EARLY MIOCENE MOLLUSCA FROM MCMURDO SOUND, ANTARCTICA (ANDRILL 2A DRILL CORE), WITH A REVIEW OF ANTARCTIC OLIGOCENE AND NEOGENE PECTINIDAE (BIVALVIA)

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Abstract: *Retrotapes andrillorum* n. sp., *Hiatella* cf. *arctica* (Linnaeus, 1767), ?*Yoldia* sp. (internal mould), and six taxa of Pectinidae are reported from the Burdigalian section of the ANDRILL 2A core, drilled in McMurdo Sound, Ross Sea. The pectinids are *Adamussium* cf. *jonkersi* Quaglio *et al.*, 2010, *Antarctipecten* n. gen. *alanbeui* (Jonkers, 2003), *Austrochlamys forticosta* n. sp., *Austrochlamys* cf. *marisrossensis* Jonkers, 2003, *Ruthipecten* n. gen., n. sp. (not named), and a fragmentary specimen representing an unnamed genus and species. In a revision of Antarctic Pectinidae, *Austrochlamys* Jonkers, 2003, *Ruthipecten* n. gen. (proposed for *Chlamys* (*Zygochlamys*) *tuftsensis* Turner, 1967, reported only from Wright Valley and the Vestfold Hills, not present in ANDRILL 2A), *Leoclunipecten* n. gen. (proposed for *Austrochlamys gazdzickii* Jonkers, 2003, reported only from Oligocene rocks of King George Island, not present in ANDRILL 2A) and the unnamed genus in ANDRILL 2A are assigned to subfamily Chlamydinae, tribe Chlamydini, whereas *Adamussium* Thiele, 1934 and *Antarctipecten* n. gen. are assigned to subfamily Palliolinae, tribe

Adamussiini. The diverse Pectinidae in ANDRILL 2A suggest sea temperatures roughly 5°C warmer than at present in the Ross Sea during Early Miocene time.

Key words: Antarctica, Miocene, new genera, new species, palaeotemperatures, Pectinidae.

KNOWLEDGE of the faunal, floral and climatic history of Antarctica is crucial for understanding the climatic history of the Earth, and so for predicting where its future climate is heading. However, because Antarctica is largely hidden in ice, little of its geology and fossils can be seen at the surface. Sedimentary sequences deposited on the Antarctic continental margins offer hope of accessing the Cenozoic history of the Antarctic ice sheet (Cooper and Eittreim 1993). Consequently, a number of drilling projects have attempted to produce cores through the Cenozoic sedimentary record around the margins of the continent, to help reveal its biotic and climatic history (DSDP Sites 270 and 272, Dell and Fleming 1975; CIROS-1, Barrett 1989; CRP 1-3, Cape Roberts Science Team 1998, 1999; ANDRILL 1B, Naish *et al*. 2007, McKay *et al*. 2009; ANDRILL 2A, Harwood *et al.* 2010). Mollusca are the most diverse macrofossils in these as in most other Cenozoic marine rocks around the world, and are important for their contribution to understanding past sea temperatures, based on the uniformitarian principle that the temperatures defining present-day distributions are a guide to the temperature range at which the same species or genus lived in the past. Mollusca have been recorded previously from DSDP Sites 270 and 272 in the Ross Sea (Dell and Fleming 1975), the CIROS-1 drill core from McMurdo Sound, Ross Sea (Beu and Dell 1989), the CRP-1 drill core from Cape Roberts, McMurdo Sound (Jonkers and Taviani 1998; Taviani *et al.* 1998), the CRP-2/2A drill core (Taviani and Jonkers 2001), and the CRP-3 drill core (Taviani and Beu 2001). The geochemical composition of bivalves from the CRP drill cores also has been used for palaeoenvironmental reconstruction and dating (Taviani and Zahn 1998; Lavelle 1998, 2000, 2001). An overview of macrofossil evidence for palaeotemperatures based on the three Cape Roberts drill cores was provided by Taviani and Beu (2003), and Taviani *et al.* (2010) provided a preliminary list of macrofossils observed in the ANDRILL 2A core. We describe here the better-preserved Mollusca present in the Early Miocene section of the ANDRILL 2A core, as it is notable among these Antarctic cores for its well-preserved molluscs. ANDRILL 2A was drilled late in 2007 to a depth of 1138.54 m from an 8.5 m-thick floating ice platform over 380 m of water in southwestern McMurdo Sound, Ross Sea, at 77°45.488′S, 165°16.613′E. The lower part of the drill core from which the present material was extracted is 60 mm in diameter. We also include a review of the generic classification of Antarctic Oligocene and Neogene fossil Pectinidae (scallops), necessitated by the unusually high diversity of scallops recovered in the core, and the uncertainty of their classification in previous studies (e.g., Jonkers 2003).

Analyses of downhole measurements, stratigraphy, sedimentology, petrology, geochemistry, magnetic polarity stratigraphy, and an initial interpretation of the age of the rocks intersected in the ANDRILL 2A core were provided by Harwood *et al.* (2010). The date of the Pliocene-Pleistocene boundary at 2.59 Ma is adopted here (Gibbard *et al.* 2010). Acton *et al*. (2010, fig. 2) noted that the entire ANDRILL 2A core below 375 m below seafloor (mbsf) is Early Miocene (Burdigalian) in age. However, the most recent age model for the core (Fielding *et al*. 2011; R. Levy, GNS Science, pers. comm. 14 March 2012; Fig. 1) and correlation with the geomagnetic polarity scale demonstrate that the Burdigalian section extends up to 310 mbsf; the core below this level is entirely Burdigalian. The core below 375 mbsf was deposited almost continuously, although the level of resolution does not rule out the possibility of minor hiatuses. Fragmentary macrofossils were reported by Taviani *et al.* (2010, table 5) from depths of 23.13–1063.73 mbsf in this core, but all identifiable and taxonomically describable molluscs remaining after strontium isotope sampling come from the Burdigalian (Early Miocene) interval between 376.80 mbsf and 999.80 mbsf and are described here.

MATERIAL AND METHODS

Most information on Antarctic and Southern Ocean Oligocene to living Pectinidae in the present report is derived from the excellent, well illustrated, data-rich revision by Jonkers (2003). We have examined very little of the material described by Jonkers (2003), our concepts of species all follow Jonkers (2003) and the illustrations therein, and our revision of austral pectinid classification consists of amplification of and amendments to Jonkers's (2003) monograph revealed by the present new material. In preparing the present report, we had access to: (1) the ANDRILL 2A fossils; (2) type material of *Adamussium alanbeui* Jonkers, 2003 and *Austrochlamys marisrossensis* Jonkers, 2003 in GNS Science, Lower Hutt (GNS); (3) a collection of Argentinian Cenozoic *Zygochlamys* species presented to GNS by Dr Miguel Griffin (La Plata Museum, Argentina) and illustrated, in part, by Jonkers (2003, pls 4–5); (4) rubber replicas of most of the type specimens of Southern Ocean *Austrochlamys* species, gathered by C. A. Fleming when preparing his description of *Austrochlamys heardensis* (Fleming, 1957) along with rubber replicas of three specimens of *A. anderssoni* (Hennig, 1911) from Cockburn Island presented to GNS by H. Jonkers; (5) a large collection of New Zealand Cenozoic fossil Pectinidae in GNS; (6) fragmentary specimens of *A. anderssoni* from Scallop Hill Formation, McMurdo Sound, collected and recorded by Speden (1962, figs 3, 9) (GS7510, Brown Peninsula, one large abraded fragment; GS7511, Black Island, 19 fragments); (7) a collection of eight specimens of *Ruthipecten* n. gen. *tuftsensis* (Turner, 1967) from Marine Plain on loan from Museum Victoria, Melbourne, and three specimens from the same locality on loan from Museum of New Zealand Te Papa Tongarewa, Wellington; (8) a reference collection of other world Pectinidae in GNS, including specimens of *Zygochlamys patagonica* (King, 1832), *Austrochlamys natans* (Philippi,

1845) and *Adamussium colbecki* (Smith, 1902); (9) specimens of most Chilean Plio-Pleistocene Pectinidae revised in his monograph by Herm (1969) and presented to GNS by D. Herm (Bayerischen Staatssammlung für Paläontologie und Historische Geologie, München), including a few of his illustrated specimens; and (10) photographs of the holotype of *Ruthipecten* n. gen. *tuftsensis* sent by A. Baldinger (Museum of Comparative Zoology, Harvard University, Cambridge, USA) and of the holotype of *Leoclunipecten* n. gen. *gazdzickii* (Jonkers, 2003) sent by P. Bucktrout (British Antarctic Survey, Cambridge, UK). Statements about other Southern Ocean pectinid characters, taxonomy and distribution are all from Jonkers (2003) unless otherwise stated. Most Southern Ocean pectinid specimens other than the ANDRILL 2A material referred to below have not been examined by us, and we describe only ANDRILL 2A material in this report, apart from type species of new genera described to amplify generic diagnoses.

The ANDRILL 2A specimens were separated from the core in the Crary Laboratory, McMurdo Station, taken to Istituto de Scienze Marine, Bologna, for initial preparation, and then sent to GNS, Lower Hutt for final preparation and photography. Final preparation consisted of cleaning with a compressed air-driven drill or a mounted needle under a light microscope, and brushing all but very delicate specimens under water. Specimens were whitened with MgO and photographed with a Nikon D-100 digital camera. The ANDRILL 2A material described here is all deposited in the USNM Department of Paleobiology.

LIST OF TAXA WITH DEPTH AND LITHOLOGY

A stratigraphic log of the ANDRILL 2A core, its ages and sedimentary sequences (Fielding *et al*. 2011), and the positions of described samples in the core are shown in Fig. 1. Fielding *et al*. (2010) divided the core into 13 lithostratigraphic units. We examined fossils from five of these units, in 11 specific segments, summarized here. The lithology is added below from Fielding *et al.* (2010, fig. 1), and more detailed lithologies at sampling points are added from the ANDRILL 2A detailed log (4 m per printed page; available at: http://doi.pangaea.de/10.1594/PANGAEA.743224).

Lithostratigraphic unit 7, 339.92–436.18 mbsf. Diamictite and sandstone; ‘Fossils (bivalves, gastropods, and serpulid tubes) are locally abundant and may also be associated with bioturbation’ (Fielding *et al*. 2010, p. 94):

376.80–376.85 mbsf: *Antarctipecten* n. gen. *alanbeui* (Jonkers, 2003), one articulated, complete specimen (Fig. 7B–C), two other articulated, fragmentary specimens, and several fragments. Detailed log: medium to coarse sandstone, no large clasts.

377.19–377.26 mbsf: *Hiatella* sp., internal moulds, three valves visible. Within same unit as above.

429.25–429.28 mbsf: *Austrochlamys* cf. *marisrossensis* Jonkers, 2003, two fragments (Fig. 3E); *Retrotapes andrillorum* n. sp., part of one small valve; echinoid fragments and small spines. Detailed log: base of fine to coarse sandstone with dispersed clasts, interbeds of siltstone; no diamictite.

429.92–430.02 mbsf: *Retrotapes andrillorum* n. sp., holotype (Figs 8A-E); sediment as in overlying unit.

430.54–430.68 mbsf: Pectinid concentration; many pieces and ca. 10 half-valves of *Austrochlamys forticosta* n. sp., holotype and paratypes (Figs 4A–E); Pectinidae n. gen., n. sp. (Fig. 6C), fragments of one articulated specimen and (possibly) other valves, attached to fragments of *A. forticosta* n. sp.; *Retrotapes andrillorum* n. sp., parts of two valves; *Hiatella* cf. *arctica* (Linnaeus, 1767) (Figs 9A, C), complete specimen, two valves slightly offset; polychaete tubes and Bryozoa on surfaces of many scallops. Detailed log: distinct bed of siltstone to fine sandstone, finer-grained than above or below, including ca. 20% diagenetic carbonate. Macrofossils arranged haphazardly, some closely spaced, fused together by carbonate cement, others separate but at high angles to each other.

Lithostratigraphic unit 8, 436.18–607.35 mbsf. Heterogeneous assemblage of diamictite and other terrigenous lithologies; all fossils from subunit 8.1, 436.18–502.69 mbsf, sandstone, diamictite, and (mainly) mudstone with or without dispersed clasts (Fielding *et al*. 2010, p. 94):

459.0 mbsf: *Austrochlamys forticosta* n. sp., half-valve, paratype (Fig. 4G); *Hiatella* cf. *arctica* (Fig. 9B), small valve in sediment attached to surface of scallop. Detailed log: interlaminated siltstone to very fine sandstone.

466.5–469.0 mbsf: *Austrochlamys forticosta* n. sp. (Fig. 4F), two half-valves, paratypes. Detailed log: 3.5 m-thick interval of sandy diamictite grading to muddy sandstone, dispersed clasts.

543.15–543.16 mbsf: ?*Yoldia* sp. (Figs 3A–C), poor internal mould of a protobranch bivalve. Detailed log: base of 27 cm-thick bed of sandy mudstone, rare clasts.

Lithostratigraphic unit 10, 648.74–778.34 mbsf. Diamictite; dominant lithology very dark greenish grey, clast-poor, muddy diamictite (Fielding *et al*. 2010, p. 96):

740.84–740.86 mbsf: *Adamussium* cf. *jonkersi* Quaglio, Whittle, Gazdzicki and Simões, 2010 (Fig. 7A), internal mould of LV; anterior third of valve. Detailed log: medium to coarse sandy diamictite, minor silt.

Lithostratigraphic unit 12, 904.66–996.69 mbsf. Diamictite with subordinate sandstone and minor mudstone (Fielding *et al*. 2010, p. 98):

917.39–917.67 mbsf: *Ruthipecten* n. gen., n. sp. (Fig. 6B), internal mould of strongly inflated specimen on segment of entire core. Detailed log: ‘917.39–917.49 mbsf, whole-round sample: Taviani macrofossil sample’ within thick interval of coarse sandy diamictite.

Lithostratigraphic unit 13, 996.69–1040.28 mbsf. Interlaminated siltstone and sandstone, largely devoid of diamictite (Fielding *et al*. 2010, pp. 98–99):

999.76–999.80 mbsf: *Antarctipecten* n. gen. *alanbeui* (Figs 7D–E), one complete articulated specimen. Detailed log: ‘articulated bivalve shell at 999.78 mbsf’, within 20 cm-thick bed of sandy siltstone, rare dispersed clasts.

AGES OF ANTARCTIC SCALLOP-BEARING FORMATIONS

In order to understand time ranges and the order of appearance of Antarctic Oligocene and Neogene scallops, the ages of formations containing them must be defined. The ANDRILL 2A core below 310 mbsf is entirely Burdigalian (late Early Miocene) in age (Acton *et al.* 2010, fig. 2; R. Levy, GNS Science, pers. comm. 14 March 2012). Diatom, dinoflagellate and calcareous nannofossil biostratigraphy and $^{40}Ar/^{39}Ar$ dating of lavas have been used to date the scallop-bearing formations of King George Island, Antarctic Peninsula: Oligocene (Polonez Cove Formation, Low Head and Oberek Cliff Members, Early Oligocene, late Rupelian; Destruction Bay Formation, Late Oligocene, Chattian) and Early Miocene, Aquitanian (Cape Melville Formation) (Birkenmajer and Gazdzicki 1986; Jonkers 1998*a*; Quaglio *et al.* 2008; 2010, fig. 1). Cape Melville Formation was expressly stated to be Early Miocene, and to overly Late Oligocene Destruction Bay Formation unconformably, by Troedson and Riding (2002, p. 512) based on dinoflagellate biostratigraphy. Anelli *et al*. (2006) also accepted an Early Miocene age for Cape Melville Formation. Other formations not otherwise mentioned in the present report also were dated by Jonkers (1998*a*) and Smellie *et al.* (2006): Hobbs Glacier Formation, James Ross Island (Late Miocene, ca. 9.9 Ma, Tortonian; although Smellie *et al.* (2006, p. 183) pointed out that this $^{87}Sr/^{86}Sr$ date on barnacle calcite possibly is inaccurate) and deposits at Fiordo Belén, also on James Ross Island (Late Miocene, Messinian, 6.8 Ma); both contain *Austrochlamys anderssoni*.

The two scallop-bearing formations around the McMurdo Sound area, Prospect Formation and Scallop Hill Formation, correlated by Webb (1972, p. 230) simply because they contain scallops, are now known to be very different in age. K/Ar dates of 3.7 ± 0.3 Ma and 3.9 ± 0.3 Ma on basalt cones erupted through the late Neogene deposits in Wright Valley (Vucetich and Topping 1972) established an Early Pliocene or older age for Prospect Formation (>3.9 Ma). Prentice *et al.* (1993) mapped late Neogene rocks of Wright Valley, including Prospect Formation. They identified *Ruthipecten* n. gen. *tuftsensis* occurrences in a bed 10 cm thick, 'commonly stacked parallel to bedding', as well as 'less well-preserved shells … in moderate-to-low concentration in five other beds of the gravel lithofacies and two beds of the mud lithofacies' (Prentice *et al.* 1993, p. 228). They also determined an $^{87}Sr/^{86}Sr$ age of 5.5 ± 0.4 Ma for *R. tuftsensis* from Prospect Formation (Prentice *et al.* 1993). McArthur *et al.* (2006, p. 134) adjusted this age to 6.0 Ma using the revised global $^{87}Sr/^{86}Sr$ calibration of McArthur and Howarth (2004). (Note that strontium stratigraphy was updated by McArthur *et al*. (2012), but no new calibrations have been attempted here). Prospect Formation is unambiguously Late Miocene (Messinian).

Eggers (1979) reviewed the stratigraphy, distribution and age of Scallop Hill Formation on Brown Peninsula, McMurdo Sound, concluding that it overlies Aurora Trachyte (2.25 Ma; Kyle *et al.* 1979) and underlies Nubian Basalt (2.2 Ma) and Melania Basalt (2.1 Ma; Kyle *et al.* 1979). As the Pliocene–Pleistocene boundary is now placed at 2.59 Ma (Gibbard *et al.* 2010), this indicated an Early Pleistocene age for Scallop Hill Formation. Leckie and Webb (1979) reported at least five distinct scallop-bearing lithofacies in the formation, nearly all occurring in loose blocks and apparently all resting on moraine, and suggested that the entire unit represents material ploughed up by a glacier advancing northwards along the east coast of Black Island. 'A preferred explanation for the mode of occurrence of the consolidated sediments on Scallop Hill involves glacial transport during a Ross Sea Glaciation and deposition as erratics' (Leckie and Webb 1979, p. 54). Webb and Andreasen (1986) were unable to recognize a contact of Scallop Hill Formation on Aurora Trachyte, and dated basalt boulders from within Scallop Hill Formation at 2.58 and 2.62 Ma. This still indicates an Early Pleistocene age (<2.58–>2.2 Ma) for Scallop Hill Formation. The incomplete and highly abraded nature of all scallop specimens in Scallop Hill Formation also strongly supports a glacial transport origin for the formation.

Sørsdal Formation in the Vestfold Hills, East Antarctica, is dated as Early Pliocene (*Fragilariopsis barroni* diatom zone, 4.5–4.1 Ma; Harwood *et al.* 2000; Whitehead *et al.* 2001). Whitehead *et al.* (2006*b*, p. 92) pointed out that the revision of diatom biostratigraphy of Pagodroma Group by Whitehead *et al.* (2004) demonstrates a revised age of 4.2–4.1 Ma for Sørsdal Formation (Zanclean). Therefore, Sørsdal Formation (late Early Pliocene, 4.2–4.1 Ma) is significantly younger than Prospect Formation (Late Miocene, 6.0 Ma). This removes any biostratigraphical significance for the supposed Pliocene foraminiferan in both formations, *Ammoelphidiella antarctica* (Conato and Segre 1974, p. 12) (= *Trochoelphidiella onyxi* Webb 1974, p. 195; Gazdzicki and Webb 1996, p. 156; Jonkers *et al.* 2002, p. 589). Hirvas *et al*. (1993) and Colhoun *et al*. (2009) showed that a younger till unit, deposited during 3.5–2.6 Ma, overlies Sørsdal Formation in Heidemann Valley, Vestfold Hills, and in some localities contains shell material, including scallops, ploughed up from Sørsdal Formation by glacial action. Quilty (in Hirvas *et al*. 1993, plate 1) illustrated well-preserved, moderately diverse Foraminifera and other microfossils from the younger till, and recorded a diverse diatom flora.

The age of Cockburn Island Formation on Cockburn Island (type formation and locality of *Austrochlamys anderssoni*) has been the subject of much debate. Several dates on Cockburn Island Formation were based on $^{40}Ar/^{39}Ar$ dates on underlying basalt (Webb and Andreasen 1986; 3.65 ± 0.3 Ma; Lawver *et al.* 1995) and $^{87}Sr/^{86}Sr$ ratios on shells (Dingle *et al.* 1997; 4.7 Ma). Jonkers and Kelley (1998) re-examined the age of Cockburn Island Formation based on new $^{40}Ar/^{39}Ar$ dates and diatom biostratigraphy, concluding that the age is 3.0–2.8 Ma. Jonkers (1998*b*) later concluded that dates on lavas (Lawver *et al.* 1995) indicate an age younger than 2.8 Ma, roughly coeval with Scallop Hill Formation. McArthur *et al.* (2006) and Williams *et al.* (2010) again determined an Early Pliocene age (4.66 +0.17/-0.24 Ma) for Cockburn Island Formation from $^{87}Sr/^{86}Sr$ ratios of *A. anderssoni* shells, and considered that the diatom age evidence requires reinterpretation. Their date of 4.7 Ma confirms that determined by Dingle *et al.* (1997) and demonstrates that Cockburn Island Formation was deposited at 4.7 Ma (early Zanclean) and is older than Sørsdal Formation (late Zanclean). McArthur *et al.* (2006) suggested that all the scallops in Cockburn Island Formation were reworked from older rocks, but the excellent preservation of the scallop shells (Fig. 3D) and the occurrence of fragile specimens of *Adamussium cockburnensis* Jonkers, 2003 make reworking exceedingly unlikely. Reworking is, however, highly likely for Scallop Hill Formation, from which only abraded fragments of *A. anderssoni* have been collected.

Ages adopted here are shown in Fig. 2. Note that the time scale is that of Gradstein *et al*. (2012), whereas dates based on $^{87}Sr/^{86}Sr$ ratios discussed above use the time-scale calibration of McArthur and Howarth (2004) and have not been recalibrated.

SYSTEMATIC PALAEONTOLOGY

Repository abbreviations. BAS – British Antarctic Survey, Cambridge, UK; GNS – GNS Science, Lower Hutt, New Zealand; MCZ – Museum of Comparative Zoology, Harvard University, Cambridge, Mass., USA; NMNZ – Museum of New Zealand Te Papa Tongarewa, Wellington, New Zealand; NMV – Museum Victoria, Melbourne, Australia; SMNH – Swedish Museum of Natural History, Stockholm, Sweden; USNM – United States National Museum of Natural History, Washington, DC, USA; ZPAL – Institute of Palaeobiology, Polish Academy of Sciences, Warsaw, Poland.

