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Geothermal wolpertinger engineering in the 'N-German' Molasse basin: let endo-tracers haunt it, too

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Typifying geothermal reservoirs as petrothermal, 'aquifer-like EGS' a.s.f. may be tricky. Quite a few drillings in Malm 'aquifers' beneath the Molasse were typified as 'unsuccessful', though 'petrothermal' (MOECK-2014-2017) might fit much better – which, however, would have required a different well-path orientation and wellbore completion, different legal steps and participatory decision-making, a.s.f.. Growing (over-)emphasis on avoiding human-felt seismicity imposes operational changes to stimulation protocols – altering stimulation outcomes in ways that additionally blur the petro-/'hydrothermal'(aquifer-like) frontier. Three stimulation concepts are known so far: 'longitudinal', (elongated-)volume-steered aquifer-like EGS; 'transversal', area-steered multi-frac-HDR-EGS, with area and geometrical complexity augmented by 'wing cracks' (JUNG-2013), with frac-induced $\Delta\sigma$ to be compensated by well-path ∼45° deviation (ZEEB-KONIETZKY-2015); LEARY-MALIN-POGACNIK-2011ff, which we roughly abbreviate as 'augmented-radius effective-well' concept; with reservoirs being categorized by:
1° temperature, depth,
2° whether sufficient-size 'heat exchanger' naturally preexists, or needs to be enhanced, or created 'from scratch' → common 'hydro-'/'petrothermal' definition, obfuscating spatial variability (MALIN-LEARY: the actual crux) within target formation,
3° time-dependent ratio advective (hyperbolic) / non-advective (parabolic) terms in heat transport equation → ratio increases with fluid turnover (∼operation time) for multi-frac-HDR-EGS,
4° time-integral ratio longitudinal-advective (∼Tf = fluid turnover time, meterable by inter-well tracer tests) / transversal-conductive (∼Tf squared) contributions to thermal service life Tth>(>)Tf ,
5° pragmatic 'collect-and-select' (SAUTER-2009, PHILIPP-2009, HÖRDT-2009, MOECK-2009),
__→__5.1° (over-)regionally: 'geothermal plays' (MOECK-BEARDSMORE-2014),
__→__5.2° (sub-)regionally: 'deep-geothermal benchmarks' (PHILIPP-et-al.-2014)
To what extent can such distinctions be drawn before drilling/stimulating... a first/second/... well?
A wealth of hydrocarbon exploration data might have enabled 5° without relying on dedicated-geothermal sites.
For all EGS candidates Horstberg/Gr.Schönebeck/KTB/Urach/Soultz-s.-Forêts/St.Gallen/Espoo, as well as Malm formations beneath the Molasse, 2°–4° could only be told post-festum, and tracer data (where available) indicate aquifer-like/petrothermal superposition.
Fluid transport parameters controlling Tth can be metered only by tracer tests, but the fluid transport 'agenda' often gets superseded by seismicity 'mono-focus'.
Yet, the 'soft' stimulation approach (ZANG-ZIMMERMANN-et-al.-2016ff) also comes with added benefits regarding tracer signal sensitivity to Tth-controlling parameters. 'Softening' the stimulation also turns out to increase the usefulness of accompanying tracer tests – which were else questionable (Ghergut-et-al.-2013: single-well-typical loss of sensitivity, inversion ambiguity). Particularly the stimulation protocols presented by KWIATEK and MARTÍNEZ-GARZÓN 2017ff, alternating injection/outflow++, provide excellent conditions for a tracer-assisted monitoring of stimulation outcome.
The poster shows how 'endo-tracers' aid correcting EGS design, by recognizing and quantifying 'aquifer-like'/petrothermal components.
Primary purpose of reservoir engineering is not to avoid human-felt seismicity, but to improve energy output, while reducing overall costs-per-output. The 'valid' EGS concept is not necessarily one that survives 'Popper's razor' (falsification by evidence pieces like those collected by JUNG-2013); rather, the 'valid' EGS will be one that people are willing to live with and pay for (Rorty's anarchism) – in possibly different shapes in Finland, France, Switzerland, Germany ... 'Endo-tracers' aid in evaluating EGS engineering concepts – particularly in formations with low natural-fracture density, and the day may come for EGS development beneath the Molasse basin to grow 'petrothermally'.