Causality between induced seismicity b-value reduction and stress state of existing fractures

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The Gutenberg–Richter distribution of earthquakes is a power law relationship and it holds for laboratory scale earthquakes (acoustic emission) to subduction zone earthquakes as well as induced seismicity. The gradient of the power law is known as the b-value, which can be considered the ratio of the number of the larger earthquakes to small ones. Larger earthquakes are often observed in low b-value regions, or alternatively a b-value reduction has been observed before some main shocks. Some authors have argued that b–value is negatively correlated with differential stress level. Therefore, a b-value anomaly found in time-space analysis may be used for detection of an area of stress concentration and used for earthquake prediction or hazard risk assessment.

In the field of induced seismicity where b-value reduction has also been observed, the physical mechanism of b-value reduction has not been well understood. Since induced seismicity related with fluid injection usually occurs at depths around 1000 ~ 5000 m, a significant tectonic loading to cause a stress change during the short time period of a hydraulic stimulation might not be expected. We used borehole analysis and focal mechanism information to investigate the stress state on the existing fractures that caused induced seismicity. Then we divide the catalog into the groups with varying normalized shear stress threshold and estimated the b-value. We found that b-value for the events that occurred along higher shear stress fractures were significantly lower (figure 1a) than those from the moderate/lower shear stress fractures (figure 1b). Thus, b-value dependency on the shear stress can be observed for induced seismicity on a reservoir scale. Therefore, we propose that the reason for the observed b-value reductions in induced seismicity on a reservoir scale is the events that occur along higher shear stress fractures. Supposing that the earthquakes occur along well-orientated fractures, the b-value dependence on differential stress can be translated to dependence on shear stress. Thus, our observations about b-value are consistent with the conventional interpretations of b-value.

Keywords: b-value, Shear stress, induced seismicity