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May 1984

NATURAL ENVIRONMENT RESEARCH COUNCIL
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Work carried out under contract to the Department of Energy

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ABSTRACT

This paper presents a review of Mesozoic magnetic anomalies in the Newfoundland Basin and to the west of Iberia (North Atlantic). Revised spreading rates prior to the 84 Ma reversal boundary of anomaly 34 have been combined with a magnetic reversal sequence tied to the stratigraphic timescale of Kennedy and Odin (1982) to derive 2-D magnetic models. The identification of anomalies 24 to 34 by Kristoffersen is substantiated, and an additional magnetic lineation within the Cretaceous magnetic quiet zone is proposed as an isochron which may correlate with the GATAN reversed polarity interval. The identification and significance of the J anomaly in North Atlantic reconstructions for 84 Ma, 106 Ma and closure, shows that the initial motion of Iberia can be explained by an instantaneous rotation about a pole off the SW coast of France which is compatible with the magnetic anomaly identification. The Tertiary motion of Iberia related to the Pyrenean compression is accommodated by a small rotation about a pole at 34°.4'N 19°.4'W. In contrast to many previous proposals, the new reconstruction places Galicia Bank east of Flemish Cap.

INTRODUCTION

Magnetic anomaly 34 (84 Ma) is the oldest unambiguous anomaly in the Newfoundland Basin and to the west of Iberia (Figures 1 and 2). Mesozoic magnetic anomaly sequences prior to anomaly 34 have been discussed for both these areas (Keen et al., 1977; Sullivan, 1983; Group Galice, 1979) and for the area of the J anomaly in the west Central Atlantic (Rabinowitz et al., 1979; Tucholke and Ludwig, 1982). Keen et al. (1977) and Sullivan (1983) have proposed that the J anomaly lies adjacent to the ocean-continent transition in the western Newfoundland Basin. West of Iberia the complex tectonics and bathymetry in the region of the ocean-continent boundary (OCB) south of 40°N complicates any analysis of possible Mesozoic anomalies. However, the J anomaly has been tentatively associated with the Madeira - Tore Rise as a possible northern extension of its identification south of the Azores-Gibraltar plate boundary (Rabinowitz et al., 1979). Sibuet and Ryan (1979) propose that the J anomaly marks the initiation of sea-floor spreading between Iberia and the Grand Banks. This is supported by Tucholke and Ludwig (1982) who propose that the J anomaly ridge south of the Newfoundland Ridge was formed by an edifice building volcanism, that began as early as M4 time, becoming progressively younger to the south with the establishment of 'real' drift between Iberia and the Grand Banks commencing at about M0 time. However, Masson and Miles (in prep.) believe that spreading in the proto-Iberia - Newfoundland basin could have propagated north during this time producing an OCB which, not being an isochron, confined the J anomaly to the southern Newfoundland Basin.

In this context, the correct identification of magnetic anomalies and dating of the oceanic crust is fundamental to the resolution of North Atlantic reconstructions and in particular to the Iberia-Europe-North America closure. This paper reviews the Cretaceous magnetic reversal stratigraphy and the complications of poorly constrained sea-floor spreading rates in magnetic anomaly identification, and proposes a magnetic anomaly sequence off the Grand Banks and Iberia which is used to constrain a reconstruction around the Biscay triple junction.

MAGNETIC REVERSAL CHRONOLOGY

The geomagnetic reversal timescale of Lowrie and Alvarez (1981) back to anomaly 34 (84 Ma) is adopted in this paper. The Cretaceous magnetic quiet zone (CQZ) occurs prior to anomaly 34 spanning the early Aptian-Santonian stages and is preceded by the M or Keathley sequence of anomalies. Figure 3 shows two alternative magnetic reversal timescales covering the period from the top of M series to anomaly 34. The differences in absolute dating are due to the alternative stratigraphic timescales proposed by Harland et al. (1982) and Kennedy and Odin (1982). The Lower Cretaceous stage boundaries have been poorly defined in terms of absolute dating until the recent revision by Kennedy and Odin (1982) in which an attempt has been made to date each boundary individually rather than by interpolation between sparse control points. As this should provide an improved quantitative age resolution, it has been adopted in this paper (Fig. 3, lower). The construction of the reversal sequence on the Kennedy and Odin (1982) stratigraphic timescale was completed in two parts. First, the Aptian/Barremian boundary corresponding to the old reversal of anomaly MO (Channell et al., 1979) at 112 Ma (Kennedy and Odin, 1982) was used as calibration at the top of the M series and the old boundary of the middle reversed polarity interval comprising anomaly M24 was calibrated at 145 Ma - Middle Oxfordian - (Kennedy and Odin, 1982) following Cande et al. (1978). The intervening M series anomalies were linearly interpolated. Second, significant reversals or periods of mixed polarity within the CQZ for which there is good evidence published, were included in their relevant stratigraphic position (Van Hinte, 1976; Percherski and Kramov, 1973).

SPREADING RATE MODELS

Magnetic anomalies are generally identified by comparison with synthetic profiles generated from a model. Such models comprise a magnetic reversal timescale tied to spreading rate controls, usually defined in terms of periods of constant spreading, determined from geological and geophysical controls that may be locally or regionally derived.

Spreading rates applied to the reversal timescale adopted in this paper include those of Kristoffersen (1978), for reversals post-dating anomaly 33, and estimates derived from DSDP site 550 which sampled oceanic basement 10 km SW of Goban Spur on the Celtic margin (Leg 80 Scientific Party, 1982). A minimum age of 97 Ma for the oceanic crust at site 550, latest Albian on the Kennedy and Odin (1982) timescale, gives a half-spreading rate of 9 mm/yr between anomaly 34 and the DSDP site.

