Natural Resources Canada's Induced Seismicity Research

Honn Kao
Geological Survey of Canada

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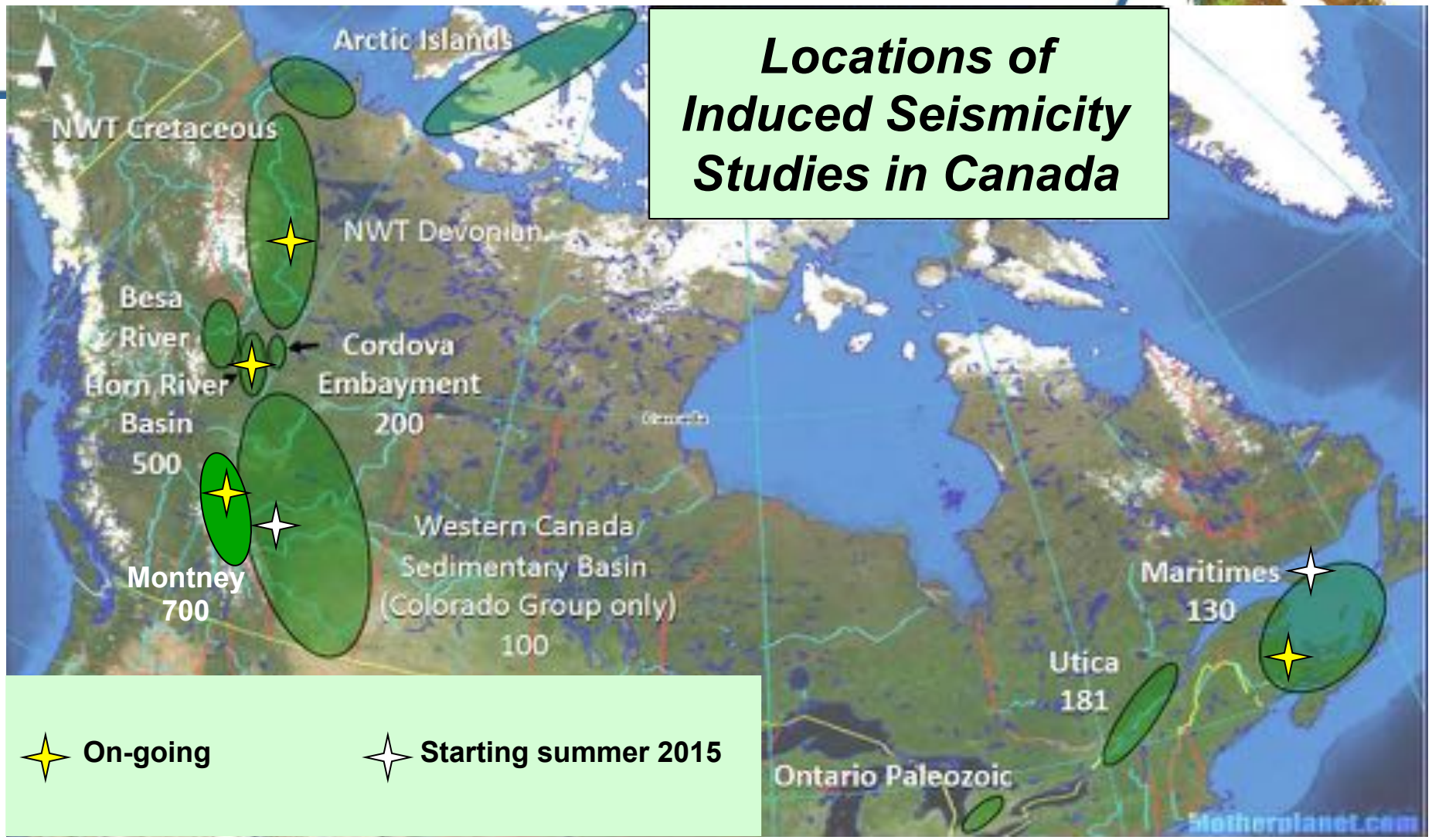
Contributors: Amir M. Farahbod, John F. Cassidy, Maurice Lamontagne, David Snyder, Denis Lavoie

Natural Resources Canada | Ressources naturelles Canada

Canada

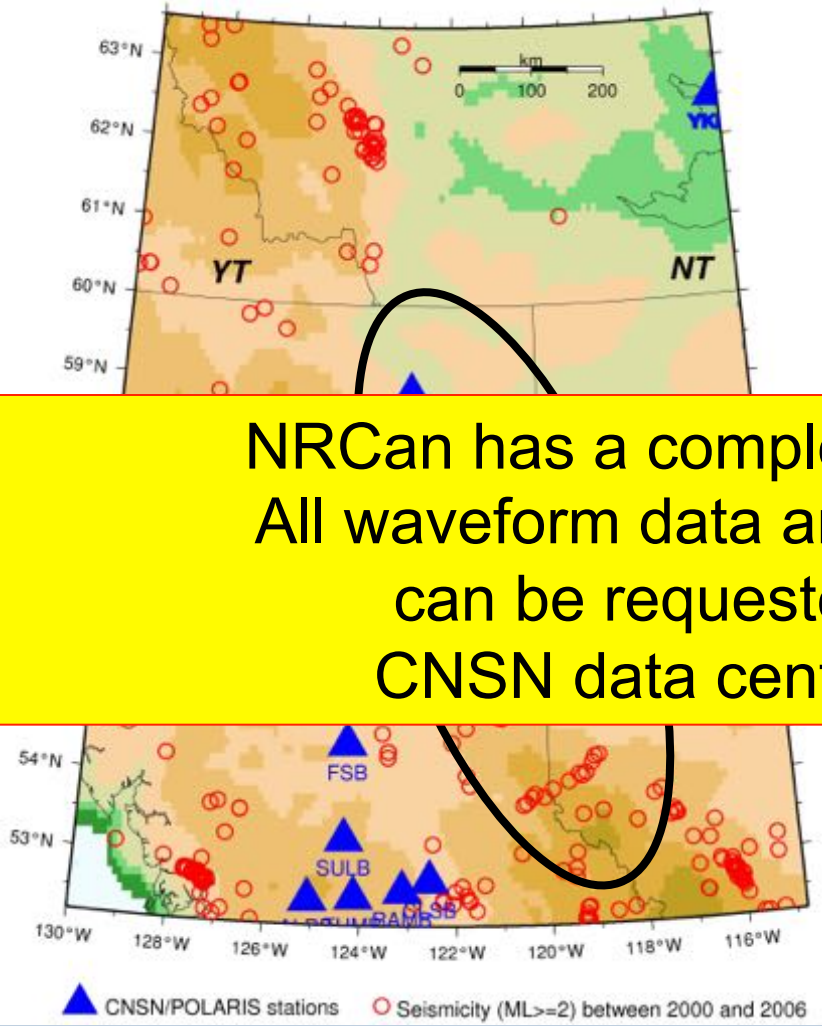
Project Goals and Outlines

- Initiated in 2012 with both internal and external funding sources
- A coordinated effort involving both public and private sectors to address critical knowledge gaps in induced seismicity related to unconventional shale gas development
- Improved earthquake monitoring for major shale gas production areas
- Detailed studies of background seismicity to establish pre-development reference lines
- Focused case studies to examine pre-/post-development variations

