Seismic Refraction Measurements around the Faeroe Islands

By P. Hedebol Nielsen.

Abstract.

In 1972 a refraction seismic project NASP took place between Iceland and Scotland. It gave observations from the Faeroe Islands where the main results are: The Iceland-Faeroe Ridge has a crust of Icelandic type whereas the Faeroese shelf seems underlain by continental crust. The thickness of the basalt lavas of the islands seems to vary around 3 km. On the shelf the P-wave velocity of the »basement« seems to decrease from about 6.1 km/s in the northwest to about 5.3 km/s in the east.

Introduction.

In the summer of 1972 a seismic project, named NASP (= North Atlantic Seismic Project), was carried out in the North Atlantic Ocean from Iceland to Scotland (see fig. 1). The present work is mainly based upon NASP-data but only the Faeroe Islands and their shelf will be treated (other reports on NASP in this region have been given by Bott et al. 1974, and Casten and Nielsen 1975).

The North Atlantic Seismic Project was planned and organized by the Department of Geology at Durham University under leadership of Prof. M. H. P. Bott. Institutions from several countries participated with seismic stations, most of

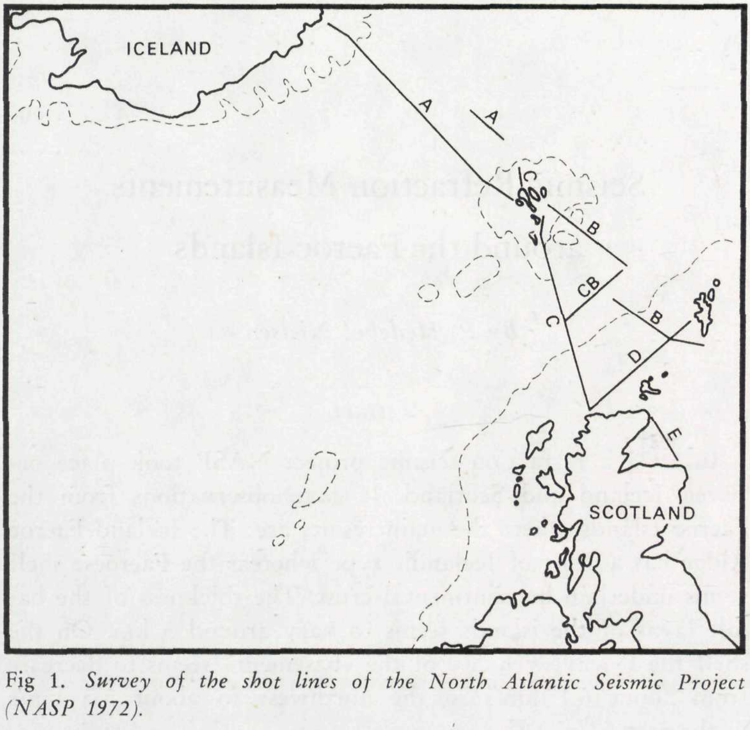

Fig 1. *Survey of the shot lines of the North Atlantic Seismic Project (NASP 1972).*

which were based on land, but two ships (the British ship »Miranda«, and the Soviet ship »Mikhail Lomonosov«) occupied a number of stations at sea.

All shots were fired in the sea by slowly burning fuse, and most of the relevant loads consisted of 300 lbs. or 600 lbs. of Geophex, and all shots consisted of one single load. The shots were fired along the lines shown on fig. 1, and the spacing was around 10 km for most of the shots, which are relevant to the Faeroe Islands. It can be added that only shots on the lines A, B and C gave usable signals on the Faeroe Islands.

The stations F1 . . . F6 on the Faeroe Islands were organized by the University of Aarhus (Denmark), but equipment and personnel came from a number of Danish and West German institutions. All these stations were equipped with MARS-instrumentation (Berckhemer 1970); except for F2 and F3 they all had 3 vertical geophones, about a hundred metres apart; the approximate characteristics of the geophones were: resonance frequency 2Hz, and a low pass filter 20 Hz. The stations F2 and F3 had a horizontal geophone besides vertical geophones; for more details see Casten (1974).

The station DU4 was a 3-component station run by Durham University (description of instrumentation: Long 1974). The stations outside the Faeroe Islands were of different types and run by different organizations but these travel times and distances, when used here, are taken from the thesis of Smith (1974). The arrivals at the Danish stations on the Faeroe Islands were picked or repicked, and travel times for first arrivals observed on the Faeroe Islands can be found as table 2 in the appendix. The positions are given in table 1 in the appendix, and the positions of the shots were usually found by the use of Decca and radar fixes, and the error of a position is then rather small. Especially on line A Decca could not be used, instead Loran was used giving a larger error of the positions, but the error will probably not exceed 1..2 km. The positions of the geophones are all well defined but the connection between the geophone positions and the channels on the registrations is not always clear for the stations F1...F6; further, the geophone sites are very inhomogeneous so that changes of distance with a hundred metres gave no systematic change of travel time (except F6 which was placed on the rather homogeneous basalt of the lower series). The positions of the stations F1...F6 are therefore »mean values« giving an error of about a hundred metres.

Geophysical structure of the Faeroe Islands.

The surface rocks of the Faeroe Islands consist almost exclusively of Tertiary basalt lavas, including some basalt intrusions. The basement of these lavas is found nowhere on the islands and the dip of the lavas is everywhere small (Noe-Nygaard 1962, 1974, Rasmussen and Noe-Nygaard 1969). The lava flows have been dated to be between 50 and 60 Ma old (1 Ma = 10^6 years) (Tarling and Gale 1968). The topography of the islands is rather rough, especially of the north-eastern islands, and in the northern parts heights of nearly 900 m are reached.

The basalt layers mentioned cannot be studied in any detail by using NASP-data, because nearly all ranges are too big to give first arrivals in the top layer. However, these layers were studied by Pálmason (1965), who found the following structure:

	V_p	V_s
upper series	3.9 km/s	2.2 km/s
middle series and lower series	4.9 km/s	2.7 km/s
basement	6.4 km/s	3.4 km/s

The three series are basalt lavas and crop out on the islands. The depth of the unknown basement was found to be between 2.5 km and 4.5 km beneath Streymoy. From these results Pálmason inferred that the structure was of the Icelandic type (Båth 1960, Pálmason 1971, Pálmason and Seamundsson 1974), but the lines were too short to give reliable results for the basement (Pálmason 1965).

In 1970 further seismic work was done on the islands (Casten 1973); line 1 (fig. 2) was fired and observed by a number of stations on the islands. Unfortunately, the telemetric hydrophone buoys failed so the shots were observed on land only (Casten 1974). However, the apparent velocities seem to confirm Pálmason's previous results except that the apparent velocity of the basement was found to be lower, namely 5.9 km/s (Casten 1973).

Besides the seismic work the gravitational field has been measured and a detailed map of Bouguer anomalies with topographic corrections has been published by Saxov (1969). The gravitational field is according to these maps rather uniform over the islands with values between +17 mgal and +40 mgal (1 mgal = 10^{-5} m/s^2). The general trend is an increase in an easterly direction with a wide minimum in the northwest.

A few other geophysical works on the Faeroe Islands can be mentioned: Abrahamsen (1967), Saxov and Abrahamsen (1964, 1966), Schrøder (1971), and Hansen and Søndergaard (1973).

The shelf around the Faeroe Islands.

A relatively broad shelf surrounds the islands, this shelf including the islands will be called the Faeroe Block. Towards northeast the shelf is bounded by the deep Norwegian Sea. Towards southeast the shelf is separated from the British Shelf by the Faeroe — Shetland channel with depths of more than 1 km. To the south the channel divides into two channels, one continues into the Rockall trough after crossing the Wyville Thomson rise, the other channel terminates between the Faeroe Islands and the Faeroe Bank. Between Iceland and the Faeroe Islands there is the aseismic Iceland—Faeroe ridge, from which the Faeroe Block is separated by a short scarp. The crest of the ridge is a plain with depths around 400 m, whereas the Faeroe Block is characterized by depths not significantly greater than 250 m.

The Iceland—Faroe ridge has been found underlain by anomalous oceanic crust of the Icelandic type (Bott et al. 1971, Johnson & Tanner 1971), whereas the Rockall plateau to the southwest of the Faeroe Islands seems to be underlain by continental crust (Scrutton 1972, Roberts, Ardus & Dearnley 1973). It is therefore of importance for the understanding of the development of the North Atlantic Ocean to know whether the Faeroe Islands are underlain by continental crust or not; the assumption that the Faeroes are continental seems to improve the model for the opening of the Atlantic Ocean (Bott & Watts 1970).

