20. MESOZOIC MAGNETOSTRATIGRAPHY OF MAUD RISE, ANTARCTICA[1]

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ABSTRACT

A paleomagnetic investigation of the Late Cretaceous sediments of the Maud Rise, Antarctica, recovered in Holes 689B and 690C provides a fairly complete magnetostratigraphic record ranging from Chron C33N through Chron C29R. The Cretaceous/Tertiary boundary is shown to occur in Chron C29R at Site 690.

INTRODUCTION

Leg 113 of the Ocean Drilling Program included recovery of an uppermost Mesozoic and Cenozoic biogenic sedimentary sequence which drapes the basaltic basement of the Maud Rise. The open ocean setting of Maud Rise situated some 700 km north of the continental margin of East Antarctica affords a unique high latitude biostratigraphic sequence for detailed magnetobiochronological study. This paper describes the magnetostratigraphy of the Late Cretaceous sediments of this sequence and focuses particularly on the record across the Cretaceous-Tertiary boundary (K/T). The magnetostratigraphic assignments for the high resolution Cenozoic sequence are presented elsewhere by Spieß (this volume).

Four holes were drilled at Site 689 located near the crest of the Maud Rise in a water depth of 2080 m (Fig. 1). In Hole 689B the extended core barrel (XCB) was used to drill foraminifer-bearing nannofossil chalks of Upper Cretaceous age. A section of similar lithology and equivalent age was recovered in Hole 690C at Site 690 on the flank of Maud Rise some 116 km southwest of Site 689. Hole 690C terminated at 321.6 mbsf in oceanic alkali basalts.

Shipboard studies (Barker, Kennett, et al., 1988) indicated that an essentially complete K/T boundary sequence is preserved at Site 690 and possibly at Site 689. This discovery extends the global database of marine K/T boundary sites to Antarctica for the first time. It is generally accepted, following the classic studies of uplifted marine sections in the Umbrian Apennines (Alvarez et al., 1977), that the K/T boundary occurs within the later part of the reversed polarity interval Chron C29R. Magnetostratigraphic studies are thus complementary to biostratigraphical assignments for an independent verification of this first-order chronostratigraphic boundary.

In order to aid the establishment of Late Mesozoic biostratigraphic zonal schemes that are applicable to the Antarctic region of the Southern Ocean it is necessary to utilize magnetostratigraphic control. Therefore determination and assignment of polarity magnetozones for the Maud Rise sites to the geomagnetic polarity timescale (Berggren et al., 1985) is an essential precursor to achieving this objective.

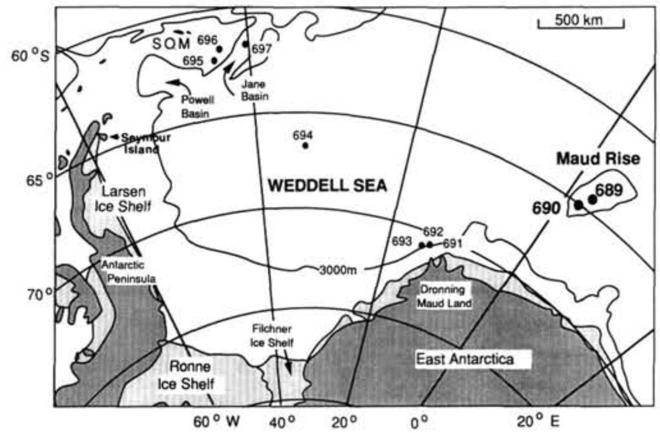

Figure 1. Location of the Maud Rise off East Antarctica and other Leg 113 drill sites. SOM = South Orkney microcontinent.

SAMPLING AND MEASUREMENT

The extended core barrel recovery of Late Cretaceous sediments in Hole 689B was only 45% but improved to 80% in Hole 690C. Sampling for paleomagnetic study was of necessity constrained to drilling biscuits of a size sufficient to ensure that no inversion during coring had occurred. Most samples taken were standard volume (10 cm^3) cylindrical specimens but a few were cut cubically to fit 6 cm^3 sampling boxes. A downcore sampling frequency interval of 25 cm was adopted throughout the recovered sections, but this was not always possible because of drilling disturbance. A higher sampling density was used for Sections 113-689B-25X-5 and 113-690C-15X-4 which contain the K/T boundary intervals. In total, 165 samples comprising 75 from Hole 689B and 90 from Hole 690C were obtained for shore-based investigation.