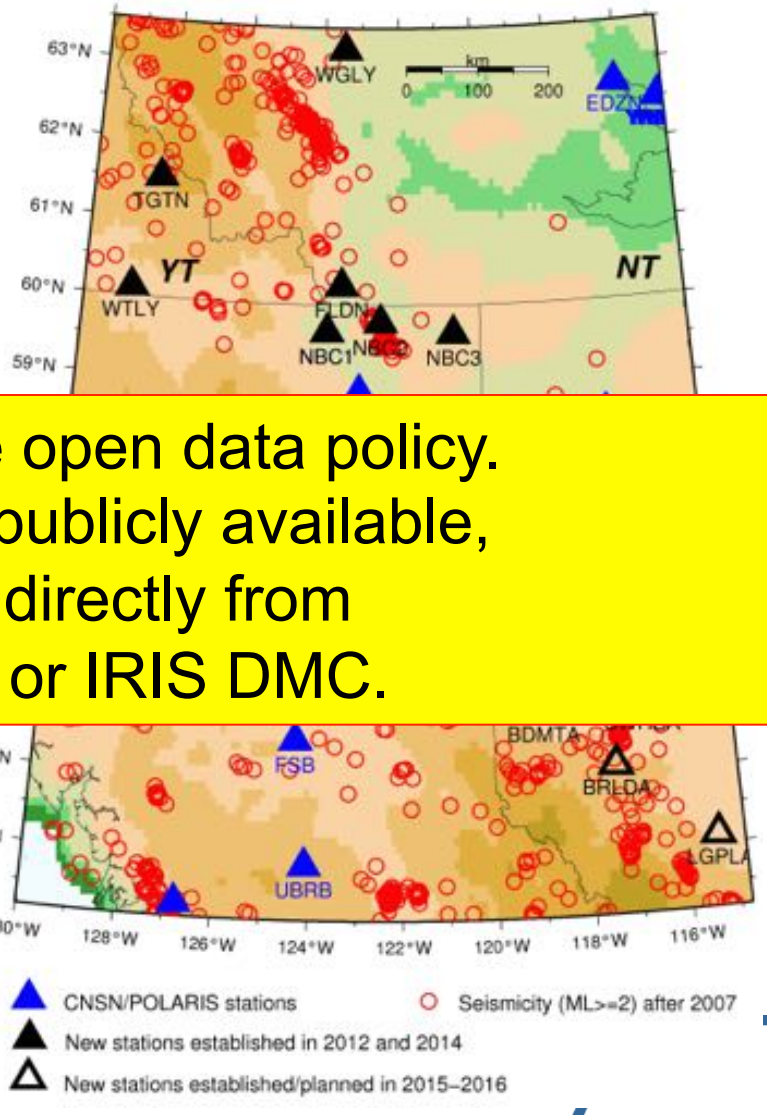

Locations of Induced Seismicity Studies in Canada
Arctic Islands
NWT Cretaceous
NWT Devonian
Besa River
Horn River Basin
500
Cordova Embayment
200
Western Canada Sedimentary Basin (Colorado Group only)
100
Montney
700
Maritimes
130
Utica
181
Ontario Paleozoic
On-going
Starting summer 2015

Northeast BC and Western AB

Seismic stations before 2012

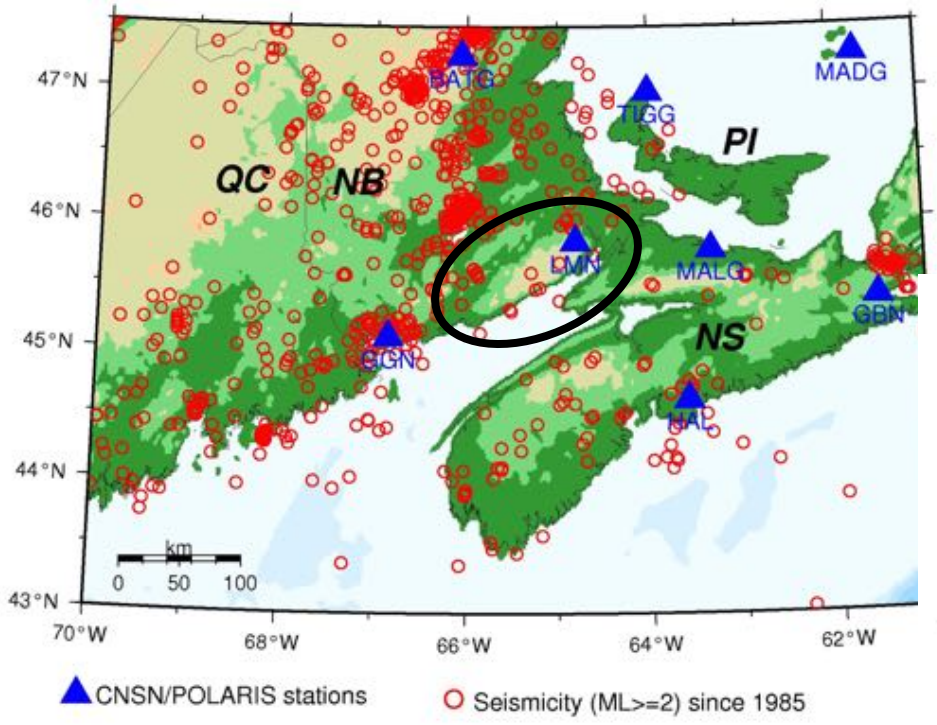


Seismic stations now and future



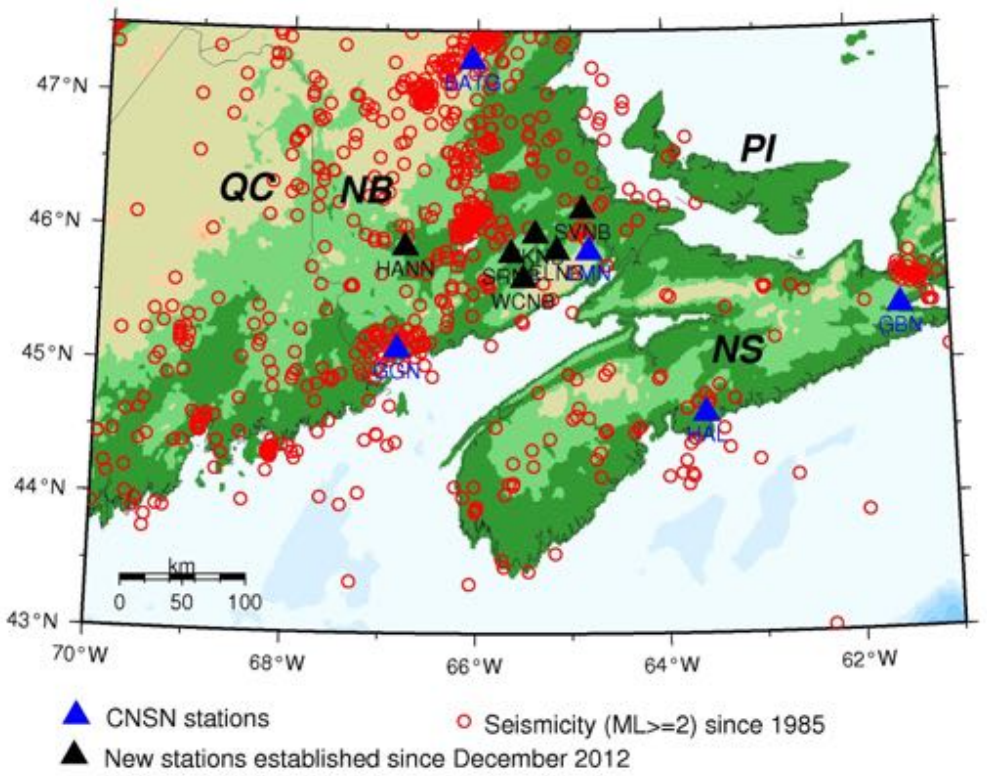
NRCan has a complete open data policy.
All waveform data are publicly available,
can be requested directly from
CNSN data center or IRIS DMC.

