up of the Gondwana margin, South China and the Japan arc were separated from Gondwana during the Late Devonian–Carboniferous. Williams et al. (2014) cautioned that consideration of life strategy and facies control should be factored in when drawing biogeographical conclusions from Japanese lower and middle Paleozoic faunas. They noted widely divergent signals from different groups as evidence for this caution.

Ostracodes are small crustaceans (usually <1 mm) that bear a bivalved calcitic shell. Among them, myodocope ostracodes are benthic or planktonic, and podocope ostracodes are benthic or nectobenthic. Here, I examined podocopes because Recent species are demonstrably useful for defining biogeographical regions (Titterton and Whatley, 1988; Tanaka, 2008) and therefore they are important taxa for reconstructing paleogeography (Schallreuter and Siverter, 1985; Williams et al., 2003; Perrier and Siveter, 2014; Tanaka et al., 2019; but see Pour et al., 2011; Mohibullah et al., 2012). In Japan, some Paleozoic ostracodes were described from Southwest Japan (Kuwano, 1987; Tanaka et al., 2012, 2013, 2018, 2019; Stocker et al., 2016; Siveter et al., 2018). However, little is known about Paleozoic ostracodes from Northeast Japan, and all the existing works were written before the 1970s using optical photographs only (Ishizaki, 1963, 1964a, b, 1967, 1968). This study aims to describe the ostracodes from the Pennsylvanian Nagaiwa Formation that previously were studied by Ishizaki (1963, 1964b) and consider the paleogeographic position of Japan during the Pennsylvanian based on the ostracode assemblages.

Geological setting

The geology of Japan is subdivided into Southwest Japan and Northeast Japan by a large structural lineament "Fossa Magna" (Koto, 1888) (Fig. 1.1). In Northeast Japan, the South Kitakami belt is composed of Ordovician ultramafic, igneous,

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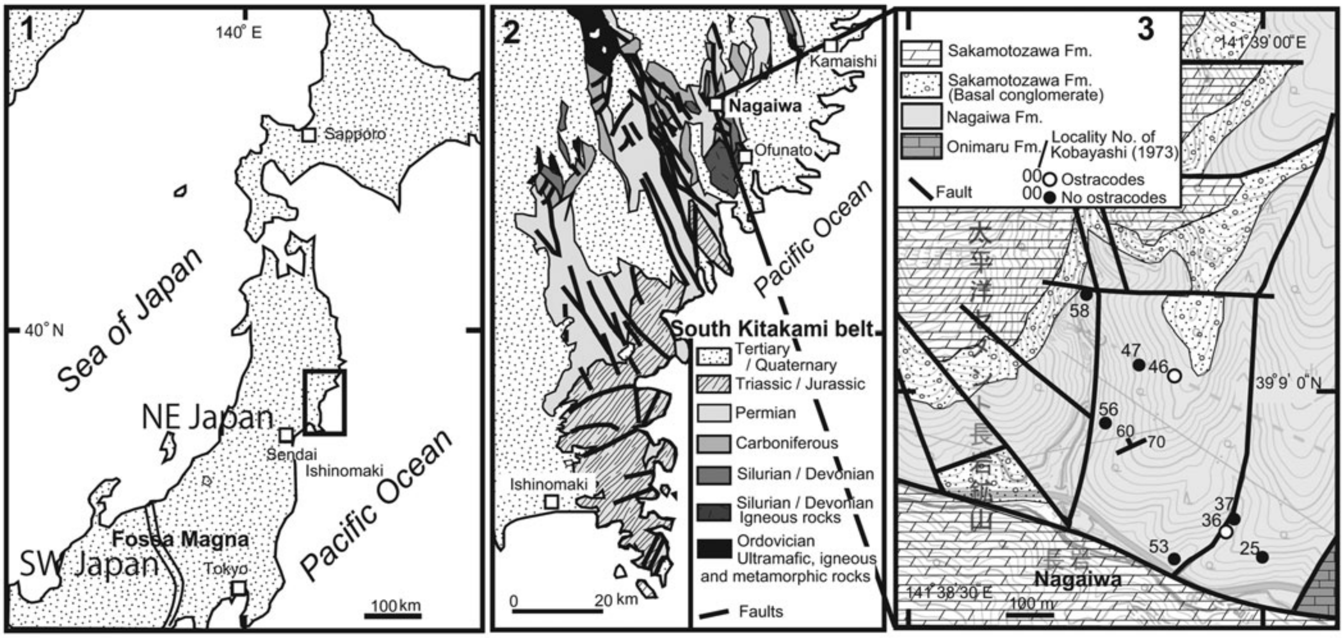

Figure 1. Locality map of the Nagaiwa Formation. (**1**) Northeast Japan (NE Japan) and Southwest Japan (SW Japan) are geologically divided by Fossa Magna. Rectangular box shows area in Figure 1.2. (**2**) Magnified map of South Kitakami belt showing Paleozoic and Mesozoic (Triassic/Jurassic) rocks that are sporadically distributed and deformed by many faults (map based on Isozaki et al., 2010, and Kawamura et al., 2013). (**3**) Detailed geological map of the study area and sample locality. The geological map, sample locality, and each number of sample locality is based on Kobayashi (1973). White circle shows that ostracodes were recovered, shaded circles show that there were no ostracodes. Abbreviation: Fm., Formation; No., Number.

and metamorphic rocks, Silurian/Devonian igneous rocks, and Paleozoic–Mesozoic sedimentary rocks (Isozaki, et al., 2010; Kawamura et al., 2013). Carboniferous strata are sporadically distributed in the northern part of Nagaiwa, ∼15 km NNW of Ofunato City, Iwate Prefecture, Japan (Fig. 1.2).

The Nagaiwa Formation unconformably overlies the Mississippian Onimaru Formation and is unconformably covered by the lower Permian Sakamotozawa Formation (Kobayashi, 1973). According to Kobayashi (1973), the Nagaiwa Formation is subdivided into Lowermost, Lower, Middle, and Upper members. The Lowermost Member consists of sandstone, mudstone, and no fossils. The Lower Member is composed of mudstone and black to gray massive limestone. The mudstone contains a sponge genus, *Chaetetes*, and the limestone contains many fossils such as fusulinids, crinoids, calcareous algae, bryozoans, corals, and small foraminifers. The Upper Member mainly consists of non-fossiliferous limestone, mudstone, and chert (Kobayashi, 1973). The Middle Member, which is formed of dark-gray to gray massive limestone and mudstone, contains many crinoids and fusulinids; sometimes, gastropods and small foraminifers occur in the limestone, which contains siliceous nodules. Based on the fusulinid biostratigraphy, the Lowermost and Lower members are comparable to the *Millerella* Zone, and the Middle and Upper members correspond with the *Profusulinella* Zone, showing that the Nagaiwa Formation was deposited during the early Bashkirian to early Moscovian (Kobayashi, 1973).

Materials and methods

Based on the lithologic character and reports of the fossils collected by Kobayashi (1973), I collected eight fossiliferous localities from the Nagaiwa area, Ofunato City, Iwate Prefecture, Northeast Japan (Figs. 1.3, 2). Approximately 2 kg of limestone rocks were collected from each sample locality. Among them, one sample was from the Lower Member at sample locality No. 25 of Kobayashi (1973), which is dark gray massive limestone; three samples (Loc. 38, 37, 53 of Kobayashi, 1973) were recovered from the Middle Member and consisted of dark gray massive limestone; and four samples (Loc. 46, 47, 56, 58 of Kobayashi, 1973) of light gray dolomitic limestone and some altered mudstones were collected from the Upper Member. The rocks were split into ∼2–4 cm^3, washed with running water, placed on a 16-mesh (1 mm) sieve attached to a 235-mesh (63 μm) sieve, and arranged in a bucket where the upper sieves were filled with 5% acetic acid. After two weeks, the sieves were picked up and rinsed in water inside a large bucket to remove the acid from residue. The residue was collected into a beaker and dried in an oven at 60°C for one day. The ostracode specimens were picked under a binocular microscope (Olympus SZH10) at ×20 magnification and stored in faunal slides.

Repositories and institutional abbreviations.—Ishizaki's type specimens have been deposited in the Institute of Geology and Paleontology, Tohoku University, Sendai, Miyagi, Japan (IGPS-number); Jiang et al.'s (1995) types have been deposited in the Xinjiang Petroleum Administration Bureau (Xj-number). All figured specimens reported here have been preserved in the collection of the Tohoku University Museum (IGPS-number).

Systematic paleontology

The terminology of Paleozoic ostracodes follows Vannier et al., 1989.

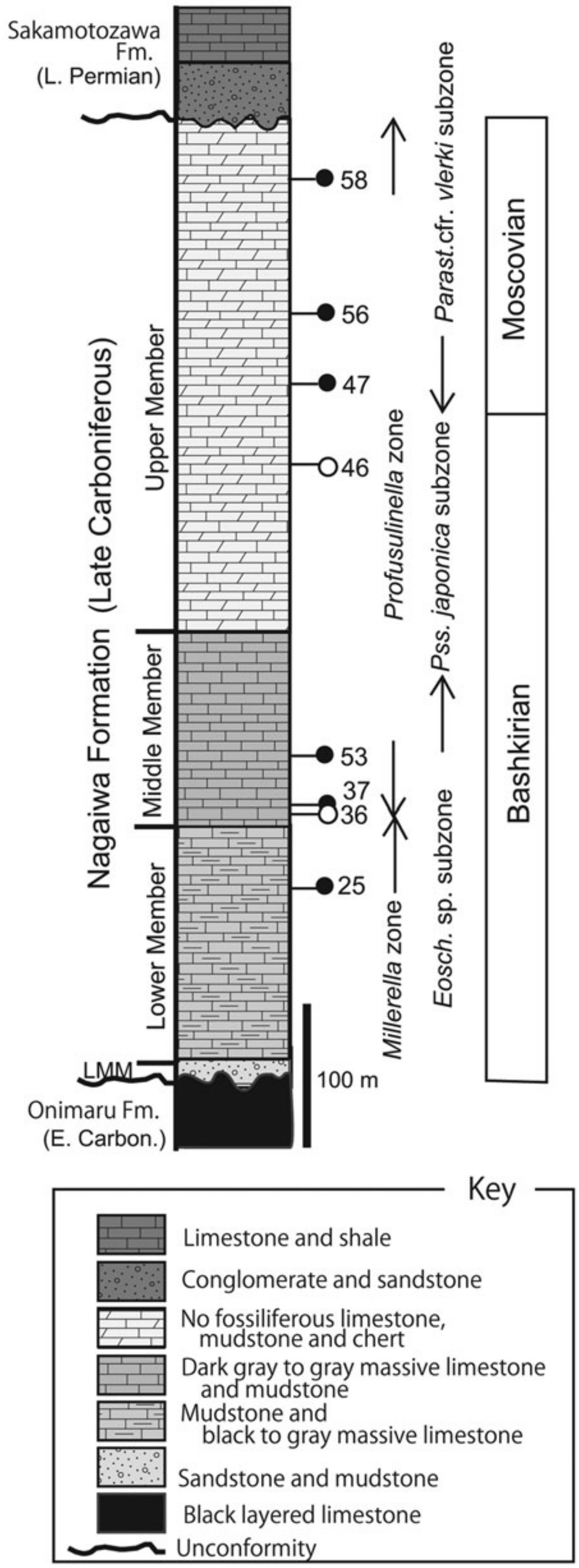

Figure 2. Column of the Nagaiwa Formation, fusulinid biostratigraphy, and each horizon of sample locality and number of sample localities (altered Kobayashi, 1973). Abbreviations: E, Early; *Eosch*., *Eoschubertella*; Fm., Formation; L., Lower; LMM, Lowermost Member; *Parast*., *Parastaffella*; *Pss*., *Pseudostafella*.

Class Ostracoda Latreille, 1802
Subclass Podocopida Sars, 1866
Order Beyrichiocopida Pokorný, 1954
Suborder Beyrichicopina Scott, 1961
Superfamily Paraparchitoidea Scott, 1959
Family Paraparchitidae Scott, 1959
Genus *Samarella* Polenova, 1952

Type species.—*Samarella crassa* Polenova, 1952 (VNIGRI Z5-116), from the upper part of the Givetian Stage of the central Devonian field, Samarkaya Luka (Syzran), Penza region (Yulovo-Ishim), Russia, by original description.

Samarella hataii Ishizaki, 1964
Figure 3.1–3.5

1964b *Samarella hataii*, Ishizaki, p. 37, pl. 1, figs. 10a–c.
1977 *Samarella* ? *hataii*; Hanai et al., p. 15.

Holotype.—Holotype, a carapace IGPS-78405; type locality: Nagaiwa, Ofunato City, Iwate Prefecture, Northeast Japan, Bashkirian to Moscovian.

Occurrence.—Locality 36 of Kobayashi (1973), Middle Member of the Nagaiwa Formation, Nagaiwa, Japan.

Material.—One carapace, length = 640 µm, height = 308 µm, IGPS-112670.

Remarks.—Ishizaki (1964b) placed this species into the genus *Samarella* with some doubt because the adductorial sulcus (S2) is present in the left valve but is missing from the right valve. Hanai et al. (1977) mentioned that the generic identification is questionable. The present study revealed there is no S2 in both valves, showing that Ishizaki's described S2 is the result of compression by fossilization, as he mentioned in the comments on the genus. Furthermore, the right valve overlaps the left valve in the dorsal area, and the left valve overlaps the right valve in the ventral area, which is the definition of the genus *Samarella* (Polenova, 1952). *Samarella hataii* is similar to *Shivaella suppetia* Sohn, 1971, from the Late Mississippian Platy Limestone Member of the Alapah Limestone, Little Chander Lake, Brooks Range, Alaska, USA, in sharing a widely arched umbo with that taxon, but it differs in that it has a widely arched anterior and ventral margins, an acute posterior margin, and no dorsal spine.

Suborder Palaeocopina Henningsmoen, 1953
Superfamily Kirkbyoidea Ulrich and Bassler, 1906
Family Kirkbyidae Ulrich and Bassler, 1906
Genus *Kirkbyella* Coryell and Booth, 1933

Type species.—*Kirkbyella typa* Coryell and Booth, 1933 (Columbia University Paleo. Coll. Cat. No. 27545) from the Pennsylvanian Wayland Shale Member of the Graham Formation, Texas, USA, by original description.

Kirkbyella sp. 1
Figure 3.6–3.10, 3.19, 3.20

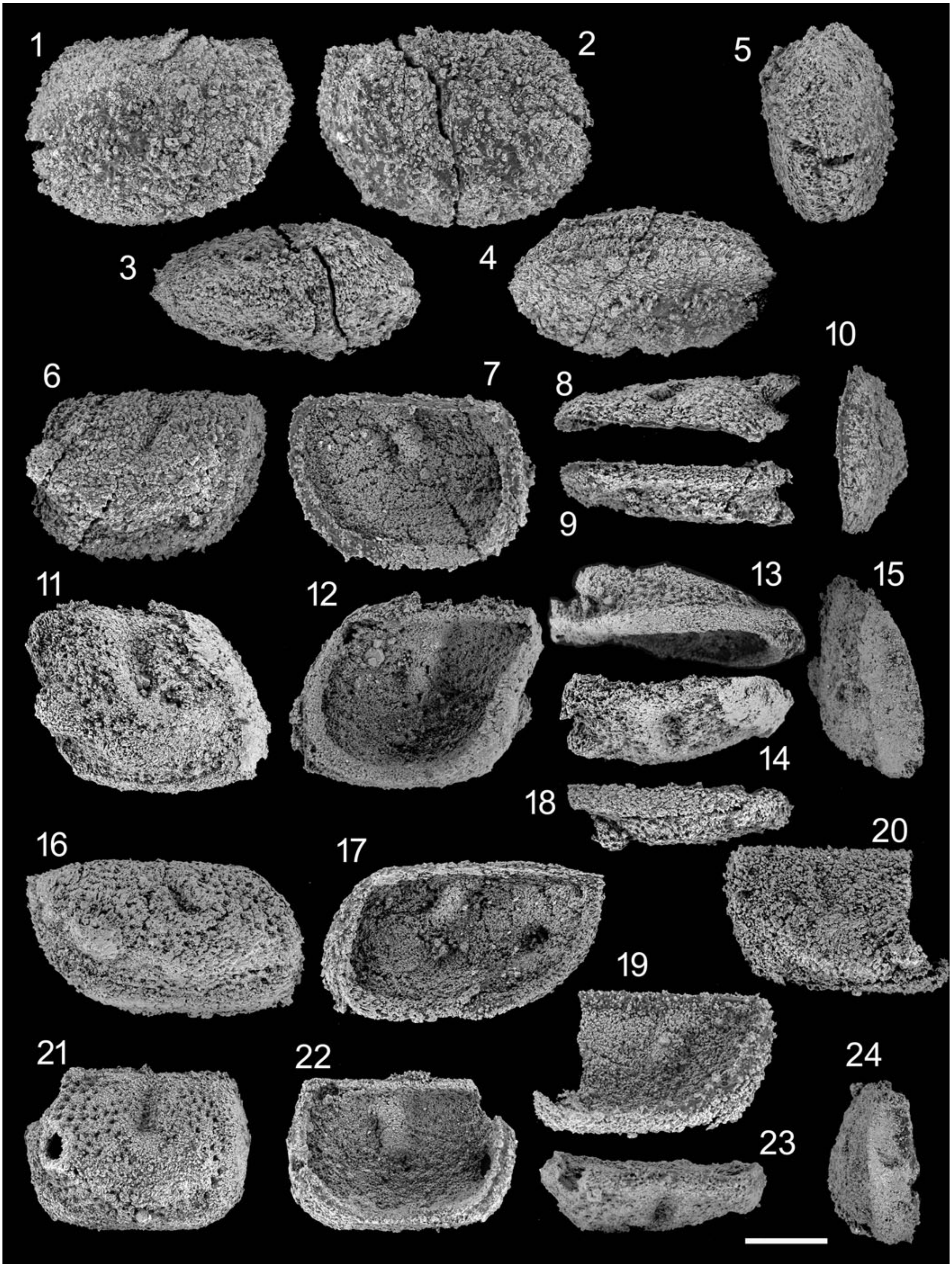

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Figure 3. Scanning electron micrographs of ostracodes from the Pennsylvanian Nagaiwa Formation. (**1–5**) A carapace of *Samarella hataii* Ishizaki, 1964b, IGPS-112670; (**1**) left lateral view, (**2**) right lateral view, (**3**) dorsal view, (**4**) ventral view, (**5**) anterior view. (**6–10**) A right valve of *Kirkbyella* sp. 1, IGPS-112671; (**6**) outer lateral view, (**7**) inner lateral view, (**8**) dorsal view, (**9**) ventral view, (**10**) anterior view. (**11–15**) A right valve of *Kirkbyella* sp. 2, IGPS-112673; (**11**) external view, (**12**) internal view, (**13**) ventral view, (**14**) dorsal view, (**15**) anterior oblique view. (**16–18**) A right valve of *Kirkbyella* sp. 3, IGPS-112674; (**16**) external view, (**17**) internal view, (**18**) dorsal view. (**19, 20**) A left valve of *Kirkbyella* sp. 1, IGPS-112672; (**19**) outer lateral view, (**20**) inner lateral view. (**21–24**) A right valve of *Kirkbyella* sp. 4, IGPS-112675; (**21**) external lateral view, (**22**) internal view, (**23**) dorsal view, (**24**) anterior view. Scale bar = 200 µm.

Occurrence.—Locality 36 of Kobayashi (1973), Middle Member of the Nagaiwa Formation, Nagaiwa, Ofunato City, Iwate Prefecture, Northeast Japan, Bashkirian.

Materials.—A right valve, length = 541 µm, height = 406 µm, IGPS-112671; a left valve, height = 332 µm, IGPS-112672.

Remarks.—*Kirkbyella* sp. 1 is similar to *Kirkbyella typa* Coryell and Booth, 1933, from the Pennsylvanian Wayland Shale Member of the Graham Formation, Texas, USA; it has a broad bend terminating in a knob-like structure, but *K*. sp. 1 differs from *K. typa* in that it has a straight dorsal margin, develops a narrow carina, and has an obliquely extending S2. This species is similar to *Kirkbyella pterygia* Jiang in Jiang et al., 1995, from the Pennsylvanian Shiqiantan Formation, northern slope of Bogduo Mountain, Xinjiang, China, in that it has a broad bend terminating in a knob-like structure, but it differs in that it has a smooth surface, broadly arched ventral margin, and obliquely extending S2. *Kirkbyella* sp. 1 is similar to *K*. sp. of Jiang et al. (1995), discovered from the Pennsylvanian Dongtujinhe Formation in the Boluohuolo Mountain, Wenquan area, Xinjiang, China, in that it has a smooth surface; however, *K*. sp. 1 is distinguished by the presence of an obliquely extending S2, a broadly arched ventral margin, and the broad bend terminating in a knob-like structure.

Kirkbyella sp. 2
Figure 3.11–3.15

Occurrence.—Locality 36 of Kobayashi (1973), Middle Member of the Nagaiwa Formation, Nagaiwa, Ofunato City, Iwate Prefecture, Northeast Japan, Bashkirian.

Materials.—A right valve, length = 541 µm, height = 431 µm, IGPS-112673.

Remarks.—*Kirkbyella* sp. 2 is similar to *Kirkbyella typa* of Coryell and Booth (1933) from the Pennsylvanian Wayland Shale Member of the Graham Formation, Texas, USA, with an undulated dorsal margin, but *K*. sp. 2 differs from *K. typa* in that it has an obliquely extending S2, fine reticulation, and a narrowly convex anterior margin. This species is also similar to *Kirkbyella pterygia* Jiang in Jiang et al., 1995, from the Pennsylvanian Shiqiantan Formation, northern slope of Bogduo Mountain, Xinjiang, China, in that it has a broad bend terminating in a knob-like structure, but it differs in that it has fine reticulation, a sub-parallelogram lateral outline, and an obliquely extending S2. *Kirkbyella* sp. 2 is similar to *K*. sp. of Jiang et al. (1995) discovered in the Pennsylvanian Dongtujinhe Formation in the Boluohuolo Mountain, Wenquan area, Xinjiang, China, in that it has a broad bend terminating in a knob-like structure; however, *K*. sp. 2 is distinguished by the presence of an obliquely extending S2, a sub-parallelogram lateral outline, and a fine reticulated surface.

Kirkbyella sp. 3
Figure 3.16–3.18

Occurrence.—Locality 36 of Kobayashi (1973), Middle Member of the Nagaiwa Formation, Nagaiwa, Ofunato City, Iwate Prefecture, Northeast Japan, Bashkirian.

Materials.—A right valve, length = 652 µm, height = 357 µm, IGPS-112674.

Remarks.—*Kirkbyella* sp. 3 has ornamentation that is similar to *Kirkbyella* sp. 2 from the same locality, but *K*. sp. 3 differs from *K*. sp. 2 in its longer and flatter lateral outline. This species is also similar to *Kirkbyella pterygia* Jiang in Jiang et al., 1995, from the Pennsylvanian Shiqiantan Formation, northern slope of Bogduo Mountain, Xinjiang, China, in that it has a broad bend terminating in a knob-like structure, but it differs in having a fine reticulation, a sub-parallelogram lateral outline, and an obliquely extending S2. *Kirkbyella* sp. 3 is similar to *K*. sp. of Jiang et al. (1995) discovered in the Pennsylvanian Dongtujinhe Formation in the Boluohuolo Mountain, Wenquan area, Xinjiang, China, in having a broad bend terminating in a knob-like structure; however, *K*. sp. 3 is distinguished by the presence of an obliquely extending S2, a sub-parallelogram lateral outline, and a finely reticulated surface.

