Seismic Measurements on The Faeroe Island, 1970

(A preliminary report)

By Uwe Casten)*

Introduction

Bathymetric studies of the northern part of the Atlantic Ocean show the structure of a submarine rise connected with the Iceland plateau and with a SE-extension towards Scotland (Fig. 1). While the ocean floor in the north and in the south lies in depths of several thousand metres the rise shows a depth of about 600 m under sea level and comes with the Faeroe Islands over sea level (maximum height of the islands: 882 m). This so-called Iceland-Faeroe-Ridge is to be seen in connection with the Brito-Arctic basalt province which extends from Scotland over the Faeroe Islands and Iceland to Greenland.

It seems to be so that the basalts are not erupted submarine, because pillow lava could not be found. So the Faeroe Islands may be fragments of a unity of plateau basalts, which did not sink down. Looking also for horizontal movements in the earth's crust — what may be actual with respect to the Mid-atlantic Ridge — it may be possible that the basalts are underlayed by crustal rests of continental structure. Otherwise a crustal structure of the oceanic type is expected.

Seismic deep sounding is a method to find the crustal struc-

*) Laboratory of Applied Geophysics, Aarhus University, Carl Blochsgade 28, DK—8000 Århus C, Denmark.

Fig. 1. *The ocean floor of the North Atlantic. A reproduction of the Society's Atlantic Ocean floor map: Copyright 1968 National Geographic Society.*

ture down to the Mohorovicic discontinuity, which departs the crust from the mantle. To find an answer to the structure and origin of the Faeroe Islands the application of seismic sounding is necessary and was therefore used be the author.

The Known Structure of the Faeroe Islands:

Detailed information of the geology of the Faeroe Islands is given by *Rasmussen* and *Noe-Nygaard* (1969). *Pálmason* (1965) made the first seismic refraction measurements of the basalt lavas of the islands. Together with a review of geophysical measurements as given by *Saxov* and *Abrahamsen* (1966) a compilation of the geological stratigraphic column and the geophysical results leads to the following structure of the Faeroe Islands:

The islands are built up of Tertiary basalt lavas with volcanic ashes and agglomerates. The visible stratigraphic sequence with a thickness of 3000 m consists of three series. This is

