THE CHEMICAL AND ISOTOPIC CHANGES IN THE LOW TEMPERATURE AREAS OF LAUGARNES, ELLIĐAÁR AND REYKIR.

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ABSTRACT

The chemical and isotopic composition of geothermal water in three low-temperature areas in Iceland is described. These areas, Laugarnes, Elliðaár, and Reykir, are of particular interest because they supply the city of Reykjavík with hot water.

Compositional changes are considered and special attention given to their causes as well as to the possible distribution of the different groundwater systems. Improved estimates of the reaction times of the different groundwater systems are obtained by the use of tritium data.

A flow map of the different hot and cold groundwater systems, based on the available data, is presented.

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1 INTRODUCTION

1.1 Scope of work

The author of this report participated in the UNU Geothermal Training Programme in Reykjavik for 3 months. The programme consisted of a 5 week introductory lecture course and a project. The field of specialisation of the author is chemistry and isotopes, and a project of this nature was chosen.

The chemical and isotopic changes in the water from three geothermal low-temperature areas, which supply the city of Reykjavík with hot water, are studied. For this purpose 10 wells, which show typical behaviour in chemistry for the different areas, have been selected. Some well data are given in Table 1.1.

The changes in chemistry have been monitored closely since the nineteen-fifties. Oxygen-18 samples were collected in the years 1980 to 1982. It is shown that cold water mixes with the hot geothermal water. An attempt is made to determine where this water comes from and, in some cases, to predict future changes in the water chemistry. The chemistry is used to determine the changes in water quality. The recharge areas of the cold water and the approximate groundwater flow times are determined by isotopes.

1.2 Location of the geothermal areas

The location of the geothermal areas and the selected wells is shown in Fig. 1.1.

The Laugarnes and Elliðaár areas are located within the city-boundaries of Reykjavík. The Laugarnes area is located in the northern part of the city and the Elliðaár area in the eastern part. The elevations of the areas are 15 and 40 m above sea level, respectively.

The Reykir area is situated approximately 15 km NE of Reykjavík. It is divided into two sub-areas, South-Reykir and North-Reykir, each at an elevation of 40 to 80 m above mean sea level. The sub-areas are 2-3 km apart and are separated by hills that rise to an elevation of 220-250 m above sea level.

2 GEOLOGY AND HYDROGEOLOGY

2.1 Geology of Iceland

Iceland lies on the Mid-Atlantic Ridge, which represents the constructive boundary of the European and the American plates.

The main geological formations of Iceland are shown in Fig. 2.1. The oldest formation is Tertiary (3-16 m.y.) and consists of a lava succession generally dipping gently towards the volcanic zones. The second formation is of Quaternary, Plio-Pleistocene age (0.7-3.1 m.y.). The sucession consists of alternating sequences of lavas and hyaloclastites. The former were formed during the interglacial periods, whereas the hyaloclastites were formed as a result of subglacial eruptions during the ice ages. The third and youngest formation is contained within the Neovolcanic Zone and is composed of Upper-Pleistocene and Postglacial formations (< 0.7 m.y.). This zone constitutes the zone of rifting. The rifting within the Neovolcanic zone is mainly accompanied by distinct fissure swarms. Generally a central volcano is formed at the central part of each fissure swarm. These volcanoes are the center of magmatic activity within the fissure swarms and it has been shown from studies in the deeply eroded regions that a high percentage of intrusions occur in the cores of these volcanoes (Saemundsson, 1979).

2.2 Hydrogeology of the Laugarnes and Elliðaár area

Reykjavík lies 8-10 km north of the volcanically active Reykjanes rift zone. It is located near the southern end of the Tertiary plateau basalt series of western Iceland, which are bounded by Quarternary volcanics, on the southern outskirt of the Kjalarnes central volcano (Fridleifsson, 1973).

The Reykjavík area is covered by horizontal olivine basalts of late interglacial age, down to a depth of 30 to 50 m (Thorsteinsson and Elíasson, 1970). Underneath this lava flow there are found mostly marine sediments of up to 60 m in thickness, which are layered on a major discordance. Beneath, alternating lavas and hyaloclastites are found. This sequence is of Plio-Pleistocene age. Thick hyaloclastite formations are common in the upper 500 to 1000 m, but basaltic lavas are predominant in the lower parts of the wells, which are commonly up to 2 km deep.

In the Elliðaár area dolerite intrusions are found in the basaltic layer. The main occurrence of the dolerite intrusions is at a depth of more than 1000 m.

The Plio-Pleistocene strata in the Laugarnes area appear to dip 3 to 12 degrees to the southeast (Thorsteinsson and Elíasson, 1970). These strata occur at 250 to 300 m lower elevation in wells of the Elliðaár area.

Aquifers are predominantly found at the contacts of lavas and hyaloclastites. Table 2.1 lists the occurence of aquifers in different rock types (Tómasson et al. 1975). The Laugarnes geothermal area has been found to be fed by three aquifers (Thorsteinsson and Elíasson, 1970). A geological and hydrogeological cross-section is shown in Fig. 2.2. The temperature of these aquifers is 110.C to 120.C for aquifer A, 135.C for aquifer B and 146.C for aquifer C. Aquifer B is the main aquifer with a contribution of 80%. Mixing of these waters yields an average well discharge temperature of 125 to 130.C.

The recharge area of the Laugarnes area has been mapped by deuterium (Árnason, 1977). By comparing the deuterium content of the precipitation in Iceland to that of the geothermal water, the Langjökull area has been shown to provide the recharge for the Laugarnes geothermal field.

As in the Laugarnes area, aquifers in the Elliðaár area occur at contacts between hyaloclastites and lavas. The Elliðaár area is fed by at least two different groundwater systems. The northern part of the Elliðaár area is probably fed by the same recharge area as the Laugarnes area. The other recharge area for the southern part of this geothermal field is most likely east of Reykjavík, at a distance of less than 45 km (Árnason and Tómasson, 1970; Tómasson et al. 1975).

2.3 Hydrogeology of the Reykir area

The Reykir geothermal field is situated between the Kjalarnes and the Stardalur central volcanoes. The low-temperature field is thus superimposed on the margins of extinct, eroded high-temperature fields (Tómasson et.al., 1975). It is found from the alteration pattern of the minerals that this field is an old high-temperature field, just as the Laugarnes field. A swarm of faults and fissures extends through the area.

Only the northern part of the North-Reykir field is covered by glacial sediments. At the end of the last glaciation, these sediments had been covered by the sea up to an elevation of approximately 40 m.

In the largest part of the area the hyaloclastites reach the surface and dominate down to a depth of 1000 m. They are intercalated by lavas, which become more dominant at greater depths. Dolerite intrusions are rare in the uppermost 1000 m, but their number tends to increase with depth (Tómasson et.al., 1975).

The strata down to a depth of 2000 m are of Plio-Pleistocene age. These strata dip gently toward the neovolcanic zone (Ingvar Birgir Fridleifsson, personal communication).

Aquifers are irregularly distributed through the geological section. As in the Reykjavík geothermal fields, the productive aquifers are in contact with lavas and hyaloclastites (Tómasson et. al, 1975). It is believed that the geothermal aquifers are both horizontally and vertically connected to faults.

Fig. 2.3 shows a temperature cross-section of the Reykir field. It shows two tongues of ascending water. In this report these areas of higher temperature are represented by the wells MG-37 and MG-35. Even though this profile is NW-SE, it has to be kept in mind that the main groundwater flow direction is correlated with the direction of the faults and fissures (NE-SW).

There is a main groundwater boundary dividing the Reykir fields into two hydrological systems. This boundary strikes NE-SW and is shown in Fig. 1.1. At the boundary, mixing probably occurs between the two systems. Recharge areas for the geothermal waters are believed to lie in a north-easterly direction, some tens of kilometers distant.

3 CHEMISTRY

3.1 Introduction

The interpretation of the chemical data is mainly done with plots of chemical components vs. time. They show the changes with time that have occurred in the different wells. A comparison is also made between different wells, and every geothermal area shows its own characteristic chemical composition. Furthermore, chemical components in the deep water were calculated with a computer programme, described by Arnórsson et. al. (1982). The activity of silica in the deep water was plotted against the equilibrium fit made by Arnórsson et. al.

3.2 The Laugarnes area

The Laugarnes geothermal field yields water of about 130.C. It is the hottest of the areas investigated. From this area two wells were selected, wells G-5 and G-35. The most obvious changes are observed in well G-5, mainly because of the longer time-sequences available. The well G-5 was drilled in 1959 to a depth of 741 m, whereas well G-35 was drilled in 1979 to a depth of 2857 m. Well G-5 is located farther northwest, nearer to the coast.

Due to the temperature dependence of the silica concentration in geothermal water, the silica content of the Laugarnes area is higher than that of the other areas. However, the most obvious change in chemical composition is the decrease of silica (Fig. 3.1.a). At the temperatures in question, the concentration of silica is believed to be governed by equilibrium with chalcedony (Arnórsson, 1975). Figure 3.1.j shows that the calculated chalcedony temperature is decreasing with time. This means that cooler water is coming into the groundwater system.

This is also shown by the decrease in fluoride (Fig 3.1.b). The geothermal water contains fluoride in concentrations between 0.8 and 1.0 ppm. In cold groundwater the fluoride content is 0.1 ppm or less (Einar Gunnlaugsson, personal communication). Therefore a decrease in fluoride also indicates mixing with cold groundwater.

In contrast to the decrease in silica, fluoride and carbon dioxide, the concentration of total dissolved solids (TDS) (Fig. 3.1.c) remains fairly constant. This can be explained by the increase in chloride and sulfate (Fig. 3.1.d and 3.1.e). The average increase in the chloride is 10 ppm, while the increase in sulfate is 6 ppm. The increase in sulfate is also observed in well G-35 (Fig. 3.1.h), in spite of the short time sequence available. It is not likely that the sulfate is coming from oxidation of hydrogen sulfide in this area. Firstly, the hydrogen sulfide content remains fairly constant, and secondly, there is too little hydrogen sulfide to increase the sulfate by 6 ppm.

The TDS are 100 ppm higher in the Laugarnes area than in the Elliðaár area. This, together with the increase in chloride and sulfate, suggests that the intruding water has a fairly high salt content.

Together with the increase in the concentration of anions, carbon-dioxide decreases by 7 ppm (Fig. 3.1.f). This may be due to the mixing of hot and cold water, which leads to supersaturation with respect to calcite and instantaneous precipitation. The changes in pH (Fig 3.1.g) obviously support this. But this equilibrium is attained so quickly that all the samples show saturation with respect to calcite. In spite of the likely precipition of calcite, the concentration of calcium is increasing slightly (Fig. 3.1.k). This is further evidence that seawater is coming into the system, because the calcium content of the seawater is much higher than that of the geothermal water.

If all the changes in chemistry are taken into account, it is most evident that cold seawater is mixing with the geothermal water. The influence of the seawater is also shown by the decrease of the Na/K ratio (Fig. 3.1.i). The Na/K ratio of seawater is very low, so that a decrease of this ratio in the geothermal water also indicates the influence of seawater in the system.

3.3 Elliðaár area

From this area, two wells have also been selected, G-30 and G-31. The wells were drilled in 1969 to a depth of 1316 m and 1613 m, respectively. The discharge temperatures are 95.C and 90.C, respectively.

Chemically, the two wells show only small differences. Thus the chemistry of well G-31 is mainly discussed in this paper.

Cold water comes into the system also in the Elliðaár area as evidenced by the decrease in the concentration of silica (Fig. 3.2.a), fluoride (Fig. 3.2.b) and TDS (Fig. 3.2.c).

The silica content decreases by 30 ppm, which can mean that more cold water comes into this geothermal system than into the Laugarnes system. Fluoride reaches a minimum of 0.25 ppm in well G-31 (Fig. 3.2.b) and 0.2 ppm in well G-30 (Fig. 3.2.f). These values are very close to the fluoride content of the precipitation. The TDS decreases by 15 ppm, which can be interpreted to mean that the colder water is diluting the geothermal water.

Although the chloride concentration is increasing (Fig 3.2.d), it is most likely that the cold water comes from local cold groundwater. The reasons for this assumption are the following. Firstly, the local cold groundwater of the Elliðaár area contains about 20 ppm of chloride (Einar Gunnlaugsson, personal communication). Secondly, the sulfate is decreasing by 7 ppm (Fig. 3.2.e). This can only be caused by dilution with non-saline water.

The most obvious changes occurred during the years from 1973 to 1979. In the most recent years, when samples were taken more frequently, there seems to be an obvious correlation between pumping rates and inflow of cold water into the system. The winter of 1981/82 e.g., which was quite cold, shows minima for silica, fluoride and sulfate, while chloride is high. This can be explained by high pumping-rates and a correspondingly larger inflow of local cold water into the geothermal groundwater system. This influence is even larger at well G-30. Figure 3.2.f shows the fluoride concentration, which displays an extreme minimum for this period.

The colder water coming into the field is already decreasing the temperature of well G-30 (Fig. 3.2.g). This well is located further to the northeast than well G-31. There are two interpretations possible. Firstly, that the cold water is coming from a northerly direction, the same direction as the geothermal water. Secondly, since the well G-30 is located near to the river Elliðaár, there could be cold water coming into the well from the river through fractures and fissures. It is, however, difficult to draw a good conclusion about the flow direction of the groundwater, because only two wells are taken into account. This cold water drawn into the Elliðaár geothermal field seems be local water recharged by precipitation and coming mainly from a northerly direction.

3.4 Reykir area

From the Reykir area six wells have been selected. Three are from the North-Reykir field and three are from the South-Reykir field. Well data are given in Table 1.1.

Chemical differences between the wells are present. Some of them can be correlated with different discharge temperatures. The rest must be explained by other factors.

South-Reykir

Changes in chemistry are most obvious in well MG-17 and to a lesser degree in well MG-18. In well MG-18 the changes are also found later than in well MG-17.

Well MG-16 does not show any changes in chemistry. Figure 3.3.o shows the constant silica content of this well. All the other components of this well are also fairly constant. Due to this it is believed that this well represents the unchanged water composition of this geothermal field.

Well MG-17 and MG-18

The silica decreases by 15 and 12 ppm respectively in the two wells (Fig 3.3.a and Fig. 3.3.g). This can also be clearly seen in Fig. 3.3.p where the activity of silica versus temperature is plotted for the two wells. The trend of log ($H4SiO4$) is downwards. Assuming that the geothermal water has been in equilibrium with chalcedony, this shows that the equilibrium is now disturbed and that the water is possibly undersaturated already. The fluoride concentration decreases down to 2 ppm in both wells (Fig. 3.3.b and 3.3.h). The chloride content remains fairly constant in both wells (Fig 3.3.d). The TDS decrease by 15 ppm in well MG-17 (Fig 3.3.c), while in well MG-18 only a slight decrease can be seen (Fig. 3.3.i).

