Mapping the Structure of the Nechako Basin using Earthquake Waves

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ABSTRACT

During the last decade, unusual hot, dry summers and mild winters in central British Columbia led to an abundance of mountain pine beetles, which have destroyed millions of lodgepole pine (the province's most commercially harvested tree). This is having a significant and negative impact on the people and communities who make a living by forestry in central British Columbia. Minerals or energy extraction may provide alternate economic opportunities for the region. To assist in this, we are undertaking a passive source seismic mapping to help assess the hydrocarbon and mineral potential of the Nechako Basin area in central BC. The Nechako Basin has been the focus of limited hydrocarbon exploration since the 1930's. Twelve exploratory wells were drilled and oil stains on drill chip samples and the presence of gas in drill stem tests attests to the presence of a hydrocarbon system. Seismic data collected in the 1980's were of generally poor quality with little energy penetrating the volcanic cover. In this study, we will utilise recordings of distant earthquakes to map the sediment thickness, crustal thickness, and overall geometry of the Nechako Basin. An array of seven seismic stations was deployed in September, 2006 to sample much of the basin. The results of this study will complement independent active source seismic studies that are planned for the region, by providing images using waves coming "from below," and by providing constraints on the shear wave velocity. The results of this research will also complement MT studies that are currently underway, providing critical new information on porosity, fractures, and fluids. We present preliminary results of this research.

INTRODUCTION

- **To assist minerals or energy extraction as alternative economic opportunities for BC**
- **To contribute to independent active source seismic studies planned for the region**
- **To provide critical new information on porosity, fractures, and fluids for MT studies**

Study Area

Figure 1. Location of study area. Filled triangles (and four-character station codes) indicate the locations of the seven broadband seismic stations.

Table 1. Location of broadband seismic stations in the Nechako Basin.

Seismic Station Location	Code	Latitude	Longitude	Elevation (km)
Anahim Lake, BC	ALRB	52.5103	-125.084	1.237
Cack Lake, BC	CLSB	52.7587	-122.555	0.792
Fletcher Lake, BC	FLLB	51.739	-123.106	1.189
SW Quesnel, BC	RAMB	52.632	-123.123	1.259
South of Vanderhoof, BC	SULB	53.2786	-124.358	1.171
Tatla Lake, BC	TALB	52.0147	-124.254	1.127
Thunder Mountain, BC	THMB	52.5489	-124.132	1.126

Typical Site

Figure 2. Photograph of Nechako seismic station RAMB, showing the typical station layout, with solar panels and satellite dish.

METHOD

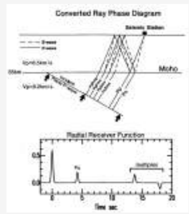


Figure 3. Cartoon illustrating the receiver function method. When incident P-waves from distant earthquakes encounter S-wave velocity boundaries beneath a seismic station (top), some of the energy is converted to an S-wave (Ps). The amplitude and arrival time of the Ps phase, relative to the direct P-wave, provides constraints on the velocity contrast, and depth to the interface.

Using waveforms from distant earthquakes

Advantages

- **Provide information on shear wave velocity**
- **Relatively inexpensive**
- **Simple**
- **Site-specific**
- **Interface-geometry**

DATA

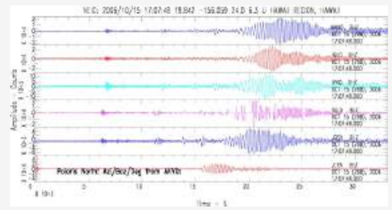


Figure 4. Sample waveforms (Magnitude 6.3 earthquake near Hawaii) recorded on the Nechako seismic stations. These waves contain information on the subsurface structure of the Nechako Basin.

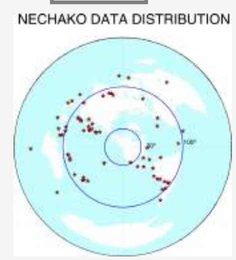


Figure 5. Distribution of teleseisms recorded during the first year of array operation. Stars indicate large (M>6) distant earthquakes. The map is centred on the Nechako Basin seismic array, with distances of 30◦ and 100◦ indicated. This is the useful distance range for receiver function studies.

