Monitoring and Mitigating Hydraulic Fracturing Induced Seismicity: Some Practical Considerations based on Canadian Experiences

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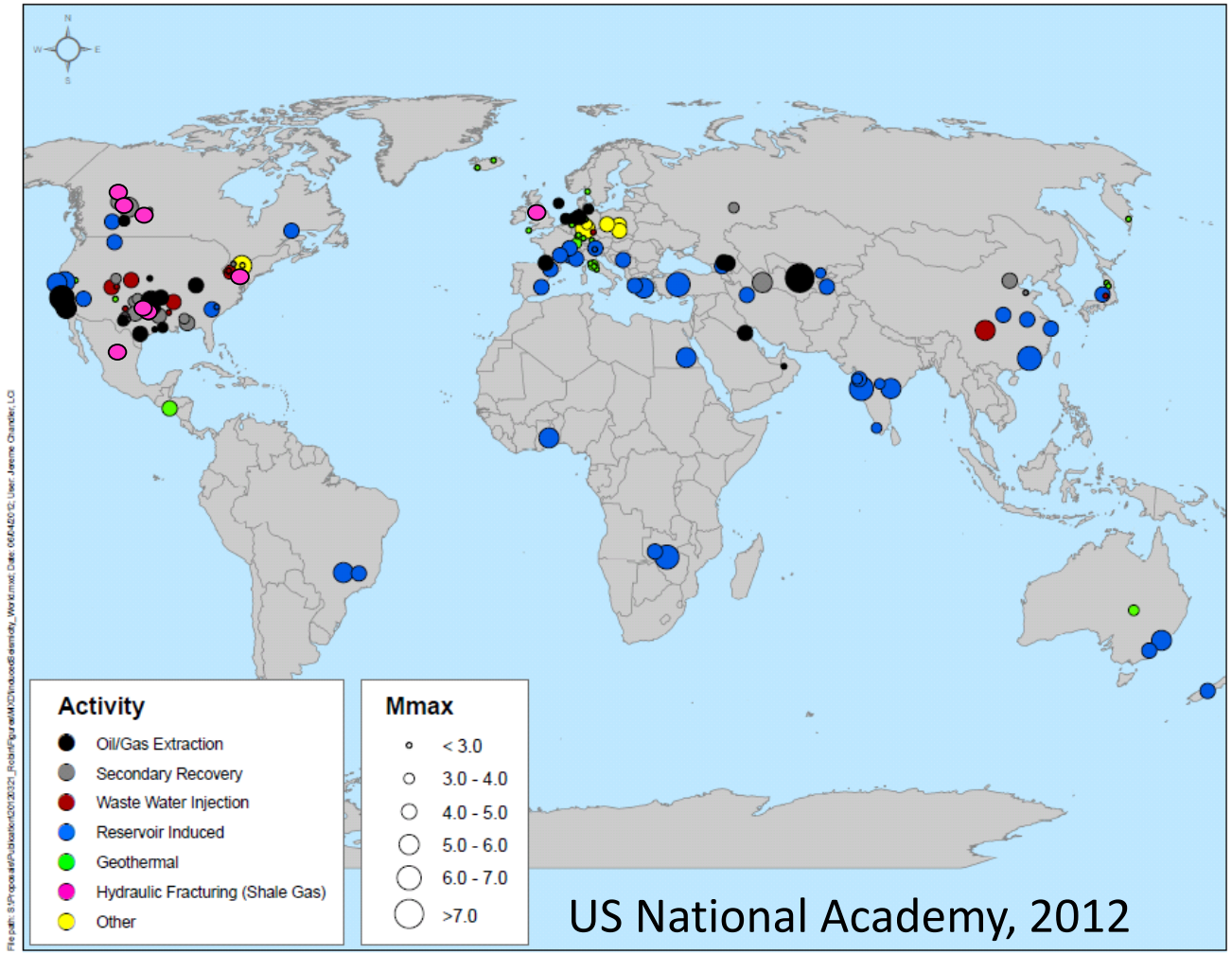
AGIS Induced Seismicity Workshop March 2015

IMaGE™

ITASCA Microseismic and Geomechanical Evaluation

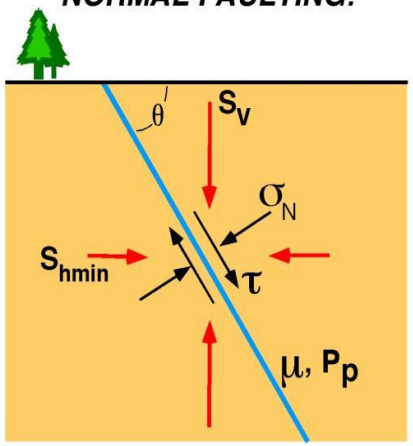
Induced/Triggered/Anomalous Seismicity



US National Academy, 2012

No damage and rare (several cases/70 felt events from 3,000,000 fracs)

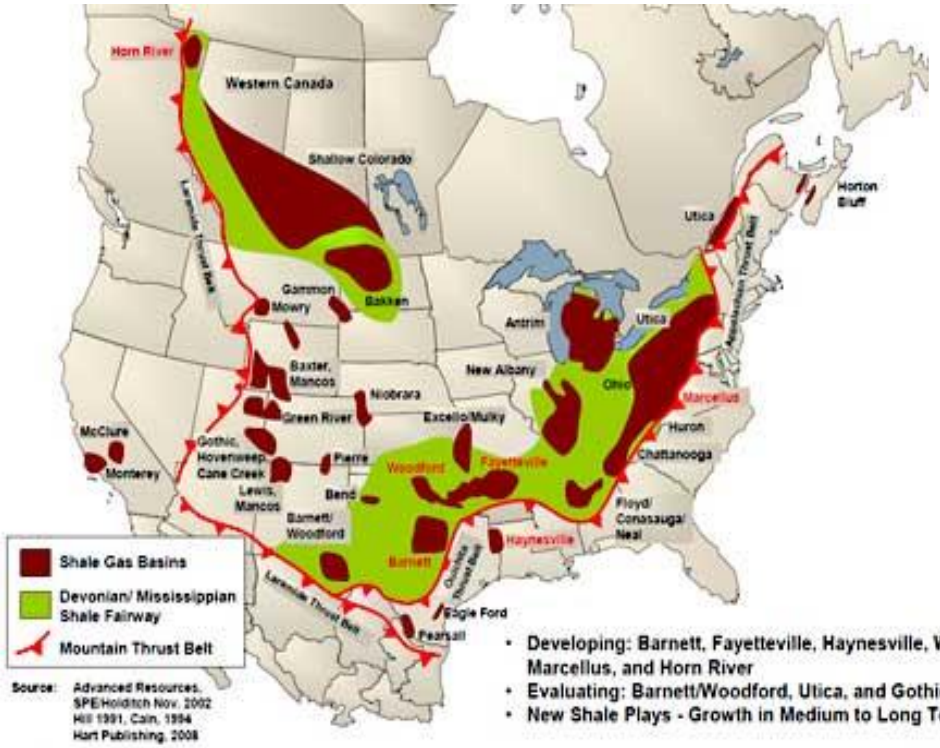
COULOMB FAILURE LAW, NORMAL FAULTING:

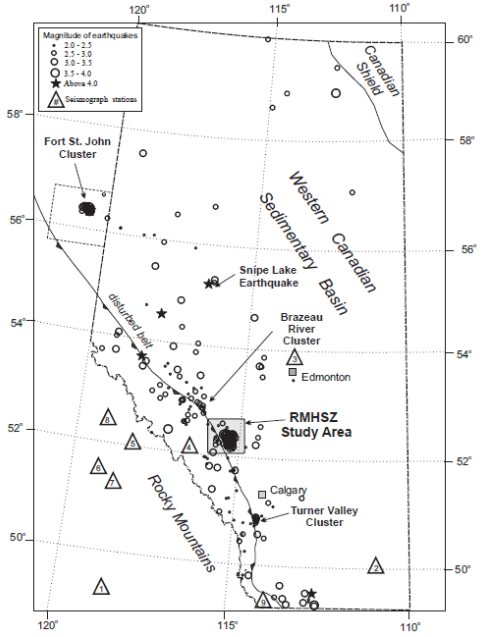


$\tau_{critical} = \mu (\sigma_N - P_p) + S$

μ = 0.6 - 1.0 (Byerlee's Law)

