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Structural and petrophysical characterization: from outcrop rock analogue to reservoir model of deep geothermal prospect in Eastern France

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The Scientific Interest Group (GIS) GEODENERGIES with the REFLET project aims to develop a geological and reservoir model for fault zones that are the main targets for deep geothermal prospects in the West European Rift system. In this project, several areas are studied with an integrated methodology combining field studies, boreholes and geophysical data acquisition and 3D modelling. In this study, we present the results of reservoir rock analogues characterization of one of these prospects in the Valence Graben (Eastern France). The approach used is a structural and petrophysical characterization of the rocks outcropping at the shoulders of the rift in order to model the buried targeted fault zone. The reservoir rocks are composed of fractured granites, gneiss and schists of the Hercynian basement of the graben. The matrix porosity, permeability, P-waves velocities and thermal conductivities have been characterized on hand samples coming from fault zones at the outcrop. Furthermore, fault organization has been mapped with the aim to identify the characteristic fault orientation, spacing and width. The fractures statistics like the orientation, density, and length have been identified in the damaged zones and unfaulted blocks regarding the regional fault pattern. All theses data have been included in a reservoir model with a double porosity model.
The field study shows that the fault pattern in the outcrop area can be classified in different fault orders, with first order scale, larger faults distribution controls the first order structural and lithological organization. Between theses faults, the first order blocks are divided in second and third order faults, smaller structures, with characteristic spacing and width.
Third order fault zones in granitic rocks show a significant porosity development in the fault cores until 25 % in the most locally altered material, as the damaged zones develop mostly fractures permeabilities. In the gneiss and schists units, the matrix porosity and permeability development is mainly controlled by microcrack density enhancement in the fault zone unlike the granite rocks were it is mostly mineral alteration. Due to the grain size much important in the gneiss, the opening of the cracks is higher than in the schist samples. Thus, the matrix permeability can be two orders higher in the gneiss than in the schists (until 10 mD for gneiss and 0,1 mD for schists for the same porosity around 5%).
Combining the regional data with the fault pattern, the fracture and matrix porosity and permeability, we are able to construct a double-porosity model suitable for the prospected graben. This model, combined with seismic data acquisition is a predictable tool for flow modelling in the buried reservoir and helps the prediction of borehole targets and design in the graben.