Images of intraplate volcanism: The upper crustal structure below Tariat volcanic zone, Mongolia, imaged with magnetotellurics

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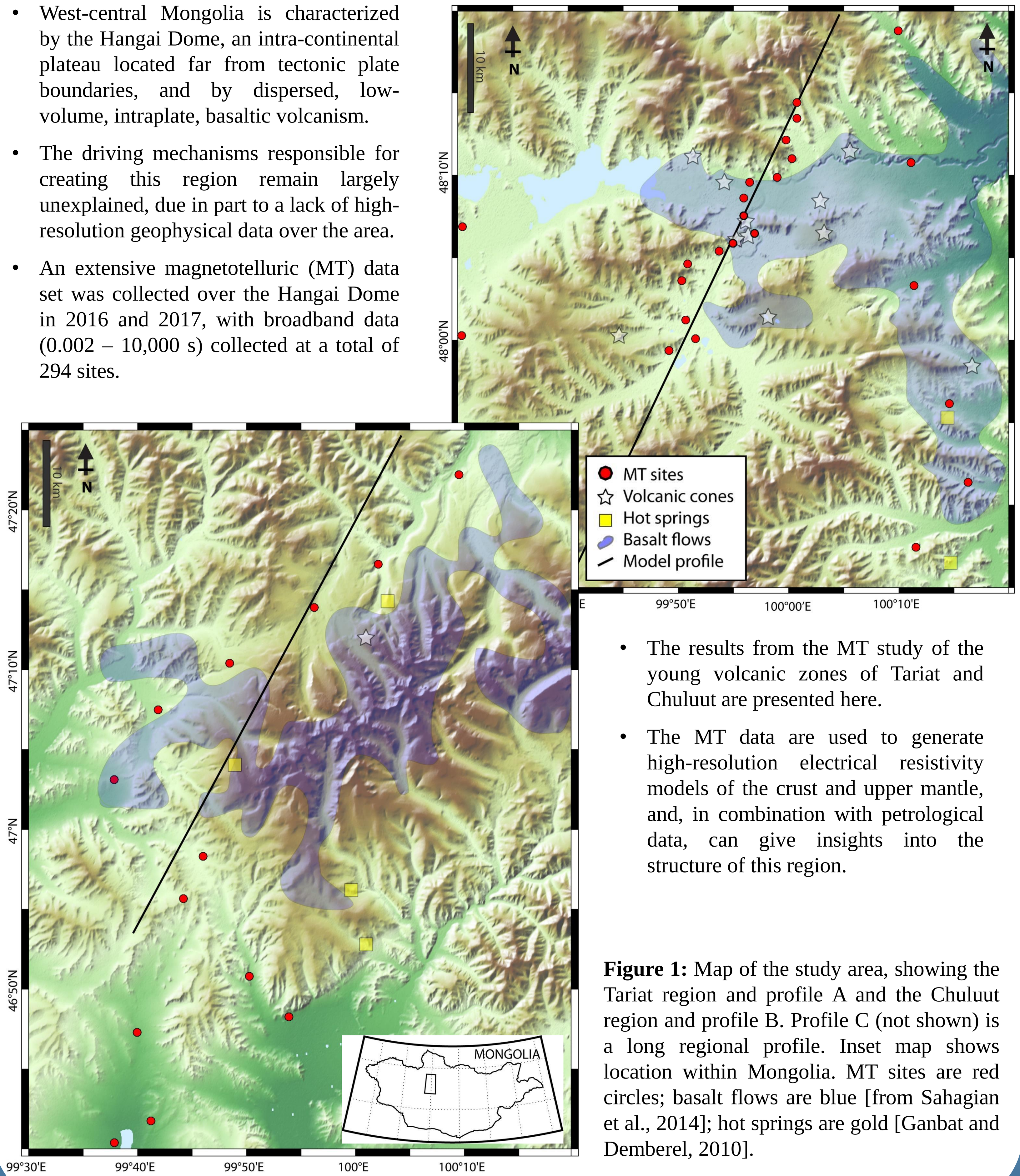
1. Introduction

- West-central Mongolia is characterized by the Hangai Dome, an intra-continental plateau located far from tectonic plate boundaries, and by dispersed, low-volume, intraplate, basaltic volcanism.
- The driving mechanisms responsible for creating this region remain largely unexplained, due in part to a lack of high-resolution geophysical data over the area.
- An extensive magnetotelluric (MT) data set was collected over the Hangai Dome in 2016 and 2017, with broadband data (0.002 – 10,000 s) collected at a total of 294 sites.



