ORKUSTOFNUN

ÞORLÁKSHÖFN
GEOLOGICAL REPORT

HAUKUR TÓMASSON geologist
ODDUR SIGURÐSSON geologist
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P R E F A C E

This report is prepared in connection with the proposed harbour project at Þorlákshöfn, for the Icelandic Harbour Authority, in close contact and cooperation with the consulting engineers :

Hostrup-Schultz and Sörensen associated
with Almenna verkfræðistofan h/f,

Verkfræðiþjónusta dr. Gunnars Sigurðssonar,

Fjarhitun h/f and the Danish Hydraulic Institute.

The aim of the geological survey was to determine the age, origin and distribution of the geological formations at the project site and fit them into the geological history of the area as far as possible.

The report also deals with a study of borrow areas for construction materials, geophysical investigations, results of drillings and geothechnical evaluation of results.

1. GENERAL GEOLOGY OF THE ÞORLÁKSHÖFN AREA

1.1 Geological setting

The bedrock in the Þorlákshöfn area is of two types : Móberg, formed during Pleistocene glaciations, and basaltic lavas, formed during interglacial periods and postglacial time. The oldest rocks are exposed in Hlíðarendafjall and are formed during the 2nd last interglacial (see fig. 1.1).

A marine transgression occurred in finiglacial times, and eroded the steep coastal cliff at Hlíðarendafjall and Hjallafjall and left marine sediments at the foot of Hjallafjall. Following the transgression was a regression with a sea level lower than at present. The Heiðin Há lava formed the coast from Þorlákshöfn and westwards. This lava is 6000-7000 years old and flowed when the sealevel was at least 8 m lower than at present. From east came an enormous lava flow, the Þjórsárhraun lava, and formed the coast between Ölfusá and Þjórsá a little earlier and at a still lower sealevel. The youngest lava is the Kristnitökuhraun lava which flowed in the year 1000 A.D. Between Þjórsárhraun and Heiðin Há lavas is the Ölfusá bar, a coastal bar covered with eolian sand.

1.2 Former geological work in the area

The geology of the area dealt with in this report is relatively well known. Four different geological maps cover the area totally or partly. The oldest of these is "Geologisk Kaart over Islands sydlige lavland med omegn", which was made by Þ. Thoroddsen in 1897 and published with his book, "Landskjálftar á Íslandi", in 1899. Thoroddsen travelled in the area in 1883 (Thoroddsen Þ. 1958) and recognized the two main rock types of the area and also the old marine sediments at the foot of Hjallafjall. He also noted that Heiðin Há was a shield volcano.

Kjartansson described the marine sediments and coastal cliffs and included the area in a geological map occuring in his "Årnesingasaga" (Kjartansson G. 1943). Einarsson studied the geology of Hellisheiði and also covered the eastern part of the area. He discussed the Kristnitökuhraun lava and found the place of origin for the Leitahraun lava, and states that this lava flowed into the ocean at Þorlákshöfn (Einarsson Þ. 1961).

The area is also covered by the geological map of Iceland, Sheet 3, (Kjartansson G. 1960) where the distribution of postglacial, interglacial basalts, and móberg is shown.

1.3 The interglacial basaltic series

The interglacial basaltic series are found in Hlíðarendafjall and around Kerlingarberg. The series are in fact two formations, the lower one from the 2nd last interglacial period and the higher from the last interglacial period. The two formations are separated by a tillite bed. The tillite is of variable thickness and is exposed at the western end of Hlíðarendafjall and north of the farm Hlíðarendi. The móberg at Kerlingaberg was formed during the same time and therefore occurs at the same stratigraphic horizon.

The two basaltic formations are made of thin lava flows. The thickness of individual flows is extremely varying and does not often reach over 1 m. The rock is coarse grained and the thinner flows tend to be very vesicular. The lower basaltic series is the oldest rock found in the area. The test quarry at Hlíðarendafjall is in this series. At the quarry site the rock is fine grained and the layers are thicker than usually and develop scoriaceous bottoms and tops.

1.4 The last glaciation

During the glaciation most of the móberg mountains in the vicinity of Þorlákshöfn were formed by subglacial eruptions.

Geitafell is one of them, made of coarse grained palagonite breccia with traces of pillows, especially near the top. When the magma had melted its way through the ice sheet, basaltic lavas flowed subaerially (Kjartansson, 1943). The contact between the lavas on top of Geitafell and the móberg below therefore indicates the thickness of the glacier at the time of the formation of the mountain.

Sandfell, east of Geitafell, is also formed during the last glaciation. It is made of fine bedded scoria with layers of pillows. The top of the mountain is made of reworked palagonite breccia. The basalt is very porphyritic.

Other signs of the last glaciation in the area are not quite as spectacular as Geitafell and Sandfell. On Krossfjöll there is a small area covered with ground moraine. Small amount of moraine can also be found at the foot of Kerlingarberg. Glacial striations are very common on the higher interglacial lava series. Their direction is generally about N 150° A, indicating the direction of ice movement from the highlands. Roche moutonnées are also common, notably on Krossfjöll.

1.5 Finiglacial time

The Retreat of the ice sheet was not continuous. There were periods during finiglacial time when the icesheet advanced. Two such periods are recognized in Iceland. During the period that preceded the former advance (12.000 years ago) Hjallafjall is believed to have formed. Hjallafjall is essentially a similar formation as the interglacial basaltic series, thin bedded basaltic series which originates from a crater in the neighbourhood of Skálafell. The rock type is olivine tholeiite, coarse grained and the thinner layers tend to be vesicular.

In the cold period that followed, the ice advanced again and eroded the top of Hjallafjall slightly. The last advance was followed by a retreat which occurred approximately 10.000 years ago and marks the end of the Pleistocene ice age and the beginning of Holocene.

The retreat of the glacier was followed by a marine transgression cutting the steep cliff which is almost continous from Hlíðarendafjall to Hjallafjall. This marine transgression left some beach sediments, sand, gravel and big boulders. This formation is exposed at the foot of Hjallafjall, but it is elsewhere covered by postglacial lavas. Beach sediments are found up to the elevation of 55 m in Hjallafjall and mark the highest sea level of the marine transgression.

1.6 Postglacial time

Volcanic activity plays the leading part in the postglacial morphology of the area ; it can be divided into three groups.

a. Shield volcanos
b. Fissure eruptions
c. Cinder- and spatter cones

A fairly clearcut distinction between these groups exists in the area. Below, the lavas in the Þorlákshöfn area will be dealt with, starting with the oldest and ending with the youngest (see age relationship diagram fig. 1.2).

Selvogsheiði is a shield volcano older than both the Leitahraun lava and Heiðin Há. It is impossible to trace the lava that flowed from Selvogs-heiði since they are all covered by younger formations. On top of Selvogsheiði there are several splendid examples of hornitoes formed around the crater. The crater itself is filled by a solidified lava lake.

Búrfell and Raufarhóll formations are of cinder- and spatter cone character. They seem to be of a similar age, older than the Leitahraun lava.
Búrfell is formed by 2 craters. Lavas from there surround the cone and have also flowed down the steep coastal cliff at Hlíðarendafjall but did not reach far. The lava is very scoriaceous and porphyritic.
The Raufarhóll formation is rather similar to Búrfell. There is one crater, Raufarhóll, just south of Krossfjöll and Ásar is probably another crater. Here, again, the lava is very scoriaceous and does not flow far from its source.

Heiðin Há is a shield volcano just south of Bláfjöll. Lava from Heiðin Há flowed mainly southwards, but also to a less extent north across Bláfjöll. East of Geitafell the Heiðin Há lava is not exposed. This lava also flowed around Selvogsheiði and formed a new strip of land from there to Þorláks-höfn. The eastern margin of this lava north from Þorlákshöfn is near to Ásar where the Heiðin Há lava is distinguished from another lava, Leitahraun, coming from the north and spreading out on the flat country. The lava from Heiðin Há is coarse grained and is typical for lavas from shield volcanos, made of thin bedded basaltic series, well exposed along the coast west from Þorlákshöfn. Peculiar for this lava is that it seems to rise slightly towards the coast. This may be because of some hindrance to the flow of the lava. This hindrance could perhaps have been a beach ridge or the ocean itself. Similar behaviour has been observed for the Þjórsárhraun lava (Einarsson, T., 1966).

Evidence from boreholes in Þorlákshöfn indicates that the lava flowed during times when the sea level was at least 8 m lower than at present. The stratigraphical position and the low sea level during the time of formation of the Heiðin Há lava indicate it to be 6000-7000 years old.

Litlahraun lava is only seen in a very small area and the rest of the lava and its place of origin is covered by younger lava (Leitahraun).
In a way this lava is a key to the postglacial stratigraphy in the area. This is because it is the only field evidence for distinguishing between the lava from Heiðin Há, south of Hlíðarendafjall, and the younger Leitahraun lava. The Litlahraun lava is clearly seen above the pahoehoe type surface of the lava from Heiðin Há, but is also clearly submerged by the Leitahraun lava.

The Leitahraun lava is a shield volcano type of lava. One could therefore expect a shield volcano as its source. But only a relatively small and inconspicuous crater is found under the southern side of Bláfjöll located slightly just outside the geological map (fig. 1.1).

Here we deal only with the part of the lava which flows southwards from the crater. Other parts of it have been accurately mapped and described elsewhere (Einarsson Þ., 1961, Jónsson J., 1971).

The Leitahraun lava flowed between Litli-Meitill and Geitafell. There it split up into two main branches. One flowed east of Krossfjöll and down to the plain, where it spreads out, forming a tongue shaped body having its western margin south of Ásar.
Another small tongue flowed down over the interglacial basaltic series near the farm Litlaland, but did not spread out.

The other major branch of the lava flowed westwards between Geitafell and Búrfell and then changed direction and flowed eastwards at the foot of Hlíðarendafjall.

This lava is the only one in the neighbourhood of Þorlákshöfn that has been dated accurately. During the constructions of Hlíðardalsskóli some charcoal was found below this lava. These remains were dated by the C^{14} method, and gave the age of 4600 years (Kjartansson G. 1966).

The Kristnitökuhraun lava originates from a crater row, just south of Stóri-Meitill. This lava is well documented in Icelandic history and is believed to have flowed in A.D. 1000 (e.g. Einarsson Þ., 1960). It has an aa type of surface and is rather scoriaceous.

1.7 The Ölfusá Bar

All the described lavas have been formed during relatively short time interval. The Ölfusá bar is quite different; it is still in creation so to speak. The bar is covered by eolian sand. In the borehole ÞB II eolian sand is found down to the elevation -3.3 m.

Evidence from ÞB-II in Þorlákshöfn indicates that the coast moved further south, from it´s present position with the formation of a bar when the mean sea level was about 6 m lower that at present. Since then the bar has been eroded back and in the vicinity of ÞB-II has never, since its time of formation, been eroded so far landwards.

The erosion of the bar to-day is certainly partly due to the marine transgression which is known to have started on the Reykjanes peninsula 9000 years ago (Þórarinsson 1957). Other aspects of the mechanical and static equilibrium of this bar will be discussed in the next chapter.

1.8 Earthquakes and tectonics

The Reykjanes peninsula is the landward extension of the Mid-Antlantic Ridge. The Mid-Atlantic Ridge is characterized by frequent earthquakes. On the Reykjanes peninsula at least three earthquakes with magnitude of $6 < M < 7$ and several smaller ones have occurred since 1910 (Stefánsson, 1967). A microearthquake study at Hjalli recorded several events (Ward et al, 1969). The most recent demonstration of this was last September when an earthquake shook the SW part of the country. In 1896 several earthquakes occurred slightly affecting Þorlákshöfn; of 50 houses only 8 were slightly damaged. At Hjalli one of nine houses collapsed and one was badly damaged (Thoroddsen 1899). This is the only report of damage in Þorlákshöfn due to earthquakes.

In the area north of Þorlákshöfn there are numerous faults and fractures. This is the southern end of the "Selvogsheiði - Langjökull fracture zone"

(Sæmundsson K., 1967). The faults form steplike features on the south slope of Heiðin Há. Most of the fractures are faults striking approximately NE, which is also the trend of most crater rows and móberg ridges in the vicinity.

Along this fracture zone it is unusually well displayed how the older rocks are more faulted than the younger ones. In Heiðin Há there are three major faults each with vertical displacement of approximately 10 m to the SE. In the Leitahraun lava there are numerous fractures but no vertical displacement is observed. In the Kristitökuhraun lava no fractures have yet been formed. The dominant direction of tectonic features in the area is SW-NE, but other directions are also found. In Krossfjöll fractures striking NNW to NW are found, but do not show any vertical displacement younger than the glacial erosion.
At the SW end of Hlíðarendafjall there are some fractures with no vertical displacement; they are almost parallel to the old coast line there and indicate along with the straight character of the old coast line that this line may have been tectonically directed.

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2. MORPHOLOGICAL AND SEDIMENTARY STUDIES

The southern coast of Iceland from Þorlákshöfn and eastwards to Höfn í Hornafirði is for the most part made up of sand. This sand is brought to the coast by the numerous great rivers flowing into the sea in this reach. At the sea this material is reworked and sorted by wave and wind action and has formed a more or less continuous bar along the coast. This bar is in a mechanical equilibrium, rather than a static one as similar quantities of material are brought to it by rivers and coastal currents as is eroded and brought to deeper waters. In long span of time this bar or the coast is not in equilibrium. This can clearly be seen where there are remnants of former bars far inland for example east of the Þjórsá river.

At Þorlákshöfn the sand coast extends from Hafnarvík and to the mouth of the Ölfusá river and even slightly further east. This is mostly the Ölfusá bar which extends between two lava flows, the Heiðin Há lava in the west and Þjórsárhraun in the east. Leitarhraun in between does not quite reach the bar and has no direct influence on its shape or composition to-day, although it is evident that the sea has eroded the lava front behind the present bar at one time.

The source of most of the material in the Ölfusá bar and the sea bottom out the bar is the transport of Ölfusá, which together with some of its tributaries has been studied for some time with regard to sediment load and its petrographical composition.

Suspended sediment load is measured in Ölfusá at Selfoss and Hvítá at Iða, besides some measurements in major tributaries. Bedload has been calculated for Hvítá at two sites, using the modified Einstein equation giving a result of the same order of magnitude for both cross sections. The results of these measurements are listed in the following table 2.1.

Table 2.1

	Sediment load tons 10^3/year	Grain size groups tons 10^3/year				
		clay 0.002	fine silt 0.002-0.02	coarse silt 0.02-0.2	sand 0.2-2	gravel 2 mm
Hvítá, Iða, Susp.	850	145	230	220	255	-
" Svartagil, bedl.	550	-	-	70	400	80
" Útverk, bedl.	680	-	-	170	490	20
Ölfusá, Selfoss, susp.	1026	90	280	310	340	-

As seen from this table suspended load and bedload may be overlapping a little, but probably not very much as the coarsest grains in the suspended sedimentload just reach the upper limit of sand size. Probable total load of coarse silt is 300.000 tons per annum and of sand 600.000 tons per annum. These are the grain sizes of interest for the Þorlákshöfn project. The fine silt and clay are deposited farther out at greater depths.

Results of the mineralogical investigations on these materials are given in table 2.2, calculated in ratios between the most important classes which are light tephra, dark tephra and basalt.

The light and dark tephra are classified as light and dark glass in the mineralogical examination. The light glass is entirely light tephra although fragments of rhyolite may occur. The dark glass is probably mainly fragments of moberg, but it is also partly "true tephra", i.e. airborne volcanic material.

The results of the investigations on the material from Hvítá and Ölfusá are not quite comparable to the results from Þorlákshöfn as standards and investigation methods differ a little.

They do, however, clearly show that a lot of sorting action is taking place in the river channel in the way that light tephra is rather in suspension than dark tephra or basalt and it increases in quantity towards the sea.

Table 2.2

	Grain size mm	Light tephra / Dark tephra Lt/Dt	Basalt / Dark tephra B/Dt	Total / Basalt + tephra T/B+Dt+Lt
Hvítá, Iða	>0.42	1.333	0.445	1.23
Suspended material	0.42-0.062	0.602	0.313	1.41
	0.062-0.02	0.617	0.047	1.43
Hvítá, Útverk	2-1	0.476	9.717	1.15
Bed material	0.59-0.2	0.729	1.645	1.02
	0.2-0.12	0.671	1.544	1.01
Ölfusá, Selfoss	>0.42	2.500	0.761	1.18
Suspended material	0.42-0.21	1.250	0.708	1.41
	0.21-0.062	1.428	0.333	1.32
	0.062-0.02	2.000	0.045	1.47

The origin of the sediment load is from two major sources, i.e. glacier erosion and soil erosion. Most of the light tephra originates in postglacial eruptions in the volcano Hekla and is gradually being washed out of the soil cover and sorted out of the river beds. After the greatest tephra-producing eruptions of Hekla the sediment load of Ölfusá may have multiplied.

The mechanical properties of the sediments in the Ölfusá bar, the sea outside it and around Þorlákshöfn is shown in table 2.3. The location of the samples is shown on fig. 2.2. All material is well sorted with sorting coefficient 1,5 ± 0,3 with the exception of the coarsest material on shore and in the river where it goes up to 2,25. The median diameter is mostly between 0.2 - 0.3 mm.

The grouping of the different grain sizes is quite natural. The finest materials are always at considerable depths and in the shelter at the Hafnarvík bay. See fig. 2.2.

The finest material contains up to 50% coarse silt but is elsewhere sand. The material at less depths and less sheltered locations and in the river is mostly sand. On the shore of the Ölfusá bar there is coarse sand and fine gravel. South of the Hafnarnes peninsula there is a rock bottom which changes into a gravel bar east of it, separating the rock bottom from the sand in the bay.

The petrographical composition is shown on figs. 2.3 and 2.4 besides being listed in table 2.3. (On fig. 2.3 the light tephra is expressed as percentage of the dark tephra.) Maximum light tephra is found at the mouth of the Ölfusá river and another in Hafnarvík; very rapid decrease in light tephra occurs near the present harbour. The basalt expressed as percentage of dark tephra, shown on figure 2.4, shows a maximum outside the present harbour and a marked minimum in Hafnarvík. Another less marked minimum is outside the mouth of Ölfusá.

Figs. 2.3. and 2.4 indicate clearly two different sources of material in the Þorlákshöfn area. All the light tephra and most of the dark one is from the Ölfusá river but most of the basalt and some of the dark tephra is formed by coastal erosion and carried by a current along the shore from the west. The harbour is just at the contact between the two material currents.

Development and stability of the Ölfusá bar will not be discussed here in detail. We must, however, mention the maximum of light tephra in Hafnarvík, shown on fig. 2.3. From borehole ÞB-II it is evident that the bar in this reach is rather retreating, but has been in this vicinity for quite a long time, or since the sea level was 5-6 m lower than at present. This means that the formation of the bar started a short time after the flow of the Heiðin Há lava, and this location was at that time more sheltered than to-day.

Now, the mouth of the Ölfusá river is located on top of the Þjórsárhraun lava, but at a lower sea level this could not have been the case. The mouth has at that time been much further west, along the lavafront of Þjórsárhraun or even still further west, as far as Hafnarvík.

In connection with the present erosion of the bar, it is possible that the maximum of the light tephra in Hafnarvík represents old deposits from the Ölfusá river. The gradual movement of the mouth of Ölfusá towards east will cause continuous erosion of the bar in the west, as the resulting along-shore current seems to be eastward and these two factors make it more and more difficult for the Ölfusá material to reach Hafnarvík. The sand transport from the area west of Þorlákshöfn is so little that it can not replenish the diminishing quantity, coming from Ölfusá.

All these facts do indicate that sediment transport will not be a major problem in Þorlákshöfn. The harbour is situated where the main sediment material in the Ölfusá bar is being eroded and brought towards east, while the other main source, eroded lavas to the west, is much smaller and just reaches the harbour area.

Table 2.3

Sample	d-50	Sorting $\sqrt{\frac{d\ 85}{d\ 15}}$	Depth	d-50		0.21-0.42	
				Lt/Dt	B/Dt	Lt/Dt	B/Dt
1	-	-					
2	-	-					
3	0.50	1.50	10	0.024	0.524	0.026	0.632
4	0.29	1.35	8			0.029	0.657
5	0.33	1.55	5			0.219	0.625
6	0.28	1.79	4			0.250	0.125
7	0.23	1.33	5			0.280	0.140
8	0.25	1.55	7			0.500	0.022
9	0.28	1.43	10			0.319	0.128
10	0.28	1.39	10			0.283	0.130
11	0.28	1.63	10			0.400	0.111
12	0.26	1.75	15			0.372	0.093
13	0.21	1.50	10			0.364	0.136
14	0.19	1.20	12	0.095	0.500	0.452	0.214
15	0.17	1.80	11	0.105	0.500	0.552	0.184
16	0.26	1.63	11			0.385	0.385
17	0.18	1.98	11	0.219	0.781		
18	0.21	1.48	18			0.229	0.743
19	0.25	1.55	23			0.059	0.500
20	-	-	-	-	-	-	-
21	-	-	-	-	-	-	-
Þ(1)5	0.3	1.60	0			0.463	0.268
Þ(2)5	1.3	2.25	0	1.667	2.417	0.450	0.200
Þ(3)6	1.7	2.25	0	2.846	1.538	0.636	0.364
S(1)3	0.6	1.18	0	0.200	1.880	0.512	0.140
01	0.4	1.58	-	0.583	1.208	0.343	0.657
02	0.45	2.09	-	0.300	1.100	0.121	0.879
03	0.5	2.25	-	0.700	0.867	0.279	0.349

3. BORROW AREAS FOR ROCK FILL

3.1 Introduction

This report describes possible borrow sites for rockfill to be used in the proposed harbour project at Þorlákshöfn.

Geologically and geographically the borrow sites fall into three groups :

A. Borrow sites at Hjallafjall
B. " " " Hlíðarendafjall
C. " " in the Heiðin Há lava

All the borrow sites are of a rather similar character, thin bedded basaltic series of interglacial (Hlíðarendafjall), finiglacial (Hjallafjall) and postglacial (Heiðin Há-lava) age.

Marine erosion during higher sea level in finiglacial times has formed the steep cliffs in Hjallafjall and Hlíðarendafjall and left big rounded boulders and marine sediments at the foot of the cliffs.

This formation is mostly covered by postglacial lavaflows but is exposed near the farm Hjalli.

Volume weight determinations were done by the Building Research Institute and Orkustofnun. Los Angeles abration tests and the freezing-thawing tests were made by the Building Research Institute. For locations of the above borrow sites, see the geological map, fig. 1.1.

3.2 Borrow sites in Hjallafjall

Hjallafjall is made of series of thin bedded basaltic lava flows. These flows originate from a single finiglacial eruption in the neighbourhood of Skálafell. The thickness of the flows is extremely varying, minimum being approximately 0.2 m and maximum 3-4 m. A characteristic of the lava series is the wild mixing of flows of different thickness. The thicker flows are often of lenticular shape with limited lateral extent. It is to be expected that a section perpendicular to the Hjallafjall cliff is just as varying as the one exposed on the cliff. Three samples were taken for volume weight determination from a locality near the SW-end of Hjallafjall.

Sample	I	II	III
Volume weight water saturated dry surface	2.467	2.389	2.757 g/cm^3
Volume weight, dry	2.244	2.179	2.595

Sample I is extremely vesicular and representative for the thinnest flows.

Sample II is probably representative for most of the flows less or equal to 1 m in thickness. The sample is very vesicular, but the vesicules are small. Sample III is coarse grained and gives the density of the thickest flows and the higher extreme for density at Hjallafjall.

All three samples from Hjallafjall were submitted to a freezing-thawing test. The samples were submerged in water and went through 300 cycles of frost and thaw. After this treatment the samples were visually evaluated. The samples showed little or no marks after this treatment.

The Los Angeles abration test

Sample I, II and III were crushed and mixed, to meet the specification of the test. The loss of material was 47.8% by weight. This high percentage is partly due to that two third of the material were from sample II, and therefore, of the lowest unit weight. Similar test of the rounded boulders, described later, will probably yield lower percentage of lost material.

3.3 The NE part of Hjallafjall

This is the area NE of the Hjalli farm towards the end of Hjallafjall. From a locality about halfway between the farms Hjalli and Riftún the character of the lava series changes somewhat.

Here, the general thickness of the flows increases and the vertical cliff of Hjallafjall changes towards a gentle slope, indicating a more resistant material against marine erosion. In this area the thickness of individual flows reaches up to 4 m. The talus on and below the steep slope of Hjallafjall in this area seems also likely to yield a considerable amount of rocks of sufficient size.

In an area SW of the Hjalli farm rounded rocks occur at the foot of the cliff. These are a natural selection of rocks eroded from the cliff during period of higher sea level. Volume weight determinations on fragments of these ricks were made by Orkustofnun. The results are listed below, and should give a fairly good picture of the volume weight of the rocks.

Dry	Water saturated dry surface
2.38 g/cm^3	2.57 g/cm^3
2.77 "	2.86 "
2.74 "	2.83 "
2.72 "	2.83 "
2.68 "	2.79 "
2.79 "	2.87 "
2.69 "	2.79 "

The size of this area is approximately 0.04 km^2. If worked, this area should yield very high percentage of rocks. This, coupled with the talus above the area, could form possibly the best borrow site in Hjallafjall.

3.4 Borrow sites in Hlíðarendafjall

Hlíðarendafjall is essentially the same type of formation as Hjallafjall.

It is made of 2 series of basaltic lava flows of varying thickness, formed during 2 interglacial periods. The two series are separated by a layer of tillite. The tillite is best exposed in the SW end of Hlíðarendafjall where it reaches a thickness of 11 m, but in other places it is completely lacking. The bed is seen exposed behind the farm Hlíðarendi where it is a fluvial conglomerate. The higher basaltic formation is for the most part made of thin flows not exceeding 1 m in thickness. The rock is coarsely grained rather similar to the rock in Hjallafjall.

3.5 The old Quarry at Hlíðarendi

The quarry is in the lower basaltic series. Here, the rock type is unusually dense and finegrained for basaltic series of this type and flows reaching up to 5 m in thickness are found. The area in which the thick flows are found is topographically well defined, because of its greater resistance against marine erosion. The rocktype at this locality is tholeiite basalt. This type of basaltic lavas trends to be thicker than the olivine tholeiite basalts, most common here. The tholeiites also tend to develop scoriaceous tops and bottoms. This can be seen in the test quarry where a scoriaceous layer is exposed between flows A and B (see fig. 3.1). The scoriaceous layer is infilled with clay. Similar scoriaceous horizons should be expected at the bottom of each thick lava at this site. Based on observations of similar lavas, the average thickness of the scoria horizons is expected to be of the order of 1 m.

At the site of the test quarry it should be possible to work four lavas. These are marked A, B, C and D on fig. 3.1. Layer A is the lowest one. It was penetrated by a pneumatic drill and found to be at least 5 m thick. It should be possible to work this lava without groundwater problems. The test quarry was made in layer B. Above layer B two thick lavas are exposed, layer C and D. The bottom of layer D is not exposed. On top of D there are two thin layers.

Approximately 200 m towards SW the layers A, B and C are found again. The layer D seems to have thinned out and is replaced by a few thinner beds. At this locality layer A and B could easily be worked, where they form low terraces at the foot of the hill. But here the rocktype is somewhat changed, getting more coarse grained and has perhaps lower density. Between this locality and the test quarry there is a slight depression in the hill. This could indicate a less resistant material. The flows are not exposed here and they might be thinner. Three samples were taken from the test quarry for unit weight determination.

Sample	IV	VII	VIII	
Volume weight water saturated dry surface	2.854	2.596	2.771	g/cm^3
Unit weight dry	2.756	2.374	2.647	"

Sample IV is perhaps representative for the optimum in density. Sample VII is near the lower margin in density. Sample VIII is regarded as a fairly good "average" rock.

These three samples were mixed and used in the Los Angeles abration test. The results gave 20.6% by weight loss of material. This value is perhaps slightly low because half of the material was of the optimum volume weight.

In the higher series of this locality there is an area of 50 m extension where 2 flows reach a thickness of up to 3.5 m. This is at the top of the higher series. At this locality the tillite is not exposed, but it is not expected to be very thick.

3.6 Heiðin Há

This is a lava flow of similar character as the series described earlier. The lava is postglacial and flowed during a period of a lower sea level and consists of basaltic flows of varying thickness. Along the coast line westwards from Þorlákshöfn a section of the top of the lava is exposed and these individual flows reach a thickness up to 2 m.
The rock itself is very vesicular and the vesicules tend to form horizontal zones in the rock, sometimes leaving the rock with a bandy appearance.

Geologically, this lava should be workable almost anywhere, but one should be aware of the experience from Hjallafjall where the flows are thickest in the NE part of Hjallafjall. This means that it is not possible to extrapolate the general thickness of flows for any great distance. Therefore, in a quarry near the proposed harbour one could encounter flows which are either thinner or even thicker than the flows exposed in the section along the coast. Two samples from this lava were taken for density determination :

	Sample V	Sample VI
Volume weight water saturated dry surface	2.454 g/cm^3	2.733 g/cm^3
Dry	2.197 "	2.611 "

Sample V should give the average for the vesicular part of the lava.

Sample VI should give an average for the more dense part of the lava.
Los Angeles abration test gave on mixture of the two samples 33.9% by weight loss.

3.7 Summary and Conclusions

The most promising borrow area for the boulders of 10 tons weight and over is the foot of the cliffs in the Hjalli area. There, the marine abrasion has selected the most resistant rock to be left over and many of the boulders there are of the order of 5 - 12 tons. Smaller rocks are abundant in the talus and there is even gravel and sand available in the former shoreline terrace. The distance from the project site is 9 km. No blasting is needed in this area. Groundwater level is near the surface, but can be lowered by a drainage ditch. This borrow area will yield the highest percentage of useful material. The wet unit weight is about 2.8 g/cm^3 in the large rocks but can be as little as 2.5 g/cm^3 for the smaller fractions in the talus.

For blasting, two quarry sites are most convenient. One is in Hlíðarendafjall where a dense basalt is outcropping. The other is in the Heiðin Há lava at Þorlákshöfn which is very vesicular. The quarries will most likely yield too much of the smaller fractions and only a small percentage of the largest rocks required. The Heiðin Há lava seems to have unit weight around 2.4 - 2.7 g/cm^3; the rock at Hlíðarendafjall 2.6 - 2.8. The high values and the nature of the flows at Hlíðarendafjall indicate this to be the best place for quarrying rock. The distance from the harbour is 5 km.

4. GEOPHYSICAL INVESTIGATIONS OF THE HARBOUR SITE AT ÞORLÁKSHÖFN

4.1 Seismic studies at Þorlákshöfn

In September 1973 some seismic refraction profiles were surveyed along the coastline north of Þorlákshöfn. The equipment used was an ABM seismograph with 12 geophones on a straight line. Small dynamite charges were blown at a certain distance from the first geophone. The seismograph records the time elapse from the explosion to the arrival of the first sound wave to each geophone. Plotting the time against distance gives a sound velocity graph from which one can calculate the depth to strata posessing different physical properties. The results of these studies and location of profiles are exhibited on figs. 4.1 and 4.5.

In October 1973 the seismic refraction survey was continued this time on sea, with the same ABM seismograph, but now connected to a floating hydrophone cable pulled by a boat. The dynamite charges were blown on the sea floor. The theory is very much the same as in seismic studies on land. Locations were determined by simultaneous readings on two theodolites stationed on the coast. The results of this survey is shown in table 4.1. On figs. 4.1 and 4.2 locations of the profiles are shown along with the depth to the basement rock and sound velocity in the other formations. Figure 4.3 demonstrates 4 types of characteristic seismic refraction diagrams encountered at Þorlákshöfn. Altogether some 63 profiles were surveyed, 50 offshore and 13 on land.

Using the measured sound velocity the thickness of each stratum can be calculated and some of its physical properties such as relative density and hardness estimated.

The greater part of the harbour area was found to be covered by a rather thick layer of material having an average sound velocity of 1.75 km/sec. This layer appears slightly consolidated which fits well with the measured volume weight of samples from the ÞB-I drillhole at depth of around 15 m, 2.3 - 2.5 g/cm^3. The top 5 m or so of the material could be quite unconsolidated but still not detected by the seismic refraction because the seismic velocity in watersaturated unconsolidated sediments lies relatively close to the recorded sound velocity of the sediments below.

