1D Crustal Velocity Model for West-Central Montana

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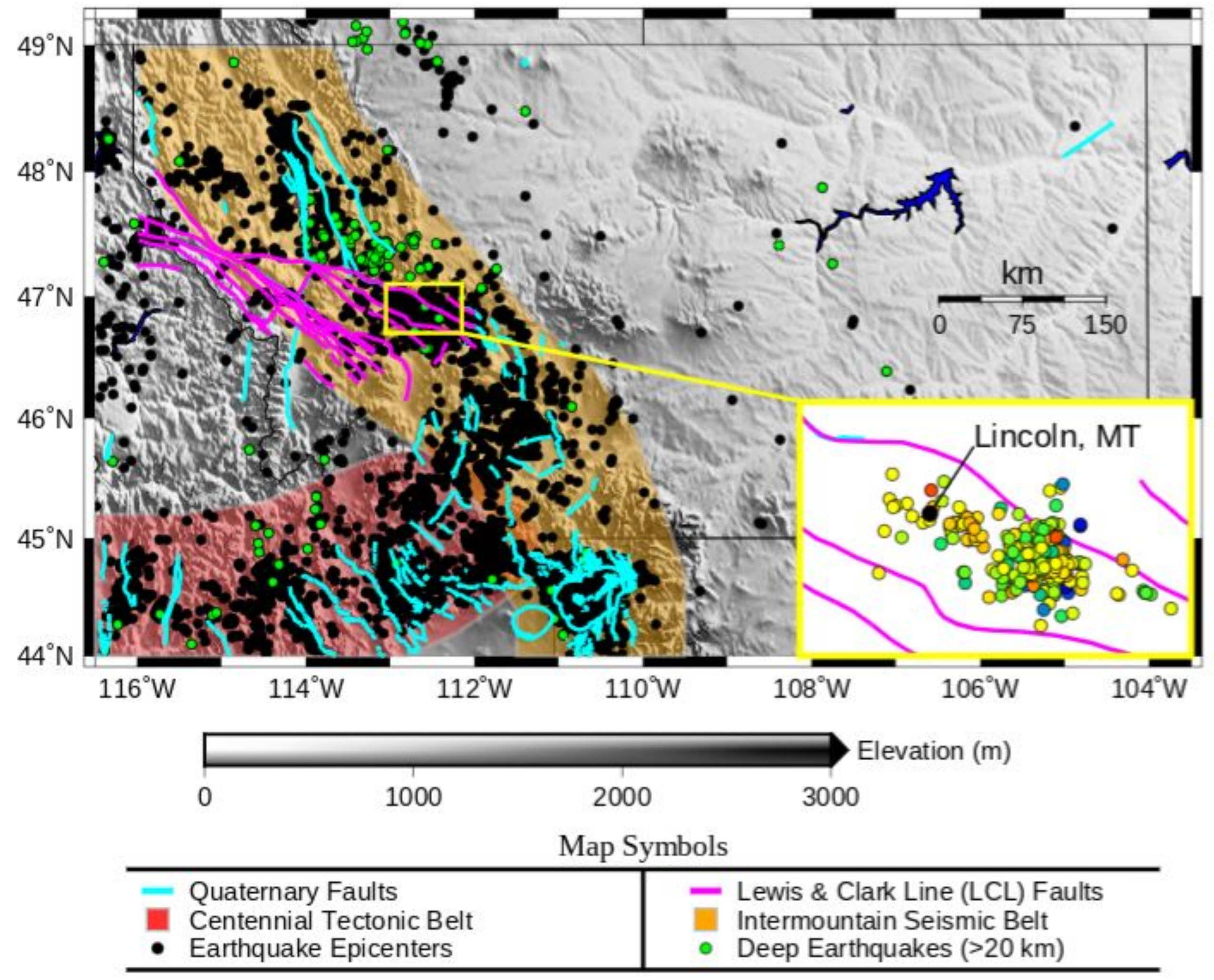
1. Introduction & Motivation