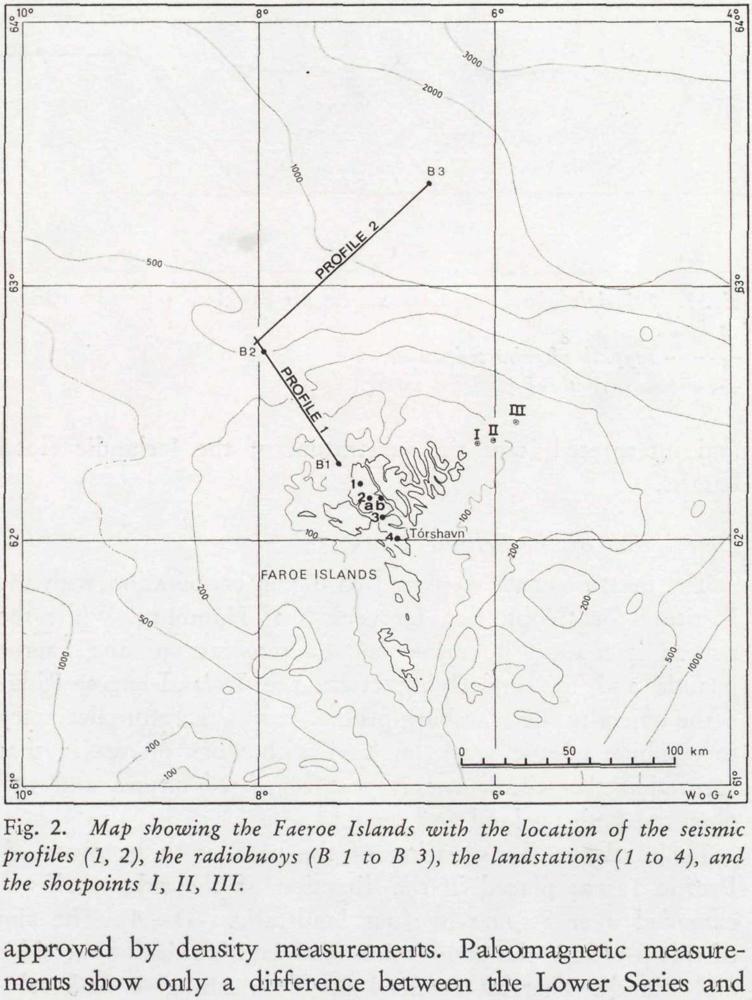

Fig. 2. *Map showing the Faeroe Islands with the location of the seismic profiles (1, 2), the radiobuoys (B 1 to B 3), the landstations (1 to 4), and the shotpoints I, II, III.*

approved by density measurements. Paleomagnetic measurements show only a difference between the Lower Series and the Upper and Middle Series together, while the seismic investigations show a P-wave velocity of 3.9 km/s for the Upper Series and a velocity of 4.9 km/s for the Middle and Lower Series. A third seismic layer of unknown thickness under the known three series is given by the velocity of 6.4 km/s. On Iceland *Pálmason* (1969) found a velocity of 6.35 (6.5) km/s

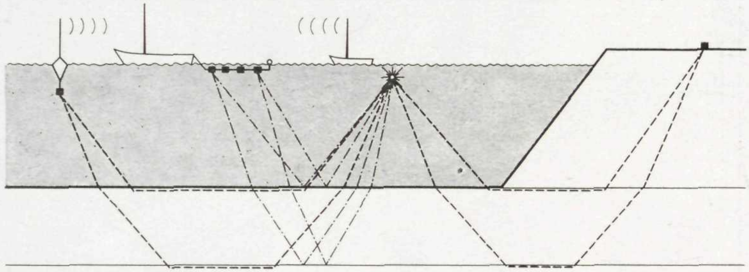

Fig. 3. *Principle of seismic sea-measurements combined with observations on land.*
— — — *raypath of refracted waves*
— · — · — *raypath of reflected waves.*

and interpreted it as the substratum of the Icelandic flood basalts.

Description of the Seismic Work:

The measurements were carried out in cooperation with the Institute for Geophysics, University of Hamburg. While the author is mainly interested in the structure of the Faeroe Islands and the underlying crust, the Iceland-Faeroe-Ridge is the object to the Hamburg people. It was therefore necessary to combine seismic work on land with work on sea in that form that the seismic energy was generated on sea and was observed both on land and on sea.

Fig. 2 shows the situation of the profiles to be observed. Profile 1 was placed in the direction of the ridge and was extended over Strømø by four landstations (1—4). The aim of this profile is the observation of discontinuities of the ridge and islands. Thereby reversed profiling can give real velocities. Profile 2, placed more or less perpendicular to Profile 1, shall give only the structure of the ridge. The profiles were fixed by radiobuoys with hydrophones as detectors. An additional profile crossing the islands in NE-SW direction was planned with three shots on sea on both ends of the profile (reversed profile) and observating by four landstations. This project should give the structure of the islands perpendicular to the striking of the rise but failed for reasons of communication. Only the shots I, II, III were observed by station 2 b. Table 1 gives the geographical coordinates of the positions of the landstations, radiobuoys and the three shotpoints northeast of the islands.

Table 1

Station	1	62°13'38.2"	7°07'27.3"
	2 a	62 09 58.9	7 04 03.4
	2 b	62 10 09.0	6 57 13.7
	3	62 05 16.2	6 58 22.5
	4	62 00 32.5	6 49 52.5
	B 1	62°18.2'	7°19.5'
	B 2	62 44.8	7 57.8
	B 3	63 23.6	6 33.8
	Shot I	62°23.1'	6°09.5'
	Shot II	62 23.9	6 01.1
	Shot III	62 28.2	5 49.4

The coordinates together with shotpoint data were used for calculating the distances. Fig. 2 shows that the landstations were not placed exactly in the direction of the profile. For reasons of very rough topography it could not be made better.