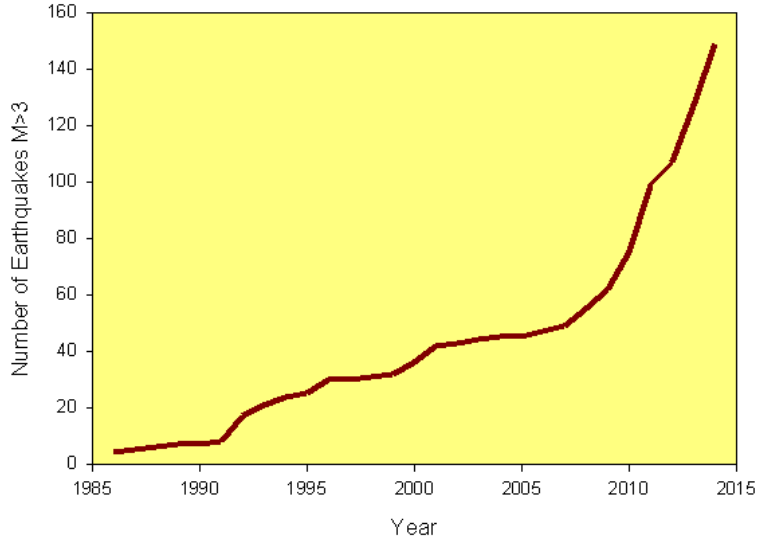
Western Canada Sedimentary Basin



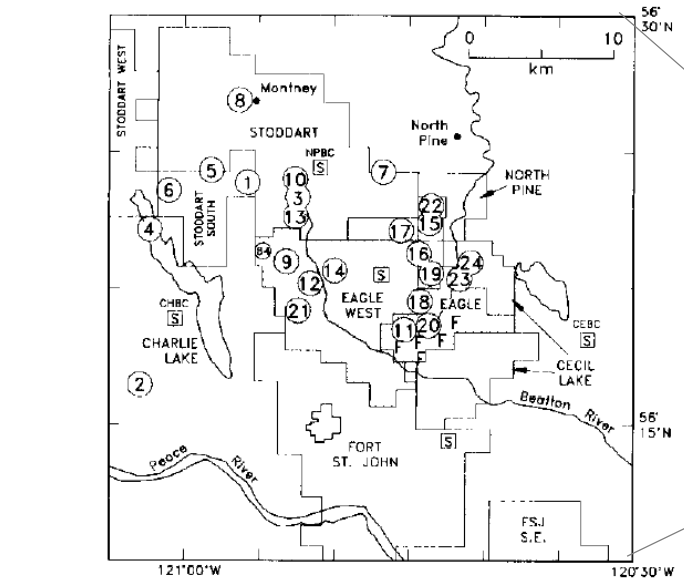


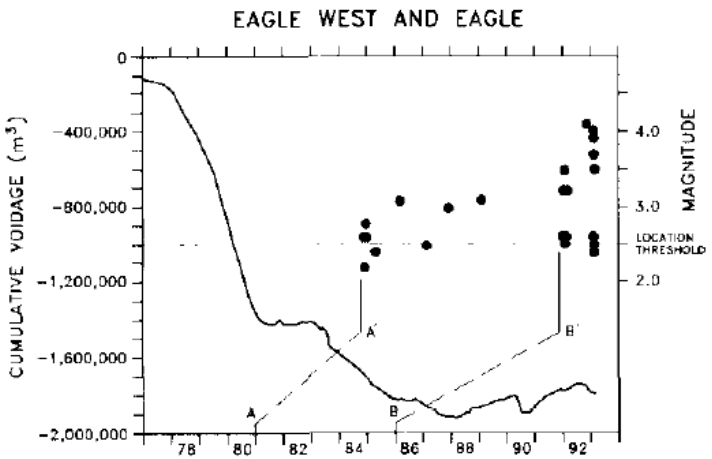
Baranova et al., 1999

NRCan Reported Earthquakes NEBC/NWAB

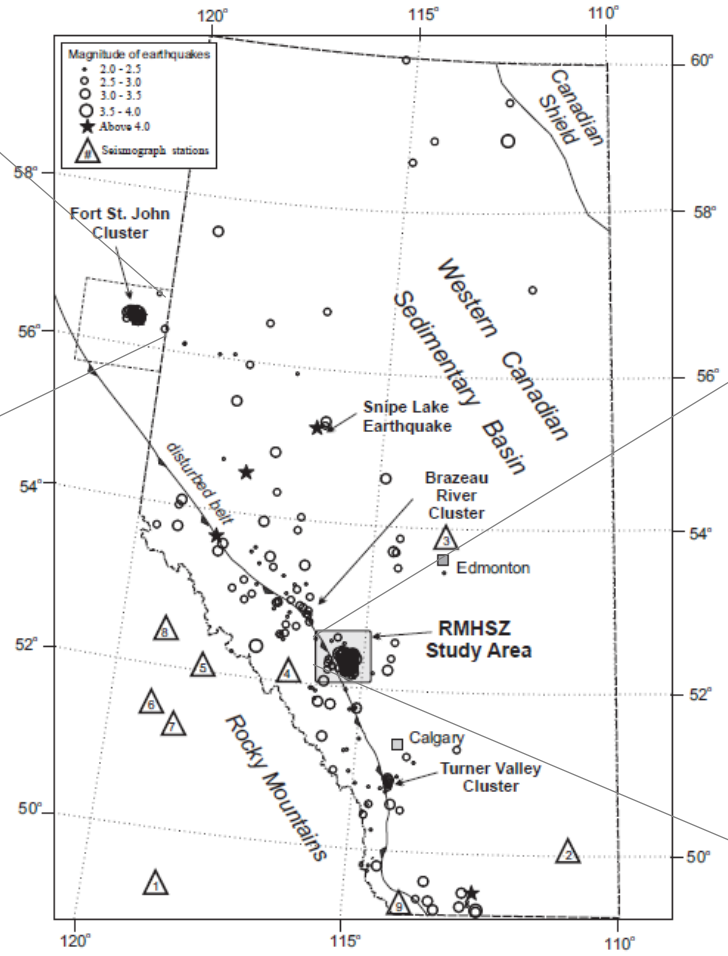


Early Examples of Induced Seismicity



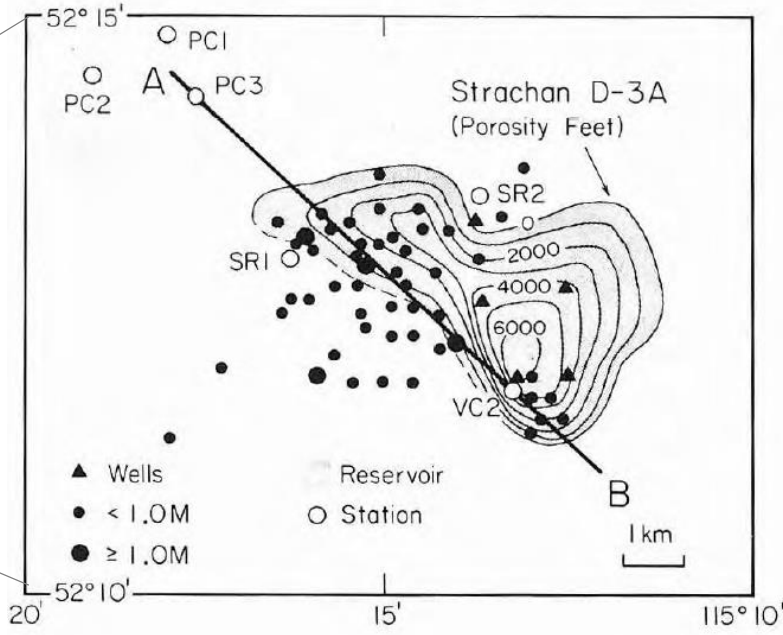


Horner el al., 1994

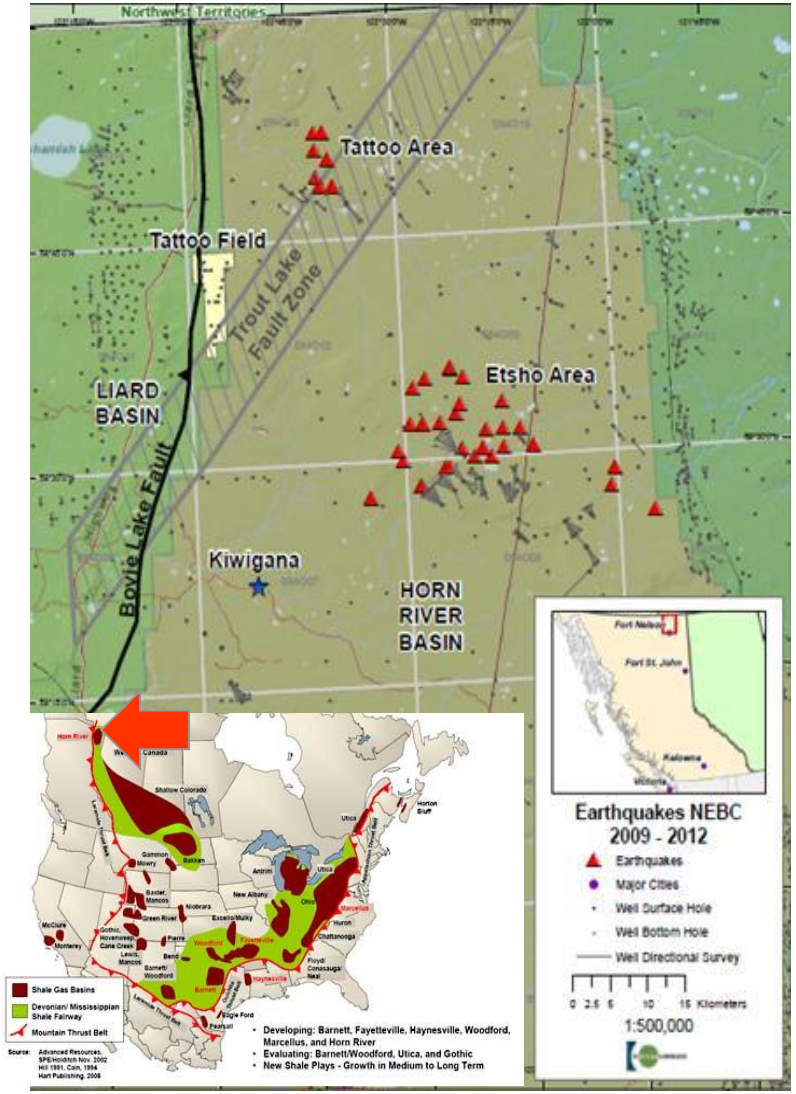


Baranova et al., 1999

Wetmiller, 1986



