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FREE-AIR GRAVITY ANOMALY OF THE EASTERN GRAND BANKS OF NEWFOUNDLAND

P.R. Miles

Internal Document No. 190

September 1983

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

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INTRODUCTION

The Institute of Oceanographic Sciences (IOS) has undertaken three geophysical surveys over the eastern Grand Banks continental margin. A shipboard gravimeter was operated on all these cruises and a compilation of the data has been merged with the Natural Resource map series of Atlantic offshore Canada (Canadian Hydrographic Service, 1974). The resultant chart, in two sheets, covers the east Grand Banks continental margin east of 50°W at a scale of 1:1,000,000.

Figure 1 shows the general bathymetry of the region and outlines the area covered by this report. The area consists of both rifted and transform type margins; with the continental fragments of Flemish Cap and Orphan Knoll forming major bathymetric features. Rifted margins lie adjacent to the Newfoundland Basin and north of Flemish Cap, while transform margins are present east of Flemish Cap and south of the Grand Banks (Haworth & Keen, 1979; Keen and Barrett, 1981; Miles & Masson, in prep.; Sullivan, 1983). Relatively deep water basins, Flemish Pass and Orphan Basin, lie between the continental fragments and adjacent continental shelves. Seismic refraction studies show these basins to be two areas of deeply subsided continental crust characterised by extensive crustal thinning (Keen and Barrett, 1981). Masson and Miles (in prep.) propose that the Newfoundland Basin has the oldest rifted margin in this region formed by a propagating rift which migrated northwards from the SE Newfoundland Ridge between Hauterivian time (118 Ma, magnetic anomaly M4) and the lowermost Aptian (112 Ma, anomaly M0) using the timescale of Kennedy and Odin (1982). The sea-floor spreading centre is interpreted to have terminated at a transform boundary separating Flemish Cap and Galicia Bank (Iberia) to the east.

DATA SOURCES

Two major sources of data have been used in the preparation of these charts:

(1) Unpublished survey data from the following IOS cruises: Starella 1/79, Farnella 1 + 2/81 and Discovery 111. These data were compiled at 1:1,000,000 during the cruises.

(2) Published contour maps: Twenty-one sheets from the Canadian 1:250,000 free-air gravity natural resource maps (Canadian Hydrographic Service, 1974;

Haworth, 1974; Haworth and McIntyre, 1975).

Figure 2 shows the combined IOS tracks and areal coverage of the Natural Resource maps. The Canadian data, being part of an extensive survey of offshore eastern Canada, are primarily confined to the shelf areas and do not extend to Orphan Knoll or out into the Newfoundland Basin (Figure 3). Figure 3 also shows that the 1 x 2 deg. sheet coverage for the area of this report, identified by the Marsden subsquare notation.

The merging of these two data sets provides a continuous measurement of the free-air gravity field across the eastern Grand Banks margin.

DATA REDUCTION

All IOS gravity data were tied to the International Gravity Standardization Net 1971 (IGSN71, IAG, 1971a) using land gravimeter connections togravity base stations at Hull (UK), St. Johns (Newfoundland) and Bedford Institute of Oceanography (Halifax, Nova Scotia). The IOS data were reduced to the 1967 International Geodetic Reference System GRS 1967 (IAG, 1971b). With the exception of two sheets (marked * in Figure 3), the Canadian data were tied to the Potsdam system and reduced to the earlier GRS 1930 (IAG, 1971b). To transform the Canadian data into values compatible with the IOS data set, the Natural Resource maps were recontoured during reduction from 1:250,000 to 1:1,000,000 after the addition of 6.5 mgal. (IAG, 1971b).

DATA ACCURACY

The accuracy of marine gravity measurements is limited by the accuracy of the ship navigation mainly because the Eotvos correction, which is dependent on the position, course and speed of the ship, is very sensitive to small errors. In addition, the IOS data were not corrected for gravimeter drift, which on the Farnella cruise rose to 0.25 milligal per day.

The consistency of the data can be assessed from the comparison of measured values at track cross-over points. The Canadian data have a root mean square cross-over error of 3.30 milligals for the whole map series (Haworth, 1974), consistent with a contour interval of 5 milligals. The IOS data had 33 cross-over points of which 4 were used to tie in a poorly constrained Starella track over Orphan Knoll and another 5 were excluded from the statistics owing to excessive errors introduced by course changes or high gravity gradients. The root mean square cross-over error for the remaining IOS data was 3.18 milligals.