Sussex Basin, New Brunswick



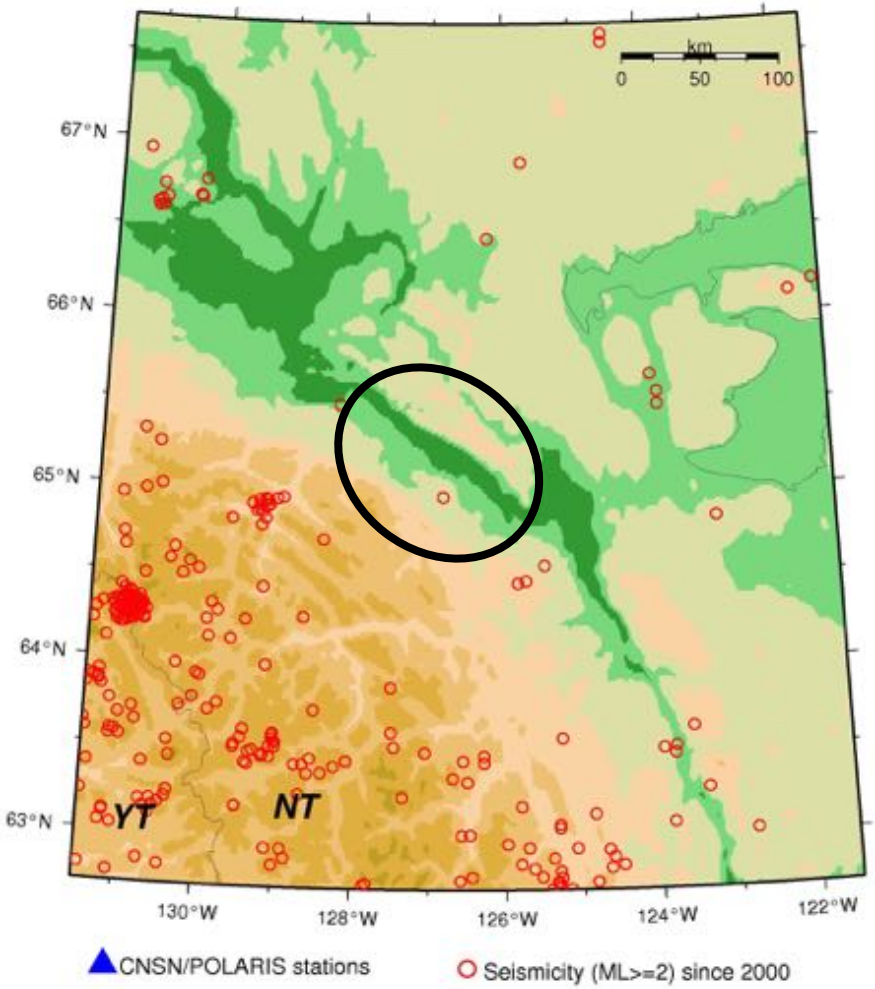
Seismic stations before 2012

Seismic stations now

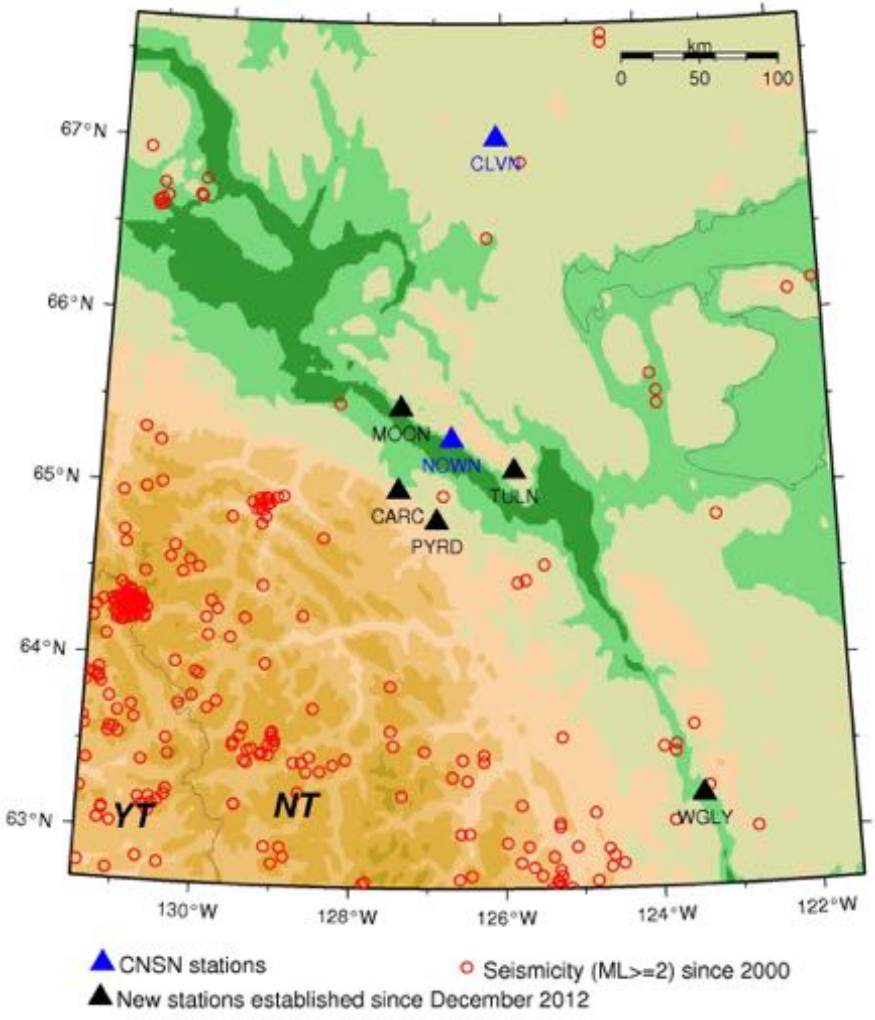


Norman Wells, Northwest Territories

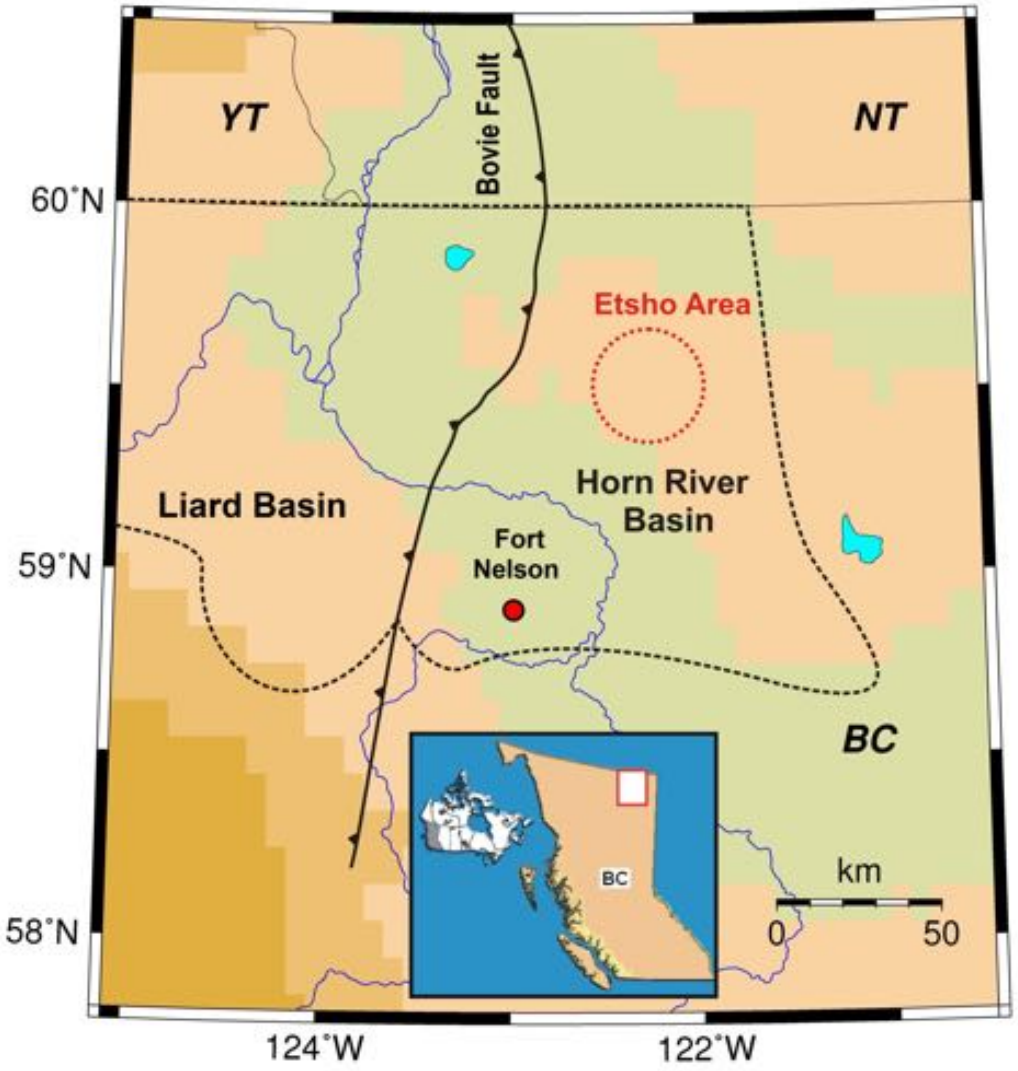
Seismic stations before 2012



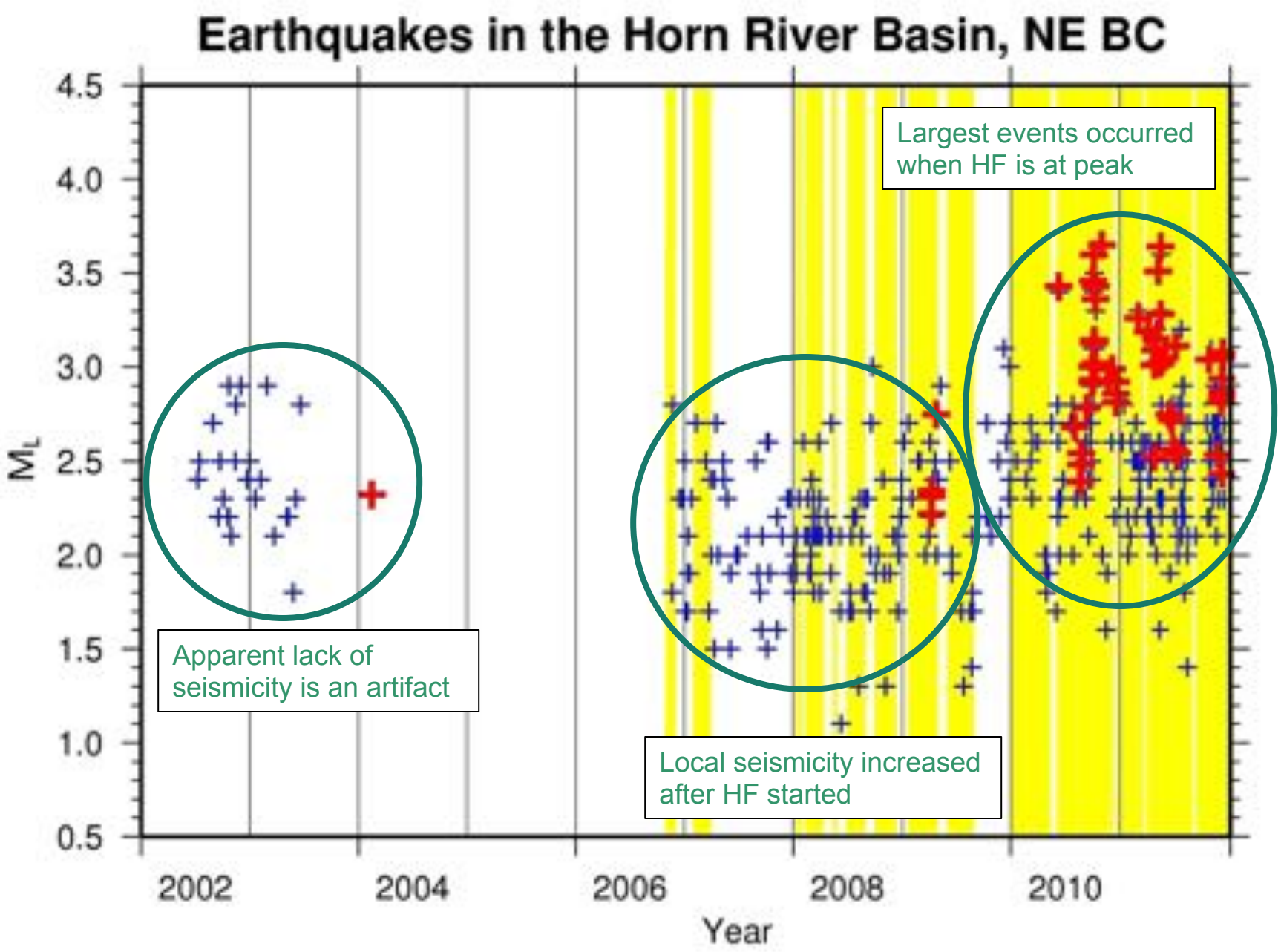
Seismic stations now



