A new fossil *Adamussium* (Bivalvia: Pectinidae) from Antarctica

Fernanda QUAGLIO[1], Rowan Jane WHITTLE[2], Andrzej GAŹDZICKI[3]
and Marcello Guimarães SIMÕES[4]

[1]*Instituto de Geociências, Universidade de São Paulo USP,
Rua do Lago 562, Cidade Universitária, São Paulo, Brazil, CEP 05508-080
<quaglio@usp.br>*

[2] *British Antarctic Survey, Madingley Road, High Cross, Cambridge,
Cambridgeshire, CB3 0ET, United Kingdom
<roit@bas.ac.uk>*

[3] *Instytut Paleobiologii PAN, Twarda 51/55, 00-818, Warszawa, Poland
<gazdzick@twarda.pan.pl>*

[4] *Departamento de Zoologia, Instituto de Biociências, Universidade Estadual Paulista – UNESP,
Distrito de Rubião Júnior s/n, CEP 18618-000, Botucatu, São Paulo, Brazil
<btsimoes@ibb.unesp.br>*

Abstract: *Adamussium jonkersi* sp. nov. is described from the Late Oligocene Destruction Bay Formation, Wrona Buttress area, King George Island (South Shetlands), West Antarctica. The unit, characterized by volcanic sandstone, is a shallow marine succession deposited in a moderate- to high-energy environment. The thin-shelled pectinids, collected from the lower part of the unit, are preserved mostly as complete valves. Shell thickness, sculpture pattern and umbonal angle suggest a free-living, inactive swimming life habit.

Key words: Antarctica, *Adamussium*, Pectinidae, Destruction Bay Formation, Oligocene.

Introduction

Species of the pectinid genus *Adamussium* are recorded from the latest Early Oligocene onwards (Jonkers 2003; Quaglio *et al.* 2008). The living member of the genus, the circum-Antarctic species *Adamussium colbecki* (Smith, 1902), was the subject of several studies focusing on its geographical distribution (Schiaparelli and Linse 2006), systematics (Barucca *et al.* 2005), ecology (Stockton 1984), physiology (Chiantore *et al.* 2003; Heilmayer *et al.* 2005) and environmental analysis (Corsi *et al.* 2004; Caroli and Bottoni 2010).

Currently, four species of *Adamussium* are known, all restricted to Antarctica. Here we describe a new species from the middle Late Oligocene Destruction Bay Formation, cropping out at Wrona Buttress, King George Island (KGI).

Background

Four species attributed to the genus *Adamussium* have been identified so far from Cenozoic deposits and Recent records from Antarctica. The species *A. alanbeui* Jonkers, 2003 and *A. auristriatum* Quaglio *et* Anelli, 2008, from Oligocene to Early Miocene rocks, are the oldest known species of this genus (Jonkers 2003; Quaglio *et al.* 2008). Specimens of *A. alanbeui* and *A. auristriatum* were collected from CIROS-1 and CRP-2/2A drill-cores, Ross Sea, with additional specimens recorded in deposits of the Polonez Cove Formation, Lions Rump area, and the Cape Melville Formation, Melville Peninsula, both at KGI (Jonkers 2003; Quaglio *et al.* 2008). The second-oldest species, *A. auristriatum*, is recorded from the Early Oligocene Polonez Cove Formation, Vauréal Peak area, KGI (Quaglio *et al*. 2008). Much younger are *A. colbecki cockburnensis* Jonkers, 2003, found in the Late Pliocene Cockburn Island Formation, cropping out at the homonymous island, and *A. c. colbecki*, identified from the Late Pliocene to Early Pleistocene cores of CRP-1, James Ross Island and from Recent records around Antarctica (Jonkers 2003). The time ranges of all *Adamussium* species are shown in Fig. 1.
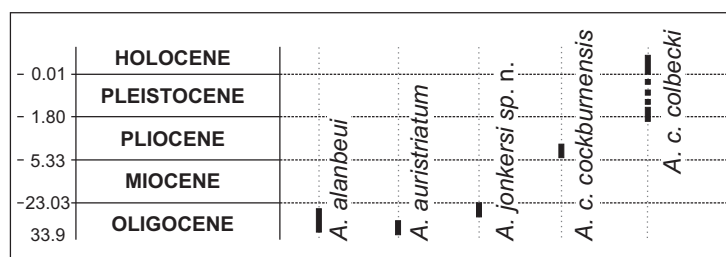

Fig. 1. Stratigraphic ranges of *Adamussium* species (data from Jonkers 2003 and Quaglio *et al.* 2008).

