Forum

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

COMMENT

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Wilson et al. (2002) use $^{40}Ar/^{39}Ar$ 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 $^{87}Sr/^{86}Sr$ data.

The last occurrence of *Dictyococcites bisectus* correlates to C6Cn 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 C6C, 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 $^{87}Sr/^{86}Sr$ ages given for core CRP-2A (Lavelle, 2000; Wilson et al., 2002) are based on the $^{87}Sr/^{86}Sr$ age tables of McArthur et al. (2001). Direct correlation of $^{87}Sr/^{86}Sr$ 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 $^{87}Sr/^{86}Sr$ 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 $^{87}Sr/^{86}Sr$ 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 C6Cn.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 $^{40}Ar/^{39}Ar$ 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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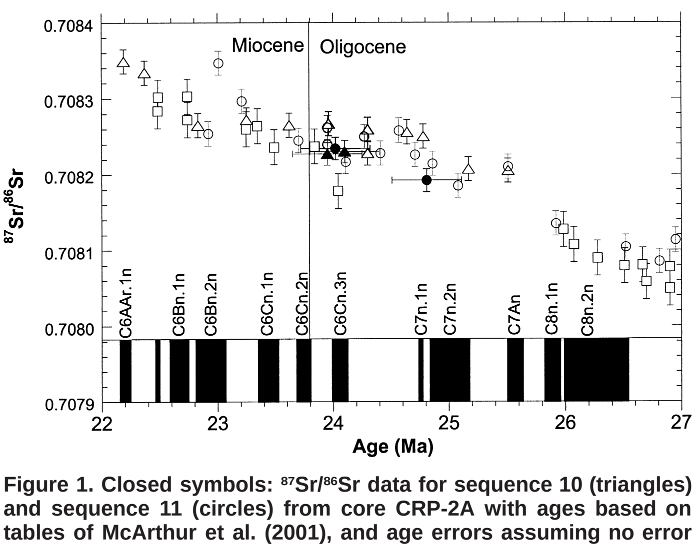

Figure 1. Closed symbols: $^{87}Sr/^{86}Sr$ data for sequence 10 (triangles) and sequence 11 (circles) from core CRP-2A with ages based on tables of McArthur et al. (2001), and age errors assuming no error in the tables. Open symbols: $^{87}Sr/^{86}Sr$ data from Deep Sea Drilling Program Site 522 (circles: 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. $^{87}Sr/^{86}Sr$ values have been normalized to NBS 987 standard value of 0.710240.

REFERENCES CITED

Cande, S.C., and Kent, D.V., 1995, A new geomagnetic polarity timescale for the late Cretaceous and Cenozoic: Journal of Geophysical Research, v. 100, p. 6093–6095.
Channell, J.E.T., Galeotti, S., Martin, E.E., Billups, K., Scher, H., and Stoner, J.S., 2003, Eocene to Miocene magnetostratigraphy, biostratigraphy, and chemostratigraphy at ODP Site 1090 (sub-Antarctic South Atlantic): Geological Society of America Bulletin, v. 115, p. 607–623.
Lavelle, M., 2000, Strontium isotope stratigraphy and age model for CRP-2/2A, Victoria Land Basin, Antarctica: Terra Antartica, v. 7, p. 611–619.
McArthur, J.M., Howarth, R.J., and Bailey, T.R., 2001, Strontium isotope stratigraphy: LOWESS Version 3: Best fit to the marine Sr-isotope curve for 0–509 Ma and accompanying look-up table for deriving numerical age: Journal of Geology, v. 109, p. 155–170.
Oslick, J.S., Miller, K.G., Feigenson, M.D., and Wright, J.D., 1994, Oligocene-Miocene strontium isotopes: Stratigraphic revisions and correlations to an inferred glacioeustactic record: Paleoceanography, v. 9, p. 427–443.
Reilly, T.J., Miller, K.G., and Feigenson, M.D., 2002, Latest Eocene–earliest Miocene Sr isotopic reference section, Site 522, eastern South Atlantic: Paleoceanography, DOI 10.1029/2001PA000745.
Shackleton, N.J., Hall, M.A., Raffi, I., Tauxe, L., and Zachos, J., 2000, Astronomical calibration age for the Oligocene-Miocene boundary: Geology, v. 28, p. 447–450.
Watkins, D.K., and Villa, G., 2000, Palaeogene calcareous nannofossils from CRP-2/2A, Victoria Land Basin, Antarctica: Terra Antartica, v. 7, p. 443–452.
Wilson, G.S., Lavelle, M., McIntosh, W.C., Roberts, A.P., Harwood, D.M., Watkins, D.K., Villa, G., Bohaty, S.M., Fielding, C.R., Florindo, F., Sagnotti, L., Naish, T.R., Scherer, R.P., and Verosub, K.L., 2002, Integrated chronostratigraphic calibration of the Oligocene-Miocene boundary at 24.0 ± 0.1 Ma from CRP-2A drill core, Ross Sea, Antarctica: Geology, v. 30, p. 1043–1046.
Wise, S.W., Jr., Schlich, R., and 28 others, 1992, Proceedings of the Ocean Drilling Program, Scientific Results, Volume 120: College Station, Texas, Texas A&M University.

