Ciesielski, P. F., Kristoffersen, Y., et al., 1991
Proceedings of the Ocean Drilling Program, Scientific Results, Vol. 114

20. MAGNETOSTRATIGRAPHY OF SEDIMENTS FROM SITES 701 AND 702[1]

Bradford M. Clement[2] and Ernest A. Hailwood[3]

ABSTRACT

During Leg 114 of the Ocean Drilling Program 12 holes were drilled at seven sites in the subantarctic South Atlantic Ocean. A major objective of this cruise was to document the development of the deep-water passageway that formed as the Meteor and Islas Orcadas rises rifted and spread apart. We report here the results of a magnetostratigraphic study of the sediments recovered at Site 701, a deep-water site located within the gateway, and Site 702, a shallow-water site located near the crest of the Islas Orcadas Rise. The sequence of Pliocene-Pleistocene reversals observed at Site 701 is readily correlated with the Brunhes Chron through Chron C3A. Although correlation is more difficult in the older sections at Site 701 because of coring gaps and the lack of tight biostratigraphic control, it is possible to correlate the late Miocene sequence of reversals with Chrons C4A and C5. The polarity sequence observed in the very weakly magnetized middle to upper Eocene nannofossil chalks recovered from Hole 702B is correlated with Chrons C18 through C21. The correlation of the polarity sequences at these two sites provides a temporal framework for these sediments and makes it possible to calibrate southern high-latitude biostratigraphic datums to the geomagnetic polarity time scale.

INTRODUCTION

Leg 114 of the Ocean Drilling Program (ODP) drilled seven sites in the subantarctic South Atlantic to study the influence of regional tectonics on the oceanographic history of the Southern Ocean. A specific objective of Leg 114 was to obtain stratigraphic sections documenting the development of a deep-water gap, or gateway, that formed between the Islas Orcadas and Meteor rises during the Eocene and promoted deep-water circulation between the antarctic and the South Atlantic oceans. In order to obtain these stratigraphic sections, shallow-water sites were drilled on both the Islas Orcadas (Site 702) and Meteor (Sites 703 and 704) rises and a deep-water site was located over Eocene age oceanic crust (Chron C22) between the two rises (Site 701). Site 701 is within the gateway that formed as the Islas Orcadas and Meteor rises rifted and spread apart. The sections obtained at Sites 701 and 702 provide deep- and shallow-water records of the circulation that developed between the Atlantic and the Southern Ocean as the gateway deepened and widened.

Site 701 (51°59′S, 23°12′W) is located on the western flank of the Mid-Atlantic Ridge in a water depth of 4636.7 m. Three holes (701A, 701B, and 701C) were drilled at Site 701, using the advanced piston corer (APC) and the extended core barrel (XCB). Hole 701A was drilled with the APC to a total depth of 74.8 m below seafloor (mbsf), taking eight cores with an average recovery of 69.7%. Ten cores were taken with the APC and four with the XCB, spanning the interval from 70 to 203 mbsf, in Hole 701B. The average recovery in Hole 701B was 72.5%. Hole 701C reached a total depth of 481.3 mbsf, using the APC to recover 24 cores and the XCB to recover 27 cores, with an average recovery of 68.8%. Drilling disturbance is slight to moderate in the intervals cored using the APC, but is more significant in the intervals cored using the XCB. Much of the interval cored using the XCB contains drilling biscuits that have clearly rotated about a vertical axis during and after entry into the core barrel.

The stratigraphic section recovered at Site 701 consists of mostly biosiliceous and diatom ooze with some siliceous mud/clay and clay-bearing diatom ooze. The sediments range in age from Quaternary to middle Eocene, and important hiatuses exist in the record in the lower upper Pliocene, the upper lower Miocene, the upper lower and upper Oligocene, and the upper middle and lowermost upper Eocene. Deposition at this site was primarily below the carbonate compensation depth (CCD) or south of the carbonate productivity zone during the Eocene to Quaternary. Therefore, the age control at this site is provided by siliceous microfossil biostratigraphy (Ciesielski, this volume).

Site 702 (50°56.786′S, 26°22.117′W) is located on the central part of the Islas Orcadas Rise in a water depth of 3083.4 m. Two holes were cored at this site: Hole 702A was cored using the APC to a total depth of 33.1 mbsf, and Hole 702B was cored using the APC and XCB to a total depth of 294.3 mbsf. Recovery was good above 205 mbsf, averaging 87%, but dropped dramatically below this depth because of the occurrence of chert stringers within the chalk sequence. The stratigraphic section recovered at Site 702 consists of a thin layer of diatom ooze overlying a thick sequence of nannofossil ooze to indurated nannofossil chalk. Nannofossil and planktonic foraminifer biostratigraphy indicate that the carbonate section recovered at this site is of late Eocene to late Paleocene age.

We report here the results of a magnetostratigraphic study of the sediments cored at Sites 701 and 702. Sediments at these sites exhibit both normal and reverse polarity magnetizations, which are interpreted as records of geomagnetic polarity reversals. Correlation of the magnetic polarity zones observed in these sediments with the geomagnetic polarity time scale (Berggren et al., 1985) provides a temporal framework for lithostratigraphic and paleoceanographic studies.

METHODS

Shipboard paleomagnetic measurements included both pass-through and discrete-sample remanence measurements. The pass-through, three-axis cryogenic magnetometer was used to measure the archive halves of core sections aboard *JOIDES Resolution*. In some instances, a core as a whole was too disturbed to warrant measuring using the pass-through

[1] Ciesielski, P. F., Kristoffersen, Y., et al., 1991. *Proc. ODP, Sci. Results*, 114: College Station, TX (Ocean Drilling Program).

[2] Dept. of Geology, Florida International University, Miami, FL, 33199.

