12. PRELIMINARY PALEOMAGNETIC RESULTS FOR SEDIMENTS FROM SITE 263, LEG 27

Kenneth E. Green and Aviva Brecher, Massachusetts Institute of Technology
Earth and Planetary Sciences Department, Cambridge, Massachusetts

ABSTRACT

Paleomagnetic measurements on four cores recovered at Site 263 of sediments thought ot be of Albian to early Barremian age (100-115 m.y.) reveal three periods of reversed geomagnetic field. Statistically significant clustering sample remanent inclination values suggests that the average paleolatitude calculated for the site is highly reliable. There is close agreement between the site's paleolatitude according to these data (44.3° ±5.5°) and that computed from the Cretaceous pole for continental Australia of about 48.4°.

EXPERIMENTAL METHODS

We have carried out paleomagnetic studies on 41 samples from 13 intervals in four sediment cores recovered at Site 263, located at 23°20'S, 110°58'E, in the Cuvier Abyssal Plain. The samples were cut and oriented by R. D. Jarrard at Scripps Institution of Oceanography, as described elsewhere in this volume. The 6-cc samples consist of very firm kaolinitic, quartz-bearing clay. Sample positions are given in Table 1 and are plotted in Figure 1. Because the sedimentation rate was initially thought to be 8 cm/thousand years (Core Log, this volume), up to five samples were taken from each interval to improve the statistical significance of the measurements. The natural remanent magnetization (NRM) of the samples was measured on a 5-Hz Schonstedt (SSM-1A) spinner magnetometer with a sensitivity of better than 1×10^{-7} emu.

The components along the vertical and the horizontal sample axes were measured by one of two means. In the first method, a six-spin procedure similar to that described by Doell and Cox (1965) was carried out, and a daily correction for machine drift and holder moment was applied. A second method was developed to handle samples with very low intensity of one of the horizontal components, typically on the order of 1×10^{-7} emu/cc, which is near the machine limit. In the second method, 12 spins facilitate subtraction of the effects due to nonsample sources: the differences between these spins give the same set of four replicate measurements as before. Because these samples were spun in the closest position to the detector, they show some variation due to nonideal shape (cubic) and inhomogeneity. Thus, some of the variation in replicate measurements about different spin axes is real and due to nondipole contributions. An arithmetic mean and standard deviation for each component were calculated. The mean was used to determine the sample inclination and declination. Those samples with a standard deviation about the total remanent moment greater than 20% are not considered reliable, since their remanence is not well described by a dipole; they are noted in Table 1 as having a large nondipole component (LNC).

In order to remove secondary magnetic components, all samples were partially demagnetized (cleaned) in alternating fields (AF). To determine the amount of AF cleaning necessary, 15 samples were cleaned to a peak field value of 100 oe in 25-oe steps. The intensity and direction upon progressive AF cleaning, for four representative samples, are plotted in Figures 2a and 2b. The results for these 15 samples indicate that most of the soft, secondary component of remanence was removed in 50-oe AF peak fields. Thus, the 26 remaining samples were AF demagnetized in 50-oe fields. In all cases the polarity remained the same as that of NRM after 50-oe cleaning, with the intensity reduced typically by 10% to 43%.

RESULTS

Table 1 lists the results of measurements on the 41 samples. Inclinations are given with respect to the present horizontal, assuming vertical drill holes (positive downward). Negative inclinations correspond to normal polarity for these southern hemisphere cores. Because the absolute orientation is not known, declinations are relative to a given core barrel. Shearing during drilling and recovery may produce considerable scatter in the declinations for samples from different intervals. For these reasons, declinations are of no use in calculating paleocoordinates. The residual moments (after stepwise AF demagnetization) are also listed in Table 1, expressed as a percentage of initial NRM.

The inclinations and intensities (emu/cc) of both NRM and the residual after 50-oe cleaning, taken from Table 1, are plotted versus depth for the 41 samples in Figure 1. Note that the AF cleaning reduces the scatter in sample inclinations within each of the 13 sampling intervals. The inclination to be expected at Site 263, due to a present axial geocentric dipole, is marked at 40.8°. Note also that there is no simple correlation between NRM intensity and depth and that both normal and reversed polarity samples have similar intensities. Figure 3 shows the distribution of NRM inclinations, separately for normal and reversed samples, on 5° histograms,

TABLE 1
Results of Measurements (41 samples)

