REPROCESSING OF MULTICHANNEL SEISMIC REFLECTION PROFILES ACROSS THE NECHAKO BASIN, BRITISH COLUMBIA: NEW INSIGHTS AND ASSESSMENT OF POTENTIAL CONTRIBUTION FROM MT RESULTS

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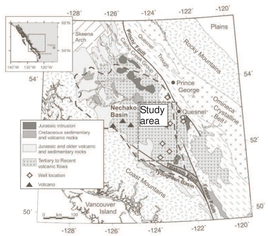
GOALS

Multichannel seismic reflection profiles were collected by Geoscience BC in 2008 to characterize the Nechako Basin, British Columbia. These challenging data revealed a complicated network of variably deformed sub-basins interspersed with near-surface volcanic units. To extract as much information from these data as possible, the goals of this Geoscience BC-funded project were to reprocess select seismic reflection profiles and, where possible, assess whether information derived from coincident magnetotelluric (MT) models could be used to help in the seismic processing. Specifically, we aimed to:

1) Convert the inverted resistivities in the MT models to seismic velocities using empirically-derived relationships from well logs and physical property studies of the major rock units in the Nechako region
2) Link lithological contacts within the MT models to reflective boundaries on the reprocessed seismic sections

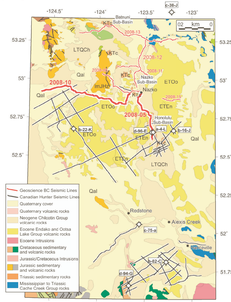
1 Regional Context

The Nechako Basin consists of a broad region of sub-basins on the interior plateau of southern British Columbia between the Coast Mountains and the Rocky Mountains. The nature of the Nechako Basin remains enigmatic, despite some limited effort at exploration in the 1980s and 1990s, because the basin is overlain by more recent sedimentary, volcanic and glacial deposits. Recently, Geoscience BC have endeavoured to better characterize the Nechako Basin using a multi-disciplinary approach involving geological mapping, rock property analyses, magnetotelluric soundings and multichannel seismic reflection imaging.



Map adapted from Calvert et al., 2011.

2 Geophysical Surveys

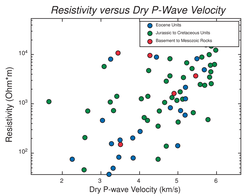


Geological study area map courtesy of Nathan Hayward, originally adapted from Riddell 2006.

To complement the extensive network of seismic lines acquired by Canadian Hunter during the early exploration phase of the Nechako Basin in the 1980s, Geoscience BC acquired 330 km of new Vibroseis seismic reflection data in 2008. These data were of better quality than the CH data but nonetheless revealed similar reflectivity patterns. Imaging beneath the volcanic units remained poor (Calvert et al., 2011). Meanwhile, magnetotelluric studies of the Nechako Basin have proven useful for delineating the depth extent of the volcanic units (Spratt and Craven, 2011) and so offer a complementary dataset against which to re-examine the Geoscience BC seismic reflection data. For our project, lines 2008-5, 2008-10, 2008-12 and 2008-13 have been reprocessed. Herein, we focus on lines 2008-5 and 2008-10 (highlighted on map) for which coincident magnetotelluric models are available.

3 Physical Property Measurements

Geophysical laboratory measurements on rock samples from three key units of the Nechako Basin (the Eocene volcanic units, the Jurassic to Cretaceous sedimentary units and the older basement and Mesozoic rocks) reveal a non-unique and scattered relationship between the physical properties of interest to this study, namely electrical resistivity and P-wave seismic velocity (Andrews et al., 2011). From these (shown below) and an independent study of available well logs, simple empirical relationships were derived.



