National Energy Authority
ORKUSTOFNUN

SULTARTANGI HYDROELECTRIC PROJECT

GEOLOGICAL REPORT

BJÖRN JÓNASSON

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National Energy Authority
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C O N T E N T S

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APPENDIX

1. INTRODUCTION

This report is prepared by the Electric Power Department of the National Energy Authority. It deals with the site geology of the Sultartangi Hydroelectric Project (Exh. 1).

The powerhouse location is planned in the course of Thjórsá about 1 km downstream of the confluence of Thjórsá and Tungnaá and the dams will extend from Sandafell in the west to Vadalda and again from that hill in a southeasterly direction to a moberg ridge, which is to a large extent covered with postglacial lavas. Thus, the right abutment of the dam and the powerhouse with related structures are situated in quaternary rocks (Old formation), which are generally fairly watertight but left bank dikes and related structures are located on postglacial lava (Young formation) which is generally highly permeable, though to a varying degree.

According to the present design of structures af Sultargangi the maximum lake level elevation is supposed to be at 303 m yielding a head of 37,2 m. In accordance with this the capacity of the power plant will be 150 MW.

Information on the geology was mainly obtained by core drilling and general geological mapping. The part of the work dealt with in this report was mainly accomplished in late 1974 and in the midst of summer 1975. A total of 301,3 m were drilled these two years. These investigations were an extention of the geological studies carried out in summer 1971, which included the drilling of four core boreholes, ST-1, ST-3, ST-4 and TH-3b, a total of 193,7 meters, with the purpose of locating structures according to a previous plan as well as general geological mapping in the Sultartangi area and its surroundings. That summer two shallow holes, SB-1 and SB-2, totalling 30,9 m, were also drilled on a proposed site for a bridge across Thjórsá (Exh. 1). (Kaldal, I. and S. Víkingsson, 1972).

In 1965 3 core drillings, TH-2, 3 and 4, totalling 128,6 meters, were carried out in the area mostly for groundwater studies in the postglacial lavas.

In October and November 1974 five core boreholes, ST-5, 6, 7, 8 and 9, totalling 119,8 m, were drilled in the Vadalda area. These holes were drilled with regard to the location of the dams of the Sultartangi project, which then was planned 0,5 - 1,0 km farther downstream than suggested in the previous plan (Thoroddson and partners, 1972). Boreholes ST-5 and ST-6 ar located on the left bank of Thjórsá and Tungnaá at Tangafoss, but ST-7, ST-8 and ST-9 are situated on the lava margin west and south of Vadalda on the proposed damsite (Exh. 1).

At the same time a rather great number of trenches were excavated by a Caterpillar D-9 bulldozer in the first place in the search of material for dam construction (impervious core), and secondly for geological studying of the uppermost part of the lava THi whereon a great part of the dam will be situated.

In addition seismic survey was conducted on the proposed damsite, mainly between Thjórsá and Vadalda (Hólmjárn, J. et al., 1974).

In June to August 1975 four core boreholes were drilled (ST-10, 11, 12 and 13) in Sandafell about 1 km downstream of the confluence of Thjórsá and Tungnaá, altogether 181,5 m. They were all drilled with regard to the locating of the powerhouse (Exh. 1).

The relatively extensive drilling in such a restricted area, at the proposed powerhouse site, is partly due to irregularities in the stratigraphy as there appear two basaltic lava layers in ST-11 and ST-13 which are not present in ST-10 and ST-12. The margins of these two layers therefore are somewhere in between the two pairs of boreholes and furthermore the lower layer is highly scoriaceous, at least in boreholes ST-11 and ST-13 and in Sandafell just above the confluence, and is consequently highly permeable. Other layers are very tight.

2. GEOLOGY

As more thoroughly discussed below the stratigraphical section is divided into two units, Old formation (middle quaternary) on one hand and Young formation (recent and late quaternary) on the other (see Exhs. 2 and 10). The division is made with regard to the great age difference of the rocks in the Sultartangi area. These two series of strata also differ markedly in general characteristics such as porosity.

The Sandafell and Vadalda hills together with contemporary rocks concealed below postglacial lavas belong to the so-called Old formation (age 0, 7 - 2, 4 million years), but the moraine and tillite resting on the Old formation and the lava flows surrounding Vadalda and reaching down to Thjórsá, as well as interbeds and moberg (Skammalda moberg) make up the Young formation (age ≤ 10. 000 - 12. 000 years except the Skammalda moberg, being most likely ≤ 70. 000 years old).

2. 1. Old formation

This formation dates from the Matuyama magnetic epoch beginning 2, 4 million years ago and ending 0, 7 million years ago with the advent of the present magnetic epoch, Brunhes. During this epoch the magnetic polarity was reversed as compared to the present normal state. Within the Matuyama there occurred three magnetic events of normal polarity, each lasting a comparatively short time. Olduvai, the earliest, occurred about 2 million years ago, the second one, Gilsá, began ∿ 1, 8 million years ago and lasted for 0, 2 million years, but the most recent one, termed Jaramillo, occurred just 1 million years ago.

The normally magnetized layers on top of the conglomerate in Sandafell (Exhs.11) probably belong to the Gilsá magnetic event rather than Olduvai and the same most likely applies to the normal basalt in Vadalda.

The pile of strata in the lowest part of Sandafell is characterized by slightly feldspar- and olivin porphyritic (≤ 10%), coarse-grained basalt, doleritic basalt. Yet, the uppermost layer in Vadalda as well as the lowest but one layer in Sandafell (cf. Exh. 11, ST-11 and ST-13) consist of fine-grained tholeiite basalt. (Tholeiite is a subdivision of basaltic rocks, with respect to chemistry).

In the lower part of Sandafell sedimentary layers are only to be found in one place, consisting of conglomerate highly varying in thickness (0,5 - 6,9 m). A fairly thick sedimentary layer is also to be found above the pile of strata discussed in this report, i.e. above the elevation of the proposed structures, (see Kaldal, I. and S. Víkingsson, 1972). Up to now this layer has been considered to be the same as the one found underlying the reversely magnetized fine-grained topmost basalt layer in Vadalda as described below.

Sandafell

As shown on Exh. 11 all the boreholes in the Sandafell hill (ST-10 - ST-13) terminate in the same layer, i.e. reversely magnetized doloritic basalt. The same is also true of boreholes ST-4, ST-5 and ST-6 on the other side of Thjórsá.

In boreholes ST-11 and ST-13 there are two basalt layers intercalated between the above layer and the conglomerate layer. The lower one is highly scoriaceous and permeable tholeiite, but the upper one is composed of fairly impermeable doleritic basalt. These layers do not appear in ST-10 and ST-12, here the conglomerate rests directly on the "bottom" doleritic basalt and reaches 7 m thickness. Somewhere in this interval, i.e. between ST-10 and ST-12 on one hand and ST-11 and ST-13 on the other, the margins of these two layers are to be found below the conglomerate (see chapter 3). The overlying doleritic basalt layer tends to even out this irregularity in the stratigraphy (Geological map, Exh. 3) having overrun a river channel or alluvial plain (cf. the conglomerate) whereby its lower part has brecciated, as can be seen on the graphic core logs (Exhs.7 and 8). This layer is by far the thickest in boreholes ST-10 and ST-12. The brecciated basalt is overlain by a rather dense, doleritic basalt layer, the uppermost layer in boreholes ST-10 and ST-11.

Vadalda

At the roots of Vadalda there appears a normally magnetized doleritic basalt layer (Exh. 9) in which boreholes ST-7, ST-8 and ST-9 terminate. This doleritic layer belongs to the upper part of the pile of strata penetrated by the boreholes in Sandafell. This layer is overlain by a sedimentary layer appearing both on the north-western side of the hill as a moberg-like, well consolidated conglomerate (at least 6 m thick) with basaltic and rhyolitic pebbles and on the south-eastern flank of the hill where it consist of tillite, > 5 m thick. On top of this sedimentary layer, i.e. forming the topmost part of Vadalda, there rests fine-grained reversely magnetized basalt, dense, fine-jointed and flow-banded.

The sedimentary layer and the topmost basalt in Vadalda probably are the same as found in rather poor openings farther to the west in Sandafell (cf. Kaldal, I. and S. Víkingsson, 1972) uphill from ST-10 and ST-11.

2.2. Young formation

This formation is very young geologically, ≤ 10-12.000 years old, except the moberg, which is probably ≤ 70.000 years old. It is composed of moberg (Skammalda moberg), tillite, recent basaltic lavas (tholeiite) and interbeds (Exh. 10) consisting primarily of tephra (ash and pumice).

Vadalda is concealed by a rather thin moraine/tillite cover, which is probably present in drillhole ST-8, and is about 9,0 m thick in ST-9 on the eastern side of the hill. The tillite is also fairly thick, 8,5 m, in drillhole ST-6, but has been washed and weathered away in ST-5 and ST-7.

Two lavas have flowed down the passage between Thjórsá and Vadalda, THf (∿ 6.000 years ago) and THi (∿ 3.000 years ago). These two lava flows rest on interbeds, each about 10 m thick in drillhole TH-3b, which is the only hole located between Thjórsá and Vadalda penetrating through both tha lavas and the underlying interbeds.

In drillhole TH-2 south-east of Vadalda the same interbeds are much thinner, 3,6 m and 6,3 m respectively. None of the ST-holes drilled in 1974 strikes the THf lava, but in TH-3b its thickness is about 16,0 m and on the proposed damsite the maximum thickness of the lava according to a seismic survey is 9,0 m while the width of the lava tongue is approximately 1.000 m (see Exh. 5, section A-A, Hólmjárn, J. et al., 1974).

The lava flow THi conceales any indication of the lava THf in the Vadalda area. It is by far thickest at Thjórsá, about 25 m in ST-5 and 6, but thinns out in the direction of Vadalda. In TH-3b it is nearly 14,0 m thick and at the lava margin by Vadalda it is 10 m and 8 m in ST-7 and ST-8 respectively. On th southeast of Vadalda the lava seems to be of even thickness as can be seen in ST-9 and TH-2 where the thickness is 11,0 and 13,0.

2.3. Tectonics

Results of precise measurements of the strike and dip in the Old formation in Sandafell show a strike of N 76° E and a dip of 1,8° - 2,0° in a southerly direction.

According to studies of aerial photographs the tectonic lines in Sandafell follow two dominant sets of directions, a SW-NE trend on one hand and the strike direction on the other, i.e. N 70-80° E. There is clear connection between strike direction and tectonic trends. This tectionic trend is probably older than the dominating SW-NE direction in southern Iceland.

Dip

Very precise measurements of the dip of strata in the Old formation in Sandafell were carried out. They were based on comparing contacts of strata in boreholes ST-11 and ST-13 to identical contacts in Sandafell upstream of the confluence of Thjórsá and Tungnaá.

Measurement I :
The contacts of the doleritic basalt underlying the conglomerate and the tholeiite in ST-11 and ST-13 and two points of the same contact just upstream of the confluence of the rivers, altogether 4 points. The dip is 2,0° in a southerly direction.

