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Geochemistry and Origin of Geothermal Waters in NE Borgarfjördur, W-Iceland

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ABSTRACT

There is an extensive geothermal activity in the NE part of the Borgarfjördur region associated with an extensive earthquake activity connected with both the Western volcanic zone and the Snæfellsnes transverse zone. The reservoir temperatures are up to 150 °C. The main features in bedrock geology are Quaternary basaltic lavas, 0.8-3My old, closest to the active rift zone and Tertiary basalts older than 3My further to the west and north. Some postglacial lava-flows, younger than 11000y are encountered and both active and extinct central volcanos occur in the area. About once a year earthquake swarms of low magnitude with direction NNE-SSW connected to the western volcanic zone occur in the eastern part of the area. In the north and western parts earthquakes up to magnitude 6 have occurred. To the east on the border of the intern highland there are two big glaciers, Langjökull and Eiríksjökull. The hot springs in the Reykholtsdalur valley towards west appear to occur at the intersection of northwesterly oriented young faults and northeasterly trending faults or dykes. The Húsafell geothermal field in the eastern part is associated with an extinct central volcano and the thermal manifestations occur along a layer of acidic tuff. The westernmost part of the Húsafell hot spring area is of a different type and origin than the main geothermal field. Between those two fields are several others with lower temperatures. In the northern part of the area there is also extensive geothermal activity. There is a distinct difference in geochemistry of waters in the different geothermal fields and the recharge areas can clearly be differentiated by the stable isotope ratios. The water in most of the fields is classified as sulfate water with a few samples falling on the border line to bicarbonate water. The Húsafell water has the highest concentration of fluoride of any geothermal water in Iceland due to reaction with acidic rocks within the extinct central volcano. The recharge areas are both local and the glaciers and mountains in the eastern highlands.

1. INTRODUCTION

An extensive geothermal activity is found in the NE part of the Borgarfjördur region. The activity is due to an ongoing tectonic activity connected with both the Western volcanic zone and the Snæfellsnes transverse zone. There are many separate geothermal fields, connected with fracture zones and central volcanoes. The recharge is also from different sources as learned from studies of stable isotopes in the waters. The reservoir temperatures are up to 150 °C in the most active system. This paper reports studies of four of the systems, Reykholt, Húsafell, Stóriás and Kirkjuból, mostly performed during the last ten years and are still ongoing as there is increasing development in the area due to continuously growing tourism.

The main features in bedrock geology in the area (Figure 1) are Quaternary basaltic lavas, 0.8-3My old, closest to the active rift zone, interglacial hyaloclastite breccias and tuffs and Tertiary basalts older than 3My further to the west and north. The hills between the valleys are covered by ground moraines. Some postglacial lava-flows, younger than 11000 y are encountered and both active and extinct central volcanos occur in the area.

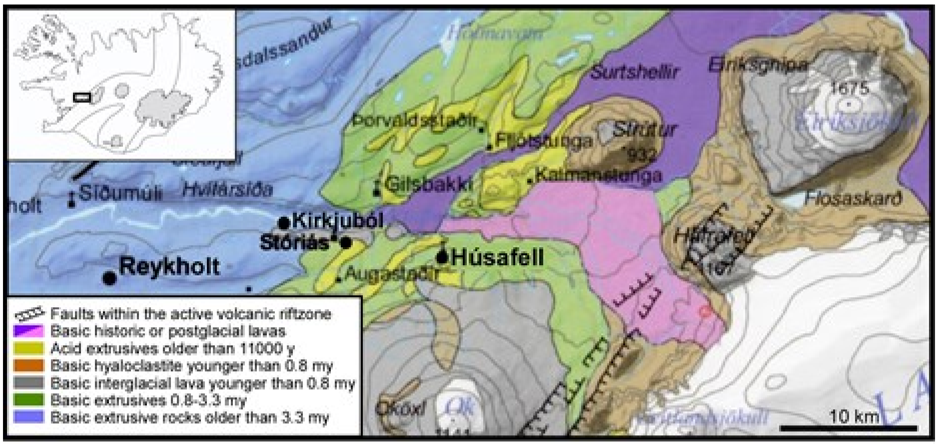

Figure 1: Geological map of the area, showing the location of the four sites studied; Reykholt, Húsafell, Kirkjuból and Stóriás. The location of the area is indicated on the map of Iceland shown in the upper left corner. Modified from Jóhannesson, and Saemundsson (2009).

The tectonic systems are quite complicated and there has been an extensive earthquake activity in recent times (Einarsson et al., 1974). About once a year earthquake swarms of low magnitude with direction NNE-SSW connected to the western volcanic zone occur in the eastern part of the area. In the north and western parts earthquakes up to magnitude 6 have occurred, connected to the

Snæfellsnes transverse zone. The western margin of the geothermal surface manifestations in Borgarfjördur appear to coincide with the Borgarnes anticline (Georgsson et al., 1984).

