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A New Free-Air Anomaly Map of the South-West Approaches Continental Margin, with comments on it's major features

D.G. Masson

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June 1982

NATURAL ENVIRONMENT RESEARCH COUNCIL

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Work carried out under contract to the Department of Energy

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Introduction

During the last twenty years, a large amount of gravity data has been collected over the continental margin to the south-west of the British Isles. A number of previous publications have discussed the gravity anomalies over small areas of the margin (e.g. Day and Williams, 1970; Gray and Stacey, 1970; Buckley and Bailey, 1975; Blundell, 1975; Scrutton, 1979) but only in two recent papers (Roberts *et al*., 1981 and Lalaut *et*. *al*., 1981) has a compilation of available data for a larger area been presented. Neither of these latter two anomaly maps is entirely satisfactory. Much of the map published by Roberts *et al*., was created by merging together previously published contoured charts; no attempt was made to integrate geographically overlapping data sets; the map of Lalaut *et al*., which covers the continental margin only south of 51°N, does not include a large amount of the data held at IOS.

A new free-air anomaly map has therefore been prepared by compiling all the available data and recontouring it.

Data Sources

IOS Data: R.R.S. Discovery Cruises 90, 91 and 93
R.R.S. Shackleton Cruises 6/76 and 6/79
M.V. Oil Hunter 1977

The M.V. Oil Hunter data was collected by S & A Geophysical Ltd. under contract to IOS during the shooting of a multichannel seismic survey (Continental Margin or CM Survey).

Other Data Sources

Cambridge University (Department of Geodesy and Geophysics, unpublished data; Day and Williams, 1970).

Edinburgh University (Shackleton cruises 5/76, 4/77 and 3/79; Scrutton, 1979 and unpublished data).

Marine Science Laboratories, Menai Bridge, N. Wales (H.M.S. Hecla and R.R.S. Challenger, 1973; Buckley and Bailey, 1975).

University of Durham (R.R.S. Discovery, September, 1966; Gray and Stacey, 1970).

Hydrographic Department (M.O.D.) (unpublished data)

Data Compilation

With the exception of the unpublished data supplied by the Hydrographic Department (MOD), which is in the form of a contoured chart plotted at a scale of 1:1 million, IOS has obtained copies of all the above data in the form of free-air anomaly values plotted along track at a scale of 1:1 million. The Hydrographic Department chart covers an area bounded approximately by 48°and 51°N, and 7° and 11°W (figure 2). Within this area, the new anomaly map is largely derived from the Hydrographic Department chart, with only minor modifications due to more recent data. Over the remainder of the study area (figure 1, 2) the new map has been produced by compiling all the data and recontouring the resulting data base.

Reduction of Gravity Data

The majority of the gravity measurements used in the present compilation were made with respect to the International Gravity Standardisation Net 1971 (IGSN 1971) and reduced to free-air gravity anomaly values using the International Gravity Formula 1967 (IGF 1967), although some of the data recorded in the early and mid-1986s must certainly have been reduced to other standards. Unfortunately, the documentation of the reduction of this early data is difficult or even impossible to find, and accordingly, the required corrections cannot easily be calculated. Table 1 summarises the various combinations of reduction formulae which might have been used, and indicates the variations in anomaly values which would result.

The lack of documentation pertinent to the reduction of some early data can be compensated for by analysis of differences in free-air anomaly values observed at track cross-overs. Systematic cross-over errors would be expected to occur between data sets reduced to different base levels or using different reduction formula. Expected mean values of systematic cross-over errors should be 5, 9 or 14 mgals (table 1).

Cross-over Errors

Cross-over errors were analysed for all points where ship's tracks cross on the compiled data base, except for those where the crossing was highly oblique and thus the exact point of crossing difficult to determine. This exercise allowed systematic errors between the various surveys to be determined; the spread or the cross-over error values also allowed a minimum useful contour interval for the final chart to be chosen.

