Structurally constrained inversion in Geochron space

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Introduction

A new inversion framework is proposed that directly incorporates stratigraphic and structural information into the inversion process. The Occam2D inversion code for magnetotelluric (MT) data (deGroot-Hedlin and Constable, 1990) was modified to perform the model smoothing step in Geo-Chronological (Geochron) space. In Geochron space, the effects of geological processes such as faulting and folding are removed. To a certain extent, the physical properties of a geological unit are independent of such processes. Therefore, performing smoothing in Geochron space should allow for the recovery of continuous geological units across any spatial discontinuities, resulting in models which are more geologically realistic, and are therefore easier to interpret. We apply this methodology on real data collected in the Amundsen sedimentary basin in northern Canada and compare the results to those obtained using a standard Occam inversion.

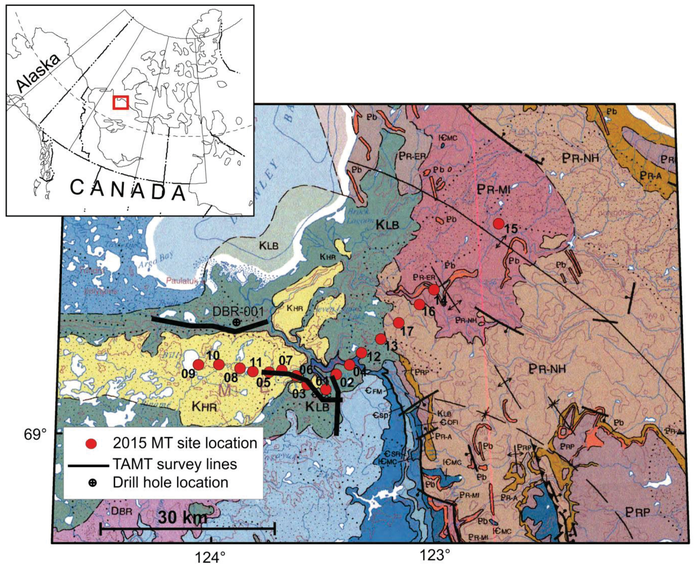

Figure 1. Geological map of the Brock Inlier showing the MT. From Spratt et al. (2016), modified from Okulitch (2000).

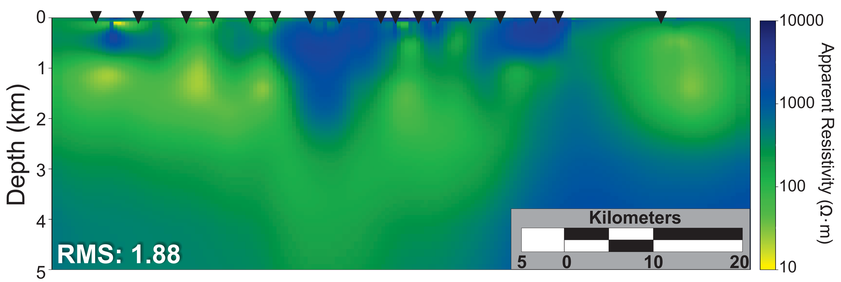

Figure 2. 2-D model resulting from a standard Occam-style smooth inversion. Black triangles indicate MT station locations shown as red circles on Figure 1.

Inverting with structural constraints

Rather than attempting to interpret a smooth, unconstrained inverse model in terms of the geological structures, we directly integrate the known or inferred structural information of the region into the inversion process. Faults and unit boundaries are built into the model to prevent smoothing across these discontinuities. Although structural features such as faults and folds may give rise to abrupt lateral changes in the geology, it is reasonable to expect that the physical properties of a given geological unit should remain more or less as they were at the time of deposition (Mallet, 2004). Within the Geochron inversion framework, present day deformed geology is mapped it to its initial configuration at the time of deposition (Figure 4), and model smoothing is applied in this space. The result is an inverted model (Figure 5) that more closely resembles the hypothesized geology in Figure 3.

