

Data report: late Eocene–early Oligocene ostracods at IODP Site U1411, off Newfoundland, North Atlantic¹

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Chapter contents

Abstract	1
Introduction	1
Methods and materials	2
Results	2
Acknowledgments	2
References	3
Figures	7
Tables	10
Plates	11
Appendix	17

Abstract

At the present, typical North Atlantic Deep Water ostracod faunas are characterized by the dominance of *Krithe* species and the association with *Henryhowella* and *Poseidonamicus*. The fauna may have originated during the Eocene–Oligocene. Because there are only a few taxonomic studies on Eocene–Oligocene ostracod taxa in the North Atlantic deep-sea sediments, the ostracod taxa are poorly understood. Here I report and illustrate 23 taxa from the upper Eocene–lower Oligocene sediments at Integrated Ocean Drilling Program Site U1411 in the North Atlantic Ocean and describe the taxa systematically.

Introduction

Under the North Atlantic Deep Water (NADW), modern ostracod faunas are characterized by *Krithe*, *Poseidonamicus*, *Henryhowella*, and *Abyssocythere* (Dingle and Lord, 1990). Benson (1975) named the faunas with *Krithe*, *Poseidonamicus*, *Henryhowella*, and *Abyssocythere* as the psychrosphere fauna and considered that it appeared during the Eocene–Oligocene transition. Using foraminifer stable isotope and Nd isotopes, some studies hypothesize that the NADW was initially formed during the early Oligocene (e.g., Via and Thomas, 2006; Katz et al., 2011). The formation of the psychrosphere fauna is being argued (e.g., Dall’Antonia et al., 2003), but it may be linked to the formation of NADW. Because some of the characteristic taxa originated from the early Paleogene, the psychrosphere fauna may have been formed before the late Eocene (e.g., Steineck et al., 1984; Guernet and Bellier, 2000). In the North Atlantic Ocean, the Eocene–Oligocene ostracods are poorly understood, with only limited data (Ducasse and Peypouquet, 1979; Coles and Whatley, 1989; Whatley and Coles, 1991; Coles et al., 1994; Coles, 1996; Guernet and Bellier, 2000) (Fig. F1). Previously, Coles and Whatley (1989) described 3 new genera and 21 new species from the upper Eocene to lower Oligocene sediments at Deep Sea Drilling Project (DSDP) Sites 549, 550, and 558. Coles et al. (1994) studied the taxonomy and biostratigraphy of the genus *Krithe* in the North Atlantic Ocean and proposed 4 new taxa of *Krithe* from the upper Eocene to lower Oligocene sediments at Sites 549 and 550. Guernet and Bellier (2000) reported 51 taxa from the upper Eocene sediments at Ocean Drilling Program (ODP) Sites 1052 and 1053. Here, I report and illustrate 23 taxa of

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late Eocene–early Oligocene ostracods from Integrated Ocean Drilling Program (IODP) Site U1411, off Newfoundland in the North Atlantic Ocean. At IODP Site U1407, Yamaguchi et al. (2017b, 2017c) already reported and described 32 ostracod taxa from Maastrichtian–Thanetian sediments.

Methods and materials

At Site U1411 (41°37′5.94″N, 48°59′59.94″W), three holes were drilled on the seafloor of the southeast Newfoundland Ridge at 3299 m water depth (see the “[Site U1411](#)” chapter [Norris et al., 2014]; Fig. [F1](#)). We took 39 sediment samples of ~20 cm³ volume from the working halves of Cores 342-U1411B-16X through 28X (Table [T1](#)). All the core sediments consist of two lithologic units: silty clay with nannofossils at 140–235 m core composite depth below seafloor (CCSF) and nannofossil chinks with foraminifers at 235–266 m CCSF (lithostratigraphic Units II and III, respectively). The sediments are pinkish to white in color. Using planktonic biostratigraphy, the core sediments are dated to be ~37.9–33.4 Ma, late Eocene to early Oligocene, and correlate to nannofossil Zones NP18–NP21 of Martini (1971) and foraminiferal Zones E14–O1 of Wade et al. (2011). The paleodepth at 34 Ma is estimated to be around 3000 m.

For extracting ostracod specimens, we washed samples using a sieve with 32 µm openings. Ostracod specimens were picked from fractions >150 µm using a fine brush under a binocular microscope. The specimens were observed and their photos were taken with a JSM-6500F scanning electron microscope (SEM) (JEOL Ltd.) (Pl. [P1](#), [P2](#), [P3](#), [P4](#), [P5](#)) and an optical microscope in order to identify them to the species level and describe morphological characteristics.

For illustrating the internal structures of the new species, the specimens were immersed in tap water in a Petri dish and observed under transmitted light on a VHX-2000 digital microscope (Keyence, Ltd.). Images of the internal structures were also captured. Using the focus stacking system equipped with the digital microscope, deep-focus images of the internal structures were made (Pl. [P6](#)). Image outlines were drawn to identify shapes of marginal pore canals and vestibulum (Fig. [F2](#)). Valve length and valve height of the specimens were measured using the digital microscope (Table [T1](#), [T2](#); Fig. [F3](#)). The SEM and the digital microscopes are hosted at the Center for Advanced Marine Core Research at Kochi University (Japan).

For systematic descriptions, higher taxonomy followed Brandão et al. (2017). The general terminology of the morphology followed Sylvester-Bradley and Benson (1971) and Horne et al. (2002). The terminology for characteristics of *Krithë* and trachyleberids followed Coles et al. (1994) and Yasuhara et al. (2015), respectively. According to Athersuch et al. (1989), carapace size is classified as follows:

Small: <500 µm long

Medium: 500–650 µm long

Large: >650 µm long

All the specimens were registered and deposited at the National Museum of Nature and Science (NMNS) (Tsukuba, Japan) and the Scripps Institution of Oceanography (SIO) (University of California, San Diego), which are Micropaleontological Reference Centers for the International Ocean Discovery Program (Table [T1](#)). The catalog numbers at NMNS and SIO have prefixes of MPC and SIO-BIC, respectively.

Results

Preservation of the specimens is good overall. The specimens are translucent to white in color; some have secondary calcite. External structures, such as carinae, spines, and reticulation, are well preserved. Calcareous ooze and nannofossils are attached to the surface of the specimens and often cover muscle scars and pores. We identify 23 taxa that belong to 2 suborders (Platycopida and Podocopida) and 12 families (Bairdiidae, Bythocyprididae, Bythocytheridae, Cytherellidae, Cytheruridae, Eucytheridae, Krithidae, Loxoconchidae, Paracytherideidae, Pontocyprididae, Trachyleberididae, and Xestoleberididae) (Table [T3](#)). The Krithidae and Trachyleberididae taxa are diversified, with six species each. See the [Appendix](#) for taxonomic notes.

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- Initial receipt:** 10 February 2017
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Figure F1. Location of Site U1411 and other ocean drilling sites discussed.

