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Tracer SWIW tests in propped and un-propped fractures: parameter sensitivity issues, revisited

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Single-well injection-withdrawal (SWIW) or 'push-then-pull' tracer methods appear attractive for a number of reasons: less uncertainty on design and dimensioning, and lower tracer quantities required than for inter-well tests; stronger tracer signals, enabling easier and cheaper metering, and shorter metering duration required, reaching higher tracer mass recovery than in inter-well tests; last not least: no need for a second well. However, SWIW tracer signal inversion faces a major issue: the 'push-then-pull' design weakens the correlation between tracer residence times and georeservoir transport parameters, inducing insensitivity or ambiguity of tracer signal inversion w. r. to some of those georeservoir parameters that are supposed to be the target of tracer tests par excellence: pore velocity, transport-effective porosity, fracture or fissure aperture and spacing or density (where applicable), fluid/solid or fluid/fluid phase interface density. Hydraulic methods cannot measure the transport-effective values of such parameters, because pressure signals correlate neither with fluid motion, nor with material fluxes through (fluid-rock, or fluid-fluid) phase interfaces. The notorious ambiguity impeding parameter inversion from SWIW test signals has nourished several 'modeling attitudes':

(i) regard dispersion as the key process encompassing whatever superposition of underlying transport phenomena, and seek a statistical description of flow-path collectives enabling to characterize dispersion independently of any other transport parameter, as proposed by Gouze et al. (2008), with Hansen et al. (2016) offering a comprehensive analysis of the various ways dispersion model assumptions interfere with parameter inversion from SWIW tests;

(ii) regard diffusion as the key process, and seek for a large-time, asymptotically advection-independent regime in the measured tracer signals (Haggerty et al. 2001), enabling a dispersion-independent characterization of multiple-scale diffusion;

(iii) attempt to determine both advective and non-advective transport parameters from one and the same conservative-tracer signal (relying on 'third-party' knowledge), or from twin signals of a so-called 'dual' tracer pair, e. g.: using tracers with contrasting reactivity and partitioning behavior to determine residual saturation in depleted oilfields (Tomich et al. 1973), or to determine advective parameters (Ghergut et al. 2014); using early-time signals of conservative and sorptive tracers for propped-fracture characterization (Karmakar et al. 2015); using mid-time signals of conservative tracers for a reservoir-borne inflow profiling in multi-frac systems (Ghergut et al. 2016), etc.

The poster describes new uses of type-(iii) techniques for the specific purposes of shale-gas reservoir characterization, productivity monitoring, diagnostics and engineering of 're-frac' treatments, based on parameter sensitivity findings from German BMWi research project "TRENDS" (Federal Ministry for Economic Affairs and Energy, FKZ 0325515) and from the EU-H2020 project "FracRisk" (grant no. 640979).