OCEANOLOGICA ACTA 1978 - VOL. 1 - N° 3

ART. N° 415
Contribution COB N° 584

The Jan Mayen Ridge synthesis of geological knowledge and new data

Rift
Microcontinent
Transform fault
Extinct axis
Ridge jump
Sea-Floor spreading
Norwegian-Greenland sea
Multichannel seismic reflection
Rift
Microcontinent
Faille transformante
Axe éteint
Saut de dorsale
Expansion des fonds océaniques
Mer de Norvège et de Groenland
Sismique reflexion multicanaux

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Received 27/1/78, in revised form 4/4/78, accepted 10/4/78.

ABSTRACT

The Jan Mayen Ridge and its southern extension were studied by means of multichannel reflection seismic profiles gathered during the Cepan 1 (Cercle Polaire Atlantique Nord) 1975 survey. These data have been interpreted with reference to the evolution of the Norwegian-Greenland Sea, which may be chronologically summarized as follows: 1) opening of the Norwegian basin from the now-extinct Aegir axis 60 myrs ago (magnetic anomalies 23 to 20); 2) westward jumping of the spreading axis: this new axis (Iceland Plateau Extinct Axis) lasted between 5 D and 6 A anomaly times (24 to 18 myrs); 3) second westward ridge jump leading to the setting of the currently active Kolbeinsey ridge. Three sedimentary units are separated by two unconformities. The lowermost unit, characterized by strong reflectors and high velocity, may represent paleozoïc and mesozoïc series. It is separated from the second unit by a low-angular unconformity (horizon 0). The series of the second unit are of post-opening age, probably deposited on an old slope dipping to the east and of deltaïc type in the northern area. At the top of this unit, Paleocene to early Oligocene in age, there is a high-angular Oligocene unconformity (horizon A), underlying the beds of the third uppermost unit (late middle Oligocene age to Recent). The good quality of the sections permits a tentative explanation of the origin of the different basalt flows. The northern part of the Ridge is affected by horst and graben tectonics. During the Oligocene epoch, the Ridge broke into two parts along an accident which we interpret as a rift trending SW-NE, the age of which is situated between the definitive extinction of the Aegir axis and the begining of the Iceland Plateau Extinct Axis (I.P. Extinct Axis). In the Northern area of the Ridge, at 68° latitude, the rift is shifted westwards with respect to its southern branch by what we shall suggest to be a transform fault (discussion).

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RÉSUMÉ

Synthèse des connaissances géologiques et données nouvelles sur la ride de Jean Mayen

L'étude de la ride de Jan Mayen et son prolongement Sud a été effectuée à l'aide des profils sismiques multicanaux obtenus lors de la campagne Cepan 1 de 1975. L'interprétation des données a été faite dans le cadre de l'évolution de la mer de Norvège et du Groenland. Cette évolution se résume en trois étapes : 1° ouverture du bassin norvégien à partir de l'axe d'Aegir actuellement éteint il y a 60 ma (anomalies magnétiques 23 à 20);

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2° saut de dorsale vers l'Ouest. L'activité du nouvel axe (Islande-Jan Mayen) a duré de l'anomalie 5 D à l'anomalie 6 A (24 à 18 ma); 3° un second saut de dorsale dont résulte la mise en place de la dorsale de Kolbeinsey actuellement active. —
La série sédimentaire est subdivisée en trois unités par deux discordances. La première unité, à la base, caractérisée par des réflecteurs énergiques et une vitesse de tranche élevée peut représenter le Paleozoïque et le Mésozoïque. Elle est séparée de la seconde par une faible discordance (horizon 0). Les séries de la deuxième unité sont d'âge post-ouverture et ont été vraisemblablement déposées sur une pente à pendage Est et de type deltaïque dans la partie nord de la ride.
Au sommet de cette série d'âge paléocène à oligocène inférieur, se trouve la discordance angulaire (horizon A) marquant la base de la série supérieure (Oligocène moyen à supérieur-Récent).
La bonne qualité des profils nous a permis d'attribuer une origine aux flots de basalte. La partie nord de la ride est affectée par un tectonique de horsts et de grabens.
La ride, à l'Oligocène, s'est cassée en deux parties le long d'un accident que nous interprétons comme un rift d'orientation S.O.-N.E. et dont l'âge est compris entre l'extinction de la ride d'Aegir et le début d'activité de l'axe de Jan Mayen-Islande. Dans la partie nord de la ride, à la latitude 68°, le rift a subi un décrochement vers l'Ouest par rapport à sa partie Sud. Nous présentons des arguments pour l'interpréter comme une faille transformante.

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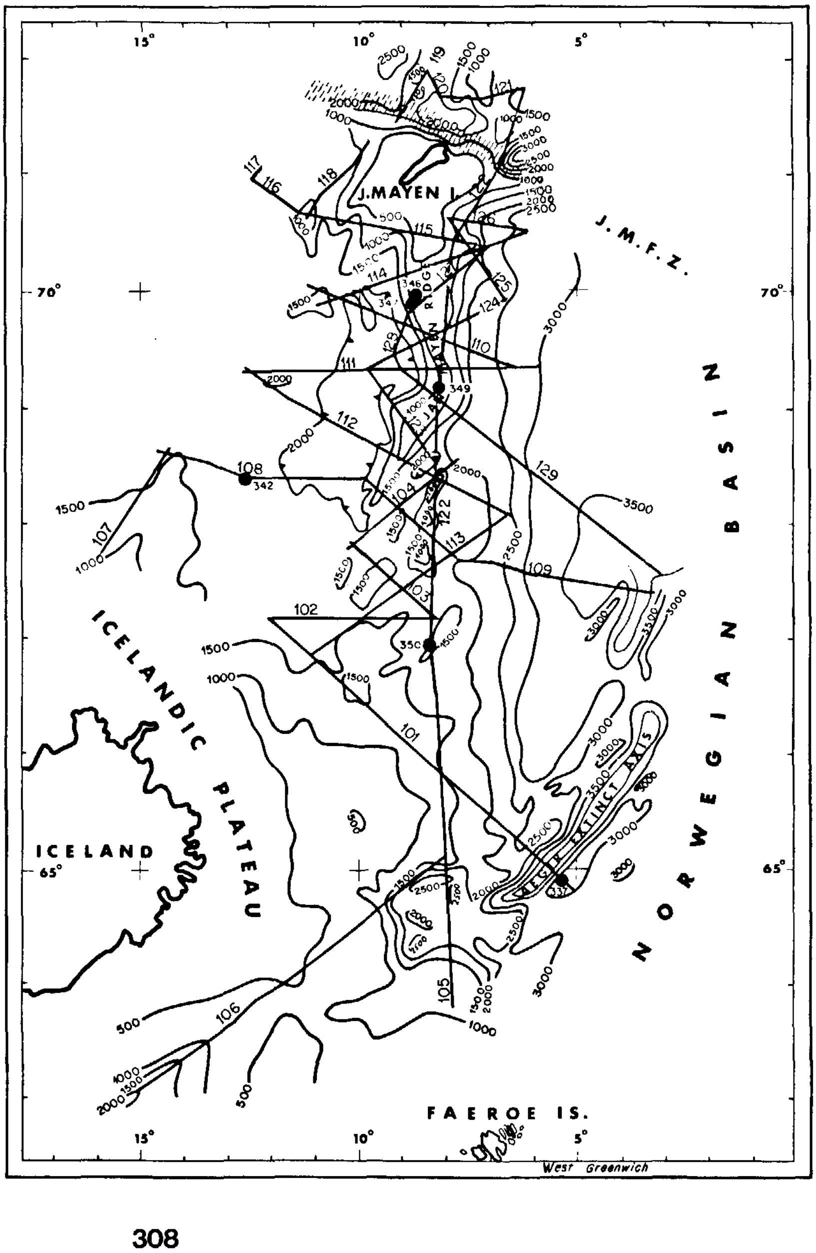


Figure 1
Location map of the Cepan 1 seismic survey (bathymetry in metres).

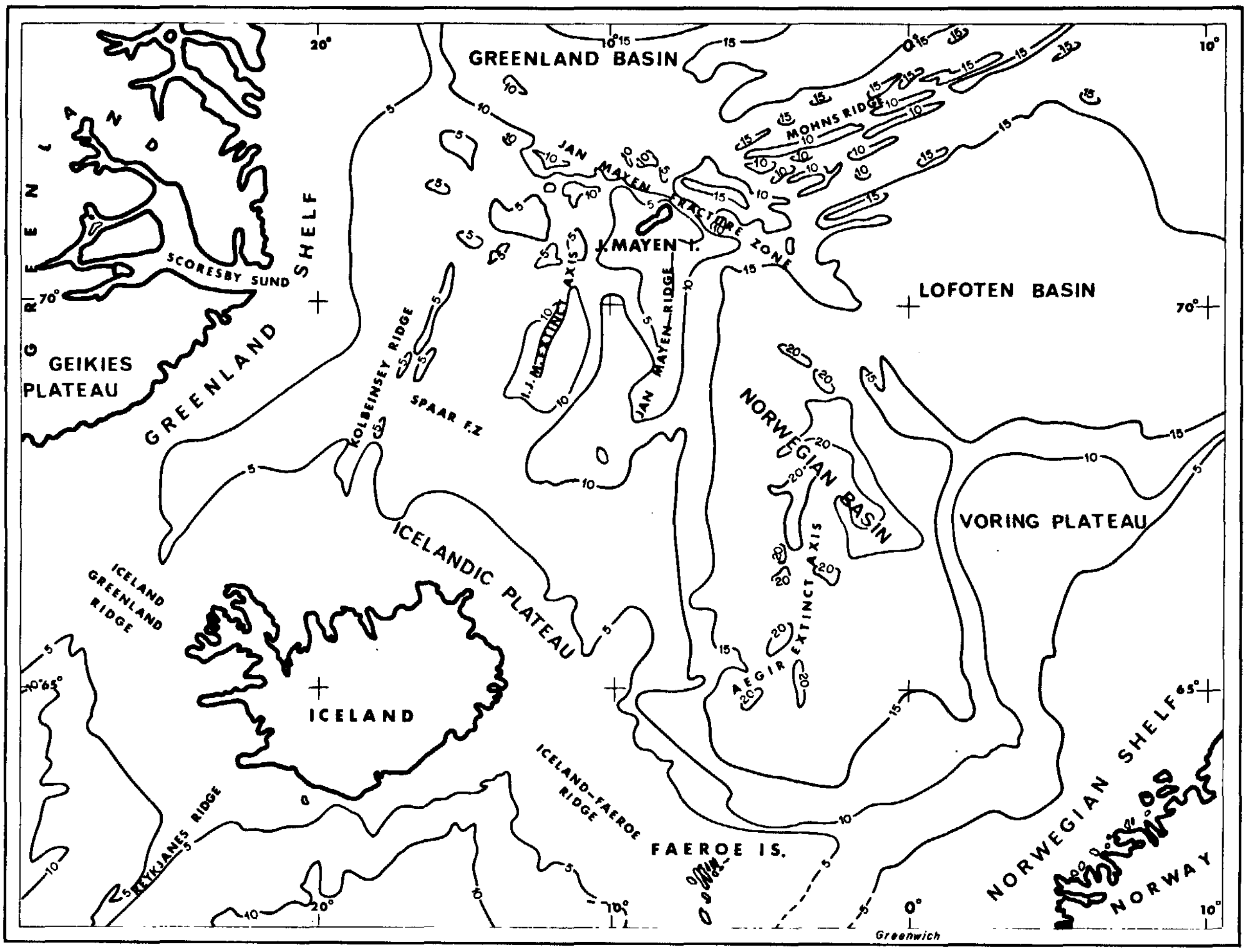


Figure 2
General map of the Norwegian-Greenland Sea (bathymetry in fathoms).

Our purpose is to present some results of the interpretation of the Cepan 1 survey (Cercle Polaire Atlantique Nord-North Atlantic Arctic Circle) carried out in 1975 (Fig. 1). The survey was limited to the Jan Mayen Ridge and its southern extension (3 and 15°W and 63 and 72°N). Several lines were extended to the oceanic areas to the East and West of the Ridge, in order to definê as precisely as possible the boundaries of this morphological unit.

The survey includes some 5 000 km of 24-channel seismic reflection profiles with an Ifp (Institut Français du Pétrole) Flexichoc source, established from the RV "Jean Charcot" of Cnexo (Centre National d'Exploitation des Océans). About 2 500 km of these profiles were processed, and the bathymetry and total magnetic field were recorded continuously.

The survey had a twofold objective. In the first place it was designed to confirm the existence of a sedimentary series which had already been observed in earlier investigations. Secondly it was intended to examine the tectonic style of the Jan Mayen Ridge, in relation to the spreading of the oceanic basins located to the East and West.

