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Numerical modeling of regional stress distributions for geothermal exploration

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Any high-enthalpy unconventional geothermal projectcan be jeopardized by the uncertainty on the presence of the geothermal resource at depth. Indeed, for the majority of such projects the geothermal resource is deeply seated and, with the drilling costs increasing accordingly, must be located as precisely as possible to increase the chance of their economic viability. In order to reduce the "geological risk", i.e. the chance to poorly locate the geothermal resource, a maximum amount of information must be gathered prior to any drilling of exploration and/or operational well. Cross-interpretation from multiple disciplines (e.g., geophysics, hydrology, geomechanics . . .) should improve locating the geothermal resource and so the position of exploration wells ; this is the objective of the European project IMAGE (grant agreement No. 608553), under which the work presented here was carried out. As far as geomechanics is concerned, in situ stresses can have a great impact on the presence of a geothermal resource since they condition both the regime within the rock mass, and the state of the major fault zones (and hence, the possible flow paths). In this work, we propose a geomechanical model to assess the stress distribution at the regional scale (characteristic length of 100 kilometers). Since they have a substantial impact on the stress distributions and on the possible creation of regional flow paths, the major fault zones are explicitly taken into account. The Distinct Element Method is used, where the medium is modeled as fully deformable blocks representing the rock mass interacting through mechanically active joints depicting the fault zones. The first step of the study is to build the model geometry based on geological and geophysical evidences. Geophysical and structural geology results help positioning the major fault zones in the first place. Then, outcrop observations, structural models and site-specific geological knowledge give information on the fault zones family sets and their priority rule. In the second step, the physical model must be established, including constitutive equations for the rock mass and the fault zones, initial state and boundary conditions. At such large scales, physical laws and parameters are difficult to assess and must be constrained by sensitivity analysis. In the last step of the study, the results can be interpreted to highlight areas where the mechanical conditions favor the presence of a geothermal resource. The DEM enables accounting for the strong stress redistributions inherent to highly-segmented geometries, and to the dilational opening of fault zones under shearing. A 130x150 square-kilometers region within the Upper Rhine Graben is used as a case-study to illustrate the building and interpretation of a regional stress model.