Utilizing Ground Motion in the Traffic Light System to Better Estimate Potential Damages Caused by Induced Seismic Events

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Introduction

Induced seismicity is regulated in Western Canada through programs including the 'Traffic Light System', which informs operational responses to induced seismic events depending on the local magnitude (Alberta Energy Regulator, 2018). While the structure of these regulations focuses on local magnitude, it is becoming increasing evident that determination of ground motion, including Peak Ground Acceleration (PGA), is more important for estimating potential damages and sensed seismic events (Yenier et al. 2016). With increasing public scrutiny for the oil and gas industry to effectively manage induced seismic events, the consideration of local shaking impacts will provide improved management of potential damages and public perception (e.g. Bommer et al. 2015). In this study, we demonstrate the significant role of surficial sediments in seismic propagation within the Western Canada Sedimentary basin using seismic wave simulation.

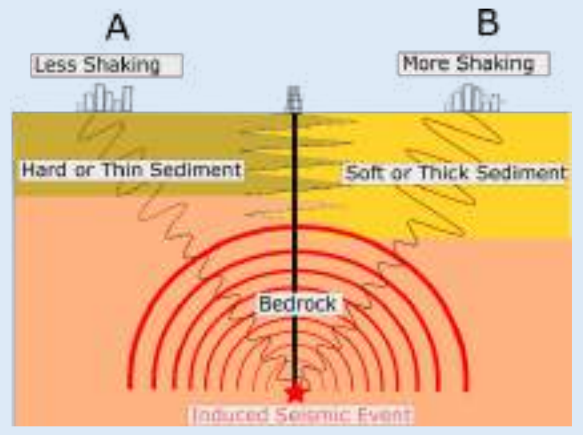
Traffic Light System (Alberta Energy Regulator)

Effects of Upper Sedimentary Units

Estimation of the potential ground motion at ground level must consider:

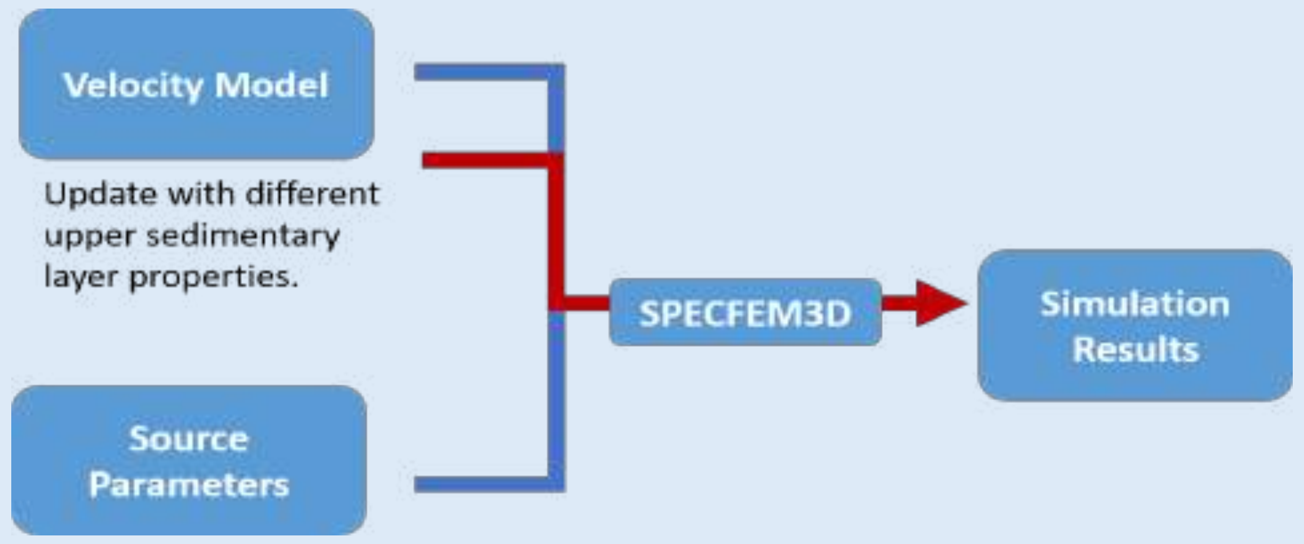
1. Local site effects.
   - Impedance of sedimentary units
   - Thickness of sedimentary units
   - Surface topography
2. Distance from the hypocenter.
   - Depth
   - Lateral Distance
3. Magnitude of the induced seismicity.

Spatially variable surficial sediment ary impedance and thickness, and differing source depths, can cause variations in ground motion, even from seismic events of the same local magnitude.



Conceptual model of variable ground motions caused by an induced seismic event with different impedances of sediments.

Induced Seismic Modelling



Velocity Model

Update with different upper sedimentary layer properties.