[3] Dept. of Oceanography, The University, Southampton SO9 5NH, U.K.

cryogenic magnetometer, yet it was still possible to recover discrete samples from undisturbed intervals or biscuits from that core. Discrete samples were recovered by pressing 7-cm^3 plastic cubes into the working halves of the sediment cores. At depths where the sediment became too stiff to sample by pressing the plastic boxes into the sediment, oriented sections were removed from the core and cubes were cut using a double-bladed (blade spacing 2.54 cm) diamond saw. Samples were taken at intervals ranging from 0.25 to 1.5 m. The standard ODP orientation conventions were used during sampling; the positive Z axis is directed downcore and the positive X axis is perpendicular to the split face of the working half of the core section and is directed into the core half. Within-core orientation was maintained by orienting the samples with respect to the split face of the core and the vertical axis (the long axis of the core). The cores were split so that a reference line on the core liner remained in the center of the working half of the core. The Eastman-Whipstock orientation tool was not used at these sites to provide between-core orientation. For this reason the declinations obtained from measuring sediment cored with both the APC and the XCB cannot be related to geographic north, and therefore, only the inclinations are used to interpret the polarity of magnetization.

The direction and magnitude of the magnetization of discrete samples were measured aboard ship using a Molspin fluxgate spinner magnetometer. Progressive alternating field (AF) demagnetization studies were conducted by demagnetizing specimens in three orthogonal positions, using a Schonstedt single-axis AF demagnetizer, at progressively higher field levels.

The magnetization of the archive halves of the core sections was measured at 5- to 10-cm intervals using the three-axis, pass-through cryogenic magnetometer. Archive halves were measured instead of whole-round core sections so that the sediment could be partially demagnetized using the set of three mutually orthogonal Helmholtz coils that are mounted in-line with the cryogenic magnetometer. Measuring the archive halves also allowed us to visually inspect each core section prior to measurement, making it possible to identify and note intervals of mechanically disturbed sediment before the cores were measured. The pass-through demagnetizer was physically limited to a peak field of 9 mT during Leg 114 because of equipment limitations. Results from progressive AF demagnetization of discrete samples indicate that treatment at fields greater than 9 mT is required to remove completely overprints in some intervals of sediment recovered at Site 701. For this reason the results of the pass-through measurements are not considered to represent the characteristic magnetizations, and therefore, the pass-through data from Site 701 are not used in this study. Because the sediments recovered at Site 702 were so weakly magnetized, it was not possible to demagnetize the samples at fields greater than 15 mT before the magnetizations dropped below the noise level of the magnetometer. Although the limited demagnetization studies from these sediments are not conclusive, based on the behavior during treatment ranging from 5 to 15 mT it appears that AF treatment at 9 mT is likely to isolate the characteristic remanent magnetizations of these sediments. The pass-through magnetometer record of the magnetization of the sediments recovered at Site 702 is considered to be the most reliable record of magnetization polarity in these sediments because the larger volume of measured material brought the magnetizations well above the noise level of the magnetometer.

After the cruise, discrete samples from Site 701 were measured in the Texas A&M University paleomagnetics laboratory using a Molspin fluxgate-spinner magnetometer and a Schonstedt AF demagnetizer. Additional detailed progressive AF demagnetization studies were conducted by demagnetizing specimens at increasing peak AF strengths, in increments of 5 mT up to peak fields of 80 to 90 mT. All discrete samples from Site 701 were progressively demagnetized at 10-mT increments up to at least 30 mT.

NOMENCLATURE

The terminology used to describe polarity intervals has become somewhat confused because each of the polarity time scales published recently uses a different nomenclature (Ness et al., 1980; Cox, 1982; Berggren et al., 1985; for a review see Tauxe et al., 1987; Hailwood, 1989). These different nomenclatures arose from the need to specify precisely each polarity unit independent of its age (which may be subject to change with further numerical age calibration of the reversal sequence) and to correct the anomaly 5–Chronozone 9 miscorrelation (Miller et al., 1985; Berggren et al., 1985). Here, we correlate polarity zonations observed in the sediment sequences with the reversal pattern in the marine magnetic anomaly records (Heirtzler et al., 1968; LaBrecque et al., 1977). For this reason, we favor a nomenclature that identifies the polarity intervals in terms of the anomaly sequence and use the nomenclature of LaBrecque et al. (1983). However, we still refer to the four most recent intervals of dominant polarity by their commonly used names (Brunhes, Matuyama, Gauss, and Gilbert).

RESULTS

Site 701

The siliceous sediments cored at Site 701 exhibit straightforward magnetizations. Examples of progressive AF demagnetization are shown in Figure 1, plotted as vector end-point diagrams (Zijderveld, 1967). Samples yielding both normal and reverse polarity magnetizations exhibit characteristic magnetizations, defined by nearly linear decay toward the origin, which were isolated after treatment at 15 to 20 mT.

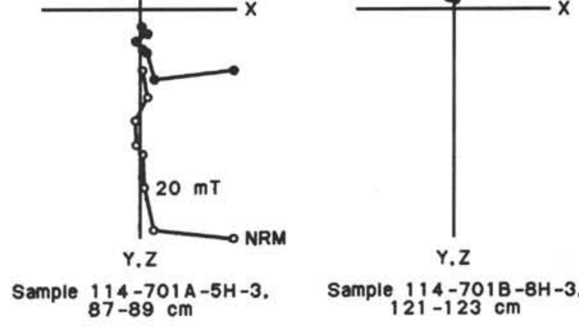

Figure 1. Results of progressive AF demagnetization of two samples yielding reverse (A) and normal (B) polarity magnetizations plotted as orthogonal, vector end-point diagrams. Open symbols represent projection onto the vertical (XZ) plane. Solid symbols represent projection onto the horizontal (XY) plane. Intensities are normalized to natural remanent magnetization values.

