45. THE *J*-ANOMALY IN THE CENTRAL NORTH ATLANTIC OCEAN[1]

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ABSTRACT

The *J* anomaly is a linear zone of high-amplitude magnetic anomalies, observed in the eastern North Atlantic north of the Canary Island lineament and the western North Atlantic north of the New England seamounts. Analyses of these anomalies show that the anomalous amplitude zones were formed at the Mid-Atlantic Ridge axis and thus define isochrons. Along strike, the *J* anomaly can be separated into two regions, one of high and one of intermediate anomaly amplitudes. In the eastern Atlantic where these amplitude variations are best documented, the boundary between the two regions occurs at a change in strike in the magnetic lineation pattern. The anomalous distribution of magnetization which is responsible for the unusual shape of the *J* anomaly includes crust slightly younger than *M*-1 to slightly younger than *M*-0. The *J* anomaly was probably caused by a large increase in the intensity of magnetization. DSDP Site 384 is between anomalies *M*-2 and *M*-3, and thus does not lie within the inferred zone of anomalous magnetization.

INTRODUCTION

The Mesozoic or *M*-sequence of magnetic anomalies has been well mapped in the central Atlantic Ocean both in the west (the Keathley sequence of Vogt et al., 1971) and in the east (Hayes and Rabinowitz, 1975). The western Atlantic sequence has been convincingly shown by Larson and Pitman (1972) to be correlatable with similar magnetic lineations found in three separate areas of the Pacific Ocean. On the basis of biostratigraphic data from DSDP holes, the crust beneath these Mesozoic sequences of anomalies is believed to have been formed 108 m.y.B.P. (anomaly *M*-0) to 153 m.y.B.P. (anomaly *M*-25) (Larson and Hilde, 1975). The 108 m.y.B.P. isochron (*M*-0) is thought to mark the beginning of a long period of dominantly normal polarity known as the Cretaceous normal interval (80-108 m.y.B.P.). Furthermore, the observed magnetic signature over crust formed prior to 153 m.y.B.P. (*M*-25) is generally of very low amplitude and is defined as a magnetically quiet zone, the origin of which remains speculative (e.g., Rabinowitz, 1974).

Pitman and Talwani (1972) observed a high-amplitude linear magnetic anomaly on both sides of the North Atlantic which they called the *J* anomaly. In the western North Atlantic, this anomaly could be traced from the New England Seamounts to the Newfoundland Ridge; in the eastern North Atlantic, from the Canary Islands to the Azores-Gibraltar Ridge. After correlation of the Keathley sequence of magnetic anomalies with the Mesozoic sequence (Larson and Pitman, 1972) the *J* anomaly has been correlated either with anomalies *M*-2 to *M*-4 (Luyendyk and Bunce, 1973; Laughton and Whitmarsh, 1974; Hayes and Rabinowitz, 1975) or with anomaly *M*-17 (Barrett and Keen, 1976; Uchupi et al., 1976). The reason it is difficult to identify the exact portion of the Mesozoic sequence to which the *J* anomaly corresponds is that its shape cannot be accounted for by the standard plane-layer model of magnetic anomalies (i.e., uniform magnetization and constant depth and thickness of the source layer).

Here we demonstrate that the *J* anomalies in the eastern and western Atlantic were formed at the Mid-Atlantic Ridge axis, that they are isochrons, and that the magnetization distributions responsible for their unusual shape are centered within crust formed between anomalies *M*-0 and *M*-1. The widths of these crustal zones of anomalous magnetization distribution are $\sim$50 km.