EVOLUTION OF THE AREA

On the basis of the schema presented by Talwani and Eldholm (1977), we may briefly describe the stages of evolution of the zone limited to the North by the Jan Mayen fracture zone, to the South by the Iceland-Greenland Ridge-Iceland Faeroe Ridge and to the East and West by the Norway and Greenland margins (Fig. 2).

The opening of the North-East Atlantic appears to have begun slightly less than 60 myrs ago. The oldest formally recognized anomaly in the basins to the North (Greenland and Lofoten basins) and South (East, and West Reykjanes) of the region in question is anomaly 24 (Avery *et al.*, 1968; Vogt, Avery, 1974). More recently, several authors have mentioned the possibility of an anomaly 25 on sketch maps (Johnson *et al.*, 1975, along the South-East Greenland margin; Talwani, Eldholm, 1977, along the Norwegian margin in the Lofoten basin and the East Greenland margin in the Greenland basin).

We observed along the western flank of the Hatton Plateau the existence of an anomaly probably related to that defined by Johnson *et al.* (Rockall-Hatton Cepm survey unpublished data). According to LaBrecque *et al.*, 1977, the opening of these basins would date from 56 to 59 myrs, i. e. the middle or upper Paleocene.

Talwani and Eldholm, 1977, have stated that the first anomaly recognized in the Norwegian basin is anomaly 23, but they estimate that the basin opened just prior to this anomaly, probably at the same time as the two contiguous north and south basins. They have also

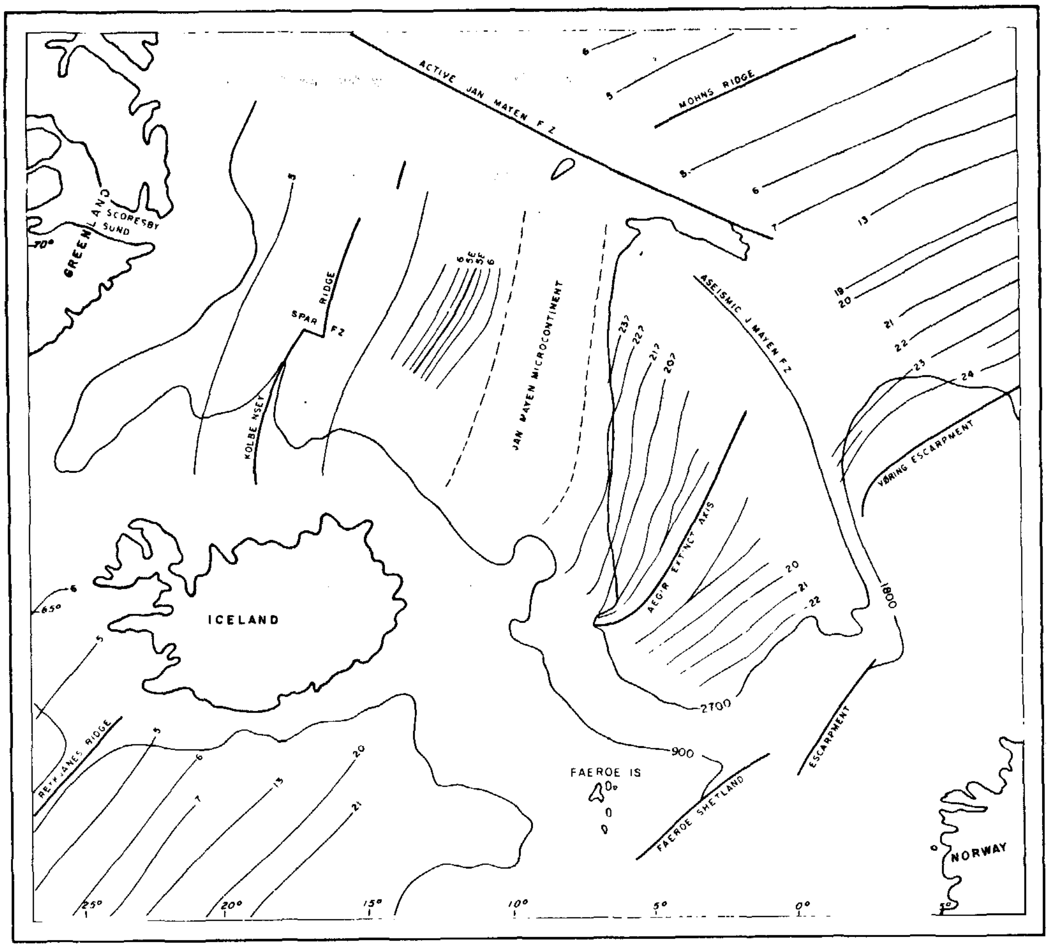


Figure 3
Magnetic anomalies of the Norwegian-Greenland Sea (after M. Talwani and O. Eldholm, 1977).

tentatively identified anomalies 23-20. Other more recent anomalies may exist, but cannot be defined with certainty. The basalts of Dsdp site 337 at the edge of the extinct axis have been dated as being about 25.5 ± 2.4 myrs old, and correspond to anomaly 7 (Initial Reports of the Deep Sea Drilling Project, Volume 38). In the adjacent basins to the North and South, the spreading rate declined sharply between anomalies 19 and 7 (Johnson *et al.*, 1970 and 1973). This variation has perhaps been even more noticeable in the Norwegian basin. The activity of the Aegir Ridge slowed down so considerably that one may speak of a cessation of oceanic spreading. It is likely that during this period the oceanic crust was formed in a fan-shaped pattern open to the North (Talwani and Eldholm, 1977, p. 980).

This event appears to be related to the extinction of the spreading axis of the Labrador Sea at the time of anomaly 13, i. e. 40 myrs ago (Kristoffersen and Talwani, 1977). The motion of Greenland relative to Norway changed from northwards to WNW at the time of jointing with the North American plate.

During the same period, a change of azimuth of the Jan Mayen fracture zone occurred, the eastern (currently aseismic) segment related to the northern motion of Greenland being relayed by the western (currently active) segment, trending WNW.

After ceasing its activity in the Norwegian basin, the spreading axis jumped to the zone immediately west of the Jan Mayen Ridge. The new spreading axis (I-P Extinct Axis) was most probably active between anomalies 5 D and 6 A.

Tensional forces seem to have affected the Jan Mayen Ridge crust and its southern extension. This point will be discussed further.

A new westward ridge jump occurred prior to anomaly 5, producing the currently active Kolbeinsey Ridge (Meyer *et al.*, 1972).

If one accepts the continental origin of Jan Mayen Ridge (Johnson, Heezen, 1967) and its southern extension, it may be assumed that this morphological entity broke away from Greenland at the time of origin of the intermediate ridge, i. e. 24-18 myrs ago. In other words, the tectonic events which preceded the drift of the micro-continent occurred just at the end of the Oligocene epoch.

PHYSIOGRAPHY OF THE REGION (Fig. 4)

Between 71 and 65°30'N, the bathymetric map shows that a strip lying at a depth of between 2 000 and 3 000 m and from 40 to 50 km wide marks the eastern boundary of the Jan Mayen Ridge and its southern extension. The Jan Mayen Ridge *sensu stricto* proceeds continuously from Jan Mayen Island to latitude 68°30'. Initially trending North/South, it changes direction to the South-West from latitude 69°. South of the Ridge, the bathymetry reveals interrupted alignments of heights, trending South and South-West.

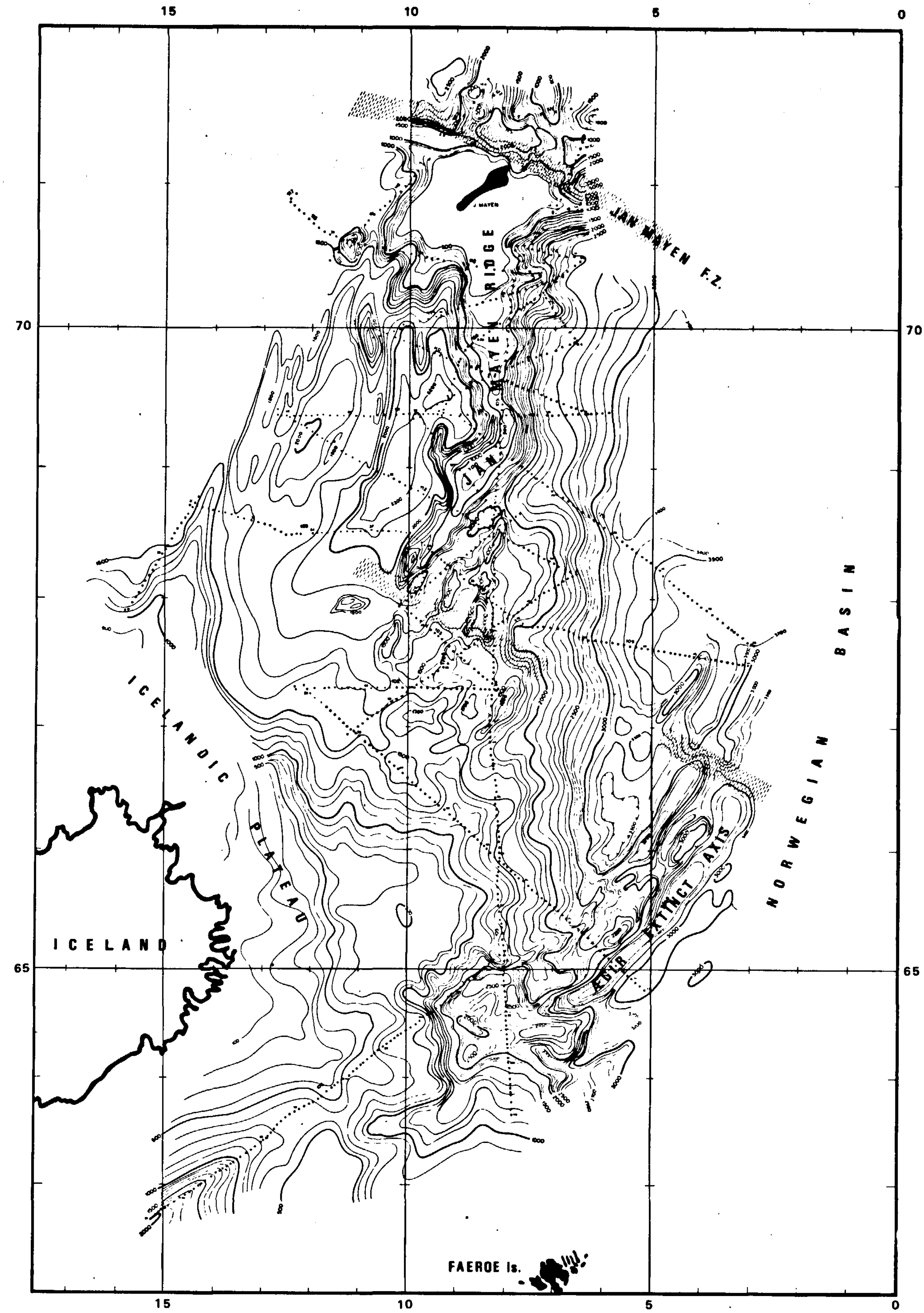
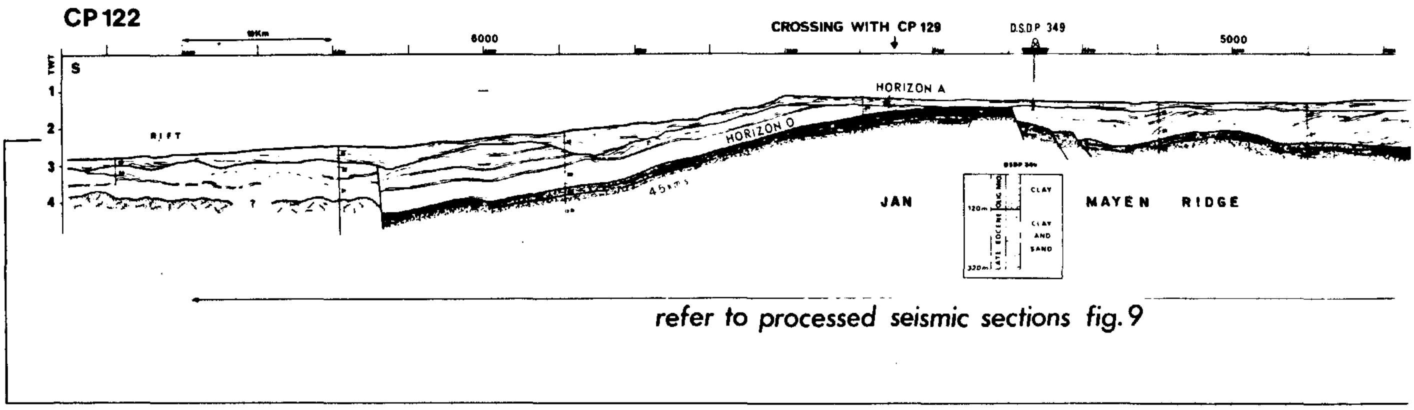
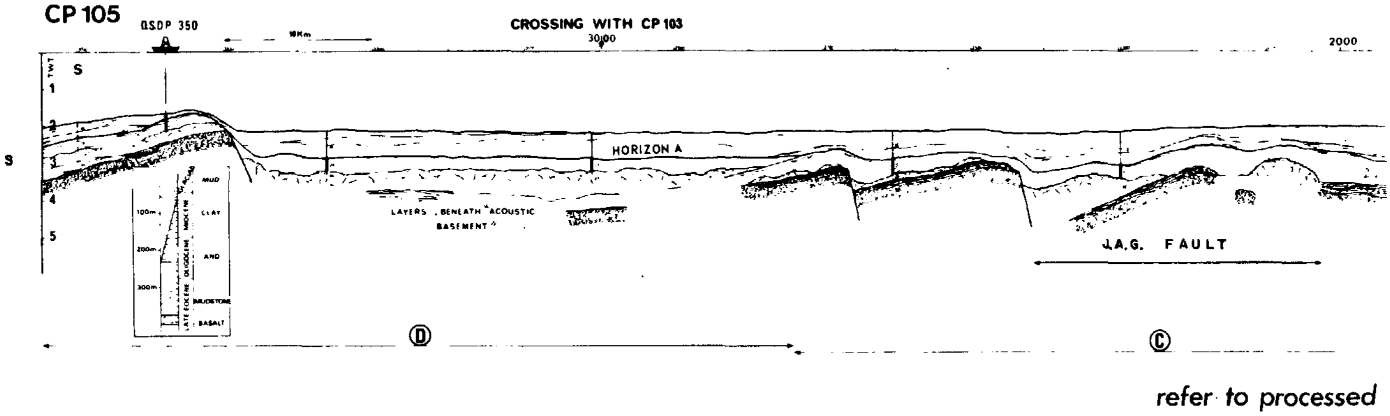
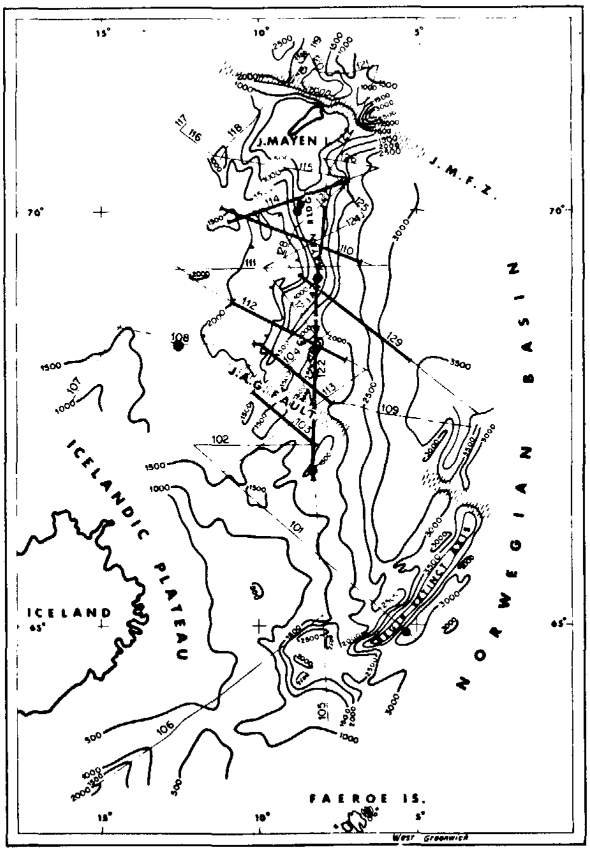