Other abbreviations and conventions. LV – left valve; mbsf – metres below sea floor; RV – right valve. Dimensions are in mm, and are cited as: L – length (parallel to hinge line), H – height (orthogonal to length), and inflation (for a few articulated bivalves; normal to both length and height).

Remarks. The classification of Bivalvia used here follows Bouchet and Rocroi (2010). Authorities for all names above the rank of genus can be found in the same work, and references to them are not repeated here.

Class BIVALVIA Linnaeus, 1758

Subclass PROTOBRANCHIA Pelseneer, 1889

Superfamily NUCULANOIDEA H. Adams and A. Adams, 1858

?Family YOLDIIDAE Dall, 1908

?Genus YOLDIA Möller, 1842

Type species. *Yoldia hyperborea* Torell, 1859, by subsequent designation, ICZN 1966, Opinion 769.

Occurrence of type species. Extant, Arctic Ocean.

Diagnosis. Shell moderately large (most species 15–30 mm long), elongate-oval, thin-shelled, strongly compressed laterally, posterior weakly rostrate; rostrum defined mainly by narrower, more tapering shape than anterior end, weakly compressed beneath rostrum in some species; gaping at both ends; exterior smooth; hinge with large central resilifer and numerous similar chevron-shaped teeth both anterior and posterior to umbo; pallial sinus deep, extending to beneath umbo.

?*Yoldia* sp.

Figures 3A–C

Material examined. USNM 545843, ANDRILL 2A, 543.15–543.16 mbsf, one internal mould of a protobranch bivalve.

Dimensions. L 12.1, H 8.5 mm.

Diagnosis. A small, moderately inflated, elongate, weakly rostrate bivalve with a vague indication of a former taxodont hinge.

Description. Internal mould only; moderate-sized, laterally compressed, shape similar to that of extant *Yoldia* species, that is, relatively tall, height 70% of length; posterior end a weakly produced rostrum, ventral margin inclined upwards but dorsal margin not descending below anterior hinge line; short section of central hinge line minutely sinuous, formed as mould of taxodont teeth (Fig. 3C); remainder of hinge not visible.

Remarks. The single ANDRILL 2A specimen lacks shell material, indicating that it was an aragonitic shells affected by diagenesis. The ANDRILL 2A specimen is much smaller than the living Antarctic species *Yoldia* (*Aequiyoldia*) *eightsi* (Couthouy in Jay, 1839) (Dell 1990, p. 10, figs 2, 5) (L 29.0, H 18.6 mm; Dell 1990, p. 7) or most other species referred to *Yoldia*. Given the lack of shell material, and so of any knowledge of almost all characters, a fuller identification must await the collection of better material.

Dell and Fleming (1975, p. 696, pl. 1, fig. 2) recorded a *Yoldia* species 13.2 mm long from DSDP Site 272, Ross Sea (77°07.62′S, 176°45.61′W), at 147–156 cm in sample 272-23-3. Their shell is similar to the present one, but a little more elongate and less obviously rostrate. The same authors recorded *Y.* (*Aequiyoldia*) *eightsi* from two horizons in Site 270 in the same area (77°26.48′S, 178°30.19′W), in samples 270-36-6, at 76–80 cm, and 270-17-1, at 70–76 cm, but these are larger shells, L 22 mm and 18.5 mm. *Yoldia* sp. was also recorded from various horizons of Late Oligocene age in the CRP-2/2A drill core (Cape Roberts Science Team 1999, pp. 137, 141, fig. 5.14b; Taviani *et al*. 2000, pp. 516–518, figs 2B, 5; Taviani 2001, p. 179, fig. 1C, as *Yoldia* (*Aequiyoldia*) sp.). Finally, Whitehead *et al*. (2006, p. 145, fig. 6i) also recorded a single mould of *Yoldia* (*Aequiyoldia*) sp. from the Late Miocene Battye Glacier Formation in East Antarctica. The ANDRILL 2A specimen is slightly shorter and more inflated than all these earlier records.

Subclass AUTOBRANCHIA Grobben, 1895

Order PECTINIDA Gray, 1854

Superfamily PECTINOIDEA Rafinesque, 1815

Family PECTINIDAE Rafinesque, 1815

Remarks. Study of the six taxa of Pectinidae present in ANDRILL 2A led us to reconsider the taxonomy of the Oligocene–Neogene Pectinidae of the Antarctic–subantarctic region, revised excellently by Jonkers (2003). The present review constitutes amplification and amendment of Jonkers's work rather than a full revision, and it is only necessary to list most species in appropriate genera here (Table 1). Only the material from ANDRILL 2A is described in full. Because of the lack of several critical characters for the classification of the following scallops in the scheme of subfamilies and tribes proposed by Waller (1991, 2006), we had difficulty classifying them. Characters of the LV preradial microsculpture are critical for placement in the tribes, and are not known (and probably never knowable) for many of these Antarctic fossils extracted from drill cores, or collected from outcrops that have weathered in an extreme climate. However, the living type species of

Austrochlamys Jonkers, 2003, *Austrochlamys natans* (Philippi, 1845) provides these characters for the genus *Austrochlamys*.

Subfamily CHLAMYDINAE Teppner, 1922

Diagnosis. Pectinidae with plesiomorphic macrosculpture of radial costae with further costae intercalated or subdivided, increasing in number during ontogeny (tribe Chlamydini), later fixed in number, without further intercalated and subdivided costae (tribes Mimachlamydini and Aequipectinini); with plesiomorphic LV preradial microsculpture of simple antimarginal ridgelets (Chlamydini), intersecting later with commarginal ridges to develop into closely spaced, hemispherical pits (Mimachlamydini and Aequipectinini); without carinae on internal expressions of exterior costae, except in a few unusual genera (Chlamydini) or consistently with internal carinae (Mimachlamydini and Aequipectinini); plesiomorphic microsculpture after preradial area of obvious commarginal ridges in most Chlamydini, modified variously by intersection with antimarginal ridgelets, later forming a characteristic herringbone pattern (Mimachlamydini); commarginal ridges sinuous, curved towards ventral margin of disc in costal interspaces in later taxa (Aequipectinini). Posterior auricles small, with concave posterior outline in most taxa (Chlamydini, Mimachlamydini), auricles later becoming more equal (Aequipectinini). Most taxa retaining functional ctenolium and deep byssal notch as adults (chlamydoid shell form, resulting from a byssally attached life; Chlamydini, Mimachlamydini) although some reduce depth of notch, lose ctenolium and become reclining as adults (aequipectinoid shell form; some Chlamydini, most Aequipectinini).

Remarks. The content of subfamilies and tribes of Pectinidae is dependent on Waller's (1991, 2006) interpretation of the phylogenetic history of each group, and they are not all definable clearly by simple morphological characters. We follow

Waller (1991, 2006) for the content and classification of Pectinidae and its subdivisions.

Tribe CHLAMYDINI Teppner, 1922

(= Austrochlamydini Jonkers, 2003)

Diagnosis. Chlamydinae with plesiomorphic sculpture of antimarginal ridgelets present from edge of prodissoconch on LV and from edge of proximal calcitic area on RV, but variously modified by intersection with commarginal ridges in many taxa; with small posterior auricles with a weakly concave posterior outline, at least in early lineages; most taxa retaining much larger anterior auricles than posterior ones into adulthood, retaining a deep byssal notch in the RV, although some relatively large taxa, e.g., *Equichlamys bifrons* (Lamarck, 1819), *Zygochlamys delicatula* (Hutton, 1873) become free-lying when adult, lose the ctenolium and develop a shallow byssal notch; with complexly subdivided and intercalated radial costae, increasing in number as shell grows; lacking prominent, narrow carinae on interior expressions of radial costae (internal rib carinae), except in a few species, e.g., *Equichlamys bifrons*, *Notochlamys hexactes* (Lamarck, 1819); with simple and, in most taxa, low, narrow resilial and dorsal hinge teeth; and with shagreen microsculpture, at least in early lineages and on proximal area of disc of many Cenozoic and living taxa.

Remarks. Tribe Austrochlamydini was proposed by Jonkers (2003, p. 59) solely for *Austrochlamys* Jonkers, 2003. Dijkstra and Marshall (2008, p. 50) simply included *Austrochlamys* in Chlamydini, regarding these tribe names as synonyms. Supposedly distinctive characters listed in Jonkers's (2003, p. 59) diagnosis of Austrochlamydini were the prosocline shape, the macrosculpture without a fixed number of costae and with costae increasing in number during ontogeny by both bifurcation and intercalation, the prominent commarginal lamellae throughout ontogeny, the lack of shagreen microsculpture, the presence of a deep byssal notch, and the microsculpture of low, narrow, closely spaced antimarginal ridgelets on the LV preradial area (observed only in extant specimens of *Austrochlamys natans*; Jonkers 2003, pl. 2, fig. a). The weakly sculptured LV preradial area, bearing only low antimarginal ridgelets, and the presence of radial costae increasing by both bifurcation and intercalation are plesiomorphic characters shared with tribe Chlamydini. A further character not mentioned by Jonkers (2003), but also a plesiomorphic one shared with Chlamydini, is the absence of internal rib carinae. The prosocline shape and the presence of a deep byssal notch merely result from a chlamydoid habit, reflecting a byssally attached lifestyle, at least in the juvenile stage; they are not significant for phylogeny. The majority of scallops, including most Chlamydini, lack shagreen microsculpture; its only significance is that all scallops bearing it belong in Chlamydini. Shagreen microsculpture (name based on the similarity to leather manufactured from shark skin) consists of two sets of intersecting, thin lamellae each lying at roughly 45–60° to the radial costae, with an outer layer normal to the main, vertical lamellae. Shagreen that has not been abraded has an extremely thin, outer false surface formed by the outer layer, parallel to the valve surface, but the outer surface is very easily abraded. The more usually encountered abraded surface reveals minute, closely overlapping, ventrally directed cups formed by the intersecting lamellae, arranged like fish scales. Shagreen was illustrated well by Waller (1991, pl. 1, fig. 7) on *Chlamys islandica* (Linnaeus, 1758), by Beu and Darragh (2001, figs 13G–H) on *Equichlamys bifrons* (Lamarck, 1819), by Beu and Darragh (2001, fig. 17G) on *Notochlamys hexactes* (Lamarck, 1819), and most clearly by Beu and Darragh (2001, figs 19F–H) on *Semipallium foulcheri* (Tenison Woods, 1865). This character is useful for distinguishing *Austrochlamys* from the earlier (Eocene–Early Miocene) South American species of *Zygochlamys* Ihering, 1907 (= *Psychrochlamys* Jonkers, 2003; Dijkstra and Marshall 2008, p. 63), which have areas of shagreen microsculpture between the radial costae on parts of the disc. Shagreen microsculpture was lost during the evolution of the clade, and Middle Miocene to extant species of *Zygochlamys* also lack shagreen. Antimarginal ridgelets are difficult to discern on most Antarctic fossil scallops, but their presence is demonstrated in *Austrochlamys* and *Leoclunipecten* n. gen. by Jonkers's (2003, pl. 2, figs c, e; pl. 3, figs a–c) illustrations. They ride over the commarginal ridges in *Austrochlamys*, but certainly not the radial costae in *Leoclunipecten* n. gen. *gazdzickii* (Jonkers 2003, pl. 3, fig. c; unexpectedly, commarginal ridges are not visible in this photograph). The majority of listed characters, then, are plesiomorphic and indicate a position early in the phylogeny of Cenozoic scallops, before such apomorphic characters had evolved as a fixed number of undivided costae and the presence of carinae on the edges of the internal expressions of the radial costae – the characters that distinguish all other scallops from Chlamydini (Waller 1991, 2006). A position in subfamily Chlamydinae clearly is indicated.

The final character of Austrochlamydini listed by Jonkers (2003) that requires reassessment, therefore, is the obvious microsculpture of unusually prominent commarginal lamellae. Commarginal ridges are present also on *Zygochlamys* species (e.g., Dijkstra and Marshall 2008, figs 53A–F, 54A–F), although they are lower, narrower and more closely spaced than those of *Austrochlamys* and *Leoclunipecten* n. gen., and are modified into frills by the antimarginal ridgelets over most intercostal surfaces. They also do not ride over the radial costae. Weak commarginal ridges also characterize many other genera of Chlamydini (e.g., *Talochlamys* Iredale, 1929; Beu and Darragh 2001, fig. 29g–h; Dijkstra and Marshall 2008, figs 42C–F, 46A–F, 49A–F), but they do not form obvious, dominant microsculpture on chlamydinine taxa other than *Austrochlamys* and *Leoclunipecten* n. gen. Waller (1991, 2006) showed that dominant commarginal ridges without antimarginal ridgelets on the adult disc and auricles are limited to subfamilies Pectininae (tribes Pectinini, Amusiini, Aequipectinini, and Decatopectinini) and Palliolinae (tribes Palliolini and Mesopeplini; Waller 2006, figs 1.2–1.3). However, the prominent commarginal ridges of *Austrochlamys* and *Leoclunipecten* n. gen. definitely accompany antimarginal ridgelets in at least some specimens and we can see no reason to regard these genera, and our other new genus *Ruthipecten*, as anything other than Antarctic–subantarctic genera of tribe Chlamydini.

Austrochlamys is very similar to *Zygochlamys* in most characters and likely evolved from *Zygochlamys* during Oligocene–Early Miocene time. It is distinguished mainly by its more prominent commarginal ridges, by having fewer, more prominent radial ridges in early species (*A. forticosta* n. sp.), and by lacking the characteristic, obvious, wide, evenly concave LV radial interspaces and narrow-crested LV radial costae of *Zygochlamys*. *Leoclunipecten* n. gen. seems to be another, flatter and wider relative of *Austrochlamys* and *Zygochlamys*, again distinguished from *Zygochlamys* by its more prominent commarginal ridges. The relationships of *Ruthipecten* n. gen. are less obvious; it seems unlikely to have evolved from the much more closely sculptured genus *Zygochlamys*. The relationships of this most distinctive of Antarctic pectinid genera must be sought elsewhere.

Genus AUSTROCHLAMYS Jonkers, 2003

Type species. *Pecten natans* Philippi, 1845, by original designation.

Occurrence of type species. Late Pleistocene to extant, Southern Ocean.

Diagnosis. Chlamydini of moderately large size (H 100–140 mm), of weakly prosocline shape, with small posterior auricles with concave posterior outline, retaining byssal attachment and corresponding large RV anterior auricle, deep byssal notch and functional ctenolium in adults; with relatively few (10–12) coarse primary radial costae in early species, more numerous (30–35) in later species; with radial interspaces crowded with many intercalated and subdivided secondary and tertiary costellae; all radial sculpture overridden by many prominent, narrow, commarginal ridges.

Remarks. Commarginal ridges ride over the radial costae in unabraded extant specimens of the type species of *Austrochlamys*, *A. natans*, as well as on most fossils. If antimarginal ridgelets are visible at all on fossils, they are present only in the interspaces between costae and commarginal ridges, but Jonkers (2003, pl. 2, figs c, e) demonstrated that they ride over all other sculpture in extant specimens of *A. natans*, so the condition in fossils evidently is due to abrasion.

Included species. *Austrochlamys anderssoni* (Hennig, 1911) (Figs 3D, F), Late Miocene–Early Pliocene (ca. 10–4.1 Ma, Tortonian–Zanclean), Antarctic Peninsula and Vestfold Hills; reworked fragments in Pleistocene rocks on Antarctic Peninsula and around McMurdo Sound. Apparently formerly circum-Antarctic.

Austrochlamys forticosta n. sp., Early Miocene (Burdigalian), 430.54–469.0 mbsf, ANDRILL 2A drill core.

Austrochlamys heardensis (Fleming, 1957), Late(?) Miocene, Laurens Peninsula, Heard Island; Corinth Head, Heard Island (USGS 25002, 2 valves, in USNM; not seen; Jonkers 2003, p. 83); large sample (not seen) from block of rock dredged in 579 m of water 70 km NE of Heard Island, dated at 3.62–2.5 Ma (late Pliocene, Piacenzian) by diatom biostratigraphy (Quilty *et al.* 2004).

Austrochlamys marisrossensis Jonkers, 2003, Early Miocene, Ross Sea drill cores; tentatively recorded here from ANDRILL 2A (Burdigalian).

Austrochlamys natans (Philippi, 1845), living, southern South America (southern Chilean fiords and Magellan Strait to Cape Horn; Jonkers 2003, fig. 20). P. G. Quilty (School of Earth Sciences, University of Tasmania, Hobart, pers. comm. 31 Jan. 2012) stated that *A. natans* also lives around Tasmania.

Austrochlamys walosseki Jonkers, 2003, late Pleistocene (–Holocene?) fossils, Falkland Islands shelf (not seen), Campbell Plateau around Auckland Islands, southern New Zealand (two specimens examined in NMNZ, M118772) (Jonkers 2003, figs 20, 22) (proposed as a subspecies of *A. natans*, but in our opinion such stratigraphically segregated forms constitute distinct species).

Austrochlamys anderssoni (Hennig, 1911)

Figures 3D, F

1911 *Myochlamys Anderssoni* n. sp.; Hennig, p. 11, pl. 1, figs 1–5; pl. 2, figs 1–2.

1957 *Chlamys* (*Zygochlamys*) *anderssoni* (Hennig, 1911); Fleming, text-fig. 1C.

1962 *Chlamys* (*Zygochlamys*) *anderssoni* (Hennig, 1911); Speden, p. 751, figs 3, 9, 10.

1969 *Chlamys* (*Zygochlamys*) *anderssoni* (Hennig); Vella, p. 768.

1985 *Chlamys patagonica anderssoni* (Hennig, 1911); Beu, p. 7.

1996 *Chlamys anderssoni* (Hennig, 1910); Gazdzicki and Webb, p. 156, fig. 5.

1997 *Zygochlamys anderssoni* (Hennig, 1911); Gazdzicki and Studencka, fig. 2.

1998*a* *Zygochlamys anderssoni* (Hennig); Jonkers, p. 162, fig. 3a.

1998*b* *Zygochlamys anderssoni* (Hennig, 1911); Jonkers, p. 68, pl. 1, fig. 1.

2000 *Zygochlamys anderssoni* (Hennig); Jonkers, pp. 247–252, fig. 2A.

2002 ‘*Zygochlamys*’ *anderssoni* (Hennig, 1911); Jonkers *et al*., p. 579, figs 3a–b.

2003 *Austrochlamys anderssoni* (Hennig, 1911); Jonkers, p. 64, pl. 3, fig. b; pl. 6, figs c–d; pl. 13, figs a–g.

2010 *Austrochlamys anderssoni*; Williams *et al*., pp. 306, 308–310, figs 3a–i.

2011 *Austrochlamys anderssoni*; Nývlt *et al.*, p. 379.

2011 *Austrochlamys anderssoni*; Pirrie *et al*., pp. 180–186, figs 3a–e, 4.

Type material. Lectotype designated by Jonkers (2003, p. 64) SMNH Mo.2064a, a LV (Jonkers 2003, pl. 6, fig. d), with two paralectotypes, SMNH Mo.2063a, Mo.2066; rubber replica of last at GNS WM7929, plaster replica from WM7929 at BAS (Jonkers 2003, p. 64); all from Cockburn Island Formation (Early Pliocene, Zanclean), Cockburn Island, Antarctic Peninsula. The small paralectotype RVs illustrated by Hennig (1911, pl. 1, figs 1, 3–4) are missing (Jonkers 2003, p. 64).

Material examined. Rubber impression from paralectotype SMNH Mo.2066, GNS WM7929; GNS WM15713, rubber replicas of BAS DJ.634.6, DJ.851.9.1, and DJ.854.11, sent by H. Jonkers; fragmentary specimens from Scallop Hill Formation, McMurdo Sound, collected and recorded by Speden (1962, figs 3, 9): GS7510, Brown Peninsula, one large abraded fragment; GS7511, Black Island, 19 fragments (all in GNS); NMV P302320, small slab of fawn siltstone with two moulds of juvenile valves, Sørsdal Formation (Early Pliocene), lower lens (Graveyard Sandstone Member), Pickard’s Cairn, Marine Plain, Vestfold Hills.

Other material. Jonkers (2003, pp. 64, 82–83) listed much further material in BAS, SMNH and Instituto Antártico Argentino, most from Cockburn Island Formation, Cockburn Island, but also from Fiordo Belén, W James Ross Island, Antarctic Peninsula; between Cape Gage and Ekelöf Point, James Ross Island; 1.7 km west of the Obelisk, Ulu Peninsula, James Ross Island; and Black Island and Brown Peninsula, McMurdo Sound, Ross Sea.

Distribution. Austrochlamys anderssoni is the most abundant and widespread Antarctic and subantarctic fossil pectinid. It is recorded from Cockburn Island Formation (Early Pliocene, 4.7 Ma) on Cockburn Island, Antarctic Peninsula (type locality), Hobbs Glacier Formation and Fiordo Belén, James Ross Island, northern Antarctic Peninsula (Late Miocene; Jonkers 2003, p. 83), Mendel Formation, northern tip of James Ross Island (Late Miocene; Nývlt *et al.* 2011, p. 379), between Cape Gage and Ekelöf Point, James Ross Island, reworked specimens in diamictite (Jonkers 2003, p. 83), tentatively from about 1.7 km west of the Obelisk, Ulu Peninsula, James Ross Island, fragments from small pockets of sediment beneath volcanics (Jonkers 2003, p. 83), Sørsdal Formation (late Early Pliocene, 4.2–4.1 Ma), Marine Plain, Vestfold Hills, East Antarctica (Adamson and Pickard 1986; Pickard *et al*. 1988; Harding 2005, pl. 8, figs A, C–D; P. G. Quilty, University of Tasmania, pers. comm. August 2011), Scallop Hill Formation (earliest Pleistocene) on Black Island, Brown Peninsula and nearby localities in McMurdo Sound (reworked fragments; Speden 1962, Vella 1969), and reworked specimens in permafrost at Brandy Bay, northern James Ross Island, Antarctic Peninsula (Pirrie *et al.* 2011). The other species we retain in *Austrochlamys* are all much less common and widespread than *A. anderssoni.*

Dimensions. H up to 137.5 mm (Jonkers 2003); illustrated specimens: H 112.1, L 103 mm; H 124.7, L 116 mm (Jonkers 2003, caption to pl. 13, p. 116; lengths measured from figures).

Diagnosis. A large *Austrochlamys* species with 13–15 primary radial costae on juvenile specimens, 30–35 apparent primary costae on adults, many subdivided and intercalated secondary and finer costae filling radial interspaces closely, and obvious coarse commarginal ridges over the entire surface.

