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Analysis of Seismic Multiplets properties throughout hydraulic stimulations: case study of Soultz-sous-Forêts EGS reservoir, France.

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Aseismic motions appear significant in geothermal reservoirs. However, detecting and characterizing such movement is not so straightforward as it often derives from indirect observations. For the hydraulic stimulation of the Soultz-sous-Forêts, France EGS reservoir, in 1993 a slow slip was inferred from borehole shift observations. We therefore investigate if the seismicity associated with the 1993 hydraulic stimulation shows any sign attesting for the occurrences of slow slip movements.

We focus our work on the analysis of repeating earthquakes defined by similar waveforms with a high degree of correlation, suggesting a common source mechanism and location. The occurrences of such events are hypothesized to be driven by the surrounding slow slip movement.
Precisely, we analyze large datasets recorded from a borehole seismic network. Thousands of recorded seismic events are identified as repeating earthquakes and are thus classified in hundreds of multiplets. We verify that indeed these events have collocated sources, by comparing the sources dimensions estimated through spectral analysis with the inter-event distances assessed through cross-correlation analysis.

We observe that, despite similar waveforms and comparable sources dimensions, the amplitudes of the repeated events vary significantly on a single asperity (up to a factor 100). We interpret this variation of amplitude as a variation of seismic slip on the asperity. It therefore provides a local measurement of the variation of seismic slip at the scale of the patch.

We then investigate the multiplets properties over the time of the stimulation taking also into account the hydraulic data of the injection. In particular, we observe an increase in event amplitudes (for more than one order of magnitude) over time. We suppose that the associated slip variation is related to the fluid pressure as we observe a large-scale dependence of this amplitude through the stimulation.
We also analyse the b-value of the multiplets amplitude distribution. We find that this parameter decreases with time and distance from the injection well, consistently with observations from other geothermal context (e.g. Basel). This reveals the existence of numerous slow slip episodes at the reservoir scale.