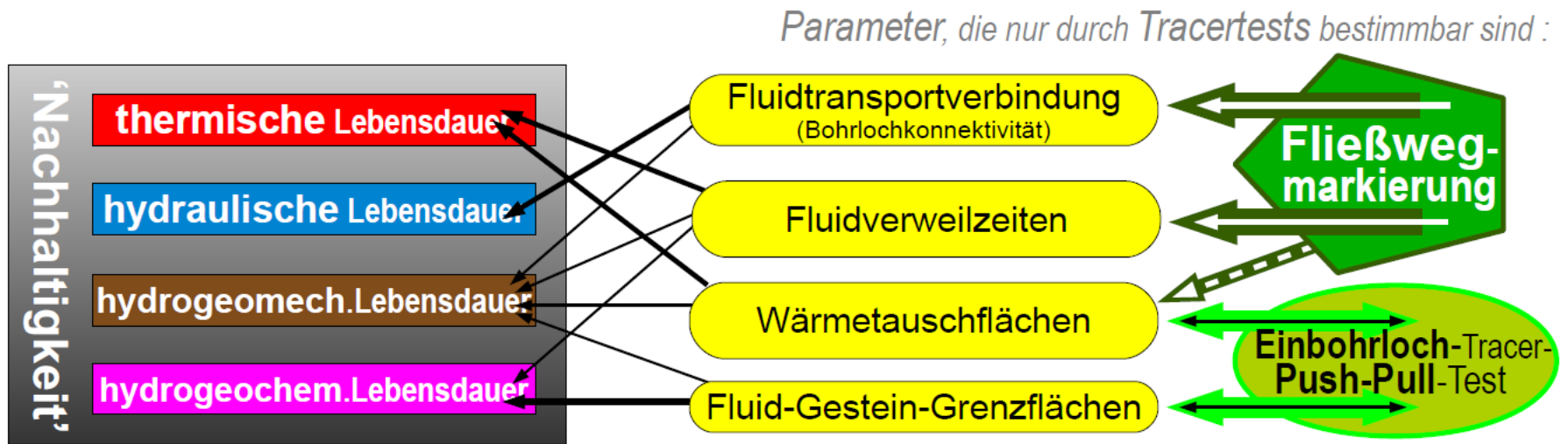# Tracer-assisted characterization of (deep) geothermal reservoirs
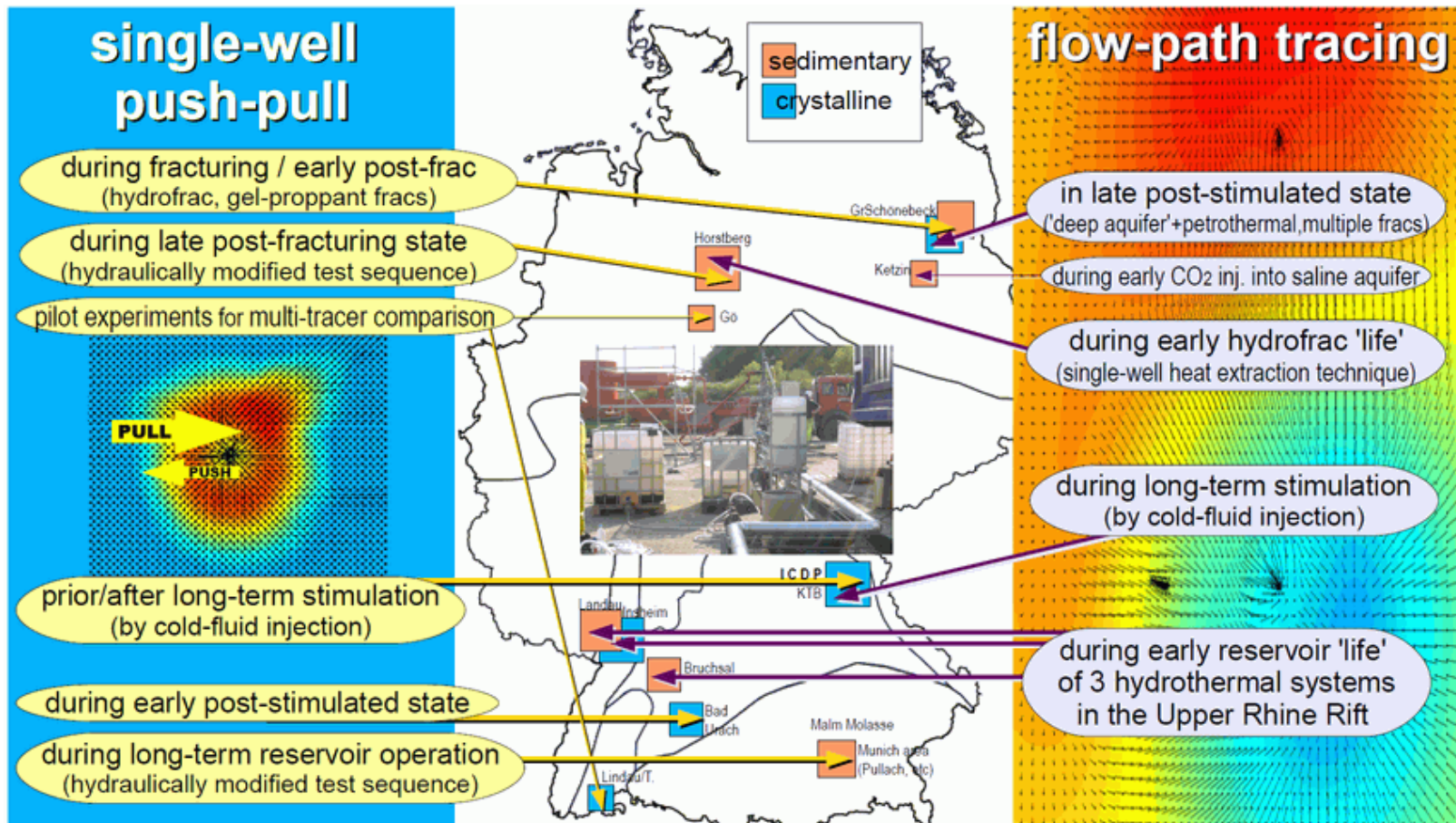
focus :   multi-zone inflow profiling during single-well backflow and production

