3-D Joint inversion of MT+AMT data over Proterozoic Dalma Volcanics, Eastern India

Roshan K. Singh\textsuperscript{1}, Shalivahan\textsuperscript{1*} and Ved P. Maurya\textsuperscript{2}
\textsuperscript{1} IIT (ISM), Dhanbad, India, roshanmanjitsingh@gmail.com, shalivahan@iitism.ac.in
\textsuperscript{2} Observatório Nacional, Rio de Janeiro –Brazil, vedankur@gmail.com

SUMMARY

The Proterozoic Dalma volcanics (DV) and its northern fringe within the North Singhbhum Mobile Belt (NSMB) has been established as a metallogenic province by geological and geophysical studies. Regional 2-D Magnetotelluric studies in the area crossing the Singhbhum Group of Metapelites (SGM), DV and Singhbhum GroUp of Quartzite and Pellete (SGQP) reported three prominent conducting features, one within DV and other two at northern and southern margins of DV. Further, it has been shown that the conducting feature in the northern margin of DV (i.e., between DV and SGM) is more robust as compared to the others. Due to limited MT resolution the shallow conducting 3-D features could not be mapped. These tempted us to acquire Audio Magnetotelluric (AMT) data sets in the northern fringe of DV. The data was acquired at an interval of ~ 500m for a profile length of ~7.5 km. 3D MT+AMT joint inversion for impedance data was performed to obtain resistivity cross-section of the area. Resistivity cross-sections from the 3D joint MT+AMT inversion for the impedance data is in broad agreement with previous 2-D results but with modified dimension and location. Shallow conducting feature lies at the northern end of SGM whereas a conducting feature with a maximum depth of 500 m is present at the boundary of SGM and DV. A distinct and well developed conducting feature lies within DV is observed upto a depth of ~ 2.5 km. SGQP is marked by a well-developed resistive feature upto a depth of ~ 1 km.

Keywords: Joint inversion, 3D inversion

INTRODUCTION

The Eastern Indian Craton (EIC) comprises of Chotanagpur Gneissic Complex (CGC) at the northern end, a mobile belt known as North Singhbhum Mobile Belt (NSMB) in central part and a craton, Singhbhum Craton (SC) at the southern end. Geological (Deb, 2014) and geophysical studies (Shalivahan et al., 2014) studies establishes EIC as a Proterozoic metallogenic province. Deb (2014) showed that most of the gold occurrences of the NSMB are present in the meta-sedimentary belt lying north of the DVs. There are four gold deposits reported in northern fringe of DV in meta sediments-meta basics, meta sediments-meta volcanics with percentage of sulfides varying from 0.5% to 1.5 % and chlorite schist, quartzites are Lawa (23° 01’N, 86° 05’E), Maysera (23° 03’ N, 86° 01’E), Pahardha (22° 30’, 85° 16’) and Parasi (22° 57’ N, 85° 40’ E) (Figure 1). Evolution of the Proterozoic DVs has been linked with the metallogenic belts lying at the northern fringes of the DVs. The Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) studies of rock samples show the presence of gold, silver, copper, lead, zinc and uranium. The conductor in the northern fringe of DVs was linked with VMS or Au-VMS deposits (Maurya et al., 2015). Tectonism related to such type plume activity might be a probable cause for volcanicogenic massive sulfide (VMS) setting in this area (Sarkar and Deb, 1974; Sarkar, 1984). Maurya et al. (2015) carried 2-D modelling for regional investigation of Dalma and its adjoining Singhbhum Group of Metapelites (SGM) and Singhbhum Group of Quartzite and Pellettes (SGQP) formations. They reported three prominent conducting features, one within DV and other two at northern and southern margins of DV. Further, they concluded that the conducting feature in the northern margin of DV is more robust as compared to the other two conductors. However, they were unable to model MT frequencies less than 0.1 Hz, due to presence of strong 3-D effects and hinted towards the presence of shallow conducting heterogeneties producing 3D influence on MT short periods. Taking into account of these observations, we further acquired 16 AMT sites with better spatial cover over Dalma and SGM regions. In this paper we try to map the shallow conducting features and the deep conducting features and establish any link between them using joint 3D MT + AMT inversion for impedance data with the help of ModEM code (Egbert and Kelbert, 2012; Kelbert et al., 2014).

Geological Background

Dalma volcanic is ~200 km long and 3-7 km wide, an arcuate belt and comprises mainly of green schist facies rocks of Singhbhum group and meta-
volcanics. It is a part of NSMB which lies to the north of Singhbhum Shear Zone (SSZ) between Singhbhum nucleus in the south and Chottanagpur Gneissic Complex (CGC) in the north (Figure 1). The northern fringe of DV is mostly covered by magnetite-quartz-biotite-sericite schist. Phyllites and quartzites form the host rock. The northern fringe of DV is also characterized by intrusives such as ultramafic, quartz veins and amphibolites. The presence of volcanic tuffs, quartzites, metapelites, felsic volcanics, carbon phyllites and graphitic rocks in the study area is indicated by the Petrographic studies (Chatterjee et al., 2013).