North Atlantic spreading rates during the M series are only available from results south of the SE Newfoundland Ridge-Azores-Gibraltar line with half rate values between 9 and 17 mm/yr

(Vogt and Einwich, 1979; Lowrie, 1979; Rabinowitz et al., 1979; Barret and Keen, 1976). Two approximate estimates of 9 and 13 mm/y for the half spreading rate are the only control from these results covering the late M series and the values from the western Central Atlantic may not even be representative between Iberia and the Grand Banks (Vogt and Einwich, 1979; Lowrie, 1979). However, the poor magnetic anomaly definition and limited extent of Lower Cretaceous oceanic crust in the Iberia-Newfoundland Basin makes alternative assessments of spreading rates impossible. For this reason two models are included in figures 4 and 5 as examples of the possible spatial relationship between anomaly 34 and the end of the M series. With little control over the spreading rate during the early part of the CQZ off Iberia and the Grand Banks, figures 4 and 5 show the following. First, pre-anomaly 34 spreading in the Newfoundland Basin needs to be greater than either model if the proposed J anomaly extension north of the SE Newfoundland Ridge is to be correlated with anomalies M3 or MO (Tucholke and Ludwig, 1982; Sullivan, 1983). Second, no corresponding J anomaly is clearly identifiable off the Iberian margin and, third, if the anomalies labled X in the figures are to be dated, then correlation with the CQZ reversal following MO should be taken. This could be the GATAN reversed polarity interval (Van Hinte, 1976). Correlation of the X anomaly with earlier reversals MO-M3 would imply that sea-floor spreading in the proto Iberia-Newfoundland basin pre-dated the DSDP ages of transitional crust south of Galicia Bank (Group Galice, 1979). It is considered that the identification of anomalies 24 to 34 in these areas by Kristoffersen (1978) is substantiated.

RECONSTRUCTIONS

The reconstructions shown in figures 6 to 8 followed three steps. First, the identification and digitisation in geographic co-ordinates of anomalies 24, 34 and X between Iceland and the Newfoundland-Azores-Gibraltar line following Kristoffersen (1978). Second, selection of the OCB position off the European, North American and Iberian continental margins as closure constraints (Montadert et al., 1979; Group Galice, 1979; Sullivan, 1983) and third, the generation of a set of rotation poles to describe the plate motions between initial separation and anomaly 34 time (Saunders et al., 1983).

The 84 Ma reconstruction (Fig. 6) is primarily constrained by the clear anomaly 34 identification throughout the North Atlantic (Figs. 1 and 2) and is a modification of the reconstruction by Kristoffersen (1978). The anomaly 34 identification off the Labrador margin was taken directly from Srivastava (1978). Compensation for the north-westward early Tertiary Pyrenean movement of Iberia was made following the interpretation of Grimaud et al. (1982) by rotating Iberia clockwise by 6.4 deg about a pole at $34^{\circ}.4'$N $19^{\circ}.4'$W. This corrects the anomaly 34 overlap of the Iberian and North American plates by proposing that Kings Trough (Fig. 1) is a transform fault showing a significant amount of opening (Grimaud et al, in press). The post anomaly 34 opening of Biscay can only be estimated from this pre-Tertiary relationship of Europe and Iberia. A north-south opening of about 60 km has been approximated as this appears to satisfy Kristoffersen's (1978) tentative anomaly 34 identification in the Bay of Biscay as well as the constraint of anomaly 34 coincidence in the North Atlantic around the Biscay triple junction (Table 1). The Europe-North America pole for anomaly 34 in this paper is identical to that of Kristoffersen (1978) with a small difference in rotation probably due to modified anomaly identification between Iberia and the Grand Banks. Closure of the Labrador Sea is a compromise between the solutions of Srivastava (1978) and Le Pichon et al. (1977) neither of whose poles for Greenland were particularly compatible with the reconstruction controls to the south. This position of Greenland is approximate and is included to provide a regional context for the reconstructions. The Rockall Plateau and Faroes Block are here considered as one integral rigid plate unit and are not moved relative to Europe for the anomaly 34 reconstruction.

Generation of the 106 Ma reconstruction (Fig. 7) first required an Europe-North America reconstruction to initial separation. This was constrained by matching the OCB west of Goban Spur and Porcupine Bank identified by Roberts et al. (1981) and Masson et al. (in press) with that north-east of Flemish Cap (IOS, unpublished data). The finite difference pole of Kristoffersen (1978) between anomaly 34 and initial separation produced a large cross-over of the conjugate OCB delineations. A new finite difference pole to initial separation (table 1) placed North America approximately 100 km further south relative to Europe than did Kristoffersen's (1978) solution (Fig. 7). This avoided OCB overlap off the Celtic margin and closed Rockall Trough without introducing problems on the Hebrides or Malin continental margins to the north of Ireland. An overlap does occur between the

SE Rockall Plateau and Porcupine Bank in this reconstruction (R.A. Scrutton, personal communication). However, in view of the rigid plate assumption used, particularly in regard to Porcupine Bank and the Hatton-Rockall Basin, some localised adjustment is possible but this is outside the scope of this paper. This solution also appears not to contravene the contiguity of the Charlie-Gibbs Fracture Zone (Scrutton and Megson, this volume).

From the above Europe-North America closure it was possible to define the initial position of Iberia by matching (a) the OCB along the North Biscay margin (Montadert et al., 1979) with an assumed, though poorly defined, OCB lying off the base of the continental slope north of Iberia, and (b) the OCB in the Newfoundland Basin (Sullivan, 1983) with a north-south trending change in magnetic anomaly character off the Iberian margin (Group Galice, 1979), picked as the OCB by Sullivan (1983) (Fig. 7). Rotation of Iberia about the finite difference pole (table 1) between anomaly 34 and initial separation with Europe/ N. America produced alignment of the X anomaly isochron (106 Ma) to complete fig. 7 with the interpretation of a transform fault separating Galicia Bank and Flemish Cap.

Full rotation of Iberia by 32 degrees gives the initial separation position (Fig. 8). This does not produce any OCB overlaps or contravene the palaeomagnetic results of Vandenberg (1980) but effectively closes the Bay of Biscay and Iberia-Newfoundland Basin with a minimum amount of 'gap'. Galicia Bank lying to the east of Flemish Cap does not require to be moved relative to Iberia during the early stages of spreading as in the reconstructions of Le Pichon et al. (1977), Lefort (1980) and Sullivan (1983). It is suggested that the commencement of sea-floor spreading in the southern Iberia-Newfoundland Basin occurred sometime during the time of the J anomaly and propagated northwards towards the southern edge of Galicia Bank up to the latest Aptian (Masson and Miles, in prep.). Spreading in the Bay of Biscay was initiated in the Aptian, but post anomaly MO (Montadert *et al.*, 1979), generating the transform margin between Flemish Cap and Galicia Bank.

CONCLUSION

The magnetic models show that if the proposed J anomaly in the Newfoundland Basin is to be correlated with anomaly MO-M3 then the initial sea-floor spreading rate must have exceeded 13 mm/yr. The anomaly correlations, X, within the CQZ adjacent to the Grand Banks and Iberian margins, is seen to align during the proposed reconstruction at 106 Ma and the continental separation position suggests a relatively straightforward initial motion of Iberia relative to Europe and North America.

