Gondwana Research xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Gondwana Research

journal homepage: www.elsevier.com/locate/gr

The Paleocene of Antarctica: Dinoflagellate cyst biostratigraphy, chronostratigraphy and implications for the palaeo-Pacific margin of Gondwana

V. Bowman [a,*], J. Ineson [b], J. Riding [c], J. Crame [a], J. Francis [a], D. Condon [c], R. Whittle [a], F. Ferraccioli [a]

[a] British Antarctic Survey, High Cross, Madingley Road, Cambridge CB3 0ET, UK
[b] Geological Survey of Denmark and Greenland, Øster Volgade 10, DK, 1350 Copenhagen K, Denmark
[c] British Geological Survey, Environmental Science Centre, Keyworth, Nottingham NG12 5GG, UK

ARTICLE INFO

Article history:
Received 15 June 2015
Received in revised form 16 October 2015
Accepted 26 October 2015
Available online xxxx

Handling Editor: A.S. Collins

Keywords:
Cretaceous-Paleocene
Antarctic Peninsula
Gondwana
Biostratigraphy
Palaeogeography

ABSTRACT

The Paleocene (66–56 Ma) was a critical time interval for understanding recovery from mass extinction in high palaeolatitudes when global climate was warmer than today. A unique sedimentary succession from Seymour Island (Antarctic Peninsula) provides key reference material from this important phase of the early Cenozoic. Dinoflagellate cyst data from a 376 m thick stratigraphical section, including the Cretaceous–Paleogene boundary, is correlated with biozones from New Zealand, the East Tasman Plateau and southeastern Australia. A detailed age model is suggested for the López de Bertodano (LDBF) and Sobral (SF) formations based on dinoflagellate cyst biostratigraphy and U–Pb dating of zircons, supported by correlated magnetostratigraphy and strontium isotope values from macrofossils. The top of the LDBF is confirmed as latest Maastrichtian to earliest Danian (~66.2–65.65 Ma) in age. The overlying SF is mostly Danian in age, with an inferred hiatus near the top overlain by sediments dated as ?late Thanetian. Rare *Apectodinium homomorphum* first appear in the uppermost SF; the earliest *in situ* record from Antarctica. The distribution of marine and terrestrial fossils from uppermost Cretaceous to Eocene sediments in Patagonia, Antarctica, New Zealand and Australia required both sea and land connections between these fragments of Gondwana. Fossil evidence and reconstructions of Antarctic palaeogeography and palaeotopography reveal evidence for persistent embayments in the proto-Weddell and Ross Sea regions at this time. We conclude that a coastal dispersal route along the palaeo-Pacific margin of Gondwana could explain the fossil distribution without requiring a transAntarctic strait or closely spaced archipelago. A region in the West to East Antarctic boundary zone, elevated until the early Paleogene, perhaps acted as a site for high elevation ice caps. This supports fossil, geochemical and sedimentological evidence for cold climate intervals and significant sea level falls during the Maastrichtian and Paleocene.

1. Introduction

The Paleocene (66–56 Ma) was a time of cooler global climate between the greenhouse phases of the mid Cretaceous and Eocene (Zachos et al., 2001; Royer, 2006; Zachos et al., 2008). During the Paleocene, global biotas changed significantly in response to several major environmental perturbations. It is possible that a period of intense volcanic outgassing during the latest Maastrichtian to earliest Danian from the Indian Deccan Peninsula had global effects (Chenet et al., 2009; Courtillot and Fluteau, 2010; Schoene et al., 2014). Furthermore, there was a major meteorite impact at the Cretaceous–Paleogene (K–Pg) boundary coincident with mass extinctions of marine plankton and major changes in terrestrial vegetation (Schulte et al., 2010; Molina, 2015). There is a growing volume of evidence to suggest that some key components of the modern Southern Ocean marine fauna had their origins in the Early Cenozoic (Crame et al., 2014). However, despite recent work on Paleocene successions in the low and mid palaeolatitudes (e.g. Hollis et al., 2012, 2014; Storme et al., 2014), little is known about the implications of these events for high southern latitude biota, or indeed what they can tell us about Antarctic palaeogeography in the final phases of Gondwana fragmentation.

