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Taxonomy of Maastrichtian–Thanetian deep-sea ostracodes from U1407, IODP Exp 342, off Newfoundland, Northwestern Atlantic, part 1: Families Cytherellidae, Bairdiidae, Pontocyprididae, Bythocytheridae, and Cytheruridae

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Abstract. In ocean drilling sites, the taxonomy of Paleocene ostracodes has been poorly investigated. We describe and illustrate 18 ostracode taxa from Cretaceous–Paleocene sediments at U1407 of Integrated Ocean Drilling Program Expedition 342 off Newfoundland, Northwestern Atlantic; these 18 taxa belong to the families Cytherellidae, Bairdiidae, Pontocyprididae, Bythocytheridae, and Cytheruridae, and include five new species: *Bythoceratina subumbonata* sp. nov., *Bythoceratina wilsoni* sp. nov., *Cytheropteron newfoundlandense* sp. nov., *Cytheropteron americanum* sp. nov., and *Nemoceratina (Pariceratina) guerneti* sp. nov. Our identification and description of the taxa enable us to assess paleobiodiversity and paleoenvironments on the seafloor in the North Atlantic.

Key words: Cretaceous, Integrated Ocean Drilling Program Expedition 342, North Atlantic, Ostracoda, Paleocene

Introduction

The deep-sea ecosystem has changed in response to global climatic changes (e.g. Cronin and Raymo, 1997; Yasuhara *et al.*, 2009b). The taxonomic diversity of deep-sea ostracodes clearly has been sensitive to changes in water temperature during the interglacial-glacial periods (e.g. Cronin and Raymo, 1997; Yasuhara *et al.*, 2009a, b, c). The pre-Quaternary deep-sea ostracodes are less studied than the Quaternary. Poor definition and identification of taxa result in mistakes on diversity and climatic interpretations of the pre-Quaternary deep-sea ostracodes as well as paleoenvironments. Previously Paleocene ostracodes were reported at 29 ocean drilling sites (Figure 1; Table 1). Only 15 species were described as new in five studies (Benson, 1977; Guernet, 1985; Coles and Whatley, 1989; Boomer, 1994; Yasuhara *et al.*, 2015).

In the Integrated Ocean Drilling Program (IODP) Expedition (Exp) 342, Cretaceous and Paleogene sediment cores were drilled off Newfoundland to investigate

oceanography and marine ecosystems in the North Atlantic during the greenhouse period. Here we report deep-sea ostracode species of the families Cytherellidae, Bairdiidae, Pontocyprididae, Bythocytheridae, and Cytheruridae from Paleocene sediments at U1407 of IODP Exp 342 and describe five species new to science.

Material and methods

At Site U1407 (41°25'30"N, 49°48'28.8"W), three holes were drilled on the seafloor of the Southeast Newfoundland Ridge at 3073 m depth (Norris *et al.*, 2014; Figure 1). We took 28 sediment samples of 10–40 cc volume from working half cores of Core 21X–22X of Hole A, Core 19X of Hole B, and Core 14X–18X and 20X of Hole C (Figure 2). All the core sediments consist of two lithological units: nannofossil chalks with radiolarians (Lithological subunit Va of Norris *et al.*, 2014) at 146 to ~205 mcd and nannofossil chalks at ~205 to 221 mcd (Lithological subunit Vb). They show pinkish to white

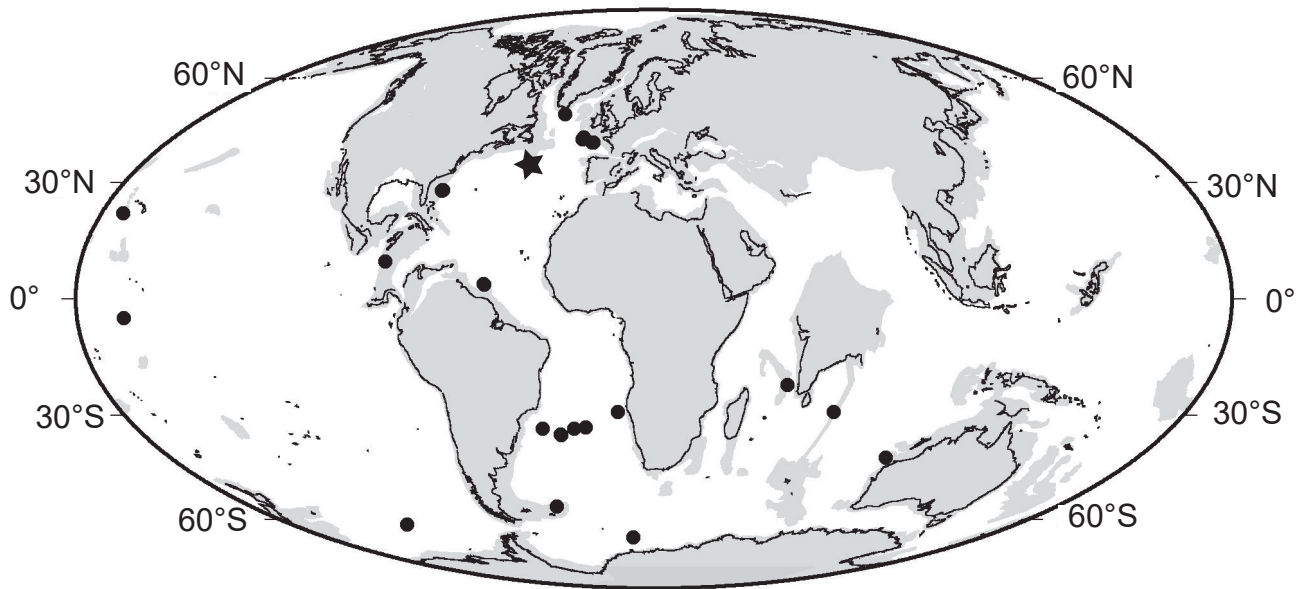


Figure 1. Ocean drilling sites (star and circles) with reports of the Paleocene ostracodes and paleogeography at 60 Ma. The star marks the study site. The paleogeography was generated using the online service Ocean Drilling Stratigraphic Network (<http://www.odsn.de/odsn/services/paleomap/paleomap.html>). Details of the sites and references are shown in Table 1.

hues. Using the planktic biostratigraphy, the core sediments are dated as ~66.3–57.4 Ma, the latest Cretaceous to Paleocene (Expedition 342 Scientists, 2012; Norris *et al.*, 2014). They are correlated to the nannofossil Zones UC20 and NP3–NP9 of Martini (1971) and Burnett (1998), the foraminiferal Zone P3–P4 of Wade *et al.* (2011), and the radiolarian Zone RP6–RP7 of Sanfilippo and Nigrini (1998) (Figure 2; Table 2). The paleo-depth at 60 Ma is estimated to be around 1800 m (Expedition 342 Scientists, 2012; Norris *et al.*, 2014).

For extracting ostracode specimens, we washed samples using a sieve of 32 μm opening. Then ostracode specimens were picked up from fractions of $>150 \mu\text{m}$ using a fine brush under a binocular microscope. The specimens were observed and their photos were taken with a scanning electron microscope (SEM) JSM-6500F (JEOL Ltd.) (Figures 3–8) and an optical microscope in order to identify them at species level and describe their morphological characters.

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 with a digital microscope, VHX-2000 (Keyence, Ltd.). Images of the internal structures were also captured. Using the focus stacking system capability of the digital microscope, deep-focus images of the internal structures were made (Figures 9, 10). To identify shapes of marginal pore canals, vestibulum, and reticulation, outlines of the images were drawn

(Figure 11). The specimens were measured, using the digital microscope (Table 3). The scanning electron and the digital microscopes are hosted at Center for Advanced Marine Core Research, Kochi University.

The preservation of the specimens is good. The specimens show translucent to white in color. The external relief such as carinae, spines, and reticulation is well preserved. Calcareous ooze and nannofossils are attached to the surface of the specimens and often cover muscle scars and pores. We identify 18 taxa of the families Cytherellidae, Bairdiidae, Pontocyprididae, Bythocytheridae, and Cytheruridae, including five new species. Seven taxa of Cytherellidae, Bairdiidae, and Pontocyprididae do not have adequate enough characters for species identification and are left in open nomenclature. Some taxa of Cytheruridae occur rarely in the sediment samples.

For the systematic description, the combination of the higher taxonomic ranks was referred to Brandão *et al.* (2016). The general terminology of the morphology followed Sylvester-Bradley and Benson (1971) and Horne *et al.* (2002). According to Athersuch *et al.* (1989), carapace size is classified: small ($< 500 \mu\text{m}$ long); medium ($500\text{--}650 \mu\text{m}$ long); large ($> 650 \mu\text{m}$ long).

All the specimens are registered and deposited in the National Museum of Nature and Science, Tsukuba (NMNS) and Scripps Institution of Oceanography (SIO), University of California, San Diego, that are the Microfossil Reference Centers for the International Ocean Discovery

Table 1. Ocean drilling sites yielding Paleocene ostracodes.

Site	Ocean region	Reference
DSDP Site 20	South Atlantic	Benson (1975)
DSDP Site 21	South Atlantic	Benson (1975); Yasuhara <i>et al.</i> (2015)
DSDP Site 214	Indian Ocean	Guernet (1985)
DSDP Site 219	Indian Ocean	Guernet (1985)
DSDP Site 329	South Atlantic	Bergue and Nicolaidis (2012)
DSDP Site 356	South Atlantic	Benson (1977); Yasuhara <i>et al.</i> (2015)
DSDP Site 357	South Atlantic	Benson (1977)
DSDP Site 363	South Atlantic	Yasuhara <i>et al.</i> (2015)
DSDP Site 390	Caribbean Sea	Guernet (1982)
DSDP Site 400	North Atlantic	Ducasse and Peypouquet (1979)
DSDP Site 401	North Atlantic	Ducasse and Peypouquet (1979); Yamaguchi and Norris (2012)
DSDP Site 403	North Atlantic	Ducasse and Peypouquet (1979)
DSDP Site 404	North Atlantic	Ducasse and Peypouquet (1979)
DSDP Site 433	Equatorial Pacific	Malz (1981)
DSDP Site 516	South Atlantic	Benson and Peypouquet (1983)
DSDP Site 549	North Atlantic	Whatley and Coles (1991); Coles (1996)
DSDP Site 550	North Atlantic	Whatley and Coles (1991); Coles (1996)
ODP Site 689	Southern Ocean	Majoran and Dingle (2002)
ODP Site 762	Indian Ocean	Guernet and Galburn (1992)
ODP Site 865	Equatorial Pacific	Boomer (1994); Boomer and Whatly (1995); Yamaguchi and Norris (2015)
ODP Site 1001	Caribbean Sea	Aumond <i>et al.</i> (2009)
ODP Site 1049	North Atlantic	Guernet and Bellier (2000)
ODP Site 1050	North Atlantic	Guernet and Bellier (2000)
ODP Site 1051	North Atlantic	Guernet and Bellier (2000)
ODP Site 1052	North Atlantic	Guernet and Bellier (2000)
ODP Site 1260	North Atlantic	Guernet and Danelian (2006)
ODP Site 1261	North Atlantic	Guernet and Danelian (2006)
IODP Site U1370	South Pacific	Alvarez Zarikian (2015)
IODP Site U1407	North Atlantic	This study

Program. The catalog numbers at NMNS and SIO have the prefixes of MPC and SIO-BIC, respectively. Abbreviations: C = carapace, LV= left valve, RV = right valve.

Systematic description

Order Platyco-pida Sars, 1866
Suborder Platyco-pina Sars, 1866
Family Cytherellidae Sars, 1866

Genus *Cytherella* Jones, 1849
Cytherella sp.