Fig. 3 shows the principle of the applied seismic method. On sea the research vessel »Meteor« of the German Hydrographic Institute and under charter the 30 tons ship »Ingerd« from Vestmanhavn operated together. The latter was used as shooting vessel with radioconnection to »Meteor«. The profiling was done by shooting in intervals along the planned profiles. The generated seismic energy (explosives of 45, 90, and in some cases 180 kg) was registrated as refracted waves by the hydrophones on the profile ends and by the geophones on land. On sea the received signals were transmitted by the buoys with SW-radio to »Meteor« and then registrated on magnetic tape in analog form. On land the geophones were cableconnected to the registration equipments (type Lennartz)

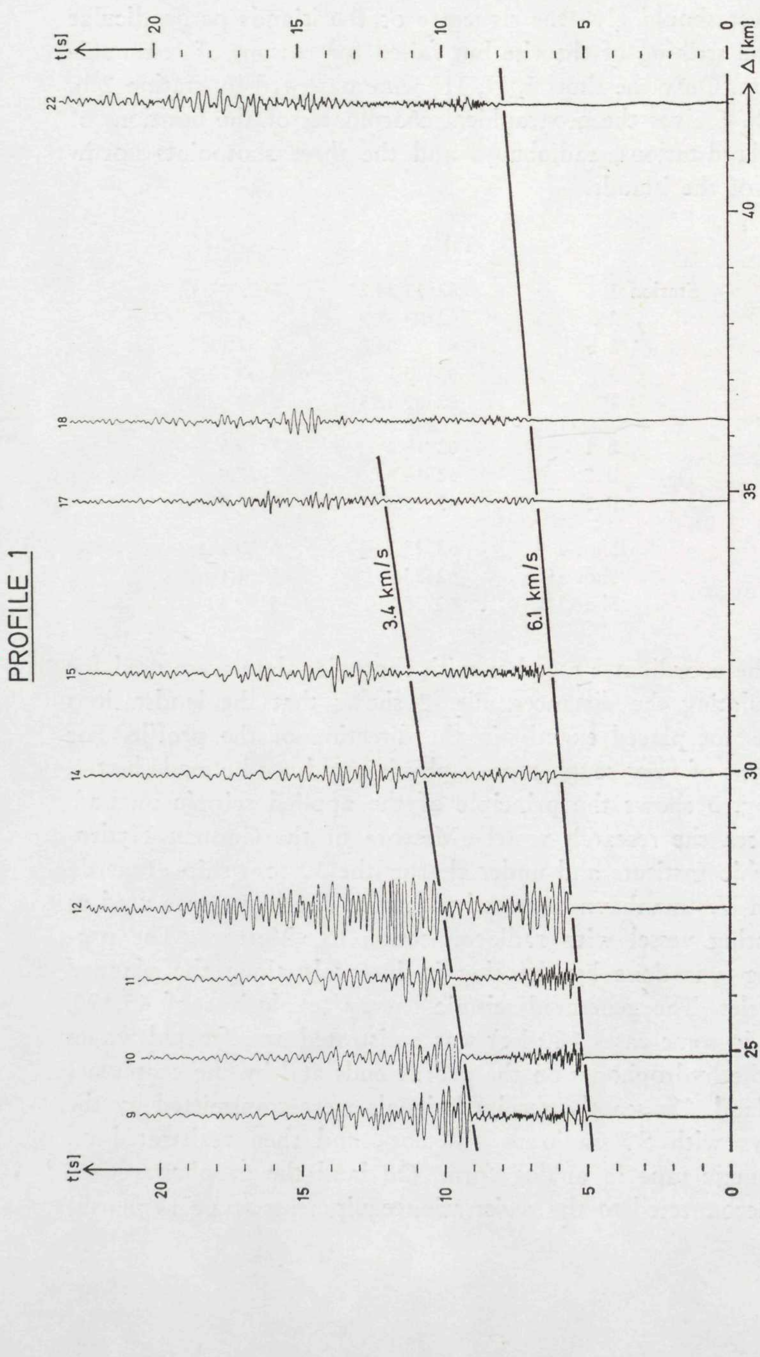

Fig. 4. Mounting of the seismograms from shotpoint 9 to 22 of Profile 1.

