Crustal Structure from Gravity and Magnetic Anomalies in the Southern Part of the Cauvery Basin, India

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Abstract: The gravity and magnetic data along the profile across the southern part of the Cauvery basin have been collected and the data is interpreted for crustal structure depths.The first profile is taken from Karikudito Embalecovering a distance of 50 km. The gravity lows and highs have clearly indicated various sub-basins and ridges. The density logs from ONGC, Chennai, show that the density contrast decreases with depth in the sedimentary basin, and hence, the gravity profiles are interpreted using variable density contrast with depth. From the Bouguer gravity anomaly, the residual anomaly is constructed by graphical method correlating with well data and subsurface geology. The residual anomaly profiles are interpreted using polygon and prismatic models. The maximum depths to the granitic gneiss basement are obtained as 3.00 km. The regional anomaly is interpreted as Moho rise towards coast. The aeromagnetic anomaly profiles are also interpreted for charnockite basement below the granitic gneiss group of rocks using prismatic model.

Key words : Cauvery Basin, Gravity, Variable density contrast, Granitic gneiss basement, Magnetic, Charnockite Basement

1. INTRODUCTION

The Cauvery basin is located between 9^{o}N-12^{0}N latitudes and 78^{o}30^{1}E - 80^{o}30^{1}E longitudes on the east coast of India and covers 25,000 sq. km on land and 35,000 sq. km offshore. It consists of six sub-basins and five ridge patterns. The basement is comprised of the Archean igneous and metamorphic complex predominantly granitic gneisses and to a lesser extent khondalites.Sastri et al (1973, 1977 and 1981) and Venkatarengan (1987) provided the earliest details on stratigraphy and tectonics of the sedimentary basins on the east coast of peninsular India. The Cauvery basin has come into existence as a result of fragmentation of the eastern Gondwanaland which began in the Late Jurassic (Rangaraju et.al, 1993). Lal et al (2009) have provided a plate tectonic model of the evolution of East coast of India and the NE-SW trending horst and grabens of Cauvery basin are considered to be placed juxtaposing fractured coastal part of Antarctica, located west of Napier Mountains The Cauvery basin is a target of intense exploration for hydrocarbons by the Oil and Natural Gas Corporation (ONGC) and has been extensively studied since early 1960. This is one of the promising petroliferous basins of India. Many deep bore-wells have been drilled in this basin in connection with oil and natural gas exploration. These wells revealed a wealth of information about the stratigraphy and density of the formations with depth. The Cauvery basin is for the most part covered by Holocene deposits. Sediments of late Jurassic to Pleistocene age crop out in three main areas near the western margin of the basin and gently dip towards the east. The oldest sediments in this basin are Sivaganga beds of late Jurassic age. The maximum sediment thickness of the basin is about 6000m (Prabhakar and Zutshi, 1993).O.N.G.C.

conducted gravity and magnetic surveys in the Cauvery basin in 1960s (Kumar, 1993) and presented the Bouguer gravity anomaly map. Avasthi et al (1977) have published gravity and magnetic anomaly maps of Cauvery basin. Verma (1991) have analyzed few gravity profiles in the Cauvery basin. Subrahmanyam et al (1995) has presented offshore magnetic anomalies of Cauvery basin. Ram Babu and Prasanti Lakshmi (2004) have interpreted aeromagnetic data for the regional structure and tectonics of the Cauvery basin. The geological and geophysical work clearly delineated the presence of a number of ridges and sub-basins trending in NE-SW directions (Prabhakar and Zutshi, 1993 and Hardas, 1991): They are: i. Pondicherry sub-basin ii. Tranquebar sub-basin iii.Tanjavur sub-basin IV.Nagapattinam sub-basin v. Palk Bay sub-basin and vi. Mannar sub basin and i. Madanam Ridge ii. Kumbakonam Ridge iii.Karaikal Ridge iv. Mannargudi Ridge v. Mandapam Ridge. The gravity and magnetic surveys are carried out in the entire Cauvery basin along nine profiles, at closely spaced interval, and placing the profiles at approximately 30 km interval and perpendicular to various tectonic features. In this paper gravity and magnetic anomaly profile is PP' presented along the tectonic map of Prabhakar and Zutshi (1993).The gravity anomalies are interpreted with variable density contrast for granitic gneiss basement and the aeromagnetic profiles are interpreted for the chornockite basement below the granitic gneiss group of rocks