ACKNOWLEDGEMENTS

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TABLE 1 Reconstruction Poles

EUR/IB	(a)	34.4N	19.4W	-6.4	Pyrenean convergence
	(b)	23.0S	84.0W	+0.6	Biscay closure to Anomaly 34
	(c)	44.5N	1.5W	-32.0	FDR Anomaly 34 initial opening
EUR/NAM	*	69.3N	147.6E	+20.2	FR for Anomaly 34
		70.0N	13.0E	+5.0	FDR Anomaly 34 initial opening
EUR/GRE		7.5N	131.0E	+10.9	FR for Anomaly 34
		70.0N	13.0E	+5.0	FDR Anomaly 34 initial opening
EUR/ROC		70.0N	13.0E	+5.0	FR for initial opening

(*) after Kristoffersen (1978), FR - Finite rotation; FDR - Finite difference rotation. Europe is kept fixed.

REFERENCES

Barret, D.L. and Keen, C.E., 1976. Mesozoic magnetic lineations, the magnetic quiet zone and sea-floor spreading in the NW Atlantic. Journal of Geophysical Research, v.81, p.4875-4884.

Cande, S.C., Larson, R.L. and La Brecque, J.L., 1978. Magnetic lineations in the Pacific Jurassic quiet zone. Earth and Planetary Science Letters, v.41, p.434-440.

Channell, J.E.T., Lowrie, W. and Medizza, F., 1979. Middle and early Cretaceous magnetic stratigraphy from the Cismon section, northern Italy. Earth and Planetary Science Letters, v.42, p.153-166.

Grimaud, S., Boillot, G., Collette, B., Mauffret, A., Miles, P.R. and Roberts, D.G., 1982. Western extension of the Iberian-European plate boundary during the early Cenozoic (Pyrenean) convergence: a new model. Marine Geology, v.45, p.63-77.

Grimaud, S., Boillot, G., Collette, B., Mauffret, A., Miles, P.R. and Roberts, D.G., in press. Reply to comment by Oliver et al. on: Western extension of the Iberian-European plate boundary during the early Cenozoic (Pyrenean) convergence: a new model. Marine Geology.

Group Galice, 1979. The continental margin off Galicia and Portugal: acoustical stratigraphy, dredge stratigraphy and structural evolution. In: Sibuet, J.C. and Ryan, W.B.F. et al., Init. Rep. DSDP v.47, p.633-662 Washington (U.S. Govt. Printing Office).

Harland, W.B., Cox, A.V., Llewellyn, P.G., Pickton, C.A.G., Smith, A.G. and Walters, R., 1982. A geologic timescale. 131 pp. Cambridge University Press.

Keen, C.E., Hall, B.R. and Sullivan, K.D., 1977. Mesozoic evolution of the Newfoundland Basin. Earth and Planetary Science Letters, v.37, p.307-320.

Kennedy, W.J. and Odin, G.S., 1982. The Jurassic and Cretaceous timescale in 1981. In: Numerical dating in stratigraphy. G.S. Odin (ed), pt. 1, p.557-592.

Kristoffersen, Y., 1978. Sea-floor spreading and the early opening of the North Atlantic. Earth and Planetary Science Letters, v.38, p.273-290.

Lefort, J.P., 1980. Un 'fit' structural de l'Atlantique nord: arguments geologiques pur correler les marquers geophysiques reconnus sur les deux marges. Marine Geology, v.37, p.355-369.

Leg 80 Scientific Party, 1982. Goban Spur transect is drilled. Geotimes, v.27, No. 5, p.23-25.

Le Pichon, X., Sibuet, J-C., and Francheteau, J., 1977. The fit of the continents around the North Atlantic Ocean. Tectonophysics, v.38, p.169-209.

Lowrie, W., 1979. Geomagnetic reversals and ocean crust magnetisation. In: Deep drilling results in the Atlantic Ocean, Ocean crust M. Talwani, C.G. Harrison and D.E. Hayes (eds.). Maurice Ewing Series 2, A.G.U., Washington.

Lowrie, W. and Alvarez, W., 1981. One hundred million years of geomagnetic polarity history. Geology, v.9, no.9, p.392-397.

Masson, D.G. and Miles, P.R., in prep. Mesozoic sea-floor spreading between Iberia, Europe and North America.

Masson, D.G., Montadert, L. and Scrutton, R.A., in press. Evolution of the Goban Spur: history of a starved margin. Init. Rep. DSDP Leg 80.

Montadert, L., Roberts, D.G., De Charpel, O. and Guennoc, P., 1979. Rifting and subisdence of the northern continental margin of the Bay of Biscay. In: Montadert, L., Roberts, D.G. et al. Init. Rep. DSDP v.48, p.1025-1060 (U.S. Govt. Printing Office) Washington.

Percherski, D.M. and Kramov, A.N., 1973. Mesozoic palaeomagnetic scale of the USSR. Nature, v.244, p.499-501.

Rabinowitz, P.D., Cande, S.C., and Hayes, D.E., 1979. The J anomaly in the central North Atlantic Ocean. In: Tucholke, B., Vogt, P.R. et al., Init. Rep. DSDP, v.43, p.879-885 (U.S. Govt, Printing Office), Washington.

Roberts, D.G., Masson, D.G. and Miles, P.R., 1981. Age and structure of the southern Rockall Trough: new evidence. Earth and Planetary Science Letters, v.52, p.115-128.

Saunders, M.R., Miles, P.R. and Storey, M.W., 1983. The graphical simulation of tectonic plate motion. Computers and Geosciences, v.9, p.245-254.

Sibuet, J.C. and Ryan, W.B.F., 1979. Site 398: Evolution of the west Iberian passive continental margin in the framework of the early evolution of the North Atlantic Ocean. In: Sibuet, J.C., Ryan, W.B.F. et al. Init. Rep. DSDP, v.47, p.761-775. (U.S. Government Printing Office) Washington.

Srivastava, S.P., 1978. Evolution of the Labrador Sea and its bearing on the early evolution of the North Atlantic. Geophysical Journal of the RAS, v.52, p.313-357.

Sullivan, K.D., 1983. The Newfoundland Basin: Ocean-continent boundary and Mesozoic sea-floor spreading history. Earth and Planetary Science Letters, v.62, p.321-339.

Tucholke, B.E. and Ludwig, W.J., 1982. Structure and origin of the J anomaly ridge, western North Atlantic Ocean. Journal of Geophysical Research, v.87 (B11), p.9389-9407.

