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Fracking Minimizing the Risk

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Introduction

This paper analyses the environmental impact and geomechanical conditions for successful and sustainable hydraulic fracturing ("fracking") treatment in Alberta. Fracking increases reservoir contact by increasing downhole surface area. However, this increase comes with drawbacks, as there have been reports of induced seismicity and of groundwater contamination associated with fracking. Using borehole breakouts, focal mechanisms and mini-frac data I was successfully able to constrain the stress field of the Fox Creek/Crooked Lake region (Alberta). My work suggests that strike-slip faults orientated approximately 9° & 69° could potentially be activated by fluid injection in the Duvernay. However, in Alberta (Canada), induced seismic events attributed to hydrocarbon extraction are rare, and only induced seismicity of low magnitude (<M_w 4.5) has been recorded, therefore my study concludes that induced seismicity does not pose a high risk to public safety.

Theory and/or Method

Studying the current stress regime can help us understand the recent tectonic evolution of a basin. A rocks intrinsic physical properties combined with the stress field determines a whether or not failure will occur. Additionally, information on crustal stresses can predict the propagation of hydraulic fractures, determine which critically stressed faults are likely to slip during fluid injection and resolve the optimal orientation for inclined and horizontal wells. Therefore, understanding the stress state is of utmost importance to scientists working in the upper crust (*Bell et al.,* 1994).

There are many ways to calculate the orientation of the 3 main principal stresses in the crust. It is possible to use earthquake focal mechanisms, hydraulic fracturing and borehole breakouts.

