Utilizing Traffic Light System Modified by Ground Motion to Manage Induced Seismicity

Yiru Zhou, Mei Li, Neil Fleming, Ryan Green

The ReDeveLoP Challenge
Calgary, Alberta
May 27 – 31, 2019

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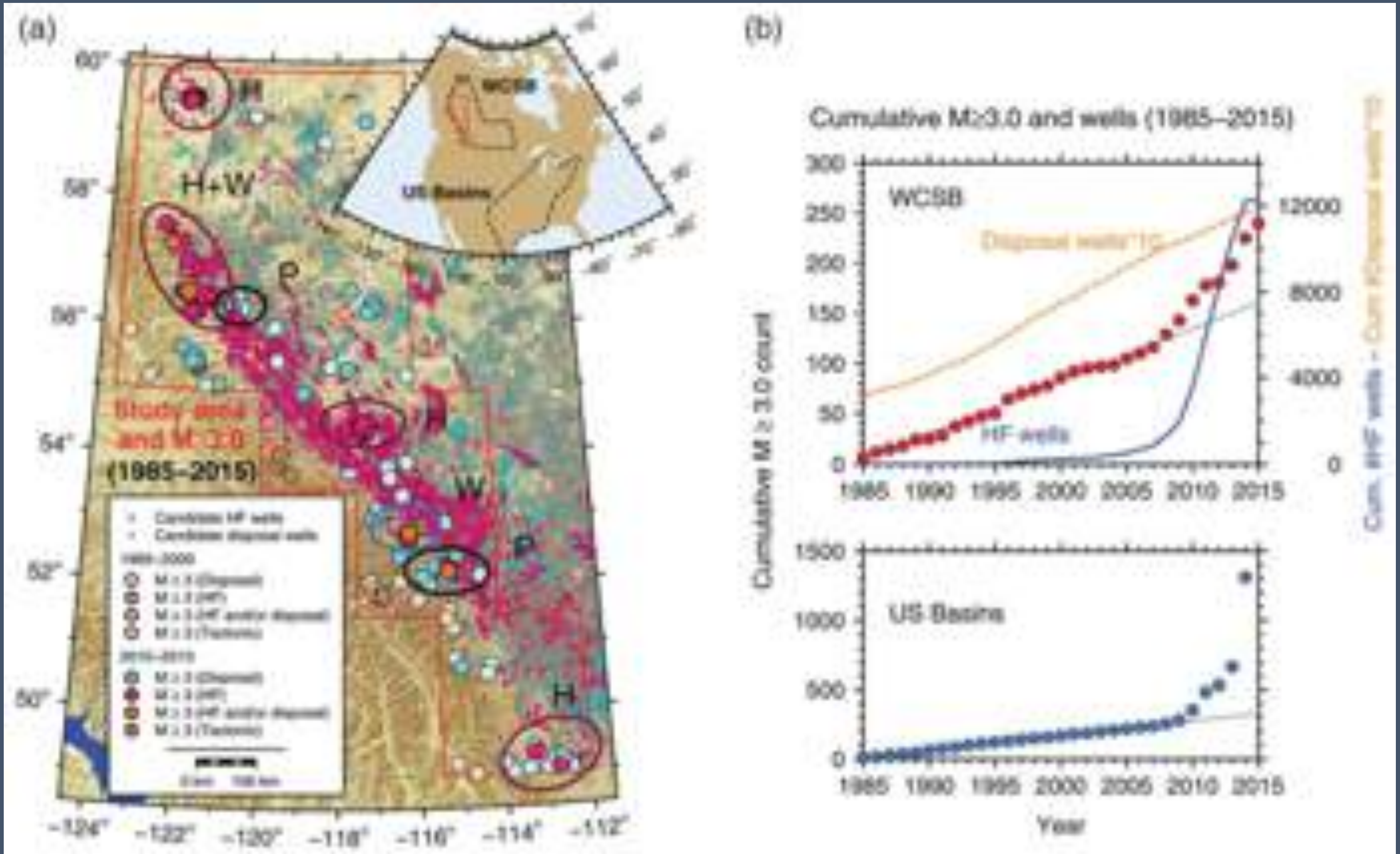
Seismicity events are highly correlated in time and space with hydraulic fracturing in western Canada



Seismicity and wells in the Western Canada Sedimentary Basin (WCSB)(Atkinson,2016)

- Hydraulic Fracturing usage has significantly increased since 2009
- Seismicity in the WCSB has increased during same period

Public Risk

- Induced seismicity has the potential to:
  - Damage public and private infrastructure
  - Negatively affect public perception of the oil and gas industry
  - Negatively affect personal well-being and mental health

"The traffic light system…, in our opinion, [is] not working to ensure the safety and wellbeing of our Town and its Residents."

- Town of Fox Creek, April 10, 2018

Current Alberta Traffic Light System Utilizes Local Magnitude

Traffic Light System (Alberta Energy Regulator)