A key to structural questions of this kind is the gravitational

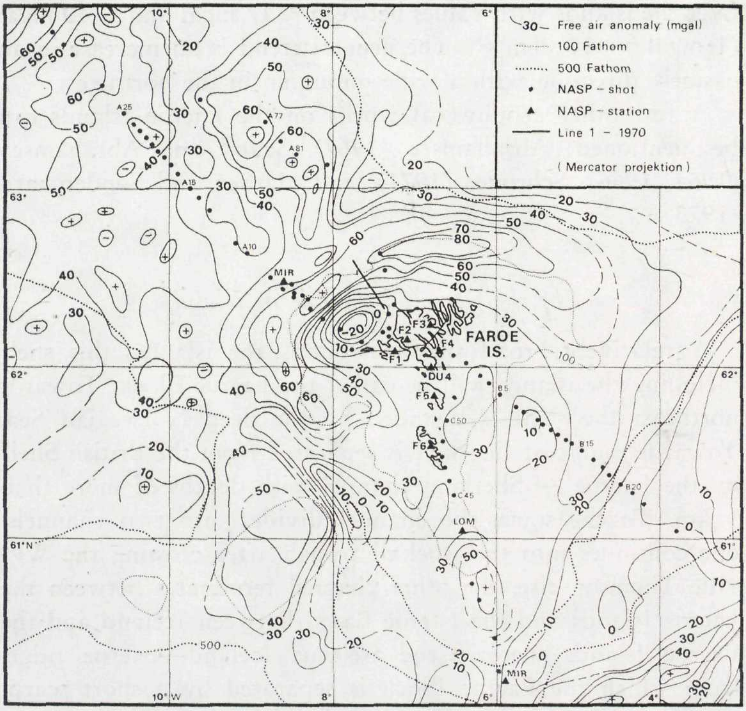

Fig. 2. *Free air anomalies around the Faeroe Islands. The map is based on the data published by Fleischer et al. (1974) and Bott & Watts (1970). All NASP shots which gave usable first arrivals on the Faeroe Island are shown.*

field and a number of maps of this field have been published (Bott & Watts 1970, Fleischer 1971, Bott et al. 1971, and Fleischer et al. 1974). From these gravity data a number of models of the crust have been constructed, all of which indicate a less dense crust for the Faeroe Islands than for the Iceland—Faeroe ridge. In this way the gravitational field points towards a crust of more continental than oceanic affinity beneath the Faeroe Islands (see fig. 2).

Two features of the gravitational field can be mentioned: a gravity maximum south of the Faeroe Islands and a gravity minimum on the shelf northwest of the islands (see fig. 2); the minimum is much deeper than indicated from measurements on land.

A number of magnetic field measurements in the region have been published (Avery et al. 1968, Fleischer et al. 1974, Schrøder 1971, see also Voigt & Avery 1974). It is found that the basalt areas are characterized by irregular, high frequency magnetic anomalies, but on the deeper parts of the shelf east of the Faeroe Islands the frequency is significantly decreased and evidence from seismic reflection profiles indicates that the lavas give way for sediments (Bott & Watts 1970 and Korsakov 1972).

NASP travel time for stations on the Faeroes.

The station F6 shows some peculiarities which will be discussed later, but otherwise the stations on the Faeroe Islands give rather uniform results. Characteristic graphs of reduced travel times are given as fig. 3. Some intercept times and least square velocities can be found as table 3 in the appendix.

All shots in the range up to about 25 km give first arrivals which are consistent with a direct wave of about 5 km/s (Pálmason 1965 found 4.9 km/s) but at longer distances the lines A and C (north) (= line C north of e. g. the station F1) seem to differ significantly from the lines B and C (south).

The shots of line A and line C (north) recorded by the stations on the islands give an apparent velocity of appr. 6 km/s on the shelf but with significant scatter. Line C (north) does not extend outside the shelf but line A gives an apparent velocity of appr. 8 km/s in the range above 170 . . . 200 km; for shorter distances the apparent velocity is appr. 7 km/s outside the shelf.

Stacked seismograms for line A are given as fig. 4. It is seen that there are late, poorly defined arrivals of large amplitude; these arrivals are probably S-arrivals which can be expected because the large contrast between the sea water and the basalt in the sea bed will cause conversion from P-waves

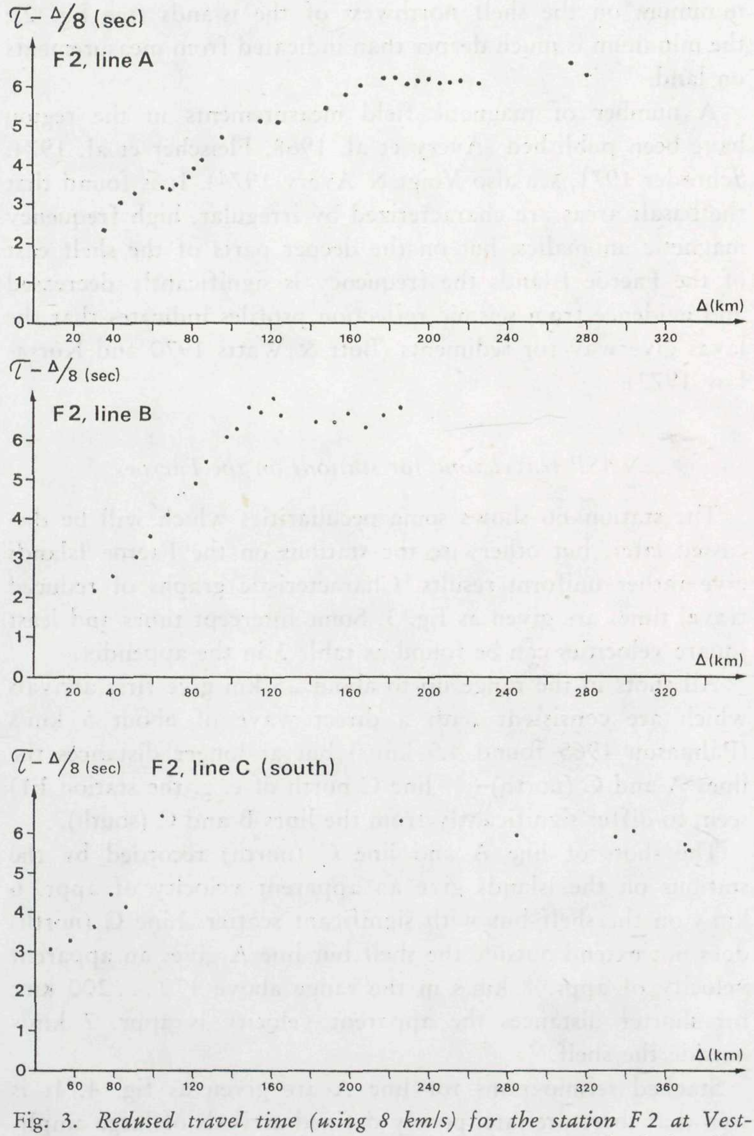

Fig. 3. *Redused travel time (using 8 km/s) for the station F 2 at Vestmanna on the Faeroe Islands. No correction for water depth has been applied.*