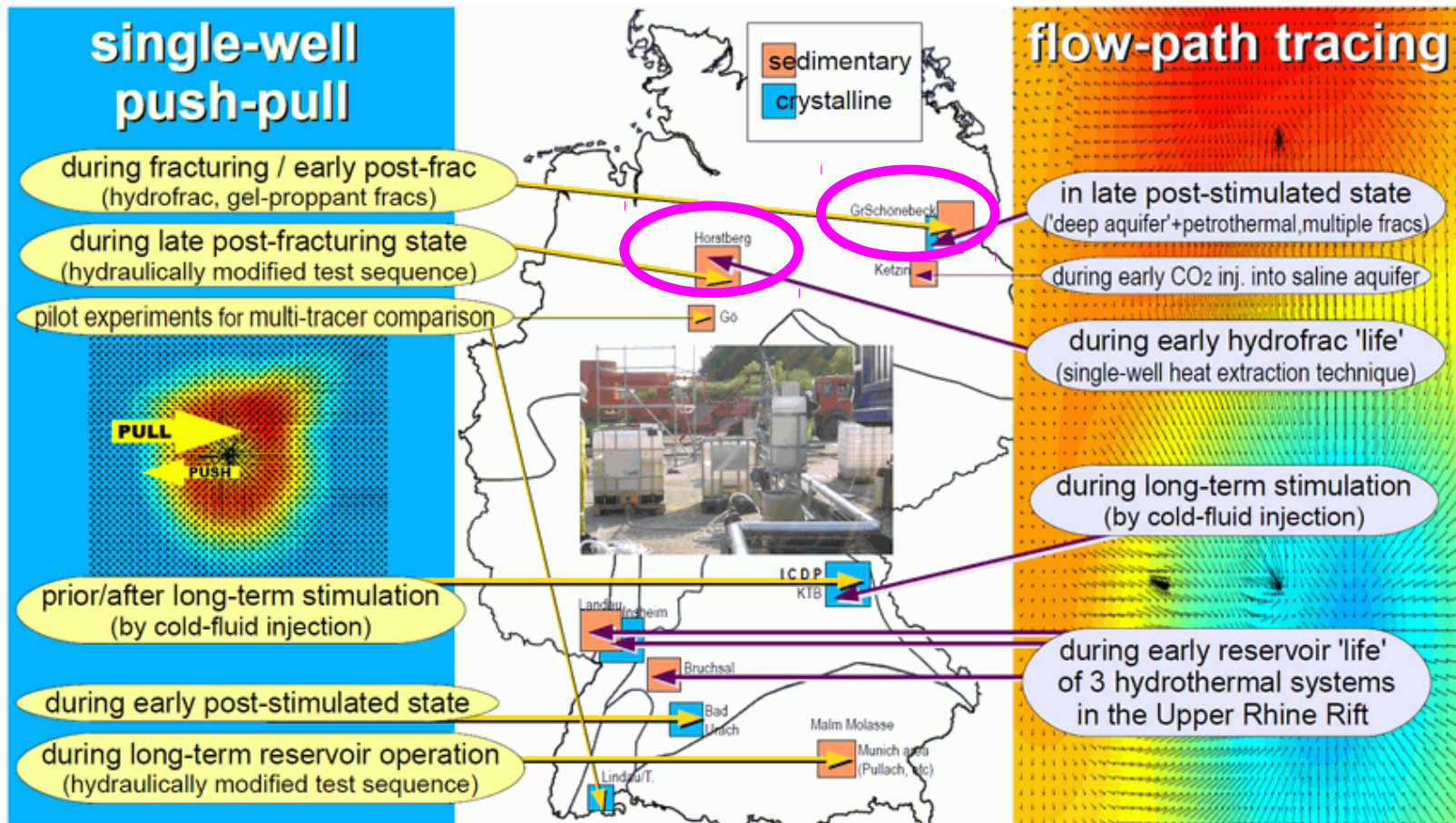Ghergut, Sauter, Behrens – University of Göttingen, Germany

Tracertestziele

Tracertesterfahrungen

Tracer-based inflow profiling in single-well backflow and production (Ghergut, Sauter, Behrens – Univ. Göttingen)

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Tracer test 'experience' : ??

- parameter inversion receipts (?)
- flow-path tracings : RTD interpretation is straightforward (?)
- insensitivity w.r. to target parameters (!) (esp. hydrogeol. params. in SW tests)

Two examples from the NGB

Two examples from the NGB

- <u>Gr.Schönebeck</u> : exploit insensitivity of SW signals w.r. to hydrogeol. params. in order to enable/improve inflow profiling

- <u>Horstberg</u> : use 'frac tracing' to predict thermal lifetime, despite insensitivity of tracer signals w.r. to frac parameters

Basic need for inflow profiling

- (un-)conventional reservoirs
- oil | gas | geothermal | (storage)
- multi-zone reservoirs
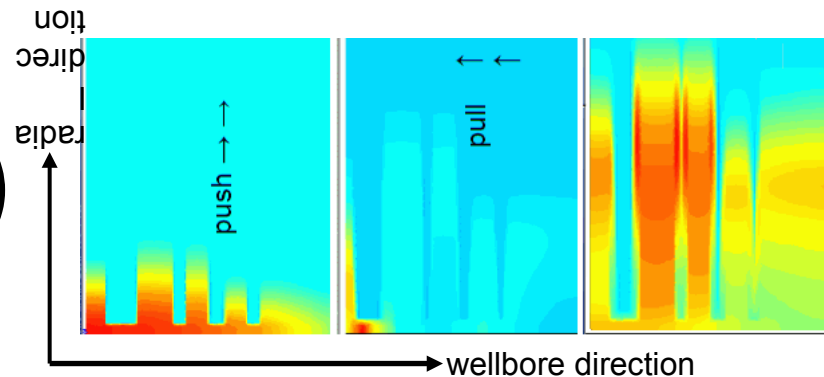- lengthy horizontal wells
- heterogeneous formations

Tracer-based inflow profiling in single-well backflow and production (Ghergut, Sauter, Behrens – Univ. Göttingen)

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Tracer options for inflow profiling

NRT (not reservoir-transported)

resman.no/uploads/files/World.Oil.mag_Oct-13_Reservoir_Mgmnt_RESMAN.pdf

tmoffices.eu/PatentNo=GB2469488&DocType=B&JournalNumber=6378 (2010)

RT (reservoir-transported)

Practitioner's motivation for RT

- NRT: misinvestment at prospective stages
- NRT: conflicts irreg. wellbore geometry

- RT: opportunity given during stimulation or fracturing (inj.-backflow, +production)

numbers and symbols don't matter

Scientist's motivation for RT

Single-well major **drawbacks** :
 1 : tracer arrival time ≠ reservoir size
 2 : insensitivity to reservoir hydrogeology