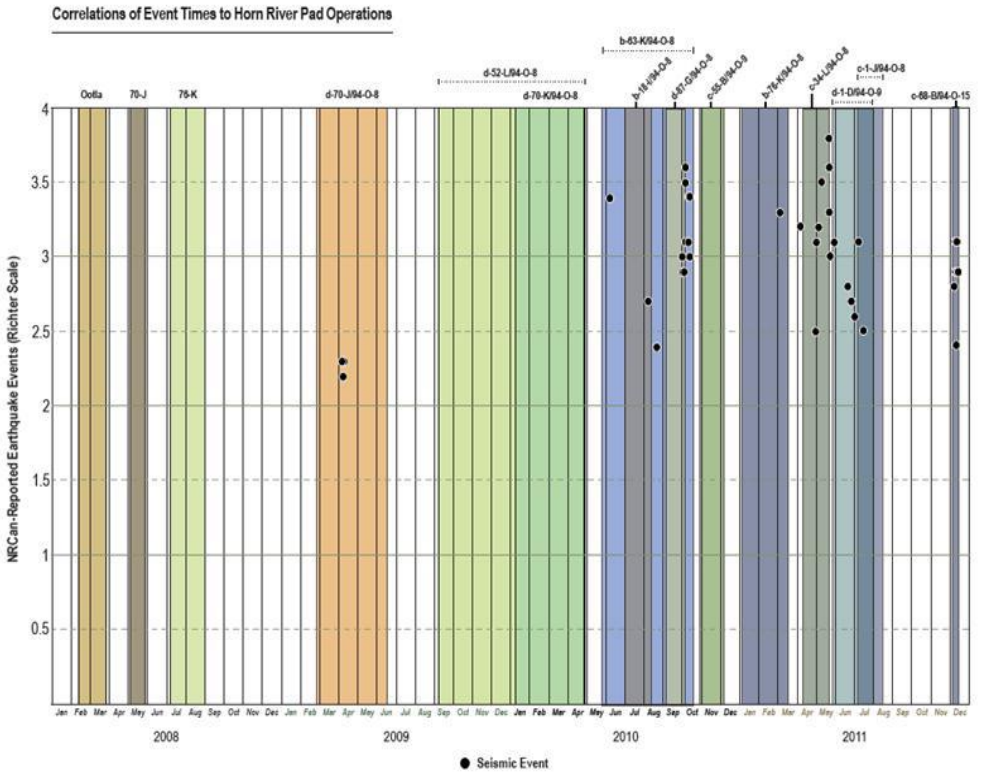
Horn River Basin NE BC Canada



BC Oil and Gas Commission Report

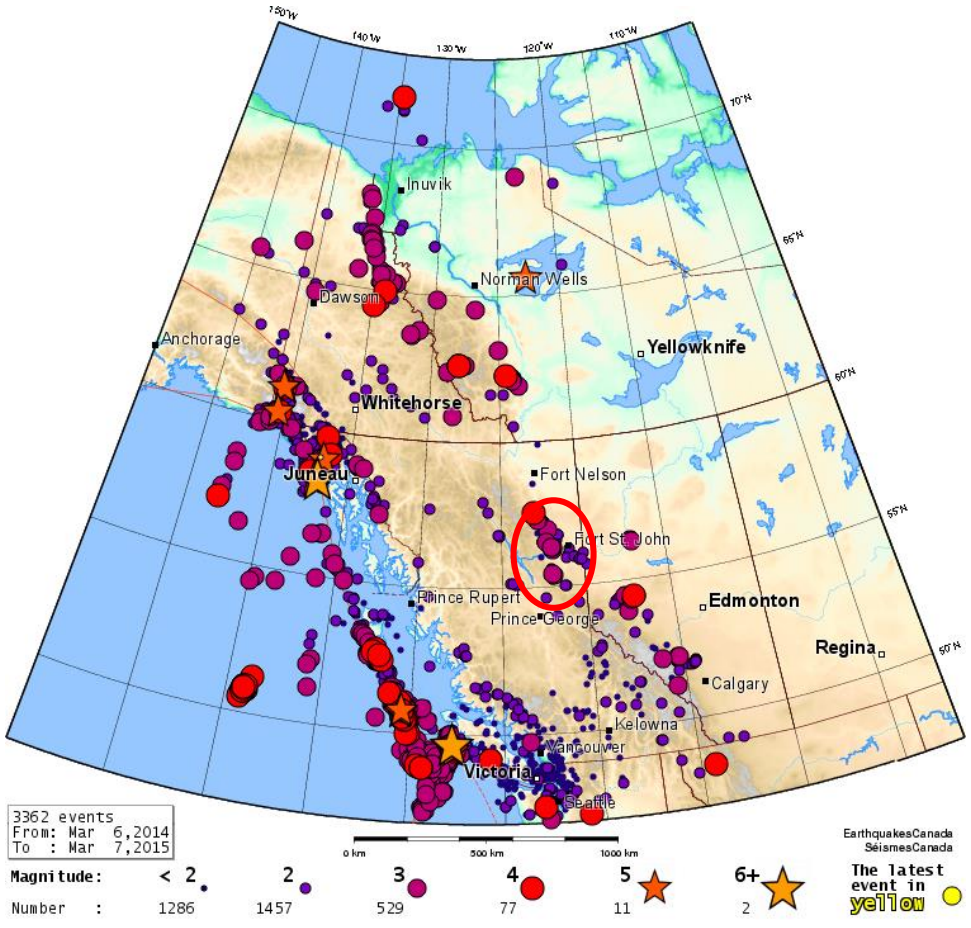
August 2012

38 events up to M_L 3.8

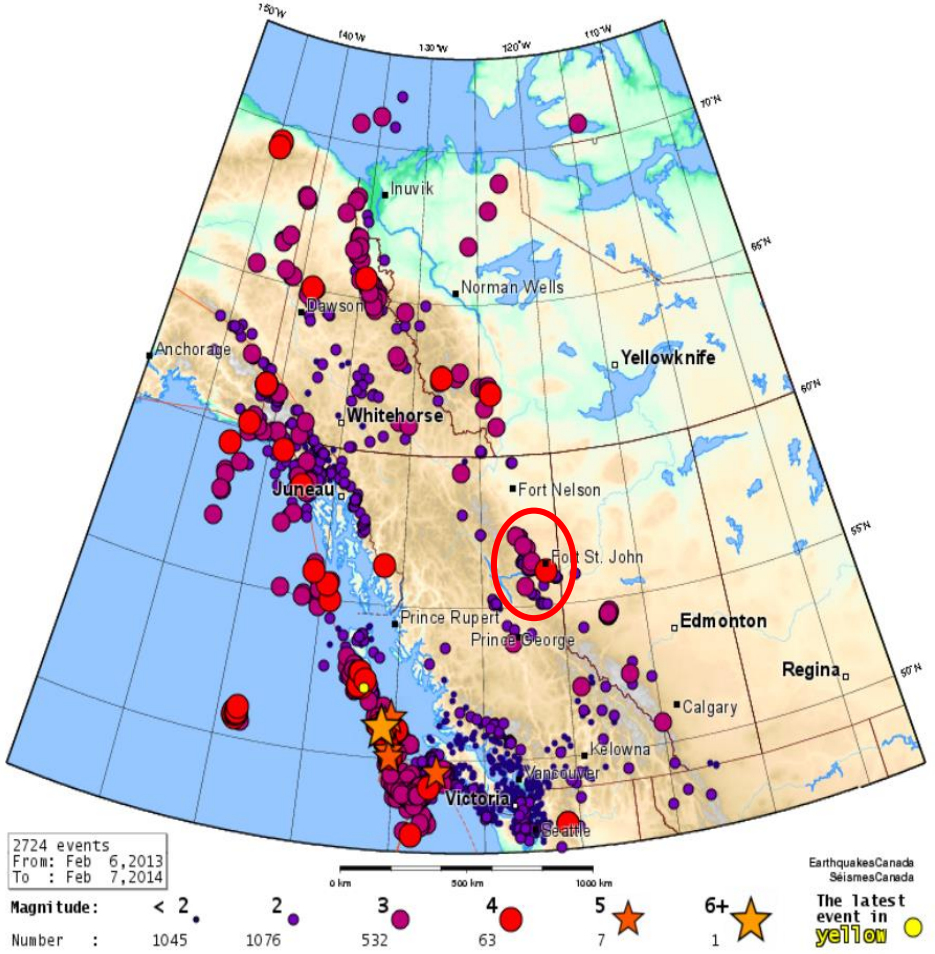


Recent Canadian Examples

Feb 2013 – Feb 2014

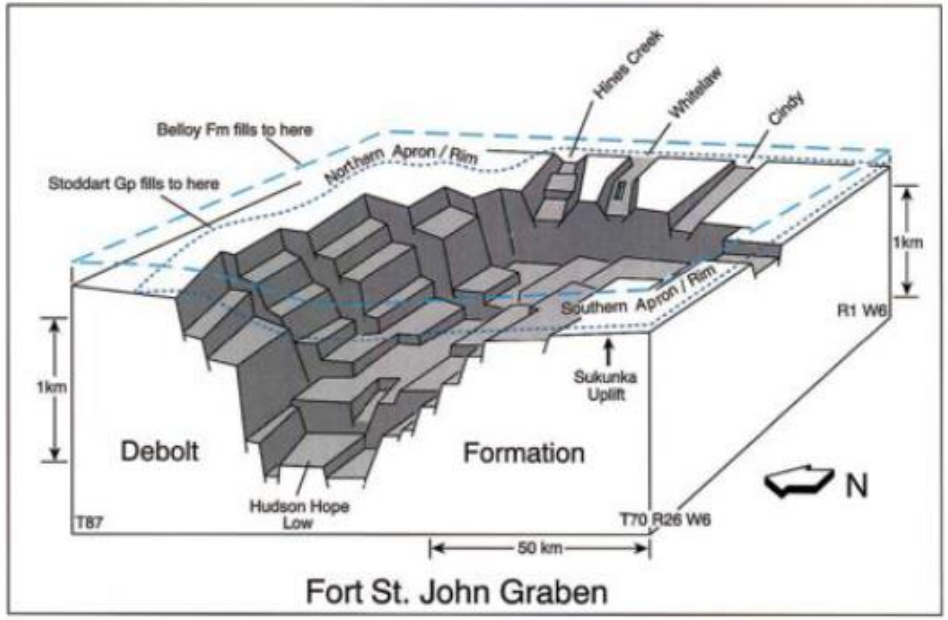


March 2014 – March 2015

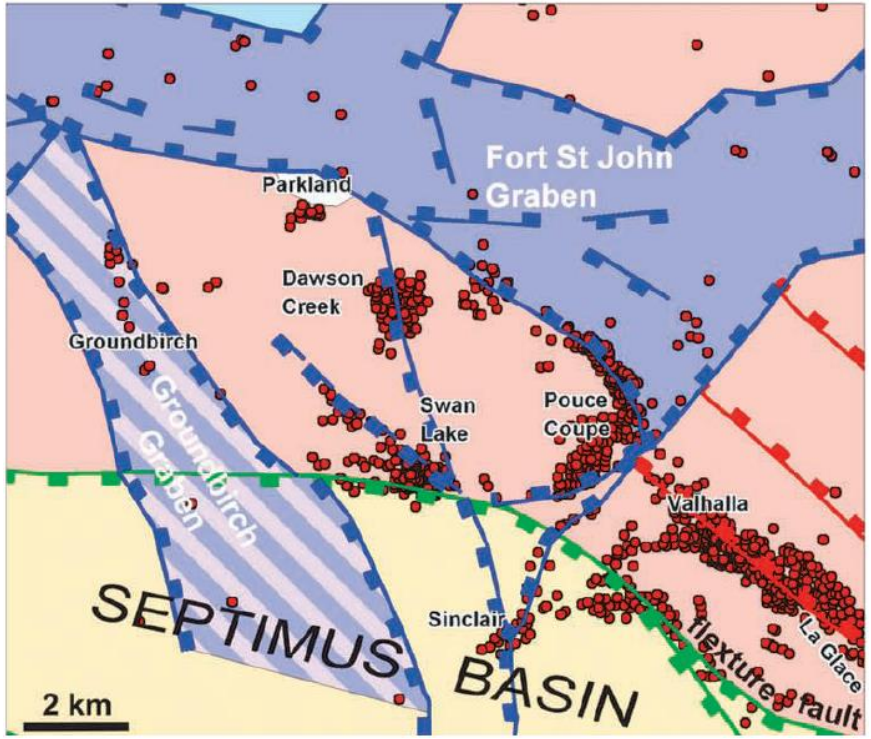


NRCAN website

Tectonic Setting: Montney

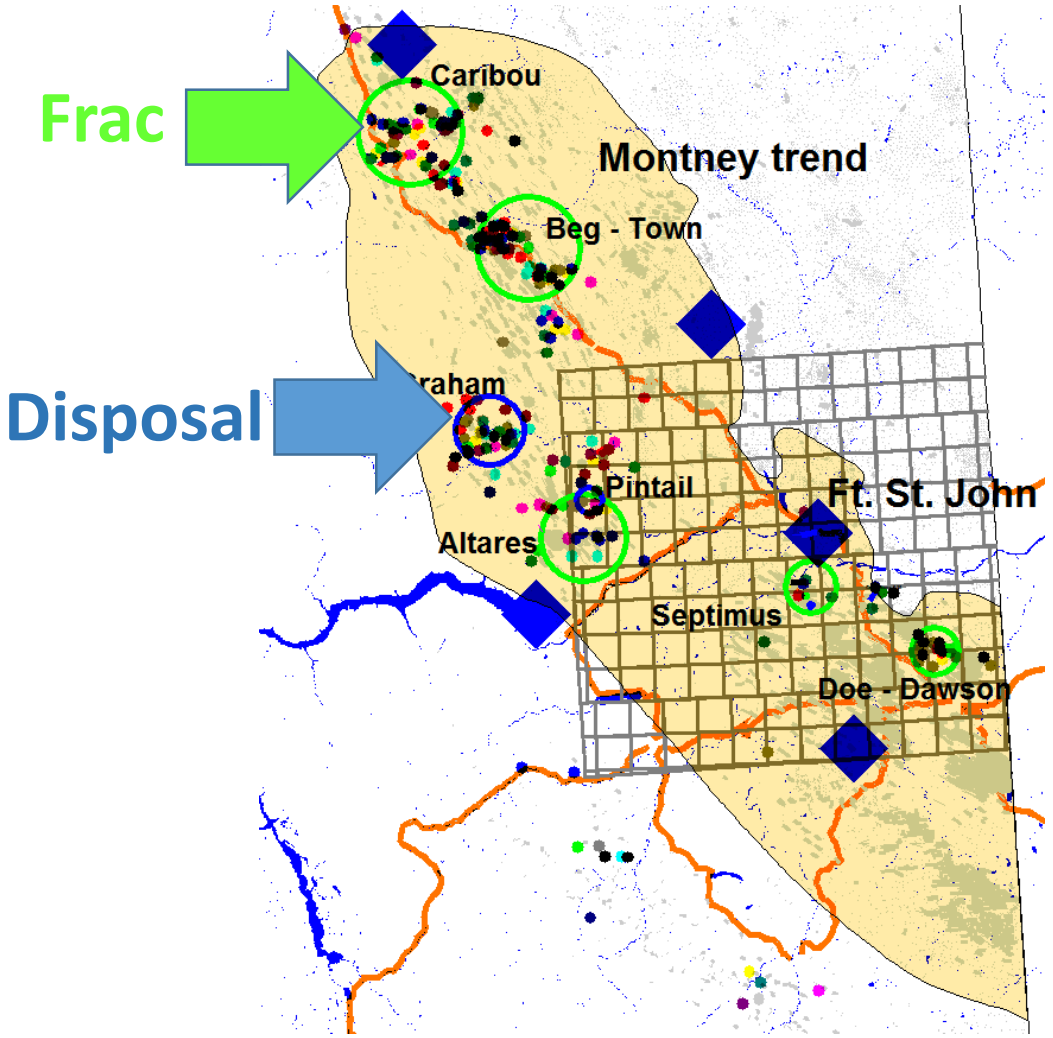


O'Connell 1994



Berger 2009

Montney Trend



BCOGC Report Dec 2014

Aug 1/13 to Oct 10/14 293 events

Magnitudes 1 to 4.4 M_L

38 Waste injection events

193 Hydraulic fracturing events

450 wells/7,500 stages

700-3,500m^3/stage

2.6% stages cause events

“Encouraged” to monitor

CAPP Guidelines/Industry Protocols

Assess Hazard

- Geomechanical conditions
- Past seismicity
- Local experiences
- Risk (public/infrastructure)

