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FAST TRACK PAPER

ODP Site 1092: revised composite depth section has implications for Upper Miocene 'cryptochrons'

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SUMMARY

An Upper Miocene magnetic polarity stratigraphy has been developed for the C3r to C5ABn interval of ODP site 1092 from the sub-Antarctic South Atlantic (Evans & Channell 2003). New data from X-ray fluorescence (XRF) scanning of half cores has led to development of a revised composite depth section for the site. This has implications for the magnetostratigraphic interpretation. Using the shipboard-derived composite section, four subchrons were identified within the normal polarity zone correlative to C5n.2n. The revised composite section results in subchrons C5n.2n-2 and C5n.2n-3 of Evans & Channell (2003) becoming a single subchron recorded in two overlapping cores. The revised number of polarity subchrons within C5n.2n is now three, rather than four, which is consistent with the number of 'cryptochrons' recognized in marine oceanic anomaly data.

Key words: cryptochrons, magnetostratigraphy, Miocene, South Atlantic.

1 INTRODUCTION

ODP Site 1092 is located in the sub-Antarctic South Atlantic (46°24.7′S, 7°4.8′E, water depth = 1974 m). A magnetic polarity stratigraphy was presented for two time intervals (1.95 to ∼3.6 Ma and ∼5.9 to ∼13.5 Ma) by Evans & Channell (2003). As is routine aboard the R/V *Joides Resolution*, composite stratigraphic depths (metres composite depth; mcd) for site 1092 were constructed from multisensor track (MST) data. Magnetic susceptibility, gamma-ray attenuation porosity (GRAPE) and light reflectance data were used to correlate among holes at the site and to derive an optimal record (splice) of the sedimentary section (Shipboard Scientific Party 1999). The composite depths for ODP site 1092 have now been revised using X-ray fluorescence (XRF) scans of half-cores. These new data have allowed improved correlation among the holes at the site. The revised metres composite depth (rmcd) scheme has resulted in significant changes in hole-to-hole correlation, particularly within the interval correlative to subchron C5n.2n.

Using the shipboard composite section, Evans & Channell (2003) identified four reverse polarity subzones within the polarity zone correlative to C5n.2n. The four polarity subzones were considered to be correlative to 'cryptochrons' in the polarity timescale of Cande & Kent (1992) and were labelled as C5n.2n-1 to C5n.2n-4. The results imply that 'cryptochrons' originally identified within marine magnetic anomaly 5 by Blakely (1974) signify polarity reversals rather than solely geomagnetic intensity minima. On the revised composite depth scale, the reverse polarity subchrons labelled as C5n.2n-2 and C5n.2n-3 by Evans & Channell (2003) become a single subchron recorded in two different holes. The result supports the revised composite depth scale and indicates three, not four, subchrons within C5n.2n.

2 REVISED COMPOSITE DEPTHS

Shipboard MST data (magnetic susceptibility, GRAPE) and light reflectance data from site 1092 are often too uniform, particularly in the Upper Miocene section (120–185 mcd), for precise hole-to-hole correlation. As part of a project to assess carbonate sedimentation in the southern oceans, Westerhold & Bickert (in preparation) have measured most of the archive halves of cores from site 1092 using the XRF core scanner at the Universität Bremen (Röhl & Abrams 2000). Fe and Ca intensity data, measured every 2 cm, are often more variable than shipboard MST data and generally provide an efficient means of hole-to-hole correlation.