Description. Shell large (H 100–137 mm), umbonal angle low, ca. 105°; moderately tall, H exceeding L in all specimens; weakly prosocline, retaining functional ctenolium and large byssal notch in adults. Best-preserved juvenile specimens from Sørsdal Formation, Vestfold Hills, with prominent, narrow, well-raised, consistent commarginal lamellae covering entire valve surface, similar to those of

Austrochlamys natans, 8–9 per 1 mm near ventral margin of specimens 10–14 mm high; much more closely spaced on auricles (Fig. 3F). Antimarginal sculpture not discernible, probably of fine, very low antimarginal ridgelets as in *A. natans* (Jonkers 2003, pl. 2, fig. a) on preradial area and between commarginal ridges lower down disc. Commarginal lamellae only slightly reduced when passing over radial costae. Primary radial costae 13–15 on juvenile specimens, with one narrow secondary costa intercalated in centre of most relatively wide interspaces, two secondary costae in a few. Intercalated costae increase in prominence with growth, increasing apparent primary costae to 30–35 in adults; intercalated costae increasing obvious, prominent radial costae on adults to 50-60. Juvenile LV with fine, close antimarginal ridgelets covering LV preradial area; fine, low commarginal ridges extending well up onto preradial area (Harding 2005, pl. 8, fig. C).

Remarks. Austrochlamys anderssoni is illustrated here as an example of a more standard, relatively finely sculptured species of *Austrochlamys*, contrasting markedly in sculptural prominence with the new species described below. The earliest details are unclear on the juvenile LV illustrated by Harding (2005, pl. 8, fig. C), and we have not been able to examine this specimen (evidently a latex cast from a natural mould; not recognized in NMV). These juvenile specimens in fawn diatomaceous siltstone are secondary calcite replacements from the lower fossiliferous horizon (Graveyard Sandstone Member) of Sørsdal Formation.

Austrochlamys cf. *marisrossensis* Jonkers, 2003

Figure 3E

1975 *Chlamys* (*sensu lato*) n. sp. aff. *natans* (Philippi); Dell and Fleming, p. 697, pl. 1, fig. 6.

1998 '*Chlamys*' sp. 1; Jonkers and Taviani, p. 494, figs 2–4.

2003 *Austrochlamys marisrossensis* n. sp.; Jonkers, p. 63, pl. 15, figs c–d.

Type material. Holotype GNS TM8237, ?LV, locality GS15509, DSDP Site 272, 77°07.62′S, 176°45.61′W, Ross Sea, core 33, section 2, 309.5 mbsf, collected by DSDP Leg 28 shipboard party, 6 Feb. 1975; Early Miocene (ca. 18 Ma, Burdigalian, in CRP-1; Lavelle 1998).

Material examined. Jonkers (2003, pp. 63, 83) referred also to *Austrochlamys marisrossensis* fragments from the same site and depth as the holotype (GNS TM8237, one ?LV fragment) and from the CRP-1 drillhole, 77.008°S, 163.755°E, 16 km ENE Cape Roberts, Ross Sea, 62.19–62.25 mbsf. The latter were also reported as '*Chlamys* sp.' by Cape Roberts Science Team (1998, p. 102, fig. 19) and Taviani (2001, p. 179, fig. 1b). We also tentatively refer here two small fragments of disc from ANDRILL 2A, 429.25–429.28 mbsf (Fig. 3E), USNM 545826–7. The fragments are too small to be able to distinguish valve type. The location is only 1.3 m higher in the core than the pectinid concentration at 430.54–430.68 mbsf with common *A. forticosta* n. sp. described below.

Distribution. Austrochlamys marisrossensis is recorded only from Early Miocene sections in drill holes in the Ross Sea. All material is fragmentary.

Dimensions. USNM 545826, ANDRILL 2A, 429.25–429.28 mbsf: largest fragment (Fig. 3E) H 11.9, L 23.4 mm; USNM 545827, other referred fragment: H 7.4, L 9.7 mm.

Diagnosis. A small species (maximum H of known material ca. 50 mm; incomplete?) of *Austrochlamys* with relatively few, narrow radial costae; commarginal sculpture of closely spaced frills, continuous across rib crests and interspaces; antimarginal sculpture of fine riblets interrupted by commarginal ridges. Radial macrosculpture apparently absent from posterior disc flank (damaged?).

Description. A detailed description and illustrations of *Austrochlamys marisrossensis* were provided by Jonkers (2003, p. 63, pl. 2, fig. g; pl. 3, fig. a; pl. 15, figs c–d).

Remarks. The fragments from ANDRILL 2A, 429.25–429.28 mbsf have microsculpture of obvious, widely spaced commarginal ridges as in the specimens from slightly lower in the hole assigned here to *Austrochlamys forticosta* n. sp. However, these fragments bear much more numerous, narrower, more closely spaced primary radial costae than *A. forticosta* n. sp. Therefore, they much more closely resemble the younger species referred to *Austrochlamys*, notably *A. natans*, *A. anderssoni* and, in particular, *A. marisrossensis* than they do the specimens from lower in ANDRILL 2A. We are not able to assign the fragments to a species with any confidence, but the width of the primary costae is most nearly similar to that of *A. marisrossensis*.

Austrochlamys forticosta n. sp.

Figures 4A–G

Derivation of name. From Latin, *fortis* (strong, powerful, robust) and *costa* (a rib), referring to the few, prominent radial costae of this species.

Type material. Holotype USNM 545830, umbonal areas of two formerly articulated valves cut by core-splitter at an oblique angle, in ANDRILL 2A, from the pectinid concentration at 430.54–430.68 mbsf (Figs 4B–C); three illustrated paratypes: USNM 545831, illustrated RV anterior auricle (Fig. 4A), and two other paratypes cut by both drill and core-splitter (USNM 545833, Fig. 4D; USNM 545832, Fig. 4E); six paratype fragments from the same horizon not illustrated (USNM 545834); two paratypes from ANDRILL 2A, 466.5–469.0 mbsf, one a very incomplete RV cut by both drill and core-splitter, with base of anterior auricle remaining (USNM 545841; Fig. 4F), the other incomplete paratype (USNM 545842) from the same horizon, a central area of disc cut by both drill and core-splitter; one incomplete paratype, USNM 545839, from ANDRILL 2A, 459.0 mbsf, coarsely radially sculptured central area of disc cut by both drill and core-splitter (Fig. 4G), with small *Hiatella* valve attached to disc.

Type locality and horizon. Collected only from the 38.5 m-thick interval between 430.54 and 469.0 mbsf in the ANDRILL 2A core (Burdigalian).

Dimensions. ANDRILL 2A, 430.54–430.68 mbsf: holotype RV fragment: H 35, L 50 mm, LV fragment: H 33, L 52 mm; H estimated from large size of LV posterior auricle to have been originally ca. 130, L 120 mm; USNM 545839, paratype, 459.0 mbsf: L >59 mm, estimated originally 70+ mm, H highly incomplete; USNM 545841, paratype, 466.5–469.0 mbsf: H >48 mm, L >59 mm; second specimen highly incomplete; both estimated originally 70+ mm. *Austrochlamys forticosta* n. sp. may well have reached a similar size to *A. anderssoni* (137 mm; Jonkers 2003, p. 65).

Diagnosis. A large (H >100 mm), coarsely and sparsely radially costate species of *Austrochlamys* with ca. 10–12 wide primary costae; byssal fasciole swollen above rest of RV anterior auricle.

Description. Shell large (available fragments to L 59 mm, estimated originally >100 mm), thick; umbonal angle very low (95°) on one measurable umbonal fragment, presumably larger (ca. 110–115°?) on complete adult shells. Macrosculpture of nine to ten wide, moderately elevated primary radial plicae with almost flat to gently convex crests and gently convex edges, all without obvious subdividing grooves in material examined; each gently concave radial interspace as wide as or a little wider than one plica, bearing none to two moderately wide secondary costae or up to three narrower tertiary costellae, each arising either by intercalation or by subdivision from edges of primary costae. Obvious microsculpture of low, closely spaced, flat-topped to narrower, raised commarginal ridges, 4–5 per 1 mm over outer area of disc of large specimens; commarginal ridges anastomose frequently where flat-topped; faint antimarginal ridgelets visible between commarginal ridges on LV anterior auricle of one paratype, otherwise not discernible (abraded?). Separate RV anterior auricle paratype cut by drill around disc margin and slightly trimmed along dorsal margin, umbonal area and lower part of byssal fasciole missing; otherwise shaped as in *Austrochlamys anderssoni*, with moderately long, flat, upper, radial area and deeply arcuate byssal notch, byssal fasciole slightly arched above flat, radially oriented area; radially oriented area bearing four or five vaguely defined, wide, closely spaced radial ridges; entire auricle crossed by five deep, narrow grooves (growth steps), biarcuate in conformity with growth lines. LV posterior auricle large, tall, with weakly concave posterior margin sloping slightly forwards towards umbo, bearing seven narrow, raised, moderately widely separated radial costae. Resilifer normal; one low, narrow resilial tooth on each side, confluent with lower border of valve-margining ridge in LV; RV hinge and other characters not preserved.

Remarks. *Austrochlamys forticosta* n. sp. is much the most common pectinid in ANDRILL 2A. However, no specimen is complete. The pectinid concentration, a zone of weakly concentrated scallop shells at 430.54–430.68 mbsf was illustrated by Taviani *et al.* (2010, fig. 12a) and Fielding *et al.* (2010, fig. 6), revealing at least eight thick-shelled, coarsely costate valves of *A. forticosta* n. sp. in the split core face. The sample available consists of 10 incomplete specimens cut through by both the drill and the core-splitter, along with numerous other fragments, including an almost complete RV anterior auricle. Although this material includes specimens from both working and archival halves of the core, none can be reassembled to produce an even moderately complete specimen, and it is most unfortunate that the core was split before the shells were extracted. Nevertheless, as no more material might ever be collected, and it is obvious that this material represents a single species with much coarser sculpture than any previously named species of *Austrochlamys*, we think it worth naming here.

We interpret this new species as an extremely robust, coarsely and sparsely ribbed species of *Austrochlamys*, with many fewer radial costae of much higher profile and wider amplitude than in the well-known younger species *A. natans* and *A. anderssoni*, and with the byssal fasciole swollen above the flat, upper, radially oriented area of the RV anterior auricle, rather than depressed below it as in other *Austrochlamys* species. The many fewer radial plicae (wide costae) clearly differentiate the new taxon from all other species referred to *Austrochlamys*, and from all other Antarctic scallops. Specimens examined have the following rib counts: (a) holotype, 430.54–430.68 mbsf: 10 primary costae on LV umbonal fragment, nine on RV umbonal fragment, secondary sculpture of one narrow costa in centre of each primary interspace on LV, two or three still narrower ones in each interspace on RV; (b) USNM 545839, paratype, 459.0 mbsf: five primary costae on fragment with L >59 mm, and from none to two low, widely spaced, secondary costae in each radial interspace; (c) USNM 545841, paratype, 466.5–466.9 mbsf: nine primary costae on specimen with L >59 mm, and from none to two narrow, widely spaced secondary costae in each wide radial interspace, and three low, wide costae on the disc flank. In comparison, Jonkers (2003: 64) stated that *A. anderssoni* has ca. 30 narrow primary radial costae, and intercalated and bifurcated secondary costae make up a total of ca. 70 costae near the ventral margin of large specimens. Jonkers (2003: 61) also stated that *A. natans* has ca. 20 primary costae and ca. 10–15 intercalated and bifurcated secondary costae, although his illustrations (Jonkers 2003, pl. 14; pl. 15, figs a–b) demonstrate that this species has ca. 30–39 primary radial costae. The separate RV anterior auricle (USNM 545831; Fig. 4A) has had its umbonal end cut off by the drill and its dorsal margin trimmed slightly by the core splitter, but what remains is very similar to that illustrated for *A. anderssoni* by Jonkers (2003, pl. 13, figs a–b) (Fig. 3D). It bears about five vaguely defined radial costae on the upper, radially directed area of the auricle. We assume that *Austrochlamys forticosta* n. sp. was simply ancestral to the later species of *Austrochlamys*, and costal width and prominence decreased while costal number increased with time from ca. 10–12 to ca. 30 in a simple lineage, but we only tentatively refer it to *Austrochlamys.*

Genus RUTHIPECTEN n. gen.

Type species. *Chlamys* (*Zygochlamys*) *tuftsensis* Turner, 1967

Occurrence of type species. Late Miocene–Early Pliocene, Antarctica.

Derivation of name. Named in fond memory of Ruth (‘Ruthie’) Turner, a great malacologist who devoted her life to MCZ, and who is the author of the type species; combined with the suffix *pecten* (Latin, a comb), used in the names of many scallops. Gender masculine.

Diagnosis. A genus of Chlamydini with moderate-sized (H 55 mm, a few specimens to H 73 mm), strongly inflated, weakly prosocline, thick shell. Umbonal angle low, ca. 105°. LV of most specimens slightly more inflated than RV. Auricles asymmetrical, anterior ones longer than posterior; LV anterior auricle with straight anterior margin, RV anterior auricle with anterior margin moderately deeply embayed by acute byssal notch, which is functional in adults. Macrosculpture of four to nine (five on most specimens) prominent, widely spaced, relatively narrow costae each bearing a few large, sparse, irregularly placed, radially elongate nodes, particularly near ventral margin of disc; several narrow, widely spaced secondary and tertiary radial riblets in each wide interspace, leaving wide interspaces bearing only commarginal sculpture; disc and auricular microsculpture of low, vaguely defined, widely spaced commarginal ridges on most specimens (abraded?). Antimarginal sculpture and preradial microsculpture not seen. Without internal rib carinae; other internal characters not seen.

Included species. Besides *Ruthipecten* n. gen. *tuftsensis* (Turner, 1967), the unnamed species in ANDRILL 2A described below is the only species we refer to *Ruthipecten* n. gen.

Remarks. Beu (1985, pp. 7–8) remarked that '*Chlamys*' *tuftsensis* is not related phylogenetically to *Zygochlamys* Ihering, 1907, and to the other species that subsequently were referred to *Austrochlamys* by Jonkers (2003). However, '*Chlamys*' *tuftsensis* was placed in *Austrochlamys* by Jonkers (2003, p. 66). The genus *Ruthipecten* is now provided for the distinctive Antarctic scallop in Prospect and Sørsdal Formations, and related species. *Ruthipecten* n. gen. *tuftsensis* differs from species of *Austrochlamys* in its smaller size (most specimens H ca. 55 mm, H up to 73 mm, Jonkers (2003, pp. 65–66); compared with up to ca. 100 mm for *A. natans* and 137 mm for *A. anderssoni*), its more equidimensional shape, its larger auricles with, in particular, markedly longer (antero-posteriorly) posterior auricles, its markedly greater inflation, and in having only four to nine (five on most specimens) major radial costae elevated in prominence above their neighbours, and bearing sparse, radially elongate nodules at irregular intervals down each costa, with one to three, rarely up to five, narrower, secondary radial costae and numerous low, narrow, widely spaced tertiary costellae in the wide interspaces between the prominent costae. Obvious but probably abraded, widely spaced commarginal ridges cross the wide, flat radial interspaces. Little is known of the finer sculptural details. We think it unlikely that

Ruthipecten n. gen. is closely related phylogenetically to *Austrochlamys, Leoclunipecten* n. gen. or *Zygochlamys*, and we do not know its origins.

Ruthipecten n. gen. *tuftsensis* (Turner, 1967)

Figures 5A–F

1965 ‘Extinct undescribed interglacial pecten’; Nichols, p. 443, fig. 8.

1967 *Chlamys* (*Zygochlamys*) *tuftsensis* n. sp.; Turner, p. 450, figs 3–5.

1985 *Chlamys tuftsensis* Turner, 1967; Beu, p. 7.

1988 *Chlamys tuftsensis*; Pickard *et al.*, p. 159.

1998*a* *Chlamys* (*Zygochlamys*) *tuftsensis* Turner; Jonkers, p. 165, fig. 3c.

2003 *Austrochlamys tuftsensis* (Turner); Jonkers, p. 66, pl. 1, fig. h; pl. 12, figs f–l.

Type material. Holotype MCZ 256085 (Fig. 5A), four paratypes MCZ 256086, one paratype supposedly GNS TM8457 (although this specimen is not now present in GNS), all from 162 m above present-day mean sea level, Prospect Formation (Late Miocene, Messinian, 6.0 Ma), Prospect Mesa, immediately below (south of) Bull Pass, Wright Valley, ca. 40 km inland from McMurdo Sound, Victoria Land, ca. 77°32′S, 162°25′E (not seen). Webb (1972) reviewed the palaeontology of Prospect Formation and concluded that it was deposited in marine fiord conditions in no more than 100 m of water. The location of Prospect Mesa was shown on the air photo by Turner (1967, fig. 1) and on maps by Vucetich and Topping (1972, fig. 3), Prentice *et al.* (1993, figs 3, 14) and Jonkers (2003, fig. 9).

Material examined. Eight specimens of *Ruthipecten* n. gen. *tuftsensis* from Marine Plain reported by Harding (2005) in Museum Victoria: NMV P302292, incomplete RV internal mould; P302294, incomplete internal mould of articulated shell; P302296, two counterparts of large RV; P302297, RV internal mould and part of LV, LV hinge revealed (Fig. 5C); P302310, incomplete RV; P302315, laterally compressed RV internal mould; P302316, incomplete RV internal mould (Fig. 5B); P302318, incomplete RV exterior, the only reasonably complete exterior seen from Marine Plain (Fig. 5D); three incomplete, articulated but decorticated specimens in NMNZ (M234191), Marine Plain trench no. 2, Vestfold Hills, collected by J. Pickard, 10 January 1981 (68°38.00′S, 078°8.00′E) (Figs 5E–F).

Other material. Valves and fragments of *Ruthipecten* n. gen. *tuftsensis* from the type locality are present in many collections; Jonkers (2003, p. 66) cited material in the Australian Museum, Sydney, BAS and MCZ; also many specimens in other collections from Sørsdal Formation (late Early Pliocene, Zanclean, 4.2–4.1 Ma), Marine Plain, Vestfold Hills, Ingrid Christensen Coast, East Antarctica (Pickard *et al.* 1988; Harding 2005). Adamson and Pickard (1986) described the Cenozoic stratigraphy and geological history of the Vestfold Hills oasis, and Quilty *et al.* (2000) described the stratigraphy and depositional environments of Sørsdal Formation more fully. Harding (2005, p. 22) reported that specimens of *R. tuftsensis* occur in both the upper (Graveyard Sandstone Member) and lower fossiliferous units in Sørsdal Formation, although this needs confirmation as several specimens studied by Harding are actually *Austrochlamys anderssoni*.

Distribution. We are aware of specimens of *Ruthipecten* n. gen. *tuftsensis* only from Prospect Formation in the Wright Valley (type locality) and from Sørsdal Formation in the Vestfold Hills.

Dimensions. Holotype: H 59, L 56, inflation 12 mm; paratype: H 55, L 51, inflation 18 mm; paratype: H 46, L 44, inflation 14 mm (Turner 1967, p. 452); Sørsdal Formation, Marine Plain: NMNZ M.234194: H 68.5, L 59.6 (both incomplete), inflation 21.0 mm; H 58.3, L 56.8 mm; NMV P302292: H 58, L 45 mm (both incomplete); P302296: H

70.6, L 69.3, inflation ca. 20 mm; P302297: H 69.2, L 70.8, inflation ca. 21 mm; P302316: H 52.2, L (incomplete) 44 mm; P302318: H 43.6, L (incomplete) 38.1 mm.

Diagnosis. A species of *Ruthipecten* n. gen. with moderate-sized, strongly inflated, weakly prosocline, thick shell; macrosculpture of four to seven widely spaced, relatively narrow costae each bearing a few large, sparse, radially elongate nodes; disc and auricular microsculpture of low, vaguely defined, widely spaced commarginal ridges on most specimens.

Description. Valves wide (antero-posteriorly elongate, H only slightly greater than L in most specimens, L slightly greater than H in a few) with macrosculpture of few prominent, relatively narrow, well-raised, widely spaced radial costae, five on most specimens; interspaces wide, with relatively weak, widely spaced, secondary and tertiary costae. Microsculpture of low, weak, rather vague commarginal ridges present on some better-preserved specimens from Prospect Formation; no other microsculpture observed. Better-preserved specimens from Prospect Formation bear low nodules on primary costae at irregular intervals, particularly at sparse minor growth steps, but more prominent nodules present on many specimens from Sørsdal Formation. Some specimens from Sørsdal Formation with prominent contraction of disc surface around outer margin, rendering nodules on primary radial costae particularly prominent; contraction not seen on Prospect Formation specimens.

Remarks. The lack of prominent microsculpture on specimens of *Ruthipecten* n. gen. *tuftsensis* from Prospect Formation apparently results from abrasion of the valve surfaces. One specimen from Sørsdal Formation has the outer shell material missing, but the inner layer of the disc and auricles is preserved in such a way as to reveal a long ctenolium with 17 teeth, extending at least partly up the groove between the disc and the auricle (Fig. 5C). Because of incompleteness it is impossible to estimate how many teeth formed the functional ctenolium. A prominent contraction of the disc surface is observed on almost all Sørsdal Formation specimens (Figs 5B, D–F). As most specimens showing the contraction are internal moulds, the apparent contraction also possibly reflects a greatly thickened marginal disc area. However, the one Sørsdal Formation specimen retaining most of its shell (Fig. 5D) also shows the prominent marginal contraction on the outer surface, enhancing the prominence of the large nodules above the contraction. The contraction is at the outer margin of the disc on all Sørsdal Formation specimens we have seen, and evidently represents a severe environmental change, which explains its absence from Prospect Formation specimens. We can see no consistent differences between specimens from the two widely separated localities of different age, but valve surfaces are preserved differently in the two formations. Prospect Formation specimens have all been dug out of relatively loose sediment and retain complete shells, whereas most Sørsdal Formation specimens have been collected from surface exposures of hard rock and lack most shell material. We stress that significant differences between the two populations possibly are masked by the distinct preservational modes in the two localities.

We have little information on the microsculpture of this species. Juvenile specimens from Sørsdal Formation, Vestfold Hills, revealing prominent commarginal microsculpture and assigned to ‘*Chlamys*’ *tuftsensis* by Harding (2005, pl. 8, fig. C) are now identified as *Austrochlamys anderssoni*, following new photographs sent by P. G. Quilty (University of Tasmania, pers. comm. August 2011).

Ruthipecten n. gen., n. sp.

Figure 6B

Material examined. USNM 545845, ANDRILL 2A, 917.39–917.67 mbsf (Burdigalian), one internal mould of a medium-sized, strongly inflated pectinid; umbonal area cut off by the drill.

Dimensions. H very incomplete, estimated originally ca. 50 mm; L 52.1 mm, inflation of internal mould of one valve 14 mm.

