Geoelectric Response of the Crust and Upper Mantle, Lake Nipigon Area, Ontario

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Summary

Magnetotelluric data collected in the Proterozoic Nipigon Embayment and surrounding western Archean Superior Province is used to investigate the geoelectric dimensionality in the area of Lake Nipigon in northwestern Ontario, Canada. The objective of the study is to better define the bulk crustal and mantle electrical resistivity of the area by first understanding the complexity of the structures influencing the MT responses and secondly by applying appropriate modelling methods to the data. The western Superior Province is characterized by subparallel, east-west trending, fault-bounded subprovinces or terranes each with distinct rock types, structures, ages, and metamorphic conditions. The Nipigon Embayment consists of Proterozoic rocks that uncomformably overlie and intrude the basement rock of the western Superior Province. The Sibley Group, located south of Lake Nipigon, consists of primarily flat lying sedimentary rocks deposited in a half-graben structure.

The magnetotelluric method is a passive electromagnetic technique that uses natural, time-varying electric and magnetic fields in order to examine the electrical resistivity structure of the subsurface. The nature of the spatial distribution of the resistivity is referred to as the geoelectric dimensionality and can be described as predominantly one-dimensional (flat-layered), two-dimensional (resistivity is invariant in the direction of the geoelectric strike), or three-dimensional. The magnetotelluric tensor contains frequency-domain transfer functions relating different components of the measured horizontal electric and magnetic fields and can be used to investigate the dimensionality and determine the geoelectric strike. These parameters were determined using methods based on magnetotelluric tensor decomposition and mathematical invariants of the tensor such as evaluation of the phase-skew and the WALDIM method.

Dimensionality results from the western Superior Province around Lake Nipigon indicate that the general behaviour is three-dimensional, particularity at the longer periods (deeper penetration). The phase skew, which provides a robust measure of the three-dimensionality in the presence of local distortion, is relatively low at many sites (less than 0.2) suggesting that two-dimensional modelling of data from selected sites provides reliable resistivity models. In contrast, results from the Nipigon Embayment indicated one-dimensional structure at short periods (shallow penetration) and three-dimensional structure at longer periods.

Two-dimensional models were determined for approximately north-south profiles in the Superior Province using a non-linear conjugate gradient inversion method. The resulting resistivity models show a number of significant resistivity variations in both the crust and mantle that can be interpreted using their spatial relationship to the subprovinces. The MT responses in the Nipigon Embayment contrastswith those in the surrounding Superior Province and suggest that the Proterozoic tectonic processes affected the resistivity of the whole crust and the underlying mantle.