30. PALEOMAGNETISM OF THE CRETACEOUS SECTION, SITE 462[1]

Maureen B. Steiner, California Institute of Technology, Division of Geological and Planetary Sciences, Pasadena, California[2]

ABSTRACT

Studies of paleomagnetism in lower Campanian sedimentary rocks appear to show the reversed interval of polarity bounding the young end of the Cretaceous long normal interval. In addition, cores from both Hole 462 and Hole 462A also display a deviation of directions within this reversed interval, interpreted to represent an excursion of the geomagnetic field direction, possibly an aborted polarity reversal. Inclinations of lower Campanian samples give a paleolatitude of 6.8°S ± 3.7°. Sparser sampling in Santonian through Cenomanian strata suggests a relatively constant paleolatitude of this site for Campanian through Cenomanian time.

INTRODUCTION

Both Hole 462 and Hole 462A at Site 462 of Leg 61 (7.2°N, 165.0°E) yielded large portions of Upper Cretaceous sediments (Campanian through Cenomanian). A study of paleomagnetism in this interval was undertaken to refine the correlation between biostratigraphic (particularly nannofossil) ages and the geomagnetic reversal pattern of Late Cretaceous time. Of particular interest was the reversed interval corresponding to Anomalies 33 and 34 of the oceanic magnetic anomaly sequence. This reversed interval forms the younger boundary of the Cretaceous long normal interval.

Initial sampling was conducted at an average spacing of 75 cm through the recovered portions of 45 meters of coring. Resampling in and across the boundaries of the reversed interval resulted in larger sample densities in some parts, to the extreme of one sample every 2 cm at one place in the core. Thirty-six samples were obtained in Hole 462, and 34 in Hole 462A. The strata are so hard that sampling had to be done by coring with a diamond bit. The induration is such that distortion during the ship coring process is not a problem for these samples.

Sampling was initiated at a point in the core at which the foraminiferal zones predicted (I. Premoli Silva, personal communication, 1978) that the upper boundary of the Anomaly 33–34 reversed interval should occur. The prediction was based on earlier studies of strata at Gubbio, Italy, where an apparently complete section of the uppermost Cretaceous was studied jointly by paleontologists and paleomagnetists. Correlation of biostratigraphic and magnetostratigraphic ages led to the proposal of a magnetostratigraphic type section for the Upper Cretaceous–Paleocene (Premoli Silva, 1977; Alvarez et al., 1977). A change in inclinations consistent with a change of polarity was observed in Site 462 Campanian sediments at precisely the point predicted by the foraminifers.

Sample measurements were performed largely on the shipboard Digico magnetometer. The samples' intensity and stability to demagnetization permitted the use of this spinner magnetometer for most of the measurements. The problems encountered in measurements on the basalt samples with the Digico (see Steiner, this volume) did not occur in this study. Stepwise alternating-field (AF) demagnetization was performed on 26 of the 70 samples, in steps of 12.5, 25, 50, 75, 100, 125, 150, 200, 250, 300, 350, and 400 Oe. Because AF demagnetization had a minimal effect on these samples, 34 more were demagnetized only at 100 Oe. Ten samples were additionally subjected to thermal demagnetization on shore. Thermal demagnetization was done in a furnace (Schonstedt Corp.) in which the temperature was monitored independently of the control unit. The field in the cooling chamber is ±15 γ. Measurement during thermal treatment was done with an SCT cryogenic magnetometer. Thermal demagnetization and measurement equipment are housed inside a mu-metal room in which the ambient field is approximately 50 γ.

NRM DIRECTIONS

Natural remanent magnetization (NRM) inclinations are shown in Figure 1. Normal polarity inclination at this site during Late Cretaceous time was negative, since the site was in the southern hemisphere at that time (Larson and Chase, 1972; Lancelot and Larson, 1975). NRM inclinations clearly show a change in the sign of the inclination consistent with a polarity reversal in the Campanian. Inclinations are very shallow, consistent with a predicted near-equatorial location (Larson and Chase, 1972). The paleomagnetic data of Hammond et al. (1975) also suggest a near-equatorial location during Late Cretaceous time for the nearby Ontong–Java Plateau.

Cores from both Site 462 holes, 500 meters apart, show this very obvious change in sign from negative (normal) to positive (reversed) inclinations, and back again, at precisely the same depths within each core. Both inclination changes occur within a core and within core segments, not at breaks between segments. Unfortunately, they do not occur within single unbroken pieces of core, so relative declination could not be determined. Below the return to negative (normal) inclina-

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[2] Present address: University of Wyoming, Laramie, Wyoming.

