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Constraining early to middle Eocene climate evolution of the southwest Pacific and Southern Ocean

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ABSTRACT

Studies of early Paleogene climate suffer from the scarcity of well-dated sedimentary records from the southern Pacific Ocean, the largest ocean basin during this time. We present a new magnetostratigraphic record from marine sediments that outcrop along the mid-Waipara River, South Island, New Zealand. Fully oriented samples for paleomagnetic analyses were collected along 45 m of stratigraphic section, which encompasses magnetic polarity Chrons from C23n to C21n (~51.5–47 Ma). These results are integrated with foraminiferal, calcareous nannofossil, and dinoflagellate cyst (dinocyst) biostratigraphy from samples collected in three different expeditions along a total of ~80 m of section. Biostratigraphic data indicates relatively continuous sedimentation from the lower Waipawan to the upper Heretaungan New Zealand stages (i.e., lower Ypresian to lower Lutetian, 55.5 to 46 Ma). We provide the first magnetostratigraphically-calibrated age of 48.88 Ma for the base of the Heretaungan New Zealand stage (latest early Eocene). To improve the correlation of the climate record in this section with other Southern Ocean records, we reviewed the magnetostratigraphy of Ocean Drilling Program (ODP) Site 1172 (East Tasman Plateau) and Integrated Ocean Drilling Program (IODP) Site U1356 (Wilkes Land Margin, Antarctica). A paleomagnetic study of discrete samples could not confirm any reliable magnetic polarity reversals in the early Eocene at Site 1172. We use the robust magneto-biochronology of a succession of dinocyst bioevents that are common to mid-Waipara, Site 1172, and Site U1356 to assist correlation between the three records. A new integrated chronology offers new insights into the nature and completeness of the southern high-latitude climate histories derived from these sites.

1. Introduction

During the early Eocene, the Earth experienced a long-term global warming event culminating ~52 to 50 Ma in the early Eocene climatic optimum (EECO; e.g., Zachos et al., 2008). The EECO was followed by a cooling trend that continued over the ensuing middle to late Eocene, and ultimately drove the Earth's climate into a glacial mode with the inception of major Antarctic ice-sheets near the Eocene–Oligocene boundary (Miller et al., 1991; Zachos et al., 2008). In the ice-free world of the early and middle Eocene, the Pacific Ocean played a key role in the heat transport, primarily because of its greater extent relative to the Atlantic Ocean (Huber and Sloan, 2001; Huber and Nof, 2006). Sedimentary records from the southern Pacific Ocean are particularly important for understanding the evolution of global climate during early Paleogene because they lay at the interface between tropical and polar components of this global climate engine.

The climate history of the southern Pacific has become better known in recent years through the application of new paleotemperature proxies to continental margin sedimentary records, namely from Ocean Drilling Program (ODP) Site 1172 in the East Tasman Plateau (Bijl et al., 2009, 2013a), from the Canterbury Basin, onshore eastern New Zealand (e.g. Burgess et al., 2008; Hollis et al., 2009, 2012), and from Integrated Ocean Drilling Program

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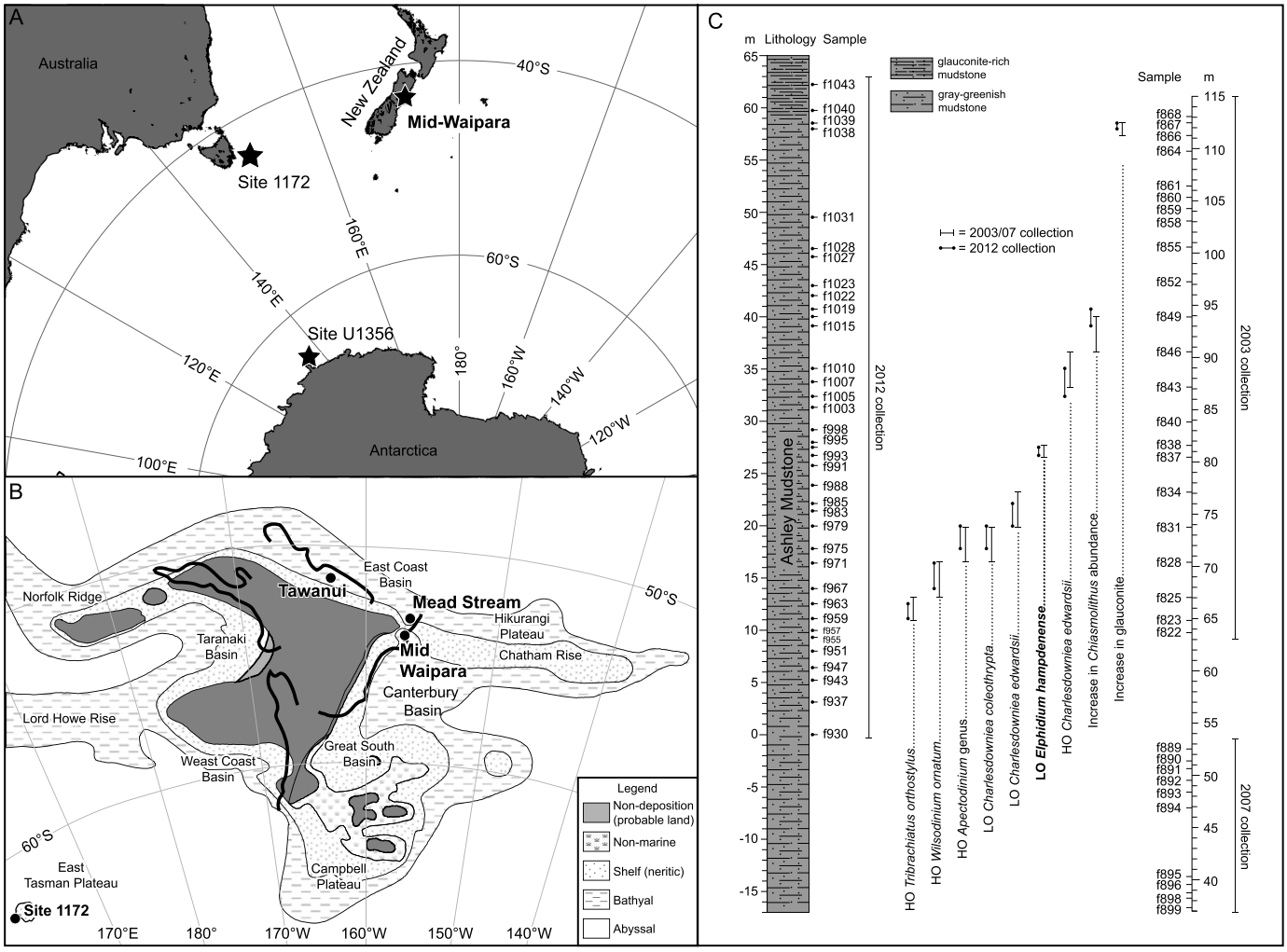

