Imaging the Nechako Basin, British Columbia, using Magnetotelluric Methods

J.E. Spratt*
Geoscience BC, Vancouver, B.C.
Geological Survey of Canada, Ottawa, ON
jspratt@nrcan.gc.ca
and
J. Craven
Geological Survey of Canada, Ottawa, ON

Summary

Magnetotelluric (MT) data was collected at 734 sites, along 7 profiles, within the Nechako Basin, located in the Intermontane Belt of the Canadian Cordillera, in an effort to evaluate the technique as a tool both for oil and gas exploration and geological characterization of the sedimentary basin. The potential for hydrocarbons has been noted within several interior basins of British Columbia; however, an important impediment to hydrocarbon exploration is the inability of traditional geophysical methods to image structures beneath the basaltic lava sheet that covers much of the basins. One- and two-dimensional modelling of the MT data indicate that the method is capable of both penetrating and imaging these surface volcanics. Initial interpretation suggests that the basalts are not as thick or widespread as initially believed. The Nechako sediments are imaged as a shallow conductive layer overlying the resistive crystalline basement rocks. Structural breaks are observed that are an indication of fault systems that carry these deeper materials towards the surface. Variations in conductivity within the sedimentary packages may result from changes in mineralogy of the sediments, changes in percent porosity or possibly chemical changes in the fluid within the pore spaces. Determining the causes for these conductivity variations may contribute to a better understanding for hydrocarbon potential in the region.

Introduction

In response to the destructive effects of the mountain pine beetle (MPB) in areas of British Columbia and its implications on the forestry industry, a number of projects with the aim of improving the mineral and petroleum potential of the affected region have been initiated. Limited exploration to date provided some evidence for the potential for oil and gas reservoirs within the interior basins in central B.C., including the Nechako sedimentary basin (Hannigan et al., 1994; Hamblin, 2008). As part of the MPB project, in the fall of 2007, a magnetotelluric survey was designed and data was collected throughout the southern Nechako region with the aim of contributing to a better understanding of the extent to which hydrocarbon resources are present in the region (Spratt et al., 2007; Spratt and Craven, 2008; Figure 1).

The Nechako basin is an Upper Cretaceous to Oligocene sedimentary basin located in the Intermontane Belt of the Canadian Cordillera (Figure 1). The basin is made up of overlapping sedimentary sequences that formed in response to terrane amalgamation to the western edge of ancestral North America (Monger et al., 1972; Monger and Price, 1979; Monger et al., 1982; Gabrielse and Yorath, 1991). The Stikine and Quesnel volcanic arc terranes, separated by the oceanic Cache Creek terrane lie beneath the Nechako basin (Struik and MacIntyre, 2001). Up to Eocene times, the tectonic processes were dominated by transpressional shortening, with westward directed thrusting between the Stikine and Cache Creek terranes prior to 165 Ma (Best, 2004). East-west extension associated with regional transcurrent faulting began in the Late Cretaceous, and was accompanied by the extrusion of basaltic flows of the Neogene Chilcotin group, and volcanics of the Eocene Endako and Ootsa Lake groups. It has been suggested that the Chilcotin Group can reach a thickness of ~200 m and averages ~100 m (eg. Mathews, 1989); however, new studies suggest that it is comparatively thin (< 50 m) across most of its distribution and only thick (> 100 m) in paleochannels (Andrews and Russell, 2008). The presence of the surface basaltic flows, Tertiary volcanic rocks has prevented uniform and consistent seismic-energy penetration and, along with the Pleistocene glacial deposits covering much of the area, complicate the interpretation of other modern subsurface imaging methods. It has been shown that the magnetotelluric (MT) method can be useful in resolving geological structures less favorable for characterization by seismic methods (Unsworth, 2005, Spratt et al, 2007). As the method is sensitive to, but not impeded by, the surface volcanic rocks and can detect variations within the different units, it can be useful in locating the boundaries of the Nechako Basin and defining its internal structure.

