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SEISMIC REFRACTION MEASUREMENTS

IN SOUTH-EAST ICELAND IN 1976

HALÍNA GUÐMUNDSSON

OS-JHD-7716
OS-ROD-7827

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1 INTRODUCTION

In the summer of 1976 nine seismic profiles were shot in South-East Iceland in order to measure the P-wave velocities and depth to different layers in the crust (Fig. 1).

The project was initated by Gudmundur Pálmason but Egill Hauksson was in charge of the field measurements. Three of the profiles (I, VIII and IX) more or less follow the main road from Kirkjubæjarklaustur to Kálfafellsstaður and were intended to fill into the established general picture of the crustal structure of SE-Iceland (Pálmason, 1971). The other profiles (II, III, IV, V, VI and VII) were aimed at recording the seismic structure of particular sheet swarms and intrusive centers, occuring in the area, and especially if possible to determine, whether layer 3 is on the surface in this area or not (Walker, 1974). The latter profiles were selected with reference to reconnaisance geological mapping by Ingvar B. Friðleifsson and Helgi Torfason.

2 SOME INFORMATION FROM PREVIOUS STUDIES

Previous studies of the crustal stucture of Iceland by explosion seismic have been made by Båth (1960), Tryggvason and Båth (1961) and Gudmundur Pálmason (1963, 1965, 1967, 1971).

So far approximately 80 seismic refraction profiles varying from 20 to 140 km in length have been shot all over Iceland, (Pálmason, 1963, 1971), in order to study the structure and nature of the upper part of the crust. The following main conclusions were reached at as to the nature and the stratigraphical postion of these layers:

Layer 0 has velocity of $P \simeq 2.4$-3.3 km/sec. It is identified as Quaternary volcanic rocks and postglacial basalt lavas. Generally it is found at the surface in the Neovolcanic zone, with common thickness of a few hundred meters, up to 1 km.

Layer 1 has velocity of $P_1 \simeq 4.1$-4.5 km/sec. Its nature is basaltic and it consists of more or less horizontal lava flows with thin intercalations of sediments. It is generally found beneath the layer 0 within the Neovolcanic zone, but appears on the surface in Northern and Eastern Iceland. The average thickness of this layer is about 1 km.

Layer 2 with velocity of $P_2 \simeq 5.0$-5.2 km/sec is found below layer 1 all over Iceland except in the Reykjanes peninsula, where it appears to be missing or is too be detected (Pálmason, 1971). In South-Eastern Iceland it is found on the surface as gabbroic and acid intrusions as well as flood basalts.

Layer 3 has velocity of $P_3 \simeq 6.3-6.5$ km/sec. The lower P wave occur mainly on the shorter profiles, while on longer profiles the velocity approches a value of about 6.5 km/sec which is believed to be the velocity in layer 3. The depth to this layer varies from one part of Iceland to onother. For instance in the South-East the depth is 1.2-1.8 km, in the Northern part of Iceland the depth is 3-4.5 km, in the South-West it is 1.6-1.9 km, in the central part of Southern Iceland more than 4 km. Böðvarsson and Walker (1964) suggest that this layer consists of a heterogeneous mixture of basaltic lavas and intrusions.

Layer 4 with a P-wave velocity of about 7.2 km/sec, is probably to be equated to the anomalous upper mantle as observed under the crestal zones of the mid-ocean ridges. It is found at a depth of 8-16 km (Pálmason, 1971), shallower in South-western Iceland (8-9 km) than in Northern and Southern Iceland (14-16 km). Several hypotheses have been offered as to the nature of this layer (Ewing, 1959; Bott, 1965; Oxburgh & Turcotte, 1968; Vogt, 1969). They assume that mantle convection is in process in the crestal zones on the mid-ocean ridges.

In SW-Iceland the layer 3/layer 4 boundary appears to coincide with temperature close to melting range of basalts and somewhat lower temperature in Northern and Southeastern Iceland (Pálmason, 1971).

Of all surveyed profiles only 5 can be compared with the studies in South-East Iceland presented here. Three of them were measured by Guðmundur Pálmason, 1971 (profiles nr. 28, 29, 30). Their interpretation allowed the following conclusions:

1. Layer 2 occurs on the surface (layer 1 is absent).

2. Layer 3 is found at a relatively shallow depth (1.2-2.0 km below sea level).

   On profile 30, which runs in a S-W direction from Viðborðsfjall, the velocities are somewhat lower than on the other two profiles. This could indicate an existence of layer 1 at the S-W end of the profile, where flood basalts are the predominant surface rock.

In Southern Iceland 2 profiles were shot, i.e. profile 31, Síða-Fljótshverfi, with the shot point at Kirkjubæjarklaustur, and L8, which is about 90 km long and partly runs along the same road as profile 31, with the shot point in lake Heiðarvatn, (Pálmason, 1971). More detailed information about these profiles is to be found later on in this report.

3 PRESENT STUDIES

3.1 Field measurements

In the summer of 1976 nine seismic refraction profiles were shot in order to record the P-wave velocities and depths to different layers in South-East Iceland, disignated with Roman numbers as follows:

I	Systravatn - Jökulsárlón
II	Miðfellsá - Kálfafellsdalur
III	Brókarpyttur - Staðarós
IV	Staðarós - Brókarpyttur
V	Skinneyjarhöfði - Svínalón
VI	Svínafellsjökull - Viðborðshraun
VII	Viðborðshraun - Skinneyjarhöfði
VIII	Jökulsárlón - Klaustur
IX	Jökulsárlón - Kálfafellsstaður

Most of the profiles were reversed: I with VIII, III with IV, V with VI and VII. The shots were commonly fired in lakes or in the sea. The length of the profiles is between 20 and 100 km, only profile II is very short, or only about 4 km long. The approximate location of the profiles is shown in Fig. 1, and in greater detail in Figures 2, 3, 4, 5. An ABEM instrument was used for the measurements. It has six channels and seismometers with frequency of 6 HZ and a resistance of 530Ω. The shot time was transmitted by radio to the recording station. In some cases communication between transmitter (shot point) and receiver (geophone station) was impossible by radio. In such cases the explosion time was decided in advance and recorded on the tape recorder along with the Rugby time signal. This was done on profile I between Klaustur and Fagurhólsmýri. This method has several disadvantages like traffic disturbances or unusual delay at the shot point or the receiver and also reduces the quality of the data.

3.2 Method of locating measuring points

Location of the seismic points (shot points and geophones) were marked on aerial photographs. In order to find the right location of those points on a map (1:50000) and furthermore to find the distance from the shot point to the geophones along the profile line two computer programs were prepared by Gunnar Thorbergsson (1977):

1. Program GT MYND to find the map coordinates of seismic points.
2. Program GT SKOT to find the distance between the shot point and each of the geophone stations along the profile.

Both programs were run on the computer IBM 370. Program GT MYND is based on linear transformation from the photo coordinate system into the rectangular coordinate system of the map. For this purpose the following information is needed as an input:

A. Several (3-8) "fixed-points" (points, which are easily visible both on the photograph and on the map) were chosen, as far away from each other as possible. Then the following parameters were obtained from the map (1:50000):

a) Coordinates with an accuracy of up to 100 meters.

b) Elevation of these "fixed points" in meters above sea level.

c) Average elevation of the photograph.

From the aerial photograph were read:

d) Coordinates in millimeters measured from two edges of the photo. (The photo coordinate system and the map coordinate system must both have the same orientation (for instance both clockwise) photography is assumed to be vertical).

e) Width of the photograph in mm.

f) Flight altitude in meters.

Photocoordinates (in mm) and elevations (in m) of seismic stations (geophones and shot points). Based on this input GT MYND program translates the photo coordinate system to the center of the photo, makes corrections for paralax due to elevation of the "fixed points" and calculates the best (in the sense of least squares) linear transformations from this corrected system in the photo to the rectangular coordinates system of the map. Then the transformation is used to calculate map coordinates for an unlimited number of points, with an accuracy of up to 100 m in most cases.

The output from GT MYND is directily used as an input for GT SKOT, which uses simple Pythagoras'law to calculate the distance between the shot point and the geophones along the profile, with 100 m accuracy.

3.3 Description of the profiles

Profile Systravatn - Jökulsárlón - Klaustur (I-VIII)
(Figs. 1,2,3,6,12)

The length of this profile is nearly 95 km.
Profile VIII, with shot point in Jökulsárlón, runs through Breiðamerkursandur, Svínafell, Fagurhólsmýri, Núpsstaður, Prestbakki, Kvísker. The distance between geophone stations along the profile varies from less than 1 km near the shot point to more than 10 km towards the end of the profile (Fig. 2)

At the shot point in Jökulsárlón (Figs. 6 and 12) layer 1 seems to be on the surface about 2 km thick with P-wave velocity of 4.2 km/sec. It is underlain by 3.3 km thick layer 2 with an apparent P-wave velocity of 5.9 km/sec. At a distance of about 30 km the P_3-wave is observed as a first arrival. The velocity of layer 3 is 6.5 km/sec and its minimum thickness is estimated to be about 10 km. The profile is sufficiently long to record also the P_4-wave as a first arrival at a distance of 80 km. The apparent velocity of P_4 is 7.5 km/sec, but there are only two data points which indicate this speed. Therefore the estimation of the P_4 velocity and the depth to layer 4 is not quite reliable.

Profile IX (Fig. 1) runs from the same shot point as profile VIII (Jökulsárlón), but in the opposite direction (eastwards). The length of this profile is only 22 km and the first geophone is located about 5 km from the shot point (Fig. 3). Six points on this profile indicate a very definite straight line indicating an apparent velocity of 6.05 km/sec and corresponds well to the value received on profile VIII (discussed previously), for the same layer (Fig. 6). This velocity of layer 2, unusually high and increasing eastwards, can be explained by sloping-up boundary between layers 2 and 3 eastwards of Jökulsárlón. It is very likely that there is layer 1 on the top of layer 2, and if so it is not thicker than 1 km (since P_1-wave appears as a first arrival at a distance of 5 km) and gets thinner eastwards from Jökulsárlón.

The thickness of the 6.0 km/sec cannot be calculated since the P_3-wave does not appear as a first arrival at distance of less than 22.5 km. An estimate of the minimum thickness can, however, be obtained as about 2.5 km to layer 3, assuming that the last point belonging to the profile is also the first one for the next layer.

Profile VIII was reserved with profile I (Figs. 1,2,6), but the quality of the field data is rather poor. Out of 10 receiving stations only 4 can be used and therefore interpretation in this case is hardly possible (Fig. 6).

Fortunately seismic refraction work has previously been done in this area (Pálmason, 1971, profiles nr. 31 and L8), nearly at the same location as profile I. Profile nr. 31 has shot point near Kirkjubæjarklaustur and runs northeastwards, while L8 has shot point in lake Heiðarvatn and partly runs along the same route as profile 31.

In order to get an idea of the general picture of the crustal structure at Systravatn area, profile nr. I was completed by additional informations from profiles nr. 31 and L8 (Pálmason, 1971), assuming similar geological conditions at Kirkjubæjarklaustur and Heiðarvatn. On the time-distance plot for this profile (Fig. 6) dotting line shows data completed by information from profiles 31 and L8. Black points show those receiving stations along profile I, which gave reliable outcome. The interpretation gives the following (Fig. 6,12) results.

Layer 0 is found to be 0.2 km thick with a velocity of 3.3 km/sec. It is underlain by layer 1 with a velocity of 4.5 km/sec and has thickness of about 4 km. Layer 2 has velocity of 5.5 km/sec and thickness of approximately 5 km. A total depth to layer 3 is about 9 km. Apparent velocity of P_4-wave is 7.2 km/sec and the thickness of layer 3 is 6.1 km, which gives a total depth of about 15.5 km to layer 4.

