Near surface resistivity structure estimated from time domain electromagnetic data recorded along a profile in HFT Zone in Mohand area, Uttarakhand, India

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SUMMARY

Time-domain electromagnetic (TDEM) data were recorded using Fast TEM device deployed in a coincidence loop geometry at 24 stations along a profile in the Himalayan Frontal Thrust (HFT) zone in Mohand area, Uttarakhand, India. The profile is approximately 1.6 km long and extends from the Indo-Gangetic plain in the south to the north of HFT in the Khajnawar Rao, a seasonal river bed. The processed data at each station was inverted using Occam and Marquardt inversion techniques to obtain 1D resistivity depth models at each station. A stacked geoelectrical section is generated along the profile from the inverted models. North and south-dipping beds are reflected on either side of the Mohand anticline thrust, passing nearly through the middle of the profile. Resistivity variations are interpreted in terms of the tectonics geometry of the fault zone, geological and geo-hydrological scenario of the area. A near-surface resistive layer (> 200 Ω-m) consisting of dry fluvial deposits, gravels, pebbles, and boulders of varying sizes can be seen throughout the profile. A very low resistivity (~ 10 Ω-m) is observed in the fault core zone. This zone is exposed along the river terrace zone on the west bank of Khajnawar Rao. The derived resistivity variations explain the geological and geo-hydrological scenario of the area and are consistent with the information available in the literature.

Keywords: Near-surface resistivity structure, Himalayan Frontal Thrust (HFT), Time Domain Electromagnetic (TDEM), Sub-Himalaya

INTRODUCTION

Loop source time-domain electromagnetic is a controlled source electromagnetic (EM) method in which the transient decay of the magnetic field is measured after switching off the current injected through a transmitter (Tx) loop. The switching-off of the Tx current induces eddy currents in the finitely conducting subsurface. This induced current diffuses downward and outward in the subsurface. The diffusion process generates a time decaying secondary magnetic field in the absence of primary field. The measured decay characteristics of the secondary magnetic field are a function of the resistivity distribution of the subsurface formation. The decay rate of the transient is slower in a conductive formation, whereas it is faster in a resistive formation. The theoretical concepts of TDEM are given in various literature (Kaufman, A. A. et al., 1983, Nabighian et al., 1991). The recorded transient response is inverted in terms of resistivity distribution of subsurface formation (Danielsen, 2003). The TDEM method is fast and accurate for mapping the depth and thickness of resistivity structure. It is less sensitive to the lateral variation of resistivity than the DC resistivity method, thus used as an efficient and accurate alternative to the conventional DC resistivity methods. In the present study, we have used the TDEM method to delineate resistivity structure along a profile passing through the HFT zone in the Sub-Himalayan region in and around Mohand, Uttarakhand, India. The resistivity structure is further interpreted in terms of geological, tectonics and geo-hydrological formation of the area. Additional Radiomagnetotelluric data were recorded along the complete profile and perpendicular shorter transects to retrieve shallow high resolution data. However, here we only focus on the TDEM data.

The main aim of our study is to improve the near-surface geological information for an improved understanding of the tectonic process and its surface manifestations.

DATA RECORDING AND INVERSION

We recorded TDEM data using TEM-FAST 48 portable device. Twenty-four stations spread along a 1.6 km long profile in the HFT zone in the Mohand area were recorded. A coincident loop setup geometry with a single square of 50m x 50m wire loop was used in the field measurement. The transmitting current was 3.8A, and the recording time range was set from 4 to 2024 µs. The southern end of the profile is located in the Piedmont zone, which is the northern limit of the Indo-Gangetic plain in the study area. As defined in the geological literature (e.g. Srivastava et al. 2016), the Himalayan Frontal Thrust (HFT) passes nearly perpendicular to the profile line at the 10th station from the south with visible outcrops at the surface. The remaining 14 stations are located in the HFT hanging wall zone on the north of the HFT. The location of stations are shown in Figure 1.

