

Integrated chronostratigraphic calibration of the Oligocene-Miocene boundary at 24.0 ± 0.1 Ma from the CRP-2A drill core, Ross Sea, Antarctica

COMMENT

J.E.T. Channell*

E.E. Martin*

Department of Geological Sciences, University of Florida, P.O. Box 112120, Gainesville, Florida 32611, USA

Wilson et al. (2002) use $^{40}\text{Ar}/^{39}\text{Ar}$ data from the Cape Roberts Project CRP-2A core to assign absolute ages to polarity chrons in the vicinity of the Oligocene-Miocene (O-M) boundary, and estimate an age of 24.0 Ma for the O-M boundary. The identification of polarity chron 6Cn.2n, marking the O-M boundary, relies on biostratigraphy and $^{87}\text{Sr}/^{86}\text{Sr}$ data.

The last occurrence of *Dictyococcites bisectus* correlates to 6Cn and is believed to be a reliable datum even at high southerly latitudes. In the nannofossil range chart given by Watkins and Villa (2000) for core CRP-2A, the highest stratigraphic occurrence of (rare) *Dictyococcites bisectus* is at 144.44 m below seafloor (mbsf). This horizon is overlain by barren samples at 140.22 and 136.63 mbsf (top of studied section). As noted by Watkins and Villa (2000), barren samples above the 144.44 mbsf level indicate the possibility that the datum may not represent a "true" last occurrence. The last occurrence of the diatom *Lisitzinia ornata* in the 256.9–259.2 mbsf interval of core CRP-2A is cited as evidence that this level corresponds to 6C, based on observations at Ocean Drilling Program (ODP) Holes 747A and 748B. At Hole 747A, the occurrence of *Lisitzinia ornata* at the end of its range is rare and sporadic, and the magnetic stratigraphy at both holes, particularly Hole 748B, is difficult to interpret (see Wise et al., 1992).

The $^{87}\text{Sr}/^{86}\text{Sr}$ ages given for core CRP-2A (Lavelle, 2000; Wilson et al., 2002) are based on the $^{87}\text{Sr}/^{86}\text{Sr}$ age tables of McArthur et al. (2001). Direct correlation of $^{87}\text{Sr}/^{86}\text{Sr}$ data to polarity subchrons close to the O-M boundary is possible at ODP Hole 747A (Oslick et al., 1994), Deep Sea Drilling Program (DSDP) Site 522 (Reilly et al., 2002), and ODP Site 1090 (Channell et al., 2003). The $^{87}\text{Sr}/^{86}\text{Sr}$ curve derived from these locations is flat immediately prior to the O-M boundary (Fig. 1). We conclude that it is not possible to resolve

ages in the 23.5 to 25 Ma (C7–C6C) interval of the CK95 time scale (Cande and Kent, 1995) using strontium isotopes.

The biostratigraphic and $^{87}\text{Sr}/^{86}\text{Sr}$ data do not rule out an interpretation in which the normal polarity zone(s) of sequences 10 and 11 in core CRP-2A is (are) one (both) of the normal polarity subzones of C7n, rather than 6Cn.3n as interpreted by Wilson et al. (2002). If the normal polarity zone of sequence 10 corresponds to C7n.1n and the normal polarity zone of sequence 11 corresponds to C7n.2n, then the $^{40}\text{Ar}/^{39}\text{Ar}$ ages from core CRP-2A are consistent with polarity chron ages 0.88 m.y. younger than CK95, consistent with the Shackleton et al. (2000) age for the O-M boundary at 22.92 Ma.

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*E-mail: Channell—jetc@ufl.edu; Martin—emartin@geology.ufl.edu.

