INVESTIGATION OF CURRENT CHANNELLING EFFECT IN MAGNETOTELLURIC FIELD DATA

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Abstract : ***Magnetotelluric (MT) is an electromagnetic geophysical exploration technique to study the electrical resistivity structure of earth's surbsurface. Field data were collected in period range 0.001 to 1000 s from Roorkee-Gangotric profile in Garhwal Himalaya of Uttarakhand, India. MT data collected from Higher Himalayan region showed a strong telluric current channeling effect at 6 MT sites. Swift skew and Phase Sensitive Skew (PSS) parameter for these sites were analysis and observed high values. High values of Groom-Bally decomposition parameter, twist and shear were analyzed in the entire period range at these sites. On the basis of these analyses, it can be inferred that these 6 MT sites show strong current channeling effects and complex 3D structure of higher Himalaya.***

Index Terms - Magnetotellurics (MT), Current Chanelling, Field data, Garhwal Himalaya.

I. INTRODUCTION

The Himalayas originated as a result of continental collision tectonics and under thrusting of the Indian Plate beneath the Eurasian Plate. At least 1400 km of convergence has been accommodated by a combination of under thrusting of Indian lithosphere, crustal shortening, horizontal extrusion and lithospheric delimitation [1]. Geophysics deals with the estimation of physical properties of the subsurface from related physical fields measured on or near the earth's surface. MT method is one of the methods used to study the distribution of electrical conductivity in earth's interior. In magnetotellurics, natural time varying orthogonal horizontal electric and magnetic field components are measured simultaneously. The measured electric and magnetic field components are analyzed in terms of electrical resistivity distribution in the earth's interior. Measured orthogonal electric and magnetic field components are linearly related through appropriate transfer function [2, 3]. Geophysical data obtained from magnetic, gravity, seismic and geoelectric methods is used to study the earth crustal and upper mantel structure in the Himalayan region. Electrical conductivity structures of various part of Himalayan region have been delineated using magnetotelluric and geomagnetic depth sounding methods. The current channelling has been reviewed in a paper by Jones [4], where this effect is explained as a high concentration of current induced in the local conductor by external source fields. These currents are channeled by local conductor in a frequency independent ohmic-like manner (i.e., anomalous DC currents). While analyzing dimensionality of the MT data, one goal is to find out which part of the region can be explained with a 2D regional model overlain by local, shallow, horizontally elongated conductors oriented differently. Such a model has been referred to as the channelling model, in which the regional electric fields are strongly distorted and polarized in one single direction due to high concentration of currents that are channelled by the local conductors and where the phase exceeds 90^0. In strong current channelling case phase greater than 90^0 has been observed [5]. In this case the tensor decomposition schemes [6] for recovering the regional fields fail and are unable to determine the regional strike when the distortion parameter 'shear' is greater than 40^0 [7]. Numerous attempts have been made, using the current channelling structures, to model the large phase anomalies. Livelybrooks et al. [8] explained this way a large phase anomaly found in a survey across the Trillabelle ore body. Weckmann [9] modeled phase greater than 90^0 in a survey in Nambia with a conductive local ring structure and Pous et al. [10] attempted to model more regional large phase anomalies found in Tenerife Island by using 3D highly conducting channel structures.

II. MT DATA COLLECTION AND RESPONSES

MT data was collected in the Garhwal Himalayan corridor passing through the major Himalayan thrusts. During 2004–06, in the frequency range 1000 – 0.001 Hz along the 300 km (along road) profile, extending from Himalayan Foothill region to Higher Himalayan region [11, 12]. The recorded MT time domain data were transformed to the frequency domain impedance tensor using magnetotelluric processing (MAPROS) code [13], figure 1. The entire data set has been analyzed using Groom and Bailey [6] decomposition. The distortion parameters and the regional geoelectric strike are estimated, frequency-by-frequency, by fitting the measured data at each site using the 'strike' code of McNeice and Jones [7]. The measured impedance tensor is distorted by local small scale structure and may also have 3D effects.

