J. Ind. Geophys. Union (January 2005)
Vol.9, No.1, pp.21-28

Structural analysis of magnetic anomalies across Gondwana Outlier near Tiruvuru, Krishna District, Andhra Pradesh

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ABSTRACT
Geological contacts associated with an outlier in biotite gneiss and sandstones near Tiruvuru, Krishna district, Andhra Pradesh, were investigated employing magnetic method. The contacts, which are generally favourable for ground water occurrence, were precisely located based on the analysis of magnetic data by analytical signal approach and spectral analysis. Further, the data were subjected to modeling and the results are found to agree well with those obtained from analytical methods. In addition, the results were also examined by correlating the magnetic signals with known geology in order to improve the reliability of interpretation and the results are presented here.

INTRODUCTION

Delineation of structures like geological contacts is not only a pre-requisite, but also of paramount importance for ground water exploration in areas underlain by different rock formations. The ground water potential, mode of occurrence and its relation to geological contacts between two different formations near Tiruvuru, Krishna district, Andhra Pradesh has given ample scope for exploring them employing magnetic method. Presence of thick impermeable clayey soil over geohydrologically favorable sandstone has limited the recharge of the aquifers from ground surface. Thus, the contacts between sandstone and biotite gneiss have become the loci for recharge of the area and hence concerted efforts were made to locate the contacts.

The Geological Survey of India (GSI) has carried out some preliminary seismic surveys to determine the lateral extension of the outlier located near Tiruvuru (Sarma, Suryabhanu & Rama Rao 1968). Regional magnetic surveys were carried out in the area by Murthy, Varaprasada Rao & Bhimashankaram (1982) Murthy, Gyasuddin & Sitaramaiah (1983) as a part of geophysical mapping of Pakhal-Cudappah tract. The Central Ground water Board (India) has undertaken geophysical surveys employing seismic and electrical methods (Ramam et al. 2000), wherein the low velocity and moderate resistive zones were identified in the crystalline formations underlying the sandstone.

Magnetic method, being a faster, economical and versatile geophysical tool, is not only capable of delineating such contacts appropriately, but also useful in mapping aquifers associated with other structures. Hence, a semi detailed investigation using magnetic method for delineating accurately the geological contacts in sedimentary regions covered by thick impermeable top soil underlain by shallow basement rocks were carried out. The results presented here as a case study, clearly show the applicability of the magnetic method in such studies.

GEOLOGY AND STRUCTURE

The area of investigation is spread between latitudes 17^0 01′15″ N to 17^0 07′30″ N and longitudes 80^0 32′30″ E to 80^0 37′30″ E and is near Tiruvuru of Krishna district, Andhra Pradesh, (Figure 1). Here, a tiny outlier of younger Gondwana sediments (Kamthi sandstones) in the metamorphic Archeans crystallines (biotite gneisses) was reported by Ziauddin (1954). The geology of the area exhibit biotite-muscovite gneisses with soil cover of 1.5 to 3 m (Krishnan, 1960 and Rammohan Rao 1979). The most important unexposed geological feature of the area is the contact between sandstone and biotite gneiss. Venkataraman (1961) reported that the Kamthi sandstone occurs as an outlier in biotite gneiss over an area of about 17 sq. km striking EW.

Structurally, the area is complex and marked by a number of NE-SW and N-S trending fault systems

(Shyamprasad 1995) and they are very well evidenced by the presence of Kattaleru River and its tributaries. Tiruvuru is covered by different types of metamorphic rock and is surrounded by sedimentary of different ages. On the regional scale, the major rock types, such as quartzites, limestones, phyllites etc. of Pakhal age are exposed along west and north west of Tiruvuru and sedimentary formations of Gondwana along east. Similarly, different types of metamorphic rocks like quartz, felspathic gneisses, schists and amphibolites are found in north of Tiruvuru. The gneissic terrain is mostly weathered and the amphibolite dykes standout as boulders in the rolling gneissic country. The gneissic terrain is traversed by many dyke like bodies of amphibolites of varying lengths and thickness.

