I.O.S.

A COMPILATION OF GEOPHYSICAL DATA ON THE EAST GREENLAND CONTINENTAL MARGIN AND ITS USE IN GRAVITY MODELLING ACROSS THE CONTINENT-OCEAN TRANSITION

BY
C.I. URUSKI AND L.M. PARSON

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INSTITUTE OF OCEANOGRAPHIC SCIENCES

INSTITUTE OF OCEANOGRAPHIC SCIENCES

Wormley, Godalming,
Surrey, GU8 5UB.
(0428 - 79 - 4141)

(Director: Dr. A.S. Laughton FRS)

Bidston Observatory,
Birkenhead,
Merseyside, L43 7RA.
(051 - 653 - 8633)

(Assistant Director: Dr. D.E. Cartwright FRS)

Crossway,
Taunton,
Somerset, TA1 2DW.
(0823 - 86211)

(Assistant Director: M.J. Tucker)

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WORMLEY

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C.I. Uruski* and L.M. Parson

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* *Present address:*

Department of Geology
Science Laboratories
University of Durham
South Road
DURHAM, DH1 3LE

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INTRODUCTION

The area discussed by this report covers the East Greenland continental margin from 58°N to 70°N, extending eastwards from the Greenland coast to 16°W in the north and 25°W in the south (Figs. 1 and 2). The geophysical data discussed comprise seismic reflection profiles, magnetic and gravity data from a variety of sources, resulting in a dataset of considerable size, but of varying quality and density (Figs. 3, 4; Table 1). For ease of presentation of the large volume of data, the study area has been divided into a southern and a northern part by the 65°N parallel, the two halves being referred to throughout as Area 1 and Area 2, respectively. All data have been compiled on Mercator projection charts at 1:1 million scale at a standard latitude of 65°N and reduced for presentation in this report. All available marine geophysical data between East Greenland and the presently-active Kolbeinsey-Iceland-Reykjanes spreading axis have been used to constrain three two-dimensional gravity models computed along ship's tracks approximately orthogonal to the East Greenland margin. The structure of the margin derived from the models across the continental margin in the southern area is compared with the more complex margin to the north of Denmark Strait.

GEOLOGICAL CONTEXT

The plate tectonic history of the region has been most recently summarised by Nunns (1983a). South of the Denmark Strait, Greenland separated from Rockall Plateau immediately prior to anomaly 24 time (early Eocene, 53 Ma on the timescale of Kennedy & Odin, 1982). Subsequent seafloor spreading formed a continuous sequence of magnetic anomalies up to the presently-active Reykjanes Ridge. Within the Denmark Strait, the shoal area separating East Greenland from Iceland, and in the ocean basin to the northwest and north of Iceland, the oldest oceanic magnetic anomalies are not easily identified. In the extreme southwest of Area 2, however, anomalies 24-20 can be speculatively extrapolated from Area 1, but elsewhere anomaly 6 or 6a (Miocene) is the oldest of the readily identifiable anomalies in the area. Larsen and Jacobsen (in Brooks & Nielsen, 1982) among others, have speculated that a failed rifting episode of approximately anomaly 24 age may have occurred as far north as Scoresby Sund (70°30'N, 23°00'W), although conclusive evidence for such a rift is still not available. In addition, Nunns (1983a, 1983b) has inferred the presence of a series of weak, fanning anomalies (20-12) in an area of equivocal magnetic signature bounded by the Denmark Strait, East Greenland coastline and the

Iceland-Greenland Rise. These anomalies he believes to have developed during an anti-clockwise rotation of the Jan Mayen Block between the middle Eocene and early Oligocene (Nunns, 1983b).

This paper concentrates on the earliest phase of continental rifting and seafloor spreading along the East Greenland margin. Magnetic anomalies have been used throughout to define the extent and age of oceanic crust, providing constraints on the position of the ocean-continent transition (OCT) used in the gravity models. Although the OCT zone in Area 1 has been established with some degree of confidence in this way, its precise position north of the Denmark Strait is uncertain because of the difficulties in interpreting anomaly patterns in that area.

MAGNETIC DATA

(a) Area 1 (Fig. 3)

South of the Denmark Strait, anomaly 24 can be readily recognised along much of the margin, for the most part exhibiting a characteristic 24A/24B double peak, although south of 59°N, the two peaks of the double anomaly converge. 24B is dated at approximately 56 Ma (latest Palaeocene of Kennedy & Odin, 1982) and the weakly sinuous trace of this anomaly records the approximate line of separation between this section of East Greenland and the Rockall Plateau, but, as will be demonstrated in later discussion, the precise line is far from firmly established. The identification of the younger magnetic anomalies to the east of 35°W has been recently summarised by Nunns (1983a) who used extensive marine and aeromagnetic datasets unavailable to the authors to establish an unequivocal oceanic fabric. The correlations made during the course of this compilation confirm and substantiate much of Nunns' work within and northeast of the Irminger Basin.

Anomaly traces of note include that of anomaly 13 (32 Ma) (Fig. 3) the offsets of which are interpreted as resulting from a series of oceanic fracture zones which may record changes in spreading rate and direction. A number of these proposed fracture zones correspond to those identified by Vogt et al. (1980) using aeromagnetic data. The position of Fracture Zone 1 is further supported by an offset on the gravity anomaly pattern (Fig. 5). The change in wavelength and amplitude of the anomaly pattern clearly seen on profiles around anomaly 19 may be related to a variation in spreading rate associated with the re-orientation of the spreading direction occurring to the north of the Denmark Strait referred to above. The position and significance of the earliest oceanic anomalies 24B and 24A are further discussed below with reference to the significance of dipping seismic reflector sequences observed at depth adjacent to the OCT.

(b) Area 2 (Fig. 4)

Correlations of pre-anomaly 6 magnetic anomalies in the northern study are more speculative than in Area 1. Early workers (Vogt et al., 1980) identified anomalies 20 and 21, although the correlations are barely recognisable north of the Denmark Strait (Fig. 4). The oldest seafloor spreading anomalies 24B/24A have been tentatively traced northwards to approximately 67°50'N, 30°00'W using a small number of profiles. Further northeast, over the continental shelf, the familiar long wavelength, oceanic-type anomalies are confused by a high-frequency waveform. These high-frequency anomalies increase in amplitude towards the coast and could arise from the presence of oceanic, transitional, or dyke-intruded continental crust at decreasing depth landwards (e.g. Larsen, 1978). It has been speculated that some form of oceanic-type crust exists close to or onshore at the East Greenland coast (unpublished GGU report, Greenland Geological Survey). Individual anomalies, however, are impossible to identify. Unlike Area 1, the location of the OCT north of the Denmark Strait using magnetic anomalies remains more uncertain. The significance of this to the gravity modelling is discussed below.

GRAVITY DATA

Contoured free-air gravity anomaly maps are presented on Figures 5 and 6. Some of the data were collected prior to 1971 and these values had to be reduced by 15 milligals to tie them into the IGSN '71 (Coron, 1973). Even so, some cross-over errors were large and several lines were excluded for this reason. Prior to 1971, automatic computation of cross-coupling errors was not in general use and corrections were done by hand. Inaccuracies resulting from this method of computation could easily exceed 10 milligals, but in general cross-over errors were less than 5 milligals.

(a) Area 1 (Fig. 5)

One of the most outstanding features of much of the southern study area is a narrow linear gravity high, locally exceeding 110 milligals and lying sub-parallel to and, for the most part, landward of the continental shelf edge. It is most easily recogniseable in Area 1, but extends northwards into the southern part of Area 2, and has a total length of nearly 500 km. To the south of Denmark Strait it is interrupted by several gravity lows or saddles, here tentatively related to sediment accumulations recognised at the shelf edge on seismic reflection data published by Johnson et al. (1975). North of 63°N, the marginal high broadens towards the Denmark Strait, and at about 63°50'N overlaps the oldest magnetic anomaly (24B) and thus the ocean-continent transition (OCT).

At 60°17'N, 41°00'W, the sharp easterly deflection of the 20, 30 and 40 milligal isogals cannot be correlated with a sediment accumulation. This offset is considered to locate the western end of Fracture Zone 1 (FZ1) identified in the ocean basin by offsets of the magnetic anomaly pattern (Fig. 3).

The free-air gravity anomaly throughout the main part of the Irminger Basin is characterised by very low gradients except for the ocean floor adjacent to the Reykjanes Ridge. Crust younger than anomaly 6, however, exhibits high-frequency variations in gravity anomaly, dominated by a general northeast-southwest linear fabric sub-parallel to the active spreading axis. The westerly jump of spreading ridge north of the Denmark Strait from the Aegir axis to the position of the presently-active Kolbeinsey Ridge may be responsible for a change in sediment supply and thus gravity signature.

(b) Area 2 (Fig. 6)

In the extreme south of Area 2, the broadening linear gravity high traced northeastwards from Area 1 becomes less recogniseable and cannot be traced beyond the junction of the Greenland-Iceland Rise and the Denmark Strait at around 65°50'N, 35°00'W. Gravity values over the Strait itself show little variation and a negligible regional gradient - a pattern closely resembling that of the Iceland-Faeroes Ridge to the east of Iceland (Fleischer, 1971). Further north, a comparable gravity high lies along the Blosseville shelf edge at around 68°40'N, 24°W, sub-parallel to the oceanic anomalies 24-20 immediately to the south. In contrast to the anomaly mapped in Area 1, it is less continuous and of smaller amplitude, peaking at around 60 milligals. Between 67°45'N, 31°00'W and 68°10'N, 28°50'W, a further discrete linear gravity high of similar amplitude but much shallower gradient strikes approximately ENE immediately adjacent to the coast, and is separated from the more oceanward high by a trough with a value of less than 10 milligals. If the proposed OCT position in this area (Brooks & Neilsen, 1982) is correct, then the more landward of these two highs could originate from an OCT crustal density contrast (the so-called 'edge' effect) while the more oceanward high could be related to sediment loading or basement structure. Immediately east and south of the outer gravity high, the ocean basin is characterised by a relatively smooth gravity field with anomaly values just below zero milligals along its axis. Ocean floor younger than Miocene age (anomaly 6), however, again presents a more irregular gravity field in the east with discontinuous gravity highs locally peaking at values in excess of 70 milligals. Fracture zones identified by Vogt et al. (1980) truncate the linear anomalies which derive from the spreading fabric and the line of the presently-active Kolbeinsey Ridge.

SEISMIC REFLECTION DATA

More than 1000 km of 12-channel seismic reflection data, collected by Durham University and processed by the Western Geophysical Company of America under an IOS/DEn contract, have provided seismic coverage on the continental margin to the north and south of Denmark Strait. These data, coupled with several thousand kilometres of single-channel data collected by other institutions (see Table 1) have been used in the compilations presented here.

Sequence boundaries have been traced as either angular seismo-stratigraphic unconformities or sharp junctions between units of contrasting seismic character. Several such boundaries may be followed over much of the area, but three are of particular interest. Two of these horizons, U and E, lie within the post-rift sedimentary section, which locally exceeds three seconds two-way time (TWT) in thickness, and represent unconformities suggested to be correlatable with regional North Atlantic seismostratigraphic events discussed below. The third and lowest event, B, is seen as a widespread high-amplitude reflector at the base of the unequivocally sedimentary sequence. It was formerly considered to be 'acoustic' basement, but is now known to overly at depth a thick sequence of "dipping reflectors" of the kind recently discussed by Mutter et al. (1982), among others. The event B is now regarded, at least in part, as a broadly diachronous horizon evolving both during the break-up and earlier rifting phases as well as the subsequent early oceanic spreading history. It is discussed here in some detail because of its importance not only to the evolution of the East Greenland margin, but also to similar passive continental margins throughout the world.

(a) Basement and Reflector B

A prominent seismic reflector lies at the base of an assumed sedimentary sequence recognisably stratified throughout the survey area, extending beneath much of the outer shelf continental slope and rise and the landward parts of the ocean basin (Figs. 7-11). In most early seismic profiles, it marked the level of acoustic basement (Johnson et al., 1975), although more modern processing reveals the deep (dipping) reflector sequences (Figs. 8-11). Early workers (Featherstone, 1976; Featherstone et al., 1977) referred to this surface as 'B' and, although they recognised a suite of oceanward-dipping sub-B reflectors, they were unable to assess their attitude at depth in the section. They speculated that these reflectors formed part of a sequence of synrift sediments floored by an unresolved basement of unknown composition, surmised to be of stretched and thinned continental crust.

Following the recognition of similar dipping reflector sequences (DRS) on many passive margins throughout the world (Talwani & Eldholm, 1972; Roberts et al., 1979; Hinz, 1981) it is now widely believed that the DRS are predominantly of volcanic origin and are thought to consist to a large extent of initially subaerial basaltic lava flows. On profiles A and B, well-developed sequences of these reflectors may be recognised up to 1.5 seconds two-way time (TWT) below the level of B (Figs. 7-11). Elsewhere within Area 1, single-channel seismic records indicate that these dipping horizons continue eastwards onto oceanic crust at least as far as anomaly 19 in places (unpublished seismic profiles; pers. comm., Bezart, CNEXO). Within oceanic crust, therefore, the top of the DRS coincides with the top of oceanic layer 2. The character of reflector B appears to change as a function of its distance from the shelf break, being a relatively smooth surface adjacent to unequivocal continental crust, and locally becoming uneven where it marks the top of oceanic crust (Fig. 10).

Over oceanic crust, the sub-B reflectors may be horizontal or may even have a landward dip resulting in apparently open anti-formal structures within the sub-B sequence (Figs. 10, 11). In profile A (Fig. 9), reflector B may be traced landwards onto undoubted continental crust, shallowing beneath the clearly stratified post-rift sediments of the continental shelf. Reflector B and the immediately underlying horizons eventually outcrop as a series of westward-facing scarps at around 64°30'N, 38°10'W (at the western end, Fig. 9). The magnetic anomaly pattern over this area of outcrop is complex, and although the topographic expression of the scarps is too severe to correspond to individual lava flows, convincing comparisons of their profiles can be made with stacked subaerial lava sheets.

(i) Sub-B reflectors: Area 1

South of Denmark Strait, the most striking examples of sub-B reflectors are confined to the area interpreted as thinned continental crust lying to the south of 63°N and west of anomaly 24B between 61°N and 63°N. Here, magnetic anomalies are typically of long wavelength and low amplitude and cannot be correlated between adjacent survey lines. To the south of 61°N, high frequency anomalies predominate, possibly as an effect of the shallow intrusion of dyke swarms.

These typically oceanward-dipping reflectors give way northwards, without apparent break, into an area of sub-horizontal sub-B reflectors. This second zone is not confined to the continental side of the ocean-continent boundary, as defined by anomaly 24B, but crosses onto oceanic crust and extends as far east as anomaly 21 at 65°N.

West of anomaly 24B, a strong high-frequency component becomes prominent in the magnetic profiles in a similar fashion to that overprinting magnetic anomaly profiles in Area 1 further south, again possibly indicating the shallowness of landward ends of sub-B reflectors and/or dykes.

The most oceanward occurrences of dipping reflectors are characterised by shorter discontinuous seismic events, locally sub-horizontal but for the most part, dipping weakly eastwards. Throughout this zone, magnetic anomalies are consistently oceanic-type and easily correlated between profiles.

(ii) Sub-B reflectors: Area 2

Dipping reflector sequences are difficult to resolve over much of the central and western section of Area 2. Sparse sub-B reflectors here underly thick, possibly sedimentary sequences and are associated with crust of equivocal magnetic character, displaying high frequency, low amplitude fluctuations in western parts of the Area.

The area bounded to the east by the Icelandic Plateau and to the south by the Denmark Strait, however, is characterised by nearly horizontal regular sub-B reflectors similar to those of the northern part of Area 1. To the east of about 20°W, at approximately the line of the anomaly 5 magnetic anomaly, a narrow zone of westward dipping reflectors is apparent,. Closer to the Kolbeinsey Ridge, however, the top of the oceanic crust becomes typically more rugged and no coherent sub-B reflectors are seen. Throughout Area 2, the character of the DRS and magnetic correlations is confusing, presumably due to the more complex rifting and spreading history in the area.

North of the Denmark Strait, reflector B may be a composite event, representing a combination of volcanics derived from the failed rift of anomaly 24 age to the west and volcanics associated with the subsequent break up commencing at anomaly 6 to the east. The junction between the two suites of volcanics appears to coincide with changes in both the character of the magnetic anomaly and the attitude of the sub-B reflectors. At this point, (X on Figure 11) the magnetic anomaly profile becomes recognisably oceanic, and the sub-B reflectors become more continuous and regularly orientated. The sub-B reflectors are particularly well developed at the southeast end of the profile where they underly the north-western margin of the Iceland Plateau. The western edge of the Plateau is marked by a series of vertical offsets in Reflector B resulting in a total step-up towards the southeast of about a kilometre. This discordance in Reflector B is discussed below. The offsets may be in part tectonic or they may represent the terminal ends of lavas associated with the seafloor spreading at the Kolbeinsey Ridge.