Measurement II :
The contacts of tholeiite and "bottom" doleritic basalt in the same boreholes as above and the contact of the doleritic basalt and normal magnetized non-porphyritic tholeiite located about 0,7 km upstream of the confluence of Thjórsá and Tungnaá, altogether 3 points. Between

these layers, i.e. above the confluence, there appears tillite (bottom moraine) of highly variable thickness with large boulders (≥ 1 m ɸ This point of observation is selected with regard to the limited erosion it has been subject to. The observed dip is 1,8° in a southerly direction.

Tectonic lineations

Studies of the core samples from boreholes SB-1, SB-2, ST-1, 3 and 4, drilled in 1971, revealed that the core from the Old formation in ST-4 belongs to two layers, which were not logged separately on previous graphic core logs (see Kaldal, I. and S. Víkingsson, 1972). The upper layer is scoriaceous tholeiite but the lower one consists of doleritic basalt, (Exh. 12).

The above studies thus may point to the presence of a fault having a displacement of 5-8 m somewhere between boreholes ST-4 and ST-13.

3. GEOLOGICAL SECTIONS

Section A-A (Exh. 9) connects boreholes ST-5, TH-3b, ST-7, ST-8 and ST-9 and shows approximately the stratigraphy on the proposed damsite extending from Thjórsá to the southeast of Vadalda. In fact TH-3b lies about 250 m north of the damsite, but as it is the only borehole located midway between Thjórsá and Vadalda, the section is made to run through it (Exh. 1).

Section B-B (Exh. 9) connects boreholes ST-4, ST-5 and ST-6 located on the left bank of Thjórsá/Tungnaá running parallel to it through the eastern part of the powerhouse site.

Section C-C (Exh. 10) runs through boreholes ST-10, ST-4, TH-3b, ST-7, ST-8, ST-9 and TH-2 and is projected from there to the so-called Skammalda moberg (see location of section on Exh. 2). Thus the section shows the general stratigraphical relationship in the proposed powerhouse- and damsite areas.

The section is inaccurate from borehole ST-9 to the Skammalda moberg as there is only one borehole in this interval, i.e. TH-2, which is as much as 750 m outside the section and does not reach the Old formation. The graphic core log is actually extended almost unchanged in both directions.

Sections ST-10 - 12, ST-10 - 11, ST-11 - 13 and ST-12 - 13 (Exh. 11) connect respective boreholes, which are located in Sandafell, as shown on Exh. 1, in the area of the proposed powerhouse site. They show clearly the irregularity in the stratigraphy. Two rock layers appearing right below the conglomerate in ST-11 and ST-13 are not found in ST-10 and ST-12. Their margins therefore are somewhere between the two sets of boreholes.

The above correlations are schematic as far as sections ST-10 - 11 and ST-12 - 13 are concerned and the margins of the basalt layers underneath the conglomerate are probably steeper and/or tongue shaped extending farther in the direction of drillholes ST-10 and ST-12. Consequently the conglomerate does not reach the thickness shown on the above-mentioned sections near the margins of these rock layers (cf. Exh. 3).

Sections S-6 - ST-12 - ST-10, (S-6 is a stake in measured cross section in Thjórsá) and ST-4 - ST-13 - ST-11 (Exh. 12) show the relative position of strata in the left bank of Thjórsá (Young formation) to that in Sandafell (Old formation)on the right bank of Thjórsá and are obtained by correlation between the above boreholes (S-6 not included). For location see Exh. 1.

As discussed in the chapter on geology the presence of a fault between ST-4 and ST-13 may clarify the irregularity of the stratigraphy, but the location and direction of such a fault is rather uncertain. Yet it probably strikes approximately SW-NE in accordance with the general pattern in southern Iceland. The displacement may amount to 5-8 m.

In the first section there is also some uncertainty as to the thickness of the conglomerate as well as the interbed (tillite or eolian deposits/tephra underneath the lava THi, but in this case no correlation is made to the borehole on the left bank of Thjórsá.

In the latter section there is also some uncertainty as to the thickness of the tillite underlying the lava THi in the interval from ST-4 to Thjórsá, but most likely it thickens in the direction of Thjórsá.

Where correlation is based on boreholes and known contacts, such as at lava margins, contacts are drawn with unbroken line, but in cases of uncertain or projected contacts dashed lines are used.

The limits between scoriaceous surface material and solid lava are not drawn because they are indistinct and variable as can be seen on Table II.

4. DESCRIPTION OF TRENCHES

In Table II is a description of 10 bulldozer trenches, all of which are located on the proposed damsite, which is shown on Exh. 1. East of Vadalda there are two damsite alternatives.

Trench No. 4, 6, 7 and 8 are on lava west of Vadalda
" " 9, 10, 14 and 15 " " " east " "
" " 12 and 13 on moraine on the eastern flank of Vadalda

The topmost part of the lava west of Vadalda is, as can be seen in Table II, clearly different from what it is east of the hill as west of it the rought scoria is clay-filled and there are heaps of pumice together with loessial soil and layered sand/silt fillings between pumice and scoria. These are not to be found east of the hill.

Vadalda is widely covered with moraine, the first 0,6 m of which are very sandy (i.e. weathered), but below it is very hard (tillite) and dense. When ripped it breaks into flakes due to pseudo-layering.

Trench No. 8, eastern part (cf. c in Table II), extends beyond the margin of lava THi.

0,5 m	Loessial soil and eolian sand with boulders, raised by frost action.
0,2 m	Pumice, black and coarse.
1,0 m	Pumice, black and light, rich in feldspar phenocrysts, cross-bedded. At bottom lava boulders with large feldspar phenocrysts.
1,2 m	Sand, black and coarse, feldspar phenocrysts, either rounded or not.
1,0 m	Sand and pumice, black with light grains of pumice, layered.
3,9 m	

5. PERMEABILITY MEASUREMENTS

As can be seen on the graphic core logs, Exhs. 5, 6, 7 and 8, the Old formation and the tillite in the Young formation is almost completely watertight in all instances since the widely fractured bedrock is everywhere very clay-filled. Yet there is one exception as the lowest but one basalt layer in boreholes ST-11 and ST-13, which is very scoriaceous tholeiite, is highly permeable and appreciably lowers the ground water table. This is shown on Exh. 11. On the other hand the lavas and interbeds of the Young formation are often highly pervious.

As to lava THi the middle section is least permeable (ST-5, Exh. 5), but as could be expected the lava margin at Vadalda is highly permeable (ST-7, ST-8 and ST-9, Exh. 6), due to the combined factors of very broken, vesicular and scoriaceous lava. In this connection it should be pointed out that the results of permeability measurements at the middle section of borehole ST-8 are not reliable due to difficult circumstances when tested and a faulty flow meter.

The contact zones of lavas and interbeds are conspicuously most permeable together with the scoriaceous surface zone of the lava (ST-5, ST-6, ST-7 and ST-9, Exhs. 5 and 6), the thickness of which is very variable as shown on Table II. With regard to leakage the surface scoria and lava margins are by far the most critical places from an engineering geological standpoint.

REFERENCES

Hólmjárn, J. et al., 1974 "Sultartangi Hydroelectric Project. Reflection survey". National Energy Authority Report, photocopied, in Icelandic.

Kaldal, I. and S. Víkingsson, 1972 "Sultartangi. Geological report". National Energy Authority Report, mimeographed, in Icelandic.

Thoroddsen and partners, 1972 Sultartangi Hydroelectric Project. Appraisal report. The National Power Company, Iceland. Mimeographed rep.

TABLE I

LOCATION AND DEPTH OF CORE BOREHOLES AT SULTARTANGI

No. of hole	Coordinates X	Y	Elevation of casing m	Depth	Elevation of bottom m
ST-5	576,091	409,220	284,3	35,1	249,2
ST-6	575,884	409,442	282,5	35,2	247,3
ST-7	575,472	408,758	281,1	14,2	266,9
ST-8	575,440	408,752	281,6	13,0	268,6
ST-9	574,360	408,512	289,7	22,3	267,4
ST-10	576,678	409,136	305,7	65,1	240,6
ST-11	576,487	409,215	302,2	48,5	253,7
ST-12	576,620	408,994	284,3	40,5	243,8
ST-13	576,422	409,143	287,3	27,4	259,9

T A B L E I I

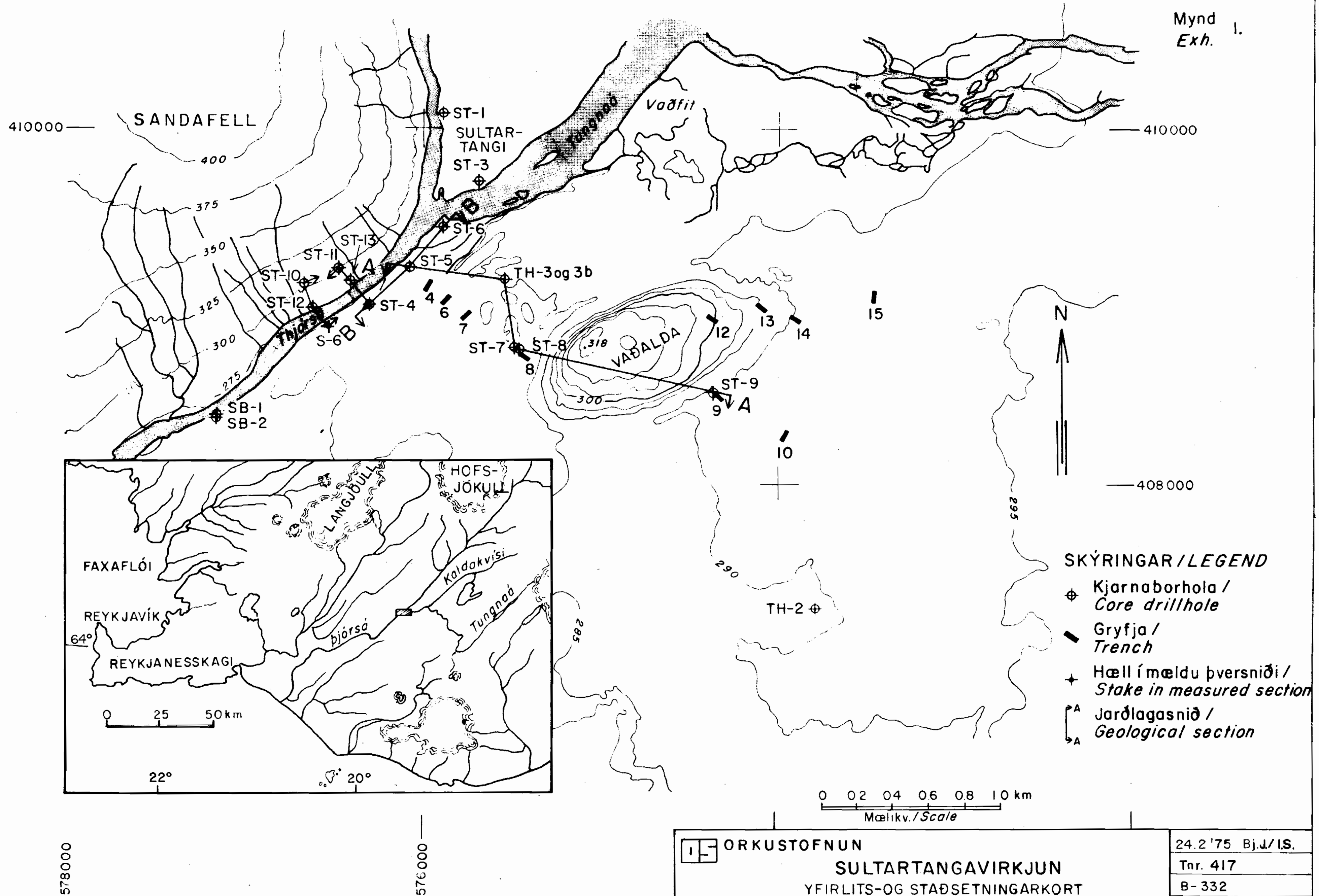
Description of trenches on the proposed damsite from Thjórsá to the east of Vadalda

