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Matrix-fractures contact surface changes as an indicator of induced thermal-hydraulic-mechanical processes in deep rock

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Long-term physical and structural changes in a fractured-porous system subject to THM stress (typically, a deep geothermal reservoir under exploitation) essentially correlate with the specific area (s) of the contact surface between fractures and rock matrix. This parameter is not properly captured by standard hydraulic or geophysical tests, nor by flow-path tracings in highly-dispersive flow fields. A single-well tracing method that increases the sensitivity of tracer breakthrough curves (BTCs) w. r. to the surface-area parameter s is described (the 'dual-tracer push-pull' method), and illustrated with results of its application for three crystalline formations in Germany (KTB, Urach, Lindau). Fluid salinity and heat as an artificial tracer could further be used to complement the information returned by injected solutes. A simplified way of estimating s from tracer tests is proposed in terms of mid-late BTC approximations.

Determining s from tracer BTCs presupposes reliable knowledge of tracer physicochemical behaviour under reservoir conditions. A tentative interpretation of BTC differences between different tracers, beyond the amount accountable for by their different diffusion coefficients, can first rely on structure-activity considerations (Behrens 1986), before tracer physicochemical properties are quantified by appropriate laboratory experiments. A field push-pull test can substitute the required laboratory investigations if at least one assuredly 'reference' tracer is injected alongside with the tracers whose physicochemical behaviour is less secured. - A analogous approach had been used by Snodgrass and Kitanidis (1998), Istok et al. (2001) to get in situ estimates of natural attenuation rates. In the practice of deep reservoir tracing, there are physical and financial limitations to test design and duration. Insufficient flushing volumes may render BTC peak regions unusable for fracture characterization, and insufficient outflow volumes can make characteristic ‘mid-late’ BTC slopes difficult to recognize.

A further important measure of reservoir performance can be provided by a truncated time moment analysis of tracer BTCs. A parametric plot of normalized 0th- against 1st-order truncated time moments of tracer BTCs can yield a flow-capacity repartition, if derived from a flow-path tracing, or one by matrix freight, if derived from a single-well push-pull test. Such repartitions present the advantage of being invariant to bulk discharge rates (as long as the hydraulic regime doesn’t change qualitatively) and insensitive to tracer BTC normalization uncertainties (as these typically incur from poorly-defined analytical calibration standards or from the difficulty of knowing how much of the injected tracer actually reached the target formation). In order to calculate time moments, measured tracer BTCs need to be extrapolated for large times according to some transport model, however the result is relatively insensitive to the particular choice of matrix blocks’ shape and geometry. Flow-capacity diagrams derived from standard flow-path tracings had been interpreted by Shook (2003) as a ‘geometric characterization’ of the reservoir. Flow-capacity and matrix freight repartitions obtained from several tracings conducted in Germany in deep sedimentary and crystalline formations before and/or after massive hydraulic stimulation are compared and explained.

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References:

Behrens H (1986) Water tracer chemistry - a factor determining performance and analytics of tracers. In: Symposium on Underground Water Tracing (eds: Morfis A, Paraskevopoulou P) (Proc 5th Int Symp SUWT, Athens, Greece), 121-133

Istok JD, Field JA, Schroth MH (2001) In Situ Determination of Subsurface Microbial Enzyme Kinetics. Ground Water 39(3), 348-355

Shook GM (2003) A simple, fast method of estimating fractured reservoir geometry from tracer tests. Geothermal Resources Council Transactions 27, 407-411

Snodgrass MF, Kitanidis PK (1998) A Method to Infer In Situ Reaction Rates from Push-Pull Experiments. Ground Water 36(4), 645-650