Summarizing the interpretation of profile Systravatn - Jökulsárlón (Fig. 6) the main problem is as follows:

A relatively high velocity in layer 2, (which seems to occur near the surface at Jökulsárlón) seems to be a characteristic seismic velocity for the structure of this area. Eastwards from Kirkjubæjarklaustur the depth to layer 2 decreases and the velocity of this layer increases, becoming abnormally high or close to 6.0 km/sec eastward from Jökulsárlón. The question is whether it is the same layer as layer 2 according to

Guðmundur Pálmason, or whether it is a quite different layer - a sort of intermediate layer between layers 2 and 3, typical for this area. How can the velocity increase in layer 2 eastwards be explained? Is it because of a sloping boundary between the layers 1 and 2 or because of a density increase in the rocks (due to intrusions in the neighbourhood, different petrographical compositions of the rocks, less porocity etc.)?

Profile Brókarpyttur - Staðarós - Brókarpyttur and Miðfellsá - Kálfafellsdalur (III, IV, II) (Figs. 1,4,7,11,12,13)

Along this 18 km long profile (Fig. 4) were 23 recording stations. The distance between geophone stations varies from 200 m near the shot points and all the way along profile IV to 4 km at the end of the profile III. The quality of measurements is fairly good indicating a rather obvious two layer case in seismic interpretation (Fig. 7). It appears that layer 1 is at the surface with a velocity of 4.5 km/sec, and it is underlain by layer with a velocity of 6 km/sec. Under the shot point af Brókarpyttur (profile III) the thickness of layer 1 is about 1.5 km, but only about 0.7 km at the other end of the profile, under Staðarós (profile IV). The minimum thickness of the second layer is 1.8 km (assuming that the offset distance to this layer would be 18 km and that the velocity of the third layer is 6.5 km/sec). If so, the depth to the third layer would be about 2.5 km at Brókarpyttur (close to the glacier) and about 3.5 km at Staðarós (by the seaside).

The short profile II at Kálfafellsdalur (shot at Miðfellsá) shows the existence of layer 1 at the surface with a velocity of 4.6 km/sec. This corresponds well with data received at profile III (shot at Brókarpyttur) mentioned above.

Summarzing the interpreted data of profiles in Kálfafellsdalur from the seismic refraction method the following conclusion can be made:

In Kálfafellsdalur layer 1 is the surface underlain by a layer, dipping southwards. This is indicated both by calculated depth under the shot points and northwards increase in velocity of the second layer as well (Figs. 7,11,12).

From a geophysical point of view the structure of the layers mentioned above looks fairly regular. Geological studies in Kálfafellsdalur (Fridleifsson,I.B., Torfason,H.) has shown that the valley is made up of hyaloclastites in its northern part changing into lavas in its southern part up to the seaside. Both the hyaloclastite formation and lavas are cut by large amount of nearly vertical dykes and many sheet swarms dipping at various angles (Fig. 11).

There are very many rather thin dykes and sheets (most of them less than 5 m) and appear close to each other. They are more or less randomly distributed in the valley. For the reasons just mentioned and because the wave length in this area is about 1 km, these intrusions (dykes, sheets) do not appear on seismic refraction diagram as disturbing intrusive bodies. But, very likely their influence from them can be seen in the rather high velocity of the second layer (6.0 km/sec) in this area. Seismic velocity in the area corresponds to the average velocity of basaltic lavas, hyaloclastites and highly dence and numerous dykes and sheets (Fig. 11).

It will be discussed later (in chapter 4, p. 15) how the above mentioned "second layer" should be classified - whether it is layer 2 or layer 3 as defined by Pálmason. From the present research work, based on only one profile in Kálfafellsdalur it is a difficult to judge. It is rather believed at the present stage that the second layer corresponds to layer 2 and therefore marked "1" on the pictures. But, as will be discussed later on (p. 15) it is also possible to call the

the second layer "layer 3", which would mean the absence of layer 2 in Kálfafellsdalur.

<u>Profile Svínafellsjökull - Skinneyjarhöfði</u> (Svínafellsjökull - Viðborðshraun - Skinneyjarhöfði - V, VI, VII) (Figs. 1,5,8,9,10,12,13)

This profile is 22 km long (Fig. 5) and the data is based on 22 measured points (geophones) along the profile with a satisfactory quality (Fig. 8). Profile VII is an extention of profile VI. The composition of points on time distance plot (Fig. 8) (time of P-wave arrival to each geophone) suggests irregularity or discontinuity in stratigraphy close to Viðborðsfjall. At about 4 km south of the shot point at Svínafellsjökull on both time-distance plots (profile V, VI) there is a high velocity layer forming an anticline close to the surface at Viðborðsfjall, but dipping steeper to the south. There are a few possible ways of interpreting this irregularity, but the one shown in Fig. 8 seems to be the most reliable model of the geology of the area (Fig. 9) and is therefore believed to be the most realistic one. Fig. 9 presents a geological map of the Mýrar area (by Annels 19). Seismic reversed profile V and VI are also drawn on this map. It can be seen, that the seismic "high velocity layer" corresponds well to the large gabbroic intrusion at Viðborðsfjall.

Detailed geological cross sections (L-L and M-M) very close to the seismic profile line have been drawn by Helgi Torfason and presented in Figs. 5 and 10. In order to compare the seismic profile to a geological cross section both were drawn in the same scale (Fig. 10). It can be seen, that the high velocity layer on the seismic profile corresponds to exposed plutons and gabbro-pluton formation on geological section.

<u>As seismic interpretation suggests this large gabbroic intrusion might be connected to layer 3, which in fact could mean that</u>

at the Viðborðsfjall area layer 3 lies on the surface or is close to it (although the Fig. 8 suggests layer 3 to be the surface it might also be at 100 or 200 m depth). Interpretation of the seismic measurements at Svínafellsjökull gave the following results: At the shot point close to Svínafellsjökull (profile VI) layer 2 appears to be at the surface with a velocity of 5.0 km/sec. The depth to layer 3 seems to be approximately 1 km assuming velocity in layer 3 of 6.5 km/sec (Figs. 8 and 10). At Skinneyjarhöfði (profile V) layer 1 with a P_1-wave velocity of 4.0 km/sec appears on the surface. It is about 1 km thick at the shot point but thins out at approximately 15 km distance northwards. (It does not appear on the other end of the profile). Layer 1 is underlain by layer 2 with a P-wave velocity of 5.2 km/sec. An estimate of approximate thickness of this layer gives value of 2.5 km. The depth to layer 3 at Skinneyjarhöfði would then be 3.5 km (Fig. 8,10).

Generally speaking, the structure along the profile at Mýrar area shows "steep" dipping and thinning of layer 1 northweastwards and layer 3 coming close to the surface in the NW part of the profile (at Viðborðsfjall).

Three of the previous profiles were run in the neighbourhood of the Svínafellsjökull - Skinneyjarhöfði profile. These were no. 28,29,30 described in Pálmason's work from 1967. The shot point profile 30 is quite close to the middle point of profiles VI and VII (Viðborðsfjall), and the interpretation gave the following information: ...... "Profile 30 runs from a shot point near Viðborðsfjall to the southwest. Near the shot point layer 2 is at the surface. The delay time of the P_3-wave increases considerably to the southwest, which could be due to an increased thickness of layer 2, or to the existence of an increasing thickness of layer 1, or perhaps to both. The most probable cause is an increased thickness of layer 1. The depth to layer 3 at the shot point is about 2 km. If the increase in delay time along the profile is assumed to be due to the existence of layer 1, the inferred depth to layer 3 near the end of the profile is about 3.1 km". These informations are in good agreement with the present interpretation of profiles V and VI.

4 MAIN CONCLUSIONS

The present work is based on data obtained from 9 refraction profiles that were measured in 1976. The conclusions are presented on Figs. 12 and 13 which show seismic cross sections A-A and B-B (see location map, Fig. 1) and also in the tables I and II.

Cross section A-A (Fig. 12) runs through the shot points at Systravatn (I), Jökulsárlón (VIII, IX), Staðarós (IV) and Skinneyjarhöfði (V), but cross section B-B (Fig. 13) through Jökulsárlón (VIII, IX), Miðfell (II), Brókarpyttur (III) and Svínafellsjökull (VI). Numbers in brackets stand for the names of profiles which began at shot point mentioned in front of the bracket.

As can be seen on Figs. 12 and 13 layer 0 with P-wave velocity of 3.3 km/sec is found only under the shot point at Systravatn where it is about 200 m thick.

Layer 1 is found on the surface in all of the measured profiles, except at Systravatn where it is about 4 km thick and is overlain by layer 0. The P-wave velocity varies between 4.0 - 4.6 km/sec and the thickness decreases to about 1 km to NE. At Svínafellsjökull layer 1 seems to be absent thus layer 2 occurs on the surface.

Layer 2 is recorded at all profiles varying in thickness between 2-5 km having P-wave velocity 5-6.2 km/sec. It is observed that as moving eastwards from Systravatn to Suðursveit and Mýrar velocity increases, whereas depth to layer 3 decreases in that direction. Total depth to layer 3 is about 9.5 km at Systravatn, about 5 km at Jökulsárlón and probably about 1 km at Svínafellsjökull. Svínafellsjökull is the only place (out of nine measured profiles) where layer 2 appears on the surface and has rather shallow depth to layer 3. So thickness of layer 2 decreases both eastwards (Systravatn - Suðursveit - Mýrar) and northwards (Skinneyjarhöfði - Svínafell) (Figs. 12,13).

Layer 3 also appears in all those profiles which were long enough to record P_3-wave as a first arrival. Its velocity is close to value of 6.5 km/sec. Depth to its upper boundary is quite variable, about 9 km at Systravatn, 5 km at Jökulsárlón and seems quite close (probably a few hundred of even only ten of meters) to the surface in the neighbourhood of Viðborðsfjall.

Layer 3 and its upper boundary represent in many ways the most interesting problem in the refraction interpretation. In Iceland this layer is probably equatable to the oceanic layer (Raitt, 1963), although the average velocity of the oceanic layer is commonly given as 6.7-6.8 km/sec.

Until recently layer 3 had not been identified at shallower depth than 500 m (in Stardalur Quaternary central volcano - Fridleifsson and Kristjánsson 1972).

If interpretation of profile V-VI is correct the refraction data suggest very strongly that in Eastern Iceland layer 3 is shallower than elsewhere in the country and comes up very close to the surface at Viðborðsfjall. So far the nature of layer 3 is not defined but several hypotheses have been made (these will be mentioned in a separate geological report by Friðleifsson)

Walker's hypothesis os especially interesting. It identifies layer 3 to very intense regional intrusions exposed at the surface in Southeastern Iceland (Walker, 1975): ...."Such swarm of intrusive sheets could give the appropriate seismic velocity, and each volcanic centre more over has a sheet at shallower depth; in short, the identity of layer 3 with a sheet swarm has all the merits of the metamorphoic zone model. It could be tested by measurements of seismic velocity made within the sheet swarm in SE Iceland. This swarm is remarkably similar to the sheeted complex in the Troods Mountains of Cyprus, a complex which constitutes a distinct layer in what is widely acknowledged to be a portion of ancient oceanic crust (Gass 1968, Gass and Masson Smith 1963). Seismic velocities measured in the nearsurface part of the cheeted complex (Matthews et al. 1971) are relatively low. The average in it and the associated gabbro is 5.2 km/sec - but this may be due to the presence of open cracks at or near the surface". ...."Layer 3 in Iceland and the sheeted "complex" in Cyprus are equated with one another".

The present seismic profiles in SE Iceland are supposed to give answer to Walker's hypothesis.

Two areas, Kálfafellsdalur and Mýrar (measured with profiles III,IV,V,VI,VII) are known as intense regions of intrusions (swarms of sheets, dykes etc.). At Mýrar (profile Skinneyjarhöfði - Svínafellsjökull) (Figs. 8,10) refraction seismic seems to agree with Walker's hypothesis showing gabbroic intrusion as a large massive of high velocity comming near the surface at Viðborðsfjall. Velocity is believed to be 6.5 km/sec, eventhough apparent velocity has greater value, probably because of sloping formation.