	NO. OF TRENCH / DESCRIPTION OF MATERIAL / THICKNESS OF LAYERS WITH INCREASING DEPTH	4	6	7	c) 8	9	10	12	13	14	15
LAVA	Loessial soil-sand, mixed with ash and pumice with boulders raised from scoria by frost action	0, 1-0, 5m	0, 2-0, 5m	0, 1-0, 3m	0, 4-0, 5m	~0, 9m	0, 4-0, 5m			0, 3-0, 7m	0, 2-0, 5m
LAVA	Pumice black/coarse ≤ 5 cm ϕ	0, 0-0, 3		0, 0-0, 1	0, 2-0, 5	0, 2-0, 4	0, 0-0, 2			0, 0-0, 2	0, 2
LAVA	Pumice light/finer ≤ 2 cm ϕ	0, 0-1, 1		0, 0-1, 7							
LAVA	Loessial soil	a) 0, 0-1, 0		a) 0, 0-0, 1	0, 0~0, 3						
LAVA	Sand, layered	a) 0, 0-1, 0		a) 0, 0-0, 6							
LAVA	Silt, layered			0, 0-0, 3							
LAVA	Scoria, grain size gravel-boulders, max.~0, 7 m ϕ, mixed with light pumice	b) > 2, 0	b) 1, 3-1, 6	b) > 4, 0	b) > 2, 7	1, 5-1, 8	≥ 2, 0			1, 9-2, 5	3, 0
MORAINE	Sandy-weathered surface of moraine							0, 6m	~0, 6m		
MORAINE	Very well consolidated moraine/tillite, pseudo-layering, very fine grain size							1, 4	e) > 0, 7		
	MAX. DEPTH OF TRENCH	6, 0m	1, 8m	7, 0 m	4, 0 m	2, 6 m	2, 5 m	d) ~2, 0 m	1, 8 m	2, 8 m	3, 4 m

Notes:

a) Local, in depressions on both sides of a lava knoll.
b) The scoria is mixed with clay-silt or sand.
c) Valid for western part of trench.
d) In trench 0, 5 m deep water.
e) The pseudo-layered tillite is overlain by a mixture of consolidated moraine, coarse, ~0, 5 m.

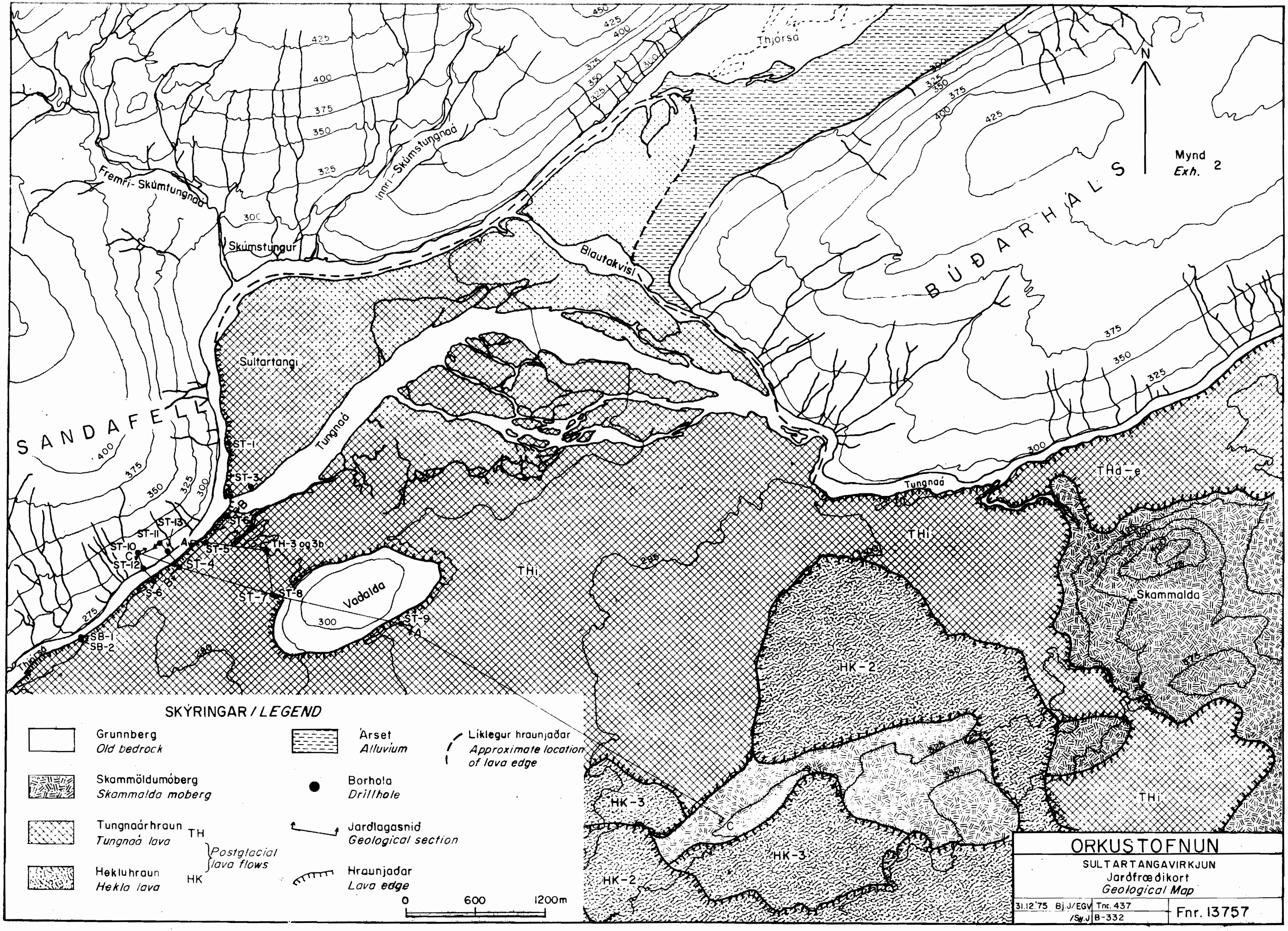
Mynd 1.
Exh.

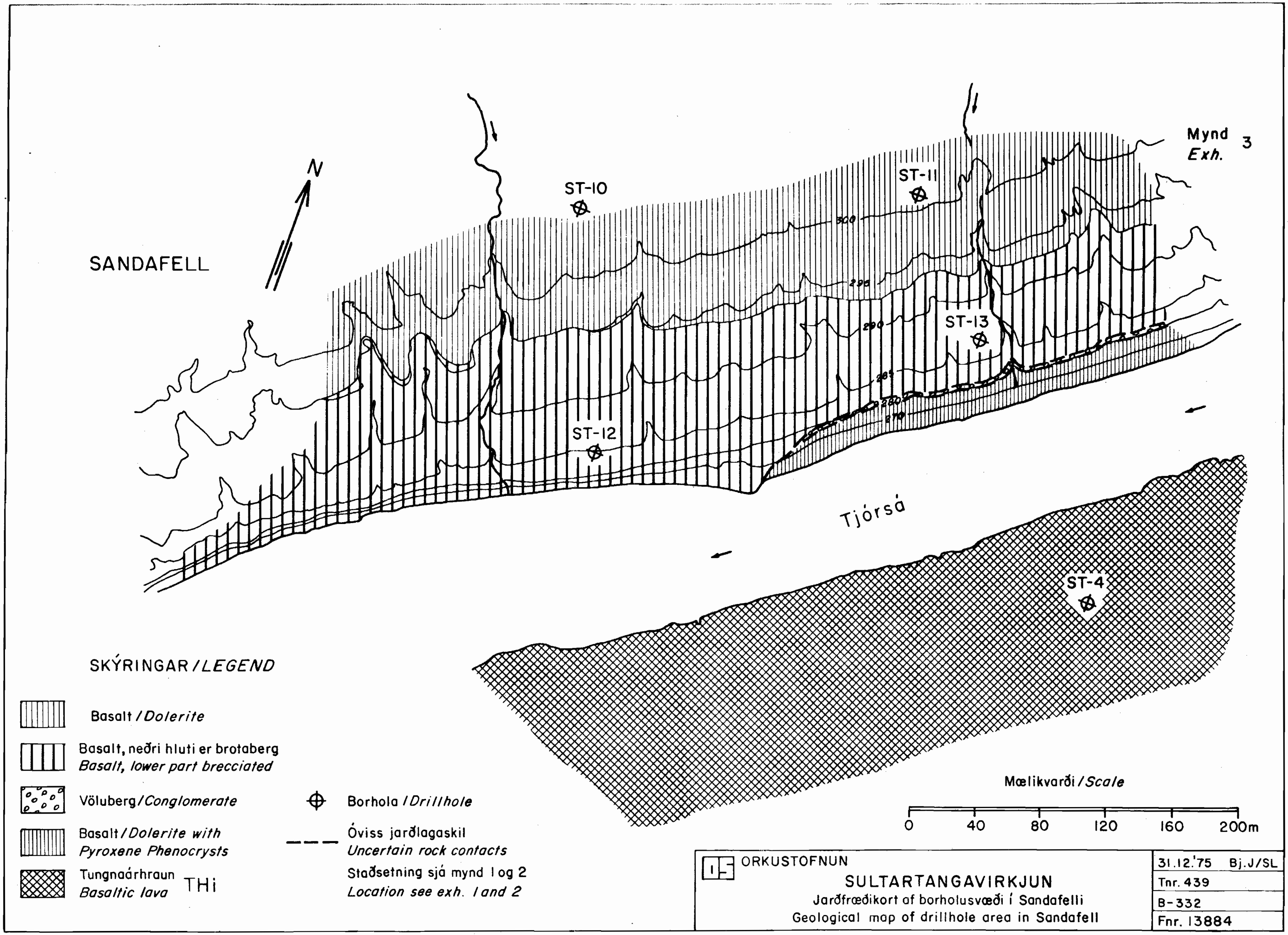


SKÝRINGAR / *LEGEND*

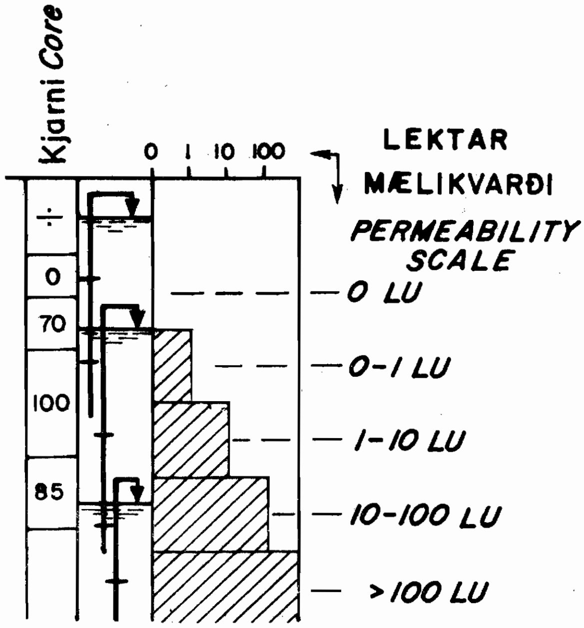
- Kjarnaborhola / *Core drillhole*
- Gryfja / *Trench*
- Hæll í mældu þversniði / *Stake in measured section*
- Jarðlagasnið / *Geological section*