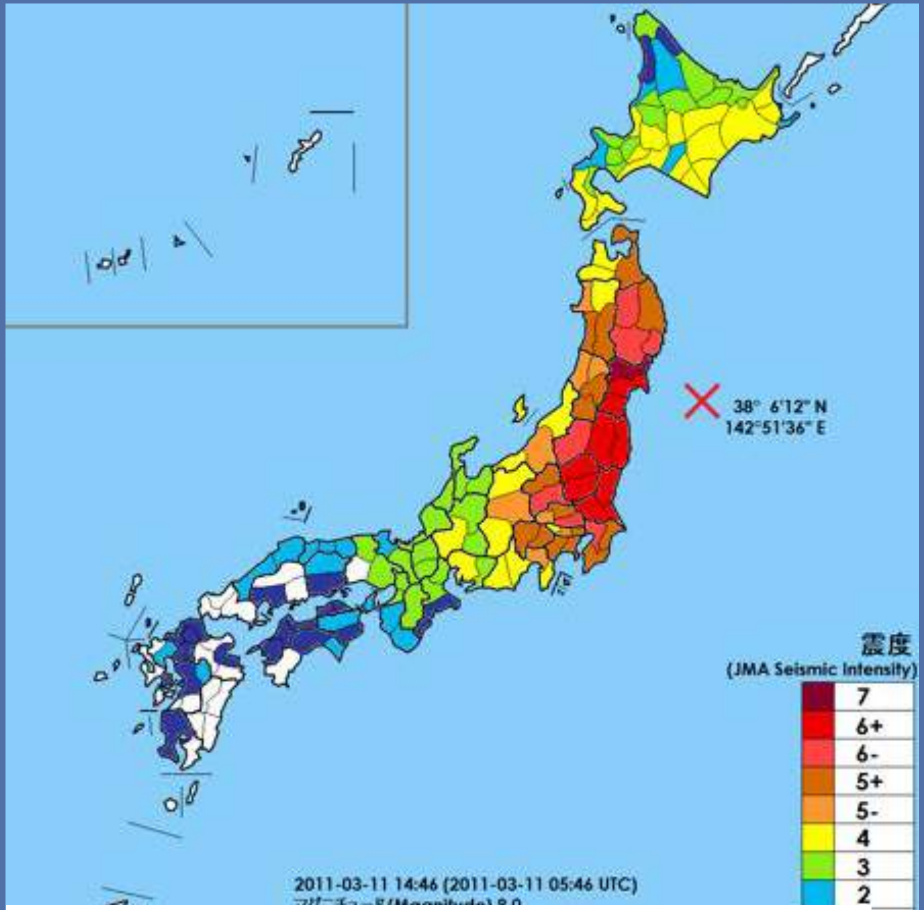
- Local Magnitude M_L :
  - A measure of the energy released at the earthquake's **SOURCE**

Globally Utilized Seismicity Measurements

Source Local Magnitude

oilandgasinfo.ca/all-about-fracking/induced-seismicity/

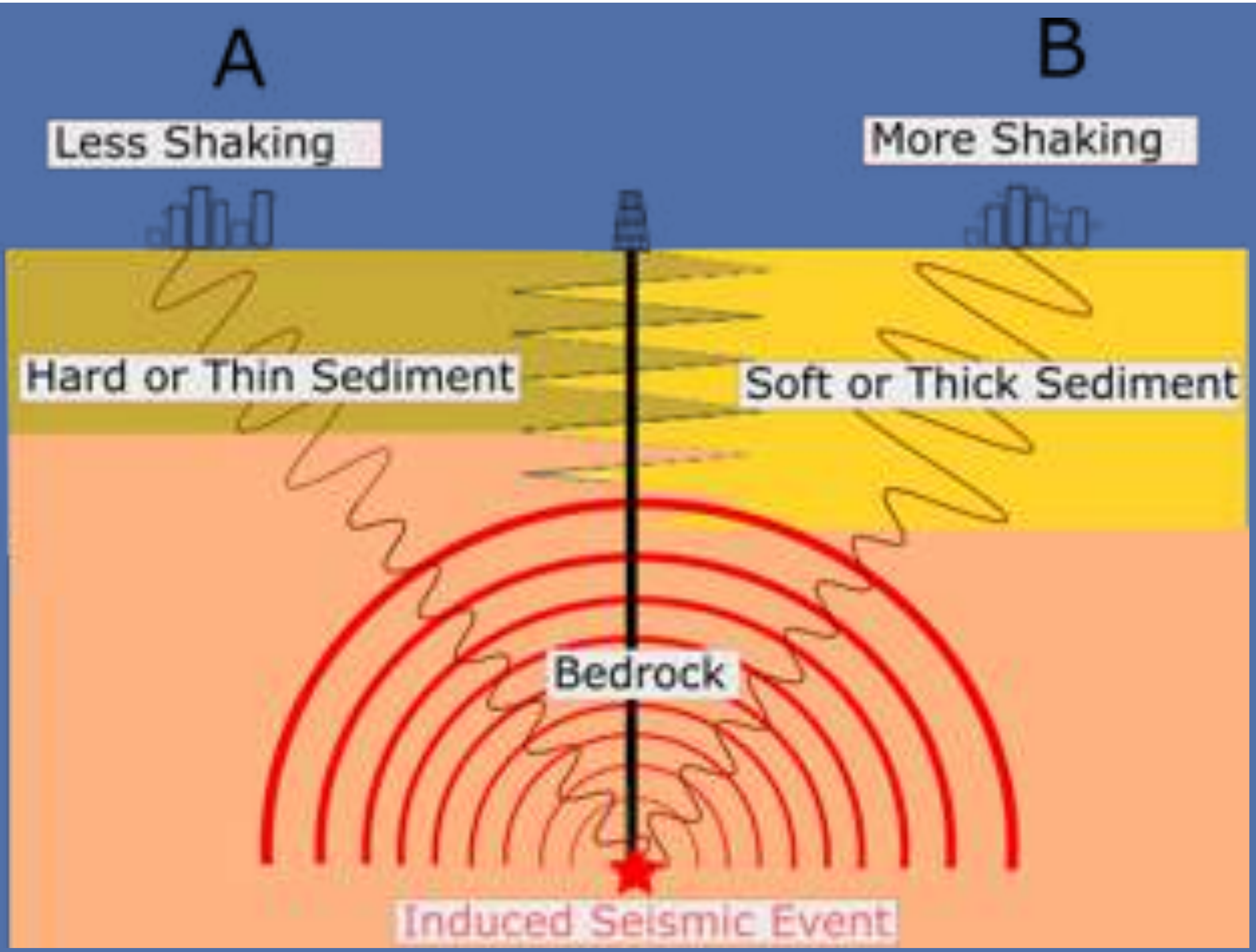
Surface Ground Motion



Japan Meteorological Agency Seismic Intensity Scale

https://wikivisually.com/wiki/Japan_Meteorological_Agency_seismic_intensity_scale

Conceptual Understanding of Ground Motion



Conceptual model of variable ground motions caused by an induced seismic event under different local site effects

