

UNIVERSITY OF CALGARY | Program for Undergraduate Research Experience (PURE)

FINAL REPORT AND REFLECTION

“STRUCTURE IMAGING IN THE AREA OF MT. MEAGER”

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INTRODUCTION

The Garibaldi Volcanic Belt, in southwestern British Columbia, is a zone of recent volcanism in the northernmost segment of the Cascade Arc. According to Natural Resources Canada, South Mt. Meager project, which taken place in this area, is the most advanced geothermal power project in all Canada (Natural Resources Canada, 2017). However, our knowledge about the source of this geothermal heat, and how it connects to the surrounding volcanic belt is very limited. To better characterize this geothermal resource, we installed a dense array of close to 60 seismometers across Mt. Meager that operated for several weeks during the summer of 2019. These instruments are comprised of Inova Hawk nodal systems connected to 10 Hz three-component geophones. In addition to these seismic instruments, our deployment also includes a 3-km long fiberoptic distributed acoustic sensing (DAS) cable.

We mainly focus on studying a background reference model in this study. we have successfully come up with a background reference model in this region. Batholiths Continental Dynamics project performed by University of Arizona, have installed 42 broadband seismometers beneath the Coast Mountains Batholith (CMB) in central western British Columbia (Zandt etc., 2005). South part of the Batholith stations, about 200 kilometers long, east-west orientated, across coast complex terrane and Stikine terrane, were selected by us for data acquisition. Two additional stations, PHC and CBB, from the Canadian National Seismic Network (CN) network were also included in our analysis in order to decrease the azimuth gap.

Passive Seismic Tomography (PST) is the geophysical technique that I applied in this study. PST is like taking a Computed tomography (CT, as is used in medical imaging) scan of the earth. Advanced seismometers can record very small earthquakes, known as microearthquakes, from all over the world. Unlike reflection or refraction survey, PST survey uses local earthquake and ambient noise to infer the deep earth structure. When enough recordings have been made, seismologists use the recording data and apply with mathematical and computational method to calculate a model which includes physical properties of the earth, such as bulk modulus, shear modulus and Poisson's ration etc., seismic wave is an elastic wave, the speed of seismic waves depends on the earth material's physical properties that they travel through, like bulk modulus, shear modulus and density. In general, seismic waves travel slower through warmer, less dense materials, like hot magma. In contrast, seismic waves travel faster through high pressured materials, like cold, rigid crust. When the first arrival times and the distance between the stations and where the earthquake occurred are known precisely, we are able to calculate and assign the slowness value to the portions of the Earth that those seismic rays traveled through. By visualizing the structure of the interior earth, we are able to identify the location of the hot magma zone and the locations of the cold dense host rock with decent resolution images. Seismic tomography is a geophysical technique that allow us to image Earth's structure at all scales, especially useful for complicated maintain range area (Perkins, 2019).

METHOD

There are five steps in this study.

First of all, data acquisition from the study area. Since local earthquakes are main data source for calculate a velocity model, and based on the location of Mt. Meager, we have focused our study area in the zone between latitudes from 51N to 53N and the longitude from 129W to 121W. Searching the Earthquakes Canada database between June 1st 2005 and Nov. 30th 2006 reveals a total of 82

earthquakes in this area. Waveform requests were made through irisFetch program, which allows us to download data from the Incorporated Research Institution (IRIS) DATA Management Center. Two pieces of information were attained from this search, the earthquake origin time and the epicenter location (latitude and longitude). We did not use the depth information from Earthquake Canada because they are not accurate. Instead, we used HYPYINVERSE (Klein,2002) to relocate the hypocenters based on our arrival picks in step four.

Then, select good events. We first cut all events that have magnitude less than 0.9 ML. Second, we cut events that have large background noise. we applied an auto P-phase arrival time picker (Kalkan, 2017) to provide a reference point, events with large background noise will not have a reference point, therefore, almost all events without an auto picker reference point been cut. We have in total 48 good events after these two procedures, figure 1 shows the location of these events and also the location of stations.