Results from discrete sample measurements from the upper 200 m of Holes 701A, 701B, and 701C are plotted in Figure 2. Because no between-core azimuthal orientation was available, only the inclination record is presented. The steep inclinations (69°) expected at the latitude of Site 701 make it possible to determine the polarity on the basis of the inclination data alone. In Figure 2 the characteristic inclinations from each hole are plotted vs. sub-bottom depth. Also shown are core recovery plots for each hole. Gaps in core recovery result in incomplete inclination records, thereby complicating the interpretation of the polarity zonations defined by the inclination records. For this reason we constructed a composite polarity log based on the inclination records obtained from the three holes cored at this site. Although there are depth offsets in the levels of some reversal boundaries in different holes—ranging up to 5 m for the depth of the Brunhes/Matuyama boundary in Holes 701A and 701C—most of the differences fall within the uncertainties of the placement of the recovered material within the cored interval. Correlation of ash layers in the three holes (Ciesielski, Kristoffersen, et al., 1988) also indicates slight depth offsets between the three holes. These offsets may result from the placement of recovered material within the cored interval, calculation of the mud-line depth, and offsets in the ship's location during drilling (Ruddiman et al., 1987). The composite polarity log was constructed by assigning normal (reverse) polarity to depth intervals characterized by more than one sample yielding a negative (positive) inclination from the three holes.

The upper 200 m of sediment cored at Site 701 is assigned an age ranging from Quaternary to late Miocene based primarily on diatom biostratigraphy (Ciesielski, Kristoffersen, et al., 1988). Two important hiatuses occur within this interval. The uppermost hiatus is located between 65 and 72 mbsf and separates upper Pliocene sediments from underlying lower Pliocene sediments. The second hiatus in this interval is placed between 184 and 193 mbsf in Hole 701B and 177.3 and 178.3 mbsf in Hole 701C. This hiatus represents a missing interval of upper Miocene sediments.

The lithology, biostratigraphic age assignment, and composite polarity log for Site 701 are plotted vs. depth in Figure 3. Also shown is the preferred correlation of the polarity zonation with the geomagnetic polarity time scale. Within the biostratigraphic constraints it is possible to correlate the composite polarity zones with the Brunhes Chron through Chron C3A. The depths and correlated ages of the reversal boundaries in each of the three holes are given in Table 1.

The normal polarity zone occurring from 0 to approximately 20 mbsf is correlated with the Brunhes Chron, and the predominantly reverse polarity interval from 20 to 70 mbsf is correlated with the Matuyama Chron. The Pliocene/Pleistocene boundary is placed within Cores 114-701A-5H and 114-701C-5H, suggesting that the very short normal polarity interval occurring at 50 mbsf in Hole 701A and 47 mbsf in Hole 701C may be correlated with the Olduvai Subchron. The contact between the upper and lower Pliocene (between 67.3 and 72 mbsf in Hole 701C) is an unconformable boundary. Thus the normal polarity interval occurring from 67 to 74 mbsf (Hole 701C) is correlated with the Gauss Chron, but it represents an abbreviated record of the Gauss because of the hiatus. The reverse polarity zone from 74 to 140 mbsf is correlated with the Gilbert Chron, and the three short subchronozones within this interval may be correlated with three of the four subchrons within the Gilbert. Because the present biostratigraphic constraints are not sufficient to aid in the correlation of these short subchronozones, we assumed a constant sedimentation rate through the Gilbert and chose the correlation that gave the best fit to the straight-line assumption (Fig. 4). Therefore the correlation of these subchronozones with the Nunivak, Sidufjall, and Thvera Subchrons should be considered tenuous. Using the same assumption of a constant