Diagnosis. A species of *Ruthipecten* n. gen. with eight or nine widely spaced radial costae, one wide central rib interspace, and one secondary costa in centre of central interspace; nodules low, rounded.

Description. Size moderate, ca. 50 mm high, equidimensional; strongly inflated, inflation of one valve 14 mm; macrosculpture of eight or nine relatively narrow, widely spaced radial costae of semicircular cross-section, with wide, flat interspaces; central disc interspace wider than others, bearing one median secondary costa; low, rounded nodules indicated vaguely at intervals down each costa, tending to be arranged in commarginal rows. Interior characters, valve surface, umbo and auricles not seen.

Remarks. Being an internal mould of only the distal two-thirds of a valve makes analysis of the characters and relationships of this specimen difficult. It differs from *Ruthipecten* n. gen. *tuftsensis* in its larger number of relatively wide, prominent primary costae, which presumably were wider still when the shell was complete, and in having an obvious (if vague) secondary costa in only the centre of the valve. The internal moulds of nodes also seem to be arranged in regular commarginal rows, and so possibly represent commarginal folds or growth steps rather than isolated nodes. However, the sparse, widely spaced primary radial costae and the great inflation are much more in agreement with *Ruthipecten* n. gen. than with any other Antarctic scallop genus we are aware of. It seems feasible that this was an earlier species in a clade that includes *Ruthipecten* n. gen. *tuftsensis*, but only more complete material would allow more certain classification of this species.

Genus LEOCLUNIPECTEN n. gen.

Type species. *Austrochlamys gazdzickii* Jonkers, 2003

Occurrence of type species. Late Early Oligocene (Rupelian), Polonez Cove Formation and possibly Boy Point Formation, Lion's Rump area (Jonkers 2003, fig. 4a), King George Island, South Shetland Islands.

Derivation of name. From Latin, *leo* (lion) and *clunis* (buttocks or rump), combined with the suffix *pecten* (Latin, a comb), used for the names of many scallops; referring to the type area of the type species, the Lion's Rump, King George Island; 'the Lion's Rump scallop'. Gender masculine.

Diagnosis. A genus of moderate-sized Chlamydini with a relatively long (antero-posteriorly), weakly inflated disc; umbonal angle ca. 115°. Macrosculpture of ca. 65–75 low, flat-crested, closely spaced radial costae, with sharply defined edges and flat-bottomed interspaces; microsculpture of widely spaced, prominent commarginal ridges and very fine antimarginal ridgelets. Byssal notch wide, deep; byssal notch and ctenolium functional in adults; LV anterior auricle tall; posterior auricles short, with forward-sloping, concave posterior outlines.

Included species. The one other species we are aware of that might possibly be considered to belong in *Leoclunipecten* n. gen. is '*Chlamys*' *mawsoni* Fletcher, 1938 (Fletcher 1938, p. 106, pl. 10, figs 1–2; Jonkers 2003, p. 57, pl. 15, fig. e) from

Ronarc'h Peninsula, Kerguelen Island, of Miocene age (Lauriat-Rage *et al.* 2002; locality: Jonkers 2003, fig. 13) (holotype: South Australian Museum, Adelaide, T1368; plaster cast examined GNS WM5536). Jonkers (2003, pp. 57–59) commented on the apparently great convexity of the one known incomplete, distorted specimen (a LV), the unusually tall LV anterior auricle, and the lack of commarginal ridges on the disc. However, it appears that the great inflation is a distortion artefact. The holotype of *C. mawsoni* is similar to *Leoclunipecten* n. gen. *gazdzickii* in having at least 70 low, narrow, closely spaced radial costae and no other obvious sculpture, but the lack of commarginal sculpture suggests that *C. mawsoni* is not related to *Leoclunipecten* n. gen. Fuller analysis of the relationships of *C. mawsoni* must await the collection of better material, including the RV.

Remarks. It is obvious on comparing specimens of *Austrochlamys natans* (type species of *Austrochlamys* Jonkers, 2003; Jonkers 2003, pl. 15, figs a–b), *A. anderssoni* (Fig. 3D; Jonkers 2003, pl. 13, figs a–g) and '*Austrochlamys*' *gazdzickii* (Jonkers 2003, pl. 12, figs a–d) that these species belong in two distinct genera. '*Austrochlamys*' *gazdzickii* has a much larger number of lower, narrower, more uniform, much more closely spaced radial costae and a wider, much flatter disc than in the species we consider to be correctly assigned to *Austrochlamys* sensu stricto, listed above. Jonkers (2003, p. 64) pointed out that '*A*'*. gazdzickii* differs from *A. natans* in its longer (antero-posteriorly) and more nearly equidimensional disc, its markedly lesser convexity, its much higher number of radial costae (ca. 65–75 similar costae, compared with ca. 30–39 primary costae and 10–15 intercalated and bifurcated secondary costae on *A. natans*, and ca. 30 primary costae and ca. 30–40 intercalated and bifurcated secondary costae on *A. anderssoni*) that are lower, narrower, more sharply defined and much more closely spaced than in *Austrochlamys*, its more widely spaced commarginal ridges, its markedly deeper byssal notch with more nearly parallel dorsal and ventral margins of the longer RV anterior auricle, and its greater auricular asymmetry. The RV anterior auricle is much longer and narrower and the RV posterior auricle is shorter and more forward-sloping in *Leoclunipecten* n. gen. *gazdzickii* than in species we refer to *Austrochlamys*. In our opinion, these differences are generic characters, and we propose the new genus *Leoclunipecten* to include '*Austrochlamys*' *gazdzickii*.

Leoclunipecten n. gen. *gazdzickii* (Jonkers, 2003)

Figure 6A

1984 *Chlamys anderssoni* (Hennig); Gazdzicki, pl. 19, fig. 2.

1984 *Chlamys* (*Chlamys*) *anderssoni* (Hennig, 1911); Pugaczewska *in* Gazdzicki and Pugaczewska, p, 96, pl. 15, figs 1–3; pl. 19, fig. 4.

1985*a* *Chlamys anderssoni* (Hennig, 1911); Gazdzicka and Gazdzicki, p. 728, fig. 2.

1985*b* *Chlamys anderssoni* (Hennig, 1911); Gazdzicka and Gazdzicki, p. 543, fig. 2.

1986 *Chlamys anderssoni* (Hennig); Birkenmajer and Gazdzicki, p. 222, pl. 1, fig. b.

1991 *Chlamys anderssoni* Hennig; Birkenmajer *et al*., p. 664

1998*a* '*Chlamys*' sp.; Jonkers, fig. 3d.

2003 *Austrochlamys gazdzickii* n. sp.; Jonkers, p. 63, pl. 1, fig. g; pl. 3, fig. c; pl. 12, figs a–d.

Type material. Holotype BAS P.2856.1 (LV; Jonkers 2003, pl. 12, fig. b) (Fig. 6A); paratype BAS P.2856.38, with 14 articulated specimens, 85 LVs and 150 RVs (mostly fragmentary) at BAS, from Polonez Cove Formation (late Early Oligocene, Rupelian), Battke Point and nearby localities, Lions Rump area, King George Island, South Shetland Islands (Jonkers 2003, p. 63) (not seen).

Other material. The type material, the further material in BAS listed by Jonkers (2003, p. 83) and the material collected by Polish Antarctic expeditions in the Lion's Rump area, King George Island, and stored in the Institute of Palaeobiology, Polish Academy of Sciences (Gazdzicki 1982, 1984; Gazdzicki and Pugaczewska, 1984) is the only known material of *Leoclunipecten* n. gen. *gazdzickii*; we have not seen any. Although it has become well-known from the obvious pectinid coquina in the Low Head Member of Polonez Cove Formation at Low Head on King George Island (Gazdzicki 1982, 1984; Gazdzicki and Pugaczewska 1984; Birkenmajer and Gazdzicki 1986), Jonkers (2003, p. 83, fig. 4) recorded *Leoclunipecten* n. gen. *gazdzickii* also from Battke Point, Godwin Cliffs and Mazurek Point, King George Island. Jonkers (2003, p. 64) also indicated a possible record from the CRP-1 drillhole, Ross Sea, based on '*Chlamys*' sp. 2 of Jonkers and Taviani (1998, p. 495). These authors stated that it 'bears some resemblance to an undescribed scallop which occurs in abundance in the Polonez Cove Formation on King George Island' (external moulds of small fragments only, 9.1 x 3.5 and 8.7 x 4.2 mm).

Distribution. Leoclunipecten n. gen. *gazdzickii* is recorded only from the Lions Rump area of King George Island, from Polonez Cove Formation and possibly from Boy Point Formation, both of late Early Oligocene (Rupelian) age. The possible record by Jonkers (2003, p. 64) from the CRP-1 drillhole, Ross Sea, is based on equivocal small fragments.

Dimensions. *Austrochlamys gazdzickii* holotype: H 45.6, L 43.5 mm; large paratype (Jonkers 2003, pl. 12, fig. b) H 68.9 mm, L 67.0 mm (Jonkers 2003, caption to pl. 12; lengths measured from figures).

Diagnosis. As for the genus; only the type species is included.

Description. Shell of moderate size (H 53–75 mm), disc relatively long (antero-posteriorly), almost equidimensional, at most weakly prosocline, very weakly inflated;

umbonal angle ca. 115°. Macrosculpture of ca. 65–75 low, even, flat-crested, sharply defined, closely spaced radial costae, most costae similar and not segregated into primary, secondary or lesser ranks; a few costae intercalated or subdivided to produce secondary costae in some specimens; with flat-bottomed interspaces each equal in width to or slightly narrower than one costa; microsculpture of widely spaced, prominent commarginal ridges, serrating the costal margins or riding over costal crests, and many very fine antimarginal ridgelets. Byssal notch wide, deep; RV anterior auricle long and narrow with subparallel dorsal and ventral margins; byssal notch and ctenolium functional in adults; LV anterior auricle tall, with anterior and dorsal margins meeting approximately at a right angle; posterior auricles short, with forward-sloping, concave posterior outline. Without internal rib carinae. Preradial microsculpture and internal characters unknown.

Remarks. The photograph of the holotype (Fig. 6A) supplied by P. Bucktrout (BAS) clearly reveals the characters of this genus and species. The Polish scientists who first collected *Leoclunipecten* n. gen*. gazdzickii* on King George Island, from a formation then of unknown age, naturally assumed that it was the well-known, abundant, very widespread Antarctic species now identified as *Austrochlamys anderssoni*. However, the wider and much flatter shape and the much greater number of similar, even, primary radial costae in *L. gazdzickii* than in *A. anderssoni* readily distinguish these genera and species.

Pectinidae n. gen., n. sp.

Figure 6C

Material examined. In ANDRILL 2A, 430.54–430.68 mbsf (within the pectinid concentration, Burdigalian), a small, thin-shelled pectinid is present. The several poor fragments apparently represent at least one articulated specimen, part of which is attached to one of the large pieces of *Austrochlamys forticosta* n. sp.; illustrated fragment USNM 545835, three other small fragments USNM 545836.

Distribution. Known only by the specimens recorded here.

Diagnosis. Shell small, weakly inflated, biconvex; macrosculpture of narrow, closely spaced radial ridges; commarginal sculpture of low, narrow, widely spaced ridges; entire surface bearing fine antimarginal ridgelets riding over all other sculpture.

Description. Shell of moderate size (H ca. 40–50 mm), thin, fragile, with low inflation, but valves apparently equally inflated; shape apparently chlamydoid, acline or weakly prosocline, umbonal angle relatively low (not measurable), with height slightly greater than length, but available specimen very incomplete. Macrosculpture of relatively narrow, closely spaced but low, weakly defined radial costae (ca. 0.5–0.7 mm wide, with interspaces each ca. 0.5–1 mm wide, so costal crests are 1.5–2 mm apart near distal margin of disc), forming low, evenly convex radial folds, with flat-bottomed interspaces each slightly wider than one costa. Commarginal sculpture of very low, narrow, widely spaced ridges (ca. 2.5–3 per 1 mm on distal area of disc) of relatively low, semicircular cross-section; entire surface crossed by very fine, straight, antimarginal ridgelets that ride over both radial macrosculpture and commarginal ridges.

Remarks. Few characters are visible of this unnamed pectinid, and its dimensions are not measurable. Several valves seem to have been compressed together between two much larger valves of *Austrochlamys forticosta* n. sp., part of the shell has been dissolved during diagenesis, and the matrix is harder than the thin shell material, so that little preparation was possible. The indication of a chlamydoid shell form suggests that it had a large, functional byssal notch and the anterior auricles were markedly longer than the posterior ones, but such characters are not visible on the fragments available. This shell is similar in many characters to the common Australian and New Zealand species assigned to *Talochlamys* Iredale, 1929 (Beu 1995, pp. 17–19; Beu and Darragh 2001, pp. 95–111; Dijkstra and Marshall 2008, pp. 51–60) but differs in its lower, narrower and more numerous radial costae and its more prominent commarginal ridges, showing that the similarity is superficial. Rather than a juvenile specimen, these fragments apparently represent a small, weakly inflated, finely sculptured chlamydine reaching ca. 40-50 mm in height. Unfortunately, only the collection of more material will reveal the characters and relationships of this scallop.

We are not aware of any other relatively small, finely sculptured Antarctic pectinid of chlamydoid form even vaguely similar to this one, and it evidently represents an unnamed genus. The style of commarginal ridges, relatively low and thick compared with those of *Austrochlamys* and *Leoclunipecten* species, the very narrow, closely spaced radial costae, and the fact that the antimarginal ridgelets clearly ride over all other sculpture suggest that this unnamed genus is not closely related phylogenetically to the other taxa described here. Antimarginal ridgelets are not obvious on most fossil specimens described above, although the poor preservation of other specimens does not rule out antimarginal ridgelets having been present originally. Relatively small chlamydoid scallops such as *Talochlamys gemmulata* (Reeve, 1853), *T. dichroa* (Suter, 1909), *T. pulleiniana* (Tate, 1887), and *Mimachlamys asperrima* (Lamarck, 1819) (illustrated by Beu and Darragh 2001, Jonkers 2003, Dijkstra and Marshall 2008) make up most of the pectinid fauna of New Zealand and southern Australian temperate waters, and the diversity of larger taxa similar to *Austrochlamys* and *Adamussium* is low in these waters. Therefore, it is surprising that small chlamydoid taxa form such a minor proportion of the Antarctic fauna – although the proportion possibly is biased to an unknown extent by the difficulty of collecting small, fragile shells from Antarctic outcrops and drill cores.

Subfamily PALLIOLINAE Korobkov *in* Eberzin, 1960

Diagnosis. Pectinidae with inner crossed-lamellar aragonite area withdrawn from shell margin and hinge area, largely limited to inside pallial line; shell structure of area between pallial line and valve margin of irregularly foliated calcite, forming small patches of laths of uniform orientation producing small reflective surfaces, contrasting with uniformly reflective surface of this area in Chlamydinae; auricles relatively small in relation to disc size, anterior and posteriro auricles similar in size, posterior margins of posterior auricles convex outwards; early (Albian-Paleocene) taxa with relatively prominent radial costae that are wider than their interspaces on RVs and narrower than their interspaces on LVs, macrosculpture later highly varied in different genera; antimarginal microsculpture relatively coarse, uniform and continuous in costal interspaces but absent from costal crests.

Remarks. Waller (2006, p. 10) recognized Palliolinae as a subfamily of Pectinidae, based largely on his interpretation of the evolutionary history of morphologically complex scallops in the Eocene and Oligocene of Europe and North America, that is, it is a difficult group to characterize morphologically. Waller (2006, pp. 12, 14, 15, 20) also established the new tribes Pseudentoliini, Eburneopectinini, Serripectinini, and Mesopeplini within subfamily Palliolinae. Tribe Adamussiini was established by Waller (pers. comm. *in* Beu and Darragh 2001, p. 10) and was more formally established by Waller (2006, p. 13).

Tribe ADAMUSSIINI Habe, 1977

Diagnosis. Palliolinae of moderate size, inflation weak, disc almost circular; macrosculpture of narrow radial costae on RV anterior auricle of most taxa, but disc otherwise smooth in many taxa; fine antimarginal ridgelets present at least on anterodoral and posterodorsal areas of disc and on auricles; auricles relatively small, almost equal, with serrate dorsal margins in most taxa; byssal notch and ctenolium functional in juveniles but shallow and not functional in adults; with obvious, widely separated gill suspensor muscle scars ventral to adductor scar in RV.

Remarks. Waller (2006, pp. 13, 14) included in Adamussiini an unnamed genus to include species formely included in *Eburneopecten* Conrad, 1865 in Paleocene and Eocene rocks of the Northern Hemisphere, along with the Southern Hemisphere genera *Duplipecten* Marwick, 1928, *Lentipecten* Marwick, 1928, and *Adamussium* Thiele, 1934. *Eburneopecten* sensu stricto was transferred by Waller (2006, p. 14) to the separate tribe Eburneopectinini. Beu and Darragh (2001) added *Victoripecten* Beu and Darragh, 2001 to Adamussiini. Waller (2006, p. 14) noted that the specimen identified as a possible ancestor of *Adamussium* from Oligocene rocks in the CIROS-1 drill core, McMurdo Sound, by Beu and Dell (1989, p. 136) – that is, *Antarctipecten* n. gen. *alanbeui* (Jonkers, 2003) of this report – was nicely intermediate between *Lentipecten* and *Adamussium*. These taxa are all characterized by the loss of major radial costae and the adoption of a free-lying, rapidly swimming habit to avoid rapidly swimming predators, but this amusioid shell form has also been adopted by a wide range of other, phylogenetically unrelated Palliolinae. In particular, the European Cenozoic fossil genus *Pseudentolium* Cox, 1948 resembles *Lentipecten* and *Adamussum* closely, but lacks obvious gill suspensor muscle scars (among other differences) and was placed by Waller (2006, p. 12) in the separate tribe Pseudentoliini.

Genus ADAMUSSIUM Thiele, 1934

Adamussium Thiele 1934, p. 807. Type species: *Pecten colbecki* Smith, 1902, by original designation.

Occurrence of type species. Pleistocene and living, circum-Antarctic.

Diagnosis. Moderate-sized, very thin-shelled Adamussiini with a wide disc, umbonal angle correspondingly wide (ca. 135–140°); biconvex, almost equivalve, LV slightly more inflated than RV in some species; auricles moderately long, almost equal, posterior auricle with outwardly convex posterior margin; with macrosculpture of several low, wide, widely spaced radial folds; with microsculpture in which fine but obvious commarginal lirae interrupt continuity of antimarginal ridgelets.

Remarks. The distinguishing characters of *Adamussium* are the relatively wide umbonal angle and the obvious macrosculpture of several low, wide, radial folds. The obvious radial folds are unique in Adamussiini; they constitute the secondary re-acquisition of radial macrosculpture. The first five of the included species (listed below) were compared in a useful table by Quaglio *et al.* (2010, p. 297, table 2). The table is repeated here, slightly simplified (Table 2); the last species listed below is too incomplete to include.

Included species. Adamussium auristriatum Quaglio *et al.,* 2008, Polonez Cove Formation (late Early Oligocene, Rupelian), King George Island.

Adamussium cockburnensis Jonkers, 2003, Cockburn Island Formation (Early Pliocene, Zanclean, 4.7 Ma), Cockburn Island, Antarctic Peninsula (proposed as a subspecies of *A. colbecki*, but in our opinion such stratigraphically segregated forms constitute distinct species).

Adamussium colbecki (Smith, 1902), Pleistocene, CRP-1 drillhole, McMurdo Sound, Ross Sea (1.1 Ma; Jonkers 2003, p. 69), and Fiordo Belén, James Ross

Island, Antarctic Peninsula (1.9 Ma; Jonkers 2003, p. 69); Holocene uplifted beaches around the Ross Sea; living all around Antarctica (Schiaparelli and Linse 2006).

Adamussium jonkersi Quaglio *et al.*, 2010, Destruction Bay Formation (Late Oligocene, Chattian), King George Island; tentatively in ANDRILL 2A.

Adamussium n. sp.? cf. *A. colbecki* (Smith, 1902) of Stilwell *et al.* (2002), from resedimented clasts in Battye Glacier Formation, Beaver Lake, Amery Oasis, western margin of Prince Charles Mountains, East Antarctica.

Adamussium cf. *jonkersi*, Quaglio, Whittle, Gazdzicki and Simões, 2010

Figure 7A

2002 *Adamussium* n. sp.? cf. *A. colbecki* (Smith, 1902); Stilwell *et al.*, fig. 2a–c, g–h, k, r.

2010 *Adamussium jonkersi* n. sp.; Quaglio, Whittle, Gazdzicki and Simões, p. 295, figs 4–6.

Type material. Holotype of *Adamussium jonkersi* ZPAL/L3/41, RV, with three paratypes ZPAL/L3/38–40, 42; one paratype BAS P.2904.10.1, 11 specimens in total in the two collections, all from lower part of Destruction Bay Formation (Late Oligocene, Chattian) at base of Wrona Buttress, Destruction Bay, King George Island, South Shetland Islands (none seen). The material from Battye Glacier Formation, Amery Oasis, illustrated by Stilwell *et al.* (2002, fig. 2a–c, g–h, k, r), which also should be compared with the ANDRILL 2A specimen, is lodged in the Australian Commonwealth Palaeontological Collection, Canberra (not seen).

Material examined. USNM 545844, ANDRILL 2A 740.84–740.86 mbsf (Burdigalian), a partial internal mould of a LV with a little of the inner shell material adhering (Fig. 7A), referred tentatively to *Adamussium* cf. *jonkersi*.

Distribution. Adamussium jonkersi is recorded only from Destruction Bay Formation (Late Oligocene, Chattian), Destruction Bay, King George Island; a single ANDRILL 2A specimen tentatively is referred here.

Dimensions. ANDRILL 2A specimen: H 38 mm, estimated originally ca. 40 mm, L estimated ca. 37 mm (assuming centre of curvature of drill cut is near centre of disc of shell).

Diagnosis. Shell small for genus; internal reflections of radial costae weakly defined, narrow-crested, rather closely spaced for genus.

Description. Anterior third of a valve, remainder cut off by drill during collection; small for genus (H ca. 40, L ca. 37 mm); apparently a LV, anterior auricle incomplete; remnant of outline of anterior auricle small; no other auricular characters visible. Internal reflections of radial costae very narrow-crested, weakly defined, rather closely spaced for genus. Disc outline shape and microsculpture not visible.