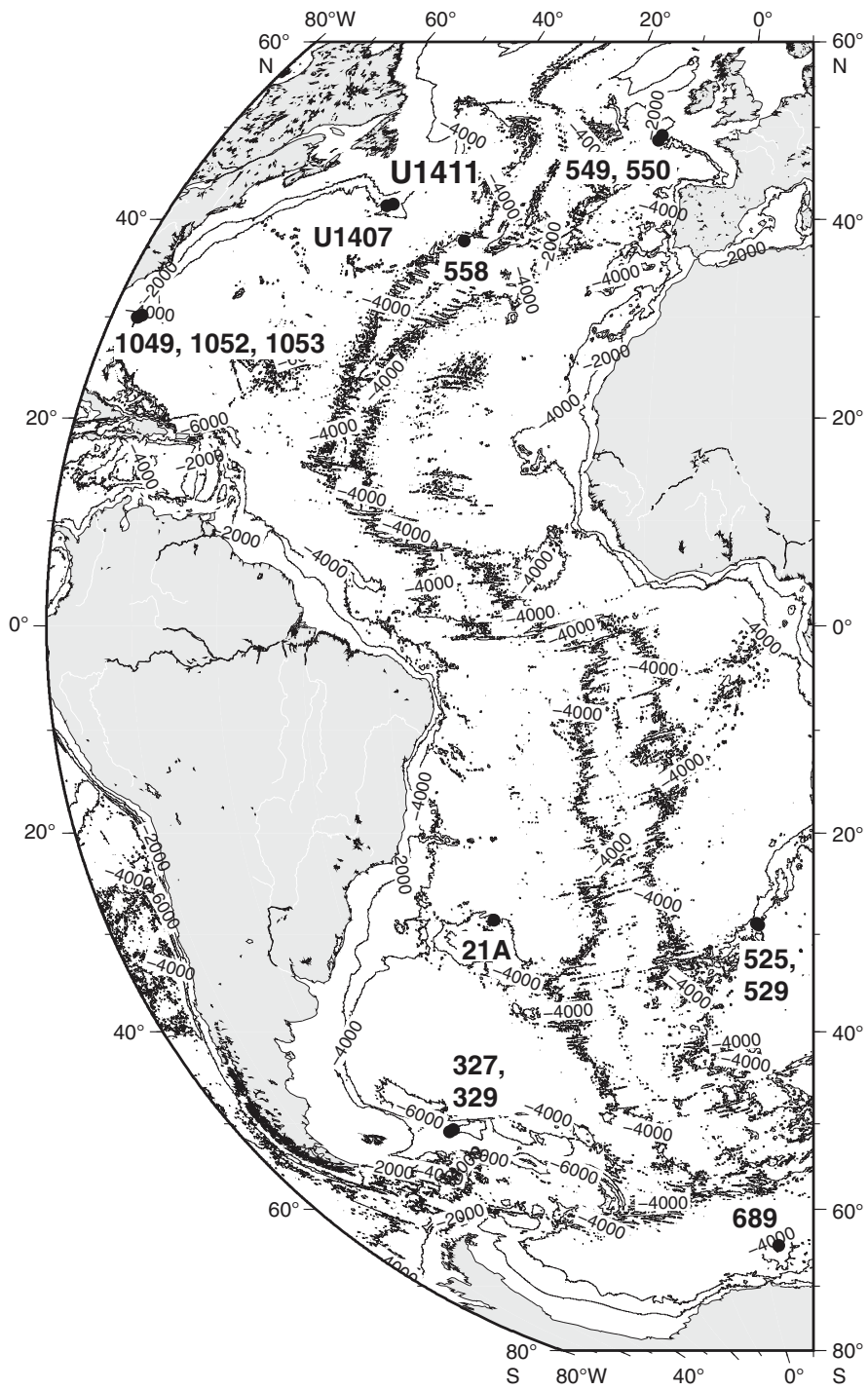


Figure F2. Tracing of specimens in Plate P6. AD = antero-dorsal radial pore canal (designed by Coles et al. [1994]). Scale bars = 100 μm . **A.** *Argilloecia* sp., Specimen MPC-15259, adult left valve. **B, C.** *Krithe crassicaudata* van den Bold; (B) Specimen MPC-15266, adult left valve; (C) Specimen MPC-15265, juvenile left valve. **D.** *Krithe dolichodeira* van den Bold, Specimen SIO-BIC-C12210, adult right valve. **E.** *Krithe pernoides pernoides* (Bornemann), Specimen MPC-15269, adult left valve. **F.** *Krithe trinidadensis* van den Bold, Specimen MPC-15271, adult right valve. **G.** *Parakrithe vermunti* (van den Bold), Specimen MPC-15272, adult left valve.

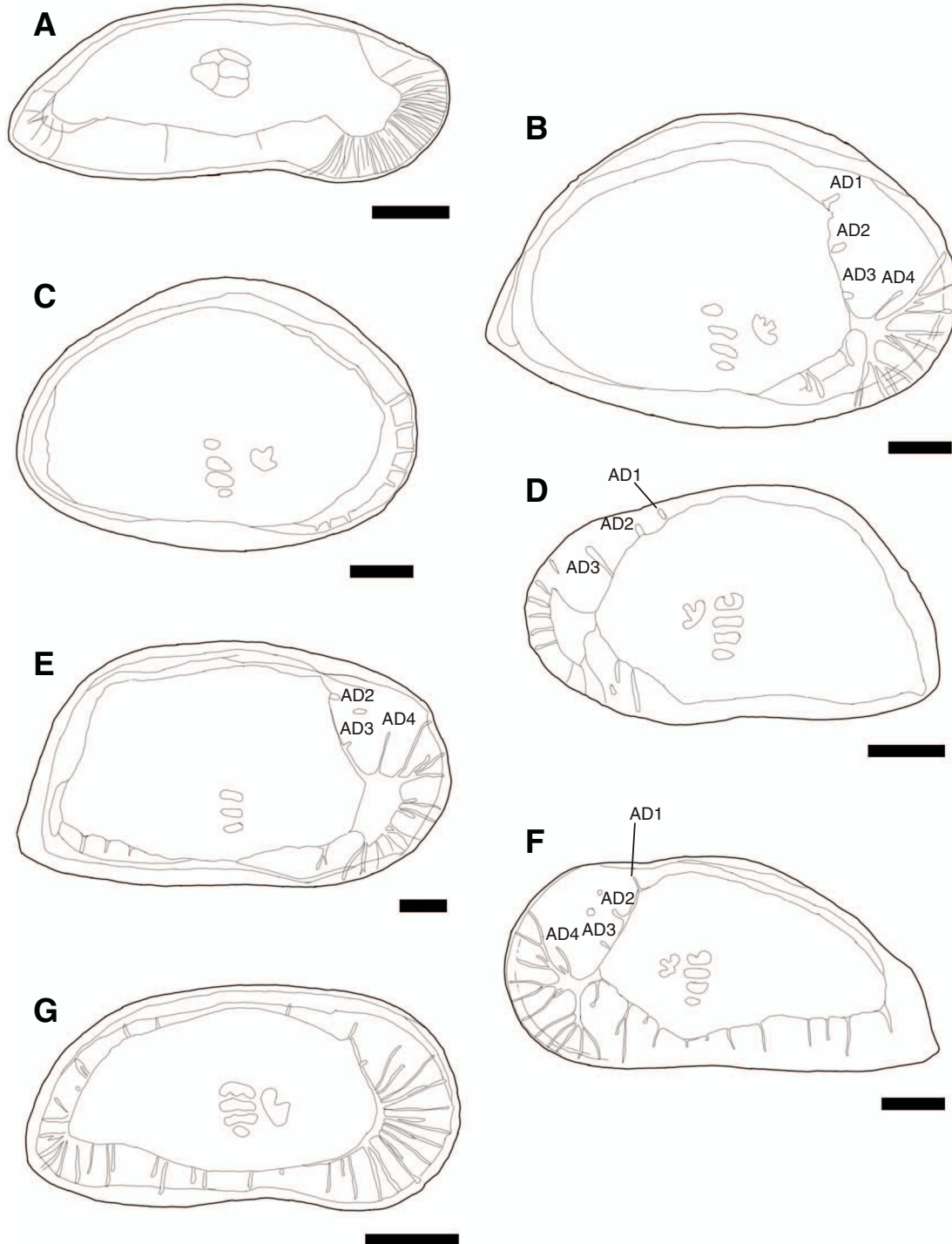


Figure F3. Plot of *Krithe crassicaudata* and *Messinella* valve length vs. height. Detailed *K. crassicaudata* measurements are shown in Table T2. *Messinella* measurements are from van den Bold (1969). LV = left valve, RV = right valve.