The only onshore exposure of strata of this age in the Antarctic is on ice-free Seymour Island, at ~64° South, in the James Ross Basin at the tip of the Antarctic Peninsula (Fig. 1; Elliot et al., 1994; Montes et al., 2010; Bowman et al., 2012, 2013a). During the Cretaceous and Paleogene, sediments of the Marambio Group that now form much of the island were being deposited in mid shelf and deltaic settings in a back-arc basin at a similar palaeolatitude (Lawver et al., 1992; Hathway, 2000; Crame et al., 2004; Martos et al., 2014). The succession is highly fossiliferous, is suitable for magnetostratigraphical analysis (Tobin et al., 2012), and has several ash beds (airfall tuffs) preserved above the K–Pg boundary (Fig. 2).

* Corresponding author. Tel.: +44 1223 221400; fax: +44 1223 362616.
E-mail address: vanessa.bowman@bas.ac.uk (V. Bowman).

http://dx.doi.org/10.1016/j.gr.2015.10.018
1342-937X/

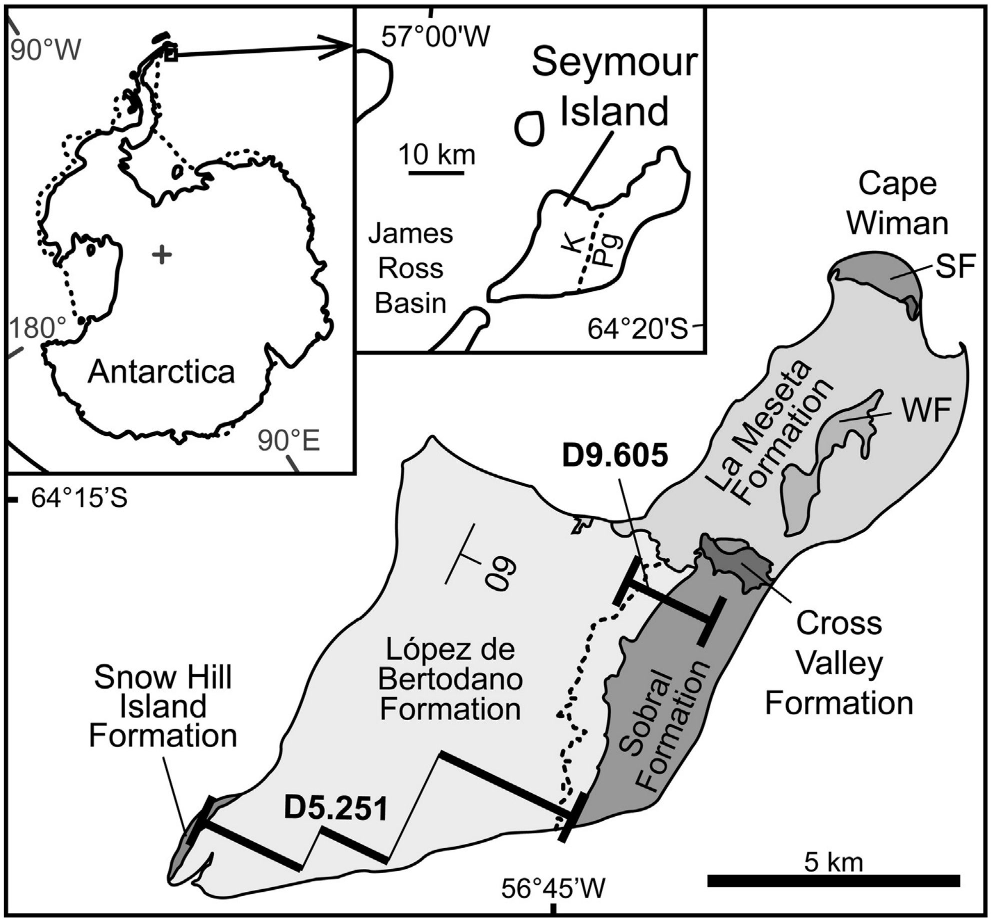

Fig. 1. Locality and geological map of Seymour Island, James Ross Basin, northeastern tip of the Antarctic Peninsula. Geology after Montes et al. (2010). K, Cretaceous; Pg, Paleogene; SF, Sobral Formation; WF, Weddell Formation. Approximate position of British Antarctic Survey stratigraphical section lines D9.605 (composite of section lines D9.600, D9.601, D9.602, D9.603 and D9.604) and D5.251 (composite of D5.201, D5.212, D5.215, D5.218, D5.219, D5.220, D5.222 and D5.229; after Bowman et al., 2012, 2013a, 2014).

Previous work has refined the age of the oldest part of the Seymour Island succession (the uppermost Snow Hill Island Formation and the López de Bertodano Formation) as Maastrichtian to earliest Danian using dinoflagellate cyst biostratigraphy correlated to magnetostratigraphy and strontium isotope stratigraphy (Askin, 1988a; McArthur et al., 1998; Bowman et al., 2012; Tobin et al., 2012; Bowman et al., 2013a). A new measured section through the uppermost López de Bertodano Formation, across the K–Pg boundary, and through the overlying Sobral Formation in the central part of the island (Fig. 1) is the focus of this paper.

