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Remote Dynamic Earthquake Triggering in Shale Gas Basins in Canada and Implications for Triggering Mechanisms

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Here we investigate the occurrence of remote dynamic triggering in three sedimentary basins in Canada where recent fluid injection activity is correlated with increasing numbers of earthquakes. In efforts to count as many small, local earthquakes as possible for the statistical test of triggering, we apply a multi-station matched-filter detection method to continuous waveforms to detect uncataloged local earthquakes in 10-day time windows surrounding triggering mainshocks occurring between 2013-2015 with an estimated local peak ground velocity exceeding 0.01 cm/s. We count the number of earthquakes in 24-hour bins and use a statistical p-value test to determine if the changes in seismicity levels after the mainshock waves have passed are statistically significant.

The p-value tests show occurrences of triggering following transient stress perturbations of $<$ 10 kPa at all three sites that suggest local faults may remain critically stressed over periods similar to the time frame of our study ($\sim$2 years) or longer, potentially due to maintained high pore pressures in tight shale formations following injection. The time window over which seismicity rates change varies at each site, with more delayed triggering occurring at sites where production history is longer. The observations combined with new modeling results suggest that the poroelastic response of the medium may be the dominant factor influencing instantaneous triggering, particularly in low-permeability tight shales. At sites where production history is longer and permeabilities have been increased, both pore pressure diffusion and the poroelastic response of the medium may work together to promote both instantaneous and delayed triggering. Not only does the interplay of the poroelastic response of the medium and pore pressure diffusion have implications for triggering induced earthquakes near injection sites, but it may be a plausible explanation for observations of instantaneous and delayed earthquake triggering in general.