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Expected fluid residence times, thermal breakthrough, and tracer test design for characterizing a hydrothermal system in the Upper Rhine Rift Valley

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MOTIVATION

can we predict the thermal lifetime of a (fault-dominated / heterogeneous) hydrothermal reservoir from tracer test results?

Relying on the structural-hydrogeological model proposed by J. Meixner (2009) for a particular hydrothermal system on the East side of the Upper Rhine Rift Valley (being used to demonstrate electricity production by means of a well doublet), we set up a distributed-parameter model enabling to simulate fluid ages, temperature evolutions and tracer test signals for a number of contrasting assumptions w. r. to

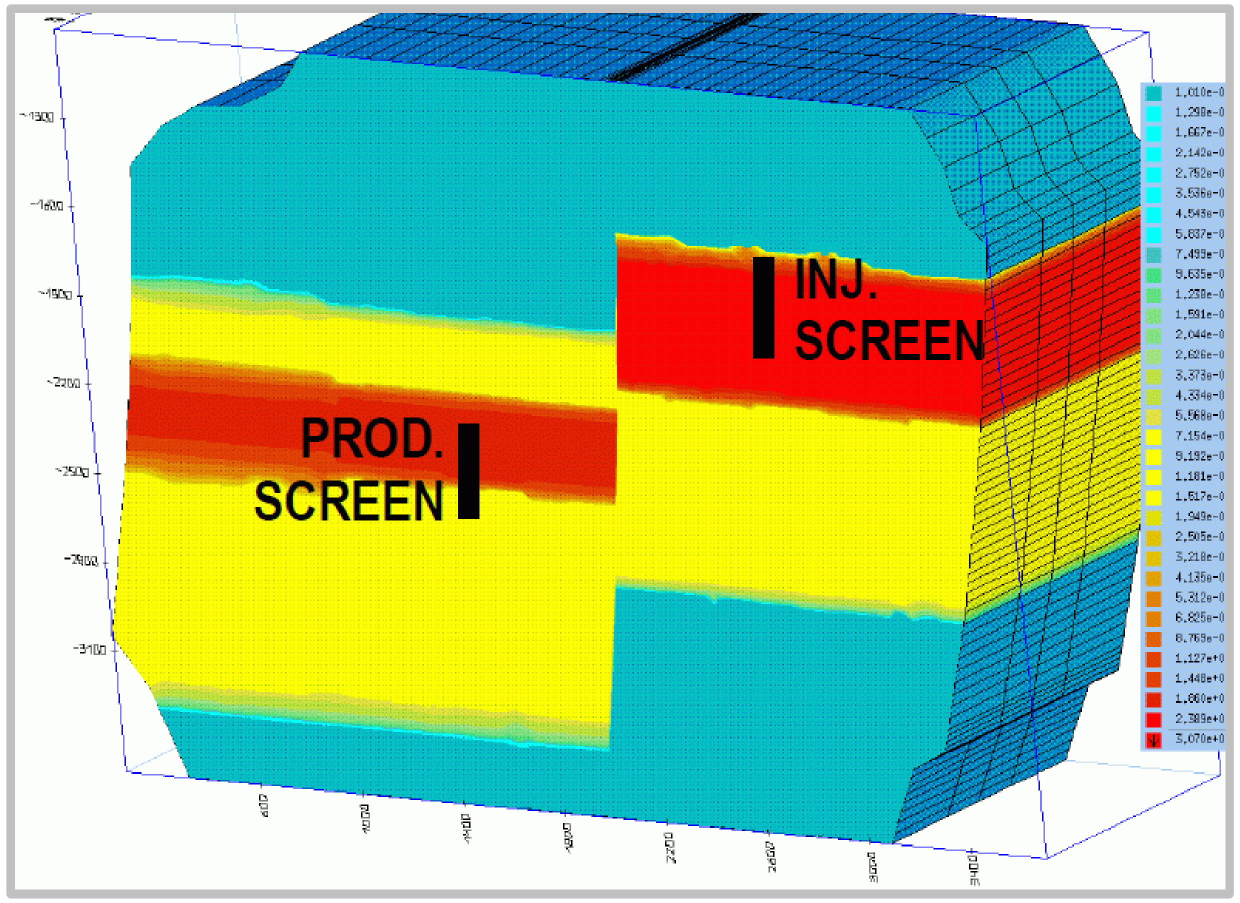
(a) the nature of boundary conditions and hydrogeological characteristics of remotely situated, large-scale natural faults,
(b) the degree of permeability contrast between different system compartments,
(c) the hydrogeological characteristics of a naturally-occurring fault, located between injection and production wells.

