# GPS-mapping of geothermal areas in West Iceland

## Phase 1: Kleppjárnsreykir, Deildartunga, Hurðarbak South in Reykholtsdalur
## – An overview –

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We report here the first results from a project to map systematically and in detail the geothermal areas in West Iceland. The purpose of this effort is to relate the geothermal manifestations and individual springs to local structural features such as faults and fractures. The present state of the geothermal activity is also documented to provide a base of knowledge against which later changes can be determined.

As this work progresses and a wider coverage is obtained, we hope to reveal the geometric relationship of the geothermal activity to major structural features such as past and present plate boundaries, intra-plate volcanic systems, as well as intra-plate earthquakes.

In recent years, work of this type is greatly facilitated by the GPS-technology. Relatively inexpensive instruments can be acquired for mapping of structures at the resolution of 1-2 meters. Structures are mapped in the field by carrying GPS-receivers around them and storing the location data for later processing in the lab. Our choice of the method is influenced by the results of GPS mapping of earthquake fractures in the South Iceland Seismic Zone-SISZ (e.g. Einarsson et al., 2002) that proved to be successful for accurately locating fault structures and showing their general and local tectonic trends.

In this report we document the mapping results of selected geothermal areas in Reykholtsdalur. These areas are located within the Borgarfjörður Block that is bounded to the east by the active Reykjanes-Langjökull Rift Zone, and in the far west by the extinct Snæfellsnes Rift Zone (Jóhannesson, 1980). The Borgarfjörður Block was formed as a part of the Eurasian Plate but was later accreted to the North-America Plate when the main locus of rifting jumped to the Reykjanes-Langjökull Rift Zone about 7 Ma (Kristjánsson and Jónsson, 1998, Khodayar and Einarsson, 2002). The recent intra-plate Snæfellsnes Volcanic Zone stretches perpendicular to the rift zones. The 1974 Borgarfjörður intra-plate earthquakes occurred near the eastern tip of this volcanic zone (Einarsson et al., 1977), just one valley farther north from Reykholtsdalur.

Our work is based on extensive earlier works in this region. The location, geochemistry, and discharge of the hot springs in Iceland were studied systematically in 1944 (National Research Council, 1944). Studies in the eighties focused on the mapping of the springs, their geology, geophysics, geochemistry, and the modelling of the host fractures especially in Bær (Georgsson et al., 1981), Klettur-Runnar and Kleppjárnsreykir-Deildartungahver (Georgsson et al., 1978), as well as Sturlurreykir-Vellir (Georgsson et al., 1984). Recently, Torfason (2003) described the general location of the springs and made a synthesis of data available to date.

We used the GPS technique to carry out surface mapping of geothermal manifestations in South and West Iceland in the autumn of 2004. Below is an overview of the outcome of the campaign that concentrated on three geothermal areas in Reykholtsdalur in West Iceland. The mapping is a part of the "*Bergsprungur í*

*skjálftabeltum og gosbeltum"* Project. We selected the areas of Kleppjárnsreykir, Deildartunguhver, and Hurðarbak south. Details of this first investigation will be presented in a BS report (HB) at the University of Iceland, Faculty of Natural Sciences. A paper will follow (in preparation) where we interpret the GPS data with respect to our other results obtained from the Borgarfjörður Block. The goal of that paper will be to clarify whether the geothermal activity is controlled by the intra-plate earthquakes, by reactivation of older tectonic settings, or by both.

We define four geothermal areas within the mapped zone: Kleppjárnsreykir, Kársnes, Deildartunguhver, and Hurðarbak South (Fig. 1).

A total of 36 geothermal features were mapped in the Kleppjárnsreykir sub-area. Geothermal alteration, swampy sediments, related vegetation, algae, and steam are the features of these manifestations, which appear through the soil above the underlying Holocene sediments. In Kleppjárnsreykir itself, cemented caps cover at least one spring but bursting water and steam break through many of the constructions. Most manifestations are small pools with one or several "eyes", some with bursting boiling water coinciding with the hottest zones. The hottest zones, however, are aligned along distinct tectonic directions. Measured temperatures range from 99,9°C to 90,1°C in Kleppjárnsreykir itself, from 92,8°C to 54,8°C north of Björk, and from 59,1°C to 65,2°C east of Skrúður. Geothermal manifestations in these three localities form a general NNW line together, in accordance with the suggestions of Georgsson et al. (1978). In detail, however, Kleppjárnsreykir shows a more northerly direction. North of Björk, the outline of the geothermal zone has a NE direction with a bend to the N-NNW. Similarly, the hottest points inside the zone are aligned NE and northerly, but NNE and WNW alignments are also present. The hot spots in the channel east of Skrúður has a net N-S orientation.

