Tracer tests for characterizing deep (enhanced) geothermal systems in Germany: a progress report

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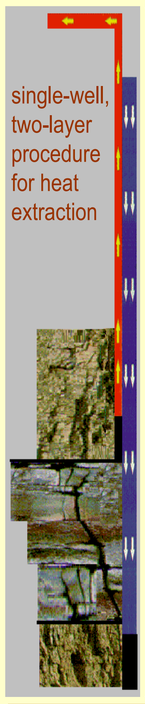
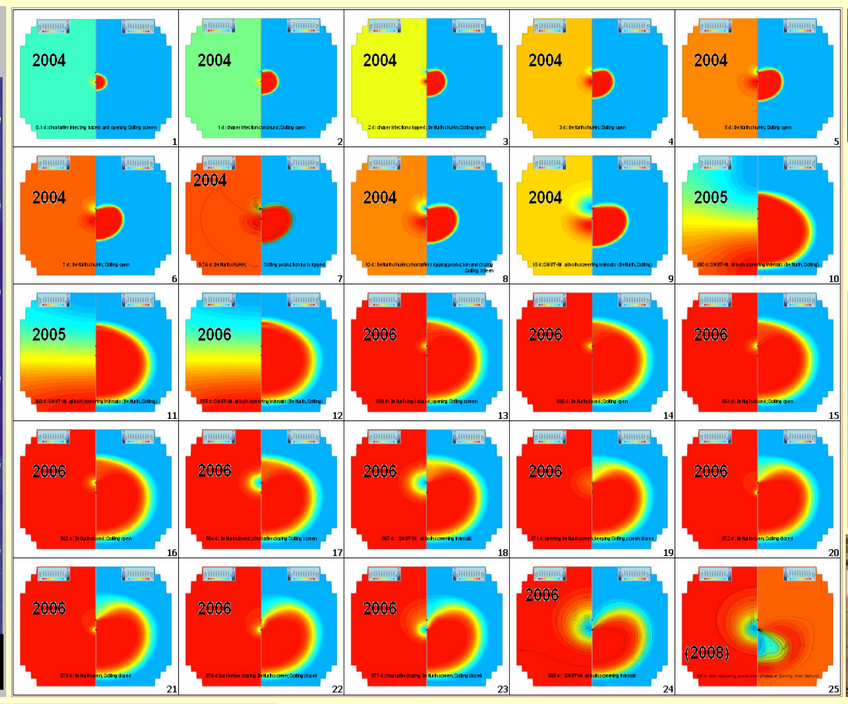
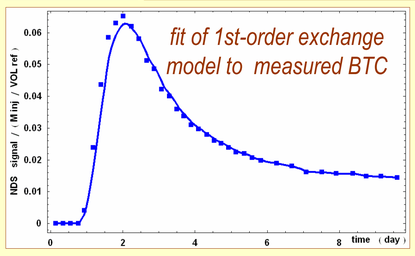
Tracer tests (artificial spikings) are indispensable in characterizing fluid-based geothermal reservoirs: they provide the only means for determining fluid residence times and fluid-rock contact-surface (i.e., heat exchange) areas; hydraulic and geophysical methods are largely insensitive w.r. to these parameters. Mostly, tracer tests can be conducted in parallel with hydraulic or hydro-mechanical experiments, without major additional expenses.

Over the last five years (2003-2007), two single spikings and three complex spiking sequences were conducted in ~4 km deep crystalline or sedimentary formations (candidate or actual geothermal systems) in Germany, comprising: single-well intra-layer push-pull, dual-scale push-pull, single-well inter-layer and inter-well flow-path tracings.