Figure 4
Bathymetric map of the Jan Mayen Ridge and adjacent areas (in metres) (from Cepan 1 and Vema tracks).

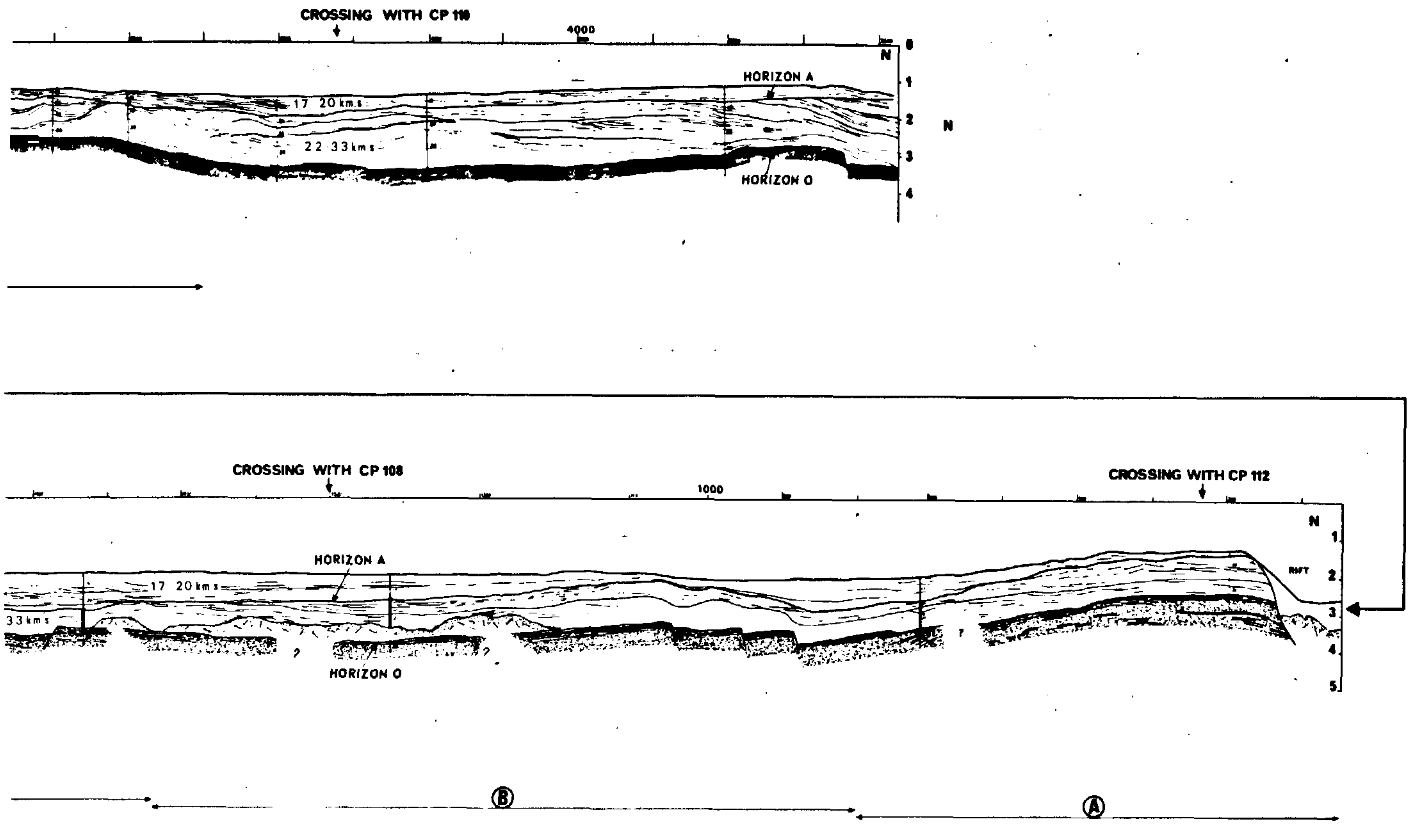






Figures 5

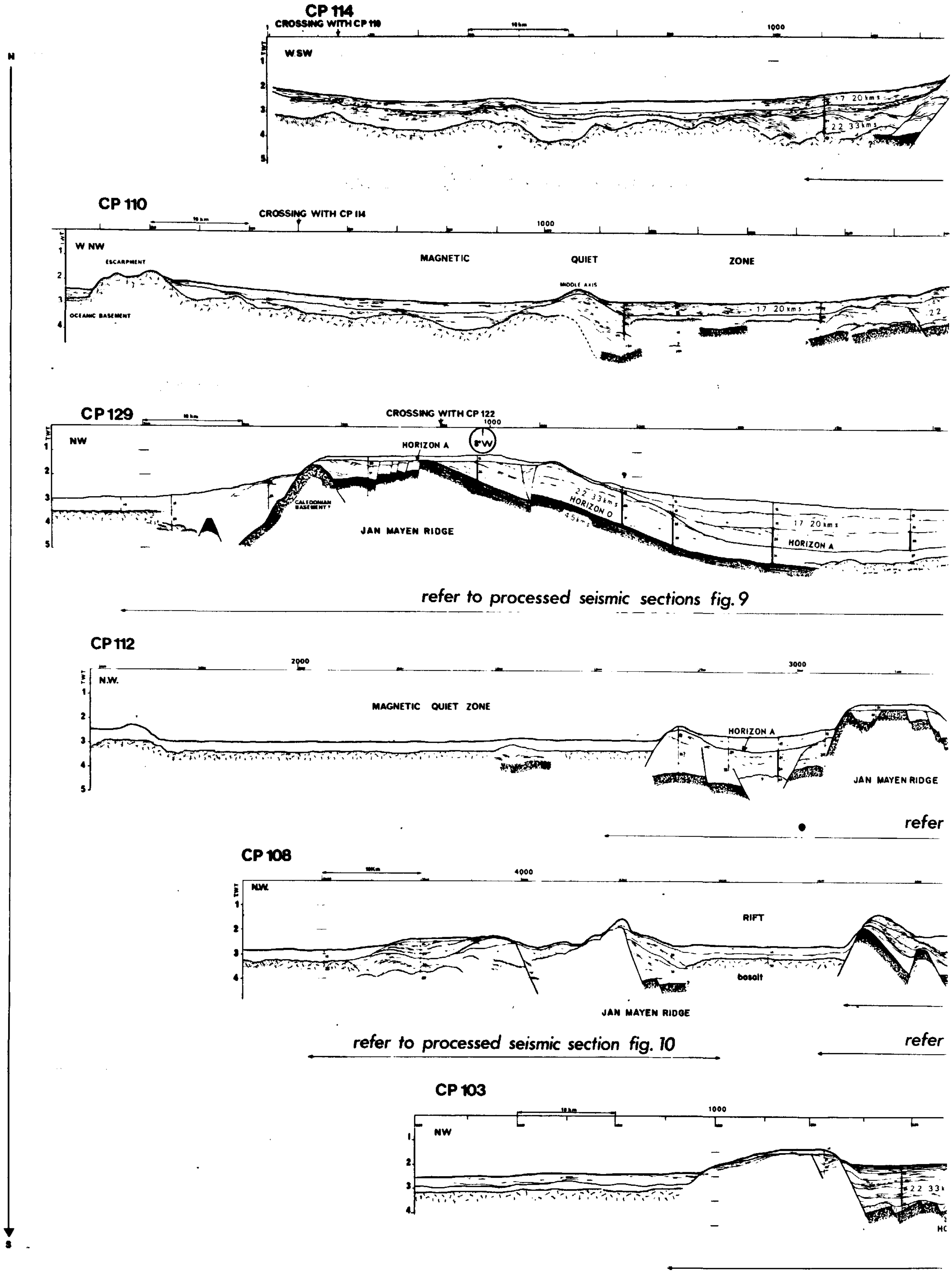
Time-sections of profiles CP 122 and CP 105. Location of time-sections of Figures 5 and 6 is shown on the opposite map by heavy line. In both Figures interval velocities are given in kilometers per second. Horizons A and O represent the Oligocene unconformity (see Dspd 349 on section CP 122), and the base of post-rift series respectively. Except for CP 110, parts of processed seismic profiles are referenced below each section. In Figure 6, the 8° W encircled sign shows the crossing of each section with this longitude (same as Fig. 11). In both Figures, crossings of the sections are also mentioned.



seismic sections fig. 11

Figure 5 *a*

The two time-sections lie from north to south on more than 330 *km, along the Ridge, and show the evolution of this feature. From the north, they cross the Ridge, the rift and the Jag fault, and reach the Dsdp* 350. *Note the faulted blocks on each side of this fault, and the reflectors below the basalt on site* 350 *(see also Fig. 8-D).*