To the east on the border of the intern highland there are two big glaciers, Langjökull and Eiríksjökull.

2. GEOTHERMAL FIELDS STUDIED

The geothermal systems in the area and the geochemistry of the waters have been studied by many scientists through time as compiled in Georgsson et al. (1984) and Kristmannsdóttir et al. (2005a). Many of those studies have not been published internationally, only in Icelandic reports. There exist chemical analyses from springs in Borgarfjördur from early last century, but the first analysis of a comparable quality to present day analyses are from 1949 for the Reykholt field and from 1967 for the Húsafell field (Kristmannsdóttir et al., 2005a). During the last years especially the fields at Stóriás, Húsafell and Kirkjuból have been under development and new data collected, both from springs and new wells. There have been drilled several new wells and drilling and exploration are ongoing. New wells have also been drilled in the Reykholt field, the last one in 2018. In this paper studies from those four geothermal fields are reported. Especially from the eastern part of the area there are reported more detailed geochemical studies than previously published as well as studies of the origin and complicated connection between the fields.

2.1 Reykholt

The Reykholt geothermal field (Fig. 1,2) is believed to be the largest and most active low temperature geothermal field in Iceland covering an area of almost 300 km^2 (Georgsson et al., 1984). It is located in Tertary basaltic lava formations older than 3.3 My. The center and main upflow zone of the field is in Reykholt-Kópareykir (Figure 2).

Figure 2: A map showing the relative location of the four geothermal fields studied as well as some more details of the Reykholt geothermal field, temperature range and yield of the natural springs. Modified from Georgsson et al. (1984).

The Reykholtsdalur valley was transgressed by the sea after the last glaciation and the sediments in the lowlands are probably a mixture of fresh water and marine deposits. Older geothermal precipitations are also encountered indicating higher temperatures than at present. The reason for the extensive geothermal activity is the ongoing tectonic activity opening up the faults and fractures in the area. The hot springs in the Reykholtsdalur valley appear to occur at the intersection of northwesterly oriented young faults and northeasterly trending faults or dykes (Georgsson et al., 1984). The activity of the Reykholt geothermal field varies with time and is believed to depend mostly on the intensity of tectonic activity and how recently there have been movement on faults opening up the water channels and enhancing circulation and heat mining of the geothermal systems. No long term monitoring of the total yield in the field has been made, but occasional observations show some changes with time (Georgsson et al., 1984, Kristmannsdóttir et al., 2005a).

Iceland's biggest hot spring, Deildartunguhver, is one of the active geothermal manifestations, yielding almost 200 L/s of boiling hot water. Numerous wells have also been drilled in the Reykholt geothermal field, the last one at the Reykholt site in 2018. Half of the water from Deildartunguhver is piped to the towns Akranes and Borgarnes for the use in a municipal district heating system 40 km and over 70 km away, respectively. A big luxury spa is also heated by water from Deildartunguhver. Nearly all farmhouses in the Reykholtsdalur walley are heated by geothermal water. In the Reykholt village all houses, a church, a museum, an old school as well as a hotel and many greenhouses are heated by geothermal water from wells in Reykholt. Still only a fraction of the resources are utilized.

2.2Húsafell

The Húsafell geothermal field is associated with an extinct central volcano (Saemundsson and Noll, 1974, Georgsson et al., 1984). The thermal manifestations appear in seven main locations (Figure 3). In the eastern part the springs are connected to a northerly fault whereas in the western part of the area the springs occur along a border of a layer of acidic tuff and basaltic lava (Figure 4). Fractures cutting this border are the main upflow zones of geothermal water. The hot springs yield water of temperature 22-61,5 °C and the total flow was measured as 19 L/s in 1981 (Haraldsson and Georgsson, 1981).

