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Aeromagnetic Analysis to Locate Potential Ground Water Zone - A Case Study from South Indian Shield

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ABSTRACT

Analysis of total intensity Aeromagnetic anomaly image and the apparent susceptibility image of Eastern Dharwar Craton (EDC), in conjunction with hydrological and geomorphological data has resulted in delineating an hitherto un mapped fault structure. The occurrence of ground water in the study area is found to be controlled by E-W & NW-SE trending dykes. Spectral and quantitative analysis of the aeromagnetic data of the study area has indicated 150 m thick top layer associated with weathered and sheared granite gneissic terrain. This is a profitable zone for ground water exploitation.

INTRODUCTION

Total intensity aeromagnetic field data collected over crystalline metamorphic horizons of hard rock terrains provide useful information regarding variations in lithology, structural grain and fabric of the rocks. These maps help in delineating different structural inhomogeneities that include fault-fracture systems, dykes, shear zones, intrusives and so on. These structural features indirectly help in locating groundwater resources. A correlative study of the aeromagnetic maps with hydrological information (including drainage pattern, wells, surface tanks, well data etc.) helps in understanding the potentiality of the groundwater occurrence in a given area. The analytical aeromagnetic maps like the Reduction to equator (REQ), Reduction to pole (RTP), apparent susceptibility, derivative, filtered and continuation maps can also be used in the correlative study to extract useful geohydrological information at depth.

Astier and Paterson (1987) have shown, in crystalline basement complex of some parts of west Africa, a direct correlation between the yield of boreholes and wells and their proximity to faults and dykes. Their studies further indicated favorable zones for groundwater at the sites of fault intersections. Astiers (1969), Chandra and Reddy (1987), Rama Rao et al., (2000) have studied the relation between the fault fractures and the occurrence of potential groundwater zones. Here, we present an analysis of the aeromagnetic data and its correlation with the available hydro-geomorphological information in deriving suitable structural elements in locating groundwater, in Akuledu watershed area of the drought prone district of Anantapur, A.P., India.

GEOLOGY AND MORPHOLOGY OF AKULEDU WATERSHED AREA

The study area, Akuledu water shed, is located in a part of Eastern Dharwar Craton (EDC) of south Indian shield. This area is drought prone and bounded by the latitudes 14°47' 01"and 14° 47' 29"N and longitudes 77°29'35" and 77°37'30" E (Survey of India toposheet Nos. 57 F/5 and 57 F/9 ;Raghu and Reddy, 2011)—Fig-1a. Major part of the area is occupied by the hornblend-biotite gneisses of the eastern Dharwar craton. The western edge of the area is covered with metabasalt (GSI, 2002) and remnants of the late Achaean green stone belt (Fig 1a).

Dolerite dykes trend in NW-SE and E-W direction and occupy the region between 77° 32′- 77°38′ (Fig- 1a, b). The eastern part of the study area is covered by extensive granite exposures and form as ridges. A series of NNE to NS lineaments cut across the granite complex and is traversed by quartz reef in the western edge (Fig 1a). Most of the drainage channels originate from the elevated topography (Sisodia and Sinha, 1979) and drain into the large Singanamala tank located between longitudes 77° 40′- 77° 43′E. The ground water system is totally controlled by the secondary porosity developed by fractures, intense shearing and emplacement of dykes. Three surface tanks aligned in the N-S direction in the vicinity of Mortadu village around 77° 34′ E longitude is an interesting feature (Fig 1b). The drainage channels from the elevated terrain in the west traverse in E-W direction and feed these three tanks. From there on, the drainage channels take an N-E direction (Fig 1b) at the village Mortadu.

Majority of the dug and borewells, in the vicinity of the three tanks are bordered by the E-W dykes in the North and NW-SE trending dykes in the South. Another cluster of wells occupy the region located towards north of the E-W trending dykes bounded by 77°36′- E 77° 38′ E longitude. The lineament trending in NE direction starting from 77° 34′ to 77° 40′ E appears to be the limiting boundary for the wells. The large Singanamala tank is fed by radially distributed drainage channels as shown in Fig 1b.

