FLUID/ROCK INTERFACES AND RESERVOIR CHARACTERIZATION BY SINGLE-WELL DUAL-TRACER PUSH-PULL TESTS

I. Ghergut[1], H. Behrens[1], A. Niemi[2], M. Nottebohm[1], T. Licha[1], M. Sauter[1]
[1]University of Göttingen, Geoscience Centre; [2]Uppsala University, Earth Science Dept.
iulia.ghergut@geo.uni-goettingen.de

Keywords: R&D, tracers, single-well, push-pull, fluid-rock interface, brine-CO_2 interface

Whenever dealing with fluids in georeservoirs, it is likely that their residence times (in sub-systems or compartments of interest) and fluid-rock interface densities will play some, often significant role. In particular,

a) the reservoir size or transport-effective porosity (as resulting from fluid residence time averaging),
b) reservoir heterogeneity (as expressed by fluid residence time distributions), and
c) fluid-rock and fluid-fluid interface densities (area-per-volume ratios)

represent controlling parameters in geotechnical applications like deep-ground waste disposal, CO_2 capture and sequestration, geothermal energy extraction, or spent radionuclide depositing. To quantify (a), (b) and (c), fluid spikings (tracer tests) provide the method of choice. Hydraulic and geophysical methods cannot determine fluid transport parameters unambiguously, because the signals they detect correlate neither with fluid motion, nor with material fluxes through rock/fluid interfaces.

In the context of CCS, tracer tests are not only indispensable for candidate site assessment and characterization, but also potentially useful for intra- and post-injection monitoring purposes. For instance:

i. single-phase conservative tracers with well-defined diffusion and sorption properties enable to determine single-phase fluid residence times and fluid-rock interface densities;
ii. liquid-phase tracers added closely before CO_2 injection enable to quantify the displacement of native reservoir brines by the CO_2 plume (Ghergut et al. 2009);
iii. conservative tracers partitioning between two fluid phases enable to determine phase interface areas or the volume of one of the phases (Behrens et al. 2009);
iv. reactive tracers with specific milieu-dependencies of their reaction rates enable to assess temperature, pH, redox potential values or other physico-chemical parameters along their flow path (Nottebohm and Licha 2011).

In contrast with seismic, geophysical, hydraulic methods, the use of tracer tests for characterizing deep georeservoirs, and especially the use of *single-well* spikings is rather new in Germany. Elsewhere worldwide, single-well injection-withdrawal techniques have been used for various practical and theoretical purposes in subsurface investigations, e. g. to assess: residual oil saturations (Tomich et al. 1973); in-situ biodegradation and/or sorption rates (Istok et al. 1997, Schroth et al. 2001), in the realm of contaminant hydrology; heat exchange parameters (Kocabas and Horne 1987) for geothermal energy use; or for quantifying multi-rate diffusion in heterogeneous porous media (Haggerty et al. 2001), but also for quantifying advection-dispersion processes (Leap and Kaplan 1988), important aspects of SWIW test interpretation being analyzed by Neretnieks (2007).

We develop dual-tracer single-well techniques for quantifying fluid-rock and fluid-fluid interface densities in (multi-)porous media. Within CCS, fluid/rock interfaces play an essential role in the mid- and long-term trapping mechanisms ('residual' and 'mineral' trapping), and they can compensate what 'structural' and 'solubility' trapping may fail to ensure.

To define fluid-rock or fluid-fluid interface densities as spatially-distributed parameters at arbitrary scales, we largely adopt (and adapt) the formalism from Carrera et al. (1998).

When natural flow is negligible compared to experimentally applied forced-gradient flow fields, the single-well, dual-tracer push-pull procedure was found to be particularly suited for reducing the ambiguity of quantification between advective-dispersive and non-advective parameters – excepting the case when *equilibrium* processes (like fast-equilibrium sorption or partitioning) are used as the main 'probe' for quantifying rock/fluid interfaces; in this latter case, single-well push-pull tests turn out to be *less sensitive than inter-well* flow-path tracings.

Single-well push-pull tests can be designed both as a dual-tracer and as a dual-scale method:

A) using solute tracer pairs with different diffusion, sorption and/or partitioning coefficients enables to characterize fluid-rock or fluid-fluid interface densities at scales comparable to that of hydrodynamic dispersion;
B) using solutes and heat as a tracer, fluid-rock interface densities can be quantified at different scales *across* the flow direction;
C) using either comparable tracers with different fluid flushing ('push') volumes allows to characterize transport at different scales *along* the flow direction (sufficient 'pull' volume provided).

We illustrate the application of these principles with results from deep georeservoir testings in Germany. We present sensitivity analyses of tracer 'pull' signals w. r. to transport parameters at different georeservoir scales, and in particular w. r. to CO_2/brine/rock interface densities.

Acknowledgement: Tracer test modeling and parameter sensitivity analyses were conducted within the GEBO G6 project funded by Baker Hughes (Celle, Germany) and by the Science and Culture Ministry of Lower Saxony (MWK Niedersachsen, Germany). Laboratory studies on tracer physico-chemistry (Research Team Dr. Licha, Nottebohm et al.) are funded by the EU (FP7), within the MUSTANG project (grant no. 227286).

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