

Eocene ostracode assemblages with *Robertsonites* from Hokkaido and their implications for the paleobiogeography of Northwestern Pacific

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Abstract: We report on Eocene ostracode species from Hokkaido, northern Japan for the first time and discuss their paleobiogeographic implications. Five species were found in the lower part of the Sankebetsu Formation in the Haboro area, and the Akabira and Ashibetsu Formations in the Yubari area, central Hokkaido. The ostracode assemblages are characterized by *Robertsonites*, a circumpolar Arctic genus of the modern fauna. This finding marks the southernmost occurrence of the Eocene record of the genus, as well as the oldest occurrence. As the characteristics of the Eocene Hokkaido fauna are similar to those of the modern-day fauna in the Seto Inland Sea, a contrast in species composition is observed between the Seto Inland Sea and Kyushu. This contrast is attributable to differences in sea temperature. Five species are described, including *Robertsonites ashibetsuensis* sp. nov.

Keywords: Eocene, Hokkaido, Ostracoda, paleobiogeography, *Robertsonites*

1. Introduction

We describe the systematics of Eocene ostracodes from Hokkaido, northern Japan, for the first time and discuss their paleobiogeographic implications.

As the Eocene records a prominent global-scale climate change, termed the terminal Eocene cooling (although recent papers refer to the Eocene–Oligocene climate transition; e.g., Prothero, 1994), provincialism in faunas and floras of the Eocene should represent a significant starting point for the reconstruction of paleoenvironments during the Tertiary (e.g., pollen: Ozaki, 1992; mollusks: Honda, 1994; Matsubara, 2002; Oleinik and Marincovich, 2003). Ostracodes potentially record paleoclimatic information related to the shallow-marine realm, although few studies have investigated Eocene ostracodes in the Northwest Pacific region (e.g., Yamaguchi *et al.*, 2005; Yamaguchi, 2006; Fig. 1).

Previous studies on Eocene ostracodes from Southwest Japan have suggested the presence of provincialism around the Japanese Islands. According to Yamaguchi *et al.* (2005, in press), the Eocene ostracode fauna from Kyushu contains many species also found in the coeval fauna from the East China Sea, but none of the species of the contemporaneous fauna from the Seto Inland Sea (Yamaguchi *et al.*, 2005; Yamaguchi, 2006). The faunas of both Kyushu and the East China Sea contain warm-water taxa that are not found in the fauna of the Seto Inland Sea. During the Eocene, Kyushu and the

Seto Inland Sea were located around paleolatitudes of approximately 33–34 °N and 37–38 °N, respectively (Otofujii, 1996). This latitudinal separation between the two areas would have led to faunal differences due to oceanographic variations. On this basis, Yamaguchi *et al.* (2005) concluded that the Eocene faunal difference between Kyushu and the Seto Inland Sea should reflect the difference in paleoclimate that caused the provincialism. This hypothesis requires testing based on evidence obtained from areas north of the Seto Inland Sea; however, there exist insufficient records of Eocene ostracodes from Hokkaido: previous studies undertaken by Hanai (1970) and Hanagata (2002) provided neither illustrations nor taxonomic descriptions.

2. Lithostratigraphy and geologic age

Eocene strata, composed mainly of terrestrial and shallow-marine deposits with coal seams, are exposed in several areas in Hokkaido. We examined samples from the following Eocene units: the Akabira and Ashibetsu Formations in the Sorachi area, the Poronai Formation in the Ishikari area, the lower part of the Sankebetsu Formation in the Haboro area, and the Shitakara Formation in the Shiranuka area. These formations have been dated based on fossil planktic foraminifers, calcareous nannofossils, dinoflagellate cysts, and radio-isotopic analyses of pyroclastic layers (e.g., Okada and Kaiho, 1992; Kurita, 2004; Fig. 2).

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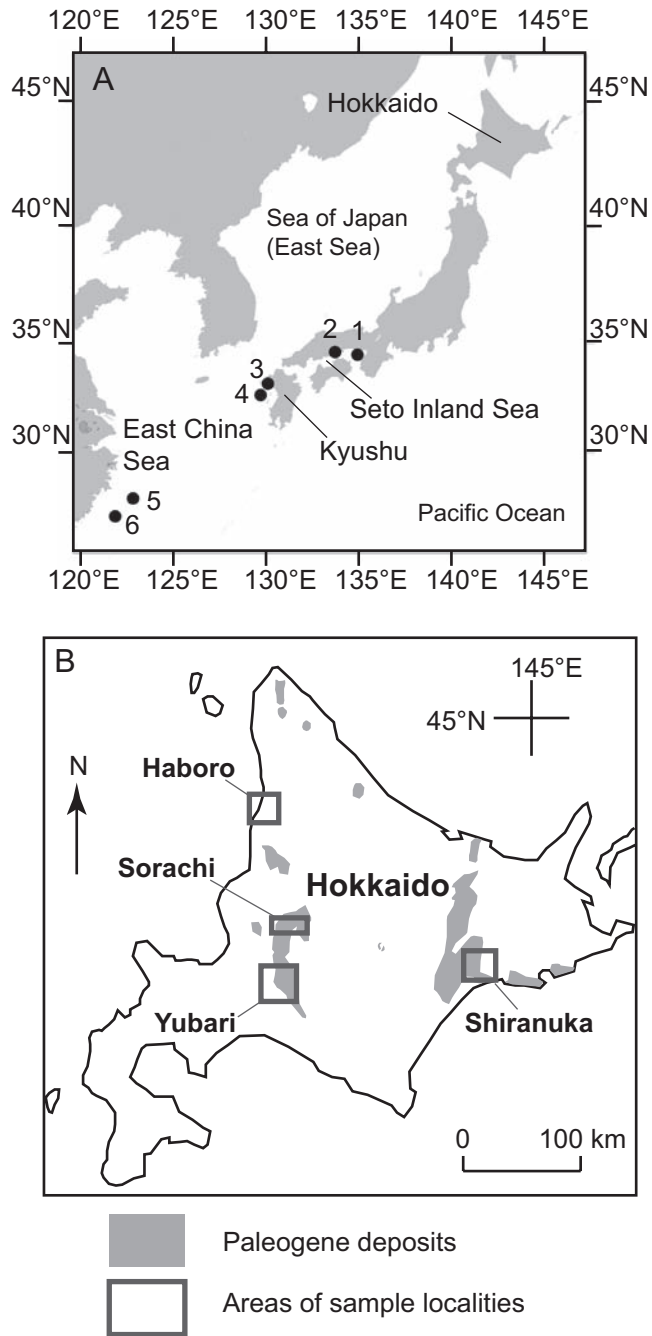


Fig. 1 A: localities of Eocene marine ostracodes around the Japanese Islands. 1, Middle–Upper Eocene Iwaya Formation (Yamaguchi *et al.*, 2005). 2, Upper Eocene–lowermost Oligocene sequence (Yamaguchi *et al.*, in press). 3, uppermost Eocene–lowermost Oligocene Kishima Formation (Yamaguchi *et al.*, 2006). 4, Middle Eocene–Lower Oligocene Iojima Group (Yamaguchi, 2006). 5, Lower Eocene Oujiang and Middle Eocene Wenzhou Formations (Yang *et al.*, 1990). 6, Lower Eocene Oujiang Formation (Liu, 1989). B: distribution of Paleogene strata and localities of examined samples in Hokkaido. Geology after Editorial Committee of Hokkaido (1990).