Only one significant systematic error was discovered, this being between the CM-survey and all the remaining data sets. These cross-over differences varied between 2 and 24 mgals (figure 3), with a mean of 10.98 mgals; the CM-survey gravity anomaly values were relatively lower in every case. At first, it was believed that this may have been related to the unusually high gravimeter drift observed during the acquisition of the data (43 mgals in 49 days; Tidelands Geophysical, 1978) but no obvious time related trends could be seen in the cross-over error magnitudes. A fixed error of -11 mgals was therefore assumed, and a correction of 11 mgals applied. Such a fixed error is relatively close to the calculated difference of -9.2 mgals which would arise if the IGF 1930 (rather than the IGF 1967) had been used in combination with the IGSN 1971 in the data reduction.

A re-examination of cross-over errors after this correction had been made showed that 90% of the values were under 10 mgals (figure 4) with a mean error of 4.5 mgals. The possible peak in cross-over errors at 14 mgals (Table 1) is clearly not present. Equally clearly, the accuracy of the data is not great enough to resolve the presence or absence of the remaining, 5 mgal, potential error (Table 1).

Many of the errors in excess of 10 mgals occurred in areas of high gravity gradient, and could therefore be accounted for in terms of relatively small navigational inaccuracies. Other relatively large cross-over errors are associated with the older data sets, to which cross-coupling corrections may not have been applied, and which relied largely on celestial and dead-reckoning naviation. Day and Williams (1970) and Gray and Stacey (1970) have shown that the mean cross-over error in such surveys was in the order of 10 mgals.

As one might expect, cross-over errors between lines from different surveys tend to be greater than those between lines from the same survey. Overall, it was considered reasonable to use a 10 mgal contour interval.

Discussion: major features of the gravity anomaly map

On a regional scale, the relatively shallow areas of Porcupine Bank and the Goban Spur are associated with broad areas of large positive gravity anomalies (compare figures 1 and 2), bounded oceanward by steep anomaly gradients. Steep anomaly gradients also occur along the North Biscay continental slope. Over the remainder of the study area, the anomalies are generally smaller ($< \pm 40$ mgals) with relatively shallow gradients.

The NE-SW trending anomalies over the Celtic Sea reflect the structural grain in this area (Robinson *et al.*, 1981). Two NE-SW orientated gravity minima in this area

(AA′, figure 2) represent the Haig Fras and Cornubian granite trends. The recent dredging of Hercynian granites from the southern edge of the Goban Spur (Auffret et al., 1979) may indicate that the two granite trends extend to the edge of the continent, but this is not obvious from the gravity map.

Three isolated gravity highs (>60 mgals), all associated with prominent magnetic anomalies (Roberts and Jones, 1979), occur at the edge of the continental shelf (B, figure 2). These may be an indication of buried basic igneous bodies of unknown age (Segoufin, 1975).

The deep sedimentary basin underlying the Porcupine Seabight (figure 1) is marked, in general, by a gravity low relative to the surrounding area. However, two distinct gravity anomaly provinces can be defined within this basin, separated by a weak E-W trending gravity lineament at $51^{\circ}15'$ N. North of this line, the basin is dominated by an axial N-S trending elongate gravity maximum, which reaches +70 mgals (C, figure 2) superimposed on the general gravity low which marks the basin. This high, which is associated with a negative magnetic anomaly, has been modelled by Buckley and Bailey (1975). Their E-W models across the Seabight (figure 5) predict a zone of crustal thinning below the axis of the trough, although the steep gravity gradients observed on one profile at $51^{\circ}45'$N also necessitated the inclusion of a basic igneous body within the deepest sedimentary layers. Multichannel seismic reflection profiles across the Seabight do show evidence of an igneous body within pre-Albian strata; however, it is not coincident with the observed gravity high (as was stated by Roberts _et al_., 1981) and indeed has no obvious gravity anomaly signature (figure 2). IOS does not hold or have access to any multichannel seismic reflection data crossing the axial high modelled by Buckley and Bailey; their predicted occurrence of a relatively shallow (<5 km) igenous body cannot therefore be proven or disproven.

South of 51°15'N, the gravity field within the Seabight is relatively flat, and a broad gravity minimum reflects the deep sedimentary basin observed on seismic reflection profiles. E-W to ENE-WSW gravity trends at the southern end of the Seabight basin (D, figure 2) probably reflect basement trends in this area (Roberts _et al_., 1981, figure 8).

2-D gravity models are not conclusive as regards the deep structure underlying the Porcupine Seabight. All the published models (Buckley and Bailey, 1975; Bailey, 1975; Blundell, 1975) indicate substantial crustal thinning beneath the trough, with the zone of thinning broadening southward. However, the statement of Bailey (1975) that the trough is underlain by "quasi-oceanic crust" cannot be substantiated, since it could also be underlain by thinned continental crust.

