



Near-Surface Volcanic Rocks in the SE Nechako Basin, BC: Results of Interpretation of Seismic Reflection Data using First-Arrival Tomographic Inversion

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Summary

Near-surface estimates of P-wave velocity are derived from the tomographic inversion of seismic first-arrivals, to investigate the character of rocks in the south-eastern Nechako Basin. Near-surface seismic imaging is poor due in part to an extensive cover of Eocene and Neogene volcanic rocks, Quaternary drift, and vegetation. The depth of maximum ray density (~272-277 m) derived from the tomographic models constrains the thickness and extent of Eocene Endako Group volcanic rocks near well b-82-C, where rays converge on underlying high-velocity (3900 ms^{-1}) sandstone refractor.

As Eocene volcanic rocks have a typically higher mean (depth interval, 0-175 m) velocity (~2400-3200 ms^{-1}) than Chilcotin Group volcanic rocks and Quaternary drift (~1500-2500 ms^{-1}), interval velocity may be used to constrain the distribution of the Eocene rocks. Chilcotin Group rocks of the breccia rich Bull Creek facies, exhibit low interval velocities (~1500-1700 ms^{-1}) and a greater depth of maximum ray density in the Chilcotin River area. These results are consistent with the interpretation of an increased thickness of the Chilcotin Group in paleochannels. Regionally the Chilcotin Group has a limited affect on interval velocity, suggesting that it is thin and/or of a lithology which has a similar velocity to the underlying rocks. The presence of low interval velocity is more commonly indicative of thicker drift.

Introduction

The Nechako Basin is Jurassic to Oligocene in age (Hickson 1990), and formed over and in part from, the accreted terranes of the western Canadian Cordillera (Struik and MacIntyre 2001), in the interior plateau of southern British Columbia (Fig. 1). There are a number of impediments to the interpretation of the basin's stratigraphy and structure, and therefore evaluation of the basin's hydrocarbon and mineral potential. The basin is overlain often by a combination of Eocene volcanic rocks of the Endako and Ootsa Lake groups, Neogene volcanic rocks of the Chilcotin group, Quaternary drift (Riddell 2006) and dense vegetation. Understanding of the extent, thickness and lithological variation of the volcanic rocks is limited by the low density of surface exposures. Regionally incomplete mineralogical descriptions and sparse geochronology may also have lead to incorrect identification (Haskin et al. 1998) of the volcanic rocks in the field.

Recent studies (Andrews and Russell 2007; 2008) have suggested that the Chilcotin Group is regionally thin (<50-25 m), with locally thicker accumulations (>100 m) confined to paleochannels. The Chilcotin Group consists primarily of basaltic flows, with some hyaloclastite, tephra and pillow basalt and weathered

paleosols (Andrews and Russell 2007; Riddell 2006). Geological maps (Riddell 2006) and well stratigraphy (Ferri and Riddell 2006) show that the Endako and Ootsa Lake groups consist of vesicular basaltic to andesitic flows and intermediate to felsic flows respectively, both with tuff, breccia, and sedimentary rocks.

