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Frictional properties of a faulted shale gas play: implications for induced seismicity

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Injecting fluids into the subsurface is necessary for a number of industries to facilitate the energy transition (e.g., geothermal, geologic CO₂ sequestration or hydrogen storage). One of the biggest challenges is that fluid injection induces seismicity, which can lead to damaging events. It is currently not possible to predict the exact nature of seismicity that will occur due to fluid injection prior to operations.

Using laboratory friction experiments and in-situ microseismic analyses, we investigate the role frictional behaviour may have on the rate and magnitude of induced seismicity. This study focuses on the Horn River Basin shale gas play (British Columbia, Canada), where hydraulic fracturing activity has resulted in felt induced seismicity. Microseismic data from this field highlights fault planes that cut across the stratigraphy, including overburden and reservoir shales of varying mineralogy and underburden dolomites.

Our experimental friction results on samples recovered from core at reservoir depths show that both the frictional strength and stability vary considerably across the different lithologies; transitioning from very velocity-strengthening with friction coefficients of 0.3 – 0.4 in the overburden shales to more velocity-weakening and friction coefficients of 0.55 – 0.7 in the reservoir shales and an analogue of the underburden dolomite.

Spatial clustering analysis of the microseismicity allowed us to discriminate the operationally induced fracturing from fault reactivation events. We then examined the variations in the seismic b-value of the event magnitude-frequency distribution. These events were further differentiated by depth, separating them into their lithological horizons. The results show, for both fracturing and faulting events, higher seismic b-values of 1.4 – 1.5 occur in the overburden shales, which then decrease into the upper reservoir shales to 0.8 – 1.1, and then increase into the lower reservoir shales and underburden dolomite to 1.1 – 1.4. These trends correlate well with the laboratory measurements of frictional a-b values that define the degree of velocity-strengthening to velocity-weakening in the different gouges across the same lithological units.

These results suggest that knowledge of the frictional behaviour of the subsurface prior to operations, derived from mineralogical compositions and laboratory testing on cored material, may help improve our understanding of the potential rate and magnitude of induced seismicity that may occur due to subsurface fluid injection.

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