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Interpretation of single-well push-pull spikings conducted in deep crystalline formations (Soultz-s.-F. in the Upper Rhine Graben, and KTB-VB at the German site of ICDP)

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Two somewhat contrasting model approaches are presented, both aimed at interpreting long-term return signals from tracer push-pull tests conducted at single wells penetrating increased-permeability features in crystalline rock, about 4 km deep.

The general idea is that single-well tracer push-pull tests, owing to the flow-field reversal, should provide privileged access to advection-independent parameters of solute transport, like the density of fluid-rock contact surface areas (Sauter et al., 2002). The latter is equivalent to the heat exchange area for a liquid-based geothermal system.

At the geothermal site of Soultz-sous-Forêts in the Upper Rhine Graben, the French BRGM, in cooperation with EGI Utah and other partners, conducted a comprehensive tracer testing programme, whose results were presented in detail by Sanjuan et al. (2004, 2006), Rose et al. (2006). Of these results, we pick the tracer return signals detected during post-stimulation backflow periods at borehole GPK-2 between 2000 and 2002 (as published by Sanjuan et al., 2004) and attempt to interpret them in terms of a single-well injection-withdrawal sequence. Two chemically dissimilar organic tracers have been used by BRGM; however the difference between their return signals seems not significant enough to allow quantifying fluid-rock contact surfaces from this difference alone (additional / a priori information on coefficients of solute exchange across these surfaces would be required). Instead, the tracer return signals enable characterizing the nature of solute exchange processes within the spiked volume of the assumed fractured-porous formation (highly altered crystalline rock). At least one rapid-exchange (E-7 / d), slightly dispersive (Pe$\sim$12) component and one moderate-exchange (2E-8 / d), less dispersive (Pe$\sim$20) component appear to act within few hundred metres and, respectively, within at least 1 km radial distance from the borehole. - An alternative component of extremely fast exchange (increase of solute exchange fluxes by factor E+5) can as well reproduce the available data, but is physically implausible. For a reliable determination of heat exchange areas at geothermally relevant space scales, additional tracer testings (including heat backflow tests) would be required.

At the German site of ICDP (Intl. Continental Scientific Drilling Program, with 'Kontinentale Tiefbohrung' at Windischeschenbach in NE Bavaria), a sequence of multi-tracer push-pull tests was conducted by the Göttingen Group between 2004 and 2006 at the pilot hole (KTB-VB) in hydraulically depleted, stimulated and post-stimulated states (following a long-term pumping test, and massive injection tests, respectively). Here, the spiking design was such that significant differences occurred between the signals of various simultaneously-injected tracers, enabling - at least theoretically - to quantify fracture densities; furthermore, the differences between solute and heat backflow signals produced under different hydraulic regimes can be used to characterize hydro-thermo-mechanical processes induced by massive cold-water injection.
Both spiking-derived informations are relevant to a future geothermal project at this site.

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