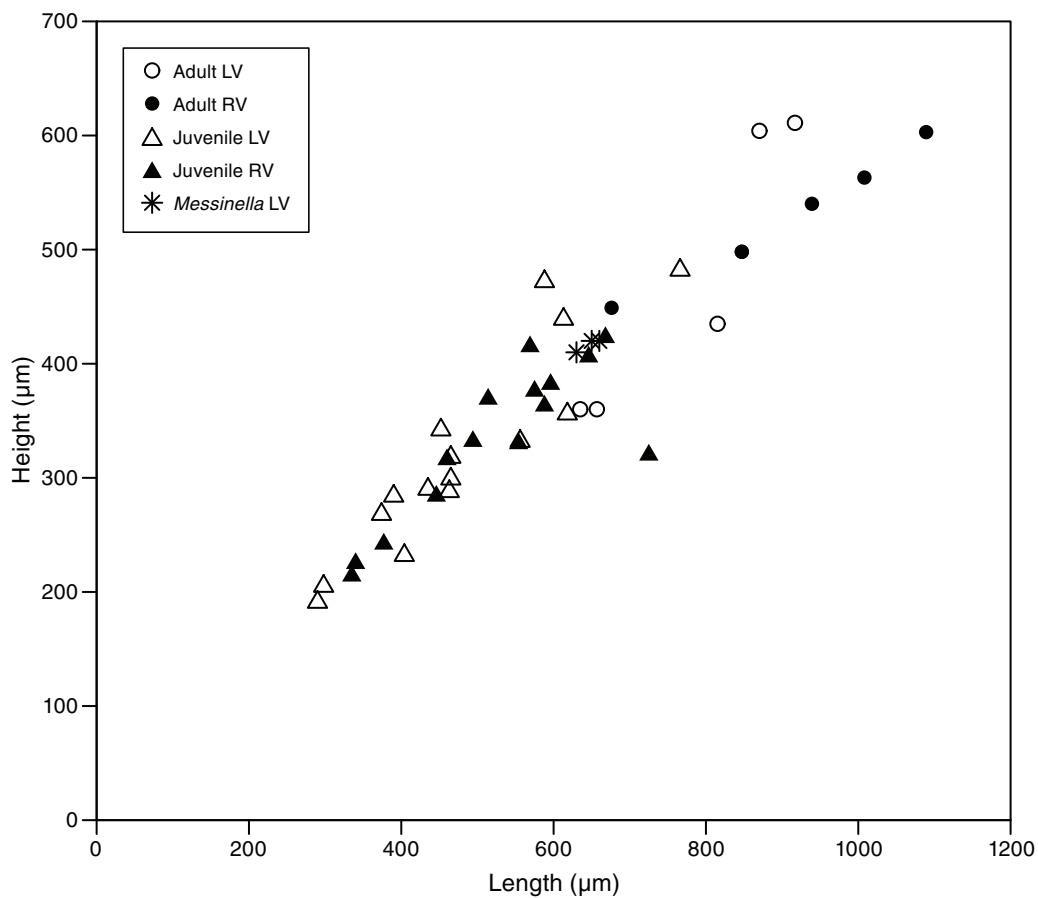


Table T1. Specimen measurements and features, Hole U1411B. This file is available in [CSV format](#).

Table T2. *Krithe crassicaudata* measurements, Hole U1411B. This file is available in [CSV format](#).

Table T3. Ostracod taxa counts from Hole U1411B sediments. This file is available in [CSV format](#).

Plate P1. Scanning electron microscope (SEM) images. Scale bars = 100 μm . 1, 2. *Cytherella* sp. (1: Specimen MPC-15258, adult left valve, external view; 2: Specimen SIO-BIC-C12204, adult right valve, external view). 3, 4. *Bairdoppilata* sp. Specimen MPC-15282, juvenile left valve (3: external view, 4: internal view). 5, 6. *Bythocypris* sp. Specimen MPC-15281, adult left valve (5: external view, 6: internal view). 7, 8. *Argilloecia* sp., Specimen MPC-15259, adult left valve (7: external view, 8: internal view). 9, 10. Bythocytheridae gen. et sp. indet., Specimen MPC-15260, adult right valve (9: external view, 10: internal view).

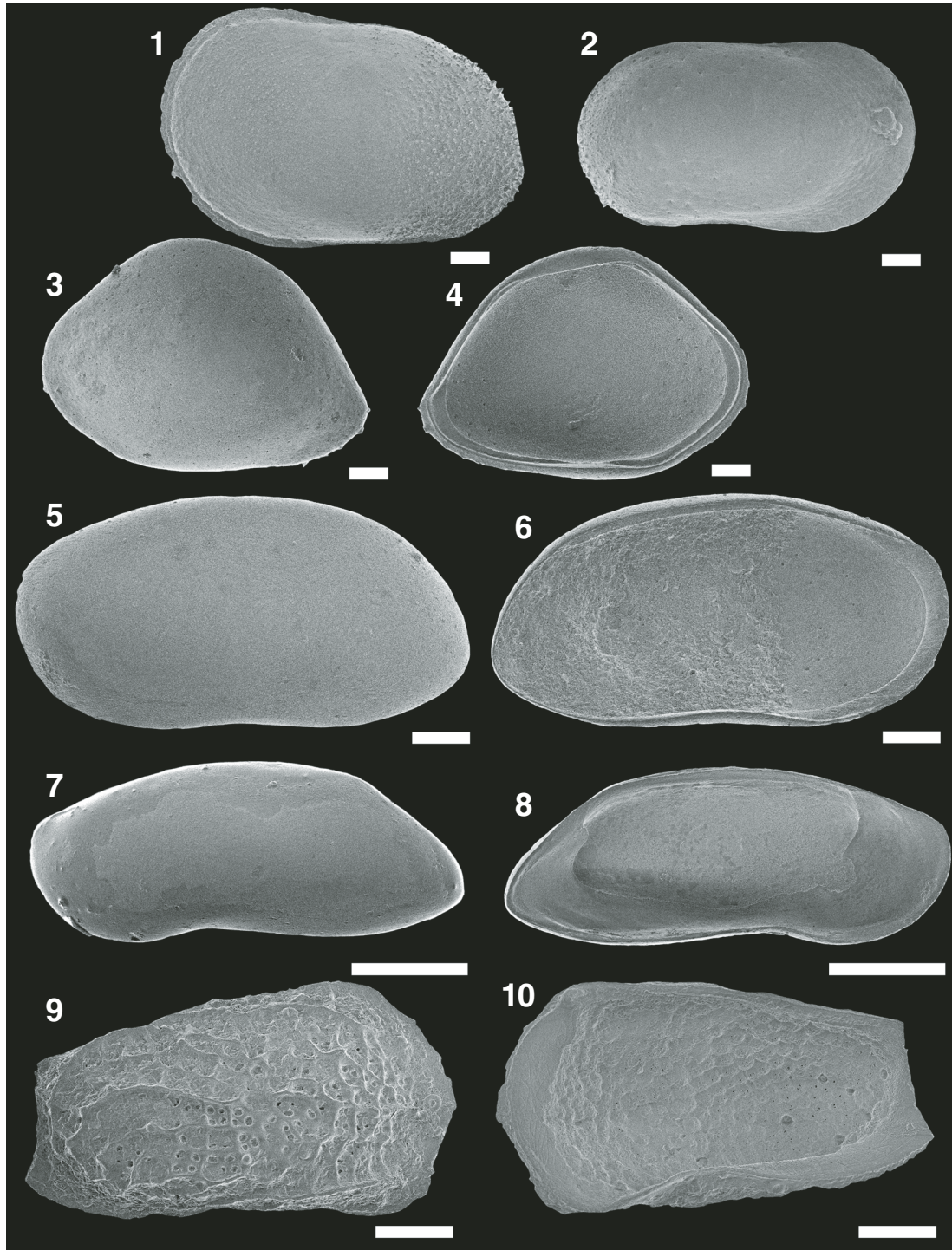


Plate P2. SEM images. Scale bars = 100 μm . Arrows = anterior direction. 1. *Aversovalva formosa* Coles and Whatley, Specimen MPC-15261, adult left valve (external view). 2. *Cytheropteron americanum* Yamaguchi, Matsui, and Nishi, Specimen MPC-15262, adult right valve (external view). 3. *Pelecocythere* sp., Specimen MPC-15263, adult right valve (external view). 4. *Eucythere* sp., Specimen MPC-15264, adult right valve (external view). 5–8. *Krithe crassicaudata* van den Bold; (5, 6) Specimen MPC-15266, adult left valve (5: external view, 6: dorsal view); (7, 8) Specimen MPC-15265, juvenile left valve (7: external view, 8: dorsal view).