OS ORKUSTOFNUN SULTARTANGAVIRKJUN YFIRLITS-OG STAÐSETNINGARKORT *KEY-AND LOCATION MAP*	24.2 '75 Bj.J/I.S.
	Tnr. 417
	B-332
	Fnr. 12517


Mynd 2
Exh. 2
N
BÚÐARHÁLS
SANDAFELL
Sultartangi
Tungnaá
Blautakvísl
Thjórsá
Skúmstungur
Innri-Skúmstungnaá
Fremri-Skúmtungnaá
Vaðalda
Skammalda
THi
THd-e
HK-2
HK-3
ST-1
ST-3
ST-4
ST-5
ST-6
ST-7
ST-8
ST-9
ST-10
ST-11
ST-12
ST-13
TH-3 og 3b
SB-1
SB-2
SKÝRINGAR / LEGEND
Grunnberg
Old bedrock
Skammöldumóberg
Skammalda moberg
Tungnaárhraun TH
Tungnaá lava
Hekluhraun HK
Hekla lava
Postglacial lava flows
Árset
Alluvium
Borhola
Drillhole
Jarðlagasnið
Geological section
Hraunjaðar
Lava edge
Líklegur hraunjaðar
Approximate location of lava edge
0 600 1200m
ORKUSTOFNUN
SULTARTANGAVIRKJUN
Jarðfræðikort
Geological Map
31.12.'75 Bj.J/EGV Tnr. 437
B-332
Fnr. 13757


Mynd 3
Exh.
SANDAFELL
N
ST-10
ST-11
ST-12
ST-13
ST-4
300
295
290
285
280
270
Tjórsá
SKÝRINGAR / LEGEND
Basalt / Dolerite
Basalt, neðri hluti er brotaberg
Basalt, lower part brecciated
Völuberg / Conglomerate
Basalt / Dolerite with
Pyroxene Phenocrysts
Tungnaárhraun
Basaltic lava
THi
Borhola / Drillhole
Óviss jarðlagaskil
Uncertain rock contacts
Staðsetning sjá mynd 1 og 2
Location see exh. 1 and 2
Mælikvarði / Scale
0
40
80
120
160
200m
ORKUSTOFNUN
SULTARTANGAVIRKJUN
Jarðfræðikort af borholusvæði í Sandafelli
Geological map of drillhole area in Sandafell
31.12.'75 Bj.J/SL
Tnr. 439
B-332
Fnr. 13884

MYND 4 *Exh.*	ORKUSTOFNUN Raforkudeild KJARNA-, LEKTAR OG JARÐVATNSÚTSKÝRING *NOTE ON CORE PERMEABILITY AND GROUND WATER*	18/9'70 HT/EK Tnr. 204 B – Ým. Fnr. 9586



LEKTAR-OG JARÐVATNSÚTSKÝRING
NOTE ON PERMEABILITY AND GROUND WATER

Jarðvatnsborð er sýnt með örvum. Neðri endi örvarinnar og þverstrikin sýna holudýpið, þegar jarðvatnsborðið var mælt. Ef jarðvatn breytist ekkert í borun, nær örin í botn.

Ground water levels are shown by arrows. Base of the arrows and the horizontal bars indicate the hole depth when the water level was measured. If no change in level was observed during drilling, the arrow reaches the bottom of the hole.

1 LU = Lugeon Unit = 1 l/mín/m í 76 mm Ø holu við þrýsting 10 kg/cm^2

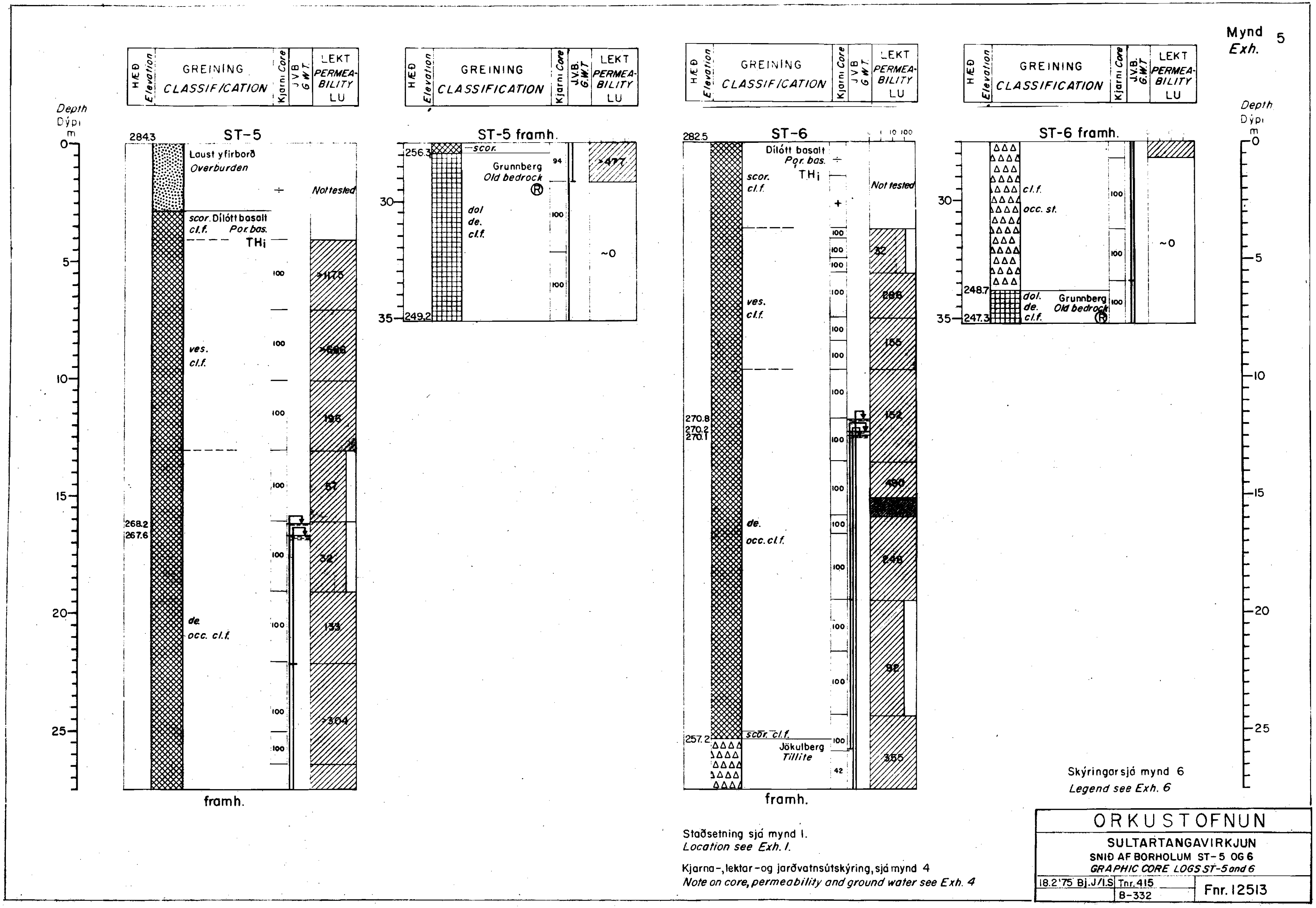
1 LU = Lugeon Unit = 1 l/min/m in 76 mm Ø hole at pressure 10 kg/cm^2

Hæðartölur jarðvatns eru ritaðar smærra letri en hæðartölur bergs, á borholusniðum.

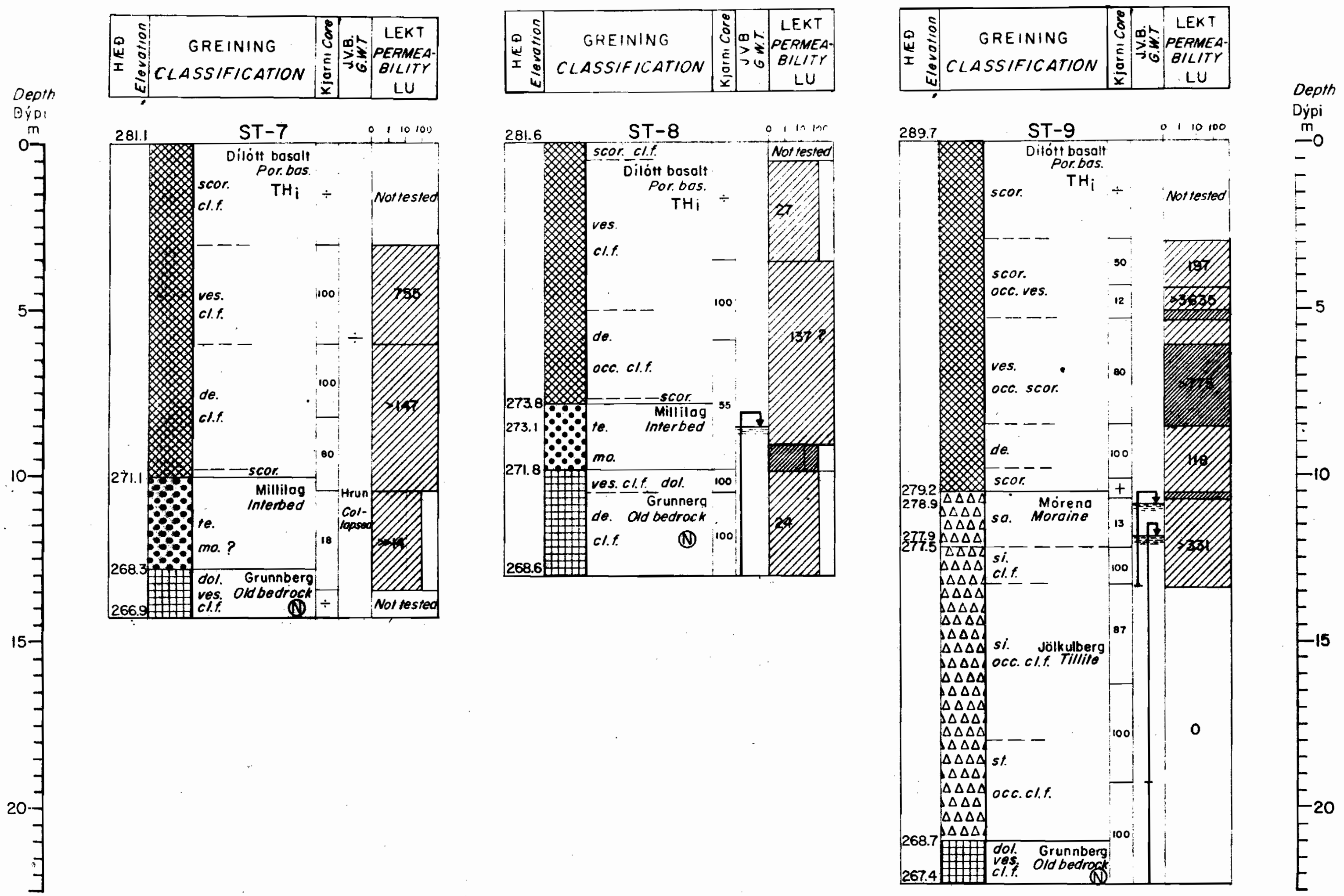
Figures for ground water levels are shown with smaller lettering on graphic core logs.