The depth of water table generally varies between 60-75 m in the study area with a weathered granite thickness

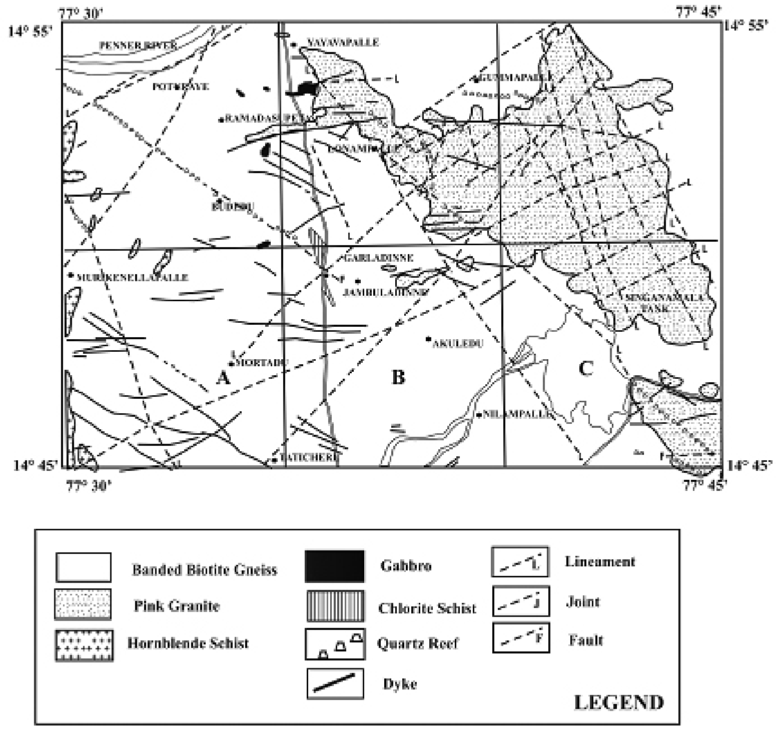

Figure 1a. Generalized geological map of the area. The area marked A, B and C is present study area and belongs to Akuledu Vanka water shed in EDC (Sisodia and Sinha, 1979).

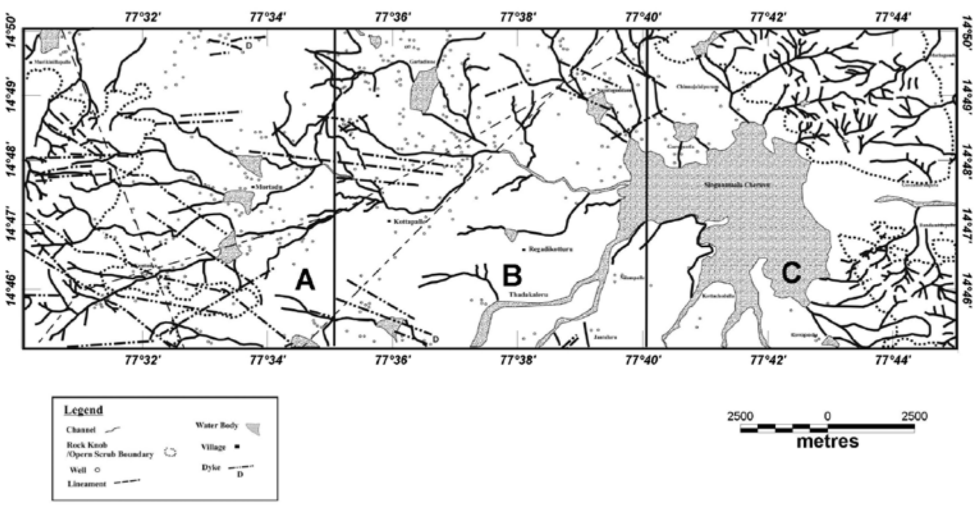

Figure 1b. Study area with the drainage channels and wells. The western part is composed of metabasalt and hornblend schist of late Archean green stone belt. The eastern part is covered by granite hills and traversed by NNE-SSW and N-S lineaments.

of 8-13 m (Raghu and Reddy, 2011). Construction of check dams across some of the drainage channels seems to have effectively increased the water yield. However, analysis of aeromagnetic maps/images, help in better understanding some of the geohydrological scenario and provide a deeper subsurface view of the terrain under study.