Kirkbyella sp. 4
Figure 3.21–3.24

Occurrence.—Locality 36 of Kobayashi (1973), Middle Member of the Nagaiwa Formation, Nagaiwa, Ofunato City, Iwate Prefecture, Northeast Japan, Bashkirian.

Material.—One right valve, length = 529 µm, height = 369 µm, IGPS-112675.

Remarks.—*Kirkbyella* sp. 4 resembles *Kirkbyella typa* Coryell and Booth, 1933, from the Pennsylvanian Wayland Shale, Texas, USA, in that it has a straight but slightly posteriorly elongate S2. *Kirkbyella*. sp. 4 differs from *K. typa* in that it has a higher and shorter lateral outline, a straight dorsal margin, and finer ornamentation. *Kirkbyella* sp. 4 is also similar to *Kirkbyella pterygia* Jiang in Jiang et al., 1995, from the Pennsylvanian Dongtujinhe Formation at Boluohuolo Mountain, Wenquan area, Xinjiang, China, in that it has a prominent tubercle at the end of the ventral ridge. *Kirkbyella*

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sp. 4 differs from *K. pterygia* in that it has finer ornamentation, a wider flat area along the anterior margin, and a 4:3 length-height ratio in lateral view.

Genus *Kirkbya* Jones, 1859

Type species.—*Dithyrocaris permiana* Jones, 1850 (type specimen was not designated), from the Permian limestone of Byer's Quarry northeast England, UK, by original description. Topotype specimens (PM OS 7305–7307) have been deposited in The Natural History Museum, London.

Kirkbya nipponica Ishizaki, 1964
Figure 4.1–4.4

1964b *Kirkbya nipponica* Ishizaki, p. 32, pl. 1, figs. 3a, b.
1977 *Kirkbya*? *nipponica*; Hanai et al., p. 9.

Types.—Holotype, one right valve IGPS-78392; paratype, one left valve IGPS-78398; type locality: Nagaiwa, Ofunato City, Iwate Prefecture, Northeast Japan, lower Bashkirian–lower Moscovian.

Occurrence.—Locality 46 of Kobayashi (1973), Upper Member of the Nagaiwa Formation, Nagaiwa, Japan.

Material.—One left valve, length = 1560 µm, height = 920 µm, IGPS-112676; one right valve, length = 1540 µm, height = 840 µm, IGPS-112677.

Remarks.—Ishizaki (1964b) placed this species in the genus *Kirkbya*. Hanai et al. (1977) regarded the generic identification as questionable because of the poor preservation of the type specimen. I extracted this species from Loc. 46 of Kobayashi (1973), but many fossil specimens from this locality were deformed by diagenesis. However, present materials show a posterior shoulder and a more acutely curved posterior cardinal angle than anterior ones, and these characteristics are diagnostic of *Kirkbya*. *Kirkbya nipponica* is similar to *Kirkbya parva* Buschmina, 1975, from the Mississippian of Kamenka Creek, Kolyma, Far East Russia, but *K. nipponica* differs from *K. parva* in that it has an acutely curved posterior cardinal angle, a prominent shoulder, and a more rounded lateral outline. *Kirkbya nipponica* Ishizaki, 1964b, is similar to *Kirkbya* sp. of Ishizaki (1967) from the early Permian Tassobe Formation, South Kitakami Massif, Northeast Japan, by having a straight dorsal margin, but it differs in that it has a prominent anterior shoulder, an acutely curved posterior cardinal angle, and prominent rims.

Kirkbya nagaiwensis Ishizaki, 1964
Figure 4.5

1964b *Kirkbya nagaiwensis* Ishizaki, p. 33, pl. 1, figs. 5a, b.
1977 *Kirkbya nagaiwensis*; Hanai et al., p. 8.

Holotype.—Holotype, one carapace, IGPS-78400; type locality: Nagaiwa, Ofunato City, Iwate Prefecture, Northeast Japan, Bashkirian.

Occurrence.—Locality 46 of Kobayashi (1973), Upper Member of the Nagaiwa Formation, Nagaiwa, Japan.

Material.—One right valve, length = 1580 µm, height = 580 µm, IGPS-112678.

Remarks.—Specimens from this locality were deformed by diagenesis. However, present materials show an elongated lateral outline similar to the type specimen of Ishizaki (1964b). *Kirkbya nagaiwensis* is similar to *Kirkbya punctata* Kellett, 1933, from the Pennsylvanian Stanton Limestone, Kansas, USA, in its elongated lateral outline, but it differs in that it has a prominent rim, a rather flat shoulder, and coarser ventral reticulation. *Kirkbya nagaiwensis* Ishizaki, 1964b, is similar to *Kirkbya inornatum* Roth, 1929, from the Carboniferous Wapanucka Limestone Pontotoc County, Oklahoma, USA, in its slightly sinuate ventral margin, but it differs in its reticulation, an acutely curved posterior cardinal angle, and prominent rims. *Kirkbya nagaiwensis* is also similar to *Kirkbya jolliffana* Bradfield, 1935, from the Carboniferous Dornick Hills Formation, northwest of Berwyn, Oklahoma, USA, in its elongated lateral outline, but it differs in having a prominent inner rim (marginal ridge), coarser reticulation, and no nodes on the dorsal area.

Kirkbya sarusawensis Ishizaki, 1968
Figure 4.8–4.13

1968 *Kirkbya sarusawensis* Ishizaki, p. 13, pl. 1, fig. 7.
1977 *Kirkbya sarusawensis*; Hanai et al., p. 9.
1995 *Kirkbya vivata* Jiang in Jiang et al., p. 106, pl. 97, figs. 16, 17.
2016 *Kirkbya sarusawensis*; Stocker et al., p. 101, fig. 4a, d, g.

Holotype.—Holotype, one right valve IGPS-78410; type locality: west of Nanatsumori and 1 km north of Sarusawa, Daito Town, Iwate Prefecture, Northeast Japan, the Mississippian Takezawa Formation.

Occurrence.—Mississippian Takezawa Formation, Daito Town, Iwate Prefecture, Northeast Japan; Pennsylvanian Azigan Formation, Kunlun Mountain, Xinjiang, China; Pennsylvanian (middle Moscovian) Ichinotani Formation, Mizuboradani Valley, Takayama City, Gifu Prefecture, central Japan; Locality 46 of Kobayashi (1973), Upper Member of the Nagaiwa Formation, Nagaiwa, Japan.

Material.—One deformed left valve, IGPS-112679; one deformed right valve, IGPS-112680; one deformed juvenile valve, IGPS-112681.

Remarks.—Ishizaki (1968) described this species as new based on its slightly dorsally protruded anterior lobe. Specimens from this locality were deformed by diagenesis. However, these specimens show the anterior lobe lower than the posterior lobe, as opposed to the opposite in Ishizaki's (1968) description. *Kirkbya sarusawensis* Ishizaki, 1968, is similar to *Kirkbya knuepferi* Kozur, 1985, from the late Permian Nagyvisnyó Formation, Mihalovits Steinbruch, north

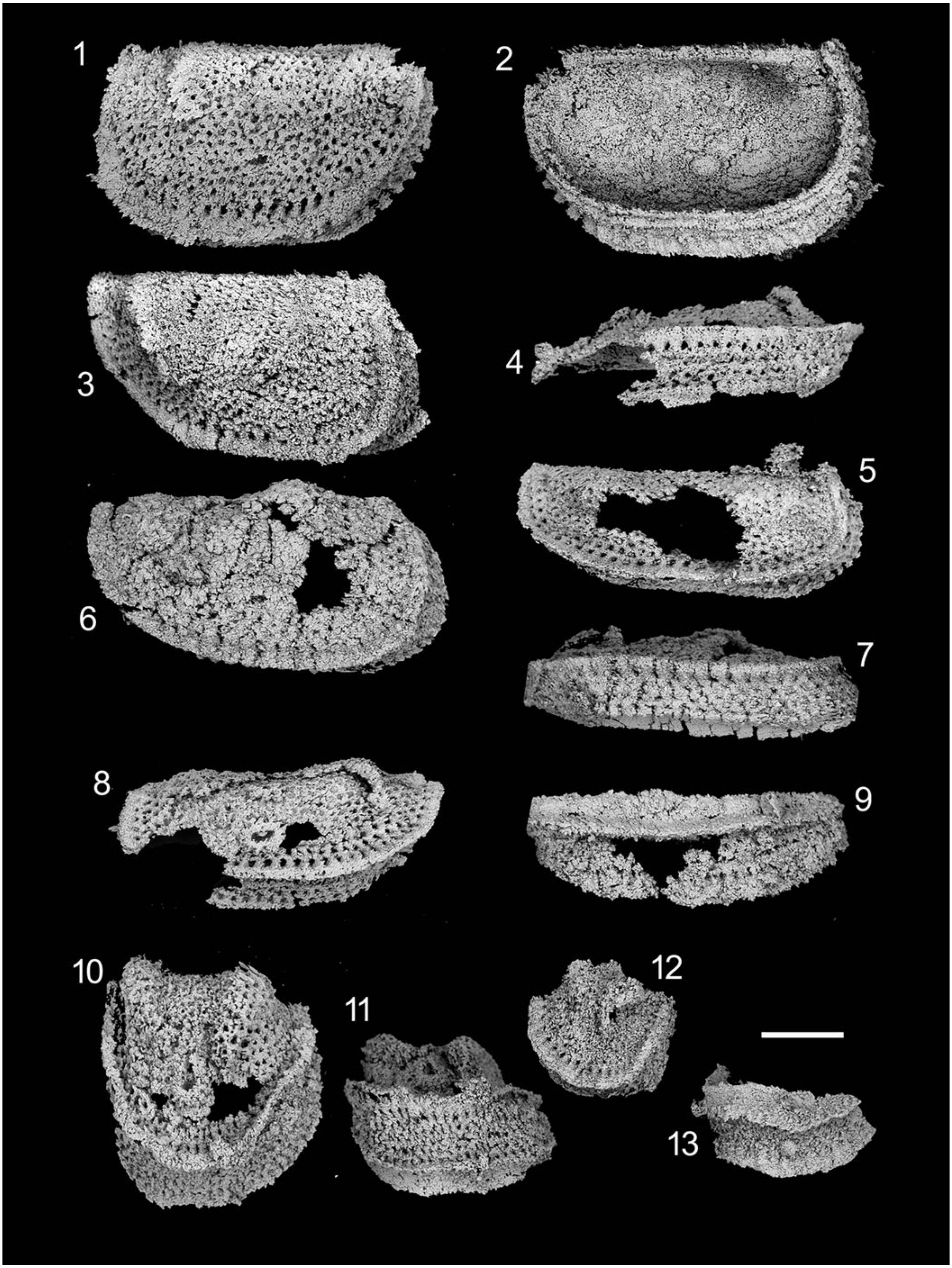

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Figure 4. Scanning electron micrographs of ostracodes from the Pennsylvanian Nagaiwa Formation. (**1, 2**) A left valve of *Kirkbya nipponica* Ishizaki, 1964b, IGPS-112676; (**1**) external view, (**2**) internal view; (**3, 4**) a right valve of *Kirkbya nipponica* Ishizaki, 1964b, IGPS-112677; (**3**) external view, (**4**) ventral view. (**5**) *Kirkbya nagaiwensis* Ishizaki, 1964b, external view of right valve, IGPS-112678. (**6, 7**) A right valve of *Kirkbya* sp., IGPS-112682; (**6**) external view, (**7**) ventral view. (**8–13**) Deformed specimens of *Kirkbya sarusawensis* Ishizaki, 1968; (**8**) lateral view of left valve and (**9**) its ventral view, IGPS-112679; (**10**) lateral view of right valve and (**11**) its ventral view, IGPS-112680, (**12**) lateral view of juvenile specimen and (**13**) its ventral view, IGPS-112681. Scale bar = 400 μm.

Hungary, in its less protruded anterior lobe, but it differs in that it has coarse reticulation, a prominent posterior lobe, and a widely arched velate ridge. *Kirkbya sarusawensis* is also similar to *Kirkbya clarocarinata* (Knight, 1928a) figured by Zhang and Liang (1987) from the Pennsylvanian Taiyuan Formation, Xingyang, Henan, South China, in its less protruded anterior lobe, but it differs in that it has an evenly arched velate ridge, a knob-like posterior lobe, and no smooth antero-dorsal area.

Kirkbya sp.
Figure 4.6, 4.7

Occurrence.—Locality 46 of Kobayashi (1973), Upper Member of the Nagaiwa Formation, Nagaiwa, Japan.

Material.—One right valve, length = 1620 μm, height = 900 μm, IGPS-112682.

Remarks.—*Kirkbya* sp. resembles *Kirkbya nipponica* Ishizaki, 1964b, in its similar lateral outline and prominent rims, but it differs in having a coarser reticulation, a less prominent posterior shoulder, and an anterior lobe.

Order Hollinocopida Henningsmoen, 1965
Suborder Hollinocopina Swartz, 1936
Superfamily Hollinoidea Swartz, 1936
Family Hollinellidae Bless and Jordan, 1971
Genus *Jordanites* Bless, 1967

Type species.—*Jordanites rawihinggili* Bless, 1967 (Geologisch & Mineralogisch Instituut of the Rijksuniversiteit of Leiden, No. Fe361-1) from the Westphalian D (Pennsylvanian) of the Coal-mine, Mosquitera, Asturias, Spain, by original description.

Jordanites modica (Jiang in Jiang et al., 1995)
Figures 5, 6

1964b *Hollinella tingi*; Ishizaki, p. 30, pl. 1, fig. 1.
1977 *Hollinella* (*Hollinella*) *tingi*; Hanai et al., p. 7.
1995 *Hollinella modica* Jiang in Jiang et al., p. 96, pl. 96, figs. 12–17.

Types.—Holotype, a complete carapace Xj-1817; paratypes, three carapaces Xj-1819, Xj-1820a, 1820b; type locality: Pennsylvanian Kalawuyi Formation, Tarim Basin, Xinjiang, China.

Occurrence.—Pennsylvanian Kalawuyi Formation, Tarim Basin, Xinjiang, China; Locality 36 of Kobayashi (1973), Upper Member of the Nagaiwa Formation, Nagaiwa, Japan.

Material.—One female carapace, length = 689 μm, height = 455 μm, IGPS-112683; one female left valve, length = 639 μm, height = 480 μm, IGPS-112684; one male carapace, length = 589 μm, height = 455 μm, IGPS-112685; two juvenile carapaces, length = 529 μm, height = 394 μm, IGPS-112686, length = 517 μm, height = 369 μm, IGPS-112687.

Remarks.—The figured specimens in this study have a fused lobe 1 (L1) and lobe 2 (L2), large lobe 3 (L3), and inconspicuous lobe 4 (L4), which is consistent with the generic character of *Jordanites* designated by Bless (1967). Ishizaki (1964b) identified the specimens from the Nagaiwa Formation as *Hollinella tingi* Patte, 1935, from the Permian of southeastern China, as a result of its outline and ornamentation, but it differs in that it has a straight dorsal margin, rounded lateral outline, fused L1 and L2, and a widely arched anterior margin. *Jordanites modica* (Jiang in Jiang et al., 1995) is similar to *Jordanites rawihinggili* Bless, 1967, from the Pennsylvanian of Asturias, northwestern Spain, in its sub-quadrate lateral outline, but it differs in that it has ornamentation, a prominent L3, and an acutely arched posterior margin. *Jordanites modica* is also similar to *Jordanites cristinae* (Bless, 1967) of Asturias, northwestern Spain, in its acutely arched posterior margin, but it differs in that it has a dorsally protruded L3, a dorsally inflated L1, and a more inflated carapace. *Jordanites modica* (Jiang, 1995) is somewhat similar to *Jordanites henanensis* Zhang in Zhang and Liang, 1991, from the Pennsylvanian Taiyuan Formation, Xingyang, Henan, South China, in its prominent L3, but it differs in that it has a subquadrate lateral outline, surface ornamentation, and a prominent L1. *Jordanites modica* (Jiang in Jiang et al., 1995) is similar to *Jordanites reticularis* Błaszyk and Natusiewicz, 1973, from Mississippian samples from a borehole, northwestern Poland, in its sub-quadrate lateral outline, but it differs in that it has a prominent L3, no reticulation, and an acutely arched posterior margin.

Jordanites michinokuensis new species
Figures 7.16–7.23, 8, 9.1–9.4

Types.—Holotype, a female left valve IGPS-112688; paratype, a male left valve IGPS-112691; type locality: Locality 36 of Kobayashi (1973), Middle Member of the Nagaiwa Formation, Nagaiwa, Ofunato City, Iwate Prefecture, Northeast Japan, Bashkirian.

Diagnosis.—Valve sub-quadrate; dorsal margin slightly concave, anterior margin narrowly arched, posterior margin broadly arched in female, narrowly arched in male; smooth surface with straight adductorial sulcus (S2) extending obliquely from one third border of dorsal margin to median area; a broad bend running from mid-anterior area to mid-ventral area.

Occurrence.—Only known from the type locality.

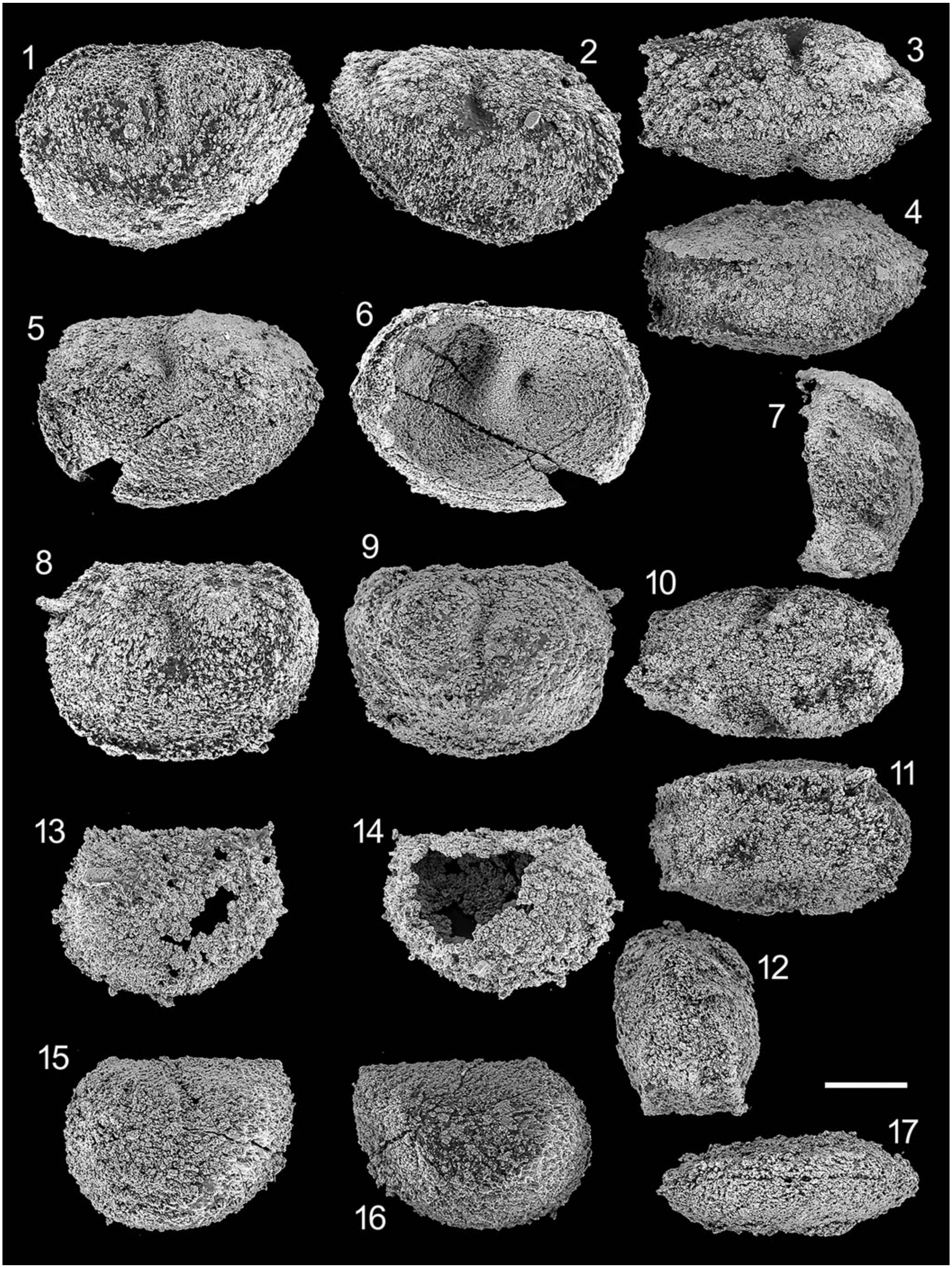

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Figure 5. Scanning electron micrographs of ostracodes from the Pennsylvanian Nagaiwa Formation. (**1–4**) A female carapace of *Jordanites modica* (Jiang in Jiang et al., 1995), IGPS-112683; (**1**) left lateral view, (**2**) right lateral view, (**3**) dorsal view, (**4**) ventral view; (**5–7**) a female left valve of *Jordanites modica* (Jiang in Jiang et al., 1995), IGPS-112684; (**5**) external view, (**6**) internal view, (**7**) anterior view; (**8–12**) a male carapace of *Jordanites modica* (Jiang in Jiang et al., 1995), IGPS-112685; (**8**) left lateral view, (**9**) right lateral view, (**10**) dorsal view, (**11**) ventral view, (**12**) anterior view; (**13, 14**) a juvenile carapace of *Jordanites modica* (Jiang in Jiang et al., 1995), IGPS-112686; (**13**) left lateral view, (**14**) right lateral view; (**15–17**) a juvenile carapace of *Jordanites modica* (Jiang in Jiang et al., 1995), IGPS-112687; (**15**) left lateral view, (**16**) right lateral view, (**17**) ventral view. Scale bar = 200 μm.

Description.—Prominent dimorphism. In external lateral view, valve sub-quadrate; dorsal margin slightly concave, anterior margin narrowly arched, ventral margin broadly convex, posterior margin broadly arched in female, narrowly arched in male; smooth surface with straight adductorial sulcus (S2) extending obliquely from one third border of dorsal margin to median area; fused lobe 1 (L1) and lobe 2 (L2), indistinct lobe 3 (L3) and lobe 4 (L4); in female, a broad bend running from mid-anterior area to middle mid-ventral area. In internal lateral view, narrow contact margin, two prominent depressions corresponding to L1 and L3. In dorsal and ventral views, valve half-moon outline, deep S2 in dorsal view, prominent bend parallel to ventral margin.

Etymology.—“Michinoku” is an ancient word for northeastern Japan.

Materials.—A female left valve, length = 788 μm, height = 431 μm, IGPS-112688 (holotype); a male left valve, length = 689 μm, height = 369 μm, IGPS-112691 (paratype).

Remarks.—The genus *Jordanites* is quite similar to the *Hollinella* (Bless, 1968), but the two genera are distinguished, respectively, by L1 and L2 being fused or not (Bless, 1968; Crasquin et al., 2018). *Hollinella samarensis* Polenova, 1952, from the late Givetian, Russian Platform, has fused L1 and L2, and therefore this species is re-designated as *Jordanites samarensis* (Polenova, 1952) n. comb. in this study. *Jordanites michinokuensis* n. sp. is similar to *J. samarensis* (Polenova, 1952) n. comb. from the Russian Platform in its widely convex ventral margin, but it differs in having a slightly concaved dorsal margin, narrowly arched posterior margin, and indistinct L3. This species is also similar to *Jordanites krasnodonensis* Fohrer in Fohrer et al., 2007, from the middle Moscovian (Pennsylvanian) of the Donets Basin, Ukraine, in its indistinct L1, but it differs in that it has an elongate lateral outline, obliquely extending S2, and no postero-ventral spine.

