Report on Geothermal Observations on the Island of Surtsey

By
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On 5th, 6th, 7th and 8th of August 1970, observations and measurements of geothermal heat were made under the auspices of the Institute of Science of the University of Iceland on the island of Surtsey.

Measurements were made in those parts of the island that have been created from tuff, and the temperature was also measured in the upflow of gases in the lava and near the craters.

Measurements in the tuff were effected by the plunging of a metal bar down to the depth that was to be measured, and a mercury thermometer was inserted in the hole to the bottom. Thermometer readings were then taken after three minutes had elapsed.

This method enabled temperatures to be measured down to a depth of 140 cm in those areas where the tuff had not substantially hardened. In other areas the tuff had hardened so much that it was not possible to penetrate more than a few tens of centimetres down, and in a few places it was not even possible to reach a depth of 10 cm, for there the tuff was so compact that it could hardly be cut up with a shovel.

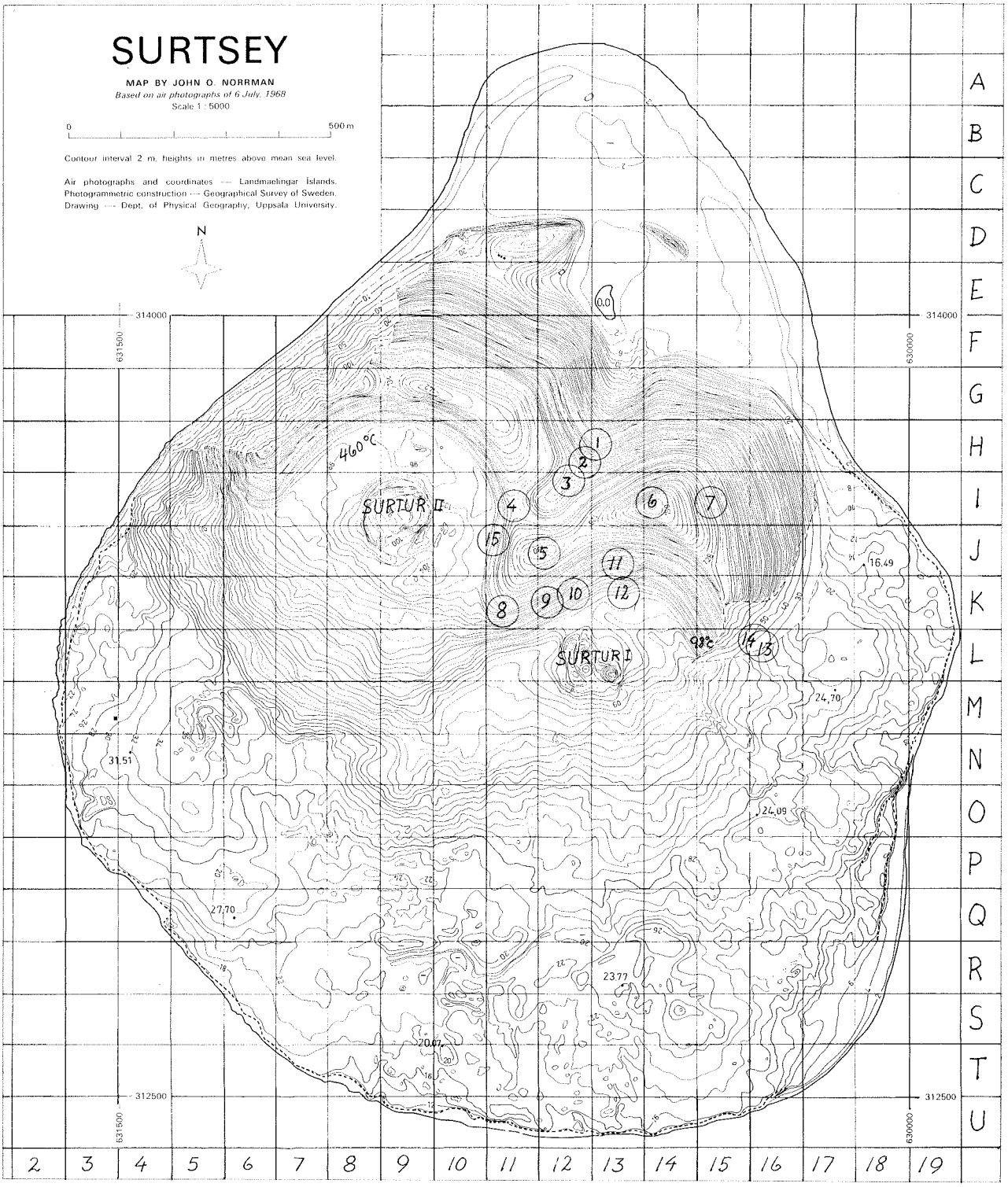
Measurements in the lava were made by inserting a thermometer into an upflow vent, from which hot air or steam was rising, and then making readings a little later. In these measurements mercury thermometers were used for temperatures below 250°C, and "Rototherm"-type thermometers for higher temperatures. In a few places both types of thermometers were used, between which there was quite good correspondence, although the "Rototherm" thermometer seemed to show a rather lower temperature, or approx. 10–20°C.