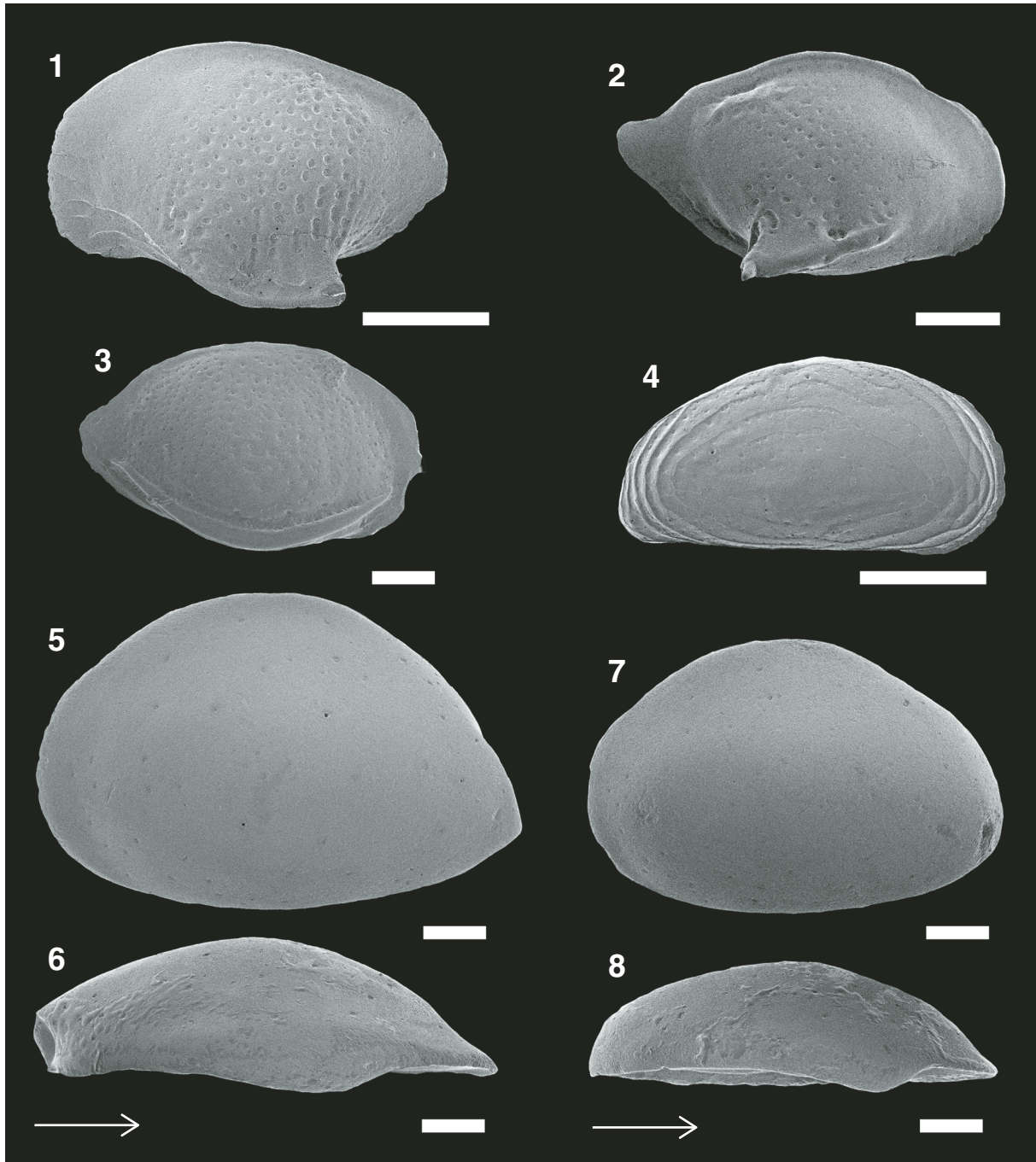


Plate P3. SEM images. Scale bars = 100 μm . 1–4. *Krithe crassicaudata* van den Bold; (1, 2) Specimen MPC-15266, adult left valve (1: internal view, 2: hingement); (3, 4) Specimen MPC-15265, juvenile left valve (3: internal view, 4: hingement). 5, 6. *Krithe dolichodeira* van den Bold, Specimen SIO-BIC-C12210, adult right valve (5: external view, 6: internal view). 7, 8. *Krithe pernoides pernoides* (Bornemann), Specimen MPC-15269, adult left valve (7: external view, 8: internal view). 9, 10. *Krithe trinidadensis* van den Bold, Specimen MPC-15271, adult right valve (9: external view, 10: internal view).

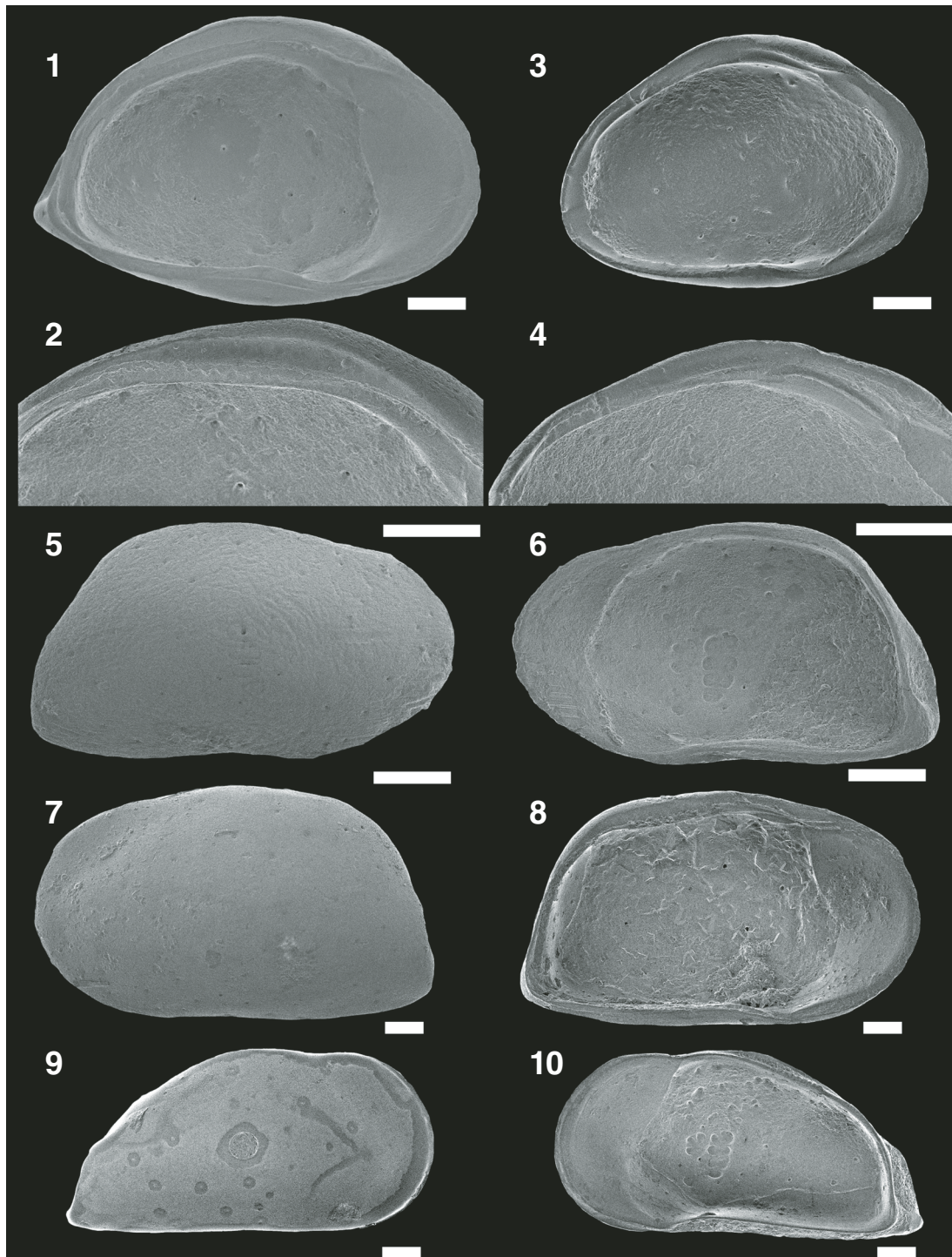


Plate P4. SEM images. Scale bars = 100 μm . 1, 2. *Parakrithe vermunti* (van den Bold), Specimen MPC-15272, adult left valve (1: external view, 2: internal view). 3, 4. *Loxoconcha* sp., Specimen MPC-15273, adult right valve (3: external view, 4: internal view). 5. *Paracytheridea* sp., Specimen MPC-15274, adult left valve (external view). 6. *Croninocythereis tridentiferae* Yasuhara, Hunt, Okahashi, and Brandão, Specimen MPC-15276, adult right valve (external view). 7. *Poseidonamicus pseudorobustus* Coles and Whatley, Specimen SIO-BIC-C12216, adult right valve (external view).