CP 114
CROSSING WITH CP 110
1000
W.S.W
17 20 km/s
2.2 3.3 km/s
CP 110
CROSSING WITH CP 114
1000
W NW
ESCARPMENT
OCEANIC BASEMENT
MAGNETIC
QUIET
ZONE
MIDDLE AXIS
17 20 km/s
2.2
CP 129
CROSSING WITH CP 122
1000
NW
HORIZON A
8°W
CALEDONIAN BASEMENT ?
JAN MAYEN RIDGE
2.2 3.3 km/s
HORIZON O
4.5 km/s
17 20 km/s
HORIZON A
refer to processed seismic sections fig. 9
CP 112
2000
3000
N.W.
MAGNETIC QUIET ZONE
HORIZON A
JAN MAYEN RIDGE
refer
CP 108
4000
N.W.
RIFT
basalt
JAN MAYEN RIDGE
refer to processed seismic section fig. 10
refer
CP 103
1000
NW
2.2 3.3
N
S

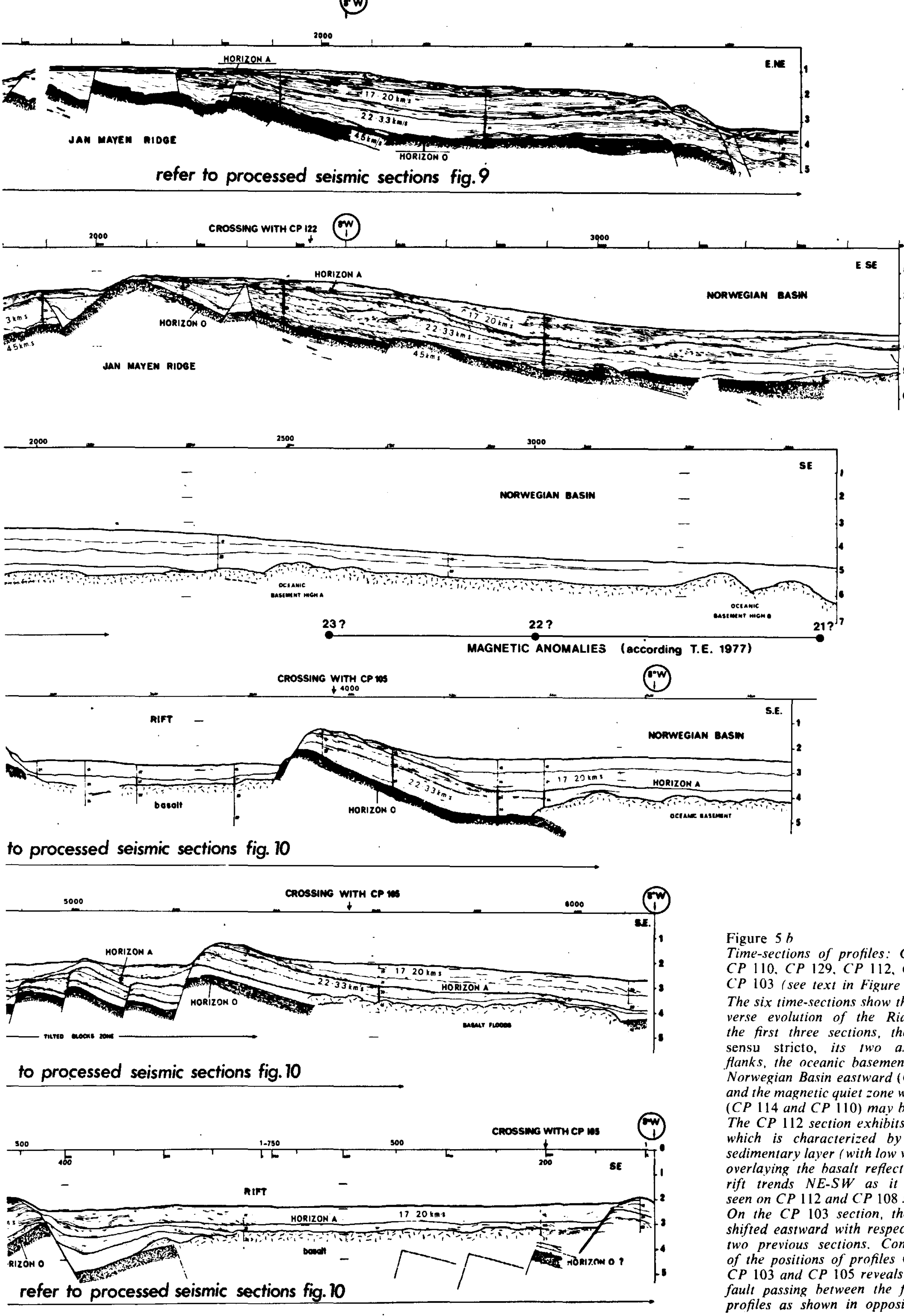


Figure 5 *b*

Time-sections of profiles: CP 114, CP 110, CP 129, CP 112, CP 108, CP 103 (see text in Figure 5).

The six time-sections show the transverse evolution of the Ridge. On the first three sections, the Ridge sensu stricto, *its two asymetric flanks, the oceanic basement of the Norwegian Basin eastward (CP 129) and the magnetic quiet zone westward (CP 114 and CP 110) may be noted. The CP 112 section exhibits the rift which is characterized by a thin sedimentary layer (with low velocity) overlaying the basalt reflector. This rift trends NE-SW as it can be seen on CP 112 and CP 108 sections. On the CP 103 section, the rift is shifted eastward with respect to the two previous sections. Comparison of the positions of profiles CP 108, CP 103 and CP 105 reveals the Jag fault passing between the first two profiles as shown in opposite map.*

These two units, Jan Mayen Ridge and its southern extension, are separated by a trough which reaches locally a depth of 2 000 m, and whose direction lies parallel to the southern portion of Jan Mayen Ridge *sensu stricto*.

The zone of interrupted alignments is connected to the Icelandic Plateau by a glacis.

To the west, the Jan Mayen Ridge is bordered by a depression deeper than 2 000 m, itself bordered to the west by an escarpment marking the boundary of a zone which is generally shallower than the depression, and which also defines a magnetic quiet zone.

In the Norwegian basin, there is an axis with a maximum depth of 3 800 m. This feature shades off northwards beyond 66°30′.

STRATIGRAPHY

The horizons discussed in this section are mentioned on the time sections (Figs 5 *a* and 5 *b*).

Horizon A

The combined study of seismic profiles and Dsdp wells enabled us to identify Horizon A, which corresponds to the first unconformity encountered below the sea bed, with certainty.

On the flat top of the Jan Mayen Ridge, this horizon intersects all the underlying series at an angle of 12-13° (see profiles 129, Fig. 6). On the Dsdp 349 site, it marks the contact between the Upper Eocene and the Oligo-Miocene, and although it does not exhibit a significant stratigraphic gap, the break is clearly marked in the sedimentation: the upper unit consists of muds and volcanic ashes, while the lower unit is of shaly formation (mudstone), together with interbedded conglomerates, breccia and sandstones.

On the eastern flank of the Ridge, Horizon A deeply scours the underlying series. On profile 124 it may be estimated that 900 m of sediments have been eroded and redeposited downstream from the slope as turbidites.

In the Norwegian basin, Horizon A is tangent to the oceanic basalts. On the other hand, on profile 108, on the east flank, it appears to be conformable with the underlying series. This difference implies that at the time when this unconformity was created, a great difference of elevation existed between the Ridge itself and its southern extension. A portion of the Ridge may even have emerged when the southern zone remained below sea level.

The interval velocities show different values: 1.7-2 km/s for the upper part, 2.2-3.3 km/s for the lower part. This contrast is due to lithology and to variations in compaction of sediments of different ages.

The ante-unconformity sediments are of high-energy mode: beds of sandstones and conglomerates exist in well 349; moreover, on section 122 just North of the well, the highly disturbed deposits appear to be of deltaic type, with shifts of channel axes. Similar patterns are observed on section 110.

South of the Ridge, the deposit appears to be of medium energy, and the sediments appear conformable and bedded. This difference strengthens the interpretation offered above: deposit of subaerial deltaic series to the North and deeper slope series to the South.

Although no well drilled the complete series (from mud line to horizon 0), we believe that these sediments post-date the opening of the Norwegian basin and that they date from the Upper Paleocene to recent periods.

Horizon 0

In our interpretation, which is not yet, unfortunately, confirmed by any well, this horizon represents the unconformity surface on which the post-opening series were deposited.

The age and nature of the underlying formations can only be inferred. However, we feel that by analogy with neighbouring continents, particularly Greenland, they may be Caledonian granites or metamorphic rocks, as may be the case on the western edge of the plateau of the Jan Mayen Ridge (*Cf.* profiles 112 and 129, Figs 5 *b*, 6 and 7).

At other points, Paleocene overlies an apparently sedimentary formation with strong reflectors, possibly indicating interbeds of limestone, shale and dolomite. Our velocity analyses show that these formations are very fast, up to 4 km/s, consistent with Paleozoic, marine Zechstein or Mesozoic. Identical velocities were obtained by refraction on the northern part of the Jan Mayen Ridge by Lamont (Eldholm, Talwani, 1973).

The 0 marker is generally affected by faults which give to the region a tectonic style consisting of horsts and grabens (especially frequent on the Ridge) and tilted blocks (zone south of the Ridge).

Horizon basalt

Several Dsdp wells (337, 348, 350) reached basalts, which made it possible to define the corresponding seismic horizon.

We have distinguished three types of basalt markers:

1. diffraction hyperbole marker, wavy and constituting the top of large masses of material. This is generally associated with magnetic anomalies.

2. marker associated with considerable basalt extrusions through tension cracks not far from the ocean continent boundary, as on profile 108 beyond point 5 500 (Fig. 7). Interrupted markers often appear below this horizon, as on profile 105 at points 1 300 and 1 500 (Fig. 8);

3. flat marker comparable to that of the basalts already known on the Vøring plateau (Dsdp 338 and 342). This basalt is probably spread on a sedimentary unit, and depending on its thickness it masks more or less the underlying horizons: profile 108 between points 4 400 and 4 600, profile 112 between 1 800 and 2 400. It is sometimes completely interrupted and allows deeper markers to appear: profile 112 between points 3 450 and 3 550.

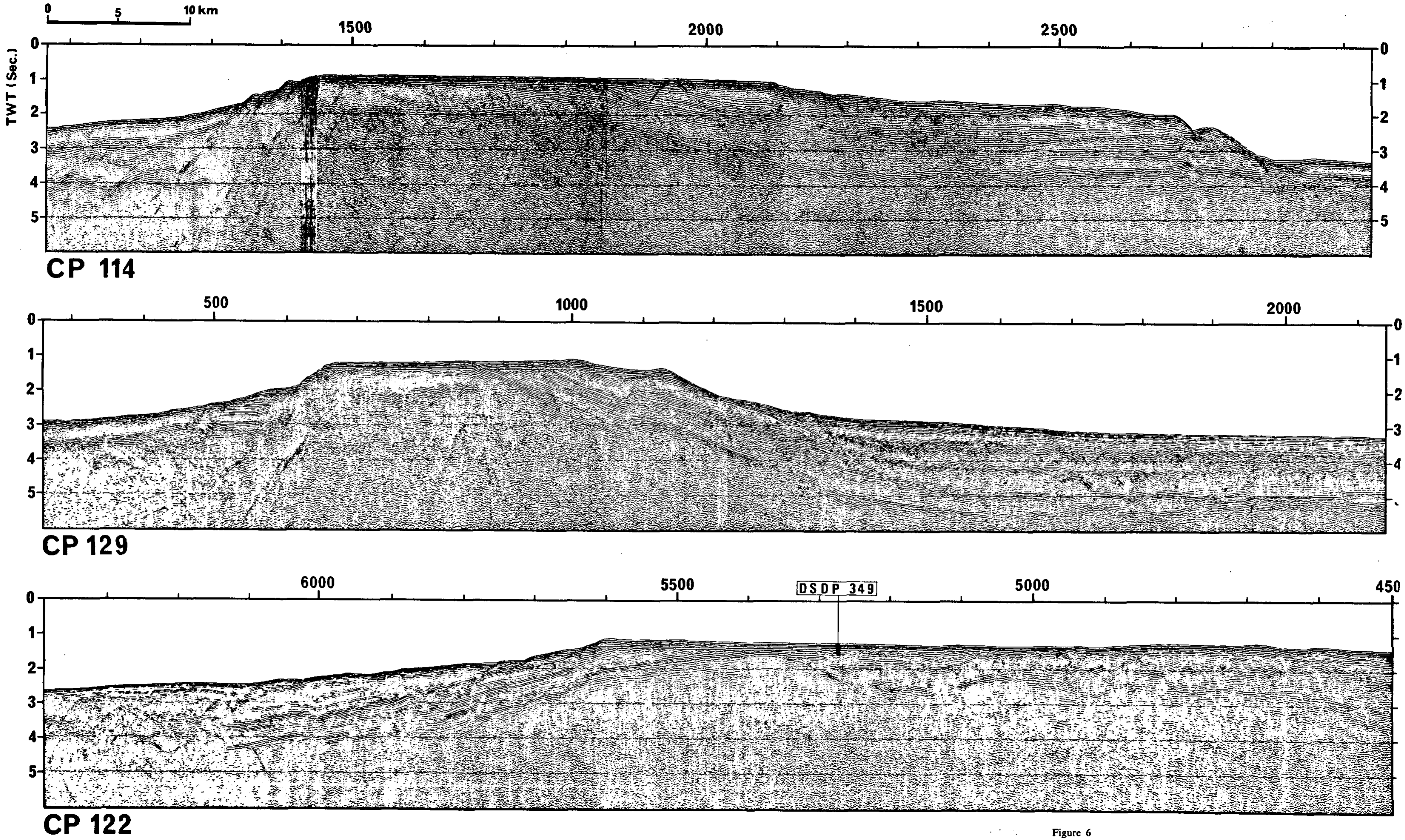


Figure 6
Processed seismic sections (24 fold) of profiles: CP 114, CP 129, CP 122.