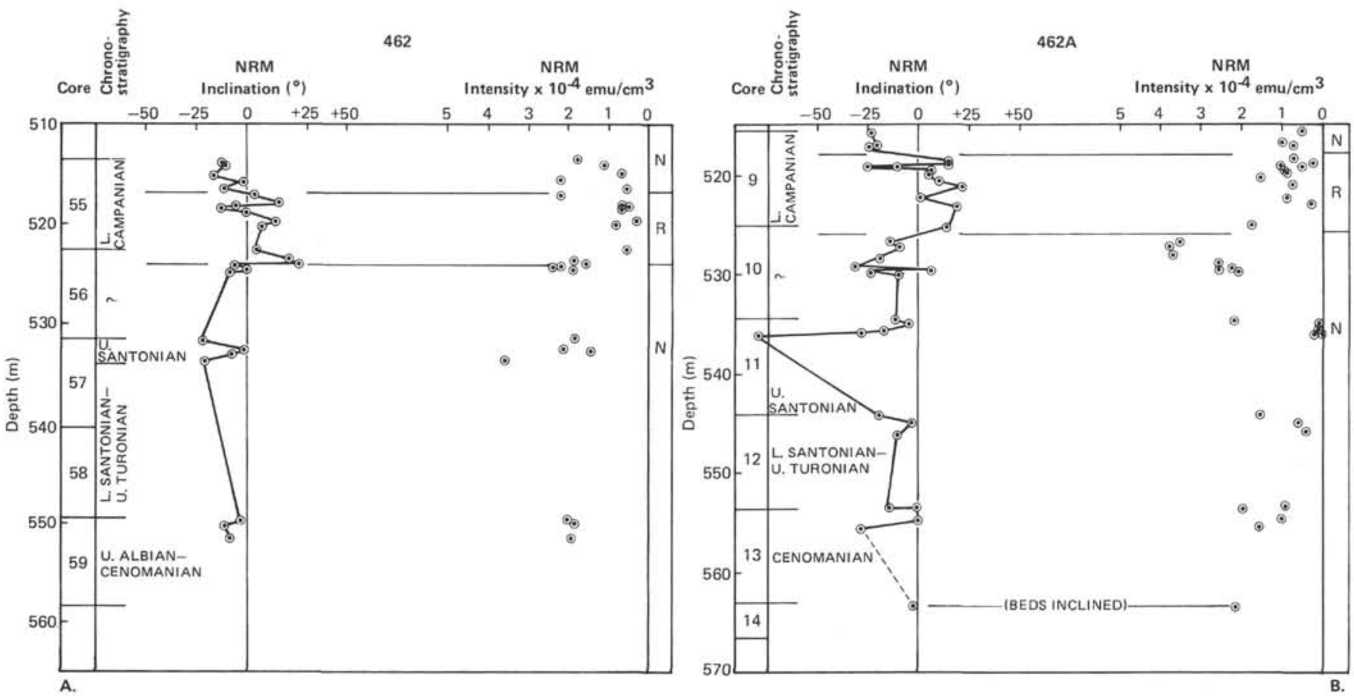

Figure 1. NRM inclinations and intensities for (A) Hole 462 and (B) Hole 462A. N = Normal; R = Reverse.

tions, the remainder of the sedimentary part of the cores maintains negative (normal) inclinations. The beds containing positive (reversed) inclinations are lower Campanian (Premoli Silva, et al., this volume). The underlying sediments of negative inclinations represent time from Santonian through Cenomanian.

Despite the shallowness of the inclinations and the dispersion of the data, the occurrence of a shift in direction at the same depths, representing the same time within two cores 500 meters apart, indicates that this is a feature of the geomagnetic field. Its occurrence in a time know to encompass the Anomaly 33–34 reversed interval, its occurrence in two cores, and the consistent normal polarity below it strongly suggest that this is a reversal of polarity, specifically the reversed interval between Anomalies 33 and 34.

