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Preliminary Results from a Magnetotelluric Study of the Garibaldi Volcanic Belt Geothermal System, British Columbia, Canada

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ABSTRACT

New magnetotelluric (MT) soundings have been conducted at Mount Meager in the Garibaldi volcanic belt (GVB) situated in southwestern British Columbia, Canada approximately 150 km north of Vancouver. Mount Meager is one of a chain of young (< 11 k yr) stratovolcanoes in the GVB. Fluids near the surface have temperatures greater than 250 °C, the highest such temperature of any potential geothermal resource in Canada. The new MT data complement two earlier datasets provided by Frontier Geosciences and NRCan. The data have been analyzed to determine the 3D electrical conductivity structure of this portion of the belt in order to elucidate the local and regional controls on permeability thought to be a primary control on the potential of the area sustain fluid production rates at elevated temperatures. Previous studies had demonstrated correlations between increased temperature gradients and conductivity in addition to a 2D model that demonstrated a zone of enhanced electrical conductivity thought to be due to a montmorillonite-dominated cap atop a more resistive zone related to chlorite and sericite alteration. The limited bandwidth and aperture of the prior work could not map out the full lateral extent of the zones, nor could it detect or rule out the presence of any channels between the conductive and resistive areas. The precise boundaries and depths of these features, plus their relationship to permeability controls within the GVB have been modelled using standard 3D finite difference methods using rectilinear meshes. Soon, a novel finite element 3D method recently developed to handle the complex structure and topography expected in this area will be utilized. The new data and enhanced modelling techniques will map and image reliably the fundamental fluid conduits within the potential reservoir, and provide an enhanced understanding of the complex fluid and alteration regimes controlling permeability within this portion of the GVB.

1. INTRODUCTION

Advantages gained in geothermal resource development are complicated by the risk related to finding hot aquifers able to sustain flow over long periods of time. Previous studies in Canada (1975-85) provided essential insight into Canada's regional thermal regime, but these earlier studies lacked essential geoscience required to explore successfully for geothermal reservoirs that can remain productive over the lifetime of the project development.

The Garibaldi Volcanic Belt (Figure 1) is comprised of a chain of young (< 11 ka old) volcanoes located in southwestern British Columbia, a region also known to have abundant thermal springs. NRCan, along with BC Hydro, conducted initial exploration drilling at one of the volcanoes, Mount Meager in the 1980's. These results defined geothermal fluids with temperatures higher than 250 °C, making it the greatest temperature geothermal resource in Canada. While this will produce electricity, the fluid production rate was not sufficient to offset the cost of the 60 km of transmission lines required to reach the site (power generation is a function of both temperature of the fluid and the rate that at which the fluid can be produced to surface). A key outcome of this research project was that while a world class thermal resource had been found, the geologic conditions required to make it economical were not. Lack of knowledge of the regional controls on permeability poses a significant exploration risk for industry exploration in the region despite the known world class thermal resource.

MT data are sensitive to changes, both spatial and temporal, in subsurface electrical resistivity which itself is a function of key geothermal reservoir properties such as porosity, permeability and the salinity and temperature of the fluids within the pore spaces. Images, 3D volumes and maps arising from the MT data will be used at Mount Meager to delineate the subsurface variations of these parameters. The MT method is one of the few geophysical techniques able to investigate electrical resistivity a broad range of depths, and therefore it affords a unique opportunity to image permeable zones connecting deeper, hotter fluid sources to the surface. The technique is also sensitive to lithology and faulting. The controls on the fluid systems and permeability exerted by these important factors can also be detected. Electrical conductivity is highly sensitive to the degree of partial melting, and therefore MT images and maps can additionally be used to identify crustal magma chambers driving heat and fluids into the local geothermal systems.