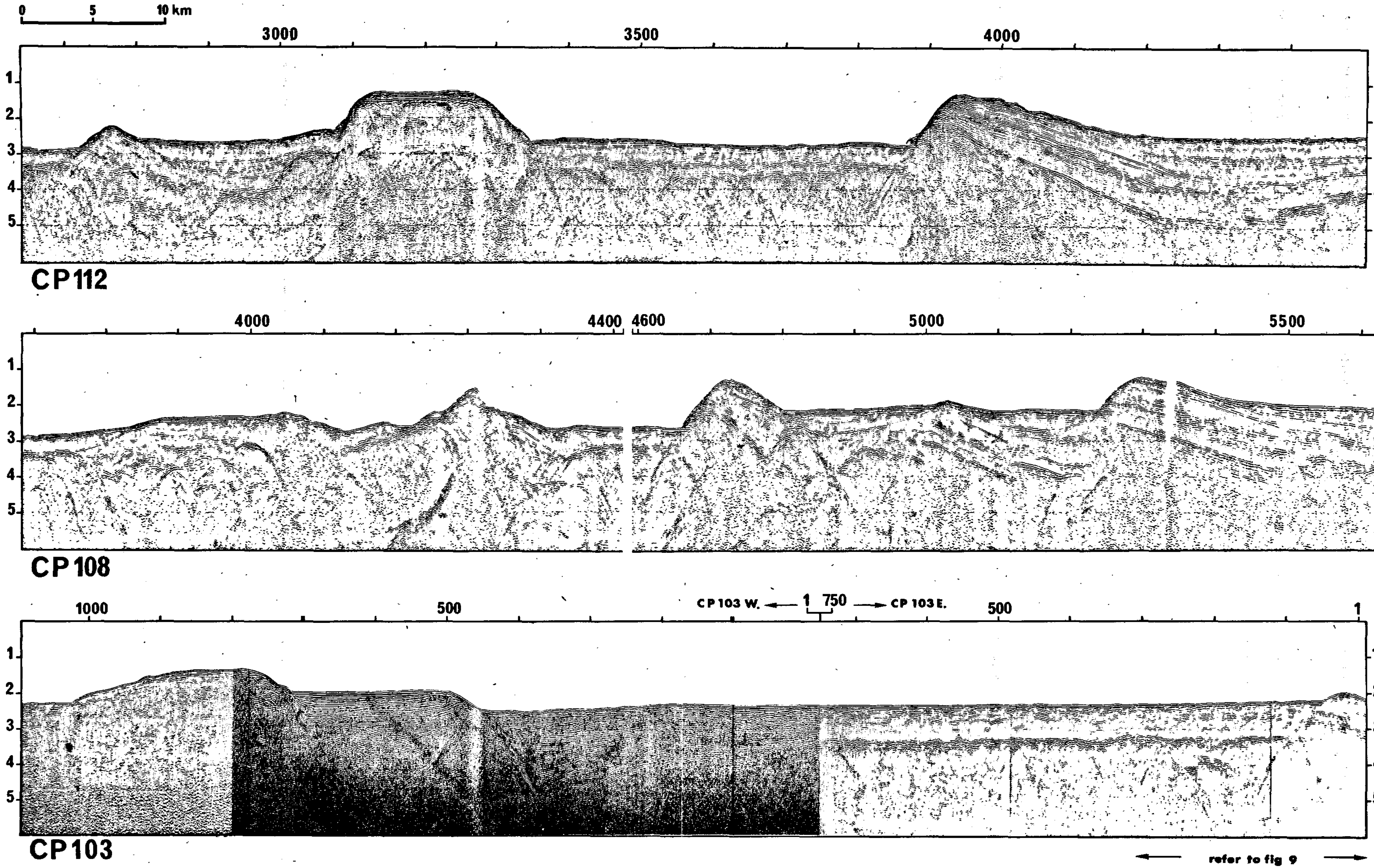


Figure 7
Processed seismic sections (24 fold) of profiles: CP 112, CP 108, CP 103.

This basalt is sometimes relayed by tuff beds. It is not magnetic and may have emerged through fissures or faults such as the Vøring escarpment or the faults in profile 108 at point 4 680. At well 350 on profile 105, it corresponds to a fresh basalt covered with tuff and volcanic breccia to a thickness of 20 m. Markers are visible below.

The diversity of the basalts and their mode of formation do not reflect the same phenomenon. Certain basalts constitute the true oceanic basement, while others merely form a seismic screen under which the sedimentary formations exist.

STRUCTURAL RESULTS (Fig. 6)

Eastern oceanic zone

The extinct Aegir axis, which crosses the Norwegian basin, is clearly defined by bathymetry, especially in its southern branch. North of 67°, the path of the axis is less certain and even seems to shift westward. This would not be obvious from the gravity data. Moreover, in the zone northwest of the basin, we followed two basaltic alignments, "*a*" and "*b*". Near the Jan Mayen Ridge, the "*a*" alignment approximately follows anomaly 23 (?) as determined by Talwani and Eldholm (1977).

We extended this axis southwards further than anomaly 23, up to section 13 in Figure 11, and interrupted it southwards at latitude 67°30', because to the south it would align with the axis on which Dsdp site 350 was located, which appears to be of different origin and composition. It would appear to extend south of 67°30', as shown in the structural sketch. Axis "*b*" also appears to be interrupted at latitude 67°30', and two basaltic alignments are observed in the southern compartment. All the alignments are parallel to the Aegir axis and to the ocean-continent boundary defined in Figure 10. They intersect the magnetic anomalies, with the exception of anomaly 23 mentioned above, which coincides approximately with the basaltic swelling "*a*". We do not have enough magnetic profiles in this basin to confirm existing models or to suggest a new one.

The ocean-continent boundary East of Jan Mayen Ridge also appears to be shifted at the same latitude as the Aegir axis, in the same direction and in the same order of magnitude.

It should also be noted that in the compartment south of this line, which we called the J.A.G. Fault, our alignments of the basaltic basement, the ocean-continent boundary, and the Aegir axis are parallel to the "C" gravimetric axis revealed by Talwani and Eldhom (1977) (*cf.* Fig. 10).

The southern extremity of the Aegir axis is interrupted suddenly at 65°N by east-west depression which is visible on section 24 in Figure 11. According our interpretation, this depression may be a fracture zone more or less parallel to the Iceland Faeroe ridge.

Magnetic quiet zone

This zone lies between the Jan Mayen Ridge and the IP Extinct Axis.

This topographically low zone is characterized by the absence of substantial variations in magnetism and relief (Johnson *et al.*, 1972); with the exception of a north-south anticline axis called the Middle axis, the continuity of which is uncertain but nevertheless possible. On each side of this axis, one may note on profile 110 (Fig. 5 *b*) the existence of a reflector which is indicative of basalt, and on the axis itself, a layout of markers comparable to that of the series of the Jan Mayen Ridge. We believe that this axis is covered by a sedimentary series draping a basement of continental origin. To the South at the level of profile 108 (Figs 5 *b* and 7), it is connected to the Jan Mayen Ridge through a fault with a large throw.

The characteristics of this magnetically quiet zone and the presence of an axis of continental origin lead us to consider it to be a collapsed edge of the rift created before the split of the Jan Mayen Ridge from its original continent, while the present Greenland margin lies at the opposite edge of the rift.

According to this theory, the median axis of this zone is a microcontinental fragment of the same origin as the Jan Mayen Ridge, separated from the latter by a narrow collapsed basin, following intense distension closely associated with magmatic extrusion phenomena.

The Jan Mayen Ridge

We have used this term to define a precise structural unit, which includes the entire zone bounded on the structural diagram by the two dashed lines. It thus includes the magnetic quiet depression described above (Fig. 10).

North zone

Between 71 and 69°N, the Ridge trends North-South. Its northern boundary is poorly defined, due to the basaltic extrusions which mark the contact with the Jan Mayen fracture zone.

Structurally, the asymmetry of the lateral slopes appears mainly at the level of Horizon 0 and affects all the upper horizons similarly. The western slope is steep and generally complicated by a series of step faults. To the east, in the direction of the Norwegian basin (Figs 5 *b* and 6), the slope is uniform.

In the central zone of the Ridge, the basement is affected by faults which have created a system of horsts and grabens reflecting the effects of the opening of the Norwegian basin on the Greenland margin. The basement faults which appeared at the beginning of the Tertiary played a subsequent role during the breaking up of the Ridge.

Along the entire Ridge, the unconformity associated with Horizon A is horizontal. The underlying series appear to have undergone intense erosion in a subaerial environment. The sediments deposited on the erosional surface date from the Oligocene and are horizontal. Thus no deformation seems to have subsequently affected the region. This may be observed on profiles 114, 110, 129 and 112. The latter profile also shows the same occurrence on the high point located at S.P. 3 950. The southern extremity of the Ridge narrows and only its western portion remains. It plunges to a depth of 1 000 m on profile 112, to 1 500 m on profile 108, and becomes completely buried further south.