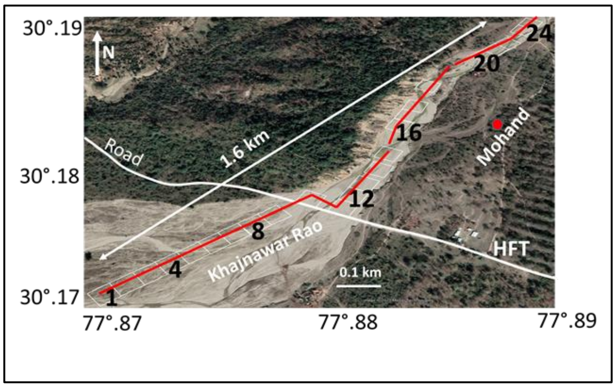

Figure 1 Location map of the study area showing TDEM stations.

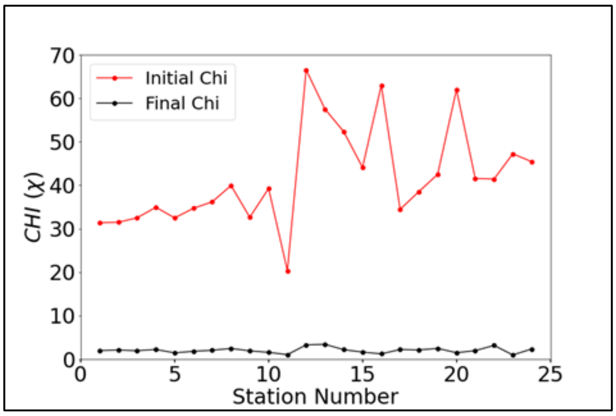

Figure 2 Initial and final error (chi) for all stations data using Marquardt inversion.

1D inversion of transient response at each station is done using the EMUPLUS code (cf. Haroon, A., Yogeshwar P., et al., 2015; Yogeshwar et al., 2020) for smooth model (Occam's) and minimum layered model (Marquardt) inversion. Initial and final errors (Chi) are shown in Figure 2. Convergence is achieved in all station data; however, some stations show larger misfit errors. The used field data error is set a minimum percentage error of 3%.

Comparison of smooth and layered inverted models at selected station along with the data and the fitted responses are shown in Figure 3. All three models

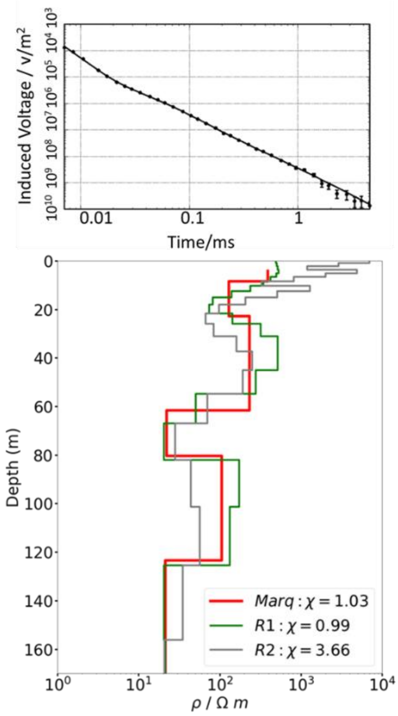

Figure 3 Top panel shows data and fitted response and bottom panel shows comparison of 1D layered and smooth inversion of TDEM response recorded at station 11.

are in general consistent within small variations. Subsequently, 1D inverted models were stitched together and interpolated between the stations to generate a smooth 2D image along the profile, as shown in Figure 4.

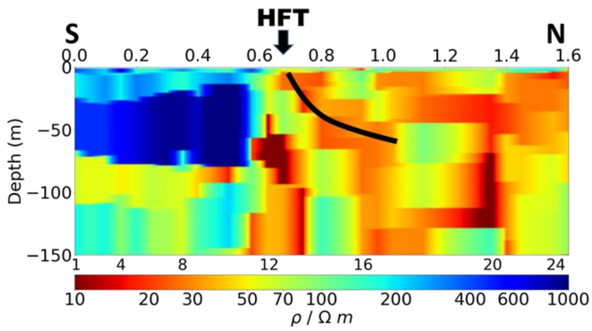

Figure 4 2D resistivity-depth section obtained by stacking and smoothing of 1D models along the profile.

