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# VII. PALEOMAGNETISM OF SEDIMENT CORES COLLECTED FROM THE CENTRAL EQUATORIAL PACIFIC (GH82–4 Area)

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## Introduction

Siliceous sediments in the central equatorial Pacific (Fig. VII–1) have stable remanent magnetization in general (Yamazaki, 1986; Yamazaki *et al.*, 1991). As the ages of these sediments can be determined using siliceous microfossils independently of magnetostratigraphy, these sediments are suitable for paleomagnetic studies. Siliceous sediments played an important role in establishing the polarity reversal timescale (e.g. Theyer and Hammond, 1974; Opdyke *et al.*, 1974). Due to slow sedimentation rates, however, it is difficult to deduce details of the behavior of the geomagnetic field during a polarity reversal from pelagic sediments. Deep-sea sediments of slow sedimentation rate, on the other hand, have an advantage for studying configuration of the geomagnetic field averaged for $10^5$ to $10^6$ years, such as long-term non-dipole components (Schneider and Kent, 1988, 1990).

A paleomagnetic study of sediment cores obtained from the GH82–4 area in the south of the Nova Trough, central equatorial Pacific (Fig. VII–1) were carried out as a part of the research program, "Geological Study of Deep-sea Mineral Resources". The aim of the paleomagnetic measurements is to offer basic data through magnetostratigraphy in understanding a sedimentation history of this area and its relation to the growth of manganese nodules.

Sedimentation rates and a period of hiatus formation are estimated from magnetostratigraphy in this area, and they are compared with those in the GH81–4 area located about 300 km northwest of the GH82–4 area (Fig. VII–1). Further I interpret the paleomagnetic data on the viewpoints of the time-averaged magnetic field. The geomagnetic polarity time scale of Harland *et al.* (1982) was used in this article.

## Samples and measurements

Piston cores were obtained at closely-spaced 20 sites in the GH82–4 Area (Table VII–1). Water depth of these sites ranges from 5200 to 5800 m. The cores were composed mainly of siliceous clay or siliceous ooze because the study area is within the organic high-productivity province along the equator and the water depth is below the Carbonate Compensation Depth which is about 5000 m here at present (Berger and Winterer, 1974). Several cores were intercalated by a few calcareous turbidite layers. The thickness of the layers is in the order of 10 cm. Description of core lithology is

Keywords: magnetostratigraphy, hiatus, non-dipole, deep-sea sediment, Central Pacific Basin, Hakurei-Maru, Nova-Canton Trough

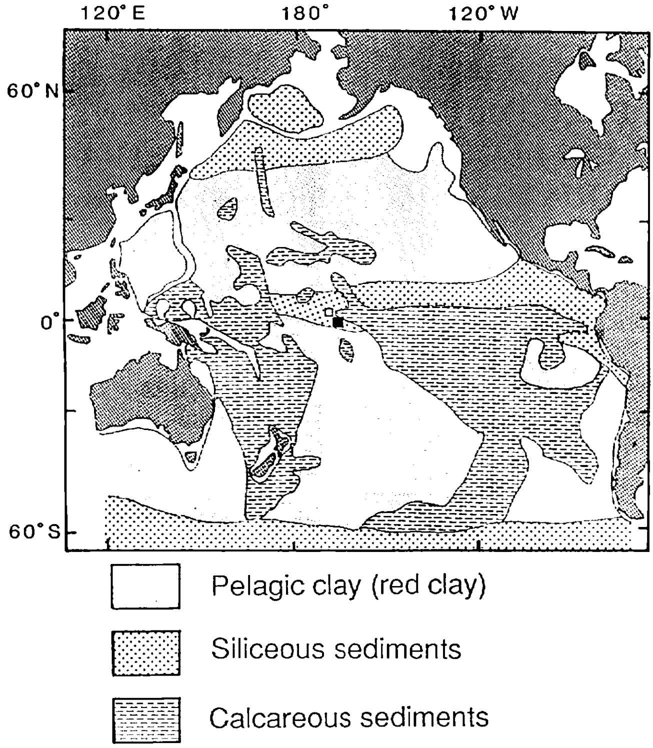
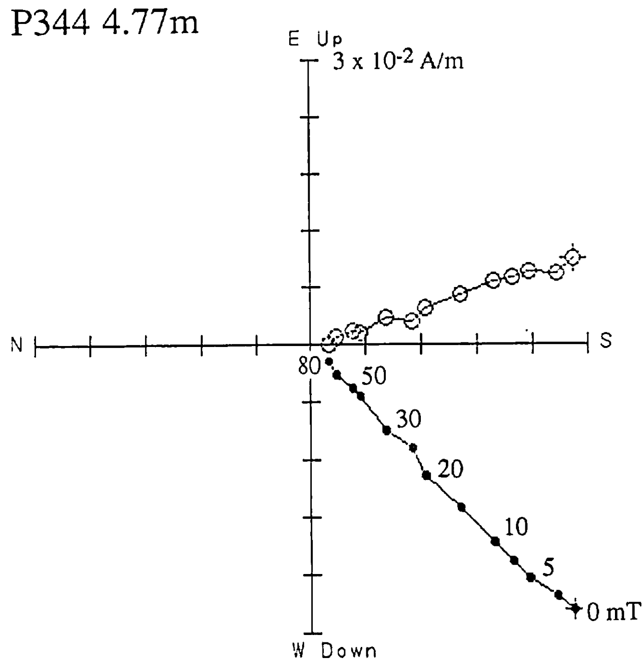



Fig. VII-1 Distribution of deep-sea sediments in the Pacific after Davies and Gorsline (1976). A solid square indicates the location of the study area. An open square is the GH81-4 area.

given in Nishimura and Ikehara (chapter VI, this volume).

Cores were split into halves on board soon after the recovery, and samples for paleomagnetic measurements were taken continuously with plastic cubic cases of about 7 $cm^3$ each. The samples were sealed up carefully to avoid dehydration. Measurements of the remanent magnetization were done after the cruise in 1982 using an SCT's three-axis cryogenic magnetometer. Every third subsample was measured at about 7 cm intervals in general. However, subsamples which lie close to a polarity boundary or in weakly magnetized parts were measured continuously.

Several pilot samples were chosen from each core, and stepwise alternating-field (AF) demagnetization experiments were carried out to investigate the stability of the remanent magnetization. A three axis tumbler system was used for the AF demagnetization experiment. It is revealed that most samples have been little affected by secondary magnetizations. The progressive change of the vector endpoints shows a nearly linear trend (Fig. VII-2). A soft secondary component of probably viscous origin could be removed by the AF of 5 mT or less. Based on the results of the progressive AF demagnetization experiments, the peak field of the routine AF demagnetization was chosen between 2.5 and 12.5 mT, and the rest of the samples were demagnetized by that field.



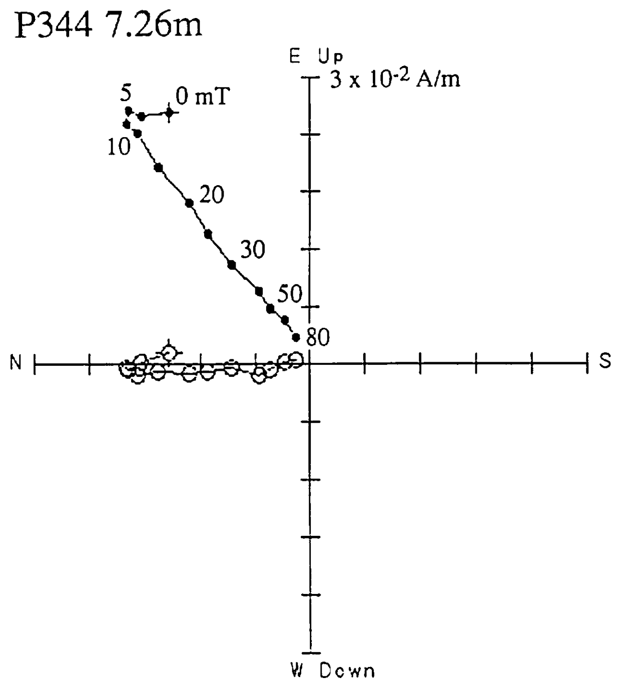




Fig. VII-2 Orthogonal plots of progressive alternating-field demagnetization data. Solid and open circles represent projections of vector endpoints on the horizontal and vertical plane, respectively. Horizontal components are relative.

The direction and intensity of the remanent magnetization of each core after the AF demagnetization and interpretation of the polarity are shown in Figure VII-3. Because the cores were not oriented horizontally, the declination is relative. Although sampling sites are close to the equator, the polarity of the remanent magnetization could be recognized from inclinations. The inclination expected for these sites (less than 2° in latitude) from the hypothetical geocentric axial dipole field is shallower than ± 4°. However, observed inclinations were usually several degrees deeper than the prediction (Fig. VII-3). This result is further discussed later.

**Magnetostratigraphy**

*Cores with continuous sedimentation*

Cores P337, P340, P342, P343, P344, P352, P354 and P355 show the polarity reversal sequences which can be correlated with that of the standard from the Brunhes to Matuyama chron, and have no clear hiatus. The age of Core P355 goes back to the latest Gilbert chron (about 3.5 Ma). The bottom of Core P342 may also be in the Gilbert chron, but there is a possibility of sedimentary hiatus between 6.2 and 6.8 m in depth, at which the core shows rather gradual lithological change from siliceous clay to siliceous ooze downward and a decrease in the remanent intensity. The *Mesocena quandrangula* Zone (ca. 1.3 to 0.79 Ma, Berggren *et al.*, 1980) recognized by Nishimura and Ikehara (chapter VI, this volume) was useful for the identification of the Jaramillo subchron (Chron 1r-1, 0.92 to 0.97 Ma). Intensity drops within the Brunhes chron (at 3.6 m of Core P340, at 4.7 m and 5.7 m of Core P343, at 3 m and 4.6 m of Core P344) correspond to calcareous turbidite layers.

These cores have fairly uniform sedimentation rate throughout the Quaternary (Fig. VII-4). The rate ranges from 2 to 9 m/m.y. It seems that the sedimentation rates of Cores P342 and P355 have decreased in the Brunhes chron, and there is a possibility of sedimentary hiatus within the Brunhes chron. But the decrease may be caused by disturbance of the cores during operation, as several tens centimeters of surface sediments are sometimes lost. The mean sedimentation rate during the Quaternary in the GH82-4 area is a little higher than that in the GH81-4 area, 3 to 6 m/m.y. (Yamazaki, 1986). The increase in sedimentation rate around the Jaramillo subchron found in the GH81-4 area does not occur in this area.

*Cores with hiatuses*

Cores P336, P338, P339, P341, P345, P346, P347, P348, P349, P350, P351 and P353 include hiatuses of various durations. Most of these cores were capped by Quaternary sediments of several tens of centimeters to several meters in thickness. The hiatuses usually correspond to horizons of a sharp lithological change from siliceous clay to siliceous ooze downward, which accompanies a drop of the remanent intensity.

