Dynamics of Fault Activation by Hydraulic Fracturing in Overpressured Shales

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ABSTRACT

Fluid-injection processes such as disposal of saltwater or hydraulic fracturing can induce earthquakes by increasing pore pressure and/or shear stress on faults (Deng et al., 2016). Natural processes, including transformation of organic material (kerogen) into hydrocarbon and cracking to produce gas, can similarly cause fluid overpressure. Here we document two examples from western Canada where earthquakes induced by hydraulic fracturing are strongly clustered within areas characterized by pore-pressure gradient in excess of 15 kPa/m. By contrast, despite extensive hydraulic fracturing activity associated with resource development, induced earthquakes are virtually absent in the same formations elsewhere. Monte Carlo analysis indicates that there is negligible probability that this spatial correlation developed by chance. A detailed analysis was undertaken within a 400-km^2 region in Alberta, Canada where uniquely comprehensive data characterize dynamic interactions between well completions at 6 drilling pads (Bao and Eaton, 2016). Seismicity is strongly clustered in space and time, exhibiting spatially varying persistence and activation threshold. The largest event (M_L 4.4) can be reconciled with a previously postulated upper bound on magnitude, only if the cumulative effect of multiple treatment stages is considered. Induced seismicity from hydraulic fracturing reveals contrasting signatures of fault activation by stress effects and fluid diffusion. Patterns of seismicity indicate that stress changes during operations can activate fault slip to an offset distance of > 1 km, whereas pressurization by hydraulic fracturing into a fault yields episodic seismicity that can persist for months.

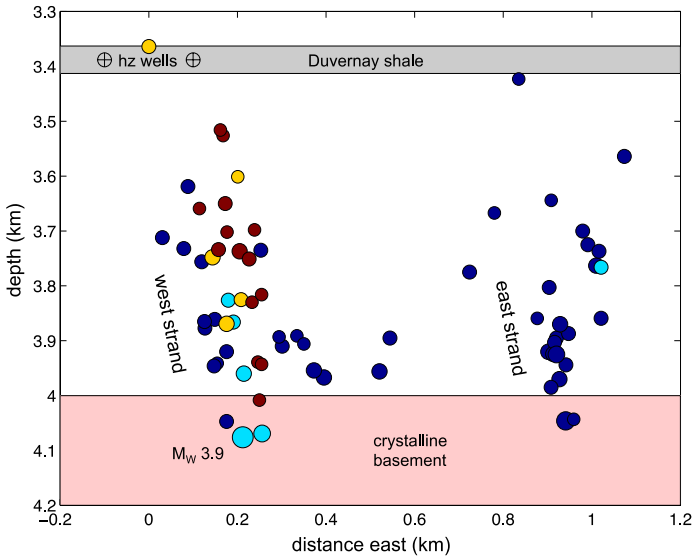

Figure 1: Cross-section through a cluster of induced seismicity, showing east and west fault strands inferred from double-difference event locations (Bao and Eaton, 2016). Dark blue symbols show events that occurred during hydraulic fracturing in two horizontal (hz) wells. Light blue, yellow and red symbols show events during subsequent sequences.

REFERENCES

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