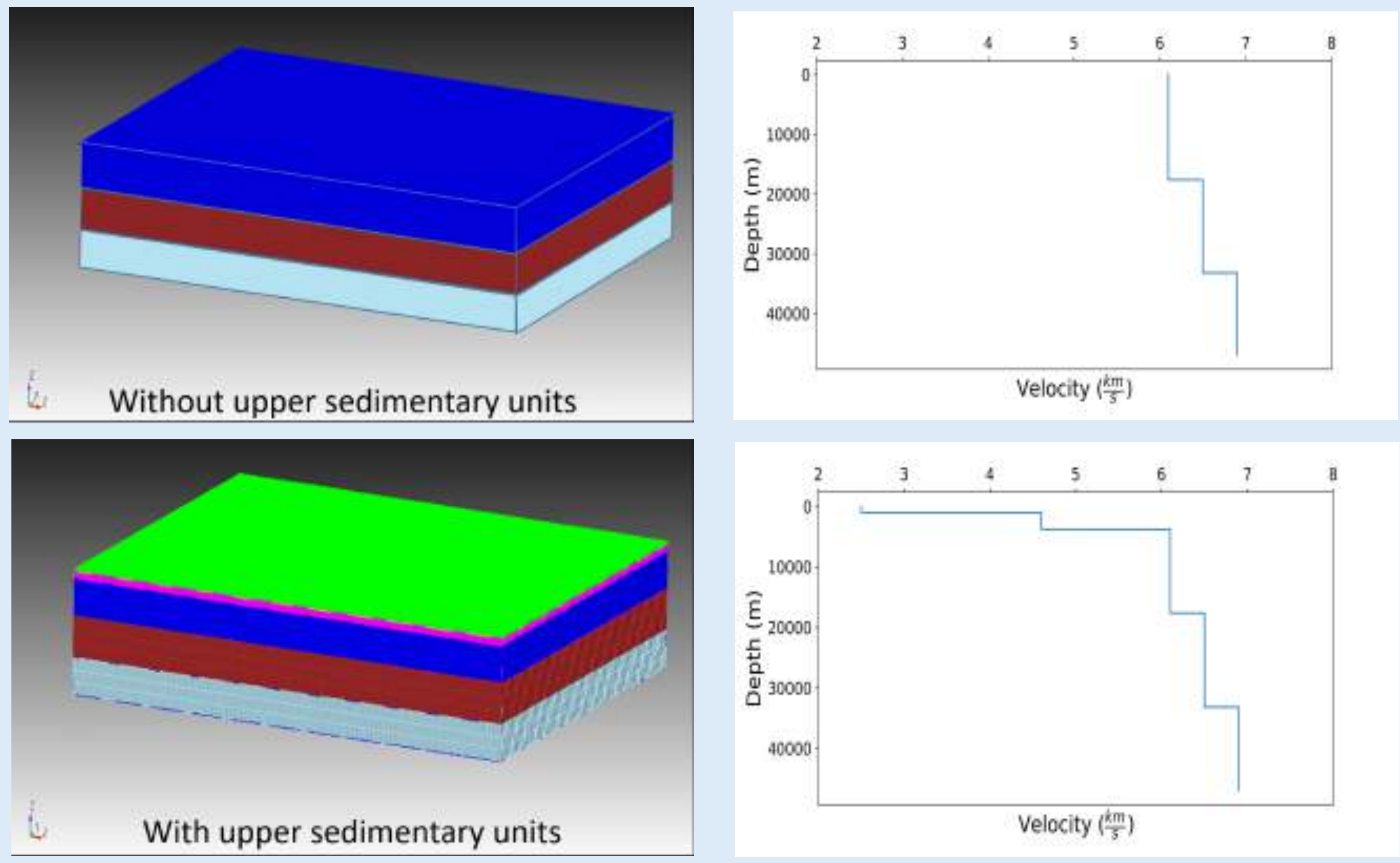
Source Parameters

SPECFEM3D

Simulation Results

Modeling method

Velocity Models

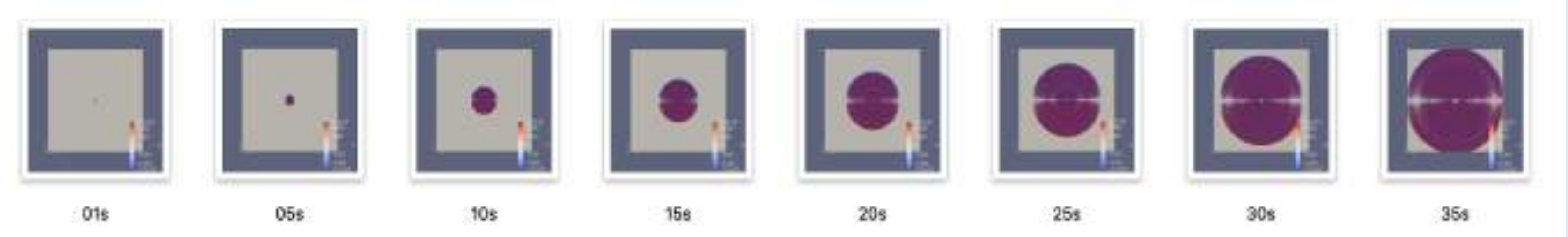


Velocity Models and Velocity Profiles created using Trelis. Crust data from CRUST1.0 (Laske, G., Masters., G., Ma, Z. and Pasyanos, M) b. Right figures show the velocity models and the left plot show the corresponding velocity profiles. The total thickness of both velocity models is 47km.