Avoid Faults

- Alter well design
- Alter staging

Communicate/ Prepare

- Mitigation plan
- Authorize reaction

Monitor

- Traffic light system
- Induced seismicity

Respond (Mitigate)

- Elevate process
- Alter pumping

BCOGC

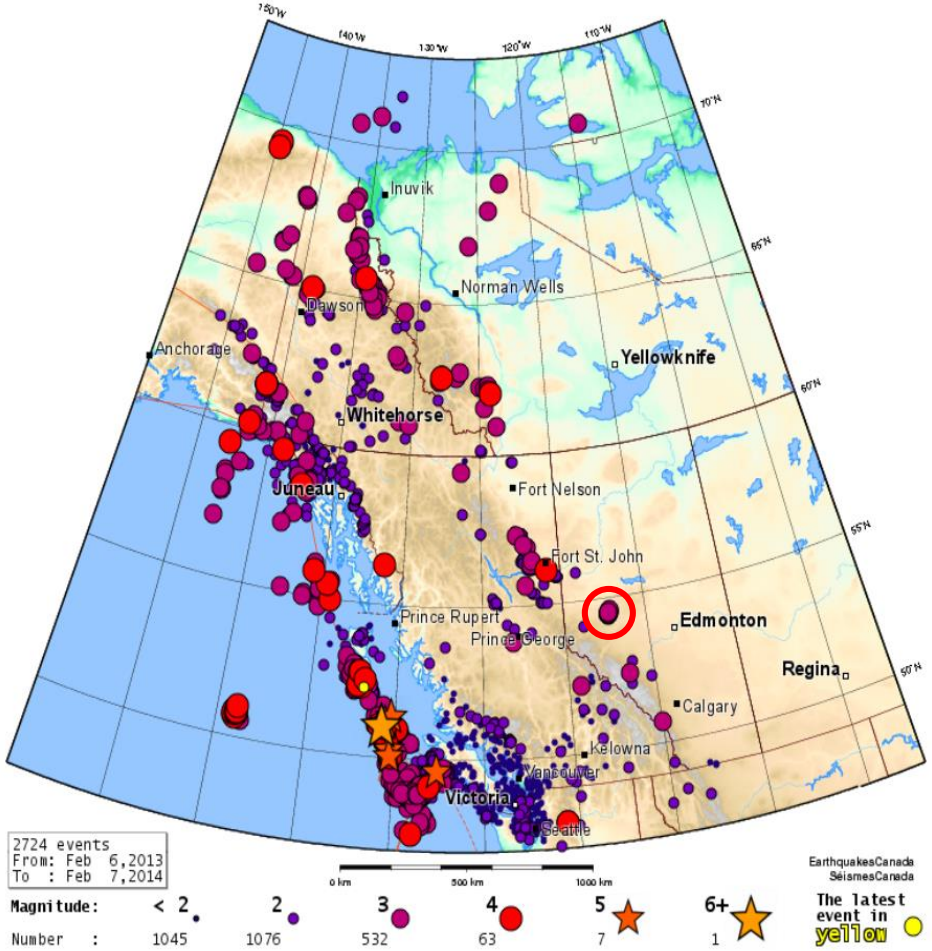
>M 4

M 2-4

<M 2

Recent Canadian Examples

Feb 2013 – Feb 2014



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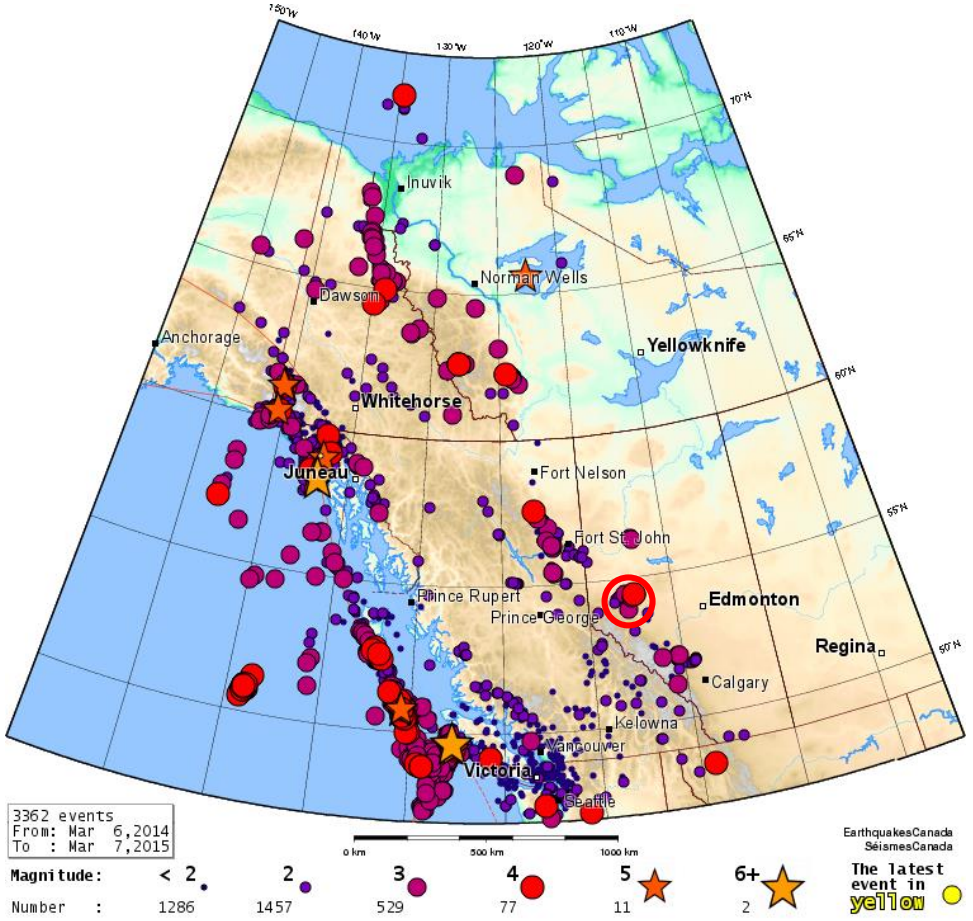
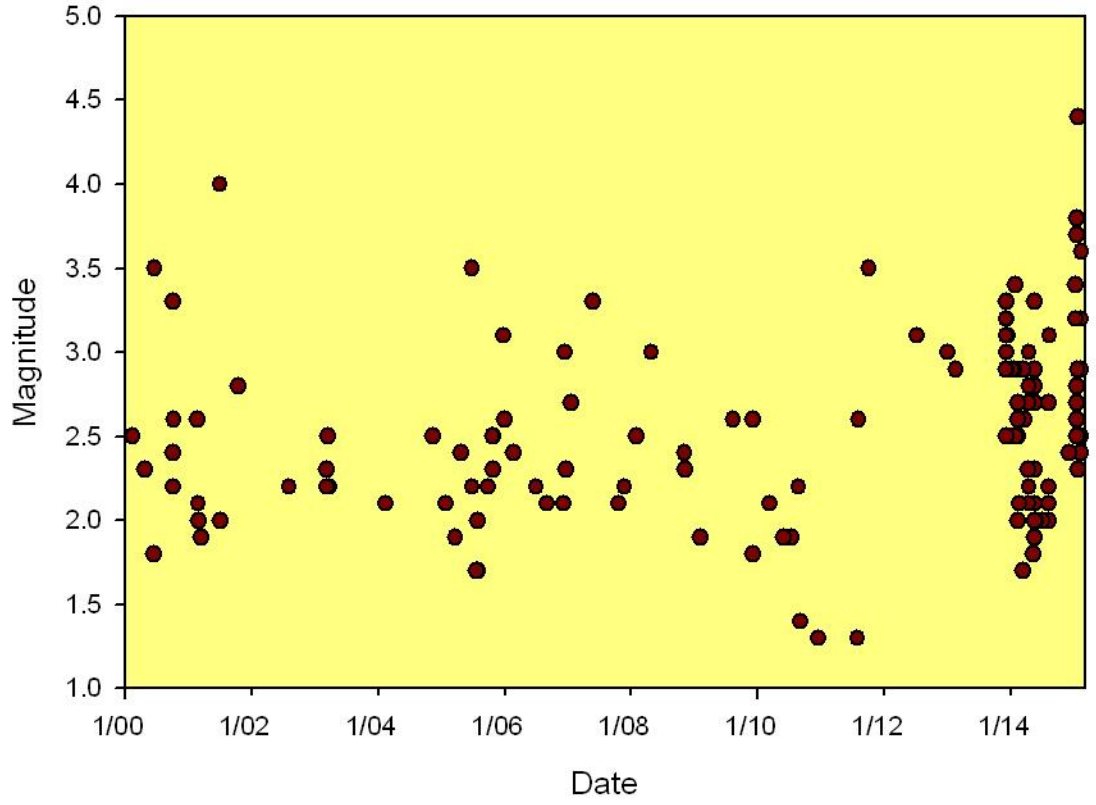