**AMT data Acquisition**

AMT sounding for 16 sites were acquired with an average spacing of ~500 m over both DV and SGM domain. Time series were collected for 2E (North and East) and 3H (North, East and vertical) components at each site. At each site the time series were collected for all five components using MTU-5A equipment from Phoenix Geophysics Ltd. To measure the electric field Pb-PbCl2 electrodes were used whereas for the magnetic field induction coils have been used. The length of the electrical dipole was ~100m. AMT data have been processed using the extra-hybrid approach by Shalivahan et al. (2006). In total these 16 AMT soundings and 7 MT soundings acquired earlier (Maurya et al. 2015) have been used for interpretation. The average station spacing of MT soundings is of ~1.5 km covering a profile length of ~10 km. MT data covers frequencies between 320 - 0.00055 Hz whereas AMT data has been acquired in the frequency range of 10 kHz - 10 Hz.

**Setting up 3-D Inversion**

Joint 3-D MT+AMT inversion for impedance (Z) have been performed data using ModEM code (Egbert and Kelbert, 2012; Kelbert et al., 2014). To perform the inversion the model domain have been discretized into 20 X 85 X 50 cells with horizontal cell dimension of 0.15 km x 0.15 km. Along the vertical direction the initial cell size was 0.015 km and it increases by a factor of 1.2 towards the edge of last five cells. Near-surface heterogeneities are included in the inversion by providing fine model discretization (Meqbel et al. 2014). This also helps to recover a better data fits. To obtain optimum value of initial half-space resistivity inversion has been performed for various values of resistivity namely 10, 50, 200 and 500 ohm-m which converged to RMS of 2.44, 2.27, 2.40 and 2.50 respectively. Error floor was computed based on the % of square root of product of off-diagonal components. Error floor of 20% and 10 % for diagonal and off-diagonal components of full impedance was used. Despite having not the minimum RMS with 10 ohm-m uniform resistivity, the final interpretation has been performed with this as the features are well developed and consistent with 2D results.

**Results and Discussions**

Joint MT+AMT 3D inversion model of impedance data is shown in Figure 2. It shows the regional resistivity cross section of the area for a maximum depth of 4 km (Fig. 2a) and 1 km (Fig. 2b) respectively. It is observed that two shallow conducting features C1 at the northern end of SGM and C2 at the northern boundary between SGM and DV. These conductors extend up to a maximum depth of ~500 m and are well-developed laterally as well. Dalma volcanics is marked by distinct conducting feature C3. This feature can be seen along the DV up to a depth of ~2.5 km. At the southern end of DV another conducting feature C4 is seen. Within SGQP we find a resistive feature R1 which appears up to a depth of ~1 km. To the south of this resistor a conductor C5 at a depth of 500 m is developed which extends beneath R1. Thus, all the prominent geological domain in the study area are delineated. Figure 2b shows the model upto 1 km only. It is observed that the shallow resistors and conductors are mapped which were not delineated in previous MT studies. Further, conducting feature all along the boundary of SGM and DV and within DV are observed and establishes the link between shallow and deep conducting features.

**Conclusion**

2D MT studies (Maurya et al. 2015) showed the presence of three conductors (i) at the northern boundary of Singhbhum Group of Metapelite and Dalma Volcanics, (ii) within Dalma Volcanics (iii) at the southern boundary of Dalma Volcanics and Singhbhum Group of Quartzite and Metapelites. Further, they indicated that the presence of shallow conducting heterogeneities which was not mapped due to the limited resolution of MT data. Therefore, 16 AMT soundings were acquired in the northern fringe of Dalma Volcanics. These along with earlier acquired MT data of Maurya et al. (2015) has been used to map the various geological domains, delineate the shallow 3D features and establish link between these shallow features to the earlier mapped deep conducting features. Joint MT+AMT 3D inversion of impedance data was performed to obtain the resistivity cross-section. The model establishes the boundaries of the geological domain within the study area. Further, it also delineates the shallow and deep conducting feature and establishes the link between them which was not observed in earlier MT studies.

**Acknowledgement**

The authors are thankful to N. Meqbel for providing 3D grid software.
References


Figure 1: Geological map (modified after Saha, 1994) showing major lithologies of North Singhbhum Mobile Belt and its adjoining area with MT locations (top left), zoomed MT/AMT locations in the northern fringes of Dalma Volcanics (bottom). Star symbol shows the gold reporting in neighboring locations. The red rectangle broadly shows the location of conductor (C1) in the northern fringe of Dalma Volcanics from previous 2-D MT studies (adapted from Maurya et al. 2015). SPSZ corresponds to South Purulia Shear Zone; SSZ corresponds to Singhbhum Shear Zone.
Figure 2: (a) Joint MT+ AMT inversion for impedance data upto a maximum depth of 4 km. The dashed rectangle shows the area upto a depth of 1 km and the extracted portion is shown in (b).