Audiomagnetotellurics Studies over a Mineral Prospecting of a Proterozoic Volcanics, Eastern India

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Summary

Recent studies in the northern fringes of DVs in North Singhbhum Mobile Belt have clearly identified the importance of northern fringes of Dalma Volcanics and its surrounding areas. The results from these works motivated us to carry our work in Dalma Volcanics (DV). AMT measurements over 21 sites were acquired over the prospective areas in order to image the shallow as well as deep 3-D structures. AMT soundings covers two major lithologies Singhbhum Group of Metapelites (SGM) and Dalma Volcanics (DV) with rock types such as carbon phyllites, quartzites, tuffs, rhyloties dominated with basalts of Proterozoic ages. AMT sites of SGM mostly corresponds to 3-D structures, whereas, DV region AMT sites depicts 2-D structure mostly for entire frequency range. We performed 3-D inversions using AMT data for Z, VTF and Z+VTF to investigate the Proterozoic DVs and adjoining lithologies. The conductivity models from AMT inversion using Z+VTF found two conductors, consistent with previous 2-D MT survey with reasonable fits. We performed sensitivity tests through forward modeling, confirming the presence of conducting features as the consequence of data fit, not the artifact.

Introduction

Eastern Indian Craton (EIC) is one of the richest provinces in terms of major minerals prospects. EIC comprises of Chottanagpur Gneissic Complex (CGC) at the northern end, a mobile belt called as North Singhbhum Mobile Belt (NSMB) in central part and Singhbhum Craton (SC) at the southern end. All the three major geological domains and their boundaries are interesting in terms of metallogeny of the area and intermediate sub domains amongst them are potential areas for hosting valuable mineralization. The palaeo-Proterozoic deformed and metamorphosed Singhbhum supracrustal rocks constitute the so-called NSMB - an important belt in term of metallogeny. NSMB basically constitutes Singhbhum Group Metapelites (SGM), Dalma Volcanics (DVs) and Singhbhum Group Quartzite and Pelites (SGQP). Evolution of Proterozoic age DVs has been linked with the metallogenic belts lying at its northern fringes of DVs. Shalivahan et al. (2014) described Eastern Indian Craton (EIC) as a metallogenic province using Magnetotelluric (MT) measurements. (Deb, 2014) described the northern fringe of Dalma Volcanics (DV) lying north of EIC is significantly promising for gold.

Maurya *et al.* (2015) carried 2-D modelling for regional investigation of Dalma and its adjoining SGM and SGQP formations. They reported three prominent conducting features, one within the central part of Dalma 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 other two conductors. They also hinted towards the presence of shallow conducing features producing 3-D influence on short period MT data

Taking into account of these observations, we acquired 21 AMT sites. In the present paper, we performed 3-D inversions using ModEM code (Kelbert et al., 2014) for AMT data sets to map important conducting zones which was not possible with the previous regional MT surveys. AMT data consists of frequencies between 10 kHz - 10 Hz .The acquired time series for all sites is processed using extra-hybrid processing technique following Shalivahan et al (2006). Following, Jones et al. (2012), phase tensor skew along with negligible real part of induction arrows for AMT sites below DV indicates towards 2-D structure in general. Whereas, underneath SGM these suggests the geo-electrical structure mostly a combination of 2D and 3D. 3-D structure of the region was inferred by large induction arrows and the change in orientation of phase ellipses. Trends of phase ellipses orthogonal to induction arrows indicates towards 2-D structures. Some AMT sites, L02, L11 (Figure 2) at shorter periods probably shows the inconsistency between phase tensor and VTF strike. This might be related to their data sensitivities, as VTF is sensitive to off profile 3-D structure.

Geological Background.

The Proterozoic DVs ~ 200 km long and ~ 6 km wide, of the NSMB lies north of the SSZ and lies between the Singhbhum nucleus to the south and the CGC in the north (Figure 1). The Dalma Formation conformably overlies the SGQP and is represented by a thick succession of mafic–ultramafic volcanic rocks with lenses of basic agglomerates (Chakraborti and Bose, 1985; Mazumder, 2005). The rocks of the DVs are classified into lower and upper members. The lower member comprises phyllites, quartzites, shale, high magnesian komatiitic serpentinised peridotites, lavas and vitric tuffs with quench textures, and volcano-clastics (Gupta and Basu, 2000). The upper member is represented by high iron low potash tholeiitic basalts along with some rhyolites. Intrusives such as ultramafic, quartz veins and amphibolites also occur in the northern fringe of DV. Petrographic studies also show the presence of volcanic tuffs, quartzites, metapelites, felsic volcanics, carbon phyllites and graphitic rocks (Chatterjee et al. 2013).