To the west of the Porcupine Seabight, the Porcupine Bank is marked by a large gravity maximum (up to 80 mgals). This can be readily attributed to the effects of bathymetry (Buckley and Bailey, 1975) and gravity profiles across the Bank can be satisfactorily modelled using the bathymetry and assuming a crustal thickness of some 28 km (figure 5), as deduced from seismic refraction data by Whitmarsh et al., (1974).

The western edge of Porcupine Bank is marked by a steep gravity gradient flanked oceanward by a NW-SE trending linear negative anomaly, which can be traced southward for some 450 km, as far as 48°N (E, figure 2). Evidence from seismic reflection profiles and magnetic anomalies suggests that the outer edge of this linear negative anomaly coincides with the approximate position of the continent-ocean transition (Roberts et al., 1981). Near 49°N, a small NW-SE trending positive anomaly (F, figure 2) is superimposed on the oceanward edge of this linear negative. This is associated with a prominent negative magnetic anomaly, and corresponds to a region where the continent-ocean transition may be marked by a (? fault-bounded) escarpment (Roberts et al., 1981; figure 8). Recent IPOD drilling (Leg 80) has sampled basalt from the ridge immediately to the east of this escarpment. This confirms the gravity models of Scrutton (1979) who suggested that the ridge was basaltic in nature but does not resolve whether the ridge is oceanic in origin, or is composed of continental crust heavily intruded by basaltic dykes or buried beneath basic extrusive rocks.

Over the Goban Spur, gravity anomalies trend predominantly NW-SE, reflecting the underlying fault controlled basement topography (figure 5 of this paper and Roberts et al., 1981, figures 7, 8). This is particularly noticeable on the southern flank of the Spur, where the basement structure has profoundly influenced the morphology of the margin in addition to the gravity anomaly pattern (figures 1 and 2). Here, elongate gravity maxima (G, figure 2), which mark the structural and bathymetric highs of the Granite Cliff and Austell Spur, are separated by gravity minima (H, figure 2) which coincide with King Arthur and Whittard Canyons.

Further to the east, the gravity anomaly map precisely defines the shape of the Meriadzek Terrace (figure 1), a bathymetric high again underlain by a basement block. Oceanward of the Meriadzek Terrace, the continent-ocean transition is marked by a steep gravity gradient at the southern edge of Trevelyan Escarpment (figures 1, 2). The Escarpment itself is marked by a linear E-W trending gravity anomaly (I, figure 2). The westward extent of this anomaly may mark the western limit of the area affected by the Late Eocene compressive movement which apparently formed the escarpment (Montadert, Roberts et al., 1979) since seismic reflection profiles across the area of the anomaly show clear evidence of deformation affecting sediments as young as Eocene in age, while profiles further west do not.

Little can be deduced from the gravity anomaly patterns over the ocean basins adjacent to the margin. Low-amplitude anomalies parallel to the margin and parallel to the isochrons in the oceanic crust appear to characterise the area west of Goban Spur (figure 2). A broad negative anomaly occurs over oceanic crust seaward of the Trevelyan Escarpment, and a large (50 mgal) positive anomaly over the Armorican Seamount (J, figure 2).

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I would like to thank T.J.G. Francis, P.R. Miles and R.B. Whitmarsh for reviewing the manuscript and suggesting a number of ways in which it could be improved.

Table 1

Variation in free-air anomaly value according to reduction procedure used (all values are for latitude 50°)

Reduction Method	Anomaly Difference (mgals) relative to IGF 1967 + IGSN 1971	
	Value given by IAG (1967)	Value given by Woollard and Godley (1980)
IGF 1967 + IGSN 1971	-	-
IGF 1967 + Potsdam	+14	+14.7
IGF 1930 + IGSN 1971	-9.2	-9.17
IGF 1930 + Potsdam	+4.8	+5.53

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Figure Captions

Figure 1: Bathymetry of South-West Approaches Continental Margin. Contour interval 400m.

