The Jan Mayen Ridge: present status

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At present, there is no direct evidence of rocks predating the late Paleocene opening of the Norwegian-Greenland Sea on the Jan Mayen Ridge. A review of the available geophysical data, DSDP drilling results and plate tectonic reconstructions convincingly indicates a continental nature of the northern part of the ridge. On the other hand, there is still considerable uncertainty about the southern part of the ridge and its possible continuation towards Iceland. Two reflectors, *A* and *O*, have been mapped regionally. *A* appears to reflect an unconformity of middle Oligocene age. Most investigators have indicated that *O* forms a late Paleocene rift unconformity associated with the opening of the Norwegian-Greenland Sea. By analogy with the North Sea and the continental margin off Norway we propose that it should be investigated whether this reflector might be older, relating to an earlier Mesozoic regime of tension.

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Introduction

At present, most investigators accept the idea that the Jan Mayen Ridge is a microcontinent. The continental fragment, originally a part of the Greenland continental margin, was formed by a westward shift in the plate boundary at Oligocene/Miocene time. Naturally, a continental nature raises questions about its resource, particularly hydrocarbon, potential. This unknown factor also influenced the agreement between Iceland and Norway about exploitation of resources in this region.

Physiographically, the Jan Mayen Ridge is a flat-topped north–south trending ridge extending southwards from the island of Jan Mayen. The ridge block, which decreases in width and plunges to the south, is bounded by a steep narrow slope towards the Iceland Plateau and a gentle slope towards the Norway Basin (Figs. 1 and 2). At 69°N the ridge trend changes towards the southwest. The ridge breaks up into a regime of individual seamounts at about 68.5°N with no bathymetric relief south of 67.6°N. The island of Jan Mayen is entirely composed of volcanic material not older than 0.5 Ma (Fitch *et al.* 1965), and appears to be a feature associated with the mid-oceanic ridge-transform system adjacent to the western Jan Mayen Fracture Zone.

Because of the current interest in information about the structure, composition, and evolutionary history of the ridge, we shall here summarize the results that have become available. In addition, we include the results obtained during a survey by the Seismological Observatory, University of Bergen, on board R/V 'H.U. Sverdrup' in 1978. This survey recorded three multichannel seismic profiles and nine sonobuoys on the northern Jan Mayen Ridge. The reflection profiles, all of which are located north of 70°N (Fig. 3), also include magnetic data. Preliminary results of the survey have been presented by Sundvor *et al* (1979), and here we include the final interpretation of the data. Although a number of institutions have studied the ridge (Table 1), many fundamental questions are still unsolved or poorly understood. Therefore, we conclude by outlining some of the problems towards which future research efforts will have to be directed.

A discussion of the Jan Mayen Ridge requires emphasis on three fundamental questions:

1. Definition of the extent of the continental fragment.
2. Timing of the events leading to the formation of the new plate boundary and the subsequent continental separation.
3. Definition of present structural elements and trends together with estimates of the nature and composition of sedimentary and basement rocks.

This approach requires extensive analysis of all the data of which the multichannel seismic profiles have proved most valuable. The first two subjects

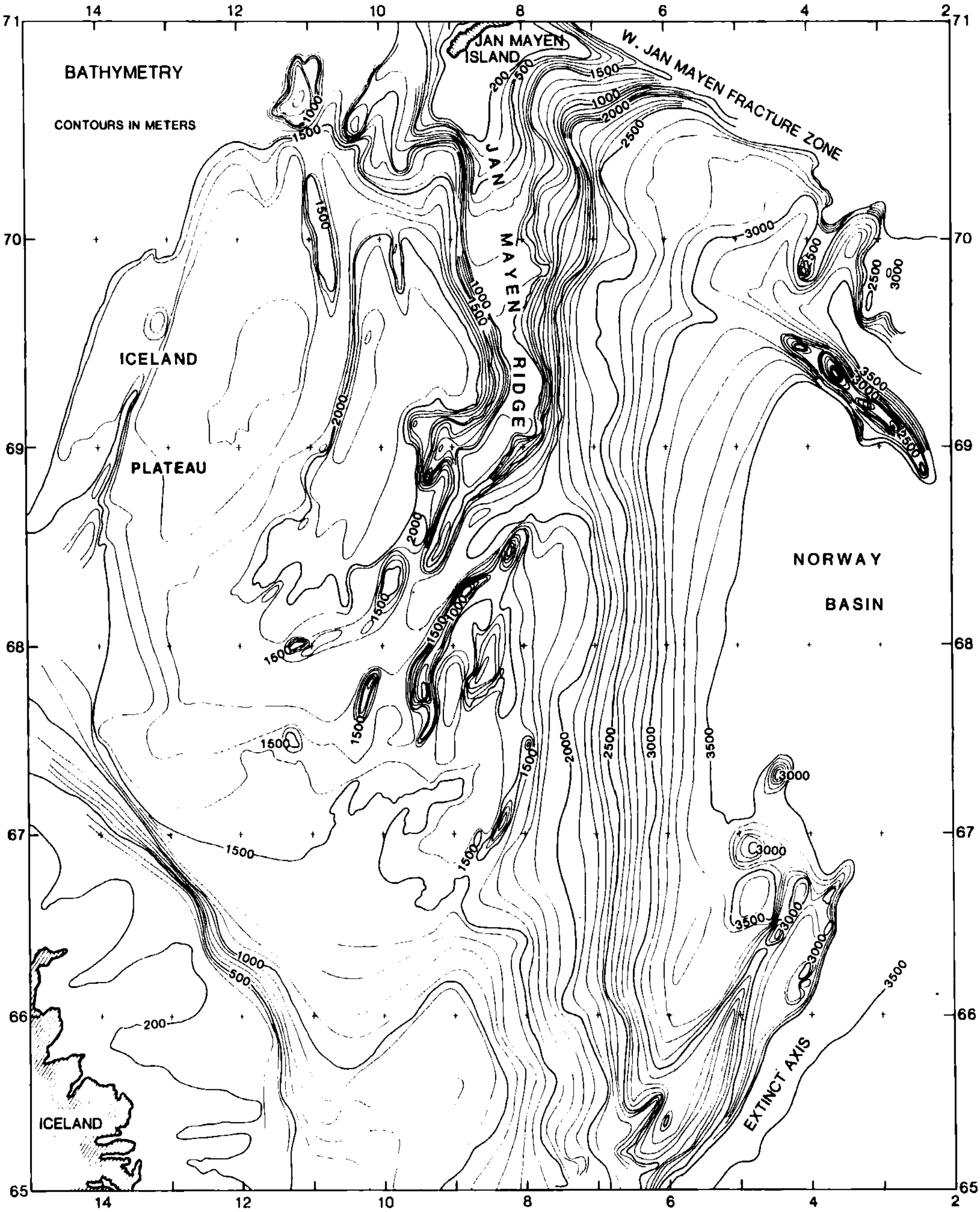

Fig. 1. Bathymetry of the Jan Mayen Ridge and adjacent areas (Olafsson 1983).

relate closely to an understanding of the plate tectonic sequence of events in the Norwegian-Greenland Sea, particularly the complicated Cenozoic westward migration of the spreading axis south of the Jan Mayen Fracture Zone.

