Marine Seismic Investigation of the Shelf around the Faeroe Islands

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Abstract

Shallow seismic profiling shows that the basaltic shelf around the Faeroe Islands extents roughly to the 200 m depth contour. Outside the basaltic shelf the basalts are overlain by sediments of presumed Tertiary age which dip outwards at a low angle.

Introduction

The Faeroe Islands are surrounded by a broad shelf which is part of the Faeroe-Iceland-Greenland ridge in the northern Atlantic Ocean. It is generally assumed that the ridge consists largely of volcanic rocks surrounded by sediments. More than 3 km of Lower Tertiary basalt lavas are exposed on the Faeroe Islands (Rasmussen and Noe-Nygaard 1969). Based on gravimetric and deep reflection seismics it seems likely that the Faeroe shelf is resting on continental crust (Bott and Watts 1971, Bott and others 1974, Nielsen 1976).

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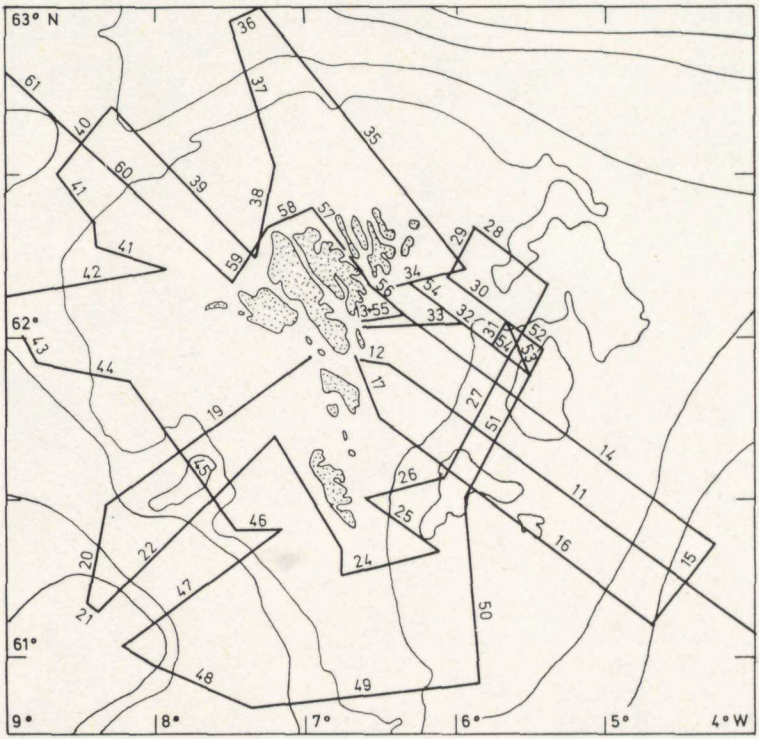

Fig. 1. *A sketch of the survey lines made by »Dana« around the Faeroe Islands during the summer 1979. (Line 18 in the sounds Nólsoyarfjørður and Skopunarfjørður has been omitted for clarity).*

1. mynd: *Kort sum vísir siglingarleiðirnar við »Danu« á sumri 1979.*

The shelf around the Faeroe Islands has been subject to several investigations in the last few years. A detailed bathymetric survey has been performed inside the 200 m depth contour (Rasmussen 1977). The shelf, including the banks to the southwest, has been sampled by dredging (Waagstein and Rasmussen 1975, Waagstein 1977). A magnetic and bathymetric survey covering the shelf including Bill Bailey Bank and Lousy Bank (Nielsen 1977) is completed and the results are being compiled. The survey supplements earlier studies