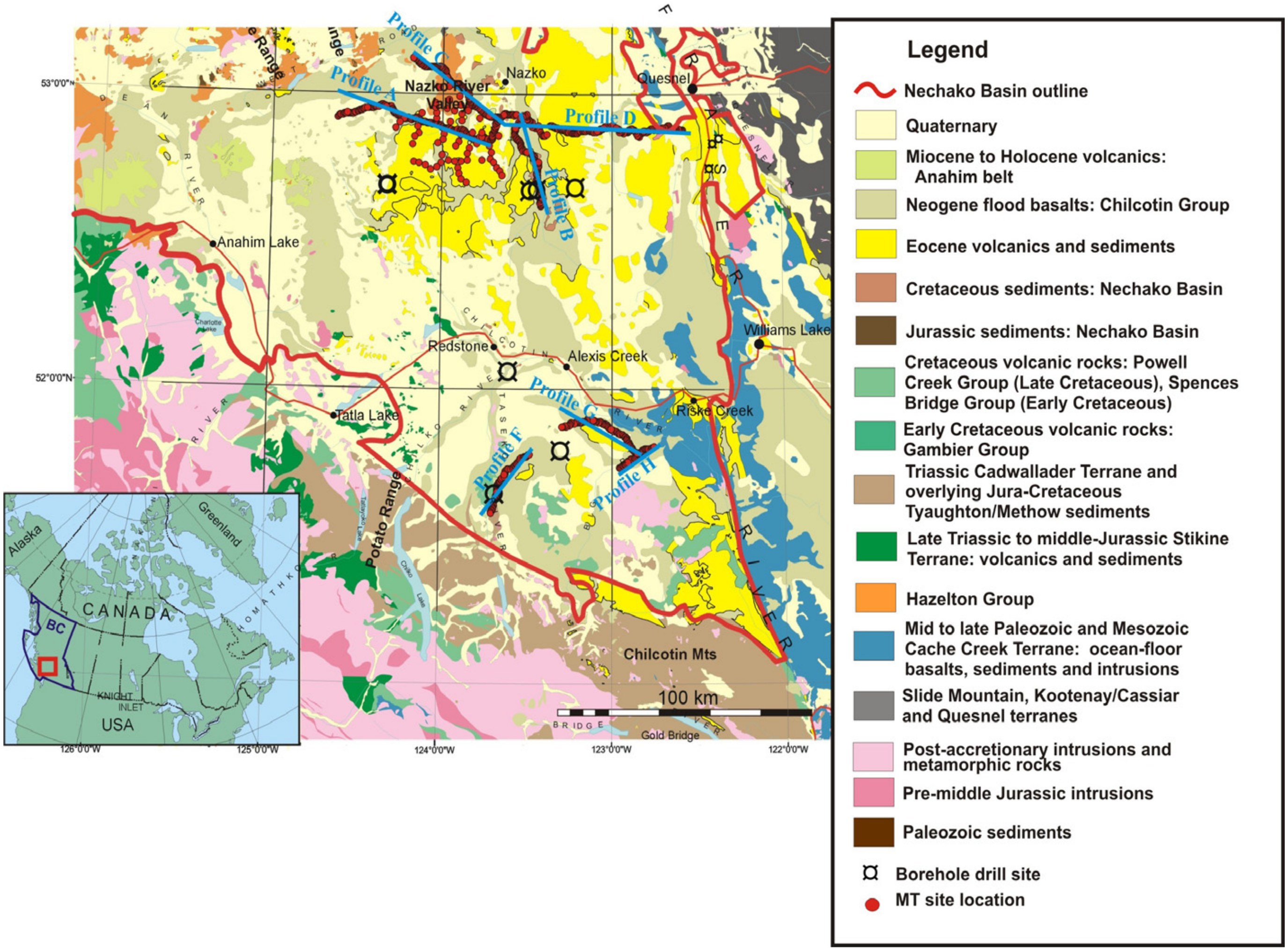

Figure 1: Geology map of the Nechako basin showing the location of magnetotelluric sites and boreholes.

Theory and/or Method

Magnetotellurics (MT) is a method that provides information on the electrical conductivity of the subsurface of the Earth by measuring the natural time-varying electric and magnetic fields at its surface. Apparent resistivity and phase lags can be calculated at any measured frequency from these mutually perpendicular fields. Since the depth of penetration of these fields is dependent on frequency (lower frequencies penetrate deeper) and the conductivity of the material (the lower the conductivity, the greater the depth), estimates of depth can be made for the calculated apparent resistivities and phases.

The MT method is sensitive to contrasts in the resistivity of juxtaposed materials and can therefore distinguish between some lithologic units. Basalt and igneous rocks, for example, commonly have electrical resistivity values > 1000 Ohm-m, whereas sediments are less resistive, with values ranging between 1 – 1000 Ohm-m. In the crust, other factors that can greatly influence the overall conductivity of a specific unit include the presence of saline fluids, changes in porosity, and the presence of graphite films or interconnected metallic ores. In addition to defining structure, the MT method may be able to provide some estimate of bulk properties such as porosity and percent salinity, important factors in the exploration for hydrocarbons (Unsworth, 2005).

Examples

One- and two-dimensional models have been generated for all of the MT data collected within the Nechako Basin, using the WingLink™ interpretation software package. In general, the models clearly reveal the three main lithologic units: the resistive surface basalts, the conductive Nechako sediments, and the resistive underlying volcanoclastic and basaltic rocks of the basement terranes (Figure 2).

The resistive near-surface feature reaches depths up to 200 m, but is limited in lateral extent. This suggests that the volcanic cover is either to thin too be detected by MT methods (less than ~ 50 m), or it is not as widespread as initially presumed. If these basalts are indeed thin, other exploration techniques used to investigate the mineral or oil and gas potential of the underlying sediments should be reconsidered.