Measurements of the natural remanent magnetization (NRM) of the samples were undertaken using either a Digico "complete results" spinner magnetometer or a single-axis CCL cryogenic magnetometer. All samples were subjected to alternating field (AF) demagnetization employing either a Highmoor demagnetizer to peak field values of 60 mT or a built-in demagnetizer incorporated in the cryogenic magnetometer system, which allows demagnetization to a peak field of 35 mT. Typical examples of demagnetization behavior are shown in the orthogonal vector plots and normalized intensity decay curves of Figure 2. These demagnetization procedures efficiently removed the effects of

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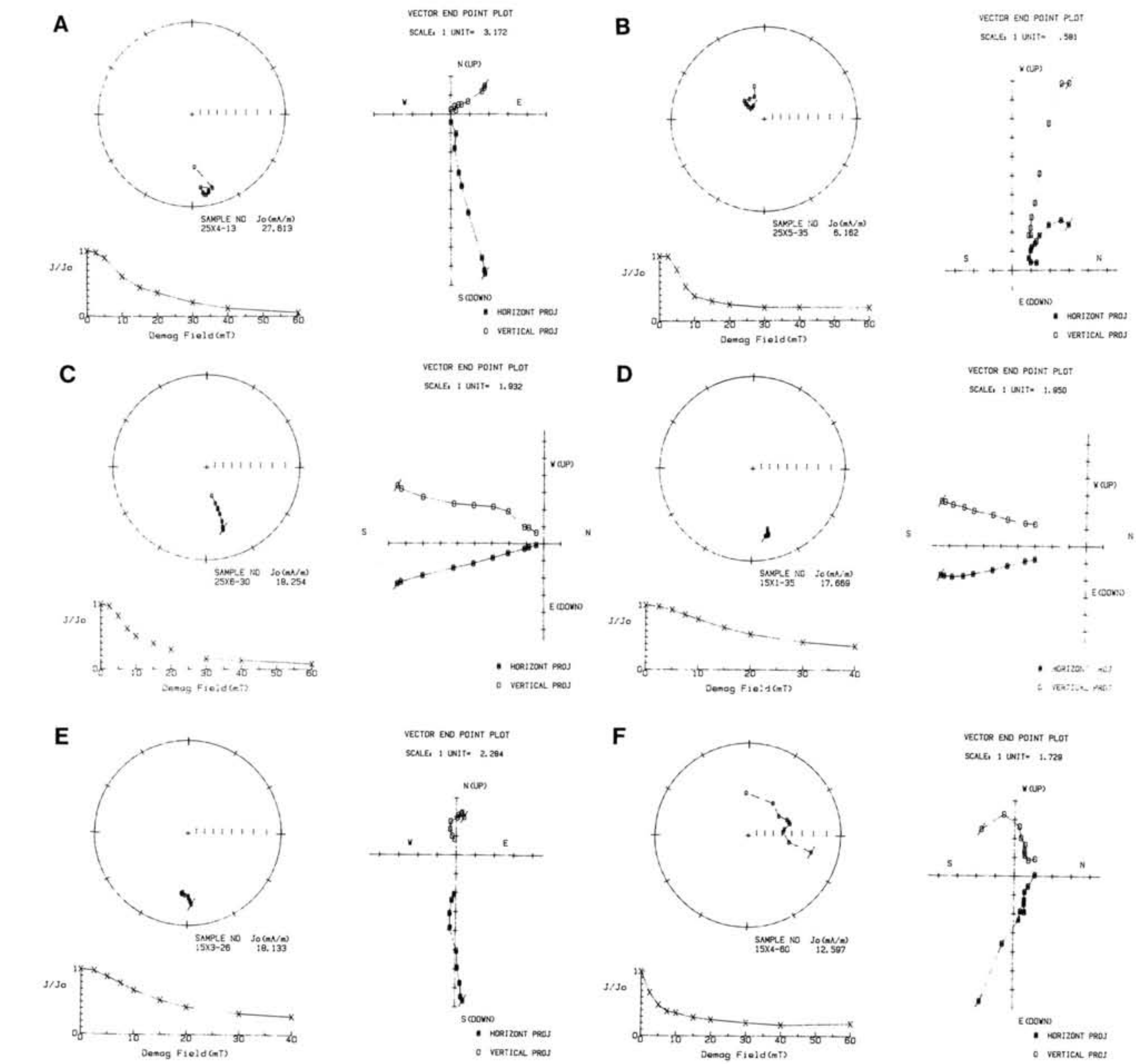