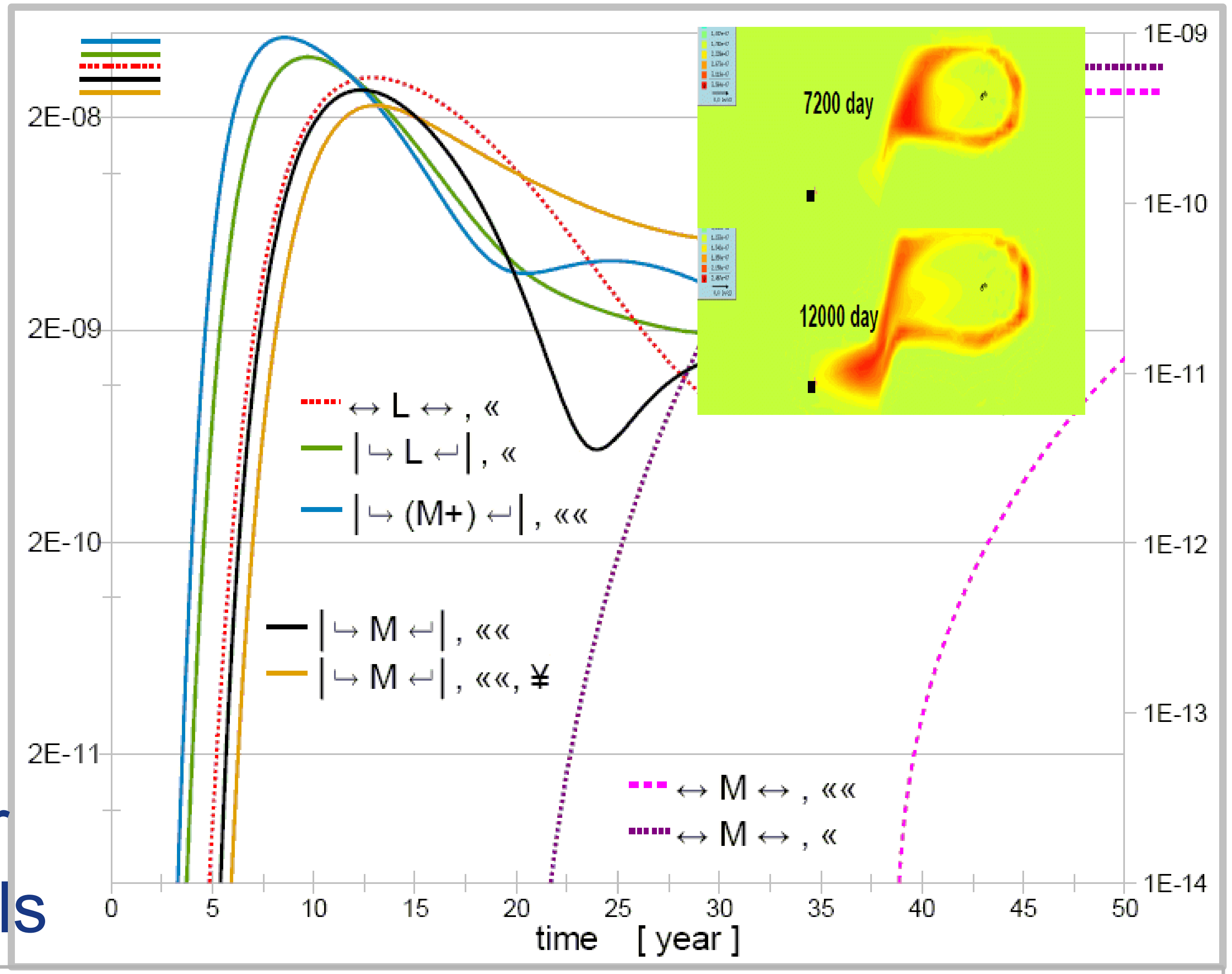
It appears that a spike dimensioning allowing for tracer signals to become detectable during the first few years after tracer injection in any of the contrasting a/b/c scenarios is not feasible in practice. In some of the a/b/c cases considered, the system will act like a very large reservoir, with fluid residence times in the order of decades, and extreme dilution of injected tracers. On practical reasons, the spike dimensioning will be limited to some hundred kilogram of one or two organic tracers. This implies that part of the contrasting a/b/c scenarios will remain indistinguishable during the first three years after tracer injection. However, for the assumed reservoir structure, **there is no 1 : 1 correspondence between early-vs.-late appearance of tracer and small-vs.-large reservoir.** Therefore, we further examine the questions:

- **How much information will be lost, how much uncertainty will affect temperature predictions, as a consequence of the chosen practical ceiling on injected tracer quantities?**
- **Can single-well, dual-tracer push-pull tests contribute to reducing the ambiguity of inter-well early-signal inversion?**

Jörg Meixner (2009) Konzeptionelle hydrogeologische Modellansätze als Vorstudie für ein integriertes Standortmodell. Diplomarbeit, KIT, AGW.

MODEL PARAMETRIZATION

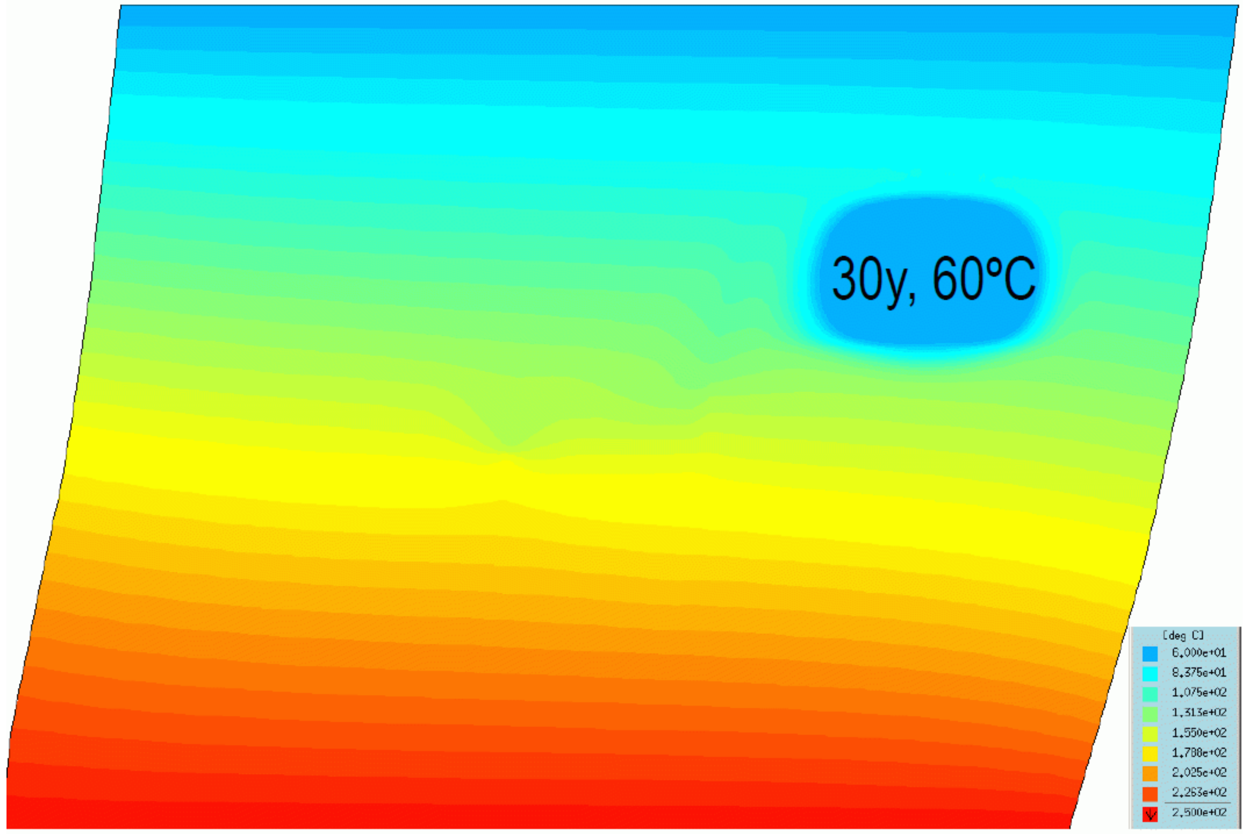


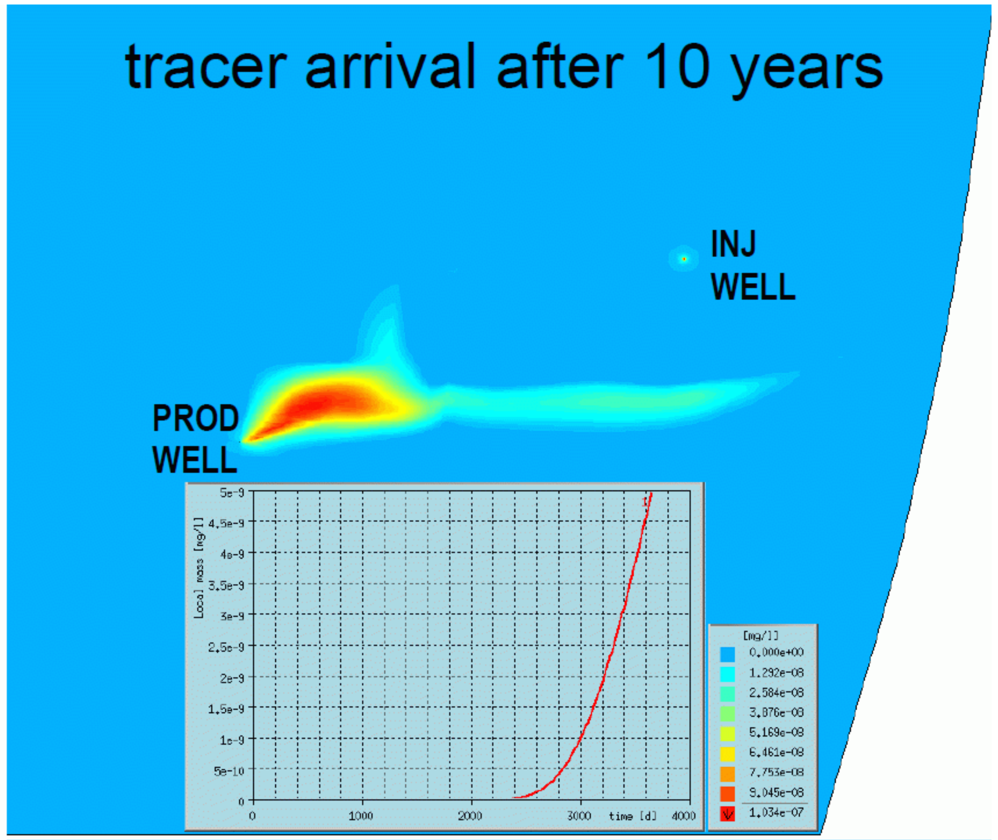


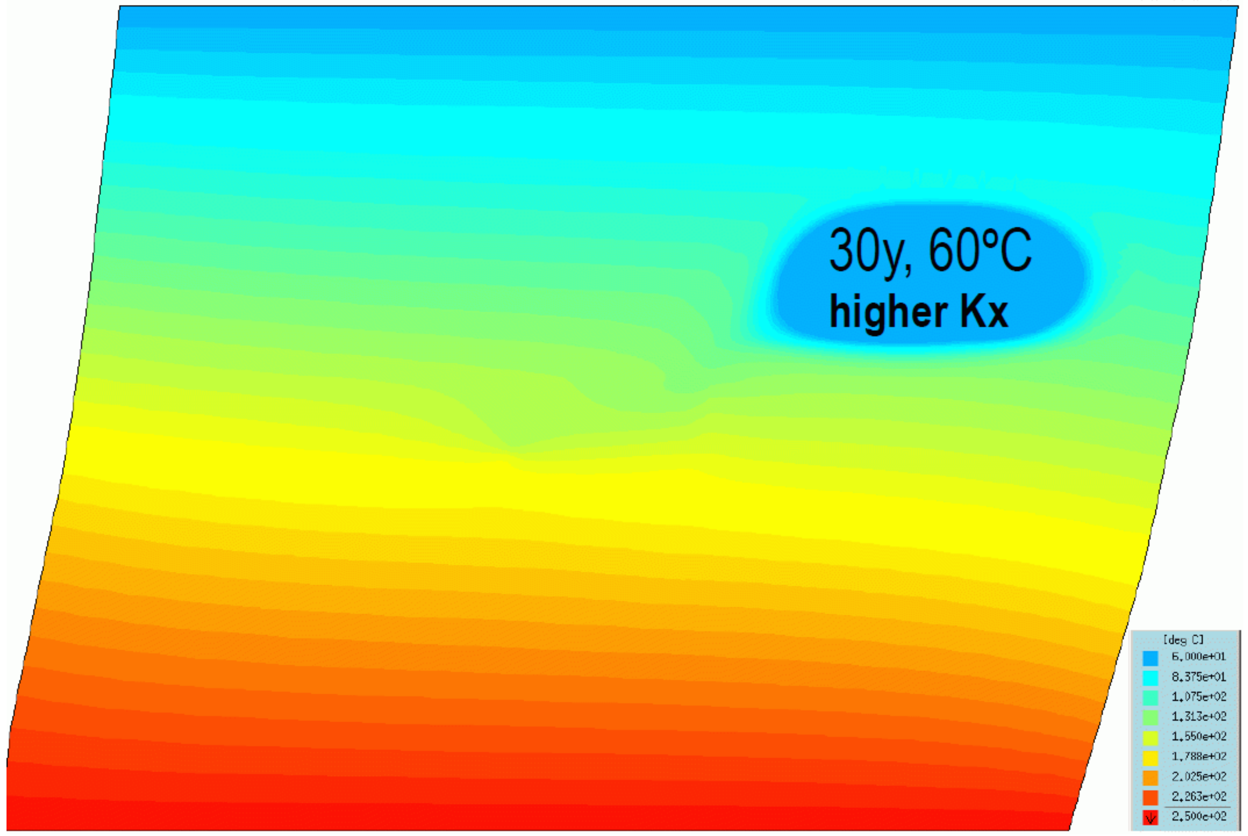
MODEL PREDICTIONS : tracer signals

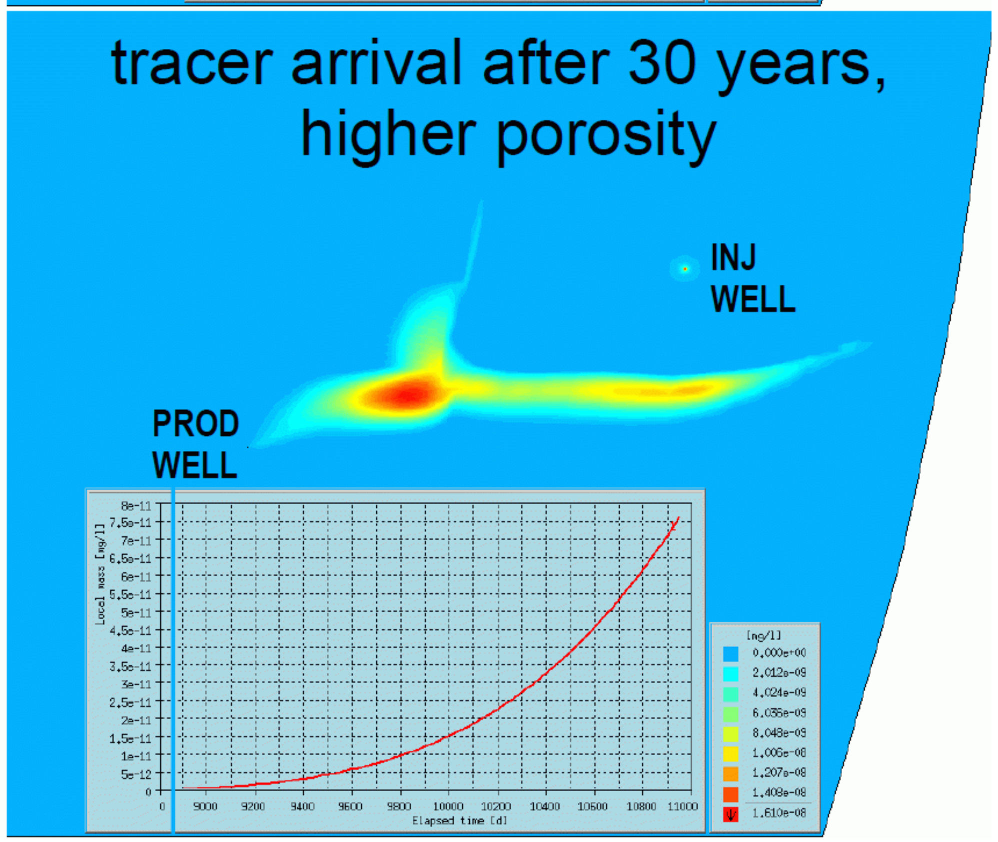
L / M+ / M	very large / large / moderate hydraulic transmissivity of large-scale fault situated between inj. and prod. wells
|↕ (...) ↵|	remotely-situated faults act either as flow barriers, or like vertical drains (Kv » Kh)
↔	remote faults act like drains horizontally (Kh » Kv)
«« / «	very high / high permeability contrast between adjacent aquifer layers (in yellow and red)
¥	increased anisotropy of permeability (ratio between horizontal and vertical permeability components within aquifer layers)