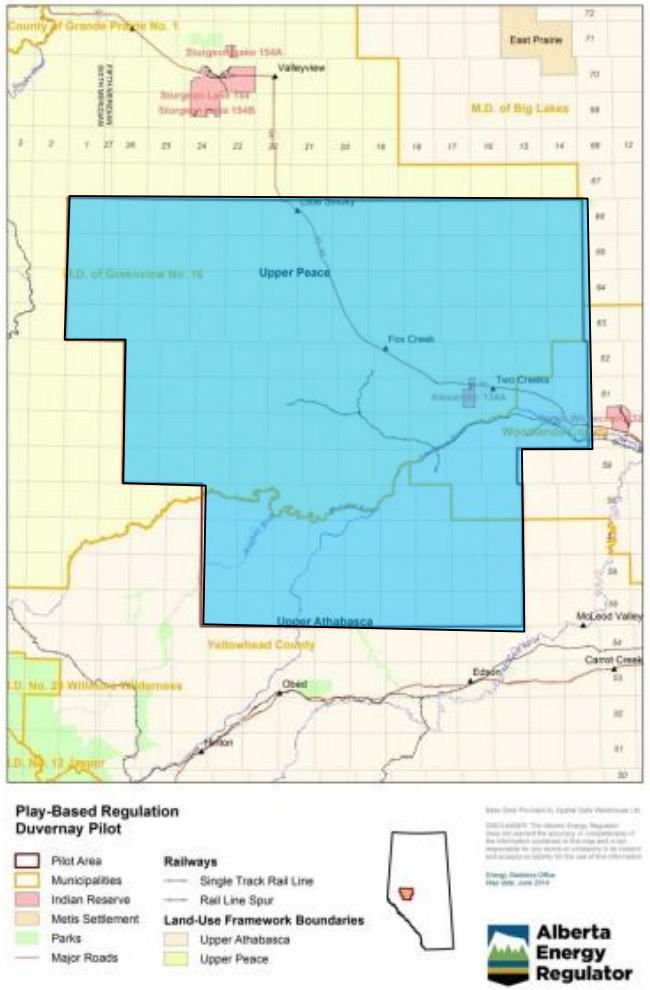
NRCAN website

Duvernay Shale: Seismicity with time



NRCAN website

Alberta Energy Regulator: Duvernay

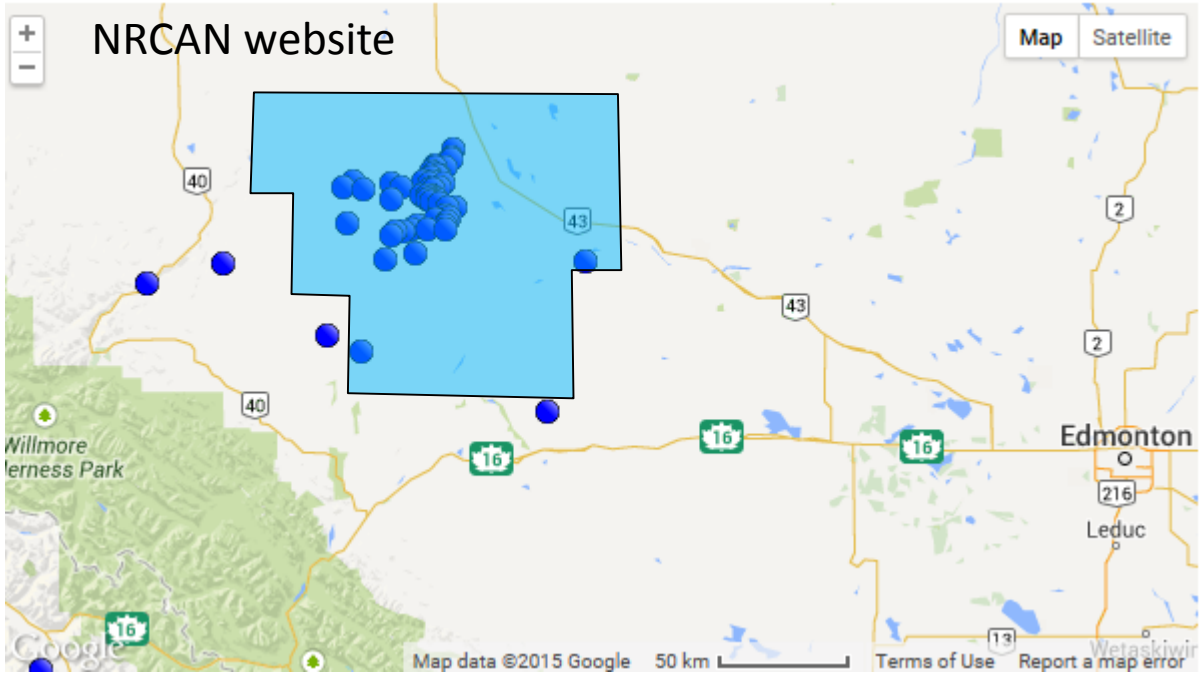


AER/BCOGC

>M 4

M 2-4

<M 2



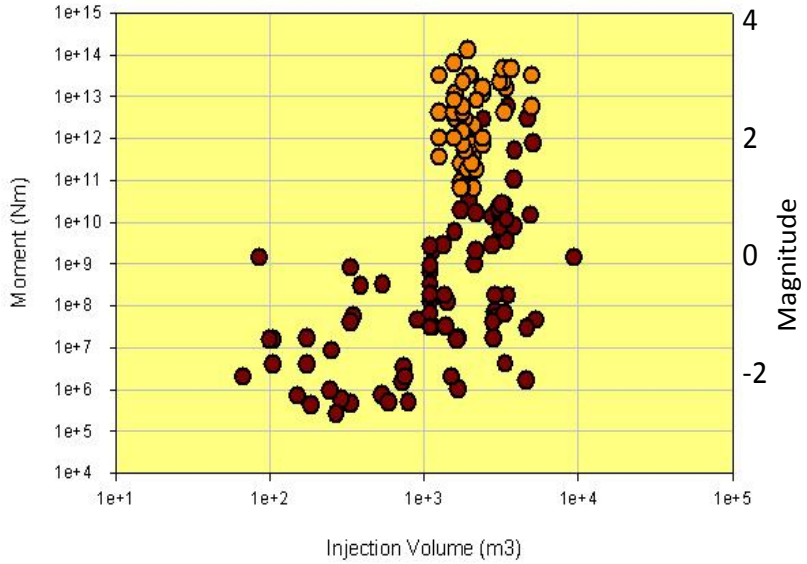
AER Subsurface order 2015-007: Mandatory monitoring to at least M_L 2