3-D Inversion:

For AMT data inversion, the model is discretized into 35 X 60 X 22 cells, with horizontal cell dimensions of 0.15 km X 0.15 km, increasing with a factor of 1.2 towards the edges for last five cells. The starting cell thicknesses is 15 m, which increases downwards by a factor of 1.2. The maximum depth of the model considered is ~ 5.0 km. The trade-off parameter, λ starts from 1000 and ends on 10^{-8} while inversion progress for the criterion of minimum RMS improvement of ~0.001 between two successive iterations. We performed 3-D inversion with different starting model half space resistivity and found minimum RMS fits for the 50 ohm-m half space resistivity for the considered AMT datasets. Thus, all inversion results were produced for initial half space resistivity of ~50 ohm-m.

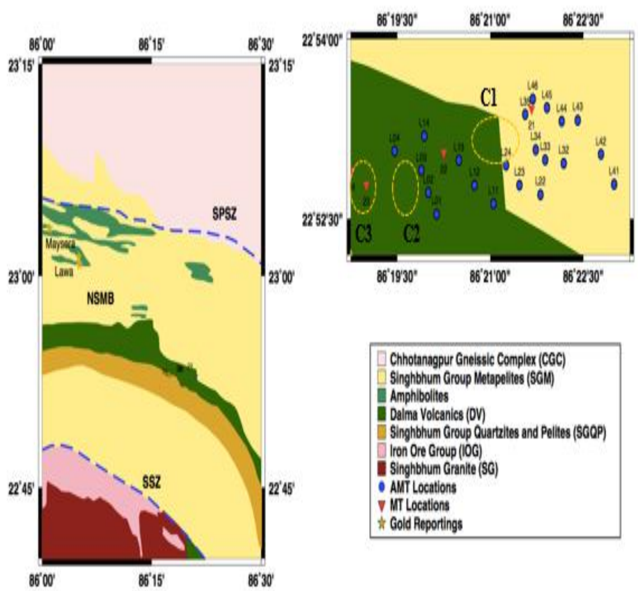

Figure 1: *Geological map (modified after Saha, 1994) showing major lithologies of North Singhbhum Mobile Belt and its adjoining area with MT locations (left), zoomed MT/AMT locations in the northern fringes of Dalma Volcanics (top right). Star symbol shows the gold reporting locations in nearby areas. Locations of the conductors (C1, C2, & C3) found in MT studies (after Maurya et al. 2015).*

Results and Discussions

Inversion for Z and VTF were performed individually by varying the error floor to achieve the optimum fit for them. RMS of ~4.0 for VTF inversion (Fig. 3; left) with 5 % error floor and RMS of ~ 4.3 for Z inversion (Fig. 3b; middle) with 10 % error floor is obtained. Finally, joint Z+VTF inversion was performed using above optimized error conditions. The final obtained RMS for joint inversion is ~ 4.7 (Fig 3; right). Inversions reveal near surface conducting heterogeneities and shallow resistive features, mostly related to carbon phyllites and tuffs. There is no significant change (4.0-4.7) in RMS indicating that for AMT data sets both Z and VTF are similar and insensitive to major model features which indicates that the off profile conductors C1 and C2 have been mapped. The conducting features start appearing from depth of about 50 m. These conductive features are well developed from 100 m depths onwards. At a depth of ~ 200 m alternating conductors and resistors are observed in close spatial association for both Z (Figure 3; middle) and Z+VTF (Figure 3; right) inversions. The moderately conducting volcanics persists mostly for 500 m depths (Figure 3; middle & right). As depth increases, resistive nature of volcanism depletes and conductive nature of volcanism increases its volume significantly. A moderate conductivity of 50 ohm-m resistivity envelops the conducting features less than 10 ohm-m at depth of ~ 400 m (Fig 3; middle and right). These conducting features also resolves shallower extent of conductors C1 and C2. These deep conductors mostly observed in small patches from Z+VTF inversion. However, conductor, C1, is having larger dimension in Z inversion. In an overview, AMT data evidences the possible shallow extension of conductors C1 and C2 for shallow and intermediate depths, delineated from previous 2-D MT studies from Maurya et al. (2015).