In drillhole ÞB I there was a boulder layer about 1 m thick at an elevation of - 12.1 m MLWS. A similar (probably the same) layer was found during the construction of the south pier at elevation - 10 to - 11 m (MLWS). This layer is not likely to show up in seismic refraction studies because it is too thin and probably has a sound velocity very close to the rest of the sediments.

Below the sediments is the basement rock. It can be detected in a few of the seismic profiles. It has an average sound velocity of 3.5 - 4.0 km/sec. and is supposed to be an interglacial basaltic lava. Samples of this lava were collected in the drillhole ÞB I at an elevation of - 33 m MLWS.

The margin of error in these calculations is not less than $\pm$ 30%.

4.2 Measurement of the magnetic field at Þorlákshöfn

For this purpose a proton precession magnetometer was used. It measures the total magnetic field with a margin of error of $\pm$ 1γ. A map of the magnetic field over the main part of the harbour area was made by sailing lines with a close spacing to as shallow a water as possible.
For reference a long profile along the coastline was measured; a part of it was on top of the Heiðin Há lava and the rest over the sand beach with no sign of the lava.

Theoretically, the magnetic field is the more irregular the closer one is to the magnetic body. From the magnetic gradient one can calculate to some degree the distance to the magnetic body. When passing from a body magnetically oriented to another with a different orientation or non-magnetic the theoretical calculation gives the same average magnetic intensity above both bodies but a maximum field at the edge of the magnetic one and a minimum just beyond the edge.

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Table 4.1

Seismic sounding in
Thorlákshöfn 16.10.73.

No.A	Time m/sec.	Depth, m	Distance to profile, m	Direction	Sound veloc.	Thickness of sedim. m	Depth to solid rock m
1	13.38	7.5	5	225°	1.69	>22.0	>29.0
2	13.45	8.5	5	225°	1.85	>20.5	>28.0
3	13.50	7.5	10	225°	1.90	>22.0	>29.0
4	13.53	8.0	5	225°	1.85	>22.5	>30.0
5	13.57	11.5	9	225°	1.85	>18.5	>29.5
6	14.02	7.5	0	45°	1.91	>14.5	>22.0
7	14.06	8.5	0	45°	1.71	>19.0	>27.5
8	14.11	9.0	5	45°	1.71	>16.0	>25.0
9	14.17	8.0	3	45°	1.85	>15.0	>23.0
10	14.22	7.0	3	45°	1.87	10.5	17.5
11	14.27	8.5	0	225°	1.82	>13.0	>21.5
12	14.36	10.0	1	225°	1.86	>12.0	>22.0
13	14.39	8.0	3	225°	1.76	>16.5	>24.5
14	14.47	20.0	5	225°	1.77	>14.5	>34.5
15	15.36	3.5	5	45°	1.70	>22.0	>26.0
16	16.02	8.5	36	315°	1.69	>22.0	>30.0
17	16.13	5.5	36	45°	1.71	32.5	37.5
18	16.16	5.5	37	45°	1.51	>28.5	>33.5
19	16.25	3.5	31	20°	1.76	34.0	37.0
20	16.28	4.0	10	30°	1.80	>19.5	>23.0
21	16.39	5.5	33	0°	1.82	>24.0	>29.0
22	16.50	5.0	50	0°	1.79	>28.0	>32.0
23	17.03	9.0	55	180°	1.70	27.0	35.0
24	17.12	7.5	50	300°	1.07	33.0	39.5
25	17.16	4.0	40	50°	1.61	40.5	43.5
26	17.22	8.0	50	80°	1.93	>25.0	>32.0
27	17.28	9.0	56	90°	1.52	>33.0	>41.0
28	17.39	6.0	40	0°	1.94	>27.0	>32.0

Seismic sounding in
Thorlákshöfn 17.10.73

No.B							
1	13.26	8,5	42	110°	1.69	>28.0	>35.5
2	13.37	8.0	25	0°	1.72	>25.5	>32.5
3	13.41	6.0	48	0°	1.51	18.5	23.5
4	13.46	7.0	40	70°	1.80	>24.0	>30.0
5	13.55	9.5	40	180°	1.81	>25.0	>33.5
6	14.37	4.5	44	320°	1.79	>34.0	>38.0
7	14.50	4.5	52	20°	1.71	>45.0	>49.0
8	14.45	6.5	40	80°	1.76	>28.0	>34.0
9	14.52	7.0	40	210°	1.74	>22.5	>29.0
10	14.56	10.0	40	210°	1.66	>28.0	>37.5
11	15.01	8.5	45	35°	1.75	>25,5	>34.0
12	15.05	8.5	45	20°	1.68	>26.5	>35.0
13	15.11	6.5	40	20°	1.72	>27.5	>34.0
14	15.18	6.5	40	260°	1.80	17.5	24.0
15	15.22	6.5	48	270°	1.79	>33.5	>40.0
16	15.26	4.5	50	20°	1.87	>30,5	>35.0
17	15.33	8.5	48	100°	1.70	>23,0	>31.5
18	15.37	6.5	35	270°	1.76	>26.5	>33.0
19		16.0	40	140°	1.74	>22,0	>38.0
20		18.0	40	100°	1.66	>20,0	>38.0
21		13.0	45	130°	1.74	>24,5	>37.5

The magnetic map of the harbour area (see fig. 4.4) shows a very even magnetic field except close to the shore next to the northern pier. This means that a magnetic body is not within some 20 m below sea level.

From the profile along the shore line (see fig. 4.5) one can clearly see the passage from above the Heiðin Há lava over to the thick sediment layer, which is close to the H2 bench mark.

The low sound velocity in front of the solid lava ($V \leq 3.0$ km/sec) may be due to some breaking up of the lava along the margin or even closely spaced boulders.

All the magnetic measurements are in good correlation with the seismic refraction studies.

5. GEOLOGICAL INVESTIGATIONS OF THE HARBOUR SITE AT ÞORLÁKSHÖFN

5.1 Earlier investigations

Investigations in connection with harbour construction at Þorlákshöfn have been performed at several stages. The first stage was accomplished before and during the construction of the present harbour facilities in 1963-1965 consisting of core drilling and sounding in the harbour area. The actual construction also gave information about the geology. Of the results obtained at that stage, not all are preserved, but the Icelandic Harbour Authority has furnished us with available results. The core drilling amounted to 7 holes totalling 135 m. Other soundings were 19 primitive soundings in 1966, total depth 40-50 m, and 16 Borro soundings, 75 m total depth.

During 1962-1966 several drillings for cold water supply were carried out near the harbour area. All these holes were shallow and gave limited information for our purpose. Accurate location and identification of many of the holes is also uncertain.

The second stage was carried out after the completion of the present harbour, but mainly in 1971. It was performed directly by the Icelandic Harbour Authority and consisted of Borro soundings, water jets and Stenuick percussion drilling to find the depth to bedrock in the extended harbour area. Some sampling was also done. A part of this field work was done on land south of the present harbour revealing shallow depth to bedrock, as expected, as this is on top of the Heiðin Há lava flow. These results will not be included in the present report, except that logs of 54 holes drilled during this stage, 254 m total depth, will be included. Total known drilling at this stage is 381 m in 130 holes.

5.2 Present investigations

The present investigations in the harbour area consist of core drillings and extensive geophysical studies, i.e. seismic measurements in 63 profiles and measurements of magnetic anomalies in the harbour area. Sampling of bottom material was done in two ways:

a) Sampling with a small bucket sampler was done at 30 locations. Eight of the samples were taken by the Icelandic Harbour Authority, these are marked I-VIII (Roman numerals). The samples collected by Orkustofnun in connection with the Þorlákshöfn project are marked 1-22 (Arabic numberals). Other sand samples used for the preparation of this report, are Ö I-III and a few samples marked S and P. These samples were also collected by Orkustofnun. Locations of the above samples are shown on figs. 2.2 - 2.4 and fig. 5.1.

b) Sampling with the Kullenberg sampler was done at 10 locations in the harbour area. The sampler penetrated the sediments up to 1.5 m but usually about 1.0 m. The samples are marked S 1-10 with a Roman numberal behind. S 2 II means a sample from location 2, from the lower part of the hole. S 2 I means a sample from the upper part of hole 2.
The material recovered by the Kullenberg sampler was very much mixed up when recovered, so that a clear distinction between the material at the top of the hole and at the bottom is lacking.
The range of compaction of the material recovered with the Kullenberg sampler is shown on fig. 5.4, and locations of the samples on fig. 5.1.

All samples were sieved and analysed petrographically and specific gravity and unit weight determinations were made on many of the samples (see appendix 2).
A complete list of samples sieved and analysed petrographically is included in appendix 4.
This list also serves as a key to the grain size analyses in appendix 3.

5.3 Core drillings

Work on the core drilling started on September 27th and ended on 4th of December.
During this time three holes were drilled in the formations at Þorlákshöfn totalling 60.6 m. Graphic logs of the holes appear in fig 5.2.
Locations and further information on the holes are included in appendix 1.

Sampling was done by means of a core barrel (CB) in the lava formation and washings (WC) were collected wherever possible. "Undisturbed" samples (UDS) were taken by means of a 80 cm long soil sampler (see fig 5.2).

Grain size sorting coefficient defined as $s = \sqrt{\frac{d85}{d15}}$ and some petrographic parameters were found for the sand, and are included on the graphic logs (fig. 5.2). The petrographic parameters are calculated from the grain size containing d_{50} (the median diameter) whenever possible.

5.4 Geology of the project site

The model envisaged of the geology at the Þorlákshöfn harbour site, is that of a postglacial lavaflow, the Heiðin Há lava (HH-2), flowing into the ocean at a sea level 8 m lower than at present. The glowing hot material explodes and forms scoria and sand (HH-1) until the lava can flow on dry land on top of the sand and scoria. On the contact between the lava and scoria-sand, pillows could have developed.

During a marine transgression, the margin of the lava was eroded, leaving a layer of rounded stones (HH-3) directly overlying the scoria-sand (HH-1). With the transgression in progress the rounded stones were covered with marine sand (YS-1), rather coarse grained first, but getting finer grained towards the top.

For a further clarification of the geological history see the stratigraphic column in fig 5.2 and the geological section in fig 5.3.

The evidence from the drillholes is interpreted as follows. At the bottom of hole ÞB I a basalt is found possibly an interglacial lava formation (ID). In some of the seismic profiles a layer of higher velocity of sound is found at a similar depth. But elsewhere it must be further down.

The velocity of sound in this layer is 3-4 km/sec, which is normal for lava flows of this age.

Overlying the ID lava there is a volcanic formation (HH-I) related to the Heiðin Há lava. The HH-I is formed in the sea at around 8 m lower sea level than at present. The thickness is at least 20 m. It consists of volcanic sand, scoria and even breccia and pillow lava. The velocity of sound in this formation is 1.75 km/sec, indicating a slight consolidation or cementation. The magnetic measurements in the harbour area do not indicate the presence of continuous pillow lava there, nor the existense of an interglacial lava formation (ID) near the surface. This is also confirmed by the seismic results. The seaward extension of this formation is not known and is probably outside the area of interest.

The formation HH 2 is the subaerial lava flow from Heiðin Há formed the same eruption as HH 1. It is a normal basaltic lava flow with pahoehoe type surface. It reaches down to - 7 M.L.W.S. It was also found in most of the old holes and below it one reached the HH 1 formation, which consists of pillow lava, sand or breccia in these holes. The thickness of the HH 2 formation is about 12 m at the coast. First after the eruption this formation reached considerably further out at Hafnarnes than at present, but is steadily being eroded by the sea.

The third formation HH 3 consists of reworked material from the above mentioned two formations. This is a layer of rocks, stones and boulders mixed with sand and gravel. The rock fragments are sometimes rounded. The sand in the interstices has the same composition as the sand at Hafnarnes before mixing takes place with the Ölfusá material. This layer was encountered in former drillings (see fig 5.5) but was interpreted as a thin lava flow. During the construction of the present harbour this layer was excavated and found to be rounded boulders. Borro soundings reach down to this layer in many cases, but have probably penetrated it furthest out where this layer becomes gravel and on the coast in Hafnarvík where a few holes have probably penetrated into it or through it and into the underlying HH 1 formation (see fig 5.6 - 5.10).

Reflection sounding performed by Alpine Geophysical Associates gave two strong reflectors as indicated by the preliminary report on these measurements. The lower one is probably the top of the HH-3 formation and further out the top of the HH 1 formation. This is reproduced on fig. 5.1 from the preliminary copy supplied by the Alpine Geophysical Associates.

The young sediments (YS) is the uppermost formation. It is mostly sand and coarse silt and one distinct tephra layer is found in it at least in hole ÞB I. It is quite possible that the upper strong reflector is this tephra layer. The top of this layer and down to 1 m depth is well sampled but further down it is only sampled in one hole. But as far as we know the sedimentation environment, after the formation of the HH formations, has been similar to the one today except a slow transgression has taken place, we can assume that the material is rather coarser grained as we go down through the sediments than at the surface. The Borro soundings and water jet holes do also indicate this to be the case. On land this formation is only eolian sand, but because of the transgression it reaches well below sea level.

5.5 Technical aspects

In connection with the harbour construction there are two main geotechnical questions, i.e.

1. The sability of the materials for foundation.
2. The possible excavation methods.

Most of these materials are fairly good for foundation. The formation HH 2 is excellent and the HH 1 and 3 formations are good for most purposes. This material is possibly overlying soft marine sediments, but the depth down to it is at least 35 m. These marine sediments, if existing, are therefore well compacted and consolidated. The HH 1 formation is mostly sand of varying grain size, but usually coarser than the overlying sediments. The range in compaction for this material is shown on fig. 5.4, sample Þ-1, which shows a rather small range and medium porosity. The grains are very irregular in shape and the angle of internal friction for this material is high. The HH 3 is coarse gravel and boulders and will behave as such or like the sand in the interstices. This sand is the same as the one discussed below.

The young sediments (YS) are mostly sand but contain some coarse silt. The range in porosity from the loosest dry packing to maximum packing is shown in fig. 5.4, sample Þ-2. This material is much more rounded than the sand in HH 1 and therefore of a more normal technical behaviour in relation to grain size.

None of these formations are likely to cause difficulties in foundation of a rubble mound brake water, which can take some settlement without harm.

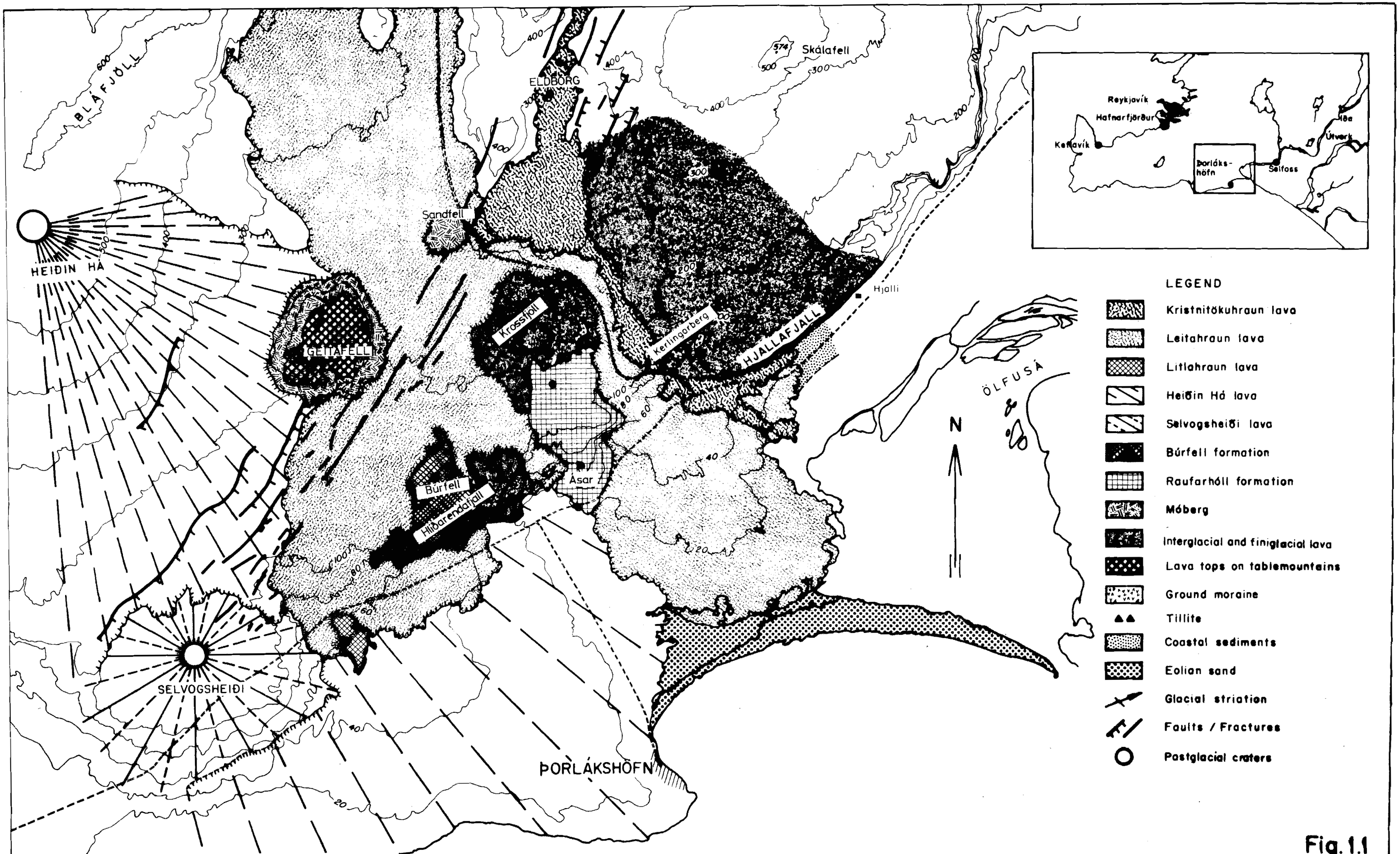
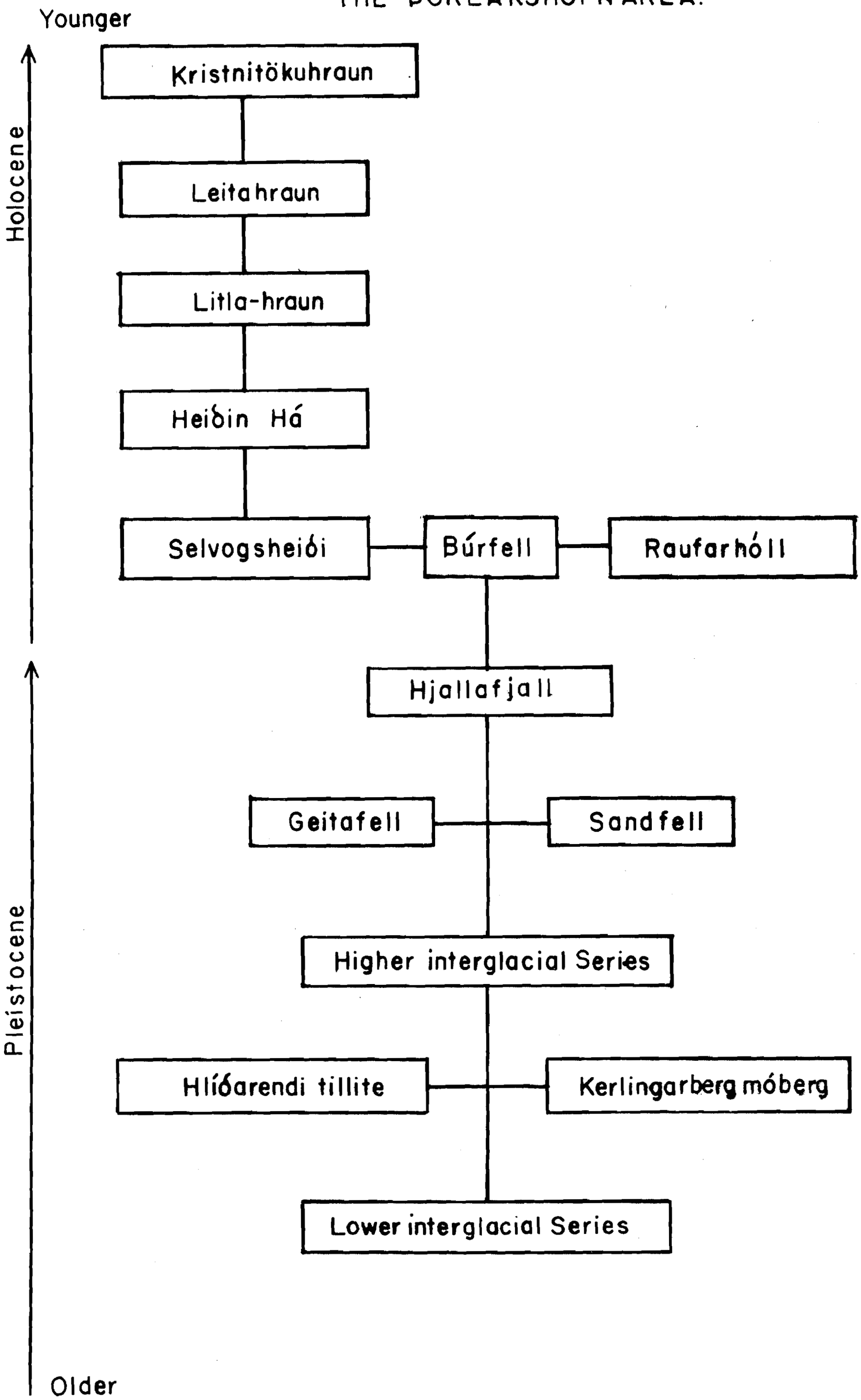


Fig. 1.1

ORKUSTOFNUN
ÞORLÁKSHÖFN
Geological Map
Tnr. 6
B-175
Fnr. 11573

FIG I.2

AGE RELATIONSHIP OF THE VOLCANIC FORMATIONS IN THE ÞORLÁKSHÖFN AREA.



Fnr 11580

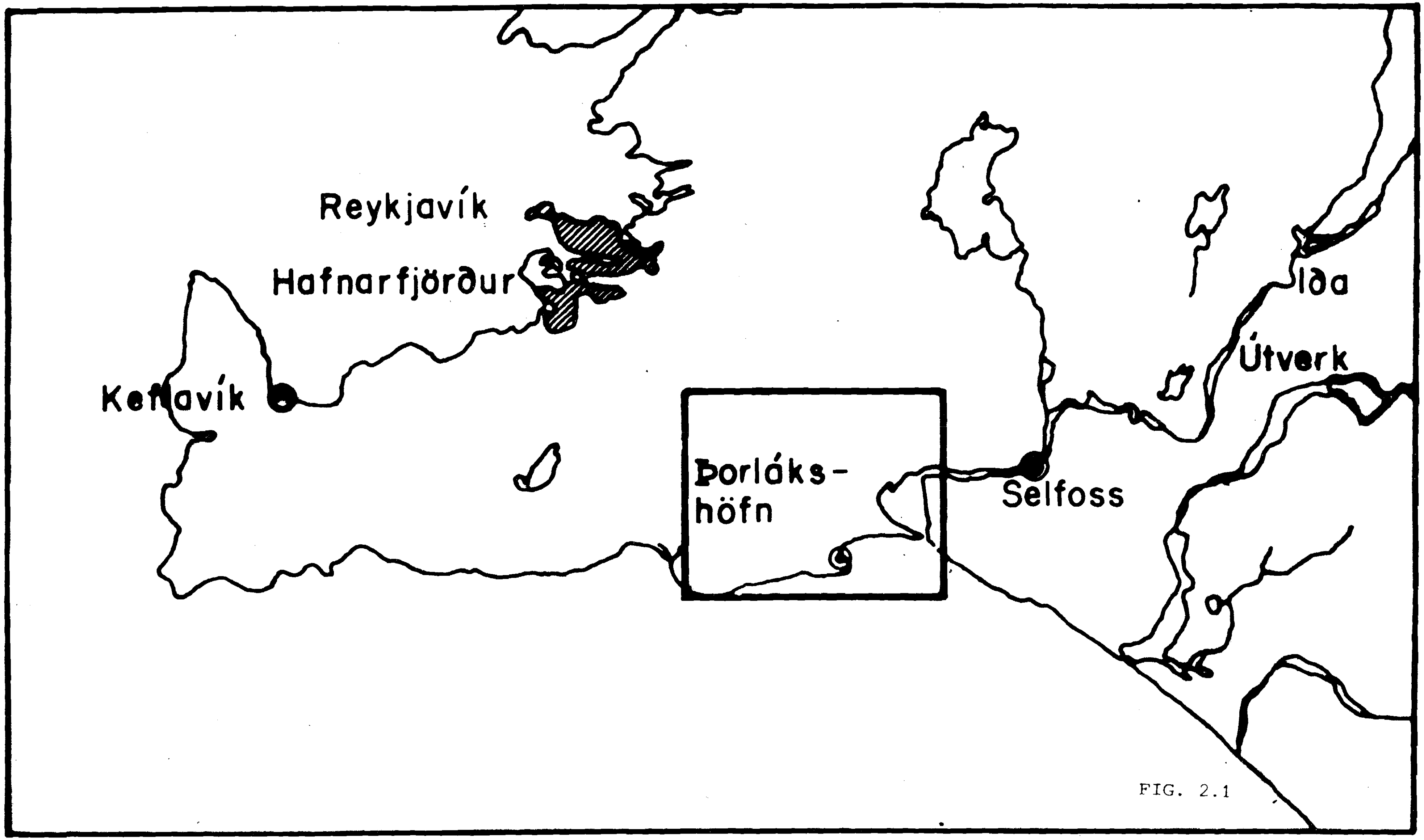


FIG. 2.1

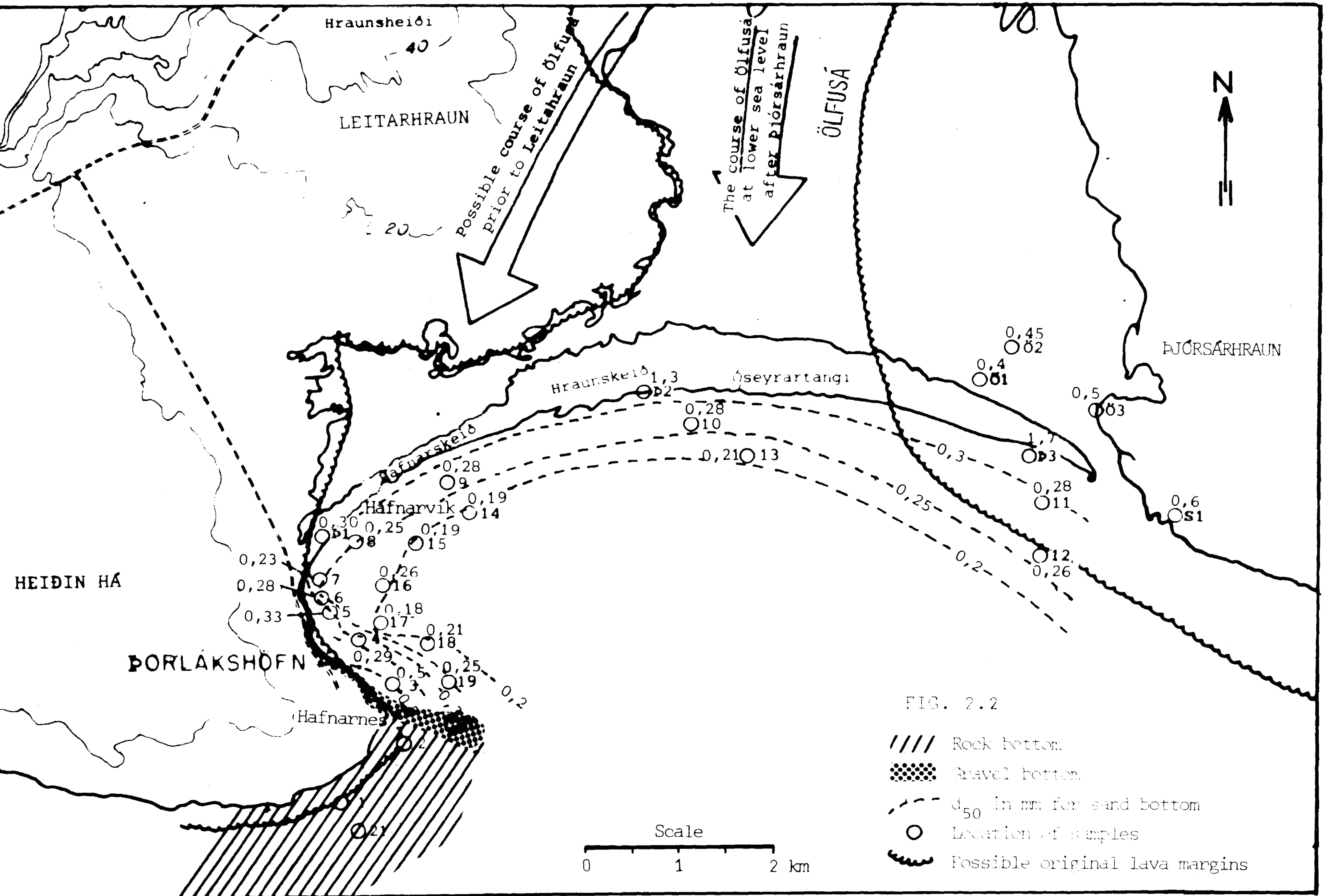

Hraunsheiði
40
20
LEITARHRAUN
Possible course of Ölfusá prior to Leitahraun
The course of Ölfusá at lower sea level after Þjórsárhraun
ÖLFUSÁ
N
ÞJÓRSÁRHRAUN
Hraunskeið
Óseyrartangi
Hafnarskeið
Háfnarvík
HEIÐIN HÁ
ÞORLÁKSHÖFN
Hafnarnes
Scale
0
1
2 km
Rock bottom
Gravel bottom
d_{50} in mm for sand bottom
Location of samples
Possible original lava margins