Material and methods

Geological setting.—The most extensive outcrops of the Destruction Bay Formation (DBF) occur in coastal cliffs to the northwest of Melville Peninsula (KGI, South Shetlands), named Wrona Buttress, where the unit reaches 90 m (Troedson and Riding 2002) to 100 m thick (Birkenmajer 1987) (Figs 2A, B; 3). Other exposures are found at the northern and southern edges of Cape Melville (Troedson and Riding 2002) (Fig. 2B). The DBF is the middle unit of the Moby Dick Group (see Fig. 2C), which also includes the lower Sherratt Bay Formation (olivine-augite basalt lavas) and the upper Cape Melville Formation (fossiliferous
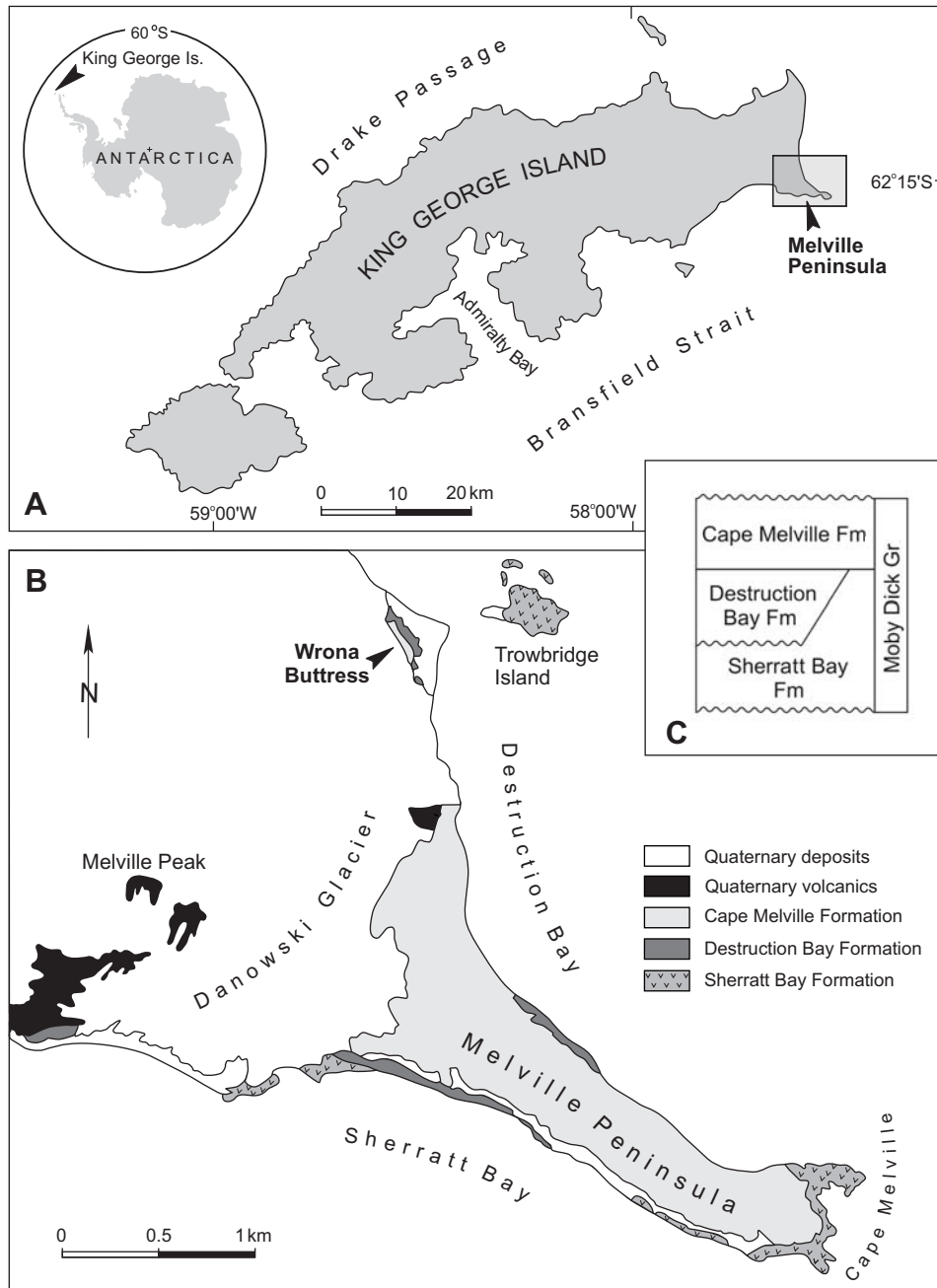
Fig. 2. Location maps of the Destruction Bay Formation and other related units. **A**. Melville Peninsula and vicinity, King George Island, West Antarctica. **B**. Destruction Bay Formation and other units of the Moby Dick Group. **C**. Subdivision of the Moby Dick Group (from Birkenmajer 1982).
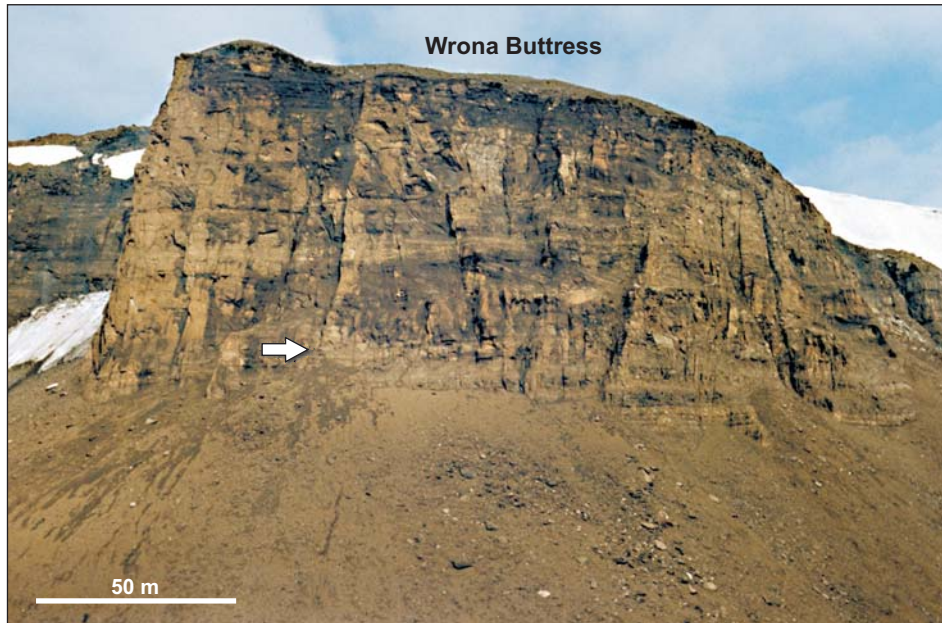
Fig. 3. Wrona Buttress. Exposure of the horizontally bedded Destruction Bay Formation, which the pectinids were collected from (arrowed). Photograph by A. Gaździcki, January 1981.