The profile distance from station one in km, and TDEM station numbers are shown on top and bottom of the Figure 4, respectively.

RESULTS AND DISCUSSION

The study area is located in the Sub-Himalayan region, where the Upper and Middle Siwaliks Group of rock are exposed in the immediate vicinity of the Indo-Gangetic plain (IGP). TDEM stations are passing through the HFT, which is the northern limit of the IGP. Upper Siwaliks conglomerate in the area has been classified as a sandy matrix showing both coarsening and fining upward in stratigraphic sequence (Rohtash et al., 1991). The conglomerate is mainly composed of cobble to pebble clasts of quartzite, limestone, sandstone, and shale. Exposure of Middle and Upper Siwaliks subgroups can be seen in the area. The middle Siwalik subgroup comprises sandstone dominated intervals which pass upward transitionally into the Upper Siwaliks boulder conglomerate sequence. The general stratigraphy of the hanging wall zone can be described from top to downward: Top thin soil cover are fluvial sediments, 1-3 m thick loamy sand soil, and 2-3 m thick pebble-cobble (Wesnousky et al., 1999). A trench in the study area shows that the HFT reaches the surface and is covered by a thin (~ 10 m) fluvial material on top of the bedrock (Senthil et al., 2006). The boundary between Siwalik bedrock and alluvial deposits of the floodplain is abrupt and steep.

A 2D resistivity-depth section was obtained by stitching and smoothing 1D models along the profile, as shown in Figure 4. The derived resistivity-depth image shows a resistivity discontinuity at the HFT location. High resistivities are observed in the south of the HFT, whereas relatively low resistivity and low angle dipping resistivity features are observed in the north of the HFT. Based on the low resistivity trend in the north of the HFT, low angle north dipping beds are shown by a black line. This low resistivity zone is consistent with the fault core zone exposed on the west bank of the Khajnawar Rao (Srivastava et al., 2016). TDEM stations 12, 13 and 14 correspond to the low resistivity fault core zone, a highly pulverised fault gouge with a resistivity value (~10 Ω-m). On the north of the HFT, a gouge dominated damage zone is observed; these zones are dipping and represented by a resistivity between 20-50 Ω-m. The low resistivity indicates highly fractured and water-saturated thrusting beds. Similar alternative low resistivity zones are continued in the north along the profile.

In the southern zone of the HFT, the near-surface top layer is fluvial deposits represented by resistivity in the range of 200-400 Ω-m. The thickness of this layer is minimum (~ 3m) near HFT, which increases in the south and reaches up to 20 m. These are older alluvial flood plain deposits (Wesnousky et al. 1999). Beneath this resistive (> 300 Ω-m) thick Middle Siwaliks sandstone layer is present. Further, low resistivity (~ 50 Ω-m) thick, saturated aquifer zone is present beneath this layer.

CONCLUSIONS

TDEM data at 24 stations along a profile passing through the HFT zone in Mohand, Uttarakhand area were recorded and inverted in terms of resistivity distribution of the near-surface formation. The dry top surface layer is resistive (> 200 Ω-m), representing thin fluvial sediments deposited of Khajnawar Rao, seasonal river. The thickness of this layer varies along the profile from 3 -20 m. Followed the fluvial sediments cover, in the northern zone of profile highly jointed and fractured, partially and fully saturated with water, Upper and Middle Siwaliks formations are present. The average resistivity of this zone is 40 Ω-m. The dominant rocks in Upper Siwaliks and Middle Siwaliks are conglomerate and sandstone respectively. In the southern end of the profile, the rocks are more compacted and represented by high resistivity (> 500 Ω-m) formations. The fault core zone is a fine material partially and fully saturated with water, represented by low resistivity (~ 10 Ω-m). Further analysis of 2D and possible 3D effects in TDEM data and the integration of existing RMT data will further improve the interpretation.

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