DEMO UP STORAGE

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Geophysical Methods for Characterizing and Monitoring the in-situ CO_2 Mineral Storage Site in Helguvik, Iceland – Field Experiments and Modelling Results

poster abstract

This presentation participates in OSPP
EGU
Outstanding Student & PhD candidate Presentation contest

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1. Objectives

The DemoUpStorage project is the first field-scale **in-situ CO_2 mineral storage** project that utilizes saline water instead of freshwater for injection. Here, we present the **geophysical site characterization** – performed in Summer 2023 – and **modeling** results, investigating the effect of **secondary mineral precipitation on seismic velocity variations in basaltic strata** and the **feasibility** of **crosshole seismic timelapse monitoring** of in-situ CO2 mineral storage sites.

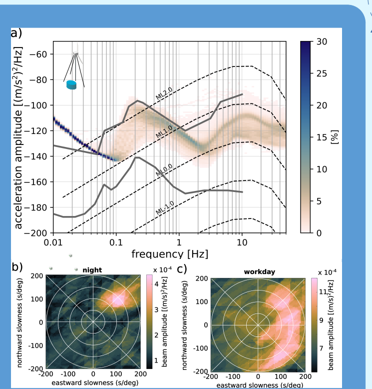
2. Geophysical Characterization of the Helguvik Pilot Site

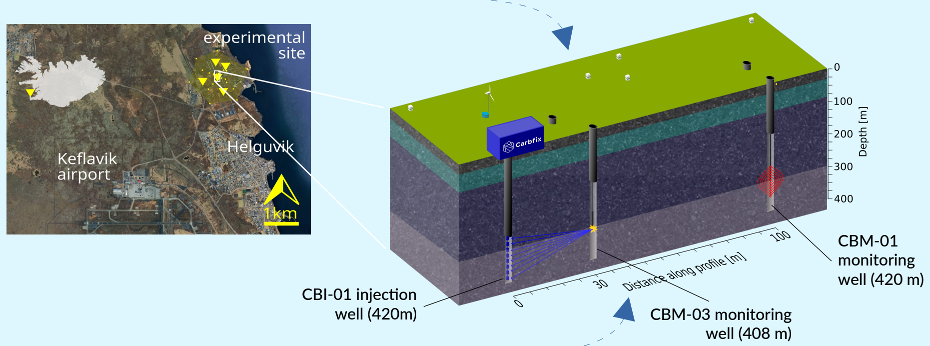
The **Helguvik pilot site** was characterized in Summer 2023 in terms of **background seismicity, ambient noise field, straticgraphic layering an d porosity & permeability distribution**. For details see Junker et al. (2025)

find paper here

Background seismicity & ambient seismic noise field

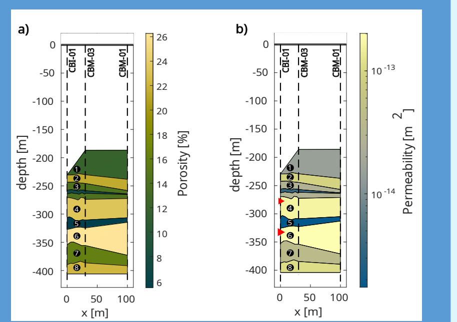
- Characterized using the **backbone seismic network** & a **nodal array**
- High anthropogenic **seismic noise level** due to nearby industries
  - → Idea of local ambient noise tomography abandonned
- **Network sensitive** to events ML ≥ 0.4 (night) to ML ≥ 0.8 (day)
  - → No local background seismicity above the detection limit observed





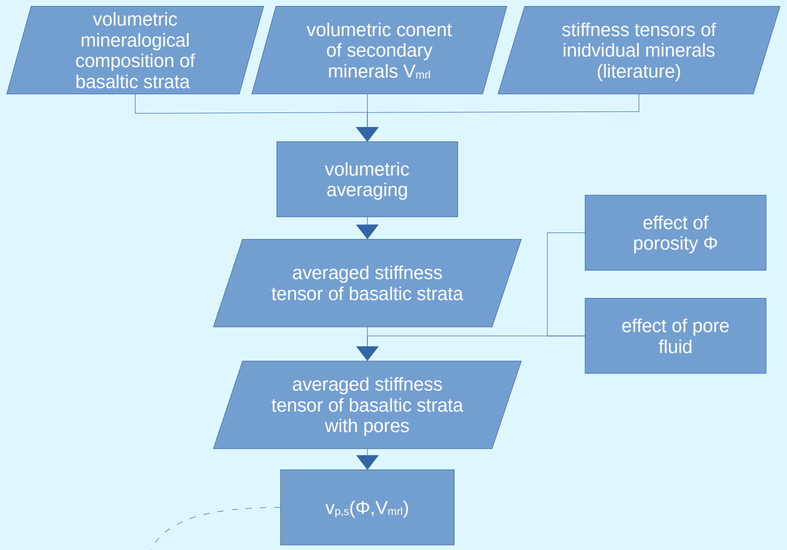
Stratigraphic layering & porosity/permeability distribution

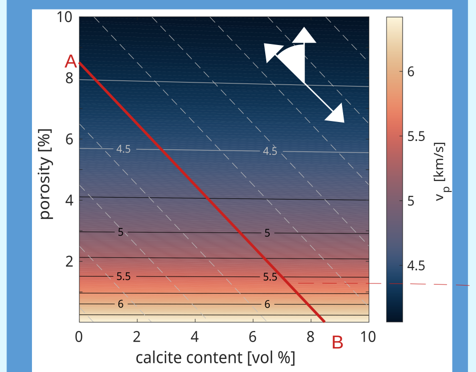
- **Cross-hole seismic** fatray- & single-hole **electrical resistivity** tomographies
- **Decameter thick stratigraphic layering** (lava flows, sedimentary interlayers) with varying seismic velocities and electrical resistivities, governed by **porosity**
- **Excellent agreement** between seismic velocities and electrical resistivities
- Results **compared** to **wireline logging** and the **mineralogical composition** of drill cuttings to build a **detailed model** of the future **injection site**