(b) Post-B seismic stratigraphy

In seismic sequences studied throughout the East Greenland margin covered by Area 1, two readily recognisable angular unconformities, U (the older) and E, have been mapped overlying the extensive basal reflector "B".

(i) Unconformity U

Unconformity U separates a well-bedded sequence below from a relatively transparent sequence above. It is a strong reflector which downlaps onto reflector B without any recognisable erosion, in the approximate position of oceanic anomaly 23 (Lower Eocene) (Figs. 7 & 10). This appears to be the same feature as Unconformity U of Featherstone (1976) and Featherstone et al. (1977). That is of a similar geometry, again downlapping onto reflector B at anomaly 23, but sharply truncating the underlying sediment sequences. The reason for the contrast in depositional/erosional character of Unconformity U is not clear from the present database.

(ii) Unconformity E

Unconformity E is an erosional unconformity which has locally cut down to the level of Unconformity U between 62° and 64°N, removing much of the U-E sequence seen further west. The U to E sequence, where observed, is typically almost seismically transparent, although occasionally characterised by discontinuous reflectors dipping weakly eastwards and onlapping Unconformity U.

The age of Unconformity E is speculative although Armstrong (1981) has suggested that it represents an equivalent of the R4 event recognised by Roberts (1975) and Roberts et al. (1979) throughout the Rockall margin.

Over Rockall Plateau, R4 is thought to represent a siliceous-rich horizon associated with the initiation of overflow of deep Norwegian bottom water across the Wyville Thomson Ridge (Roberts, 1975). In the Rockall Trough, however, the reflector previously correlated to R4 has been dated as mid-Miocene following DSDP drilling at Leg 94 (Masson & Kidd, in press). No direct correlation between E and R4 is possible, however, due to the absence of sampling and dating on the East Greenland margin. The commencement of a similar deepwater overflow across the Denmark Strait, although not necessarily a contemporaneous event, could, nonetheless, be responsible for such an erosional feature as Unconformity E.

(iii) Area 2

Armstrong (1981) proposed a seismic stratigraphy for this area on the basis of one processed multi-channel seismic profile (Line F, Fig. 2). He recognised seven 'unconformities' which he referred to as U_1 to U_7. He correlated U_1 with the mid-Oligocene global regression of Vail et al. (1977), but a recalibration of the ocean floor age by Nunns (1983a, 1983b) means that U_1 cannot be older than basal Miocene.

Hinz and Schluter (1980) have discussed an interpretation of seismic reflection profiles in the area in terms of four depositional sequences GR1 to GR4, where the upper boundary of the oldest sequence (GR4) is of upper Miocene (Tortonian) age. Despite the incorporation of the new multi-channel seismic data to the north of the Denmark Strait, however, it is not possible to correlate satisfactorily seismic unconformities within the basin. It is doubted that the establishment of a regionally correlated seismic stratigraphy is possible without a deep drilling programme.

(iv) Sedimentary Basins

The greatest accumulations of sediments are restricted to three major basins; the Irminger Basin, the Blosseville Basin and the restricted ocean basin to the north of Denmark Strait. The main depocentres of the Irminger Basin are the continental rise of southeast Greenland and the Eirik Ridge (which falls outside the study area). The continental slope has been heavily incised by canyons, with much of the sediment supplied by these canyons transported southwards by contour currents. The Blosseville Basin occupies the continental shelf from 67°N to 68°30'N. It lies on downwarped ocean crust of probable Eocene age. This basin has effectively ceased its depositional development. Marginal sediments have prograded across this basin and are now actively filling the ocean basin to the east.

(c) Isochron compilations

Charts illustrating contoured two-way seismic travel time have been constructed both for depth to Reflector B and for sediment thickness above Reflector B (Figs. 12-15).

For most of the study area, isochron patterns of depth to Reflector B are similar to the bathymetric contours, especially at the shelf edge and steep downwards gradient towards the ocean basin. Notable differences are recognised, however, in Area 2 (Fig. 13). A southeastward-facing scarp downthrows B approximately 1.0 second (TWT) immediately adjacent to the Blosseville Coast between 68°00'N, 28°30'W and 68°40'N, 25°50'W. We call this the Blosseville Escarpment. East of the escarpment, a narrow trough up to 4.0 seconds deep (TWT), which has no expression in the bathymetry, contains the thickest sedimentary accumulation (greater than 4.0 seconds TWT) found in either Area 1 or 2. The basin (the Blosseville basin) is bounded to the southeast by a basement high which coincides with the 'outer'marginal gravity high discussed above.

A more extensive west- and northwest-facing drop in Reflector B can be traced from 66°25'N, 25°30'W to 69°20'N, 21°30'W, and is reflected in a linear gradient in the free-air anomaly. On seismic profiles it is seen in some areas as a large-scale single escarpment, in others as a series of sharp steps in Reflector B (e.g. between 0850 and 1020 hours on day 221, [Fig. 11]). It is referred to here as the Icelandic Plateau Escarpment.

Although the northern and western limits to the dataset available prevent a complete interpretation, the Blosseville Escarpment appears to converge northwards with the line of the coastal flexure and Tertiary dyke swarm mapped by Wager & Deer (1938), which by about 69°N coincides with the likely position of the OCT as suggested by Brooks and Neilsen (1982). It is tempting to speculate that the Blosseville Coastal Flexure, the Blosseville Escarpment and possibly the more oceanward Blosseville Basin all represent contemporaneous features associated with the initial Early Tertiary rift system of eastern Greenland north of the Denmark Strait.

GRAVITY MODELLING

Gravity models across the continental margin were designed to try to establish the possible cross-sectional profile of both the Moho and the base of the sequence of sub-B reflectors. Distributions and densities of the sequences shallower in the section to be incorporated into the model were derived from seismic reflection and refraction studies, some of which have been referred to above. Assumptions of values for more fundamental parameters, such as mantle densities and depth to Moho were extracted from the published literature and modified accordingly. Worzel (1974) used a density of 3.3 Gg/m^3 for sub-continental upper mantle, and a sub-oceanic density of 3.2 Gg/m^3. Early gravity models across the East Greenland margin include those of Featherstone (1976) and Armstrong (1981) who, despite acknowledging the likelihood of upper mantle density variations, made no attempt to model them. Workers on the conjugate W. Rockall margin (Scrutton, 1972; Livermore, 1980) however, include in their models variations in upper mantle densities which are incorporated in the present models. In the work presented here, density variations have been accommodated in all the models.

The three seismic profiles discussed above, Lines A, B and C (Figs. 7-11), were selected to constrain three gravity models across the OCT. Individually, each of the lines was chosen for its demonstration of aspects of continental margin evolution, and collectively they provide a basis for studies of the contrasting structure along the east Greenland margin. While together these studies present a speculative model of the deep crustal structure along the margin, the number of assumptions that have been made in their construction reduces the value of conclusions that can be drawn from them. The lack of seismic refraction data to constrain deep crustal structure and velocities, as well as the uncertainty of the gravity field outside the models are important restrictions to full interpretation.

(a) Line A (Fig. 16)

Line A, the most southerly of the processed Durham multichannel seismic lines, is accompanied by good gravity data and offers a suite of interval velocities for its upper section derived from the commercial processing. The velocities were transformed to approximate densities using the Nafe-Drake relationship (Nafe & Drake, 1973). Refraction data was not available for this area to constrain the deeper velocity structure.

At its closest point, the shallow water area of the Denmark Strait lies

500 km to the northeast of this line and is considered to have negligible gravity effect on it. Therefore two-dimensional modelling is considered to be valid. Sub-continental and sub-oceanic upper mantle densities of 3.3 Gg/m^3 and 3.2 Gg/m^3 were used and a density gradient was constructed by including columns of intermediate values in the upper mantle commencing landwards of anomaly 24B and extending to beneath oceanic crust. Crustal density was assumed to be 2.8 Gg m^{-3}.

The calculated anomaly was first approximately fitted to the observed profile by varying the shape of the Moho along the model. It was considered unlikely that short wavelength anomalies would originate at the Moho, so this interface was varied smoothly across the model. The remaining misfits were reduced by the inclusion of a layer representing the sub-B reflector unit. A density of 2.5 Gg/m^3 was assumed for this unit. A lower density was considered unreasonable due to the depth of burial of this unit and to the probability that it is composed of a high proportion of igneous material. If this density were to be increased significantly, the sub-B layer would have to be disproportionately thick. Furthermore, a density of 2.5 Gg/m^3 is compatible with a mixed composition of sediments, pyroclastics and/or volcanogenic sediments. A large (20 milligal) misfit was reduced at the northwestern end of the profile by the insertion of a low density body (2.7 Gg/m^3) below the inner shelf at this point. There is no geophysical evidence for such a body other than the gravity anomaly, but it may correspond either to an acid intrusion (such as are mapped elsewhere close to the east Greenland margin) or an anomalously low density segment of ?gneissic basement.

A good fit was obtained by varying the thickness of the sub-B reflector sequence. Two of the basement structures so modelled are in part substantiated by the seismic reflection profile (α on Fig. 9 and β on Fig. 10). At kilometre 185 in the gravity model an oceanward-facing escarpment in the gravity model coincides with a change in seismic character of the sub-B sequence located at α. The basement high at kilometre 220 in the gravity model underlies what appears to be an antiformal structure (β in Fig. 10) in the sub-B sequence and coincides approximately with the position of anomaly 24B. Not inconsiderable debate in the literature is centred on the significance of such elevated basement structures at passive margins OCTs (e.g. Schuepach & Vail, 1980) and this example is further assessed in a summary section at the end of this report.

(b) Line B (Fig. 17)

Line B is an unprocessed single-channel seismic reflection profile. It crosses the shelf edge to the south of profile A where the marginal sediment wedge is narrowest, where the upper sections of the dipping reflector sequence are particularly well-defined and beyond any gravity effect of the Denmark Strait/Iceland hotspot. Density values used in the uppermost parts of the gravity model remain the same as in model A but, in an attempt to provide an alternative model for the deeper crust, variations to crustal densities in the deeper layers have been effected. Without essential refraction data in the area to constrain these parameters, this flexibility of the modelling demonstrates the non-uniqueness of this technique.

(c) Line C (Fig. 18)

This northernmost line, more than 300 km north of the narrowest part of the Denmark Strait, represents the most complicated and least well-constrained gravity model presented here. Although interval velocities have been used on this processed section to derive densities for upper layers, the uncertainty regarding both the crustal composition and its age in the area allow several interpretations of the lower crustal structure.

An initial problem stems from a difference in the thickness of the crust over the length of the line. A 30-km depth to Moho at the northwestern end of the line, as assumed for continental crustal thickness in the foregoing models, results in oceanic crust at the southeastern end of the line having an anomalous crustal thickness of around 28 km. As has been discussed above, it is likely that the whole length of Line C is underlain by some form of transitional or buried oceanic crust, with a more appropriate crustal thickness of between 10 and 12 km. The depth of the Moho was then varied accordingly to match the calculated and observed curves.

If the suggestions of Nunns (1983a, 1983b) for the ages of seafloor north of the Denmark Strait are correct, the crust below the northwest part of Line C was formed by seafloor spreading some time between anomalies 24 and 19, after which it cooled and subsided until a recommencement of seafloor spreading at around the time of anomaly 6A. The temperature/density gradient existing between the young, warm mantle and the older cooler mantle has, therefore, been represented in the model between kilometres 80 and 120 by the inclusion of vertical bodies of intermediate densities 10 kilometres wide below the postulated junction between the two sections of crusts. These vertical bodies extend to an assumed depth of compensation of 80 kilometres.

Following the upper mantle variations, the base of the sub-B reflector was then estimated, and the observed and calculated curves were fitted by varying its depth along the model according to data provided by the seismic reflection profiles and isochron compilations. The northwestern end of the line is characterised by a thick blanket of sediments which overlie a low density area. The character of the underlying sequence is not seen on reflection records but may be analogous to the more oceanward sub-B accumulations modelled in the other gravity models. This section of the profile also overlies the northern end of the Blosseville Basin. A shallow, northeasterly-trending ridge in the surface of reflector B is identified at around 67°40'N, 26°30'W (Fig. 13). The ridge plunges below the overlying sediment to the north-east, towards line C where, although unresolved on available seismic reflection records, it is identified as a subdued feature in the gravity model between 70 and 80 km. The oceanward flank of this marginal ridge can be modelled by a moderately steep escarpment required to fulfil gravity conditions if the Moho is to remain smooth. A small basement high occurs in the position of anomaly 6A, speculatively a product of renewed igneous activity associated with seafloor spreading. The seismic section and line drawing of Figure 11 show that the sub-B reflectors change direction of dip at this point, perhaps in a drape structure over the possible basement high. Further southeast, the sub-B unit thickens below the Icelandic Plateau, attaining a maximum of 3.5 kilometres at kilometre 180 of the model (Fig. 18).

DISCUSSION

(a) Sub-B reflectors

(i) Distribution and character

Over most of Areas 1 and 2, reflector B is represented by a smooth horizon which extends from below the continental shelf, across the continental margin and onto oceanic crust. Close to the East Greenland coast, at its westernmost limit, it may itself represent or immediately overly true continental basement, and at its easternmost limit, it almost certainly corresponds to the upper surface of oceanic layer 2 (Fig. 19). The intervening crustal transitional zone is one which has attracted considerable attention in recent years, focussing geophysical interest on many passive continental margins throughout the world (e.g. Hinz, 1981). A debate continues as to whether the sub-B reflectors (and therefore B itself) have formed by volcanic activity in an intercontinental rift environment or at an actively-spreading mid-ocean ridge axis. Or, if a combination of the two, what are the relative proportions of each component?

The smooth reflector B and the underlying reflectors occur in extensive areas of oceanic crust from the edge of the ocean-continent transition zone, as defined by anomaly 24B, up to anomaly 19 in places (Bezart, pers. comm. and unpublished CNEXO data). Reflector B and dipping sub-B reflectors can also be clearly recognised more than 70 kilometres landwards of anomaly 24B in Area 1. Thus, as well as forming the upper part of the oldest oceanic layer 2, the reflector sequences contribute significantly to the continental crust.

The seismic character of the sub-B reflectors varies both along and across the margin in a similar way to the DRS studied on the Rockall and Norwegian Sea margins (Leg 81, Scientific Party, 1982; Mutter et al., 1982). Towards the central part of the margin south of Denmark Strait, they are dominated by a striking series of oceanward-dipping reflectors (Figs. 7 and 8). In this area they diverge oceanward and with depth, closely resembling the oceanward-dipping 'sub-basement' reflectors described by other workers (Roberts et al., 1979; Hinz, 1981; Mutter et al., 1982). To the east of anomaly 24B in the extreme south of the area, sub-B reflectors become more discontinuous and increasingly sub-horizontal within oceanic crust, extending as far as anomaly 21 (Fig. 19).

Further northwards, adjacent to the Denmark Strait, the sub-B reflectors locally flatten out (Fig. 10) and may dip landwards close to the OCT (Figs. 19 & 20). Between the positions of anomalies 24B and 23 there are no easily recognisable sub-B reflectors, but eastwards of anomaly 23 they occur as clearly developed oceanward-dipping events. Although with unmigrated seismic sections with poor velocity control it is often difficult to determine true dips, there is an apparent flattening-out of the reflectors at a depth of about five seconds (TWT).

To the north of Denmark Strait (e.g. Fig. 11), the reflectors are discontinuous throughout, locally dipping landwards below the East Greenland Rise, slope and shelf edge. In the same seismic section (Fig. 11) to the southeast of anomaly 6A, the sub-B reflectors in younger crust are seen to dip towards the Kolbeinsey spreading axis and become more recognisable and continuous beneath the Icelandic Plateau (oceanic crust of about 9.5 Ma). Their distribution and location in relation to oceanic magnetic anomalies is summarised in Figure 20.

(ii) Models for formation

Despite attempts to sample equivalents to the East Greenland sub-B reflectors on passive continental margins elsewhere in the world by deep drilling (DSDP Legs 48 & 81; Montadert, Roberts et al., 1979; Leg 81, Scientific Party, 1982), their composition at depth and their origin remain in debate. Speculation on their likely mode of formation and its significance in terms of the early evolution of passive margins has been discussed by a number of workers (Hinz, 1981; Mutter, 1982; Norwegian Seabed Working Group [NSWG], 1984).

Early workers (Featherstone, 1976, Featherstone et al., 1977) considered that the sub-B reflectors were confined to an area of thinned continental crust south of the Denmark Strait. On the basis of the limited seismic reflection profile coverage available to them, they proposed that the sub-B reflectors represented sediments prograding onto an area of stretched continental crust. The idea was still considered a possibility by Roberts et al. (1979) who referred to a "sedimentary wedge of deltaic aspect." The identification of sub-B reflectors in basaltic oceanic crust, and the recovery of exclusively basaltic lava from the uppermost part of the DRS off Rockall (Leg 81 Scientific Party, 1982) clearly do not support these proposals.