This leads to a similar conclusion as for the Elliðaár area. In this geothermal field, cold water is intruding from a southerly direction and diluting the geothermal water. The diluting water is most likely local groundwater recharged by precipitation.

In well MG-17 carbon dioxide has increased by 7 ppm (Fig. 3.3.e). This is probably because of mixing with cold water, which contains more carbon dioxide, and because calcite is more soluble in cold water than in hot water.

However, there already came enough cold water into the system to decrease the temperature of well MG-17 by 2.C (Fig 3.3.f), while the temperature of well MG-18 still remains fairly constant (Fig. 3.3.j). It will be a question of time when the first changes will be found in well MG-16.

North-Reykir

Well MG-37

This well has the second highest discharge temperature in the area, and a correspondingly high silica content.

The most remarkable component in this well is sulfate. It is 10 to 20 ppm higher than in the other wells (Fig. 3.3.k) and shows a slight decrease. The center of the old high-temperature geothermal area is believed to be located at the NW-side of the groundwater boundary, where the highest temperature is still found. The sulfate would come into the groundwater due to dissolution of secondary minerals. The decrease in sulfate can be explained by dilution. By looking at the Ca/Cl ratio (Fig. 3.3.q), it can be seen that the calcium content increases slightly with increasing chloride. This indicates that the cold water coming into the system is most likely fresh water with similar calcium content as the geothermal water. The slight increase in the calcium content with increasing chloride in this well might be due to the higher solubility of calcite in cold water. This suggests that this well is already influenced by cold water.

Well MG-5

Well MG-5 does not show any changes in chemistry with time. The silica remains constant (Fig. 3.3.l), so that it is not likely that cold water is entering the system. The decrease in the sulfate concentration (Fig. 3.3.n) and the increase in total dissolved solids (Fig. 3.3.m) in the year 1977 may have been due to initial drilling fluid influence. It should be noted whether the slight increase in the sulfate content continues in the next few years. This would mean that the groundwater is flowing from well MG-37 in the direction of well MG-5.

Well MG-35

The time-sequences available from well MG-35 are too short and the scatter in the data too large for any conclusions to be drawn. It has a slightly higher content of TDS than well MG-5, due to the higher discharge temperature.

Summarizing, it can be said that the greatest changes have been observed in the South-Reykir area, where cold water flows into the geothermal system from a southerly direction.

For the North-Reykir area, no distinct trend with time can be seen, but well MG-37 is of particular interest. There, cold water is probably entering the system. Longer time sequences are required to prove this, however. There is evidence that the water, most likely at shallow depth, flows from well MG-37 to well MG-5.

4 OXYGEN-18

4.1 Introduction

During the years 1980 to 1982 oxygen-18 samples were collected, with the hope that they would help explain the changes in the chemistry. Due to difficulties in the laboratory, no deuterium is currently being measured. Plots of oxygen-18 vs. time are shown in Figs. 4.1.a and 4.1.b for the two geothermal fields in Reykjavík and for the Reykir geothermal field. The most recent distribution of the 0-18/0-16 ratios is shown in Fig. 4.2.

4.2 Laugarnes area

The Laugarnes area is characterized by low oxygen-18 values. Fig 4.1.a shows that both wells have obviously lower oxygen-18 than those in the Elliðaár area. For comparison two analyses from wells G-5 and G-34 (also located in the Laugarnes area) are used (Einar Gunnlaugsson, personal communication):

Well	Date	Cl(ppm)	Sulfur-34	Deuterium	Oxygen-18
5	820303	44.4	+9.0	-66.8	-10.1
34	820303	171.9	+14.3	-61.9	-9.9

From the chloride content and the sulfur-34 values it is obvious that well G-34 discharges water that originates for the largest part in the ocean. For comparison, the sulfur-34 value of the ocean is +20 o/oo. This suggests that the seawater coming into the system has a very low 0-18/0-16 ratio, probably slightly less than -10.0 o/oo. To prove this, oxygen-18 samples were taken in the bay north of Reykjavík, but they have not been analyzed yet. With this assumption, Fig. 4.2 shows that well G-35 is not yet as influenced by the cold water as well G-5, but the oxygen-18 is shifting toward the same value. Another possible explanation of the low oxygen-18 in the geothermal area might lie in the recharge areas. If the center of the glacier Langjökull is taken as the recharge area for the Laugarnes and Seltjarnares areas, the calculated oxygen-18 values, according to Árnason (1977), would be -10.5 o/oo and -13.0 o/oo, respectively (Fig. 4.3). Mixing with seawater would then have increased the 0-18/0-16 ratio. A third source of the low oxygen-18 might be the basalts, which have a relatively low oxygen-18 content. But the values found by Muehlenbach et. al. (1974) are not low enough to provide sufficient explanation of the low values presented in this report.

4.3 Elliðaár area

Of the wells investigated, the two in the Elliðaár area show the highest 0-18/0-16 ratios. The highest values are found in well G-30, which is believed to be most strongly influenced by local cold groundwater. The most recent oxygen-18 value is -8.45 o/oo. This is equal to the value that can be calculated from the deuterium content of the precipitation found by Árnason, (1977). According to the meteoric water line, the calculated oxygen-18 value is -8.5 o/oo.

This leads to the conclusion that the water coming into the Elliðaár system is nearly unchanged precipitation. It is therefore most likely that the cold water is of a young age. Tritium measurements would give good information about the age of the water and the degree of mixing.

4.4 Reykir area

Using the knowledge gathered from the Laugarnes and Elliðaár areas, the oxygen-18 data of the Reykir area is easy to interpret.

The highest oxygen-18 value is found (18 = -8.69 o/oo) in well MG-17. This shows that the intruding cold water originates from local precipitation in the area. Plotting the oxygen-18 against temperature (Fig. 4.3) indicates the flow direction. The groundwater is flowing from well MG-17 to MG-18 and most likely to well MG-5. This could be possible if the groundwater boundary is correlated with a major fault. It can then likewise act as an aquifer.

It can not be ascertained whether the quite high oxygen-18 value of well MG-16 is already influenced by incoming precipitation or whether this represents the "original" oxygen-18 of the geothermal water. Because this well did not show any changes in chemistry, it is assumed that this well represents the initial oxygen-18 content of the geothermal water. The same is believed to hold for well MG-35.

Well MG-37 shows the lowest oxygen-18 of the area (Fig. 4.1.b). This could be correlated with intruding saline water, probably of reasonable age.

No correlation between the oxygen-18 and the relatively high sulfate content of this well is found. Exchange with sulfate as a reason for changes in oxygen-18 values is therefore excluded. But further study would be helpful.

5 TRITIUM

5.1 Introduction

The tritium data presented in this report are 20 years old. Samples were taken only from the Laugarnes and Reykir areas. The data are represented by the tritium vs. time sequences shown in Fig 5.1, 5.2 and 5.3. The data are not time corrected, but the measured values are plotted.

However, these data give some useful information about the reaction times of the areas.

Due to atomic bomb experiments, the tritium content of the precipitation was strongly increased. A small increase had occurred already in the late nineteen-fifties, while the major tritium peak of the (summer-) precipitation was found in 1963 (= 1000 TU).

5.2 Laugarnes area

Well G-4 was drilled in 1959 to a depth of 2198 m. Only water of aquifer C is pumped from the well.

The tritium data show only a little scatter around 1 TU, which is probably just the noise of the measurement. This means that in this time period no recent water (younger than 5 years) was coming into the deep system.

5.3 Reykir area

The measurements of the Reykir area give different results. The wells from which the tritium samples were taken are shallow (approximately 700 m deep or less). The casing of these wells is only a few meters deep (10 to 50 m). The wells are no longer used for production. Recently some of the old wells were cemented to prevent downflow of cold water through them.

In the North-Reykir area young water is coming into the system with a delay of only 3 years. The tritium peak is very flat (only 5 TU), which means that only a very small amount of younger water is mixing with the geothermal water.

In contrast, the South-Reykir area has a longer reaction time (5 years), but a higher peak was found (45 TU). This can mean that more water came into this system than into the North-Reykir area.

The conclusion can be drawn that a constant amount of young water is probably mixing with the geothermal water at shallow depth, even at less than 100 m, because of the very short casings. Because of the quite uniform geological formation sequence of the Reykir area with depth, it is likely that the water is flowing down to greater depth, and that tritium might now (20 years later) be found also in the "new" production wells. This awaits further research.

6 GROUNDWATER FLOW MAP

To summarize the results from the previous chapters, a groundwater flow map of the whole area has been made (Fig. 6.1). It shows the flow directions of the geothermal and cold waters and the possible recharge areas. The recharge areas of the geothermal waters are as given by Árnason (1977). For the cold water intrusions the recharge areas are determined as described in the previous chapters. To give a more detailed subdivision of the different recharge areas, detailed studies with the aid of isotopes (Tritium, oxygen-18, deuterium, and maybe even carbon-14) would be very useful.

7 CONCLUSIONS AND SUGGESTIONS

1) The groundwater flow of the geothermal water is correlated with the main direction of the faults (NE-SW). The cold water, on the other hand, is most likely flowing through the sedimentary layers, and for this reason its flow direction is not strictly related to the main fault direction.

2) The groundwater boundary in the Reykir area is most likely correlated with a major fault, which acts simultaneously as an aquifer.

3) To understand the dynamics of the different geothermal groundwater systems, a correlation of pumping rates with the changes in chemistry would be very useful. It appears that the most water is drawn into the system in wintertime when the pumping rates are highest.

4) Changes in silica occur in the Reykir area approximately 5 to 7 years in advance of the changes in temperature. In the Elliðaár area this time difference is only 3 to 5 years.

5) The oxygen-18 of the geothermal water is possibly determined by the very low oxygen-18 content of the glacier Langjökull.

6) It is found that the intruding water in the area of Elliðaár and South-Reykir has the same oxygen-18 values as the local precipitation.

7) Because of the low oxygen-18 values found it is assumed that very little or no oxygen-18 shift has occured.

8) The intruding saline water is depleted with respect to oxygen-18, and mixing leads to an 0-18/0-16 ratio of -9.5 o/oo.

9) Analyses of tritium in the new production wells would be helpful in understanding the dynamics of the different groundwater systems.

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TABLE 1.1 Selected well data (Gunnlaugsson, 1983)

Well number	year of completion	depth (m)	surface level (m above sea level)	length of liner (m)
G-4	1959	2198	15	64
G-5	1959	741	15	68
G-30	1969	1316	27	100
G-31	1969	1613	41	101
G-34	1978	3085	17	328
G-35	1979	2857	17	276
MG-5	1970	1592	51	133
MG-16	1973	2033	66	213
MG-17	1973	1765	60	387
MG-18	1973	2043	51	184
MG-35	1976	1903	82	246
MG-37	1977	1999	44	252

TABLE 2.1 Occurrence of aquifers in different rock types of 29 drillholes (Tómasson et. al., 1975)

Rock type	Aquifers/circulation loss			total number
	< 2 l/s	2-20 l/s	> 20 l/s	
Lavas	44	27	2	73
Hyaloclastites (x)	29	12	4	45
Dolorites		1	1	2
Lavas and hyaloclastites	53	38	20	111
Lavas and doerites	13	1	3	17
Hyaloclastites (x) and dolerites	5	2	1	8

ORKUSTOFNUN

TABLE 3.1 Chemical and isotopic analyzes.

