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Earthquake size controlled by injection pressure and preexisting faults: case study of the 1993 Soultz-sous-Forêts injection

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The injection of fluid in the upper crust, notably for the development or exploitation of deep geothermal reservoirs, is often associated with the rise of induced seismicity. The occurrence of large seismic events during such operations needs to be reduced in order to preserve infrastructures and population nearby the injection site. However it is not clear how the injected fluid influences the characteristics of the induced events. Here we investigate the microearthquakes that occurred during one of the hydraulic stimulation in Soultz-sous-Forêts, France in 1993 and study the link between the injected fluid and the source properties of the induced earthquakes when aseismic slip is known to occur. We take advantage of the deep borehole accelerometers that were running during this experiment in the vicinity of the injection zone. We estimated the moments and radii of all recorded events using a spectral analysis and classified them into 663 repeating sequences. We show that events follow the typical scaling law between radius and moment but fluctuations of moments are important while the radius of the events remain similar. Repeating events on a given asperity with a well-defined radius, are shown to experience very different stress drops questioning the involved mechanisms. We also evidence an increase of the average event radius (and moments) over the course of the injection that follows the increase of the wellhead pressure but also an evolving access to preexisting fault zones of the reservoir. Two different populations of events are characterized. These observations suggest that the fluid pressure has both a direct and an indirect control on the rupture size of the induced events.