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Mid-Tertiary macroinvertebrate-rich clasts from the Battye Glacier Formation, Prince Charles Mountains, East Antarctica

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Abstract: Macrofossils discovered in the Battye Glacier Formation (Pagodroma Group) of the Prince Charles Mountains, East Antarctica, provide important insight into marine life of the mid-Tertiary, rarely preserved elsewhere on the continent. Recorded are five species of macroinvertebrates; these are *Adamussium* n. sp.? cf. *colbecki* (Smith, 1902) (Bivalvia), *Laternula?* sp. (Laternulidae), Mytilidae genus and species indeterminate (Bivalvia), Bivalvia genus and species indeterminate, and Polychaeta genus and species indeterminate. Based on stratigraphical data and faunal composition, the clasts are dated as no younger than Early Miocene. This is one of the oldest reports of *Adamussium* from Antarctica, previously known from the Late Pliocene to Recent with a possible record in the Late Oligocene–Early Miocene. Palaeoecological data and facies analysis indicate that these taxa inhabited a shallow- to mid-shelf marine environment of normal salinity that was oligotrophic. The substrate was a soft, pebbly and sandy bottom that was sufficiently mobile to sponsor deep burrowing forms.

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Introduction

Tertiary macrofaunal remains are relatively scarce and distributed sporadically in the stratigraphical record of Antarctica (Webb 1991). This paucity of palaeontological data renders the recovery of fossil materials from almost any stratigraphical level a significant discovery. This is true even when the specimens occur in sediment clasts that have been removed from their stratigraphical context (Harwood & Levy 2000). Glacial erosion and transportation of Tertiary sedimentary materials and their inclusion in glacial sediments provide a useful means to increase the palaeontological record from Antarctica by providing a window into subglacial basin stratigraphy. This paper documents a Tertiary marine macrofauna recovered in glacially-transported sedimentary clasts from the Prince Charles Mountains area, East Antarctica. Comparison of this macrofauna to other Antarctic fossil assemblages enables a tentative age assignment and consideration of depositional environment.

Tertiary molluscan faunas of Antarctica

The phylum Mollusca dominates known Tertiary shallow marine assemblages from widely distributed areas of the Palaeocene of Seymour Island (see Zinsmeister & Macellari 1988, Stilwell & Zinsmeister unpublished data, Stilwell *et al.* unpublished data), Eocene of Seymour and Cockburn islands, McMurdo Sound and Prydz Bay (see Stilwell & Zinsmeister 1992, Quilty *et al.* 1999, Stilwell 2000, Stilwell unpublished data), Oligocene of King George Island (see Birkenmajer & Gazdzicki 1986, Gazdzicki 1989) and Early–Late Oligocene boundary of McMurdo Sound and Ross Sea (Dell & Fleming 1975, Beu & Dell 1989), Early Oligocene–Early Miocene? of CRP-1 and CRP-2 Drillholes, Cape Roberts (Jonkers & Taviani 1998, Taviani *et al.* 2000), Late Miocene of James Ross Island (see review by Jonkers 1998a), and Pliocene of Cockburn Island and Vestfold Hills, East Antarctica (see Jonkers 1998b, Quilty *et al.* 2000, Stilwell unpublished data). Our knowledge of molluscan fossils from the mid-Tertiary, especially the Late Oligocene to Middle Miocene interval (see Jonkers 1998a), is very scant indeed, with assemblages of low diversity recorded.

Macrofossil-rich clasts from the Battye Glacier Formation

During the 2000–2001 summer, two baseball-sized, fossil-bearing clasts were recovered from the Middle to Upper Miocene Battye Glacier Formation (Pagodroma Group), exposed along the western margin of the Prince Charles Mountains/Lambert Graben, along Beaver Lake (Fig. 1). Hambrey & McKelvey (2000) and McKelvey *et al.* (2001) noted that the geomorphological setting of the Battye Glacier Formation is similar to that of the Middle Miocene Fisher Bench Formation on Fisher Massif, *c.* 80 km further south (Laiba & Pushina 1997). As a result, these workers considered the age of the Battye Glacier Formation to also be Middle Miocene (Hambrey & McKelvey 2000, McKelvey *et al.* 2001).

