Clogging of colloids during fluid reinjection in porous media: implications for injectivity under geothermal conditions

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Geothermal fluids are often loaded with mineral and organic particles in suspension, various additives, microorganisms, heavy metals, etc. These compounds often result in significant problems on the sustainability of production and the maintenance of injectivity in the short term and, in the long term, on the stability and continuity of the resource.

As the migration and deposit of fines concern numerous industrial applications, the physics of colloidal particles in porous media has been widely studied. Historically, most of experimental studies were based on macroscopic measurements, mostly with corefloods. Since the media (rocks) are opaque, mechanisms occurring at the pore scale are difficult to obtain. Lately, interesting results on colloidal deposition and permeability damage have been obtained using microfluidic devices (Delouche et al., 2022; Dincau et al., 2022; Duchêne et al., 2020; Kim et al., 2022). However, experiments are often conducted on simplified pore-network micromodel or microchannels with or without constrictions, that are not reproducing real porous media. Thus, in this work we focus on micromodels representative of a rock-like porous medium from the intrinsic properties point of view (permeability, porosity, geometry of the pores...), to describe the characteristics of permeability damage processes under conditions similar to those of geothermal energy (high flow rates, high permeability ...). The use of microfluidics, which allows direct visualization of the phenomena involved at the pore scale and their quantification through advanced optical methods, was coupled to other important measurements such as pressure.

More particularly, two experimental set-ups have been developed and used, based on different visualization techniques: optical imaging and laser-induced fluorescence (LIF) imaging. Both systems have been designed to integrate the following tools: particle concentration monitoring, pressure drop kinetic, direct visualization of the micromodel in which the fluids are injected. The use of these two technics allows us to access complementary information at various scales. With fluorescence, we obtain the concentration field that includes the depth of the micromodel, whereas with classical optical imaging we obtain a better resolution of the images and therefore a better understanding of the mechanisms that result from the interaction between hydrodynamics (velocity, pore geometry, ...) and DLVO forces (particle-particle and particle-surface).

Here, we show how the multiscale interactions between particles and the solid matrix control the distribution of colloids, with a major mechanism involving the shear-induced formation of aggregates at flow conditions that were not investigated so far. Clogging of pore-throats is a key mechanism for reducing permeability, but pore bodies can also be critical deposition zones under certain conditions and stages of injection. Significant hydrodynamic effects have thus been observed.

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