CO_2 fixation by calcite in high-temperature geothermal systems in Iceland

Frauke Weise
Thráinn Fridriksson
Halldór Ármannsson

Prepared for Rannís, Hitaveita Suðurnesja hf.,
Orkuveita Reykjavíkur, Landsvirkjun and Orkustofnun

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ICELAND GEOSURVEY
Reykjavík: Orkugardur, Grensásvegur 9, 108 Reykjavík, Iceland - Tel.: 528 1500 - Fax: 528 1699
Akureyri: Rangárvellir, P.O. Box 30, 602 Akureyri, Iceland - Tel.: 528 1500 - Fax: 528 1599
isor@isor.is - www.isor.is

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Cooperators

Abstract

The goal of this study is to quantify the amount of carbon dioxide (CO_2) fixed in bedrock in three high-temperature geothermal systems in Iceland in order to determine the importance of CO_2 fixation in rock to the CO_2-budget of geothermal systems. A total of 654 drill cutting samples from 14 wells in Reykjanes, 16 wells in Hellisheidi, and 12 wells in Krafla were selected for carbon analysis. The amount of CO_2 in the drill cuttings ranged between 0.0 and >400 kg/m^3. In the uppermost 500 to 1000 m in the geothermal systems the CO_2 content is commonly of the order of 100 kg/m^3 but it decreases sharply below that depth and very little CO_2 is present below 1500 m. Because CO_2 is concentrated in the upper part of the wells the results can be used to calculate the CO_2 load of the bedrock in kg/m^2. The CO_2 loads computed for individual wells range between 17 and 42 ton/m^2 for Reykjanes, 5 and 103 ton/m^2 for Hellisheidi, and 37 and 92 ton/m^2 for Krafla. These values and published estimates of the areal extent of these systems were used to calculate the total amount of CO_2 fixed in the bedrock. The resulting values are 56, 1600 and 2200 Mt for Reykjanes, Hellisheidi, and Krafla, respectively. These values and available age estimates for these systems were used to constrain the fixation rate of CO_2 in these systems. The resulting values are 560 to 5600 t/yr for Reykjanes, 4100 to 23500 t/yr for Hellisheidi, and 7500 to 20000 t/yr for Krafla. Comparison of these values to measured natural atmospheric CO_2 emissions from Reykjanes (5000 t/yr) and Krafla (100,000 to 150,000 t/yr) illustrates that the CO_2 that is fixed in the caprock of geothermal systems is a considerable fraction of the total amount of CO_2 that is released from geothermal systems.

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1 Introduction

Volcanic geothermal systems receive heat from magma located in magma chambers or smaller intrusions in the roots of the systems. In addition to the heat, these systems also appear to receive a considerable amount of CO_2 from the magma. The CO_2 in geothermal systems may be derived from other sources, such as metamorphic decarbonization reactions, but in general, the magmatic contribution is the most important. In Iceland, magma appears to be the only source of CO_2 in the geothermal systems (Ármannsson et al., 2005). Processes that remove CO_2 from the geothermal systems, or the geochemical sinks for geothermal CO_2, are atmospheric emissions, calcite precipitation, and dissolution in enveloping groundwaters that can transport the CO_2 away from the systems. The input of magmatic CO_2 into individual systems is not known, although attempts have been made to estimate the total amount of magmatic CO_2 released from the mid ocean ridges (Marty and Tolstikhin, 1998) and Icelandic volcanic/geothermal systems (Óskarsson, 1996; Ármannsson et al., 2005). Similarly, very little is known about the relative importance of the three geochemical sinks for CO_2 in geothermal systems.

Understanding the CO_2 budget of geothermal systems is important for a variety of reasons. This has implications for the global CO_2 geochemical cycle because the CO_2 budget of volcanic geothermal systems is a component of the global volcanic CO_2 budget. Improved understanding of the CO_2 budget of geothermal systems has implications for the evaluation of the environmental impact of geothermal power production. It is, for instance, debated whether the CO_2 released from geothermal power plants should be considered anthropogenic or not as some argue that initial increase in CO_2 emissions will be counteracted by decreased natural emissions in the future (see Bertani and Thain, 2002 and Sheppard and Mroczek, 2004). Considerations of the interactions between the different geochemical sinks for CO_2 in geothermal systems are conspicuously absent from the current debate. Finally, quantification of the relative magnitudes of the fixation of CO_2 in calcite and groundwaters, on one hand, and natural atmospheric emissions on the other, can be considered as a natural experiment to determine the capacity of bedrock and groundwaters to capture CO_2. The physical and hydrological conditions above the geothermal reservoirs are not the most favorable conditions for CO_2 mineral sequestration. This is because the stability of calcite is limited by the high temperature, and convection and boiling provide a mechanism for vertical transport of CO_2 from the core of the system toward the surface. However, the results of this study will, nevertheless, provide critical background information for the planning of field scale CO_2 mineral sequestration experiments.

In the last decade or so, significant advances have been made in studies of atmospheric CO_2 emissions from volcanic geothermal systems. A few studies have also shown that significant quantities of geothermal CO_2 dissolve in shallow groundwater systems, overlying the geothermal/magmatic systems (Gíslason et al., 1992; Aiuppa et al. 2000). However, until now limited attention has been paid to the process of CO_2 fixation in calcite. A unique opportunity to study the CO_2 fixation in calcite in Icelandic geothermal systems is provided by the great number of geothermal wells that have been drilled in recent years. Drill cuttings, collected at 2 meter intervals throughout the entire depth of the wells, allow very detailed studies of the amount of CO_2 that is fixed in the rocks.

In this study we measured the CO_2 content of 654 samples of drill cuttings from 40 wells in three high temperature geothermal systems in Iceland. We used this data to estimate the total amount of CO_2 fixed in rocks in these systems over their lifetime. By comparing these results to observed atmospheric emissions of CO_2 from these systems, we were able to compare the relative importance of these two geochemical sinks for geothermal CO_2. The results of this work represent a significant progress towards understanding the CO_2 budget of geothermal systems, but the third geochemical sink for CO_2, i.e., dissolution in groundwater, has not yet been quantified.

It must be noted that we do not claim to present the first attempt to quantify the abundance of calcite in drill cuttings from geothermal wells in Iceland. Tómasson and Kristmannsdóttir (1972) determined the relative amounts calcite and other alteration minerals in cuttings from five wells at Reykjanes by thin section point counting using an optical microscope. However, because the results of Tómasson and Kristmannsdóttir (1972) are presented in terms of volume percent of alteration minerals but not of the total rock volume their results are not compatible with the results of this study.

It must also be noted that in this study there is no attempt to determine which process or processes are responsible for calcite precipitation in and around geothermal systems. Arnórsson (1978, 1989) has demonstrated how boiling of calcite saturated geothermal solutions leads to calcite precipitation. While boiling is generally accepted as a very important mechanism for calcite precipitation in geothermal systems, other authors, such as Simmons and Christenson (1994) have pointed out that calcite can also form under sub-boiling conditions by replacement reactions and by interactions of CO_2-rich steam heated waters with rocks near the surface. The objective of this study is simply to quantify the amount of CO_2 fixed in geothermal systems, not to determine what mechanism was responsible for its fixation.

2 Methods

2.1 Samples

In this study, a total of 654 drill cuttings samples from three high-temperature areas in Iceland were analyzed for carbon content. Sample selection was generally done in two steps in order to constrain high-CO2 anomalies. In the first step approximately 10 samples per well were selected and analyzed. In the second step the results of the first 10 samples were used in order to select samples from depth levels above and below samples add samples from depth levels close to the samples that had high CO2 content in the first step. Time constraints, the total number of samples and the depth of the wells in the study areas limited the overall number of samples. At certain depths in some drill holes, no drill cuttings were available due to total loss of the circulation fluid. Thus, it was not possible to achieve a regular grid of data points.

All the wells studied in the Krafla and Reykjanes areas were drilled for the production of steam and hot water for energy and warm water supply. In Hellisheidi two re-injection wells were considered in addition to production wells. They are located in close to the geothermal system. Table 1 gives an overview of the number of tested samples and drill holes. Well reports from Hellisheidi, Krafla and Reykjanes are listed in Appendix 1. A complete list of results for individual cuttings samples can be found in Appendix 2.

Table 1. *Overview of samples of drill cuttings.*

Area	Number of Samples	Number of Wells
Hellisheidi	247	16
Krafla	172	10
Reykjanes	235	14
Overall	**654**	**40**

The samples analyzed in this study were selected from drill cuttings collected at 2 m intervals during drilling. For inclined wells the "drilling depth" refers to the length of the drill string rather than the real vertical depth (Z-coordinate) below the surface. Information about inclination, azimuth, X-, and Y-coordinates at certain depths of inclined wells were applied to calculate the X-, Y-, and Z-coordinates of the drill cuttings samples. The top of all drillholes in the Reykjanes area is considered to be 20 m.a.s.l. The X- and Y-coordinates for Reykjanes and Hellisheidi are defined with a ±20 m and for Krafla ±100 m deviation respectively. The Z-coordinate is accurate with respect to the distance between the samples depth but the real absolute value may be up to 8 m lower since the top of the drillholes is located up to 8 m above the surface due to the elevation of the drill platform. The accuracy of the selected coordinates is considered more than adequate for the present use of the data. Information about the locations of wells and the origin of drill cuttings are from drill reports that are listed in Appendix 2.

It should be mentioned that doubts can arise regarding the validity of drill chip samples representing the rock due to contamination with drilling material. During drilling, steel casings are fixed in the well by cement. At certain depths, at the beginning of a new section, the remaining cement at the bottom of the previous section has to be drilled through. Thus, drill chip samples from several meters below those sites could contain cement, which could strongly affect the CO_2 concentration of the given sample. However, close inspection of the data set in this study and casing depths of the wells involved indicates that the CO_2 concentrations determined in this study are not affected by cement contamination.

2.2 Carbon measurements

About 5 g of drill cuttings were ground to a fine powder using a carbide ball mill. The pulverized rock samples were combusted in oxygen in a CM5200 Auto sampler Furnace from UIC Inc. Coulometrics. The total carbon in the CO_2-containing gas stream was determined with an UIC Inc. Model 504 CO_2 Coulometer.

A known mass of about 20 mg from each sample taken from the 5 g of pulverized rock is combusted in oxygen at 950 °C to convert all carbon to CO_2. The sample combustion gases are swept through a barium chromate scrubber to ensure complete oxidation of carbon to CO_2. Non-carbon combustion products are removed from the gas stream by a series of chemical scrubbers. The CO_2 is then measured with the CO_2 coulometer. The coulometer cell is filled with an appropriate solution containing monoethanolamine and a colorimetric pH indicator. Platinum (cathode) and silver (anode) electrodes are positioned in the cell, which is then placed in the coulometer cell compartment between a light source and a photometric detector in the coulometer.

As a CO_2 gas stream passes into the cell, the CO_2 is quantitatively absorbed, forming a titratable acid. This acid causes the color indicator to fade. A photodetector monitors the change in the color of the solution as percent transmittance (%T). As the %T increases the titration current is automatically activated to an electrochemically generated base at a rate proportional to the %T (approximately 1500 µg/ minute). When the solution returns to its original color (original %T), the current is terminated. The Coulometer is based on the principles of Faraday's Law. Each faraday of electricity expended is equivalent to 1 GEW (gram equivalent weight) of CO_2 titrated, which is important for calibration. By knowing the total weight of the sample and the weight of contained carbon therein, the weight percentage of carbon can be calculated.

Calcite standards of 5.01% and 25.02% were used to verify the accuracy and precision of the measurements. The standards were made from calcite from Helgustadanáma, eastern Iceland, mixed with 99.9% aluminum oxide (Al_2O_3) from Alfa Aesar. Based on the ratio of the molecular weights of carbon (12 g/mol) and calcite (100 g/mol), 5.01% calcite is equivalent to 0.60% carbon. The arithmetic mean of 12 readings was 0.58% with a standard deviation of 0.01. 25.02% calcite is equivalent to 3.00% carbon. The arithmetic mean of 3 readings was 2.99% with a standard deviation of 0.09 (see Table 2). The accuracy of the instrument is acceptable for the purpose of the carbon measurements presented in this study.

Table 2. *Results of standard analyses.*

Calcite (wt%)	Carbon (wt%)	Number of readings	Arithmetic mean (wt%)	Standard deviation (wt%)
5.01	0.60	12	0.58	0.01
25.02	3.00	3	2.99	0.09

2.3 Background carbon

The aim of the carbon measurements is to get an estimate of the amount of CO_2 that has been fixed in the rock by precipitation of carbonate minerals as a result of reactions between the rock and the geothermal fluids. Some CO_2 may have been present in the rock before the beginning of the accumulation of geothermal calcite. It is, therefore, necessary to evaluate the initial CO_2 content of the unaltered basalts. Not all magmatic CO_2 is released during cooling and crystallization of the basalts; some of it may be present in fluid inclusions in crystals as well as trapped in undegassed glass after the basalt has cooled. In order to provide an estimate of the CO_2 content of unaltered basalts, a total of 16 samples from several different lava formations in the Reykjanes area, the Krafla area and the east coast of Lake Mývatn were collected. The carbon in the background samples was measured using the same method and procedure as the drill chip samples. The values range between 0.004 and 0.141 wt% carbon and the median is 0.02 wt%. This corresponds to a median value of 0.08 wt% CO_2. Location and values of background samples are shown in Appendix 2.

In Figure 1 the results of background carbon measurements (weight percent carbon dioxide) are shown as red dots. The CO_2 content of Tertiary basalts from Reydarfjördur, eastern Iceland (Flower et al., 1982) is shown for comparison as blue triangles. The Reydarfjordur basalts have not been exposed to zeolite facies alteration and are thus comparable to the background samples.

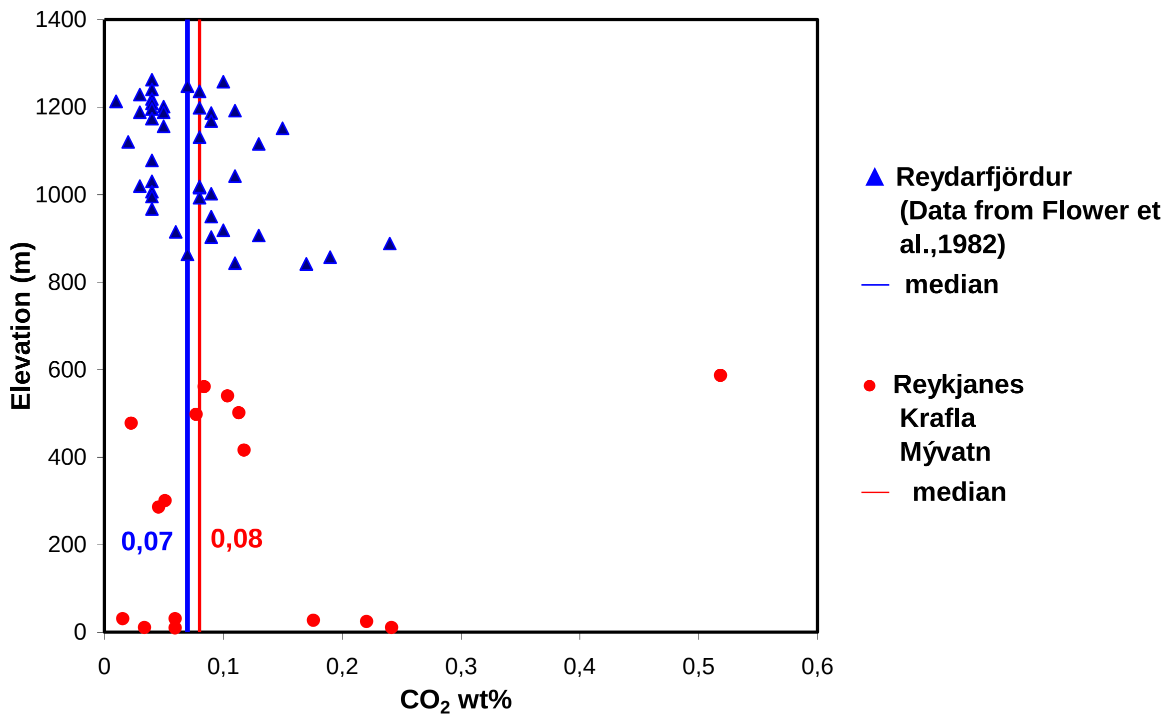

Figure 1. *Carbon content of background samples of fresh basalts. Carbon content of Tertiary basalts from eastern Iceland is shown for comparison. Carbon content is shown as a function of altitude for convenience. The high carbon outlier of this study may have contained organic material.*

The median carbon dioxide content of the relatively unaltered basalt lavas in Reydarfjördur is 0.07 wt% CO_2 (Flower et al., 1982). The median for Reykjanes, Krafla and Mývatn is 0.08 wt% CO_2 and, thus, very close to this value. Hence, we assume that 0.08 wt% CO_2 appears to be a reasonable background value for unaltered basalts and consequently this value is subtracted from the measured carbon content of the drill chip samples from Reykjanes, Krafla and Hellisheidi prior to further calculations.

2.4 Data treatment

The first step in evaluating the data was to subtract the background carbon from the measurement readings. Then the weight percentage of CO_2 was converted into tons of CO_2 per unit volume of rock by multiplying by the density of basalt. The determination of the density of the rock is not as straightforward because the rocks in the reservoir zone are not homogenous. However, for the sake of simplicity a value of 2.7 t/m^3 was used for the calculations below. The density of calcite is also equal to 2.7 t/m^3 (Deer et al., 1992) so the amount of calcite in the rock will not affect the bulk density. The concentration of CO_2 in the rock is computed by

$$\mathbf{CO_2\ (wt\ \%)\ /\ 100\ *\ 2{,}700\ kg/m^3 = CO_2\ (kg/m^3).}$$

The results of this work are presented as kg CO_2 per m^3 rock. All carbon measurement readings and the derived CO_2 values are listed in Appendix 2.

3 Results

3.1 Vertical distribution patterns

In Figures 2, 4 and 5 data points from three selected wells from Hellisheidi, Krafla, and Reykjanes, respectively, as well as the average for each area are plotted as the amount of CO_2 as a function of depth. Comparable figures for all the wells considered in this study are shown in Appendix 2. The average CO_2-depth profiles for the geothermal systems were determined by grouping data points from all wells in the given system, into 100 m and 200 m intervals respectively. The average carbon content for each interval is plotted as a function of the mean depth of that interval.

Hellisheidi

The values for fixed CO_2 in the Hellisheidi area range between 0.0 kg/m^3 and 300.9 kg/m^3. The highest value measured was in HE-11 (see table and figure in Appendix 2). Figure 2 shows the CO_2 content as a function of depth in drill holes HE-14, HE-16 and HE-21 as well as the average for all 14 analyzed production wells in the area. The re-injection wells HN-02 and HN-03 were excluded from the calculation of the average area because they are located outside the geothermal system.

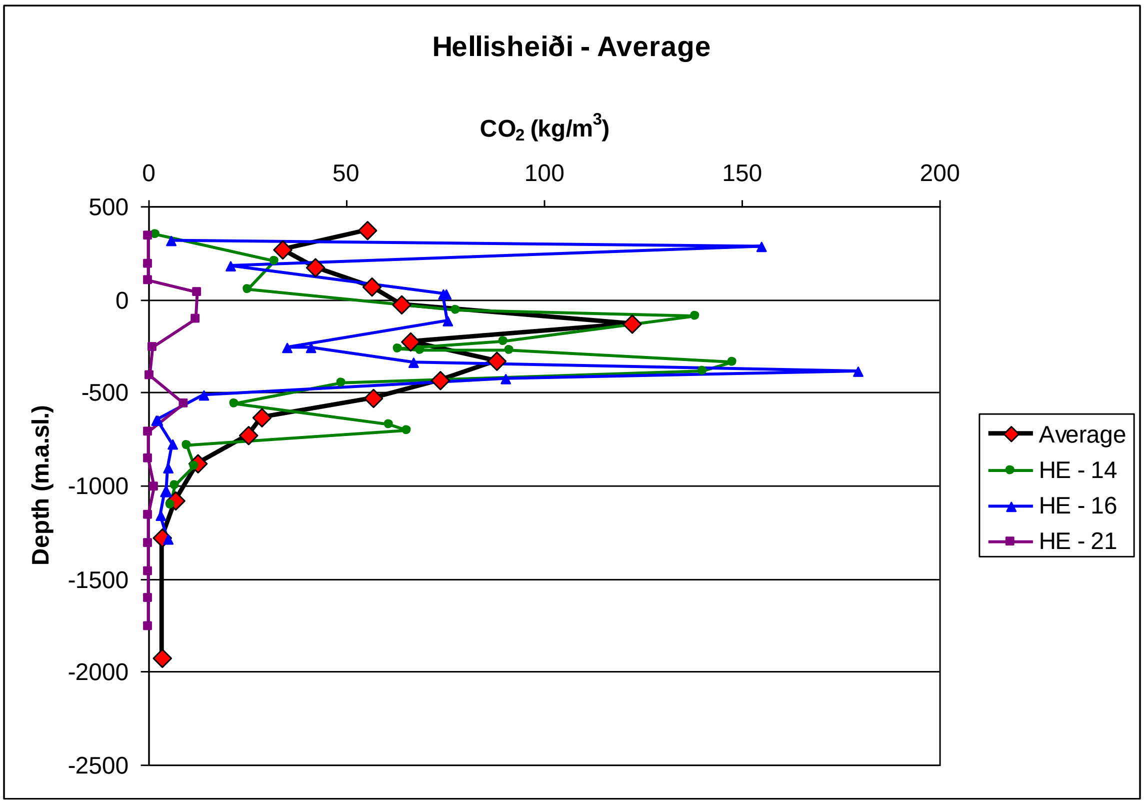

Figure 2. *Selected CO_2–depth profiles for Hellisheidi.*

The overall pattern of the distribution of fixed CO_2 in Hellisheidi basalts shows values below 50 kg/m^3 CO_2 from zero to about 250 m below surface. Below that depth the average CO_2 content increases abruptly to 120 kg/m^3 at 550 m depth. The CO_2 content is relatively high to a depth of about 800 m below the surface but at greater depths the CO_2 content decreases sharply, approaching zero. Below 1650 m depth, there is almost no CO_2 fixed in the rock. The results for well HE-14 reflect this trend except that lower values are found near the surface and slightly higher values in the CO_2 rich zone. The results for HE-16 give an example of large differences between adjacent values but adherence to the average pattern and concentration of fixed CO_2. Well number HE-21 differs from all other Hellisheidi production wells considered regarding the amount of fixed CO_2. This well is located about 1.5 km south of the other wells. Although this well shows the same relative distribution of CO_2 as a function of depth, the absolute values are only about 10% of the average in the area.

The CO_2 profiles for the two re-injection wells (HN-02 and HN-03) do not show the typical distribution pattern (see Figure 3 compared to Figure 2), as they are not located directly in the high-temperature area but in its vicinity, west of the production well field. An interbedded warm outflow zone, probably resulting from mixing of deep and shallow fluids was identified in this area (Björnsson et al., 2006). The CO_2 bearing water of this outflow zone leading to mineral precipitation could be the cause of the occurrence of calcite in these wells although there is no direct influx of magmatic CO_2 from below.