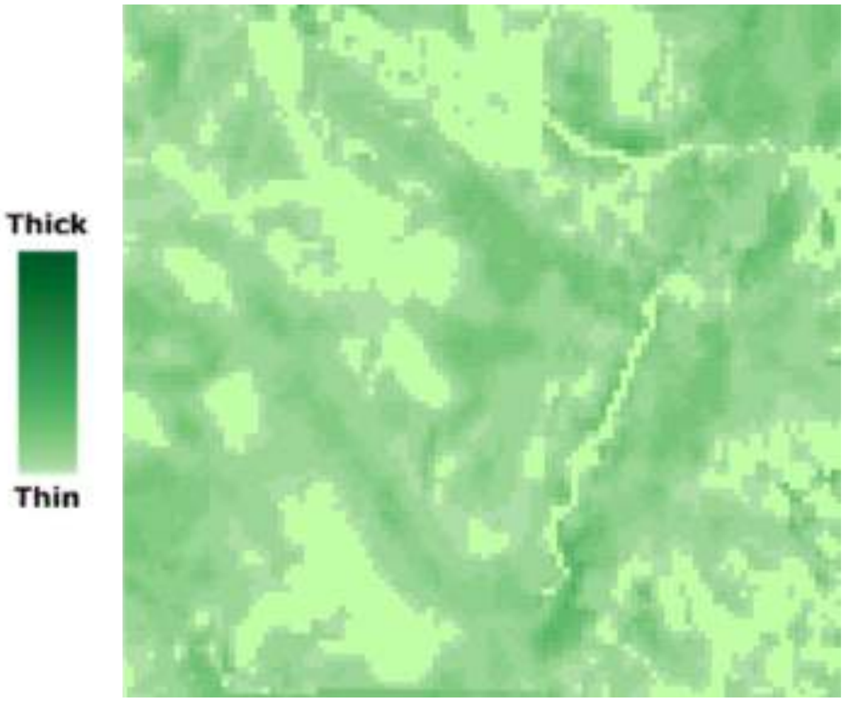
1. Magnitude of the induced seismicity

2. Distance from the hypocenter
- Depth
- Lateral Distance

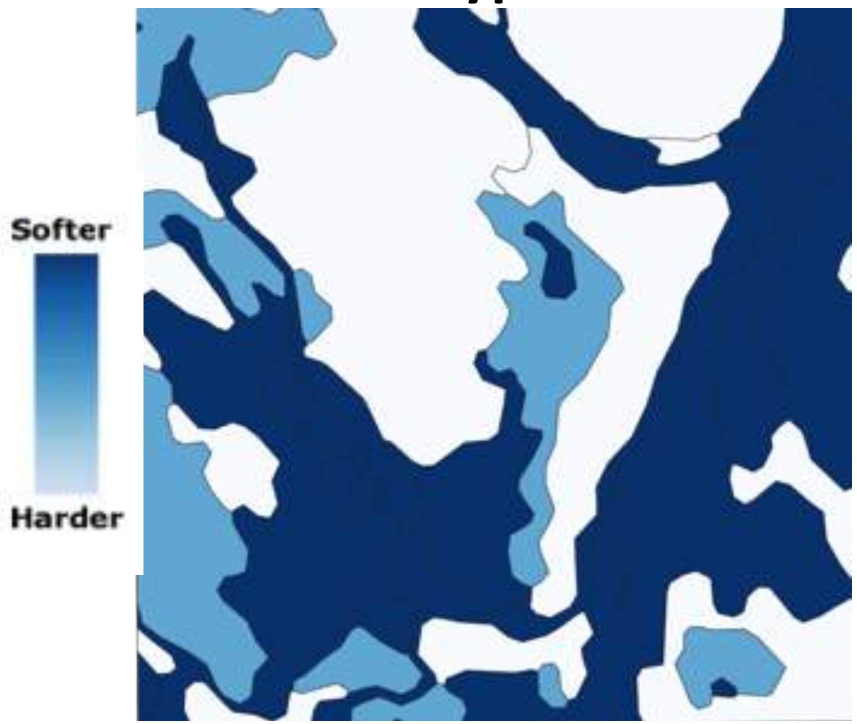
3. Local site effects
- Sediment impedance
- Sediment thickness
- Surface topography

