# The Induced Seismicity Team

## *Summary presentation of scientific and socio-political perspectives submitted in the 2018 Dragon's Den Competition*

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The ReDeveLoP Challenge
Calgary, Alberta
Apr.30 – May 4, 2018

# Induced Seismicity

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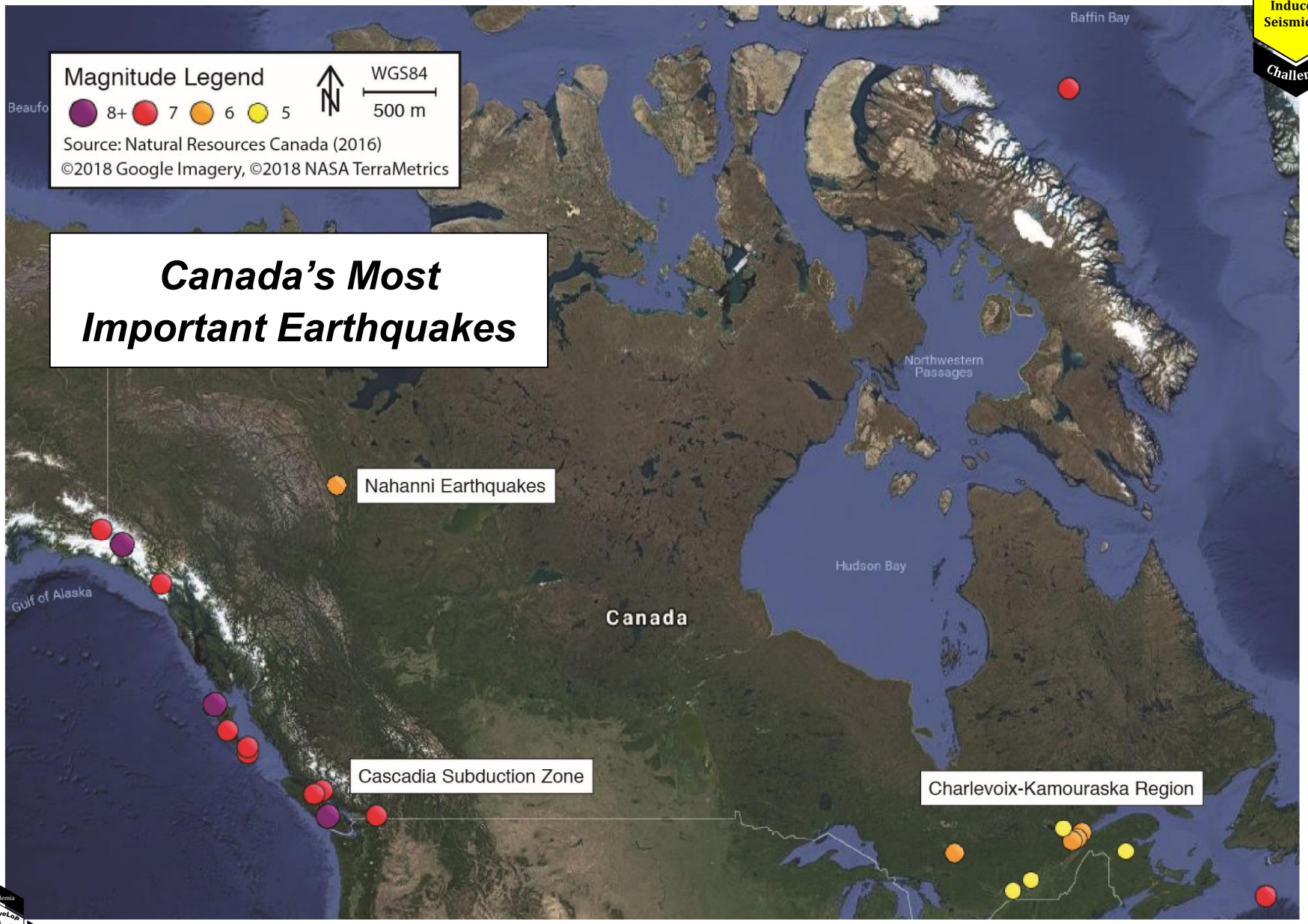
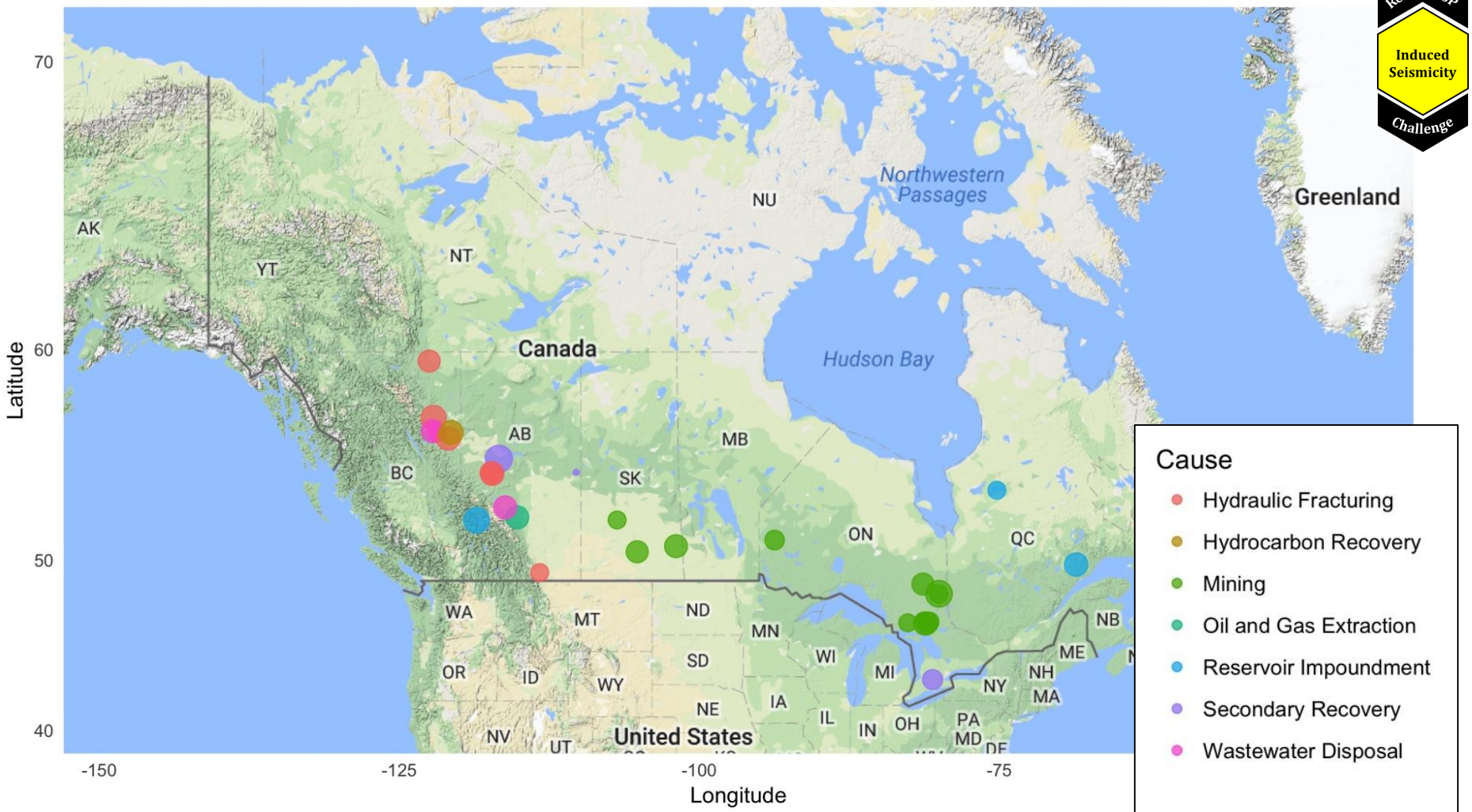
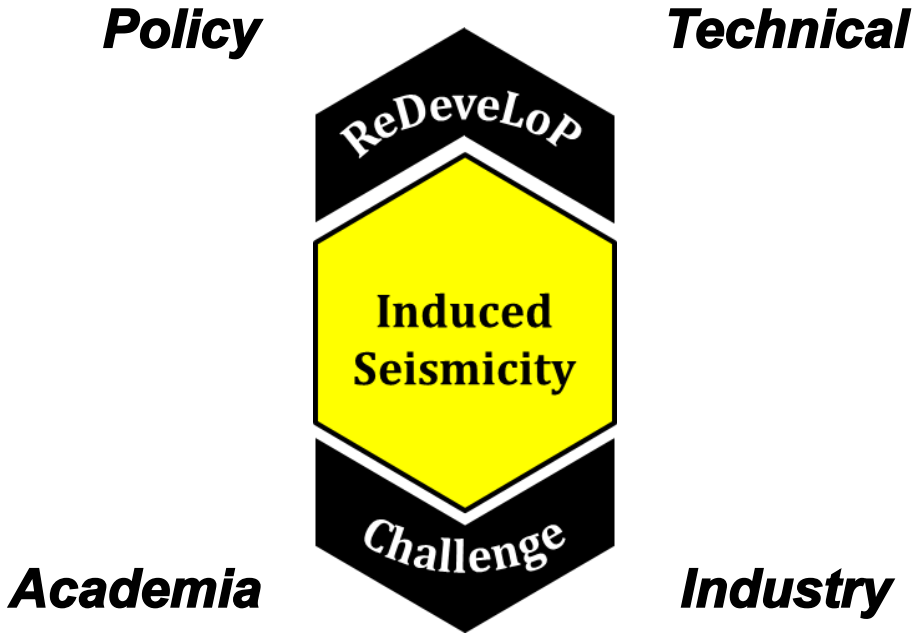

