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Exploration of the Reykjanes Thermal Brine Area

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1. Introduction.

The Reykjanes Thermal Area is unique among high tempera-ture areas in Iceland as the thermal fluid is not meteoric water but of sea water origin. The composition of the brine issued in boiling springs differs, however, from ordinary sea water in some respects. Na^{+} and Cl^{-} con-centrations have increased 1.6 times, K^{-} and Ca^{++} 5 to 6 times, but Mg^{++} and SO_4^{--} have been reduced about 30 times. This chemistry and reservoir temperatures of 250-290°C render the Reykjanes Area especially favourable for the production of sea chemicals. A plant producing 250.000 tons per year of NaCl and byproducts of K, KOH, NaOH, and $CaCl_2$ has been projected and feasibility studies carried out (see B.Líndal, this symposium). In order to attain this capacity, the plant must withdraw 350 liters/sec of brine from the reservoir of the hydrothermal system. This flow of brine would be about 20 times the natural surface flow from the area at present and it is therefore obvious that a through investigation of the size and the nature of the hydrothermal system has to be undertaken, before the area can be recommended for the projected utilization. Under the increased load the chemistry of the brine might change and reservoir temperature and pressure decrease. Invasion of cold seawater or fresh groundwater might also occur if the pressure in the hot reservoir is lowered.

Investigations of the area were initiated in 1968 and intensified in 1969 and 1970. At present (August 1970) the regional survey and exploratory drilling are mostly completed. This paper outlines the most significant re-sults obtained.

2. Geological Setting.

The Reykjanes Thermal Area is located in the active volcanic belt in the extreme southwest of Iceland (fig. 1). The active volcanic belt in Iceland is the sub-areal continuation of the crest of the Mid-Atlantic Ridge.

The area around Reykjanes is mostly covered by post-glacial basalt lava flows (fig. 2). Relatively low hyaloclastite ridges of Pleistocene age protrude through the lava fields in a few places. The recent volcanic activity is characterised by lava producing fissure eruptions and central eruptions. The latter led to the formation of small shield volcanoes. The fissure eruptions are younger than the central eruptions and two of them are believed to have formed after the first settlement in Iceland some 1000 years ago.

The peninsula of Reykjanes is crossed by an intensely fractured NE-SW trending fault zone which is the continuation of the median fault zone of the Mid-Atlantic Ridge. The fractures are small normal faults and tension cracks. They are most closely spaced in a narrow belt which runs through the thermal area. The central part of the fault zone has subsided. There has been a movement on some of the faults over a period of time which is reflected by larger displacements in the older formations.

A geological section through the thermal area based on study of drillbits is presented in fig. 3.

3. The Uppermost Part of the Hydrothermal System.

The Reykjanes Thermal Area is one of 17 high temperature areas in Iceland (Bödvarsson, 1961), all of which are located in the active volcanic belt. Underground temperatures are above 200°C at depth of a few hundreds of meters in the four high temperature areas explored to date by drilling. This is to be contrasted with the low temperature areas found in the Tertiary basalts where temperatures are less than 150°C in the uppermost 1000 metres.

The Reykjanes Thermal Area is one of the smallest high temperature areas in Iceland. Visible thermal activity on the surface covers only about 1 km^2. The surface expression of the thermal activity is that typical of the high temperature areas, namely hot ground, mud springs, steam vents, and solfataras. There are, however, three hot springs with clear saline water, which is unique for thermal water compositions in Iceland.

The results of a shallow temperature survey are shown in fig. 4. Infrared survey was carried out in the area in 1966 and repeated in 1968. The results of this survey are given by Pálmason et.al. (This symposium). On the basis of these surveys the natural surface heat output in the thermal area was estimated to be 15 Gcal/h.

Direct current resistivity measurements have been carried out in the thermal area and the surrounding region. The measurements consisted of resistivity profiling (Wenner-array, a=300 m) and depth sounding (Schlumberger-array, (L/2) =900 m). The results are shown in fig. 5. Ordinarily recent lava flows saturated with fresh water have a resistivity of 1000-5000 Ωm but on Reykjanes the resistivity is much lower, lying in the range 6-20 Ωm. Within the thermal area values of 1-3 Ωm are obtained. These low values were taken to indicate that the hyaloclastite formation and the post-glacial lavas were impregnated with sea water. This has been confirmed by exploratory drilling. According to the results of the resistivity survey the thermal area is not larger at a depth of 600 metres than it is at the surface. Drilling indicates that boiling brine is encountered within the 3 Ωm isoline.

An areomagnetic survey was flown with a proton precision magnetometer at an altitude of 150 metres followed by a more detailed ground survey. The most pronounced magnetic low found is associated with the thermal area (fig. 6). This magnetic low is considered to have formed as a result of the hydrothermal alteration when primary magnetite is destroyed by the sulphate bearing thermal brine. Weaker magnetic low was also found which trends northeast from the thermal area and coincides with the hyaloclastite ridge of Sýrfell. This low is probably due to weaker magnetisation of the hyaloclastite than the surrounding lava fields. The reason for the third magnetic low pattern on the map running NW-SE through the thermal area is not known.

4. Crustal Structure and the Lower Part of the Hydrothermal System.

Studies of explosion seismology (fig.7) show a low velocity layer (V_p about 3.0 km/sec) reaching a depth of 900 meters. This low velocity layer is found at the surface everywhere in the active volcanic belt (Pálmason, 1970) and is considered to correspond to porous and rather fresh volcanic breccias, pillow lavas, and individual lava flows with low degree of compaction (density 2.1-2.5 g/cm^3). This has been verified by exploratory drilling in the area. Cores of intensely altered hyaloclastite from 300 metres and 570 metres depth had a porousity of 32% and 23% respectively. Below the surface layer to a depth of 2600 metres the P-velocity is 4.2 km/sec which is similar to that of the Tertiary flood basalts in Iceland. The average density of this layer is 2.6 g/cm^3. An exploratory drillhole reaching 1750 metres depth indicates that this formation is mainly built up of basaltic lava flows with thick interbeds of hyaloclastites. A core of hyaloclastite at 1370 metres depth had a porousity of 19%. No cores were obtained from the basalt lavas but in other areas, where this type of formation is found, an average porousity of

3-5% can be expected. In the following these two seismic layers will be referred to as the hyaloclastite and the basalt formations respectively.

Although the hyaloclastite formation is highly porous, only a few good aquifers have been encountered in exploratory wells in this formation. On the other hand, numerous good aquifers have been encountered in the lava flows and in the interbeds of the basalt formation. In an exploratory well penetrating to 1750 metres depth, at least 10 aquifers were encountered between 1000 and 1750 metres depth. The drillhole was drilled with water as circulating fluid and the integrated loss in the basalt formation exceeded 120 liters/sec (fig.8). Despite the expected relatively low overall porousity in the basalt formation scoriaceous contacts between lava flows and interbeds are expected to be very porous and highly permeable. Joint fractures and faults seem also to form channels of substantial permeability.

The third seismic layer under the Reykjanes Peninsula has a P-velocity of 6.5 km/sec and an average density of 2.9 g/cm^3. It is underlain at 8.5 km depth by layer 4 which has a P-velocity of 7.2 km/sec and an average density of 3.1 g/cm^3 (Pálmason, 1970). Layer 3 is considered to correspond to the "oceanic layer" generally found on the floor of the oceans and layer 4 to the anomalous upper mantle as observed under the crestal zone of the mid-ocean ridges.

