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# The use of novel DNA nanotracers to determine groundwater flow paths – a test study at the Grimsel Deep Underground Geothermal (DUG) Laboratory in Switzerland

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Groundwater flow in fractured media is heterogeneous and takes place in structures with complex geometry and scale effects, which make the characterization and modeling of the groundwater flow technically challenging. Surface geophysical surveys have limited resolution of permeable structures, and often provide ambiguous results, whereas the interpretation of borehole flow logs to infer hydraulic flow paths within fractured reservoirs is usually non-unique. Nonetheless, knowledge of the hydraulic properties of individual fractures and the role they play in determining the larger-scale flow within the fracture network (i.e. the overall flow conditions) is required in many hydrogeological and geo-engineering situations, such as in geothermal reservoir studies. Tracer tests can overcome some of the aforementioned limitations by providing strong constraints on the geometry and characteristics of flow paths linking boreholes within both porous media and fracture-dominated types of reservoirs. In the case of geothermal reservoirs, tracer tests are often used to provide estimates of the pore/fracture volume swept by flow between injection and production wells. This in turn places constraints on the swept surface area, a parameter that is key for estimating the commercial longevity of the geothermal system. A problem with conventional tracer tests is that the solute species used as the tracer tend to persist in detectable quantities within the reservoir for a long time, thereby impeding repeat tracer tests. DNA nanotracers do not suffer from this problem as they can be designed with a unique signature for each test. DNA nanotracers are environmentally friendly, sub-micron sized silica particles encapsulating small fragments of synthetic DNA which can be fabricated to have a specified, uniquely detectable configuration. For this reason, repeat tracer tests conducted with a differently-encoded DNA fragment to that used in the original will not suffer interference from the earlier test.

In this study, we present the results of tests of applying novel DNA nanotracers to characterize groundwater flow properties and the flow pathways in a fracture-dominated reservoir in the Deep Underground Geothermal (DUG) Laboratory at the Grimsel Test Site in the Swiss Alps. This study is motivated by subsequent comparisons of similar characterizations of fractured rock masses after hydraulic stimulation. These will take place at the DUG Lab at the end of 2016. The results of the flow-path characterization are also compared with those obtained from classical solute tracer tests.