Vandenberg, J., 1980. New palaeomagnetic data from the Iberian peninsula. Geologie en Minjbow, v.59, p.49-60.

Van Hinte, J.E., 1976. A Cretaceous timescale. American Association of Petroleum Geologists Bulletin, v.60, p.498-516.

Vogt, P.R. and Einwich, A.M., 1979. Magnetic anomalies and sea-floor spreading in the western North Atlantic, and a revised calibration of the Keathley (M) geomagnetic reversal chronology. In: Tucholke, B.E. and Vogt, P.R. et al. Init. Rep. DSDP, v.43, p.857-876 (U.S. Govt. Printing Office) Washington.

FIGURE CAPTIONS

Figure 1. Celtic and Iberian margins magnetic anomaly identification. D - Discovery, SH - Shackleton and MB - Marcel Bayard from IOS; V - Vema, C - Conrad and SNEL - Snellius. Bathymetry in metres.

Figure 2. SE Grand Banks - Newfoundland Basin magnetic anomaly identification: BIO - Bedford Institute, FARN - M.V. Farnella (IOS). Bathymetry in metres.

Figure 3. Magnetic reversal timescales tied to the alternative stratigraphic timescales of Harland et al. (top) and Kennedy and Odin (bottom; adotped in this paper). CQZ reversals and mixed polarity zones compiled from various publications (see text).

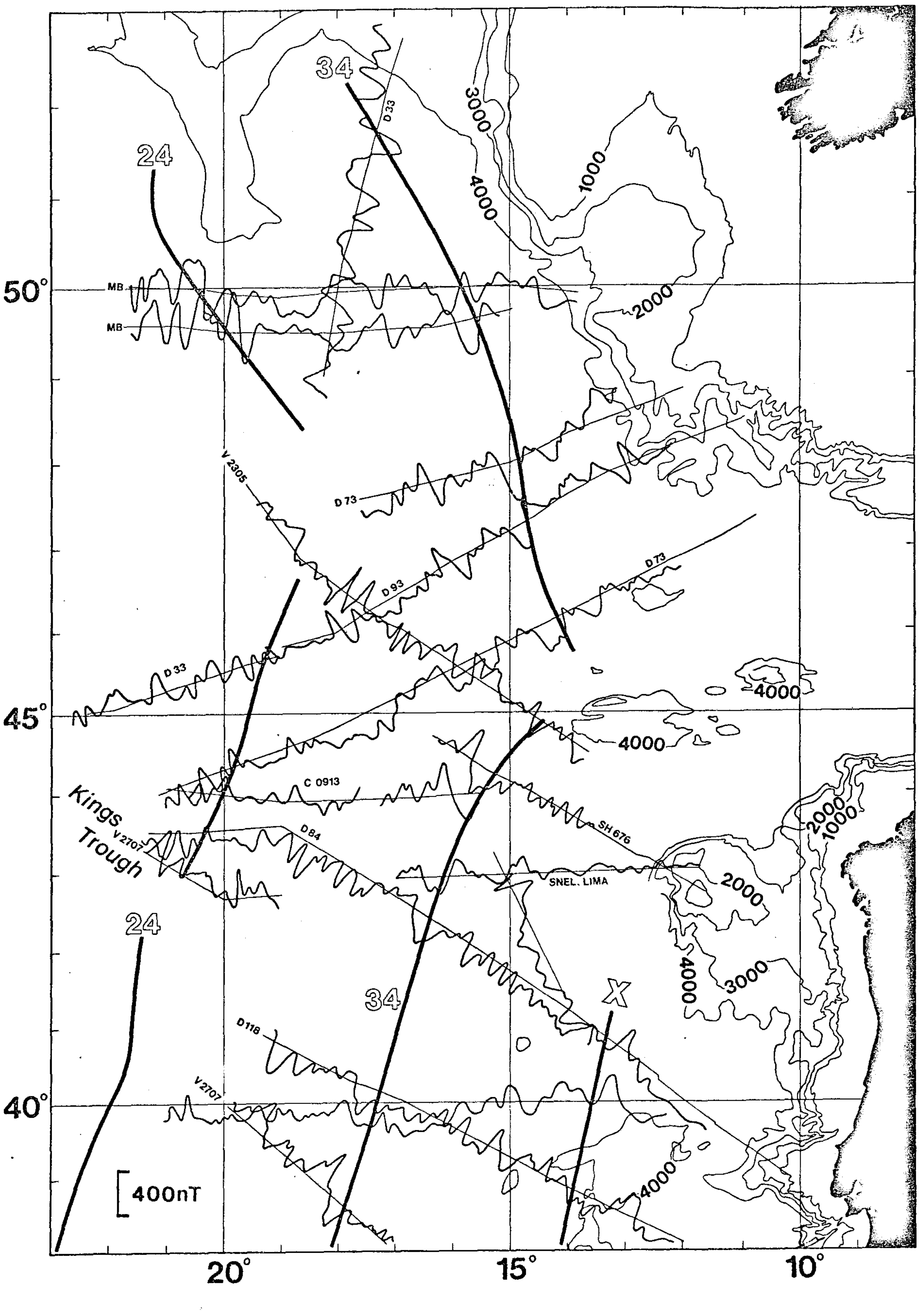
Figure 4. Selected magnetic profiles orthogonal to anomaly lineations west of Iberia with correlations as in Fig. 1. Lower model assumes 9 mm/yr half-spreading rate continues back to M series; upper model has half-spreading rate of 13 mm/yr before 96 Ma. Both models agree with Kristoffersen (1978) post anomaly 33. Model parameters: Inc = 65^{o}, Dec = 24^{o}W, Rem Inc = 35^{o}, Magnetisation = 7A/m, layer thickness = 2 km.

Figure 5. Selected magnetic profiles orthogonal to anomaly lineations in the Newfoundland Basin with correlations as in Fig. 2. Model parameters: Inc = 60^{o}, Dec = 13^{o} W, Rem Inc = 35^{o}, Magnetisation = 7 A/m, layer thickness = 2 km.

Figure 6. Reconstruction to anomaly 34 (84 Ma). Open circles = Euro-Iberia, filled circles = N. America. Dashed lines = OCB in part after Sullivan (1983), Montadert et al. (1979) and Group Galice (1979). X = CQZ anomaly (106 Ma). Heavy double line is southern Grand Banks transform defining the early motion of Africa relative to North America.

Figure 7. Reconstruction to 106 Ma - anomaly X from Iberia and N. America coincide. Thin double lines represent proposed Flemish Cap/Galicia Bank transform.

