The State Electricity Authority

GEOLOGICAL REPORT
ON THE ALUMINIUM PLANT SITE
AT STRAUMSVIK

by

Haukur Tomasson, geologist S.E.A.

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Íslenzka Álfélagið h/f

Icelandic Aluminium Company Ltd.

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1. Introduction

The geological report here presented is prepared for the Swiss Aluminium Company and contains the results of investigation of foundation conditions and a ground water study at the site of the proposed Aluminium Smelter at Straumsvík. The investigation was performed by the State Electricity Authority in the winter and early summer of 1966. It comprises drilling of 14 diamond core drillholes at the site totalling 330 m in depth, geological interpretation of the results, ground water measurements in drillholes, geophysical measurements both in drillholes and on the ground.

Previously some geological investigation had been carried out at this site, mainly some geological mapping and drilling of one water well. This was done in 1962 and 1963 by the State Electric Power Works. In 1964 and 1965 some borrosoundings and two diamond drillholes were done in the harbour area at Straumsvík. The results from these diamond drillholes are included in this report.

The authors are both responsible for the chapters 2 and 3, but J. Tómasson performed most of the field work for these chapters. H. Tómasson is mainly responsible for the rest of the report. Also contributing were geophysicists and mathematicians of the S.E.A. staff.

2. Geological setting

The rock formations on the Reykjanes penisula are divided into three formations.

1. Dolerite formation, a coarse grained olivine basalt. Lava flows from the latest interglacial or/and interstadials.
2. Móberg formation (Palagonite formation); tuffs, breccias and pillowlavas. Formed by subglacial basaltic eruptions during glacials.
3. Postglacial lava formation. Basalt lava flows formed after the last glacial.

The Dolerite formation is the bedrock in Reykjavík and the main part of Hafnarfjördur and again in a large area on the penisula near Keflavík, besides some smaller scattered localities. It is generally the oldest outcropping rock and is originated from several volcanoes some of which are now covered by younger volcanic products. At Straumsvík the Dolerite formation is underlying the postglacial lava flows.

Móberg formation is the bedrock in most mountains in the Reykjanes penisula, it stands up as mountains because; the subglacial volcanism forms long narrow ridges along the eruption fissures but central volcanoes steep mountains which often are capped by usual lava flows formed when the volcano was high enough to protrude through the glaciers. Lateral extension of each subglacial volcano is small. Most of the Móberg is from the last glaciation.

Postglacial lava flows cover the main part of the Reykjanes penisula. Most of them are originated in eruption fissures near the Móberg mountains. All known lava flows in this area are either basaltic or olivine basaltic in composition. The main difference between this formation and the dolerite formation being that the dolerite has been overrun by ice. Postglacial lavas are defined here as the lava flows which never have been overrun by ice. In the coastal zone of Reykjanes they might be as much as 15.000 years old. At Straumsvík the surface layers are postglacial lava flows.

During late and postglacial time substantial fluctuations in sealevel have taken place. These fluctuations are because of isostatic recovery of the land from depression during the last glacial due to ice load, and of world wide eustatic rise of sealevel from the melting of the ice. The sealevel was highest almost 50 m higher than at present 12-15.000 years ago and some 10 - 6.000 years ago it was substantially lower than at present, and the present trend is slow transgression.

3. Geology at Straumsvík

Outcropping in the neighbourhood of Straumsvík are 3-4 post-glacial lava flows. On the actual construction site, the lava flow Kapelluhraun usually forms the surface. But to the east and west of it older lava flows are outcropping. Through the drilling 2 or 3 not outcropping lavaflows were discovered. The dolerite is underlying the postglacial lavas and is also outcropping east of the project area. Now these layers will be described in more detail in chronological order and started with the oldest one.

The dolerite lava flows are coarse grained olivine basalt. Plagioclase has a composition from labrador to bytownite. Incipient alteration can be traced and joints are óften filled with clay. The precise location of the vents is unknown but probably the dolerites originate from several vents in the neighbourhood which now are either covered by younger layers or eroded away. The dolerites probably date from the last interglacial or from interstadials during last glacial. They are underlying the postglacial lavas at Straumsvík and were encountered in several drillholes. The bedrock under the harbour might be dolerite although it could also be lava flow Db. Small outcrop of dolerite is north of the road to Hafnarfjörður 500 m from the front of Kapelluhraun and also Hvaleyrarholt in Hafnarfjördur is dolerite. Further to the north and east it becomes the dominating surface bedrock formation. The dolerite is generally in many thin individual flows without interbeds. The surface is smoothed through glacier erosion and has therefore no fragmental surface as has the postglacial lava. Usually the dolerite is covered with a blanket of moraine although such has not been encountered in the drillholes at Straumur. The permeability of the dolerite is usually rather high although much lower than for the postglacial lavas.

Petrographically all the postglacial lava flows can be classified as basalt or olivin basalt. The plagioclase has a composition from labrador to bytownite and all contain some olivine. The main difference being that the D lava flows have larger and denser phenocrysts of feldspar and H has much coarser groundmass. All the K lava flows are very similar with rather fine grained groundmass and spread phenocrysts of plagioclase and glomeroporphyritic groups of plagioclase, pyroxenes and olivines.

The oldest postglacial lava flow is Db which is a feldspar porfyritic basalt. The accurate location of the vents from which this flow came is not known but probably it is at the mountains some 10 km to the south of Straumsvík. This is a major lava flow which probably is covering wide areas to the south and west of Straumsvík although to a great extend now covered with still younger flows. In the project area the topography of the dolerite bedrock has substantial influence on its altitude. It forms depression conform with depressions in dolerite bedrock and seems to end at a doleritic hill, which might be bedrock in Straumsvík or part of it. The flow is encountered in some of the holes at an elevation of ÷ 17 m and shows there no marks from flowing in water. Therefore this flow must be from a time when the sealevel was much lower than at present, probably as much as 15 to 20 m. From that the age of the flow can be estimated as 9.000 year before present or slightly younger. This flow seems to have a type of surface called pahoe-hoe lava (Icelandic helluhraun) which has little or no scorious surface but might have a blocky layer on the top. The thickness is not known but probably of the order of 10-20 m.

A layer of sand is found intercalated between Db and the above laying lava flows. Also this sand layer covers the dolerite where Db is not found and it might also be intercalated between Db and the dolerite but is not encountered in any drillhole as no one penetrates the layer Db. The sand is also found intercalated between the flows Kc and Kb. From the samples obtained of the sand it is obviously of marine origin, as there are numerous shell fragments. The grain size seems to be varying from coarse silt to gravel. The sand layer on the bottom of Straumsvík is most likely continuation of this same layer. The sand layer is formed during postglacial transgression of the sea. At that time when the sealevel was more than 10 m lower than at present material transport was possible because a shallow sandy coast extended from Álftanes to Straumsvík. When transgression had progressed further the coast in the neighbourhood of Straumsvík was all rocky coast with minimum material transport. That is the reason why little sand has been added in the bottom of Straumsvík since the formation of the sand encountered in the drillholes. The sand is mainly near the present coast and is not encountered in the line of holes furthest away from the sea. The thickness can be as much as 10 m where dolerite is underlying and 5 m on top of Db but only a couple of meters where the lava flow Kc is encountered. The age of this sand is probably 9.000-7.000 years.

The second oldest postglacial lava flow is Kc which is dark gray fine grained basalt with spread feldspar phenocrysts. This flow is probably from an eruption fissure near Undir-hlíðar approximately 8 km from Straumsvík to the southeast. The extension of this flow is not known as it is everywhere covered by younger flows. In the investigated area it has a rather small extension and has followed a depression in Db. The thickness of Kc is approx. 7-8 m where encountered in drilling. The age is from the time of the transgression of the sea as the sandlayer is both underneath and above. When the lava flowed sealevel has been approximately 10 m below present level. Near its front Kc seems to be highly scoriaceous and an a-a lava but further inland it might be pahoe-how lava.

The flow Kb is a light gray basalt of petrography similar as Kc. The accurate location of the vent is not known but it is probably an eruption fissure near the mountains 7-15 km to the south. The Kb in the investigated area is present in most of the drillholes but its extension to the east has been limited by the same high in Db which stopped Kc. But these two flows have more than filled the depression in Db as the front of Kb has stopped two subsequent lava flows from east. It also forms the main part of the submerged cape which partly closes Straumsvík. The thickness of Kb is 10-15 m and it is in the project area usually a-a lava (apalhraun) with thick scoriaceous horizont on top. At the time Kb flowed sea-level was approximately 7 m lower than at present. The age of this flow is probably more than 7.000 years.

The flow Da is a feldspar porfyritic basalt with fine grained and glassy matrix. This is a small flow originated in a vent

Rauðhóll only 2 km from the project area just west of Hvaleyrarholt. It has reached the front of Kb. The age is indicated by the fact that it flowed when sealevel was at least 4 m lower than at present which indicates an age not much lower than for Kb. The thickness in the drillholes is only 2-3 m and it is a pahoe-hoe lava.

The lava flow H is a coarse grained light gray olivine basalt. This flow is outcropping on the west margin of the project area and has a local name Hvaleyrarhraun. It is originated from an eruption fissure near Undirhlíðar 7 km away to the south east and has a substantial extension there east of Kapelluhraun. In the project area it is underlying Kapelluhraun Ka as far as the front of Kb. The thickness in drillholes is 5-8 m and it is a typical pahoe-hoe lava (helluhraun). At the time Hvaleyrarhraun (H) flowed the sea-level seems to have been similar as to day or slightly lower. The age can not be determined accurately but can hardly be more than 5.000 years.

The flow Ka, or as its local name is Kapelluhraun, is petrographically identical to Kb. It is originated in an eruption fissure at Undirhlíðar or in the same vicinity as flow H and Kc, and flowed to the sea at Straumsvík as a 2-3 km wide lava flow. This is by far the youngest flow here and the only flow in historical time. It probably is slightly less than 1000 years old. In project area it usually forms the surface layer. It is usually a-a lava with a thick scoriaceous surface but close to sea it has much less scorious surface. The thickness of the lava is 10-15 m and the scoriaceous layer can be 5-7 m of it or approximately half the thickness.

As a foundation the basalt lava is excellent. Even the scoriaceous surface is adequate for moderate loads. The scoria can be moved by bulldozers without any blasting and can be compacted to a stable surface. Lava tunnels or cavities are not likely to occure in a-a lava with thick scorious surface as flow Ka or Kb but are much more common in the pahoe-hoe lava type which are the statigraphically lower lava flows and flow H. The sand layer will hardly be a problem because it is not made up of compressive material and also it is so far below surface that unit loads should be well within the bearing capacity of the sand especially as it is well confined between lava flows, and already under substantial loads. In the harbour on the other hand the sand layer should be given more attention as it is not confined except to one side and also closer to the surface.

4. Permeability

The permeability of the rock units at Straumsvík is mainly of three different categories.

1. The permeability of the interglacial dolerite.
2. The permeability of sand or silt.
3. The permeability of postglacial lava flows.

The last has by far the highest permeability.

The interglacial dolerite is usually highly permeable rock and a good aquifer but here it must be considered as the tight rock in comparison to the permeability of the postglacial lava flows. No permeability tests where performed and no other means of estimating the permeability are available.
The permeability coefficient for it should not be more than 1/100-1/1000 of the permeability coefficient for postglacial lavas.

The sand and silt is intercalated between postglacial lavas and causes there irregularity in the sea tides because of its much lower permeability. No means of estimating its permeability accurately is available but from other data it can be assumed to have a permeability coefficient k from 10^{0} to 10^{-3} depending on the silt content.

The postglacial lavas are extremely permeable and only limestone with solutions channels can be more permeable. Usual testing procedure for these highly permeable strata can not give very accurate or reliable data but in this case we have by nature excellent permeability test on a big scale because of the sea tides which reach far into the land from the shore. The use of tidal effect in ground water for estimating the permeability is not known to the authors of this report so that no standard procedure is known to be fit for this purpose. This has made the study more complicated and time consuming than otherwise would have been the case.

The measurements of the sea tides in drillholes where performed the 25th to the 27th of April and measured in 10 holes and again the 6th to the 7th of June measured in 5 holes including the one which is farthest away from sea. At the same time the electrical resistivity was measured in the ground water. The measurements were performed by the personnel of S.E.A. geothermal department.

Three methods where tried to estimate the permeability coefficient of the lava. This coefficient for lava must be highly varying because of the heterogenity of the lava flows and much higher at contacts than in dense lava. Darcy's law on ground water flow states that a linear relationship is between velocity of ground water flow and the pressure gradient is not strictly valid here because the flow is not only laminar but partly turbulent. In turbulent ground water flow the velocity increases slower by increasing gradient than with a laminar flow. Because of the heterogeneity of the lava flows and also because we are using tidal waves where no steady state can be obtained, the actual relationship between groundwater velocity and pressure gradient can not be worked out but has to be assumed to be linear. Permeability coefficient calculated in this manner can only be a rough approximation mainly valid within range of pressure gradients observed in the ground water. At a much higher gradient the error could be substantial. The three methods are following.