FIG. 2.2

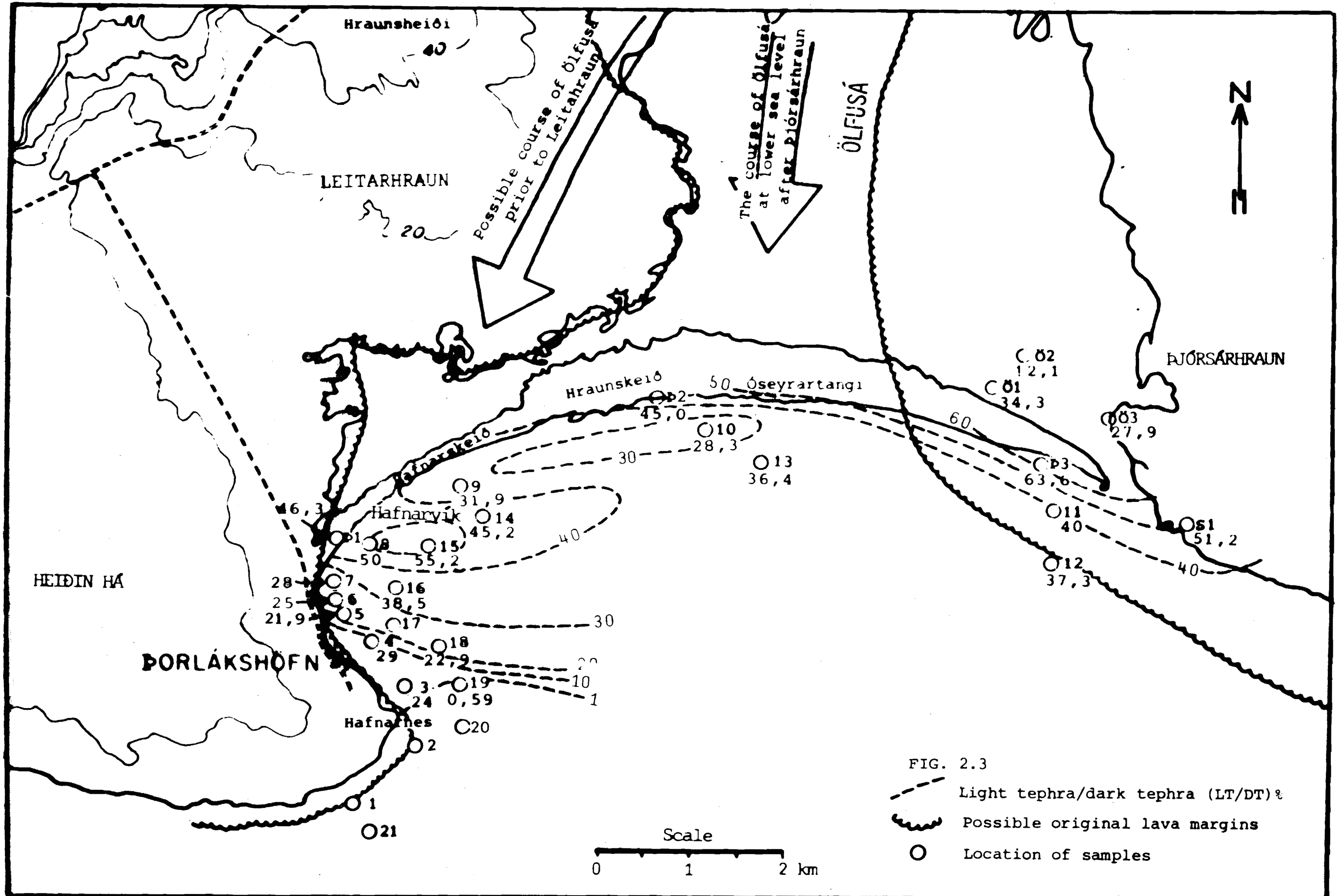


FIG. 2.3

Light tephra/dark tephra (LT/DT)%

Possible original lava margins

Location of samples

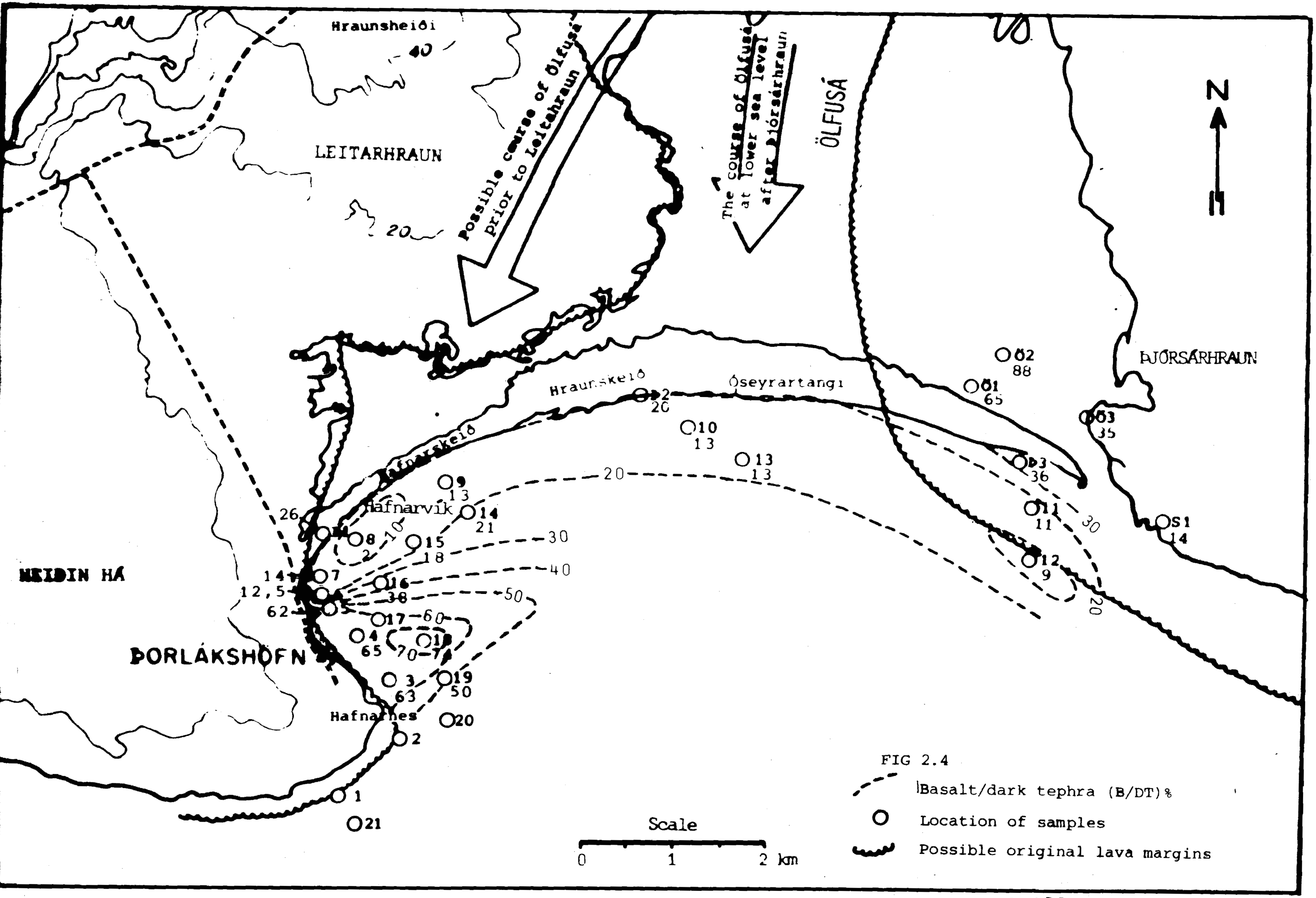


FIG 2.4

B-175 TNR 12 FNR 11594

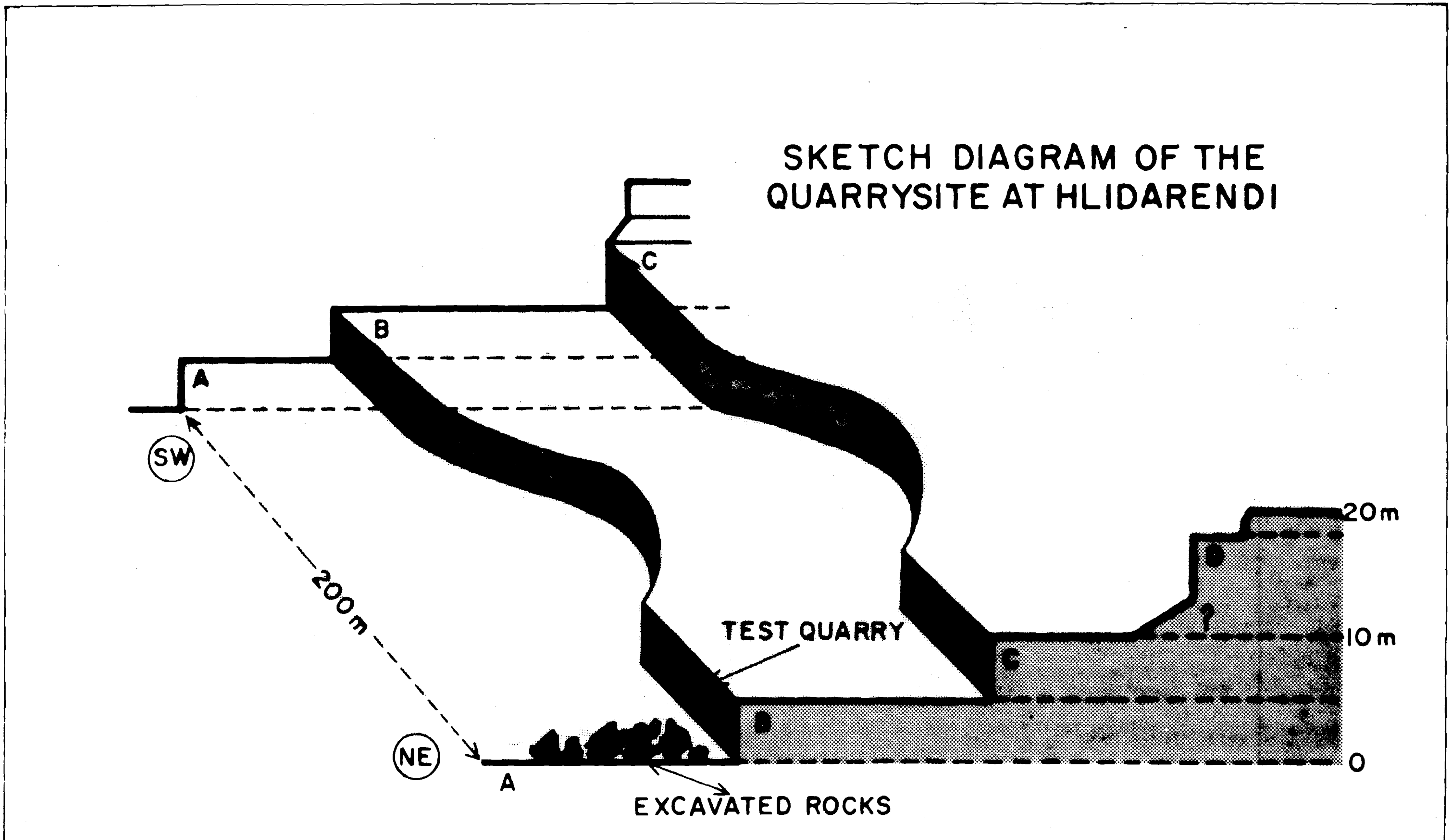
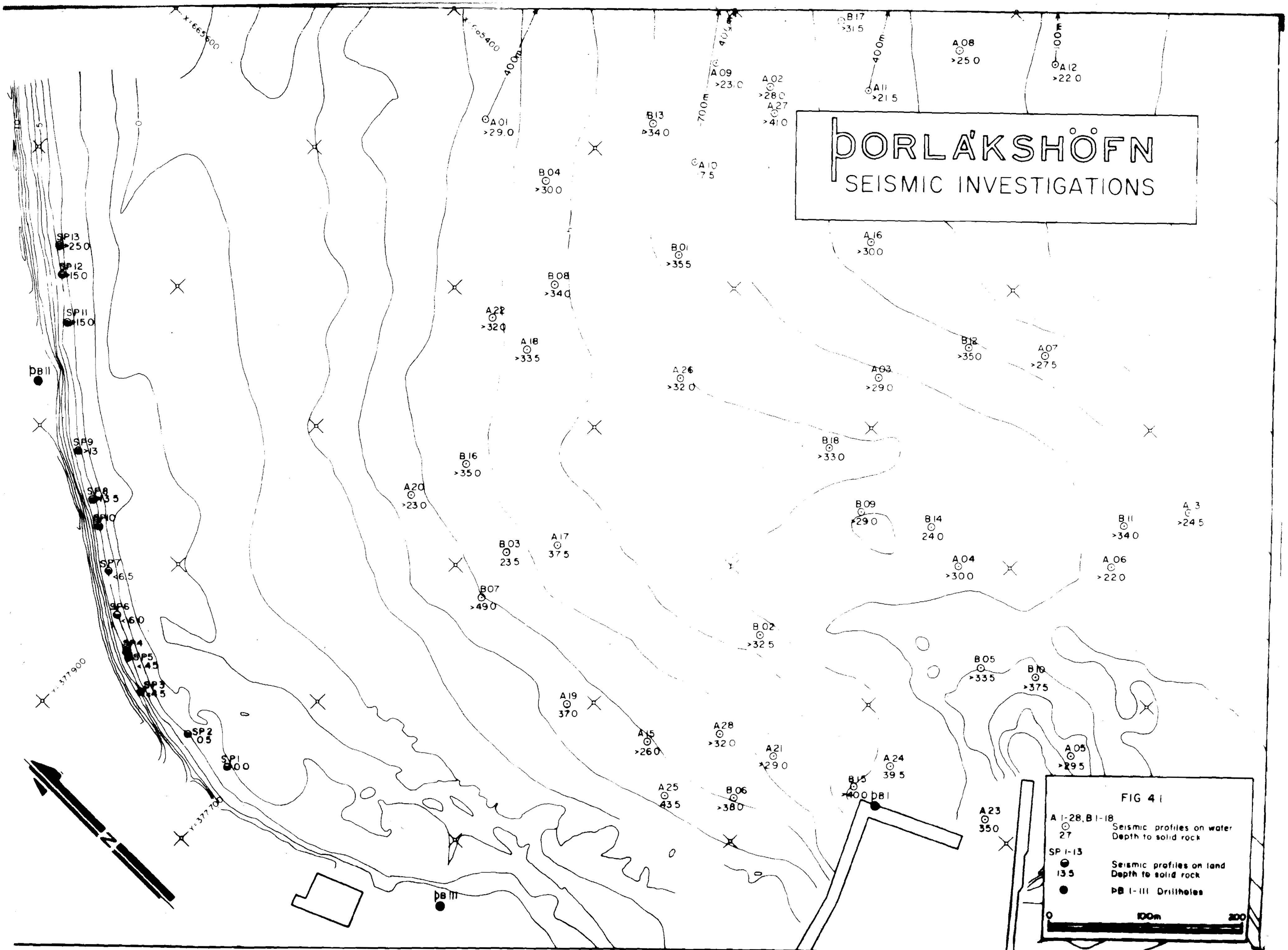


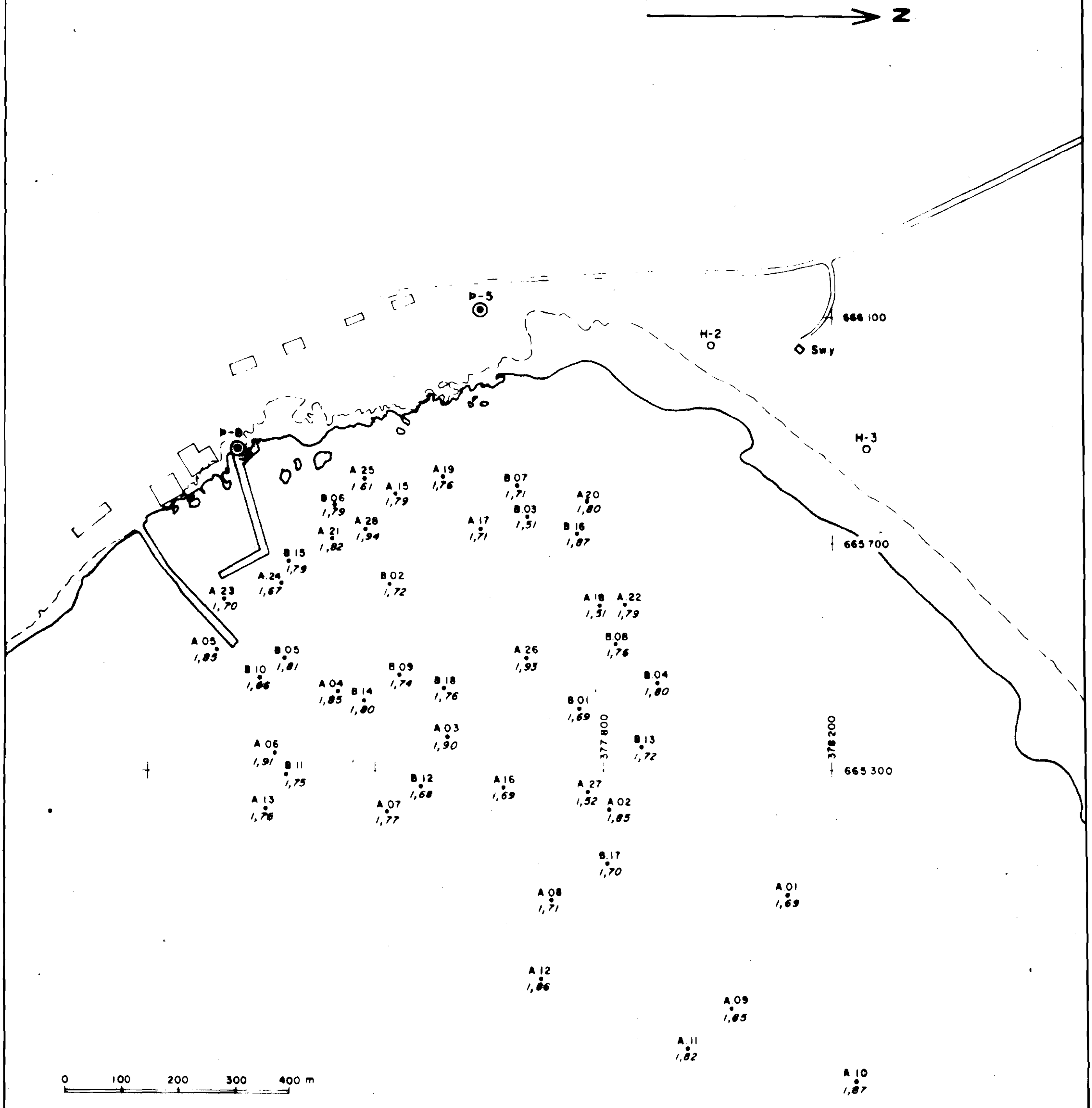
FIG. 3.1

Tnr. 10 B-175 Fnr. 11587



ÞORLÁKSHÖFN
SEISMIC INVESTIGATIONS
FIG 4.1
A 1-28, B 1-18
27
Seismic profiles on water
Depth to solid rock
SP 1-13
13.5
Seismic profiles on land
Depth to solid rock
ÞB I-III Drillholes
0
100m
200
N
SP13 >25.0
SP12 >15.0
SP11 >15.0
SP9 >13
SP8 >13.5
SP10
SP7 <6.5
SP6 <6.0
SP4
SP5 <4.5
SP3 <4.5
SP2 0.5
SP1 0.0
ÞB II
ÞB III
ÞB I
A 01 >29.0
A 09 >23.0
A 02 >28.0
A 27 >41.0
A 11 >21.5
A 08 >25.0
A 12 >22.0
B 17 >31.5
B 13 >34.0
A 10 7.5
B 04 >30.0
B 01 >35.5
A 16 >30.0
B 08 >34.0
A 22 >32.0
A 18 >33.5
A 26 >32.0
A 03 >29.0
B 12 >35.0
A 07 >27.5
B 18 >33.0
B 16 >35.0
A 20 >23.0
B 09 >29.0
B 14 24.0
B 11 >34.0
A 3 >24.5
B 03 23.5
A 17 37.5
A 04 >30.0
A 06 >22.0
B 07 >49.0
B 02 >32.5
B 05 >33.5
B 10 >37.5
A 19 37.0
A 15 >26.0
A 28 >32.0
A 21 >29.0
A 24 39.5
A 05 >29.5
A 25 43.5
B 06 >38.0
B 15 >40.0
A 23 35.0
400m
700m
100m

FIG. 4.2



ORKUSTOFNUN

Þorlákshöfn
Location of seismic profiles and velocity in bottom sediment

14.11.73	GS/SL	Tnr 4 B-172	Fnr. 11522

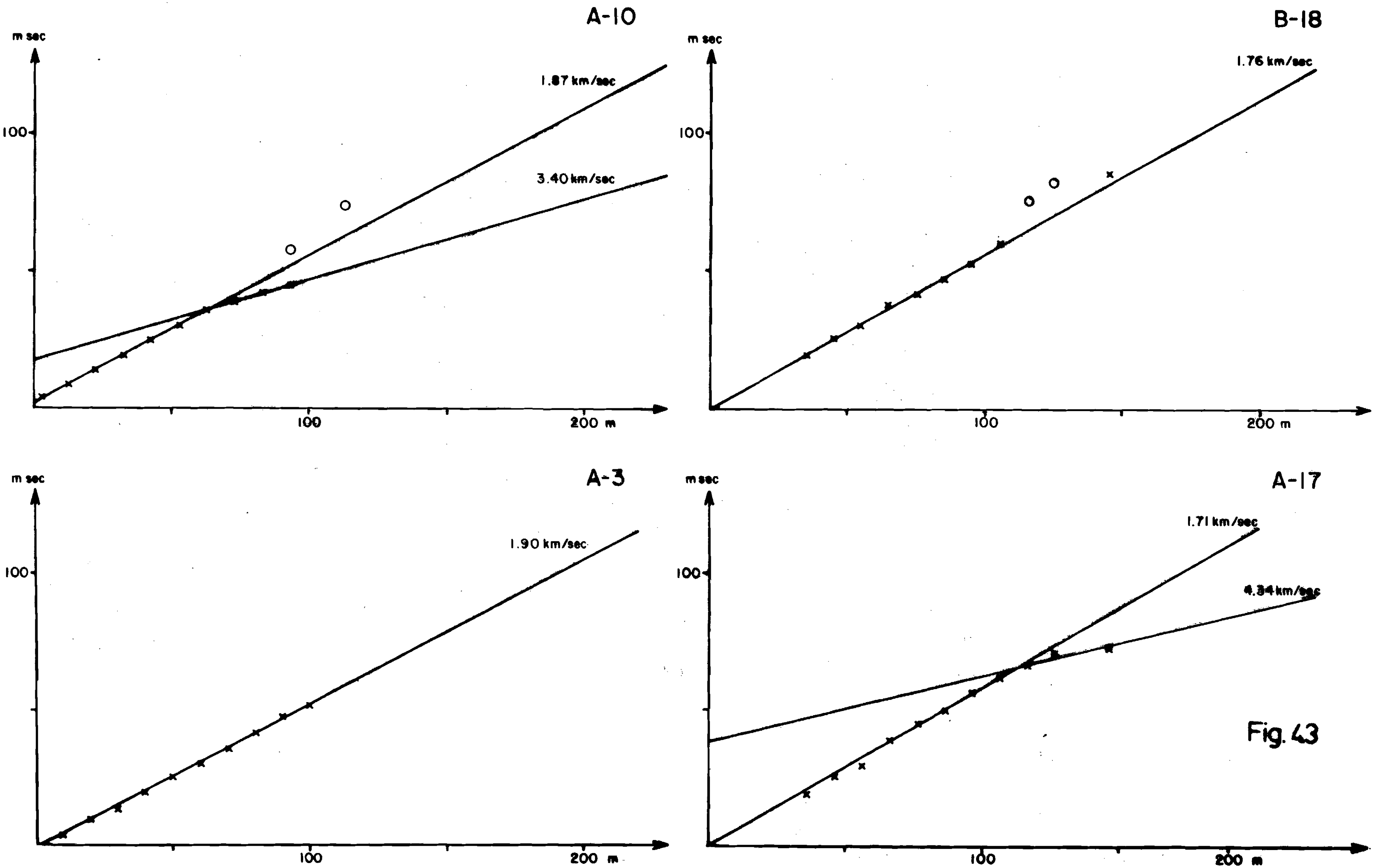


Fig. 43

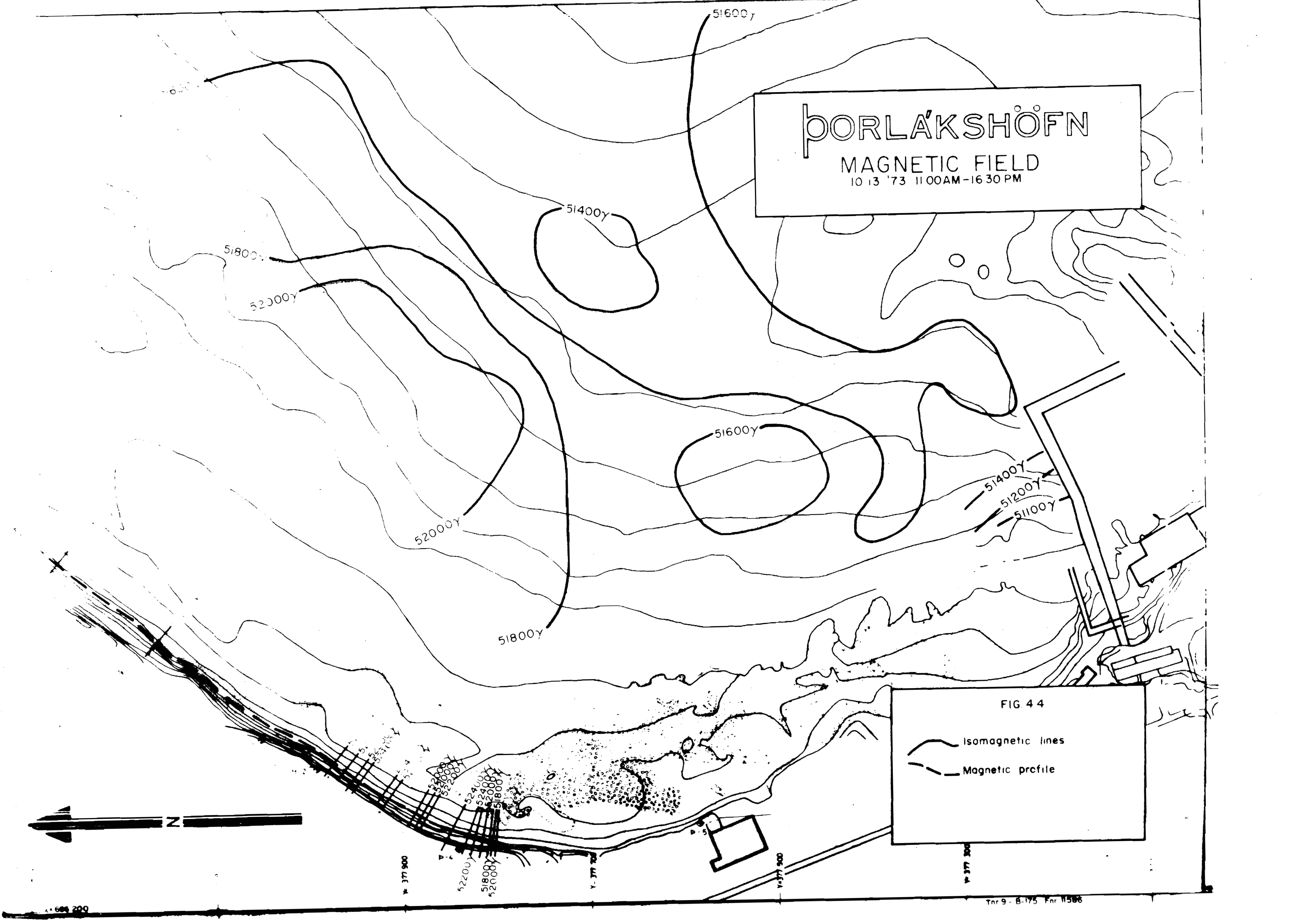
ORKUSTOFNUN

ÞORLÁKSHÖFN

Representative seismic refraction diagrams

Tnr. 23
B-175

Fnr. 11605



Þorlákshöfn
MAGNETIC FIELD
10 13 '73 11 00 AM - 16 30 PM
FIG 4 4
Isomagnetic lines
Magnetic profile
51600γ
51400γ
51800γ
52000γ
51600γ
52000γ
51800γ
51400γ
51200γ
51100γ
52400γ
52200γ
51800γ
N
Tnr 9 - B-175 Fnr 11586

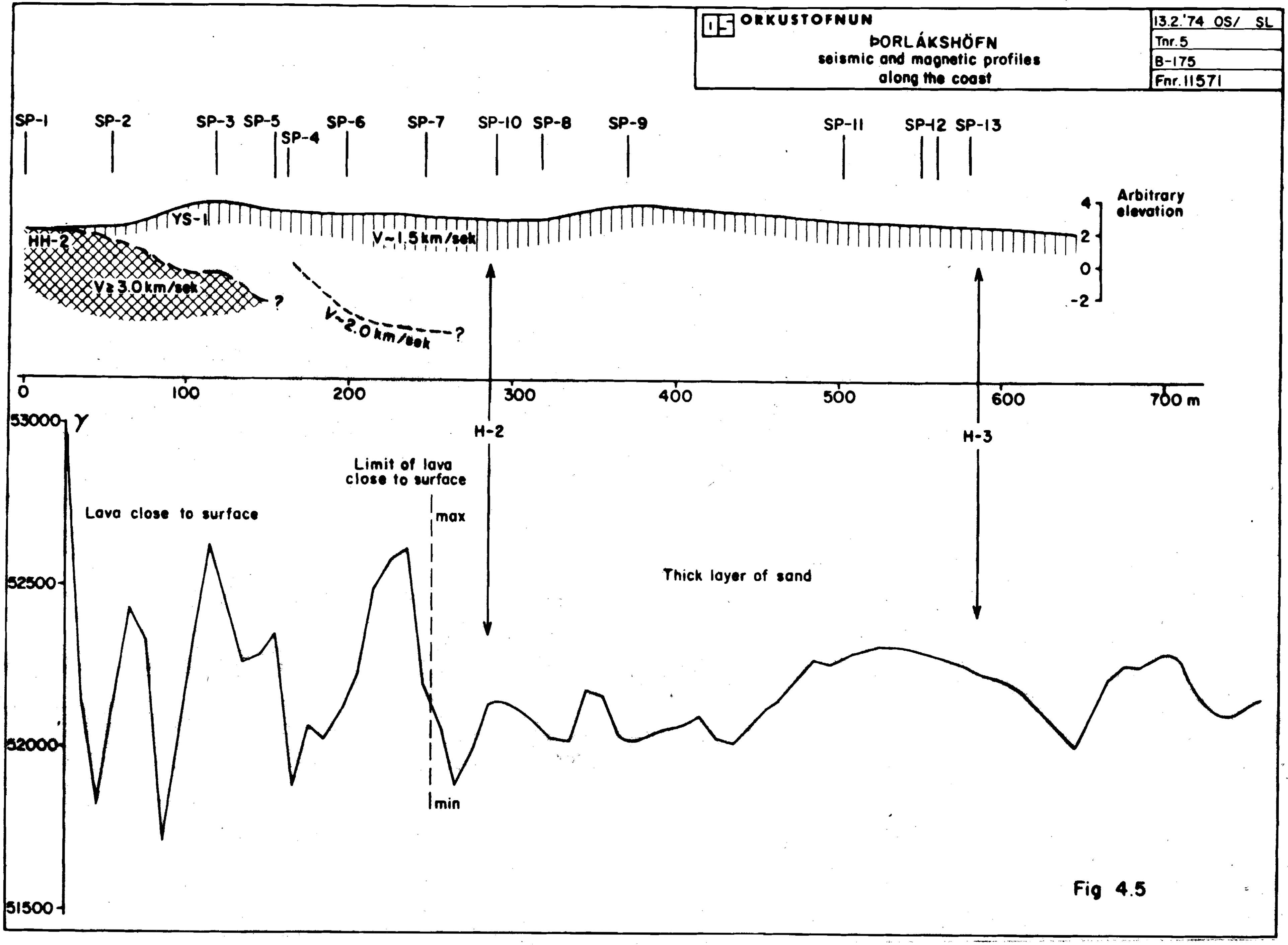
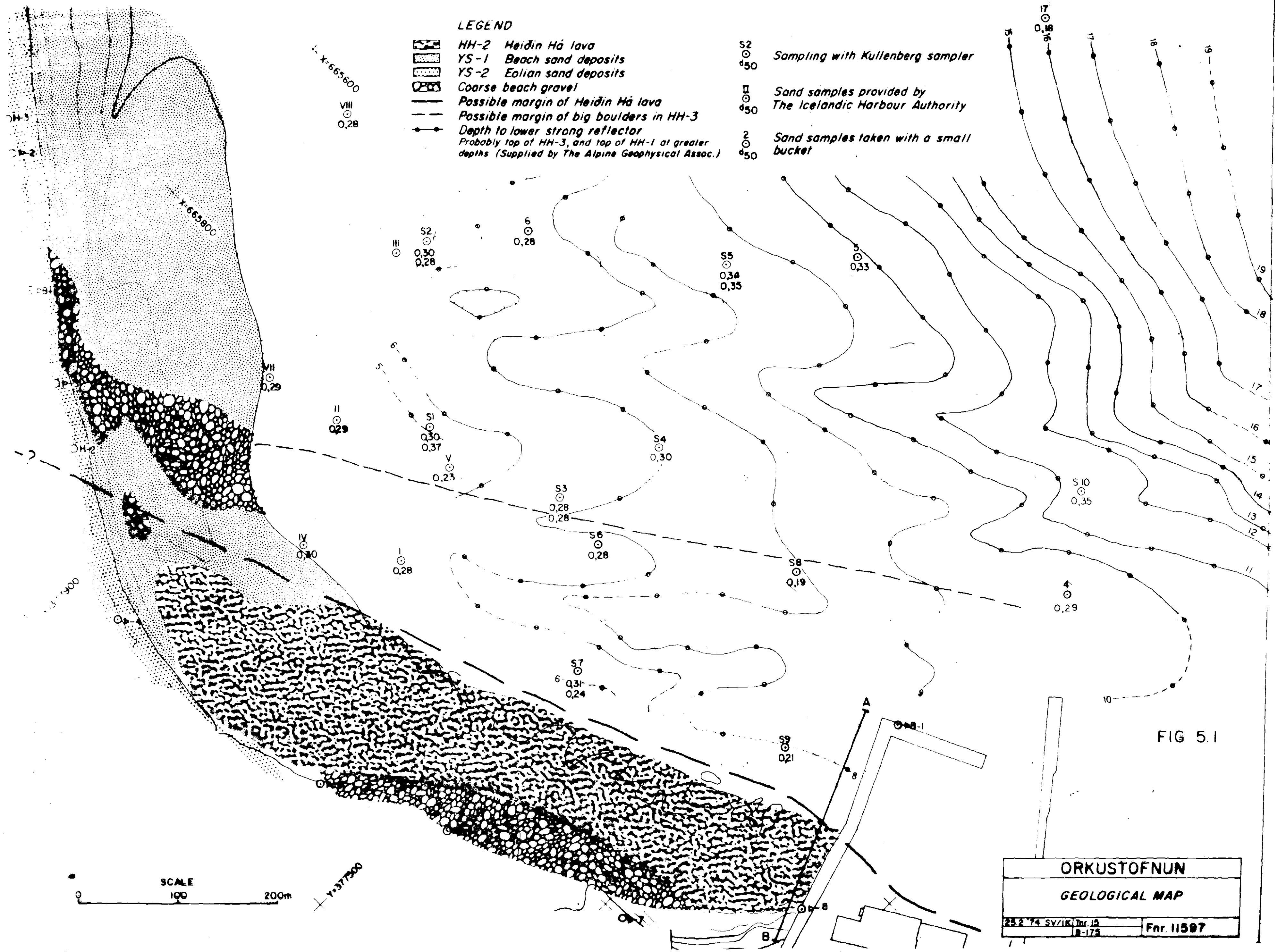