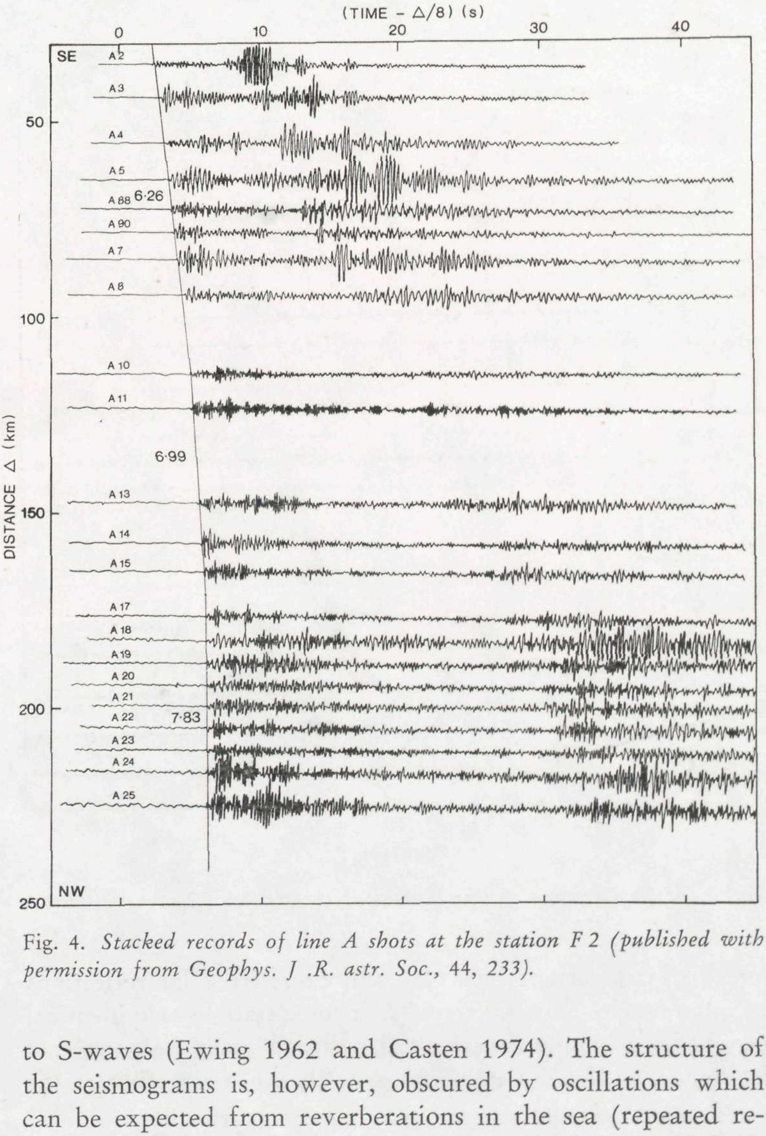

Fig. 4. *Stacked records of line A shots at the station F 2 (published with permission from Geophys. J .R. astr. Soc., 44, 233).*

to S-waves (Ewing 1962 and Casten 1974). The structure of the seismograms is, however, obscured by oscillations which can be expected from reverberations in the sea (repeated reflections between the surface and the bottom of the sea, Pekeris 1948, Officer 1958 and Casten 1974). Note, however, that the

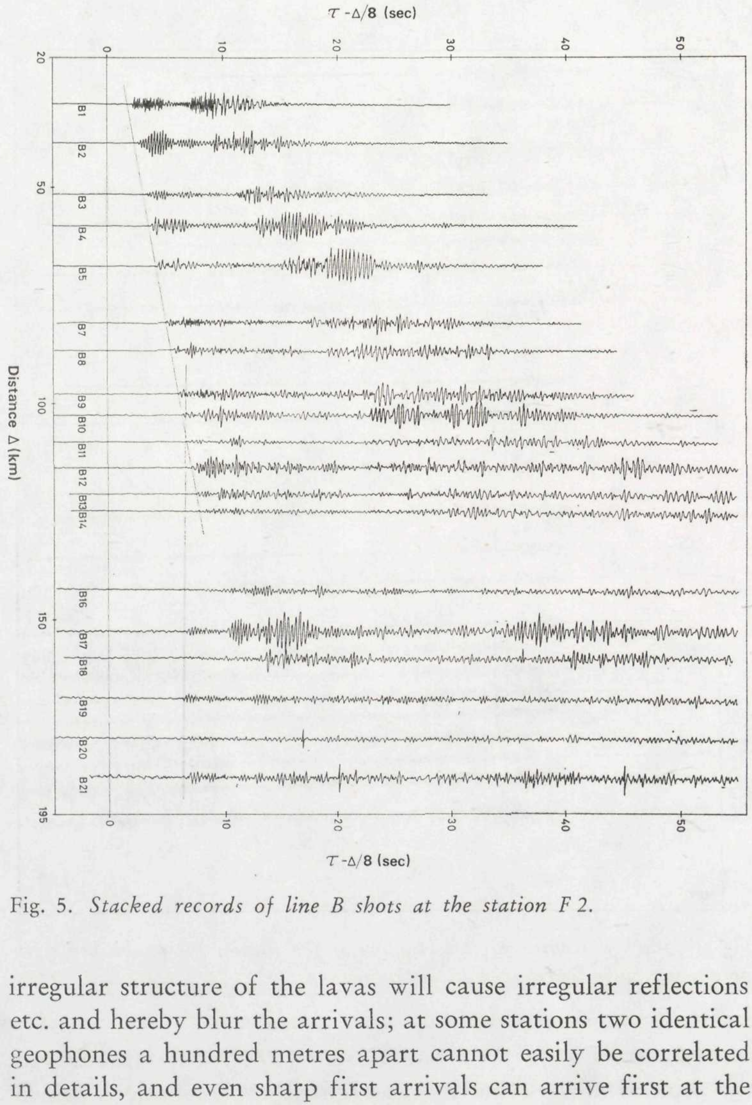

Fig. 5. *Stacked records of line B shots at the station F 2.*

irregular structure of the lavas will cause irregular reflections etc. and hereby blur the arrivals; at some stations two identical geophones a hundred metres apart cannot easily be correlated in details, and even sharp first arrivals can arrive first at the most distant geophone.

The frequency content is seen to vary from shot to shot but no analysis has been made.

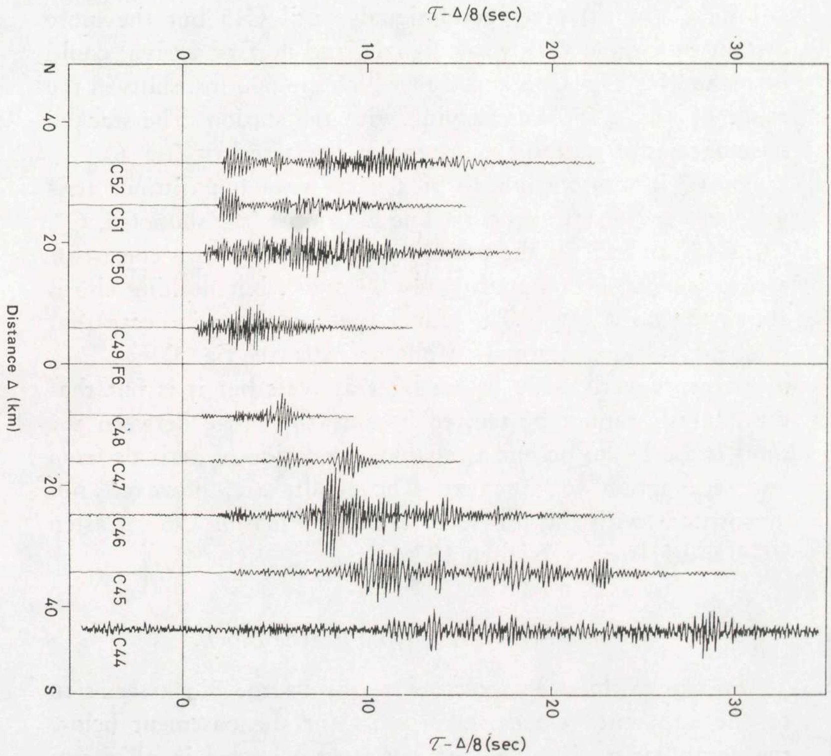

Fig. 6. *Stacked records of line C shots at the station F 2.*

The shots of line C (south) give apparent velocities around 5 km/s within a range of 100 km or so. For more distant shots the apparent velocity is appr. 8 km/s, when observed. However, when the shots closest to the islands, B1 . . . B3 and C49 . . . C52, are more distant than about 25 km then the apparent velocity seems to be about 6 km/s (see fig. 3).

Stacked seismograms for line B are shown as fig. 5, and it is seen that the arrivals of 5 km/s continue as second arrivals after the weak first arrivals of 8 km/s. The late arrivals of large amplitude and of an apparent velocity of appr. 3 km/s are probably again S-arrivals.

Line C (south) gives good signals until C45 but the more distant shots give very weak signals, and no first arrival could be picked for e. g. C43 and C44 which are 600 lbs. shots in the range of 40 . . . 150 km varying with the station. The stacked seismograms of station F 6 are rather characteristic (fig. 6).

For F2 it was possible to pick very weak but distinct arrivals for very distant shots on line C (south) (the shots C5, C7, C8, C13, and C15); the corresponding seismograms consist of a surprisingly short signal (a few seconds), but nothing else is above the noise level. The travel times seem to indicate that these arrivals are »normal« Moho-arrivals (see fig. 3).