Figures 3A–D, 9A

Description.—Carapace robust and large (874–1182 µm long). In external view, lateral outline elliptical. RV larger than LV. In LV, anterior margin round; posterior margin round; dorsal margin straight; ventral margin straight or slightly curved. In RV, anterior margin round;

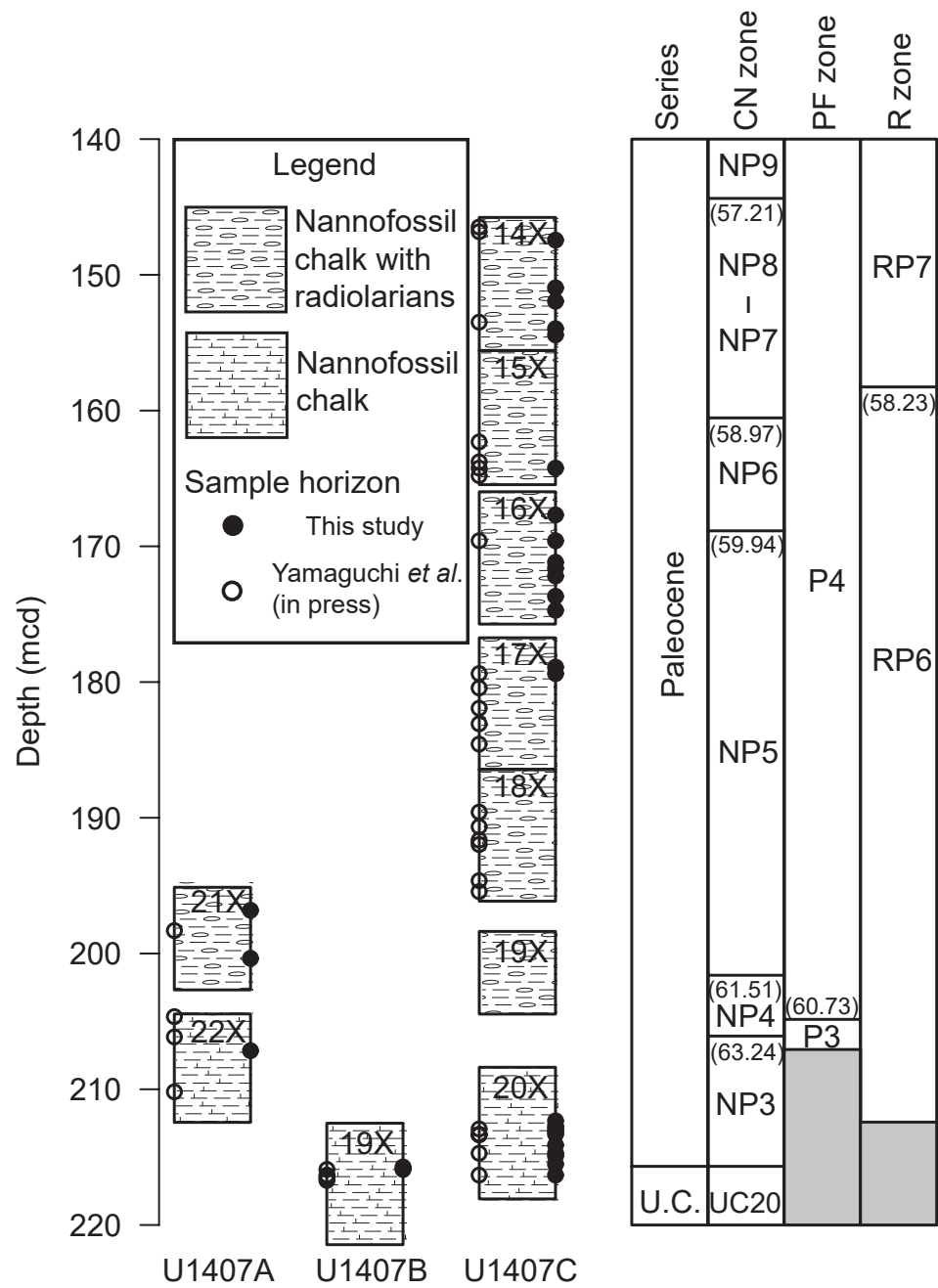


Figure 2. Lithostratigraphy and stratigraphic position of the examined samples. The biostratigraphic zones are referred to Martini (1971) and Burnett (1998) for calcareous nannofossils (CN), Wade *et al.* (2011) for planktic foraminifers (PF), and Sanfilippo and Nigrini (1998) for radiolarians (R). The lithostratigraphy and recovered cores are from Norris *et al.* (2014). Numerals within parentheses near the biostratigraphic zonal boundaries indicate the geological ages of the boundaries, according to Gradstein *et al.* (2012). There is a hiatus between the top of the Cretaceous and the base of the Paleocene (Norris *et al.*, 2014). Abbreviation: U. C. = Upper Cretaceous.

posterior margin round; dorsal margin arched; ventral margin slightly curved. Maximum length through middle of carapace; maximum height across postero-dorsal corner. Smooth surface. Dorsal outline ovate; anterior edge

angular with indent; posterior edge round with indent; lateral margins round. LV overlapped by RV dorsally. Maximum width near posterior one-third of length. Depression near central area. Dorsal suture running straight from pos-

Table 2. Biostratigraphic events and geological ages (Norris *et al.*, 2014). Abbreviation: T = top, B = base, X = faunal crossover.

Taxon	Boundary of Zones	Datum event	Depth of the mid-points		Age (Ma)
			(CSF-A: mbsf)	(CCSF: mcd)	
Calcareous nannofossils	NP8/NP9	B <i>Discoaster multiradiatus</i>	132.18	144.37	57.21
	NP6/NP7	B <i>Discoaster mohleri</i>	148.35	160.54	58.97
	NP5/NP6	B <i>Heliolithus kleinpellii</i>	156.67	168.86	59.54
	NP4/NP5	B <i>Fasciculithus tympaniformis</i>	171.18	201.6	61.51
	NP3/NP4	B <i>Ellipsolithus macellus</i>	175.93	206.08	63.25
		B <i>Cruciplacolithus intermedius</i>	186.7	215.68	65.47
	Top of UC20	T <i>Micula murus</i>	186.7	215.68	66.04
Planktic foraminifera	P3/P4	B <i>Globanomalina pseudomenardii</i>	174.33	204.85	60.73
Radiolarians	RP6/RP7	X <i>Bekoma campechensis</i> - <i>Bekoma bidartensis</i>	146.07	158.26	58.23
		T <i>Anthocyrtis mespilus</i>	177.25	207.4	62.00

terior edge to anterior one-fourth, then diverting to right near anterior one-fourth, and extending thence straight to anterior edge. In internal view, adont-type hingement.

Material.—MPC-29096, C, adult, 342-U1407C-20X-4W, 4-6, Danian; SIO-BIC-C12178, LV, adult, 342-U1407C-20X-3W, 134-136, Danian; SIO-BIC-C12179, RV, adult, 342-U1407C-20X-3W, 94-96, Danian.

Measurements.—Table 3.

Remarks.—This species is similar to *Cytherella consueta* Deltel, 1964 in lateral outline, but is different from the latter species in having a more gently round posterior half of the lateral margin in dorsal view. *Cytherella consueta* was originally described from the upper Eocene in France and reported from Paleocene–Eocene sediments in ODP Site 1049–1053, North Atlantic (Guernet and Bellier, 2000).

Order Podocopida Sars, 1866
Suborder Bairdiocopina Gründel, 1967
Superfamily Bairdioidea Gründel, 1967
Family Bairdiidae Sars, 1866
Genus *Cardobairdia* Bold, 1960
Cardobairdia sp.

Figures 3E, F, 9B

Cardobairdia sp. Guernet, 1982, p. 52, pl. 3, figs. 2, 3.
Cardobairdia cf. *asymmetrica* (Bold). Guernet and Bellier. 2000, p. 257, pl. 1, figs. 3–6.

Material.—MPC-29095, RV, adult, 342-U1407C-16X-5W, 22-24, Selandian.

Measurements.—Table 3.

Occurrence.—Middle Eocene sediment at DSDP Site 390, North Atlantic (Guernet, 1982); lower Paleocene–middle Eocene sediments at ODP 1049, upper Paleocene–middle Eocene sediments at ODP Sites 1050 and 1051, lower Paleocene–upper Eocene sediments at ODP Site 1052, and middle–upper Eocene sediments at ODP Site 1053, North Atlantic (Guernet and Bellier, 2000); middle Paleocene sediments at IODP Site U1407, North Atlantic (this study).

Genus *Neonesidea* Maddocks, 1969
Neonesidea cf. *cymbula* (Deltel, 1964)

Figures 3G–I, 4A, 9C

cf. *Bairdia cymbula* Deltel, 1964, p. 139, 140, pl. 2, figs. 21, 22.

Description.—Carapace robust and large (919–1275 µm long). LV larger than RV. In external view, lateral outline subpentagonal: anterior margin round; posterior margin angular and pointed postero-dorsally, forming caudal process; lower half of posterior margin slightly curved; posterior margin curved near upper one-third of height and running straight toward apex of dorsal margin; dorsal margin arched; ventral margin curved. Maximum length across middle of height; maximum height across middle of length. Marginal denticles along lower half of posterior margin of LV. Surface with punctae in central area and foveolae in peripheral area. Dorsal outline hexagonal: anterior edge tapering; posterior edge angular; lateral margins arched. Maximum width across middle of length. Dorsal suture slightly sinuous. In internal view, adont-type hingement. Anterior marginal zone width less

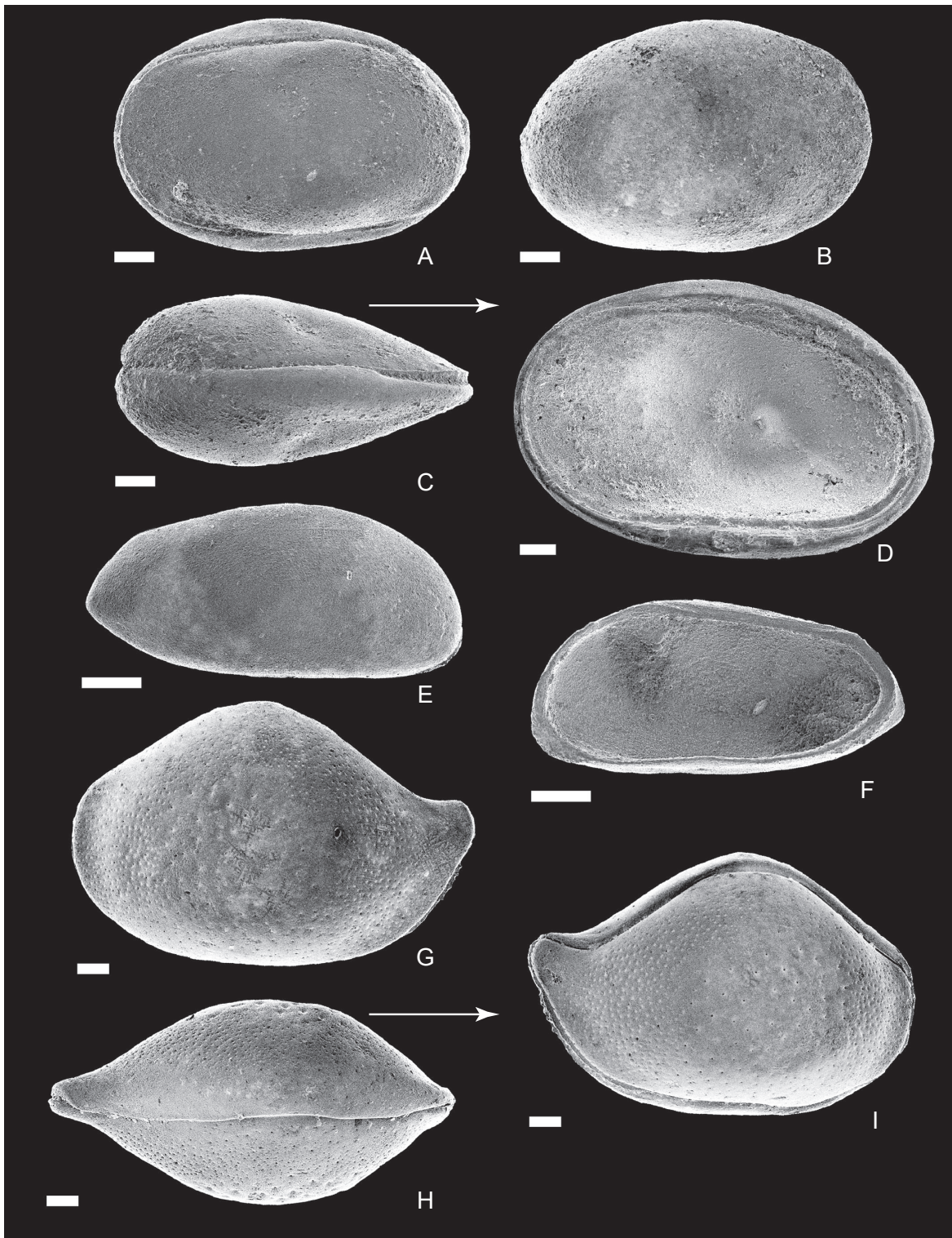


Figure 3. SEM images of ostracode species. **A–D**, *Cytherella* sp. (MPC-29096 and SIO-BIC-C12179); A, left external view of carapace (MPC-29096); B, right external view of carapace (MPC-29096); C, dorsal view of carapace (MPC-29096); D, internal view of adult RV (SIO-BIC-C12179); **E, F**, *Cardobairdia* sp. (MPC-29095); E, external view of adult RV; F, internal view of adult RV; **G–I**, *Neonesidea* cf. *cymbula* (Deltel, 1964) (MPC-29102); G, left external view of adult carapace; H, right external view of adult carapace; I, dorsal view of adult carapace. All scale bars equal 100 μ m. All arrows show the anterior direction.