Kjarni: Tölur sýna kjarnaheimtur í %
÷ kjarnataka ekki reynd.

Core: Numbers indicate % core recovery
÷ core sampling not attempted.


Mynd 5
Exh.
Depth
Dýpi
m
HÆÐ Elevation
GREINING CLASSIFICATION
Kjarni Core
JVB G.W.T.
LEKT PERMEABILITY LU
ST-5
284.3
Laust yfirborð
Overburden
scor. Dílótt basalt
cl.f. Por.bas.
THi
ves.
cl.f.
de.
occ. cl.f.
268.2
267.6
Not tested
>1175
>686
195
57
32
133
>304
framh.
ST-5 framh.
256.3
scor.
Grunnberg
Old bedrock
dol
de.
cl.f.
249.2
94
>477
~0
ST-6
282.5
Dílótt basalt
Por. bas.
THi
scor.
cl.f.
ves.
cl.f.
de.
occ. cl.f.
270.8
270.2
270.1
257.2
scor. cl.f.
Jökulberg
Tillite
Not tested
32
286
155
152
490
246
92
355
42
framh.
ST-6 framh.
cl.f.
occ. st.
248.7
247.3
dol.
de.
cl.f.
Grunnberg
Old bedrock
~0
Skýringar sjá mynd 6
Legend see Exh. 6
Staðsetning sjá mynd I.
Location see Exh. I.
Kjarna-, lektar- og jarðvatnsútskýring, sjá mynd 4
Note on core, permeability and ground water see Exh. 4
ORKUSTOFNUN
SULTARTANGAVIRKJUN
SNIÐ AF BORHOLUM ST-5 OG 6
GRAPHIC CORE LOGS ST-5 and 6
18.2.'75 Bj.J/I.S
Tnr.415
B-332
Fnr. 12513

Mynd 6
Exh.



SKÝRINGAR – *LEGEND*

- Laust yfirborðslag / *Overburden*
- Basalthraun / *Basaltic lava*
- Millilag / *Interbed*
- Mórena, Jökulberg / *Moraine, Tillite*
- Grágrýti / *Dolerite*
- Ⓝ Rétt segulmagnað / *Normally magnetized*
- Ⓡ Öfugt segulmagnað / *Reverse magnetized*

SKAMMSTAFANIR:
ABBREVIATIONS:

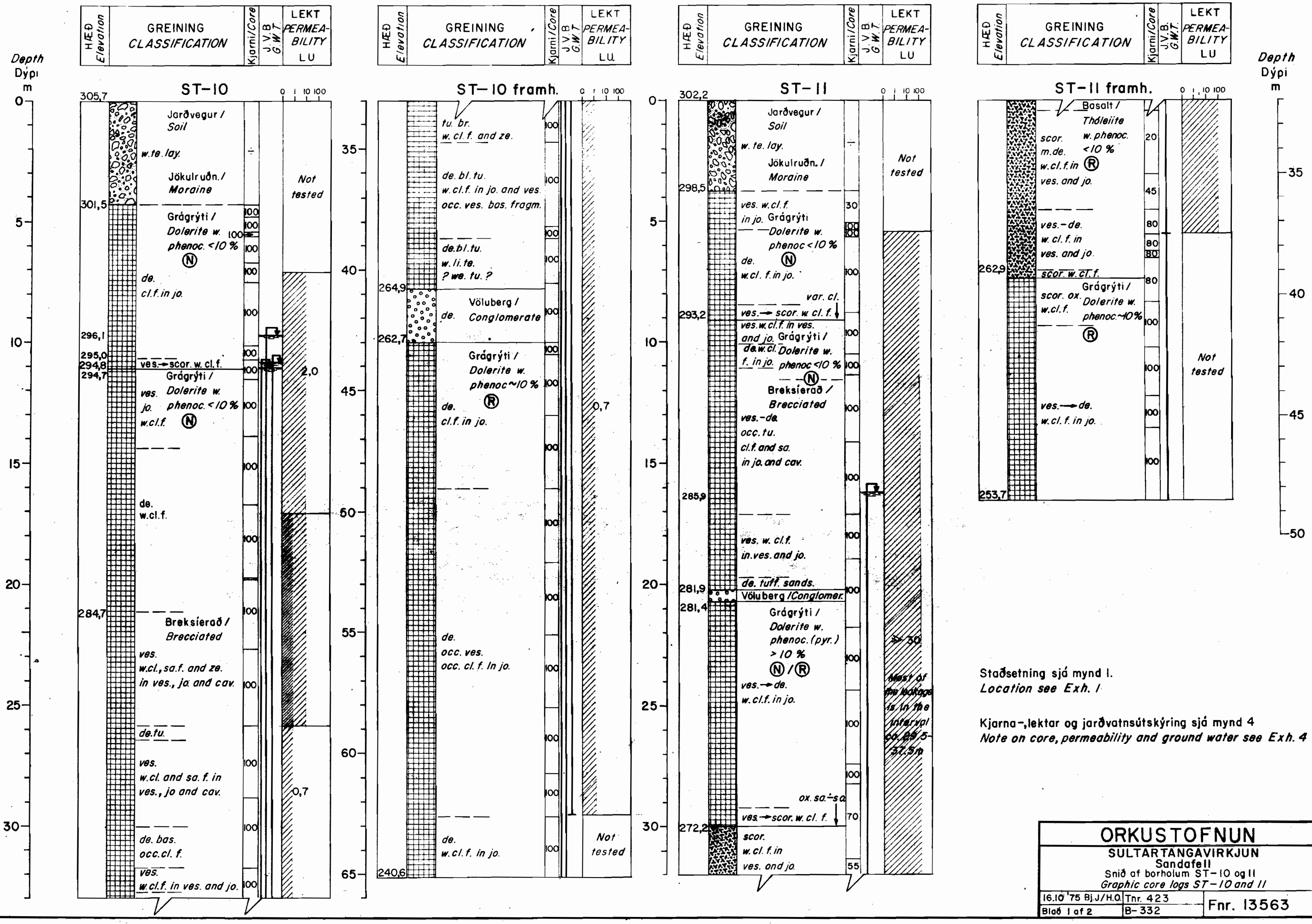
bas.	=	*basalt* / basalthraun
de.	=	*dense* / þétt
dol.	=	*dolerite* / grágrýti
cl.f.	=	*clay fillings* / leirfyllt
mo.	=	*moraine* / mórena
occ.	=	*occationally* / á stökum stað
por.	=	*porphyritic* / dílótt
sa.	=	*sandy* / sandrík
scor.	=	*scoriaceous* / gjallkennt
si.	=	*silty* / siltríkt
st.	=	*stony* / steinaríkt
te.	=	*tephra* / gjóska
ves.	=	*vesiculor* / blöðrótt

Staðsetning sjá mynd I.
Location see Exh. I.

Kjarna-, lektar- og jarðvatnsútskýring, sjá mynd 4
Note on core, permeability and ground water see Exh. 4

ORKUSTOFNUN
SULTARTANGAVIRKJUN
SNIÐ AF BORHOLUM ST-7, 8 OG 9
GRAPHIC CORE LOGS ST-7, 8 and 9
18.2.'75 Bj.J./IS. Tnr. 416 B-332 Fnr. 12514

Mynd 7
Exh.



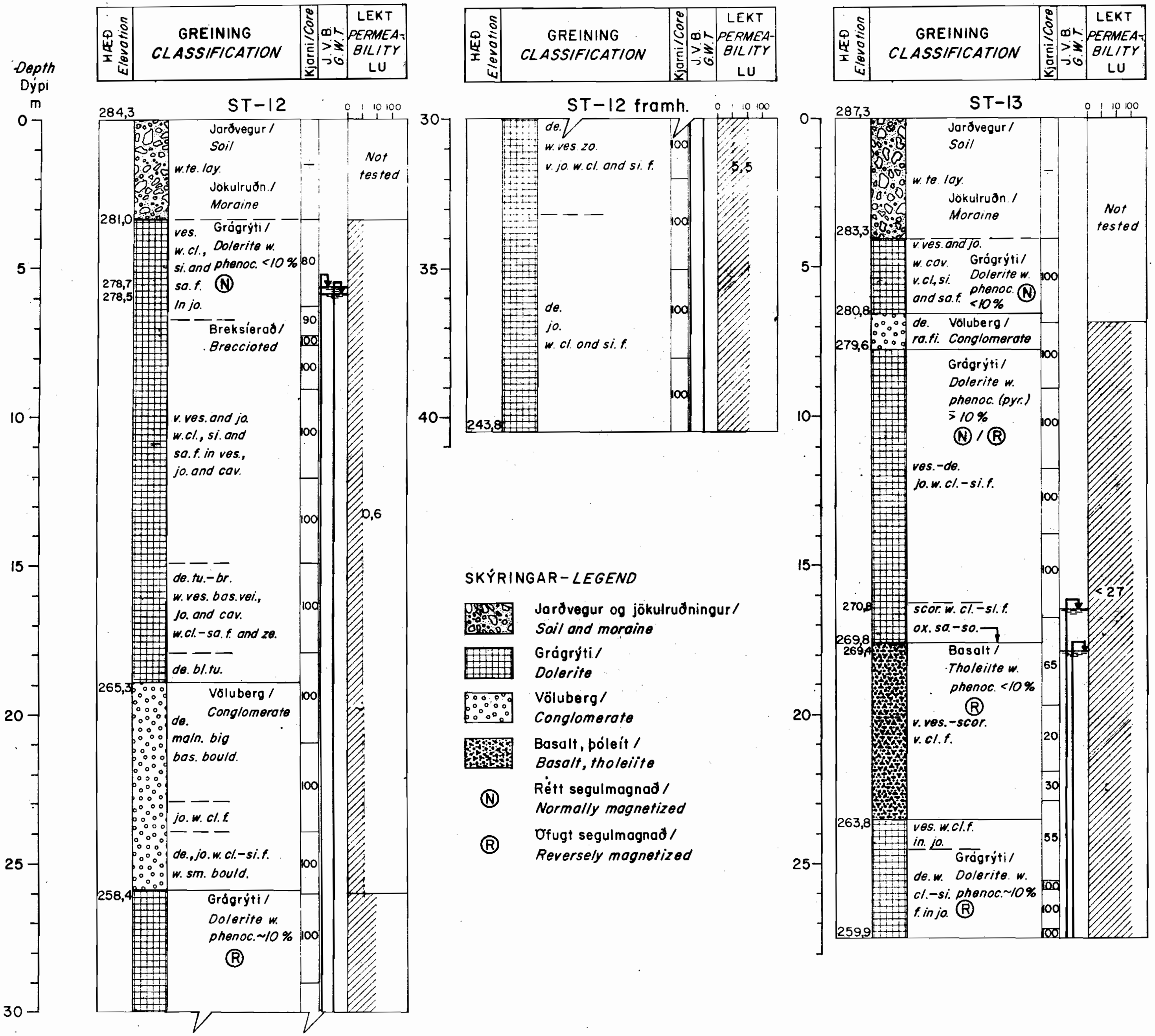
Staðsetning sjá mynd I.
Location see Exh. I

