Resistivity Models of Southwestern Canada: New insights into lithospheric structure, magma bodies, and geothermal systems

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SUMMARY

Three new 3-D resistivity models allow a fresh look at the lithospheric structure of southwestern Canada. The largest of these models is centred on the southeastern Canadian Cordillera and spans hundreds of kilometres. Another model is focused on the central Garibaldi volcanic belt, from Mount Garibaldi to the Bridge River Cones. The final model surrounds the Mount Meager volcanic complex, an area that is currently in the early stages of geothermal development.

The Cordillera model has a horizontal resolution of 5 km and extends to a depth of 400 km. It is the first regional-scale 3-D resistivity model of the southern Canadian Cordillera. This study focuses on crustal-scale resistivity anomalies including the southern Alberta-British Columbia conductor and the Canadian Cordilleran Regional conductor. It also investigates the transition from thin Cordilleran lithosphere to thick cratonic lithosphere, providing new insight into the deep structure of western North America.

The Garibaldi model has a horizontal resolution of 1.5 km and extends to a depth of 40 km. This 3-D resistivity model is preliminary, but it includes conductors below Mount Meager and Mount Cayley. Additional fieldwork at Mount Cayley is scheduled for August 2022 and an update will be provided at the 25th EM Induction Workshop.

The Mount Meager model has a horizontal resolution of 0.25 km and extends to a depth of 20 km. Following two field campaigns in 2019 and 2020, this study builds on magnetotelluric results from the 1980s and early 2000s. This 3-D resistivity model provides a regional view around the geothermal target, including a potential magma body and associated deep hydrothermal systems.

This abstract gives an overview of these three studies, along with key results. Together, they present an exciting new view of the geologic structure and geologic evolution of southwestern Canada.

Keywords: Canadian Cordillera, Garibaldi Volcanic Belt, Mount Meager, Magnetotellurics, Geothermal

INTRODUCTION

The Juan de Fuca plate, offshore southwestern British Columbia (BC) and northwestern Washington, subducts beneath the North American plate at the Cascadia subduction zone, as illustrated in Figure 1 at the end of the abstract. The tectonic convergence rate between these two plates is approximately 40 mm/year (Kreemer et al. 2014). In contrast to the Juan de Fuca plate, the Explorer plate to the north is subducting at a rate of only 5-20 mm/year (Hutchinson et al. 2020).

Dehydration of the subducting slab releases volatiles into the overlying mantle of the North American plate, lowering its melting point and creating a region of partial melt, which leads to volcanism at the surface (Stern 2002). The chain of volcanoes resulting from this subduction is called the Cascade volcanic arc. The northern segment of the arc, from Glacier Peak in Washington to Silverthrone Caldera in BC, is the Garibaldi volcanic belt (GVB; Figure 2).

Mount Baker is the most voluminous volcanic complex in the GVB, Glacier Peak is the most-recently active with an eruption in the mid-1700s and Mount Meager is the most-recently active in Canada with a major eruption ~2400 years ago (Hickson 1994). The most recent volcanism in the GVB has been rhyolitic-to-dacitic at Mount Meager, dacitic at Mount Cayley and Mount Garibaldi, and andesitic at Mount Baker and Glacier Peak (Hickson 1994). This illustrates a change from felsic composition in the north to intermediate silica content in the south.

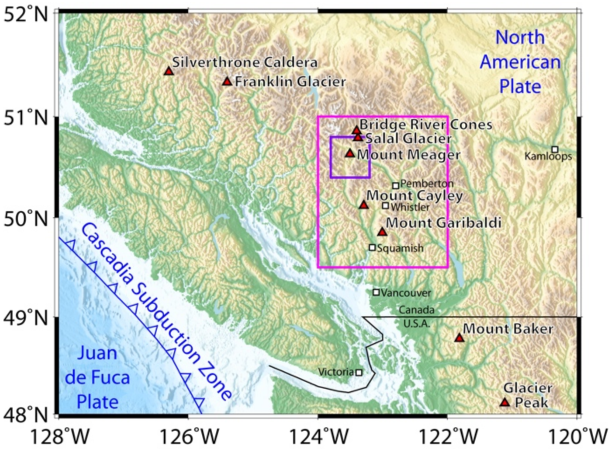

Figure 2. Map of southwestern BC and northwestern Washington with the Canada-U.S.A. border (black line), population centres (squares), volcanic centres (triangles) and two study areas: central GVB (pink) and Mount Meager (purple).

BC has a range of significant geothermal resources in settings that include volcanic systems, fault-hosted systems, and hot dry rock. Volcanic systems are found in the GVB, including at Mount Meager and Mount Cayley, and fault-hosted systems are found near the southern Rocky Mountain Trench (SRMT). Both fault-hosted geothermal systems and hot dry rock resources are found in the Columbia Mountains.