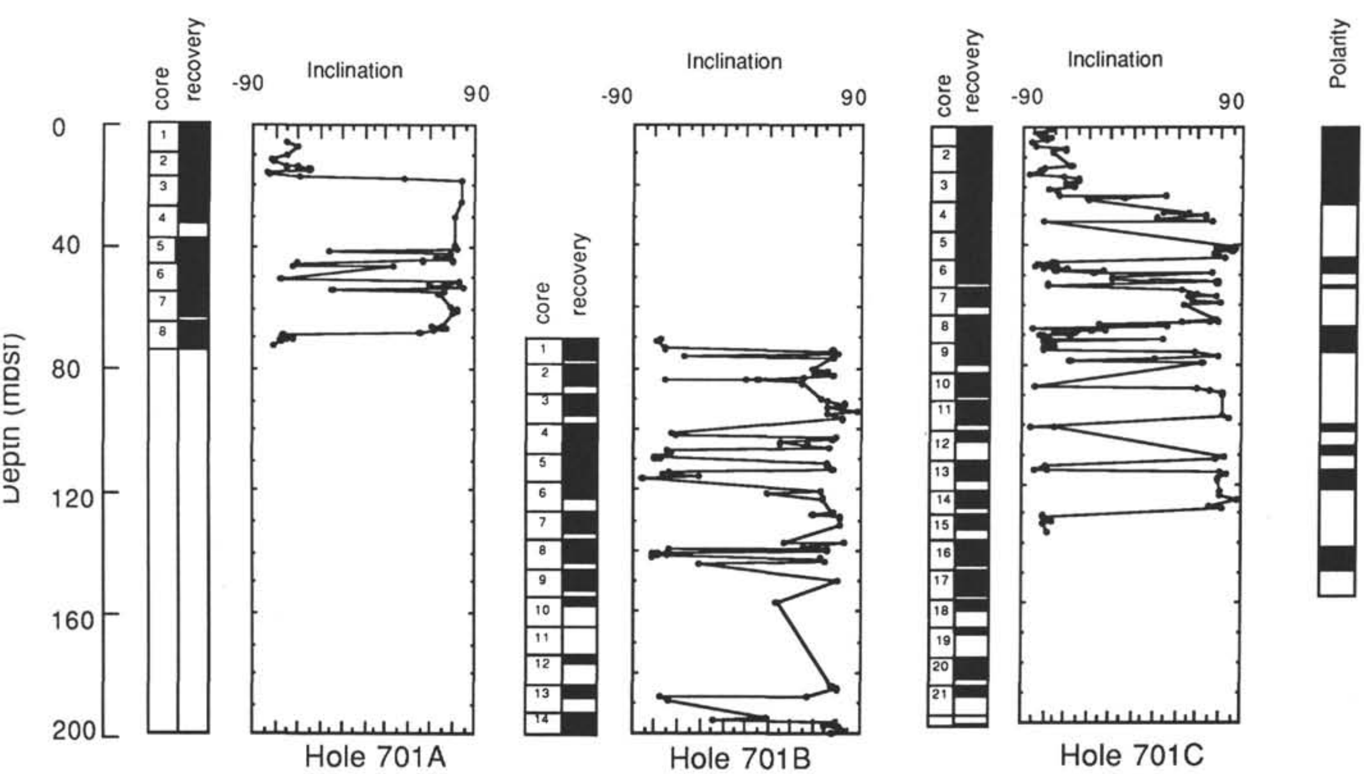

Figure 2. Inclination records (in degrees) obtained from the upper 200 m of Holes 701A, 701B, and 701C plotted vs. sub-bottom depth. The core recovery for each hole is also indicated. The composite polarity zonation was constructed using the inclination records from all three holes.

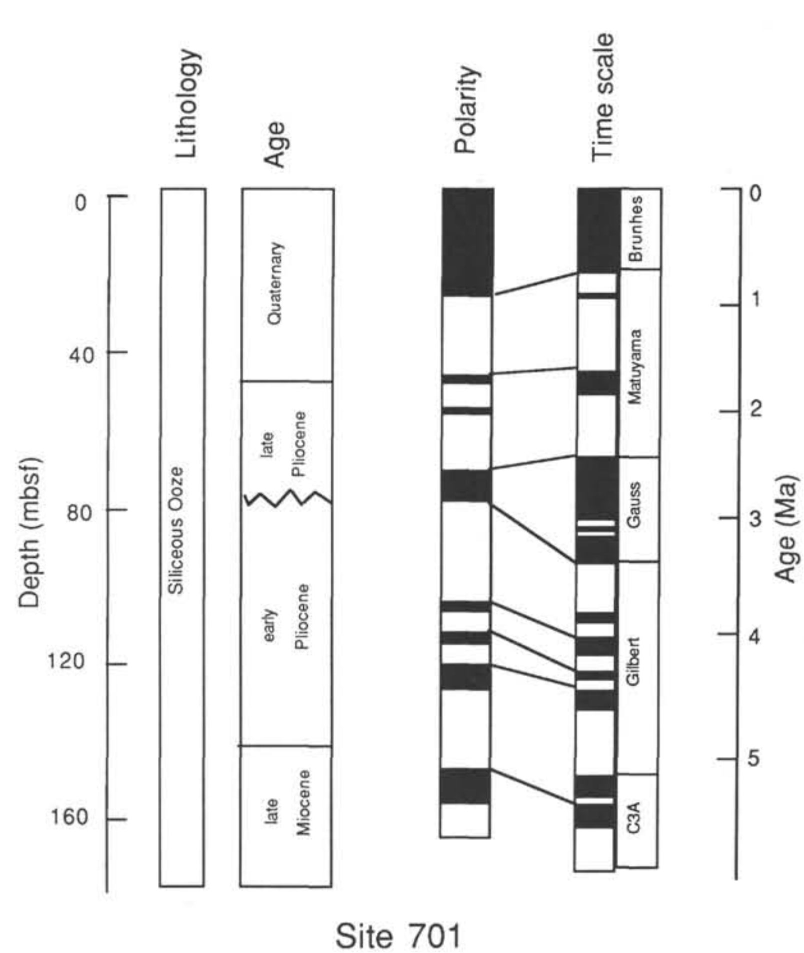

Figure 3. Lithology, biostratigraphic age, and composite polarity for Site 701 plotted vs. sub-bottom depth. The composite polarity zonation is correlated with the geomagnetic polarity time scale. See Table 1 for a listing of the depths of the reversal boundaries.

sedimentation rate, the normal polarity chronozone extending from 140 to 144 mbsf is correlated with Chron C3AN2.

The polarity zones in the deeper interval of Hole 701C (150 mbsf) are more difficult to correlate with the geomagnetic polarity time scale because of the occurrence of significant gaps in the record as the result of intervals of coring disturbance and poor core recovery. In addition, the biostratigraphic control commonly can not constrain the correlation in intervals of the Miocene and Oligocene that are characterized by frequent polarity reversals. Within the middle to upper Miocene sequence, however, it is possible to correlate the long polarity interval from 204 to 245 mbsf with the long normal polarity interval in Chron C5. Based on this correlation, the two short normal polarity chronozones from 178 to 199 mbsf are correlated with the two youngest normal polarity intervals in Chron C4A (Fig. 5 and Table 1).

The sediment recovered in Cores 114-701C-27X through 114-701C-43X is late Oligocene through early Miocene in age, based on diatom biostratigraphy (Ciesielski, Kristoffersen, et al., 1988). The first-appearance datum of *Rocella gelida* and *Bogorovia veniamini* at 387 mbsf in Core 114-701C-41X suggests that the Oligocene/Miocene boundary occurs just above this depth, based on correlations made at other southern high-latitude sites (Fenner, 1984; Gombos and Ciesielski, 1983). The *B. veniamini* datum, however, has been demonstrated to be diachronous, occurring in the early to late Oligocene at low-latitude sites (Fenner, 1984). The age range of this section as determined by the diatom biostratigraphy encompasses an interval of the geomagnetic polarity time scale characterized by frequent polarity reversals. Without much tighter biostratigraphic constraints it is difficult to correlate the polarity reversal sequences observed from 260 to 345 mbsf. Figure 5 shows the interpretation obtained by correlating the thick interval of reverse polarity from 290 to 324 mbsf with the only long interval of reverse polarity in this portion of the time scale, Chron C6CR. Assuming constant sedimentation rates, the polarity zones bounding this reverse polarity zone can be correlated with Chrons C6C through C7, as shown in Figures 5 and 6 and Table 1. Refinement of the diatom zonations in this interval and reexamination of late Oligocene–early Miocene sequences from other southern high-latitude sites may make it necessary to revise this correlation; at present, however, this correlation provides the best fit with the existing biostratigraphic data and the assumption of constant sedimentation rates.