ORKUSTOFNUN
ÞORLÁKSHÖFN
seismic and magnetic profiles
along the coast
13.2.'74 OS/ SL
Tnr.5
B-175
Fnr.11571
SP-1
SP-2
SP-3
SP-5
SP-4
SP-6
SP-7
SP-10
SP-8
SP-9
SP-11
SP-12
SP-13
Arbitrary elevation
4
2
0
-2
YS-1
HH-2
V~1.5km/sek
V≥3.0km/sek
V~2.0km/sek
?
0
100
200
300
400
500
600
700 m
53000
52500
52000
51500
γ
H-2
H-3
Limit of lava close to surface
max
min
Lava close to surface
Thick layer of sand

Fig 4.5



LEGEND
HH-2 Heiðin Há lava
YS-1 Beach sand deposits
YS-2 Eolian sand deposits
Coarse beach gravel
Possible margin of Heiðin Há lava
Possible margin of big boulders in HH-3
Depth to lower strong reflector
Probably top of HH-3, and top of HH-1 at greater depths (Supplied by The Alpine Geophysical Assoc.)
S2 d_{50} Sampling with Kullenberg sampler
II d_{50} Sand samples provided by The Icelandic Harbour Authority
2 d_{50} Sand samples taken with a small bucket
X=665600
X=665800
Y=377500
SCALE
0
100
200m
ORKUSTOFNUN
GEOLOGICAL MAP
25.2.'74 SV/IK
Fnr. 11597

FIG 5.1

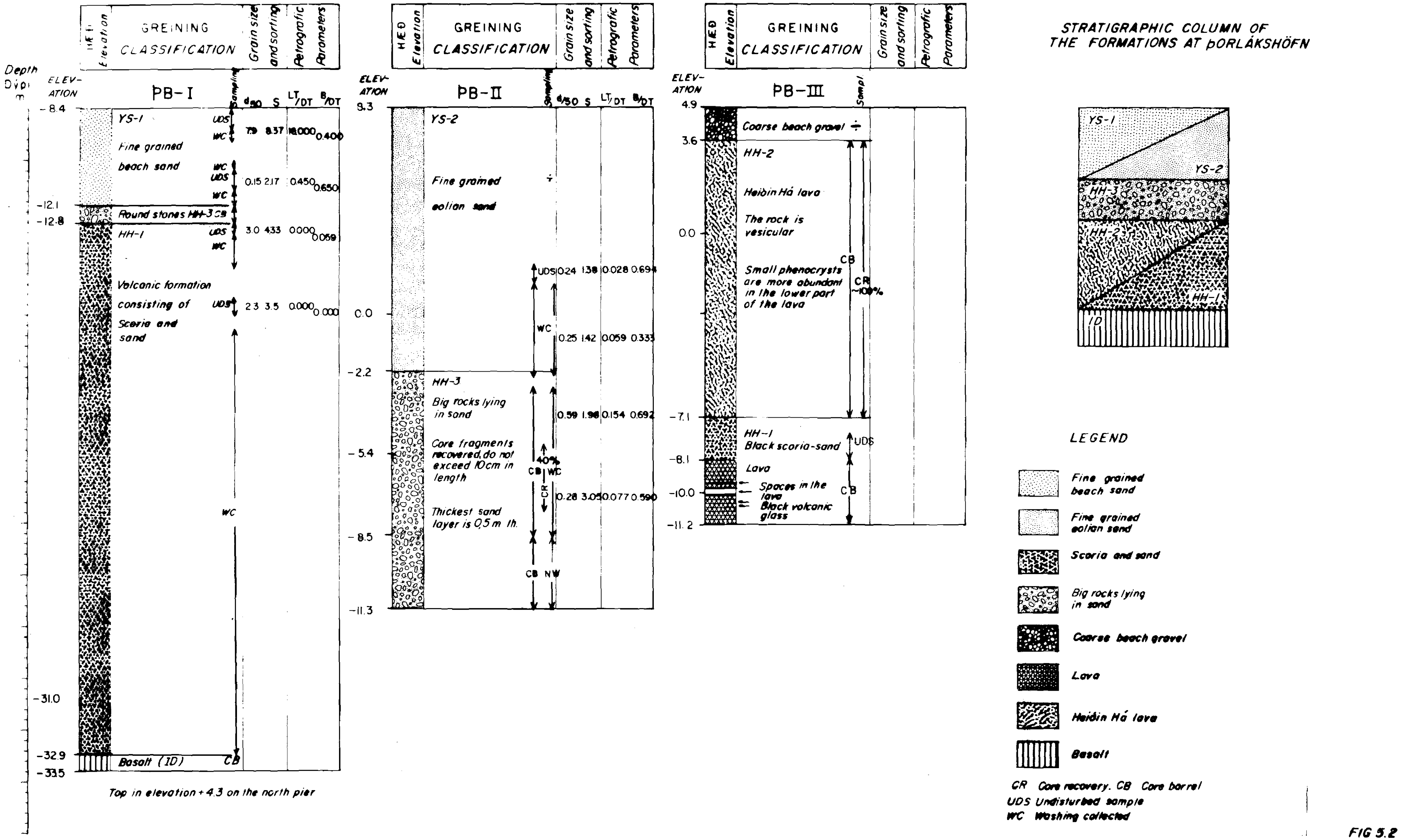
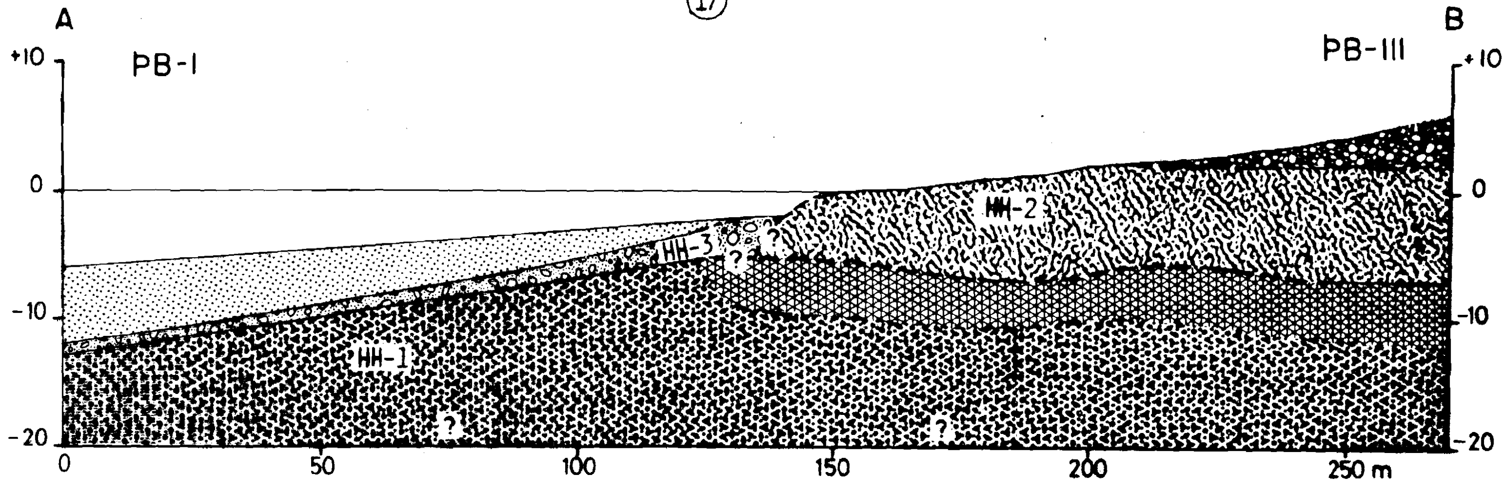


FIG 5.2

ORKUSTOFNUN		
ÞORLÁKSHÖFN		
Graphic Core Logs B-I, II, III Stratigraphic Colum		
28.12.'73 HT/P	Tnr. 24 / B-175	FNR. 11606

(17)



LEGEND

HH-1 SCORIA-SAND
HH-1 SCORIA-SAND AND PILLOW LAVA
HH-2 HEIDIN HA LAVA
HH-3 LAYER OF ROUNDED BOULDERS
YS-1 MARINE SAND DEPOSITS
COARSE BEACH GRAVEL

ALL ELEVATIONS ARE RELATIVE TO MEAN LOW WATER SPRINGTIDE

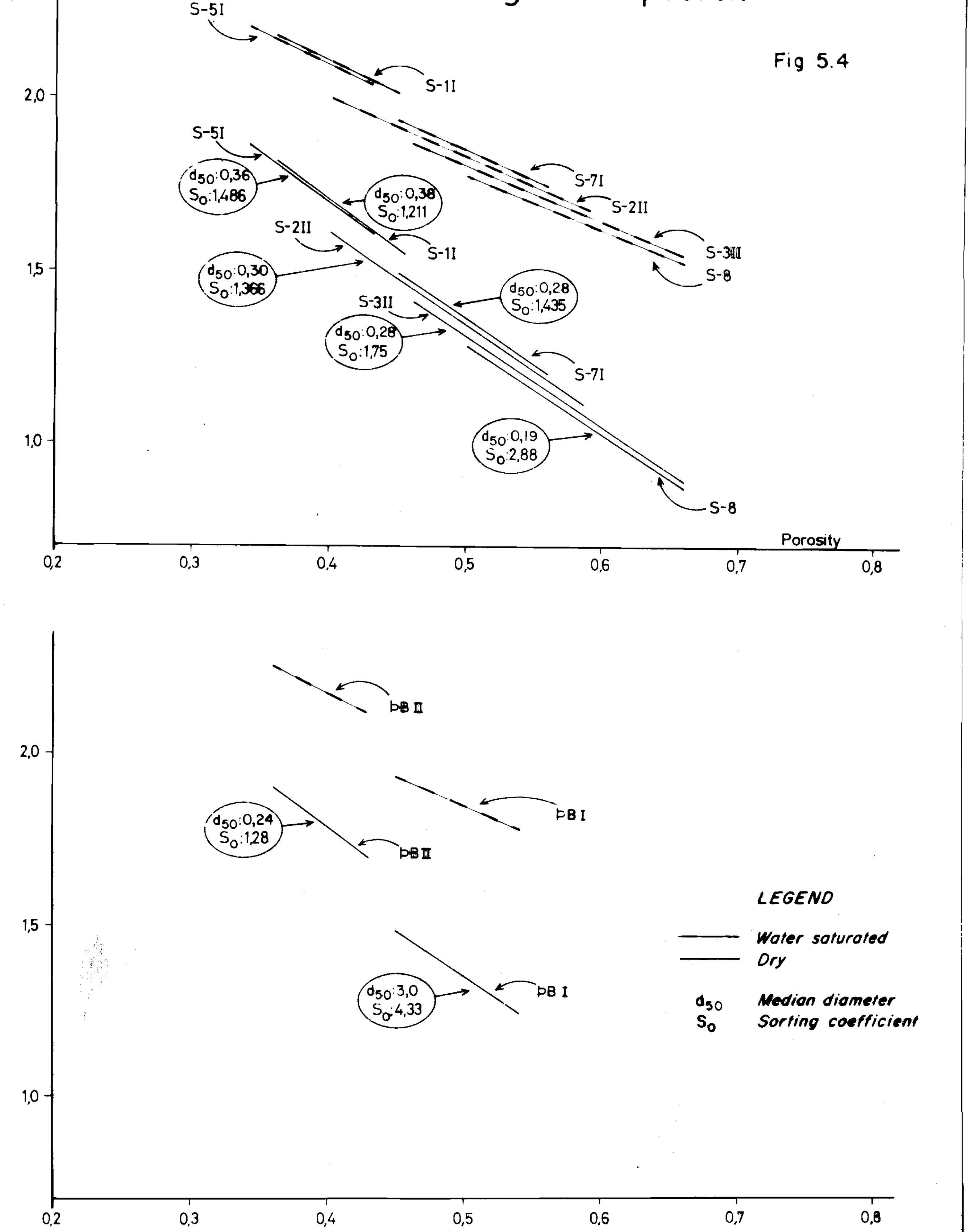
FOR LOCATION SEE FIG 5.1

Fig 5.3

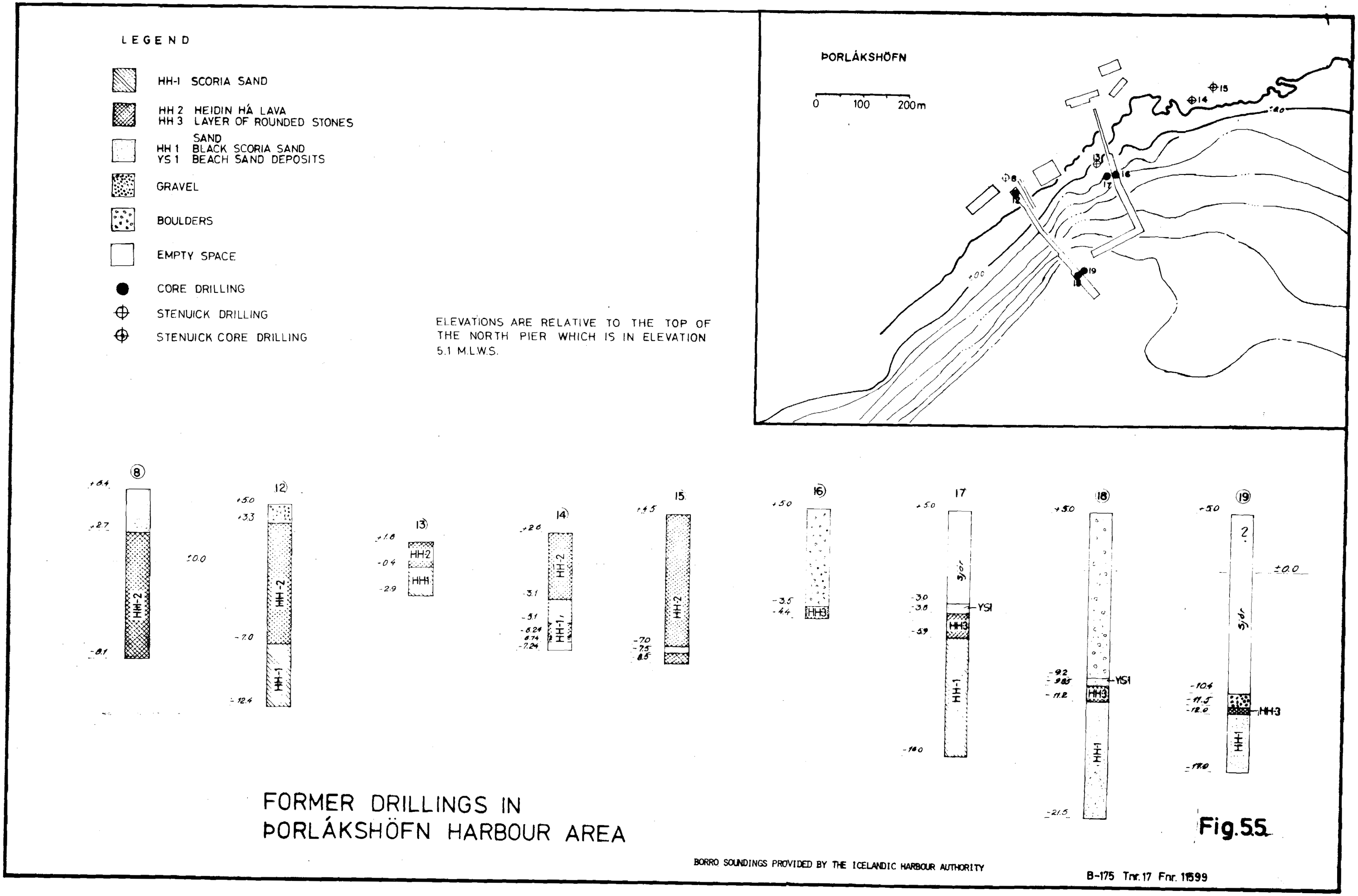
ORKUSTOFNUN	22.12.74 HT/
GEOLOGICAL SECTION IN THE HARBOUR AREA	Tnr. 14
	B-175
	Fnr. 11596

Range of compaction

Fig 5.4



OS ORKUSTOFNUN	23.12.'73
	Tnr. 15
RANGE OF COMPACTION	B-175
	Fnr. 11598



FORMER DRILLINGS IN
ÞORLÁKSHÖFN HARBOUR AREA

Fig.55.

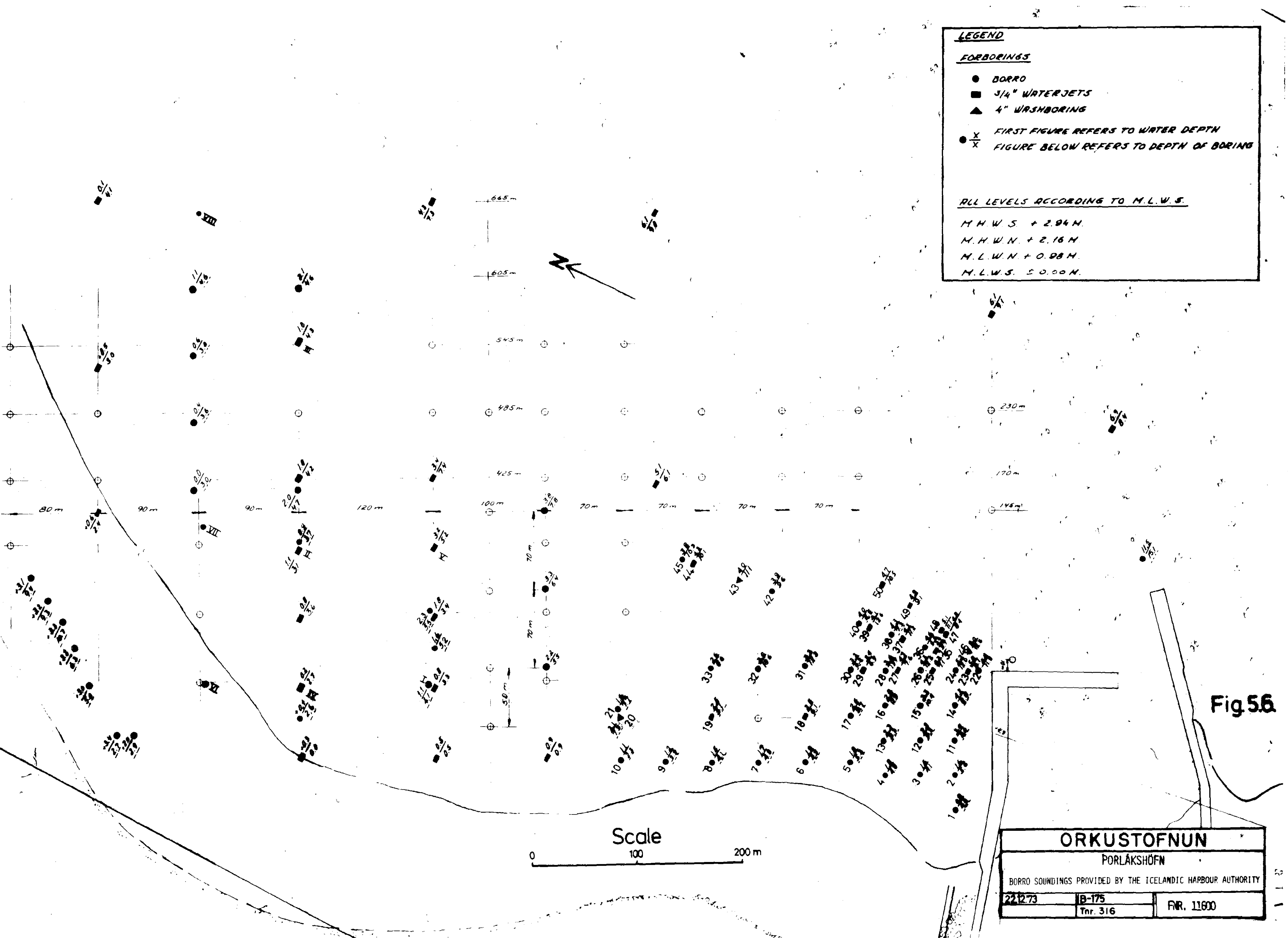
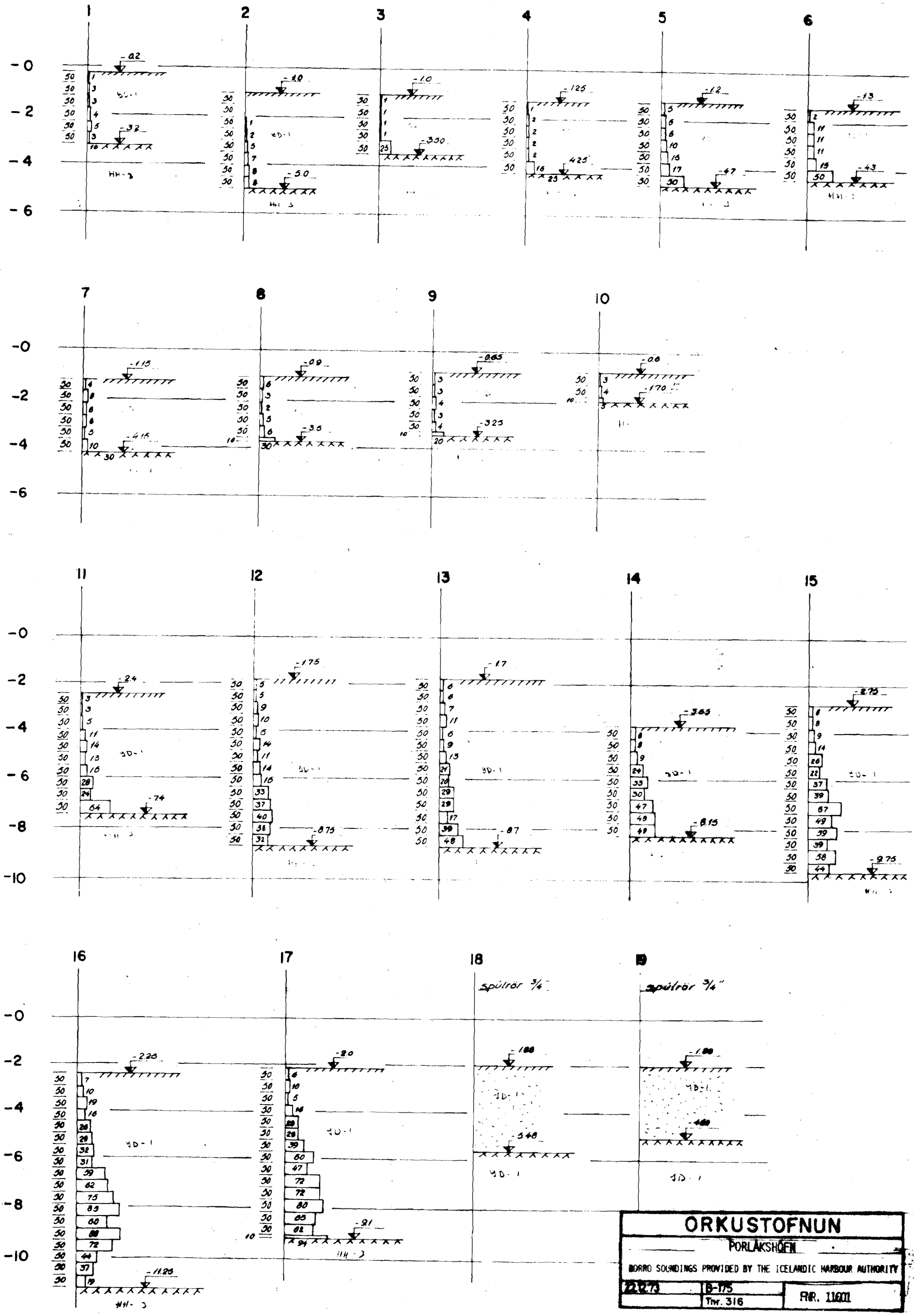

LEGEND
FORBORINGS
BORRO
3/4" WATERJETS
4" WASHBORING
FIRST FIGURE REFERS TO WATER DEPTH
FIGURE BELOW REFERS TO DEPTH OF BORING
ALL LEVELS ACCORDING TO M.L.W.S.
M.H.W.S. + 2.94 M.
M.H.W.N. + 2.16 M.
M.L.W.N. + 0.98 M.
M.L.W.S. ± 0.00 M.
Scale
0
100
200 m
ORKUSTOFNUN
ÞORLÁKSHÖFN
BORRO SOUNDINGS PROVIDED BY THE ICELANDIC HARBOUR AUTHORITY
22.12.73
B-175
Tnr. 316
FNR. 11600

Fig. 5.6

Fig.57.



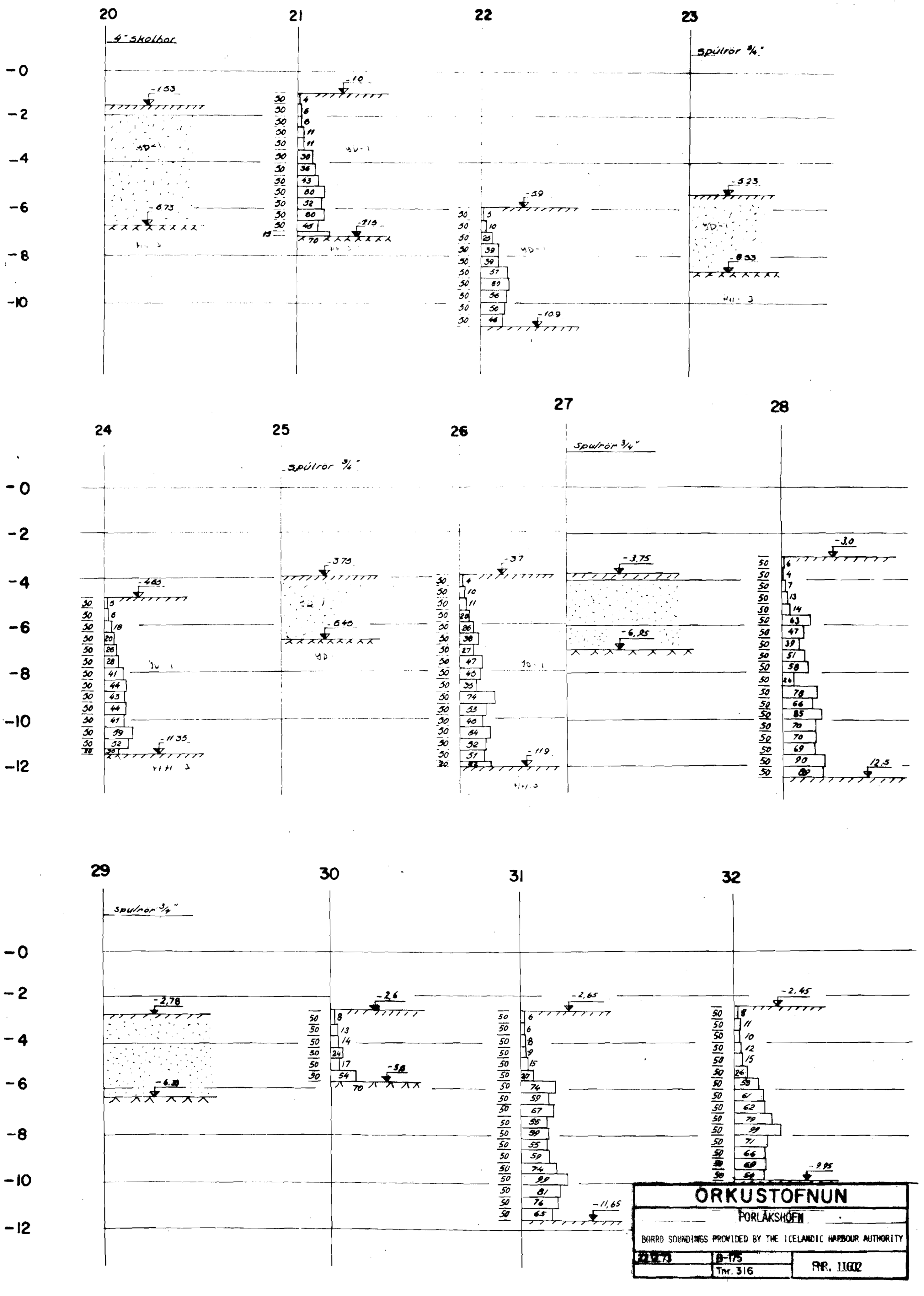
ORKUSTOFNUN

ÞORLÁKSHÖFN

BORRO SOUNDINGS PROVIDED BY THE ICELANDIC HARBOUR AUTHORITY

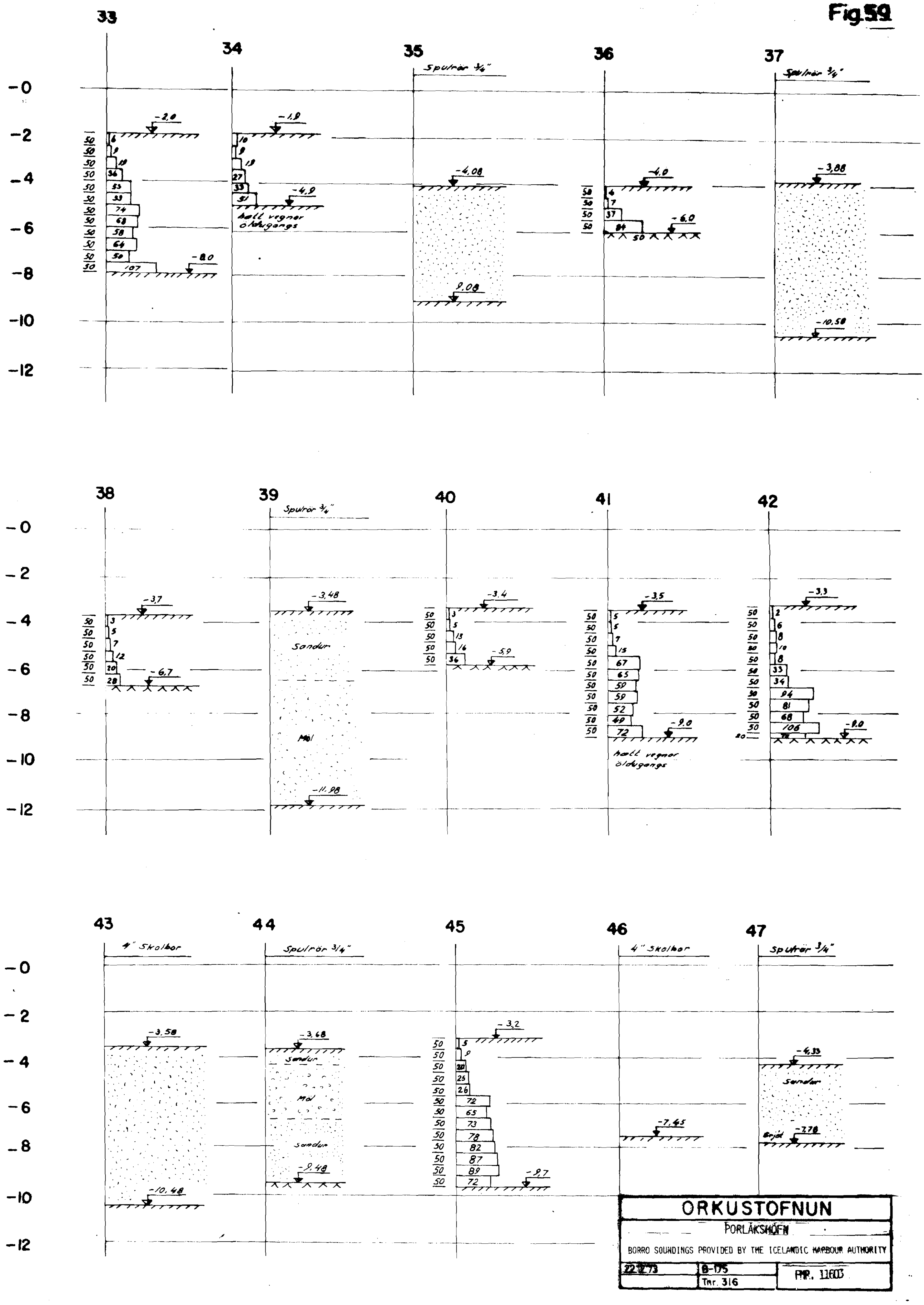
22.12.73 | B-175 | Tnr. 316 | FNR. 11601