Bally (1981) attempted to associate margins characterised by listric faulting (e.g. Montadert et al., 1979) with those characterised by oceanward-dipping reflectors. His suggested mechanism of formation of thick oceanward-dipping reflector sequences in half-graben does not, however, allow for their symmetrical development as demonstrated, for example, by the East Greenland and Rockall conjugate margins. By contrast, Hinz (in NSWG, 1984) points to an interesting correlation in that dipping reflectors only occur on margins where listric extensional faulting is apparently not an important process. No examples of 'Biscay'/'rotated block' margins have been seen to be characterised by the same style of dipping reflector sequences although the structure and character of the crust underlying the DRS remains unknown.

One of the two most popular models under debate has been proposed by Mutter and co-workers (Mutter et al., 1982) during discussion of the oceanward dipping reflector sequences associated with the continental margin adjacent to the Voring Plateau off Norway. The model involves subaerial basaltic lava eruption during the earliest stages of seafloor spreading, which is maintained by the successive intrusion of feeder dykes at the spreading centre as the crust moves apart (Fig. 21a). In this model, successive lava flows form the reflectors which are underlain by a sheeted dyke complex. An alternative model proposed by Hinz

(1981) envisages that immediately prior to continental separation and spreading, linear zones of volcanic fissuring allow the extrusion of basalt and/or pyroclastics from the incipient mid-ocean ridge onto attenuated continental crust (Fig. 21b). In either model, extrusive sheets or flows may initially dip landwards from a elevated source, but may reverse their dip as the ocean widens and the lithosphere cools and subsides. Variations in water depth at the incipient spreading centre, due to uplift/subsidence variations during extrusion, could contribute to variations in the style of extrusion, either as extensive sheet flows in subaerial and shallow water conditions, or more restricted hummocky forms in submarine conditions.

(iii) Discussion of models

While discounting a wholly sedimentary origin for the reflector sequences, we can envisage a compromise/composite DRS model where the main part of the sub-B reflectors is formed by lava flows, accompanied by an unknown (and variable) proportion of either volcaniclastic input, originating from the fully evolved or nascent mid-ocean ridge, or sedimentary input derived from the adjacent continental mass. The variations in the seismic character of the DRS from passive margins around the world have been explained initially by Mutter *et al.* (1982) as due to variations in water depth during extrusion, but may also reflect variations in supply rate, rate of spreading, effects of weathering on the upper surfaces of layers and the variable contribution of interleaved sediments. Furthermore, the densities which satisfy the gravity model could be interpreted to suggest that the sedimentary component may be substantial in places. For instance, in the gravity model of seismic line C, a moderately low density layer of (2.4 Gg/m^{-3}) satisfactorily represents the sub-B reflector sequence (Fig. 18).

(iv) Magnetic anomalies and the OCT

The interpretation of oceanic magnetic anomalies in areas of transitional crust and areas of dipping reflector sequences may be difficult for a number of reasons. The superposition of individually cooled and magnetised lava sheets, reheated by later flows, their subsequent weathering on sheet surfaces (if subaerial) and the interbedding of sediments and/or pyroclastics may all contribute to a confused magnetic picture. Figures 19 and 20 illustrate the distribution of sub-B reflectors and oceanic anomalies.

(v) Linear magnetic anomalies other than oceanic anomalies

Both the Icelandic Plateau and the Blosseville Escarpments have associated prominent magnetic anomalies, as can be predicted for step-like basement features. The Blosseville Escarpment lies oceanwards of the Coastal Flexure of Wager & Deer (1938) and is associated with a large amplitude negative magnetic anomaly. The Icelandic Plateau Escarpment is associated with a large positive anomaly which cuts across the line of anomaly 6 in Area 2, overlying older crust to the north. It is speculated that the origins of the Blosseville Escarpment and the Coastal Flexure may be the same as they appear to converge to the north and they have similar orientations and attitudes.

The western margin of the Icelandic Plateau between 66°30'N, 25°30'W and 69°20'N, 21°00'W (Fig. 13) is easily recognised on seismic reflection profiles (e.g. Fig. 11) and has been mapped by Hinz & Schluter (1978) as a continuous linear feature between 300 and 400 km long in Area 2. The Iceland Plateau Escarpment coincides with a 20 to 30 milligal linear gravity anomaly and a large linear positive magnetic anomaly. The amplitude of the magnetic anomaly exceeds 500 nT where the relief of the feature is greatest and decreases in proportion to relief.

Armstrong (1981) suggested that at least part of the Iceland Plateau Escarpment is formed by a westward downthrowing normal fault. His reflection data have been re-processed and reflectors are seen to pass through the proposed fault plane without a break. Minor deformation appears to be present but may be confused by velocity "pull-up" effects.

Diachronous structures similar to the Iceland Plateau Ecarpment have been discussed from either side of both the Reykjanes and Kolbeinsey Ridges (Vogt, 1971; Vogt et al., 1980). Vogt (1974), in addition, studied basement structures which converge on the spreading axes away from Iceland, and proposed irregularities in magmatic processes for their origin. The Iceland Plateau Escarpment, however, appears to diverge from the Kolbeinsey Ridge towards the north and, if extrapolated, would approach the entrance of Scoresby Sund. Although equally speculative, it is possible that the Iceland Plateau was formed by sub-aerially extruded lavas and that its marginal escarpment may represent a palaeo-coastline built up by subsequent lava flows which have been cooled and solidified on contact with sea water. Its apparent linearity may argue against such an origin but, on a small scale, some deviations are observed. A more precise understanding of the feature is not possible with the available data set.

CONCLUSIONS

(1) The Ocean-continent transition

(i) To the south of the Denmark Strait, the Ocean-continent transition is best defined by a zone immediately landward of oceanic anomaly 24B (or 24 where 24A and 24B have merged). Within and to the north of the Denmark Strait the position of the OCT may be tentatively identified with the broad zone between the East Greenland Coastal Flexure and the initial oceanic magnetic anomaly. The anomaly pattern of Nunns (1983a) favoured by the authors restricts the OCT to a narrow zone immediately eastwards of the East Greenland Coastal Flexure.

(ii) This work is in broad agreement with that of Nunns (1980), and Nunns (1983a, 1983b) in that most of the Denmark Strait and the ocean basin to the north is believed to be underlain by oceanic crust.

(iii) The lack of oceanic-type magnetic anomalies to the north of Denmark Strait may be due to their being masked by thick lava sequences and sediment.

(iv) Unlike other examples of passive continental margins characterised by dipping "sub-basement" reflector sequences where the OCT can be identified by the variations in attitude or occurrence of the dipping reflectors, throughout the East Greenland margin dipping reflectors are seen on continental, transitional and oceanic crust and cannot be used to locate the OCT.

(2) Nature and distribution of dipping (sub-B) reflector sequences

A reflector referred to as B, formerly thought to be acoustic basement, is seen to overlie series of dipping, or sub-horizontal seismic reflectors and to transgress continental, transitional and oceanic crusts. Reflector B is a smooth horizon, for the most part, and apparently forms the upper surface of layer 2 over oceanic crust.

The composition of sub-B reflectors is unknown, although their unbroken continuation from oceanic to continental areas, and the results of drilling programmes on other passive margins, appear to support an extrusive basaltic origin.

Sub-B reflectors of approximately 10 Ma age are observed within the oceanic crust of the Icelandic Plateau. Here, there is no doubt that they formed by a sea-floor spreading process, either sub-aerially in an analogous situation to Iceland today, or under shallow submarine conditions.

Tentative interpretations of seismic profiles to the north of the Denmark

Strait indicate that sub-B reflector lavas may interleave with sediments. Gravity models suggest the incorporation of a lower density (i.e. 2.4 Gg/m^{-3}) for the sub-B section than might be expected for a wholly basaltic section.

(3) Post-reflector B sediments

(i) To the south of Denmark Strait, two unconformities, U and E, are recognised and mapped within the post-B sediment interval. The age of unconformity U is inferred to be lower Eocene from the position of its pinch-out on oceanic crust of anomaly 23 age. Unconformity E is undated, although a possible analogy with the Eocene/Oligocene regional reflector of Rockall Plateau (R4), is drawn.

(ii) To the north of the Denmark Strait, the post-B seismic sequence is undifferentiated although as many as six unconformities have been locally identified. The age of the oldest of these reflectors is reassessed as earliest Miocene in closer agreement with Hinz and Schluter's (1980) upper Miocene age.

(iii) The ocean basin to the north of the Denmark Strait is constricted to the east by the Icelandic Plateau Ecarpment and to the south by the Denmark Strait structural high. It appears to cross the continental shelf and extends towards Scoresby Sund where it contains more than 2.6 kilometres of sediments.

(4) Structure

Several large-scale features are recognised on seismic reflection, gravity and magnetic data. These features include the Icelandic Plateau Escarpment, the Blosseville Escarpment, the Blosseville Shelf Flexure, the marginal gravity highs, oceanic "outer highs" and fracture zones.

(i) The Icelandic Plateau Escarpment (IPE) is between 300 and 400 kilometres long. It marks the boundary between the ocean basin to the west and the Icelandic Plateau to the east. It is proposed that it may represent a palaeo-coastline, formed by igneous activity around 10 Ma ago (during the Miocene). This escarpment is associated with a linear magnetic anomaly which has been confused with oceanic anomaly 6 in the past. The escarpment is, however, clearly time-transgressive.

(ii) It is proposed here that the Blosseville Escarpment represents an offshore continuation of the East Greenland Coastal Flexure. It is further proposed that the onshore sections of the coastal flexure represent the emergent parts of a "Hinge Zone" which has been interpreted elsewhere as a boundary between normal and thinned continental crust at passive margins (e.g. Austin & Uchupi, 1982).

(iii) The Blosseville Shelf Flexure is inferred principally from gravity modelling which requires that the main crustal layer be downwarped below a load of sub-B reflectors and post-B sediments. The origin of this structure probably lies in the geometry of the original split between Greenland and the Rockall/Faeroes/European plate.

(iv) The marginal gravity high peaking between 61°N and 62°N is suggested to be caused partly by a basement ridge associated with an example of a margin "hinge zone" feature referred to above. Further north, the displacement implied by such a 'hinge' decreases closer to Iceland. At 63°N, the regional sedimentary wedge becomes prominent, and its uncompensated load forms a significant component of the marginal gravity anomaly. The amplitude of the marginal anomaly, however, decreases northwards, and to the north of the Denmark Strait, the marginal gravity high bifurcates. The inner high marks the line of the Coastal Flexure/Blosseville Escarpment while the outer gravity high overlies the oceanward-prograding sediment wedge.

(v) 'Outer highs' are elevated and/or rough areas of "acoustic basement" which have been formerly considered by many authors to be margin-parallel markers of the ocean-continent boundary, coinciding with a change from sub-aerial to submarine extrusive conditions. Although they are observed on several sections off east Greenland, the oceanic magnetic anomalies at these localities reveal great variation in age, and the inference must be that the features are of a local importance rather than a continuous structure.

(vi) Gravity, magnetic and seismic data all support the position and extent of Fracture Zone One. Other fracture zones referred to in the text are largely speculative or derived from the suggestions of other workers.

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TABLE 1 - Survey Details

ORGANISATION	CRUISE I/D	MAGNETICS (km)	GRAVITY (km)	S - SINGLE-CHANNEL M - MULTI-CHANNEL S.R.P. (km)	TOTAL TRACK LENGTH (km)
Durham University	SH 73	2,100	2,400	S 900	2,600
	SH 74	3,000	3,250	S 1,400	3,500
	SH 77	2,600	2,750	M 1,900	2,750
Institute of Oceanographic Sciences	ST 79		3,500	S 3,000	3,200
Western Geophysical	ICE (Spec.)			M 875	875
Centre National pour l'Exploitation des Oceans	JC 69	200	50		250
	CEPM 77			S 4,800	5,050
U.S. Navy	LY 12A	200			500
	LY 12B	1,250	50		1,300
	LY 12D	250			250
	LY 21A	800			800
	LY 21B	2,900		S 2,400	3,500
	LY 21C	200			950
	LY 21E				700
	LY 21F				2,750
	LY 32A				750
	LY 32B	900			1,400
	W 1933014	350			350
	KEA 0171				1,050

TABLE 1 - Survey Details (continued)

ORGANISATION	CRUISE I/D	MAGNETICS (km)	GRAVITY (km)	S - SINGLE-CHANNEL M - MULTI-CHANNEL S.R.P. (km)	TOTAL TRACK LENGTH (km)
Lamont-Doherty Geological Observatory	V 1716	100			250
	V 2302	1,200	700		1,650
	V 2303	1,500	2,200		3,700
	V 2304				
	V 2702	1,450	1,200	S 500	1,550
	V 2703	100	50		150
	V 2706				
	V 2801	650	200	S 1,300	1,500
	V 2802	1,400	1,450	S 1,450	1,450
	V 2803	350	250		350
	V 2910	1,100	1,100	S 1,100	2,000
	V 2911	450	300	S 600	1,000
	V 3008	200	150	S 650	650
	V 3009	2,300	600	S 2,650	2,700
	V 3010	800	700	S 550	900
Deep Sea Drilling Project	Leg 12	900			900
	Leg 49	700			1,500
Deutsche Hydrographische Institut	KT 1		4,850		6,200
	ME 28	500	400		1,050
TOTALS		28,450	25,700	24,075	60,025

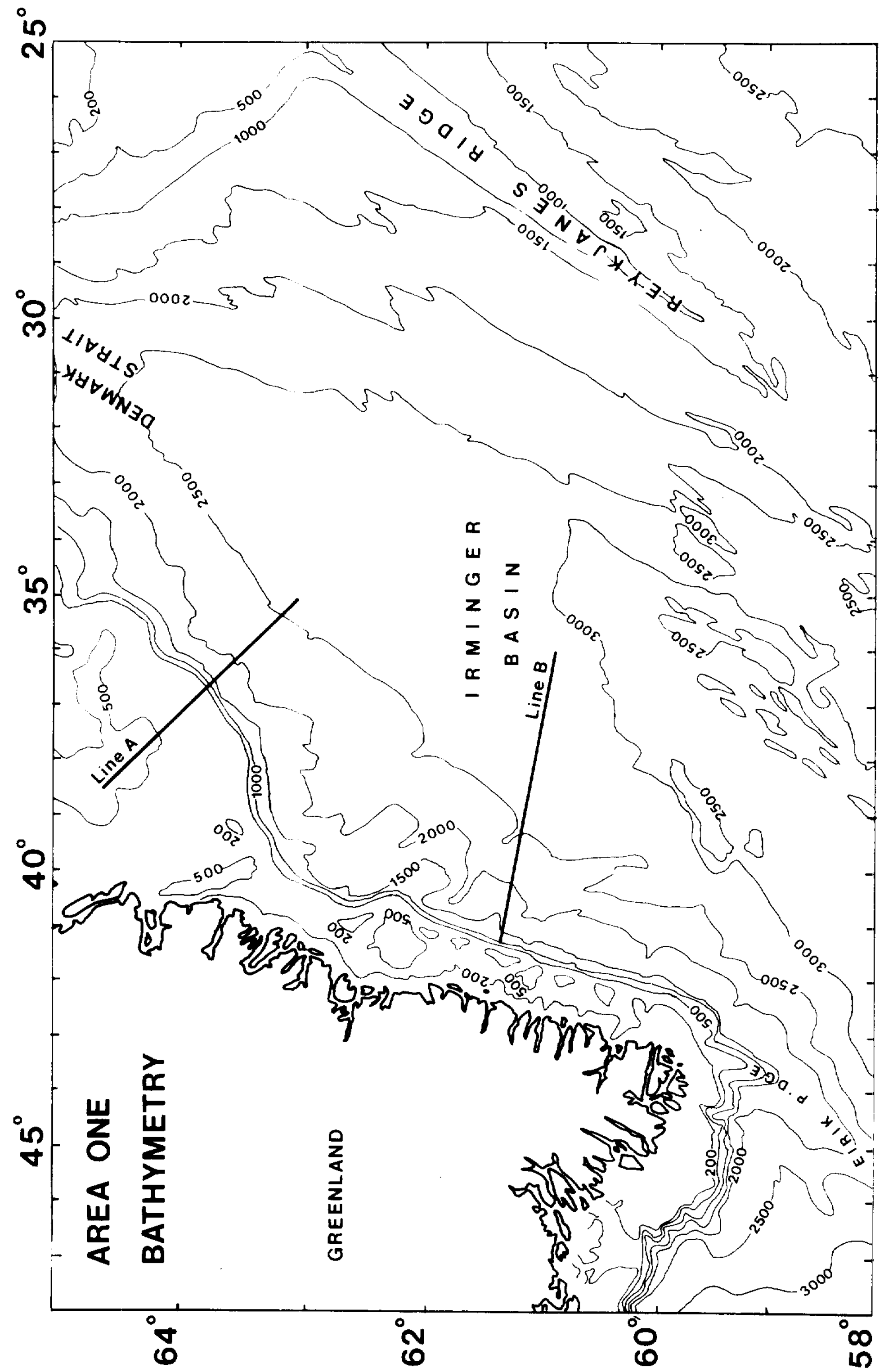

Figure 1 Bathymetry of Area One, illustrating principal topographic features discussed in text and the location of seismic reflection profiles A and B used to control gravity models. Contour interval is 500 m, with additional 200 m contour.