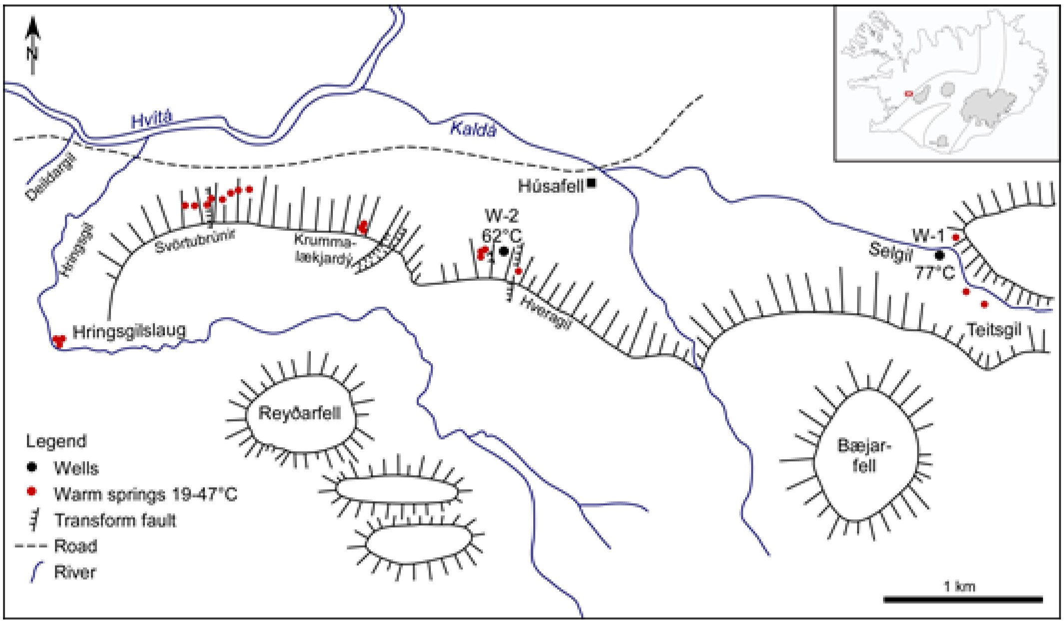

Figure 3. A map showing the thermal manifestations in Húsafell. Modified from Haraldsson and Georgsson (1981) with later information.

Figure 4: A picture taken soon after the first snowfall in autumn in Húsafell showing clearly the geothermal manifestations in the hill just west and south of the farmhouse (not in the picture). The dark line up in the hill shows the border of a layer of acidic tuff along which the geothermal water flows.

Two deep wells have been drilled in Húsafell. One well, 418 m deep, was drilled in the easternmost part in 1986 and yielded 21 L/s of 77 °C hot water (Björnsson and Kristmannsdóttir, 2003). Another well, 606 m deep, was drilled in the western part of the field in 2002, up in the hill just west of the farmhouse and was oriented 30° diagonally into the mountain (Sæmundsson, 2002). That well yielded 20 L/s of 62 °C hot water. Both wells are artesian.

The group of springs farthest towards the west, Hringsgil, occur in a deep gully cutting a rhyolicic columnar formation (Figure 5).The latest wells in Húsafell were drilled there in 2016-2018. In all there were drilled 9 shallow wells, 120-220 m deep, near to the Hringsgil spring. None of the wells did hit any main upflow zone, even though the last one gave about 4 L/s of 46 °C hot water by pumping, whereas previous digging into the hottest spring yielded about 1 L/s artesian of 42 °C hot water. From the drilling experience it is assumed that the water is an effluent along a fracture or horizontal layer from another geothermal field.

There are no available records of possible changes in activity through time in the Húsafell field and there have not been measured any changes in the artesian yield of the two wells.

Figure 5: An overview of the Hringsgil gully towards north. A drill rig is drilling a well at the location of the warmest geothermal manifestations, 42 °C.

In the Húsafell field the geothermal water from the two artesian wells and a hot spring is used for the heating of a holiday resort containing a hotel, about one hundred cottages, a swimming pool, numerous jaccussi pools as well as several farm houses, a sculpturs workshop and a fish farming plant. In Húsafell there has been a steady increase in tourism during the last ten years and drilling is ongoing in parts of the field and planned in others.

2.3 Stóriás

Áslaugar is a row of hot springs located within the property of the farm Stóriás (Figure 1, 2) on a hill NE of the farmhouse. Connection to geological features is not clear, but probably the field is connected to NE lying faults. The highest measured temperature in the spring is almost 74 °C. There have been drilled several shallow wells near to the hot springs. A 203 m deep well drilled in the year 2003 almost at the spot of the hot spring yields almost 40 L/s artesian of 77 °C hot water, (Björnsson and Kristmannsdóttir, 2012). The main aquifer was encountered at 202 m depth.

The water is used to heat the farmhouse as well as two groups of summerhouses in the neighborhood and a restaurant. Only a fraction of the artesian water is utilized.

2.4 Kirkjuból

At the farm Kirkjuból there are several lukewarm springs, of temperatures up to 29 °C, which appear to lie along two lines elongated towards northeast as observed by Georgsson and Björnsson (1985). From magnetic measurements made by those authors there appear to be two parallel faults cutting the area and that the geothermal system is connected to them. The present authors have identified crossing faults in the field and located a well accordingly. There have been drilled several shallow wells at the site, 60-150 m deep, but they have not hit warmer water than 32 °C, even though the chemistry indicates that the reservoir temperatures may be 60-70 °C. A study of all data from the field, geology and the results of drilling indicates that a well there probably needs to be over 200 m deep to hit a proper aquifer.