Pálmason (1971) found close correlation between extinct central volcanoes and shallow depth to layer 3. Furthermore he found clear correlation between small scale features of the gravity field (Einarsson, 1954) and the depth to layer 3. Strong positive gravity anomalies coincide with some of the central volcanoes where shallow depths to layer 3 have been recorded. Viðborðsfjall is a gabbroic intrusion and a large central volcanoe (Fridleifsson, 1976; Torfason). Bouger anomaly also reaches maximum at Viðborðsfjall. This information, plus interpretation of seismic profile V-VI, agree with Walker's hypothesis, that layer 3 is very close to the surface or at the surface in S-E Iceland.

But what about intrusions (dykes, sheets) in Kålfafellsdalur? Do they also represent layer 3? This question is difficult to answer, until "layer 3" has been defined more exactly.

Refraction seismic in Kålfafellsdalur shows layers of velocities 4.5 km/sec and 6.0 km/sec, with a boundary at the depth of about 3 km. Velocity of 4.5 km/sec corresponds well to layer 1 but it is questionable whether velocity of 6 km/sec is layer 2 with high velocity or layer 3 with low velocity. Taken as layer 2 the high velocity could be due to the many intrusions (dykes and sheets) in the area (see p. 10).

On the other hand it might as well be layer 3 with low velocity corresponding to the presence of open cracks near the surface. Such an explanation was offered by Walker on the sheet swarms in Cyprus (see p. 14,15).

Still, it could be a layer typical for the area having true velocity of 6 km/sec, a sort of intermediate layer between layers 2 and 3.

More detailed studies, both geophysical and petrographical, could help to solve this problem.

TABLE 1 A

Profile	pkt(No)	Aerial photograph No.	No of amer. map (1:50000)	Flight altitude in ft	Name of the area	Map coordinates X	Map coordinates Y	Hight in meters a.s.l.	Distance from the shot point in km	Time of P-wave arrival in sec
I	Shot	11174			Systravatn	7077,02	349,29	50		
1	761	7522	5918 IV	18000	Kálfafell	7093,69	367,21	60	24,48	x
2	762	7512	5918 IV	18000	Núpsstaður	7095,02	373,48	40	30,16	6,42
3	763	12516	5918 I	18000	Skeiðarársandur	7093,20	382,97	60	37,38	?
4	764	9041	5918 I	18000	Skeiðarársandur	7092,96	388,96	80	45,52	8,6
5	765	9046	6019 III	18000	Skaftafell	7101,32	402,33	180	58,36	10,8
6	766	12481	6018 IV	18000	Öræfi	7092,23	411,75	90	64,31	x
7	767	12531	6018 IV	18000	Svínafell	7094,69	410,15	90	63,40	x
8	768	4451	6018 IV	18000	Fagurhólsmýri	7084,26	418,74	20	69,85	13,12
9	769	15324	6018 I	18000	Kvíárjökull	7091,11	429,38	40	81,35	x
10	7610	15349	6019 II	18000	Kvísker	7095,82	429,67	40	82,58	14,0
II	Shot				Miðfellsá	7122,86	445,62	190		
1	7611	15375	6019 I	18000	Kálfafellsdalur	7122,99	445,92	190	0,33	0,13
2	7612	15375	6019 I	18000	Kálfafellsdalur	7123,04	446,29	190	0,69	0,22
3	7613	15375	6019 I	18000	Kálfafellsdalur	7123,16	446,62	180	1,04	0,30
4	7614	15375	6019 I	18000	Kálfafellsdalur	7123,40	447,33	160	1,79	0,45
5	7615	15375	6019 I	18000	Kálfafellsdalur	7123,52	447,92	160	2,39	0,58
III	Shot				Brókarpyttur	7124,98	445,92	190		
1	7616	15375	6019 I	18000	Kálfafellsdalur	7125,13	445,22	200	0,72	0,25
2	7617	15375	6019 I	18000	Kálfafellsdalur	7125,09	445,47	200	0,46	0,17
3	7618	15375	6019 I	18000	Kálfafellsdalur	7124,95	445,68	200	0,24	0,12
4	7619	15375	6019 I	18000	Kálfafellsdalur	7124,73	446,20	190	0,38	0,15
5	7620	15375	6019 I	18000	Kálfafellsdalur	7124,50	446,52	190	0,77	0,25
6	7621	15375	6019 I	18000	Kálfafellsdalur	7124,06	446,81	190	1,28	0,38
7	7622	15375	6019 I	18000	Kálfafellsdalur	7123,91	447,31	160	1,75	0,50
8	7615	15375	6019 I	18000	Kálfafellsdalur	7123,52	447,92	160	2,48	0,65
9	7623	15375	6019 I	18000	Kálfafellsdalur	7124,00	448,54	160	2,80	0,71
10	7624	15375	6019 I	18000	Kálfafellsdalur	7123,57	448,72	160	3,14	0,82
11	7625	15375	6019 I	18000	Kálfafellsdalur	7123,20	449,23	160	3,76	0,93
12	7626	15375	6019 I	18000	Kálfafellsdalur	7122,76	449,52	160	4,23	1,36?
13	7627	15376	6019 I	18000	Kálfafellsdalur	7122,58	449,74	160	4,51	1,07
14	7628	15375	6019 I	18000	Kálfafellsdalur	7122,55	450,13	160	4,86	1,11
15	7629	15375	6019 I	18000	Kálfafellsdalur	7122,36	450,46	160	5,24	1,20
16	7630	15375	6019 I	18000	Kálfafellsdalur	7122,17	450,75	160	5,59	1,25
17	7631	15375	6019 I	18000	Kálfafellsdalur	7121,92	451,18	160	6,09	1,32
18	7632	15375	6019 I	18000	Kálfafellsdalur	7121,59	451,85	140	6,83	1,42
19	7633	15375	6019 I	18000	Kálfafellsdalur	7120,81	452,12	90	7,47	1,58
20	7635	9320	6119 IV	19000	Kálfafellsstaður	7118,58	454,91	40	11,04	2,20
21	7636	9320	6119 IV	19000	Kálfafellsstaður	7117,25	457,85	20	14,22	2,72
IX	Shot				Jökulsárlón	7103,80	439,38	20		
1	7679	15380	6019 II	18000	Stemmulón	7105,38	444,04	20	4,92	1,44
2	7680	15380	6019 II	18000	Stemmulón	7107,88	445,77	20	7,59	1,84
3	7681	9318	6019 II & 6119 III	18000	Hali	7110,78	447,24	20	10,52	2,30
4	7682	9318	6019 II & 6119 III	18000	Hali	7112,29	450,40	15	13,92	2,90
5	7683	9319	6119 III	18000	Suðursveit	7114,42	453,28	40	17,50	3,46
6	7636	9319	6119 III	18000	Suðursveit	7117,25	457,85	20	22,86	4,38

TABLE 1 B

Profile	pkt(No)	Aerial photograph no.	No of amer. map (1:50000)	Flight altitude in ft	Name of the area	Map coordinates X	Map coordinates Y	Hight in meters a.s.l.	Distance from the shot point in km	Time of P-wave arrival in sec
IV	Shot				Staðarós	7115,35	459,35	0		
1	7642	9320	6119 IV	19000	Kálfafellsstaður	7115,93	459,36	0	1,27	0,30
2	7640	9320	6119 IV	19000	Kálfafellsstaður	7116,79	458,81	10	1,80	0,42
3	7640	9320	6119 IV	19000	Kálfafellsstaður	7116,79	458,27	10	1,80	0,42
4	7636	9320	6119 IV	19000	Kálfafellsstaður	7117,25	457,85	20	2,42	0,55
5	7639	9320	6119 IV	19000	Kálfafellsstaður	7117,55	457,08	40	3,16	0,72
6	7638	9320	6119 IV	19000	Kálfafellsstaður	7117,73	455,85	40	4,23	0,94
7	7635	9320	6119 IV	19000	Kálfafellsstaður	7118,58	454,58	40	5,49	1,16
8	7637	9320	6119 IV	19000	Kálfafellsstaður	7119,28	454,22	40	6,46	1,44
9	7633	15375	6019 I	18000	Kálfafellsdalur	7120,81	452,12	90	9,06	1,90
10	7632	15375	6019 I	18000	Kálfafellsdalur	7121,59	451,85	140	9,76	2,04
11	7631	15375	6019 I	18000	Kálfafellsdalur	7121,92	451,18	160	10,49	2,14?
12	7630	15375	6019 I	18000	Kálfafellsdalur	7122,17	450,75	160	10,98	2,24
13	7628	15375	6019 I	18000	Kálfafellsdalur	7122,55	450,13	160	11,70	2,34
14	7627	15375	6019 I	18000	Kálfafellsdalur	7122,58	449,74	160	12,03	2,42
15	7626	15375	6019 I	18000	Kálfafellsdalur	7122,76	449,52	160	12,32	2,46
16	7625	15375	6019 I	18000	Kálfafellsdalur	7123,20	449,23	160	12,81	2,52
17	7623	15375	6019 I	18000	Kálfafellsdalur	7124,00	448,54	160	13,85	2,74
18	7615	15375	6019 I	18000	Kálfafellsdalur	7123,52	447,92	160	14,06	2,76
19	7614	15375	6019 I	18000	Kálfafellsdalur	7123,40	447,33	160	14,47	2,78
20	7613	15375	6019 I	18000	Kálfafellsdalur	7123,16	446,16	180	14,94	1,84
21	7611	15375	6019 I	18000	Kálfafellsdalur	7122,99	445,92	190	15,46	2,94
22	7621	15375	6019 I	18000	Kálfafellsdalur	7124,06	446,81	190	15,27	2,94
23	7616	15365	6019 I	18000	Brókarjökull	7125,13	445,22	200	17,19	3,20
V	Shot				Skinneyjarhöfði	7122,58	476,74	0		
1	7643	9323	6119 IV	15500	Skinneyjarhöfði	7123,24	475,90	0	1,07	0,31
2	7644	9323	6119 IV	15500	Skinneyjarhöfði	7124,52	474,48	10	2,98	í ólagi
3	7645	9323	6119 IV	15500	Skinneyjarhöfði	7125,01	476,99	10	2,44	0,60
4	7665	9339	6119 I	19000	Borg	7126,05	477,85	5	3,64	0,92
5	7664	9339	6119 I	19000	Borg	7126,60	478,87	5	4,55	1,12
6	7663	9339	6119 I	19000	Borg	7127,12	479,12	5	5,61	1,40
7	7662	9339	6119 I	19000	Borg	7127,95	479,82	5	6,19	1,52
8	7661	9333	6119 I	15500	Brúnhólskirkja	7129,86	480,30	20	8,11	1,86
9	7660	9333	6119 I	15500	Brúnhólskirkja	7131,06	480,16	20	9,15	2,08
10	7659	9333	6119 I	15500	Brúnhólskirkja	7132,80	479,44	10	10,57	2,40
11	7658	9333	6119 I	15500	Brúnhólskirkja	7133,76	479,69	20	11,57	2,52
12	7646	9333	6119 I	15500	Brúnhólskirkja	7134,48	480,21	5	12,40	2,68
13	7647	9342	6119 I & 6120 II	19000	Hornafjarðarfljót	7135,53	480,45	17	13,48	2,88
14	7648	9342	6119 I & 6120 II	19000	Hornafjarðarfljót	7136,98	480,89	20	14,99	3,12
15	7657	4230 B	6120 II	16800	Viðborðsfjall	7137,84	480,65	25	15,76	3,22
16	7656	4230 B	6120 II	16800	Viðborðsfjall	7138,55	480,22	30	16,35	3,24
17	7655	4230 B	6120 II	16800	Viðborðsfjall	7139,22	479,38	20	16,86	3,30
18	7654	4229	6120 II	16800	Svínalón	7139,85	481,07	20	17,81	3,54
19	7653	4229	6120 II	16800	Svínalón	7140,66	480,36	40	18,44	3,58
20	7652	4229	6120 II	16800	Svínalón	7141,57	479,80	20	19,24	3,70
21	7651	4229	6120 II	16800	Svínalón	7142,16	479,12	40	19,73	3,80
22	7650	4229	6120 II	16800	Svínalón	7142,94	479,19	60	20,51	3,94
23	7649	4229	6120 II	16800	Svínalón	7143,82	478,72	20	21,34	4,06