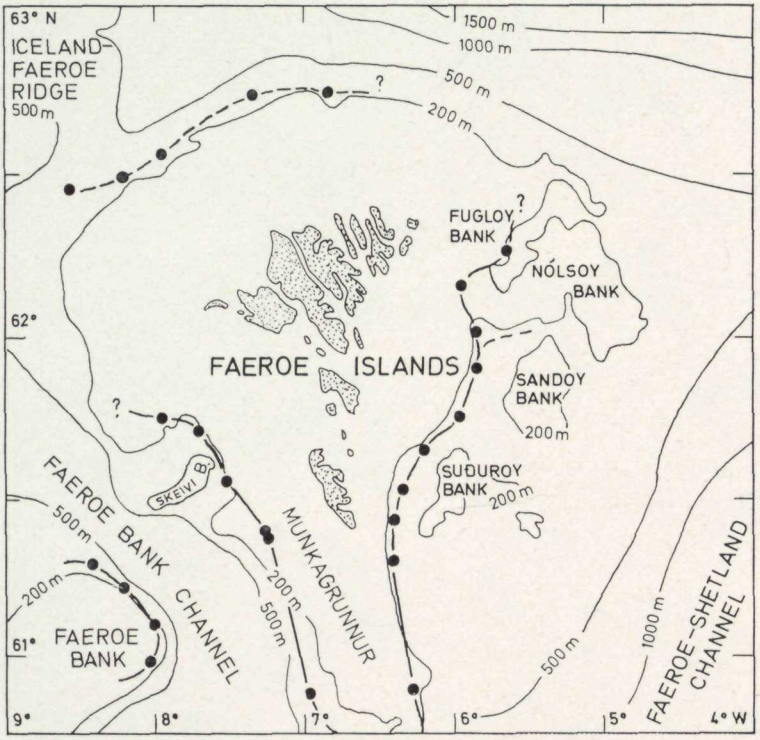

Fig. 2. *The map shows the boundary of the Faeroese basalt areas according to the measurements made on board »Dana«; see the text for details.*

2. mynd: *Kortið vísir basaltútjaðarin so sum hann var funnin við »Danu« 1979.*

by Dobinson (1970), Schrøder (1971) and Fleischer and others (1974). The shallow structure of the shelf has been investigated by a few seismic reflection profiles (Stride and others 1967, Talwani and Eldholm 1972, Himsworth 1973, Korsakov 1974, Talwani 1974). Some of the above studies have been reviewed by Bott (1975) and Waagstein (1977).

In order to further elucidate the geological structure of the upper parts of the shelf and especially to map the extent of

basalts on the sea floor, the Faeroese government and the Geological Survey of Denmark carried out a seismic survey. The survey was carried out on the research vessel »Dana«, 6—22 July in 1979, with equipment on loan from the Geological Survey of Greenland. About 2300 km of shallow seismic profiles were obtained (Fig. 1).

This initial report describes the survey and presents some preliminary results.

Methods

The sea bottom was investigated chiefly by seismic methods, by using the same principle as a recording echo sounder. A 10—20 cu inch airgun (Bolt) operated at 120 atm or a 4 KJ nine electrode sparker array (EG & G 402) was used as sound source. The sound signal reflected from the sea floor or layers in the substrate was detected by a short hydrophone streamer (EG & G 265). After amplification and filtering of the seismic signal, the reflections were recorded on a facsimile recorder (EPC 3200 and 4500). An example of the records is shown on Fig. 4. The depth was measured by a Simrad

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Fig. 3 (left). *Side-scan record from Djúpini (line 57).*

The side-scan emits a narrow sound beam perpendicular to the course of the ship just above the sea floor. The sound reflected (or rather scattered) from the obstacles on the sea floor is recorded. The record resembles a negative photography of the sea bottom as illuminated by a projector just above the sea floor.

The darker areas mark the parts of the sea bottom which protrude or for other reasons reflect more sound energy than average. The white area in the upper central part marks the acoustic shadow behind a protruding feature. The lower half shows the bottom on the port side (west) of the ship. Interpreted geologically the picture probably shows an outcrop of basalt, with an outline controlled by intersecting joints. The dark areas between the outcrops possibly indicate a rather coarse grained sediment.

3. mynd: *Dømi um ljóðmynd (side scan mynd) av botninum (siglingarlinja 57), Djúpini, sum vísir basalt, sum stingur seg upp við legugrýti ímillum (svart).*

SM50 sounder. The local morphology of the sea bottom was investigated by side-scan sonar (Edo Western 515T/606). The side-scan system was operative only on the last day of the survey. The magnetic field was measured by a proton magnetometer (Geometrics G803). Position was determined by an integrated satellite navigator sonar doppler system (Magnavox). The positional accuracy is well within 200 m when the system is working properly but in many cases the navigator system caused troubles. A description of such marine investigations is given by, e.g. McQuillin and Ardus (1976).

Results

The basaltic shelf

Most of the wide shelf around the Faeroe Islands consists of basalt like the Faeroe Islands themselves. The submerged basalt area is characterized by strong, short-waved magnetic anomalies and lack of seismic penetration. The eroded basalt flows often form inclined steps clearly visible on bathymetric and seismic profiles and side-scan records (Fig. 3). The inclination of such steps and of rare internal reflections in the basalts suggest that the flows are dipping towards the limit of the basalts east and west of the islands (Fig. 4).

Also the top of Faeroe Bank to the southwest consists of basalt.

Young sediments partly fill shallow depressions on top of the basalt but rarely exceed a thickness of 50 m. Glacial overdeepened depressions occur in the fiords between the islands and may be empty (e.g. Skopunarfjørður) or filled with 50—150 m of sediment (e.g. Nólsoyarfjørður, Djúpini).

