The use of shear motions for the stimulation of EGS reservoirs

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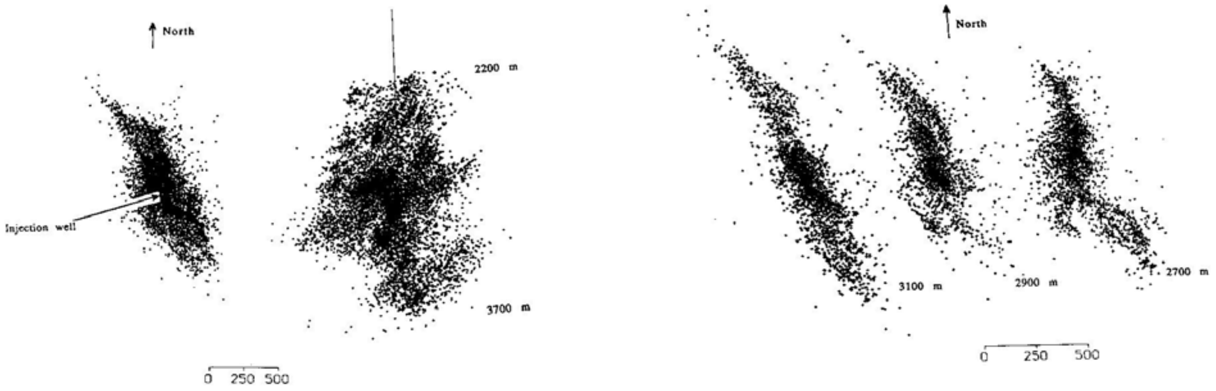
The classical application of hydraulic fracturing for the stimulation of oil and gas reservoirs implies the injection of proppant (sand) in the hydraulic fracture. The objective of this procedure is to maintain the fracture hydraulic conductivity at a satisfactory value when the borehole pressure drops back to production levels. But the use of proppant in high temperature geothermal reservoirs (larger than 150°C) is limited by chemical interactions between the sand and the geothermal fluids.

For geothermal reservoirs it has been proposed to rely on shear dilatancy for the economical development of Enhanced Geothermal Systems, more generally known as EGS reservoirs. The objective is to build up progressively the pore pressure in the rock mass so as to decrease the effective normal stress supported by critically preexisting fractures. The lower the effective normal stress for which slip motion occurs, the larger the dilatancy associated with shear (Barton et al., 1985), and therefore the larger the permanent increase in hydraulic conductivity of the fracture at the end of stimulation.

This concept has been tested in the mid-eighties, in particular at the granite test site of Le Mayet de Montagne in central France (depth range of testing between 250m and 840 m). Results demonstrated the efficiency of the technique but outlined the role of the minimum principal stress magnitude as a limiting factor for the efficiency of the technique (Bruel and Cornet, 1995, Cornet and Yin, 1995, Cornet and Morin, 1997).

In the early nineties, the deep granite formation encountered at a depth of 1500 m near Soultz sous-Forêts, in the Rhine graben, was selected by the European Commission for developing an EGS reservoir in real in situ conditions (Gerard et al. 2006). On this site, two reservoirs have been developed, the first one at depths ranging from 2800 m to 3600 m, the second one at depths ranging from 4500 m to 5000 m. For both reservoirs it was found that, by increasing progressively the formation pressure, it was possible to create fresh shear zones. These fresh shear zones have revealed to constitute key features for the development of the reservoirs. Precise regional stress evaluations (Cornet et al., 2007; Valley and Evans, 2007) help show that the formation of these fresh shear zones are consistent with the Hoek and Brown shear failure criterion (Hoek and Brown, 1980) as applied to this rock mass.

But shear simulations generate micro seismic events, the magnitude of which may not be compatible with the surface use of land. In fact, in some occasions, they have even resulted in the stopping of the projects. Interestingly, results from Soultz outline the existence of large scale non-seismic shear motions that are associated with repeated small scale, small magnitude, micro-seismic events known as multiplets (Cornet et al., 1997, Bourouis and Bernard, 2006, Calo et al., 2011). The identification, in real time, of these multiplets may help identify the occurrence of large aseismic motions, as well as their rate of growth. This real time identification of aseismic slips may be taken to advantage for controlling the stimulation process as it proceeds, so as to limit the magnitude of induced micro seismic events in order to avoid detrimental surface effects.



A)

B)

The fresh shear zone created during the 1993 GPK1 stimulation at Soultz (Cornet and Jones, 1994).
A) left: horizontal projection ; right: vertical projection in a plane oriented NNW-SSE;
B) cross sections at various depths through the vertical projection.
Note the change with depth of the orientation of the stimulated zone.

References

Barton N., Bandis S. C., and Bakhtar K. (1985). Strength, deformation and conductivity coupling of rock joints. *Int. J. Rock Mech. Min. Sc. and Geooech. abs.* **22** :: 121-140

Bourouis, P., and Bernard, P. (2007). Evidence of coupled seismic and aseismic fault slip during water injection in the geothermal site of Soultz (France), and implications for seismogenic transients. *Geophys. J. Int.* **169**, 723-732

Bruel D. and Cornet F.H. (1995) Forced fluid flow through fractured reservoirs modelling; in *Fractured and jointed rock masses* (Myer et al. ed.), pp 503-510 (Balkema, Rotterdam)

Calo, M., Dorbath, C., Cornet, F. H., and Cuenot, N. (2011). Large scale aseismic motion identifed through 4D P-wave tomography. *Geohys. J. Int.* **186**, pp 1295-1314

Cornet F.H. and Jones R. (1994) Field evidence on the orientation of forced water flow withnrespect to the regional principal stress direction; in *Rock Mechanics-Models and measurements; challenges from industry* (Nelson and Laubach ed.) pp 61-69, Balkema, Rotterdam

Cornet F.H. and Morin R. (1997). Evaluation of hydromechanical coupling in a granite rock mass from a high volume, high pressure injection experiment: Le Mayet de Montagne, France; *Int. J. Rock Mech. Min. Sc.,* **34**(3-4): paper nb 207

Cornet F. H. and Yin, J. M. (1995). Analysis of induced seismicity for stress ¯field determination and pore pressure mapping. *Pure App. Geophys.,* **145**, 677-700

Cornet, F. H., Berard, Th. and Bourouis, S. (2007). How close to failure is a natural
granite rock mass at 5 km depth. *Int. J. Rock Mech. Min. Sc.,* **40**(7-8), 47-66

Gérard A., Genter A., Kohl T., Lutz P., Rose P., and Rummel F. (2006) The deep EGS (Enhanced Geothermal System) project at Soultz-sous-Forêts (Alsace, France) *Geothermics,* **35**(5-6):473-483

Hoek, E., and Brown, E. T. (1980). *Underground Excavations in Rock.* The Institute
of Mining and Metallurgy, London