AEROMAGNETIC ANOMALY MAPS OF THE STUDY AREA

The National Geophysical Research Institute (NGRI) carried out aeromagnetic survey over parts of the EDC and The Proterozoic Cuddapah Basin during 1980-82. The

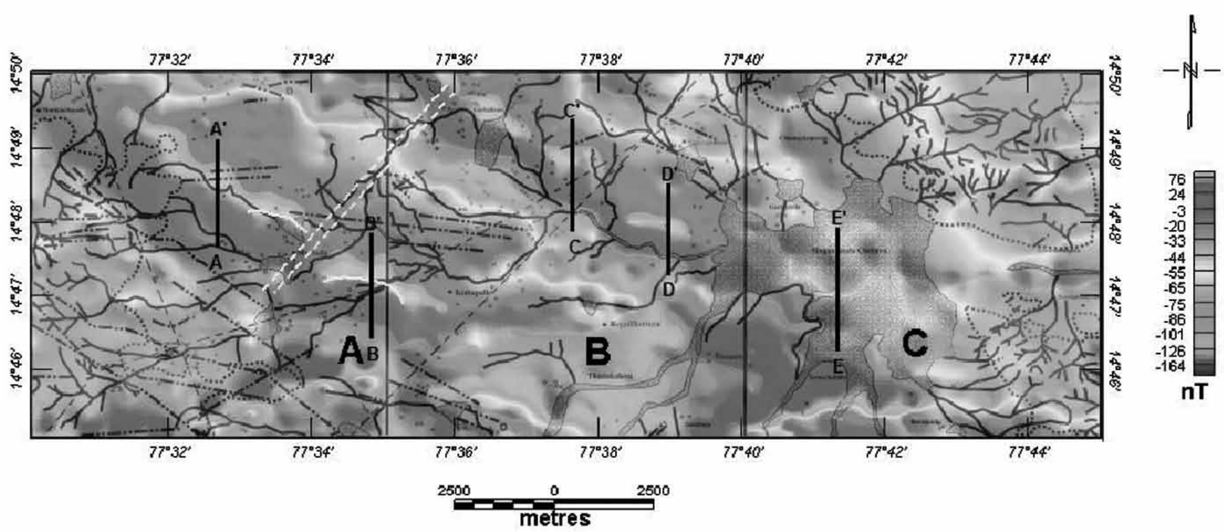

Figure 2. Total intensity aeromagnetic image of the Akuledu water shed area. Observe the shift and "drag" feature on the positive anomaly. Double dashed line (Yellow colour) in NE direction is the inferred fault. Showing the location of Interpreted profiles AA',BB',CC',DD' and EE'

aeromagnetic data was collected along N-S lines, each line being separated by 1000 m at a height of 150 m with a rubidium vapor magnetometer mounted in the tail boom, fixed on an aircraft. Fig.2 is the aeromagnetic anomaly map of the present study area.

ANALYSIS OF THE AEROMAGNETIC ANOMALY FIELD OF THE STUDY AREA

There are two prominent positive anomaly closures with amplitude range of ~100 nT (pink colour). These two anomaly closures trend in NW-SE direction. The anomaly in the middle part of the study area (bounded by 77° 36′ – 77° 40′E longitude) is associated with the Garladinne fault-fracture ,which is occupied by a quartz reef (Part B in Fig 1b). The diamagnetic character of the quartz gives rise to a negative susceptibility and hence the anomaly at this latitude appears as reversely magnetized and results in a positive anomaly. The positive anomaly, at this geomagnetic latitude, may be caused also due to reverse magnetization and/or depletion of magnetic minerals from the source either due to intense shearing or any other geological process. There are no dykes located in the vicinity of this anomaly. This feature continues towards SE and terminates in the Singanamala Tank.

The second prominent positive anomaly in the western part also trends in NW-SE direction and is wider than the above. This anomaly zone is bordered by E-W dykes in its northern edge and by NW-SE trending dolerite dykes in the south. Three N-S trending tanks are located in this anomaly zone. This anomaly seems to be dislocated in the region 77°34′E; 14° 48′N at Mortadu village. There are no quartz reefs in this anomaly zone. Also, there are no surface exposures, except soil cover. It consists of weathered pediplain of granite gneiss with more than 10 m deep weathered material and this forms good recharge and storage for ground water (Raghu and Reddy, 2011).