FREE-AIR ANOMALY CHARTS

The charts, inside back cover, are two sheets contoured at 10 milligal intervals at a scale of 1:1,000,000 at 46°N. Anomaly values at the foot of the continental slope, in Orphan Basin and on the shelf below minus 10 milligals are shaded for contrast.

1. General features of the gravity field at passive margins.

Free-air gravity anomalies at passive margins typically exhibit a linear belt of positive anomalies of 40 to 100 milligals approximately parallel to and bordering upon the shelf edge. At the foot of the continental slope there is generally a negative anomaly of 20 to 40 milligals. Examples of this type of free-air anomaly distribution can be seen on the Grand Banks sheets along the southern margin of Flemish Cap, the western margin of the Newfoundland Basin adjacent to Grand Bank, and to a lesser extent along the NE margin of Flemish Cap and Orphan Knoll. The change in nature of the anomaly at the eastern extremity of Flemish Cap (47°N, 43°W) may be indicative of the change from a rifted margin to the south of Flemish Cap and a transform margin to the east as proposed by Masson and Miles (in prep).

The characteristic passive margin free-air anomaly is caused by a combination of factors. These are (1) the edge effect derived from continental margin crustal thinning, (2) the marginal sediment wedge at the base of the continental slope, and (3) basement ridges near the edge of the shelf, although the latter may be of limited consequence along the Canadian margin (Keen and Hyndman, 1979). The contributions from both edge effect and sediment wedge will naturally be influenced by the amount and type of isostatic compensation in the area. The continental margins of eastern Canada are, in general, not in isostatic equilibrium (Keen and Hyndman, 1979; Keen and Barrett, 1981).

2. Flemish Pass and Orphan Basin

Seismic refraction studies by Keen and Barrett (1981) have shown that the crustal structure beneath Flemish Pass and Orphan Basin are similar even though the former shows a graben-like configuration physiographically very different from Orphan Basin. The deep crustal structure of these basins suggests that they both consist of stretched continental crust 20 to 22 km thick - about 60 per cent of the average continental crust thickness of 35km. Keen and Barrett (1981) propose that these crustal thicknesses may be generally representative of subsided continental crust near the ocean-continent boundary and cite the Hatton-Rockall Basin as an additional example. However, the question of an entirely non-oceanic origin of the latter remains an important aspect of North Atlantic tectonics. Gravity models across Orphan Basin to Orphan Knoll (Keen and Barrett, 1981) suggest that, unlike the outer shelf of the NE Grand Banks, Orphan Basin is isostatically compensated. Three large positive anomalies lie along the edge of the outer shelf adjacent to Orphan Basin and Flemish Pass. Haworth and MacIntyre (1975) suggest that these may be caused by an extension of the thin continental crust from Orphan Basin beneath the thick sediments of the shelf edge consequently generating a lack of isostatic equilibrium. This effect may also exist beneath the continental shelves farther north.

3. Flemish Cap and Orphan Knoll

Deep drilling has shown Orphan Knoll to be a continental fragment which subsided rapidly during the earliest Tertiary (Ruffman and Van Hinte, 1973). No direct measurement of the crustal thickness beneath Orphan Knoll is available but Keen and Barrett (1981) infer 25 to 28 km. South of Orphan Knoll the anomaly field is characterised by the effects of buried basement ridges, some trending parallel to the adjacent ocean-continent boundary, which extend to the eastern side of Flemish Cap. The northern 'intracontinental' margin of Flemish Cap has a lower gradient than the rifted margin on the southern side. Haworth and MacIntyre (1975) note that the Bouguer gravity anomaly centre is located some 50 km north of the area of high frequency magnetic anomalies associated with a shallow pre-Cambrian bedrock which suggests that the centre of the continental fragment is not coincident with the shallowest point. The western boundary of Flemish Cap shows a ridge of gravity coincident with a buried basement ridge extending north from Beothuk Knoll and associated with high magnetic anomalies.