Geophysical data: main ridge block

Gravity

The free-air gravity field shows an obvious first-order relationship with the bathymetry (Talwani

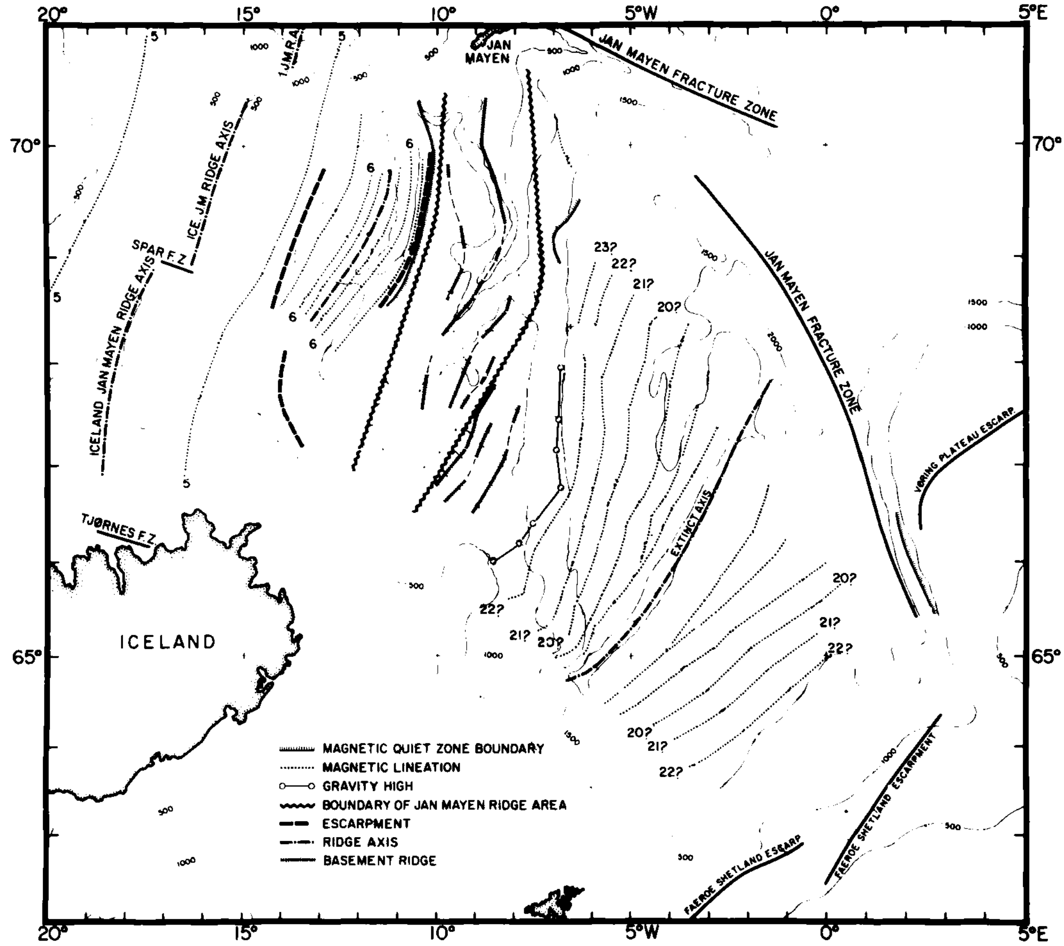

Fig. 2. Main structural elements and magnetic lineations in the Norway Basin and on the Iceland Plateau. Compiled mainly from data presented by Talwani & Eldholm (1977). Depths in uncorrected fathoms.

& Grønlie 1976; Grønlie *et al.* 1979). However, closer inspection reveals that the maximum amplitudes lie just east of the western edge of the ridge block. This asymmetry probably reflects a buried structural high (Eldholm & Windisch 1974). The absence of crustal information makes gravity modelling somewhat ambiguous; Grønlie & Talwani (1982) had to introduce a low-density upper crust underneath the ridge to match the observed anomalies.

Magnetics

Shipborne measurements reveal well developed linear magnetic anomalies in the Norway Basin and on the Iceland Plateau (Talwani & Eldholm 1977). A marked change in magnetic character occurs just west of the base of the western ridge slope and on the lowermost slope towards the Norway Basin as indicated by the magnetic quiet zone in Fig. 4. This is also shown by a detailed aeromagnetic survey over the main ridge north of 68.2°N conducted by the Norwegian Petroleum Directorate (Navrestad & Jørgensen 1979). With the exception of some high amplitude short wavelength anomalies in the vicinity of Jan Mayen (north of 70.5°N), the main ridge block represents a magnetic quiet zone. The quiet zone also extends somewhat west of the ridge proper where the sediments are relatively thin.

Seismic refraction

Velocity measurements from expendable sono-

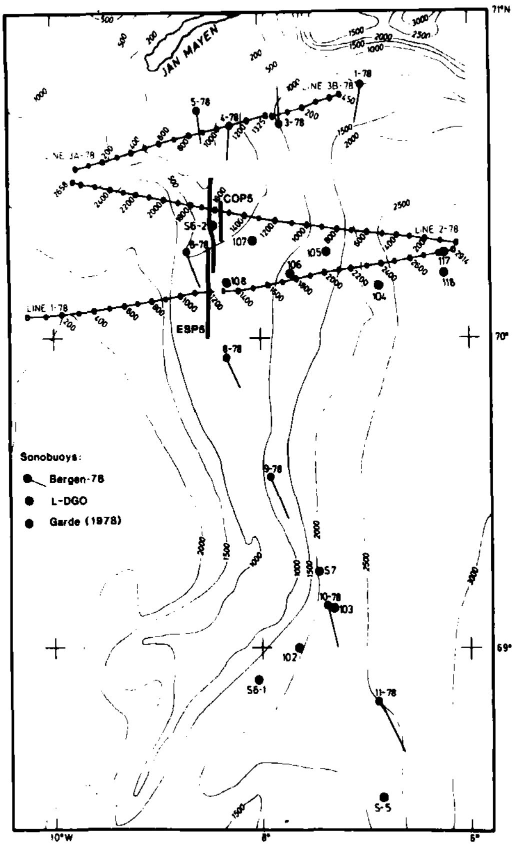

Fig. 3. Bergen-78 survey. Lines 1–3B are multichannel seismic profiles with shotpoints. Only line 1, shotpoints 1300–2180, have been processed, whereas the others have been interpreted from the near-trace records. Also shown are location of sonobuoys and the ESP/COP profiles recorded by Lamont-Doherty Geological Observatory in 1978. Simplified bathymetry in meters.

Table 1. Jan Mayen Ridge.

