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Estimation of deep subsurface temperatures in the Roer Valley Graben, using a new numerical model of borehole temperature recovery

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Information on the thermal state of the upper crust is a prerequisite for establishing deep geothermal systems. By far the most abundant source of information on deep subsurface temperatures are bottom hole temperatures (BHT), which are routinely taken shortly after drilling in hydrocarbon exploration wells. Sequences of three or more BHTs are then corrected for the effect of drilling fluid using models of thermal recovery, often by highly simplified line-source or Horner-based methods. Unfortunately, assessment of subsurface temperatures using BHTs remains fraught with uncertainty. Studies that compare corrected BHTs to formation temperatures report differences of up to 15 °C. Furthermore, it is unknown whether these errors are related to systematic errors in the correction methods or to uncertainty of the input parameters.

Here we present a new 2D finite difference model of the thermal recovery of a borehole after drilling. As the thermal parameters of both the drilling fluid and the lithologies were taken into account, the model has been used to evaluate of the sensitivity of the corrected BHTs to these parameters. The model was applied to a large dataset of BHTs in the Roer Valley Graben, the northwestern branch of the European Cenozoic Rift System. In a number of wells, the simulated formation temperatures have been compared to relatively accurate ($\sim \pm 3$ °C) drill-stem test temperatures.

Model results indicate a total parameter uncertainty of corrected BHTs of ± 4 °C. The calculated temperatures were highly sensitive to the assumed duration of circulation of drilling fluid. The sensitivity to the thermal diffusivity of the drilling fluid and the lithology was much lower, approximately 1.5 °C. The simulated temperatures fell within the uncertainty range of the drill-stem test temperatures. This is in line with earlier studies, and shows that a physically based model which takes into account heat flow in both the borehole and the lithologies performs much better than the often used empirical Horner approximation or line source methods.

The new set of corrected BHTs, drill-stem test temperatures and a number of detailed temperature logs were used to assess the thermal state of the Roer Valley Graben. The regional heat flow showed little variation between the rift basin and the adjacent structural highs, which is related to the low amount of crustal stretching, and suggests a passive rifting mode. However, a number of local thermal anomalies exceeding +10°C were found at 1000 to 1500 m below the surface. These are probably related to groundwater flow along basin bounding faults.