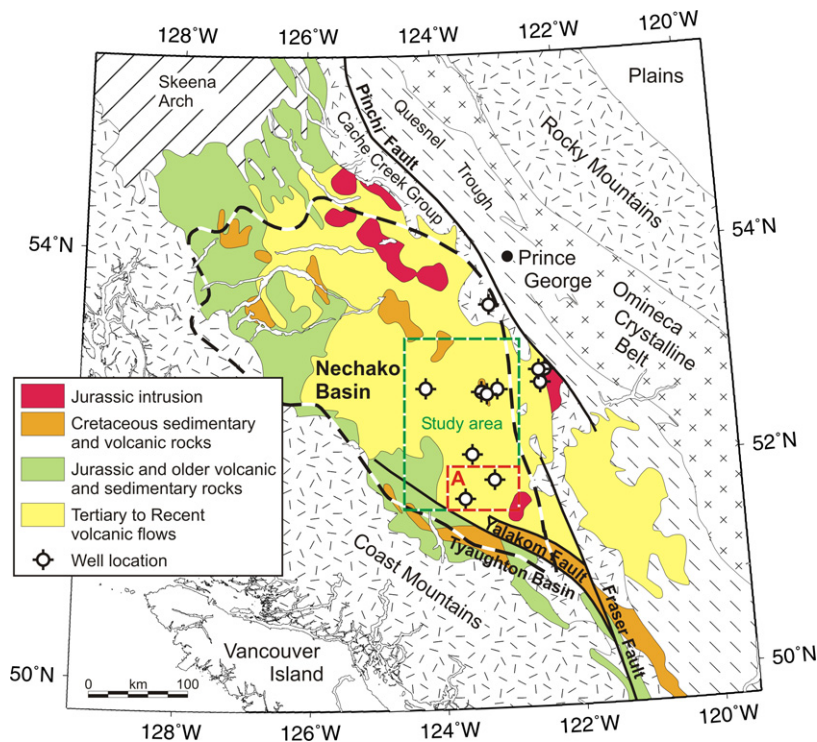


Figure 1: Location of the Nechako Basin and simplified geology of its western Canadian Cordillera setting. Red dashed box shows the Block A area of focus. Green dashed box shows the broader study area.

Seismic reflection data acquired by Canadian-Hunter in the 1980s gave poor images of the near-surface; therefore we use seismic velocity, estimated from tomographic inversions of first-arrivals from these seismic reflection data, to help constrain the distribution and thickness of the near-surface volcanic rocks.

Tomographic Inversion Method

First-arrival tomographic inversion is used to derive an estimate of the subsurface seismic P-wave velocity from the travel times of the first-arrivals from the source to each receiver of a seismic reflection profile. These models were calculated for all (~ 790 km total) straight seismic profiles using the Pronto software (Aldridge and Oldenburg 1993). Starting model parameters were guided by well sonic logs. A high-density of near-surface rays suggest a well-constrained estimate of the P-wave velocity for depths to ~400-500 m, however ray penetration in some areas constrained velocity to a depth of ~900 m.

Constraints on Distribution and Thickness of Volcanic Rocks in the Block A area.

Ray paths from the tomographic models give information of layer thicknesses of near-surface rocks. The depth of maximum ray density (DMRD) can be determined along each seismic profile. The DMRD is continuous along most models and thus defines a layer that provides an estimate of the refractor depth. At ties of seismic model profiles with well b-82-C, the DMRD is at depths of ~272 and ~277 m. Well b-82-C sampled ~221 m (Fig. 2) of the Endako Group volcanic rocks (Ferri and Riddell 2006). The DMRD coincides with a sandstone, of a high (sonic) velocity (~3900 ms⁻¹), immediately below the slower (~2400-3400 ms⁻¹) Endako Group (Fig. 2) and thus the DMRD constrains the thickness of the volcanic rocks.

Northeast of well b-82-C (Fig. 3), the DMRD has a greatly increased depth (>500 m), which may result from an increased thickness of the Neogene Chilcotin Group rocks that outcrop at this location.