Attempts were made to use later arrivals but it is felt that the analysis cannot be trusted because the range between the shots is too big to permit a reliable correlation of arrivals from one seismogram to the next. The results are, however, not inconsistent with the previous results (Pálmason 1965, Casten 1974 and Casten & Nielsen 1975).

Crustal Structures of the Faeroe Block.

The key to the deep structure of the Faeroe Block seems to be the apparent velocity of 6 km/s for the basement below the basalt lavas. This velocity has been observed in all directions close to the islands, and when graphs of reduced travel times are drawn for first arrivals from a single shot then the velocity of 6 km/s reappears in most cases as the apparent velocity between the stations for distances above 25 km (see fig. 7). Only two persistent exceptions have been found, namely the most distant shots on line B where Moho-velocities appear in both directions and the station F6 on Suðuroy (fig. 7). The ship station MIR(D) on the border of the shelf towards northwest can be included in this 6 km/s area.

The conversion of waves from outside into waves of approx. 6 km/s has been discussed in details for line A by Bott et al. (1976) and seems to indicate a deep layer of this approximate velocity below the basalt lavas.

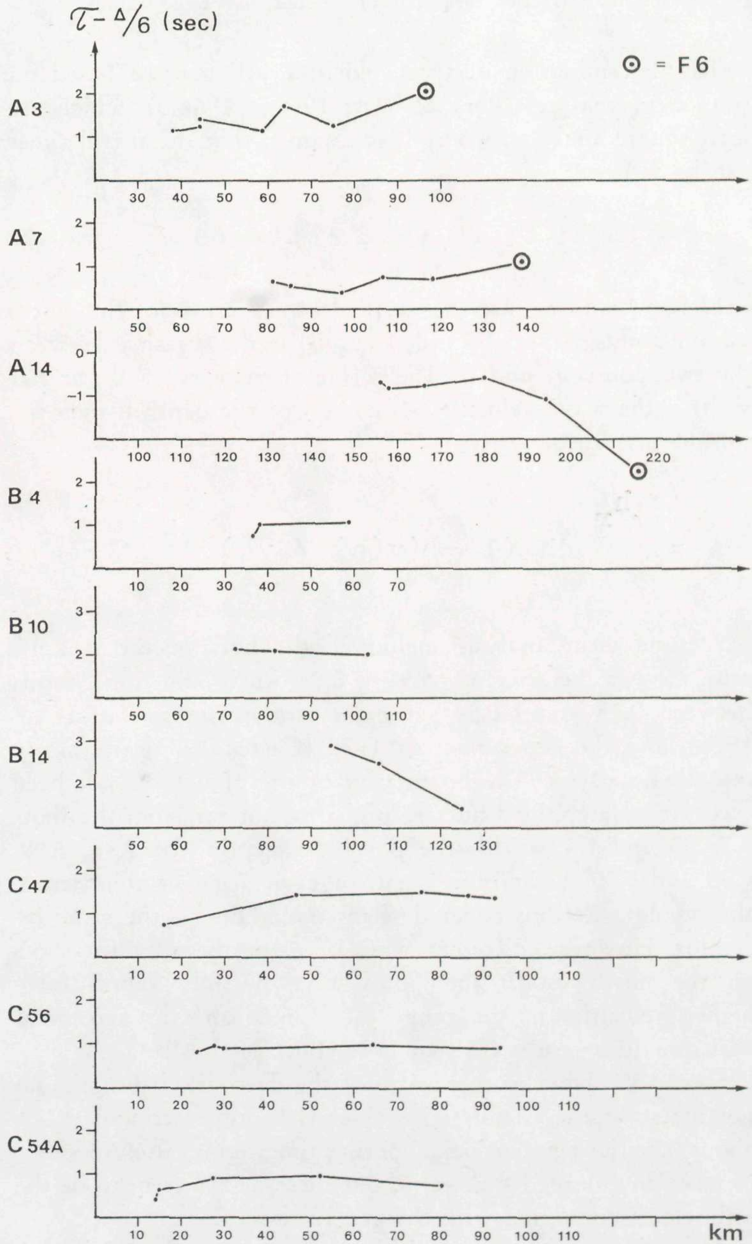

Fig. 7. *Reduced travel times (using 6 km/s) for selected shots. The tendency to an apparent velocity of appr. 6 km/s between the stations is evident. The points represent the stations F 1, F 2, F 3, F 4, F 5, F 6, DU 4 and MIR(D) when the shots have been recorded at these stations.*

The determination of true velocities will here be based on time term analyses (Bery & West 1966 a, 1966 b), which are least square analyses, where it is assumed that the travel times can be written

$$\tau(A,B) = a_A + a_B + d(A,B) / v_r$$

Here a_A and a_B are the socalled »time terms« of the observation points A and B, and d (A, B) is the distance between the two points A and B. The refractor velocity is v_r, and if v (h) is the wave velocity as function of the depth h then the time terms can be written

$$a = \int_0^{h_r} dh\ (1 - (v(h) / v_r)^2)^{\frac{1}{2}} / v(h)$$

A time term analysis including all shots in the 6 km/s area gave a velocity of 5.90 ± 0.04 km/s and time terms between 0.25 s and 0.54 s for the land stations (Bott et al. 1976), and the experiment of 1970 (Casten 1973) fits nicely into this analysis. The boundaries of the area have not been accurately determined but are probably not far from the shots A7, B3 and C49. With the possible exception of A88, A89, C58 and C59, which give small or even negative time terms, the whole area thus covered seems underlain by the same refractor. However, different ways of using the data for shots on the northwestern shelf only give possibly significantly higher velocities in the range 6.1 . . . 6.2 km/s in agreement with previous results (Casten 1974, Bott et al. 1974).

Shot A3 is close to the centre of the deep gravity minimum northwest of the islands (fig. 2) and the time term of A3 is about 0.3 s larger than neighbouring time terms, also A4 seems to have an enlarged time term, but these delays seem to be the only effect connected with the gravity low.

The other apparent velocities of 7 and 8 km/s of line A were treated by Bott et al. (1976) who found true velocities of 6.73 ± 0.12 and 7.79 ± 0.10 km/s and time terms around $^3/_4$ s and 2.5 s for these refractors below the ridge. The two refractors were reversed by using DU5 in Iceland and a station established by the Soviet ship »Lomonosov« in the middle of line A. The two refractors were identified as corresponding to layer 3 on Iceland (Pálmason & Sæmundsson 1974) and Moho, respectively.

On line C (south) the apparent velocity of 5 km/s is poorly reversed by the ship station LOMFS(A) and a time term analysis of the corresponding data gave the velocity 4.91 ± 0.27 km/s. This result is not inconsistent with a direct wave in basalt lavas to the south of C49 and a wave in the 6 km/s basement to the north of C49. The velocity of 4.91 km/s is, however, based on very few observations and therefore uncertain, but the fit is rather good for the shots C45 . . . C49, when the boundary between 5.90 km/s basement to the north and the 4.91 km/s area to the south is assumed to be about 5 km north of C49 (except that the shots closest to F6 show a somewhat lower velocity).

The similar apparent velocity (5 km/s) of line B cannot be reversed. A number of ship stations were, certainly, occupied in the Faeroe—Shetland channel, but no true reversal of the shots in question (B1 . . . B14) was obtained, and the results point at a complicated structure in the channel. However, a velocity of 4.9 km/s is unlikely because negative time terms seem unavoidable for the shots. A more realistic velocity is probably 5.3 km/s. In the same manner as for line C (south) the stations on land get negative time terms which are again explained by assuming a wave in the 6 km/s basement below the islands, but the fit is rather poor, probably because the azimuths of the shots are far from constant, so that the distance travelled in the basement varies from shot to shot. This varying azimuth also explains the low apparent velocity found by station F5 (table 3).

It was mentioned earlier that F6 shows some irregularities, and observations at F6 of line A have been omitted from the analysis so far. The trouble is that signals from A1 . . . A7 are late at F6, later than expected from other stations and arrivals from line C (north). A speculative explanation could be that there is an area of lower velocities to the west of the islands between F6 and line A.

The boundaries of the gravity high to the south of the Faeroe Islands are close to LOMFS(A) and C36 according to the map (fig. 2). Signals from this area are very weak or absent on the islands but the ship station LOMFS(A) gives a well defined apparent velocity of 6.60 km/s. The stations on the islands, except F6, have either no arrivals in this region or Moho-arrivals, and MIR(B) south of the gravity high gives only two weak arrivals from the region. This means that an interpretation must rely on LOMFS(A) from which only travel times and distances are available. However, the assumption of a basement with a velocity of 6.60 km/s below the gravity high and with time terms of about $^2/_3$ s gives a satisfying fit.

