Preliminary First-Arrival Modelling Constraints on the Character, Thickness and Distribution of Neogene and Eocene Volcanic Rocks in the Southeastern Nechako Basin, South-Central British Columbia (NTS 092N, O, 093B, C)

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Hayward, N. and Calvert, A.J. (2009): Preliminary first-arrival modelling constraints on the character, thickness and distribution of Neogene and Eocene volcanic rocks in the southeastern Nechako Basin, south-central British Columbia (NTS 092N, O, 093B, C); *in* Geoscience BC Summary of Activities 2008, Geoscience BC, Report 2009-1, p. 151–156.

Introduction

The Nechako Basin is a primarily Mesozoic sedimentary basin located between the Rocky and Coast mountains of southern British Columbia (Figure 1). The basin formed over, and in part from, the accreted terranes of the western Canadian Cordillera. Transpressional tectonic processes were dominant until the Eocene (Best, 2004), when there was a shift to a dextral transtensional regime (Price, 1994). This episode of transtension was responsible for the formation of the Yalakom and Fraser faults, and was associated with widespread volcanism.

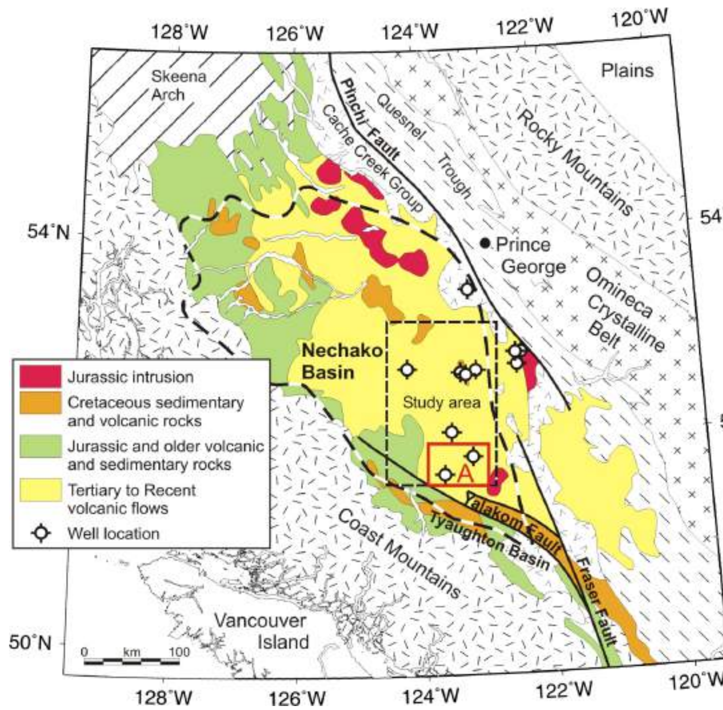

Figure 1. Location of the Nechako Basin and simplified geology of its western Canadian Cordillera setting. Black dashed box shows the broad study area. Red dashed box shows the focus region (block A) of this report.

This volcanism resulted in a regionally extensive blanket of rocks of the Eocene Endako and Ootsa Lake groups. These rocks were later overlain by volcanic rocks of the Neogene Chilcotin Group and Quaternary drift and glacial deposits (e.g., Riddell, 2006). The Endako and Ootsa Lake groups consist, respectively, of basaltic to andesitic and intermediate to felsic flows, with tuff, breccia and sedimentary rocks (e.g., Riddell, 2006). The Chilcotin Group consists of a number of facies (Mathews, 1989; Farrell et al., 2007; Gordee et al., 2007), which are primarily dominated by basaltic lavas or tuffs.

Interpretation of the basin's near-surface stratigraphy and structure are precluded by Quaternary deposits, vegetation and the negative impact of the near-surface volcanic rocks on seismic reflection imaging. Seismic reflection data acquired by Canadian Hunter in the 1980s were reprocessed in 2006 by Arcis Corporation. Although seismic imaging is generally improved, near-surface resolution, especially in association with volcanic rocks, remains poor.

A component of this study investigates the velocity, thickness and distribution of the near-surface rocks in the southeastern Nechako Basin using tomographic models derived from first arrivals from the seismic reflection data. Interpretation of these models is aided by surface geological maps (e.g., Riddell, 2006) and seven wells (drilled by Canadian Hunter Exploration Limited, Esso, Honolulu Oil Corporation Limited and Hudson's Bay Oil and Gas Company Limited). Preliminary results from the block A area (Figure 1) are presented here.