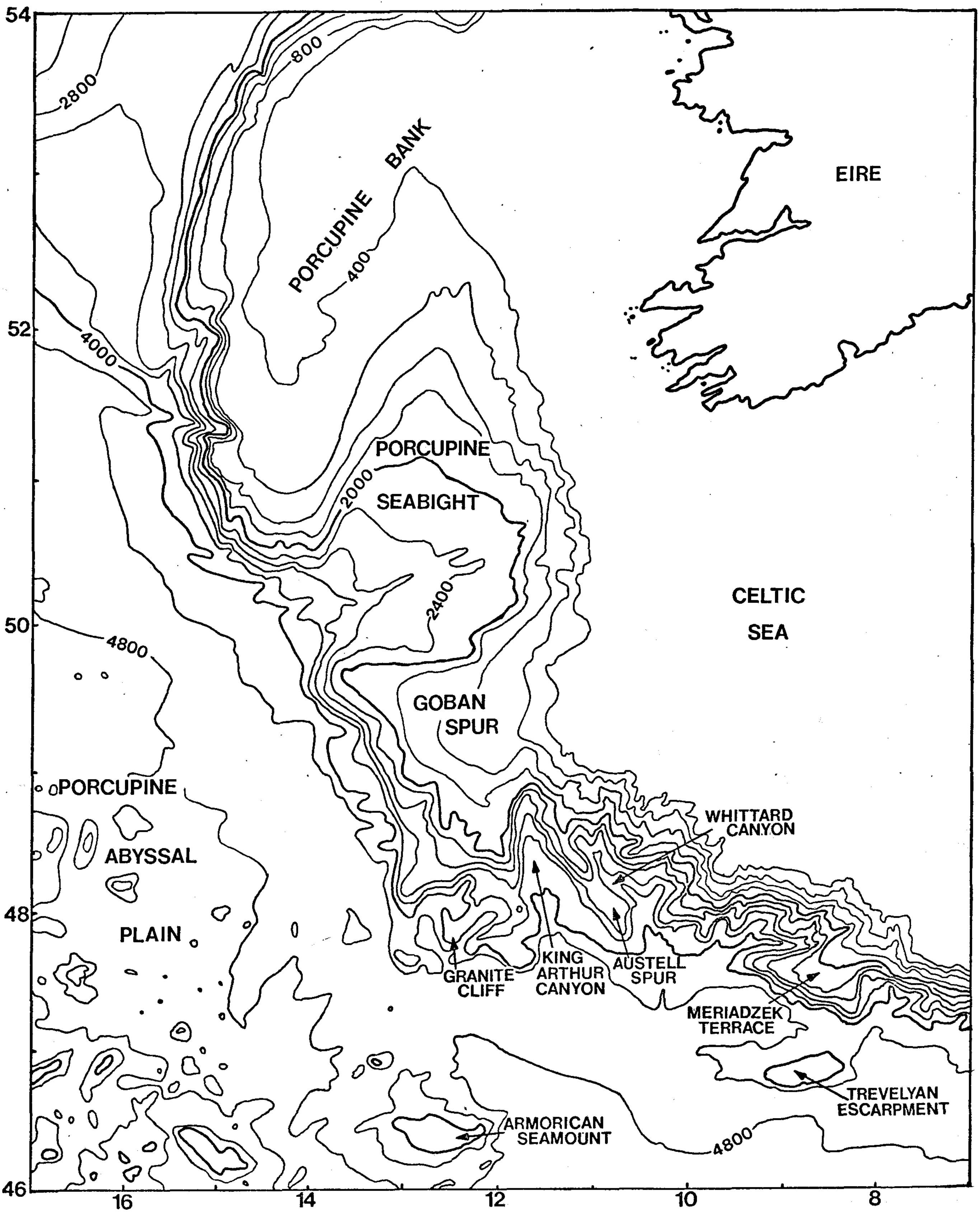
Figure 2 (see rear pocket): Free-air gravity anomaly map of the South-West Approaches Continental Margin (covers same area as figure 1). Contour interval 10 mgals. Ship's tracks shown by dotted lines. Lower case letters indicate sections illustrated in figure 5. Upper case letters mark features referred to in the text. Stippled area in the Porcupine Seabight indicates extent of extrusive (or? intrusive) igneous body seen on multichannel seismic reflection records. Box outlined by heavy line at the S.W. corner of figure is the area of the Hydrographic Department (MOD) contoured chart.