marine shale, siltstone and fine sandstone) (Birkenmajer 1982, 2001; Birkenmajer *et al.* 1983; Troedson and Riding 2002). The DBF consists of pale gray to brown sub-horizontal volcanic sandstone, fine to medium and medium to coarse-grained, with occasional muddy and gravelly sandstone beds, tabular to channelized, displaying tabular to trough cross-bedding, with parallel and cross laminations (Troedson and Riding 2002).

Fossils occur throughout the unit, except in the uppermost subunit (Troedson and Riding 2002), and are more common in the bottom to the middle part of the unit (Birkenmajer 1982, 1987). Fossils include brachiopods (Biernat *et al.* 1985), foraminifers (Birkenmajer and Łuczkowska 1987), molluscs (belemnites, Birkenmajer *et al.* 1987; bivalves, Studencka 1991; gastropods, Birkenmajer 1982, 1987; Troedson and Riding 2002), cnidarians (solitary corals, Roniewicz and Morycowa 1987), as well as fish and wood fragments (Birkenmajer 1982, 1987; Troedson and Riding 2002; see also Beu 2009).

The pectinid species here described was collected from the lower part of the unit (Fig. 3), ranging from subunits 1 to 2 of Troedson and Riding (2002).

The Moby Dick Group records a glacial event in West Antarctica, with the DBF being an interglacial phase, followed by the glacial deposits of the Cape Melville Formation (Birkenmajer 1987). The DBF, dated as Late Oligocene (25.3 ± 0.8 Ma; Dingle and Lavelle 1998), is interpreted as a shallow marine succession originating from the reworking of basaltic lavas and tuffs of the underlying

Sherratt Bay Formation (Birkenmajer1982). The basal subunits were deposited in a moderate-energy environment and the upper subunits were deposited in a high-energy environment, with a shallowing-upward tendency showing possible prograding architecture (Troedson and Riding 2002).

Fossil collection. — The studied shells were collected by A. Gaździcki during the 5th Polish Antarctic Expedition to *Artowski* Station (1980/1981) and by M. Lavelle and D. Hornby in February 1996. The material includes eleven specimens with thin recrystallized shells, some of them are partial internal and external moulds with some preserved shell material. All examined specimens are still retained in the rock matrix. The specimens are housed in the collections of the Institute of Paleobiology PAS in Warsaw, Poland, under catalogue number ZPAL/L3/38–42, and the British Antarctic Survey (BAS) in Cambridge, United Kingdom, under number P.2904.10.1.

Measurements and classification. — Specimens were measured with reference to the hinge line. The length, height and width are in relation to the greatest measured lines parallel, perpendicular and orthogonal to the hinge line, respectively. Elongation and obesity indexes were calculated according to Stanley (1970). Abbreviations in tables are as follows: AA, length of the anterior auricle; E, elongation; H, height; L, length; LV, left valve; O, obesity; OL, length of the outer ligament; RN, rib number; RV, right valve; UA, umbonal angle; W, width.

Pectinid specimens from Wrona Buttress have some of the diagnostic characters of the genus *Adamussium* proposed by Jonkers (2003, p. 67). The characters include: extremely thin shells with low costae formed by simple crenulation of the disc, a straight hinge, and commarginal lirae.

Systematic paleontology

Family Pectinidae Rafinesque, 1815
Genus *Adamussium* Thiele, 1934

Type species: *Pecten colbecki* Smith, 1902; holotype: a right valve collected from 18 m depth off Franklin Island, Ross Sea, Antarctica, during the "Southern Cross" Expedition; Natural History Museum, London, number 1902.5.16.147 (Jonkers 2003).

