

# Induced Seismicity

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Alberta Energy Regulator/Alberta Geological Survey

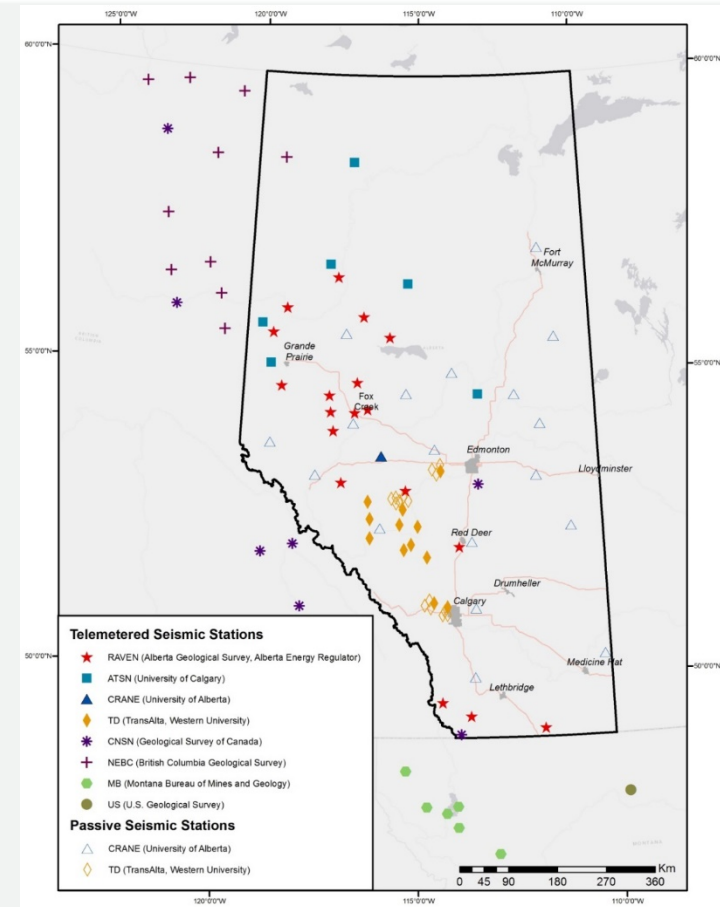
Dec 3<sup>rd</sup>, 2019 RISC Webinar



# **Seismic Monitoring and Accessible Communication of the Data**

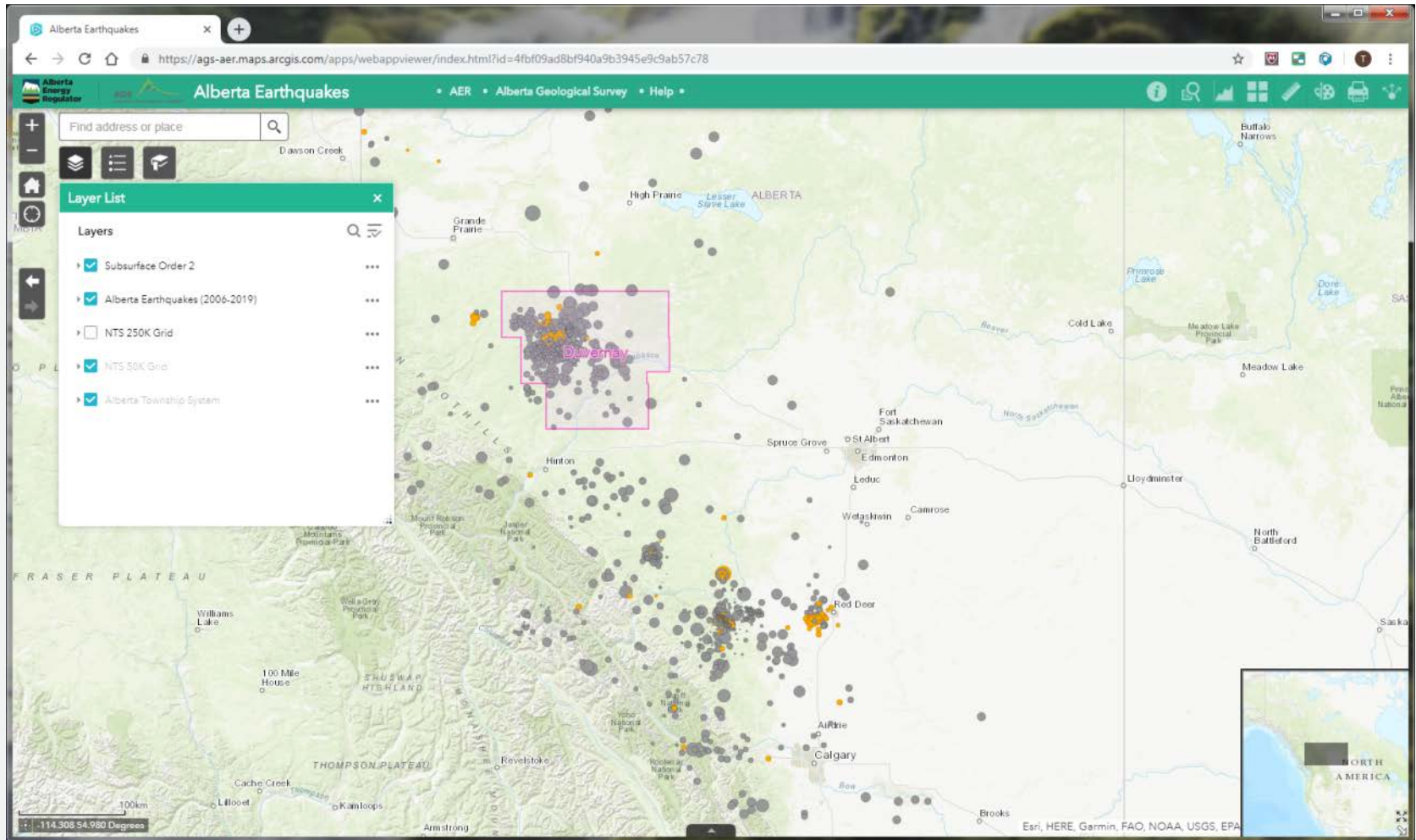
# Seismic Monitoring in Alberta

Since 2010, the AER, through the Alberta Geological Survey (AGS), has been directly monitoring natural seismicity levels in Alberta and assessing subsurface energy resource operations (mainly completion activities such as hydraulic fracturing) for potential links to induced seismicity



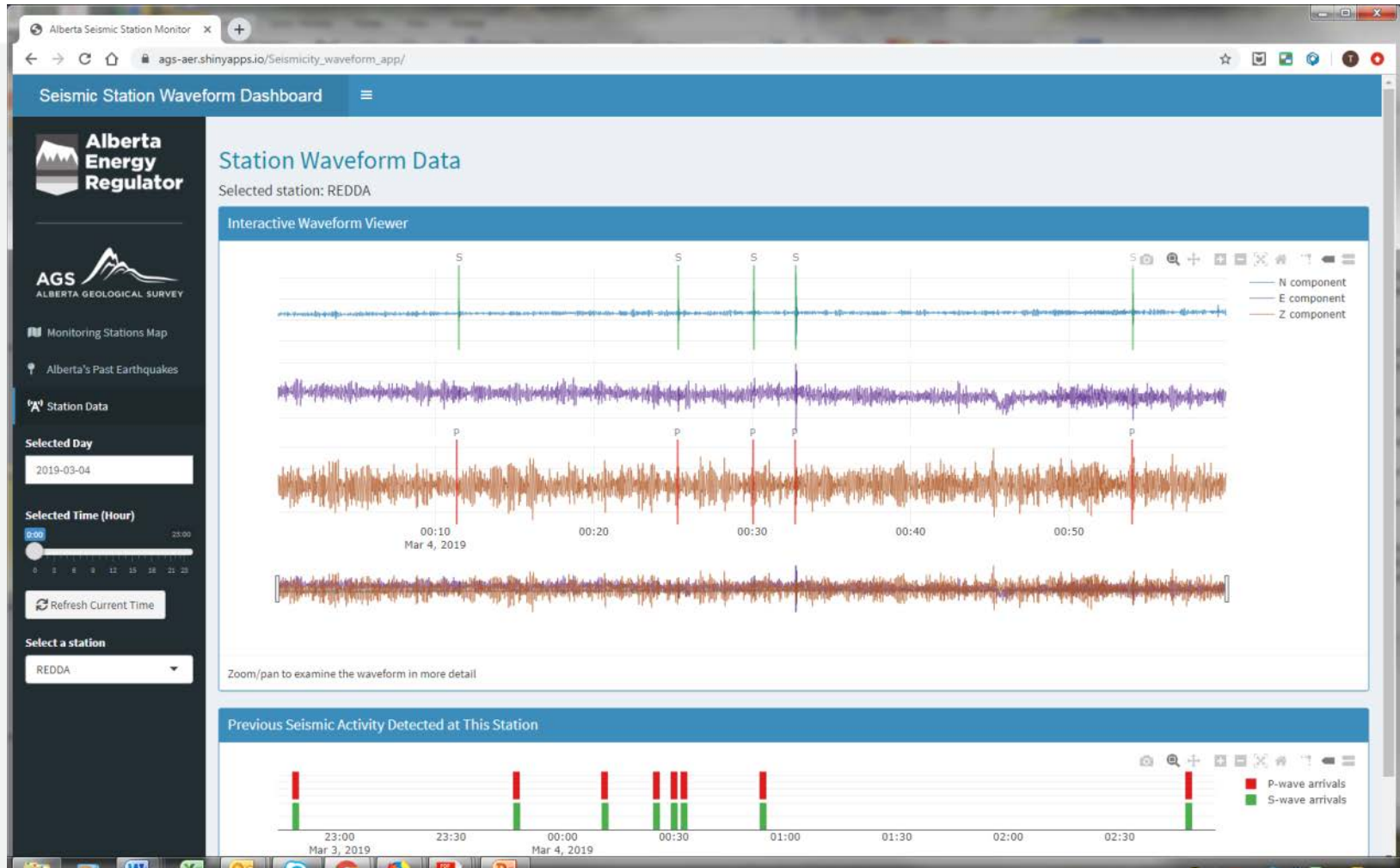
Stern, V.H., Schultz, R.J., Shen, L., Gu, Y.J. and Eaton, D.W. (2013): Alberta earthquake catalogue, version 1.0: September 2006 through December 2010; Alberta Energy Regulator, AER/AGS [Open File Report 2013-15](#), 29 p.