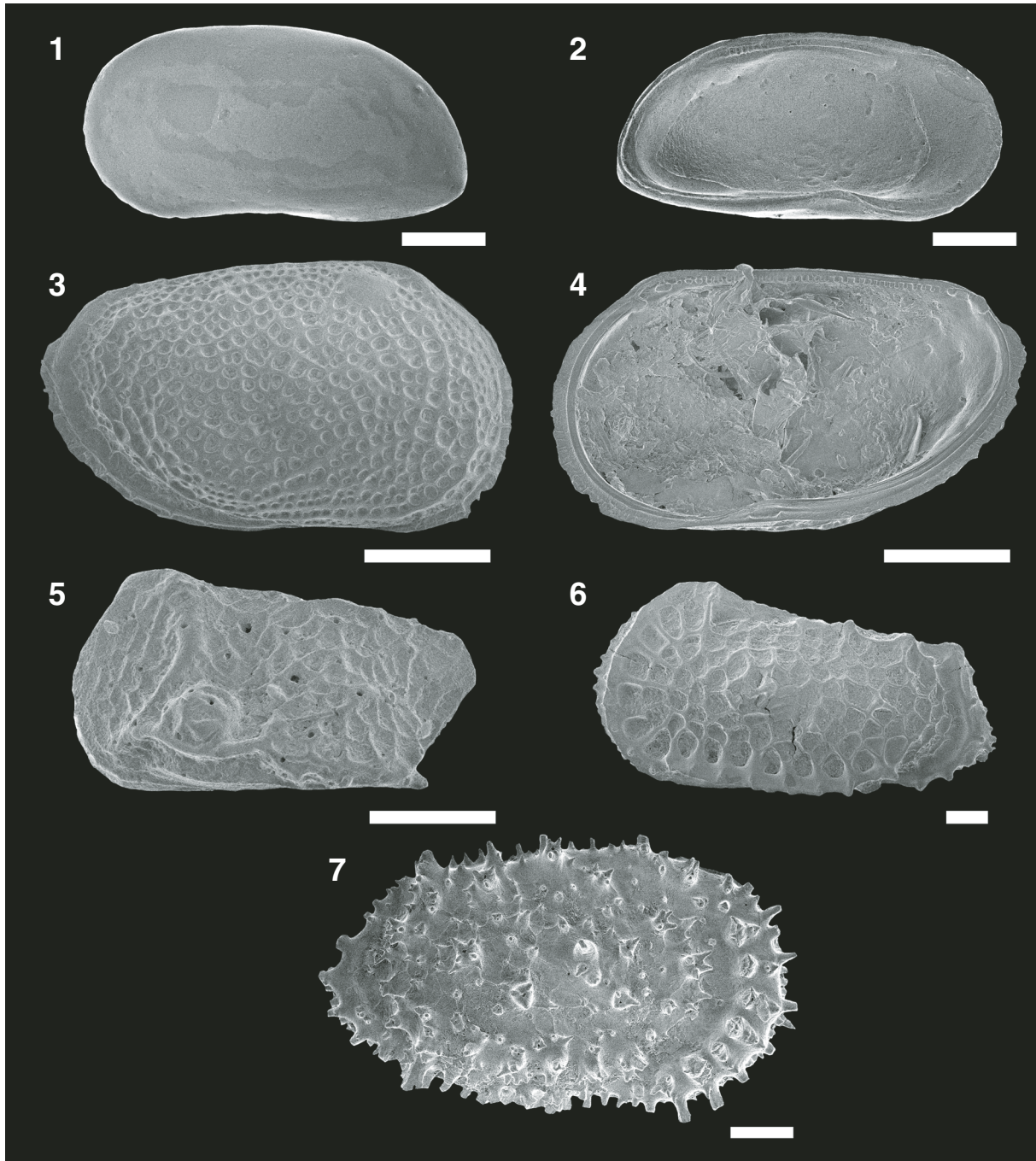


Plate P5. SEM images. Scale bars = 100 μm . Arrow = anterior direction. 1. *Dutoitella mimica* Dingle, Specimen MPC-15278, adult right valve (external view). 2. *Henryhowella asperrima* (Reuss), Specimen SIO-BIC-C12216, adult right valve (external view). 3–6. *Pennyella* sp., Specimen MPC-15277, adult right valve (3: external view, 4: internal view, 5: hingement, 6: muscle scars). 7, 8. *Trachyleberidea* sp., Specimen MPC-15283, juvenile left valve (7: external view, 8: internal view). 9. *Platyleberis* sp., Specimen MPC-15280, adult right valve (external view).

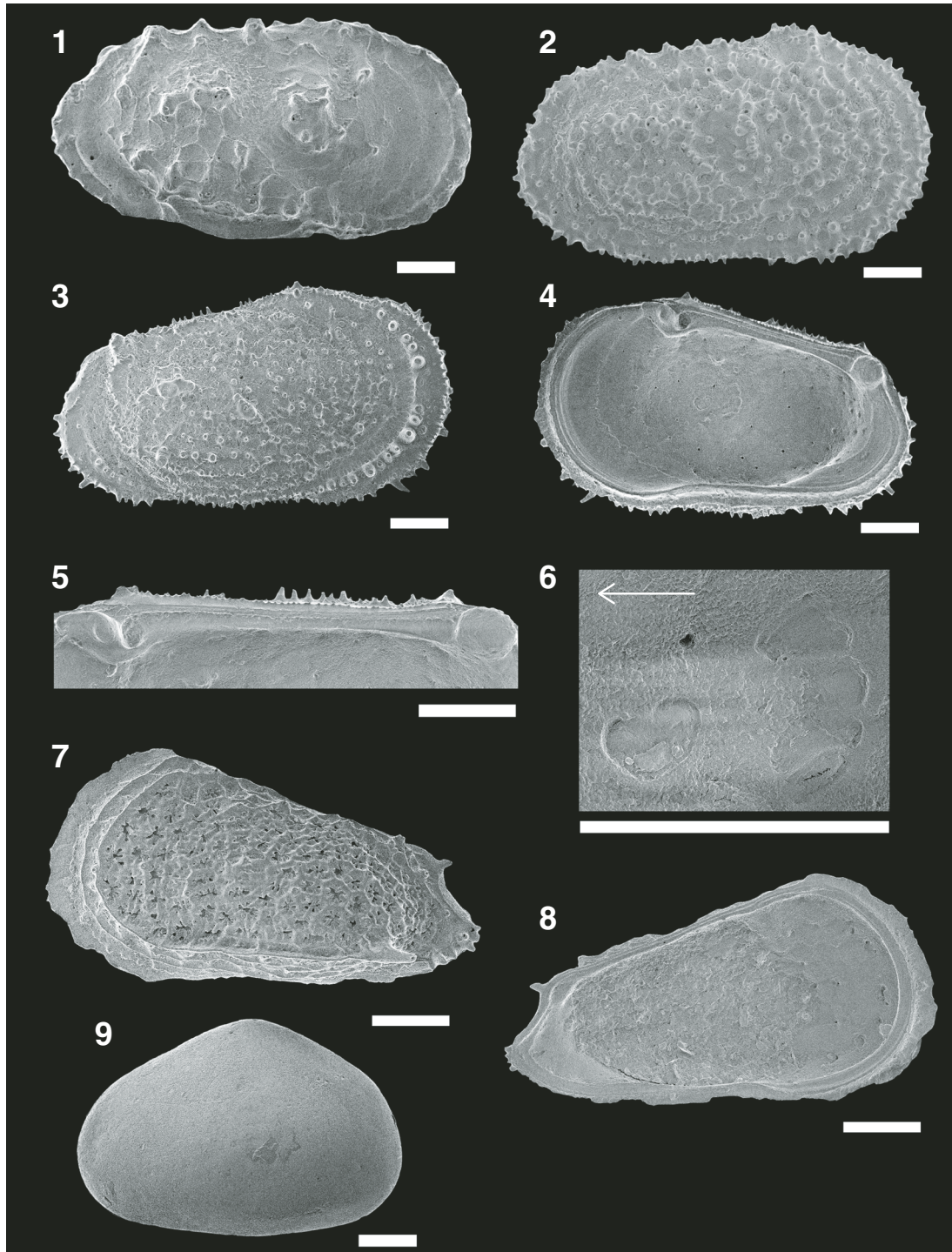
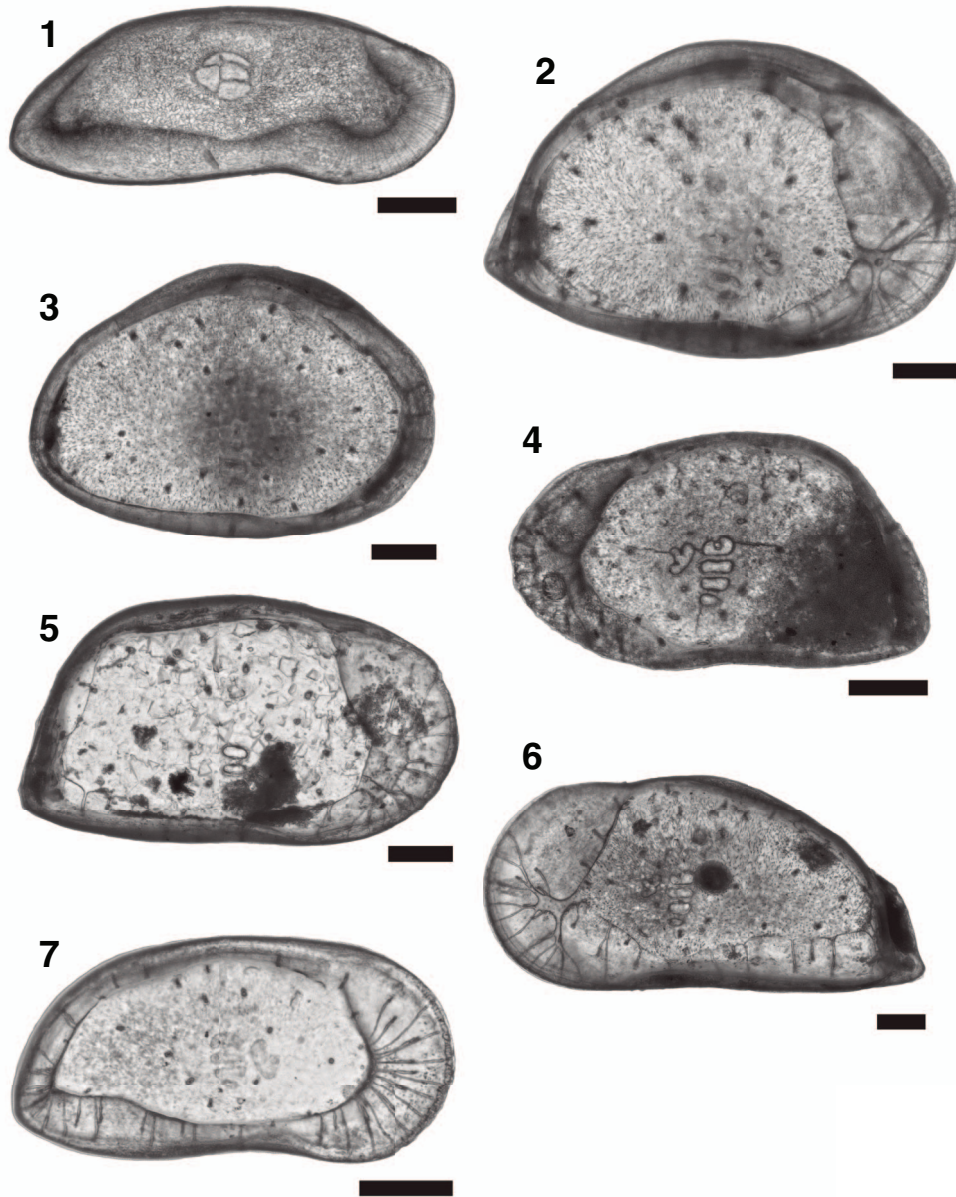