Adamussium jonkersi sp. nov.
(Figs 4–6, Table 1)

Etymology: After H.A. Jonkers, for his noteworthy contribution to the paleontological studies of pectinids of the Southern Ocean.

Material. — Holotype, right valve (L3/41). Paratypes, right valves (L3/38, 40, P.2904.10.1) and left valves (L3/39, 42).

Diagnosis. — Radial sculpture of 7–9 broadly undulating, well-developed main plicae, intercalated with faintly developed secondary plicae on the ventral
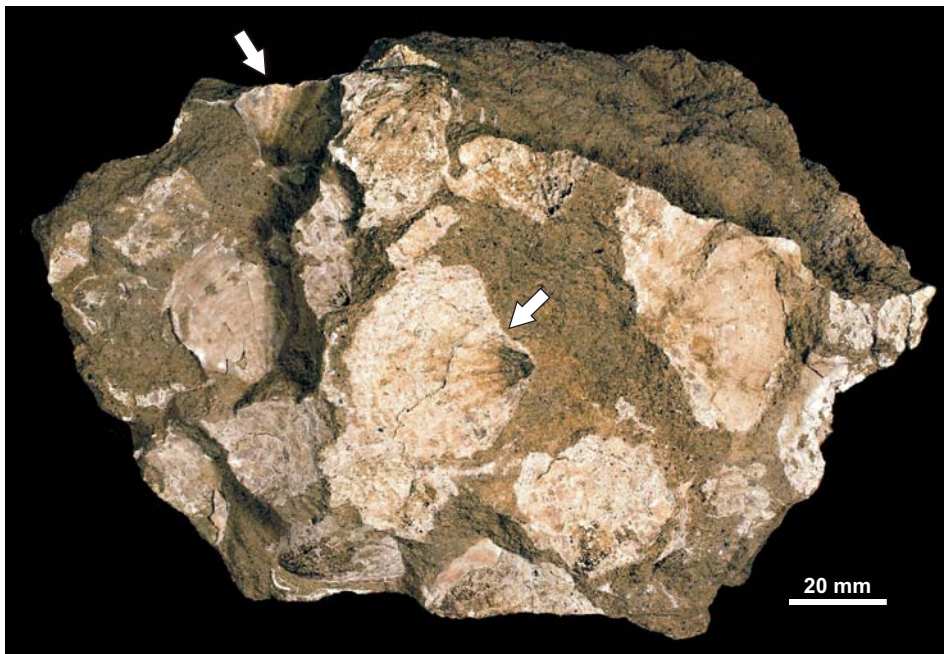
Fig. 4. *Adamussium jonkersi* sp. nov., shell bed: hand sample with paratype ZPAL/L3/40 (arrowed at center) and holotype ZPAL/L3/41 (arrowed at top left). Image by G. Dziewińska and M. Dziewiński.

part of the disc of most specimens; commarginal sculpture of distinct but weak lirae, with groups almost equally and closely spaced down the entire shell; RV anterior auricle rounded, with 3–4 radial costae observed internally.

Description. — Shell moderate to small in size, suborbicular (chlamydoid to aequipectinoid); dorsal margin short, ventral margin wide and rounded; equant; apparently very compressed, with moderately convex valves, LV more convex than RV; beaks orthogyrate; umbonal angle narrow (*ca*110°); radial sculpture of 7–9 broadly undulating, well-developed main plicae, intercalated with faintly developed secondary plicae towards ventral part of disc; commarginal sculpture of distinct but weak lirae, in groups almost equally and closely spaced down entire shell; hinge line straight; RV auricles apparently asymmetrical, anterior auricle rounded, with 3–4 radial costae observed internally.

Table 1

Measurements of representative specimens of *Adamussium jonkersi* sp. nov.
(* specimen incomplete)

Specimen	Valve	H	L	W	E	O	OL	AA	UA	RN
ZPAL/ L3/ 40	RV	40.8	38.4	11*	0.94	3.71	24.5	11.5	110°	9
ZPAL/L3/ 41	RV	49.5*	53.5	6.8*	1.08	7.28	–	–	–	9
P.2904.10.1	RV	49.8	44.2	–	0.89	–	–	–	100°	8

Table 2

Comparative features of *Adamussium colbecki colbecki*, *A. c. cockburnensis*, *A. alanbeui*, *A. auristriatum* and *A. jonkersi* sp. nov. ([1] according to Jonkers 2003; [2] according to Quaglio *et al.* 2008; [3] specimens from Destruction Bay Formation at Wrona Buttress; – not observable).