Much of the fossil material from the Battye Glacier Formation is derived from the largest clast (PCM 00-93A), which is

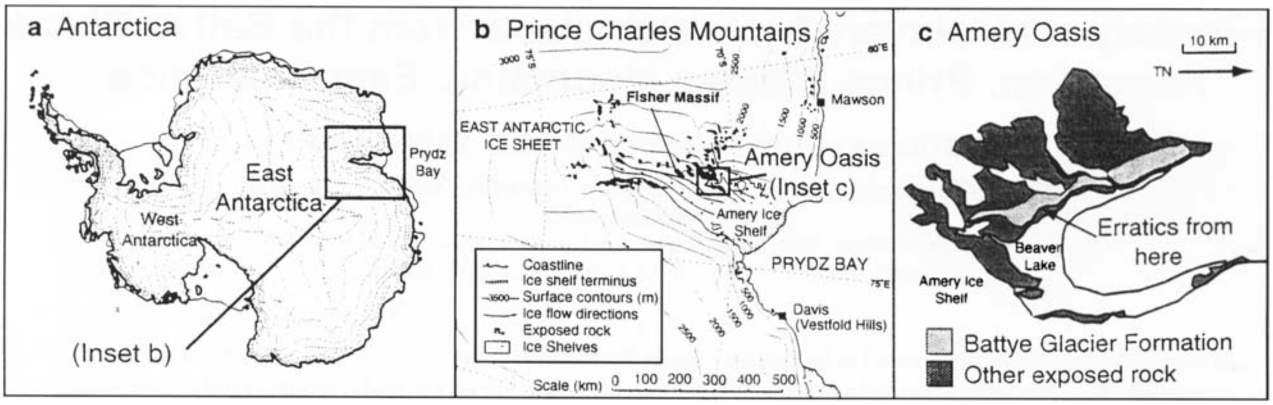

Fig. 1. Location map of the Amery Oasis, Prince Charles Mountains, East Antarctica, where the fossils described in this paper were collected: **a.** map of Antarctica showing Prydz Bay region, **b.** detail of the Prince Charles Mountains with location of Amery Oasis, **c.** simplified geologic map of the Amery Oasis with arrow showing the outcrop of the Battye Glacier Formation and the location of the fossiliferous clasts.

angular with approximate dimensions of 12 x 10 x 5 cm. Clast PCM 00-93C broke into two fragments during collection of about 3–4 cm diameter. Clast PCM 00-93B, also some 3–4 cm diameter, was recovered approximately 20 m up-section from the larger clast. Preliminary preparation of these clasts for siliceous, organic and calcareous microfossils did not yield microfloras and microfaunas.

The assemblage of shallow marine invertebrates preserved within these clasts is depauperate, but significant. It is dominated by bivalves and calcareous worm (polychaete) tubes. Five species of invertebrates are recognised in the clasts; these are *Adamussium* n. sp.? cf. *A. colbecki* (Smith, 1902) [Pectinidae] (Fig. 2a–c, g–h, k, r), *Laternula?* sp. [Laternulidae] (Fig. 2i, m–n), Mytilidae genus and species indeterminate (Fig. 2j), Bivalvia genus and species indeterminate (Fig. 2o–p), and unidentified calcareous worm tubes belonging to the Polychaeta (Fig. 2d–f, l, q). An age of Early Miocene is inferred from the molluscs. Marine diatoms within the enclosing sediments of the Battye Glacier Formation provide an upper age limit of Middle to Late Miocene for the clasts (Harwood unpublished data).