Plate P6. Transmitted light optical microscope images of internal structures of specimens. All the images were captured. Scale bars = 100 μm . 1. *Argilloecia* sp., Specimen MPC-15259, adult left valve. 2, 3. *Krithe crassicaudata* van den Bold; (2) Specimen MPC-15266, adult left valve; (3) Specimen MPC-15265, juvenile left valve. 4. *Krithe dolichodeira* van den Bold, Specimen SIO-BIC-C12210, adult right valve. 5. *Krithe pernoides pernoides* (Bornemann), Specimen MPC-15269, adult left valve. 6. *Krithe trinidadensis* van den Bold, Specimen MPC-15271, adult right valve. 7. *Parakrithe vermunti* (van den Bold), Specimen MPC-15272, adult left valve.



Appendix

Systematic paleontology of selected taxa

Suborder CYPRIDOCOPINA Jones, 1901

Superfamily PONTOCYPRIDOIDEA Müller, 1894

Family PONTOCYPRIDIDAE Müller, 1894

Genus *ARGILLOECIA* Sars, 1866; emend. Maddocks, 1991

Argilloecia sp.

(Fig. F2A; Pl. P1, figs. 7, 8; Pl. P6, fig. 1)

Description: Adult carapace robust and medium (591–598 µm long). In external view, lateral outline elongated subtrapezoidal: anterior margin round; posterior margin tapering; dorsal margin gentle arched; ventral margin curved, concave up in the anterior. Surface smooth. In internal view, anterior and ventral marginal zones are well developed. Anterior marginal pore canals: 46 straight or straightly curved. Adductor muscle scars round, formed by five scars: in anterior row, three elliptical scars; in posterior row, two subtriangular scars.

Remarks: In the lateral outline, this species is similar to *Argilloecia* sp. of Yamaguchi et al. (2017b) that was reported from upper Paleocene sediments at Site U1407. However it is different from the Paleocene species in having five adductor muscle scars.

Suborder CYTHEROCOPINA Baird, 1850

Superfamily CYTHEROIDEA Baird, 1850

Family BYTHOCYTHERIDAE Sars, 1866

Gen. et sp. indet.

(Pl. P1, figs. 9, 10)

Description: Adult carapace thin and small (384 µm long). In external view, lateral outline subrectangular: anterior margin angular with apex near middle; dorsal and posterior margins slightly sinuous. Maximum height across antero-dorsal corner. Surface ornamented with primary and secondary reticulations and spines. Primary reticulation formed by distinct horizontal muri and polygonal fossae. In secondary reticulation, fossae are round. Conjunctive and disjunctive spines on postero-central area. In internal view, lophodont-type hingement: round tooth of anterior element; smooth median groove. Anterior and postero-ventral marginal zones developed.

Remarks: Only two specimens were obtained from Sample 342-U1411B-26X-7W, 40–42 cm. The species is similar to Gen. et sp. 1 of Guernet and Bellier (2000) in the lateral outline and reticulated ornaments. Gen. et sp. 1 was reported from Maastrichtian sediments at ODP Site 1049, northwestern Atlantic. It is different from the Maastrichtian taxon in the direction of muri on the antero-ventral area. The Eocene species shows horizontal muri on the area, whereas the Maastrichtian taxon exhibits convexly curved muri.

Family EUCYTHERIDAE Puri, 1954

Genus *EUCYTHERE* Brady, 1868

Eucythere sp.

(Pl. P2, fig. 4)

Eucythere cf. *circumcostata* Whatley and Coles: Majoran and Widmark, 1998, p. 853, fig. 3.4; Majoran et al., 1998, p. 63, pl. 1, fig. 14; Majoran and Dingle, 2002, p. 148, fig. 3.5.

Eucythere sp. Bergue and Nicolaidis, 2012, p. 52, fig. 2.22.

Description: Adult carapace robust and small (385 µm long). Lateral outline ovate: anterior margin round; posterior margin round with apex at lower one-third of the margin; dorsal margin slightly arched; ventral margin curved with concave up near middle. Postero-dorsal corner angular. Posterior cardinal angle obtuse. Maximum length across middle of anterior margin; maximum height across antero-dorsal corner. Surface with five concentric carinae and punctae: first and second carinae distinct on anterior and posterior areas; third carina distinct on postero-central area. Punctae distributed along concentric carinae.

Stratigraphic distribution: Maastrichtian–Chattian. The species occurs from Maastrichtian sediments at DSDP Site 525 (Majoran et al., 1998), southeastern Atlantic, and ODP Site 689 (Majoran and Widmark, 1998), Southern Ocean, and from Danian–Chattian sediments at Site 689 (Majoran and Dingle, 2002). It is reported from the Oligocene at DSDP Site 329, southwestern Atlantic (Bergue and Nicolaidis, 2012).

Remarks: As pointed out by Majoran and Dingle (2002), the species is different from the types of *E. circumcostata* Whatley and Coles, 1987, in lacking punctae on the central area.