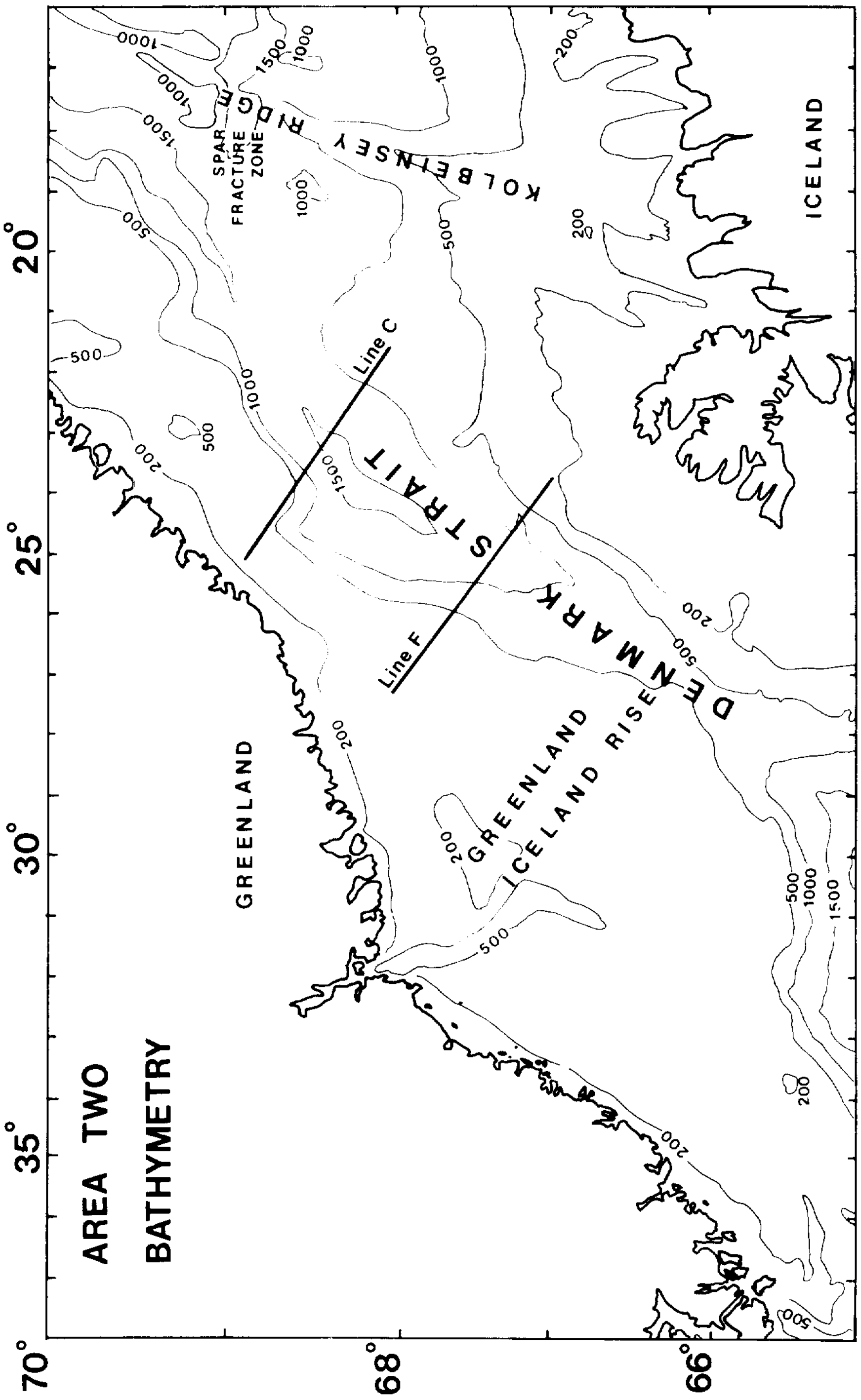

Figure 2 Bathymetry of Area Two, illustrating principal topographic features discussed in text and the location of seismic reflection profile C used to control gravity models. Seismic profile F is from Armstrong (1982) see text. Contour interval is 500 m, with additional 200 m contour.

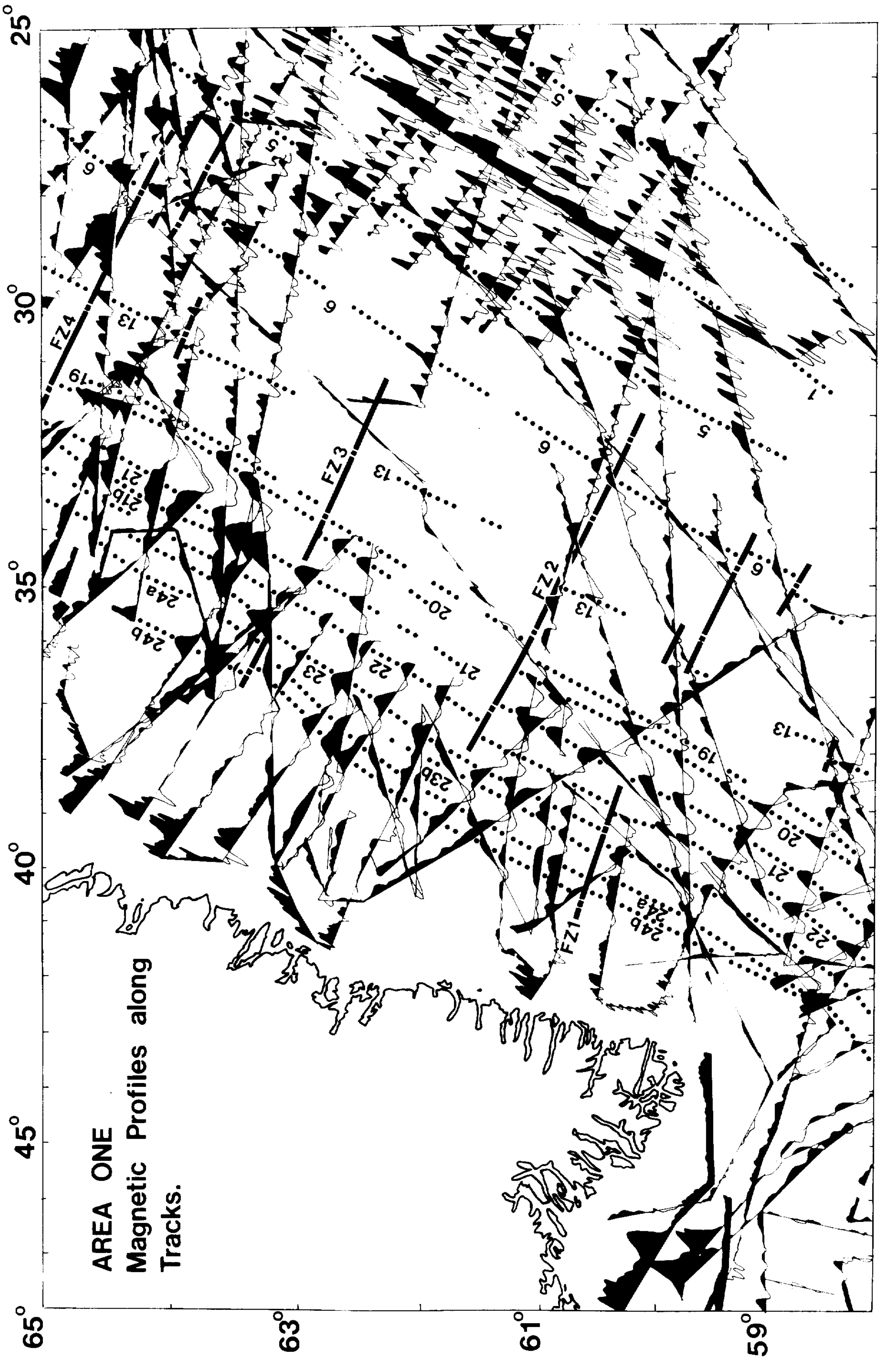

Figure 3   Magnetic anomaly profiles along ship's tracks in Area One. Dotted lines indicate correlations of principal "anomalies" between tracks. Broad dot-dash lines locate probable positions of major fracture zones discussed in text.

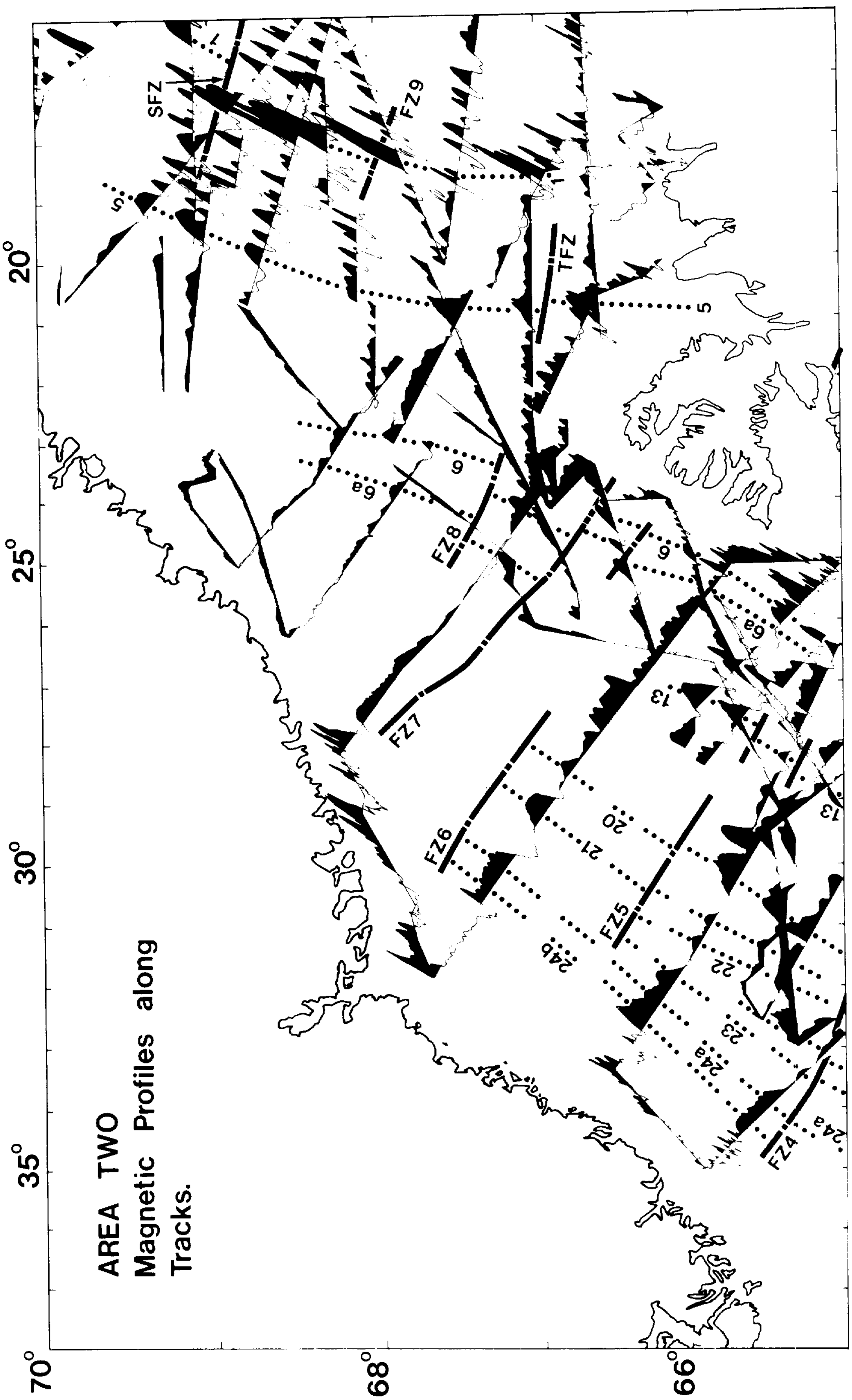

Figure 4 Magnetic anomaly profiles along ship's tracks in Area Two. Dotted lines indicate correlations of principal anomalies between tracks. Broad dot-dash lines locate probable positions of major fracture zones discussed in text. SFZ = Spar Fracture Zone; TFZ = Tjoners Fracture Zone (after McMaster et al., 1977).

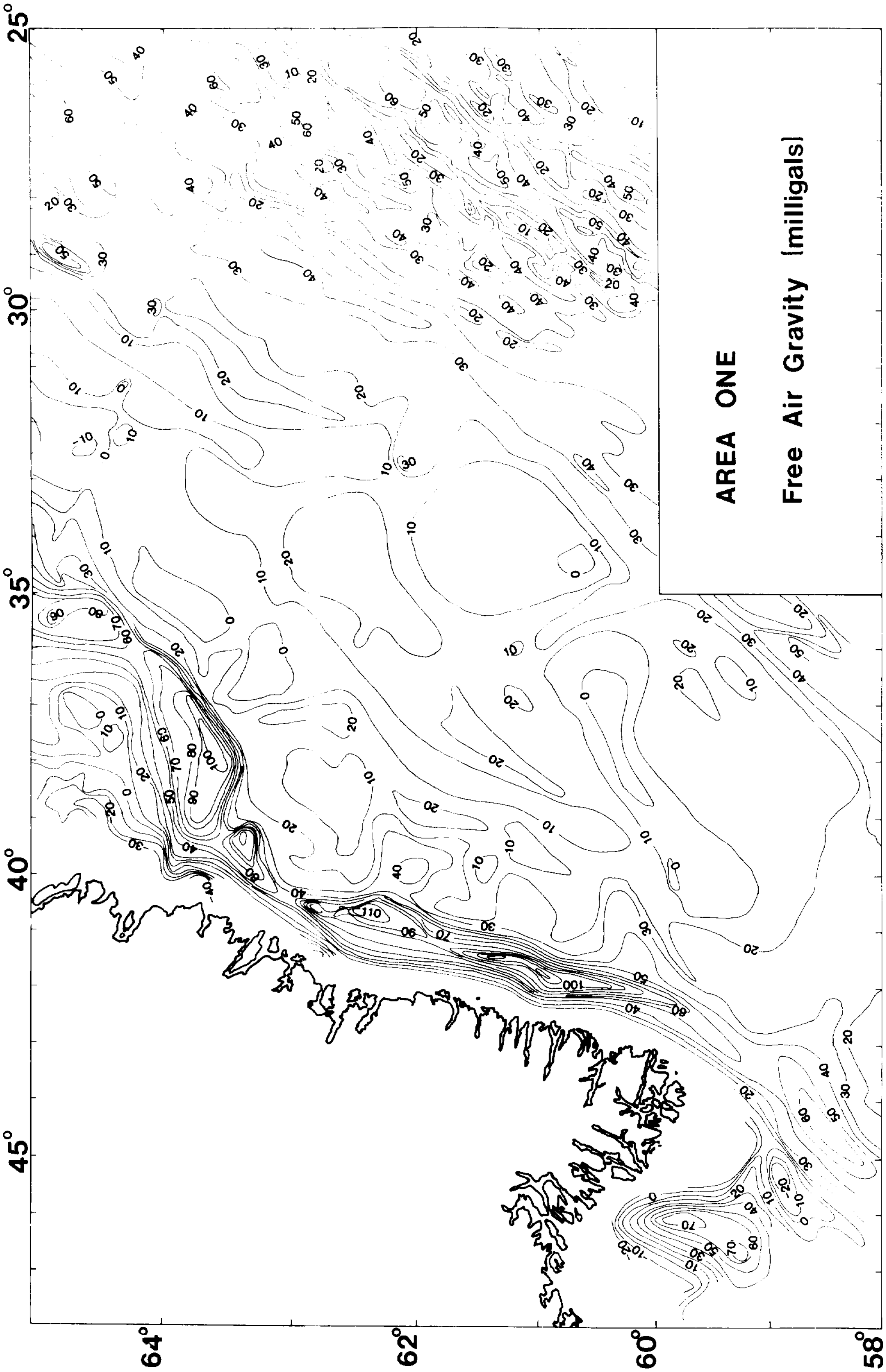

Figure 5 Contoured free-air gravity anomaly for Area One. Contour interval 10 mgal.