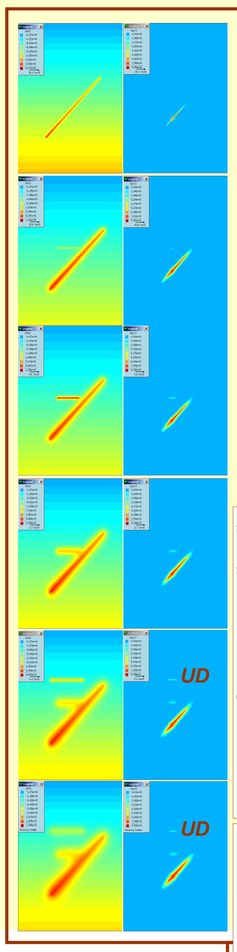


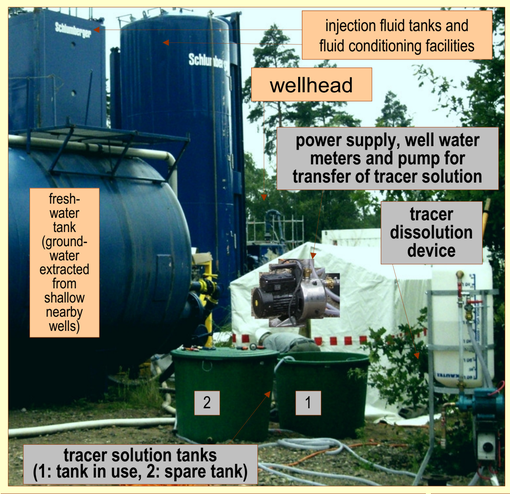


Horstberg (water-induced fault in tight clay/sandstone layers): time sequence shows evolution of pressure (left half) and tracer concentration (right half) fields on idealized 2-D fault projection.

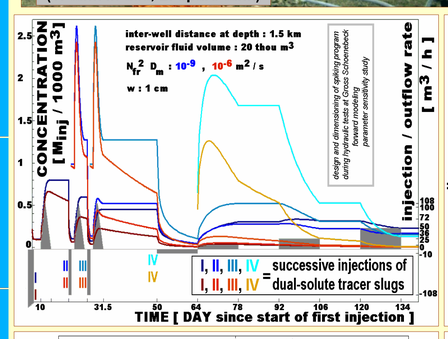
Main results: estimation of inter-layer flow capture angle, from extrapolated tracer recovery; flow-storage distribution of induced fault, from statistical time-moment analysis of measured tracer breakthrough.

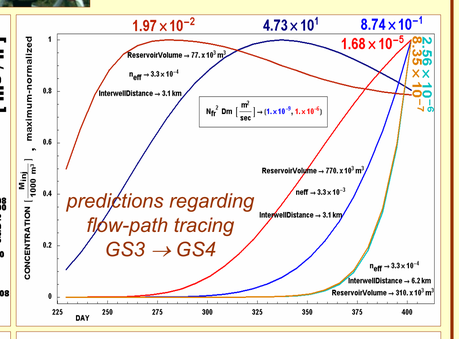
Similar single-well test sequences are proposed for the new borehole to be drilled in **Hannover** as of 2008.