Institutions	Major contributions
U.S. Naval Oceanographic Office Naval Research Lab.	Johnson & Heezen 1967 Vogt *et al.* 1970 Johnson *et al.* 1972 Johnson 1975 Vogt *et al.* 1980
Lamont-Doherty Geological Observatory	Eldholm & Windisch 1974 Talwani & Eldholm 1977 Grønlie *et al.* 1979 Grønlie & Talwani 1982
Bundesanstalt für Geowissenschaften und Rohstoffe	Hinz & Schlüter 1978 Garde 1978
Centre National d'Exploration des Océans	Gairaud *et al.* 1978 Unternehr 1982
Norwegian Petroleum Directorate	Navrestad & Jørgensen 1979
Seismological Observatory, University of Bergen	Sundvor *et al.* 1979
Deep Sea Drilling Project	Talwani, Udintsev *et al.* 1976 Talwani *et al.* 1978
University of Durham	Nunns 1980

buoys have been reported by Eldholm & Windisch (1974), Talwani & Eldholm (1977), Garde (1978), and Sundvor *et al.* (1979).

The sonobuoys recorded in 1978 have been reduced by the standard slope-intercept procedure. In addition, interval velocities have been determined where wide-angle reflection hyperbolas can be identified (Table 2). The new results have been integrated with those of the earlier surveys and presented as seismic structure sections in Fig. 5. The scattered profiles on the eastern ridge flank south of 69.6°N have been compiled as a function of water depth only (Fig. 6).

In general, the individual velocities group together and can be correlated between profiles. The correlated refractors show a structural high beneath the western ridge flank, a gentle southerly dip of the layers just south of the Jan Mayen Island and a regional eastward dip towards the Norway Basin. Beneath the main ridge block, average refractor velocities of 1.8, 2.2, 2.7, 3.1, 3.9, and 5.5 km/s have been computed. The 2.7 refractor can only be correlated at water depths greater than 1.1 km; this may indicate that it thins towards the main ridge. The average velocities are indeed similar to those of Myhre (1984), who demonstrated that the velocity stratification of the Jan Mayen Ridge was similar to that of the Norwegian and East-Greenland margins landward of the continent-ocean boundary. On the other hand, adjacent profiles in the Norway Basin and the Iceland Plateau reveal a typical oceanic crustal structure (Myhre & Eldholm 1981).

We suggest that the 5.5 km/s refractor probably represents an eastward dipping basement surface, but note the observations of a deeper 6.4 km/s refractor in profiles 9/78 and S7. On the eastern ridge flank at a water depth of about 2.2 km the correlation of adjacent refractors is not obvious except for the very uppermost part of the sediments. This may imply a change in crustal nature with oceanic velocities in profiles 1/78, 11/78, S5,

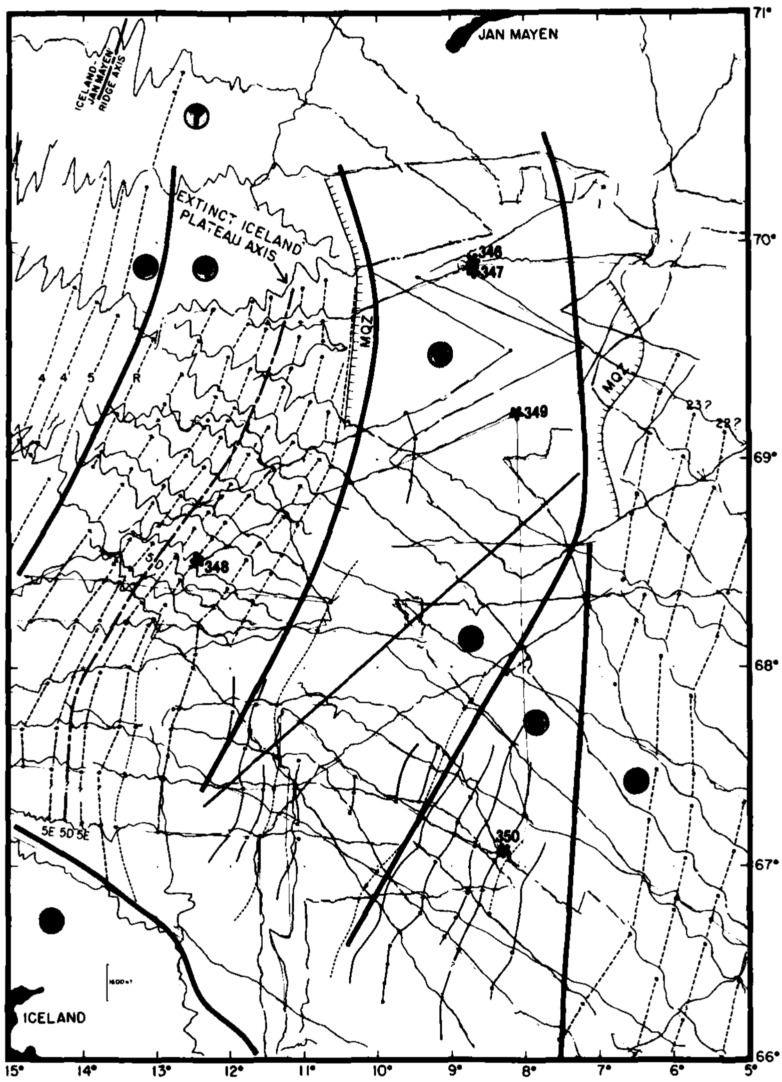

Fig. 4. Magnetic anomalies plotted along tracks showing the character of the field across the Jan Mayen Ridge (Grønlie *et al.* 1979). Numbers and bold lines refer to various provinces described by Talwani *et al.* (1978). MQZ is the magnetic quiet zone boundary.

and 117. Although a definite interpretation of the seismic velocities in terms of crustal nature may be ambiguous, it has to be concluded that the velocity-depth functions representing the ridge and the adjacent basins are quite different.

Two-ship expanding spread and constant offset profiles (Stoffa & Buhl 1979) on top of the ridge (Fig. 3) were also recorded in 1978 as a part of a cooperative program between Lamont-Doherty Geological Observatory and the Universities of Bergen and Oslo. The interpretation shows shallow seismic velocities similar to those from the sonobuoys, whereas the crustal thickness is 15 km shallowing to the north. B. Johansen (pers. comm. 1983) proposes that the results of the expanding spread profile are indicative of continental crust.

Seismic reflection

Analysis of the single-channel reflection records in the adjacent basins has shown that varying thicknesses of relatively transparent sediments are underlain by oceanic basement formed by sea-floor spreading. On the Jan Mayen Ridge a structural high along the western flank bounds an eastward dipping sedimentary sequence underlying the central ridge and the eastern ridge flank. This sequence is truncated by an erosional unconformity (reflector A). Above the unconformity

Table 2. Results of sonobuoys recorded by University of Bergen in 1978. Figures in parentheses indicate assumed velocities. r denotes interval velocity from wide-angle reflection hyperbolas. All units in km and km/s.