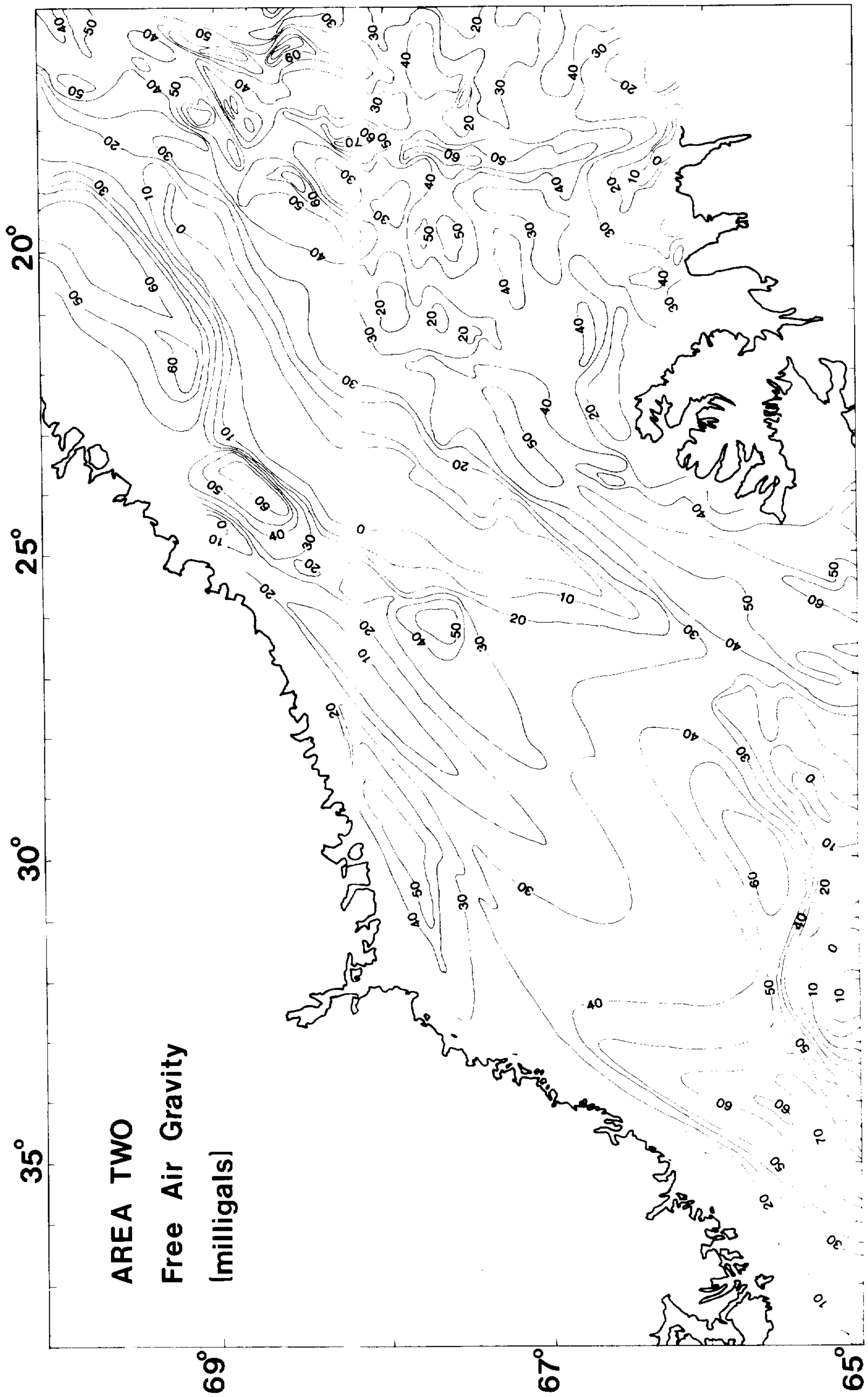

Figure 6 Contoured free-air gravity anomaly for Area Two. Contour interval 10 mgal.

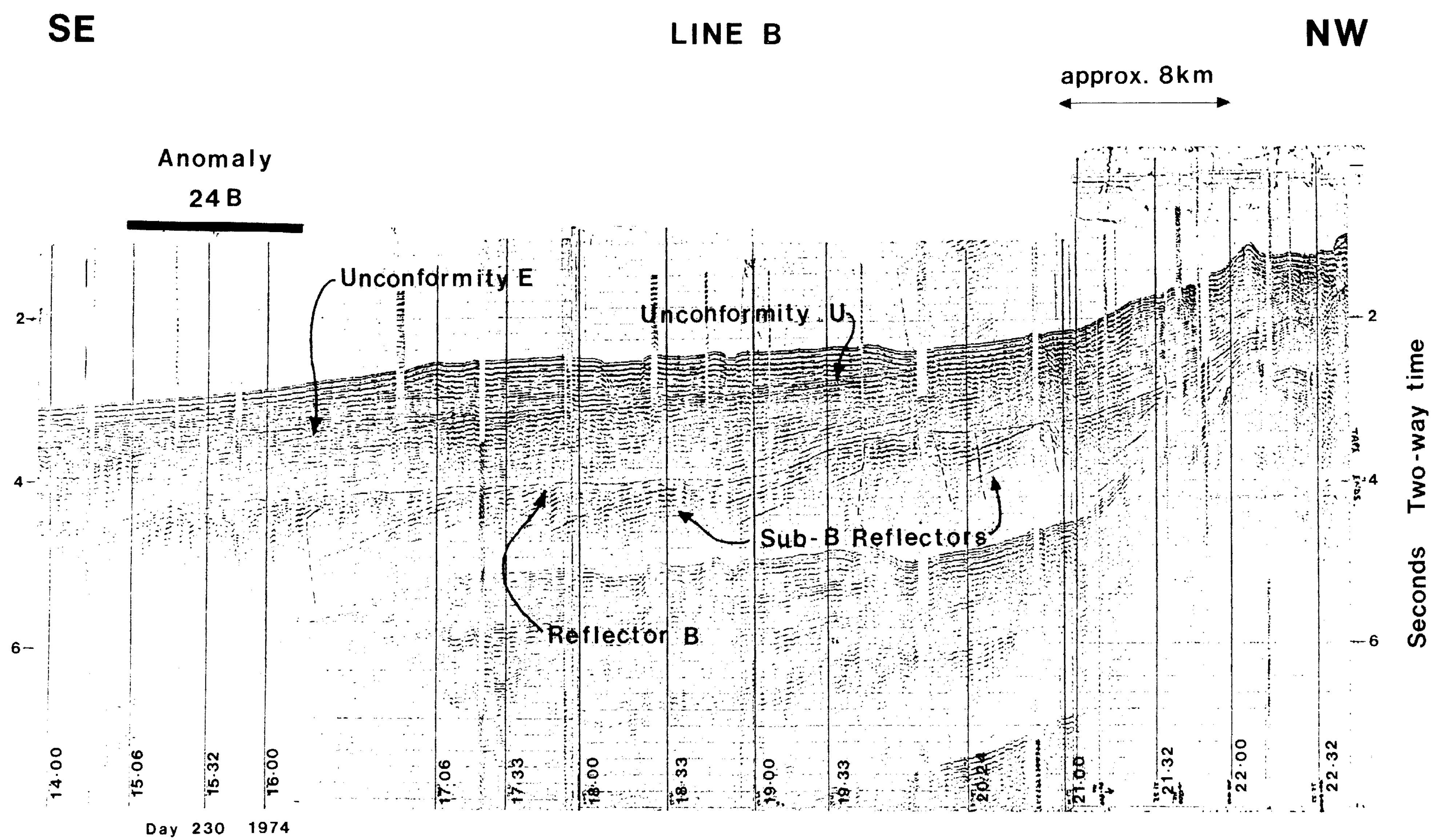

Figure 7 Detail of original single-channel seismic profile B, located in Figure 1. Note orientation cf. to Figures 9-11. E, U and B refer to major seismic events discussed in text.

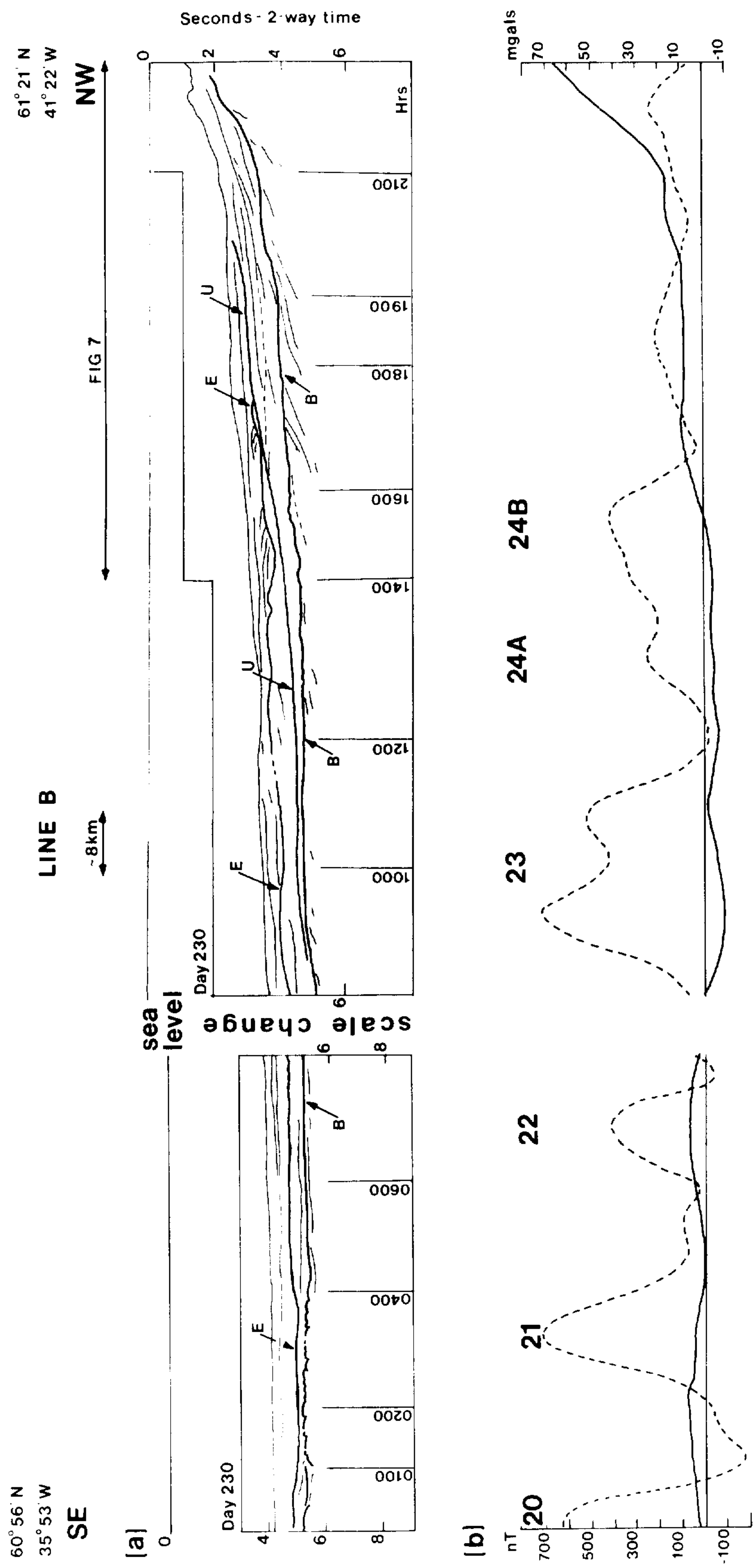

Figure 8 (a) Line drawing interpretation of seismic profile B. Reference times included at bottom of figure.

(b) Magnetic anomaly profile (dashed line) and free-air gravity (unbroken line) profiles recorded along profile B.

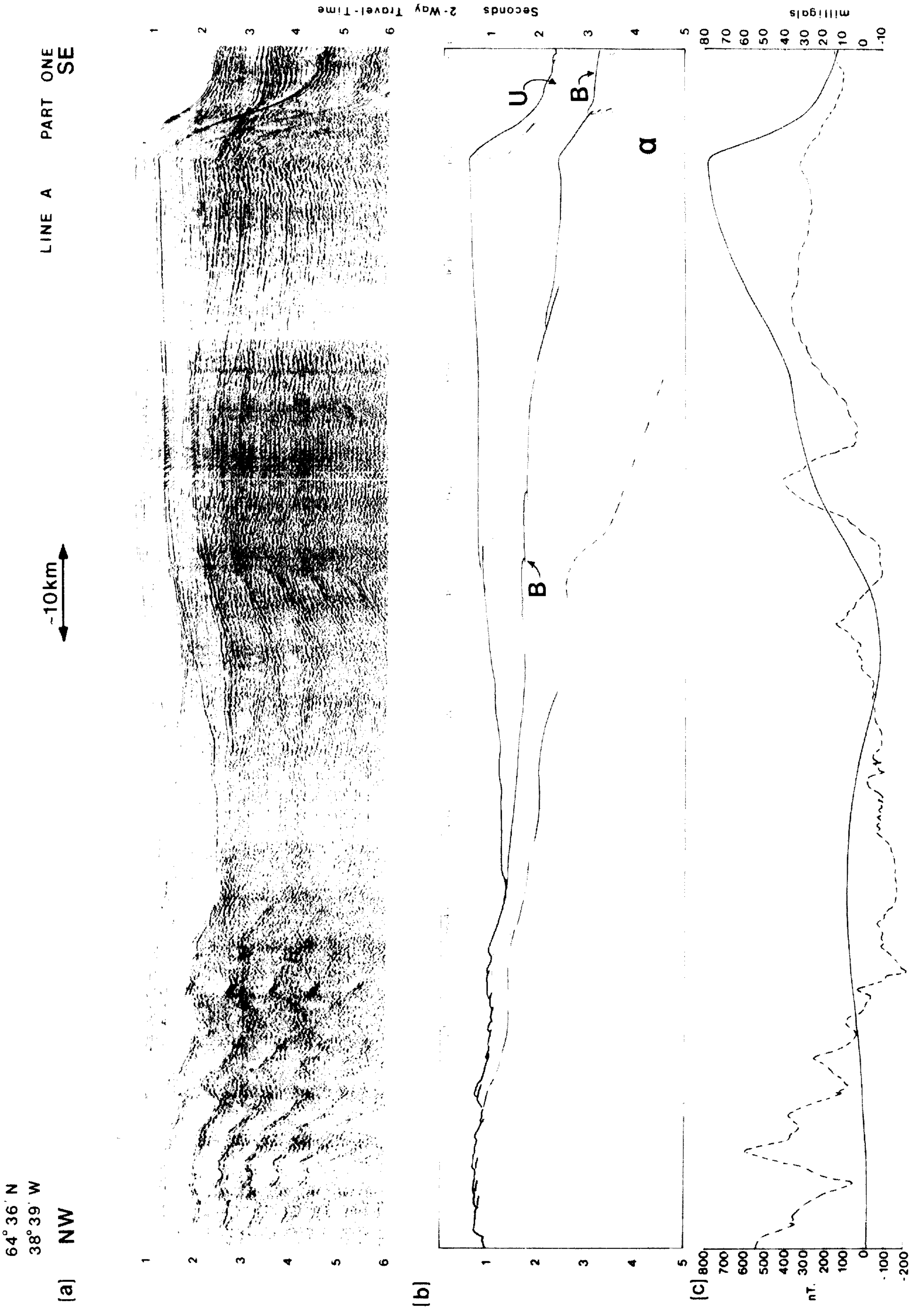

Figure 9 Multi-channel seismic profile A (Part 1, NW section)
(a) (located on Fig. 1). 12-channel record, deconvolved before stack, stacked with time variant filter applied.

(b) Line drawing interpretation of Figure 9a. U and B refer to major unconformities discussed in text. Reference times are included at top of figure.

(c) Magnetic anomaly profile (dashed line) and free-air gravity profile (unbroken line) recorded along Figure 9a.