Table 3. Measurements of the registered and illustrated specimens. Abbreviation: H = holotype, P = paratype, R = right valve, L = left valve, C = carapace, A = adult, J = juvenile.

Catalog number	Species	Type	Valve types	Growth stage	Length (μm)	Height (μm)	Sample identifier	Depth of sample (mcd)	Age	Figure
MPC-29087	<i>Aratrocypris praealta</i> Whatley <i>et al.</i> , 1985	R	A		421	226	342-U1407C-16X-5W, 22-24	172.2	Selandian	4D, E, 9D
SIO-BIC-C12171	<i>Aratrocypris praealta</i> Whatley <i>et al.</i> , 1985	R	A		479	245	342-U1407C-16X-5W, 22-24	172.2	Selandian	
MPC-29088	<i>Argilloecia</i> sp.	L	A		523	224	342-U1407C-16X-3W, 62-64	169.6	Thanetian	4F, G, 9E, 11A
SIO-BIC-C12184	<i>Argilloecia</i> sp.	R	A		547	253	342-U1407C-16X-3W, 62-64	169.6	Thanetian	
MPC-29089	<i>Bythoceratina</i> cf. <i>umbonata</i> (Williamson, 1848)	R	A		807	338	342-U1407B-19X-3W, 24-26	215.72	Maastrichtian	5L, 6A, 10B
MPC-29090	<i>Bythoceratina</i> cf. <i>umbonata</i> (Williamson, 1848)	L	A		781	360	342-U1407C-20X-6W, 45-47.5	216.33	Maastrichtian	
SIO-BIC-C12156	<i>Bythoceratina</i> cf. <i>umbonata</i> (Williamson, 1848)	L	A		704	325	342-U1407C-16X-6W, 123-125	174.71	Selandian	
SIO-BIC-C12157	<i>Bythoceratina</i> cf. <i>umbonata</i> (Williamson, 1848)	L	A		759	337	342-U1407C-16X-6W, 123-125	174.71	Selandian	5K
MPC-29091	<i>Bythoceratina subumbonata</i> sp. nov.	H	R	A	729	357	342-U1407C-16X-4W, 70-72	171.18	Selandian	4I, 5A, C
MPC-29092	<i>Bythoceratina subumbonata</i> sp. nov.	P	R	A	768	366	342-U1407C-14X-4W, 67-69	150.97	Thanetian	
SIO-BIC-C12152	<i>Bythoceratina subumbonata</i> sp. nov.	P	L	A	1000	443	342-U1407C-17X-2W, 114-116	179.38	Selandian	4H, J, 5B, 9F
SIO-BIC-C12153	<i>Bythoceratina subumbonata</i> sp. nov.	P	L	A	866	431	342-U1407C-16X-6W, 20-22	173.68	Selandian	
MPC-29093	<i>Bythoceratina wilsoni</i> sp. nov.	H	R	A	850	402	342-U1407C-20X-5W, 114-116	215.52	Danian	5F, H, J, 10A
MPC-29094	<i>Bythoceratina wilsoni</i> sp. nov.	P	L	A	760	394	342-U1407C-20X-5W, 54-56	214.92	Danian	5E, G, I
SIO-BIC-C12154	<i>Bythoceratina wilsoni</i> sp. nov.	P	R	A	718	312	342-U1407C-20X-4W, 124-126	214.12	Danian	
SIO-BIC-C12155	<i>Bythoceratina wilsoni</i> sp. nov.	P	L	A	696	318	342-U1407C-20X-4W, 124-126	214.12	Danian	5D
MPC-29095	<i>Cardobairdia</i> sp.	R	A		648	304	342-U1407C-16X-5W, 22-24	172.2	Selandian	3E, F, 9B
MPC-29096	<i>Cytherella</i> sp.	C	A		874	566	342-U1407C-20X-4W, 4-6	212.92	Danian	3A–C
SIO-BIC-C12178	<i>Cytherella</i> sp.	L	A		1182	790	342-U1407C-20X-3W, 134-136	212.32	Danian	9A
SIO-BIC-C12179	<i>Cytherella</i> sp.	R	A		864	468	342-U1407C-20X-3W, 94-96	212.72	Danian	3D
MPC-29097	<i>Cytheropteron americanum</i> sp. nov.	H	R	A	384	215	342-U1407C-20X-4W, 124-126	214.12	Danian	6G, H, I, 10D
SIO-BIC-C12175	<i>Cytheropteron americanum</i> sp. nov.	P	L	A	441	233	342-U1407A-21X-4W, 74-76	200.36	Selandian	6F
SIO-BIC-C12185	<i>Cytheropteron americanum</i> sp. nov.	P	R	A	476	299	342-U1407C-20X-4W, 124-126	214.12	Danian	
MPC-29098	<i>Cytheropteron newfoundlandense</i> sp. nov.	H	L	A	411	232	342-U1407C-14X-2W, 18-20	147.45	Thanetian	7A, D, F, 10E
MPC-29099	<i>Cytheropteron newfoundlandense</i> sp. nov.	P	R	A	417	245	342-U1407C-16X-5W, 22-24	172.2	Selandian	7C, E, G
SIO-BIC-C12173	<i>Cytheropteron newfoundlandense</i> sp. nov.	P	R	A	441	254	342-U1407C-14X-2W, 18-20	147.45	Thanetian	7B
SIO-BIC-C12174	<i>Cytheropteron newfoundlandense</i> sp. nov.	P	L	A	422	244	342-U1407C-16X-3W, 62-64	169.6	Thanetian	
MPC-29108	<i>Eucytherura</i> sp. 1	L	A		353	198	342-U1407B-19X-3W, 42-44	215.92	Maastrichtian	7H
MPC-29109	<i>Eucytherura</i> sp. 2	R	A		309	191	342-U1407B-19X-3W, 42-44	215.92	Maastrichtian	7I
MPC-29110	<i>Hemiparacytheridea</i> sp.	L	A		372	201	342-U1407A-21X-2W, 20-22	196.82	Selandian	7J
MPC-29100	<i>Nemoceratina</i> (<i>Pariceratina</i>) <i>guerneti</i> sp. nov.	H	L	A	657	288	342-U1407C-15X-6W, 116-118	164.24	Thanetian	6B
MPC-29101	<i>Nemoceratina</i> (<i>Pariceratina</i>) <i>guerneti</i> sp. nov.	P	L	A	635	285	342-U1407C-14X-5W, 18-20	151.95	Thanetian	6C, D, E
SIO-BIC-C12158	<i>Nemoceratina</i> (<i>Pariceratina</i>) <i>guerneti</i> sp. nov.	P	L	A	589	236	342-U1407C-20X-5W, 34-36	214.72	Danian	10C
SIO-BIC-C12159	<i>Nemoceratina</i> (<i>Pariceratina</i>) <i>guerneti</i> sp. nov.	P	L	A	600	241	342-U1407A-22X-2W, 120-122	207.15	Selandian	
MPC-29102	<i>Neonesidea</i> cf. <i>cymbula</i> (Deltel, 1964)	C	A		1275	833	342-U1407C-14X-6W, 117-119	154.44	Thanetian	3G, H, I
SIO-BIC-C12176	<i>Neonesidea</i> cf. <i>cymbula</i> (Deltel, 1964)	L	A		919	609	342-U1407C-16X-2W, 20-22	167.68	Thanetian	4A
SIO-BIC-C12177	<i>Neonesidea</i> cf. <i>cymbula</i> (Deltel, 1964)	R	A		905	536	342-U1407C-16X-4W, 113-115	171.61	Selandian	9C
MPC-29103	<i>Pedicythere</i> sp. 1	L	A		452	181	342-U1407C-20X-4W, 44-46	213.32	Danian	8C
Not applicable	<i>Pedicythere</i> sp. 2	L	A		354	215	342-U1407A-21X-2W, 20-22	196.82	Selandian	8D
MPC-29104	<i>Pelecocythere</i> sp.	R	A		740	492	342-U1407C-14X-6W, 70-72	153.97	Thanetian	8A, B, 10F, 11B
SIO-BIC-C12186	<i>Pelecocythere</i> sp.	L	J		539	376	342-U1407C-17X-2W, 65-67	178.89	Selandian	
MPC-29086	<i>Zabythocypris</i> sp.	C	A		536	328	342-U1407C-20X-4W, 24-26	213.12	Danian	4B, C

