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Geophysical and structural characterisation of a granodioritic MD-BTES test-site

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Geothermal energy and thermal energy storage are essential components in balancing a decarbonated future energy supply. The north-eastern shoulder of the Upper Rhine Graben (URG), with its Variscan basement belonging to the Mid-German Crystalline High, is a potential target area for heat storage projects. Ganodioritic units in the city area of Darmstadt provide suitable thermo-mechanical properties to implement a Medium Deep Borehole heat exchanger Thermal Energy Storage (MD-BTES). This study focuses on the structural architecture of such crystalline units, representing a heterogeneous fracture and fault network. An approach combining geophysical characterisation and the analysis of surface fracture network analogue is performed to quantify the dimensions and topology of such a fracture network in the subsurface.

Two 2D seismic profiles helped to characterise the deep subsurface structures of the BTES demo site area and to localise the boundaries between the unweathered basement, the weathered basement, and the overlying sedimentary layers. The weathered basement and Permian volcano-sedimentary and Quaternary fluviatile units build the near-surface groundwater aquifer. This shallow aquifer requires a detailed investigation, performed through electrical resistivity mapping, near-surface S-wave refraction seismic survey, ground-penetrating radar lines and radon emanations profiles, combined with shallow geotechnical drillings. Selected surface analogues are located in the northern Odenwald Massif, the most extensive outcropping section of the Mid-German Crystalline High. The first analogue is a pit located 150 m apart from the BTES demo site. The second is the Mainzer Berg quarry in the Sprendlinger Horst, at a 12 km westbound distance, which belongs to Variscan granodioritic and granitic units with similar properties. Derived from these analogues, the fracture length distribution follows the power-law with an exponent about -2. The main relevant orientations identified are trending N030°E -N040°E, N090°E -N100°E, N120°E -N130°E and N165°E, with an overall fracture density of 3.06 frac.m^{-1} for the demo site subsurface. Additionally, the connectivity of the fracture network is heterogeneous due to clustering. Such clustering also affects weathered horizons, which constitute the near-surface groundwater aquifer.

These fracture network properties are then implemented into sub-surface semi-artificial discrete fracture network (DFN) models to quantify at the first-order the flow properties of such heat storage rocks. This approach allows a successful characterisation of the BTES site, improves the local reservoir model accuracy and ensures an optimal assessment of the storage system behaviour.