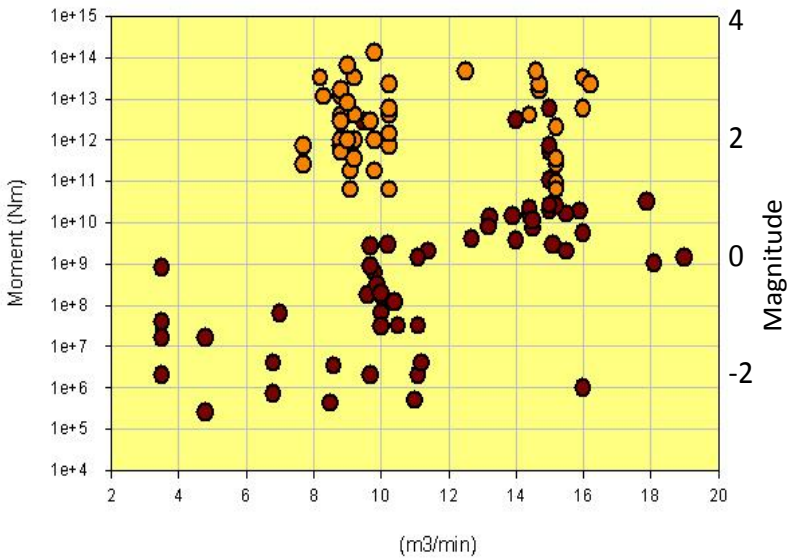
Impact of Operation Changes

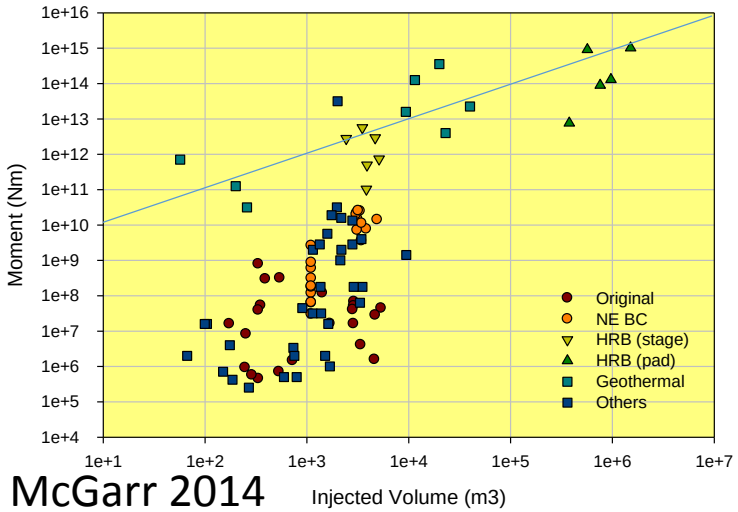
- Change rate?
- Change volume?
- Skip stages?
- Shut down?
- Flow back?

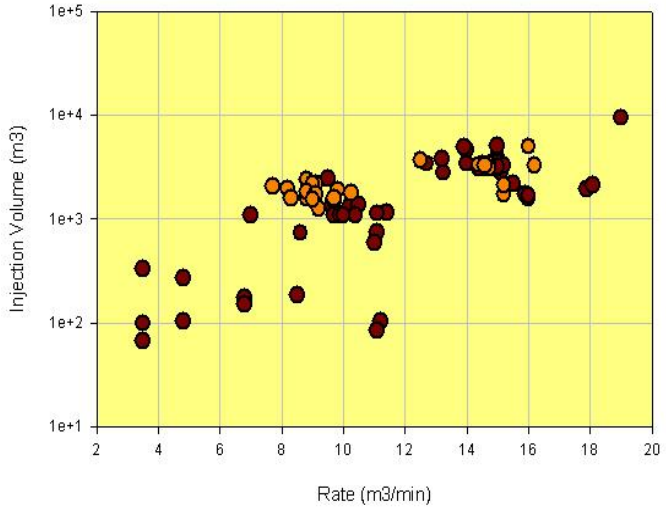
AER Subsurface order 2015-007: M>2 .. "*must* implement its induced seismicity plan in a manner that eliminates or reduces further seismic events caused by or resulting from hydraulic fracturing operations."

Changing Injection Parameters





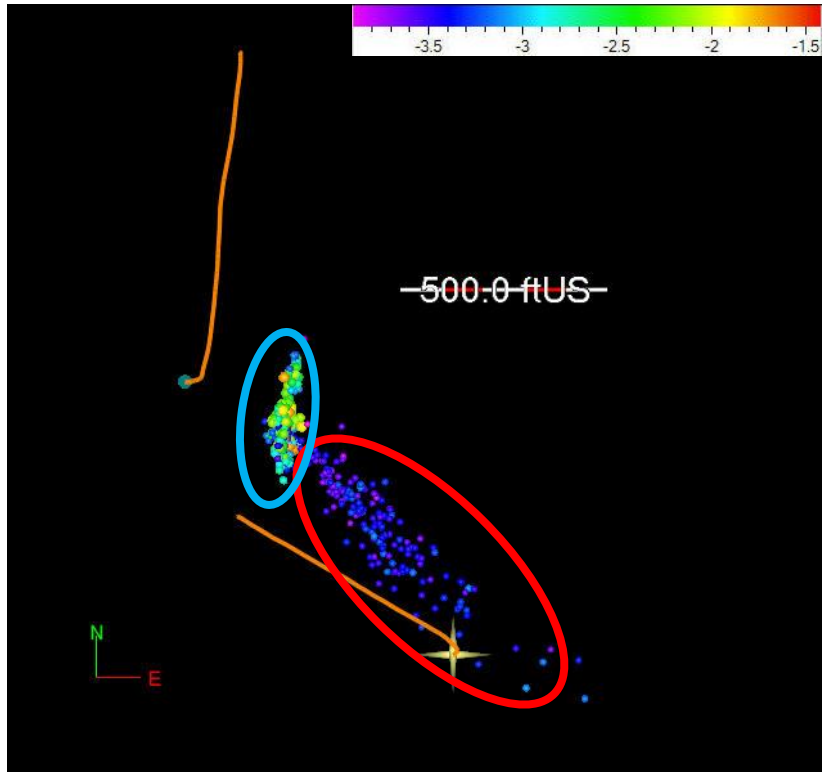




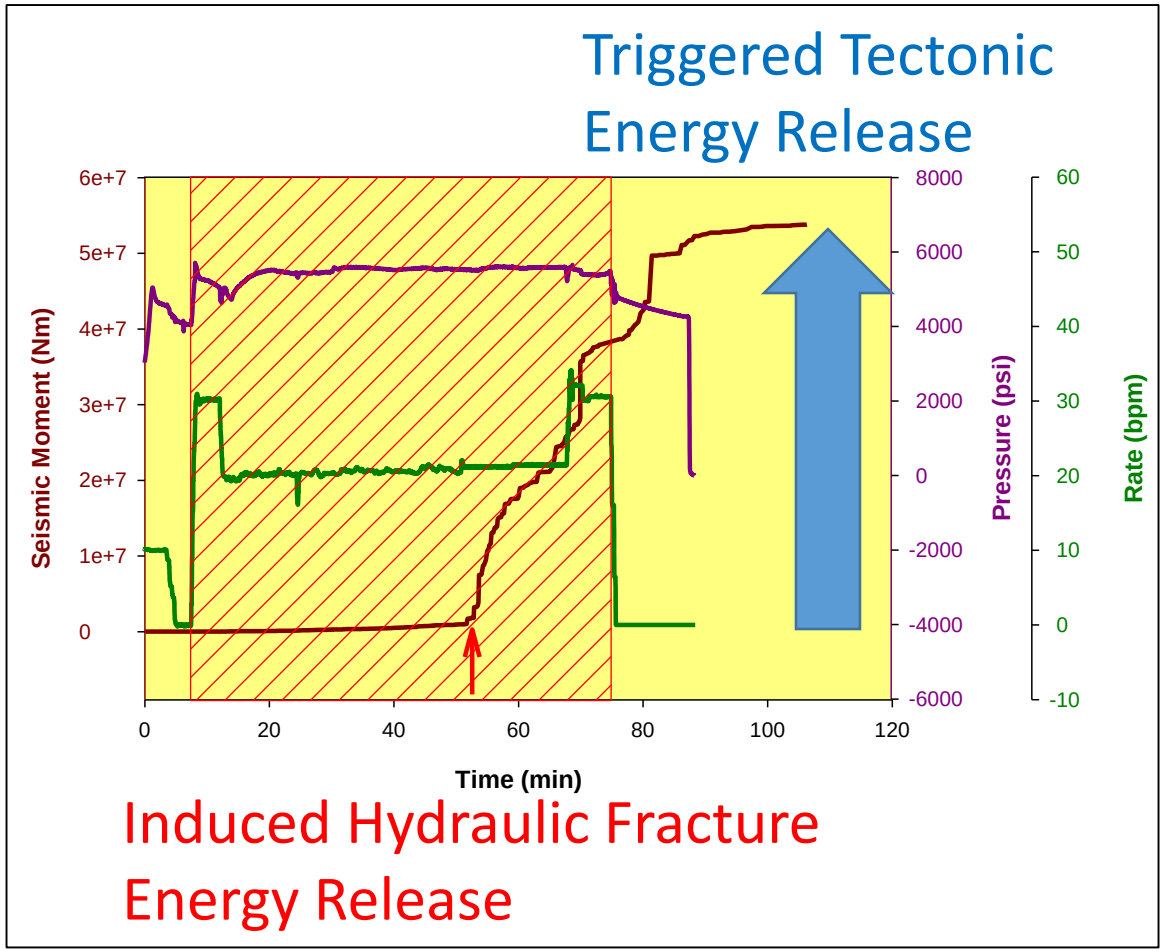
Orange symbols: Montney induced seismicity
Courtesy Dan Walker BCOGC