1. By measuring the vertical velocity in holes.
2. By estimating the volume of water flowing out between high tide and low tide through a cross section. The gradient is assumed to be the one existing at low tide.
3. By using equations for heat conduction where the surface temperature has a regular periodic variations which decrease in amplitude and lag in time away from a boundary. The equations for heat conduction are analogous to Darcy's law on ground water flow and it may therefore be assumed that the decrease in amplitude and lag in time of the tidal wave follow the same mathematical equations as the temperature variations. This possibility was pointed out for the author by Techn. lic. Helgi Sigvaldason, mathematician at S.E.A. who also converted the formulas to the form used here.

The measuring of the vertical velocity is simply done by measuring the elevation of the ground water in the hole at two different times between which the rise or fall of ground water has been fairly uniform. The pressure gradient is assumed to be the ground water slope near low tide on figure 11. The vertical velocity so measured is water velocity which is much higher than aquifer velocity used for computing permeability coefficient. The difference being due to the porosity of the rock. The porosity of the rock is not known but will be assumed to be in the range 10-40% and a 20% porosity will be the value usually used for the calculation here. By using that, water velocity becomes five times aquifer velocity. The computed vertical aquifer velocity is not the right one for calculation of permeability coefficient but some near horizontal vector component of it has to be used, but it is not known and can not be assumed with any degree of confidence. It is though in all probability a substantially shorter vector than the horizontal one so that it may be assumed to be an upper limit and the vertical one a lower limit of the actual velocity vector which should be taken into the computations.

In table I the measurements of vertical velocity are listed together with calculated horizontal velocity and a computed permeability coefficient for both vertical and horizontal velocity vectors.

The equations used are:

$$k_1 = \frac{V_v}{i} \qquad (1)$$

where k is the permeability coefficient; V_v vertical velocity and i the ground water gradient and

$$k_2 = \frac{V_h}{i} = \frac{V_v}{i^2} \qquad (2)$$

where V_h is the horizontal velocity.

Because we are using flood waves the actual velocity vector is changing all the time between the limits of horizontal and vertical velocity we can only state that the real permeability coefficient for the postglacial lavas is within the two limits of k calculated in table I.

The second method estimates the volume of aquifer emptied through a cross section from high tide to low tide. For that, figure 11 is used and flow lines are calculated from, where tidal effect is negligible at 1 to 1,5 km from the sea, and to the sea. The volume of aquifer is fairly well known from the isopach map (figures 11c) showing the difference between ground water at time 9^{14} and 14^{11}.
This volume can be directly used to calculate water velocity.

The pressure gradient is here assumed to be the ground water gradient near low tide in figure 11.

In table II are listed calculations of permeability coefficient from three flow lines on figure 11 together with areal of longitudinal section of emptied aquifer, depth of aquifer at various cross section, and the ground water gradient. The permeability coefficient is based on the assumption that porosity volume is 20%.

The equation used here for the calculation is

$$K = \frac{A}{5\ ht\ i} \qquad (3)$$

where A is areal of longitudinal section along flow line of the emptied aquifer, h the depth of the aquifer and t the time elapsed between map B and A on figure 11.

A comparison of k value calculated according to method one and two showes that k according to method 2 is between the two extremes of method one. Method 2 is more reliable and gives one figure in stead of the intverval that table I gives. But both methods have a weak point in determination of the pressure gradient which is highly varying and unstable because we are using waves but we do not have steady state of ground water flow.

The third method does escape this handicap of the two first methods as there are used mathematical equations computed for the periodic variations we have here and the gradient does not enter the formulas.

These equations are derived from the analogy of the laws for heat conduction to Darcy's low on ground water conduction. For mathematical solution see Carslaw and Jaeger:

Conduction of heat in solids page 46-50 and Theory of Ground Water Movement by P. Ya. Polubarinove-Kochina page 498-501. In short the delay of the period and decrease in amplitude away from the shore are used for this calculations. The basic equation in Polubarinova Rochina is

$$\frac{\delta h}{\delta t} = \frac{k}{n} \cdot \frac{\delta}{\delta x}\left(h\frac{\delta h}{\delta x}\right) + \phi(t) \qquad (4)$$

where n is the area porosity, x distance $\phi(t)$ external influence. Otherwise the same symbols as previously. By replacing the multiplier h by a constant value h which in this case is the average depth of the aquifer we obtain a linear equation

$$\frac{\delta h}{\delta t} = \frac{k}{n}\bar{h}\,\frac{\delta^2 h}{\delta x^2} + \phi(t) \qquad (5)$$

This equation is analogous to a equation in Carslaw and Jaeger on heat conduction which has been solved for a given periodic ϕ (t)

$$\phi(t) = A\cos(\omega t - \epsilon) \qquad (6)$$

For a large t the solution has the form

$$h(x,t) = Ae^{-x\sqrt{\omega/2a}}\cos\left(\omega t - \epsilon - x\sqrt{\omega/2a}\right) \qquad (7)$$

A: the amplitude of sinusoidal tidal wave (cm) ω frequency of the tidal wave (sec $^{-1}$). ϵ a constant;

$$a = \frac{k}{n}\cdot\bar{h} \quad (\text{cm}^2/\text{sec.}) \qquad (8)$$

Equation (7) gives two possibilities to determine a based on delay of the wave and damping of amplitude. The equation based on delay of the wave is

$$a = \frac{1}{2\omega} \cdot \frac{x^2}{S^2} \qquad (9)$$

where S is the delay of the wave in seconds. The equation based on damping of amplitude is:

$$a = \frac{\omega}{2} \cdot \frac{x^2}{(\ln A/H)^2} \qquad (10)$$

where A is the amplitude of the tidal wave in the sea and H the amplitude at distance x from the sea.

In table III are some of the results of the calculation of the permeability coefficient based on equations 9 and 10 and in figure 14 are diagrams showing measurements of decrease in amplitude, delay of waves and in comparison k/n based on equations 9 and 10.

The result shows that the permeability coefficient calculated in this manner is of similar magnitude as with the other methods. All three methods do therefore support the conclusion that the permeability coefficient for the postglacial lavas at Straumsvík is in the range 10-100 cm/sek.

5. Electrical Resistivity

On the graphic core logs are lines showing electrical resistivity measured in the drillholes at the same time as tides where measured. It shows that the electrical resistivity is much lower in the holes closest to the sea than in the ones farthest away. It also often shows lower resistivity at high tide than at low tide and also frequently the resistivity decreases with depth. This is because of sea water which is mixed with the ground water but increases with depth. The resistivity for sea water is at the coast 60-65Ωm but for fresh potable water it is 350-400 Ωm. It can be seen from the graphic logs that a substantial mixing of salt water is near ground water surface some hundred meters away from sea. At the water well the thickness of fresh water is about 8 m at least at the size of tides when the measurements are done.

The equipment for this measurement was made at the geothermal department of S.E.A. and sketch showing the principle of that instrument is on figure 15.

The electrical resistitivity of the surface layers was performed by the geothermal department in/the beginning of June and used the instrument set up shown in figure 15. Three profiles were measured. One along the road south of it another near the line of the drillholes with numbers in the fifties and the third along the line of the drillholes with numbers in the seventies. The result is that lava flows above ground water have a resistivity 10.000-20.000 Ωm in the upper part and usually about half of this in the lower part. Down in the ground water this measurement gave similar results as direct measurement in the holes.

6. Location of wells

The postglacial lava aquifer has a transmissibility 10 to 100 times higher than a good sand aquifer. It is therefore capable to give water in big quantities.
The main limiting factor being the presence of salt water at the shore and under the aquifer. The amount of fresh water flowing through the lava is not known but a rough estimate can be done from the distance from water divide on Reykjanes to the sea and from the fact that no surface run - off is in this area so all precipitation flows to the sea as ground water. The average precipitation is capable of producing run-off 50-100 l/sec km^2. The distance from the water divide is

approximately 15 km so that ground water run-off can be of the orders of magnitude 75-150 l/sec on each km of the coast. At Straumsvík the run-off is probably higher because the dolerite diverts some ground water flow from areas substantially east of Straumsvík to the Straumsvík area. But hardly can it do more than to make the higher figure above a fairly conservative estimate of the ground water flow. Independent of the transmissibility of the lava aquifer we can never take more from it in the long run than the inflow of fresh water.

On figure 16 are curves showing drawdown in wells based on various assumptions on the depth of pump under drawdown. The equation used is in a paper from U.S. Geological Survey Water-Supply Paper 1536-I in an article by Rey Bentall: Methods of Determinating Permeability, Transmissibility and Drawdown. The curves are based on the assumption that the permeability coefficient is k = 10 cm/sek. It can be seen from these curves that the aquifer can give enormous quantities of water with very small drawdown when the pump is submerged 8 m. But if such quantity overruns the inflow of fresh water sea water will penetrate into the well. It is therefore advisable to have the pump much less submerged or of the order 1 or 2 m.

With such submergence the thin fresh water aquifer can not be tapped very much from each hole and in order to use the aquifer effectively there have to be many wells. The wells should be arranged on a line parallel to the coast in a distance at least 600 m from the shore. A test well for pumping tests can be located anywhere where above mentioned criteria is fullfilled but for obtaining more overall picture of the aquifer a test well should be drilled near the east end of the project area. As it is unlikely that 100 l/sec or more can be taken continuously from one well an especially wide hole is not necessary for the water wells here. A diameter 30 cm or so should be enough.

A few holes drilled with Sullivan drill rig with a flush bit could be very valuable to investigate the aquifer before the wells are drilled. The cost of such holes can be estimated at less than 1000 kr. per meter and should be drilled just down to ground water table. It is especially valuable to investigate the thickening of the aquifer away from the tidal effect which can be useful to estimate how much can be taken from a single hole.

Table I

Vertical velocity measurements

Hole no	Tidal wave no	Gradient i	Vertical water velocity cm/min	Vertical aquifer velocity V_v= cm/sec	Horizontal vector of aquifer velocity V_h= cm/sec	Permeability coefficient $k_I = \frac{V_v}{i}$ cm/sec	Permeability coefficient $k_2 = \frac{V_h}{i} \frac{V_v}{i^2}$ cm/sec
50	1	0.0045	0.9659	0.0032	0.71	0.71	158
50	1	0.0045	0.2205	0.0007	0.16	0.16	34
52	1	0.0055	0.9888	0.0032	0.58	0.58	105
52	3	0.005	0.3893	0.0013	0.24	0.24	42
62	1	0.0023	1.1460	0.0038	1.66	1.66	664
62	4	0.0023	0.4428	0.0015	0.65	0.65	283
65	1	0.0031	1.0000	0.0033	1.06	1.06	343
65	2	0.0031	0.1391	0.0005	0.16	0.16	52
75	1	0.0014	1.1046	0.0037	2.64	2.64	1888
75	1	0.0014	0.4496	0.0015	1.07	1.07	765
74	1	0.0014	1.395	0.0038	2.71	2.71	1939
74	2	0.0014	0.3500	0.0012	0.86	0.86	612
84	1	0.0013	1.1046	0.0037	2.85	2.85	2189
84	4	0.0013	0.0978	0.0003	0.23	0.23	177
63	1	0.0055	1.0625	0.0035	0.64	0.64	115
63	4	0.0055	0.4788	0.0016	0.29	0.29	52
73	1	0.0017	1.1627	0.0039	2.29	2.29	1349
73	1	0.0017	0.3472	0.0012	0.71	0.71	415
56	1	0.0034	0.9444	0.0031	0.91	0.91	268
56	1	0.0034	0.2803	0.0009	0.26	0.26	77

T a b l e II

$K = \frac{A}{5hti}$ t = 15000 sec

	A - Area of emptied aquifer in m^2	h - depth of aquifer	i	k cm/sec
I	876	12 m	0,006	16,22
II	1010	15 m	0.017	5,28
III	710	10 m	0.020	4,73

Table III

Tide wave 1

Hole	Delay of time in sec.	Damping of amplitude	Depth of aquifer	a_s K/n	a_n K/n	$k = \frac{K}{n} \cdot \frac{1}{2,95}$ a_s	a_n
84	188609	133984	1600	117	83	40	28
73	138912	221484	1750	79	126	27	43
74	402116	925750	1400	201	462	69	158
75	309836	811829	1500	206	541	70	185
62	335722	343000	2000	167	171	57	58
63	1250512	1275750	1750	714	729	244	249
65	317543	855120	2000	159	427	54	146
50	33789	13386	1200	28	11	10	4
52	116880	100039	1650	70	60	24	20
56	88920	370245	2000	44	185	15	63
Tide wave 5							
54	125179	491840	1850	67	265	23	90
64	121030	855119	1500	348	427	119	146
74	144840	472312	1400	72	236	25	81
84	188609	70867	1600	119	44	41	15
Water hole	121722	95530	1750	69	54	24	18

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ICELANDIC ALUMINIUM
COMPANY LTD.