Figure 3: Histogram of cross-over errors between CM-survey and all other surveys.

Figure 4: Histogram of all cross-over errors after correction of the CM-survey.

Figure 5: (a) and (b). Two-dimensional gravity models across the Porcupine Seabight (from Buckley and Bailey, 1975). Solid profiles are observed free-air gravity anomalies, dotted profile are calculated anomalies corresponding to the models. Densities used in the model are in gm/cm . Profiles located in figure 2. C marks axial gravity high indicated on figure 2.

(c). Free-air anomaly profile (above) and interpreted multichannel seismic reflection profile (below) across the Goban Spur Continental Margin (unpublished IOS data). Profile located in figure 2. Note the broad correspondence between basement highs and gravity anomaly maxima. Arrow marks the approximate position of the continent-ocean transition. F marks gravity high indicated on figure 2.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52
50
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14
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8
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EIRE
PORCUPINE
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CELTIC
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GOBAN
SPUR
PORCUPINE
ABYSSAL
PLAIN
WHITTARD
CANYON
GRANITE
CLIFF
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ARTHUR
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TERRACE
TREVELYAN
ESCARPMENT
ARMORICAN
SEAMOUNT

FIG. 1

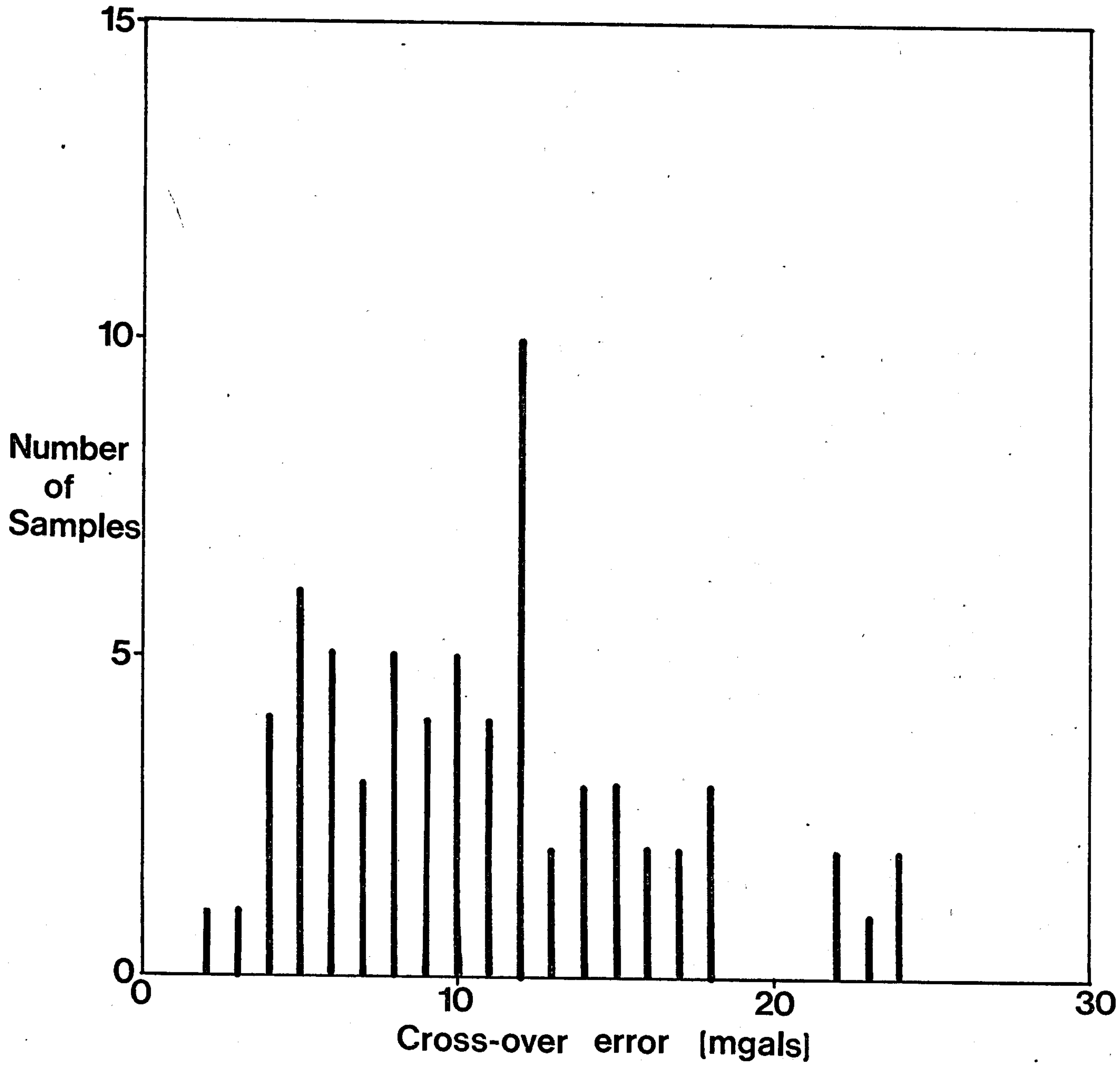
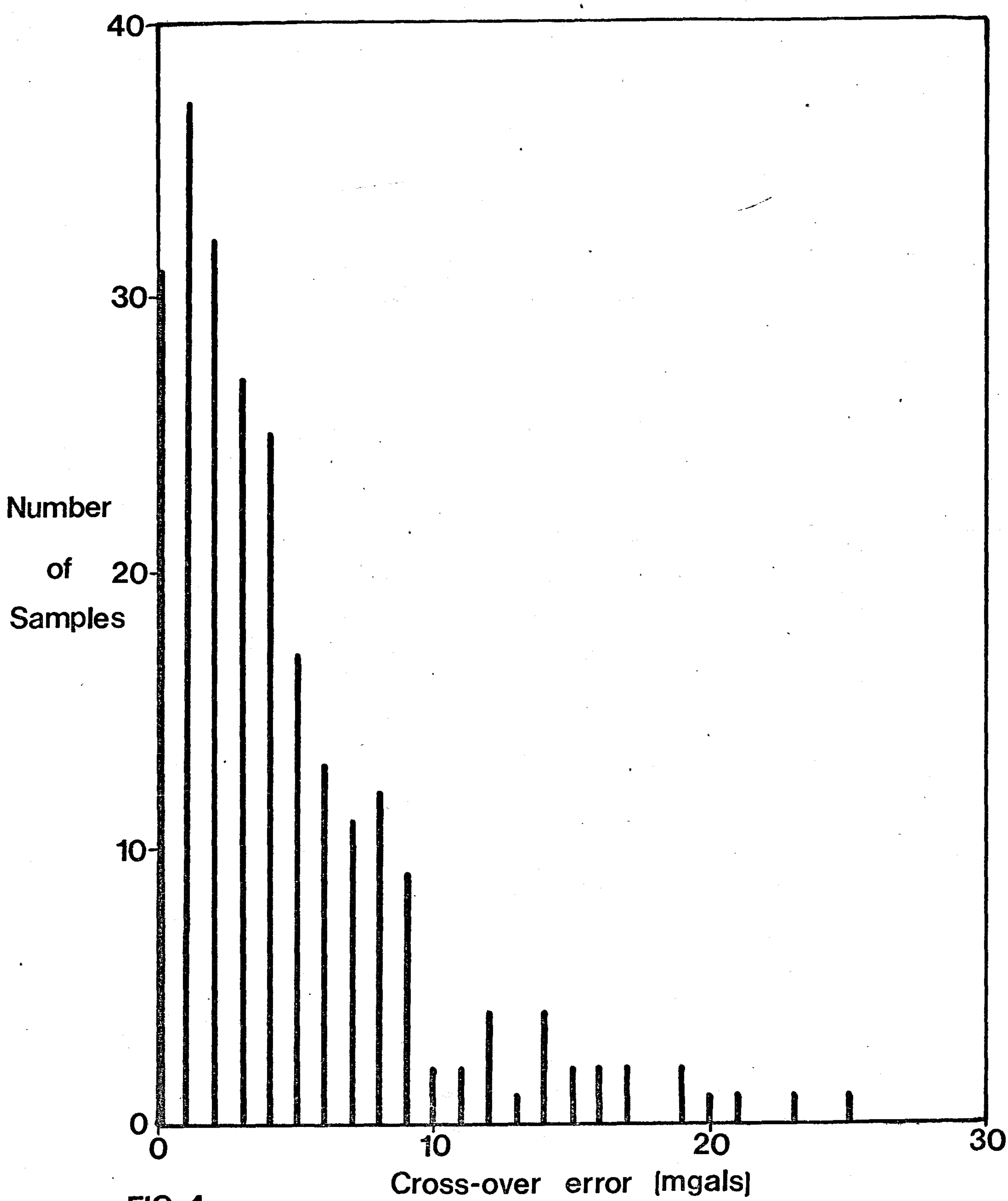