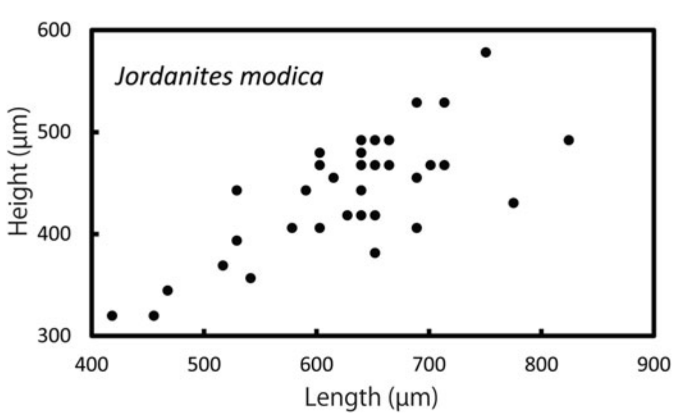

Figure 6. Ontogenetic change of length/height of *Jordanites modica* (Jiang in Jiang et al., 1995).

Jordanites sp.
Figure 7.24, 7.25

Occurrence.—Locality 36 of Kobayashi (1973), Middle Member of the Nagaiwa Formation, Nagaiwa, Ofunato City, Iwate Prefecture, Northeast Japan, Bashkirian.

Material.—One carapace, length = 874 μm, height = 505 μm, IGPS-112692.

Remarks.—*Jordanites* sp. is similar to *J. samarensis* (Polenova, 1952) n. comb. from the Russian Platform in its widely arched posterior margin, but it differs in that it has an antero-ventrally protruded anterior margin, less prominent L3, and indistinct L1.

Family Hollinidae Swartz, 1936
Genus *Thuringobolbina* Zagora, 1967

Type species.—*Thuringobolbina thuringica* Zagora, 1967 (?Geological Institute of the University of Jena, Org.-Nr.: P1028, however, the specimen has not been discovered in the collections yet, as noted by Groos-Uffenorde et al., 2022) from the Borehole Beulwitz 12, depth 137–139 m, middle part of the tentaculate nodular limestone (Early Devonian), Thuringia, Germany, by original description.

Thuringobolbina ikeyai new species
Figure 7.6–7.8

Types.—Holotype, a female left valve, length = 1046 μm, height = 603 μm, IGPS-112693; paratype, a male left valve, length = 984 μm, height = 468 μm, IGPS-112694; type locality: Locality 36 of Kobayashi (1973), Middle Member of the Nagaiwa Formation, Nagaiwa, Ofunato City, Iwate Prefecture, Northeast Japan, Bashkirian.

Diagnosis.—Valve oblate pentagonal outline; dorsal margin slightly sinuate, anterior margin widely arched; long spatula-shaped antero-ventral structure, short fin-shaped postero-ventral projection; surface ornamented by short spines, indistinct adductorial sulcus (S2) with small pit at central area.

Occurrence.—Only the type locality.

Description.—Prominent dimorphism, female more inflated than male. In external lateral view, valve oblate pentagonal outline; dorsal margin slightly sinuate, anterior margin widely arched, ventral margin broadly convex, postero-ventral straight,

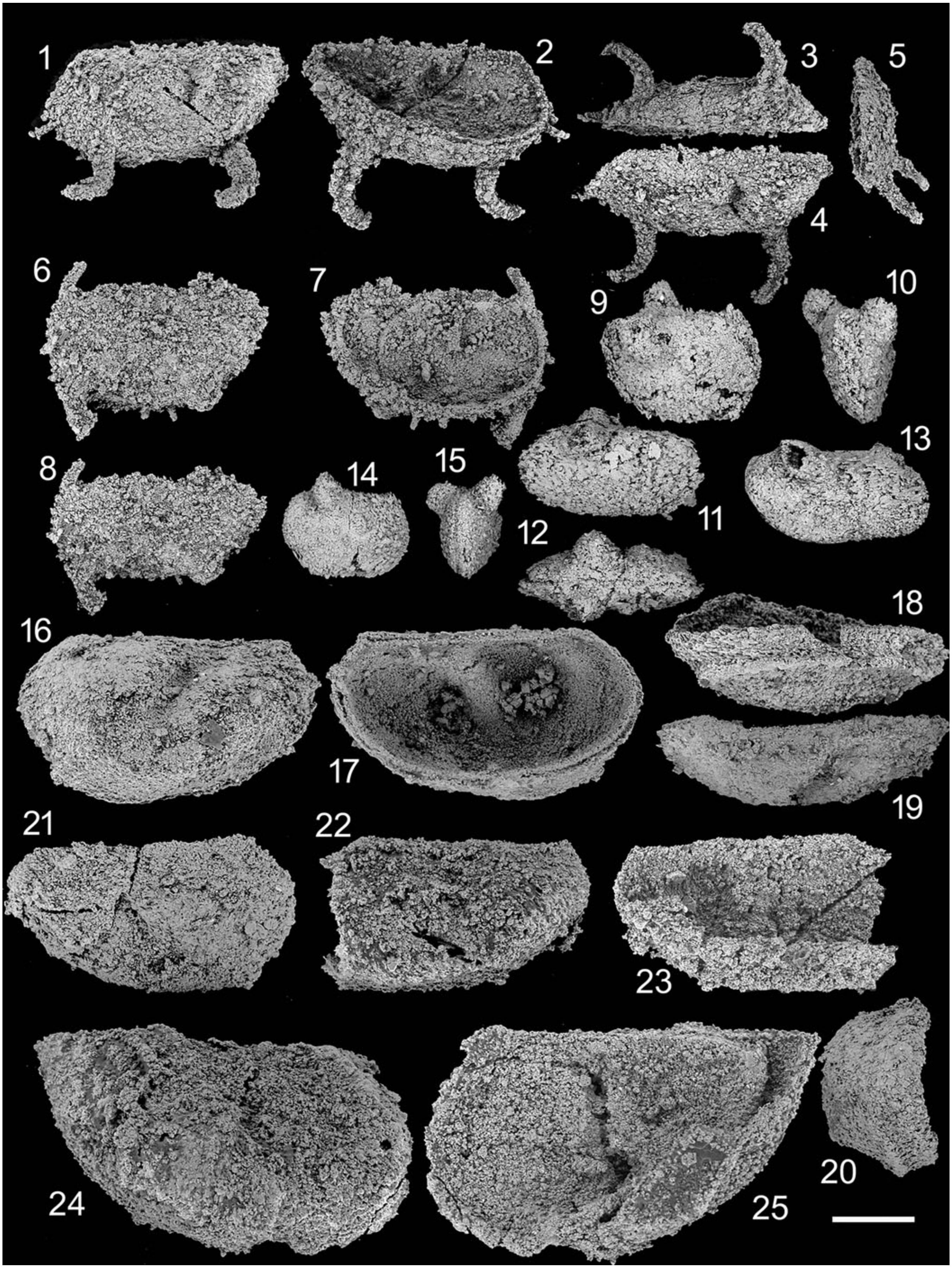

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Figure 7. Scanning electron micrographs of ostracodes from the Pennsylvanian Nagaiwa Formation. (**1–5**) A right valve of *Thuringobolbina* sp., IGPS-112695; (**1**) right external view, (**2**) internal view, (**3**) ventral view, (**4**) dorsal view, (**5**) posterior view. (**6, 7**) A female left valve of *Thuringobolbina ikeyai* n. sp., IGPS-112693 (holotype); (**6**) external lateral view, (**7**) internal view; (**8**) an external view of left valve of male *Thuringobolbina ikeyai* n. sp., IGPS-112694 (paratype). (**9, 10**) A female carapace of *Aechmina iwatensis* n. sp., IGPS-112696 (holotype); (**9**) right side view, (**10**) posterior view; (**11, 12**) a male carapace of *Aechmina iwatensis* n. sp., IGPS-112697 (paratype); (**11**) right lateral view, (**12**) dorsal view; (**13**) a male right valve of *Aechmina iwatensis* n. sp., IGPS-112698 (paratype); (**14, 15**) a juvenile carapace of *Aechmina iwatensis* n. sp., IGPS-112699 (paratype); (**14**) right lateral view, (**15**) anterior view. (**16–20**) A female left valve of *Jordanites michinokuensis* n. sp., IGPS-112688 (holotype); (**16**) external lateral view, (**17**) internal view, (**18**) ventral view, (**19**) dorsal view, (**20**) posterior view; (**21**) a male right valve of *Jordanites michinokuensis* n. sp., IGPS-112689 (paratype); (**22, 23**) a male left valve of *Jordanites michinokuensis* n. sp., IGPS-112690 (paratype); (**22**) external lateral view, (**23**) internal view. (**24, 25**) A carapace of *Jordanites* sp., IGPS-112692; (**24**) left lateral view, (**25**) right lateral view. Scale bar = 400 μm for (**1–15**) and 200 μm for (**16–25**).

postero-dorsal margin convex; anterior and posterior cardinal angle equal; horn-like antero-cardinal spine, long spatula-shaped antero-ventral structure curved postero-ventrally, short fin-shaped postero-ventral projection extending postero-ventrally, triangular protrusion on postero-dorsal margin, several spines developed from mid-anterior margin to posterior margin; surface ornamented by short spines, indistinct adductorial sulcus (S2) with small pit in central area. In internal lateral view, narrow contact margin.

Etymology.—In honor of Emeritus Professor Noriyuki Ikeya (Shizuoka University) who was the author's supervisor.

Materials.—A female left valve IGPS-112693 (holotype), a male left valve IGPS-112694 (paratype).

Remarks.—*Thuringobolbina ikeyai* n. sp. is similar to *Thuringobolbina sibirica* Melnikova, 2000, from the Middle Ordovician sediments from the Nizhnyaya Taimyra River, northern Taimyr Peninsula, Russia, in its anterior cardinal spine and antero-ventral projection, but it differs in that it has a spine, widely arched anterior margin, and sinuate dorsal margin. This species is also similar to *Thuringobolbina*? *blessi* Becker and Sánchez de Posada, 1977, from the Early Devonian Moniello Formation, Asturias, northern Spain, in its antero-ventral projection, but it differs in that it has a short postero-ventral projection, postero-dorsal triangle projection, and indistinct S2. *Thuringobolbina ikeyai* n. sp. is similar to *Thuringobolbina*? *australis* Shallreuter, 1988, from the Devonian of New South Wales, Australia, in its anterior cardinal spine and antero-ventral projection, but it differs in that it is ornamented by spines, possesses no ventral spine, and has a sinuate dorsal margin.

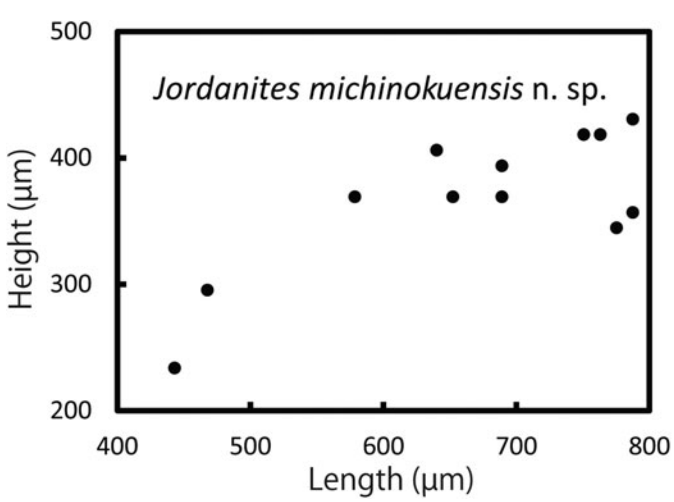

Figure 8. Ontogenetic change of length/height of *Jordanites michinokuensis* n. sp.

Thuringobolbina sp.
Figure 7.1–7.5

Occurrence.—Locality 36 of Kobayashi (1973), Middle Member of the Nagaiwa Formation, Nagaiwa, Ofunato City, Iwate Prefecture, Northeast Japan, Bashkirian.

Material.—One right valve, length =1157 μm, height = 578 μm, IGPS-112695.

Remarks.—*Thuringobolbina* sp. resembles *Thuringobolbina*? *blessi* Becker and Sánchez de Posada, 1977, from the Early Devonian Moniello Formation, Asturias, northern Spain, in its oblate pentagonal lateral outline, but it differs in that it has a hook-like projection at the antero-ventral and postero-ventral areas, an obtuse posterior cardinal angle, and a long spine at the postero-ventral end. *Thuringobolbina* sp. is also similar to *Thuringobolbina*? *australis* Shallreuter, 1988, from the Devonian of New South Wales, Australia, in its widely arched ventral margin, but it differs in that it has surface ornamentation, no ventral spine, and a sinuate dorsal margin.

Suborder Binodicopina Schallreuter, 1972
Family Aechminidae Bouček, 1936
Genus *Aechmina* Jones and Holl, 1869

Type species.—*Aechmina cuspidata* Jones and Holl, 1869 (a type specimen was not designated and subsequently was assigned by Kempf, 1986) from the Wenlock limestone of Croft's Quarry near West Malvern, England, UK, by original description. After that, *A. cuspidata* from the Lower Elton Formation, Gorstian Stage from Wenlock Edge, Shropshire, England, was deposited in The Natural History Museum, London (specimen No. PM OS 6640) by Professor David Siveter (University of Leicester) in 1984; this specimen in considered to be the primary reference specimen.

Aechmina iwatensis new species
Figure 7.9–7.15

?1987 *Aechmina* sp. C Adachi, p. 4, fig. 2.

Types.—Holotype, a female carapace IGPS-112696; paratypes, a male carapace IGPS-112697, a male right valve IGPS-112698,

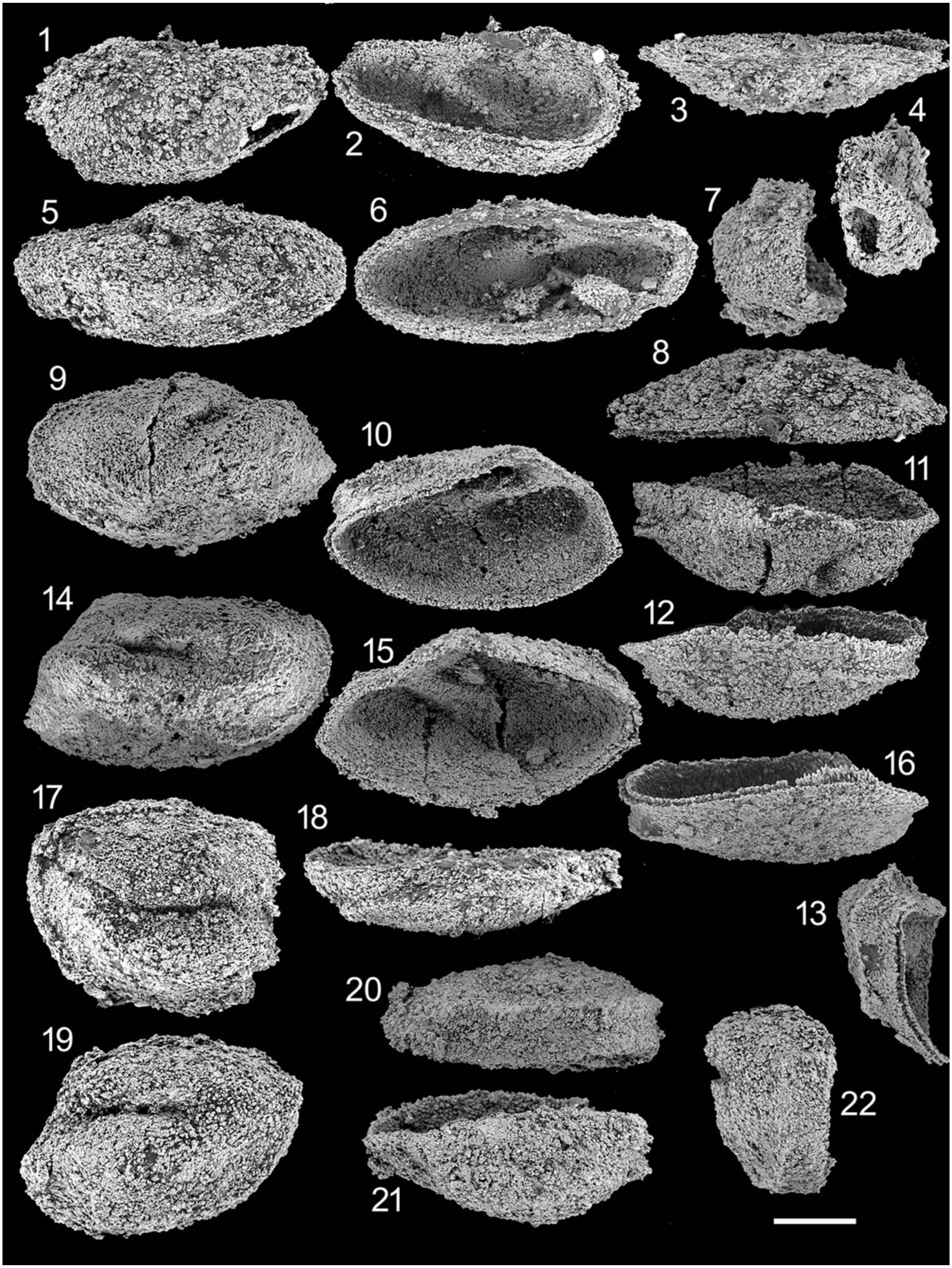

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Figure 9. Scanning electron micrographs of ostracodes from the Pennsylvanian Nagaiwa Formation. (**1–4**) A male left valve of *Jordanites michinokuensis* n. sp., IGPS-112691 (paratype); (**1**) external lateral view, (**2**) internal view, (**3**) dorsal view, (**4**) posterior view. (**5–8**) A right valve of *Punctoprimitia tomokoae* (Ishizaki, 1964b), IGPS-112700; (**5**) external lateral view, (**6**) internal view, (**7**) anterior view, (**8**) dorsal view. (**9–13**) A male right valve of *Punctoprimitia tumida* (Ishizaki, 1964b), IGPS-112701; (**9**) external lateral view, (**10**) internal view, (**11**) dorsal view, (**12**) ventral view, (**13**) anterior view; (**14–16**) a male left valve of *Punctoprimitia tumida* (Ishizaki, 1964b), IGPS-112702; (**14**) external lateral view, (**15**) internal view, (**16**) ventral view; (**17, 18**) a female right valve of *Punctoprimitia tumida* (Ishizaki, 1964b), IGPS-112703; (**17**) external view, (**18**) ventral view; (**19–22**) a female left valve of *Punctoprimitia tumida* (Ishizaki, 1964b), IGPS-112704; (**19**) external lateral view, (**20**) ventral view, (**21**) dorsal view, (**22**) posterior view. Scale bar = 200 μm.

a juvenile carapace IGPS-112699; type locality: Locality 46 of Kobayashi (1973), Upper Member of the Nagaiwa Formation, Nagaiwa, Ofunato City, Iwate Prefecture, Northeast Japan, Bashkirian.

Diagnosis.—Carapace sub-ovate; dorsal margin straight, anterior margin widely arched toward mid-anterior, ventral margin slightly sinuate in male, straight in female, posterior margin narrowly arched at one-third height; prominent dorsal lobe backwardly truncated at one-third from anterior end. In dorsal view, left lobe located anteriorly.

Occurrence.—Upper Member of the Ichinotani Formation, Mizuyagadani-Valley, Fukuji District, central Japan, Pennsylvanian; Locality 46 of Kobayashi (1973) from Upper Member of the Nagaiwa Formation, Nagaiwa, Ofunato City, Iwate Prefecture, Northeast Japan, lower Bashkirian–lower Moscovian.

Description.—Prominent dimorphism. In lateral view, carapace subovate; dorsal margin straight, anterior margin widely arched toward mid-anterior, ventral margin slightly sinuate in long form, straight in female, posterior margin narrowly arched at one-third height, anterior and posterior cardinal angles are equal in female, larger anterior cardinal angle in male; prominent dorsal lobe backwardly truncated at one-third from anterior end. In posterior view, left dorsal lobe is higher than right dorsal lobe. In dorsal view, left lobe is located anteriorly.

Etymology.—The species is named after Iwate Prefecture, the local name according to the type locality.

Material.—A carapace, length = 755 μm, height = 706 μm, IGPS-112696 (holotype), a long form carapace, length = 891 μm, height = 529 μm, IGPS-112697 (paratype), a long form right valve, length = 843 μm, height = 491 μm, IGPS-112698 (paratype), a juvenile carapace, length = 397 μm, height = 509 μm, IGPS-112699 (paratype).

Remarks.—*Aechmina iwatensis* n. sp. is similar to *Aechmina akumame* Stocker et al., 2016, from the middle Moscovian (Pennsylvanian) Ichinotani Formation, Fukuji, central Japan; it has a straight dorsal margin, but *A. iwatensis* n. sp. differs from *A. akumame* in that it has a sinuate or straight ventral margin, narrowly arched posterior margin, and backwardly truncated dorsal lobe. *Aechmina iwatensis* n. sp. probably was assigned to *Aechmina* sp. C of Adachi (1987) from the Pennsylvanian Ichinotani Formation based on the position of the dorsal knob, although Adachi (1987) only showed the species with a simple illustration. This species is similar to *Aechmina tianshanensis* Jiang in Jiang et al., 1995, from the Pennsylvanian Dongtujinhe Formation, Xinjiang, China, in its spineless dorsal lobe, but it differs in its straight or sinuate ventral margin, a narrowly arched posterior margin, and a backwardly truncated dorsal lobe. *Aechmina iwatensis* n. sp. is also similar to *Aechmina* sp.? of Dewey (1983) from the "Middle" Carboniferous of the Port au Port Peninsula, western Newfoundland, Canada, in its backwardly truncated dorsal lobe, but it differs in having a straight dorsal margin, a sinuate or straight ventral margin, and lack of a small knob-like swelling in front of the dorsal lobe. This species is also similar to *Aechmina* sp. A of Becker and Sánchez de Posada (1977) from the Early Devonian Moniello Formation, Asturias, northern Spain, in its backwardly truncated dorsal lobe, but differs in that it has a shorter dorsal lobe, a dorsal lobe projected at one-third from the anterior end, and a straight or sinuate ventral margin. *Aechmina iwatensis* n. sp. is similar to *Aechmina serrata* (Stewart, 1936) from the Middle Devonian Silica Shale Formation, Ohio, USA, in its straight dorsal margin, but it differs in that it has a sinuate or straight ventral margin, narrowly arched posterior margin, and has a short dorsal lobe.

Order Platycopida Sars, 1866
Suborder Kloedenellocopina Scott, 1961
Superfamily Kloedenelloidea Ulrich and Bassler, 1908
Family Kloedenellidae Ulrich and Bassler, 1908
Genus *Punctoprimitia* Stewart and Hendrix, 1945

Type species.—*Haploprimitia simplex* Stewart, 1936 (Ohio State University, no. 18172) from the Middle Devonian, Blue Shale (Zone 1) of Silica Shale in the quarry at Silica, Ohio, USA, by original description.

Punctoprimitia tomokoae (Ishizaki, 1964)
Figure 9.5–9.8

1964b *Glyptopleurina tomokoae* Ishizaki, p. 34, pl. 1, figs. 6a, b, text-fig. 2.
1968 *Glyptopleurina* cf. *tomokoae*; Ishizaki, p. 15, pl. 1, fig. 8.
1977 *Glyptopleurina tomokoae*; Hanai et al., p. 14.

Types.—Holotype, an adult right valve IGPS-78393; paratype, a left valve IGPS-78403; type locality: Nagaiwa, Ofunato City, Iwate Prefecture, Northeast Japan, lower Bashkirian–lower Moscovian.

Occurrence.—Locality 36 of Kobayashi (1973), Middle Member of the Nagaiwa Formation, Nagaiwa, Ofunato City, Iwate Prefecture, Northeast Japan, lower Bashkirian–lower Moscovian.