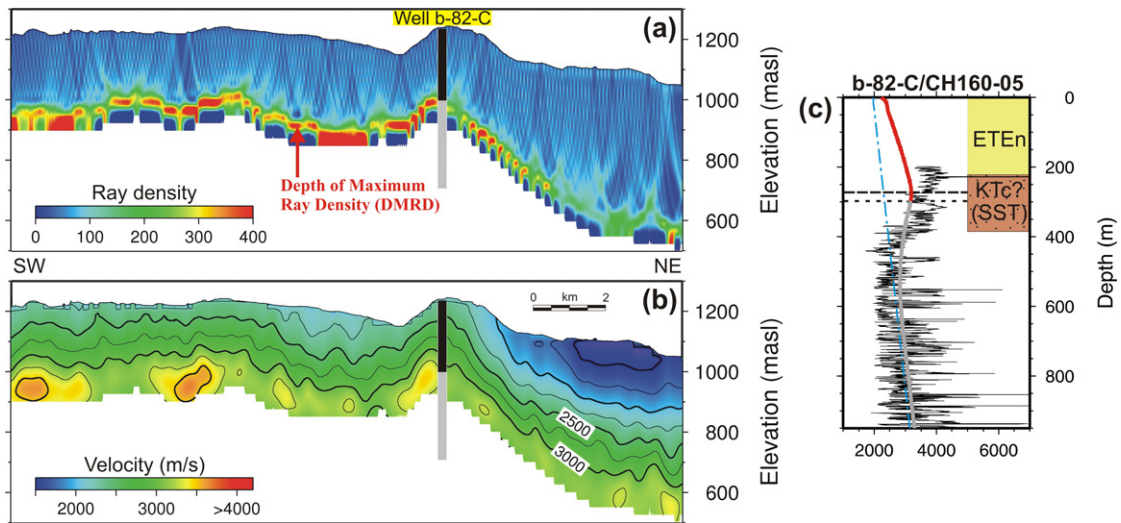


Figure 2: First-arrival tomographic inversion model of seismic profile through well b-82-C (a) Ray density (b) Velocity. Heavy lines - Endako Group and Cretaceous sedimentary rocks in well b-82-C (Ferri and Riddell 2006). (c) Comparison of model with sonic log and stratigraphy. ETEn - Endako Group; KTc - Taylor Creek Group (SST - Sandstone). Red (Grey) line – (un)constrained model. Blue line – initial model. Black dashed/dotted line - depth of maximum ray density/base of ray coverage.

