3-D refraction tomography in the eastern Nechako Basin, BC: recovering intra- and sub-volcanic velocity structure in a complex volcanic and sedimentary system

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① Background & objectives

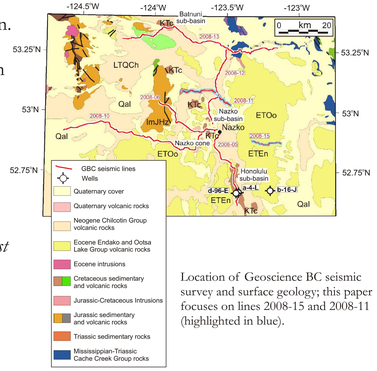
▶The architecture of the Nechako Basin is not well understood because of the complex tectonism and poor seismic imaging inside and below volcanic sequences.

▶The south-central part is considered the most prospective, with structural trapping elements and potential Cretaceous and Jurassic sources and reservoirs.

▶The 2008 Geoscience BC seismic survey consists of seven seismic lines with crooked geometry acquired in the east-central part of the basin.

▶**Goal:** To develop a refraction tomography model and use it to distinguish structural and compositional heterogeneity in a region with poor interpretability of seismic data.

▶The Cretaceous rocks in this area are *of particular interest* for exploration because they contain all the hydrocarbon shows identified in the Canadian Hunter wells (Calvert and Hayward, 2009).



Location of Geoscience BC seismic survey and surface geology; this paper focuses on lines 2008-15 and 2008-11 (highlighted in blue).

② FAST - 3-D First Arrival Seismic Tomography

▶The algorithm is based on Zelt and Barton (1998) regularized tomographic method; it inverts first-arrival traveltimes to find a geologically reasonable velocity model with a minimum amount of structure.

1 Forward calculation of traveltimes, ray paths and model update uses a 3-D velocity-model parameterization with a uniform node spacing.

2 Inversion of traveltimes is realized so that the data are fit according to their assigned uncertainties while solving for the model parameters that satisfy two structure constraints:

▶*lambda,* which controls the long-wavelength structure in the initial iterations and allows short-wavelength structure in later iterations (Zelt et al., 2006);

▶*sz*- the ratio of vertical and horizontal smoothing/flatness.

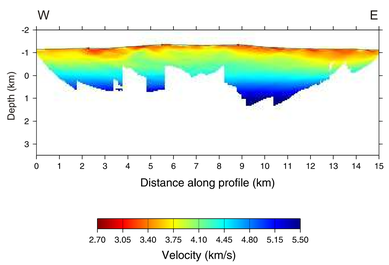
③ Initial velocity models and results

▶Topography was incorporated into the starting models with a fixed overlying starting velocity of 1.2 km/s.

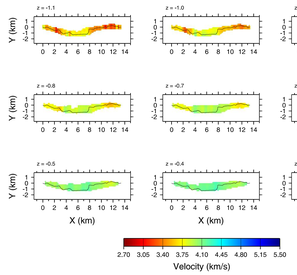
▶We used two velocity-depth relationships to generate one-dimensional starting models for lines 2008-15 and 2008-11; the starting models were used to evaluate the differences between the observed and estimated times of first arrivals:

✓ linear increase with depth $v=v_0+(z-z_0)dv$, where z_0 is the reference depth for velocity v_0 and dv is the velocity gradient

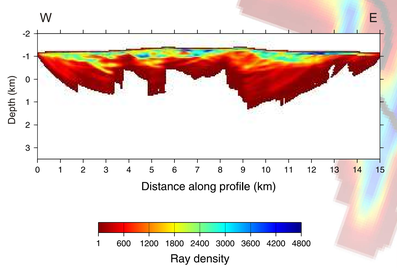
Seismic line	Surface velocity (km/s)	Elevation of surface velocity (m)	Velocity gradient (s^{-1})
2008-15	3.3	1400	0.9



Tomographic velocity model for line 2008-15, characterized by smooth structures.



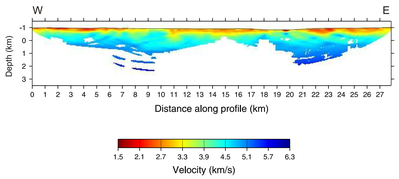
Horizontal slices of the velocity model for line 2008-15 at depth intervals of 100 m, showing mostly large-scale velocity anomalies.



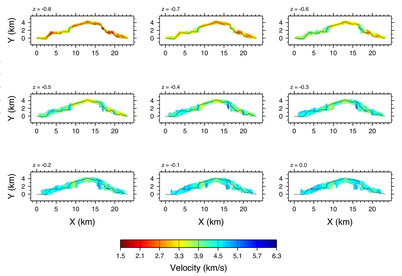
Ray density along line 2008-15, showing rays penetrating 2.7 km below the surface.

✓ exponential increase with depth $v=v_{lim}-(v_{lim}-v_0)\exp(-\quad(z-z_0))$, where v_{lim} is the maximum velocity (constant, 6 km/s) and is the exponential decay.

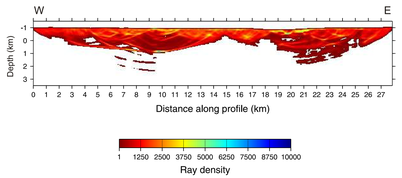
Seismic line	Surface velocity (km/s)	Elevation of surface velocity (m)	Exponential decay
2008-11	2.6	1024	0.0007



Tomographic velocity model for line 2008-11, showing a heterogeneous shallow section.



Horizontal slices of the velocity model for line 2008-11 at depth intervals of 100 m.



Ray density along line 2008-11, showing rays penetrating 2.7 km below the surface.

④ Conclusions

▶Starting velocity models differ because of lateral variations in the thickness and seismic velocities of near-surface rocks and the underlying rocks.

▶ Some correlation of the near-surface modeled velocity with the known surface geology has been observed for both seismic lines, with the thickness of the near-surface layer varying considerably along the lines:

✓high-velocity anomalies of 3.5 km/s correspond to volcanic cover

✓low-velocity anomalies of 2.5 km/s correspond to sedimentary deposits.

▶The 3-D method correctly addresses out-of-plane effects resulting from the crooked line geometry and ray-bending.

▶The recovered velocity models are most reliable at depths of less than 1.5 km.

⑤ Future work

▶Refine the current velocity models and develop detailed velocity models for the rest of the lines that will constrain near-surface rock types, particularly beneath the volcanic cover, and permit a more detailed interpretation of the seismic-reflection data than is currently possible.

Acknowledgments

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References

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