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Material.—One right valve, length = 775 µm, height = 369 µm, IGPS-112700.

Remarks.—*Punctoprimitia tomokoae* (Ishizaki, 1964b) is similar to *Punctoprimitia simplex* (Stewart, 1936) from the Middle Devonian Silica Shale Formation, Ohio, USA, in having a slit sulcus, but it differs in that it has an elongated lateral outline, concave dorsal margin, and obliquely extending S2. *Punctoprimitia tomokoae* is also similar to *Punctoprimitia* cf. *P. simplex* Becker and Sánchez de Posada, 1977, from the Early Devonian Moniello Formation, Asturias, northern Spain, in its elongated lateral outline, but it differs in that it has an acutely curved anterior margin, rather flat L2 and L3, and narrowly arched posterior margin.

Punctoprimitia tumida (Ishizaki, 1964)
Figure 9.9–9.22

1964b *Glyptopleurina tumida* Ishizaki, p. 35, pl. 1, figs. 7a, b, text-fig. 3.
1977 *Glyptopleurina tumida*; Hanai et al., p. 14.

Types.—Holotype, a right valve IGPS-78394; paratype, a right valve IGPS-78396; type locality: Nagaiwa, Ofunato City, Iwate Prefecture, Northeast Japan, lower Bashkirian to lower Moscovian.

Occurrence.—Locality 36 of Kobayashi (1973), Middle Member of the Nagaiwa Formation, Nagaiwa, Ofunato City, Iwate Prefecture, Northeast Japan, lower Bashkirian–lower Moscovian.

Materials.—One male right valve, length = 640 µm, height = 468 µm, IGPS-112701; one male left valve, length = 602 µm, height = 480 µm, IGPS-112702; one female right valve, length = 578 µm, height = 492 µm, IGPS-112703; one female left valve, length = 603 µm, height = 480 µm, IGPS-112704.

Remarks.—In the present study, I found a pair of right and left valves with dimorphism: the male is higher from lateral view and flatter from dorsal view than the female. *Punctoprimitia tumida* (Ishizaki, 1964b) is similar to *Punctoprimitia simplex* (Stewart, 1936) from the Middle Devonian Silica Shale Formation, Ohio, USA, in its rounded lateral outline, but it differs in that it has a narrow S2, an undulated dorsal margin, and an obliquely extending S2. *Punctoprimitia tumida* is also similar to *Punctoprimitia* cf. *P. simplex* Becker and Sánchez de Posada, 1977, from the Early Devonian Moniello Formation, Asturias, northern Spain, in its inflated L2 and L3, but it differs in that it has a higher lateral outline, a rather narrow S2, and a concave dorsal margin.

Punctoprimitia sp.
Figure 10.1–10.5

Occurrence.—Locality 36 of Kobayashi (1973), Middle Member of the Nagaiwa Formation, Nagaiwa, Ofunato City, Iwate Prefecture, Northeast Japan, Bashkirian.

Material.—One right valve, length = 861 µm, height = 726 µm, IGPS-112705.

Remarks.—*Punctoprimitia* sp. is similar to *Punctoprimitia simplex* (Stewart, 1936) from the Middle Devonian Silica Shale Formation, Ohio, USA; it has a distinct and deep S2, but *P.* sp. differs from *P. simplex* in that it has a rounded lateral outline, broadly arched anterior and posterior margins, and a flat postero-dorsal area. *Punctoprimitia* sp. is also similar to *Punctoprimitia* cf. *P. simplex* Becker and Sánchez de Posada, 1977, from the Early Devonian Moniello Formation, Asturias, northern Spain, with its flat postero-dorsal area, but it differs in that it has less inflated L2 and L3, a rather narrow S2, and a straight dorsal margin.

Order Podocopida Müller, 1894
Suborder Podocopina Sars, 1866
Superfamily Bairdioidea Sars, 1888
Family Bairdiocyprididae Shaver, 1961
Genus *Pseudobythocypris* Shaver, 1958

Type species.—*Bythocypris pediformis* Knight, 1928b (type specimen was not designated) from the Pennsylvanian Henrietta Formation, eastern Missouri, USA, by original description. Shaver (1958) designated four hypotypes (U.S. National Museum 133377–133380) from the "metatype" slide of Knight (1928b).

Pseudobythocypris asiatica new species
Figures 11.1–11.8, 12

1995 *Healdia lucida* Jiang in Jiang et al., pl. 117, fig. 2.

Types.—Holotype, one female carapace, IGPS-112706; paratypes, a carapace Xj-2090, a male carapace IGPS-112707; type locality: Locality 36 of Kobayashi (1973), Middle Member of the Nagaiwa Formation, Nagaiwa, Ofunato City, Iwate Prefecture, Northeast Japan, lower Bashkirian–lower Moscovian.

Diagnosis.—Carapace subovate; dorsal margin arched, anterior margin narrowly arched; longest at mid-height, highest slightly behind mid-length from anterior end. Prominent dimorphism: in lateral view, female more elongated than male; in dorsal and ventral views, posterior area of female more inflated than male; in anterior view, female is more rounded than male.

Occurrence.—Pennsylvanian Tahaqi Formation, Kunlun Mountains, Xinjiang, China; locality 36 of Kobayashi (1973), upper Member of the Nagaiwa Formation, Nagaiwa, Japan.

Description.—In lateral view, carapace subovate; dorsal margin arched, anterior margin narrowly arched, ventral margin slightly sinuate in right valve, straight in left valve, posterior margin narrowly arched; longest at mid-height, highest slightly behind mid-length from anterior end; left valve larger than right valve, overlap along anterior to lower half of posterior margin via ventral margin. In dorsal and ventral views, carapace fusiform. In anterior view, carapace ovate outline. Prominent dimorphism: in lateral view, female more elongated than male; in dorsal and ventral views, posterior area of female more

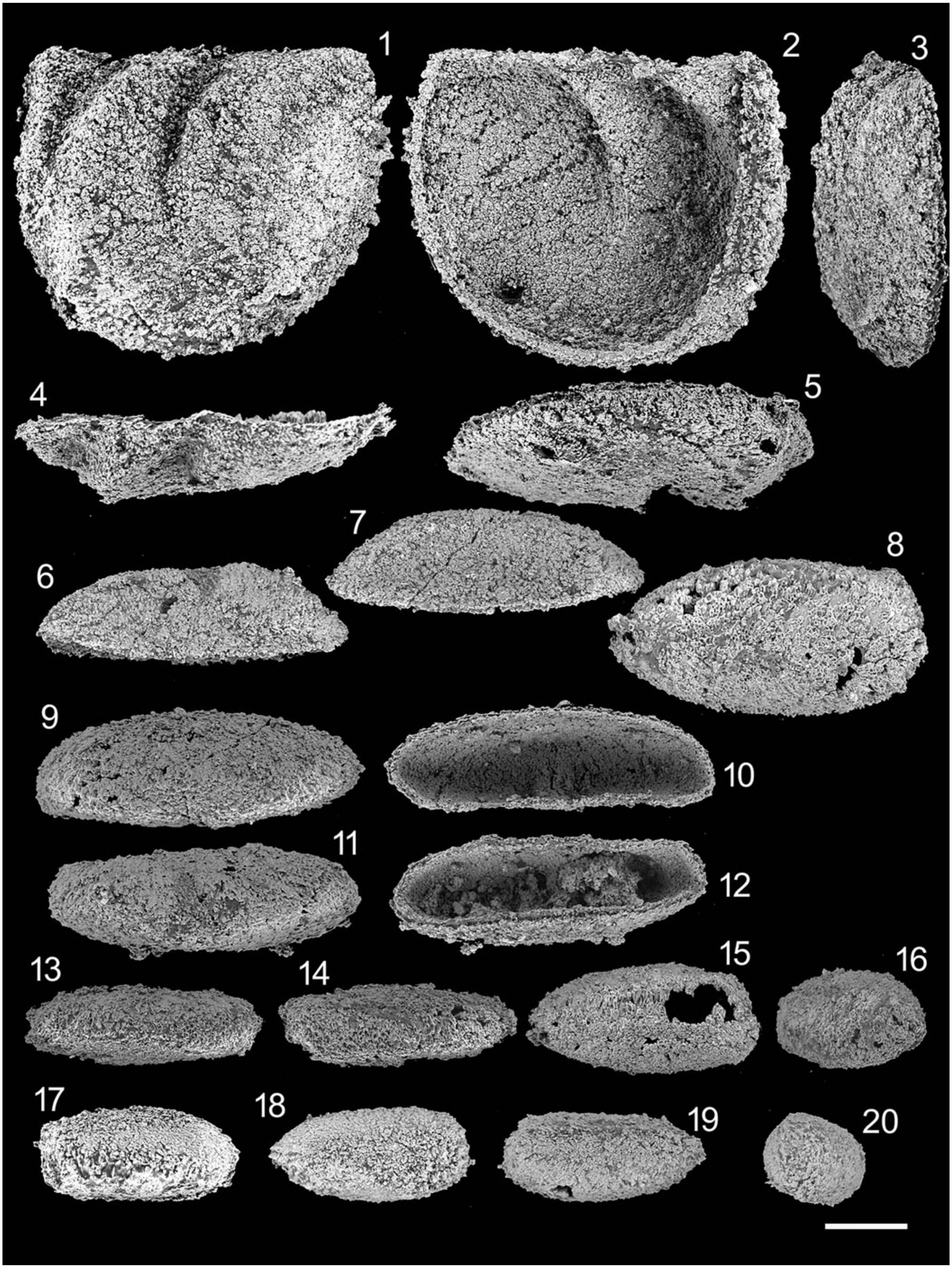

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Figure 10. Scanning electron micrographs of ostracodes from the Pennsylvanian Nagaiwa Formation. (**1–5**) A right valve of *Punctoprimitia* sp., IGPS-112705; (**1**) external lateral view, (**2**) internal view, (**3**) anterior view, (**4**) dorsal view, (**5**) ventral view. (**6–8**) A carapace of *Platyrhomboides tohokuensis* n. sp., IGPS-112717 (holotype); (**6**) right lateral view, (**7**) left side view, (**8**) dorsal view. (**9, 10**) A left valve of *Platyrhomboides japonica* n. sp., IGPS-112718 (holotype); (**9**) external lateral view, (**10**) internal view; (**11, 12**) a right valve of *Platyrhomboides japonica* n. sp., IGPS-112719 (paratype); (**11**) external lateral view, (**12**) internal view; (**13–16**) a juvenile carapace of *Platyrhomboides japonica* n. sp., IGPS-112720 (paratype); (**13**) left lateral view, (**14**) right lateral view, (**15**) dorsal view, (**16**) posterior view. (**17–20**) A carapace of *Waylandella* sp., IGPS-112728; (**17**) right lateral view, (**18**) dorsal view, (**19**) ventral view, (**20**) anterior view. Scale bar = 200 µm.

inflated than male; in anterior view, female is more rounded than male.

Etymology.—So named because the species has been reported only from Asia.

Materials.—One male carapace, length = 566 µm, height = 332 µm, IGPS-112706 (holotype); one male carapace, length = 640 µm, height = 295 µm, IGPS-112707 (paratype); one possibly male carapace, Xj-2090 (paratype).

Remarks.—Jiang in Jiang et al. (1995) described *Healdia lucida* from the Pennsylvanian Shiqiantan and Tahaqi formations, Xinjiang, China. He designated one carapace as holotype (Xj-2078) and three carapaces as paratypes (Xj-2078a, 8957, 2090). However, one paratype (Xj-2090) with a straight ventral margin is not *Healdia lucida*, because *H. lucida* was described as having a convex ventral margin (Xj-2078, 2078a, 8957).

Pseudobythocypris asiatica n. sp. is similar to *Pseudobythocypris pediformis* (Knight, 1928b) from the Pennsylvanian Henrietta Formation, eastern Missouri, USA, with that taxon sharing an arched dorsal margin, but it differs in that it has a narrowly arched (not protruded) posterior margin, is longest at mid-height, and has a more inflated carapace. This species is also similar to *Pseudobythocypris parallela* (Knight, 1928b) from the Pennsylvanian Henrietta Formation, eastern Missouri, USA, in its elongated lateral outline, but it differs in that its highest point is situated more backwardly from the anterior end, is longest at mid-height, and has a wider arched posterior margin. *Pseudobythocypris asiatica* n. sp. is similar to *P. kellettae* (Cordell, 1952) from the Pennsylvanian Bonner Spring Formation and the Canville Limestone from Missouri, USA, in its narrowly arched anterior margin, but it differs in its backwardly located highest point from the anterior end, longest point at mid-height, and a more inflated outline from dorsal view. This species is also similar to *P. parallela* (Knight, 1928b) of Glebovskaya (1939) from the Pennsylvanian–Permian of Vyarta, northern Ural, Russia, in its straight ventral margin, but it differs in that it has a narrowly arched posterior margin, is longest at mid-height, and has a more acutely arched dorsal margin. *Pseudobythocypris asiatica* n. sp. is similar to *Healdianella darwinuloides* Posner, 1951, from the Mississippian of the western part of the Moscow Basin in its overlapped left valve from posterior to anterior margin via ventral margin, but it differs in that it has a longer lateral outline, a highest point situated slightly behind mid-length from the anterior end, and a straight ventral margin in the left valve.

Pseudobythocypris siveteri new species
Figures 11.13–11.20, 13

Types.—Holotype, one female carapace, IGPS-112708; paratype, one male carapace IGPS-112709; type locality: Locality 36 of Kobayashi (1973), Middle Member of the Nagaiwa Formation, Nagaiwa, Ofunato City, Iwate Prefecture, Northeast Japan, Bashkirian.

Diagnosis.—Carapace sub-trapezoidal; anterior margin arched toward antero-ventral direction, posterior margin broadly arched toward postero-ventral direction, protruded two-thirds height from venter; longest at one-third height. In dorsal and ventral views, carapace bullet-shaped.

Occurrence.—Only the type locality.

Description.—In lateral view, carapace sub-trapezoidal; dorsal margin widely arched, anterior margin arched toward antero-ventral direction, protruded at mid-height from venter, ventral margin straight in left valve, concave at mid-length from anterior end in right valve, posterior margin broadly arched toward postero-ventral direction, protruded two-thirds height from venter; longest at one-third height, highest at mid-length from anterior end; left valve larger than right valve, overlap along all margins, typically prominent overlap at ventral margin. In dorsal and ventral views, carapace bullet-shaped. In posterior view, carapace ovate outline. Prominent dimorphism: in lateral view, female more rounded than male; in dorsal view, female more inflated than male.

Etymology.—In honor of Emeritus Professor David J. Siveter (University of Leicester) who is an excellent paleontologist and the author's supervisor.

Materials.—One female carapace, length = 492 µm, height = 271 µm, IGPS-112708 (holotype); one male carapace, length = 468 µm, height = 234 µm, IGPS-112709 (paratype).

Remarks.—*Pseudobythocypris siveteri* n. sp. is similar to *P. phaseoella* (Stover, 1956) from the Middle Devonian Windom Shale Member of the Moscow Formation from western New York, USA, in its antero-ventrally truncated anterior margin, but it differs in that it has a more inflated lateral outline, a widely arched dorsal margin, and bullet-shaped outline from the dorsal view. This species is also similar to *Pseudobythocypris kellettae* (Cordell, 1952) from the Pennsylvanian Galesburg Shale from Missouri, USA, in its overlapped left valve to right valve at the ventral margin, but it differs in that it has a shorter anterior margin, a protruded posterior margin at two-thirds height from venter, and a bullet-shaped outline from the dorsal view. *Pseudobythocypris siveteri* n. sp. is similar to *P. pediformis* (Knight, 1928b) from the Pennsylvanian upper Fort Scott Limestone of the Henrietta Formation, Missouri, USA, in its protruded anterior margin slightly below mid-height, but it differs in that it has broadly arched anterior and posterior

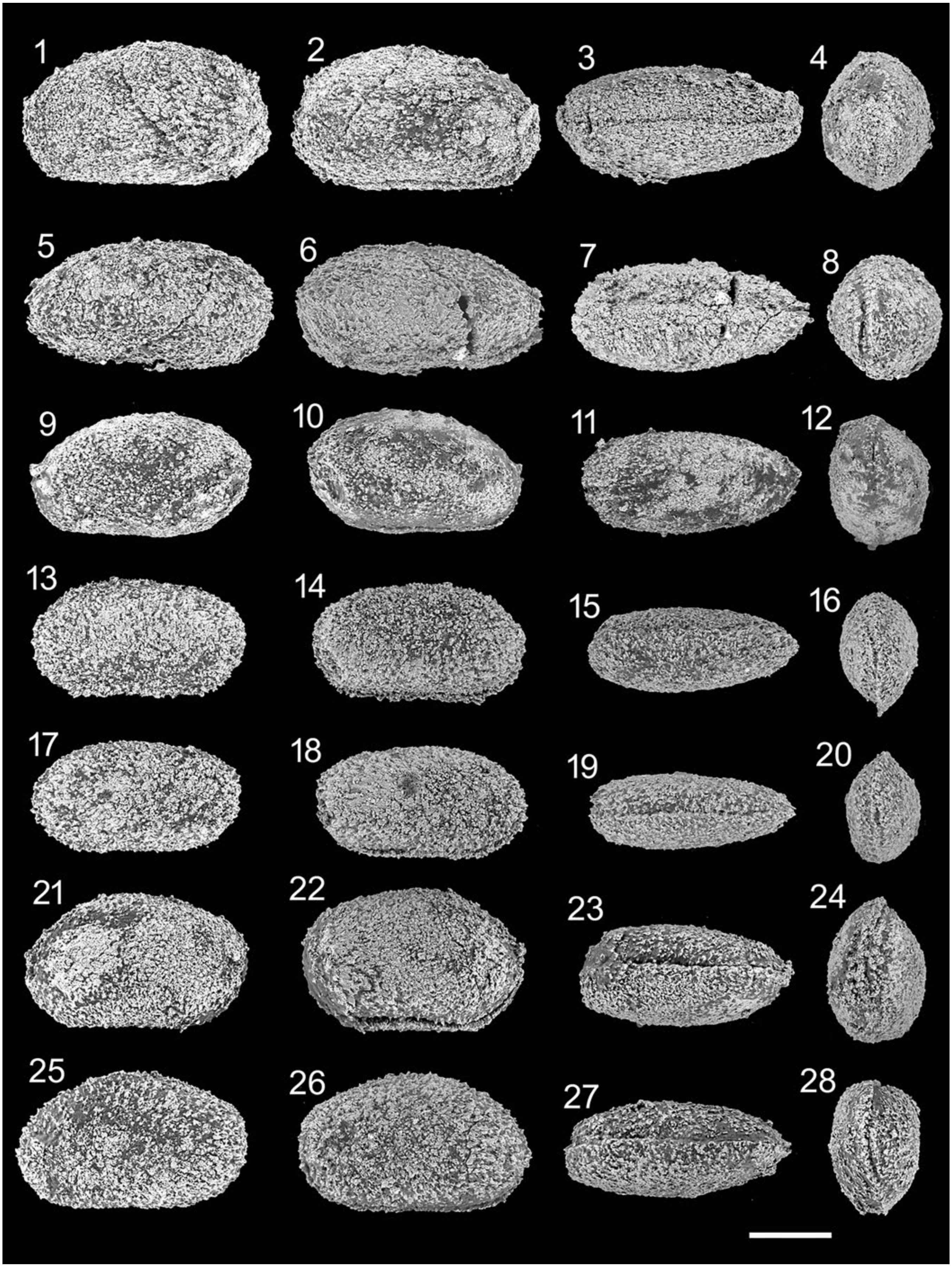
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Figure 11. Scanning electron micrographs of ostracodes from the Pennsylvanian Nagaiwa Formation. (**1–4**) A female carapace of *Pseudobythocypris asiatica* n. sp., IGPS-112706 (holotype); (**1**) left lateral view, (**2**) right lateral view, (**3**) ventral view, (**4**) anterior view; (**5–8**) a male carapace of *Pseudobythocypris asiatica* n. sp., IGPS-112707 (paratype); (**5**) left lateral view, (**6**) right lateral view, (**7**) ventral view, (**8**) anterior view. (**9–12**) A carapace of *Healdia* sp., IGPS-112727; (**9**) left lateral view, (**10**) right lateral view, (**11**) dorsal view, (**12**) posterior view. (**13–16**) A female carapace of *Pseudobythocypris siveteri* n. sp., IGPS-112708 (holotype); (**13**) left lateral view, (**14**) right lateral view, (**15**) dorsal view, (**16**) anterior view; (**17–20**) a male carapace of *Pseudobythocypris siveteri* n. sp., IGPS-112709 (paratype); (**17**) left lateral view, (**18**) right lateral view, (**19**) ventral view, (**20**) posterior view. (**21–24**) A female carapace of *Pseudobythocypris zipangu* n. sp., IGPS-112710 (holotype); (**21**) left lateral view, (**22**) right lateral view, (**23**) ventral view, (**24**) posterior view; (**25–28**) a male carapace of *Pseudobythocypris zipangu* n. sp., IGPS-112711 (paratype); (**25**) left lateral view, (**26**) right lateral view, (**27**) ventral view, (**28**) posterior view. Scale bar = 200 μm.

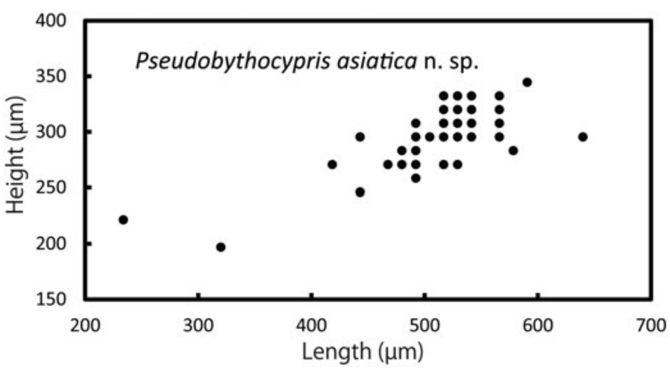

Figure 12. Ontogenetic change of length/height of *Pseudobythocypris asiatica* n. sp.

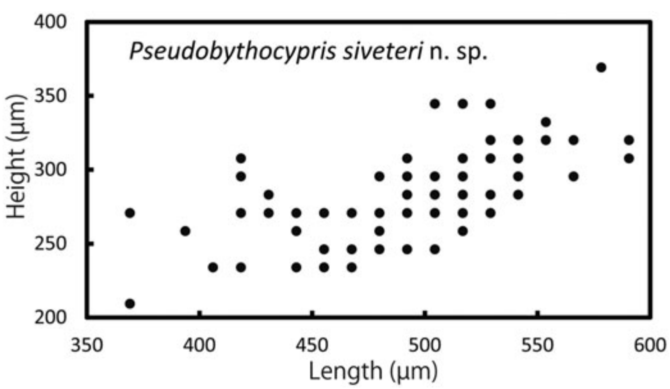

Figure 13. Ontogenetic change of length/height of *Pseudobythocypris siveteri* n. sp.

margins, and a bullet-shaped outline from the dorsal view. *Pseudobythocypris siveteri* n. sp. is also similar to *P. deesensis* (Bradfield, 1935) of Shi (1987) from the Pennsylvanian Taiyuan Formation, Shanxi, China, in its antero-ventrally directed anterior margin, but it differs in that it has a widely arched posterior margin, more rounded lateral outline, and a bullet-shaped outline from the dorsal view.

Pseudobythocypris zipangu new species
Figure 11.21–11.28

Types.—Holotype, one female carapace, IGPS-112710; paratype, one male carapace IGPS-112711; type locality: Locality 36 of Kobayashi (1973), Middle Member of the Nagaiwa Formation, Nagaiwa, Ofunato City, Iwate Prefecture, Northeast Japan, Bashkirian.