Alberta Local Site Effects

- **Sediment Thickness**



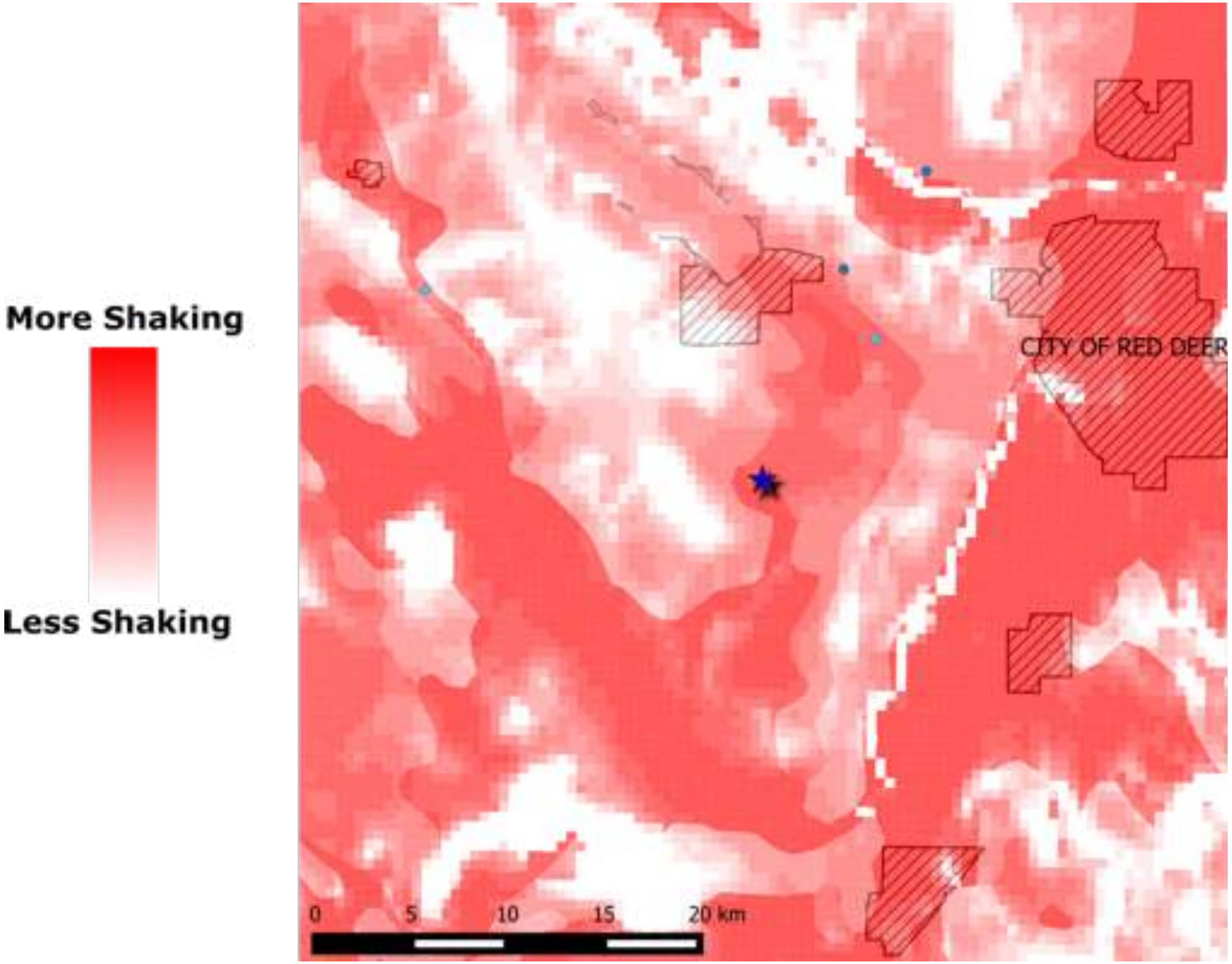
- **Sediment Type**



Data from: Alberta Geological Survey, AltaLis, Earthquakes Canada

Alberta Local Site Effects

Shear Wave Velocity in the Upper 30 m (VS_{30})



Data from: Alberta Geological Survey, AltaLis, Earthquakes Canada

Question:

Same local magnitude seismic events potentially leads to different ground motions, due to local site effects

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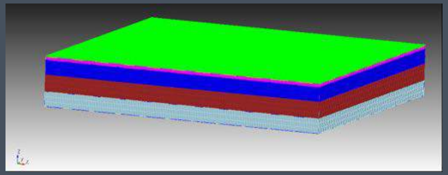
Is ground motion (Peak Ground Acceleration, PGA, and Peak Ground Velocity, PGV) a better metric?

How do we study the feasibility of PGA and PGV to modify TLS?

Velocity Model

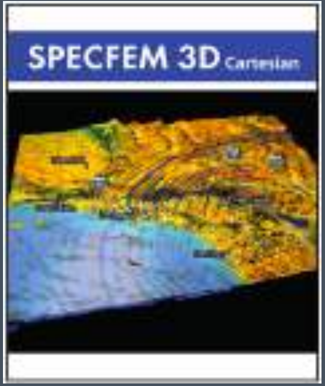
different upper sedimentary layer model



Velocity model

Source Parameters

SPECFEM3D

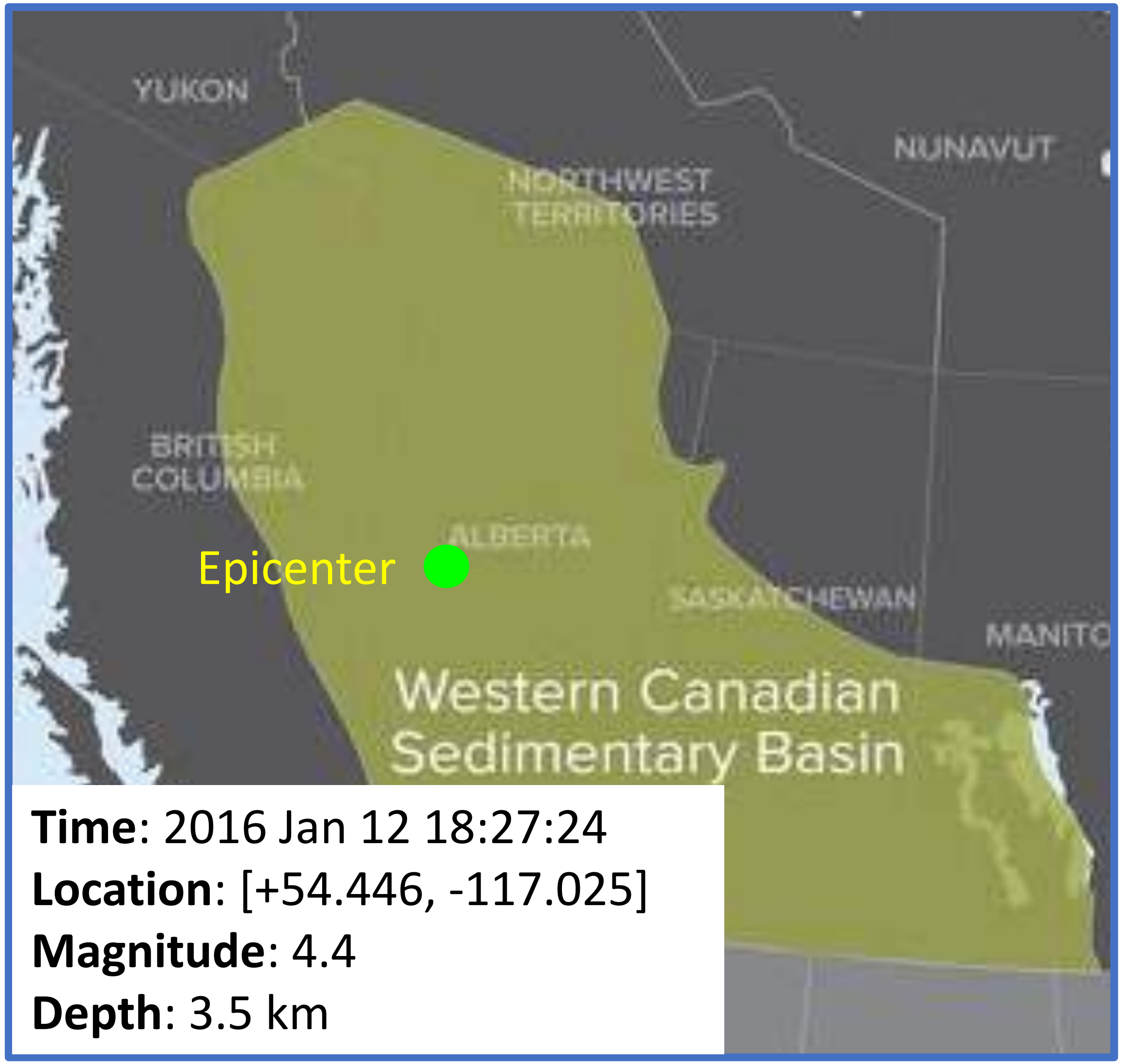


SPECFEM(Computational Infrastructure for Geodynamics , 2018)