Keywords: *seismic reflection, structural geology, seismic stratigraphy, first-arrival tomography, velocity models*

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First-Arrival Tomographic Velocity Modelling

An estimate of the seismic P-wave velocity was derived from the traveltimes of the first arrivals from the source to each receiver of a seismic reflection profile (Figure 2). Velocity variations can provide details of the character and structure of near-surface rocks, poorly imaged by seismic reflection profiles. The focusing of rays (ray density) in the model may reveal the thickness of the near-surface volcanic rocks or layers within them. First-arrival tomographic velocity models have been used effectively in a range of geological environments, including the Tofino Basin (Hayward and Calvert, 2007) and the Devil's Mountain fault (Hayward et al., 2006).

Method

First-arrival (the direct wave and subsurface refractions) tomographic-inversion velocity models were calculated (e.g., Calvert et al., 2003) for all straight seismic profiles. First arrivals picked during seismic reflection processing by Arcis were manually edited in the ProMAX™ software package (Landmark Graphics Corporation) in order to correct picking errors.

The Pronto software package (Aldridge and Oldenburg, 1993) was used to model the seismic velocity. First-arrival times to all locations in a subsurface velocity grid (25 m grid spacing) were derived from a finite-difference solution to the eikonal equation. Source-to-receiver ray paths along the steepest direction of descent were created through the traveltime grid. A one-dimensional (1-D) starting model was estimated from the results of a few trial inversions. In order to obtain a realistic final model, the starting model was constrained by the sonic velocity logs (Figure 3). Setting the top of the starting model to 2000 m/s with a gradient of 1.25 (m/s)/m most effectively mimics the regionally variable well sonic velocities. A perturbation in the velocity model was calculated from the difference between the calculated and observed first-arrival traveltimes, for each of 15 iterations, to give a final velocity model.

Maximum ray penetration is controlled by the subsurface geology and maximum source-receiver offset (2550 m except for CH-159-02 and -02A at 1350 m). An estimate of P-wave velocity is well constrained for depths of up to ~400–500 m.

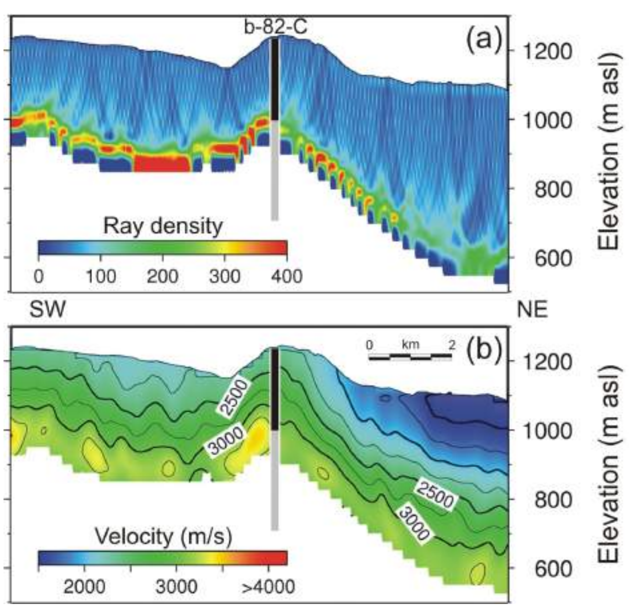

Figure 2. First-arrival tomographic ray density **(a)** and velocity model **(b)** derived from seismic reflection data in the vicinity of well b-82-C.

Thickness Constraint of the Near-Surface Volcanic Rocks in Block A

Volcanic rocks were intersected by four wells in the southeastern Nechako Basin. In block A, well b-82-C sampled ~221 m (Ferri and Riddell, 2006) of Eocene Endako Group volcanic rocks (Figure 3). Rays in the models of two seismic lines, which tie with the well, converge at depths of ~255 m (Figure 2a) and ~288 m. These ray-density maxima are located immediately below the base of the Eocene volcanic rocks (~2400–3400 m/s) in higher velocity (~3900 m/s) Cretaceous sandstone of the Taylor Creek Group (Figure 3). Therefore, at well b-82-C, maximum ray density is an analogue for volcanic rock thickness. Else-