HYDROGEOLOGY

Occurrence of ground water is common in both the geological formations viz. the Precambrian gneisses and lower Gondwanas - Kamthis (Shyamprasad 1995) in the area though the water bearing properties vary from rock type to rock type. Biotite gneisses are compact and less susceptible to weathering and the thickness of weathered zone ranges between 6.0 to 12.0 m. These formations do not possess primary porosity and tend to become ground water repositories with the development of secondary porosity and permeability due to weathering and fracturing. As water in these rocks occur under water table conditions and is restricted to weathered, fractured and jointed horizons, the area is extensively developed by dug wells and shallow borewells. Dug wells tapping this zone vary in depth from 5-11 m and depth to water varies from 2.3 to 6.8 m below ground level with an yield ranging from 25 to 150 m^3/ day.

In Tiruvuru area, as Kamthi sandstone of lower Gondwana (10-50m of thickness) are covered by thick soil of ferruginous clay (2-4 m thick), ground water occurs in these formations under water table and semi confined conditions indicating poor ground water potential within these rocks. Majority of the open wells in the area tap water table aquifer down

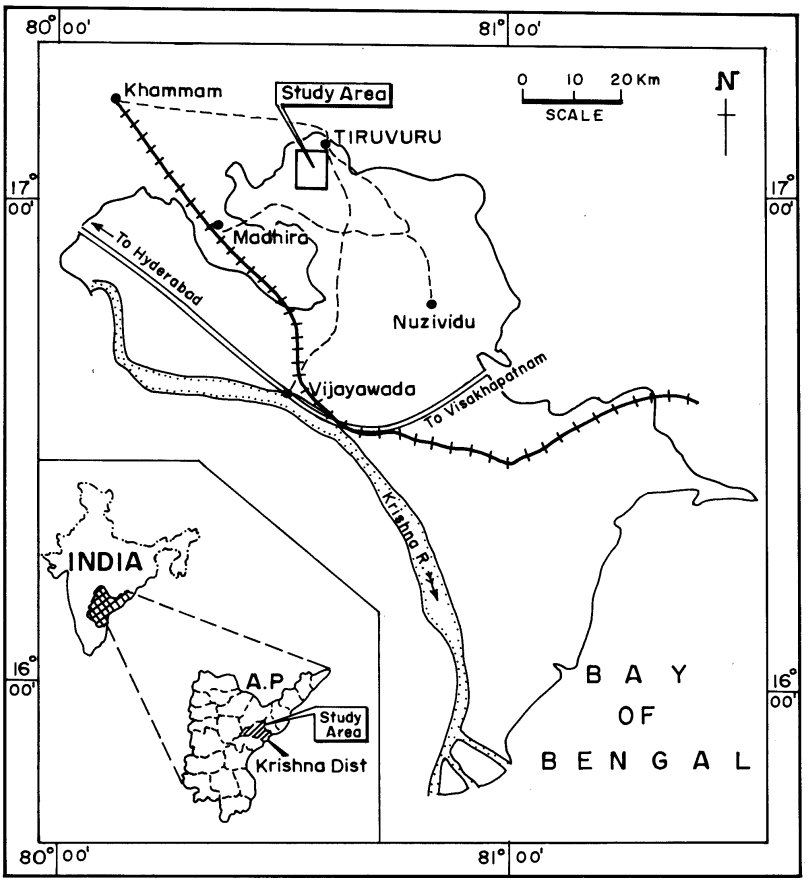

Figure 1. Location map of Tiruvuru and adjoining area, Krishana district, Andhra Pradesh, India.

