Exploring possible causative mechanisms for earthquakes triggered by hydraulic fracturing: examples from the Montney Basin, BC, Canada.

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The Dawson-Septimus area near the towns of Dawson Creek and Fort St. John, British Columbia, Canada has experienced a drastic increase in seismicity in the last ~ 6 years, from no earthquakes reported by Natural Resources Canada (NRCan) prior to 2013 to a total of ~ 200 cataloged events in 2013 – 2019. The increase follows the extensive horizontal drilling and multistage hydraulic fracturing activity that started to extract shale gas from the unconventional siltstone resource of the Montney Formation. In addition to hydraulic fracturing, ongoing wastewater disposal in the permeable sandstones and carbonates located stratigraphically above and below the Montney formation may also be contributing to elevated seismicity in the region. Earthquakes occur in close spatial and temporal proximity to hydraulic fracturing wells, at distances up to ~ 10 km. The expected diffusion time scales in the low-diffusivity siltstone rock units and the temporal and spatial scale of seismic activity beg questions about the possible processes controlling the location and timing of earthquakes.

Here, we investigate the causative mechanisms for two of the largest events in the Montney Basin, British Columbia: the August 2015 M4.6 earthquake near Fort St. John, and the November 2018 M4.5 earthquake near Dawson Creek. Both events are thought to have occurred within the crystalline basement, ~2 km below the injected shale units (Montney formation). We use a finite-element 3D poroelastic model to calculate the coupled evolution of elastic stress and pore pressure due to injection at several hydraulic fracturing stages. Initially, we consider a simple layered model with differing hydraulic parameters based on lithology. Subsequently, also considering the seismicity distribution for each sequence, we introduce hypothetic hydraulic conduits connecting the injection intervals with the crystalline basement, where the respective mainshock occurred. We test a range of permeability values ($10^{-15}$ m$^2$– $10^{-12}$ m$^2$) commonly implemented for fault zones.
Our results show that, for both cases, the poroelastic stress perturbation may be not sufficient to trigger events in the basement. Instead, a scenario with a high-permeability ($10^{13}$ m$^2$–$10^{12}$ m$^2$) conduits connecting the Montney formation to the fault responsible for the mainshock could better explain the relationship between the hydraulic stimulation and the timing of the two M > 4 earthquakes. For the 2018 M4.5 event, aftershock distribution can be mainly attributed to earthquake-earthquake interaction via static Coulomb stress transfer from the mainshock slip. In addition to the modeling of single well/event sequences, future work will include the long-term poroelastic effect due to multiple disposal wells located in the region.