Figure 2. Typical examples of behavior during progressive alternating field demagnetization of samples from Holes 689B and 690C. Equal area stereographic projections have arbitrary declination as cores are unoriented azimuthally. **A.** Sample 113-689B-25X-4, 13–15 cm. **B.** Sample 113-689B-25X-5, 35–37 cm. **C.** Sample 113-689B-25X-6, 30–32 cm. **D.** Sample 113-690C-15X-1, 35–37 cm. **E.** Sample 113-690C-15X-3, 26–28 cm. **F.** Sample 113-690C-15X-4, 60–62 cm.

low coercivity viscous magnetization components and generally enabled a stable end-point or a directional trend to be determined for a majority of the samples.

DISCUSSION

NRM Intensity Variation

Downhole variation in NRM magnetization intensities are broadly similar for both sites (Fig. 3). Intensities vary between 0.04 and 115 mA/m. The higher values occur in the uppermost Cretaceous and earliest Paleocene reflecting mainly an increasing component of altered volcanic ash at this stratigraphic level (see below). The lowest values are typical of the semi-indurated chalks.

At Site 689 there is an abrupt fall in intensity below 257 mbsf (between Samples 113-689B-28X-1, 102–104 cm, and -28X-2, 18–20 cm) from about 7.1 to about 0.15 mA/m. This change takes place close to a prominent chert layer, located stratigraphically within the calcareous nannofossil *Biscutum magnum* Zone. The underlying foraminifer-bearing nannofossil chalks are dominantly of low intensity. The NRM intensities of the lowermost samples from Section 113-689B-30X-3 (about 278 mbsf) show a rise to slightly higher values about 0.40 mA/m. This could be indicative of the proximity to the underlying igneous basement. Hole 689B terminated at a depth of 297.3 mbsf in nannofossil chalk; a projected basement contact was anticipated at about 320 mbsf from interpretation of the seismic profile at the site (Barker, Kennett, et al., 1988). A much greater intensity of 11.35

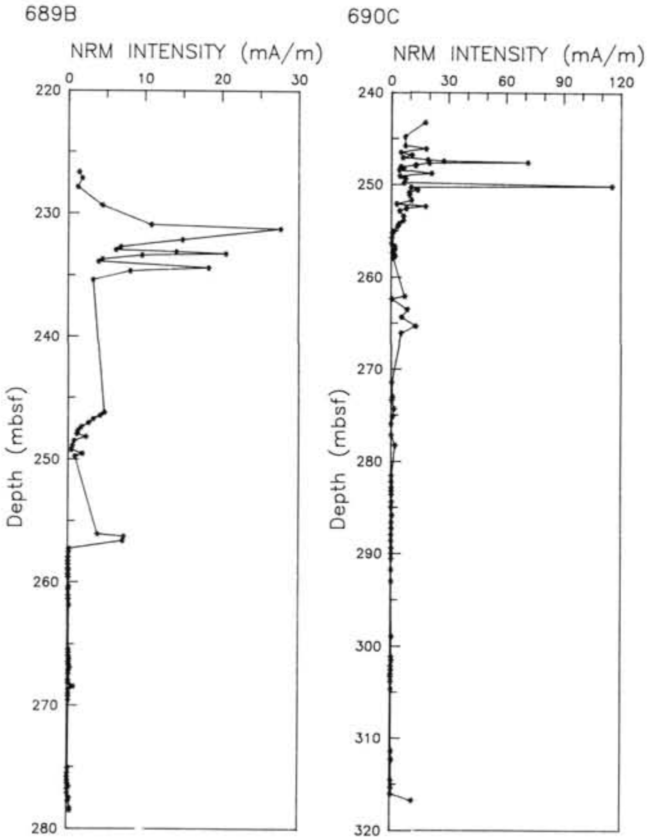

Figure 3. Comparison of the downhole NRM intensity variation of the Late Cretaceous through early Paleocene sediment sequence at Holes 689B and 690C.