Site 702

As discussed previously, the sediments recovered at Site 702 exhibit very weak magnetizations, averaging less than 0.1 mA/m. It was not possible to conduct detailed progressive AF demagnetization studies of these sediments because at fields greater than 10 to 15 mT the magnetization of the discrete

Table 1. Ages and depths of polarity reversal boundaries in Holes 701A, 701B, and 701C.

Polarity interval	Age (Ma)	Sample interval (in cm)	Depth interval (mbsf)
Hole 701A			
Brunhes			
base	0.73	2H-6, 88/2H-7, 6	16.68/17.36
Olduvai			
top	1.66	5H-6, 36/5H-6, 90	44.66/45.20
base	1.88	6H-3, 125/6H-4, 55	50.55/51.35
Gauss			
top	2.47	8H-2, 140/8H-3, 90	68.26/69.2
Hole 701B			
Gauss			
base	3.40	1H-3, 106/1H-4, 28	74.06/74.78
Nunivak			
top	4.10	3H-6, 43/4H-3, 29	96.93/101.79
base	4.24	4H-3, 104/4H-4, 39	102.54/103.39
Sidufjall			
top	4.40	4H-6, 43/4H-6, 122	106.43/107.22
base	4.47	5H-2, 29/5H-3, 39	109.79/111.39
Thvera			
top	4.57	5H-4, 108/5H-5, 39	113.58/114.39
base	4.77	5H-6, 108/6H-3, 8	116.58/120.58
Chron C3AN2			
top	5.68	8H-3, 72/8H-3, 122	140.22/140.72
base	5.89	8H-4, 111/8H-5, 44	142.11/142.94
Hole 701C			
Brunhes			
base	0.73	3H-5, 110/3H-5, 130	22.90/23.10
Olduvai			
top	1.66	5H-6, 140/6H-1, 90	43.70/45.20
base	1.88	6H-4, 10/6H-6, 19	48.90/51.99
Gauss			
top	2.47	8H-2, 90/8H-3, 140	65.70/67.70
base	3.40	9H-1, 88/9H-2, 98	73.68/75.28
Nunivak			
top	4.10	11H-4, 110/11H-6, 140	97.40/100.70
base	4.24	11H-6, 140/13H-1, 90	100.70/111.70
Thvera			
top	4.57	13H-1, 90/13H-3, 40	111.70/114.20
base	4.77	13H-4, 40/13H-4, 120	115.70/116.50
Chron C3AN2			
top	5.68	16H-1, 22/16H-2, 21	139.53/141.01
base	5.89	16H-3, 121/16H-4, 108	143.51/144.88
Chron C4AN1			
top	7.90	20H-1, 129/20H-2, 75	178.59/179.55
base	8.21	20H-4, 105/20H-6, 30	182.85/185.10
Chron C4AN2			
top	8.41	21H-1, 117/21H-2, 21	187.97/188.51
base	8.50	21H-3, 53/22H-2, 128	190.33/199.18
Chron C5N			
top	8.92	22H-5, 138/22H-6, 55	203.68/204.35
Chron C6C			
top N2	23.27	29X-3, 40/29X-3, 120	266.20/267.0
bottom N2	23.79	29X-6, 120/31X-1, 110	271.5/282.9
top N3	24.04	31X-4, 110/31X-5, 30	287.4/288.1
bottom N3	24.21	31X-6, 30/32X-1, 18	289.6/291.48
Chron C7			
top N1	25.50	35X-5, 37/31X-5, 105	324.86/325.54
bottom N2	25.97	37X-3, 20/37X-5, 11	342.0/344.91

samples dropped below the noise level of both the shipboard and shorebased cryogenic magnetometers. Results of AF demagnetization at low fields (5 to 15 mT), however, suggest that the magnetizations are not complex and that treatment at 9 mT, using the shipboard pass-through demagnetizer, may in fact provide a reasonable estimate of the characteristic polarity of the sediment. Because the pass-through measurements average over a much greater volume than the discrete samples, even after treatment at 9 mT, the signal remained well above the noise level of the shipboard magnetometer. For this reason the pass-through data are considered to be the best

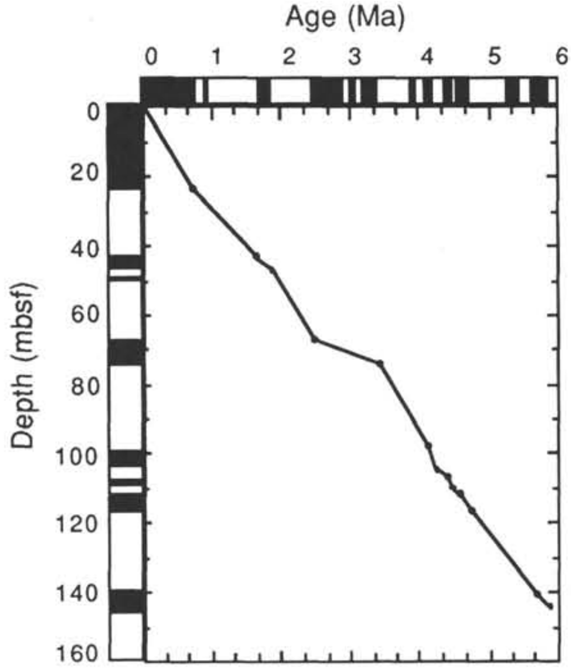

Figure 4. Age vs. depth plot for Site 701 constructed using the correlation shown in Figure 3.