RAFORKUMÁLASTJÓRI	19.7.'66 H.T./H.Y.
STRAUMSVIK	Tnr. 13
AREAL GEOLOGY	B - 330
	Fnr. 7518

The map is based on but modefied from the Geological map of Iceland by Guðmundur Kjartansson

Fig. I

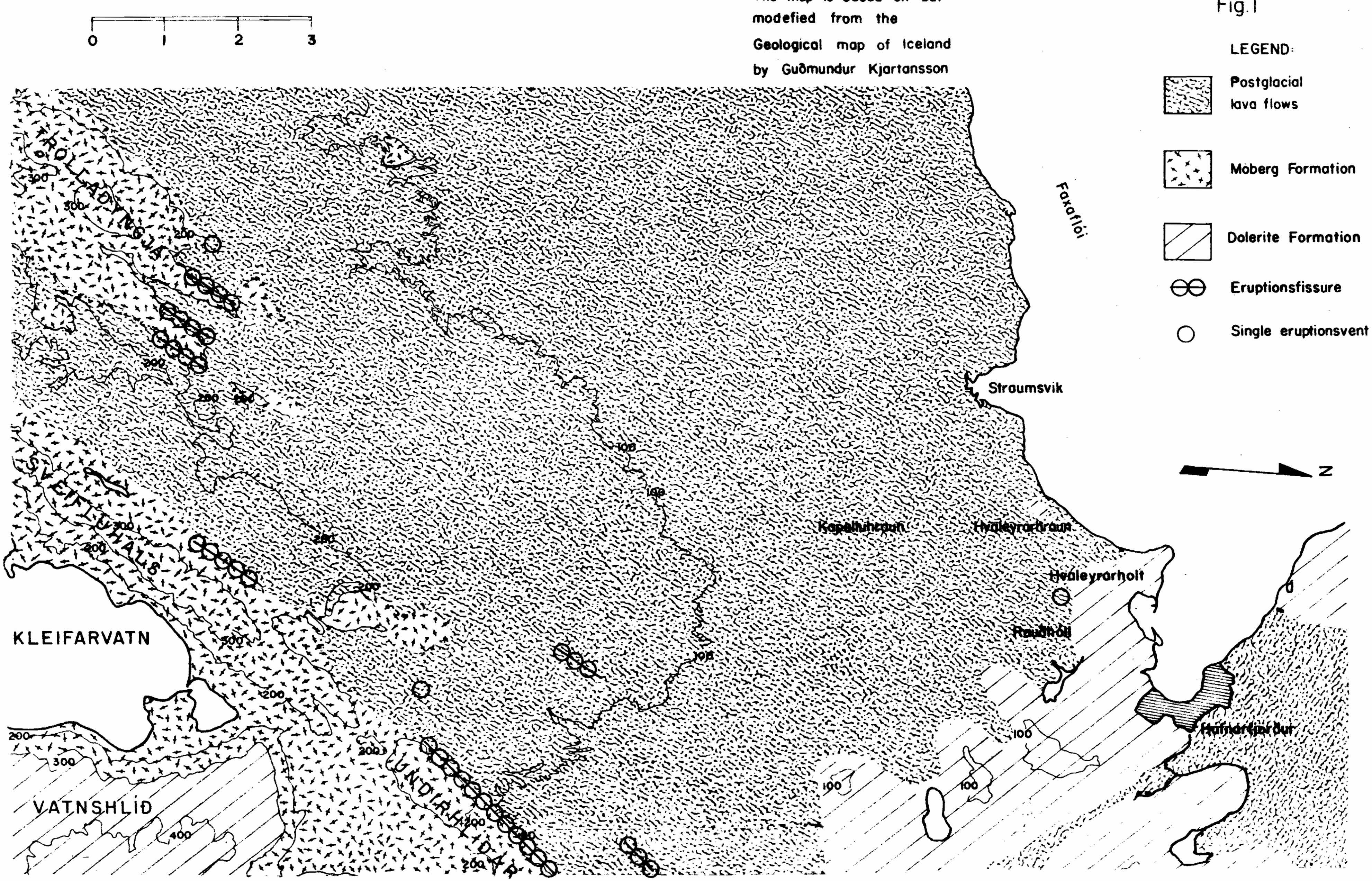
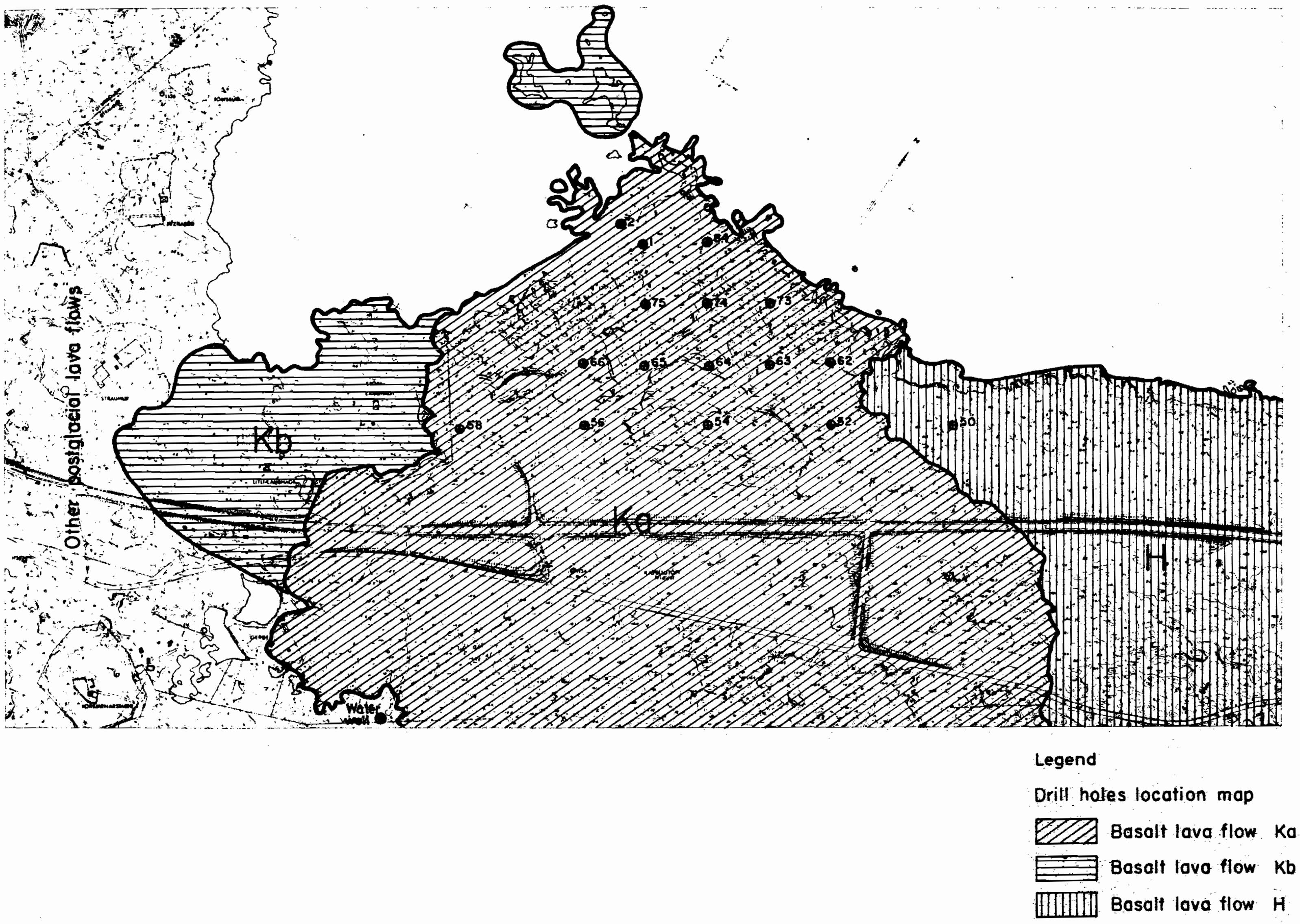


Fig. 2



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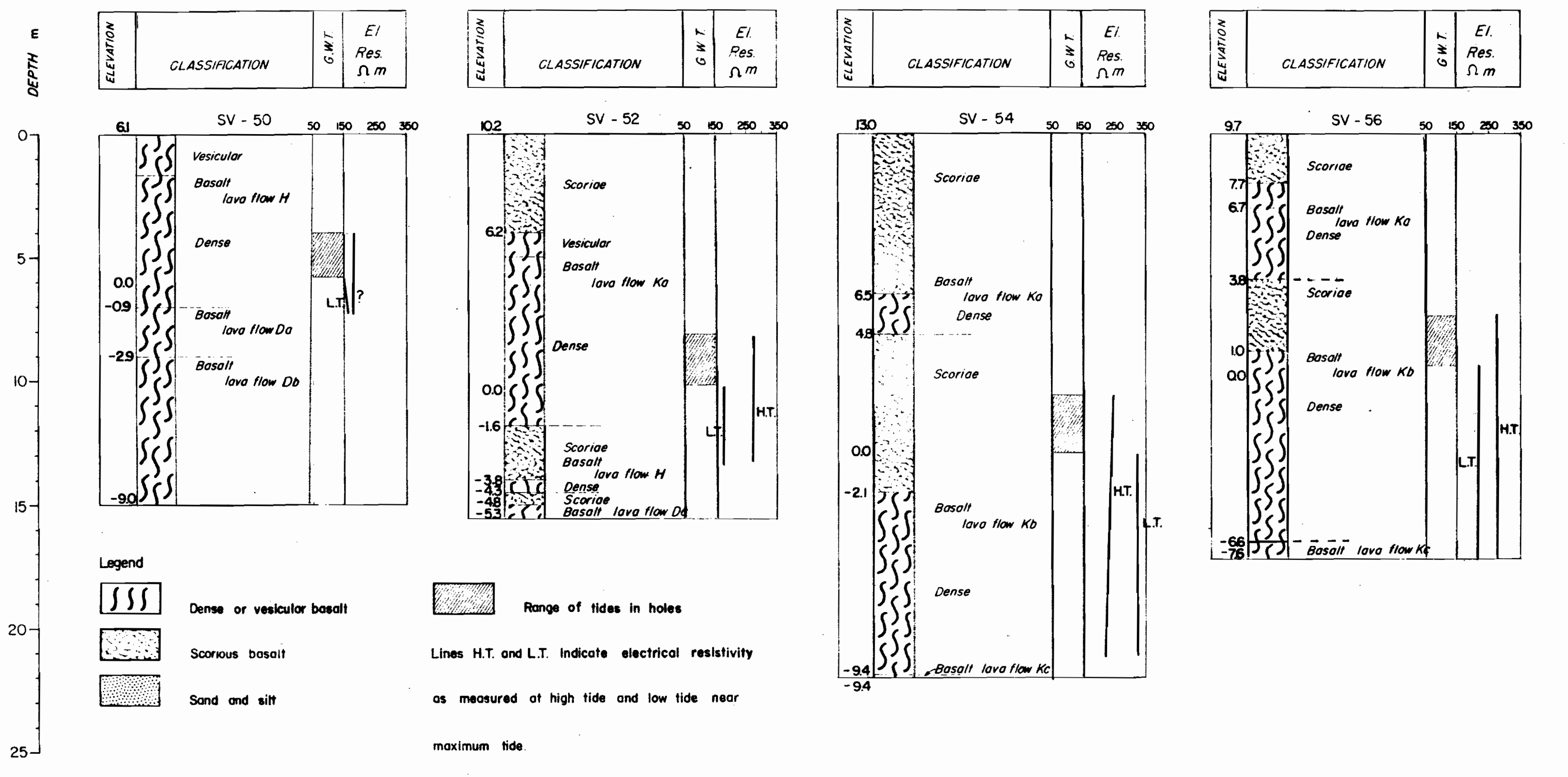
RAFORKUMÁLASTJÓRI

STRAUMSVÍK

GEOLOGICAL MAP

14.7.66 HT/HF	B-330 Tnr. 9	Fnr. 7511

Fig. 3



Note: Elevations are in the Reykjavik Elevation System stratigraphic units are explained in Stratigraphic Column on Figure 7.

