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Numerical modelling of thermal convection related to fracture permeability in Dinantian carbonate platform, Luttelgeest, the Netherlands

Lindsay Lipsey (1,2), Maarten Pluymaekers (2), Jan-Diederik van Wees (1,2), Jon Limberger (1), and Sierd Cloetingh (1)

(1) Utrecht University, Earth Sciences, Utrecht, Netherlands (l.c.lipsey@uu.nl), (2) TNO, Utrecht, Netherlands

The presence of convective fluid flow in permeable layers can create zones of anomalously high temperature which can be exploited for geothermal energy. Temperature measurements from the Luttelgeest-01 (LTG-01) well in the northern onshore region of the Netherlands indicate variations in the thermal regime that could be indicative of convection. This thermal anomaly coincides with a 600 m interval (4600 – 5200 m) of Dinantian carbonates showing signs of increased fracture permeability of ∼60 mD.

For the purpose of geothermal energy exploration, it is of interest to know whether or not convection can occur in a particular reservoir, where convection cells are likely to develop and the temperature enhancements in convective upwellings. Three-dimensional numerical simulations provide insight on possible flow and thermal structures within the fractured carbonate interval. The development and number of convection cells is very much a time dependent process. First longitudinal rolls fill the domain, increasing in width until ultimately transforming into a more complex polyhedral structure. The model relaxes into a steady-state five-cell convection pattern. Furthermore, geometric aspects of the carbonate platform itself likely control the shape and location of upwellings.

Convective upwellings can create significant temperature enhancements relative to the conductive profile and in agreement with the observations in the Luttelgeest carbonate platform. This enhancement is critically dependent on the aquifer thickness and geothermal gradient. Given a gradient of 39 °C/km and an aquifer thickness of 600 m, a temperature of 203 °C can be obtained at a depth of 4600 m directly above upwelling zones. Contrarily, downwelling zones result in a temperature of 185 °C at the same depth. This demonstrates the strong spatial variability of thermal anomalies in convective fractures aquifers at large depth, which can have a strong effect on exploration opportunity and risk of prospective areas. Numerical models can facilitate in exploration workflows to assess thermal variation and location of upwelling zones.