DEMAGNETIZATION

Alternating-field (AF) demagnetization had only minor effects on the sample directions. Median destructive fields were greater than 150 Oe, and generally greater than 200 Oe (Figs. 2A and 2B, Table 1). The normal inclinations generally steepen, while the reversed inclinations become shallower or remain the same. All reversed samples show initial rises in intensity during demagnetization (Fig. 2B), implying removal of an oppositely directed component. Most normal samples show a continual decrease in intensity with demagnetization (Fig. 2A). The present inclination at the site is +14°. However, the demagnetization behavior of both normal and reversed samples indicates the removal of an upward-directed (negative) component from all samples. This may be a drilling-imposed remanence, as seen in the basalts of these holes (Steiner, this volume).

AF demagnetization did not, however, significantly reduce the dispersion of the directions. Because of the lack of response and because some samples have a brown-red or brown color, thermal demagnetization was performed. Ten samples were treated, four from each polarity and two from the "excursion" to be discussed later. Nine of the samples had been AF-demagnetized at 100 to 400 Oe before this treatment. Samples were dried for 48 hours, during which time they were repeatedly measured. Drying clearly had no effect on their directions. A small (viscous?) remanence in the AF-demagnetized samples appeared to have been acquired in transport from the ship. This remanence was present even though samples had been stored for four months in the mu-metal room prior to measurement. It disappeared after the first heating (150°C), and directions were then the same as the directions measured on board ship.

Samples were heated to 150, 250, 350, 450, 560, 620, 630, 645, 655, 665, and 675°C. Thermal demagnetization also had no effect on sample directions (Fig. 3A). After the disappearance of the apparent viscous (?) remanence, no change occurred up to at least 620° to 645°C. No difference in response was evident among the normal and reversed samples. The response of the one NRM sample was not different from that of the AF-treated samples. That neither thermal or AF demagnetization was able to reduce the dispersion of directions suggests that the dispersion is probably a real reflection of the geomagnetic field. Such dispersion is an expected feature at such near-equatorial locations as this one.

Thermal demagnetization suggests that the main carrier of the remanence may be magnetite. Although no Curie point measurements have been made, thermal de-

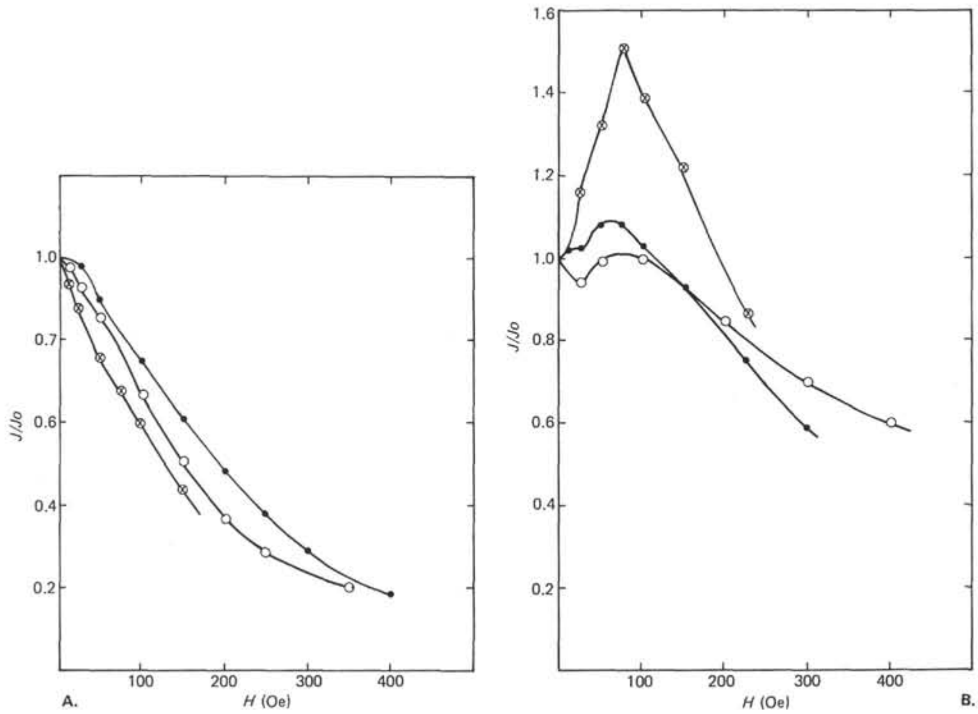

Figure 2. Response to alternating-field demagnetization (H) of normal samples (A) and reversed samples (B). J/J_0 is the normalized magnetization.

magnetization shows blocking temperatures near the magnetite Curie point (Fig. 3B). Loss of 93 to 98% of the remanence occurred after heating to 620°C. Changes of direction generally did not occur below 620°C. Very small changes in direction often occurred with the 620°C step, but the general direction remained the same until the 645°C step. With the 645°C step, larger directional changes occurred (Fig. 3A), but directions still remained in the same range through the 665°C step. It would appear that, although magnetite carries most of the remanence, hematite is present and also carries a small remanence in roughly the same direction.

