Modelling and Investigation of Airborne Electromagnetic Data and Reprocessing of Vibroseis Data from the Nechako Basin of South-Central British Columbia (NTS 093B, C, F, G), Guided by Magnetotelluric Results

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Introduction

In 2007, magnetotelluric (MT) data were collected in the Nazko region of the Nechako Basin, with two additional lines acquired in the south of the basin (Figure 1; Craven, 2009; Spratt and Craven, 2009b). The goal was to aid in the exploration for hydrocarbon reserves within the Nechako Basin. The MT method was considered particularly promising because the shallow geological structure of large parts of the Nechako Basin—basaltic flows of the Neogene Chilcotin Group and volcanic rocks of the Eocene Endako and Ootsa Lake Groups—complicate interpretation of seismic data that are more commonly used for hydrocarbon exploration (Spratt and Craven, 2009b). There are large seismic impedance contrasts within and between these units, and between these units and the sedimentary rocks of the basin. These result in considerable scattering of the seismic energy. In contrast, these units are mostly electrically resistive and therefore transparent to the MT method. The 2007 MT data have been interpreted for two-dimensional (2-D) Earth models (Spratt and Craven, 2008, 2009a, b), and three-dimensional (3-D) modelling and interpretation is currently being carried out (Drew et al., 2010). The MT data successfully penetrated the near-surface volcanic rocks to image the Nechako Basin sedimentary rocks and the basement beneath.

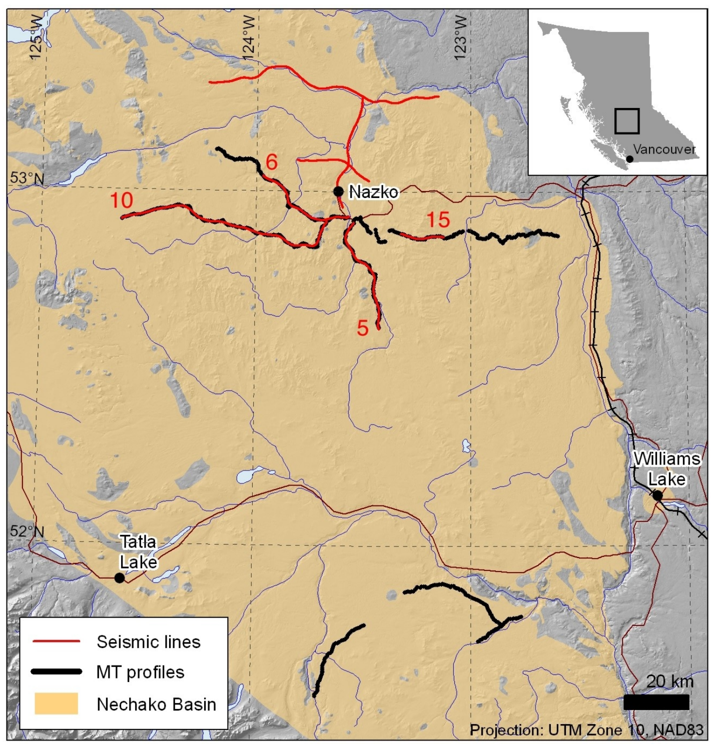

Figure 1. Location of the magnetotelluric (MT) survey lines (black) and the Geoscience BC seismic lines (red) within the Nechako Basin of south-central British Columbia. Red numbers indicate seismic line numbers. Base map from Natural Resources Canada (2004, 2007); digital elevation model prepared by K. Shimamura; outline of Nechako Basin after Massey et al. (2005).

The ZTEM system (Geotech Ltd., 2009) is an airborne electromagnetic (EM) system that measures the magnetic part of the MT response. This means that it is a relatively deep-penetrating airborne EM system. Also, because it is an airborne system, data can be acquired quickly and effi-

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ciently over large areas. A ZTEM survey is therefore an attractive proposition for the Nechako Basin, potentially extending the subsurface images derived from the 2007 MT survey data to the rest of the basin. However, the ZTEM system is new and its capabilities are not truly understood. Therefore, one goal of the project summarized in this paper is to perform numerical modelling and inversion studies to assess what can be expected from any ZTEM surveys performed in the Nechako Basin.

The second goal of this project is to use the Earth models derived from the MT data to aid the reprocessing and migration of the Geoscience BC vibroseis data that were acquired in 2008 (Calvert et al., 2009). The MT-derived models generally indicate the location of the interface between the surface volcanic rocks and the sedimentary rocks of the basin, including variability in the depth to this interface. Reprocessing of the vibroseis data will be performed to see if the interfaces in the MT-derived models can be observed and enhanced in the seismic sections. Also, the conductivities in the MT-derived models will be converted to seismic velocities, and these velocities tried in the reprocessing. As a final goal, existing geophysical and geological data will be integrated with the MT-derived Earth models to develop and refine the tectonic history of the Nechako Basin.