The luke warm water is utilized by a heat pump by for heating the farmhouses, as well as a hotel in a rebuilt barn and cowshed.

3. GEOCHEMISTRY OF THE WATERS

In table 1 are listed chemical analysis of typical geothermal waters from all the studied fields as well as data of the stable isotopes of hydrogen and oxygen. In general geothermal waters in the Borgarfjördur area are non saline and have thus rather low mineralization, with maximum TDS of around 400 mg/L (Kristmannsdóttir et. al., 2005a). The pH of the waters is generally lower than common for Icelandic low temperature geothermal waters or 9.2-9.4 (Kristmannsdóttir, 2004). The water in a few locations (Stóriás, Hringsgil, Kirkjuból) show higher pH. The water in the area is nearly all classified as sulfate water with a few samples falling on the border line to bicarbonate water (Kristmannsdóttir et al., 2005a). On a Giggenbach Na-K-Mg ternary diagram samples from Húsafell and Reykholt fall near the line for fully equilibrated waters and samples from the other fields fall within the zone of partially equilibrated waters, indicating mixing with cold groundwater (Kristmannsdóttir et al. 2005a). The recharge areas of the geothermal fields are clearly differentiated by the stable isotope ratios, with the range of -90 to -72.5 for δH^2 ‰ and -12.2 to -10.06 (Figure 6).

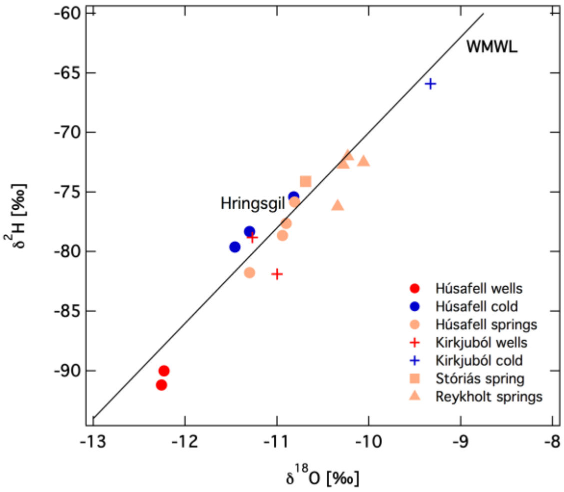

Figure 6. δ^2H plotted against δ^{18}O for the geothermal water in the area. The location of the world meteoric line (Craig, 1961) is shown for comparison.

Table 1: Chemical analysis of typical waters from all the studied fields

Location	Reykholt	Stóriás spring	Húsafell W-1	Húsafell spring	Krumma-lækjardý spring	Svörtu-brúnir spring	Hringsgil spring	Kirkjuból well 1
Temp.°C	100	73.8	76.7	36.8	25,1	21,5	40	29
pH°C	9.25/24	9.75/24	9.32/24	9.43/20	9,33/20	9,37/21	9,83/20	9.84/22
SiO_2 mg/L	171.9	100.2	79.8	38.4	28.3	38.4	107.8	74.0
B mg/L	0.29	<0.20	0.42	0.17	0.16	0.13	0.10	0.18
Na mg/L	81.8	49.3	88.0	44.8	39.9	40.3	50.8	58.1
K mg/L	3.6	0.99	1.6	0.43	0.30	0.19	0.43	0.24
Ca mg/L	2.2	1.7	4.7	4.7	6.4	2.9	2.0	2.2
Mg mg/L	<0.002	0.003	0.002	0.074	0.14	0.13	0.002	0.003
CO_2 mg/L	30.4	24.9	23.3	24.6	22.4	26.2	28.9	15.4
H_2S mg/L	1.52	0,12	0.34	<0.03	-	-	-	<0.03
Fe µg/L	7.0	1.5	5.0	7.4	1.02	8.56	<20	3.5
Al µg/L	276	93.2	58.9	1.64	3.58	9.87	12,0	10.8
Cond. µS/cm 25°C	419	242	502	229	210	195	227	346
Rn Bq/L	5.9	4.8	3.0	-	-	-	-	9.4
δH^2 ‰	-72.5	-74.1	-90.0	-81.77	-78.64	-77.62	-75.84	-78.8
$\delta^{18}O$ ‰	-10.06	-10.69	-12.23	-11.3	-10.94	-10.9	-10.81	-11.27
SO_4 mg/L	61.1	15.9	69.3	26.6	28.5	19.8	15.0	32.9
Cl mg/L	33.1	10.3	35.9	18.4	16.5	12.3	9.2	15.7
F mg/L	2.24	1.3	14.2	5.3	4.6	3.4	1.6	2.8
Tot. Diss. Sol. mg/L	382	195	308	151	136	131	201	194