REPLY

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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 $^{40}Ar/^{39}Ar$ 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 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).

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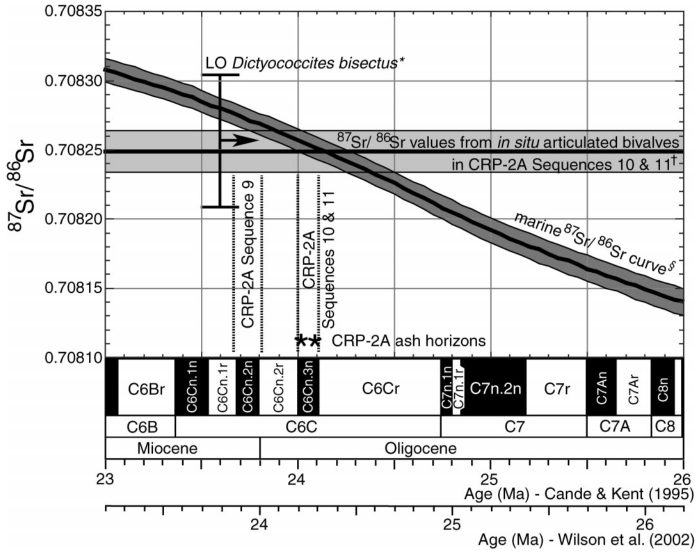

Figure 1. Correlation of chronostratigraphic data from core CRP-2A with the marine Sr curve (McArthur et al., 2001) and geomagnetic polarity time scale (Cande and Kent, 1995). *Southern Ocean age of 23.6 ± 0.1 Ma as reported in Wilson et al. (2002). †Data given in Table 1. §LOWESS fit from McArthur et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

We conclude that the coincidence of diatom and nannofossil datums with $^{87}Sr/^{86}Sr$ and $^{40}Ar/^{39}Ar$ 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 $^{40}Ar/^{39}Ar$ data from the CRP-2A core (Wilson et al., 2002; McIntosh, 2000).

REFERENCES CITED

Cande, S.C., and Kent, D.V., 1995, Revised calibration of the geomagnetic polarity time scale for the Late Cretaceous and Cenozoic: Journal of Geophysical Research, v. 100, p. 6093–6095.

Channell, J.E.T., Galeotti, S., Martin, E.E., Billups, K., Scher, H., and Stoner, J.S., 2002, Eocene to Miocene magnetostratigraphy, biostratigraphy, and chemostratigraphy at ODP Site 1090 (sub-Antarctic South Atlantic): Geological Society of America Bulletin, v. 115, p. 607–623.

Lavelle, M., 2000, Strontium isotope stratigraphy and age model for CRP-2/2A, Victoria Land Basin, Antarctica: Terra Antartica, v. 7, p. 611–619.

McArthur, J.M., Howarth, R.J., and Bailey, T.R., 2001, Strontium isotope stratigraphy: LOWESS Version 3: Best fit to the marine Sr-isotope curve for 0–509 Ma and accompanying look-up table for deriving numerical age: Journal of Geology, v. 109, p. 155–170.

McIntosh, W.C., 2000, $^{40}Ar/^{39}Ar$ geochronology of tephra and volcanic clasts in CRP-2A, Ross Sea, Antarctica: Terra Antartica, v. 7, p. 621–630.

Oslick, J.S., Miller, K.G, Feigneson, M.D., and Wright, J.D., 1994, Oligocene-Miocene strontium isotopes: Stratigraphic revisions and correlations to an inferred glacioeustatic record: Paleoceanography, v. 9, p. 427–443.

Shackleton, N.J., Hall, M.A., Raffi, I., Tauxe, L., and Zachos, J., 2000, Astronomical calibration for the Oligocene-Miocene boundary: Geology, v. 28, p. 447–450.

Wilson, G.S., Lavelle, M., McIntosh, W.C., Roberts, A.P., Harwood, D.M., Watkins, D.K., Villa, G., Bohaty, S.M., Fielding, C., Florindo, F., Sagnotti, L., Naish, T.R., Scherer, R.P., and Verosub, K.L., 2002, Integrated chronostratigraphic calibration of the Oligocene-Miocene boundary at 24.0 ± 0.1 Ma from the CRP-2A drill core, Ross Sea, Antarctica: Geology, v. 30, p. 1043–1046.

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

* $^{87}Sr/^{86}Sr$ 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).