Remarks. The ANDRILL 2A specimen resembles a LV of *Adamussium jonkersi*, as well as the very weakly and narrowly costate but moderately well inflated species illustrated by Stilwell *et al.* (2002, fig. 2a–c, g–h, k, r) from resedimented clasts in Battye Glacier Formation, Amery Oasis, East Antarctica. Quaglio *et al.* (2010) pointed out the relatively small size of their material of *A. jonkersi* (mean H 45 mm) and the ANDRILL 2A specimen is within the size range of *A. jonkersi*. The illustrations by Stilwell *et al.* (2002) were stated to be at natural size, so the Battye Glacier Formation specimens also are similar in size to the ANDRILL 2A specimen. Battye Glacier Formation is early Late Miocene by diatom biostratigraphy (Whitehead *et al.* 2004, fig. 11, event 4) so the reworked fossils presumably are Early or Middle

Miocene. This material seems to indicate the presence of an unnamed, narrowly costate *Adamussium* species in Antarctica during Early and possibly Middle Miocene time.

Genus ANTARCTIPECTEN n. gen.

Type species. *Adamussium alanbeui* Jonkers, 2003

Occurrence of type species. Oligocene–Early Miocene, Antarctica and South Shetland Islands.

Derivation of name. From Antarctica, the area of occurrence of the genus, combined with the suffix *pecten* (Latin, a comb), used in the names of many scallops. Gender masculine.

Diagnosis. A genus of Adamussiini with small, weakly inflated, acline, slightly dorso-ventrally elongate, thin shell (height up to 50 mm, most specimens smaller). Umbonal angle low, ca. 110–115°. Auricles only slightly asymmetrical, anterior slightly longer than posterior; RV anterior auricle with semicircular anterior margin, shallowly embayed below by small byssal notch, not functional in adults. Without obvious macrosculpture, other than elevation of the widely spaced commarginal ridgelets into high, thin lamellae on unusually well-preserved specimens, particularly on LV anterior auricle; some unusually well-preserved specimens bear 6-8 faint to low radial folds on LV, particularly on anterior half of valve; one specimen observed with two obvious radial ridges and a third weak one in centre of RV anterior auricle, forming very low nodules where crossed by commarginal ridgelets. Microsculpture of narrow, raised, relatively widely spaced commarginal ridgelets (3–5 per 1 mm on central and distal areas of disc) and very fine, closely spaced antimarginal ridgelets. Without internal radial ridges; one very short, thin resilial tooth present on each side of resilifer in LV; other internal characters not seen.

Included species. Only the type species is included in the new genus.

Remarks. Until now, the type species of this new genus has been placed in *Adamussium*, following the suggestion by Beu and Dell (1989, p. 136) – a suggestion based more on ignorance of its characters, and of scallop classification in general in the 'dark ages' before Waller (1991) began to establish scallop phylogeny, than on any real insights into scallop classification. It is now clear that there are numerous (five recorded so far) Oligocene–living *Adamussium* species around Antarctica, all agreeing with the extant type species, *A. colbecki*, in being wide, equidimensional shells with a wide umbonal angle (135–140°), with sculpture of several low, wide, relatively obvious radial folds in the shell, crossed by low but obvious commarginal ridgelets in most specimens and by very fine antimarginal ridgelets in all. They also all have slightly longer auricles (antero-posteriorly) than *Adamussium alanbeui*. Therefore, it now appears that *Adamussium alanbeui* belongs in a genus distinct from *Adamussium*, having little or no obvious radial macrosculpture, smaller size, lesser inflation, slightly taller shape concomitant with a narrower umbonal angle (110–115°), a much shallower byssal notch, and shorter auricles than the radially folded species referred to *Adamussium*. Although the material seen originally by Beu and Dell (1989) lacked all sign of radial macrosculpture, one of the specimens referred here tentatively by Jonkers (2003, pl. 16, fig. f) has six or seven obvious, very low, widely spaced radial folds, and the well-preserved specimen described below from ANDRILL 2A, 376.80–376.85 mbsf, bears very faint radial ridges on the anterior half of the LV. Very weak radial macrosculpture seems to be a definite but variably present and variably preserved character of *A. alanbeui*, but is much weaker than in species referred more certainly to *Adamussium*, listed under that genus above. We propose the new genus *Antarctipecten* for *Adamussium alanbeui* alone.

Waller (2006, pp. 14–15, fig. 1.2) demonstrated that *Eburneopecten* Conrad, 1865 is not applicable to this or any other extra-North American pectinid. The type species, *E. scintillatus* (Conrad, 1865), evolved from a coarsely ribbed *Dhondtichlamys* species (Waller 2001) in the Early to Middle Eocene of eastern North America and is not related phylogenetically to any of the other taxa previously referred to *Eburneopecten*.

It is still possible, as suggested by Beu and Dell (1989) and Waller (2006, p. 14), that the superficially smooth little 'saucer scallop' *Antarctipecten* n. gen. *alanbeui* was ancestral to *Adamussium*, but that now seems unlikely, in view of the variety of smooth Adamussiini recognized in Australia and New Zealand. Beu and Darragh (2001, p. 122), when proposing the genus *Victoripecten*, pointed out at least three groups of superficially similar, but independently evolved, smooth 'saucer scallops' in Eocene–Miocene rocks of New Zealand, as well as *Victoripecten* in southern Australia. The three obvious New Zealand groups are *Duplipecten* Marwick, 1928, *Lentipecten* Marwick, 1928 (= *Janupecten* Marwick, 1928, a lineage that gradually evolved the smooth, final, Oligocene species *L. hochstetteri* (Zittel, 1864); tribe Serripectinini; Beu *et al*. 2012, p. 31), and the unnamed Miocene genus that usually has been known incorrectly as *Lentipecten*. Other New Zealand genera of these poorly understood, very similar taxa possibly remain to be recognized. Tribe Serripectinini evolved two other similar, almost smooth species, *Serripecten semilaevis* (McCoy, 1876) (Middle Miocene, southern Australia; Beu and Darragh 2001, p. 89, figs 25E, 26A–D, 27A–B) and an unnamed Australian Oligocene *Serripecten* species (Beu and Darragh 2001, p. 81, fig. 22C). Loss of most or all macrosculpture to produce a smooth, thin, light, weakly inflated shell (the amusioid form; Waller 1991, p. 10) that could swim away from rapidly moving predators evidently was a common response to severe predation pressure during the warm period of the early to mid-Cenozoic, even in Antarctica. Relationships with several of the genera recognized in New Zealand are possible for *Antarctipecten* n. gen. *alanbeui*, but in view of the small size of the type species (smaller than any Australian or New Zealand taxa of this group) and the fact that several, superficially similar genera evolved in neighbouring seas, a close phylogenetic relationship will always remain difficult to demonstrate. Also, the prominent commarginal microsculpture now known to be present on *A. alanbeui* is not present on any other species of Adamussiini we have examined, other than the type species, *Adamussium colbecki*. The end result in *Antarctipecten alanbeui* is a shell resembling a diminutive version of the adult form of *Adamussium colbecki*, with quite similar auricles other than a much less strongly sigmoidal LV anterior auricular margin, a narrower umbonal angle and much weaker commarginal sculpture, but with more closely spaced commarginal lamellae and much weaker radial macrosculpture on the disc.

Antarctipecten n. gen. *alanbeui* (Jonkers, 2003)

Figures 7B–E

1984 *Eburneopecten* sp.; Pugaczewska *in* Gazdzicki and Pugaczewska, p. 95, pl. 19, fig. 1; pl. 21, fig. 2.

1989 *Adamussium*? n. sp.; Beu and Dell, p. 136, figs 7–14.

2001 ?*Adamussium* n. sp.; Taviani *et al.*, p. 518, fig. 7a.

2003 *Adamussium alanbeui* n. sp.; Jonkers, p. 70, pl. 3, figs d–e, g; pl. 16, figs a–h; pl. 17, figs a–b.

2008 *Adamussium* cf. *A. alanbeui* Jonkers 2003; Quaglio *et al.*, p. 156, fig. 10a–d.

2010 *Adamussium alanbeui* Jonkers, 2003; Taviani *et al.*, p. 140, fig. 13b.

Type material. Holotype GNS TM8228, two paratypes GNS TM8229–8230, all from CIROS-1 drillhole, eastern McMurdo Sound, Ross Sea, 77°34′55″S, 164°29′56″E, in

197.5 m of water, types at 454.39 mbsf, 215.57 mbsf, and 174.64 mbsf, respectively; Oligocene.

Material examined. Specimens of *Antarctipecten* n. gen. *alanbeui* are present at two Early Miocene (Burdigalian) horizons within ANDRILL 2A: 376.80–376.85, USNM 545823 (Fig. 7B–C) and three other fragmentary specimens, USNM 545824; and 999.76–999.80 mbsf, USNM 545846 (Fig. 7D–E).

Other material. Jonkers (2003, p. 70) referred here also material from the CRP 2/2A drillhole, of Late Oligocene–Early Miocene age, and from Polonez Cove Formation (late Early Oligocene, Rupelian) and Cape Melville Formation (Early Miocene, Aquitanian) on King George Island, South Shetland Islands (listed in detail by Jonkers 2003, p. 81). Quaglio *et al.* (2008, p. 156, fig. 10a–d) also tentatively referred material to *Adamussium alanbeui* from the Low Head Member of Polonez Cove Formation (late Early Oligocene) at Vauréal Peak, King George Island; their illustrations show specimens that agree with *Antarctipecten* n. gen*. alanbeui* (none seen).

Distribution. *Antarctipecten* n. gen. *alanbeui* is recorded from late Early Oligocene to late Early Miocene (Rupelian–Burdigalian) rocks in drill cores in the Ross Sea and from outcrops on King George Island. It is assumed to have had only a Rupelian–Burdigalian age range (ca. 30–16 Ma), although both its upper and lower limits are poorly constrained. These are all the possible Antarctic localities of Oligocene and Early Miocene age, suggesting that *A. alanbeui* had a circum-Antarctic distribution.

Dimensions. Holotype: H 34.9, L 32.6 mm; paratype TM8230, LV: H (slightly incomplete) 43.9, L 45.7 mm; USNM 545823, ANDRILL 2A, 376.80–376.85 mbsf: fragmentary LV, H 12.8, L 13.0 mm; USNM 545824, fragmentary RV, H 9.6, L 10.8

mm; USNM 545846, 999.76–999.80 mbsf, remaining fragment: RV H 28.9, L 35.9 mm; LV H 20.6, L 35.4 mm. Jonkers (2003, p. 70) mentioned specimens possibly reaching up to H 60 mm, but we have not seen specimens larger than H 45 mm.

Diagnosis. Shell small (H up to 50 mm, few specimens exceeding 45 mm), very thin, fragile, acline; auricles almost symmetrical, short; umbonal angle low (ca. 110–115°); without obvious macrosculpture, other than faint, very narrow radial costae on LV of a few well-preserved specimens, particularly on anterior half of disc; microsculpture of obvious commarginal ridges, raised into high lamellae in groove between disc and auricle on well-preserved specimens; and fine antimarginal ridgelets.

Description. Shell small, thin, weakly inflated, acline, slightly dorso-ventrally elongate (height up to 50 mm, most specimens smaller). Umbonal angle low, ca. 110–115°. Auricles only slightly asymmetrical, anterior slightly longer than posterior; RV anterior auricle with semicircular anterior margin, shallowly embayed below by small byssal notch. On LV, unusually widely spaced, well raised, very narrow commarginal ridgelets cover distal two-thirds of disc and entire auricles, spaced 3–5 per 1 mm over central and outer part of disc (varying slightly in spacing); lower and more closely spaced over anterior and posterior areas of disc and on auricles. On anterior end, on either side of shallow depression between auricle and disc, particularly on lower half of LV anterior auricle, ridges are more elevated than elsewhere, raised into high, thin, biarcuate lamellae, 6–8 per 1 mm over lower half of auricle; noticeably further apart near umbo, decreasing in spacing regularly down auricle towards anterior margin. Despite weakening dorsally, commarginal lamellae extend to dorsal margin, serrating dorsal outline very weakly. Surface between commarginal ridges closely covered with minute antimarginal ridgelets on auricles and distal two-thirds of disc; all microsculpture evidently abraded off umbonal third of valve; antimarginal ridgelets do not cross commarginal ridges. Under very oblique lighting, after whitening with MgO, eight or nine very weak radial ridges visible on LV, particularly on anterior half; two ridges slightly more prominent than remainder, only slightly weaker than those shown on *Antarctipecten* n. gen. *alanbeui* by Jonkers (2003, pl. 16, fig. f; Cape Melville Formation, Early Miocene, King George Island). Remaining radial ridges very faint, little more than slight angulations of valve surface. Resilifer normal; one very short, extremely thin resilial hinge tooth on each side of LV resilifer. Pallial line faintly discernible on interior; no other internal characters visible, central aragonite area removed through diagenesis. Exterior of RV smooth apart from one prominent commarginal fold near umbo, matched by partial commarginal depression in LV. Very low commarginal ridgelets present on both anterior auricle and remnant of incomplete RV posterior auricle, but not on RV disc. RV anterior auricle with two prominent and one weaker radial ridgelets in centre, forming minute nodules where crossed by commarginal ridgelets; sculptured area elevated slightly to form narrow, central radial band of minute nodules. Trace of ctenolium a narrow, sharply defined ridge extending full height of junction between RV anterior auricle and disc.

Remarks. In ANDRILL 2A, specimens of *Antarctipecten* n. gen. *alanbeui* are present in only the lowest and highest macrofossiliferous horizons studied. At 376.80–376.85 mbsf, one articulated, complete, free specimen is present (USNM 545823; Fig. 7B–C), cut by the drill so only the umbonal two-thirds is preserved (illustrated by Taviani *et al.* 2010, fig. 13b); its beautifully preserved sculpture is described above. It is accompanied by two other less well-preserved, small, articulated specimens and a number of further fragments (USNM 545824), all removed from a matrix of soft, almost free-running, muddy fine sandstone. At 999.76–999.80 mbsf, one good articulated specimen of *A. alanbeui* (with valves slightly offset) is present (USNM 545846; Fig. 7D–E), sectioned by the core splitter. This specimen is in hard, pale grey mudstone. The dorsal half of the LV is complete and has now been cleaned, whereas the RV is slightly incomplete (posterior auricle missing and edges slightly chipped), and the thin layer of matrix adhering to the shell can be only partially cleaned off. Compression has produced down-turned edges to the conjoined discs below the auricles and a slight twisting of the RV umbo. Three weak but obvious radial folds in the central area of the LV and three very faint ridges anterior to the more prominent ones seem to be true radial ridges as on the specimen described above from higher in the core, although the three central ones give the impression of having been enhanced by compression. Apart from the radial ridges and the compression artefacts, this specimen is strikingly similar in size, preservation and general appearance to the material in CIROS-1 and CRP-2/2A, and particularly to the holotype. No sculpture is visible on the RV, whereas very fine commarginal ridges and exceedingly fine antimarginal ridgelets are clearly visible on cleaner parts of the LV, although not on the auricles. The RV anterior auricle has the same semicircular anterior end and very shallow byssal notch as on other material referred to *A. alanbeui*.

The other material from 376.80–376.85 mbsf confirms the identity. One specimen is a very incomplete, formerly articulated pair of valves with faint signs of commarginal sculpture, agreeing in all characters with the more usual material of *Antarctipecten* n. gen. *alanbeui* seen in other cores and in outcrop, and at 999.76-999.80 mbsf in ANDRILL 2A. Another specimen is a highly incomplete, formerly articulated pair of valves with the LV posterior auricle well preserved, showing the same commarginal and antimarginal sculpture as on the well-preserved specimen, but less well-preserved. The fourth sample is a collection of fragments from valves up to ca. 20 mm in height, with characters as in other material of *A. alanbeui* from other Antarctic cores. We are in no doubt that the specimen with prominent sculpture is an unusually well-preserved specimen of *A. alanbeui*. Comparison showed that some remnants of similar, relatively prominent microsculpture are preserved on the type material of *Antarctipecten* n. gen. *alanbeui*. The holotype (GNS TM8228), a LV, is remarkably well preserved, again, for a specimen extracted from a drill core, although most of the anterior auricle is missing. The small remaining apical portion of the anterior auricle bears six or seven prominent, well raised commarginal lamellae, as in the specimen from ANDRILL 2A, 376.80–376.85 mbsf, although no lamellae are present on the disc of the holotype. The much larger paratype (GNS TM8229) illustrated by Jonkers (2003, pl. 16, figs b–c; pl. 17, figs a–b), from CIROS-1, 215.57 mbsf, bears many very low, irregularly spaced, commarginal ridgelets over the auricles and disc of both valves, but little of the more prominent lamellae present on the ANDRILL 2A specimens. However, it does have six prominent lamellae on the apical fifth of the auricle, spaced as in the ANDRILL 2A specimens. It also has five weakly elevated, widely separated groups of low commarginal lamellae on the LV anterior auricle, with interspaces decreasing in width regularly towards the valve margin, suggesting the possibility that these are annual growth rings. If so, this specimen lived for seven years. The other paratype, GNS TM8230 (CIROS-1, 174.64 mbsf) is less well preserved than the holotype and the first paratype, and the poorly preserved RV reveals no microsculpture, but the exterior mould of the LV bears the remnants of many fine commarginal and antimarginal ridgelets. These characters confirm that all the examined material is conspecific, but varies markedly in preservation of sculpture.

Subclass HETERODONTA Neumayr, 1884

Order VENERIDA Gray, 1854

Superfamily VENEROIDEA Rafinesque, 1815

Family VENERIDAE Rafinesque, 1815

Subfamily CHIONINAE Frizzell, 1936

Genus RETROTAPES del Rio, 1997

Type species. *Retrotapes ninfasiensis* del Rio, 1997, by original designation.

Occurrence of type species. Puerto Madryn Formation (Late Miocene; del Rio 2004), Peninsula Valdés, Chubut Province, Argentina.

Diagnosis. A genus of Chioninae with ovate-triangular to subcircular outlines; commarginal sculpture of prominent, thin, widely spaced lamellae; lunule clearly defined by marginal groove; escutcheon defined weakly by marginal depression.

Remarks. Del Rio (1997) proposed *Retrotapes* for species previously placed in *Eurhomalea* Cossmann, 1920 (type species: *Venus rufa* Lamarck, 1818, extant, Peru and Chile) and several other genera, but differing from *Eurhomalea rufa* in having a clearly depressed, groove-margined lunule and a weakly defined escutcheon, whereas both lunule and escutcheon are lacking in *E. rufa. Eurhomalea rufa* also is more elongate (antero-posteriorly), is less inflated, has more nearly central umbones, and is more quadrate in shape than species assigned to *Retrotapes*; *E. rufa* has parallel, only weakly convex dorsal and ventral outlines. *Eurhomalea rufa* also has weak sculpture of low, wide, commarginal ridges (or widely spaced, shallow, commarginal grooves), whereas the common Argentinean–Falkland Islands living species *Retrotapes exalbida* (Dillwyn, 1817) has much more prominent sculpture of prominent, thin, widely spaced commarginal lamellae, 3 mm apart over the outer part of large specimens. The type species of *Retrotapes, R. ninfasiensis* del Rio (1997, p. 82, figs 15–18, 40), is similar to *R. exalbida* but taller, more robust and a little more weakly sculptured. Other species previously assigned to *Eurhomalea* but included by del Rio (1979) in *Retrotapes*, such as *R. lenticularis* (G. B. Sowerby I, 1835) (del Rio 1997, figs 19–21; Huber 2010, illustrated p. 373) are similar in shape and sculpture to *R. exalbida*, with an obvious lunule, but have weaker sculpture. Huber (2010, pp. 373, 717–718) stated that *E. rufa* has a lunule, and synonymized *Retrotapes* with *Eurhomalea*. However, *Eurhomalea rufa* was illustrated well by del Rio (1997, figs

10–14). Her dorsal view (del Rio 1997, fig. 12) clearly shows that *E. rufa* has no escutcheon, and a lunule is represented only by a narrow, shallowly concave area, not differentiated from the rest of the valve surface by a groove, depressed margin, or distinctive sculpture. In our opinion the lack of a differentiated lunule and escutcheon in *E. rufa* demonstrates that *Retrotapes* is a genus distinct from *Eurhomalea*.

Eurhomalea was assigned to Subfamily Chioninae, rather than its traditional position in Tapetinae, by Fischer-Piette and Vukadinovich (1977), Smith (1998, p. 358), Kappner and Bieler (2006), and Mikkelsen *et al.* (2006), based on both molecular sequences and shell morphology. The species used for molecular sequencing by both Kappner and Bieler (2006, table 1) and Mikkelsen *et al*. (2006, p. 503) was, however, *Eurhomalea lenticularis*, that is, they analysed *Retrotapes* rather than *Eurhomalea*. Both genera therefore seem referable to Chioninae, although obviously *E. rufa* needs to be sequenced to confirm this position, and it is still possible that *Eurhomalea* sensu stricto belongs in Tapetinae.

Paleomarcia tatei Fletcher, 1938, *P. kergueleni* (Tate, 1900), and *Frigichione permagna* (Tate, 1900) from the Miocene of Kerguelen Island (Lauriat-Rage *et al.* 2002, figs 3c, 4a–d) are similar to *Retrotapes exalbida* and *R. andrillorum* n. sp. in sculpture and overall appearance, but are taller and more evenly subcircular in outline. It is possible that *Frigichione* is a senior synonym of *Retrotapes*, but the Kerguelen material is too poorly preserved to be able to reach any certainty about differentiating characters.

Retrotapes andrillorum n. sp.

Figures 8A–E

Derivation of name. We have great pleasure in naming this new species after the ANDRILL science team, who collected this new material, and the ANDRILL Project, which has brought to light so much new information on the Cenozoic history of Antarctica. The ending adopted is '-*orum*', 'of … men and women together' (International Commission on Zoological Nomenclature 1999, Article 31.1.2).

Type material. Holotype USNM 545829, ANDRILL 2A, 429.92–430.02 mbsf (Burdigalian), one complete articulated specimen, sectioned by the drill; ca. 4/5 of LV and dorsal 1/3 of RV remaining (Figs 8A–E).

Material examined. Type material; USNM 545828, ANDRILL 2A, 429.25–429.28 mbsf, part of one small valve, cut by the drill; USNM 545837, ANDRILL 2A, 430.54–430.68 mbsf (within the pectinid concentration), two partial valves of one specimen, cut by both drill and core splitter. Neither sample is well-enough preserved to add anything to the description of the new species.

Type locality and horizon. Collected only from an interval less than 1 m thick in ANDRILL 2A, from 429.25–430.68 mbsf.

Distribution. Known only by the material listed above.

Dimensions. Holotype: L 44.4 mm, estimated originally 46 mm, H 36.5 mm; inflation of two slightly separated but still articulated valves 26.6 mm, estimated originally 28 mm; estimated inflation of closed, articulated valves 25 mm; shell thickness near ventral margin 1.7 mm. Other fragments not measurable.

Diagnosis. An evenly oval, moderate-sized (L 46 mm) species of *Retrotapes* with an evenly inflated surface, sculpture of low, narrow, commarginal ridges up to 2 mm apart, a well-demarcated, depressed lunule, and a thick, grooved, right posterior cardinal tooth.