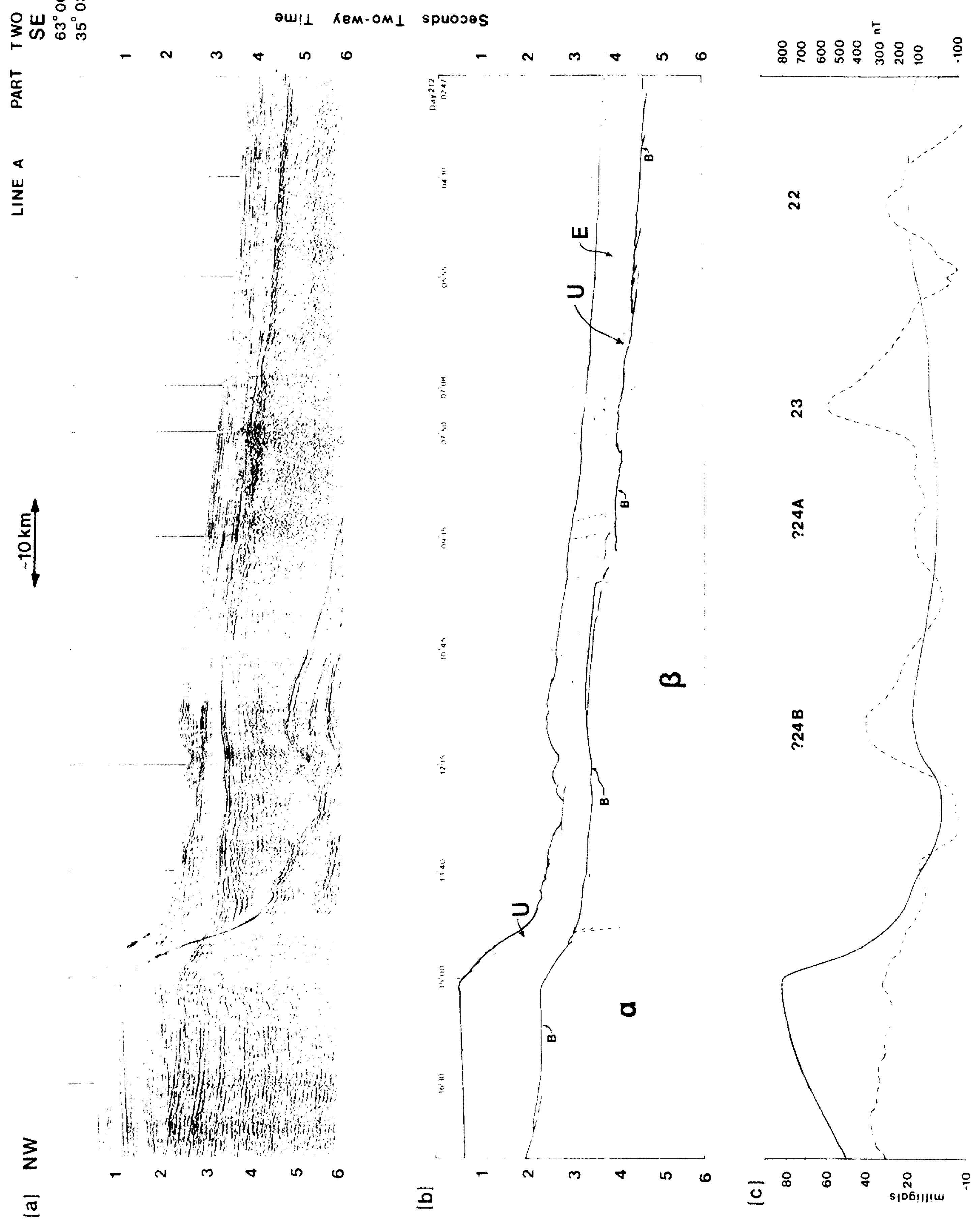

Figure 10 (a) Multi-channel seismic profile A (Part 2, southeastern section), located on Figure 1.
(b) Line drawing interpretation of Figure 10a. U, B and E refer to major unconformities discussed in text.
(c) Magnetic anomaly profile (dashed line) and free-air gravity profile (unbroken line) recorded along 10a. Interpreted positions of magnetic anomalies 24b to 22 indicated.

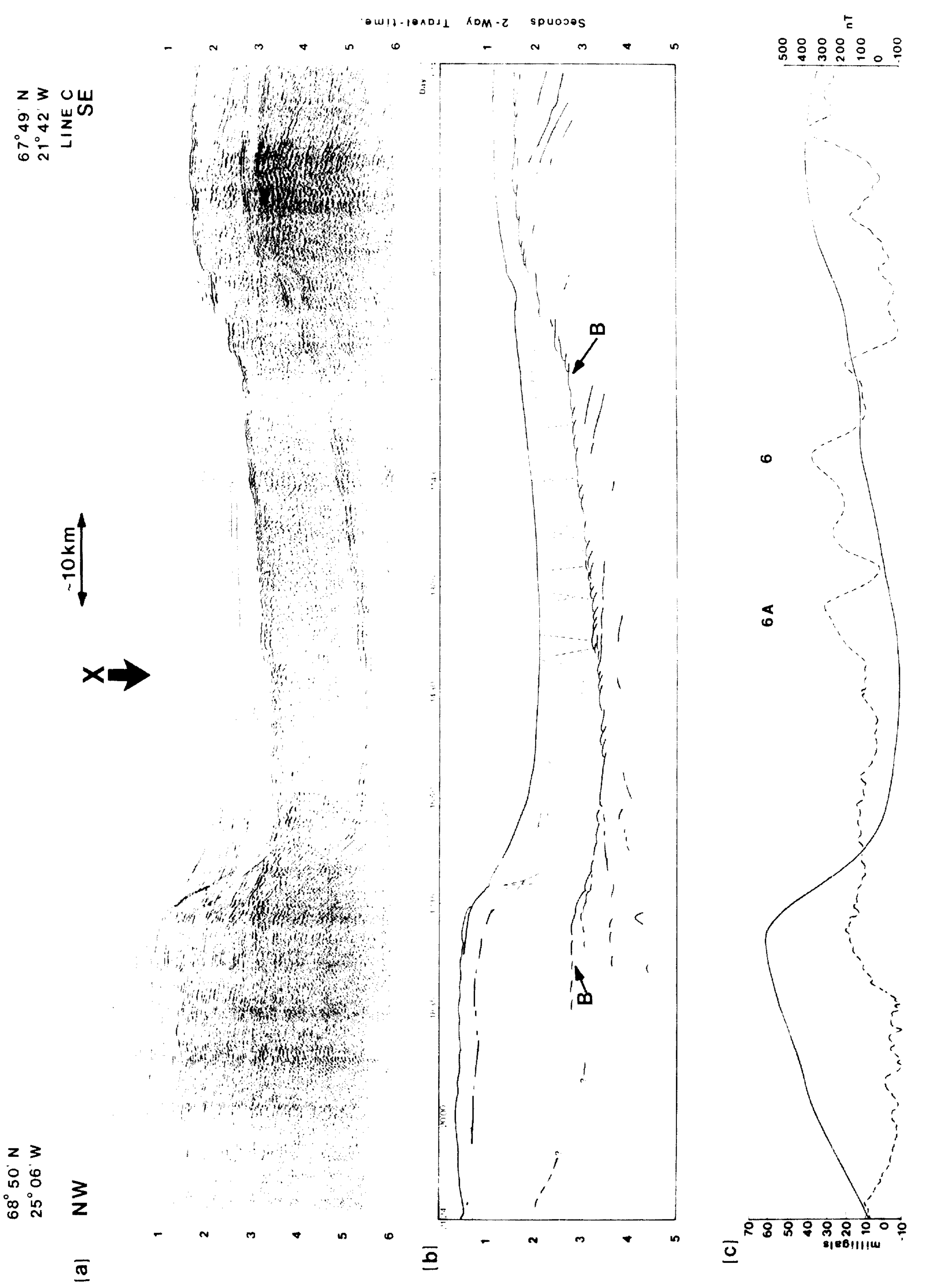

Figure 11 (a) Multi-channel seismic profile C, located on Figure 1. Significance of X discussed in text. Processing sequence as for section A.

(b) Line drawing interpretation of Figure 11a. B refers to major unconformity discussed in text.

(c) Magnetic anomaly profile (dashed line) and free-air gravity profile (unbroken line) recorded along Figure 11a.

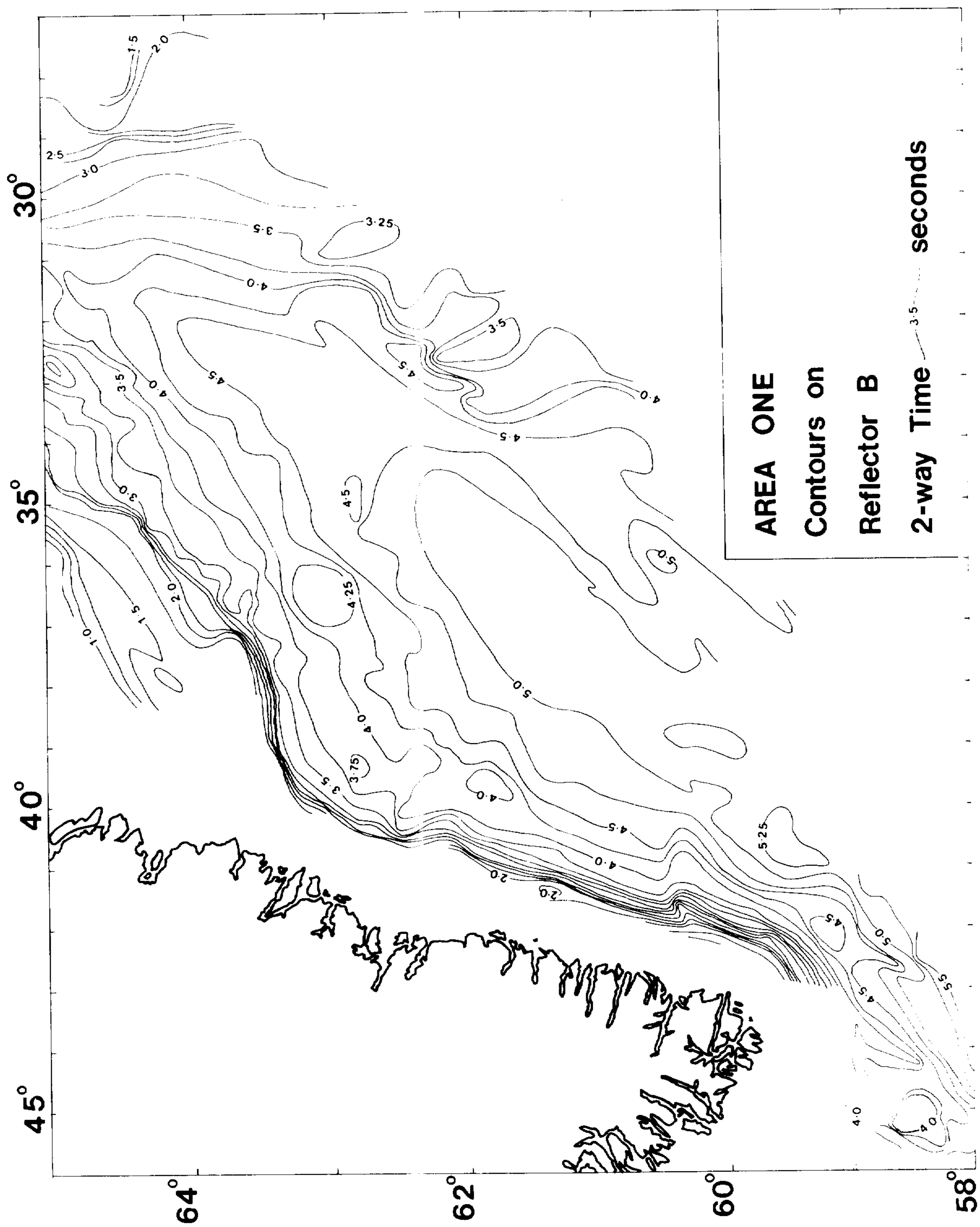

Figure 12 Contoured isochron chart of depth to 'break-up' unconformity (Reflector B) for Area One in seconds two-way time. Contour interval is 0.25 seconds (TWT).

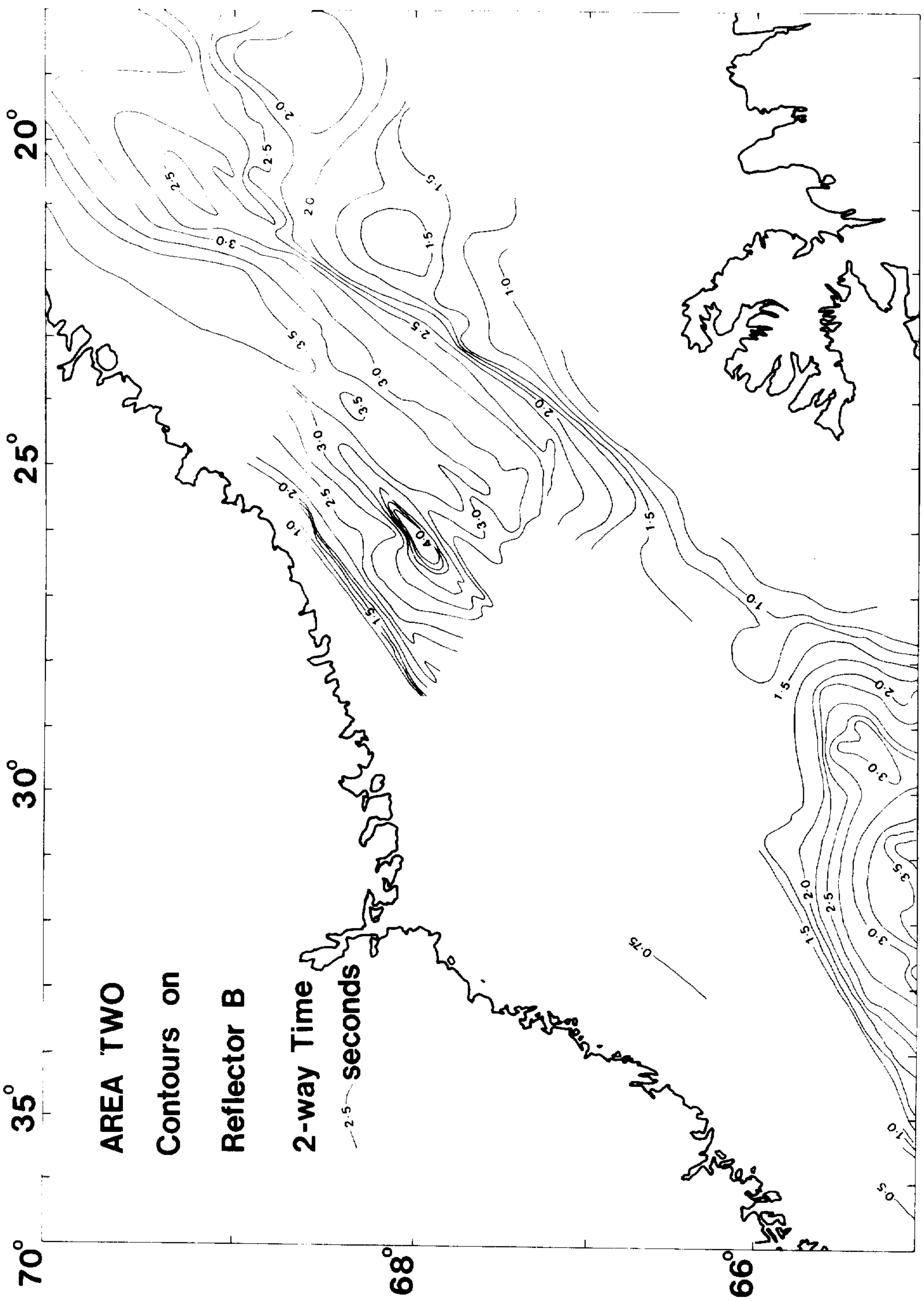

Figure 13 Contoured isochron chart of depth to 'break-up' unconformity (Reflector B) for Area Two in seconds two-way time. Contour interval is 0.25 seconds (TWT).