About 49 geothermal features were mapped in six hot and cold geothermal sub-areas in Kársnes. These sub-areas are of different sizes. Four of them are of some extent with clear tectonic orientations, but the two others are isolated features. We discuss here only the four main zones. The outline of the two largest zones to the west and north-northwest is respectively N-S and northerly, and the hottest points within these zones form a northerly orientation primarily, but also WNW, and NW. Measured temperatures are between 98,1°C and 50,5°C, and surface manifestations are similar to those in Kleppjárnsreykir. However, water from Reykjadalsá river overflows the geothermal zones locally here. The two other main sub-areas are "cold" zones with temperatures between 20°C and 11,4°C. One of these zones is on the northern shore of the Reykjadalsá river where the 11 mapped features show a clear E-W alignment. The other zone is in a cultivated field farther north in the Kársnes peninsula.

The southernmost geothermal zones in Kársnes appear to be aligned on a NNW line, as suggested by Georgsson et al. (1978), though N-S and E-W tectonic directions have strong influence. The northernmost geothermal zone in Kársnes, however, is dominantly northerly. This zone is parallel and possibly associated with Deildartunguhver rather than with the systems of south Kársnes. This interpretation differs from the interpretation of Georgsson et al. (1978).

In Deildartunguhver, about 56 mapped geothermal features form a general NNE line together, in agreement with the mapping of Georgsson et al. (1978). In detail, however, the springs present a slightly different but interesting tectonic pattern. Except the last two features to the northeast, measured temperature range from 83,3°C to 98,5°C, with the majority of the springs above 90°C. The dominant strike of the hot springs is more

northerly than NNE, and a small part of the springs is locally aligned along the E-W, NE, and NNW directions. In Deildartungahver, a few major springs are located at the intersection of northerly and E-W, or northerly and NE mode (I) fractures. Southwest of Deildartunguhver, the manifestations are in anoxic and swampy sediments with the presence of algae. Locally, cold water from the man-made stream covers these geothermal manifestations. Farther north, manifestations are on dry and hard surfaces of Holocene sediments that are consolidated by geothermal alteration. From there to Deildartunguhver, the “eyes” are bigger, the steam and bursting boiling water are common, deposition more prominent, but algae are almost absent.

We identified three types of structures in Hurðarbak South. They form a NNE line together, but in detail, each type has its distinct tectonic orientation. (a): A “cold” geothermal zone where 6 mapped features have a temperature between 16°C and 19,2°C. Both the outline of the zone and the alignment of the manifestations within it are N-NNE. Swamps, surrounding green vegetation, and individual pools with algae characterise this sub-area, but the very low temperature allows us to suggest either this zone is cooling down, or is nascent. (b): Two zones of cold springs were identified due to the presence of liquid or running water in a frozen surrounding. They do not enter the geothermal zones. The westernmost zone has a NNE direction and the 5 mapped features have 5,2°C temperature. The easternmost zone strikes NW with two features mapped and 3°C temperature. (c): A total of 44 features were mapped in two hot geothermal zones. The main geothermal zone is to the south, with temperatures ranging from 96,9°C to 54°,4°C. This zone has a general NE orientation that bends sharply to N-S. The most spectacular manifestations inside of this zone are with much steam, deposition, bigger “eyes”, and bursting boiling water. These are also oriented NE. Swampy areas and algae are more associated with the N-S portion of the main zone where the hottest points are mostly northerly. The second zone is smaller, and is located farther north, just south of the road to the Hurðarbak farm. The few geothermal features mapped in this zone have between 95,5°C and 99,8°C temperature. A concrete construction hides the main spring, but the manifestations outside of it are with bursting water, discharge, and deposition on hard surfaces. A few host fractures are also visible. The outline of the zone is generally northerly, but individual manifestations can together form a NW line.

A second geothermal zone exists north of the road, by the Hvítá river, but it was not mapped during this campaign.

Generally, no regional fracture was identified in the immediate surrounding of the four geothermal zones, and the tectonic aspect of the geothermal activity will be treated in detail separately.