PRESENTATION OF DATA

Profiles of the total intensity of residual magnetization crossing the *J* anomaly in the western and eastern Atlantic (see Figures 1 and 2 for location) are shown in Figure 3. Anomalies *M*-0 to *M*-4 can be easily identified on profiles 11 and 12, taken south of the New England Seamounts in the western Atlantic; in general, however, it is difficult to identify these anomalies on profiles from farther north in the western Atlantic and on profiles from the eastern Atlantic. One reason for the difficulty in identifying these anomalies is that they are highly skewed. In order to eliminate the

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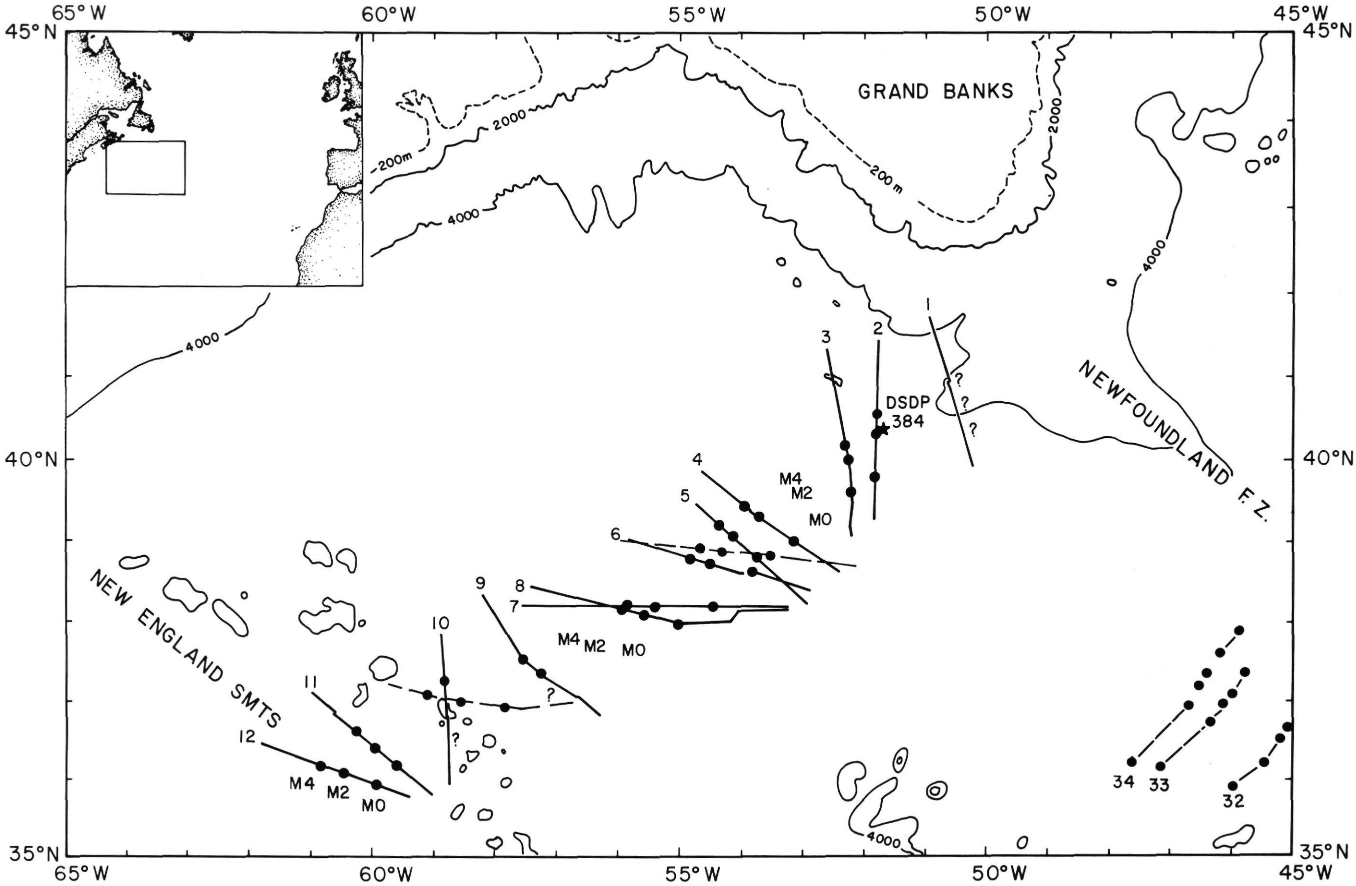

Figure 1. *Location of magnetic data in western Atlantic used in this study. Solid lines: profiles shown in Figures 3 and 4. Dashed lines: additional profiles not shown. Black dots: location of anomalies* M-0, M-2, *and* M-4, *as identified in Figures 3 and 4. Bathymetry from Uchupi (1971).*

skewing effect caused by non-vertical magnetization vectors and the trends of the magnetized "blocks," the profiles presented in Figure 3 have been transformed to the pole, using the technique of Schouten and McCamy (1972) (Figure 4). If the assumptions inherent in that technique are correct, the transformed anomaly profiles should define a square-wave pattern, as is most evident in the western profile 12 and the eastern profile 23 (Figure 4).