Case Study: Horn River Basin, BC



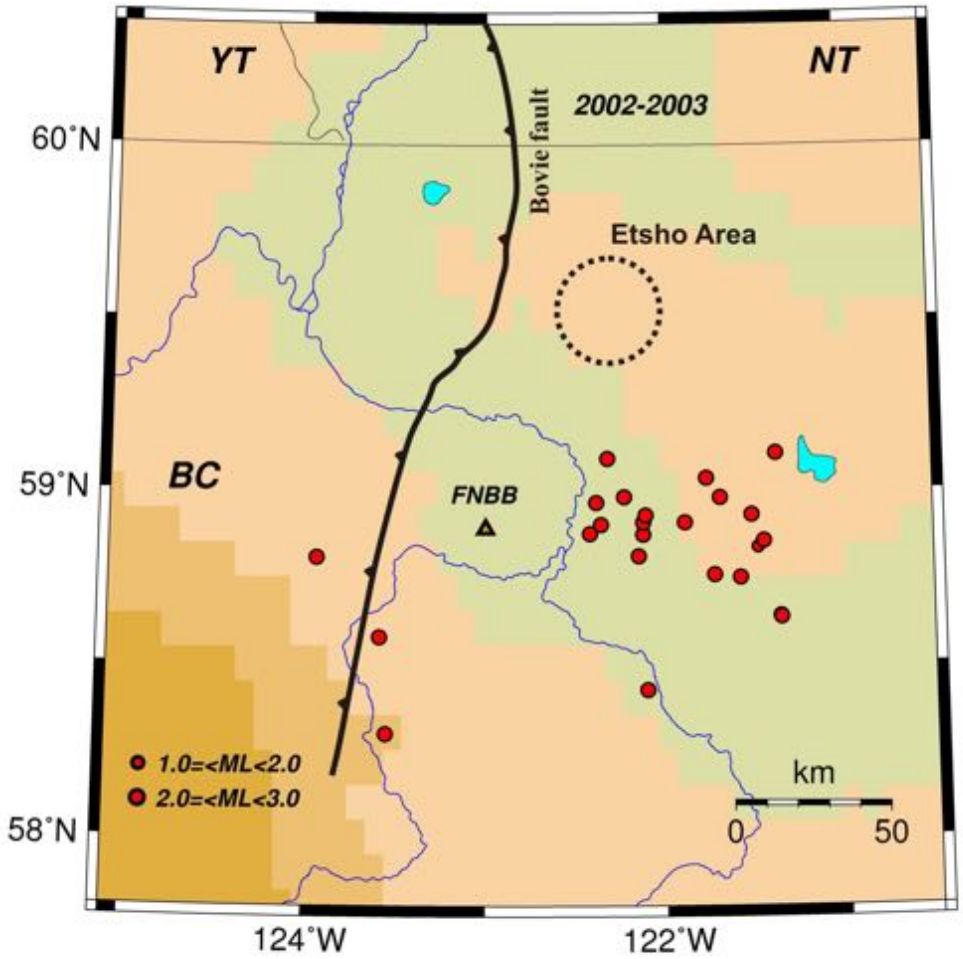
- A major shale gas production area in British Columbia
- Hydraulic fracturing started in as early as late-2006
- Most HF operations in the Etsho area
- Peak shale gas production in 2010 and 2011
- Historically, this area had few earthquakes.