Temperature gradients in shallow drillholes in southwest Iceland suggest that the upper boundary of layer 3 in this region may have a temperature of 350 to 400°C (Pálmason, 1970). This would imply that under the Reykjanes thermal area the 350°C isotherm is to be found at about 2600 m depth. The nature of the 2-3 layer boundary is not known but combined seismic and temperature data suggest that is is a boundary between metamorphic facies of basaltic rocks, perhaps a greenschist-amphibolite boundary. The density and high degree of alteration expected in layer 3 suggests a low permeability of this layer and it is questionable whether ground water can circulate below the 2-3 boundary although the low permeability might be balanced by the low viscousity of the water which would be close to critical temperature and pressure.

The ground water in the hyaloclastite formation is of sea water origin. The sea water is, however, extensively diluted with downward percolating rain water in the uppermost 100-200 metres (see table 1). The ground water in the basalt formation is also of sea water origin and it is thought that the ground water moves through a deep convection cycle within this formation. High heat flow from lower rock formations, which causes a high temperature gradient in the uppermost part of the crust, is considered to be responsible for this convection. At least a part of this heat is thought to come from relatively shallow magmatic intrusions. The high heat flow causes a temperature of some 300°C near the bottom of the basalt formation. The thermal brine receives its high temperature by slow circulation through this hot rock.

Thermal brine with a temperature of 250-290°C reaches the top of the basalt formation under the Reykjanes thermal area. This hot brine rises also through the hyaloclastite formation to the surface through a narrow zone of 1 km^2. The hot brine boils and cools in the upflow zone of the hyaloclastite formation. It is believed that only a very minor fraction of this hot brine reaches the surface in hot springs but that most of it descends after cooling on the boundary of the upflow zone and flows into the hyaloclastite formation. The heat output at the surface is mostly in the form of convection and loss of steam and is estimated to be about 15 Gcal/h.

Not much is known of the extent of the convection of hot brine within the basalt formation and the total volume of hot exploitable brine. The planned sea chemicals plant needs 350 litres/sec for 15 years or 0.14 km^3 of hot brine with the same salinity as sea water. If the hot brine would be extracted from the basalt formation at a depth of 1000-2600 metres and assuming 5% porousity, which is a conservative estimate since there are thick interbeds with a porousity of 15-20%, the sea chemicals plant would extract hot brine from 1.75 km^3 of the basalt formation over a period of 15 years.

5. The Thermal Fluid and Alteration.

The composition of the saline thermal water is comparable with that of sea water in many respects. As compared with sea water, however, the thermal brine contains less SO_4^{--} and much less Mg^{++} but the concentrations of SiO_2, K^+, and Ca^{++} are higher (table 1). Indeed all studies favour that the saline thermal water is of sea water origin and that the difference in the composition of the two results from relatively non-complex hot water/rock interactions and flashing. In deep drillholes (1000-1750 metres) the salinity of the thermal brine is a little lower than that of sea water. In hot springs and shallow drillholes (300 metres) it is on the other hand 10-50% higher which is considered to result from flashing in the upflow zone.

The hydrothermal alteration of the basalts and hyaloclastites at depth in the Reykjanes Thermal Area is in most ways comparable with hydrothermal alteration at depth of other drilled high temperature areas in Iceland despite the enormous differences in the composition of the associated waters (see table 1). The most significant mineralogical differences include the existence of hydrothermal alkali feldspar and anhydrite at Reykjanes which is related to the composition of sea water flowing into the thermal system. On the whole the hydrothermal minerals have lower density than the primary minerals so the hydrothermal alteration reduces the porousity of the rock.

Table 1. Major component composition of the thermal brine at Reykjanes and fluids from other high temperature areas. Concentrations in ppm.

	Locality	Depth of drillhole	Temp. °C	ph/°C	Eh volts 25°C	SiO_2	B	Na^+	K^+	Ca^{++}	Mg^{++}	Total carb. as CO_2	SO_4^{--}	S^{--}	Cl^-	F^-	Total diss. solids
1	Reykjanes, spring		99	6.2/99	0.02	544	12.0	14325	1670	2260	123	5.0	206	0.2	29100	0.2	52160
2	Reykjanes, drillhole 2	300	190	7.2/23	0.13	374	11.6	11380	1607	1915	8	754	60		21610	0.2	38200
3	Reykjanes, drillhole 8	1754	253	5.75/20		477		8450	1260	1654	21		141		17900		31032
4	Reykjanes, drillhole 7	59	10			3		3150	200	66	"low"		276		4170		9716
5	Njardvíkurheidi, drillhole 1	500				76		9170	359	3776	24		1535		20070		36576
6	Geysir, Geysir Area		84	8.7/84	0.06	509	1.27	209	22	0.8	0.03	135	114	0.7	122	11.5	1133
7	Námafjall, drillhole 3	670	268	7.15/268	0.29	591	0.69	133	28	1.1	0.03	188	62	119	20	1.5	822
8	Sea Water			7.6/20		3		10520	416	386	1282		2640		19800		

Reported compositions for drillholes are those of the water feeding these drillholes. Eh of wet steam drillholes is that of the aqueous fraction. Njardvíkurheidi, 20 km north of the Reykjanes Thermal Area. The Geysir Area is located in the Southern Lowlands of Iceland and Námafjall in northeast Iceland.

During the hydrothermal alteration the glass is first attacked and subsequently olivine and pyroxene, and lastly plagioclase. The most conspiceous hydrothermal minerals are montmorillonite and chlorite. Quartz and calcite are abundant, calcite especially in the uppermost 600 metres. Pyrite is widely dispersed and prenite below 350 metres. Analcime is found to depths of 1700 metres in drillhole 8 and in other drillholes to about 600 metres depth. Other zeolites occur in the uppermost 400-600 metres. Alkali feldspar is most abundant in the upflow zone down to depths of about 150 metres. Hematite is found near the surface, and opal above 300 metres.

The concentration of SO_4^{--} in thermal brine is much lower than in sea water which is due to its precipitation in the form of anhydrite which has been identified in the altered rock. The concentrations of Ca^{++} and SO_4^{--} in the thermal brine are of the order of magnitude expected for the solubility of anhydrite according to data of Booth and Bidwell (1950). Under the 100-200 metres layer of cold sea water the concentrations of anhydrite are locally high in drillholes near the edge of the upflow zone. These high concentrations are considered to result from invasion of sea water into hot rock but the solubility of anhydrite falls rapidly with increasing temperature. Such invasions are particularly expected to find place during tectonic disturbances.

Epidote appears at a depth of 450-650 metres as it does in other drilled high temperature areas. It is thought that epidote forms only at a relatively high temperatures, perhaps above 200°C.

The hydrothermal alteration on the surface and within the upflow zone in the Reykjanes Thermal Area is more extensive than the present hydrothermal activity. The presence of epidote at 450 metres in a drillhole about 1 km southwest of the active area is therefore taken to indicate extinct high temperature activity. This activity may have become extinct as a result of reduction of the size of the upflow zone but lateral shift to the northeast is though considered more likely. Invasion of cold sea water during tectonic disturbances may be responsible for these changes.