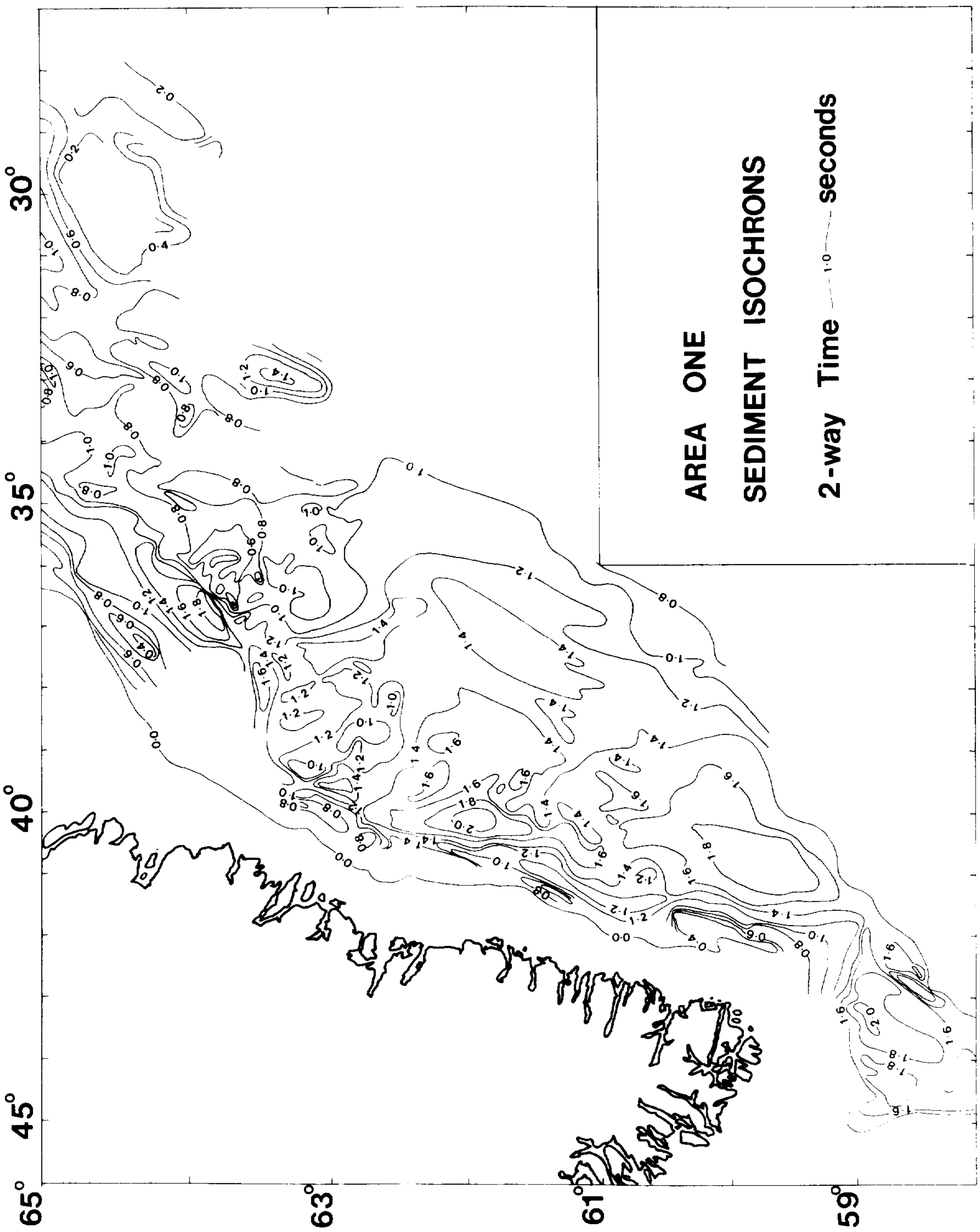

Figure 14 Contoured isochron chart of sediment thickness(above Reflector B) in Area One in seconds two-way time. Contour interval is 0.2 seconds (TWT).

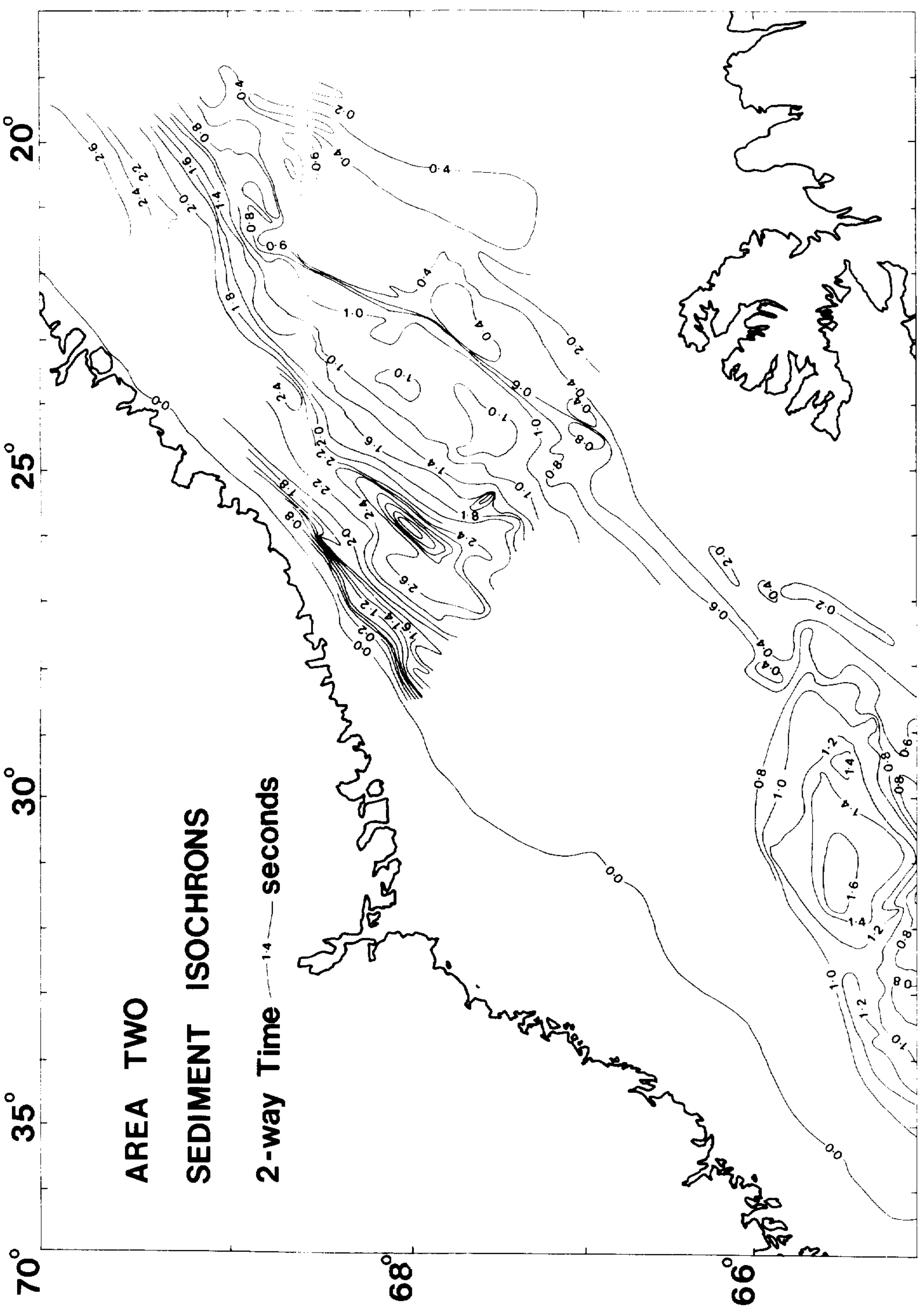

Figure 15 Contoured isochron chart of sediment thickness (above Reflector B) in Area Two in seconds two-way time. Contour interval is 0.2 seconds (TWT).

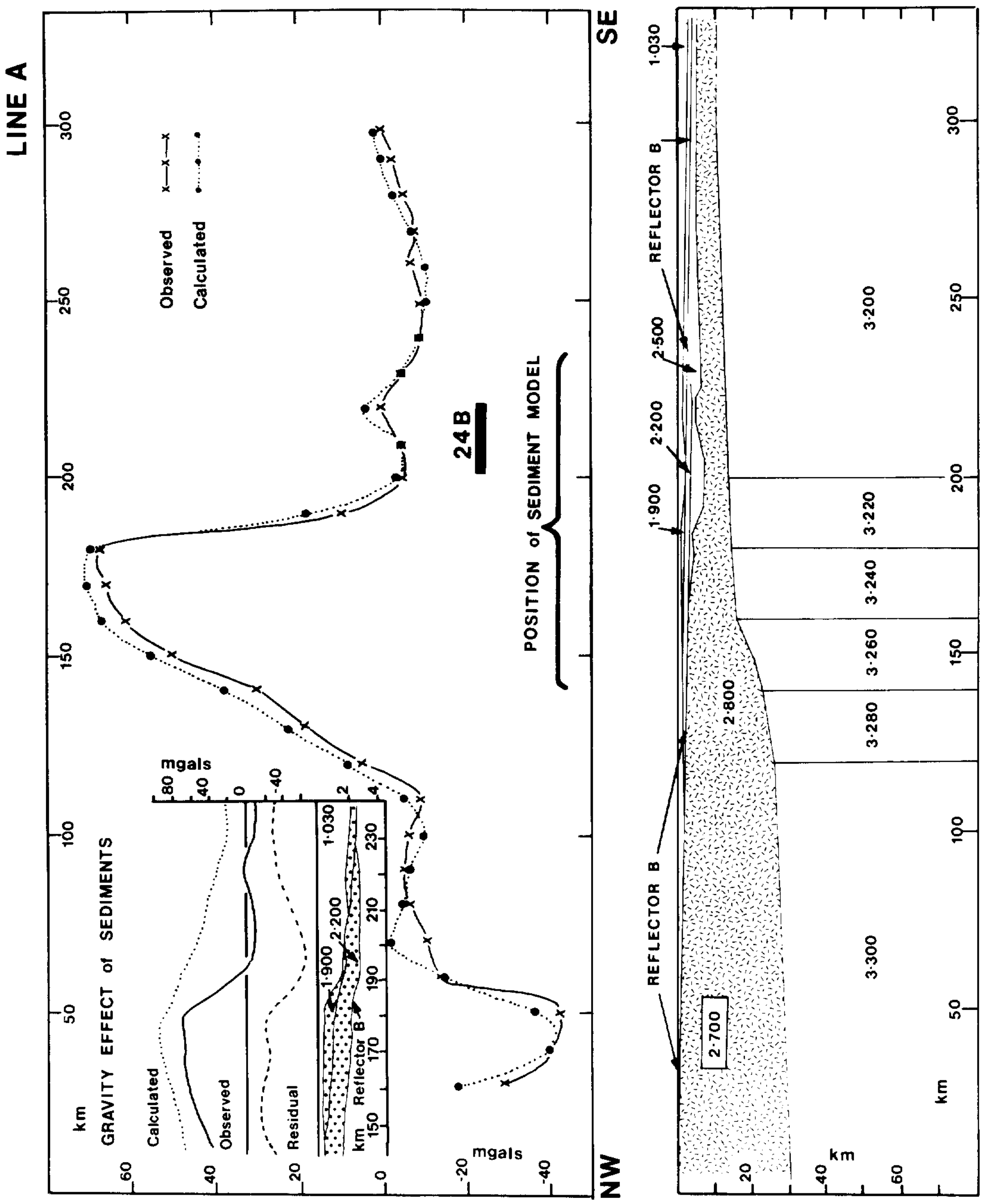

Figure 16 Free-air gravity model for seismic Profile A. Lower section of figure illustrates distribution of prisms of different densities in Gg/m^3. Ornamented area identifies crust. Upper section of figure compares observed (shipboard measurements) and calculated profiles. Position of the earliest identifiable magnetic anomaly 24B is marked.

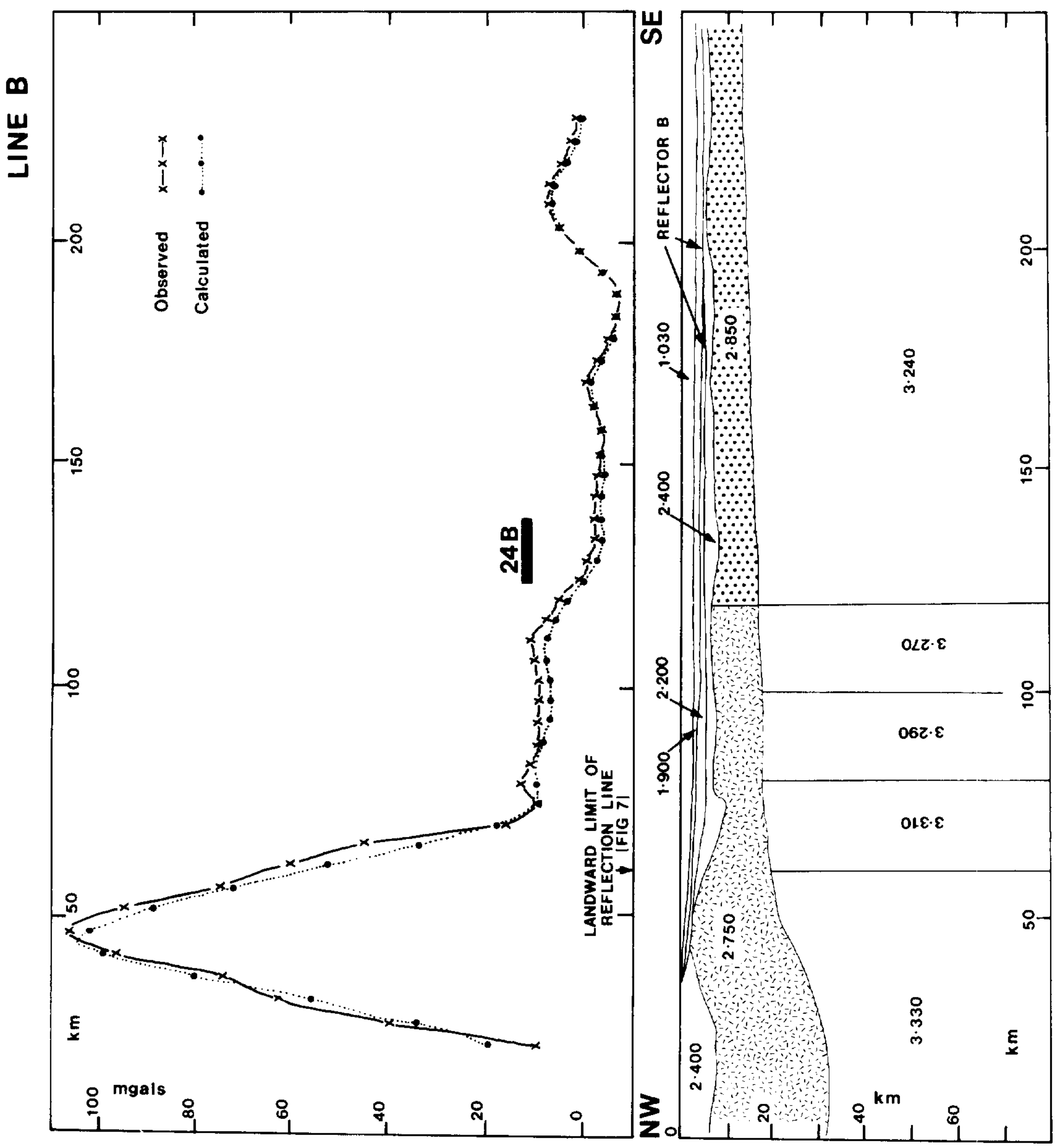

Figure 17 Free-air gravity model for seismic Profile B. Lower section of figure illustrates distribution of prisms of different densities in Gg/m^3. Ornamented area identifies crust. Upper section of figure compares observed (shipboard measurements) and calculated profiles . Position of the earliest identifiable magnetic anomaly 24B is marked. Inset in upper section of figure illustrates theoretical free-air gravity profile obtained without taking into account variation of basement form. For discussion, see text.

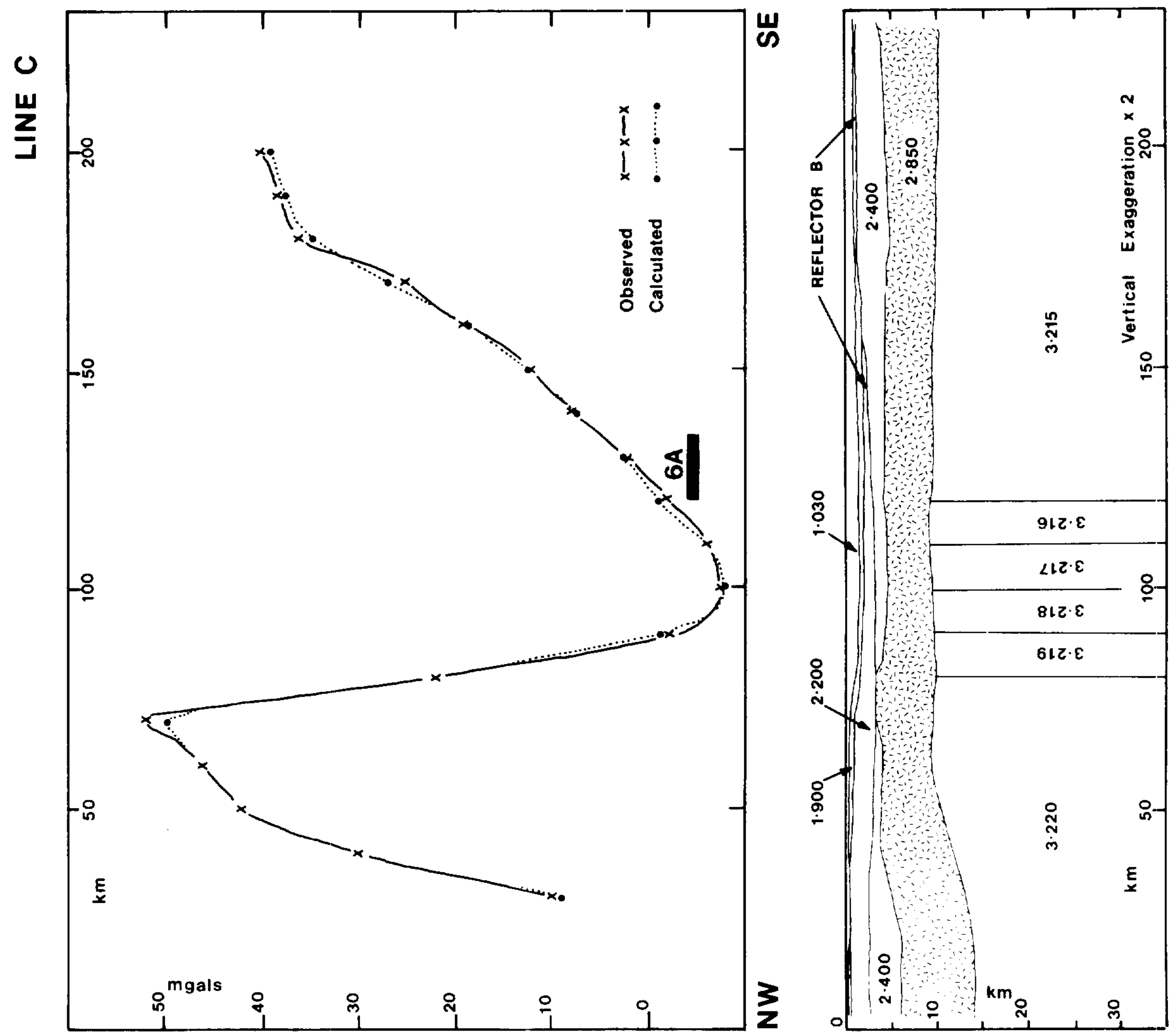

Figure 18 Free-air gravity model for seismic Profile C. Lower section of figure illustrates distribution of prisms of different densities in Gg/m^3. Ornamented area identified crust. Upper section of figure compares observed and calculated profiles. Position of the earliest identifiable magnetic anomaly 6A is marked. Note vertical exaggeration compared to Figures 16 and 17.

