EGU21-14795
https://doi.org/10.5194/egusphere-egu21-14795
EGU General Assembly 2021

Testing hypotheses of stress drop variations with hydraulic fracturing induced seismicity in the Horn River basin

Adam Klinger, Joanna Holmgren, and Max Werner
University of Bristol, Earth Sciences, Earth sciences, United Kingdom of Great Britain – England, Scotland, Wales
(adam_klinger@hotmail.com)

Source parameters can help constrain the causes and mechanics of induced earthquakes. In particular, systematic variations of stress drops of fluid-injection induced seismicity have been interpreted in terms of the role of fluids, differences between tectonic and induced events, and self-similarity. The empirical basis for the variations, however, remains controversial. Here, we test three hypotheses about stress drops with observations of seismicity induced by hydraulic fracturing in the Horn River basin (Canada). First, stress drop is self-similar and independent of magnitude. Second, stress drop increases with distance from the point of fluid injection, which might be expected if in-situ effective stresses increase away from the point of fluid injection. Third, stress drops estimated with empirical Green's functions (EGFs) are systematically larger than those estimated from direct fits to source models, which is expected if seismic waves attenuate in a frequency-dependent manner or experience site effects.

We probe the hypotheses with a large microseismic dataset collected during hydraulic fracturing operations in the Horn River shale gas play in British Columbia. 90,000+ seismic events were recorded by three borehole geophone arrays with a moment magnitude range of $-3 < M_w < 0.5$. To calculate corner frequencies, we assume small, co-located seismic events can be approximated as EGFs, which effectively remove propagation and site effects from a larger target event. We target 34 $M_w > 0$ events and search for EGFs over a 100 m radius for each event, choosing only those EGFs that satisfy multiple quality criteria. This study builds on previous work that estimated stress drops from direct fitting of standard Brune source models and found systematic high frequency resonances recorded by the geophones.

Of the 34 target events, we retrieve corner frequency and stress drop estimates for 22 events to test the three hypotheses. We observe that stress drop appears relatively constant over M_w, but the magnitude range ($0 < M_w < 0.5$) is currently too limited to draw strong conclusions. Second, stress drop appears to decrease, rather than increase, with distance from the point of injection (with a moderate Pearson's correlation co-efficient of -0.5 ± 0.2); this could be caused by a direct hydraulic connection causing a reduction of in-situ effective normal stresses distal to the point of

injection. Third, we observe no systematic difference between stress drops from direct source fits and EGF-based estimates, although stress drop uncertainties are large compared to standard earthquake source studies because of limited azimuthal coverage and high-frequency instrument resonances. These initial results do not support the systematic variations of stress drop for fluid-injection induced seismicity that have been observed in other datasets.