Geophysical Site Characterization and Monitoring of CO_2 Mineralization in Basaltic Complexes, Helguvik, Iceland

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Carbon Storage through CO_2 Mineralization (CSCM) using Saline Water

CSCM is seen as a technology with **great potential** to **reduce anthropogenic CO_2 emissions** as **climate mitigation measure**. At present, CSCM requires large amounts of **freshwater** for storage. In the **DemoUpStorage** project in Helguvik, Iceland, we use **saline water** for the **CO_2 injection** instead. The **management and operation** of the Helguvik experimental site and the CO_2 injection are handled by our project partner ***Carbfix hf***. With geophysical and geochemical methods, we evaluate the **mineralization efficiency** and the **location** of **carbonate precipitation**. Here we focus on an **in-depth geophysical site characterization** using **crosshole seismic** and **electrical resistivity data**.

Geophysical Site Characterization & Monitoring Concept

The geophysical monitoring concept comprises 4 parts for both characterization and monitoring:

Crosshole seismics

- layering/lithological units
- changes in porosity & mineralogy, fluid replacement

Single-hole Electrical Resistivity Tomography

- layering/groundwater variations
- changes in porosity & fluid content, groundwater variations

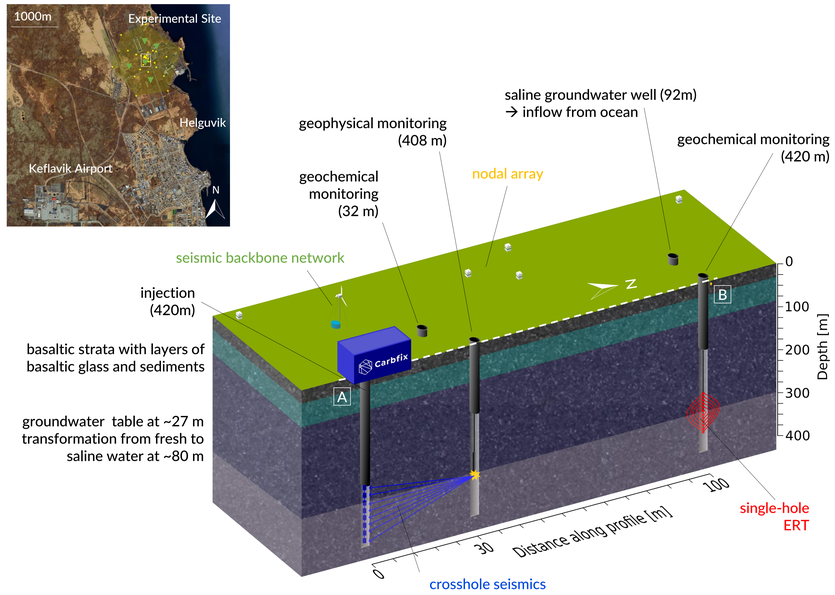
Nodal Array for Ambient Noise Tomography

- regional geological features (layering/lithological units)
- changes in porosity & mineralogy, fluid replacement

Seismic Backbone Network

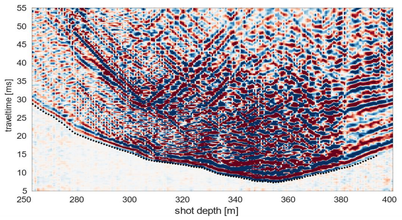
- potentially induced seismicity

The Helguvik Experimental Site



Data & Methodology

Crosshole seismics



p-wave sparker in geophys. well, 24 ch. hydrophone chain in injection well

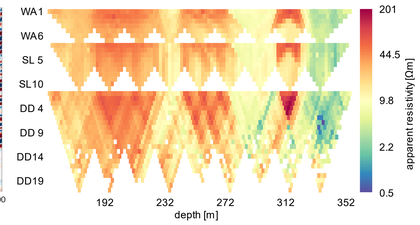
150 Hz high-pass filtering and diversity stack (5 shots)

first arrival picking

removal of weak anisotropy

fat-ray tomography using inv2dm

Electrical Resistivity Tomography



single-hole Wenner, Dipole-Dipole and Schlumberger measurements in all three deep wells with 2 m electrode spacing

removal of outliers

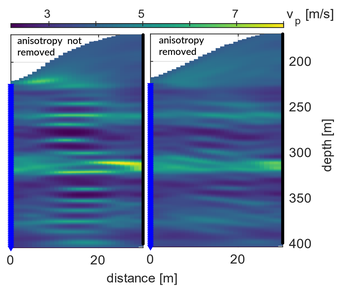
calculation of linear mixed effects error model

combined inversion of all measurements using pygimli

Discussion of Underground Structures Revealed by Crosshole Seismic- and Electrical Resistivity Tomography