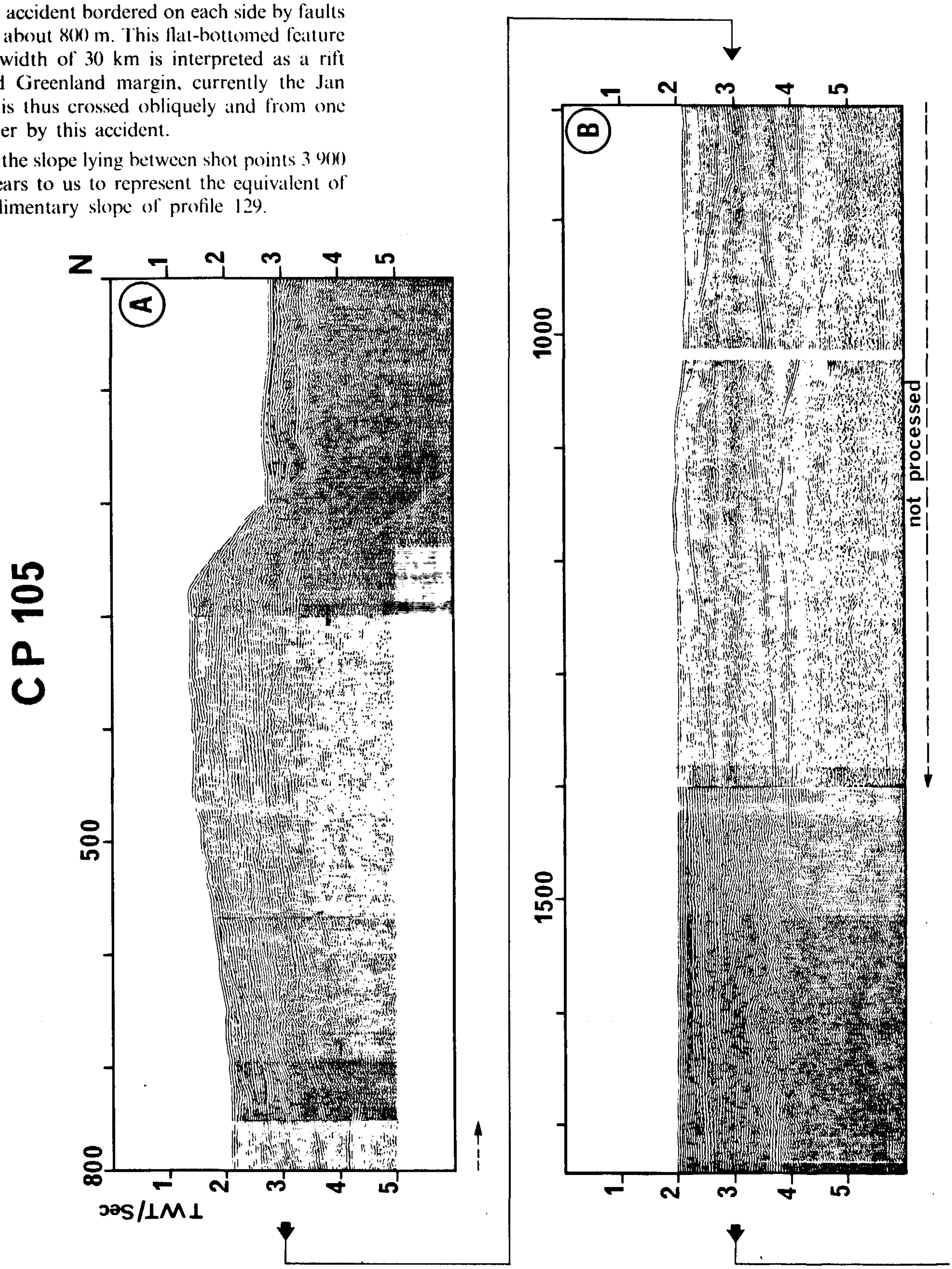
Median zone

Comparison of profiles 129 and 112 reveals identical structural features (Figs 6 and 7). However, a new element appears on CP 112. The Ridge is broken into two parts by an accident bordered on each side by faults whose throw is about 800 m. This flat-bottomed feature of an average width of 30 km is interpreted as a rift valley. The old Greenland margin, currently the Jan Mayen Ridge, is thus crossed obliquely and from one side to the other by this accident.

On profile 112, the slope lying between shot points 3 900 and 4 400 appears to us to represent the equivalent of the eastern sedimentary slope of profile 129.

Turning to profile 108 (Fig. 7), it may be observed that the tectonic effects of rifting broke the slope into tilted blocks, bounded by a frontal fault plunging toward the central part of the rift. On the other side of the rift, the basement is broken by faults, with the same throw.

The essential characteristics of the rift valley are associated with the presence of basalt or tuff, which marks the bottom of the rift. At certain points, the marker is



interrupted and allows other horizons to appear. This event has been plotted on Figure 10 under the term "window". It may be the result of a distension which occurred shortly after deposit of the basalt or discontinuous basalt flows.

Above the basalt, the low thickness of the sedimentary series (average 800 m) is slightly higher than that penetrated in Dsdp site 348, which reached the basalt at 520 m. Assuming that the sedimentation rates are identical in both zones, the age of the rift would be

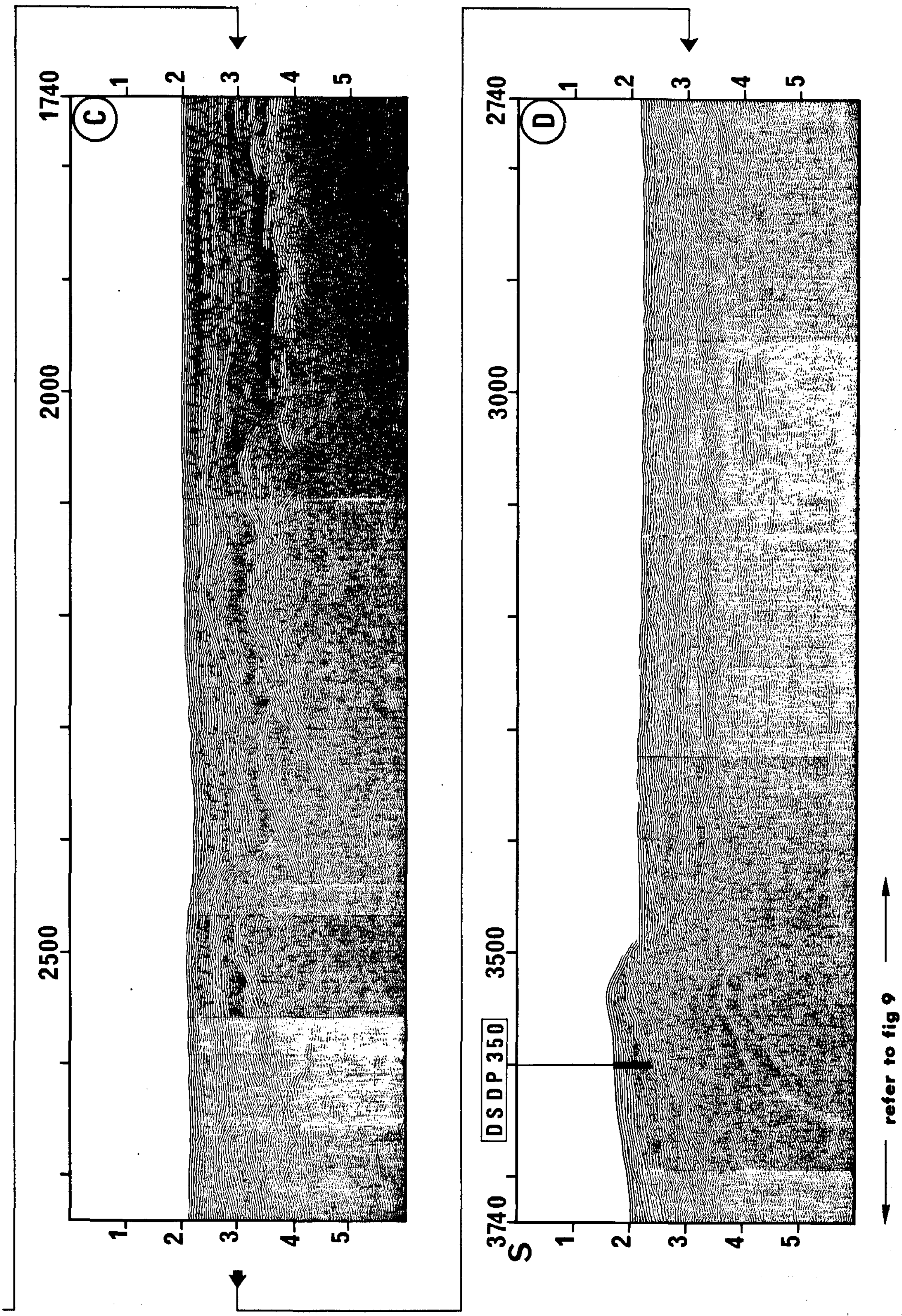


Figure 8
Processed seismic section (24 fold) of profile: CP 105.

subcontemporaneous or slightly older than that of the initiation of the split between the Jan Mayen Ridge and the continent of Greenland.

The southern zone

Comparison of profiles 108 and 103 (Fig. 5 *b*) reveals a similarity of structural features between the median and southern zones.

A flat zone exists on profile 103, covered by a thin layer of sediments deposited on a basaltic flat layer.

On either side of this zone, the frontal faults of the tilted blocks are antithetical, and plunge towards the central depressed area. It may be noted that the eastern block is more deeply buried than the western block and the eastern blocks of profile 108, and that the apparent width of this flat zone is greater at the level of 103, probably due to a deeper burial which, further southward, causes all the structural features to disappear under a thick sedimentary and/or volcanic layer (see caption of Fig. 11).

This tendency has already been mentioned in the northern zone.

The general characteristics are identical in profiles 108 and 103, and we interpret the zone bounded by shot points 400 W and 100 E to be the southern extension of the rift. On profile 105, the eastern zone of the rift is intersected obliquely and spreads from Dsdp site 350 up to shot point 2 000. The rift is also characterized by a succession of faulted and tilted blocks; furthermore, the profile shows that markers exist under the basalts, which may be interpreted as sedimentary strata. These may consist of Paleocene series or older formations.

The question remains unanswered as to whether this zone (zone 3 of Talwani, Udintsev, 1976) is oceanic, or whether, as we believe, it forms part of the old Greenland margin.

The puzzling question of basalts of the Dsdp 350 must be examined from CP 103 and 105 profiles. Unfortunately, CP 103 do not pass on the Dsdp site. However, the drilling is on the CP 105 which intersects CP 103. On each side of the rift, except on the high of the CP 103 between shot points 750 and 1 050, the presence of basalt should be noted (Fig. 9). This could be explained by its higher position when the basalt was deposited. This basalt which is overlaid by late Eocene sediments, could be correlated with the tholeiitic basalts of the Greenland Geikies Plateau of the late Paleocene to early Eocene (Thanetian to Sparnacian). It would thus be older than the basalt of the rift which—according our interpretation—(see p. 350) is of late Oligocene to early Miocene origin. The basalts deposited on the hills of CP 103 would have been deposited before the opening of the rift. This effusion of a basaltic liquid on to continental crust over a relatively short period seems to parallel that which occurred on the Geikies Plateau, and probably marks the initial rifting episode immediately prior to the onset of plate separation between Greenland and Europe (N. J. Soper *et al.*, 1976).

In conclusion, as far as this section is concerned we should point out the main structural features of the region lying between 71 and 66°30′ are identical from north to south and consist of:

- a ridge, probably of continental origin, bordered on either side by oceanic basins, the eastern one dating from the Paleocene and the western one dating from the Middle to Upper Oligocene;
- a uniform eastern slope of the ridge in the direction of the Norwegian basin, which connects with the oceanic basalts;
- a zone west of the Ridge characterized by a great number of faults and subsided blocks immediately adjacent to the ridge, and by a magnetic quiet zone, probably corresponding to a collapsed area from which a median axis emerged parallel to the Jan Mayen Ridge;
- a rift oriented south-west-north-east which initially broke the Ridge south of 68°30′ into faulted and tilted blocks, and which has probably been filled by products of the erosion of the edges, over which basalts and/or tuffs were subsequently deposited;
- a shift in tensional forces from East to West between the extinction of the ridge of the Aegir Basin, which appears to have lasted from the Upper Eocene to the Upper Oligocene (Dsdp 337) and the starting of the IP Extinct Axis, dating from the Upper Oligocene (Dsdp 348).

The action of these forces on a rigid continental crust probably resulted in a break up of Jan Mayen Ridge which was at the time still attached to the Greenland plate or just beginning to break away.

It further appears likely that this tectonic event did not go beyond the stage of a rift.

The continental origin of the Dsdp site 350 area constitutes the geometrical problem of the Norway basin, whose oceanic floor is wider to the North and narrower to the South. In view of the paucity of our data, we are unable to solve this problem.