The limit of the basaltic shelf

The basalt disappears below sediments on the outer shelf or slope around the Faeroe Islands (Fig. 2). The basalt contact towards the sediments varies in character. To the southeast, south and southwest the top of the basalt falls 2—10°, seldom more, beneath the sediment sequence. The estimated depth of

seismic penetration of the overlying sediments is 200—500 m and the basalt drops below this depth within a few kilometres. The contact is mostly straight and seems to follow the stratification of the basalt (Fig. 4). North of 62° N the eastern contact becomes flat and irregular. The basaltic basement thus occurs at less than a few hundred metres depth below Nólsoy Bank and is possibly exposed somewhere on the bank. North and northwest of the Faeroe Islands (lines 35, 37, 39 and 60) the outermost part of the shelf has an irregular topography (cf. Fleischer and others 1974). The irregular zone is 10—15 km wide and seems to consist of sediments. The sediments show little or no seismic penetration and their thickness is unknown. However, the magnetic data suggest that the basaltic basement occurs at shallow depth until the edge of the shelf. Just beyond the shelf edge a wedge of transparent sediments overlies a basement reflector and this is presumed to be basalt. The strong reflector is lost a few kilometres downslope beneath several hundred metres of sediments. The supposed limit of shallow basaltic basement is shown as a stippled line on Fig. 2. Exposures of basalt reappear on the Iceland-Faeroe Ridge. Due west of the northern Faeroe Islands shallow basaltic basement extends farther to the west than the survey lines.

The sedimentary shelf

Thick sediments occur on the outer shelf east of the Faeroe Islands. The sediments can be divided into two major stratigraphic units.

The lower unit consists of well-bedded sediments which dip outwards at a low angle. The oldest strata overlie the sloping basalt-sediment contact conformably or nearly so (Fig. 4). The lower unit is well seen along the western side of Sandoy Bank and Suðuroy Bank and in the channel between the banks. In this area the inclined beds apparently crop out on the sea floor in many places. The channels (broad valleys) separating Sandoy and Suðuroy Banks from each other and from the basaltic inner shelf are cut down into the lower sediments.

The channels resemble marginal and transverse channels described from many glaciated shelves.

The upper sediment unit rests unconformably on the lower unit or directly on the basalt. The upper sediments are irregularly bedded. They attain a thickness of up to a few hundred metres in the channels but in most places they are much thinner. The channel fillings show a high or moderate seismic transparency and probably consist dominantly of fine grained sediments. The internal structure of the channel fillings indicates several stages of erosion and deposition (Fig. 4). The thin sediment cover on top of Sandoy and Suðuroy Banks and farther east is much less transparent and probably includes a large fraction of coarse grained glacial material. In this area the underlying series is barely visible. The low-transparency layer continues a little down the slope towards the Faeroe-Shetland Channel.

Thick sediments also occur on the outer shelf west of the islands in a small area facing the Faeroe Bank Channel (Fig. 2). A lower series of outward dipping sediments also exists here beneath a cover of younger sediments (cf. Stride and others 1967).

Discussion

The regularity of the contact between basalts and lower sediments suggests that the contact follows the bedding of the basalt flows. This impression is supported by observations of the dip of flows on the basaltic shelf. The dip of the contact, i. e. flows is steeper than the likely original dip of the flows. The basalts are therefore tilted. This tilting is consistent with the idea of updoming of the basalt plateau (Schrøder 1971, Waagstein 1977).

The conformable contact between basalts and sediments (Fig. 4) indicates that the oldest parts of the lower sediments have also been tilted. Assuming an early date of doming (Waagstein 1977) the oldest sediments only slightly postdate the basalts dated at 50—60 mill. years, i.e. Lower Tertiary

(Tarling and Gale 1968). Some of the sediments are probably tuffaceous (Waagstein and Rasmussen 1975).

The lower sediment unit attains a thickness of roughly 2 km in the vicinity of Sandoy and Suðuroy Banks according to gravity (Bott and Watts 1971) and seismic evidence (Korsakov 1974).

The sediments of the upper unit are supposed to be of Quaternary age. The Faeroese ice sheet probably reached the 400 m depth contour to the southeast of the Faeroe Islands (Waagstein and Rasmussen 1975). The large areas of poor seismic penetration on the eastern sedimentary shelf are therefore probably covered by glacial drift.

Acknowledgements

The authors wish to thank the Geological Survey of Greenland for the opportunity to make the survey around the Faeroe Islands. We also wish to thank all on board »Dana« for good cooperation. One of the authors, P. H. Nielsen, acknowledges a grant from »Statens Naturvidenskabelige Forskningsråd«.

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ÚRTAK

Saman við Føroya-Íslands-Grønlandsrygginum er føroyski landgrunnurin partur av Norðuratlantska basaltøkinum. Í Føroyum eru basaltfláirnar samanlagdar meira enn 3000 m. Hildið verður at skorpan undir føroyska basaltháslættanum er meginlandsskorpa.