The sediments just above the hiatuses of Cores P338 (at 0.5 m in depth), P339 (1.1 m), P350 (4.5 m) and P351 (0.6 m) are younger than the age of the Brunhes/Matuyama boundary, 0.73 Ma. Those of Cores P341 (2.7 m), P345 (2.9 m?), P346 (3.6 m), P347 (2.75 m) and P349 (2.75 m) are between the Brunhes/Matuyama boundary and the Jaramillo subchron (0.73 to 0.92 Ma), and that of Core P353 (4.7 m) is between the Olduvai subchron and the Gauss chron. A hiatus of Core P345 at

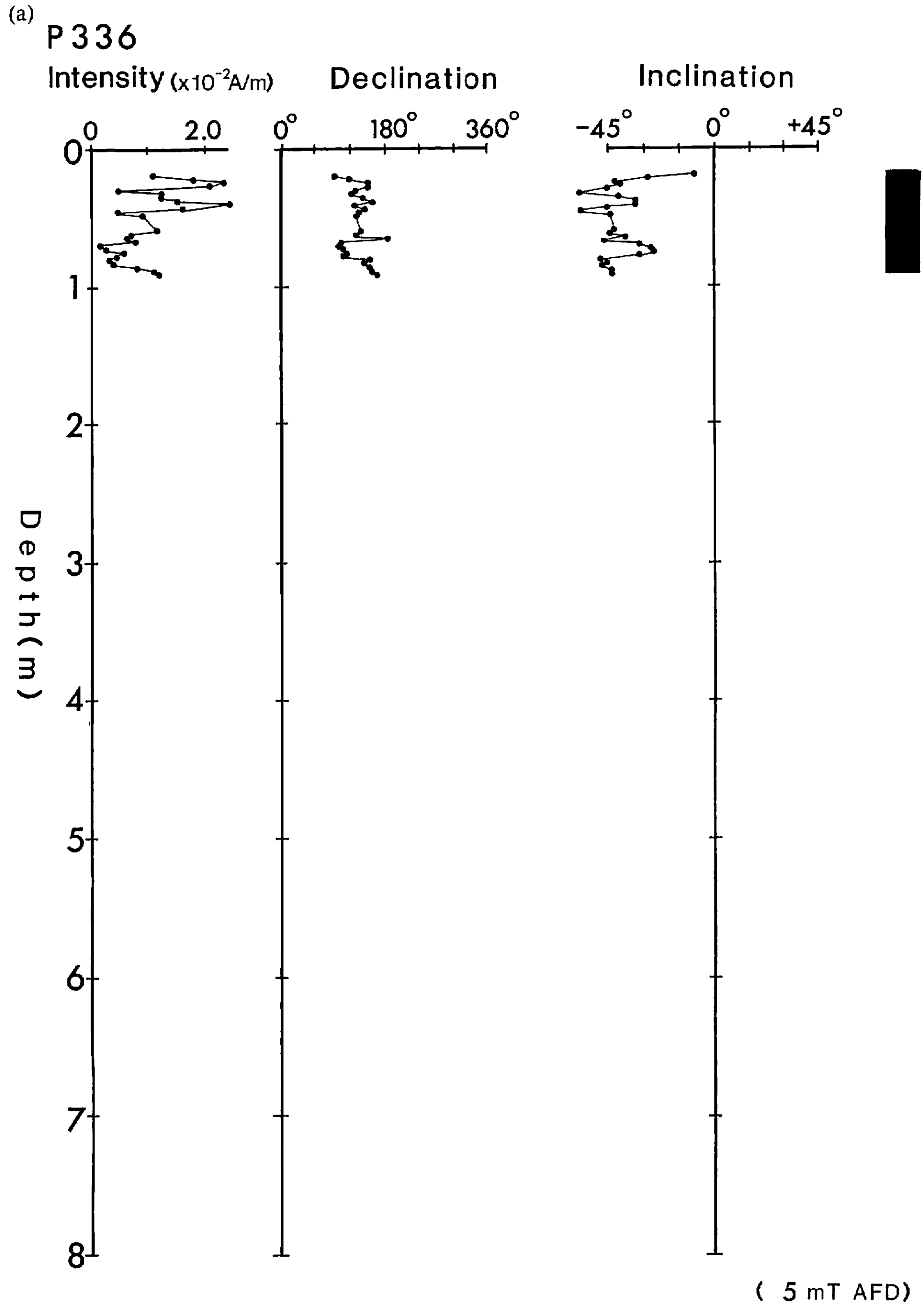



Fig. VII-3(a) to (t) Remanent magnetization of each core after partial alternating-field demagnetization. Declination is relative. Interpretation of magnetic polarity is shown on right column (solid represents normal, open reverse, dotted undetermined).

(b)

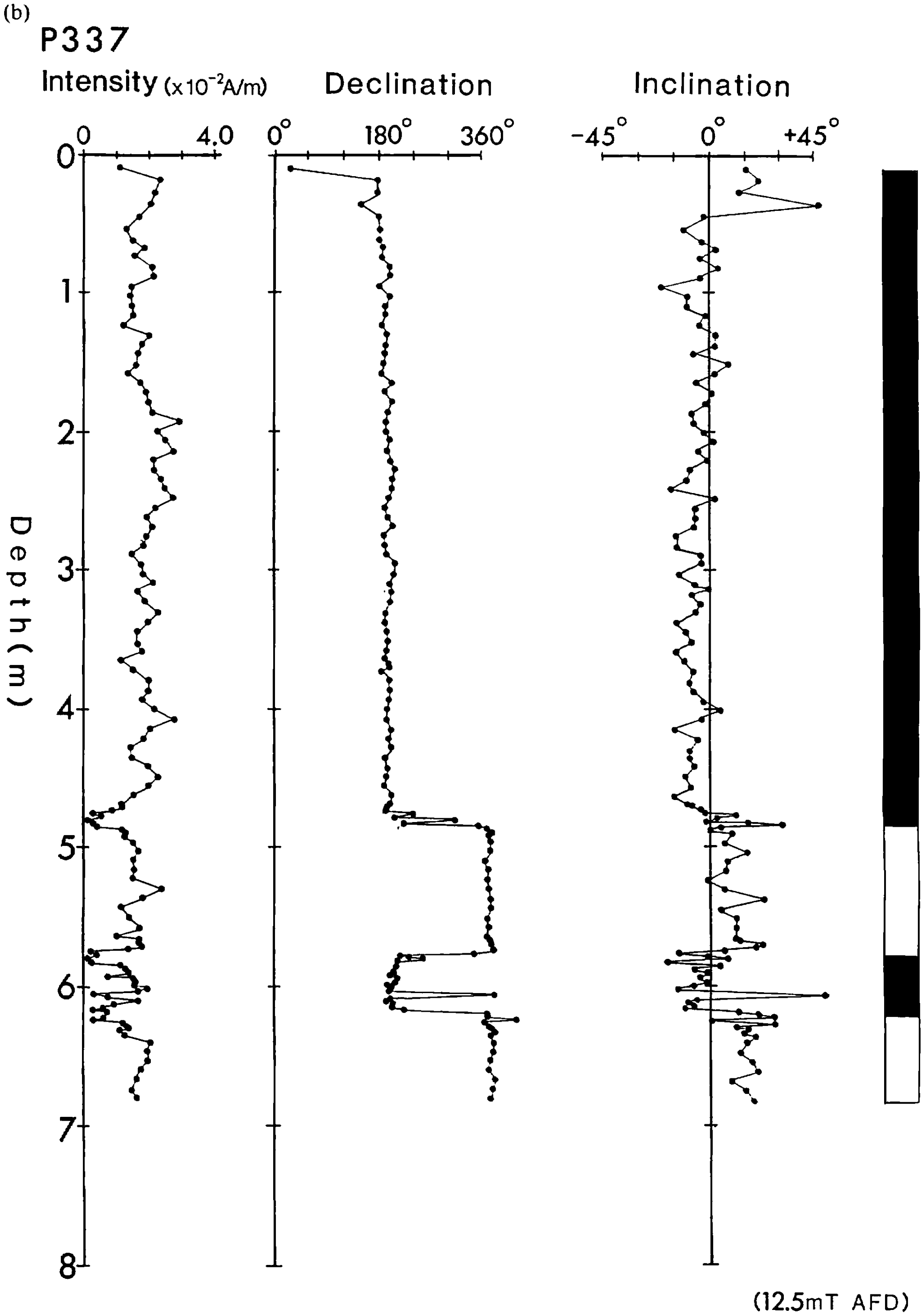



Fig. VII-3 (continued)

(c)

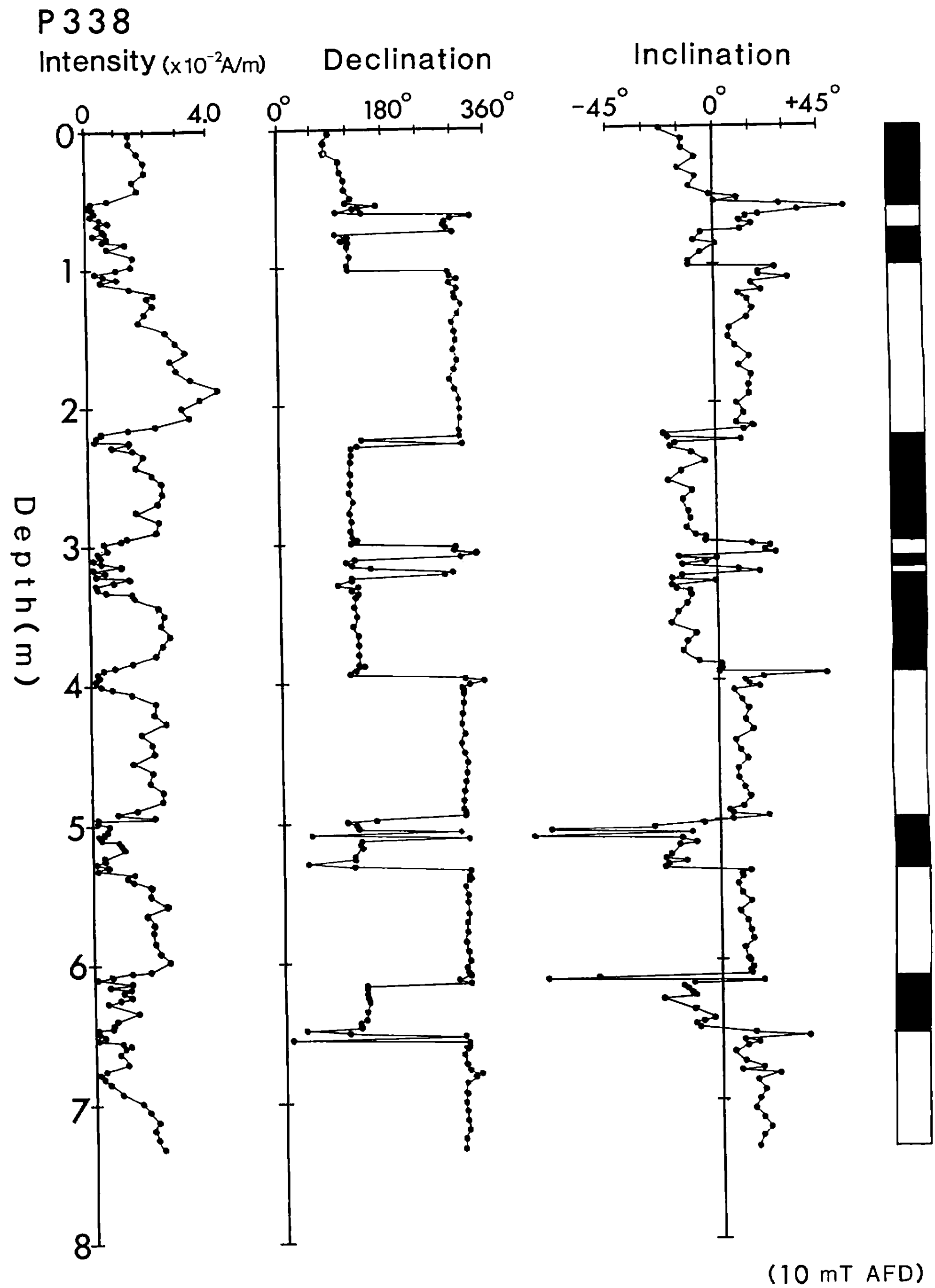



Fig. VII-3 (continued)

(d)

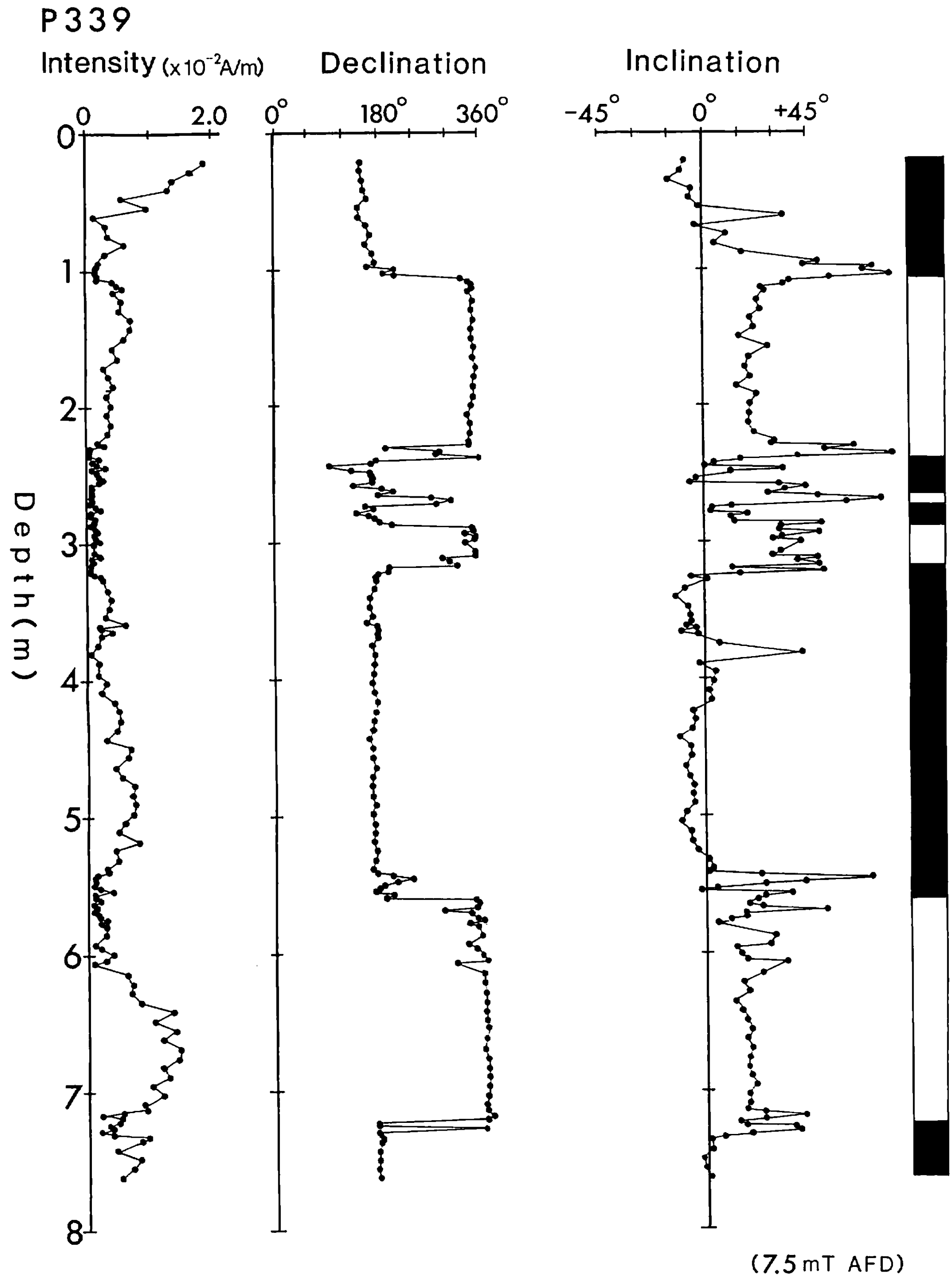



Fig. VII-3 (continued)