The relative concentrations of Na^+, K^+, Ca^{++}, and Mg^{++} differ much between sea water and the thermal brine but these cations are far the most abundant in the thermal brine. The ratio to Cl^- of the total positive charge of these ions in thermal brine and sea water is similar if loss of Ca^{++} by SO_4^{--} precipitation is taken into account. The ratio Cl/Na is slightly higher in the thermal brine than in sea water. This is explained by precipitation of Na^+ to form alkali feldspar and simultaneous solution of K^+. According to data of Helgeson (1969) the calculated ratio Na/K at a given temperature is similar to that expected for Na /K bearing solutions in equilibrium with alkali feldspar.

The concentrations of Ca^{++} and Mg^{++} in the thermal brine are considered to be governed by ionic exchange reactions with montmorillonite and chlorite. Evidence favours that most of the Mg^{++} of sea water percolating into the rocks is precipitated at low temperatures (see table 1). The silica concentrations are governed by the solubility of quartz and the silica content of brine from deep drillholes has been used to estimate the temperature of the brine feeding these drillholes.

The content of some trace elements in the thermal brine is low (table 2) and quite comparable with the trace element content of other thermal waters in Iceland of similar temperature but having widely different major component composition. Other trace elements which are relatively high in sea water are also high in the thermal brine.

The gas content of the thermal brine issuing from drill-

Table 2. Trace element composition of the thermal brine at Reykjanes and fluids from other high temperature areas.

Locality	ppb						ppm		
	Fe	Ga	Ge	Mo	Ti	V	Li	Br	I
Reykjanes spring	192	2.6	5.5	10.9	6.1	0.7	7.4	98.0	0.5
Reykjanes, drillhole 2	485	7.6	6.0	6.1	5.2	2.5			
Geysir, Geysir Area	12.5	1.5	23.6	47.0	1.0	15.1	0.2	0.2	0.0
Námafjall, drillhole 3	21.4	0.7	58.8	4.1	1.4	2.1			
Sea Water	2	0.5		0.3		0.3	0.1	65.0	0.05

The Geysir Area is located in the Southern Lowlands and Námafjall in northeast Iceland.

Table 3. Gas compositions of thermal fluids feeding high temperature drillholes. Concentrations in moles $x10^{-4}$.

Locality	Temp. °C	CO_2	H_2S	H_2	N_2	O_2	CH_4
Reykjanes drillhole 2	190	171.3	3.1	0.18	7.3	0.91	0.02
Námafjall drillhole 4	259	12.9	7.7	14.0	2.6	0.0	0.84
Hveragerdi drillhole 8	217	3.43	0.38	0.34		0.0	0.01

Námafjall is located in northeast Iceland and Hveragerdi in south Iceland.

holes is very high compared with gas contents of other drilled high temperature areas. Most of the gas is CO_2 (table 3). Its concentration in the brine at depth is about 750 ppm. The molar concentration of hydrogen and hydrogen sulphide in the brine fluid are of the same order of magnitude as in drillholes of other areas of similar temperature. The unusually high CO_2 content may be due to supply of this compound from a juvenile source. If the CO_2 is derived from the altered rock only by leaching, which appears also possible, this leaching must find place at depths greater than the upflow zone because the amount of hydrothermal calcite in that zone strongly suggest increased carbon content in the rock.

The average content of K_2O in 25 samples of drillbits in the uppermost 1000 metres is 7 times higher than in 19 samples of fresh rocks of the Reykjanes area (table 4). The addition of K_2O is considered to result from precipitation of K^+ from ascending cooling brine. Assuming that ascending thermal brine had the same Na^+ content as sea water and was in equilibrium with alkali feldspar, cooled from 250°C to 200°C, this observed addition of K^+ in the

<u>Table 4.</u> The content of K_2O in fresh- and hydrothermally altered rock from Reykjanes.

	no.of samples	average content %	conc. range %
Fresh rock	19	0.13	0.08-0.26
Altered rock	25	0.91	0.20-6.35

altered rock would require, for 15% porousity, that the hot brine had to be exchanged 13 times in the upflow zone. These preliminary results suggest therefore that circulation time of hot brine through the upflow zone must be at least one order of magnitude less than the duration of hydrothermal activity in the system. Since it is considered that the increased K^{++} content of the thermal brine relative to sea water was leached from the altered rock, it follows that the size of the hydrothermal system below 1000 metres must be at least 6 times larger than the volume of hot rock above 1000 metres. Otherwise there would not have been sufficient quantity of potassium available for leaching.

6. Production Characteristics.

Since the hydrothermal system is considered to be more extensive in the basalt formation than in the hyaloclastite formation, it appears quite possible to drill production holes outside the thermal area as seen on the surface. However, drilling in the loosely cemented hyaloclastites and scoriaceous lavas and their sandy interbeds around the thermal area has proved to be extremely difficult and expensive. Also the presence of cold sea water at 100-200 metres depth on the southern edge of the upflow zone increases the danger of invasion of cold sea water into drillholes and corrosion of casings on their outside. Drilling within the thermal area is not so difficult because here the altered rocks are well cemented and not with open cracks.

In the hyaloclastite formation the hydrostatic pressure of the hot brine is as much as 10 atmospheres lower than that of cold sea water at the same depth. During drilling there is therefore no difficulty in preventing the holes from blowing. On the other hand this low pressure in the hydrothermal system increases the danger of invasion of cold sea water into production drillholes. As mentioned before local concentrations of anhydrite in the altered rocks to 600 metres depth by the southern edge of the upflow zone are taken to indicate sudden invasion of cold sea water into hot rock. The last time this happened was during an earthquake in the summer of 1967. This was indicated by a sudden increase in the SO_4^{--} and Mg^{++} content of the hot brine in surface springs.

There appear to be few permeable aquifers above 700 metres but they are much more frequent in the basalt formation below 1000 metres. A cap of a series of basalt lavas are found at a depth of 900-1100 metres so invasion of cold sea water into the hydrothermal system is not so likely in the basalt formation under this cap rock as it is in the hyaloclastite formation above. It is therefore more desirable to exploit thermal brine from drillholes which penetrate well into the basalt formation and not rely on permeable aquifers within the hyaloclastite formation.

The rocks of the hyaloclastite formation and interbeds of the basalt formation are frequently very soft and poorly cemented so there is much danger that drillholes will collapse which penetrate such soft rocks. These soft rocks must therefore be cased off in production drillholes and aquifers to be exploited lined with perforated casings. However, exactly how a drillhole should be cased, can only be decided after it has been drilled. Present results favour that all good production drillholes should be cased to the bottom.

7. Production Drilling.

If drilling of production holes will be initiated, the drillholes will be located near the central part of the upflow zone between drillholes 2 and 8 (see fig. 5). Each drillhole would be about 1800 metres deep. The cost of drilling and casing one hole would be about $ 110.000. By comparison with experience of previous drilling in the area, individual drillholes should not deviate more than 20% from original cost estimates. There is much more uncertainty with the mass flow of individual holes. The inflow into drillhole 8, which is 1750 metres deep, is thought to be about 50-100 l/sec (inferred from loss of circulation fluid during drilling) and therefore 3-6 such holes would be required to provide 350 l/sec, which is the needed quantity for the sea chemicals plant. The durability of production holes is also uncertain. Usually mass flow of individual drillholes decreases with time so additional drillholes will be needed to maintain the original total output. A final answer of the production potential of the area, the number of drillholes required, and their durability can only be given by direct testing, that is, drilling of production holes in steps and judgement of the success of each step after the drillholes have been blowing over a period of time. Each step does not cost less than $ 110.000.

