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September 21-23 2020
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Geothermal prospecting – examining the structure of Mt. Meager

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Summary

Numerous hot springs dot the Garibaldi Volcanic Belt, which is a zone of recent volcanism in the northernmost segment of the Cascade Arc in southwestern British Columbia. Fluids with temperatures greater than 250°C at Mt. Meager make it the warmest geothermal resource in Canada. Geothermal energy is a clean and renewable energy and Mt. Meager hosts some of the greatest potential geothermal energy across all Canada (Natural Resources Canada, 2017). The source of this geothermal heat, and how it connects to the surrounding volcanic belt serves as the focus of a temporary earthquake monitoring network that operated during the summer of 2019. Our investigation of the subsurface structure of the Mt. Meager geothermal system included the deployment of an array of 59 earthquake monitoring sensors. The sensors were arrayed in a configuration designed to attain uniform sampling of Mt. Meager in the area between Meager Creek and the Lillooet River.

Theory and Method

To better characterize the Mt. Meager geothermal resource, we installed a dense array of close to 60 seismometers across an area spanning approximately 20 by 20 km centered on the geothermal well that operated for several weeks during the summer and fall of 2019 (**Figure 1**).

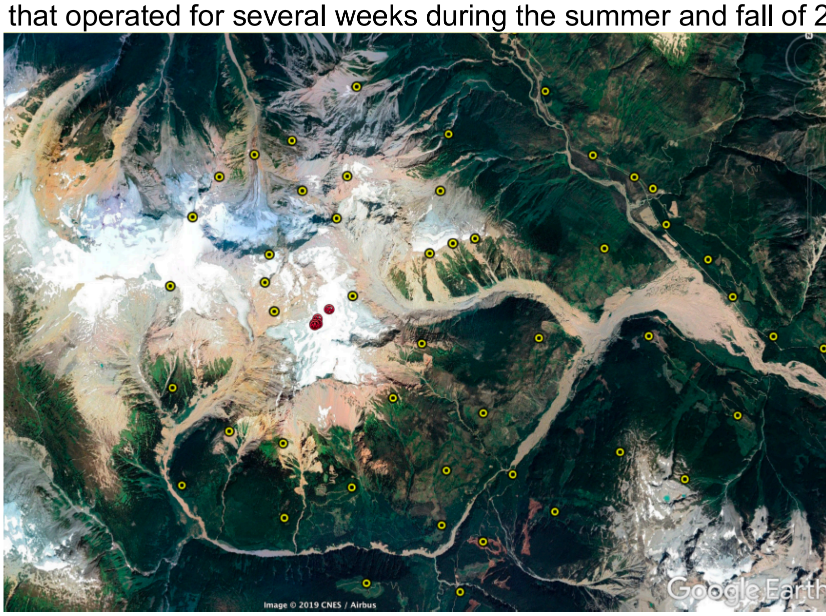

Figure 1. Google Earth map of Mt. Meager earthquake monitoring stations (yellow circles) and detected events that (red dots) occurred on July 13, 2019. The events appear to have occurred at a depth of just over 4 km.

Using recordings of local earthquakes at other permanent and temporary seismic stations across the Garibaldi Volcanic Belt, we constructed a reference seismic model that serves as a background for our focused Mt. Meager investigation. This model reveals the area to be characterized by low seismic velocities in general and that seismic velocities gradually increase from the crust into the upper mantle. The snapshot of local seismicity attained by our brief earthquake monitoring deployment will provide additional constraints on the pattern of faults and fractures within Mt. Meager that allow for fluid circulation through this geothermal system. Knowledge of the locations of potential geothermal heat sources and the plumbing system through which that heat is transported to the surface will aid future efforts in geothermal exploration.

The array of instruments that we deployed in 2019 is primarily comprised of Inova Hawk nodal systems connected to 10 Hz three-component geophones. To extend the capabilities of our monitoring array, we also deployed a broadband three-component in the late summer and fall of 2019. This broadband instrument is sensitive to signals from teleseismic and regional earthquakes and accordingly provides complementary observations to the nodal array. Sampling Mt. Meager and the surrounding area in its entirety allows us to characterize crustal structures associated with high geothermal heat and how those structures vary regionally. Specifically, using observations from this array we will attempt to map the pathways of geothermal fluids as well as magma chambers by identifying the distribution of low seismic wavespeeds.