Project Components

Modelling and Assessment of ZTEM Data

The ZTEM system is an airborne EM system that measures the vertical component of the magnetic field that arises from electric currents induced in the subsurface by naturally occurring time variations of the Earth's magnetic field (Geotech Ltd., 2009). The measured vertical component is referenced to the horizontal components of the magnetic field that are measured simultaneously at a base station. The ratios of the vertical to horizontal components of the magnetic field, which are known as magnetic transfer functions, depend on the conductivities of the subsurface. The ZTEM data can therefore be used, in principle, to provide quantitative information on the structure of the subsurface.

The ZTEM system is unique among airborne EM methods in that it uses the Earth's natural magnetic field as its source. This means that the ZTEM system is sensitive to deeper structures than conventional airborne EM systems. Depending on the conductivities involved, ZTEM data can be sensitive to structures as deep as 2 km. It therefore has the ability to provide information on the structure of the Nechako Basin down to, and including, the Cretaceous sedimentary rocks. Also, because it is an airborne method, any ZTEM survey could cover the entire Nechako region if desired—it is not limited to following roads, as is the case with the vibroseis method.

In 2007, broad-band and high-frequency (MT) data were collected at 734 sites throughout the Nechako region (Spratt and Craven, 2008, 2009a, b; Craven, 2009). The data were collected along seven main profiles, and along a series of closely spaced shorter lines arranged specifically to enable 3-D interpretation. The data collected along the profiles have been inverted to give 2-D models of the subsurface conductivity structure extending to depths of more than 10 km (Spratt and Craven, 2008, 2009a, b). The models show the general pseudolayered sequence that is typical of the Nechako Basin: near-surface Chilcotin volcanic rocks (which are electrically resistive), Cretaceous sedimentary rocks (which are relatively conductive) and crystalline basement (which is resistive). The models also show significant variability along the profiles, reflecting the true complexity of the geology in the Nechako region.

In this project, the 2007 MT data and the conductivity models derived from them will be used to model and assess the data that would likely be acquired if a ZTEM survey were to be carried out over the Nechako Basin. Firstly, the subset of the 2007 MT data that corresponds to typical ZTEM data (i.e., vertical transfer functions for the narrower ZTEM frequency band) will be inverted to construct 2-D conductivity models. These models will be compared with the models obtained from the inversion of the MT data. This exercise will indicate the best possible outcome of performing a ZTEM survey in the Nechako Basin, as if the MT data were measured on the ground rather than on a moving platform and the horizontal and vertical components of the magnetic fields were measured at coincident locations. Secondly, synthetic ZTEM data will be computed for the 2-D conductivity models derived from the MT data. The synthetic ZTEM data will then be inverted to construct 2-D conductivity models, and these models will be compared with those constructed from the MT data. This comparison will identify those features of the 2-D MT-derived conductivity models that the ZTEM data would be sensitive to, and those features that would be invisible to the ZTEM survey.

MT-Guided Reprocessing of Vibroseis Data

The MT data can 'see' the general structure of the Nechako Basin—Eocene volcanic rocks overlying Cretaceous sedimentary rocks overlying crystalline basement—with relative ease. In contrast, the vibroseis data collected by Geoscience BC in 2008 (see Calvert et al., 2009) provide a highly variable view of the sedimentary basin depending on the complexity of the near-surface geology and, more specifically, the thickness and structure of the overlying Eocene volcanic rocks. Consequently, the quality and interpretability of the resulting seismic images of the subsurface are diminished. In this component of the project, the models derived from the MT data will be used to guide reprocessing of the vibroseis data. Specifically, the vibroseis data coincident with the MT profiles will be reprocessed to see if the contacts between the various units that appear on the 2-D MT-derived conductivity models can be made to appear in the seismic sections. Also, the conductivities in the MT-derived models will be transformed to seismic velocities and these velocities used in the reprocessing and migration of the vibroseis data. This transformation will be based on measured seismic velocities and conductivities of samples of the major rock units in the Nechako region. The MT-derived models will be used to define the spatial location and extent of each unit. Two-dimensional vertical sections of seismic velocity will then be created using the typical conductivities and seismic velocities for each unit (Jegen et al., 2009).

Integration of MT-Derived Models in a Tectonic History of the Nechako Basin

In addition to the MT and vibroseis data mentioned above, significant amounts of other historical and recently acquired geophysical and geological data exist for the Nechako region. In particular, airborne gravity data were collected in 2008 (Dumont, 2008a, b). Stratigraphic and well-log information is available from a number of boreholes in the Nechako region (Ferri and Riddell, 2006). Also, both large-scale and local-scale passive seismic data, from which we hope to obtain 3-D images of the Nechako region, have being collected (Idowu et al., 2009; Kim et al., 2009). The information on the Earth's subsurface available from these complementary datasets will be integrated with that from the MT data to produce a consistent history of the tectonic evolution of the Nechako Basin.

Conclusions

When this paper was written, preliminary reprocessing of the vibroseis data from lines 5, 10, 12 and 13 was underway, with geometry setup, data-quality control, refraction statics, common depth-point sorting, residual statics and conventional velocity analysis and migration having been completed for line 5 and partially completed for the others. So far, there has been no improvement in the seismic sections produced. However, it is expected that improvements will be obtained once guiding of the reprocessing by the MT-derived Earth models begins.

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