Fig.58



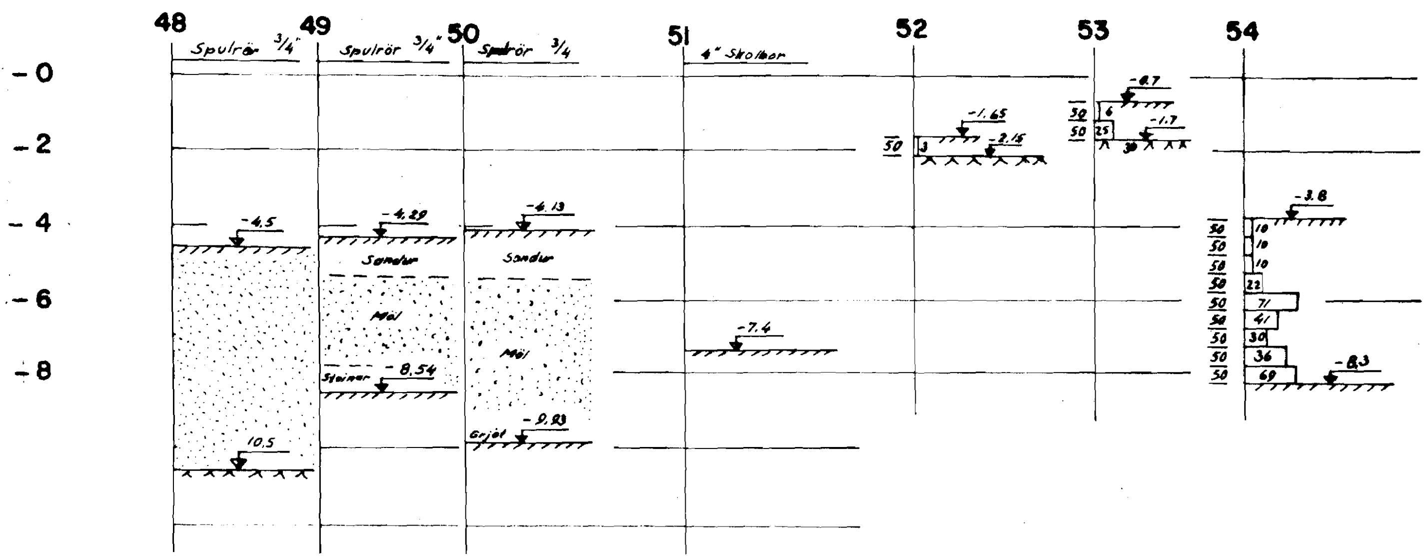
20
21
22
23
24
25
26
27
28
29
30
31
32
4" skelbor
spúlrör 3/4"
-0
-2
-4
-6
-8
-10
-12
ORKUSTOFNUN
ÞORLÁKSHÖFN
BORRO SOUNDINGS PROVIDED BY THE ICELANDIC HARBOUR AUTHORITY
Tnr. 316
FNR. 11602

Fig.59



33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
-0
-2
-4
-6
-8
-10
-12
Spulrör 3/4"
4" Skolbor
hall vegnar öldugangs
Sandur
Möl
-2,0
-8,0
-1,9
-4,9
-4,08
-9,08
-4,0
-6,0
-3,88
-10,58
-3,7
-6,7
-3,48
-11,98
-3,4
-5,9
-3,5
-9,0
-3,3
-9,0
-3,58
-10,48
-3,68
-9,48
-3,2
-9,7
-7,45
-4,33
-7,78
ORKUSTOFNUN
ÞORLÁKSHÖFN
BORRO SOUNDINGS PROVIDED BY THE ICELANDIC HARBOUR AUTHORITY
22.12.73
B-175
Tnr. 316
FNR. 11603

Fig5.10



LOCATION SEE FIG. 5.6

ORKUSTOFNUN		
ÞORLÁKSHÖFN		
BORRO SOUNDINGS PROVIDED BY THE ICELANDIC HARBOUR AUTHORITY		
22.12.'73	B-175	FNR. 11004
	Tnr. 316	

APPENDIX 1

Drill Logs

ÞB-I

This hole is located on the north pier. The top of the hole is at elevation + 4.3 M. L. W.S. (according to the Icelandic Harbour Authority) and has coordinates approximately

x : 665668
y : 377220

Actual drilling in the bottom sediments started at elevation - 8.4 M. L. W.S. (see fig. 5.2).

÷ 8.4 - ÷ 12.1	(YS - 1)	Fine grained sand The undisturbed sample from elevation 8.4 - 9.2 M. L. W.S. shows bimodal grain size distribution with a very high light tephra/dark tephra ratio (LT/DT). When compared to the LT/DT ratios further down in this hole, and also in other holes it is clear that there one must be dealing with a layer of light tephra. Further down the amount of tephra decreases.
÷ 12.1 - ÷ 12.8	(HH 3)	This is a hard layer. Using a core barrel 4 small pieces of stones were recovered. One of the stones has a clearly round surface indicating marine erosion. This and the character of the drilling indicate that this layer is made of rounded stones.

÷ 12.8 - ÷ 32.9	(HH 1)	Volcanic formation. The material consists of scoria and sand. The material is petrographically extremely homogeneous as indicated by the LT/DT ratio and the grains are very angular indicating little marine erosion and mixing.
÷ 32.9 - ÷ 33.5	(ID)	Basaltic rock. No traces of volcanic glass were found in the core. This is therefore not likely to be a pillow lava. The depth at which this rock is found indicates it to be an interglacial basaltic lava. One should therefore expect a marine or glacial sediments on top of it. This is not recognised. This may be due to the fact that when not mixed with tephra, it is hard to distinguish between the volcanic scoria and dark marine sand.

<u>ÞB-II</u>

The hole is located on sand dunes, approximately 1 km north pier in Þorlákshöfn. It has coordinates

x : 665968.64
y : 378132.59

and the top is at 7.98 m above mean low sea level. The dept is 19.3 m.

+ 8.0 - ÷ 2.2	(YS - 2)	Fine sand, small amount of fine grained light coloured tephra. The topmost 5 m are exposed on the beach in the sand dunes, and the material looks similar down to ÷ 2.2 m. A characteristic of this sand is the great sorting and the uniformity of the material through the formation.

÷ 2.2 - ÷ 11.3		Formation related to the Þorlákshöfn lava. This formation is not a lava, but more likely consists of stones, lying in sand. A few rounded pebbles were recovered. Core fragments recovered, do not exceed 10 cm in length. Thickest continuous layer of sand was around 0.5 m thick.

ÞB-III

This hole is located on the coast approximately 360 m north of the north pier at Þorlákshöfn. The top of the hole is at elevation 4.88 M.L.W.S. the depth is 16.1 m and its coordinates are

x : 666059.27
y : 377464.64

4.9 - 3.6		Coarse beach gravel. This gravel is found along the coast on top of the lava.
3.6 - ÷ 7.1	(HH-2)	Heiðin Há lava. The rock is very vesicular. Unbroken core fragments reach up to 1 m in length. Plagioclase phenocrysts are hardly visible in the higher part of the lava but become more abundant near the bottom.
÷ 7.1 - ÷ 8.7	(HH-1)	Black scoria. The grains are angular and the material is petrographically very homogeneous and coarse grained.
÷ 8.7 - ÷ 11.2	(HH-1)	This is a lava formation. The rock is not as vesicular as the lava above, and is not continuous, but there occur spaces in it. Unfortunately no data is available on the infillings of

these spaces since all washing was lost in this formation.

The volcanic glass indicates rapid cooling in water. No rounded stones were recovered and the lava is more continuous than in the lower formation in ÞB-II. This formation is therefore not likely to be big boulders lying in sand.

A quick look at the petrology of this formation and the lava above reveals considerable difference. This difference could either be due to actual chemical difference between two lavas or due to different cooling environment.

The nature of the scoria, the top of the lower formation and the volcanic glass seem to indicate that the lower lava formation is the subaqueous form of the Heiðin Há lava but not a separate volcanic formation.

Since volcanic glass is not very abundant it is likely that we are dealing with large pillows, which could also to some extent explain the spaces in the lava.

APPENDIX 2. Petrological examinations and density determinations

SAMPLE NO	THIN SECTION NO	GRAIN SIZE mm	PETROLOGICAL COMPOSITION % OPAQUE	DARK GLASS n>1.54	LIGHT GLASS n<1.54	ALTERED GLASS	BASALT	GABBRO	RHYOLITE	SEDIMENT	PLAGIO-CLASE	PYROXENE	OLIVINE	CALCITE	ZEOLITE	QUARTZ	No OF GRAINS COUNTED	DENSITY	
K-753 PB-I	2510	0.42-0.85	sp.	5	90		2	3									269	2.08	
—	2502	0.21-0.42	5	27	55	3	4	1	1		1	sp	sp	2			581	2.44	
—	2503	0.105-0.21	7	32	36	4	11	1	1		4	1	sp.	1	1		695	2.68	
K-754 PB-I	2511	0.21-0.42	3	30	50	2	11	4	sp.				sp.		sp.		310	2.49	
—	2504	0.105-0.21	5	40	18	3	26	2			2	3			sp.	sp.	932	2.88	
—	2505	0.053-0.105	4	41	9	1	28	2			5	8	sp.		1		299	2.91	
K-755 PB-I		4-8																2.87	
—	2506	2-4		83			8	9									206	2.89	
—	2507	0.85-2		85			5	10									271	2.91	
K-756 PB-I		4-8																2.85	
—	2508	2-4		99		1											154	2.87	
—	2509	0.85-2	1	97		1		1									294	2.88	
K-757 PB-II	4213	0.21-0.42	13	36	1	3	25	12	sp.	sp	6	2	1		sp.		857	2.90	
—	4212	0.105-0.21	11	27	sp	3	33	12	sp.	sp.	2	7	4				846	3.05	
K-758 PB-II	4215	0.21-0.42	11	51	3	4	17	6	1		5	1	1		sp.	sp.	607	2.85	
—	4214	0.105-0.21	16	28	sp	3	28	10	sp.		4	7	3		sp.		797	2.98	
K-759 PB-II	4218	0.85-2	4	26	9	1	10	50	sp								368	2.96	
—	4217	0.42-0.85	6	26	4	2	18	44									518	3.00	
—	4216	0.21-0.42	14	36	1	1	20	24	sp.		sp.	2	3				491	3.01	
K-760 PB-II	4220	0.21-0.42	13	39	3	2	23	16			1	1	2		sp.		614	2.96	
—	4219	0.105-0.21	17	29	1	2	27	15			1	5	5				645	3.04	
K-761 3	4239	0.42-0.85	15	42	1	1	22	12	1		1			4			348	2.91	
—	4238	0.21-0.42	15	38	1	2	24	10			6	2	1	1			421	2.95	
K-762 4	4241	0.21-0.42	19	35	1	2	23	11			4	3	1	1	sp.		547	2.96	
—	4240	0.105-0.21	10	27	1	2	31	10	sp		2	11	6	sp.		sp.	578	3.07	
K-763 5	4242	0.42-0.85	4	12	38	1	35	8			1	sp.		2	sp.	sp.	476	2.71	
—	4243	0.21-0.42	16	32	7	6	20	7	2	sp.	4	5	1	sp			506	2.92	s.z.
K-764 6	4245	0.21-0.42	20	40	10	15	5	2	1		6	1		1			524	2.79	s.z.
—	4244	0.105-0.21	16	39	3	3	23	7	sp.		2	4	1	1	sp.	sp.	642	2.94	
K-765 7	4247	0.21-0.42	10	50	14	8	7	1	1	sp.	3			4	1	1	358	2.71	
—	4246	0.105-0.21	19	30	3	7	28	4		sp.	6	2	sp.	1		1	341	2.92	
K-766 8		0.42-0.85																2.35	
—	4249	0.21-0.42	11	46	23	8	1	2	1	sp	1			4	1	1	563	2.70	
—	4248	0.105-0.21	17	39	5	5	20	6			5	2	sp.	1	1	1	677	2.91	
K-767 9	4250	0.21-0.42	10	47	15	10	6	5	sp	sp	5	sp		2		sp.	585	2.76	
—		0.105-0.21																2.94	
K-768 10		0.42-0.85																2.54	
—	4251	0.21-0.42	14	46	13	11	6	4	sp	1	3			1		1	519	2.75	
—		0.105-0.21																2.92	
K-769 11	4252	0.21-0.42	10	45	18	12	5	4	1	1	3	1		1		sp.	516	2.74	
—		0.105-0.21																2.89	
K-770 12		0.42-0.85																2.37	
—	4253	0.21-0.42	16	43	16	8	4	3	sp.		3	1		3			566	2.76	
—		0.105-0.21																2.95	
K-771 13	4254	0.21-0.42	15	44	16	9	6	4			4			3		1	540	2.75	
—		0.105-0.21																2.92	
K-772 14	4280	0.21-0.42	9	42	19	9	9	4	sp.	1	2	1		2		1	582	2.76	
—	4255	0.105-0.21	7	42	4	7	21	11	sp.		3	3	1	sp.		sp.	498	2.92	
K-773 15	4281	0.21-0.42	15	38	21	6	7	4	2		2	1	sp.	4		sp.	408	2.75	s.z.
—	4256	0.105-0.21	22	38	4	4	19	3	sp.	sp	3	3	sp.	2		sp.	558	2.90	
—		0.053-0.105																3.02	
K-774 16		0.42-0.85																2.35	
—	4257	0.21-0.42	13	39	15	6	15	3		sp	3	1	1	3	sp.	1	551	2.71	
—		0.105-0.21																2.86	
K-775 17		0.21-0.42																2.82	
—	4258	0.105-0.21	8	32	7	7	25	9			3	6	2	2			605	2.95	
—		0.053-0.105																2.98	
K-776 18	4259	0.21-0.42	9	35	8	2	26	11		sp	6	2	sp.	2	sp.	sp.	605	2.41	
—		0.105-0.21																2.98	
K-777 19	4260	0.21-0.42	36	34	2	3	17		1		3	2	sp.	2		1	557	2.91	s.z.
—		0.105-0.21																2.49	
K-779 I	2512	0.21-0.42	11	43	10	5	17	7	sp	sp.	5	1		1			681	2.84	
—		0.105-0.21																3.00	
K-780 V	2514	0.21-0.42	25	32	8	9	13	1	1		5	2	1	3			525	2.86	s.z.
—	2513	0.105-0.21	31	26	3	14	13		1		2	7	2	1			535	2.96	s.z.
K-781 VI	2515	0.21-0.42	13	37	7	4	21	7	sp.		7	1	1	1	sp.	sp.	736	2.91	
—		0.105-0.21																3.08	
K-782 II	2516	0.21-0.42	7	43	9	2	19	9	sp.		7	1	1	1			561	2.87	
—		0.105-0.21																3.00	
K-783 III	2517	0.21-0.42	8	47	12	3	17	5	sp.		4	sp.	1	1	1	sp.	624	2.83	
—		0.105-0.21																2.99	
K-784 IV	2518	0.21-0.42	9	42	16	7	13	5	sp.		4	1	1	sp.	sp.	sp.	568	2.80	
—		0.105-0.21																2.99	
K-785 VII	2519	0.21-0.42	12	32	8	3	30	6	sp.		4	1	1	1		sp.	638	2.87	
—		0.105-0.21																3.03	
K-786 VIII	4261	0.21-0.42	12	42	4	3	23	11	sp.	1	3	1	1	1	sp.		580	2.89	
—		0.105-0.21																3.09	

Fnr 10286

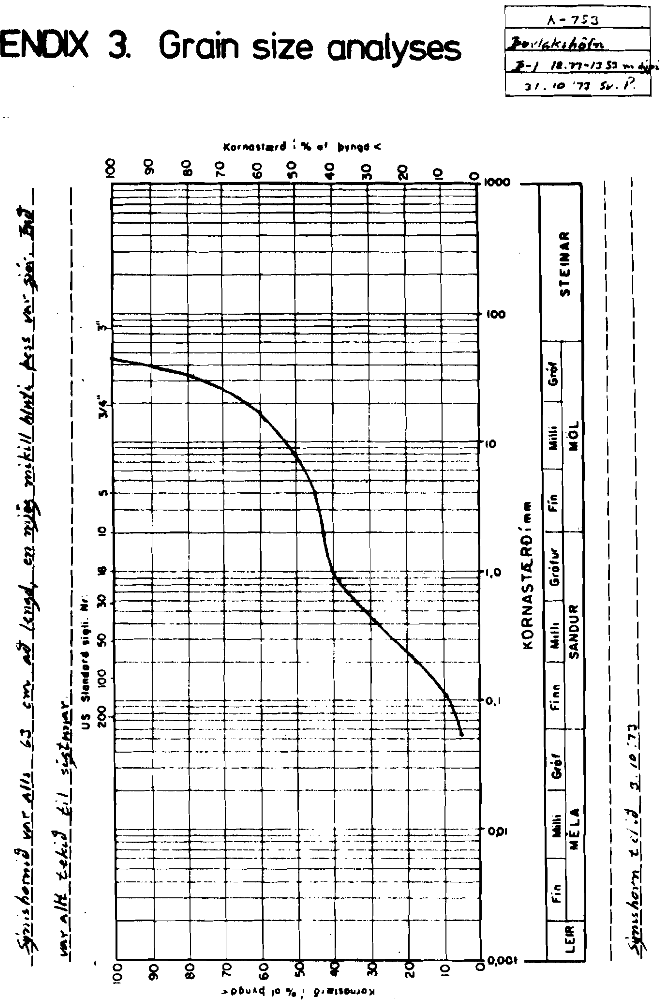
Berggreining og eðlisþyngdarmælingar á sýnishornum frá Ölfusárós og nágrenni 1973

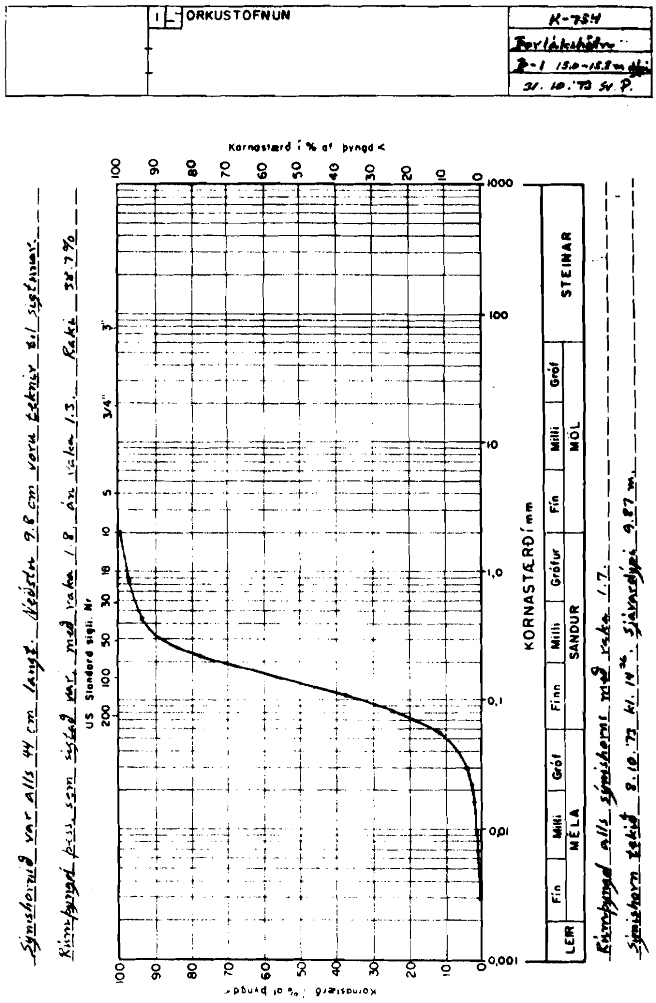
Sp. = vottur < 0.5 %

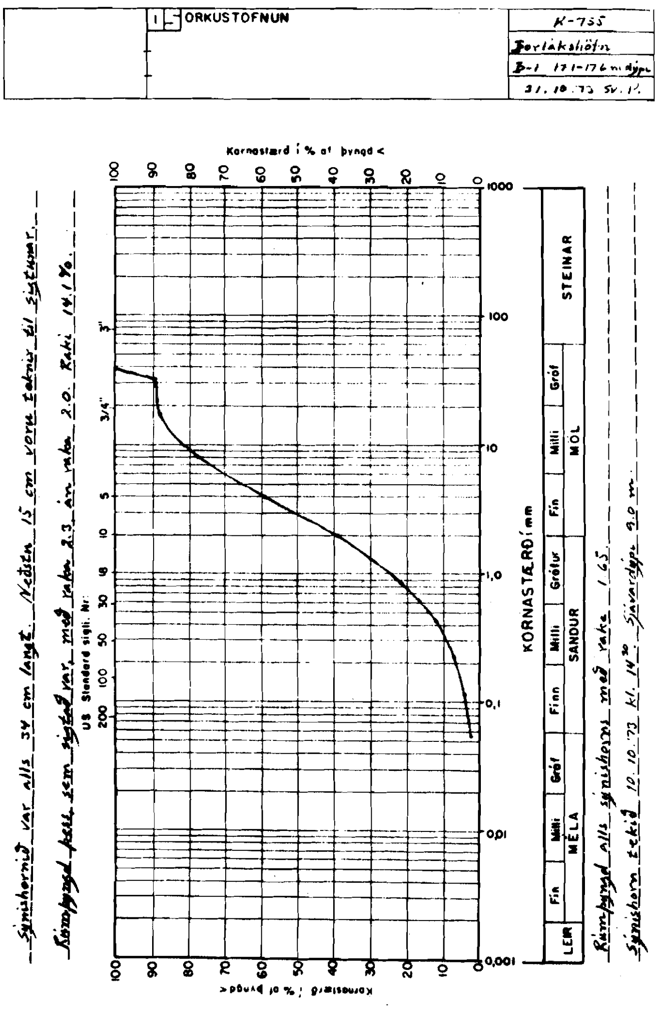
SAMPLE NO	THIN SECTION NO	GRAIN SIZE mm	PETROLOGICAL COMPOSITION % OPAQUE	DARK GLASS n>1.54	LIGHT GLASS n<1.54	ALTERED GLASS	BASALT	MOBERG	RHYOLITE	SEDIMENT	PLAGIOCLASE	PYROXENE	OLIVINE	CALCITE	ZEOLITE	QUARTZ	No OF GRAINS COUNTED	DENSITY	
K-802	4262	0.42-0.85	6	25	5	3	47	6	1	1	4	1			sp.	1	361	2.94	
–	4282	0.21-0.42	8	43	22	10	6	4		1	7				sp.	sp.	417	2.99	
K-803 Þ-3	4265	2-4	6	9	43	1	7	9	19							5	109	2.53	
–	4264	0.85-2	7	13	37	2	20	11	6		1			sp	sp	2	205	2.64	
–	4263	0.42-0.85	14	26	34	5	7	5	1	1	5			1		1	371	2.66	
–	4283	0.21-0.42	11	33	21	7	12	3	2	1	7	sp.		1	sp.	1	509	2.69	
K-804 Þ-1	4268	0.42-0.85	sp.	2	97	sp								1			522	2.21	S.2.
–	4267	0.21-0.42	14	41	19	3	11	3	sp.		4	1	sp.	2	sp.	1	582	2.81	
–	4266	0.105-0.21	13	42	6	4	19	4	sp.		5	4	1	2		sp.	423	2.94	
K-809 Þ-2	4285	0.85-2	6	12	20	3	29	14	7	1	1					7	249	2.71	
–	4284	0.21-0.42	13	40	18	6	8	4	2	1	5			2		1	544	2.72	
K-806 Ö-1	4270	0.42-0.85	14	24	14	4	29	7	sp.		6	1	sp.			1	375	2.80	
–	4269	0.21-0.42	10	35	12	5	23	7	1	sp	5	1	sp		sp.	1	515	2.83	
K-807 Ö-2	4273	0.85-2	9	34	23	10	21	2	1								164	2.83	
–	4272	0.42-0.85	8	30	9	3	33	8	1	1	6	sp.				1	367	2.87	
–	4271	0.21-0.42	14	33	4	5	29	7	sp.	1	3	3	sp				531	2.94	
K-808 Ö-3		0.85-2																2.80	
–	4275	0.42-0.85	8	30	21	4	26	3	1		5	sp				1	501	2.74	S.2
–	4274	0.21-0.42	12	43	12	7	15	4		sp.	5	1	sp		sp.		502	2.81	

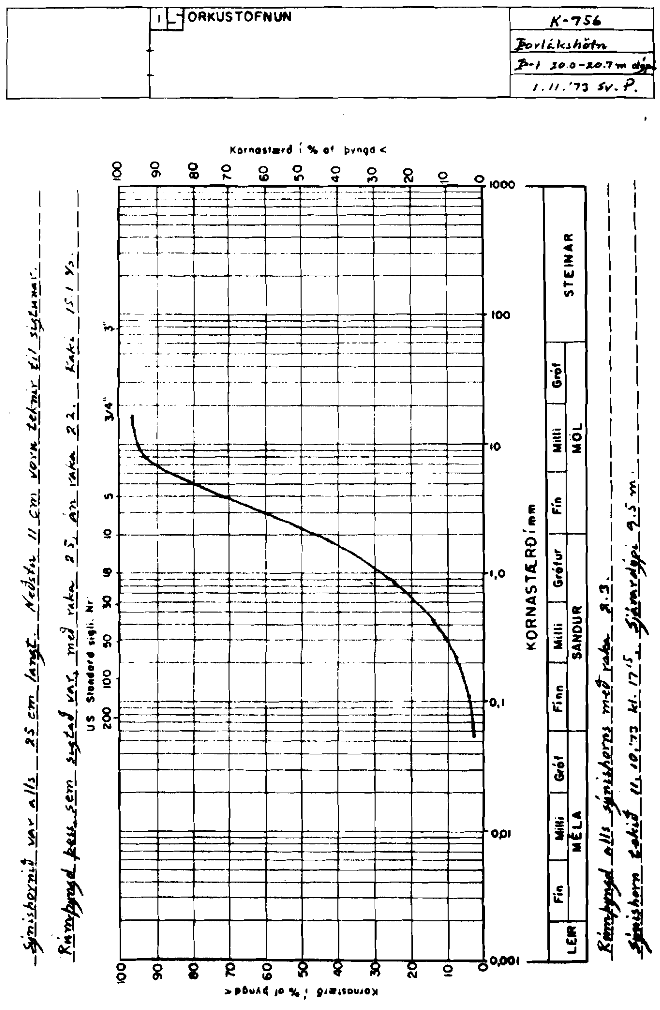
Fnr 10286

APPENDIX 3. Grain size analyses





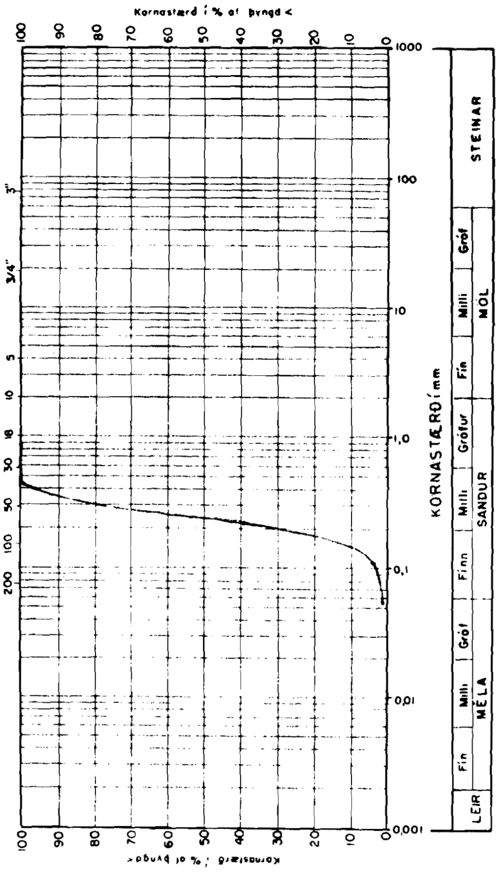




	ORKUSTOFNUN	K-757
		Þorlákshöfn
		Þ-2 6.1-6.9 m dýpi
		20. 11. '73 Sv. P.

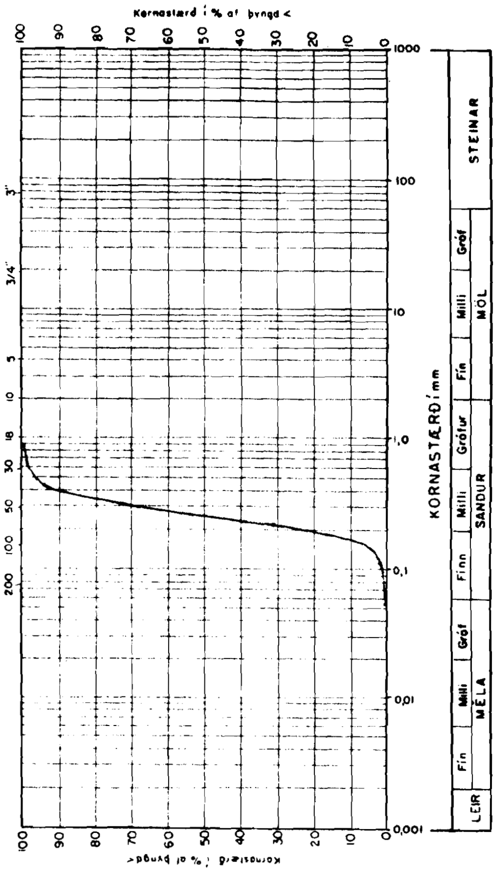
Sýnishornið var alls 52 cm langt. Neðstu 11.5 cm voru tekin til sigtunar.