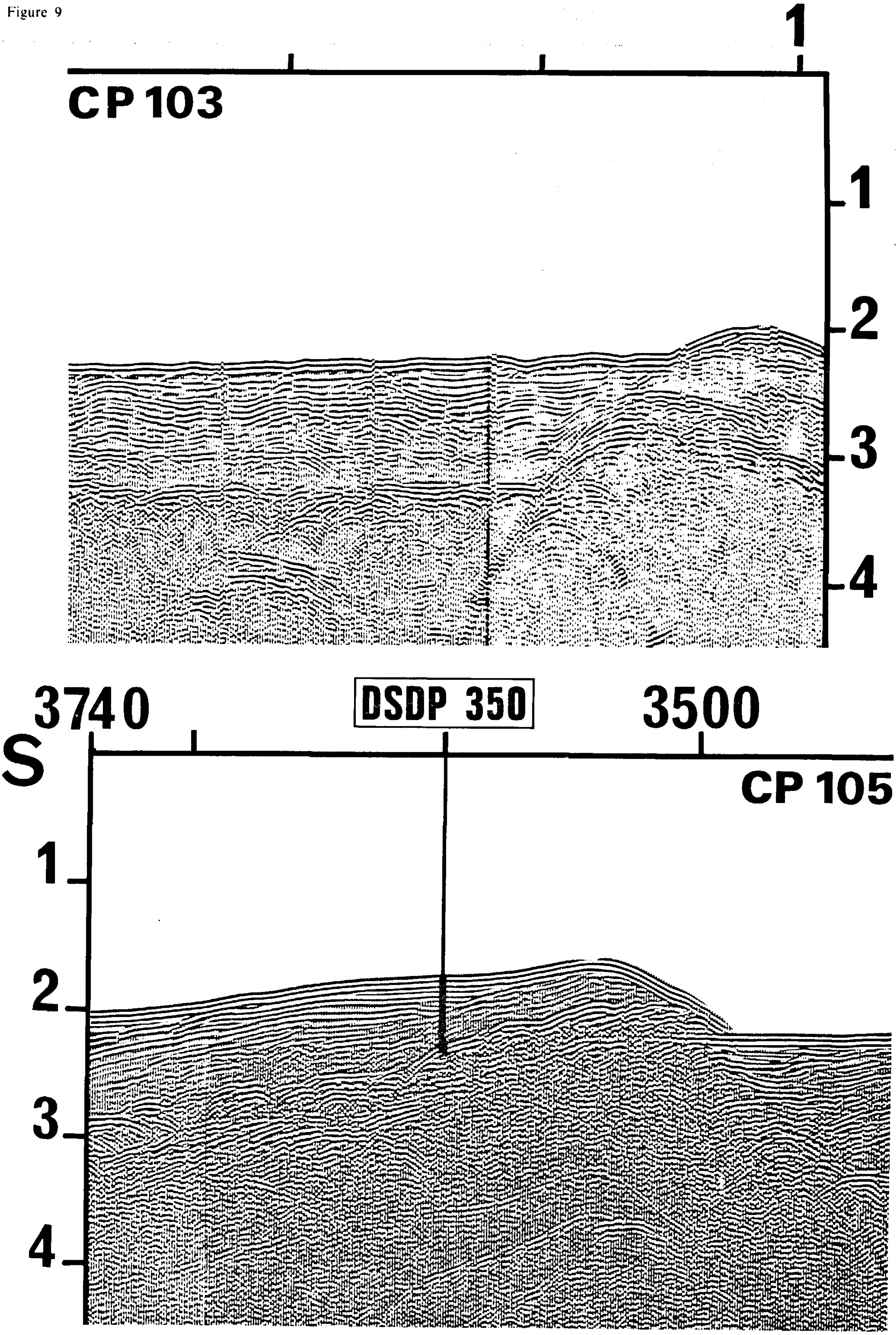
It is possible that the different phases of evolution of the Norwegian basin and the Jan Mayen Ridge partly overlapped. The rift may in fact have acted on the margin of the old continent of Greenland before the spreading of the Aegir Ridge had been completed. The rifting may have begun earlier, perhaps during the Upper Eocene, with a paroxysmal phase at the end of the Oligocene, when subaerial erosion affected the highest points of the Ridge.

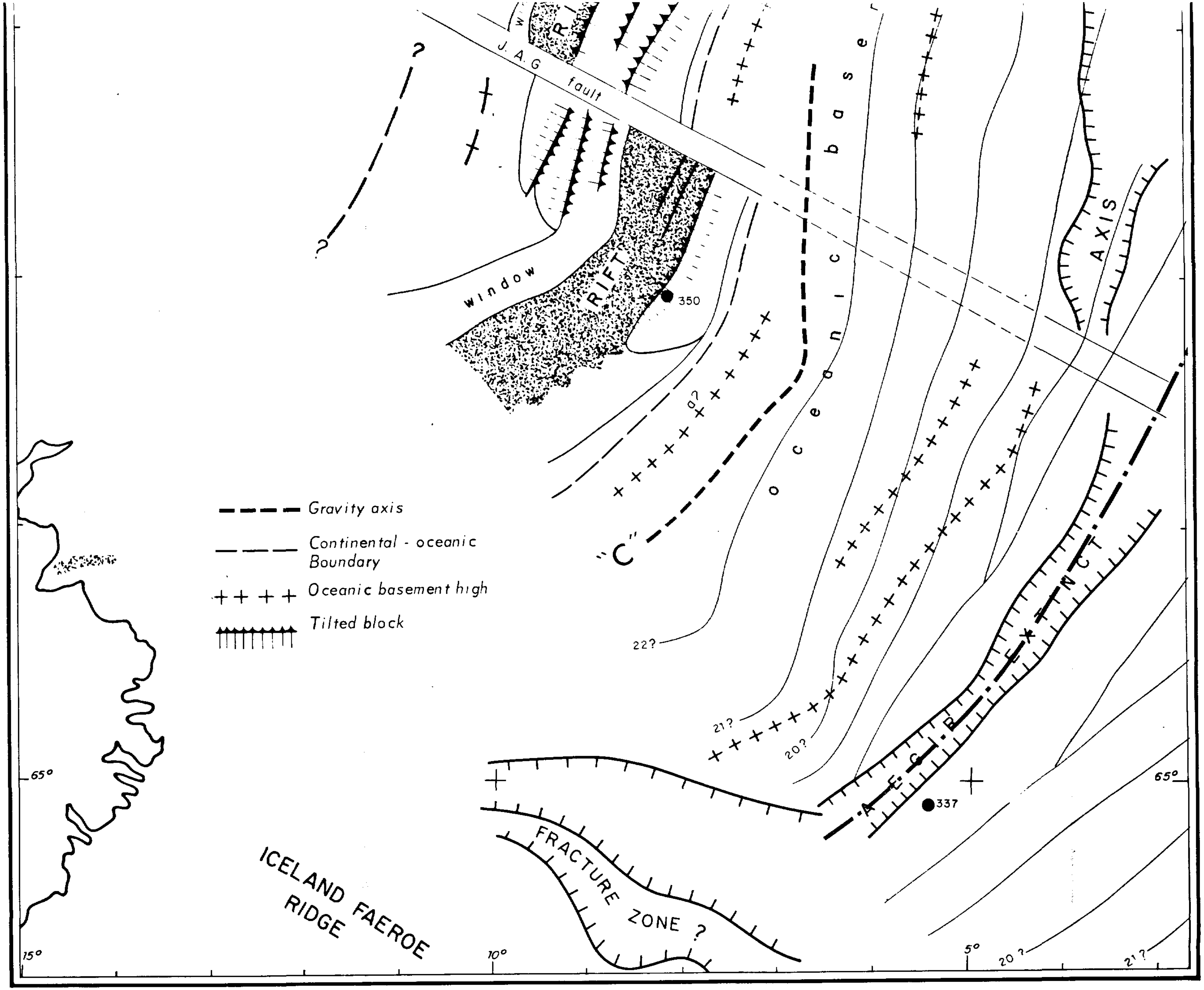
J.A.G. fracture zone

The structural similarities in profiles 108 and 103 are clearly visible in Figures 5 *b* and 7. However, it is impossible to align the rift axis using the two profiles, and a shift of about 60 km must be accepted. Moreover, the alignment of the high points on each side of the rift raises the same problem. It must be accepted that the Jan Mayen Ridge *sensu stricto* ends suddenly at its extremity and is relayed by the high point of profile 103 located between S.P. 800 and 1 000. It may be noted that the top of this high was subjected to aerial erosion similar to that observed on profiles 129 and 112, which produced the horizontal unconformable surface of the late Oligocene.

The shift of the two above-mentioned blocks occurred along a line parallel to profiles 103 and 108. However,

Figure 9





Gravity axis
Continental - oceanic Boundary
Oceanic basement high
Tilted block
J. A. G fault
window
RIFT
oceanic basement
"C"
350
337
AEGIR
EXTINCT
AXIS
ICELAND FAEROE RIDGE
FRACTURE ZONE ?
22?
21?
20?
20 ?
21 ?
65°
15°
10°
5°

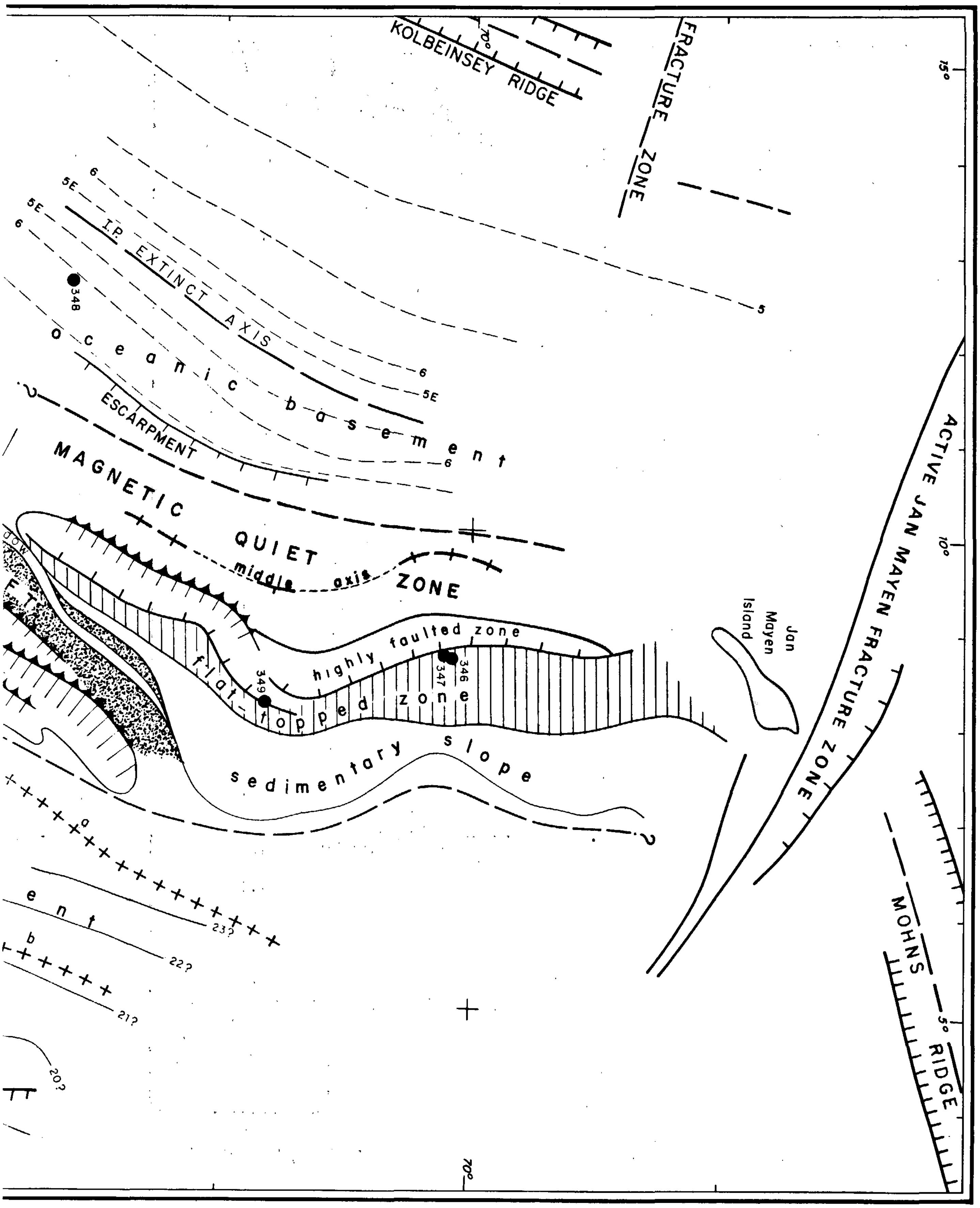


Figure 10

Structural sketch map of the Jan Mayen microcontinent and adjacent areas (Magnetic anomalies after M. Talwani and O. Eldholm, 1977). The coloured magnetic anomalies and gravity axis in the Norwegian Basin are discussed in the text. On Jan Mayen Ridge s. lato *area note the break up of the Ridge by the rift and the westward shift along the Jag fault.*

