Interpreting subsurface connectivity patterns in order to better understand Induced Seismicity Controls in the BC Montney

Steve Rogers
WSP Golder
Afshin Amini
WSP Golder; University of British Columbia

The increasing occurrence of induced seismicity at felt magnitudes and above, is well documented. In the Western Canadian Sedimentary Basin and particularly the Montney Formation, with the majority of the observed events have been related to hydraulic fracturing operations. The generally acknowledged cause behind the observed induced seismic events is injection induced pore pressure changes, causing stress changes on existing geological structures, triggering shear failure and the generation of a seismic event. However significant uncertainty is associated with how these critical structures connect back to active stages and therefore receive pressure. With some wells directly intersecting critical structures, some hydraulic fractures extending away from the well to reach the critical structures, whilst many induced events, can only be explained by pressure diffusion through a network of existing natural structures that provide both distal and lateral connection away from active stages.

Whilst much effort has been placed into attempting to understand operational controls on hydraulic stimulation that influence induced seismicity, there has been little consideration on the network of subsurface structures that connect wells to critical structures and the role they may play. Much of this is because these features are typically below seismic resolution and therefore hard to image. However, by calculating diffusivity (the ratio of pathway permeability to storage) patterns based upon the time of flight between injection initiation and induced events, and the distance travelled, patterns can be determined that help to explain the rather chaotic response to stimulation, Figure 1.

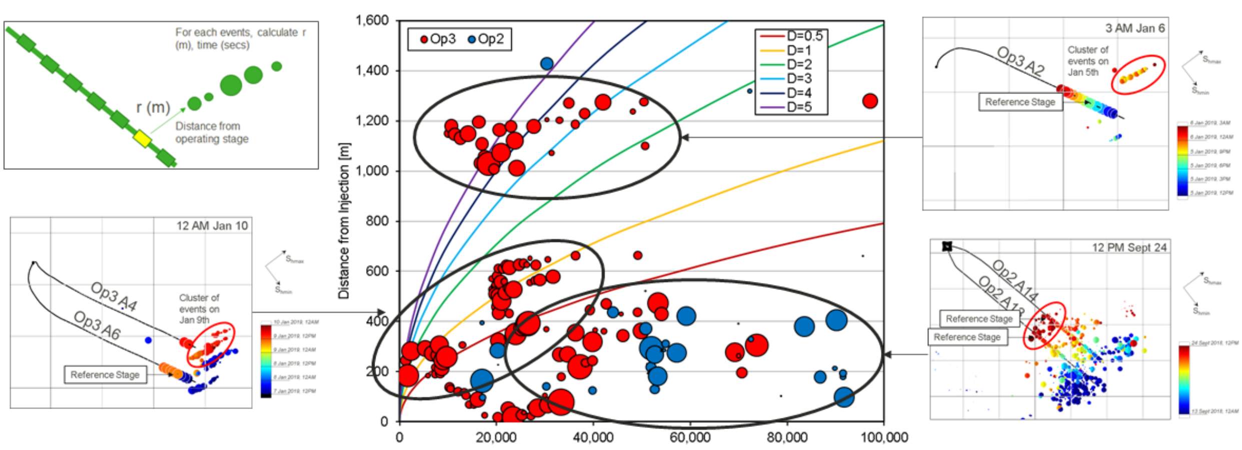

Figure 1: Examples of distance-time plots for a number of induced events. The coloured lines represent diffusivity curves for given values in the formula Distance = $\sqrt{(4\pi.Dt)}$ *where D = diffusivity and t = time of flight*

When these observations are combined with Discrete Fracture Network (DFN) simulations of likely structural fabric combinations, including both natural and hydraulic fractures, it is found they can provide a framework to explain event generation. These models are based upon subsurface data from the KSMMA region of BC, provided by 3 Montney Operators for a project sponsored by the BC OGC. Using a simple rule-based approach to capture the geomechanical aspects of the process, it can be shown that structural connectivity is a significantly critical missing component of the induced seismicity causation pathway, with the stochastic representations of structure and connection to the well, demonstrating good agreement between modeled and observed induced seismicity patterns, Figure 2.

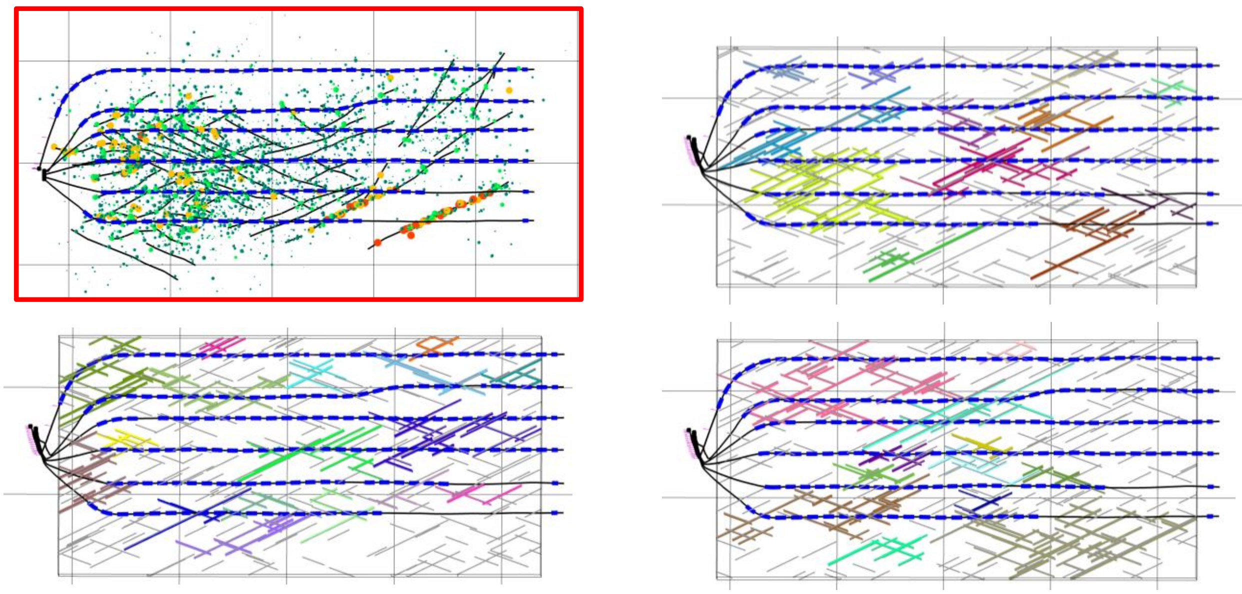

Figure 2: Example DFN model developed for a pad from observed events (top left), honouring the intensity of observed seismic lineaments, the size of observed linements and their orientation. Cluster analysis of the DFN shows patchy connectivity, explaining why limited higher magnitude seismicity occurs on a pad. The three other images represent 3 equi-probable structural realisations of the interpreted seismic lineaments (top left).

With structural connectivity identified as a critical component, these models offer an approach to test alternative completion designs that reduce unfavourable connections as a means to reduce the number of events. The aim is event reduction without significantly impacting the overall economics of the well pad development, providing a route to economic mitigation of induced seismicity.