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# Single-well tracer test sensitivity w. r. to hydrofrac and matrix parameters (case study for the Horstberg site in the N-German Sedimentary Basin)

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At the geothermal pilot site Horstberg in the N-German Sedimentary Basin, a complex field experiment program was conducted (2003–2007) by the Federal Institute for Geosciences and Natural Resources (BGR) together with the Leibniz Institute for Applied Geosciences (GGA), aimed at evaluating the performance of innovative technologies for heat extraction, for direct use, from a single geothermal well[1],[2]. The envisaged single-well operation schemes comprised inter-layer circulation through a large-area hydrofrac (whose successful creation could thus be demonstrated), and single-screen 'huff-puff' in suitable (stimulated) layers, seated in sandstone-claystone formations in 3–4 km depth, with temperatures exceeding 160 °C.

Relying on Horstberg tracer-test data, we analyze heat and solute tracer transport in three characteristic hydraulic settings:

- (A) single-screen, multi-layer push-pull, with spiking and sampling at lower well-screen in low-permeability sandstone layer ('Detfurth'), from which hydrofrac propagation (through several adjacent layers) was initiated;
- (B) single-screen, single-layer push-pull, with spiking and sampling at upper well-screen within a more permeable sandstone layer ('Solling');
- (C) inter-layer vertical push through above-mentioned hydrofrac, with spiking at well-screen of A, and sampling at well-screen of B.

Owing to drill-hole deviation, the hydraulically-induced frac will, in its vertical propagation, reach the upper sandstone layer in a certain horizontal distance $X$ from the upper well-screen, whose value turns out to be the major controlling parameter for the system's thermal lifetime under operation scheme C (values of $X$ below $\sim$8 m leading to premature thermal breakthrough, with the minimum-target rate of fluid turnover; however, the injection pressure required for maintaining the target outflow rate will also increase with $X$, which renders scheme C uneconomical, or technically-infeasible, when $X$ exceeds $\sim$15 m). Tracer signals in C are, as well, sensitive w. r. to $X$, but the effects of increasing $X$, upon tracer signals, are largely indistinguishable from those of increasing Solling porosity.

Further numerical simulations of heat and solute tracer transport in above-named test settings reveal significant disparities between parameter sensitivities attainable in the same kind of test (A, B) conducted at different layers, as well as between solute concentration and temperature signal sensitivities w. r. to transport parameters in one and the same test (C). Why? – Test A features fracture flow, and dual-continuum transport, whereas test B features single-continuum flow and transport (within the host rock, with negligible losses to the hydrofrac). Flow is rapid in test A (being fracture-dominated), but slow in test B (being confined to the host rock). In test C, fluid first flows through the hydrofrac mainly, next it 'must' flow through the upper sandstone; heat transport is dominated by matrix diffusion across the hydrofrac (along which it thus experiences strong retardation), whereas solute transport is dominated by matrix micro-fissure and intra-particle diffusion within the upper sandstone (where it experiences strong retardation).

We examine the implications of these findings upon the inversion of transport-effective hydrofrac parameters from measured tracer signals, and upon the tracer-based predictability of the system's thermal lifetime under different operation schemes.

[1] http://www.geothermal-energy.org/pdf/IGAstandard/SGW/2005/jung.pdf
[2] http://www.geothermal-energy.org/pdf/IGAstandard/WGC/2010/2272.pdf

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