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Tracing a fossil hydrothermal system using thermochronology and numerical modeling

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New apatite fission track data from boreholes in the Mesozoic-Cenozoic Roer Valley Graben in the southern Netherlands show a number of partially reset samples with much younger ages than would be expected from their 1 to 2 km burial depth. Although these ages could be partly related to deep burial prior to late Cretaceous inversion of the basin, two wells show an overturned age-depth relation that is indicative of a local thermal pulse. A plausible explanation for these data is a hydrothermal flow system driven by a 10 to 40 m thick magmatic dyke that has been found in two wells along a boundary fault of the basin.

To test whether a hydrothermal or magmatic heat pulse can explain the observed fission track data we have constructed a new inverse numerical model of heat conduction and advection, which was coupled with fission track annealing algorithms. The modeled thermal pulse was superimposed on the long term thermal evolution derived from a 1D burial history model.

The model simulates the thermal response to a fixed fluid flow velocity in a horizontal aquifer connected to a vertical feeder fault, and the thermal recovery after removing this fluid velocity field. Due to this relatively simple model setup the computational demand was low and Monte Carlo sampling could be used to estimate the key characteristics of the hydrothermal flow system: age, duration, temperature of the feeder fault and flow velocity.

Preliminary results show that the fission track data can be explained by a hydrothermal flow event around 130 Ma, which matches the independently dated emplacement of the magmatic dyke. Wells close to the boundary fault containing the dyke show partial reset ages in samples taken from multiple depths, while wells further away from the fault show resetting only in samples taken from permeable sand formations. Hydrothermal flow has affected aquifers at up to 2.5 km distance from the feeder fault, showing that this previously unnoticed hydrothermal event has significantly altered the thermal history of the basin.