Rúmþyngd þess, sem sigtað var með raka 2.19, án raka 1.80. Raki 21.8 %

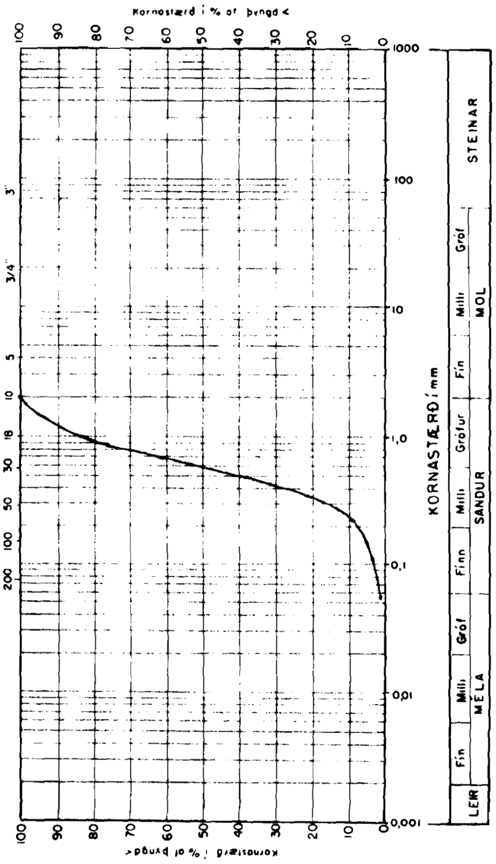


Rúmþyngd 1.15 sýnishorns með raka 2.12

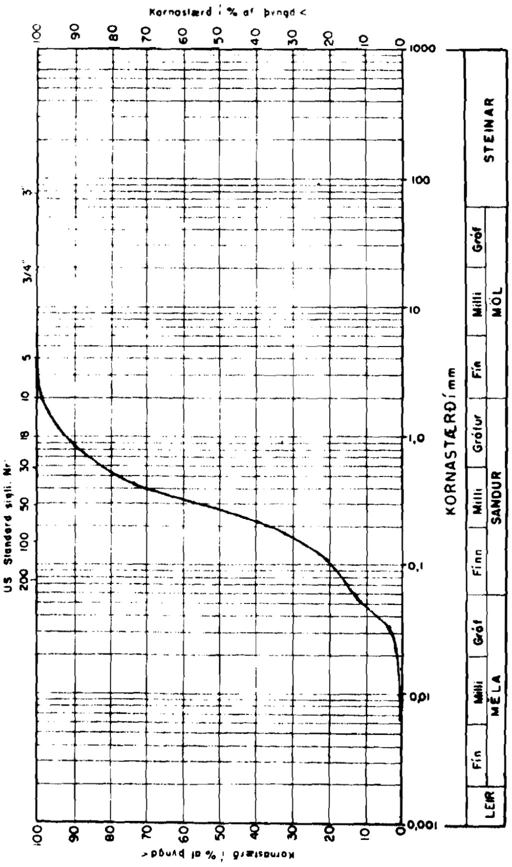
	ORKUSTOFNUN	K-758
		Þorlákshöfn
		Þ-2 6.0-10.4 m dýpi
		20. 11. '73 Sv. P.



	ORKUSTOFNUN	K-759
		Þorlákshöfn
		Þ-2 [illegible] 17.4 m dýpi
		20. 11. '73 Sv. P.



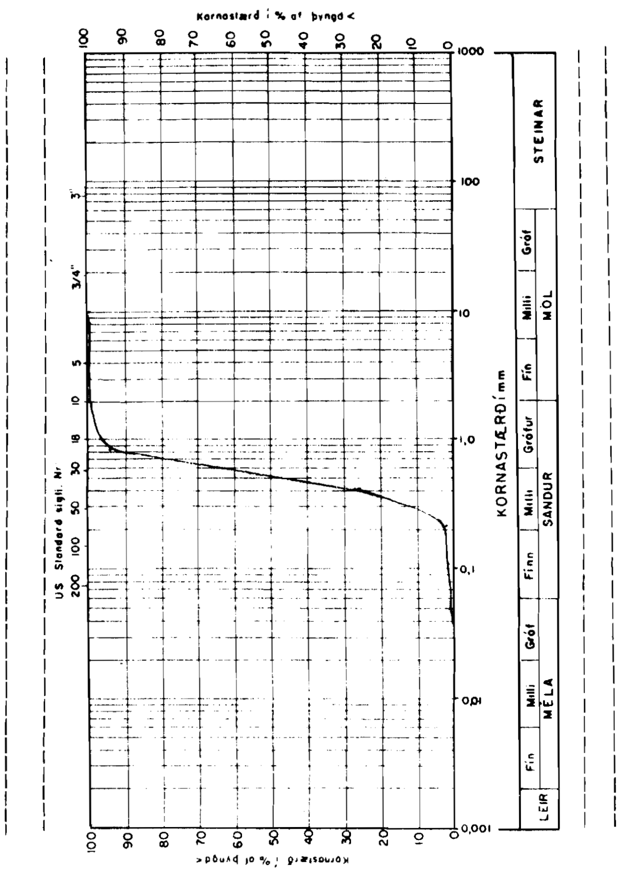
	ORKUSTOFNUN	K-760
		Þorlákshöfn
		Þ-2 14.5-16.2 m dýpi
		20. 11. '73 Sv. P.



Tekið 15/10 S.Z. B.J.B.

ORKUSTOFNUN

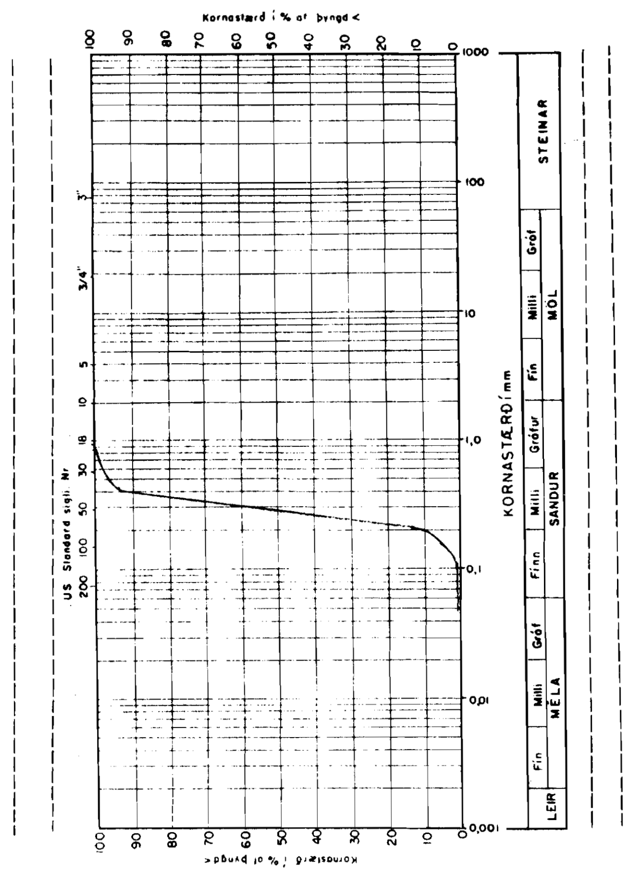
K-761 Þorlákshöfn Sýni 3 dýpi 10 m 27.11.1973 S.Z.



Tekið 15/10 1973 S.Z. B.J.B.

ORKUSTOFNUN

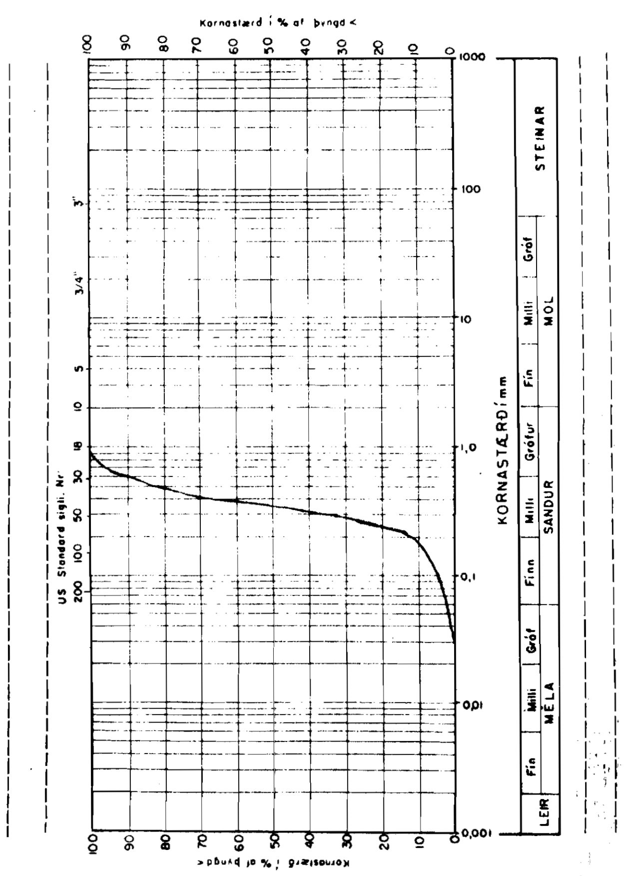
K-762 Þorlákshöfn Sýni 4. dýpi 8 m 27.11.1973 S.Z.



Tekið 15/10 1973 S.Z. B.J.B

ORKUSTOFNUN

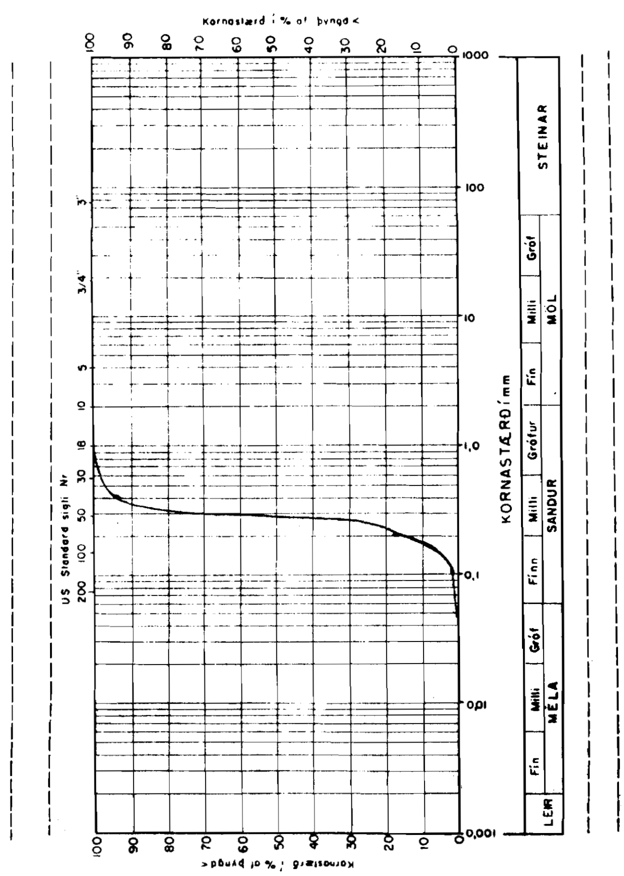
K-763 Þorlákshöfn Sýni 5 dýpi 5 m 27.11.1973 S.Z.



Tekið 15/10 1973 S.Z. B.J.B.

ORKUSTOFNUN

K-764 Þorlákshöfn Sýni 6 dýpi 4 m 27.11.1973 S.Z.



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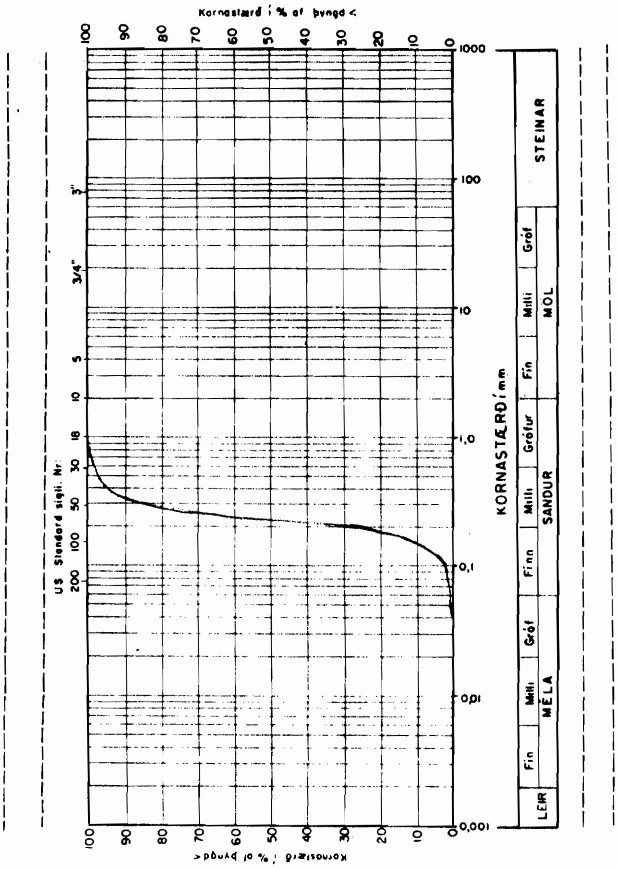

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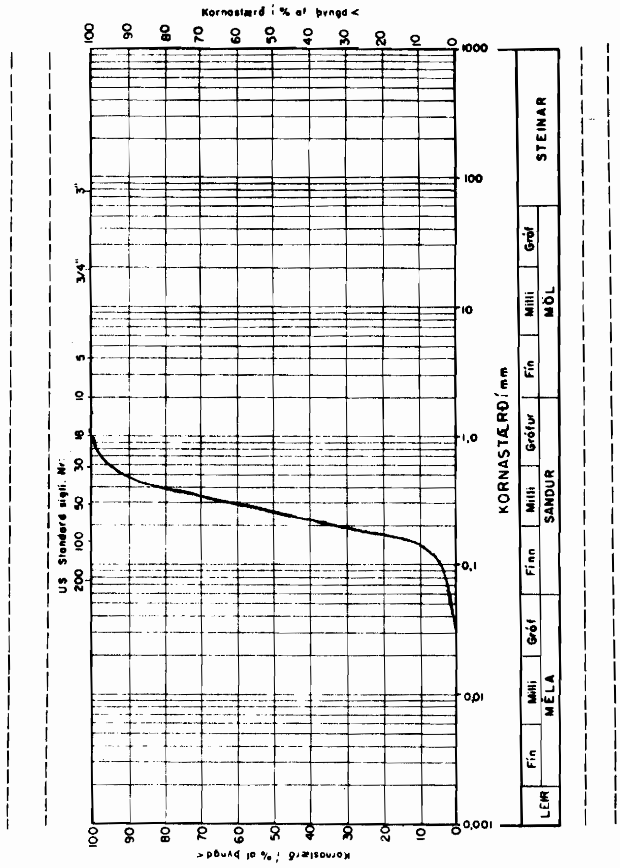
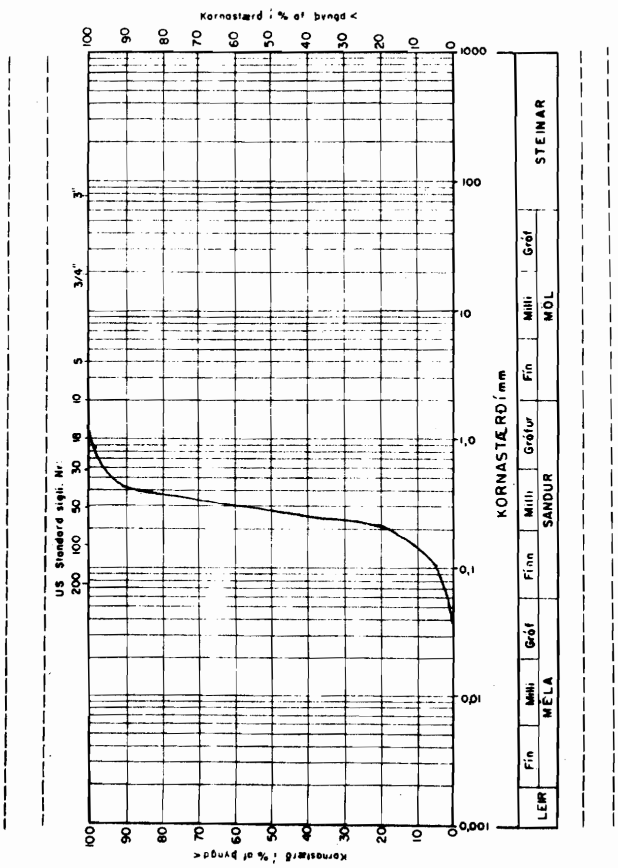
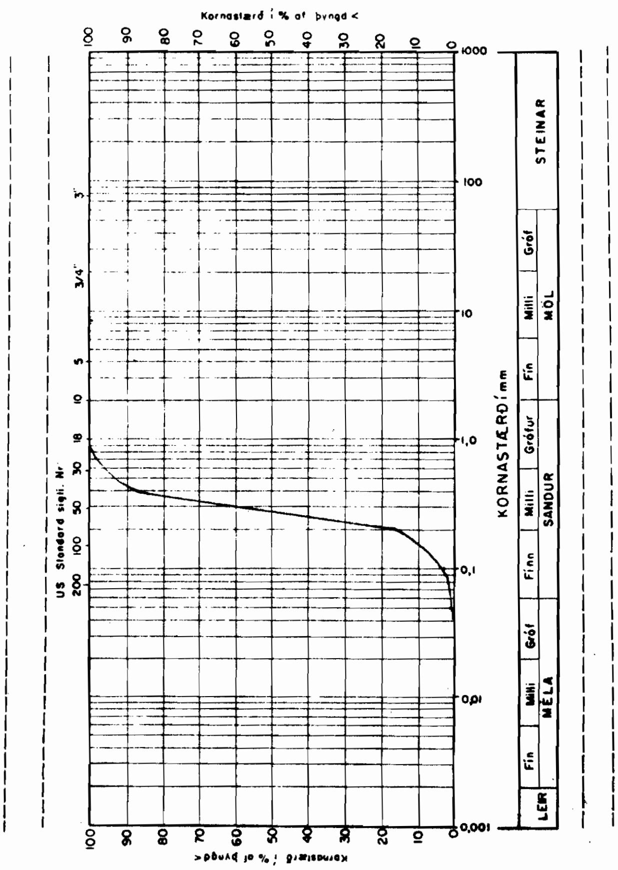


Tekið 15/10 1973 S.Z. B.Y.B.	ORKUSTOFNUN	K-767 Þorlákshöfn Sýni 9 dýpi 10 m 27.11.1973 S.Z.



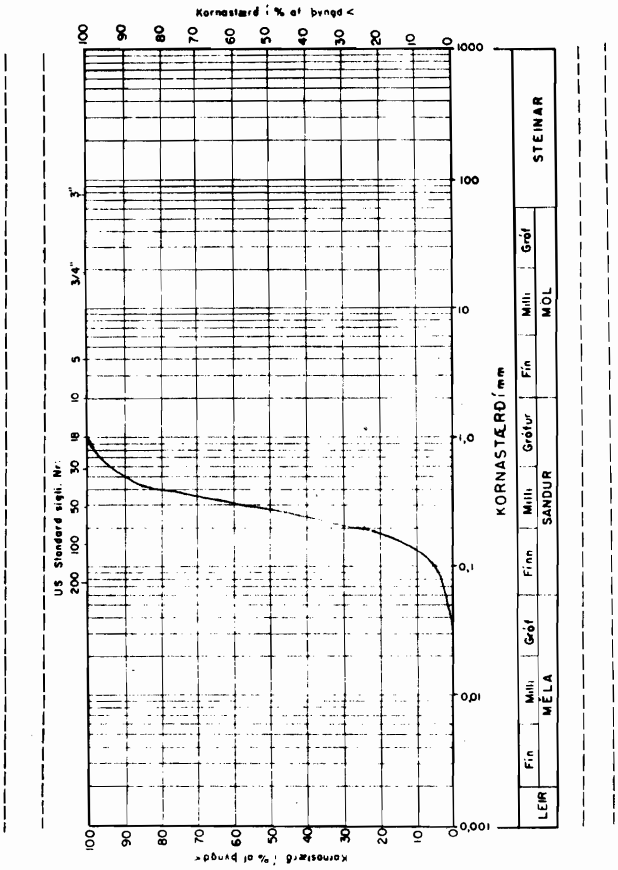
Tekið 15/10 1973 S.Z B.Y.B	ORKUSTOFNUN	K-768 Þorlákshöfn Sýni 10 dýpi 10 27.11.1973 S.Z.



Teki Ð
15/10 1973
S.Z. B.J.B.

ORKUSTOFNUN

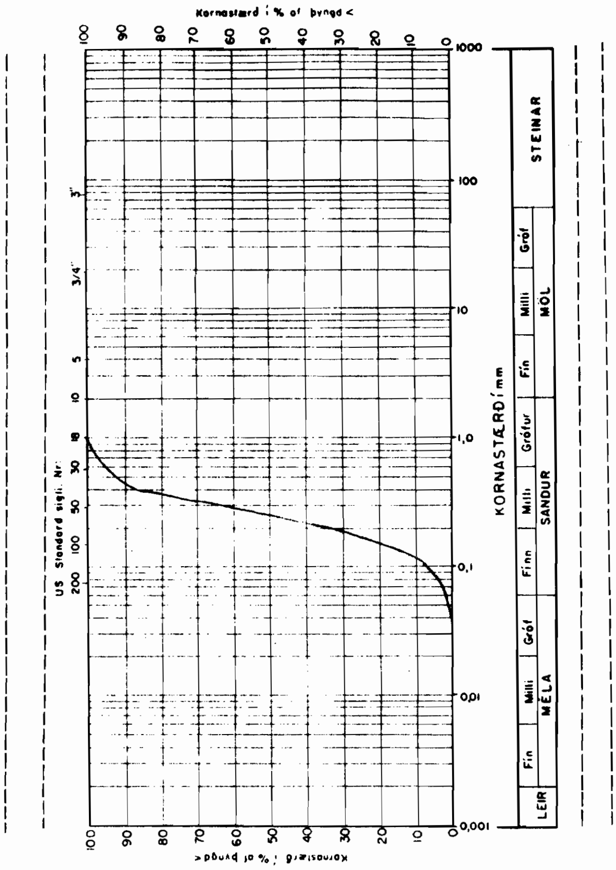
769-K
Þorlákshöfn
Sýni 11 dýpi 10m
29.11.1973. S.Z.



Teki Ð
15/10 1973
S.Z. B.J.B

ORKUSTOFNUN

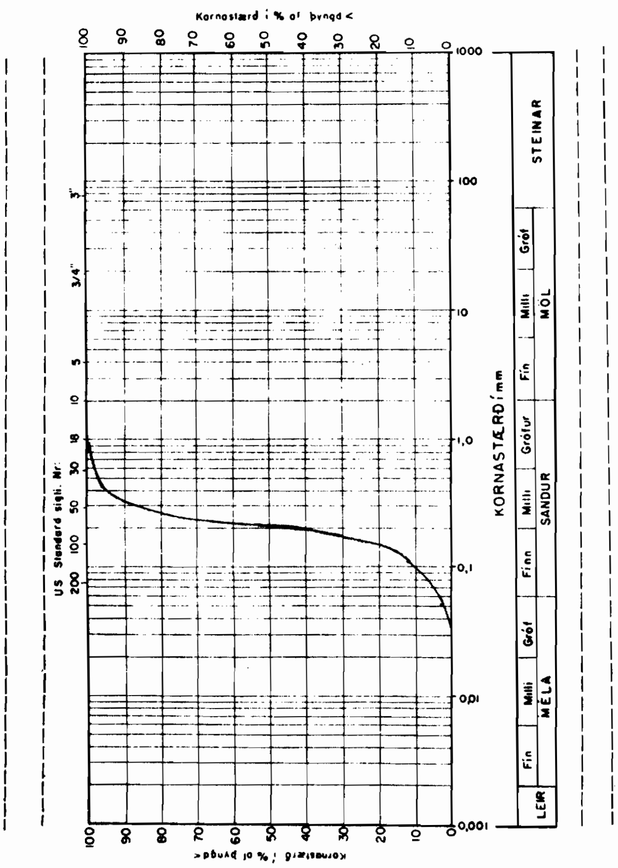
K-770
Þorlákshöfn
Sýni 12 dýpi 15m
29.11.1973. S.Z.



Teki Ð
15/10 1973.
S.Z. B.J.B.

ORKUSTOFNUN

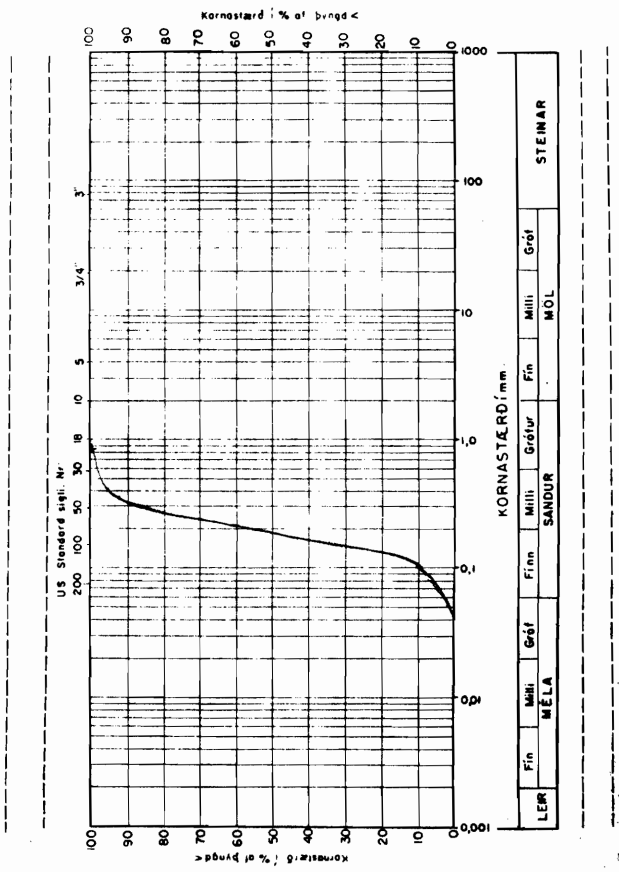
K-771
Þorlákshöfn
Sýni: 13. dýpi: 10m
27.11 1973 S Z



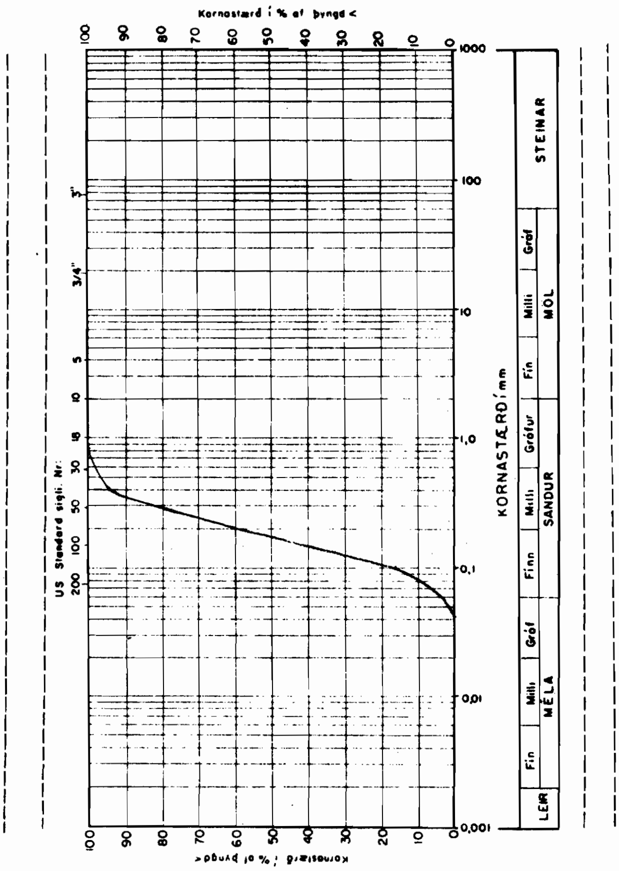
Teki Ð
15/10,1973
S.Z. B.J.B

ORKUSTOFNUN

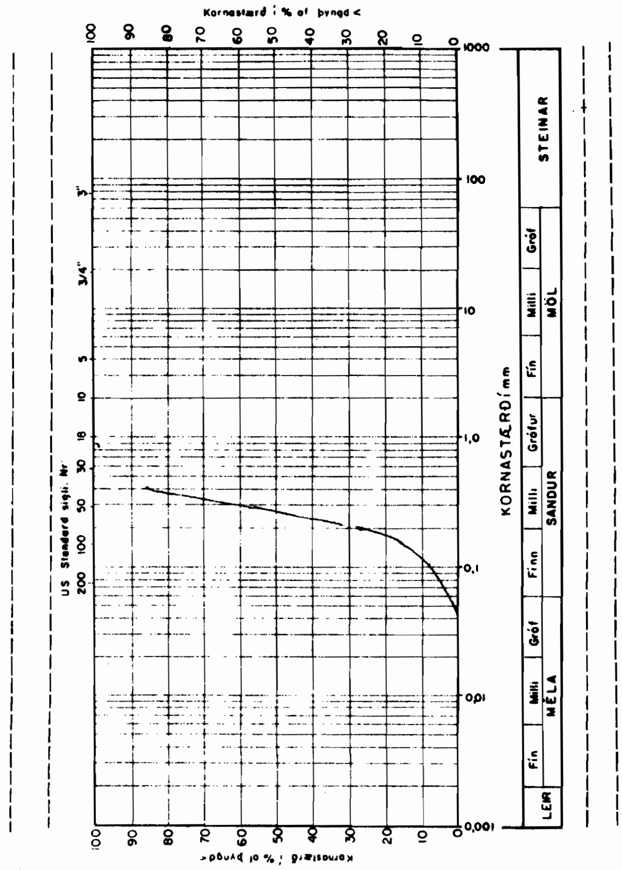
K-772
Þorlákshöfn
Sýni: 14 dýpi 12m
26/11. 1973. S.Z.



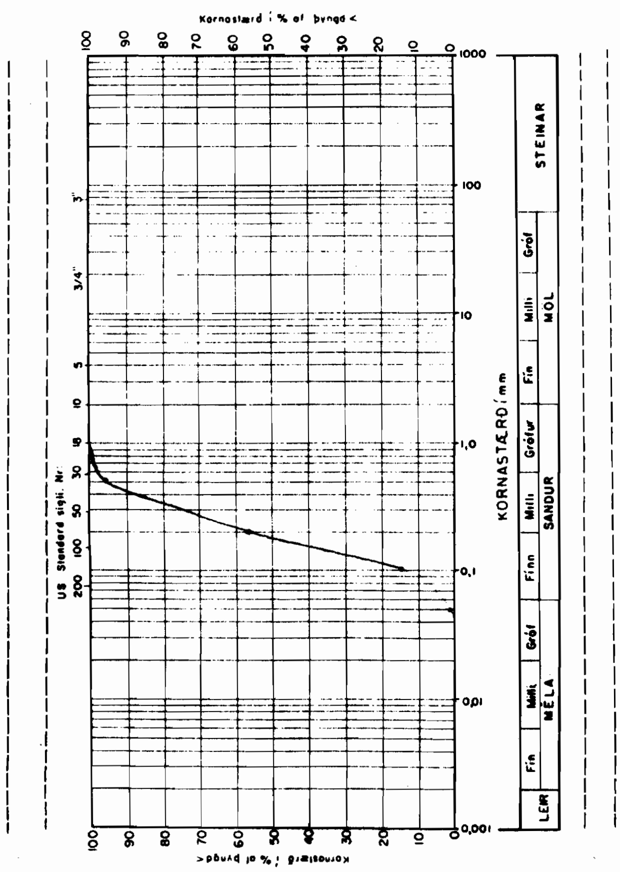
Teki J 15/10 1973. S.Z. B.J.B.	ORKUSTOFNUN	K-773 Þorlákshöfn Sýni 15. dýpi 11m 27.11.1973 S.Z.