e.g. McGarr 2014

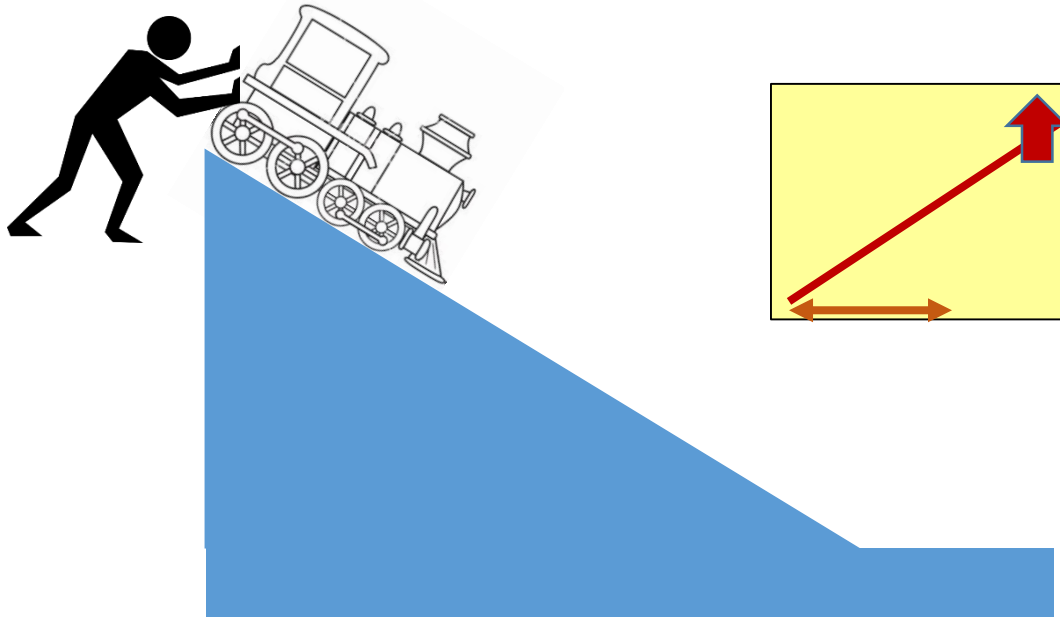
Microseismic Fault Activation Example

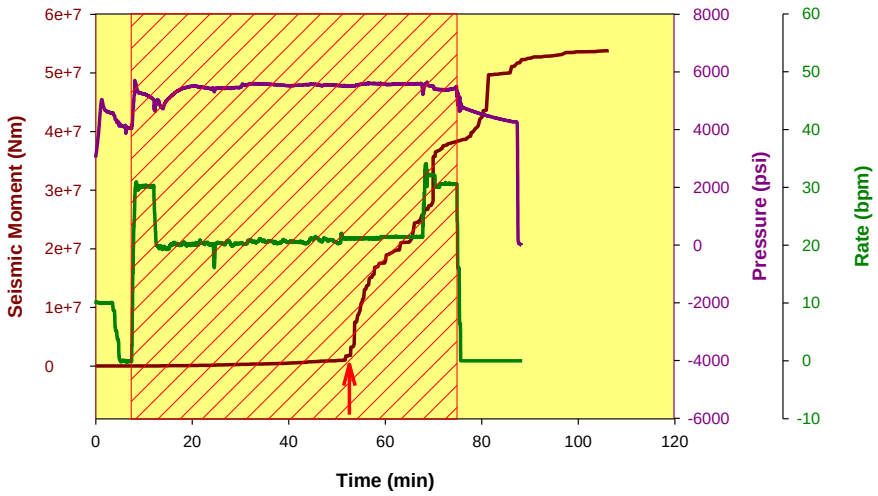


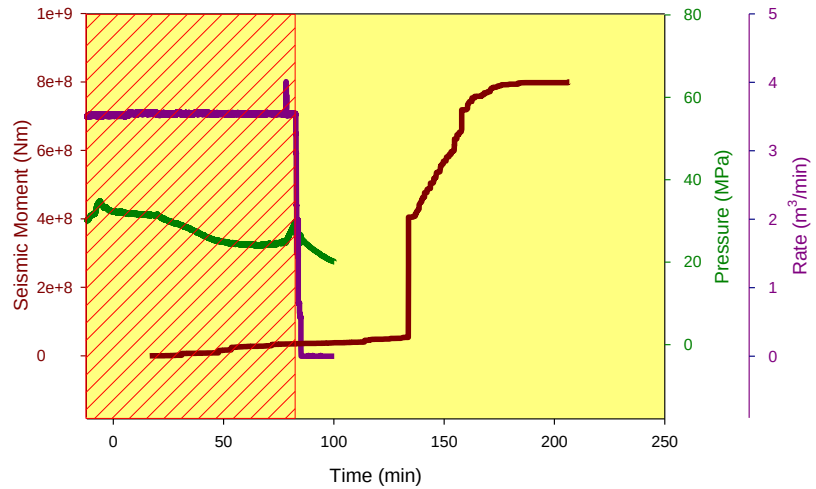
SPE116596



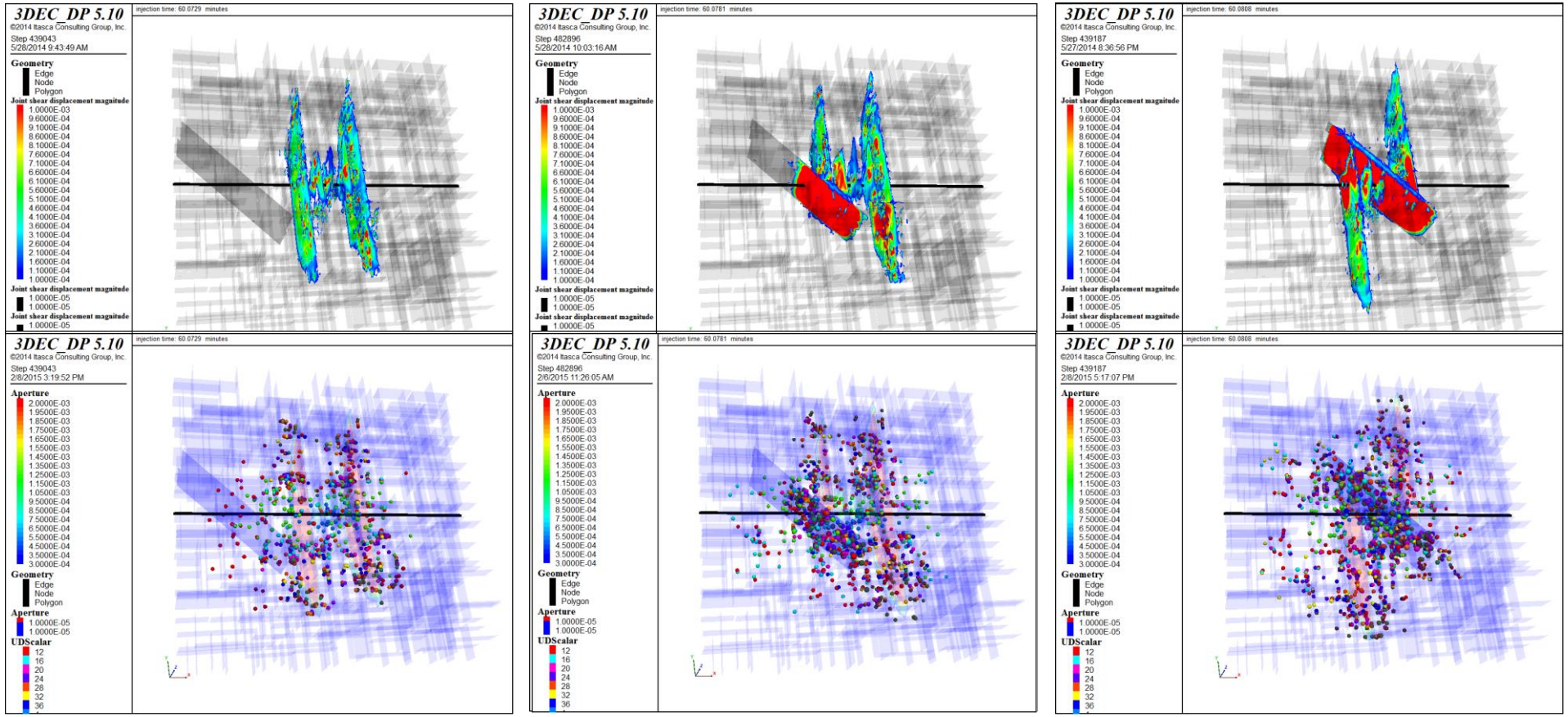
Energy Release Rate Trends







Induced Seismicity Application: Fault Activation



Key Questions

Definition of ‘best practices’

How can we better characterize (hazard)?

Reliability of traffic light systems?

Cumulative effect of repeated fracturing?

What is the effectiveness of various mitigation options?

Does $50 oil reduce hazard??