Profile	Lat. (N)	Long. (W)	Water depth	V1	H1	V2	H2	V3	H3	V4	H4	V5	H5	V6
1-78	70°47.0′	7°01.2′	0.97	(1.80)	0.82	2.48	0.22	2.84	0.69	3.56	1.10	4.76		
3-78	70°39.8′	7°47.9′	1.05	1.78	0.77	2.14	0.35	2.64	0.67	4.16	1.11	5.77		
4-78	70°39.6′	8°16.8′	0.24	(1.80)	0.12	2.30	0.92	3.90	1.46	6.08				
5-78	70°42.4′	8°35.9′	0.11	2.86	0.28	3.97								
6-78	70°16.4′	8°41.7′	0.62	2.17	0.53	2.87	0.28	3.53	0.49	5.16				
8-78	69°56.3′	8°20.1′	0.76	(2.11)	0.36	3.11	0.37	3.67	1.18	4.94				
9-78	69°33.5′	7°54.5′	1.27	1.86r	0.66	2.65	0.33	3.20	0.78	3.85	1.04	5.33	1.72	6.69
10-78	69°08.3′	7°22.2′	2.21	1.94	0.70	2.52	0.97	3.32	1.15	5.17				
11-78	68°49.3′	6°52.8′	2.50	1.69r	0.33	2.13r	0.74	2.76	0.43	3.00	0.71	4.36	1.25	6.05

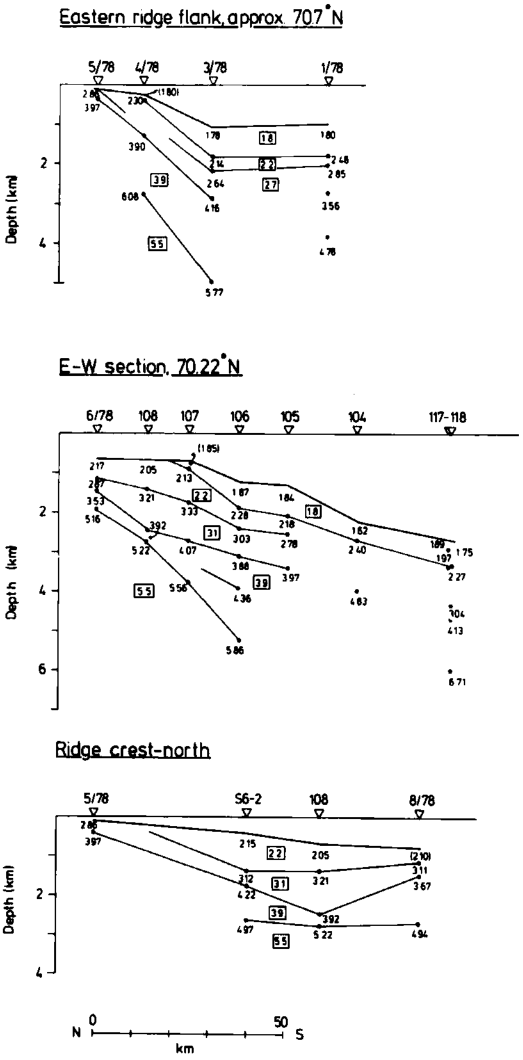

Fig. 5. Seismic structure sections at the northernmost Jan Mayen Ridge. Locations in Fig. 3.

a few hundred meters of horizontally stratified sediments have been deposited (Fig. 7) (Eldholm & Windisch 1974).

The various multichannel seismic surveys have added much more to the detailed geological framework (Gairaud *et al.* 1978; Garde 1978). Despite the fact that there are differences between the various profiles, a first-order structural and depositional pattern has emerged. This is also shown by the interpreted Bergen-78 profiles (Fig. 8). Hence, we have compiled the available information in terms of a simplified east-west type section representing the northern Jan

Mayen Ridge (Fig. 9). As shown in Figs. 8 and 9 the ridge structure may be divided into main rock units by two regional unconformities, *A* and *O*, and the basement surface. Here we have labeled the reflectors in accordance with Gairaud *et al.* (1978). The available data show:

— Oceanic basement is relatively easy to follow on either side although the exact termination towards the ridge is open for judgement in many profiles. On the western side its termination can normally be constrained to a 10 km wide zone. On the eastern side it is possible that younger lava flows mask the oldest oceanic basement and part of the microcontinent.

— The sediments above reflector *A* continue onto the oceanic basement. On the eastern ridge flank there is evidence of active erosion and mass movements with redeposition in the Norway Basin.

— Between reflectors *O* and *A* there is a sequence of eastward dipping layers. Both reflector *O* and part of the above-lying sequence are faulted, indicating an extensional tectonic regime forming horsts and grabens and rotated fault blocks.

— The sequence below reflector *O* shows no consistent reflection patterns but definite layering is observed locally.

— The surface of the structural high along the western ridge flank is acoustically opaque, similar to reflector *O*. In Fig. 9 it has been shown as a separate unit. Gairaud *et al.* (1978) tentatively suggest it to be Caledonian basement, but the relationship of this high and reflector *O* has not been definitely established and a continuation of reflector *O* into the structural high under the western ridge flank as indicated on profile 1-78 (Fig. 8) cannot be ruled out.

Deep sea drilling results

DSDP sites 346, 347 and 349 (Fig. 4) penetrated reflector *A* and the existence of an unconformity at this level was confirmed. The above-lying sediments consisted of glacial deposits as well as sandy muds and biogenic siliceous oozes of middle Miocene to middle Oligocene age. Below the unconformity a massive terrigenous sandy mudstone was recovered. This unit was dated as early Oligocene to late (and middle?) Eocene (Talwani, Udintsev *et al.* 1976).

Geophysical data: southern extension

The magnetic signature changes considerably on the southeastern Iceland Plateau (Fig. 4). Although the region south of the Jan Mayen Ridge cannot be characterized as magnetically quiet, few clear lineations have been identified. The seismic profiler data reveal a region of accentuated buried basement topography characterized by deep sediment-filled depressions between basement peaks or ridges (Fig. 7). However, the existence of the so-called 'opaque layer' has precluded a detailed mapping of these features. The 'opaque layer' is a smooth horizon which covers large parts of the Iceland Plateau (Eldholm & Windisch 1974; Talwani & Eldholm 1977). The origin of the reflector has not yet been conclusively determined. Its smooth surface and low velocity, 3.27 km/s (Myhre & Eldholm 1981), suggest it represents a volcanic horizon, in places masking underlying sediments and basement. Thus, it is difficult to determine whether the Jan Mayen Ridge block terminates or continues southwards as a buried structure. Talwani & Eldholm (1977) noticed that the ridge continued southward into several narrow buried ridges and depressions that could be traced by the isostatic gravity anomalies. In places these structures interrupt the 'opaque layer' forming so-called 'holes' in the 'opaque layer' (Fig. 7). They proposed that the continental fragment continued into area 2 of Fig. 4, either as a thin fragment of structurally deformed continental crust or as a region of continental slivers intermingled with oceanic crust possibly intruded as dykes. Gairaud *et al.* (1978) have proposed a southeasterly trending fracture zone, the J.A.G. Fault, between 67 and 68°N. South of the fracture zone the continental fragment is offset 20–30 km to the east and extended approximately 100 km to the south without any defined termination. Both Gairaud *et al.* (1978) and Garde (1978) have proposed a rift zone within the continental crust in this region. This rift zone appears to be associated with the area of 'holes' (Talwani & Eldholm 1977).