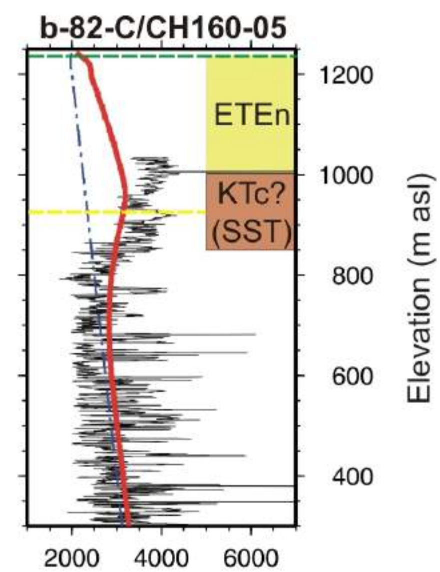

Figure 3. Comparison of tomographic velocity model (red line) with well sonic logs (black line) and stratigraphy (Ferri and Riddell, 2006). Blue dot-dashed line shows the starting velocity model. Yellow dashed line shows the base of the velocity model at well b-82-C. Green dashed line shows the ground surface at the well. Abbreviations: ETEn, Eocene Endako Group; KTc, Cretaceous Taylor Creek Group; SST, sandstone.

where, maximum ray density, primarily controlled by high-velocity layers, provides thickness constraint and information on the internal layering of near-surface volcanic and sedimentary rocks.

Points of maximum ray density (>100 ray paths), automatically picked every 5 m along each model profile, were manually edited to remove artifacts. The depth of the layer of maximum ray density (LMRD) in block A responds to changes in the local geology. The LMRD in the vicinity of well b-82-C (~270 m) can be traced over most of central block A (Figure 4). This interpretation suggests that rocks of the Endako Group cover this region below a thin veneer of outcropping younger volcanic rocks and/or drift deposits (Figure 5). The northwesterly continuation of the Eocene rocks is terminated by the outcrop of Cretaceous Spences Bridge Group volcanic rocks (Figure 5).

A striking feature of the LMRD in block A is the greatly increased depths of >500 m to the northeast (Figure 4). These anomalous depths may be the result of thicker Eocene Endako Group or Neogene Chilcotin Group rocks, which outcrop at this location (e.g., Riddell, 2006).

Seismic Interval Velocity of the Near-Surface Volcanic Rocks in Block A

The near-surface (0–175 m) interval velocity was extracted from each velocity model to investigate local and regional velocity variation. Comparison of the interval velocity with surface geology (e.g., Riddell, 2006) shows typical values of ~2500 m/s, with slightly lower velocities commonly in association with the outcrop of Chilcotin Group rocks and Quaternary deposits (Figure 5). High interval velocities (~3000 m/s) are coincident with the outcrop of Spences Bridge Group volcanic rocks towards the northwestern corner of block A. Rocks of the Eocene Endako and Ootsa Lake groups and Cretaceous Taylor Creek Group are shown to have typically higher interval velocities than the Neogene Chilcotin Group volcanic rocks and Quaternary drift deposits.

Interval velocities are anomalously low (down to ~1500 m/s) in northeastern block A (Figure 5). These velocity lows correspond to the deeper LMRD (Figure 4) and to the outcrop of Chilcotin Group volcanic rocks and Quaternary deposits (Figure 5).