ORKUSTOFNUN UNU LAUGARNES G-5
1984-08-02 HKH

SAMPLE NUMBER	TEMP	OHMM	PH/TEMP	SIO2	NA	K	CA	MG	CO2	SO4	H2S	CL	F	DISS. SOLIDS	O-18
0000400105590306000	0.0	0.0	9.50/20	166.4	0.0	0.0	0.0	0.00	0.0	21.6	0.1	31.2	1.00	336.0	0.0
0000400105590312000	130.0	0.0	9.35/20	167.2	61.0	2.6	2.6	1.10	29.9	21.6	0.0	34.8	1.10	328.0	0.0
0000400105591222000	0.0	0.0	9.58/20	171.2	0.0	0.0	0.0	0.00	0.0	0.0	0.0	30.7	1.10	346.4	0.0
0000400105600125000	0.0	0.0	9.48/20	168.8	0.0	0.0	0.0	0.00	0.0	19.4	0.0	29.9	1.20	335.2	0.0
0000400105600210000	0.0	0.0	9.46/20	170.8	0.0	0.0	0.0	0.00	0.0	19.3	0.0	30.2	1.20	336.0	0.0
0000400105600215000	0.0	0.0	9.47/20	168.8	0.0	0.0	0.0	0.00	0.0	20.1	0.0	29.5	1.20	336.0	0.0
0000400105630306000	130.0	0.0	8.70/20	162.4	56.7	2.5	4.0	0.00	22.0	19.2	0.5	30.0	1.10	324.0	0.0
0000400105651202000	0.0	0.0	9.35/20	172.0	50.5	1.8	1.9	0.40	26.8	17.1	0.4	28.2	0.90	317.0	0.0
000040010577012620	143.0	37.7	9.56/20	146.0	0.0	3.0	2.8	0.02	12.4	27.9	0.0	42.2	1.06	336.3	0.0
000040010580011000	128.0	38.5	9.22/23	145.0	61.8	3.0	2.7	0.00	14.7	22.7	0.5	38.4	0.96	324.0	-9.4
0000400105800528007	143.0	33.5	9.46/25	142.0	64.9	3.1	3.2	0.00	23.4	24.4	0.1	43.4	1.00	339.0	-9.7
0000400105801118016	0.0	34.4	9.62/21	156.0	64.3	3.2	3.2	0.01	17.1	25.5	0.0	43.3	1.03	313.7	-9.9
0000400105810511008	127.2	39.2	9.48/23	152.4	59.6	3.0	2.7	0.05	16.6	20.7	0.0	42.3	0.85	287.8	-9.6
0000400105811125020	101.9	33.3	9.40/22	149.8	63.5	2.8	2.8	0.01	18.9	24.2	0.2	42.0	0.96	331.5	-9.8
0000400105820114000	0.0	0.0	9.51/23	151.4	63.7	3.4	2.7	0.00	19.0	24.8	0.8	42.8	1.00	0.0	0.0
0000400105820212000	129.4	0.0	9.48/19	137.1	64.1	2.9	3.1	0.00	23.1	27.6	0.5	43.9	0.90	0.0	0.0
0000400105820303000	129.3	0.0	9.40/22	137.4	64.2	2.9	3.1	0.00	23.8	26.6	0.6	44.4	0.70	0.0	0.0
0000400105820330000	129.0	0.0	9.49/23	141.1	63.9	2.9	3.1	0.00	18.2	29.2	0.5	46.4	1.00	0.0	0.0
0000400105820511007	0.0	30.8	9.32/22	146.2	62.2	2.9	3.1	0.01	19.6	28.6	0.2	46.3	1.13	331.3	-9.4
0000400105821111000	129.6	0.0	9.50/21	142.4	62.7	2.8	3.0	0.00	17.1	27.6	0.9	40.3	0.70	0.0	0.0
0000400105830321000	130.2	35.8	9.56/19	146.8	0.0	0.0	0.0	0.00	18.6	24.0	0.6	38.6	0.00	0.0	0.0
0000400105830811000	130.0	0.0	9.58/23	147.2	0.0	0.0	0.0	0.00	18.5	0.0	0.4	37.2	0.00	0.0	0.0
0000400105840404000	0.0	32.0	9.47/22	154.7	0.0	0.0	0.0	0.00	17.3	0.0	0.3	48.0	0.00	0.0	0.0

```
ORKUSTOFNUN UNU                     LAUGARNES G-35
1984-08-02  HKH
===============================================================================================================
SAMPLE NUMBER         TEMP  OHMM  PH/TEMP  SIO2     NA      K      CA    MG    CO2   SO4   H2S     CL     F    DISS.  O-18
                                                                                                                SOLIDS
===============================================================================================================


000040013580052800075  0.0  36.3  9.46/25 145.4    59.6    2.4    3.2  0.00  22.0  18.5   0.1    41.7  0.78   322.0  -9.0
00004001358011190167   0.0  40.0  9.63/21 171.0    58.9    2.7    2.5  0.01  20.5  19.3   0.0    21.2  0.85   296.7  -7.6
00004001358111250202 102.4  31.3  9.40/22 152.6    66.6    2.4    3.8  0.01  20.1  21.1   0.2    50.0  0.78   345.2  -9.8
00004001358201130000 127.0   0.0  9.56/23 141.1    68.1    2.8    3.4  0.00  18.7  21.5   0.8    51.9  0.50     0.0   0.0
00004001358205120073 126.0  30.3  9.32/21 147.3    63.6    2.5    4.1  0.01  20.3  21.1   0.3    55.2  0.82   331.1  -9.6

00004001358303230000 126.2  35.2  9.60/21 151.4     0.0    0.0    0.0  0.00  20.3  20.9   0.6    42.2  0.00     0.0   0.0
```

```
ORKUSTOFNUN UNU                     ELLIDAAR G-30
1984-08-02  HKH
===============================================================================================================
SAMPLE NUMBER         TEMP  OHMM  PH/TEMP  SIO2     NA      K      CA    MG    CO2   SO4   H2S     CL     F    DISS.  O-18
                                                                                                                SOLIDS
===============================================================================================================


00004001306909100000   0.0   0.0  9.50/20 120.0    68.5    2.8    2.0  0.20  50.0   0.1   0.0    56.0  0.60   240.0   0.0
00004001306912190207 110.0   0.0  9.30/23 109.0     0.0    0.0    0.0  0.00   0.0   0.0   0.0    17.1  0.00     0.0   0.0
00004001307702282012 105.0  51.3  9.46/22  86.0    41.8    1.5    1.9  0.02  23.0  18.3   0.0    18.2  0.38   245.1   0.0
00004001307906123018 100.0  55.6  9.63/20  94.3    41.6    1.7    2.0  0.08  23.3  13.6   0.3    18.4  0.41   249.0   0.0
00004001308005280078   0.0  54.0  9.56/24  82.8    43.3    1.4    2.2  0.00  28.8  13.7   0.1    18.1  0.32   209.0  -8.6

00004001308011190168   0.0  54.0  9.69/21  89.0    42.2    1.5    2.0  0.00  23.0  13.6   0.0     8.5  0.39   193.4  -8.3
00004001308105110079  98.1  57.0  9.42/23  83.2    40.7    1.5    1.9  0.04  24.8  14.6   0.0    20.0  0.32   211.8  -8.2
00004001308111300207  99.7  51.3  9.40/23  86.3    42.9    1.5    1.9  0.01  26.3  14.5   0.0    18.1  0.39   204.6  -8.6
00004001308201120000  98.0   0.0  9.59/23  86.0    38.1    1.7    1.9  0.00  24.3  14.5   0.2    19.8  0.20     0.0   0.0
00004001308203300000  97.6   0.0  9.60/23  81.6    43.9    1.4    2.0  0.00  23.9  13.4   0.1    19.2  0.10     0.0   0.0

00004001308205070066  97.0  47.6  9.45/21  84.5    40.6    1.3    2.0  0.01  25.2  13.7   0.1    20.1  0.37   183.8 -10.0
00004001308211220000  98.9   0.0  9.48/21  91.3    45.1    1.3    2.2  0.00  25.2  14.0   0.2    18.7  0.20     0.0   0.0
00004001308303280000  96.8  52.6  9.67/19  82.0     0.0    0.0    0.0  0.00  25.3  14.5   0.1    19.8  0.00     0.0   0.0
00004001308308230000  96.2   0.0  9.60/25  78.7     0.0    0.0    0.0  0.00  23.0   0.0   0.1    20.2  0.00     0.0   0.0
00004001308311170000   0.0  50.0  9.52/22  82.6     0.0    0.0    0.0  0.00  24.7   0.0   0.1    19.8  0.00     0.0   0.0

00004001308405150000  94.7   0.0  9.54/22  79.4     0.0    0.0    0.0  0.00  24.7   0.0   0.1     0.0  0.00     0.0   0.0
```

```
ORKUSTOFNUN UNU                        ELLIDAAR G-31
1984-08-02  HKH
======================================================================================================================
SAMPLE NUMBER          TEMP  OHMM PH/TEMP  SIO2     NA      K     CA   MG   CO2   SO4   H2S     CL    F   DISS.  O-18
                                                                                                       SOLIDS
======================================================================================================================

00004001316907060052   0.0   0.0 9.65/ 0 108.0    0.0    0.0    0.0 0.00   0.0   0.0   0.0   15.9 0.00     0.0   0.0
00004001316907130056   0.0   0.0 9.65/ 0 116.0    0.0    0.0    0.0 0.00   0.0   0.0   0.0   16.9 0.00     0.0   0.0
00004001317305000077   0.0  52.6 9.03/20  93.0   42.0    0.8    2.4 0.06  27.1  19.8   0.0   16.8 0.70   229.5   0.0
00004001317701282009  90.0  57.1 9.70/20  89.0   41.8    1.4    2.3 0.03  18.1  17.1   0.0   16.3 0.39   209.5   0.0
00004001318005280076  87.0  33.8 9.68/24  73.1   45.3    1.0    1.8 0.00  28.4  12.2   0.1   19.1 0.26   198.0  -8.7

00004001318011190169  91.0  55.5 9.68/22  93.0   41.7    1.4    2.3 0.00  21.2  13.0   0.0   11.8 0.39   184.5  -9.0
00004001318111190166  87.7  51.3 9.52/24  78.2   43.2    1.0    1.7 0.08  25.3  13.1   0.0   18.8 0.33   199.4  -8.9
00004001318203300000  89.8   0.0 9.68/23  75.0   44.8    1.0    2.0 0.00  25.5  12.2   0.1   18.9 0.10     0.0   0.0
00004001318205070065  87.0  50.0 9.63/21  84.5   42.4    1.1    2.0 0.01  23.9  12.0   0.0   21.4 0.32   186.7  -8.8
00004001318206020000  91.3   0.0 9.62/25  96.3   46.0    1.1    2.1 0.00  22.3  12.5   0.1   20.9 0.20     0.0   0.0

00004001318207280000  91.3   0.0 9.61/21  83.5   46.2    1.2    2.2 0.00  23.6  13.3   0.1   20.1 0.20     0.0   0.0
00004001318303280000  89.8  49.8 9.83/18  79.0    0.0    0.0    0.0 0.00  23.6  12.9   0.1   21.1 0.00     0.0   0.0
00004001318311170000  89.7  48.1 9.60/22  79.4    0.0    0.0    0.0 0.00  21.3   0.0   0.1   20.0 0.00     0.0   0.0


ORKUSTOFNUN UNU                        N-REYKIR MG-5
1984-08-02  HKH
======================================================================================================================
SAMPLE NUMBER          TEMP  OHMM PH/TEMP  SIO2     NA      K     CA   MG   CO2   SO4   H2S     CL    F   DISS.  O-18
                                                                                                       SOLIDS
======================================================================================================================

26024001057704202042  77.0  47.6 9.61/24  75.0   29.5    1.0    2.0 0.00  25.4  22.3   1.0   23.7 0.77   176.0   0.0
26024001057709142056   0.0   0.0 9.80/24  82.0   43.0    1.0    2.1 0.01  24.5  21.0   0.9   13.5 0.68   188.0   0.0
26024001057906123017  81.0  58.8 9.42/20  71.2   42.1    1.1    2.1 0.06  26.8  17.1   0.3   10.5 0.69   211.0   0.0
26024001058005270073  79.0  52.6 9.51/25  62.0   43.1    0.9    2.3 0.00  31.0  18.0   0.3   10.9 0.55   183.0  -9.2
26024001058012020175  77.0 111.1 9.62/22  73.0   42.6    1.0    2.0 0.00  29.1  17.7   0.9    5.1 0.69   225.5  -9.1

26024001058105110078  77.3  55.0 9.58/23  72.0   42.8    0.9    2.2 0.01  33.0  19.0   0.5   15.9 0.69   177.5  -8.7
26024001058111230168  76.6  52.6 9.53/21  67.3   42.9    0.9    2.0 0.04  30.4  17.7   0.2   10.6 0.67   193.0  -7.9
26024001058205100067  77.0  43.5 9.42/21  72.4   41.3    0.8    2.1 0.01  27.8  19.4   0.5   13.3 0.69   177.4  -9.2
26024001058304060000  77.5  51.8 9.70/21  72.7    0.0    0.0    0.0 0.00  25.4  19.6   1.0   13.5 0.00     0.0   0.0
```

```
ORKUSTOFNUN UNU                          N-REYKIR MG-35
1984-08-02  HKH
=========================================================================================================================
SAMPLE NUMBER         TEMP  OHMM  PH/TEMP  SIO2     NA      K      CA    MG    CO2   SO4   H2S     CL     F    DISS.  O-18
                                                                                                              SOLIDS
=========================================================================================================================

26024001358005270072  93.5  50.0  9.37/26  95.1    50.0    1.3    1.9  0.00  23.6  19.5   1.3    13.5  0.95  241.0  -9.0
26024001358112030216  93.4  47.6  9.31/21  98.9    48.4    1.2    1.7  0.01  28.0  21.2   1.2    12.7  0.85  229.6  -9.0
26024001358112170000  94.0   0.0  9.74/24  95.9    47.6    1.5    1.7  0.00  24.4  21.1   1.6     6.6  0.90    0.0   0.0
26024001358204180000  93.2   0.0  9.58/24  89.9    49.5    1.2    1.8  0.00  23.5  19.3   1.8     2.3  0.60    0.0   0.0
26024001358205070064  89.0  47.6  9.47/21  98.5    45.9    1.2    1.8  0.01  28.6  19.3   0.9    12.3  0.85  209.5  -9.2

26024001358304060000  93.4  48.1  9.89/20  96.4     0.0    0.0    0.0  0.00  22.2  19.6   1.8    12.2  0.00    0.0   0.0
```

```
ORKUSTOFNUN UNU                          N-REYKIR MG-37
1984-08-02  HKH
=========================================================================================================================
SAMPLE NUMBER         TEMP  OHMM  PH/TEMP  SIO2     NA      K      CA    MG    CO2   SO4   H2S     CL     F    DISS.  O-18
                                                                                                              SOLIDS
=========================================================================================================================

26024001378005270071   0.0  40.8  9.28/26  97.3    53.7    1.7    2.5  0.00  32.2  34.2   1.3    19.1  0.71  270.0  -9.5
26024001378011180165  94.0  44.4  9.42/20 109.0    50.8    1.6    3.1  0.01  24.2  32.0   1.0    19.0  1.21  230.6  -9.7
26024001378105110074  95.0  45.0  9.40/20 107.4    49.2    1.5    2.8  0.01  29.6  34.1   0.9    19.6  1.23  250.1  -9.4
26024001378111230169  92.6  41.7  9.20/21  98.8    50.1    1.5    2.6  0.05  30.0  31.6   0.5    11.1  1.23  252.7  -9.4
26024001378112210000  97.0   0.0  9.44/20  98.0    51.9    1.5    2.7  0.00  23.8  32.7   3.0    12.7  1.10    0.0   0.0

26024001378205100068  96.0  40.0  9.27/21 106.4    48.7    1.5    2.7  0.00  31.0  31.0   1.3    15.4  1.28  235.9  -9.7
26024001378207280000   0.0   0.0  9.34/21  95.6    53.0    1.5    2.8  0.00  27.2  31.3   1.1    15.4  1.20    0.0   0.0
26024001378304060000  96.5  42.9  9.43/21  99.7     0.0    0.0    0.0  0.00  26.5  32.1   2.4    17.2  0.00    0.0   0.0
```

```
ORKUSTOFNUN UNU                      S-REYKIR MG-16
1984-08-02  HKH
=========================================================================================================================
SAMPLE NUMBER          TEMP  OHMM  PH/TEMP  SIO2     NA      K      CA    MG    CO2   SO4   H2S     CL    F    DISS.  O-18
                                                                                                              SOLIDS
=========================================================================================================================

26024001167501210006 100.0  50.0  9.54/19 106.0    46.2    1.5     2.7  0.09  22.2  23.1   0.6    17.9  1.08   245.0   0.0
26024001167704252044 101.0  45.5  9.65/23 110.0    50.8    1.5     2.3  0.01  20.5  28.6   1.4    24.2  0.95   230.0   0.0
26024001168005270070   0.0  50.0  9.59/26 101.7    47.7    1.5     2.4  0.00  25.1  23.1   0.9    15.1  1.00   251.0  -9.3
26024001168105110077  99.6  48.0  9.51/23 111.6    47.1    1.7     2.2  0.01  30.0  23.8   0.9    16.0  0.96   256.8  -9.5
26024001168112030218 100.7  47.6  9.20/22 106.0    47.1    1.4     2.2  0.00  24.1  21.9   1.2    21.6  0.96   237.6   0.0

26024001168201110000   0.0   0.0  9.62/23  99.5    50.2    1.6     2.0  0.00  23.6  22.3   2.0    15.3  0.90     0.0   0.0
26024001058204180000 100.6   0.0  9.41/24  96.0    49.2    1.3     2.2  0.00  22.1  22.2   1.8    10.0  0.90     0.0   0.0
26024001168205060062 106.0  44.4  9.53/21 103.9    46.3    1.4     2.2  0.01  23.9  24.0   0.4    16.6  1.00   223.7  -9.1
26024001168211240000 100.0   0.0  9.51/19 107.2     0.0    0.0     0.0  0.00  21.2  22.6   2.0     9.5  1.10     0.0   0.0
26024001168304260000 100.2   0.0  9.57/25 102.4     0.0    0.0     0.0  0.00  23.0  22.4   0.9    15.7  0.00     0.0   0.0


ORKUSTOFNUN UNU                      S-REYKIR MG-17
1984-08-02  HKH
=========================================================================================================================
SAMPLE NUMBER          TEMP  OHMM  PH/TEMP  SIO2     NA      K      CA    MG    CO2   SO4   H2S     CL    F    DISS.  O-18
                                                                                                              SOLIDS
=========================================================================================================================

26024001177310120128  75.2  55.5  9.52/21  81.0    47.9    0.8     2.5  0.18  22.9  15.8   0.0    13.3  0.70   192.5   0.0
26024001177502050019   0.0  62.5  9.99/20  64.0    30.7    0.6     2.6  0.05  13.3  14.2   0.6    14.5  0.54   177.0   0.0
26024001177704182037  75.0  49.5  9.87/21  78.1    40.5    0.9     2.3  0.01  15.0  23.1   0.9    23.5  0.72   223.9   0.0
26024001177709142053   0.0   0.0  9.90/20  60.0    35.5    0.6     2.7  0.03  17.4  12.8   0.2    13.4  0.34   161.0   0.0
26024001177906123016  76.0  66.7  9.57/20  55.4    34.0    0.7     2.3  0.08  20.0  12.7   0.1    14.2  0.39   175.0   0.0

26024001178005270069   0.0  65.3  9.76/26  50.3    36.7    0.6     2.5  0.03  21.8  13.4   0.1    14.4  0.29   160.0  -8.3
26024001178011180163  76.0  54.0  9.76/20  74.0    40.8    0.8     2.5  0.04  18.7  17.5   0.0    12.6  0.59   141.8  -7.1
26024001178105110076  74.8  64.0  9.70/23  51.7    34.2    0.6     2.3  0.04  27.7  17.4   0.0    17.1  0.32   132.8  -8.8
26024001178111230167  74.5  62.5  9.60/21  54.1    35.8    0.7     2.5  0.03  22.0  12.7   0.2    13.6  0.41   156.4  -8.8
26024001178112210000  74.0   0.0  9.80/21  57.7    34.2    0.6     2.3  0.00  16.5  12.0   0.4    15.2  0.40     0.0   0.0

26024001178204180000  72.3   0.0  9.61/24  54.5    38.2    0.5     2.4  0.00  20.4  13.9   0.2    14.5  0.20     0.0   0.0
26024001178205100069  77.0  52.6  9.68/21  54.3    34.4    0.6     2.4  0.01  22.3  13.5   0.1    16.1  0.37   142.1  -8.7
26024001178207280000  72.3   0.0  9.77/21  51.3    38.6    0.6     2.3  0.00  20.4  13.5   0.2     3.8  0.20     0.0   0.0
26024001178211240000  71.3   0.0  9.72/19  57.9     0.0    0.0     0.0  0.00  17.2  12.7   0.5    13.9  0.20     0.0   0.0
26024001178304260000  71.9   0.0  9.67/25  54.0     0.0    0.0     0.0  0.00  20.2   0.0   0.2    15.2  0.00     0.0   0.0

26024001178308230000  70.3   0.0  9.64/25  47.2     0.0    0.0     0.0  0.00  24.0   0.0   0.1    14.9  0.00     0.0   0.0
```

```
ORKUSTOFNUN UNU                         S-REYKIR MG-18
1984-08-02  HKH
====================================================================================================================
SAMPLE NUMBER        TEMP  OHMM  PH/TEMP  SIO2     NA     K    CA    MG   CO2   SO4   H2S     CL     F   DISS.  O-18
                                                                                                         SOLIDS
====================================================================================================================


26024001187406120040 82.0  62.5  9.41/23  73.1   39.9   0.7   2.4  0.03  25.2  17.0   0.0   14.6  0.90   179.2   0.0
26024001187502050020 81.0  52.6  9.93/20  72.0   33.0   0.7   2.3  0.02  17.7  17.1   0.7   16.1  0.63   197.0   0.0
26024001188005270068  0.0  58.8  9.59/26  59.3   39.9   0.8   2.6  0.01  25.4  17.0   0.1   14.8  0.39   170.0  -9.0
26024001188105110075 77.3  28.0  9.63/23  58.6   38.4   0.7   2.5  0.03  28.5  18.6   0.0   18.5  0.42   184.1  -9.2
26024001188112030217 76.4  52.6  9.30/22  55.7   41.3   0.7   2.2  0.02  30.3  19.1   0.0   15.1  0.36   169.8  -9.1

26024001188201050000  0.0   0.0  9.73/21  69.8   40.0   0.8   3.4  0.00  21.8  17.8   0.5   15.9  0.50     0.0   0.0
26024001188205060063  0.0  51.3  9.62/21  60.9   38.4   0.6   2.5  0.02  20.4  18.2   0.1   15.3  0.44   172.2  -8.9
26024001188207280000 78.0   0.0  9.78/21  61.4   42.6   0.8   2.3  0.00  23.5  18.8   0.2   13.7  0.30     0.0   0.0
26024001188211240000 77.8   0.0  9.68/19  64.2    0.0   0.0   0.0  0.00  22.9  18.8   0.2   14.2  0.20     0.0   0.0
26024001188304260000 77.7   0.0  9.70/24  59.4    0.0   0.0   0.0  0.00  20.7  18.3   0.2   15.1  0.00     0.0   0.0

26024001188308230000 76.4   0.0  9.64/25  58.9    0.0   0.0   0.0  0.00  21.9   0.0   0.1   14.8  0.00     0.0   0.0
```

```
ORKUSTOFNUN UNU                         LÆKJARBOTNAR, COLD WATER
1984-08-02  HKH
====================================================================================================================
SAMPLE NUMBER        TEMP  OHMM  PH/TEMP  SIO2     NA     K    CA    MG   CO2   SO4   H2S     CL     F   DISS.  O-18
                                                                                                         SOLIDS
====================================================================================================================

2500      8312040122  3.7 166.7  7.73/21  12.1    8.1   0.5   4.2  1.23  14.9   2.7   0.0    9.8  0.03    51.5   0.0
```