3.1 Reykholt

The geochemistry of geothermal waters in the Reykholt geothermal field has been described in detail in several papers (Gunnlaugsson, 1980, Georgsson et al., 1984). The first comprehensive study of trace elements in geothermal waters from the Borgarfjördur region was made in 2003 (Kristmannsdóttir et al., 2005a). The geothermal water at Reykholt in the main upflow

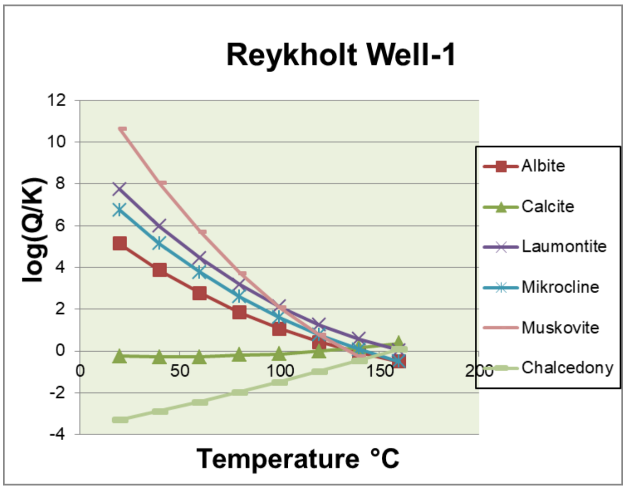

Figure 7: The relation between calculated activity products in the water from well 1 in Reykholt and corresponding equilibrium constant for the formation of selected alteration minerals (log Q/K) against temperature.

zone of the field (Table 1) has the highest concentration of dissolved solids of waters in the area. The pH of the waters in Reykholt is around 9.3 as common for boiling water in similar geological settings (Kristmannsdóttir et. al., 2005b). The silica concentration is high, and calculated silica geothermometer temperatures are about 140°C for the chalcedony geothermometer and around 160°C according to the quartz geothermometer. Alkali-feldspar geothermometers give slightly lower reservoir temperatures of about 130-140°C. Log Q/K diagrams of the water as shown in Figure 7 reveals that it is in near equilibrium with the expected alteration minerals and that the reservoir temperature is around 150°C as most of the lines cross at 0 at that temperature.

The waters from the Reykholt geothermal field have δH^2 ‰ about -72,5 and $\delta^{18}O$ ‰ of about -10.0 indicating a rather local origin according to the Deuterium map of Árnason, (1976). There is observed a slight oxygen shift for the waters from Reykholt, indicating an extensive water-rock reaction at those relatively low temperatures.

3.2 Stóriás

The geothermal water in Stóriás (Table 1) has much lower concentration of dissolved solids than the water in Reykholt field. Due to lower temperature silica concentration is lower, as well as aluminium. The water in a Stóriás has higher pH than the water in the Reykholt field or around 9.8 as is to be expected in geothermal waters below boiling reacting with basaltic rocks. Sulfate and chloride are in distinctly lower concentration as well as the main cations, sodium, potassium and calcium. The concentration of silica is high and the chalcedony geothermometer indicates reservoir temperature of 80-85 °C. A log Q/K diagram for the water from Stóriás (Figure 8) does not show as good equilibrium as for the Reykholt water, but indicates reservoir temperatures of about 75 °C and some mixing with colder water.

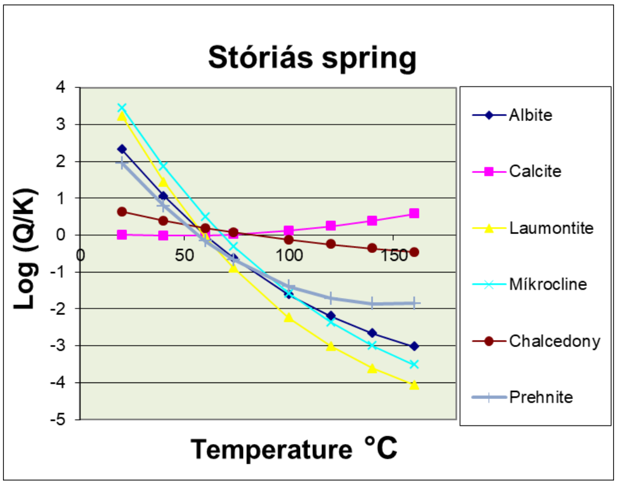

Figure 8: The relation between calculated activity products in the water from Stóriás and corresponding equilibrium constant for the formation of selected alteration minerals (log Q/K) against temperature.

The stable isotope ratios are somewhat lighter than in the Reykholt geothermal field, respectively -74.1 for δH^2 ‰ and -10.69 for $\delta^{18}O$ ‰. The origin of the water from Stóriás is probably from the mountain areas to the south and west of the field as compared with the Deuterium map of Árnason , (1976).