Features	*Adamussium c. colbecki* [1]	*Adamussium c. cockburnensis* [1]	*Adamussium alanbeui* [1]	*Adamussium auristriatum* [2]	*Adamussium jonkersi* [3]
Size	moderate (mean H = 70 mm)	moderate (mean H = 56 mm)	small (mean H < 50 mm)	moderate (mean H = 52)	small (mean H = 45 mm)
Valves	slightly opisthocline (AVH/PVH = 0.96)	opisthocline (AVH/PVH = 0.91)	acline	procline (AVH/PVH = 1.19)	apparently procline
Convexity	moderate	weak	weak	moderate	weak
Greater convexity	LV	LV	LV	RV	LV
Umbonal angle	very wide (138°)	wide (134°)	narrow (110°– 120°)	wide (130°)	narrow (110°)
Radial sculpture	20 broadly undulatin with intercalated low plicae	15 broadly undulating with intercalated low plicae	none	10–15 main plicae with intercalated low plicae	7–9 broadly undulating main plicae with intercalated low plicae at ventral margin
Com-marginal sculpture	distinct lirae with groups differently spaced	lirae regularly and widely spaced	none	lirae, weakly marked, regularly and widely spaced	distinct but weakly marked lirae, with groups almost equally and closely spaced
Micro-sculpture	wide to narrow antimarginal ridges	narrow antimarginal ridges	narrow antimarginal ridgelets	narrow antimarginal ridgelets	–
Auricles symmetry	highly symmetrical (AOL/POL = 1.02)	highly asymmetrical (AOL/POL = 1.4)	slightly asymmetrical (AOL/POL = 1.1–1.3)	highly symmetrical (AOL/POL = 1.01–1.08)	apparently asymmetrical
Auricles sculpture	none	none	none	anterior auricle with radial costae	anterior auricle with radial costae observable internally
Byssal notch	very deep (arcuate or acute)	deep	very shallow	very deep (acute)	–
Number of byssal teeth	very variable (mean = 2.5)	–	–	6	–

Comparison. — The characters of all known *Adamussium* species are summarized in Table 2. Assessing all of the characters, each species is unique, however, not many of the characters on their own indicate a clear taxonomic affinity between any two taxa. This can be seen from Table 2, where one species seems to be more related to another considering a given character (*e.g.* the similar opisthocline shape of the valves in *A. c. colbecki* and *A. c. cockburnensi*) and to a different species if another character is considered (*e.g.* the moderate convexity of the valves and symmetrical auricles in *A. c. colbecki* and *A. auristriatum*). Finally, *A. auristriatum* and *A. jonkersi* sp. nov. are similar in possessing procline valves and striated auricles. *A. alanbeui* differs from all other species by lacking radial plicae. Apart from this, Table 2 also shows that only *A. c. colbecki* and *A. jonkersi* sp. nov.
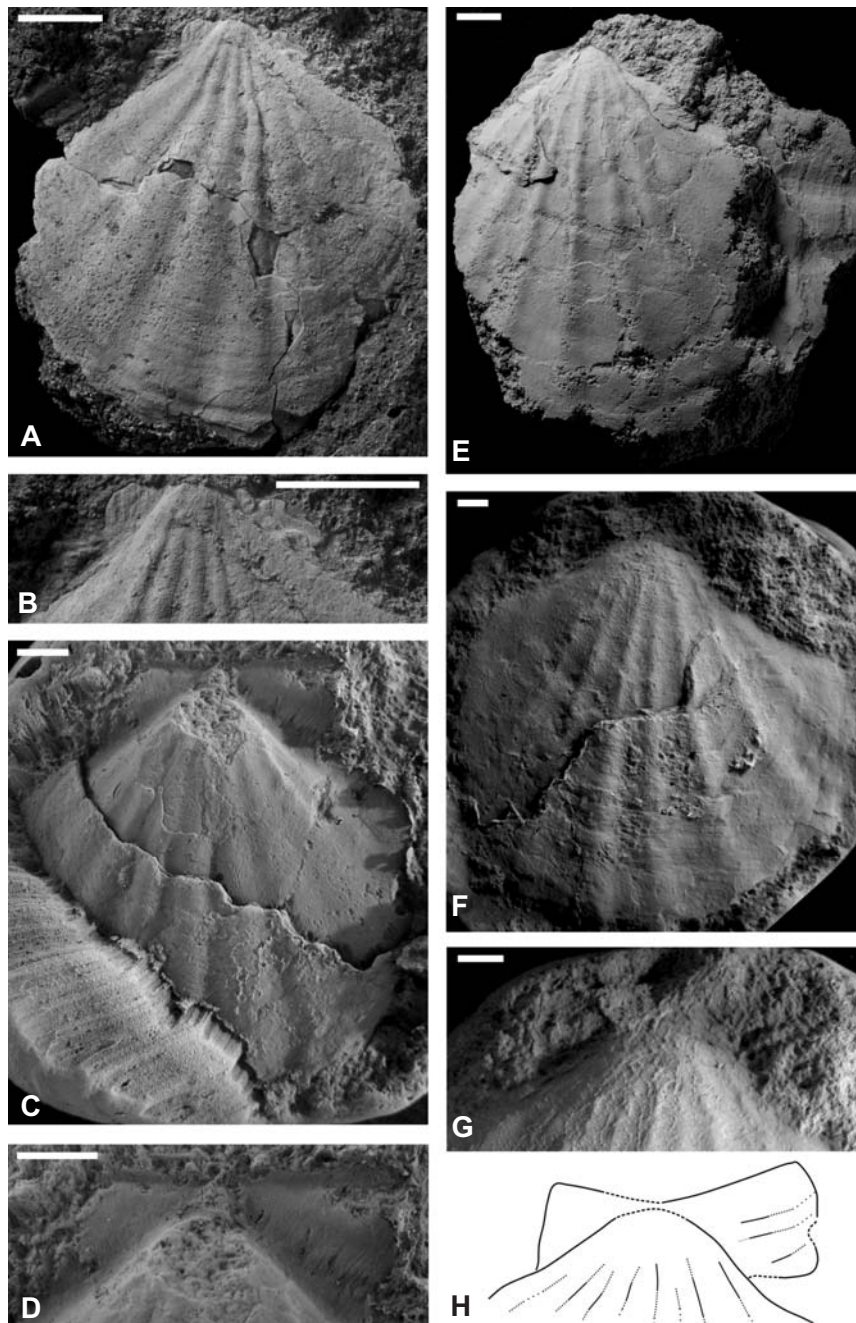
Fig. 5. *Adamussium jonkersi* sp. nov. **A–B.** External view of RV (paratype P.2904.10.1). **C–D.** Polymer clay cast of external mold of RV (holotype ZPAL/L3/41). **E.** Internal mould of LV (paratype ZPAL/L3/39). **F–G.** Polymer clay cast of external mold of RV; lower left hand side of shell only partially preserved (paratype ZPAL/L3/40). **H.** Camera lucida drawing of **G**. Scale bars 5 mm. Images of A–B by C. Gilbert; C, D, F, G by L.E. Anelli and F. Quaglio; E by G. Dziewińska and M. Dziewiński.
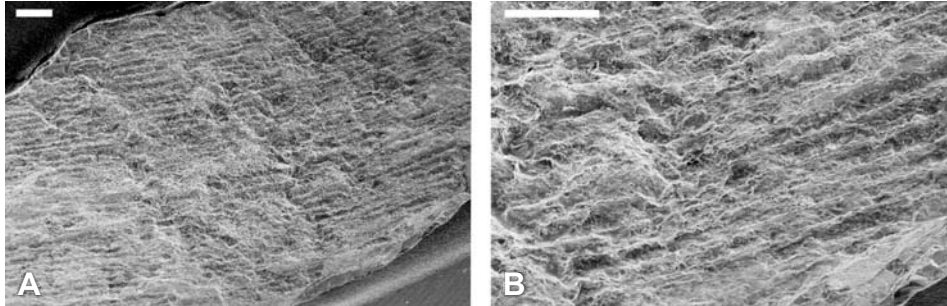
Fig. 6. Paratype ZPAL/L3/40, commarginal lirae in SEM micrographs of ventral margin of shell (umbo to the top left). Scale bars 500 μm.