EXCURSION

Within the reversed interval, in cores from both Hole 462 and Hole 462A, an "excursion" of inclinations occurs at exactly the same point within each core. The feature spans only 20 cm, but is so persistent as to occur in sediments of different colors in the two cores. It consists of a shallowing of the positive reversed inclinations, steepening into negative, apparently "normal", values and back again to typical reversed inclinations (see Figs. 4A and 4B). Because this feature occurs at exactly the same level in both holes, cores from both holes were resampled to study it in more detail. In Hole 462 it occurs in a continuous core, and samples were obtained at about every 2 cm. A continuous directional change is apparent. In Hole 462A, the core is badly fractured at the point where the excursion occurs, and only two samples could be obtained. Since the core from Hole 462 contained the feature in a continuous piece, relative declination information was obtained for the younger end of this feature. As can be seen from Figure 5 and Table 1, no change in declination occurs as inclinations swing over to negative values and back again. Therefore, despite first impressions, it is obvious that this feature is not a polarity event within the Anomaly 33–34 reversed interval.

Neither AF (all samples) nor thermal (2 samples) demagnetization affected the directions. Figure 4 shows both the NRM and AF-demagnetized inclinations. Because of its stability and because the excursion is so clearly visible in both cores at exactly the same depth, it must represent a real feature of the magnetic field.

The proximity of this feature to the reversal of polarity suggests that excursion might represent a preliminary attempt of the field to reverse. Sedimentation rates for this time have been estimated (Larson and Schlanger, this volume), although problems in the fossil control limit precision. The rate is estimated at 0.45 cm/1000 years. At this rate, this feature represents an event spanning about 9000 years (and which occurred 53,000 years before the field reversal). This duration is of the same order of magnitude as that observed for reversals of the geomagnetic field (see for example, Hillhouse and Cox, 1976), and thus lends further support to the hypothesis that the feature may be related to a reversal of the field.

Regardless of its origin, this small excursion could be of value in correlating stratigraphy, at least in nearby areas. If recorded elsewhere, it provides a distinctive marker for this particular reversed period. It is of particular value, however, in serving to warn of the dangers of interpreting reversals of polarity from inclination only. This is often the only type of data provided by

Table 1. Paleomagnetic data, Holes 462 and 462A.