(e)

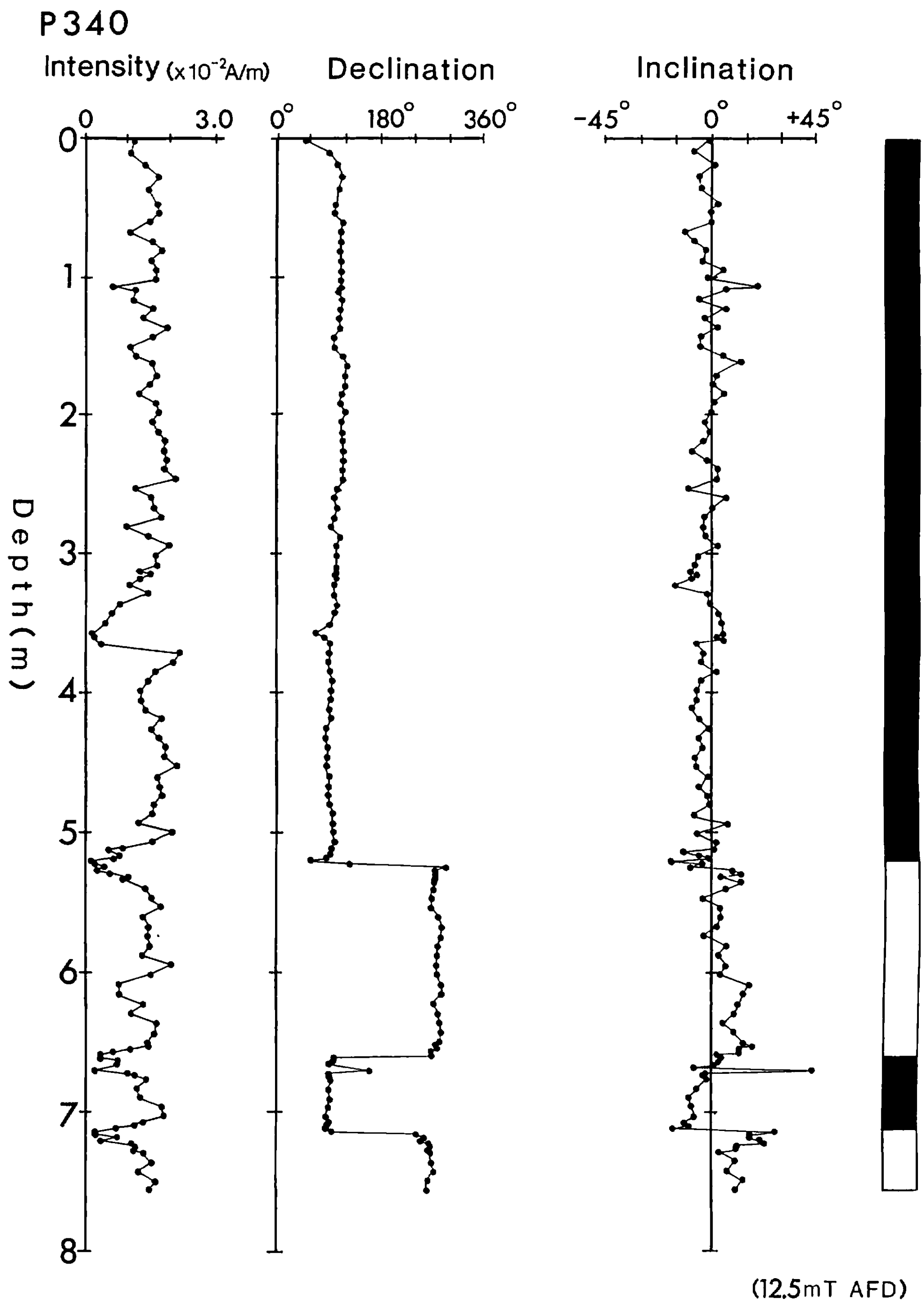



Fig. VII-3 (continued)

(f)

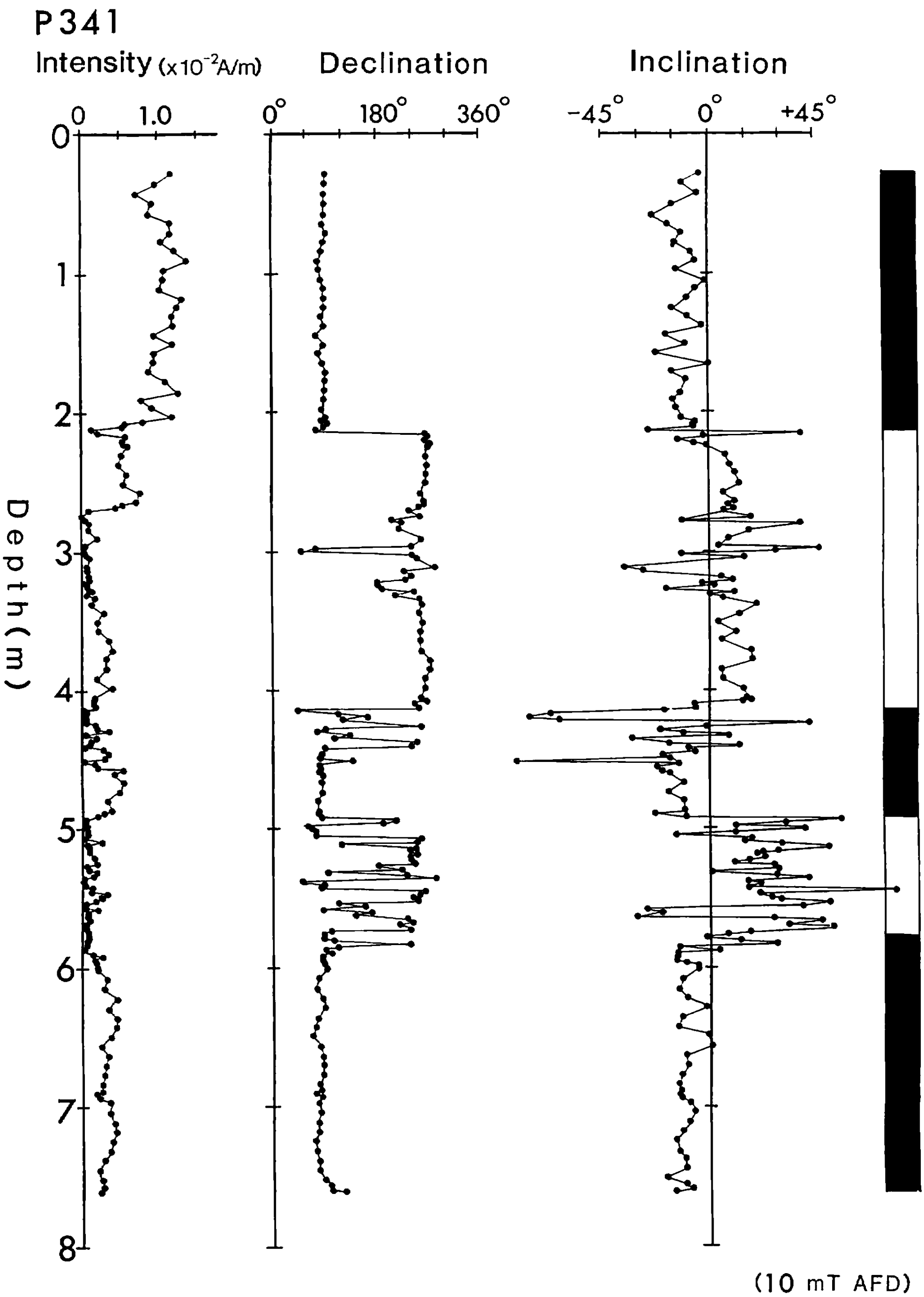



Fig. VII-3 (continued)

(g)

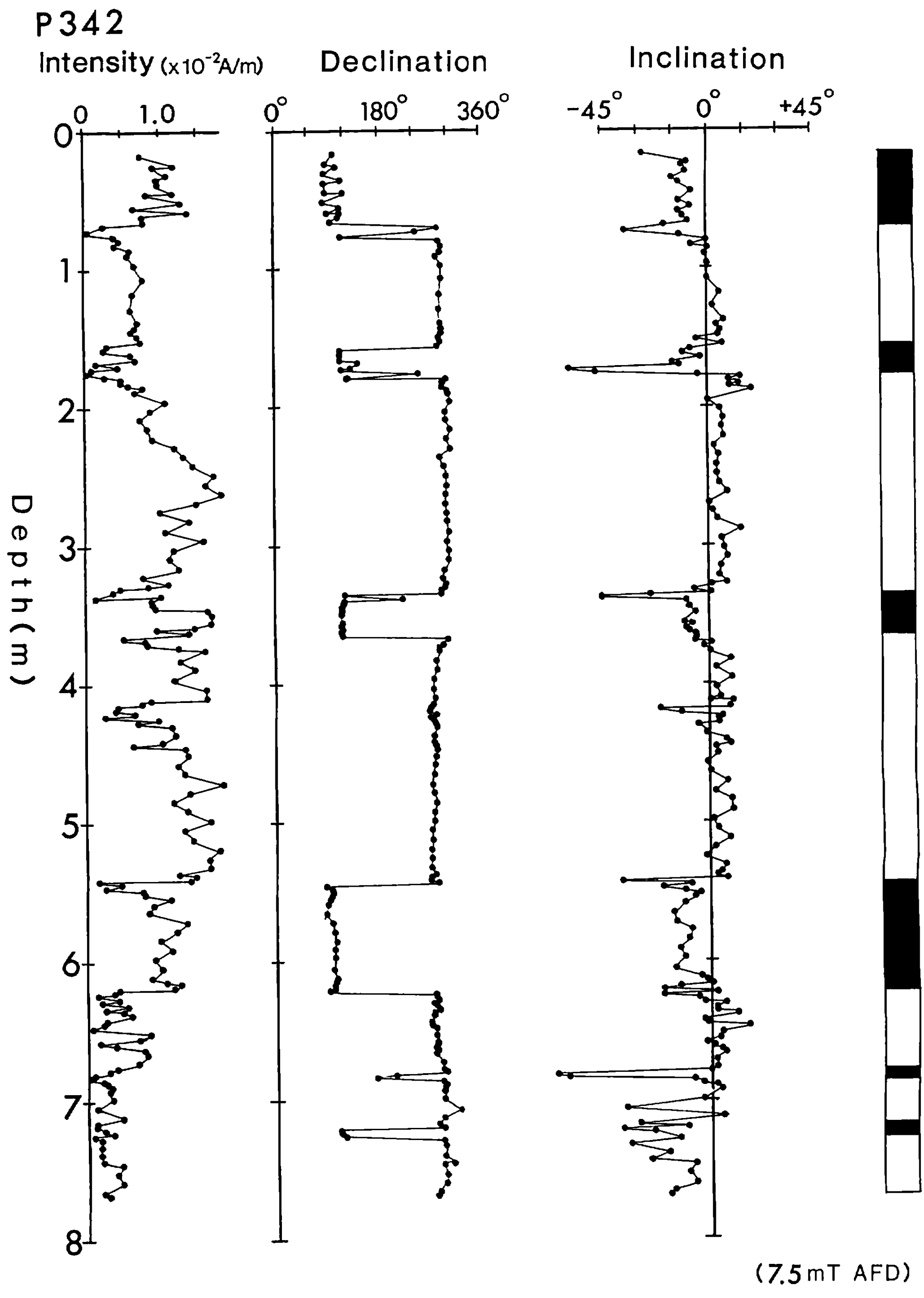



Fig. VII-3 (continued)