Kjarna-, lektar og jarðvatnsútskýring sjá mynd 4
Note on core, permeability and ground water see Exh. 4

ORKUSTOFNUN
SULTARTANGAVIRKJUN
Sandafell
Snið af borholum ST-10 og II
Graphic core logs ST-10 and II

16.10.'75 Bj.J/H.O.	Tnr. 423	Fnr. 13563
Blað 1 af 2	B-332	

Mynd 8
Exh.



SKAMMSTAFANIR:
ABBREVIATIONS:

bas.	=	*basalt-ic* / basalt, basískur
bl.	=	*black* / svart
bould.	=	*boulders* / hnullungar
br.	=	*breccia-ted* / breksía, breksíerað
cav.	=	*cavities* / holrúm, skápar
cl.	=	*clay* / leir
de.	=	*dense* / þétt
f.	=	*fillings, filled* / fyllingar, fyllt
fi.	=	*fine* / fínn (kornastærð)
fragm.	=	*fragments* / brot
jo.	=	*joints, jointed* / sprungur, sprungíð
lay.	=	*layers* / lög
li.	=	*light* / ljóst
m.	=	*more* / meira
main.	=	*mainly* / aðallega
occ.	=	*occationally* / á stökum stað
ox.	=	*oxidized* / ildað
phenoc.	=	*phenocrysts* / dílar
pyr.	=	*pyroxene* / pyroxen
ra.	=	*rather* / fremur
sa.	=	*sand* / sandur
sa.st.	=	*sandstone* / sandsteinn
scor.	=	*scoriaceous, scoria* / gjallkennt, gjall
si.	=	*silt* / silt. (méla)
sm.	=	*smaller* / minni
so.	=	*soil* / jarðvegur
te.	=	*tephra* / gjóska
tu.	=	*tuff* / túff
tuff.	=	*tuffaceous* / túffkennt
v.	=	*very* / mjög
va.cl.	=	*varved clay* / hvarfleir
vei.	=	*veins* / (basalt)-æðar
ves.	=	*vesicular, vesicles* / blöðrótt, blöðrur
w.	=	*with* / með
we.	=	*welded* / sambrætt
ze.	=	*zeolites* / geislasteinar
zo.	=	*zone* / belti

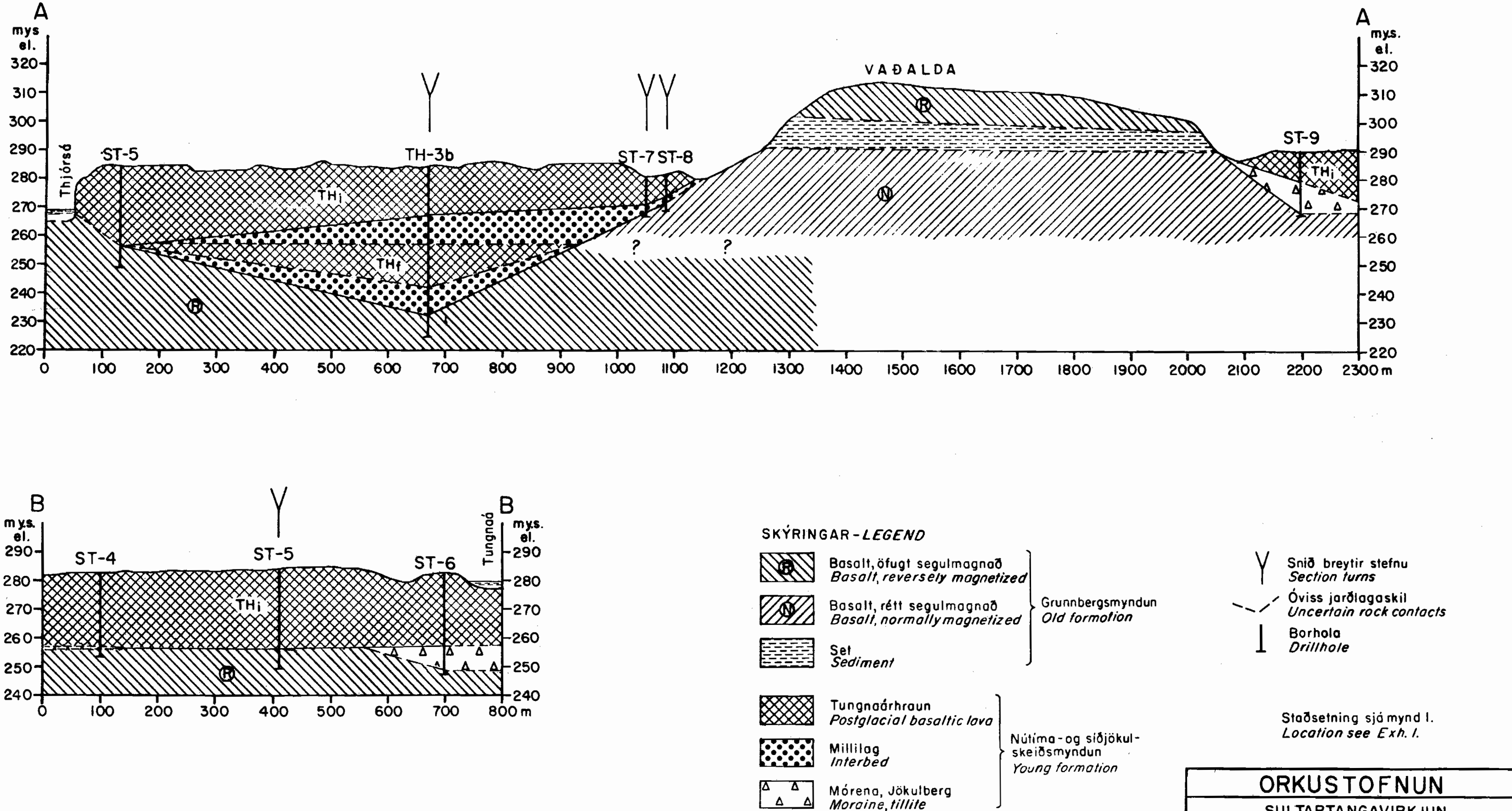
Staðsetning sjá mynd 1
Location see Exh. 1

Kjarna-, lektar- og jarðvatnsútskýring sjá mynd 4
Note on core, permeability and ground water see Exh. 4

ORKUSTOFNUN
SULTARTANGAVIRKJUN
Sandafell
Snið af borholum ST-12 og 13
Graphic core logs ST-12 and 13

16.10 '75 Bj.J/H.O.	Tnr. 424	Fnr. 13564
Blað 2 af 2	B-332	

Mynd 9
Exh.



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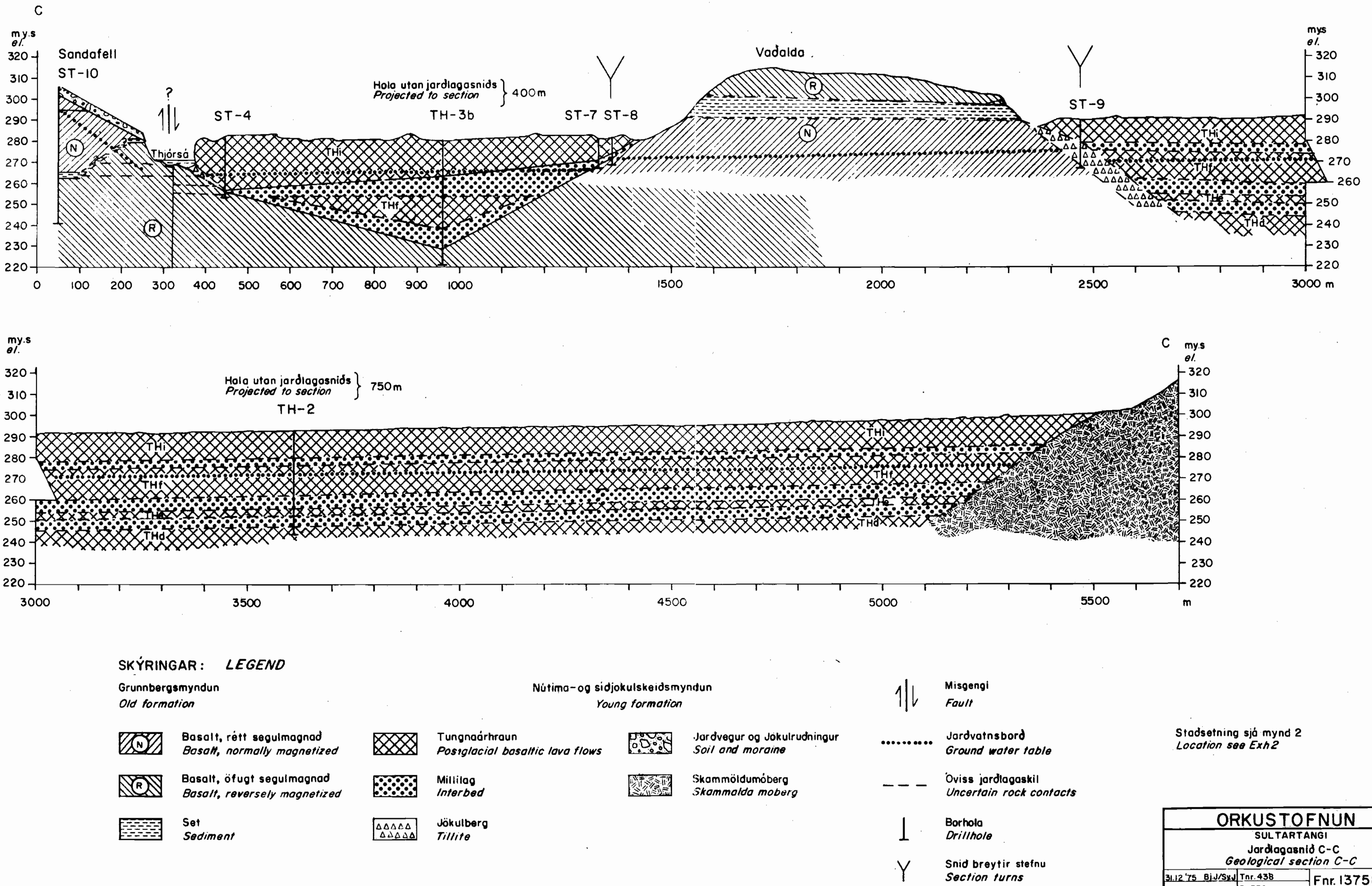
SULTARTANGAVIRKJUN

JARÐLAGASNIÐ A-A OG B-B

GEOLOGICAL SECTIONS A-A AND B-B

19.2.'75 Bj.J/IS | Tnr. 414 | B-332 | Fnr. 12512

Mynd 10
Exh.