- The results from the MT study of the young volcanic zones of Tariat and Chuluut are presented here.
- The MT data are used to generate high-resolution electrical resistivity models of the crust and upper mantle, and, in combination with petrological data, can give insights into the structure of this region.

Figure 1: Map of the study area, showing the Tariat region and profile A and the Chuluut region and profile B. Profile C (not shown) is a long regional profile. Inset map shows location within Mongolia. MT sites are red circles; basalt flows are blue [from Sahagian et al., 2014]; hot springs are gold [Ganbat and Demberel, 2010].

2. Data

- We deployed both telluric-only data-loggers (EDEs), developed by the University of Münster, and full broadband MT sites (SPAMs), provided by the Geophysical Instrument Pool Potsdam (GIPP).
- Deploying the full MT sites with sparser spacing allowed fast and efficient data collection.
- The MT data are high quality and have a very low noise level, primarily due to the remote location.

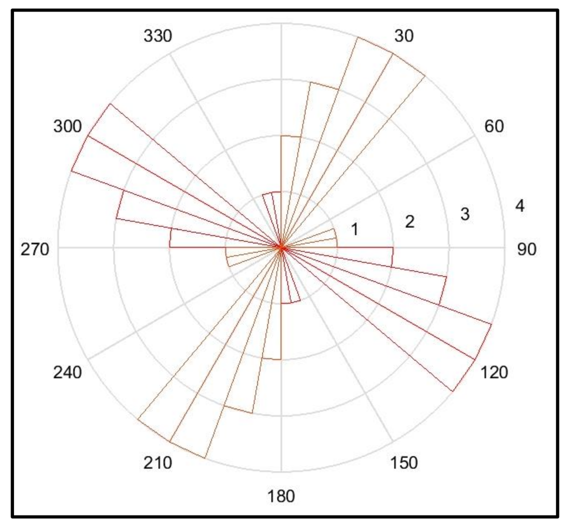


Figure 2: Average 2-D geo-electric strike direction calculated along profile A, for 1 - 1000 s.

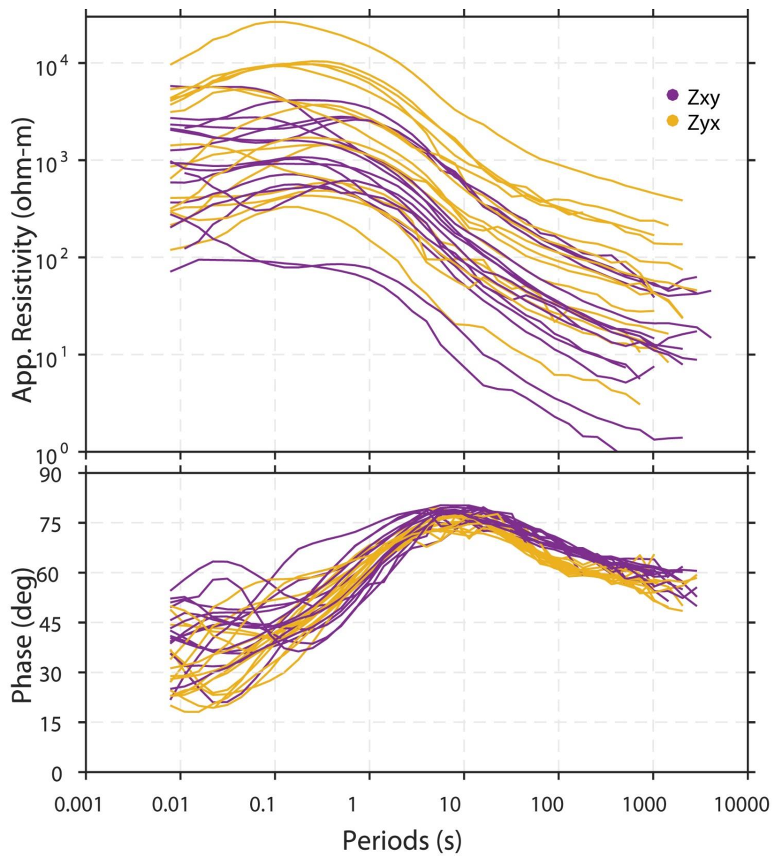


Figure 3: All MT soundings along profile A, showing apparent resistivity and phase.