Figure 8 Reconstruction to closure and location of major features. FC (Flemish Cap), GB (Galicia Bank), GS (Goban Spur) OK (Orphan Knoll), PS (Porcupine Seabight), PB (Porcupine Bank), RB (Rockall Bank).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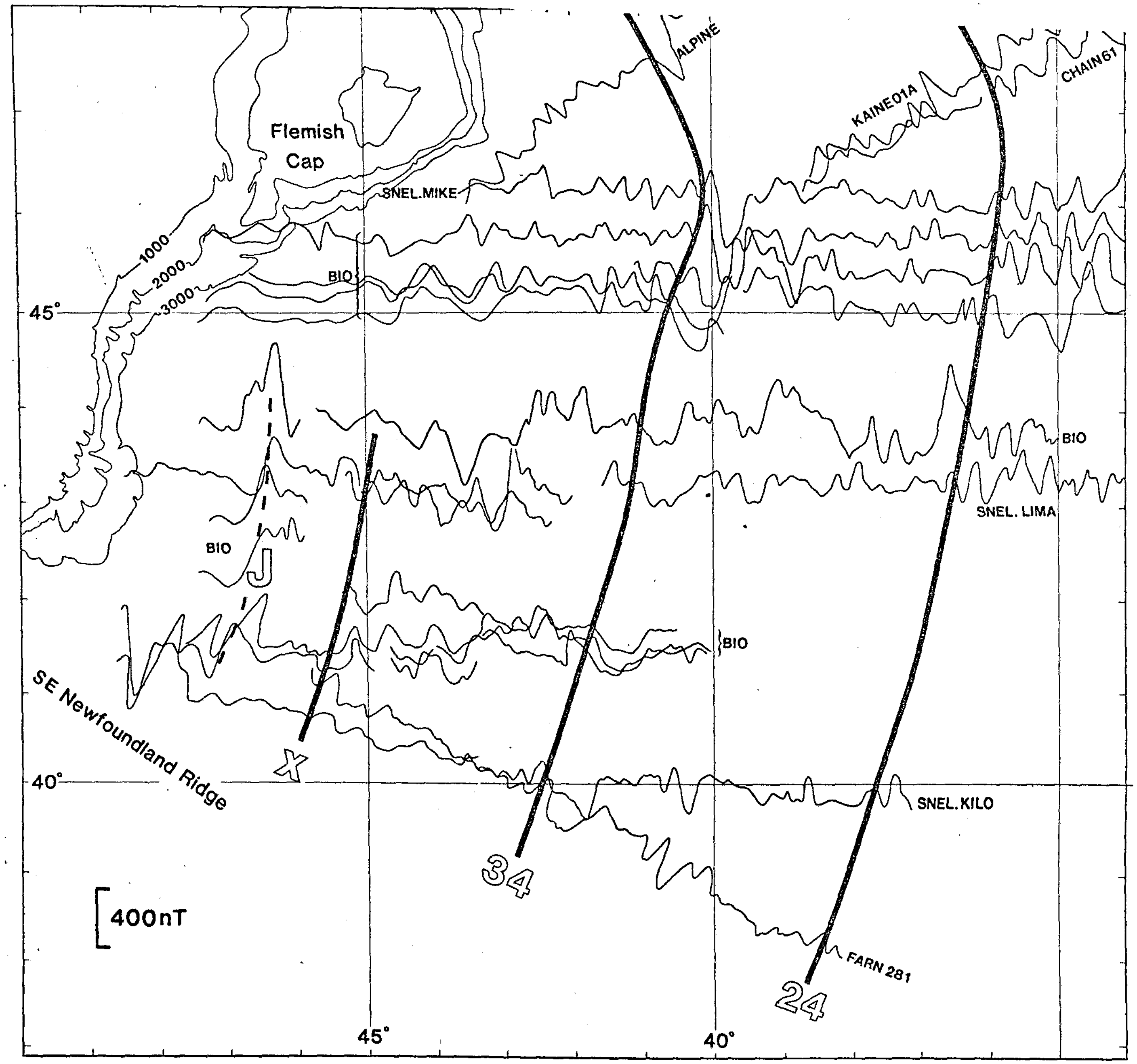
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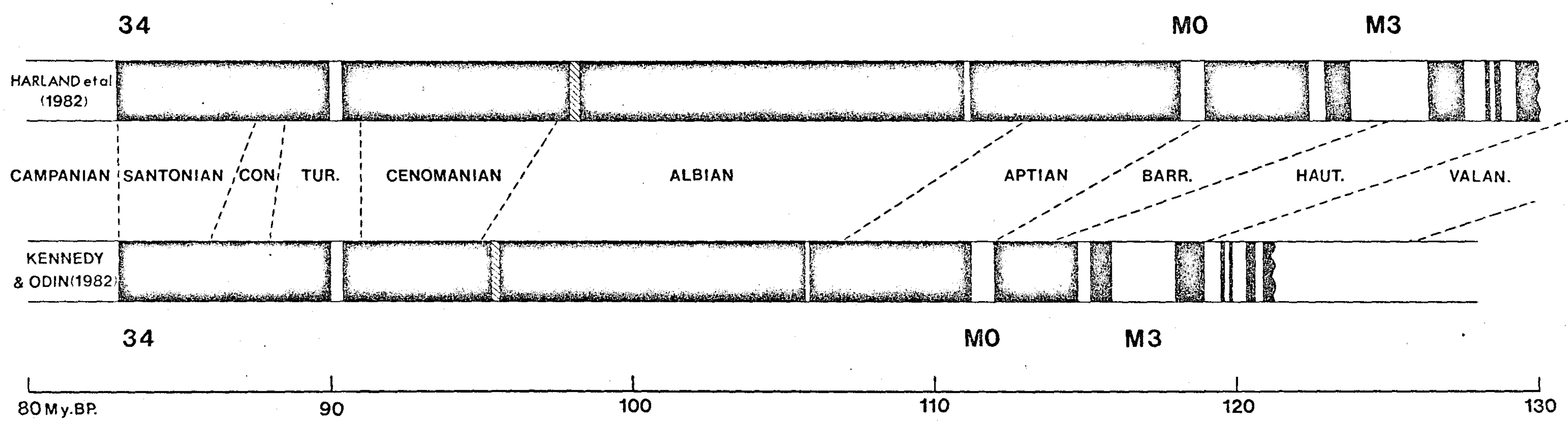
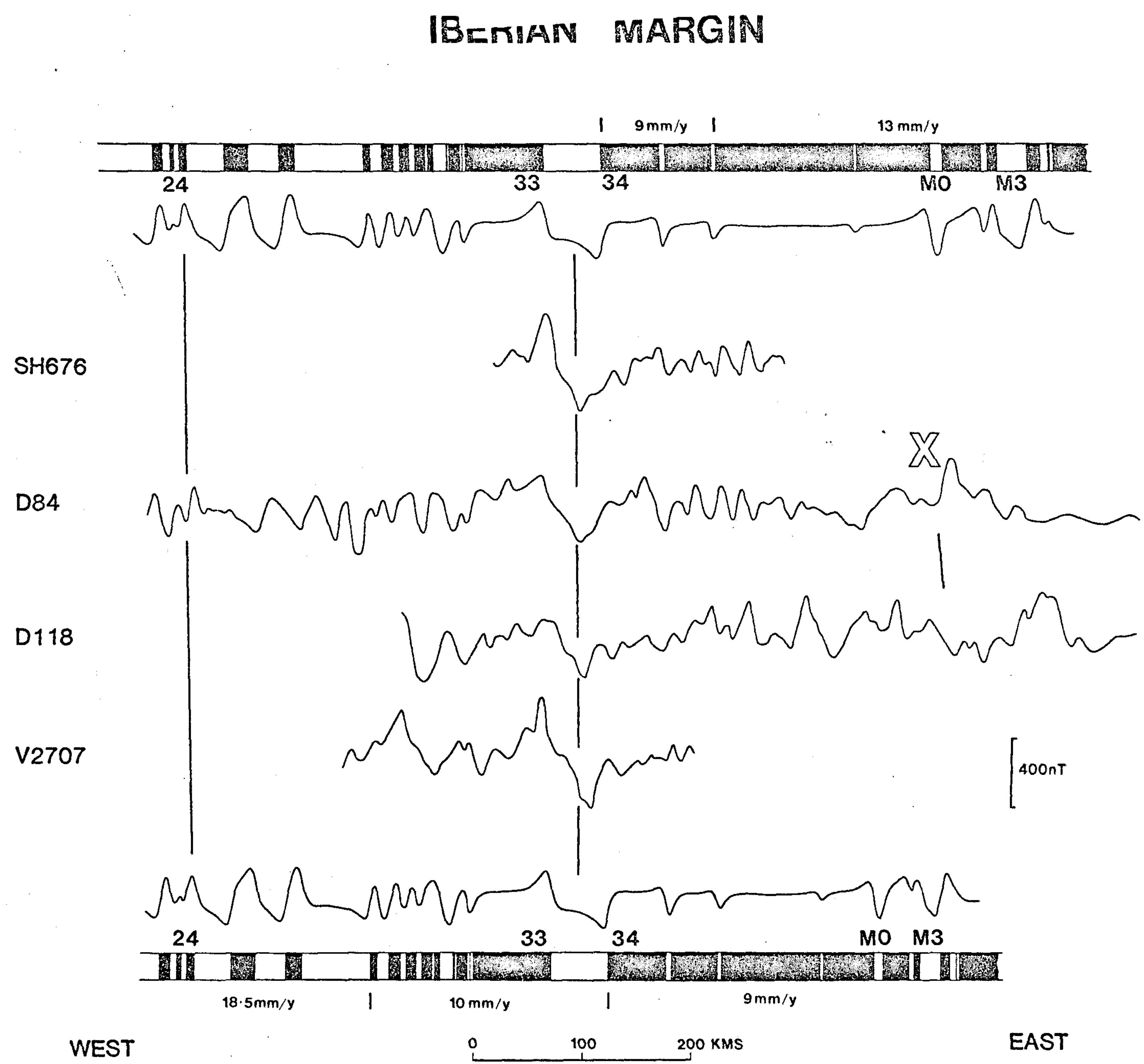