Sample (Interval in cm)	Demagnetizing Field (oe)	Magnitude[c] ($\times 10^{-7}$ emu/cc) Residue (%)	Declination Mean (°)	Inclination Mean (°)
20-1, 100-102	NRM[a]	(4.99)	192.5	–66.3
	25	86	186.3	–64.2
	50	71	186.1	–65.1
	75[a]	63	196.6	–69.4
	100[a]	53	181.2	–61.8
20-1, 102-104	NRM	(4.84)	192.1	–56.9
	25	100	189.8	–61.2
	50	57	177.9	–67.9
	75[a]	54	190.3	–64.6
	100[a]	47	194.3	–65.5
20-3, 26-28	NRM	(9.01)	31.5	58.9
	25	86	28.1	62.2
	50	78	36.7	64.8
	75	65	36.8	64.0
	100	56	28.8	63.6
20-3, 28-30	NRM	(9.75)	17.4	64.7
	25	86	27.2	61.9
	50	73	29.2	65.9
	75	62	30.2	61.8
	100	53	23.2	62.5
21-2, 0-2	NRM	(8.43)	253.3	–65.7
	50	90	257.2	–68.6
21-2, 4-6	NRM	(6.95)	224.8	–60.6
	25	96	233.8	–65.9
	50	84	237.4	–68.6
	75	81	254.2	–71.6
	100	68	255.8	–70.5
21-4, 6-8	NRM	(6.95)	263.9	64.4
	25	100	267.7	63.4
	50	77	257.7	55.1
	75	71	259.2	56.4
	100	65	263.0	57.0
21-4, 8-10	NRM	(6.77)	264.0	63.4
	25	86	253.6	62.2
	50	77	257.4	62.8
	75	67	257.1	59.0
	100	59	250.7	60.7
21-4, 12-14	NRM	(7.28)	255.7	61.9
	25	88	260.2	62.4
	50	83	258.1	64.5
	75	71	252.4	65.3
	100	64	250.4	63.4
21-4, 14-16	NRM	(8.36)	274.0	63.0
	25	88	271.0	63.5
	50	79	273.7	64.2
	75	72	274.3	65.1
	100	64	272.8	65.3
21-5, 139-141	NRM	(2.69)	185.0	–54.1
	25	98	191.7	–59.3
	50	84	193.4	–60.2
	75	74	200.5	–63.8
	100	66	200.7	–67.9
22-1, 0-2	NRM	(4.79)	144.0	–48.3
	25	95	147.2	–50.7
	50	80	147.7	–55.1
	75	69	149.7	–56.5
	100	63	144.1	–55.5
22-1, 2-4	NRM	(4.21)	143.9	–46.9
	25	98	148.5	–55.5
	50	83	153.7	–56.9
	75	77	158.4	–56.1
	100	66	162.1	–54.8

TABLE 1 – *Continued*

Sample (Interval in cm)	Demagnetizing Field (oe)	Magnitude[c] ($\times 10^{-7}$ emu/cc) Residue (%)	Declination Mean (°)	Inclination Mean (°)
22-1, 4-6	NRM	(3.92)	136.8	–49.1
	25	96	149.7	–58.9
	50	85	144.8	–58.7
	75[a]	65	147.0	–57.7
	100	63	147.3	–59.2
22-1, 6-8	NRM	(4.55)	145.8	–51.9
	25	96	148.7	–61.4
	50	79	149.6	–60.6
	75	70	146.4	–64.1
	100	62	149.2	–62.0
22-1, 8-10	NRM	(3.80)	146.2	–51.6
	25	91	145.3	–57.8
	50	75	146.8	–59.9
	75	68	150.4	–59.7
	100[a]	65	146.8	–59.7
22-3, 0-2	NRM[a]	(2.15)	270.9	–40.1
	50a	77	238.3	–39.5
22-3, 2-4	NRM	(4.67)	225.2	–59.5
	50[a]	83	235.5	–63.8
22-3, 4-6	NRM	(4.19)	221.0	–51.3
	50	88	219.9	–58.3
23-1, 144-146	NRM	(4.33)	145.7	–32.0
	50[a]	74	132.9	–48.6
23-1, 146-148	NRM	(3.49)	138.3	–49.1
	50[a]	82	134.6	–62.2
23-1, 148-150	NRM	(3.79)	152.1	–55.5
	50[a]	77	161.0	–61.8
23-2, 103-105	NRM	(3.58)	224.0	55.7
	50	86	243.0	67.7
23-2, 105-107	NRM	(3.44)	225.7	48.0
	50	86	239.5	59.9
23-2, 107-109	NRM[a]	(2.93)	242.1	56.6
	50[a]	100	245.0	64.1
23-2, 109-111	NRM	(2.86)	279.9	53.2
	50[b]			
23-2, 111-113	NRM[a]	(2.48)	255.8	42.9
	50[a]	61	309.2	46.0
23-3, 102-104	NRM	(6.50)	136.2	–66.0
	50	68	132.0	–63.3
23-3, 104-106	NRM	(6.42)	125.6	–75.3
	50	75	116.8	–67.6
23-3, 106-108	NRM	(5.20)	160.0	–38.5
	50[a]	70	126.7	–55.3
23-4, 84-86	NRM	(3.56)	175.2	–50.9
	50	88	184.6	–56.9
23-4, 86-88	NRM	(5.90)	175.8	–72.6
	50	64	186.8	–69.1
23-4, 88-90	NRM	(5.43)	180.9	–59.8
	50	64	174.0	–61.6
23-5, 61-63	NRM	(5.88)	151.5	–59.1
	50	52	129.3	–63.1
23-5, 63-65	NRM	(4.71)	136.8	–55.2
	50	70	124.6	–60.7
23-5, 65-67	NRM	(4.84)	141.0	–51.7
	50	72	131.7	–53.6
23-5, 67-69	NRM	(5.37)	123.3	–66.7
	50	72	115.9	–66.7
23-5, 69-71	NRM	(5.89)	136.8	–64.2
	50	69	136.7	–63.3