GEOTHERMAL HEAT IN TUFF

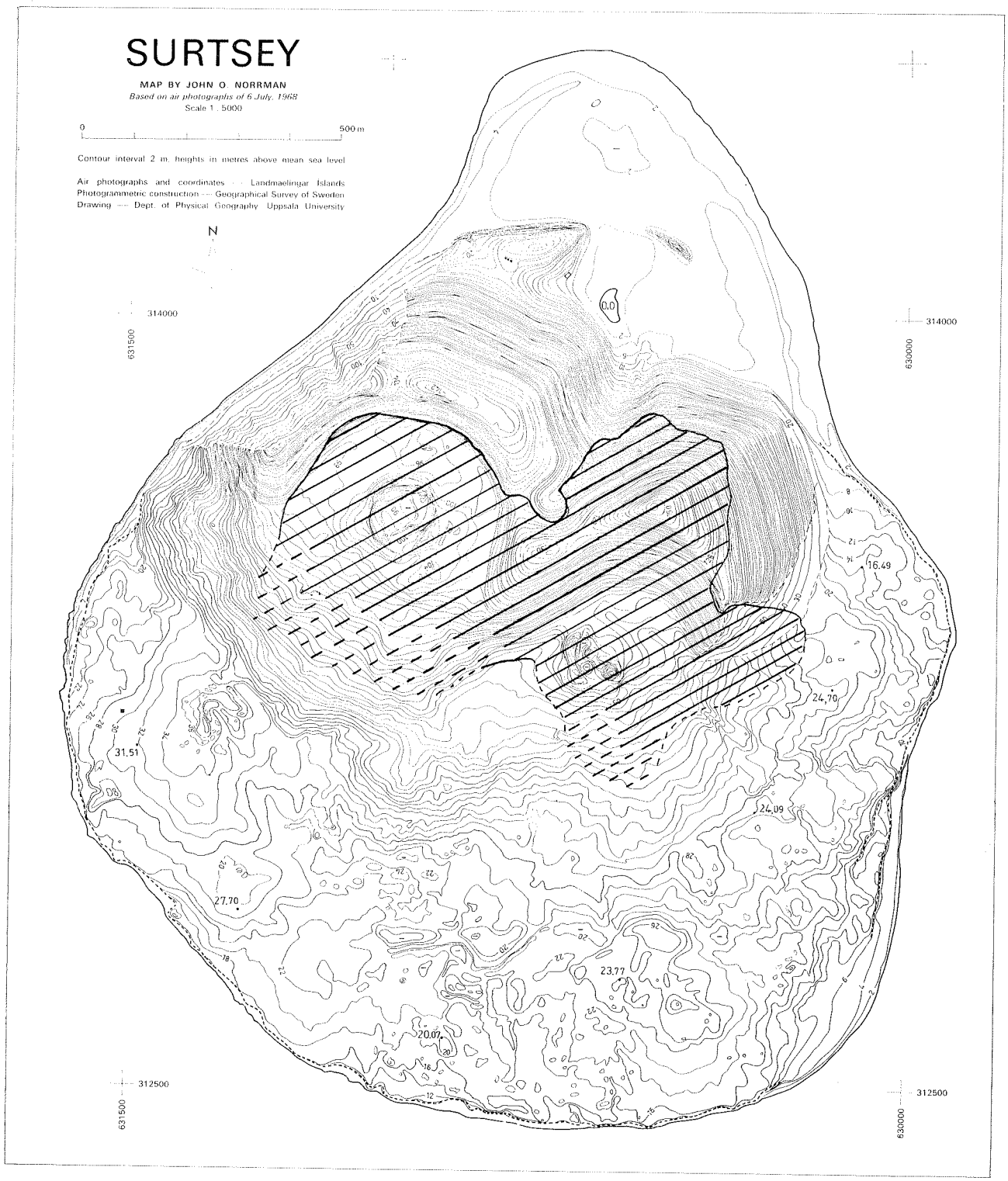
Geothermal heat in tuff is found in an extensive area in the mountain north of Surtur I, which will be referred to here as "Strompfjall". The heat is in the whole interior of the crater bowl of Surtur I and extends over the rim down the mountain slope below the "Strompur" crater and a little way down from the summit in a northeasterly and easterly direction, but in quite a large area in the lower part of the mountain and at its base no increase in heat could be measured at a depth of 60–100 cm.