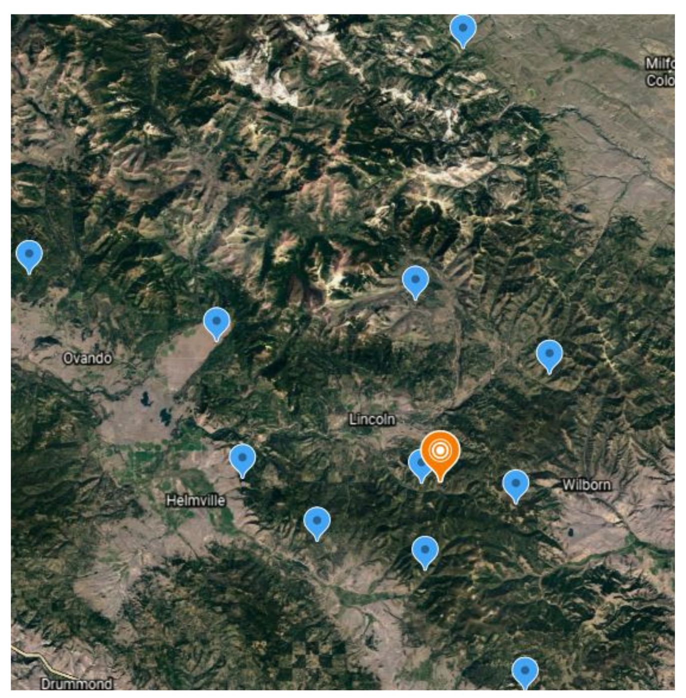
- While 90% of earthquakes occur on plate boundaries, Montana is one of the most seismically active states in the country, despite being located in the continental interior (Martens, 2017).
- Western Montana is particularly active as it lies within a zone of distributed crustal deformation, influenced by tectonic-plate motion occurring off the coasts of Washington and Oregon, the Yellowstone hotspot volcano, and the Rocky Mountains (McMahon, et al. 2019). .
- On July 6th, 2017, Lincoln, MT had a M5.8 event, the largest to occur since the 1959 M7.9 Hebgen Lake quake.
- This event created a prolific & still ongoing aftershock sequence, which has given us the perfect opportunity to create the first crustal seismic velocity model for west-central Montana.
- This will advance earthquake science in Montana and lead us to a better understanding of crustal structure & stress conditions.



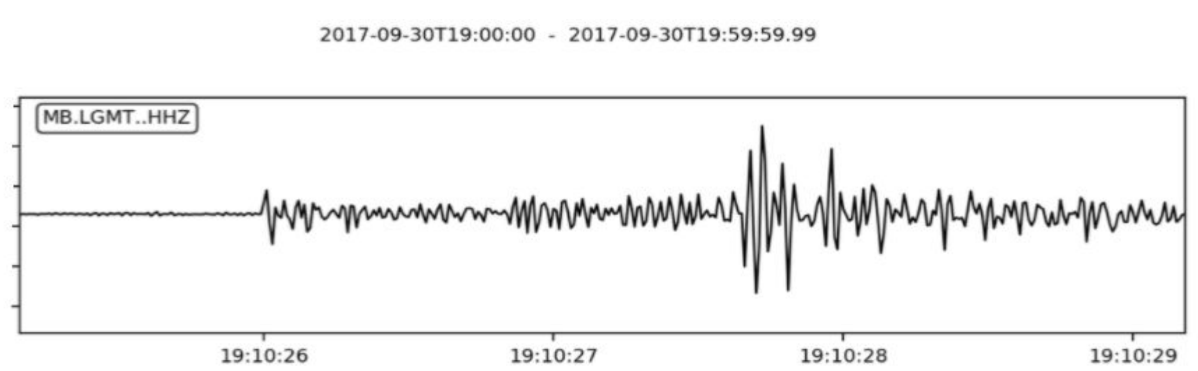
2. University of Montana Seismic Network (UMSN)

- UM stations use digital, 3 component, broadband seismometers.
  - Components: Vertical, N-S, E-W
  - A component from one of the UM stations can be seen in the figure below.
- This is a significant upgrade in technology compared to the short period, analog seismic stations used to create past velocity models, which only recorded one component data (vertical).

