Adapted numerical modelling strategy developed to support EGS deployment

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Context

The exploitation of Enhanced/Engineered Geothermal Systems (EGS), for electricity and/or heat production, is a promising way to increase the amount of renewable energies contribution in the energetic mix in Europe. In regard to the required production characteristics (production temperature and flowrate) for the economical viability of EGS, the favourable targeted geological systems are deep and fractured. In order to reduce the risks and the prohibitive costs linked to the depth of such geothermal systems, numerical modelling is a useful tool to understand such deep fractured systems and to help in the construction and in the management of the deep infrastructures (wells architecture, stimulation of wells, implementation of adapted network of wells). Nevertheless, this forces to a change of paradigm in comparison to « classical » reservoir modelling based on mechanics of continuum media. 3D Discrete Fracture Network (DFN) approach looks fairly adapted to catch the mechanical and hydraulic phenomena in the fractured rock mass at different scales.

3D multiscale DFN based models

The objective of the construction of the Discrete Fracture Network is to integrate at a defined scale the singularities (fault zones, fractures etc.) of the targeted deep fractured reservoir inherited from its tectonic history (for example in Europe rifting context, flexural basin, etc.). These singularities are modelled geometrically by 2D planes or discs cutting the 3D volume taken into account at the considered scale, the 3D blocks created representing the rock matrix. These singularities can be deterministic and/or probabilistic depending on the scale studied and the existence of data of the deep reservoir (3D seismic profiles, well logging) or surface outcrops analysis. The conceptualisation of the fractured rock mass is a crucial step for such DFN models especially to integrate in its geometry the role of the tectonic sequence responsible for the present-day fracture network. This is performed by making a hierarchical ranking of the fractures sets in time and space, considering structural analysis or interpretation models (such as Riedel model). As mentioned above this DFN can be established at different scales, from the regional scale to the vicinity of the geothermal well (Fig. 1). Of course one single discontinuity represented by a 2D plane at a given scale can be modelled by a 3D DFN at a lower scale in order to integrate its real 3D geological structure.