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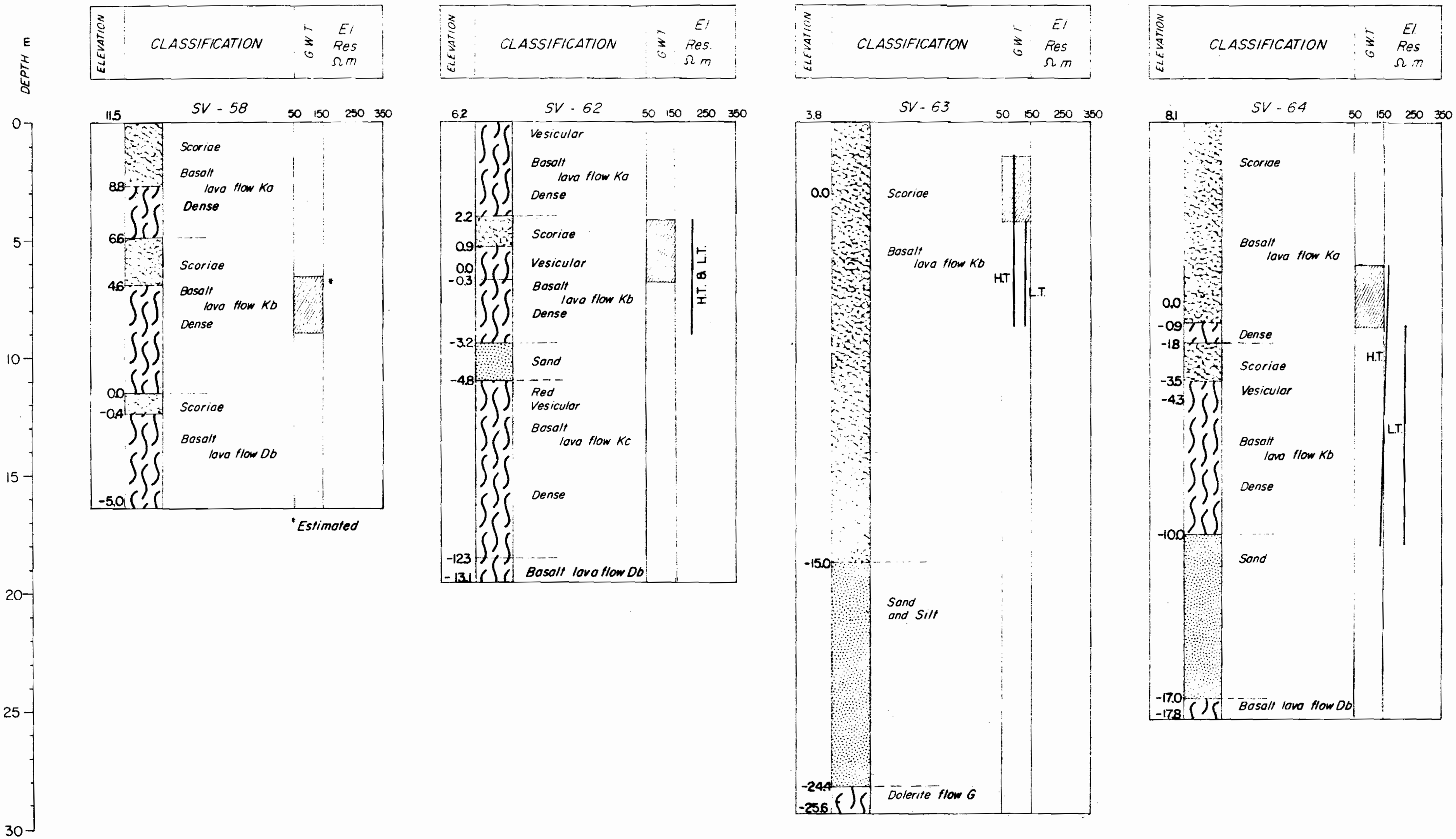
RAFORKUMÁLASTJÓRI		
STRAUMSVÍK GRAFIC CORE LOGS		
3.6.66 JT/KÞ	Tnr. 3	Fnr. 7481
sheet 1 of 4	B - 330	

Fig.4



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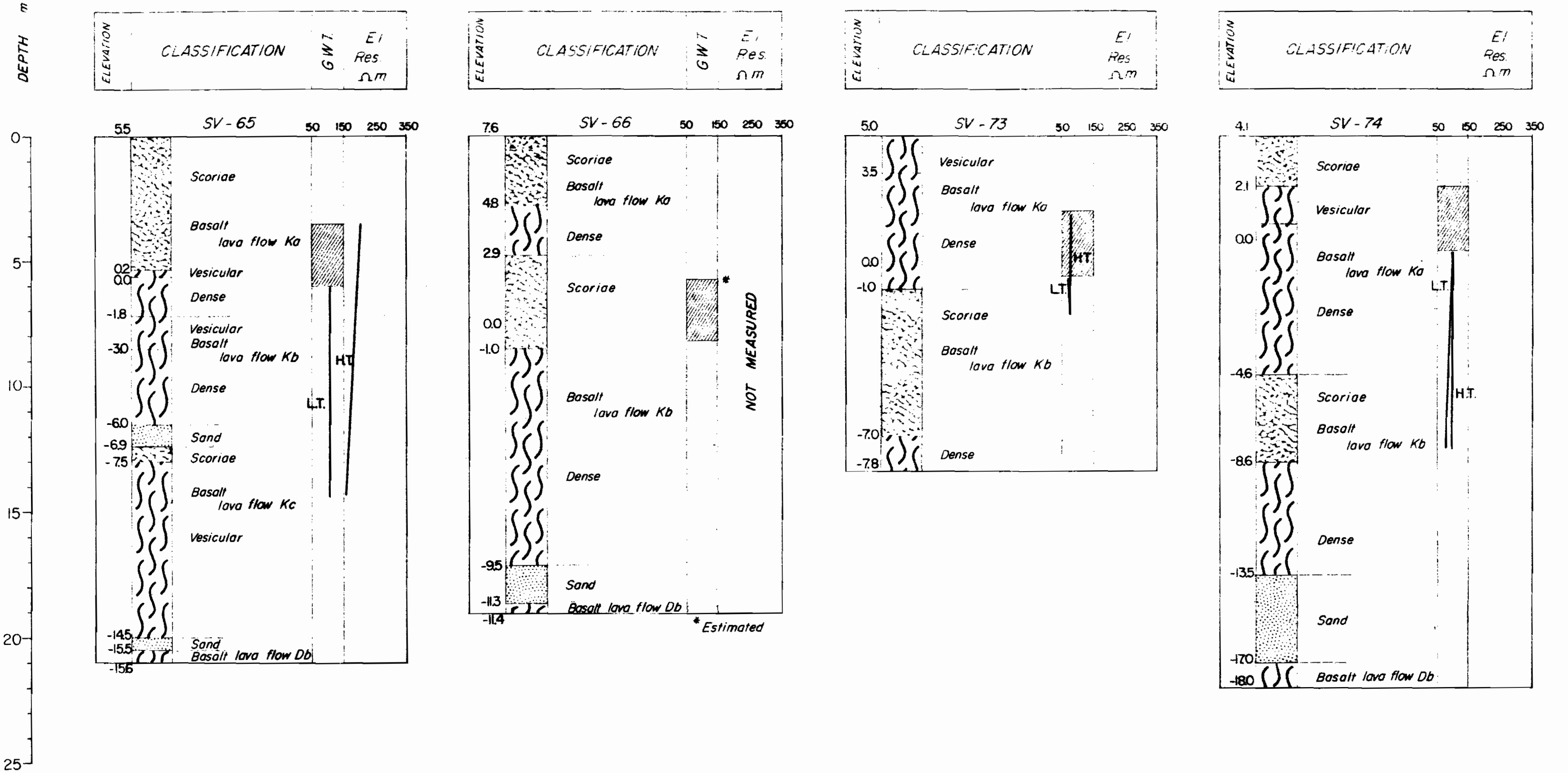
Note: For legend and notes see fig.3

RAFORKUMÁLASTJÓRI
STRAUMSVÍK
GRAFIC CORE LOGS

3.6.'66 J.T/Kb.	Tnr. 6	Fnr. 7484
sheet 2 of 4	B-330	

Fig.5



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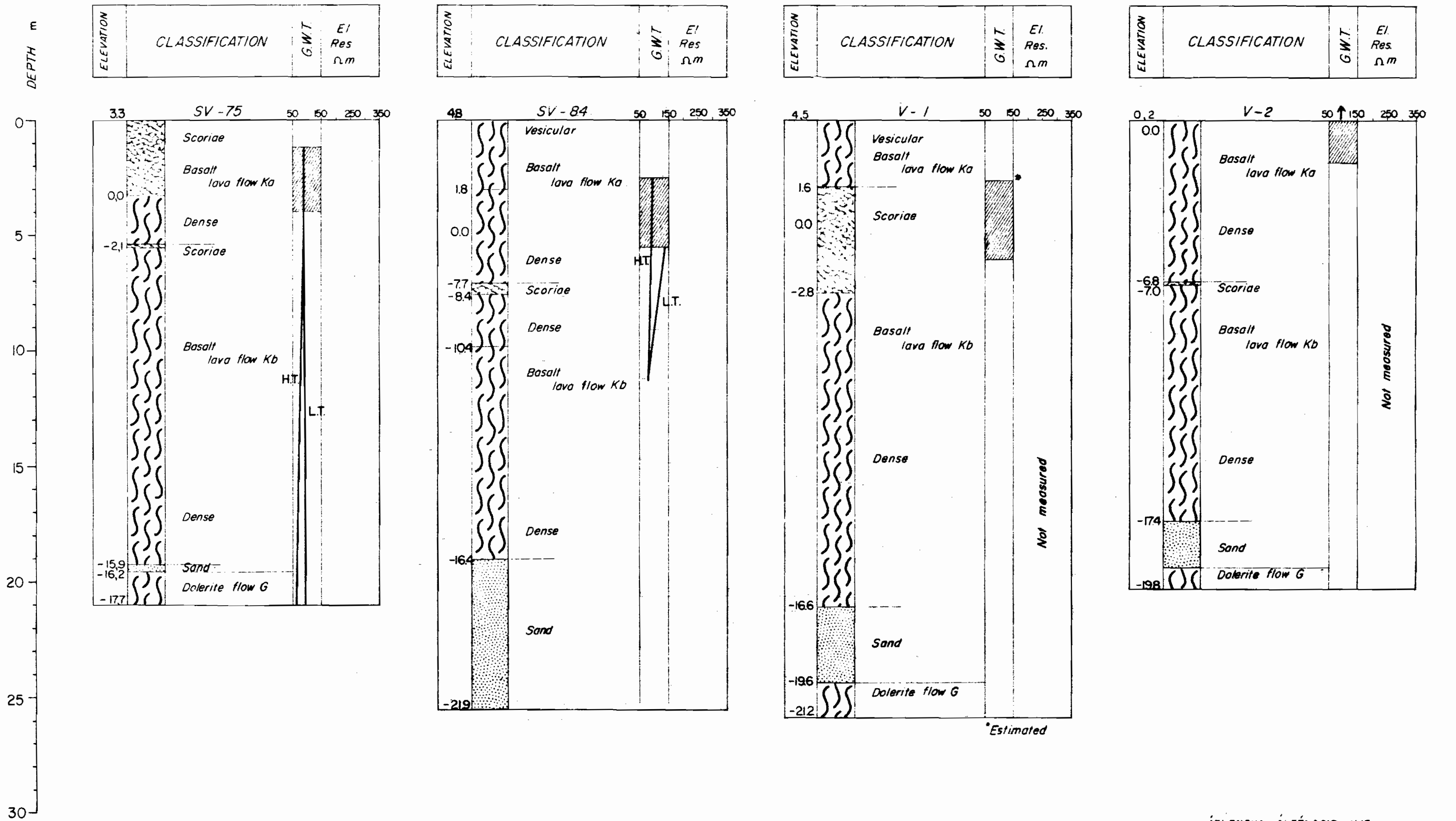
Note: For legend and notes see fig.3

RAFORKUMÁLASTJÓRI		
STRAUMSVÍK GRAFIC CORE LOGS		
3.6.66 J.T./KÞ	Tnr. 4	Fnr. 7482
sheet 3 of 4	B - 330	

Fig.6



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Note: For legend and notes see fig.3