(h)

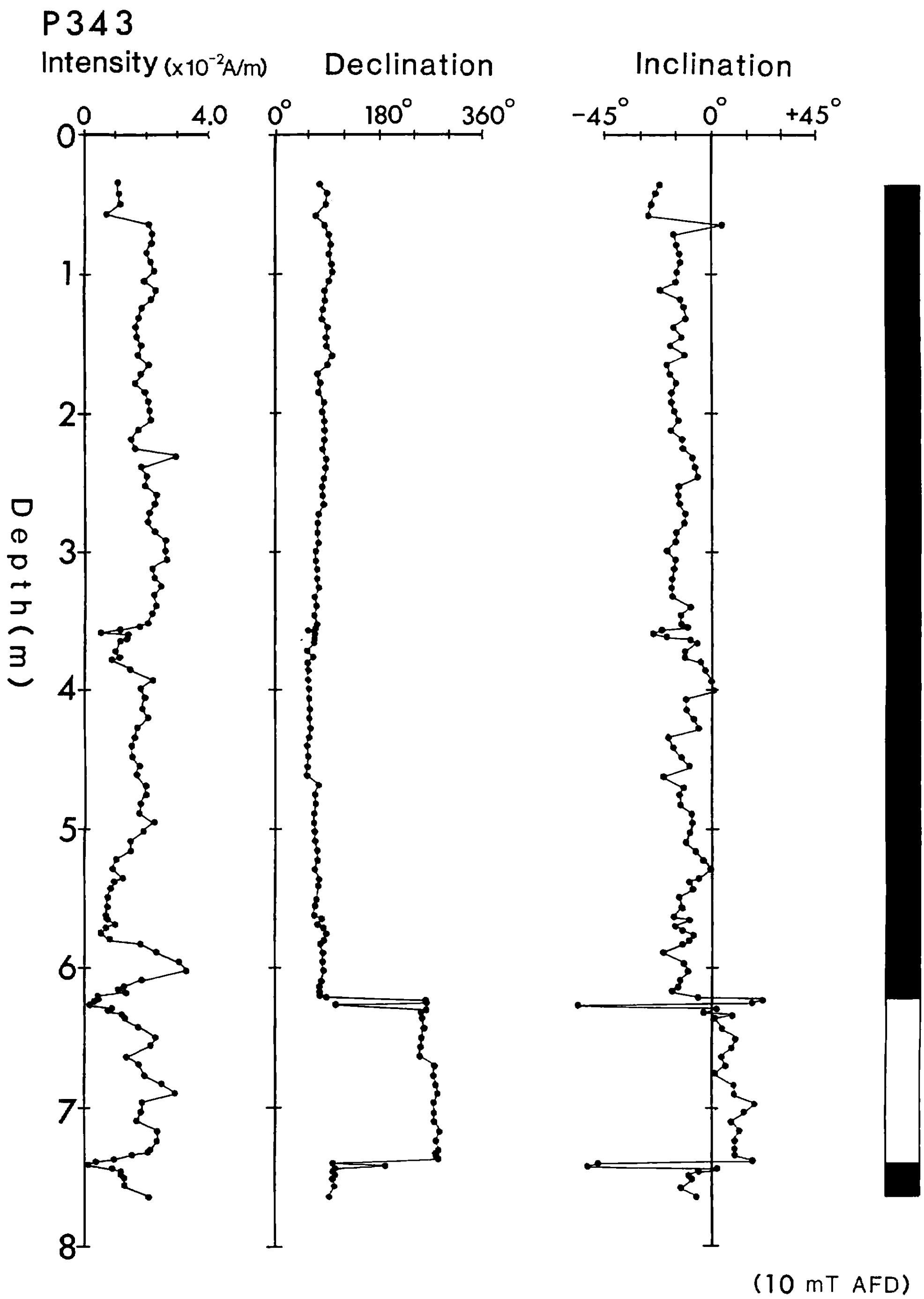



Fig. VII-3 (continued)

(i)

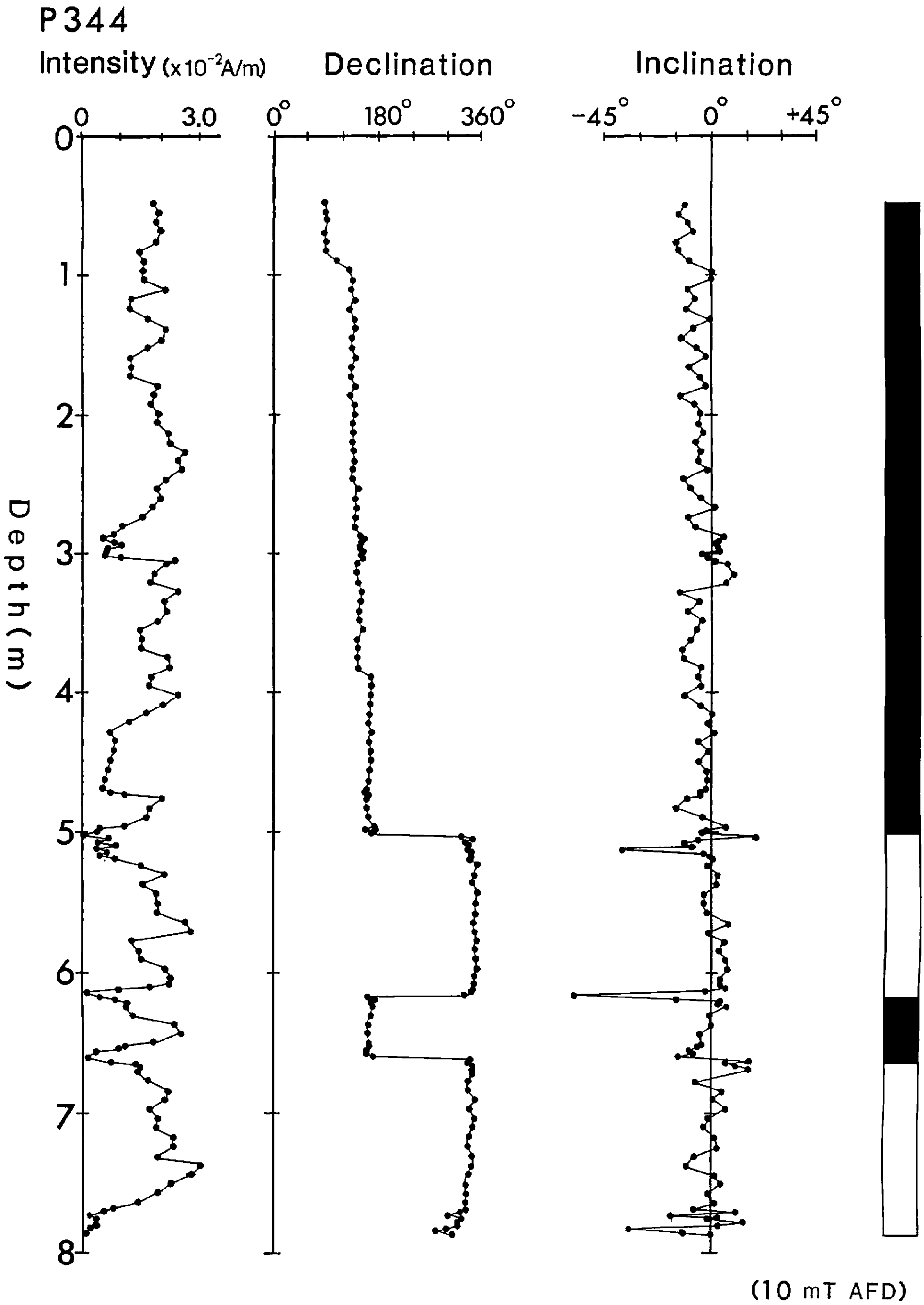
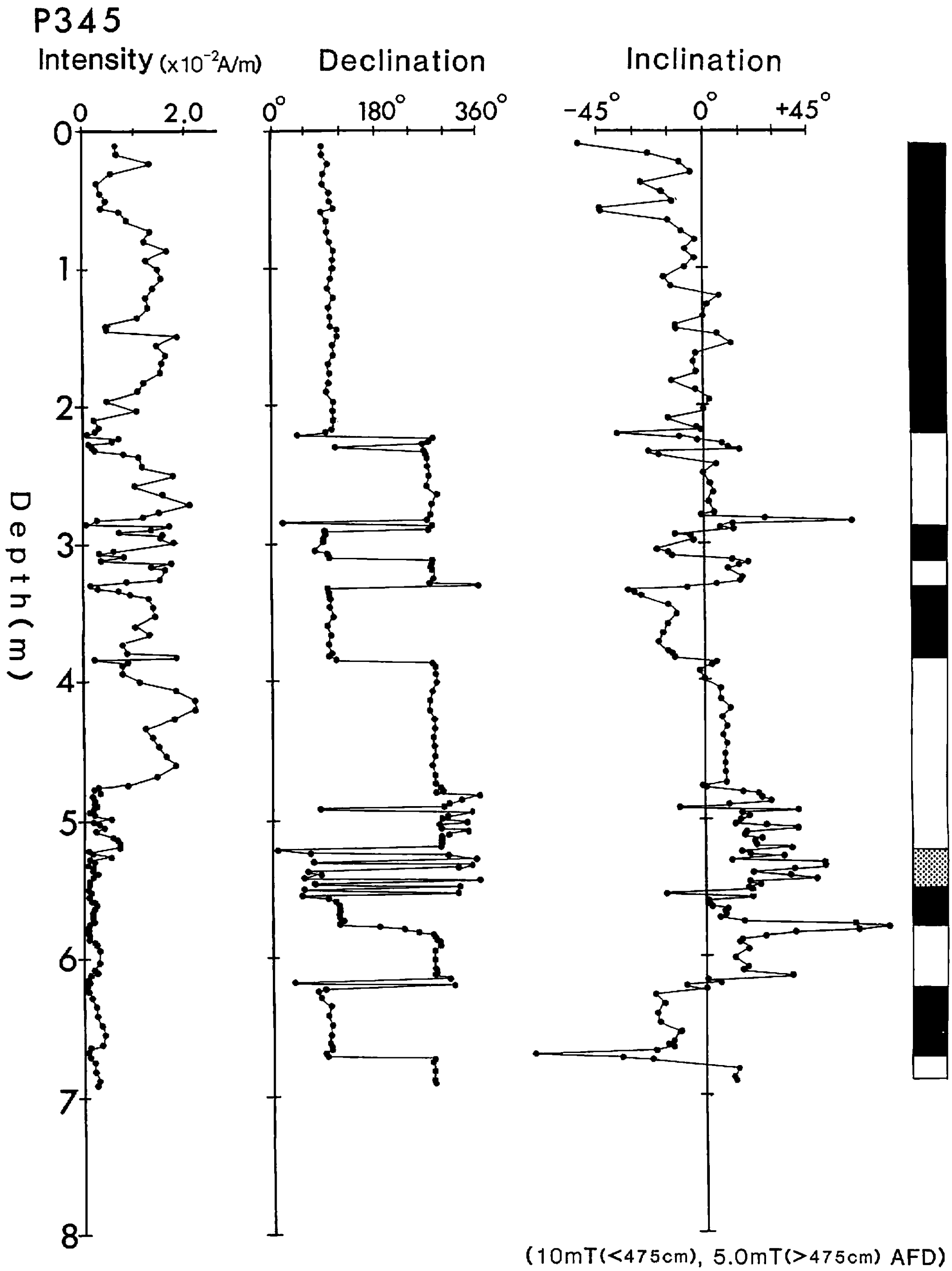



Fig. VII-3 (continued)

(j)