Staðsetning sjá mynd 2
Location see Exh 2

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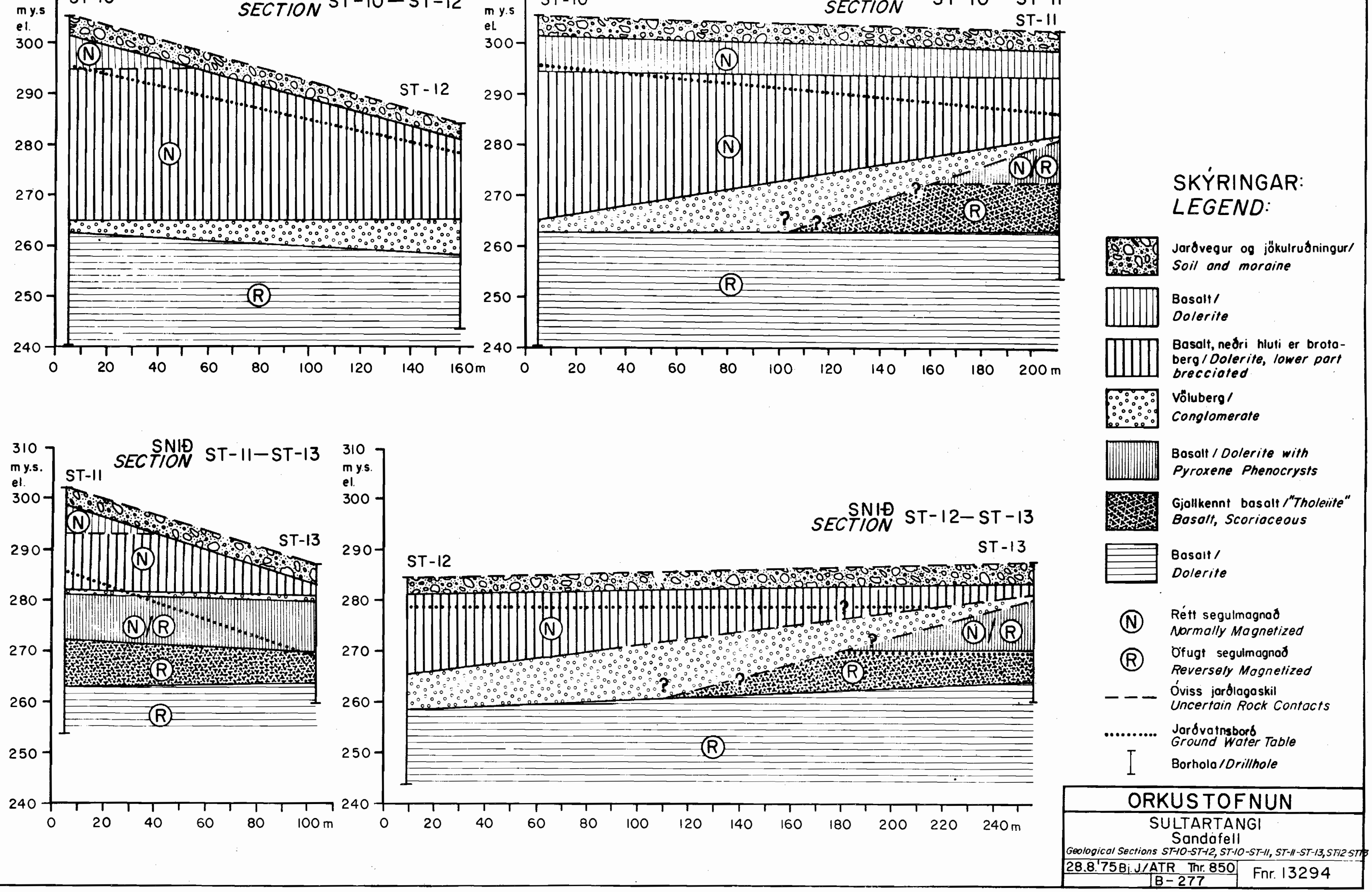
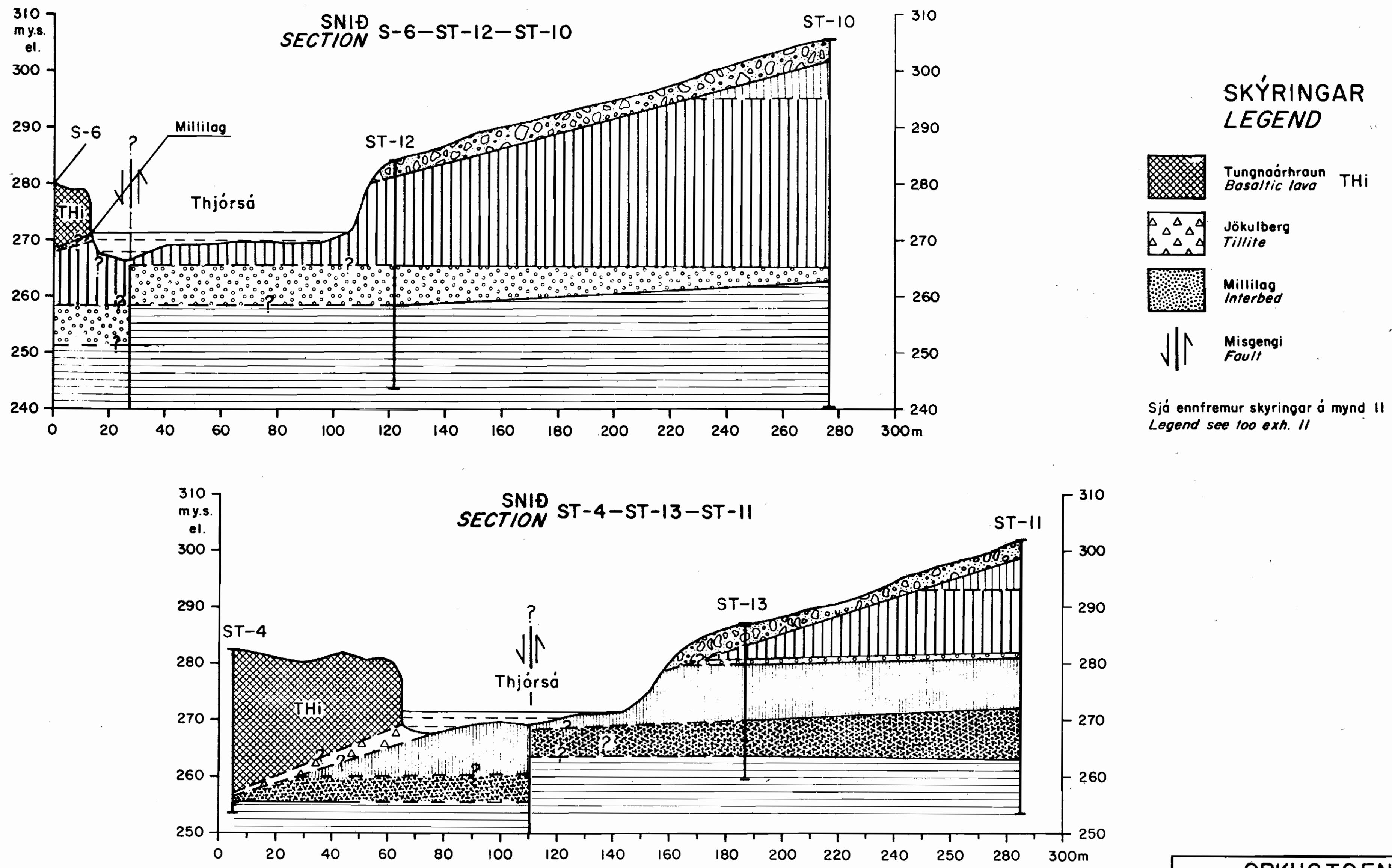
SULTARTANGI
Jarðlagasnið C-C
Geological section C-C
31.12.'75 BjJ/SvJ Tnr. 438 B-332
Fnr. 13758

Mynd 11
Exh.


SNIÐ SECTION ST-10—ST-12
ST-10
ST-12
SNIÐ SECTION ST-10—ST-11
ST-11
SNIÐ SECTION ST-11—ST-13
ST-13
SNIÐ SECTION ST-12—ST-13
m y.s. el.
310
300
290
280
270
260
250
240
0 20 40 60 80 100 120 140 160 m
0 20 40 60 80 100 120 140 160 180 200 m
0 20 40 60 80 100 m
0 20 40 60 80 100 120 140 160 180 200 220 240 m
N
R
N/R
?
SKÝRINGAR:
LEGEND:
Jarðvegur og jökulruðningur/ Soil and moraine
Basalt/ Dolerite
Basalt, neðri hluti er brotaberg/ Dolerite, lower part brecciated
Völuberg/ Conglomerate
Basalt/ Dolerite with Pyroxene Phenocrysts
Gjallkennt basalt/"Tholeiite" Basalt, Scoriaceous
Basalt/ Dolerite
Rétt segulmagnað Normally Magnetized
Öfugt segulmagnað Reversely Magnetized
Óviss jarðlagaskil Uncertain Rock Contacts
Jarðvatnsborð Ground Water Table
Borhola/Drillhole
ORKUSTOFNUN
SULTARTANGI
Sandafell
Geological Sections ST-10-ST-12, ST-10-ST-11, ST-11-ST-13, ST12-ST13
28.8.'75 Bj.J/ATR Tnr. 850
B-277
Fnr. 13294

Mynd 12
Exh.



ORKUSTOFNUN

SULTARTANGI

Geological sections S-6—ST-12—ST-10, ST-4—ST-13—ST-11

25/9 '75 Bj.J/SL	Tnr. 851 / B-277	Fnr. 13381

APPENDIX

Ground water

In the Sultartangi area two main ground-water systems are present, so called "bedrock" ground water existing in the Old formation and "lava" ground water found in the recent and late quaternary rock series, the Young formation.