record of magnetization polarity from Hole 702B. The inclination record obtained using the shipboard pass-through cryogenic magnetometer after AF treatment at 9 mT is shown in Figure 7. The preferred correlation of the observed polarity zones with Chrons C18 through C20 is also shown in Figure 7 and listed in Table 2. Correlation of the dominantly normal polarity zone in Cores 114-702B-17X to 114-702B-21X with the time scale is not straightforward. The simplest interpretation is that the reverse polarity zone in Cores 114-702B-13X to 114-702B-17X represents Chron C21R and that at least the upper part of the underlying normal polarity zone represents Chron C21N. This interpretation is consistent with the available nannofossil data, which place these sediments in Zones NP16 to NP15. The short reverse polarity zone in Core 114-702B-20X may represent part of Chron C21R and the normal polarity zone extending from the lower part of this core to the upper part of Core 114-702B-21X may be correlated with Chron C22N. This correlation, however, requires the presence of a stratigraphic hiatus within Core 114-702B-20X. Until detailed biostratigraphic studies can examine this possibility, however, the correlation with Chrons C21R and C22N remains uncertain.

CONCLUSIONS

The southern high-latitudes have played an important role in the Earth's climatic evolution, and understanding how this role has changed through time is an important step in understanding how the Earth's climate has changed. It has been difficult to unravel the oceanographic history of the Southern Ocean partly because of the inaccessibility of the area and partly because the standard, low-latitude biostratigraphic zonations typically can not be applied to sediments recovered from the high latitudes. As a result, the timing of events and rates of change are less well constrained than in the low latitudes. It is for this reason that magnetostratigraphic studies of high-latitude sediments are important. Magnetostratigraphic studies provide an additional time framework that is independent of latitude, and therefore can provide controls on

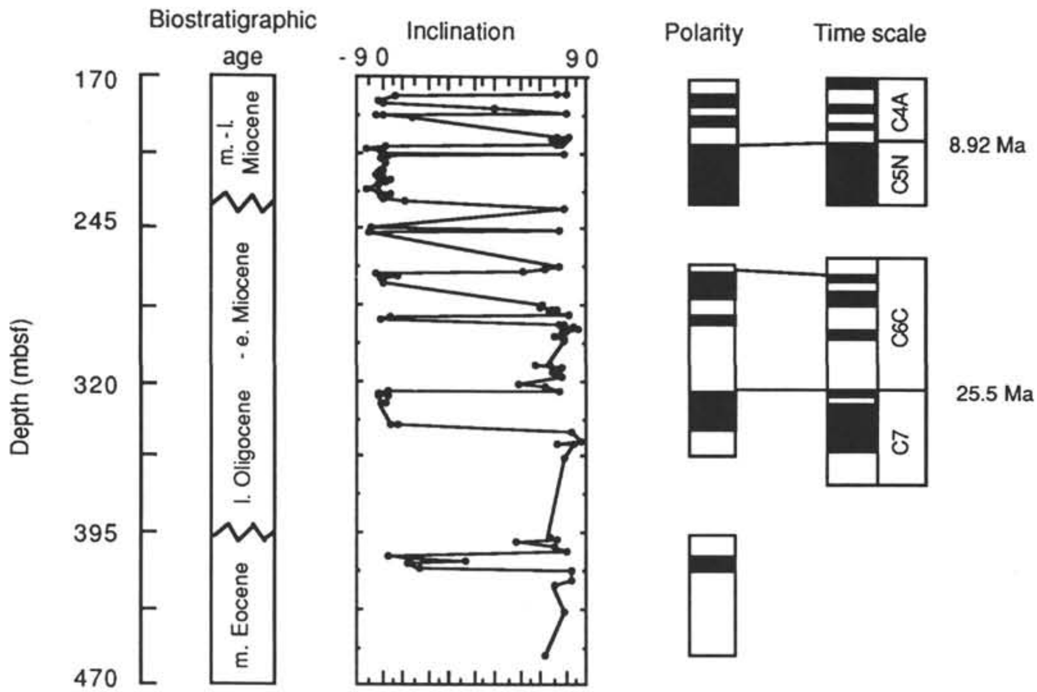

Figure 5. Biostratigraphic age, inclination record (in degrees), and polarity for the deeper (150 mbsf) interval of Hole 701C plotted vs. sub-bottom depth. The polarity zonation is correlated with portions of the geomagnetic polarity time scale. See Table 1 for a listing of the depths of the reversal boundaries.