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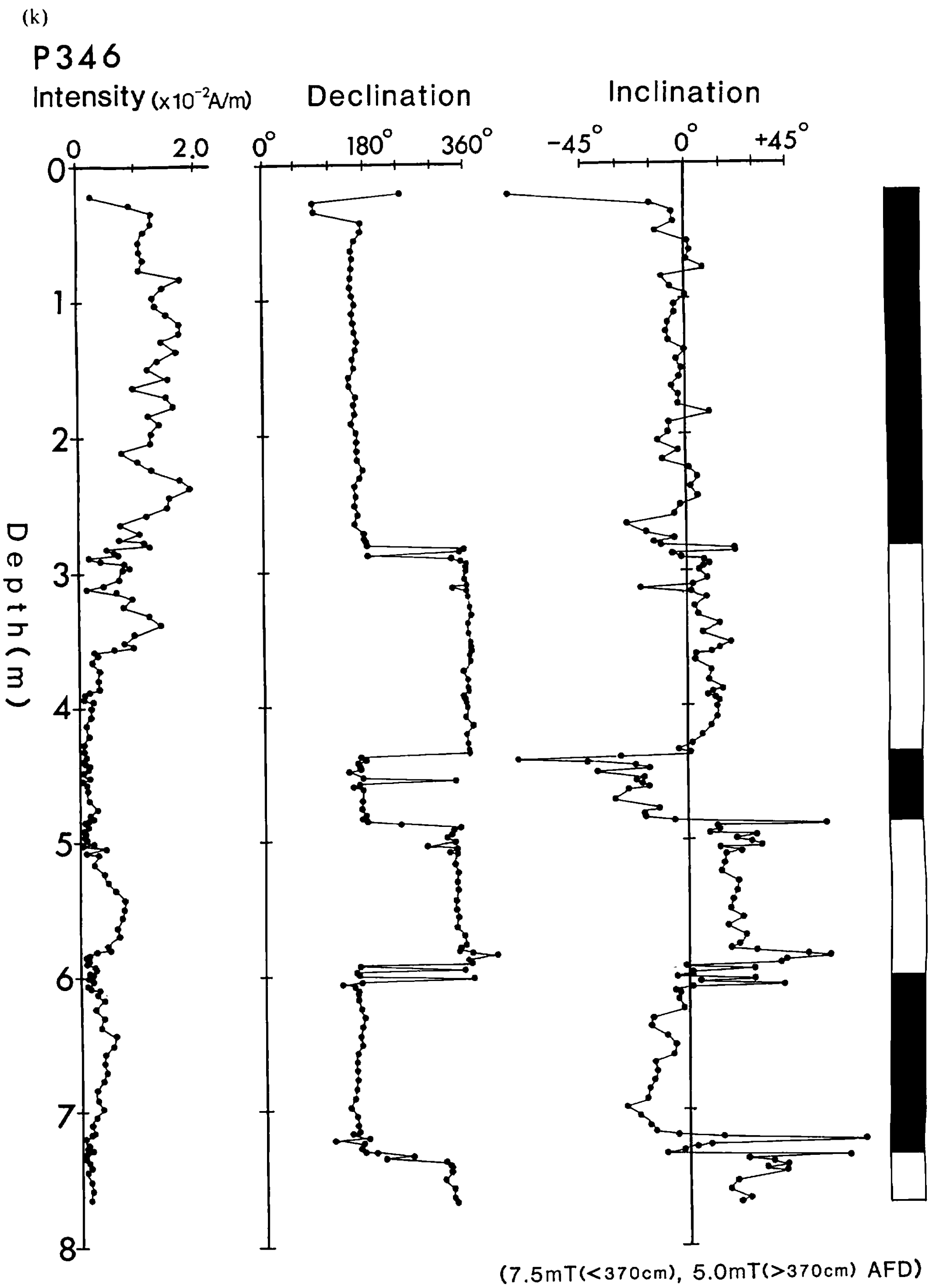
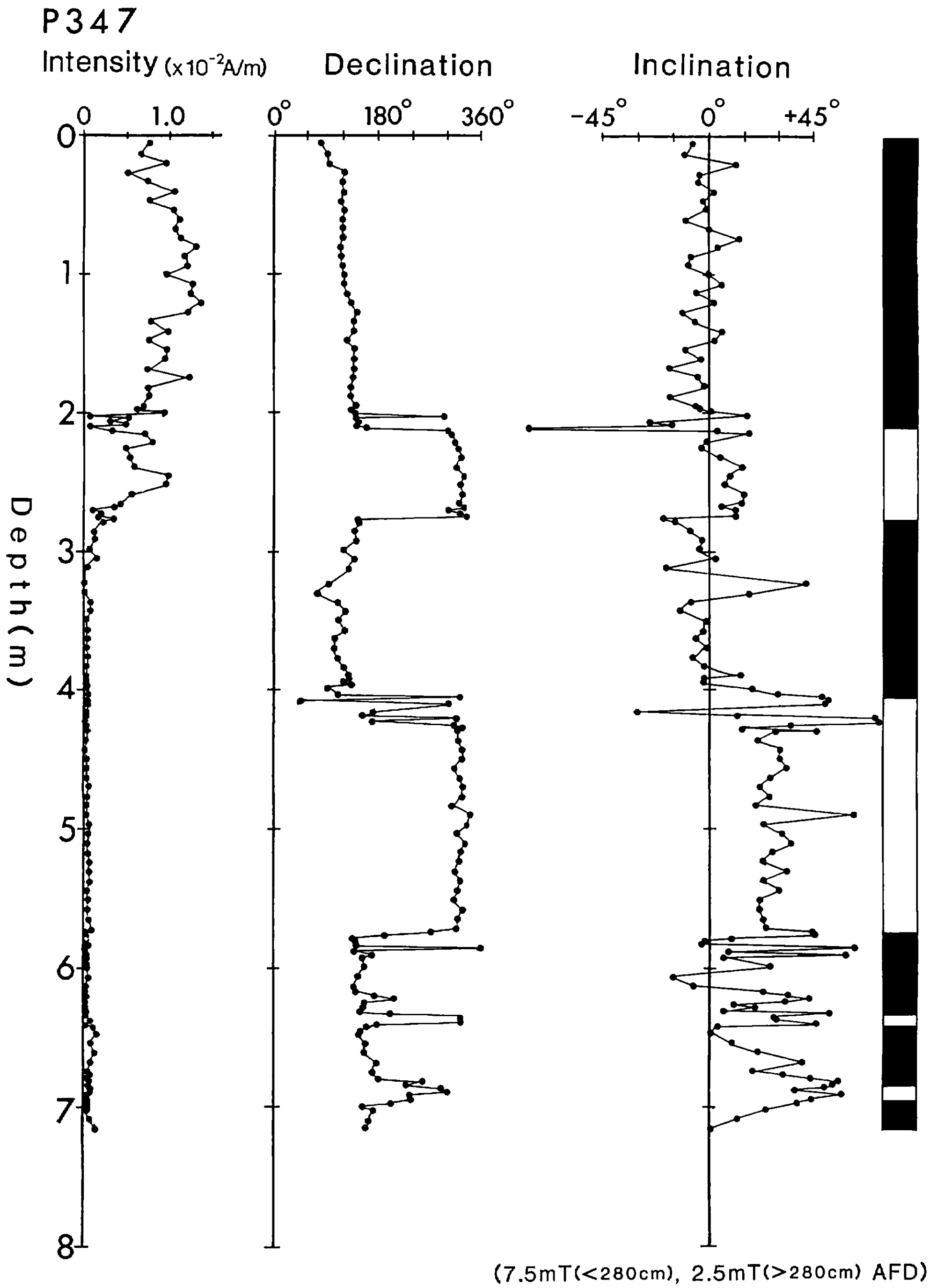



Fig. VII-3 (continued)

(l)

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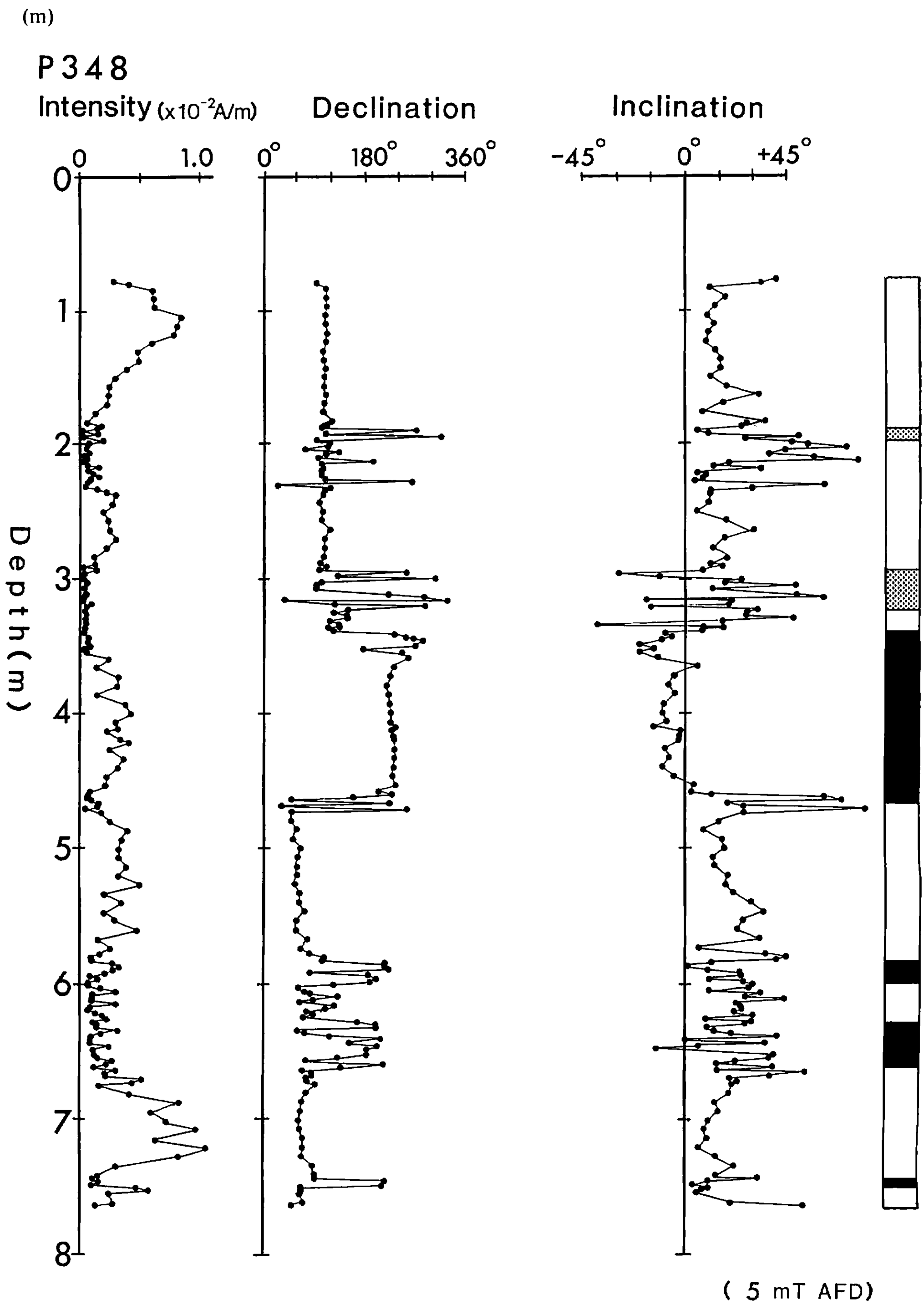



Fig. VII-3 (continued)

(n)