HEAT vs. TRACER TRANSPORT









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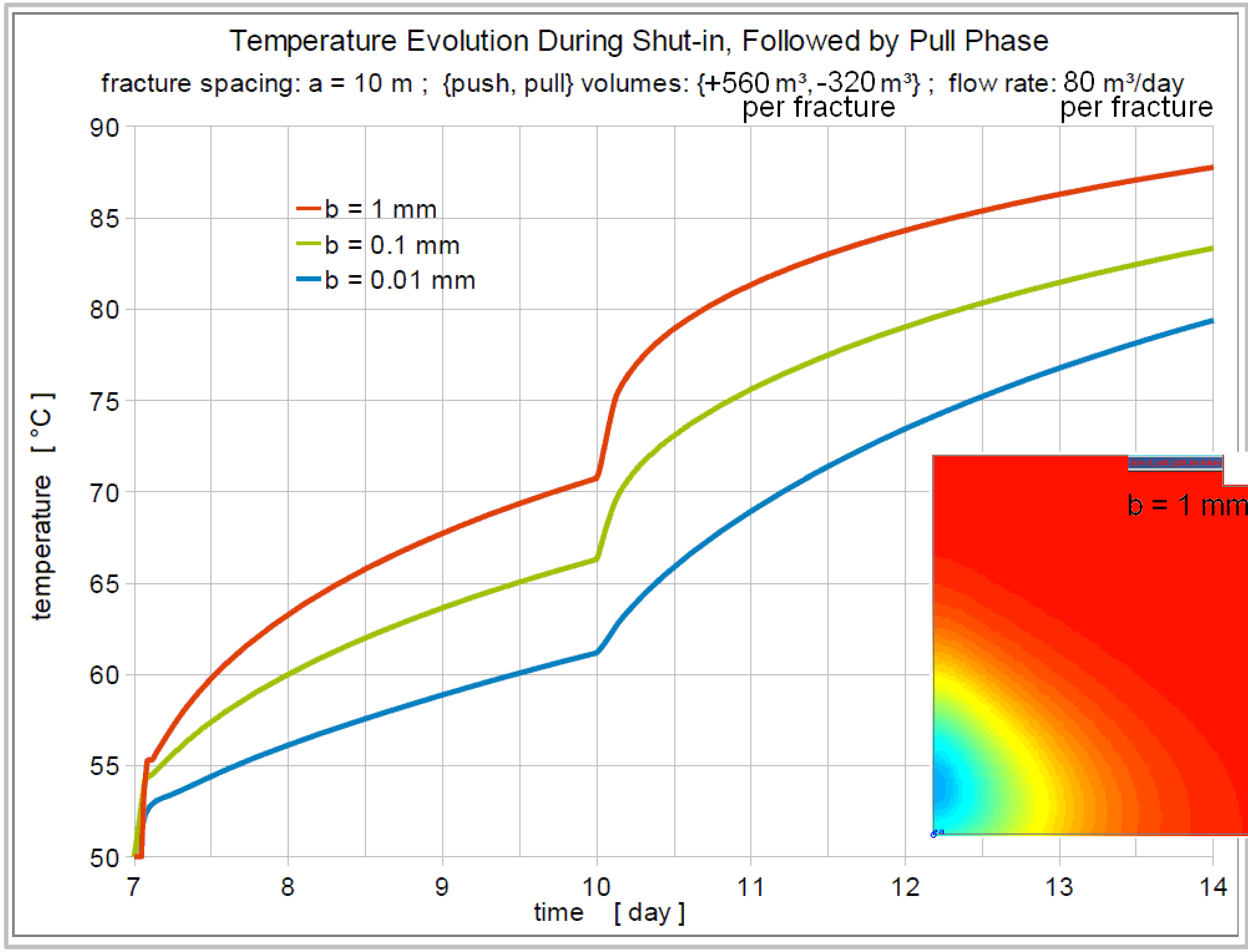
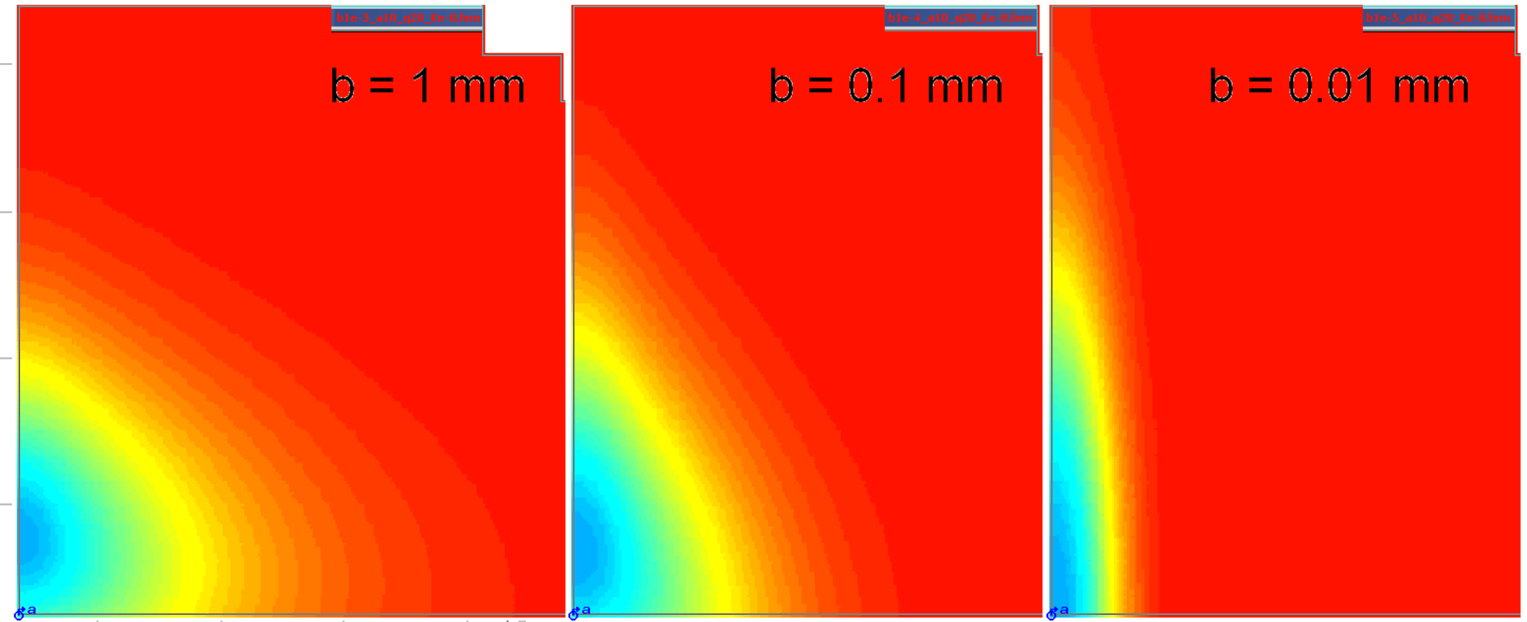
SINGLE-WELL PUSH-PULL TESTS





heat push – **pull**
versus
heat push – **shut-in** :

no loss of sensitivity
w.r. to fracture aperture

Wärme-Push-Shut-in-Tests an der geothermischen Reinjektionsbohrung: Sensitivität der Temperatursignale gegenüber der Kluftapertur, bei einer gleichmäßigen Kluftdichte von 1 / (10 m). Angegebene Fluidvolumina und Fließrate verstehen sich „pro Kluft" (bei einer verfilterten oder offenen Bohrlochstrecke von 300 m entsprechen sie einer Gesamtfließrate von 28 L/s und einem Push-Volumen von etwa 16 000 m³).