mA/m characterizes Sample 113-690C-22X, CC (11–13 cm), which is the basal sediment sample taken for paleomagnetic study from Hole 690C at a depth of 316.8 mbsf. This sample occurs at a level only 20 cm above the contact with basaltic basement fragments immediately below which 1.71 m of normally magnetized amygdaloidal pyroxene-olivine basalt was recovered. Intensities between 316 mbsf and 281 mbsf in Hole 690C are low (mean value, 0.35 mA/m) corresponding with the dominant calcareous claystone and muddy chalk lithologies. Sample 113-690C-18X, CC (13–15 cm) shows an increased NRM intensity to 2.09 mA/m occurring at an equivalent biostratigraphic level (upper part of *Biscutum magnum* Zone) to the abrupt increase noted above in Hole 689B. Variable intensities typify the overlying late Maestrichtian muddy nannofossil chalks up to the anomalously high intensities encountered in Core 113-690C-15X at approximately 250 mbsf.

Magnetostratigraphic Assignment

As these drill sites are located at high latitude it is acceptable to use the inclination of the remanent magnetization vector as a reliable index of magnetic polarity. The expected axial dipole field inclination at the two sites is approximately $-77°$ given that the paleolatitude of the Maud Rise in Late Cretaceous to early Paleogene times was not significantly different from that of its present day location. In the Southern Hemisphere negative inclination records normal polarity and positive inclination reverse polarity. Downhole magnetozones are inferred from the inclination values determined after magnetic cleaning by alternating field demagnetization to peak fields of between 15 and 30 mT. For a majority of the samples used in this study these peak fields are sufficient to remove any normal magnetization overprint acquired in the Brunhes Chron. Median destructive field values are normally in the range between 2 and 28 mT. Even if a stable end point is not reached after demagnetization at the peak field value, from the directional trend or by examination of any tendency of the remanent vector to group at intermediate field values, the sign of the inclination can often be reliably determined and hence the polarity inferred.

Figure 4 shows the downhole inclination data together with the interpreted magnetozones for Hole 689B. Clearly the magnetic cleaning affects some improvement in revealing the magnetostratigraphy of the Late Cretaceous sequence at this site. The resolution of the polarity boundaries at 260 mbsf and at 277 mbsf is particularly prominent. Nonetheless, the true fidelity of the inferred magnetozones is obscured by the constraint imposed by sampling gaps in the intervals of non recovery. Better recovery from Hole 690C reveals generally a much sharper definition of the polarity record (Fig. 5). The shallow negative inclinations occurring between 262 and 266 mbsf suggest either imperfect magnetic cleaning or an unknown rotation error in the drilling biscuits sampled in this interval. The latter explanation is probable as microfaulting is noted in Core 113-690C-17X from which the anomalous samples are taken.

Considering the polarity zonations for Hole 689B and Hole 690C in combination there is sufficient evidence to decipher the Late Cretaceous magnetostratigraphy for the Maud Rise. Above the normally magnetized basaltic basement (Barker, Kennett, et al., 1988) the oldest calcareous sediments of presumed late Cam-

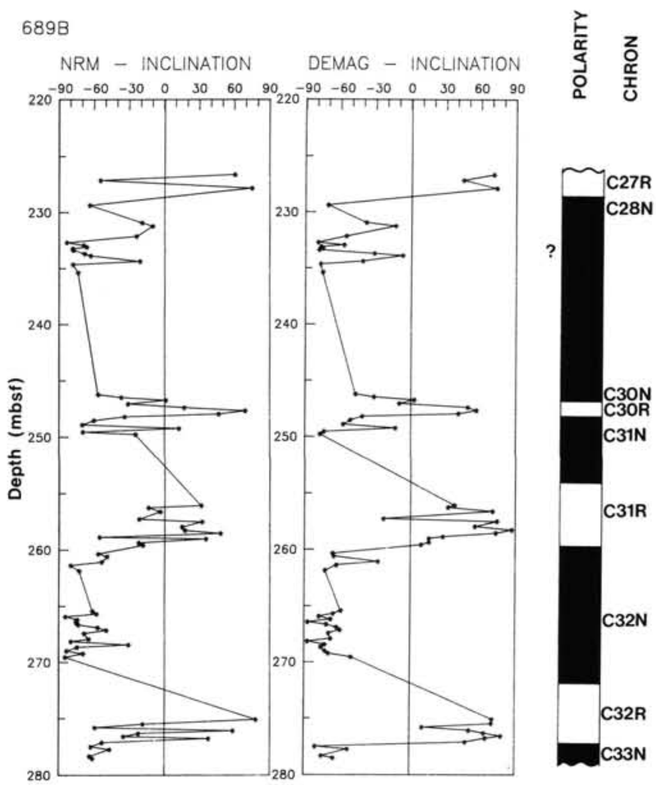

Figure 4. Downhole NRM inclination and "cleaned" inclination data for Hole 689B together with inferred magnetic polarity zonation and the chron assignment. Black is normal polarity and blank is reverse polarity.