# Interactive Earthquake Map

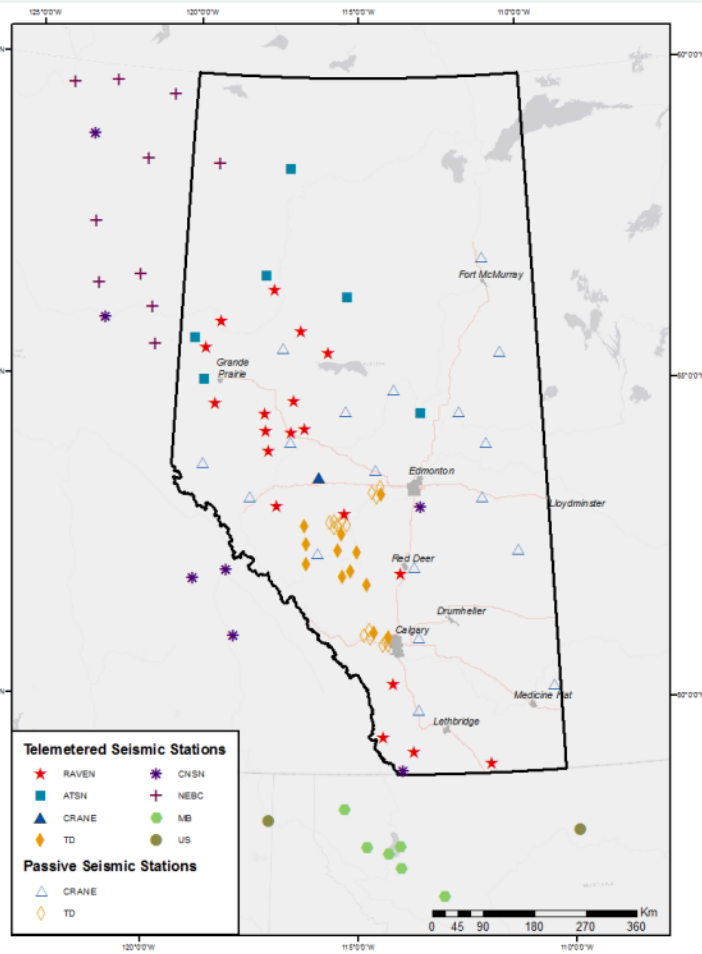


<http://ags-aer.maps.arcgis.com/apps/webappviewer/>

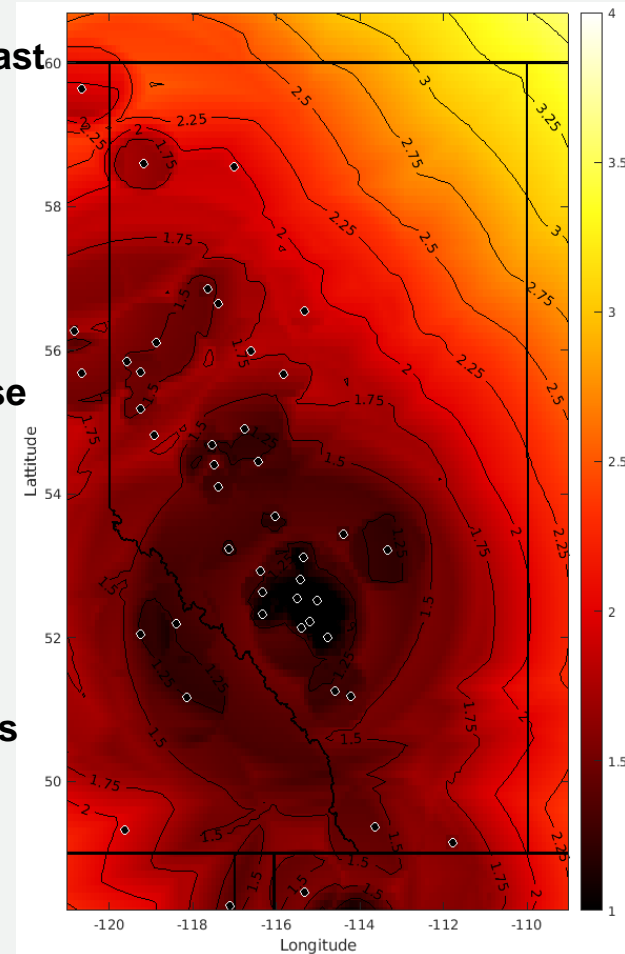
# Alberta Seismic Monitoring Stations



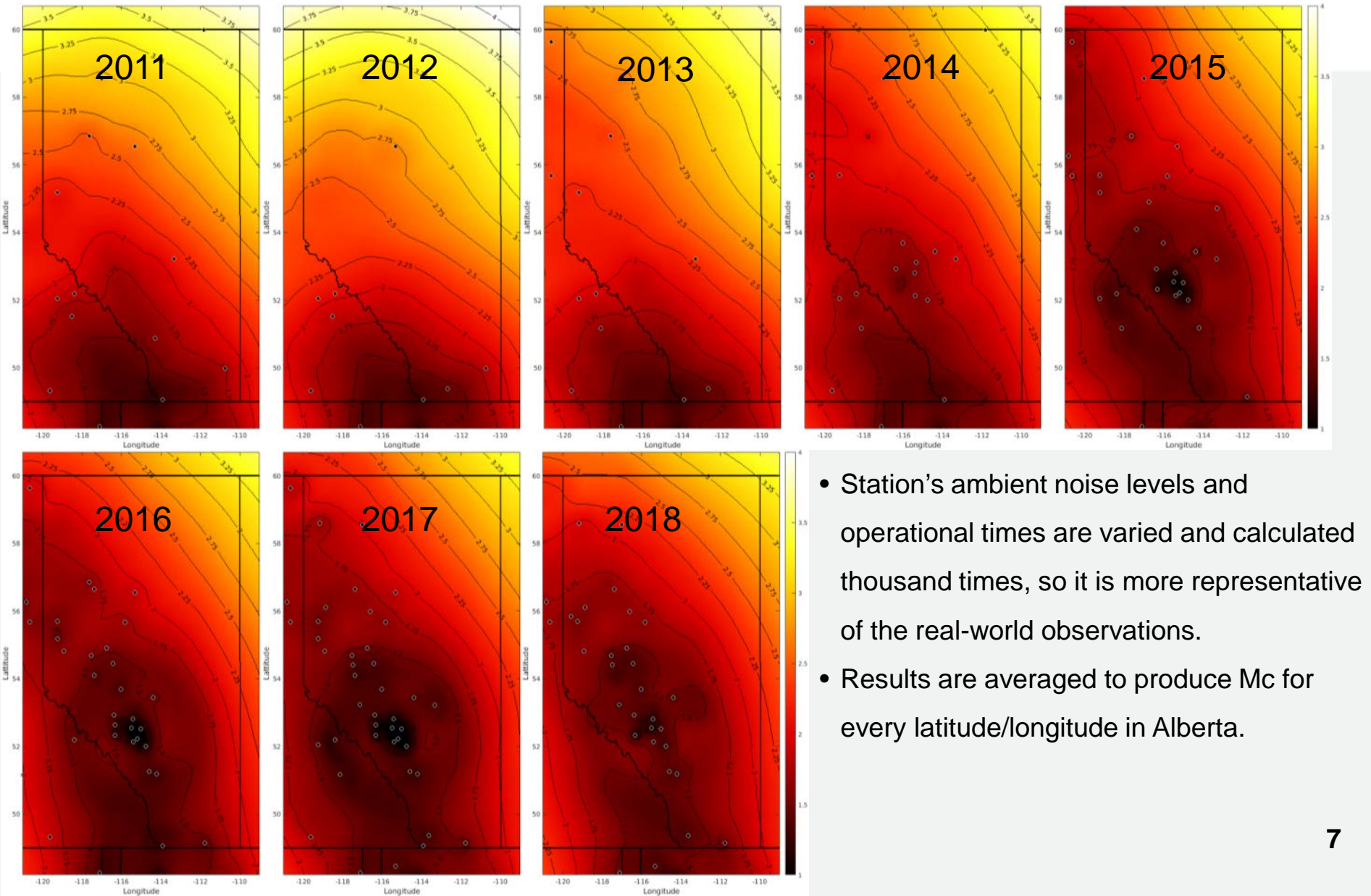
# Synthetic Mc



- Real-time stations with at least one year of data are used.
- Represents the ideal case scenario, as station performance varies:
  1. Diurnal and annual noise at the stations affects their detection capabilities,
  2. Stations are not always operating due to various hardware issues.