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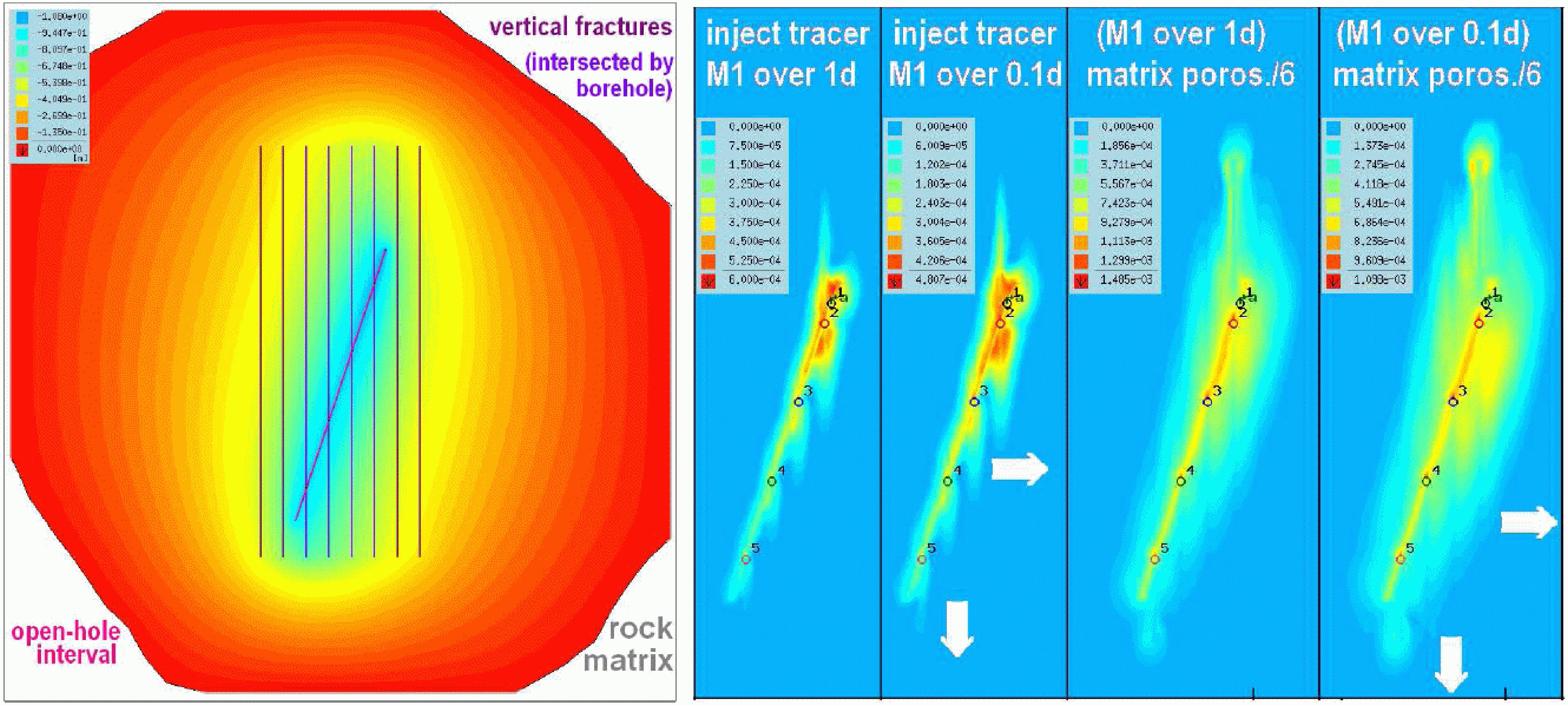
SINGLE-WELL PUSH-PULL TESTS

solute tracer push–backflow : sensitive w.r. to fissure aperture and/or density



Tracer-Push-‘Back-Tests an der geothermischen Reinjektionsbohrung. Im offenen Bohrlochbereich wird eine finite Anzahl gleichmäßig verteilter Klüfte angetroffen.
Durch Variieren der Push-Dauer lässt sich (unabhängig von Fließrate bzw. Push-Volumen) die Sensitivität der Tracer-Pull-Signale gegenüber Kluftdichte und -apertur gegenläufig beeinflüssen.
Durch Erhöhen von Fließrate bzw. Push-Volumen lässt sich die Sensitivität der Tracer- wie auch Wärme- Pull- oder Shut-in-Signale gegenüber der Kluftapertur erhöhen.

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