Above the measurement points 13 and 14 there is an almost perpendicular tuff wall, from which vapour could be seen ascending over an area of about 100 sq m close to the top of the mountain, but on the top itself above, a little to the north, no steam was visible. In the easternmost part of the crater bowl of Surtur I the heat is probably greatest, for 98°C was measured there at a depth of less than 10 cm a few tens of metres up the slope. A little higher up in that area some 100°C hot steam issues from a small N–S running fissure. A little to the north of that point is an area where the tuff has hardened so much that samples can only be taken with a hammer and chisel and it mostly resembles concrete.

As already mentioned, the whole of the crater bowl of Surtur I is more or less hot. This thermal area extends uninterruptedly along the mountain ridge between Surtur I and Surtur II, the



Measuring points



The thermal area on Surtsey

vapours issuing from the small craters on the slope being 98—100°C hot. In the hollow to the east of Surtur II there is considerable heat, which extends up to the gap east of the crater, but just to the north of there no heat was found, nor was there any in the hollow above the Svartagil ravine. To the north, in the crater hollow of Surtur II, there is little heat in the tuff, in some places none at all, and nowhere does it extend more than a few tens of metres from the edge of the lava. For instance, at a distance of 20 m from the edge of the lava only 12°C were measured at a depth of 100 cm, whereas at the edge of the lava steam with a temperature of 105°C came up. This was to the N—E of Surtur II. In other places there was sometimes a little heat at a distance of up to 35 m from the edge of the lava.

Despite numerous observations it was not possible to detect heat in the mountains "Bunka" or "Bondi" (Bauer's Peak), and although the watchers on Surtsey thought they had seen vapours rising at certain places, no heat was found there on closer investigation. In those areas devoid of geothermal heat, the temperature is very even at differing depths, or 10—12°C.

In the thermal areas the increase in heat with increasing depth is on the whole fairly even, but its rate varies in the different observation places. The temperature appears to cease to rise when the boiling-point of water is reached, which may be at a depth of from less than 10 cm up to a few metres, if the increase in heat is proportionately as great in the colder areas, such as where 100°C is reached at a depth of less than one metre. Nowhere in the tuff was a temperature higher than 100°C measured with any certainty, but where the lava and the tuff meet water vapour rose up at one point with a temperature of 105°C.

A distinct difference is emerging in the appearance of those areas where the tuff is hot and in those where there is no underlying heat. In cold areas the tuff is still loose and weathers very rapidly. It can be seen that mud streams have run down the slopes, leaving behind screes in the upper part and filling themselves up in the lower part near the foot of the mountain. Near the summit large boulders are strewn about in many places, either lava bombs or sometimes fragments of sediment thrown up with the tuff, from around which loose material has since been weathered away and they have remained on their own. In such places it is sometimes possible to find plagioclase crystals several cm in diameter. If the tuff here is dug into with a shovel, it is found to be loose and fresh. Where there has been any significant geothermal heat, the tuff has been much less weathered. The contours of the mountain are smoother, and the mud streams have not managed to make any deep impression. Loose volcanic material has been blown away less, so that the surface boulders are not so conspicuous. If diggings with a shovel are attempted there, the tuff is found to be firm and in some places even so hard that it cannot be dug into.

Of particular interest are the measurements at points 1, 2 and 3, taken on 6th August. Then it was necessary to find a depth of about 100 cm in order to reach a temperature of 100°C. On the next day, 7th August, measurements were again made at the same points, when the heat had risen so much that a depth of only 10 cm was necessary to reach the same temperature, and the surface of the tuff was very hot. This increase in temperature occurred at measuring points 1, 2 and probably also 3, and it was maintained on all the days during which measurements were continued. On 15th August measurements were again made there, and the temperature was the same as on the days 7th to 9th August.

In many places in the tuff where there is underlying heat, fissures running in various directions are visible. They appear, however, to lie mostly in a circle around Surtur I, though there are many exceptions to this and they are difficult to trace for more than short distances. Hot steam rises from some of these fissures, though by no means everywhere, and heat does not seem to be limited to such places. It is strange what sharp boundaries these thermal areas have, there being only a few metres between places where there is considerable heat and places where no heat could be measured. Compared with observations made in the summers of 1968 and 1969, the thermal areas have spread out in most directions, e.g. no heat could be detected in the Svartagil ravine at measuring points 1, 2 and 3 in the summer of 1969.

A sort of carpet of steam is frequently visible above the thermal areas, thus showing roughly where their boundaries lie.

The temperature of the tuff appears to be the deciding factor as to whether palagonitization occurs. Where there has been heat for a number of years, various intermediary stages can be found in the palagonitization, and in places where this change is most advanced the tuff may be considered to have become firm rock. Where no geothermal heat is to be found, not the slightest change in that direction can be detected.