Magnitude Legend
8+ 7 6 5
WGS84
500 m
Source: Natural Resources Canada (2016)
©2018 Google Imagery, ©2018 NASA TerraMetrics
Canada's Most Important Earthquakes
Baffin Bay
Beaufo
Northwestern Passages
Nahanni Earthquakes
Hudson Bay
Gulf of Alaska
Canada
Cascadia Subduction Zone
Charlevoix-Kamouraska Region




# *Canada's Induced Seismicity*

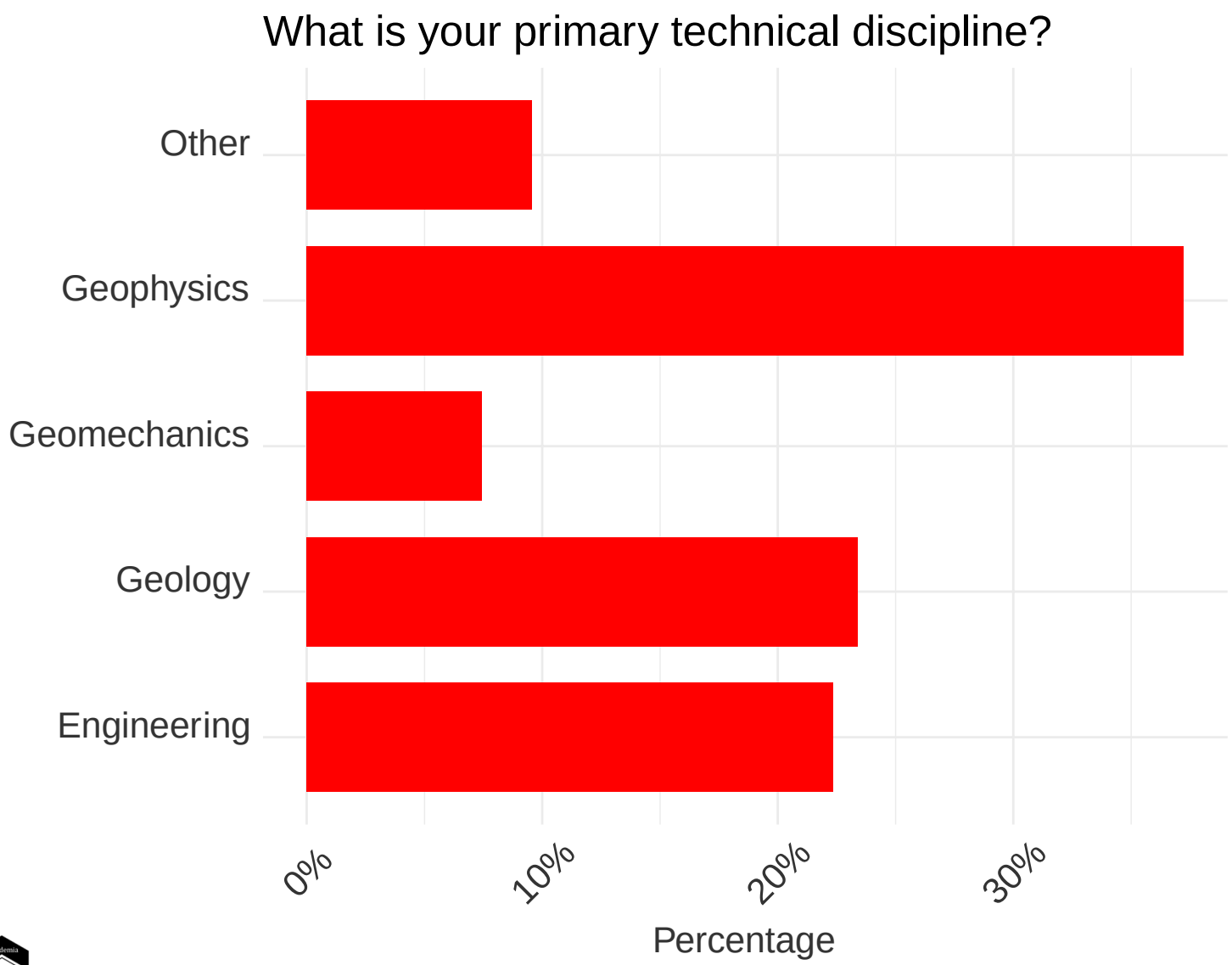



***Survey → Industry Experience***

***Technical → Mechanisms & Likelihood***

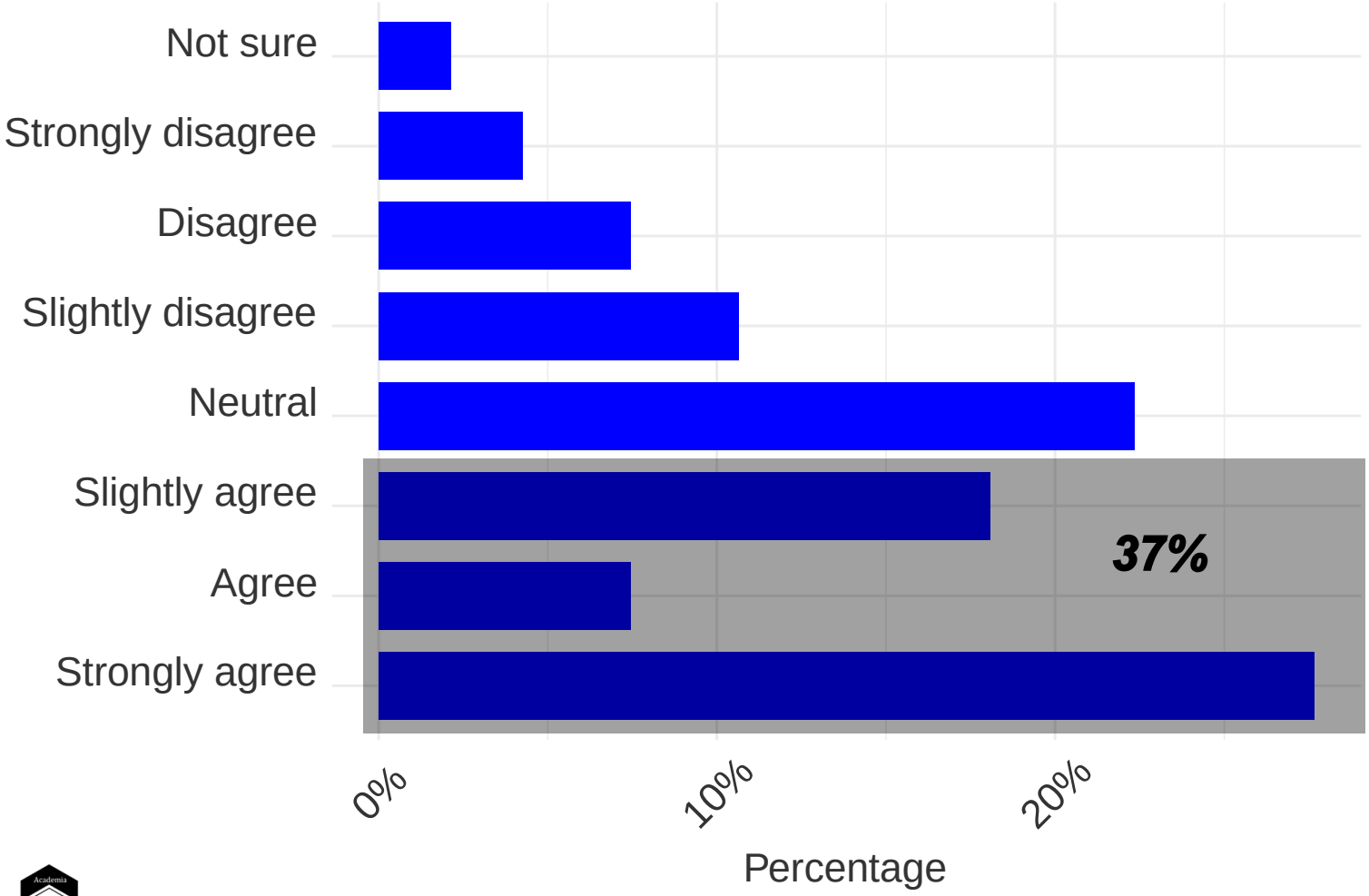
***Policy → Regulations & Recommendation***