TABLE 1 – *Continued*

Sample (Interval in cm)	Demagnetizing Field (oe)	Magnitude[c] ($\times 10^{-7}$ emu/cc) Residue (%)	Declination Mean (°)	Inclination Mean (°)
23-5, 140-142	NRM	(4.86)	357.1	–76.5
	50	79	344.6	–66.5
23-5, 142-144	NRM[a]	(4.11)	341.1	–81.0
	50	78	337.0	–68.6
23-5, 144-146	NRM	(4.27)	9.1	–68.2
	50	84	3.0	–66.6

[a]Samples have a large nondipole component (LNC) and are not considered reliable.

[b]Sample 23-2, 109-111 was not measured after 50-oe cleaning because of instrumental difficulties.

[c]Magnitude ($\times 10^{-7}$ emu/cc) given in parentheses.

and illustrates how much the clustering improves after partial (50-oe) AF demagnetization. Figure 4 is a set of 5° histograms, combining both normal and reversed samples, again showing the much improved clustering after AF cleaning, as well as the effect of removing the unreliable LNC samples.

The arithmetic mean inclination, its standard deviation, α^*_{95}, k^*, and the number of samples are listed in Table 2 for various groups of samples.[1] The standard deviation may be a more realistic measure than the α^*_{95} for the true error in the mean inclination. Thus, in determining the site paleolatitude, the mean inclination and the standard deviation for the 32 samples considered reliable after 50-oe AF cleaning were calculated as paleocolatitudes[2] and plotted as small circles around the site's present location to give a locus within which the paleopole must lie. Figure 5 shows this plot, together with a portion of the polar wandering curve for Australia, taken from McElhinny (1973, p. 306).

DISCUSSION

The inclinations of normal and reversed samples are clearly consistent with each other, as seen in the histograms of Figures 3 and 4. The pronounced clustering of the NRM inclinations about the mean in Figure 4a is an indication that the sediments have been relatively undisturbed since they acquired their remanence. The displacement of the mean inclination value, by about 4°, following partial AF demagnetization, suggests that a uniform secondary component of magnetic moment was thereby removed. As noted above, the declinations cannot be compared for samples which are not contiguous. No correlation was found between NRM intensity and the normal/reversed state. The sample mineralogy has not yet been investigated, so that chemically induced self-reversals cannot be excluded. Since the stability behavior of NRM in both normal and reversed samples is similar, there is no reason to presume that reversed remanence is secondary and that inclinations would revert to normal upon demagnetization in higher fields. Confirmation of these reversal events must await further extensive, continuous sampling of the cores (joint report with R. D. Jarrard, in preparation). At least one reversal in our data (Samples 20-3, 28-30 cm, Table 1) has been confirmed by R. D. Jarrard at Scripps (this volume, his Sample 20-3, 30-32 cm).