3. Resistivity Models

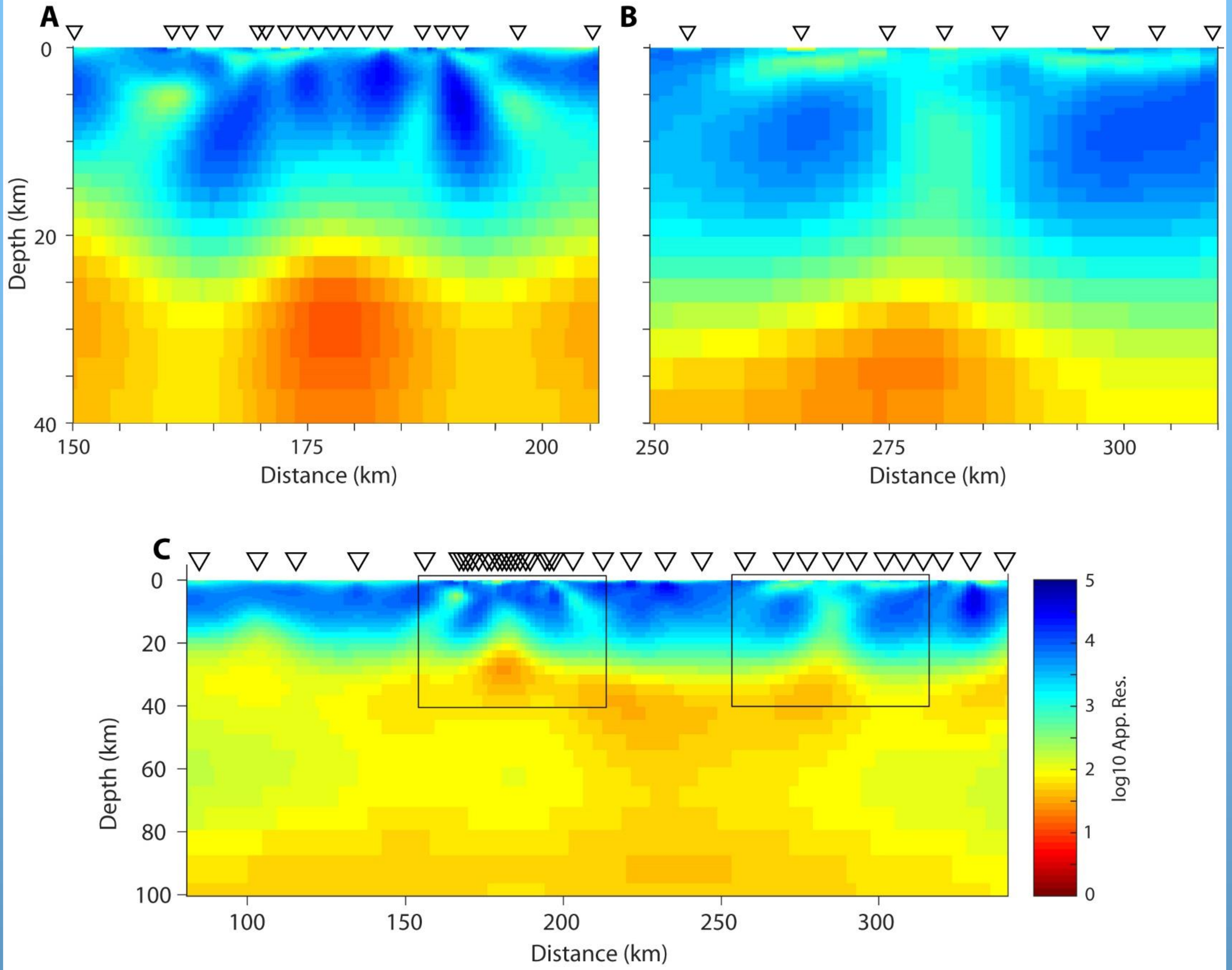


Figure 4: The 2-D resistivity models obtained from the inversion of MT data (triangles) along small profiles A and B (shown on maps in Figure 1) and along regional profile C. Model RMS misfit reached 2.45, 2.35, and 3.50, respectively, with 5% error floors on phase (~1.4°) and 10% on apparent resistivity. We used the EMILIA inversion algorithm from Kalscheuer et al. [2010], which is based on a damped Occam approach. All model depths are below the average surface elevation of 2000 m. The seismic crust-mantle boundary is at approximately 50 km. Anomalous features in the upper crust appear below the volcanic zones of Tariat and Chuluut. They are believed to represent hydrothermal alteration from past conduits of hot magma and an accumulations of fluids. Melt is generated in the asthenosphere at depths of ~90 km.

