

PhD study on monitoring underground sequestration of geothermal H₂S

Applications are invited for a 3-year PhD fellowship at the Nordic Volcanological Center (NordVulk), University of Iceland, in collaboration with Aarhus University, Denmark. The position is available from June 1st 2021, and no later than July 1st, 2021.

Title:

Monitoring underground sequestration of H₂S released by geothermal energy exploitation

Research area:

Geophysics, mineralogy

Project description:

Geothermal fluid re-injection is a key step in mitigating air pollution caused by geothermal exploitation. The acid gases re-injected are expected to mineralize but monitoring mineralization processes in the subsurface is challenging. This PhD project focuses on establishing an integrated methodology for monitoring the mineralization of H₂S into pyrite in the shallow reservoir underneath Nesjavellir geothermal power plant in Southwest Iceland.

Hot water has been injected in the Nesjavellir shallow aquifer since the beginning of power production in 1990, resulting in thermal pollution of the Þingvallavatn lake but also in a clear geophysical anomaly, likely related to the mineralization of smectite upon basalt alteration. In 2020, hydrogen sulfur (H₂S) started to be re-injected, dissolved in hot water. Both thermal pollution and H₂S sequestration may cause environmental problems, such as an enrichment of H₂S in shallow aquifers due to re-dissolution of primary and secondary sulfides, or an exsolution of a buoyant H₂S-rich phase due to depressurization of the injected below the equilibrium partial pressure H₂S. These risks need to be monitored closely and mobilize a large group of scientists at the Nesjavellir site. Based on tracer test monitoring, H₂S is expected to mineralize as pyrite upon water-rock interaction and associated dissolution of iron from the basalt. Conductive and polarizable anomalies associated with pyrite mineralization could be detected by geophysical monitoring of shallow wells at Nesjavellir. This project combines geochemical datasets with geophysical monitoring to constrain a reactive transport model for the shallow subsurface at Nesjavellir, in order to predict and quantify pyrite mineralization upon H₂S injection. The scope of the PhD is two-fold: (i) to better understand the observed geophysical responses before and after injection of H₂S, based on geophysical forward simulations of reactive transport models, including data from geochemical monitoring and (ii) to develop a methodology for integrating 3D time-lapse geophysics onto mass transport and pyrite mineralization rate simulations.

Based on geochemical results, as well as reactive transport simulations with the software ToughReact, the PhD student will build possible hydrogeochemical models of pyrite and smectite distribution at different times after injection. He/she will further use these hydrogeochemical models to calculate the forward response of the different geophysical methods in-use at the site: electrical resistivity tomography and time-domain induced

polarization, transient electromagnetic, casing-to-surface resistivity tomography, self-potential and borehole logging (resistivity, induced polarization and neutron-neutron). This will allow evaluating how long after the start of H₂S injection the conductive and polarizable anomalies associated to pyrite mineralization can be detected. Results from the forward simulation will be, in turn, used to optimize the geophysical monitoring carried out at the site (every summer for surface measurements and every 6 months for borehole logging). Finally, the student will interpret the 3D time-lapse resistivity and induced polarization models provided by geophysics and contribute to incorporating this knowledge onto reactive transport models.

The strong geophysics and geochemistry components of this project make it particularly suitable for candidates who are interested in working at the interface of different geosciences and willing to interact with a large group of scientists. The relative proportion of geophysics, geochemistry and hydrogeology to be included of the PhD project will be determined together with the student, taking his/her personal preferences into consideration.

The successful applicant will be enrolled as a PhD candidate at University of Iceland, with possibility of joint degree at Aarhus University (Denmark).

Relevant courses at University of Iceland and Aarhus University include: Geophysical Inversion, Electrical and Electro-Magnetic Methods, Geothermal Energy, General Geochemistry, Geochemical Analyses, Mineralogy.

The knowledge and experience achieved in the PhD project will serve for optimizing the monitoring of future full-scale H₂S and CO₂ reinjection projects at geothermal sites.

The PhD project is closely tied to two on-going research projects at Nesjavellir: GECO (<https://geco-h2020.eu/demo-sites/>) focusing on geochemistry and funded by the European Union as well as GEMGAS (<https://hgg.au.dk/projects/gemgas-iceland-h2s-monitoring/>) focusing on geophysical aspects and funded by the Icelandic Research Fund.