RAFORKUMÁLASTJÓRI

STRAUMSVÍK
GRAPHIC CORE LOGS

3.6.66 J.T./KÞ	Tnr. 5	Fnr. 7483
sheet 4 of 4	8-330	

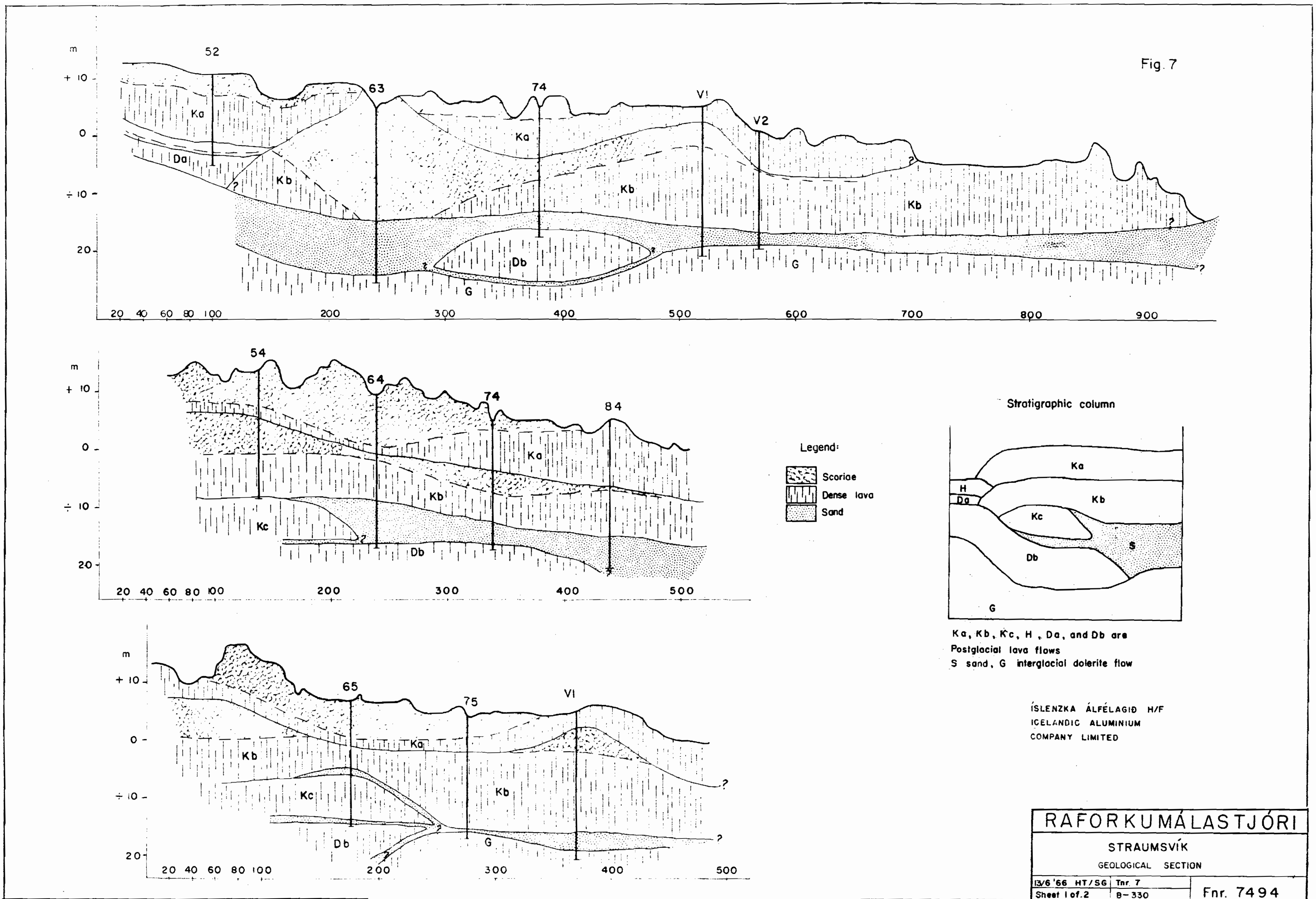
Fig. 7
m
+10
0
÷10
20
52
63
74
V1
V2
Ka
Da
Kb
Db
G
20 40 60 80 100 200 300 400 500 600 700 800 900
54
64
74
84
Kc
20 40 60 80 100 200 300 400 500
65
75
V1
Legend:
Scoriae
Dense lava
Sand
Stratigraphic column
H
S
Ka, Kb, Kc, H, Da, and Db are
Postglacial lava flows
S sand, G interglacial dolerite flow
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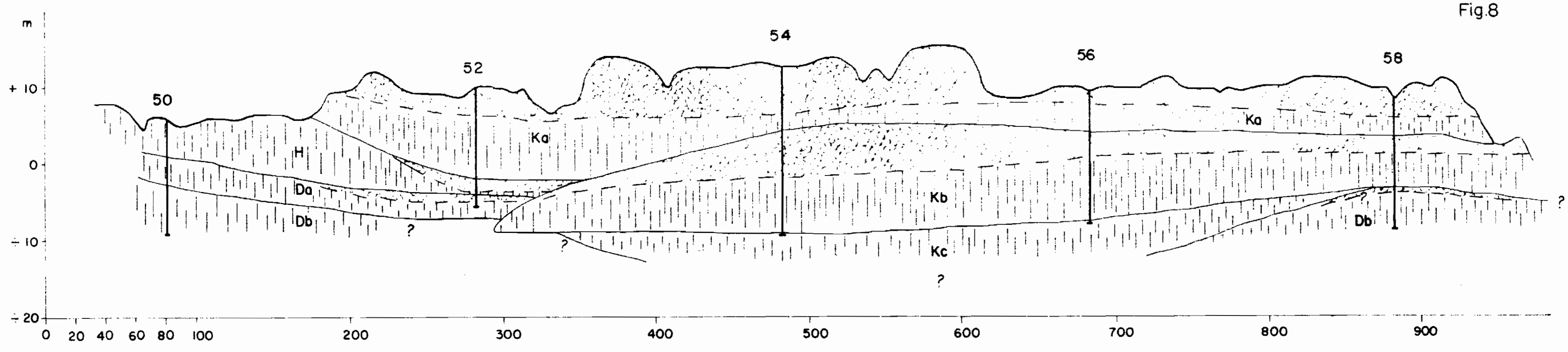
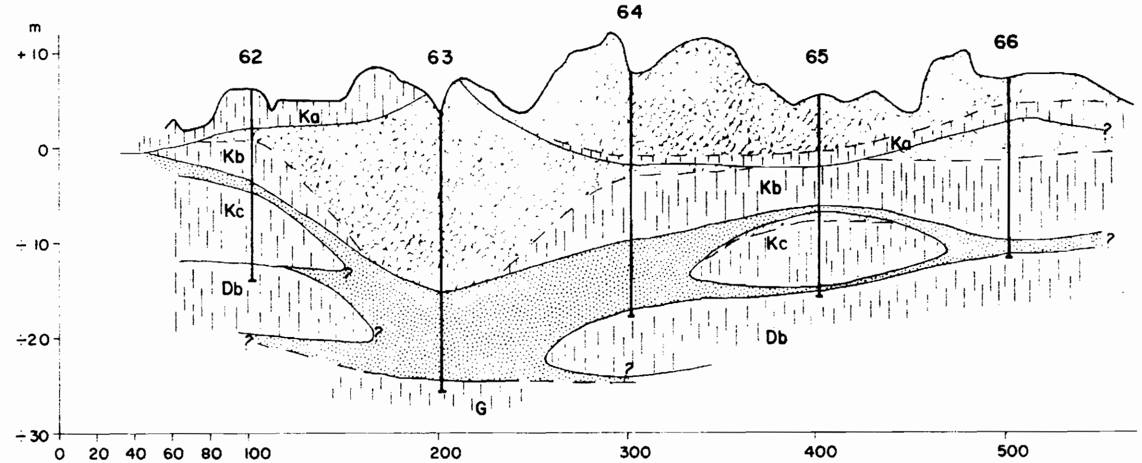
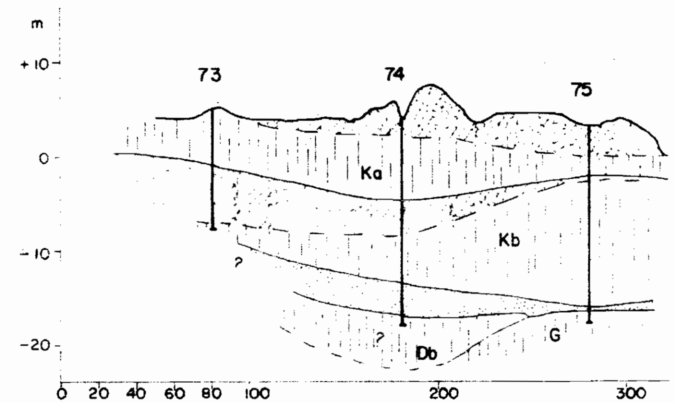
COMPANY LIMITED
RAFORKUMÁLASTJÓRI
STRAUMSVÍK
GEOLOGICAL SECTION
13/6 '66 HT/SG
Tnr. 7
Sheet 1 of 2
B-330
Fnr. 7494

Fig.8







Note:
For legend see
fig.7

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COMPANY LIMITED

RAFORKUMÁLASTJÓRI

STRAUMSVÍK

GEOLOGICAL SECTION

13/6'66 HT/HY	Tnr. 7	Fnr 7493
Sheet 2 of 2	B-330	

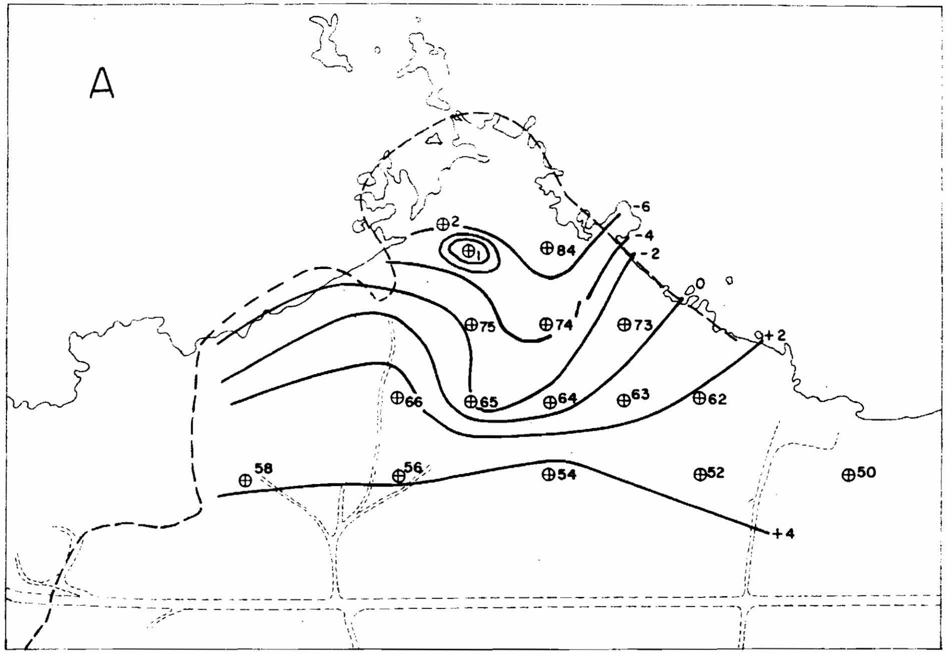
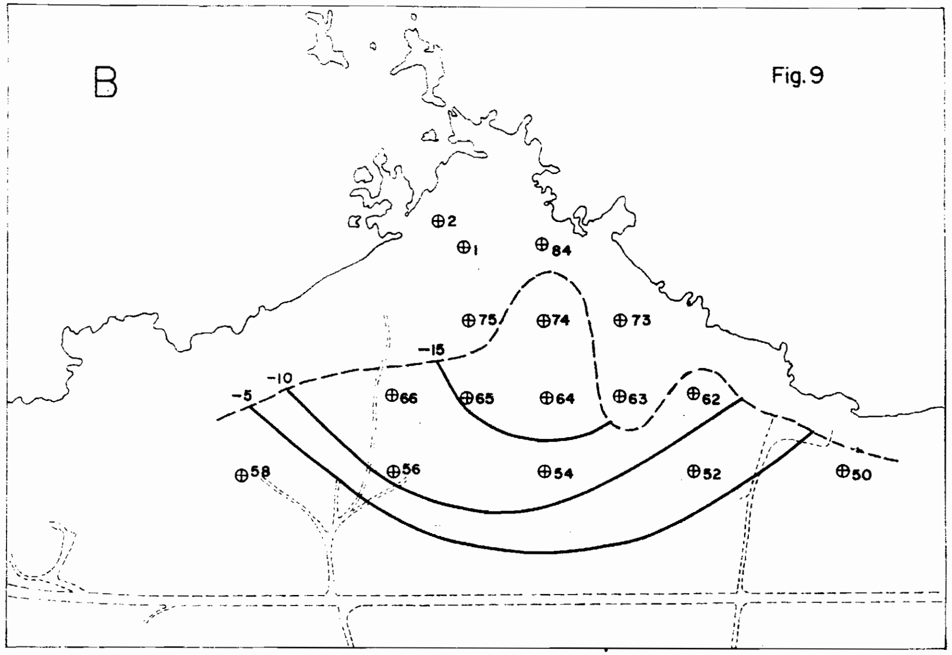
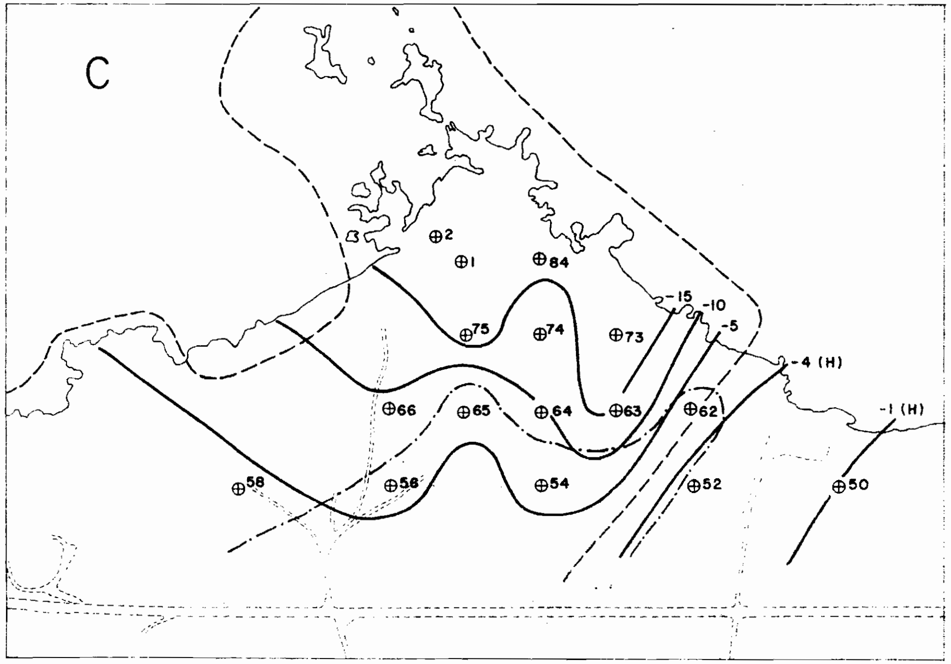