After comparing with the model profile, the transformed profiles from south of the Canary Islands in the eastern Atlantic, we identified anomalies *M*-0 to *M*-4, as shown in Figure 4. Because of the dense track coverage in the eastern Atlantic, it is possible to trace these anomaly lineations continuously northward into the region where the *J* anomaly had been previously identified. Subsequently, this knowledge gained in our study of the eastern Atlantic aided the identification of anomalies *M*-0 to *M*-4 north of the New England Seamounts in the western Atlantic. A positive anomaly is observed over crust just younger than *M*-0 (especially in the eastern Atlantic), and can be shown to be an artifact of the magnetization changes (or crustal structure) considered responsible for the unique character of the *J* anomaly, and not a manifestation of a field reversal. Furthermore, it is evident on the transformed profiles that anomalies *M*-2 to *M*-4 are not within the high-amplitude zone. That anomalies *M*-2 to *M*-4 appear to be within a high-amplitude zone in the observed magnetic anomaly profiles is only a consequence of their extreme skewness (compare profiles in Figure 3 with Figure 4).

We have reconstructed the North Atlantic to its configuration at *M*-0 time, using a finite rotation obtained from well-determined *M*-0 lineations south of the New England Seamounts and Canary Islands (Hans Schouten, personal communication). The locations of the anomaly we have identified as *M*-0 within the *J* anomaly align very well in this reconstruction (Figure 5). This confirms our interpretation of anomaly *M*-0 within the *J* anomaly.

INTERPRETATION

The along-strike variations in the amplitudes of anomalies *M*-0 to *M*-4 are shown in Figure 6. The peak-to-peak amplitude of each anomaly was measured on the transformed profiles in Figure 4. It is necessary to use the transformed profiles here in order to eliminate the variations in amplitude which result from their high degree of skewness. The profiles in Figure 4 were not corrected to account for variations in amplitude resulting from any latitudinal variations in