Diagnosis.—Dorsal margin widely arched, anterior margin equally arched, ventral margin sinuate, concave at one-third distance from anterior end, posterior margin unequally arched; longest at mid-height from venter, highest point slightly forward of mid-length from anterior end. Prominent dimorphism: in lateral view, female more rounded than male.

Occurrence.—Only the type locality.

Description.—In lateral view, carapace bean-shaped; dorsal margin widely arched, anterior margin equally arched between dorsal and ventral half, protruded anteriorly at mid-height, ventral margin sinuate, concave at one-third distance from anterior end, posterior margin unequally arched between ventral and dorsal margin, postero-ventral margin widely arched, postero-dorsal margin narrowly arched, protruded at one-third of height from venter; longest at mid-height from venter, highest point located slightly forward of mid-length from anterior end. Left valve larger than right valve, overlap along antero-dorsal to postero-dorsal margin via ventral margin. In dorsal and ventral views, carapace rice-shaped. In anterior view, carapace has ovate outline. Prominent dimorphism: in lateral view, female more rounded than male; in dorsal and ventral views, female more inflated than male.

Etymology.—According to the book "The Travels of Marco Polo," Zipangu is located off the east of China, and the palace was made of gold (Komroff, 2001); thus, Zipangu has been considered as Japan, and the palace has been thought to refer to the Chusonji Konjiki-do Temple in Iwate Prefecture (type locality of this species).

Materials.—One female carapace, length = 480 μm, height = 320 μm, IGPS-112710 (holotype); one male carapace, length = 468 μm, height = 308 μm, IGPS-112711 (paratype).

Remarks.—*Pseudobythocypris zipangu* n. sp. is similar to *P. pecki* (Cordell, 1952) from the Pennsylvanian Lawrence Formation from Missouri, USA, in its equally arched anterior margin, but it differs in that it has a protruded posterior margin at one-third height from venter, is longest at mid-height from venter, and does not have an overlapped left valve along dorsal margin of right valve. *Pseudobythocypris zipangu* n. sp. is also similar to *Pseudobythocypris oblongata* (Cordell, 1952) from the Pennsylvanian Muncie Creek Shale from Missouri, USA, in its bean-shaped lateral outline, but differs in that it has a sinuate ventral margin, a widely arched postero-ventral margin, and no overlap between left valve and right valve along the dorsal area. *Pseudobythocypris zipangu* n. sp. is similar to *P. cytherellinoides* (Kummerow, 1953) from the Early Devonian Zorgensis Limestone, Trautenstein, Germany, in its bean-shaped lateral outline; it differs in that

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the left valve overlaps the right valve at anterior and posterior areas, having a sinuate ventral margin, and has an acutely arched anterior margin. This new species is also similar to *P. lucasensis* (Stewart, 1936) from the Middle Devonian Silica Shale Formation, Ohio, USA, in its bean-shaped lateral outline, but it differs in that it has a widely arched dorsal margin, is highest near mid-length from anterior end and has an acutely arched dorso-posterior margin.

Family Bairdiidae Sars, 1888
Genus *Bairdia* McCoy, 1844

Type species.—*Bairdia curtus* McCoy, 1844 (type specimen was not designated) from the Carboniferous of Ireland by original description. Sohn (1960) erected a new genus, *Orthobairdia*, and included *B. curta* McCoy, 1844, in the genus *Orthobairdia*. The type species of *Orthobairdia* is *Orthobairdia cestriensis* (Ulrich, 1891), and the lectotype (U.S. National Museum 41789) was designated by Sohn (1960) among Ulrich's 12 cotype specimens.

Bairdia hanaii Ishizaki, 1963
Figure 14.17–14.19

1963 *Bairdia hanaii* Ishizaki, p. 165, pl. 4, figs. 1a, b.
1977 *Bairdia hanaii*; Hanai et al., p. 16.

Holotype.—Holotype, right IGPS-78380; type locality: Nagaiwa, Hikoroichi Town, Ofunato City, Iwate Prefecture, Japan, the Pennsylvanian Nagaiwa Formation.

Occurrence.—Pennsylvanian Nagaiwa Formation, Nagaiwa, Hikoroichi Town, Iwate Prefecture, Northeast Japan; Locality 46 of Kobayashi (1973), Upper Member of the Nagaiwa Formation, Nagaiwa, Japan.

Materials.—Two carapaces, length = 2000 µm, height = 870 µm, IGPS-112712, length = 1410 µm, height = 500 µm, IGPS-112713.

Remarks.—*Bairdia hanaii* Ishizaki, 1963, is similar to *Bairdia aluca* Kotschetkova, 1983, from the Pennsylvanian (Bashkirian) Akavasian Horizon, Chalyabinsk region, Kizil, southern Urals, Russia, in its elongated lateral outline, but it differs in that it has an acuminated dorsal margin, a longer posterior process, and a rightward bending posterior process in ventral view. *Bairdia hanaii* is also similar to *Bairdia proxima* Tkatscheva in Ivanova et al., 1975, from the Carboniferous deposits, western slope of the North Urals, Russia, in its less elongated lateral outline, but it differs in that it has a longer posterior process, a more antero-ventrally curved anterior margin, and an acuminated dorsal margin.

Bairdia sp.
Figure 14.20–14.22

Occurrence.—Locality 46 of Kobayashi (1973), Upper Member of the Nagaiwa Formation, Nagaiwa, Japan.

Material.—Two carapaces, length = 777 µm, height = 490 µm, IGPS-112714, length = 1250 µm, height = 783 µm, IGPS-112715; one left valve, length = 510 µm, height = 312 µm, IGPS-112716.

Remarks.—*Bairdia* sp. is similar to *Bairdia foveosa* Jiang in Jiang et al., 1995, from the Pennsylvanian of Xinjiang, China, in sharing a widely arched anterior margin, but it differs in that it has a widely arched dorsal margin, a dorsally directed posterior end, and is longest at mid-height from anterior end. *Bairdia* sp. is similar to *Bairdia auricula* Knight, 1928b, from the Pennsylvanian Henrietta Formation, eastern Missouri, USA, in its straight ventral margin, but it differs in that it has widely arched anterior and dorsal margins, a narrower posterior margin, and a short posterior projection.

Family Beecherellidae Ulrich, 1894
Genus *Platyrhomboides* Harris, 1957

Type species.—*Platyrhomboides quadratus* Harris, 1957 (Museum of Comparative Zoology at Harvard University No. 4648) from the Ordovician Bromide Formation, Bromide horizon, 15 feet below top of zone 10 of U.S. Highway, Simpson section, Oklahoma, USA, by original description.

Platyrhomboides tohokuensis new species
Figure 10.6–10.8

Holotype.—Holotype, a carapace IGPS-112717: Locality 36 of Kobayashi (1973), Middle Member of the Nagaiwa Formation, Nagaiwa, Ofunato City, Iwate Prefecture, Northeast Japan, Bashkirian.

Diagnosis.—Trowel-like carapace. In lateral view, trapezoidal outline; anterior margin protruded toward anterior, posterior margin protruded postero-ventrally, longest at one-fifth height from venter, highest point at two-thirds from anterior end.

Occurrence.—Only the type locality.

Description.—Trowel-like carapace. In lateral view, trapezoidal outline; dorsal margin straight, anterior margin protruded toward anterior, ventral margin widely arched or straight, posterior margin protruded postero-ventrally, longest at one-fifth height from venter, highest point at two-thirds from anterior end. In ventral view, carapace trowel-like outline, left valve larger than right valve.

Etymology.—The provincial name where the type specimens were discovered.

Materials.—A carapace, length = 566 µm, height = 271 µm, IGPS-112717 (holotype).

Remarks.—The genus *Platyrhomboides* has been reported from Middle Ordovician–Late Devonian (Becker and Wang, 1992). This report provides the youngest fossil record of the genus, extending the geological time range into the Pennsylvanian. *Platyrhomboides tohokuensis* n. sp. is similar to

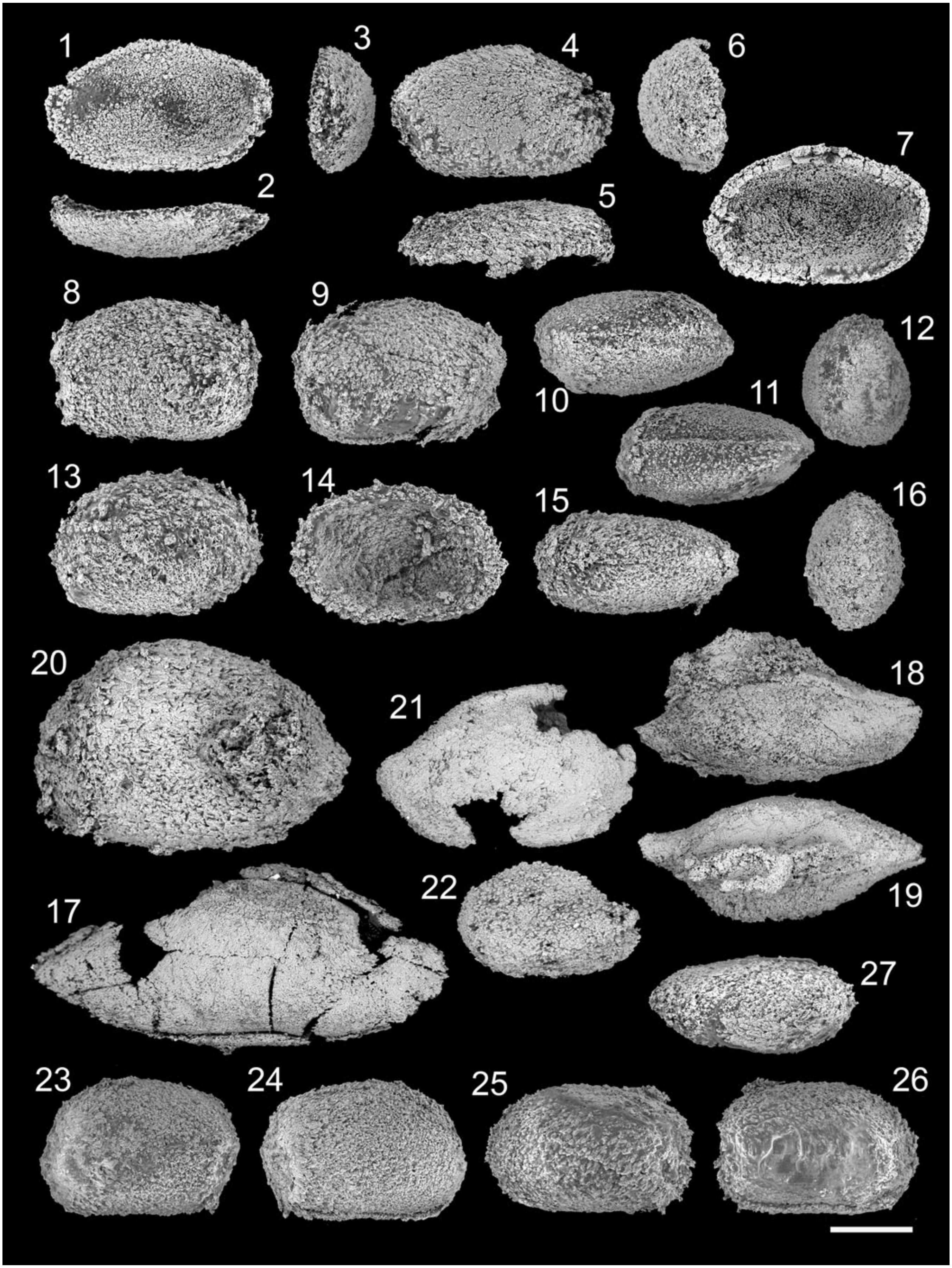

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Figure 14. Scanning electron micrographs of ostracodes from the Pennsylvanian Nagaiwa Formation. (**1–3**) A left valve of *Healdia* cf. *H. simplex* Roundy, 1926, IGPS-112722; (**1**) lateral view, (**2**) dorsal view, (**3**) anterior view; (**4–7**) a right valve of *Healdia* cf. *H. simplex* Roundy, 1926, IGPS-112721; (**4**) external lateral view, (**5**) dorsal view, (**6**) anterior view, (**7**) inner view. (**8–12**) A female carapace of *Healdia ofunatensis* n. sp., IGPS-112723 (holotype); (**8**) left lateral view, (**9**) right lateral view, (**10**) dorsal view, (**11**) ventral view, (**12**) anterior view; (**13–16**) a male carapace of *Healdia ofunatensis* n. sp., IGPS-112724 (paratype); (**13**) left lateral view, (**14**) right lateral view, (**15**) dorsal view, (**16**) anterior view. (**17**) A carapace in right lateral view of *Bairdia hanaii* Ishizaki, 1963, IGPS-112712; (**18, 19**) a carapace of *Bairdia hanaii* Ishizaki, 1963, IGPS-112713; (**18**) right lateral view, (**19**) ventral view. (**20–22**) *Bairdia* sp., (**20**) left lateral view of carapace IGPS-112714, (**21**) right lateral view of carapace IGPS-112715, (**22**) left valve IGPS-112716. (**23, 24**) A female carapace of *Healdia rikutyuensis* n. sp., IGPS-112725 (holotype); (**23**) left lateral view, (**24**) right lateral view; (**25–27**) a male carapace of *Healdia rikutyuensis* n. sp., IGPS-112726 (paratype); (**25**) left lateral view, (**26**) right lateral view, (**27**) dorsal view. Scale bar = 200 μm for (**1–16, 20, 22–27**). Scale bar = 400 μm for (**17–19, 21**).

Platyrhomboides quadratus Harris, 1957, from the Ordovician Bromide Formation, Simpson and West Spring Creek, Oklahoma, USA, in its quadrate lateral outline, but it differs in that it has trowel-like outline in ventral view, a slightly protruded anterior margin, and a widely arched dorsal margin in the left valve. This species is also similar to *Platyrhomboides* sp. A of Becker and Wang (1992) from the middle to late Silurian of Shaanxi Province, Inner Mongolia, China, in its straight dorsal margin in the right valve, but it differs in that it has a narrowly arched anterior margin, a widely arched ventral margin, and a shorter dorsal margin. *Platyrhomboides tohokuensis* n. sp. is similar to *Platyrhomboides* sp. C of Becker and Wang (1992) from the Lower Devonian (lower Emsian) in Guangxi, China, in its widely arched ventral margin, but it differs in that it has a protruded anterior margin, a straight dorsal margin in the left valve, and a lower posterior end than that of the anterior.

Platyrhomboides japonica new species
Figures 10.9–10.16

Types.—Holotype, a left valve IGPS-112718; paratypes, a right valve IGPS-112719, a juvenile carapace IGPS-112720; type locality: Locality 36 of Kobayashi (1973), Middle Member of the Nagaiwa Formation, Nagaiwa, Ofunato City, Iwate Prefecture, Northeast Japan, Bashkirian.

Diagnosis.—Wheat-seed shaped carapace. In lateral view, dorsal margin widely arched in left valve, straight in right valve; anterior margin narrowly arched antero-dorsally, ventral margin widely arched or straight, posterior margin protruded postero-ventrally.

Occurrence.—Only the type locality.

Description.—Wheat-seed shaped carapace. In lateral view, oblong outline; dorsal margin widely arched in left valve, straight in right valve, anterior margin narrowly arched antero-dorsally, ventral margin widely arched or straight, posterior margin protruded postero-ventrally. In internal view, wide marginal border in right valve. In ventral view, carapace has ship-like outline, left valve larger than right valve. In posterior view, carapace has oblate outline.

Etymology.—The name where the type specimens were discovered.

Materials.—A left valve, length = 780 μm, height = 270 μm, IGPS-112718 (holotype), a right valve, length = 740 μm, height = 260 μm, IGPS-112719 (paratype), a juvenile carapace, length = 540 μm, height = 180 μm, IGPS-112720 (paratype).

Remarks.—The genus *Platyrhomboides* has been reported from Middle Ordovician–Late Devonian (Becker and Wang, 1992). This report provides the youngest fossil record of the genus with *P. tohokuensis* n. sp. and extends the geological time range into the Pennsylvanian. *Platyrhomboides japonica* n. sp. is similar to *Platyrhomboides quadratus* Harris, 1957, from the Ordovician Bromide Formation, Simpson and West Spring Creek, Oklahoma, USA, in its straight or a widely arched ventral margin, but it differs in that it has a widely arched dorsal margin, slightly tapered anterior and posterior margins, and less prominent anterior and posterior cardinal angles. This species is also similar to *Platyrhomboides* sp. A of Becker and Wang (1992) from the middle to late Silurian of Shaanxi Province, Inner Mongolia, China, in its straight dorsal margin in right valve, but it differs in that it has narrowly arched anterior margin, broadly arched ventral margin, and less truncated posterior. *Platyrhomboides japonica* n. sp. is similar to *Platyrhomboides* sp. B of Becker and Wang (1992) from the Lower Devonian (lower Emsian) of the Guangxi, China, in its narrowly arched anterior margin, but it differs in that it has a widely arched or a straight ventral margin, a widely arched dorsal margin in the left valve, and a higher posterior end than that of the anterior.

Suborder Metacopina Sylvester-Bradley, 1961
Superfamily Healdioidea Harlton, 1933
Family Healdiidae Harlton, 1933
Genus *Healdia* Roundy, 1926

Type species.—Healdia simplex Roundy, 1926 (type specimen was not designated) from the Mississippian Graham Formation, Stephens County, Texas, USA, by original description. Kellett (1935) designated the plesiotype (U.S. National Museum No. 90108) from the Middle Pennsylvanian Stanton Formation, Kansas, USA.

Healdia cf. *H. simplex* Roundy, 1926
Figures 14.1–14.7, 15

Occurrence.—Locality 36 of Kobayashi (1973), Middle Member of the Nagaiwa Formation, Nagaiwa, Ofunato City, Iwate Prefecture, Northeast Japan, Bashkirian.

Materials.—One right valve, length = 456 μm, height = 258 μm, IGPS-112721; one left valve, length = 529 μm, height = 295 μm, IGPS-112722.

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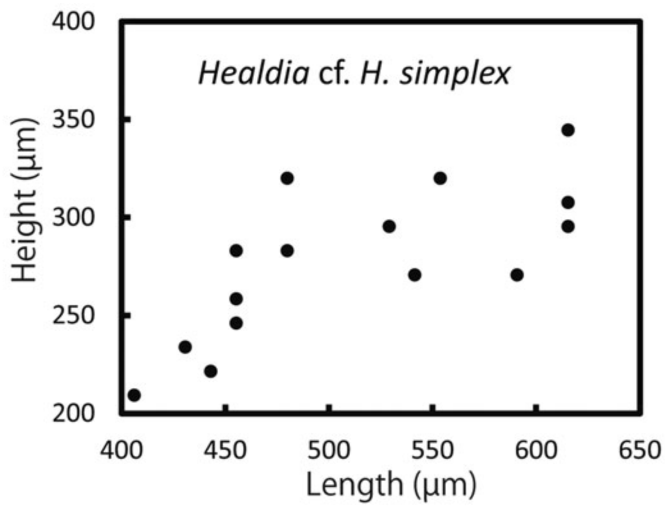

Figure 15. Ontogenetic change of length/height of *Healdia* cf. *H. simplex* Roundy, 1926.

Remarks.—Roundy (1926) described this species from the Pennsylvanian of Graham County, Texas, USA, but did not designate type specimens. Subsequently, in March 1935, Bradfield (1935) designated a plesiotype (Indiana University Paleontological Collections No.2098) of *Healdia simplex* using a complete carapace from the Pennsylvanian of the Ardmore Basin, Oklahoma, USA. Kellett (1935) designated plesiotypes (U.S. National Museum No. 90108) from the Middle Pennsylvanian Stanton Formation, Kansas, USA, on March 11, 1935. Since the publication date of Bradfield (1935) is not precisely known, it is not possible to determine whether or not of Kellett's (1935) plesiotypes have priority. Bradfield's (1935) plesiotype of *H. simplex* is similar to *H.* cf. *H. simplex* in its triangular lateral outline, but it differs in that it has its highest point slightly forward from the mid-length, a straight posterior half of the dorsal margin, and a more dorsally situated maximum length. Kellett's figured plesiotype (Kellett, 1935, pl. 16, fig. 2) of *H. simplex* of is similar to *H.* cf. *H. simplex* in its triangular lateral outline, but it differs in that it has its a straight ventral margin, a straight posterior half of the dorsal margin, and does not have an inflated valve.

Healdia cf. *H. simplex* is also similar to *Healdia magna* Jiang in Jiang et al., 1995, from the Pennsylvanian Shiqiantan Formation, Xinjiang, China, in its antero-ventrally protruded anterior margin, but it differs in that it has a longer lateral outline, an unequally arched posterior margin, and its highest point slightly forward of the mid-length from the anterior end. *Healdia* cf. *H. simplex* resembles *Healdia askynensis* Kotschetkova, 1983, from the Pennsylvanian (Bashkirian) Kizil Formation, southern Ural Mountains, Russia, in that it has a depressed postero-ventral area, but *H.* cf. *H. simplex* differs from *H. askynensis* in that its highest point is slightly forward of the mid-length from the anterior end, has a more rounded anterior margin, and has an elongated outline from the dorsal view.

Healdia ofunatensis new species
Figures 14.8–14.16, 16

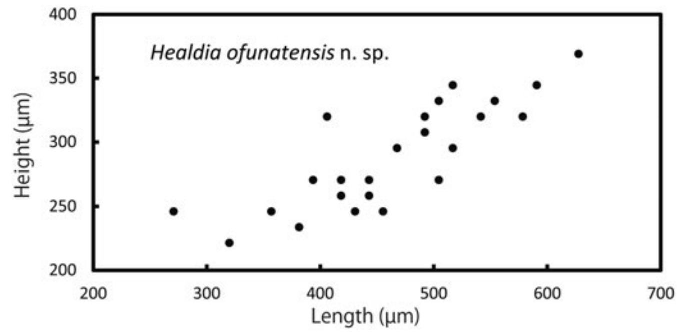

Figure 16. Ontogenetic change of length/height of *Healdia ofunatensis* n. sp..

Holotype.—Holotype, one female carapace, IGPS-112723; paratype, one male carapace IGPS-112724, type locality: Locality 36 of Kobayashi (1973), Middle Member of the Nagaiwa Formation, Nagaiwa, Ofunato City, Iwate Prefecture, Northeast Japan, Bashkirian.

Diagnosis.—Ovate carapace; dorsal margin symmetrically arched, ventral margin sinuate, concaved at mid-length from anterior end; longest at mid-height, highest at mid-length from anterior end; left valve larger than right valve, prominent overlap at ventral and postero-dorsal margins. Rice-shaped outline in dorsal view.

Occurrence.—Only the type locality.

Description.—In lateral view, ovate carapace; dorsal margin symmetrically arched, anterior margin widely arched toward antero-dorsal direction in left valve, tapered anteriorly in right valve, ventral margin sinuate, concave at mid-length from anterior end, posterior margin widely arched postero-dorsally or protruded at mid-height; longest at mid-height from venter, highest at mid-length from anterior end; left valve larger than right valve, overlap along entire margin, typically prominent overlap at ventral and postero-dorsal margins. In dorsal and ventral views, carapace rice-shaped. In posterior view, carapace has ovate outline. Prominent dimorphism: in lateral view, female more rounded than male; in dorsal view, female more inflated than male; in posterior view, female wider than male.

Etymology.—Ofunato, the name of the city where the type specimens were discovered.

Materials.—One female carapace, length = 505 µm, height = 332 µm, IGPS-112723 (holotype); one male carapace, length = 504 µm, height = 271 µm, IGPS-112724 (paratype).