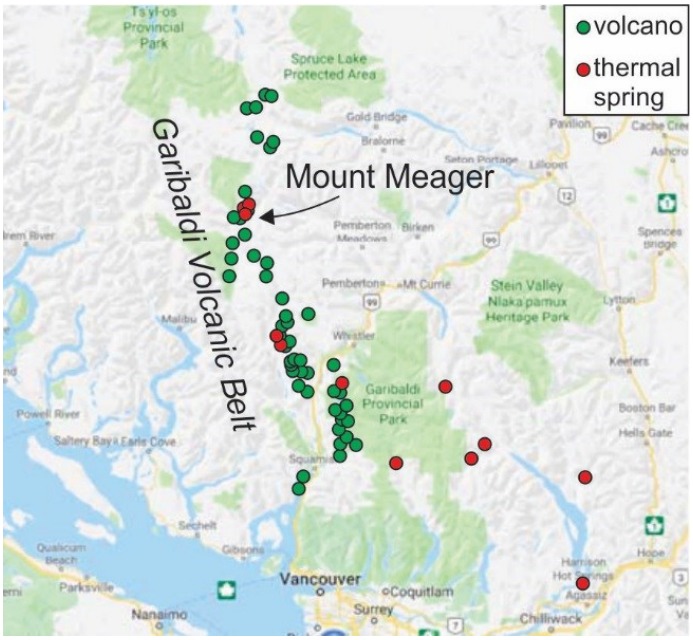

Figure 1: Survey Setting

2. PREVIOUS DATA

2.1 1982 Data

Alongside the drilling, NRCan collected a small MT dataset (green dots in Figure 2 along Meager Creek). The data is summarized in Jones and Dumas (1993) who incorporated the data into a regional legacy data set collected to the south. The subsequent 2-D model provided evidence of shallow conductors at the Meager Creek fault zone but their spatial extent was difficult to ascertain with the existing data. Nonetheless, the authors noted a correlation in the data with increasing temperature and suggested features in their model could be related to clay alteration.

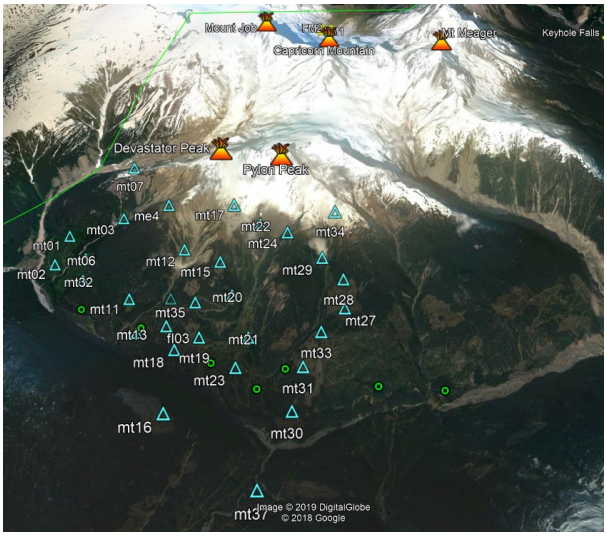

Figure 2: Map of Mount Meager Area. Triangles are 2001 MT site locations, and green circles are the original 1982 data.

2.2 2001 Data

In 2001, a larger data set (cyan triangles in Figure 2) was collected by Frontier Geosciences Inc. as part of the South Meager Geothermal program undertaken by the Crew Development Corporation. The goal of this program was to ascertain the subsurface structure of the south slope of Meager Creek. The dataset was graciously provided to the current project by Frontier Geosciences. To help with 2019 survey planning, inversions using a simple one-dimensional algorithm was performed on the combined legacy datasets and shown below. Three-dimensional inversions were also undertaken but these are not discussed here due to their preliminary nature.

2.3 Preliminary 1-D Inversions

Occam 1d inversion (Constable et al., 1987) models were calculated from the legacy data using the determinant average of the impedance tensor at each site. Occam algorithms have the advantage of not introducing structure into a model unless warranted by the data. Also, the determinant invariant has the advantage of encapsulating the information in the full MT tensor without the need of assigning a coordinate system, whilst providing a crude estimate of subsurface feature geometries when contoured. Figure 3 is a

screen grab of resistivity at 200 m depth (non topo corrected) showing a low resistivity region in the southern portion of the survey area with its northernmost point at site 19. A second less conductive region is apparent in the central portion of the survey area as well. Shallow conductors such as these are commonly associated with smectite-zeolite clay alteration (e.g. Tsukamoto et al, 2018). Induction arrows, plotted to point towards conductors, show a complicated pattern but do generally indicate major conductors within the survey limits and to the north of the legacy survey data. The long arrow at site mea82_003 is an artifact explained in Jones and Dumas (1983).