4. Other features

The 100 milligal high on the northern side of the SE Newfoundland Ridge adjacent to the shelf edge (43°N, 49°W) may well correlate with the tectonic trend which runs parallel with the southern margin of the Grand Banks and diverts the trend of gravity and magnetic anomalies on the shelf. In the Newfoundland Basin a ridge of gravity trends northwards at 47°.5'W from the SE Newfoundland Ridge. The proposed magnetic J anomaly (Sullivan, 1983) lies immediately oceanward of this gravity high and, with possible significance, both terminate by latitude 45°5'N. This ridge may well be associated with the early formation of the Newfoundland Basin, proposed by Masson and Miles (in prep.), outlined in the introduction to this report. A small gravity ridge (approx. 70 milligals), which separates part of the northern Flemish Pass from Orphan Basin is the result of a depositional feature, Sackville Spur which extends NE from the outer shelf of the Grand Banks at 48°N 47°W. Finally, the prominent gravity low to the west of Flemish Pass in the NW corner of the south sheet of the accompanying charts is the northern end of the Jeanne d'Arc Basin on the eastern Grand Banks shelf. Borehole data from the southern end of this low has detailed over 2 km of Jurassic sediments (Amoco and Imperial Oil, 1974).

CONCLUDING REMARKS

Orphan Knoll is now widely accepted to be an isolated continental block adjacent to the ocean continent boundary. The gravity compilation over this feature presented in this report illustrates that additional work on the type and amount of isostatic compensation, crustal thickness and the relationship to the potential field distribtuion on the conjugate NE Atlantic margin can be recommended.

ACKNOWLEDGEMENTS

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FIGURE CAPTIONS

Figure 1. Regional setting showing the main bathymetry with the 200m and 1-4 km contours. The area covered by the gravity charts is outlined.

Figure 2. Track coverage. IOS tracks: 1-Starella 1/79; 2-Farnella 1 + 2/81, 3-Discovery 111 - Canadian data coverage stippled.

Figrue 3. Details of Canadian Hydrographic Service Natural Resource Map series covering the chart area. Sheets available to IOS at time of compilation are shown inside the double line. Sheets marked '*' are IGSN 71, 1967 spheroid.