Figure 5 shows that there is close agreement between the calculated paleocolatitude and the previous data for Australia for the Cretaceous. The two sites used for the Cretaceous pole, K in Figure 5, were dated radiometrically at 104 m.y. and 93 m.y. (McElhinny, 1973, p. 306). However, this agreement cannot constrain the ages of the sampled sediments, since the mean paleocolatitude circle is nearly tangential to the polar wandering curve.

The inclination changes apparent between several contiguous samples at various intervals (Figure 1) could be attributed to secular variation effects and thus would be compatible with the sedimentation rates initially proposed of about 8 cm/1000 yr. However, over the largest sampled interval of about 10 cm, the sample inclinations seem to average out quite well. Since the secular variation is presently smoothed out in roughly 2000 years, a maximum sedimentation rate of about 5 cm/1000 yr is implied. Further contiguous sampling of longer intervals would provide more conclusive evidence of this effect.

[1]α_{95} is the semi-angle of the 95% confidence cone about the mean paleocoordinates. The indeterminacy of the sample declinations prevents meaningful estimates of α_{95}. The declinations were arbitrarily set to 0° for the calculation of the tabulated α^*_{95} which should be considered a minimum value of α_{95}. The same assumption was made in calculating k^*, the accuracy parameter, using the usual formulas:

$$\alpha^*_{95} = \cos^{-1}\left[1 - \frac{N-R}{R}\left\{\left(\frac{1}{0.05}\right)^{1/N-1} - 1\right\}\right]$$

$$k^* = \frac{N-1}{N-R}$$

where N = number of samples, and $R^2 = (\Sigma l_i)^2 + (\Sigma m_i)^2 + (\Sigma n_i)^2$, l_i, m_i, n_i being direction cosines for moment vectors.

[2]The paleocolatidue, p, or alternatively, the paleolatitude, L, are defined from their relationship to the inclination of the remanent moment, I, by: $\tan I = 2 \cot p = 2 \tan L$.