Simulation Results

The Study Area – WCSB

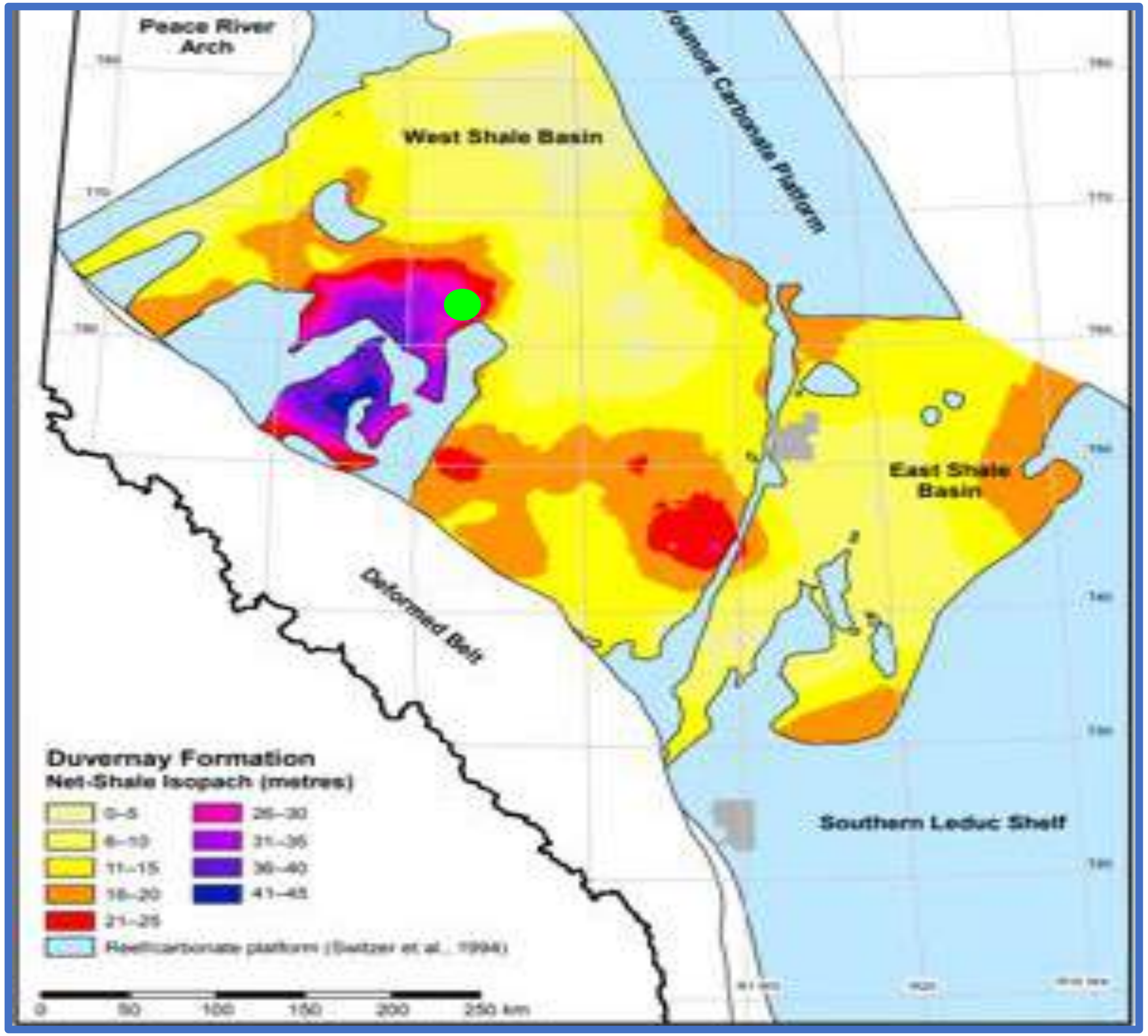
Geographic Location



Time: 2016 Jan 12 18:27:24
Location: [+54.446, -117.025]
Magnitude: 4.4
Depth: 3.5 km

Western Canadian Sedimentary Basin (Packer Plus, 2018)

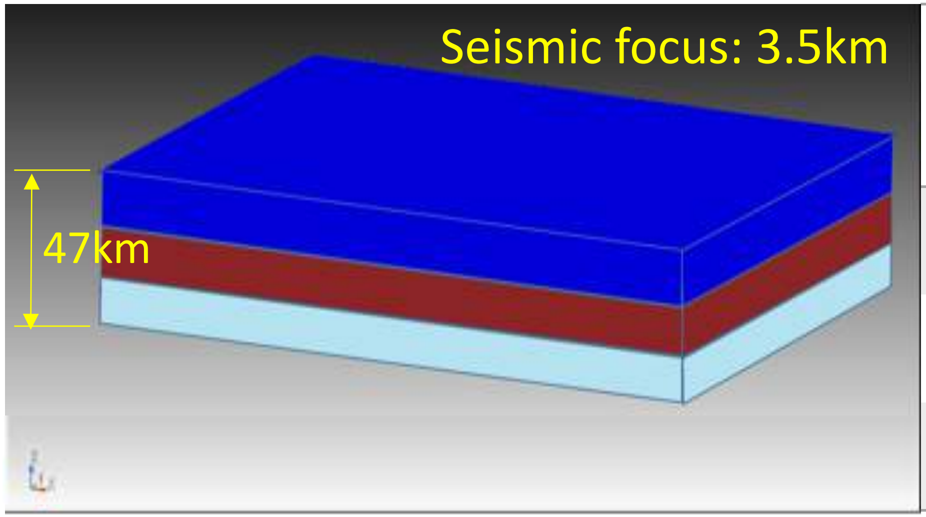
Geology



Duvernay Shale Formation Thickness(ERCB, 2012)