CRETACEOUS MAGNETIC STRATIGRAPHY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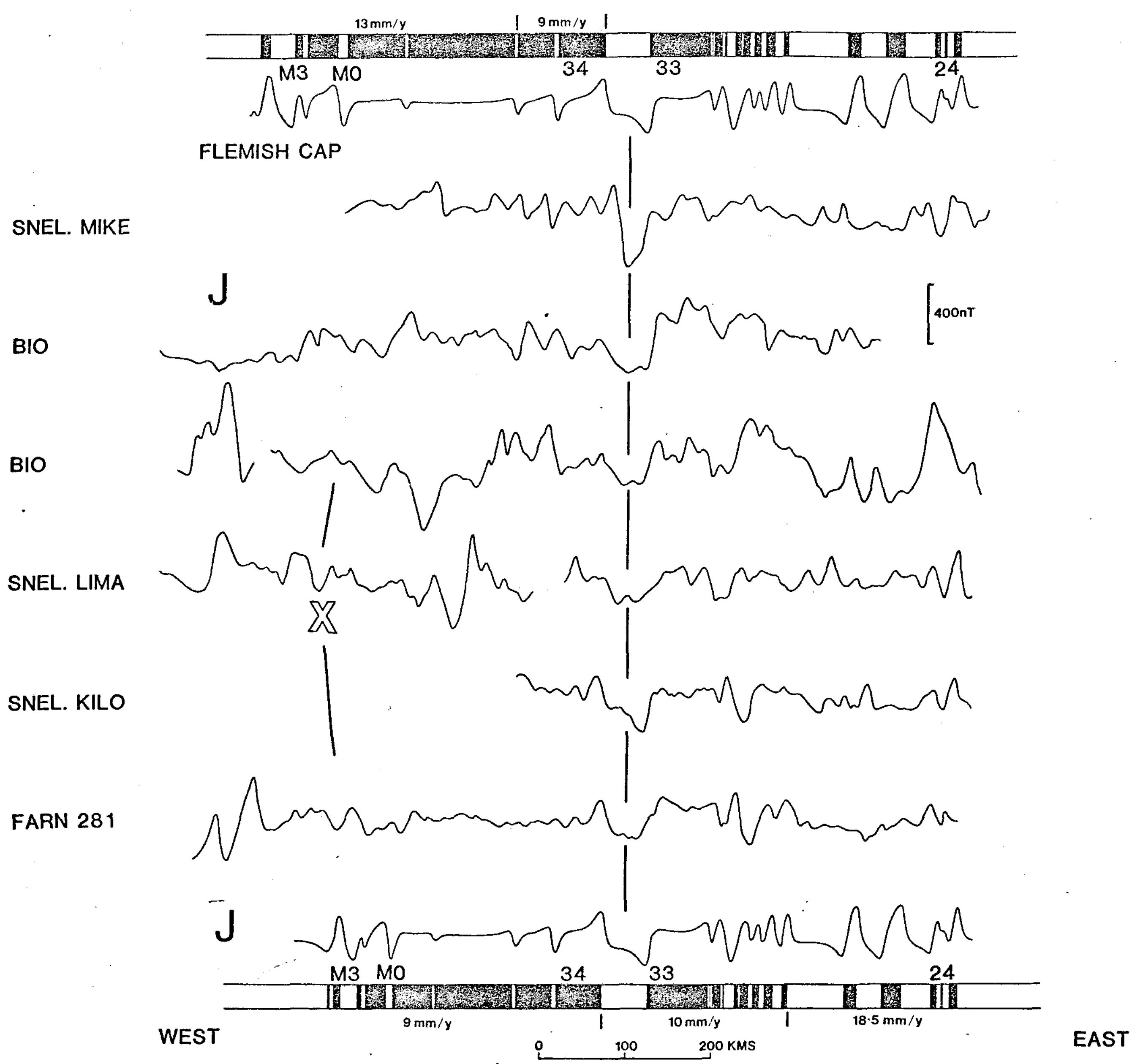

