Induced Seismicity Risk Management Strategies: Montney Case Study

Dario Baturan\(^{(1)}\), Emrah Yenier\(^{(1)}\), Bogdan Batlai\(^{(2)}\), Brad Bialowas\(^{(2)}\), John Nieto\(^{(2)}\)

(1) Nanometrics Inc.
(2) Canbriam Energy Inc.

Summary

Change of in-situ stresses due to hydraulic fracturing activities may induce earthquakes on critically-stressed faults when pressure pathways exist for communication to the nearby faults. Although such events are mostly small in magnitude and typically generate ground shaking well below the perception threshold, a small number of M>3 events, correlated with fracturing operations, have been observed in western Alberta and north eastern British Columbia. This has raised concerns on potential risks associated with induced seismicity. Regulatory bodies have mandated risk mitigation strategies to control the associated operational activities. These strategies include induced seismicity monitoring (ISM) programs, which involve the deployment of real-time seismic networks in the vicinity of operation sites. In this study, we present learnings on the management of induced seismicity risk from a 2-year monitoring program of multi-pad hydraulic fracturing site in western Canada.

A quantitative measure of seismic risk includes assessment of potential hazards and their social, environmental, and economic impacts. In induced seismicity, risk mitigation strategies can be applied to both hazard and exposure components. Seismic hazard, referring to the level of ground shaking that may occur at a given probability, can be reduced by minimizing the likelihood of inducing large events. In the presented case study, this is achieved by conducting detailed geologic and geophysical analysis prior to drilling in order to characterize the pre-existing structures in the region. Wellbore placement and drilling design are carefully implemented by avoiding mapped faults and lineaments that may pose induced seismicity risk. A surface ISM network, consisting of 8 high quality three-component broadband seismometers, was deployed in March 2015. Phase arrivals and amplitude picks from detected events are manually reviewed in near real time. The computed event locations and magnitudes are posted in a web portal for review. A traffic light protocol has been put in place with near real time notification for any events larger than ML2 as per BC OGC guidance.

Figure 1.a shows the seismic activity detected by the ISM network. A total of 1771 events have been detected within the region of interest (ROI). 90% of the observed seismicity is smaller than ML0.5, and are confined at depths 1.0km to 3.5km. In 2015, 19 events with ML>1.0 were observed, two of which were ML2.1 and ML2.3. This number dropped to 6 ML>1.0 events in 2016, the largest being ML1.3. From hazard point of view, the largest recorded peak ground acceleration (PGA) is 0.0018g obtained during the ML2.3 event in 2015. The 0.02g ground motion monitoring threshold defined by BC Oil and Gas Commission (BCOGC) has not been exceeded by any events at any monitoring stations.

Recent seismicity observed in the area shows some lineaments around major faults, as illustrated in Figure 1.b. One may interpret such features as activation of un-mapped fault segments. However, care should be taken against over-interpretation of ISM catalogs with the absence of operational information. Figure 2 indicates that majority of events illustrated in Figure 1.b are well correlated with the timing of hydraulic
fracturing operations in the area. Accurate locations of these events obtained from microseismic monitoring align with the well pads and timing of individual stages, as shown in Figure 3. Additionally, an examination of magnitude recurrences in Figure 4 suggest a steep b-value of 1.68 for these events, suggesting that they are associated with the secondary natural fracture system in the region.

The ISM network detected additional 2392 events outside the ROI during monitoring period. 178 of these events are larger than M_L2.0, most of which are believed to be induced by hydraulic fracturing and water disposal activities in the region. The largest event detected outside the network is the M_w 4.6 August 17, 2015 earthquake located at 75 km north of the network. It generated a PGA of 0.0023g at the nearest ISM station, larger than the maximum PGA recorded from events within the ROI. A M_L 3.8 large event has been recently induced by another operator drilling and completing directly across a large strike-slip fault at 2.5 km south of the ROI (indicated by red star in Figure 1.a). This event created a PGA of 0.046g, exceeding the ground motion monitoring threshold set by BC OGC. The seismic activity observed outside the ROI and the associated ground motions suggest that although the number of fault activations by hydraulic fracturing operations in the region is small, such events are capable of generating M>3 earthquakes with ground motions exceeding the perception threshold at the epicentral area. No major events being induced within the ROI highlights the success of implemented induced risk management strategies even though the operations were conducted in proximity of existing faults.

![Figure 1. (a) Events detected by an ISM network in Northeast BC since March 2015. Lines represent identified major faults, triangles indicate ISM stations, and rectangle shows monitoring region of interest. (b) A closer-look at the recent seismicity observed within the region of interest (ROI) in 2016, where events are color-coded based on magnitude.](image)
Figure 2. Origin times of seismicity detected by the ISM network within the area of interest. Vertical lines represent start and end times of hydraulic fracking operations at three neighboring well-pad in the region.

Figure 3. Events detected by the ISM network during frac operations on each well-pad (open circles). Accurate locations of the same events obtained from microseismic monitoring are shown by color circles, which are grouped based on frac stages.
Figure 4. Magnitude recurrence relationship for relatively large hydraulic fracturing events detected by the ISM network. Event sizes are based on moment magnitudes obtained from microseismic analysis. Bars show number of events at different magnitude bins, and circles indicate the cumulative number of events larger than a given magnitude. Fitted Gutenberg-Richter relationship and the associated b-value are also shown.