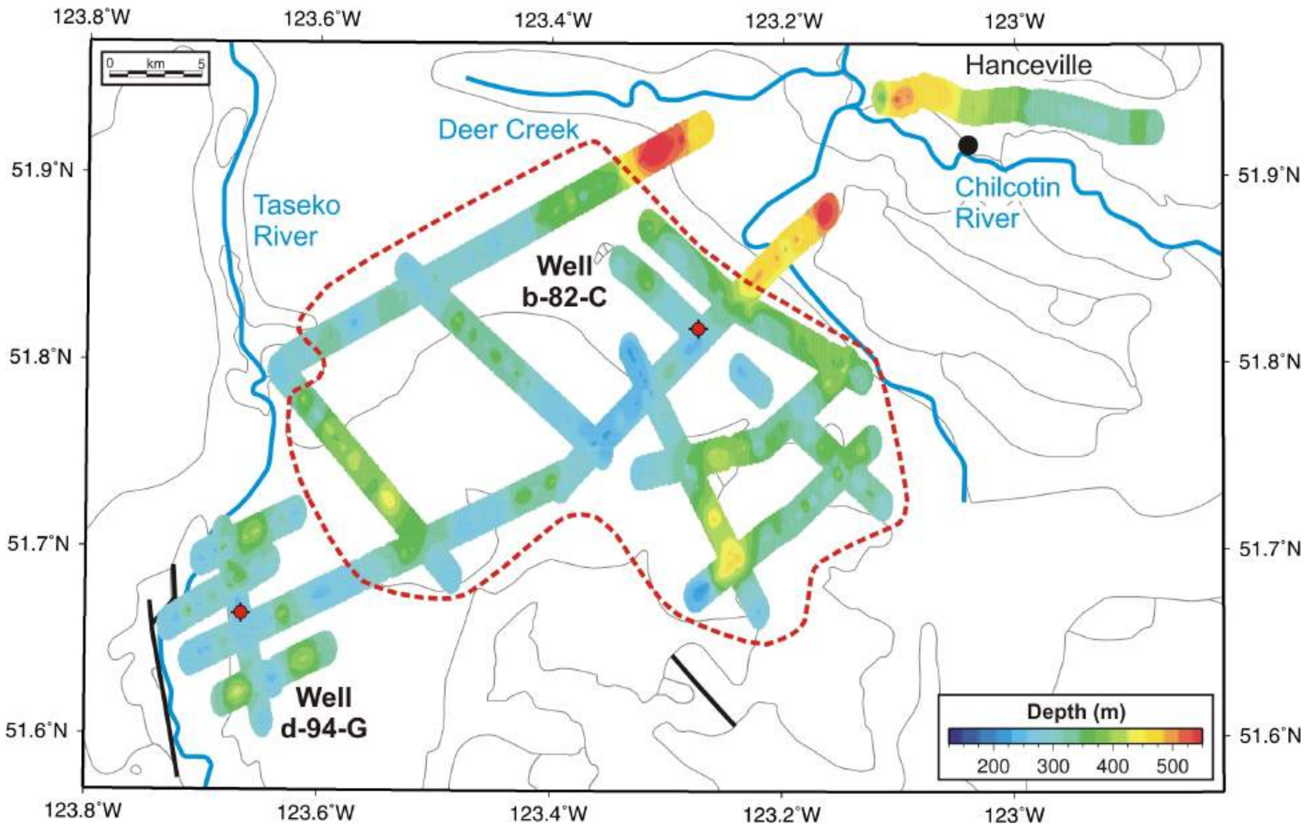

Figure 4. Depth (below ground) to the layer of maximum ray density (LMRD; density >100 ray paths) from first-arrival tomographic inversion. Thin grey lines show the surface geology (*modified from* Riddell, 2006). See Figure 5 for unit identification. Heavy red dashed line shows the probable presence of Eocene volcanic rocks. Blue lines are rivers.