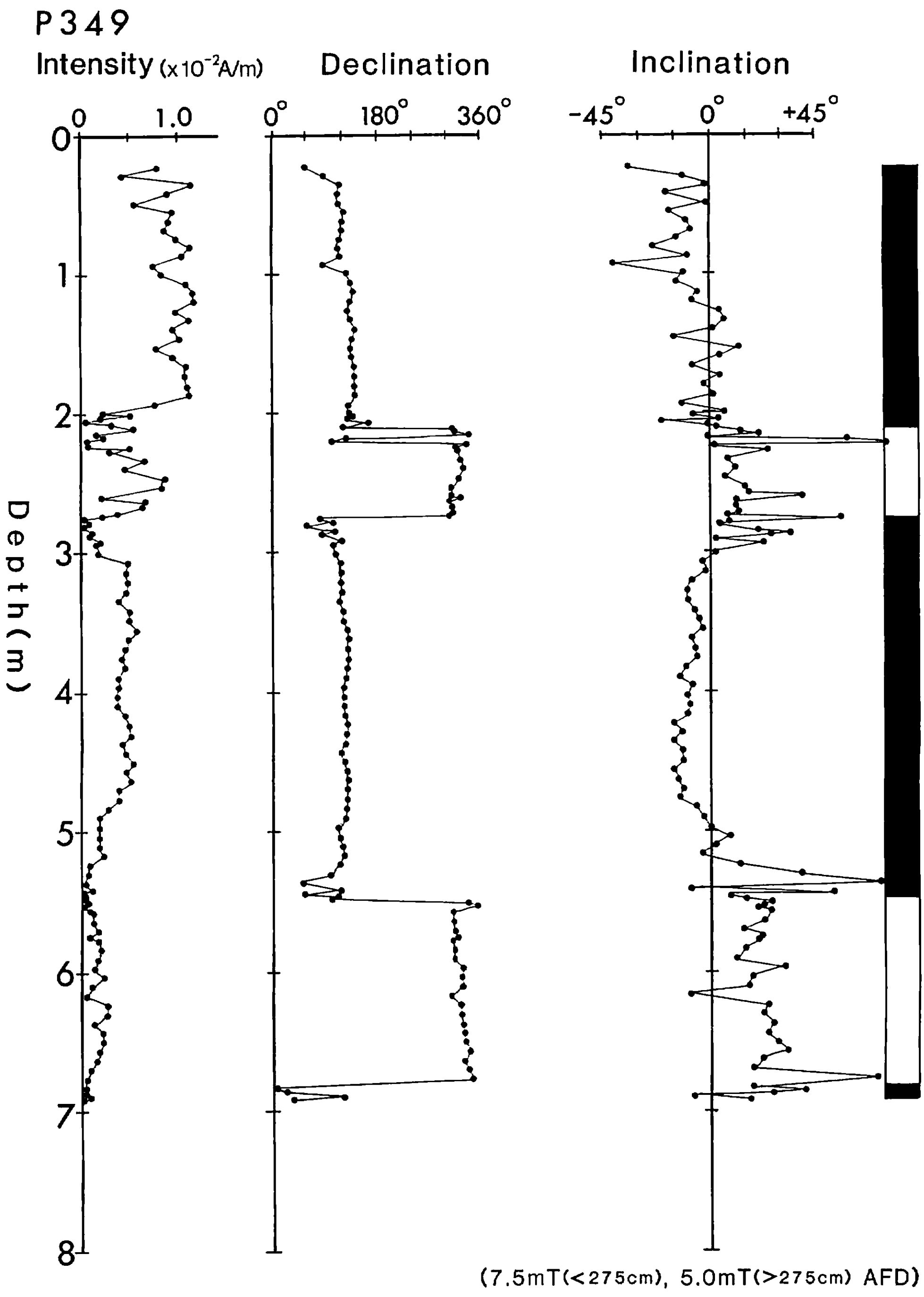
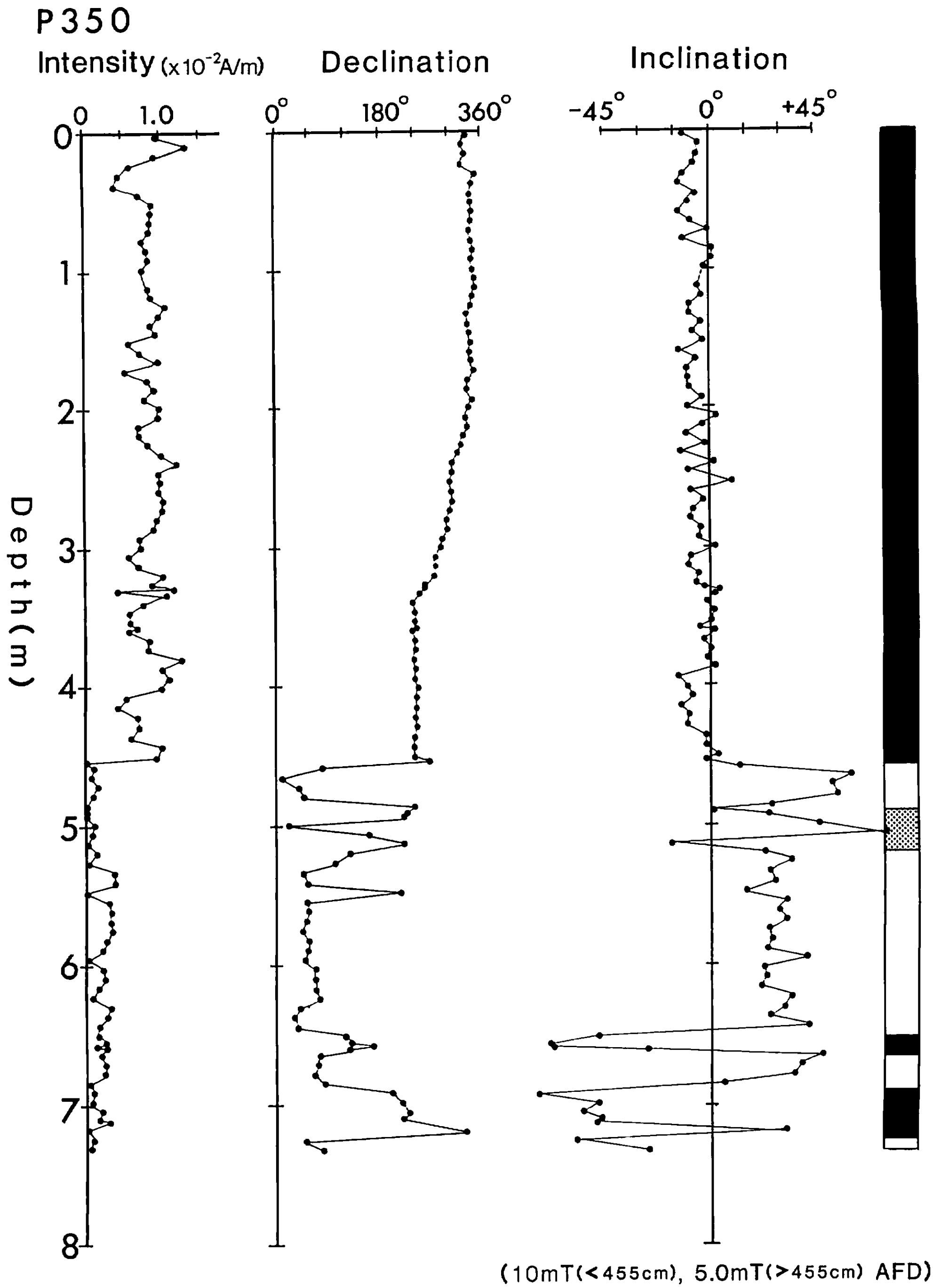



Fig. VII-3 (continued)

(o)

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(p)

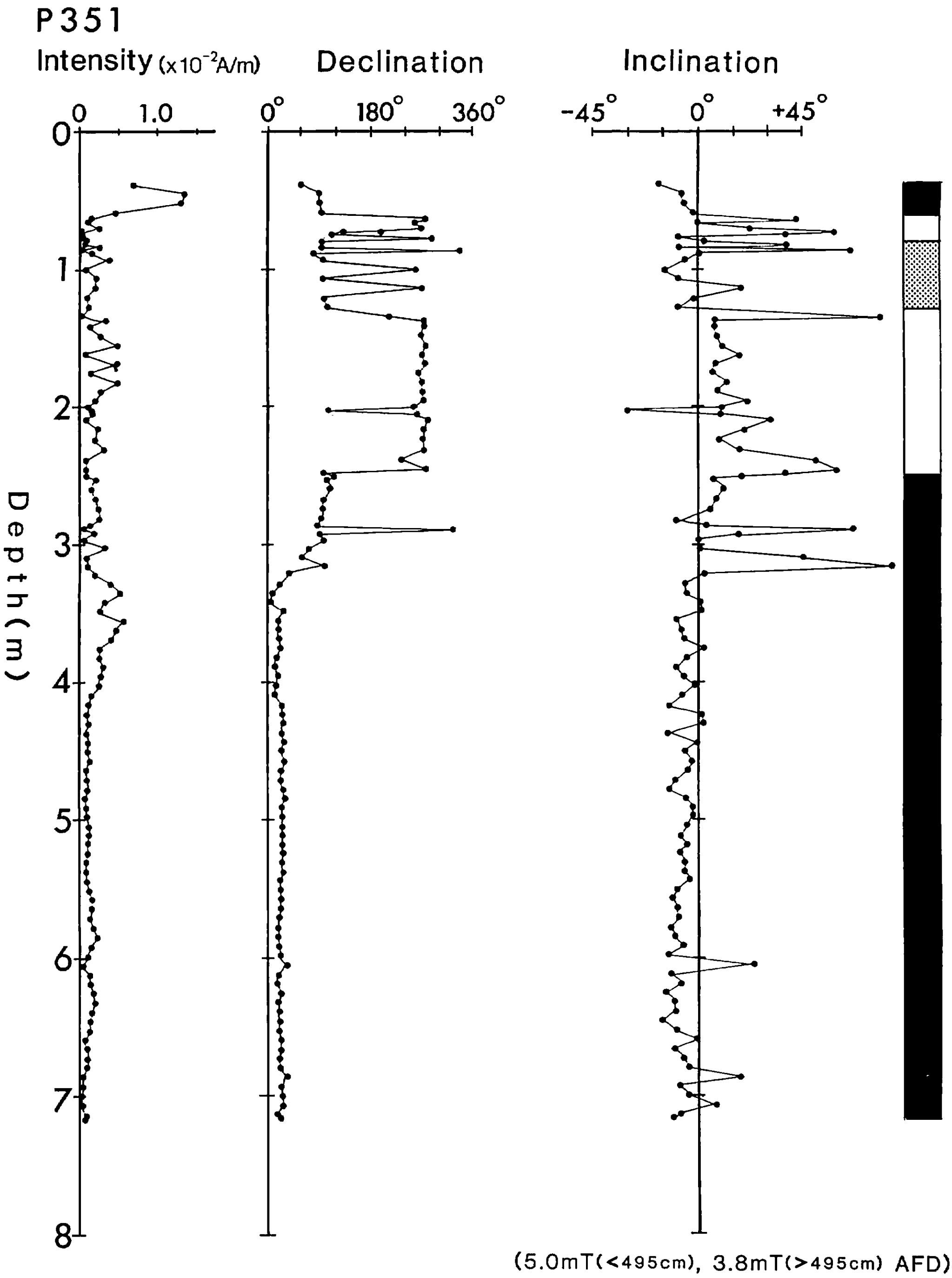


Fig. VII-3 (continued)

(q)

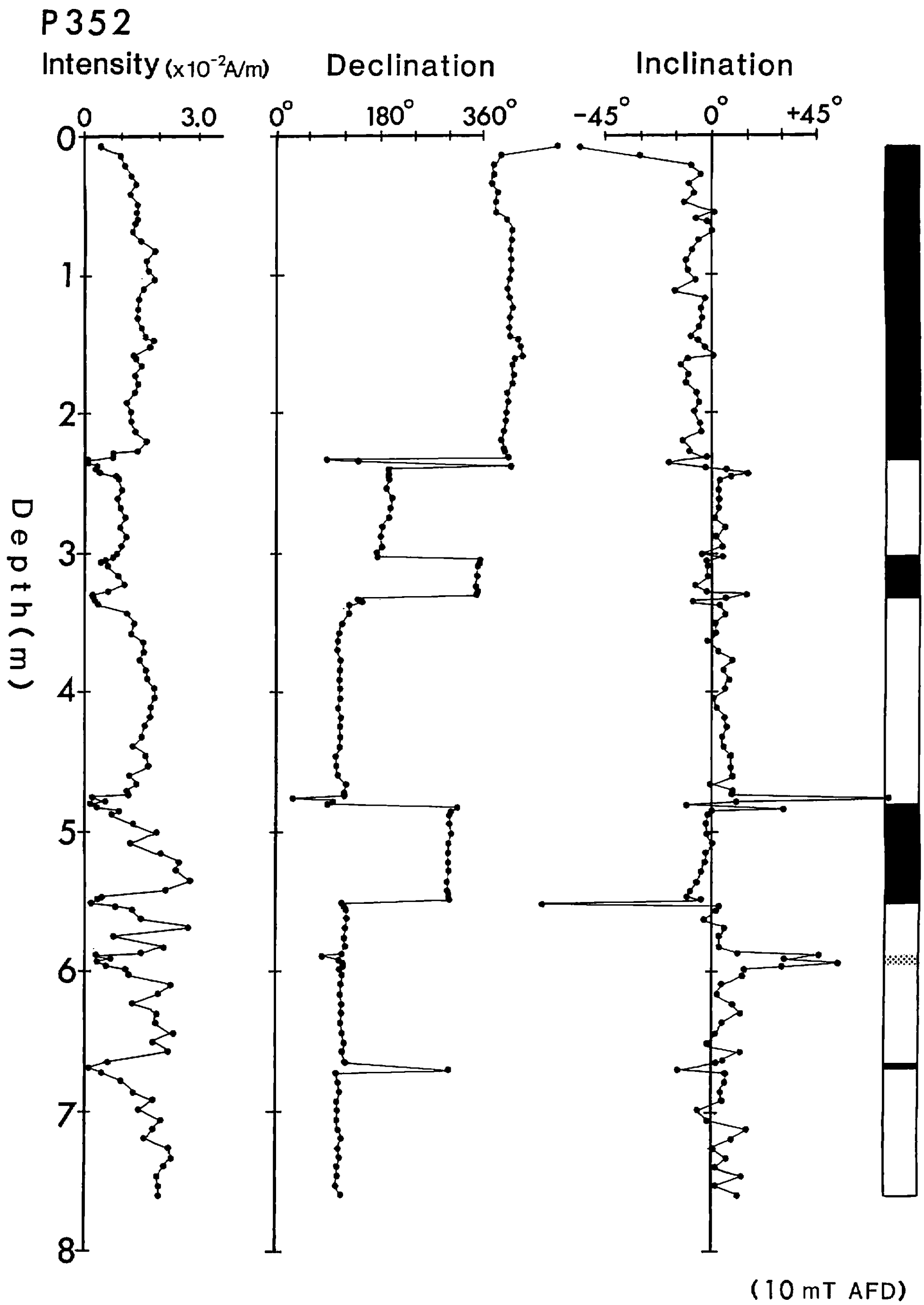


Fig. VII-3 (continued)