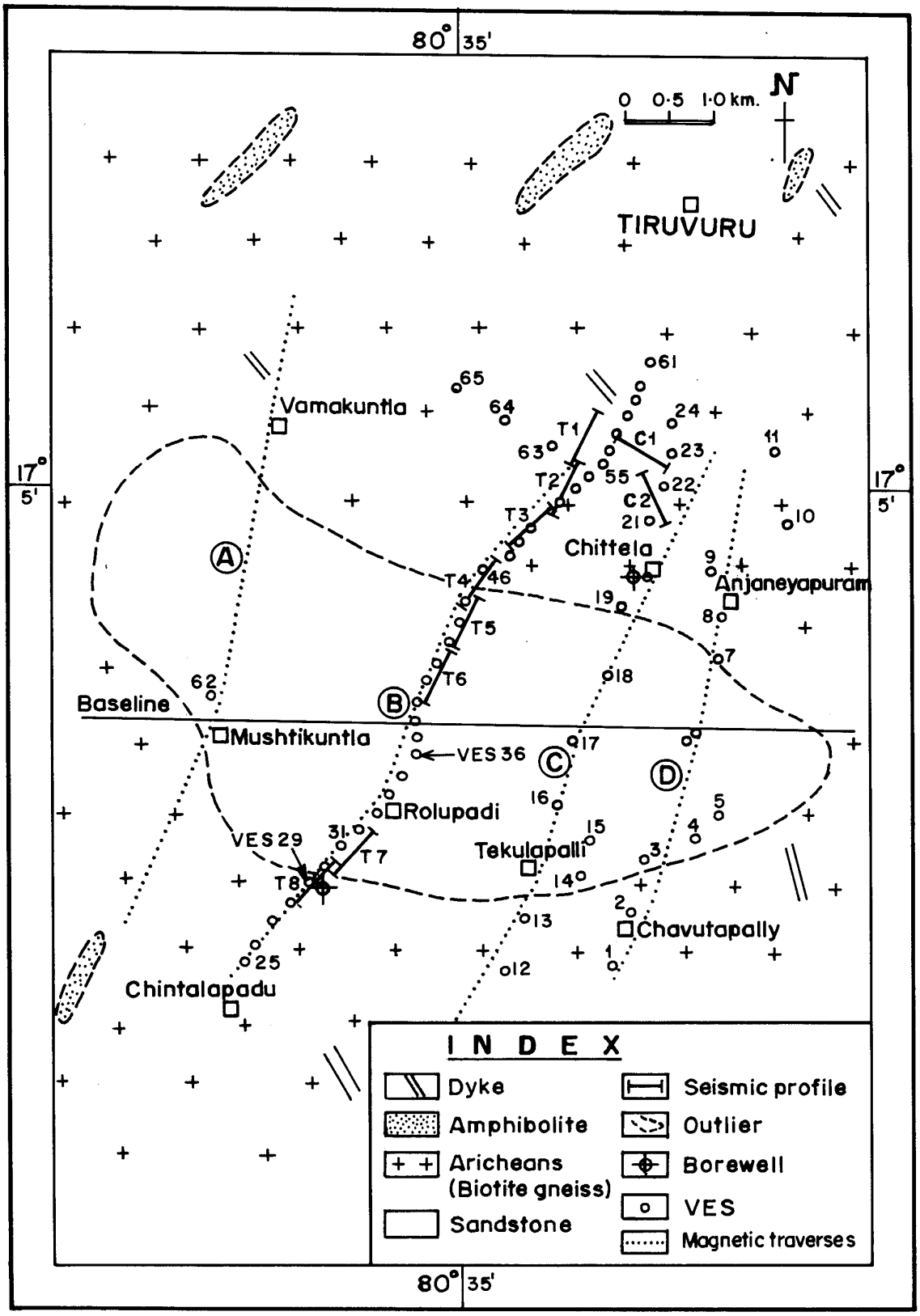

Figure 2. Geology and lay out map of geophysical surveys in the area of investigation.

to 8-13 m. Depth to water in these wells vary from 2-5 m and the yield range between 60-200 m^3/day. Some of the dug wells have penetrated the contact of biotite gneiss, which are found to yield moderate ground water; however, deeper aquifers are yet to be tapped.

GEOPHYSICAL INVESTIGATIONS AND DATA ACQUISITION

For the present study, the Tiruvuru outlier and its contacts form an interesting area of investigation for mapping of structures favorable for ground water prospecting. Accordingly, a semi detailed geophysical investigation employing magnetic method was carried out to understand the structures favorable for ground water potentiality of the area. Also, deep aquifers of fractured biotite gneiss within bedrock below sandstone have been investigated for possible potential ground water locations.

In all, measurements along four magnetic profiles [as marked in Fig. (2)] which are perpendicular to the strike of the outlier and each of length approximately 8kms running approximately N-S were carried out. All the four profiles constitute around 31.0 line km covering an area of 80 sq.km. The total number of observations including the base station readings is 626 at an average of 155 measurements per profile. The