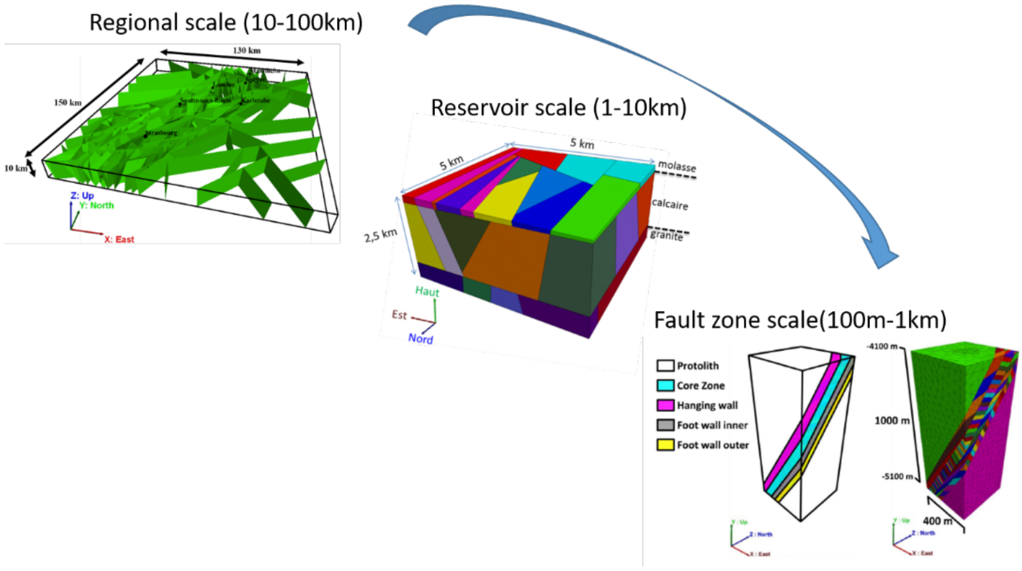

Fig. 1: Examples of DFN at different scales for deep geothermal reservoirs

Once the DFN is constructed, the use of DFN numerical codes integrating adequate physical resolution for both the fractures and the matrix (balance equation resolution and constitutive behaviour law) for the problem considered enable to catch specific schemes of fractured systems. In comparison with codes based on continuum media theory, DFN based models can highlight reorientation and redistribution of field variables in the 3D blocks representing the rock matrix as well as preferential response in favourably oriented fracture planes. For instance, for mechanical problems, such models can show the effect of stress tensor reorientation and stress redistribution in the 3D model (see Maury 2018) as well as preferential mechanical response (shear and/or displacements) in favourably oriented fracture planes with respect to solicitation modelled. Moreover for a same physic different models at complementary scales are useful to determine/refine boundary conditions or constitutive behaviour.

Example: test of well trajectory in order to optimise hydraulic stimulation

To illustrate the potential of such DFN models an example of numerical modelling of the hydraulic stimulation of a set of fractures cutting the open hole of a deep geothermal well is represented (Fig 2.). These simulations aim at estimating the hydroshearing phenomenon in a 3D fracture network due to the hydraulic overpressure imposed in the wellbore; this phenomenon leads to irreversible shear displacements in favourably oriented fractures with respect to the *in situ* stress state and to a potential increase of their permeability. The numerical simulations are performed with the code 3DEC© (Itasca 2016), using a hydromechanical coupling algorithm considering the flow in the fractures (blocks matrix impermeable) and mechanical behaviour of both fractures and matrix (elastoplastic law with Coulomb criterion for fractures and elastic behaviour for matrix). As shown in Fig. 2 such simulations allow to test different well trajectories in the fractured reservoir in order to optimise the hydraulic stimulation of the wellbore, meaning to get an increase of the well injectivity for limited hydraulic overpressure at the well head thus avoiding deleterious risks (*e.g.* induced seismicity).

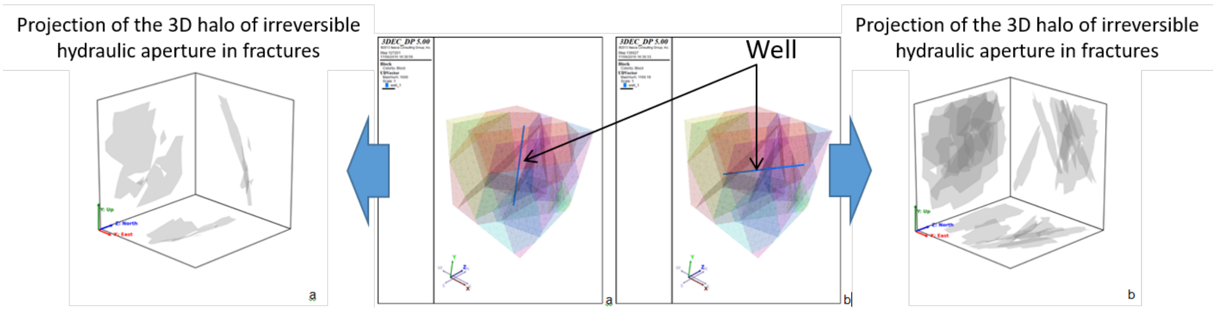

Fig. 2: test of well trajectory in the 3D fracture network with the resulting increase of hydraulic aperture in the fracture (the projection on the faces of the model of the 3D halo is illustrated)

References

Itasca Consulting Group, Inc. (2016) 3DEC — Three-Dimensional Distinct Element Code, Ver. 5.2. Minneapolis: Itasca

J. Maury, T. Guillon, M. Peter-Borie, A. Blaisonneau, (2018), Modelling of the stress field: from regional to reservoir scale, International Symposium on Energy Geotechnics SEG 2018, Lausanne, Switzerland