THE CRATER BOWL OF SURTUR I

In the easternmost part of the crater bowl of Surtur I there is much heat. About 10 metres below the top of the lava a temperature of 92°C was measured approx. 5 cm below the surface. It was not possible to penetrate deeper. In the upper part of the slope a temperature of 100°C was measured in steam emission from a N—S lying fissure. There were a few other fissures there having a similar direction. A little to the west on the slope there is a large area of hardened tuff. At the bottom of the crater bowl are many vents, from which steam rises. Measurements showed that the temperature of the steam is between 60 and 80°C, usually 70—75°C. Farther out in the lava there is also some emission of steam, mainly along the fissures. There the heat is in some places considerably higher, maximum 220°C, and the emission seems to contain less vapour, or even very little. Measurements of the steam emission from small craters in the inside of the crater bowl gave readings of 98—100°C generally.

THE CRATER BOWL OF SURTUR II

There is much heat in the lava all around Surtur II. Steam rises in many places at the edges of the lava, where it adjoins tuff. Steam also rises at some distance inside the lava areas. The temperature in the steam vents is in most places 70—90°C, although a measurement of 105°C was found in one place. Furthermore, hotter currents of drier air rise up from the lava, but they are less conspicuous. There the temperature is usually above 100°C, and at one place northwest of Surtur II a temperature of about and above 400°C, maximum 460°C (390-410-430-460), was measured at a few points. This place is on a fissure parallel to the edge of the lava, about 20—30 m inside the lava beneath "Bóndi" (Bauer's Peak). Quite a strong air current ascends from the fissure, and it is accompanied by slight hissing sounds. No vapour is visible in this air, and there is not much precipitation around the fissure, mostly a stony crust, reddish-brown in colour.

It seems that the lava-shield of Surtur II has subsided somewhat since the end of the eruption there, for parallel fissures go through the lava a little distance inside the edge of the lava; the lava-shield has probably subsided in the middle and the fissures formed all around it, though they cannot everywhere be traced and it is difficult to estimate the total extent of the subsidence. In some of these fissures there is heat, in others not, and the fissure in which the temperature is highest may be considered a part of this fissure system, though irregularities in formation cannot be detected there.

South, also southeast and east, of Surtur II there is heat in a quite extensive area, temperatures of about and above 200°C, maximum 220°C, being measured in a few places. At a place that has been named "The Grill" there is a very big upflow of heat, and the quantity of air is so great that it makes a whistling sound, but a temperature of only 150°C was measured there.

Southwest of Surtur II there is also heat in the lava in a large area, and this thermal area extends quite a long way down into the lava. One measurement taken there showed a temperature of more than 250°C, but there was insufficient time to make more detailed observations.

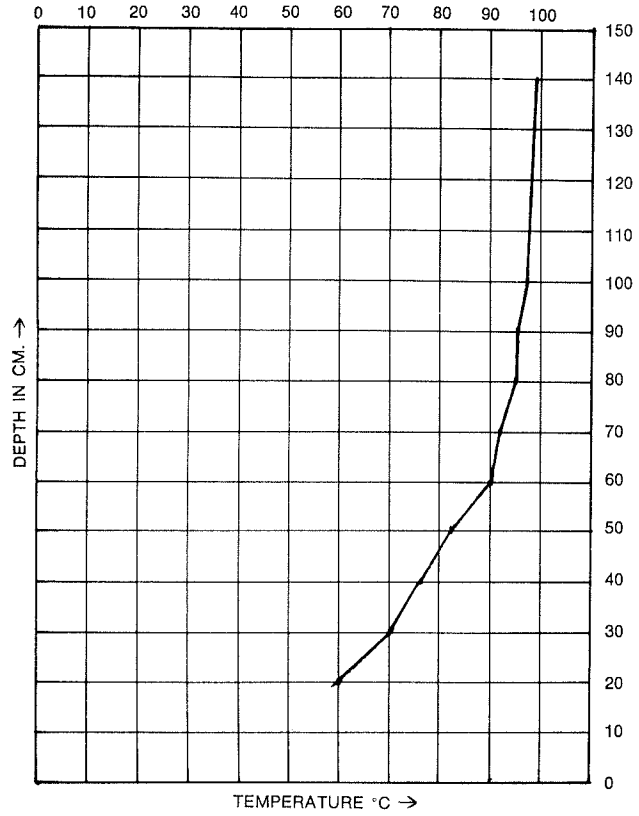
Where there is much heat in the lava, sand and tephra that has been blown into the area has changed colour and become red. This change seems to occur at a temperature of about 100°C and just below, when a layer of red sand often forms under a dark surface layer, whereas lower down, where the heat is greater, the sand is again dark. Moisture also seem to be necessary for the production of this change.