Figure 4 is a plot of resistivity at 600 m depth and shows that the conductive zone at 200m depth has become a more resistive feature, indicative of a transition to resistive alteration products in the subsurface related perhaps to chlorite epidote alteration.

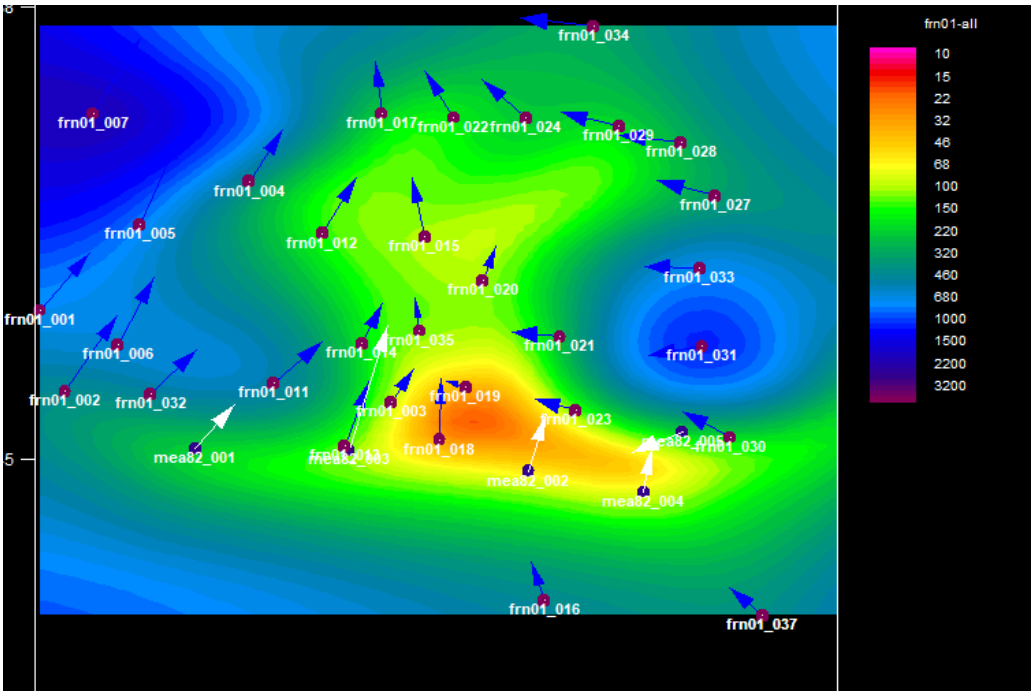

Figure 3: Contoured resistivities at 200m depth from 1D inversions.