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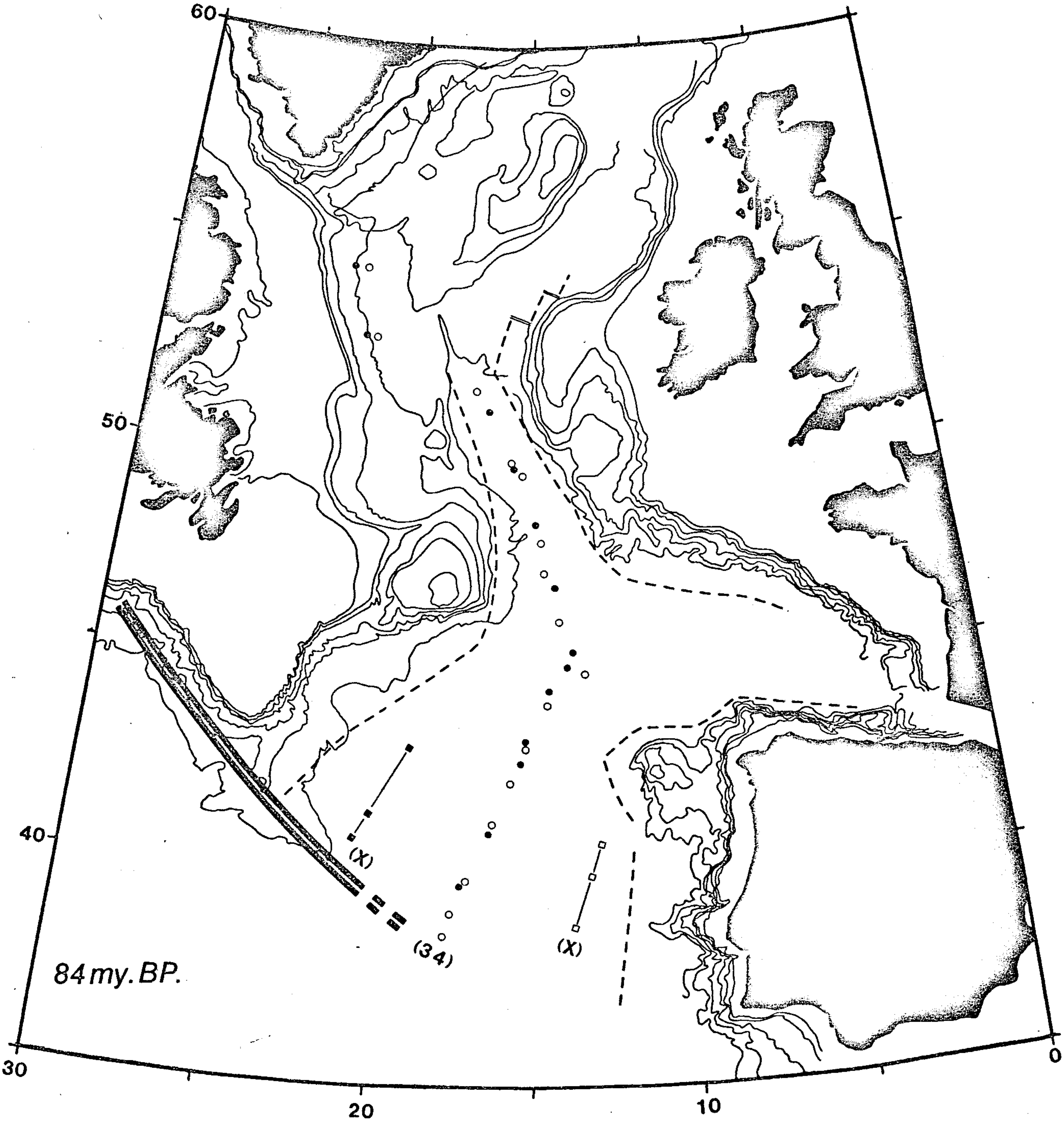
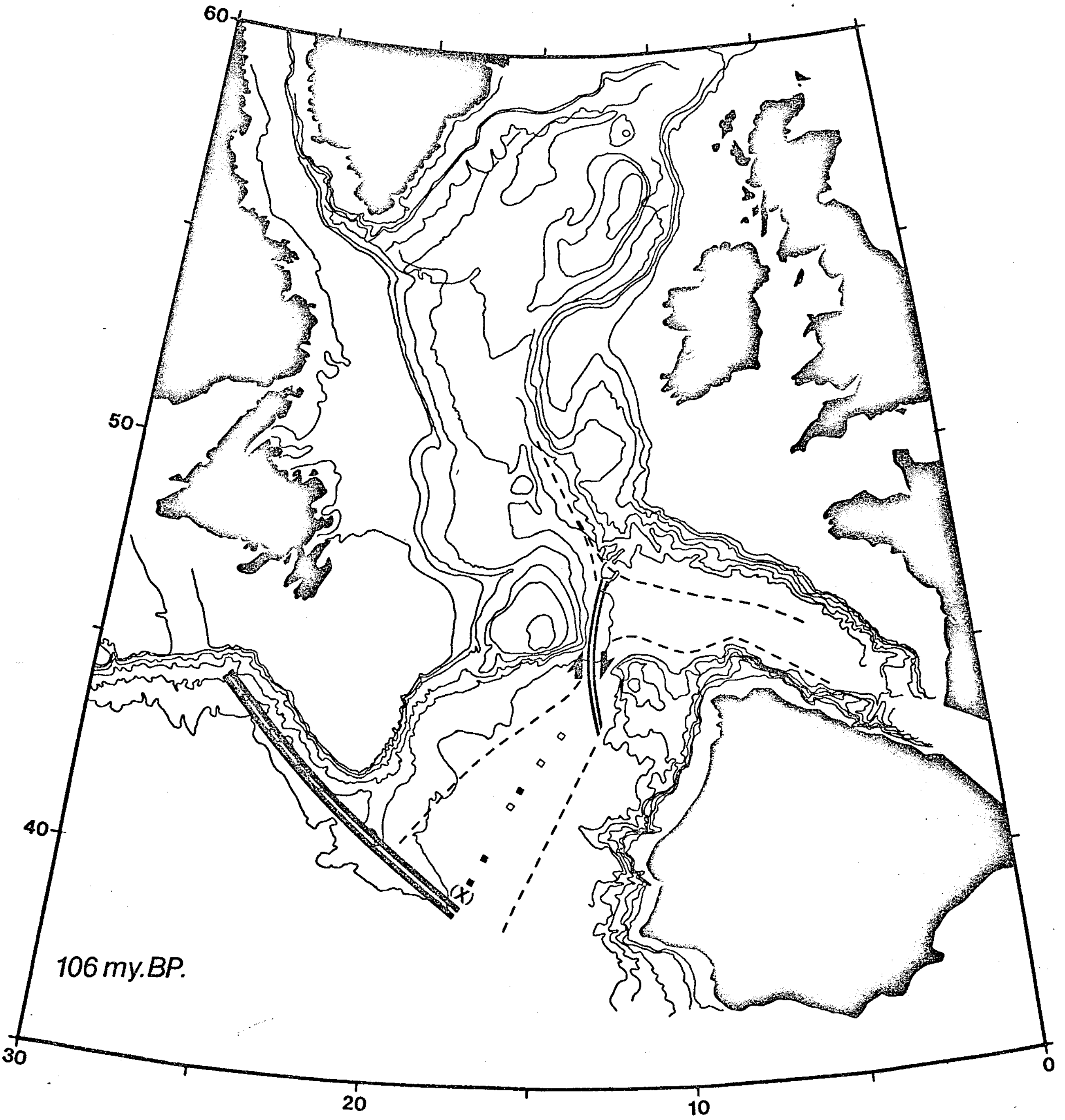