FIG. 3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10
0
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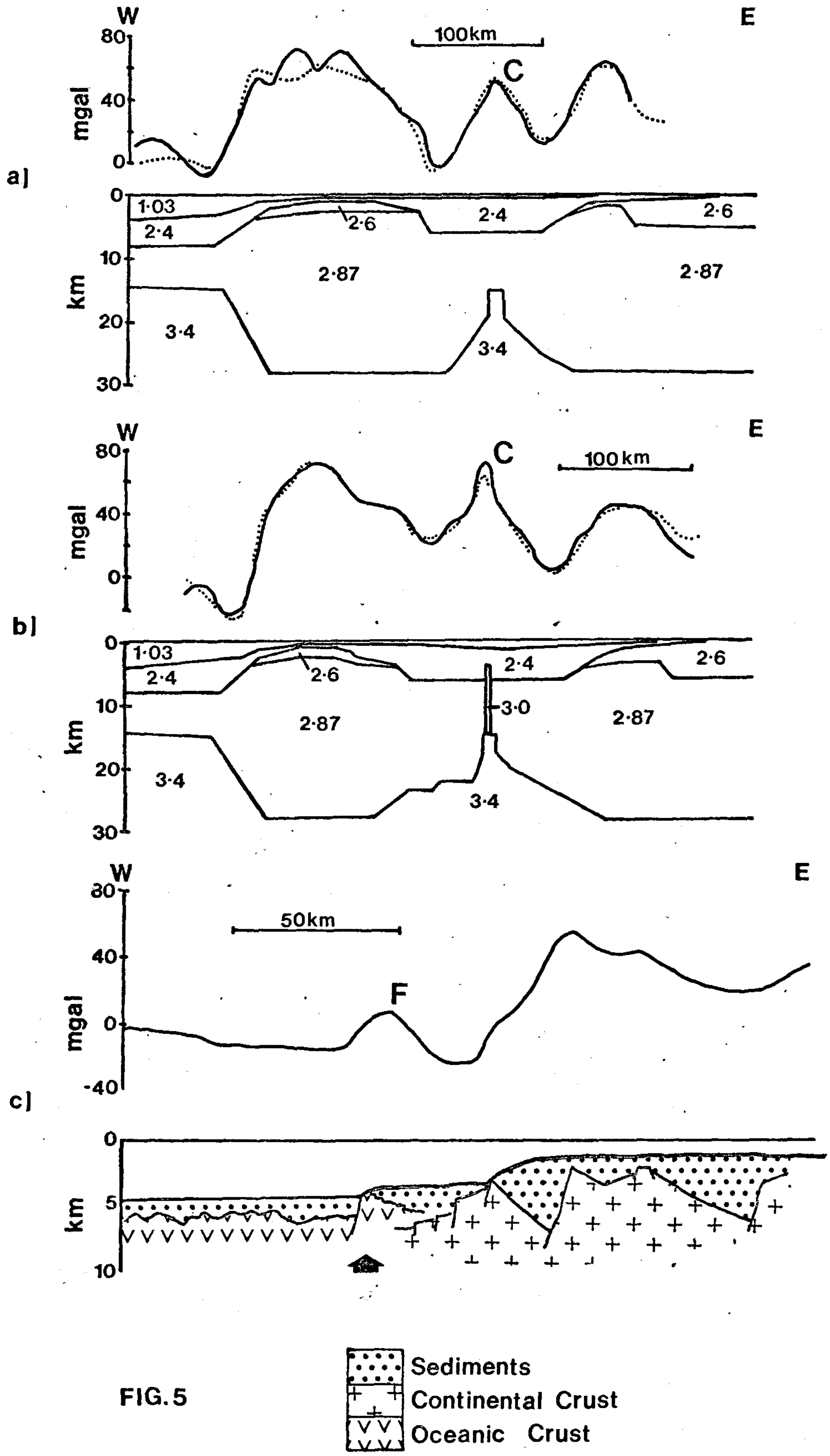
10
20
30
Cross-over error (mgals)
FIG. 4