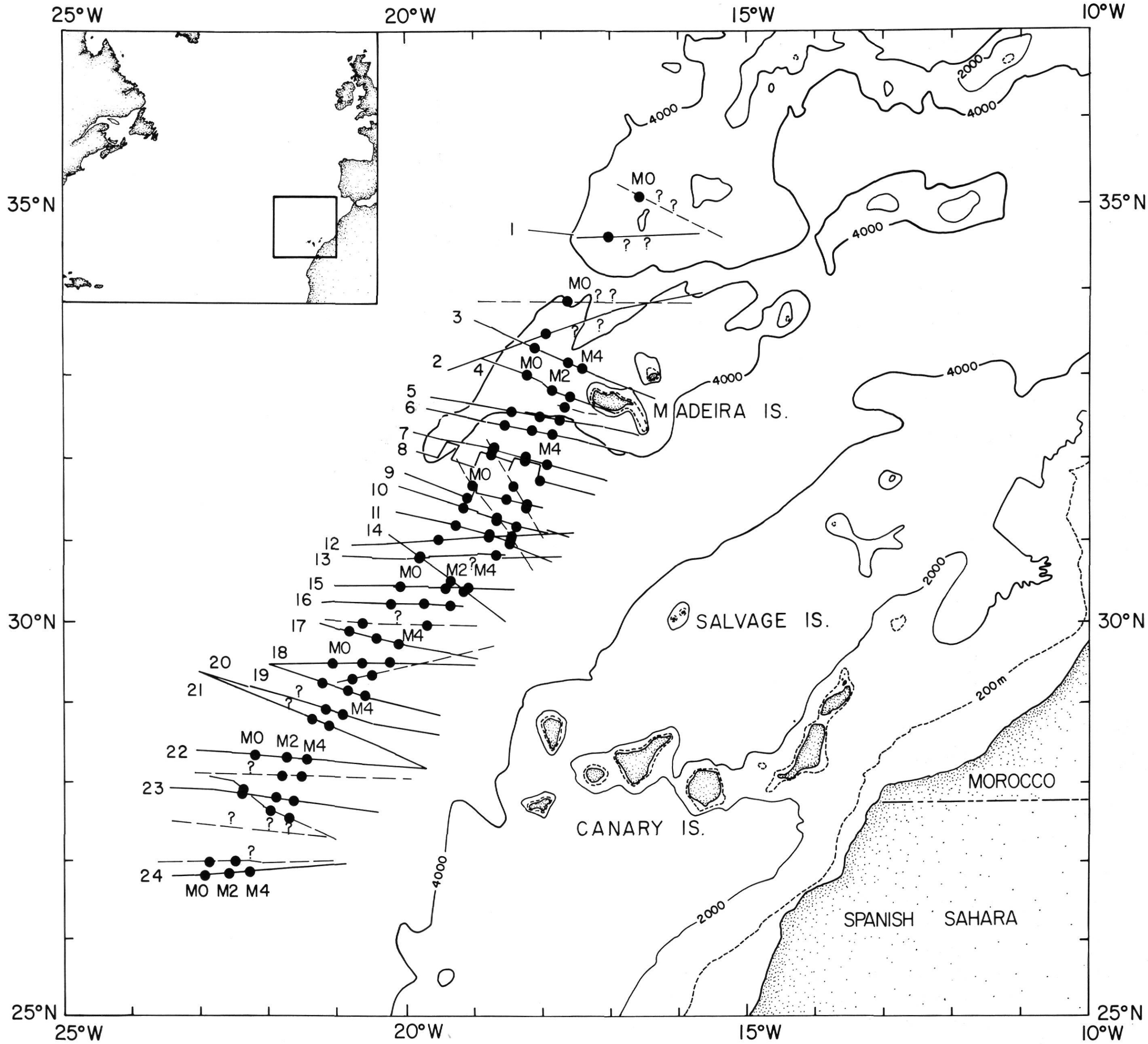

Figure 2. *Location of magnetic data in eastern Atlantic used in this study. Conventions same as in Figure 1.*

field intensity at the time of magnetization. Theoretically, these variations are small, and would give rise to amplitude changes less than 3 per cent of the observed anomaly. Although the origin of the distance axis in Figure 6 is arbitrary, it corresponds to a once-contiguous point chosen from the reconstruction of Figure 5. The following observations derive from Figure 6 and Figure 4:

1) The zone of large amplitudes that characterizes the *J* anomaly is observed between the New England Seamount/Canary Islands (profile 18 on the eastern side, 175 km mark) and the Azores-Gibraltar Ridge/Newfoundland Ridge. The zone is approximately 350 km long, and can be subdivided into two distinct parts. North of profile 8 (west side) and profile 10 (east side) ($\sim$300 km mark), the anomaly amplitudes are about 800 γ peak to peak; south of these profiles, they drop to about 500 γ. This change in amplitude occurs at a "kink" in the trend of the lineations which may correspond to a fracture zone. The northern region will be called the high-amplitude region, the southern region the intermediate-amplitude region.

2) Peak-to-peak variations in the amplitudes of *M*-0 to *M*-4 are roughly symmetrical with regard to the ridge axis. The amplitude variations associated with the seaward side of *M*-0 are not (Figure 6a). This may be because the zone of reversed polarity responsible for *M*-0 was slightly narrower in the western Atlantic than in the eastern Atlantic.

3) The amplitudes of anomalies *M*-4, *M*-3, or *M*-2 do not appear to vary significantly along strike. These anomalies lie outside the large-amplitude zone and have an average peak-to-peak amplitude of about 300γ.

