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Preliminary experimental set-up for the investigation of colloid/nanoparticle transport in fractures of hydrothermally altered granite

Madeleine Stoll[1], Gopala Krishna Darbha[1], Florian Huber[1], Eva Schill[1], Thomas Kohl[2] and Thorsten Schäfer[1]

[1] Karlsruhe Institute of Technology (KIT), Institute for Nuclear Waste Disposal (INE), Karlsruhe, Germany;
[2] Karlsruhe Institute of Technology (KIT), Institute of Applied Geosciences (AGW), Division of Geothermal Research, Karlsruhe, Germany
madeleine.stoll@kit.edu

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ABSTRACT

Colloidal material may influence different processes in the exploration and exploitation of geothermal reservoirs. For example, colloids in heavy drilling mud may clog naturally permeable structures or naturally occurring colloids may represent nuclei for scales or form scaling themselves. Therefore, the interaction between colloids and water-effective migration pathways is essential to describe transport processes in geothermal systems.

The overall aim of this study is to elucidate the influence of the surface roughness, flow channel geometry, surface charge and clay content in fractures on the transport behavior of colloids and possible reduction in permeability and porosity caused by the immobilization of these particles or secondary phase formation. Migration experiments in drill cores, which contain natural water-bearing fractures or mechanically induced fractures (by means of tri-axial tests) shall be conducted by using a bottom-up methodical approach. These flow and colloid transport processes will be examined by drill core experiments (including natural fracture geometry) using differently altered granite samples (from geothermal reservoir rocks from Soultz-sous-Forêts (France) and rocks from the Grimsel Massive (Switzerland). The experimental work is accompanied by 3-D flow and mass transport modeling using commercial software packages (ANSYS Fluent/COMOSL Multiphysics).

At first, simplified laminar flow experiments under geochemical conditions of colloid stability against agglomeration/flocculation are carried out to test the applicability of such experiments with respect to flow conditions in a geothermal reservoir. For this purpose a synthetic fracture flow cell has been designed with the dimensions of 38 mm in diameter and an aperture of 0.75 mm. For a controlled increase in complexity both sides of the synthetic fracture can be assembled with both acrylic glass and/or granite. To investigate the transport of colloids/nanoparticles through this fracture flow cell fluorescence particles of different sizes and materials (carboxylated polystyrene and silica spheres) are used. At the fracture flow cell outlet the fluorescence signal of the colloids is measured continuously by means of a luminescence spectrometer (Aminco Bowman Series 2 Luminescence Spectrometer, Thermo Scientific) yielding colloid residence time distributions (breakthrough curves). Conservative solute tracer (Amino-G) experiments are performed to verify the flow and transport conditions. For a more detailed process understanding and for approaching the conditions in the geothermal reservoir in Soultz-sous-Forêts parameters like flow rate (2–172 mL/h corresponding to Re numbers of ~0.015–1.34), colloid size (25–1000 nm), ionic strength (0.001–1 M NaCl) and pH (5 & 9.6) are systematically varied. Post mortem analysis of the granitic fracture surface using a fluorescence microscope is planned to obtain information on the colloid deposition/attachment behavior and spatial distribution as function of e.g. mineralogy or surface roughness.

Within the range of analytical uncertainty (~10 %), current results have shown that an attachment of 25 nm polystyrene particles does not occur on the granite surface (colloid recovery=100±10 %) independent of pH conditions (pH 9.6 and 5) and flow rates (2–172 mL/h) chosen. As expected, colloids show an earlier first arrival and a more pronounced tailing in the measured breakthrough curves compared to the conservative tracer Amino-G (100 % Recovery). The 3D model is able to accurately simulate the experimental Amino-G breakthrough curve providing confidence in the experimental setup and results. Moreover, first results of the particle transport modeling corroborates the high colloid recovery of >96 % observed. Regarding the 1000 nm polystyrene particles, differences seem to occur compared to the results for the 25 nm particles (given the following conditions: pH 5; 7.1 mL/h, granite surface). Here, a decrease in recovery down to ~76–90 % was detected indicating an interaction of the particulate phase with the fracture surface leading to a deposition/attachment.