TABLE 1 C

Profile	pkt (No)	Aerial photograph no.	No of amer. map (1:50000)	Flight altitude in ft	Name of the area	Map coordinates X	Map coordinates Y	Hight in meters a.s.l.	Distance from the shot point in km	Time of P-wave arrival in sec
VI	Shot				Svínalón	7144,44	477,90	10		
1	7666	4229	6120 II	16800	Svínalón	7144,04	478,22	20	0,51	0,17
2	7649	4229	6120 II	16800	Svínalón	7143,84	478,70	20	1,00	0,27
3	7667	4229	6120 II	16800	Svínalón	7143,56	478,90	50	1,33	0,37
4	7650	4229	6120 II	16800	Svínalón	7142,96	479,18	60	1,96	0,50
5	7651	4229	6120 II	16800	Svínalón	7142,18	479,10	40	2,56	0,60
6	7652	4229	6120 II	16800	Svínalón	7141,59	479,78	20	3,41	0,74
7	7653	4229	6120 II	16800	Svínalón	7140,35	480,35	40	4,48	0,92
8	7654	4229	6120 II	16800	Svínalón	7139,88	481,05	20	5,54	1,12
9	7655	4230 B	6120 II	16800	Viðborðsfjall	7139,22	479,38	20	5,43	1,07
10	7656	4230 B	6120 II	16800	Viðborðsfjall	7138,55	480,22	30	6,33	1,20
11	7657	4230 B	6120 II	16800	Viðborðsfjall	7137,84	480,84	25	7,15	1,34
12	7648	9342	6120 II & 619 I	19000	Hornafjarðarfljót	7133,76	479,69	20	8,04	1,52
13	7647	9342	6120 II & 6119 I	19000	Hornafjarðarfljót	7135,53	480,45	17	9,27	1,72
VII	Shot				Skinneyjarhöfði	7122,58	476,74	0		
1	7645	9323	6119 IV	15500	Skinneyjarhöfði	7125,01	476,99	10	2,44	3,68
2	7664	9339	6119 I	19000	Borg	7126,60	478,87	5	4,55	3,34
3	7662	9339	6119 I	19000	Borg	7127,95	479,82	5	6.19	5,12
4	7661	9339	6119 I	15500	Brúnhólskirkja	7129,86	480,30	20	8,11	2,78
5	7660	9333	6119 I	15500	Brúnhólskirkja	7131,06	480,16	20	9,15	2,56
6	7659	9333	6119 I	15500	Brúnhólskirkja	7132,80	479,44	10	10,57	2,28
7	7658	9333	6119 I	15500	Brúnhólskirkja	7133,76	479,69	20	11,57	2,04
8	7646	9333	6119 I	15500	Brúnhólskirkja	7134,48	480,21	5	12,40	1,80
VIII	Shot				Jökulsárlón	7003,80	439,38	20		
1	7668	15358	6019 II	18000	Jökulsárlón	7102,86	438,97	10	1,02	0,38
2	7677	15358	6019 II	18000	Jökulsárlón	7102,70	441,38	10	2,28	0,80
3	7678	15358	6019 II	18000	Jökulsárlón	7104,03	442,39	20	3,02	0,90
4	7669	15348	6019 II	18000	Breiðamerkursandur	7102,32	437,29	20	2,56	0,85
5	7670	15348	6019 II	18000	Breiðamerkursandur	7101,70	436,45	30	3,60	0,90
6	7671	15348	6019 II	18000	Breiðamerkursandur	7100,16	434,88	30	5,79	1,36
7	7675	15348	6019 II	18000	Breiðamerkursandur	7099,48	432,74	40	7,92	1,64
8	7610	15349	6019 II	18000	Kvísker	7095,82	429,67	40	12,57	2,50
9	769	15324	6018 I	18000	Kvíárjökull	7091,11	429,38	40	16,16	3,30
10	7676	15324	6018 I	18000	Kvíárjökull	7089,07	426,68	50	19,46	3,84
11	768	4451 (12472)	6018 IV	18000	Fagurhólsmýri	7084,26	418,74	20	28,43	5,30
12	766	12481	6018 IV	18000	Öræfi	7092,23	411,75	90	29.97	5,60
13	767	12531	6018 IV	18000	Svínafell	7094,69	410,15	90	30,63	5,70
14	765	9046	6019 III	18000	Skaftafell	7101,32	402,33	180	37,15	6,65
15	7672	9041	5918 I	18000	Skeiðarársandur	7094,68	393,15	90	47,14	8,10
16	764	9041	5918 I	18000	Skeiðarársandur	7092,27	388,96	80	51,74	?
17	763	12516	5918 I	18000	Skeiðarársandur	7093,20	382,97	60	57,42	9,7
18	762	7612	5918 IV	18000	Núpsstaður	7095,02	373,48	40	66,51	?
19	761	7522	5918 IV	18000	Kálfafell	7093,69	367,21	60	72,90	?
20	7673	12385	5918 IV	18000	Brúnahraun	7084,75	361,04	60	80,65	13,2
21	7674	11174	5818 II	18000	Prestbakki	7075,85	349,03	50	94,57	15,0

TABLE 2

		P-wave velocity in km/sec					Layer thickness in km			
		V_o	V_1	V_2	V_3	V_4	h_o	h_1	h_2	h_3
I	Systravatn - Jökulsárlón	3.3	4.5	5.5	6.5	7.2	0.2	4.2	5.0	6.1
II	Miðfellsá - Kálfafellsdalur	-	4.6							
III	Brókarpyttur - Staðarós	-	4.5	5.8						
IV	Staðarós - Brókarpyttur	-	4.6	6.3			-	1.6	0.7	
V	Skinneyjarhöfði - Svínalón	-	4.0	5.2	12.0(?)		-	0.9	2.6(?)	
VI	Svínafellsjökull - Viðborðshraun	-	-	5.0	7.0(?)				1.0(?)	
VII	Viðborðshraun - Skinneyjarhöfði									
VIII	Jökulsárlón - Klaustur	-	4.1	5.9	6.5	7.5	-	1.2	3.3	9.8
IX	Jökulsárlón - Kálfafellsstaður	-	?	6.05			?			

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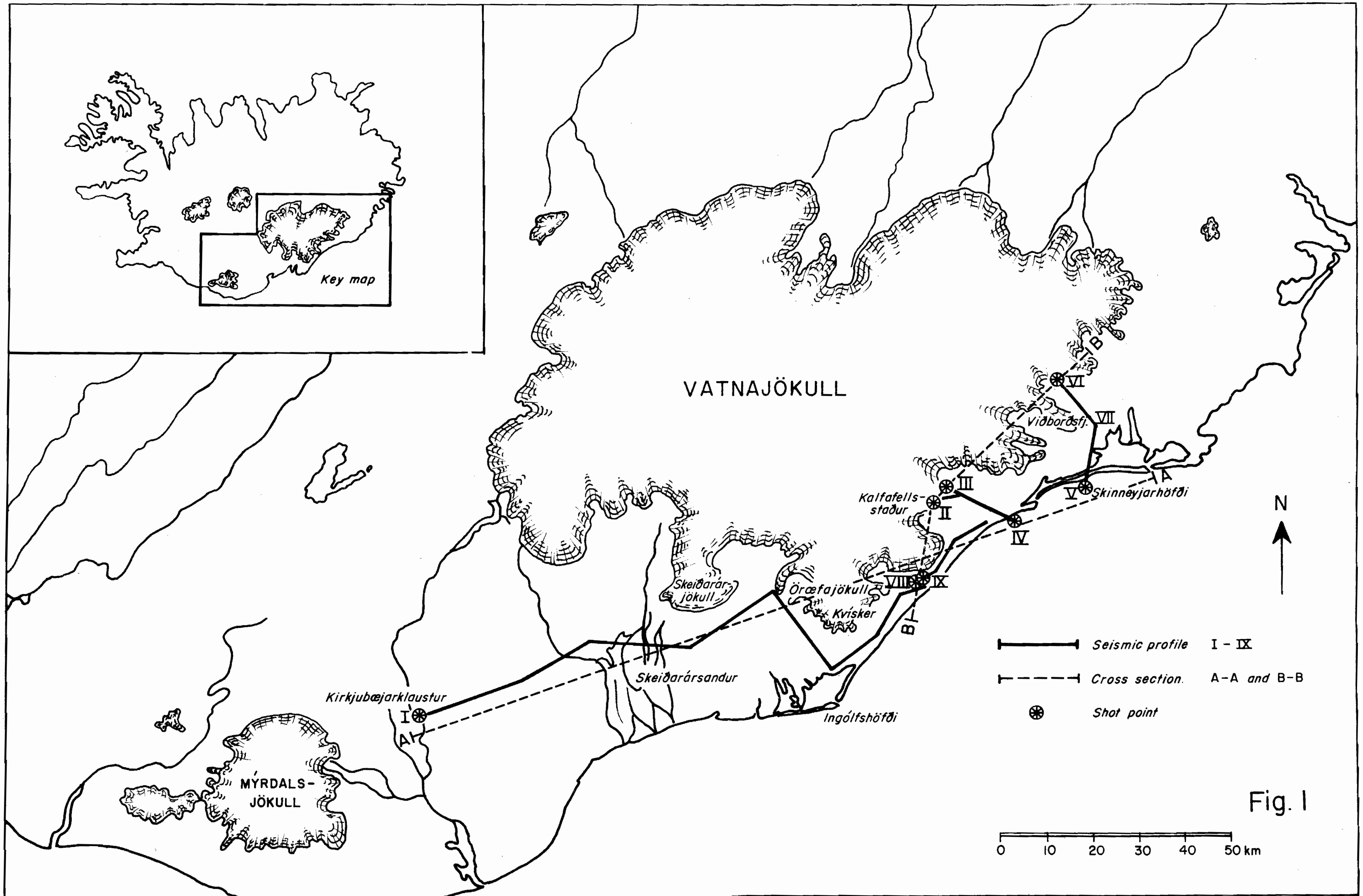