Description. Shell thick and solid, rectangularly oval and typically venerine in shape; umbones low, directed well forwards, situated at anterior fifth of length. Outlines evenly oval apart from slight straightening of posterior and ventral margins; anterior margin incomplete. Sculpture of regular, even, narrow, widely spaced, slightly raised commarginal ridges over entire exterior, 1.3–2.0 mm apart over central to distal area of disc, becoming much more closely spaced towards anterior and posterior ends; interspaces flat, bearing weak commarginal ridgelets. Inner ventral margins smooth. Hinge similar to that illustrated by del Rio (1997, figs 22, 24) for *Retrotapes exalbida*, shallowly arched with central down-curved area beneath umbo bearing cardinal teeth; two rather narrow cardinal teeth in left valve, the posterior shallowly grooved medially, margined above by short, thin posterior lateral rim on edge of nymph; long, moderately wide nymph separated from escutcheon by deep, narrow ligamental groove; area anterior to cardinal teeth deeply excavated. Right hinge with thick, obviously grooved posterior cardinal tooth, and thinner, short, near-vertical median and anterior cardinal teeth in front; nymph long, moderately wide, ceasing abruptly at declining posterior margin, as in left valve; separated from escutcheon by deep, narrow ligamental groove. No anterior lateral teeth present. Lunule tall and narrow, weakly concave, slightly but sharply and abruptly excavated below valve surface, but lacking obvious marginal groove; sculptured with very fine, closely spaced commarginal ridges. Escutcheon weakly defined, a narrow flat area above ligamental groove margined by low, rounded angling ridge along postero-dorsal margin of disc, sculptured finely as on lunule.

Remarks. The holotype of *Retrotapes andrillorum* n. sp. was preserved in moderately well cemented, pale grey, highly quartzose, coarse sandstone to fine conglomerate, that is, some grains are ca. 6 mm in diameter, although most are ca. 2–3 mm. The matrix remaining inside the shell bears bryozoans and other invertebrate fragments.

The shell is not as strong as the matrix, so the valves were separated and the hinge revealed only with difficulty. We have not revealed other internal characters, such as the muscle scars and pallial line, to avoid further damage to the already incomplete shell. The two other specimens are very incomplete and add nothing to knowledge of the species.

Retrotapes andrillorum n. sp. clearly has a hinge very similar to that illustrated by del Rio (1997) for other *Retrotapes* species. The new species resembles the living Argentinean–Falkland Islands species *R. exalbida* (Dillwyn, 1817) in shape and sculpture, and there is little doubt that *R. andrillorum* n. sp. is correctly referred to *Retrotapes. Retrotapes andrillorum* n. sp. differs from *R. exalbida* in its smaller size (*R. exalbida* reaches at least 83 mm long), slightly longer (antero-posteriorly) and narrower shape, and markedly greater inflation. *Retrotapes exalbida* and *R. ninfasiensis* also differ in having a weak postero-ventral ridge demarcating a weakly defined postero-dorsal area, whereas *R. andrillorum* n. sp. is evenly inflated. The right posterior cardinal tooth also is shorter, thicker, and more obviously grooved in *R. andrillorum* n. sp. than in *R. exalbida*. In both valves, the ligamental nymph is much less clearly distinguished from the posterior lateral tooth than in *R. exalbida*; the nymph is a wide ridge with a smooth ventral half and a rugose dorsal half. Also, the lunule of most or all other species referred to *Retrotapes* is demarcated by a very narrow groove, whereas an actual groove seems not to be present in *R. andrillorum* n. sp. However, the abrupt, sharp-edged depression below the valve surface in *R. andrillorum* n. sp. demarcates the lunule just as obviously as in other species. A narrow groove possibly is masked by a light coating of carbonate cement, which is difficult to remove entirely from the holotype. Abbott and Dance (1982, p. 360, top right fig.) illustrated *R. exalbida* in colour, but wrongly included it in *Humilaria* Grant and Gale, 1931. The crenulate inner ventral margin of *Humilaria* species demonstrates the inappropriateness of such a position. All other South American and Antarctic Cenozoic fossil species referred to *Retrotapes* by del Rio (1997) are slightly taller and more triangular in shape than either *R. andrillorum* n. sp. or *R. exalbida*, with more protruding, more nearly central umbones than either of these species. Consequently, they also have a shorter, wider cardinal hinge area and longer, more upright cardinal teeth than in *R. exalbida* and *R. andrillorum* n. sp.

Order uncertain

Superfamily HIATELLOIDEA Gray, 1824

Family HIATELLIDAE Gray, 1824

Genus HIATELLA Daudin *in* Bosc, 1801

Type species. *Hiatella monoperta* Bosc, 1801 (= *Mya arctica* Linnaeus, 1767), by subsequent designation (Winckworth 1932, p. 247).

Occurrence of type species. At least Eocene–living, cosmopolitan, in a huge range on environments; poorly known, in view of the poorly understood taxonomy of the genus. Jurassic *Hiatella* specimens illustrated by Schneider and Kaim (2012) are extremely similar to *H. arctica*.

Diagnosis. Shell small to moderate-sized, elongate, surface chalky in many specimens, most species elongate-quadrate, posterior end markedly longer than anterior, gaping slightly at both ends; shape modified by habitat in many specimens; one or two prominent posterior umbonal-ventral ridges present in most species, bearing tubular spines in many species; hinge with prominent, thick ligamental nymph and one or two weak teeth, more consistently present in juvenile than in adult specimens; interior ventral margin smooth; pallial sinus deep. Boring, burrowing, or nestling in crevices and in disused burrows of other bivalves.

Remarks: The extensive synonymy of the genus *Hiatella* was listed by Keen (*in* Moore 1969, p. N700). Synonymies for all other species described above are exhaustive, whereas that provided here for *Hiatella* cf. *arctica* includes only New Zealand and Antarctic references and a reference to Huber's (2010) recent treatment. Lamy's (1924) synonymy lists should be consulted to begin to establish a complete synonymy. Several further synonyms were listed by Keen (*in* Moore 1969, p. N700). We have not included references to South American specimens usually referred to *Hiatella solida* (G. B. Sowerby I, 1834), as this seems likely to be distinct. A complete synonymy for the long-lived, almost ubiquitous, variably shaped, cosmopolitan species *Hiatella arctica* would be as long as the rest of this report, and it is very unclear which names should be included as synonyms, so we have not attempted to compile a complete synonymy. *Hiatella* is simply too poorly understood taxonomically for realistic synonymies to be compiled at present for any species. Investigating the type material of the more than 60 synonyms is also beyond the scope of this paper, in view of the poorly understood taxonomy.

Hiatella cf. *arctica* (Linnaeus, 1767)

Figures 9A–C

1767 *Mya arctica*; Linnaeus, p. 1113.

1767 *Solen minutus*; Linnaeus, p. 1115.

1801 *Hiatella monoperta*; Bosc, p. 120.

1843 *Hiatella minuta* (Linnaeus, 1767); Gray, p. 252.

1873*a* *Saxicava arctica* Linnaeus; Hutton, p. 60.

1873*b* *Saxicava arctica* Linnaeus; Hutton, p. 18.

1873 *Saxicava arctica*, L.; Martens, p. 41.

1880 *Saxicava australis* (Lamarck); Hutton, p. 134.

1904 *Saxicava arctica* Linnaeus; Hutton, p. 88.

1913 *Saxicava arctica* Linné, 1767; Suter, p. 1012, pl. 55, figs 6–6a.
1924 *Saxicava arctica* (Linnaeus, 1767); Lamy, p. 219.
1924 *Saxicava arctica*; Bucknill, p. 111, pl. 9, fig. 6.
1937 *Hiatella australis* (Lamarck, 1818); Powell, p. 61.
1937 *Hiatella antarctica* (Philippi, 1845); Powell, p. 61.
1966 *Hiatella australis* (Lamarck, 1818); Fleming, p. 33.
1975 *Hiatella arctica* (Linnaeus); Dell and Fleming, p. 697.
1976 *Hiatella arctica* (Linnaeus, 1767); Powell, p. 131, pl. 17, fig. 17.
1979 *Hiatella arctica* (Linnaeus, 1767); Powell, p. 428, pl. 75, fig. 17.
1990 *Hiatella arctica* (Linné, 1767); Beu and Maxwell, p. 401.
2001 *Hiatella* sp.; Taviani *et al.*, p. 521, fig. 2g.
2009 *Hiatella arctica* (Linnaeus, 1767); Spencer *et al.*, p. 200.
2010 *Hiatella arctica* (Linnaeus, 1767); Huber, p. 275, 3 figs; p. 276, 2 figs; p. 670.

Material examined. USNM 545825, ANDRILL 2A, 377.19–377.26 mbsf, three internal moulds (one very incomplete) of *Hiatella*, L up to 28 mm; USNM 545838, ANDRILL 2A, 430.54–430.68 mbsf (within the pectinid concentration), one specimen, the two valves only slightly offset, moderately large (L 24.8 mm) (Figs 9A, C); USNM 545840, ANDRILL 2A, 459.0 mbsf, one small valve (L 6.1 mm) attached to surface of a scallop fragment (*Austrochlamys forticosta* n. sp.), with spines preserved on both umbonal-ventral posterior ridges (Fig. 9B); all Burdigalian.

Distribution. Jurassic(?) (Schneider and Kaim 2012); at least Early Eocene–Recent, cosmopolitan, ubiquitous in an enormous range of environments.

Dimensions. USNM 545825, ANDRILL 2A, 377.19–377.26 mbsf: H 16.3, L (incomplete) 28.7 mm; USNM 545838, 430.54–430.68 mbsf, articulated shell with valves slightly offset, whole specimen measured: H 16.8, L 24.6 mm; USNM 545840, 459.0 mbsf: H 3.9, L 6.1 mm.

Diagnosis. Shell small, elongate-quadrate, posterior end much longer than anterior, with two prominent umbonal-ventral radial ridges demarcating prominent postero-dorsal area; tubular spines on radial ridges of most specimens.

Description. Shell small (L 6–28 mm), relatively thin, elongate-quadrate, with short, semicircular anterior end and long, subquadrate, narrowly gaping posterior end; surface irregularly folded and puckered on many specimens; sculpture of irregular, commarginal, sharply raised, anastomosing riblets, closely spaced over anterior end but distant and rather lamellar posteriorly; two prominent umbonal-ventral posterior radial ridges present on most specimens, in young specimens ornamented with small tubular spines. Prominent ligamental nymph obvious in most specimens; hinge teeth not seen.

Remarks. Dell (1964, pp. 222–226) discussed the taxonomy and distribution of *Hiatella* species extensively, listing 53 names proposed for extant species. Lamy (1924) also provided extensive and apparently complete synonymies for the several species he recognized (in the synonym *Saxicava* Fleuriau-Bellevue (1802, pp. 349, 354), type species (by monotypy) *Saxicava striata* Fleuriau-Bellevue, 1802, = *Mya arctica* Linnaeus, 1767; Lamy 1924, p. 219). Species recognized by Lamy (1924) are *S. arctica*, *S. rugosa* (Linnaeus, 1767), *S. pholadis* (Linnaeus, 1767), *S. solida* (G. B. Sowerby I, 1834), *S. australis* (Lamarck, 1818) and var. *angasi* A. Adams *in* Angas, 1865, *S. similis* Deshayes, 1863, and *S.* (*Saxicavella*) *plicata* (‘Montagu, 1808’) [actually *Mytilus plicatus* Gmelin, 1791]. However, numerous other species of uncertain value have been proposed, e.g., Powell (1960, p. 183) listed *H. antarctica* (Philippi, 1845), *H. bisulcata* (Smith, 1877) and *H. subantarctica* (Preston, 1913) from

Antarctica, and Powell (1951, p. 79) listed four further names proposed for Antarctic–subantarctic specimens. Distinguishing all these supposed species remains highly uncertain, and it is not known whether they all refer to the single species *H. arctica* or not. Huber (2010, p. 670) pointed out that at least nine generic synonyms and more than 60 species synonyms, and additional varietal names, have been proposed for *Hiatella*, and several recent authors have suggested recognising only *H. arctica* until the taxonomy is revised based on type specimens and sound nomenclature; he recognized only *H. arctica*, illustrating 'forms' *antartica*, *spinifera*, *australis*, and *flaccida* (Huber 2010, pp. 275–276).

Southern South American shells referred to *Hiatella solida* differ from most others in reaching a relatively large size (up to at least 46 mm long) and in retaining the hinge teeth at this size, whereas in most other parts of the world specimens more than about 15–20 mm long have lost their hinge teeth (Dell 1964) or, in some cases, never have them (Schneider and Kaim 2012). Dell (1964) adopted the name *H. solida* for southern South American specimens, although other South American authors such as Rios (1994, p. 294) used the name *H. arctica* for South American shells, listing *H. solida* as yet another synonym, and Forcelli (2000, p. 168) confused the situation still further by recognising both *H. arctica* and *H. antarctica* (Philippi, 1845) living in southern South America. GNS specimens from southern South America identified as *H. solida* reach a much larger size than any New Zealand specimens seen (WM15890, beach, Ensenada Bay, Beagle Channel, L 46.7 mm; WM7685, Puerto Williams, Navarino Island, Beagle Channel, L 39 mm), but so do specimens identified as *H. australis* from southern Australia (GNS WM1242, Botany Bay, New South Wales, L 43.6 mm; WM1299, Nornalup Inlet, Western Australia, L 41.6 mm), whereas New Zealand specimens maintain a fairly uniform size over the entire country (GNS RM3499, Coopers Beach, Northland, L 20.7 mm; RM4877, Pukerua Bay, Wellington, L 17.2 mm; RM1128, Kaingaroa, Chatham Island, L 23.1, L 21.3 mm). These size ranges suggest that several species should be recognized.

Powell (1955, p. 44) also confused the issue by identifying small subantarctic specimens, up to only 8 mm long, as *Hiatella* cf. *antarctica*, following Hedley (1916), although all more recent New Zealand cataloguers have recorded only *H. arctica* from the New Zealand region, most recently Spencer *et al*. (2009, p. 200). Hedley (1916, p. 34, pl. 4, figs 51–53) recorded '*Saxicava*' *antarctica* from Macquarie Island, the southernmost of the New Zealand subantarctic islands, reaching only 8 mm in length, illustrating a completely smooth exterior. It seems possible, then, that still another very small species occurs widely in subantarctic areas, although this is as inconclusive as all other aspects of *Hiatella* taxonomy. The taxonomy and biogeography of *Hiatella* remain exceedingly poorly understood (Dell 1964; Gordillo 2001; Huber 2010, pp. 275–276, 670; Schneider and Kaim 2012), and comparisons of molecular sequences are required to resolve the taxonomy of this conchologically highly conservative genus.

The material in ANDRILL 2A closely resembles the species living now around New Zealand and occurring commonly as fossils there at many localities (Early Eocene–Recent; Beu 1971; Beu and Maxwell 1990, p. 401). ANDRILL 2A specimens are small (not over 28 mm long) and specimens with the shell preserved have two postero-dorsal ridges or carinae, which bear narrow spines on some specimens (Fig. 9B). They seem not to be conspecific with the much larger, thicker, more inflated, shorter and taller shells illustrated by Whitehead *et al.* (2006*a*, p. 135, fig. 6a–g) from the Lambert Graben embayment (Late Miocene), East Antarctica. Shells from the Lambert Graben embayment resemble large (L up to 45 mm), better-preserved, tall, articulated specimens with huge, thick ligamental nymphs from Sørsdal Formation (late Early Pliocene) at Marine Plain, Vestfold Hills (Harding 2005, pl. 9, figs d–e), and all likely represent a single unnamed, short, robust, Antarctic *Hiatella* species. Hirvas *et al.* (1993, pp. 90–91) identified the Sørsdal Formation specimens as *Hiatella arctica*, but specimens we have examined represent a distinct, probably unnamed, larger and more robust species. Specimens recorded from CRP-2/2A by

Cape Roberts Science Team (1999, pp. 139–140, 143, fig. 5.14c) and Taviani *et al.* (2001, p. 521, fig. 2g) again are similar to small specimens from New Zealand. All we can do with the present ANDRILL 2A material is record it and its close similarity to the common shallow-water species identified in New Zealand as *Hiatella arctica*, as the taxonomy cannot be resolved from shell characters alone. The small, well-preserved specimen on the surface of a scallop valve from ANDRILL 2A, 459.0 mbsf (USNM 545840) retains tubular spines on the posterior ridges, whereas there is little sign of spines on the single posterior ridge on the other well-preserved specimen from 430.54–430.68 mbsf (USNM 545838); its upper posterior ridge fades out a few mm below the umbo. Dell and Fleming (1975, p. 697) recorded one small specimen as *H. arctica*, ca. 10 mm long, from DSDP Site 270, drilled in the Ross Sea (77°26.48′S, 178°30.19′W), in 634 m of water. The *Hiatella* specimen is from core 270-14-1 (23–24 cm), from a depth of ca. 120 m in the Miocene part of the core. They pointed out that the southernmost published record today is at 60ºS (Dell and Fleming 1975, p. 699). However, an apparently undescribed species of *Hiatella* is known to be living now in the fiords deeply indenting the Antarctic Peninsula, such as Marguerite Bay (M. Taviani, personal observation; Hart and Taviani *in* Whitehead *et al.* 2006*a*, p. 135).

In summary, we recognize three Antarctic fossil and living *Hiatella* species: (1) A small species, up to only 28 mm long, occurring in Oligocene–Early Miocene rocks, and indistinguishable from New Zealand specimens identified as *Hiatella arctica*; (2) an apparently unnamed, much larger, tall, robust species with huge nymphs occurring in Late Miocene–Pliocene rocks (Sørsdal Formation and Lambert Graben embayment); and (3) another probably unnamed species recorded by Hart and Taviani *in* Whitehead *et al.* (2006*a*, p. 135) living in fiords such as Marguerite Bay along the Antarctic Peninsula. These all seem to be distinct from both *Hiatella solida* and *H. australis*. All three Antarctic species require extensive further research to determine their identity. This record suggests that an apparently cosmopolitan species identified here as *Hiatella arctica* inhabited Antarctica during relatively warm Oligocene and Miocene time, but was replaced by a much larger, taller, thicker-shelled *Hiatella* species without obvious macrosculpture during cooler Late Miocene–Pliocene time.

Beu (1971) pointed out that Strauch (1968) determined that North Atlantic specimens of *Hiatella arctica* increase in size regularly northwards, that is, as water temperature decreases. They attain a length of only 7.4 mm in Barbados, but up to 47 mm and rarely to 70 mm in the Arctic Ocean. Strauch (1968) concluded that shell length of *H. arctica* could be used as an indirect measure of sea temperature. If we assume that the ANDRILL 2A specimens are conspecific with the species identified as *H. arctica* in New Zealand, based on uniformitarian principles using the known sea temperature of the area inhabited at present by *H. arctica* around New Zealand, the length of ANDRILL 2A specimens can be used as an indirect temperature measure in the same manner as it was by Strauch (1968). As the largest specimens from around New Zealand reach little more than 23 mm long, a size range with a maximum at about 28 mm would be expected to be reached in the southern New Zealand area at present, although it is difficult to quantify how far south in view of the poorly known taxonomy of this genus. The sea temperature around southernmost New Zealand at present is roughly 5°C warmer than in the Ross Sea. Therefore, 28 mm-long specimens of *Hiatella arctica* in Burdigalian rocks in ANDRILL 2A suggest that the sea temperature was ca. 5°C warmer in the Ross Sea during Burdigalian time than it is at present. This is far from a definite determination, however, and the taxonomy and temperature range of *Hiatella* are major tasks for the future.

DISCUSSION

Faunal overview

The most obvious character of the Burdigalian molluscan fauna of core ANDRILL 2A is an unusually high diversity of Pectinidae for an Antarctic fauna. We record

Adamussium cf. *jonkersi*, *Antarctipecten* n. gen. *alanbeui*, *Austrochlamys forticosta* n. sp., *Austrochlamys* cf. *marisrossensis*, *Ruthipecten* n. gen., n. sp., and a fragmentary, apparently unnamed new genus and species. Apart from the six epifaunal pectinids, we record only the infaunal protobranch bivalve ?*Yoldia* sp. at 543.15–543.16 mbsf, the infaunal venerid bivalve *Retrotapes andrillorum* n. sp. from three horizons, and the nestling and boring hiatellid bivalve *Hiatella* cf. *arctica* from three horizons. However, the presence of well-preserved aragonitic shells of *Retrotapes* and *Hiatella* suggests that aragonitic molluscs have been removed from other parts of the core through diagenesis. Examples of several types of diagenetic alteration in the core, through to complete dissolution of carbonate, were shown by Panter *et al*. (2010, figs 31, 32). Other less well-preserved specimens present in the core are not discussed here, as none is identifiable to species level or, in most cases, even to genus or family. They were listed by Taviani *et al.* (2010, table 5). Geochemical data from some of the best-preserved pectinids and venerids from ANDRILL 2A provided strontium isotope ages and palaeotemperature measurements for the environment of the Ross Sea during the Miocene (Marcano *et al*. 2009). Unfortunately, some of the best material that might have amplified knowledge of fossil scallops in the present paper was destroyed in strontium isotope dating (Acton *et al*. 2010, table 3); e.g., 366.80–366.85 mbsf, ‘well-preserved, articulated *Adamussium*? sp.’; 430.54–430.68 mbsf (the pectinid concentration), ‘costate pectinid, articulated; well-preserved’ (presumably an articulated specimen of *Austrochlamys forticosta* n. sp.); 1063.71–1063.73 mbsf, ‘*Adamussium* cf. *alanbeui,* well-preserved, with umbo, sliced’.

Of the pectinid genera present in ANDRILL 2A, the present paper demonstrates that *Ruthipecten* n. gen. is the only one so far strictly limited to the Antarctic continent, although the unnamed genus and species possibly also belongs in this category; its geographical range is unknown. *Austrochlamys* is still extant around southern South America, where it also occurs as Holocene fossils dredged on the shelf (Jonkers 2003). It is also recorded as a late Pleistocene or Holocene fossil on the Campbell Plateau, southern New Zealand (Jonkers 2003; Dijkstra and Marshall 2008), but is not now living around the Antarctic continent (Jonkers 2003). However, it had a rather long history (at least Early Miocene to late Early Pliocene, ca. 20–4 Ma) of occurrence in seas now represented by rocks exposed on the continent (Jonkers 2003; new data here). *Adamussium* and *Antarctipecten* n. gen. both occur as fossils at King George Island, South Shetland Islands (Jonkers 2003; Quaglio *et al*. 2010), as well as in Ross Sea droll holes. *Adamussium* also occurs fossil on the mainland of Antarctica (Stilwell *et al*. 2002), and *Adamussium colbecki* is the only large scallop now living around Antarctica (Dell 1990; Jonkers 2003; Schiaparelli and Linse 2006). The genus *Leoclunipecten* n. gen. is not known from the Antarctic continent, as it is recorded only from King George Island and possibly from Kerguelen Island (Jonkers 2003). The present paper demonstrates that *Antarctipecten* n. gen., *Ruthipecten* n. gen. and *Leoclunipecten* n. gen. are extinct, whereas *Austrochlamys* and *Adamussium* still survive.

