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Application of magnetotelluric data to geothermal exploration at Watson Lake, Yukon

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Summary

The community of Watson Lake, Yukon depends on diesel generators for electric power generation, making it reliant on fuel shipments from the south. Geothermal energy production is being explored as a potential alternative energy source for the community. Studies have shown that relatively high heat flow values are found over much of the southern Yukon. To utilize subsurface heat, the Tintina Fault system could potentially provide a source of permeable, fractured rock that would allow for fluid circulation that would recover the heat (Majorowicz and Grasby, 2014; Witter et al., 2018). However, the exact location of the Tintina fault in the vicinity of Watson Lake is poorly constrained due to extensive glacial till cover.

Previous 2D magnetotelluric (MT) studies in the area were undertaken as a part of the Slave-Northern Cordilleran Lithosphere Evolution (SNORCLE) transect (Ledo et al. 2002) and imaged the Tintina fault as a near vertical zone of high electrical resistivity with low resistivity areas near the surface. The broad station spacing of 10-15 km in the SNORCLE data limits the resolution of near-surface features that are important for geothermal exploration. A survey grid with narrower station spacing and 3D geometry is therefore required (Figure 1).

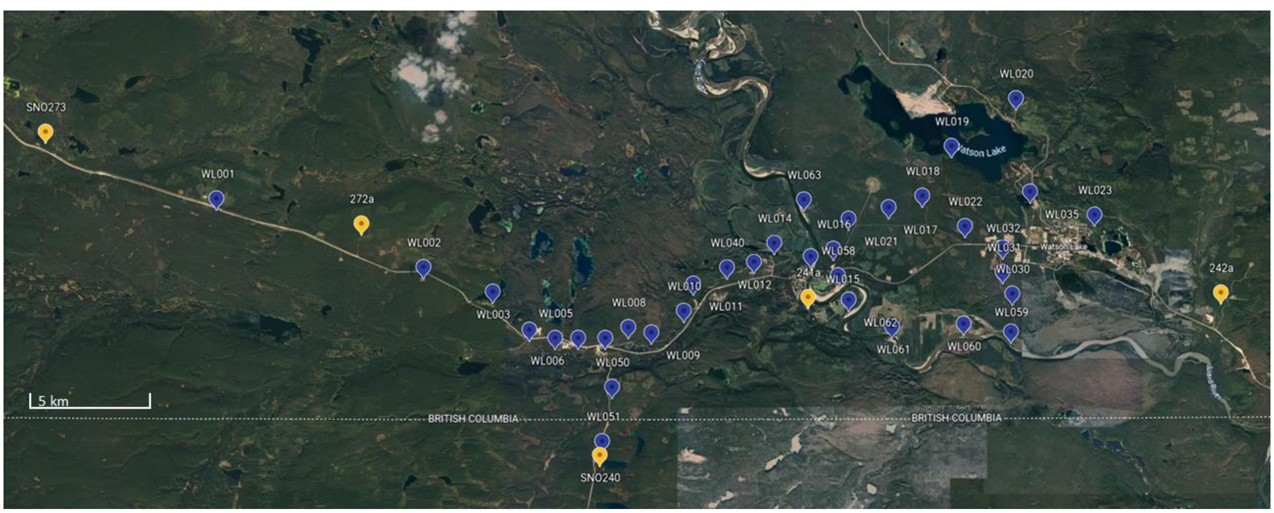

Figure 1: Map of the survey area showing MT station locations near Watson Lake, Yukon. Blue markers show the locations of the Summer 2021 station locations, yellow markers show the locations of the SNORCLE stations.