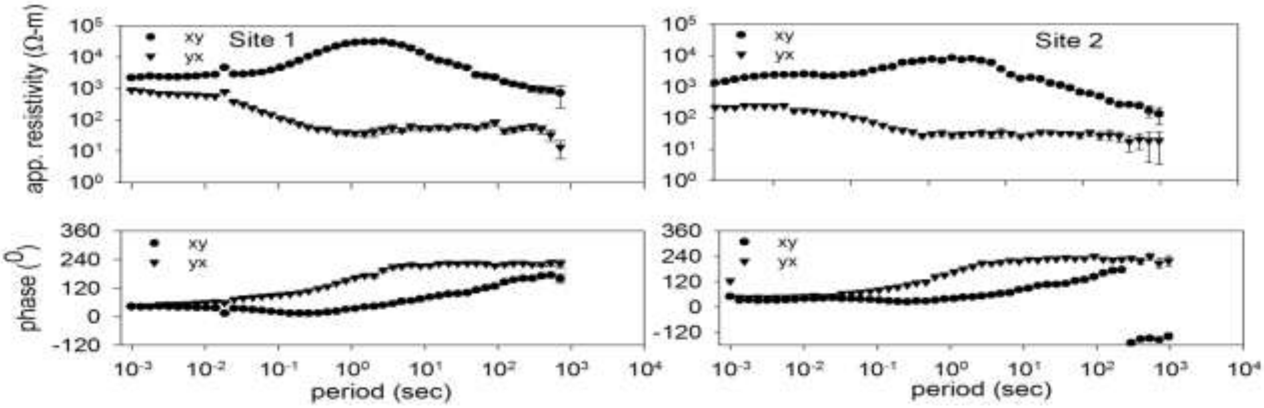

Figure 1: MT Response with higher phase in Higher Himalaya

III. CURRENT CHANNELING IN FIELD DATA

Current channeling effects have been observed at 6 MT sites in the Higher Himalaya, the phases exceeding 90^0 above the period of 0.1 s (Figure 1). The Swift skew [14] parameter for these 6 sites was analyzed and it was observed that these 6 sites have Swift skew value greater than 0.2 at periods above 0.001 s (Figure 2 a). The Phase Sensitive Skew [15, 16] parameter for these 6 sites was analyzed and it was observed that only 4 sites have PSS value greater than 0.3 at periods above 0.1 s (Figure 2 b). The Groom-Bailey decomposition was also used at these 6 sites. It was observed that shear was the more distorted parameter at these sites. The twist and shear values in the entire period range (0.001 s to 1000 s) at these sites are shown in Figure 3. On the basis of these analyses, it can be inferred that these 6 MT sites show strong current channelling effects.