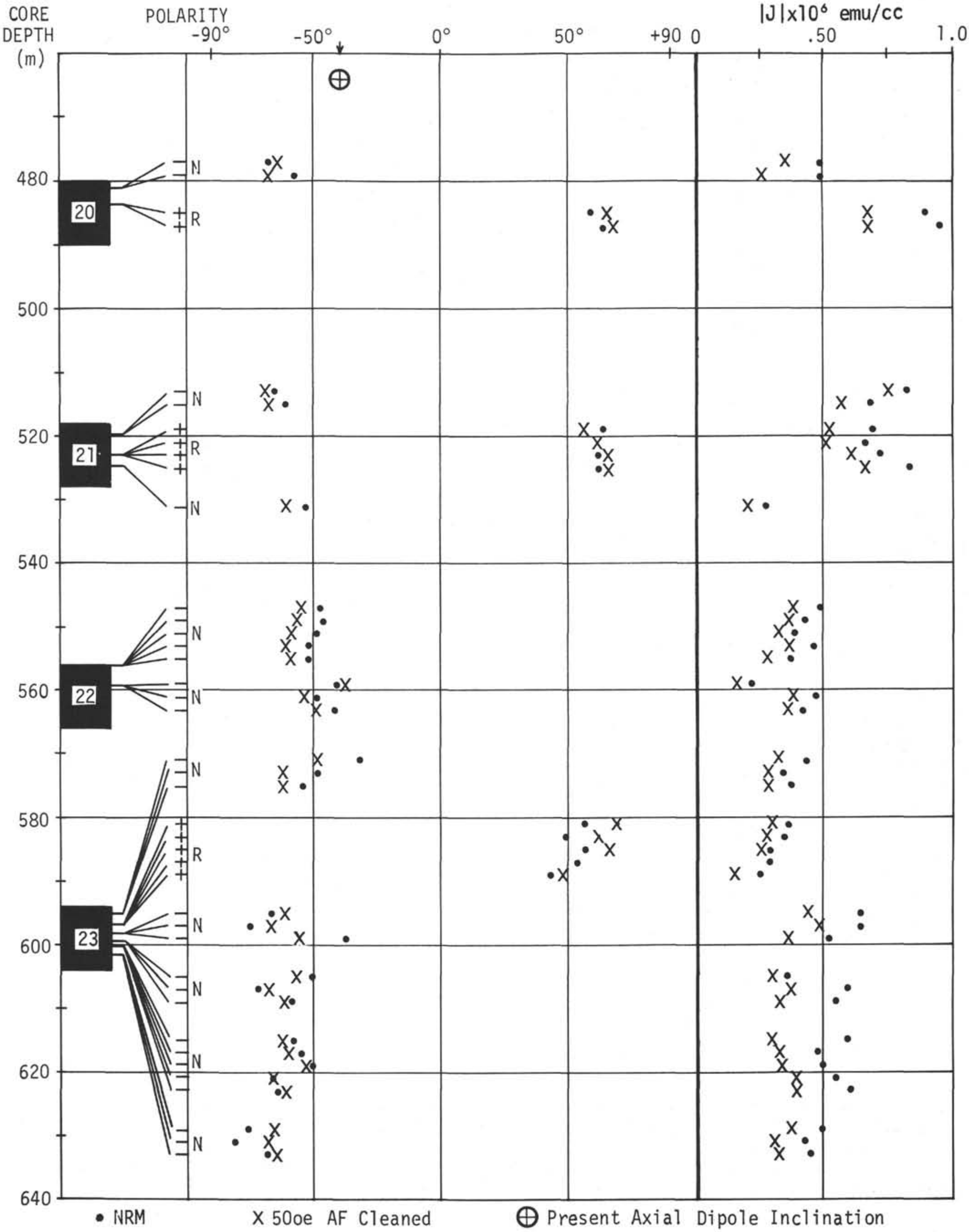

Figure 1. *Inclination and magnetization intensity (NRM and after 50-oe cleaning) of 41 samples. Sample interval is given on the left. Shading indicates the core recovered. Depth is in meters below the ocean floor.*