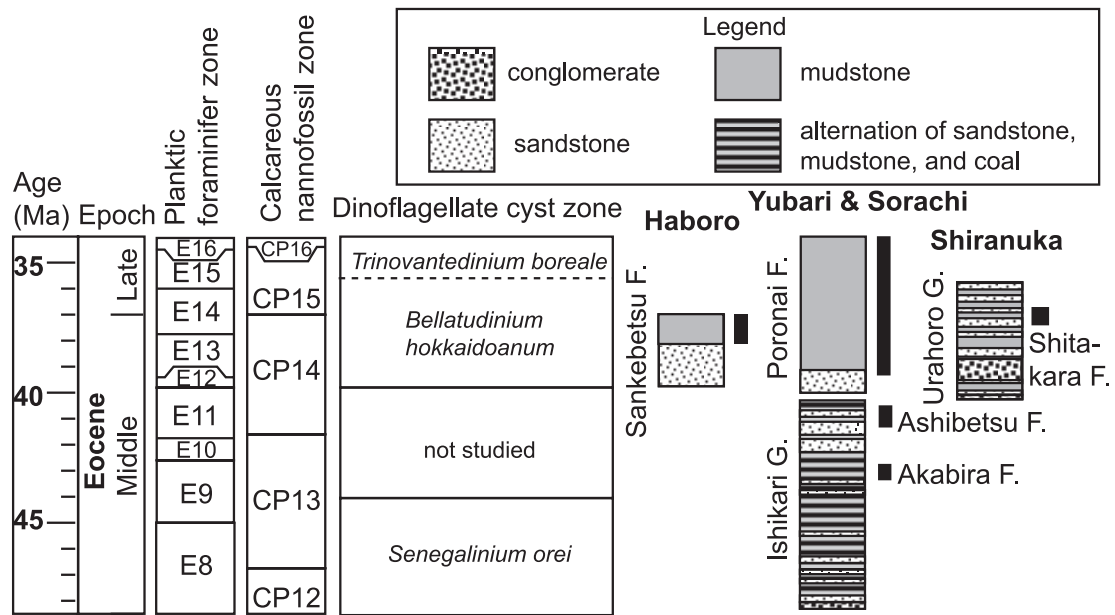


Fig. 2 Chronostratigraphy of examined strata in Hokkaido. Modified partly after Kurita (2004). Black bars indicate the locations of examined formations. The employed time scale is the Geologic Time Scale 2004 (Luterbacher *et al.*, 2004). Planktic foraminifer, calcareous nannofossil, and dinoflagellate cyst biostratigraphies are based on Berggren and Pearson (2005), Okada and Bukry (1980), and Kurita (2004), respectively.

2.1 Ashibetsu and Akabira Formations (Middle Eocene)

These formations consist of shale beds and alternating beds of shale and sandstone that represent marine intervals in the coal-bearing deposits of the Ishikari Group in the Sorachi area. These strata yield the Ishikarian molluscan fauna, indicating a Middle Eocene age (Mizuno, 1964). This age assignment is supported by fission track dating of the underlying Yubari and Wakkanabe Formations (ca. 44–42 Ma; Tanai, 1986) and the ages of calcareous nannofossils in the overlying Poronai Formation (late Middle Eocene; Okada and Kaiho, 1992).

2.2 Poronai Formation (Middle–Upper Eocene)

The Poronai Formation, which overlies the Ishikari Group in the Sorachi and Ishikari areas, is dominantly mudstone, and has a thickness of 600 m. It is correlated with the calcareous nannofossil Zone CP14–CP15 of Okada and Bukry (1980) (Okada and Kaiho, 1992) and the dinoflagellate cyst *Bellatudinium hokkaidoanum* and *Trinovantedinium boreale* Zones (Kurita, 2004). Fossil planktic foraminifers from the formation indicate a Middle–Late Eocene age (~40–34 Ma; Kaiho, 1983).

2.3 Lower part of the Sankebetsu Formation (Middle Eocene)

This formation unconformably overlies the Lower Eocene Haboro Formation, and consists of fine- to medium-grained sandstone with a thickness of 100 m.

The formation yields numerous molluscan fossils. The formation also yields calcareous nannofossils of the CP14–CP15a Zone of Okada and Bukry (1980) (Okada, 1981) and dinoflagellate cysts of the *B. hokkaidoanum* Zone (Kurita, 2004), which together indicate a Middle Eocene age.

2.4 Shitakara Formation (Middle Eocene)

The Shitakara Formation is a transgressive phase in the coal-bearing Urahoro Group, and consists of mudstone and sandstone with a thickness of less than 300 m. The formation yields abundant fossil foraminifers and molluscs, and corresponds to the dinoflagellate cyst *B. hokkaidoanum* Zone of the Middle Eocene (Kurita, 2004).

3. Material and methods

Nineteen samples were collected from mudstone layers in the four formations described above. Five of the samples are the same as those examined by Kurita (2004), who analyzed dinoflagellate cysts (Fig. 3, 4).

To extract fossil ostracodes, 80–570 g of each rock sample was disaggregated using a saturated sodium sulfate solution, naphtha, and sodium hexametaphosphate. The disaggregated samples were washed through a 250 mesh (63 μm opening) sieve, and the larger fractions were dried in a homothermal oven. Fractions coarser than 125 μm were extracted from the larger fractions using a sieve.