Data and Methods

The study centred on the southeastern Canadian Cordillera used magnetotelluric (MT) data from 331 locations (Figure 3). These data included 110 Lithoprobe sites, 22 EarthScope USArray sites, and 19 sites from other studies. The additional 180 MT soundings were collected by the University of Alberta between 2002 and 2018. The 3-D inversion used impedance and tipper data at 18 periods, logarithmically spaced between 1 and 18,000 s. The resistivity model has a horizontal resolution of 5 km and extends to a depth of 400 km.

The study focused on the central GVB used MT data from 77 locations (Figure 4). The 3-D inversion used impedance and tipper data at 24 periods, logarithmically spaced between 0.017 and 800 s. The resistivity model has a horizontal resolution of 1.5 km and extends to a depth of 40 km.

The study focused on Mount Meager used MT data from 66 locations (Figure 5). These data included 2, 30, 22 and 12 soundings from 1982, 2001, 2019 and 2020, respectively. The 3-D inversion used impedance and tipper data at 29 periods, logarithmically spaced between 0.0025 and 1,000 s. The resistivity model has a horizontal resolution of 0.25 km and extends to a depth of 20 km. ModEM (Kelbert et al. 2014) was used in all three studies.

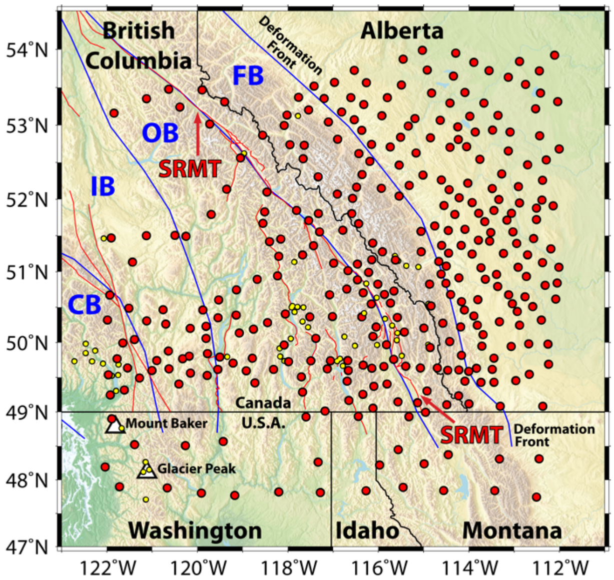

Figure 3. MT stations (red dots) used in the 3-D inversion to create the resistivity model centred on the southeastern Canadian Cordillera. Political boundaries (black lines), morphogeological boundaries (blue lines), major faults (red lines), thermal springs (yellow dots), and major volcanic centres (white triangles) are also shown. CB = Coast belt; IB = Intermontane belt; OB = Omineca belt; FB = Foreland belt; SRMT = southern Rocky Mountain Trench.

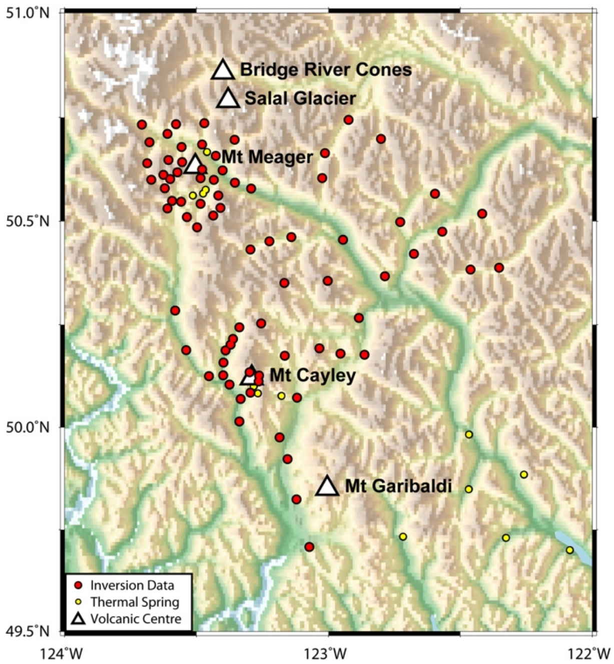

Figure 4. MT stations (red dots) used in the 3-D inversion to create the resistivity model focused on the central Garibaldi volcanic belt.