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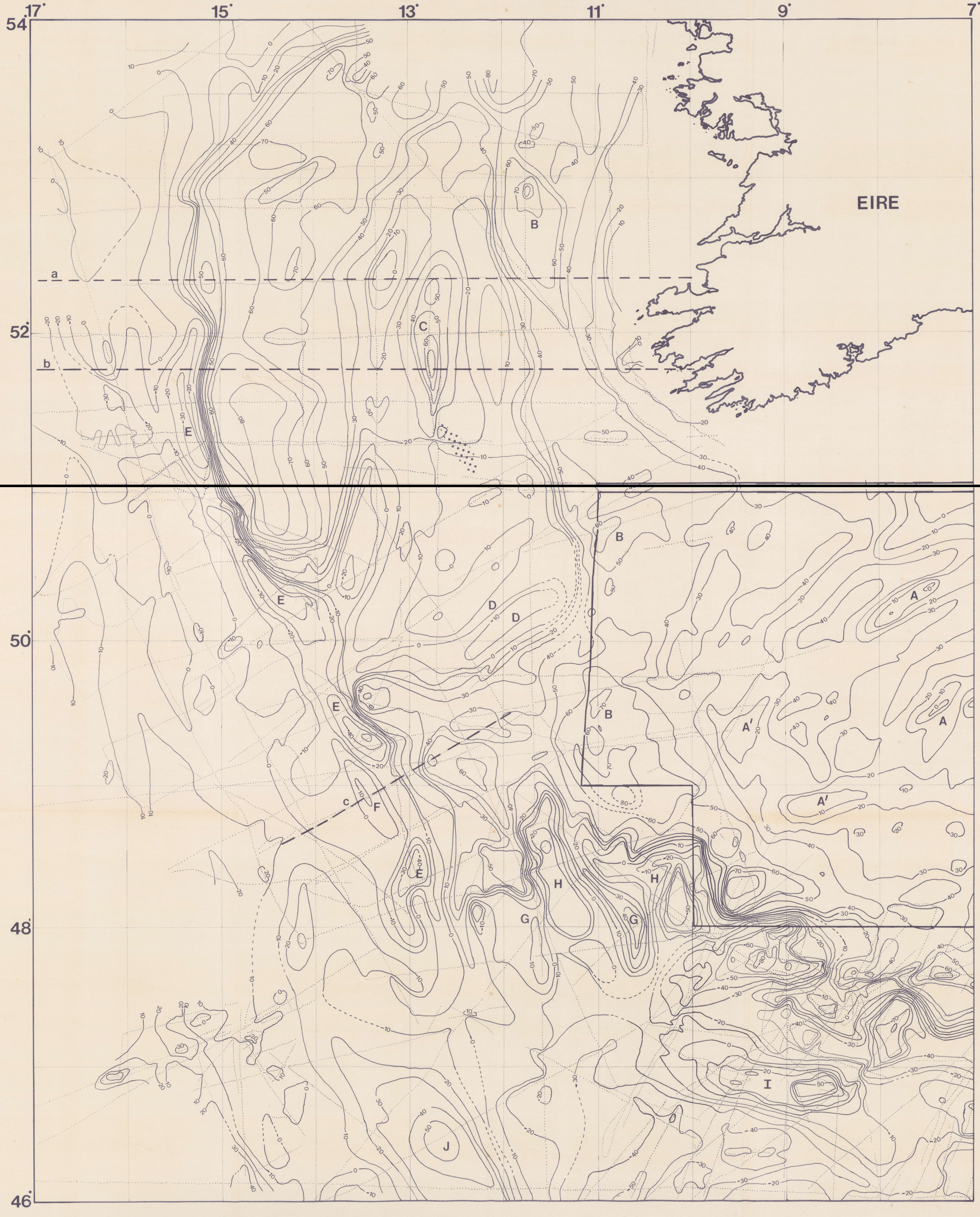
Sediments
Continental Crust
Oceanic Crust

FIG.5



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