Can these be turned into an **advantage ?**

Groß Schönebeck : case study

EGS of ‚deep-aquifer' type, collecting' contributions from crystalline and sedimentary formations
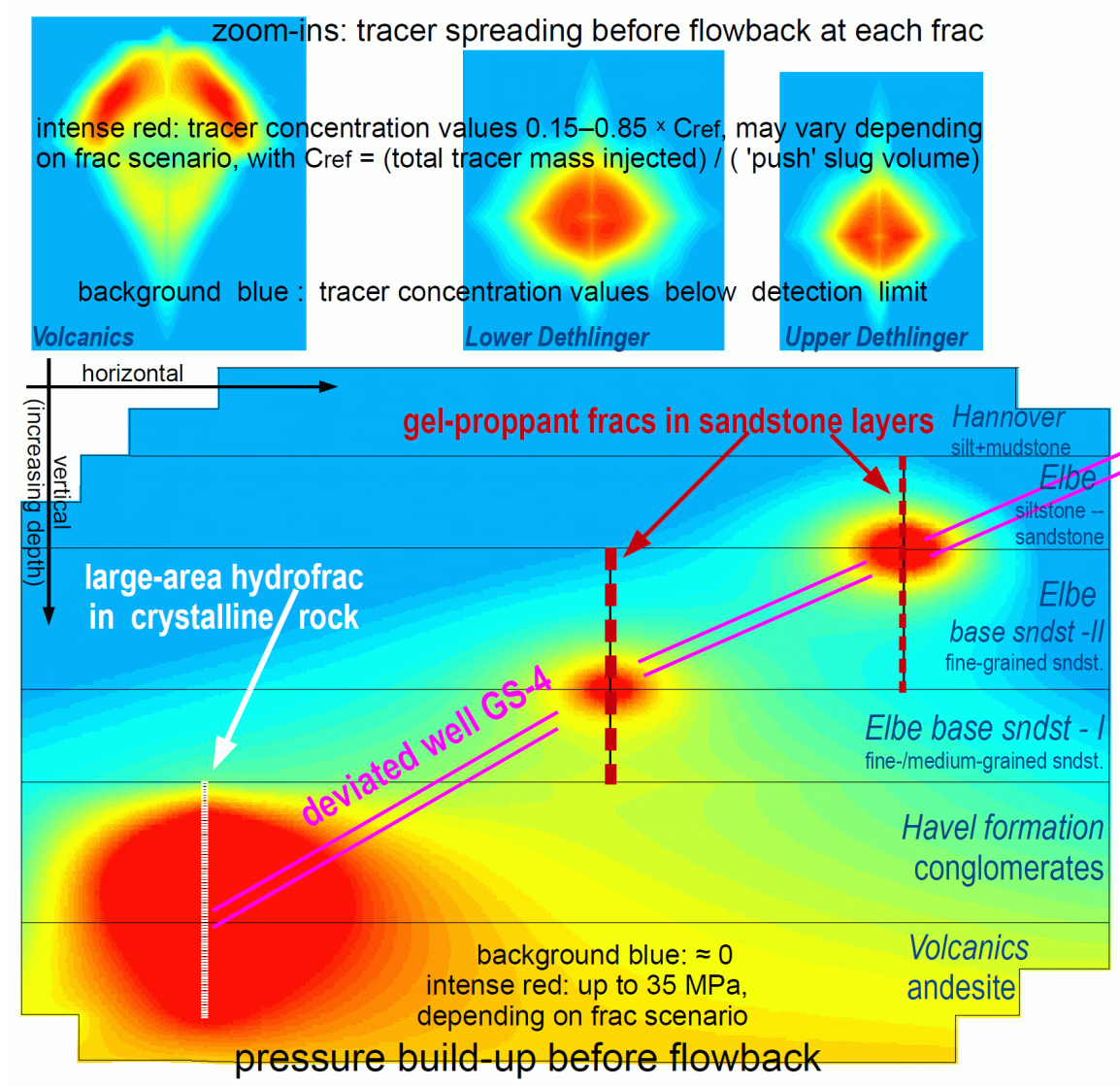(multiple-frac system)

Aims:
– predict thermal lifetime
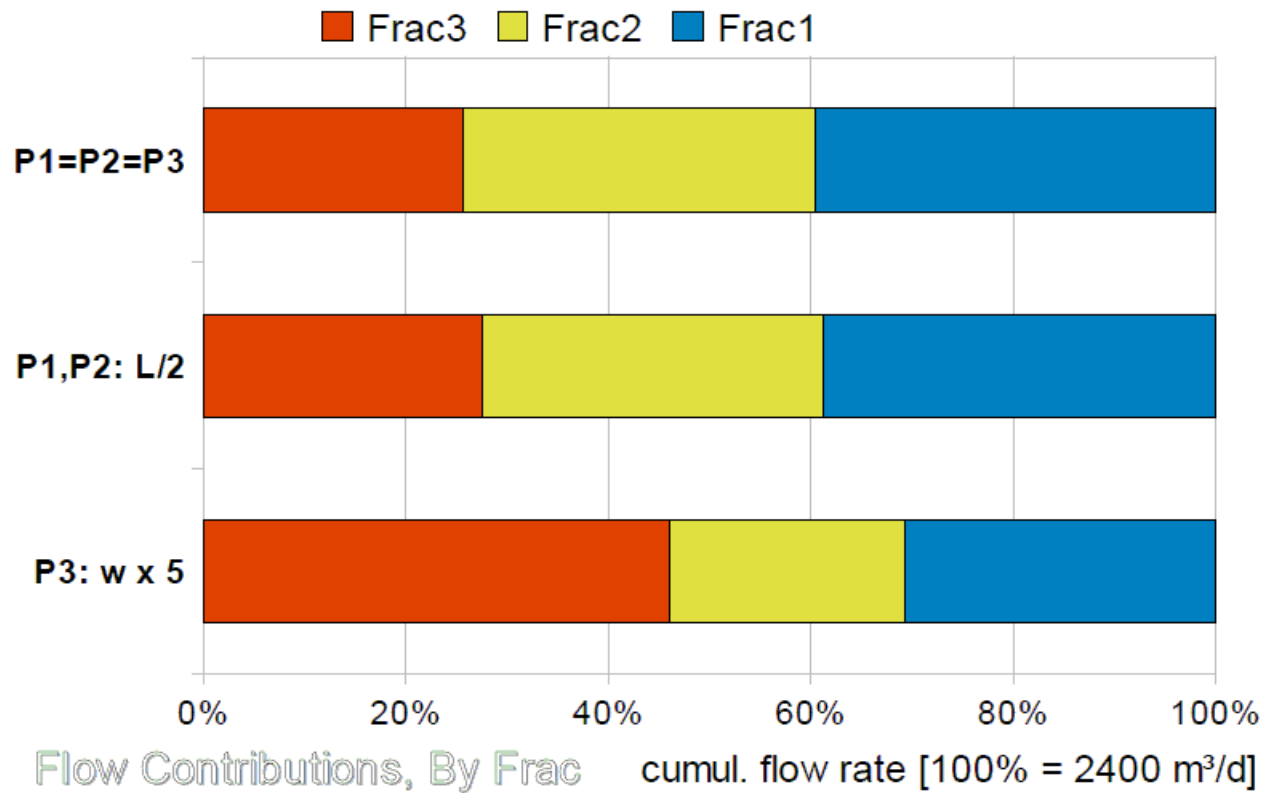– control reservoir hydraulics
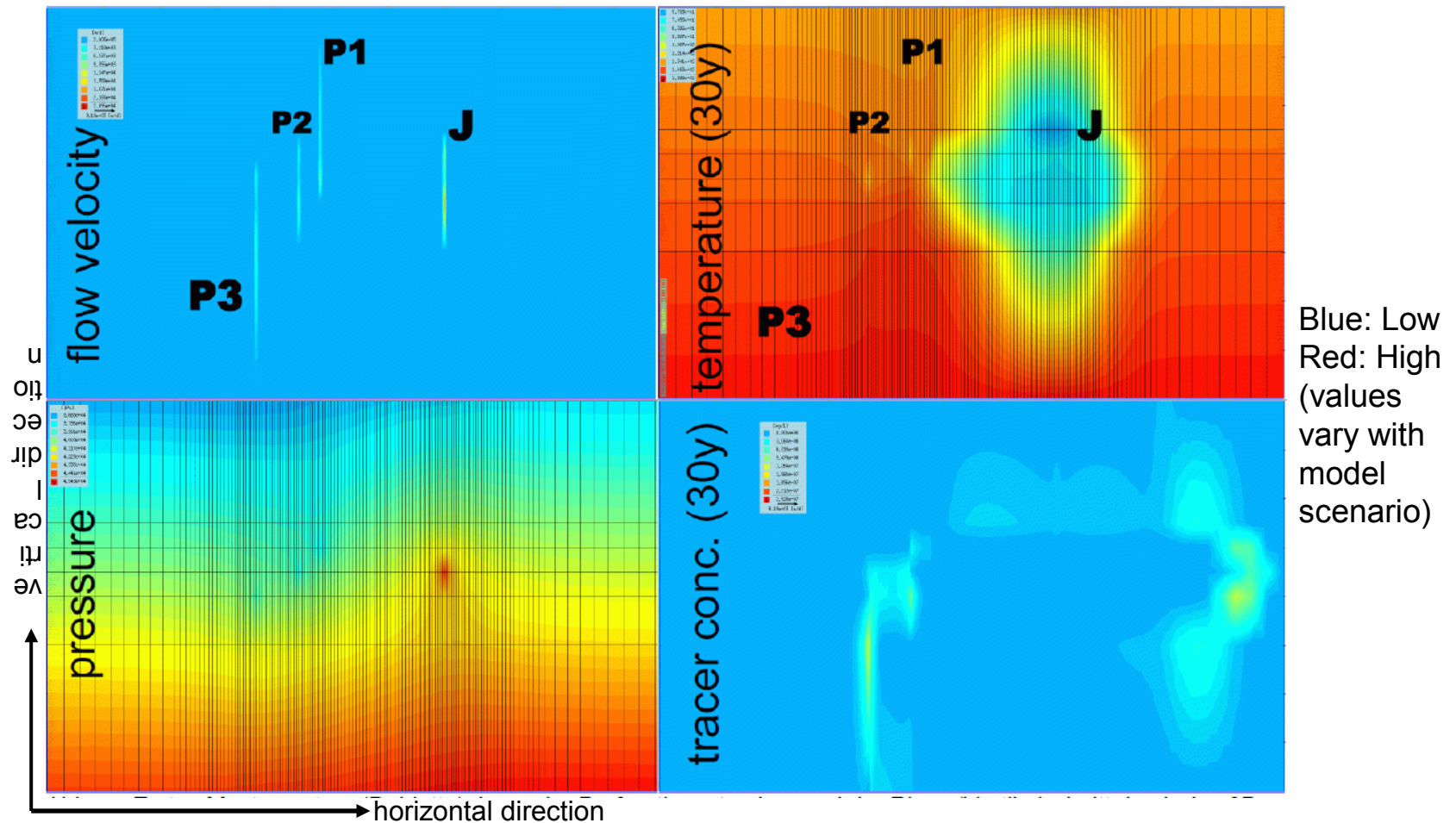
GS-4 :