The presence of the exceptionally high discharge of boiling hot water at Deildartunga (180 l/s), Kleppjárnsreykir, and Hurðarbak is still an enigma. The understanding of the origin of these springs needs an interpretation within a more general context with respect to the past and present tectonic weaknesses in the Borgarfjörður area. Therefore, a detailed GPS mapping of the geothermal manifestations in Reykholtsdalur, from Reykholt and Norður Reykir in the east to Klettur, Runnar and Bær in the west, is a complement to our published (Khodayar, 1999; Khodayar and Einarsson, 2002; Khodayar et al., 2004) and unpublished data from the field and aerial photographs in Borgarfjörður. With the interpretation of these data sets along with the role of the 1974 intra-plate earthquakes in Borgarfjörður, we hope to contribute to a better understanding of the geothermal activity in Borgarfjörður.

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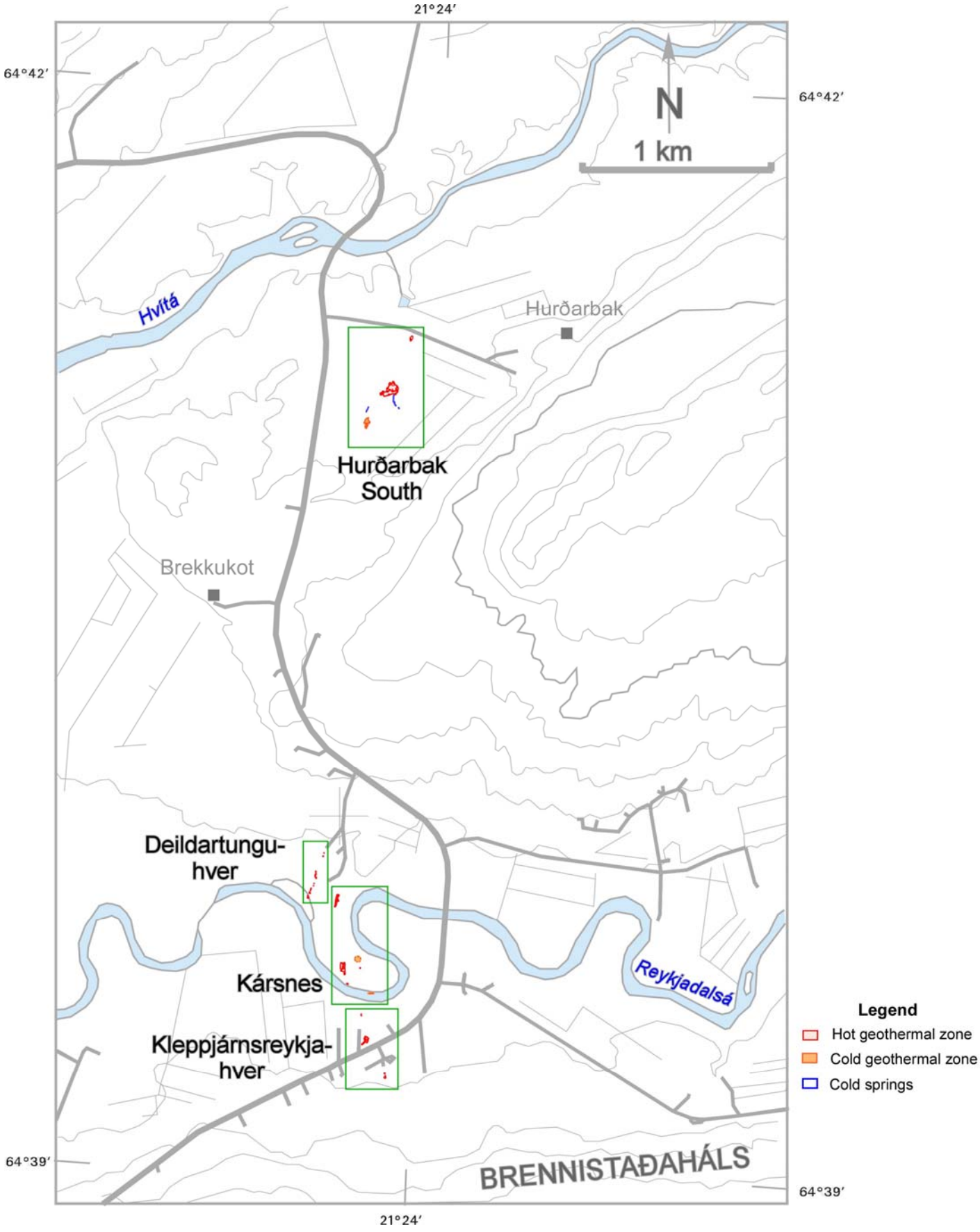


*Fig. 1. Location of the geothermal zones mapped with GPS.*