Fig. 9





A The structures for bottom of layer Ka

- – – – The outer limit of Ka
- ——— +2 structure conture lines

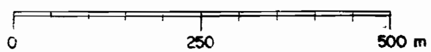
B The structures for top of layer Db

- – – – The outer limit of Db
- ——— -5 structure conture lines

C The structures for bottom of layer Kb

- – – – The outer limit of Kb
- ——— -5 structure conture lines, for layer Kb
- ——— 4 (H) ——— " ——— " ——— H
- –·–·– The outer limit of Kc

Note: Elevations are from normal sea level in the Reykjavík Elevation System



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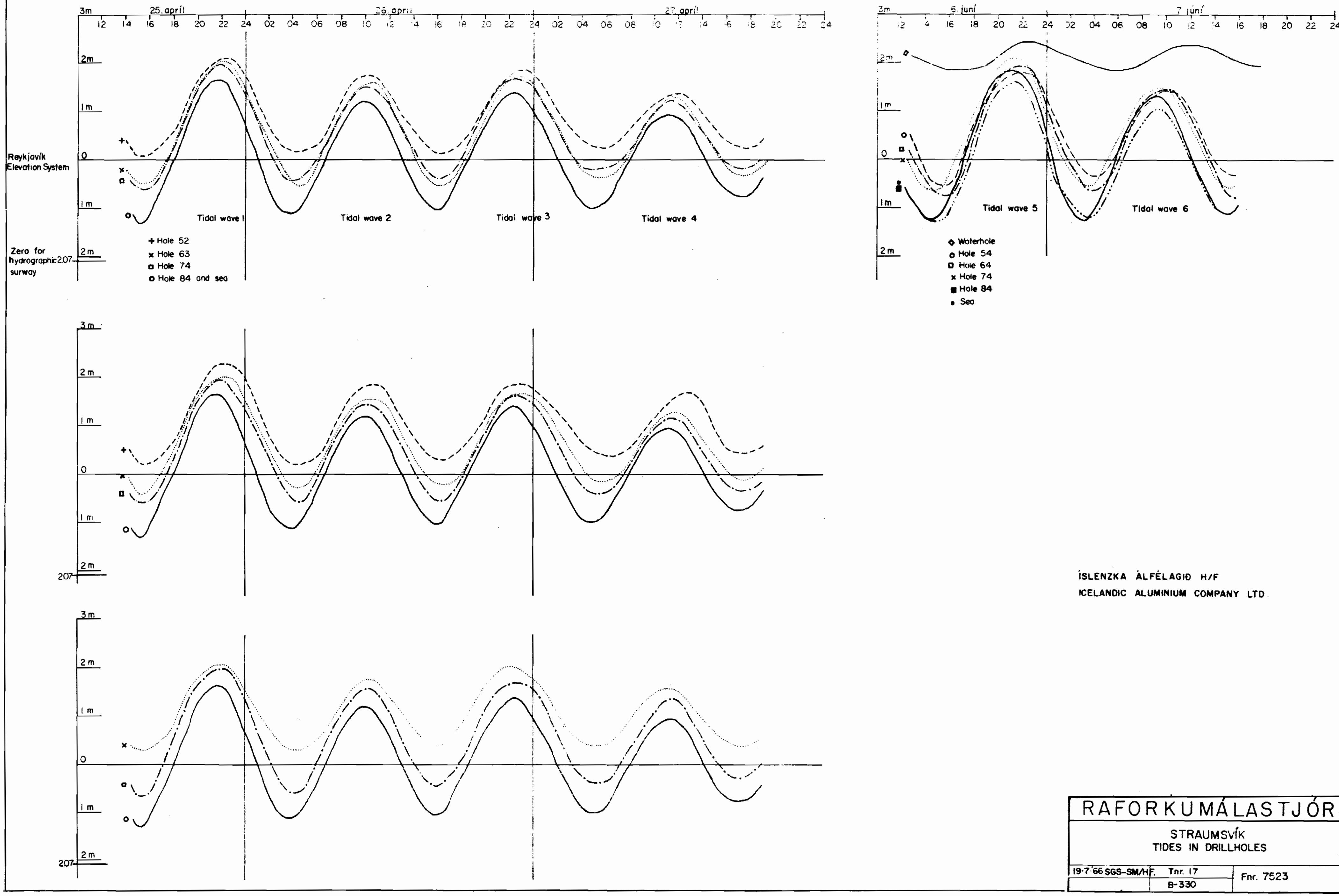
RAFORKUMÁLASTJÓRI		
STRAUMSVÍK STRUCTURE CONTURE MAPS		
13.7.'66 HT./Gyða	Tnr. 10 B-330	Fnr. 7512

Fig. 10



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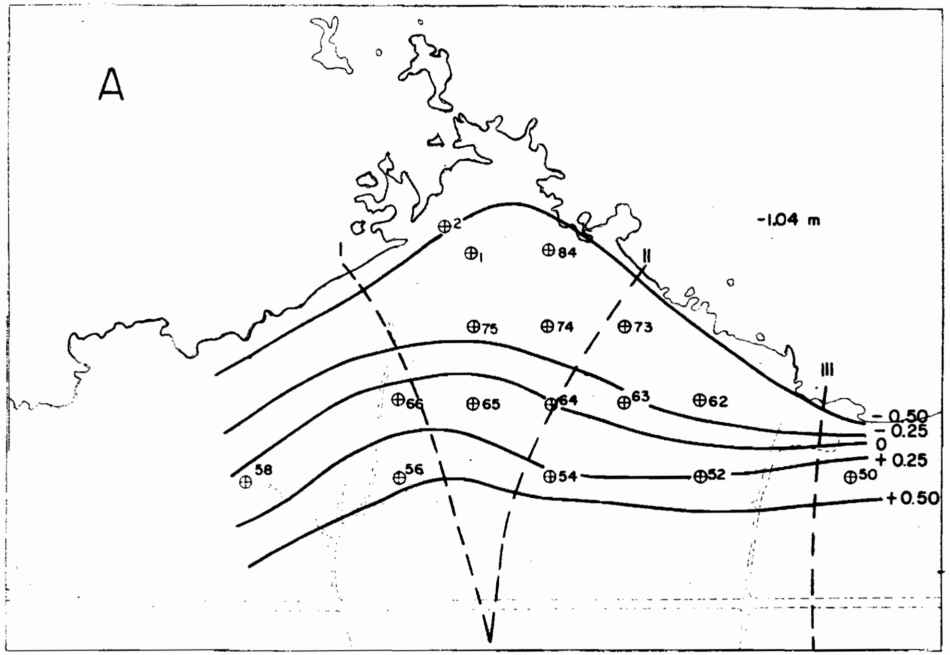
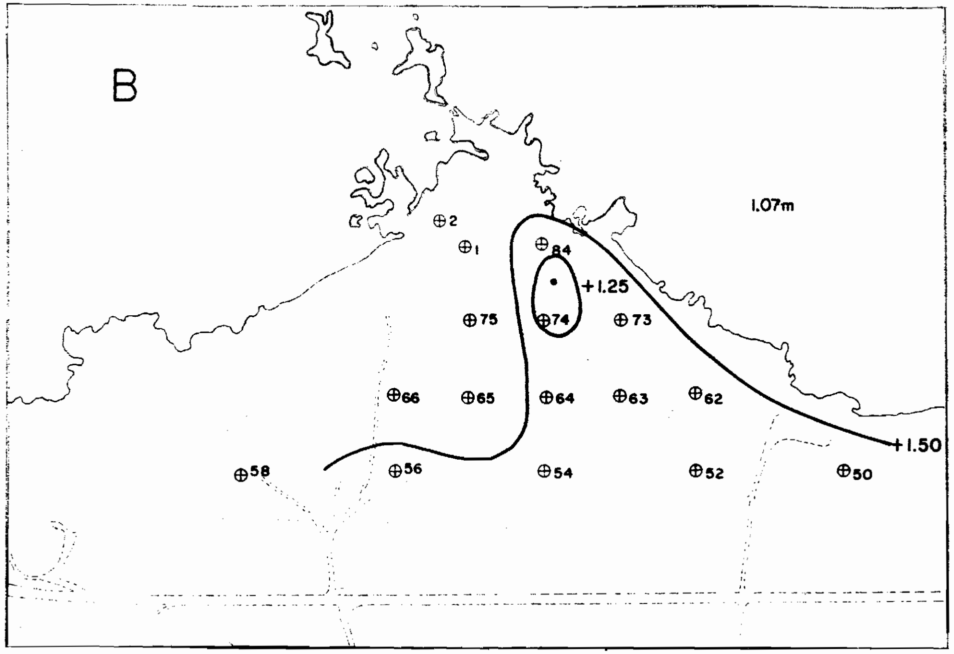
RAFORKUMÁLASTJÓRI

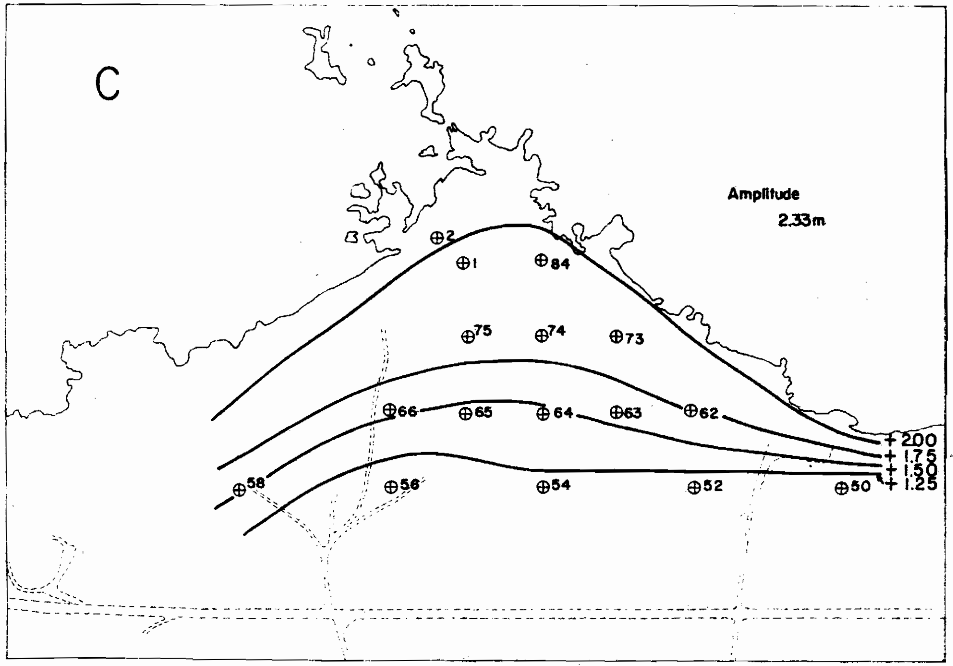
STRAUMSVÍK
TIDES IN DRILLHOLES

19·7·'66 SGS-SM/HF. Tnr. 17 B-330 Fnr. 7523

Fig II







A Reconstructed contours for ground water potential lines (surface) at 14[II] the 7th of June
Tides going down near low tide