The temperature of the bedrock ground water is stable and rises with depth in accordance with the geothermal gradient. Only minor seasonal fluctuations in the ground-water table are observed. The lava ground water is cold (3-5 °C) with some seasonal variations in temperature and there occur fluctuations of a few meters of the ground-water table, at least seasonal ones.

Thus, the lava ground water can be regarded as an open system in which the temperature of the water follows the mean annual air temperature in the respective area and fluctuations in ground-water table are relative to the amount of precipitation. The bedrock ground water, on the contrary, is a closed system where the water temperature is equal to that of the rock and due to spreading little or no variations in the ground-water table occur.

The flow of water in the lava aquifer is much more rapid than in the bedrock aquifer primarily because the rocks composing the recent and late quaternary formation are much more porous than the older rocks and consequently have much higher k-value. The main reasons for the above behaviorial difference between the two ground-water systems are thus the different k-values of the two aquifers.

Since the renewal of explorations in the Sultartangi area in 1974 the elevation of the ground water table in the project area has been observed regularly. Simultaneously temperature measurements of the ground water, from water table down to the bottom of the holes, have been conducted from time to time. Such measurements were done for the first time in Iceland in summer and autumn 1974 in the area from Thórisvatn to Búrfell by the Electric Power Department of the National Energy Authority under the supervision of G. Sigbjarnarson (unpublished). These temperature measurements have yielded valuable information on the presence and the behaviour of the ground water not least in the Sultartangi area where the two main ground-water systems can be differentiated on grounds of temperature measurements alone.

According to temperature measurements in drillholes in the Sultartangi area the ground water is divided into the following groups with regard to temperature degree :

GROUP	GROUND-WATER SYSTEM	DRILLHOLES
I	Bedrock ground water	ST-10 ST-12 ST-11 ST-13
II	Lava and bedrock ground water - Mixed	TH-3b ST-6 ST-5 ST-4 SB-2
III	Lava ground water	TH-2
IV	Percolating water	ST-8 ST-9

Bedrock ground water

The bedrock ground-water system appears most clearly in the boreholes of group I (ST-10, 11, 12 and 13) and also at the bottom of TH-3b in group II.

As shown on Exh. 15 the temperature curve in drillholes ST-10 and ST-12 particularly is rather uniform. They are spaced only about 160 m apart and both penetrate exactly the same layers. By simple calculations, viz. direct extrapolation of the temperature curve the temperature at 100 m depth would be about 20 °C in ST-10 and near 32 °C in ST-12. Similar curves for drillholes ST-11 and ST-13 are irregular, as they are disturbed by cold percolating water. In both cases the disturbance reaches down to the contact of the scoriaceous tholeiite and underlying doleritic basalt, where the curve indicates a sudden rise in temperature (cf. Exh. 11). According to the lowest measurements in ST-11 and ST-13 the temperature at 100 m depth should be 15.5 °C and 27.3 °C respectively.

It is noteworthy that the drillholes located closer to the river, i.e. ST-12 and ST-13, show an appreciably higher thermal gradient (about 10° C at 100 m) than the holes farther uphill. A probable explanation is that a fault running inbetween boreholes ST-13 and ST-4, as shown on Exh. 12, thwarts normal flow of the bedrock water causing flowing-up of water of higher temperature than in ST-10 and ST-11, creating a "false geothermal gradient".

After the drilling of borehole ST-13 the ground-water table was initially as high as the top of the scoriaceous tholeiite layer, as shown on Exhs. 8 and 11. Furthermore Exh. 11 illustrates indisputably that this layer, which is highly porous, lowers the ground-water table.

It is fairly certain that ground water in considerable quantities enters Thjórsá through the fault zone especially from the scoriaceous tholeiite layer.

On November 15th 1975 when measurements of ground-water elevation and temperature were carried out, running of water into hole ST-13 could be heard distinctly, indicating that a leakage path had opened for percolating water and the water table was now found to be in the porphyritic doleritic basalt about 6 m higher up than previously.

East of Thjórsá a clear-cut demarcation between the bedrock and lava ground-water systems can be observed in drillhole TH-3b. As can be seen on Exh. 15 there is a sharp temperature divergence at the contact of lava THf and the interbed, which indicated that the interbed is clay/silt rich retaining the distinct demarcation between ground-water systems.

According to temperature measurements the geothermal gradient in TH-3b should show 19,4 °C at 100 m depth in the Old formation.

Lava ground water

As shown on Exh. 15 the lava ground water, groups II and III, is divided into two branches on basis of temperature, viz. a ground-water stream between Thjórsá and Vadalda, about 3 °C, very clearly demonstrated in borehole TH-3b, flowing above the bedrock ground water and a ground-water stream south and east of Vadalda, of somewhat higher temperature or at least 5°C, such as in TH-2.

The two ground-water streams can also be differentiated clearly by comparision of the elevation of the ground-water table in boreholes TH-2 and TH-3b during the period 1966-1975. It reveals that during 1966-1973 the ground-water table rose 12 m in TH-2 and 5 m in TH-3b. In 1970 a considerable rise in the water table took place, but during 1971-72 the maximum rise occuring in TH-2 and TH-3b was 4 m and 2 m respectively. Comparable rising also occured in TH-1, TH-6, TH-8 and TH-9 farther east, which together with TH-2 represent the southern ground-water stream. The general rising of the water level mainly occurred as a direct consequence of increased water storage due to the Langalda diversion.
The northern ground-water stream, the Thjórsá-Vadalda branch, is also affected by the diversion, yet to a much less degree, as the above comparison between TH-2 and TH-3b shows.

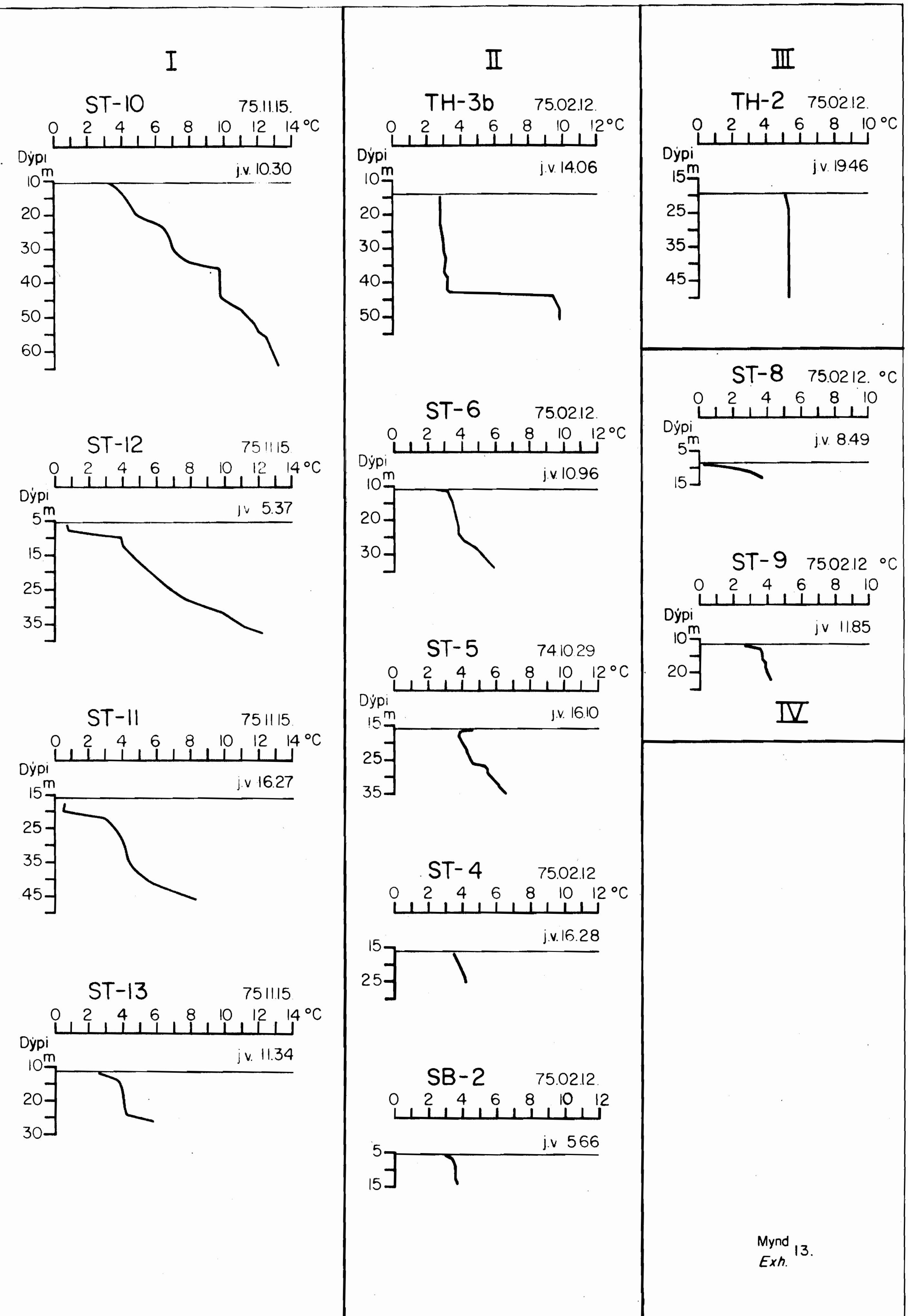
In group II only borehole TH-3b shows distinctly the differentiation between lava and bedrock ground water; in all the other holes mixing between the systems takes place, as is obvious on Exh. 15.

In ST-6 only mixing of some of the lava ground water takes place, as indicated by the low temperature 3-4 °C, but below 25 m depth, which is the depth of the contact between lava and tillite, the bedrock ground water is dominating. The thermal gradient according to temperature measurements below this limit indicates 20 °C at 100 m depth.

In ST-5 there is total mixing in the lava ground water. Here, there is hardly any difference in the gradient on either side of the contact between lava and bedrock. Extrapolation of temperature measurements from contact of lava and old bedrock down to bottom yield 15 °C at 100 m. As later measurements have shown some caving has taken place in the hole at this contact and the same applies to ST-4 where the lava ground water is equally mixed as in ST-5 and shows gradual rising of temperature downwards.

In drillhole SB-2 the lava ground water is only slightly heated or mixed as compared to the ground water in TH-3b and does not show the same mixing as observed in ST-5 and ST-4. At the bottom, at the contact between interbed and old bedrock, the presence of unmixed bedrock ground water is observable.

Group IV shows melt-water, viz. cold percolating water in ST-8, which is too shallow to reach the actual ground-water stream, and similar water is obviously to be found in the uppermost part of ST-9, while further down either mixed ground water or bedrock ground water of higher temperature is met with.



Mynd 13.
Exh.

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SULTARTANGAVIRKJUN
Jarðvatnshitamælingar
Ground water temperature measurements

76.05.03.Bj.J/GSJ
Thr. 440
B-332
Fnr. 13991