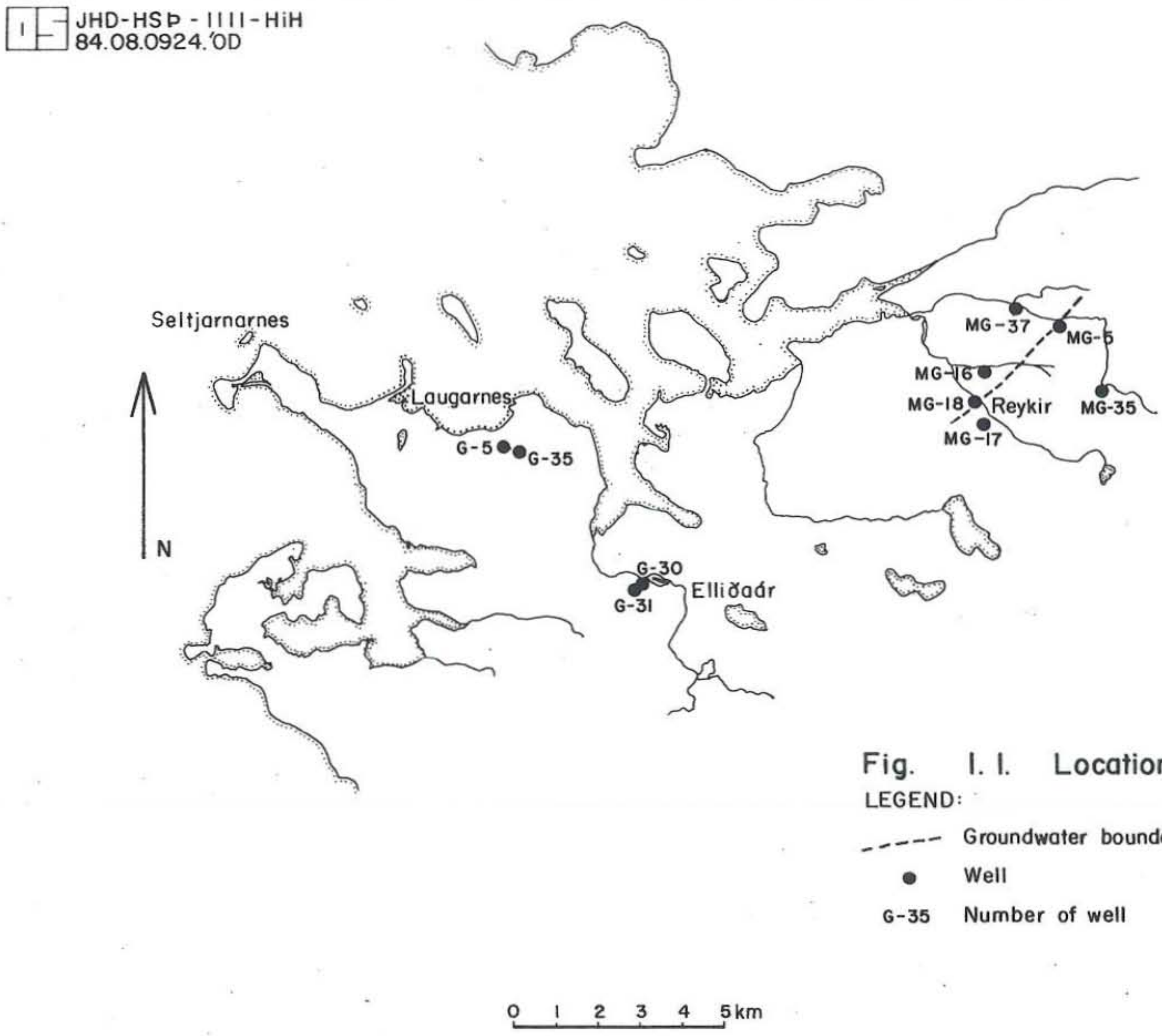

Fig. I. I. Location of the geothermal areas

LEGEND:

- - - - Groundwater boundary

● Well

G-35 Number of well

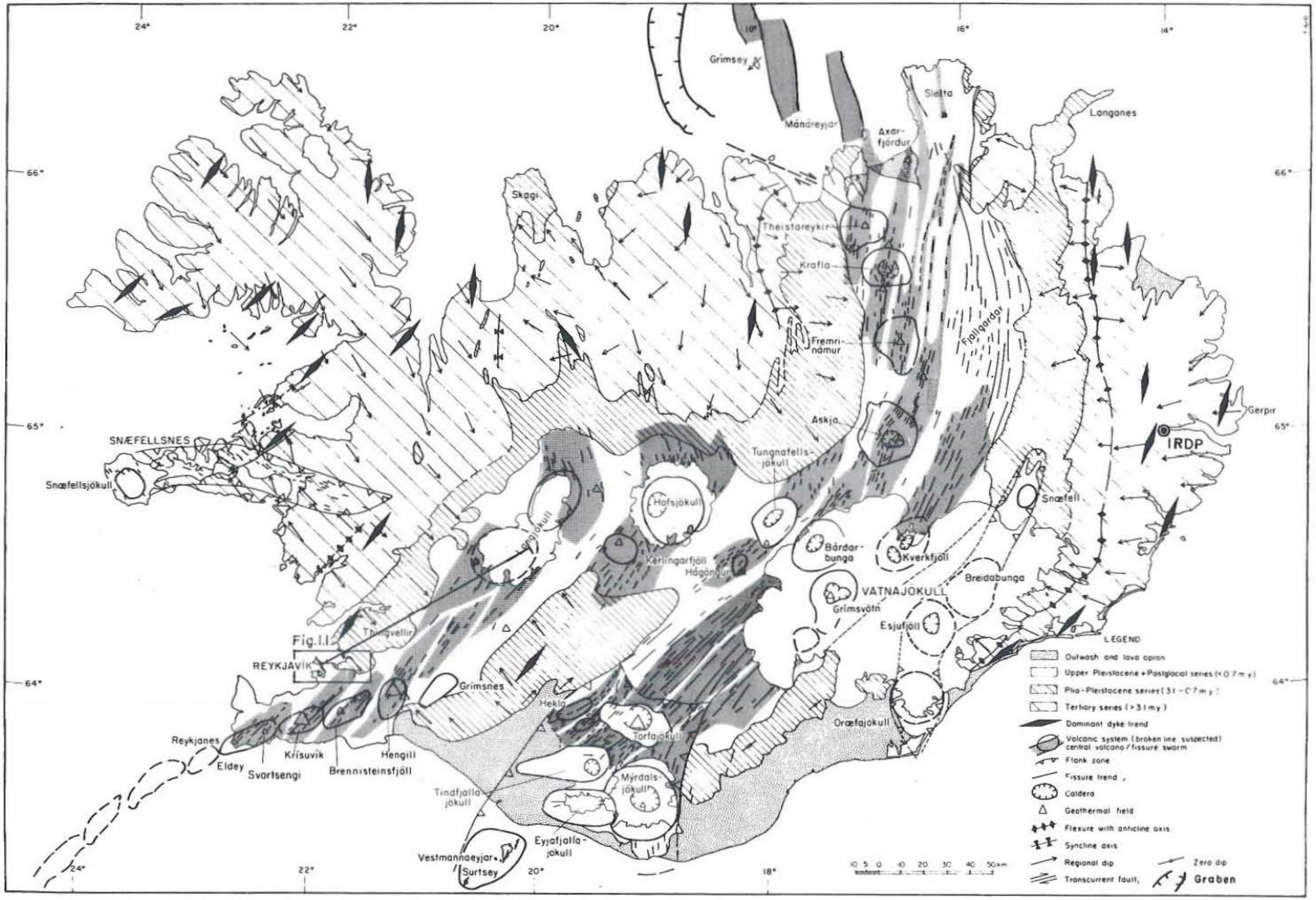

Fig. 2.1. Tectonic map of Iceland (Sæmundsson, 1978)

