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Investigating the Effect of Pressure Partitioning on Induced Seismicity in the Montney Formation

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Summary

A 4.5 ML earthquake occurred in November 2018, close to the city of Fort St. John, British Columbia during hydraulic fracturing within the Lower Montney Formation in Septimus field. Analysis of the DFIT (Diagnostic Fracture Injection Testing) data in the Septimus field suggests that a major fault may act locally as a stress barrier causing *~4 MPa* difference in minimum horizontal stress gradient across the fault. Also, several pressure segments and overpressured regions (*15 kPa/m*) can be seen within the study area (Figure 1). The objective of this project is to investigate the pore pressure partitioning in the reservoir. We will run different completion/production scenarios and monitor how the stress will change on the fault using Mohr-Coulomb failure criteria. The project will add value to the previous studies by providing recommendations for mitigating the risk of induced seismicity in the presence of pressure compartmentalization.

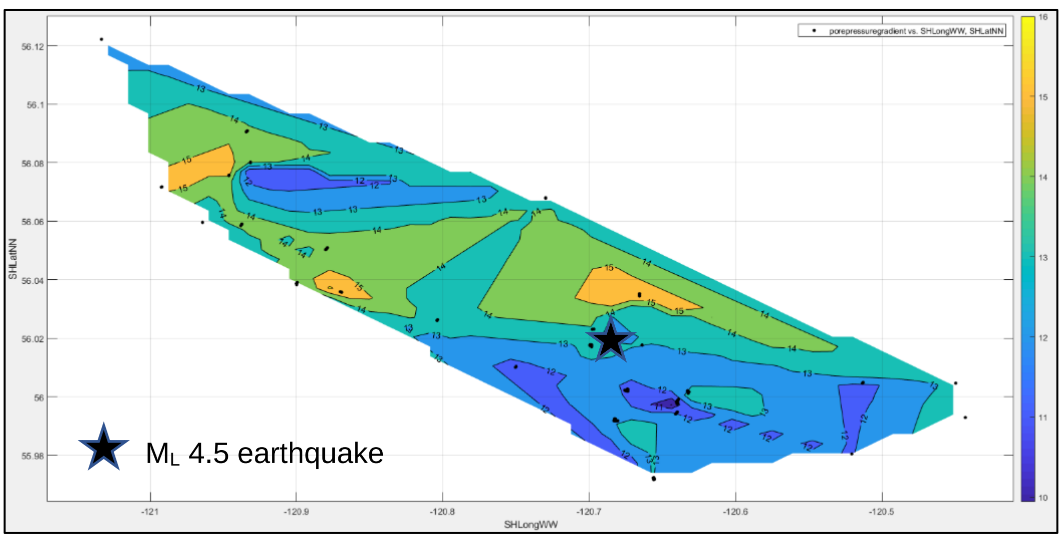

Figure 1- Pore pressure gradient in the Septimus field. There are several pressure compartments within the reservoir. The earthquake locates in proximity to the overpressured areas.

Background Theory

Previous relevant studies are summarized below.

Hydraulic fracturing in overpressured shales- Most of earthquakes induced by hydraulic fracturing in Montney formation occur within areas characterized by high pore pressure gradient *(> 15 kPa/m*) (Eaton, 2017).

Poroelastic stress triggering of the induced seismicity- In the case of Hydraulic fracturing, which lasts for hours to days, the increase of fluid pressure near the injection point may not be significant immediately after the HF operation due to the low permeability of the shale formation. Instead, poroelastic stressing may play a dominant role before the diffusion of pore pressure takes effect (Deng et al., 2016). Segall and Lu (2015) found that poroelastic stress dominates over pore pressure at large distances and can have a significant impact on seismicity rate.

Hydraulic fracture design in the presence of highly stressed layers- A design of HF in variable stress rock is significant. If fracture stimulation is initiated in high stress zones, unbounded height growth reduces lateral propagation. Hydraulic fracturing initiating from low stress layers, can increase stress within the same zone, and also can reduce stress in higher stress layers above and below (Ueda et al., 2018).

The effect of local stresses on fracture propagation derived from microseismic events- Fractures will propagate in the direction of maximum horizontal stress which is controlled by the regional stress in the area. In contrast, local complex geologies often influence fracture growth and orientation in random direction. The presence of geological structures such as anticlines and dipping layers results in considerably different fracture response in some stages compared to other stages not affected by the same local stresses (Preiksaitis et al., 2014).

