3D Geoelectrical model of Sub-Himalayan Region - A Magnetotelluric study

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Keywords

Magnetotelluric, 3D inversion, Sub-Himalayan region

Summary

First three dimensional (3D) geoelectrical model of Sub-Himalaya, Uttarakhand region has been presented. The model is obtained by 3D inversion of 22 sites Broad Band Magnetotelluric (BBMT) data recorded from the region. Investigated region extends from Indo-Gangetic Plane (IGP) in south to the Lesser Himalayan region in the north and crosses two major Himalayan thrusts: Main Frontal Thrust (MFT) and Main Boundary Thrust (MBT). MATLAB based AP3DMT code (Singh *et al*. 2017) has been used for this purpose. The motivation for applying 3D inversion to the MT data is that no assumption about the geoelectric strike direction is needed and the investigated sites need not be projected along a 2D profile line. To keep the optimum computation time, we have selected full impedance tensor at 49 periods in range from .002 to 541 s for 3D inversion. The 3D geoelectrical model of the region demonstrates better resolved resistivity features specially, in shallow depth (< 10 km). Shallow conducting features (< 10 Ωm) are associated with Piedmont fault (PF), MFT and MBT. Southern region represented by a low resistivity (< 50 Ωm) zone at shallow depth (5-7 km). Geologically this zone representing the loose sediments of the Indo-Gangetic Plains (IGP) whose thickness increases in the south. Highly resistive (> 500 Ωm) layer below the IGP sediments is the basement rock, representing the resistivity of top of the subducting Indian Plate. The model is may be used to constrain geodynamical model of the region and may be further improved by increasing data density.

Introduction

The Himalaya is one of the youngest and highest mountain range, which originated from continental collision tectonics and underthrusting of the Indian Plate beneath the Eurasian Plate. Regional N-S compression, resulting from horizontal movement of rock masses along the north dipping thrust planes, caused crustal shortening, horizontal extrusion and lithospheric delamination (Le Fort 1975; Molnar 1990). In this process, leading upper brittle portion of the subducting Indian crust has been sliced and stacked up southwards to form the Himalayan mountain belt. Southernmost part of the Himalayan region consists of Sub-Himalayan and in further north is Lesser Himalayan region. Two major thrusts: Main Frontal Thrust (MFT) and Main Boundary Thrust (MBT) are located in this zone. Indo-Gangetic plane lies in south of MFT in which Piedmont fault is located (ref). To map the geometry of various faults and thrusts system magnetotelluric method has been used along a few transects Himalayan collision zone (Lemonnier, *et al.* 1999; Gokarn *et al.* 2002, Israil et al. 2008, Miglani *et al*. 2014). These studies are mainly based on 1D or 2D inversion approximation of realistic 3D geological model. In presence of strong 3D features, 1D/2D inversion may add significant error in realistic 3D model. At the same time for conducting 2D inversion, locations of MT sites need be projected along a profile line. To overcome approximation and error, in the present study we have used 3D inversion to the MT data recorded from southern zone of Uttarakhand Himalayan region which include Indo-Gangetic plane, Sub-Himalayan and part of Lesser Himalayan region. First 3D geoelectrical model of studied region has been presented based on 3D inversion of 22 MT sites data from the region. The 3D model reveals conducting features which support the existence of oblique and transverse tectonic in the study area.

Theory and/or Method

Broadband MT survey was conducted in the Indo-Gangetic plane, Sub Himalayan and Lesser Himalayan region. The MT system used in this survey was Metronix, *MT system*, with A-06 data acquisition system, MFS-06 induction coil magnetometer and EFP-06 electrodes. The recorded time domain data were transformed to the frequency domain impedance tensor using the magnetotelluric processing code, MAPROS (Friedrichs 2003). Locations of 22 MT sites along with major tectonic features are shown in Figure 1

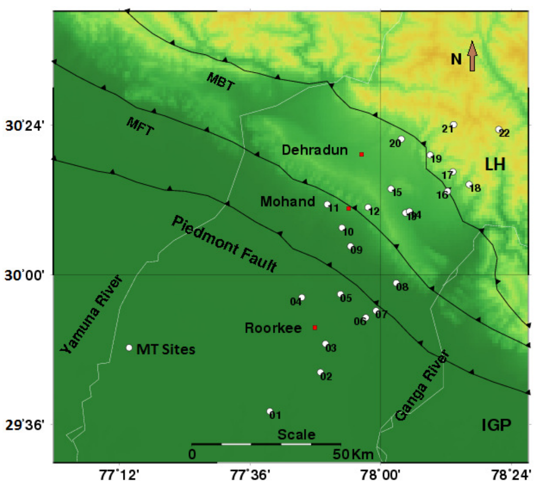

Figure 1: Tectonic map of the study area and MT sites locations

3D Inversion of MT data

In order to optimize computational time, we have chosen a subset of periods of full impedance tensor (Z_{xx} ,Z_{xy}, Z_{yx}, Z_{yy}) in the period range of 0.002 to 541 s. The error floor was set to 10% of product $|Z_{xy}|$ and $|Z_{yx}|$ for all the four components. The 3D model grid dimensions were Nx=68, Ny=62 and Nz=33 cells in x, y and z direction respectively, with 7 air layers. Below the surface, the top layer thickness was 50 m and the thickness of each subsequent layer increased by a factor of 1.2, extending up to100 km. Horizontal grid spacing in x & y direction was 1.6 km and 1.5 km respectively in the central zone of the model domain. Total of 24 planes were padded around the central region, six in each horizontal direction with increasing distance by a factor of 1.8. With this grid, the dimension of the model domain has become 300x300x100 km in x, y and z directions, respectively. Model domain was discretized using the above criteria and implemented using a Grid generator code written in MATLAB. The model covariance parameter values were set as 0.4 in the x and y-directions and 0.1 in the z-direction. Initial guess model was a 100 Ωm homogeneous half space. Inversion run converged from initial normalized RMS misfit values of 6.14 to 1.24 in 84 iterations. Geoelectrical and geological features of 3D inverted model are discussed in the following.