Here this positive anomaly may be inferred to be caused due to intense shearing and reworking of the gneissic material during emplacement of dykes and subsequent depletion of magnetic minerals. Generally, offsets in continuity of the magnetic trends/lineaments, abrupt terminations of magnetic lows and/or highs, drag features, contour nosings, alignment of highs or lows are some of the direct indicators of faults/shear zones (Gay and Jr, 1972). Persistent offset in the magnetic trends and drag features on either side of fault indicates strike slip environment, even though large scale strike slip faults do not leave any morphological evidence for strike slip faulting. In the low geomagnetic latitude area, like the present one, an intensely sheared tectonic zone with a possibility of depletion and/or destruction of magnetic minerals occurring can be identified by the characteristics of positive magnetic anomaly closures, all along the shear zone. Taking the above criteria (Gay and Jr, 1972) the dislocation of anomaly pattern with drag features in the vicinity of the middle tank, as indicated in Fig.2 at Mortadu Village, is inferred due to strike slip faulting along NE direction. This seems to be the reason for the change in the trends of drainage channel from E-W to NE direction at the location of the middle tank. Presence of more number of wells, confined between the NW-SE and EW dykes, along the inferred strike slip fault, indicate a good subsurface water regime in this watershed area. The NS alignment of the three tanks closely follows the inferred dislocation of the positive anomaly caused due to the fault along which

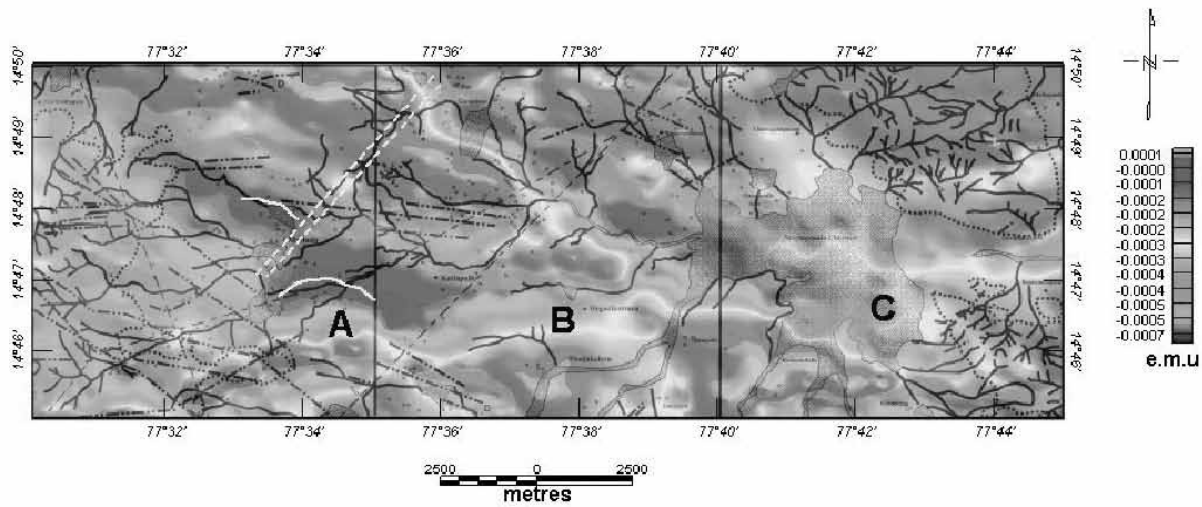

Figure 3. Apparent Susceptibility image of the study area derived from the aeromagnetic image (Fig 2). Observe the "drag" feature and shift at Mortadu village. Double dashed line (Yellow colour) shows the inferred strike slip fault.

the NE trending drainage flows.