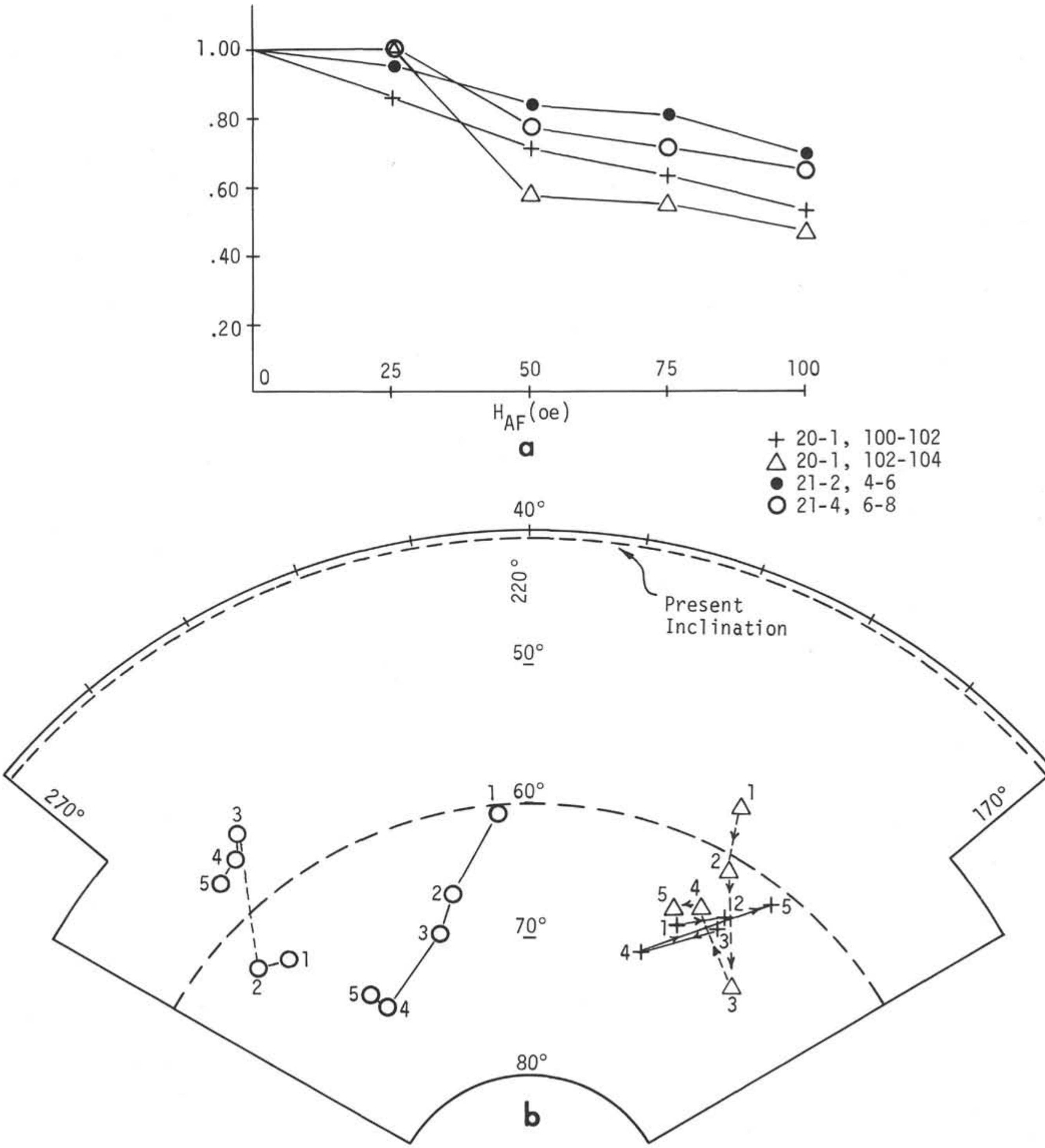

Figure 2. *(a) Normalized intensities of remanence of four representative samples at each stage of partial demagnetization. Samples 20-1, 100-102 cm, 20-1, 102-104 cm, 21-2, 4-6 cm are of normal polarity. Sample 21-4, 6-8 cm has reverse polarity. (b) Directions of remanence for samples for each stage of partial AF demagnetization. The corresponding AF peak fields are: 1-NRM; 2-25 oe; 3-50 oe; 4-75 oe; 5-100 oe. Note decreased rate of change in inclination with AF cleaning above 50 oe. Present axial geocentric dipole inclination is marked at 40.8°.*

