GEORG

GEOTHERMAL RESEARCH GROUP

ANNUAL REPORT
YEAR 2013

H_2S sequestration into geothermal systems

Project ID: 11-04-003

Coordinator: Andri Stefansson

Start date: 2012

Duration: Three years

Partners: Reykjavik Energy, Landsvirkjun and MIT, USA

1 General status of the project

Hydrogen sulfide (H_2S) is among the major components in geothermal fluids, with concentrations ranging from a few ppb to levels of hundreds of ppm. Hydrogen sulfide is volatile and is commonly emitted into the atmosphere from geothermal power plants, causing potential environmental problems.

Several methods are employed in cleaning H_2S emissions including oxidation to form elemental sulfur or sulfuric acid. One proposed method includes injection of H_2S into geothermal systems where it may be mineralized into sulfides including pyrite. Reykjavík Energy is currently test such an injection into the geothermal system at Hellisheidi, where geothermal gas (CO_2, H_2S, N_2 and H_2) is being separated in a gas abatement station and the H_2S and CO_2 stream mixed at the surface with waste water and condensed steam prior to injection into the geothermal aquifer having temperatures >200°C.

In this project laboratory experiments are being conducted to study the interaction of H_2S-rich water with basaltic rocks, the geochemistry of sulfur in geothermal systems is being assessed. Using the data obtained from the experimental work together with geochemical modelling and data on the geochemistry of sulfur in geothermal system, the optimal conditions for H_2S sequestration into geothermal systems will be assessed.

The project is divided into three major tasks:

(i) H_2S oxidation under geothermal conditions
(ii) H_2S-water-rock interaction and H_2S mineralization rate
(iii) H_2S geochemistry and sequestration into geothermal systems.

During the first year of the project, the experimental work was planned as well as designing and constructing the high-temperature flow-through reactors. The experiments are then planned to be conducted in 2014. In addition, the geochemistry of sulfur (sulfate and sulfide) in geothermal systems in Iceland including at Hellisheidi and Krafla were studied. These results together with the experimental work planned in 2014 will be used to assess prospective of H_2S injection and sequestration into geothermal systems.

The work during 2012-13 was carried out by a M.Sc. student Jóhann Gunnarsson Robin and the three postdoctoral researchers Hanna Kaasalainen, Nicole S. Keller and Snorri Guðbrandsson, all at the University of Iceland.

1.1 Project progress/time schedule:

During the year 2012-2013, the project progress was according to schedule and we have worked on all aspects of the project, these including:

(i) H_2S oxidation under geothermal conditions
(ii) H_2S-water-rock interaction and H_2S mineralization rate
(iii) H_2S geochemistry and sequestration into geothermal systems

In order to carry out the above tasks three essential parts were needed: firstly, design and construction of a high-temperature and pressure flow-through reactor for experimental work on H_2S sequestration and oxidation in geothermal systems, secondly, sampling of geothermal waters for sulfur speciation and multiple sulfur isotope analysis and thirdly, sample preparation and analysis of multiple sulfur isotopes. In 2012-13 all of these tasks have been undertaken or finished as a part of this project.

The status of the project mid year 2013 is as follows,

i) High-temperature flow-through reaction system has been designed, constructed and tested. This was done in close collaboration between the partners of this project at UI, LV and RE. It includes three sets, cabable of running fluid-rock experiments in the flow-through mode at 25-500°C and up to 250 bar pressure. The apparatus is constructed of inert materials, titanium, inconell and high-pressure plastic (PEEK). The apparatus is placed at the UI.

ii) Samples have been collected of two-phase geothermal fluids at Krafla for sulfur speciation and isotope analysis. Both liquid water and vapor phases were collected from two-phase and single phase vapor well discharges.

iii) An extraction line has been set up for sample preparation for multiple sulfur isotope analysis at UI. These samples were then analyzed using mass spectrometer at MIT (USA).

In 2013-14 it is planned to continue this work by finishing experimental work on H_2S oxidation and H_2S-water-rock interaction and mineralization rate under geothermal conditions. In addition, it is planned to set up a model to understand the source and reactions of H_2S in geothermal systems using multiple sulfur isotopes, i.e. tasks i), ii) and iii) of this project.

In 2012-13 the following people have worked on the project: Snorri Guðbrandsson and Andri Stefánsson together with assistance from LV and OR on the experimental apparatus and H_2S oxidation and H_2S-water-rock interaction experiments. Jóhann Gunnarsson-Robin, Nicole S. Keller, Hanna S. Kaasalainen, Andri Stefánsson and Shuhei Ono on sampling and analysis of multiple sulfur isotopes in geothermal fluids at Krafla.

2 Project Management

The participating group in the project are University of Iceland (UI), MIT, USA (MIT), Reykjavik Energy (OR), and Landsvirkjun (LV). The role of the individual participants are: access to sampling and instrumental facilities (UI, MIT), data on fluid composition (UI, OR, LV) and access to geothermal power plants and sites (OR, LV). The Science Institute, University of Iceland (UI) head office is responsible for the financial management of the project.

The main leaders of the research project are: from UI: Andri Stefansson, professor in geothermal geochemistry; from MIT: Shuhei Ono, professor of isotope and sulphur geochemistry; from OR: Ingvi Gunnarsson, scientist; from LV: Sigurdur H. Markússon, project manager. The group will have access to other scientists and technical help within their institutions.

3 Student involvement

During the first year of the project the following students and postdoctoral researchers were involved:

Jóhann Gunnarsson Robin – Master studentat the University of Iceland. Project: Sulfur Geochemistry in the Krafla geothermal system. Expected date of finish fall 2014.

Snorri Guðbrandsson – PhD student at the University of Iceland. Project: Experimental study of H_2S sequestration.

Nicole S. Keller – Postdoctoral Researcher at the University of Iceland. Project: Sulfur Isotopes in the Krafla Geothermal System.

Hanna S. Kaasalainen – Postdoctoral Researcher at the University of Iceland. Project: Sulfur geochemistry in geothermal fluids.

4 Publications and disseminations

Kaasalainen, H., Stefánsson A. (2013) Sulfur chemistry in geothermal fluids, Iceland. GSA Abstracts with Programs 45, No. 7.

Keller N.S., Stefánsson A., Ono S. and Gunnarsson Robin J. (2013) Sulfur isotope systematics of geothermal fluids, Krafla, Iceland. Min. Mag. 77, 1445.

Stefánsson A. (2013) H_2S sequestration into geothermal systems. Georg Open Day.

5 Cost statement

An over view of the cost for 2012-13 together with explanations is shown in Table 1.

Table 1. Budget overview for 04.2012-04.2013[f]

Explanation	Georg	Other financing [e]	Total
Salaries [a]	3125	3770	6895
Operational expenses [b]		3483	3483
Travel expenses [c]		1500	1500
Overhead [d]		305	305
Total:	**3125**	**9058**	**12183**

[a] Salaries of students and postdoctoral researchers working as a part of this project. Salary cost of permanent staff (UI, LV, OR, MIT) are not included here.
[b] Operational expenses includes various consumables for reactors and sampling as well as chemical analysis. Material for reactors provided by LV and parts for reactors already available at UI (fittings, valves, pumps etc.) are not included here.
[c] Travel expenses related to sampling and chemical analysis of sulphur isotopes
[d] Overhead of 2.5% (Science Institute, University of Iceland)
[e] Other financing includes: Orkurannsóknarsjóður Landsvirkjunar, Rannís and other financing.
[f] The budget overview was based on cost for 9m in 2012 and 3 m in 2013 for the relevant accounts according to Science Institute, University of Iceland (RH).