B Reconstructed contours for ground water potential lines (surface) at 09[14] the 7th of June
Tides going up near high tide

C An Isopach map showing the difference between ground water level near high tide at time 09[14] and low tide at time 14[II] the 7th of June

Note: Elevations are from normal sea level in the Reykjavík Elevation System

I, II and III Lines calculated according to method two

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0 250 500m

RAFORKUMÁLASTJÓRI		
STRAUMSVÍK GROUND WATER MAP		
14.7.66 H.T./Gyða	Tnr. II B-330	Fnr. 7513

	RAFORKUMÁLASTJÓRI STRAUMSVÍK METHODS TO ESTIMATE THE PERMEABILITY COEFFICIENT	19.7.'66 HT/HF B-330 Tnr. 18 Fnr. 7525

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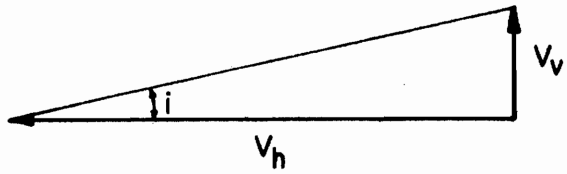
Fig. 12

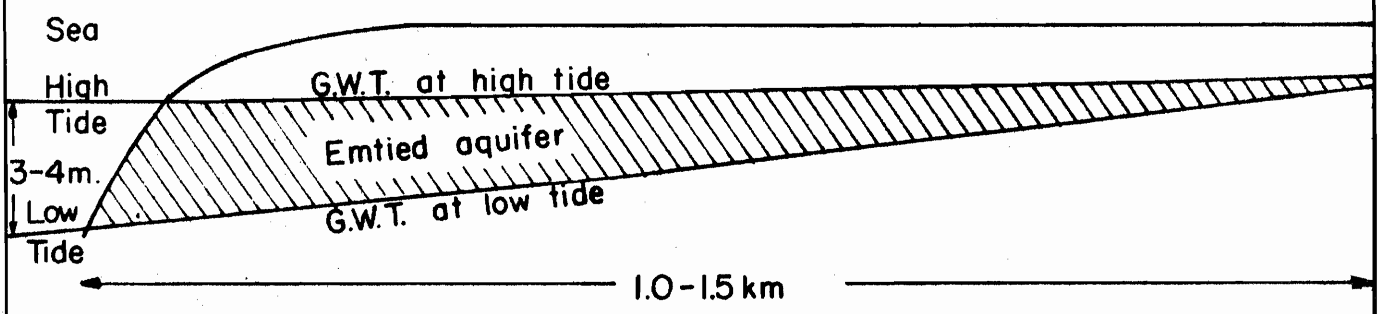


Method one on estimating

the permeability coefficient

SCHEME EXPLAINING THE VELOCITY VECTORS

$$K_1 = \frac{V_v}{i} \qquad K_2 = \frac{V_h}{i} = \frac{V_v}{i^2}$$



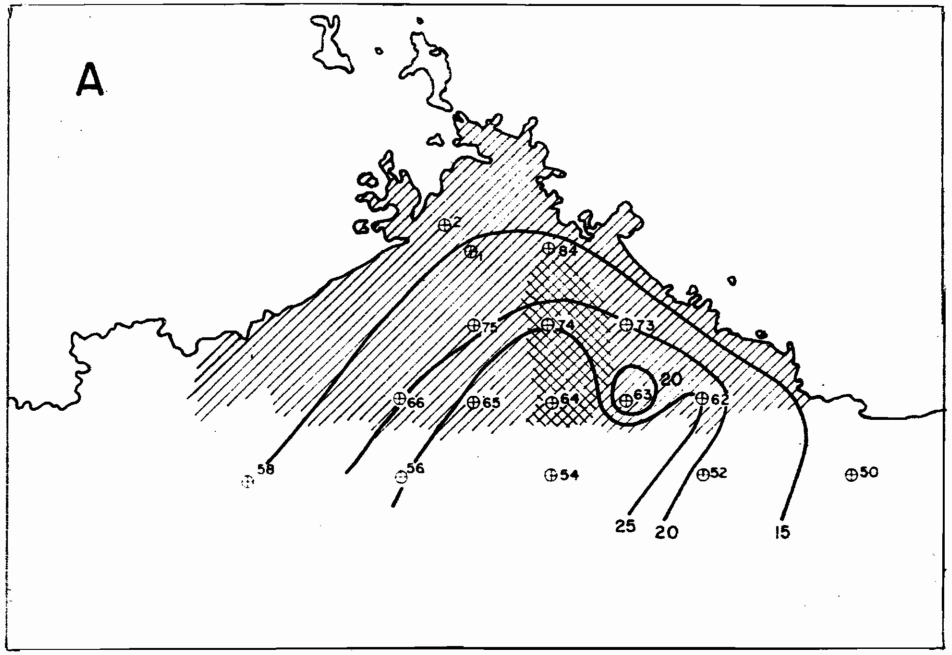
Method two on estimating the

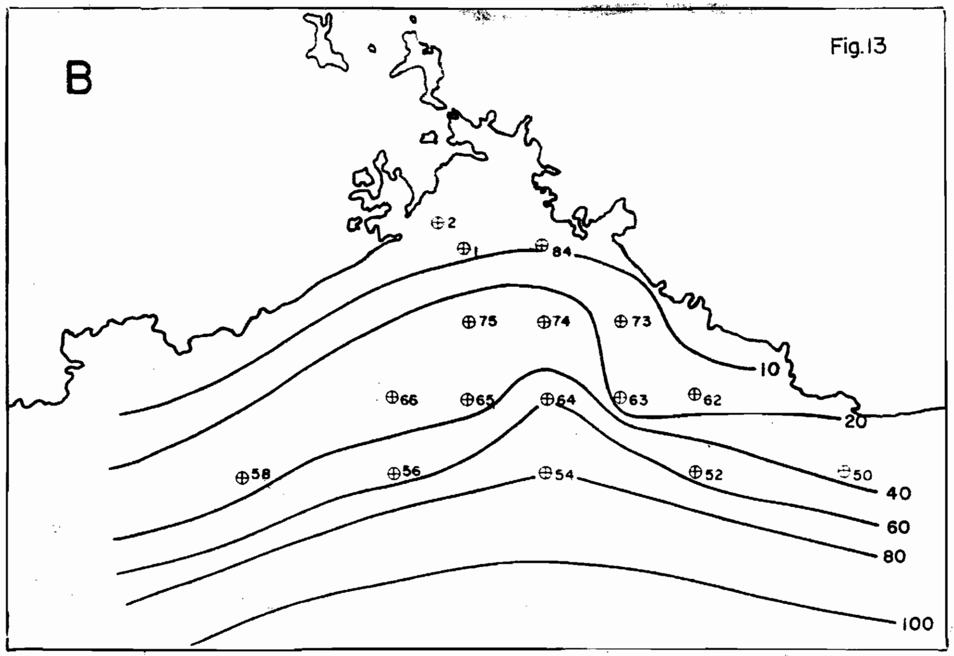
the permeability coefficient

scheme explaining area of emtied

aquifer A, and a permeability coefficient

$$K = \frac{A}{5\,i\,ht}$$





A —— The depth of the aquifer measured down to the dolerite flow

(single-hatched pattern) The aproximate extent of the sand layer lying between lava flows or directly on the dolerite

(cross-hatched pattern) A thick sand layer lying on the lava flow Db

B A map showing in minutes the delay of the tidal wave from the sea to the different drill holes

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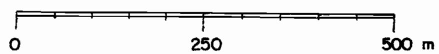