(r)

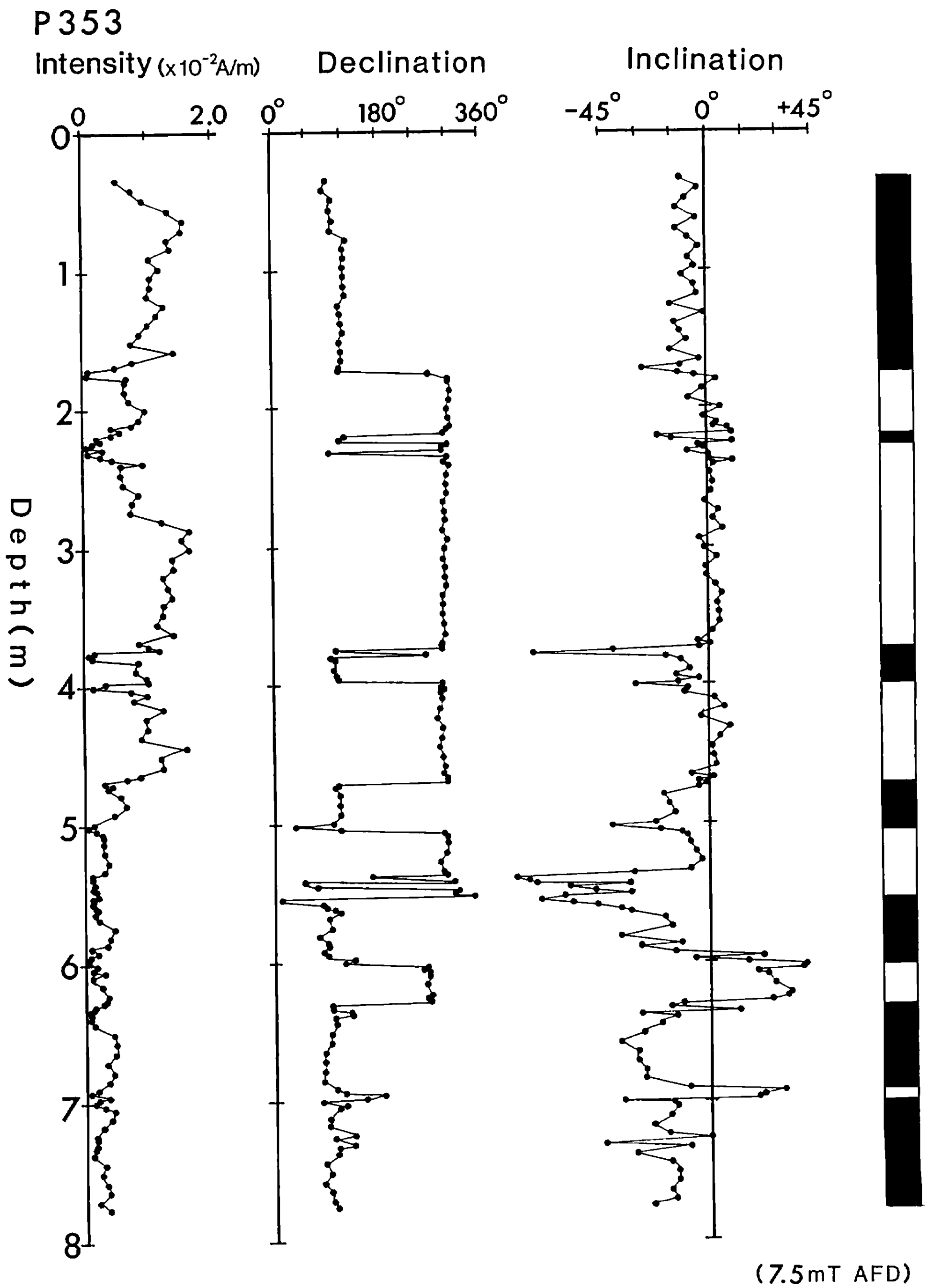


Fig. VII-3 (continued)

(s)

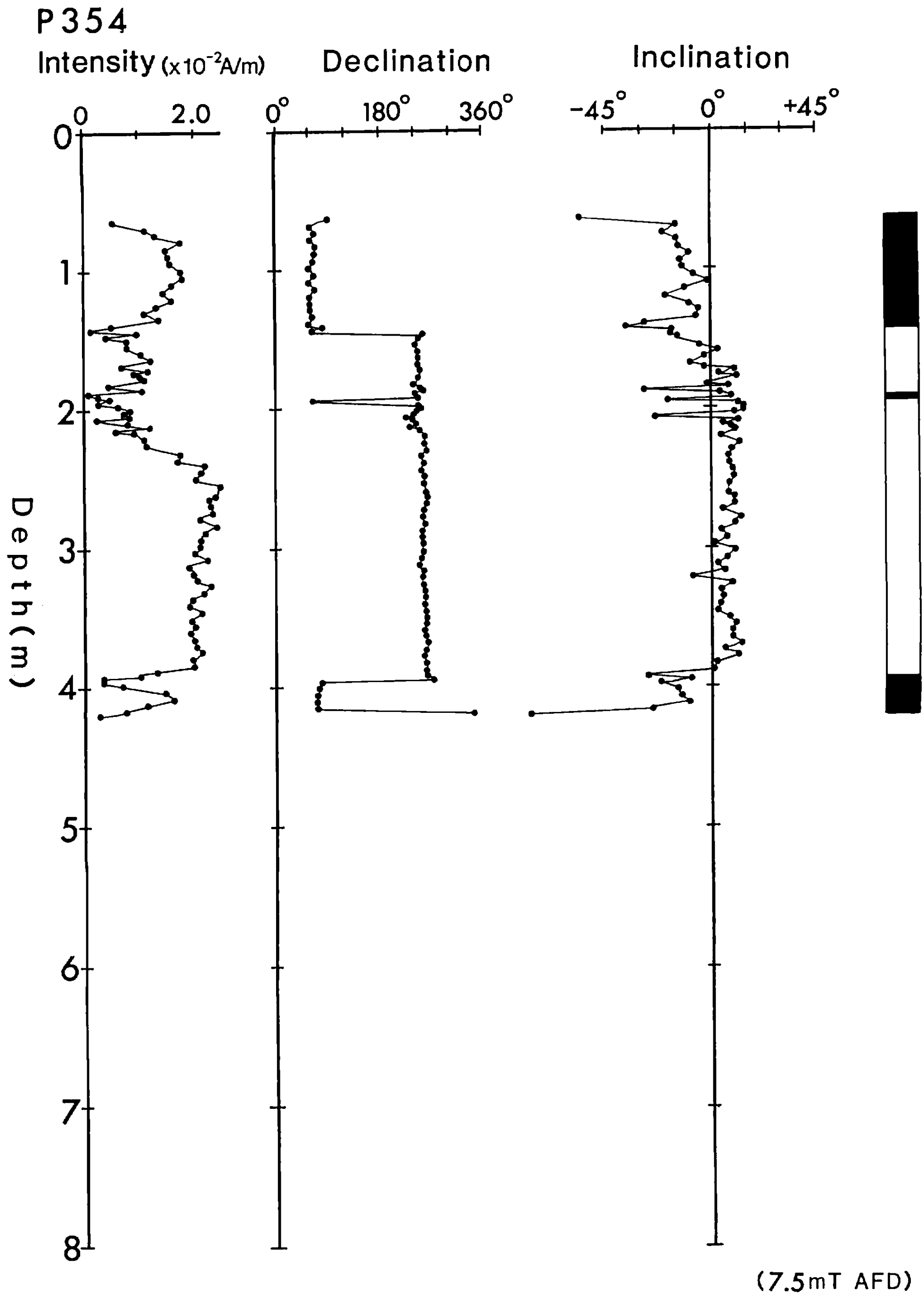


Fig. VII-3 (continued)

(t)

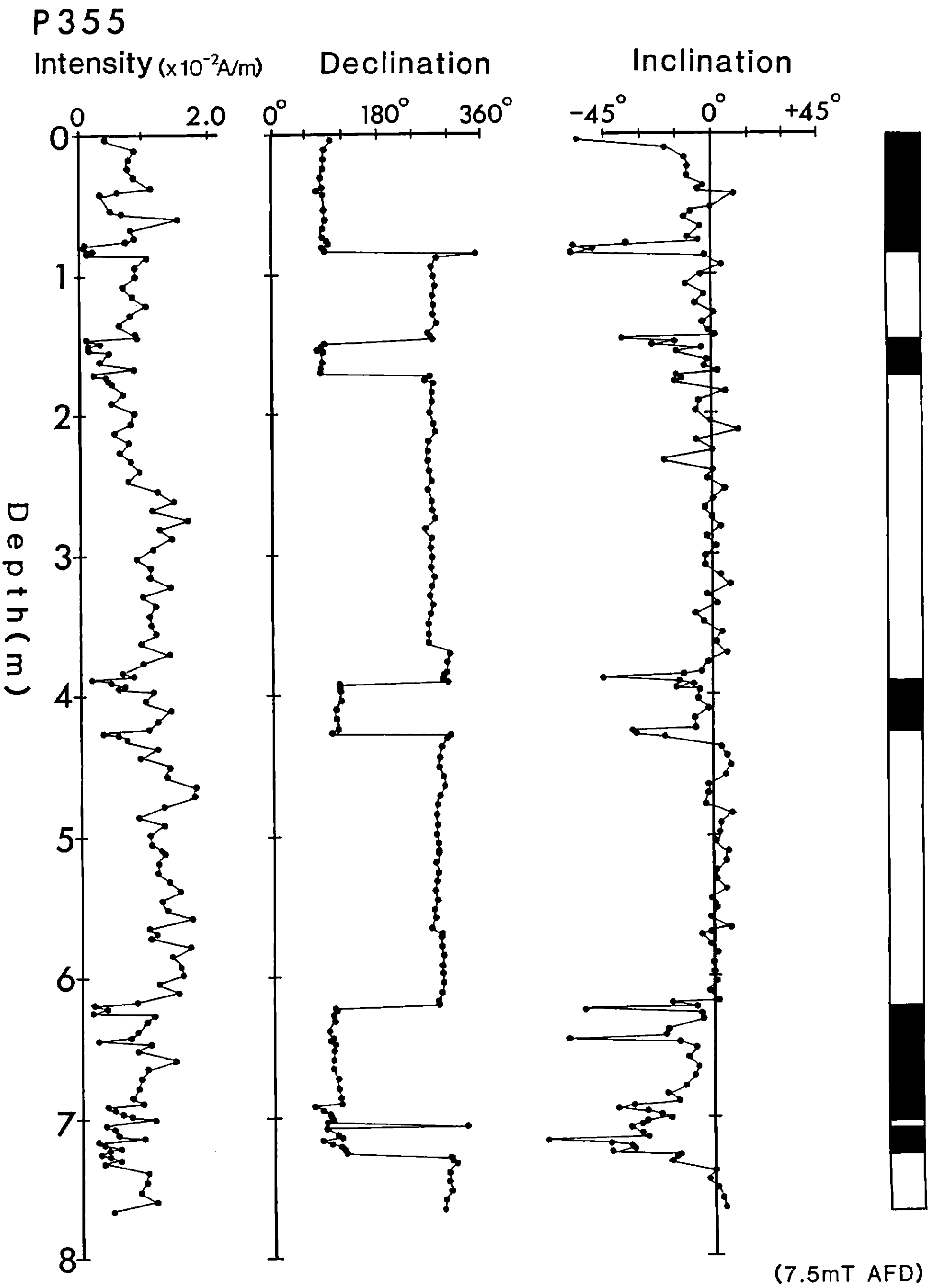


Fig. VII-3 (continued)