are morphologically distinct. Therefore, the small morphological differences between the other species possibly indicate either environmentally induced modifications (morphoclines) or gradual, anagenetic evolution.

Despite the poor preservation, *Adamussium jonkersi* sp. nov. easily can be differentiated from *A. auristriatum* by its weaker valve convexity, narrower umbonal angle, apparent asymmetry of auricles, and the fewer plicae, which are better-defined and more widely separated that in *A. auristriatum*, and with intercalated fine plicae observable only at the ventral margin of the valves. *Adamussium jonkersi* sp. nov. also differs from both subspecies *A. colbecki colbecki* and *A. colbecki cockburnensis* in its apparently procline valves, narrower umbonal angle, and the presence of radial costae on the RV anterior auricle.

Shell microsculpture. — The commarginal sculpture of *Adamussium jonkersi* sp. nov. is composed of distinct but weak lirae, in groups almost equally and closely spaced down the entire shell. Unlike other species of the genus, the microsculpture is not observed in SEM images (Fig. 6). Several explanations for this are possible, including the loss of ridgelets through ontogenetic development during life, the loss of this fragile microsculptural pattern during diagenetic recrystallization of the shell, or even because this microsculptural feature is absent (at least at the ventral margin of the available shell material studied under SEM).

Paleoecology. — According to Stanley (1970), pectinids with a swimming habit are characterized by an inequivalve condition, with the lower (right) valve being more convex than the upper valve, the presence of a thin shell with plicae, a broad umbonal angle (around 105° to 130°), and gapes adjacent to the auricles. Jonkers (2003), based on Stanley (1970), considered that swimming pectinids have an umbonal angle greater than 108° and a ratio between the anterior and posterior auricle lengths smaller than 1.7. However, Hayami (1991) stressed that the presence of radial folds results in an increase in drag coefficient. Stanley (1970) also affirmed that byssally attached pectinids, on the other hand, possess elongated anterior auricles, a byssal notch with no adjacent gapes, and a narrow umbonal angle. Of the features cited above, *A. jonkersi* sp. nov. displays an umbonal angle indicating that

specimens range from byssate to swimming habits (100° to 110°), an apparently slight inequivalve condition, and a rather thin shell with broad undulating plicae, which point to a free-swimming habit. The plicate shell, a character present in all *Adamussium* species other than *A. alanbeui*, increases frictional drag in the water, thus reducing swimming capability due to the high-energy demand for swimming (Hayami 1991). The auricles are apparently asymmetrical. However, because of the incomplete preservation of the fossils, the features that would point to a truly byssate habit, such as the presence of a ctenolium and a wide byssal notch adjacent to the anterior auricle, are not observable. Despite the poor preservation, we infer a free-living, non-active swimming habit for *A. jonkersi*. More specifically, we suppose that it had the ability to clap its valves in order to escape from a potential predator. However, this condition does not exclude the possibility that this scallop lived byssally attached during younger stages, as many pectinids do (Stanley 1970; Gould 1971).