Farahbod et al. (2014, 2015)

Seismic Baseline for NE BC

Pre-HF Background Seismicity (2002-2003)

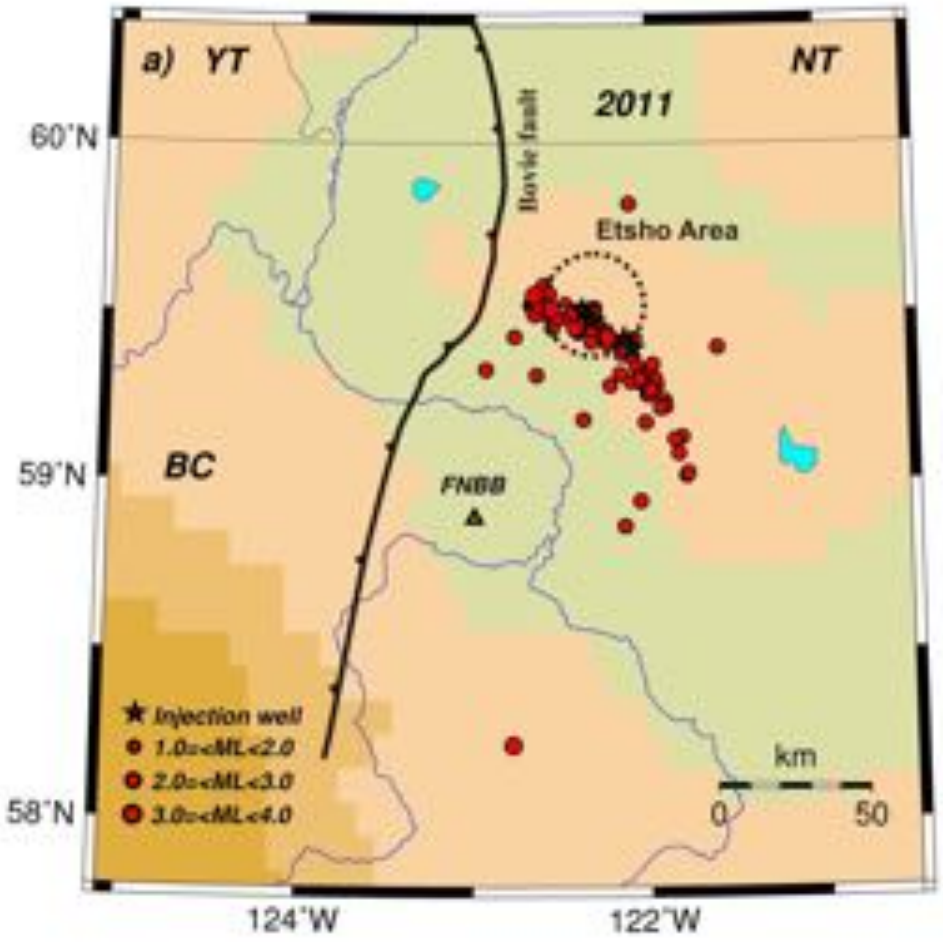


- 4 years before HF
- 24 earthquakes located
- M_L between 1.8 and 2.9, most are smaller than 2.5 (detection threshold of CNSN)
- Most occurred in the southern HRB, none was in the shale gas production area (Etsho)

Farahbod et al. (2014)

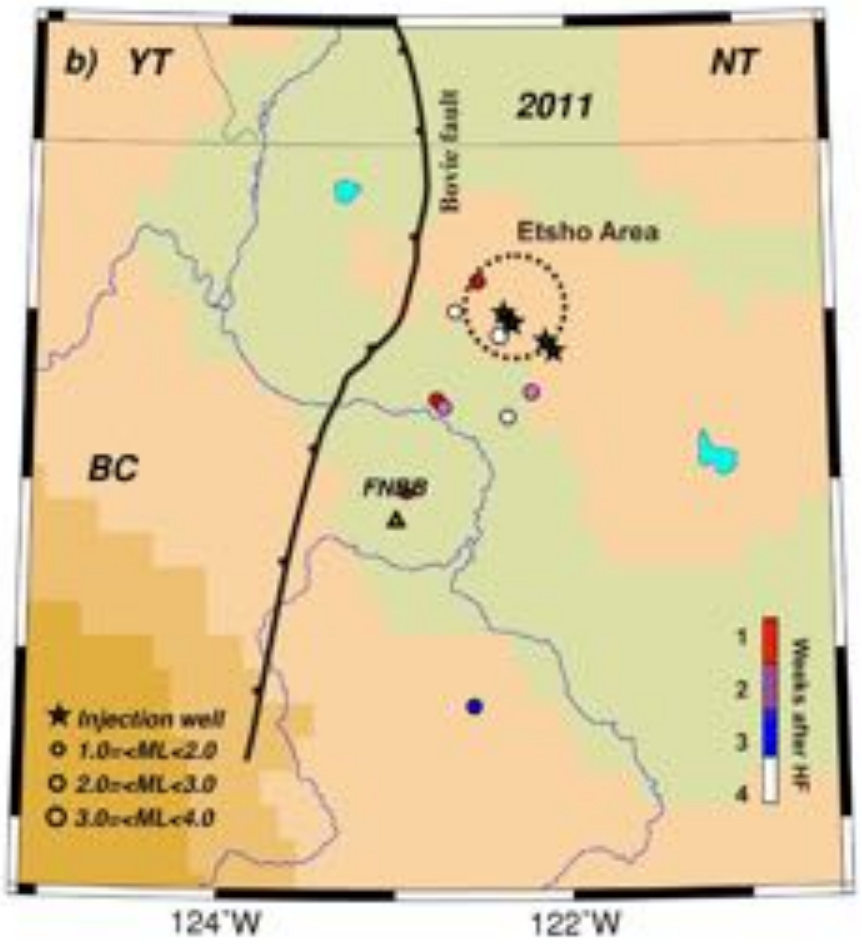
Regional Seismicity During Peak HF Period