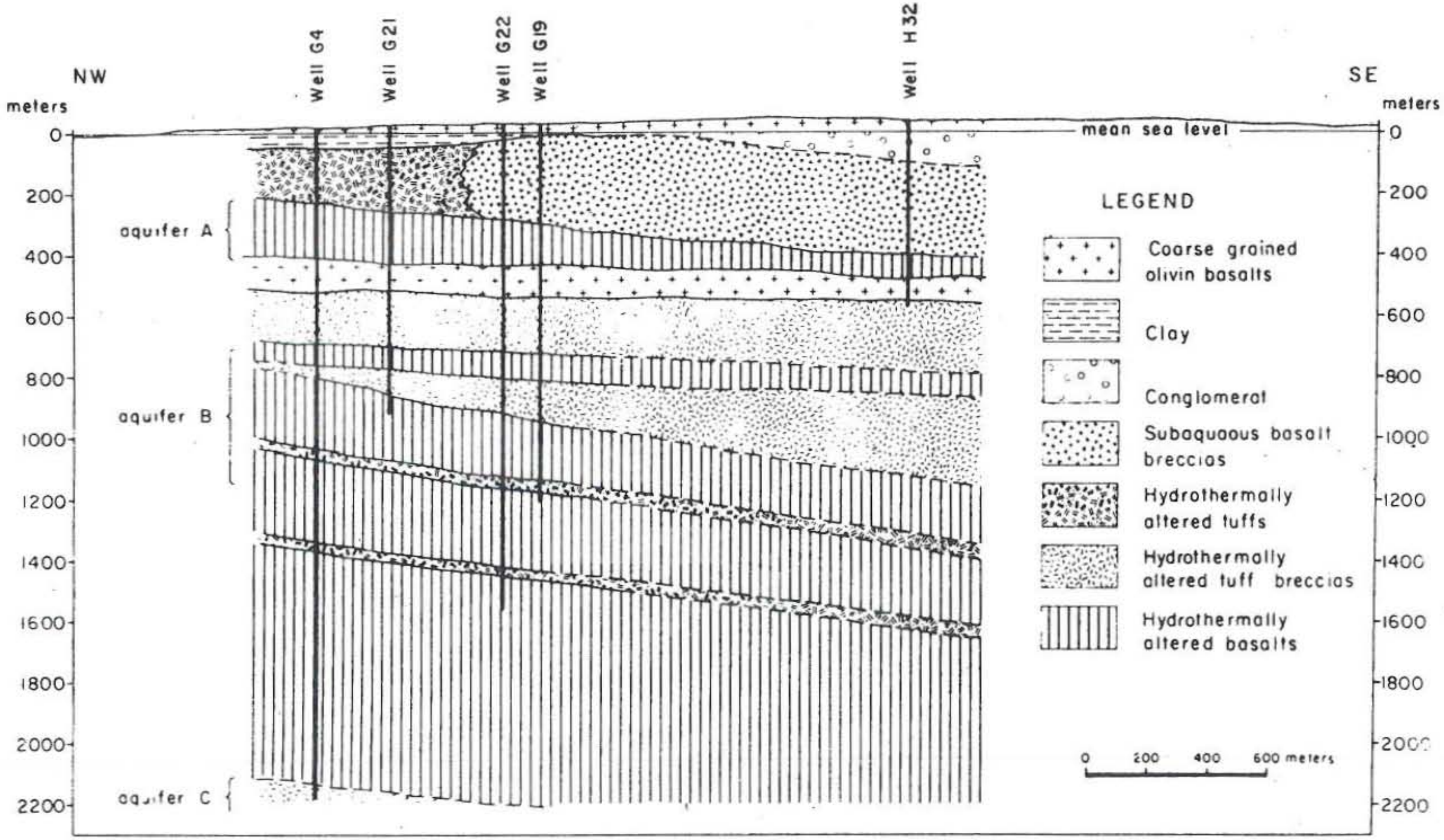

Fig. 2.2.– *Generalized NW to SE geologic cross-section through the Laugarnes area.*
(Thorsteinsson and
Elíasson, 1970)

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A model of geothermal water in Mosfellssveit.
(Zhou Xi-Xiang, 1980)

80.09.09
ZHOU/EBF
HSÞ Mosfellssv
F-20011.

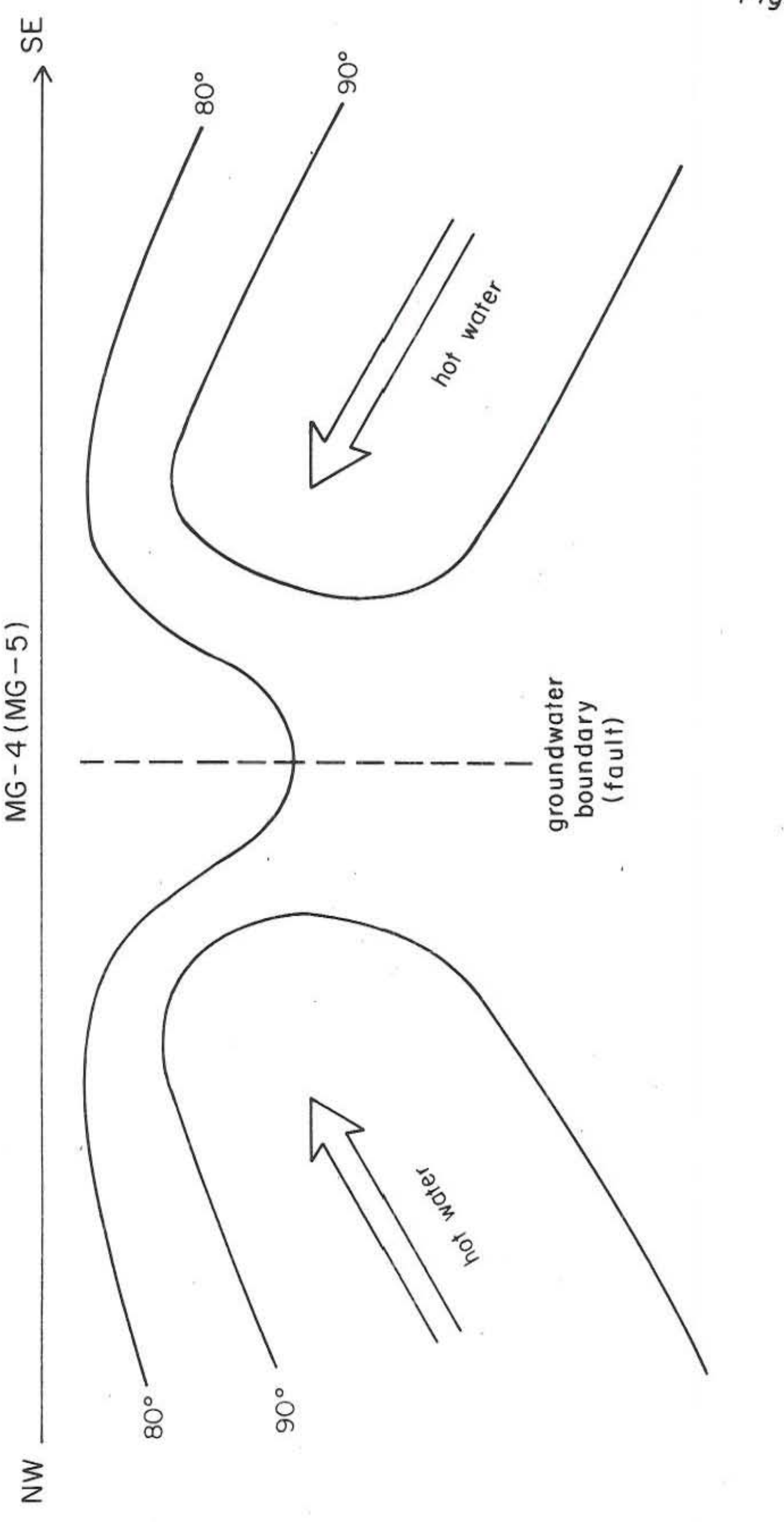


Fig. 2.3

JHD-HSÞ-IIII-HiH
84.08.0927. ÓD

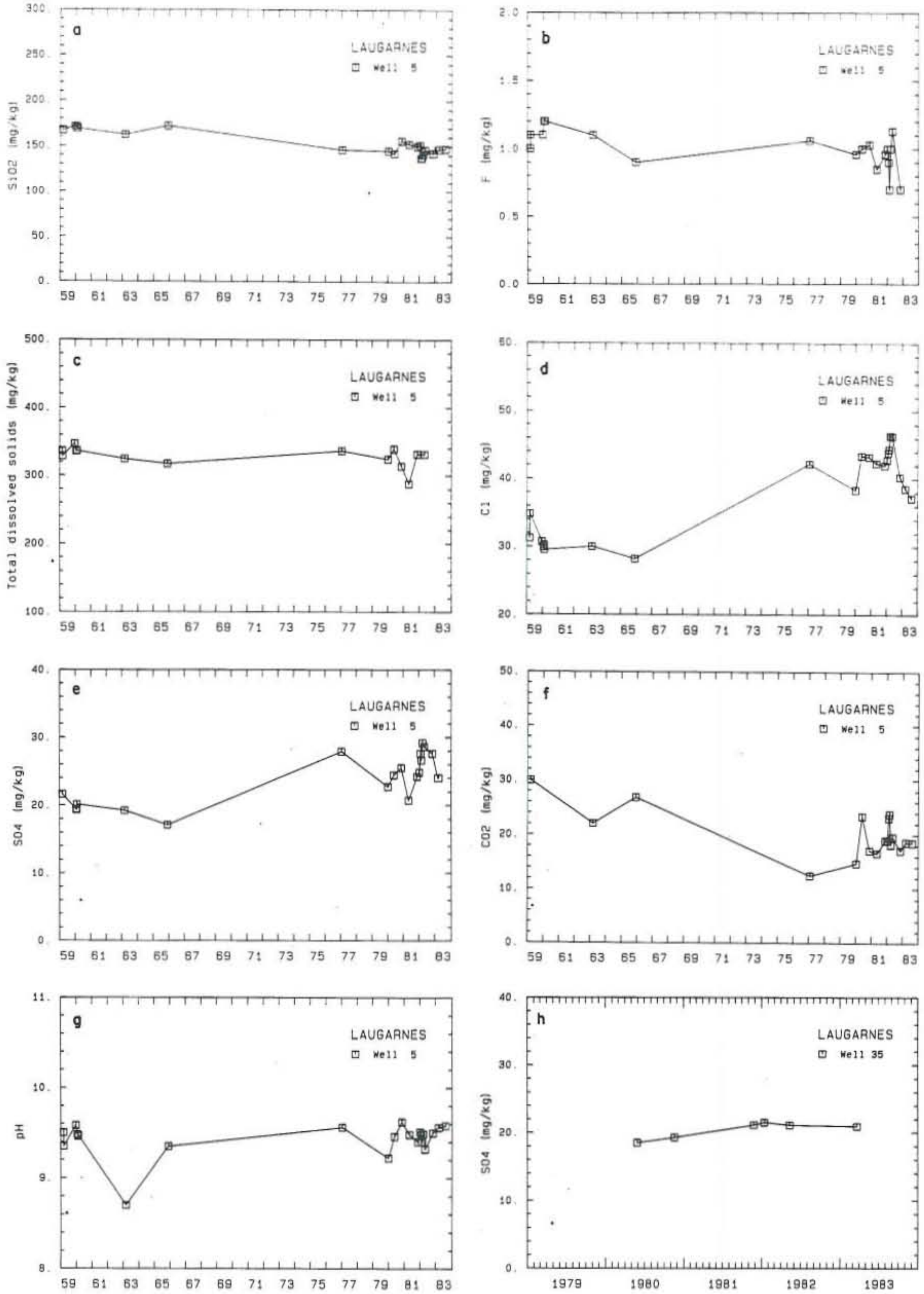


Fig. 3.1. a–h: Different chemical components versus time; Laugarnes area

JHD-HSP-IIII-HiH
84.08.0927 T-'OD

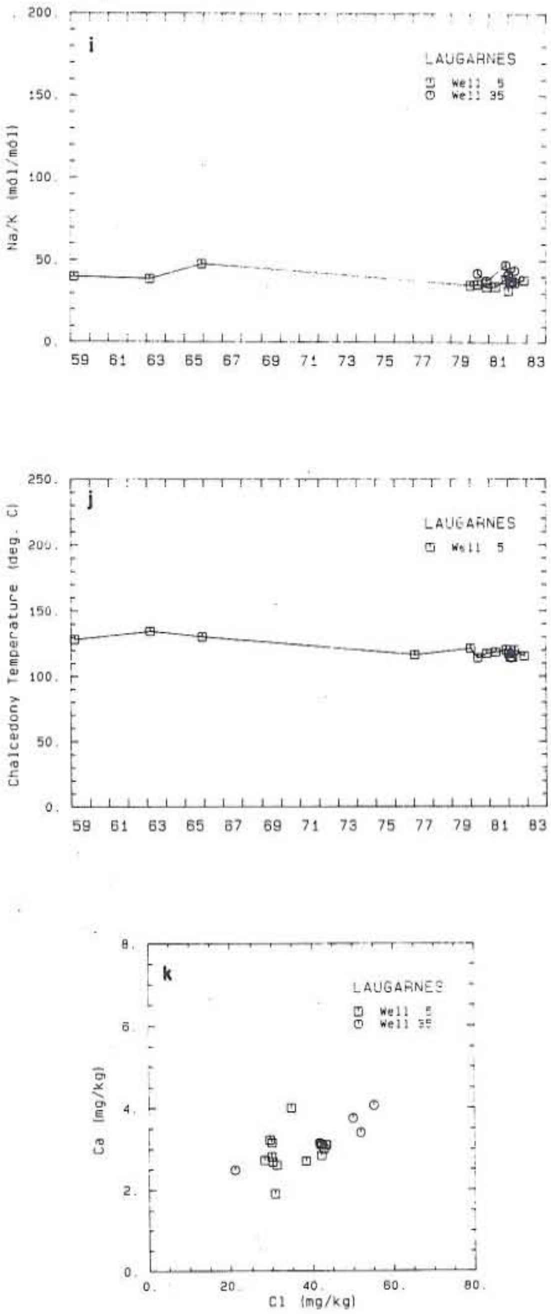


Fig. 3.1.i: Na/K -ratio versus time, j:chalcedony temperature versus time. k: Ca versus Cl, Laugarnes area