Taphonomy. — The assemblage is composed of thin-shelled specimens, preserved as disarticulated, complete or partially fragmentary valves. The shells are in a convex-up orientation, concordant with bedding (Fig. 4). The sedimentological features of the unit indicates an estuarine environment to lower-energy tidal flat (Birkenmajer 1982). The disarticulation of the shells and their preservation in a convex-up orientation indicate lateral transport of the valves for a short distance due to traction currents. Indeed, as demonstrated by the experimental studies of McKittrick (1987) and Simões *et al.* (2006), convex shells always settle down in a concave-up (unstable) orientation. Hence, the convex-up attitude (stable orientation) of the shells in relation to bedding is achieved when waves, currents and bioturbation are present in the environment (Simões *et al.* 2006). Hence, despite their reclinant, free-living mode of life, the studied shells of *Adamussium jonkersi* are parauthocthonous (*sensu* Kidwell *et al.* 1986), and were deposited in a low- to medium-energy environment.

Final comments

The modern representative of the genus *Adamussium*, *A. c. colbecki*, is an endemic Antarctic species with a circum-Antarctic distribution (Dell 1972, 1990), and is found in almost all sites protected from high-energy water conditions around Antarctica (Schiaparelli and Linse 2006). Some studies have shown that this Antarctic species is highly sensitive to temperature increase, suggesting that it is physiologically adapted to low environmental temperatures (Viarengo *et al.* 1999; Peck *et al.* 2004). Because its ancestral lineage can be traced back to the Oligocene, we conclude that this important component of the Recent Antarctic fauna probably had an evolutionary past related to the Cenozoic cooling history of the continent. In this way, the new taxon contributes to the knowledge of the fossil record of the genus and potentially will help future studies of environmental change in Antarctica during the Cenozoic.

References

BARUCCA M., OLMO E., CAPRIGLIONE T., ODIERNA G. and CANAPA A. 2005. Taxonomic considerations on the Antarctic species *Adamussium colbecki* based on molecular data. *In:* P. Luporini and M. Morbidoni (eds) Polarnet Technical Report, Proceedings of the Fifth PNRA Meeting on Antarctic Biology, Messina: 48–52.

BEU A.G. 2009. Before the ice: Biogeography of Antarctic Paleogene molluscan faunas. *Palaeogeography, Palaeoclimatology, Palaeoecology* 284: 191–226.

BIERNAT G., BIRKENMAJER K. and POPIEL-BARCZYK E. 1985. Tertiary brachiopods from the Moby Dick Group of King George Island (South Shetland Island, Antarctica). *Studia Geologica Polonica* 81: 109–141.

BIRKENMAJER K. 1982. Pre-Quaternary fossiliferous glacio-marine deposits at Cape Melville, King George Island (South Shetland Islands, West Antarctica). *Bulletin de L'Academie Polonaise des Sciences, Série des sciences de la Terre* 29 (4): 331–340.

BIRKENMAJER K. 1987. Oligocene–Miocene glacio-marine sequences of King George Island (South Shetland Islands), Antarctica. *In*: A. Gaździcki (ed.) Palaeontological results of the Polish Antarctic expeditions. Part I. *Palaeontologia Polonica* 49: 9–36.

BIRKENMAJER K. 2001. Mesozoic and Cenozoic stratigraphic units in parts of the South Shetland Islands and Northern Antarctic Peninsula (as used by the Polish Antarctic programmes). *In*: K. Birkenmajer (ed.) Geological results of the Polish Antarctic expeditions. Part XIII. *Studia Geologica Polonica* 118: 7–188.

BIRKENMAJER K. and ŁUCZKOWSKA E. 1987. Foraminiferal evidence for a Lower Miocene age of glaciomarine and related strata, Moby Dick Group, King George Island (South Shetland Islands, Antarctica). *In*: K. Birkenmajer (ed.) Geological results of the Polish Antarctic expeditions. Part VI. *Studia Geologica Polonica* 90: 81–123.

BIRKENMAJER K., GAŹDZICKI A. and WRONA R. 1983. Cretaceous and Tertiary fossils in glacio-marine strata at Cape Melville, Antarctica. *Nature* 303 (5912): 56–59.

BIRKENMAJER K., GAŹDZICKI A., PUGACZEWSKA H. and WRONA R. 1987. Recycled Cretaceous belemnites in Lower Miocene glacio-marine sediments (Cape Melville Formation) of King George Islands, West Antarctica. *In*: A. Gaździcki (ed.) Palaeontological results of the Polish Antarctic expeditions. Part I. *Palaeontologia Polonica* 49: 49–62.