The only remaining refractor seems to be Moho. The Moho-arrivals from line A are reversed by use of observations from Iceland and the Faeroe Islands, and a time term analysis using DU5 (Iceland) and a station occupied by Soviet ship »Lomonosov« in the middle of line A gave the true velocity 7.79 $\pm$ 0.10 km/s and time terms close to 2.5 s for line A (Bott et al. 1976). A time term analysis of all Moho arrivals at the Faeroese stations gave a true velocity of 7.61 $\pm$ 0.22 km/s (Casten & Nielsen 1975).

A number of time term analyses has been made using NASP-data from Scotland (IGS1), Shetland (UKAEA, DU1) and Iceland (DU5) together with Faeroese data, and the velocities were found to vary between 7.8 and 8.3 km/s, with lower values for line A and higher values for line B. Except for line A the fit of the time term models is, however, rather poor, probably because lateral inhomogeneities of the crust make the time terms dependent on the directions; this explains possibly the low value 7.61 km/s found previously for the Faeroe Block itself.

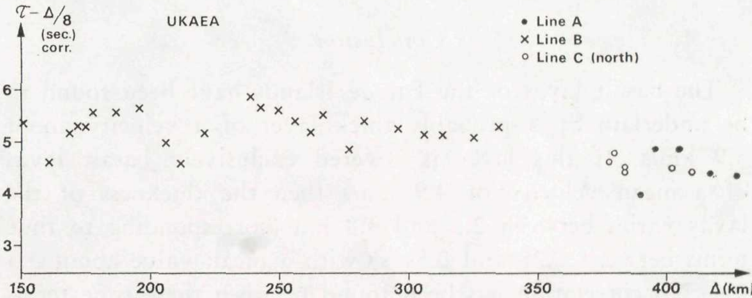

Fig. 8. *Reduced travel times (using 8 km/s) for the array stations UKAEA (Shetlands, 60° 15!03 N, 03° 34!79 W). Only the shots B 1 . . B 29, C 54 A . . C 59 and A 1 . . A 5 are shown.*

Whatever the true velocity below the Faeroe Block might be it is found that the Moho time terms increase more than 0.5 s from line A ((2 . . 3 sec) to line B (3 . . 4 sec) and the time terms of F1 and F2 are found to be significantly smaller than the time terms of F3, F4 and DU4. According to the observations made at the array station UKAEA on the Shetlands the Moho time terms increase about 0.5 s when going from the shots A1 . . A5 and line C (north) to line B (see fig 8).

On the British side of the Faeroe-Shetland channel a time term analysis of the NASP-data has revealed a rather uniform structure with Moho time terms of 2 . . 3 s where the higher values are caused by sediments, and the velocity was found to be 7.99 ± 0.02 km/s (Smith & Bott 1975). The Moho time terms for the Faeroese side of the channel are higher, but the decrease across the channel may start at the »escarpment« on the Faeroese side (Casten & Nielsen 1975).

The results of line C (south) are rather uncertain, but the Moho time terms are probably not very different from those of line B.

Conclusion.

The basalt lavas of the Faeroe Islands have been found to be underlain by a probably thick layer of a velocity about 5.9 km/s. If this layer is covered exclusively basalt lavas of a mean velocity of 4.9 km/s then the thickness of the lavas varies between 2.2 and 4.8 km (corresponding to time terms between 0.25 and 0.54 s) with a mean value about 3.5 km. No correlation has been found between these time terms and the gravity anomalies on the islands.

On the northwestern shelf the velocities below the basalt lavas may be slightly higher, perhaps 6.2 km/s, but no effect has been found to be caused by the very deep and narrow gravity minimum of about 40 mgal. The time terms of the 6 km/s refractor are rather irregular in the region, but the increase of 0.3 s found at A3 can hardly be compared with the gravity minimum which requires a structure with a thickness of more than 5 km and a density contrast of at least 0.2 g cm^{-3} (Fleischer et al. 1974 and Casten 1974). The simplest explanation seems to be a granite batholith (Schrøder 1971).

The data from line B indicates a (unreversed) velocity of perhaps 5.3 km/s, Moho seems to be the only other refractor observed in the region.

The velocities of 5.9 to 6.2 km/s and 5.3 km/s point towards a continental structure, just as the gravity data (Bott & Watts 1970). The Moho time terms of line B are around 3.5 s and give a depth to Moho of 24 km, if the velocity above Moho is taken as 5.3 km/s (a very low crustal velocity) and below Moho as 8.2 km/s. On the British side of the Faeroe-Shetland channel the depth to Moho has been found to be close to 25 km (Smith & Bott 1975), but the structure of the channel itself has not been revealed yet.

According to observations at the array station UKAEA in the Shetlands (fig. 8) the shots in the gravity low on line B may have Moho time terms slightly higher than the shots closer to the Faeroes, thus indicating a basin of low velocities. Across the Faeroes from line B to line A (e. g. from F4 to F2) the Moho time terms seem to decrease corresponding to a higher crustal velocity or a more shallow Moho, but the slight decrease of the gravity field in the same direction points towards a light »high velocity« material (e. g. granite).

To some extent line C (south) resembles line B but the very weak signals from shots south of C45 make the interpretation highly uncertain. The weak signals may be an indication of a relatively thin basalt layer underlain by a low velocity material to the north of the gravity high on line C (south), but other explanations are possible. In connection with the gravity high an apparent velocity of 6.6 km/s and time terms about $^{2}/_{3}$ s have been found, and it can be mentioned that gravity highs on the British side of the Faeroe-Shetland channel are connected with a refractor of 6.48 $\pm$ 0.06 km/s (Smith & Bott 1975), but this is, of course, no proof of a similar structure on the Faeroese side.

By use of time term analyses on data for line A on the Iceland-Faeroe ridge Bott et al. (1976) found a three layer model for the ridge. The velocities were found to be appr. 5.0 km/s for the top layer and 6.73 $\pm$ 0.12 km/s and 7.79 $\pm$ 0.10 km/s for the refractor below, and the depths of these were found to be appr. 5 km and 27 km assuming layers of constant velocities.

The north-south striking area of relatively low free air anomalies on the ridge has been interpreted as a trough filled with light material (Fleischer et al. 1974), and this corresponds to relatively high time terms for the 6.73 km/s refractor at the station MIR(D), and the shots A8 and A10 (Bott et al. 1971, 1976). The crustal structure of the ridge differs thus significantly from that of the Faeroe Block and is more like the structure of Iceland, although the Moho velocity on the ridge is higher than the velocity in Iceland (appr. 7.2 km/s, see Pálmason & Sæmundsson 1974).

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APPENDIX

The appendix contains three tables:

First table gives positions etc. for shots that were observed on the Faeroe Islands together with the positions of the Faeroe stations and a few ship stations. The positions of the Faeroe stations F1..F5 are given as »mean values« with an error about 100 m. The positions of the drifting ship stations are rough mean values and they have not been used for calculation of the distances; otherwise the positions at sea can be expected to have errors less than 1 km in most cases (see Smith 1974 and Smith & Bott 1975).

Second table contains travel times for first arrivals observed at the Faeroese stations. Each observation is given as 3 numbers which are (starting from above): distance (km), travel time (s) and azimuth (degrees) of the shot. The arrivals have been classified according to the letter which succeeds the travel time; the classification is highly subjective but it gives an indication of the possibility that late arrivals have been picked etc.

Third table contains some intercept times and apparent velocities. The travel times were corrected for water depth and shot depth in the following manner: by use of the formula for time terms the shot was moved to the surface of the sea, and the sea water of velocity 1.5 km/s was substituted by a fictitious material of velocity 4.5 km/s; the assumed refractor velocity is given as v . The estimated standard deviation of the observed travel times is given as »s. d.« and the number of observations is given as N.

Table 1.

