Melt distribution between the crust and mantle beneath the Dabbahu-Manda Hararo rift segment, Afar, from 3D magnetotelluric imaging

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The magnetotelluric data set

(Ebinger et al., 2010)

The Dabbahu-Manda-Hararo magmatic segment

2008-2009 MT sites
2010 MT sites (for 3D)
MT measures a 4 complex components tensor. The method, based on induced EM fields is very sensitive to 3-D structures.

With a 3D interpretation

- No a priori assumption on the geological structures
- All data collected are used in the inversion (number x2 compared to 2D inversion)
3D MT inversion: Methodology

We applied our full 3D MT inversion code to perform the inversion of 2 data sets independently (Hautot and Tarits, 2009)
3D MT inversion: Methodology

The 2 starting models are uniform half-space (25 ohm-m)

Dabbahu (north)

Hararo (south)

Full 3D inversion: resistivity distribution in the 3D grid that fits all data
Results

Dabbahu (North, active segment)

rms error = 4.1
Results

Hararo (South, currently not active segment)

rms error = 3.4
Results

Vertical cross-sections along profiles

Dyke 2005
**Results**

**Vertical cross-sections along profiles**

Receiver function analysis (Hammond et al., 2011)

- **Upper mantle**
- **Crust**
- **Dyke 2005**
- **Western Plateau**
- Streched & intruded crust
- Vp/Vs < 1.9
- Vp/Vs 1.85-2.2
- Vp/Vs < 1.9
- Dahla Basalts
- Manda-Harraro Volcanic segment

![Diagram of vertical cross-sections along profiles with color legend and scale for resistivity (ohm–m)]
Results

Resistivity maps: Upper Mantle (> 20 km depth)

- No significant difference between Dabbahu (North) and Hararo (South) regions
- Average resistivity of 15-20 ohm-m
- Low value implies the presence of melt/liquid in the mantle
Results

Resistivity maps: Lower Crust (15-20 km depth)

Independent inversion of the Dabbahu (North) and Hararo (South) data set:
- Similar resistivity structures
- Continuity of the structures from North to South

Large conductive bodies: Suggest large distribution of partial melt
Results

Resistivity maps: Mid Crust (8-15 km depth)

Conductive bodies to the North:
Mid crustal magma chambers beneath Ado'Ale and Dabbahu Volcanic complex?

No melt storage beneath Hararo region
Results

Resistivity maps: Upper Crust (3-5 km depth)

Image of the top of the mid crustal magma chambers to the North beneath Ado'Ale and Dabbahu Volcanic complex

Poor coverage of MT sites at shallow depth: Geometry not fully constrained.
Discussion

Vertical sections along the rift zone

Resistivity structures differ from SE to NW only at crustal depths ~ 15 km
Resistivity of liquids in the mantle ~0.2-1 ohm-m (Alkali-hydrous - basaltic melt, Gaillard et al., 2008). Percolation threshold =1 %

Mantle resistivity from model ~20 ohm-m

1% melt: melt resistivity should be ~0.2 ohm-m
(with a dry mantle resistivity @1200-1300 C: ~1000 ohm-m)

If melt resistivity ~1 ohm-m, then the % melt should be ~5-10 %: would percolate in the SE
Summary

• The 3D resistivity inversion of the MT data sets provide the image of the crust-upper mantle structure beneath an active and inactive magmatic segment.

• The structure of the crust beneath the Dabbahu region (active) confirms results from other studies with 2 magma sources at crustal depth. MT constrain their depth and geometry.

• From the lower most part of the crust to the mantle, the resistivity structures are similar. Low resistivity suggest highly conductive phase, probably melt (deep source).

• Results suggest that the nature of the liquid and percolation threshold could be discussed from these data and compared with results from geochemistry and other field studies.