If the sea chemicals plant will be established, it is assumed that the plant will pay a certain sum annually for the thermal brine and steam for 15 years. This annual payment must cover all production and research expenses for the exploitation of brine and steam. In a feasibility study report for the sea chemicals plant (Líndal and Lúdvíksson, 1969) the annual payments were assumed to be $ 400.000.

Present results of the studies of the hydrothermal area favour that sufficient supply of brine can be recovered from the area for NaCl production as appears in the feasibility study report. However, exploitation costs of brine and steam are still very uncertain and will remain so until it is known how many production drillholes will be required and until the durability of the holes and piping is known.

If sufficient quantity of thermal brine can be extracted from 7 drillholes and if each drillhole will last for 5 years, the annual payments from the sea chemicals plant would need to be about $ 410.000, which is very close to the estimate in the feasibility study report. The numerous permeable aquifers penetrated by drillhole 8 (1750 metres deep) suggest that drilling of 7 holes is sufficient although direct testing only can give a decisive answer. The direct testing is, however, so costly that it cannot be recommended unless the outlook for the construction of the sea chemicals plant is very favourable.

It is considered most desirable to carry out production test drilling in steps of 3 drillholes and subsequently study their mass flow over a period of time and possible changes of the hydrothermal reservoir, before the next step is initiated. It is desirable to initiate as soon as possible tests of corrosion and scaling in pipes, but it is expected that the high salinity of the thermal fluid may raise problems of such nature.

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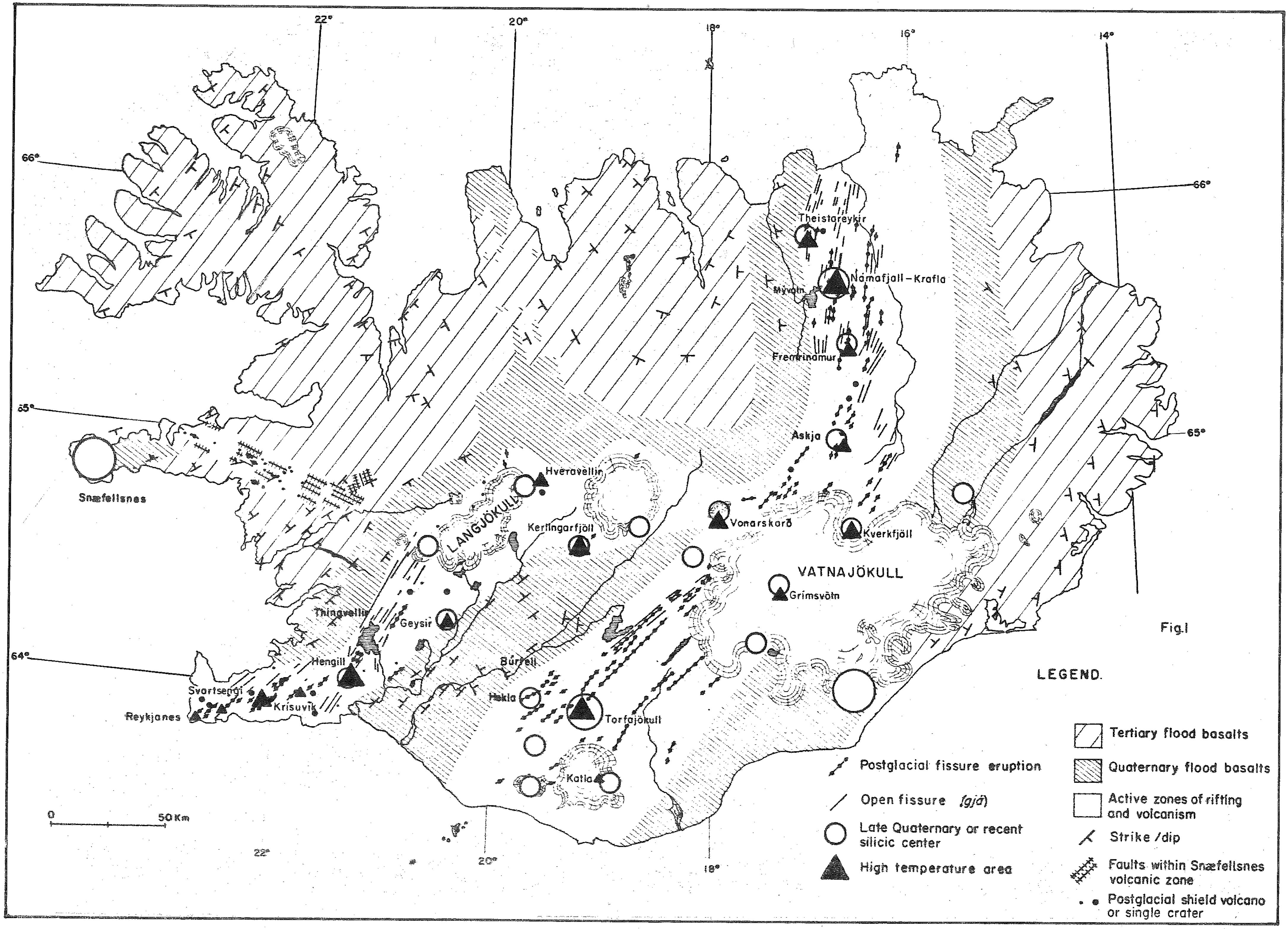

22°
20°
18°
16°
14°
66°
65°
64°
Snæfellsnes
Theistareykir
Námafjall - Krafla
Mývatn
Fremrinámur
Askja
Hveravellir
Kerlingarfjöll
LANGJÖKULL
Vonarskarð
Kverkfjöll
VATNAJÖKULL
Grímsvötn
Thingvellir
Geysir
Hengill
Búrfell
Svartsengi
Krísuvík
Reykjanes
Hekla
Torfajökull
Katla
0
50 Km
LEGEND.
Tertiary flood basalts
Quaternary flood basalts
Active zones of rifting and volcanism
Strike /dip
Faults within Snæfellsnes volcanic zone
Postglacial shield volcano or single crater
Postglacial fissure eruption
Open fissure (gjá)
Late Quaternary or recent silicic center
High temperature area