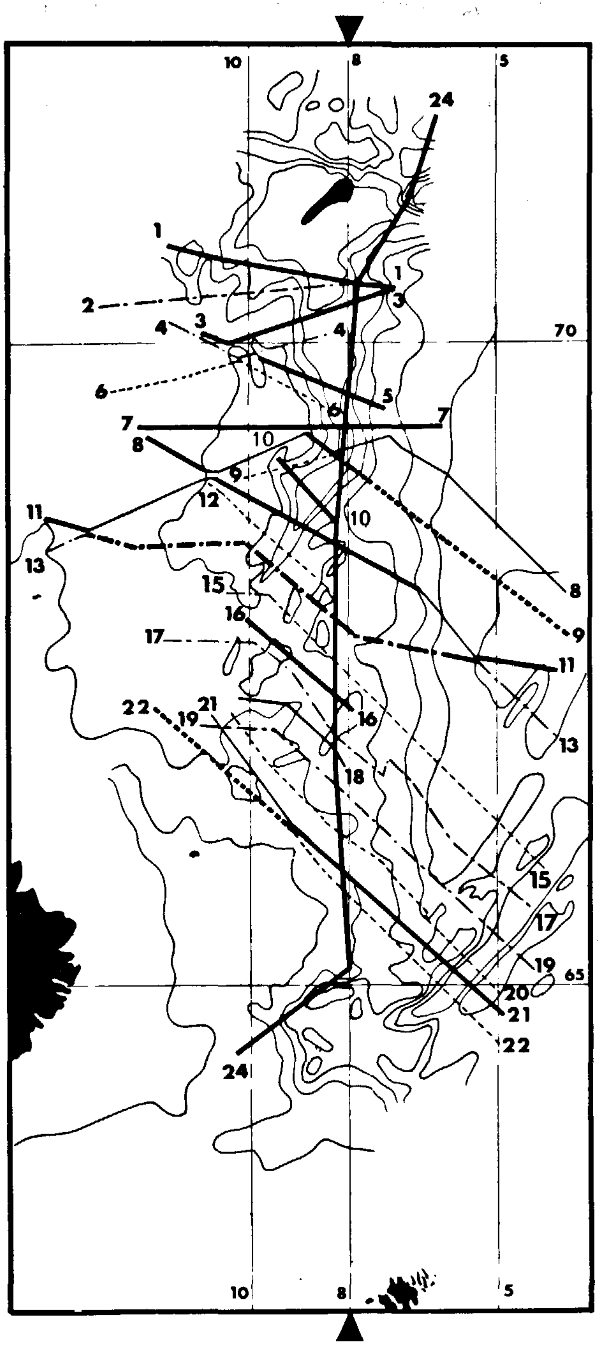
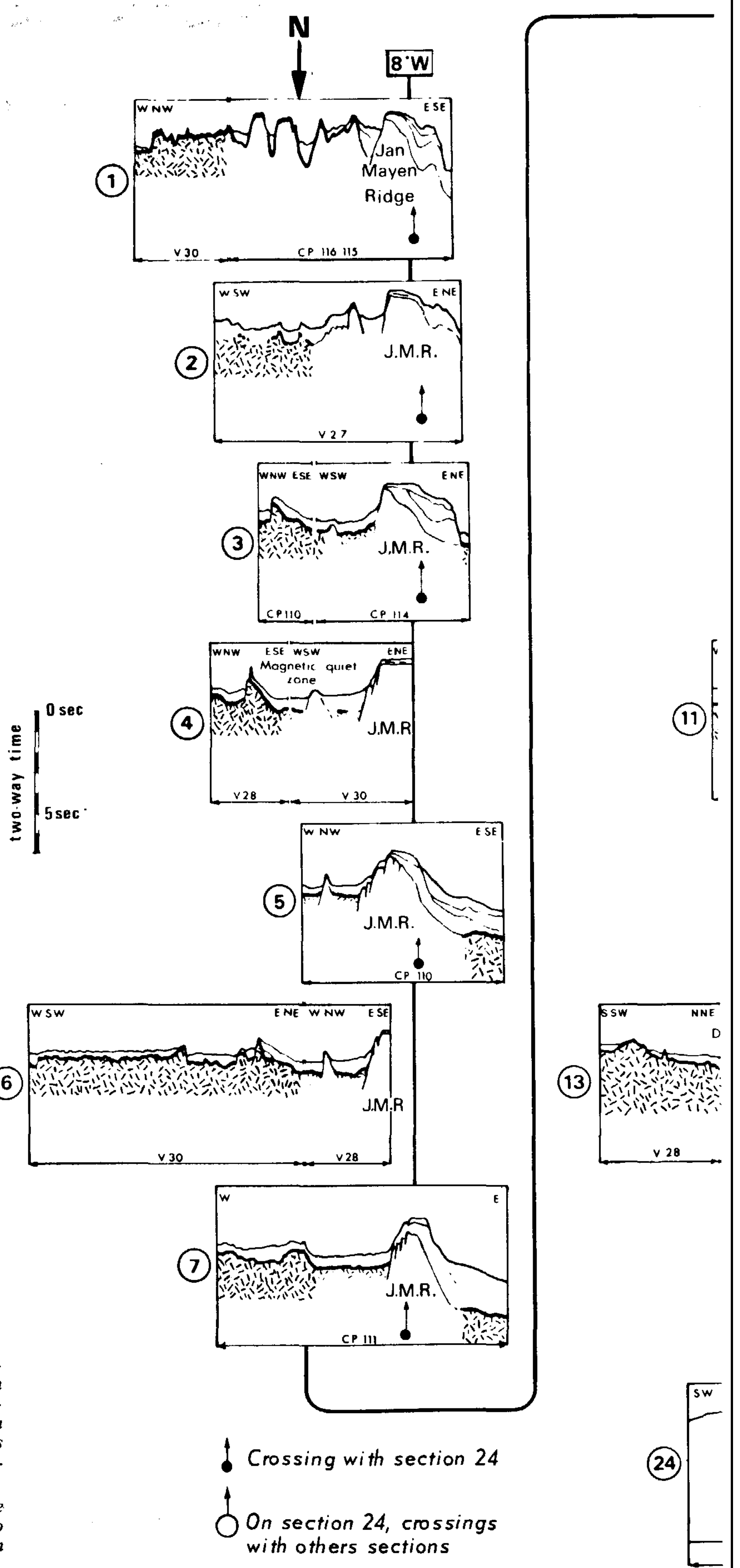
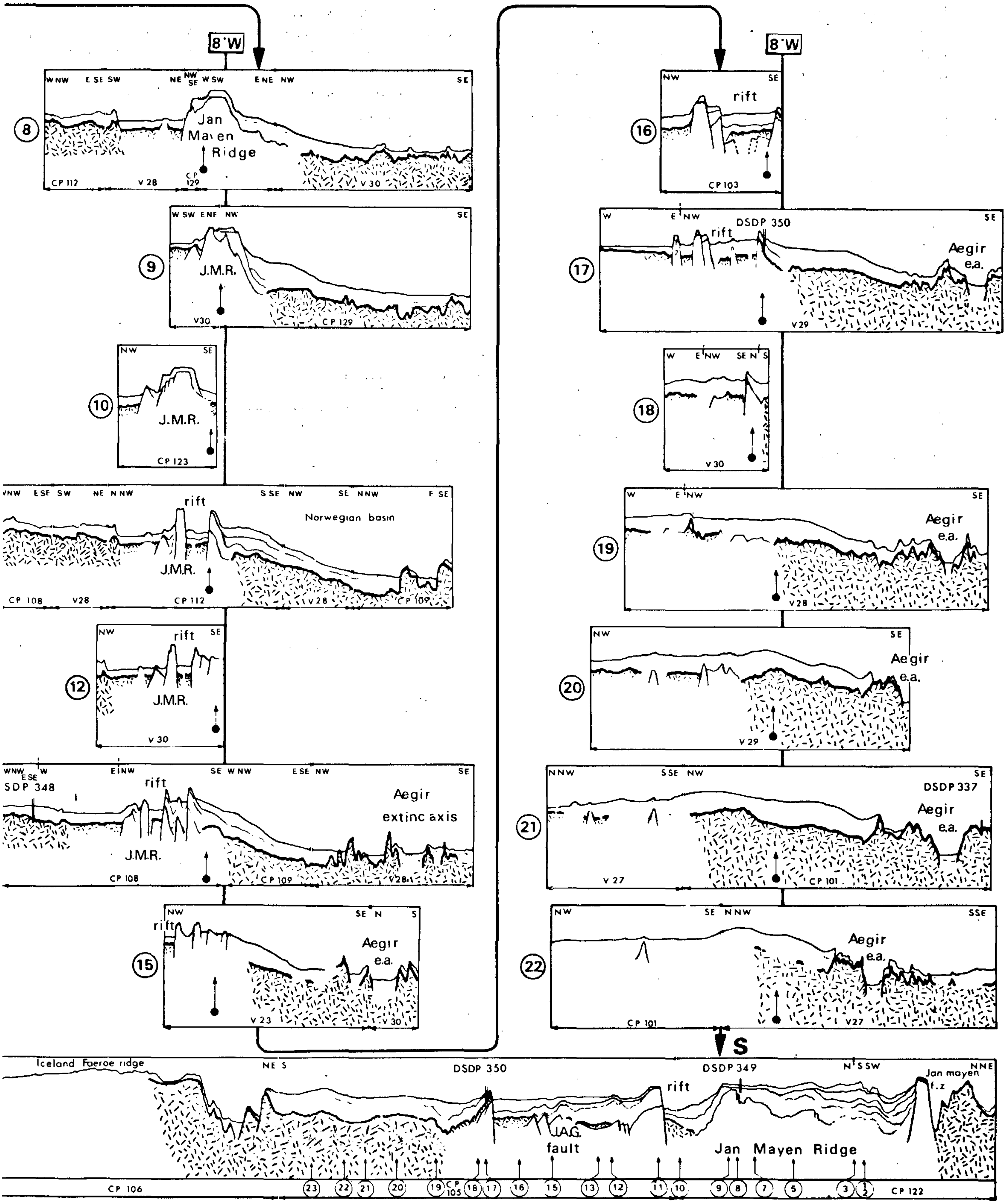



Figure 11

North to South structural evolution of the Jan Mayen Ridge. The time-sections presented in this Figure are either singletrace Vema (Talwani-Eldholm, 1977), or monitor Cepan 1 lines. See below each section the identification of the utilised profile records, and above the orientation of each one. These sections are aligned on 8° W. On the location map light and heavy lines represent Vema and Cepan 1 profiles respectively. Dotted, dashed and continuous lines are used to distinguish each section.

Note the evolution of the Jan Mayen Ridge (J.M.R.). This blocklike ridge at its northern end, is fragmented southward by the rift into elongated tilted blocks, which lie at a lower elevation and even disappear under a thick sedimentary cover at its southern end.


8°W
Jan Mayen Ridge
J.M.R.
rift
Norwegian basin
DSDP 348
Aegir extinc axis
Aegir e.a.
DSDP 350
DSDP 337
S
Iceland Faeroe ridge
DSDP 349
J.A.G. fault
Jan Mayen Ridge
Jan mayen f.z

profile 105 intersects this line at point 2 100. A considerably tilted block and a basaltic dome may be observed. Furthermore, and as pointed out above, the northern branch of the extinct Aegir axis was shifted westward with regard to the southern branch. The magnitude of this shift is comparable to that observed in the shift of the rift.

Owing to the poor density of our seismic lines, it is impossible to provide absolute proof of the relationship between the two events, but its high probability is based on two lateral shifts of virtually the same magnitude and direction.

Moreover, we are unable to provide more details concerning the effect of this fault on the layout of the magnetic anomalies between the extinct axis and the Ridge (Fig. 10).

According to our interpretation: (1); in the Norwegian Basin a transform fault exists shifting the branches North and South of the Aegir axis (2); the continent-ocean eastern boundary of the Ridge is affected at 68°30′ by a shift of the same direction and magnitude as the Vøring and North Shetland escarpment on the Norwegian margin at 64° latitude, and the major accident of Scoresby Sund on the Greenland continent at 70° latitude (3); the rift of the Jan Mayen Ridge is also shifted in the same direction and magnitude.

The above-mentioned tectonic events raise two questions:

– what was the nature of the major accident which involved both the continent and the oceanic basalt?

– did the rift start the oceanization process?

In answer to the first question, we favour the hypothesis of an accident strike slip fault running through the old Laurasia continent which must have induced the transform fault in the middle of the Norwegian Basin, the jigsaw-shaped form of the eastern Ridge boundary and finally the fault perpendicular to the rift.

Although no magnetic anomaly could be observed, it is likely that the rift began as a spreading center for a very short period, and led to a transform fault which shifted the northern part of the Ridge westwards. If the rift did not evolve, this fault could be said to be a potential transform fault.

Our identification and positioning of the J.A.G. fracture zone was made with the greatest objectivity compatible with the density of our seismic grid. We believe that the evidence of its existence is a valuable new element. Moreover, it appears that the combination of the fracture zone and the rift provides a continuous image of the Jan Mayen Ridge *sensu lato*, by correlating the different high points and depression alignments.

The data presented in this article thus shed further light on the hypothesis according to which the Jan Mayen Ridge is no more than the old margin of the continent of Greenland, and show that at the time when the spreading axis jumped from the Aegir ridge to the I-JM axis, an intermediate rift affected what was then the Greenland continental margin.

Acknowledgments

The authors wish to thank the Comité d'Études Pétrolières Marines (Cepm) and the Centre National d'Exploitation des Océans (Cnexo) for permitting them to use the data of the Cepan 1 survey for this article. They thank the Lamont-Doherty G.O. for authorizing publication of sections of the Vema Cruises. They have benefited from discussions with colleagues, including L. Montadert and J. R. Delteil. They thank R. Donatien (Ifp), who as geophysicist responsible for seismic recordings ensured that they were of the highest quality. Finally, they thank the ship's officers and crew of RV "Jean Charcot" (Cnexo), who participated in the Norge, Cepan 1 and Cepan 3 cruises in the Norwegian-Greenland Sea in the North-East Atlantic.

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