Teki J 15/10 1973 B.J.B. S.Z.	ORKUSTOFNUN	K-774 Þorlákshöfn Sýni 16 dýpi 11m 29.11.1973. S.Z.



Teki J 15/10 1973 S.Z. B.J.B	ORKUSTOFNUN	K-775 Þorlákshöfn Sýni 17 dýpi 11m 29.11.1973, S.Z



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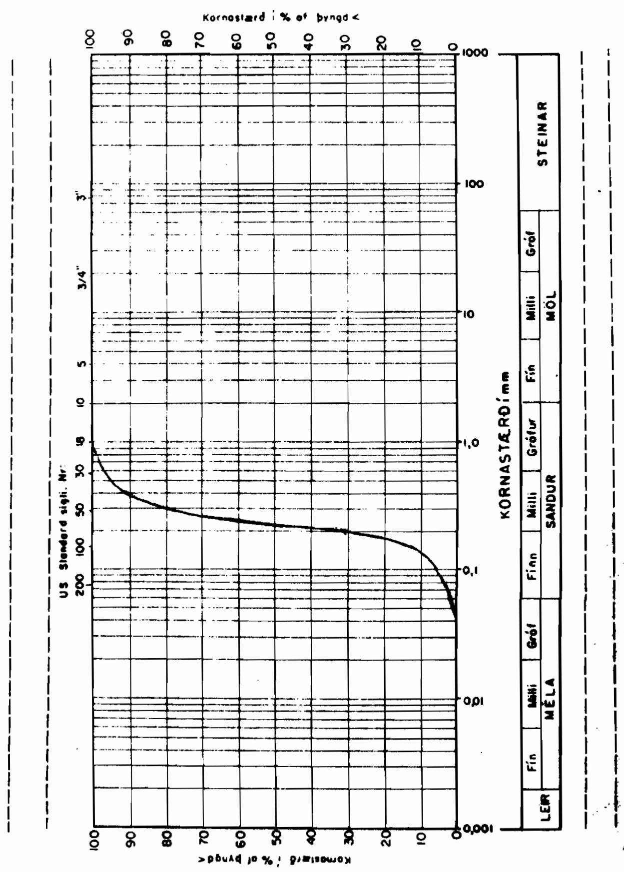

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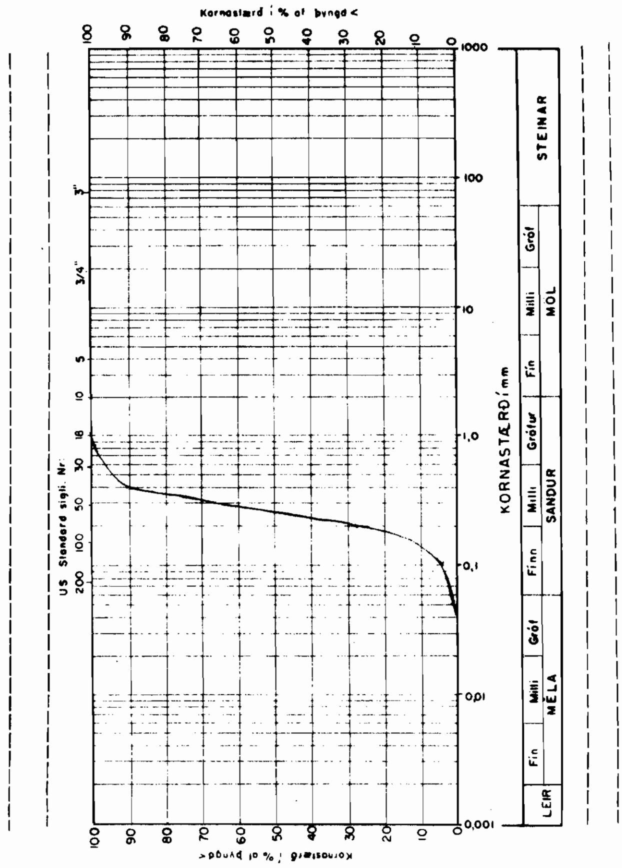
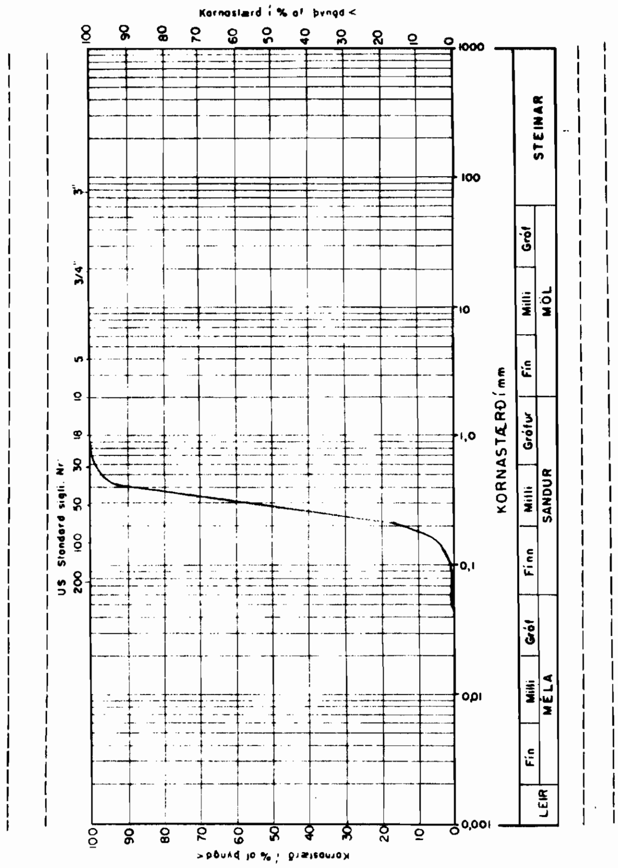


Tek. i J 15 V&H	ORKUSTOFNUN	K-779 Lína 5, Sýni I Þorlákshöfn 29.11.1973 S.Z.



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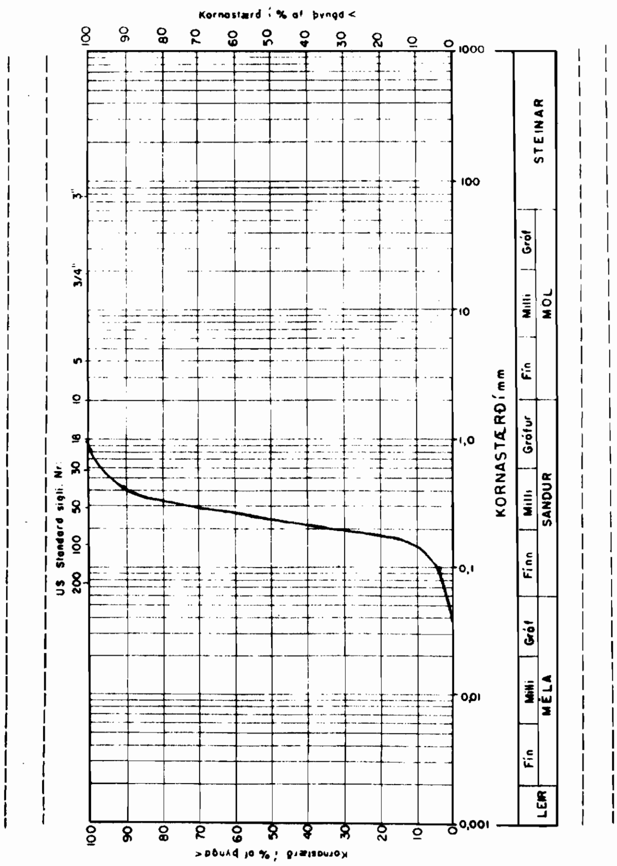
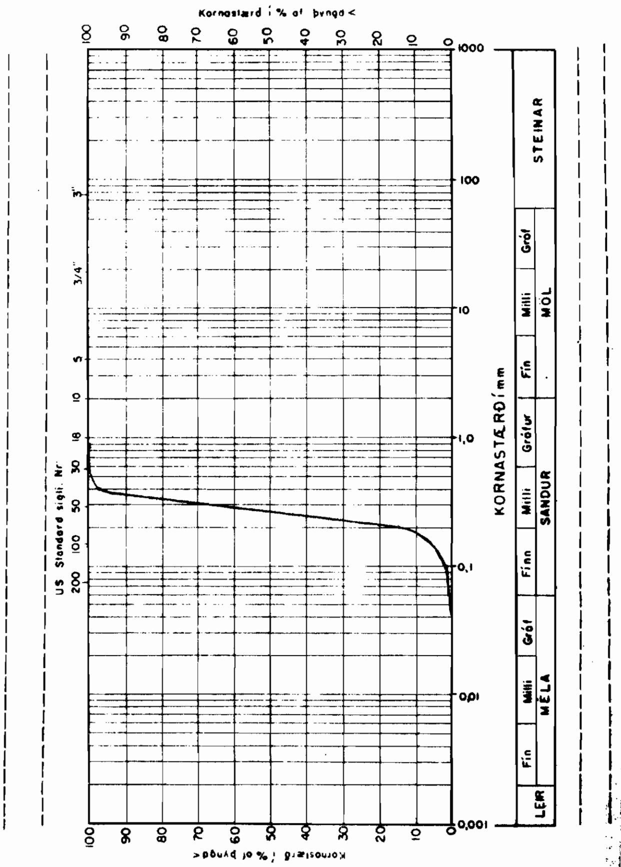


Tek. i J V&H	ORKUSTOFNUN	K-781 Þorlákshöfn Lína 7 Sýni II Dýpi 340 29.11.1973 S.Z.



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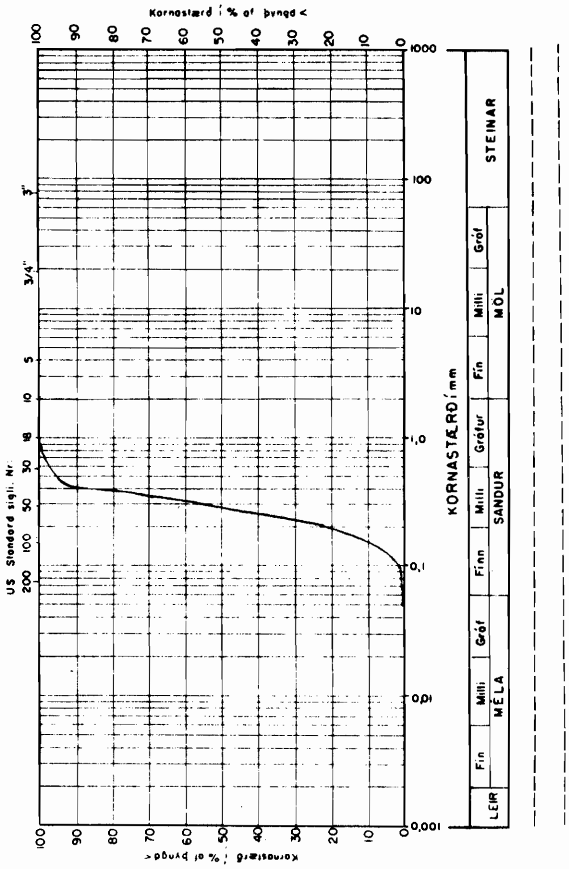

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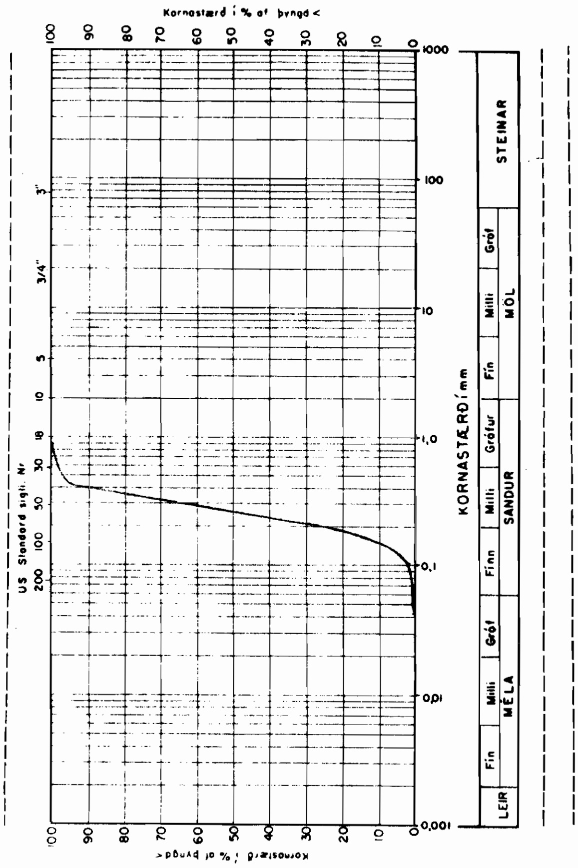
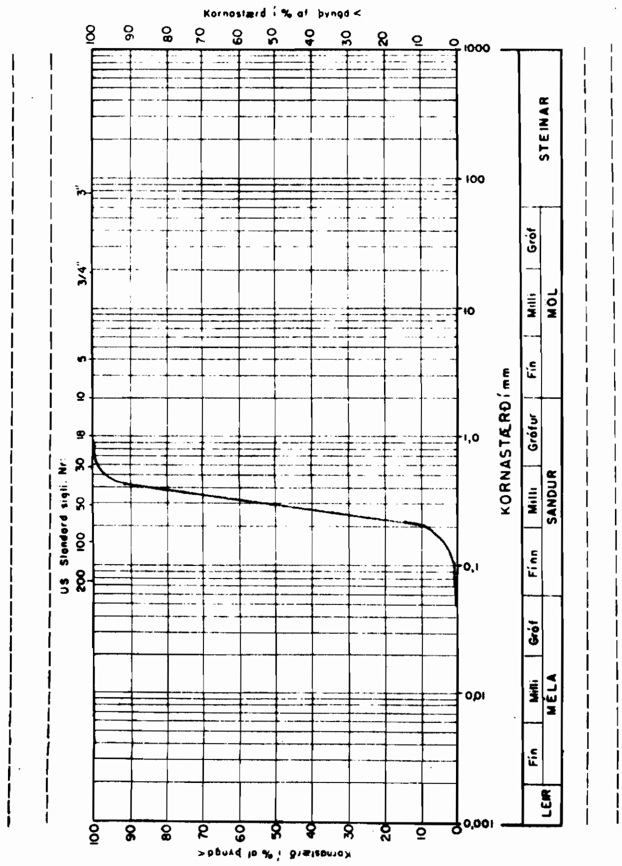
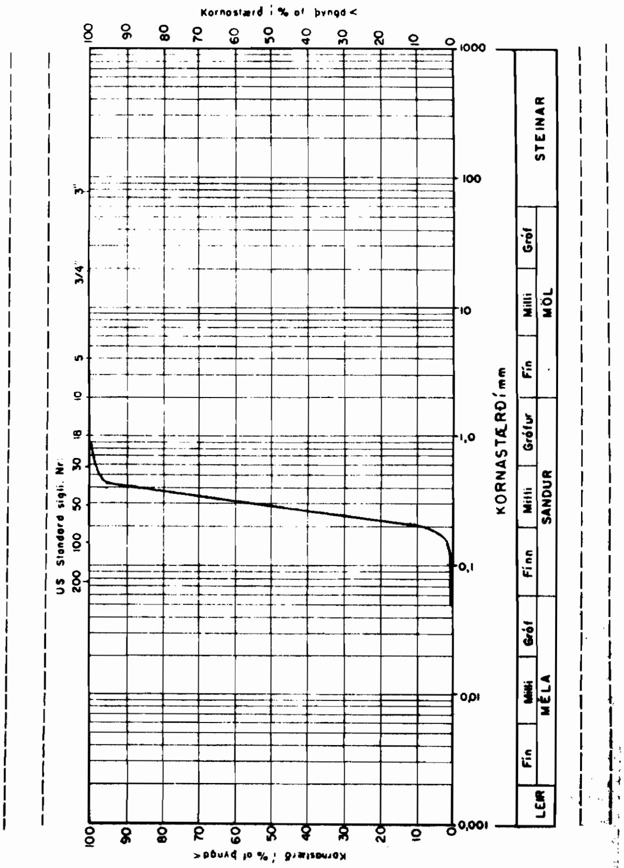


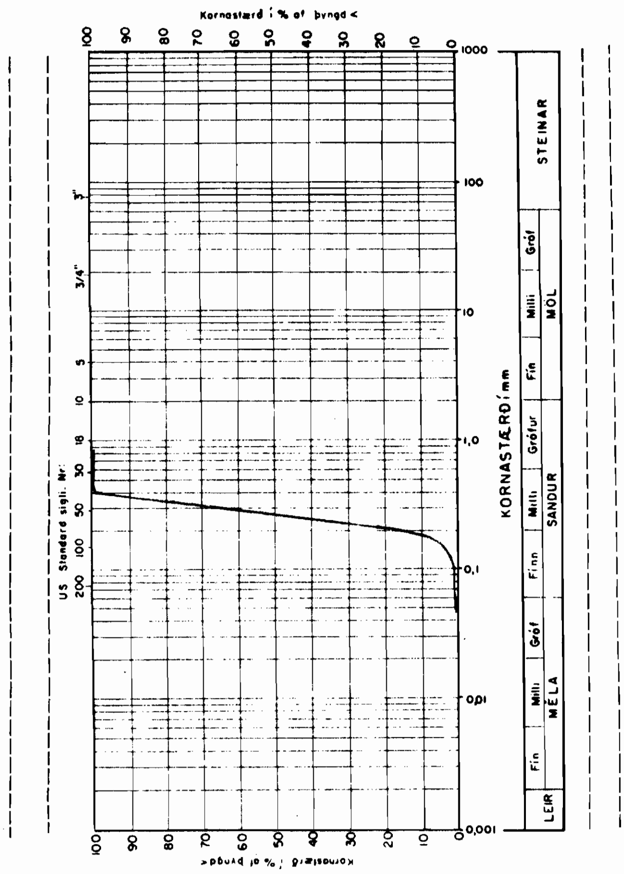
Teki J V&H	ORKUSTOFNUN	K-784 Þorlákshöfn Lína 6 sýni II dýpi 29.11.1973.SZ



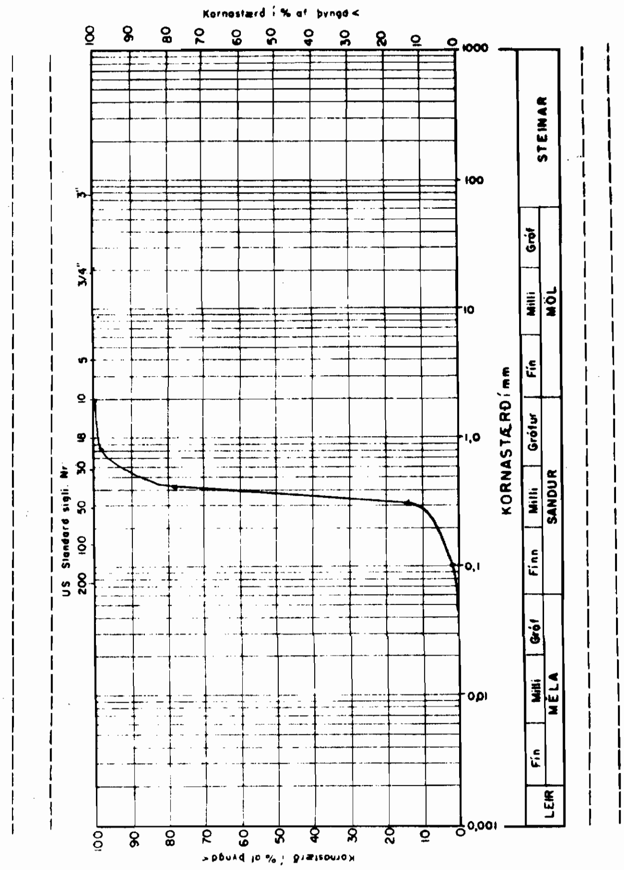
Teki J V&H	ORKUSTOFNUN	K-785 Þorlákshöfn Lína 7 sýni III dýpi 29.11.1973.SZ



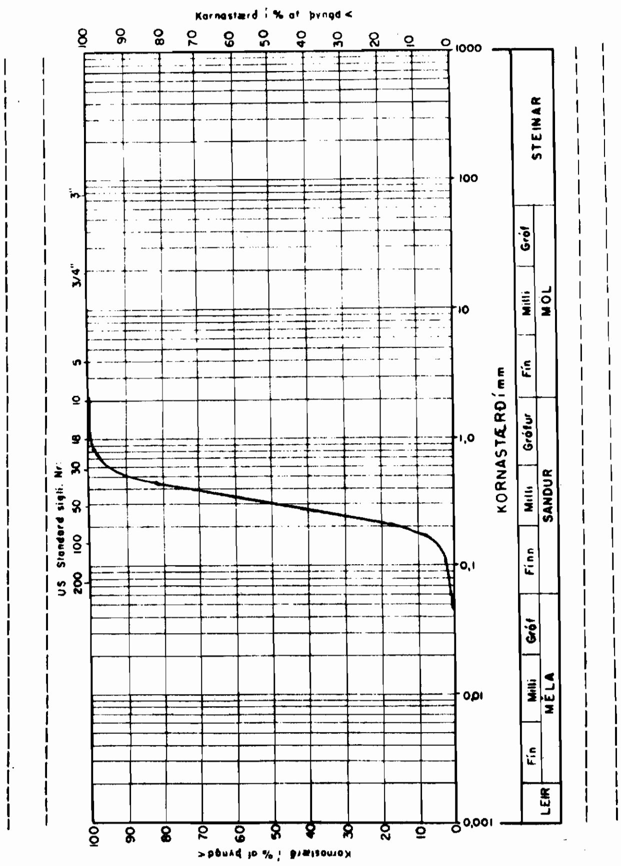
Tek. J V&H	ORKUSTOFNUN	K-786 Þorlákshöfn Lóna 7. Sini VIII 29.11.1973. S.Z.



Tek. J B.Þ.B	ORKUSTOFNUN	K-787 Þorlákshöfn S-1 I 30.11.1973 S.Z.



Tek. J B.Þ.B.	ORKUSTOFNUN	K-788 Þorlákshöfn S-1 II 30.11.1973. S.Z.



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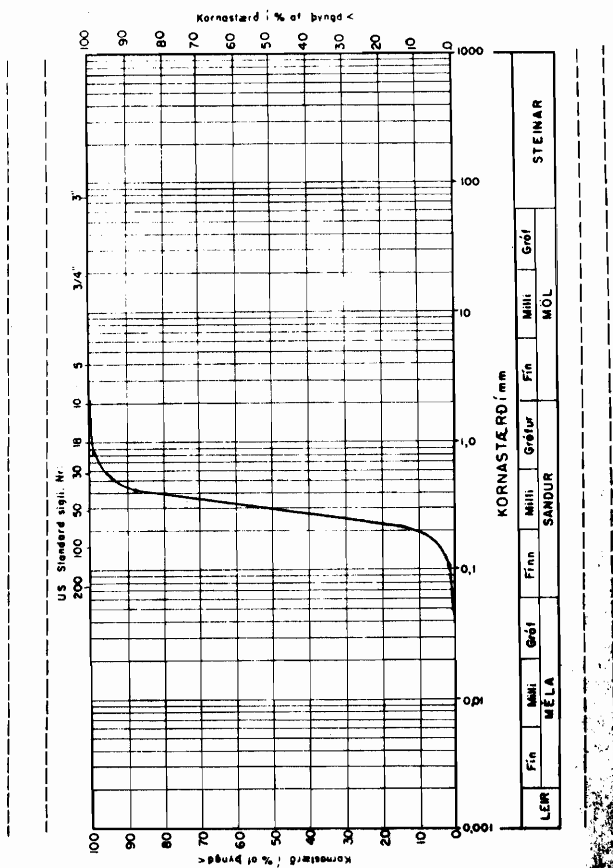
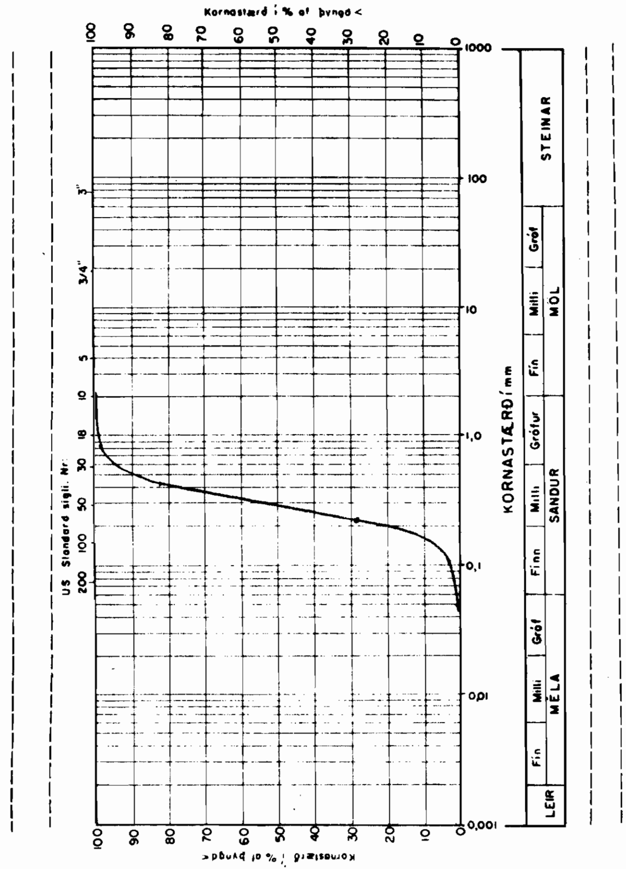
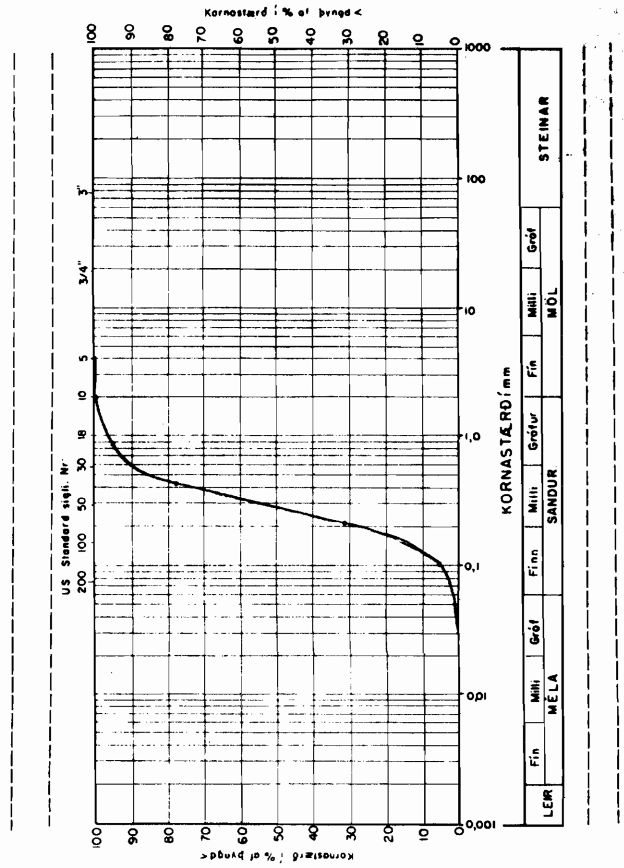


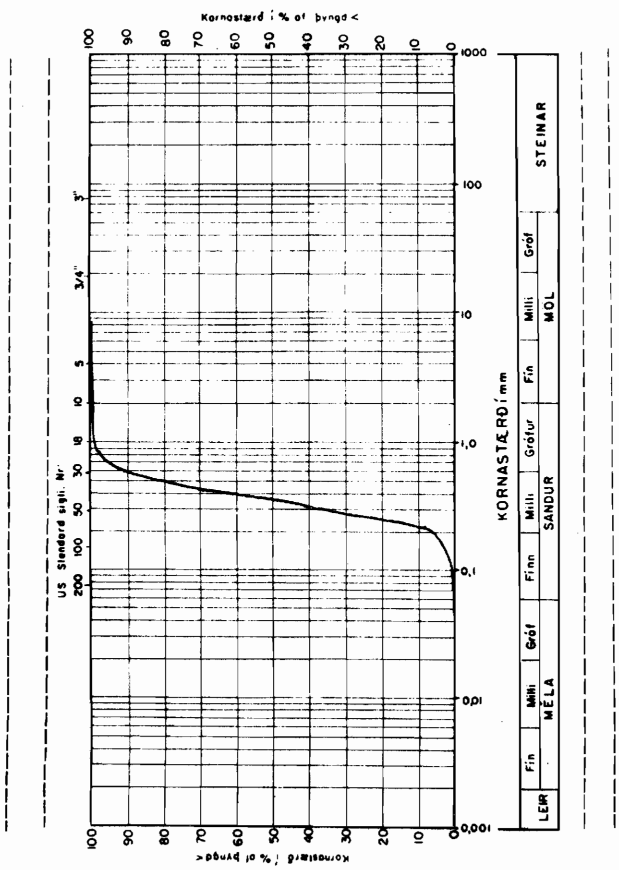
Tekið	ORKUSTOFNUN	K-790
B.7.B.		Þorlákshöfn
		S-3 I
		30.11.1973. S.Z.



Tekið	ORKUSTOFNUN	K-791
B.7.B		Þorlákshöfn
		S-3 II
		30.11.1973. S.Z.



Sjóborun	ORKUSTOFNUN	K-792
B.7.B.		Þorlákshöfn
		Sýni 5 I dýpi
		29/11. 1973. S.Z.



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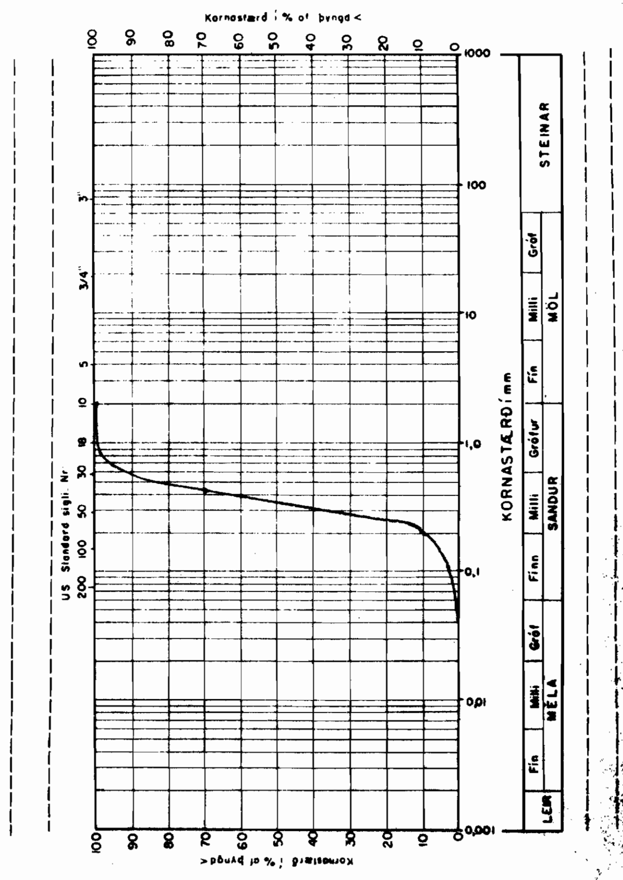
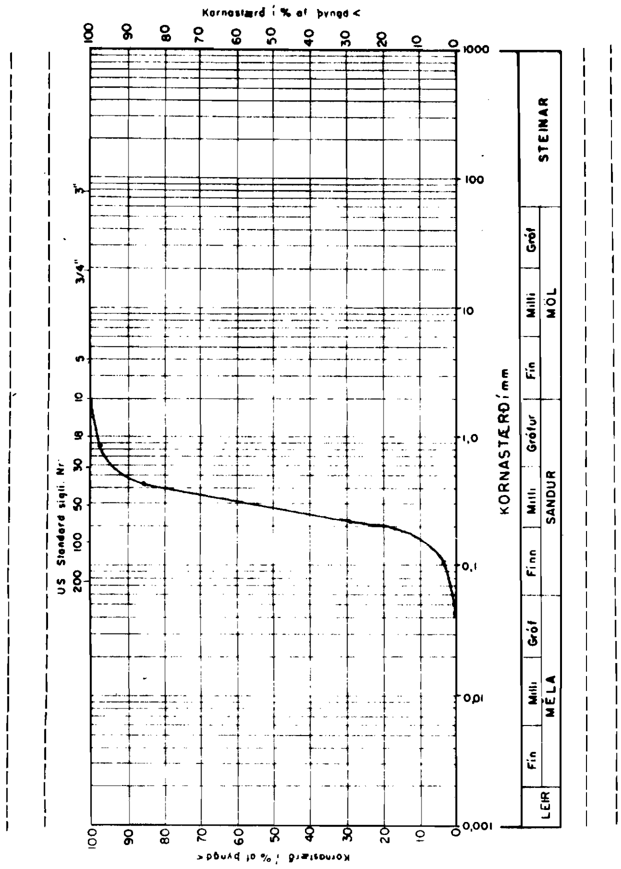
		Þorlákshöfn
		S-5 II
		30.11.1973 S.Z.