Remarks.—*Healdia ofunatensis* n. sp. is similar to *Healdia humillis* (Bradfield, 1935) from the Pennsylvanian of the Ardmore Basin, Oklahoma, USA., in its symmetrically arched dorsal margin, but it differs in that it has a sinuate ventral margin, its highest point at mid-height from venter, and prominent overlap at ventral and postero-dorsal margins. *Healdia ofunatensis* n. sp. is also similar to *Healdia yiliensis* Jiang in Jiang et al., 1995, from the Pennsylvanian Dongtujinhe Formation, Xinjiang, China, in its lateral outline, but it differs in that it has a protruded dorsal margin, a shorter ventral margin, and rice-shaped outline from dorsal view. *Healdia ofunatensis* n. sp. is also similar to *Healdia ziganensis* Kotschetkova, 1983, from the Pennsylvanian (Bashkirian) Tashasta horizon, southern Ural Mountains, Russia, in its symmetrically arched dorsal margin, but it differs in that it has a longer lateral outline, is longest at mid-height from venter, and has a sinuate ventral margin. This species is also similar to *Healdia kashirica* Kotschetkova, 1985, from the Pennsylvanian (Moscovian) Kashirian horizon, Korenevo Village, Moscow, Russia, in its symmetrically arched dorsal margin, but it differs in that it has a rounded lateral outline, tapered anterior margin in the right valve, and rice-shaped outline from dorsal view.

Healdia rikutyuensis new species
Figure 14.23–14.27

Holotype.—Holotype, one female carapace, IGPS-112725; paratype, one male carapace IGPS-112726, type locality: Locality 36 of Kobayashi (1973), Middle Member of the Nagaiwa Formation, Nagaiwa, Ofunato City, Iwate Prefecture, Northeast Japan, Bashkirian.

Diagnosis.—Carapace tetragonal outline; dorsal margin widely arched unequally, anterior margin tapered at one-third height from venter, ventral margin sinuate, posterior margin truncated at mid-height from venter; in dorsal and ventral views, carapace pear-shaped.

Occurrence.—Only the type locality.

Description.—Tetragonal outline in lateral view; dorsal margin widely arched unequally, shorter anterior and longer posterior, anterior margin tapered at one third height from venter, ventral margin sinuate, concave at mid-length from anterior end, posterior margin truncated at mid- height; longest at mid-height from anterior end, highest at one-third length from anterior end; left valve larger than right valve, overlap along entire margin, typically prominent overlap at dorsal and ventral margins; a prominent sulcus at postero-ventral area. In dorsal and ventral views, carapace pear-shaped. Prominent dimorphism: in lateral view, female more rounded than male.

Etymology.—The species is named for Rikutyu, the previous name of Iwate Prefecture, acknowledging the type locality.

Materials.—One female carapace, length = 529 µm, height = 332 µm, IGPS-112725 (holotype); one male carapace, length = 529 µm, height = 295 µm, IGPS-112726 (paratype).

Remarks.—*Healdia rikutyuensis* n. sp. is similar to *Healdia magna* Jiang in Jiang et al., 1995, from the Pennsylvanian Shiqiantan Formation, Bogduo Mountain, Xinjiang, China, in its truncated anterior margin, but it differs in that it has a tetragonal lateral outline, a widely arched dorsal margin, and a prominent sulcus at the postero-ventral area. *Healdia rikutyuensis* n. sp. is also similar to *Healdia kashirica* Kotschetkova, 1985, from the Pennsylvanian (Moscovian) Kashirian horizon, Korenevo Village, Moscow, Russia, in its truncated posterior margin at mid-height from venter, but it differs in that it has a tetragonal outline in lateral view, a sinuate ventral margin, and its highest point at one-third length from the anterior end. *Healdia rikutyuensis* n. sp. is similar to *Healdia askynensis* Kotschetkova, 1983, from the Pennsylvanian (Bashkirian) Kizil Formation, southern Ural Mountains, Russia, in its truncated anterior margin, but it differs in that it has a tetragonal lateral outline, its highest point at one-third length from the anterior end, and a depression at the postero-ventral area. This species is also similar to *Healdia ovata* Bradfield, 1935, from the

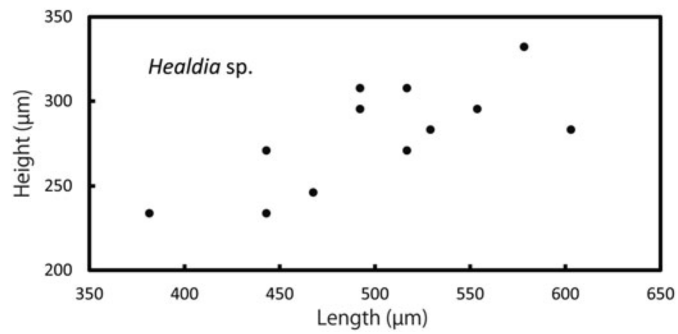

Figure 17. Ontogenetic change of length/height of *Healdia* sp.

Table 1. Ostracode species extracted from two sample localities (Loc. 36, Loc. 46) from the late Carboniferous Nagaiwa Formation, Northeast Japan. Each number shows number of specimens; white circles under C Japan (= central Japan) and Xinjiang indicate presence of the species.

	species	Loc. 36	Loc. 46	C Japan	Xinjiang
1	*Samarella hataii* Ishizaki, 1964b	1			
2	*Kirkbyella* sp. 1	2			
3	*Kirkbyella* sp. 2	1			
4	*Kirkbyella* sp. 3	1			
5	*Kirkbyella* sp. 4	1			
6	*Kirkbya nipponica* Ishizaki, 1964b		2		
7	*Kirkbya nagaiwensis* Ishizaki, 1964b		1		
8	*Kirkbya sarusawensis* Ishizaki, 1968		3	○	○
9	*Kirkbya* sp.		1		
10	*Jordanites michinokuensis* n. sp.	12			○
11	*Jordanites modica* (Jiang in Jiang et al., 1995)	39			
12	*Jordanites* sp.	12			
13	*Thuringobolbina ikeyai* n. sp.	2			
14	*Thuringobolbina* sp.	1			
15	*Aechmina iwatensis* n. sp.		4	○	
16	*Punctoprimitia tomokoae* (Ishizaki, 1964b)	12			
17	*Punctoprimitia tumida* (Ishizaki, 1964b)	17			
18	*Punctoprimitia* sp.	8			
19	*Pseudobythocypris asiatica* n. sp.	44			○
20	*Pseudobythocypris zipangu* n. sp.	2			
21	*Pseudobythocypris siveteri* n. sp.	81			
22	*Bairdia hanaii* Ishizaki, 1963		2		
23	*Bairdia* sp.		3		
24	*Platyrhomboides tohokuensis* n. sp.	10			
25	*Platyrhomboides japonica* n. sp.	7			
26	*Healdia* cf. *H. simplex* Roundy, 1926	15			
27	*Healdia ofunatensis* n. sp.	33			
28	*Healdia rikutyuensis* n. sp.	14			
29	*Healdia* sp.	12			
30	*Waylandella* sp.	1			
	Total	328	16		

Pennsylvanian Hoxbar Formation, Ardmore, Oklahoma, USA, in its left valve overlapping with the right valve along the dorsal and ventral margins, but it differs in that it has a trapezoidal lateral outline, a depression at the postero-ventral area, and a posterior margin truncated at mid-height from the venter.

Healdia sp.
Figures 11.9–11.12, 17

Occurrence.—Locality 36 of Kobayashi (1973), Middle Member of the Nagaiwa Formation, Nagaiwa, Ofunato City, Iwate Prefecture, Northeast Japan, Bashkirian.

Material.—One carapace, length = 492 µm, height = 308 µm, IGPS-112727.

Remarks.—*Healdia* sp. resembles *Healdia cara* Bradfield, 1935, from the Pennsylvanian Deese? Formation, northeastern Ardmore, Oklahoma, USA, in its straight dorsal margin, but it differs in that it has a postero-dorsally protruded posterior margin, its highest point at two-thirds from the anterior end, and a widely arched anterior margin. This species is also similar to *H. ovata* Bradfield, 1935, from the Pennsylvanian Hoxbar Formation, Ardmore, Oklahoma, USA, in its straight ventral margin, but it differs in that it has an antero-ventrally protruded anterior margin, its highest point at two-thirds distance from the anterior end, and a postero-dorsally protruded posterior margin. *Healdia* sp. is similar to *Healdia luculenta* Jiang in Jiang et al., 1995, from the Pennsylvanian Xiaohaizi Formation, Xinjiang, China, in its arched dorsal margin, but it differs in that it has a postero-dorsally protruded posterior margin, its highest point at two-thirds from the anterior end, and a sinuate ventral margin.

Genus *Waylandella* Coryell and Billings, 1932

Type species.—*Waylandella spinosa* Coryell and Billings, 1932 (Columbia University Paleontology Collection No. 25233) from

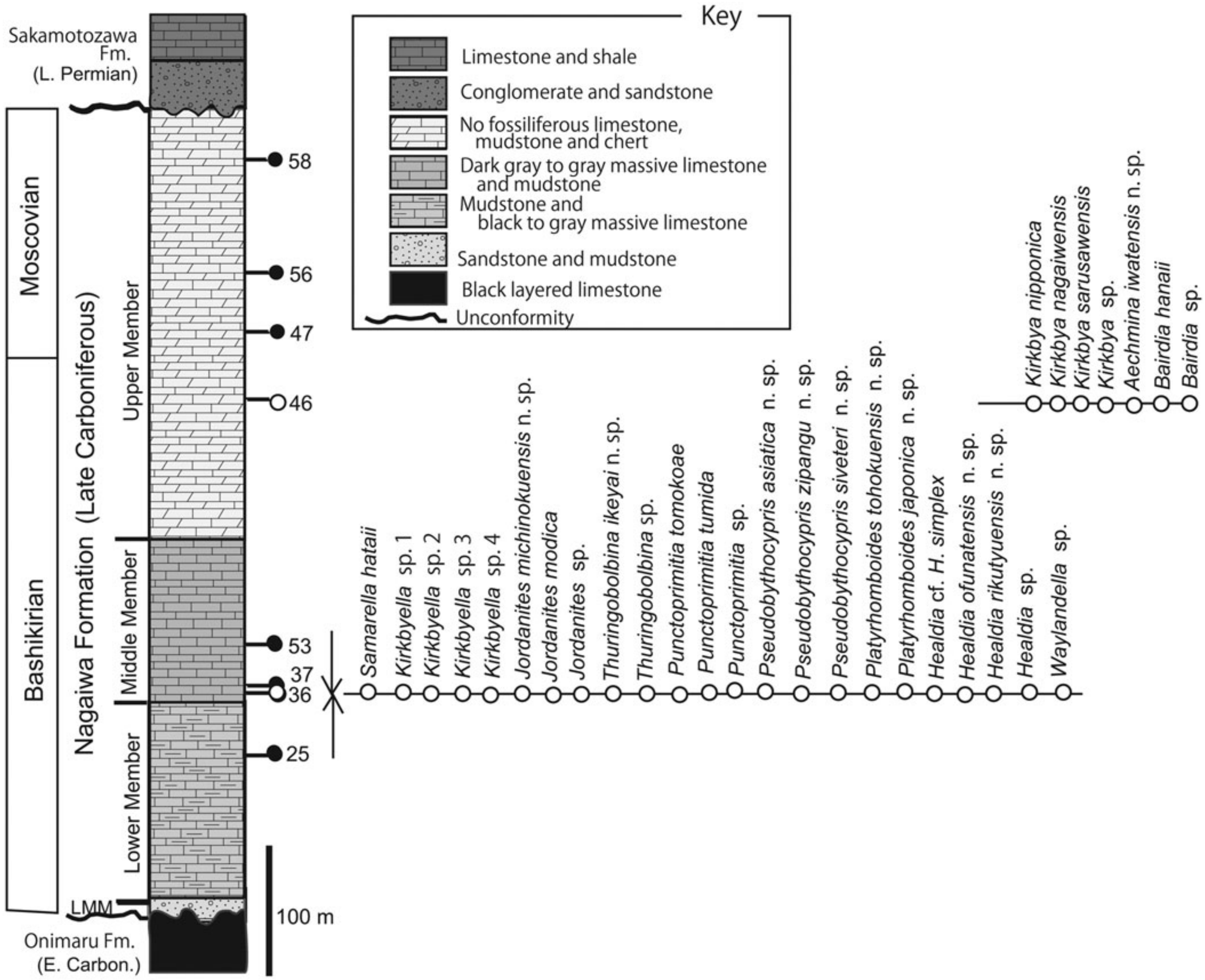

Figure 18. Ostracode assemblages from two sample localities. White circles show that ostracodes were recovered (localities 36 and 46), shaded circles show that there were no ostracodes. Abbreviations: Fm., Formation; L., Lower.

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Table 2. Hollinellid ostracodes from the Pennsylvanian. Location (Loc[s]) numbers correspond to those in Figure 12. Gray-shaded lines show the genus *Jordanites*.

Loc(s).	Species	Remarks
1	*Jordanites michinokuensis* n. sp.	NE Japan (This study)
1, 5	*Jordanites modica* (Jiang in Jiang et al., 1995)	Xinjiang (Jiang et al., 1995); This study
2	no hollinellids	Shanxi (Shi, 1987)
3	no hollinellids	Guanxi (Shi and Li, 1988)
4	no hollinellids	N China (Tianjin Institute of Geology and Mineral Resources, 1984)
5	*Hollinella glabra* Jiang in Jiang et al., 1995	Xinjiang (Jiang et al., 1995)
5	*Hollinella nodulosa* Jiang in Jiang et al., 1995	Xinjiang (Jiang et al., 1995)
5	*Hollinella valida* Jiang in Jiang et al., 1995	Xinjiang (Jiang et al., 1995)
5	*Hollinella* aff. *H. inflata* Coryell and Osorio, 1932	Xinjiang (Jiang et al., 1995, specimen is not *H. inflata* in having a protruded L3 over the dorsal margin)
6	*Hollinella orientalis* Gorak, 1958	Ukraine (Gorak, 1958)
6	*Hollinella insignita* Gorak, 1964	Ukraine (Gorak, 1964)
6	*Hollinella granuloba* Fohrer in Fohrer et al., 2007	Ukraine (Fohrer et al., 2007)
6	*Hollinella kamenka* Fohrer in Fohrer et al., 2007	Ukraine (Fohrer et al., 2007)
6	*Jordanites krasnodonensis* Fohrer in Fohrer et al., 2007	Ukraine (Fohrer et al., 2007)
7, 15	*Hollinella plauta* Kesling and Tabor, 1953	Michigan (Kesling and Tabor, 1953), New York (Stover, 1956)
8	*Hollinella elongata* Cooper, 1946	Illinois (Cooper, 1946)
8	*Hollinella grandis* Cooper, 1946	Illinois (Cooper, 1946)
8	*Hollinella minuta* Cooper, 1946	Illinois (Cooper, 1946)
8, 12	*Hollinella moorei* Cooper, 1946	Illinois (Cooper, 1946), Texas (Moore, 1929)
8, 9	*Hollinella warthini* Cooper, 1946	Illinois (Cooper, 1946); Oklahoma (*Hollinella digitata* Kellett, 1929)
8, 9, 12	*Hollinella grahamensis* (Harlton, 1927)	Illinois (Cooper, 1946); Oklahoma (Harlton, 1927); Texas (Harlton, 1927, 1929a)
8, 11	*Hollinella gibbosa* Kellett, 1929	Illinois (Cooper, 1946); Kansas (Kellett, 1929)
8, 11	*Hollinella burlingamensis* Kellett, 1933	Illinois (Cooper, 1946); Kansas (Kellett, 1933)
8, 11	*Hollinella emaciata* (Ulrich and Bassler, 1906)	Illinois (Cooper, 1946); Kansas (Ulrich and Bassler, 1906; Kellett, 1929)
8, 11	*Hollinella crassamarginata* Kellett, 1929	Illinois (Cooper, 1946), Kansas (Kellett, 1929)
8, 11	*Hollinella cushmani* Kellett, 1933	Illinois (Cooper, 1946; Tibert et al., 2013); Kansas (Kellett, 1933)
8, 11, 12	*Hollinella shawnensis* Kellett, 1929	Illinois (Cooper, 1946); Kansas (Kellett, 1929); Texas (*H. kellettae* Coryell and Booth, 1933)
8, 9	*Hollinella nowatensis* Coryell and Osorio, 1932	Illinois (Cooper, 1946); Oklahoma (Coryell and Osorio, 1932)
8, 9	*Hollinella radleae* Harlton, 1928	Illinois (Cooper, 1946); Oklahoma (Harlton, 1928)
8, 9, 12	*Hollinella reguralis* Coryell, 1928	Illinois (Cooper, 1946); Oklahoma (Coryell, 1928; *H. menardensis* Harlton, 1929b); Texas (*H. fortscottensis* Harlton, 1929a, and *H. buehleri* Harlton, 1929a)
9	no hollinellids	Oklahoma, Arkansas (Harlton, 1929b)
9	*Hollinella inflata* Coryell and Osorio, 1932	Oklahoma (Coryell and Osorio, 1932)
8, 9, 12	*Hollinella oklahomaensis* (Harlton, 1928)	Illinois (Cooper, 1946); Oklahoma (Harlton, 1928); Texas (Harlton, 1929a)
8, 11	*Hollinella kellettae* Knight, 1928a	Illinois (Cooper, 1946); Colorado (McLaughlin, 1952); Kansas (Kellett, 1933)
11	*Hollinella nebensis* Kellett, 1929	Kansas (Kellett, 1929)
11	*Hollinella digitata* Kellett, 1929	Kansas (Kellett, 1929); Texas (Coryell and Sample, 1932)
11	*Hollinella harltoni* Kellett, 1929	Kansas (Kellett, 1929); Texas (Coryell and Sample, 1932)
12	*Hollinella granifera* (Ulrich, 1891)	Texas (Harlton, 1927)
12	*Hollinella tricollina* (Ulrich, 1891)	Texas (Harlton, 1927); New York (Stover, 1956)
12	*Hollinella herrickiana* (Girty, 1909)	Texas (Delo, 1930)
12	*Hollinella occidentalis* (Girty, 1910)	Texas (Delo, 1930)
12	*Hollinella australis* Delo, 1930	Texas (Delo, 1930)
12	*Hollinella bulbosa* Coryell and Sample, 1932	Texas (Coryell and Sample, 1932)
13, 15, 21?	*Hollinella ulrichi* (Kinght, 1928a)	Missori (Knight, 1928a); Bristol (Bless, 1974); Libya (Bless and Massa, 1982, not illustrated)
13	*Hollinella buehleri* (Kinght, 1928a)	Missouri (Knight, 1928a)
14, 15?, 21?	*Hollinella radiata* Jones and Kirkby, 1867	Scottland (Jones and Kirkby, 1867); England (Latham, 1932, not illustrated); Kansas (Ulrich and Bassler, 1906); Libya (Bless and Massa, 1982, not illustrated; Bless, 1983)
14	*Hollinella avonensis* Latham, 1932	Scottland (Latham, 1932)
15	*Hollinella spinulosa* Demanet, 1949	Bristol (Bless, 1974)
15, 18	*Jordanites cristinae* (Bless, 1967)	Bristol (Bless, 1974); NW Spain (Bless, 1967, 1968, 1983)
15	*Hollinella claycrossensis* (Bless and Calver, 1970)	Coal measures (Bless and Calver, 1970; Athersuch et al., 2009)
17	*Hollinella sella* Stover, 1956	New York (Stover, 1956)
17	*Hollinella retusilobata* Stover, 1956	New York (Stover, 1956)
17	*Hollinella epakra* Stover, 1956	New York (Stover, 1956)
17	*Hollinella ampulla* Stover, 1956	New York (Stover, 1956)

18	no hollinellids	Spain (Requadt et al., 1977; Becker, 1982)
18	*Hollinella camoni* (Bless, 1968)	NW Spain (Bless, 1968)
18	*Hollinella hispanica* (Bless, 1968)	NW Spain (Bless, 1968)
18	*Hollinella philomenae* (Bless, 1967)	NW Spain (Bless, 1967, 1968)
18	*Jordanites rawihinggili* (Bless, 1967)	NW Spain (Bless, 1967, 1968)
18	*Hollinella fraderae* (Bless, 1965)	NW Spain (Bless, 1965, 1967)
18	*Hollinella* cf. *H. avonensis* (Latham, 1932)	N Spain (Bless, 1969)
19	no hollinellids	Algentina (Saravia and Jones, 1999)
16, 20	*Hollinella bassleri* (Knight, 1928a)	Belgium (Demanet, 1949); Arizona (Lundin and Sumrall, 1999 [also mentioned that *H. menadensis* is conspecific with this species])
20	*Hollinella* aff. *H. buehleri* (Knight, 1928a)	Belgium (Demanet, 1949, specimens differ from type specimen in having rounded large L3)
22	*Hollinella* aff. *H. radiata* (Jones and Kirkby, 1886)	Austria (Sanchez de Posada's, 1977, *H.* cf. *H. radiata* is also included *H.* aff. *H. radiata*; Fohrer and Samankassou, 2005)
22	*Hollinella* aff. *H. camoni* (Bless, 1968)	Austria (Sanchez de Posada, 1977)
23	*Jordanites reticularis* Błaszyk and Natusiewicz, 1973	Poland (Błaszyk and Natusiewicz, 1973)
24	no hollinellids	Hungary (Kozur, 1985)
25	*Hollinella* aff. *H. ulrichi* Knight, 1928a	Moscow Basin (Kotschetkova, 1985)
18, 25	*Jordanites camochensis* Sanchez de Posada, 1977	N. Spain (Sanchez de Posada, 1977), Moscow Basin (Kotschetkova,1985)
26	no hollinellids	Southern Urals (Kochetkova, 1983)
26	no hollinellids	Southern Urals (Kochetkova, 1984)
27	no hollinellids	Eastern Desert Egypt (Omara and Gramann, 1966)
27	no Carboniferous hollinellids	SW China (Chengdu Institute of Geology and Mineral Resources, 1983)
28	no Carboniferous hollinellids	Yangtze Gorge (Yichan Institute of Geology and Mineral Resources, 1984)
29	no Carboniferous hollinellids	Central southern China (Guan et al., 1978)
30	no hollinellids	Anhui (Chen and Bao, 1990)
31	*Jordanites henanensis* Zhang in Zhang and Liang, 1991	Henan (Zhang and Liang, 1991)
31	*Hollinella bicornuta* Zhang in Zhang and Liang, 1987	Henan (Zhang and Liang, 1987)
31	*Hollinella* aff. *H. schreteri* Kozur, 1985	Henan (Zhang and Liang's, 1991, specimen differs from the type species having rounded L2; Zhang and Liang's, 1987, *H. ulrichi* is identified as this species)
31	*Hollinella* aff. *H. bassleri* Knight, 1928a	Henan (Zhang and Liang's, 1991, specimen differs from the type species in having the L3 protruded dorsally)
31	*Hollinella* aff. *H. spinulosa* Demanet, 1949	Henan (Zhang and Liang's, 1987, specimen differs from the type specimen in having a large L2)
31	*Hollinella* aff. *H. ulrichi* Knight, 1928a	Henan (Zhang and Liang's, 1987, specimen is not the same as the type species in having a priminent postero-ventral spine)
31	*Jornanites* cf. *J. honeei* Bless, 1985	Henan (Zhang and Liang, 1987)
31	non *Jordanites rawihinggili* (Bless, 1967)	Henan (Zhang and Liang's, 1987, juvenile specimen is not the juvenile of *J. rawihinggili* because of the less prominent L2 and shape of the spines)
31	*Jordanites* aff. *J. cristinae* (Bless, 1967)	Henan (Zhang and Liang, 1987, figured as *H. cristinae*, but their specimen differs from *H. cristinae* because it lacks a ventral lobe); Zhang and Liang, 1991, identified female specimens of *J.* aff. *J. schreteri*)

the Wayland Shale, the uppermost member of the Graham Formation in North central Texas, USA, by original description.