In the Strompur crater a temperature of 98°C was measured in the steam emission, and at a distance of 30 m from the crater the temperature in the tuff was 90°C at a depth of 30 cm, but it was not possible to penetrate any deeper at that place.

BRIEF SUMMARY OF CONCLUSIONS

There is much and widespread geothermal heat active on Surtsey, both in the lava and in the tuff. In the tuff the temperature does not exceed 100°C at measurable depths, but in the lava it is in same places much higher. The thermal areas in the tuff appear to be spreading, but it is difficult to say whether the same applies to the heat in the lava, as measurements from immediately preceding years are not available. The areas around both the main craters are still hot, and seem to have changed little in the past two years. Where the temperature is greatest in the lava northwest of Surtur II, it is so high that it can only be due to glowing material(s). The heat in the tuff seems to be the decisive factor as to whether it is transformed into firm rock or not.

MEASURING POINT 1
6th August 1970



MEASURING POINT 4
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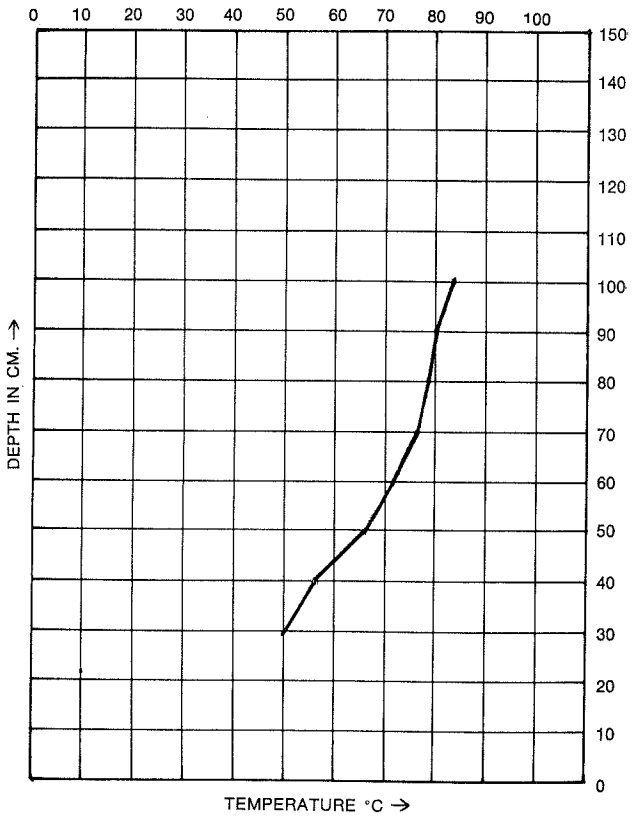