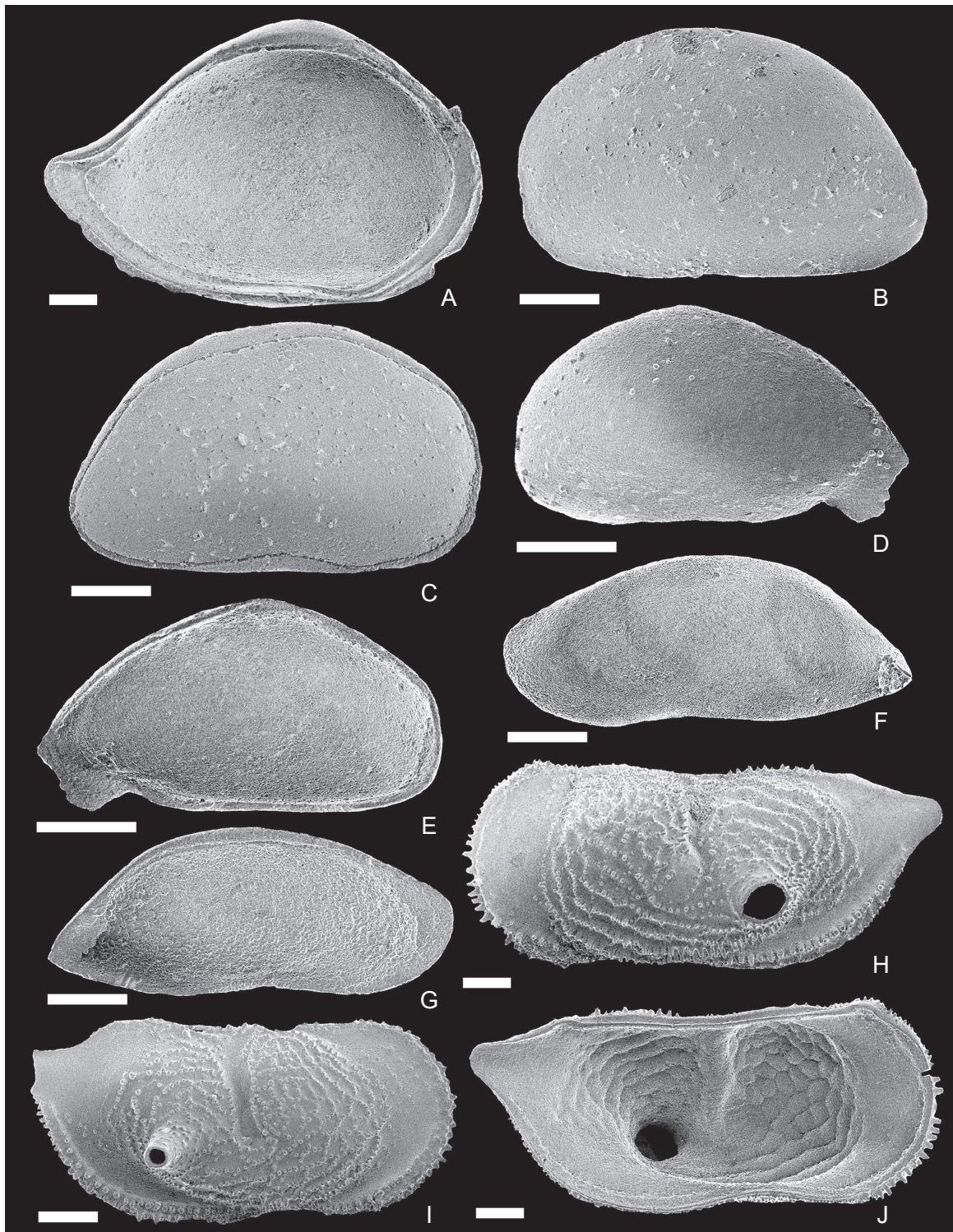


Figure 4. SEM images of ostracode species. **A**, *Neonesidea* cf. *cymbula* (Deltel, 1964) (SIO-BIC-C12176), internal view of adult LV; **B, C**, *Zabythocypris* sp. (MPC-29086); **B**, left external view of adult carapace; **C**, right external view of adult carapace; **D, E**, *Aratrocypris praealta* Whatley, Ayress, Downing, Harlow, and Kesler, 1985 (MPC-29087); **D**, external view of adult RV; **E**, internal view of adult RV; **F, G**, *Argilloecia* sp. (MPC-29088); **F**, external view of adult LV; **G**, internal view of adult LV; **H–J**, *Bythoceratina subumbonata* sp. nov. (MPC-29091 and SIO-BIC-C12152); **H**, external view of adult LV (SIO-BIC-C12152, paratype); **I**, external view of adult RV (MPC-29091, holotype); **J**, internal view of adult LV (SIO-BIC-C12152, paratype). All scale bars equal 100 μ m.

than 10% of the maximum valve length.

Material.—MPC-29102, C, adult, 342-U1407C-14X-6W, 117-119, Thanetian; SIO-BIC-C12176, LV, adult, 342-U1407C-16X-2W, 20-22, Thanetian; SIO-BIC-C12177, RV, adult, 342-U1407C-16X-4W, 113-115, Selandian.

Measurements.—Table 3.

Remarks.—The specimens are very similar to *Neonesidea cymbula* (Deltel, 1964). However, they have a more arched dorsal apex and broader carapaces than the types of the species. *Neonesidea cymbula* was originally described from the upper Eocene in France as a *Bairdia* and was reported from Paleogene sediments in the North Atlantic (Yamaguchi and Norris, 2012). Yamaguchi and Norris (2012) observed that the species did not possess teeth in its hingement and transferred it to the genus *Neonesidea*.

Family Bythocyprididae Maddocks, 1969

Genus *Zabythocypris* Maddocks, 1969

Zabythocypris sp.

Figure 4B, C

Bythocypris sp. Majoran, 1999, pl. 1, fig. 14.

Description.—Carapace robust and medium-sized (536 μm long). LV larger than RV. In external view, subtrapezoidal lateral outline: in LV, anterior margin gently rounded; posterior margin gently rounded, with apex below middle of valve; dorsal margin arched; ventral margin slightly concave; in RV, anterior margin gently rounded; posterior margin gently rounded; dorsal margin slightly arched; ventral margin sinuous, with indent near middle of valve. In RV, anterior cardinal angle approximately 140° ; posterior cardinal angle approximately 140° . Maximum length across apex of posterior margin; maximum height across antero-dorsal corner.

Material.—MPC-29086, C, adult, 342-U1407C-20X-4W, 24-26, Danian.

Measurements.—Table 3.

Occurrence.—Upper Maastrichtian sediment at ODP Site 1052 (Majoran, 1999); lower Paleocene sediment at IODP U1407, North Atlantic (this study).

Remarks.—Because the left valve is larger than the right valve, this taxon is placed to *Zabythocypris*. This species is similar to *Bythocypris* sp. 1 of Guernet and Bellier (2000) in its lateral outline, but is distinguished from that taxon by having a right valve with the anterior cardinal angle of less than 150° . *Bythocypris* sp. 1 was reported from Eocene sediments at ODP Sites 1049–1053, North Atlantic.

Suborder Cypridocopina Jones, 1901

Superfamily Pontocypridoidea Müller, 1894

Family Pontocyprididae Müller, 1894

Genus *Aratrocypris* Whatley, Ayress, Downing, Harlow, and Kesler, 1985

Aratrocypris praealta Whatley, Ayress, Downing, Harlow, and Kesler, 1985

Figures 4D, E, 9D

Aratrocypris praealta Whatley, Ayress, Downing, Harlow, and Kesler, 1985, p. 71, pl. 2, figs. 8–13; Alvarez Zarikian, 2015, pl. 2, figs. 16, 17.

Description.—Carapace thin and small (421–479 μm long). In external view, lateral outline subovate to subtriangular: upper half of anterior margin slightly curved; lower half of anterior margin tapering towards a plough-like antero-ventral structure, having truncation and marginal denticles; posterior margin round; dorsal margin arched with apex at middle of maximum length; ventral margin slightly curved and indented at posterior one-fourth. Smooth surface. In internal view, adont-type hingement, extending from dorsal apex to postero-dorsal corner and steeply inclined to the horizontal.

Material.—MPC-29087, RV, adult, 342-U1407C-16X-5W, 22-24, Selandian; SIO-BIC-C12171, RV, adult, 342-U1407C-16X-5W, 22-24, Selandian.

Measurements.—Table 3.

Occurrence.—Miocene sediment at DSDP Site 56, upper Paleocene to middle Eocene sediments at DSDP Site 277, lower Eocene at DSDP Site 207A, South Pacific (Whatley *et al.*, 1985); Oligocene sediment at IODP U1367B, South Pacific (Alvarez Zarikian, 2015); middle Paleocene sediments at IODP Site U1407, North Atlantic (this study).

Genus *Argilloecia* Sars, 1866

Argilloecia sp.

Figures 4F, G, 9E, 11A

Description.—Carapace robust and medium (523–547 μm long). In external view, lateral outline subtriangular: anterior margin round; posterior margin tapering near ventrally one-third, forming caudal process; dorsal margin arched; ventral margin curved. Smooth surface. In internal view, adont-type hingement. Adductor muscle scars four. Anterior three elongated and arranged vertically; posterior one elongated vertically with indent at middle. Anterior marginal zone width less than 10% of the maximum valve length.

Material.—MPC-29088, LV, adult, 342-U1407C-16X-3W, 62-64, Thanetian; SIO-BIC-C12184, RV, adult, 342-U1407C-16X-3W, 62-64, Thanetian.

Measurements.—Table 3.

Remarks.—This species is similar to *Argilloecia* sp. B of Boomer (1999) from Oligocene–Miocene sediments at DSDP Site 463, equatorial Pacific, but is different from the latter taxon in having a more elongated lateral outline.

Suborder Cytherocopina Baird, 1850

Superfamily Cytheroidea Baird, 1850

Family Bythocytheridae Sars, 1866

Genus *Bythoceratina* Sars, 1866

***Bythoceratina subumbonata* sp. nov.**

Figures 4H–J, 5A–C, 9F

Bythoceratina umbonata (Williamson). Coles, 1996, pl. 2, figs. 12, 13.

Bythoceratina sp. Yamaguchi and Norris, 2012, p. 35, fig. 3.3.

Diagnosis.—A *Bythoceratina* species with a deep subrectangular subcentral sulcus and reticulation of muri with short tubercles on the central area, smooth surface in the anterior and posterior areas, short tubercles along the ventral margin, and lacking a vestibulum.

Description.—Carapace robust and large (729–1000 μm long). In external view, lateral outline rectangular: anterior margin round; posterior margin round with projection at one-fourth of height, forming caudal process; dorsal margin sinuous and indented at middle; ventral margin sinuous. Maximum length across apex of caudal process. Subcentral sulcus deep, subrectangular. Central area swelled. Tubercles projected on posteroventral area. Marginal rims and marginal denticles along anterior margin and lower half of posterior margin. Surface ornamentation of reticulation and tubercles. Reticulation formed by muri with short tubercles. Tubercles arranged on marginal rims: five to seven rows of tubercles concave upward in ventral area; tubercles arranged horizontally in dorsal area; four to six rows of tubercles in postero-dorsal area; vertical rows of tubercles in antero-dorsal area; tubercles arranged along subcentral sulcus. Smooth surface on anterior and posterodorsal areas. In internal view, lophodont-type hingement: in LV, half-round socket of anterior element, smooth median bar, half-round socket of posterior element; in RV, round tooth of anterior element, smooth median furrow, round tooth of posterior element. Anterior marginal zone less than 10% of the maximum valve length. Marginal pore canals absent.

Etymology.—Named after the similarity to *Bythoceratina umbonata*. The prefix “sub-” means “nearly.”

Types.—Holotype: MPC-29091, RV, adult, 342-U1407C-16X-4W, 70-72, Selandian. Paratypes: MPC-29092, RV, adult, 342-U1407C-14X-4W, 67-69, Thanetian; SIO-BIC-C12152, LV, adult, 342-U1407C-17X-2W, 114-116, Selandian; SIO-BIC-C12153, LV, adult, 342-U1407C-16X-6W, 20-22, Selandian.

Occurrence.—Middle Eocene to upper Oligocene sedi-

ments at DSDP Site 549 and 550, North Atlantic (Coles, 1996); upper Paleocene sediments at DSDP Site 401, North Atlantic (Yamaguchi and Norris, 2012); middle to upper Paleocene sediments at IODP U1407, North Atlantic (this study).

Measurements.—Table 3.

Remarks.—This new species differs from *Bythoceratina umbonata* (Williamson, 1848) in its surface being ornamented with rows of spines except for the smooth anterior and posterior areas and the absence of a vestibulum. *Bythoceratina umbonata* is often regarded as a species of *Monoceratina* and is reported in the Cenomanian to Maastrichtian sediments in Europe (e.g. Kaye, 1964; Szczechura, 1964). According to photographs of topotypes by Kaye (1964), *B. umbonata* has the overall surface covered with reticulation. Szczechura (1964) in studying Cretaceous–Paleocene *Monoceratina* species in Poland, observed the presence of vestibula in most of them. *Bythoceratina subumbonata* sp. nov. is similar to *B. dania* Jørgensen, 1976 in the lateral outline and surface ornamentation but is distinguished from the latter species by having a larger carapace, fewer spines along the dorsal margin and in the anterior and posterior areas, and a more rounded posterior half of the ventral margin. *Bythoceratina dania* was originally described from the Maastrichtian in Denmark and is 580–650 μm long.

***Bythoceratina wilsoni* sp. nov.**

Figures 5D–J, 10A

Nodobythere? sp. 2, Guernet and Bellier, 2000, pl. 6, fig. 12.

Diagnosis.—A *Bythoceratina* species that has a narrow subcentral sulcus, a swelling in the ventro-central area, surface ornamentation of concentric fine carinae around a spine, a fine dorsal carina, and curved fine carinae before the sulcus.