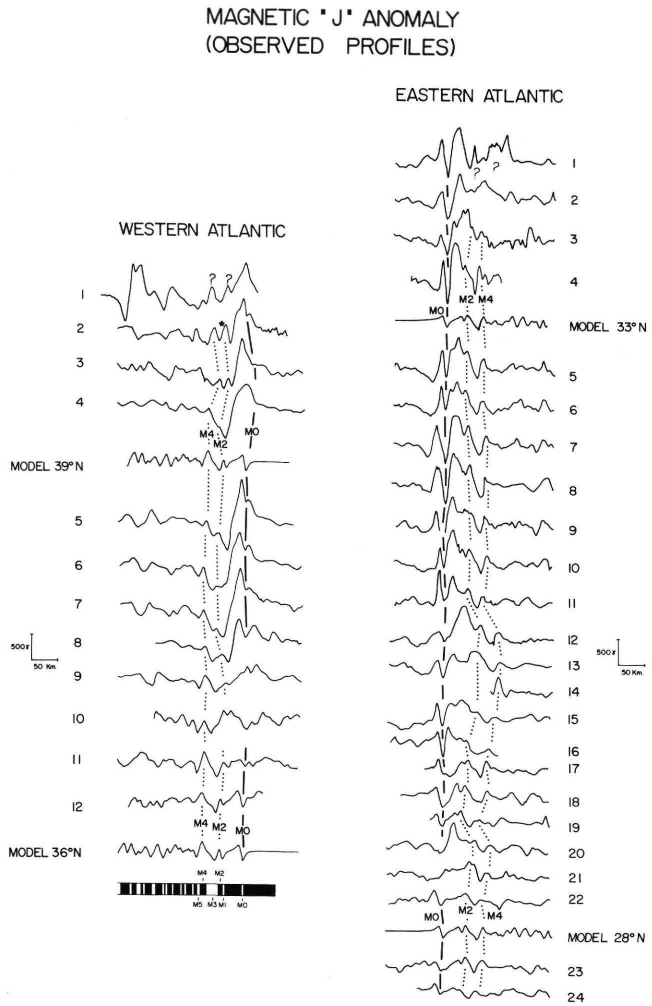

Figure 3. *Total intensity magnetic anomaly profiles projected with azimuths of 140° (western) and 110° (eastern). Identifications shown for anomalies* M-0, M-2, *and* M-4. *Model parameters: top of layer = 6 km; layer thickness = 0.5 km; remanent magnetization intensity = 0.01 emu/cc; remanent inclinations and declinations based on Lower Cretaceous paleomagnetic pole for North America of Van der Voo and French (1974) at 72°N, 194°E; spreading rates = 0.85 cm/year in western Atlantic and 0.80 cm/year in eastern Atlantic, and are based on Mesozoic polarity reversal time scale of Larson and Hilde (1975); blocks of normal polarity are black. Star on profile 2 (western Atlantic) indicates relative position of DSDP Site 384.*