For the entire stratigraphic column (Mwenifumbo and Mwenifumbo, 2010):

$$v = 2.375 + 1.39 * log(\rho)$$

For shales and sandstones (Mwenifumbo and Mwenifumbo, 2010):

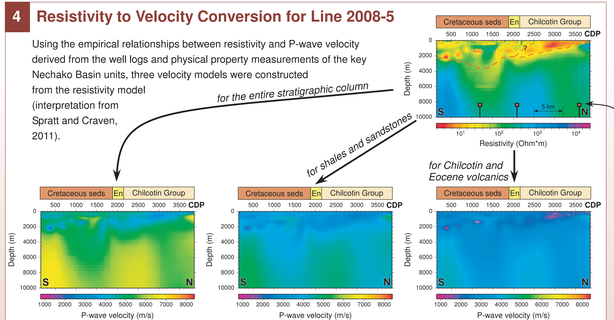
$$v = 1.915 + log(\rho)$$

For Chilcotin and Eocene shallow volcanic units (Kellett, pers. communication):

$$v = 1.077 + 1.01 * log(\rho)$$

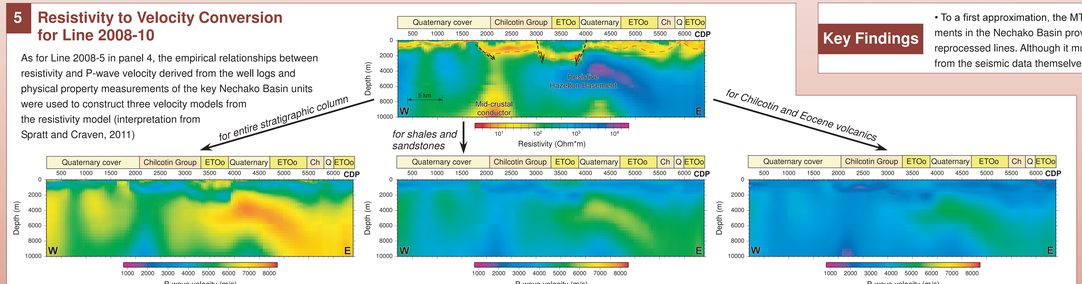
4 Resistivity to Velocity Conversion for Line 2008-5

Using the empirical relationships between resistivity and P-wave velocity derived from the well logs and physical property measurements of the key Nechako Basin units, three velocity models were constructed from the resistivity model (interpretation from Spratt and Craven, 2011).



5 Resistivity to Velocity Conversion for Line 2008-10

As for Line 2008-5 in panel 4, the empirical relationships between resistivity and P-wave velocity derived from the well logs and physical property measurements of the key Nechako Basin units were used to construct three velocity models from the resistivity model (interpretation from Spratt and Craven, 2011)



Key Findings

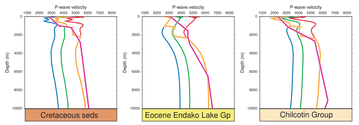
- To a first approximation, the MT-derived velocities based on well logs and physical property measurements in the Nechako Basin provided a surprisingly decent starting model for velocity analysis of the reprocessed lines. Although it must be stressed that the same information could have been obtained from the seismic data themselves, albeit in a more time-consuming manner.
- However, for the shallowest seismic data, the MT-derived velocities are consistently too high and must be lowered significantly during the velocity analysis to create an interpretable shallow section.
- Interpretation of the MT and seismic data together shows some good correspondence between structures, particularly for Line 2008-10, but limitations remain due to the differing resolutions and targeted physical properties of the two methods.

References

- Andrews, G., Quane, S., Enkin, R.J., Russell, K., Kushnir, A., Kennedy, L., Hayward, N., and Heap, M., 2011. Rock physical property measurements to aid geophysical surveys in the Nechako Basin Oil and Gas Region, central British Columbia. Geoscience BC Report 2011-10, 40 pp.
- Calvert, A.J., Hayward, N., Spratt, J.E., and Craven, J.A., 2011. Seismic reflection constraints on upper crustal structures in the volcanic-covered central Nechako Basin, British Columbia. Canadian Journal of Earth Sciences, 48, 1021-1037.
- Mwenifumbo, C.J., and Mwenifumbo, A.L., 2010. Analysis of well logs from the Nechako Basin. Geological Survey of Canada, Open File 6542, 36 pp.
- Riddell, J.M. (compiler), 2006. Geology of the southern Nechako Basin, NTS 92N, 92O, 93B, 93F, 93G. BC Ministry of Energy and Mines and Petroleum Resources, Petroleum Geology Map, 2006-1, 3 sheets, 1:400,000 scale.
- Spratt, J.E., and Craven, J.A., 2011. Near-surface and crustal-scale images of the Nechako Basin, British Columbia, Canada, from magnetotelluric investigations. Canadian Journal of Earth Sciences, 48, 987-999.