Some core sections within the shipboard composite splice were not scanned for XRF because the working and archive halves had been too heavily sampled (partly for u-channels to generate the magnetic data). For core sections without XRF data, shipboard magnetic susceptibility could be adequately matched to core sections with Fe intensity data from XRF scans. Some cores from outside the splice had to be stretched or squeezed to conform with the overall depth scale of the shipboard composite section. Drilling-related expansion and contraction in these poorly consolidated sediments contributes to the lack of precise correlation of depth scales between holes (Shipboard Scientific Party 1999). The depth scale of the shipboard composite section (with no stretching or squeezing of cores within

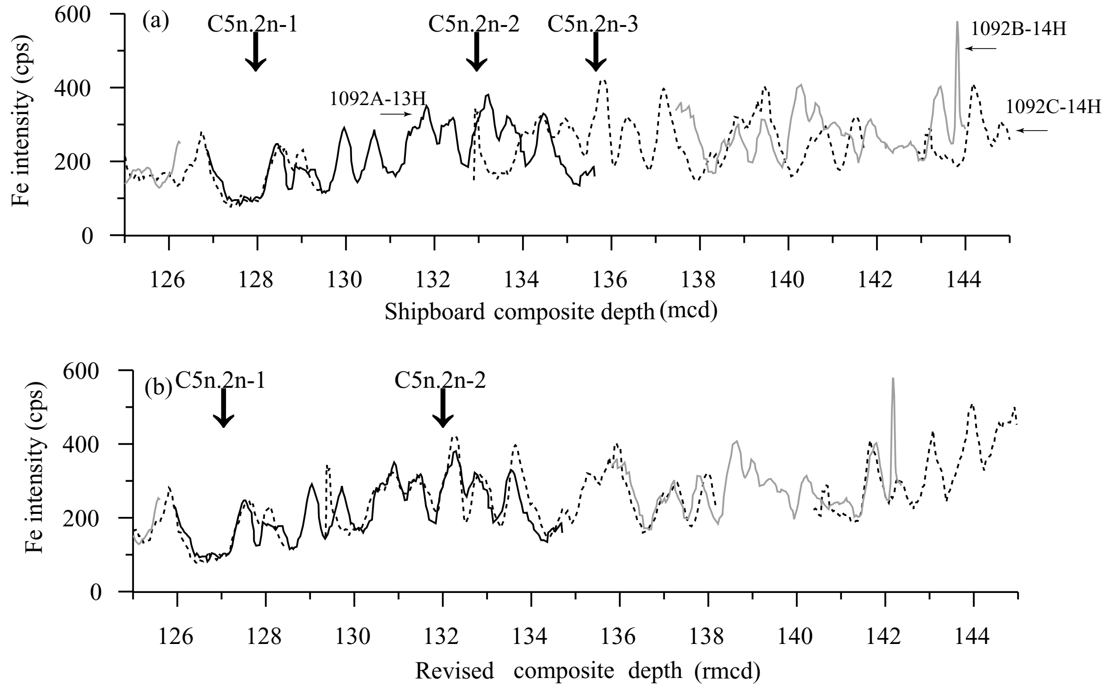

Figure 1. (a) Fe intensity (XRF) data plotted as a five-point moving average on the shipboard composite depth (mcd) scheme, with the position of the three subchrons identified in core sections 1092C-13H-6, 1092A-13H-4 and 1092C-14H-2 (C5n.2n-1 to 3) by Evans & Channell (2003). The thick dark curve indicates data from hole 1092A, the grey curve data from hole 1092B and the broken curve data from hole 1092C. (b) Fe intensity (XRF) data plotted as a five-point moving average on the revised composite depth (rmcd) scheme. Curve notation as for Fig. 1(a). On the revised composite depth (rmcd) scheme, C5n.2n-2 and C5n.2n-3 merge into a single subchron (C5n.2n-2).

the splice) was adhered to in the construction of the revised composite section (rmcd).