We provide a detailed age model for the succession, across the K–Pg boundary into the Paleocene in order to provide a robust stratigraphical context for this key reference section. The emphasis is on dinoflagellate cyst biostratigraphy and correlating significant bioevents with known biozonation schemes in the mid to high southern latitudes that have been correlated to the International Timescale (Gradstein et al., 2012) (Partridge, 2006; Bijl et al., 2013; Crouch et al., 2014). The overall age model includes previous work on palynomorphs and other fossil groups (Askin, 1988a,b; Harwood, 1988; Huber, 1988; Wrenn and Hart, 1988; Zinsmeister and Macellari, 1988; Olivero and Zinsmeister, 1989; Olivero and Medina, 2000; Thorn et al., 2009; Crame et al., 2014; Witts et al., 2015). Supporting evidence also includes magnetostratigraphical tie-points (Tobin et al., 2012; Vandenberghe et al., 2012), U–Pb isotope dates from zircons extracted from airfall tuff horizons (this study) and strontium isotope analyses from macrofossils (McArthur et al., 1998). Close taxonomic similarity of the Paleocene dinoflagellate cyst floras across remnants of the palaeo-Pacific margin of Gondwana provides a broader context for this study. This involves analysis of the final fragmentation of Gondwana and the Late Cretaceous to Eocene palaeogeographical and palaeotopographical evolution of Antarctica.

2. Field and palynological methods

A new 376 m composite section was measured and sampled throughout the uppermost López de Bertodano and Sobral formations in central Seymour Island (D9.605; Figs. 1, 2). This is located at 64°16′17.28″S, 056°43′1.38″W to 64°16′16.02″S, 056°40′53.16″W. The section was measured using a Jacob's staff and Abney level with finer intervals established by tape measure. All sub-sections were correlated lithologically in the field. The uppermost López de Bertodano and Sobral formations strike ~020° north-northeast, and gently dip (~9°) towards the east-southeast (Fig. 1). The López de Bertodano Formation crops out in the southern and central parts of the island. It is overlain unconformably by the Sobral Formation, the upper part of which is also exposed on the northern tip of the island at Cape Wiman (Fig. 1). Section D9.605 comprises several sub-sections (D9.600 to D9.604) that, when combined, form a contiguous succession through the part of the island where the Sobral Formation is most fully developed (Fig. 2). Between each sub-section, individual beds were traced along strike in order to avoid areas of poor exposure in the field (e.g. across mud-filled valleys) to ensure accuracy of measurement and sampling along a continuous stratigraphical section.

The base of section D9.605 overlaps with the top of section D5.251 (Thorn et al., 2009; Bowman et al., 2012, 2013a,b; Witts et al., 2015),