Earthquake source parameter analysis shows hydraulic fracturing induced events are consistent with fault reactivation under regional stress in northeastern British Columbia, Canada

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An increasing number of M3+ earthquakes have been associated with Hydraulic Fracturing (HF) injection activity in low-permeable tight shale formations in the Western Canada Sedimentary Basin (WCSB) in the last decade. These include a \(M_w 4.6\) on 08/17/2015 near Ft. St. John, a \(M_l 4.5\) on 11/30/2018, and two \(M_l 3.2\) on 10/05/2019, 10/08/2019 near Dawson Creek, British Columbia. Increased seismic activity in the Dawson-Septimus area prompted a temporary deployment of seismic stations in a joint effort between McGill University and the Ruhr University Bochum in order to perform higher-resolution monitoring relative to the regional seismic station coverage. Here, we use waveform data from that deployment of 22 (dominantly broadband) stations in close proximity to numerous HF wells in an area of roughly 60 x 70 km², between July 2017 and August 2019, as well as records from 6 additional seismic stations northwest of the study area. In total, we detect 6222 local earthquakes, of which 5325 surpass a quality control criterion of having a horizontal location error ≤ 3 km. An investigation of the spatial and temporal correlation between injection and earthquake initiation using a cross-correlation based event similarity analysis during seismically active time periods reveals a high degree of event similarity within various clusters and a strong correlation with individual injection episodes at specific HF wells. In addition, event clusters also exhibit similar patterns in daily cumulative seismic moment, independent of differences in waveform characteristics.

As individual clusters may represent the activation of specific geological structures, we perform double-difference relative relocation of seismicity to identify fault orientations. In addition, we invert for focal mechanism solutions per event cluster to check consistency with structures inferred with relocated hypocenters, and perform spectral fitting for source parameter analysis. Event relocations are performed on individual families, where the total catalog is divided into subsets corresponding to 24 seismic active time periods where 43 event families are active. Relocating each earthquake family separately allows us to successfully relocate 4571 out of the total 5325 events. The relative relocations align in two dominant orientations, with one roughly perpendicular to the maximum horizontal regional stress orientation, and the other at low angles to the maximum regional stress orientation on a regional scale around individual HF wells. Focal mechanism estimates for events with \(M > 2.0\) result in two primary groups of faulting
mechanisms: strike-slip deformation on faults implied by lineations striking at low angles to $S_H$, and thrust-faulting deformation on faults implied by lineations perpendicular to $S_H$. Seismic moment and corner frequency estimates from single spectrum and spectral ratio fitting as well as scaling relations will be presented.