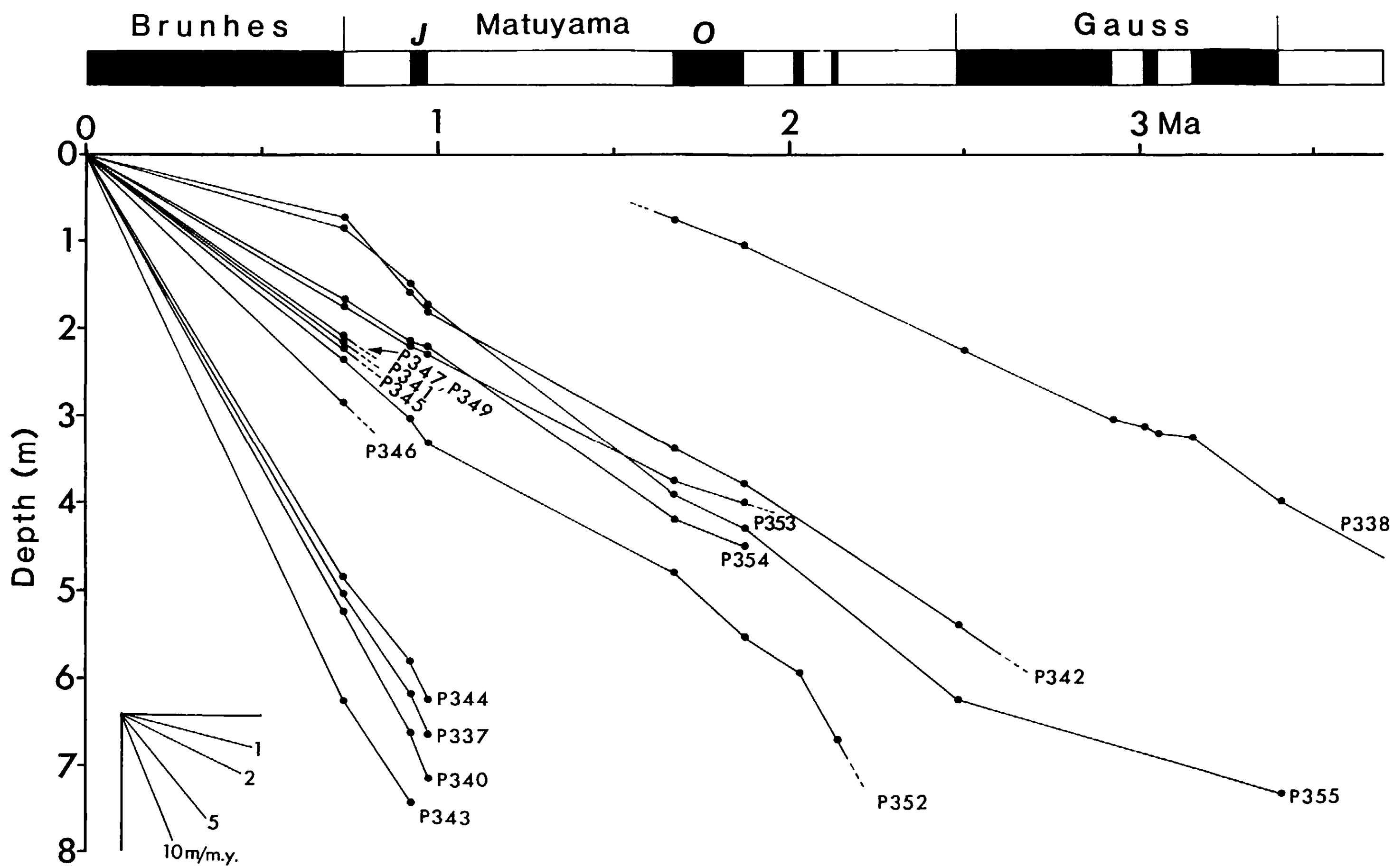


Fig. VII-4 Core depth versus paleomagnetically estimated age. J: Jaramillo subchron, O: Olduvai subchron.

2.9 m is estimated from a break of the correlation to the standard reversal time scale, but the horizon is not clear because there is no lithological change. This core has another clearer hiatus at 4.8 m, which accompanies an apparent lithological change. Cores P336 and P348 have no, or very thin if any, Quaternary sediments. Core P336 has the magnetization of the normal polarity. It would not, however, correspond to the Brunhes chron judging from its unique lithology of semi-consolidated clay and deep inclination of about −45°, that is, a paleolatitude of about 30°S.

The polarity reversal sequence below the hiatus of Core P338 can be correlated to that of the standard from the Olduvai subchron to Chron 3.2r in the Gilbert chron (1.6 to 4.4 Ma). Except for Core P338, however, it is difficult to determine the age of sediments below the hiatuses from the polarity reversal patterns. The pattern of Core P345 below 5.8 m resembles to Chron 5C (16.20 to 16.98 Ma). The long normal-polarity interval of Core P351 might correspond to Chron 6 (19.41 to 20.50 Ma).

The fact that the ages of the oldest sediments above the hiatuses of most cores distribute around the Brunhes/Matuyama boundary suggests that the early Pleistocene is a period of hiatus formation in the GH82-4 area, although the ages of the youngest sediments below the hiatuses are not clear. The hiatus formation in this period is similar to the GH81-4 area (Yamazaki, 1986).

**Time-averaged magnetic field**

It is well known that the first order description of the time-averaged geomagnetic field is the geocentric axial dipole field (represented by the Gauss coefficient $g_1^0$ in the spherical harmonic analysis). However, the evidences for existence of small, but important, second-order terms, in particular an axial quadrupole ($g_2^0$) component, have been accumulated (Wilson and Ade-Hall, 1970; Merrill and McElhinny, 1977, 1983; Coupland and Van der Voo, 1980; Livermore *et al.*, 1983). Recently Schneider and Kent (1988, 1990) examined Pliocene and Pleistocene paleomagnetic data of deep-sea sediment cores from the world oceans, and concluded that long-term non-dipole components are dominantly axially symmetric and that the amplitude of the axial quadrupole ($g_2^0$) varies with polarity ($g_2^0/g_1^0=0.026$ for normal; 0.046 for reversed) but not for the axial octupole ($g_3^0$) ($g_3^0/g_1^0$)$=-0.029$ for normal; $-0.021$ for reversed).

It is useful to express deviations of the direction of paleomagnetic field from that of the geocentric axial dipole field as inclination anomalies (Cox, 1975). The inclination anomaly ($\Delta I$) is defined as the difference between observed inclination ($I_o$) and the expected inclination from the geocentric axial dipole field for a site latitude ($\theta$):

$$\Delta I = I_o - \tan^{-1}(2\tan\theta)$$

The sign of the reversed polarity (both observed and dipole inclinations) are inverted to give normal polarity equivalents. Schneider and Kent (1988) showed that at equatorial latitudes the average inclination anomaly during the Brunhes chron is $-2.37° \pm 0.50°$, and that of the Matuyama chron (except for periods of normal polarity subchrons such as the Jaramillo) is $-4.30° \pm 0.71°$.

*Result*

The average inclination anomalies within the Brunhes and Matuyama chrons were

Table VII-1 Positions of cores from GH82-4 area and inclination anomalies during the Brunhes.

| Core | Latitude (S) | Longitude (W) | Depth (m) | Brunhes (N) | | | | Matuyama (R) | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | n | *Io* | *ΔI* | σ | n | *Io* | *ΔI* | σ |
| P336 | 0°53.63' | 166°25.77' | 5434 | | | | | | | | |
| P337 | 1°32.97' | 167°36.36' | 5667 | 63 | -6.3 | -3.2 | 5.8 | 26 | -12.4 | -9.3 | 6.8 |
| P338 | 1°47.70' | 168°03.61' | 5537 | 7 | -12.3 | -8.7 | 5.2 | | | | |
| P339 | 1°40.52' | 166°44.32' | 5403 | | | | | | | | |
| P340 | 1°52.67' | 166°53.31' | 5687 | 82 | -1.8 | 2.0 | 5.7 | 32 | -9.2 | -5.4 | 6.3 |
| P341 | 1°00.05' | 166°24.68' | 5377 | 30 | -10.5 | -8.5 | 5.9 | 9 | -3.7 | -1.7 | 8.8 |
| P342 | 0°49.18' | 166°08.68' | 5174 | 15 | -10.9 | -9.3 | 5.2 | 32 | -4.7 | -3.1 | 3.9 |
| P343 | 1°54.65' | 167°27.55' | 5791 | 97 | -12.9 | -9.1 | 5.7 | 18 | -9.2 | -5.4 | 4.9 |
| P344 | 1°43.48' | 167°21.77' | 5791 | 75 | -5.3 | -1.9 | 5.8 | 32 | -1.8 | 1.6 | 5.9 |
| P345 | 1°22.65' | 166°56.40' | 5648 | 33 | -10.8 | -8.0 | 13.6 | | | | |
| P346 | 1°11.87' | 166°55.25' | 5323 | 39 | -5.1 | -2.7 | 7.0 | 18 | -5.7 | -3.3 | 9.6 |
| P347 | 1°14.37' | 166°37.33' | 5169 | 31 | -3.3 | -0.8 | 7.3 | 12 | -8.8 | -6.3 | 6.4 |
| P348 | 1°10.83' | 166°41.65' | 5292 | | | | | | | | |
| P349 | 1°03.94' | 166°23.94' | 5309 | 26 | -7.5 | -5.4 | 11.0 | 12 | -13.8 | -11.7 | 10.2 |
| P350 | 0°45.17' | 166°04.76' | 5219 | 49 | -4.9 | -3.4 | 5.0 | | | | |
| P351 | 1°10.01' | 166°05.35' | 5382 | | | | | | | | |
| P352 | 0°59.05' | 166°04.70' | 5517 | 37 | -6.3 | -4.3 | 4.0 | 31 | -5.6 | -3.6 | 3.6 |
| P353 | 0°49.07' | 166°14.03' | 5249 | 21 | -8.3 | -6.7 | 4.4 | 32 | -2.1 | -0.5 | 4.6 |
| P354 | 1°06.33' | 166°08.23' | 5353 | 14 | -11.4 | -9.2 | 5.3 | 39 | -6.6 | -4.4 | 4.1 |
| P355 | 0°50.34' | 166°09.43' | 5164 | 13 | -6.8 | -5.1 | 7.0 | 43 | 1.5 | 3.2 | 6.3 |

n : number of samples.
*Io* : average observed inclination (the sign of the reversed polarity was inverted).
*ΔI* : inclination anomaly.
σ : standard deviation of the observed inclination.

calculated for each core presented above (Table VII-1). The data within polarity transitions and periods of normal polarity in the Matuyama chron (the Jaramillo and Olduvai subchrons) were excluded. The mean inclination anomaly during the Brunhes chron obtained from 16 cores is $-5.3°(\pm 3.4°; 1\sigma)$, and that for the Matuyama chron is $-3.8°(\pm 4.1°)$ for 13 cores. It is estimated that the Brunhes chron was sampled evenly because most cores used are reached to the Brunhes/Matuyama boundary, but the data of the Matuyama chron were biased toward the later part of the period. Here simple arithmetic averages were employed. The simple averaging of inclination-only data causes a systematic bias toward shallower inclination compared with the estimation based on more sophisticated methods such as a maximum likelihood technique of McFadden and Reid (1982). However, the bias is negligibly small, an order of 0.1°, in the equatorial latitudes. Non-vertical penetration of a corer, which is usually within a few degrees (Seyb *et al.*, 1977), may have occurred, and this probably caused the scatter of the mean inclination anomalies among cores.

Correction for the movement of the Pacific plate was not applied. Based on the model AM1-2 of Minster and Jordan (1978), the effect of the plate motion to the inclination anomalies is about 0.5° for the age of 1 Ma. It is thus considered that the inclination anomalies in Table VII-1 are a little ($\sim$0.2°) overestimated for the Brunhes chron, and a little ($\sim 0.5°$) underestimated for the Matuyama chron.

As a result the inclination anomalies recorded in the sediment cores from the GH82-4 area agree with the analysis by Schneider and Kent (1988). Although included in the range of the error, the mean inclination anomaly of the Brunhes chron in the GH82-4 area may be a little larger than that of the global analysis. This suggest a possible contribution of non-zonal components, but more data are needed to test this possibility.

**Summary**

A paleomagnetic study was performed on 20 siliceous sediment cores collected from the central equatorial Pacific (GH82-4 area). Primary remanent magnetization direction is easily recovered from all cores after the AF demagnetization. It is estimated from magnetostratigraphy that some cores have continuous sedimentation, and the ages of the bottom of the cores are 1 to 3.5 Ma. The average sedimentation rate of these cores during the Quaternary ranges from 2 to 9 m/m.y. Other cores have hiatuses of various durations. Hiatus formation would have been intensified in the early Pleistocene. Deeper inclinations than expected from the geocentric axial dipole suggest contributions of long-term non-dipole components. The inclination anomalies in the Brunhes and Matuyama chrons are similar in magnitude to the global analysis by Schneider and Kent (1988).

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