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Understanding fluid driven ruptures, from natural earthquakes to reservoirs induced seismicity

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The relation between hydraulic fracturing (HF) and local earthquakes has been investigated increasingly during the last decade, yet the mechanisms for the nucleation of relatively larger (M > 2) events are poorly understood. Part of the limitation rests in a lack of seismograph data at close distances to HF-induced events. In order to better constrain the mechanisms for inducing earthquakes near hydraulic fracturing wells, here we present new data from eight broadband stations deployed at distances ranging from ∼1-10 km of a horizontal well bore for a period bracketing several weeks prior to and several months following a HF stimulation in the Montney Basin area, British Columbia, Canada.

We first apply a multi-station STA/LTA event detection algorithm on continuous waveform recordings to build a local, preliminary catalog within the 10 km-radius study area for the period between 2015/05/28-2015/10/15, detecting 645 events on a minimum of three stations. We calculate hypocenters for 393 of the 645 detections using absolute P and S phase arrivals at four stations with continuous GPS timing records, and exclusively S-P arrival times for the other four stations with partial loss of GPS timing; 105 out of the 393 events pass the criteria of having horizontal and vertical errors smaller than 4 km. We then apply a multi-station matched-filter detection method in order to detect a larger number of local earthquakes. We build 60 templates based on the waveform similarity of the 105 initial (robust) locations in the preliminary catalog. Using a cutoff of 7*(Mean Average Deviation) value, we detect an additional 643 events, of which 422 are confirmed as real detections using visual inspection. Comparing the multi-station matched filter (MMF) catalog to daily injection volumes suggests a positive temporal correlation between fluid injection and the seismic activity, with most events spatially correlated with active well locations (distances of <5 km). Among the detected earthquakes, a subset of events display unique waveforms characterized by an impulsive broadband onset, followed by protracted low frequency ringing (<5 Hz), similar to some of the long-period type events observed in volcanic environments. They locate in close proximity to the horizontal wells and show lower stress drops relative to the remaining detected events. We speculate that some sort of fluid resonance potentially related to fluid movement along existing fracture may cause the lower frequency resonance observed in the latter part of the earthquake signal