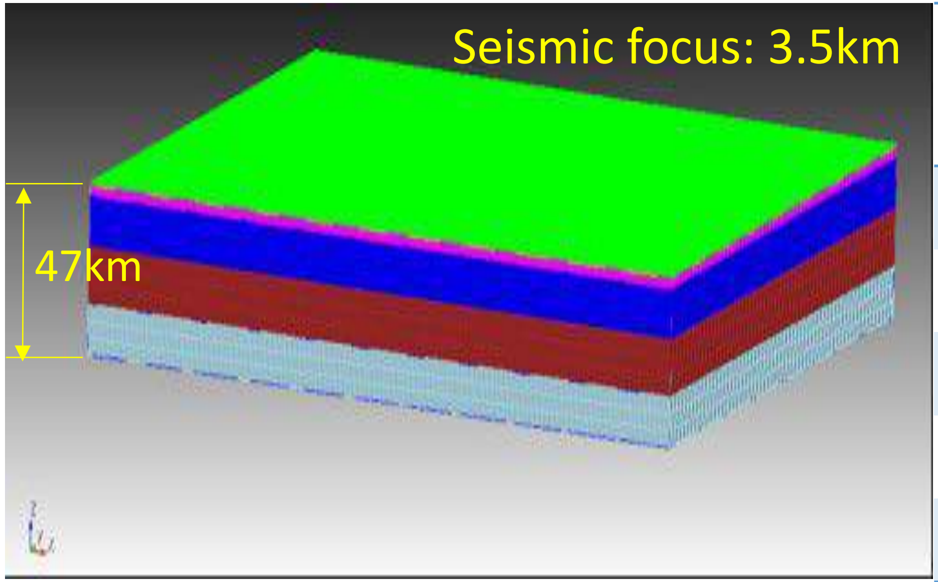
Numerical Models

Without upper sedimentary units:



Layer	Depth (km)	V_P (km/s)	V_S (km/s)	Impedance (km·g)/(s·cm³)
1	0 - 17.6	6.1	3.5	102.0
2	17.6 - 33.1	6.5	3.7	119.6
3	33.1 - 47	6.9	3.9	139.0

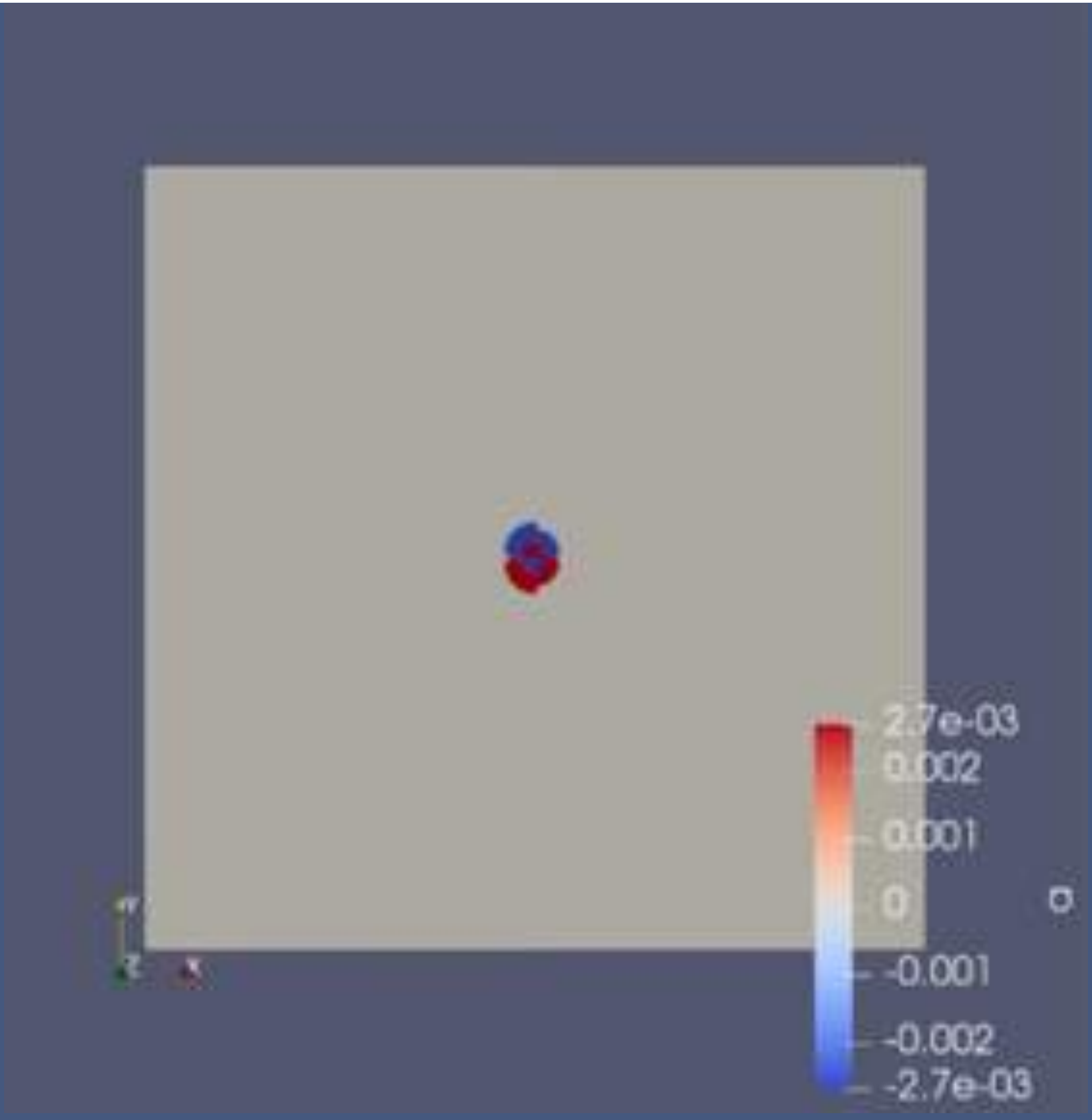
With upper sedimentary units:



Layer	Depth (km)	V_P (km/s)	V_S (km/s)	Impedance (km·g)/(s·cm³)
1	0 - 1.0	2.5	1.1	13.2
2	1.0 -3.8	4.6	2.6	52.1
3	3.8 - 17.1	6.1	3.5	102.0
4	17.1 - 33.1	6.5	3.7	119.6
5	33.1 - 47	6.9	3.9	139.0