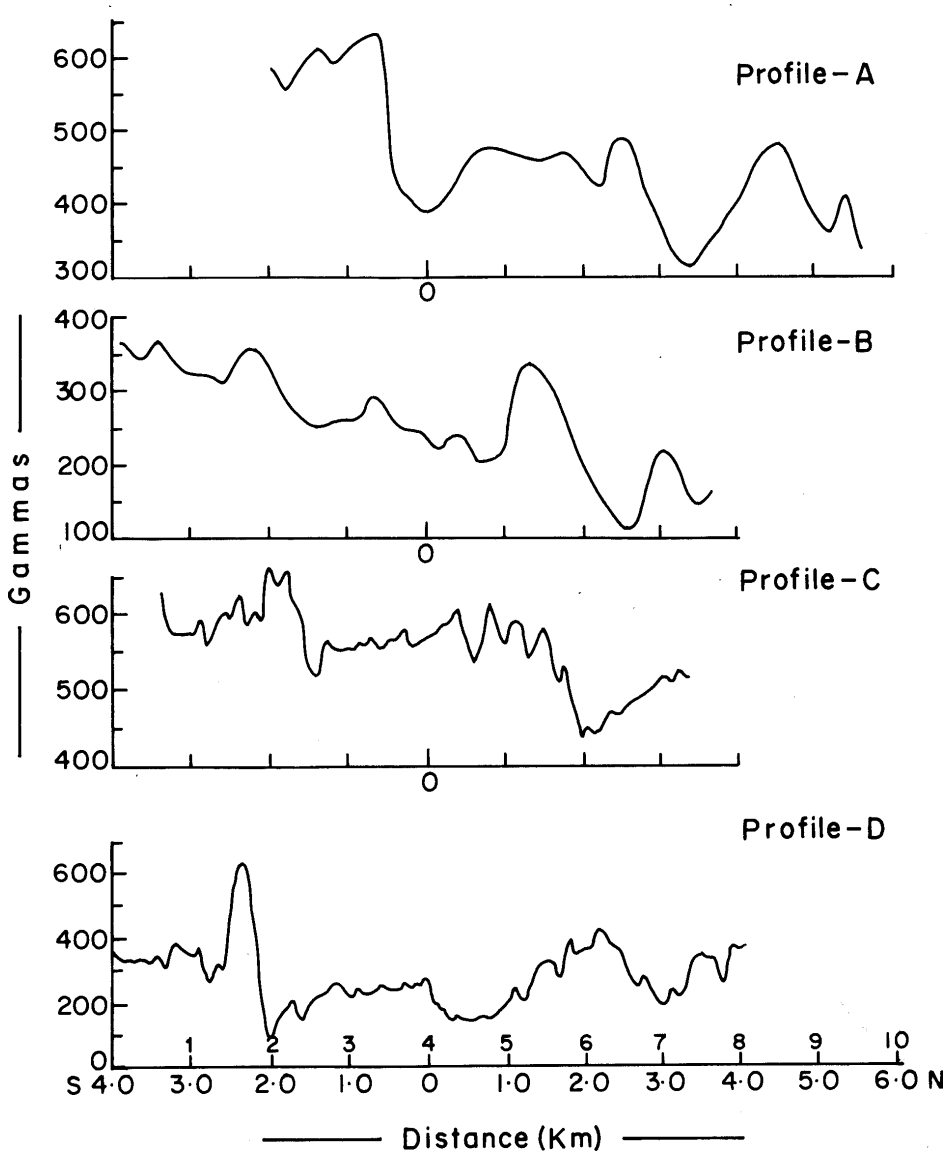

Figure 3. Stacked profiles of vertical magnetic field.