Next, pick arrival times from the good events. Processing included cutting the daily long records to 3 minutes segment window that contains 7201 samples. We then applied a waveform passband filter from 3 to 18 Hz, as we found that this bandpass filter works well for picking body waves at stations within the Coast Belt Zone. Differently, we used a lower frequency range between 3 and 12 Hz for stations on southern Vancouver Island (Savard, 2018). FIGURE 2a shows an example of the traces in the pick window with P-phase arrival pick.

Next, relocate the location of the selected events. We used the software, HYPYINVERSE, to relocate the locations. HYPYINVERSE uses a flat earth model to iteratively calculate the events' hypocenters based on our arrival time picks. FIGURE 3 shows how much does it change in terms of distance for the inversed hypocenter compare with the original hypocenter.

Last, calculate a velocity model. We calculated a 1D P-phase velocity model by using Velest-1D-INVERSION (Kissling etc., 1994). The software needs an initial model, arrival time picks and station locations. Our initial model from the Coast Belt model (Clowes, 1995). 701 picks were made in step two for inverse the velocity model.

DISCUSSION AND RESULTS

Kissling (1994) defines in the Velest Users' Guide that only events who have an azimuthal gap (GAPs) less than 180° are well locatable. In order to decrease the azimuthal gap, which is a measure in degree that the greatest angle without observation for an earthquake event, we have added two additional stations, PHC and CBB. We requested waveform data for PHC and CBB stations from Natural Resources Canada (NRCAN) database. FIGURE 2b shows an example of the P-phase arrival pick by using Pyrocho snuffler for these data. We found that the 1D Velest velocity model without these two stations have residual at 0.112 second, but the model with additional stations have residual at 0.148 second. GAPs were between 174 and 315 with average of 245 for the first one and GAPs were between 145 and 309 with average of 233 for the second. The GAP indeed decreased by adding those two CN stations (PHC and CBB), but the residual unexpectedly increased by 0.036 second. I think the reason is because CN stations are too far from the events (average greater than 200km). We also used two different initial models to verify the influence of the existence of the slow zone in initial model to output model. We made an initial model without the slow zone by slightly adjust the Coast Belt model.

The initial model without slow zone has residual at 0.119 second without CN stations' picks and residual at 0.154 second with CN station's Picks. On the other hand, the slow zone initial model has residual at 0.112 second without CN stations' picks and residual at 0.148 second with CN station's Picks. However, the results for both initial models tend to not have a slow zone in their final calculated models. FIGURE 4a shows the final models with slow zone introduced initial model, FIGURE 4b shows the final models without slow zone introduced initial model.