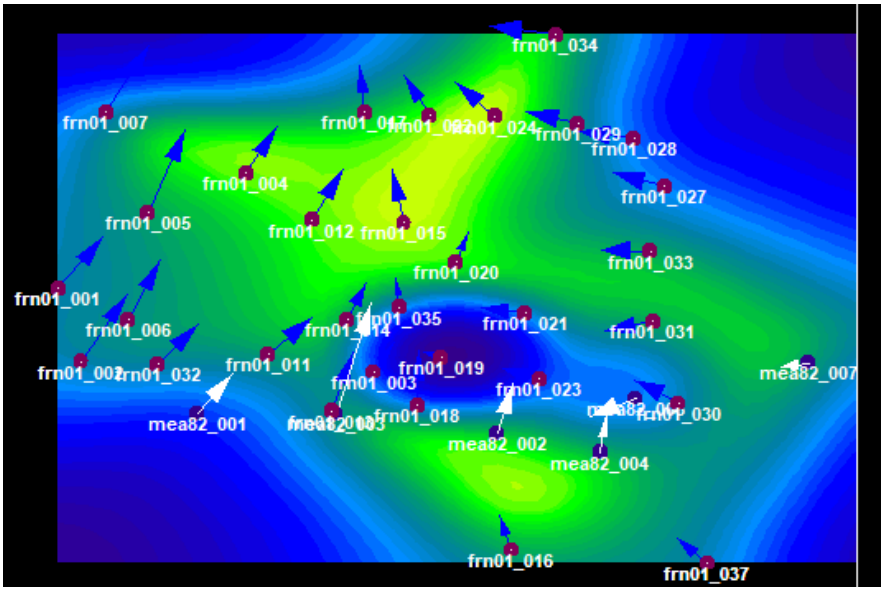

Figure 4 Contoured resistivities at 600m depth from 1D inversions.

2.4 2019 Data

At the time of writing, we have collected 80 AMT sites (Figure 5) to complement the existing coverage of broadband MT sites. The new sites have been collected to extend both the bandwidth and aperture of the legacy datasets to improve our understanding of the extent and size of conductive and resistive anomalies. As the new data is still being processed, their contribution will be presented at the conference. The linkages with other studies in the region as part of the project (gravity, broadband and MT, seismic tomography) will also be explored.

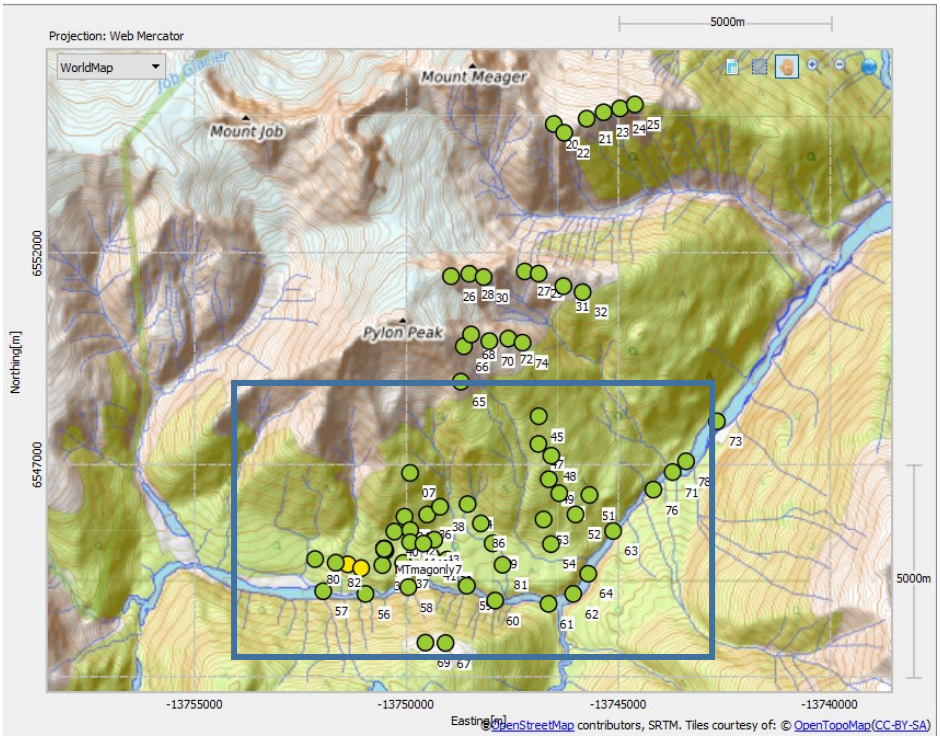

Figure 5: 2019 site locations. Blue box indicates approximate area of Figures 3 and 4.

CONCLUSIONS

Legacy data from the Meager Creek area of British Columbia have been analyzed for one-dimensional conductivity variations. The models show multiple conductive zones with the southernmost conductor overlying a resistive feature consistent with typical clay alteration expected in hydrothermal systems commonly investigated by electromagnetic techniques. The sites from the 2019 survey are still being processed at the time of this writing and so discussion of the new data, plus integrated geophysical models will be presented at the conference.

ACKOWLEDGEMENTS

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