# Statistical Mc (2011 – 2018)



# E-Mail Alert system

- Multiple individuals receive notification of an earthquake
- Occurs ~5 min post event
- Location accuracy 10 km wrt the magnitude

Event ID: 639797

latitude: 52.9792 longitude: -117.2145 depth: 2 time : 5/21/2017 21:08:03.374 magnitude: 2.180000

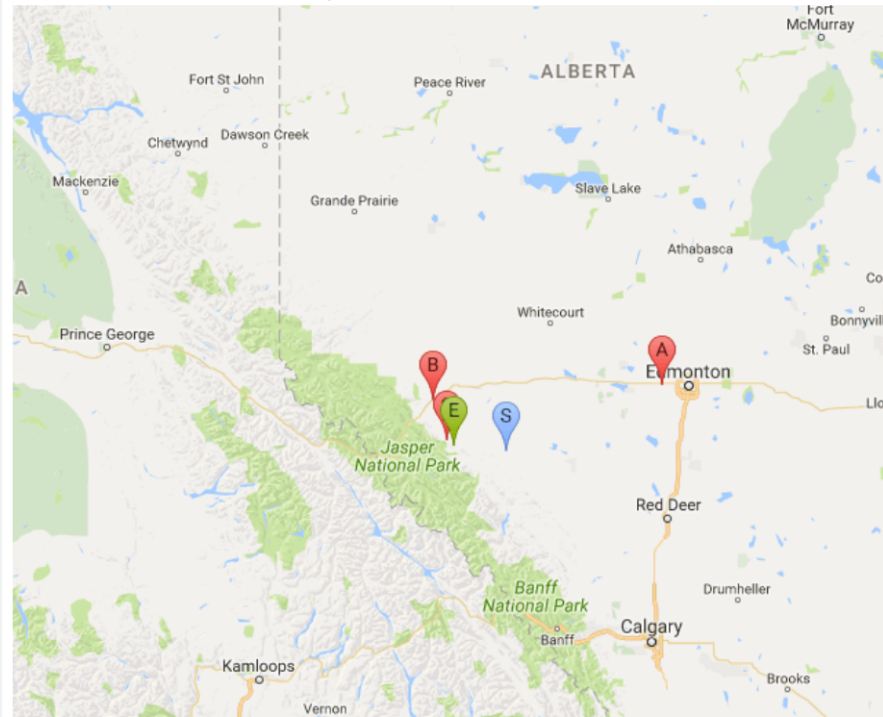
Nearest City: Spruce Grove Distance: 229.777756 km

Nearest Town: Hinton Distance: 53.013627 km

Nearest Small Settlement: Cadomin Distance: 9.316578 km

Marker E indicates the estimated earthquake location. A B C are respectively City, Town and Small Settlement

Nearest Station: Marker S - TD09A, Distance from event location : 55.762922 km



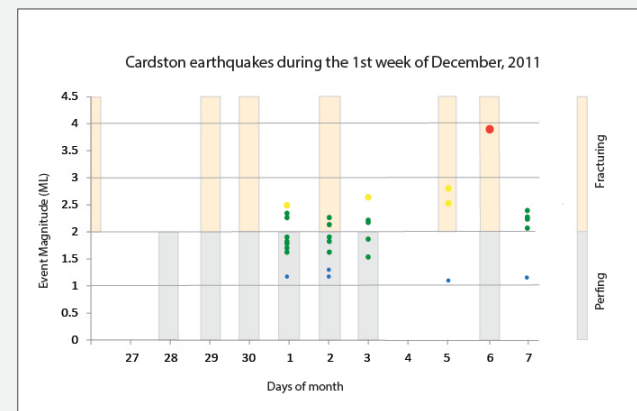
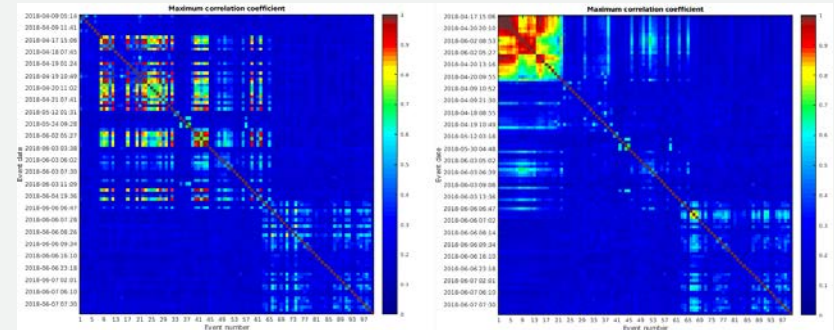
# History of Induced Seismicity in Alberta

# Determining if an Earthquake was Induced or Natural

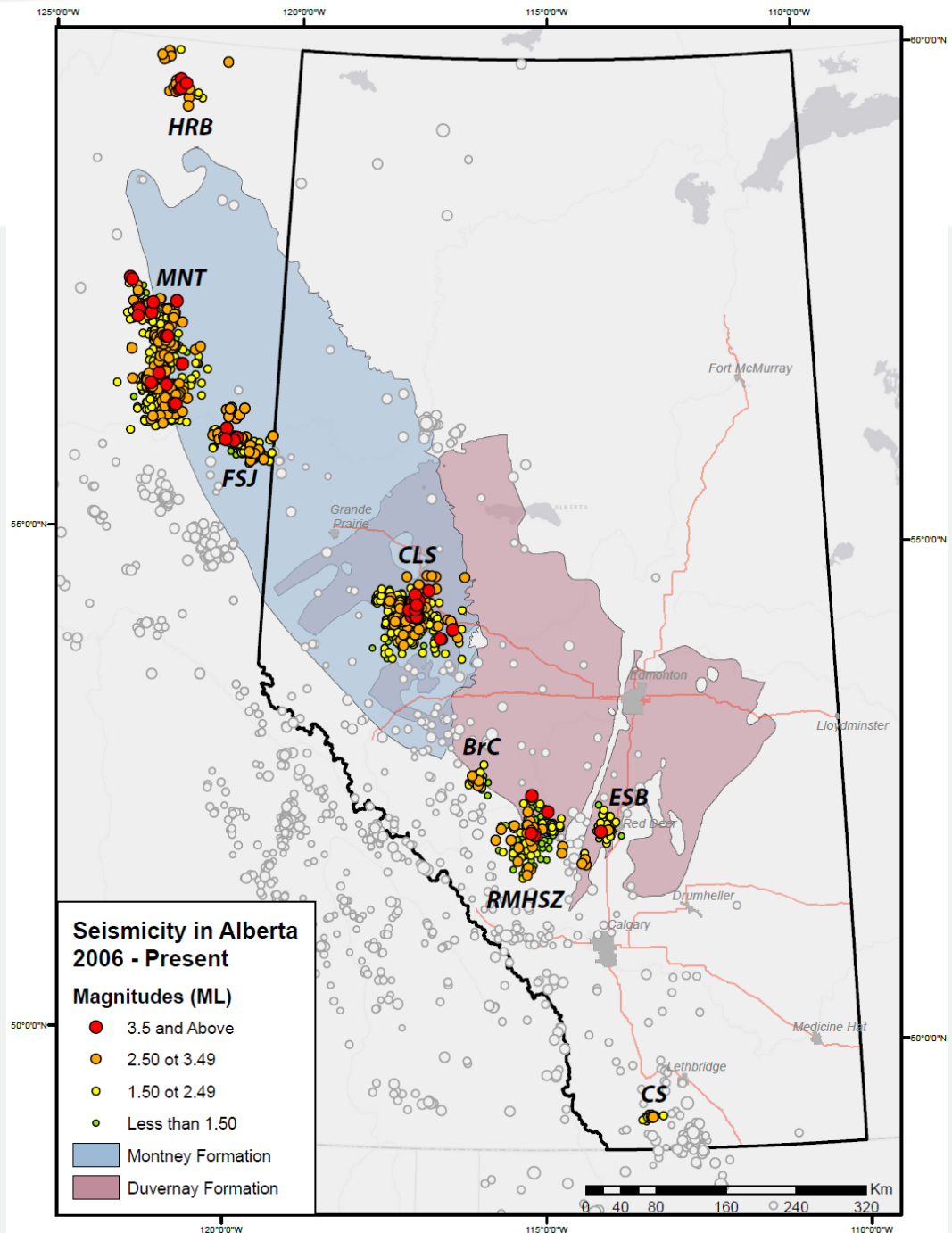
- 》 Are earthquakes occurring in an area that has not commonly had earthquakes?
- 》 Is there an increase in the rate of earthquakes in this area?
- 》 Are the earthquakes occurring at the same time as the suspected human activity?
- 》 Are the earthquakes within a reasonable distance from the suspected human activity?
- 》 Are the human-caused changes in stress/forces on a fault large enough to explain the seismicity?