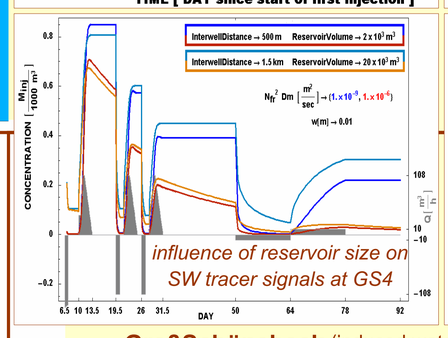


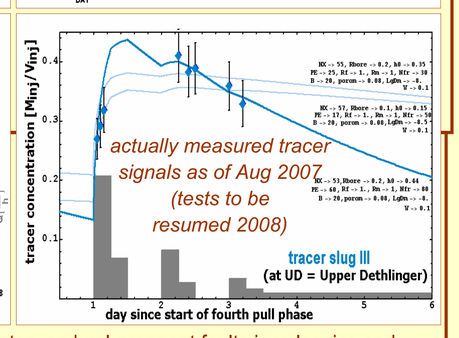


field setup for fluid spiking and sampling

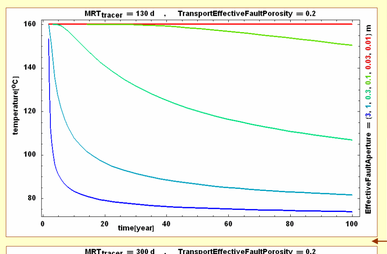


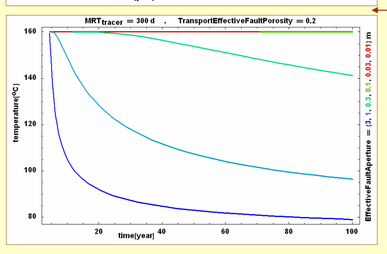


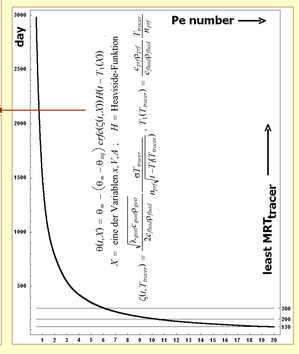




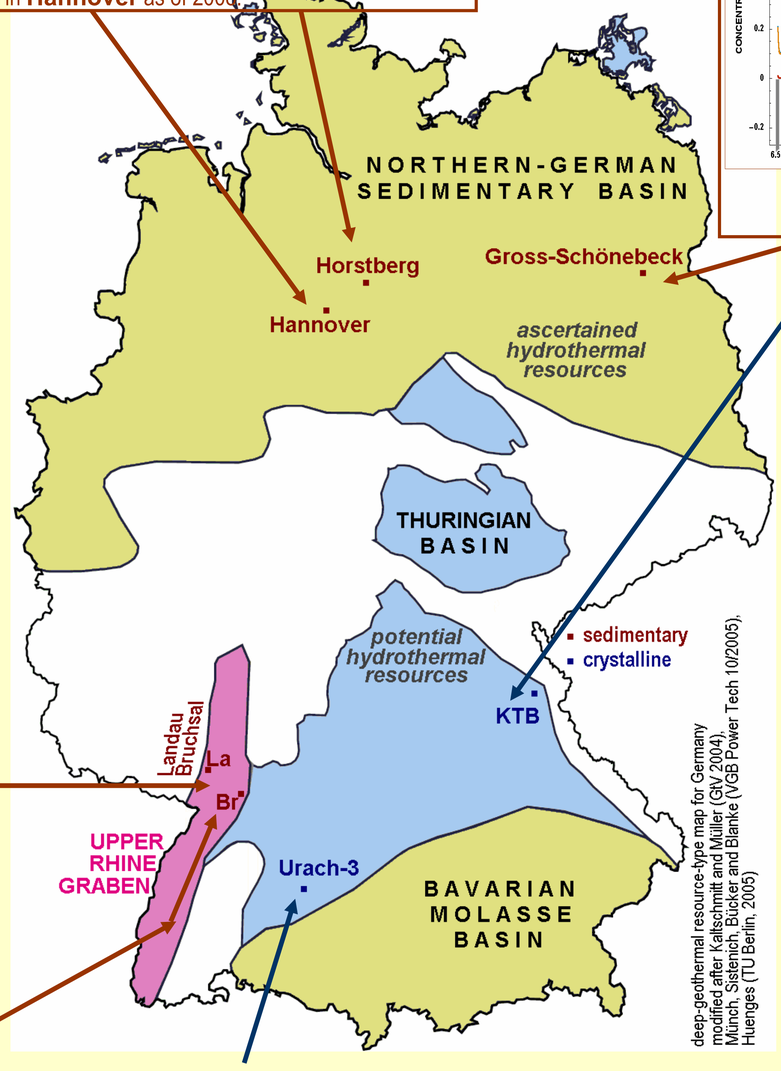
GroßSchönebeck (induced water- and gel-proppant faults in volcanics and sandstone layers, tests ongoing): provisional estimation of fault transport properties





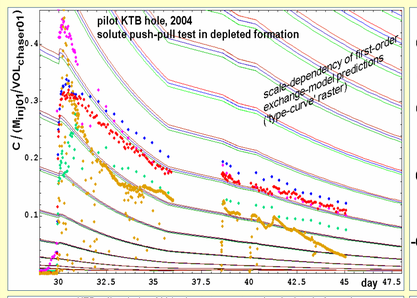


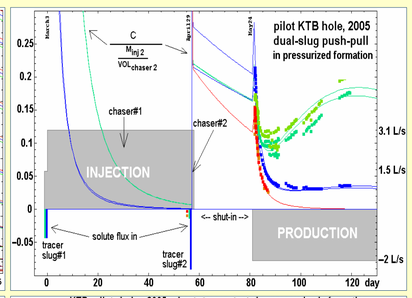
Landau (hydrothermal system): improved estimation of least reservoir size (and thus of earliest thermal breakthrough) from lowered detection limits in tracer analytics