Site wise RMS misfit for AMT data sets using VTF, Z and Z+VTF inversions are shown in Figure 4. The RMS misfit of AMT data for VTF, Z and Z+VTF (Figure 4; middle) does not varies much. Sites below most of the SGM and few DV sites are more than 5.0. A close inspection of RMS variation with the obtained results suggests that these higher RMS may be attributed to extreme resistivity contrast or situation of extreme current channeling, associated with near surface resistor-conductor pair at the SGM-DV boundary. Generally, misfits are larger in AMT inversions data fitting possibly due to the presence of extreme contrast situation in form of alternating shallow resistors and conducting heterogeneities. In addition, AMT data added shallower conducting heterogeneities in the obtained results, producing larger misfits.

Conclusions:

New 3-D AMT results added the shallow extension of regional deposit scale conductors from previous MT studies over DV and SGM lithology. The dimension, location and size of these shallow conductors, possibly linked with mineral prospecting of the area, properly marked by the present study. Larger RMS of most SGM sites mostly concludes the presence of extreme resistivity contrast situation**,** which was not recovered through inversion. 3-D AMT results also maps near surface conducting heterogeneities consistent with the presence of carbon phyllites and tuffs. In general, AMT 3-D model up to 200 m, depicts resistor and conductors with close spatial association corresponds to upper Dalma members. Model features becomes mostly conducting with depth up to 500m, corroborates to conducting lower Dalma member. The existence of Dalma conductors more clearly developed at deep levels comparison to shallow levels. Z and Z+VTF results both shows presence of shallow resistors and conductors. As the depth increases from 20 meters to 100 meters the resistors dominates in both Z and Z+VTF results. The resistive features below DV and SGM can be clearly be observed. The VTF shows the presence of a conductors below SGM at this depth. The resistive features below SGM become prominent as depth increases and this is clearly evident in Z+ VTF results as compared to Z data

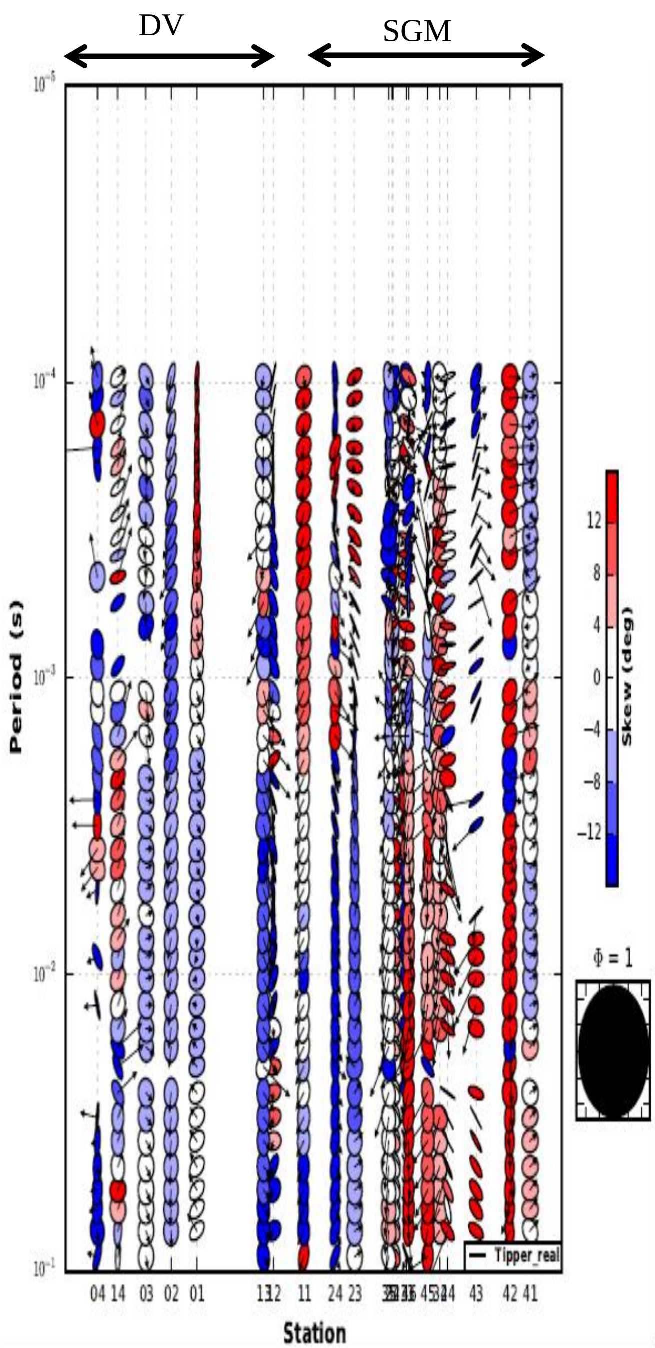

Figure 2. Phase tensor ellipses along with real part of induction arrows for AMT sites drawn ellipses normalized with maximum phases means major axis of ellipses is unit and minor axis formed by the ration between minimum and maximum phases at each periods. Station axis heads towards east direction. Ellipses are colored with phase tensor skews, β.

