Chapter-1

INTRODUCTION

A subsurface mass declares its existence by producing some fields around it. Contour map of the field at a datum level reveals its structural configuration and also its location below it. Geophysical fields, such as gravity and magnetic responses of a subsurface body, when contoured on a datum level, the contoured data provides a qualitative interpretation of them in terms of size, shape and location of the causative mass. A quantitative analysis of them is supposed to provide complete information about the causative mass.

To understand the subsurface geology of an area, gravity magnetic (GM) data are acquired over the area, which is irregular in general. Reduction of data to a datum level appears as the first geophysical problem in interpretation of them in terms of subsurface geology of the area. The problem of reduction of gravity data to a horizontal level from data acquired in an irregular surface was solved by Hammer (1939) from the knowledge of masses causing the irregularities at the topography. This procedure however, cannot be applied to the magnetic data acquired in an irregular terrain. It requires application of a theoretical approach of reproduction of a harmonic function in the upper half-space domain from the data specified over the boundary.

The problem of reproduction of gravity or component magnetic field in the upper half-space domain, bounded below by a half-space boundary, suggests application of Green's formula for its solution. This requires finding of Green's function for the boundary. Finding of Green's function for a horizontal boundary is straightforward, but finding it for a general boundary is an extremely difficult task. Courtillot et al (1973), Ducruix et al (1974) made the first attempt to find a numerical solution of it. They came out with a numerical approximation of Green's function for the boundary. Their approach deals with non-linear estimation of unknown parameters and for solution, it requires an iterative scheme with a good apriori knowledge of the parameters.
Alternatively, Bhattacharyya and Chan (1977) formulated the problem of upward continuation by boundary integral equations in boundary densities. They used simple layer boundary density for the gravimetric case and double layer boundary density for the magnetostatic case. In their work, they derived the gravity field as a derivative of simple layer potential and reproduced the component magnetic field as potential of double layer boundary density.

Solution of a boundary integral equation analytically is out of question, it is to be solved numerically. This requires approximation of the boundary by sub-elements, subareas in three dimensions, and evaluation of the surface integrals of $r^{-1}$ and $\partial r^{-1} / \partial n$, over the subareas and finally solution of a system of linear algebraic equations by numerical means.

To find the numerical solution of the problem, Bhattacharyya and Chan (1977) approximated the boundary by rectangular subareas and used approximate values of the integrals over them. As such, the approximated boundary appeared with gaps between the subareas, interpolation of boundary data at the centroids of the subareas came out with error because of inaccurate representation of the boundary. Further, approximation of the integrals restricted reproduction of the field with reliable accuracy at a point near the boundary.

Again, reproduction of the gravity field involves evaluation of complicated singular integrals. In some cases, depending on the geometry of the boundary, the discretised version of the integral equation in simple layer density becomes non-amenable to solution by Gauss-Seidal iterative method, a method suitable to handle a large system of linear algebraic equations as they appear in solution of a geophysical problem. Further, we know that a component magnetostatic field vanishes at infinity in $O(r^{-3}), r \to \infty$ and the potential due to a double layer density vanishes in $O(r^{-1}), r \to \infty$. As such, reproduction of a component magnetic field, as potential due to a double layer density, remains to be explained in their work.
Laskar (1984) formulated the problem of upward continuation of gravity and magnetic fields from boundary data by formulating the problems in boundary integral equation in double layer boundary density and also derived the component magnetostatic field as derivative of potential due to simple layer boundary density. However, the possibility of reproduction of both gravity and magnetic fields as potential of simple layer boundary density is left to be discussed in his work.

Since approximation of regular integrals suffices finding of reasonable solutions of the boundary equations (Laskar 1971, Bhattacharyya and Chan 1977, Kumar et al 1992), no much efforts were made to evaluate the regular integrals analytically. For a field point lying at a distance $d \leq 2D$ from the boundary; $D$ defining the largest diagonal of the nearest subarea $\Delta S$, approximate values of the integrals appear with more than 5% error (Laskar 1977). This error adversely affects the field value as the field point approaches the boundary. This necessitates analytical evaluation of the integrals at least over the subareas lying within a distance of 2D from the field point.

In this thesis, reproduction of potential fields from the data specified over a half-space boundary is formulated in boundary integral equation. Existence and uniqueness of solution of a half-space problem is discussed as a special case of a closed domain problem. In reproduction of a potential field in the upper half-space domain from boundary data, it is theoretically shown that upward continuation of gravity and magnetic fields can be carried out from a general boundary as potential of simple as well as double layer boundary density. It is also achieved by use of Green's formula without finding Green's function for the boundary. Subsequently, efficacies of the techniques are successfully demonstrated on model data. To carry out numerical work, the boundary is divided into triangular sub-areas to have the best possible approximation of it and the integrals over them are evaluated analytically. Finally, the ground magnetic data of Vishakhapatnam-Srikakulam area are continued upward to a common level grazing the highest topographic point of the area by double layer formulation of the problem and subsequently, these are continued downward for finding the depth to the magnetic causative by use of DEPTH DNC software that determines depth to causative mass from the profile potential field data. The analysis reveals the basement configuration in the relatively flat coastal
area of Vishakhapatnam region and mechanism of deformation of the landmass in the undulated hilly region of Lampaunt-Araku area that lies at the northwest of the coastal area.