# Methods used for Correlation

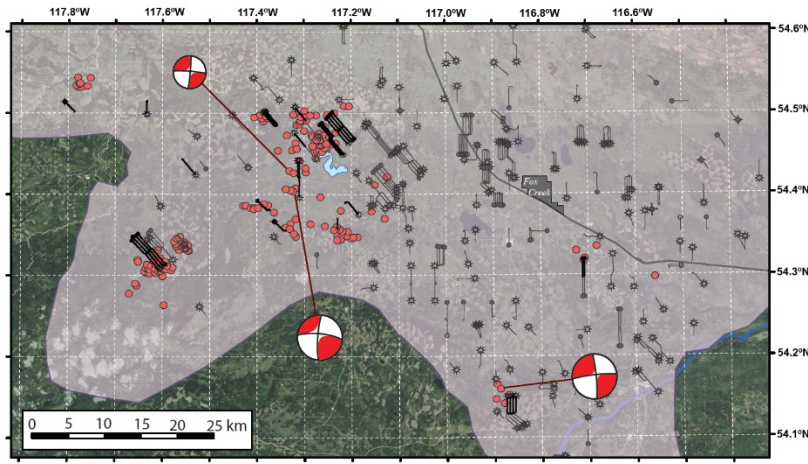
- » Cross-correlation of waveform similarity
- » Increasing Earthquake Detection Counts
- » Temporal Association Filter
- » Increased Hypocentre Resolution



# Clusters of Areas of Identified Induced Seismicity Western Canadian Sedimentary Basin

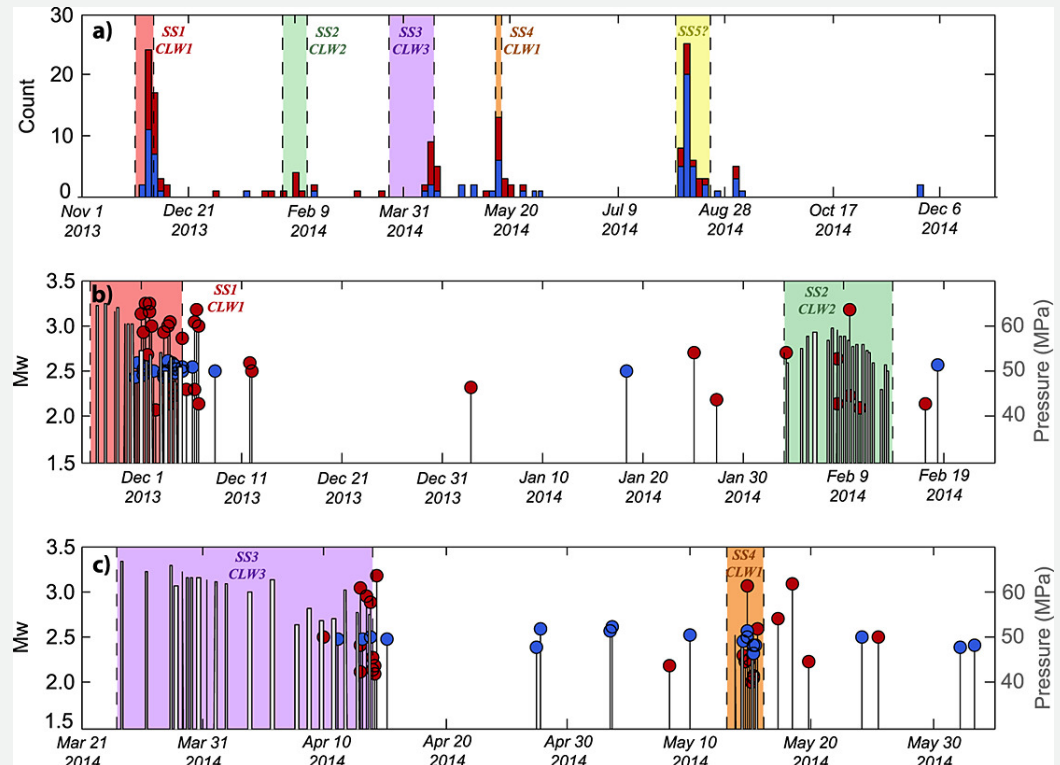


# Crooked Lake Sequence

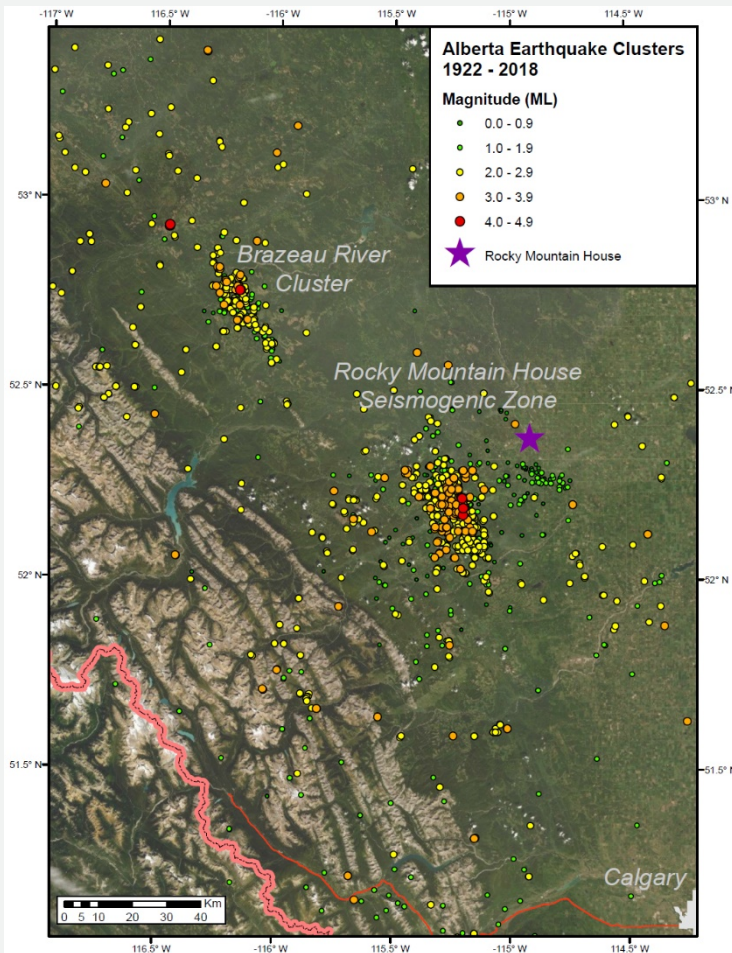


- Basement root faults
- Association with susceptible geological conditions
- Association with frequency and volume with seismogenic wells

Schultz et al. (2015a): Hydraulic fracturing and the Crooked Lake Sequences: Insights gleaned from regional seismic networks; Geophysical Research Letters, v. 42(8), p. 2750-2758

