ABSTRACT

Two dimensional mathematical modelling is carried out for both Direct Current Resistivity and Magnetotelluric analysis. In Direct Current Resistivity analysis, the governing Poisson's equation is solved using finite difference forward modelling with rectangular grids and applied Dirichlet, Neumann and mixed boundary conditions. For Magnetotelluric analysis, the governing Maxwell's equations are solved using finite element method with eight noded quadrilateral eight noded isoparametric elements. Finite element analysis is carried for both Transverse Electric(TE) and Transverse Magnetic(TM) modes independently. Computer programs have been developed for finite difference and finite element analysis in c-language and Fortran-90, respectively. Both finite difference and finite element codes are verified against the results of the analytical solutions available for simple geometries. Vertical Contact and Vertical outcropping dyke analytical responses were chosen both the cases for calibrating the software before they are used as forward model source codes for inversion of field data collected in the Archaean and Proterozoic terrains of eastern India.

Collinear dipole dipole direct current resistivity traverses were taken in different parts of the Singhbhum Archaean craton and across the Archean Proterozoic contacts in eastern India. Collinear dipole dipole configuration with dipole length 500 meters and with dipole separation varying from 500 meters to 5kms were used to study the first 3Kms of the earth's crust. *Scintrex*® 10 KW transmitter and IPR-10 and RDC-10 receivers were used for traversing. Maximum current that could be sent was 12 amperes and minimum voltage recorded was 200 micro volts. The following dipole - dipole traverses were taken

1. Ghatsila - Mosabani copper belt Singhbhum Shear Zone

2. Rajkharswan - Kharswan traverse across the Singhbhum Shear Zone

3. Dhanjori volcanic basin

4. Across the contact of Noamundi iron ore basin and the Kolhan sediments

5. Karanjia - Keonjhar traverse across the geological contact (Singhbhum granite phase II and Singhbhum granite phase III)
6. Along the Ghatsila - Dhalbhumgarh formation
7. Bisoi - Rairangapur traverse across the Singhbhum granite phase III and iron ore grou of rocks

Magnetotelluric traverse was taken across the Sukinda collision zone (or thrust zone) ne the southern margin of the Singhbhum Archaean craton and the north margin of the Proterozo eastern Ghat high grade granulite belt. *Metronix*® MMS02E system, E_x,E_y, H_x,H_y and H signals within the time period of 0.25 seconds to 4096 seconds were recorded and the PROCM software (a MT signal processing software) was used to process the data. Ultimately the processed MT data $E_x(\omega)$, $E_y(\omega)$, $H_x(\omega)$ and $H_y(\omega)$ are used to compute ϱ_{xy}, ϕ_{xy} and ϱ_{yx}, ϕ i.e., two sets of apparent resistivities and their phases. These data after mathematical rotation a taken as data for E- and H- polarization. The following Magnetotelluric field data are collect across the Sukinda collision zone near Kamakshya nagar and Bhuban:

1. Kankadahad - Tumasingha profile
2. Baragaji - Barijanga traverse

Two nonlinear global optimisation techniques namely Genetic Algorithm(GA) and Very Fast Simulated Annealing(VFSA) are applied to Direct Current Resistivity and Magnetotellur field data. Linearised inversion viz., Weighted Ridge Regression is also used to invert the Direc Current Resistivity data.

For inverting two dimensional Direct Current Resistivity and Magnetotelluric data 15 bi chromosomes were chosen to represent one parameter in Genetic Algorithm. Since, the numbe of parameters in the 2D domain will be large, the concatenated string for formation of pairs fo crossovers was long. 50 models or 25 pairs of models are chosen to start the genetic operation Multipoint crossover is chosen instead of single point crossover. The parameter domain betwe upper and lower bounds for each parameter are discretized with reasonably close intervals suc that the random walk in parameter space for global search can be more efficient. Crossov probability of 0.6 and mutation probability of 0.02 were chosen to run the genetic proces Stochastic Remainder Selection Without Replacement (SRSWR) is used to test the survival fo the fittest and to move from first generation to the second generation. About 250 generations computation are taken for this purpose.

In Very Fast Simulated Annealing (VFSA), the model parameters are discritized exactl the same way it is done for GA. Random search in the parameter space is done to find ou

the relatively higher probability models. Higher probability models are those where the discrepancy between the field data and the model response are minimum. At each iteration the temperature (a controlling parameter in Simulated Annealing) is lowered in steps from a very high initial temperature. In VFSA the temperature for all the parameters is kept same in our program and the inversion is continued upto 10,000 iterations. In the random process the error function or cost function or energy function or misfit function oscillates upto about 6000 iterations and then starts converging. Once the inverse problem starts converging, the misfit function decreases steadily and the annealing process is completed steadily at low temperature. $\frac{T_0}{\ln k}$ cooling schedule was used for VFSA.