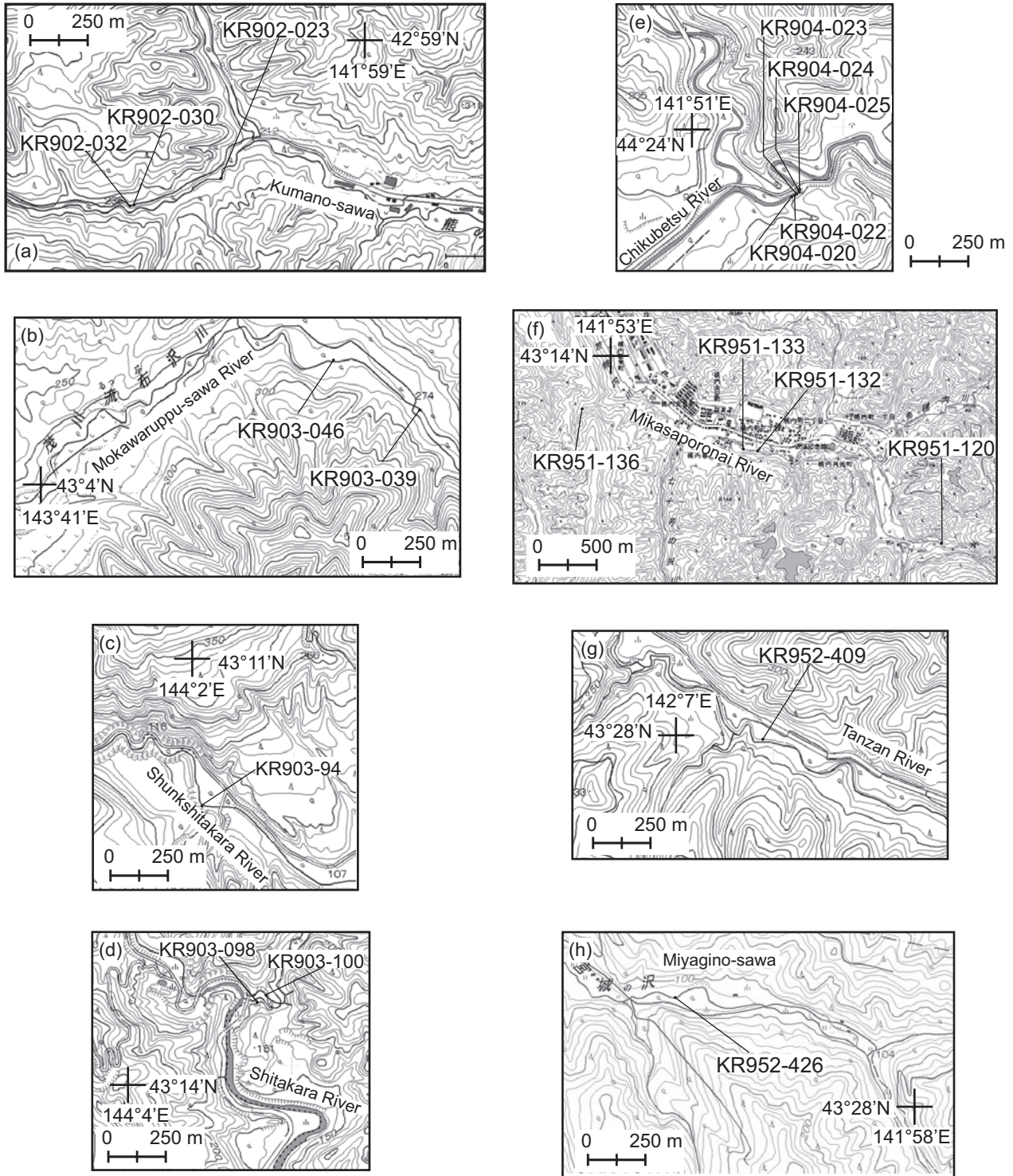


Fig. 3 Map showing localities of the samples. (a) and (e) Haboro area, (b)-(d) Shiranuka area, (f) Yubari area, (g) and (h) Sorachi area. Modified after the following 1:25,000 geomorphologic maps published by the Geographical Survey Institute of Japan: (a) Amagiriyama, (b) Kawaruppu, (c) and (d) Fubushinai, (e) Haboro-chosuichi, (f) Iwamizawa, (g) Monju, and (h) Sunagawa.

Fossil ostracode specimens were picked from the fractions. Ostracode species were identified under a binocular microscope at $70\times$ magnification. Images of the specimens were captured by scanning electron microscopy (SEM; JEOL JSM-5600 at the Graduate

School of Science and Technology, Niigata University, Japan; JEOL JSM-5310 at the Course of Earth Science, Kanazawa University, Japan).

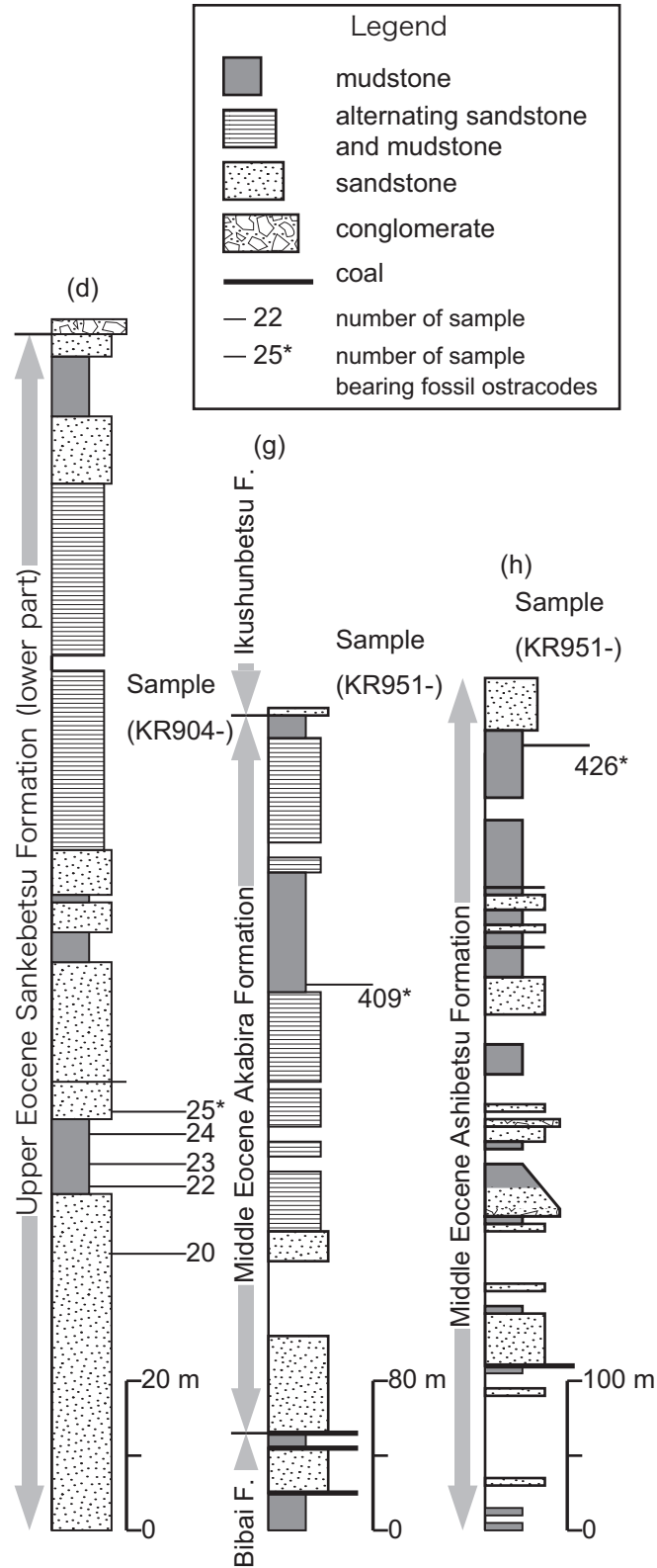


Fig. 4 Columns and sample horizons yielding fossil ostracodes.