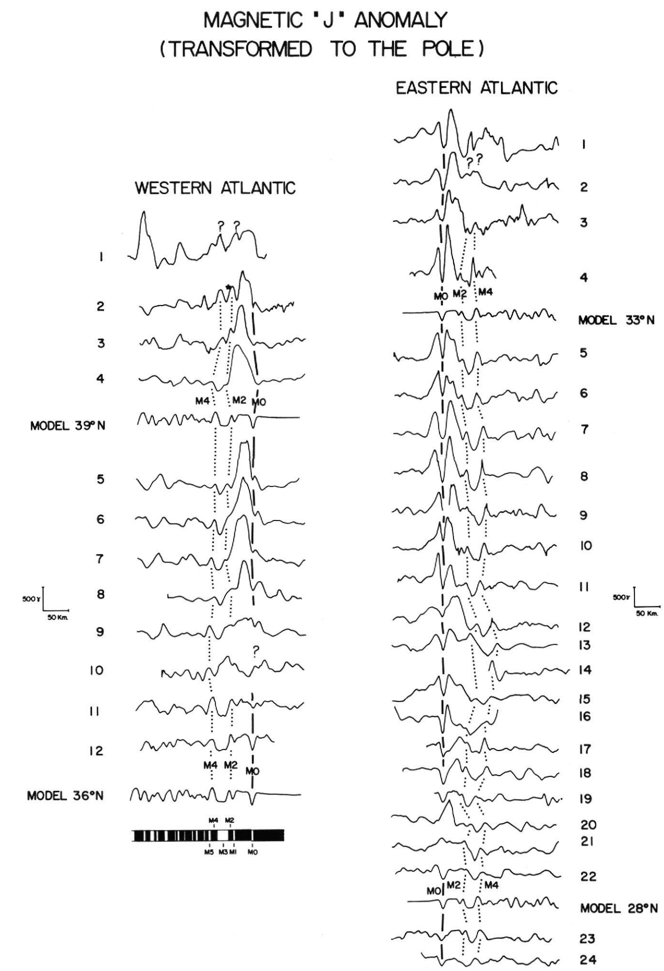

Figure 4. *Profiles shown in Figure 3, transformed to the Lower Cretaceous paleomagnetic pole of Van der Voo and French (1974) for North America. Model parameters same as in Figure 3, except skewness (θ) = 0°.*

4) Across strike, the zone of large anomaly amplitudes is constrained between the seaward side of *M*-0 and the seaward side of *M*-1. The zone is about 50 km wide, and corresponds to a time interval of 6 m.y., which gives a spreading rate of 0.8 cm/year.

Basement relief is associated with the *J* anomaly (Ballard et al., 1976; Hayes and Rabinowitz, 1975). A prominent ridge structure occurs in the region where Site 384 was drilled (Tucholke, Vogt, et al., 1975, and Site 384 Report). However, the changes in relief that are associated with the high- and intermediate-amplitude zones are insufficient to account for the anomaly amplitudes. One model that could account for the shape of the *J* anomaly zone is shown in Figure 7. In this plane-layer model (source depth 6 km, layer thickness 0.5 km) the magnetization intensity is increased by a factor of six between *M*-0 and *M*-1. We observe that the positive anomaly seaward of *M*-0 can be attributed to a nearly uniform decrease in the magnetization intensity at that time. Models could be constructed in which an increase in layer thickness contributes to the large amplitudes. However, the conclusion that the zone of anomalous magnetization distribution is confined to the region between anomaly *M*-1 and slightly seaward of *M*-0 would remain the same.

DSDP Site 384 was drilled between anomalies *M*-2 and *M*-3 and thus did not recover basement rocks from within the zone of large-amplitude magnetic anomalies; the cause of the inferred large increase in magnetization intensity at *M*-1 to *M*-0 time must therefore remain speculative. A high-amplitude magnetic anomaly zone has been associated with the Galapagos spreading center (Vogt and Johnson, 1973; Vogt and