Sample (Core-sec., cm)		Depth Sub-bottom (m)	Intensity $\times 10^{-4}$ emu/cm^3	NRM Inclination (°)	MDF (Oe)	Stable Inclination (°)
Hole 462						
55-1, 8		513.58	1.543	−12.0	195	−20.1
55-1, 35		513.85	0.995	−9.5	—	—
55-1, 148		514.98	0.578	−16.1	—	−14.3
55-2, 41		515.41	1.958	−2.0	165	−6.6
55-2, 122		516.22	0.496	−10.8	>150	−11.4
55-3, 35		516.85	1.830	2.8	275	4.0
55-3, 138		517.88	0.055	16.4	—	22.2
55-4, 3		518.03	1.278	10.8	—	—
55-4, 6	"excursion"	518.06	0.795	3.6	—	2.7
55-4, 10		518.10	0.290	−1.5	>300	−0.0
55-4, 14		518.14	0.636	−0.1	>300	0.4
55-4, 17		518.17	0.662	−2.3	—	—
55-4, 21		518.21	0.654	−5.6	>300	−4.6
55-4, 25		518.25	0.447	−11.8	315	−11.7
55-4, 28		518.28	0.638	−0.5	260	−3.1
55-4, 33		518.33	0.105	11.7	>200	7.9
55-4, 46		518.46	0.009	13.2	—	—
55-4, 70		518.70	0.351	8.6	—	—
55-4, 81		518.81	0.352	12.8	—	8.3
55-4, 95		518.95	0.307	13.0	—	—
55-4, 119		519.19	0.591	12.9	—	—
55-4, 140		519.40	0.253	15.2	—	6.0
55-5, 54		519.54	0.677	8.2	240	7.8
56-1, 12		522.62	0.458	4.1	>400	3.0
56-1, 120		523.70	1.599	21.9	—	15.9
56-2, 17		524.17	1.391	26.0	>150	16.3
56-2, 35		524.35	1.924	−6.4	130	−12.8
56-2, 54		524.54	1.703	−0.1	—	−10.4
56-2, 61		524.61	2.050	−7.8	—	—
57-1, 9		531.59	1.592	−21.8	—	−21.1
57-1, 131		532.81	1.869	−1.9	—	−4.1
57-2, 7		533.07	1.484	−6.2	—	−6.2
57-2, 69		533.69	3.066	−20.8	155	−24.3
59-1, 32		549.82	1.994	−3.4	—	—
59-1, 67		550.17	1.571	−10.1	—	−16.3
59-2, 42		551.42	1.674	−7.8	—	−18.0
Hole 462A						
9-1, 12		515.62	0.385	−24.0	—	−23.0
9-1, 134		516.84	0.850	−21.4	—	−25.0
9-2, 8		517.08	0.592	−23.5	>200	−16.4
9-2, 136		518.36	0.585	15.2	>250	19.6
9-3, 36		518.86	0.197	16.2	>350	12.1
9-3, 67		519.17	0.915	−10.3	>250	−6.1
9-3, 73		519.23	0.481	−25.5	375	−15.5
9-3, 91		519.41	0.819	6.0	>300	8.0
9-3, 145		519.95	0.694	4.7	—	13.3
9-4, 46		520.46	1.157	10.4	—	8.2
9-4, 110		521.10	0.674	22.0	—	19.5
9-5, 62		522.12	0.761	0.7	>300	0.8
9-6, 14		523.14	0.228	18.4	—	8.3
10-1, 8		525.08	1.522	14.5	>200	10.6
10-1, 146		526.46	3.091	−13.7	150	−17.0
10-2, 66		527.16	3.304	−9.8	—	−13.2
10-3, 10		528.10	3.225	−17.7	—	−22.7
10-3, 102		529.02	2.260	−32.1	>250	−33.8
10-3, 143		529.41	2.254	4.9	>450	5.8
10-4, 7		529.55	1.894	−23.0	>450	−22.8
10,CC (13)		529.73	1.837	−9.7	—	−11.2
11-1, 21		534.71	1.943	−12.0	—	−11.7
11-1, 71		535.21	0.094	−4.9	—	—
11-1, 113		535.63	0.111	−16.9	—	−12.8
11-1, 132		535.82	0.028	−28.5	—	—
11-2, 11		536.11	0.214	−79.0·	550	−80.6
12-1, 13		544.13	1.406	−19.4	—	−22.4
12-1, 67		544.67	0.584	−5.0	—	−18.7
12-2, 26		545.76	0.333	−10.6	—	−13.5
13-1, 8		553.58	0.798	−15.5	—	−20.7
13-1, 70		553.70	1.762	−1.0	75	−7.9
13-2, 14		554.64	0.871	−0.3	60	−15.5
13-2, 105		555.55	1.385	−29.4	—	−32.2
14-1, 82		564.32	1.929	−1.9	(tilted strata)	(−9.8)

Note: "Excursion" samples enclosed by dashed lines.

DSDP cores, but as these data illustrate, it is risky in shallow-inclination samples without declination control.

DISCUSSION

Paleolatitude for this site on the Pacific plate in the Late Cretaceous can be calculated from these data. These calculations assume that the Campanian inclination change does represent a reversal of polarity. The calculations exclude the "excursion" of directions, because of the belief that it represents unusual temporal behavior of the geomagnetic field. Table 2 shows the various alternatives in making the paleolatitude calculation. The dispersion in the data is expressed as one standard deviation of the mean inclination, and is transformed into degrees of latitude relative to this site. It is apparent that both holes give the same average inclination and the same dispersion. Furthermore, NRM averages are statistically the same as AF-demagnetized ones. Because of the denser sampling in the lower Campanian, the data have been divided into two parts, lower Campanian and Santonian through Cenomanian.