JHD-HSÞ-IIII-HiH
84-08-0928.T-ÓD

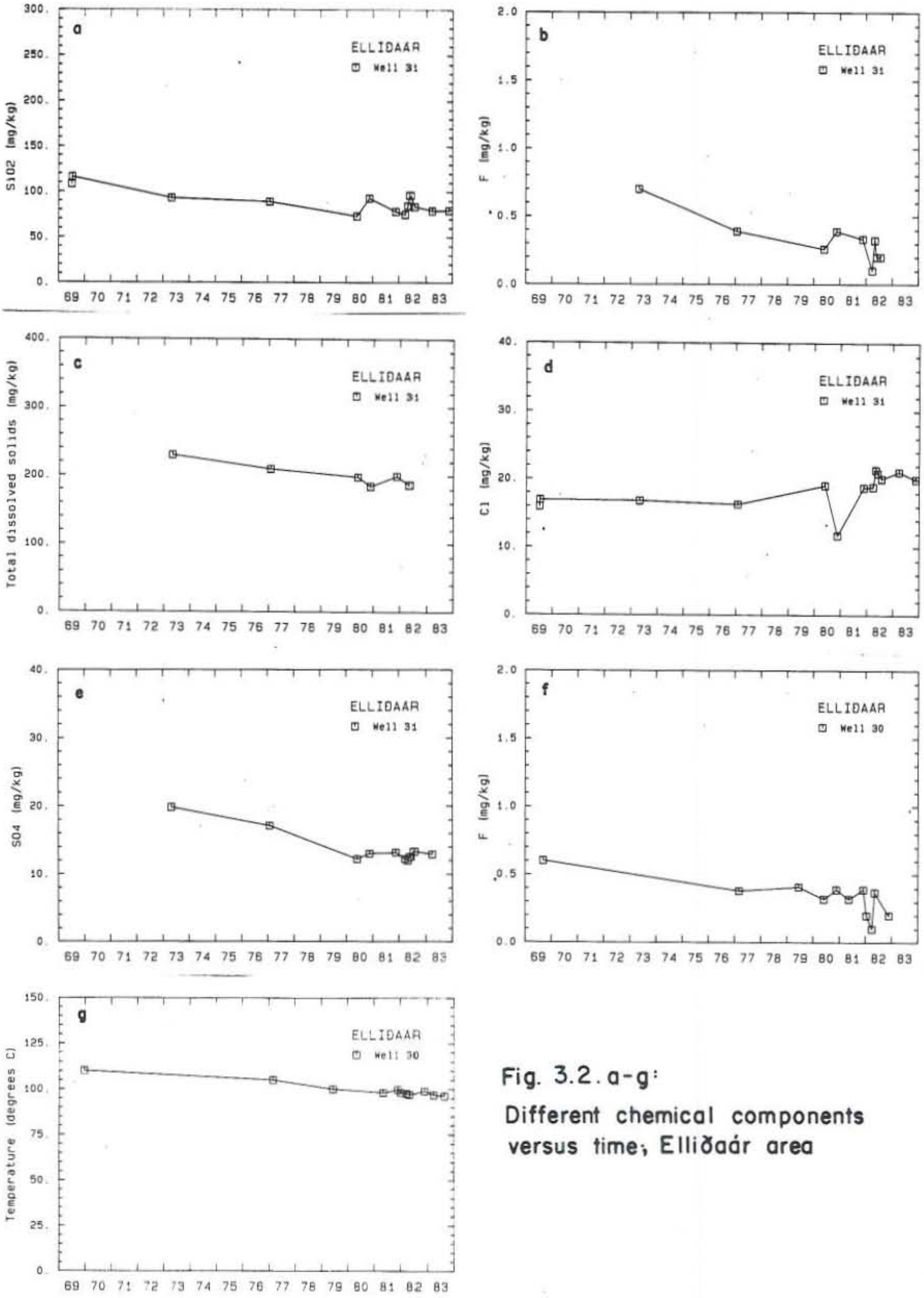


Fig. 3.2. a-g:
Different chemical components versus time; Elliðaár area

JHD-HSI--1604-HIH
84.07.0929.-T-OD

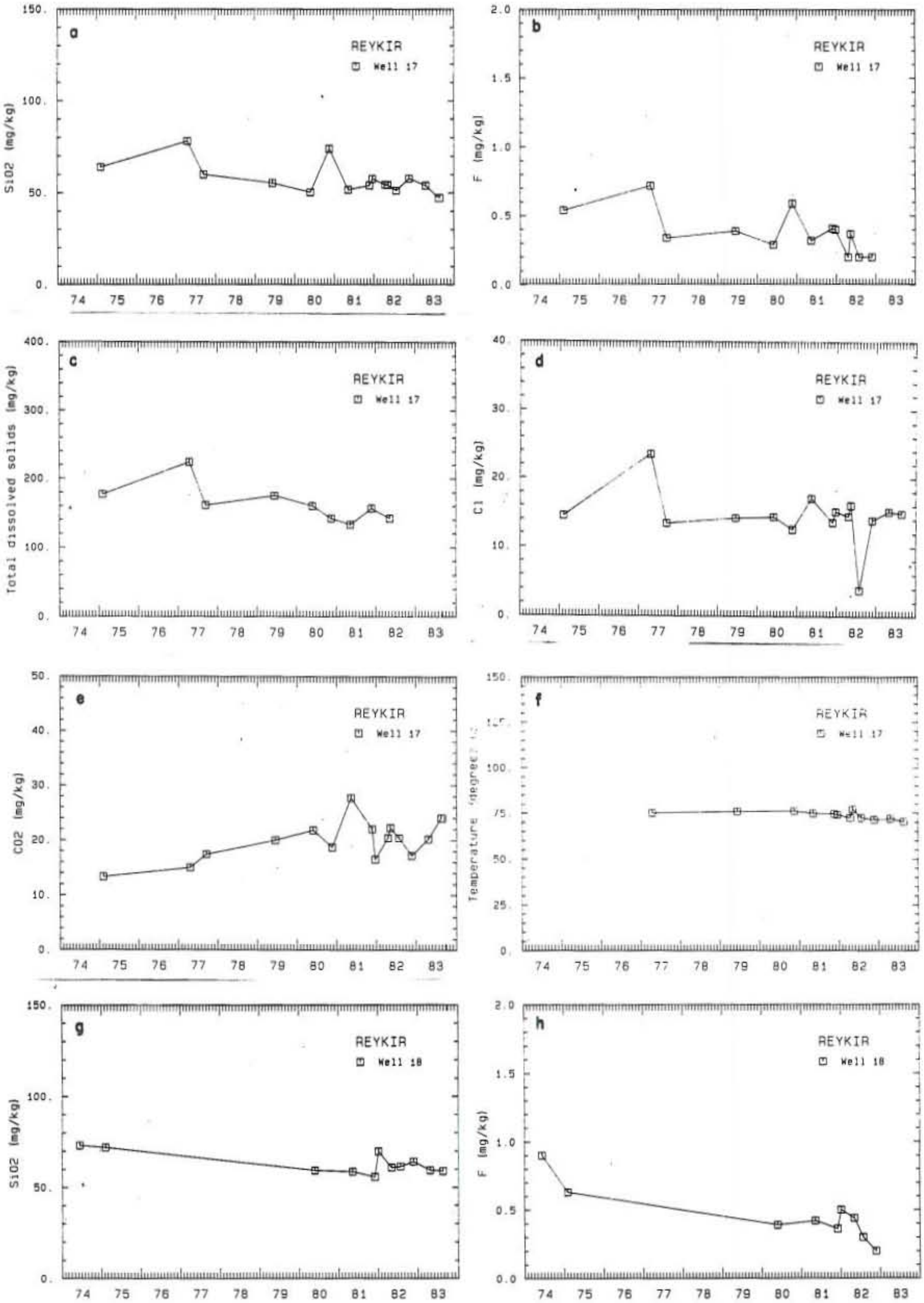


Fig. 3.3. a–h: Different chemical components versus time; Reykir area

JHD-HSÞ-1604-HiH
84.08.0929. T-'OD

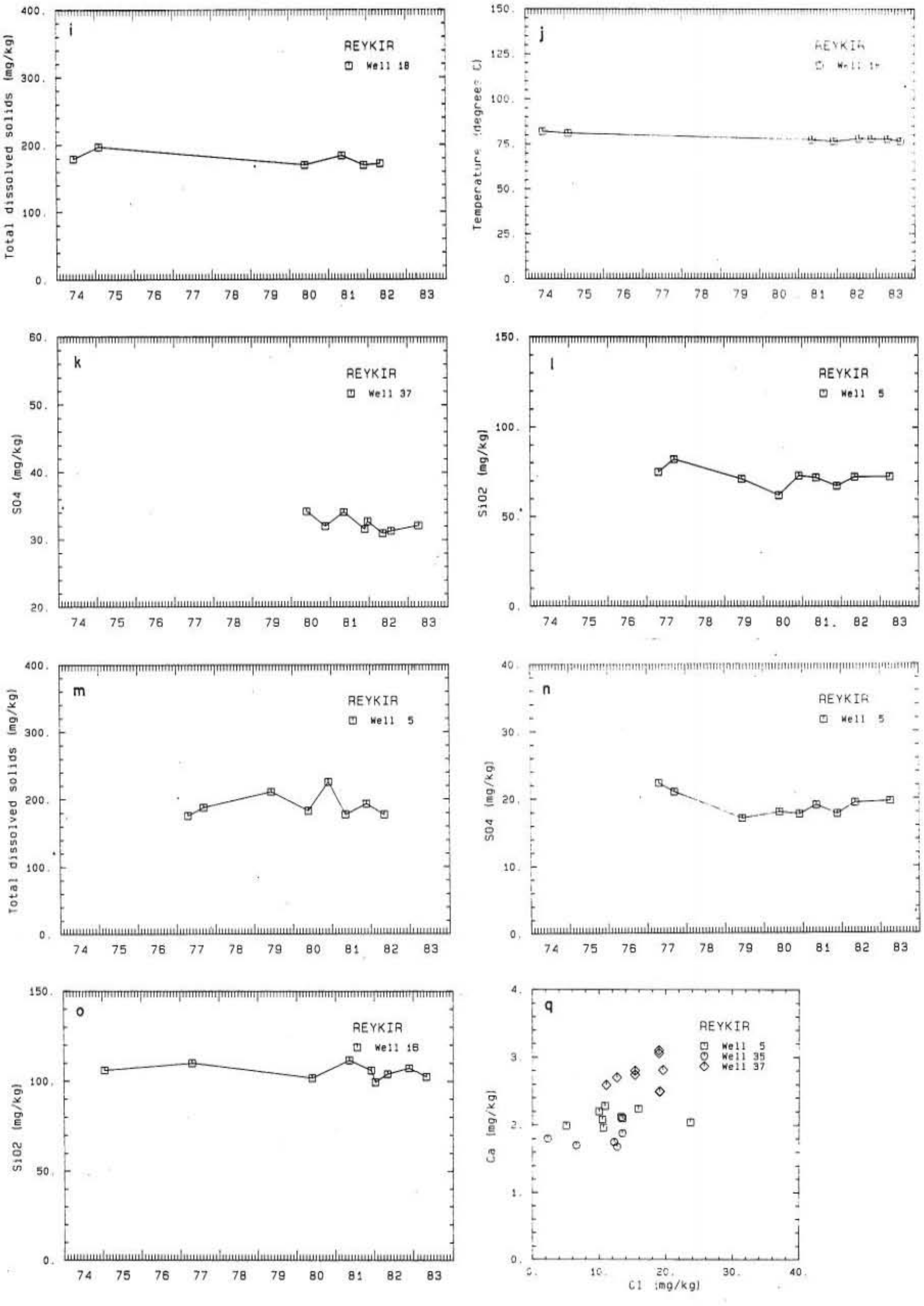
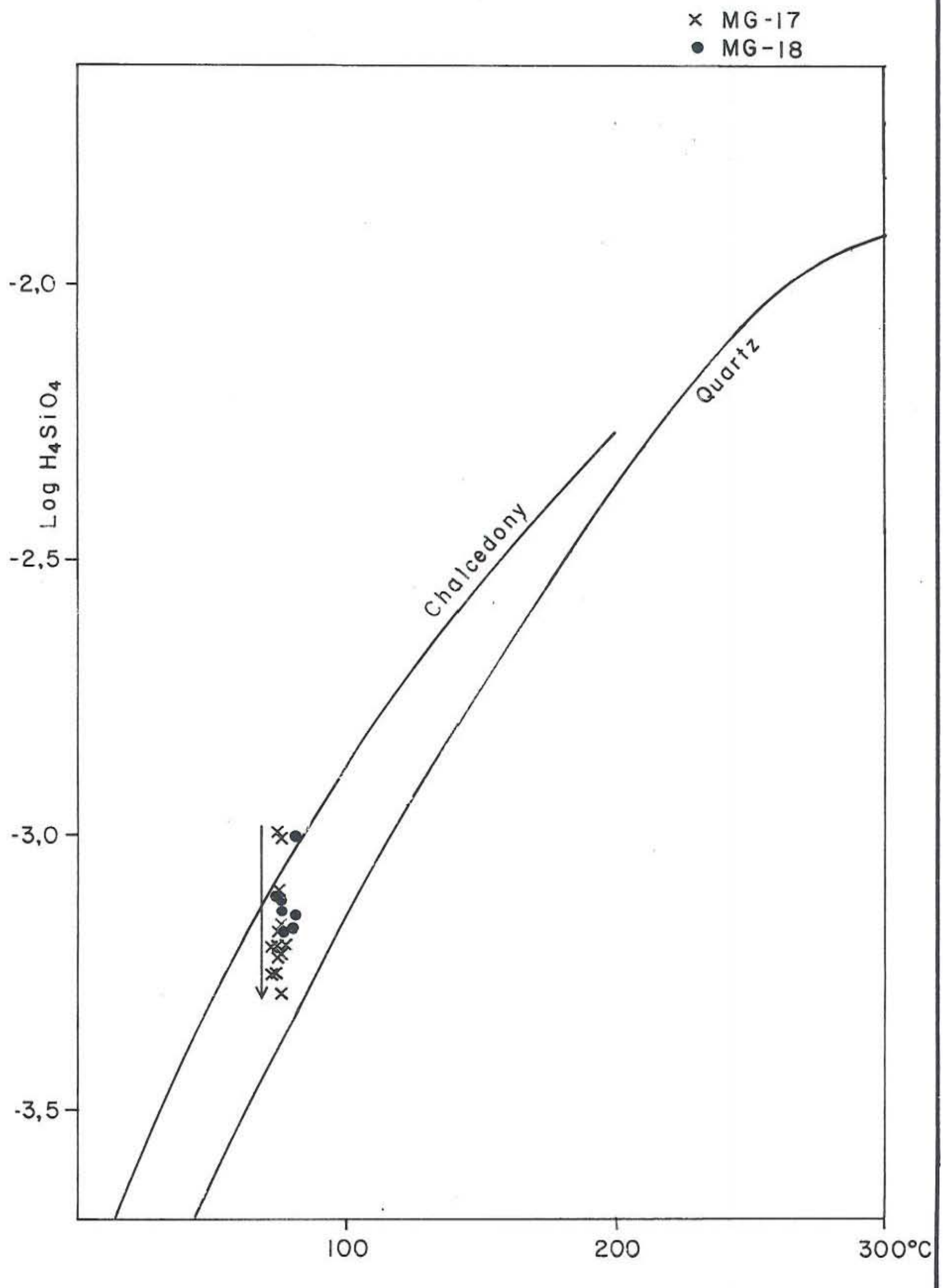