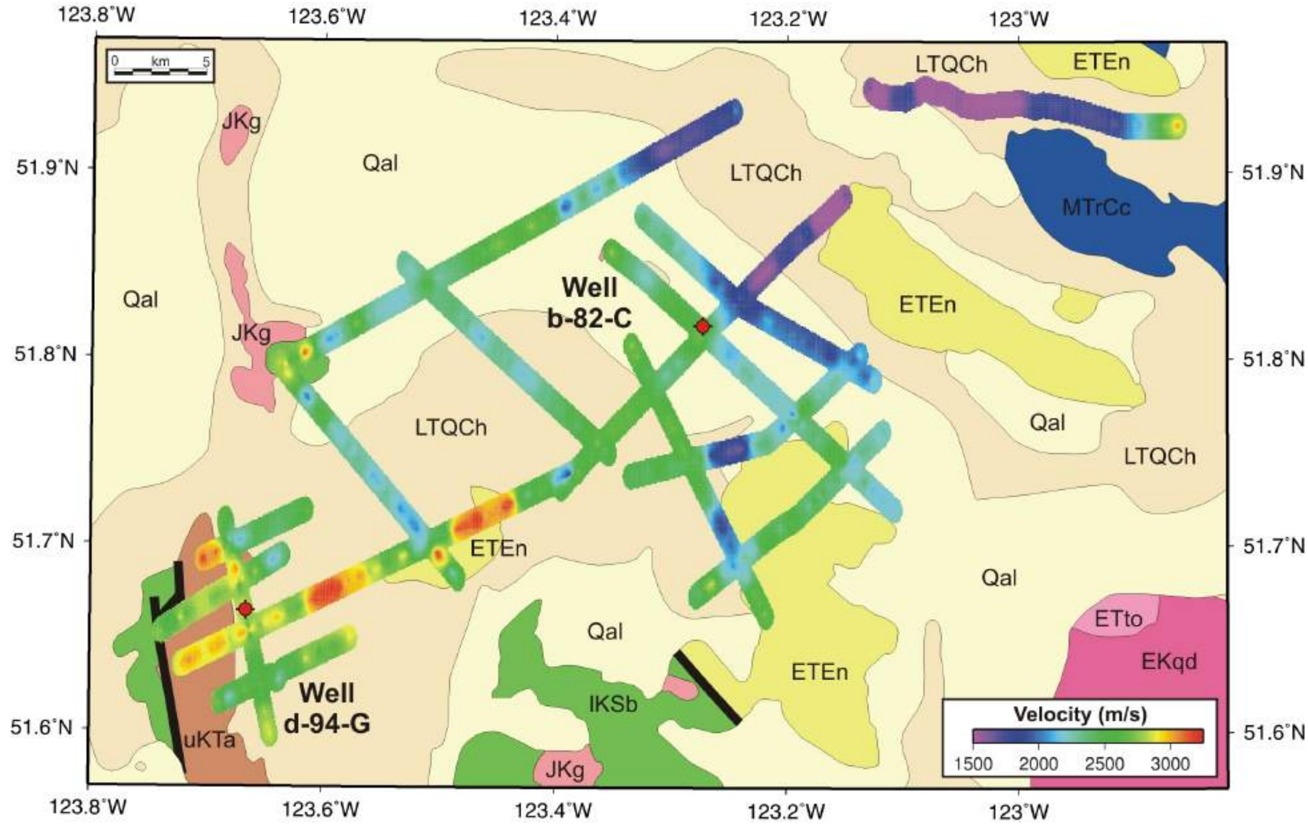

Figure 5. Interval velocity from the ground surface to a depth of 175 m, extracted from first-arrival tomographic models (underlying geology *simplified from* Riddell, 2006). Abbreviations: ETEn, Endako Group; lKSb, Spences Bridge Group; JKg, ETto, EKqd, various intrusive granitic rocks; LTQCh, Chilcotin Group; MTrCc, Cache Creek Group; Qal, drift.

Discussion

Geological mapping in the Chilcotin River area (Figure 4) has shown that, locally, the Chilcotin Group is of the Bull Canyon facies (Andrews and Russell, 2007). The Chilcotin Group is commonly lava rich, but the Bull Canyon facies is dominated by hyaloclastite, breccia and pillow lava.

Analysis of water well data and geological mapping (Andrews and Russell, 2008) have revealed that the Chilcotin Group is regionally thin (<50 m, probably <25 m). However, thicker accumulations have been attributed to local accumulation in paleo–drainage channels. The Chilcotin Group is interpreted to be ~100 m thick (Gordee et al., 2007) at Bull Canyon Provincial Park. Near Hanceville, along the Chilcotin River (Figure 4), the Chilcotin Group has a thickness of up to ~80 m (Andrews and Russell, 2007). Models of this region (Mihalynuk, 2007), based on mapped basal contacts of the Chilcotin Group and a digital elevation model, predict thicknesses of ~100–150 m on the Chilcotin River and to the south of Deer Creek (Figure 4).

Thicker accumulations of the Chilcotin Group in the Chilcotin River area (Figure 4) correspond to the regions of increased depth of the LMRD and a lower velocity. The breccia-dominated Bull Canyon facies rocks would likely have a lower seismic velocity in comparison to the lava-rich facies of the Chilcotin and Endako groups observed elsewhere. A local increase in thickness of these rocks would account for the observed lows in interval velocity and supports the interpretation (Andrews and Russell, 2008) of an increased thickness of the Chilcotin Group in paleo–river valleys.

Conclusions

The layer of maximum ray density derived from first-arrival tomographic inversion models predicts that the Eocene Endako Group overlies most of the central area of block A. In this area, the models estimate the thickness of these rocks to be fairly uniform (~221 m at well b-82-C). In northeastern block A, low interval velocities are interpreted to be related to anomalously thicker deposits of Neogene Chilcotin Group rocks of the breccia-rich Bull Creek facies. The distribution of these lows in interval velocity supports the interpretation that the Chilcotin Group is thicker in paleo–river valleys.

Acknowledgments

The authors wish to thank Geoscience BC for funding this research.

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