Seismometer (top) and digitizer (bottom)



- Seismic stations are strategically placed around the epicenter of the 2017 earthquake to collect the best quality data (see figure above).
  - Blue markers represent seismic stations, while the orange marker is the epicenter of the Lincoln event.
- Seismic data used to constrain our crustal seismic-velocity model are from the UMSN and the Montana Regional Seismic Network (MRSN).



Seismogram from UMSN station

3. Methods & VELEST

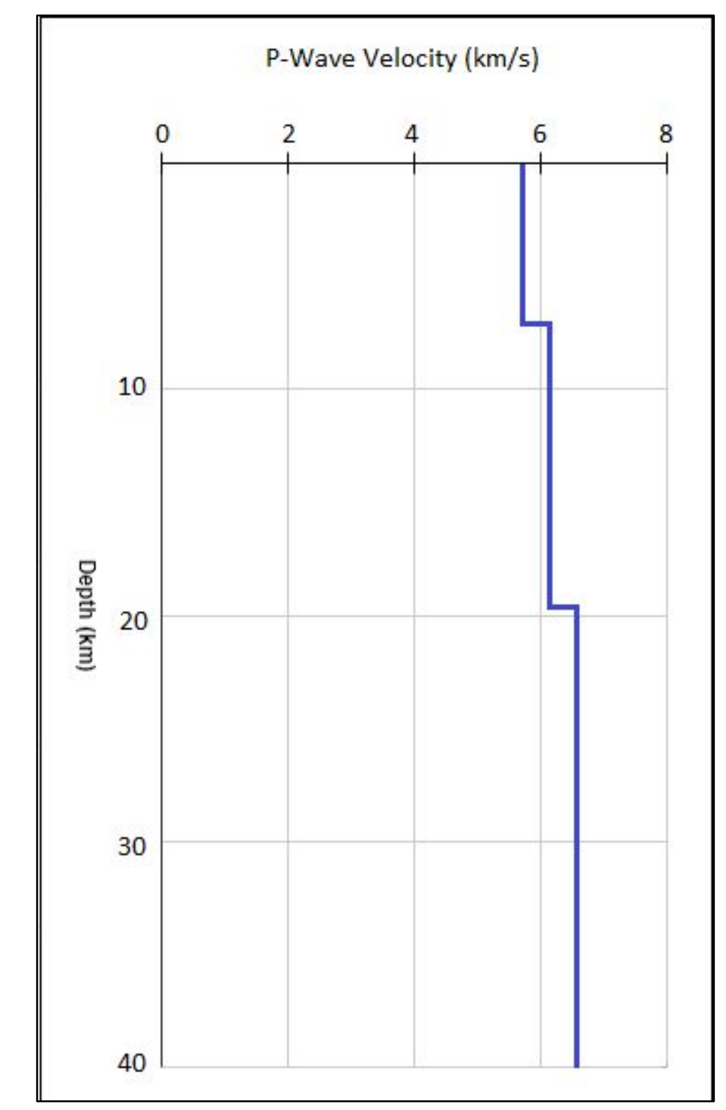
- We manually collect seismic data from UMSN and supplement with telemetered data from the MRSN.
  - Mainshock & aftershock data recorded over a 3 year period (2017-2020).
  - We select only the best seismic data to constrain the velocity model. Data are filtered based on azimuthal gap, epicentral distance, hypocenter depth, and number of recording stations.
- Once this has been done, we use the software program, VELEST, which simultaneously inverts the seismic data and parameters from several hundred well recorded earthquakes to produce a 1D velocity model (Kissling et al. 1994).
  - In order obtain effective results with VELEST, the following data inputs are required:
    - Seismic station coordinates & elevations.
    - Earthquake hypocenters & arrival times.
    - A reference velocity model to initiate the inversion process.