CAROLI S. and BOTTONI P. 2010. A new Antarctic certified reference material for trace elements: *Adamussium colbecki*. *Microchemical Journal* 96: 190–193.

CHIANTORE M., CATTANEO-VIETTI R. and HEILMEYER O. 2003. Antarctic scallop (*Adamussium colbecki*) annual growth rate at Terra Nova Bay. *Polar Biology* 26: 416–419.

CORSI I., BONACCI S., SANTOVITO G., CHIANTORE M., CASTAGNOLO L. and FOCARDI S. 2004. Cholinesterase activities in the Antarctic scallop *Adamussium colbecki*: tissue expression and effect of $ZnCl_2$ exposure. *Marine Environment Research* 58 (2–5): 401–406.

DELL R.K. 1972. Antarctic benthos. *In*: S. Russell and C.M. Younge (eds) Advances in Marine Biology 10: 1–216. New York and London: Academic Press.

DELL R.K. 1990. Antarctic Mollusca with special reference to the fauna of the Ross Sea. *Bulletin of the Royal Society of New Zealand* 27: 1–311.

DINGLE R.V. and LAVELLE M. 1998. Late Cretaceous–Cenozoic climatic variations of the northern Antarctic Peninsula: new geochemical evidence and review. *Palaeogeography, Palaeoclimatology, Palaeoecology* 141: 215–232.

GOULD S.J. 1971. Muscular mechanics and the ontogeny of swimming in scallops. *Palaeontology* 14: 61–94.

HAYAMI I. 1991. Living and fossil scallop as airfoils: an experimental study. *Paleobiology* 17 (1): 1–18.

HEILMAYER O., HONNEN C., JACOB U., CHIANTORE M., CATTANEO-VIETTI R. and BREY T. 2005. Temperature effect on summer growth rates in the Antarctic scallop, *Adamussium colbecki*. *Polar Biology* 28 (7): 523–527.

JONKERS H.A. 2003. Late Cenozoic–Recent Pectinidae (Mollusca: Bivalvia) of the Southern Ocean and neighbouring regions. *Monographs of Marine Mollusca* 5: 125 pp. Backhuys Publishers Leiden.

KIDWELL S.M., FÜRSICH F.T. and AIGNER T. 1986. Conceptual framework for the analysis of fossil concentrations. *Palaios* 1: 228–238.

MCKITTRICK M.A. 1987. Experiments on the settling of gastropod and bivalve shells: biostratinomic implications. *In*: K.W. Flessa (ed.) Paleoecology and taphonomy of Recent to Pleistocene intertidal deposits Gulf of California. *The Paleontological Society Special Publication* 2: 150–163.

PECK L.S., WEBB K.E. and BAILEY D.M. 2004. Extreme sensitivity of biological function to temperature in Antarctic marine species. *Functional Ecology* 18 (5): 625–630.

QUAGLIO F., ANELLI L.E., SANTOS P.R., PERINOTTO J.A.J. and ROCHA-CAMPOS A.C. 2008. Invertebrates from the Low Head Member (Polonez Cove Formation, Oligocene) at Vauréal Peak, King George Island, West Antarctica. *Antarctic Science* 20: 149–168.

RONIEWICZ E. and MORYCOWA E. 1987. Development and variability of Tertiary *Flabellum rariseptatum* (Scleractinia), King George Island, West Antarctica. *In*: A. Gaździcki (ed.) Paleontological results of the Polish Antarctic expeditions. Part I. *Palaeontologia Polonica* 49: 83–103.

SCHIAPARELLI S. and LINSE K. 2006. A reassessment of the distribution of the common Antarctic scallop *Adamussium colbecki* (Smith, 1902). *Deep-sea Research II* 53: 912–920.

SIMÕES M.G., RODRIGUES S.C., LEME J.M. and BISSARO JÚNIOR M.C. 2005. The settling pattern of brachiopod shells: stratigraphic and taphonomic implications to shell bed formation and paleoecology. *Revista Brasileira de Geociências* 35: 383–391.

STANLEY S.M. 1970. Relation of shell form to life habits of the Bivalvia (Mollusca). *Geological Society of America Memoir* 125: 1–296.

STOCKTON W.L. 1984. The biology and ecology of the epifaunal scallop *Adamussium colbecki* on the west side of McMurdo Sound, Antarctica. *Marine Biology* 78: 171–178.

STUDENCKA B. 1991. A new species of genus *Panopea* (Bivalvia) from the King George Island, Antarctica. *Polish Polar Research* 12 (3): 363–368.

TROEDSON A.L. and RIDING J.B. 2002. Upper Oligocene to lowermost Miocene strata of King George Island, South Shetland Islands, Antarctica: Stratigraphy, facies analysis and implications for the glacial history of the Antarctic Peninsula. *Journal of Sedimentary Research, Section B: Stratigraphy and Global Studies* 72 (4): 510–523.

VIARENGO A., MANCINELLI G., BURLANDO B., PANFOLI I. and MARCI B. 1999. The SR Ca^{2+} ATPase of the Antarctic scallop *Adamussium colbecki*: cold adaptation and heavy metal effects. *Polar Biology* 21: 369–375.