Comparison of the seismicity evolution during the 2000 and 2003 stimulations at Soultz-sous-Forêts

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The research site of Soultz-sous-Forêts (Alsace, France) was a pioneer pilot geothermal site in Europe. In this study, we use the available data from 2000 and 2003 hydraulic stimulation tests to analyze the seismicity evolution. We apply the ETAS (Epidemic-Type Aftershock Sequence) model to extract the background seismicity rate during the two stimulation periods.

For the 2003 sequence, to retrieve the nonstationary seismicity component, we use a moving window of 400 events for the whole catalog. The evolution of the background seismicity rate μ is successfully retrieved with an evolution in two peaks coherent with the wellhead pressure evolution, while the triggering parameter K is stable. At the end of the stimulation μ decrease significantly. Then we look at the evolution of ETAS parameter by selecting five clusters of seismicity. The evolution of μ for each cluster is in agreement with a propagation of the pressure away from the well with the cluster closer to the well showing one early peak only, the middle clusters showing two peaks and the far cluster showing a later peak. All clusters show a decrease of μ at the end of stimulation.

For the 2000 sequence, the background seismicity rate is less well constrained but it stays globally constant during the stimulation with some decrease after its end. We see no clear peak in μ as was present during 2003 and K is relatively low. However, μ also decreases at the end of the stimulation. The selection of clusters does not change this global behavior and all clusters present grossly the same characteristics.

Our results are in agreement with the different characteristics observed by several authors (e.g. Calo and Dorbath, 2013; Dorbath et al, 2009) between these two stimulations. On one hand, the 2003 stimulation consists in an activation of several existing structures that yields a seismicity well explained by the ETAS model with a combined effect of Coulomb stress transfer and perturbation induced by the stimulation (e.g. pore pressure variation). The evolution in space is also coherent with the finding of Calo and Dorbath (2013) that the injected water goes far from the well avoiding increase in effective stress near the well. In this case, background seismicity rate can be related to the measured pressure. On the other hand, the 2000 stimulation developed a 3D reservoir with the creation of a fresh shear zone (Cornet et al, 2015) and so the direct effects of the stimulation are dominants. However, no clear relation between the background seismicity rate and the operational parameters can be observed. At the end of stimulation, we observe a decrease of background rate corresponding to a progressive return to a natural background rate, similar to what is observed in other settings (Oklahoma, Rousse).