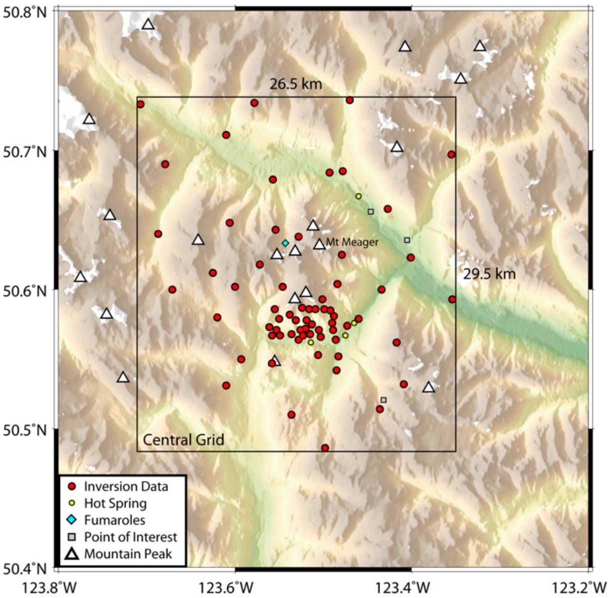

Figure 5. MT stations (red dots) used in the 3-D inversion to create the resistivity model surrounding the Mount Meager volcanic complex.

RESISTIVITY MODELS

One horizontal slice from each of the three 3-D resistivity models is shown in this abstract (Figures 6, 7 and 8). The resistivity models will be shown in more detail at the 25th EM Induction Workshop.

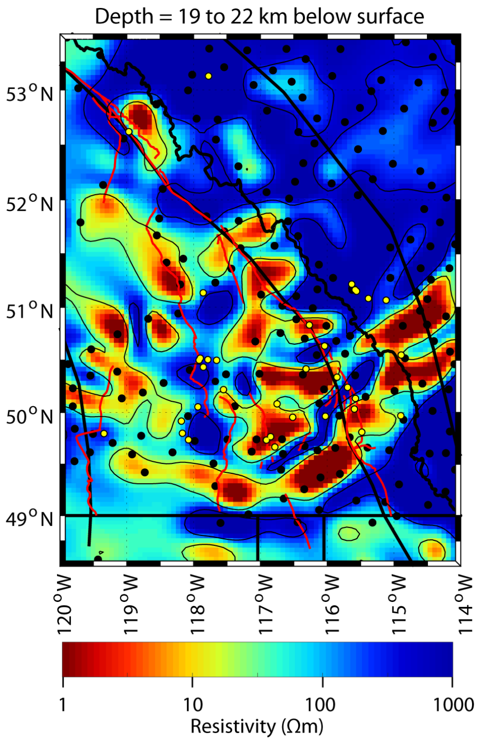

Figure 6. Horizontal slice of the 3-D resistivity model centred on the southeastern Canadian Cordillera. MT sites (black dots), thermal springs (yellow dots) and surface traces of major faults (red lines) are also shown.

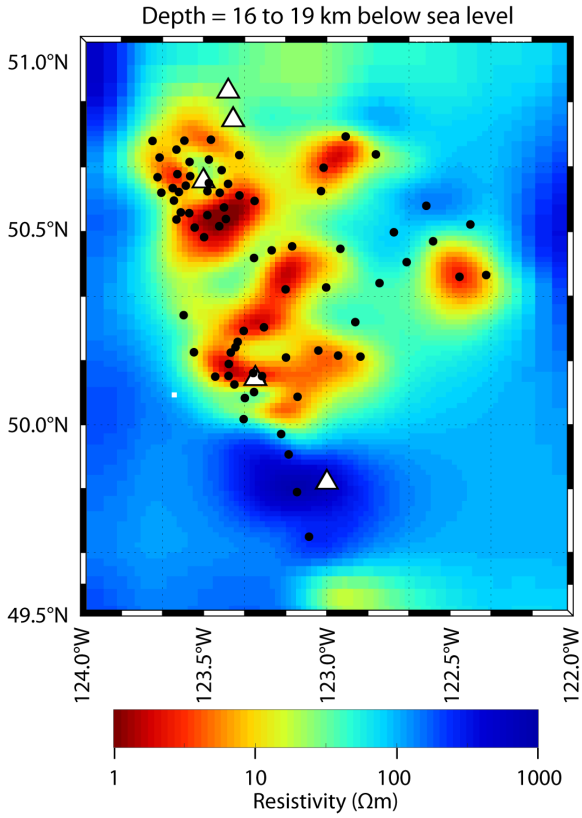

Figure 7. Horizontal slice of the 3-D resistivity model focused on the central Garibaldi volcanic belt. MT sites (black dots) and volcanic centres (triangles) are also shown.

