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Geodynamic controls on the geothermal potential in the Upper Rhine Graben, France-Germany: a multi-scale numerical modelling approach

The Upper Rhine Graben (URG), situated along the border of France and Germany, is part of the intraplate European Cenozoic Rift System. The graben is widely recognized for its abundant geothermal resources, making it a key region for energy transition initiatives. However, the characterization of the URG's geothermal potential remains poorly constrained due to its highly variable hydrothermal conditions and large observational gaps. Previous studies on fault criticality have often overlooked the role of historical plate movements, oversimplifying the intricate interactions that govern the thermal and structural evolution of the URG over the past ~40 million years.

Using the numerical geodynamic code ASPECT coupled with the landscape evolution code FastScape, we simulate the lithospheric-scale development of fault networks within the URG under geodynamically realistic stress and strain conditions. Our models incorporate various forms of structural and rheological heterogeneities inherited from the earlier Variscan Orogeny, along with a two-stage Cenozoic kinematic history involving rift-orthogonal extension followed by sinistral strike-slip. Preliminary results show the first-order impact of structural inheritance and divergence obliquity on strain localization, which shape the orientation, spacing, and strain rate of the resulting fault network. These results will lay the groundwork for subsequent basin-wide modelling with the thermo-hydro-mechanical code GOLEM, coupling geodynamically controlled basin development with heat and fluid flow simulations that involve shorter-term rock and fracture mechanics. Throughout all modelling stages, we compare our models with available geological and geophysical observations.

Author: YU, Alan (GFZ Helmholtz Centre for Geosciences)

Co-authors: GLERUM, Anne (GFZ Helmholtz Centre for Geosciences, Potsdam, Germany); BOTT, Judith (GFZ); SCHECK-WENDEROTH, Magdalena (GFZ / TU Berlin); BRUNE, Sascha (GFZ Helmholtz Centre for Geosciences, Potsdam, Germany)

Presenter: YU, Alan (GFZ Helmholtz Centre for Geosciences)