FIGURES

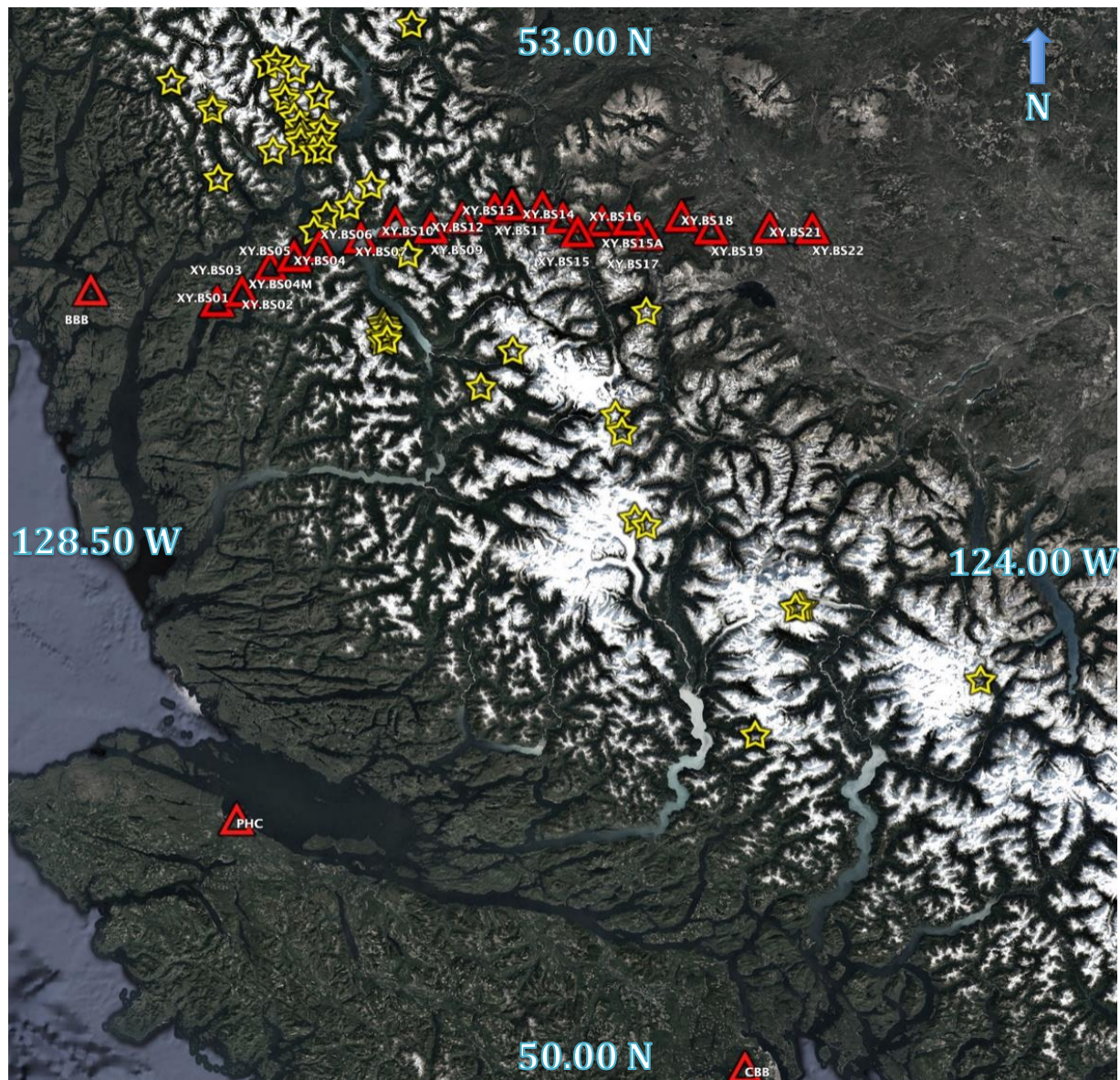


FIGURE 1 (red triangles represent stations and yellow stars represent earthquake events. this figure made by using Google Earth Pro)