Simulation Results

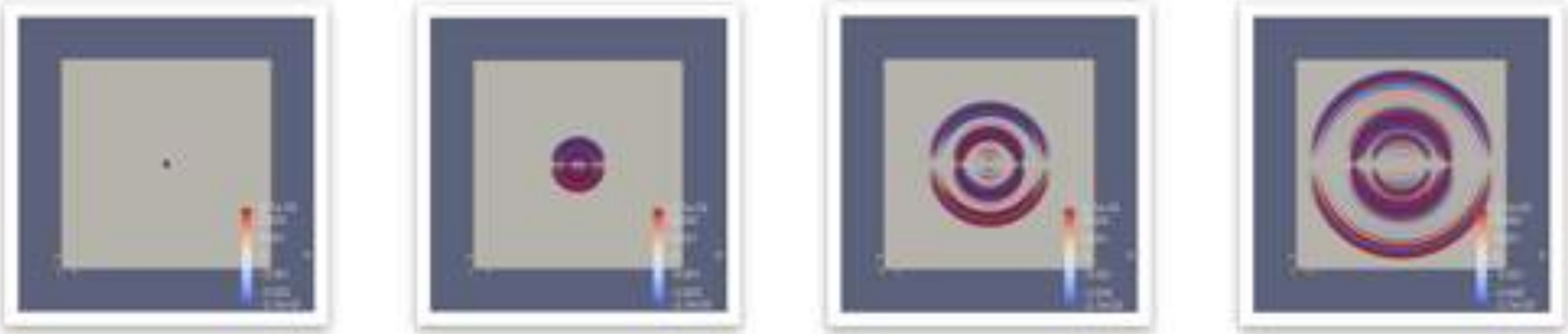
Without upper sedimentary units



With upper sedimentary units

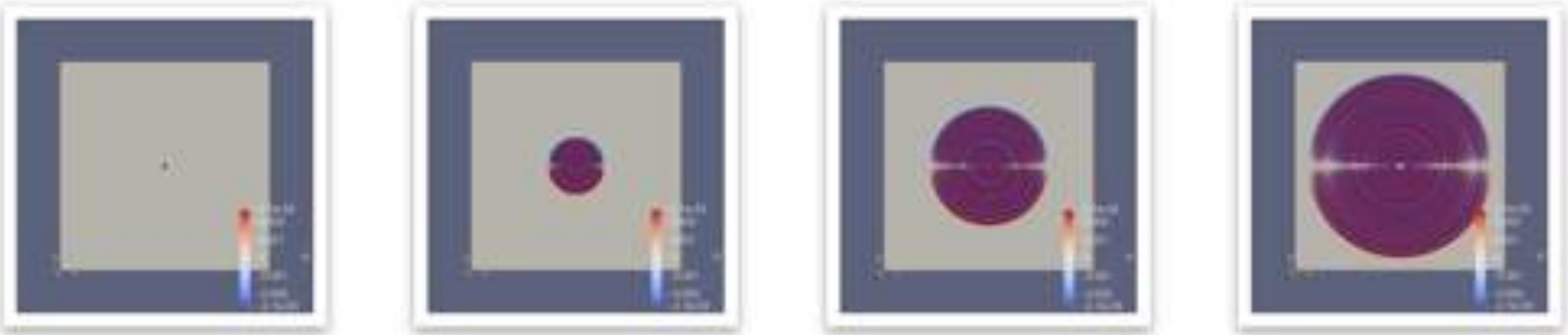
Simulation Results – Shakemaps

Without Upper Sedimentary Units:



01s 10s 20s 30s

With Upper Sedimentary Units :