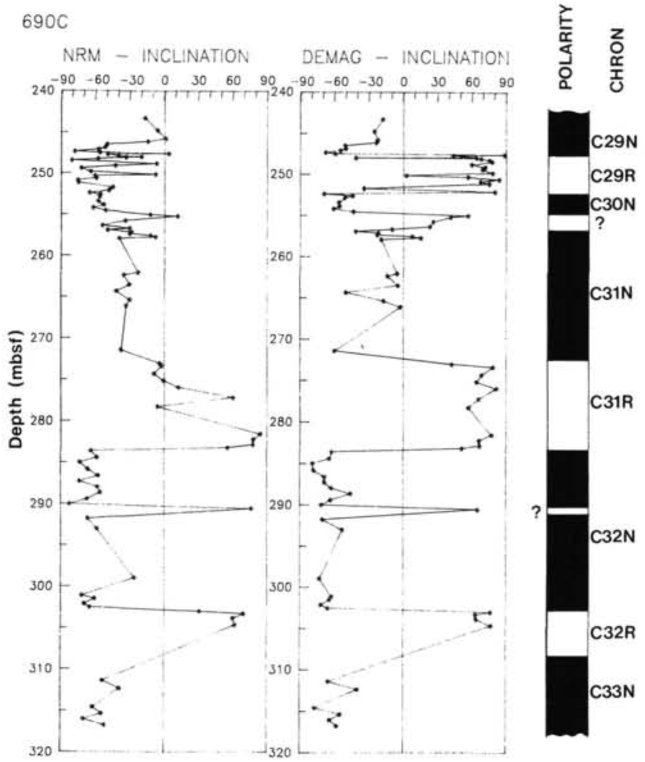

Figure 5. Downhole NRM inclination and "cleaned" inclination data for Hole 690C together with inferred magnetic polarity zonation and the chron assignment. Black is normal polarity and blank is reverse polarity.

panian age belong to a normal magnetozone. Assignment to the established geomagnetic polarity timescale suggests that this magnetozone correlates with Chron C33N. A summary of the sub-bottom depths at which the overlying chronozonal boundaries are identified for the Maud Rise holes is given in Table 1 together with the proposed chron assignments for the sequence of Late Cretaceous through earliest Paleocene age (see also Figs. 4 and 5) It is interesting to note that the Chron C32N/C31R boundary at 259.97 mbsf (Hole 689B) and 283.39 mbsf (Hole 690C) is close to the biostratigraphically determined middle/upper Maestrichtian boundary (Huber, this volume; Pospichal and Wise, this volume, chapter 30). Subchron C31R appears particularly well determined in Hole 690C as it does at DSDP Site 516 on the Rio Grande Rise in the southwestern Atlantic (Hamilton and Suzyumov, 1983) and in the uplifted pelagic marine sections such as in the Umbrian Apennines (Lowrie et al., 1980).

Table 1. Early Paleocene and Late Cretaceous magnetostratigraphic assignments for the Maud Rise Holes 689B and 690C.

Hole 689B Depth (mbsf)	Chron boundary	Hole 690C Depth (mbsf)
228.61	C27R/C28N	—
—	C28N/C28R	—
—	C28R/C29N	—
—	C29N/C29R	247.55
—	C29R/C30N	252.28
246.60	C30N/C30R	—
248.08	C30R/C31N	—
252.92	C31N/C31R	272.25
259.97	C31R/C32N	283.39
272.33	C32N/C32R	302.78
277.32	C32R/C33N	308.02

Calibration of the Maud Rise magnetozones to the geomagnetic polarity timescale provides an independent estimate of average apparent sedimentation rate. For the Late Cretaceous (Maestrichtian) this is approximately 7.4 m/m.y. at Site 690 (between 247 and 308 mbsf); it is marginally slower on the crest of the rise at Site 689.