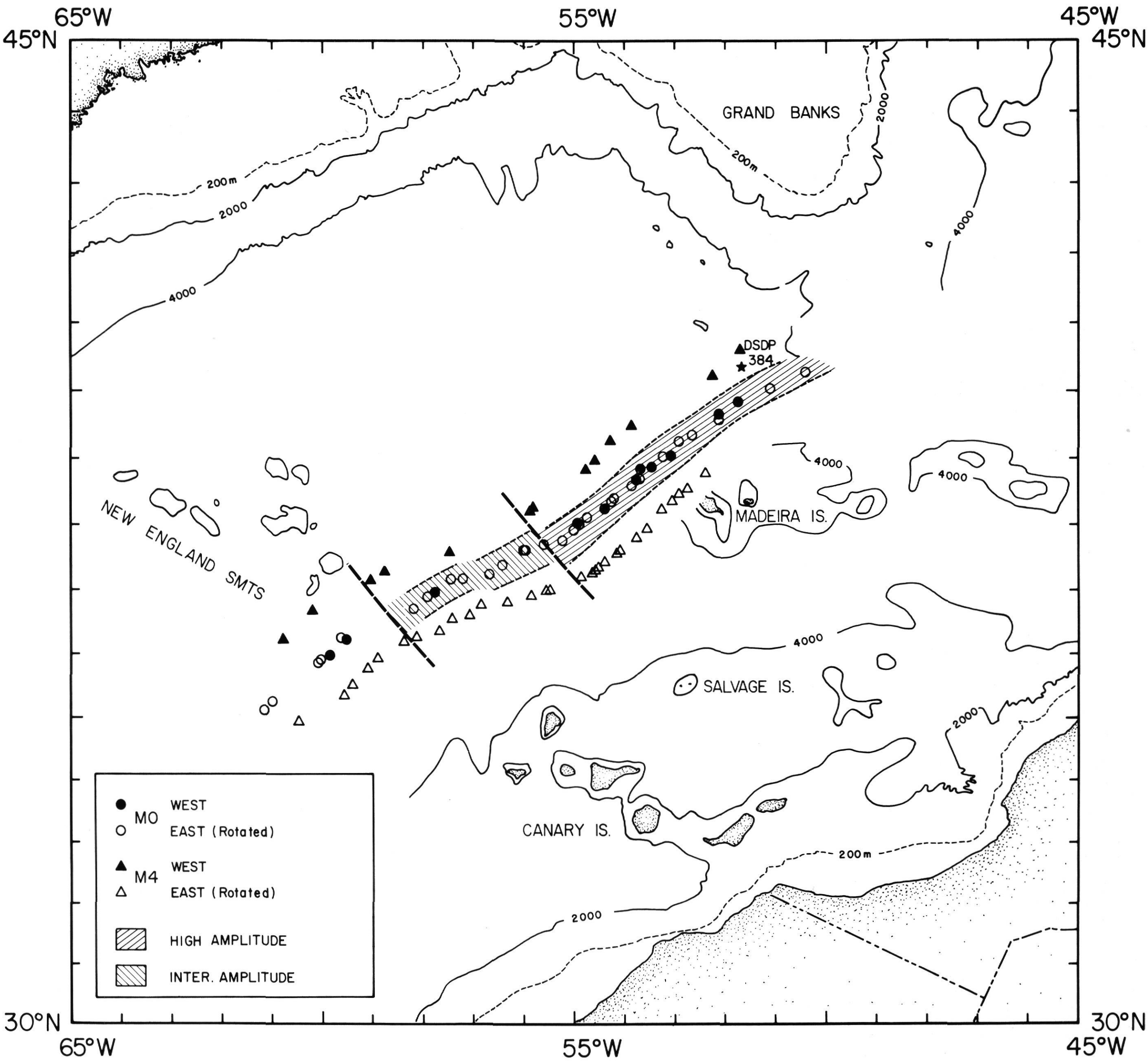

Figure 5. *Reconstruction for anomaly* M-0 *time (108 m.y.B.P.: Larson and Hilde, 1975). North America is kept fixed. Locations of anomalies* M-0 *and* M-4 *(open circles and triangles) and major underwater features on African plate have been rotated by −55.0° about a pole at 65.6°N, 20.2° W (Hans Schouten, personal communication). The extent of high- and intermediate-amplitude regions at* M-0 *time is indicated by cross hatching.*

de Boer, 1976; Anderson et al., 1975; Schilling et al., 1976). The region outlined by this high-amplitude zone is considerably different in shape from the *J* anomaly zone. The Galapagos high magnetic amplitude zone is football-shaped, whereas the *J* anomaly zone is essentially linear. Despite this difference, however, some of the features associated with the *J* anomaly zone are similar to those of the Galapagos high magnetic amplitude zone. In both areas there occur regions of uniformly high anomaly amplitudes which end abruptly.

From the study of dredged rocks collected in the Galapagos area, it has been proposed that the high magnetic amplitudes may result from enrichment with iron and titanium from material upwelling from the mantle (Vogt and de Boer, 1976), or from extensive shallow-level crystal fractionation (Anderson et al., 1975). Either of these mechanisms may be associated with the *J* anomaly. However, since there are no rock samples from the anomalous magnetization zone associated with the *J* anomaly, its origin must remain speculative.