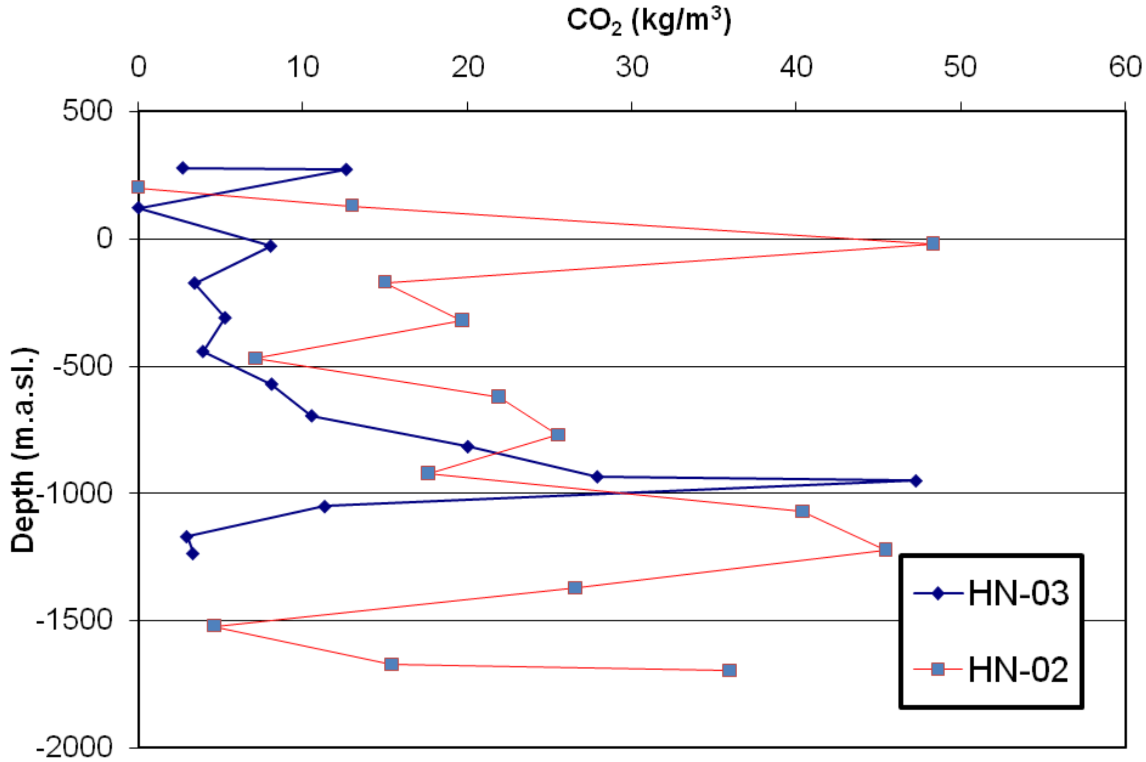

Figure 3. *CO_2-depth profile for wells HN-02 and HN-03.*

Krafla

The CO_2 content of cuttings from boreholes in the Krafla area ranges between 0.0 kg/m^3 and 426.7 kg/m^3. The highest measured value in Krafla is the highest in all three areas. However, values above 300 kg/m^3 are only observed at shallow depths in well KJ–34. As shown in Figure 4, these values are significantly higher than the average but do also reflect the trend in Krafla: the CO_2 concentrations are high near the surface and decrease steadily towards zero for fixed CO_2 at a depth of about 1300 m below surface. In about half of the wells, as shown for well KJ-29 in Figure 4, lower values are found at shallow depths but there is a correlation to the overall pattern at greater depth than 200 m below the surface.

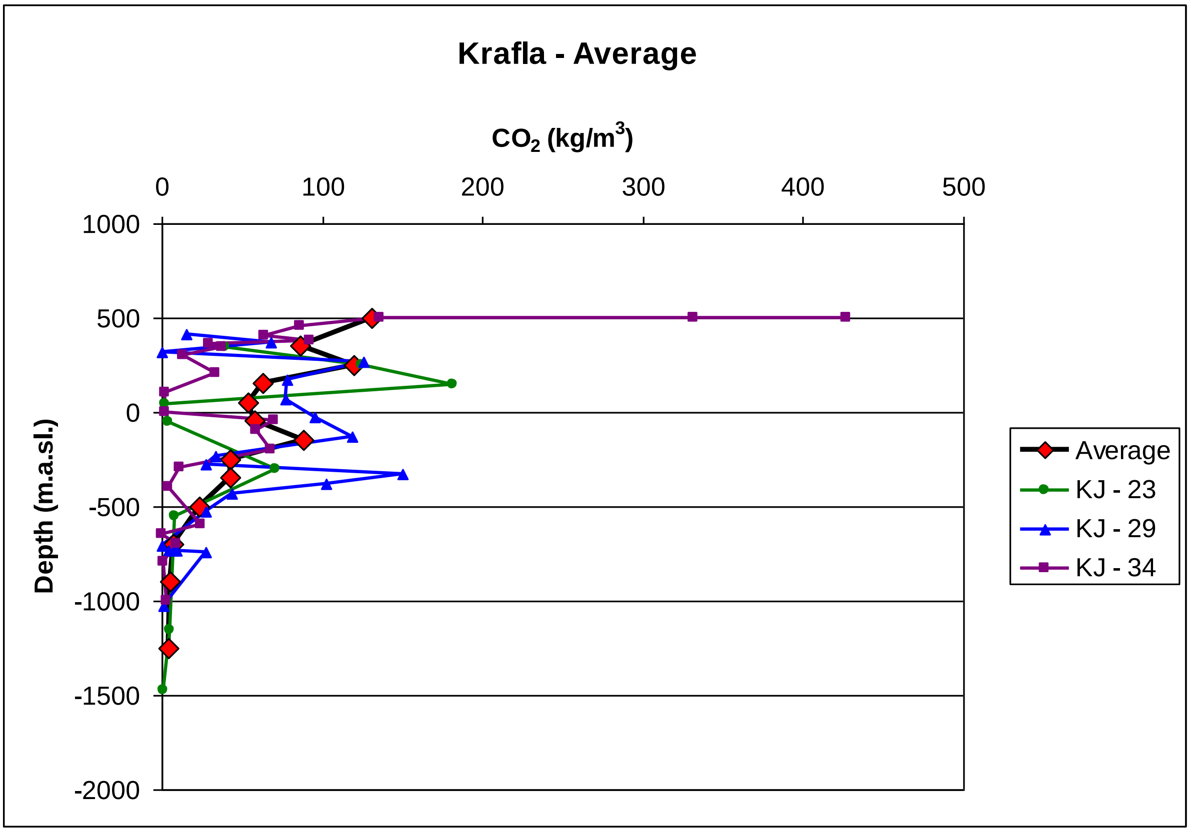

Figure 4. *Selected CO_2-depth profiles for Krafla.*

Wells KJ-21 and KJ-23 are located in the Hvíthólar field, which belongs to the Krafla geothermal system but is located about 2 km south of the other wells considered in this study. They are in good agreement with other Krafla wells in terms of the pattern of distribution. The amount of fixed CO_2 is slightly lower in the two Hvíthólar wells than in other Krafla wells (see Appendix 2).

Reykjanes

The lowest values for the three areas were recorded in Reykjanes - between 0.0 kg/m^3 and 190.2 kg/m^3. The overall pattern of the average curve in Figure 5 shows an increase of fixed CO_2 in the upper part, peaking at a depth of about 250 m below surface followed by a decrease to a depth of about 1000 m below the surface. This pattern is shown by all wells considered as the profiles for RN-21 and RN-15 show (Figure 5). Besides the peak at shallow depths, at several locations narrow peaks are found between 1100 and 1400 m depth (e.g. RN-15), as well as around 2050 m depth. The highest CO_2 concentrations in the Reykjanes area are found in samples from RN-17. In this well, the values differ greatly between neighboring samples but follow the typical pattern while the CO_2 concentrations are commonly higher by about a factor of two compared to typical values for other wells at Reykjanes.

Tómasson and Kristmannsdóttir (1972) reported calcite abundances in drill cuttings from wells RN-02, RN-03, RN-04, RN-06 and RN-08. They report the abundances of calcite and other secondary minerals in volume percentages. It is not explicitly stated in their publication whether the percentages reported refer to the total rock volume or the volume of the secondary minerals. However it seems likely that the reported values refer to secondary minerals only as the volume percentage generally add up to close to 100.

The overall pattern of calcite distribution reported by Tómasson and Kristmannsdóttir (1972) is very similar to the results of this study, i.e., the abundance increases with depth until it reaches a maximum at about 200 to 400 m depth and decreases gradually with increasing depth. Below about 800 to 1000 m depth very little calcite is present, with the exception of a few restricted peaks below 1000 m similar to the deep CO_2 peak RN-15 shown in Figure 5. However, the total amounts of calcite reported by Tómasson and Kristmannsdóttir (1972) are significantly higher than indicated by the results of this study. They reported a calcite content in excess of 10 % for many samples and several with a calcite content as high as 20 % of the volume. This corresponds to about 160 to 320 kg of CO_2 per m^3 of rock, a factor of two to four higher than the values typically found in this study. The reason for this discrepancy is not clear, it may reflect a higher degree of alteration in the wells they studied (in the south western part of the field) but it is likely that this is due to the way Tómasson and Kristmannsdóttir report their results, i.e. as volume percentages of the alteration minerals; not the total volume.

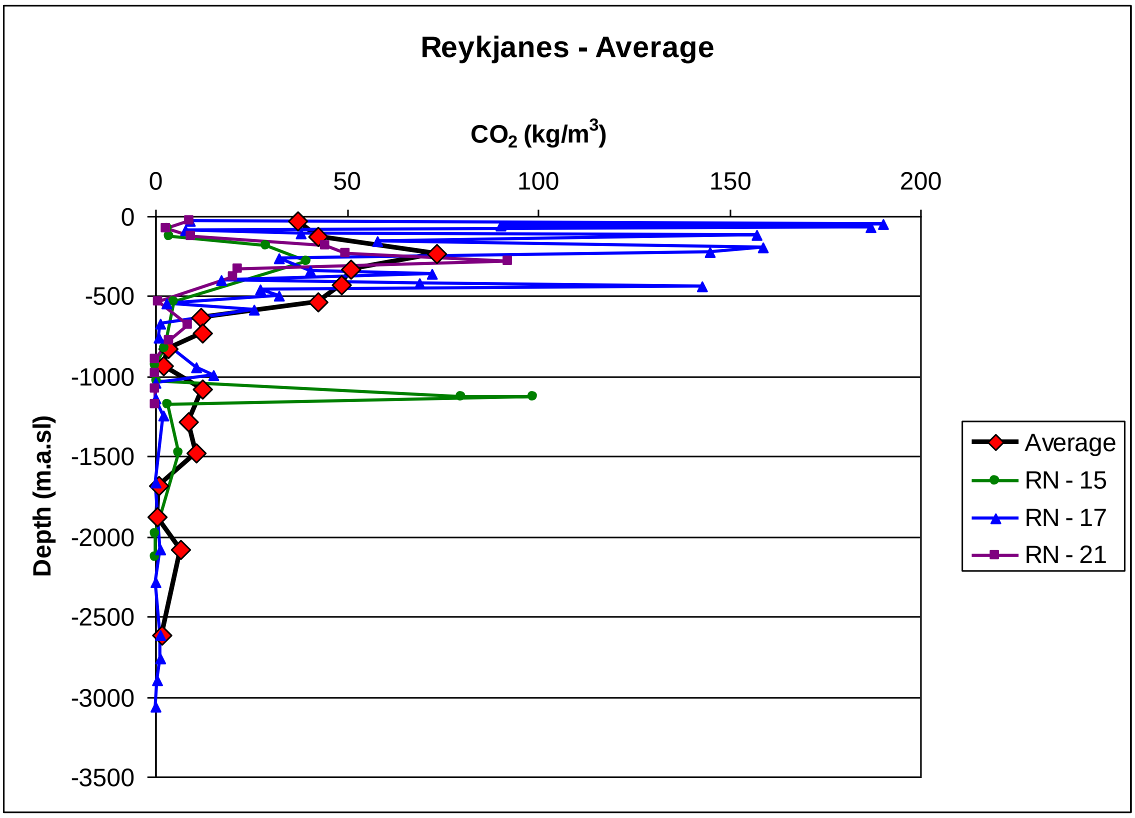

Figure 5. *Selected CO_2-depth profiles from Reykjanes.*

3.2 Spatial distribution

Setting

The vertical variation of the amount of fixed CO_2 with depth is shown in Figures 7, 8, and 9 where the amount of CO_2 is plotted as a function of depth. With the objective of visualizing the spatial distribution in the horizontal direction as well, two cross sections of each area were plotted (Figures 10, 11, and 12). The program Surfer was used to create side views of the areas based on the CO_2 value, the Z-coordinate (depth) and the X(east)- and the Y(north)-coordinates respectively. All samples, that are in reality distributed in the three-dimensional system, are thus projected on a two-dimensional slice perpendicular to the surface. In Figure 6, the white arrows illustrate the viewpoint from which the study area is viewed: Cross section II is from south to north and cross section I from east to west.

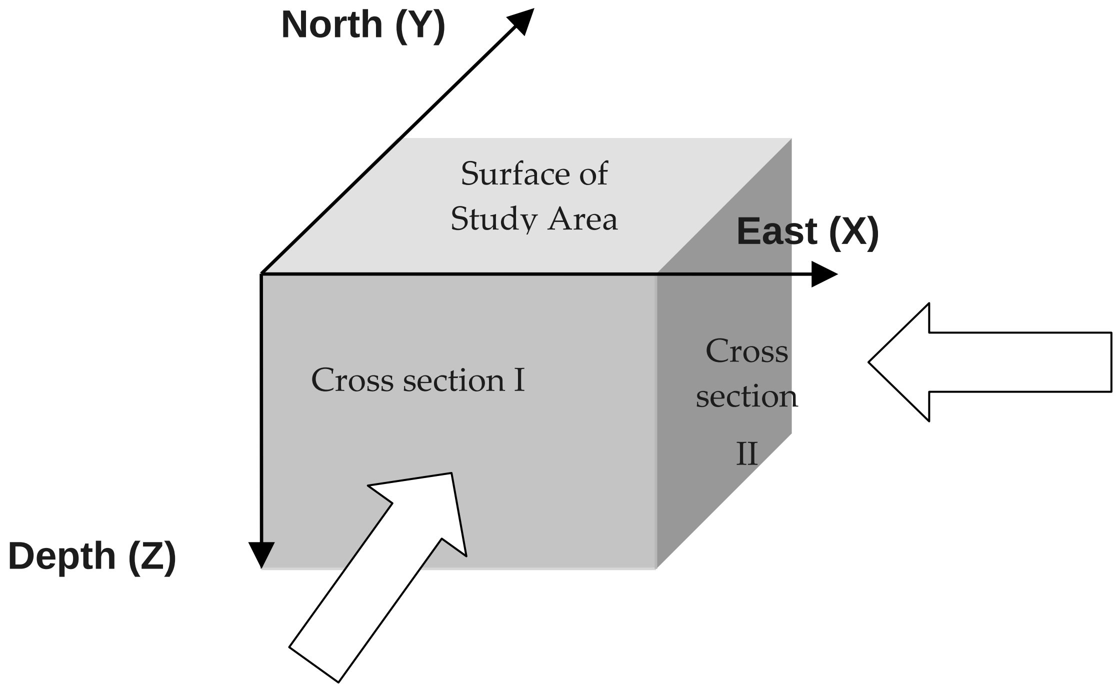

Figure 6. *Cross section perspectives.*

The colors in Figures 7, 8, and 9 visually represent the amount of fixed CO_2. In order to facilitate comparison between the three areas, the same color scale extending from deep blue (0 kg CO_2/m^3) to purple (175 kg CO_2/m^3) applies to all three areas. Black squares in the graphics show the location of the tops of the sample wells and black dots indicate the original locations of the samples. The CO_2 content between data points was interpolated using the kriging method. The top of the cross sections corresponds to the altitude of the most elevated drillhole in the area: 420 m.a.sl in Hellisheidi; 603 m.a.sl in Krafla and 20 m.a.sl. in Reykjanes.

Hellisheidi cross sections

The cross sections (Figure 7) show that most of the CO_2 in the Hellisheidi geothermal system is captured in the uppermost 1200 m with a peak around 650 m below the surface corresponding to about 250 m below sea level. Cross section II illustrates that the amount of fixed CO_2 in the bedrock decreases toward the southern part of the study area.

Krafla cross sections

Unlike Hellisheidi, the CO_2 richest area in Krafla extends to the surface (Figure 8). The highest CO_2 concentrations can be found less than a 100 m below the surface. Most of the calcite seems to be concentrated in the northern part of the area, decreasing to the south to wells number KJ–21 and KJ–23. However since no wells have been drilled so far in the area between the main well field (north) and the more southern Hvíthólar field no data was available for the 2 km in between and thus the drawing could significantly change in this section if more data were available. It can also be seen from Figure 8 that the CO_2 rich zone seems to extend to greater depths west of the Hveragil fault (i.e. west of well KJ-30) than east of it and significantly more CO_2 is fixed on the west side of the fault. Further analyses of drill cuttings from Krafla are already underway at ÍSOR, in order to better constrain the different character of the calcite fixation on each side of the Hveragil fault.

Reykjanes cross sections

Like the other cross sections, the Reykjanes cross sections (Figure 9) highlight the character of distribution already shown in the graph for averages: most CO_2 can be found in the uppermost 500 m. The CO_2 richest area barely reaches the surface like in Krafla but is located at somewhat shallower depths than in Hellisheidi.

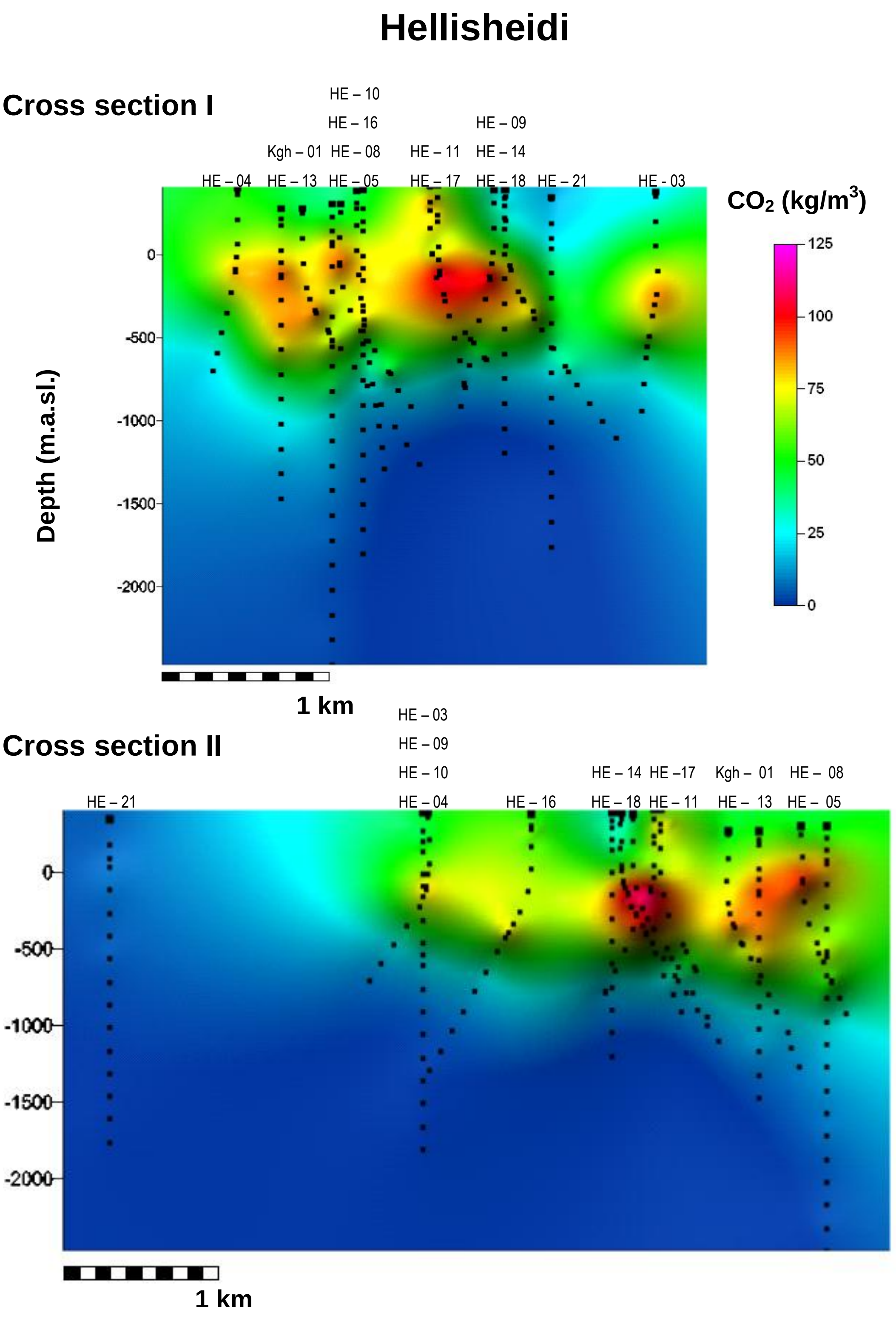

Figure 7. *Cross sections showing the distribution of CO_2 fixed in the bedrock at Hellisheidi. Cross section I extends from west to east (looking north) and cross section II from south to north (looking west). Concentration of fixed CO_2 is indicated by different colors, see bar for scale.*

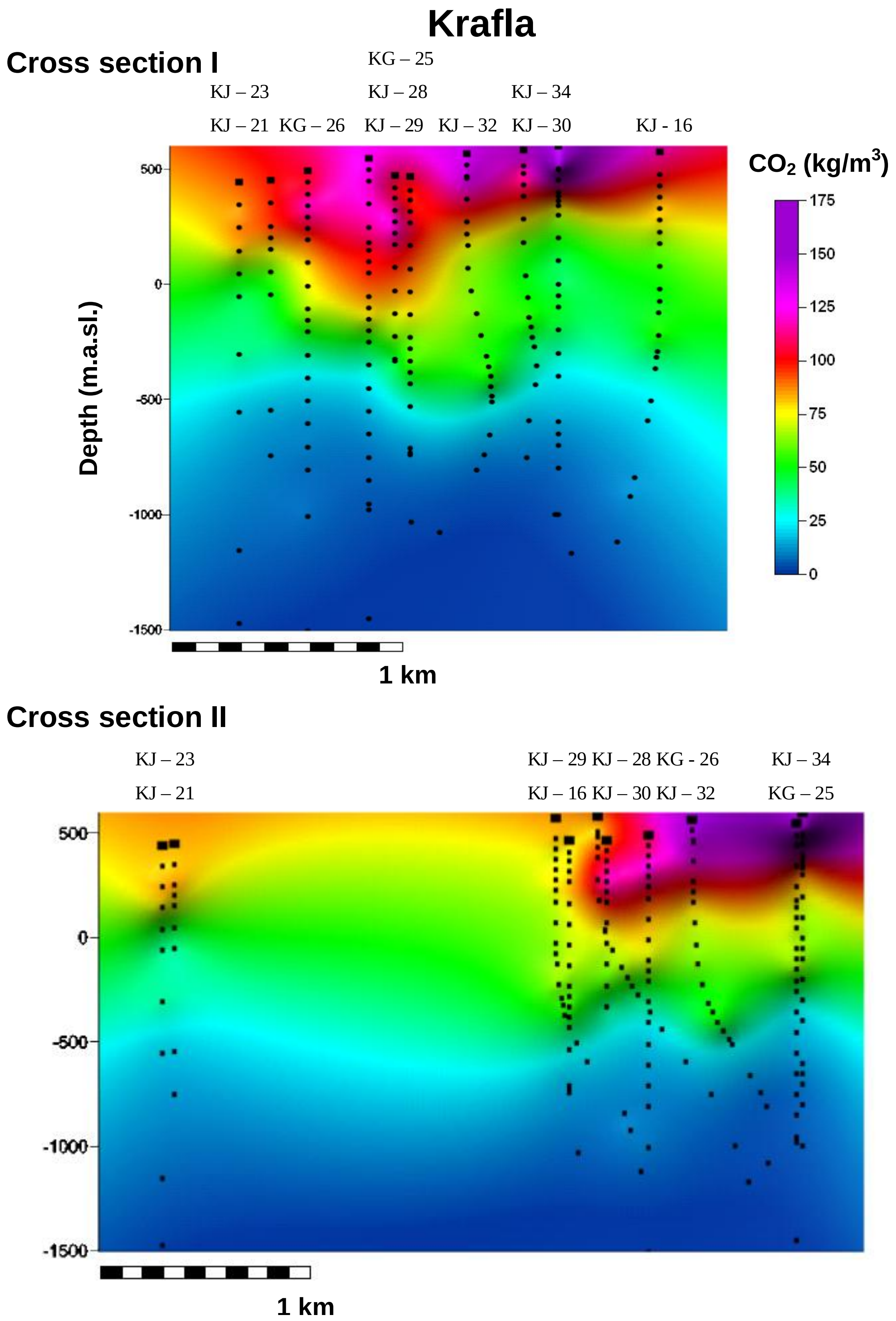

Figure 8. *Cross sections showing the distribution of CO_2 fixed in the bedrock at Krafla. Cross section I extends from west to east (looking north) and cross section II from south to north (looking west). Concentration of fixed CO_2 is indicated by different colors, see bar for scale.*