with 3 seismic channels each and also magnetic tape recording. The Lennartz equipment is described by *Berckhemer* (1970). It is an equipment proved under bad outer conditions and is used in a modified version also for sea-seismic purposes.

For reflection measurements a 600 m floating cable with 24 traces was used. Hydrophones received the seismic signals and a 24-channel equipment on »Meteor« registrated these on photographic paperfilm. Using the two-ship method the shooting vessel had to follow the end of the floating cable in a distance of about 200 m. So the reflection equipment registrated steep-angle reflections while by the refraction equipment information of wave velocities was obtained.

The whole programme could be finished within 5 days (from July 9th to July 14th). Thereby the communication between the working team on sea and the four landstations was a factor of importance. It was not possible to fix a shooting programme. Information from »Meteor« were transmitted by shipradio (1.665 MHz) and received by the landstations. Station 2 was equipped with a radiotelephone (3.150 MHz) and could be received by »Meteor« without disturbances over a distance up to 150 km. In addition to these communication facilities the telegraph station in Tórshavn made it possible to telephone by radio with »Meteor«.

The Results:

In this publication only the registrations on land shall be presented.

Mounting of the seismograms in a traveltime-distance-diagram gives the possibility to identify seismic events by applying the method of correlation (analog correlation done by eye). Fig. 4 shows the mounting for the first part and Fig. 5 for the second part of Profile 1. In Fig. 6 the signals from the three shots NE of the islands are shown. The signals are reproductions of the original seismograms from station 2. In all three cases the first events could be correlated very clearly. For the shots 9 to 17 of Profile 1 a second arrival