Positions and shot times.

position	latitude	longitude	water depth (m)	shot depth (m)	load (lb.)	shot instant (UT)	date
F1	62°05'.5N +	07°14'.6W +	-	-	-	-	-
F2	62°09'.6N +	07°05'.1W +	-	-	-	-	-
F3	62°14'.6N +	06°47'.6W +	-	-	-	-	-
F4	62°05'.5N +	06°41'.6W +	-	-	-	-	-
F5	61°50'.0N +	06°45'.4W +	-	-	-	-	-
F6	61°33'.0N +	06°46'.7W +	-	-	-	-	-
DU4	61°59'.89N	06°47'.96W	-	-	-	-	-
LOMX	64°06' N	11°55' W (appr.)		?	-	-	-
LOMFS(A)	61°02'.7N	06°25'.1W	?	?	-	-	-
MIR(B)	60°08'.0N	05°54'.0W	?	?	-	-	-
MIR(D)	62°29'.0N	08°35'.0W	?	?	-	-	-
F70.1 §	62°13'.64N	07°07'.45W	-	-	-	-	-
F70.2a §	62°09'.98N	07°04'.06W	-	-	-	-	-
F70.2b §	62°10'.01N	06°57'.23W	-	-	-	-	-
F70.3 §	62°05'.27N	06°58'.38W	-	-	-	-	-
A1	62°09'.1N	07°40'.0W	75	75	300	07 02 42.92	1972
A2	62°11'.3N	07°45'.8W	97	97	300	10 37 21.84	July 19.
A3	62°13'.3N	07°55'.0W	99	99	300	11 07 17.56	"
A4	62°16'.5N	08°07'.0W	106	106	600	11 48 00.28	"
A5	62°19'.6N	08°17'.0W	125	125	600	12 23 08.88	"
A6	62°23'.3N	08°29'.0W	247	120	1200	13 09 08.40	"
A7	62°26'.2N	08°37'.1W	393	120	1200	13 41 48.80	"
A8	62°29'.8N	08°46'.1W	474	120	1200	14 16 40.60	"

\+ "mean values"

§ stations from 1970 (see Casten 1973).

Table 1 (continued).

(Positions and shot times).

position	latitude	longitude	water depth (m)	shot depth (m)	load (lb.)	shot instant (UT)	date
A9	62°34!9N	08°58!1W	517	120	1200	15 04 27.04	1972
A10	62°38!0N	09°03!2W	507	170	600	15 27 53.29	July 19.
A11	62°41!4N	09°11!5W	471	170	600	15 58 40.21	"
A12	62°49!2N	09°25!3W	465	170	600	17 12 30.98	"
A13	62°52!2N	09°31!0W	486	170	600	17 37 45.98	"
A14	62°56!6N	09°39!0W	488	170	1200	18 13 57.57	"
A15	62°59!9N	09°44!9W	479	170	600	18 37 45.58	"
A17	63°04!9N	09°53!8W	461	170	600	19 17 41.57	"
A18	63°07!5N	09°58!7	461	170	600	19 38 01.98	"
A19	63°10!0N	10°03!5W	470	180	600	19 58 00.82	"
A20	63°12!2N	10°08!0W	457	180	600	20 18 20.40	"
A21	63°14!5N	10°12!5W	370	180	600	20 38 24.29	"
A22	63°16!9N	10°16!9W	341	180	600	20 58 05.34	"
A23	63°19!1N	10°21!5W	336	185	600	21 18 05.35	"
A24	63°21!5N	10°26!1W	328	185	600	21 38 25.70	"
A25	63°25!1N	10°33!1W	415	185	600	22 08 15.09	"
A26	63°28!8N	10°40!0W	441	185	600	22 38 43.06	"
A27	63°33!9N	10°49!5W	454	185	600	23 23 32.55	"
A29	63°39!6N	11°00!6W	324	185	600	00 08 20.06	1972
A31	63°44!1N	11°10!6W	374	185	600	11 38 26.31	July 20.
A32	63°47!5N	11°17!5W	374	185	600	12 07 48.62	"
A33	63°51!4N	11°26!2W	363	185	600	12 40 08.00	"
A34	63°54!9N	11°33!8W	317	185	600	13 08 11.95	"
A75	63°29!07N	08°59!86W	539	170	600	14 05 54.91	1972
A77	63°21!84N	08°49!53W	551	170	600	14 57 39.61	July 23.

Table 1 (continued)

(Positions and shot times).

position	latitude	longitude	water depth (m)	shot depth (m)	load (lb.)	shot instant (UT)	date
A79	63°15'.44N	08°38'.70W	533	165	600	15 47 38.89	1972 July
A81	63°11'.04N	08°26'.95W	527	195	600	16 28 25.53	23.
A84	63°03'.05N	08°04'.56W	424	185	600	17 43 15.02	"
A86	62°28'.19N	08°30'.22W	401	115	300	21 57 31.70	"
A88	62°24'.28N	08°22'.56W	185	120	300	22 27 43.30	"
A89	62°23'.19N	08°19'.43W	162	120	600	22 37 31.97	"
A90	62°25'.46N	08°28'.94W	298	140	550	23 22 26.58	"
B1	62°04'.02N	06°31'.94W	50	50	600	11 38 37.44	1972 July
B2	62°01'.42N	06°22'.87W	87	87	300	12 07 55.68	24.
B3	61°56'.89N	06°12'.26W	86	86	600	12 43 18.44	"
B4	61°54'.67N	06°05.59W	127	120	300	13 07 21.04	"
B5	61°50'.93N	05°57'.80W	184	140	600	13 37 26.55	"
B7	61°46'.71N	05°46'.14W	240	120	300	14 17 27.76	"
B8	61°44'.64N	05°40'.21W	209	120	300	14 37 24.86	"
B9	61°41'.68N	05°30'.28W	182	120	300	15 12 25.96	"
B10	61°40'.28N	05°25'.81W	182	140	600	15 27 25.32	"
B11	61°38'.41N	05°20'.00W	253	140	600	15 47 32.01	"
B12	61°36'.60N	05°14'.34W	287	140	600	16 07 19.15	"
B13	61°34'.76N	05°08'.50W	258	140	600	16 27 52.05	"
B14	61°33'.42N	05°04'.15W	210	140	600	16 42 08.02	"
B15	61°30'.99N	04°56'.69W	223	140	600	17 07 28.80	"
B16	61°27'.60N	04°48'.73W	322	140	600	17 36 56.21	"
B17	61°24'.15N	04°40'.90W	651	140	600	18 07 09.44	"
B18	61°21'.44N	04°36'.35W	850	140	600	18 27 07.36	"

Table 1 (continued)

(Positions and shot times).

position	latitude	longitude	water depth (m)	shot depth (m)	load (lb.)	shot instant (UT)	date
B19	61°18!18N	04°28!40W	1023	140	600	18 56 56.09	1972 July
B20	61°15!27N	04°20!07W	1093	140	600	19 27 06.88	24.
B21	61°12!45N	04°11!83W	1057	140	600	19 56 55.87	"
B29	61°03!04N	03°48!35W	1125	140	600	21 27 17.14	"
C5	58°52!23N	05°13!24W	89	89	300	1o 39 48.55	1972 July
C7	58°57!31N	05°11!36W	84	84	300	12 21 58.98	11.
C8	58°58!37N	05°11!24W	84	84	300	13 08 19.26	"
C13	59°11!72N	05°18!81W	99	99	300	15 12 46.79	"
C15	59°16!85N	05°20!58W	99	99	300	16 26 58.74	"
C24	59°42!50N	05°36!95W	139	139	1200	21 16 37.26	"
C32	60°12!17N	05°58!34W	1187	155	600	13 58 03.15	1972 July
C33	60°18!01N	06°00!66W	1038	155	600	14 33 57.04	12.
C36	60°23!90N	06°02!00W	440	170	600	21 12 55.83	1972 July
C37	60°30!24N	06°07!82W	338	160	600	20 26 35.96	14.
C38	60°33!76N	06°08!45W	346	160	600	19 54 53.07	"
C39	60°38!15N	06°12!47W	303	160	600	19 24 31.99	"
C40	misfire	-	-	-	-	-	"
C41	60°43!69N	06°18!03W	195	155	600	18 37 26.81	"
C42	60°49!86N	06°18!86W	171	165	600	not available	"
C43	60°55!79N	06°17!31W	140	130	600	17 07 57.28	"
C44	61°10!59N	06°29!12W	138	138	600	14 47 28.79	"
C45	61°15!50N	06°31!30W	138	138	600	14 12 31.54	"
C46	61°20!34N	06°34!81W	95	95	300	13 37 08.97	"
C47	61°25!05N	06°37!93W	61	61	300	12 07 24.87	"

Table 1 (continued)

(Positions and shot times).

position	latitude	longitude	water depth (m)	shot depth (m)	load (lb.)	shot instant (UT)	date
C48	61°29!00N	06°40!17W	55	55	300	11 42 30.19	1972 July
C49	61°34!05N	06°39!42W	65	65	600	11 08 35.06	14.
C50	61°41!78N	06°36!35W	55	55	600	10 24 00.49	"
C51	61°45!78N	06°33!0 W	60	60	1200	not available	"
C52	61°49!50N	06°31!2 W	57	57	300	09 19 53.82	"
C54A	62°13!2 N	07°19!25W	72	72	300	20 47 30.56	1972 July
C54B	62°10!7 N	07°19!63W	58	58	1200	21 13 04.50	18.
C54C	62°12!25N	07°23!3 W	93	93	300	21 32 23.06	"
C55	62°18!17N	07°19!7 W	88	88	300	20 17 47.74	"
C56	62°21!3 N	07°16!0 W	101	101	1200	19 56 35.45	"
C58	62°33.1 N	07°22!6 W	103	103	300	23 36 52.57	"
C59	62°38!6 N	07°26!15W	162	162	600	00 12 46.45	1972 July 19.