MEASURING POINT 2
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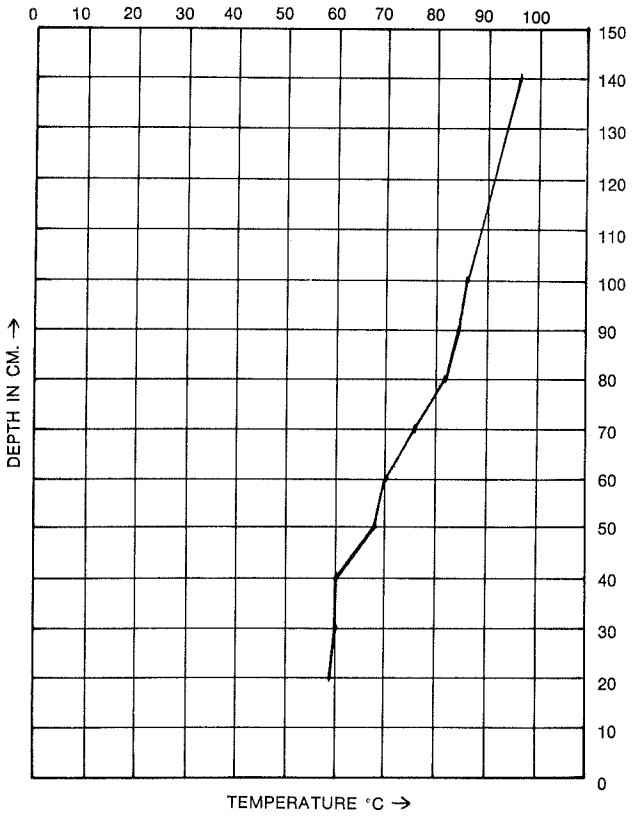
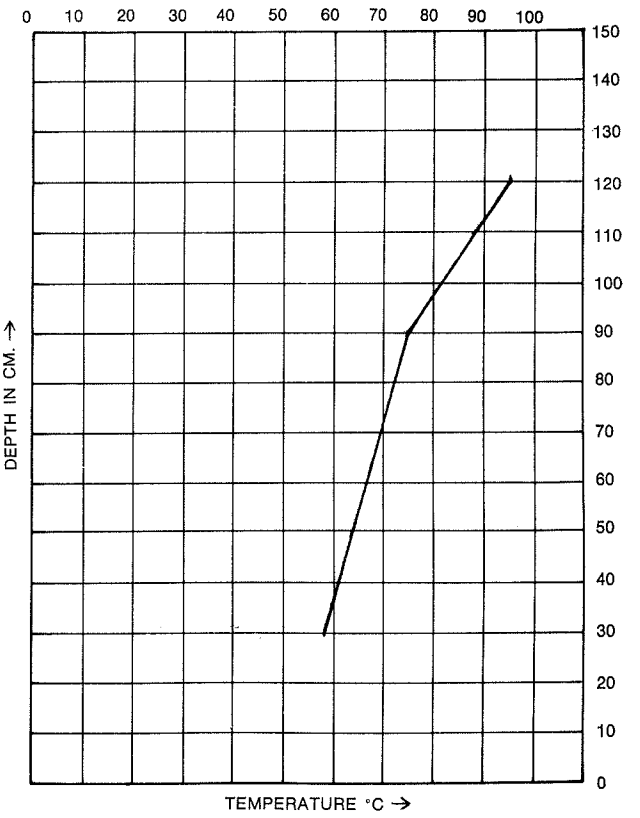
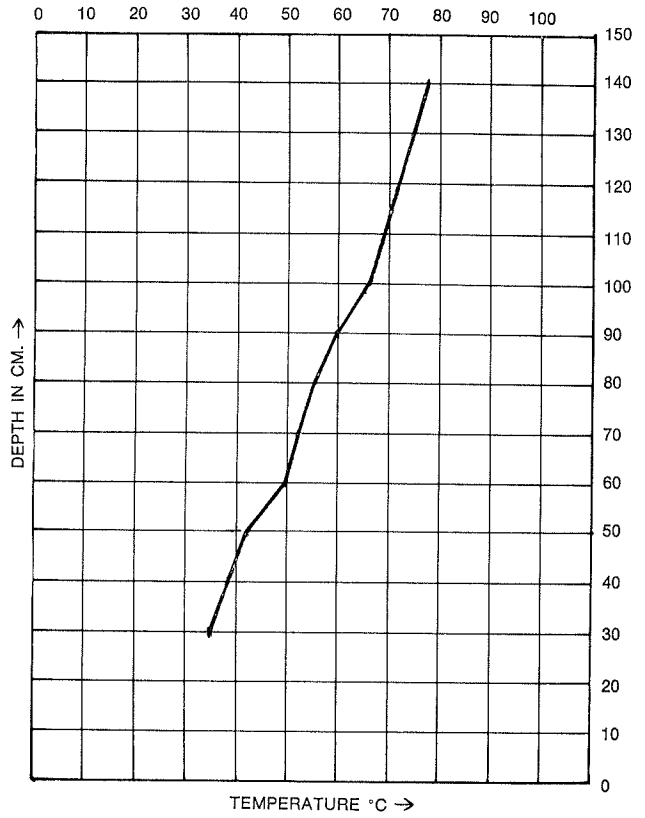