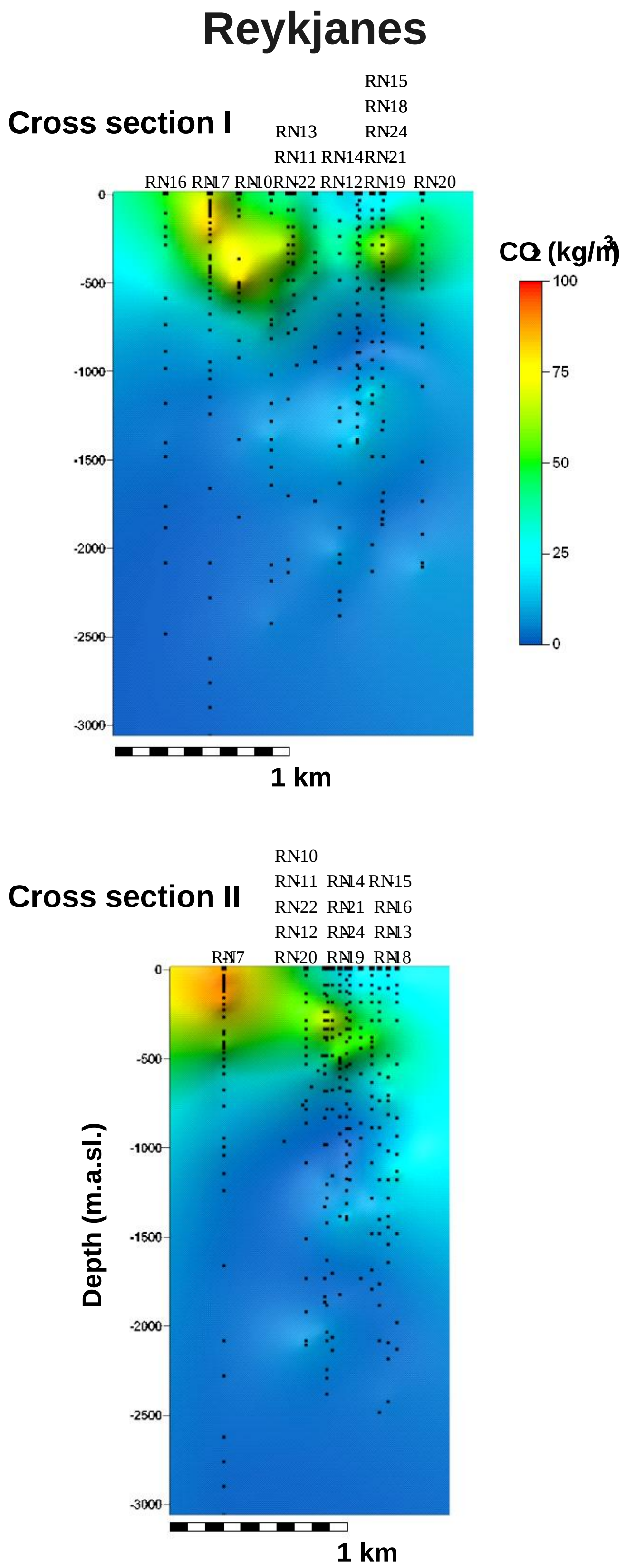

Figure 9. *Cross sections showing the distribution of CO_2 fixed in the bedrock at Reykjanes. Cross section I extends from west to east (looking north) and cross section II from south to north (looking west). Concentration of fixed CO_2 is indicated by different colors, see bar for scale.*

3.3 Mass of CO_2 fixed in the bedrock per unit surface area

The observed CO_2 concentration profiles, for each well, were used to compute the mass of CO_2 in the uppermost 1500 m of the bedrock, per unit surface area. This represents the total amount of CO_2 that is fixed in the crust, down to 1500 m, beneath a given area of the surface and is sometimes referred to as the CO_2-load of the given well. This value is a meaningful estimate of the amount of geothermal CO_2 fixed in the bedrock because almost all CO_2 has accumulated above 1500 m in these systems.

The CO_2 load of individual wells was computed by finite elements integration. The CO_2-depth profile for a given well was divided into segments so that each CO_2 measurement was at the middle of each segment. As a result, the segments were of different lengths depending on the sampling density. The total CO_2 fixed in the uppermost 1500 m of the crust (per well) was found by summing the products of the length of each segment (in m) by the measured CO_2 concentration at the center of that segment (in kg/m^3). The resulting value has the units of kg/m^2 or the more convenient t/m^2.

The computed CO_2 load of the uppermost 1500 m of the crust for individual wells and the average values for the three geothermal systems are shown in Table 3 below.

Table 3. *CO_2 load in the uppermost 1500 m of production wells.*

Reykjanes Well id	**CO_2 load (t/m^2)**	**Hellisheidi Well id**	**CO_2 load (t/m^2)**	**Krafla Well id**	**CO_2 load (t/m^2)**
RN - 10	42.5	HE - 03	70.1	KJ – 16	72.9
RN - 11	36.0	HE - 04	48.9	KJ – 21	37.4
RN - 12	16.7	HE - 05	72.9	KJ – 23	60.5
RN - 13	44.4	HE - 08	73.5	KG – 25	92.3
RN - 14	15.4	HE - 09	53.2	KG – 26	73.3
RN - 15	20.1	HE - 10	51.5	KJ – 28	81.9
RN - 16	19.0	HE - 11	103.4	KJ – 29	82.3
RN - 17	41.7	HE - 13	60.0	KJ – 30	59.2
RN - 18	28.3	HE - 14	71.7	KJ – 32	89.0
RN - 19	32.6	HE - 16	61.4	KJ – 34	82.0
RN - 20	24.6	HE - 17	93.4		
RN - 21	15.3	HE - 18	53.6		
RN - 22	36.6	KHG - 01	100.9		
RN - 24	22.1	HE - 21	5.0		
Reykjanes average	**28.2**	**Hellisheidi average**	**65.7**	**Krafla average**	**73.1**

The results were used to generate top view maps of the areas depicting the CO_2 load of the uppermost 1500 m of the crust (Figures 10, 11 and 12). In most cases the CO_2 load of a given well was projected to the X and Y coordinates of the wellhead. However, it is not appropriate to project the computed CO_2 load of the crust to the wellhead of inclined or directionally drilled wells. Therefore, we chose to use the X and Y coordinate of the depth level that bisects the mass of the accumulated CO_2 as projection points for the CO_2 load of non-vertical wells. The kriging method was used to interpolate between wells. The colors that indicate the mass of fixed CO_2 per unit surface area and the same scale is used for all three areas.

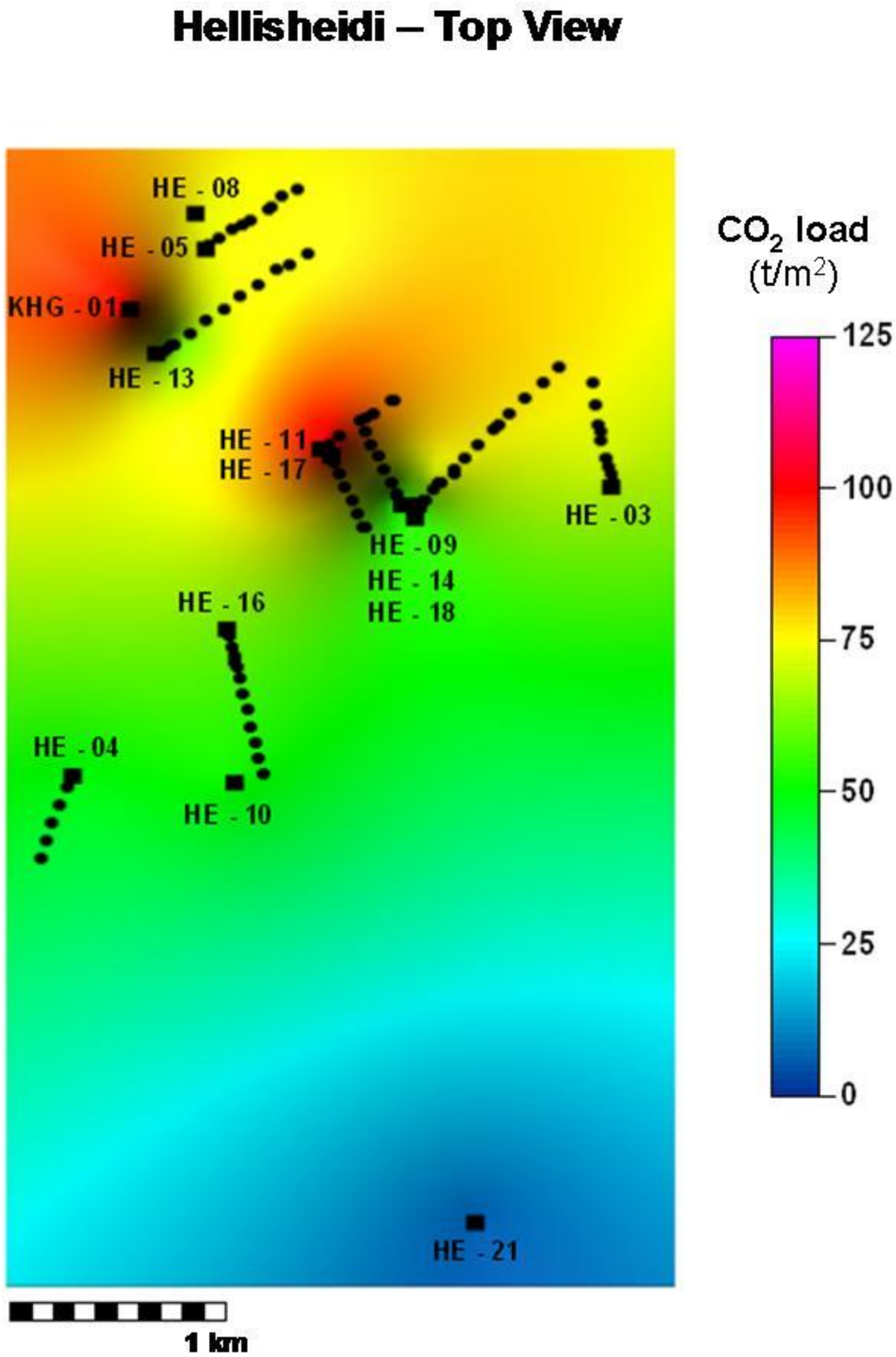

Figure 10. *CO_2 load of the uppermost 1,500 m of the crust at Hellisheidi, top view. Color scale indicates the amount of CO_2 fixed in the rock in units of tons per square meter on the surface. Black squares indicate the location of well heads and black dots indicate the X and Y location of individual rock cutting samples.*

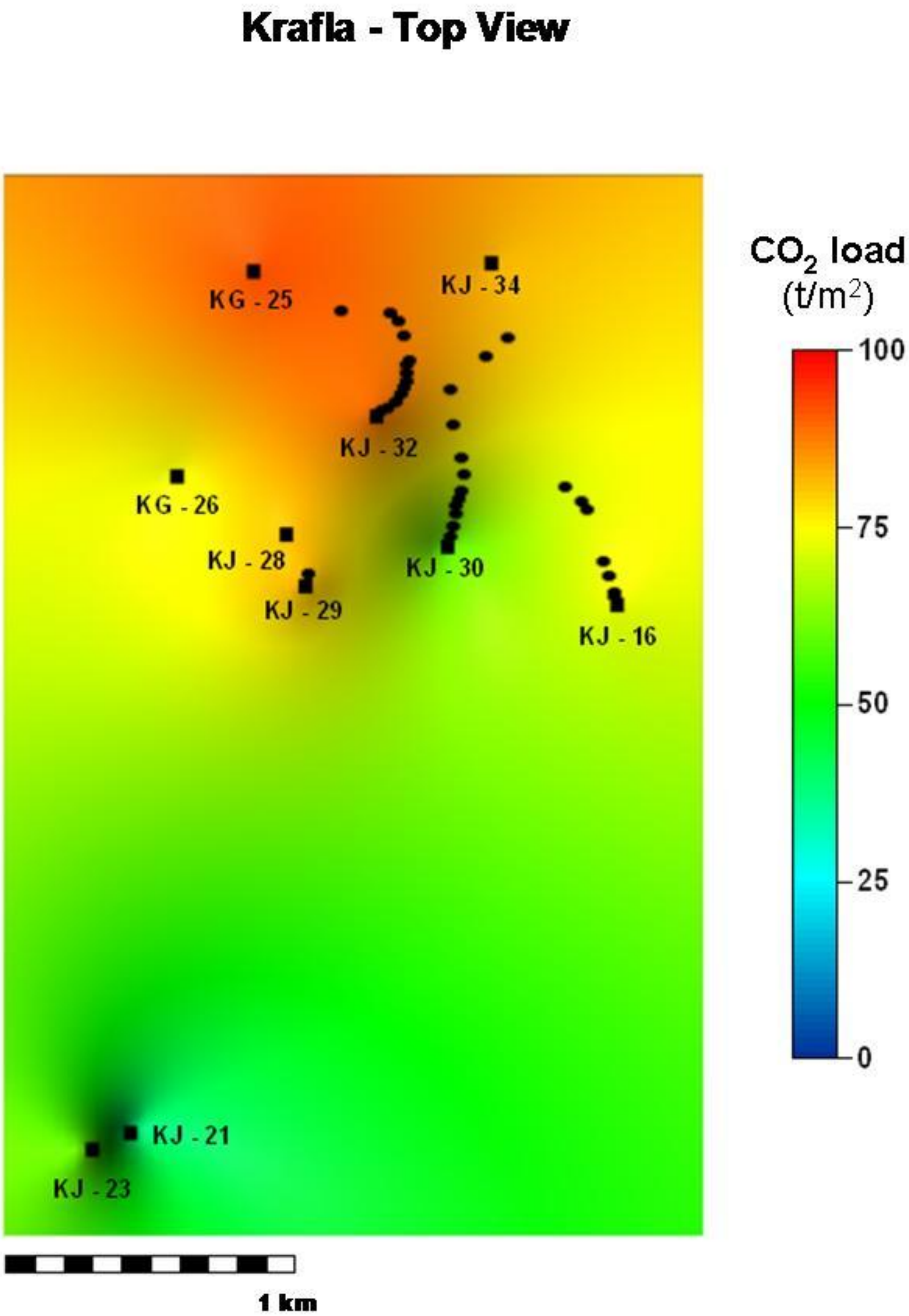

Figure 11. *CO_2 load of the uppermost 1,500 m of the crust at Krafla, top view. Color scale indicates the amount of CO_2 fixed in the rock in units of tons per square meter on the surface. Black squares indicate the location of well heads and black dots indicate the X and Y location of individual rock cutting samples.*

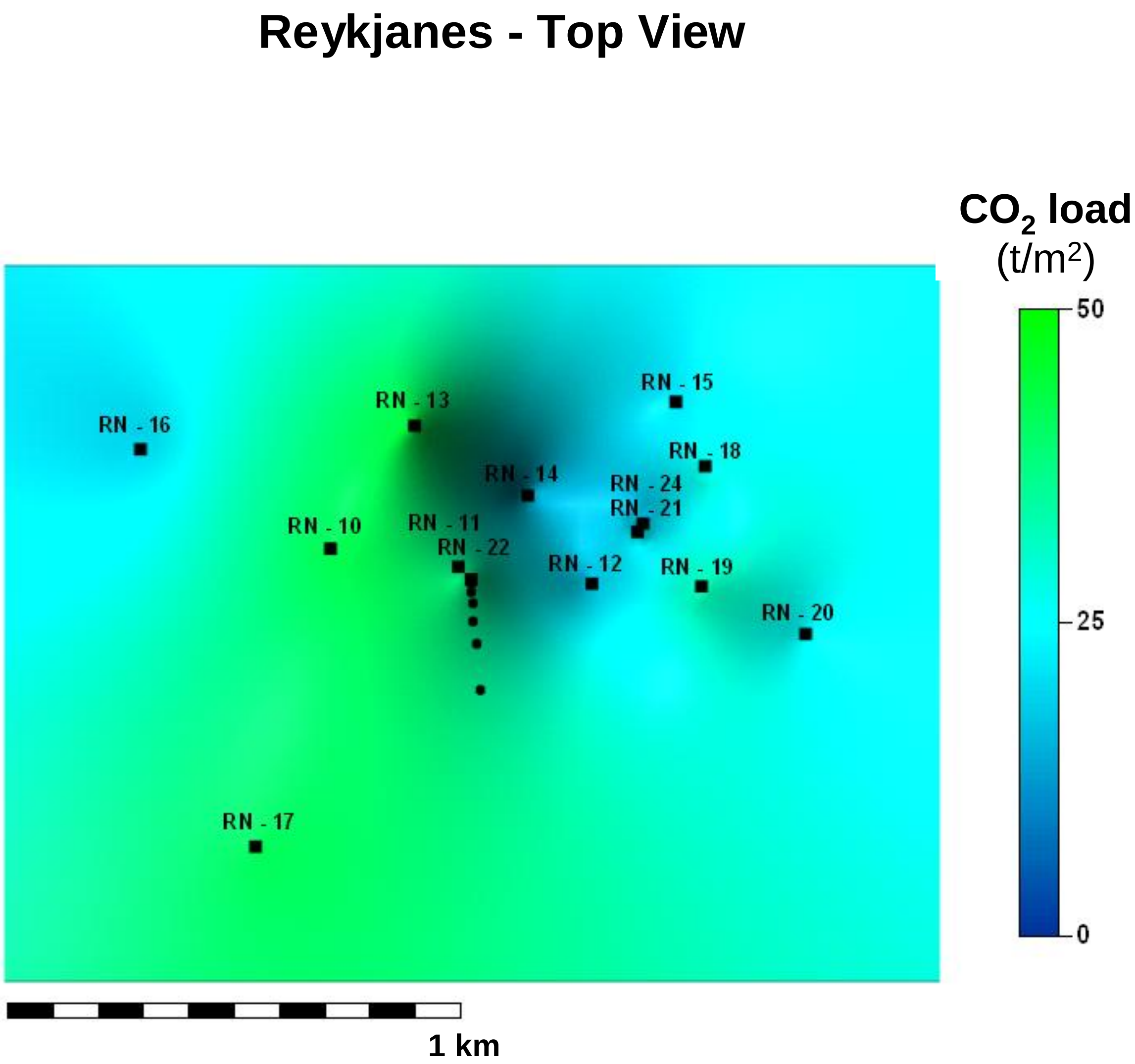

Figure 12. *CO_2 load of the uppermost 1,500 m of the crust at Reykjanes, top view. Color scale indicates the amount of CO_2 fixed in the rock in units of tons per square meter on the surface. Black squares indicate the location of well heads and black dots indicate the X and Y location of individual rock cutting samples.*

4 Discussion

4.1 Comparison of the areas

Differences and similarities between the three areas can be observed in the cross sections and graphs shown above. In order to highlight the characteristics of the distribution of fixed CO_2 in the three areas, Hellisheidi, Krafla, and Reykjanes, the average CO_2-depth profiles for the three systems are shown in Figure 13, below. Because these geothermal fields are located at different altitudes, the CO_2-depth profiles are shown in terms of m below the surface. The graph shows that in Hellisheidi there is almost as much fixed CO_2 as in Krafla while much less CO_2 is fixed in the Reykjanes area. This is in agreement with the values for the average CO_2 content (t/m^2) shown in Table 3. The average CO_2-load is 65.7, 73.1 and 28.2 t/m^2 for Hellisheidi, Krafla and Reykjanes, respectively.

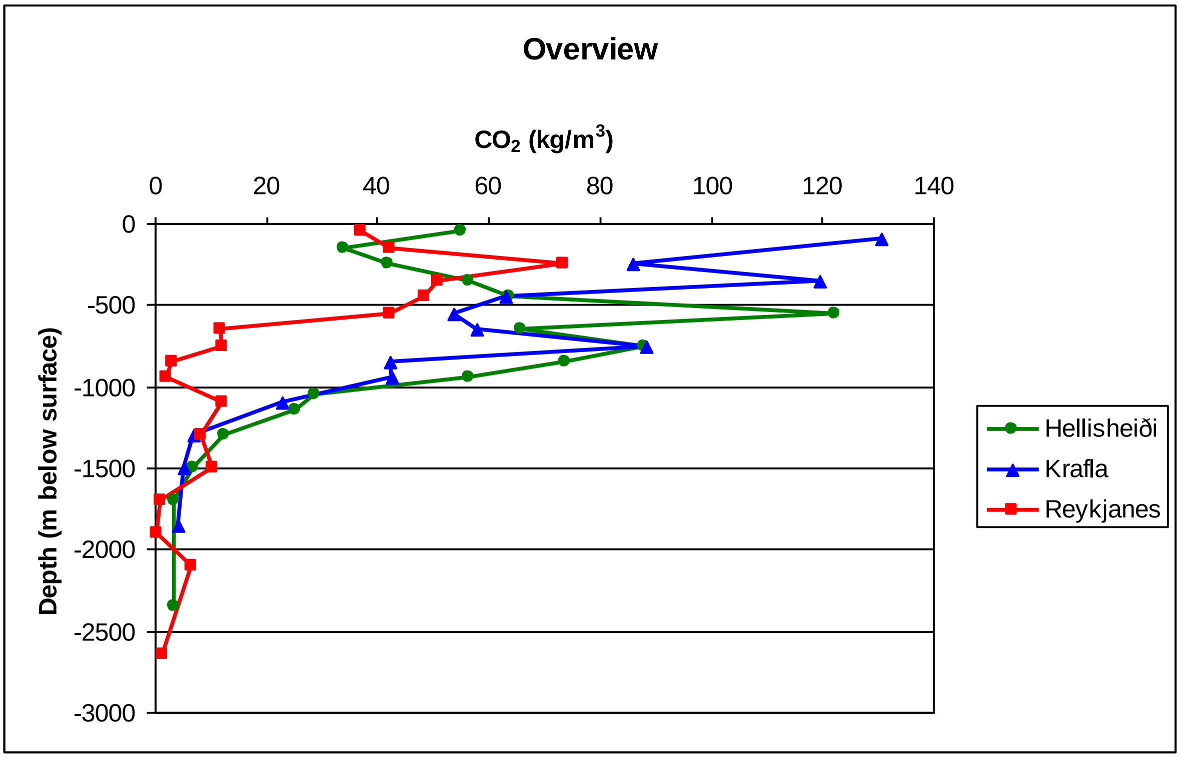

Figure 13. *Average CO_2-depth profiles for Hellisheidi, Krafla and Reykjanes.*

4.2 Total mass of fixed CO_2

The total amount of CO_2 fixed in the crust of the geothermal systems can be roughly estimated by multiplying the average CO_2-load of the wells in a given system, by its areal extent. Pálmason et al. (1985) estimated the extent of the Reykjanes geothermal systems to be 2 km^2 and Krafla 30 km^2. The determination of the extent of Hellisheidi is not as straightforward because the Hellisheidi high-temperature field is a subfield of the Hengill system, one of the most extensive geothermal systems in Iceland. A total area of around

110 km^2 is indicated by temperature distribution, surface and subsurface measurements (Gunnlaugson and Gíslason, 2005). Since the samples originate from the Hellisheidi subfield the average value can only be applied to an area of about 25 km^2 (estimate based on Björnsson et al., 2006, Figure 1).