Fig. 3.3. i – o: Different chemical components versus time,
q: Ca versus Cl; Reykir area

JHD-HSþ-1604.HiH
84.08. 0923. SyJ

Fig 3.3.p

REYKIR WELLS MG-17, MG-18



JHD-HSÞ-IIII-HiH
84.08.0930.T-'OD

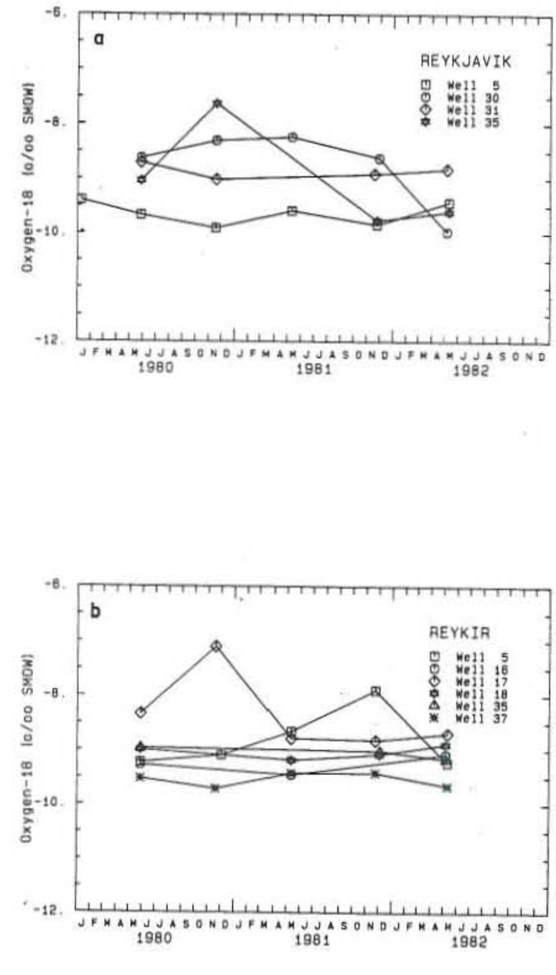


Fig. 4.1: Oxygen-18 versus time,
a: Laugarnes and Elliðaár area,
b: Reykir area

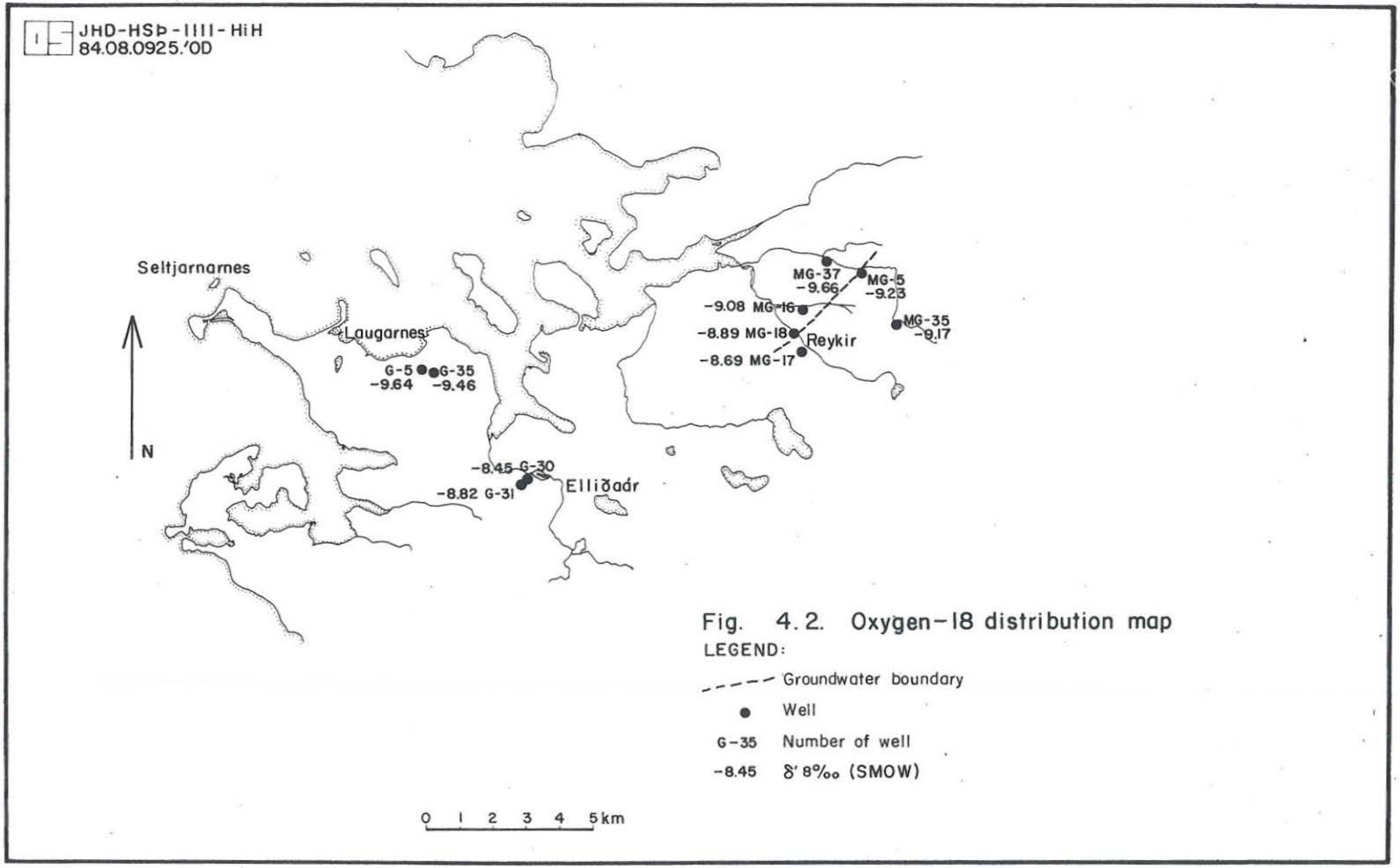


Fig. 4.2. Oxygen-18 distribution map

JHD-HSÞ-9000- HiH
84.08.0922.'OD

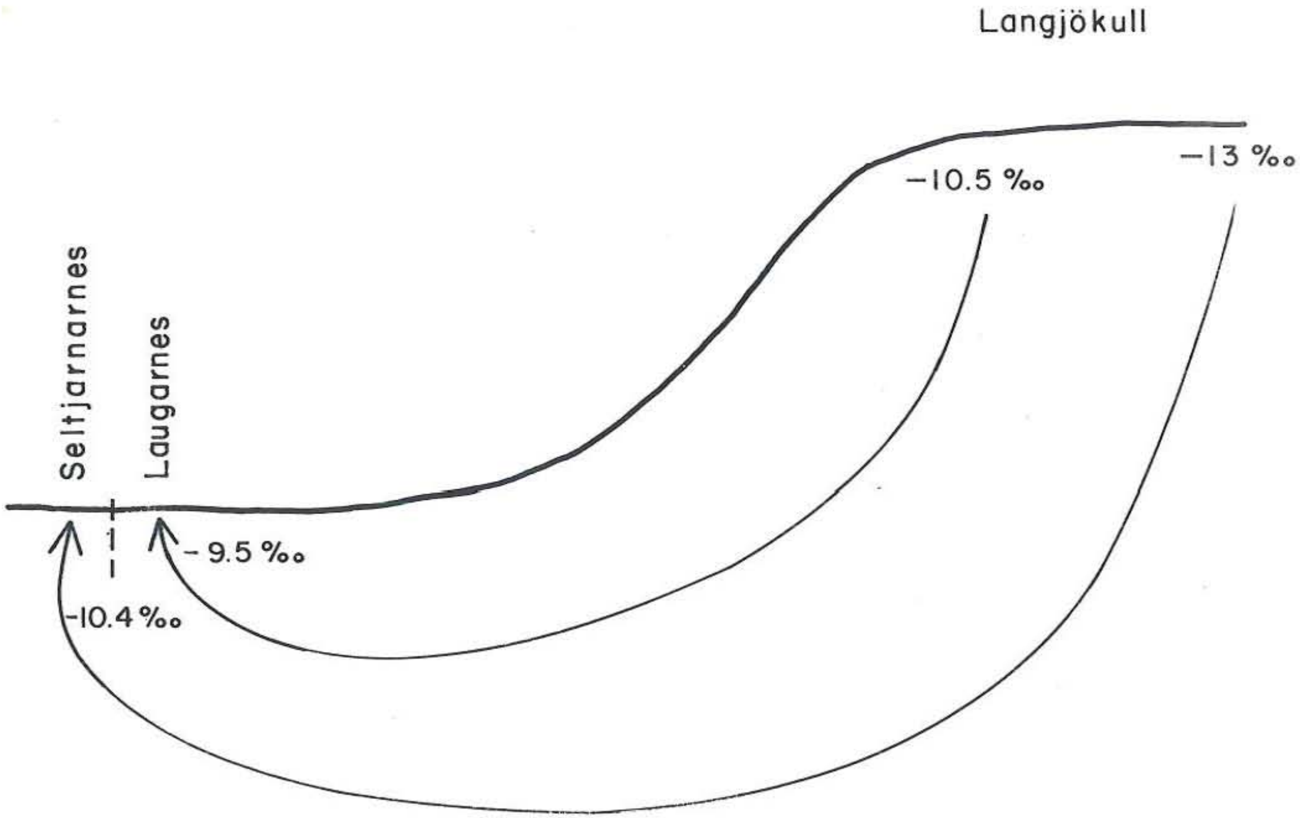


Fig. 4.3.

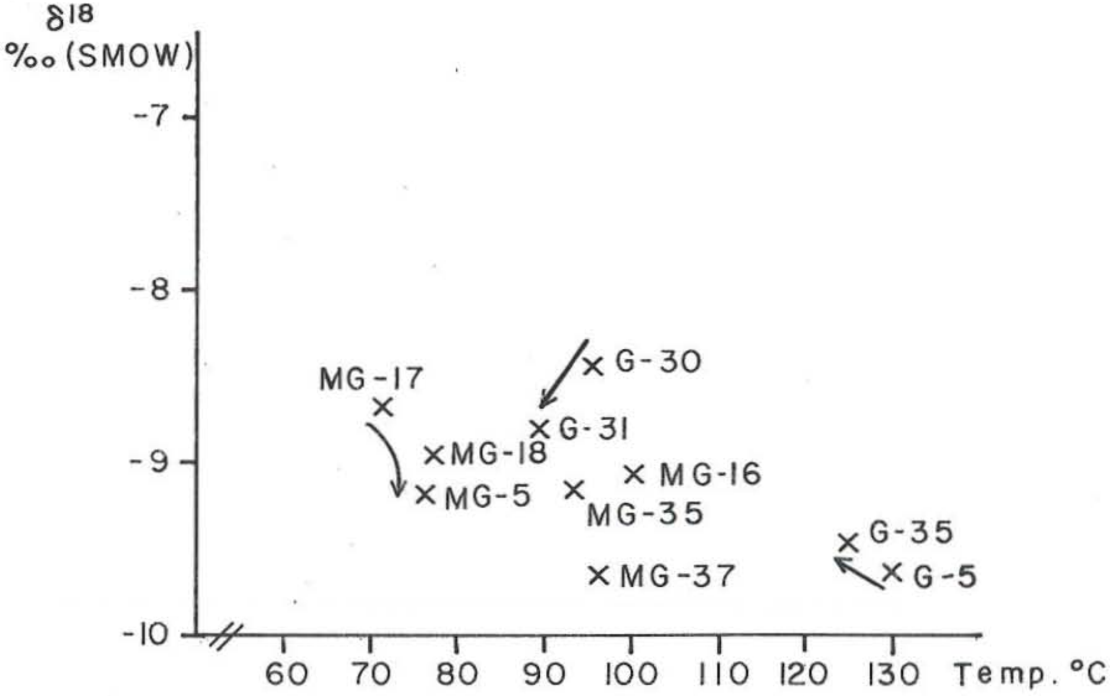
Schematic hydrogeological profile, arrows indicating possible groundwater flow systems distinguished with oxygen – 18.

Location of profile given in Fig. 2.1.