Á føroyska landgrunninum eru gjørdar botnkanningar av ymiskum slag hesu seinastu árini, bæði av fremmandum og okkum sjálvum. Fyribils úrslit okkara eru kunngjørd í Fróðskaparriti 1973, 1974, 1975, 1977 og í einari licentiatritgerð 1977. Tey fevna um eitt botnkort út á 200 m dýpi, viðgerð av botntilfari frá havbotninum uttan um Føroyar og um sigulmagnskanningar.

Til at fáa at vita meira um tey jarðfrøðiligu viðurskiftini niðri í sjálvum botninum og um hvussu langt basalttilfarið í landgrunninum røkkur út, vóru skjálvtamátingar (seismiskar rannsóknir) og upptøka av ljóðmyndum, (»side scan«, 3. mynd) settar í verk seinasta summar. Hetta var gjørt sum samarbeiði millum Føroya Jarðfrøðisavn (Føroya landsstýri) og Danmarks Geologiske Undersøgelse. Rannsóknirnar fóru fram í døgunum 6.—22. juli og til rannsóknararbeið var havrannsóknarskipið »Dana« við neyðugum tólum lánt frá Grønlands Geologiske Undersøgelse. Uppmátingarleiðin var umleið 2300 km (1. mynd). At viðgera alt hetta rúgvumikla tilfar fer at taka rúma tíð, nøkur fyribils úrslit verða tí løgd fram her.

Tað mesta av botninum út eftir landgrunninum er basalt eins og oyggjarnar sjálvar. Skjálvtamátingar vísa, at basaltbotnurin røkkur út til umleið 200 m (2. mynd). Botnurin er ofta trøpputur, slitin og fláirnar halla út í móti útryðjunum eystan fyri og vestan fyri oyggjarnar. Lægdir í botninum, helst máaðar av ísi, eru ikki óvanligar innansyndis, tær eru summar tómar, t. d. í Skopunarfirði og summar fyltar við 50—150 m av legugrýti, morenutilfari, sandi ella leiri, t. d. í Nólsoyarfirði og Djúpunum.

Uttarlaga á landgrunninum ella á hellingini gongur basaltbotnurin inn undir legugrýti. Samankomingin millum basalt og legugrýti er nakað ymisk.

Í landsynning, í sunnan og í útsynning úr Føroyum er basaltbotnskráin 2°—10°, sjáldan meira, har basaltbotnurin gongur undir legugrýti.

Eystan fyri oyggjarnar, norðan fyri 62°, er botnskráin við samankomingina millum basalt og legugrýtið lítil, so tað er ikki djúpt niður á basaltbotnin úti á Nólsoyarbanka, har hann kanska onkustaðni kemur undan.

Norðanfyri og í útnyrðing úr Føroyum (siglingarlinjur 35, 37, 39 og 60) er botnurin, sum her tykist vera legugrýti, ójavnur teir 10—15 uttastu km á landgrunninum.

Beint vestur av norðaru oyggjunum gongur basaltbotnurin longri út enn kanningarøkið í ár.

Tjúkt legugrýti kemur fyri uttarlaga á landgrunninum eystan fyri Føroyar. Á 4. mynd (siglingarlinja 11) sæst samankomingin millum legugrýti og basalt nærindis 200 m dýpdarlinjuni. Legugrýtið kann vera sundurbýtt í tveir høvuðsbólkar, ein niðari og eldri, ein ovari og yngri. Niðari bólkurin er væl lagskipaður við lítlum halli úteftir, elstu fláirnar eru samlagdar samankomingini millum basalt og legugrýti. Tær breiðu

rennurnar millum Sandoyarbanka og Suðuroyarbanka og millum bankarnar og landgrunnin innanfyri eru máaðar niður í niðara legugrýtið, tær eru líkar mongum av teimum sum eru máaðar av ísi.

Ovari legugrýtisbólkurin er mislagdur niðara legugrýtinum og basaltbotninum. Lagskipanin er ógreið. Í rennuni er tjúktin meira enn 100 m, men oftast er hon tynri. Niðara legugrýtið er umleið 2 km tjúkt uttan fyri Sandoyarbanka og Suðuroyarbanka.

Tjúkt legugrýti er eisini uttarlaga á landgrunninum vestan fyri oyggjarnar út í móti Føroyabankarennuni (2. mynd). Eisini her er ein niðari legugrýtisbólkur, har fláirnar halla úteftir.

Fig. 4 (right). *A part of the seismic recording of line 11 and its interpretation showing the basalt-sediment boundary (east of the Faeroe Islands).*

4. mynd: *Skjálvtamátingarmynd (Seismisk mynd) niður í botnin (siglingarlinja 11) eystan fyri Føroyar, nærindis 200 m dýpdarlinjuni, sum vísir samankomingina millum basalt, niðara legugrýti (tertier) og ovara legugrýti (kvarter).*