Fig. 1. A) Location of the mid-Waipara River section (South Island, New Zealand, 43.0537°S, 172.6110°E), ODP Site 1172 (Leg 189, East Tasman Plateau, 43.9598°S, 149.9283°E), and IODP Site U1356 (Exp. 318, Wilkes Land Margin, 63.3102°S, 135.9989°E). B) Paleogeographic reconstruction for the New Zealand region for the early Eocene (~56 Ma) showing the position of the mid-Waipara River, Mead Stream, and Tawanui sections; modified from Hollis et al. (2005). C) Position of the samples collected in the 2003, 2007 and the 2012 expedition, with the biostratigraphic events used to correlate the 2003 and 2012 suites; the key correlation event is the lowest occurrence (LO) of the foraminifera *Elphidium hampdenense*.

(IODP) Site U1356 on the Wilkes Land Margin, Antarctica (Bijl et al., 2013a) (Fig. 1A, B). Sea surface temperature estimates from these three regions indicate that near-tropical conditions extended close to the Antarctic margin during the EECO. As the debate continues over the veracity of absolute temperature values (Taylor et al., 2013; Inglis et al., 2015; Tierney and Tingley, 2015) and how they may be reconciled with modeled circulation patterns and temperature gradients (e.g., Huber and Caballero, 2011; Hollis et al., 2012; Lunt et al., 2012), there is a pressing need to improve correlations between localities and refine the timing of the regional climate history.

Until now, the age control for the New Zealand records has been based entirely on local biostratigraphy (Cooper, 2004; Raine et al., 2015). Moreover, the magnetostratigraphy that underpins the age model for ODP Site 1172 (Fuller and Touchard, 2004) was based on the intensity of the magnetization rather than on the inclination of the magnetic remanence as usual practice (see Tauxe et al., 2012 for details) and is not reliable, at least for the early Eocene (see also Auxiliary material). In the case of IODP Site U1356 the magnetic polarity stratigraphy for the early–middle Eocene is difficult because of very limited (~38%) sediment recovery and some discrepancies between on-board and discrete samples results (Tauxe et al., 2012).

In order to understand the Eocene climate history of the South Pacific and Southern Ocean it is critical that the succession of biotic changes that form the basis of biostratigraphic correlation are tied to the global calibration datums provided by robust magnetostratigraphy. In this paper we present the first early–middle Eocene magnetic polarity stratigraphy, based on fully oriented samples, from the mid-Waipara River section in the Canterbury Basin (South Island, New Zealand). During three field campaigns (2003, 2007, and 2012) we have sampled ~45 m of stratigraphic section for paleomagnetism and ~80 m for foraminiferal, calcareous nannofossils, and dinoflagellate cyst (dinocyst) biostratigraphy. These sediments were deposited at upper bathyal depths during the Waipawan–Bortonian New Zealand stages (NZS), i.e. the Ypresian–Bartonian international stages (Morgans et al., 2005; Hollis et al., 2009; Raine et al., 2015). We also re-investigate the early–middle Eocene magnetostratigraphy of ODP Site 1172 by analyzing discrete samples (Auxiliary material). The magnetic polarity-based correlation of this integrated dataset with the geomagnetic polarity time scale (GPTS) of Ogg and Smith (2012) allows us to improve the chronology of the composite SST proxy records for mid-Waipara, ODP Site 1172 and IODP Site U1356, constraining the timing of early–middle Eocene climate events in the Southwest Pacific and Southern Ocean.