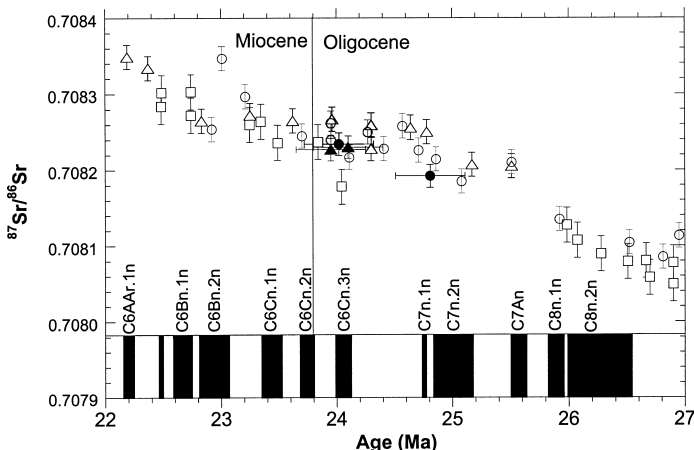


Figure 1. Closed symbols: $^{87}\text{Sr}/^{86}\text{Sr}$ data for sequence 10 (triangles) and sequence 11 (circles) from core CRP-2A with ages based on tables of McArthur et al. (2001), and age errors assuming no error in the tables. Open symbols: $^{87}\text{Sr}/^{86}\text{Sr}$ data from Deep Sea Drilling Program Site 522 (circles: Reilly et al., 2002), Ocean Drilling Program (ODP) Site 747 (triangles: Oslick et al., 1994), and ODP Site 1090 (squares: Channell et al., 2003). Ages of polarity chrons according to CK95. $^{87}\text{Sr}/^{86}\text{Sr}$ values have been normalized to NBS 987 standard value of 0.710240.

REPLY

Gary S. Wilson*

Geology Department, University of Otago, P.O. Box 56, Dunedin, New Zealand

Andrew P. Roberts

School of Ocean and Earth Science, University of Southampton, Southampton Oceanography Centre, European Way, Southampton SO14 3ZH, UK

David M. Harwood, Chris R. Fielding, David K. Watkins

Department of Geosciences, University of Nebraska, Lincoln, Nebraska 68588-0340, USA

Timothy R. Naish

Institute of Geological and Nuclear Sciences Ltd., P.O. Box 30 368, Lower Hutt, New Zealand

Fabio Florindo, Leonardo Sagnotti

Istituto Nazionale di Geofisica e Vulcanologia, Via di Vigna Murata, 605, I-00143 Rome, Italy

Reed P. Scherer

Department of Geology and Environmental Geosciences, Northern Illinois University, De Kalb, Illinois 60115, USA

Giuliana Villa

Dipartimento di Scienze della Terra, Università di Parma, Parco Area delle Scienze 157A, 43100 Parma, Italy

Mark Lavelle

Department of Earth Sciences, University of Cambridge, Downing Street, Cambridge CB2 3EQ, UK

William C. McIntosh

New Mexico Institute of Mining and Technology, Socorro, New Mexico 87801, USA

Steven M. Bohaty

Earth Sciences Department, University of California, 1156 High Street, Santa Cruz, California 95064, USA

Kenneth L. Verosub

Department of Geology, University of California, Davis, California 95616, USA

We (Wilson et al., 2002) reported an integrated chronostratigraphic data set from the CRP-2A core, Ross Sea, Antarctica. We used biostratigraphic and strontium isotope data to identify polarity chrons C6Cn.1r–C6Cn.3n (sequences 9, 10, and 11) and the Oligocene-Miocene boundary in the CRP-2A core. Chron C6Cn.3n (sequences 10 and 11) was, in turn, independently dated by single crystal laser fusion ⁴⁰Ar/³⁹Ar ages on anorthoclase phenocrysts from two discrete tephra horizons. This new calibration indicated that the geomagnetic polarity time scale in the vicinity of the Oligocene-Miocene boundary was ~0.2 m.y. older than the conventional calibration of the geomagnetic polarity time scale (Cande and Kent, 1995) and 0.9–1.3 m.y. older than the astronomical calibration of Shackleton et al. (2000). We argued that the discrepancy between our new calibration and the astronomical calibration of Shackleton et al. (2000) arose from a mismatch of three 406 k.y. eccentricity cycles or a 1.2 m.y. modulation of obliquity amplitude in the astronomical calibration.

Channell and Martin point out some limitations in the biostratigraphic data set used and contend that it is not possible to rule out correlation of the normal magnetic polarity of sequences 10 and 11 with chrons C7n.1n and/or C7n.2n, a correlation which would be consistent with the 22.92 Ma age of the Oligocene-Miocene boundary proposed by Shackleton et al. (2000).