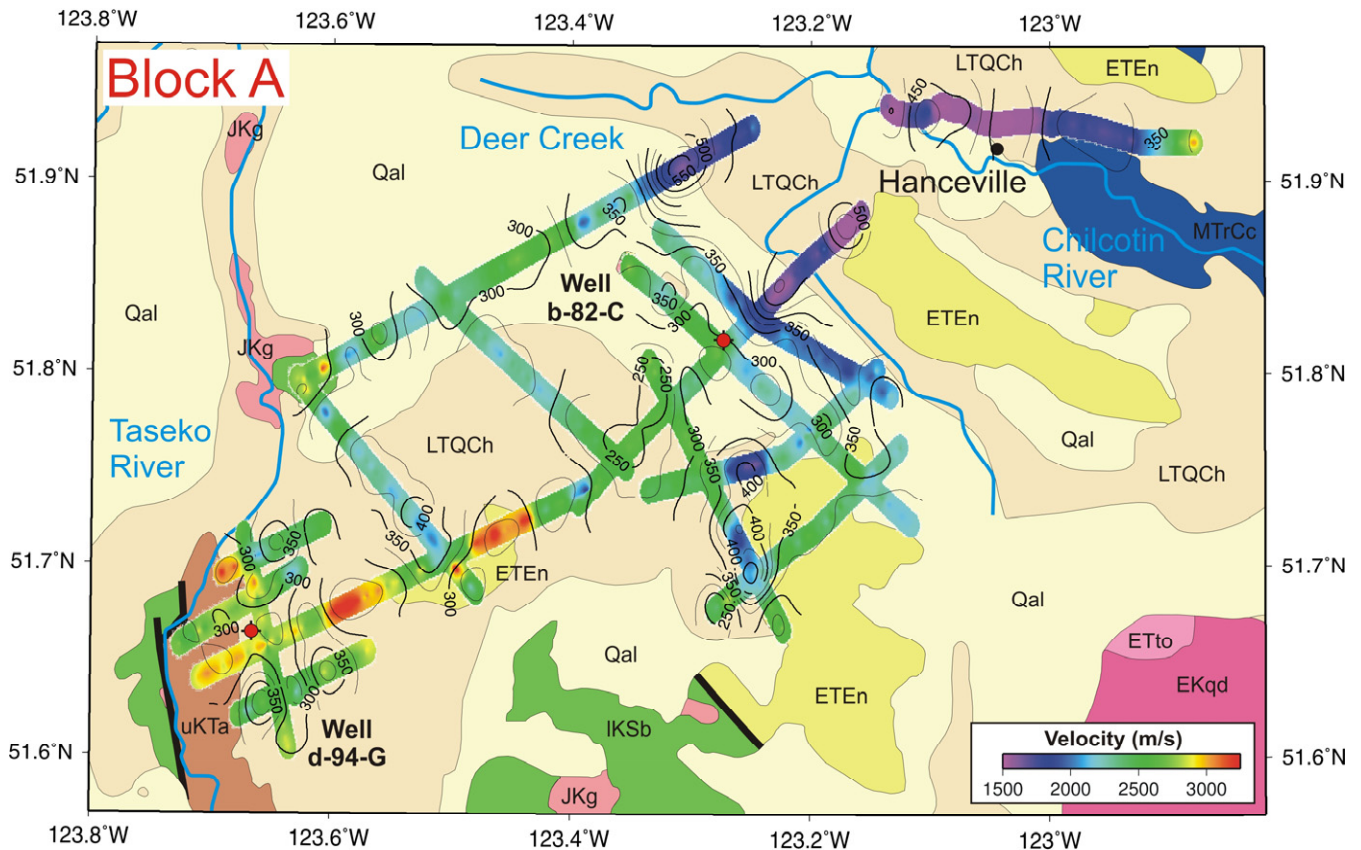


Figure 3: Mean velocity (coloured contours) to 175 m depth , and depth of maximum ray density (DMRD) (Density > 100 rays) (Contour interval 25 m), from first-arrival tomographic models in the Block A area. Geology simplified from Riddell 2006.

Near-surface Velocity Character of the Block A area.

The mean velocity, over a depth interval of 0-175 m (Fig. 3), reveals lateral velocity changes related to stratigraphic and structural variation. These interval velocities show a background of $\sim 2500 \text{ ms}^{-1}$, with slightly lower values commonly associated with the outcrop of Quaternary drift. However, northeast of well b-82-C, very low interval velocities ($\sim 1500 \text{ ms}^{-1}$) correspond to the outcrop of the Chilcotin Group.

An interval velocity high of $\sim 3000 \text{ ms}^{-1}$ is observed over the outcrop of Spences Bridge Group volcanic rocks and Cretaceous intrusive rocks (Fig. 3). Velocity highs ($\sim 3100 \text{ ms}^{-1}$) are also observed in relation to some outcrops of the Endako Group. High interval velocities ($\sim 2900 \text{ ms}^{-1}$) are observed in relation to the outcrop of Cretaceous sedimentary rocks to the west of well d-94-G (Fig. 3).

Discussion

Rocks of the Eocene Endako and Ootsa Lake groups are shown to have typically higher interval velocities ($\sim 2300\text{-}3000 \text{ ms}^{-1}$) than the Neogene Chilcotin Group volcanic rocks and Quaternary drift. Therefore, interval velocity may be used to constrain the distribution of these Eocene volcanic rocks. Regional velocity variation associated with the Eocene volcanic rocks suggests compositional or structural differences.

Locations where the Chilcotin Group volcanic rocks outcrop typically show two velocity signatures, either a velocity close to the Eocene volcanic rocks ($\sim 2500 \text{ ms}^{-1}$) or very low values ($\sim 1500 \text{ ms}^{-1}$). Along the Chilcotin River (Fig. 3), the low velocity and great DMRD correspond to thick accumulations of the breccia dominant (Andrews and Russell 2007) Bull Canyon facies of the Chilcotin Group. The high porosity and poor consolidation of these (often matrix poor; G. Andrews (pers. comm., 2008)) breccias, would lower their velocity. Recent investigations (Andrews and Russell 2008) have shown that the Chilcotin Group is regionally thin ($<25\text{-}50 \text{ m}$), with locally thicker accumulations in paleochannels. Along the Chilcotin River near Hanceville (Fig. 3), the Chilcotin Group has a thickness of $<80 \text{ m}$ (Andrews and Russell 2007). The greater DMRD and lower velocity are consistent with the interpretation of an increased thickness of the Chilcotin Group in paleochannels (Andrews and Russell 2008).

Acknowledgements

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