The resulting values for the total amount of CO_2 fixed at Hellisheidi, Krafla, and Reykjanes are 1650 Mt, 2200 Mt, and 56 Mt, respectively. The amount of fixed CO_2 in Krafla alone amounts to about 1000 times the annual anthropogenic CO_2 emissions of Iceland (2.2 Mt in 2003; UNFCCC, 2005). Although it is highly speculative to apply our results to all high-temperature areas, it gives an idea of the total amount of CO_2 fixed in calcite in the Icelandic crust. The three high-temperature areas investigated here represent less than one tenth of all high-temperature systems in Iceland regarding both surface area (533 km^2; Pálmason et al., 1985) and the number of these areas (35–40) (Ármannsson et al., 2005). Based on the (somewhat speculative) assumption that the CO_2 content of the three systems investigated is representative, the total carbon dioxide fixed in active high-temperature systems in Iceland amounts to 30–40 Gt of CO_2. If geothermal systems related to extinct central volcanoes are included in this estimate the total amount of CO_2 fixed in the Icelandic crust may be 10 to 15 times higher (assuming that about 30–40 geothermal systems have been active in the volcanic zone throughout the geologic history of Iceland and each of them was active for ~1 million years).

4.3 Calcite fixation and the CO_2 budget of geothermal systems

In order to evaluate the importance of calcite fixation in geothermal systems as a geochemical sink of CO_2 it is necessary to estimate the time it has taken the calcite to accumulate. Unfortunately, the ages of the geothermal systems considered in this study are poorly constrained; age estimates for the Hellisheidi geothermal system range between 70,000 and 400,000 years (Franzson et al., 2005). For Krafla, K. Saemundsson gives a range of 110,00 to 290,000 years (K. Saemundsson, pers. comm., June 2006) and Reykjanes is estimated to be between 10,000 and 100,000 years old (Hjalti Franzson, pers. comm., April 2006).

These age estimates, the approximate areal extent of the systems, and the average CO_2-load of the crust in the three geothermal systems (see Table 3) were used to evaluate the calcite fixation rate in these systems. The results of these calculations and a summary of input parameters are given in Table 4. Results for Hellisheidi show that the estimated CO_2 fixation rate of calcite is 4,100 to 23,500 t/yr and for Krafla and Reykjanes the estimated CO_2 fixation rates are 7,500 to 20,000 and 560 to 5,600 t/yr, respectively. These values can be compared to observed natural atmospheric CO_2 emissions from these systems (also shown in Table 4). In 2004 the atmospheric emissions from Reykjanes were 5,000 t/yr (Fridriksson et al., 2006) and preliminary data analysis indicates that geothermal soil diffuse degassing from eastern Krafla caldera (where the active geothermal activity is located) is of the order of 85,000 t/yr (Ármannsson et al., 2007). Comparison of the CO_2 fixation rate determined in this study and the observed atmospheric emissions from Reykjanes and Krafla shows that the magnitude of the CO_2 fixation is somewhere between 7.5% of the atmospheric emissions to being equal to the atmospheric emissions. These results illustrate that calcite fixation plays a considerable role in the CO_2-budget of geothermal systems, even if the lower estimates for the CO_2 fixation rate were true.

Table 4. *CO_2 fixation rates in geothermal systems. Results, input parameters and comparison to natural atmospheric emission rates from the systems.*

	Area (km²)	Fixed CO_2 (kg/m²)	Age (y)	Fixation Rate (kg/m² y)	CO_2 Emissions (kg/m² y)
Hellisheidi	25(1)	65700	70.000 - 400.000(3)	0.2 – 0.9	
Krafla	30(4)	73100	110.000 - 290.000(5)	0.3 – 0.7	4.25(2)
Reykjanes	2(4)	28200	10.000 -100.000(6)	0.3 – 2.8	2.5(7)
Iceland*	*533(8)*	*55667(9)*	*100.000 -1.000.000(10)*	*0.1 – 0.6*	*0.2 –3.8(11)*

***Data for Iceland are conjectures**

Björnsson et al., 2006; Ármannsson et al., 2007; Franzson et al., 2005; Pálmason et al., 1985; Saemundsson, K., personal communication, June 2006; Franzson, H., personal communication, April 2006; Fridriksson et al., 2006; Ármannsson et al., 2005; Average of Hellisheidi, Krafla and Reykjanes; Arnórsson, 1995 and Calculation based on data from Ármannsson et al., 2005.

5 Concluding remarks

This study represents the first attempt to quantify the amount of fixed CO_2 in Icelandic geothermal systems. We have demonstrated that almost 4 Gt of CO_2 are fixed in calcite in the uppermost 1 km of the crust in Reykjanes, Hengill, and Krafla. We have also shown that calcite fixation is a process that may be as important to the CO_2 budget of geothermal systems as atmospheric emissions are, although it seems more likely that the fixation is somewhat less important than the atmospheric emissions.

It must be reiterated that this study has only focused on two of the three geochemical sinks for CO_2 in geothermal systems. No attempt has been made to evaluate the amount of CO_2 that is transported away from the geothermal systems dissolved in ground waters. There is no reason to assume that this is a less important process than the calcite fixation for the CO_2 budget of geothermal systems and further studies are needed to address this component of the CO_2 budget of geothermal systems.

6 References

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Appendix 1: Well – Reports - ordered by area, well number and section

Hellisheidi

Franzson, H., Steingrímsson, B., Gudmundsson, B., Richter, B., Birgisson, K., Sigurdsson, Ó., Danielsen, P.E., 2001. **Hellisheidi, Well HE – 3, 1. section** (in Icelandic). Orkustofnun OS – 2001/052.

Sigvaldi, T., Hjartarson, A., Gudmundsson, Á., Steingrímsson, B., Gautason, B., Gudmundsson, B., Hermannsson, G., Franzson, H., Birgisson, K., Jónsson, S.S., 2001. **Hellisheidi, Well HE – 3, 3.section** (in Icelandic). Orkustofnun OS-2001/057.

Jónsson, S.S., Steingrímsson, B., Gudmundsson, B., Richter, B., Hermannsson, G., Danielsen, P., Thordarson, S., 2001. **Hellisheidi, Well HE – 4, 1. section** (in Icelandic), Orkustofnun OS-2001/058.

Gudmundsson, Á., Gautason, B., Gudmundsson, B., Richter, B. Hermannsson, G., Franzon, H., Sigurdsson, G., Danielsen, P.E., Thordarson, S., 2001. **Hellisheidi, Well HE – 4, 2.section** (in Icelandic). Orkustofnun OS-2001/065.

Gudmundsson, Á., Hjartarson, A., Gudmundsson, B., Hermannsson, G., Fridleifsson, G.Ó., Sigurdsson, Ó., Danielsen, P.E., Jónsson, S.S., 2001. **Hellisheidi Well HE – 4, 3.section** (in Icelandic). Orkustofnun OS-2001/081.

Jónsson, S.S., Gudmundsson, Á., Hermannsson, G., Sigurdsson, Ó., Gudlaugsson, S.TH., Steinthórsson, T., 2002. **Hellisheidi Well HE – 5, 1.section** (in Icelandic). Orkustofnun OS-2002/024.

Richter, B., Sigurdsson, Ó., Gudmundsson, Á., Gudlaugsson, S.TH., Hermannsson, G., Skarphédinsson, K., 2002**. Hellisheidi Well HE – 5, 2. section** (in Icelandic). Orkustofnun OS-2002/025.

Gudmundsson, Á., Richter, B., Franzon, H., Thordarson, S., Hermannsson, G., Danielsen, P.E., Sigurdsson, G., Danielsen, P.E., Sigurdsson, Ó., Gudnason, Ó., 2002. **Hellisheidi Well HE – 5, 3.section** (in Icelandic). Orkustofnun OS-2002/026.

Kristjánsson, B.R., Gunnarsson, G., Richter, B., Danielsen, P.E., Birgisson, K., 2003. **Hellisheidi - Well HE – 8, 1.section** (in Icelandic). 1.section. ÍSOR-2003/005.

Kristjánsson, B.R., Thordarson, S., Benediktsson, Í.Ö., Sigurdsson, Ó., Egilson, TH., Sigurdsson, Á., 2003. **Hellisheidi - Well HE – 8, 2.section** (in Icelandic). ÍSOR-2003/006.

Jónsson, S.S., Gautason, B., Gudmundsson, Á., Egilson, TH., Sigurdsson, Ó., Hermannsson, G., Birgisson, K., Gunnarsson, G., Gudnason, Ó., Danielsen, P.E., 2003. **Hellisheidi - Well HE – 8, 3.section**. ÍSOR-2003/007.

Richter, B., Gunnarsson, G., Franzon, H., Birgisson, K., Sigurdsson, Ó., Danielsen, P.E., Skarphédinsson, K., 2003. **Hellisheidi – Well HE - 9, 1.section** (in Icelandic). ÍSOR-2003/002.

Gautason, B., Gunnarsson, G., Gudmundsson, Á., Danielsen, P.E., Birgisson, K., Sigurdsson, Á., 2003. **Hellisheidi – Well HE - 9, 2.section** (in Iclandic). ÍSOR-2003/003.

Richter, B., Sigurdsson, Ó., Gunnarsson, G., Gudmundsson, Á., Birgisson, K., Skarphédinsson, 2003. **Hellisheidi – Well HE - 9, 3.section** (in Icelandic). ÍSOR-2003/004.

Gautason, B., Danielsen, P.E., Ásmundsson, R.K., Steingrímsson, B., THórisson, S., 2004. **Hellisheidi – Well HE - 10, 1.section** (in Icelandic). ÍSOR-2004/011.

Gudmundsson, Á., Richter, B., Ásmundsson, R., Birgisson, K., Thordarson, S., Sveinbjörnsson, TH., 2004. **Hellisheidi – Well HE - 10, 2.section** (in Icelandic). ÍSOR-2004/015.

Gudmundsson, Á., Jónsson, S., Richter, B., Sigurdsson, Ó., Danielsen, P.E., Hermannsson, G., Birgisson, K., Gudnason, Ó., 2004. **Hellisheidi – Well HE - 10, 3.section** (in Icelandic). ÍSOR-2004/018.

Jónsson, S.S., Richter, B., Egilson, TH., Steingrímsson, B., Birgisson, K., Sigurdsson, Ó., Ingvarsson, G.B., Sigurdsson, Á., 2004. **Hellisheidi – Well HE - 11, 1.section** (in Icelandic). ÍSOR-2004/022.

Kristjánsson, B.R., Steingrímsson, B., Björnsson, G., Thordarson, S., Blischke, A., Jónasson, H., Egilson, TH., Skarphédinsson, K., 2004. **Hellisheidi – Well HE -13, 1.section** (in Icelandic). ÍSOR-2004/023.

Blischke, A., Kristjánsson, B.R., Egilson, TH., Hjartarson, A., Ásmundsson, K., Björnsson, G., THórisson, S., Steinthórsson, T., 2004. **Hellisheidi – Well HE - 13, 2.section** (in Icelandic). ÍSOR-2004/030.

Kristjánsson, B.R., Blischke, A., Hjartarson, A., Egilson, TH., Björnsson, G., Ásmundsson, R., Jónasson, H., Sigvaldason, H., Skarphédinsson, K., 2004. **Hellisheidi – Well HE - 13, 3.section** (in Icelandic). ÍSOR-2004/037.

Gudmundsson, Á., Richter, B., Kristjánsson, B.R., Sigurdsson, Ó., Hjartarson, A., Jónasson, H., Jónsson, P.H., 2004. **Hellisheidi – Well HE - 14, 1. and 2.section** (in Icelandic). ÍSOR-2004/041.

Gautason, B., Egilson, TH., Gudmundsson, Á., Magnússon, TH.M., Sigvaldason, H., Jónasson, H., 2004. **Hellisheidi – Well HE - 14, 3.section** (in Icelandic). ÍSOR-2004/044.

Jónsson, S.S., Gautason, B., Mortensen, A.K., Danielsen, P.E., Birgisson, K., Steinthórsson, T., 2005. **Hellisheidi – Well HE - 16, 1. and 2.section** (in Icelandic). ÍSOR-2005/028.

Gudmundsson, Á., Franzon, H., Sigurdsson, Ó., Ásmundsson, R., Egilson, TH., Danielsen, P.E., Hermannsson, G., Sigurdsson, G., Jónasson, H., THórisson. S., 2005. **Hellisheidi – Well HE - 17, 1. and 2.section** (in Icelandic). ÍSOR-2005/034.

Gudmundsson, Á., Gautason, B., Kristjánsson, B.R., Danielsen, P.E., Ásmundsson, R., Sigurdsson, G., Mahmood, A.T.K., Steinthórsson, T., 2005. **Hellisheidi – Well HE - 17, 3.section** (in Icelandic). ÍSOR-2005/037.

Krafla

Gudmundsson, Á., Steingrímsson, B., Björnsson, G., Jónsson, S.S., Thordarson, S., Sigurdsson, Ó., Sigursteinsson, D., 1998. **Krafla, Well KJ - 29, 3.section** (in Icelandic). Orkustofnun OS-98084.

Gudmundsson, Á., Sigurstinsson, D., Sigvaldason, H., Franzon, H., Birgisson, K., Jónsson, S.S., Thordarson, S., 1997. **Krafla, Well KJ - 30, 2.section** (in Icelandic). Orkustofnun OS-97045.

Gudmundsson, Á., Jónsson, S.S., Sigvaldason, H., Thordarson, S., Benediktsson, S., Sigursteinsson, D., 1997. **Krafla, Well KJ - 30, 3.section** (in Icelandic). Orkustofnun .

Gudmundsson, Á., Franzon, H., Sigvaldason, H., Birgisson, K., Sigursteinsson, D., 1998. **Krafla, Well KJ - 32, 1.section** (in Icelandic). Orkustofnun.

Gudmundsson, Á., Richter, B., Sigvaldason, H., Birgisson, K., Sigurdsson, Ó., Thordarson, S., Matthíasson, M., Sigursteinsson, D., 1998. **Krafla, Well KJ - 32, 3.section** (in Icelandic). Orkustofnun OS-98058.

Reykjanes

Reykjanes RN – 22, daily drill reports (unpublished data from ÍSOR).

Appendix 2: A complete list of results for individual cuttings samples

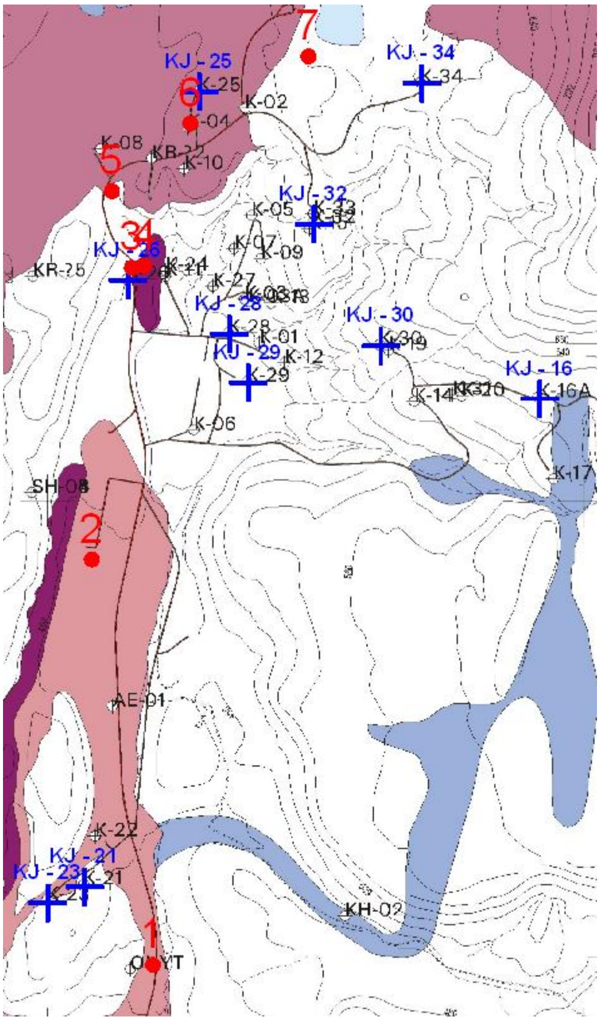
A. Background samples

Area	Number	Carbon (wt%)
Krafla	K - 1	0.032
	K - 2	0.006
	K - 3	0.031
	K - 4	0.021
	K - 5	0.028
	K - 6	0.023
	K - 7	0.141
Myvatn	8	0.012
Hverfell	9	0.014
Reykjanes	R - 1	0.004
	R - 2	0.016
	R - 3	0.060
	R - 4	0.048
	R - 5	0.066
	R - 6	0.016
	R - 7	0.009

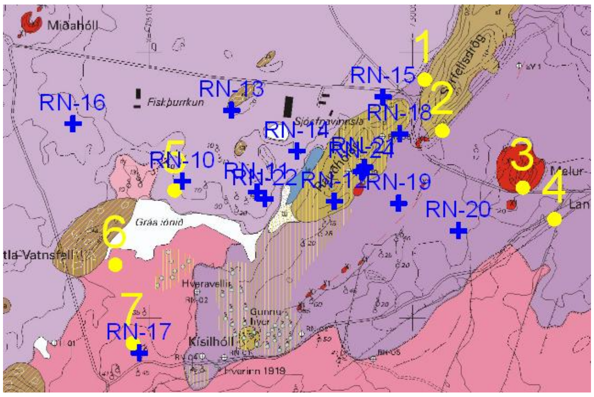
Median:

Carbon (wt%)
0.022

CO_2 (wt%)
0.081



Krafla



Reykjanes

+ Sample Well

● ● Background Sample

B. Hellisheidi data

Well Name	Number	Borehole Length (m)	Vertical Depth (m)	X	Y	Z (m.a.sl.)	Carbon C (wt%)	Captured CO_2 (kg/m^3)
HE - 03	95103	0	0	385995	395056	384		
		32	32	385995	395056	352	**0.04**	**1.5**
		180	180	385995	395056	204	**0.39**	**36.7**
		330	330	385998	395058	54	**0.35**	**32.4**
		480	478	386009	395075	-94	**0.95**	**92.1**
		630	621	386003	395118	-237	**1.63**	**159.1**
		700	684	385991	395148	-300	**1.20**	**117.2**
		782	752	385978	395191	-368	**0.86**	**83.0**
		930	874	385957	395272	-490	**1.31**	**127.5**
		1006	939	385947	395310	-555	**0.08**	**6.3**
		1080	1003	385940	395347	-619	**0.07**	**5.1**
		1266	1164	385924	395439	-780	**0.05**	**2.7**
		1456	1325	385914	395539	-941	**0.06**	**3.8**
HE - 04	95104	0	0	383492	393717	404		
		30	30	383492	393717	374	**0.57**	**54.7**
		40	40	383492	393717	364	**0.77**	**74.1**
		190	190	383491	393718	214	**0.34**	**32.1**
		340	340	383491	393721	64	**0.37**	**34.8**
		416	415	383485	393716	-11	**0.69**	**66.2**
		490	488	383479	393700	-84	**1.57**	**153.5**
		510	507	383477	393698	-103	**1.11**	**107.4**
		640	628	383457	393657	-224	**0.76**	**72.9**
		789	751	383426	393577	-347	**0.17**	**14.8**
		940	874	383396	393494	-470	**0.12**	**9.9**
		1090	994	383369	393409	-590	**0.06**	**3.9**
		1228	1105	383346	393331	-701	**0.03**	**1.1**

HE - 05	95105	0	0	384109	396154	307		
		50	50	384109	396154	257	**0.03**	**0.7**
		200	200	384107	396156	107	**0.80**	**77.6**
		350	350	384105	396160	-43	**1.60**	**156.9**
		370	370	384106	396161	-63	**1.62**	**158.4**
		500	498	384124	396176	-191	**0.42**	**39.3**
		652	639	384167	396207	-332	**0.42**	**39.6**
		800	765	384229	396255	-458	**0.82**	**79.1**
		876	826	384275	396270	-519	**0.56**	**53.1**
		950	884	384313	396295	-577	**0.18**	**15.8**
		1110	1009	384399	396346	-702	**0.89**	**86.5**
		1130	1025	384410	396351	-718	**0.99**	**96.2**
		1250	1121	384457	396408	-814	**0.04**	**2.2**
		1378	1222	384531	396441	-915	**0.08**	**5.7**
HE - 08	95108	0	0	384059	396324	309		
		80	80	384059	396324	229	**0.22**	**19.8**
		162	162	384059	396324	147	**0.24**	**21.3**
		230	230	384059	396324	79	**1.68**	**164.5**
		252	252	384059	396324	57	**0.95**	**92.4**
		380	380	384059	396324	-71	**0.72**	**69.5**
		530	530	384059	396324	-221	**0.50**	**47.8**
		680	680	384059	396324	-371	**0.17**	**15.3**
		820	820	384059	396324	-511	**0.71**	**68.4**
		830	830	384059	396324	-521	**1.39**	**135.5**
		860	860	384059	396324	-551	**1.08**	**104.9**
		980	980	384059	396324	-671	**0.21**	**19.2**
		1130	1130	384059	396324	-821	**0.79**	**76.4**
		1278	1278	384059	396324	-969	**0.28**	**25.4**
		1430	1430	384059	396324	-1121	**0.20**	**18.0**
		1580	1580	384059	396324	-1271	**0.22**	**19.8**
		1730	1730	384059	396324	-1421	**0.17**	**15.0**
		1880	1880	384059	396324	-1571	**0.05**	**3.3**
		2030	2030	384059	396324	-1721	**0.15**	**13.0**