Fig.1

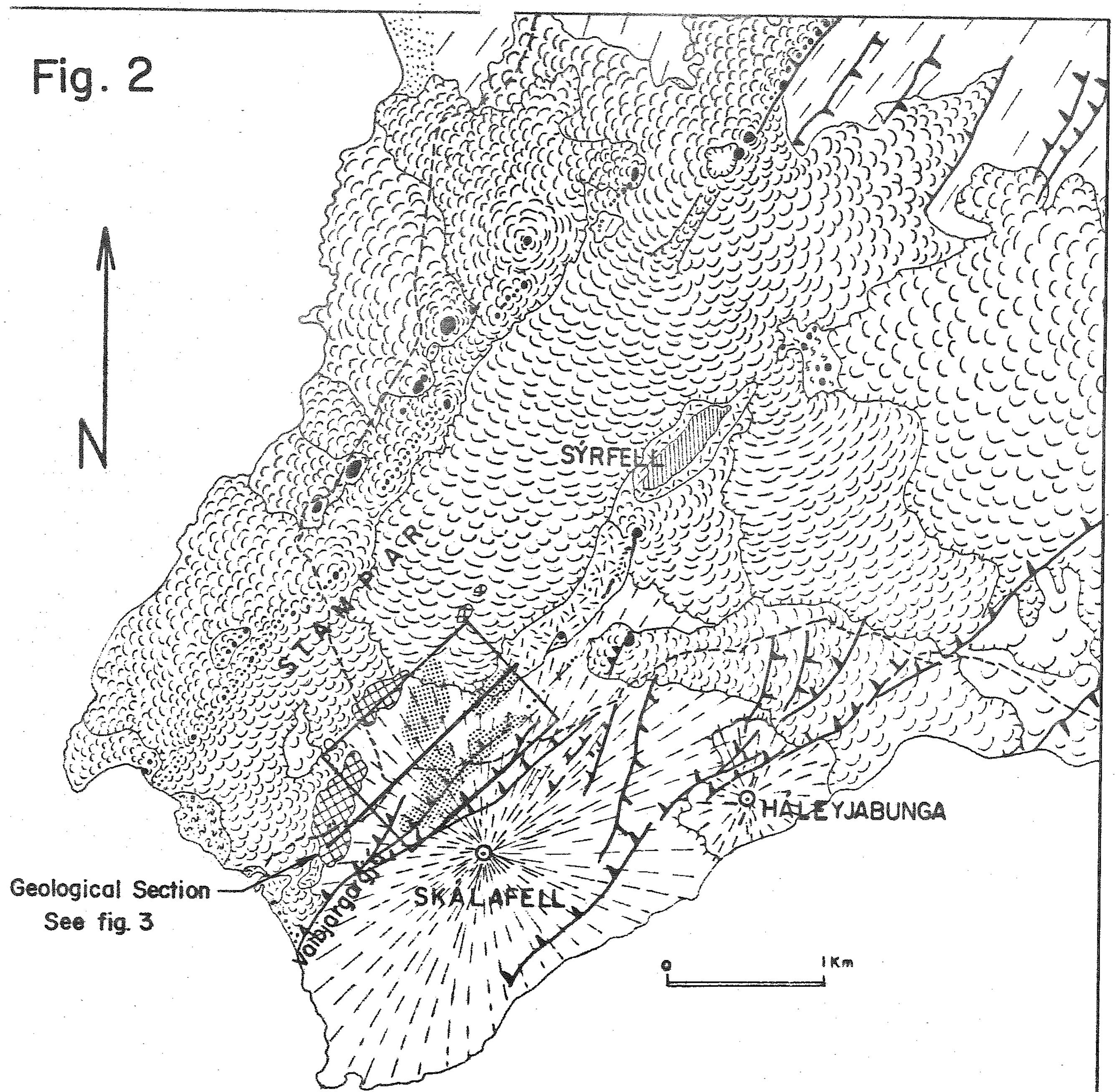
GEOLOGICAL MAP OF REYKJANES.

By Jón Jónsson.

Explanations.

- Pillow lava.
- Palagonite breccia and tuff.
- Post glacial lava from shield volcano.
- " " " " eruptive fissure.
- Crater of shield volcano.
- Eruptive fissure.
- Pyroclastic ejecta.
- Fault
- Tectonic fissure without vertical displacement.
- Basalt cover on top of palagonitic rocks (pillow lava and breccia.)
- Thermal area.