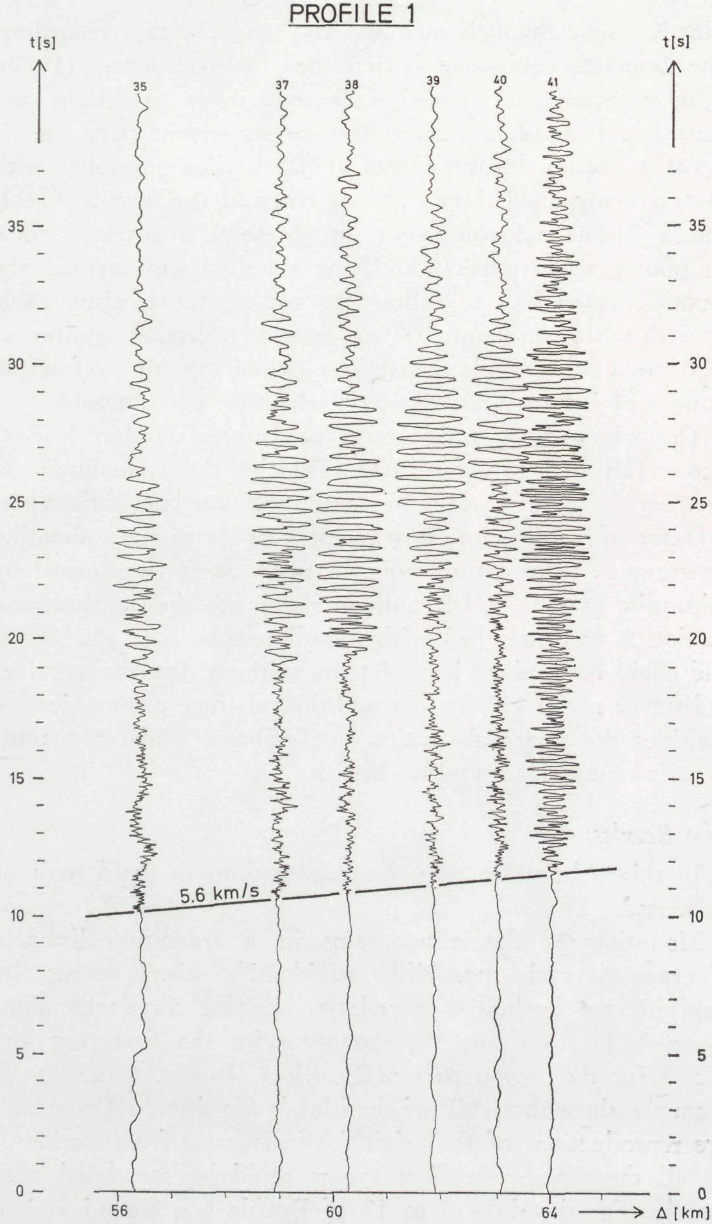

Fig. 5. *Mounting of the seismograms from shotpoint 35 to 41 of Profile 1.*

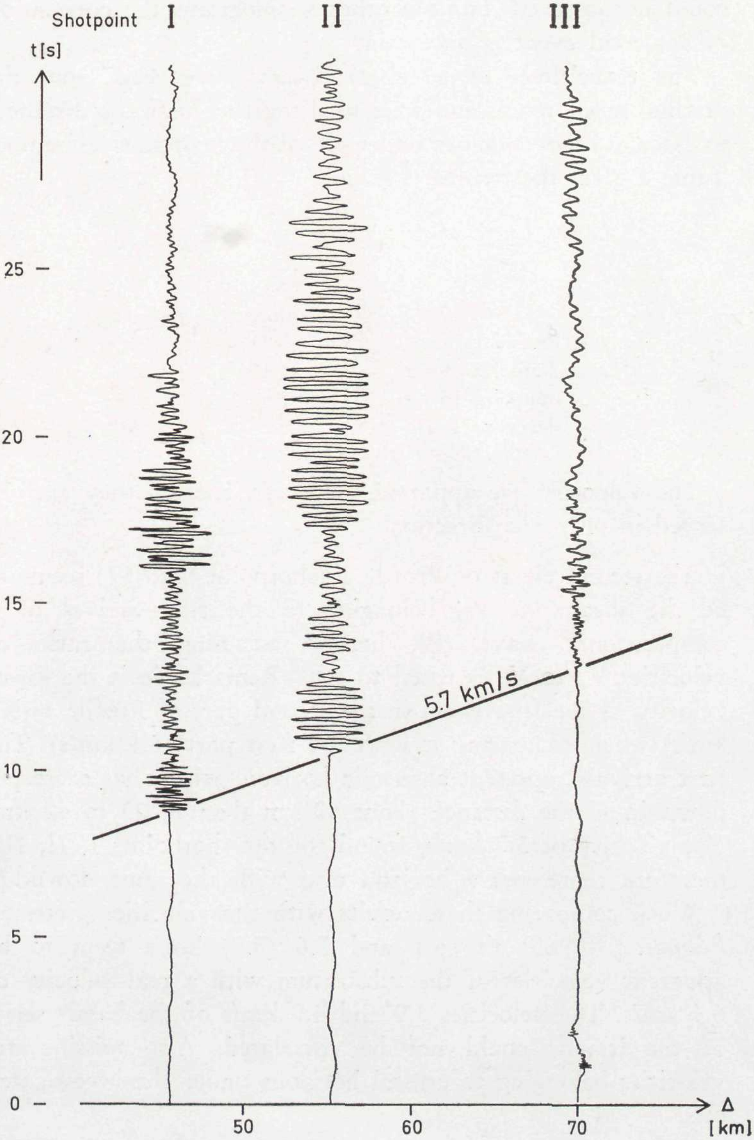

Fig. 6. *Mounting of the seismograms from shotpoint I, II, III.*

could be observed. For the other seismograms the correlation of a second event is uncertain.