Family KRITHIDAE Mandelstam cited in Bubikyan, 1958

Genus *KRITHE* Brady, Crosskey, and Robertson, 1874

Krithe crassicaudata van den Bold, 1946

(Fig. F2B–F2C; Pl. P2, figs. 5–8; Pl. P3, figs. 1–4; Pl. P6, figs. 2–3)

Krithe crassicaudata van den Bold, 1946, p. 78, pl. 7, fig. 2a–f; van den Bold, 1960, p. 158, pl. 3, fig. 7a–d; Yamaguchi and Norris, 2012, p. 36, figs. 3.11, 4.1; Yamaguchi et al., 2012, fig. 3.

Krithe sp. Cronin and Compton-Goodin, 1987, pl. 6, figs. 4, 7.

Description: Adult carapace robust and large in size (635–1089 µm long). Right valve (RV) dorsally overlapped by left valve (LV). In external view, lateral outline ovate: round anterior margin; angular posterior margin; arched dorsal margin; posterior margin concavely curved. Dorsal outline of LV half elliptical: anterior edge tapering; posterior edge angular with indent; outside margin round; dorsal contact to RV obviously curved near middle of valve. Smooth surface. In internal view, lophodont-type hingement: in LV, elongated socket of anterior element; smooth median bar; crenulated socket of posterior element. Broad

anterior marginal zone with Y-shaped vestibulum and 13 anterior radial pore canals (ARPCs). ARPC straight or bifurcated. Antero-dorsal radial pore canals (AD): short AD1–AD3 and elongated AD4. Four ovate adductor muscle scars arranged in a row. Frontal muscle scar trilobate.

Juvenile carapace robust and small to large in size (290–766 µm long). RV slightly smaller than LV. In external view, lateral outline ovate: round anterior margin; angular posterior margin; arched dorsal margin; posterior margin concavely curved. Dorsal outline of LV half elliptical: anterior edge tapering; posterior edge round; outside margin round; dorsal contact to RV obviously curved near middle of valve. Smooth surface. In internal view, lophodont-type hingement: in LV, elongated socket of anterior element; smooth median bar; half-round socket with crenulation of posterior element. Anterior marginal zone narrow. Eight straight ARPCs. Adductor and frontal muscle scars as same as adult form.

Stratigraphic distribution: Maastrichtian–Aquitainian. Coles et al. (1994) indicated that this species ranges from calcareous nannofossil Zones NP18 to NN1 of Martini (1971). Yamaguchi et al. (2017a) reported the species from the Maastrichtian at Site U1407.

Remarks: Coles et al. (1994) considered *Messinella* van den Bold, 1969, as a junior synonym of *Krithe crassicaudata*. *Messinella* was originally described from the Neogene Manchionean Formation in Jamaica. The juvenile form of the species is as large as *Messinella* species (Table T2; Fig. F3) and similar to *Messinella* species in the ovate lateral outline with the maximum height across the middle of the valve and straight-shaped ARPC. However, the juvenile form of *K. crassicaudata* is distinguished from *Messinella* species by having a trilobate frontal muscle scar and the elongated anterior element without crenulation in the hingement in the internal view, and a curved dorsal contact of LV to RV in the dorsal view. The genus *Messinella* shows one or two elongate frontal muscle scars and the lophodont-type hingement with crenulated anterior and posterior elements in the internal view and a slightly curved dorsal contact in the dorsal view (van den Bold, 1969).

***Krithe dolichodeira* van den Bold, 1946**

(Fig. F2D; Pl. P3, figs. 5, 6; Pl. P6, fig. 4)

Krithe dolichodeira van den Bold, 1946, p. 75, pl. 4, fig. 14a, b; Coles et al., 1994, p. 81, pl. 1, figs. 13–18; Ayress et al., 1999, p. 6, fig. 3, G, H; Alvarez Zarikian, 2015, pl. 2, figs. 1–3.

Parakrithe hemideclivata Ruan in Ruan and Hao, 1988, p. 272, pl. 45, figs. 12–15.

Krithe hemideclivata (Ruan and Hao, 1988), Whatley and Zhao, 1993, figs. 3, 9; Zhao and Whatley, 1997, figs. 5, 4; Irizuki et al., 2007, figs. 5, 3.

Stratigraphic distribution: Maastrichtian–present. Coles et al. (1994) illustrated that the species has persisted since calcareous nannofossil Zone NP10 of Martini (1971) (55.81–54.17 Ma). Yamaguchi et al. (2017a) reported the species from the Maastrichtian at Site U1407.

***Krithe pernoides pernoides* (Bornemann, 1855)**

(Fig. F2E; Pl. P3, figs. 7, 8; Pl. P6, fig. 5)

For comprehensive pre-1994 synonymy see Coles et al. (1994).

Krithe pernoides pernoides (Bornemann). Coles et al., 1994, p. 104, pl. 5, figs. 7–12, text-fig. 5K–Q.

Stratigraphic distribution: Lutetian–present. In the North Atlantic, Coles et al. (1994) states that the species appeared in calcareous nannofossil Zone NP15 of Martini (1971) (46.29–42.87 Ma) and persisted to Zone NN19 (1.93–0.44 Ma). This species is found in the Bay of Biscay (Pascual et al., 2009) and Holocene sediments in the Mediterranean (Fanget et al., 2013; Angue Minto'o et al., 2015).

***Krithe trinidadensis* van den Bold, 1958**

(Fig. F2F; Pl. P3, figs. 9, 10; Pl. P6, fig. 6)

For comprehensive pre-1999 synonymy see Do Carmo and Sanguinetti (1999).

Krithe trinidadensis van den Bold: Ayress et al., 1999, p. 16, figs. 2I, 2J, 7H–L, 8FF, 8GG; Do Carmo and Sanguinetti, 1999, p. 114, pl. 1, fig. 3; Rodriguez-Lazaro and Cronin, 1999, fig. 3.4, pl. 1.7–1.8; Bergue et al., 2006, fig. 7B; Bergue et al., 2013, p. 31, fig. 3M–3P; Alvarez Zarikian, 2009, pl. P7, fig. 5.

Stratigraphic distribution: Lutetian–present (Coles et al., 1994; Do Carmo and Sanguinetti, 1999). The species ranges from calcareous nannofossil Zone NP16 of Martini (1971) (42.87–40.40 Ma) to the present.

Remarks: The species shows variation in the lateral outline. The illustrated specimen is similar to the specimens of Ayress (1999, fig. 7H) and Bergue et al. (2013, fig. 3N, 3P) in an arched margin from the posterior half of the dorsal margin to the upper half of the posterior margin.

Genus PARAKRITHE van den Bold, 1958

***Parakrithe vermunti* (van den Bold, 1946)**

(Fig. F2G; Pl. P4, figs. 1, 2; Pl. P6, fig. 7)

Cytheridea (*Doloccytheridea*) *vermunti* van den Bold, 1946, p. 83, pl. 7, fig. 12a–c.

Parakrithe vermunti (van den Bold). van den Bold, 1958, p. 399, pl. 4, fig. 7a–f; Osorio, 1978, p. 68, pl. 2., fig. 4.

Description: Adult carapace robust and small (434–487 µm long). In lateral view, subovate lateral outline: anterior margin round; posterior margin round with apex near ventral one-third; dorsal margin arched; ventral margin curved, convex up near anterior one-third. Smooth surface. In internal view, merodont-type hingement: in LV, shallow socket of anterior element; smooth median bar; crenulate socket with five teeth of posterior elements. Marginal zones well developed from anterior to posterior via ventral margin. Vestibulum very narrow. Pore canals: 20 anterior and 13 posterior slightly curved or bifurcated. Four ovate muscle scars arranged vertically in a row. U-shaped frontal muscle scar.

Stratigraphic distribution: Priabonian–Messinian. This species was originally described from Oligocene and Miocene sediments in Cuba (van den Bold, 1946). It was reported from lower Oligocene–middle Miocene sediments in Trinidad (van den Bold, 1958). At Site U1411, it is found in upper Eocene and lower Oligocene sediments. In the Pacific, Steineck et al. (1988) assigned the stratigraphic range of the species as planktonic foraminifer Zones N.9–N.17 of Blow (1969), which is correlated with Zones M4 to lower PL1 of Wade et al. (2011). Osorio (1978) reported the species from the Miocene Navidad Formation in Chile.