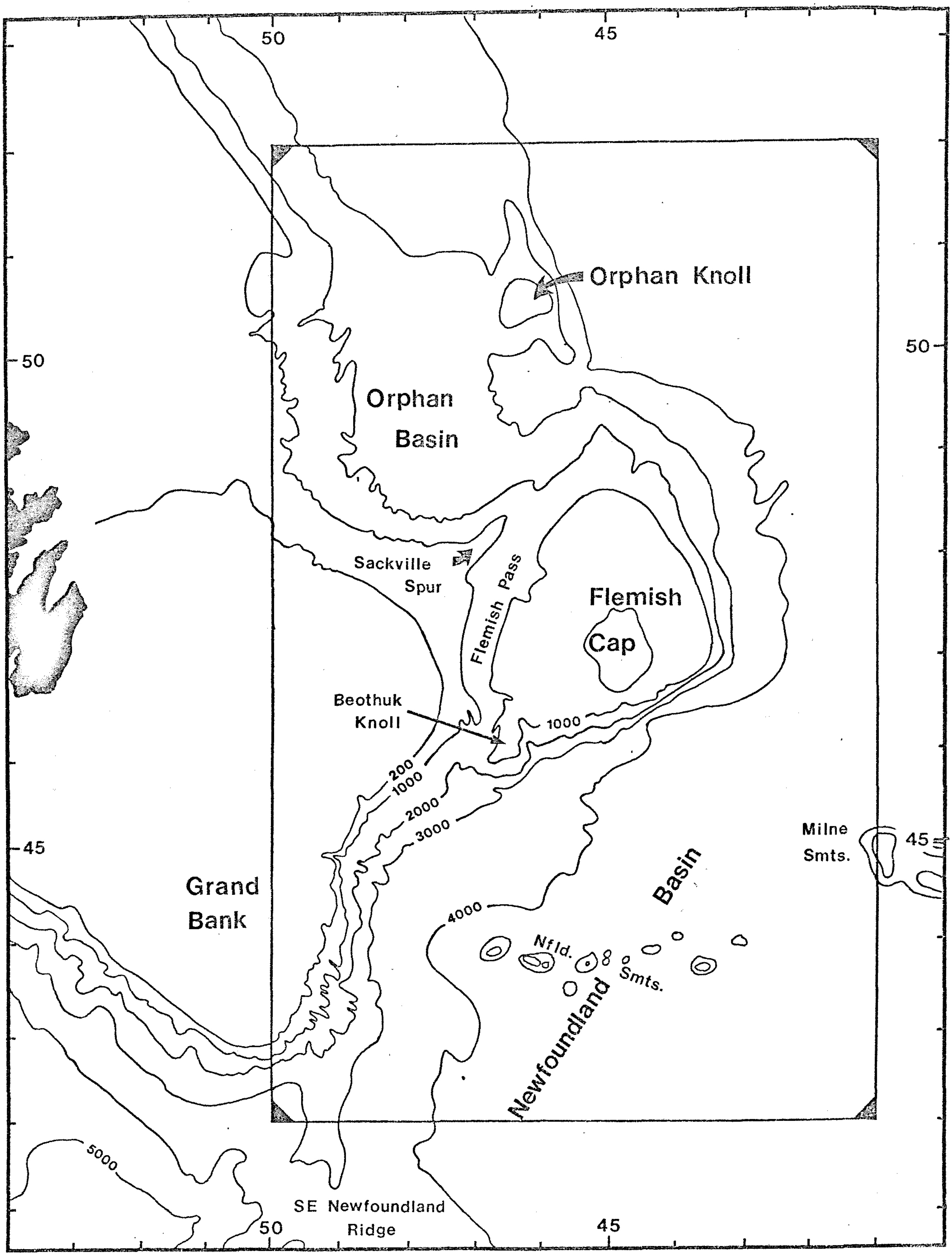
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