4. Fossil ostracodes

Samples KR904-025, KR952-409, and KR952-426 contain a total of 2 single valves and 36 carapaces of

fossil ostracodes (Table 1). The ostracode specimens are reddish or white in color and poorly preserved. Valve specimens are filled with sediment. Some specimens lack certain parts and are cracked. Sediment particles

Table 1 List of fossil ostracode species. Abbreviations: C = carapace, L = left valve, and R = right valve. Asterisk indicates a sample also analyzed by Kurita (2004).

Sample	KR904-025*			KR952-426			KR952-409		
Formation	Sankebetsu			Ashibetsu			Akabira		
Dried sample weight (g)	400			320			570		
Type of specimen	C	L	R	C	L	R	C	L	R
<i>Acanthocythereis</i> sp.									1
<i>Hanaiborchella reticularitriangularis</i>									3
<i>Hanaiborchella</i> sp.									3
<i>Robertsonites ashibetsuensis</i> sp. nov.							22	1	
<i>Robertsonites</i> sp.	1	1							
Trachyleberididae gen. et sp. indet.					5				
gen. et sp. indet.									1

are attached to specimen surfaces and infill the fossae of reticulation. More than half of the specimens are deformed and abraded.

Sample KR904-025 from the Sankebetsu Formation yielded *Robertsonites* sp., whereas KR952-409 from the Akabira Formation contained at least four species (*Robertsonites ashibetsuensis* sp. nov., *Hanaiborchella reticularitriangularis*, *Hanaiborchella* sp., and *Acanthocythereis* sp. in decreasing order of abundance). We found five molds of Trachyleberididae gen. et sp. in the sample KR952-426 from the Ashibetsu Formation.

5. Systematic description

(by Tatsuhiko Yamaguchi)

Specimens are housed at the University Museum, University of Tokyo, Tokyo, Japan (abbreviated as UMUT; registration numbers have the prefix “CA-”, meaning Cenozoic Arthropoda). Higher-level classification above generic rank follows Hartmann and Puri (1974). Morphological terminology follows the schemes of Athersuch *et al.* (1989) and Horne *et al.* (2002). Specimen dimensions were measured using a micrometer ruler under a binocular microscope. Sexual dimorphism of new species was identified via discriminant analysis and Hotelling’s T^2 -test (Appendix). Abbreviations are as follows: L = length, H = height, and W = width.

Family Cytheridae Baird, 1850

Genus *Hanaiborchella* Gründel, 1976

Hanaiborchella reticularitriangularis Yamaguchi in Yamaguchi *et al.*, 2005

Hanaiborchella reticularitriangularis Yamaguchi cited in Yamaguchi *et al.*, 2005, p. 312, Fig. 4.4–4.6.

Plate 1.1, 1.2

Registered material: UMUT-CA29556, adult carapace.

Measurement: L = 0.47 mm, H = 0.29 mm, W = 0.26 mm.

Occurrence: Middle Eocene Akabira Formation, Ishikari Group in Hokkaido (this study); Middle–Upper Eocene Iwaya Formation, Kobe Group in Hyogo Prefecture (Yamaguchi *et al.*, 2005).

Remarks: Based on the lateral outline and reticulation near the dorsomedian sulcus and between two horizontal carinae on the central area, specimens including UMUT-CA29556 are identified as *H. reticularitriangularis*. This species is similar to *H. cf. opima* of Yamaguchi (2006) in lateral outline and reticulation. *H. cf. opima* was reported from the Eocene Funazu Formation of southwestern Japan. The present specimen is distinguished from *H. cf. opima* in having a larger carapace, rounder posterodorsal margin, and coarser reticulation on the anterior area.

Hanaiborchella sp.

Plate 1.3–1.6

Registered material: UMUT-CA29557, adult carapace.

Description: Carapace robust and medium. Lateral outline subtrapezoidal: anterior margin round; posterior margin angular near ventral level; dorsal margin arched; ventral margin slightly curved. Caudal process formed by angular of posterior margin. Narrow and flattened zones along anterior and posterior margins. Maximum length from terminal of caudal process to that of anterior margin. Maximum height across anterodorsal corner.

Surface ornament with two carinae and dorsomedian sulcus. Two blunt carinae extended horizontally on central area: Upper carinae blunter than lower and running obliquely across dorsomedian sulcus; lower carinae shorter than upper and stretched parallel to ventral margin through lower terminal of dorsomedian sulcus.

Dorsal and ventral outlines ovate: anterior and poste-

rior margins angular; lateral margins asymmetrically curved. Maximum width is across the posterior of the valve. Ventral surface flattened and ornament with two carinae: Carinae narrow, arranged symmetrically on central area, and extended parallel to lateral margin.

Measurement: L = 0.67 mm, H = 0.41 mm, and W = 0.35 mm.

Occurrence: Middle Eocene Akabira Formation, Ishikari Group.

Remarks: The specimen is similar to *Eopaijenborchella sinensis* (Liu) and *H. opima* (Liu) in lateral outline, with an arched dorsal margin. These species were originally described from Eocene deposits in the East China Sea (Liu, 1989). The present specimen is distinguished from *H. opima* in having a shorter and thicker lateral outline with an apex at the posterodorsal corner. It differs from *E. sinensis* by its smaller carapace and shorter caudal process. This species is probably a new species; however, the small number of specimens and their poor preservation prevents us from assigning a new species.

Family Trachyleberididae Sylevester-Bradley, 1948

Genus *Acanthocythereis* Howe, 1963

Acanthocythereis sp.

Plate 1.7–1.9

Registered material: UMUT-CA29558, adult carapace.

Description: Carapace robust and large. Lateral outline subrectangular: anterior and posterior margins round; dorsal margin straight; ventral margin slightly curved. Central area swelled. Anterior and posterior areas flattened. Maximum length across middle of carapace. Maximum height across anterodorsal corner.

Surface ornament with reticulation and conjunctive spines. Reticulation formed by polygonal and round fossae. Muri on ventral area parallel to ventral margin. Spines arranged along anterior margin. Eye tubercle prominent. Marginal denticles attached to anterior and posterior margins.

Dorsal outline lenticular: anterior and posterior ends angular; lateral margins curved. Maximum width across posterior 1/3 of carapace.

Measurement: L = 0.86 mm, H = 0.48 mm, and W = 0.38 mm.

Occurrence: Middle Eocene Akabira Formation, Ishikari Group.

Remarks: This specimen is similar in lateral outline to females of *A. ashियाensis* Yamaguchi, *A. fujinaensis* Tanaka, *A. koreana* Huh and Whatley, and *A. japonica* Irizuki and Yamada. *A. ashियाensis* was originally described from the Oligocene Ashiya Group in southwestern Japan, whereas the other species were originally reported from Miocene strata in Korea and Japan (Huh and Whatley, 1997; Tanaka *et al.*, 2002; Irizuki *et al.*, 2004; Yamaguchi and Kamiya, 2007a). The present specimen is smaller than *A. ashियाensis*, *A. koreana*, and

A. japonica, and larger than *A. fujinaensis*. The poor preservation of this specimen prevents an assignment at the species level.