Table 2.

Distances, travel times for first arrivals and azimuths of the shots.

The travel times are given in seconds and are classified as follows:

A good arrival

B reasonably good arrival

C weak arrival

* dubious arrival

s no classification (s= second).

	F1	F2	F3	F4	F5	F6	DU4
A1	23.0km 4.60A -73°	-	-	-	-	82.3km 15.42B -35°	48.4km 9.12B -69°
A2	29.2km 5.56A -68°	35.5 6.78A -85	50.9 9.56A -96	-	66.1 11.80A -53	88.6 16.53B -36	54.6 10.08B -67
A3	37.9 7.48A -67	43.8 8.54A -81	58.5 10.89A -92	-	74.7 13.75A -54	96.5 18.13C -38	63.4 12.30C -66
A4	49.8 9.40A -65	55.1 10.16A -76	68.9 12.41A -86	-	-	107.8 20.37C -41	75.3 13.75B -65
A5	60.1 10.88A -64	65.0 11.56A -73	77.9 13.64A -82	-	97.1 17.29B -55	117.9 21.52B -42	85.6 15.22B -64
A6	72.4 13.23A -62	-	89.1 15.63B -79	-	-	130.0 23.60B -43	-
A7	81.1 14.19A -61	85.3 14.79A -68	97.0 16.57A -76	-	118.0 20.42A -54	138.8 24.23B -44	106.5 18.51B -62
A8	91.0 16.06A -60	94.9 16.55A -66	106.1 18.40A -74	-	128.4 22.21A -54	148.9 25.59B -44	116.4 20.45B -61
A10	111.5 19.18B -56	114.6 19.44A -62	124.6 21.12B -69	-	149.2 25.43C -52	-	-

Table 2 (continued).

	F1	F2	F3	F4	F5	F6	DU4
A11	120.8km 20.31A -56°	123.8km 20.56A -61°	133.4km 22.10B -67°	-	158.6km 26.43B -52°	-	145.9km 24.63B -57°
A13	145.8km 23.95A -52°	148.1 23.97C -57	156.6 25.41A -62	-	184.0 30.22C -50	-	170.7 28.23C -54
A14	156.1 25.34C* -51	158.1 25.55A -55	166.2 26.85A -61	-	194.3 31.32C* -49	216.0 33.27C -43	180.9 29.45B -53
A15	163.7 26.74A -51	165.6 26.72A -55	173.4 28.01A -60	-	-	-	188.4 30.51B -52
A17	175.3 28.23B -50	177.0 28.32B -53	184.4 29.60B -58	-	-	-	199.9 32.14B -52
A18	181.7 29.03C* -49	183.1 29.10B -53	190.4 30.58B -58	-	-	-	-
A19	187.7 29.66B -49	189.1 29.70B -52	196.3 30.94C -57	-	-	-	212.1 34.06B -51
A20	193.2 30.36B -49	194.6 30.46B -52	201.6 31.80B -56	-	-	-	217.6 34.72C -50
A21	198.8 31.03C -49	200.1 31.18B -52	207.0 32.67A -56	-	-	-	-
A22	204.5 31.71B -48	205.7 31.78B -51	212.5 33.39A -55	-	-	-	-
A23	210.0 32.36B -48	211.2 32.47B -51	217.9 33.89B -55	-	-	-	-
A24	215.8 32.98B -48	216.9 33.22B -51	223.5 34.40B -55	-	-	-	-
A25	224.5 34.18B -47	225.6 34.24B -50	232.0 35.39A -54	-	-	-	-

Table 2 (continued).

	F1	F2	F3	F4	F5	F6	DU4
A27	245.5km 36.96B -46°	-	252.4km 38.21B -52°	-	-	-	-
A31	271.0km 40.35C -46°	271.7 40.55C -48	-	-	-	-	-
A32	-	280.1km 41.28C -48	285.7 42.01A -51	-	-	-	-
A33	-	-	295.7 43.47B -51	-	-	-	-
A34	-	-	304.5 45.52C -50	-	-	-	-
A75	-	-	-	-	-	-	200.2 31.74C -33
A77	-	-	-	-	-	-	184.2 29.92C -33
A79	-	-	-	-	-	-	169.3 27.76C -33
A81	-	-	-	-	-	-	157.0 26.00C -32
A84	-	-	-	-	-	-	134.5 22.21C -29
A86	-	81.2 14.06A -64	-	-	-	-	103.0 17.93B -59
A88	-	72.3 12.54B -67	-	-	-	-	-
A89	-	69.0 12.00A -68	-	-	-	-	90.4 15.78C -61

Table 2 (continued).

	F1	F2	F3	F4	F5	F6	DU4
A90	-	78.2km 13.48A -67°	-	-	-	-	99.4km 17.30B -61°
B1	-	30.7km 6.03A 110°	-	9.0 1.97B 108	28.9 5.68A 24	-	15.9 3.18s 61
B2	-	39.9 7.55A 112	-	18.2 3.77A 115	29.3 5.38A 42	-	22.1 4.24s 82
B3	-	51.9 9.50A 117	-	30.4 5.90A 122	32.1 6.04A 66	-	31.7 6.09s 100
B4	-	58.9 10.92B 118	-	37.5 7.26B 122	36.3 6.83A 75	-	38.3 7.35s 104
B5	-	68.3 12.64B 120	-	47.1 8.99B 125	42.2 8.12A 87	-	47.0 9.22s 110
B7	-	81.2 15.05A 121	-	60.0 11.40C 125	52.7 10.08B 96	-	-
B8	-	87.6 16.42A 121	-	66.5 13.06B 125	58.5 11.44A 99	-	65.8 12.87s 115
B9	-	98.0 18.36A 121	-	76.8 14.89B 125	68.2 13.34C* 102	-	76.1 14.65s 116
B10	-	102.7 19.15B 121	-	81.5 15.69B 125	72.6 14.23A 104	-	80.8 15.51s 116
B11	-	108.9 20.47A 121	-	87.7 16.69C 124	78.5 15.27B 105	-	87.0 16.65s 117
B12	-	114.9 21.08B 122	-	93.7 18.10B 124	84.3 16.81B 106	-	93.0 17.85s 117
B13	-	121.1 22.24B 122	-	99.9 19.34B 124	-	-	99.1 19.02s 117
B14	-	125.0 22.27C 122	-	104.5 20.31C 124	94.7 18.68C 108	-	103.7 19.78s 118

Table 2 (continued).

	F1	F2	F3	F4	F5	F6	DU4
B16	-	143.1km 24.38C* 122°	-	121.9km 22.24C 124°	111.4km 21.37C 111°	-	120.9km 22.08s 119°
B17	-	152.5km 25.53C 123°	-	131.3 23.70B 125	-	-	130.2 23.12s 120
B18	-	158.7 26.51C 123	-	137.6 24.24C 126	-	-	136.3 23.76s 121
B19	-	168.0 27.32A 124	-	146.9 25.07C 126	-	-	145.6 24.76s 121
B20	-	177.2 28.84B 124	-	-	-	-	154.8 26.43s 121
B21	-	186.2 30.11B 124	-	-	-	-	163.8 27.67s 121
B29	-	-	-	192.5 30.82C 126	-	-	-
C24	-	284.7 41.57B 163	-	-	-	214.5 32.86C 162	-
C32	-	226.3 34.64C 164	-	-	-	-	-
C36	-	-	-	-	-	134.2 24.52C 162	-
C39	-	176.4 27.43C* 164	-	-	-	106.1 20.78C 163	-
C41	-	165.1 26.66C* 165	-	-	-	94.8 17.95C 164	144.0 24.73s 169
C45	-	105.0 19.58B 163	110.7 20.75B 172	-	65.2 12.99B 169	34.8 7.02A 158	83.8 15.73s 170

Table 2 (continued).