3. Influences of Secondary Mineral Precipitation on Seismic Velocities

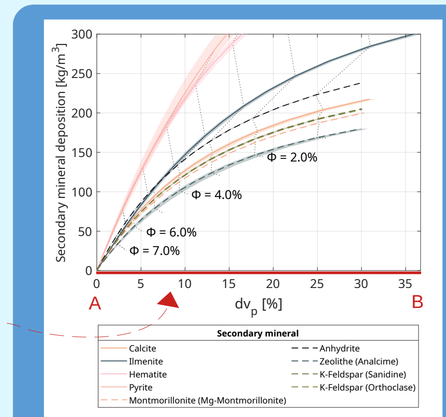
A large unknown in establishing **crosshole seismics as monitoring strategy for in-situ CO_2 mineral storage** is the **magnitude of the velocitychange** that may be expected due to the geochemical processes (host-rock dissolution, secondary mineral precipitation). Thus we implement a **rock physics modeling** approach to investigate the seismic velocity variations that can be expected. For further details see Junker et al. (in prep.):





Effect of in-situ CO_2 mineral storage operations on the elastic properties of basaltic strata:

1) Injection of dissolved CO_2 (low pH): *dissolution of host rock & release of divalent cations into pore water*
   → Φ increases (& initial $V_{calcite}$ decreases)
2) *Divalent cations react with dissolved carbon: Precipitation of secondary minerals (e.g. calcite)*
   → Φ decreases & $V_{calcite}$ increases



Estimated velocity increase dv_p due to secondary mineral precipitation

- dv_p depends on:
  - mineral species
  - initial Φ
  - mass of minerals precipitated per m^3 of host rock
- Secondary mineral precipitation in the pore-space in the order of **20 to 150 Kg minerals per m^3 of rock volume** may cause seismic p-wave velocitiy increases in the order of **dv_p = 1% to dv_p = 18%**.

4. Feasibility of Crosshole Seismic Timelapse Monitoring of in-situ CO_2 Mineral Storage

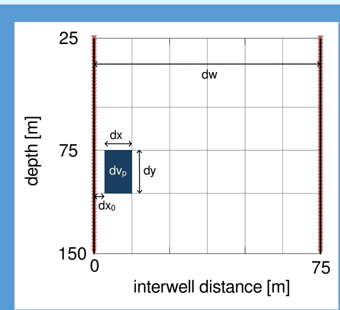
Based on the rock physics modelling result, we simulate a **crosshole seismic timelapse suvey** to analyze its limits for detecting precipitated secondary minerals. We vary the **anomaly amplitude** *dv_p*, its **lateral extent** *dx* and the **distance between the two boreholes** *dw*. We then quantify the fit of each inverted results using the objective funtion Ω_u:

$$\Omega_u = \frac{1}{n_x \cdot n_z} \sum_{i=1}^{n_x} \sum_{j=1}^{n_z} F(x,z)$$

where

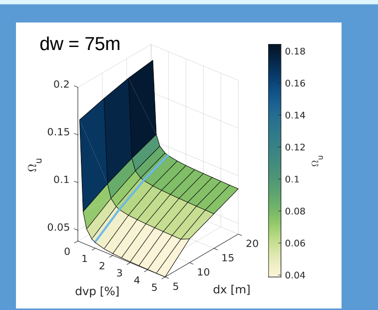
$$F(x,z) = \frac{1}{max(|\delta v_f(x,z)|)} \cdot |\delta v_i(x,z) - \delta v_f(x,z)|$$

with $\delta v_f(x,z)$ and $\delta v_i(x,z)$ being the differences between the baseline and the timelapse forward models and inversion results respectively.



Procedure per combination of dv_p, d_x and d_w

1) Generation of stochastic forward models (with velocity anomaly)
2) Forward modelling of the baseline & timelapse survey
3) Differential traveltime tomography
4) Calculation of objective function Ω_u

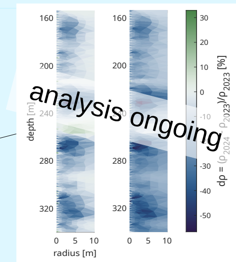


Implications for crosshole seismic surveys:

- Accurate recovery of the velocity anomaly with **dv_p ≥ 1%, dx** has minor influence
- **dv_p = 1%** corresponds e.g. to **17 $kg_{calcite}/m^3$** precipitating in the porespace
- **high** seismic **sampling rates** required (≥ 50 kHz)

5. Conclusions & Outlook

- **Synthetic seismic modelling** suggests that **velocity anomalies** as small as dv_p = 1% and withs a minimal extent of 5 m x 25 m can be **well recovered in a differential traveltime inversion**
- **Rockphysics modelling** suggests that **velocity variations in the order of up to dv_p = 18 %** can be reached given that 150 kg of secondary minerals precipitate per m³ of host-rock
- **Crosshole Seismics** and **ERT** have shown to be viable tools for **characterizing** the Helguvik pilot site in terms of **stratigraphic layers** and **porosity & permeability** distribution
- **Timelapse ERT** profiles have been recorded in summer 2024, after 8 month of CO_2 injection (137 t in total). Analysis is ongoing and first results indicate the **importance of temperature correction** to the resistivity data for accurate interpretation. For details see Brennwald et al. (in prep.)



Inverted ERT data for CBM-01 without (left) and with (right) preliminary temperature correction

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