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A transition in the style of deformation along the Rocky Mountain Trench?

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Summary

North America has grown since the Late Paleozoic as exotic terranes accreted onto the continental margin. These terranes now comprise the Canadian Cordillera. Investigating the boundaries of these terranes can provide insights into the processes by which these terranes accreted together and formed the cordillera. A number of these terrane boundaries align with the Rocky Mountain Trench, which is a prominent valley that extends along much of the length of the Cordillera. Using data from a temporary array of earthquake monitoring stations deployed along the Rocky Mountain Trench near Valemount, British Columbia we measure crustal thickness, detect and locate seismicity, and measure seismic wavespeeds. These new observations reveal that crustal properties change in the portion of the Rocky Mountain Trench near Valemount. Crustal seismicity detected during our temporary monitoring is primarily located to the east of the trench and at depths less than 10 km to the north of Valemount. However, this pattern of seismicity changes as earthquakes deepen to greater depths and are located to the west of the trench south of Valemount. Crustal thicknesses increase from north-to-south around Valemount. The depths of midcrustal discontinuities also change from north to south. Interfaces that are present at depths between 15 and 40 km to the south of Valemount are not apparent further north. Seismic wavespeeds calculated using the local earthquakes reveal the region to possess average crustal Vp values, but that shear waves propagate at anomalously high speeds (Vs) compared to these compressional waves. This setting with an elevated Vs and average Vp leads to the area being characterized by an anomalously low Vp/Vs ratio, which may be characteristic of the large portion of quartz present in the metamorphic rocks that have been deformed in the region.

Theory / Method / Workflow

The western margin of North America has been a convergent margin since the late Paleozoic and is marked by exotic terranes that accreted onto the continent that now comprise the Canadian Cordillera. The Rocky Mountain Trench (RMT) is a prominent valley in which faults that extend from Alaska to Montana parallel the eastern margin of the Canadian Cordillera. Boundaries of a number of the terranes that comprise the cordillera align with the RMT. The crustal and lithospheric thickness both dramatically decrease from east-to-west across the RMT (e. g., Cook et al., 2012, Chen et al., 2019). The sense of motion along faults within the RMT has been observed to vary along its north-south extent through the Canadian Cordillera. Towards its northern limit, the RMT exhibits dextral strike-slip displacement (e.g., Pope and Sears 1997). However, in the southern Rocky Mountain Trench there is also evidence for normal-faulting and a reduced amount of strike-slip motion (e.g. van der Velden and Cook, 1995). This difference in style of deformation on the RMT motivates further examination of its structure and pattern of deformation. A series of hot springs that align with northwest-southeast trending thrust faults lie within the Southern Rocky Mountain Trench. These faults accommodated shortening during the formation of the Canadian Cordillera in the Cretaceous.

To better understand the structure and style of faulting and deformation of the Rocky Mountain Trench and the relationship between these faults and hotsprings in the area, we deployed an array of ten broadband seismometers in the area of Valemount, British Columbia between the summers of 2017 and 2019 (**Figure 1**). This array was jointly operated by the University of Calgary, Borealis Geopower, and Nanometrics.

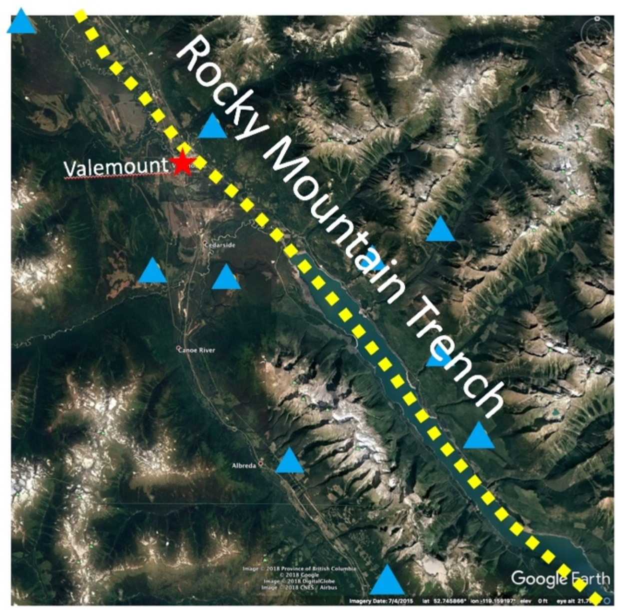

Figure 1. GoogleEarth map of Valemount broadband earthquake monitoring array. Approximate location of Rocky Mountain Trench is noted by the dashed yellow line. The position of each of the 10 broadband seismic stations is indicated by blue triangles. Each of the monitoring stations operated for approximately 14-24 months between 2017 and 2019.

Results, Observations, Conclusions

Using data recorded by our temporary earthquake monitoring array we investigated crustal structure using receiver functions and found the crust to thin from south-to-north. The deeper Moho to the south of Canoe Reach lies at a depth near 50 km and could be characteristics of portions of the southern RMT where normal faulting is more prevalent in regions of the Canadian Cordillera that are experience extensional collapse. Conversely, the thinner crust to the north of Valemount may be characteristic of the portion of the RMT that exhibits strike-slip motion. Similar to previous investigations of the lithosphere of the Canadian Cordillera, our receiver functions indicate the presence of midcrustal discontinuities at depths ranging from 20 to 40 km and appear to mark pervasive crustal layering and subhorizontal faulting.

The array of sensors detected and located 47 local crustal earthquakes during the first year of recording from 2017 to 2018. Crustal seismicity appears to primarily be located in distinct clusters in this region. A zone of shallow earthquakes lies to the north of Valemount, and is located to the east of the trench and concentrated at depths less than 10 km. Also present to the north of Valemount within the trench is a tight cluster of earthquakes that are located at depths close to 10 km. The distribution of seismicity shifts to the west of the Rocky Mountain Trench to the south of Valemount and lie at greater depths of 15-20 km.

We used the arrivals of the P and S waves from these local earthquakes to examine the seismic velocities of the crust in the area and found P-wave velocities for the upper crust to be close to 6 km/s, which is consistent with previous observations from this area and near the average observed for the upper 10-15 km of the crust. Interestingly, despite these P-wave speeds being near the average value for upper crustal rocks, our inversions for isotropic shear wavespeeds reveal elevated values and an anomalously low Vp/Vs ratio of 1.6 for the RMT crust. This anomalously low Vp/Vs value of 1.6 may be characteristic of the metamorphic rocks with large amounts of gneiss and schist that formed as the region experienced deformation. We are currently assessing whether these apparent high shear wavespeeds are due to unaccounted for anisotropy in our isotropic inversion. Structural analysis of the RMT has identified well formed mylonites and other signs of strain in the fault zone. Introducing such fabrics would cause the rocks to be an isotropic and if the fabric were prevalent would lead to anisotropic seismic wavespeeds. Ongoing efforts are being devoted to detecting whether we are able to observe an azimuthal dependence to our observed P and S wavespeeds and further constrain the presence of crustal anisotropy.

References

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