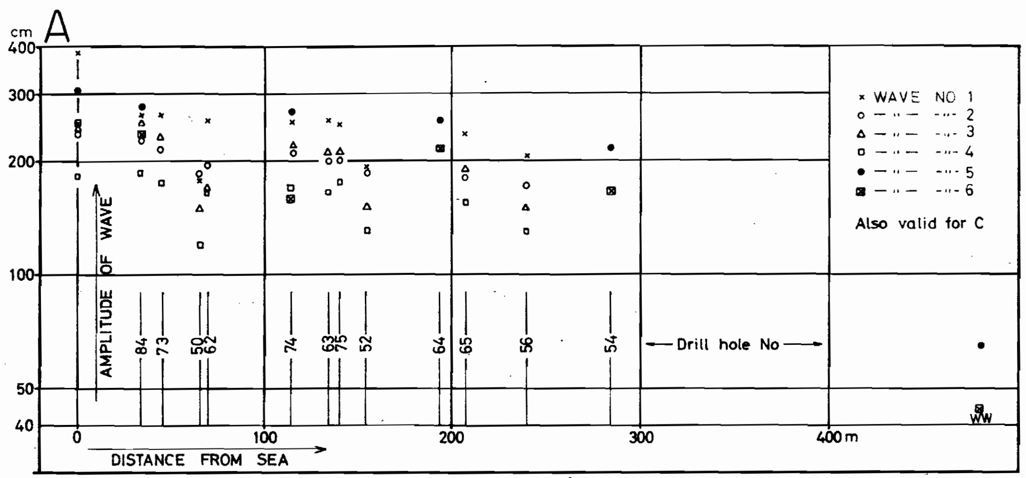
RAFORKUMÁLASTJÓRI

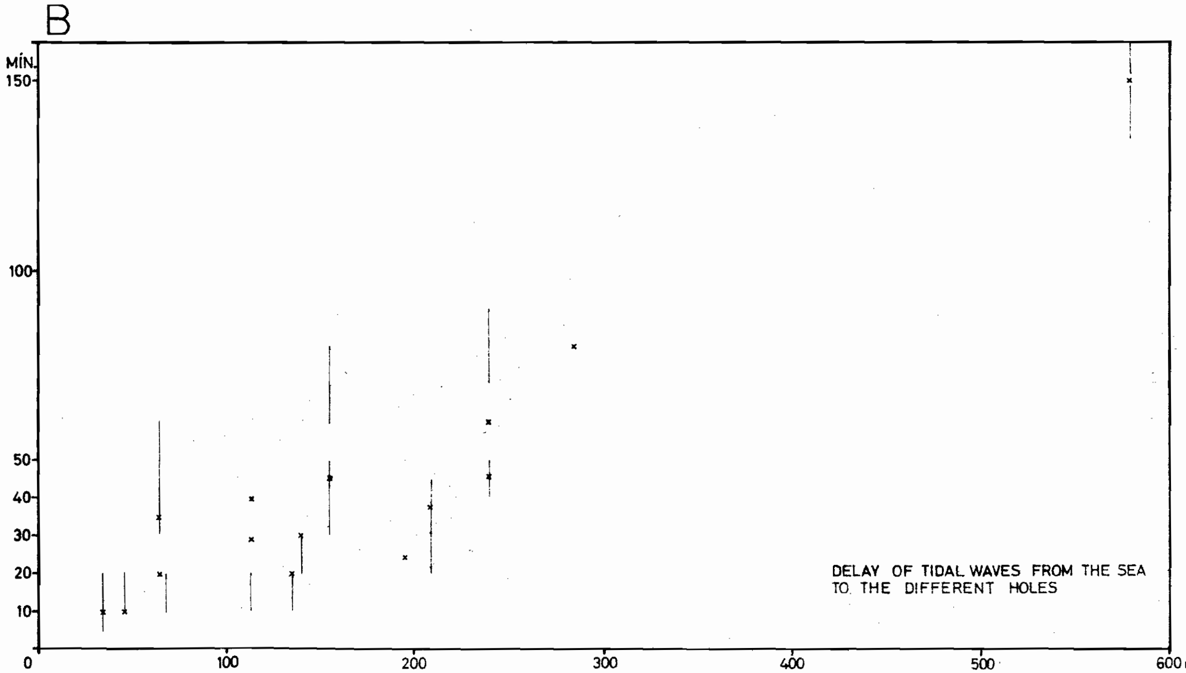
STRAUMSVÍK

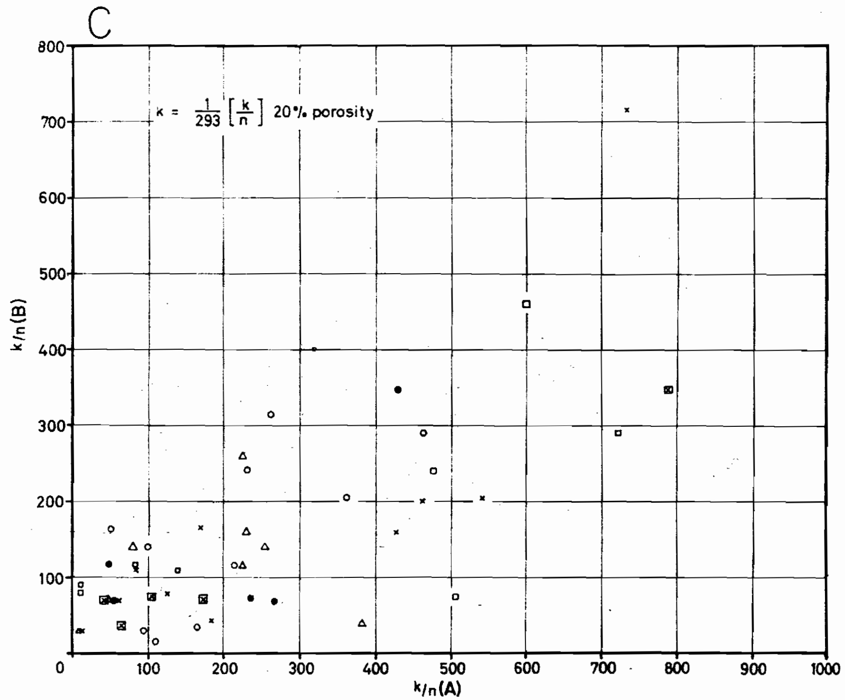
AQUIFER THICKNESS AND TIDAL WAVE DELAY

15.X.'66 H.T./Gyða	Tnr. 10 B-330	Fnr. 7520

Fig. 14







A Amplitude of tidal waves in the sea and the different drillholes, plotted at their distance from the sea.

B Delay of tidal waves in the drillholes plotted against their distance from the sea.

C Relation between permeability coefficients calculated from A and from B. k=permeability coefficient in cm/sek n=area of porosity. For 20 % volume porosity the equation in upper corner is valid.

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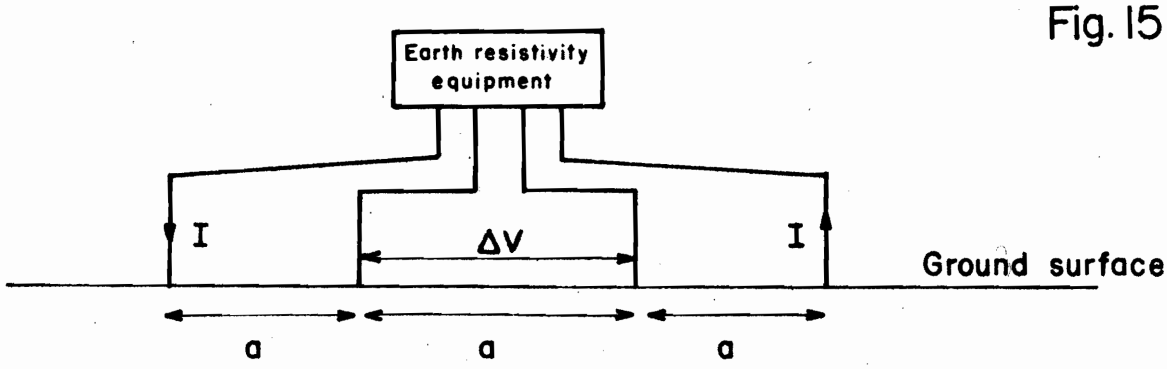
RAFORKUMÁLASTJÓRI		
STRAUMSVÍK DATA FOR PERMEABILITY CALCULATIONS		
14.766 HT/HF	B-330 Tnr. 12	Fnr. 7515

	RAFORKUMÁLASTJÓRI	15.7.'66 HT./Gyða
	STRAUMSVÍK	Tnr. 14
	EQUIPMENT FOR ELECTRICAL	B-330
	RESISTIVITY MEASUREMENTS	Fnr. 7519

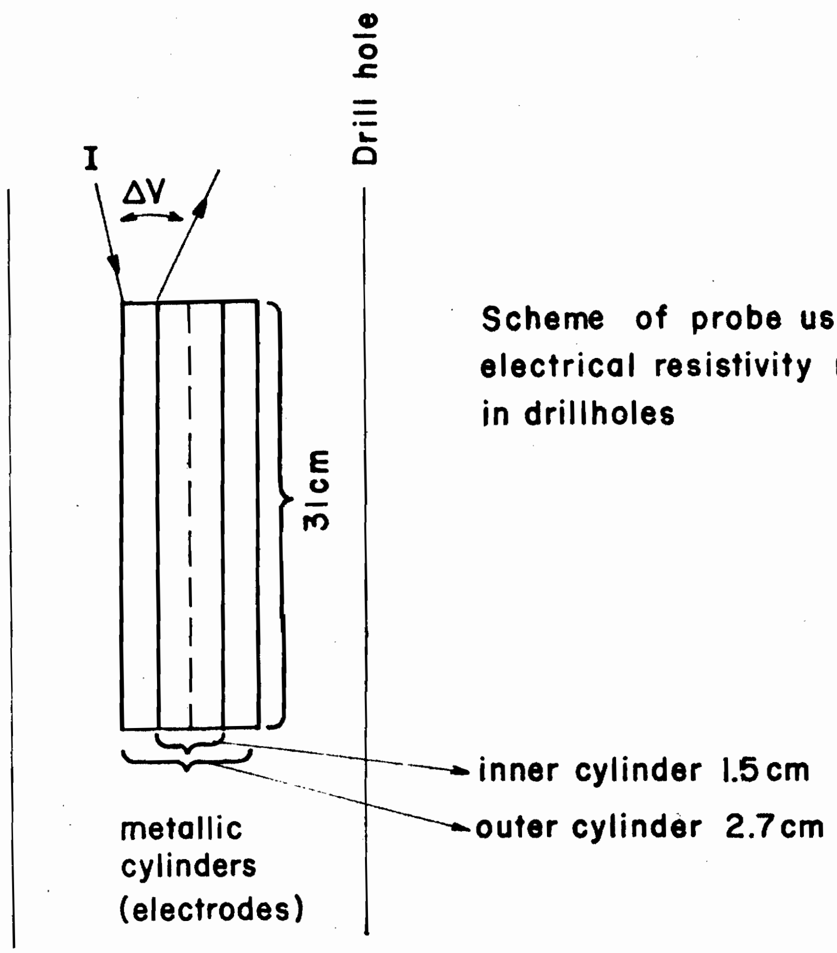
Fig. 15



Expanding spread method

$$\rho = 2\pi a \frac{\Delta V}{I}$$

Instrument set up for electrical resistivity measurements on the lava fields



Scheme of probe used for electrical resistivity measurements in drillholes

$$\rho_v = K \cdot \frac{\Delta V}{I}$$

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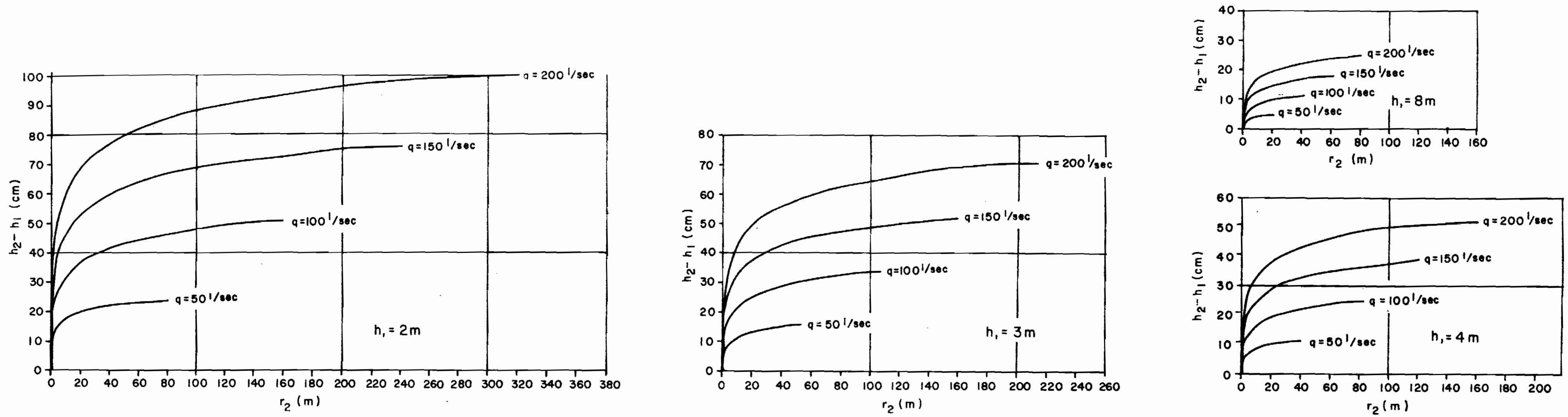
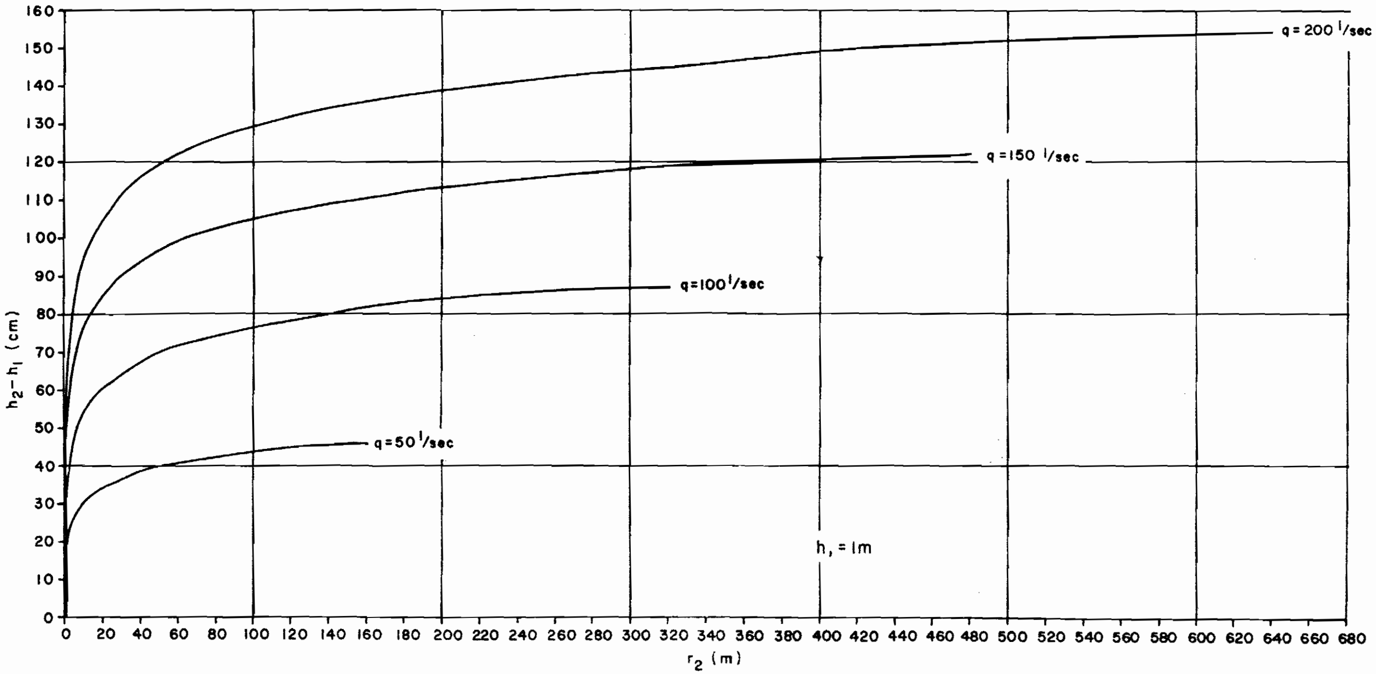
Fig.16





Equation used for this calculation:

$h_2^2 - h_1^2 = (q/\pi k)\log_e (r_2/r_1)$

h_1 = depth of pump under drawdown; h_2 = height of water surface above pump at distance r_2 from well

r_1 = radius of well = 12,5 cm; r_2 = radius of drawdown depression at height h_2 above pump

k = permeability coefficient = 10 cm/sec ; q = discharge from well in l/sec

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RAFORKUMÁLASTJÓRI		
STRAUMSVÍK		
DRAWDOWN IN WELLS		
18.7.'66 O.S./Gyða	B-330 Tnr. 16	Fnr. 7522