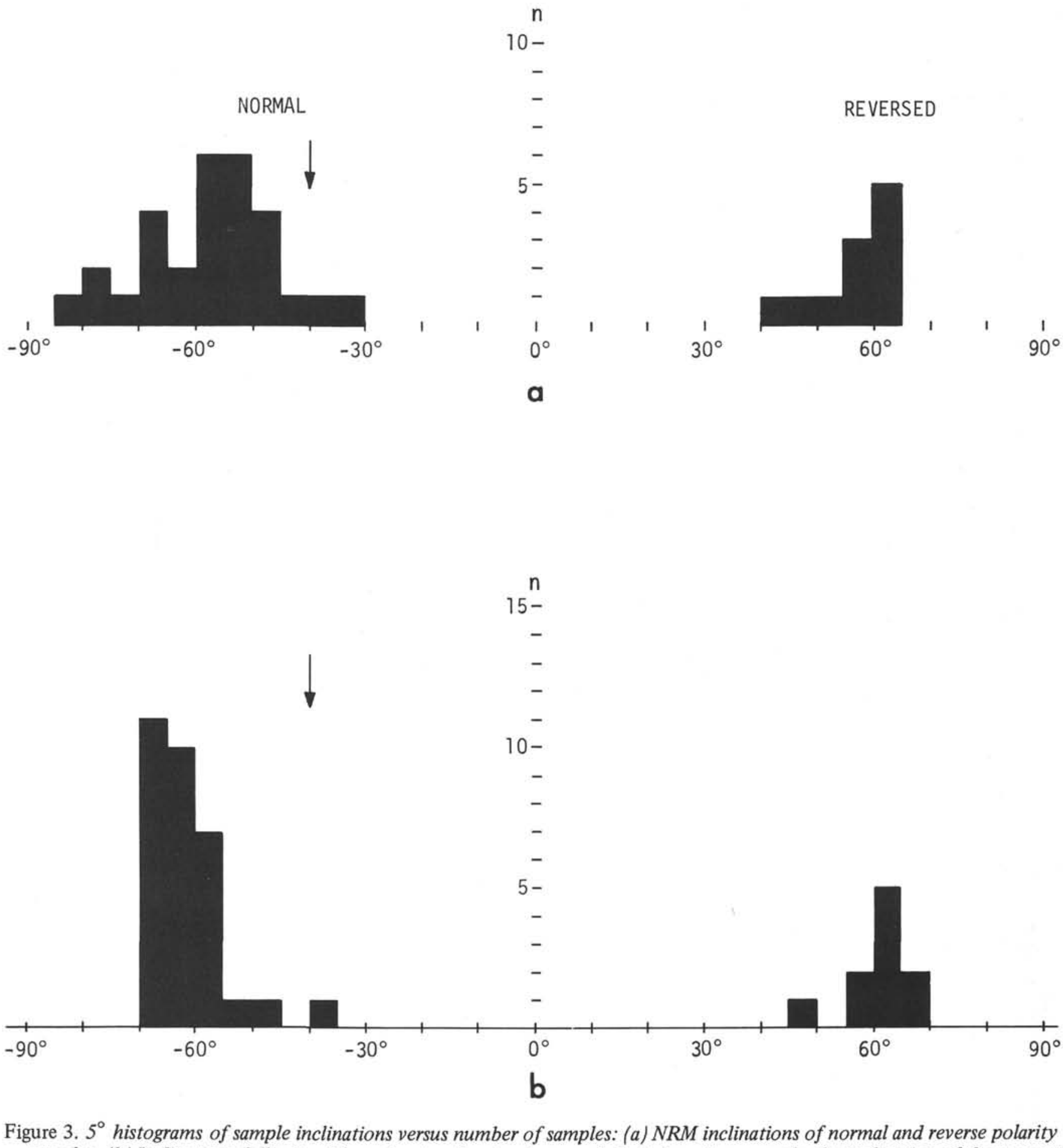

Figure 3. *5° histograms of sample inclinations versus number of samples: (a) NRM inclinations of normal and reverse polarity samples. (b) Inclinations following 50-oe cleaning showing improved clustering. Arrow marks the inclination of the present axial geocentric dipole field at Site 263.*

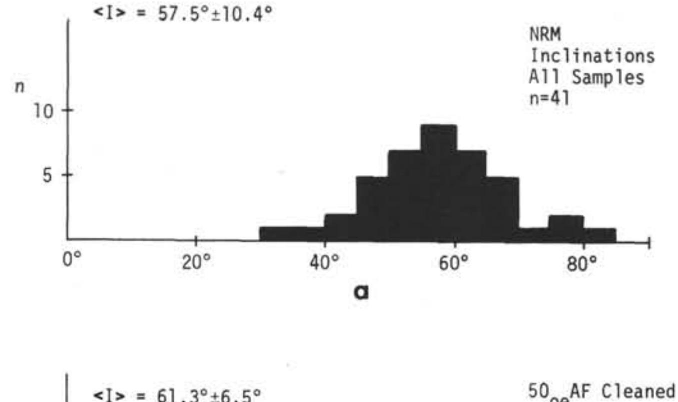

Figure 4. *5° histograms of the absolute value of the inclination versus number of samples. (a) NRM inclinations for 41 samples; arithmetic mean is 57.5°; standard deviation is ±10.4°. (b) Inclinations of 40 samples following 50-oe AF cleaning; arithmetic mean is 61.3°; standard deviation is ±6.5°. (c) Inclinations of 32 samples considered to have a reliable remanent moment following 50-oe cleaning; arithmetic mean is 62.9°; standard deviation is ±4.5°.*