Above core 1092A-12H, the shipboard composite section (mcd) is consistent with hole-to-hole correlations based on both MST and XRF data. In the shipboard splice, core 1092C-12H overlies 1092A-12H. Core 1092C-12H can be well correlated to 1092B-12H using XRF and magnetic susceptibility, and this correlation is consistent with shipboard composite depths. Correlation from 1092C-12H to the underlying core in the splice (1092A-12H) is poor for both MST and XRF data. However, 1092B-12H can be well correlated to 1092C-13H, but only when the latter is moved 90 cm up relative to 1092B-12H. This shift is the uppermost modification of the composite section depths. Below this, 1092A-13H can be well correlated to its neighbouring cores in the splice (1092C-13H and 1092C-14H), however, the correlation to 1092C-14H requires that this core should be moved up 2.58 m into 1092A-13H. The rationale for this adjustment, based on Fe intensity (XRF) data, is illustrated in Fig. 1.

3 IMPLICATIONS FOR MAGNETIC STRATIGRAPHY

Augmentation of the MST data by XRF data leads to offsets between the shipboard composite depths (mcd) and the revised composite depths (rmcd) that reach a maximum of 3.54 m in 1092C-14H (Table 1). The resulting modification of the composite section provides new composite depths for polarity zone boundaries at site 1092 (Table 2 and Fig. 2), with new age estimates for subchrons not included in the standard geomagnetic polarity

Table 1. Adjusted depths of core tops from ODP site 1092.

Core	mbsf	Ship mcd*	Offset mcd to mbsf (m)	Revised mcd (rmcd)	Offset mbsf to rmcd (m)	Offset mcd to rmcd (m)
177-1092A-						
12H	103	115.41	12.41	114.48	11.48	−0.93
13H	112.5	126.72	14.22	125.8	13.3	−0.92
14H	122	138.12	16.12	136.51	14.51	−1.61
15H	131.5	149.74	18.24	147.26	15.76	−2.48
16H	141	160.18	19.18	159.01	18.01	−1.17
17H	150.5	168.72	18.22	170.14	19.64	1.42
18H	160	179.85	19.85	181.57	21.57	1.72
19H	169.5	191.84	22.34	191.07	21.57	−0.77
20H	179	201.34	22.34	200.57	21.57	−0.77
177-1092B-						
13H	111.4	122.22	10.82	121.57	10.17	−0.65
14H	121.4	134.32	12.92	132.68	11.28	−1.64
15H	130.9	146.62	15.72	144.14	13.24	−2.48
16H	140.4	155.72	15.32	154.74	14.34	−0.98
17H	149.9	166.76	16.86	165.23	15.33	−1.53
18H	159.4	175.31	15.91	176.96	17.56	1.65
177-1092C-						
13H	108.5	119.93	11.43	119.01	10.51	−0.92
14H	118	132.82	14.82	129.28	11.28	−3.54
15H	127.5	142.70	15.20	140.22	12.72	−2.48
16H	137	155.70	18.70	151.72	14.72	−3.98
17H	146.5	166.38	19.88	162.34	15.84	−4.04
18H	156	175.79	19.79	173.91	17.91	−1.88

*Shipboard Scientific Party (1999).
Abbreviations: mbsf, metres below sea floor; mcd, metres composite depth; rmcd, revised metres composite depth.

Table 2. Position of the polarity zone boundaries at site 1092 in shipboard metres composite depth (mcd) and revised metres composite depth (rmcd). Ages of polarity chrons are from the geomagnetic polarity timescale (GPTS) of Cande & Kent (1992) 1995). Ages of polarity subchrons not featured in the GPTS are marked by an asterisk and estimated assuming constant sedimentation rates within polarity chrons.