intended as future prod. well
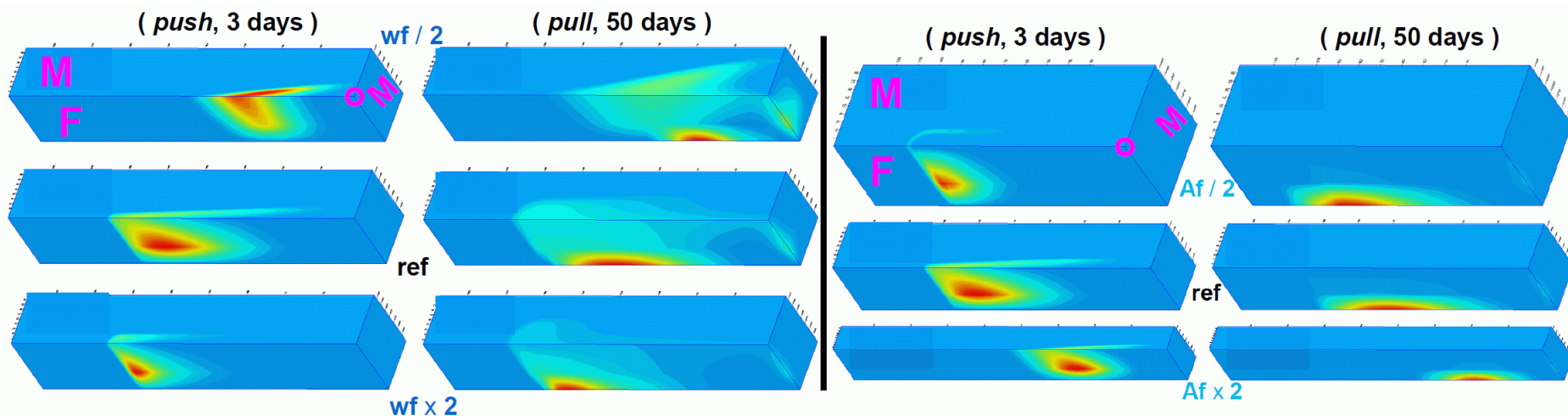
one hydro-frac two gel-prop-fracs

zoom-ins: tracer spreading before flowback at each frac

intense red: tracer concentration values 0.15–0.85 × C_{ref}, may vary depending on frac scenario, with C_{ref} = (total tracer mass injected) / ('push' slug volume)

background blue : tracer concentration values below detection limit

Volcanics   *Lower Dethlinger*   *Upper Dethlinger*

horizontal

vertical (increasing depth)

gel-proppant fracs in sandstone layers

large-area hydrofrac in crystalline rock

deviated well GS-4

Hannover silt+mudstone

Elbe siltstone -- sandstone

Elbe base sndst -II fine-grained sndst.

Elbe base sndst - I fine-/medium-grained sndst.