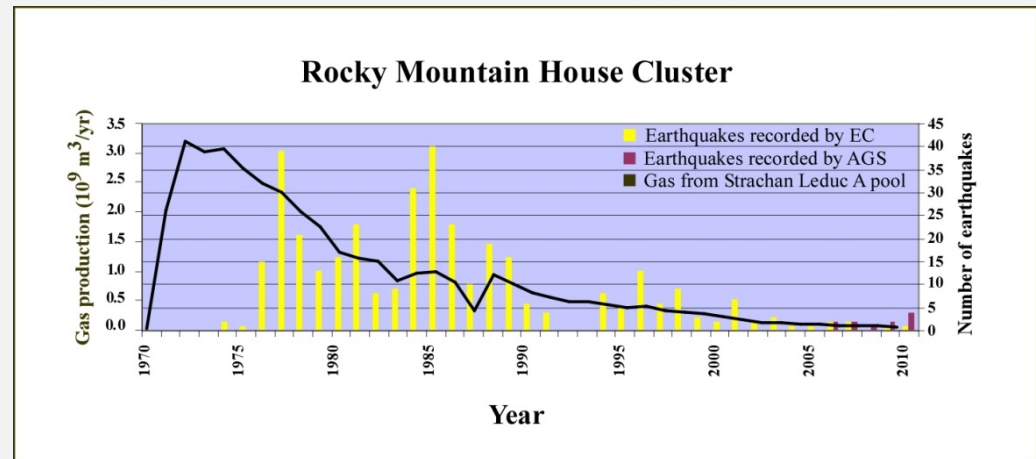


# Rocky Mountain House Sequence

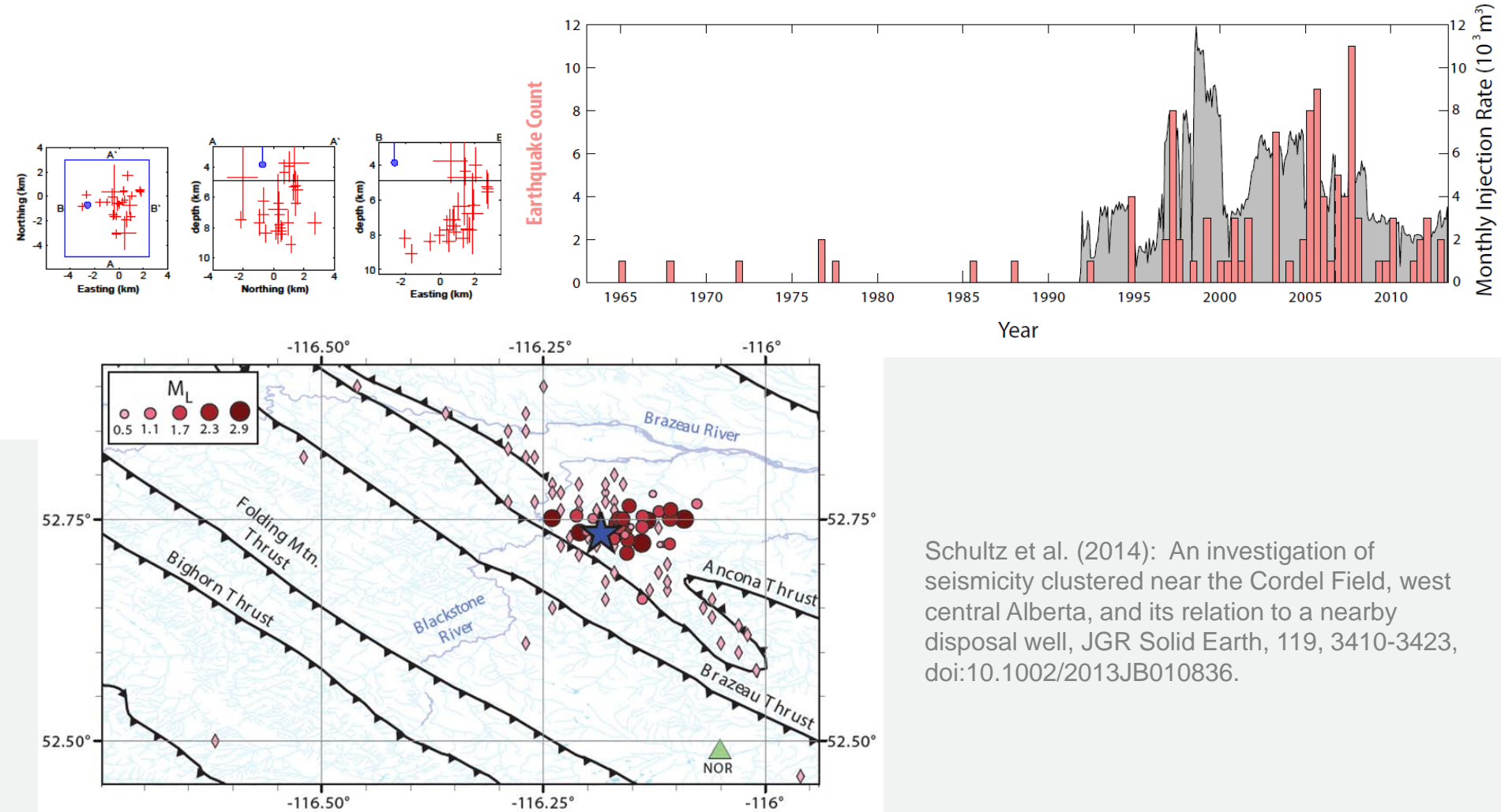


Rebollar et al. (1982): Source parameters from shallow events in the Rocky Mountain House earthquake swarm; Canadian Journal of Earth Sciences, v. 19(5), p. 907-918,

Rebollar, et al (1984): Focal depths and source parameters of the Rocky Mountain House earthquake swarm from digital data at Edmonton; Canadian Journal of Earth Sciences, v. 21(10), p. 1105-1113,

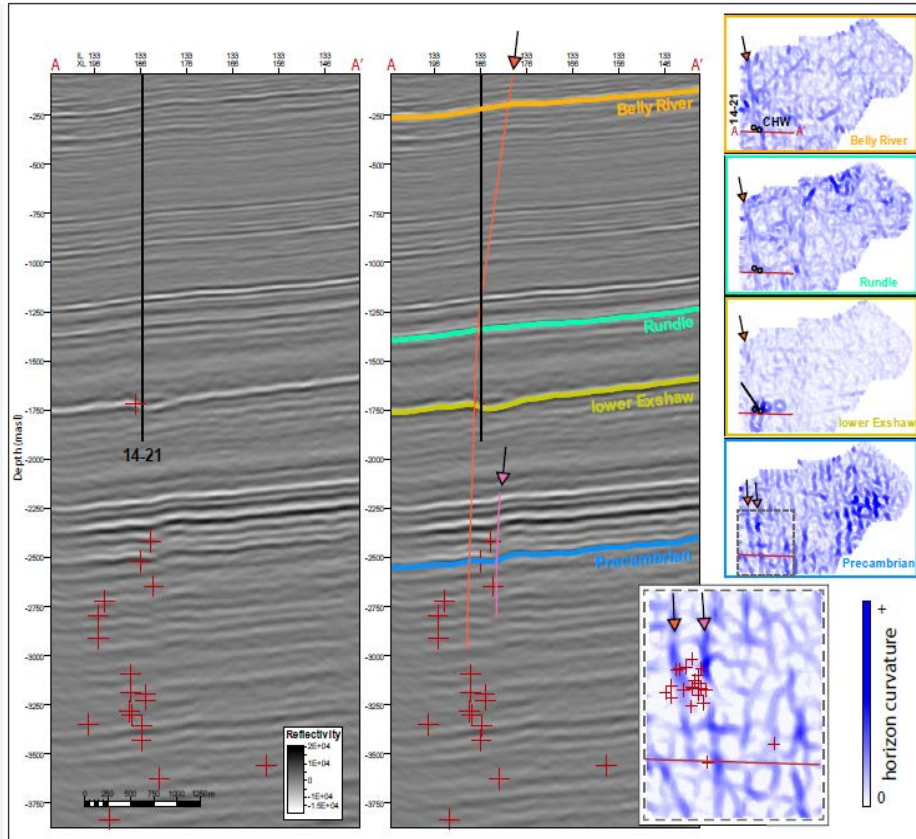


# Brazeau River Induced Seismicity Sequence

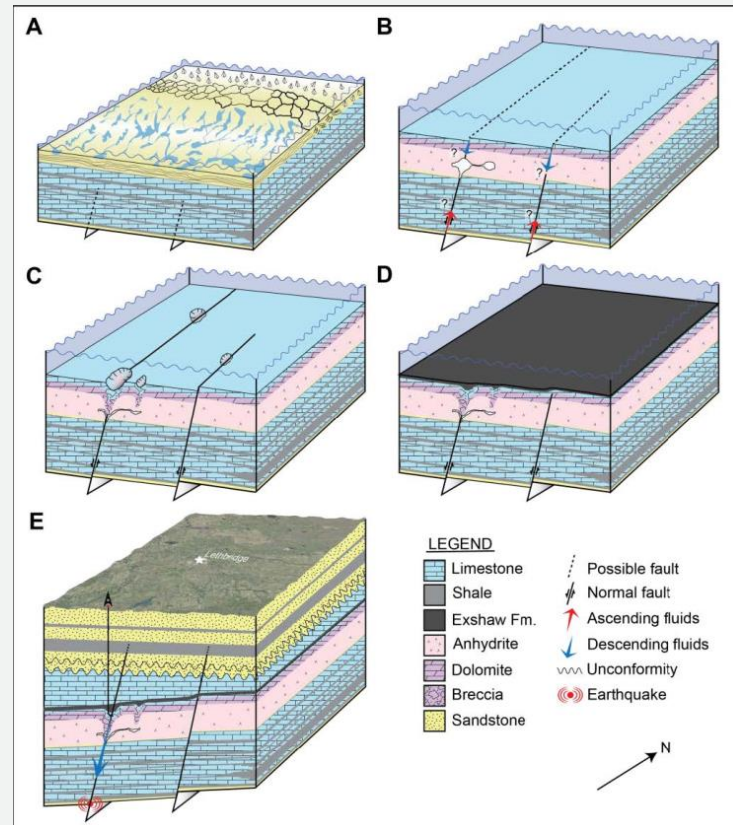


Schultz et al. (2014): An investigation of seismicity clustered near the Cordel Field, west central Alberta, and its relation to a nearby disposal well, JGR Solid Earth, 119, 3410-3423, doi:10.1002/2013JB010836.

# Cardston Induced Seismicity Sequence



Galloway et al. (2018): Faults and associated karst collapse suggest conduits for fluid flow that influence hydraulic fracturing-induced seismicity; Proceedings of the National Academy of Sciences, v. 115(43), p. E10003-E10012



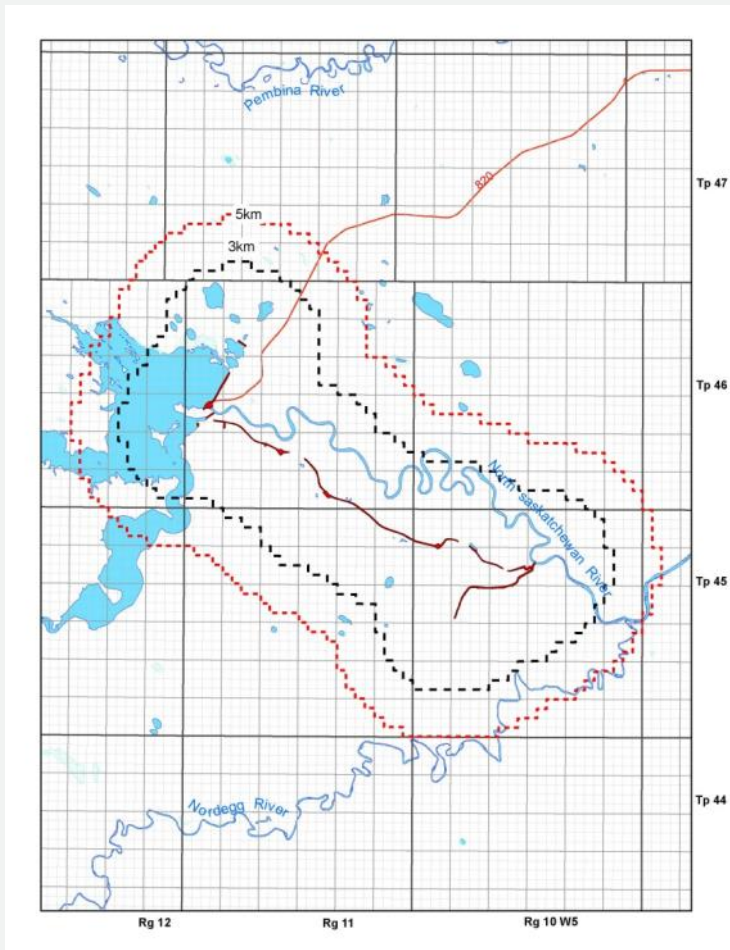
# Regulatory Instruments

# Subsurface Order No. 2

- Traffic light protocol implemented for oil and gas operations specifically targeting the Duvernay Formation in the Fox Creek area.
- Mandates assessment of hazards, monitoring, reporting, and a planned response to set magnitude thresholds.