Fig. 2



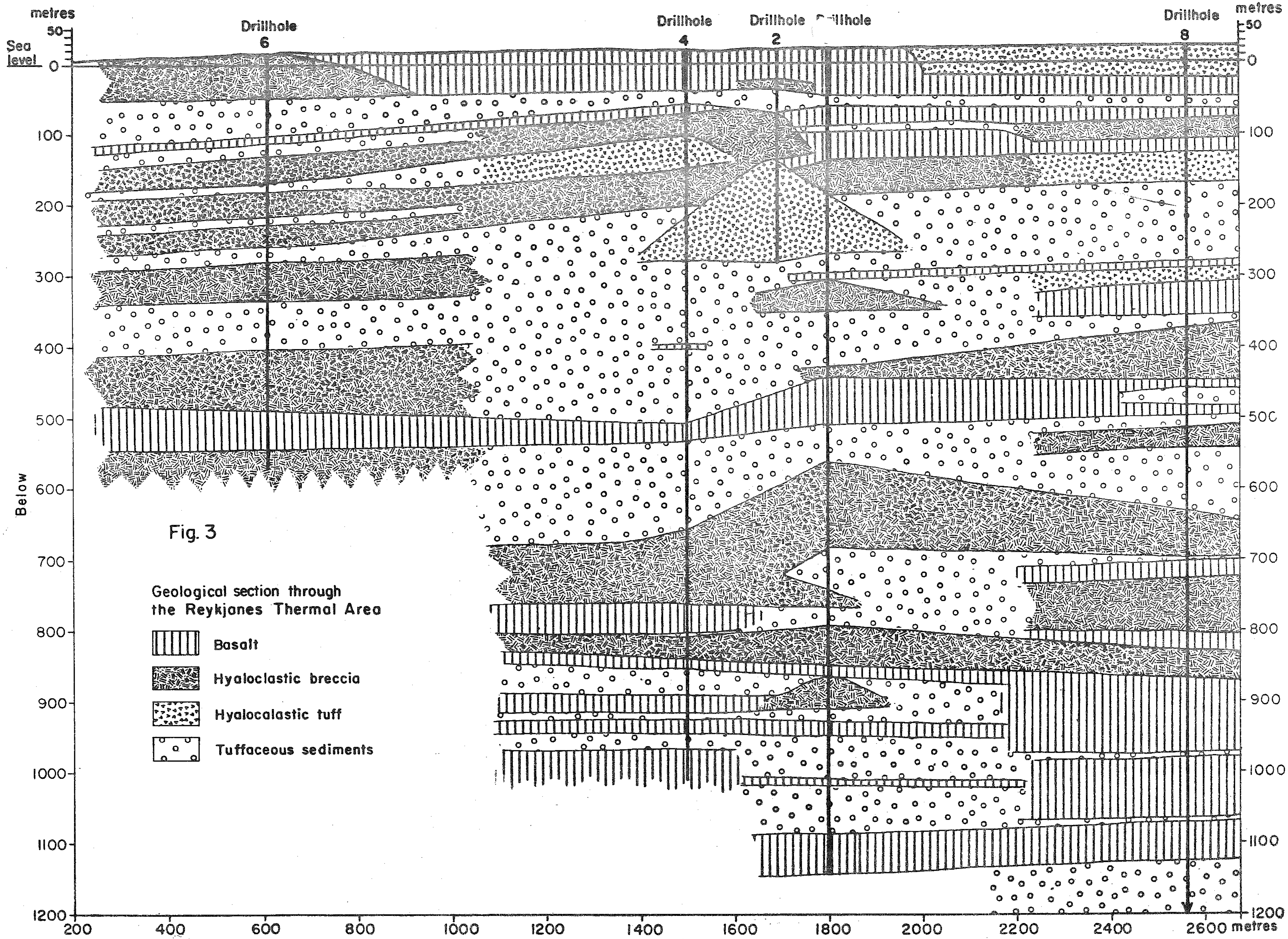


Fig. 3

Geological section through the Reykjanes Thermal Area

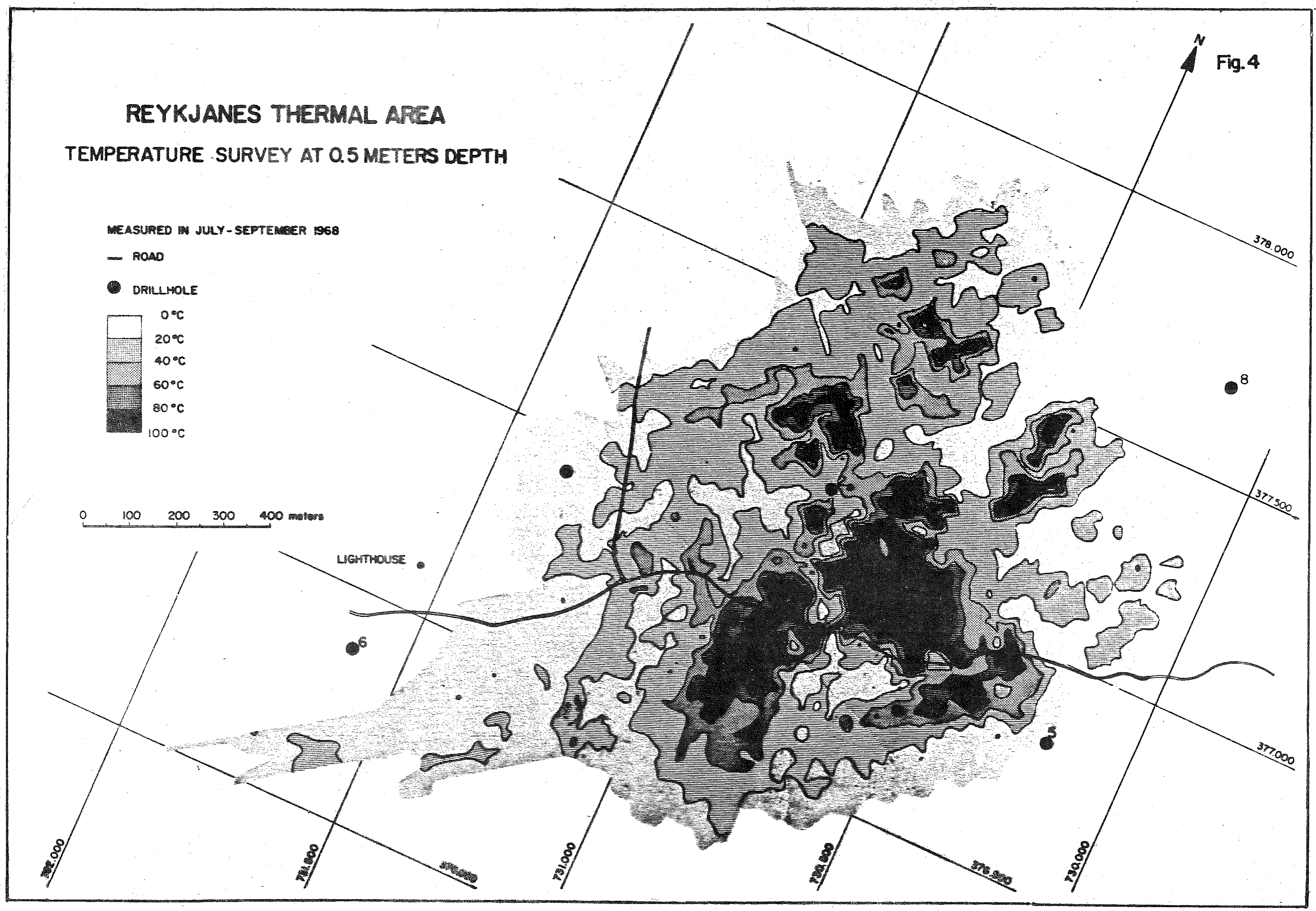
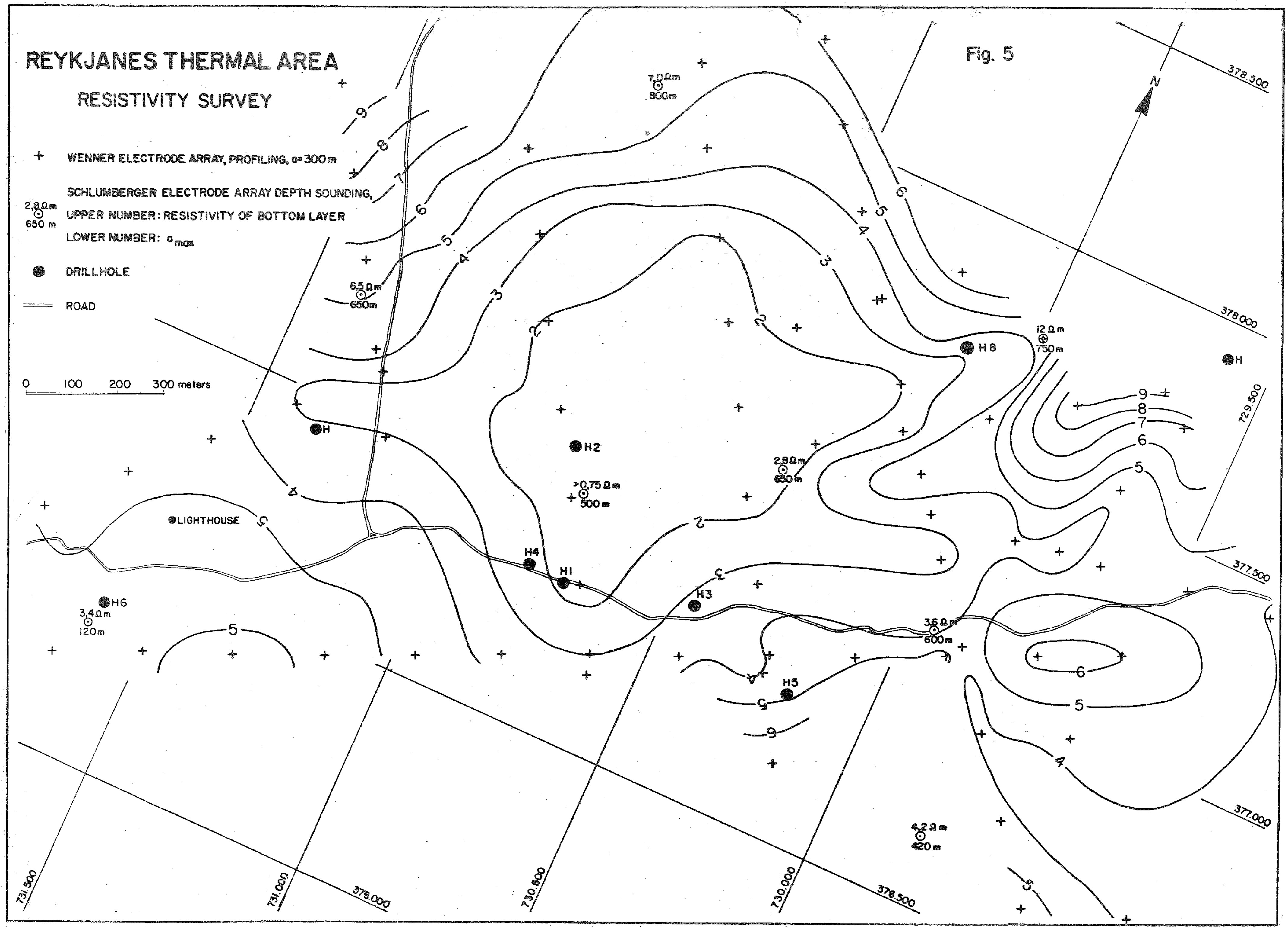