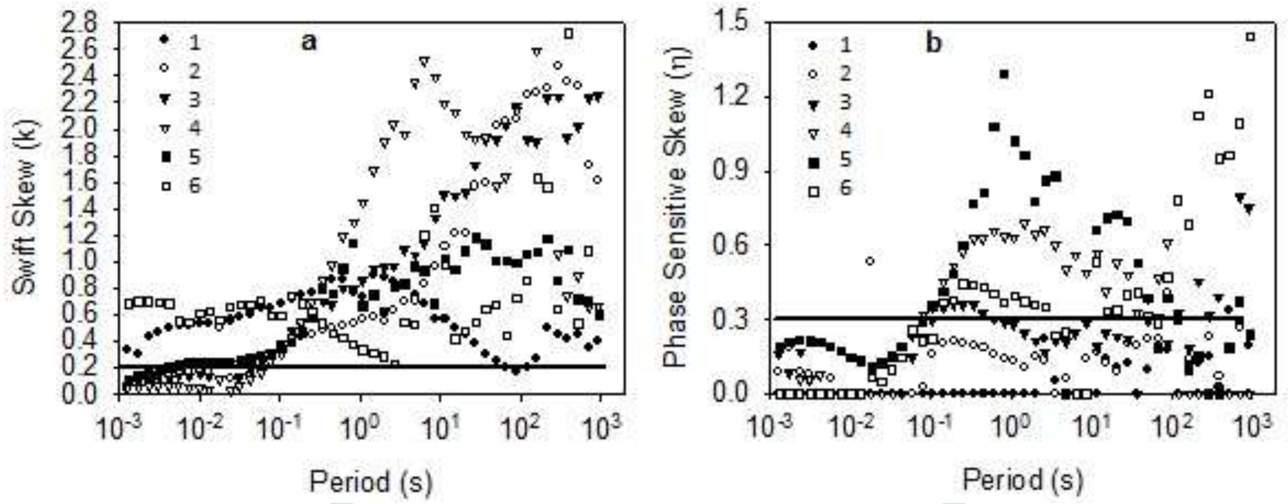

Figure 2: (a) Swift, (b) Bahr skew parameter at the 6 sites in the Higher Himalaya.

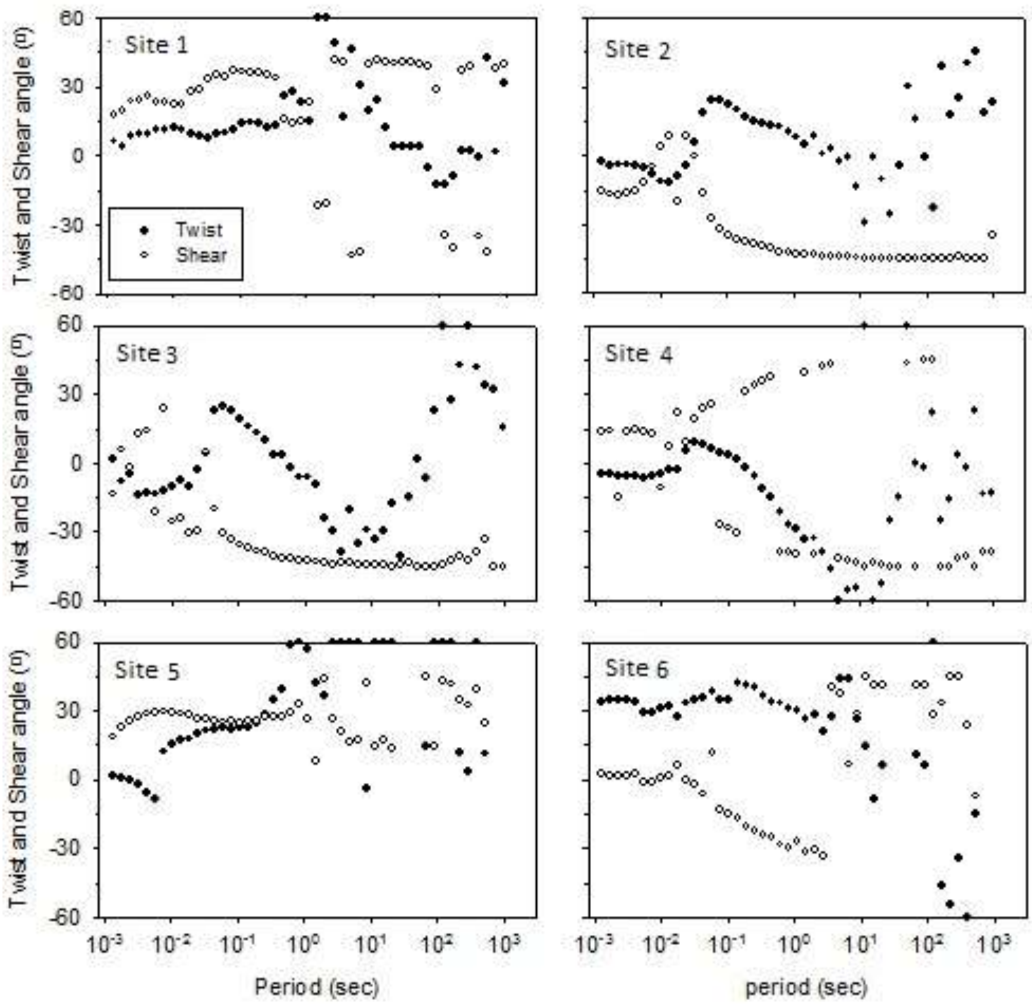

Figure 3: Twist and Shear values estimated by Groom-Bailey decomposition at the 6 sites in the Higher Himalaya.