Taphonomy

We interpret scallops in the ANDRILL 2A core as providing ample evidence of transport before deposition. Few occur as articulated shells. The single specimen of the unnamed genus in the pectinid concentration at 530.54–530.68 mbsf and the material of *Antarctipecten* n. gen. *alanbeui* from the top and bottom of the shelly interval at 376.80–376.85 and 999.76–999.80 mbsf provide the only exceptions, apart from one probably originally articulated specimen (the holotype) of *Austrochlamys forticosta* n. sp. from the pectinid concentration at 530.54–530.68 mbsf (and specimens destroyed in dating). Several specimens throughout the core appear to have been broken before deposition, and many in the pectinid concentration at 530.54–530.68 mbsf have been crushed together at high angles. The pectinid concentration at 530.54–530.68 mbsf is a transported death assemblage, suggesting the possibility that many of the other specimens have been transported into the deposition site.

Scallop shell forms and ecology

The symmetry and sculpture of pectinid shell forms are well known to reflect ecological selection pressures. Brand (2006, pp. 698–708) reviewed the literature on swimming and escape responses in scallops, and Waller (1991, p. 10) described the ecologically based shell forms consistently adopted by scallops – forms that wrongly have been assumed to have phylogenetic significance by earlier workers (Waller 1991). Studies of living specimens have shown that scallops occupy mainly coarse-grained substrates and respond much more strongly to extra-orally feeding (that is, stomach-everting) seastars than to other predators such as crabs and fish, and show little response to non-predatory, intra-orally feeding seastars – but these empirical studies took place in the North Atlantic, outside regions occupied by tropical durophagous fish. Johnson (1984, pp. 17–21) described morphological paradigms for the modes of life of scallops. G. J. Vermeij (pers. comm. to Johnson 1984) reported that although there are few extra-orally feeding seastars in the tropics, durophagous teleosts are major predators of extant scallops there, on firm level bottoms of fine grain-size but low turbidity. Consequently, weakly sculptured or smooth, thin-shelled, weakly biconvex, rapidly swimming scallops (the amusioid shell form) are much more diverse in the tropics than in temperate areas at present. Conversely, thick-shelled, strongly biconvex, strongly ribbed scallops, which cannot be opened by seastars when adult, are the more diverse shell form in temperate areas. They can be either byssally attached and asymmetrical throughout life (chlamydoid shell form) or free-lying and symmetrical as adults (aequipectinoid shell form).

Among many other studies of the ecology and genetics of the living Antarctic scallop *Adamussium colbecki*, some aspects of its growth (including fortnightly growth pauses), swimming, epifauna, predation, valve clapping to aid feeding, and other ecological aspects have been described by many authors (Stockton 1984, Barrera *et al.* 1990, Cattaneo-Vietti *et al.* 1997, 2000, Albertelli *et al.* 1998, Ansell *et al.* 1998, Chiantore *et al.* 1998, 2002, Danovaro *et al.* 1999, Vacchi *et al.* 2000, Cerrano *et al.* 2001, Regoli *et al.* 2002, Heilmayer and Brey 2003, Heilmayer *et al.* 2003, 2005, Berkman *et al.* 2004, Corsi *et al.* 2004*a*, *b*, Denny and Miller 2006, Guidetti *et al.* 2006, Lartaud *et al.* 2010, McClintock *et al.* 2010). *Adamussium colbecki* lies at the margin of swimming ability in scallops, because of the combination of its cold environment (-1.8°C), the consequent increased water viscosity and decreased power output of the adductor muscle, its reduced adductor muscle mass, and its fragile shell (Denny and Miller 2006). Its swimming ability is enhanced slightly, however, by its more resilient abductin in the resilifer than in temperate and tropical scallops (Denny and Miller 2006). Despite its marginal position among swimming scallops, *A. colbecki* is an adept swimmer (Ansell *et al.* 1998). An excellent popular account of its swimming was provided by Summers (2007).

The distribution of *Adamussium colbecki* serves as a good model for environments inhabited by the fossils, at least of tribe Adamussiini. It lives now all around Antarctica (Jonkers 2003, fig. 14) at depths of at least 4–1380 m (Dell 1990, p. 35), although empty shells have been collected in much deeper water, to at least 4545 m (Jonkers 2003, p. 14). Schiaparelli and Linse (2006) reassessed its distribution carefully, recognising that although it is circum-Antarctic, and lives to the east of Drake Passage as far north as 61°11′S off the South Sandwich Islands, dense communities of *A. colbecki* are unexpectedly sparse for a planktotroph. They live in stable environments, (a) in near-shore shallow areas, in calm settings with persistent sea-ice cover, and (b) deeper on the shelf, in areas with infrequent iceberg scour and without structured communities of suspension and filter feeders such as sponges and cnidarians. Dense communities of suspension and filter feeders evidently predate the planktotrophic larvae of *Adamussium colbecki* efficiently enough to prevent the establishment of permanent adult populations. However, dense communities of sponges and cnidarians likely are a feature of only the Pleistocene to present-day Antarctic environment, allowed by the decrease in predators during glacial climates, and probably did not restrict the distribution of scallops during Oligocene to Early Pliocene time, when the present work has demonstrated that a much greater variety of scallops inhabited Antarctica. Guidetti *et al*. (2006) also showed that genetic exchange between quite closely spaced populations of *A. colbecki* is very limited.

Austrochlamys, *Ruthipecten* n. gen., *Leoclunipecten* n. gen. and presumably the unnamed genus retained a functional byssal notch and ctenolium in the adult, and seem to have been byssally attached (chlamydoid) throughout life, although presumably facultatively releasing their byssus and swimming briefly to avoid predators. For the unnamed genus, this inference is based on its weakly prosocline, apparently chlamydoid form, as the umbonal area and auricles are not preserved. In contrast, *Adamussium* and *Antarctipecten* n. gen., with their classic amusioid shell form, were free-lying forms adapted to swimming readily to escape predators. The existence of both byssally attached and free-lying taxa in the ANDRILL 2A core, segregated to some extent at different depths, indicates that Early Miocene scallops were subject to both slow-moving benthic predators and fast-moving swimming predators in distinct environments. *Adamussium* cf. *jonkersi* was collected from a unit dominated by sandy diamictite; the partial mould is in coarse sandstone with obvious scattered fine pebbles, up to 5 mm in diameter. In contrast, the two occurrences of *Antarctipecten* n. gen. were collected from finer-grained lithologies, weakly consolidated medium sandstone (376.80–376.85 mbsf) and sandy siltstone (999.76–999.80 mbsf). The one specimen assigned to *Ruthipecten* n. gen. was collected from coarse sandy diamictite with sparse pebbles up to 15 mm in diameter, and the single record of *Austrochlamys* cf. *marisrossensis* was collected from fine to coarse sandstone. Specimens of *Austrochlamys forticosta* n. sp. were collected from lithologies varying from interlaminated siltstone and very fine sandstone (459.0 mbsf), the pectinid concentration at 430.54–430.68 mbsf in a siltstone to fine sandstone matrix, to sandy diamictite to muddy sandstone (466.5–469.9 mbsf). The unnamed genus also occurred in the pectinid concentration at 430.54–430.68 mbsf. In summary, *Ruthipecten* n. gen., *Adamussium* and some specimens of *Austrochlamys* were collected from diamictite, whereas *Antarctipecten* n. gen., the unnamed genus, and the other specimens of *Austrochlamys* were collected from finer-grained lithologies.

Based on the present-day ecology summarized above, we would have expected an association of the amusioid scallops *Adamussium* and *Antarctipecten* n. gen. with fine-grained lithologies resulting from slow, background deposition on a level bottom frequented by durophagous fish. All the other, byssally attached, radially ribbed scallops would be expected to occur in coarser lithologies resulting from current-bypassing of sediment on more irregular bottoms inhabited by benthic predators such as extra-orally feeding seastars, and possibly crustaceans and octopods. However, actual occurrences do not conform to these expectations. As noted above, the pectinid concentration at 430.54–430.68 mbsf is a transported assemblage of broken shells, suggesting that transport of other specimens explains the unexpected lithologies that some of the scallops were collected from. Sedimentary facies distribution in ANDRILL 2A was described by Passchier *et al*. (2011) and lithologies were interpreted in terms of sedimentary sequences by Fielding *et al*. (2011). Diamictite in this glacial environment was described by these authors as deposited on ‘polar continental shelves flanked by polythermal or cold ice masses’ (Passchier *et al*. 2011, p. 2358) where sediment is contributed by glacial outwash, although more dispersed clasts in finer sediment possibly result from transported sediment within glaciers, as drop-stones, indicating deposition beneath an ice shelf. Also, scallops are inefficient mantle cleaners and avoid turbid water and soft, fine-grained substrates, to the extent that temperate commercial scallop beds can be found by 'acoustic bottom discrimination techniques' to recognize gravel and other coarse substrates on which the scallops live (Brand 2006, p. 678). In view of the highly active environment expected during the deposition of diamictite off a glacially scoured coast, transport of most macrofossils and virtually all the microfossils into the deposition site seems likely in this Antarctic setting. In particular, if the specimen at 740.84–740.86 mbsf is correctly assigned to the amusioid genus *Adamussium*, it likely was transported into the diamictite deposition site. This conclusion suggests the possibility that, rather than reflecting their original ecology and such factors as whether predators were benthic seastars or fast-swimming fish, macrofossils in diamictite have all been reworked. It seems possible that scallops (and possibly most molluscs in the core) were present only during relatively warm periods when environments were less severe than during glacial periods of diamictite deposition.

Water temperature

The presence of six taxa of Pectinidae but of only two other well-preserved bivalves and no well-preserved gastropods in the ANDRILL 2A core results in part from the better preservation of calcitic scallop shells and the dissolution of most aragonitic molluscan shells in this core. A single well-preserved fragment of a smooth, subspherical gastropod, probably referrable to Naticidae, is present at 464.5 mbsf (USNM 545847), but this is the only gastropod recognized. The single large pectinid *Adamussium colbecki* inhabits Antarctic waters at present, and diverse large scallops are not encountered until the southern Magellanic shelf at 57°S in the South American sector (Jonkers 2003, fig. 20) and the subantarctic Campbell and Auckland Islands at 55°S in the New Zealand sector (Jonkers 2003, fig. 22; McArthur *et al.* 2006, fig. 5). Berkman *et al.* (2004) pointed out that the increase in sea-ice as temperatures fell through Pliocene time removed *Austrochlamys* from the Antarctic environment, leaving only *Adamussium colbecki* living there, other than very small, ecologically distinct 'glass scallops' (*Hyalopecten* and Propeamussiidae). At the southern limits of the ranges of large scallops at present, mean annual sea temperatures are now ca. 5°C warmer than in the Ross Sea, indicating in turn, by simple uniformitarian extrapolation, that Early Miocene (Burdigalian) sea temperatures in the Ross Sea region were ca. 5°C warmer than at present. We also point out above that the relatively small size (L up to 28 mm) of specimens referred to *Hiatella* cf. *arctica* indicates relatively warm sea temperatures at the time of deposition, ca. 5°C warmer than in the Ross Sea at present, assuming we can rely on the identification and on its temperature tolerances in the North Atlantic determined by Strauch (1968). Based on diatoms, Whitehead *et al.* (2004) also indicated a summer sea surface temperature of >3°C during the deposition of the late Early Pliocene Sørsdal Formation, Vestfold Hills, which contains *Austrochlamys anderssoni* and *Ruthipecten* n. gen. *tuftsensis* – the one locality where these two genera occur syntopically. They pointed out, however, that the presence of non-cryophilic cetacean fossils in Sørsdal Formation (an endemic genus and species of dolphin, a beaked whale and a baleen whale; Fordyce and Quilty 1994; Fordyce *et al.* 2002) indicates a summer sea surface temperature reaching 4–5°C at times (Quilty 1993), consistent with the Early Miocene sea temperatures indicated by the diverse Pectinidae and the size of *Hiatella* specimens in ANDRILL 2A. The unusual diversity of scallops reflects markedly warmer sea temperatures during the Early Miocene than at present in the Ross Sea region.

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FIGURE CAPTIONS

TABLE 1. Pectinidae recorded fossil from Antarctica, including subantarctic islands and islands of the Antarctic Peninsula. Species identified with an asterisk* revised in this report; all other revised by Jonkers (2003) (E = Early, L = Late).

TABLE 2. Comparison of characters of *Adamussium* and *Antarctipecten* species, modified from Quaglio *et al.* (2010, table 2).

FIG. 1. Location within the ANDRILL 2A core of the specimens studied in this report, and age of the core (updated log, sequence numbers to right of lithological log, and latest age model provided by R. Levy, GNS Science, March 2012). Depth in mbsf along left edge. For detailed log see Fielding *et al.* (2010, fig. 1) and for more detail see http://doi.pangaea.de/10.1594/PANGAEA.743224.

FIG. 2. Ages adopted for Oligocene and Neogene formations of Antarctica and the subantarctic islands, the pectinids from which are revised in this paper. Time scale from Gradstein *et al.* (2012).

FIG. 3. A–C, ?*Yoldia* sp., USNM 545843, ANDRILL 2A core, 543.15 mbsf; A, right lateral view; B, dorsal view; C, centre of Fig. 3B enlarged, showing mould of hinge teeth. D, F, *Austrochlamys anderssoni* (Hennig). D, BAS DJ.851.4, complete RV, Cockburn Island Formation (Early Pliocene), Cockburn Island, Antarctic Peninsula (BAS photo presented by H. A. Jonkers). F, NMV P302320, latex replica of natural mould of juvenile RV, with partial LV showing beneath, Sørsdal Formation (Early Pliocene), lower lens, Pickard's Cairn, Marine Plain, Vestfold Hills. E, *Austrochlamys*

cf. *marisrossensis* Jonkers, fragment, USNM 545826, ANDRILL 2A core, 429.25 mbsf. Scale bar for Fig. 3C represents 5 mm; all other scale bars represent 10 mm.

FIG. 4. *Austrochlamys forticosta* n. sp., ANDRILL 2A core. A, paratype, USNM 545831, isolated RV anterior auricle, 430.54–430.68 mbsf. B–C, holotype, USNM 545830, 430.54–430.68 mbsf, fragmentary LV (B) and RV (C) of one specimen, cut at oblique angle by core-splitter. D, paratype, USNM 545833, same horizon as holotype, most coarsely sculptured fragment seen, from valve distal margin. E, paratype, USNM 545832, same horizon as holotype, coarsely sculptured valve margin cemented to valve fragment facing in the opposite direction. F, paratype, USNM 545841, 466.5–469.0 mbsf, fragment of disc cut by core splitter. G, paratype, USNM 545839, 459.0 mbsf, fragment from near valve distal margin; valve of *Hiatella* attached near mid-dorsal margin. Scale bars represent 10 mm.

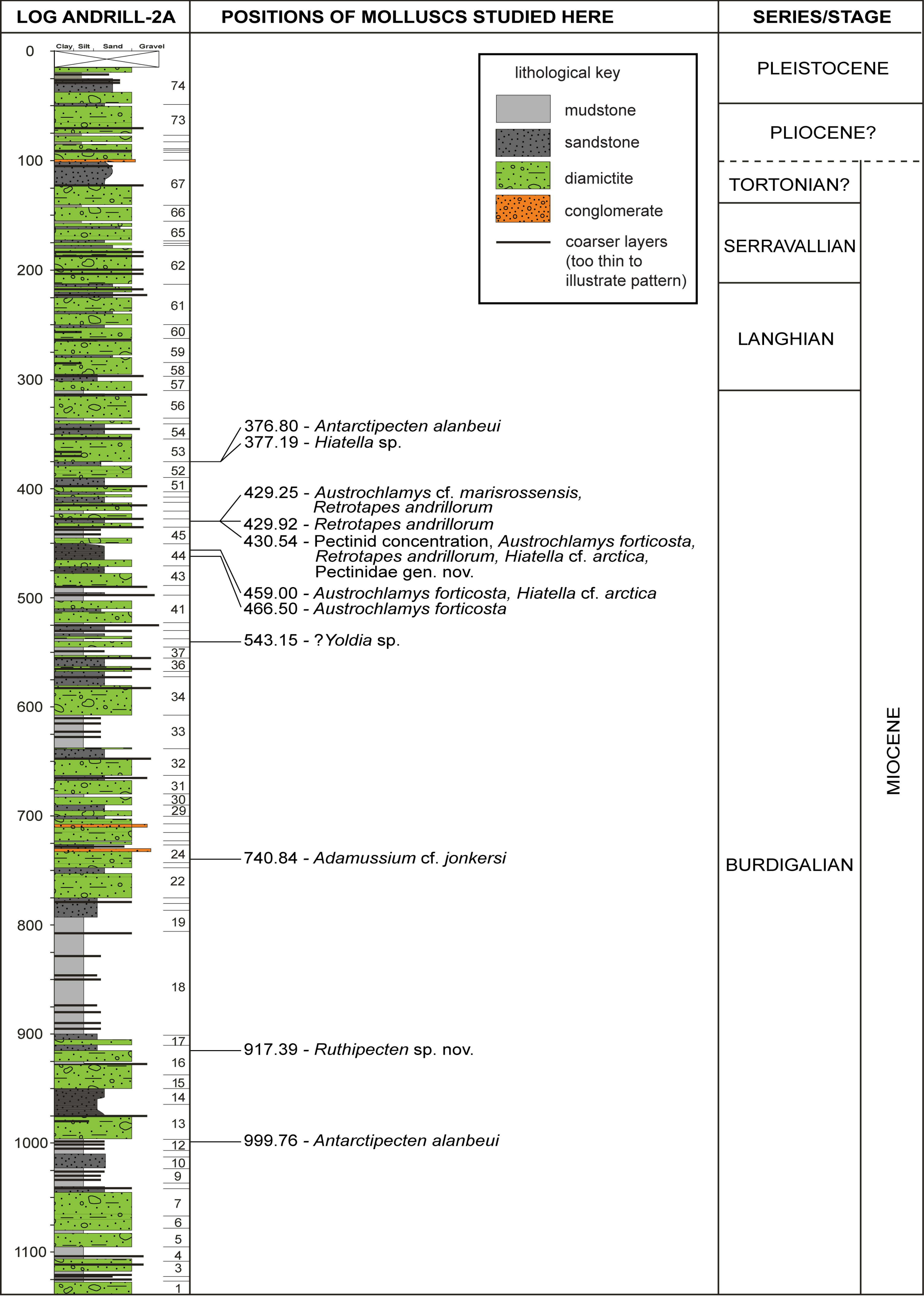
FIG. 5. *Ruthipecten* n. gen. *tuftsensis* (Turner). A, holotype, RV, MCZ 256085 (not whitened), Prospect Formation (Late Miocene), Prospect Mesa, Wright Valley (MCZ photo by Adam Baldinger, copyright President and Fellows of Harvard College). B–F, Sørsdal Formation (Early Pliocene), Graveyard Sandstone Member, Marine Plain, Vestfold Hills. B, RV?, NMV P302312, incomplete internal mould. C, NMV P302297, large RV with hinge of LV showing beneath (at top) and remnant of ctenolium. D, LV?, NMV P302318, the one Sørsdal Formation specimen seen with most shell remaining. E–F, NMNZ M234194, 2 valves of articulated specimen, internal mould, Marine Plain trench 2, collected by J. Pickard, 10 Jan. 1981. Scale bars represent 10 mm.

FIG. 6. A, *Leoclunipecten* n. gen. *gazdzickii* (Jonkers), holotype, RV, BAS P.2856.38 (not whitened), Low Head Member of Polonez Cove Formation (late Early Oligocene), Battke Point, Lions Rump area, King George Island, South Shetland Islands (BAS photo by Peter Bucktrout). B, *Ruthipecten* n. sp.?, USNM 545845, ANDRILL 2A core, 917.39–917.67 mbsf, partial internal mould cut by drill. C, Pectinidae n. gen., n. sp., fragment, USNM 545835, ANDRILL 2A core, 430.54-430.68 mbsf. Scale bars represent 10 mm.

FIG. 7. A, *Adamussium* cf. *jonkersi* Quaglio, Whittle, Gazdzicki and Simões, USNM 545844, ANDRILL 2A core, 740.84–740.86 mbsf, LV?, partial internal mould cut by drill. B–E, *Antarctipecten* n. gen. *alanbeui* (Jonkers), ANDRILL 2A core, all cut by core-splitter. B–C, USNM 545823, 376.80–376.85 mbsf, incomplete LV and RV of one specimen. D–E, USNM 545846, 999.76–999.80 mbsf, incomplete LV and RV of one specimen, slightly deformed by compaction. Scale bars represent 10 mm.

FIG. 8. *Retrotapes andrillorum* n. sp., holotype, USNM 545829, ANDRILL 2A core, 429.92–430.02 mbsf. A–B, exterior and interior of incomplete LV. C, oblique antero-dorsal view showing lunule and weakly defined escutcheon, anterior downwards. D, dorsal view of articulated shell, anterior upwards. E, interior of incomplete RV. Scale bars represent 10 mm.

FIG. 9. *Hiatella* cf. *arctica* (Linnaeus), ANDRILL 2A core. A, C, USNM 545838, 430.54–430.68 mbsf; A, LV of articulated shell, valves slightly offset; C, RV of the same articulated shell. B, USNM 545840, 459.0 mbsf, small LV attached to fragment of *Austrochlamys forticosta* n. sp. shown in Fig. 4G. Scale bars represent 10 mm.