Havel formation conglomerates

Volcanics andesite

background blue: ≈ 0
intense red: up to 35 MPa, depending on frac scenario

pressure build-up before flowback

GS-4 : flow contributions

Flow Contributions, By Frac   cumul. flow rate [100% = 2400 m³/d]

GS-3, GS-4 : flow and transport

Blue: Low
Red: High
(values
vary with
model
scenario)

GS-4 : numerical study

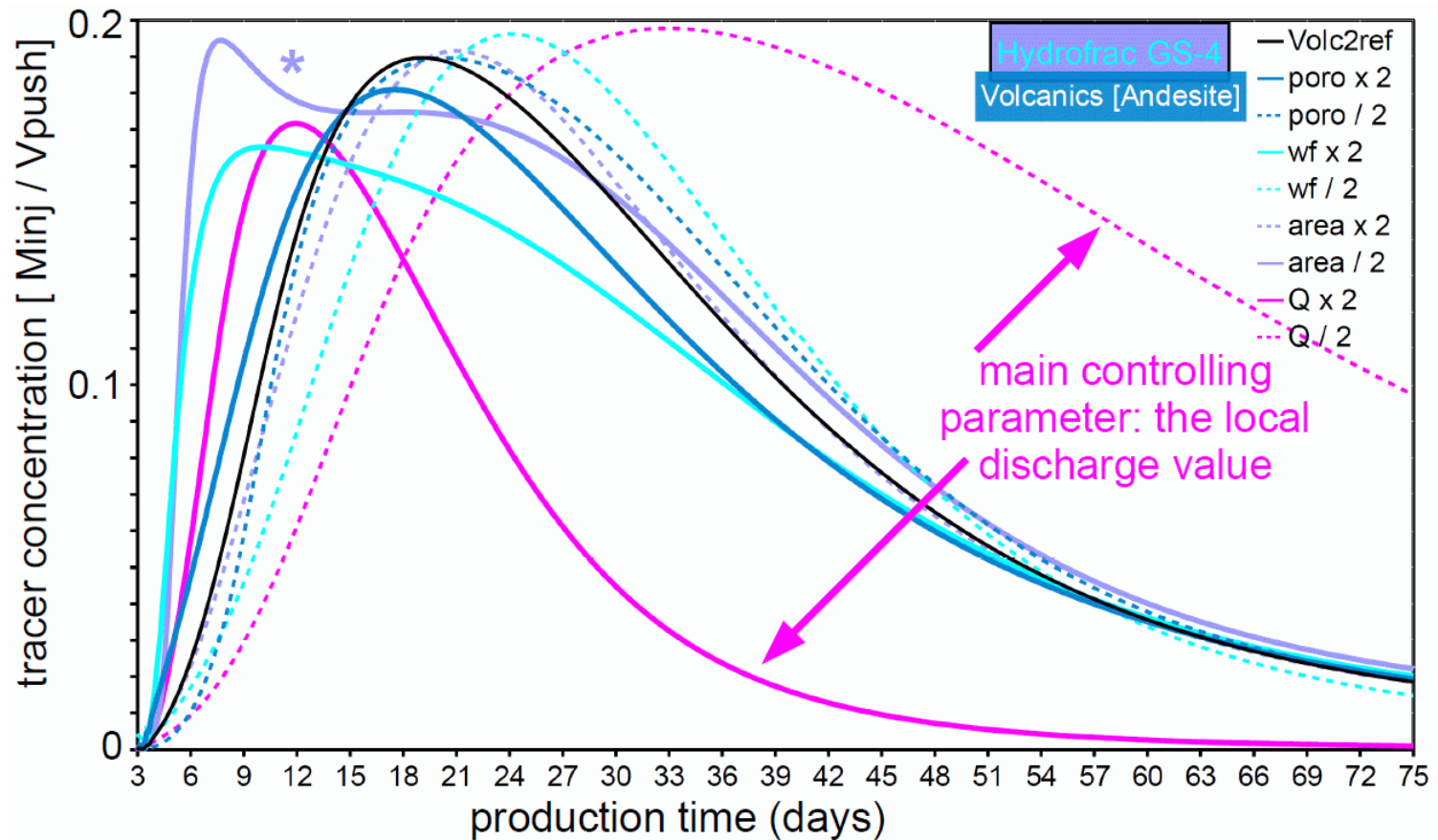## site-specific features (frac height, length, aperture) :