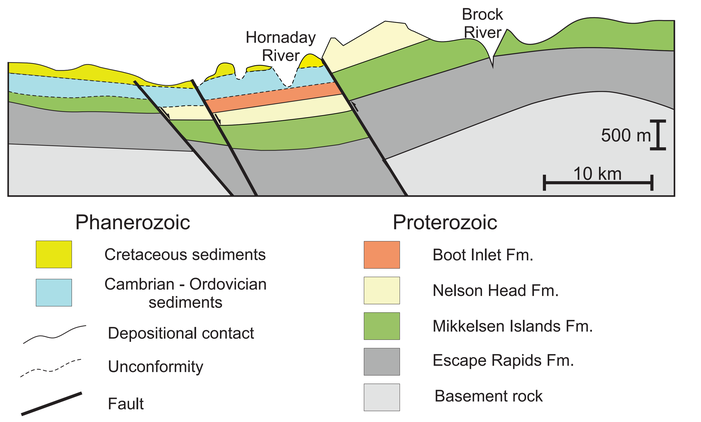

Figure 3. Postulated schematic cross section through the magnetotelluric transect, compiled from regional geology (Okulitch, 2000) and reconnaissance mapping (Rainbird et al., 2015). Modified from Spratt et al. (2016).

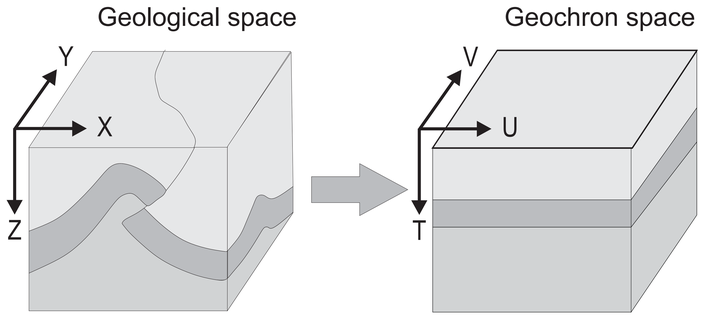

Figure 4. Present-day deformed geological space is transformed to Geochron space, in which the effects of all deformational processes have been removed. Modified from Mallet (2004).

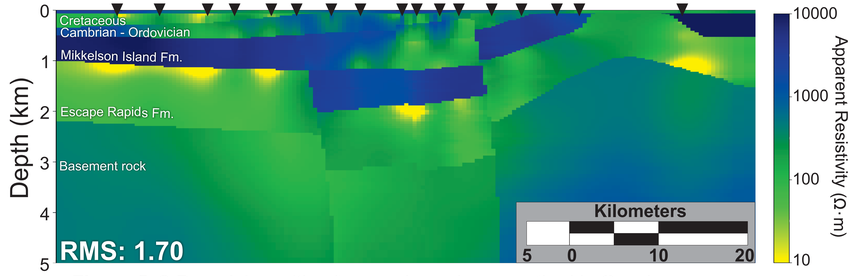

Figure 5. 2-D model resulting from an inversion smoothed in Geochron space.

Testing geological hypotheses

As Figure 5 illustrates, Geochron inversion produces models that look more like the interpreted geological cross-section. It also provides a method to test hypotheses regarding geological features, such as unit locations, thicknesses, and fault dip directions against the measured geophysical data. For instance, the dip of the westernmost fault in has been changed in Figure 6 from east- to west-dipping. While the RMS misfit of this model increases only marginally, the inversion is forced to insert the highlighted feature in order to fit the data. Borehole logs from a nearby well (~10 km to the north) suggest that most likely cause for conductive contrasts at depths around 1 km is the Escape Rapids Fm., which has shales and mudstones at its upper contact and increasing proportions of sandstone and siltstone at depth. The model in Figure 5 better complies with this interpretation, and at present there is no explanation for the highlighted feature in Figure 6. We can therefore have some confidence that the westernmost fault is likely vertical or east-dipping.

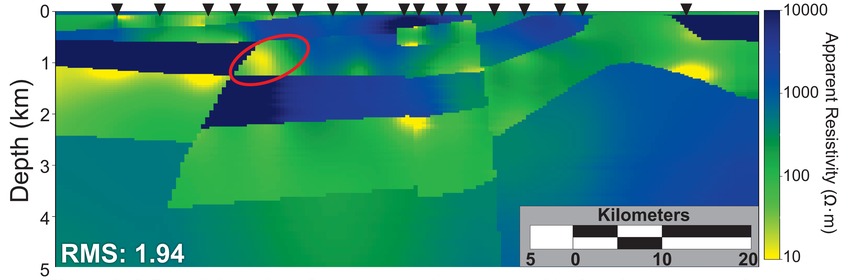

Figure 6. 2-D model resulting from an inversion smoothed in Geochron space using an alternate geological model as the structural constraint.

Conclusions

Geochron inversion is a new inversion methodology in which geological and structural data are used to constrain the produced models. Early results indicate that the technique provides a method to test and improve upon current geological interpretations. With further improvements, Geochron Inversion should provide a framework to better integrate stratigraphic and structural data directly into the inversion process.

References

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