The arcuate anomaly trend (with blue colour) having an amplitude of ~ 160nT in the southern part of the study area up to the latitude 14°47′N is associated with the hornblend biotite un weathered gneissic complex of the EDC. The arcuate shape can be inferred to be associated with a possible northward movement and/or upwarping in the subsurface crustal layers. The anomaly zone with green color having an amplitude range from 55-90 nT in western end (Fig 2) is associated with the hornblende schist rocks with metabasalt of the late Archean. The large Singanamala Tank located in the third segment of the study area seems to have been formed at the culmination of the Garladinne fault and is acting as a huge surface reservoir.

THE APPARENT SUSCEPTIBILITY MAP OF THE STUDY AREA

The susceptibility filter is a compound filter that performs a reduction to the pole on the IGRF corrected data, downward continuation to the source depth, and correction to the geometric effect of vertical square-ended prism (later divided by the total magnetic field of the study area). The map/image indicates the apparent susceptibility variation of subsurface rock matrix. Using Oasis Montaj Geosoft software, the apparent susceptibility image/map has been prepared for the study area (Fig 3). This clearly brings out the wide negative susceptibility zone related to magnetic mineral depleted horizon at depth and also shows the 'drag' feature as indicated. The drainage channel trending in NE direction at the location of drag feature is inferred due to structural control. The Garladinne fault location is also well brought out. The major drainage flows along the southern edge of this fault. The arcuate positive susceptibility trend in southern part of the area is of magnetic mineral rich granite-gneissic complex. The apparent susceptibility map clearly shows two NW-SE trending intensely sheared/weathered/fractured zones interspersed between relatively un-weathered solid hard granite-gneissic complex. The runoff pattern of drainage channels seems to be mostly confined to the sheared environment.

ANALYSIS OF THE AMPLITUDE SPECTRUM OF THE AEROMAGNETIC FIELD

Log normalized radially averaged energy spectrum computed for any aeromagnetic field data generally gives average depths to distinct magnetic horizons/markers (Spector and Grant, 1979; Naidu, 1970). A discernible magnetic property change along a vertical section of crust is helpful to understand the tectonic/geological history of the area. The log normalized radially average power spectrum for the entire area has been computed (Fig 4a). The spectrum shows two discernible segments with different slopes. The depth is computed from slope of each segment by using the formula:

$$\text{Depth} = 1/4\pi{*}(\Delta E/\Delta N).$$

Where,
$\Delta E/\Delta N$ is the slope of each segment.
ΔE is the log energy.
ΔN is the wave number increment.

In the present study, shallow magnetic layer at 150 m can be construed as the boundary. Above which, variations in magnetic lithology are prominently seen. As such, this is the region where the secondary porosity developed due to fracturing, shearing and formation of semi weathered horizon. This average depth of 150 m may profitably be drilled for extraction of groundwater, taking into consideration geological, hydrological and geophysical information.