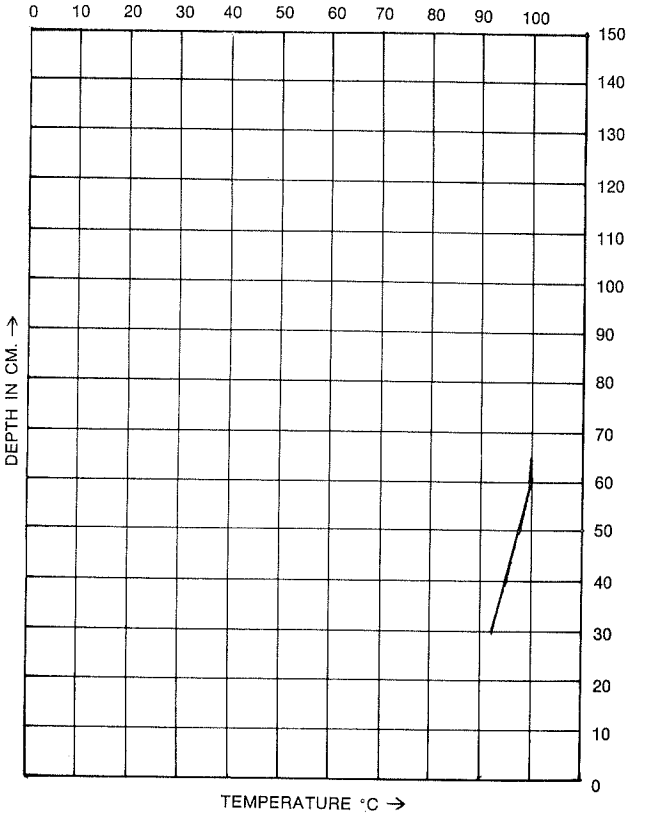
MEASURING POINT 7
7th August 1970



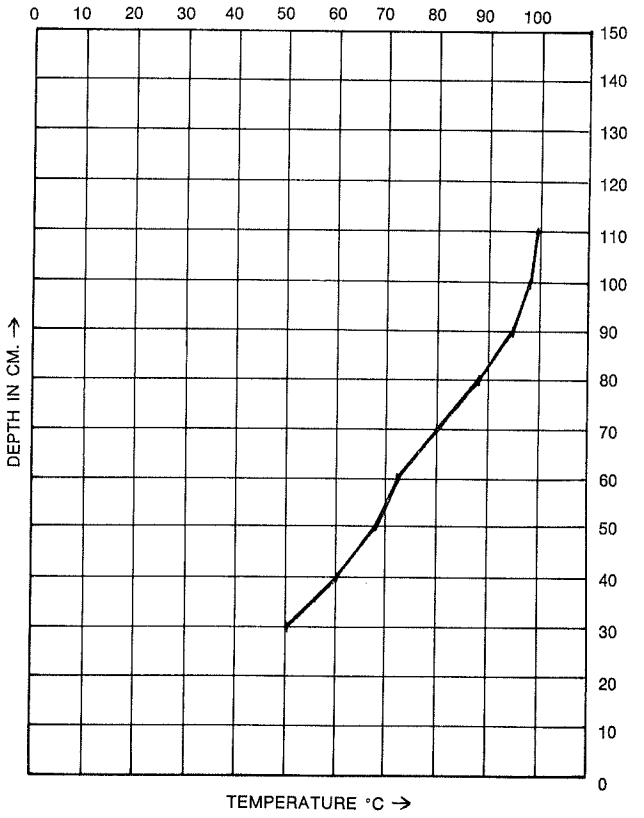
MEASURING POINT 11
7th August 1970



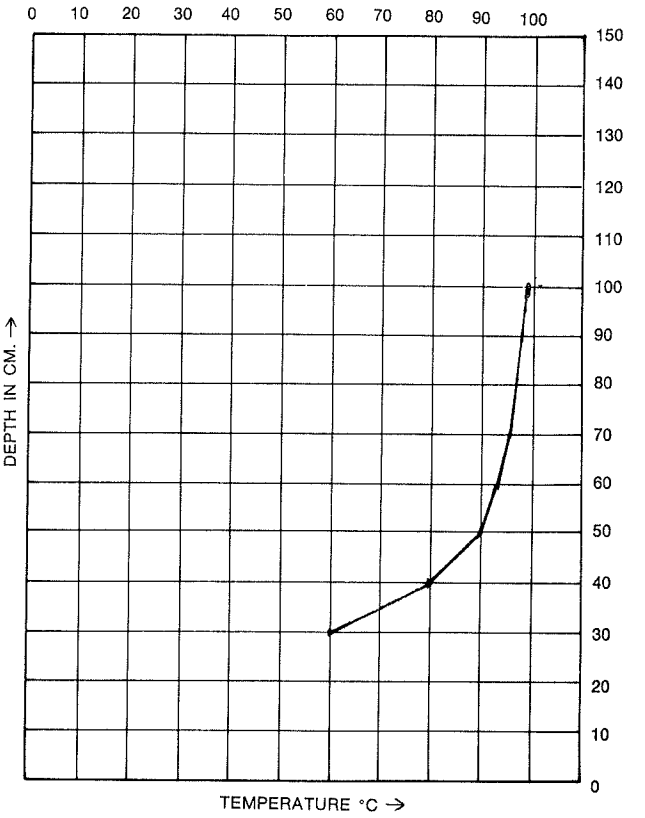
MEASURING POINT 14
8th August 1970



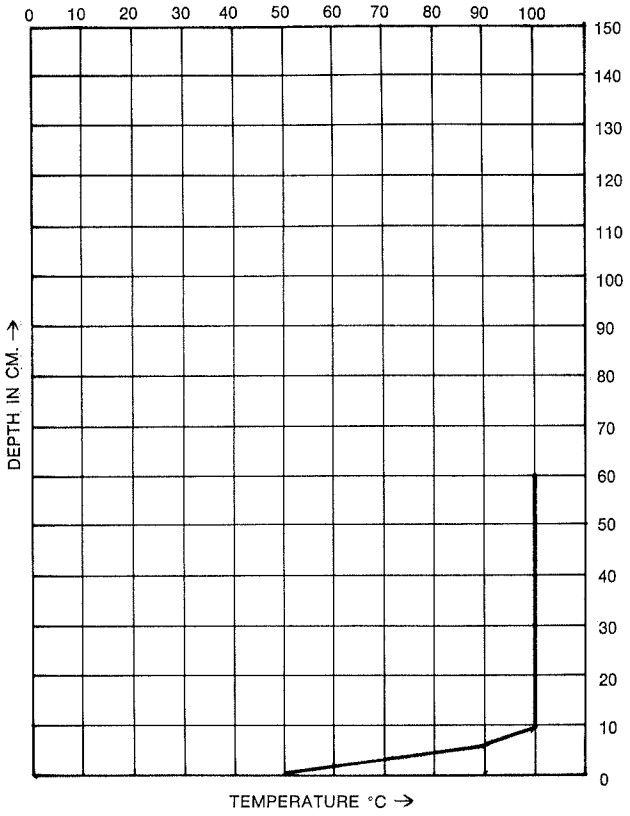
MEASURING POINT 13
8th August 1970



MEASURING POINT 15
8th August 1970



MEASURING POINT 16
7th August 1970



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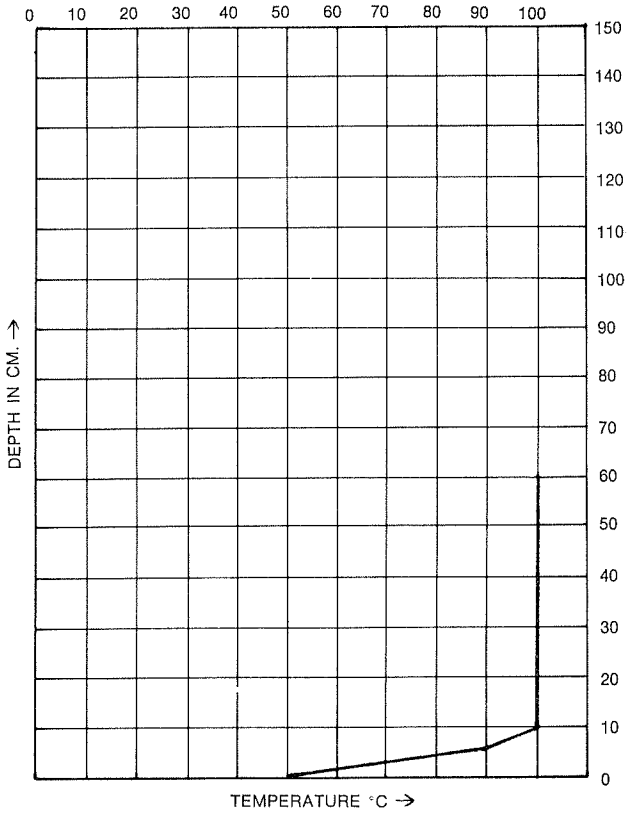
7th August 1970



Measuring Points:

Measurement 1 In the Svartagil ravine, square H-13, graph.

Measurement 2 In the Svartagil ravine, square H-12, graph.

Measurement 3 In the Svartagil ravine, square I-12, temperature at a depth of 30 cm: 30°C.

Measurement 4 In the gap above Svartagil, square I-11, graph.

Measurement 5 On the peak south of the beginning of Svartagil where squares J-11 and J-12 overlap. Temperature at a depth of 25 cm was found to be 57°C.

Measurement 6 On the high peak of Strompur mountain, square I-14. The temperature at a depth of 40 cm was 86°C, at 50 cm 90°C.

Measurement 7 East of measuring point 6, square I-15, graph.

Measurement 8 SSE of measuring point 5, square K-11. Temperature at a depth of 47 cm: 85°C.

Measurement 9 Just west of the small crater on K-12. Temperature at a depth of 40 cm: 65°C.

Measurement 10 Just east of the same small crater on K-12. Temperature at a depth of 40 cm: 65°C.

Measurement 11 Taken at the Kirkjugígur crater, square J-13, graph.

Measurement 12 On the level ground below measuring point 11, square K-13. Temperature at a depth of 40 cm: 20°C.

Measurement 13 At the foot of the slope below the tuff cliff where L-15 and L-16 overlap, graph.

Measurement 14 At same place as measurement 13, though 9 m higher on the slope, graph.

Measurement 15 West of measuring point 5 at the foot of the slope, square J-11, graph.

Measurement 16 At same place as measurement 1, graph.

Measurement 17 At same place as measurement 2, graph.

In addition to these measurements, very many observations of temperature in the tuff were taken in order to determine the boundaries of the thermal areas. Furthermore, the temperature of the steam emissions was measured in many places.