		2180	2180	384059	396324	-1871	**0.04**	**1.8**
		2328	2328	384059	396324	-2019	**0.02**	**0.0**
		2480	2480	384059	396324	-2171	**0.03**	**1.3**
		2630	2630	384059	396324	-2321	**0.08**	**5.9**
		2780	2780	384059	396324	-2471	**0.04**	**2.4**
HE - 09	95109	0	0	385090	394914	395		
		50	50	385090	394914	345	**0.07**	**4.9**
		98	98	385090	394914	297	**0.98**	**94.6**
		172	172	385090	394914	223	**0.01**	**0.0**
		240	240	385090	394914	155	**0.31**	**28.4**
		390	390	385090	394914	5	**0.50**	**47.2**
		538	538	385090	394914	-143	**0.53**	**50.0**
		690	690	385090	394914	-295	**0.78**	**75.6**
		840	840	385090	394914	-445	**0.88**	**85.3**
		990	990	385090	394914	-595	**0.34**	**32.0**
		1140	1140	385090	394914	-745	**0.02**	**0.1**
		1290	1290	385090	394914	-895	**0.01**	**0.0**
		1440	1440	385090	394914	-1045	**0.05**	**2.7**
		1590	1590	385090	394914	-1195	**0.02**	**0.0**
HE - 10	95110	0	0	384242	393678	395		
		116	116	384242	393678	279	**0.02**	**0.3**
		192	192	384242	393678	203	**0.02**	**0.0**
		252	252	384242	393678	143	**1.03**	**100.3**
		400	400	384242	393678	-5	**0.42**	**39.7**
		476	476	384242	393678	-81	**0.77**	**74.7**
		550	550	384242	393678	-155	**1.00**	**97.2**
		700	700	384242	393678	-305	**0.76**	**73.5**
		850	850	384242	393678	-455	**0.64**	**61.4**
		930	930	384242	393678	-535	**0.12**	**10.1**
		1000	1000	384242	393678	-605	**0.10**	**8.1**
		1150	1150	384242	393678	-755	**0.03**	**1.3**
		1300	1300	384242	393678	-905	**0.03**	**0.5**

		1450	1450	384242	393678	-1055	**0.02**	**0.4**
		1600	1600	384242	393678	-1205	**0.02**	**0.0**
		1750	1750	384242	393678	-1355	**0.03**	**0.7**
		1900	1900	384242	393678	-1505	**0.03**	**0.6**
		2052	2052	384242	393678	-1657	**0.04**	**2.3**
		2198	2198	384242	393678	-1803	**0.02**	**0.0**
HE - 11	95111	0	0	384646	395233	420		
		10	10	384646	395233	410	**0.04**	**1.7**
		100	100	384646	395233	320	**3.06**	**300.9**
		150	150	384646	395233	270	**0.11**	**9.2**
		260	260	384646	395233	160	**0.98**	**95.3**
		412	412	384657	395236	8	**0.37**	**34.9**
		420	416	384658	395237	4	**0.22**	**19.8**
		562	558	384682	395253	-138	**0.98**	**94.7**
		710	695	384733	395287	-275	**0.96**	**92.8**
		960	890	384857	395376	-470	**0.63**	**60.6**
		1012	929	384885	395396	-509	**0.39**	**36.5**
		1163	1038	384971	395454	-618	**0.81**	**78.1**
		1182	1052	384982	395462	-632	**0.50**	**47.5**
HE - 13	95113	0	0	383884	395670	280		
		30	30	383884	395670	250	**0.03**	**1.2**
		180	180	383884	395670	100	**0.49**	**47.0**
		330	330	383887	395668	-50	**0.42**	**39.4**
		480	477	383904	395676	-197	**0.41**	**38.8**
		556	548	383927	395691	-268	**0.44**	**41.4**
		630	613	383956	395711	-333	**1.41**	**137.6**
		650	630	383965	395717	-350	**1.67**	**163.7**
		780	731	384031	395764	-451	**0.09**	**7.2**
		800	746	384042	395772	-466	**0.47**	**44.7**
		930	843	384111	395824	-563	**0.78**	**75.5**
		1080	956	384191	395883	-676	**0.77**	**74.5**
		1230	1069	384271	395939	-789	**0.36**	**34.1**

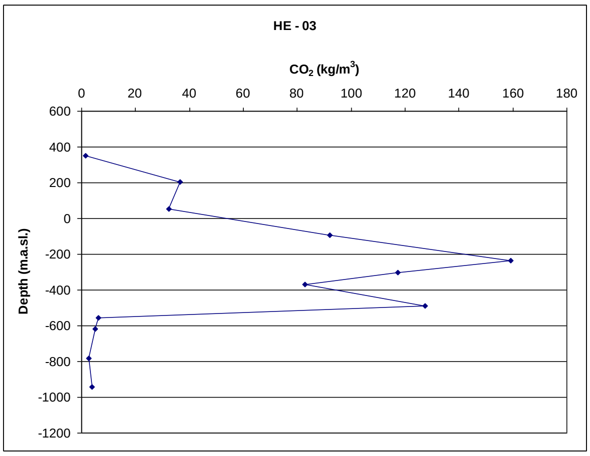
		1378	1182	384350	395992	-902	**0.11**	**8.6**
		1530	1318	384439	396068	-1038	**0.05**	**2.5**
		1680	1422	384504	396091	-1142	**0.03**	**0.7**
		1830	1543	384579	396139	-1263	**0.02**	**0.0**
HE - 14	95114	0	0	385099	394974	395		
		44	44	385099	394974	351	**0.04**	**1.7**
		190	190	385099	394974	205	**0.34**	**32.0**
		340	340	385101	394977	55	**0.27**	**25.1**
		460	457	385121	394990	-62	**0.81**	**78.0**
		490	486	385128	394995	-91	**1.42**	**138.4**
		640	618	385177	395045	-223	**0.93**	**89.8**
		696	662	385201	395070	-267	**0.66**	**63.2**
		700	665	385203	395072	-270	**0.71**	**68.6**
		706	670	385205	395075	-275	**0.94**	**91.4**
		792	735	385264	395115	-340	**1.51**	**147.9**
		850	779	385271	395142	-384	**1.44**	**140.4**
		940	846	385314	395184	-451	**0.51**	**48.9**
		1090	957	385384	395255	-562	**0.24**	**22.0**
		1240	1068	385455	395328	-673	**0.64**	**61.0**
		1280	1097	385474	395347	-702	**0.68**	**65.5**
		1390	1178	385527	395399	-783	**0.12**	**9.7**
		1540	1288	385601	395470	-893	**0.14**	**11.8**
		1690	1395	385678	395542	-1000	**0.09**	**6.6**
		1840	1498	385759	395614	-1103	**0.08**	**5.5**
HE - 16	95116	0	0	384205	394391	389		
		76	76	384205	394391	313	**0.08**	**5.7**
		108	108	384205	394391	281	**1.59**	**155.0**
		210	210	384206	394390	179	**0.23**	**20.6**
		360	360	384207	394390	29	**0.78**	**75.4**
		360 2	360	384207	394390	29	**0.77**	**74.5**
		510	507	384216	394365	-118	**0.78**	**75.5**
		660	646	384232	394312	-257	**0.37**	**34.9**

		660 2	646	384232	394312	-257	**0.43**	**40.9**
		750	725	384241	394270	-336	**0.70**	**66.9**
		810	777	384248	394241	-388	**1.83**	**179.1**
		850	812	384252	394221	-423	**0.93**	**90.4**
		960	906	384266	394166	-517	**0.16**	**14.1**
		1110	1035	384284	394092	-646	**0.04**	**1.8**
		1110 2	1035	384284	394092	-646	**0.04**	**2.2**
		1260	1164	384302	394017	-775	**0.08**	**6.2**
		1410	1293	384320	393943	-904	**0.07**	**5.0**
		1556	1418	384338	393870	-1029	**0.07**	**4.6**
		1556 2	1418	384338	393870	-1029	**0.06**	**4.3**
		1710	1551	384356	393794	-1162	**0.05**	**2.9**
		1860	1680	384374	393719	-1291	**0.07**	**4.9**
HE - 17	95117	0	0	384691	395195	419		
		70	70	384691	395195	349	**0.59**	**56.5**
		180	180	384691	395195	239	**0.88**	**85.5**
		220	220	384691	395195	199	**1.02**	**99.4**
		370	370	384694	395193	49	**0.17**	**14.8**
		450	449	384699	395185	-30	**0.24**	**21.3**
		520	518	384704	395172	-99	**2.04**	**199.6**
		542	539	384706	395166	-120	**2.02**	**198.3**
		670	656	384729	395120	-237	**1.03**	**99.9**
		820	787	384762	395056	-368	**1.22**	**119.2**
		970	921	384794	394995	-502	**0.86**	**83.1**
		1120	1055	384823	394935	-636	**0.33**	**31.0**
		1270	1190	384847	394874	-771	**0.02**	**0.0**
		1282	1200	384849	394869	-781	**0.05**	**3.3**
HE - 18	95118	0	0	385030	394973	395		
		80	80	385030	394973	315	**0.03**	**1.1**
		230	230	385028	394973	165	**0.03**	**1.4**
		380	379	385023	394983	16	**0.62**	**59.0**
		450	448	385014	394994	-53	**0.53**	**50.0**

		530	524	385005	395017	-129	**2.78**	**273.6**
		550	542	385002	395024	-147	**1.14**	**110.8**
		680	658	384974	395076	-263	**0.61**	**58.0**
		830	790	384940	395138	-395	**1.06**	**102.7**
		980	924	384910	395197	-529	**0.06**	**4.0**
		1130	1060	384883	395256	-665	**0.10**	**8.4**
		1280	1192	384857	395315	-797	**0.01**	**0.0**
		1404	1305	384833	395369	-910	**0.03**	**1.4**
KHG - 01	96852	0	0	383754	395880	280		
		60	60	383754	395880	220	**0.36**	**33.4**
		98	98	383754	395880	182	**0.81**	**78.1**
		250	250	383754	395880	30	**0.84**	**81.4**
		324	324	383754	395880	-44	**0.55**	**52.2**
		400	400	383754	395880	-120	**2.46**	**241.9**
		418	418	383754	395880	-138	**0.38**	**35.6**
		550	550	383754	395880	-270	**0.85**	**81.9**
		700	700	383754	395880	-420	**1.27**	**124.0**
		850	850	383754	395880	-570	**1.44**	**140.5**
		1000	1000	383754	395880	-720	**0.20**	**18.1**
		1150	1150	383754	395880	-870	**0.27**	**24.9**
		1300	1300	383754	395880	-1020	**0.17**	**14.4**
		1450	1450	383754	395880	-1170	**0.33**	**30.7**
		1600	1600	383754	395880	-1320	**0.04**	**1.8**
		1750	1750	383754	395880	-1470	**0.08**	**6.1**
HE - 21	95121	0	0	385370	391637	350		
		12	12	385370	391637	338	**0.01**	**0.0**
		160	160	385370	391637	190	**0.02**	**0.0**
		250	250	385370	391637	100	**0.02**	**0.0**
		310	310	385370	391637	40	**0.15**	**12.4**
		460	460	385370	391637	-110	**0.14**	**11.9**
		610	610	385370	391637	-260	**0.03**	**1.0**
		760	760	385370	391637	-410	**0.02**	**0.2**

		910	910	385370	391637	-560	**0.11**	**9.1**
		1060	1060	385370	391637	-710	**0.00**	**0.0**
		1210	1210	385370	391637	-860	**0.01**	**0.0**
		1360	1360	385370	391637	-1010	**0.04**	**1.7**
		1510	1510	385370	391637	-1160	**0.01**	**0.0**
		1660	1660	385370	391637	-1310	**0.00**	**0.0**
		1810	1810	385370	391637	-1460	**0.00**	**0.0**
		1960	1960	385370	391637	-1610	**0.00**	**0.0**
		2110	2110	385370	391637	-1760	**0.00**	**0.0**
HN - 02	96592	0	0	381139	393742	300		
		32	32	381139	393742	268	**2.72**	**267.3**
		34	34	381139	393742	266	**0.85**	**82.5**
		36	36	381139	393742	264	**0.69**	**66.5**
		100	100	381139	393742	200	**0.02**	**0.0**
		170	170	381139	393742	130	**0.15**	**13.0**
		320	320	381139	393742	-20	**0.51**	**48.3**
		470	470	381139	393742	-170	**0.17**	**15.0**
		620	620	381139	393742	-320	**0.22**	**19.7**
		770	770	381139	393742	-470	**0.09**	**7.1**
		920	920	381139	393742	-620	**0.24**	**21.9**
		1070	1070	381139	393742	-770	**0.28**	**25.5**
		1220	1220	381139	393742	-920	**0.20**	**17.6**
		1370	1370	381139	393742	-1070	**0.43**	**40.4**
		1520	1520	381139	393742	-1220	**0.48**	**45.4**
		1670	1670	381139	393742	-1370	**0.29**	**26.6**
		1820	1820	381139	393742	-1520	**0.07**	**4.6**
		1970	1970	381139	393742	-1670	**0.18**	**15.4**
		1994	1994	381139	393742	-1694	**0.38**	**35.9**
HN - 03	96593	0	0	381128	393064	300		
		24	24	381128	393064	276	**0.05**	**2.7**
		30	30	381128	393064	270	**0.15**	**12.6**
		180	180	381127	393063	120	**0.02**	**0.0**

330	330	381121	393055	-30	**0.10**	**8.0**
480	475	381153	393046	-175	**0.05**	**3.4**
630	611	381216	393029	-311	**0.07**	**5.3**
780	743	381284	393012	-443	**0.06**	**3.9**
930	871	381360	392995	-571	**0.10**	**8.1**
1080	995	381442	392977	-695	**0.13**	**10.5**
1230	1116	381529	392956	-816	**0.22**	**20.0**
1380	1234	381618	392933	-934	**0.30**	**27.9**
1400	1250	381630	392930	-950	**0.50**	**47.3**
1530	1351	381709	392909	-1051	**0.13**	**11.3**
1680	1469	381798	392884	-1169	**0.05**	**2.9**
1830	1535	381883	392854	-1235	**0.05**	**3.3**


HE - 03
CO2 (kg/m3)
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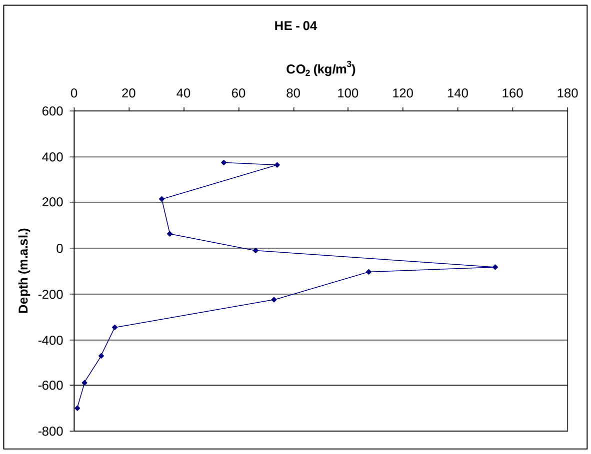
600 400 200 0 -200 -400 -600 -800 -1000 -1200
Depth (m.a.sl.)


HE - 04
CO2 (kg/m3)
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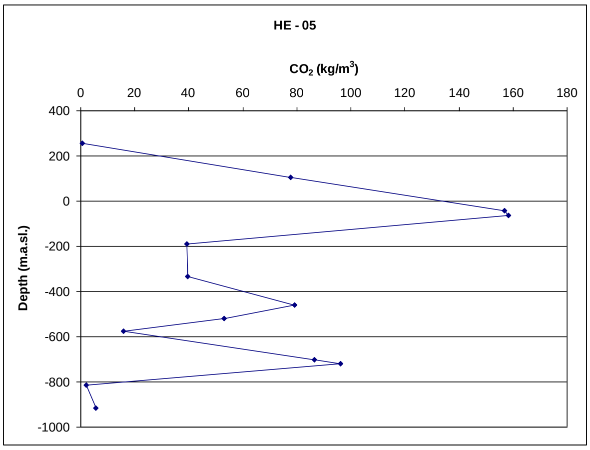
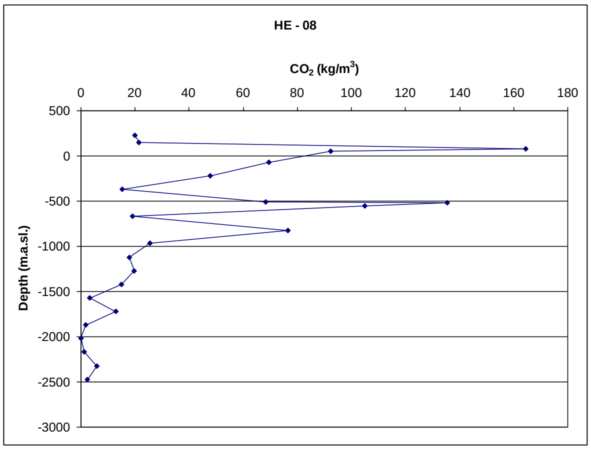
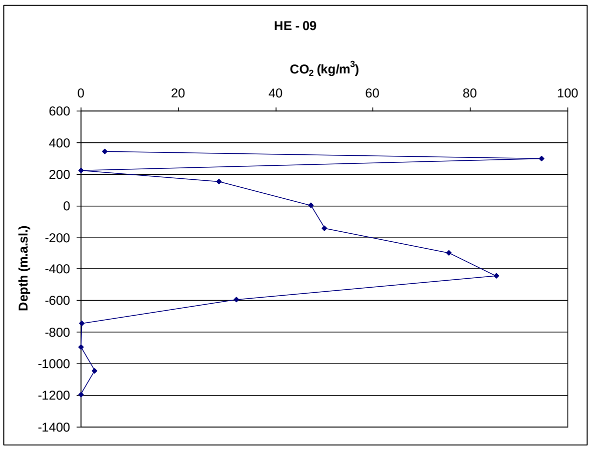
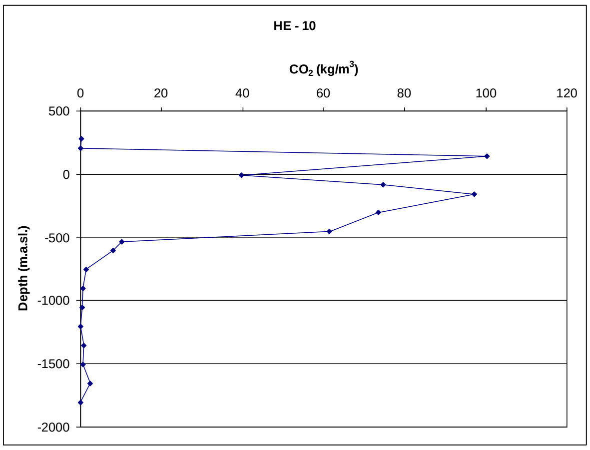
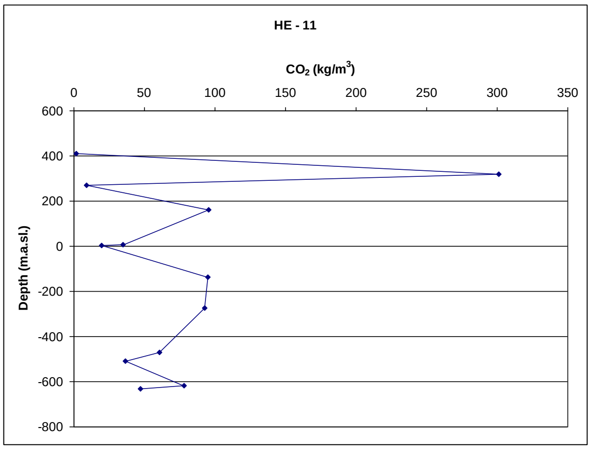
600 400 200 0 -200 -400 -600 -800
Depth (m.a.sl.)

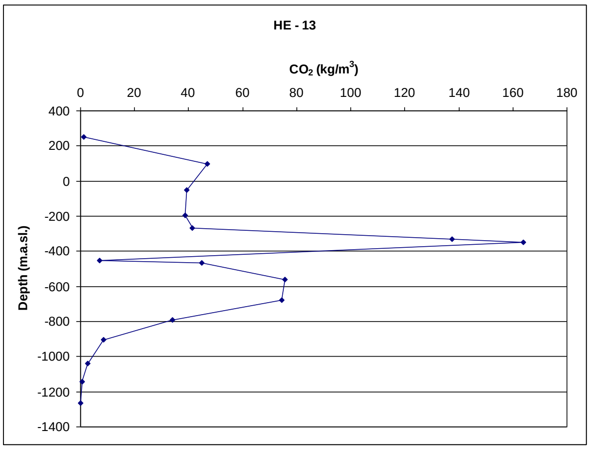

HE - 05
CO2 (kg/m3)
0 20 40 60 80 100 120 140 160 180
400 200 0 -200 -400 -600 -800 -1000
Depth (m.a.sl.)

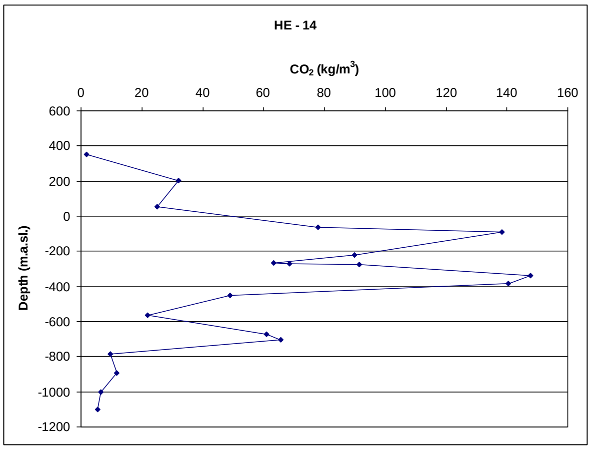

HE - 08
CO2 (kg/m3)
0 20 40 60 80 100 120 140 160 180
500 0 -500 -1000 -1500 -2000 -2500 -3000
Depth (m.a.sl.)

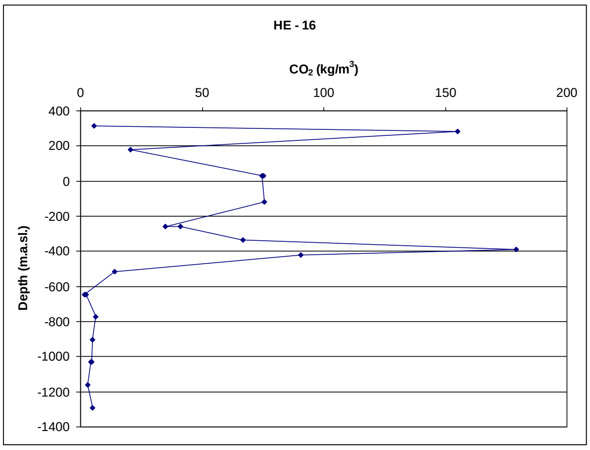

HE - 09
CO2 (kg/m3)
0 20 40 60 80 100
600 400 200 0 -200 -400 -600 -800 -1000 -1200 -1400
Depth (m.a.sl.)

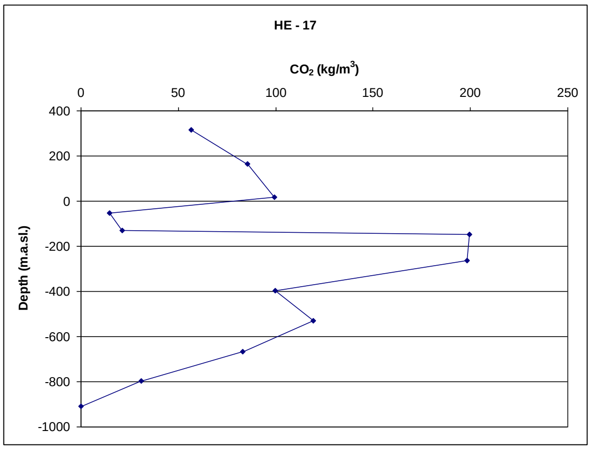

HE - 10
CO2 (kg/m3)
0 20 40 60 80 100 120
500 0 -500 -1000 -1500 -2000
Depth (m.a.sl.)