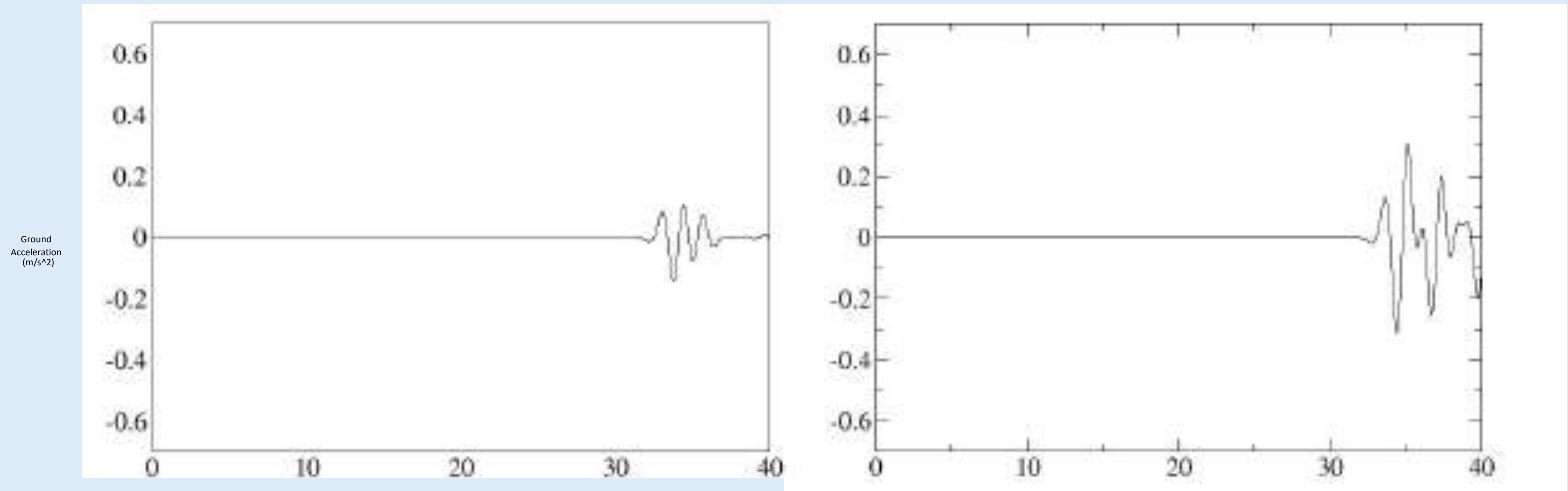
Results

Seismic wave propagation with upper sedimentary units :

Seismic wave propagation without upper sedimentary units:



Results of SPECFEM 3D modelling demonstrating seismic propagation in terms of surficial ground displacement. The displacement range of both is between -0. 27 and 0.27 cm. Time progresses from 1sec through 35 sec. Positive upward ground displacement shown in Red and negative downward ground displacement shown in Blue. it can be seen that the case including the effects of additional surficial impedance due to upper sedimentary units, the local shaking can be seen to be more intense and violent within the same amount of the time.



Results of SPECFEM 3D modelling demonstrating the ground acceleration of first arrival received at seismic station TD002 with duration of 40 sec. Left: Seismic wave at TD002 without surficial sediments. Right: Seismic wave at TD002 with surficial sediments.

Observation and Discussion

- ☐ **With same local magnitude M$_L$, simulations of seismic wave propagations demonstrate more intensive shaking with softer, unconsolidated, low-impedance surficial sediments.**
- ☐ **At same receiver location, PGA is tripled with low-impedance surficial sediments.**
- ☐ **The radiation pattern appears to be more uniform in all direction with surficial sediments compared to without.**
- ☐ **Based on the increased amplitude and intensity obtained from results, the site effect due to the existence of surficial sediments potentially lead to longer durations of shaking and larger affected area.**

- Surficial sediments conspicuously magnify the ground motions on the surface.
- Seismic events of identical magnitude can result in local differences in shaking (PGD, PGV and PGA) at ground surface. Local ground motion (PGA) is more indicative of sensed shakings and damages (physical and psychological) than local magnitude (M$_L$).
- Here we isolate the local site effect from all the other factors, and focus on the surficial sediments to improve the management of induced seismicity in terms of reducing:
  - 'Felt' events by the general public, resulting in negative shifts in public perception
  - Potential (unlikely) damages
- While reactive management of induced seismicity using local magnitude under the TLS has been effective, we argue that the end goal of reducing surface impacts would be more effectively met by directly controlling for PGA in areas of concern.

Conclusion

- Low-impedance surficial sediments theoretically play a significant role in sensed shaking within Western Canada Sedimentary Basin. Therefore, Local ground motion (PGA) is a is better metric than local magnitude (M$_L$) for estimating potential damages and sensed shaking at ground surface.
- A modified Traffic Light System adapted to respond to potential PGA has the potential to allow for greater flexibility and improved estimation of damages caused by induced seismic events.

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