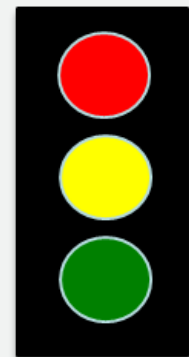
# Subsurface Order No. 6



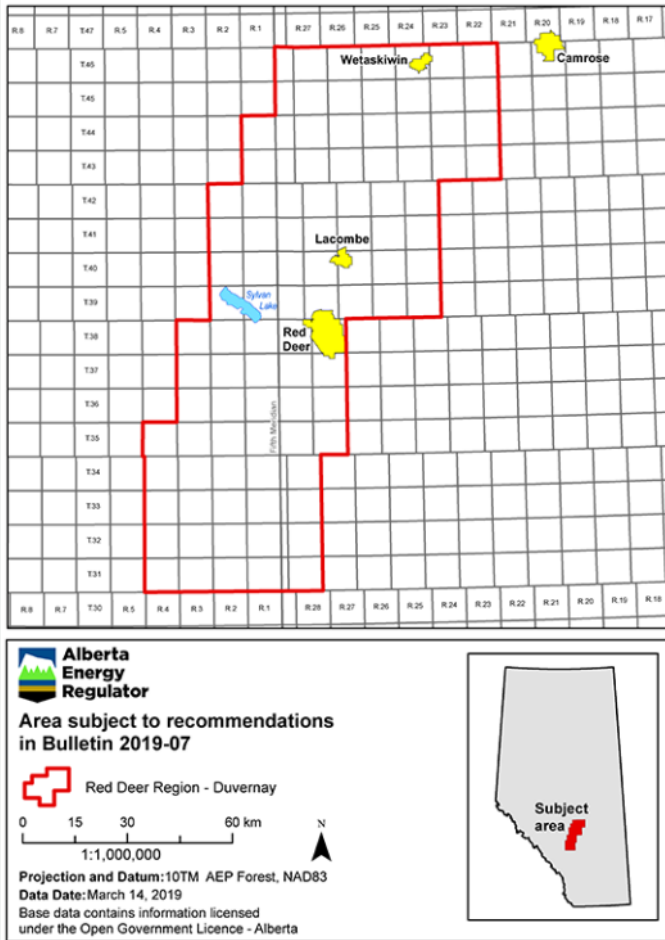
- 3 Km setback on HF activity above the Duvernay Zone oil and gas operations to Brazeau Dam – subject to performance management.
- 5 Km setback on HF activity in the Duvernay Zone and deeper formations
- 5 Km buffer around the Brazeau Dam will require monitoring, data submissions, response plan, and hazard assessment

$\geq 2.5 M_L$

$\geq 1 M_L$



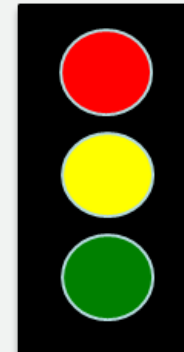
# Bulletin 2019-07- Recommendations



» Red Deer area will recommend monitoring, response plan, and hazard assessment

$\geq 3.0 M_L$

$\geq 1 M_L$



# Reporting Process

- Call into to AER hotline
- Script prepared on required information
- Email sent out to centralized email address within AER
- All  $\geq$  Red light events are posted on the AER dash board
- Events are posted on an interactive earthquake map

Please be advised that the CIC has received the following information.

**Reference Number:** 324494

**Call Date & Time:** 18/05/2017 3:58:56 PM

**Call Taken By:** GOA\taryn.hedstrom

**Caller's First Name:** [REDACTED]

**Caller's Last Name:** [REDACTED]

**Organization/Facility:** [REDACTED]

**Caller Location:** Calgary

**Primary Phone Number:** 403-305-1022

**Primary Phone Number Type:** Cell

**Primary Phone Number Ext:** N/A

**Secondary Phone Number:** N/A

**Callback Requested:** Yes

**Incident Details/Complaint Statement:** Seismic event today May 18 at 1119hrs (UTC). Mag: 2.05 local.

Last frac on pad was Jan 29 and this event may be residual activity from pad. Please call back [REDACTED]

[REDACTED]-----Resending to include Edm field centre email

**Reported Source:** [REDACTED]

**App/Lic:**

**Legal Description:** LS S T R W M

**Location Description:** 54.3089N, 117.6259W, Fox Creek

**Substance:** N/A

**Quantity/Volume:** N/A

**Incident Time:** 11:19:00

**Incident Date:** 18/05/2017

**Public Complaint Rating:**

**Agency Lead:** AER Field

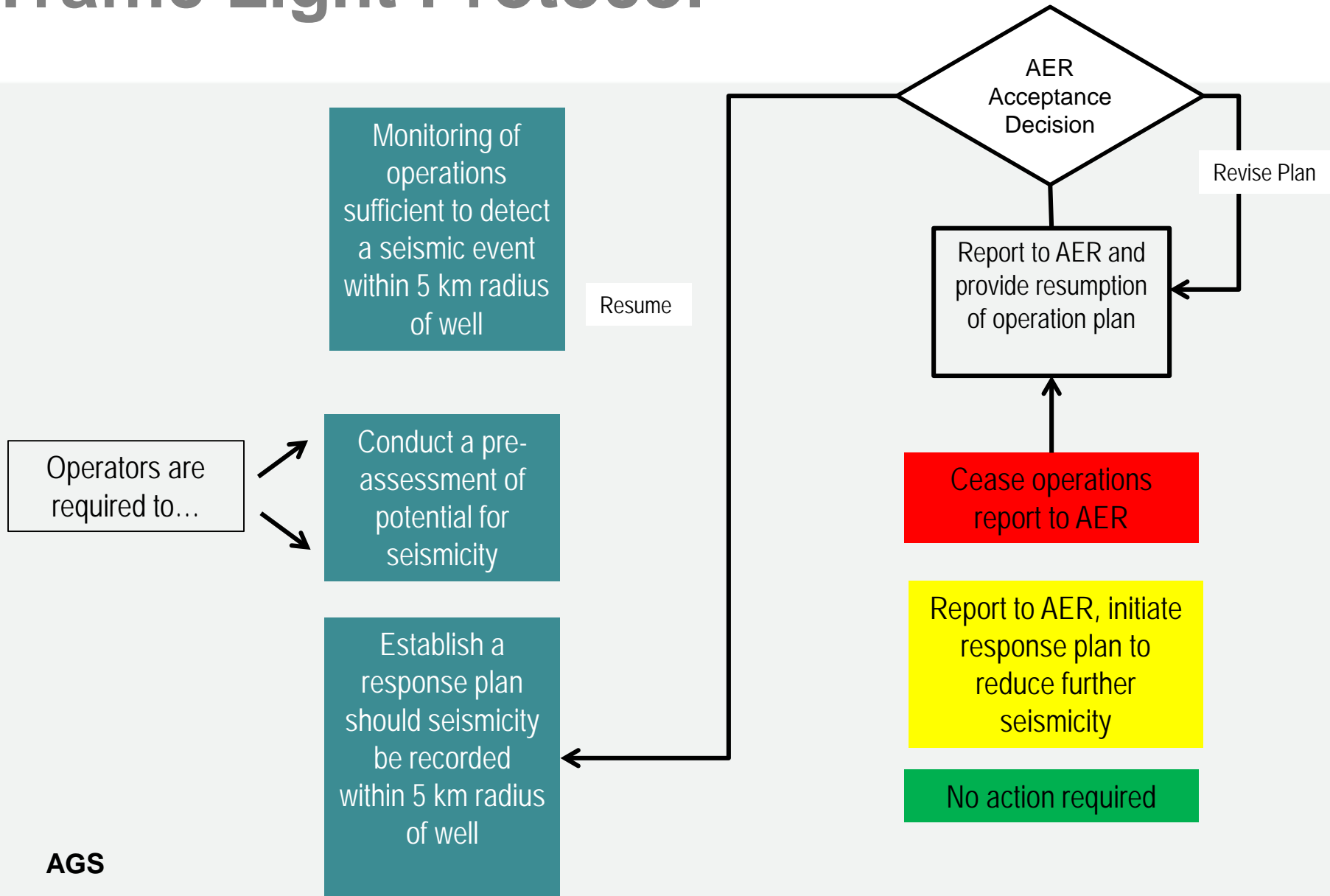
To view the full report, please use this [link](#).