It is fair to conclude that the question of the southern extension of the continental fragment is not resolved as the Iceland Plateau becomes exceedingly complex south of 67°N.

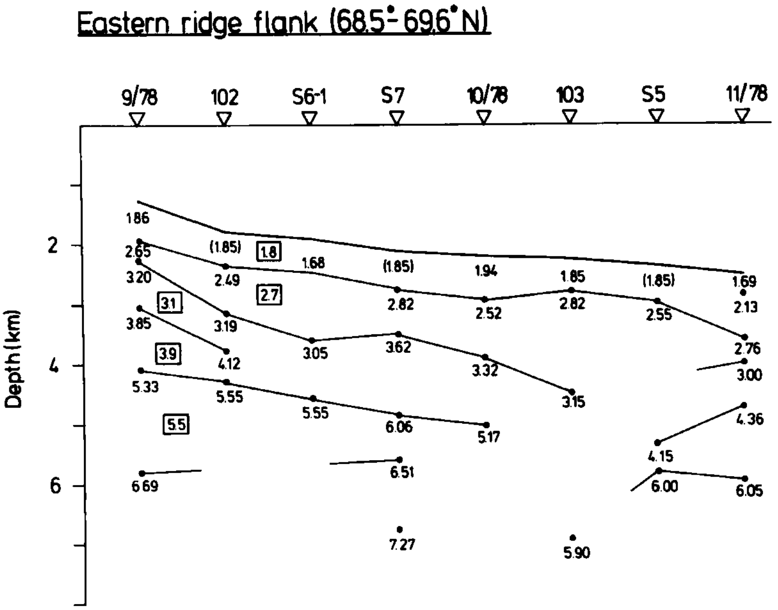

Fig. 6. Compilation of sonobuoy results for profiles on the eastern ridge flank south of 69.6°N. The profiles are plotted according to water depth. Location in Fig. 3.

Plate tectonic history

The part of the Norwegian Sea located between the Faeroe–Iceland–Greenland Ridge and the Jan Mayen Fracture Zone has undergone a complex history of evolution throughout the Cenozoic. The plate boundary has been unstable and the sea-floor spreading history is characterized by a series of westward jumps of the spreading axis from the Norway Basin to the Iceland Plateau. This history of evolution is also reflected in the pronounced elevation difference between the Norway Basin and the Iceland Plateau.

A possible continental nature of the Jan Mayen Ridge was suggested by Johnson & Heezen (1967), but a detailed plate tectonic analysis was first carried out by Elholm & Talwani (1973) and further developed by Talwani & Eldholm (1977). According to Talwani & Eldholm (1977) the spreading in the Norway Basin gradually died out between anomaly 13 and anomaly 7 time. During this time a young rift characterized by crustal extension and subsequent spreading developed adjacent to the Greenland margin. The rift moved progressively northwards towards the Jan Mayen Fracture Zone. A readjustment of the spreading axis prior to anomaly 6 time split off a part of the Greenland margin, the Jan Mayen Ridge. New sea floor developed along the extinct spreading axis at the Iceland Plateau (Fig. 4) which was active until just prior to anomaly 5 time. Then the ridge axis again jumped westward forming the present active Iceland–Jan Mayen spreading axis.

This model of evolution was mainly based on magnetic observations on either side of the northern part of the Jan Mayen Ridge, whereas the data did not allow an identification of sea-floor spreading anomalies further south (Fig. 4). The extent of the continental fragment was approximated by the magnetic quiet zone boundary. From plate tectonic considerations it was not possible to decide how far south the continental fragment continued. If the ridge continued southward it could extend as far as Iceland. This observation implies that the southern part of the Iceland Plateau between anomaly 5 and the Norway Basin is not fully understood in terms of evolutionary history. The recent plate tectonic models of Nunns (1980) and Unternehr (1982) are in general similar to the one described above, but the Jan Mayen Ridge continental fragment is proposed as acting as an independent plate in the time periods between anomalies 20-7 and 13-7, respectively.

There is some disagreement as to the detailed spreading history between the Jan Mayen Ridge and anomaly 5 east of the Iceland–Jan Mayen Ridge. Talwani & Eldholm (1977) suggested an

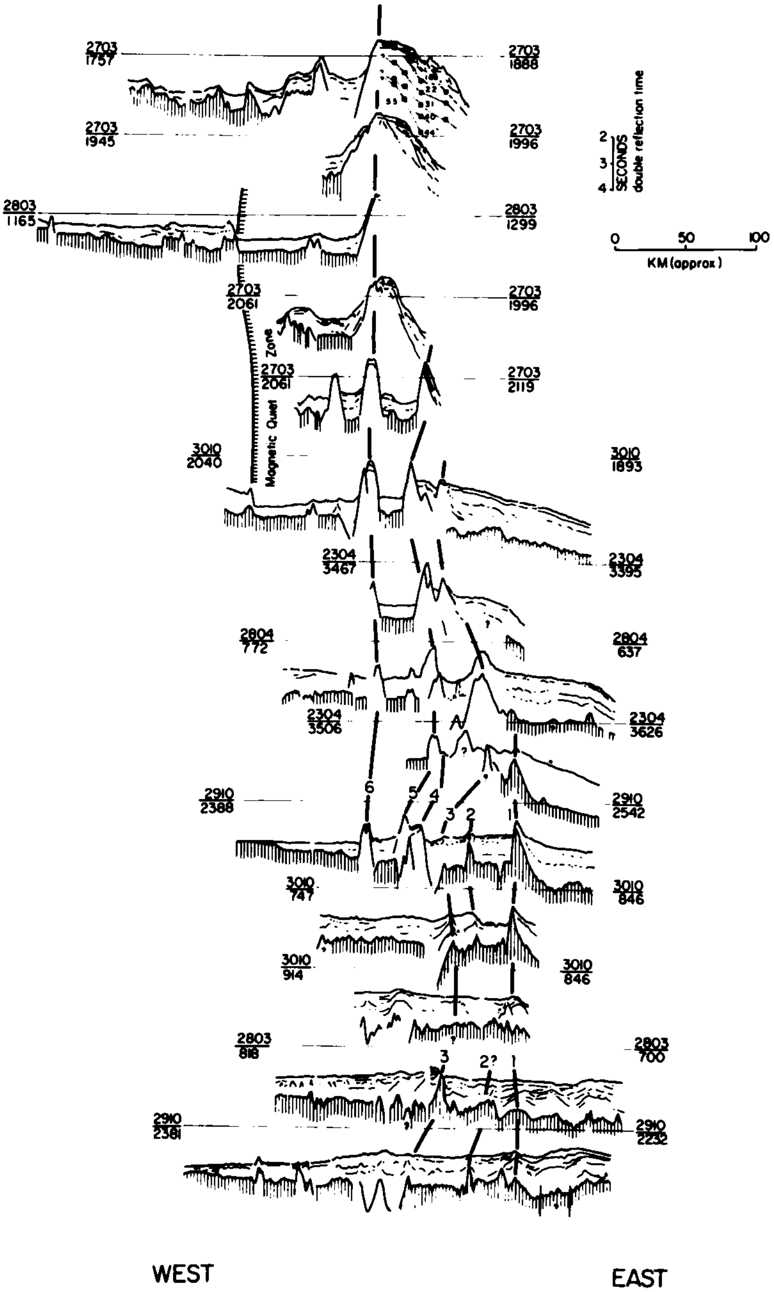

Fig. 7. Line drawings of single channel seismic reflection profiler records across the Jan Mayen Ridge. The profiles show the changing nature of the ridge from north (top) to south (bottom) Talwani & Eldholm (1977).