Description.—Carapace robust and large (696–850 μm long). In external view, lateral outline rectangular: anterior margin round; posterior margin slightly curved and tapering near horizon of dorsal margin, forming caudal process; dorsal margin slightly sinuous; ventral margin straight or slightly curved. Maximum length across apex of caudal process. Subcentral sulcus. Central area swelled, forming an ala. Ala associated with spine at terminal. Swelling in ventral area connected to spine with carina, crossing subcentral sulcus. Surface ornamentation of fine carinae; arched carina crossing subcentral sulcus on dorsal area; carinae in antero-central area often curved parallel to anterior margin; carinae concave upward below spines on ventral area; fine carinae concentric around spine in central area. Smooth surface in anterior and posterior areas. In internal view, lophodont-

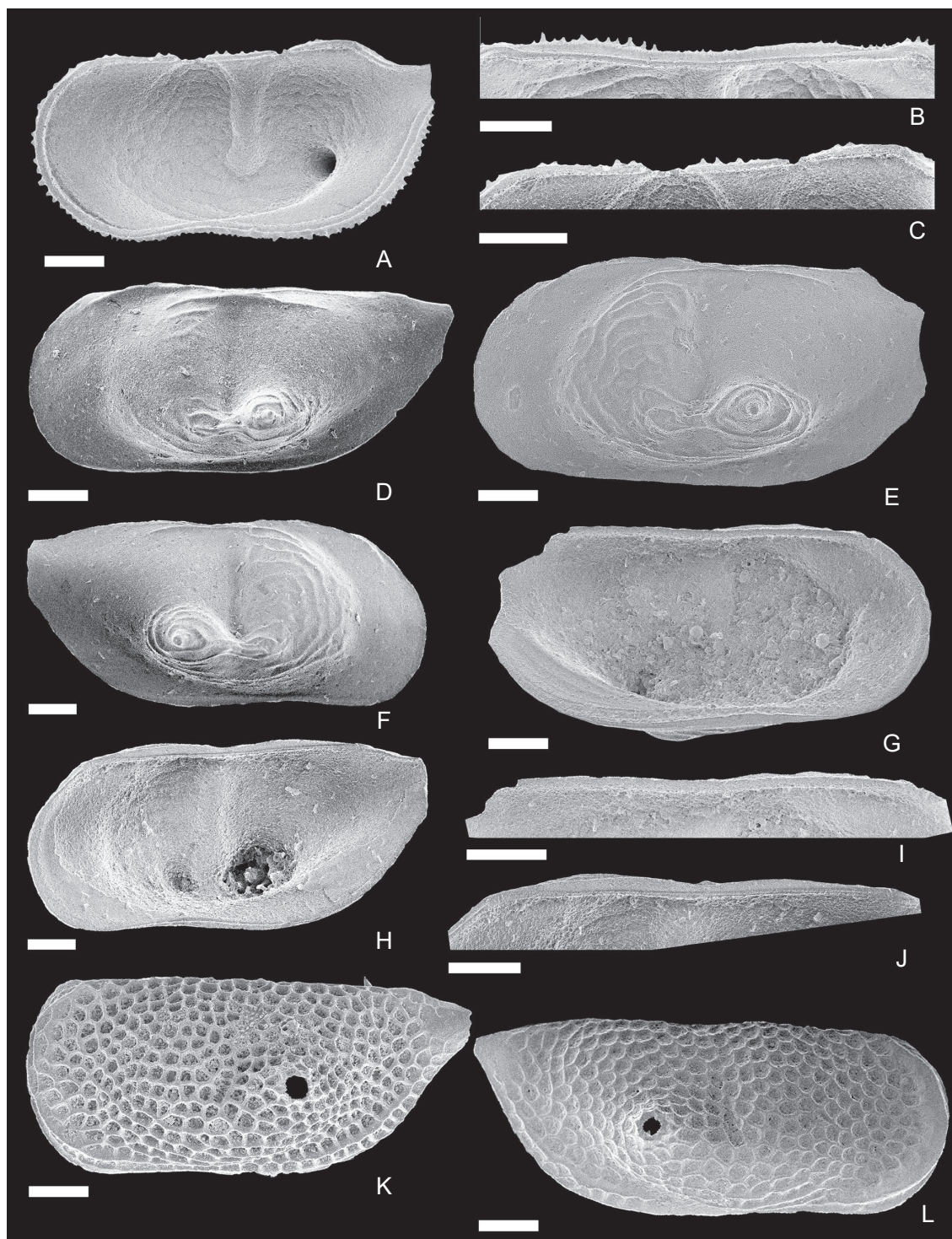


Figure 5. SEM images of ostracode species. **A–C**, *Bythoceratina subumbonata* sp. nov. (MPC-29091 and SIO-BIC-C12152); **A**, internal view of adult RV (MPC-29091, holotype); **B**, hingement of adult LV (SIO-BIC-C12152, paratype); **C**, hingement of adult RV (MPC-29091, holotype); **D–J**, *Bythoceratina wilsoni* sp. nov. (MPC-29093, MPC-29094, and SIO-BIC-C12155); **D**, external view of adult LV (SIO-BIC-C12155, paratype); **E**, external view of adult LV (MPC-29094, paratype); **F**, external view of adult RV (MPC-29093, holotype); **G**, internal view of adult LV (MPC-29094, paratype); **H**, internal view of adult RV (MPC-29093, holotype); **I**, hingement of adult LV (MPC-29094, paratype); **J**, hingement of adult RV (MPC-29093, holotype); **K, L**, *Bythoceratina* cf. *umbonata* (Williamson, 1848) (MPC-29089 and SIO-BIC-C12157); **K**, external view of adult LV (SIO-BIC-C12157); **L**, external view of adult RV (MPC-29089). All scale bars equal 100 μm.

type hingement: in LV, socket of anterior element, smooth median bar; in RV, small round tooth of anterior element, smooth median furrow, rectangle tooth of posterior element. Anterior marginal zone width less than 10% of the maximum valve length. Marginal pore canals absent.

Etymology.—In honor of Paul A. Wilson (National Oceanography Centre, University of Southampton), who studies Cretaceous and Paleogene oceanography and led IODP Exp 342 as one of the Co-Chief Scientists.

Types.—Holotype: MPC-29093, RV, adult, 342-U1407C-20X-5W, 114-116, Danian. Paratypes: MPC-29094, LV, adult, 342-U1407C-20X-5W, 54-56, Danian; SIO-BIC-C12154, RV, adult, 342-U1407C-20X-4W, 124-126, Danian; SIO-BIC-C12155, LV, adult, 342-U1407C-20X-4W, 124-126, Danian.

Measurements.—Table 3.

Occurrence.—Upper Paleocene sediments at ODP Site 1049, North Atlantic (Guernet and Bellier, 2000); lower Paleocene sediments at IODP Site U1407, North Atlantic (this study).

Remarks.—*Bythoceratina wilsoni* sp. nov. is similar to *B. (Cuneoceratina) marginata* Weaver, 1982 in lateral outline and surface ornamentation of fine carinae, but is distinguished from the latter species by having a narrower subcentral sulcus and no node in the antero-dorsal area. *Bythoceratina marginata* was originally described from the Cenomanian in England and was reported from Aptian strata in France (Babinot *et al.*, 2007). Guernet and Bellier (2000) considered that *Cytheropteron* sp. 3 of Guernet (1982) was congeneric to *Nodobythere?* sp. 2. *Cytheropteron* sp. 3 was obtained from middle Eocene sediments at DSDP Site 390, North Atlantic. However, *Cytheropteron* sp. 3 has a smooth surface without fine carinae. Guernet and Bellier (2000, pl. 6, fig. 9) illustrated a specimen with a different morphology as *Nodobythere?* sp. 2. That taxon does not possess fine curved carinae before the subcentral sulcus. We distinguish these taxa from *B. wilsoni* sp. nov.

***Bythoceratina* cf. *umbonata* (Williamson, 1848)**

Figures 5K, L, 6A, 10B

cf. *Cytherina umbonata* Williamson, 1848, p. 82, pl. 4, fig. 78.

Description.—Carapace robust and large (704–807 μ m long). In external view, lateral outline rectangular: anterior margin round; posterior margin slightly curved and tapering near horizon of dorsal margin, forming caudal process; dorsal margin straight or slightly curved; ventral margin straight or slightly curved. Maximum length across apex of caudal process. Central area swollen. Spine projected in ventro-central area. Dorsal part of central area slightly depressed. Surface reticulated;

muri frame polygonal fossae. Fossae arranged concentrically. Distinct murus running from anterior to posterior margin through ventral area. In internal view, lophodont-type hingement: in RV, round tooth of anterior element; smooth median furrow; rectangular tooth of posterior element. Anterior marginal zone width less than 10% of the maximum valve length. Marginal pore canals absent.

Material.—MPC-29089, RV, adult, 342-U1407B-19X-3W, 24-26, Maastrichtian; MPC-29090, LV, adult, 342-U1407C-20X-6W, 45-47.5, Maastrichtian; SIO-BIC-C12156, LV, adult, 342-U1407C-16X-6W, 123-125, Selandian; SIO-BIC-C12157, LV, adult, 342-U1407C-16X-6W, 123-125, Selandian.

Measurements.—Table 3.

Remarks.—The specimens are different from the typical specimens of *Bythoceratina umbonata* (Williamson, 1848) in having a shallower subcentral sulcus, reticulation on the posterior margin, and no vestibulum. This taxon is similar to *B. (Cuneoceratina) herrigi* Weaver, 1982 in its lateral outline and reticulate surface ornamentation but is distinguished from the latter taxon by having reticulation on the posterior to ventral margin and distinct convex muri in the ventral area, and by lacking a distinct rim on the dorsal margin. *Bythoceratina herrigi* was originally described from Cenomanian strata in England.

Genus ***Nemoceratina*** Gründel and Kozur, 1972
emended Weaver, 1982

Subgenus ***Pariceratina*** Gründel and Kozur, 1972

***Nemoceratina (Pariceratina) guerneti* sp. nov.**

Figures 6B–E, 10C

Bythoceratina sp. 1. Guernet, 1982, p. 52, pl. 5, fig. 8.

Bythoceratina sp. 2. Guernet, 1982, p. 52, pl. 5, figs. 6, 7.

Pariceratina sp. Coles, 1996, pl. 2, figs. 6, 7.

Pariceratina sp. 1. Guernet and Bellier, 2000, p. 274, pl. 6, figs. 4, 5.

Diagnosis.—A *Nemoceratina* species characterized by a medium-sized carapace, coarser reticulation with distinct horizontal murus in the dorsal area and four spines in the ventro-central area, a distinct perforate spine projected near the antero-dorsal corner, and long clavae projected from the posterior margin.

Description.—Carapace robust and medium to large (589–657 μ m long). In external view, lateral outline subrectangular: anterior margin round; posterior margin slightly curved and tapering slightly below horizon of dorsal margin, forming caudal process; dorsal margin straight or slightly curved; ventral margin slightly curved. Maximum length across caudal process; maximum height across middle of valve. Marginal denticles along anterior and posterior margins. Long clavae projected from