IV. CONCLUSION

The work is devoted to the magnetotelluric study of Garhwal Himalayan terrain. Garhwal Himalaya is one of the fast developing region in India. Since it was the first MT field study conducted by the group, the processing steps had to be learnt the hard way which took enormous amount of time. After processing, decomposition and dimensionality analysis, 6 of the MT response curves were found to be showing strong 3D effect in higher Himalaya region. These were not used for further 2D inversion process. High values of twist and shear, Swift skew (> 0.2) and Bahr phase sensitive skew (> 0.3) and phase exceeding 90^0 were the main criteria to define three-dimensionality character of the data and it indicated the complex 3D structure in region.

V. ACKNOWLEDGMENT

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REFERENCES

[1] Molnar, P., 1990. A review of the seismicity and the rate of active underthrusting and deformation at the Himalaya. Journal of Himalayan Geology, **1**, pp. 131-154.

[2] Tikhonov, A. N., 1950. On investigation of electrical characteristics of deep strata of Earth's crust (in Russian). Dokl. Acad. Nauk USSR, **73**,295-297.

[3] Cagniard, L., 1953. Basic theory of the magneto-telluric method of geophysical prospecting. Geophysics, **18**, pp. 605-635.

[4] Jones, A. G., 1983. The problem of current channeling: a critical review. Geophysical Surveys, **6**, pp. 79-122.

[5] Heise, W. and Pous, J., 2003. Anomalous phases exceeding 90^0 in magnetotellurics: anisotropic model studies and a field example. Geophysical Journal International, **155**, pp. 308-318.

[6] Groom, R. W., and Bailey, R. C., 1989. Decomposition of magnetotelluric impedance tensors in the presence of local three-dimensional galvanic distortion. Journal of Geophysical Research, **94**, pp. 1913-1925.

[7] McNeice, G. W. and Jones, A. G., 2001. Multisite, multifrequency tenser decomposition of magnetotelluric data. Geophysics, **66**, pp. 158-173.

[8] Livelybrooks, D., Mareschal, M., Blais, E. and Smith, J. T., 1996. Magnetotelluric delineation of the Trillabelle Sulfide body in Sudburg, Ontario. Geophysics, **61**, pp. 971-986.

[9] Weckmann, U., 2002. A new method to image crustal conductivity structures using magnetotelluric data from Namibia. Ph. D. dissertation, Free University of Berlin, Germany.

[10] Pous, J., Munoz, G., Heise, W., Melgarejo, J. C. and Quesada, C., 2004. Electromagnetic imaging of variscan crustal structures in SW Iberia: the role of interconnected graphite. Earth and Planetary Science Letters, **217**, pp. 435-450.

[11] Tyagi, D.K., 2007. 2D Modeling and Inversion of Magnetotelluric Data Acquired in Garhwal Himalaya, Ph. D. Thesis.

[12] Israil M., Tyagi, D.K., Gupta**,** P.K. and Sri Niwas, 2008, "Magnetotelluric investigations for imaging electrical structure of Garhwal Himalaya corridor, Uttarakhand, India. Journal of Earth System Sciences, **117**, 189-200

[13] Friedrichs, B., 2003. MAPROS: Magnetotelluric data processing software. Metronix GmbH, Braunschweig, Germany.

[14] Swift, C. M. J., 1967. A magnetotelluric investigation of an electrical conductivity anomaly in the southwestern United State. Ph. D. Dissertation, Geophysics Laboratory, M.I.T., Cambridge.

[15] Bahr, K., 1988. Interpretation of the magnetotelluric impedance tensor: regional induction and local telluric distortion. Journal of Geophysics, **62**, pp. 119-127.

[16] Bahr, K., 1991. Geological noise in magnetotelluric data: a classification of distortion types. Physics of the Earth and Planetary Interiors, **66**, pp. 24-38.