Geomechanical modeling of induced seismicity- The depth distribution of recorded microseismic events is highly correlated to interaction of rock strength and stress concentration due to lithological layering (Roche and Van der Baan, 2014).

Induced seismicity caused by hydrocarbon production- Gas extraction would also cause subsidence and localized changes in in-situ stress magnitudes. The volume changes decrease the vertical stress *Sv* and increase the larger horizontal stress *SHmax*. Increasing the deviatoric stress permits Mohr-Coulomb failure. There is a strong correlation between production rates and the number of earthquakes, even if there is a time lag between seismic activity and the beginning of production. Poroelastic modeling could capture this delay (Baranova et al., 1999).

Hydraulic fracture simulation integrated with microseismic interpretation- The variability in production performance within the shale wells is affected by the lateral variability in the reservoir quality (reservoir properties, faults, rock strength parameters, in-situ stress conditions), and stage positioning. The P-wave response after hydraulic fracturing provides insight into the style of stimulation, rather than to the calculation of Stimulated Reservoir Volume (SRV). However, the P-wave response after production help determine the fracture conductivity, and to estimate where reservoir fluid is produced. The S-wave analysis approximates induced fracture lengths comparable to the effective fracture lengths generated by the simulator (Alfataierge et al., 2019).

Workflow

By integrating the production data analysis and geomechanical modeling, we investigate the poroelastic effects on fault slip potential and fracture propagation patterns in the Septimus field. Discrete Fracture Network modeling will be developed to characterize the natural fracture parameters. Then we will generate a 3D planar hydraulic fracture model by using DFIT, completion and fluid injection data. The 3D geomechanical model and hydraulic fracturing simulation results together will be input for numerical dynamic simulation. Using Mohr-Coulomb failure criteria, we will monitor how the stress will change on the fault associated with different completion scenarios and hydraulic fracturing in different pressure sections.

Conclusions

Available reservoir data set from Montney formation in Septimus field was gathered and analyzed for further reservoir simulation studies. We will conduct poroelastic modeling to examine the effect of pore pressure diffusion and stress perturbation during hydraulic fracturing. The focus of this study is to investigate the effect of pressure compartmentalization on induced seismicity in the reservoir. The project will add value to the previous studies by providing recommendations for minimizing the risk of induced seismicity during hydraulic fracturing.

Acknowledgments

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References

Alfataierge, A., J. Miskimins, T. Davis, R. Benson, et al. (2019). "3D Hydraulic-Fracture Simulation Integrated With 4D Time-Lapse Multicomponent Seismic and Microseismic Interpretations, Wattenberg Field, Colorado". In: SPE Production & Operations 34, pp. 57– 71.

Baranova, V., A. Mustaqeem, and S. Bell (1999). "A model for induced seismicity caused by hydrocarbon productionintheWesternCanadaSedimentaryBasin". In: Canadian Journal of Earth Sciences 36, pp. 47–64.

Deng, K., Y. Liu, and R. Harrington (2016). "Poroelastic stress triggering of the December 2013 Crooked Lake, Alberta,inducedseismicitysequence".In:Geophysical Research Letters 43, pp. 8482–8491.

Eaton, D. (2017). "Dynamics of fault activation by hydraulic fracturing in overpressured shales". In: 79th EAGE Conference and Exhibition 2017-Workshops.

McLellan, P. and P. Eng (2016). "Fault Re-activation Predictions: Why Getting the In-situ Stresses Right Matters". In: GeoConvention.

Preiksaitis, M., S. Bowman, and T. Urbancic (2014). "Comparison of Microseismic Results in Complex GeologiesRevealstheEffectofLocalStressesonFracture Propagation". In: GeoConvention.

Roche, V. and M. Van der Baan (2014). "Geomechanical modeling of induced seismicity due to fluid injection". In: GeoConvention 283, pp. 1–4.

Ueda, K. et al. (2018). "Hydraulic Fracture Design in the Presence of Highly-Stressed Layers: A Case Study of StressInterferenceinaMulti-HorizontalWellPad".In: SPE Hydraulic Fracturing Technology Conference and Exhibition.