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Lithospheric-scale 3D structural and thermal modelling of Hessen

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ABSTRACT

The thick sediment package of the Upper Rhine Graben provides a large geothermal potential, due to high temperatures and presumably pronounced fluid flow (e.g. Guillou-Frottier et al., 2013). In order to utilize this energy resource and to minimize the risk of drilling a dry or cold well, it is crucial to understand the temperature distribution and the fluid flow in the subsurface.

For the prediction of these parameters, boundary conditions in reservoir-scale models have to be defined. Due to the fact that the temperature in the subsurface is mainly controlled by deep factors, like the lithospheric thickness and radiogenic heat production in the crystalline crust, our approach is to first build a lithospheric-scale structural model. By calculating the conductive thermal field at a lithospheric-scale, we can make first-order predictions on the deep thermal field and its controlling factors. Therefore we are able to provide boundary conditions for reservoir-scale models. As a next step we can simulate with smaller scale models the coupled heat and fluid transport, focusing on the understanding of local phenomena.

As a part of the "IMAGE" project (Integrated Methods for Advanced Geothermal Exploration) we aim to contribute to the development of an integrated and multidisciplinary approach for the exploration of geothermal reservoirs by understanding the processes and properties controlling the spatial distribution of key parameters (e.g. temperature) for geothermal exploration. Therefore we build a lithospheric-scale 3D structural and thermal model including parts of the Upper Rhine Graben and the Hessian Depression. Here we present first results of this study.

The Federal State of Hessen in central Germany is characterized at the surface by a variety of geological units (Figure 1), representing the record of different tectonic and climatic events. The most prominent and almost youngest feature is the Vogelsberg, a proof for the young volcanic history of Germany. The Tertiary volcanics of the Vogelsberg are covering a large area in the central part of Hessen, while the Tertiary sediments were mostly accommodated in the Upper Rhine Graben (URG) towards the south. The URG is part of the European Cenozoic Rift System, which developed by reactivation of different fault systems due to intraplate compressional stresses in the foreland of the Central Alps (Dézes et al., 2004). The rifting of the URG began in the Eocene, propagated northwards into the Hessian Graben during the Oligocene and is still active, shown by recent seismicity related to strike-slip and normal faulting (Dézes et al., 2004).

The Mesozoic sedimentary record is mainly represented by Triassic sediments in the Hessian Depression northeast of the Vogelsberg, while in the west the Paleozoic metamorphic rocks of the Rhenish massif are dominant. The Rhenish Massif as part of the Rhenohercynian Zone was formed during the Variscan Orogeny (Oncken et al, 1999). Almost at the same time the Northern Phylite Zone and the Mid-German Crystalline High developed, which are now located below the Mesozoic and Cenozoic sediments (Oncken, 1997).

We present a preliminary 3D structural model of the present-day configuration of the Federal State of Hessen. The sedimentary part of the model is mainly based on the 3D structural model of Arndt et al. (2011), which includes 6 geological units (Tertiary/Quaternary, Muschelkalk, Buntsandstein, Zechstein, Rotliegend and Pre Permian). For the crustal configuration we integrate seismic reflection and refraction lines (e.g. Wenzel et al., 1991) as well as the crustal thickness map of Mechie (2007). By performing gravity modelling using the software IGMAS+ (Götze & Schmidt, 2010) we constrain and further investigate the depth of the Moho and the density distribution of the sub-sedimentary crystalline crust.

Furthermore, we show results from a first calculation of the present-day 3D conductive thermal field of the Federal State of Hessen, which is based on measured rock properties (Bär et al., 2011), additional literature data and the preliminary lithospheric-scale 3D structural model.

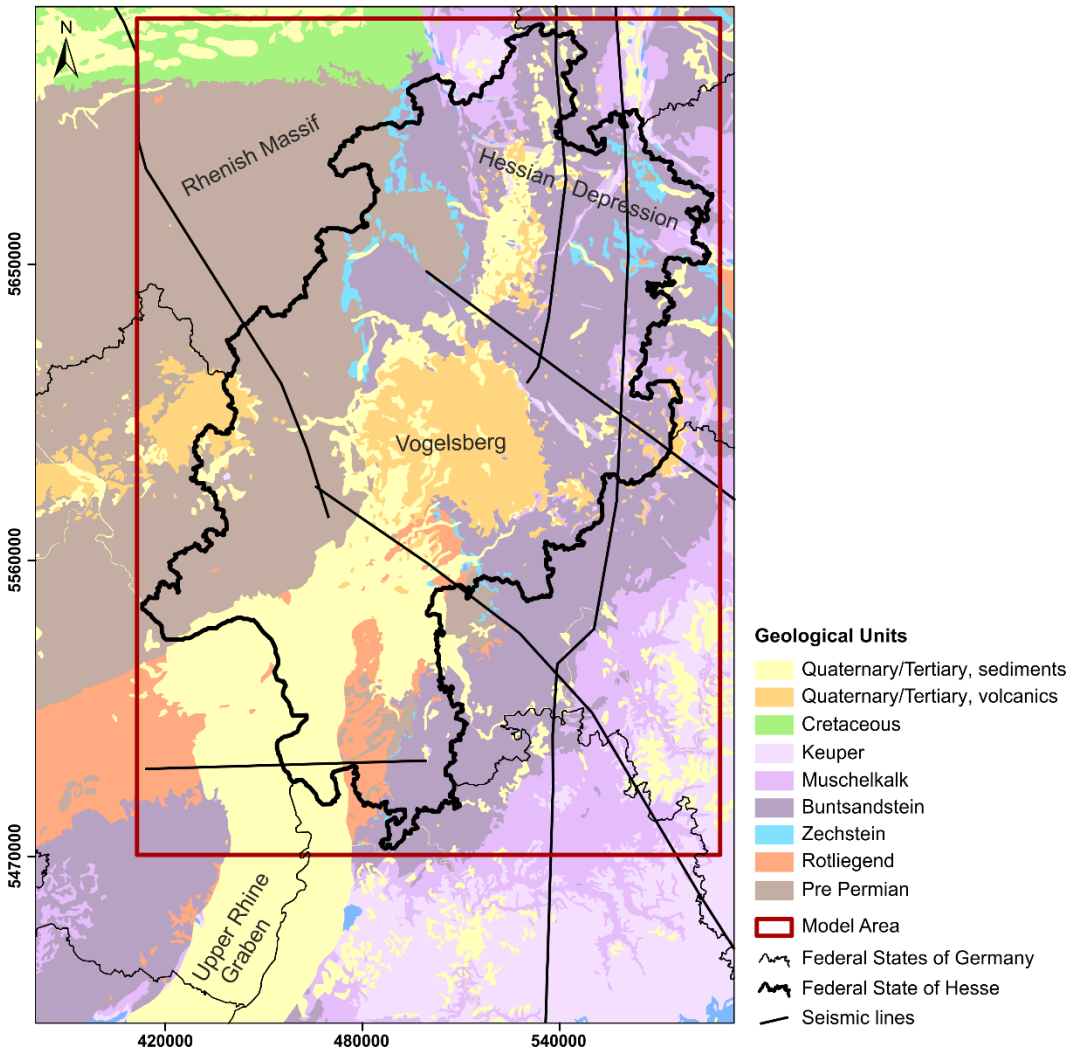

Figure 1: Geological Map (modified after GK1000, © Bundesanstalt für Geowissenschaften und Rohstoffe BGR, 2014) showing the main geological units, the model area and the location of deep seismic reflection and refraction lines (EUGEMI Working Group, 1990; Meissner and Bortfeld, 1990).

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