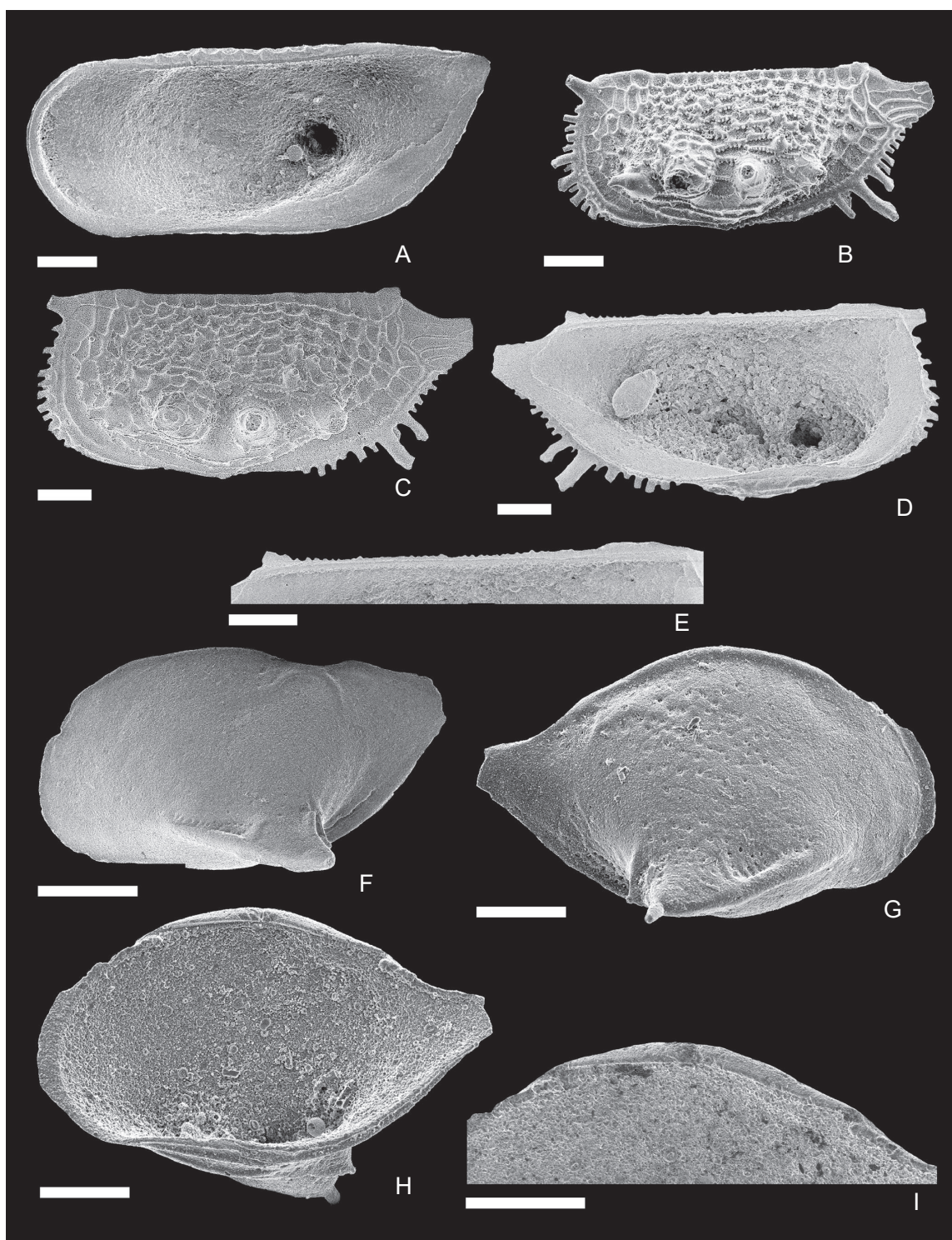


Figure 6. SEM images of ostracode species. **A**, *Bythoceratina* cf. *umbonata* (Williamson, 1848) (MPC-29089), internal view of adult RV; **B–E**, *Nemoceratina* (*Pariceratina*) *guerneti* sp. nov. (MPC-29100 and MPC-29101); **B**, external view of adult LV (MPC-29100, holotype); **C**, external view of adult LV (MPC-29101, paratype); **D**, internal view of adult LV (MPC-29101, paratype); **E**, hingement of adult LV (MPC-29101, paratype); **F–I**, *Cytheropteron americanum* sp. nov. (MPC-29097 and SIO-BIC-C12175); **F**, external view of adult LV (SIO-BIC-C12175, paratype); **G**, internal view of adult RV (MPC-29097, holotype); **H**, external view of adult RV (MPC-29097, holotype); **I**, hingement of adult RV (MPC-29097, holotype). All scale bars equal 100 µm.

posterior margin. Ventro-central area has swelling. Four round tubercles arranged horizontally in ventro-central area. Distinct perforate spine projected slightly upward at antero-dorsol corner. Reticulated surface ornamentation. Rectangular and polygonal fossae in anterior and posterior areas. Smaller rectangular and polygonal fossae and muri with papillae and pores in central area. Distinct horizontal murus presented in dorsal area. Four longitudinal muri running on caudal process. Marginal rim running from anterior to posterior margins through ventral margin. In internal view, adont-type hinge: in LV, smooth median bar. Anterior marginal zone width less than 10% of the maximum valve length. Marginal pore canals absent.

Etymology.—In honor of Claude Guernet who studied deep-sea ostracodes and reported this species for the first time.

Types.—Holotype: MPC-29100, LV, adult, 342-U1407C-15X-6W, 116-118, Thanetian. Paratypes: MPC-29101, LV, adult, 342-U1407C-14X-5W, 18-20, Thanetian; SIO-BIC-C12158, LV, adult, 342-U1407C-20X-5W, 34-36, Danian; SIO-BIC-C12159, LV, adult, 342-U1407A-22X-2W, 120-122, Selandian.

Occurrence.—Lower Paleocene at DSDP Site 390, North Atlantic (Guernet, 1982); lower to middle Eocene at DSDP Site 549 and 550, North Atlantic (Coles, 1996); lower Paleocene to upper Eocene at ODP Sites 1049, 1050, 1052, and 1053, North Atlantic (Guernet and Bellier, 2000); lower to upper Paleocene at IODP Site U1407, North Atlantic (this study).

Measurements.—Table 3.

Remarks.—The subrectangular outline and distinct three round tubercles indicate *Nemoceratina* (Weaver, 1982; Sciuto, 2014). The reticulate surface ornamentation indicates that the taxon is of the subgenus *Pariceratina*, while the hingement with a smooth bar suggests that it is of the subgenus *Nemoceratina* (Weaver, 1982). Emphasizing the character of reticulate ornamentation, we assign the species to *Pariceratina*.

Nemoceratina guerneti sp. nov. is similar to *N. liebaui* (Dingle, 1984) and *N. ubiquita* (Boomer, 1994) in its lateral outline and reticulate surface ornamentation. *Nemoceratina liebaui* and *N. ubiquita* were originally described from the Albian sediments at DSDP Site 330 and from the middle Eocene sediments at ODP Site 865, respectively. The new species is different from *N. liebaui* in having a smaller valve, coarser reticulation with larger fossae and four spines in the ventro-central area and is distinguished from *N. ubiquita* by having a smaller valve, coarser reticulation with fewer and slightly larger fossae, four spines in the ventro-central area, reticulation in the postero-dorsal area, a distinct horizontal murus in the dorsal area, a spine near the antero-dorsal corner, and long clavae from the posterior margin.

Family Cytheruridae Müller, 1894
Genus *Cytheropteron* Sars, 1866
Cytheropteron americanum sp. nov.

Figures 6F–I, 10D

Cytheropteron spp. Cronin and Compton-Gooding, 1987, pl. 5, fig. 6.
Cytheropteron sp. 2. Guernet and Bellier, 2000, p. 272, pl. 5, figs. 14, 15.

Cytheropteron sp. Bergue and Nicolaidis, 2012, p. 54, figs. 3.22, 3.23.

Diagnosis.—A *Cytheropteron* species that has an arched dorsal margin in RV, a sinuous dorsal margin in LV, a caudal process above the middle of the valve, an ala framed by a carina with two spines on the posterior side and a depression on the anterior side, feeble punctae on the ala and dorsal area, and feeble swelling near the postero-dorsal corner.

Description.—Carapace thin and small (384–476 μ m long). RV larger than LV. In external view, lateral outline subrectangular: anterior margin round; lower half of posterior margin slightly curved; upper half of posterior margin sinuous; posterior margin tapering upward at dorsal one-third, forming caudal process; dorsal margin sinuous in LV; dorsal margin arched in RV; ventral margin curved. Maximum length across caudal process; maximum height across middle of valve. Swelling in ventro-central area, forming ala. Ala framed by blunt carina and associated with two spines. Forward spine located at terminal of carina. Backward spine smaller than forward spine. Depression on anterior side of ala. Marginal rims developed along anterior, dorsal, and postero-ventral margins. Surface ornamented with foveolae in dorso-central, central, and ventro-central areas. Fine short carina below postero-dorsal corner. In internal view, merodont-type hingement: in RV, crenulate tooth of anterior element; crenulate median furrow; crenulate tooth of posterior element. Anterior marginal zone width less than 10% of the maximum valve length.

Etymology.—Named after the type locality of the new species, off North America.

Types.—Holotype: MPC-29097, RV, adult, 342-U1407C-20X-4W, 124-126, Danian. Paratypes: SIO-BIC-C12175, LV, adult, 342-U1407A-21X-4W, 74-76, Selandian; SIO-BIC-C12185, RV, adult, 342-U1407C-20X-4W, 124-126, Danian.

Measurements.—Table 3.

Occurrence.—Middle Eocene at DSDP Site 612, North Atlantic (Cronin and Compton-Gooding, 1987); lower Paleocene to upper Eocene sediments at ODP Site 1049–1053, North Atlantic (Guernet and Bellier, 2000); Paleocene at DSDP Site 329, South Atlantic (Bergue and Nicolaidis, 2012); lower to middle Paleocene sediments at IODP Site U1407, North Atlantic (this study).

Remarks.—The new species is similar to *Cytheropteron caroliniae* Whatley and Coles, 1987, *C. circummuralla* Whatley and Coles, 1987, and *C. lineopora* Whatley and Coles, 1987 in having an arched dorsal margin in RV, a sinuous dorsal margin in LV, a caudal process above the middle of the valve, and an ala with two spines, but is distinguished from these species by having a smaller valve, punctae on the ala and dorsal area, the depression on the anterior side of the ala, and feeble swelling near the postero-dorsal corner. Those species were originally described from Quaternary sediments at ODP Site 610, North Atlantic.

***Cytheropteron newfoundlandense* sp. nov.**

Figures 7A–G, 10E

Diagnosis.—A *Cytheropteron* species characterized by a smaller carapace, punctae and blunt muri in the central area, rectangular fossae along the posterior margin, feeble wrinkled carinae in the posterior area, and broad marginal zone.

Description.—Carapace thin and small (411–441 μm long). RV larger than LV. In external view, lateral outline subrectangular: anterior margin round; ventral half of posterior margin slightly curved and tapering below horizon at dorsal margin, forming caudal process; ventral margin slightly sinuous; in RV, upper half of posterior margin truncated; dorsal margin arched; in LV, upper half of posterior margin slightly curved; dorsal margin slightly arched. Maximum length across caudal process; maximum height across postero-dorsal corner in RV. Ventro-central area swollen downward, forming ala. Ala framed by carina. Surface ornamentation of foveolae; foveolae in ventro-central, central, dorso-central, and postero-ventral areas. Wrinkles vertically in posterior area. In internal view, merodont-type hingement: in LV, socket of anterior element, crenulate median bar, socket of posterior element; in RV, elongated tooth, crenulate median furrow, crenulate tooth of posterior element. Anterior marginal zone more than 10% of the maximum valve length.

Etymology.—Named after Newfoundland.

Types.—Holotype: MPC-29098, LV, adult, 342-U1407C-14X-2W, 18–20, Thanetian. Paratypes: MPC-29099, RV, adult, 342-U1407C-16X-5W, 22–24, Selandian; SIO-BIC-C12173, RV, adult, 342-U1407C-14X-2W, 18–20, Thanetian; SIO-BIC-C12174, LV, adult, 342-U1407C-16X-3W, 62–64, Thanetian.

Measurements.—Table 3.

Remarks.—The new species is similar to *Cytheropteron* sp. E of Alvarez Zarikian (2015) in lateral outline and surface ornamentation, but is distinguished from the latter taxon by having a smaller valve, fewer punctate in the central area, sparse punctate in the postero-central area,

and a more gently curved dorsal margin. *Cytheropteron* sp. E was reported from Oligocene sediments at IODP Site U1367, South Pacific, and is ~870 μm long. *Cytheropteron newfoundlandense* sp. nov. is similar to *Cytheropteron* sp. m of Yasuhara *et al.* (2009c) in lateral outline and punctae that are arranged vertically on the alae and in the dorsal area, but it lacks punctae in the anterior area and a horizontal carina in the dorsal area and a bifurcated carina on the ala. *Cytheropteron* sp. m was reported from Quaternary sediments at ODP Site 1055B, North Atlantic.

Genus *Eucytherura* Müller, 1893

***Eucytherura* sp. 1**

Figure 7H

Hemiparacytheridea sp. 2. Majoran, 1999, pl. 2, fig. 6.

Material.—MPC-29108, LV, adult, 342-U1407B-19X-3W, 42–44, Maastrichtian.