Fig. 1

ORKUSTOFNUN
Raforkudeild

SEISMIC IN S-E ICELAND
LOCATION MAP OF THE SEISMIC REFRACTION
PROFILES AND CROSS SECTIONS

'77.06.06. Ha.G/Gyða
B-ým.
T-447
F-15649

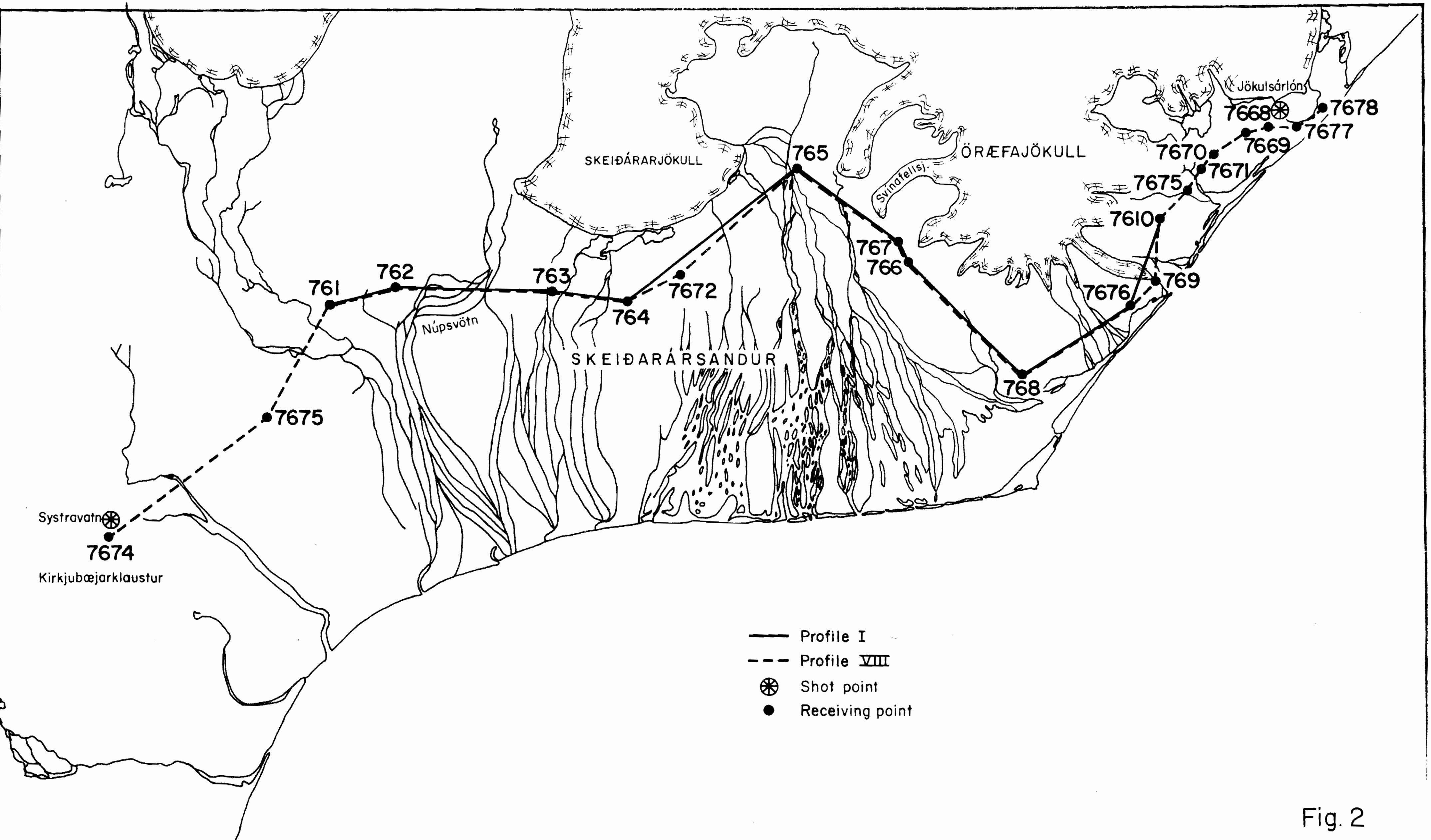


Fig. 2

ORKUSTOFNUN Raforkudeild	SEISMIC IN S-E ICELAND LOCATION OF SEISMIC PROFILES I AND VIII	77.05.03. HG/SL T.448 B-Ým F.15650