Genus *Robertsonites* Swain, 1963

Robertsonites ashibetsuensis sp. nov.

Fig. 5.1, Plate 1.10, Plate 2.1–2.6

Types: Holotype, UMUT-CA29559, male adult carapace. Paratype, UMUT-CA29560, female adult carapace; UMUT-CA29561, male adult carapace; UMUT-CA29562, female adult carapace.

Other examined material: Two male and four female adult carapaces.

Etymology: Named after the type locality.

Diagnosis: *Robertsonites* characterized by subrectangular lateral outline and surface ornament with rectangular to elongate polygonal fossae, four distinct muri along anterior and ventral margins and oblique muri on central area.

Description: Carapace robust and large. Lateral outline subrectangular: anterior margin round; posterior margins round with apex near middle; dorsal margin straight; ventral margin slightly curved. Maximum length across middle of carapace. Maximum height across anterodorsal corner.

Surface ornament with reticulation. Reticulation formed by rectangular to elongate polygonal fossae. Muri oriented parallel to anterior and ventral margins prominent relative to other muri. Four muri running along anterior and ventral areas are particularly distinct. Distinct muri on central area obliquely stretched posterodorsalward. Eye tubercle prominent. Marginal denticles attached to anterior margin. Sexual dimorphism distinct: length of male larger than that of female.

Dorsal outline subovate: anterior and posterior ends angular; lateral margins asymmetrically curved. Maximum width across posterior of valve.

Measurement: See also Appendix. Holotype, UMUT-CA29559, L = 1.10 mm, H = 0.56 mm, and W = 0.41 mm. Paratype, UMUT-CA29560, L = 0.94 mm, H = 0.51 mm, and W = 0.43 mm; UMUT-CA29561, L = 1.10 mm, H = 0.52 mm, and W = 0.55 mm; UMUT-CA29562, L = 0.97 mm, H = 0.51 mm, and W = 0.43 mm. Size range of female follows: L = 0.83–0.97 mm, H = 0.43–0.52 mm, and W = 0.34–0.45 mm. Size range of male follows: L = 1.01–1.13 mm, H = 0.52–0.56 mm, and W = 0.34–0.55 mm.

Type locality: Locality KR952-409 along the Tanzan River, Ashibetsu City. Middle Eocene Akabira Formation, Ishikari Group.

Remarks: Reticulation with distinct horizontal muri on the anterior and ventral areas is shared with *R. tsugaruanus* Tabuki, *R. reticulatus* Irizuki and Yamada, and *R. ?* sp. of Yamaguchi and Kamiya (2007a). *R. tsugaruanus* was originally described from Plio-Pleistocene

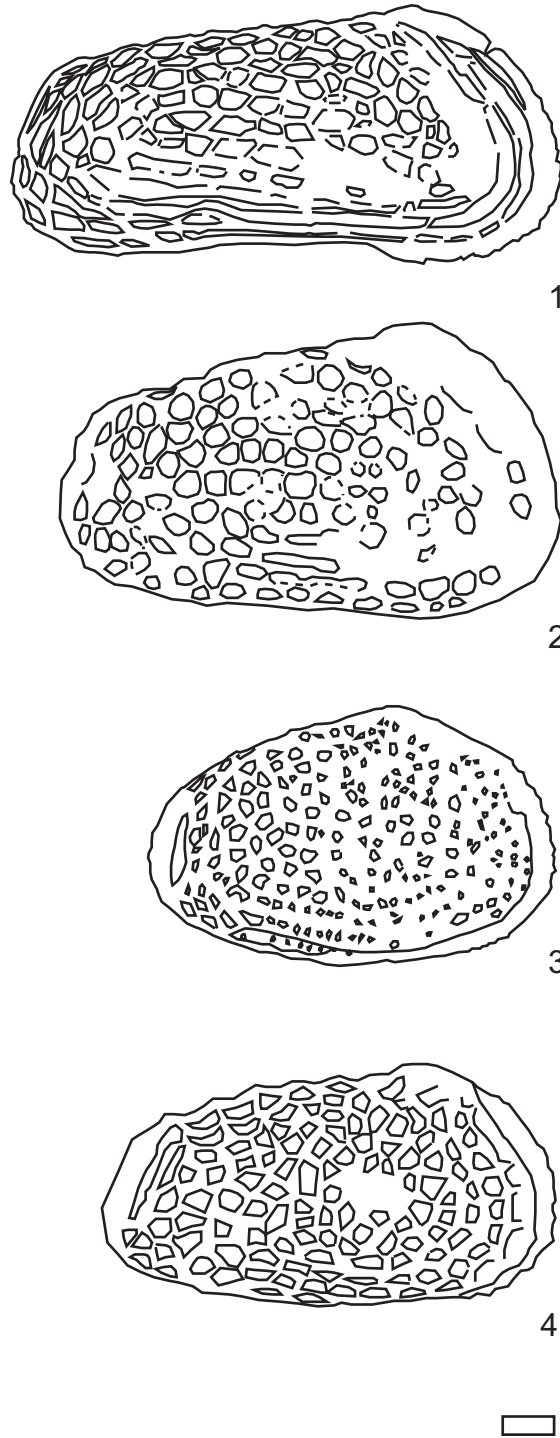


Fig. 5 Traces of right external views of *Robertsonites ashibetsuensis* sp. nov., *R. sp. R. tsugaruanus*, and *R. reticulatus*. Scale bar: 0.10 mm. 1, *Robertsonites ashibetsuensis* sp., UMUT-CA29561, male. 2, *Robertsonites* sp., UMUT-CA29564. 3, *R. tsugaruanus*, female, Yamada (2003, Pl. 3, Fig. 2). 4, *R. reticulatus*, male, Irizuki *et al.* (2004, Pl. 4.6).

strata of northeastern Japan (Tabuki, 1986), whereas *R. reticulatus* was described from Miocene strata of Central Japan (Irizuki *et al.*, 2004). *R. ?* sp. was reported from Oligocene strata in Kyushu (Yamaguchi and

Kamiya, 2007a). This new species is distinguished from *R. tsugaruanus* and *R. reticulatus* by longer carapace and rectangular and elongate-polygonal fossae in reticulation (Fig. 5). It differs from *R. ?* sp. by having elongate-

polygonal and relatively coarse fossae.

Robertsonites sp.

Fig. 5.2, Plate 2.7–2.10

Registered material: UMUT-CA29563, adult left valve lacking its anterodorsal part; UMUT-CA29564, adult carapace.

Description: Carapace robust and large. Lateral outline subtrapezoidal: anterior margin round; posterior margin slightly tapering; dorsal margin slightly arched; ventral margin curved. Maximum length across middle of carapace. Maximum height across anterodorsal corner.

Surface ornament with reticulation: Reticulation formed by round or polygonal fossae and muri. Three outer muri prominent and concentrically arranged. Pores present on muri. Eye tubercle present.