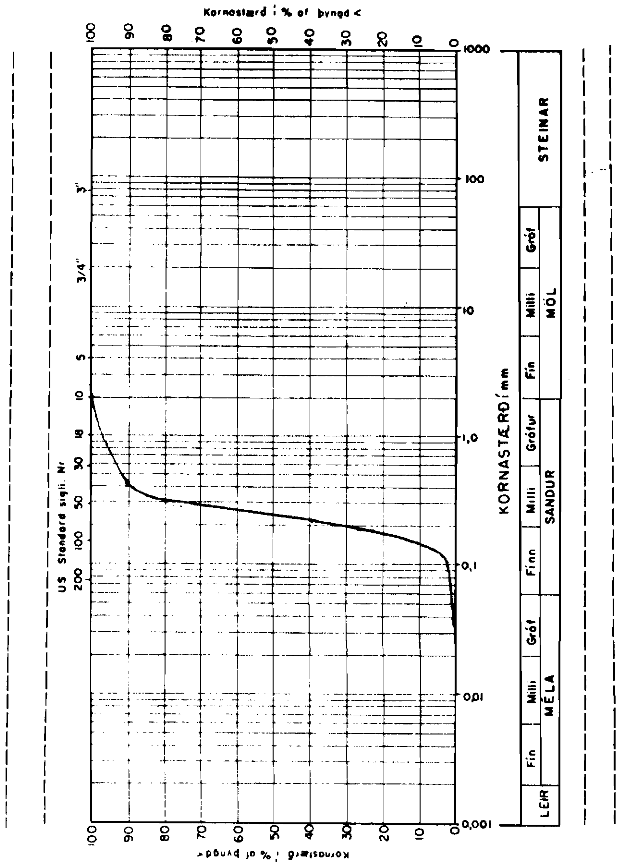


Tek. J | ORKUSTOFNUN | K-794
Þorlákshöfn
S-6B II
30.11.1973. S.Þ.

B.J.B.

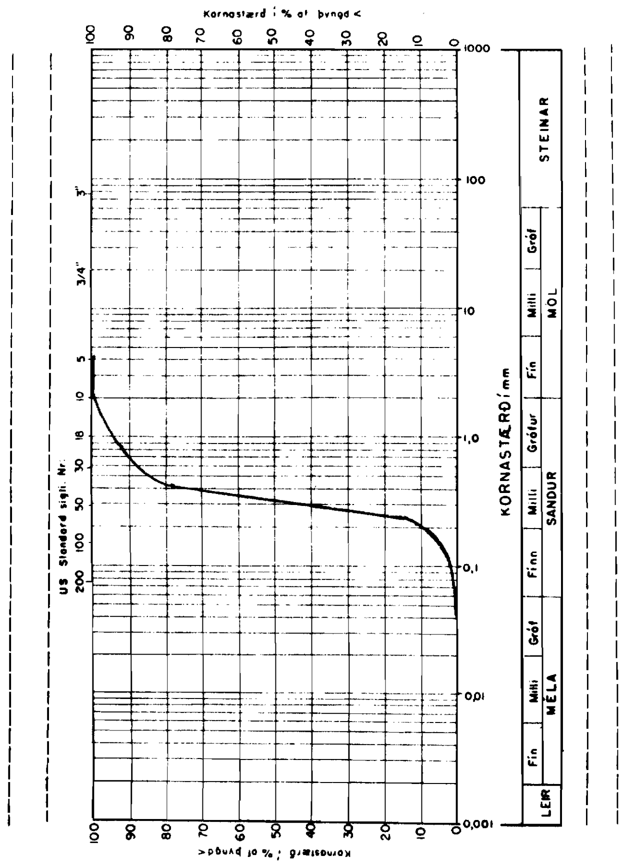


ORKUSTOFNUN | K-795
Þorlákshöfn
S-7 I
30.11.1973. S.Þ.



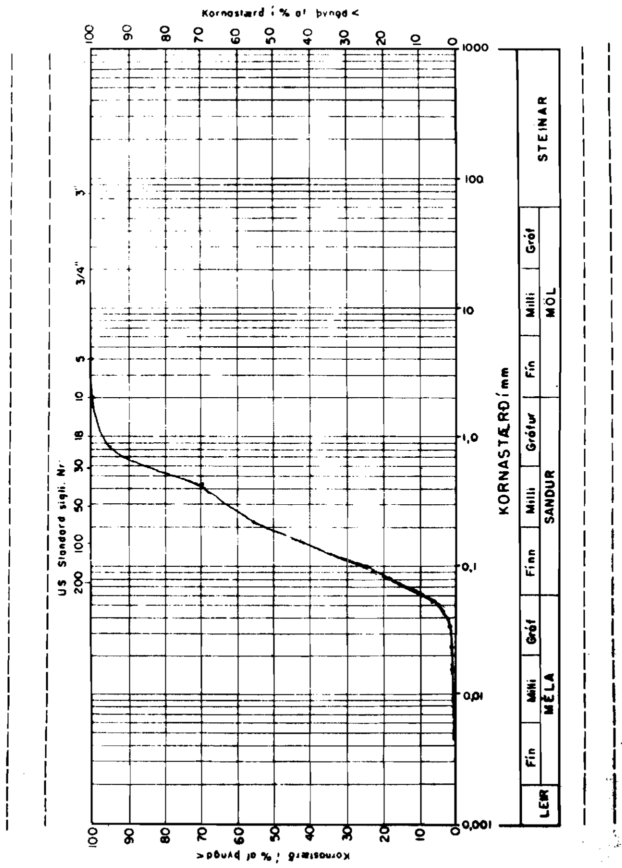
Tek. J | ORKUSTOFNUN | K-796
Þorlákshöfn
S-7 II
30.11.1973. S.Þ.

B.J.B.

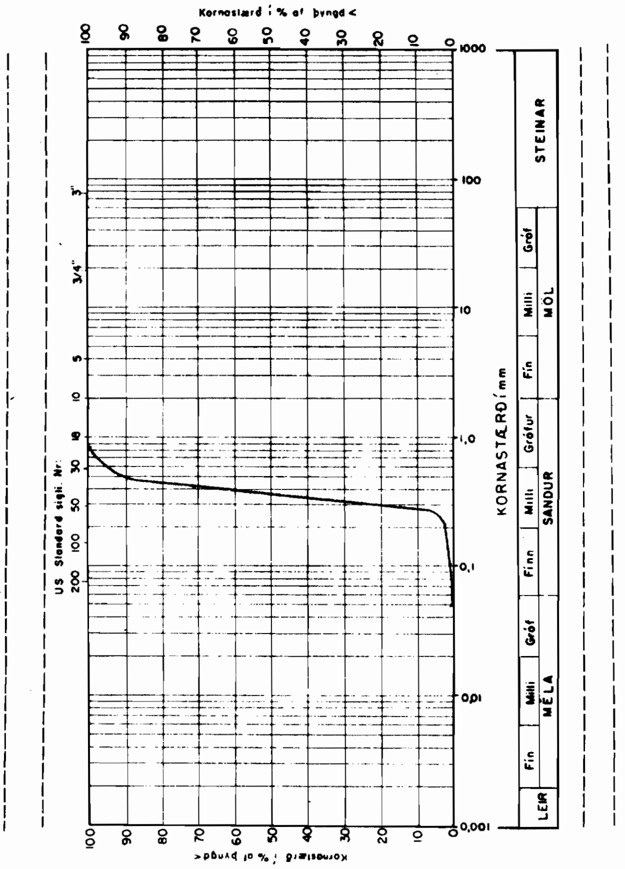


Tek. J | ORKUSTOFNUN | K-797
Þorlákshöfn
S-8
1.12.1973. S.Þ.

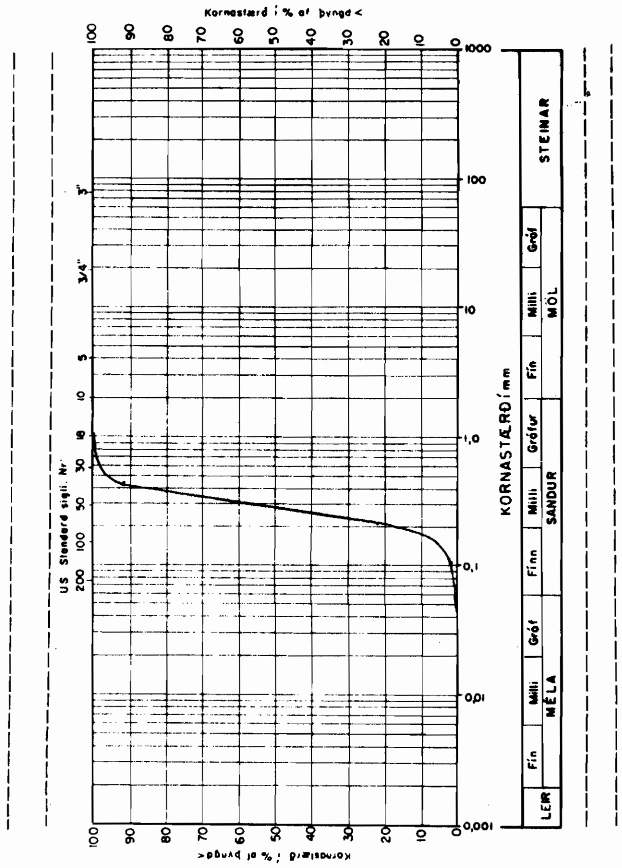
B.J.B.



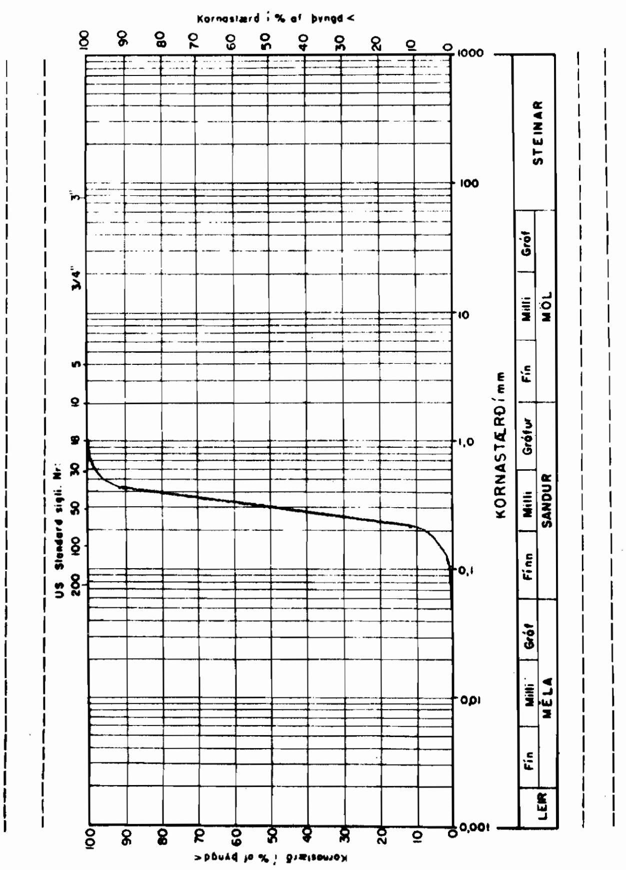
Tekið B.Y.B.	ORKUSTOFNUN	K-798 Þorlákshöfn S-10 I. 30/11 1973 S.Z.



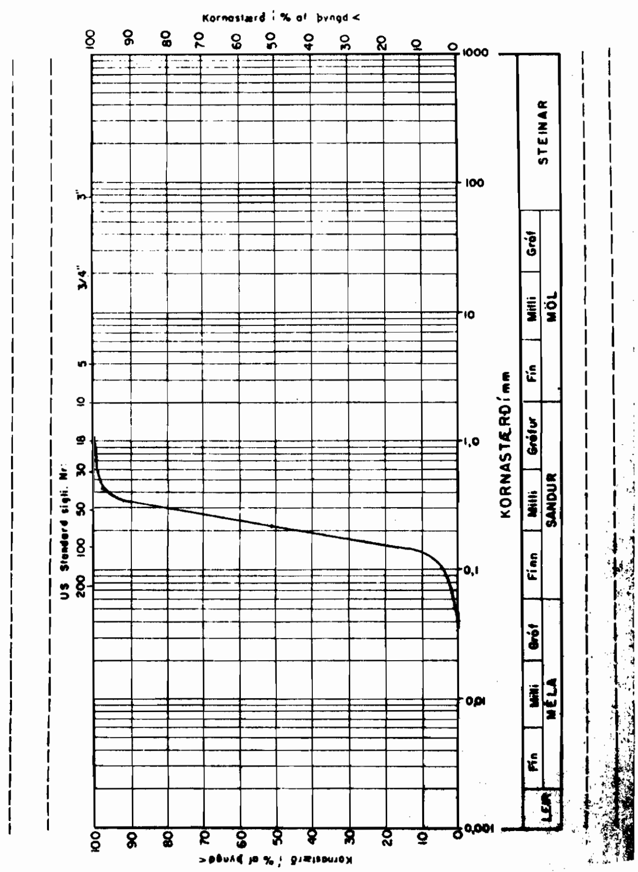
Tekið B.Y.B.	ORKUSTOFNUN	K-799 S-2 I Þorlákshöfn 30.11.1973



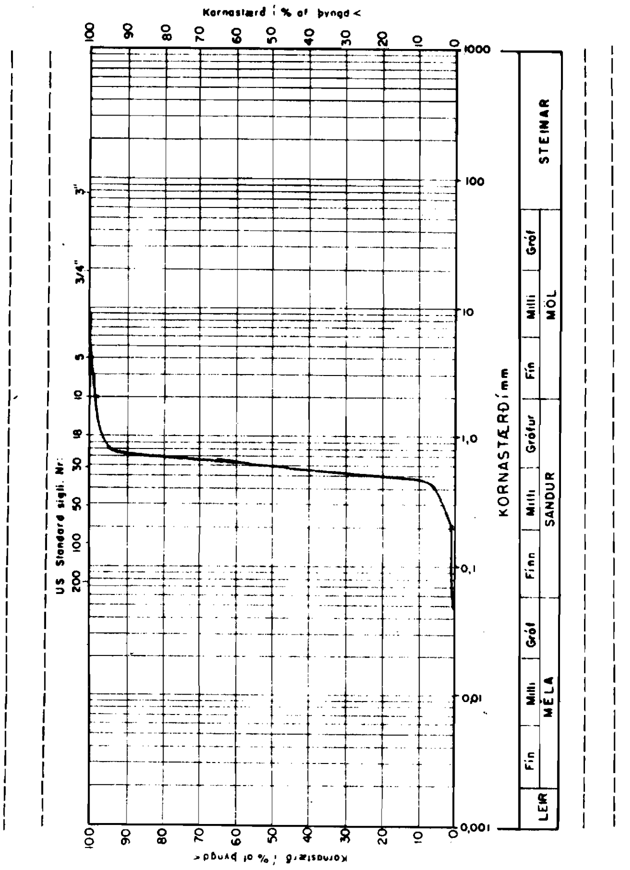
	ORKUSTOFNUN	K-800 Þorlákshöfn S-1 Hpi 29/11 1973 S.Z



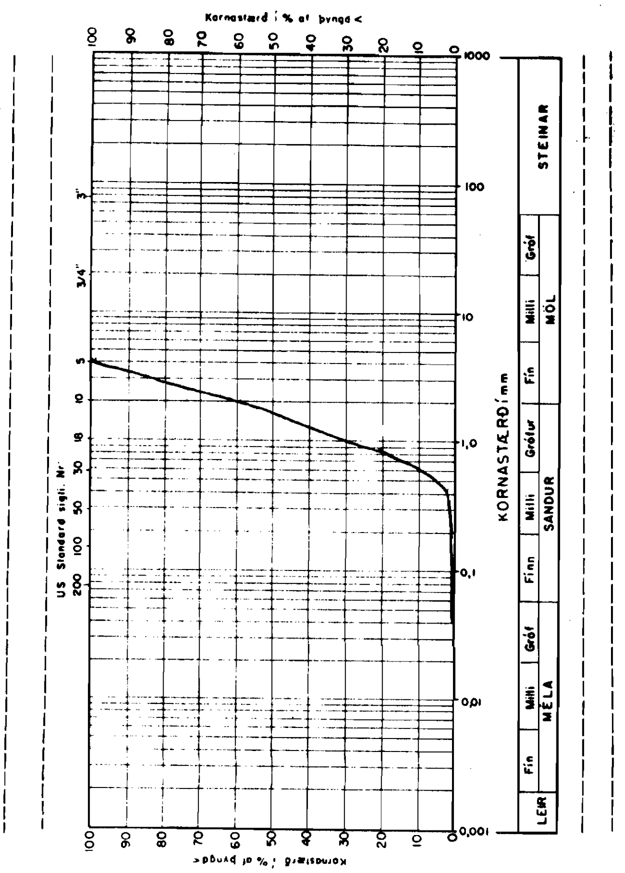
	ORKUSTOFNUN	K-801 Þorlákshöfn 3/12 1973 S.Z.



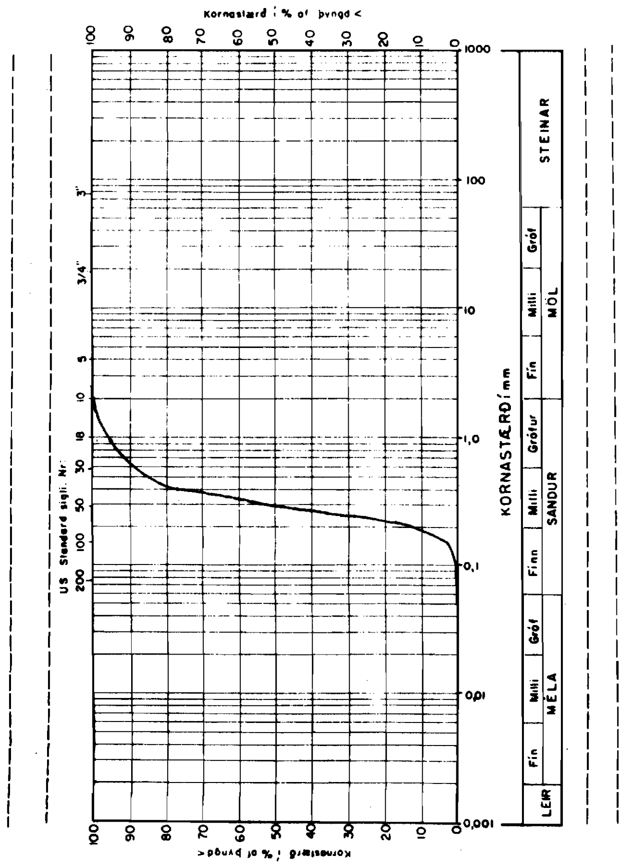
	ORKUSTOFNUN	K-802
		S①3
		6/12 1973 S.Z.



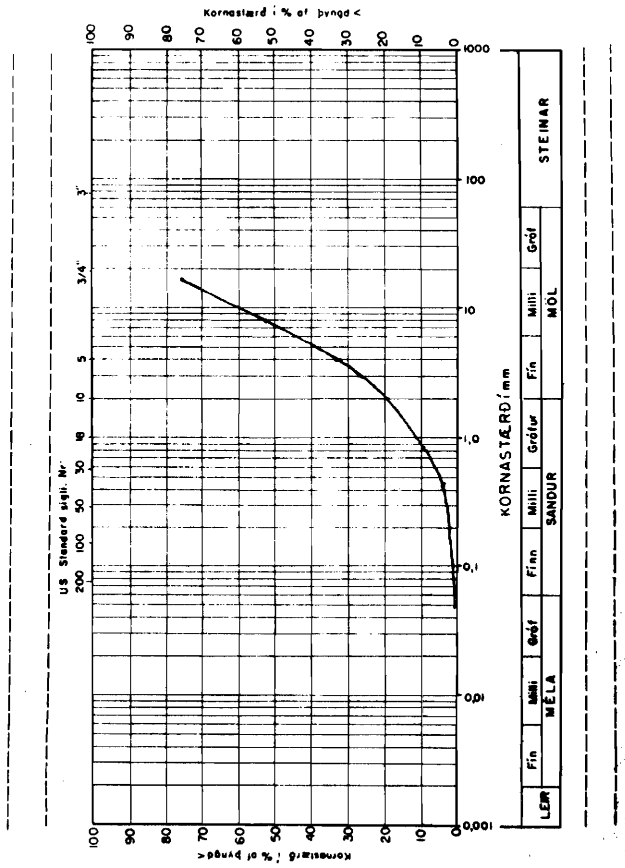
Tekið	ORKUSTOFNUN	K-803
G.D.		Þ③6
		6/12. 1973 S.Z.



Tekið	ORKUSTOFNUN	K-804
G.D.		Þ①5
		6/12 1973 S.Z.

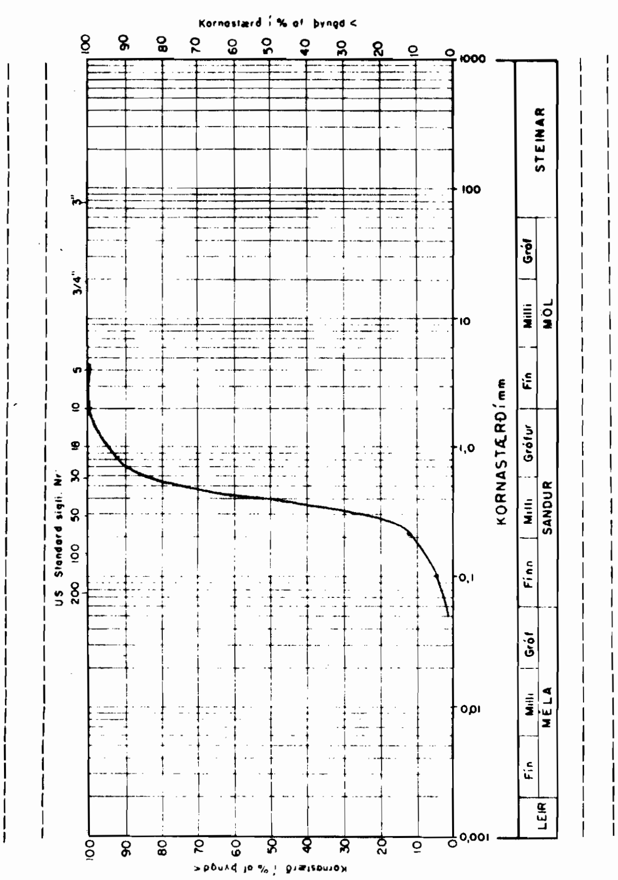


Tekið	ORKUSTOFNUN	K-805
B.J.G		Þorlákshöfn
		Hola III d. 12,6-13,6
		7/12 1973 S.Z.



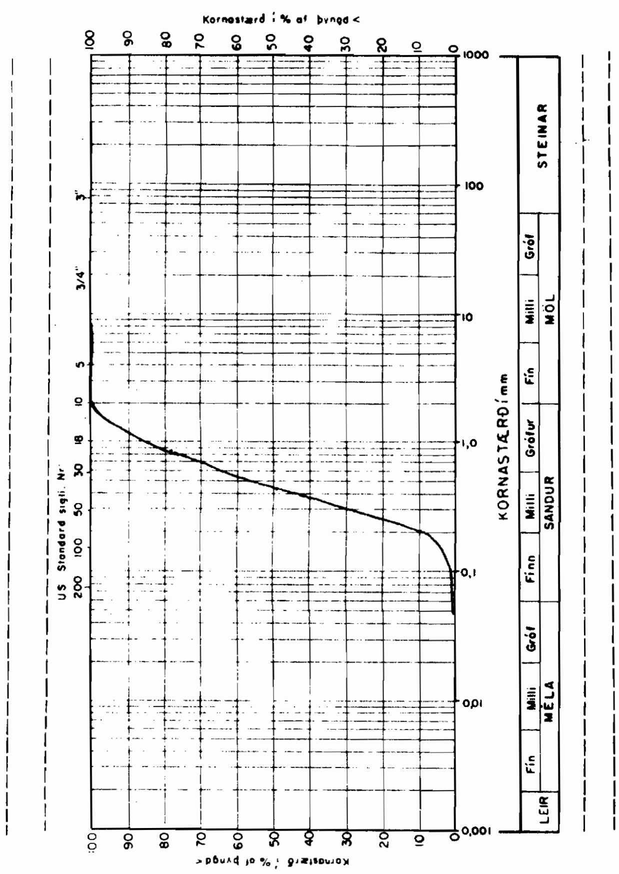
ORKUSTOFNUN

K-806
Ölfusarós
Ölfus I
8/12 1973 S.Z



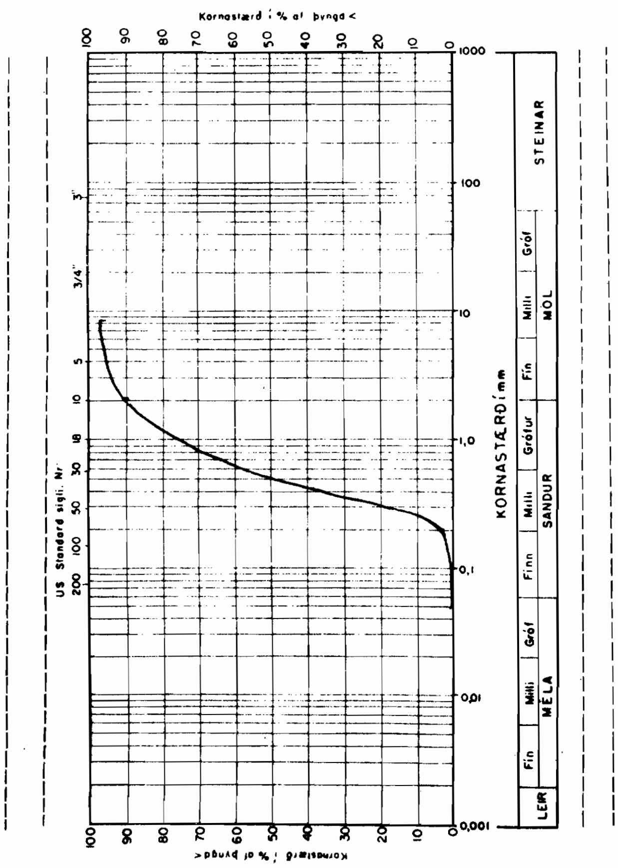
ORKUSTOFNUN

K-807
Þorlákshöfn
Ölfus II
8/12 1973 S.Z.



ORKUSTOFNUN

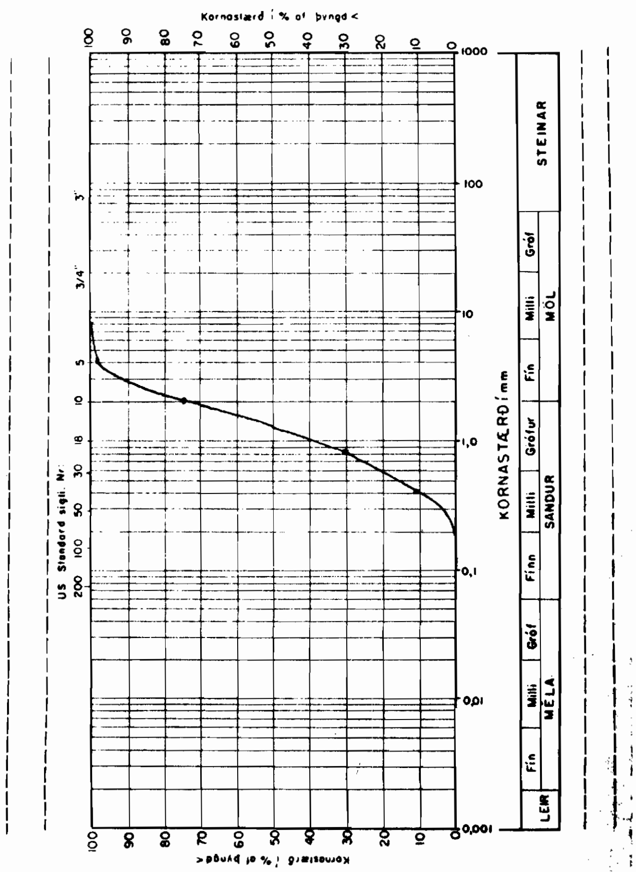
K-808
Ölfusarós
Ölfus III
8/12 1973, S.Z



Tek. 9
G.D.

ORKUSTOFNUN

K-809
pØ5
10/12 1973 S.Z.



APPENDIX 4

A Key to Laboratory Designations

Laboratory no.	Sample no.	Sampling method	Location	Other information
K-753		UDS	ÞB I	Depth 12.8 - 13.5
K-754		-	-	- 15.0 - 15.8
K-755		-	-	- 17.1 - 17.6
K-756		-	-	- 20.0 - 20.7
K-757		-	ÞB II	- 6.1 - 6.9
K-756		WC	-	- 6.0 - 10.4
K-759		-	-	- 10.7 - 13.4
K-760		-	-	- 14.5 - 16.2
K-761	3	Small bucket	Fig. 2.2-2.4	
K-762	4	-	Fig. 2.2-2.4 5.1	
K-763	5	-	-	
K-764	6	-	-	
K-765	7	-	Fig. 2.2-2.4	
K-766	8	-	-	
K-767	9	-	-	
K-768	10	-	-	
K-769	11	-	-	
K-770	12	-	-	
K-771	13	-	-	
K-772	14	-	-	
K-773	15	-	-	
K-774	16	-	-	
K-775	17	-	-	
K-776	18	-	-	
K-777	19	-	-	
K-778	20			
K-779	I	-	Fig. 5.1,5.6	Sample supplied by the Icelandic Harbour Authority
K-780	V	-	-	-

Laboratory no.	Sample no.	Sampling method	Location	Other information
K-781	VI	Small bucket	Fig. 5.1,5,6	Sample supplied by the Icelandic Harbour Authority
K-782	II	-	-	-
K-783	III	-	-	-
K-784	IV	-	-	-
K-785	VII	-	-	-
K-786	VIII	-	-	-
K-787	S 1 I	Kullenberg	Fig. 5.1	
K-788	S 1 II	-	-	
K-789	S 2 II	-	-	
K-790	S 3 I	-	-	
K-791	S 3 II	-	-	
K-792	S 5 I	-	-	
K-793	S 5 II	-	-	
K-794	S 6 II	-	-	
K-795	S 7 I	-	-	
K-796	S 7 II	-	-	
K-797	S 8 I	-	-	
K-798	S10 I	-	-	
K-799	S 2 I	-	-	
K-800	S 4 I	-	-	
K-801	S 9 I	-	-	
K-802	S 1 3	Shovel	Fig. 2.2-2.4	
K-803	Þ 3 6	-	-	
K-804	Þ 1 5	-	-	
K-805		UDS	ÞB III	Depth 12.6-13.6 m
K-806	Ö I	Shovel	Fig. 2.2-2.4	
K-807	Ö II	-	-	
K-808	Ö III	-	-	
K-809	Þ 2 5	-	-	