3.3 Húsafell

The geothermal water from both the wells in Húsafell (Table 1) has somewhat lower concentration of dissolved solids than the waters in the Reykholtasdalur field. In Húsafell the pH is around 9.3, similar to that in Reykholt, which is lower than common for Icelandic low temperature geothermal waters of similar temperature as in Húsafell. Fluoride concentration is exceptionally high, actually the highest encountered in any low temperature water in Iceland (Kristmannsdóttir et al., 2005a). The only other field in Iceland with comparable high fluoride concentrations is the Geysir high temperature area (Pasvanoglu et al, 2000). The concentration of sulfate is also high as well as chloride concentration. The concentration of alkali metals and several trace elements like boron is high as well. The concentration of silica in well 1 is about 80 mg/L and the chalcedony temperature is about 80 °C. A similar silica temperature was encountered in the springs in the eastern part of the field near to well 1 (Kristmannsdóttir, 1986). In well 2 and the springs near to it the concentration of silica and aluminium is lower due to lower temperature, but the chemical composition is otherwise similar. In the cooler springs to the west of the field occurring along the hill west and south of the farmhouse, like the Húsafell spring, Krummalækur and Svörtubrúnir springs (Figure 3, Table 1) the water has the same character as in the others, but seems to have mixed with cold groundwater. The chemical concentration of the water in Húsafell is very special as compared to low-temperature geothermal water in Iceland in general. This is due to the fact that the geothermal water has reacted with reservoir rocks in the extinct central volcano in Húsafell which are mostly rhyolitic (Kristmannsdóttir and Björnsson, 2017). A LogQ/K diagram og water from well-1 (Figure 9) shows a rather good equilibrium, indicating reservoir temperatures of 80-90 °C. For the colder springs more mixing is indicated (Figures, 10,11,12), although the Svörtubrúnir spring (Figure 11) seem to be in near equilibrium at about 40 °C.

The stable isotope ratios in the geothermal water in both wells and the warmest springs are respectively -90.0 for δH^2 ‰ and -12.2 for $\delta^{18}O$ ‰ indicating an origin of the water from northern part of the Langjökull glacier. In the western springs the water is heavier and mixed with more local water.

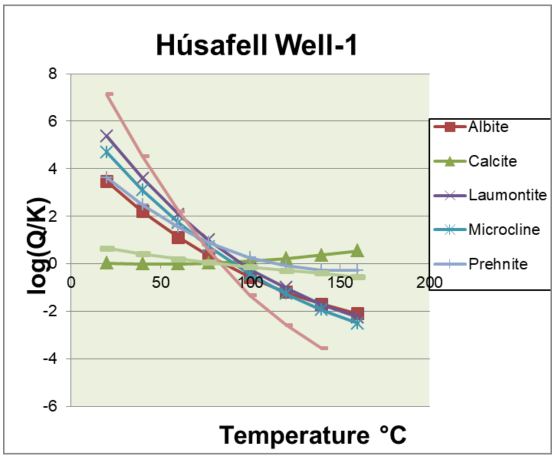

Figure 9: The relation between calculated activity products in the water from Húsafell and corresponding equilibrium constant for the formation of selected alteration minerals (log Q/K) against temperature.

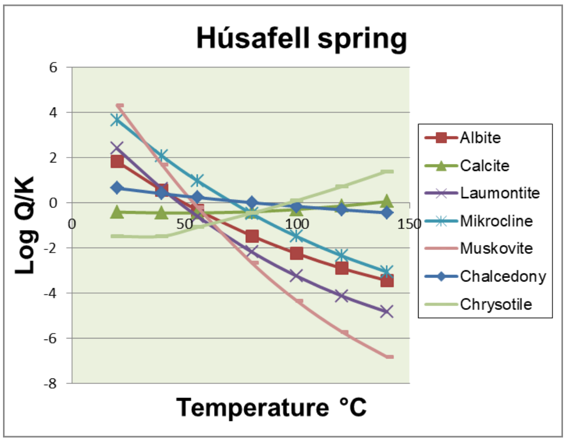

Figure 10: The relation between calculated activity products in water from a luke warm spring in the hill west of the Húsafell farmhouse, and corresponding equilibrium constant for the formation of selected alteration minerals (log Q/K) against temperature.