Dorsal outline elliptical: anterior and dorsal margins obtuse tapering; lateral margins curved with indents at anterior approximately 1/6 and 1/2. Maximum width across posterior 1/4.

Measurement: UMUT-CA29563, L = 1.01 mm, H > 0.53 mm. UMUT-CA29564, L = 0.85 mm, H = 0.51 mm, W = 0.46 mm.

Occurrence: Lower part of the Sankebetsu Formation, Middle Eocene.

Remarks: The subtrapezoidal lateral outline with reticulate ornament indicates that this species belongs to *Robertsonites*.

This species shares muri parallel to anterior and ventral margins with *R. tsugaruanus* and round and polygonal fossae with *R. reticulatus* and *R. tsugaruanus* (Fig. 5).

R. tsugaruanus differs from the present species in having smaller carapace and finer reticulation.

R. reticulatus is distinguished from the present species by having a smaller carapace and finer and angular reticulation.

R. ashibetsuensis sp. nov. differs from *R. sp.* in its shorter and thicker carapace and elongated fossae.

This species is likely a new species; however, the small number of specimens and their poor preservation precludes the description of a new species.

6. Discussion

6.1 Ostracode paleobiogeography and implications for paleoclimate

The Eocene Hokkaido fauna differs in species composition from Eocene faunas in the regions south of Hokkaido, probably because of paleoclimatic differences. The genus *Robertsonites* has not been found in any samples from the Setouchi and Kyushu areas (Yamaguchi *et al.*, 2005, in press; Yamaguchi and Kamiya, 2007b; Table 2). Its absence from regions south of Hokkaido is unlikely to have been caused by spatial variations in depositional environment. The Hokkaido

samples containing *Robertsonites* were collected from bay and outer-shelf deposits (outer shelf deposits of the Sankebetsu Formation: Kurita *et al.*, 1992; Hoyanagi, 1995; bay deposits of the Akabira Formation: Takano and Waseda, 2003), whereas the Kyushu and Setouchi samples including Middle Eocene ostracodes are inner- to outer-shelf deposits (Yamaguchi *et al.*, 2005; Yamaguchi and Kamiya, 2007b). In addition, modern *Robertsonites* species dwell in muddy bottoms influenced by a cold water-mass with a summer temperature less than 10 °C (Ozawa, 2003). These Eocene fossil records, combined with the ecology of modern-day *Robertsonites*, suggest that the Eocene fauna containing *Robertsonites* probably dwelled under cooler conditions than contemporaneous ostracodes in the Seto Inland Sea and other regions to the south.

In addition to this discrimination between Hokkaido and the Seto Inland Sea region, Yamaguchi *et al.* (2005, in press) proposed that the Eocene fauna of the Seto Inland Sea dwelled under cooler conditions than those of Kyushu. These findings suggest that there existed at least three Eocene ostracode provinces corresponding to paleoclimatic realms in the Northwest Pacific.

Hanaiborchella reticularitriangularis, a species common to the fauna from the Middle–Upper Eocene Iwaya Formation of the Seto Inland Sea area (Table 2), is absent in the coeval assemblages of Kyushu and the East China Sea. This suggests that *H. reticularitriangularis* adapted to cooler conditions than the coeval ostracodes in Kyushu and the East China Sea.

6.2 Cenozoic biogeography of *Robertsonites*

The findings of this study indicate that the stratigraphic range of *Robertsonites* should be extended downward into the Middle Eocene. The present-day distribution of this genus includes the higher-middle to high latitudes of the Northern Hemisphere and the high latitudes of the Southern Hemisphere (e.g., Neale, 1967; Tabuki, 1986; Fig. 6). *Robertsonites* was likely endemic to the North Pacific during the Eocene; it has also been reported from Pliocene–Holocene sediments around the Arctic (e.g., Tabuki, 1986; Cronin and Ikeya, 1987; Fig. 6). Miocene and older species of *Robertsonites* have only been reported from Japan (e.g., Irizuki, 1994; Irizuki *et al.*, 2004; this study), and are absent in North Europe (e.g., Keen, 1978; Ducasse *et al.*, 1985). It is therefore likely to have been endemic to the North Pacific through the Eocene to the Miocene, migrating from the Pacific to the Atlantic between the Miocene and Pliocene (Cronin, 1991).

7. Concluding remarks

This study has shown that the Eocene ostracodes from Hokkaido provide information on 1) the origin and geographic diversification of the extant ostracode genus

Table 2 Occurrences of Hokkaido ostracode species in the Seto Inland Sea, Kyushu, and the East China Sea of the Northwest Pacific. Black circle represents the occurrence of the species, while white circles indicate the occurrence of the same genus as the species. The ostracode data for these regions are sourced from Liu (1989), Yang *et al.* (1990), Yamaguchi (2006), and Yamaguchi *et al.* (2005, 2006, in press).

Region	Formation	<i>Acanthocythereis</i> sp.	<i>Hanaiborchella reticularitriangularis</i>	<i>Hanaiborchella</i> sp.	<i>Robertsonites ashibetsuensis</i> sp. nov.	<i>Robertsonites</i> sp.
Seto Inland Sea	Unnamed in Kurashiki	○				
	Iwaya		●			
Kyushu	Kishima	○	○	○		
	Funazu	○	○	○		
	Okinoshima	○	○	○		
East China Sea	Wenzhou	○	○	○		
	Oujiang	○	○	○		

Robertsonites, a modern circumpolar Arctic species, and 2) the Eocene paleobiogeographic provincialism of ostracodes in the higher middle- to high-latitude marginal seas of the Northwest Pacific.