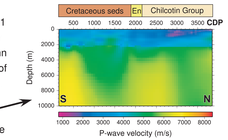
6 Building the optimal velocity model

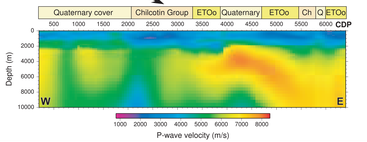
To gauge how appropriate the empirically-derived velocities were for Line 2008-5, these velocities were compared against stacking velocities (converted to depth with the Dix equation) derived from the seismic data themselves, following standard spherical gain correction, filtering, top muting, refraction and residual static corrections (from the original processing from CGG Veritas) and sorting. Comparisons from three specific CDP locations (shown as red squares) are plotted.



Velocities for entire stratigraphic column
Velocities for shales and sandstones
Velocities for Chilcotin and Eocene volcanics
Velocities (stacking, depth converted) for seismic data
Velocities for starting model based on MT results

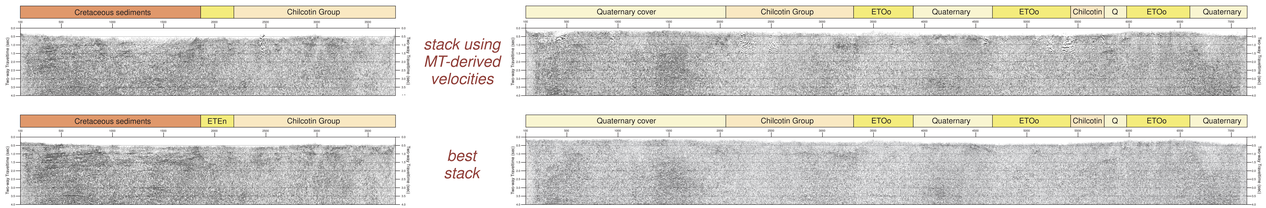
Based on these comparisons, the optimal starting velocity model was constructed using lithology-appropriate MT-derived velocities for the top 1 km, MT-derived velocities for the entire stratigraphic column below 2 km and an average of the two between 1 and 2 km. The resulting model for Line 2008-5 is shown here. The equivalent model for Line 2008-10 is shown here.





7 Final stacked results

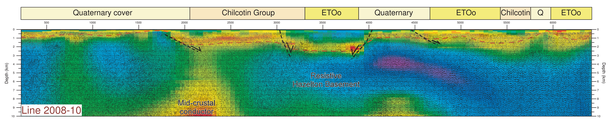
A comparison of the stacked results using only the MT-derived optimal velocity models (converted to RMS velocity) and the best stacked results obtained from the seismic data show that, as a first approximation, the MT-derived velocities do an adequate job of capturing many of the key reflections. They do, however, do a poor job in the shallowest part of the section where detailed velocity analysis is essential.

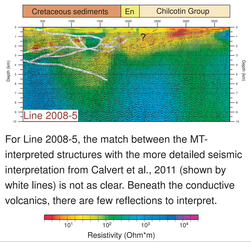


Line 2008-5 Line 2008-10

8 Interpretation

The best stacks for both lines were depth-converted using highly smoothed versions of their stacking velocities converted to interval velocities (using the Dix equation). These depth-converted sections were overlain on the resistivity models to look for similar structures to those interpreted by Spratt and Craven, 2011. For Line 2008-10, these is generally a good correspondence between the faults and boundaries interpreted from the MT sections and those observed on the seismic sections. Faults that are only imaged on the seismic sections do not involve the juxtaposition of contrasting units.





For Line 2008-5, the match between the MT-interpreted structures with the more detailed seismic interpretation from Calvert et al., 2011 (shown by white lines) is not as clear. Beneath the conductive volcanics, there are few reflections to interpret.