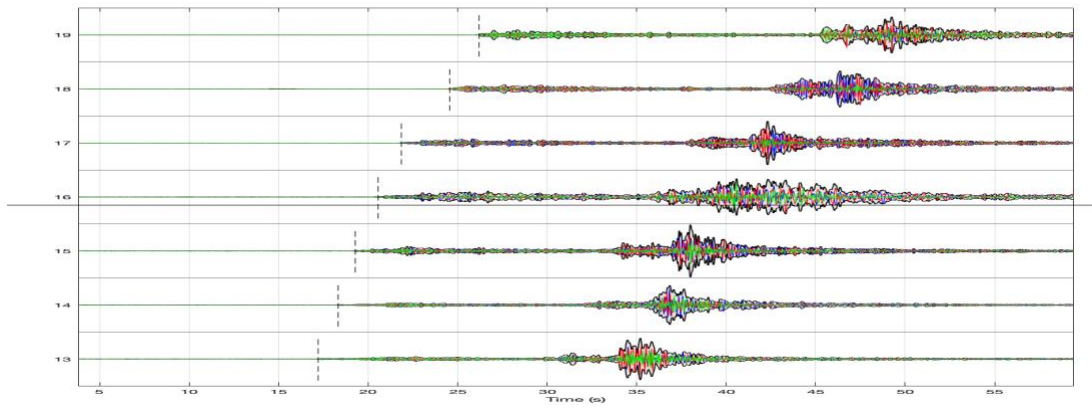


FIGURE 2a

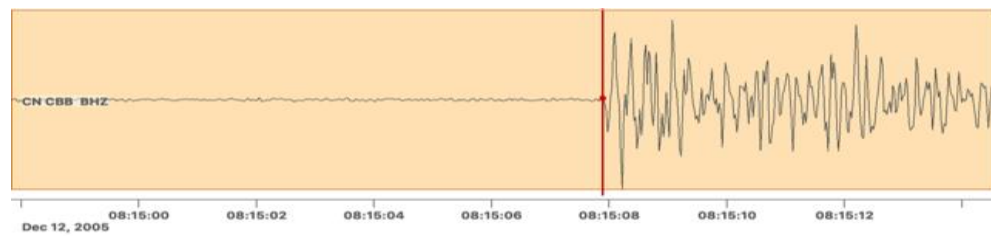


FIGURE 2b

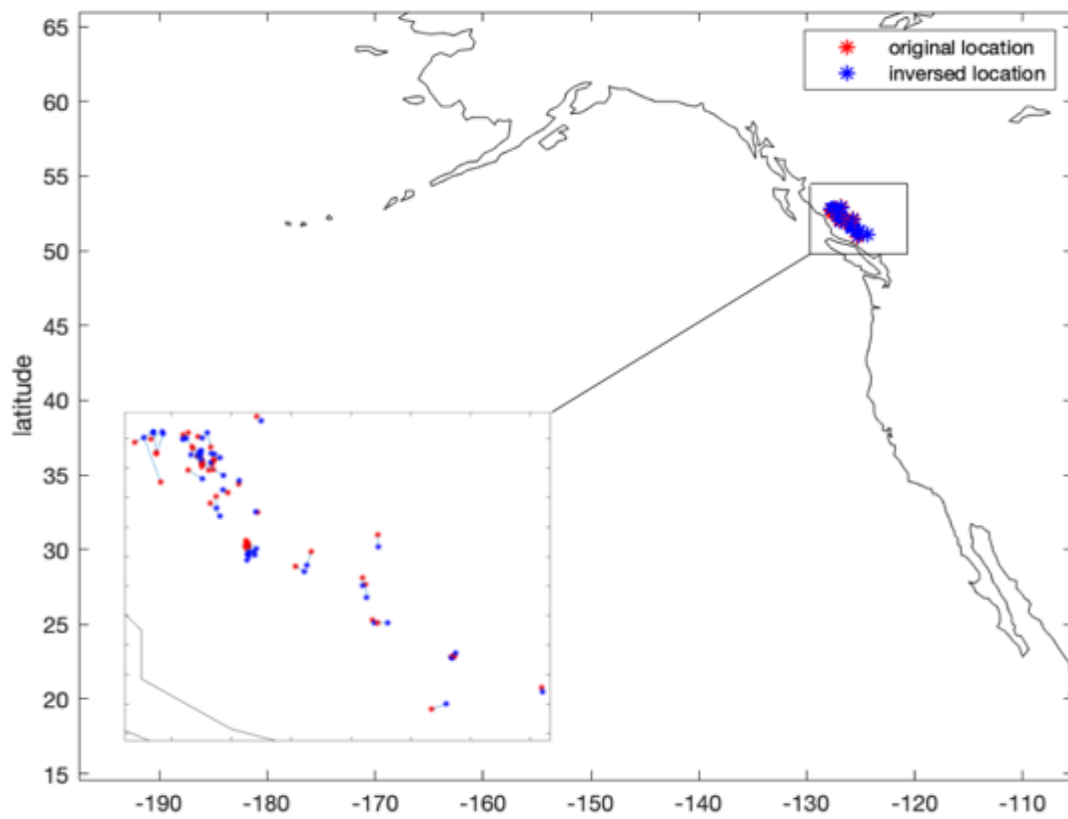


FIGURE 3

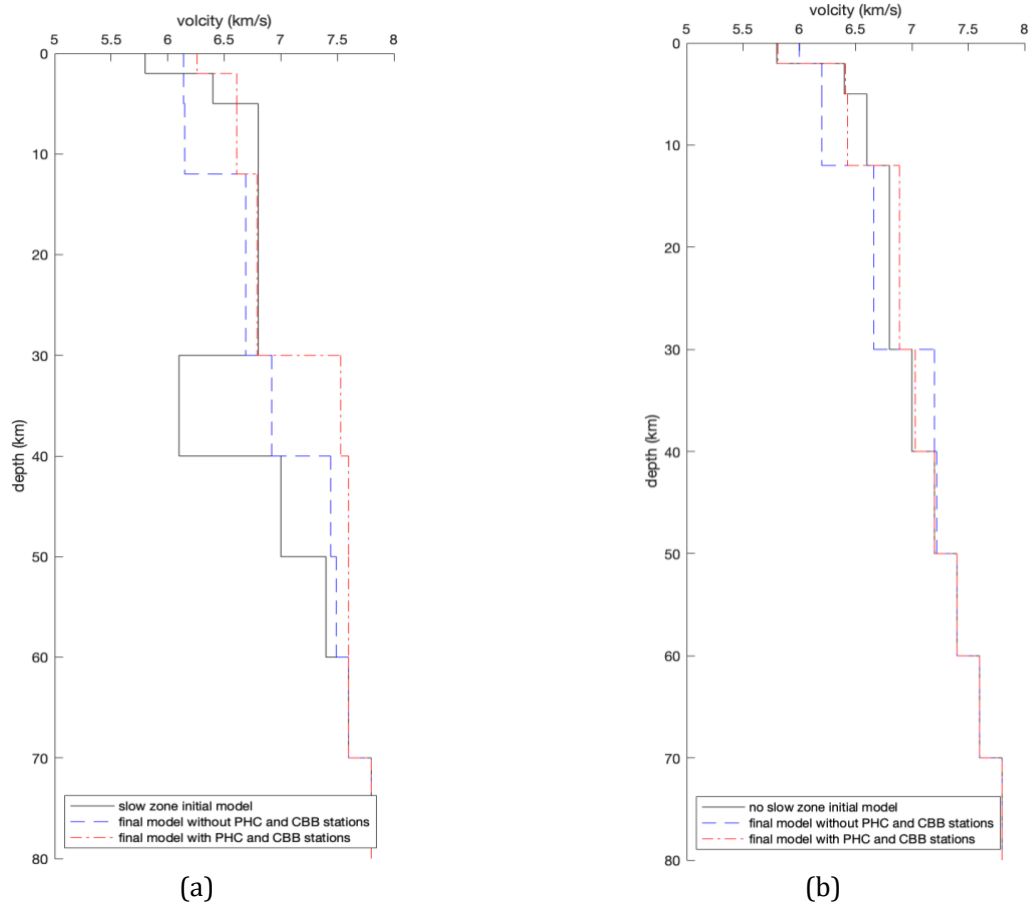


FIGURE 4

CONCLUSION

We have come up with a regional background P-phase velocity reference model in this study based on our arrival time picks. Inversed hypocenter with small misfit confirmed that our arrival picks are reliable. We found that initial model with slow zone have smaller residual in this regional, but to better understand the reason causes this, further study is required.

In the future Mount Meager data processing, I will do following adjustment from my Batholith data processing experience. First, I will avoid using events that have GAP greater than 180° , I will not expect to see a lot of events will have GAPs greater than 180° based on our dense station deployment in Mt. Meager area. Second, I will pick both P and S wave arrivals, instead of only P waves as I used with the Batholith data. Including the S wave data will allow for additional analysis, such as calculating Poisson's ratio. Furthermore, I want to combine other group's Magnetotellurics (MT) data with the seismic data to develop a Bayesian joint inversion (Dettmer, 2011). MT is a very promising geophysical method for geothermal exploration by measuring Earth's electrical resistivity induced by Earth itself (natural electromagnetic field). MT method is one of the most ideal geophysical techniques to look for conductive rocks associated with thermal excitation because it has high sensitivity to geothermal fluids that electrically conductive (Liu, 2016).

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LEARNING & SKILLS DEVELOPMENT

I have learned a lot from seismic data processing and field work by working with Dr. Gilbert during the summer. Dr. Gilbert always willing to help me to learn new methods through this project, such as different algorithms, new geophysical interpretations and alternative data processing methods. Field work is also a very valuable and delightful experience for me in this study. I went to Mt. Meager, BC in the middle of July for two weeks along with Dr. Hersh Gilbert, Dr. Jan Dettmer and Dr. Geneviève Savard, they are very accessible, friendly and willing to help me to become more professional in the field, we have deployed close to 60 seismometers across Mt. Meager, most of the sites are only accessible by helicopter. By the end of the field, I feel comfortable to talk to people about my research and where the data come from. My curiosity of geophysical research has enormously increased. I am very glad and grateful to have this research opportunity.