Contribution ID: **37** Type: **Oral Presentation**

Microcalorimetric Evaluation of Microbial Activity and Reaction Rate in Sand-packed Porous Media During Microbial-Induced Carbonate Precipitation For CO2 Leakage Remediation

Monday, 13 May 2024 11:25 (15 minutes)

Carbon capture and storage (CCS) is a key technology to reach long-term climate goals that limit the temperature rise to 1.5 $^\circ$C above pre-industrial levels. It consists in capturing CO2 from large industrial points and geological storage in underground formations, such as depleted oil and gas reservoirs, unminable coal beds, and deep saline aquifers [1]. The success of this technique depends on avoiding CO2 leakage to the surface through the complex subsurface geometric structures such as faults, fractures, and abandoned wells. Microbial induced calcite precipitation (MICP) is considered as a promising in-situ method for sealing subsurface leakage paths. This technique utilizes microbes to induce calcium carbonate precipitation, which effectively reduces the porosity and permeability of the porous media, thereby mitigating CO2 leakage risks [2].

Complex bio-geochemical interactions considering rock-microbes-reactant solution are needed to get a broad assessment of MICP efficiency in geological porous media. However, this is not an easy task due to the complexity of the microbial activity and rock-forming minerals. In this study, we aim to understand the impact of particle size, specific surface area and pore volume on microbial activity and geochemical rates during MICP. An extremely sensitive microcalorimetry technique called Isothermal titration calorimetry (ITC) is used to assess the microbial activities and reaction rates within various water-saturated reservoir rocks inoculated with bacterial solutions [3]. In the ITC experiments, 100 mg of sandstone particles with different size was placed in a reaction vessel and 200μL of bacterial solution (sporosarcina pasteurii stains) was added to the rock particles [4]. The titration ampule containing the rock-bacterial solution was lowered stepwise into the calorimeter and equilibrated for 1 hour at 35 $^\circ$C.
Seven injections of 9.948 μL of the reactant solution (calcium chloride solution) were titrated with a time interval of 420 seconds into the slurry to determine the bio-geochemical reactions by monitoring heat changes. A quasi-2D sandpack (Fluidflower) was used to identify CO2 flow patterns after MICP treatment [5].

This work shows that the bio-geochemical interactions are exothermic (thermodynamically favorable) and therefore proceed spontaneously. The reaction activity within sandstone is 10 to 18 times higher than in corresponding bulk solutions. This observation underscores the significance of available surface area in influencing both microbial colonization and the speed at which reactions occur in the MICP process.

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References

Primary author: COBOS, Jacquelin (University of Bergen)

Co-authors: Prof. SØGAARD, Erik (Aalborg University); LIU, Na (University of Bergen)

Presenter: COBOS, Jacquelin (University of Bergen)

Session Classification: MS05

Track Classification: (MS05) Microbial Processes in Porous Media: Risks and Advances