Family LOXOCONCHIDAE Sars, 1928

Genus LOXOCONCHA Sars, 1928; emend. Athersuch and Horne, 1984

Loxoconcha sp.
(Pl. P4, figs. 3, 4)

Description: Juvenile carapace thin and small (385 µm long). In external view, lateral outline subrhomboidal: anterior margin round; posterior margin round with apex near dorsal one-fourth; dorsal margin slightly arched; ventral margin sinuous with concave up area near middle. Surface reticulated with round fossae. Eye tubercle prominent. In internal view, gongyodont-type hingement: in RV, two teeth and one socket of anterior element; median groove with teeth; two elongated teeth and one socket of posterior element.

Remarks: Only one specimen was found. Lacking the anterior and posterior marginal rims and having the gongyodont-type hingement with the crenulated median element indicate the genus *Loxoconcha* s.s. Athersuch and Horne (1984) redefined *Loxoconcha* s.s. and considered it to be restricted to the Neogene and Quaternary. Ishii et al. (2005) recognized *Loxoconcha punctabella* McKenzie, Reymont, and Reymont, 1991 from the upper Oligocene sediments in Australia as *Loxoconcha* s.s. and pointed out that the genus appeared during the late Paleogene. *Loxoconcha* sp. indicates that the genus s.s. appeared during the early Oligocene. This species is different from *L. punctabella* in having a smaller carapace with a slightly curved dorsal margin.

Family THAEROCYTHERIDAE Hazel, 1967

Genus POSEIDONAMICUS Benson, 1972

Poseidonamicus pseudorobustus Coles and Whatley, 1989
(Pl. P4, fig. 6)

Poseidonamicus pseudorobustus Coles and Whatley, 1989, p. 119, pl. 5, figs. 13–15; Coles, 1996, pl. 2, fig. 10; Hunt, 2007, fig. 8.4; Bergue and Nicolaidis, 2012, p. 54, fig. 3.20–3.21.

Stratigraphic distribution: Priabonian–Chattian. At Site U1411, the species is found in sediments from calcareous nannofossil Zone NP19–NP20 (36.97–34.44 Ma). Coles (1996) indicated the range of the species correlated with

calcareous nannofossil Zone NP21–NP25 of Martini (1971) (34.44–23.13 Ma) in the North Atlantic. The species was reported from Oligocene sediments at Site 329 in the southwestern Atlantic (Bergue and Nicolaidis, 2012).

Family TRACHYLEBERIDIDAE Sylvester-Bradley, 1948

Genus CRONINOCYHEREIS Yasuhara, Hunt, Okahashi, and Brandão, 2015

Croninocythereis tridentiferae Yasuhara, Hunt, Okahashi, and Brandão, 2015
(Pl. P4, fig. 7)

Croninocythereis tridentiferi [sic] Yasuhara, Hunt, Okahashi, and Brandão, 2015, p. 121, figs. 61I–J, 66E–I, 67A–F.

Stratigraphic distribution: Middle Eocene–lower Miocene (Yasuhara et al., 2015). The lowest occurrence is from the middle Eocene in DSDP Hole 21A, North Atlantic, whereas the highest occurrence is from the lower Miocene at DSDP Site 529, southeastern Atlantic (Yasuhara et al., 2015).

Remarks: Following the agreement in gender to form the species-group names (Article 31.2 of International Code of Zoological Nomenclature), *tridentiferi*, a masculine genitive, is replaced to *tridentiferae*, a feminine genitive.

Genus DUTOITELLA Dingle, 1981

Dutoitella mimica Dingle, 1981
(Pl. P5, fig. 1)

Dutoitella mimica Dingle 1981, p. 88, figs. 37F, 41A–F, 42A–B, 43B–F, 44B; Majoran and Widmark, 1998, p. 854, fig. 3.9–3.11; Majoran and Dingle, 2001, p. 212, pl. 1, fig. 3; Majoran and Dingle, 2002, p. 147, fig. 3.1; Bergue and Nicolaidis, 2012, p. 52, fig. 3.1–3.3; Bergue et al., 2013, p. 29, fig. 2K.

Dutoitella cf. *mimica* Dingle. Majoran et al. 1998, p. 66, pl. 2, fig. 10.

Dutoitella aff. *mimica* Dingle. Majoran et al. 1998, p. 66, pl. 3, fig. 10.

Dutoitella sp. 2. Rodriguez-Lazaro and Garcia-Zaraga, 1996, pl. 1, fig. 17.

Legitimocythere presequenta (Benson). Guernet and Bellier, 2000, p. 264, pl. 3, figs. 2–3.

? *Dutoitella mimica* Dingle. Yasuhara et al. 2015, p. 74, figs. 38C–F, 39A–D.

Stratigraphic distribution: Maastrichtian–Priabonian. Originally *D. mimica* is described from Maastrichtian sediments (Dingle, 1981). At Site 689, Southern Ocean and DSDP Site 327, this species is reported from Maastrichtian sediments (Majoran and Widmark, 1998; Majoran et al., 1998). It disappeared near the calcareous nannofossil Zone NP20/NP21 boundary of Martini (1971) (34.44 Ma) (Majoran and Dingle, 2002). In the Basque Basin, the species occurs from the middle Eocene sediments (Rodriguez-Lazaro and Garcia-Zaraga, 1996).

Remarks: *Dutoitella mimica* is similar to *Dutoitella praesusmi* Coles and Whatley, 1989, in surface ornaments. *D. mimica* is distinguished from the latter species by having

fewer tubercles along the dorsal margin, three tubercles on the postero-central area, and fewer tubercles on the antero-central area. Yasuhara et al. (2015) regarded *D. mimica* of Majoran and Widmark (1998) as *Dutoitella crassinodosa* (Guernet, 1985). However the specimen of Majoran and Widmark (1998) has finer and more tubercles along the dorsal margin than *D. crassinodosa* with three tubercles along the margin.

Genus *PENNYELLA* Neale 1974; emend. Yasuhara, Hunt, Okahashi, and Brandão, 2013

Pennyella sp.

(Pl. P5, figs. 3–6)

Description: Adult carapace robust and large in size (707 µm long). In external view, lateral outline subrectangular: anterior margin round; posterior margin round with apex near middle of valve; dorsal margin slightly curved; ventral margin curved, convex up near anterior one-third. Maximum length across apex of posterior margin; maximum height across antero-dorsal corner. Surface ornament with carina and tubercles. Anterior marginal rim formed by carina running from antero-dorsal corner to ventral margin. At least 16 tubercles on anterior marginal rim. Numerous tubercles cover the central area. Four superimposed blunt tubercles near postero-dorsal corner and in central and postero-central areas. Marginal denticles along all margins. In internal view, holamphidont-type hingement: in RV, round tooth and socket of anterior element; smooth median groove; large round tooth with small crenulation of posterior element. Anterior marginal frill and anterior and posterior marginal zones developed. V-shaped frontal muscle scar.

Remarks: The species has the following characteristics of the genus *Pennyella*: the holamphidont-type hingement, tubercled ornament, lateral shape (especially in antero-

dorsal area and blunt posterior), ventral swelling, postero-dorsal spine, and width of the inner lamella. This species is distinguished from *C. tridentiferae* by having surface ornaments with finer and higher-dense spines. This species is similar to *Herrigocythere bathypteron* (Coles and Whatley, 1989) in spiny surface ornaments but distinguished from *H. bathypteron* by more tubercles on the anterior marginal rim and finer and more tubercles on the antero-central and central areas.

Genus *TRACHYLEBERIDEA* Bowen, 1953; emend. Haskins, 1963

Trachyleberidea sp.

(Pl. P5, figs. 7, 8)

Description: Juvenile carapace robust and large (745 µm long). In external view, lateral outline subtrapezoidal: anterior margin round; posterior margin tapering, forming caudal process; dorsal and ventral margins slightly sinuous. Maximum length across caudal process; maximum height across antero-dorsal corner. Marginal denticles along anterior margin and lower part of posterior margin. Anterior marginal rim running to postero-ventral area. Perforate spine at terminal of ventral rim. Spine present at antero-dorsal corner. Surface ornaments with reticulation of trefoil celation and blunt muri. Reticulation on ventral area is flattened. In internal view, lophodont-type hingement: in LV, elongate socket of anterior element; straight smooth median bar; elongated half-round socket of posterior element. Anterior marginal zone narrow. Anterior marginal frill very well developed.

Remarks: Only one specimen was obtained from the samples. The specimen shares the reticulation of trefoil celation and blunt muri and the distinct ventral rim with *Trachyleberidea mammidentata* (van den Bold, 1946). The juvenile form possibly is of *T. mammidentata*.