The similarity of the averages for both holes suggests combining the data for better statistics. Despite the large dispersion of the data, the bipolarity and approximately equal numbers of each polarity strengthens confidence in these values. From the combined demagnetized data, the samples suggest an early Campanian latitude of 6.8°S ± 3.7°. Santonian through Cenomanian paleolatitude is insignificantly different from the Campanian, $\lambda = 8.4°S \pm 3.7°$. Thus, these data appear to suggest that the Nauru Basin was stationary during the Late Cretaceous. This conclusion would imply a mean paleolatitude from early Campanian through Cenomanian time of 7.3°S ± 3.7°.

Paleomagnetic data from the nearby Ontong-Java Plateau (Hammond et al., 1975) can be used to predict a tentative paleolatitude for the Nauru Basin. This involves a somewhat uncertain assumption that there has been no relative motion between plateau and basin since Campanian time. The predicted paleolatitude for Site 462 from those data is 4.0°S (± ~2.2°). Compared with 7.3° ± 3.7°S from the data of Site 462, this suggests little or no relative motion between these two portions of the Pacific plate since Late Cretaceous time. The trend in Ontong-Java Plateau data could be interpreted to predict about a 6° increase in paleolatitude from Campanian to Cenomanian time. At present, sample density at Site 462 is small, and dispersion is large. Nevertheless, the available data for Site 462 appear to suggest no change in paleolatitude during that time.

In summary, sampling of time-equivalent sections from the lower Campanian through the Cenomanian in Holes 462 and 462A has shown the presence of the reversed interval corresponding to Anomalies 33–34, the reversed period bounding the young end of the Cretaceous long normal polarity interval. The remanence appears to be carried, at least in part, by magnetite. It appears that hematite also carries some of the remanence, and in the same direction as that of magnetite. In addition to the reversal of the field, a peculiar deviation of inclinations occurred just before the termination of this reversed period. Its record in both cores at precisely the same stratigraphic position suggests that it may have been an aborted polarity change. Paleolatitude derived from the scattered inclinations from Site 462 cores suggests a paleolatitude of 6.8° ± 3.7°S in Campanian time, and tentatively suggests a stationary paleolatitude through the Cenomanian. The data also may imply no relative motion between the Nauru Basin and the Ontong-Java Plateau since the Campanian, although this is very tentative at present.