Measurements.—Table 3.

Occurrence.—Upper Cretaceous sediments at ODP Site 1052, North Atlantic (Majoran, 1999); Maastrichtian sediments at IODP Site U1407, North Atlantic (this study).

***Eucytherura* sp. 2**

Figure 7I

Description.—Carapace robust and small (309 μm long). In external view, subrectangular lateral outline: anterior margin gently round; posterior margin gently tapering at middle of carapace, forming caudal process; dorsal margin sinuous; ventral margin slightly concave. Maximum length across middle of carapace; maximum height across antero-dorsal corner. Surface ornamentation of reticulation. Reticulation formed by round fossae and muri. Three muri distinct: first murus running near posterior half of dorsal margin to posterior area; second obliquely extending from postero-ventral corner to central area; third obliquely stretched from central area to anterior area. Two muri slightly blunt: one murus running from antero-ventral corner to anterior half of ventral margin; another present in ventral area, parallel to second distinct murus. Fossae in central area larger than those in dorsal area. Eye tubercle prominent, swollen triangularly.

Material.—MPC-29109, RV, adult, 342-U1407B-19X-3W, 42–44, Maastrichtian.

Measurements.—Table 3.

Remarks.—This species is similar to *Eucytherura* sp. 2 of Majoran (1999), reported from the Maastrichtian at ODP Site 1052, in lateral outline and reticulation, but is distinguished from the reported taxon by having smaller fossae in the dorsal and central areas and lacking the blunt

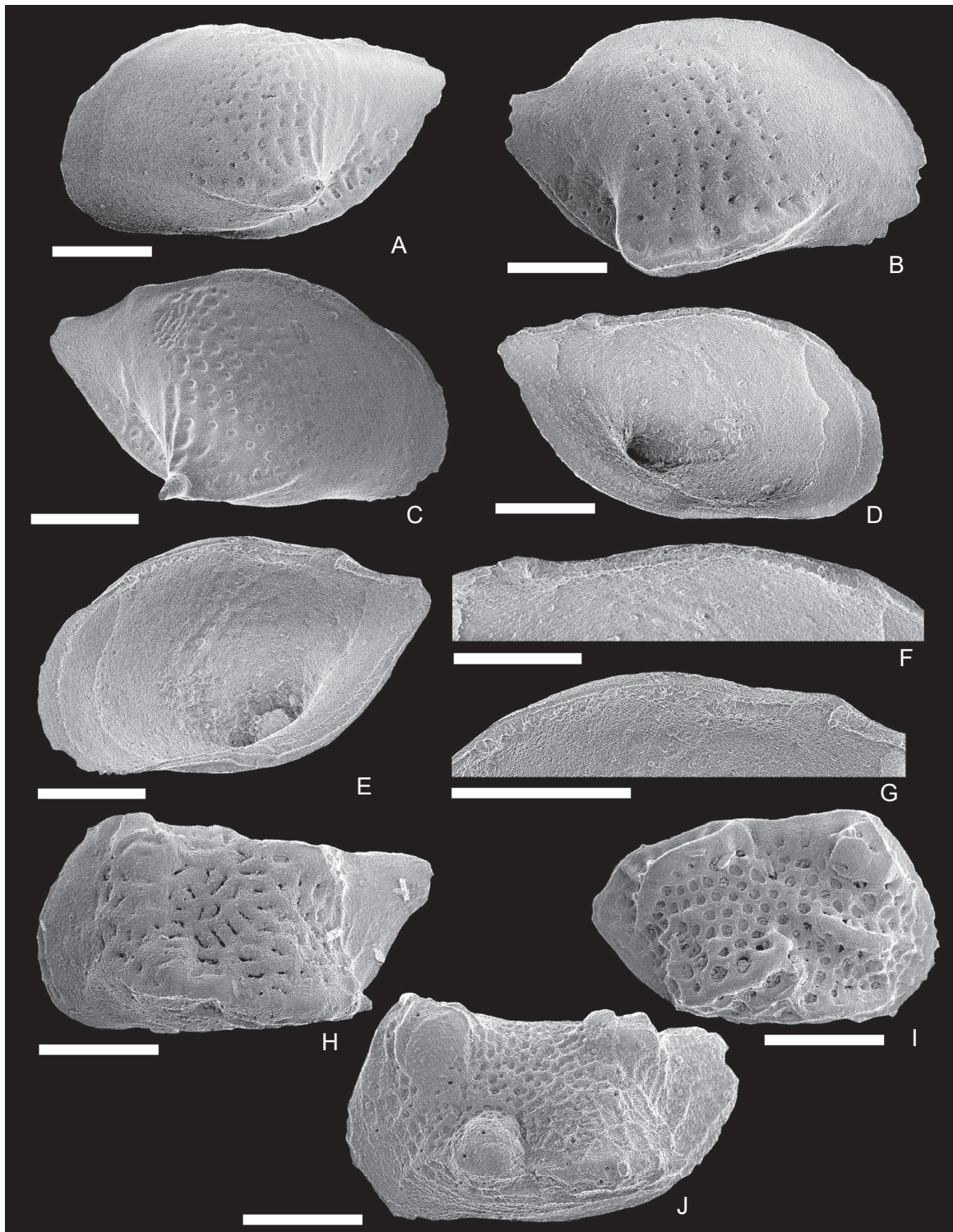


Figure 7. SEM images of ostracode species. **A–G**, *Cytheropteron newfoundlandense* sp. nov. (MPC-29098, MPC-29099, and SIO-BIC-C12173); **A**, external view of adult LV (MPC-29098, holotype); **B**, external view of adult RV (SIO-BIC-C12173, paratype); **C**, external view of adult RV (MPC-29099, paratype); **D**, internal view of adult LV (MPC-29098, holotype); **E**, internal view of adult RV (MPC-29099, paratype); **F**, hingement of adult LV (MPC-29098, holotype); **G**, hingement of adult RV (MPC-29099, paratype); **H**, *Eucytherura* sp. 1, external view of adult LV (MPC-29108); **I**, *Eucytherura* sp. 2, external view of adult RV (MPC-29109); **J**, *Hemiparacytheridea* sp., external view of adult LV (MPC-29110). All scale bars equal 100 μ m.

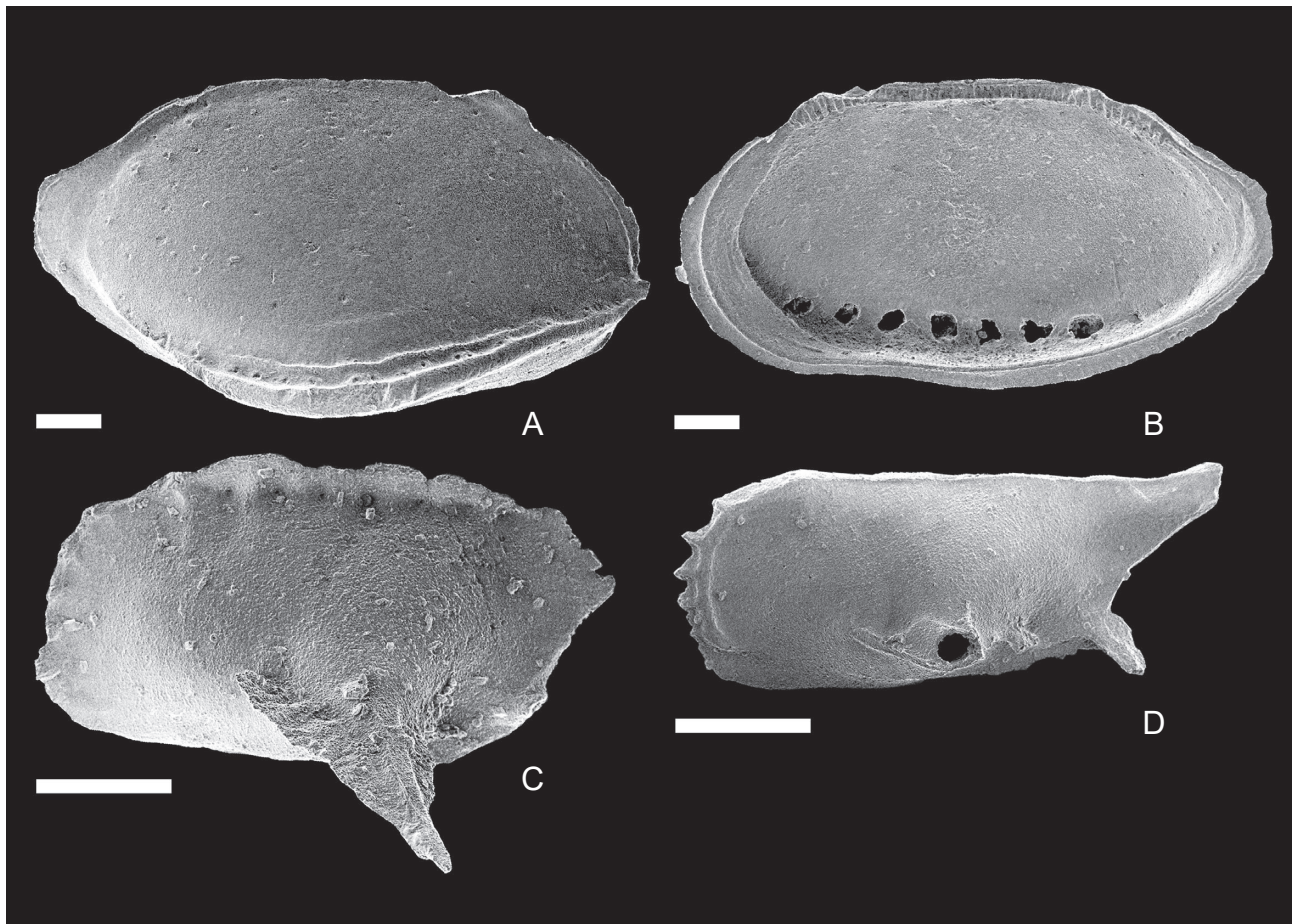


Figure 8. SEM images of ostracode species. **A, B**, *Pelecocythere* sp. (MPC-29104); **A**, external view of adult RV; **B**, internal view of adult RV; **C**, *Pedicythere* sp.1 (MPC-29103), external view of adult LV; **D**, *Pedicythere* sp.2, external view of adult LV. All scale bars equal 100 μm .

muris that stretches obliquely from the middle of the ventral margin toward the anterior area.

Genus *Hemiparacytheridea* Herrig, 1963
Hemiparacytheridea sp.

Figure 7J

Hemiparacytheridea sp. 3. Majoran, 1999, pl. 2, fig. 7.

Material.—MPC-29110, LV, adult, 342-U1407A-21X-2W, 20-22, Selandian.

Measurements.—Table 3.

Occurrence.—Upper Cretaceous sediments at ODP Site 1052, North Atlantic (Majoran, 1999); middle Paleocene sediments at IODP Site U1407, North Atlantic (this study).

Genus *Pelecocythere* Athersuch, 1979

Pelecocythere sp.