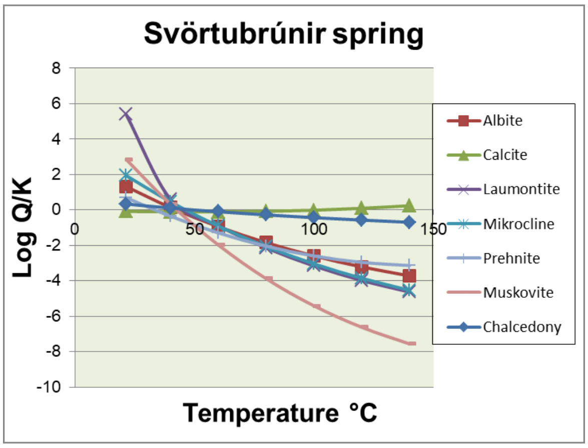

Figure 11: The relation between calculated activity products in the water from Svörtubrúnir spring and corresponding equilibrium constant for the formation of selected alteration minerals (log Q/K) against temperature.

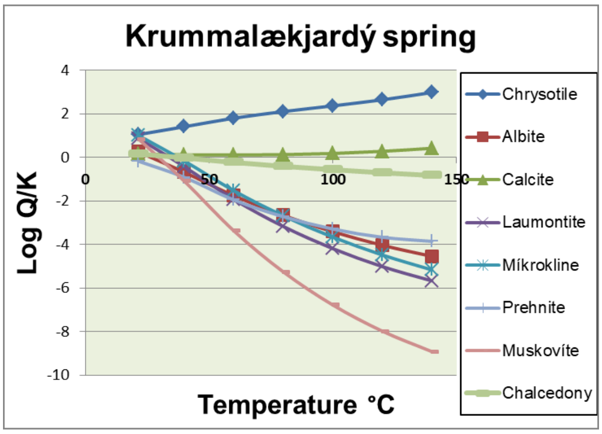

Figure 12: The relation between calculated activity products in the water from Krummalækjardý spring and corresponding equilibrium constant for the formation of selected alteration minerals (log Q/K) against temperature.

The water in the most western spring, Hringsgil is completely different from all other geothermal water in Húsafell. Total concentration of dissolved solids is lower, the pH is higher and fluoride concentration considerable lower as well sulfate concentration. Silica concentration is higher than in other geothermal water in Húsafell. The water is typical for geothermal water reacting with basaltic reservoir rocks. The stable isotope ratios are also different, -75.8 for δH^2 ‰ and -10.8 for $\delta^{18}O$ ‰, indicating an origin from the southwestern highland.

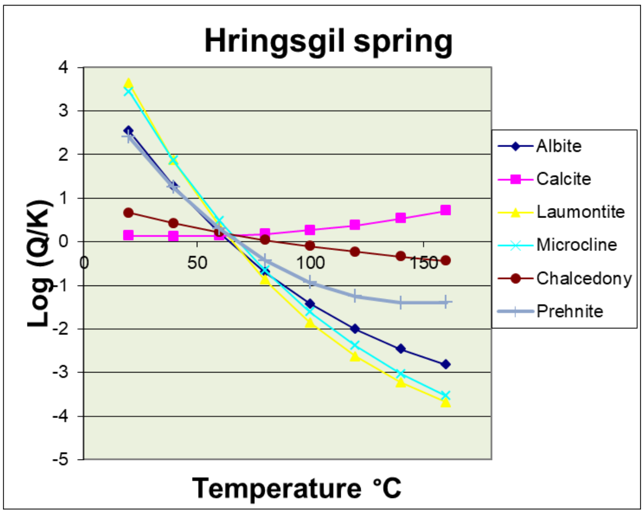

Figure 13: The relation between calculated activity products in the water from Hringsgil spring and corresponding equilibrium constant for the formation of selected alteration minerals (log Q/K) against temperature.

A comparison with water from the other fields shows that the Hringsgil water is very similar to that of Stóriás. The only difference is that the concentration of magnesium is a magnitude higher in the Hringsgil water than in the Stóraás water, which is typical for cooled water. Looking at the Log Q/K diagrams (Figures 8 and 13) they are also very similar and could almost be from the same analyses. Both the waters are of similar origin as shown by the stable isotope ratios. The Stóriás field is in over 10 km distance from Hringsgil so it is difficult to imagine a direct connection between those two, like an effluent discharge from Stóriás flowing to Hringsgil. No geological formations are encountered indicating a connection between the locations, but northeasterly fault zones are dominant in the area. A more probable explanation is that the Hringsgil water is a discharge from another unknown field of similar properties as the Stóriás field and connected to another northeastern fault zone.

3.4 Kirkjuból

The geothermal water in Kirkjuból (Kristmannsdóttir and Björnsson, 2015) has higher pH than the waters in Reykholt and Húsafell, but similar as the waters in Stóriás and Hringsgil (Table 1). Silica concentration very high considered to temperature and the chalcedony geotemperature is calculated to about 60 °C. The total concentration of dissolved solids is similar as in those fields and considerably lower than in Reykholt and Húsafell. The properties of the water are however not so similar to Stóriás that it could be effluent discharge water from that field. Concentration of fluoride is high, considerably higher than in Stóriás but much lower than in Húsafell. Magnesium concentration is very low, indicating cooling of geothermal water, but no mixing with cold groundwater. A Log Q/K diagram for the geothermal water (Figure 14) indicates mixing of water of temperatures 40-80 °C, with the most distinct equilibrium at about 60 °C.