# Industry Survey



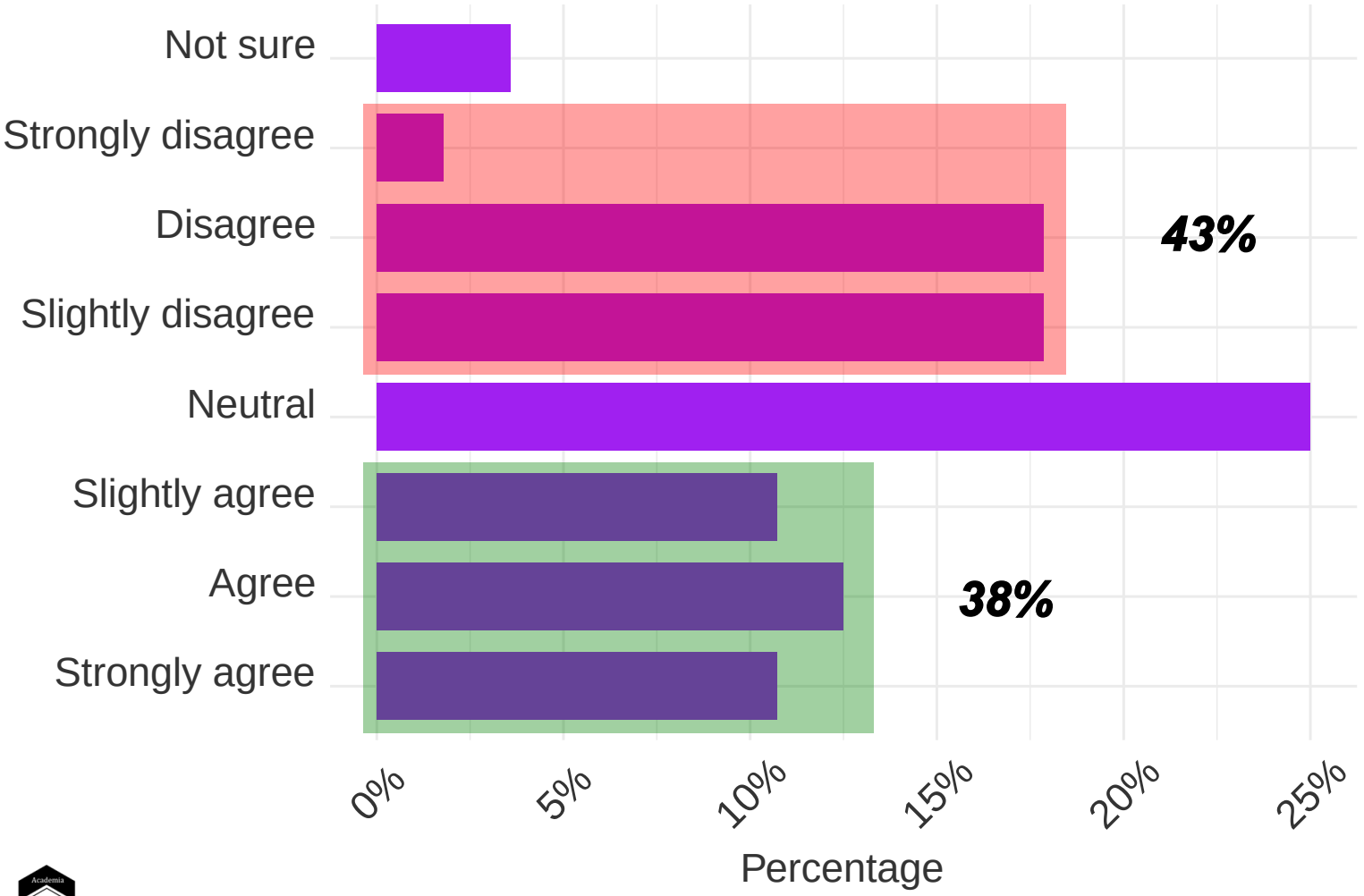
# Industry Survey

Traffic light policies have made a significant difference on drilling, completion, and operation strategies.