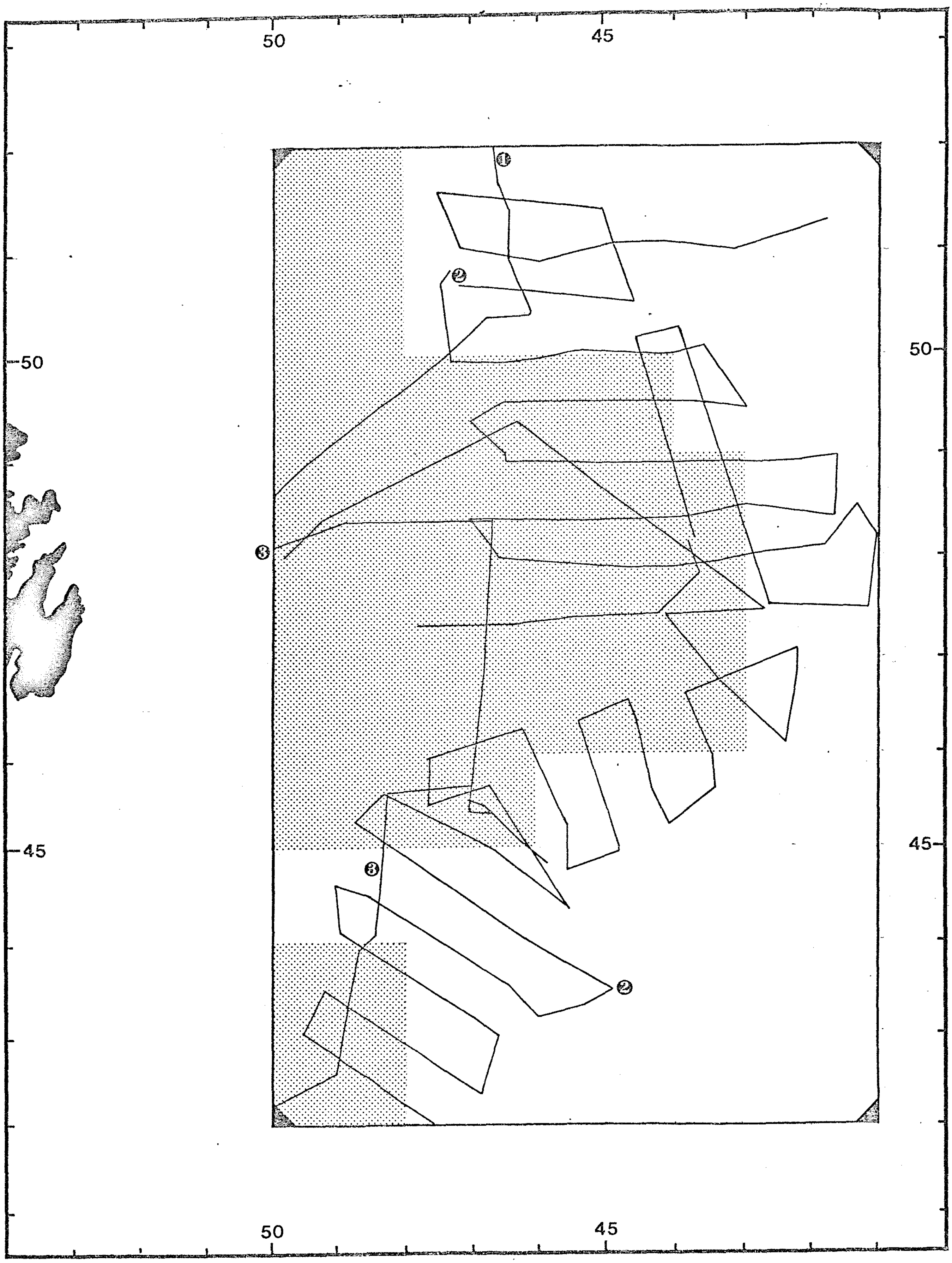
FIG 1