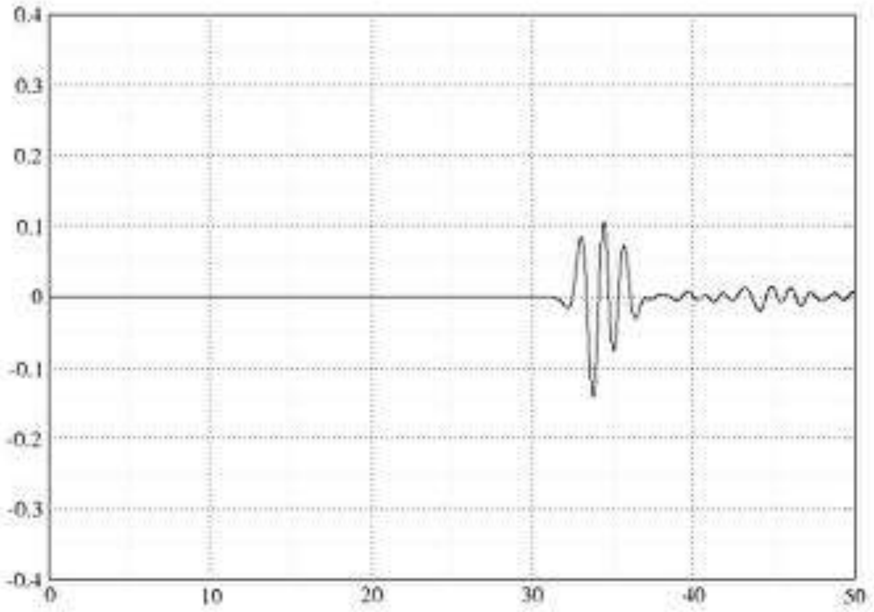


01s 10s 20s 30s

Compare Waveforms at the Same Receiver

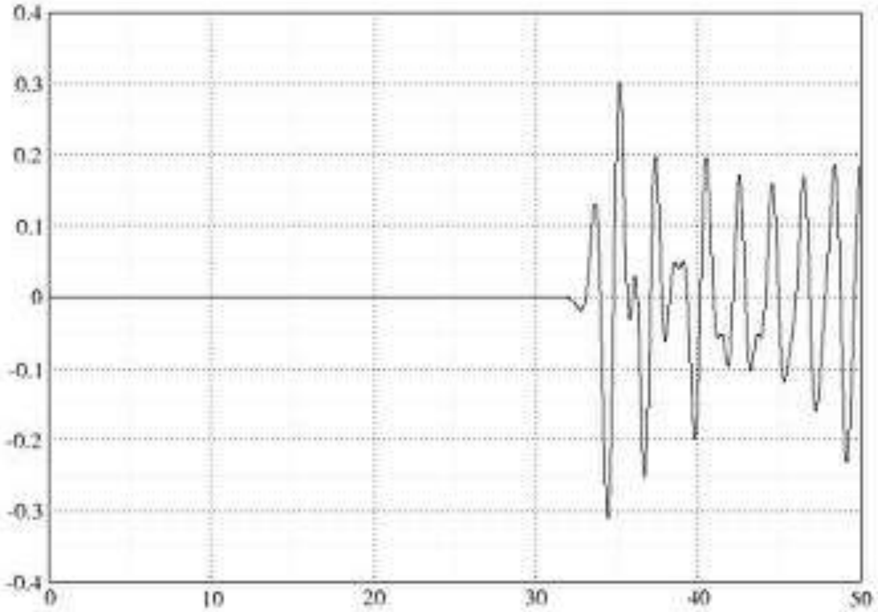
Without Upper Sedimentary Units:

Ground Acceleration (m/s^2)



Time (sec)

With Upper Sedimentary Units:



Time (sec)

Answer

Same local magnitude seismic events potentially lead to different ground motion

→

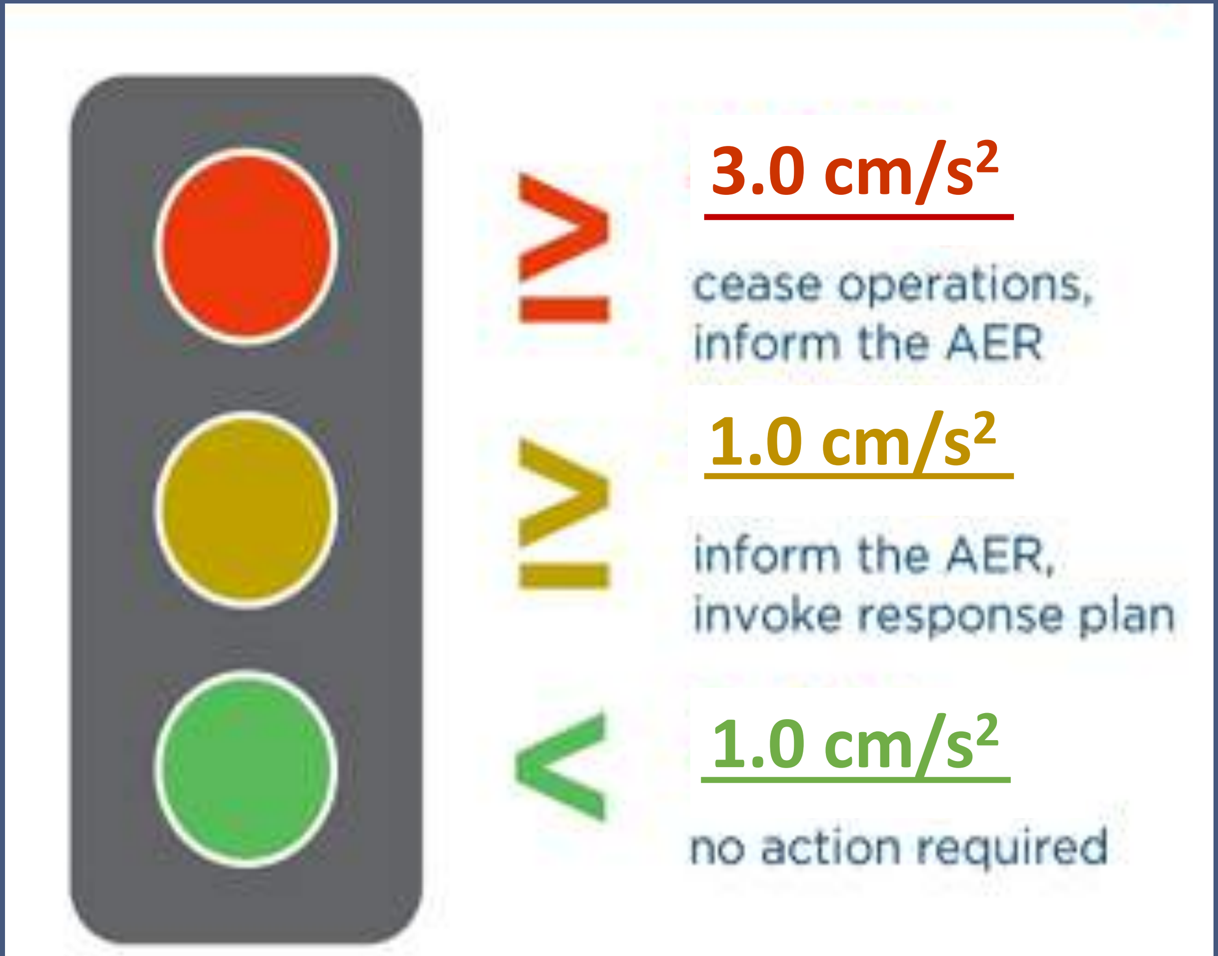
Peak ground acceleration (PGA) and peak ground velocity (PGV) are a better metric for management of induced seismicity

Policy Recommendations

PGA thresholds would apply to the ground motion felt at the nearest residence

- Greater tolerance for ground shaking in remote areas
- Greater protection for the public near residences

Ground Motion Based TLS



Conclusions

- Local site effects are a determining factor in surface ground motion resulting from induced seismicity
- Public risk from induced seismicity occurs at low levels of ground motion
- A revised TLS should utilize surface ground motion as a key factor to manage induced seismicity

Acknowledgement

- Seismic waveform data from TD and RAVEN stations were requested though Incorporated Research Institution for Seismology (IRIS).

- We use SPECFEM3D Cartesian FROM SOURCE, and we thank the Computational Infrastructure for Geodynamics (http://geodynamics.org) which is funded by the National Science Foundation under awards EAR-0949446 and EAR-1550901.

- Special thanks to Professor Giovanni Grasselli for his academic advice and support.

- Thanks to ReDeveLoP program for its support.

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Questions?
Yiru Zhou yiru4@ualberta.ca; Mei Li meili.li@mail.utoronto.ca;
Ryan Green ryan.green1@ucalgary.ca; and, Neil Fleming naflemin@ucalgary.ca