Results and discussion

The inverted 3D model in the form of y-z plane stacked slices is shown in Fig. 2.

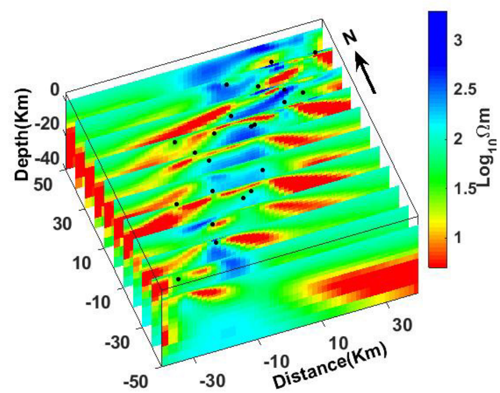

Figure 2: 3D model YZ plane slice of the inverted model obtained after inversion of (a) full impedance data with 100 ohm-m half-space as initial guess.

Profile section, y-z-plane extracted from 3D model is shown in Fig. 3. Horizontal extension of the various electrical features at two different depth levels are shown in Fig. 4.

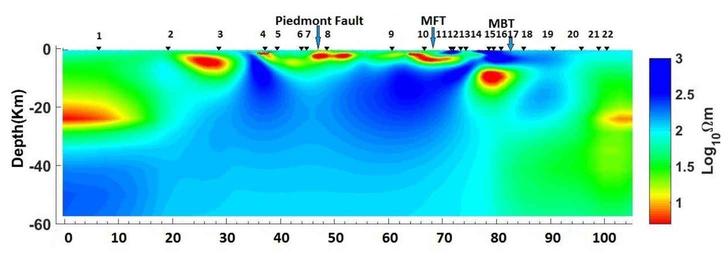

Figure 3: Profile section extracted from 3D model obtained from full impedance inversion with 100 Ωm half-space as initial guess.

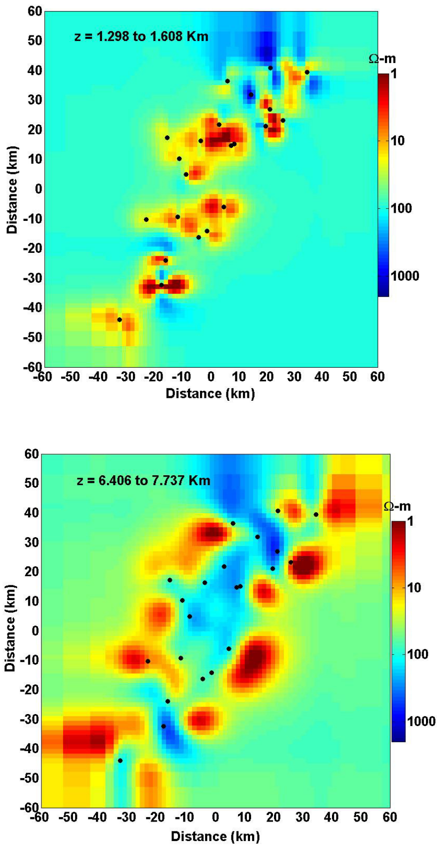

Figure 4: Depth plane slices of 3D inverted model full impedance. The depth at which these planes are extracted are 1.29 to 1.609 KM; 6.4 KM to 7.37 KM.

Important model features can be seen as conductive and resistive zones in 3D model. The southern zone is interpreted as the conductive sediments deposited by the southerly-flowing river system of the Himalaya and it defines the Indo-Gangetic Plains (IGP). It has a resistivity value less than 50 Ωm and is mainly confined to the southern part of the model (Fig. 3). The thickness of this feature appears to be increasing from north to south and it reaches up to 6 km in the southernmost parts of the model. The increasing thickness of IGP sediments is consistent with the geology of the area. Piedmont fault, MFT and MBT are seen as electrical resistivity variation around these features. Conducting features (<10 Ωm) associated with the resistive zone (~ 50 Ωm) are observed around these features.

Beneath the sediments of IGP, highly resistive feature corresponds to the basement representing high resistivity (1000 Ωm) of the subducting Indian Plate.

In the depth plains (Fig. 4) two nearly continuous conducting features are observed. These features are oriented approximately oblique and transverse to the main Himalayan arc. First feature appears to be associated with seismically active Mahendragarh-Dehradun fault (MDF) zone (Bansal & Verma 2012). Whereas the second feature is similar to an elongated conducting structure running almost normal to the Himalayan arc and it appears to be terminating in Inner Lesser Himalaya. The resistivity of this feature is <10 Ωm, and it is interpreted as a transverse feature.

The geometrical variations of these features with depth can be seen from the z-planes plotted at 1.3 and 6.4 km depths in Fig. 4. These depth planes reveal the horizontal extension of the feature at a given depth and their geometrical variation with depth in the plane at different depths.

Conclusions

First 3D geoelectrical model based on 3D inversion of magnetotelluric data recorded from Sub-Himalayan region has been presented. The model shows the electrical resistivity images of tectonic configuration, Piedmont fault, MFT and MBT in the region. In addition some 3D features aligned transverse and oblique to the main Himalayan arc also seen in the model. These features are geologically meaningful and consistent with the regional tectonic model of the region. The resolution of these features may be further improved by increasing data density in the vicinity and gap area.

References

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