Please ignore any (unreadable) numbers at matrix block cut sides; they don't matter.
Background blue: tracer concentration below detection limit;
intense red: high tracer concentration (exact values vary with model scenario, and don't really matter)
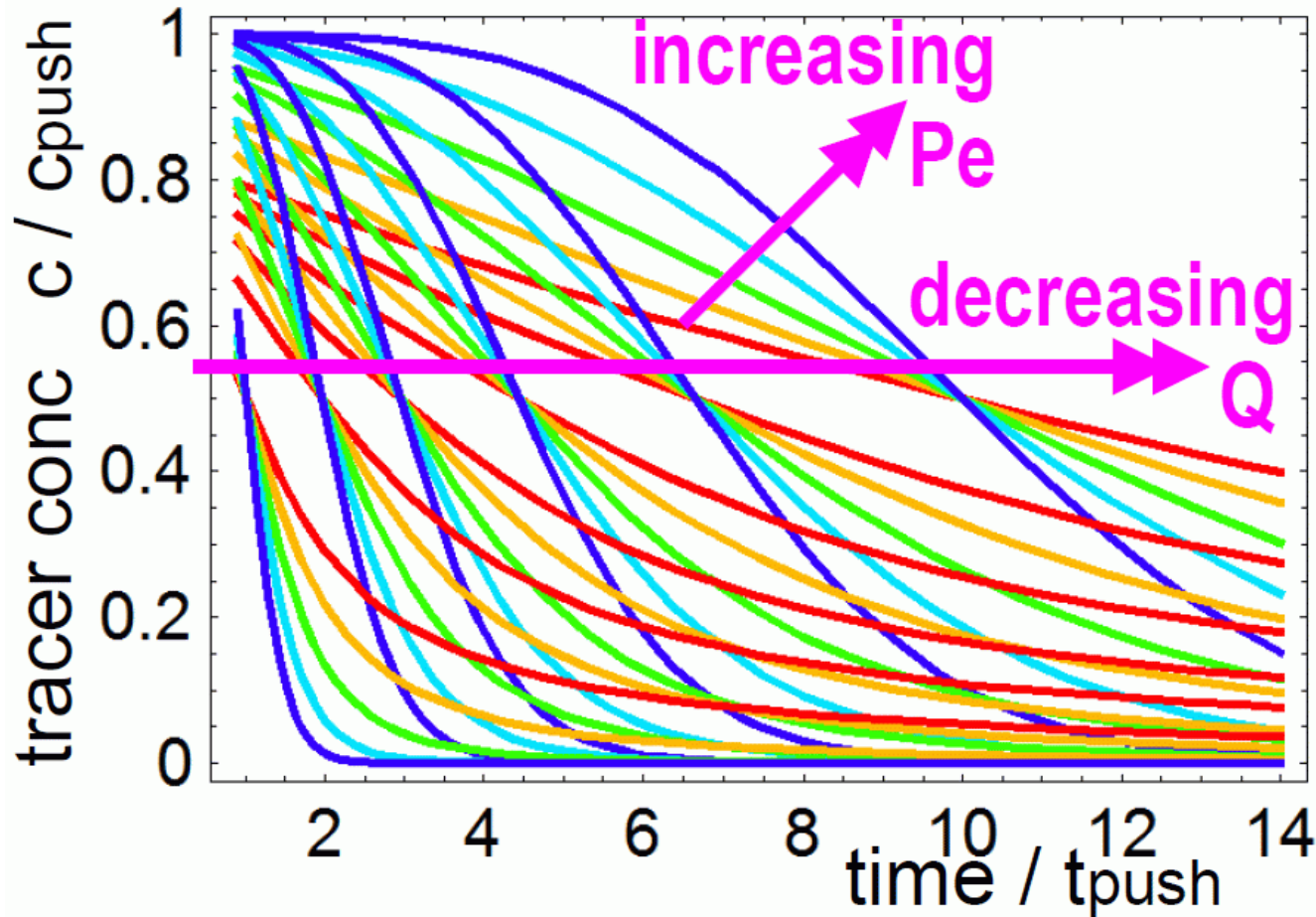
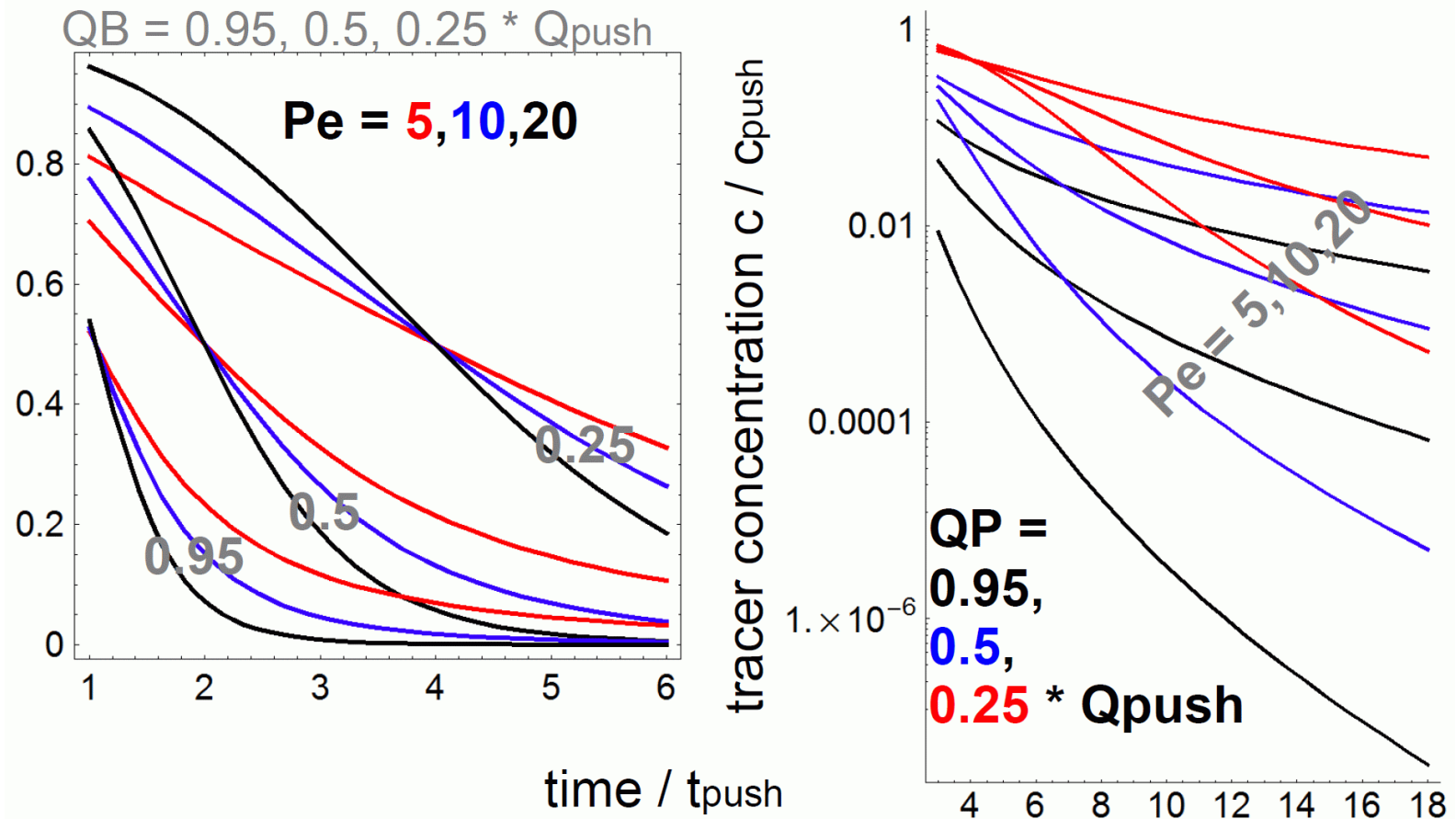# GS-4 : numerical study

insensitivity : advantage!

Semi-analytical approach

- non site-specific

- roughly preserving flow-field character
  (radial, (bi)linear)

- tracer signal = C (Pe, q/Q_{push}, time/T_{push})