Seismic station at Bandy Ranch in Ovando, MT

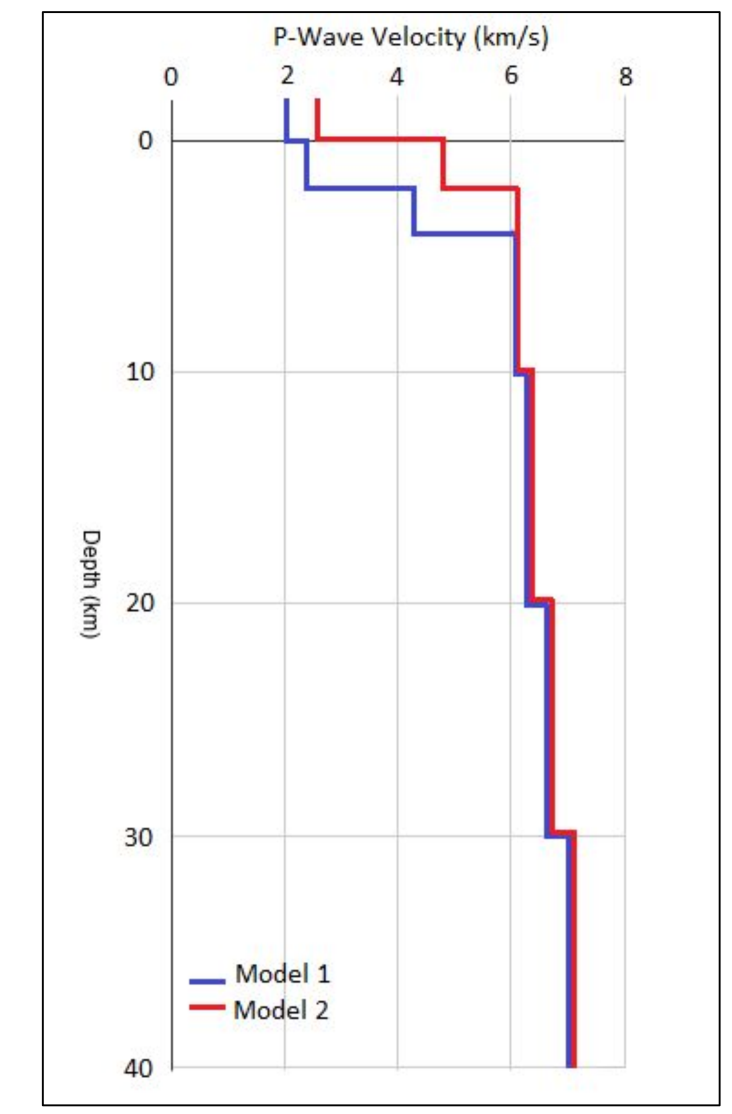
4. The Crustal Seismic-Velocity Model

- The crustal seismic velocity model describes seismic-velocity as a function of depth.
  - An integral tool for understanding the structure of the crust and for locating the origin of an earthquake.
- The last model for Western Montana was derived in 2003 and is comprised of 3 layers (Zeiler et. al, 2005).
  - However, based on the seismic data used to create it, it is most appropriate for Southwestern Montana.
- As we explore the model space, we have a handful of models that could potentially represent the seismic nature of the area.
- Our current models describe the west-central region's seismic velocities with 8 layers for an area of roughly 5,000 km^2.
  - Greater detail for shallow depths of the upper crust.

2003 Model



2021 Model



5. Summary & Outlook

- Western Montana is prone to infrequent, high magnitude earthquakes, providing rare opportunities to gather large quantities of high-quality seismic data in a particular region.
- The 2017 Lincoln event has provided a prime opportunity to collect quality seismic data that will allow us to create a much-needed crustal velocity model for this seismically active region of Montana.
- With the combination of a prolific aftershock sequence and upgraded seismometers, we are able to collect well constrained, high quality seismic data that can be used to create a velocity model that is able to describe crustal stress conditions & structure with greater accuracy.
- Not only will developing a new, regional crustal velocity model advance earthquake science in Montana, but this will also be the first model derived specifically for the west-central region of the state, as the current velocity model is most appropriate for southwestern Montana.

Looking towards the future:

- Implement our modeling process beyond our study region, allowing us to derive velocity models for other areas of western Montana that do not yet have a region specific velocity model.
- Explore the idea of combining these 1D models to create a psuedo 3D model for Western Montana as a whole.

References

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