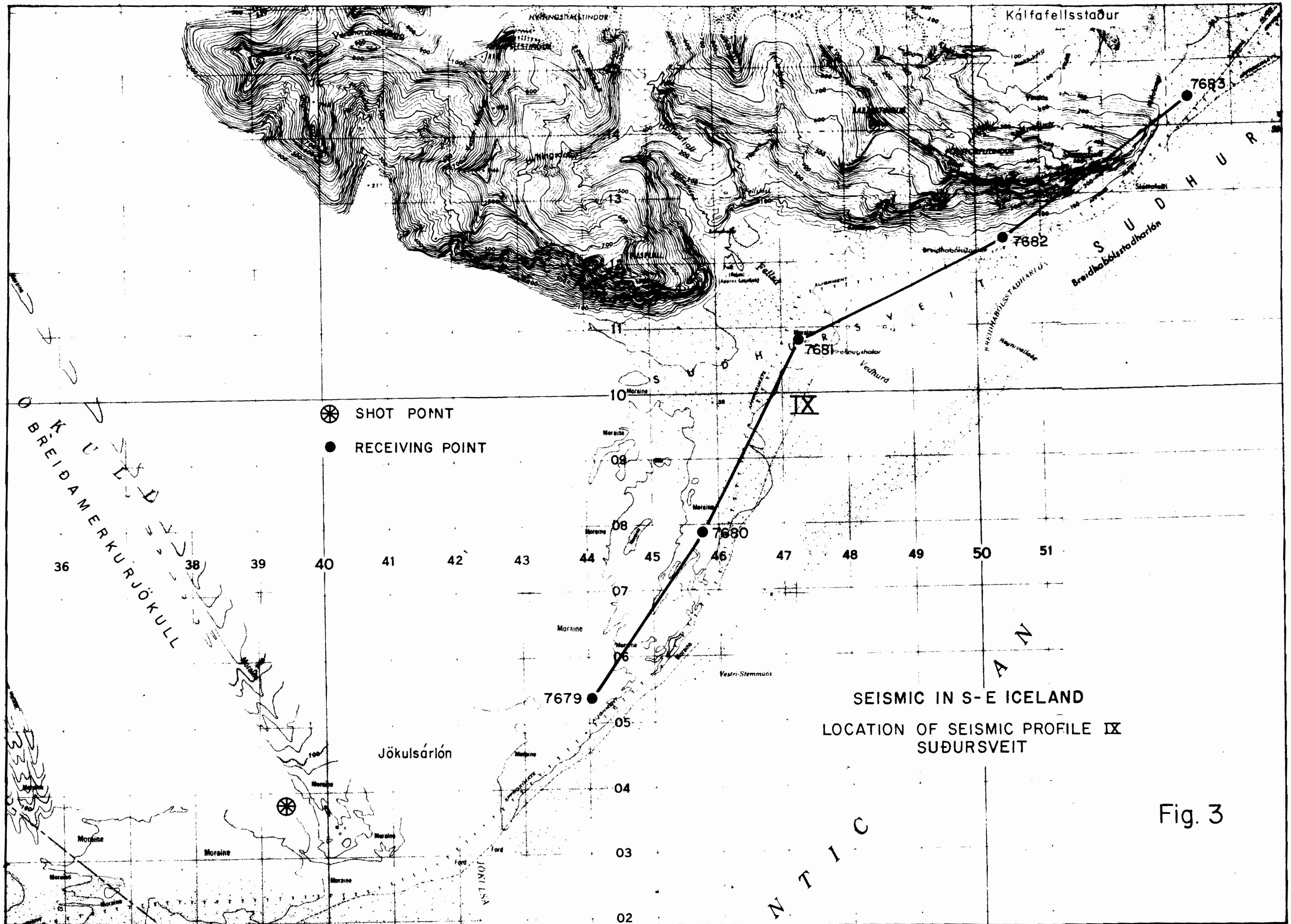


Fig. 3

8. júní 1977 Ha.G/Gyða Tnr.455 B-Ým. Fnr.15791

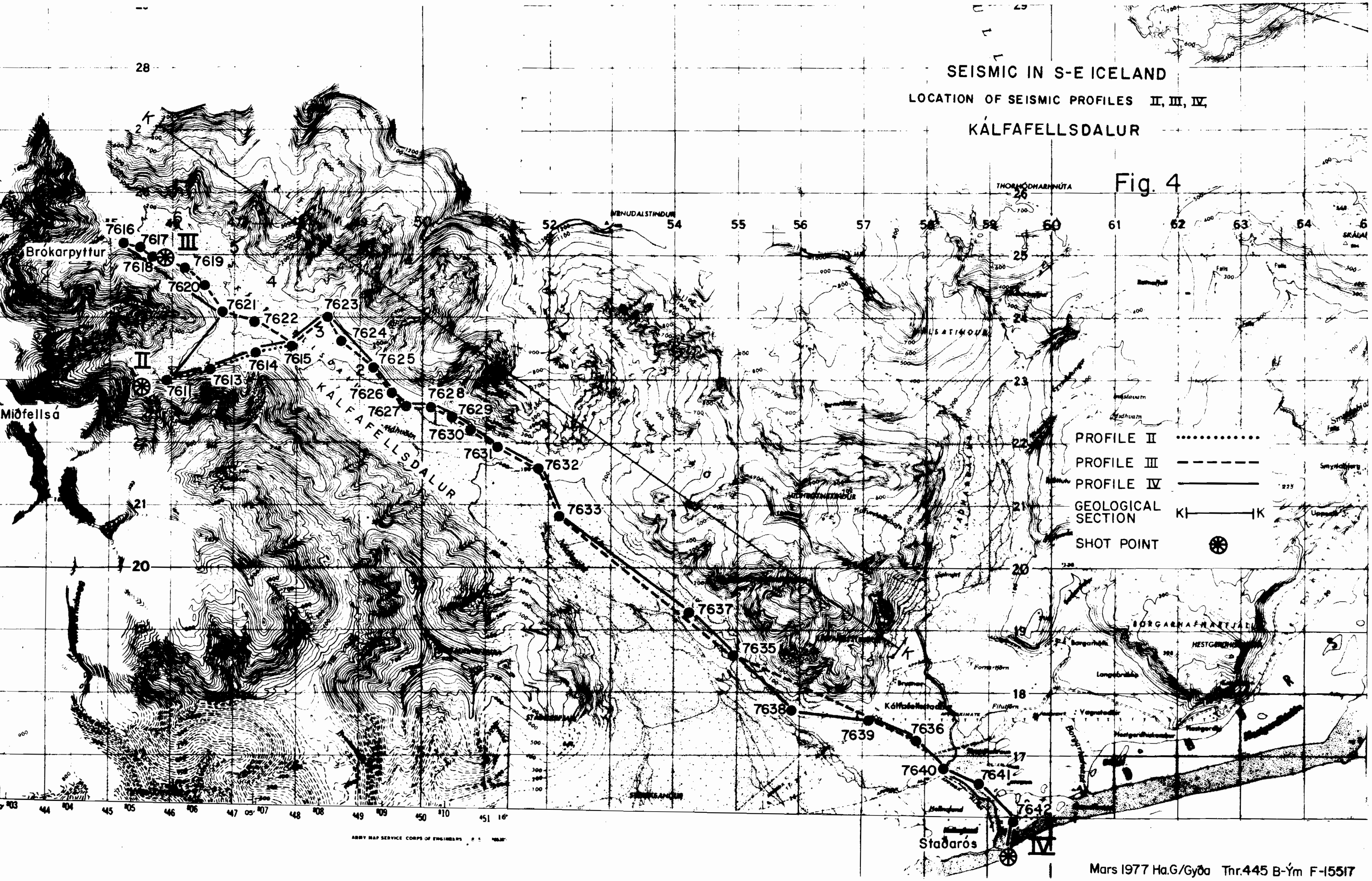
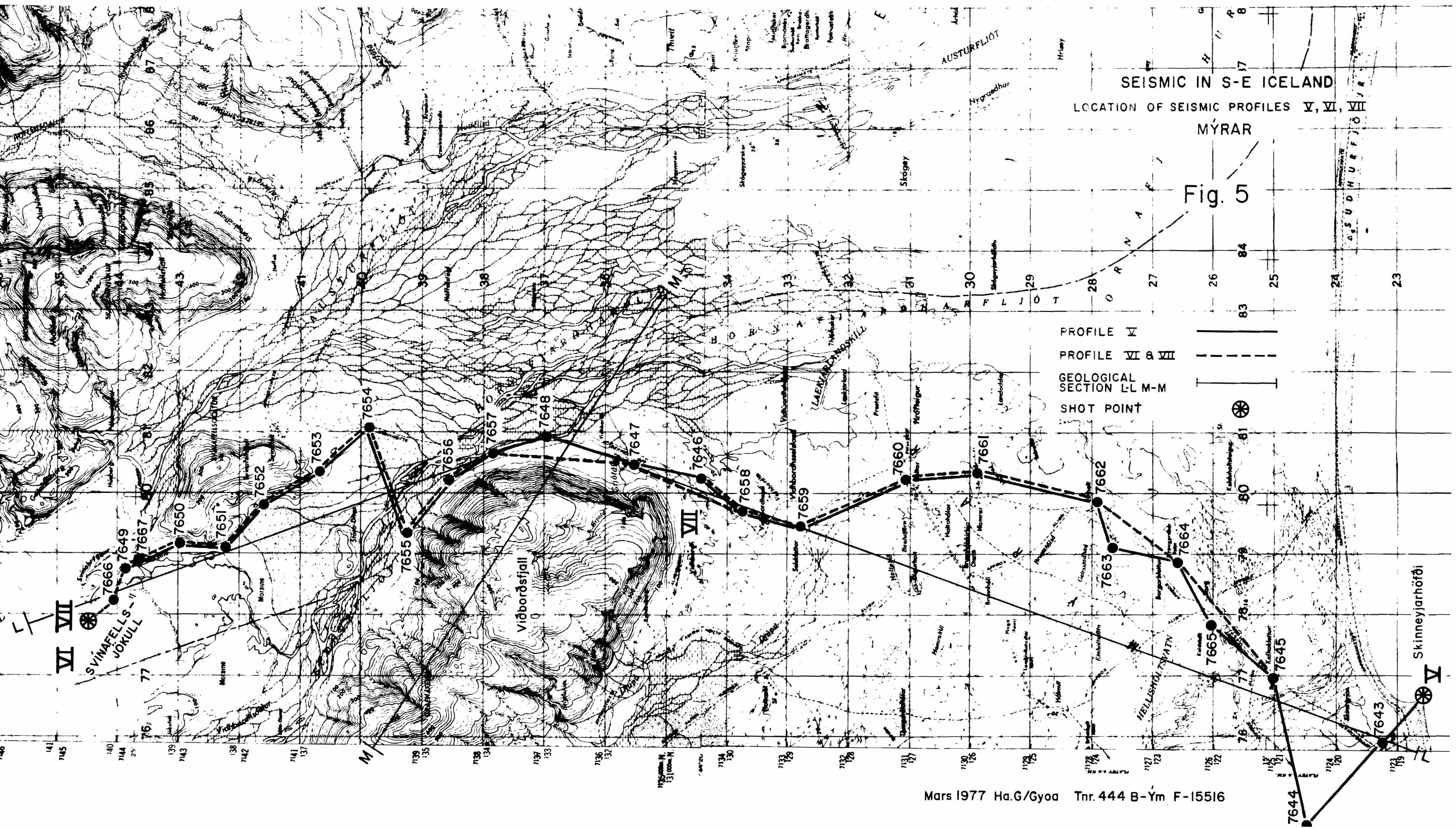
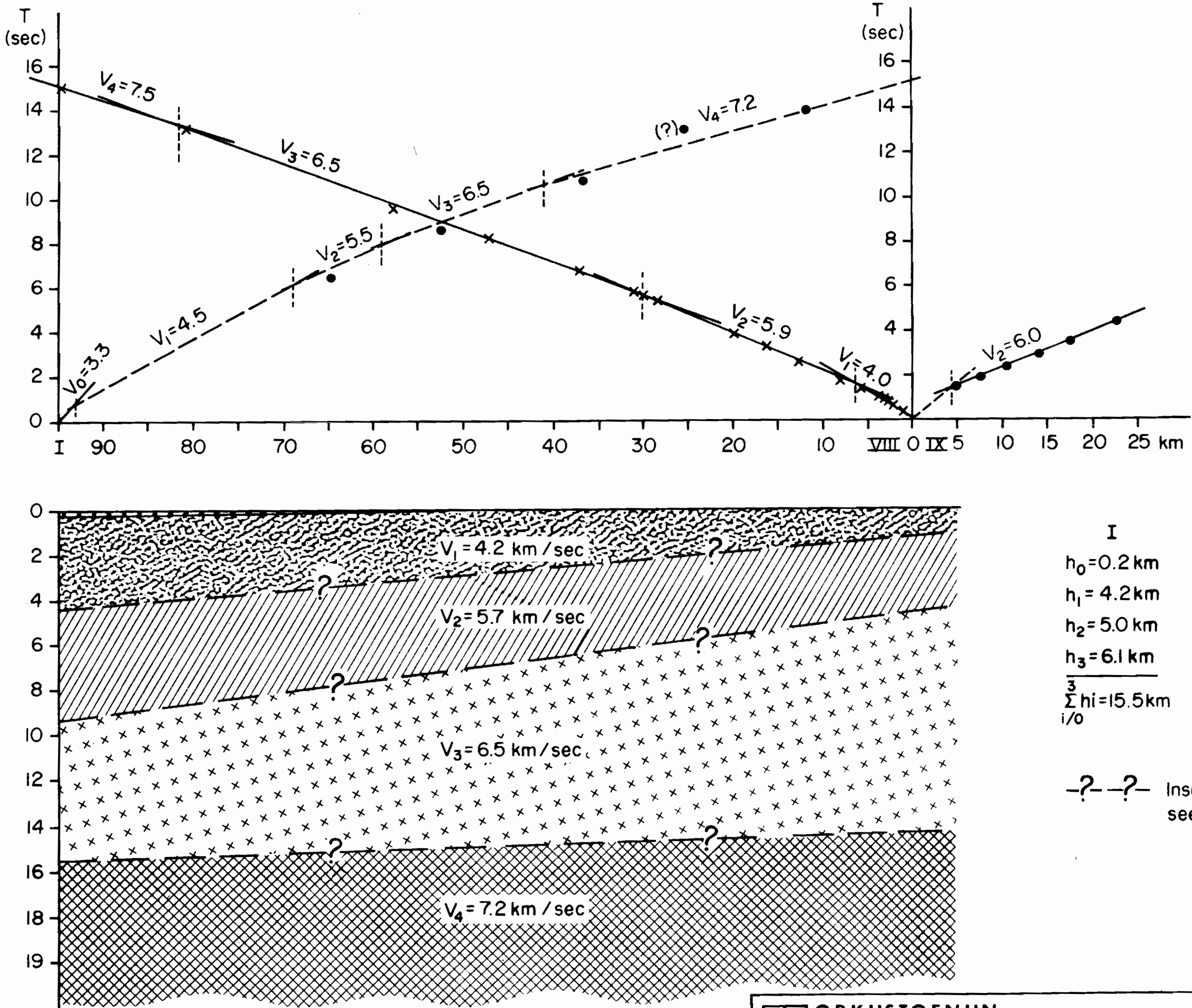


Fig. 4

Mars 1977 Ha.G/Gyða Tnr.445 B-Ým F-15517


SEISMIC IN S-E ICELAND
LOCATION OF SEISMIC PROFILES V, VI, VII
MÝRAR
Fig. 5
PROFILE V
PROFILE VI & VII
GEOLOGICAL SECTION L-L M-M
SHOT POINT
Skinneyjarhöfði
SVÍNAFELLS-JÖKULL
Viðborðsfjall
HELLISHÓLTSVATN
AUSTURFLJÓT
7643
7644
7645
7646
7647
7648
7649
7650
7651
7652
7653
7654
7655
7656
7657
7658
7659
7660
7661
7662
7663
7664
7665
7666
7667
Mars 1977 Ha.G/Gyoa Tnr. 444 B-Ým F-15516



I	VIII
h_0=0.2 km	
h_1 = 4.2 km	h_1=1.2 km
h_2 = 5.0 km	h_2 = 3.3 km
h_3 = 6.1 km	h_3 min = 9.8 km
$\sum_{i/0}^{3} hi$ = 15.5 km	$\sum_{i/1}^{3} hi$ = 14.3 km

-?- -?- Insufficient field data, see text page 9.

Fig. 6

ORKUSTOFNUN
Raforkudeild

SEISMIC IN S-E ICELAND
Time-distance plot for profiles I, VIII, IX

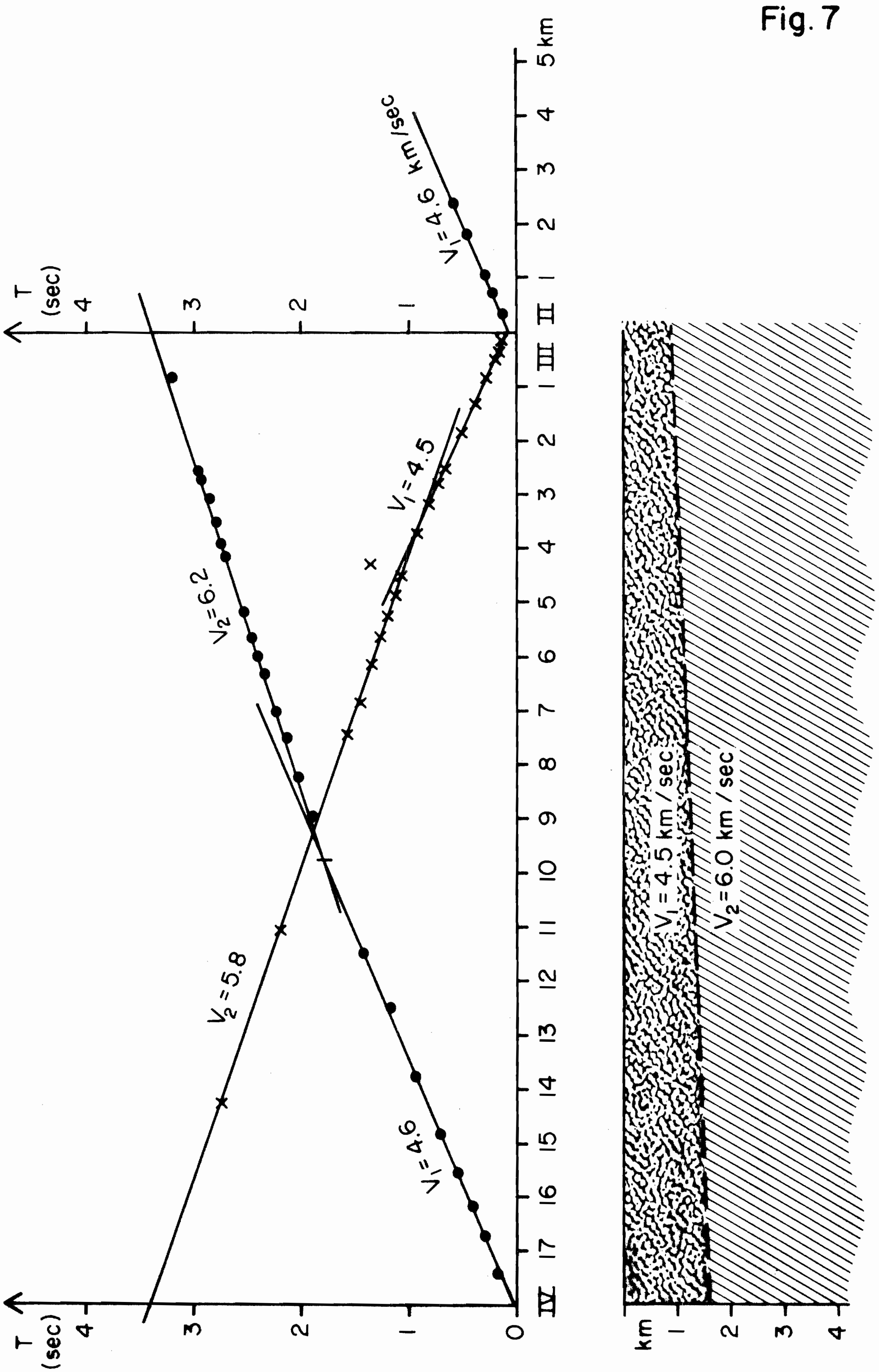
77.06.20. Ha.G/GSJ
T. 460
B-ým.
F. 15820

ORKUSTOFNUN
Raforkudeild

77.06.20. Ha.G/GSJ
T. 456
B-ým.
F. 15816

SEISMIC IN S-E ICELAND
Time-distance plot for profiles II, III, IV
Kálfafellsdalur