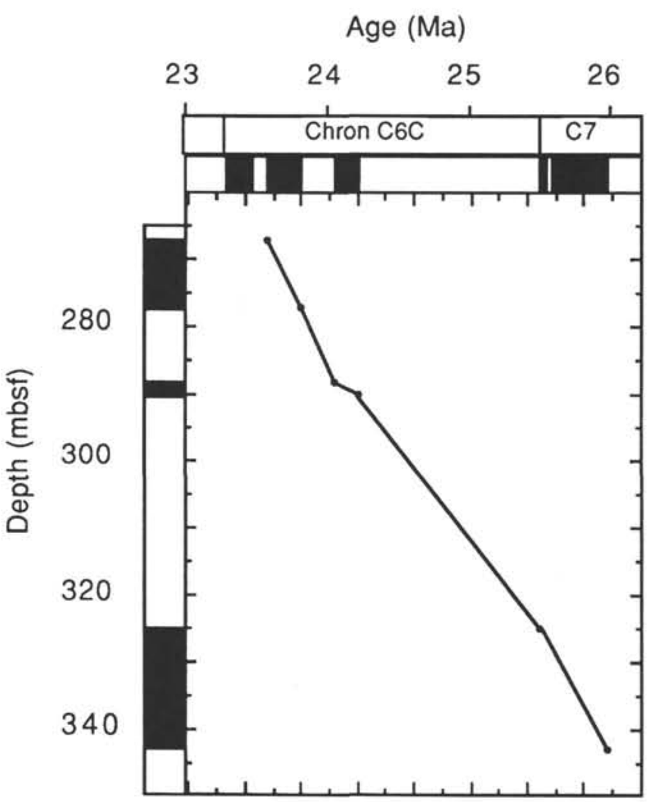

Figure 6. Age vs. depth plot for the early Miocene to late Oligocene of Hole 701C constructed using the correlation indicated in Figure 5 and Table 1.

sedimentation rates and test the isochroneity of biostratigraphic datums between the low and high latitudes. The magnetostratigraphic results obtained from ODP Sites 701 and 702 allow us to calculate sedimentation rates at these sites and to calibrate high-latitude calcareous and siliceous microfossil stratigraphies with the geomagnetic polarity time scale.

The composite section obtained from the three holes drilled at Site 701 is punctuated by hiatuses that divide the sequence into five intervals: Quaternary through upper Pliocene, lower Pliocene through uppermost Miocene, upper to middle Miocene, lower Miocene to lower Oligocene, and the middle Eocene (Ciesielski, Kristoffersen, et al., 1988). The polarity patterns observed in the four upper intervals may be correlated with the geomagnetic polarity time scale within the biostratigraphic constraints. The correlations are complicated by the hiatuses and are made by relying heavily upon the biostratigraphic tie-points and the assumption of constant sedimentation rates. The correlations presented in this paper, however, provide temporal control within these hiatus-bounded intervals of the section.

Sedimentation rates calculated based on the magnetostratigraphic results presented here are 27 m/m.y. for the Quaternary to upper Pliocene, 25.7 m/m.y. for the lower Pliocene to upper Miocene, 24.5 m/m.y. for the upper to middle Miocene, and 28.5 m/m.y. for the lower Miocene to upper Oligocene. Overall, the sedimentation rates appear to have been fairly constant during deposition at Site 701 with the important exception of the hiatuses discussed previously.

The correlation of the polarity zones observed in the nannofossil oozes and chalks recovered from Hole 702B with the middle to late Eocene Chrons C18 through C21 provides important chronostratigraphic control on this southern high-latitude carbonate sequence. Based on the magnetostratigraphic results presented here, sedimentation rates averaged 18 m/m.y. during this interval. These correlations provide constraints on the age of the middle/late Eocene boundary in the Southern Ocean, as placed by the calcareous microfossil