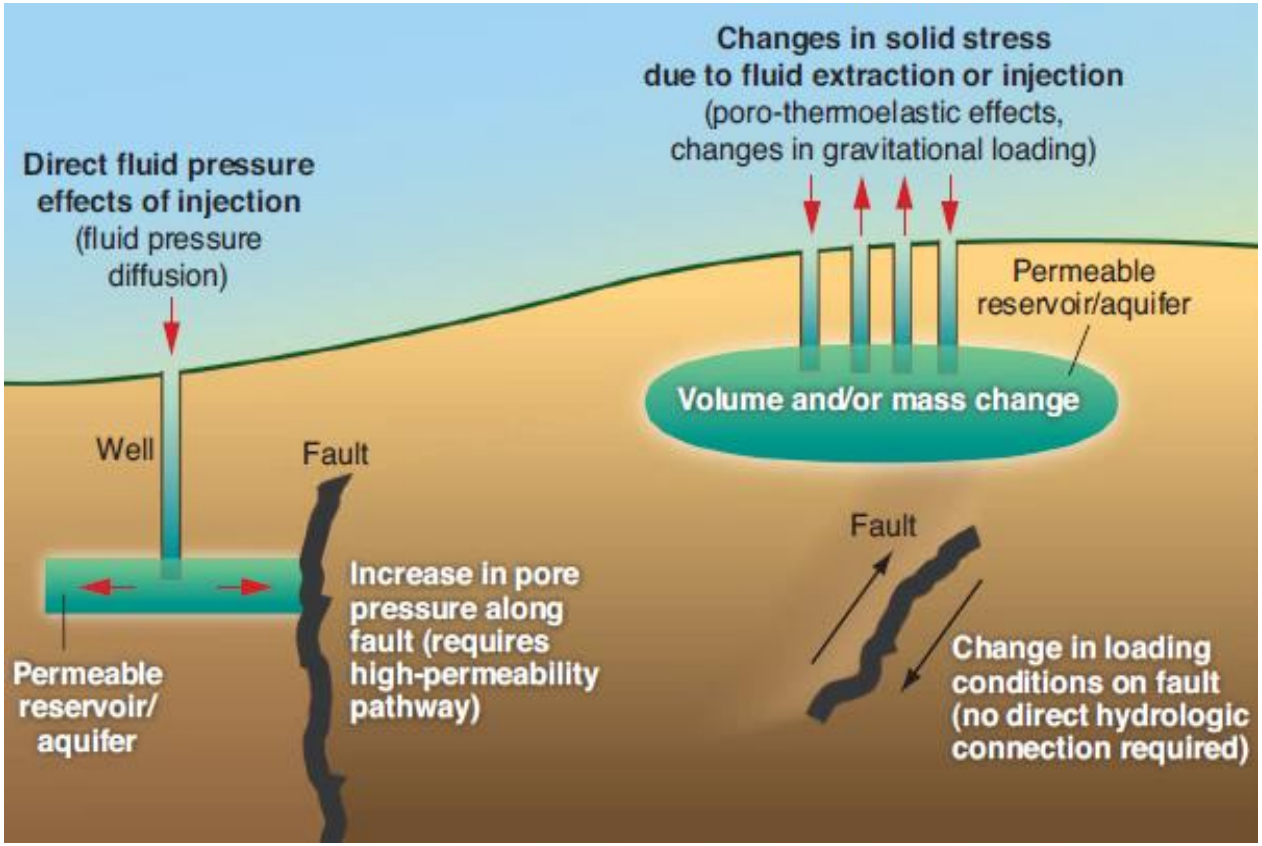
# Industry Survey

Adjusting the azimuth of wells perpendicular to the maximum horizontal stress helps mitigate induced seismicity.