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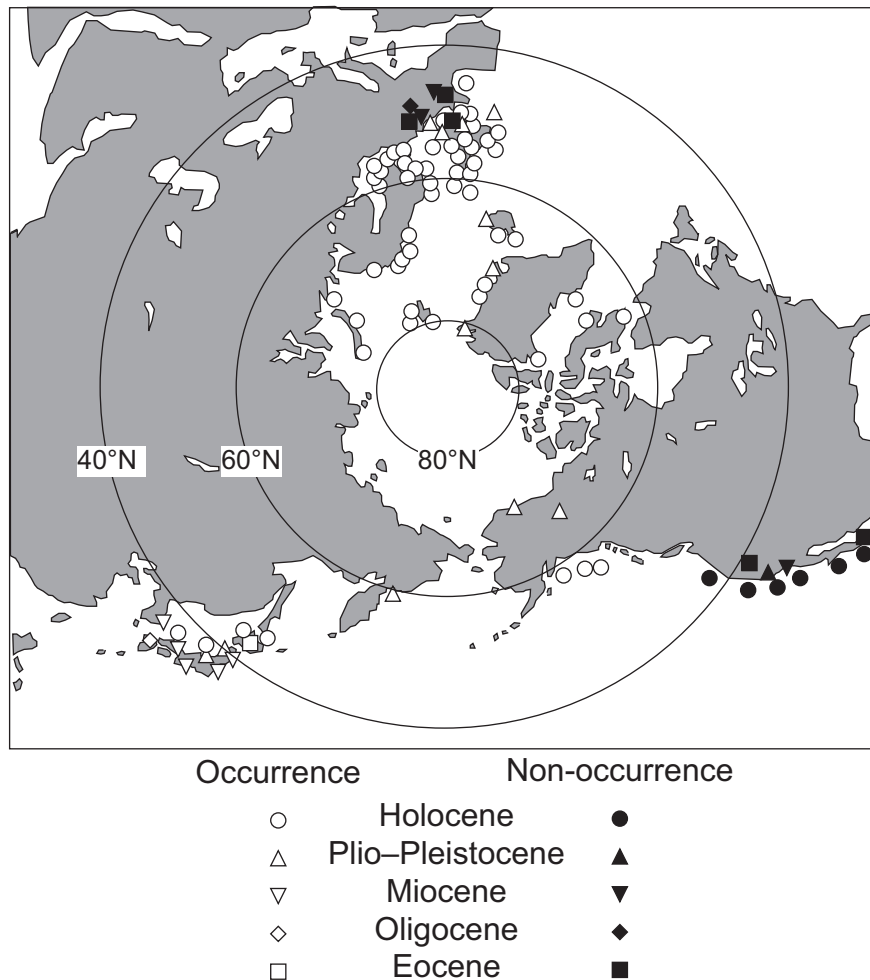


Fig. 6 Localities of Cenozoic *Robertsonites*. Modified after Tabuki (1986), Tanaka *et al.* (2002), and Yamada (2003), and compiled based on the following occurrence data: Eocene: this study; Oligocene: Yamaguchi and Kamiya (2007a); Miocene: Irizuki *et al.*, 2004; Plio-Pleistocene and modern: Stepanova *et al.* (2003) and Ozawa (2004). Non-occurrence data from Eocene to Oligocene: Marianos and Valentine (1958), Keen (1978), Ducasse *et al.* (1985), Carreño and Cronin (1993); Miocene: Finger (1983), Carbonel (1985), Ducasse and Cahuzac (1997), Janz and Vennemann (2005); Pleistocene and modern: Valentine (1976).

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北海道の始新統から産出した *Robertsonites* 属を含む 貝形虫化石の古生物地理的意義

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要 旨

北海道の始新統の貝形虫化石を初めて報告する。夕張地域の中部始新統石狩層群赤平層と幌内層から貝形虫化石5種が産出した。*Robertsonites* 属が多産した。この属は現在、北極海を中心にオホーツク海、アラスカ湾、北大西洋北部に分布する。始新統産のものは初めての報告で、最古の記録である。*Robertsonites* 属は北海道以南の始新統からはまだ報告がない。瀬戸内海の始新統岩屋層から報告されている *Hanaiborchella reticularitriangularis* も含まれていた。このことは北海道の始新世の貝形虫は、同時代の瀬戸内海の貝形虫と共通性を持つ。しかし両者の種構成は異なっていた。この貝形虫の違いは古水温の違いを反映している可能性がある。

新種 *Robertsonites ashibetsuensis* sp. nov. および他4種を記載した。

Appendix To identify sexual dimorphism in *Robertsonites ashibetsuensis* sp. nov., the lengths, heights, and widths of 10 specimens were subjected to discriminant analysis using Mahalanobis's generalized distance and Hotelling's T^2 -test, using a statistics software package, PAST (Hammer *et al.*, 2001). The specimens were divided into two statistically different morphological types ($p < 0.01$). The genus *Robertsonites* shows sexual dimorphism in terms of carapace length (Athersuch *et al.*, 1989); hence, the dimorphism of *R. ashibetsuensis* sp. nov. is assigned to be sexual. Results of the analysis and statistical test are listed in the table below. Abbreviations: D = Mahalanobis's generalized distance, P_{mis} = probability of misidentification, and P = Hotelling's p value.

Specimen	Length (mm)	Height (mm)	Width (mm)	Discriminant score	Sex
-	0.83	0.43	0.35	16.53	Female
-	0.93	0.47	0.34	3.80	Female
-	0.94	0.46	0.45	8.71	Female
UMUT-CA29560	0.94	0.51	0.43	12.05	Female
-	0.97	0.52	0.45	9.32	Female
UMUT-CA29562	0.97	0.51	0.43	7.37	Female
-	1.01	0.52	0.34	-4.27	Male
-	1.10	0.54	0.36	-15.20	Male
UMUT-CA29559	1.10	0.56	0.41	-10.10	Male
UMUT-CA29561	1.13	0.52	0.55	-8.95	Male
Discriminant function	-155.99	88.31	66.84		
D^2	19.17				
P_{mis} (%)	1.43				
P	0.00663				