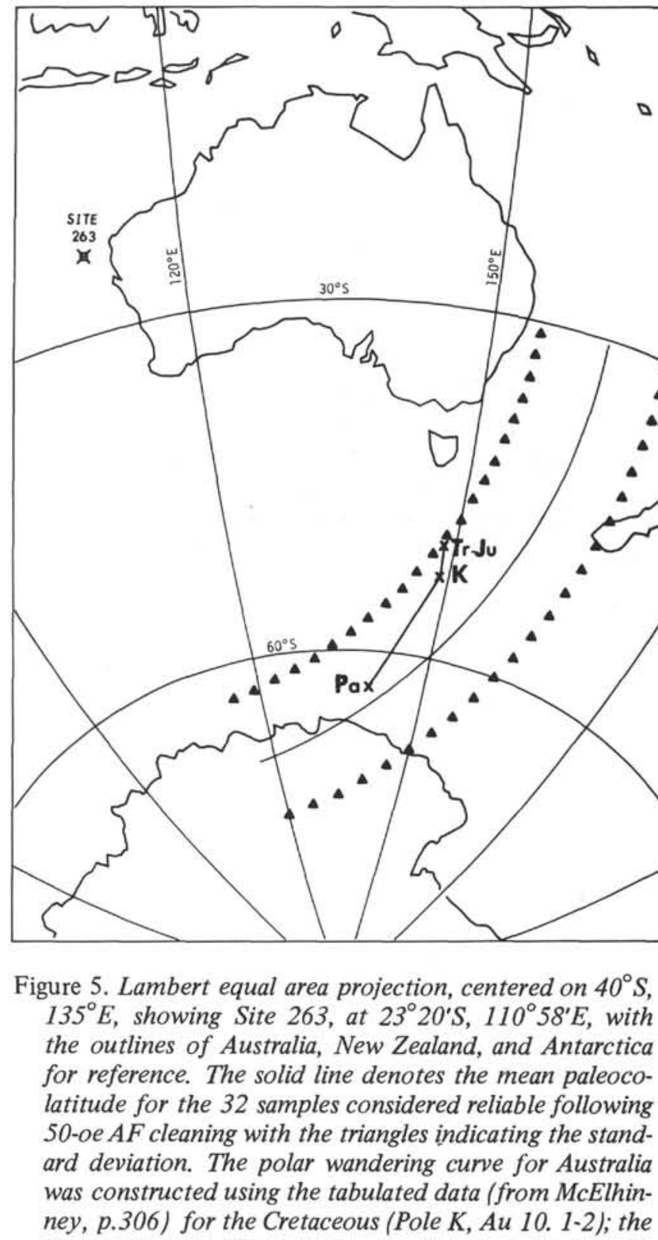

Figure 5. *Lambert equal area projection, centered on 40°S, 135°E, showing Site 263, at 23°20'S, 110°58'E, with the outlines of Australia, New Zealand, and Antarctica for reference. The solid line denotes the mean paleocolatitude for the 32 samples considered reliable following 50-oe AF cleaning with the triangles indicating the standard deviation. The polar wandering curve for Australia was constructed using the tabulated data (from McElhinney, p.306) for the Cretaceous (Pole K, Au 10. 1-2); the Triassic-Jurassic (Pole Tr-Ju, Au 8.1, 9. 1-5); and the Paleocene (Pole P, Au 11.1).*

The paleontological data used in dating this hole are still inconclusive (see Paleontology Section, this volume). Of 13 different intervals randomly sampled over a 204-meter interval, 3 are reversed in our data, indicating that a significant portion of the unsampled sediment between or within cores could be of reversed polarity. Because it is generally agreed that these cores are from the Lower Cretaceous, we would surmise that the cores predate the long normal polarity interval generally recognized for the Cretaceous (Irving and Couillard, 1973). Our sampling is too infrequent to establish a reversal stratigraphy or to allow unambiguous matching of these reversals to other cores or to a paleomagnetic time scale. We can say that it is unlikely that the samples are truly Albian, as implied by some paleontological evidence, unless they represent very short reversal events which have thus far not been found on land (Irving and Couillard, 1973). If we assume a sedimentation rate of 5 cm/1000 yr, the duration of observed reversed periods is a minimum of 1600 yr, and a maximum of 120,000 yr, based on our fragmentary data. These intervals could be stretched or shortened by assuming different sedimentation rates and are only meant as a guide. The presence and duration of these events can only be verified by further sampling.

Work now in progress will complete the study of the stability of NRM under further AF cleaning, as well as test the possibility of stable viscous remanence. The nature of the NRM, whether chemically or depositionally produced, and the magnetic mineralogy are also being investigated.

TABLE 2
Inclination by Groups

Group	N	Demagnetizing Field (oe)	Inclination Mean (°)	α^*95 (°)	k^*	Standard Deviation (°)
All samples	41	NRM	57.5	2.9	61	10.4
All samples less LNC values	36	NRM	57.5	2.8	73	9.5
All samples	40	50	61.3	1.8	158	6.5
All samples less LNC values	32	50	62.9	1.4	326	4.5
All normal	30	50	61.3	2.1	153	6.6
All reversed	10	50	61.5	3.9	157	6.5
Core 20	4	50	65.9	1.6	3369	1.4
Core 21	7	50	63.4	3.5	291	4.8
Core 22	8	50	56.6	5.0	121	2.0
Core 23	21	50	61.6	2.5	162	4.5

Note: In the computation of the tabulated values, all declinations were set to 0°, arbitrarily, and reversed inclinations were simply reversed in sign. One sample was not measured after cleaning due to instrumental difficulties.

SUMMARY

The paleomagnetic study of 41 samples from 13 intervals in four cores from Site 263 has yielded a reliable paleolatitude estimate (44.3° ±5.5°) which is consistent with the paleolatitude of 48.4° computed from the pole for the Australian plate during the Cretaceous.

The significant clustering of normal and reversed inclinations about the mean (Figures 3 and 4) strongly suggests that the three reversed polarity events uncovered are real. The presence of at least three periods of reversed polarity may indicate that the sampled sediment predates the Cretaceous normal polarity interval.

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