The traveltimes of a seismic event were read from the original seismograms and were used together with the distances to calculate the velocities under use of the least-square-method. Table 2 gives the results.

Table 2

	V_1 (km/s)	V_2 (km/s)
Profile 1:		
shotpoint 9—22	6.1	3.4
shotpoint 35—41	5.6	—
shotpoint I, II, III	5.7	—

The velocities are apparent velocities, because they are observed in only one direction.

The second event of Profile 1 (shotpoint 9 to 17) seems to be the shearwave (S) belonging to the first arrival of a compressional wave (P), hereby assuming the ratio of velocities V_p to V_s is equal to $\sqrt{3}$. Remarkable is the lower velocity of the first event in the second part of Profile 1 (5.6 km/s) when comparing it with the first part (6.1 km/s). The first arrivals represent a seismic horizon, which has a steeper downdip in the distance about 60 km than in 23 to 42 km. The velocity of 5.7 km/s, found for the shotpoints I, II, III, therefore represents a horizon also with the same downdip.

When comparing these results with the velocities given by *Pálmason* (1965) the 6.1 and 5.6 (5.7) km/s seem to be apparent velocities of the substratum with a real velocity of 6.4 km/s. The velocities 3.9 and 4.9 km/s of the basalt series of the islands could not be correlated. Also missing are velocities belonging to crustal horizons under the investigated one.

Acknowledgements

I wish to thank Professor S. Saxov and Statsgeolog J. Rasmussen for their invaluable help in planning the field work.

The seismic team on »Meteor« under the leadership of Mr. W. Weigel carried out the work on sea in an excellent cooperation with the landstations. Thereby the use of »Meteor« ship radio and a special service of the telegraph station in Tórshavn were very successful.

I should also like to express my gratitude to all the participants in the field work. They strived hard for getting good results.

This work was supported by a grant from Aarhus Universitets Forskningsfond.

REFERENCES

1. *Berckhemer, H*; 1970: Mars 66. A Magnetic Tape Recording Equipment for Deep Seismic Sounding. Zeitschr. f. Geophysik, 36, 4, pp. 501—518.
2. *Pálmason, G*; 1965: Seismic Refraction Measurements of the Basalt Lavas of the Faeroe Islands. Tectonophysics, 2 (6), pp. 475—482.
3. *Pálmason, G*; 1970: Crustal Structure of Iceland from Explosion Seismology. Science Institute, University of Iceland.
4. *Rasmussen, J. and A. Noe-Nygaard*; 1969: Beskrivelse til Geologisk Kort over Færøerne. Geological Survey of Denmark I. Series No. 24, Copenhagen.
5. *Saxov, S. and N. Abrahamsen*; 1966: Some Geophysical Investigations in the Faeroe Islands. A Preliminary Report. Zeitschr. f. Geophysik, 32, pp. 455—471.

ÚRTAK

Skjálvtafrøðiligar dýpdarkanningar vóru gjørdar í samvinnu við lærda háskúlan í Hamburg (Institut für die Physik des Erdkörpers) á rygginum millum Føroya og Íslands í døgunum 9. til 14. juli 1970. Við tveggja-skipaháttinum vóru skjálvtafrøðiligar afturvarp- og brotmátingar gjørdar á sjónum. Í Streymoy fylgdu 4 landstøðir við spreingingunum á sjónum.

Uppsetingar av skjálvtaritunum frá landstøð nr. 2 eru sýndar. Einans

ein lind kundi verða rannsakað við at bera saman skjálvtafrøðiligu viðburðirnar. Snarleikin 6,1 (5,6 · 5,7) km/s er ein P-bylgju-snarleiki og 3,4 km/s ein S-bylgju-snarleiki. Teir eru at vísa seg snarleikar hjá undirstøðinum undir basaltgrýti Føroya.