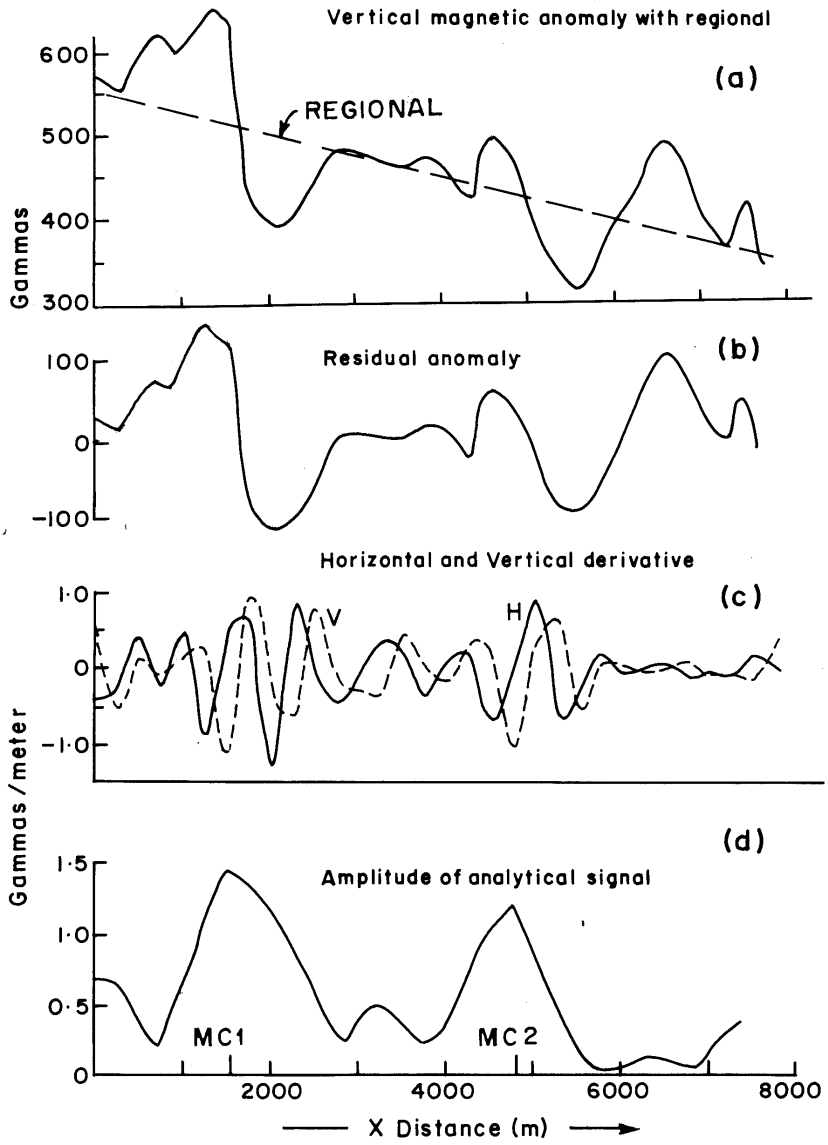

Figure 4. (a) Vertical magnetic anomaly (Profile-A), (b) residual magnetic anomaly, (c) horizontal and vertical derivatives of the anomaly and (d) the amplitude of the analytical signal of the magnetic anomaly.

measurements were made at an interval of 50m using a Fluxgate MF-2-100 magnetometer of Scintrex, Canada make which measures relative values of the vertical magnetic field intensity with a precision of 1 nT with a tripod and 5 nT if hand held. The measured magnetic observations (Fig.3) were processed and corrected for natural and instrumental variations before being interpreted.

PROCESSING AND INTERPRETATION

During processing, as a first step, a regional was removed followed by high pass filtering to enhance the magnetic signal and obtained the finer resolution of the trends, locations and dispositions of causative sources. Then the data was interpreted qualitatively to bring out the structural features of the region (i.e) location of contacts etc.

Towards this, the horizontal and vertical derivatives of the magnetic field were computed. The horizontal derivative of magnetic field is a measure of the difference in magnetic value at a point relative to its neighboring point whereas the vertical derivative is a measure of change of magnetic field with depth or height. These derivatives are based on the concept that the rate of change of magnetic field are sensitive