Depth (mcd)	rmcd	Chron	Age (Ma) CK92
121.48	120.55	Base C5n.1n	9.880
122.40	121.47	Top C5n.2n	9.920
127.92	127.00	Top C5n.2n.1	10.098*
128.01	127.15	Base C5n.2n.1	10.103*
132.88	131.95	Top C5n.2n.2	10.258*
133.02	132.16	Base C5n.2n.2	10.263*
151.31	148.60	Top C5n.2n.3	10.803*
151.43	148.95	Base C5n.2n.3	10.814*
156.60	154.12	Base C5n.2n	10.949
158.80	157.82	Top C5r.1n	11.052
160.00	159.02	Base C5r.1n	11.099
163.10	161.91	Top C5r.2n	11.476
164.54	163.37	Base C5r.2n	11.531
170.60	169.07	Top C5r.3r.1n	11.866*
170.79	169.26	Base C5r.3r.1n	11.877*
171.75	173.24	Top C5An.1n	11.935
173.00	174.42	Base C5An.1n	12.078
174.20	175.67	Top C5An.2n	12.184
174.49	175.94	Base C5An.2n	12.401
177.70	179.35	Top C5Ar.1n	12.678
178.50	180.15	Base C5Ar.1n	12.708
179.00	180.65	Top C5Ar.2n	12.775
179.42	181.13	Base C5Ar.2n	12.819
180.29	181.94	Top C5AAn	12.991
181.55	183.20	Base C5AAn	13.139
181.95	183.60	Top C5AAr.1n	13.208*
182.02	183.67	Base C5AAr.1n	13.220*
182.50	184.15	Top C5ABn	13.302

timescale (GPTS). The magnetostratigraphic interpretation (the correlation of polarity zones to polarity chrons) is the same as in Evans & Channell (2003) apart from the interval within C5n.2n. When utilizing the shipboard composite section, this normal polarity chronozone appeared to contain four thin polarity subzones that Evans & Channell (2003) associated with 'cryptochrons' in marine oceanic magnetic anomaly data. The revision of the composite section indicates that there is duplication of polarity subzones that is an artefact of miscalculations in shipboard composite depths. Polarity subchrons that were originally labelled C5n.2n-2 (recorded in core 1092A-13H) and C5n.2n-3 (recorded in core 1092C-14H), become a single subchron (relabelled as C5n.2n-2). The realignment of cores 1092A-13H and 1092C-14H within the composite section (Fig. 1b) results in coincidence of the records of C5n.2n-2 and C5n.2n-3 (Figs 3a and b). This not only ratifies the adjustment of the composite section but also reduces the number of subchrons within C5n.2n from four to three (Fig. 3), consistent with the number of 'cryptochrons' in the GPTS of Cande & Kent (1992). Normalized remanence (mean natural remanent magnetization/isothermal remanent magnetization; NRM/IRM), used as a proxy for geomagnetic palaeointensity in Evans & Channell (2003), can also be well correlated between cores 1092A-13H and 1092C-14H after revision of the composite depths (Figs 3c and d). The revised composite depths also alter the estimated duration of C5n.2n-2 and C5n.2n-3. C5n.2n-2 now has an estimated duration of 5 kyr, while the duration of C5n.2n-3 increases to 11 kyr, assuming a uniform sedimentation rate within C5n.2n.