Crosshole Seismics

The crosshole seismic data shows **clear first arrivals** for offsets up to 100 m. The varying move out velocity may be an indicator for **layering.** Later arrivals show a reflector at ~305m depth. There is a significant influence of **anisotropy** (or thin layering) on the **seismic velocities.** We correct for this as we are interested in larger, **meter scale features**. Inverted v_p ranges between 2.6 and 6.6 km/s.



Electrical Resistivity Tomography

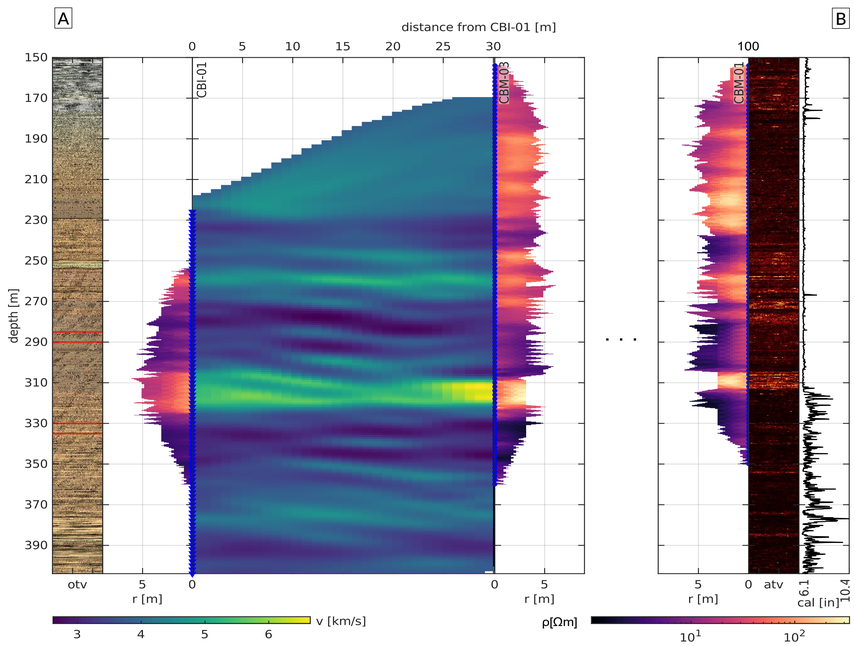
The **ERT** data shows apparent resistivities between $0.5\ \Omega m$ and $201\Omega m$ that **vary with depth**. This may be an indication for **layering**.

Inversion Results

Seismic and ERT inversions **agree well.** A **linking factor** might be **porosity.**

- **low v_p** coincide with areas of **low electrical resistivities** → indication **for high porosity/fractured rock**
- **high v_p** and **high electrical resistivities** indicate, **intact rock** masses with low porosities

Inversion results are consistent with available logs (e.g. acoustic televiewer log of CBM-01) and show a **nearly horizontal layering** with variable thickness. The caliper log show a transition from a smooth borehole wall to a rough borehole wall. This might be an indication for a **lithological boundary,** meaning that the seismic and ERT data **reveal different units** within the two lithologies.



Conclusions & Outlook

Seismic and ERT measurements provide valuable insights for CSCM Reservoir characterization that goes beyond the output of well-logging data. This includes the **continuity** of layers in **between wells** and the **thickness of layers** at a **distance from wells**.

The local geology of the Helguvik experimental site comprises **almost horizontally stratified basaltic layers** with **strong variabilities** in seismic velocities and electrical resistivity.

The **ambient noise tomography** is challenging as the Helguvik site is adjacent to an active industrial area with **a high anthropogenic noise level**. No inversion result has been achieved so far.

Injection of CO_2-saturated saline water **started** on **January 15th, 2024** at rates of 3.8t CO_2/week. So far, **no clear signal has been seen yet** in the **geophysical monitoring data**.

Over the next months, we aim to measure in a **timelapse mode** the **arrival and mineralization of the injected CO_2** with:

- **ERT** measurements in the geophysical monitoring well **every 3 hours** (since injection-start)
- **repeated crosshole seismics** and **ERT** single-hole profiles in all three deep wells in **Autumn 2024**

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