Assessing the frequency and distribution of local seismicity using the data from this brief earthquake monitoring deployment, provides constraints on the pattern of faults and fractures within Mt. Meager. Determining the locations of faults provides insight into the paths that allow fluid circulation through this geothermal system.

Results, Observations, Conclusions

Examination of the spectra of the signals recorded by the temporary seismic array indicated that variations in the amplitude of the noise closely followed the flow level in the Lillooet River as measured at the stream gauge near Pemberton (data accessed from Environment Canada, 2020). The level of noise on the instruments across much of the array increased during periods of higher discharge in the river.

Waveform similarity search techniques (e.g., FAST, Bergen et al., 2016) detected low amplitude repeating events near the central portion of Mt. Meager. This portion of the Meager massif is in the central portion of our recording array and corresponds to a position within our study area where events can be particularly well located and we are sensitive to small events. Our ongoing analysis is focused on refining our catalog of local seismicity.

A subset of the earthquakes detected here that occurred on July 13th, 2019 exhibited nearly identical waveforms (**Figure 2**). Such similarities in earthquake records may be indicative of repeating events where slip repeatedly occurs on a single patch on a fault. We will further investigate whether our array detected additional repeating events using template matching techniques, which are well suited identifying such events.

In addition to the signals that appear to be related to earthquakes, we also detected lower frequency signals that do not exhibit clear abrupt arrivals that can be related to earthquakes body waves. Instead, these low frequency signals appear as emergent arrivals and several of these events possess nearly identical waveforms, with multiple events occurring on some days. The low-frequency signals of these events appear similar to those observed following icequakes or rockfalls in other volcanic settings (Allstadt and Malone, 2014).

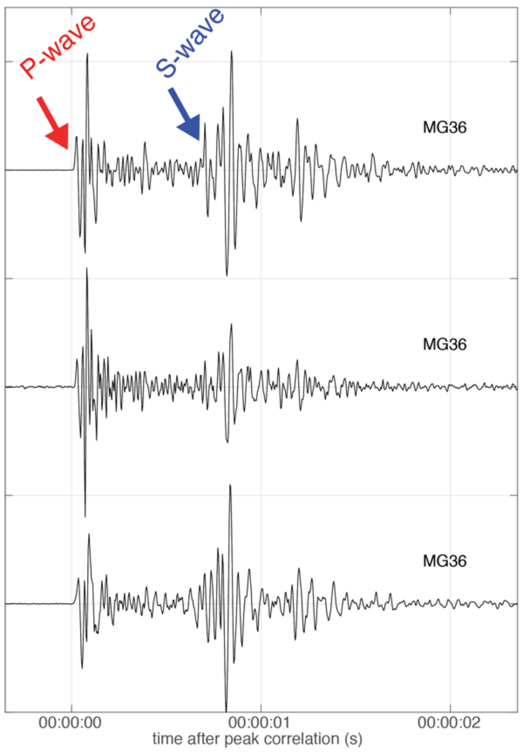

Figure 2. Waveforms of repeating earthquakes occurred on July 13, 2019. Example traces shown here were recorded on the north side of Mt. Meager. events were located towards the central portion of the Mt. Meager monitoring array (locations noted on **Figure 1**). The short time between the arrivals of the P and S waves exhibited on these waveforms (less than 1 s) support our findings that these are indeed nearby events.

Because the distribution of seismic sensors that comprises the Mt. Meager array extends over wide range of elevations we are exploring techniques that can locate these events while accounting for regions of complicated topography, (e.g. VELEST, Kissling et al., (1994) and the Source-Specific Station Term Location Package Lin, (2018)). We will also identify what signals can be detected using waveform cross-correlation techniques, as has successfully detected subtle low-frequency events in other regions.

References

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