Cretaceous/Tertiary Boundary Magnetostratigraphy

It was postulated from cursory shipboard examination that a continuous sequence spanning the Cretaceous/Tertiary boundary was preserved in the sediments recovered in Section 113-690C-15X-4 between 247.4 and 248.9 mbsf and possibly in Section 113-689B-25X-5 between 232.6 and 234.1 mbsf. In both instances a pronounced color change is observed in the vicinity of the projected K/T boundary location. This change is from white chalk to greenish altered volcanic clay in Hole 689B, whereas in Hole 690C the change is to brownish volcanogenic sediments. Extensive bioturbation partly obscures exact boundary relationships in both sections. Confirmation of these findings is the subject of multidisciplinary studies (see for example Pospichal and Wise, this volume, chapter 32; Michel et al., this volume). Detail of the inferred magnetostratigraphy of these boundary cores is of considerable relevance to such investigations.

The nature of the bioturbation and biscuiting by the XCB drilling of the boundary cores makes precise paleomagnetic sampling difficult. However, the sampling pattern adopted is dense enough to reveal the character of the polarity stratigraphy across the K/T boundary. At Hole 689B stepwise AF demagnetization of the boundary core samples to peak field values of 60 mT did not substantially alter the downhole inclination record (Fig. 6). Essentially the core is of apparent normal polarity in the interval between 228.6 mbsf and 235.4 mbsf. Biostratigraphic zonations suggest that the K/T boundary, if present, should occur at about 233.4 mbsf. At this level the paleomagnetic results show intermediate to shallow inclinations but no steep positive inclinations which would be indicative of Subchron C29R. It can be concluded that the boundary interval in Hole 689B is unlikely to be continuous, a hiatus may be present. Such a hiatus is recognized by the absence at Site 689 of the nannofossil zone CP1a (Pospichal and Wise, this volume, chapter 30).

In contrast, at Site 690, similar magnetic cleaning reveals a well defined reverse magnetozone in the interval between 247.55 mbsf and 252.28 mbsf which can be assigned to Subchron C29R (Fig. 7). Pospichal and Wise (this volume, chapter 32) place the K/T boundary at a depth of 247.81 mbsf on the basis of detailed study of calcareous nannofossil zonations and an assessment of the effects of bioturbation in displacing material. Hence, on the Maud Rise at Hole 690C, the K/T boundary is located in the upper part of Subchron C29R. This finding is in accord with other globally known marine K/T boundary sections that have been studied paleomagnetically (see, for instance, Alvarez et al., 1977; Hamilton and Suzyumov, 1983; Tauxe et al., 1984; Bleil, 1985). For Hole 690C, however, the K/T boundary is at a higher position (C29.95R) in the chronozone than is usually found in other pelagic sections (C29.75R) (Channell and Dobson, 1989). It can be shown, by using the sedimentation rate of 7.4 m/m.y. determined above, that the K/T boundary is stratigraphically only some 35,000 yr older than the Chron C29N/C29R boundary at Site 690. It seems likely therefore that the assumption of a constant sediment accumulation rate is invalid for the earliest Danian on the Maud Rise, or that bioturbation effects have modified the magnetostratigraphic record here. A