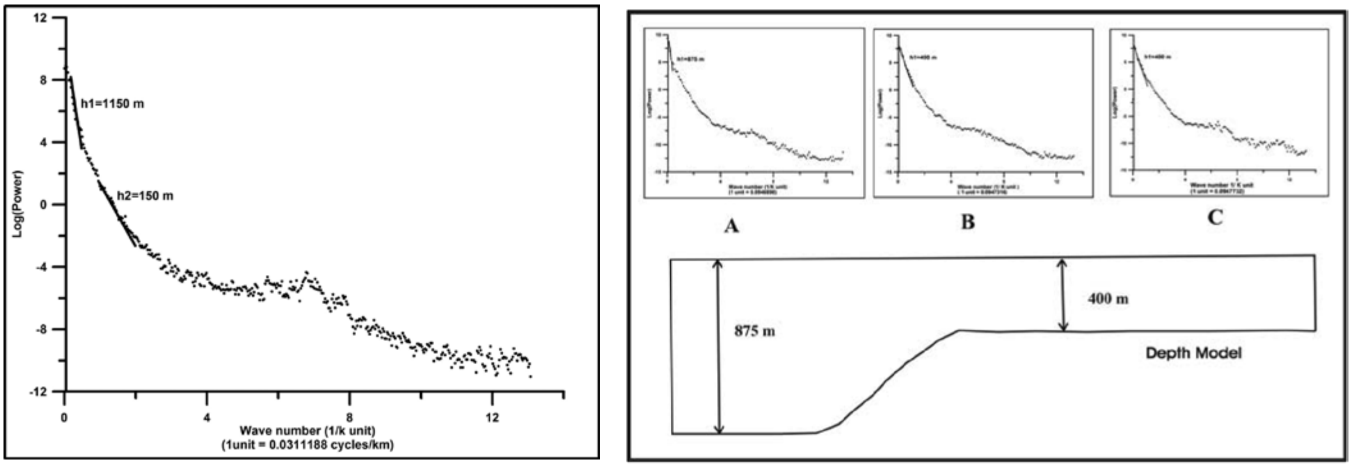

Figure 4 (a) Log normalized radially average spectrum of the entire study area. Depths are computed by Depth $= 1/4\pi * (\Delta E/\Delta N)$. (b) Log normalized radially average spectrum for regions A, B and C.

We have computed the radial power spectra for the three segments A, B and C (Fig 2) using the Oasis Montaj Geosoft software. The spectra are shown in Fig 4b.The average depth computed for the 1^{st} part (A) of the area yields a depth of 875 m, whereas the depths for parts 2 (B) and 3 (C) are around 400 m. This clearly indicates that there is a significant change in magnetic character of the rocks between segments- A and the remaining two parts. The segment A, is associated with the late Archean meta basalt and hornblende schists and is in contact with the granite-gneissic terrain at B and C.

QUANTITATIVE ANALYSIS

In the present analysis we have chosen five principal magnetic profiles AA', BB`, CC', DD' & EE' (Fig 2) for model studies. We used the MAGMOD software of Paterson, Grant and Watson, Ltd., Canada (PWG, 1982). The shape and size parameters of the interpreted five profiles are tabulated in Table 1. The profile AA' is located at western part of the Mortadu village having an amplitude of 110 nT. The depth of the causative source below this profile is 165 m with susceptibility value of -0.0026 cgs units (Fig 5a). The profile BB' is located at eastern part of the Mortadu village having an amplitude of 110 nT. The depth to the top of the body at this profile is 105 m with susceptibility value of -0.0020 cgs units (Fig 5b). The obtained negative susceptibilities from the model studies of Profile AA' & BB' indicated, the zone near Mortadu village have undergone intense shearing and reworking of the gneissic material, during the emplacement of dykes and subsequent depletion of magnetic material.

The profiles CC' and DD' are chosen near Garladinne fault-fracture (Part B in Fig 2) area. The depth of the causative source from the Profile CC' is about 100 m (Fig 5c), where as profile DD' is about 120 m (Fig 5d). The interpreted negative susceptibility from these two profiles represents the diamagnetic character of the quartz reef at Garladinne falut zone (Table 1).

The profile EE' is located near Singanamala water tank (Part C in Fig 2) with an amplitude of 120 nT. The depth to the top of the body is 240 m at this profile and it is associated with hornblende schist rock with metabasalt of late Archaean.

Table 1. : Body parameters of the five profiles AA', BB', CC', DD' and EE'.

Body Parameters	Profile AA'	Profile BB'	Profile CC'	Profile DD'	Profile EE'	Average depth
Depth	166 m	105 m	98 m	117 m	240 m	~ 150 m
Half width	250m	290 m	500 m	280 m	220 m	
Dip	62°	72°	65°	75°	77°	
Position	1525 m	730 m	1100 m	1140 m	750 m	
Dip Direction	225°	135°	225°	45°	0°	
Base Level	-22 nT	-25 nT	-14 nT	-48 nT	-24 nT	
Base Slope	4.0 nT/Km	3.0 nT/Km	4.7 nT/Km	16 nT/Km	9.0 nT/Km	
Inclination	17°	17°	17°	17°	45°	
Susceptibility	-0.0026 c.g.s	-0.0020 c.g.s	-0.0016 c.g.s	-0.0026 c.g.s	0.0020 c.g.s	

