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b-value mapping of injection-induced earthquakes and earthquake swarms

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The fluid injection is usually carried out during industrial operations targeted to permeability enhancement of hydrocarbon reservoirs and geothermal heat exchangers. These injections cause brittle rock deformation, which is expressed in the form of small seismic events. In most cases only microearthquakes with magnitudes below 2 are generated, which is namely the case of treatments in hydrocarbon reservoirs. However, treatments of geothermal fields are often associated with small-magnitude earthquakes (magnitudes from 2 to 4). Some types of natural earthquake activity, e.g. earthquake swarms are also attributed to high-pressured fluids and their migration. Recent studies of the seismicity accompanying injections indicate that the fluid triggering of seismicity is manifested by increased slope of the magnitude frequency distribution (b-value). This was the case of the Basel injection where b-value decreased with the distance from the injection well. This could indicate a correlation between the magnitudes of fluid pressure and event sizes in context of ambient stress field. For better understanding of the similarities of natural and induced seismicity we estimate spatial distribution of b-value also for injection-induced seismicity in other geothermal projects and for earthquake swarms. For estimation of the b-value we use the precise locations and event magnitudes of induced seismicity in geothermal heat exchanger Soultz-sous-Forets, France for the treatments in 2000 and 2003. Events recorded during earthquake swarms in West Bohemia/Vogtland, Czech Republic - years 2000 and 2008 are used for comparison with earthquake swarms. To estimate the spatial distribution of b-values we use each event's hypocenter as a grid point for which all events in its neighborhood are taken to determine the corresponding b-value. In all cases we obtain quite similar spatial behavior of b-value as in Basel. Both treatments in Soultz-sous-Forets show decay of b-value with distance from the well. Also both earthquake swarms show the highest b-values in the fault area where the activity started and a decrease of b-value with distance. This could support the idea that these earthquake swarms are triggered by crustal fluids and their flow.