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Thermo-mechanical models of the European lithosphere for geothermal exploration

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One of the critical exploration parameters for geothermal systems is the subsurface temperature. Temperature data are reliable up to a depth of 1 km in most parts of Europe. Accordingly, the robustness of temperature estimation rapidly decreases with depth, as temperature data from wells become sparser and unevenly distributed.

We developed a two-layer temperature model for assessing the prospective resource base of enhanced geothermal systems in Europe. The surface heat flow and the Moho depth were used to constrain the radiogenic heat production in the upper crust. Only conduction was considered for heat transfer. The most recent and comprehensive regional temperature models and maps available were directly used to constrain the 3D temperature distribution up to a depth of 6 km. The model shows high average geothermal gradients of up to 60 °C in volcanically active regions such as Iceland, parts of Italy, Greece and Turkey. Temperatures at 5 km depth range between 40 °C and 310 °C and at 10 km depth between 80 °C and 590 °C.

However, this direct use of regional models is not fully consistent with the calculated and observed heat flow. Furthermore, only fixed thermal conductivity values were assigned to the sediments and the crystalline basement.

As part of the EU FP7-funded Integrated Methods for Advanced Geothermal Exploration (IMAGE) project we are going to develop a methodology to obtain a more advanced 3D lithosphere-scale thermal model of Europe. This will include a more realistic distribution of thermal properties, according with lithological variations of the European crust. Further improvements of the thermal model, aiming at consistency between temperature and heat flow observations and tectonic model predictions, will be obtained by adopting data assimilation techniques derived from reservoir engineering best practices.

The newly derived thermal model of the European lithosphere together with compositional data will be used to estimate the strength distribution in the lithosphere. The strength distribution could be used to obtain a more reliable estimation of the stress field which is important for optimizing the pressure applied to geothermal wells to enhance flow rates, while minimizing the risks of induced seismicity.