- type-curve families
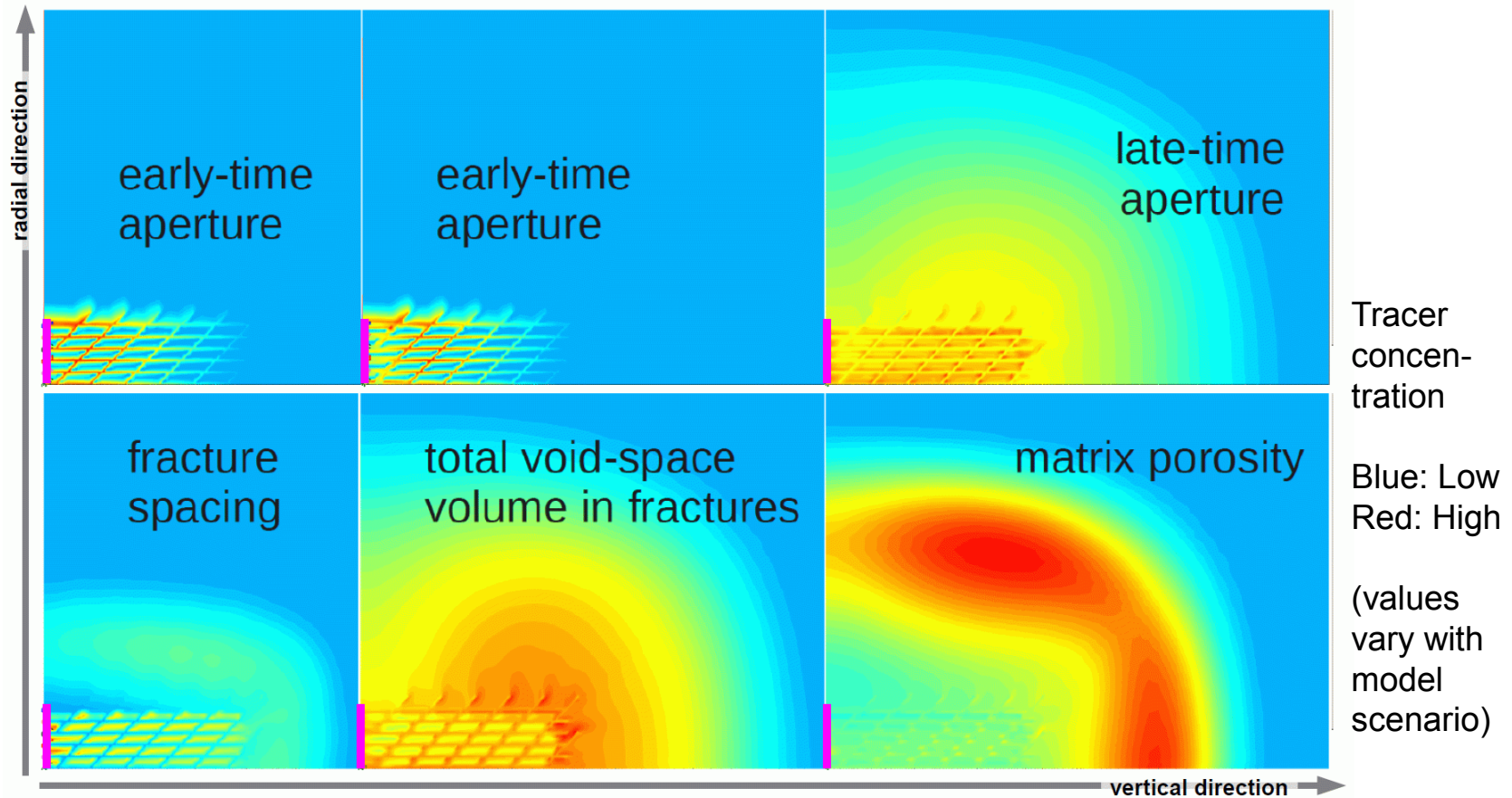
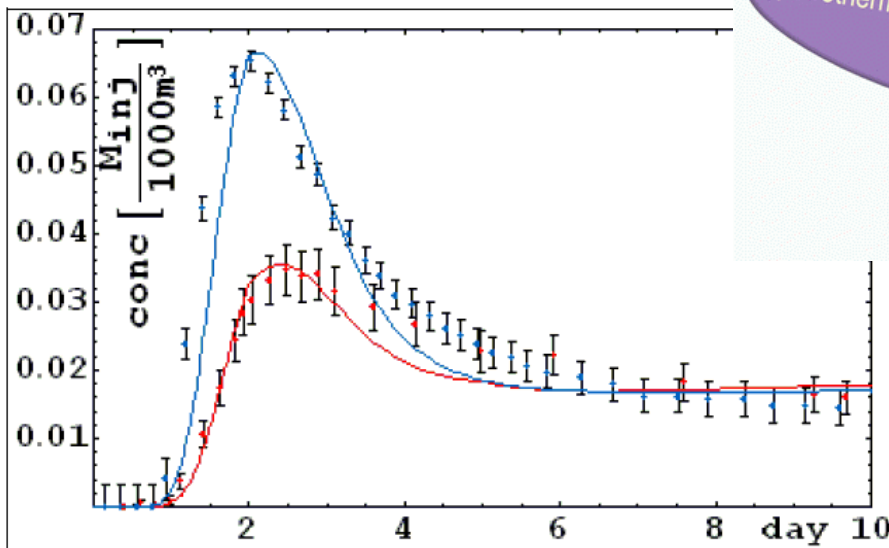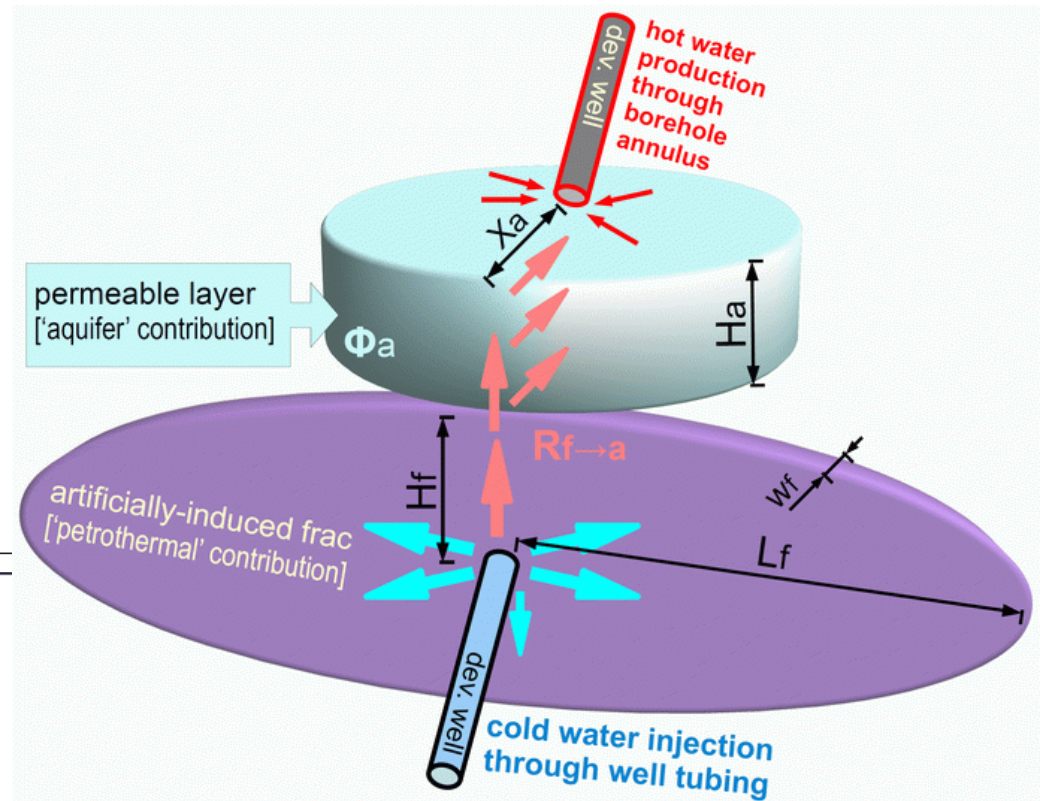# Type-curve families

Parameter inversion workflow

Outlook :