	F1	F2	F3	F4	F5	F6	DU4
C46	-	95.5km 17.52C* 164^{o}	-	-	-	25.3km 5.33C 156^{o}	74.4km 13.85s 171^{o}
C47	-	86.3km 15.92B 164^{o}	92.4 16.77A 175	-	46.7 9.29A 172	16.2 3.44A 153	65.3 12.36s 172
C48	-	78.7 14.31B 164	84.9 15.41A 176	-	39.1 7.97B 173	8.81 2.03A 144	57.8 11.07s 173
C49	65.9 11.97C* 152	70.0 12.42B 161	75.6 13.49A 175	-	30.0 5.86A 170	5.9 1.49A 73	48.6 9.15s 171
C50	55.2 10.17A 142	57.7 10.50A 154	61.7 11.18A 171	-	17.2 3.71B 152	18.4 3.48A 29	35.2 6.73s 163
C52	-	47.8 9.06A 141	48.8 9.16A 163	-	12.8 3.01A 93	33.3 6.31A 24	24.3 4.99s 143
C54A	15.1 3.14A -15	14.2 2.80A -62	27.6 5.52A -95	-	52.2 9.61A -34	80.4 14.36B -21	36.8 7.20s -48
C54B	10.8 2.15A -24	12.9 2.63A -82	-	-	48.7 8.89A -38	76.2 13.38B -22	34.1 6.53s -54
C54C	14.8 3.13A -31	16.7 3.43A -73	31.3 6.25A -98	-	52.9 9.79A -38	80.1 14.32B -24	38.4 7.39s -53
C55	24.2 4.77A -10	20.7 3.94A -39	28.6 5.67A -76	-	60.3 10.88A -29	89.1 15.60B -19	43.8 8.17s -39
C56	29.7 5.79A -2	23.5 4.73A -24	27.6 5.55A -63	-	64.0 11.59A -24	93.7 16.57C -16	46.6 8.87s -31
C58	52.0 9.40B -8	46.6 8.36A -19	45.8 8.44A -41	-	-	116.3 20.91B -16	68.6 12.43s -26
C59	62.6 11.07B -9	56.7 10.04B -19	55.6 9.94A -36	-	97.0 18.12B -21	127.0 22.30B -16	79.1 14.24s -24

Table 3.

Some least square intercept times and apparent velocities, the travel times were corrected for shot depth and water depth.

station	v_r (km/s)	shots	N	intercept (sec)	velocity (km/s)	s.d. (sec)
F2	5	C45 .. C49	4	-1.75 ±0.32	4.91 ±0.09	0.10
F3	5	C45 .. C49	4	-2.18 ±0.41	4.84 ±0.11	0.12
F5	5	C45 .. C49	4	-0.02 ±0.26	4.99 ±0.14	0.14
F6	5	C45 .. C49	5	+0.36 ±0.06	5.18 ±0.08	0.07
DU4	5	C45 .. C49	5	+0.34 ±0.31	5.45 ±0.14	0.13
LOMFS(A)	5	C41 .. C46	6	-0.04 ±0.11	4.93 ±0.11	0.09
F2	5	B3 .. B11	8	-0.36 ±0.10	5.25 ±0.03	0.06
F4	5	B3 .. B14	11	-0.02 ±0.14	5.18 ±0.05	0.15
F5	5	B3 .. B11	8	-0.38 ±0.12	5.00 ±0.05	0.09
DU4	5	B3 .. B14	10	+0.20 ±0.09	5.28 ±0.03	0.10
F1	6	A1 .. A7	7	+0.94 ±0.26	6.03 ±0.18	0.26
F2	6	A2 .. A7	5	+1.54 ±0.31	6.46 ±0.22	0.20
F3	6	A2 .. A7	6	+2.07 ±0.16	6.68 ±0.16	0.14
F5	6	A2 .. A7	4	+1.47 ±0.77	6.21 ±0.33	0.34
F6	6	A1 .. A7	6	+2.62 ±0.78	6.32 ±0.28	0.36
DU4	6	A1 .. A7	6	+1.73 ±0.56	6.33 ±0.30	0.36
MIR(D)	6	A3 .. A5	3	+0.95 ±0.54	5.71 ±0.50	0.23
DU4	6	A86 .. A90	3	+1.26 ±015	6.22 ±0.06	0.01
F2	6	A86 .. A90	4	+1.13 ±0.17	6.35 ±0.09	0.02
F1	6	C54A .. C59	7	+0.57 ±0.11	5.89 ±0.11	0.11
F2	6	C54A .. C59	7	+0.53 ±0.10	5.93 ±0.11	0.14
F3	6	C54A .. C59	6	+1.23 ±0.09	6.35 ±0.10	0.07
F5	6	C54A .. C56	5	+0.72 ±0.38	5.89 ±0.24	0.09
F6	6	C54A .. C56	5	+0.48 ±0.92	5.84 ±0.37	0.16
DU4	6	C54A .. C59	7	+0.89 ±0.12	5.92 ±0.08	0.10
F2	6	B1 .. B3	3	+1.01 ±0.04	6.09 ±0.04	0.02
F5	6	B1 .. B3	3	+0.98 ±3.20	6.37 ±4.31	0.26
F2	6	C49 .. C52	3	+1.79 ±0.17	6.58 ±0.12	0.04
F3	6	C49 .. C52	3	+1.29 ±0.19	6.21 ±0.12	0.06
F1	7	A8 .. A17	7	+2.79 ±0.23	6.92 ±0.08	0.12

Table 3 (continued).

station	v_r (km/s)	shots	N	intercept (sec)	velocity (km/s)	s.d. (sec)
F2	7	A8 .. A17	7	+2.77 ±0.20	6.97 ±0.07	0.10
F3	7	A8 .. A18	8	+2.92 ±0.26	6.95 ±0.08	0.13
F5	7	A8 .. A14	5	+4.30 ±0.65	7.18 ±0.20	0.21
DU4	7	A8 .. A19	7	+3.86 ±0.23	7.08 ±0.07	0.10
MIR(D)	7	A9 .. A24	12	+1.48 ±0.07	6.66 ±0.03	0.08
DU4	7	A75 .. A84	5	2.96 ±1.04	6.92 ±0.29	0.31
LOMFS(A)	7	C36 .. C41	4	+1.55 ±0.08	6.62 ±0.07	0.05
F1	8	A17 .. A31	11	+5.80 ±0.25	7.90 ±0.08	0.11
F2	8	A17 .. A32	11	+5.44 ±0.24	7.81 ±0.07	0.12
F3	8	A18 .. A33	11	+7.03 ±0.36	8.15 ±0.10	0.17
LOMX	8	A7 .. A12	4	+5.26 ±0.51	7.79 ±0.14	0.11
F2	8	B11 .. B21	10	+7.79 ±0.41	8.62 ±0.20	0.22
F4	8	B14 .. B29	6	+8.22 ±0.58	8.64 ±0.30	0.27
DU4	8	B14 .. B21	7	+7.12 ±0.74	8.24 ±0.36	0.27
F2	8	C7 .. C45	7	+7.16 ±0.33	8.25 ±0.07	0.25

ÚRTAK

Á sumri 1972 vórðu spreingingar (140—270 kg av spreingievni) gjørdar í havinum millum Íslands og Skotlands. Ristingarnar frá spreingingunum vórðu uppritaðar ymsastaðni í Íslandi, í Føroyum og í Norðurbretlandi. Tíðin, sum gongur frá spreingingini til ristingin varnast, sigur frá ljóðferðini í jarðarskorpuni og ljóðferðin sigur frá hvussu jarðarskorpan er sett saman. Aðalúrslitini tykjast vera: Ryggurin millum Ísland og Føroyar *samsvarar við skorpuna í Íslandi.* Føroyska *»meginlandastøðið«* (landgrunnurin) tykist hava meginlandaeyðkenni við ljóðalduferð (P-aldan) frá 6,1 km/s í útnyrðing úr oyggjunum og niður í 5,3 km/s eystan fyri oyggjarnar. Hvørji grótsløg, eru undir tí ætlandi umleið 3 km tjúkka basaltinum, siga mátingarnar ikki, men ljóðferðin og tyngdarmátingar benda á meira ella minni fest legugrýti. Eitt óført tyngdarlágmark í ein útnyrðing úr oyggjunum verður best skilt um vit hugsa okkum, at granit er undir.