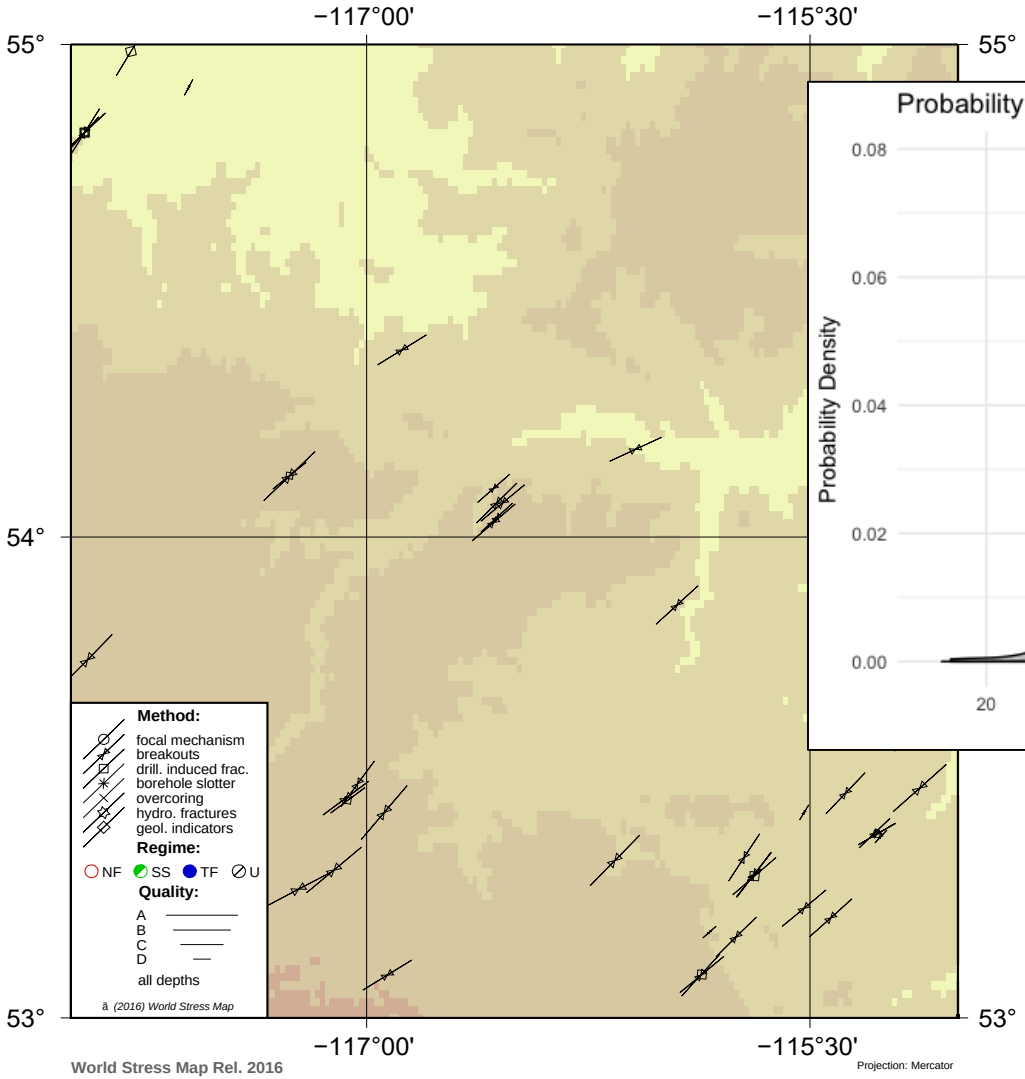
# Mechanisms of Induced Seismicity

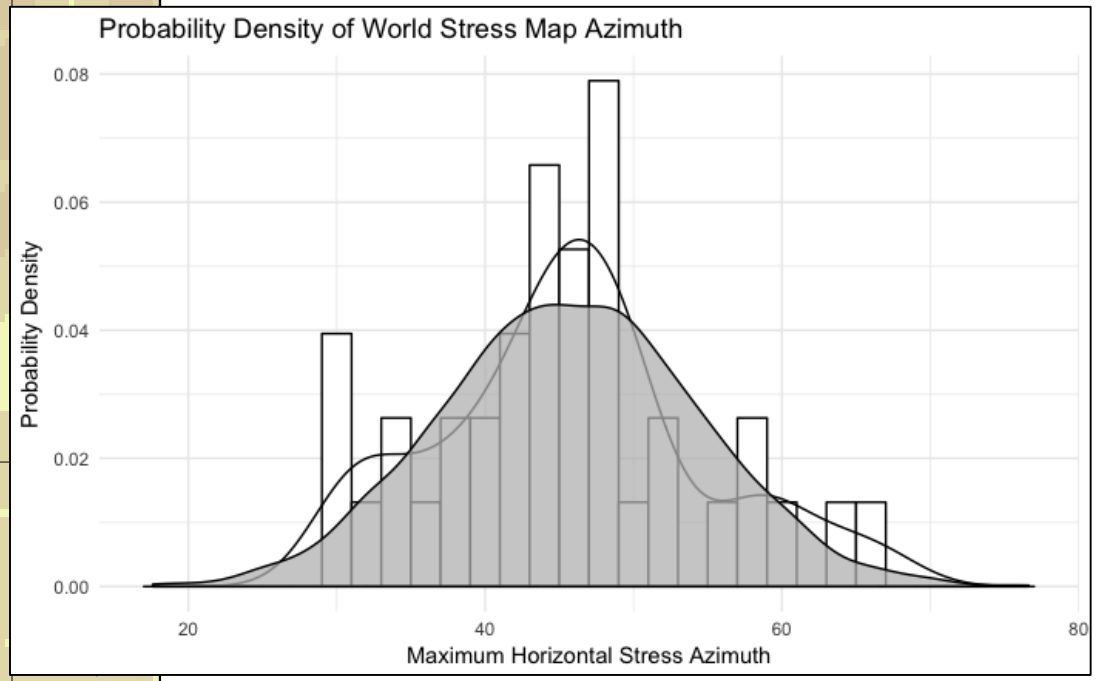
- Hydraulically connected faults
  - Pore pressure change
- Remote faults
  - Total stress change




Adapted from Ellsworth (2013)

# *In Situ Stress Conditions*




Mean $S_{Hmax}$ Azimuth: 45.7°

Standard deviation: 8.9°

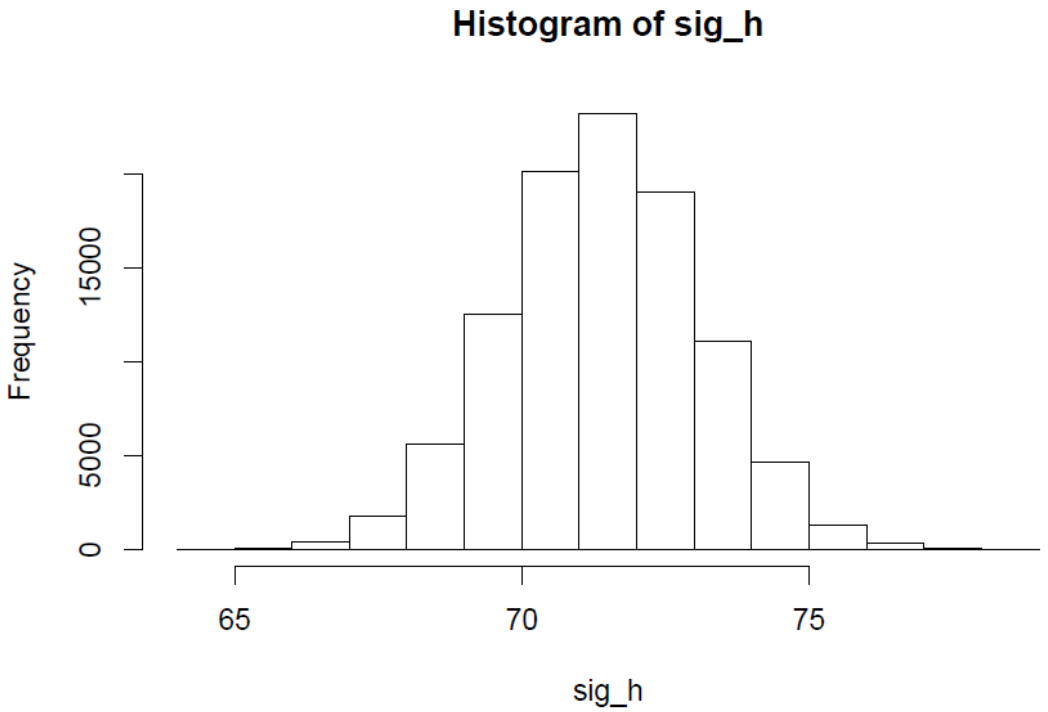
(Heidbach et al., 2008)

