Magnetotelluric survey across Singhbhum granite batholith

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Abstract. Magnetotelluric soundings have been carried out across the archaean terrain of Singhbhum granite batholith from Bangriposhi to Keonjhar for a distance of about 100 km. One-dimensional inversion models reveal that the depth of the moho varied between 23 and 40 km. The depth of the lithosphere asthenosphere boundary varied from 58 to 76 km. A zone of higher electrical conductivity detected at the base of the lower crust just above the moho is present along the entire profile. Signals within the range of 0.25 to 600 seconds, which crossed the coherency threshold of 0.8 to 0.9, could be stacked. Resistivity ranges of the crust mantle silicates below Singhbhum granite batholith vary over a wide range. Resistivity ranges are (i) 30,000–80,000 ohm for Singhbhum granite phase II, (ii) 2,000 to 9,000 ohm-m for Singhbhum granite phase III, (iii) 250 to 2,200 ohm-m for lower crust (iv) 3,000 to 47,000 ohm for the upper mantle and (v) 200 to 2300 ohm-m for the asthenosphere. Sharp break in electrical resistivity at the (i) upper crust-lower crust (ii) lower crust upper mantle and (iii) lithosphere-asthenosphere boundary is obtained along the entire profile. Signals could see up to 100 km below the granite batholith. Singhbhum granite phase II and III could be demarcated on the basis of resistivity. Low resistive zones in the lower crust and upper mantle might have formed due to (i) water (ii) combined effect of water and carbon and (iii) high temperature and partial melt.

Keywords. Magnetotelluric survey; Singhbhum granite batholith; inversion model; magnetometer array.

1. Introduction

Electrical conductivities of the crust and the upper mantle, like seismic velocity, density and magnetic susceptibility are important constraints on the physical properties for mapping large scale crust-mantle structures which may throw some light on the processes of crustal evolution. With the recognition of a distinct ancient crustal block (iron ore craton) in the Singhbhum-Orissa region of eastern India (Sarkar and Saha 1959), attention of many geologists has been drawn to this region to study the structural, petrological and geochronological aspects of this Archaean terrain. Some of the oldest exposed rocks of the earth viz older metamorphic group (OMG) and older metamorphic tonalite gneiss (OMTG) (3800 million years) are reported from this area (Basu et al. 1981). The crust under this iron ore craton is reported to have evolved over 3.0 Ga ago. Saha et al. (1988), and Ghosh et al. (1986) have given the evolutionary sequence of this region, which is dominated by the Singhbhum granite batholith and other batholiths during Archaean time. Mayurbhanj granite was emplaced along the eastern flank of the Singhbhum granite during Proterozoic time. An active sequence of geological events in this region from C 3.8–0.9 Ga has been worked out (Cf. Saha et al. 1988). The Singhbhum-Orissa iron ore craton contains
batholithic bodies of granites and granodiorites as well as Archaean-Proterozoic
volcano-sedimentary supracrustals and some mafic intrusives. This cratonic block is
bounded by the arcuate copper belt thrust zone in the north and the Sukinda thrust
zone in the south. It is surrounded in the east and north by the relatively high grade
metamorphic satpura belt and in the south by the granulite facies Eastern Ghat belt.

The major crust-forming events in the Singhbhum craton were complete by 3.0 Ga
and the major crustal growth continued up to 950 Ma (Saha et al. 1988). The area
under investigation is geologically one of the most well studied areas of the world.
Therefore, the readers are referred to the original papers (Saha et al. 1984, 1988; Saha
and Roy 1984a, b, 1988; Ghosh et al. 1986) for geological information.

Except for detailed gravity measurements of Verma et al. (1984), no significant
general physical work has been reported on this shield area. Therefore, the electrical
characterization of this ancient cratonic block of eastern India was chosen as one
of the major problems in this project. Accordingly, magnetotelluric sounding and
magnetometer array studies were proposed for the area and the programmes were
jointly undertaken by the Indian Institute of Technology Kharagpur, the Indian
School of Mines Dhanbad and the Indian Institute of Geomagnetism Bombay.
Attempts to throw light on the evolutionary history of the Singhbhum granite
batholith, based on geochronological work have been made by Basu et al. (1981), Saha
et al (1986) and Baksi et al. (1987).

2. Field work and one-dimensional inversion model

Single site magnetotelluric field was surveyed across the Singhbhum granite batholith
along the NE-SW profile (figure 1). Location of the observation points is also shown
in the figure. The field sites were chosen about 1 to 2 km inside from National Highway
No. 6 to avoid any cultural noise as far as practicable. The distances between the
observation points varied from 6:50 to 15 km. The total length of the traverse was
about 100 km.

Metronix (MMTO2E) system was used for field measurements. Two boats of
silver-silver chloride electrodes were placed at a distance of about 100 m each in two
mutually perpendicular directions (east-west and north-south) to measure the electric
field compounds $E_x$ and $E_y$. Magnetic fields ($H_x$ and $H_y$) are measured along the
east-west and north-south directions putting the induction coils in horizontally dug
grooves. Induction coils were aligned and levelled with a prismatic compass and spirit
level.

The period of measurement ranged from 0.25 to 4096 seconds in this equipment.
Measurements were done in three bands LF1 (256 to 4096 s), LF2 (8 to 256 s and
LF3 (0.25 to 8 s). Figures 2 to 4 show the samples of time series in LF3, LF2 and
LF1 bands. Observations at one field station were taken for about 12 hours; overnight
observation was preferred to day-time observation in summer. Monovariate coherency
threshold for $E_x-H_y$ and $E_y-H_x$ was kept at 0.85. Coherency threshold should be
kept within 0.8 to 0.9 (Kurtz and Garland 1976; Kaufman and Keller 1981; Rankin
and Pascal 1985a, b). Lesser the value of $H_x-H_y$ coherency, more stable will be the
computed impedances. The value of this coherency should preferably be 0.6 (Swift
1969; Rankin and Pascal 1985a, b). Typical field values of apparent resistivity, phase
and the monovariate and bivariate coherencies for the stations Dudura and Dari are
presented in tables 1 and 2. Figures 5 to 8 show the apparent resistivity and phase