If you have any questions or need to contact the CIC for any reason, please call 1-800-272-9600.

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*This is an autogenerated message. Please do not reply to this email.*

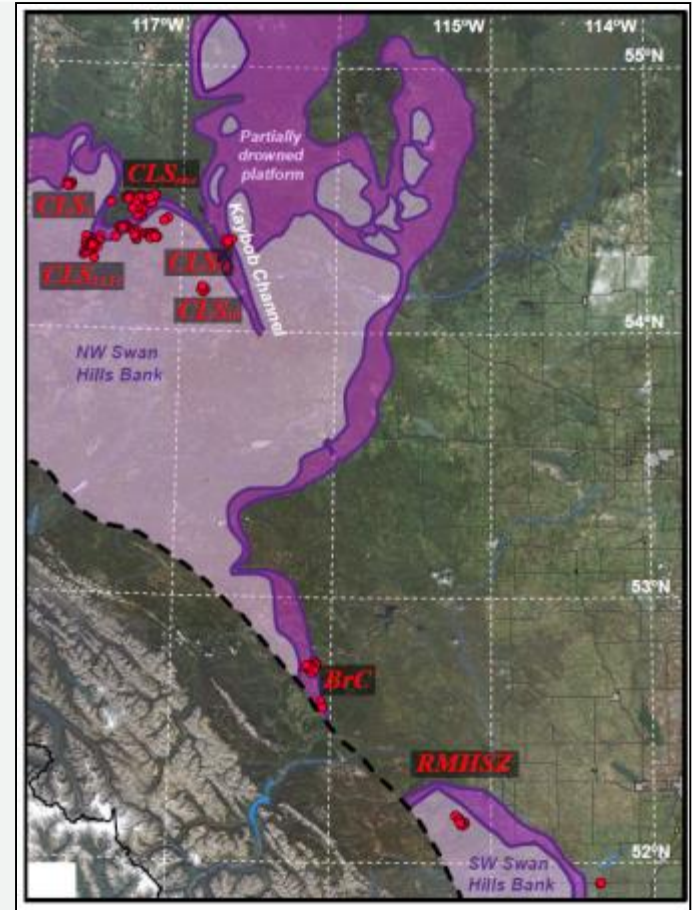
# Traffic Light Protocol



# Induced Seismicity Research

# Swan Hills Reef Spatial Association

- Swan Hills Formation is 350 million year old reef complex
- All known induced seismic events are within 20 km from margin
- Statistical analysis proved that it was coincidence and represented a true correlation

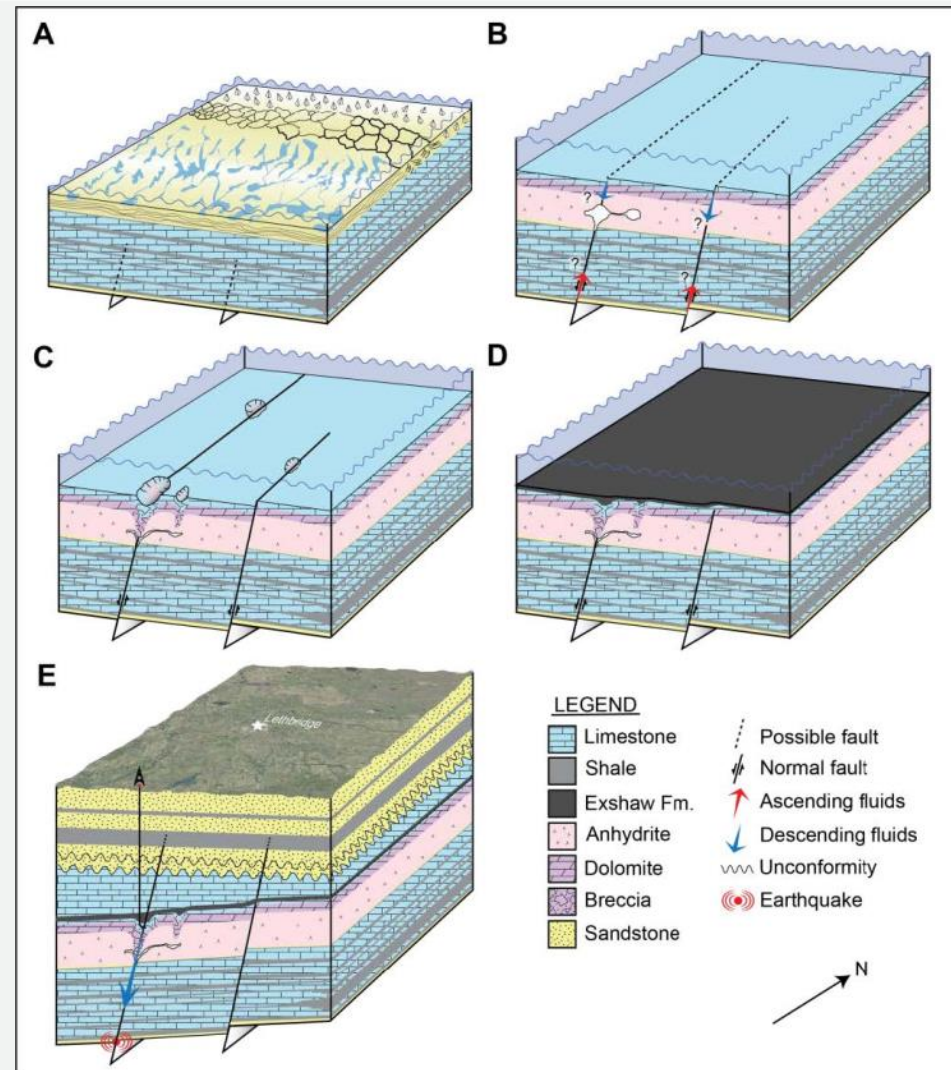


Schultz, R., Corlett, H., Haug, K., Kocon, K., MacCormack, K., Stern, V., Shipman, T., (2016), Linking fossil reefs with earthquakes: Geologic insight to where induced seismicity occurs in Alberta, *Geophysical Research Letters*, 42

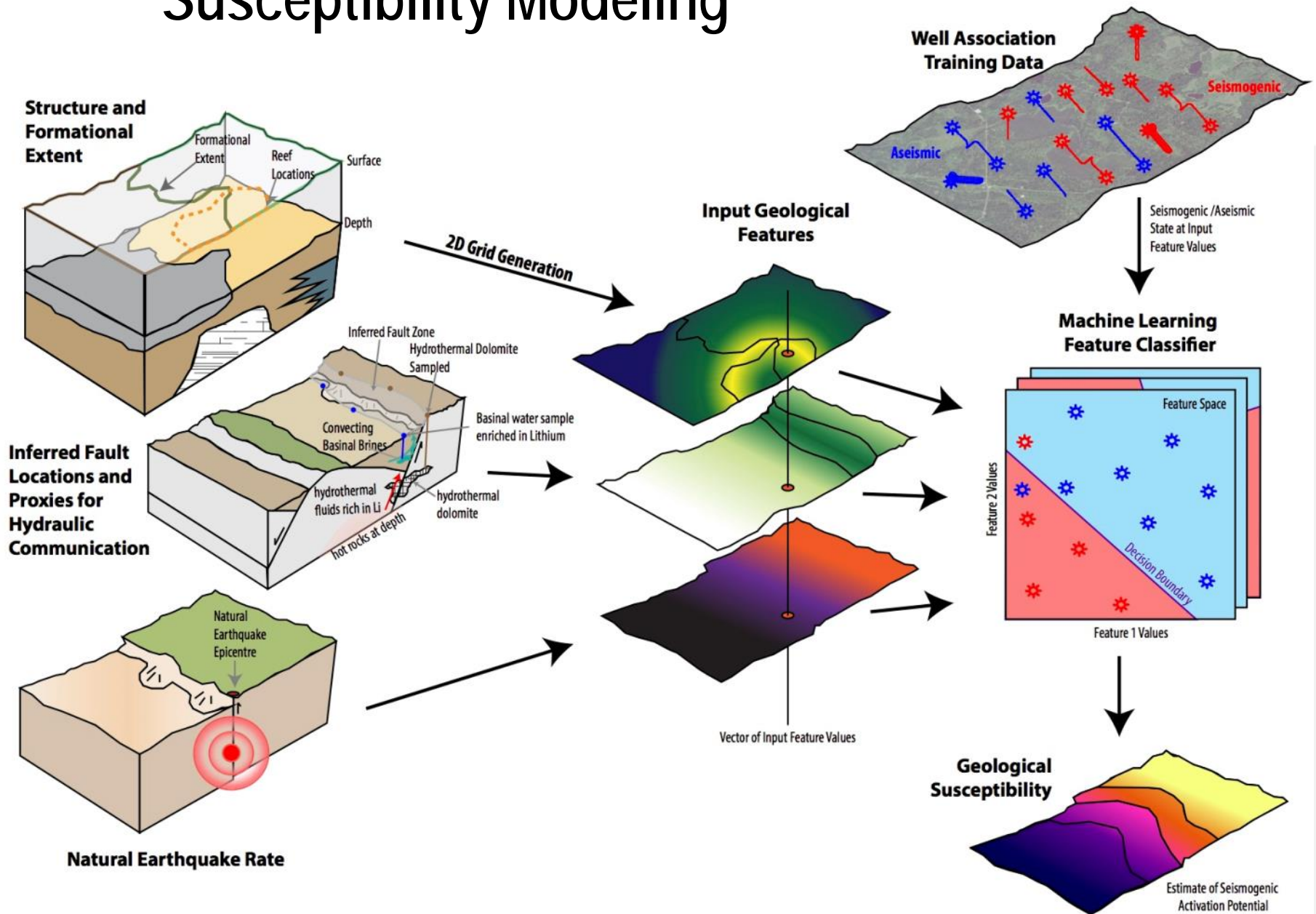
# Association with Basement Root Faults

- » Existing faults rooted in the basement
- » Fault conducts fluids
- » Faults are critically stressed