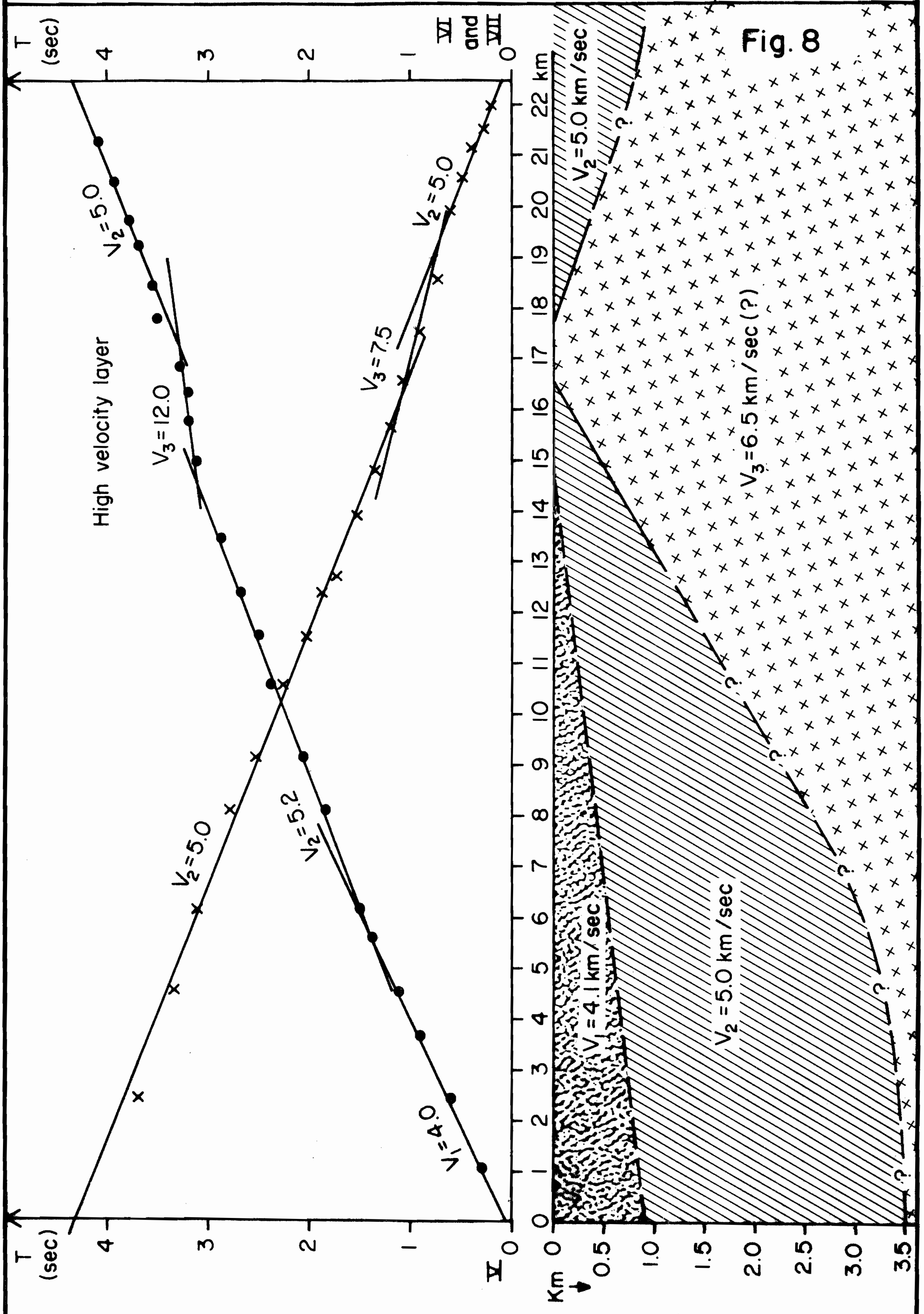
Fig. 7



ORKUSTOFNUN
Raforkudeild

SEISMIC IN S–E ICELAND
Time – distance plot for profiles V, VI, VII

77.06.20. Ha.G/GSJ
T. 455
B–ým.
F. 15815



SEISMIC IN S–E ICELAND

Geological map of Southeastern Iceland

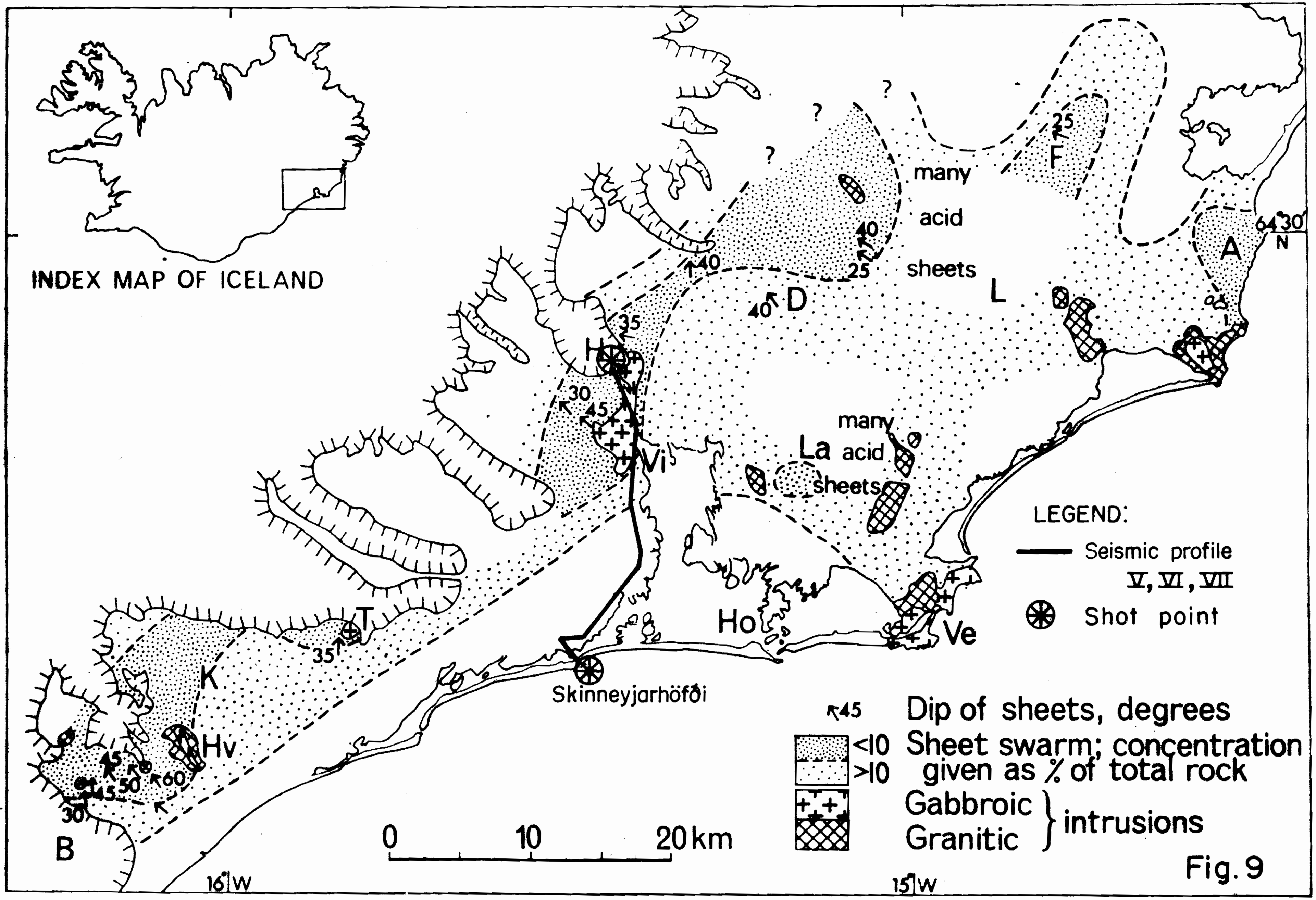


Fig. 9

77.06.20. Ha.G / GSJ

T. 461 B-vm. F 15821

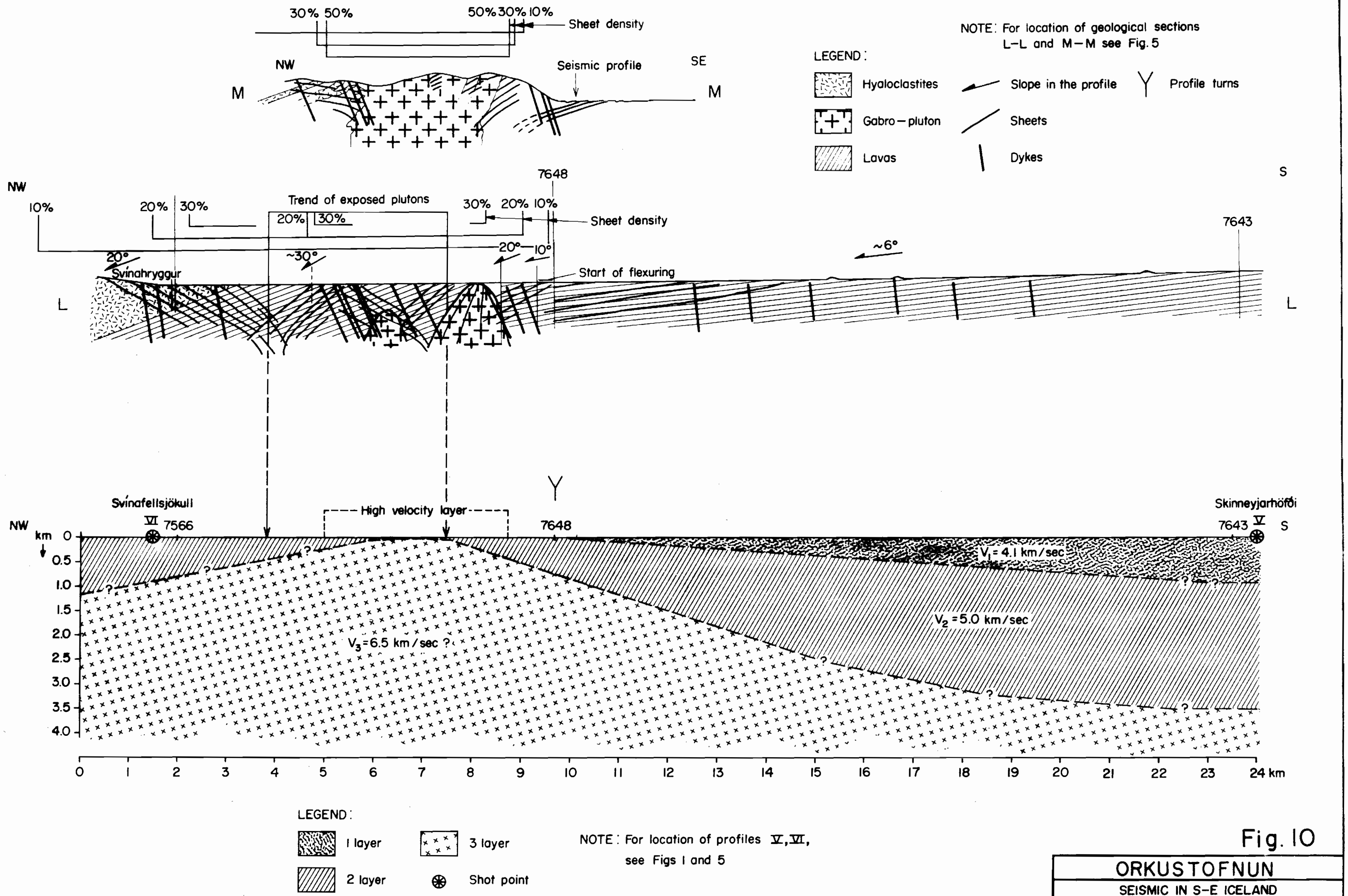


Fig. 10

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SEISMIC IN S-E ICELAND

Comparison between a geological profile and seismic profile on Mýrar

77.06.20.Ha.G/GSJ T. 462 B-ým. F. 15822

