



## Structural analysis of fluid flow paths in fractured granite

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The characterisation of fluid flow in fractured media is complex due to the fact that the access to the reservoirs is restricted to the boreholes, and the resolution of geophysical methods decreases with depth. In this respect, two fractured variscan granites have been selected to investigate the fluid flow paths; both of them are located in the European Cenozoic Rift System (ECRIS).

In the experimental geothermal site developed at Soultz-sous-Forêts (Upper Rhine Graben), seismic reflection shows that the faults in the sedimentary cover reflect only a partial amount of the structures affecting the crystalline basement, because of their younger age, and because of decollements located in Triassic levels. Thus, specific methods have been used to characterise the structure network within the basement (top of basement is at 1400 m), where the open holes of the boreholes are located.

### (1) Direct in situ investigation

Borehole seismic (VSP) has been used to investigate the structure network in the vicinity of the boreholes. The data reveal some reflections with P-S mode conversion, occurring on generally permeable structures with a size ranging from one to several hectometres. A 3D map produced by travel time modelling has been integrated into the existing static reservoir model. The network imaged by this approach explains the major hydraulic connections between the wells in the 2000-3500 m depth interval. The structural pattern revealed by this way suggests a clear expression of the variscan inheritance, which could not be identified only from the analysis of the younger sedimentary cover. The activation of these old structures can be explained by the current stress field controlled by the Alpine push.

### (2) Analogue field study and core analysis

A continuous structural analysis from centimetre to kilometre scales has been carried out on a batholith outcropping in the Catalan Coastal Ranges. A network of carbonate veins has been considered as a witness of paleo-circulations. Both the extent and the conditions of precipitations of the veins (given by geochemical data: REE, O and C isotopes) allow to consider the outcrop as a fossil geothermal reservoir. The veins studied in this analogue outcrop and on cores from the Soultz-sous-Forêts granite, considered with the hydraulic data from this geothermal site, exhibit different drainage patterns developed in a fractured granite : up to the kilometre scale, the drainage may either be localised in the major structures, or be more homogeneously or randomly distributed, implying an important contribution of the protolith. In addition, the alteration is shown to be emphasised whether a fault zone is exposed to a supergene alteration. This fact could contribute to explain the favourable reservoir conditions locally observed at the top of basements covered by sediments.

A reservoir model is then proposed, in order to position the structures and the results detailed in this work within a global sketch.