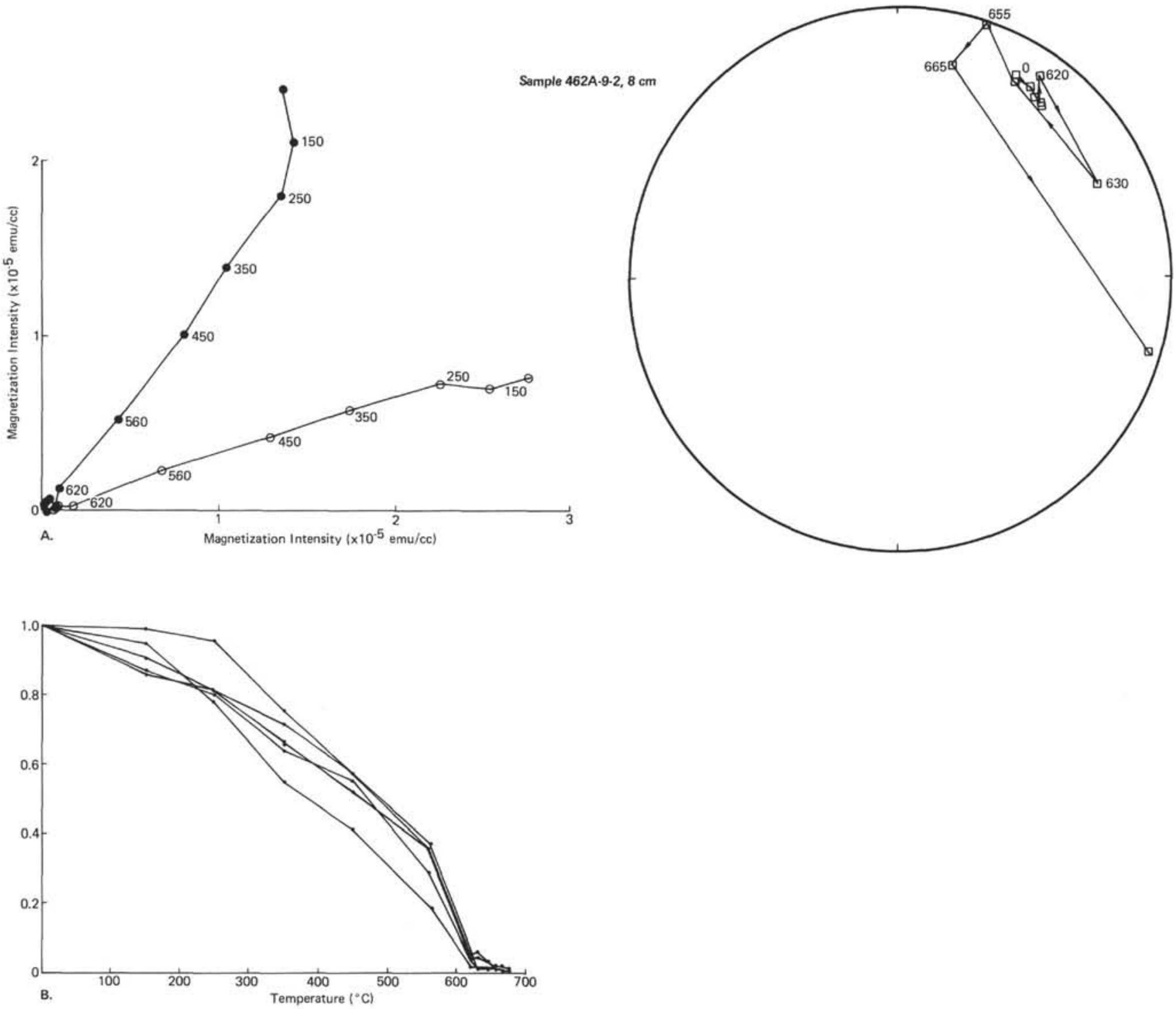

Figure 3. Typical sample responses to thermal demagnetization. A. Vector diagram and equal-area-sterographic projection. Numbers adjacent to data points are temperatures (°C). The stereonet shows the relative orientation to one another of measurements after successive heating steps; absolute azimuthal orientation of the directions is unknown since DSDP cores are azimuthally unoriented. In the vector diagram, numbers along the axes refer to the magnetic intensity in units of emu/cm^3. Solid circle path shows the horizontal projection of the demagnetization path. Again, the points are merely relative to one another, since absolute azimuthal orientation is unknown; declination is read relative to the vertical axis. The open circle path shows the demagnetization path in the vertical plane, negative inclinations being above the horizontal axis and the inclination angle measured relative to it. B. Normalized intensity (J/J_0) response to thermal demagnetization.

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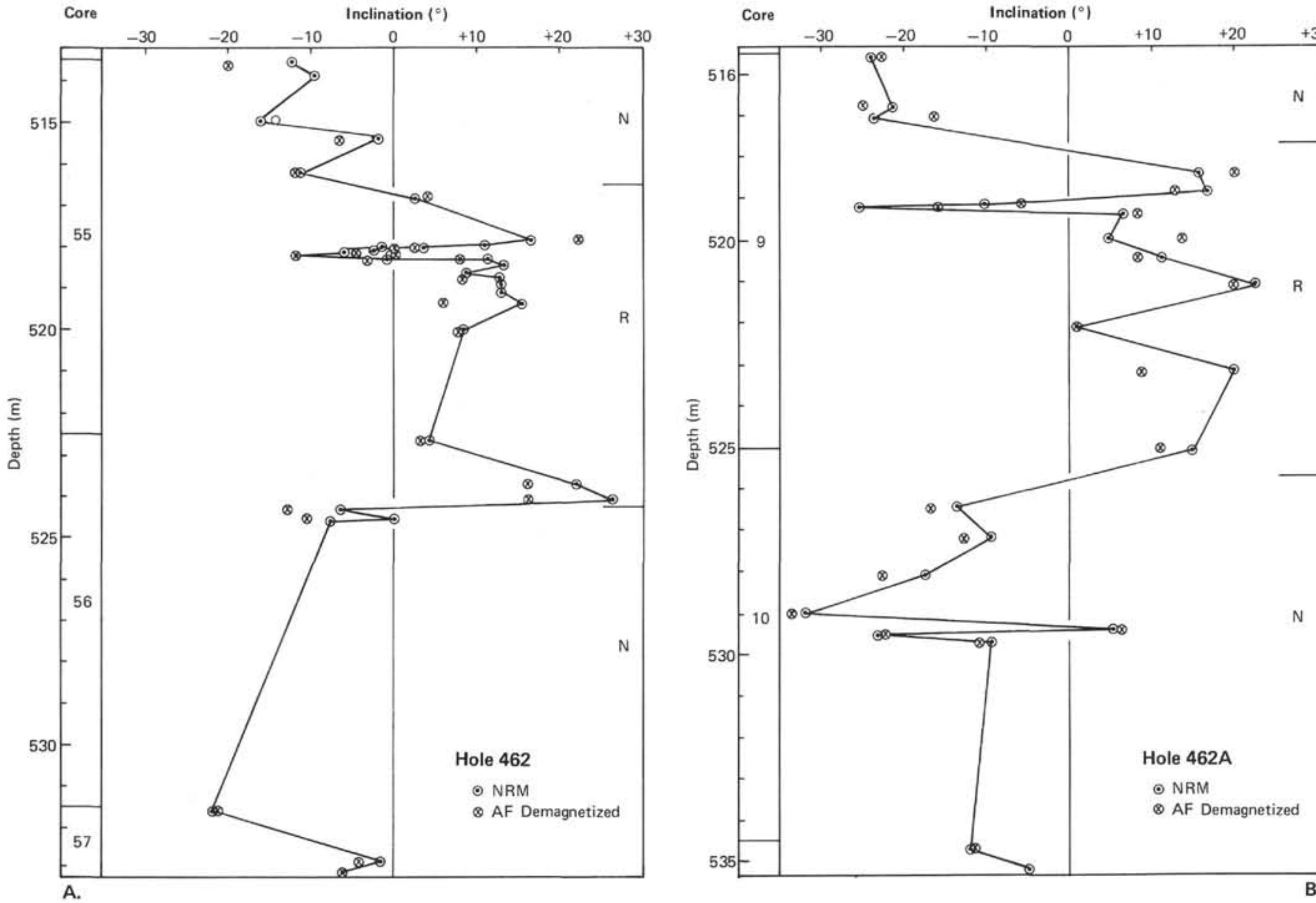