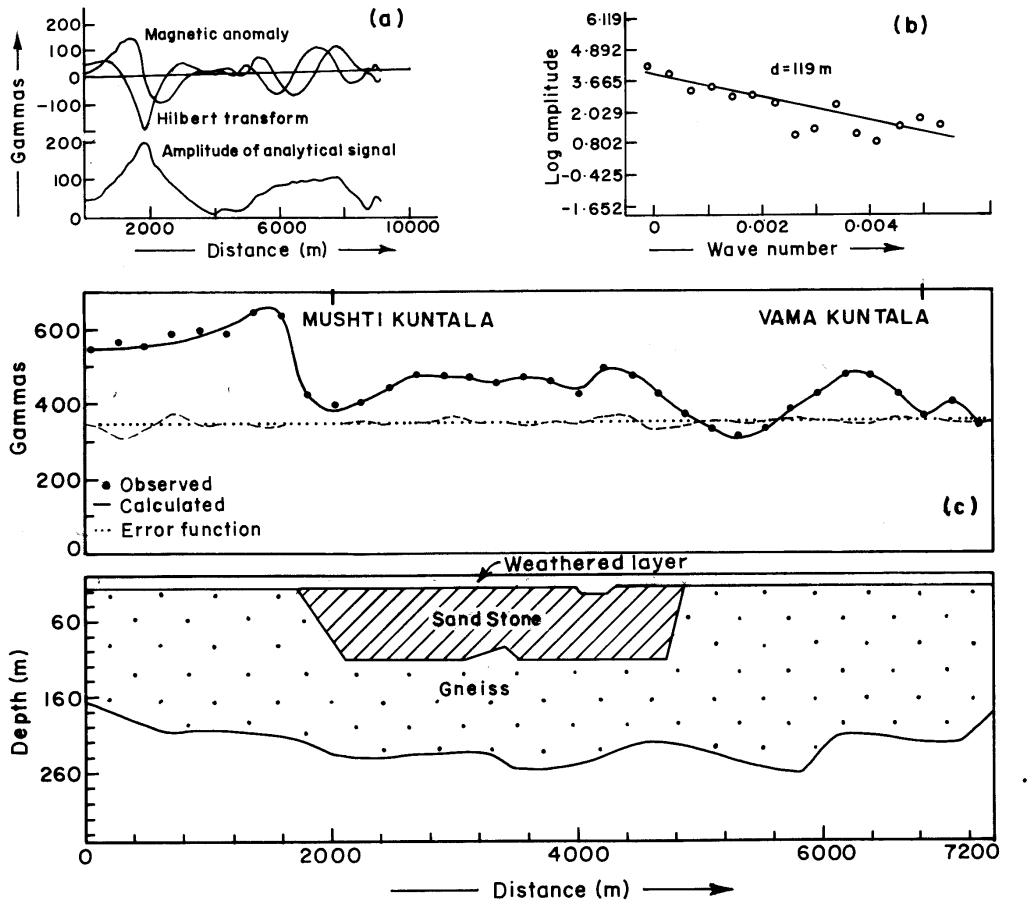

Figure 5. (a) Hilbert transform analysis, (b) Log amplitude spectrum and (c) modeling of the magnetic anomaly using the software GM-SYS.

to rock susceptibilities near the ground surface than at depth. Subsequently, the amplitude of the analytical signal (Nabighian 1972 and Sundararajan 1983), which ensures precise location of structures and boundaries of causative sources, were also computed. The two prominent peaks found on the amplitude of the analytic signal (Fig.4d) as explained hereunder corresponds to the contacts (MC1 and MC2) and the distance between these two peaks on the horizontal axis approximately yields the width of the outlier. This feature is also reflected from the residual magnetic anomaly shown in Fig.(4b). Depth determination was made based on certain characteristic points of the amplitude of the analytic signal with the application of the Hilbert transform (Nabighian 1972 and Sundararajan & Narasimha Chary 1993) and also by spectral analysis (Mohan 1978, Sundararajan & Ramabrahmam 1998). Further, the inversion of magnetic data was performed assuming the susceptibility values for sandstone and gneiss as 0.0133 and 0.01465 cgs units respectively, using GM-SYS software to constrain the interpretation through modeling. The depth to the contact as well as the width of the outlier can be inferred from the Fig. 4c. In Figure (4a-d), the vertical magnetic anomaly of profile-A, the residual magnetic anomaly, the horizontal and vertical derivatives and the amplitude of the analytic signal are shown. The plots of Hilbert transform analysis followed by spectral analysis and modeling are given in Figs (5a), (5b) and (5c). The analytic signal and the spectrum of the magnetic anomaly are expressed as follows.

If the magnetic anomaly is represented by m (x) and its Hilbert transform by h (x), then the complex analytic signal is given as:

$$ac(x) = m(x) - i\,h(x) \qquad \ldots(1)$$

Then, the amplitude of the analytic signal can be computed as:

$$aa(x) = [m^2(x) + h^2(x)]^{1/2} \qquad \ldots(2)$$

Further, the Fourier spectra of the magnetic anomalies are expressed as:

$$F(w) = |F(w)|.\, e^{i\phi(w)}$$

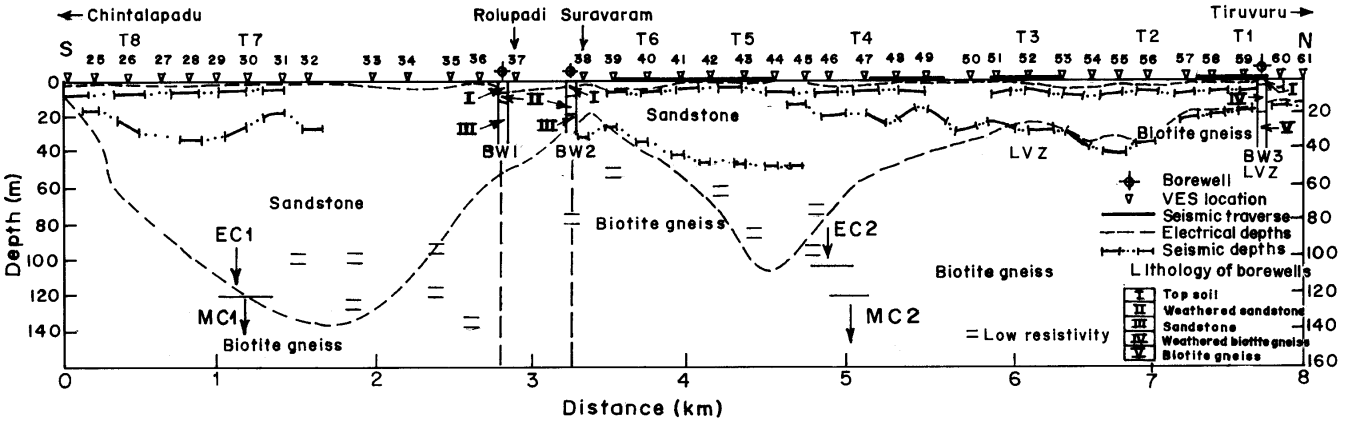

Figure 6. Integrated responses of seismic refraction and VES surveys with drilling locations.

Table. Interpreted results of Magnetic Data by various methods

Profile	Interpreted depths(m)			Inferred width of the outlier (km)		
	Spectral Analysis	Hilbert transform	Modeling	Magnetic anomaly	Amplitude of analytical signal	Modeling
(A)	119	155	120	3.4	3.5	3.5
(B)	138	130	135	3.8	3.9	3.4
(C)	101	132	105	3.7	3.8	3.8
(D)	117	115	100	3.2	3.3	3.3

Where, $|F(w)|$ and $e^{i\phi(w)}$ are the amplitude and phase spectra and w is the angular frequency, expressed in radians/meter. It is the logirthamic amplitude of the spectra $[\log|F(w)|]$ that is used here for determining the depth, which is shown in Fig.5b. The amplitude of analytical signal, which determines completely the magnetic field variation along orthogonal axes, ensures the precise location of structural features and boundaries. For targets with adequate contrast in magnetic susceptibility with respect to host rocks, the peak values indicates the position of the body/contacts and in the present case the two dominant peaks correspond to the contacts MC1 and MC2 and shown in Figure (4d).

RESULTS AND DISCUSSION

The salient feature of this study pertains to the estimation of the depth to geologic contact, which acts as a source for potential ground water resource in addition to the geometric configuration of sedimentary outlier. Accordingly, it was found that the average depth to contacts (MC1 and MC2) from magnetic interpretation based on the application of Hilbert transform, spectral analysis and modeling are 119m, 133m and 115m respectively. The average width of the outlier from magnetic anomalies, amplitude of the analytic signal and modeling are found to be 3.52 km, 3.62 km and 3.5 km respectively. The sandstone gneissic interface was assumed based on VES data. The results of all the four magnetic profiles are given in Table (Narasimha Chary 2003).

Depth to the subsurface contact and width of the outlier derived from magnetic anomaly with the corresponding geoelectrical section from VES are found to correlate well with each other (Fig.6) particularly near the bore well (BW2) at Suravaram. The approximate width of the outlier is considered to be the distance between the contacts MC1 and MC2 (magnetic) / EC1 and E C2 (electrical) on the horizontal axis.

CONCLUSIONS

Spatial location of geological contacts between two formations associated within the outlier near Tiruvuru, are established based on magnetic method. Depths to basement and fracture within the contacts are also brought out. Since the present work has bearing with ground water occurrence, the results were examined accordingly by correlating the geophysical signals with available geology of the area and are found to be a favorable zone for further exploration and exploitation of ground water. It was found that magnetic method was highly effective for delineating the contacts, depths to basement and magnetic sources within. Further, the width (N-S) of the outlier in biotite gneiss was fairly accurately determined.

ACKNOWLEDGEMENTS

The authors wish to record their profound thanks to the reviewer for his highly excellent suggestions to improve the text as presented here. One of the authors Y. Srinivas would like to thank the Council of Scientific and Industrial Research (CSIR), New Delhi for financial support.

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(Accepted 2004 August 10. Received 2004 April 23; in original form 2003 November 24)