# *Fault Slip Potential*

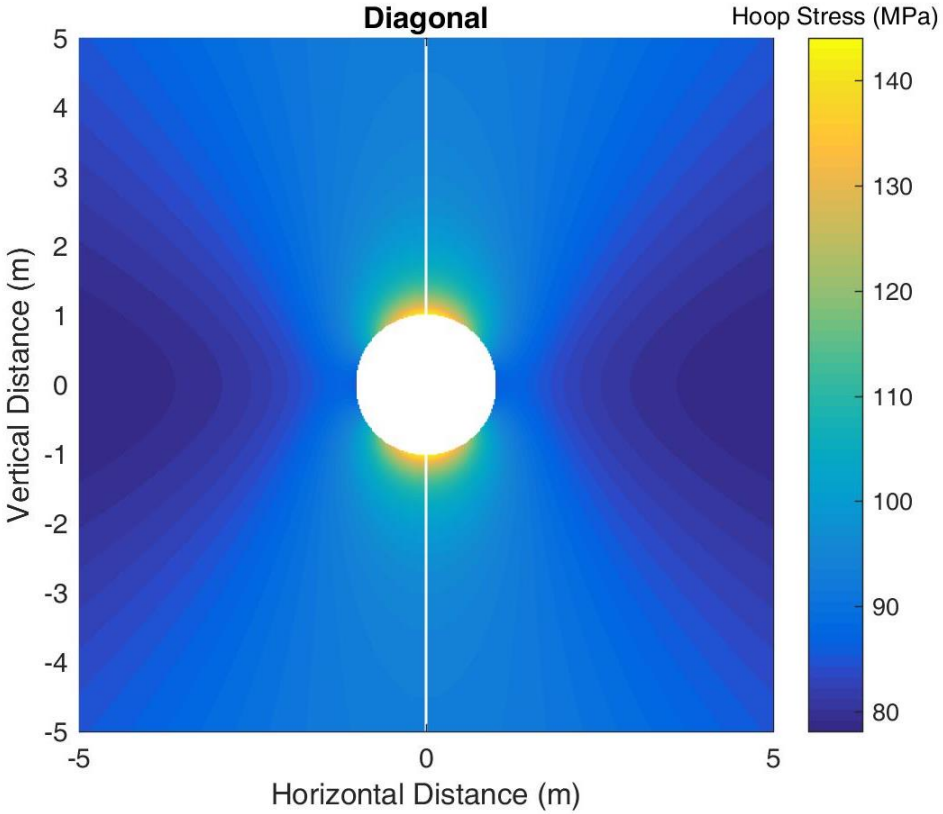
Using published stress data to plot Mohr diagram (Lele *et al.*, 2017).

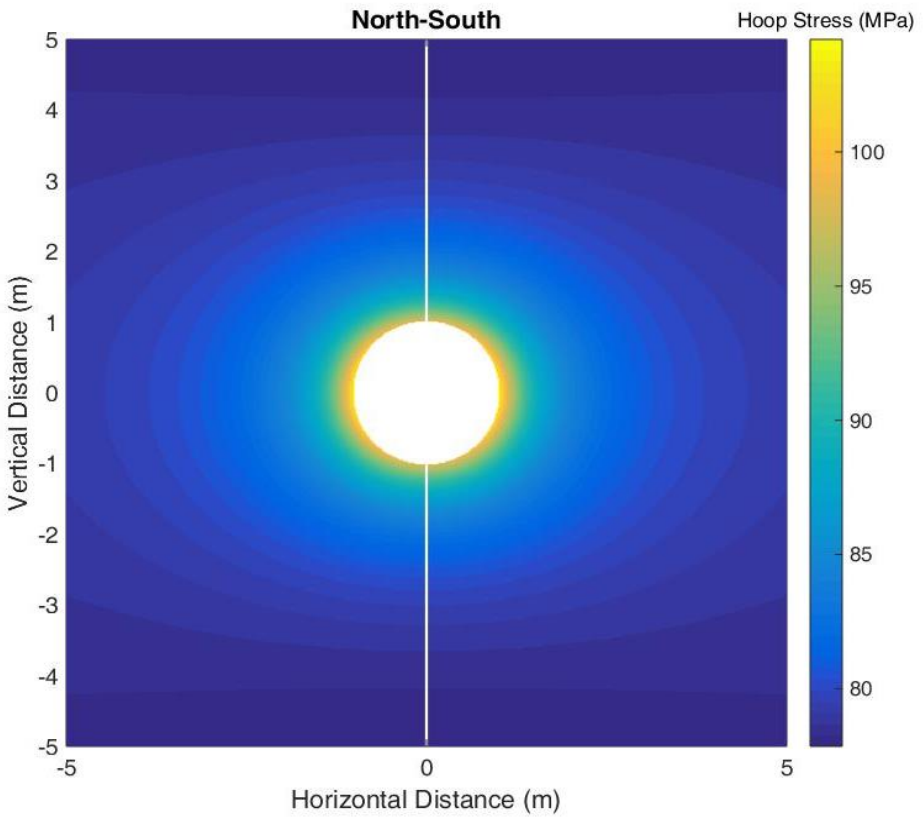
Faults with azimuths of 15° or 75° were most likely to be reactivated.