Waylandella sp.
Figure 10.17–10.20

Occurrence.—Locality 36 of Kobayashi (1973), Middle Member of the Nagaiwa Formation, Nagaiwa, Ofunato City, Iwate Prefecture, Northeast Japan, Bashkirian.

Material.—One carapace, IGPS-112728.

Remarks.—*Waylandella* sp. resembles *Waylandella spinosa* (Coryell and Billings, 1932) from the Pennsylvanian Wayland Shale, Texas, USA, in its antero-ventrally protruded anterior margin, but it differs in that it has an orthogonal posterior cardinal angle, its highest point at mid-length from the venter, and a longer lateral outline. *Waylandella* sp. is also similar to *W. boleensis* Jiang in Jiang et al., 1995, from the Pennsylvanian Dongtujinhe Formation, Xinjiang, China, in its elongate lateral outline, but it differs in that it has an antero-ventrally protruded anterior margin, widely arched dorsal margin, and a sinuate ventral margin. *Waylandella* sp. is similar to *W. insolita* Jiang in Jiang et al., 1995, from the Pennsylvanian of Xinjiang, China, in its narrowly arched anterior margin, but it differs in that it has an elongate lateral outline, its highest point at mid-length from the anterior end, and a sinuate ventral margin.

Results

Only two of the eight samples contained ostracodes, these being sample locality No. 36 (39°08′51.5″N, 141°38′56.7″E) from the Middle Member and sample locality No. 46 (39°09′00.8″N, 141°38′52.7″E) from the Upper Member. Furthermore, specimens from sample locality No. 46 were deformed due to diagenesis. Totals of 328 specimens and 16 specimens were extracted from No. 36 and No. 46, respectively (Table 1). Thirty ostracode species, including 12 genera, were identified (Table 1; Fig. 18), most of which were endemic species and 10 of which were new species. The details of each species are provided in the next section. Conodont elements that contain P_1 elements of *Neognathodus* spp. were recovered from localities No. 30 and No. 46, respectively (T. Maekawa, personal communication, March 23, 2022). *Neognathodus* is an index genus for the Bashkirian–Moscovian, and supports the determination of the age of the Nagaiwa Formation from fusulinids (Kobayashi, 1973).

Paleoecology of ostracodes from the Nagaiwa Formation

The assemblages from the Middle Member (No. 36) contained many ostracodes, including *Samarella hataii*, two *Kirkbya* species, three *Jordanites* species, two *Thuringobolbina* species, three *Punctoprimitia* species, three *Pseudobythocypris* species, two *Platyphomboides* species, four *Healdia* species, and one species of *Weylandella*. Based on a comparison with European assemblages, the ostracode fauna suggests a marine nearshore environment (Bless, 1983). *Jordanites*, *Kirkbya*, and *Healdia*, which have been reported from the Pennsylvanian paralytic coal basins of northern Spain, indicate marine nearshore to shallow offshore environments (Bless, 1983). In other localities, *Samarella*, *Thuringobolbina*, and *Punctopurimitia* have been reported from Ordovician (Russia) to Devonian (Russian Platform, northern Spain, Australia, and Ohio) sedimentary deposits. These genera, however, have not been reported previously from the Carboniferous. *Thuringobolbina* has been reported in non-polyzoan/sponge assemblages from the Devonian *Receptaculites* Limestone, New South Wales, Australia (Reynolds, 1978), where the depositional environment seems to be a fairly stable offshore shelf environment. *Thuringobolbina* has not been reported from other Carboniferous localities; thus, its microhabitat is uncertain.

Compared with ostracode species from the Middle Member, the Upper Member ostracodes are fewer and have low diversity (Fig. 18). Stocker et al. (2016) first reported a “Eiferian mega-assemblage” from central Japan (the Middle Moscovian Ichinotani Formation) composed of *Amphissites*, *Kirkbya*, *Bairdia*, *Aechmina*, and *Healdia*. The Eiferian mega-assemblage

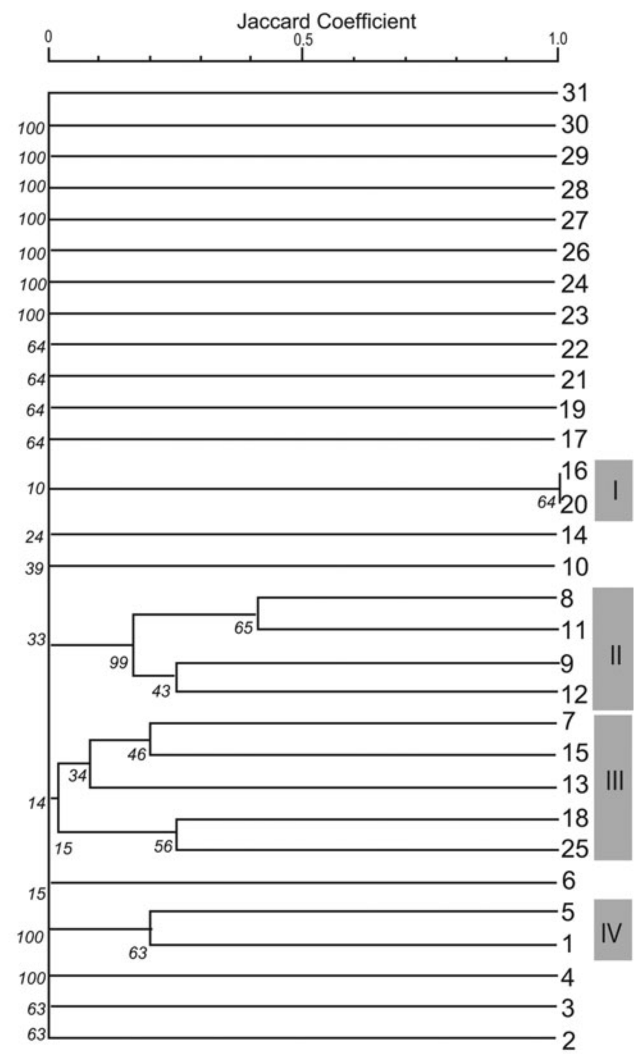

Figure 19. Dendrogram of Q-mode cluster analysis of Hollinellid ostracodes from the Pennsylvanian of the world. Original data are from Table 2 and data matrix, both attached in Supplement 1. Roman numerals correspond to localities in Table 2. Italic number of each node shows the Bootstrap values (n = 1000).

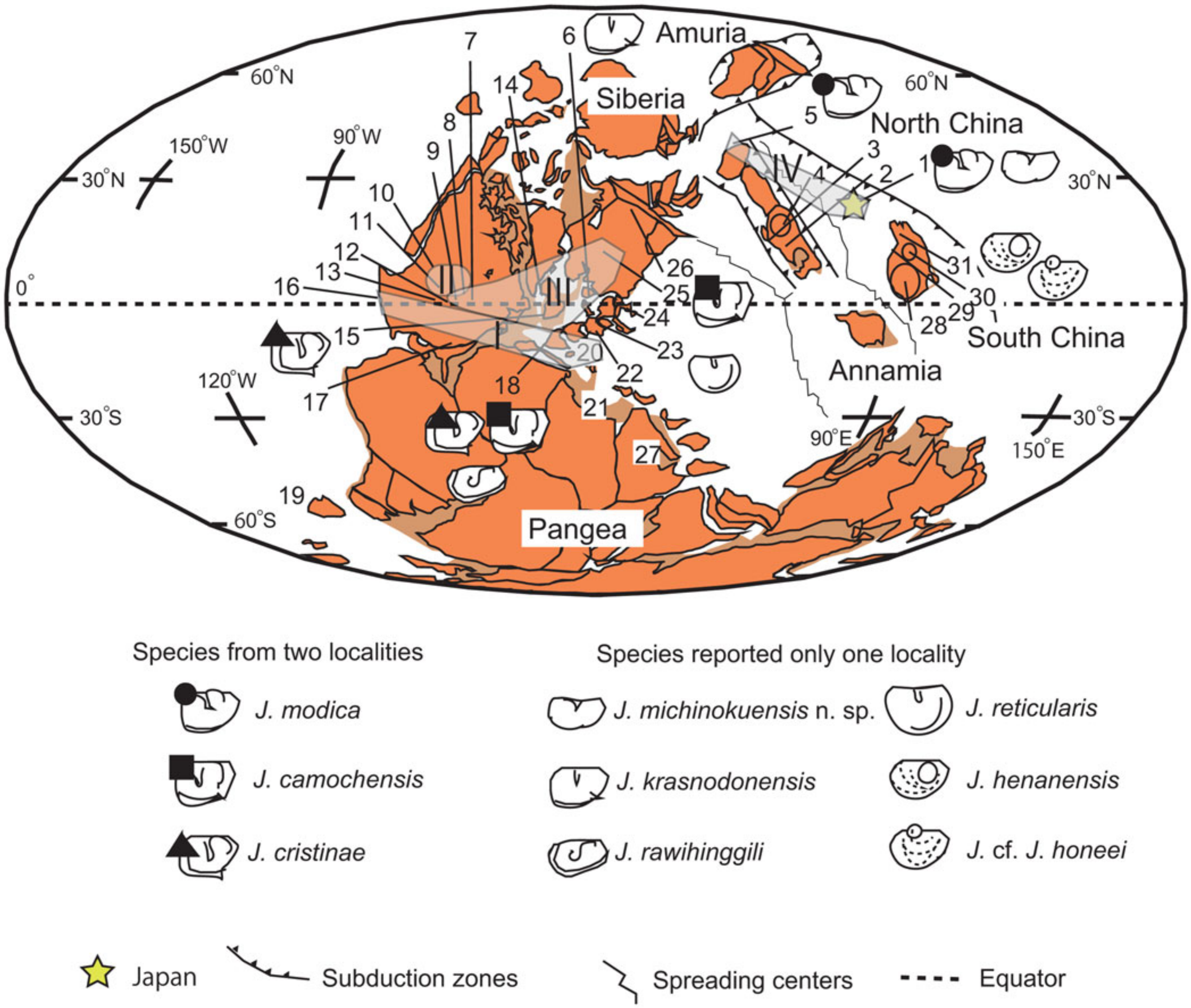

Figure 20. Paleogeographical distribution of shallow-marine *Jordanites* species during Pennsylvanian. Paleogeographic map is from Torsvik and Cocks (2017). Each Arabic numeral corresponds to the locality number in Table 2, and each Roman numeral (I–IV) shows Hollinellid association detected from Q-mode cluster analysis of Figure 19.

typically represents high-energy turbulent conditions in a shallow carbonate platform setting (Becker, 1971). In summary, the ostracode assemblages from the two sample localities of the Nagaiwa Formation indicate shallow marine conditions.

Paleogeography of the Pennsylvanian of Japan

Species of *Hollinella* and *Jordanites* were widely distributed during the Pennsylvanian in a limited range of marine-nearshore and shallow-offshore environments (Bless, 1983) as is the extant podocopid ostracode (Tanaka and Ikeya, 2002). Seventy-one *Hollinella* and *Jordanites* species have been reported from 31 localities in Pennsylvanian strata around the world (Table 2). Q-mode cluster analysis of these globally distributed hollinellid taxa connected by UPGMA (unweighted pair group method with arithmetic mean) using Jaccard coefficient in the software PAST (Hammer et al., 2001) showed that four Hollinellid associations could be recognized (Fig. 19): Association I was characterized by *H. bassleri* Knight, 1928a, at Locs. 16, 20; Association II consists of four localities (Locs. 8, 9, 11, 12) and was characterized by *H. grahamensis* (Harlton, 1927), *H. shawnensis* Kellett, 1929, and *H. oklahomaensis* (Harlton, 1928); Association III was characterized by *H. plauta* Kesling and Tabor, 1953, *J. camochensis* Sanchez de Posada, 1977, and *J. cristinae* from five localities (Locs. 7, 13, 15, 18, and 25); and Association IV consisted of two localities (Locs. 1, 5) and is characterized by *J. modica*.

Three associations (I–III) were distributed around the equatorial region of the Pangea paleocontinent, but association IV was distributed between the eastern part of North China and the South Kitakami belt (Fig. 20). Nine *Jordanites* species have been reported; with three species in two localities, and six confined to one locality (Fig. 20). *Jordanites modica* has been reported from Japan (Loc. 1 in Table 2, Fig. 20) and the

Tarim Basin (Loc. 5 in Table 2, Fig. 20), but not reported from South China (Locs. 28–32). *Jordanites camochensis* was found in Spain (Loc. 18) and the Moscow Basin (Loc. 25), *Jordanites cristinae* has been reported from southern England (Loc. 15) and Spain (Loc. 18). These two species, *J. camochensis* and *J. cristinae*, occur in the eastern margin of the Pangea paleocontinent near the equator.

Conclusions

Thirty ostracode species, including 12 genera, have been identified from the Pennsylvanian Nagaiwa Formation, Northeast Japan. The ostracode assemblages from the Nagaiwa Formation indicate a shallow marine environment and are assigned to the Eiferian mega-assemblage which typically represents high-energy turbulent conditions in a shallow carbonate platform setting. The ostracodes from the Nagaiwa Formation show no clear affinities with any other comparably aged fauna.

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Declaration of competing interests

There are no conflicts of interest to declare.

Data availability statement

Data available from the Dryad Digital Repository: https://doi.org/10.5061/dryad.j0zpc86jg

References

Adachi, S., 1987, Ostracodes from the Ichinotani Formation (Carboniferous and Permian), Fukuji, Hida Massif, central Japan: XI Congres International de Stratigraphie et de Géologie du Carbonifère Beijing, Beijing, China, 1987, Compte Rendu v. 3, p. 1–5.

Athersuch, J., Gooday, A., Pollard, J.E., and Riley, N.J., 2009, Carboniferous, *in* Whittacker, J.E., and Hart, M.B., eds., Ostracods in British Stratigraphy: The Micropalaeontological Society, Special Publication, Geological Society of London, p. 111–153.

Becker, G., 1971, Paleoecology of Middle Devonian ostracods from the Eifel region, Germany, *in* Oertli, H.J., ed. Paléoécologie des Ostracodes: Bulletin du Centre de Recherches Pau-SNPA, v. 5 (supplement), p. 801–816.

Becker, G., 1982, Fazies-anzeigende Ostracoden-Vergesellschaftungen aus dem frühen Oberkarbon des Kantabrischen Gebirges (N-Spanien): Neues Jahrbuch für Mineralogie, Geologie und Paläontologie, Abteilung B, v. 164, p. 307–338.

Becker, G., and Sánchez de Posada, L.C., 1977, Ostracoda aus der Moniello-Formation Asturiens (Devon; N-Spanien): Sonder-Abdruck aus Palaeontographica Beiträge zur Naturgeschichte Vorzeit, Abteilung A, v. 158, p. 115–203.

Becker, G., and Wang, S.-Q., 1992, Kirkbyacea and Bairdiacea (Ostracoda) from the Palaeozoic of China: Sonder-Abdruck aus Palaeontographica Beiträge zur Naturgeschichte Vorzeit, Abteilung A, v. 224, p. 1–54.

Błaszyk, J., and Natusiewicz, D., 1973, Carboniferous ostracods from the borings in northwestern Poland: Acta Palaeontologica Polonica, v. 18, p. 117–151.

Bless, M.J.M., 1965, On the two new species of marine ostracodes in the Carboniferous of Asturias, Spain: Leidse Geologische Mededelingen, v. 33, p. 177–182.

Bless, M.J.M., 1967, On the marine beds of some cyclothems in the central Carboniferous basin of Asturias with especial reference to their ostracode fauna: Notas y Comunicationes del Instituto Geológico, y Minero de España, v. 99/100, p. 91–134.

Bless, M.J.M., 1968, On two hollinid ostracode genera from the upper Carboniferous of northwestern Spain: Leidse Geologische Mededelingen: v. 43, p. 157–212.

Bless, M.J.M., 1969, On a case of dimorphism in the last juvenile stage of a hollinid ostracode from the Namurian B-C of the La Camocha Mine (Gijon, N. Spain): Brevia Geologica Asturica, v. 13, p. 31–38.

Bless, M.J.M., 1974, III. Ostracods from Croft's End marine band (base of Westphalian C) of the Bristol District: Bulletin of the Geological Survey of Great Britain, v. 47, p. 39–53.

Bless, M.J.M., 1983, Late Devonian and Carboniferous ostracode assemblages and their relationship to the depositional environment: Bulletin van de Belgische Vereniging voor Geologie, v. 92, p. 31–53.

Bless, M.J.M., 1985, Ostracodes, *in* Dreesen, R., Bless, M.J.M., Conil, R., Flajs, G., and Laschet, C., eds. Depositional Environment, Paleoecology and Diagenetic History of the 'Marbre Rouge a Crinoides de Baelen' (Late Upper Devonian, Verviers Synclinorium, Eastern Belgium): Annals de la Société Géologique de Belgique, v. 108, p. 311–359.

Bless, M.J.M., and Calver, M.A., 1970, A hollinid ostracod from the middle coal measures of Britain: Bulletin of the Geological Survey of Great Britain, v. 32, p. 61–67.

Bless, M.J.M., and Jordan, H., 1971, Classification of palaeocopid ostracodes belonging to the families Ctenoloculinidae, Hollindae and Hollinellidae, *in* Oertli, H.J., ed. Paléoécologie des Ostracodes: Bulletin du Centre de Recherches Pau-SNPA, v. 5, supplement, p. 869–890.

Bless, M.J.M., and Massa, D., 1982, Carboniferous ostracodes in the Rhadamès Basin of western Libya: paleoecological implications and comparison with North America Europe and the USSR: Revue de l' Institut Francais du Petrole, v. 37, p. 20–61.

Bouček, B., 1936, Die Ostracoden des böhmischen Ludlows (Stufe eβ): Neues Jahrbuch für Mineralogie, Geologie und Paläontologie, Abteilung B, v. 76, p. 31–98.

Bradfield, H.H., 1935, Pennsylvanian Ostracoda of the Ardmore Basin, Oklahoma: Bulletin of American Paleontology, v. 22, p. 1–173.

Buschmina, L.S., 1975, Early Carboniferous Ostracoda of the Kolymsky Massiv: Moscow, Nauka, 103 p.

Chen, D., and Bao, H., 1990, Discovery of ostracodes from the upper Wutung Group of Chaohu, Anhui and its significance: Acta Micropalaeontologica Sinica, v. 7, p. 123–139.

Chengdu Institute of Geology and Mineral Resources, ed., 1983, Paleontological Atlas of Southwest China: Beijing, Geological Publishing Press, 256 p.

Cooper, C.L., 1946, Pennsylvanian ostracodes of Illinois: Bulletin of the Illinois State Geological Survey, no. 70, p. 1–177.

Cordell, R.J., 1952, Ostracodes from the Upper Pennsylvanian of Missouri. Part I, the family Bairdiidae: Journal of Paleontology, v. 26, p. 74–112.

Coryell, H.N., 1928, Some new Pennsylvanian Ostracoda: Journal of Paleontology, v. 2, p. 377–381.

Coryell, H.N., and Billings, G.D., 1932, Pennsylvanian Ostracoda of the Wayland Shale of Texas: American Midland Naturalist, v. 13, p. 170–189.

Coryell, H.N., and Booth, R.T., 1933, Pennsylvanian Ostracoda; a continuation of the study of the Ostracoda fauna from the Wayland Shale, Graham, Texas: American Midland Naturalist, v. 14, p. 258–279.

Coryell, H.N., and Osorio, G.A., 1932, Pennsylvanian Ostracoda: an Ostracoda fauna of the Nowata Shale: American Midland Naturalist, v. 13, p. 25–39.

Coryell, H.N., and Sample, C.H., 1932, Pennsylvanian Ostracoda: a study of the Ostracoda fauna of the East Mountain Shale, Mineral Wells Formation, Mineral Wells, Texas: American Midland Naturalist, v. 13, p. 245–281.

Crasquin, S., Forel, M.-B., Yuan, A., Nestell, G., and Nestell, M., 2018, Species of *Hollinella* (Palaeocopida: Ostracoda: Crustacea) as stratigraphical indices of the late Permian–Early Triassic post-extinction interval: Journal of Systematic Palaeontology, v. 16, p. 213–224.

Delo, D.M., 1930, Some upper Carboniferous Ostracoda from the Shale Basin of Western Texas: Journal of Paleontology, v. 4, p. 152–178.

Demanet, F., 1949, Contribution a l'etude de la microfaune marine du Westphalien de la Campine: Bulletin de l'Institut Royal des Sciences Naturelles de Belgique, v. 25, p. 1–16.

Dewey, C.P., 1983, The Taxonomy and Palaeoecology of Lower Carboniferous Ostracodes and Perecarids (Crustacea from Southwestern Newfoundland and Central Nova Scotia) [Ph.D. dissertation]: St. John's, Newfoundland, Memorial University of Newfoundland, 383 p.

Ehiro, M., 2001, Origins and drift histories of some microcontinents distributed in the eastern margin of Asian continent: Earth Science (Chikyu Kagaku), vol. 55, p. 71–81.

Fohrer, B., and Samankassou, E., 2005, Paleoecological control of ostracode distribution in a Pennsylvanian Auernig cyclothem of the Carnic Alps, Austria: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 225, p. 317–330.

Fohrer, B., Nemyrovska, T.I., Samankassou, E., and Ueno, K., 2007, The Pennsylvanian (Moscovian) Izvarino section, Donets Basin, Ukraine: a multidisciplinary study on microfacies, biostratigraphy (conodonts, foraminifers, and ostracodes), and paleoecology: Journal of Paleontology, v. 81, supplement 69 (The Paleontological Society Memoir 69), p. 1–85.

Girty, G.H., 1909, Ostracoda, *in* Lee, W.T., and Girty, G.H., eds. The Manzano Group of the Rio Grande Valley, New Mexico: United States Geological Survey, Bulletin 389, p. 115–117.

Girty, G.H., 1910, The fauna of the phosphate beds of the Park City Formation in Idaho, Wyoming, and Utah: United States Geological Survey, Bulletin 436, p. 55–58.

Glebovskaya, E.M., 1939, Upper Paleozoic Ostracoda from the northern Ural Mountains: Trudy Neftyanogo Geologo-Razvedochnogo Instituta, Seriya A, v. 115, p. 165–176.

Gorak, S.V., 1958, Ostracoda from the Deyak horizon of the middle and upper Carboniferous of the Donetsk Basin: Trudy Instituta Geologicheskikh Nauk Akademii Nauk Ukrainskoy SSR, Seriya Stratigraphii i Paleontologii, v. 28, p. 3–75.

Gorak, S.V., 1964, Upper Visean and lower Namurian Ostracoda from certain regions of the northwestern part of the Greater Donetsk Coal Basin: Trudy Instituta Geologicheskikh Nauk Akademii Nauk Ukrainskoy SSR, Seriya Stratigraphii I Paleontologii, v. 48, p. 154–204, 264–271.

Groos-Uffenorde, H., Schindler, E., Becker, R.T., Dojen, C., Brocke, R., and Jansen, U., 2022, Late Early Devonian ostracodes from the Torkoz area (SW Morocco) and the Emsian/Eifelian boundary: PalZ, v. 96, p. 689–747.

Guan, S.Z., Sun, Q.Y., and Jiang, Y.W., 1978, Description of ostracodes, *in* Zhongnan Diqu Gushengwu Tuce, ed. Fossils of Central Southern China 4 Microfossils: Beijing, Geological Publishing Press, p. 115–325, 682–710.

Hammer, Ø., Harper, D.A., Ryan, P.D., 2001, PAST: paleontological statics software package for education and data analysis: Palaeontologia Electronica, v. 49. https://palaeo-electronica.org/2001_1/past/issue1_01.htm.