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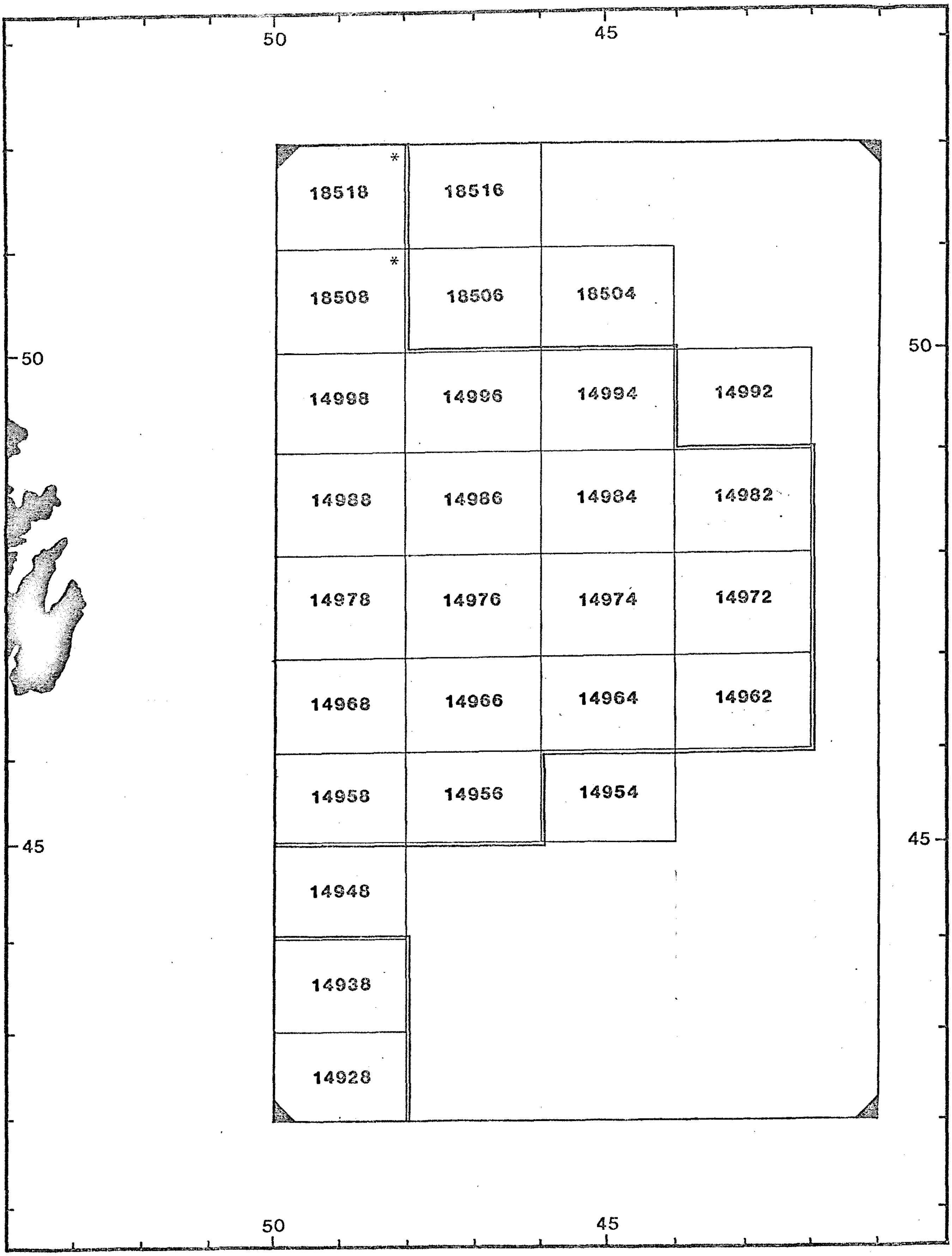
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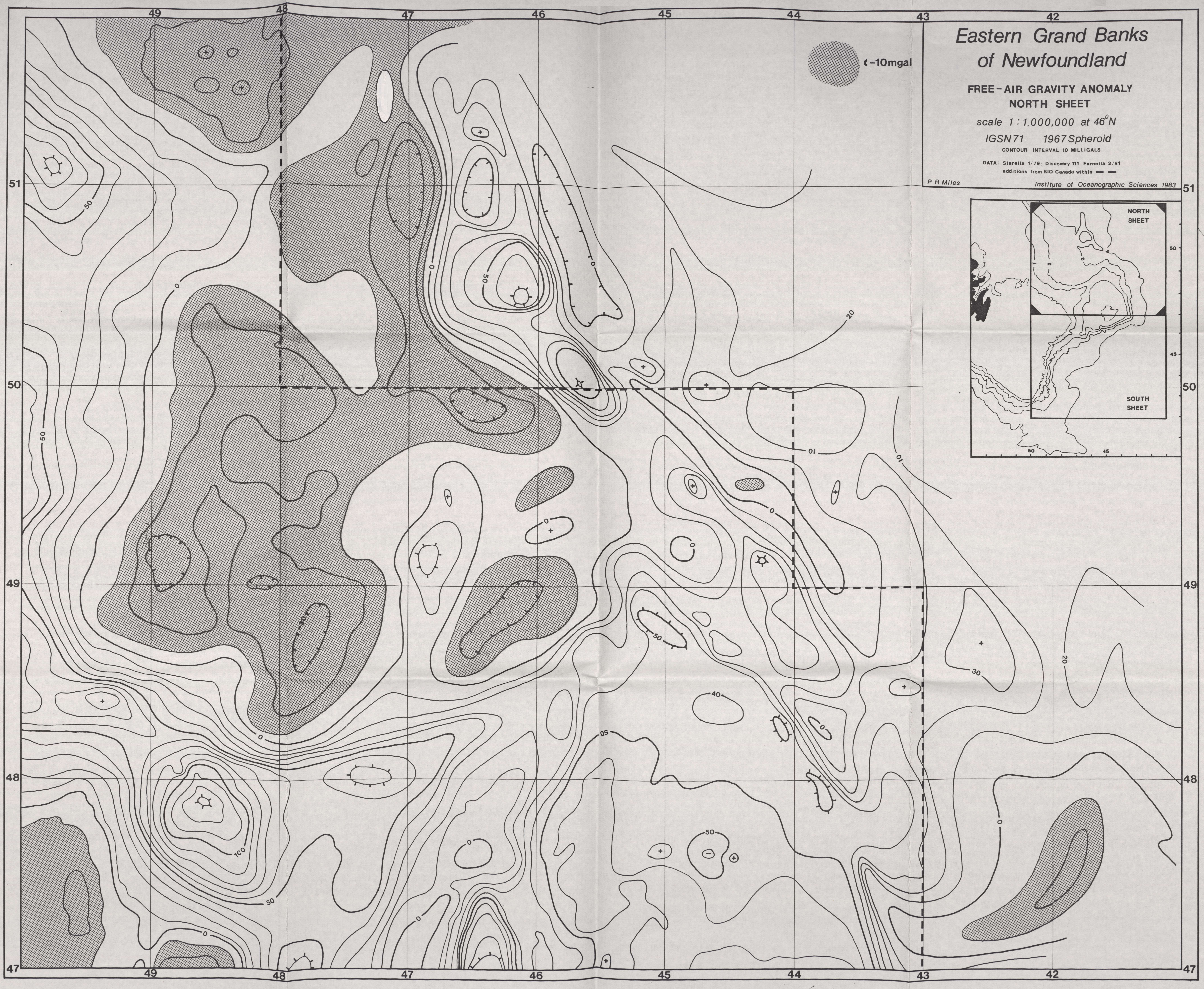