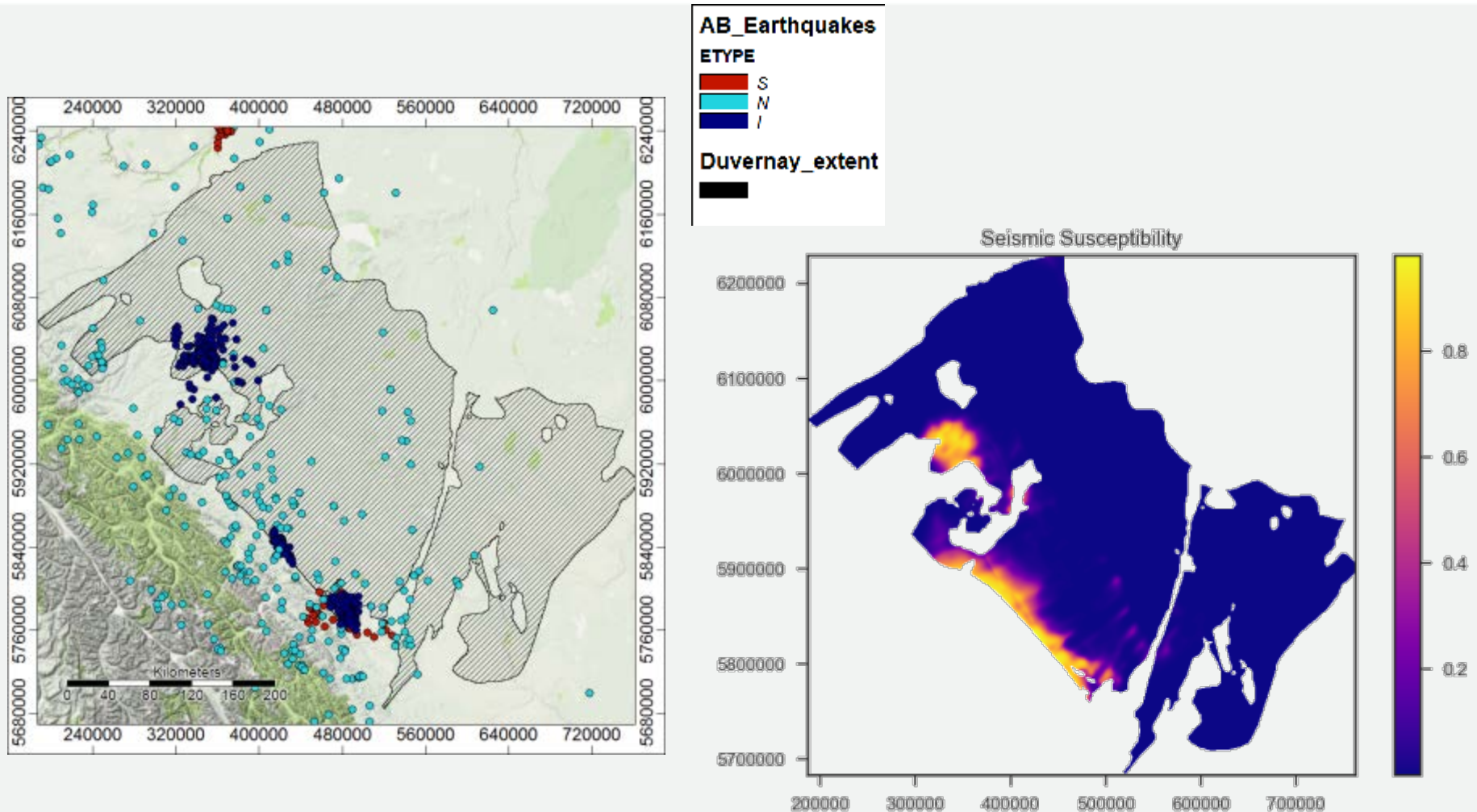
Galloway, E. J., Hauck, T. E., Corlett, H., Pana, D., Schultz, R. (2018). Faults and associated karst collapse suggest conduits for fluid-flow that influence hydraulic fracturing induced seismicity. Proceedings of the National Academy of Sciences, doi:10.1073/pnas.1807549115



# Susceptibility Modeling



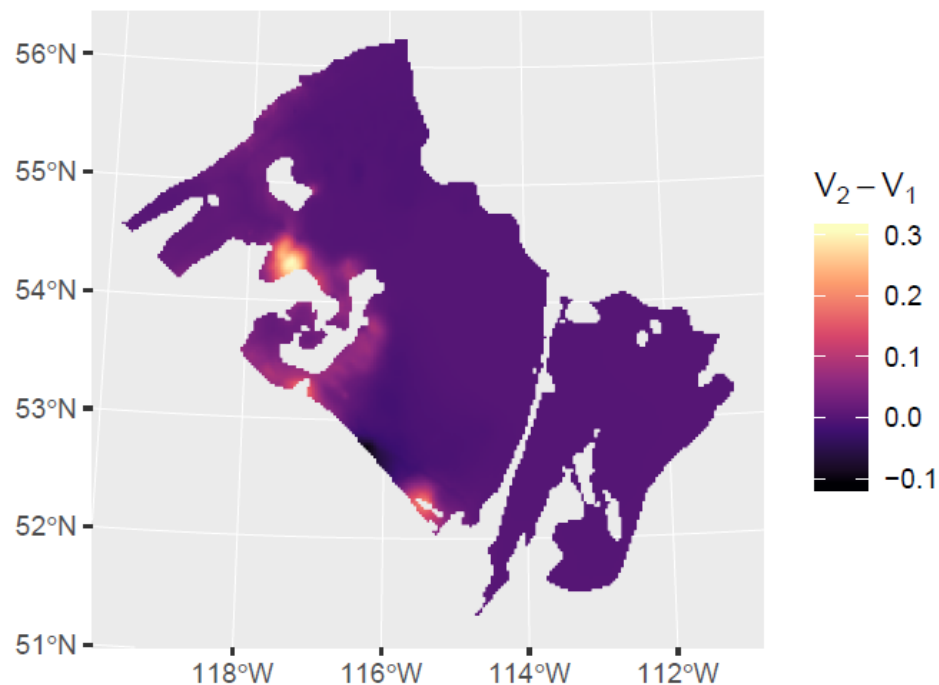
# Induced Seismicity Susceptibility



# GeoSus Model Differences

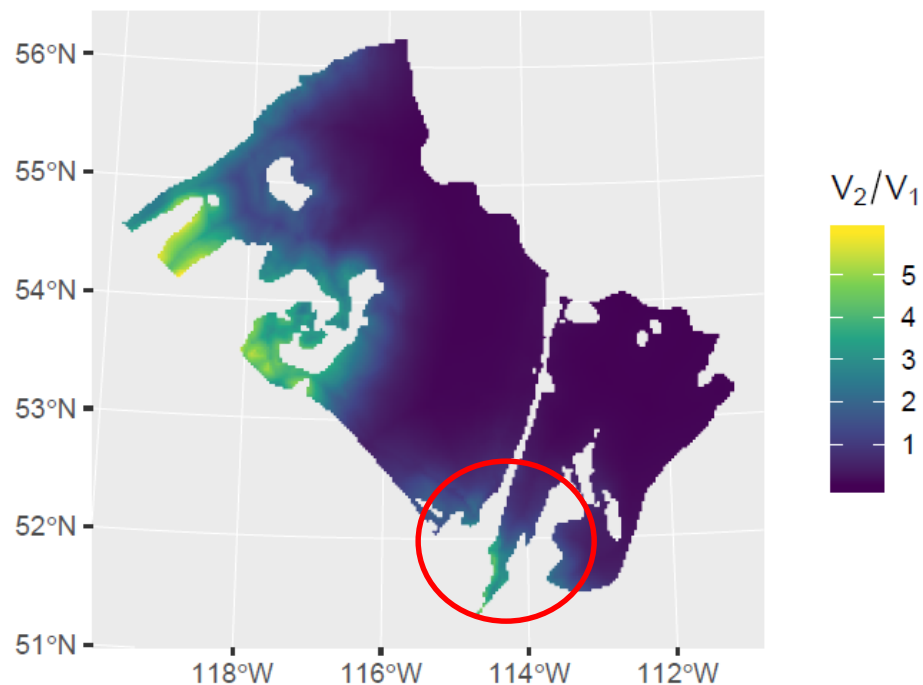
a)

Model version actual difference



b)

Model version relative change





# Questions