Qualifications and specific competences:

Applicants to the PhD position should hold a master in Geoscience (or equivalent). Experience with geophysics, geochemistry and/or hydrogeology is an advantage.

Place of employment and place of work:

The PhD student will join the NordVulk team within the Institute of Earth Sciences, University of Iceland. Furthermore, the student will be required to undertake extended visits at Aarhus University, Denmark. A cotutelle agreement between the University of Iceland and Aarhus University securing joint supervision of the student will be set up.

Contacts:

Halldór Geirsson: Main supervisor of PhD candidate at University of Iceland, Iceland

Anders Vest Christiansen: Main supervisor of PhD candidate at Aarhus University, Denmark

Léa Levy, Aarhus University: Co-supervisor of PhD candidate and member of PhD committee, provides guidance during geophysical field work and data evaluation

Barbara Kleine, University of Iceland: Co-supervisor of PhD candidate and member of PhD committee provides guidance during geochemical sampling at Nesjavellir and analytical work at University of Iceland

Thomas Ratouis (OR, Iceland): Co-supervisor of PhD candidate and member of PhD committee, provides guidance/contact for geochemical water sampling at Nesjavellir, injection data acquisition, and geochemical transport modelling with ToughReact

Application procedures

1. Before you apply

Documentation of language skills:

English language qualifications may be documented by one of the following tests:

- **TOEFL test** (internet-based), minimum score: 83. The graduate school does not accept the paper-based test, nor the TOEFL ITP test. Remember to ask the test center to send your test results to University of Iceland in order to enable verification of your test results. **University of Iceland's TOEFL code is 7949.**
- **IELTS (academic) test**, minimum average score: 6.5 points
- **Cambridge English Language Assessment:**
Cambridge Certificate of Proficiency (CPE)
Cambridge English: Certificate of Advanced English with grade A,B or C (CAE)
Cambridge English: First Certificate with grade A (FCE)

The test result must not be more than two years old at the time of application.

The English language test should be taken before applying and included in the application documents.

The following applicants are exempted from documenting their English qualifications:

- Applicants with citizenship from the following countries: Australia, Canada, Ireland, New Zealand, the United Kingdom, the United States, or one of the Nordic countries (Denmark, Finland, Iceland, Norway or Sweden).
- Applicants with a Bachelor's or Master's programme completed in Australia, Canada, Ireland, New Zealand, the United Kingdom, or the United States.

2. How to apply:

All information in the application must be in English or a Scandinavian (i.e. Norwegian, Swedish or Danish) language, preferably English. A certified English translation is required for documents written in languages other than English or one of the Scandinavian languages.

The application must contain the following information:

As a minimum all applications must include (pdf-files only, max. 10 MB, no zip):

- Personal information
- Academic background
- Names on two references. The reference letters may be sent directly to rikke@hi.is
- Curriculum vitae of applicant, including list of publications
- Motivation letter (max. 2 pages)
- Transcripts, grade point averages (weighted and unweighted), and diploma(s) for both Bachelor's and Master's degree. If the original documents are not in English or one of the Scandinavian languages then copies of the original documents as well as a certified English translation must be attached.
- Documentation of language skills if required.

After submission of the application, you will receive a confirmation e-mail.

Please be aware that you must scan/merge all documents into one large PDF file and send as an attachment to rikke@hi.is. If you wish to refer to scientific papers, large reports, theses and the likes, please indicate a URL where the information is available.

NordVulk reserves the right to verify the authenticity of your educational diploma and transcripts:

- Request additional information to verify an application.
- Reject the application if it is proven, or if the Programme Committee has reasonable belief, that the information provided is false or if the applicant refuses to provide the requested information, whether or not an offer has already been made.

Please note:

- The Programme Committee may request further information or invite the applicant to attend an interview.

All interested candidates are encouraged to apply, regardless of their personal background.

Applicants seeking further information are invited to contact:

NordVulk leader Rikke Pedersen, phone +354 525 5483 , e-mail: rikke@hi.is.