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Exploiting induced carbonate precipitation to improve reservoir storage integrity and geothermal system efficiency

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Biomineralization, through microbially, thermally, or enzyme induced carbonate precipitation (MICP/TICP/EICP), is a naturally occurring and inexpensive cementation process that can seal microfractures and pore throats that are inaccessible to cement and chemical based grouts. The porosity, permeability and thermal conductivity of porous geomaterials can therefore be controlled.

This project aims to determine the optimal compositional and injection parameters for biomineralization fluids in a range of subsurface applications relating to the low carbon energy transition. These include, improving the subsurface storage integrity of CO_2 and H_2 by reducing permeability around poorly sealed legacy wells, enhancing mineral trapping of geo-sequestered CO_2, and improving the thermal performance of well casings and ground around low-high geothermal and thermal energy storage systems. We also assess the real time response of bio-cemented samples to harsh environmental conditions representative of those in the subsurface.

Understanding the interactions between geochemical reactions and the transport properties of fluid at the reservoir scale first requires biomineralization experiments to be carried out at the pore (micron) scale. These studies are essential for understanding principles of crystal formation, growth and hydrodynamic feedback mechanisms. Using real-time in situ x-ray computed tomography, the complex and synergistic factors involved in the biomineralization process can be better understood. Correlation of microstructural and macroscopic properties during repeated precipitation and dissolution events will allow refinement of larger scale reactive transport models that assess the suitability of different injection strategies.

Carbon Capture and Storage: The ability to create large, and spatially targeted low permeability regions could be a key tool in preventing leakage of geo-sequestered CO_2 (and H_2), as well as improving/restoring CO_2 injectability and sweep efficiency. During 2-phase EICP a poor choice of injection angle and flow rate can inhibit the mixing of precipitation fluids, and therefore the efficiency of permeability reduction within a porous medium. The challenge of getting 2 fluids to mix uniformly in a tight pore space is only likely to get worse in high pressure, low permeability real world systems. We explore single-phase thermally-delayed, and pulsed EICP injection strategies that encourage better mixing within heterogeneous real-world systems. Injection cycles are repeated multiple times to target the larger (order of magnitude) reductions in permeability required to alter the flow behaviour of CO_2 and other gases.

Thermal: Cement and bentonite based grouts typically have low thermal conductivities (<1 W/m K), which is detrimental to subsurface heat exchange. They often form a poor seal at the host rock/soil interface which can increase interfacial resistance. Minerals formed by MICP at the contacts between soil grains can greatly increase the thermal conductivity of the ground, particularly in unsaturated conditions. We explore enhancing this effect further with inclusion of highly conductive additives. For thermal energy storage applications specific heat capacity can also be increased with integration of phase change materials. By developing these specialized geothermal grouts/backfill, shallower boreholes may be required, greatly reducing cost.

The findings of this project have profound implications on the commercialization of engineered biomineralization, and its role in the subsurface energy transition.

Participation

In-Person

References

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