CONCLUSIONS

1) The large-amplitude magnetic *J* anomalies define isochrons formed at the ridge axis. They are situated north of the Canary Islands in the eastern

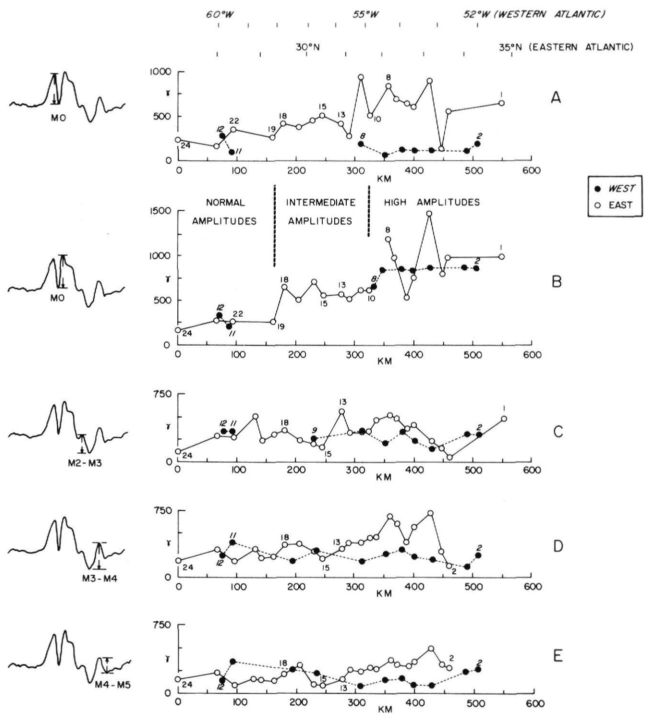

Figure 6. *Variation along strike of the peak-to-peak amplitude of anomalies* M-0 *to* M-4 *after they have been transformed to the pole. The peak-to-peak amplitude measured in each plot is indicated in the representative profile on the left. Open circles = eastern Atlantic, filled circles = western Atlantic. Peak-to-peak measurements on* M-0 *(plots A and B) define distinct regions of normal, intermediate, and high amplitudes.*

Atlantic and north of the New England Seamount Chain in the western Atlantic Ocean.

2) The *J* anomalies can be separated along strike into high and intermediate amplitude regions. In the eastern Atlantic, where they are best documented, the change in amplitudes occurs at a change in trend in the magnetic lineation pattern.

3) The anomalous magnetization distribution responsible for the unusual shape of the *J* anomaly is situated from just seaward of anomaly *M*-1 to seaward of *M*-0.

4) The *J* anomaly was most probably caused by large increases in the magnetization intensity.

5) Deep sea drilling Site 384 is between anomalies *M*-2 and *M*-3, and thus did not sample the inferred zone of anomalous magnetization distribution.

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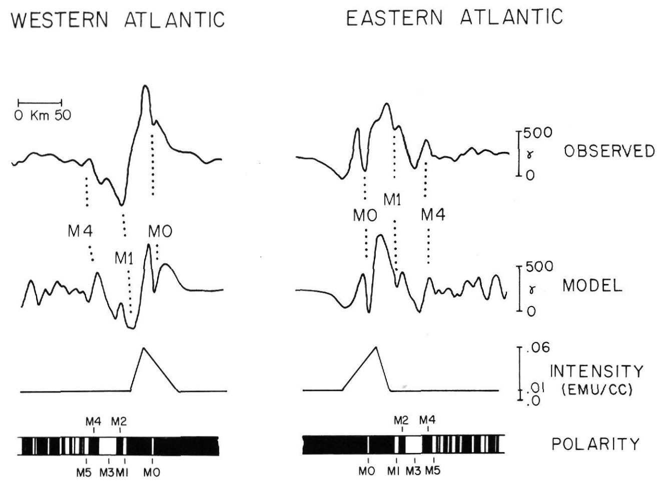

Figure 7. *Models of the* J *anomaly in the western and eastern Atlantic, assuming a plane-layer source with varying remanent magnetization intensity. Model parameters are the same as in Figure 3, except remanent magnetization varies from 0.01 emu/cc for most of model to a peak of 0.06 emu/cc between* M-1 *and* M-0. *The relative width of the reversely magnetized block corresponding to anomaly* M-0 *is half of that given by Larson and Hilde (1975).*

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