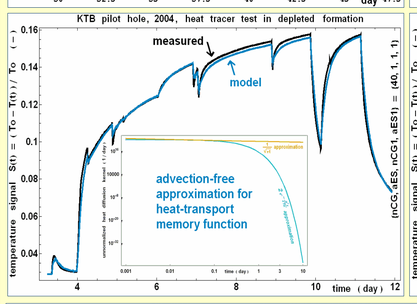


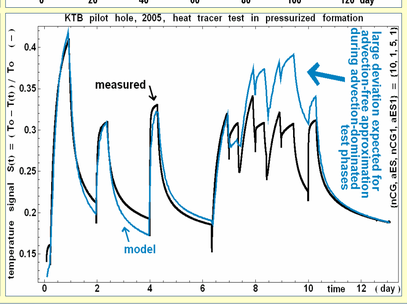
Urach-3 (HDR system): superposition of tracer push-pull signals from at least two fractures with ambiguously-determined transport properties; interpretation unclear as yet

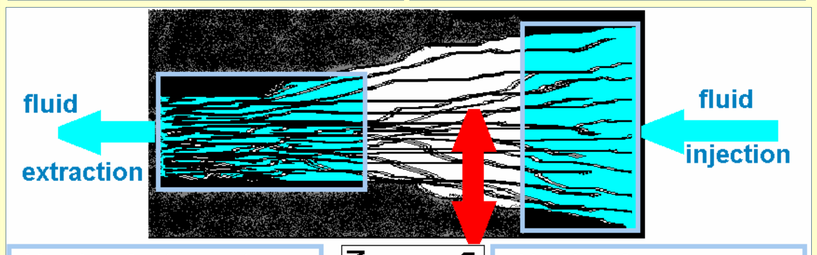
pilot KTB hole (intersecting permeable fault system in Mid-German crystalline basement): estimation of near-field and far-field fracture densities and of their increase/decrease during depletion/stimulation









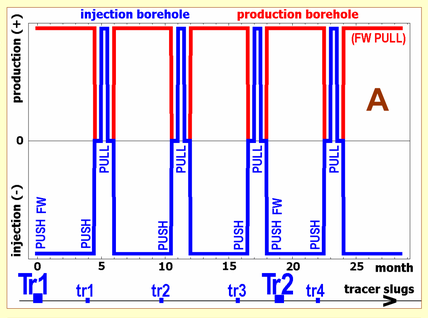


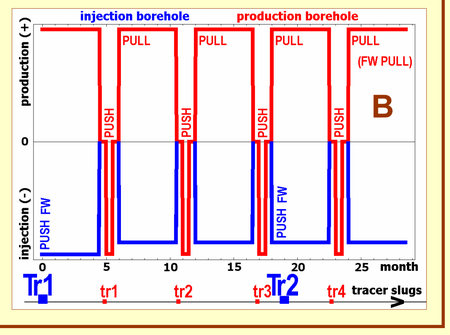
Bruchsal (hydrothermal system): example of proposed test sequence for long-term monitoring (early warning) of reservoir property changes

pro's/con's:

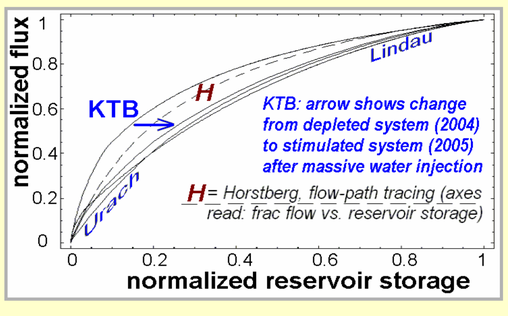
A: 'pull' phases do not require installing a production pump, however their duration is strongly limited by plant-operational constraints

B: 'pull' phases of unlimited duration, however stronger disruption to plant operation plan





Several time-rate design options for continued fluid sampling and for new spiking operations can be proposed for the Horstberg/Hannover, GroßSchönebeck, Landau, Bruchsal and KTB sites.



more details on tracer tests conducted by the Göttingen Group can be found under:
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