Examples

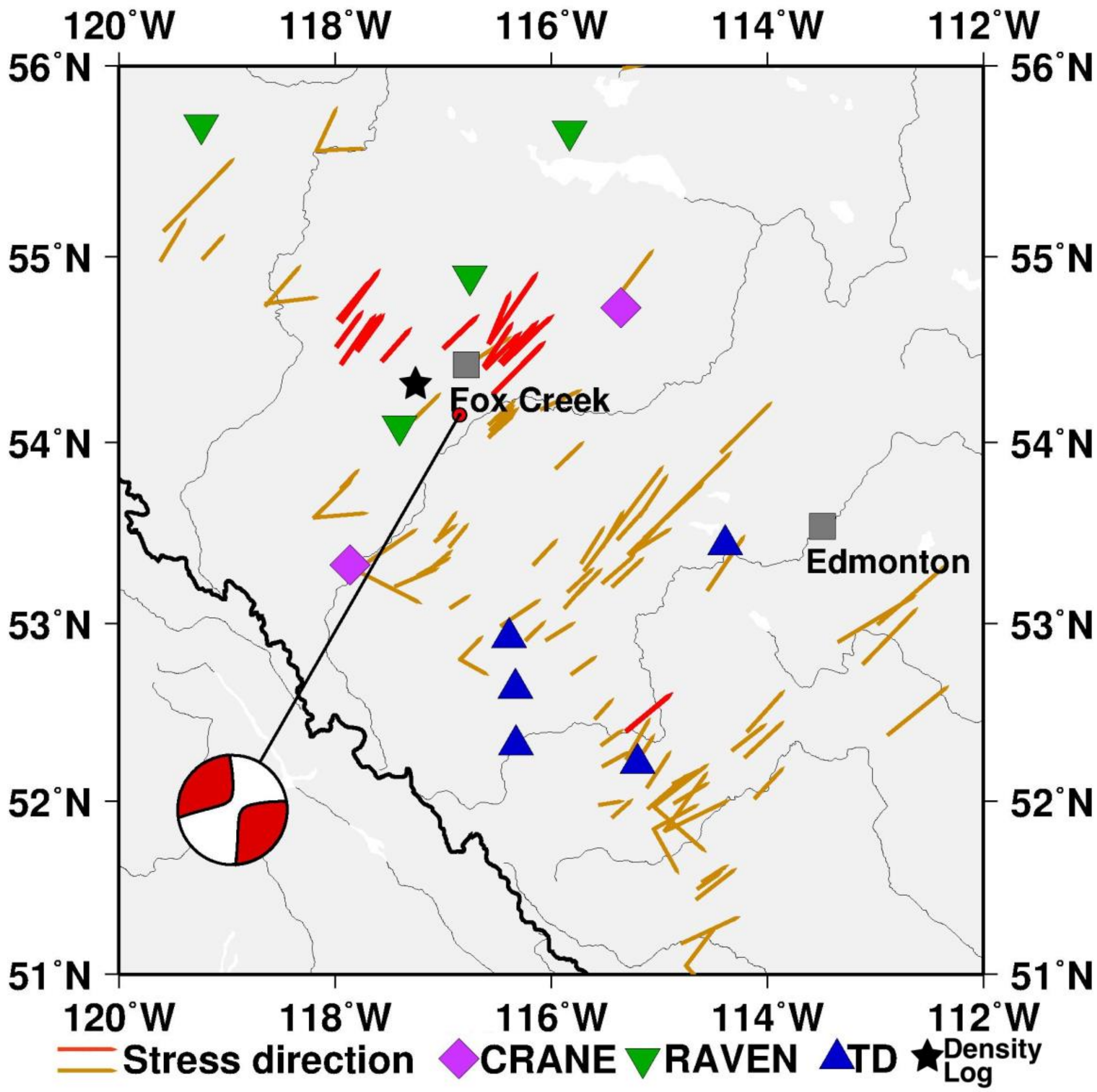

Figure 1. Updated crustal stress map depicting the current stress field and the focal mechanism for the June 13th (2015) M_L 4.4 earthquake. Red lines (Wells 1-18): orientation of the maximum horizontal stress derived from borehole breakouts and tensile fractures. Gold lines: orientation of the maximum horizontal stress from the World Stress Map (*Babcock,* 1978; *Gough & Bell,* 1981; *Fordjor et al.,* 1983; *Bell & Babcock,* 1986). Location of seismic stations relevant to this study: Crane (purple diamonds), Raven (green triangles) and TD (blue triangles).

Table 1. Stress Gradients in the Fox Creek/Crooked Lake Region. All values are reported in MPa/km.

Well Name	Pore Fluid Pressure Gradient	S_h Average Gradient	S_v Average Gradient	S_H Average Gradient (Lower bound)	S_H Average Gradient (Upper bound) μ=0.6	S_H Average Gradient (Upper bound) μ=0.8	S_H Average Gradient (Upper bound) μ=1.0
12-26-59-20W5	9.81	17.4	24	32.60	33.51	42.70	54.09

09-31-61-24W5	9.81	16.1	24	29.25	30.03	37.85	47.64
01-36-61-22W5	9.81	17.1	24	28.90	32.35	41.11	51.96
Aver-age	**9.81**	**16.87**	**24**	**30.25**	**31.96**	**40.55**	**51.23**

Conclusions

The focal mechanisms in the Crooked Lake/Fox Creek region illustrate a compressional environment controlled by strike-slip faulting events (*Frohlich et al.,* 2015; *Wang,* 2015). Because the study area is in a strike-slip regime, Andersonian faulting states that vertical faults orientated 30° from S_H max will be optimally orientated. My data from the Fox Creek/Crooked Lake region illustrates a S_H orientation of ~39°, therefore critically stressed strike-slip faults striking approximately 9° & 69°, could potentially be activated by the injection of fluids into the Duvernay formation. Additionally, the June 13th (2015) M_L 4.4 earthquake focal mechanism depicts a near vertical fault with the P-Axis (S_H) oriented 39.0$^{\pm}$0.2 degrees (*Wang,* 2015). This S_H orientation (P-Axis) is within 0.06 degrees of my overall average S_H orientation of 39.06° (derived from breakouts and tensile fractures of A,B,C,D quality). This data suggests that this fault is optimally orientated in the current stress regime and therefore most likely strikes approximately 9° or 69°. Furthermore, strike-slip faults striking ~129° degrees would be inactive in this stress regime as the stress field would increase the normal force along the fault plane and bring these faults away from failure.

The Western Canadian Sedimentary Basin has traditionally been seismically quiescent. However, this does not mean that stress in this region is low, as earthquakes are a measure of how fast the brittle crust is deforming. In areas with many earthquakes the brittle crust is deforming quickly and in areas with few earthquakes the crust is deforming relatively slowly. When looking at a tectonically stable region such as Alberta, low levels of seismicity does not mean the stress is low, it just means that over Geologic time, the lithosphere is deforming slowly.

Until recent years Alberta was believed to have been seismically inactive; however, the injection of fluids in the sub-surface still has the potential to induce seismicity throughout the province. *Schultz et al.* (2015) demonstrated the connection between seismicity and hydraulic fracturing schedules in the Duvernay formation near Fox Creek. Additionally, the M_L 4.4 Fox Creek earthquake occurred near the depth of fluid injection and is likely related to hydraulic fracturing. Although there has been much media attention regarding the connection between hydraulic fracturing and seismicity, my study concludes that induced seismicity is a rare occurrence and the magnitudes associated with earthquakes have been too small to cause damage or concern. Moreover, fracking generally is carried out in rural areas, away from cities. Alberta has a low population density (5.7 people/km^2 compared to Germany's 231 people/km^2), and most people live in urban centers. Therefore, the majority of the population is not affected by induced seismicity. Moreover, Alberta has over 175 thousand fracked wells and only a few cases of felt seismicity. Due to these factors, my thesis concludes that seismicity attributed to fracking does not pose a threat to the pubic in Alberta.

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