- add reactive tracers
- non-planar frac structures

Tracer concentration
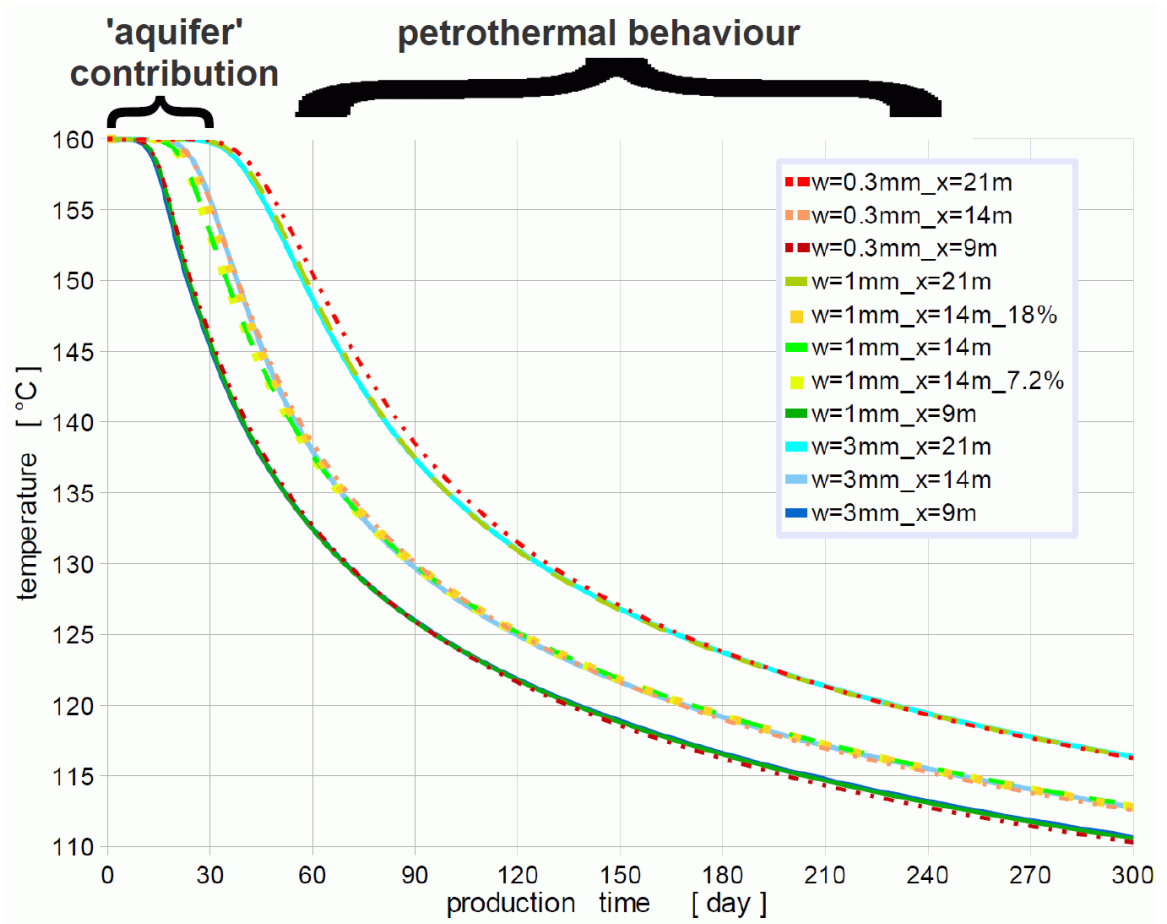
Blue: Low
Red: High

(values vary with model scenario)

Horstberg:
petrothermal
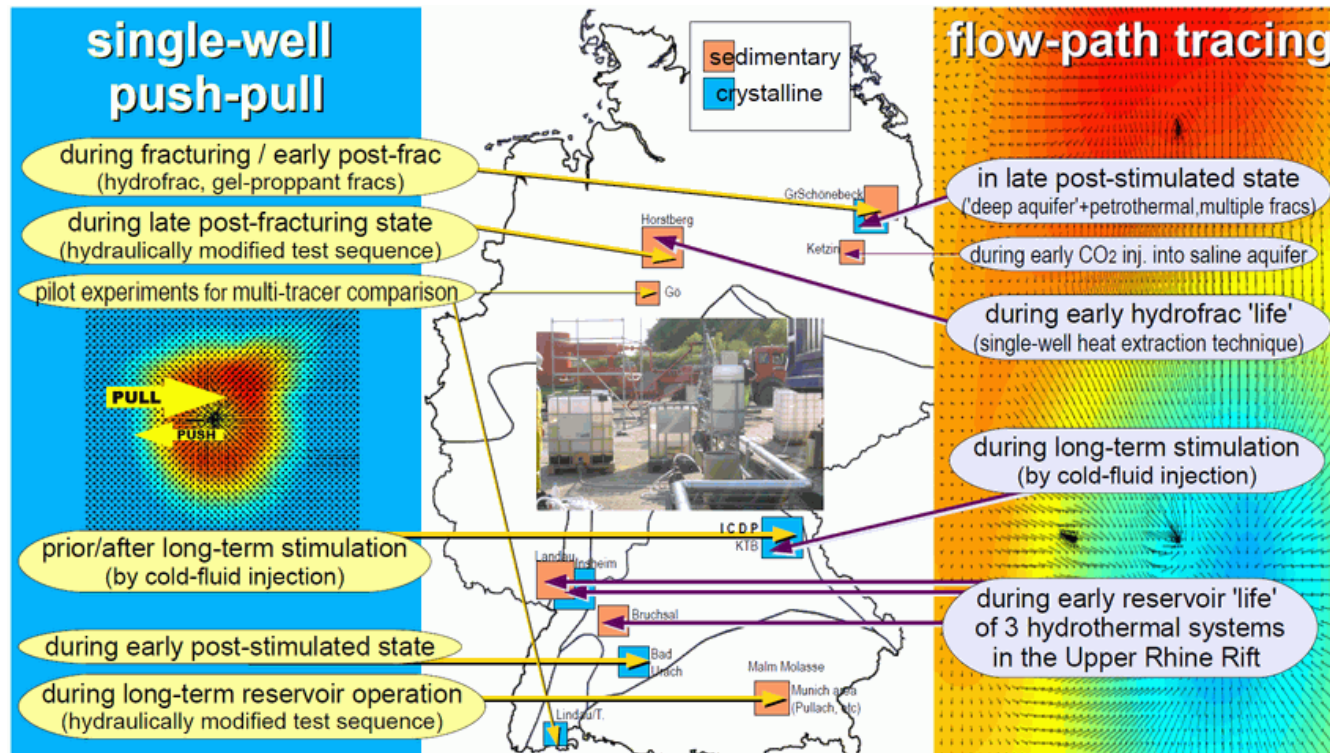
(+ 'aquifer' piece)

Hydrodynamic-diffusive exchange (single-parameter kinetic) model matching of NDS and HTO signals

Horstberg: petrothermal

(+ aquifer)

TT während Erschließung und Betrieb : ebenso selbstverständlich wie Seismik usw bei der Exploration, aber ... nicht trivial!

Wir danken Dr. Torsten Tischner und Ing. Rainer Jatho (BGR Hannover) für die stete Unterstützung in Horstberg, und Prof. Günter Zimmermann und zahlreicher Kollegen vom GFZ Potsdam für die stete Unterstützung in Groß Schönebeck.   Für die langjährige Unterstützung der Tracertest-, -auswertungs- und -interpretationsarbeit danken wir dem **BMU** sowie

gefördert durch das Niedersächsische MWK
und Baker Hughes (Celle).