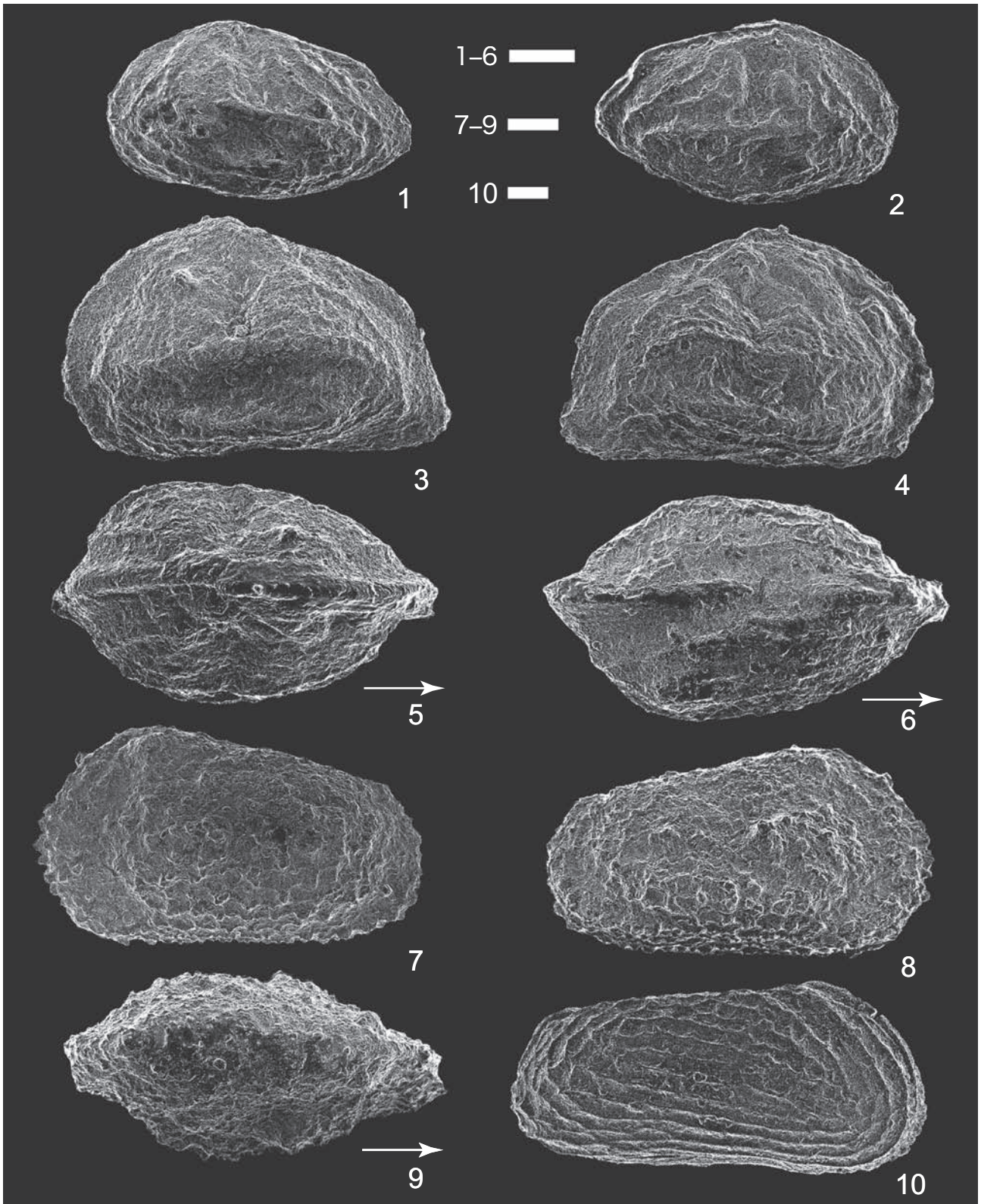


Plate 1 SEM images of fossil ostracodes. Scale bars: 0.10 mm. Arrows point in the anterior direction. 1–2, *Hanaiborchella reticularitriangularis*, UMUT-CA29556, carapace, KR952-409; 1, left lateral view; 2, right lateral view. 3–6, *Hanaiborchella* sp., UMUT-CA29557, carapace, KR952-409; 3, left lateral view; 4, right lateral view; 5, dorsal view; 6, ventral view. 7–9, *Acanthocythereis* sp., UMUT-CA29558, carapace, KR952-409; 7, left lateral view; 8, right lateral view; 9, dorsal view. 10, *Robertsonites ashibetsuensis* sp. nov., paratype, UMUT-CA29561, carapace, male, KR952-409, right lateral view.

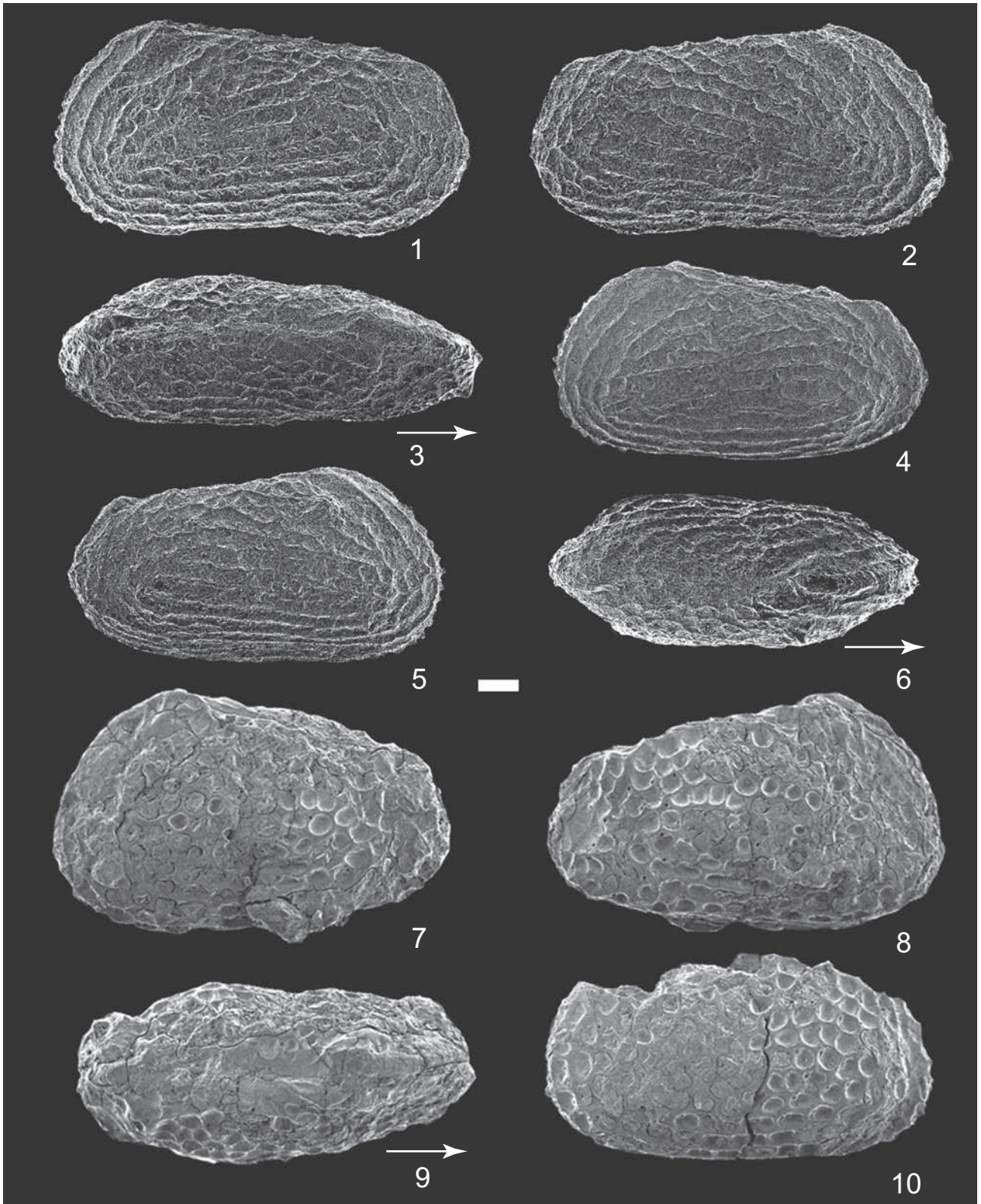


Plate 2 SEM images of fossil ostracodes. Scale bar: 0.10 mm. Arrows point in the anterior direction. 1–6, *Robertsonites ashibetsuensis* sp. nov.; 1–3, holotype, UMUT-CA29559, male, KR952-409; 1, left lateral view; 2, right lateral view; 3, dorsal view; 4–6, paratype, UMUT-CA29562, female, KR952-409; 4, left lateral view; 5, right lateral view; 6, dorsal view. 7–10, *Robertsonites* sp.; 7–9, UMUT-CA29564, carapace, KR952-426; 7, left lateral view; 8, right lateral view; 9, dorsal view; 10, UMUT-CA29563, left valve, KR952-426 left lateral view.