JHD-HSÞ-1604. HiH
84.08. 0921. SyJ

Fig. 4.4

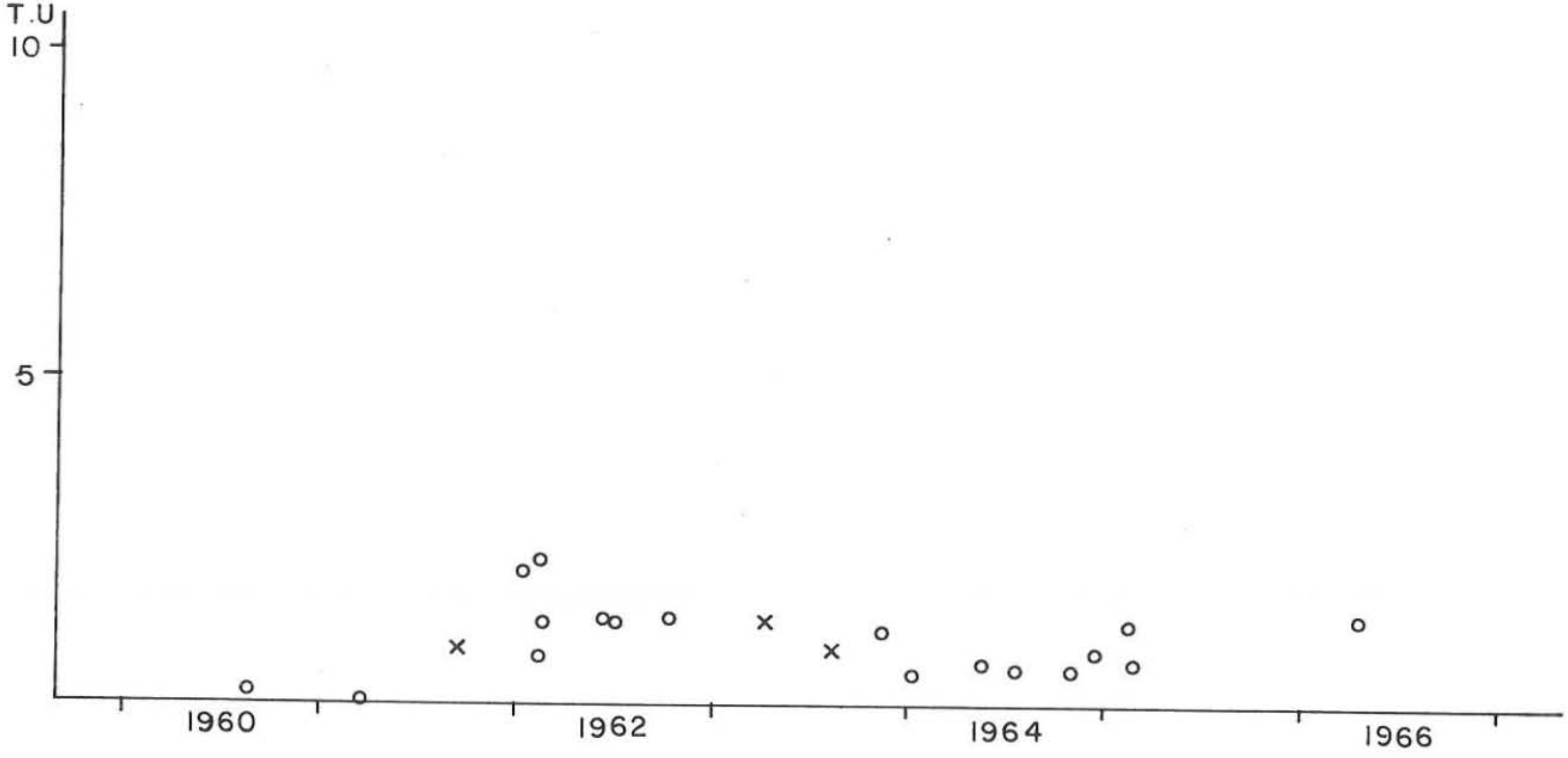
δ18 VERSUS TEMP. GROUNDWATER FLOW DIRECTIONS ARE INDICATED BY ARROWS



JHD-HSÞ-1111. HiH
84.08.0918. SyJ.

Fig. 5.1

LAUGARNES WELL G-4



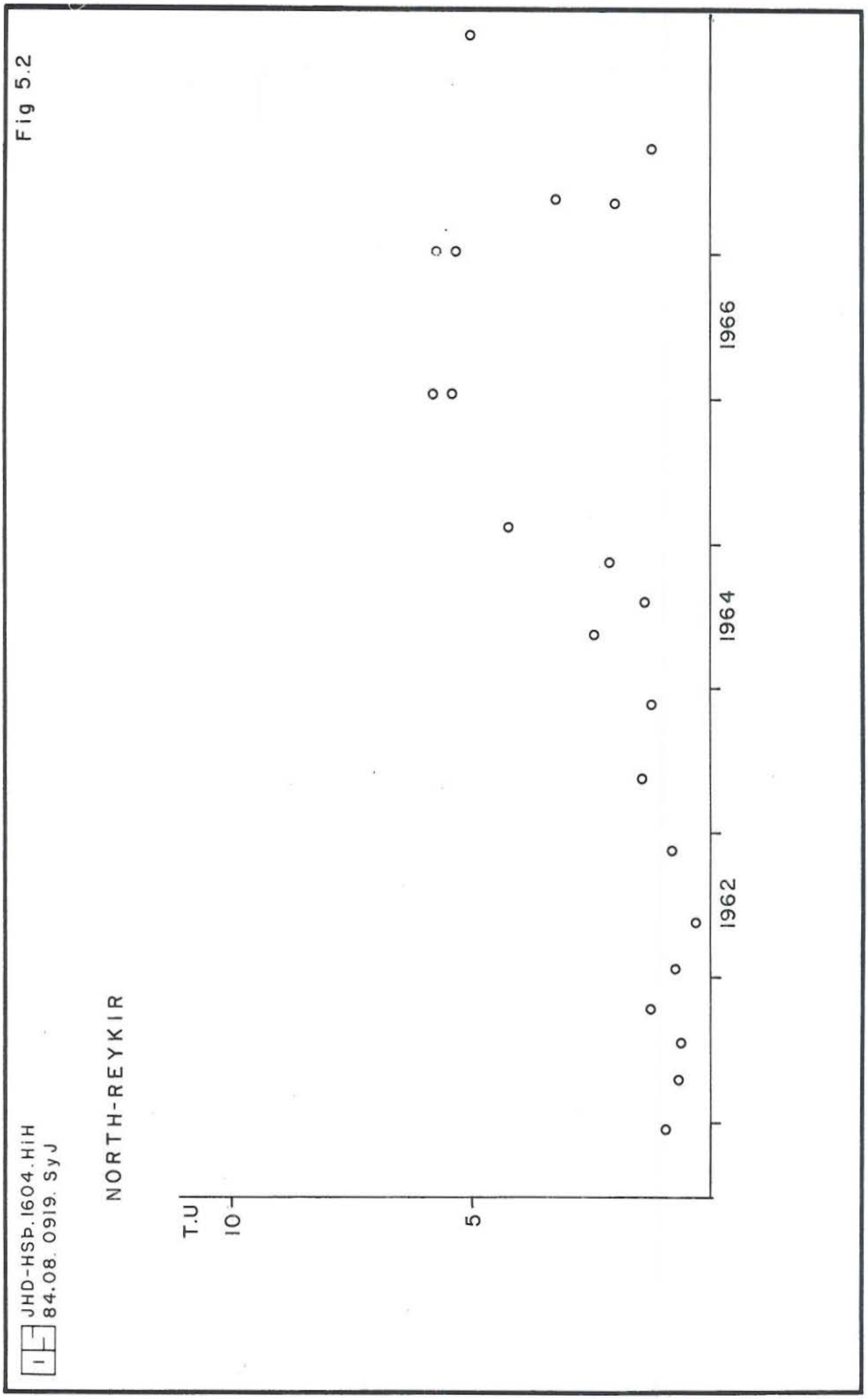


Fig 5.2

JHD-HSÞ.1604.HiH
84.08.0919. SyJ
NORTH-REYKIR
T.U
10
5
1962
1964
1966

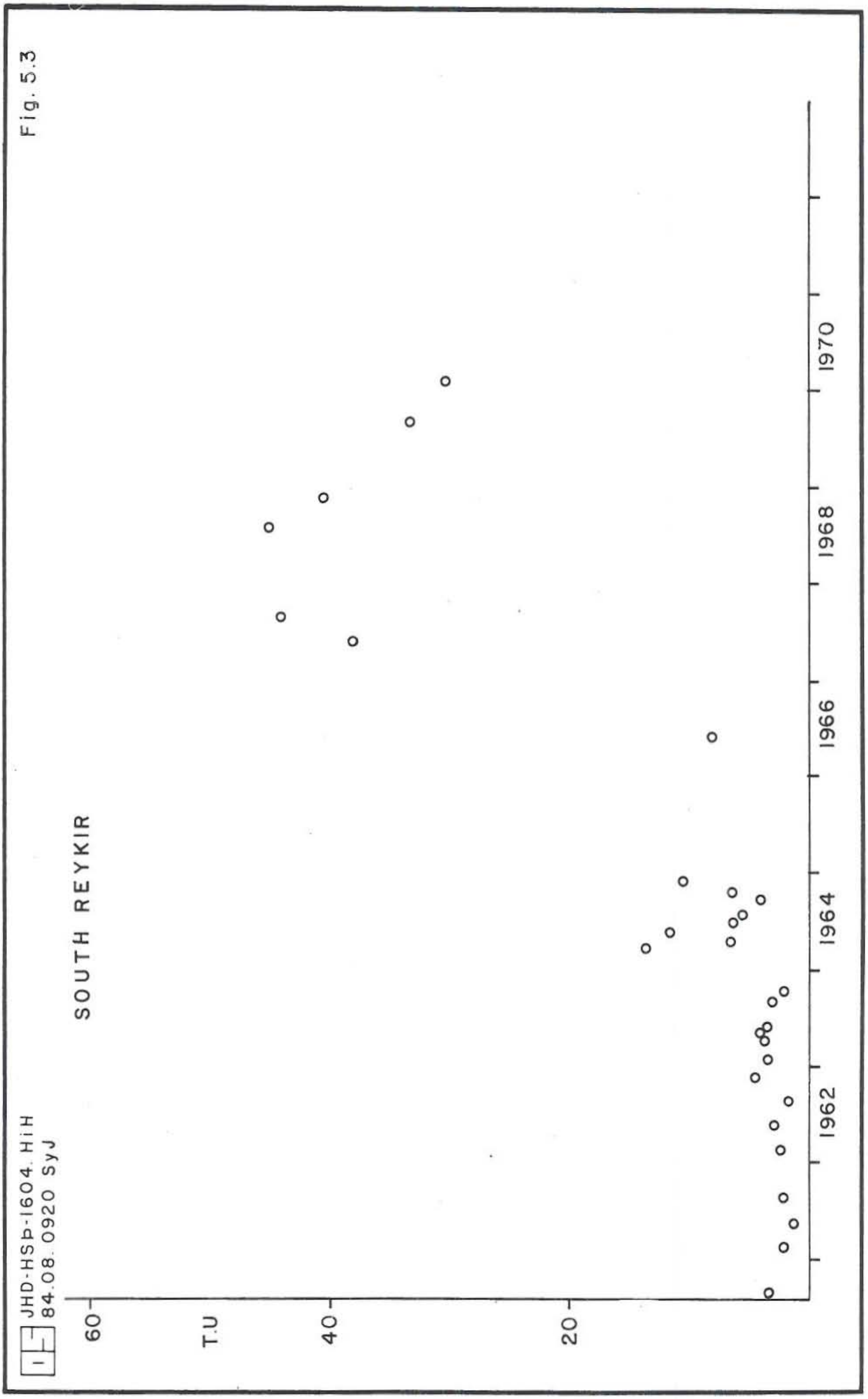

JHD-HSÞ-1604. HiH
84.08.0920 SyJ
SOUTH REYKIR
T.U
60
40
20
1962
1964
1966
1968
1970

Fig. 5.3

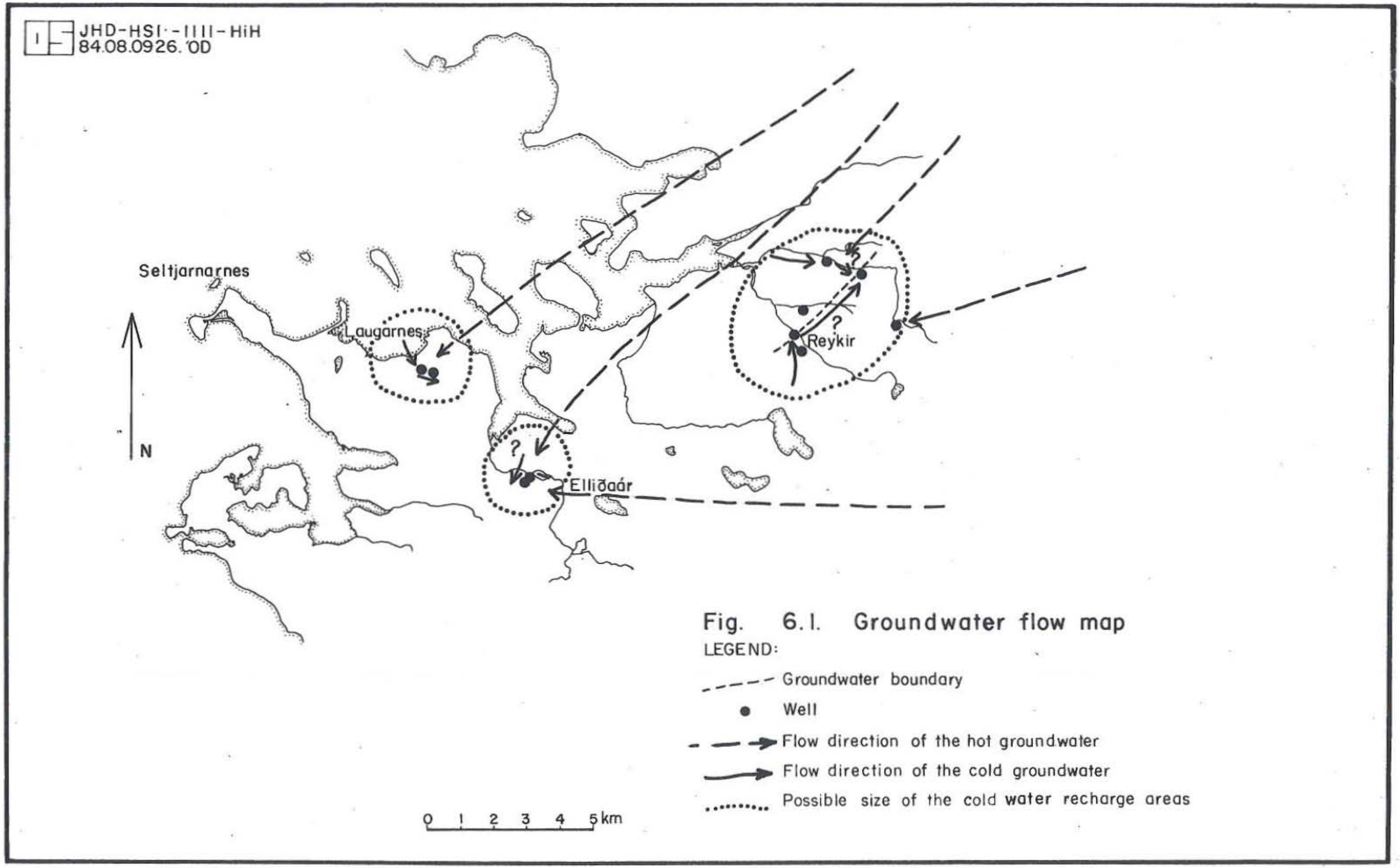


Fig. 6.1. Groundwater flow map