LOG ANDRILL-2A
POSITIONS OF MOLLUSCS STUDIED HERE
SERIES/STAGE
Clay Silt Sand Gravel
0
100
200
300
400
500
600
700
800
900
1000
1100
74
73
67
66
65
62
61
60
59
58
57
56
54
53
52
51
45
44
43
41
37
36
34
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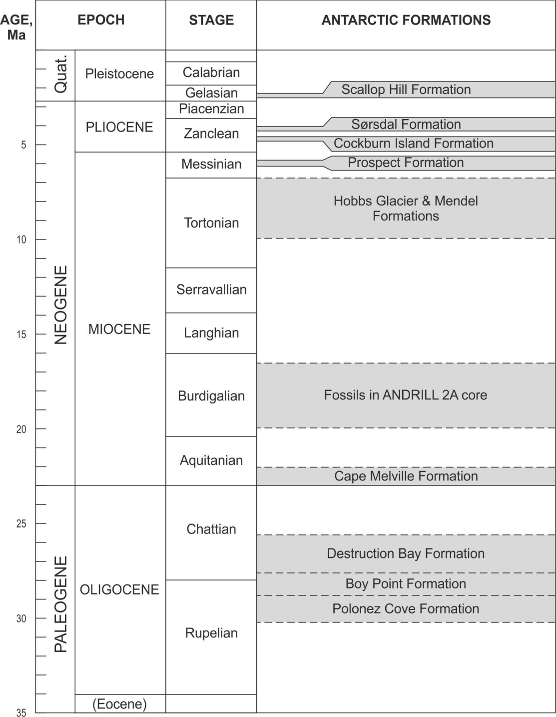
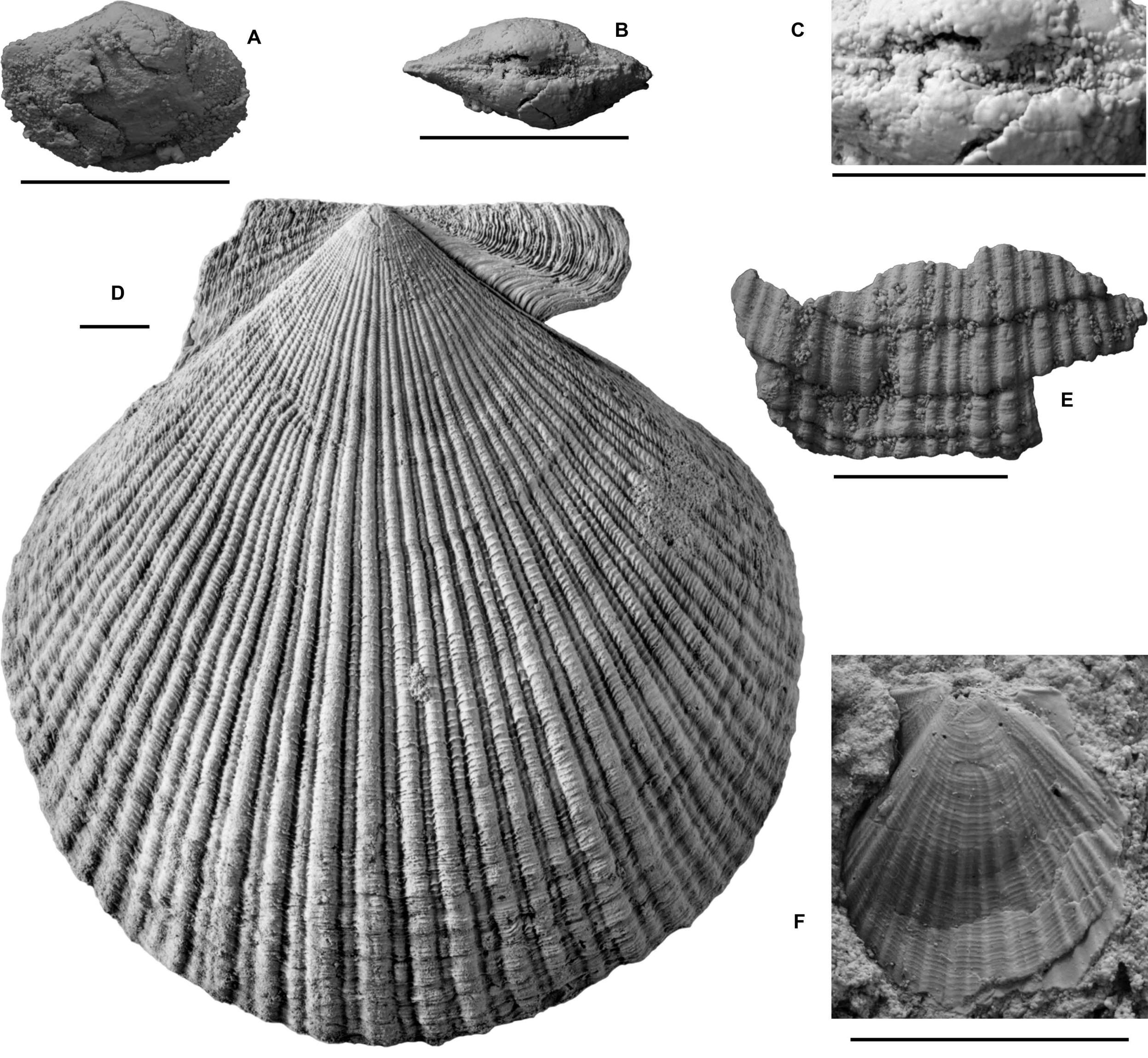
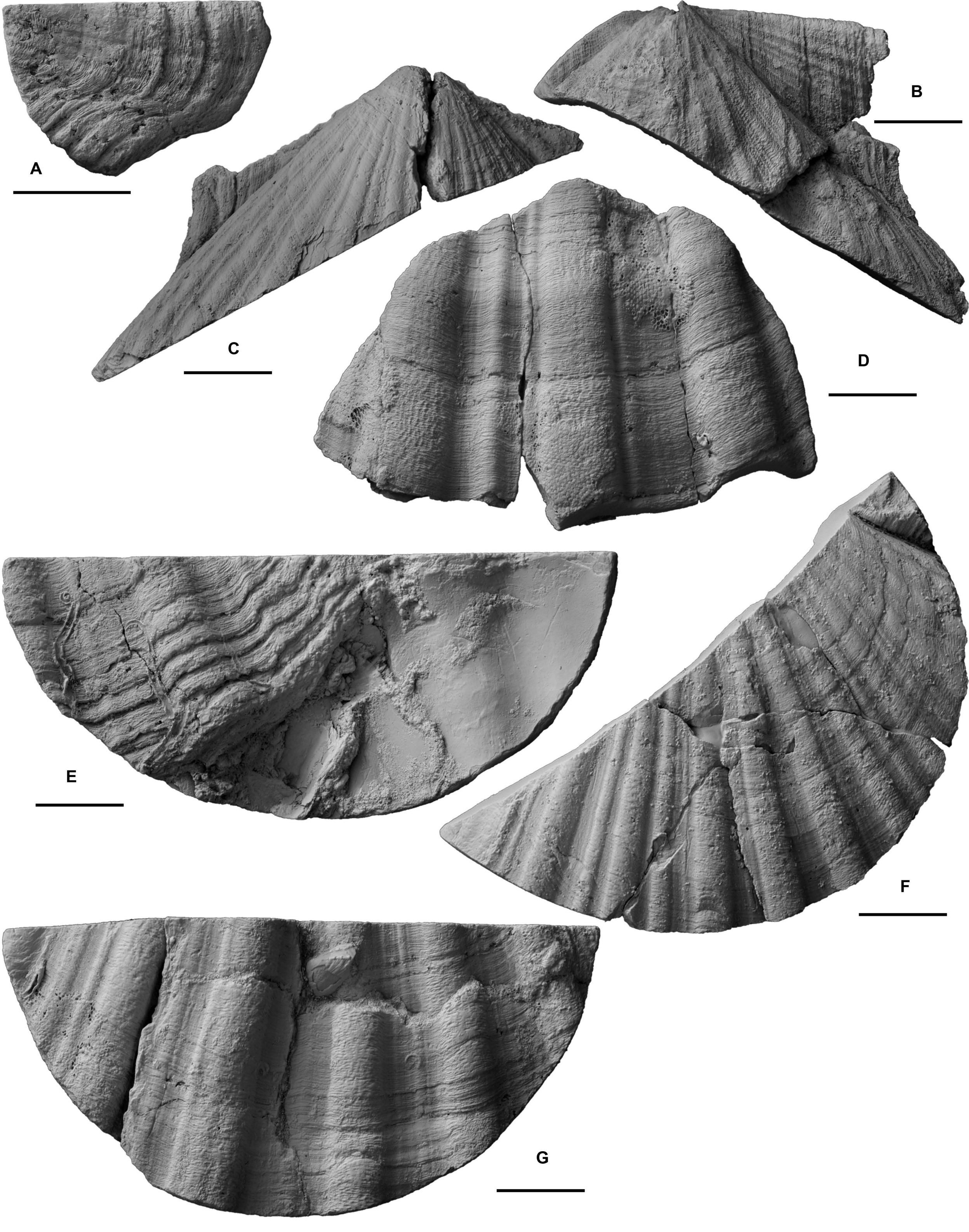
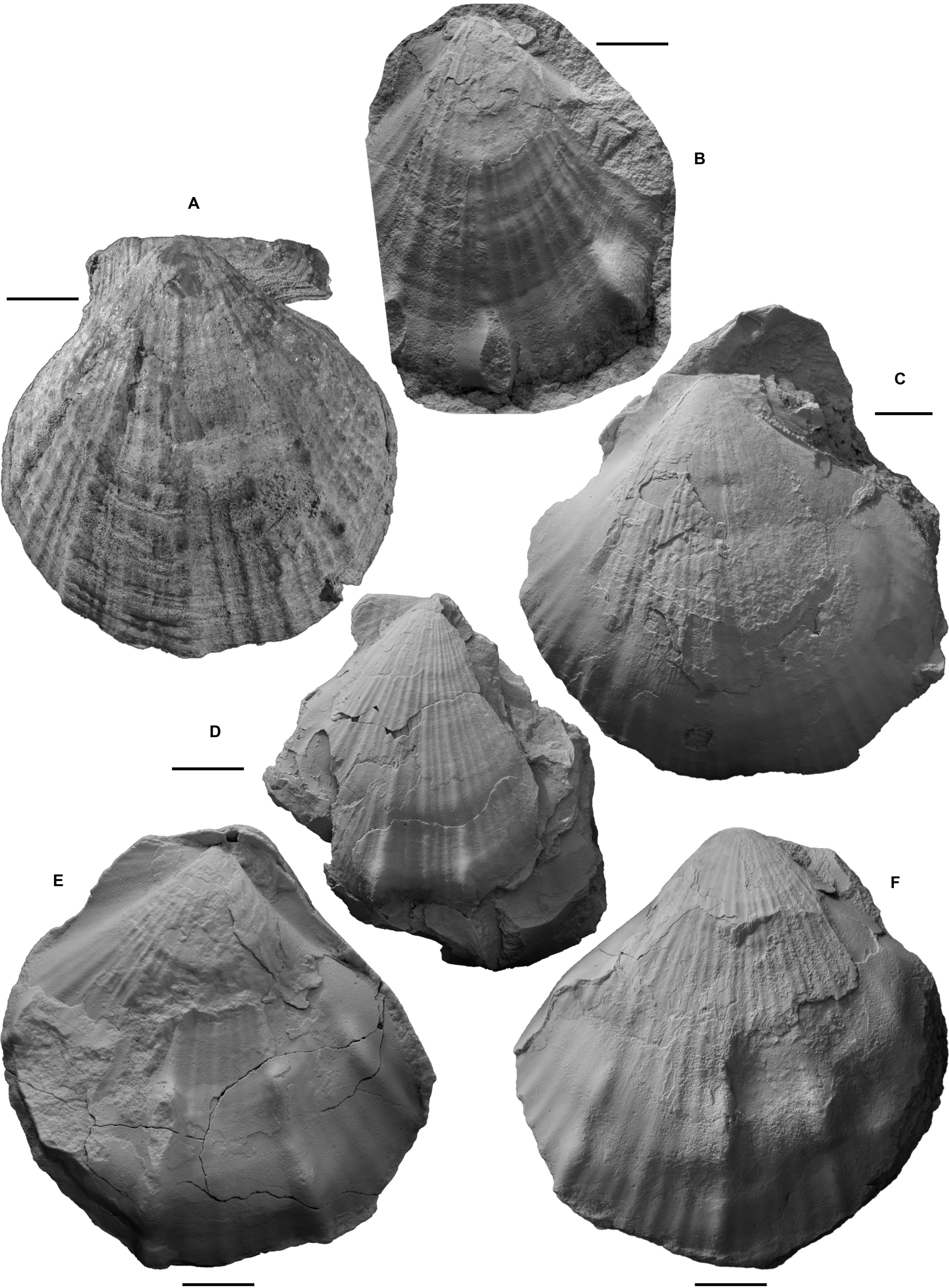
30
29
24
22
19
18
17
16
15
14
13
12
10
9
7
6
5
4
3
1
lithological key
mudstone
sandstone
diamictite
conglomerate
coarser layers (too thin to illustrate pattern)
376.80 - *Antarctipecten alanbeui*
377.19 - *Hiatella* sp.
429.25 - *Austrochlamys* cf. *marisrossensis*, *Retrotapes andrillorum*
429.92 - *Retrotapes andrillorum*
430.54 - Pectinid concentration, *Austrochlamys forticosta*, *Retrotapes andrillorum*, *Hiatella* cf. *arctica*, Pectinidae gen. nov.
459.00 - *Austrochlamys forticosta*, *Hiatella* cf. *arctica*
466.50 - *Austrochlamys forticosta*
543.15 - ?*Yoldia* sp.
740.84 - *Adamussium* cf. *jonkersi*
917.39 - *Ruthipecten* sp. nov.
999.76 - *Antarctipecten alanbeui*
PLEISTOCENE
PLIOCENE?
TORTONIAN?
SERRAVALLIAN
LANGHIAN
BURDIGALIAN
MIOCENE

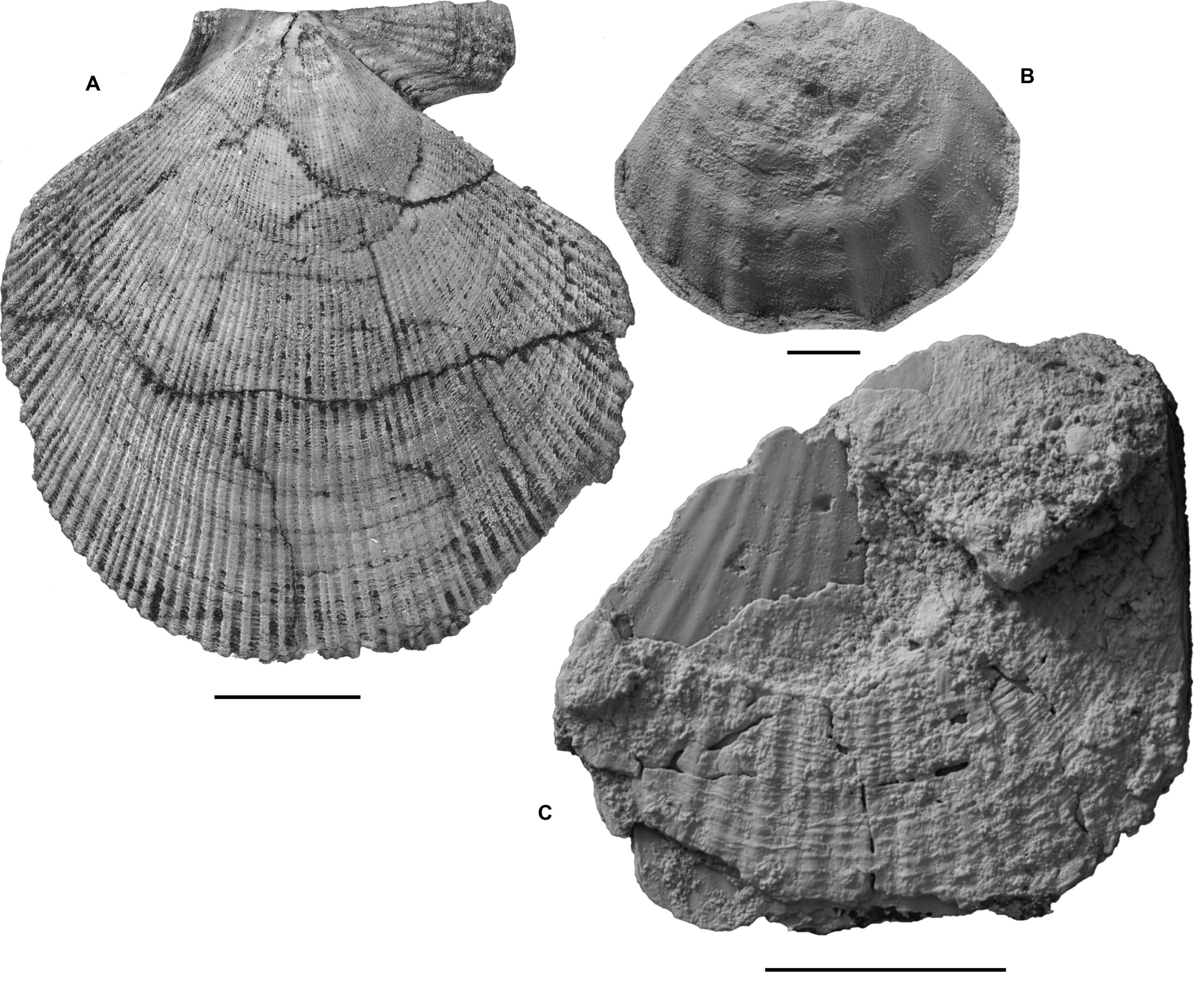


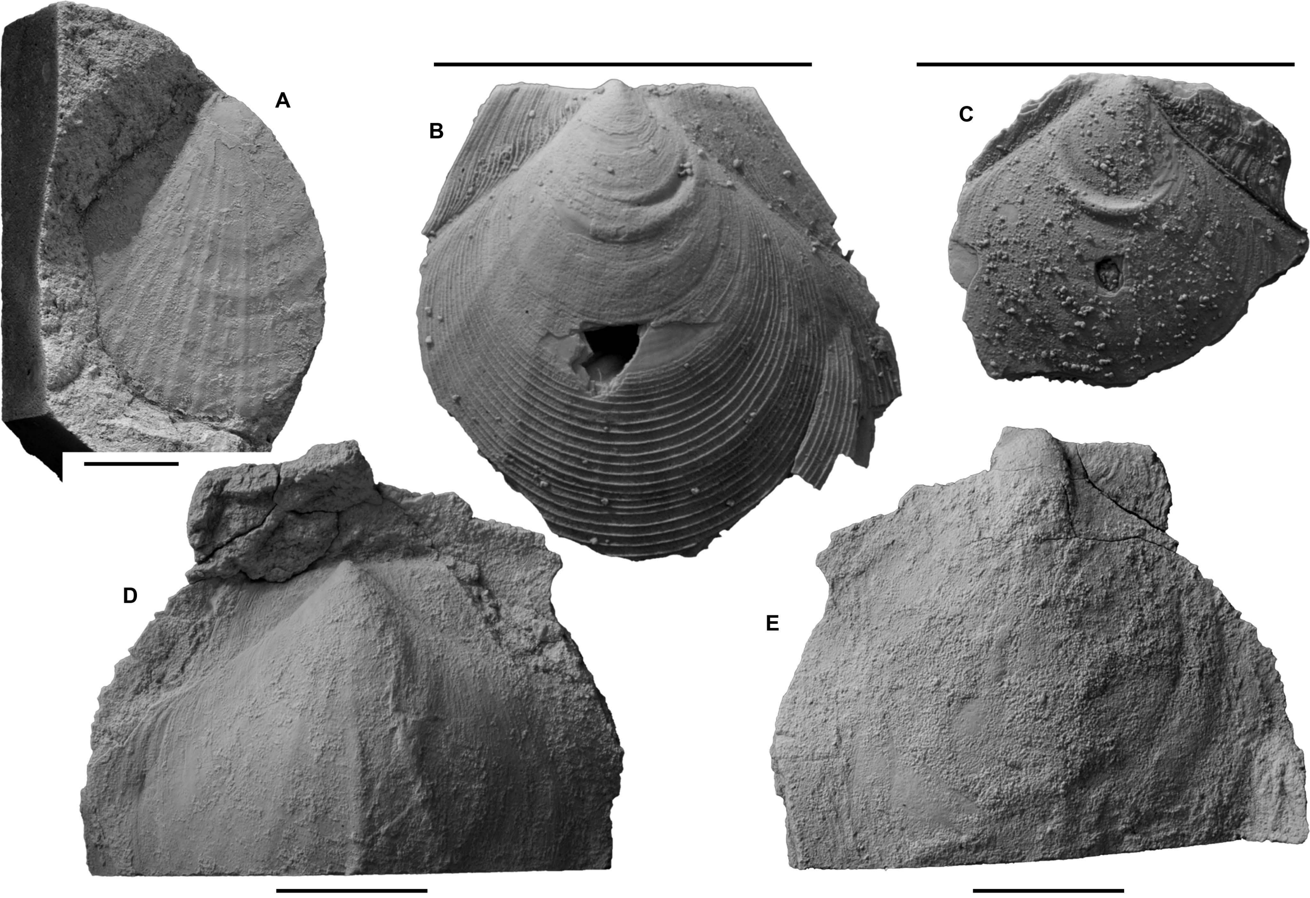
AGE, Ma
EPOCH
STAGE
ANTARCTIC FORMATIONS
Quat.
Pleistocene
Calabrian
Gelasian
Scallop Hill Formation
Piacenzian
PLIOCENE
Zanclean
Sørsdal Formation
Cockburn Island Formation
5
Messinian
Prospect Formation
Tortonian
Hobbs Glacier & Mendel Formations
10
Serravallian
NEOGENE
MIOCENE
Langhian
15
Burdigalian
Fossils in ANDRILL 2A core
20
Aquitanian
Cape Melville Formation
25
Chattian
Destruction Bay Formation
PALEOGENE
OLIGOCENE
Boy Point Formation
Polonez Cove Formation
30
Rupelian
(Eocene)
35


A
B
C
D
E
F


A
B
C
D
E
F
G


B
A
C
D
E
F


A
B
C


A
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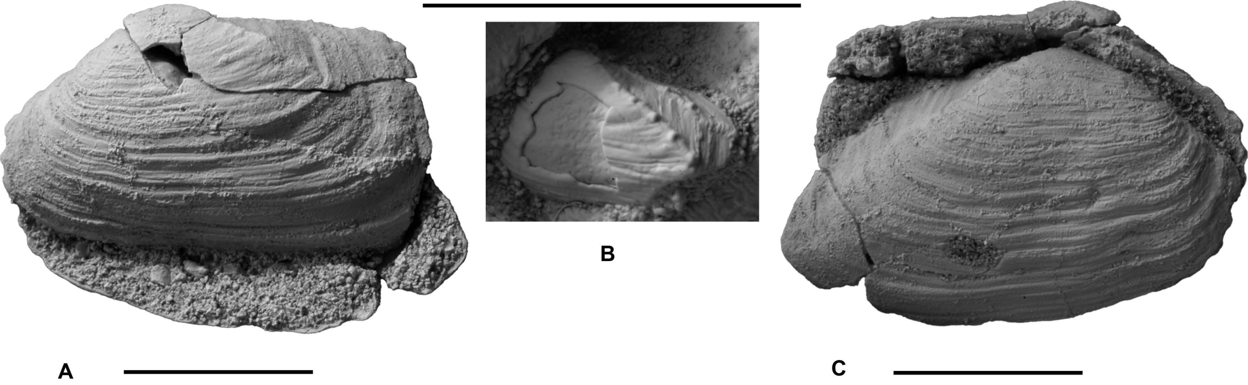
B
A
C