extinct axis in this region but were not able to identify any geologic expression of the axis. Talwani *et al.* (1978) correlated symmetric spreading type anomalies on either side of this short-lived axis. The idea of spreading in this area has been suggested by Vogt *et al.* (1970) and Johnson *et al.* (1972) who identified a negative anomaly as the axis of symmetry. On the other hand, analysis of aeromagnetic data led Vogt *et al.* (1980) and Larsen (1980) to postulate symmetric spreading along the present spreading axis from about anomaly 6C (24 my). Consequently, they as well as Nunns (1980) ruled out the existence of the Iceland Plateau extinct axis. However, this suggestion requires that sea-floor spreading type anomalies (5B–6C) must underlie a substantial

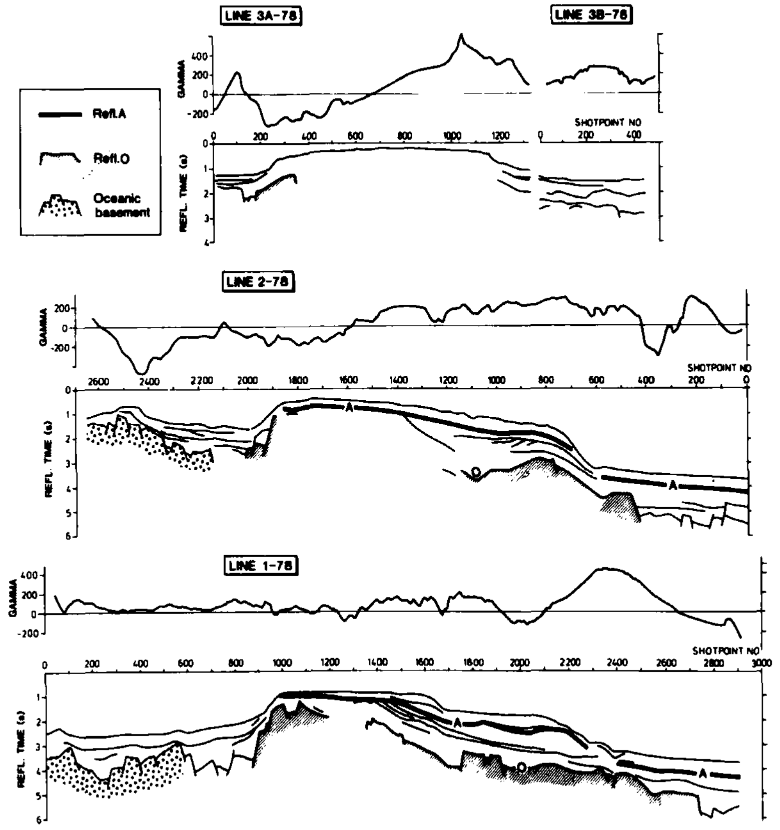

Fig. 8. Line drawings of Bergen-78 seismic profiles. The magnetic anomaly field is plotted on top of the profiles. Locations in Fig. 3.

part of the Greenland continental shelf. Aeromagnetic data (Larsen 1980) reveal weak low amplitude linear trends on the shelf. If underlain by oceanic crust the present shelf must have prograded considerably during the last 20 my. Regardless, the discussion shows that the detailed sea-floor spreading history is not yet resolved. However, the various investigators agree upon the approximate timing of the separation of the Jan Mayen microcontinent from Greenland. It appears that rifting started in the late Oligocene whereas normal sea-floor spreading was well established in the earliest Miocene. The separation of the Jan Mayen Ridge may well be associated with late Oligocene to Miocene normal faulting along the coast of Greenland (Birkenmajer 1972).

Discussion and major problems

From integrated analyses of the geophysical data and plate tectonic considerations it has been convincingly argued that the Jan Mayen ridge is underlain by continental crust (Talwani & Udintsev 1976; Talwani & Eldholm 1977; Gairaud *et al.* 1978; Garde 1978; Unternehr 1982). Nevertheless, a note of caution is appropriate as no direct evidence of rocks predating the late Paleocene opening of the Norwegian-Greenland Sea exists. By indirect reasoning, however, Udintsev & Kharin (1978) have suggested that some bottom samples at the Jan Mayen Ridge yield rocks older than the Eocene age determined by the DSDP drilling.

In particular, the nature of the rocks below reflector *O* and the western structural high is of fundamental importance in terms of crustal composition. In this respect, the relationship between the major units (Fig. 9) and the respective seismic velocities may provide additional information. In general, there is a close correspondence between refraction velocities and the interval velocities determined from the multichannel seismic data. On the northern ridge, velocities in the range 1.7–2.0 km/s are typical for the sediments above

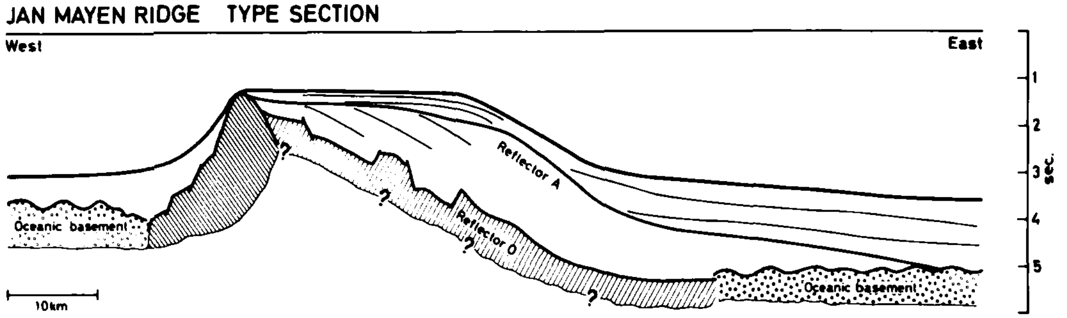

Fig. 9. Simplified geologic type section across the northern Jan Mayen Ridge. The section is based on multichannel seismic reflection data by Gairaud *et al.* (1978) and Garde (1978), as well as on those in Fig. 8. Schematic only.

reflector *A* and 2.2–3.3 km/s for the unit between reflectors *A* and *O* (Gairaud *et al.* 1978). Hinz & Schlüter (1978) report interval velocities from 4.0 to 4.5 km/s below reflector *O* whereas Gairaud *et al.* (1978) indicate 4.5 km/s. An average refractor velocity of 3.9 km/s appears to correlate with reflector *O* whereas the 5.6 km/s refractor is deeper. Unfortunately, few reliable velocity measurements exist near the western structural high and along the southern ridge extension.