Figure 4. Stratigraphic plot of the upper part of both sections showing both NRM and AF-demagnetized inclinations.

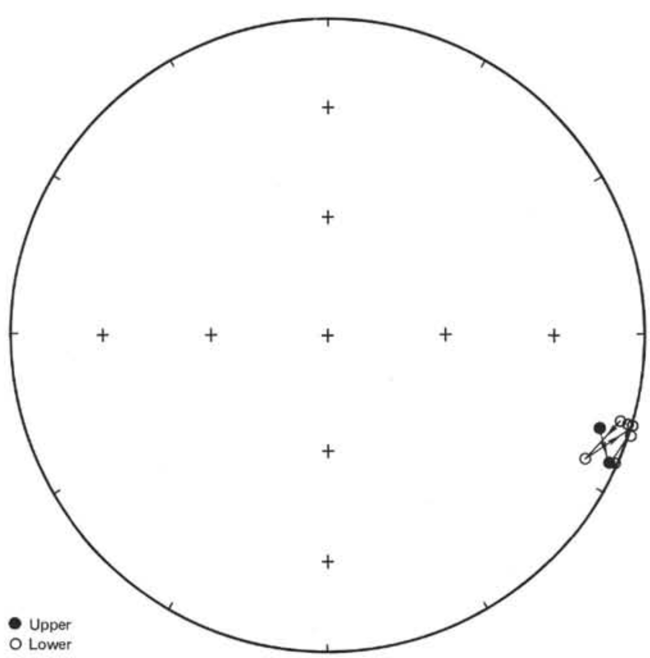

Figure 5. Equal-area stereographic plot of the relative declinations and inclinations of the "excursion" samples from the piece of continuous, unbroken core in Hole 462. Azimuthal orientation is only relative within this core piece, since azimuthal orientation is not obtained with DSDP cores.

Table 2. Calculated paleolatitude.

Site	NRM N	NRM λ_S	NRM SD	AF-Demagnetized N	AF-Demagnetized λ_S	AF-Demagnetized SD
Lower Campanian						
Combined	41	6.5	3.7	34	6.8	3.7
462	22	5.6	3.1	15	5.6	2.9
462A	19	7.7	4.1	19	7.8	4.0
Santonian-Cenomanian						
Combined	18	6.1	4.6	15	8.4	3.7
462	7	5.2	4.0	6	7.6	4.1
462A	11	6.6	5.1	9	8.8	3.6

Note: N = number; λ_S = south paleolatitude; SD = 1 standard deviation.