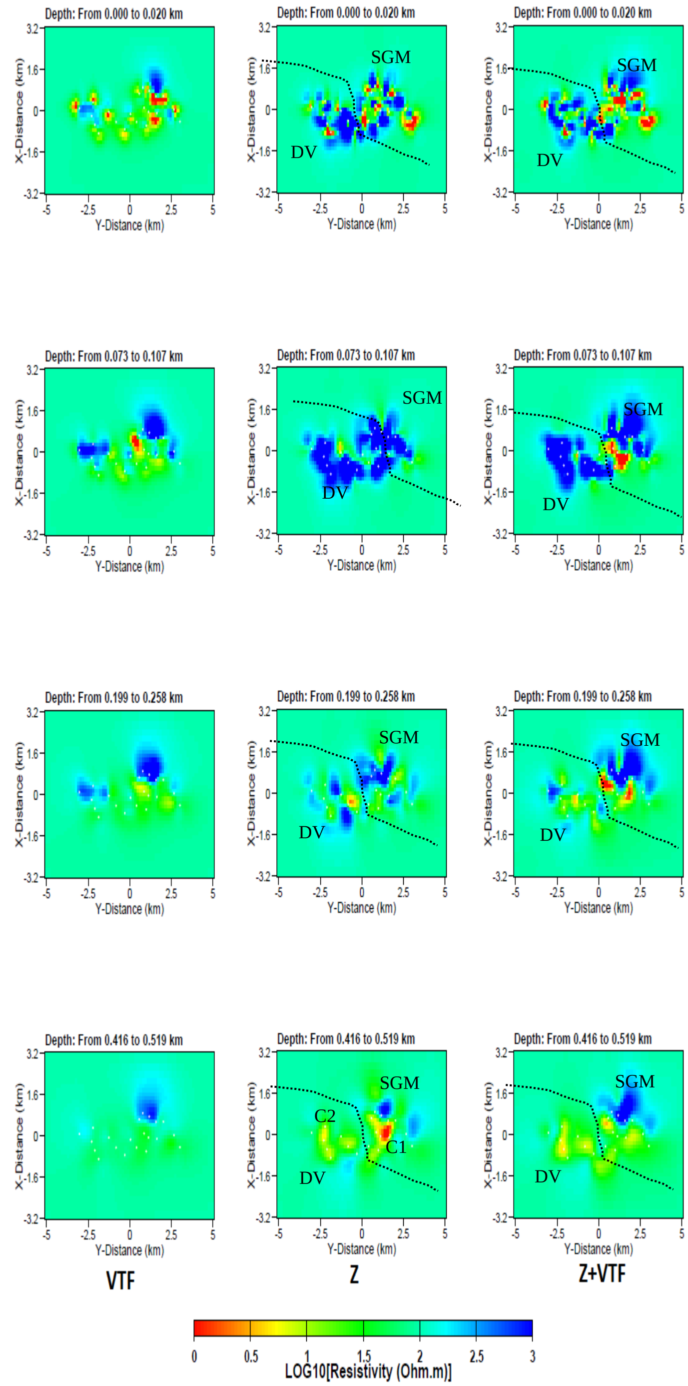

Figure 3. *Depth Slices obtained from 3-D Inversion of AMT (i) VTF data only, RMS 4.0, (ii) full impedance (Z) data, RMS 4.3, and (iii) Z+VTF, RMS 4.7. Error floors used in inversion are 10 % and 5% for Z and VTFs.*

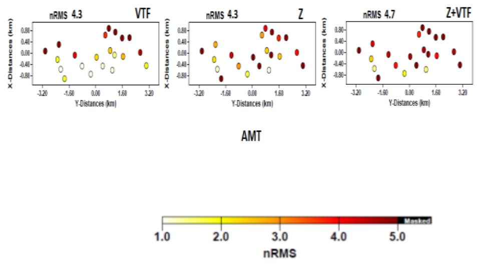

Figure 4. RMS misfit distribution of AMT inversions for VTF (left), Z (central) and Z+VTF (right) datasets

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