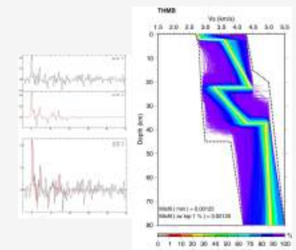


Figure 6. S-wave velocity model (right) developed by inverting receiver function. The best fitting model (Yellow) shows a crustal thickness of 40km and a pronounced low velocity zone between 20~40 km. Evidence for low velocities from surface to 2~3km. The observed receiver function is shown in the left (top, black) and the receiver function that is predicted by our model is shown in red.

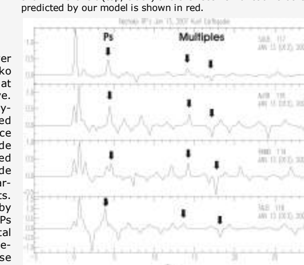
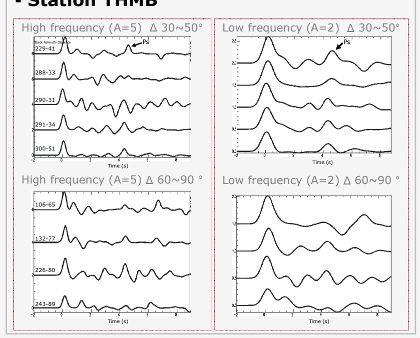


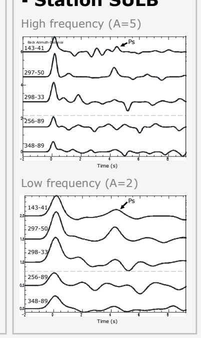
Figure 7. Sample receiver functions for select Nechako Basin stations. The arrival at "Time 0" is the direct P-wave. Subsequent arrivals are locally-generated P-to-S converted phases and free surface multiples. A small amplitude arrival at T=0, followed immediately by large amplitude arrivals, is indicative of near-surface low-velocity sediments. The large arrivals indicated by arrows are consistent with a Ps conversion from the continental Moho (near T=4 s) and free-surface mutiples of this phase near T=12-17 s.

RESULTS

- **Station THMB**



- **Station SULB**



SUMMARY

Only a few receiver functions have been calculated from the seismic waves which were recorded at the stations within the Nechako Basin. However, even those few receiver functions are consistent, and show arrivals indicative of sediments in the basin and crustal thickness variations.

The Ps converted phase near 4 second is due to the continental Moho. Since the receiver functions with low frequency show larger scale features better, the arrivals associated with Moho are easier to determine in the receiver functions with low frequency.

Also, the earlier arrivals (near 1~2 second) are associated with near-surface low-velocity sediments.

Future Plans

Additional receiver functions will be computed using the seismic waveforms from various azimuths and distances for all seven stations. Then these receiver functions will be used for construct shear-wave velocity models, including: sediment thickness, crustal thickness, and geometry (dip direction and angle) of key boundaries.

REFERENCES & ACKNOWLEDGEMENTS

Bustin, A.M.M., Hyndman, R.D., Kao, H., Cassidy J.F. (2007): Evidence for underthrusting beneath the Queen Charlotte Margin, British Columbia, from tele seismic receiver function analysis, Geophysics Journal International, Volume 171, pages 1198-1211.

Cassidy, J.F. (1992): Numerical experiments in broadband receiver function analysis, *Bulletin of the Seismological Society of America*, Volume 82, pages14 53-1474.

Cassidy, J.F. (1995): A comparison of the receiver structure beneath stations of the Canadian National Seismograph Network, *Canadian Journal of Earth Sci ences*, Volume 32, pages 938-951.

Currie, C.A., J.F. Cassidy, and Hyndman, R.D. (2001): A regional study of crustal shear wave splitting above the Cascadia subduction zone: Margin parallel crustal stress, *Geophysical Research Letters*, Volume 28, pages 659-662.

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