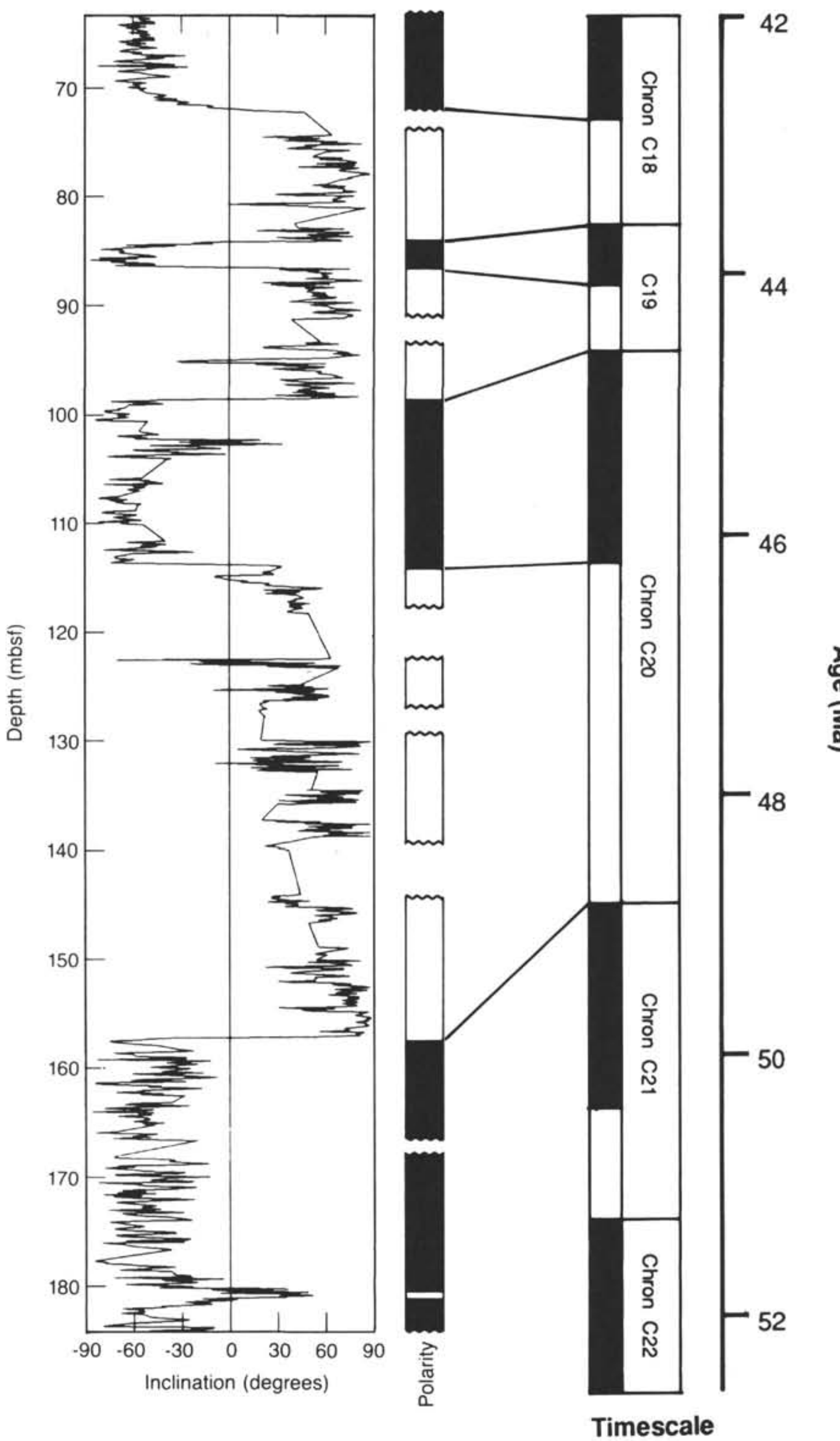

Figure 7. The pass-through inclination record (in degrees) obtained from Hole 702B plotted vs. sub-bottom depth. The polarity zones defined by the inclination record are correlated with the geomagnetic polarity time scale. See Table 2 for a listing of the depths of the reversal boundaries.

Table 2. Ages and depths of polarity reversal boundaries in Hole 702B.

Polarity interval	Age (Ma)	Sample interval (in cm)	Depth interval (mbsf)
Chron C18			
base N3	42.73	8X-6, 104/8X-6, 116	71.84/71.96
Chron C19			
top	43.6	10X-2, 45/10X-2, 46	84.25/85.26
bottom	44.06	10X-3, 115/10X-3, 125	86.45/86.55
Chron C20			
top	44.66	11X-5, 85/11X-5, 95	98.65/98.75
bottom	46.17	13X-2, 104/13X-2, 115	113.34/113.45
Chron C21			
top	48.75	17X-6, 95/17X-6, 105	157.25/157.35

stratigraphy, and make it possible to calibrate several southern high-latitude calcareous microfossil datums (Nocchi et al., this volume; Crux, this volume) with the geomagnetic polarity time scale.

ACKNOWLEDGMENTS

We thank the captain and crew of *JOIDES Resolution*, the Sedco drilling crew, the ODP marine technicians (in particular Harry Hutton), and the Leg 114 scientific party for their assistance during Leg 114. Nicholas Smalley conducted many of the shorebased laboratory measurements, and two anonymous reviewers provided valuable comments. Support for this work was provided by JOI USSAC Grant 20113.

REFERENCES

Berggren, W. A., Kent, D. V., Flynn, J. J., and Van Couvering, J. A., 1985. Cenozoic geochronology. *Geol. Soc. Am. Bull.*, 96:1407–1418.

Ciesielski, P. F., Kristoffersen, Y., et al., 1988. *Proc. ODP, Init. Repts.*, 114: College Station, TX (Ocean Drilling Program).

Cox, A. V., 1982. Magnetostratigraphic time scale. *In* Harland, W. B. (Ed.), *A Geologic Time Scale*: Cambridge (Cambridge Univ. Press), 63–64.

Fenner, J. M., 1984. Eocene-Oligocene planktic diatom stratigraphy in the low latitudes and high southern latitudes. *Micropaleontology*, 30:319–342.

Gombos, A. M., Jr., and Ciesielski, P. F., 1983. Late Eocene to early Miocene diatoms from the southwest Atlantic. *In* Ludwig, W. J., Krasheninnikov, V. A., et al., *Init. Repts. DSDP*, 71: Washington (U.S. Govt. Printing Office), 583–634.

Hailwood, E. A., 1989. The role of magnetostratigraphy in the development of geological time scales. *Paleoceanography*, 4:1–18.

Heirtzler, J. R., Dickson, G. O., Herron, E. M., Pitman, W. C., III, and LePichon, X., 1968. Marine magnetic anomalies, geomagnetic reversals and motions of the ocean floor and continents. *J. Geophys. Res.*, 73:2119–2136.

LaBrecque, J. L., Kent., D. V., and Cande, S. C., 1977. Revised magnetic polarity time scale for Late Cretaceous and Cenozoic time. *Geology*, 5:330–335.

LaBrecque, J. L., and Shipboard Scientific Party, DSDP Leg 73, 1983. Contributions to Paleogene stratigraphy in nomenclature, chronology and sedimentation rates. *Palaeogeogr., Palaeoclimatol., Palaeoecol.*, 42:91–125.

Miller, K. G., Aubry, M.-P., Khan, M. J., Melillo, A. J., Kent, D. V., and Berggren, W. A., 1985. Oligocene to Miocene bio-magneto and isotopic stratigraphy of the western North Atlantic. *Geology*, 13:257–261.

Ness, G., Levi, S., and Couch, R., 1980. Marine magnetic anomaly time scales for the Cenozoic and Late Cretaceous: a précis, critique, and synthesis. *Rev. Geophys. Space Phys.*, 18:753–770.

Ruddiman, W. F., Cameron, D., and Clement, B. M., 1987. Sediment disturbance and correlation of offset holes drilled with the hydraulic piston corer: Leg 94. *In* Ruddiman, W. F., Kidd, R. B., Thomas, E., et al., *Init. Repts. DSDP*, 94: Washington (U.S. Govt. Printing Office), 615–634.

Tauxe, L., Butler, R., and Herguera, J. C., 1987. Magnetostratigraphy: in pursuit of missing links. *Rev. Geophys. Space Phys.*, 25:939–950.

Zijderveld, J.D.A., 1967. AC demagnetization of rocks: analysis of results. *In* Collinson, D. W., Creer, K. M., and Runcorn, S. K. (Eds.), *Methods in Paleomagnetism*: New York (Elsevier), 254–286.

Date of initial receipt: 4 April 1989
Date of acceptance: 4 January 1990
Ms 114B-156