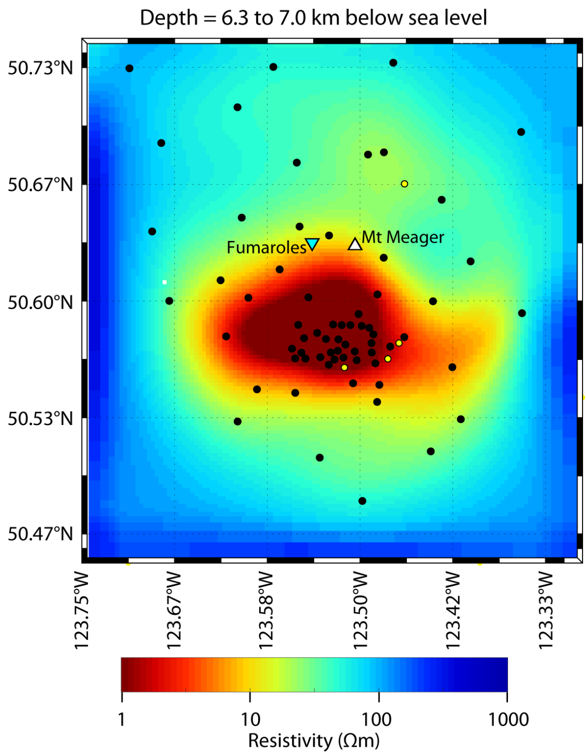

Figure 8. Horizontal slice of the 3-D resistivity model surrounding the Mount Meager volcanic complex. MT sites (black dots) and thermal springs (yellow dots) are also shown.

Conclusions

The resistivity model centred on the southeastern Canadian Cordillera exhibits low resistivity in the middle and lower crust of the Omineca belt. This is likely caused by interconnected saline fluids and possibly partial melt in the lowermost crust and uppermost mantle. Additional results, including detailed interpretations and deep lithospheric structure, will be presented at EMIW 2022.

The resistivity model focused on the central Garibaldi volcanic belt is preliminary, but it exhibits low resistivity below Mt Meager and Mt Cayley. Additional data will be collected at Mt Cayley this summer. An update will be provided at EMIW 2022.

The resistivity model focused on Mt Meager exhibits low resistivity beneath the volcanic complex in the depth range 5-10 km, possibly caused by a magma body. Additional results, including detailed interpretations, will be presented at EMIW 2022.

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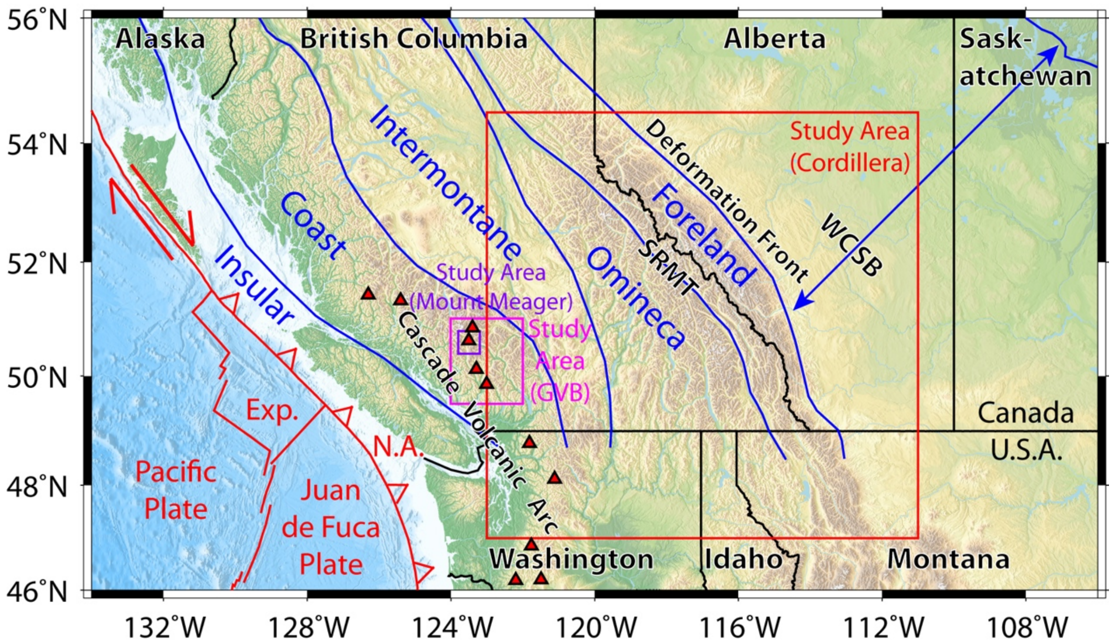

Figure 1. Map of southwestern Canada and northwestern U.S.A. with political boundaries (black lines), morphogeological boundaries (blue lines), tectonic plate boundaries (red lines), volcanoes (triangles), and three study areas: (1) centred on the southeastern Canadian Cordillera (red), (2) focused on the central Garibaldi volcanic belt (pink), and (3) surrounding the Mount Meager volcanic complex (purple). Exp. = Explorer plate, N.A. = North American plate, SRMT = southern Rocky Mountain Trench, and WCSB = Western Canada Sedimentary Basin.