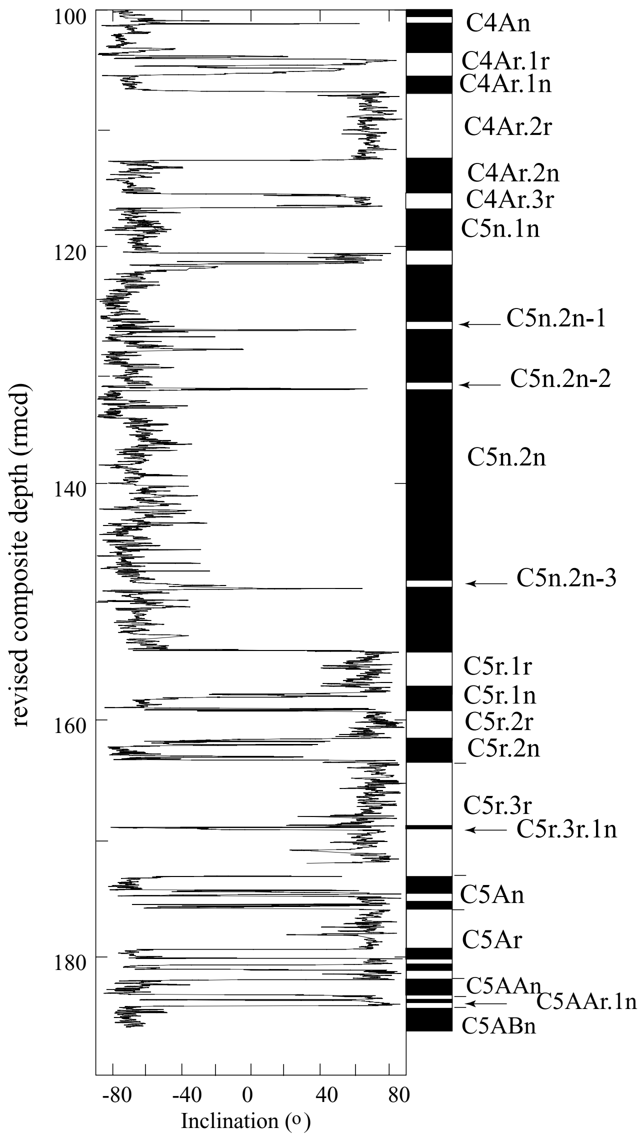

Figure 2. Inclination of the characteristic magnetization component plotted against revised composite depth (rmcd) for site 1092. Polarity chrons are labelled according to Cande & Kent (1992). Arrows indicate subchrons within C5n.2n, C5r.3r and C5AAr.1n. Polarity interpretation: black indicates normal polarity, white reverse polarity.

In the Orera Section (Spain), Abdul Aziz *et al.* (2003) found three normal polarity subzones within C5r (two within C5r.2r and one within C5r.3r) that are not represented in the GPTS of Cande & Kent (1992, 1995). This augmented C5r could be correlated with the polarity zones at site 1092 by moving the onset of C5r.3r to 179.41 rmcd (Krijgsman, private communication, 2003). The polarity zones at site 1092 correlative to these three features have thicknesses of 1.75 m (C5r.2r-1n), 0.23 m (C5r.2r-2n) and 0.38 m (C5r.3r-1n). This interpretation appears consistent with the hiatus at 180.48 rmcd advocated by Censarek & Gersonde (2002) from the diatom biostratigraphy. The hiatus was placed at 180.48 rmcd on the basis of the coincidence of the first occurrences of *Denticulopsis praedimorpha* and *Nitzschia denticuloides*, and the last occurrence