This paper significantly extends the range of the extant pectinid *Adamussium* in the stratigraphical record of Antarctica, previously known from Holocene (*A. colbecki* (Smith, 1902)) deposits and a poorly preserved species from the Upper Pliocene Cockburn Island Formation [*A.* sp. *cf. A. colbecki* (Smith)] (see review by Jonkers 1998b, pl. 1, fig. 1; Jonkers 1998a, fig. 3b). *Adamussium?* n. sp. of Beu & Dell (1989, figs 7–14) from the CIROS-1 drillhole in McMurdo Sound, of Taviani *et al.* (2000) from CRP-2/2A drill cores, and from King George Island (B. Jonkers personal communication 2001) (Oligocene–earliest Miocene?) is questionably referred to this genus as an early member of the lineage, as it is void of radial costae, so prevalent and characteristic of subsequently younger species, including the Battye Glacier Formation species. It is possible that *Adamussium* consists of a single lineage in which radial costae developed during the earliest Miocene, with a later progressive increase in the number of plicae (B. Jonkers personal communication 2001). The Cockburn Island Formation species, probably a new subspecies (B. Jonkers personal communication 2001), is only marginally larger than the Battye Glacier Formation species, but has less robust, but more numerous, radial costae, and apparently larger auricles. Other characters gleaned from the Battye Glacier Formation species include a seemingly prosocline outline, mean umbonal angle < 110°, a relatively steep dorsal disk margin, the dorsal disk margin being very gently incurved (to ventral) on the right valve and almost straight on left valve (hard to deduce in material), extremely fine and narrow antimarginal microsculpture (see posterior margin of CPC 36318), and a hint of bifurcate ribs near the ventral margin. It cannot be entirely discounted that the Battye Glacier Formation species may represent an early member of a new pectinid genus currently under investigation (B. Jonkers personal communication 2001). *Adamussium* n. sp.? cf. *A. colbecki* (Smith, 1902) from the Battye Glacier Formation is most probably a new species, but the poor preservation prevents a more accurate assessment of its affinities at genus-level.

A semi-articulated specimen of a probable *Laternula* is present in the collection, and due to its poor preservation, is only tentatively assigned to this genus. This bivalve has a seemingly smooth shell, a buttressed chondrophore, an edentulous hinge, and a subnacreous internal shell, all features in common with the Laternulidae. *Laternula* n. sp.? cf. *L. elliptica* (King & Broderip, 1831) of Jonkers (1998b, pl. 1, fig. 5) may be a related form to the Battye Glacier Formation species, but the Cockburn Island Formation species is much larger. The affinity of the mytilid species is uncertain, as most of the dorsal margin is missing, but the ventral margin and the undulating commarginal growth increments are comparable to *Botula pirriei* Stilwell & Zinsmeister (1992 p. 59, pl. 2, fig. f), from the Late Eocene of Seymour Island. A ventral margin fragment of another bivalve is characterised by coarse, commarginal ribs, but its identification within the Bivalvia is