By correlation with DSDP drilling results, both Gairaud *et al.* (1978) and Garde (1978) interpret the sediments above *A* as deposited from recent to the early (middle) Oligocene, and the lower unit to be of early Oligocene to Paleocene age assuming that reflector *O* represents a rift unconformity associated with the opening of the Norwegian-Greenland Sea. Reflector *A*, which predates the separation of the Jan Mayen Ridge from Greenland, may be related to the global fall in sea level during the middle Oligocene (Vail *et al.* 1977). This is also the time one would expect radical changes in the circulation pattern due to the establishment of a deep water passage in the incipient Greenland Sea (Eldholm & Thiede 1980). Gairaud *et al.* (1978) suggest a marked longitudinal level difference along the Jan Mayen Ridge with probable subaerial conditions on the northern part.

The rocks below reflector *O* are interpreted to be Mesozoic/Paleozoic sediments or possibly Caledonian granitic or metamorphic rocks under the western flank. Hinz & Schlüter (1978), however, indicate the possibility that reflector *O* may represent a volcanic, possibly pyroclastic, horizon. Hinz & Schlüter (1980) have also mapped a deep and faulted acoustic basement reflector on the Greenland margin south of the Jan Mayen Fracture Zone. There is evidence of sedimentary reflectors below this horizon. However, they have interpreted it as a rift unconformity of upper Oligocene age.

A comparison with seismic velocities off Norway shows that the *A–O* sequence exhibits values higher than those normally observed in Cenozoic sediments (<2.5 km/s). Assuming that the drill sites did not sample the older part of the sediments above *O* this leads towards an alternative interpretation in which unit *A–O* consists of both early Cenozoic and pre-opening, Mesozoic, sediments. In this case, the structural deformation affecting reflector *O* predates the Paleocene. Off Norway, no well-defined Cenozoic rift unconformity is observed, however, a phase of extensional tectonism was active throughout the Jurassic ending in the early Cretaceous. No rift unconformity is associated with the much later opening of the Norwegian-Greenland Sea (Jørgensen & Navrestad 1979). Evidence of Mesozoic crustal extension is also observed in East Greenland (Surlyk 1978). By analogy with the North Sea and the Norwegian margin, reflector *O* could be the Kimmerian unconformity of upper Jurassic age.

Magnetic depth estimates by Navrestad & Jørgensen (1979) suggest that the magnetic source bodies lie at the level of reflector *O*. If the 5.6 km/s refractor represents an irregular basement surface below reflector *O*, the magnetic depth estimates may not discriminate between the two levels because the thickness of the 3.9 km/s refractor is normally less than 1 km. On the other hand, if the top of the magnetic basement is reflector *O*, it could also be associated with the early Tertiary plateau basalts in East Greenland or with a pre-anomaly 23 volcanic event seen off

Norway (Eldholm *et al.* 1979), although the latter does not appear to have a magnetic signature.

In conclusion, the sequence of rocks underlying reflector *O* appears to be of pre-opening age, however, the question of the nature of the reflector and the above-lying sediments is not considered as resolved. Obviously, the various interpretations have important consequences for the existence of hydrocarbons.

Admittedly, our knowledge about the Jan Mayen Ridge geology has increased considerably in the last few years, but this review also demonstrates a great many uncertainties. This leads us to define some major objectives for future research:

- Detailed mapping of the continent-ocean boundary based on correlation of adjacent seismic profiles and the magnetic quiet zone boundary.
- Additional work related to the identification of the major rock units, particularly the pre-*O* sequence. This should include definition of comparable seismic stratigraphical levels and depositional units on the Jan Mayen Ridge and the Norwegian and East Greenland margins south of the Jan Mayen Fracture Zone preferably by drilling.
- Establishment of the subsidence history and its relationship with the contemporaneous subsidence of the adjacent oceanic crust.
- Re-examination of the magnetic anomalies in the Norway Basin and on the Iceland Plateau between anomaly 24 and 5 time to obtain a more accurate timing of the various locations of the plate boundary. It is important to estimate the amount of crustal stretching and thinning that accompanied each shift prior to establishing a new center of normal sea-floor spreading.
- Analysis of the southern extension of the continental fragment in terms of structural continuity. An approach of analysing basement trends may prove useful. It appears that north-northeast and east-southeast structural trends prevail in the region north of 68.6°N. These trends may also be representative of the southern ridge continuation and possibly be applied as diagnostic criteria.
- Systematic dredging of possible outcrops along the western ridge flank.
- Crustal studies and heatflow measurements along traverses across the ridge to obtain parameters for geodynamic modelling.

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References

Birkenmajer, K. 1972: Report on investigations of Tertiary sediments at Kap Brewster, Scoresby Sound, East Greenland. *Rapp. Grønlands Geol. unders, 48,* 85–91.

Eldholm, O. & Talwani, M. 1973: Structure and development of the Jan Mayen Ridge. *EOS 54,* 324.

Eldholm, O. & Thiede, J. 1980: Cenozoic continental separation between Europe and Greenland. *Palaeogegr. Palaeoclimatol. Palaeoecol. 30,* 243–259.

Eldholm, O. & Windisch, C. C. 1974: Sediment distribution in the Norwegian-Greenland Sea. *Geol. Soc. Am. Bull. 85,* 1661–1676.

Eldholm, O., Sundvor, E. & Myhre, A. M. 1979: Continental margin off Lofoten-Vesterålen. *Mar. Geophys. Res. 4,* 3–35.

Fitch, F. J., Grasty, R. L. & Miller, J. A. 1965: Potassium-Argon ages of rocks from Jan Mayen and an outline of its volcanic history. *Nature 207,* 1349–1351.

Gairaud, H., Jacquart, G., Aubertin, F. & Beuzart, P. 1978: The Jan Mayen Ridge synthesis of geological knowledge and new data. *Oceanologica Acta 1,* 335–358.

Garde, S. S. 1978: *Zur geologischen Entwicklung des Jan Mayen Ruckens nach geophysikalischen Daten.* Dissertation, Univ. of Clausthal, 72 pp.

Grønlie, G., Chapman, M. & Talwani, M. 1979: Jan Mayen Ridge and Iceland Plateau: origin and evolution. *Nor. Polarinst. Skr. 170,* 25–48.

Grønlie, G. & Talwani, M. 1982: The free-air gravity field of the Norwegian-Greenland Sea and adjacent areas. *Earth Evol. Ser. 2,* 79–103.

Hinz, K. & Schlüter, H-U. 1978: Der Nordatlantik - Ergebnisse geophysikalischer Untersuchungen der Bundesanstalt für Geowissenschaften und Rohstoffe an nordatlantischen Kontinentalrändern, *Erdoel-Erdgas-Zeitschrift 94,* 271–280.

Hinz, K. & Schlüter, H-U. 1980: Continental margin off East Greenland. *Proc. 10. World Petrol. Congress 2,* 405–418.