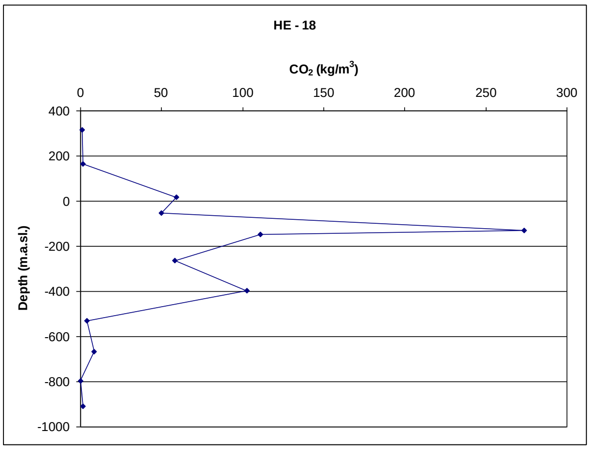

HE - 11
CO2 (kg/m3)
0 50 100 150 200 250 300 350
600 400 200 0 -200 -400 -600 -800
Depth (m.a.sl.)

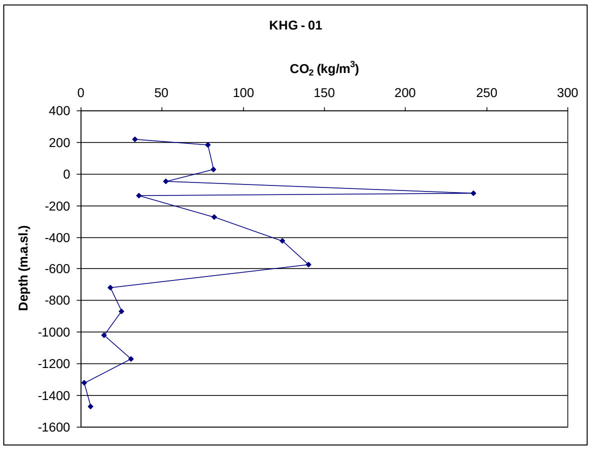

HE - 13
CO2 (kg/m3)
0 20 40 60 80 100 120 140 160 180
400 200 0 -200 -400 -600 -800 -1000 -1200 -1400
Depth (m.a.sl.)

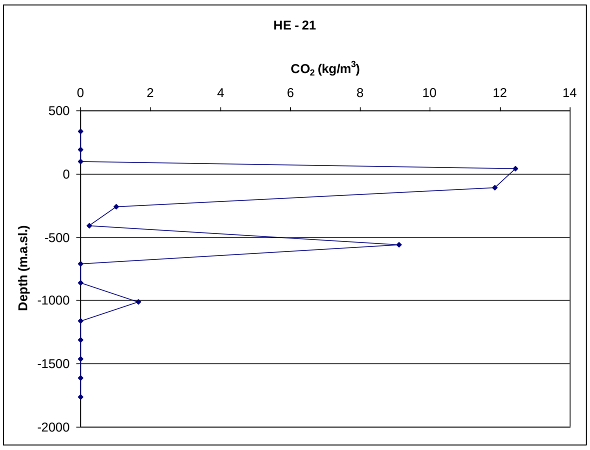

HE - 14
CO2 (kg/m3)
Depth (m.a.sl.)

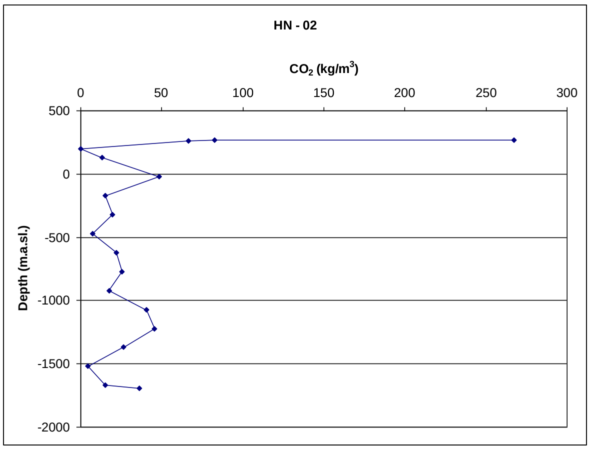

HE - 16
CO2 (kg/m3)
Depth (m.a.sl.)

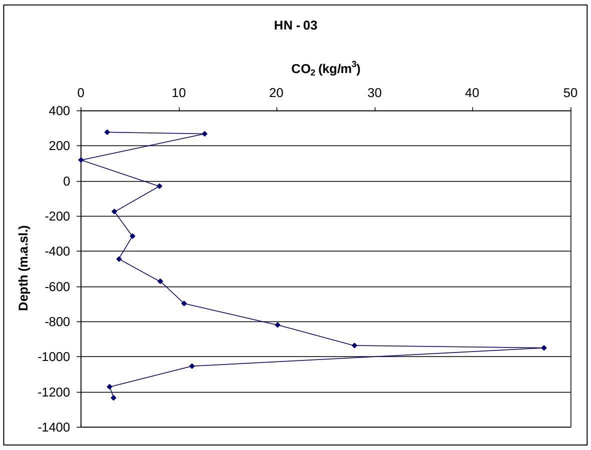

HE - 17
CO2 (kg/m3)
Depth (m.a.sl.)

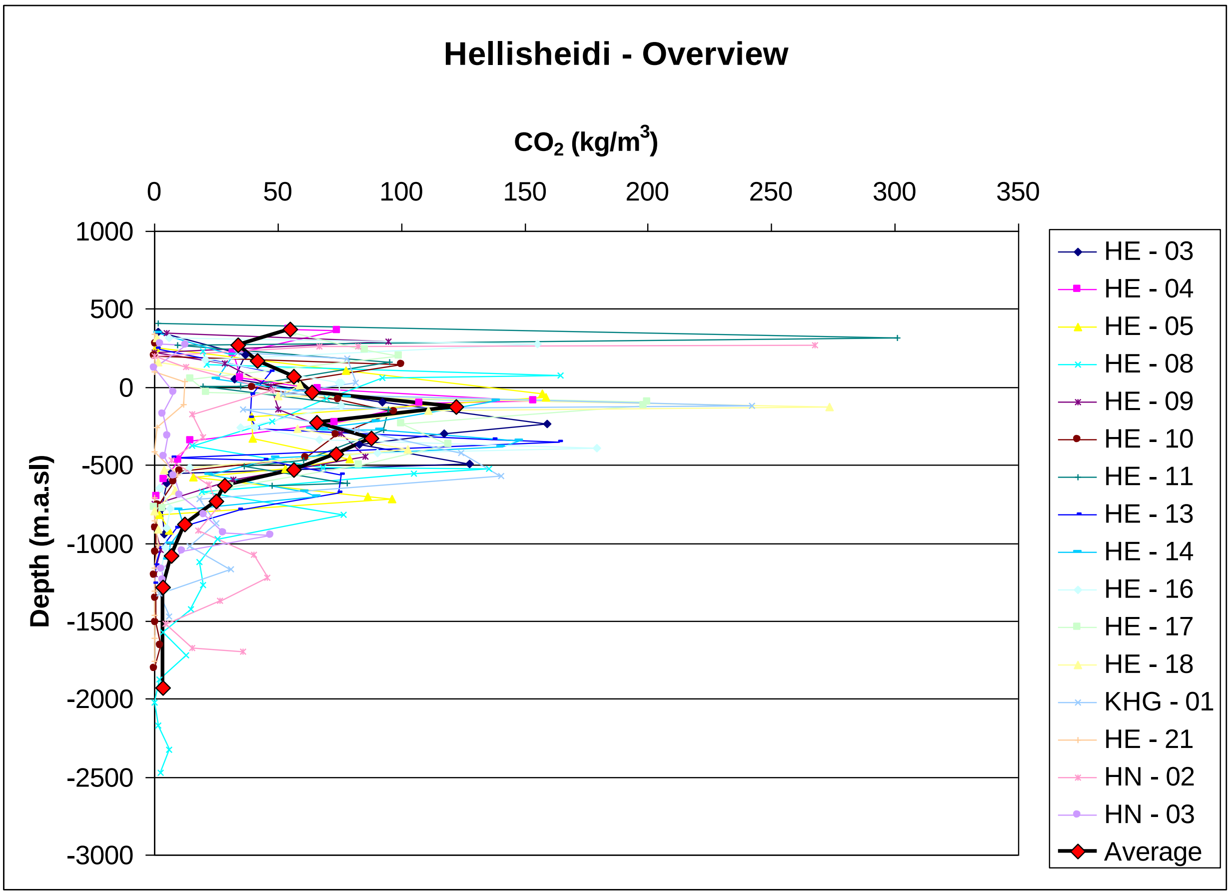

HE - 18
CO2 (kg/m3)
Depth (m.a.sl.)


KHG - 01
CO2 (kg/m3)
Depth (m.a.sl.)


HE - 21
CO2 (kg/m3)
Depth (m.a.sl.)


HN - 02
CO2 (kg/m3)
Depth (m.a.sl.)


HN - 03
CO2 (kg/m3)
Depth (m.a.sl.)


Hellisheidi - Overview
CO2 (kg/m3)
0
50
100
150
200
250
300
350
1000
500
0
-500
-1000
-1500
-2000
-2500
-3000
Depth (m.a.sl)
HE - 03
HE - 04
HE - 05
HE - 08
HE - 09
HE - 10
HE - 11
HE - 13
HE - 14
HE - 16
HE - 17
HE - 18
KHG - 01
HE - 21
HN - 02
HN - 03
Average

C. Krafla data

Well Name	Number	Borehole Length (m)	Vertical Depth (m)	X	Y	Z (m.a.sl.)	Carbon C (wt%)	Captured CO_2 (kg/m^3)
KJ - 16	58016	0	0	603830	580388	580		
		100	100	603830	580388	480	**1.30**	**126.8**
		150	150	603830	580388	430	**1.09**	**105.8**
		200	200	603830	580388	380	**0.32**	**29.5**
		250	250	603830	580388	330	**0.47**	**44.5**
		300	300	603830	580388	280	**1.58**	**154.5**
		350	350	603830	580388	230	**0.76**	**73.5**
		402	402	603830	580388	178	**0.23**	**21.1**
		500	500	603830	580388	80	**0.48**	**45.1**
		600	600	603830	580388	-20	**0.54**	**51.8**
		652	652	603830	580388	-72	**0.29**	**27.1**
		700	700	603827	580393	-120	**0.40**	**38.1**
		800	800	603825	580401	-220	**1.48**	**144.1**
		870	869	603821	580412	-289	**0.48**	**45.5**
		898	896	603818	580418	-316	**0.25**	**22.9**
		950	946	603814	580431	-366	**0.22**	**19.3**
		1100	1084	603794	580486	-504	**0.15**	**13.1**
		1200	1170	603776	580535	-590	**0.17**	**14.9**
		1500	1418	603719	580711	-838	**0.04**	**2.4**
		1598	1500	603700	580743	-920	**0.25**	**22.8**
		1800	1696	603647	580793	-1116	**0.06**	**4.0**
KJ - 21	58021	0		602134	578564	455		
		100	100	602134	578564	355	**0.81**	**77.8**
		200	200	602134	578564	255	**1.31**	**127.7**
		250	250	602134	578564	205	**1.09**	**105.8**
		300	300	602134	578564	155	**0.41**	**38.5**
		400	400	602134	578564	55	**0.06**	**3.7**
		500	500	602134	578564	-45	**0.10**	**7.5**

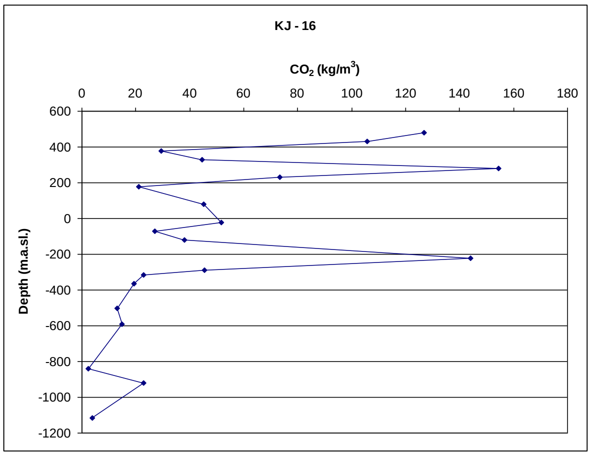
		1000	1000	602134	578564	-545	**0.08**	**6.1**
		1200	1200	602134	578564	-745	**0.10**	**8.0**
KJ - 23	58023	0		601998	578504	447		
		100	100	601998	578504	347	**0.42**	**39.8**
		200	200	601998	578504	247	**1.28**	**124.5**
		300	300	601998	578504	147	**1.85**	**181.3**
		400	400	601998	578504	47	**0.04**	**2.0**
		500	500	601998	578504	-53	**0.06**	**3.9**
		750	750	601998	578504	-303	**0.73**	**70.7**
		1000	1000	601998	578504	-553	**0.11**	**8.6**
		1600	1600	601998	578504	-1153	**0.07**	**5.2**
		1920	1920	601998	578504	-1473	**0.03**	**0.9**
KG - 25	58025	0		602563	581534	550		
		50	50	602563	581534	500	**1.59**	**155.6**
		100	100	602563	581534	450	**1.48**	**145.0**
		200	200	602563	581534	350	**1.59**	**155.9**
		300	300	602563	581534	250	**1.03**	**100.2**
		365	365	602563	581534	185	**1.25**	**121.4**
		400	400	602563	581534	150	**0.33**	**31.1**
		450	450	602563	581534	100	**0.92**	**88.9**
		500	500	602563	581534	50	**1.37**	**133.3**
		600	600	602563	581534	-50	**1.03**	**100.1**
		650	650	602563	581534	-100	**0.71**	**68.4**
		700	700	602563	581534	-150	**1.78**	**173.8**
		750	750	602563	581534	-200	**0.32**	**29.5**
		800	800	602563	581534	-250	**0.07**	**4.6**
		900	900	602563	581534	-350	**0.01**	**-0.9**
		1000	1000	602563	581534	-450	**0.06**	**3.7**
		1100	1100	602563	581534	-550	**0.07**	**4.6**
		1200	1200	602563	581534	-650	**0.08**	**5.6**
		1300	1300	602563	581534	-750	**0.05**	**3.0**
		1400	1400	602563	581534	-850	**0.08**	**6.2**

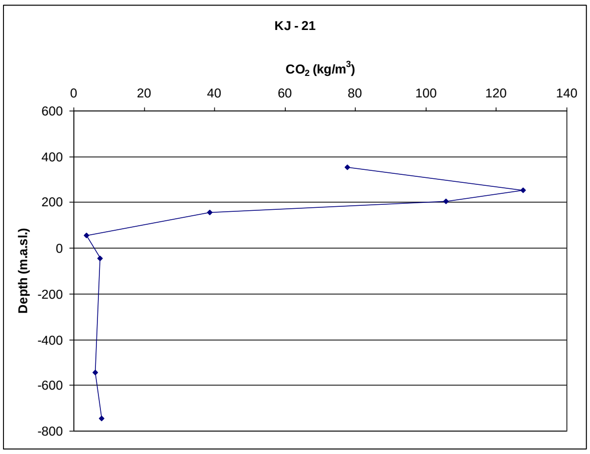
		1502	1502	602563	581534	-952	**0.01**	**-0.5**
		1526	1526	602563	581534	-976	**0.10**	**7.4**
		2000	2000	602563	581534	-1450	**0.03**	**0.7**
KG - 26	58026	0		602295	580830	495		
		50	50	602295	580830	445	**0.13**	**11.3**
		100	100	602295	580830	395	**0.61**	**58.6**
		150	150	602295	580830	345	**2.88**	**282.8**
		200	200	602295	580830	295	**1.39**	**135.6**
		250	250	602295	580830	245	**1.21**	**118.2**
		300	300	602295	580830	195	**0.45**	**42.6**
		400	400	602295	580830	95	**0.56**	**53.9**
		500	500	602295	580830	-5	**0.98**	**94.7**
		600	600	602295	580830	-105	**1.18**	**114.9**
		650	650	602295	580830	-155	**0.96**	**93.0**
		700	700	602295	580830	-205	**0.40**	**38.0**
		800	800	602295	580830	-305	**0.19**	**17.0**
		900	900	602295	580830	-405	**0.16**	**14.3**
		1000	1000	602295	580830	-505	**0.13**	**10.9**
		1100	1100	602295	580830	-605	**0.07**	**5.3**
		1200	1200	602295	580830	-705	**0.20**	**17.5**
		1300	1300	602295	580830	-805	**0.01**	**-0.9**
		1500	1500	602295	580830	-1005	**0.22**	**19.9**
		2000	2000	602295	580830	-1505	**0.00**	**-1.8**
KJ - 28	58028	0		602674	580629	475		
		52	52	602674	580629	423	**0.25**	**22.7**
		100	100	602674	580629	375	**1.07**	**103.7**
		150	150	602674	580629	325	**1.80**	**176.0**
		200	200	602674	580629	275	**2.16**	**212.0**
		250	250	602674	580629	225	**2.18**	**213.9**
		300	300	602674	580629	175	**1.17**	**113.8**
		400	400	602674	580629	75	**1.12**	**109.0**
		500	500	602674	580629	-25	**0.93**	**90.5**

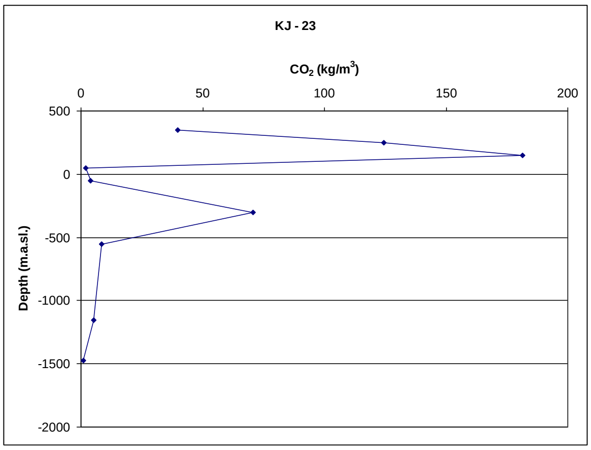
		600	600	602674	580629	-125	**0.27**	**25.0**
		700	700	602674	580629	-225	**1.09**	**105.5**
		800	800	602674	580629	-325	**0.11**	**8.9**
		806	806	602674	580629	-331	**0.06**	**4.3**
KJ - 29	58029	0		602744	580447	470		
		60	60	602744	580447	410	**0.17**	**15.0**
		100	100	602744	580447	370	**0.71**	**68.2**
		150	150	602744	580447	320	**0.01**	**-1.1**
		200	200	602744	580447	270	**1.29**	**125.7**
		300	300	602744	580447	170	**0.81**	**78.2**
		402	402	602744	580447	68	**0.79**	**76.7**
		500	500	602744	580447	-30	**0.98**	**95.0**
		600	600	602744	580447	-130	**1.22**	**118.6**
		700	700	602744	580447	-230	**0.36**	**33.3**
		750	750	602744	580447	-280	**0.30**	**27.3**
		800	800	602744	580447	-330	**1.53**	**149.6**
		850	850	602744	580447	-380	**1.05**	**102.0**
		900	900	602744	580447	-430	**0.46**	**43.7**
		1000	1000	602744	580447	-530	**0.30**	**27.5**
		1180	1180	602744	580447	-710	**0.01**	**-1.0**
		1202	1202	602744	580447	-732	**0.06**	**3.8**
		1204	1204	602744	580447	-734	**0.12**	**9.5**
		1206	1206	602744	580447	-736	**0.09**	**7.1**
		1208	1208	602744	580447	-738	**0.29**	**27.0**
		1500	1500	602744	580447	-1030	**0.03**	**1.3**
KJ - 30	58030	0		603238	580585	585		
		70	70	603238	580585	515	**0.04**	**1.6**
		100	100	603238	580585	485	**0.35**	**33.1**
		150	150	603238	580585	435	**1.57**	**153.6**
		200	200	603238	580585	385	**1.30**	**126.8**
		300	300	603235	580585	285	**0.94**	**90.9**
		400	400	603236	580590	185	**0.36**	**33.4**

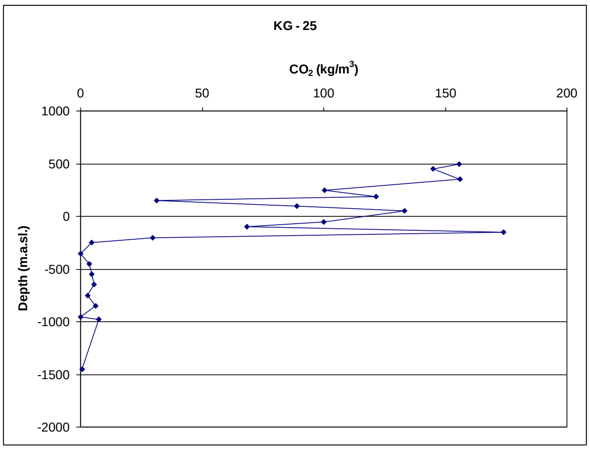
		549	545	603247	580620	40	**0.31**	**28.2**
		551	547	603247	580621	38	**0.62**	**59.0**
		650	639	603255	580655	-54	**0.46**	**43.4**
		750	727	603262	580702	-142	**1.12**	**109.3**
		800	770	603268	580727	-185	**0.83**	**79.7**
		850	812	603275	580754	-227	**0.19**	**16.7**
		900	853	603282	580780	-268	**0.13**	**10.7**
		1000	937	603291	580834	-352	**0.45**	**42.1**
		1100	1018	603289	580891	-433	**0.07**	**5.4**
		1300	1178	603258	581007	-593	**0.01**	**-0.6**
		1500	1336	603249	581128	-751	**0.13**	**10.7**
		1802	1583	603374	581241	-998	**0.05**	**2.6**
		2000	1751	603447	581309	-1166	**0.04**	**2.4**
KJ - 32	58032	0		602989	581040	572		
		50	50	602989	581040	522	**1.91**	**186.9**
		100	100	602989	581040	472	**1.77**	**173.6**
		110	110	602989	581040	462	**1.82**	**177.9**
		200	200	602989	581042	372	**1.31**	**127.8**
		300	300	602991	581044	272	**1.00**	**97.3**
		350	350	602991	581045	222	**0.80**	**77.4**
		400	400	602992	581046	172	**0.31**	**28.8**
		500	500	602994	581049	72	**0.44**	**41.9**
		600	599	603007	581055	-27	**0.54**	**51.7**
		700	696	603031	581065	-124	**0.87**	**84.0**
		800	791	603053	581083	-219	**0.41**	**38.9**
		900	883	603076	581116	-311	**0.03**	**1.4**
		950	927	603085	581138	-355	**1.17**	**113.6**
		1000	970	603092	581161	-398	**1.08**	**105.1**
		1050	1013	603096	581187	-441	**1.10**	**107.2**
		1100	1055	603099	581213	-483	**0.03**	**0.7**
		1130	1080	603099	581230	-508	**0.01**	**-1.5**
		1300	1225	603089	581318	-653	**0.04**	**2.2**
		1400	1311	603066	581363	-739	**0.01**	**-1.0**