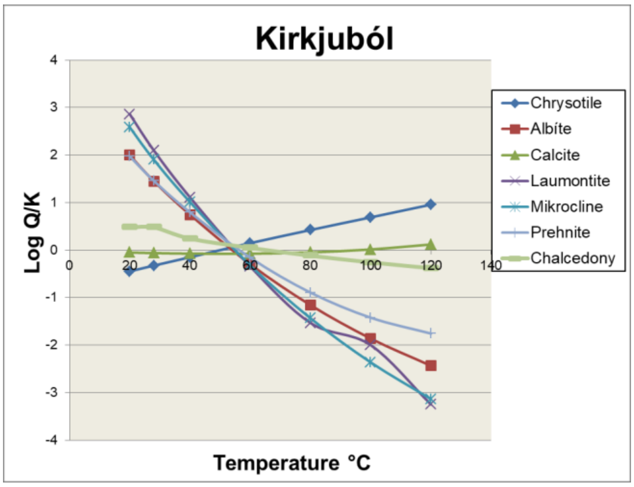

Figure 14: The relation between calculated activity products in the water from well 1 in Kirkjuból and corresponding equilibrium constant for the formation of selected alteration minerals (log Q/K) against temperature.

The stable isotope ratios in the Kirkjuból geothermal water are, -78.8 for δH^2 ‰ and -11.3 for $\delta^{18}O$ ‰, indicating an origin not so far from the highlands in the northeast.

4. CONCLUSION

In the NE part of the Borgarfjördur region there is an extensive geothermal activity in several separate geothermal fields. The systems have been studied by many scientists from early last century, but during the last ten years there has been ongoing development in the area due to increased tourism. The cause of the widespread geothermal activity is tectonic movements in both the Western volcanic zone and the Snæfellsnes transverse zone. The major geothermal system in the area the Reykholtsdalur valley appears to occur at the intersection of northwesterly oriented young faults and northeasterly trending faults or dykes. The Húsafell geothermal field in the eastern part is associated with an extinct central volcano and the thermal manifestations occur mainly along a layer of acidic tuff. The two other fields in this study, Stóriás and Kirkjuból are connected to northeasterly fault zones. The reservoir temperatures are up to 150 °C in the most active system in Reykholt,. In the Húsafell geothermal field silica and alkali geothermometers indicate reservoir temperatures of 80-85 °C, which is less than 10 °C higher than obtained by drilling sofar, but in Stóriás indicated reservoir temperatures are around 80 °C. In Kirkjuból the highest measured temperature is 32 °C, but the geochemistry of the waters indicates reservoir temperatures of 60-70 °C.

There is a distinct difference in geochemistry of waters in the different geothermal fields. The pH of the waters in Reykholt is around 9.3 as common for boiling water in similar geological settings (Kristmannsdóttir et. al. (2005b). In Húsafell the pH is also around 9.3, which is lower than common for Icelandic low temperature geothermal waters of similar temperature, due to reaction with acidic reservoir rocks in the extinct central volcano at Húsafell. The water in a Stóriás, and Kirkjuból, as well as in Hringsgil in Húsafell, show higher pH of around 9.8 as to be expected in geothermal waters below boiling, reacting with basaltic rocks. The water in the area is nearly all classified as sulfate water with a few samples falling on the border line to bicarbonate water (Kristmannsdóttir et al. 2005a). The Húsafell water has the highest concentration of fluoride of any geothermal water in Iceland due to reaction with acidic rocks. The geochemistry of the luke warm springs encountered towards west from the main geothermal field show typical trends of mixing with cold ground water. An exception is the westernmost spring in Hringsgil, which has very similar geochemical properties as the Stóriás springs some 10 km away. As the drilling of 9 shallow wells near to Hringsgil has not revealed any main upflow zone it is assumed that the water is an effluent discharge along a fracture or horizontal layer from another geothermal field. It seems fortuitous to expect any direct connection between Hringsgil and Stóriás due to the long distance. It seems more likely to assume that the Hringsgil is an effluent discharge from an unknown geothermal field connected to another fault swarm east of the Stóriás field.

The recharge water to the four fields is from different sources as demonstrated by stable isotope ratios in the waters. The recharge areas are both local as in Reykholt, from the Langjökull glacier like in Húsafell and from different areas in the mountains, either towards south and west like in the case of Stóriás or in the eastern highlands and assumed for Kirkjuból.

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