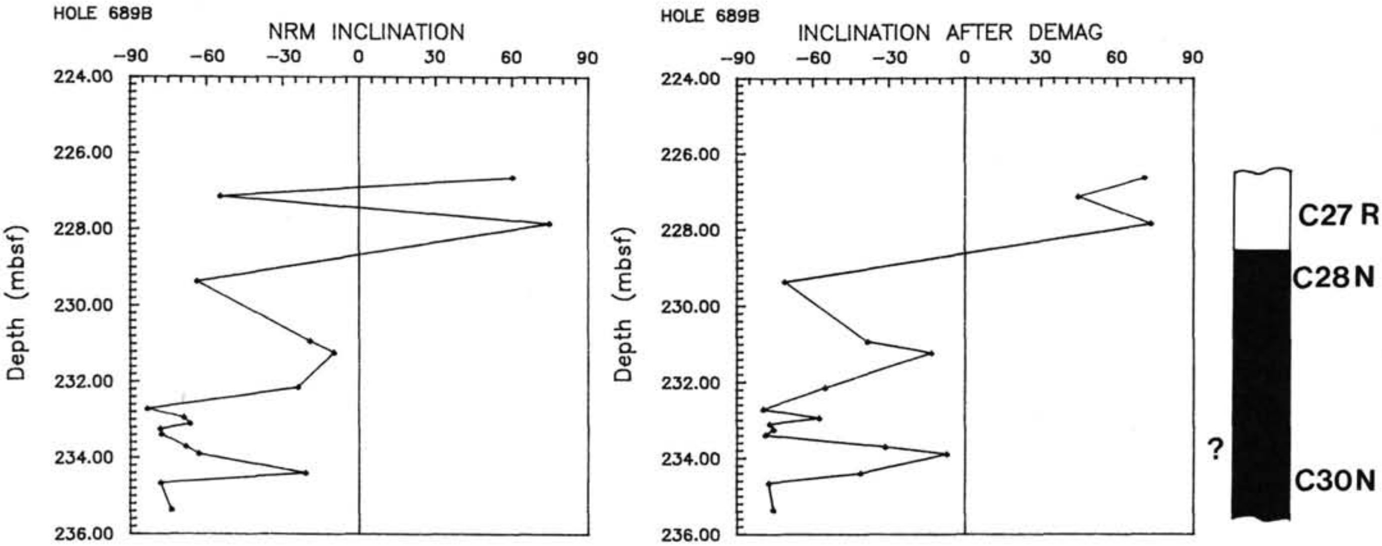

Figure 6. Inclination data for Core 113-689B-25X. Note shallow inclination values at about 234 mbsf.

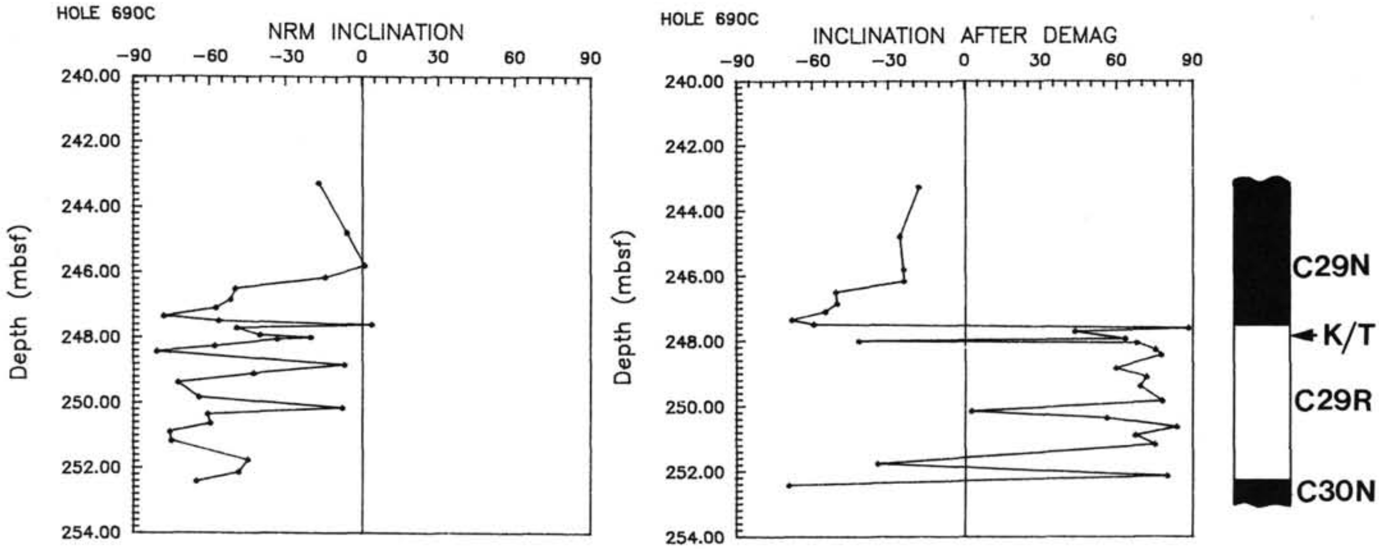

Figure 7. Inclination data for Core 113-690C-15X. Biostratigraphic position of K/T boundary is shown within the upper part of Subchron C29R.

further possibility is that a stronger normal polarity magnetization overprint remains unremoved after demagnetization for some of the samples from the earliest Danian sequence.

CONCLUSIONS

The Late Cretaceous dominantly biogenic sediments of the Maud Rise preserve a continuous magnetostratigraphic record spanning Chrons C33N to C29R. Despite the imperfections of only moderate recovery by the XCB it has proved possible to elucidate the magnetic polarity satisfactorily. Recognition of the occurrence of K/T boundary at Site 690 is validated by this study.

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