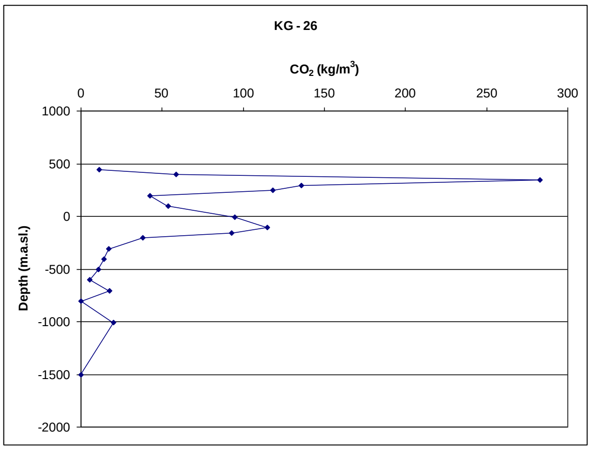
		1480	1379	603034	581392	-807	**0.02**	**0.5**
		1800	1650	602869	581399	-1078	**0.06**	**4.2**
KJ - 34	58034	0	0	603390	581566	603		
		100	100	603390	581566	503	**4.33**	**426.7**
		102	102	603390	581566	501	**3.37**	**331.9**
		104	104	603390	581566	499	**1.40**	**136.3**
		150	150	603390	581566	453	**0.89**	**86.2**
		200	200	603390	581566	403	**0.67**	**64.2**
		220	220	603390	581566	383	**0.95**	**92.3**
		240	240	603390	581566	363	**0.32**	**29.8**
		260	260	603390	581566	343	**0.40**	**37.3**
		300	300	603390	581566	303	**0.15**	**13.1**
		400	400	603390	581566	203	**0.36**	**33.9**
		500	500	603390	581566	103	**0.04**	**2.2**
		600	600	603390	581566	3	**0.04**	**2.2**
		650	650	603390	581566	-47	**0.72**	**69.8**
		700	700	603390	581566	-97	**0.62**	**59.0**
		800	800	603390	581566	-197	**0.71**	**68.4**
		900	900	603390	581566	-297	**0.13**	**11.1**
		1000	1000	603390	581566	-397	**0.06**	**4.2**
		1200	1200	603390	581566	-597	**0.26**	**24.0**
		1250	1250	603390	581566	-647	**0.02**	**0.4**
		1300	1300	603390	581566	-697	**0.11**	**8.7**
		1400	1400	603390	581566	-797	**0.03**	**1.1**
		1600	1600	603390	581566	-997	**0.05**	**2.9**

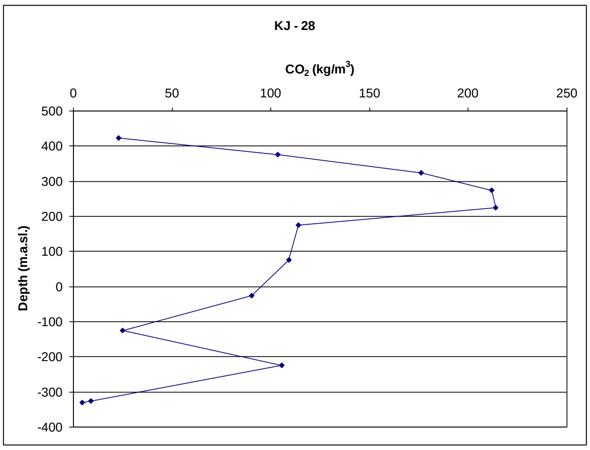

KJ - 16
CO2 (kg/m3)
0 20 40 60 80 100 120 140 160 180
Depth (m.a.sl.)
600 400 200 0 -200 -400 -600 -800 -1000 -1200

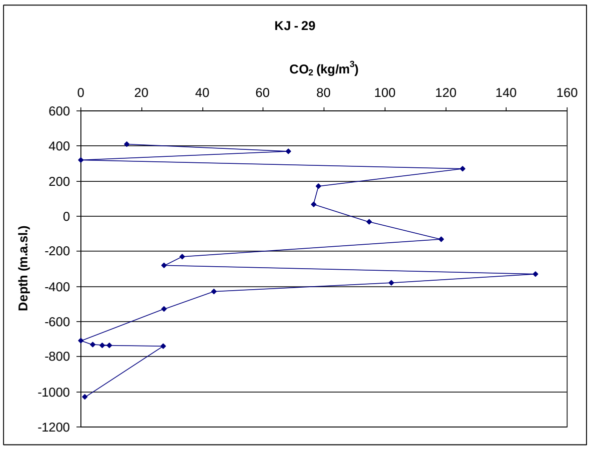

KJ - 21
CO2 (kg/m3)
0 20 40 60 80 100 120 140
Depth (m.a.sl.)
600 400 200 0 -200 -400 -600 -800

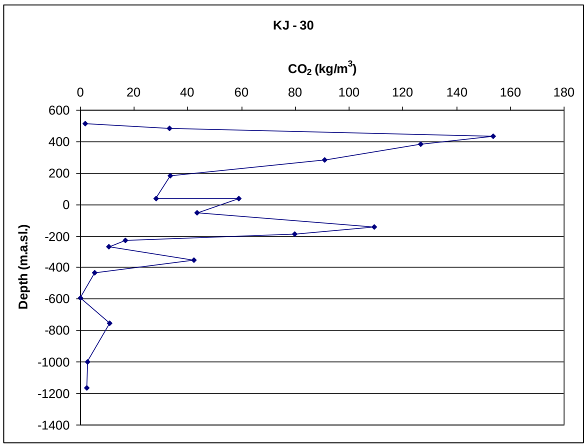

KJ - 23
CO2 (kg/m3)
0 50 100 150 200
Depth (m.a.sl.)
500 0 -500 -1000 -1500 -2000

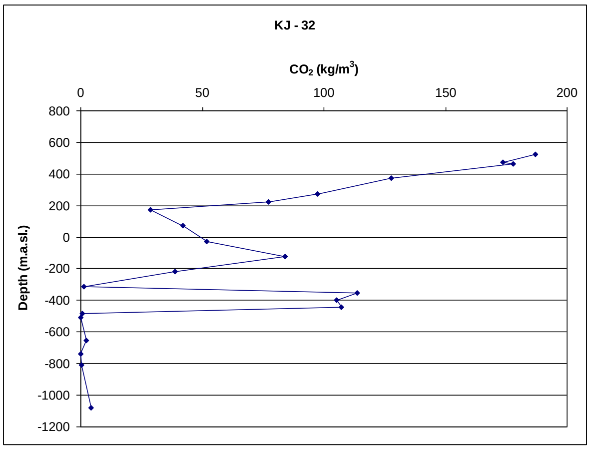

KG - 25
CO2 (kg/m3)
0 50 100 150 200
Depth (m.a.sl.)
1000 500 0 -500 -1000 -1500 -2000

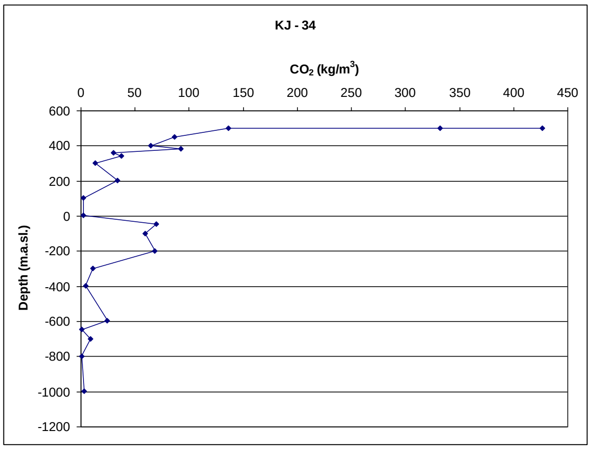

KG - 26
CO2 (kg/m3)
0 50 100 150 200 250 300
Depth (m.a.sl.)
1000 500 0 -500 -1000 -1500 -2000

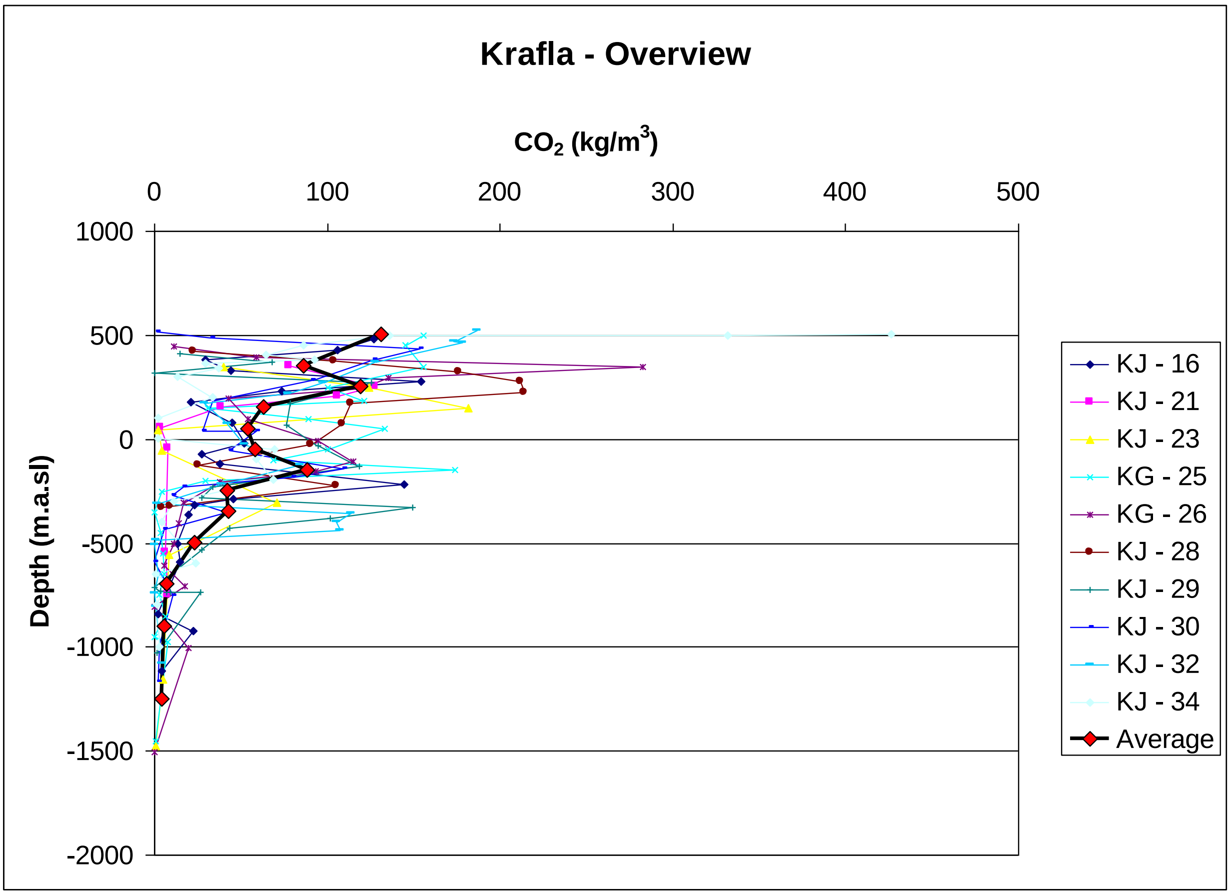

KJ - 28
CO2 (kg/m3)
0 50 100 150 200 250
Depth (m.a.sl.)
500 400 300 200 100 0 -100 -200 -300 -400


KJ - 29
CO2 (kg/m3)
0 20 40 60 80 100 120 140 160
600 400 200 0 -200 -400 -600 -800 -1000 -1200
Depth (m.a.sl.)


KJ - 30
CO2 (kg/m3)
0 20 40 60 80 100 120 140 160 180
600 400 200 0 -200 -400 -600 -800 -1000 -1200 -1400
Depth (m.a.sl.)


KJ - 32
CO2 (kg/m3)
0 50 100 150 200
800 600 400 200 0 -200 -400 -600 -800 -1000 -1200
Depth (m.a.sl.)


KJ - 34
CO2 (kg/m3)
0 50 100 150 200 250 300 350 400 450
600 400 200 0 -200 -400 -600 -800 -1000 -1200
Depth (m.a.sl.)



Krafla - Overview
CO_2 (kg/m³)
0
100
200
300
400
500
1000
500
0
-500
-1000
-1500
-2000
Depth (m.a.sl)
KJ - 16
KJ - 21
KJ - 23
KG - 25
KG - 26
KJ - 28
KJ - 29
KJ - 30
KJ - 32
KJ - 34
Average

D. Reykjanes data

Well Name	Number	Borehole Length (m)	Vertical Depth (m)	X	Y	Z (m.a.sl.)	Carbon C (wt%)	Captured CO_2 (kg/m^3)
RN - 10	18910	0		318237	374231	20		
		40	40	318237	374231	-20	**0.05**	**2.9**
		100	100	318237	374231	-80	**0.06**	**3.7**
		140	140	318237	374231	-120	**0.63**	**60.5**
		380	380	318237	374231	-360	**0.63**	**60.4**
		514	514	318237	374231	-494	**1.92**	**188.2**
		526	526	318237	374231	-506	**1.28**	**124.3**
		540	540	318237	374231	-520	**1.60**	**156.0**
		570	570	318237	374231	-550	**0.36**	**33.6**
		620	620	318237	374231	-600	**0.09**	**6.6**
		680	680	318237	374231	-660	**0.09**	**7.1**
		842	842	318237	374231	-822	**0.07**	**4.6**
		940	940	318237	374231	-920	**0.03**	**1.2**
		1400	1400	318237	374231	-1380	**0.02**	**0.4**
		1840	1840	318237	374231	-1820	**0.01**	**0.0**
RN - 11	18911	0		318521	374191	20		
		100	100	318521	374191	-80	**0.51**	**48.5**
		200	200	318521	374191	-180	**0.45**	**42.5**
		300	300	318521	374191	-280	**1.68**	**164.6**
		350	350	318521	374191	-330	**0.78**	**75.6**
		400	400	318521	374191	-380	**0.69**	**66.0**
		500	500	318521	374191	-480	**0.04**	**1.9**
		690	690	318521	374191	-670	**0.11**	**8.5**
		800	800	318521	374191	-780	**0.02**	**0.2**
		1176	1176	318521	374191	-1156	**0.06**	**3.5**
		1720	1720	318521	374191	-1700	**0.03**	**0.7**
		2080	2080	318521	374191	-2060	**0.04**	**2.1**
		2152	2152	318521	374191	-2132	**0.03**	**1.1**

RN - 12	18912	0		318815	374155	20		
		160	160	318815	374155	-140	**0.21**	**18.5**
		250	250	318815	374155	-230	**0.60**	**57.1**
		350	350	318815	374155	-330	**0.08**	**5.5**
		500	500	318815	374155	-480	**0.09**	**7.4**
		700	700	318815	374155	-680	**0.05**	**3.1**
		800	800	318815	374155	-780	**0.05**	**3.0**
		1000	1000	318815	374155	-980	**0.01**	**0.0**
		1220	1220	318815	374155	-1200	**0.27**	**24.3**
		1300	1300	318815	374155	-1280	**0.02**	**-0.4**
		1438	1438	318815	374155	-1418	**0.09**	**6.9**
		1650	1650	318815	374155	-1630	**0.03**	**1.2**
		1900	1900	318815	374155	-1880	**0.00**	**0.0**
		2050	2050	318815	374155	-2030	**0.35**	**33.0**
		2100	2100	318815	374155	-2080	**0.01**	**0.0**
		2260	2260	318815	374155	-2240	**0.03**	**1.4**
		2310	2310	318815	374155	-2290	**0.04**	**1.7**
		2398	2398	318815	374155	-2378	**0.01**	**0.0**
RN - 13	18913	0		318424	374503	20		
		50	50	318424	374503	-30	**0.22**	**19.6**
		120	120	318424	374503	-100	**0.34**	**32.1**
		500	500	318424	374503	-480	**0.52**	**49.4**
		620	620	318424	374503	-600	**0.87**	**84.2**
		720	720	318424	374503	-700	**0.38**	**35.7**
		750	750	318424	374503	-730	**0.90**	**87.1**
		830	830	318424	374503	-810	**0.14**	**12.0**
		1032	1032	318424	374503	-1012	**0.04**	**2.4**
		1200	1200	318424	374503	-1180	**0.15**	**12.5**
		1300	1300	318424	374503	-1280	**0.02**	**0.0**
		1400	1400	318424	374503	-1380	**0.34**	**31.6**
		1460	1460	318424	374503	-1440	**0.09**	**6.5**
		1560	1560	318424	374503	-1540	**0.06**	**4.1**

		1662	1662	318424	374503	-1642	**0.08**	**6.1**
		2114	2114	318424	374503	-2094	**0.05**	**3.4**
		2200	2200	318424	374503	-2180	**0.04**	**1.8**
		2442	2442	318424	374503	-2422	**0.11**	**9.0**
RN - 14	18914	0		318674	374347	20		
		100	100	318674	374347	-80	**0.06**	**4.2**
		200	200	318674	374347	-180	**0.19**	**17.3**
		340	340	318674	374347	-320	**0.15**	**13.1**
		400	400	318674	374347	-380	**0.52**	**49.6**
		460	460	318674	374347	-440	**0.73**	**70.0**
		600	600	318674	374347	-580	**0.04**	**1.9**
		880	880	318674	374347	-860	**0.04**	**1.6**
		960	960	318674	374347	-940	**0.03**	**1.2**
		1750	1750	318674	374347	-1730	**0.01**	**0.0**
RN - 15	18915	0		319001	374555	20		
		100	100	319001	374555	-80	**0.05**	**3.1**
		150	150	319001	374555	-130	**0.06**	**3.7**
		200	200	319001	374555	-180	**0.31**	**29.1**
		300	300	319001	374555	-280	**0.42**	**39.7**
		550	550	319001	374555	-530	**0.07**	**5.1**
		850	850	319001	374555	-830	**0.04**	**2.4**
		950	950	319001	374555	-930	**0.02**	**0.1**
		1050	1050	319001	374555	-1030	**0.03**	**0.6**
		1148	1148	319001	374555	-1128	**0.83**	**80.0**
		1150	1150	319001	374555	-1130	**1.02**	**98.9**
		1200	1200	319001	374555	-1180	**0.05**	**3.1**
		1500	1500	319001	374555	-1480	**0.08**	**6.1**
		2000	2000	319001	374555	-1980	**0.01**	**0.0**
		2150	2150	319001	374555	-2130	**0.01**	**0.0**

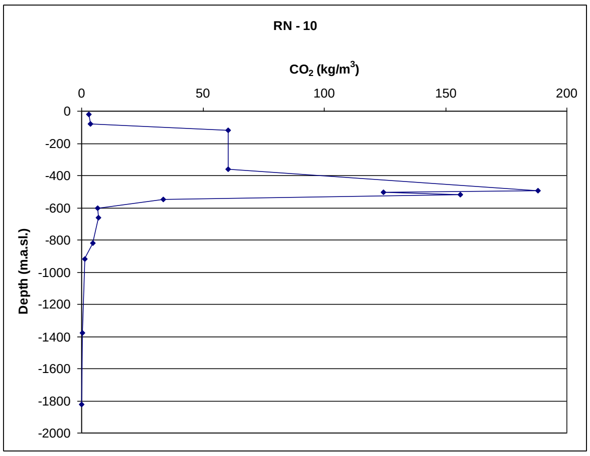
RN - 16	18916	0		317818	374452	20		
		120	120	317818	374452	-100	**0.22**	**19.6**
		200	200	317818	374452	-180	**0.50**	**47.7**
		250	250	317818	374452	-230	**0.28**	**25.3**
		300	300	317818	374452	-280	**0.14**	**11.7**
		600	600	317818	374452	-580	**0.26**	**23.9**
		750	750	317818	374452	-730	**0.07**	**4.5**
		900	900	317818	374452	-880	**0.04**	**2.1**
		1000	1000	317818	374452	-980	**0.11**	**8.5**
		1200	1200	317818	374452	-1180	**0.04**	**1.9**
		1420	1420	317818	374452	-1400	**0.09**	**6.7**
		1500	1500	317818	374452	-1480	**0.06**	**3.7**
		1780	1780	317818	374452	-1760	**0.02**	**0.0**
		1900	1900	317818	374452	-1880	**0.02**	**0.0**
		2100	2100	317818	374452	-2080	**0.01**	**0.0**
		2500	2500	317818	374452	-2480	**0.00**	**0.0**
RN - 17	18917	0		318072	373573	20		
		50	50	318072	373573	-30	**0.11**	**9.1**
		66	66	318072	373573	-46	**1.94**	**190.2**
		80	80	318072	373573	-60	**0.93**	**90.1**
		92	92	318072	373573	-72	**1.91**	**187.0**
		110	110	318072	373573	-90	**0.10**	**7.8**
		126	126	318072	373573	-106	**0.40**	**38.0**
		140	140	318072	373573	-120	**1.61**	**157.0**
		176	176	318072	373573	-156	**0.61**	**58.1**
		210	210	318072	373573	-190	**1.62**	**158.6**
		240	240	318072	373573	-220	**1.48**	**145.0**
		280	280	318072	373573	-260	**0.35**	**32.4**
		360	360	318072	373573	-340	**0.43**	**40.2**
		380	380	318072	373573	-360	**0.75**	**72.3**
		420	420	318072	373573	-400	**0.19**	**17.0**
		440	440	318072	373573	-420	**0.72**	**69.1**
		460	460	318072	373573	-440	**1.46**	**142.9**

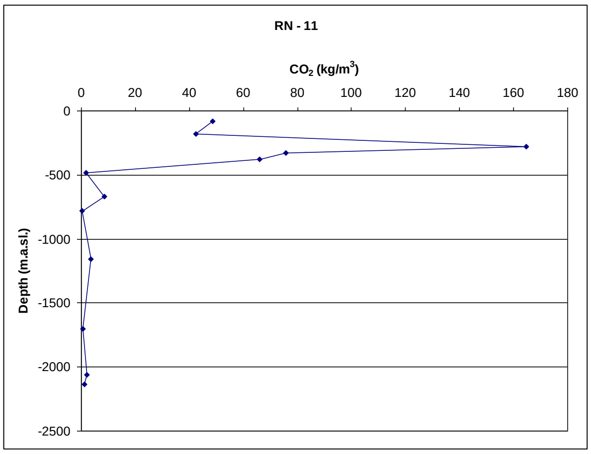
		480	480	318072	373573	-460	**0.29**	**27.2**
		520	520	318072	373573	-500	**0.35**	**32.2**
		560	560	318072	373573	-540	**0.05**	**3.0**
		600	600	318072	373573	-580	**0.28**	**25.8**
		690	690	318072	373573	-670	**0.03**	**1.1**
		780	780	318072	373573	-760	**0.03**	**0.7**
		960	960	318072	373573	-940	**0.13**	**10.5**
		1010	1010	318072	373573	-990	**0.17**	**15.0**
		1060	1060	318072	373573	-1040	**0.02**	**0.0**
		1160	1160	318072	373573	-1140	**0.02**	**0.1**
		1260	1260	318072	373573	-1240	**0.04**	**1.9**
		1680	1680	318072	373573	-1660	**0.02**	**0.0**
		2100	2100	318072	373573	-2080	**0.03**	**1.2**
		2300	2300	318072	373573	-2280	**0.02**	**0.0**
		2640	2640	318072	373573	-2620	**0.03**	**1.1**
		2780	2780	318072	373573	-2760	**0.03**	**1.0**
		2920	2920	318072	373573	-2900	**0.03**	**0.6**
		3080	3080	318072	373573	-3060	**0.01**	**0.0**
RN - 18	18918	0		319066	374412	20		
		50	50	319066	374412	-30	**0.34**	**31.2**
		100	100	319066	374412	-80	**0.02**	**0.0**
		150	150	319066	374412	-130	**0.41**	**38.8**
		200	200	319066	374412	-180	**0.92**	**88.6**
		300	300	319066	374412	-280	**0.43**	**40.7**
		400	400	319066	374412	-380	**0.75**	**72.3**
		420	420	319066	374412	-400	**1.22**	**119.2**
		450	450	319066	374412	-430	**0.77**	**73.9**
		500	500	319066	374412	-480	**0.33**	**30.8**
		550	550	319066	374412	-530	**0.14**	**11.6**
		650	650	319066	374412	-630	**0.05**	**2.7**
		730	730	319066	374412	-710	**0.03**	**0.7**
		800	800	319066	374412	-780	**0.01**	**0.0**
		900	900	319066	374412	-880	**0.01**	**0.0**