Figures 8A, B, 10F, 11B

Description.—Adult carapace thin and large (812–873 μm long). In external view, lateral outline ovate: anterior margin round; posterior margin subtriangular, forming caudal process; dorsal margin straight; ventral margin curved. Maximum length across center of caudal process; maximum height across middle. Ventral area swollen. Posterior area flattened. Surface ornamentation consists of three carinae and seven holes in ventral area. All carinae running parallel to ventral margin and meet in postero-ventral area. Holes polygonal and horizontally arranged below bottom carina. In internal view, merodont-type hinge: in RV, a half-round tooth with four indentations is anterior element; median furrow with at least 26 indentations; elongated tooth with seven indentations is posterior element. Anterior marginal zone width less than 10% of

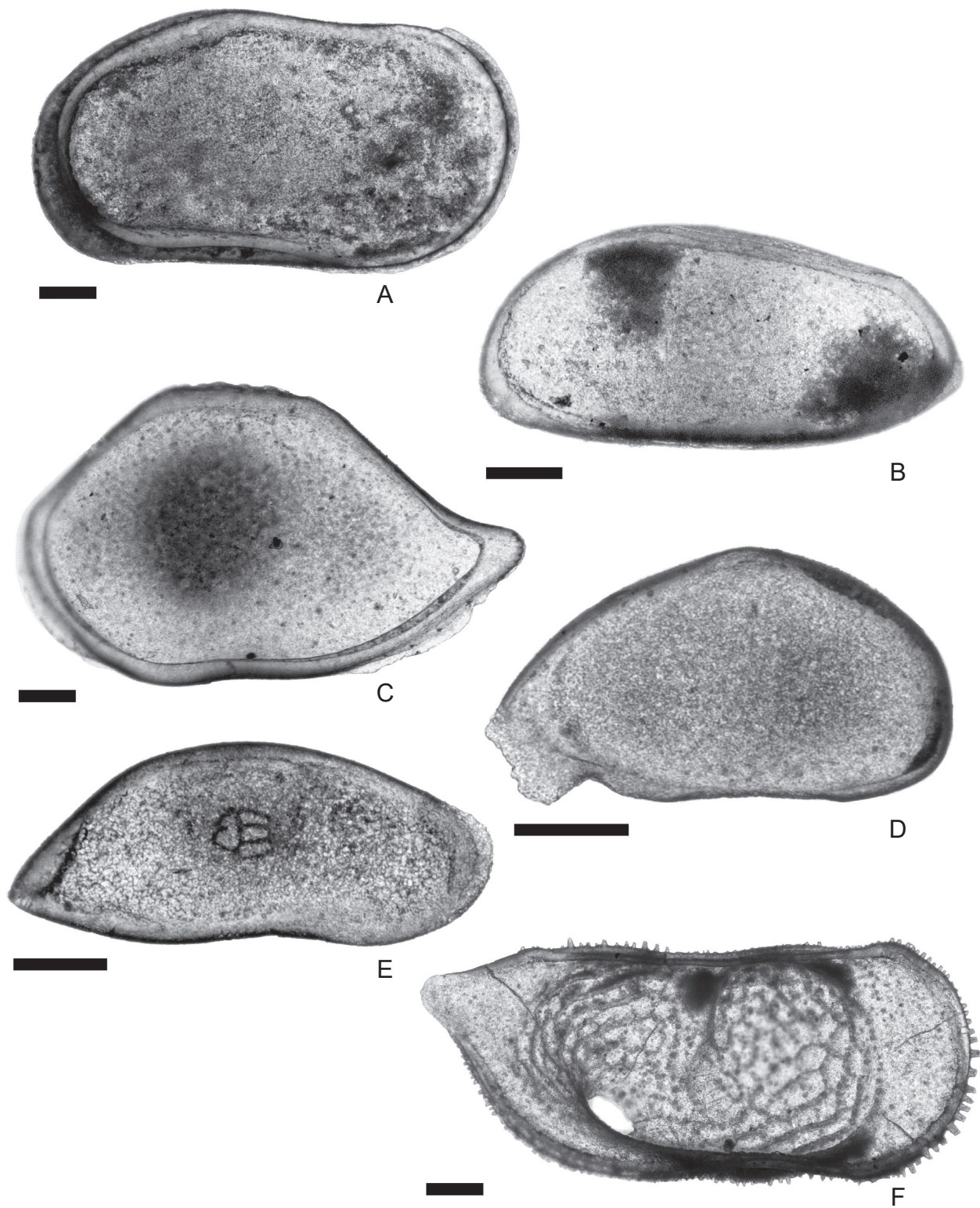


Figure 9. Light microscopic images of internal views of ostracode species in transmitted light. **A**, *Cytherella* sp. (SIO-BIC-C12178); **B**, *Cardobairdia* sp. (MPC-29095); **C**, *Neonesidea* cf. *cymbula* (Deltel, 1964) (SIO-BIC-C12177); **D**, *Aratrocypris praealta* (MPC-29087); **E**, *Argilloecia* sp. (MPC-29088); **F**, *Bythoceratina subumbonata* sp. nov. (SIO-BIC-C12152, paratype). All scale bars equal 100 µm.

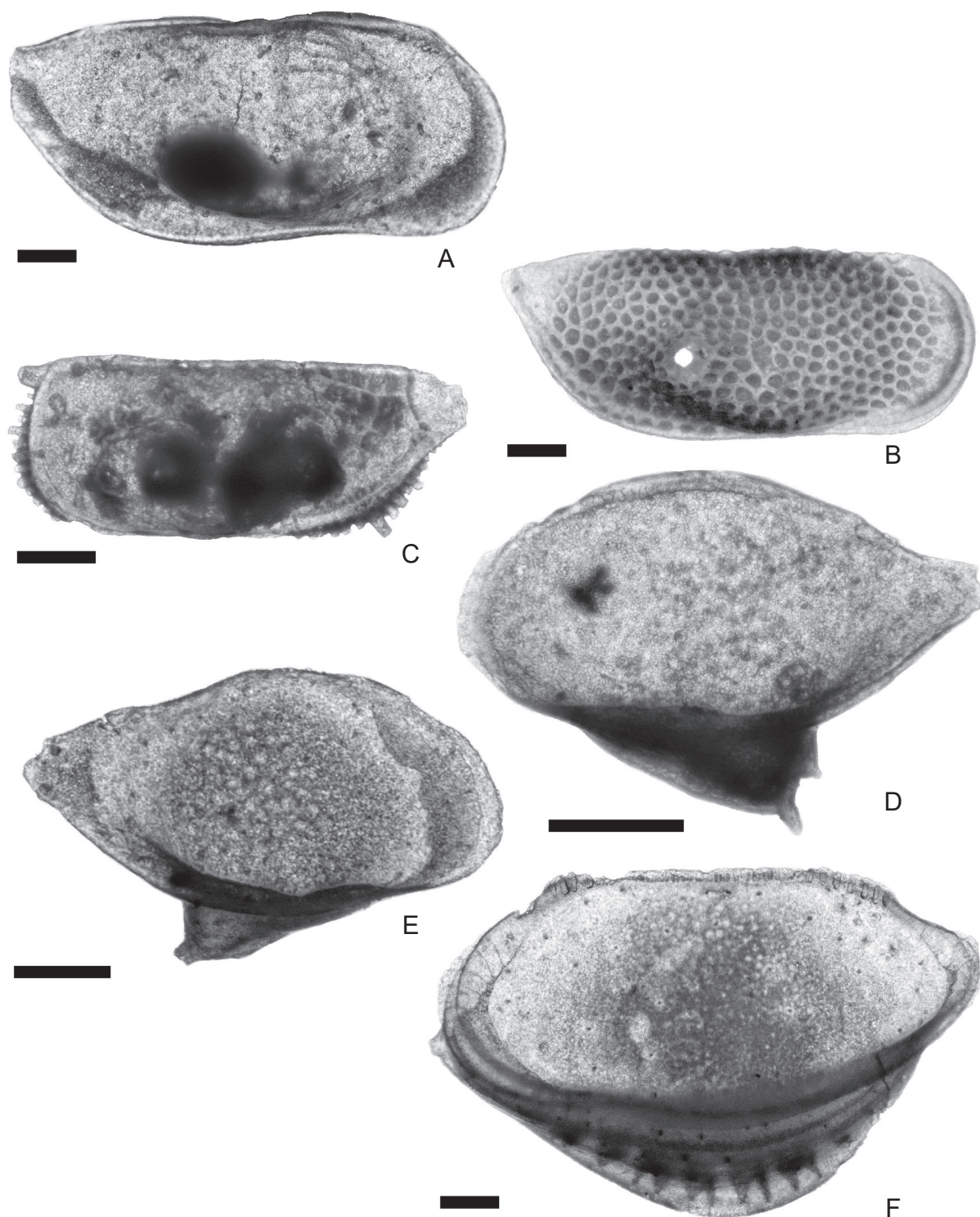


Figure 10. Light microscopic images of internal views of ostracode species in transmitted light. **A**, *Bythoceratina wilsoni* sp. nov. (MPC-29093, holotype); **B**, *Bythoceratina* cf. *umbonata* (Williamson, 1848) (MPC-29089); **C**, *Nemoceratina* (*Pariceratina*) *guerneti* sp. nov. (SIO-BIC-C12158); **D**, *Cytheropteron americanum* sp. nov. (MPC-29097); **E**, *Cytheropteron newfoundlandense* sp. nov. (MPC-29098); **F**, *Pelecocythere* sp. (MPC-29104). All scale bars equal 100 µm.

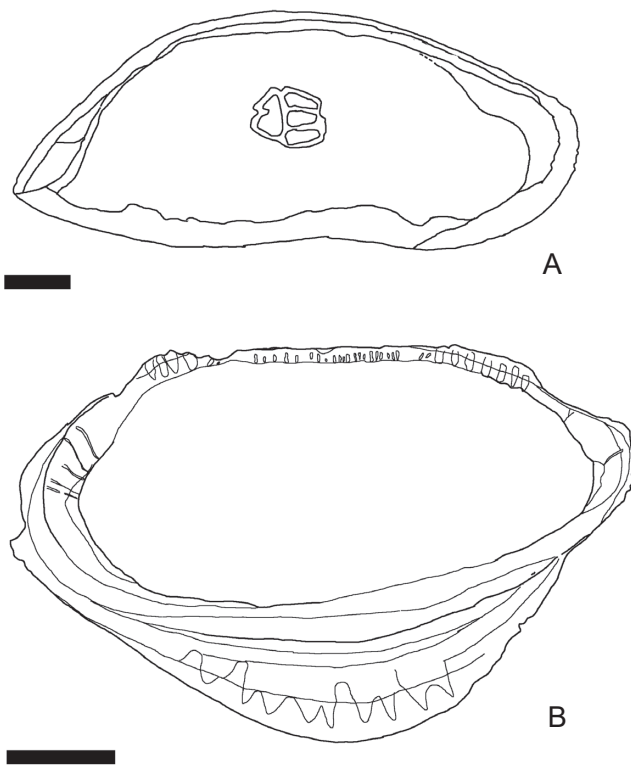


Figure 11. Sketches of the internal structure of ostracode species. **A**, *Argilloecia* sp. (MPC-29088); **B**, *Pelecocythere* sp. (MPC-29104). All scale bars equal 100 μm.

the maximum valve length. Narrow vestibulum in anterior and posterior marginal zones. Marginal pore canals moderately curved, and straight. Five anterior marginal pore canals; two posterior marginal pore canals.

Material.—MPC-29104, RV, adult, 342-U1407C-14X-1W, 70-72, Thanetian; SIO-BIC-C12186, LV, juvenile, 342-U1407C-17X-2W, 65-67

Measurements.—Table 3.

Remarks.—This species is similar to *Pelecocythere* sp. of Whatley and Coles (1987), reported from upper Pliocene sediments at DSDP Site 609, in lateral outline, but differs from the latter in lacking punctuation on the surface.

Genus *Pedicythere* Eager, 1965

Pedicythere sp. 1

Figure 8C

Description.—Carapace thin and small (452 μm long). In external view, subrectangular lateral outline: anterior margin slightly round; posterior margin tapering above middle of carapace; dorsal margin gently arched; ventral margin straight. Maximum length across tapered posterior margin; maximum height across anterior one-third

of carapace. Surface smooth. Dorsal marginal rim developed. Five hollows present along dorsal marginal rim. Ala obliquely stretched from central area toward bottom of carapace.

Material.—MPC-29103, LV, adult, 342-U1407C-20X-4W, 44-46, Danian.

Measurements.—Table 3.

Remarks.—This species is different from *Pedicythere* sp. 2 in having a larger valve and an arched dorsal margin.

Pedicythere sp. 2

Figure 8D

Pedicythere sp. A. Guernet and Bellier, 2000, p. 270, pl. 5, figs. 1, 2.

Material.—One LV, adult, 342-U1407A-21X-2W, 20-22, Selandian.

Measurements.—Table 3.

Occurrence.—Lower Paleocene to middle Eocene sediments at ODP Site 1049, middle Eocene sediments at ODP Sites 1050, 1051, and 1052, North Atlantic (Guernet and Bellier, 2000); middle Paleocene sediments at IODP Site U1407, North Atlantic (this study).

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