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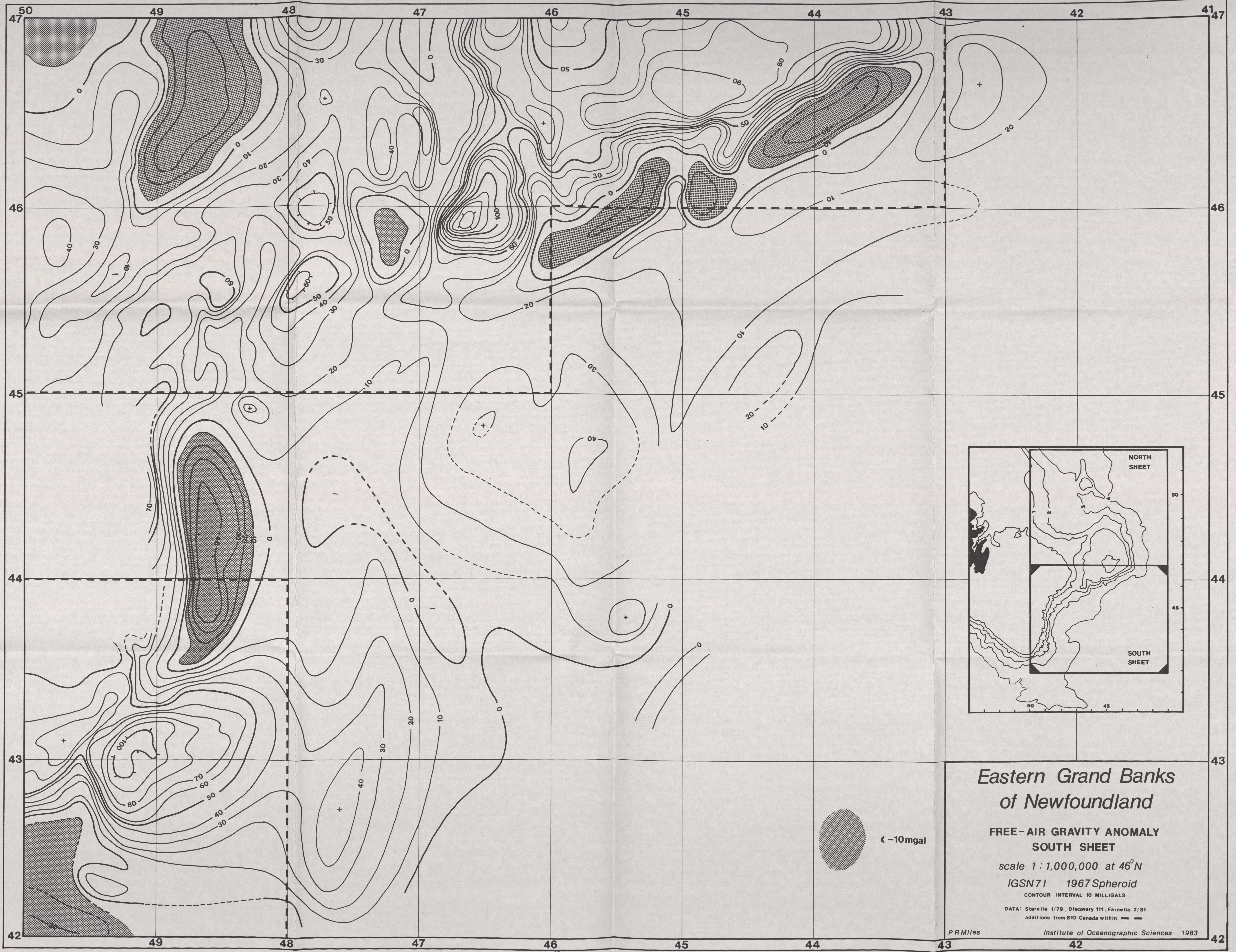
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