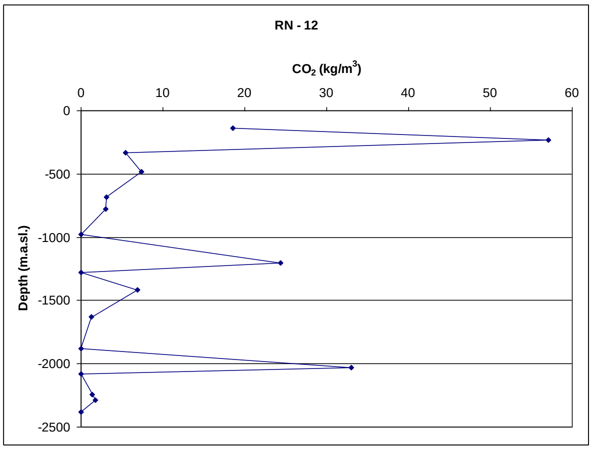
		1100	1100	319066	374412	-1080	**0.01**	**0.0**
		1300	1300	319066	374412	-1280	**0.03**	**1.0**
		1500	1500	319066	374412	-1480	**0.01**	**0.0**
		1700	1700	319066	374412	-1680	**0.01**	**0.0**
		1810	1810	319066	374412	-1790	**0.05**	**2.7**
RN - 19	18919	0		319061	374147	20		
		100	100	319061	374147	-80	**0.01**	**-0.6**
		150	150	319061	374147	-130	**0.07**	**4.6**
		250	250	319061	374147	-230	**1.24**	**120.3**
		300	300	319061	374147	-280	**1.50**	**146.5**
		350	350	319061	374147	-330	**1.55**	**151.6**
		400	400	319061	374147	-380	**0.30**	**27.9**
		500	500	319061	374147	-480	**0.49**	**46.8**
		552	552	319061	374147	-532	**0.05**	**2.8**
		600	600	319061	374147	-580	**0.08**	**6.1**
		700	700	319061	374147	-680	**0.03**	**0.5**
		850	850	319061	374147	-830	**0.05**	**3.4**
		1000	1000	319061	374147	-980	**0.06**	**3.6**
		1350	1350	319061	374147	-1330	**0.04**	**1.7**
		1750	1750	319061	374147	-1730	**0.02**	**0.2**
		1852	1852	319061	374147	-1832	**0.02**	**0.5**
		1880	1880	319061	374147	-1860	**0.02**	**0.2**
RN - 20	18920	0		319290	374041	20		
		46	46	319290	374041	-26	**0.06**	**3.7**
		152	152	319290	374041	-132	**1.01**	**97.7**
		200	200	319290	374041	-180	**0.41**	**39.1**
		300	300	319290	374041	-280	**0.29**	**26.3**
		350	350	319290	374041	-330	**0.40**	**37.2**
		402	402	319290	374041	-382	**0.61**	**58.1**
		450	450	319290	374041	-430	**0.41**	**38.1**
		500	500	319290	374041	-480	**0.39**	**36.8**
		548	548	319290	374041	-528	**0.23**	**20.4**

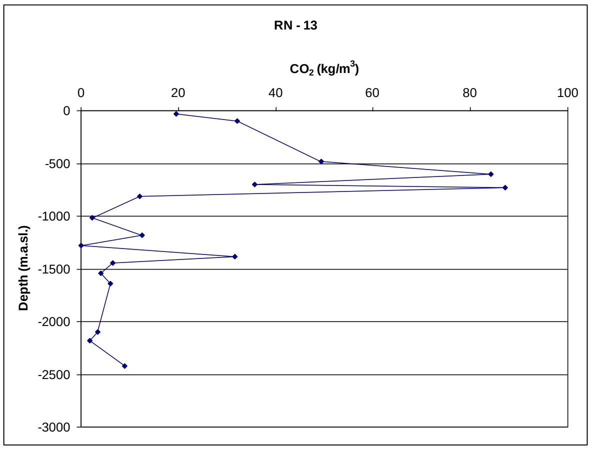
		750	750	319290	374041	-730	**0.06**	**3.6**
		800	800	319290	374041	-780	**0.04**	**1.9**
		880	880	319290	374041	-860	**0.04**	**1.6**
		1102	1102	319290	374041	-1082	**0.01**	**0.0**
		1526	1526	319290	374041	-1506	**0.02**	**0.0**
		1750	1750	319290	374041	-1730	**0.02**	**0.0**
		1940	1940	319290	374041	-1920	**0.01**	**0.0**
		2100	2100	319290	374041	-2080	**0.01**	**0.0**
		2122	2122	319290	374041	-2102	**0.18**	**16.0**
		2126	2126	319290	374041	-2106	**0.23**	**21.1**
RN - 21	18921	0		318931	374285	20		
		50	50	318931	374285	-30	**0.11**	**8.9**
		100	100	318931	374285	-80	**0.05**	**2.7**
		150	150	318931	374285	-130	**0.12**	**9.4**
		200	200	318931	374285	-180	**0.47**	**44.5**
		250	250	318931	374285	-230	**0.52**	**50.0**
		300	300	318931	374285	-280	**0.95**	**92.2**
		350	350	318931	374285	-330	**0.24**	**21.5**
		400	400	318931	374285	-380	**0.23**	**20.3**
		550	550	318931	374285	-530	**0.03**	**0.7**
		700	700	318931	374285	-680	**0.11**	**8.7**
		800	800	318931	374285	-780	**0.06**	**3.5**
		910	910	318931	374285	-890	**0.01**	**0.0**
		1000	1000	318931	374285	-980	**0.01**	**0.0**
		1100	1100	318931	374285	-1080	**0.02**	**0.0**
		1200	1200	318931	374285	-1180	**0.01**	**0.0**
RN - 22	18922	0		318551	374164	20		
		100	100	318551	374164	-80	**0.59**	**56.2**
		200	200	318551	374164	-180	**0.74**	**71.0**
		250	250	318551	374164	-230	**0.69**	**66.0**
		300	300	318551	374164	-280	**0.48**	**45.1**
		350	350	318551	374162	-330	**0.70**	**67.8**

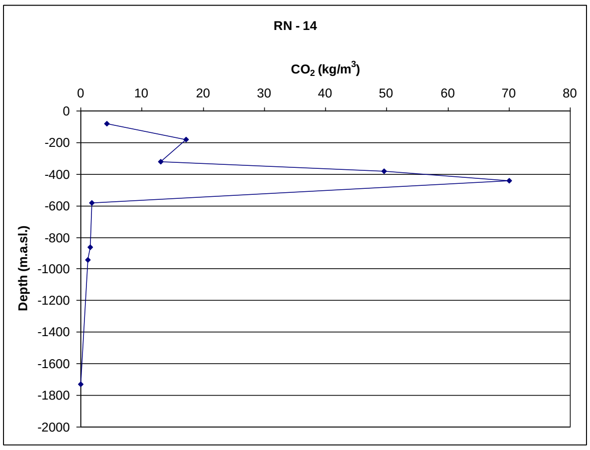
		400	400	318550	374156	-380	**0.64**	**61.8**
		410	409	318550	374154	-389	**0.44**	**41.5**
		500	497	318551	374135	-477	**0.16**	**13.9**
		590	583	318553	374109	-563	**0.63**	**59.9**
		690	676	318556	374071	-656	**0.10**	**7.5**
		800	774	318561	374022	-754	**0.19**	**16.7**
		1030	979	318571	373919	-959	**0.02**	**0.3**
RN - 24	18924	0		318920	374268	20		
		70	70	318920	374268	-50	**0.11**	**8.6**
		140	140	318920	374268	-120	**0.08**	**5.8**
		210	210	318920	374268	-190	**0.14**	**11.4**
		290	290	318920	374268	-270	**0.89**	**86.5**
		350	350	318920	374268	-330	**0.28**	**25.3**
		420	420	318920	374268	-400	**0.73**	**70.8**
		490	490	318920	374268	-470	**0.09**	**6.5**
		560	560	318920	374268	-540	**0.26**	**23.9**
		630	630	318920	374268	-610	**0.08**	**6.4**
		698	698	318920	374268	-678	**0.05**	**3.4**
		770	770	318920	374268	-750	**0.03**	**1.0**
		840	840	318920	374268	-820	**0.00**	**0.0**
		910	910	318920	374268	-890	**0.03**	**1.5**
		980	980	318920	374268	-960	**0.01**	**0.0**
		1050	1050	318920	374268	-1030	**0.00**	**0.0**
		1120	1120	318920	374268	-1100	**0.00**	**0.0**
		1190	1190	318920	374268	-1170	**0.02**	**0.0**
		1260	1260	318920	374268	-1240	**0.01**	**0.0**
		1330	1330	318920	374268	-1310	**0.01**	**0.0**
		1400	1400	318920	374268	-1380	**0.34**	**31.9**
		1408	1408	318920	374268	-1388	**0.41**	**39.0**
		1418	1418	318920	374268	-1398	**0.34**	**31.6**

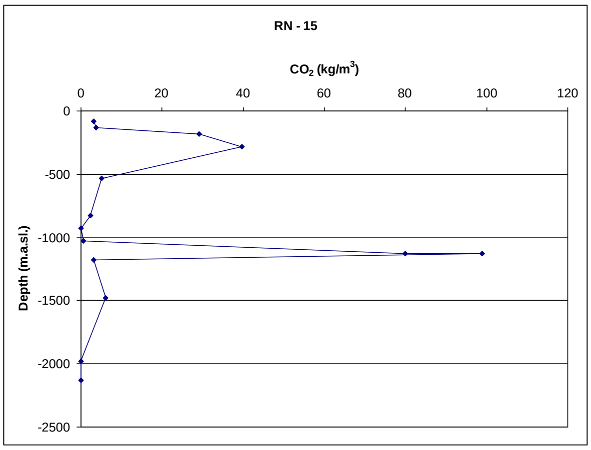

RN - 10
CO2 (kg/m3)
0 50 100 150 200
Depth (m.a.sl.)
0 -200 -400 -600 -800 -1000 -1200 -1400 -1600 -1800 -2000

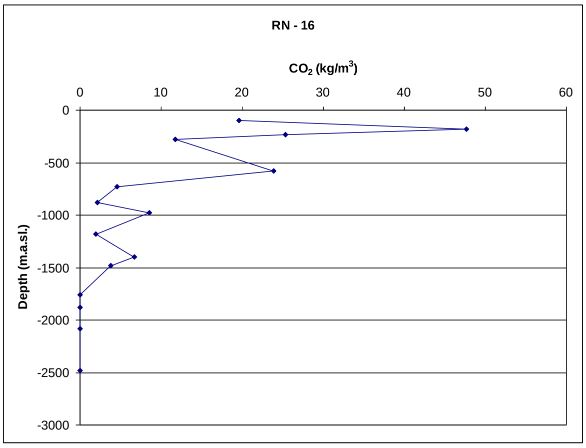

RN - 11
CO2 (kg/m3)
0 20 40 60 80 100 120 140 160 180
Depth (m.a.sl.)
0 -500 -1000 -1500 -2000 -2500

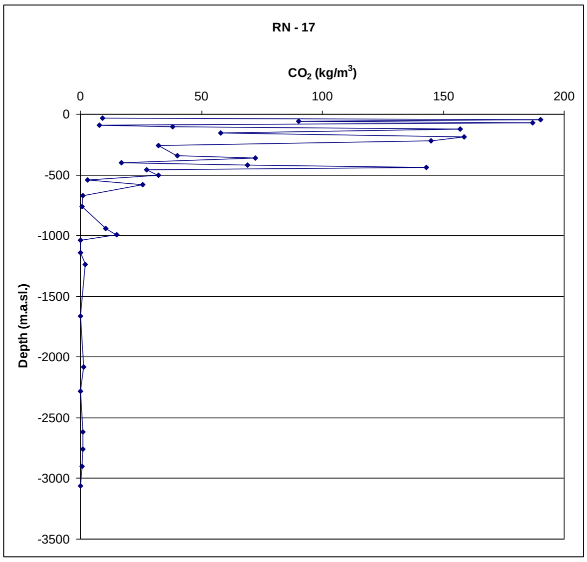

RN - 12
CO2 (kg/m3)
0 10 20 30 40 50 60
Depth (m.a.sl.)
0 -500 -1000 -1500 -2000 -2500

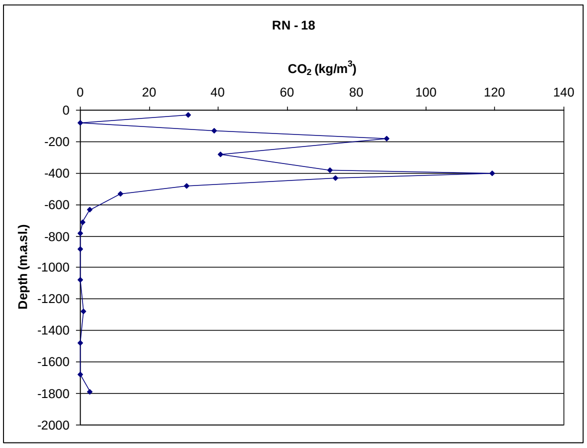

RN - 13
CO2 (kg/m3)
0 20 40 60 80 100
Depth (m.a.sl.)
0 -500 -1000 -1500 -2000 -2500 -3000

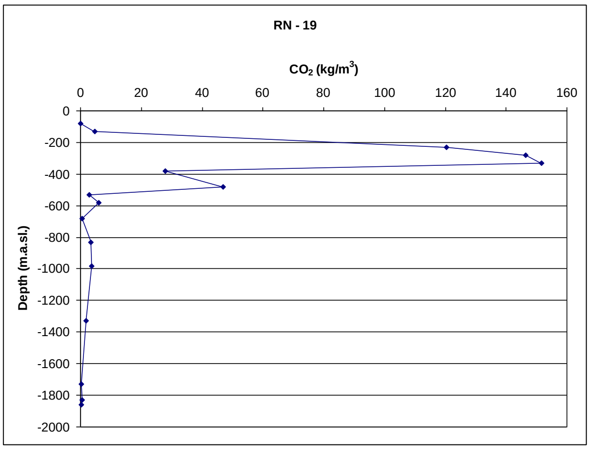

RN - 14
CO2 (kg/m3)
0 10 20 30 40 50 60 70 80
Depth (m.a.sl.)
0 -200 -400 -600 -800 -1000 -1200 -1400 -1600 -1800 -2000

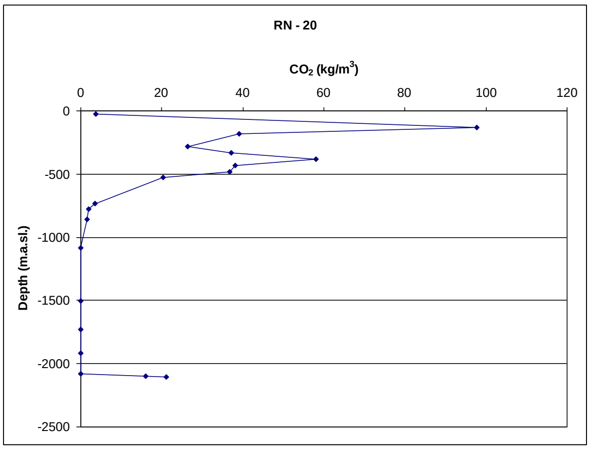

RN - 15
CO2 (kg/m3)
0 20 40 60 80 100 120
Depth (m.a.sl.)
0 -500 -1000 -1500 -2000 -2500

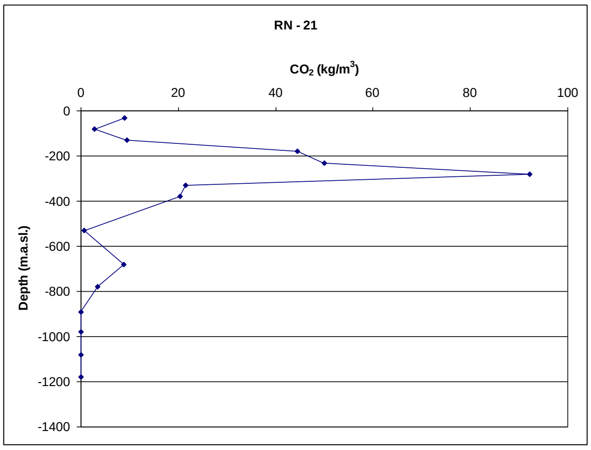

RN - 16
CO2 (kg/m3)
0
10
20
30
40
50
60
Depth (m.a.sl.)
0
-500
-1000
-1500
-2000
-2500
-3000

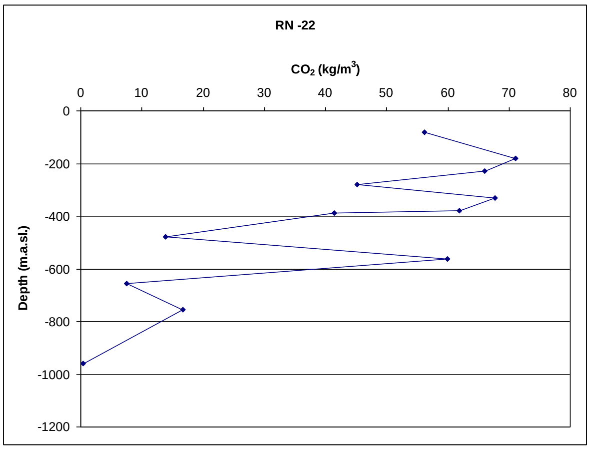

RN - 17
CO2 (kg/m3)
0
50
100
150
200
Depth (m.a.sl.)
0
-500
-1000
-1500
-2000
-2500
-3000
-3500

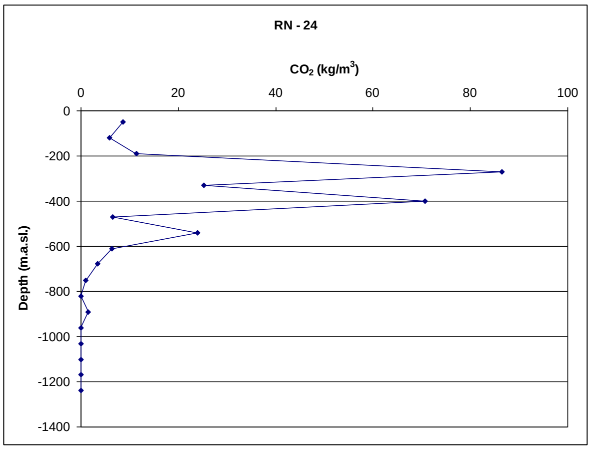

RN - 18
CO2 (kg/m3)
0
20
40
60
80
100
120
140
Depth (m.a.sl.)
0
-200
-400
-600
-800
-1000
-1200
-1400
-1600
-1800
-2000

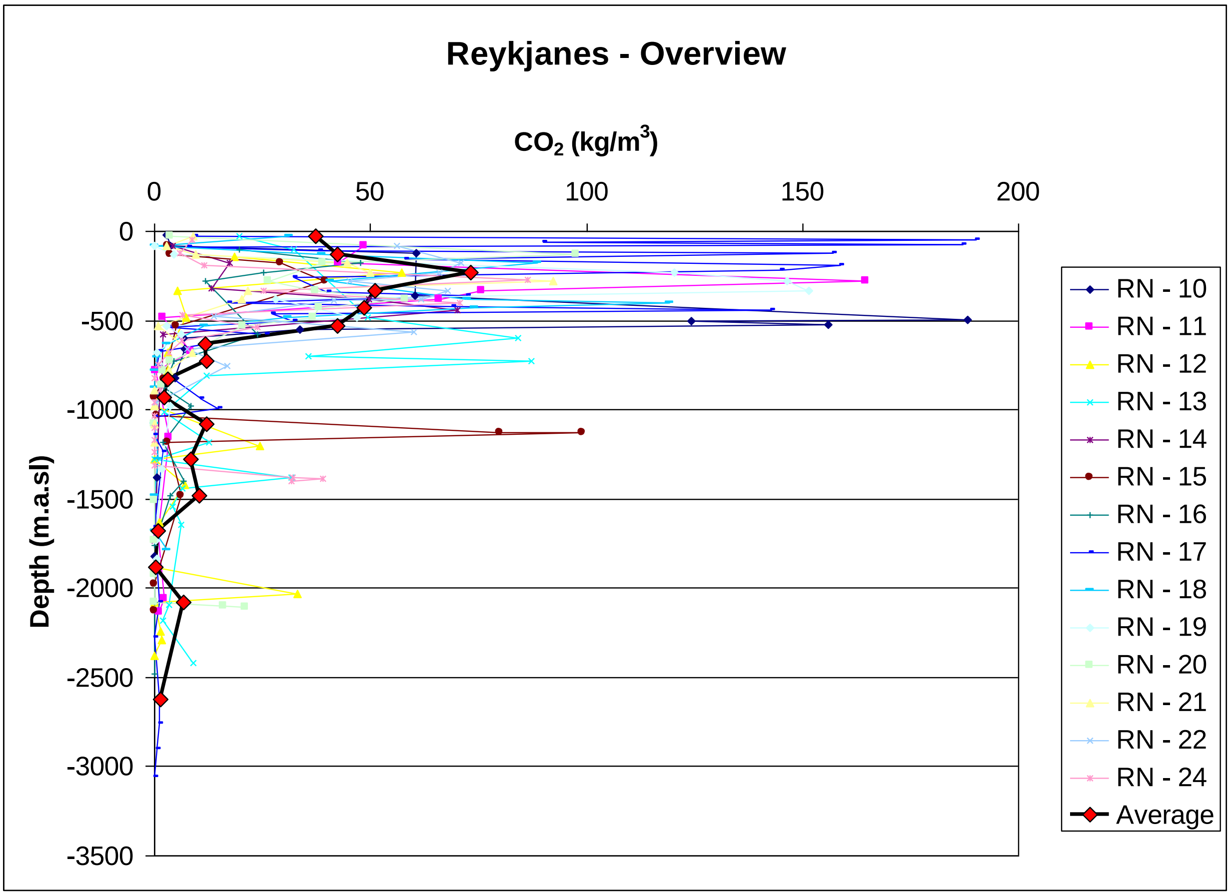

RN - 19
CO2 (kg/m3)
0
20
40
60
80
100
120
140
160
Depth (m.a.sl.)
0
-200
-400
-600
-800
-1000
-1200
-1400
-1600
-1800
-2000


RN - 20
CO2 (kg/m3)
0
20
40
60
80
100
120
0
-500
-1000
-1500
-2000
-2500
Depth (m.a.sl.)


RN - 21
CO2 (kg/m3)
0
20
40
60
80
100
0
-200
-400
-600
-800
-1000
-1200
-1400
Depth (m.a.sl.)


RN -22
CO2 (kg/m3)
0
10
20
30
40
50
60
70
80
0
-200
-400
-600
-800
-1000
-1200
Depth (m.a.sl.)


RN - 24
CO2 (kg/m3)
0
20
40
60
80
100
0
-200
-400
-600
-800
-1000
-1200
-1400
Depth (m.a.sl.)


Reykjanes - Overview
CO2 (kg/m3)
0
50
100
150
200
0
-500
-1000
-1500
-2000
-2500
-3000
-3500
Depth (m.a.sl)
RN - 10
RN - 11
RN - 12
RN - 13
RN - 14
RN - 15
RN - 16
RN - 17
RN - 18
RN - 19
RN - 20
RN - 21
RN - 22
RN - 24
Average