The sedimentary packages of the Nechako Basin are imaged as a shallow conductive layer (1 – 200 Ohm-m) that extend from the surface, or near-surface, to depths varying between 1000 – 3000 m. Along profile variations in conductivity are revealed within this unit. Causes for significantly high conductivity may include changes in the salinity of the fluids, the presence of graphite sheets, or sulphides, or may result from a significant increase in the relative porosity of the sediments. Establishing or constraining the causes of these conductivity variations may provide evidence for the presence of hydrocarbons. Several breaks in the continuity of the shallow conductor are observed along many of the profiles that suggest the presence faults that juxtapose resistive material from deeper regions against the conductive sediments. As faulting is a mechanism for developing traps for oil and reservoirs, understanding their structure is important for hydrocarbon exploration.

All of the models reveal a decrease in conductivity from ~200 Ohm-m to > 700 Ohm-m at depths varying between 1000 – 3000 m, corresponding to approximate depth estimates for the thickness of the Nechako sedimentary packages. This change likely represents the boundary between the Nechako sediments and the underlying resistive basement units, indicating that the MT data are sensitive to the base of the Nechako basin and can delineate its structural boundaries.

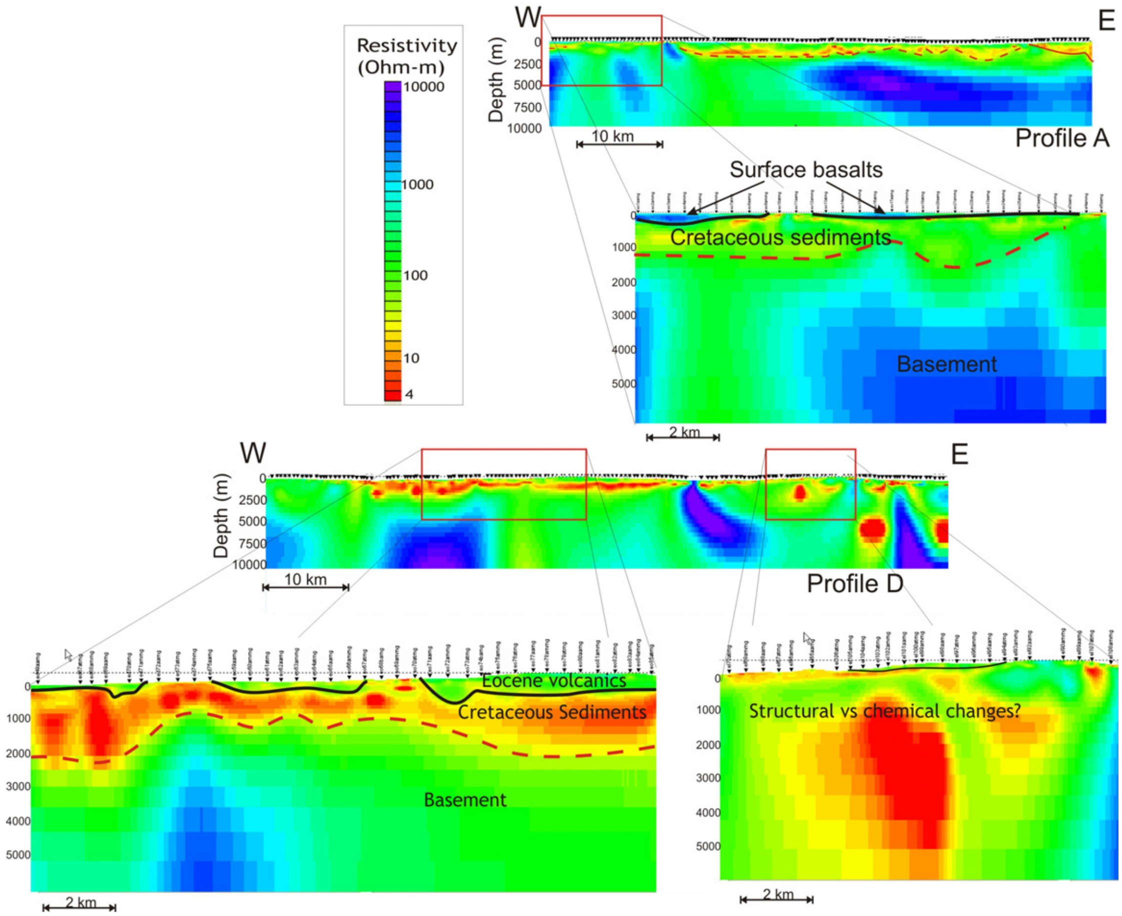

Figure 2: Examples of the two-dimensional conductivity models generated along the MT profiles in the Nechako Basin.

Conclusions

Analysis of magnetotelluric data collected throughout the Nechako Basin has yielded one-and two-dimensional models for the entire dataset. A conductivity contrast is revealed between the surface volcanics, the Nechako sediments and the underlying basement rocks. The models show the surface volcanics in isolated locations suggesting that they are either thinner, or not as widespread, as initially interpreted. The thickness of the sedimentary packages varies greatly along the different profiles as does the overall conductivity values within the unit. Structural constraints are place of the lateral continuity of the sedimentary packages. Characterizing the along strike changes will be important in assessing the potential for oil and gas within the region.

Acknowledgments

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