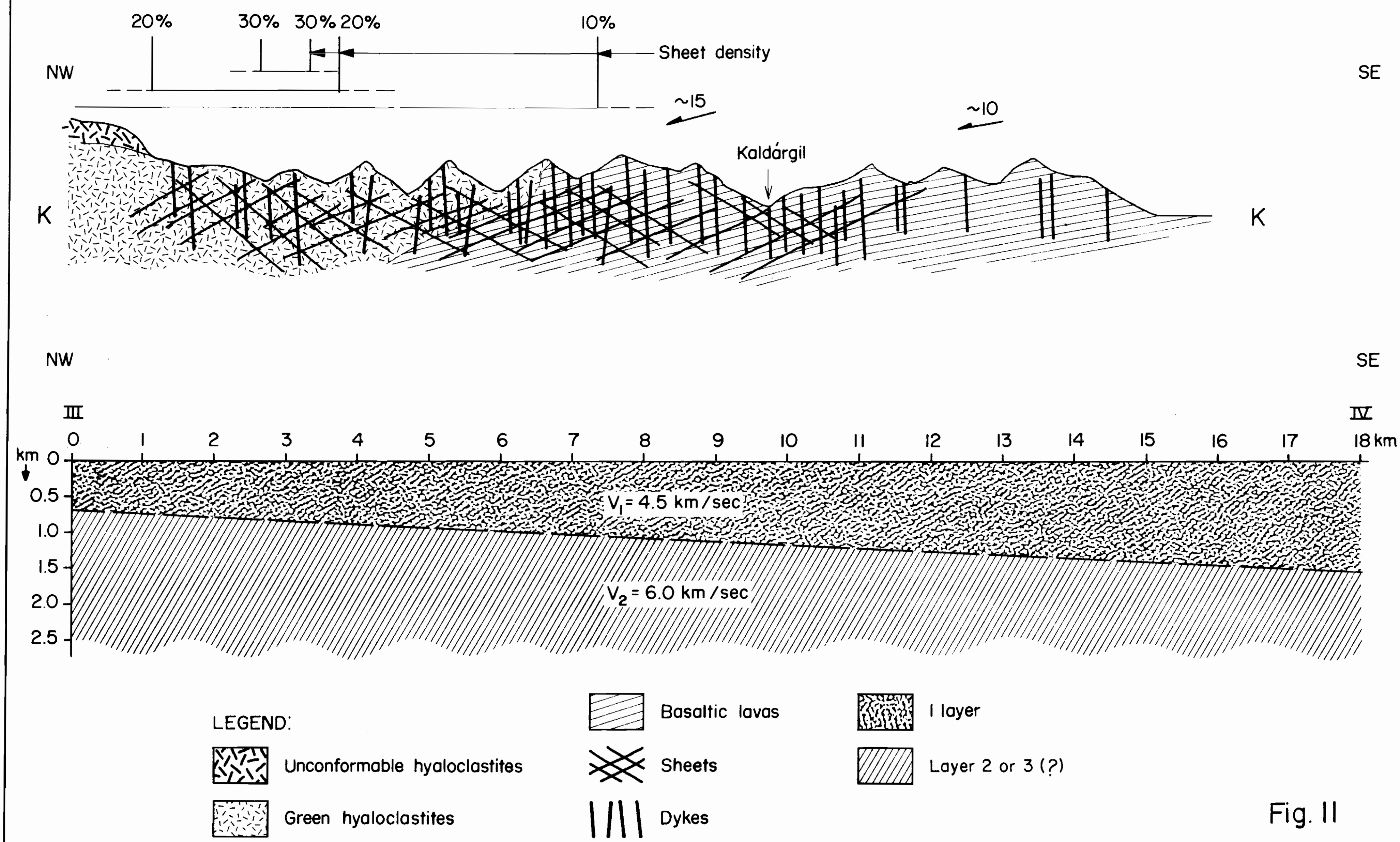

Fig. 11

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SEISMIC IN S-E ICELAND
Comparison between a geological profile and seismic profile in Kálfafellsdalur

77.06.20. Ha.G/GSJ	T. 457
B-ým.	F. 15817

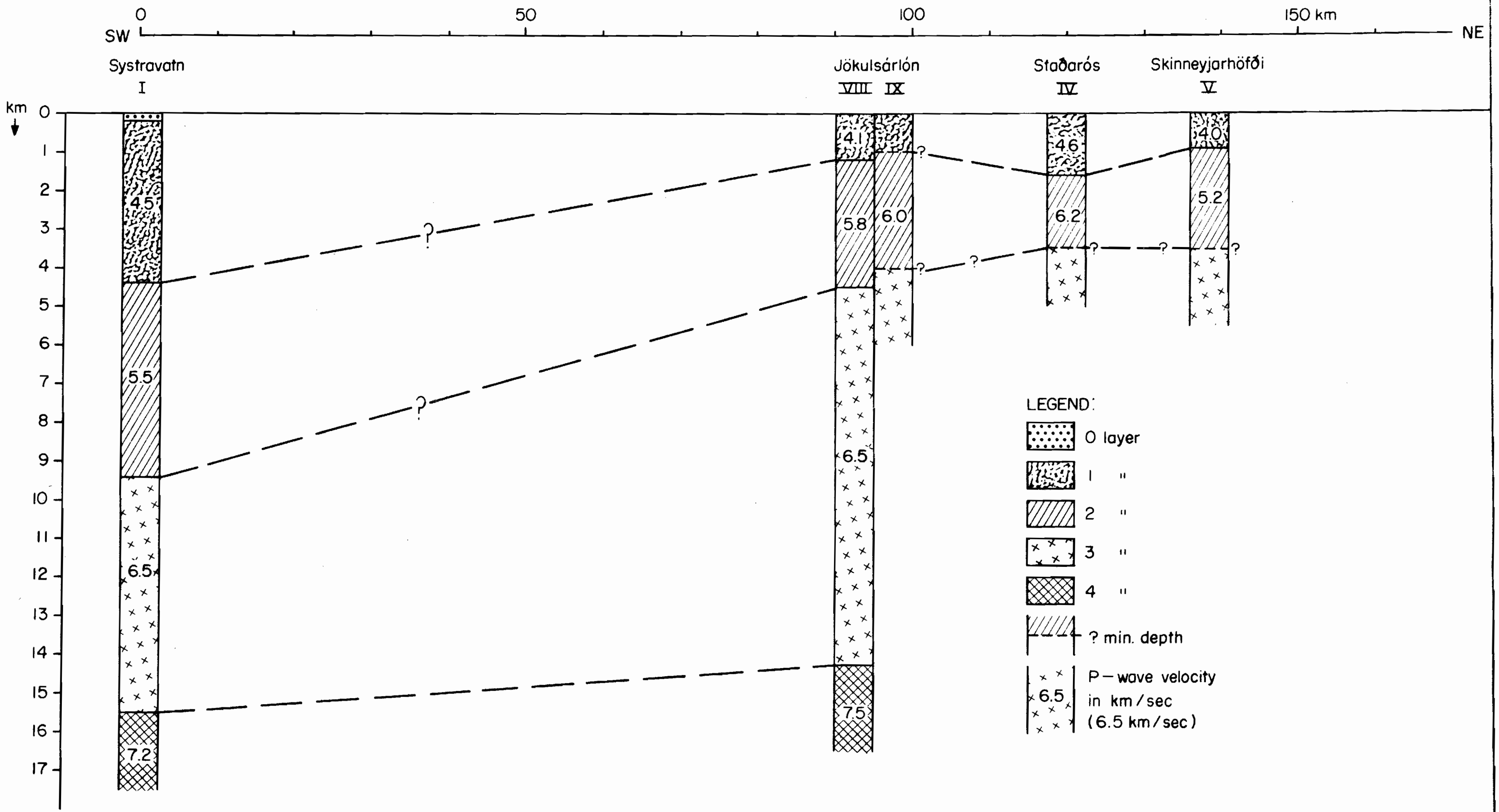

Fig. 12

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SEISMIC IN S–E ICELAND
Section A–A

77.06.20. Ha.G/GSJ
T. 459
B–ým.
F. 15819

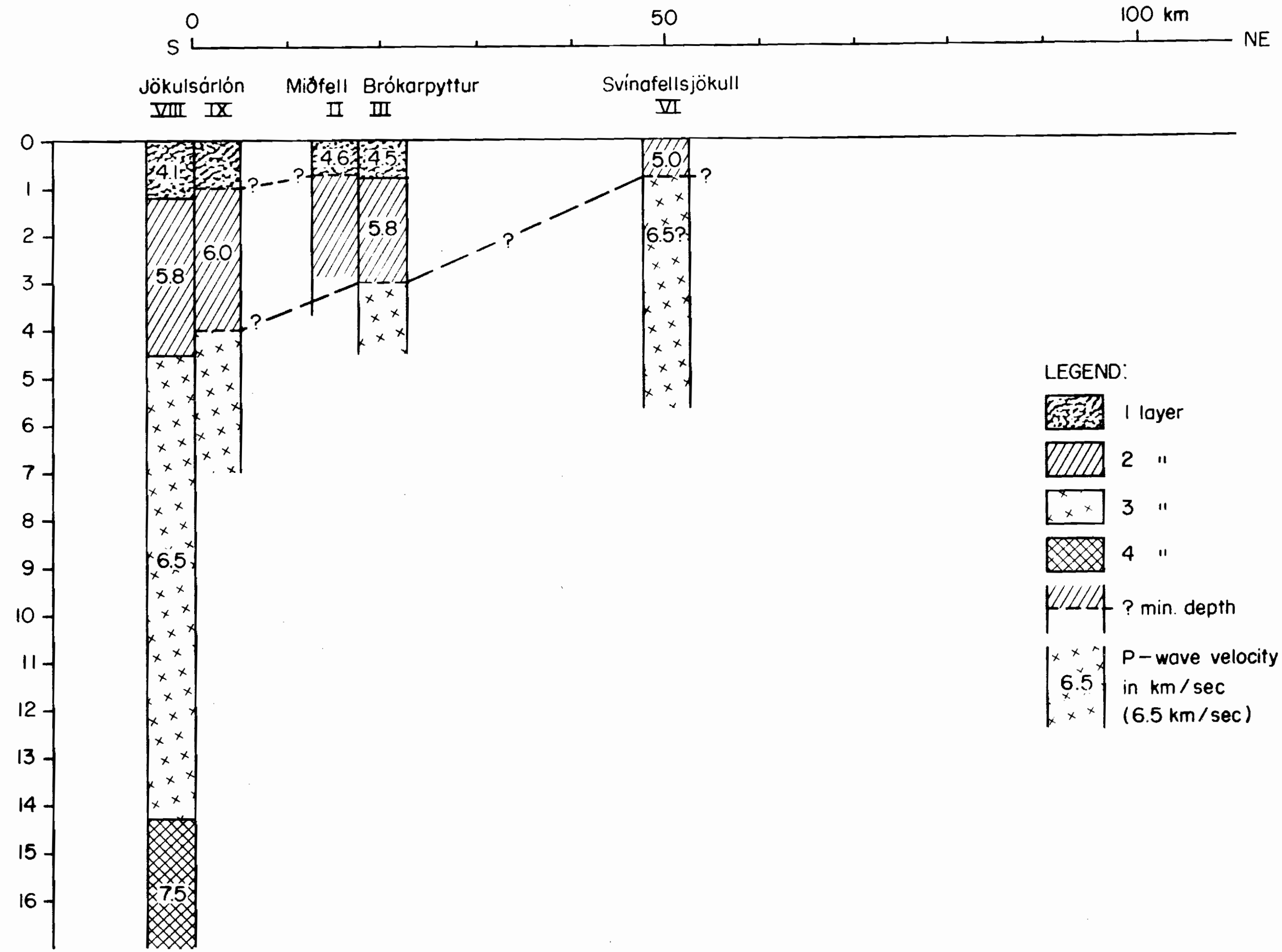

Fig. 13

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SEISMIC IN S-E ICELAND
Section B-B

77.06.20. Ha.G/GSJ
T. 458
B-ým.
F. 15818