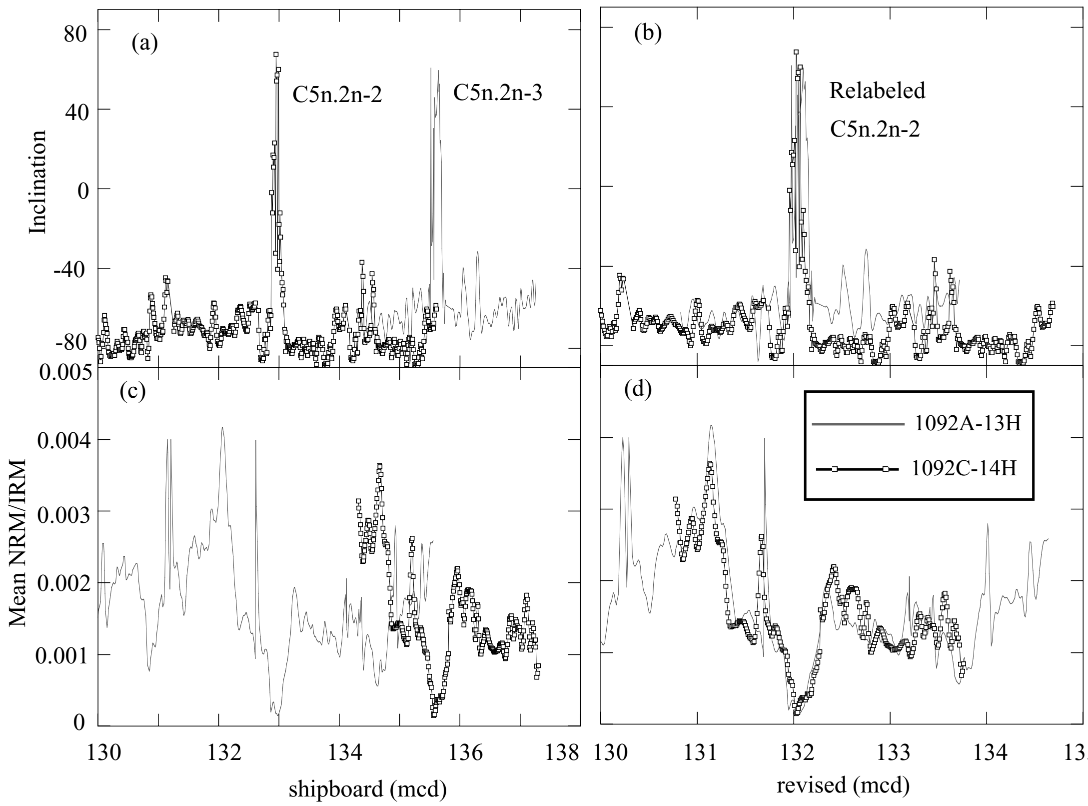

Figure 3. Site 1092. (a) Inclination of the characteristic magnetization component plotted against shipboard composite depth (mcd) showing C5n.2n-2 and C5n.2n-3 according to Evans & Channell (2003). (b) Inclination of the characteristic magnetization component plotted against revised composite depth (rmcd) showing that subchrons C5n.2n-2 and C5n.2n-3 of Evans & Channell (2003) become a single subchron (now labelled C5n.2n-2). (c) Mean of the ratio of natural remanent magnetization (NRM) to isothermal remanent magnetization (IRM), calculated for nine demagnetization steps in the 20–60 mT demagnetization range, plotted against shipboard composite depth (mcd). (d) Mean of the ratio of natural remanent magnetization (NRM) to isothermal remanent magnetization (IRM), calculated for nine demagnetization steps in the 20–60 mT demagnetization range, plotted against revised composite depth (rmcd).

of *Actinocyclus ingens* var. *nodus*, although the ages of these diatom events are poorly constrained.

In a recent study of chron C5 at ODP site 887, Bowles *et al.* (2003) found no evidence for reverse polarity subzones within C5n.2n and concluded that 'cryptochrons' of this age recognized in marine magnetic anomaly data represent fluctuations in geomagnetic field intensity. The mean sedimentation rate in C5n.2n at site 887 is 1 cm kyr^{-1}, or ∼30 per cent of that at site 1092, and it is therefore less likely that polarity intervals of the duration seen at ODP site 1092 would have been recorded at site 887.

The short duration of the reverse polarity intervals within C5n.2n at site 1092 may indicate that they are 'excursions' rather than polarity subchrons. Various criteria have been suggested to distinguish 'excursions' from polarity subchrons (Cande & Kent 1992; Gubbins 1999; Roberts & Lewin-Harris 2000). Roberts & Lewin-Harris (2000) suggested that for a polarity excursion to qualify as a polarity subchron it should be bounded by two field reversals, and that decreases in palaeointensity should be apparent at both bounding reversals. Of the three subchrons within C5n.2n at site 1092, only C5n.2n-3 exhibits a clear recovery in palaeointensity between the reversals.

The fundamental conclusion of Evans & Channell (2003) that short-duration (5–11 kyr) polarity subchrons exist within C5n.2n which are probably correlative to 'cryptochrons' interpreted from oceanic magnetic anomaly data, has not changed. However, the number of polarity subchrons within C5n.2n has been reduced from four to three by revision of composite depths at site 1092.

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