The computer program for Weighted ridge regression source code is written in 'FORTRAN90' using 10% standard deviation for all the data for fixing up weights. Only about 20 to 30 iterations are required for the convergence of the problems.

Inversion of 2D Direct Current Resistivity data reveal the following facts:

Singhbhum Shear Zone and the North Singhbhum fold belt near Ghatsila - Mosabani could be mapped by the Direct Current Resistivity method. The conducting shear zone is about 1.5km wide and is dipping about 45° northward. The contrast in resistivity south of the shear zone and the North Singhbhum fold belt could be depicted. The depth of investigation is about 2.5 to 3kms from the surface. Almost similar models are obtained along the Rajkharswan - Kharswan traverse using Very Fast Simulated Annealing and Genetic Algorithm. The geoelectrical model reveals the conducting Singhbhum shear zone and highly resistive North Singhbhum fold belt.

The geoelectrical model of the Noamundi Iron ore basin clearly reveals the contact of the Kolhan sediments and Iron ore group of rocks. The models clearly show that the highly conducting Iron ore extends upto 1.7km from the surface. The contact of the Kolhan sediments and the Iron ore group of rocks is very sharp and easily mappable in the geoelectrical model.

Geoelectrical models of the Dhanjori volcanic basin clearly mapped the volcanic trunk dipping northward by about 40° to 45°. Two more volcanic bodies (basalts) are also located. This is the first model of the Dhanjori basin based on the scientific data. Three conceptual geological models based on surface geology are available in the literature. Dipping volcanic trunk indicates that the magma might have been erupted from a great depth from the north of the Dhanjori volcanic basin. Surface rocks of the basin are weathered volcanics. That is why their resistivites are much lower than the unaltered volcanics.

Inversion of resistivity data across the traverse Karanjia - Keonjhar clearly shows that resistivity of the Singhbhum Granite Phase II (SBGA) and the Singhbhum Granite Phase III (SBGB) are significantly different. Major element geochemistry, geochronology, trace element and rare earth element geochemistry, gravity, magnetotellurics and direct current resistivity observations suggest that SBGA and SBGB are two separate granite bodies evolved from two separate parent magma in two different geological times separated by 3140 million years and 3300 million years.

Geoelectrical model of the Bisoi - Rairangapur traverse clearly demarcates the contact of the Iron ore group of rocks and the Singhbhum granite phase III (SBGB) in the eastern region. The depth of the Iron ore group of rocks is about 1.5 to 1.75km.

Geoelectrical model of the Dhalbhum section shows the presence of one conducting body. It may be due to copper ore mineralisation.

Remarkable similarity were observed between the geoelectrical models obtained by GA and VFSA. Two geneticaly different inversion approaches GA and VFSA generated two very similar earth models for all the cases. GA and VFSA together should be an important tool for resistivity inversion, when no reliable information are available for constraining the data. Other inversion approaches should preferably be used to handle non-uniqueness in an inverse problems.

GA and VFSA together was used to invert TE and TM mode apparent resistivity and phase data. MT data could see the earth's crust and upper mantle upto about 200Km from the surface over the resistive quartzites and granites. The upper and lower crust, the upper mantle are reflected in the section. Vertical faults are also mapped. Over the Sukinda thrust, the ground is conductive. The depth of penetration of the MT signal was considerably less. The whole thrust zone has appeared as the conductive zone in the model. The thickness of the upper crust is about 10/12 Km and the lower crust extends upto 40Km and beyond. Lithosphere - Asthenosphere boundary is not very clear inthese models obtained from apparent resistivity and phase for both TE and TM mode data.

The most important contributions in the thesis are Singhbhum shear zone, Dhanjori volcanic basin, Noamundi Iron Ore basin, two granite bodies near Keonjhar and the nature of contact between the Singhbhum granite and Iron Ore group of rocks could be geoelectrically mapped. It added insight to our present level of understanding about the area.

TE and TM mode magnetotelluric apparent resistivity and phases were used for 2D inversion clearly showed the conductive collision zone and Singhbhum granite contact. A few vertical fault are mapped. Signatures of the horizontal discontinuities are not very prominent in the models.

Combined GA and VFSA appears to be a good tool for 2-D inversion of geoelectrical data.

KEY WORDS: Two Dimensional Geoelectrical Problem, Finite Difference Modelling In Direct Current Resistivity Problem, Finite Element Modelling For Magnetotellurics Using Galerkin's Weights and Isoparameteric Element, Genetic Algorithm, Very Fast Simulated Annealing, Direct Current Resistivity Field Traverse Across Singhbhum Shear Zone, Dhanjori Volcanic Basin, Noamundi Iron Ore Basin, Contact Of Iron Ore Basin and Kolhan Sediments, Dhalbhum Formation, Magnetotelluric Traversing Across Sukinda Thrust.