A 3D magnetotelluric (MT) survey was undertaken during the summer of 2021 in order to locate potential sources of geothermal energy in the vicinity of Watson Lake and to better constrain the location of the Tintina fault. A total of 36 MT stations were collected with data in the frequency range of 0.001 to 100 Hz. The time series data were processed using a combination of the Egbert Processing method (Egbert, 1997) and the Phoenix EMPower software to obtain measured impedance and tipper data. This data was then utilized in combination with data from 5 of the nearby SNORCLE stations to create a 3D electrical resistivity inversion model using the ModEM inversion method (Kelbert et al. 2014).

The ModEM inversion utilized a starting model consisting of a 100 Ωm halfspace split into a grid of 72 x 140 x 77 cells in the north-south, east-west, and vertical directions respectively. The cells in the central part of the model were 500 x 500 m^2 in the horizontal direction and had a thickness of 50 m. The cell size increased geometrically away from the center by a factor of 1.3 horizontally, and by a factor of 1.1 vertically. The inversion used error floors of 5% and ran for 136 total iterations with a final RMS misfit of 1.89.

The resulting resistivity model (Figure 2) shows two shallow conducting bodies (C1 and C2) at a depth of 500 m below sea level. One conductor (C1) extends to a depth of approximately 3 km below sea level, with a resistivity in the range of 1-10 Ωm, and the other conductor (C2) extends to a depth of 10 km below sea level with a resistivity range of 10-30 Ωm. From the analysis of their electrical resistivity ranges and a comparison with the results of a gravity survey undertaken in the area (Witter, 2022) it is likely that the low resistivity is due to the presence of interconnected graphite films within the fractures of the host rock.

Two resistive bodies (R1 and R2) were also imaged in the inversion model. R1 borders the western side of conductor C1, while R2 borders the eastern side of C1, separating it from C2. Both resistors display resistivity ranges of 300-1000 Ωm and are interpreted to be part of the

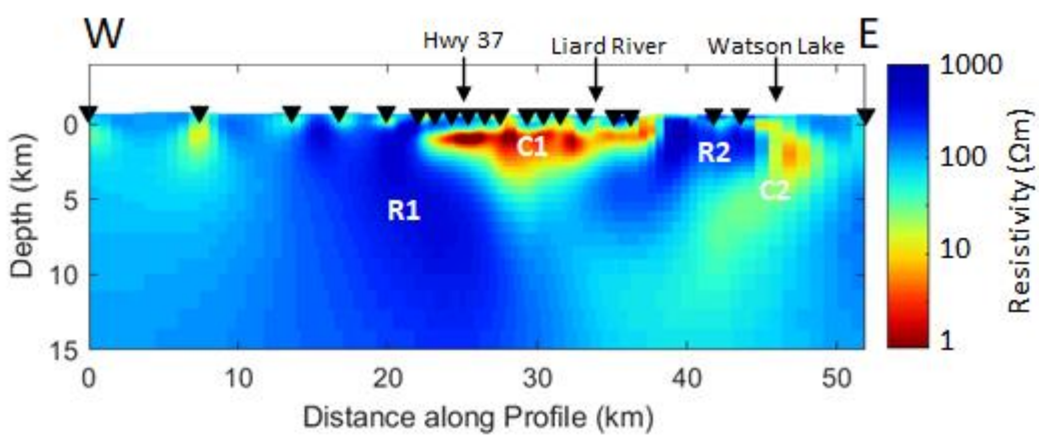

Figure 2: Vertical cross-section of resistivity inversion model. Conductors are labeled as C1 and C2, resistors are labeled as R1 and R2. The locations of Watson Lake, the Liard River, and the Highway 37 junction are indicated with arrows.

Tintina Fault zone. The fault is found to have an approximate strike in the range of N45°W – N30°W from analysis of the phase tensor data, which is consistent with mapping of the basement geology.

Further studies are necessary to identify the cause of the conducting bodies and to determine whether they are relevant to the development of a geothermal project at Watson Lake. The MT grid could be extended to the North and South to better constrain the extent of the conducting bodies. Drilling test wells would also be beneficial to better determine the composition of the conducting material and to map heat flow in the area.

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