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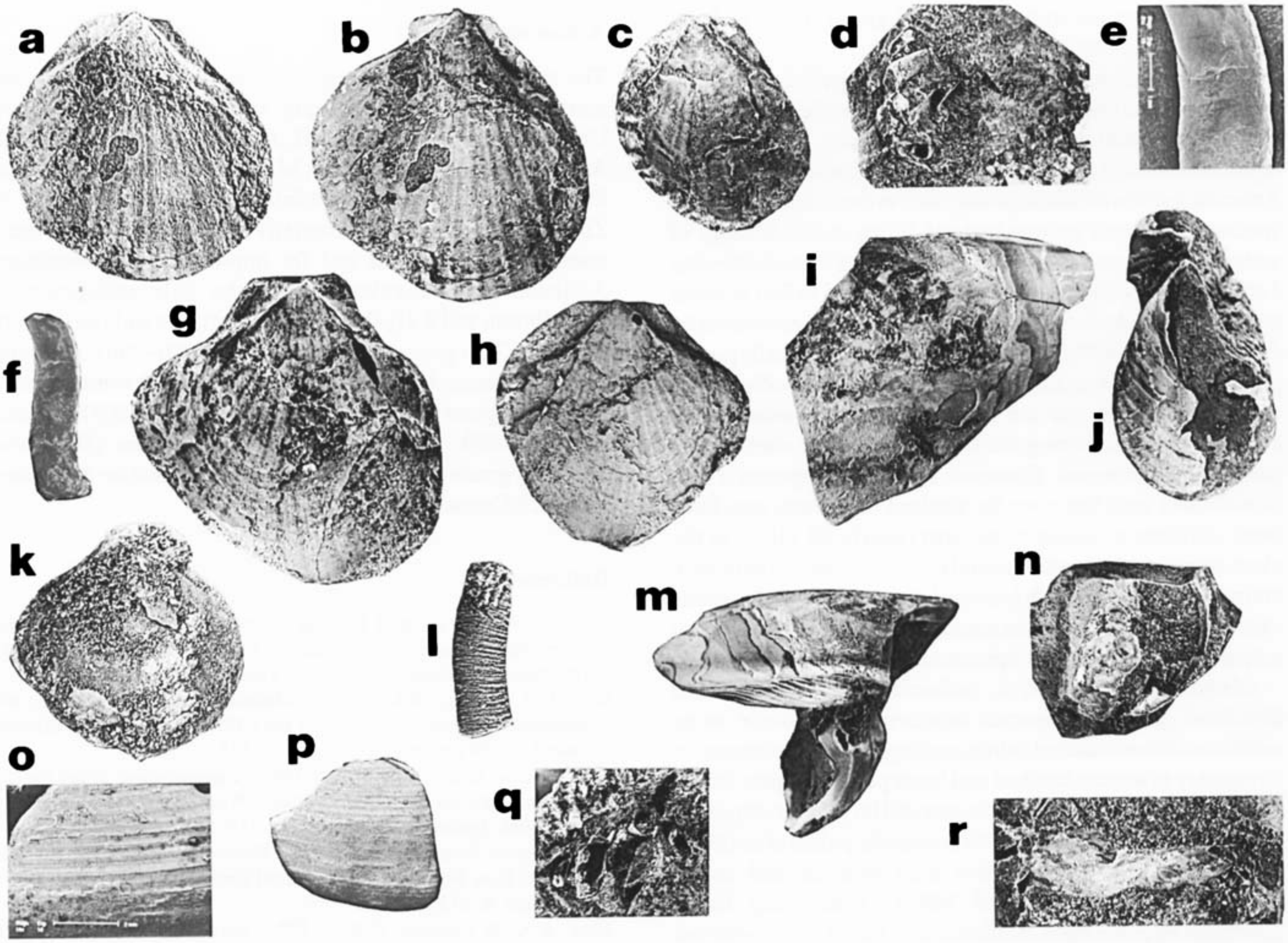

Fig. 2. Photographic illustrations of five species of fossil macroinvertebrates from two fossiliferous clasts (see text). The specimens figured here are lodged in the Commonwealth Palaeontological Collection (CPC), Canberra, Australia. The fossils were coated with ammonium chloride prior to macrophotography and with gold/platinum for scanning electron microscopy. All figures are presented at natural size unless otherwise specified: **a, b, c, g, h, k, r.** *Adamussium* n. sp.? *cf. A. colbecki* (Smith, 1902), **a.** CPC 36315, right valve exterior, **b.** same specimen uncoated to illustrate rib morphology and also an approximation of auricle morphology, **c.** CPC 36317, right? valve exterior, **g.** CPC 36318, left valve interior, **h.** same specimen, latex cast of natural mould of exterior of left valve, **k.** CPC 36319, poorly preserved articulated specimen with some original shell material, but mostly decorticated, **r.** CPC 36320, partial hinge, **d, e, f, l, q.** Polychaeta genus and species indeterminate (Serpulidae?), **d.** CPC 36321, multiple specimens of calcareous worm tubes in small block, randomly oriented, **e.** CPC 36322, SEM of polychaete, x4, **l.** CPC 36323, macrophotograph showing growth increments, x2.5, **q.** CPC 36324, multiple specimens in small block, randomly oriented, **i, m, n.** *Laternula?* sp., **i,** CPC 36325, magnified section of part of dorsal margin and central portion of disc, x2, **m.** dorsal view showing partial hinge preserved, x2, **n.** section through articulated valves, **j.** Mytilidae genus and species indeterminate, CPC 36326, poorly-preserved, articulated individual with some shell present, **o, p.** Bivalvia genus and species indeterminate, **o.** CPC 36327, SEM of commarginal sculpture, x4, **p.** same specimen, fragment of external shell, x2.