Fig. 4
REYKJANES THERMAL AREA
TEMPERATURE SURVEY AT 0.5 METERS DEPTH
MEASURED IN JULY-SEPTEMBER 1968
ROAD
DRILLHOLE
0 °C
20 °C
40 °C
60 °C
80 °C
100 °C
0
100
200
300
400 meters
LIGHTHOUSE
N
8
6
378.000
377.500
377.000
731.000
730.000


REYKJANES THERMAL AREA
RESISTIVITY SURVEY
Fig. 5
WENNER ELECTRODE ARRAY, PROFILING, a= 300 m
SCHLUMBERGER ELECTRODE ARRAY DEPTH SOUNDING,
UPPER NUMBER: RESISTIVITY OF BOTTOM LAYER
LOWER NUMBER: a max
2,8 Ω m
650 m
DRILLHOLE
ROAD
0 100 200 300 meters
N
H
H2
H4
H1
H3
H5
H6
H8
LIGHTHOUSE
7,0 Ω m
800 m
6,5 Ω m
650 m
12 Ω m
750 m
2,8 Ω m
650 m
>0,75 Ω m
500 m
3,4 Ω m
120 m
3,6 Ω m
600 m
4,2 Ω m
420 m
378.500
378.000
377.500
377.000
376.500
376.000
729.500
730.000
730.500
731.000
731.500

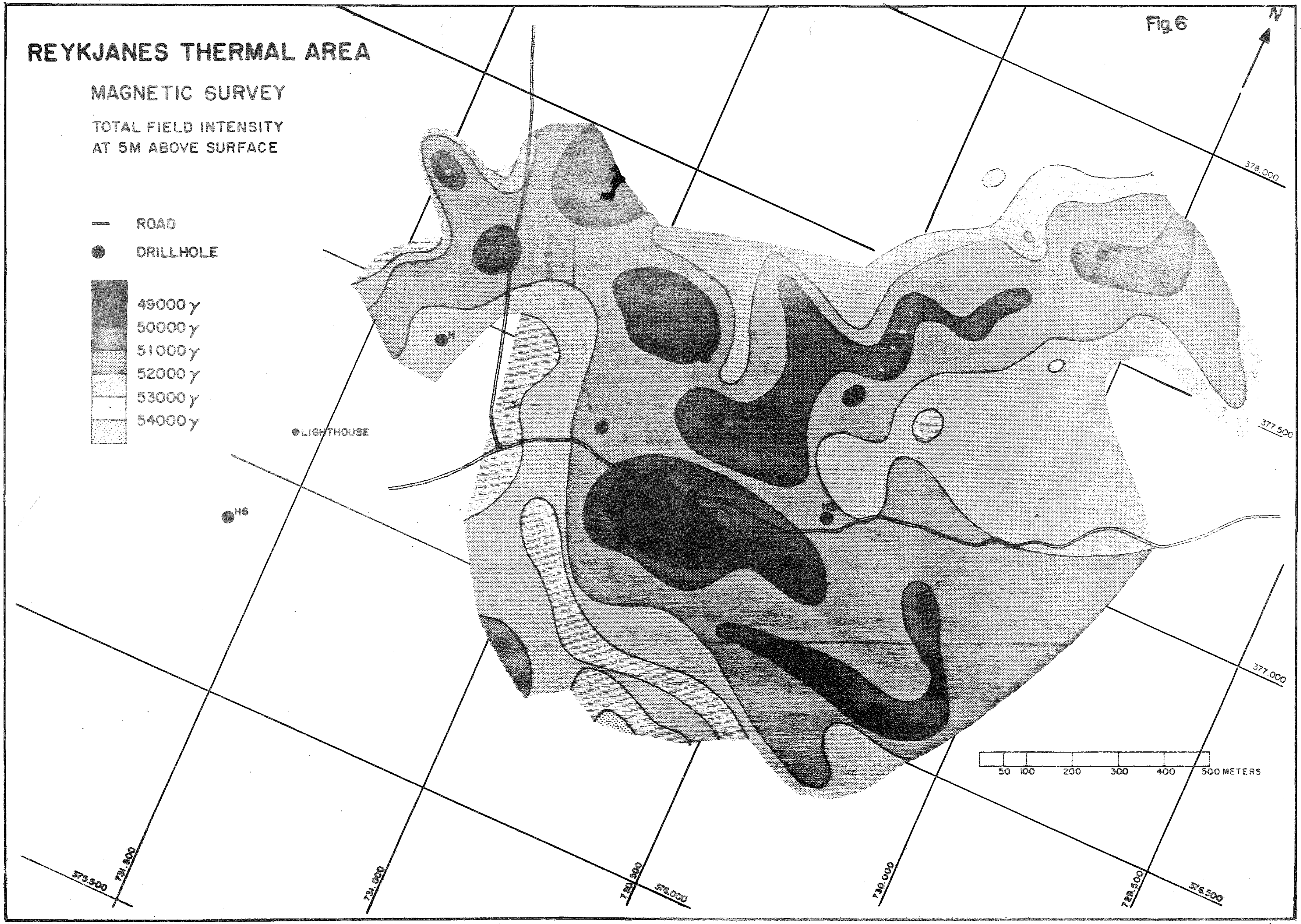
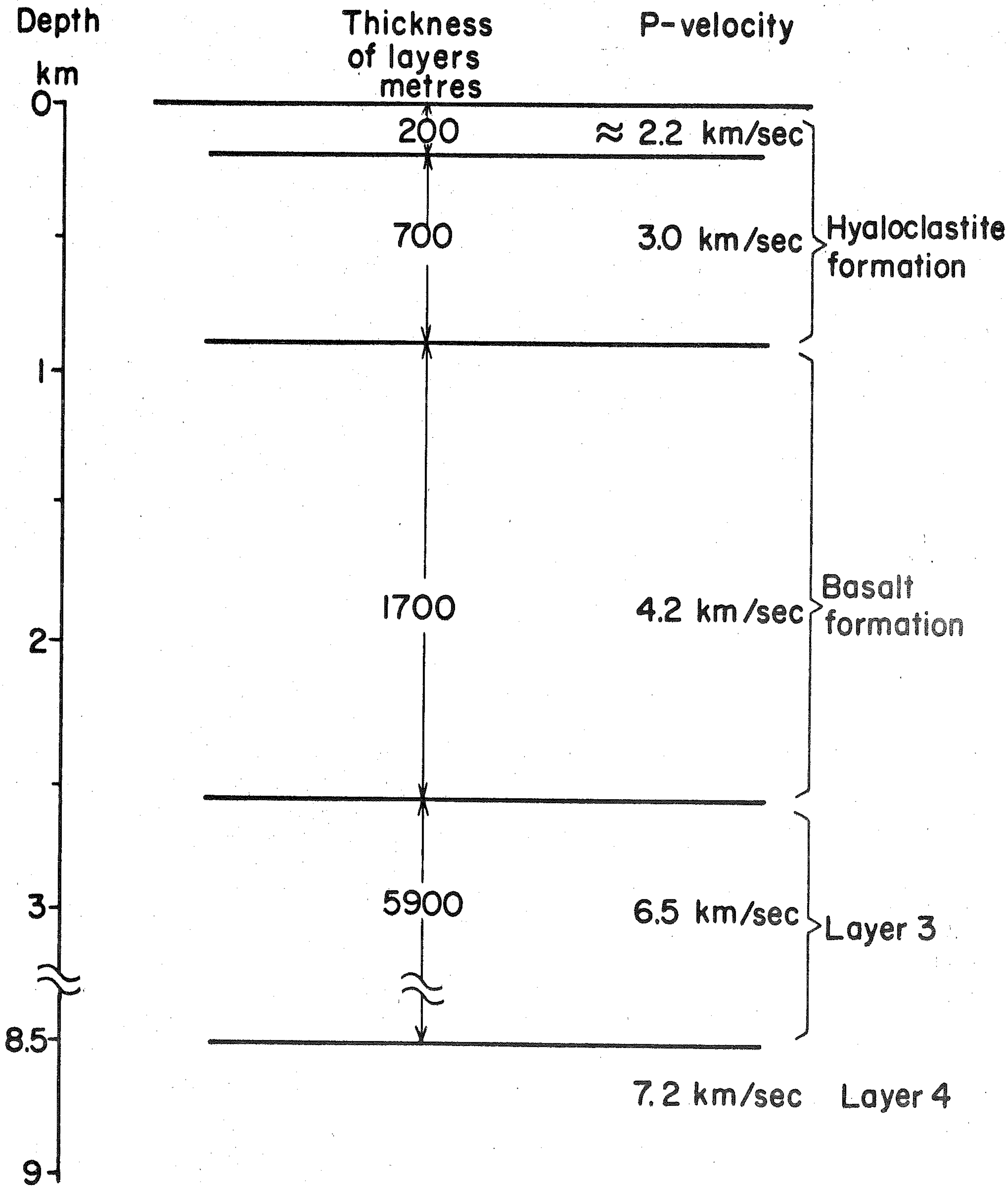