Hanai, T., Ikeya, N., Ishizaki, K., Sekiguchi, Y., and Yajima, M., 1977, Checklist of Ostracoda from Japan and its adjacent seas: The University Museum, The University of Tokyo, Bulletin, no. 12, p. 1–110.

Harlton, B.H., 1927, Some Pennsylvanian Ostracoda of the Glenn and Hoxbar formations of southern Oklahoma and of the upper part of the Cisco Formation of northern Texas: Journal of Paleontology, v. 1, p. 203–212.

Harlton, B.H., 1928, Pennsylvanian ostracods of Oklahoma and Texas: Journal of Paleontology, v. 2, p. 132–141.

Harlton, B.H., 1929a, Pennsylvanian Ostracoda from Menard County, Texas: University of Texas Bulletin, no. 2901, p. 139–161.

Harlton, B.H., 1929b, Some Upper Mississippian (Fayetteville) and Lower Pennsylvanian (Wapanucka–Morrow) Ostracoda of Oklahoma and Arkansas: American Journal of Science, v. 18, p. 254–270.

Harlton, B.H., 1933, Micropaleontology of the Pennsylvanian Johns Valley Shale of the Ouachita Mountains, Oklahoma, and its relationship to the Mississippian Caney Shale: Journal of Paleontology, v. 7, p. 3–29.

Harris, R.W., 1957, Ostracoda of the Simpson Group of Oklahoma: Bulletin, Oklahoma Geological Survey, v. 75, p. 1–333.

Henningsmoen, G., 1953, Classification of Paleozoic straight-hinged ostracods: Norsk Geologisk Tidsskrift, v. 31, p. 185–288.

Henningsmoen, G., 1965, On certain features of palaeocope ostracodes: Geologiska Föreningens I Stockholm Förhandlingar, v. 86, p. 329–394.

Ishizaki, K., 1963, On some Carboniferous ostracodes of the genus *Bairdia* from Japan: Japan Journal of Geology and Geography, v. 34, p. 161–175.

Ishizaki, K., 1964a, Middle Permian ostracodes from the Iwaizaki Limestone, Northeast Japan: Tohoku University Scientific Report Second Series (Geology), v. 36, p. 139–160.

Ishizaki, K., 1964b, On some Carboniferous ostracod genera from Japan: Saito Ho-on Kai Museum Research Bulletin, no. 33, p. 30–42.

Ishizaki, K., 1967, Ostracodes from the lower Permian Tassobe Formation, Japan: Saito Ho-on Kai Museum Research Bulletin, no. 36, p. 49–67.

Ishizaki, K., 1968, On some Carboniferous ostracodes from the Takezawa Formation, Northeast Japan: Saito Ho-on Kai Museum Research Bulletin, no. 37, p. 11–16.

Isozaki, Y., 2019, A visage of early Paleozoic Japan: geotectonic and paleobiogeographical significance of Greater South China: Island Arc, v. 28, e12296. https://doi.org/10.1111/iar.12296.

Isozaki, Y., Maruyama, S., Aoki, K., Nakama, T., Miyashita, A., and Otoh, S., 2010, Geotectonic subdivision of the Japanese Islands revisited: categorization and definition of elements and boundaries of Pacific-type (Miyashiro-type) orogen: Journal of Geography, v. 119, p. 999–1053.

Isozaki, Y., Maruyama, S., Nakata, T., Yamamoto, S., and Yanai, S., 2011, Growth and shrinkage of an active continental margin: updated geotectonic history of the Japanese Islands: Journal of Geography, v. 120, p. 65–99.

Isozaki, Y., Aoki, K., Sakata, S.. and Hirata, T., 2014, The eastern extension of Paleozoic South China in NE Japan evidenced by detrital zircon: GFF, vol. 136, p. 123–126.

Ivanova, N.O., Kotschetkova, N.M., Stepanaitys, N.E., and Tkacheva, I.D., 1975, Paleontological atlas of Carboniferous deposits in the Urals: Trudy Vsesoyuznogo Neftyanogo Nauchno-Issledovatelskogo Geologo-Razvedochnogo Instituta, Novaya Seriya, v. 383, p. 131–145, 235–238.

Jiang, X., Zhou, W., and Lin, S., 1995, Stratigraphy and Ostracods of Xinjiang in China: Beijing, Geological Publishing Press, 577 p.

Jones, T.R., 1850, Class Crustacea, *in* King, W., ed. A Monograph of the Permian Fossils of England: Annual Volumes of the Palaeontographical Society, v. 3, p. 1–258.

Jones, T.R., 1859, Notes on the species, *in* Kirkby, J.W., ed. On Permian Entomostraca from the Shell-Limestone of Durham, with notes on the species by T. Rupert Jones: Transaction of the Tyneside Naturalist's Field Club 4 (1858–1860), Newcastle-Upon-Tyne, p. 122–171.

Jones, T.R., and Holl, H.B., 1869, Notes on the Palaeozoic bivalved Entomostraca, no. IX. Some Silurian species: Annals and Magazine of Natural History, London, v. 3, ser. 4, p. 211–227.

Jones, T.R., and Kirkby, J.W., 1867, On the Entomostraca of the Carboniferous rocks of Scotland: Transactions of the Geological Society of Glasgow, v. 2, p. 213–228.

Jones, T.R., and Kirkby, J.W., 1886, Notes on the Palaeozoic bivalved Entomostraca-XX. On the genus *Beyrichia* and some new species: Annals and Magazine of Natural History, London, ser. 5, v. 17, p. 337–367.

Kawamura, T., Uchino, T., Kawamura, M., Yoshida, K., Nakagawa, M., and Nagata, H., 2013, Geology of the Hayachine San District: Quadrangle Series, 1:50,000, Tsukuba, Geological Survey of Japan, AIST, 101 p.

Kellett, B., 1929, The ostracode genus *Hollinella*, expansion of the genus and description of some Carboniferous species: Journal of Paleontology, v. 3, p. 196–217.

Kellett, B., 1933, Ostracodes of the Upper Pennsylvanian and the lower Permian strata of Kansas: I. the Aparchitidae, Beyrichiidae, Glyptopleuridae, Kloedenellidae, Kirkbyidae, and Youngiellidae: Journal of Paleontology, v. 7, p. 59–108.

Kellett, B., 1935, Ostracodes of the Upper Pennsylvanian and the lower Permian strata of Kansas: III. Bairdiidae (concluded), Cytherellidae, Cypridinidae, Entomoconchidae, Cytheridae and Cypridae: Journal of Paleontology, v. 9, p. 132–166.

Kempf, E.K., 1986, Index and bibliography of marine Ostracoda 1 Index A: Geologisches Institut der Universitaet zu Koeln Sonderveroeffentlichungen, no. 50, p. 1–762.

Kesling, R.V., and Tabor, N.R., 1953, Ostracods of the family Hollinidae from the Genshaw Formation of Michigan: Contributions from the Museum of Paleontology, University of Michigan, v. 10, p. 83–100.

Knight, J.B., 1928a, Some Pennsylvanian ostracodes from the Henrietta Formation of eastern Missouri. Part I: Journal of Paleontology, v. 2, p. 229–267.

Knight, J.B., 1928b, Some Pennsylvanian ostracodes from the Henrietta Formation of eastern Missouri. Part II: Journal of Paleontology, v. 2, p. 318–337.

Kobayashi, F., 1973, On the middle Carboniferous Nagaiwa Formation: Journal of the Geological Society of Japan, v. 79, p. 69–78.

Komroff, M., ed., 2001, The Travels of Marco Polo: New York, The Modern Library, 352 p.

Koto, B., 1888, On the so-called crystalline schists of Chichibu: The Journal of the College of Science, Imperial University, Japan, v. 2, p. 77–141.

Kotschetkova, N.N., 1983, Ostracodes of the middle Carboniferous of the southern Urals: Academy of Sciences of USSR, Institute of Geology Baskik Branch, Moscow, Publishing House, 119 p.

Kotschetkova, N.N., 1984, Ostracodes of the Moscovian Stage of the eastern slope of southern Urals: Paleontological Journal, v. 2, p. 75–81.

Kotschetkova, N.N., 1985, Pervie nakhodki ostracod v Moskovskom yaruse: Academy of Sciences of USSR Institute of Geology Baskik Branch Podmoskovya, Moscow, Publishing House, p. 56–63.

Kozur, H. von, 1985, Neue Ostracoden-Arten aus dem obern Mittelkabon (Höheres Moskovian), Mittel- und Oberperm des Bükk-Gebirges (N-Ungarn): Geologisch-Paläontologische Mitteilngen Innsbruck, v. 2, p. 1–145.

Kummerow, E., 1953. Über oberkarbonische und devonische Ostracoden in Deutschland und in der Volksrepublik Polen: Beiheft zur Zeitschrift Geologie Zeitschrift für das Gesamtgebiet der Geologie und Mineralogie sowie der angewandten Geophysik, no. 7, p. 3–75.

Kuwano, Y., 1987, Early Devonian conodonts and ostracodes from central Japan: Bulletin of the National Science Museum, Series C, Geology and Palaeontology, no. 13, p. 77–105.

Latham, M., 1932, Scottish Carboniferous Ostracoda: Transactions of the Royal Society of Edinburgh, v. 57, p. 351–395.

Latreille, P.A., 1802, Histoire Naturelle, Générale et Particuliére, des Crustacés et des Insectes, 3rd ed: Paris, Dufart, 468 p.

Lundin, R.F., and Sumrall, C.D., 1999, Ostracodes from the Naco Formation (upper Carboniferous) at the Kohl Ranch locality, central Arizona: Journal of Paleontology, v. 73, p. 454–460.

McCoy, F., 1844, A Synopsis of the Characters of the Carboniferous Limestone Fossils of Ireland: Dublin, University Press, 207 p.

McLaughlin, K.P., 1952, Microfauna of the Pennsylvanian Glen Eyrie Formation, Colorado: Journal of Paleontology, v. 26, p. 613–621.

Melnikova, L.M., 2000, Ordovician ostracodes of the Thuringian ecotype from northern Taimyr: Paleontological Journal, v. 34, p. 622–631.

Mohibullah, M., Williams, M., Vandenbroucke, T.R.A., Sabbe, K., and Zalasiewicz, J.A., 2012, Marine ostracod provinciality in the Late Ordovician of palaeocontinental Laurentia and its environmental and geographical expression: PLoS ONE, v. 7, e41682. https://doi.org/10.1371/journal.pone.0041682.

Moore, R.C., 1929, *Basslerina*, a new holliniform ostracode genus, with description of new Pennsylvanian species from Texas and Oklahoma: Journal of the Scientific Laboratories of Denison University, v. 29, p. 99–114.

Müller, G.W., 1894, Die Ostracoden des Golfes von Neapel und der angrenzenden Meeresabschnitte. Fauna und Flora des Golfes von Neapel und der angrenzenden Meeresabschnitte: Zoologische Station zu Neapel, v. 21, p. 1–404.

Omara, S., and Gramann, F., 1966, Upper Carboniferous ostracodes from Wadi Araba, Eastern Desert, Egypt: Verhandlungen der Geologischen Bundesanstalt, v. 1966, p. 148–156.

Patte, E., 1935, Fossiles Palaeozoiques et Mesozoiques du Sud-Ouest de la Chine: Palaeontologia Sinica, Ser. B, vol. 15, p. 1–50.

Perrier, V., and Siveter, D.J., 2014, Testing Silurian paleogeography using 'Europian' ostracod faunas, *in* Harper, D.A.T., and Servais, T., eds. Early Palaeozoic Biogeography and Palaeogeography: London, Geological Society of London, Memoirs, v. 38, p. 355–364.

Pokorný, V., 1954, A contribution to the taxonomy of the Paleozoic ostracods: Sbornik ústr˘edniho ústavu geologickeho (oddíl paleontologický), v. 20 (for 1953), p. 213–232.

Polenova, E.N., 1952, Ostracoda of the upper part of the Jivetjki Formation of the Russian Platform (Middle Devonian from bores in the central Volga Area): All-Union Petroleum Exploration and Geological Research Institute (VNIGRI), Leningrad-Moscow, v. 60, p. 65–156.

Posner, V.M., 1951, Lower Carboniferous ostracods of western part of Moscow Basin: All-Union Petroleum 1499 Exploration and Geological Research Institute (VNIGRI), Leningrad-Moscow, v. 56, p. 1–108.

Pour, M.G., Mohibullah, M., Williams, M., Popov, L.E., and Tolmacheva, T.Y, 2011, New, early ostracods from the Ordovician (Tremadocian) of Iran: systematic, biogeographical and palaeoecological significance: Alcheringa, v. 35, p. 517–529.

Requadt, H., Becker, G., Bless, M.J.M., Eickhoff, G., and Sánchez de Posada, L.C., 1977, Mikrofaunen aus dem Westfal der Spanischen West-Pyrenäen (Ostracoda, Conodonta, Foraminifera): Neues Jahrbuch für Mineralogie, Geologie und Paläontologie, Abteilung B, v. 155, p. 65–107.

Reynolds, L., 1978, The taxonomy and palaeoecology of ostracodes from the Devonian *Receptaculites* Limestone, Taemas, New South Wales, Australia: Palaeontographica A, v. 162, p. 144–203.

Roth, R., 1929, A revision of the ostracod genus *Kirkbya* and subgenus *Amphissites*: Publication of the Wagner Free Institute of Science, v. 1, p. 1–56.

Roundy, P.V., 1926, Mississippian formations of San Saba County, Texas. Pt. 2, the microfauna: US Geological Survey Professional Paper, no. 146, p. 5–8.

Sanchez de Posada, L.C., 1977, Ostracodes from the upper Carboniferous of la Camocha Coal Mine (Asturias, N. Spain): Revista Española de Micropaleontologia, v. 9, p. 411–438.

Saravia, P.D., and Jones, P.J., 1999, New Carboniferous (Namurian) glaciomarine ostracods from Patagonia, Argentina: Journal of Micropalaeontology, v. 18, p. 97–109.

Sars, G.O., 1866, Oversight af Norges marine ostracoder: Forhandlinger I Videnskabs-Selskabet I Christiania, v. 1865, p. 1–30.

Sars, G.O., 1888, Nye Bidrag til Kundskaben om Middlehavets Invertebratfauna. 4. Ostracoda Mediterranea: Archiv Mathematische Naturvetenskap, v. 12, p. 173–324.

Schallreuter, R.E.L., 1972. Drepanellacea (Ostracoda, Beyrichicopida) from Middle Ordovician Backsteinkalk Boulders IV. *Laterophores hystrix* sp. n., *Pedomphalella germanica* sp. n. and *Easchmidtella fragosa* (Neckaja): Berichte der Deutschen Gesellschaft für Geologische Wissenschaften A, v. 17, p. 139–145.

Schallreuter, R.E., 1988, Homeomorphy, phylogeny and natural classification: case studies involving Palaeozoic ostracods, *in* Hanai, T., Ikeya, N., and Ishizaki, K., eds. Evolutionary Biology of Ostracoda, its Fundamentals and Applications: Tokyo, Kodansha and Elsevier, p. 1041–1049.

Schallreuter, R.E.L., and Siveter, D.J., 1985, Ostracodes across the Iapetus Ocean: Palaeontology, v. 28, p. 577–598.

Scott, H.W., 1959, Type species of *Paraparchites* Ulrich & Bassler: Journal of Paleontology, v. 33, p. 670–674.

Scott, H.W., 1961, Suborder Kloedenellocopina Scott, n. suborder, *in* Moore, R.C., ed. Treatise on Invertebrate Paleontology. Part Q, Arthropoda 3, Crustacea, Ostracoda: Boulder, Colorado and Lawrence, Kansas, Geological Society of America and University of Kansas Press, p. Q180.

Shaver, R.H., 1958, A study of *Pseudobythocypris pediformis*, a new name for an old ostracod: American Midland Naturalist, v. 59, p. 120–137.

Shaver, R.H., 1961, Family Bairdiocyprididae Shaver, n. fam., *in* Moore, R.C., ed. Treatise on Invertebrate Paleontology. Part Q, Arthropoda 3, Crustacea, Ostracoda. Boulder, Colorado and Lawrence, Kansas, Geological Society of America and University of Kansas Press, p. Q364–Q365.

Shi, C.G., 1987, Ostracoda from the Taiyuan Formation of southeastern Shanxi, *in* Rui, L., and Hou, J.H., eds. Late Paleozoic Coal-Bearing Strata and Biota from Southeastern Shanxi: Nanjing, Nanjing University Press, p. 291–306.

Shi, C.G., and Li, Z.W., 1988, Records of Late Carboniferous ostracods from Jingyuan, Gansu, Northwestern China, *in* Hanai, T., Ikeya, N, and Ishizaki, K., eds. Evolutionary Biology of Ostracoda, its Fundamentals and Applications: Tokyo, New York, Kodanshia, Elsevier, p. 1293–1302.

Siveter, D.J., Tanaka, G., Williams, M., and Männik, P., 2018, Japan's earliest ostracods: Island Arc, v. 28, e12284. https://doi.org/10.1111/iar.12284.

Sohn, I.G., 1960, Paleozoic species of Bairdia and related genera: US Geological Survey Professional Paper, 330-A, p. 1–105.

Sohn, I.G., 1971, New Late Mississippian ostracode genera and species from Northern Alaska: US Geological Survey Professional Paper, 711-A, p. 1–23.

Stewart, G.A., 1936, Ostracodes of the Silica Shale, Middle Devonian, of Ohio: Journal of Paleontology, v. 10, p. 739–763.

Stewart, G.A., and Hendrix, W.E., 1945, Ostracoda of the Plum Brook Shale, Erie County, Ohio: Journal of Paleontology, v. 19, p. 87–95.

Stocker, C.P., Komatsu, T., Tanaka, G., Williams, M., Siveter, D.J., Bennett, C.E., Wallis, S., Oji, T., Maekawa, T., Okura, M., and Vandenbroucke, T.R.A., 2016, Carboniferous ostracods from central Honshu, Japan: Geological Magazine, v. 155, p. 98–108.

Stover, L.E., 1956, Ostracoda from the Windom Shale (Hamilton) of western New York: Journal of Paleontology, v. 30, p. 111–119.

Sylvester-Bradley, P.C., 1961, Suborder Metacopina Sylvester-Bradley, n. suborder, *in* Moore, R.C., ed. Treatise on Invertebrate Paleontology. Part Q, Arthropoda 3, Crustacea, Ostracoda: Boulder, Colorado and Lawrence, Kansas, Geological Society of America and University of Kansas Press, p. Q358–Q359.

Swartz, F.M., 1936, Revision of the Primitiidae and Beyrichiidae, with new Ostracoda from the Lower Devonian of Pennsylvania: Journal of Paleontology, v. 10, p. 541–586.

Tanaka, G., 2008, Recent benthonic ostracod assemblages as indicators of the Tsushima warm current in the southwestern Sea of Japan: Hydrobiologia, v. 598, p. 271–284.

Tanaka, G., and Ikeya, N., 2002, Migration and speciation of the *Loxoconcha japonic*a species group (Ostracoda) in East Asia: Paleontological Research, v. 6, p. 265–284.

Tanaka, G., Ono, T., Yuan, A., Ichida, M., and Maeda, H., 2012, Early Permian ostracods from Mugi County, Gifu Prefecture, central Japan: Paleontological Research, v. 16, p. 88–106.

Tanaka, G., Ono, T., Nishimura, T. and Maeda, H., 2013, Middle Permian ostracods from the Akasaka Limestone, Gifu Prefecture, central Japan: Paleontological Research, v. 16, p. 289–306.

Tanaka, G., Miyake, Y., Ono, T., Yuan, A., Ichida, M., Maeda, H., and Crasquin, S., 2018, Early Permian (Cisuralian) ostracods from Japan: characteristic ostracod assemblage from a seamount of the Panthalassic Ocean: Zootaxa, v. 4515, p. 1–67.

Tanaka, G. Siveter, D.J., and Williams, M., 2019, Devonian shallow marine ostracods from central Japan: Island Arc, v. 28, e12283. https://doi.org/10.1111/iar.12283.

Tazawa, J., 2004, The strike-slip model: a synthesis on the origin and tectonic evolution of the Japanese Islands: Journal of the Geological Society of Japan, v. 110, p. 503–517.

Tianjin Institute of Geology and Mineral Resources, ed., 1984, Paleontological Atlas of North China. III Micropaleontological Volume: Beijing, Geological Publishing Press, 765 p.

Tibert, N.E., Rygel, M.C., Sanders, S.C., Elrick, S.D., and Nelson, J., 2013, Temporal and spatial distribution of ostracodes across the Pennsylvanian–Permian boundary interval in eastern North America: International Journal of Coal Geology, v. 119, p. 93–105.

Titterton, R., and Whatley, R.C., 1988, The provincial distribution of shallow water Indo-Pacific marine Ostracoda: origins, antiquity, dispersal routes and mechanisms, *in* Hanai, T., Ikeya, N., and Ishizaki, K., eds. Evolutionary

Biology of Ostracoda, its Fundamentals and Applications: Tokyo, Kodansha and Elsevier, p. 759–786.
Torsvik, T.H., and Cocks, L.R.M., 2017, Carboniferous, *in* Torsvik, T.H., Cocks, L.R.M., eds. Earth History and Palaeogeography: Cambridge, UK, Cambridge University Press, p. 159–177.
Ulrich, E., 1891, New and little known American Paleozoic Ostracoda (2): Journal of the Cincinnati Society of Natural History, v. 13, 173–211.
Ulrich, E., 1894, The lower Silurian Ostracoda of Minnesota: The Geology of Minnesota, Geological and Natural History Survey of Minnesota, v. 3, p. 629–693.
Ulrich, E., and Bassler, R., 1906, New American Paleozoic Ostracoda. Notes and description of upper Carboniferous genera and species: United States National Museum, Proceedings, v. 30, p. 149–164.
Ulrich, E., and Bassler, R., 1908, New American Paleozoic Ostracoda. Preliminary revision of the Beirichiidae, with description of new genera: United States National Museum, Proceedings, v. 35, p. 277–340.
Vannier, J.M.C., Siveter, D.J., and Schallreuter, R.E.L., 1989, The composition and palaeogeographical significance of the Ordovician ostracode faunas of southern Britain, Baltoscandia and Ibero-Amorica: Palaeontology, v. 32, p. 163–222.
Wakita, K., Nakagawa, T., Sakata, M., Tanaka, N., and Oyama, N., 2021, Phanerozoic accretionary history of Japan and the western Pacific margin: Geological Magazine, v. 158, p.13–29.
Williams, M., Floyd, D.J., Salas, M.J., Siveter, D.J., Stone, P., and Vannier, J.M.C., 2003, Patterns of ostracod migration for the 'North Atlantic' region during the Ordovician: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 195, p. 193–228.
Williams, M., Wallis, S., Oji, T., and Lane, P.D., 2014, Ambiguous biogeographical patterns mask a more complete understanding of the Ordovician to Devonian evolution of Japan: Island Arc, v. 23, p. 76–101.
Yichan Institute of Geology and Mineral Resources, ed., 1984, Biostratigraphy of the Yangtze Gorge Area (3) Late Palaeozoic Era: Beijing, Geological Publishing House.
Zagora, I., 1967, Verkieselte Ostracoden aus dem Tentaculiten-Knollenkalk (Unterdevon) von Ostthüringen: Geologie, v. 16, p. 303–343.
Zhang, X.J. and Liang, X.Y., 1987, Ostracoda from the Taiyuan Formation of Xingyang and Gongxian districts, Henan: Acta Micropalaeontologica Sinica, vol.4, p. 293–312.
Zhang, X., and Liang, X., 1991, Further study on ostracodes from the Taiyuan Formation of Xingyang, Gonxian area, Henan: Acta Micropalaeontologica Sinica, v. 8, p. 65–89.

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