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Long residence times – bad tracer tests?

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Tracer tests conducted at geothermal well doublets or triplets in the Upper Rhine Rift Valley [1] all face, with very few exceptions so far, one common issue: lack of conclusive tracer test results, or tracer signals still undetectable for longer than one or two years after tracer injection. While the reasons for this surely differ from site to site (Riehen, Landau, Insheim, Bruchsal, . . .), its effects on how the usefulness of tracer tests is perceived by the non-tracer community are pretty much the same. The 'poor-signal' frustration keeps nourishing two major 'alternative' endeavours : (I) design and execute tracer tests in ***single-well*** injection-withdrawal (push-pull), ***'instead of' inter-well*** flow-path tracing configurations; (II) use 'novel' tracer substances instead of the 'old' ones which have 'obviously failed'. Frustration experienced with most inter-well tracer tests in the Upper Rhine Rift Valley has also made them be regarded as 'maybe useful for EGS' ('enhanced', or 'engineered' geothermal systems, whose fluid RTD typically include a major share of values below one year), but 'no longer worthwhile a follow-up sampling' in natural, large-scale hydrothermal reservoirs.

We illustrate some of these arguments with the ongoing Bruchsal case [2]. The inter-well tracer test conducted at Bruchsal was (and still is!) aimed at assessing inter-well connectivity, fluid residence times, and characterizing the reservoir structure [3]. Fluid samples taken at the geothermal production well after reaching a fluid turnover of about 700,000 m^3 showed tracer concentrations in the range of 10^{-8} M_{inj} per m^3, in the liquid phase of each sample (M_{inj} being the total quantity of tracer injected as a short pulse at the geothermal re-injection well). Tracer signals might actually be higher, owing to tracer amounts co-precipitated and/or adsorbed onto the solid phase whose accumulation in the samples was unavoidable (due to pressure relief and degassing during the very sampling process, and later on during sample aeration); the adsorbed and/or co-precipitated tracer amounts appear to be non-zero, but their accurate metering was not completed to date. Thus, a conservative estimate of cumulative tracer recovery amounts to (at least) 2 parts-per-thousand for the first 700,000 m^3 of fluid turnover within the geothermal well doublet. Neither do such recovery values automatically imply 'bad news' (poor inter-well connectivity), nor do they appear as implausibly low (cf. fig. 2 of [3]), considering the possibility of major vertical drainage along the large-scale fault zone that isolates the 'aquifer basin' around the re-injection well from the 'aquifer catchment' around the production well, along with the prospect of transport-effective porosity and/or thickness within these 'aquifers' being rather high, due to extensive fissuring/fracturing.

In more general terms, we argue that (a) inter-well flow-path spikings are still worthwhile being conducted even in large-scale hydrothermal reservoirs; (b) results gained from single-well tests [3] can never serve as a substitute for the kind of information (primarily: residence time distribution RTD, or flow-storage repartition FSR) being expected from inter-well tests; (c) tracer species that are 'novel' in terms of thermo-/reactivity/sorptivity/exchange at phase interfaces and thus involve some transport-*retarding* process cannot alleviate the frustration associated with long RT; (d) augmenting the tracer quantity M_{inj} to use for inter-well spiking might render the tracer signal detectable, say, one or two years earlier, but it does not make FSR available sooner, since M_{inj} cannot alter the RTD of fluids traveling through the reservoir; moreover, for inter-well configurations and reservoir structures typical of the Upper Rhine Rift Valley, the M_{inj} augmenting factors necessary to render tracer signals detectable 1 or 2 years earlier mostly range beyond the limits of the reasonably-recommendable (e. g., for Bruchsal: 2 tons, instead of 100 kg of a particular tracer).

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