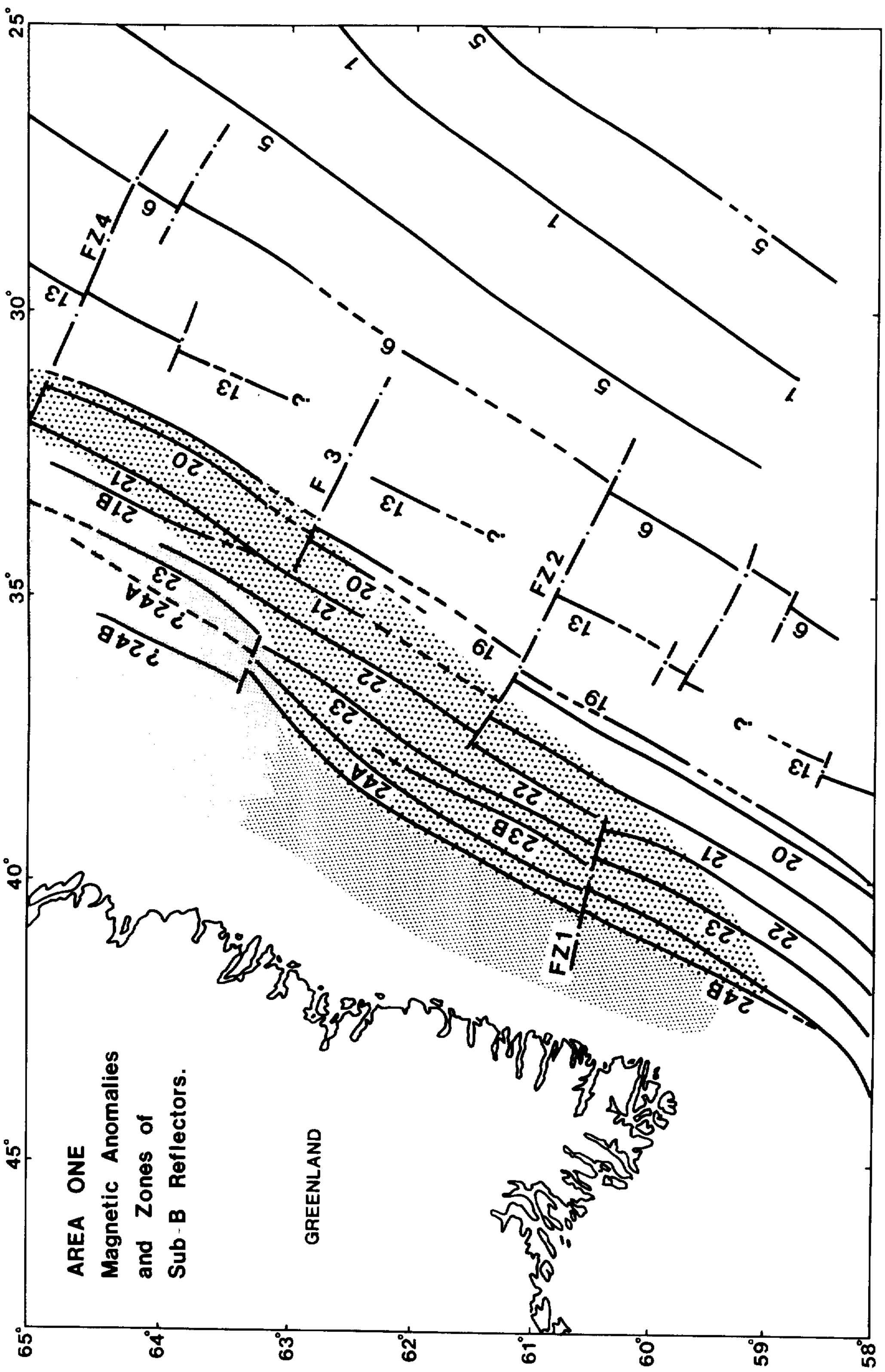

Figure 19 Sub-B reflectors distribution related to oceanic magnetic anomalies, Area One. Dense stipple indicates distribution of DRS overlying undoubted continental crust. Coarse stipple delimits distribution of shallowly inclined and/or flat-lying sub-B reflectors within undoubted oceanic crust (N.B. eastern limit reflects extent of available multichannel seismic database). Medium stipple locates area of mixed sub-B reflector character, locally prominent and of various dips.

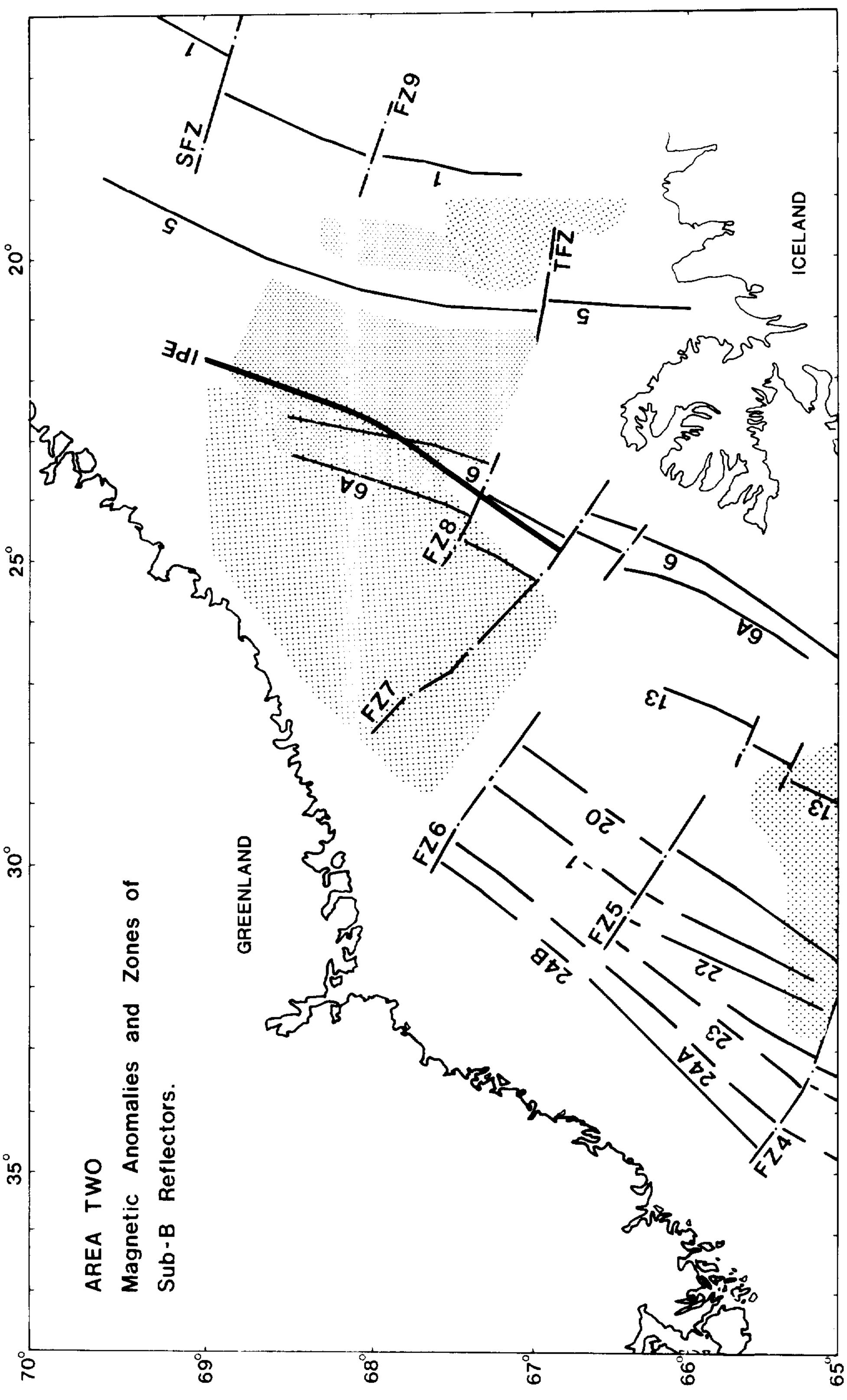

Figure 20. Sub-B reflector distribution related to oceanic magnetic anomalies, Area Two. Key as for Figure 19. Icelandic Plateau Escarpment, IPE: Spar Fracture Zone, SFZ: Tjornes Fracture Zone, TFZ.

DIPPING REFLECTORS: SEAFLOOR SPREADING MODEL
AFTER MUTTER et al (1982).

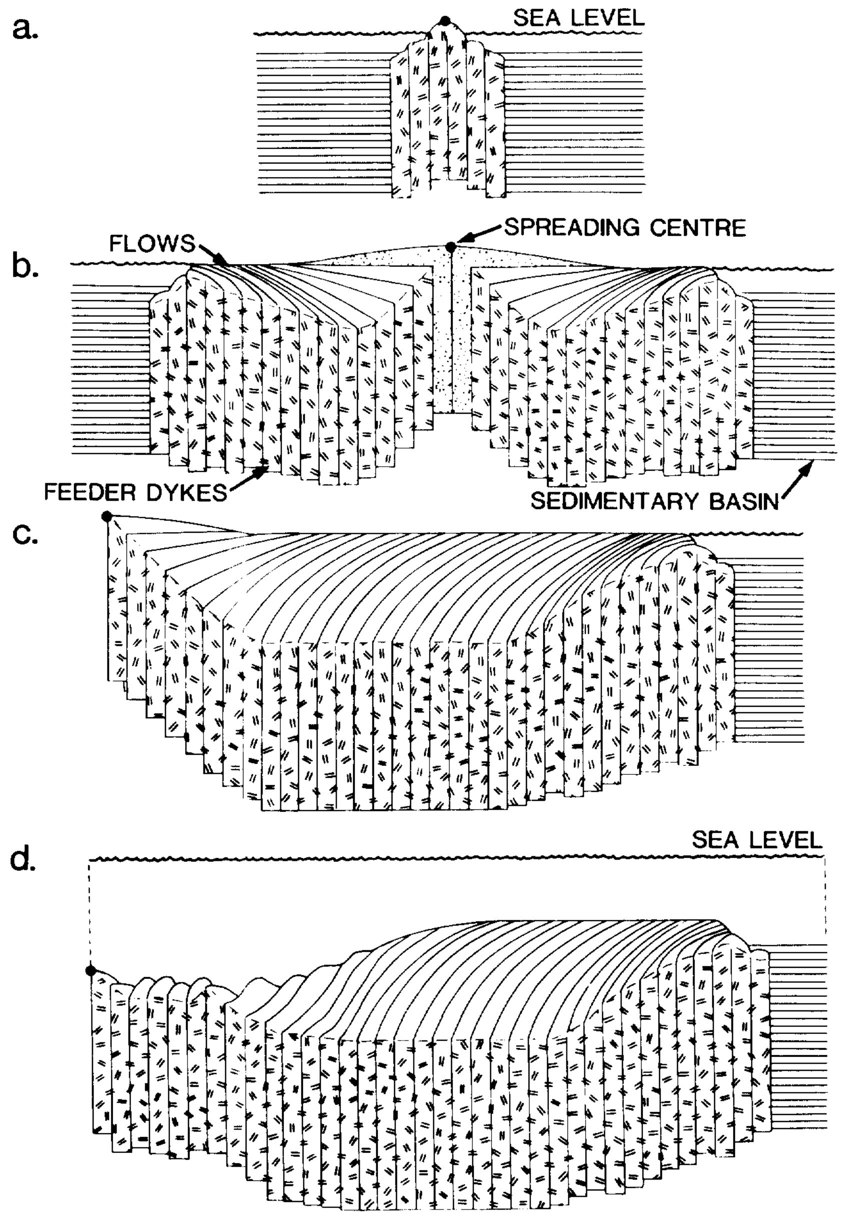

Figure 21. (a) Model of dipping reflector formation after Mutter et al. (1982) involving simultaneous feeder dyke injection and sheet flow during early continental separation. For discussion, see text.

DIPPING REFLECTORS: RIFT STAGE VOLCANIC MODEL AFTER HINZ (1981).

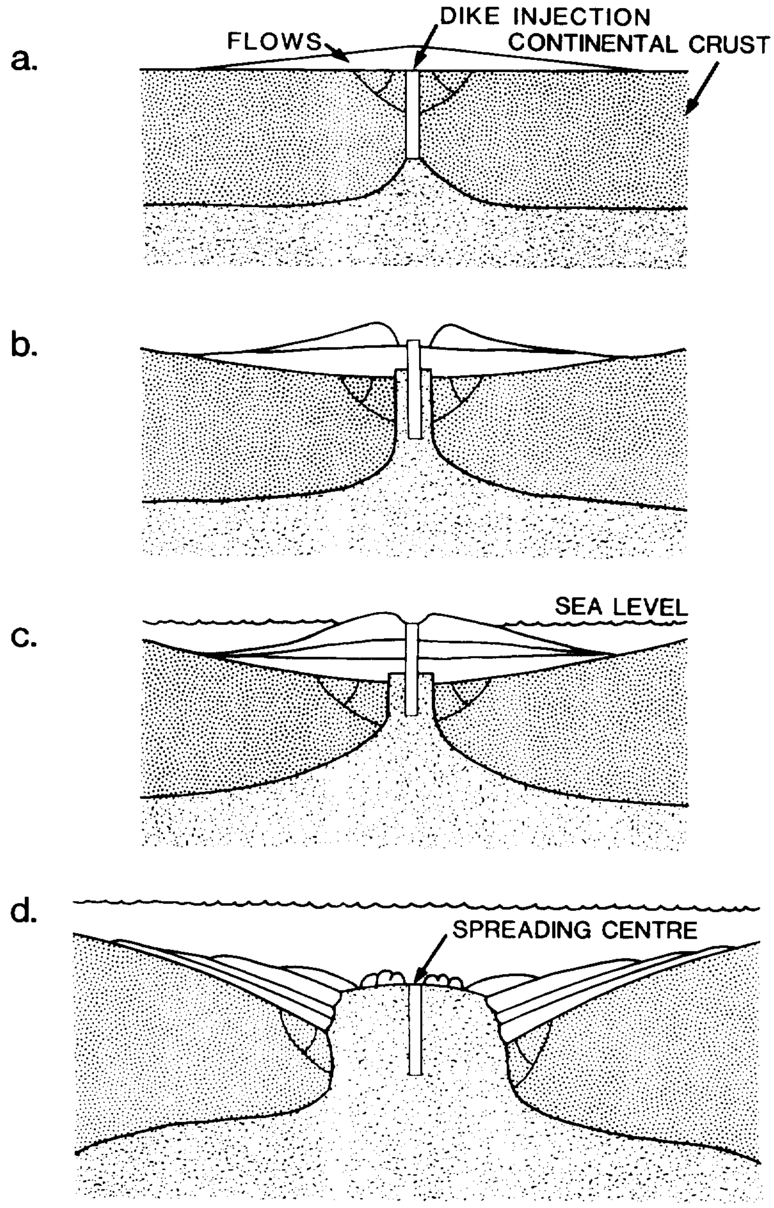

Figure 21. (b) Model of dipping reflector formation after Hinz (1981) involving sheet lava extrusion from central injection zone (black) onto thinned continental crust (stipple). For discussion, see text.