Events when HF was conducted



HF days: 84.9% Seismicity: 90.8%

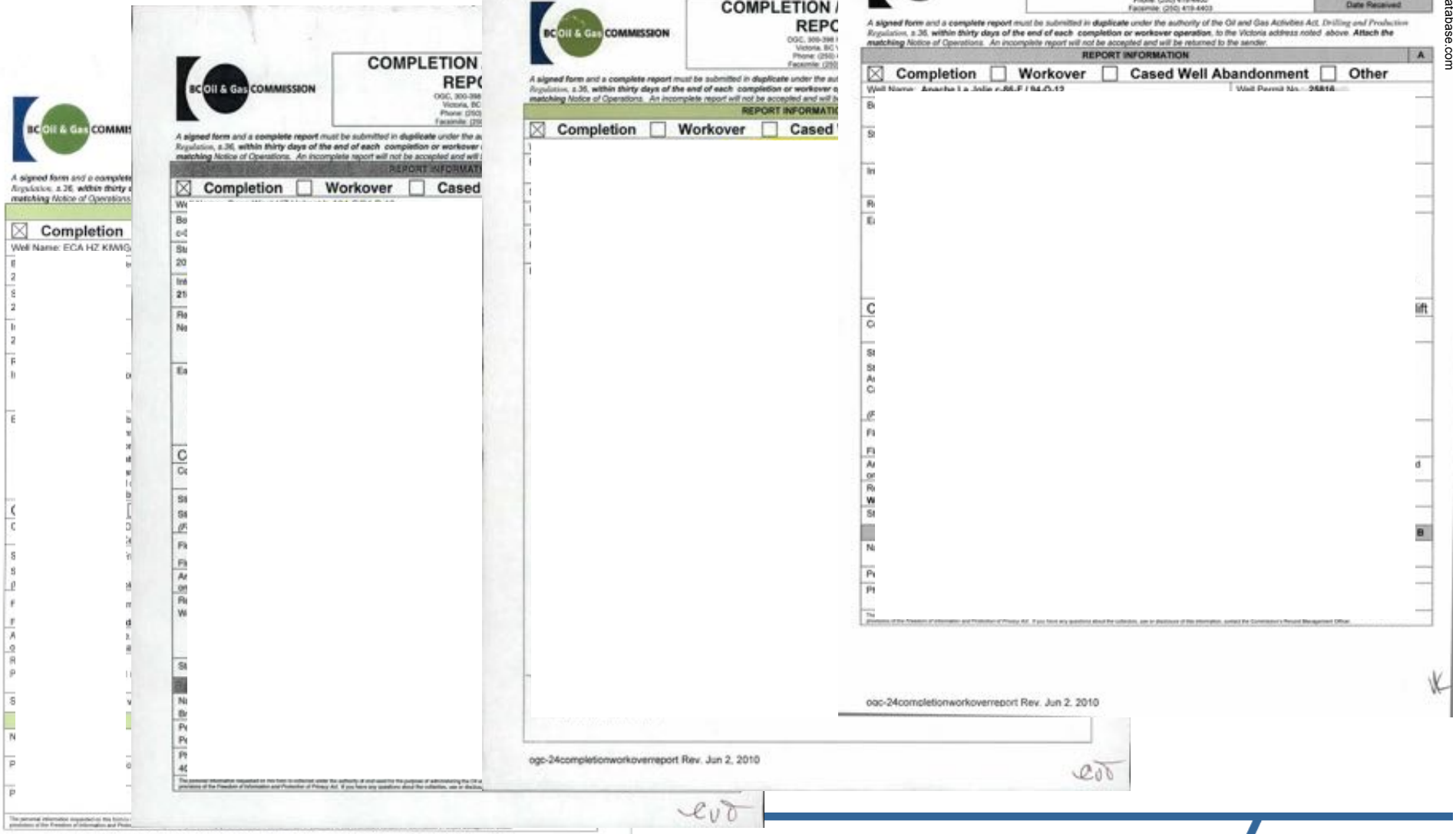
Events when no HF was conducted



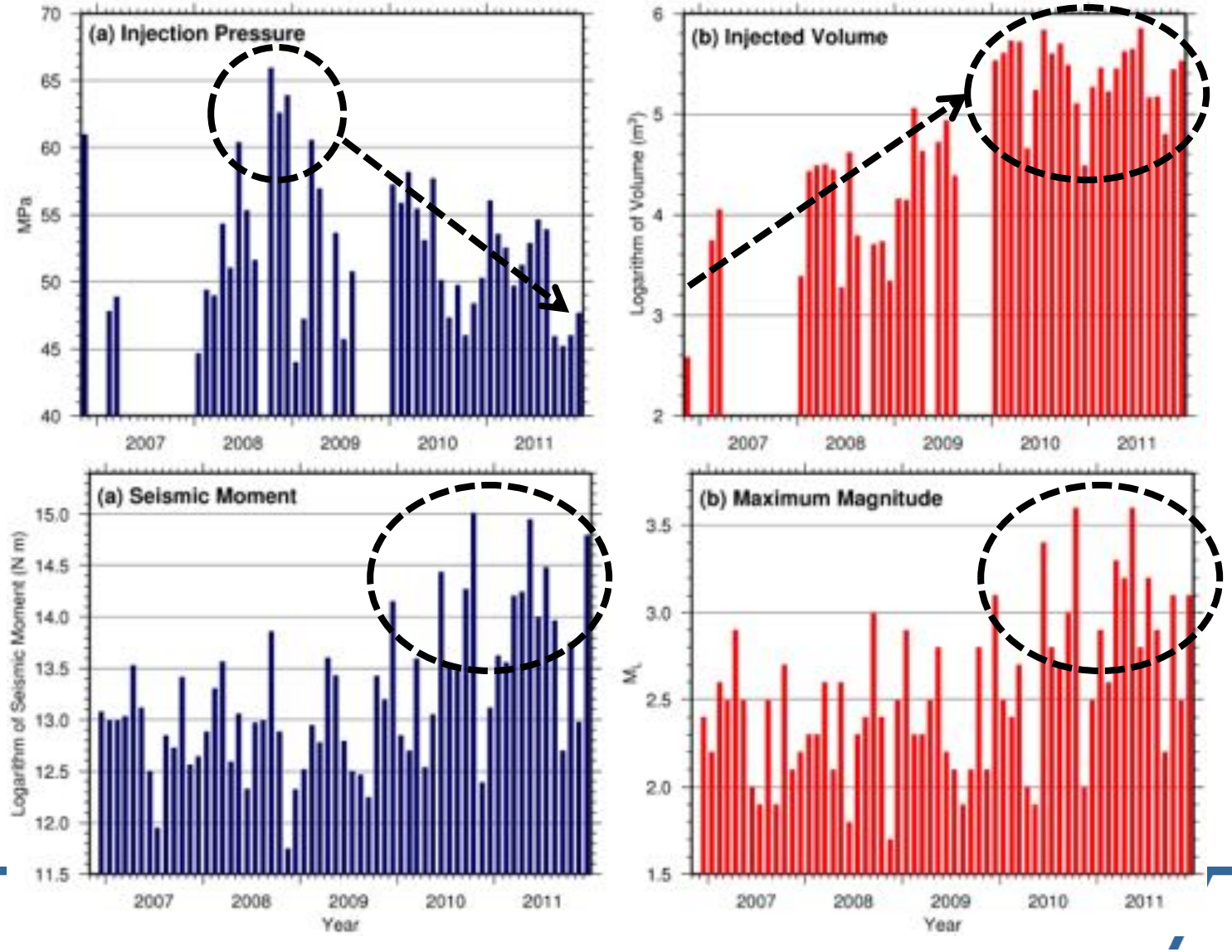
Non-HF days: 15.1% Seismicity: 9.2%

Farahbod et al. (2014)