uncertain. The calcareous worm tubes belonging to the Polychaeta (Serpulidae?) are long, nearly straight to curved, slender, hollow, tubular, thin-walled, slightly irregular in outline, nearly circular in cross-section, and the ornamentation is of closely spaced and very fine, growth increments. The irregular nature of the shell outline precludes its placement within the Scaphopoda, which it resembles closely. The polychaetes from the Battye Glacier Formation are probably conspecific with inferred coeval specimens from the CRP-1 and CRP-2/2A Drillholes, Cape Roberts (see Jonkers & Taviani 1998, figs 5–6; Taviani *et al.* 2000, p. 523). The CRP-1 and Battye Glacier Formation species is probably new (see comments by Jonkers & Taviani 1998, p. 495), but the preservation and difficulties in taxonomic assignment at this time prevent us from proposing a species name. The abundant, well preserved CRP-2/2A polychaetes of Oligocene age indicate that they were probably gregarious and most likely lived as small, branching aggregates anchored to small objects

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such as tiny pebbles and coarse sand grains (Cape Roberts Science Team 1999, Taviani *et al.* 2000).

The fossils are enclosed in well-cemented, pebbly sandstone, which is inferred to have been deposited in a shallow- to mid-shelf environment of normal marine salinity. Only general depth information can be gleaned from the molluscs. Modern Antarctic species of *Adamussium*, such as the circum-Antarctic species *A. colbecki* are eurybathyal, living in a wide range of water depths from 3 m to 800 m. Species of deep-burrowing *Laternula* live today between approximately 5 to 240 m water depth with highest densities between 20–30 m (see reviews by Jonkers 1998b, 1999). Although leached and generally poorly preserved, some specimens of *A.* n. sp.? cf. *A. colbecki* are entire, and all but one are disarticulated, suggesting some current activity sweeping the shallow Antarctic shelf in this particular environment. However, this pectinid species is very thin-shelled, such that even the weakest of currents may have been sufficient to disarticulate, sort (nearly all valves in the clasts are right valves, which are relatively heavier and stronger), and move the valves. Both *Laternula?* sp. and Mytilidae genus and species indeterminate are articulated, indicating that current activity was probably at a minimum.

Adamussium n. sp.? cf. *A. colbecki, Laternula?* sp. and Mytilidae genus and species indeterminate provide some additional data on inferred habitat ecology. Extant *Adamussium* lives today in marine habitats and hosts planktotrophic larvae that are mostly oligotrophic. Successful larval recruitment of populations may be associated with episodic pulses of available organic material, or alternative food sources, and spawn during spring (Berkman *et al.* 1991). Conversely, living *Laternula elliptica* has a lecithotrophic larval stage, released during winter, and it is apparent that plankotrophic and lecithotrophic larval strategies and release periods are probably influenced by a dependence of the larvae on seasonally produced food sources (Berkman *et al.* 1991). The three bivalve species in all likelihood occupied different niches on the Antarctic sea-floor. The epifaunal *Adamussium* most probably lived freely on the bottom in shallow depressions or possibly attached itself to pebbles/rock, whereas infaunal *Laternula* burrowed deeply into the substrate, and the mytilid bivalve was epibyssate. Of note, the pectinid probably had a functional ctenolium and may have been epibyssate, as suggested by the narrow umbonal angle. These bivalves suggest that the shallow- to mid-shelf marine habitat was perhaps an oligotrophic one of normal salinity with a soft, pebbly and sandy bottom that was mobile enough to host deep burrowing forms.

These sedimentary clasts provide an important new glimpse into the marine macrofauna of the Early Miocene, which is scarcely known from Antarctica. Further, these new data indicate that the fossil record of *Adamussium* is older than thought previously. The paucity of information available on mid-Tertiary Antarctic macrofaunas makes any fragment of fossil-bearing marine strata, including these from the Battye Glacier Formation, a substantial contribution to the understanding of past Antarctic marine ecosystems.

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