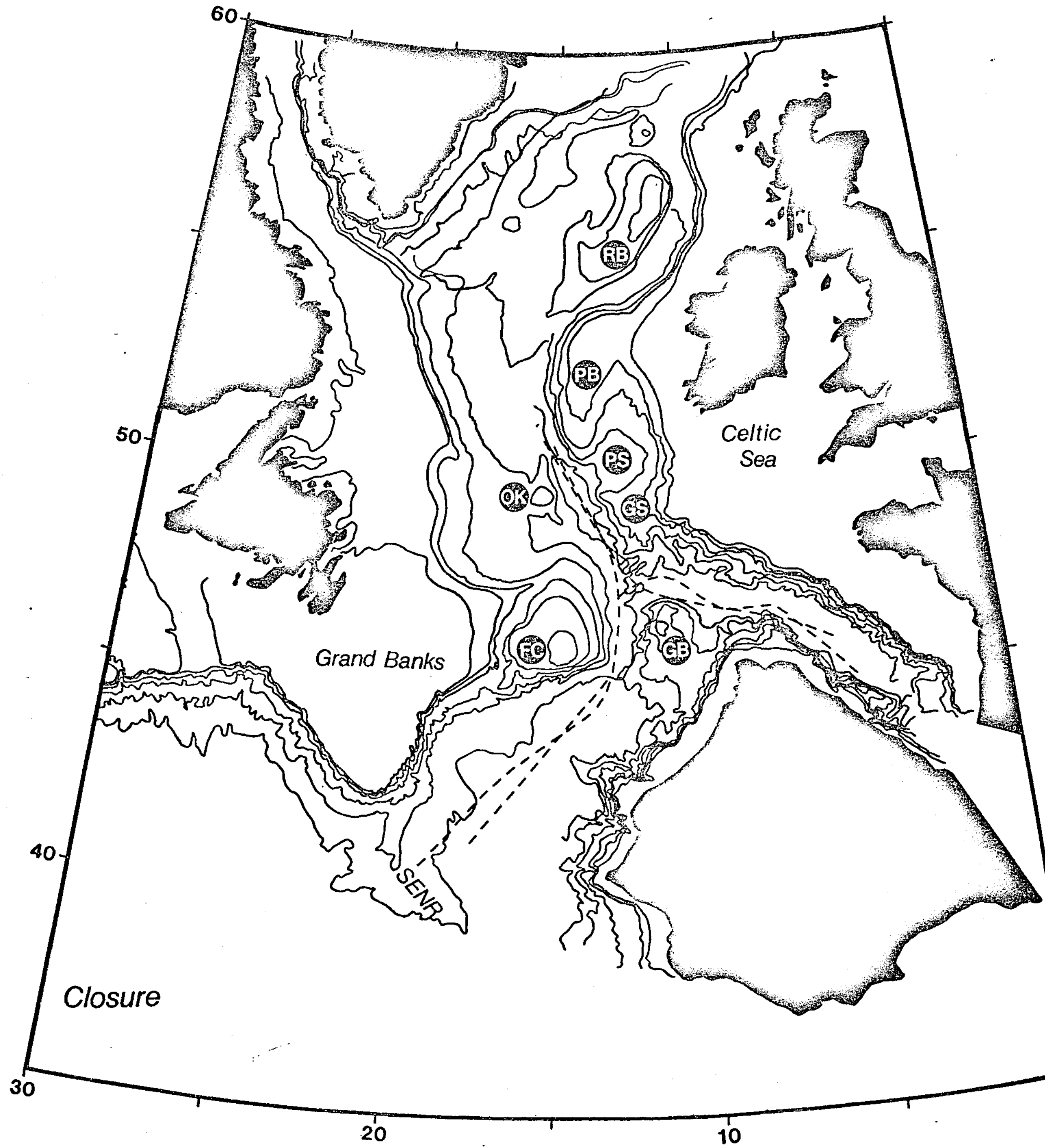


Fig. 7

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