4. Model Features & Interpretation

Upper crust
- Upper crust is mostly highly resistive, explained by the pre-Cambrian craton.
- Thin, vertically elongated features in the upper crust may represent hydrothermal alteration from ancient and transient conduits of hot magma.
- These anomalous features are spatially associated with the surface expressions of volcanism (volcanic cones and calderas) and modern-day hydrothermal activity (hot springs).

Lower crust
- The lower crust is a heterogeneous low-resistivity zone.
- Believed to be caused by accumulations of fluid.
- Depth to the top matches estimated brittle-ductile transition depth (25 km), and crustal fluids accumulate below this.
- Results imply a weak lower crust exists below the Hangai Dome.

Upper mantle
- Upper-most mantle depths (50-80 km) are characterized by a moderate resistivity; greater depths (>80 km) have a low resistivity and indicate the asthenosphere.
- Directly below the Hangai a low-resistivity feature is imaged.
- This feature is explained by an upwelling asthenosphere, with partial melt.
- This zone is a region of melt generation for intraplate volcanism, an interpretation supported by petrological analysis of basaltic lavas that indicate long-term partial melting from a single mantle source (70-100 km).
- The results are consistent with seismic data, showing a thin lithosphere below the Hangai (~60–70 km), which thickens at the edges to >120km.

5. Tariat & Chuluut Volcanism

Figure 6: Aerial view of Khorgo volcanic cone in the Tariat volcanic zone (photo from www.Mongolia-trips.com).

Petrological studies show the following:
- Average silica content of 50% (44% - 54%; basaltic)
- Average sodium content of 3.8% (2.5% - 5.5%)

Tariat is youngest volcanic field in Hangai region:
- Khorgo erupted as recently as 3 ka
- Older lavas date to 6 Ma
- Six volcanic cones created in past 11 ka

Low volume volcanism:
- Eruptions since 750 ka produced volume of >27 km^3
- Total surface lava volumes estimates of 480 km^3

Many small volcanic cones:
- 800-1200m wide
- 90-120m high
- 180-360m wide calderas

Long, thick lava flows:
- Lava flows 100-200m thick (~6 Ma), younger flows 40-60m thick (<1 Ma)

Chuluut is largest volcanic field in Hangai region
- Lavas date from 6 Ma to 300 ka

6. Conclusion

- Anomalous features in the upper crust appear below the Hangai's youngest volcanic zones of Tariat and Chuluut.
- They appear spatially associated with surface expressions of volcanism and modern-day hydrothermal activity.
- They are believed to represent hydrothermal alteration from past conduits of hot magma, which rose rapidly directly from the mantle.
- The lower crust contains accumulations of fluids.
- The upper mantle show an asthenospheric bulge indicating the source region where melt is generated.

7. Future Work

Modelling:
- Thermo-mechanical and geodynamic modeling
- MT data can provide constraints on mechanical strength and viscosity

Full 3-D Inversion:
- 3-D model of whole data set

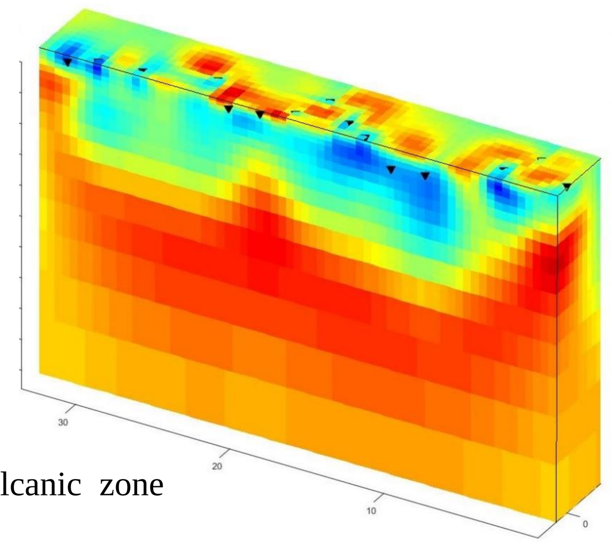


Figure 7: Full 3-D model of Tariat volcanic zone using MODEM inversion algorithm.

Evidence for fluid and melt generation in response to an asthenospheric upwelling beneath the Hangai Dome, Mongolia.
M.J. Comeau, M. Becken, J. Käufl, A. Kuvshinov, A. Grayver, et al.,
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