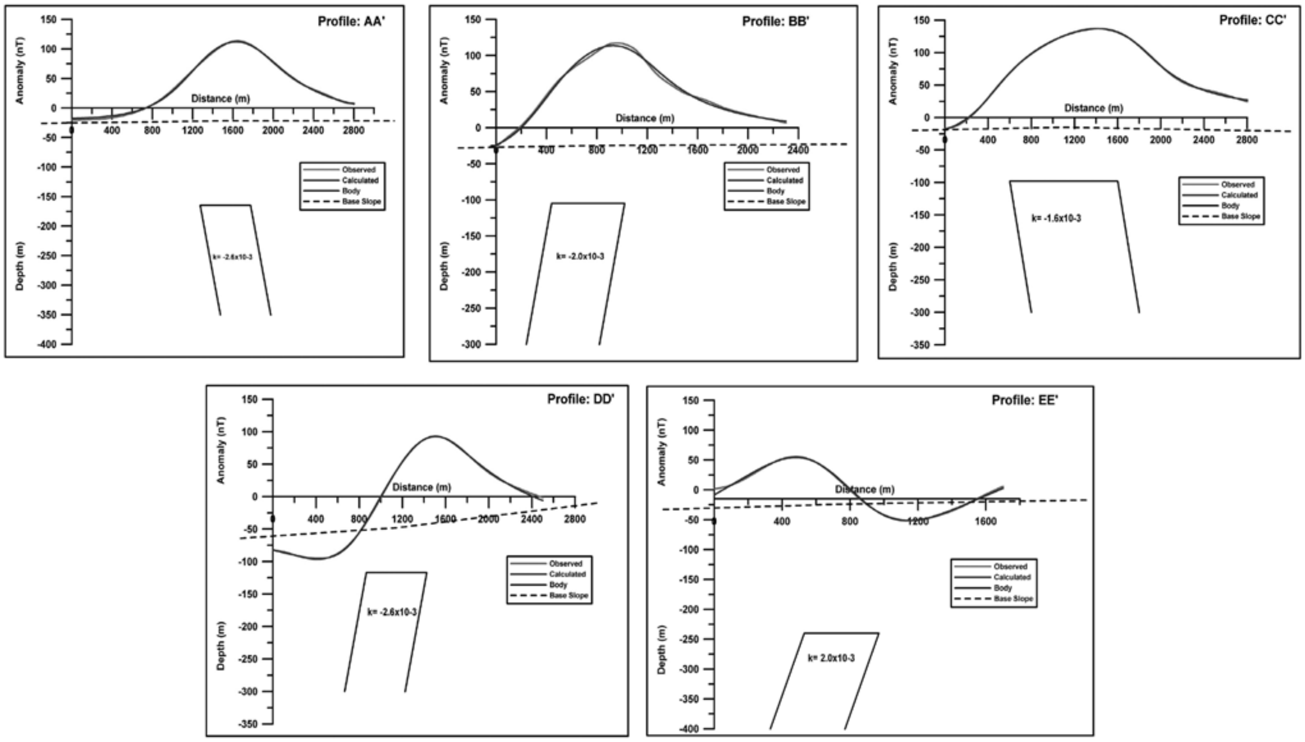

Figure 5 (**a**) Derived depth model of AA' profile, (**b**) Derived depth model of BB1 profile, (**c**) Derived depth model of CC' profile, (**d**) Derived depth model of DD' profile, (**e**) Derived depth model of EE' profile.

CONCLUSIONS

Analyses of Total intensity aeromagnetic anomaly field and the apparent susceptibility image of a part of the granite-greenstone terrain located in the EDC have been carried out. Correlation of the hydrological and geomorphological information with the aeromagnetic data has yielded:

An intensely sheared granite-gneissic terrain in contact with the late Archean green stone belt in the western part has been inferred as the causative source of the positive magnetic anomaly, in this study area.

The "drag" feature associated with the dislocated positive anomaly closures in the western part is inferred to be caused due to strike slip environment. This region is associated with a number of wells bounded by NW-SE and E-W trending dykes.

Power spectrum analysis and model studies of the aeromagnetic field indicated a subsurface magnetic marker/ horizon at a depth of 150 m. The region above the marker has been inferred to be a probable zone of sheared, fractured, weathered and semi weathered zone. The ground water potentiality may be high in this zone.

The positive magnetic anomaly closure in the segment B is associated with a sheared granite-gneissic terrain occupied by diamagnetic quartz reef.

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