Johnson, G. L. 1975: The Jan Mayen Ridge. In Yorath, C. J., Parker, E. R. & Glass, D. J. (eds.): Canada's continental margins and offshore petroleum exploration. *Can. Soc. Petrol. Geol. Mem. 4,* 225–235.

Johnson, G. L. & Heezen, B. C. 1967: Morphology and evolution of the Norwegian-Greenland Sea. *Deep-Sea Res. 14,* 755–771.

Johnson, G. L., Southall, J. R., Young, P. W. & Vogt, P. R. 1972: Origin and structure of the Iceland Plateau and Kolbeinsey Ridge. *J. Geophys. Res. 77,* 5688–5696.

Jørgensen, F. & Navrestad, T. 1979: Main structural elements and sedimentary succession on the shelf outside Nordland (Norway). *Nor. Petrol. Soc. NSS/11,* 20 pp.

Larsen, H. C. 1980: Geological perspectives of the East Greenland continental margin. *Bull. Geol. Soc. Denmark 29,* 77–101.

Myhre, A. M. 1984: Compilation of seismic velocity measurements along the margins of the Norwegian-Greenland Sea. *Nor. Polarinst. Skr. 180,* 47–67.

Myhre, A. M. & Eldholm, O. 1981: Sedimentary and crustal velocities in the Norwegian-Greenland Sea. *J. Geophys. Res. 86,* 5012-5022.

Navrestad, T. & Jørgensen, F. 1979: Aeromagnetic investigations on the Jan Mayen Ridge. *Nor. Petrol. Soc. NSS/9.* 12 pp.

Nunns, A. G. 1980: *Marine Geophysical Investigations in the Norwegian-Greenland Sea between the Latitudes of 62°N and 74°N.* Ph.D. Thesis, Univ. of Durham. 185 pp.

Olafsson, I. 1983: *The Jan Mayen Ridge and Surrounding Areas – a Marine Geophysical Study.* Cand. real. thesis. Univ. of Bergen. 127 pp.

Stoffa, P. L. & Buhl, P. 1979: Two-ship multichannel seismic experiments for deep crustal studies. *J. Geophys. Res. 84,* 7645–7660.

Sundvor, E., Gidskehaug, A., Myhre, A. M. & Eldholm, O. 1979: Marine geophysical survey on the northern Jan Mayen Ridge. *Seismol. Obs. Univ. Bergen, Sci. Rept. No. 6,* 17 pp.

Surlyk, F. 1978: Jurassic basin evolution of East Greenland. *Nature 274,* 130–133.

Talwani, M. & Eldholm, O. 1977: Evolution of the Norwegian-Greenland Sea. *Geol. Soc. Am. Bull. 88,* 969–999.

Talwani, M. & Grønlie, G. 1976: A free-air map of the Norwegian Sea. *Geol. Soc. Am. MC-15.*

Talwani, M. & Udintsev, G. 1976: Tectonic synthesis. *Init. Rept. Deep Sea Drilling Project 38,* 1213–1242.

Talwani, M. & Udintsev, G. *et al.* 1976: Initial reports of the Deep Sea Drilling Project 38, Washington (U.S. Government Printing Office). 1256 pp.

Talwani, M., Udintsev, G., Mirlin, E., Beresnev. A. F., Kanayev, V. F. Chapman, M., Grønlie, G. & Eldholm, O. 1978: Survey at sites 346, 347, 348, 349, and 350. The area of the Jan Mayen Ridge and the Icelandic Plateau. *Init. Rept. Deep Sea Drilling Project 38, Suppl.* 465–488.

Udintsev, G. B. & Kharin, G. S. 1978: Sedimentary rocks of the Jan Mayen Ridge. *Init. Rept. Deep Sea Drilling Project 38, Suppl. 95–100.*

Unternehr, P. 1982: *Etude structurale et cinématique de la mer de Norvége et du Groenland. Evolution du microcontinent de Jan Mayen.* Thesis Univ. of Bretagne, 227 pp.

Vail, P. R., Mitchum, R. M. & Thompson, S. 1977: Seismic stratigraphy and global changes of sea level. Part 4: Global cycles of relative changes of sea level. *Am. Assoc. Petrol. Geol. Mem. 26,* 83–97.

Vogt. P. R., Johnson, G. L. & Kristjansson, L. 1980: Morphology and magnetic anomalies north of Iceland. *J. Geophys. 47,* 67–80.

Vogt. P. R., Ostenso, N. A. & Johnson, G. L. 1970: Magnetic and bathymetric data bearing on sea-floor spreading north of Iceland. *J. Geophys. Res. 75,* 903–920.

References not cited in the text

Auzende, J. M., Benzart, P., Bonnin, J., Olivet, J. L., Sichler, B. & Unternehr, P. 1980: Mode de dislocation des continents lors ses stades initiaux d'ouverture. *8e Réun. ann. Sc. Terre., Soc. géol. Fr. 19.*

Austegard, A. 1974: Some earthquakes near Jan Mayen. *Nor. Polarinst. Årbok 1972,* 41–46.

Bungum, H. 1978: Reanalyzation of three focal-mechanism solutions for earthquakes from Jan Mayen, Iceland and Svalbard. *Tectonophysics 51,* T15–T16.

Bungum, H. & Husebye, E. S. 1977: Seismicity of the Norwegian Sea: The Jan Mayen Fracture Zone. *Tectonophysics 40,* 351–360.

Hinz, K. 1975: Results of geophysical surveys in the area of the Aegir Ridge, the Iceland Plateau and the Kolbeinsey Ridge (extended abstract). *Nor. Geol. Unders. 316,* 201–204.

Hinz, K. 1972: The seismic crustal structure of the Norwegian margin in the Vøring Plateau, in the Norwegian deep sea, and on the eastern flank of the Jan Mayen Ridge between 66° and 68°N. *24th Int. Geol. Congr. Section 8,* 28–36.

Johnson, G. L. 1968: Marine geology in the environs of Jan Mayen. *Nor. Polarinst. Årbok 1966,* 105–111.

Johnson, G. L. & Campsie, J. 1976: Morphology and structure of the western Jan Mayen Fracture Zone. *Nor. Polarinst. Årbok 1974,* 69–81.

Johnson, G. L., Freitag, J. S. & Pew, J. A. 1971: Structure of the Norwegian Basin. *Nor. Polarinst. Årbok 1969,* 7–16.

Meyer, O., Voppel, D., Fleischer, U., Closs, H. & Gerke, K. 1972: Results of bathymetric, magnetic and gravimetric measurements between Iceland and 70°N. *Deut. Hydrogr. Zeitschr. 25,* 193–201.

Navrestad, T. & Sørnes, A. 1974: The seismicity around Jan Mayen. *Nor. Polarinst. Årbok 1972,* 29–40.

Udintsev, G. B., Jemeljanow, E. M., Litvin, W. M., Kharin, S. G. & Krüger, P. 1977: Geologische Untersuchungen im Gebiet der Insel Jan Mayen. *Zeitschr. angew. Geol. 23,* 509–512.