A bootstrap Monte-Carlo analysis indicates that the probability of failure was 23% without pore pressure or total stress perturbations



# Wellbore Stability



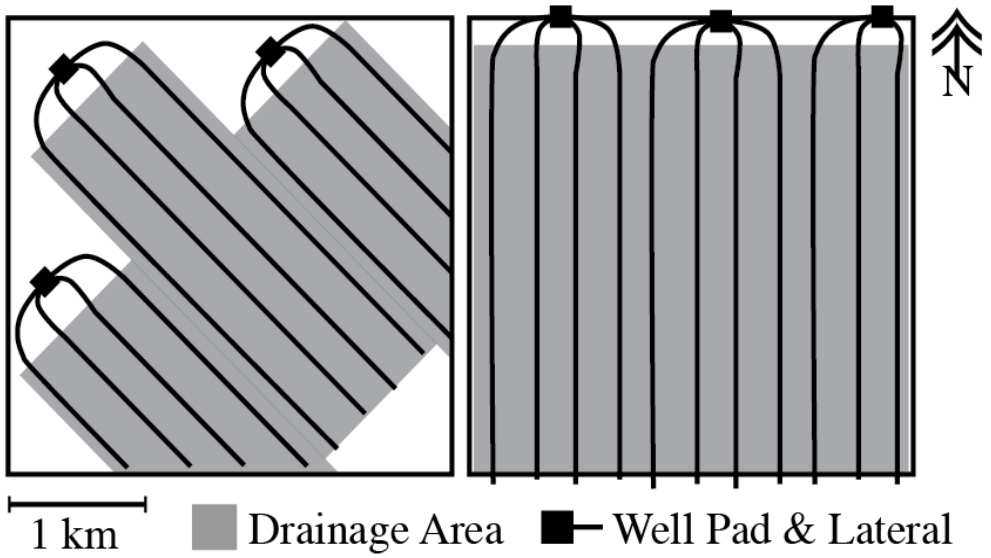
# Economics and Operations

378 wells in the Kaybob area
197 (52%) diagonal
162 (43%) north south.

No statistical difference in:

- Production
- Drilling & Completion Time

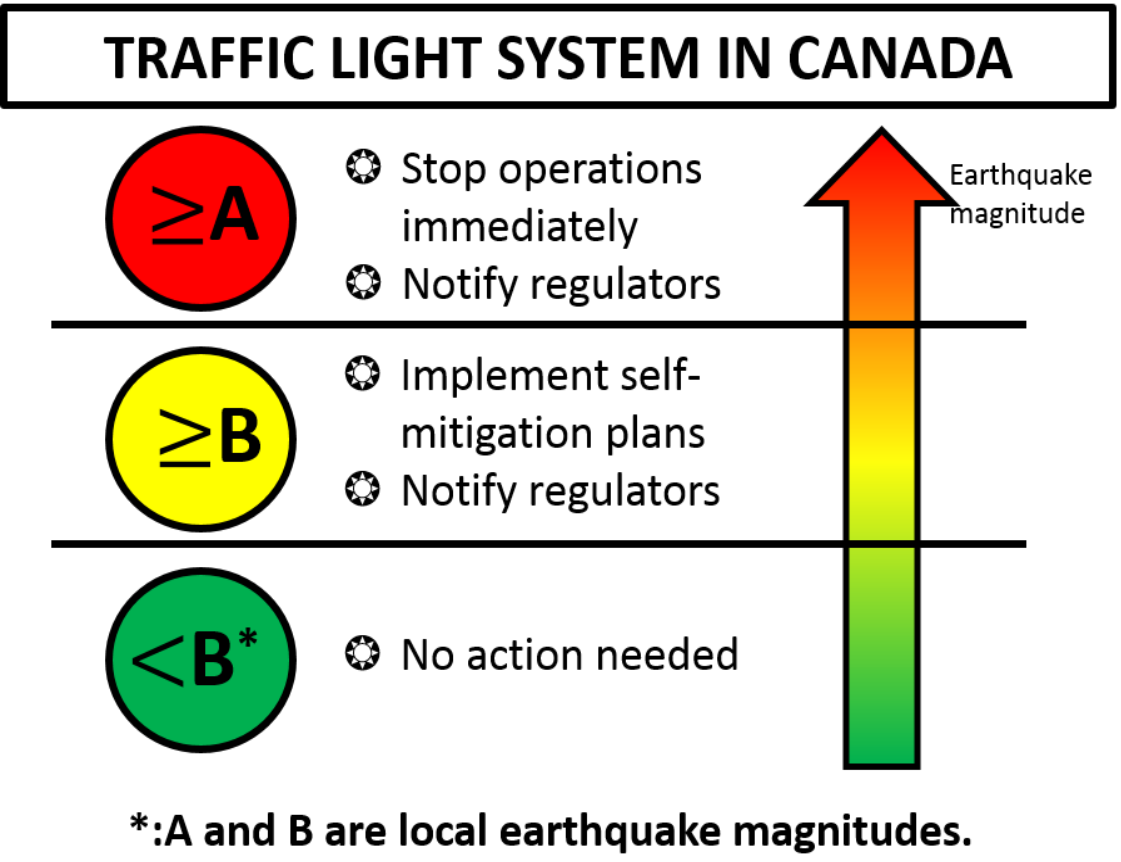
Drainage area is the key!



# Mitigation

- For operators
  - Prior to operation ➔ injection-site characterization
  - During operation ➔reducing injecting volume + rapid flow back
- For government, publish more seismic event data, so that public concerns are eased
- A dense, high-resolution microseismic network

# Regulation




- A calibrated control system
- Providing continuous and real-time **monitoring** and **management** of ground shaking and induced seismicity
- Implemented in Alberta
  - A= M 4
  - B= M 2

# Challenge

- Determining magnitudes ← collecting local reports
- Difficulty in monitoring ← time lag between injection and seismicity
- No ground motion prediction model ← lack of induced seismicity data

# Improvements of TLS

- Use Peak Ground Velocity/Peak Ground Acceleration+ earthquake magnitude
- Consider population density variance ➔ Regionalize
- More transparency

# Acknowledgements

We would like to thank Dr. Dave Eaton, Dr. Jennifer Winter and Dr. Celia Kennedy for their guidance.

The advice of Rebecca Donnell and Dr. Ryan Schultz are much appreciated.

# *Questions?*