HF Completion Reports Filed by Operators



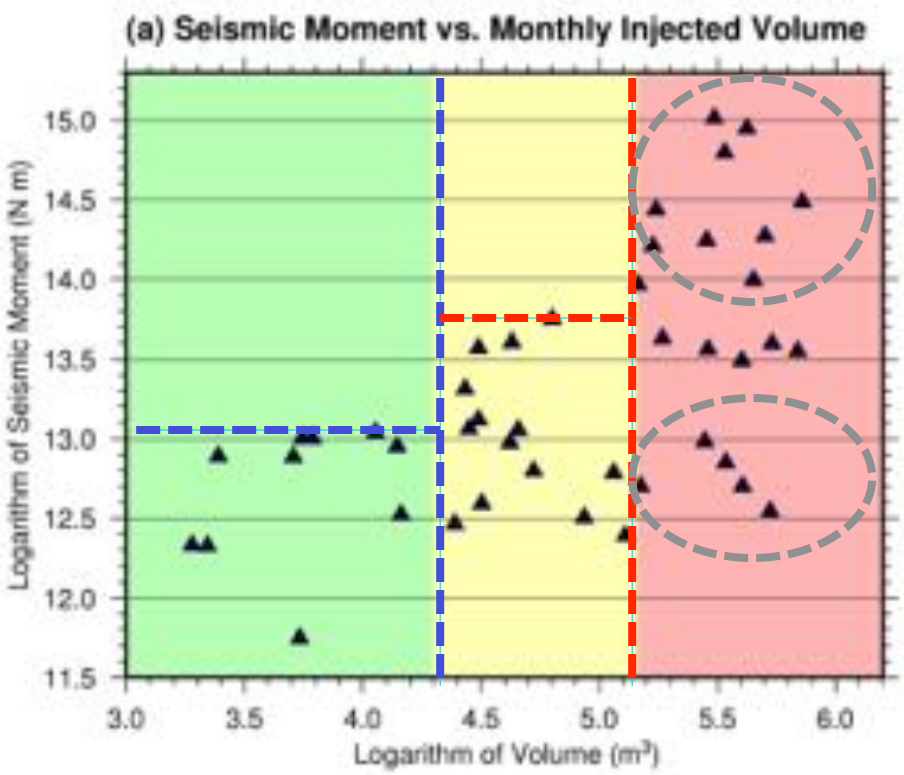
HF Operations and Seismicity

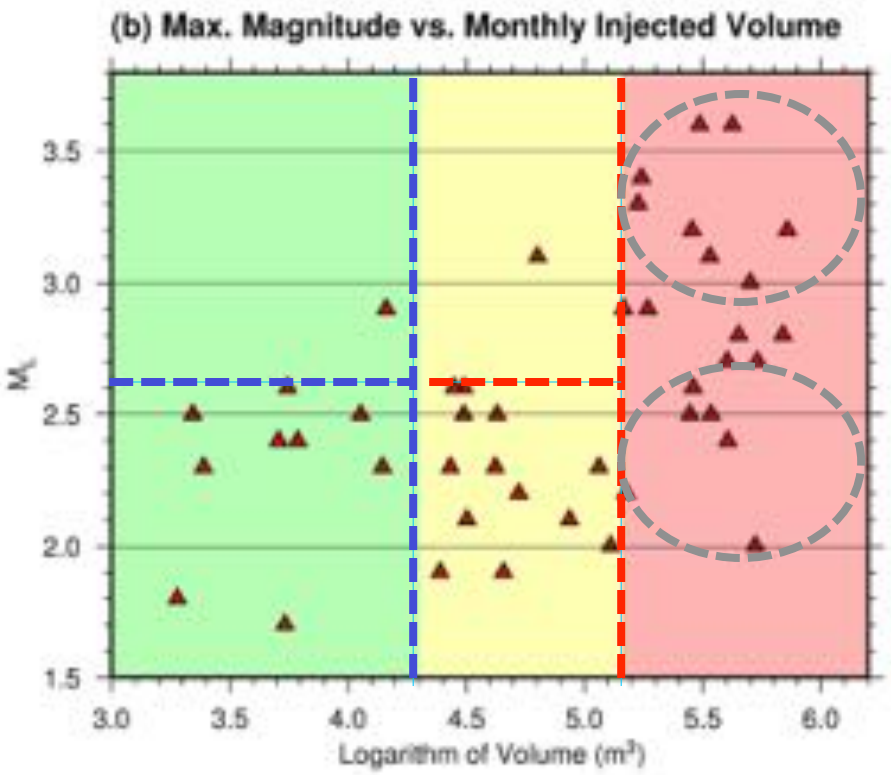


Injected Volume vs. Seismicity

~150K m^3/month

~150K m^3/month

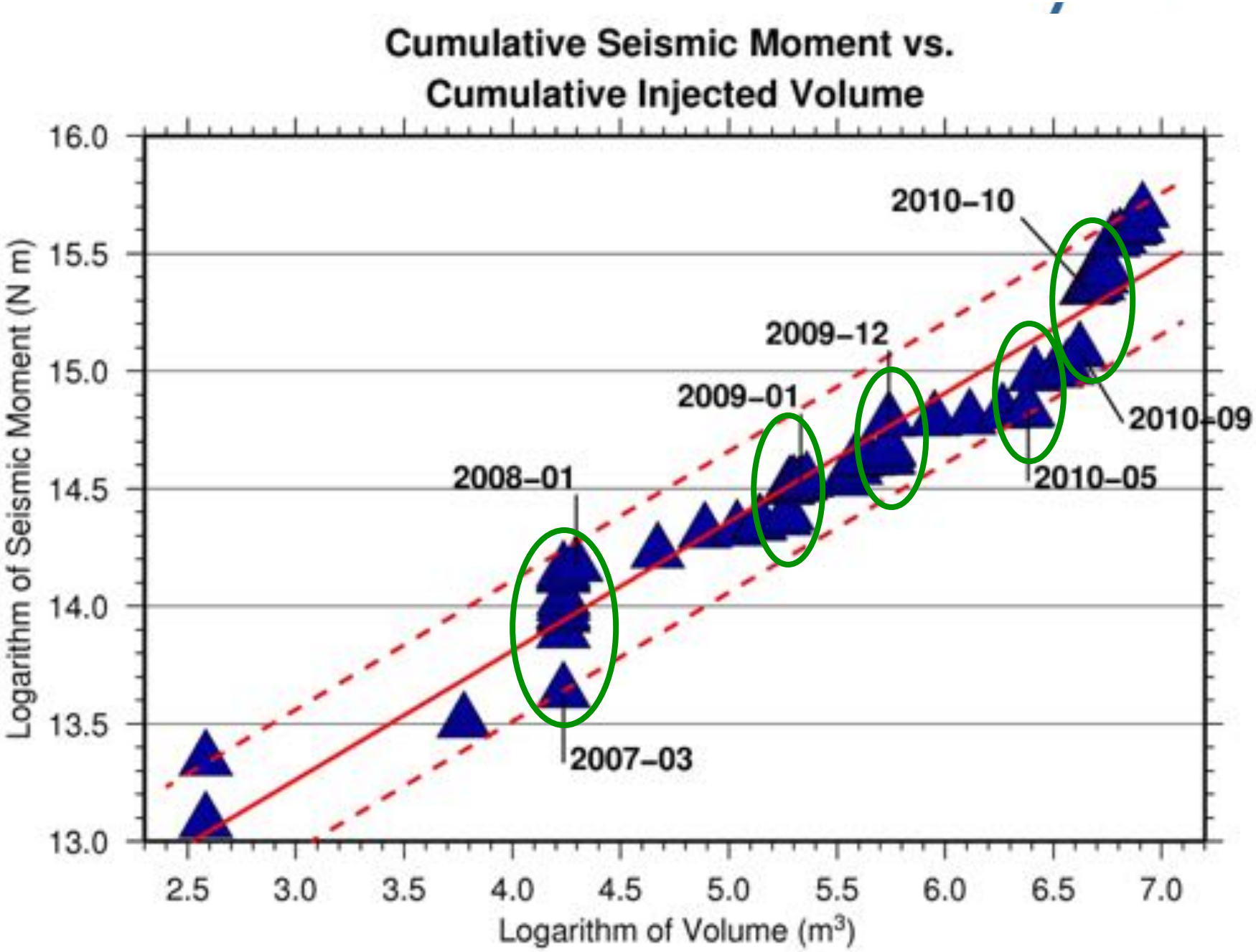




~20K m^3/month

~20K m^3/month

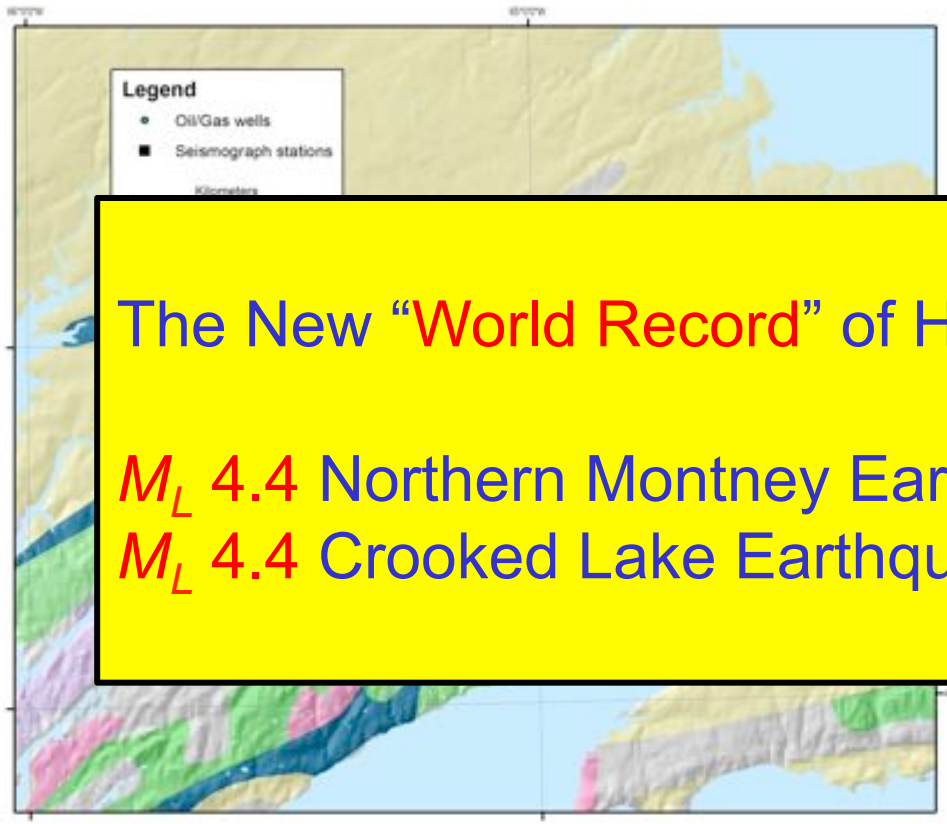
Farahbod et al. (2015)



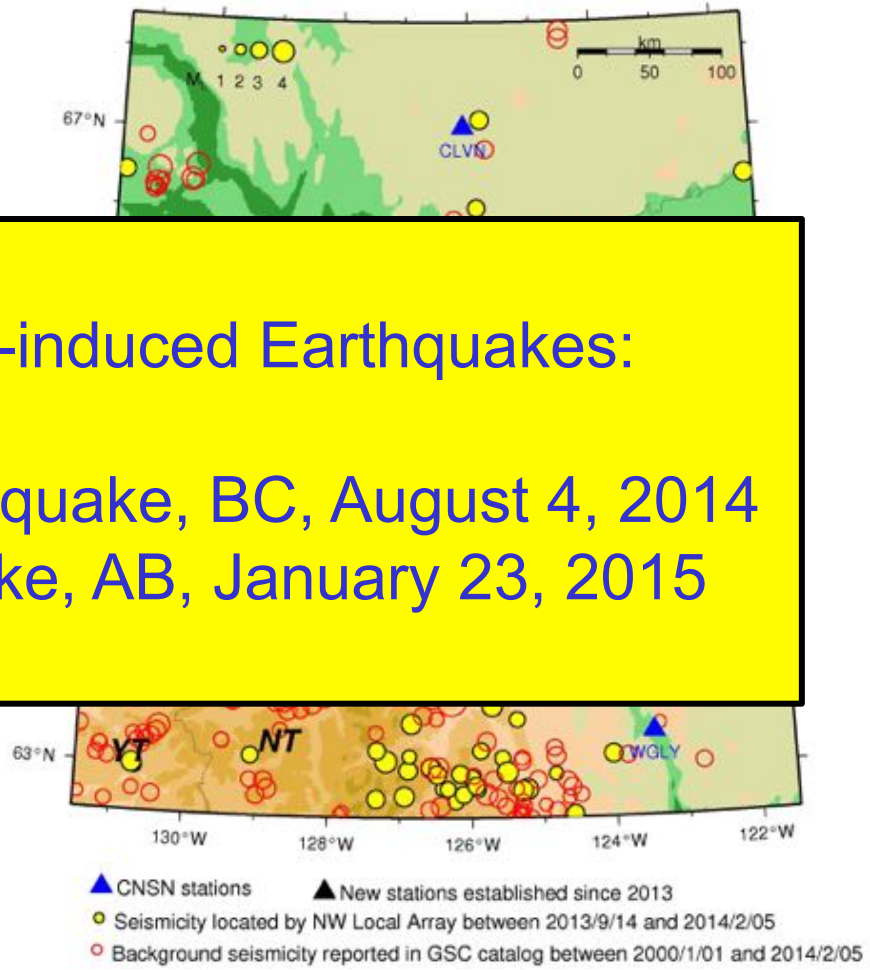
Farahbod et al. (2015)

Other Case Studies in NB and NT

Small-scale HF in NB in Aug/Sep 2014



Small-scale HF in NT in Feb/Mar 2014



The New "World Record" of HF-induced Earthquakes:

M_L 4.4 Northern Montney Earthquake, BC, August 4, 2014
M_L 4.4 Crooked Lake Earthquake, AB, January 23, 2015

Lamontagne et al. (2015)

Kao et al. (2015, in prep.)

Conclusions

- NRCan's Induced Seismicity Research now covers major shale gas basins in Canada, including BC, AB, QC, NB and NT.
- To confidently recognize any variation in regional/local seismicity that are possibly related to shale gas development, it is critical to establish a good reference for the pre-HF era.
- Taking the HRB as a whole, injected volume appears to be a more important factor than the injection pressure.
- The initial effect of an increased injected volume is an increase in earthquake frequency but not magnitude.
- Relatively large seismic moment release ($>10^{14}$ N m) occurred only when the monthly injected volume exceeded ~150,000 m^3, but large monthly injected volume != large monthly seismic moment.
- Variable time lags, from days to up to 4 months, are observed between intense HF and the occurrence of a significant local earthquake.

External Collaborators

BC Oil and Gas Commission

Alberta Energy Regulator

Northwest Territories Geoscience Office

New Brunswick Department of Energy and Mines

Ministère des Ressources Naturelles du Québec

Geoscience BC

Energy Institute of New Brunswick

Canadian Association of Petroleum Producers

University of Calgary, University of Alberta

University of Western Ontario, McGill University