In Figure 1, we demonstrate that the data presented by us (Wilson et al., 2002) allow a unique correlation of the normal magnetic polarity of sequences 10 and 11 of the CRP-2A core with chron C6Cn.3n of the geomagnetic polarity time scale. We accept that the last occurrence of *Dictyococcites bisectus* in the CRP-2A core may well not be a true last occurrence. However, it still affords a minimum age for strata at ~148 m below seafloor (mbsf) within sequence 9 and thus was plotted with an arrow (indicating a possibly older age) in Wilson et al. (2002, their Fig. 2). Combined with the strontium data from two well-preserved in situ articulated bivalves at 194.89 mbsf and 246.97 mbsf, the two normal polarity intervals within sequences 9, 10, and 11 are constrained to chrons C6Cn.2n and C6Cn.3n, respectively, and not to older normal polarity subchrons as suggested by Channell and Martin. Unfortunately, Channell and Martin (their Fig. 1) misplotted some of the strontium data from the CRP-2A core. We have included the correct values in Table 1 and point out that only two of the ages are from in situ material and the other two ages are from material of uncertain origin and indicate maximum ages only, and thus were plotted with arrows on the error bars in Wilson et al. (2002, their Fig. 2). The new Sr data from Channell et al. (2002) do not provide detailed coverage of

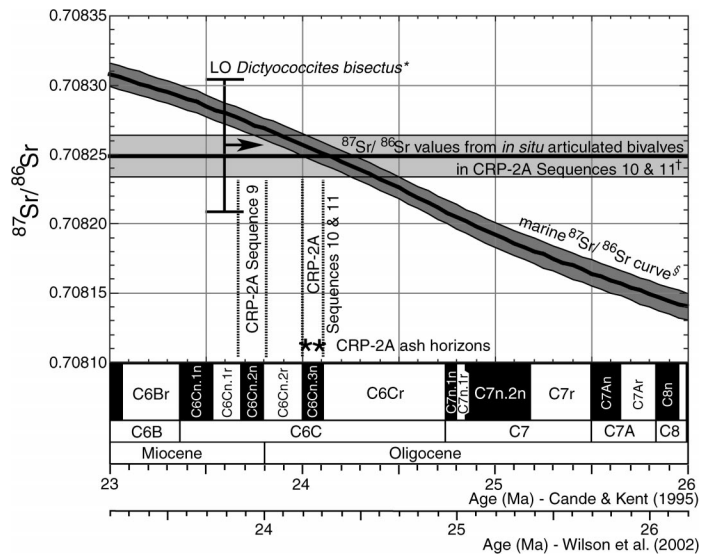


Figure 1. Correlation of chronostratigraphic data from core CRP-2A with the marine Sr curve (McArthur et al., 2001) and geomagnetic polarity time scale (Cande and Kent, 1995). *Southern Ocean age of 23.6 ± 0.1 Ma as reported in Wilson et al. (2002). †Data given in Table 1. ‡LOWESS fit from McArthur et al. (2001) including 95% confidence limits. LO is last occurrence.

the interval between 24 and 26 Ma. Thus, we have plotted our Sr data (Fig. 1) against the LOWESS fit to the marine Sr curve of McArthur et al. (2001, Fig. 1), which incorporates the data set of Oslick et al. (1994).

We conclude that the coincidence of diatom and nannofossil datums with ⁸⁷Sr/⁸⁶Sr and ⁴⁰Ar/³⁹Ar ages adequately constrains the magnetostratigraphy from the CRP-2A core and offers an opportunity to independently calibrate the Oligocene-Miocene boundary interval of the geomagnetic polarity time scale. Further testing of our calibration will require high-resolution chronologies based on independent age determinations such as the ⁴⁰Ar/³⁹Ar data from the CRP-2A core (Wilson et al., 2002; McIntosh, 2000).

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TABLE 1. STRONTIUM DATA FOR SEQUENCES 10 AND 11 OF THE CRP-2A CORE

Depth (mbsf)	Sequence	Sample	Provenance	⁸⁷ Sr/ ⁸⁶ Sr	2σ	Age*	Source	Comment
194.89	10	Articulated bivalve	In situ	0.708249	0.000015	23.95 ± 0.45	Wilson et al. (2002)	In situ, well preserved
198.75	10	Bivalve fragment	Uncertain	0.708239	0.000013	24.10 ± 0.35	Lavelle (2000)	Reworked, affords maximum age only
246.97	11	Articulated bivalve	In situ	0.708243	0.000014	24.02 ± 0.35	Lavelle (2000)	In situ, well preserved
247.67	11	Bivalve fragment	Uncertain	0.708201	0.000012	24.81 ± 0.32	Lavelle (2000)	Reworked, affords maximum age only

* ⁸⁷Sr/⁸⁶Sr age errors include the 2σ measurement error, a 2σ long-term laboratory error for standard determination (NIST-987 = 0.710249) and error in the LOWESS fit to the marine Sr curve of McArthur et al. (2001). Ages are reported with respect to the time scale of Cande and Kent (1995). Depth is in m below seafloor (mbsf).