Fig. 6
N
REYKJANES THERMAL AREA
MAGNETIC SURVEY
TOTAL FIELD INTENSITY
AT 5M ABOVE SURFACE
ROAD
DRILLHOLE
49000 γ
50000 γ
51000 γ
52000 γ
53000 γ
54000 γ
LIGHTHOUSE
H6
378.000
377.500
377.000
376.500
376.000
375.500
731.500
731.000
730.500
730.000
729.500
50 100 200 300 400 500 METERS

Seismic structure section of the Reykjanes Thermal Area.

Fig 7.



J-Reykjan. Tnr. 15 J-Jarðsv. Tnr 25 Fnr. 8637

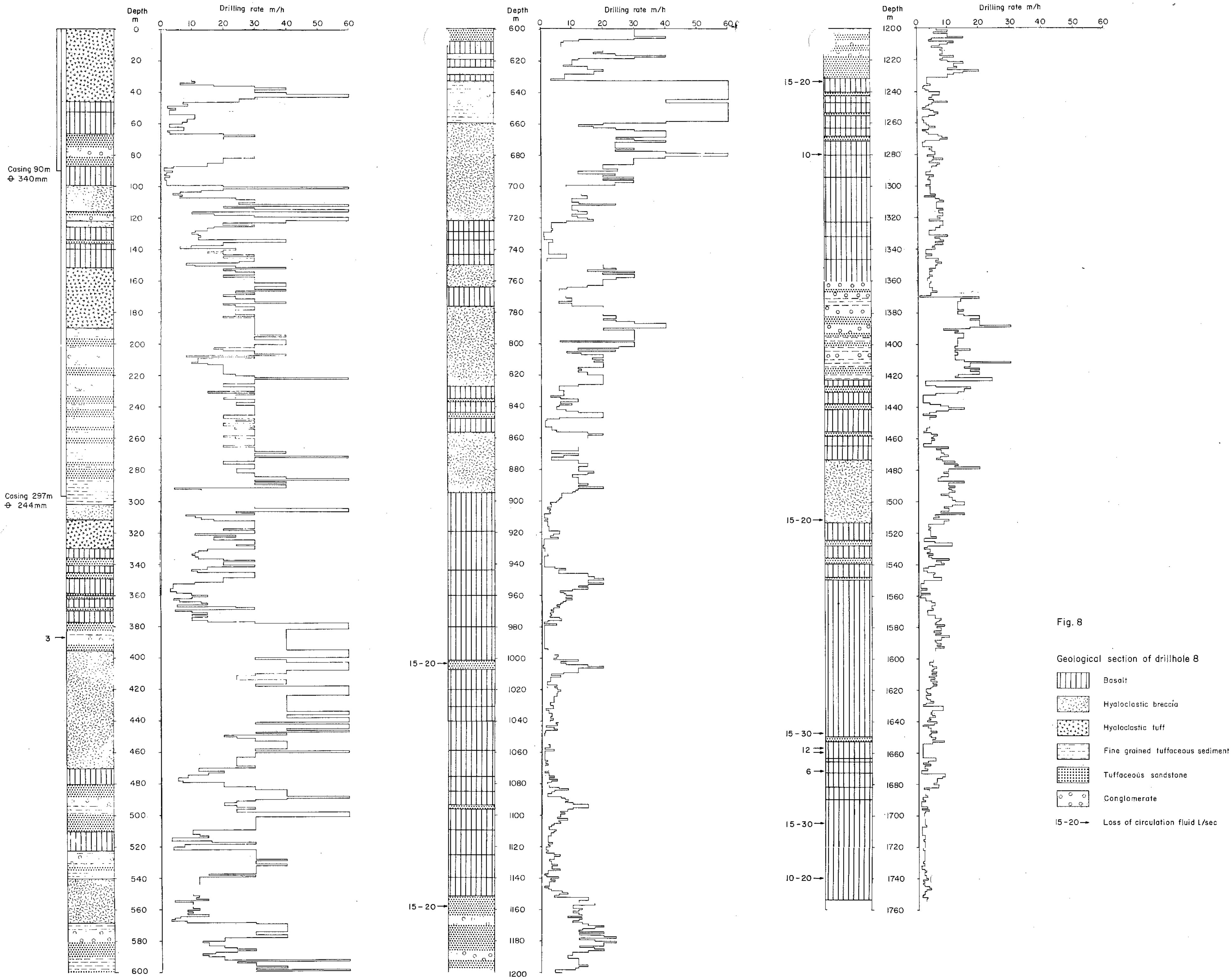


Fig. 8

Geological section of drillhole 8