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2. MATERIALS AND METHODS. GRAVITY AND MAGNETIC SURVEYS

The gravity, magnetic and DGPS(Differential Global Position System) observations are made along three profiles across the various tectonic features (Prabhakar and Zutshi, 1993) in the central part of the Cauvery basin as shown in Fig.1.Gravity measurements have been made at approximately 1.5 to 2km station interval. Gravity readings are taken with Lacoste-Romberg gravimeter and Position locations and elevations are determined by DGPS(Trimble).The HIG (Haiwaii Institute of Geophysics) gravity base station located in the Ist class waiting hall of Vridhachalam railway station is taken as the base station. The latitude and longitude of this base are $11^{0}32^{1}06.45885^{11}$N and $79^{0}18^{1}59.19866^{11}$E respectively. The gravity value at this base station is 978227.89 mgals. With reference to the above station, auxiliary bases are established for the day to day surveys. The Bouguer anomaly for these profiles is obtained after proper corrections viz (i) drift (ii) free air (iii) Bouguer and (iv) normal. The Bouguer density is taken a value of 2.0gm/cc after carrying out density measurements of the surface rocks. The gravity observations are made along available roads falling nearly on straight lines .The maximum deviations from the straight lines at some places are around 5 km. Total field magnetic anomalies are also observed at the same stations using Proton Precession Magnetometer but the data is later found to be erroneous. In order to get magnetic picture, aeromagnetic anomaly maps in topo sheets 58M, 58N, 58J, 58K, 58O, 58L, 58H covering the total Cauvery basin on land from GSI are procured and anomaly data is taken along these three profiles. The total field magnetic anomalies are observed at an elevation of 1.5 km above msl. IGRF corrections are made for this data using standard computer programs and the reduced data is used for interpreting magnetic basement.

Gravity profile along PP'

The profile (PP') runs from Karikudi(Latitude 10°01.06.84367"N and Longitude 78°33'13.8292"E) to Embale, (Latitude 9°01'08.47826"Nand Longitude 78°59'12.71739"E) covering a distance of 50 km and 23 stations are established along this profile (Fig.1).The data is collected on 20/3/2007. This profile passes across the Tanjavur sub-basin, Mannargudi ridge (Fig.1). The profile is sampled at 5 km station interval .The minimum and maximum Bouguer gravity anomalies over the basins and ridges are -45,-35,1.8 and 2,-17,0.7,.The profile is passing through one ONGC well which was drilled upto a depth, of; 1500.00 meters and did not reach granitic gneiss basement and is plotted as dotted lines in Fig.1,(Jayakondam-1).The basement depths based on sub-surface geology (Prabhakar and Zutshi, 1993), shown in Fig.1, are plotted as dotted curve. Based on this data and by trial and error method of modeling, a smooth regional curve is drawn such that the interpretation of resulting residual anomalies with quadratic density function gives rise to the depths conforming to the depths given by wells and sub-surface geology. The regional is -25mgals at the origin and continuously increases reaching a maximum of 22mgals at 50 km distance from the land border of the basin. The regional is subtracted from the Bouguer anomaly and the residual is plotted as shown in Fig 1. The residual anomaly is interpreted with quadratic density function using polygon model (BhaskaraRao and Radhakrishna Murthy1986) and also with prismatic model (BhaskaraRao 1986).The depths are obtained by iterative method using Bott's method and the results at 10th iteration are plotted as polygon and prismatic models as shown in Fig.1. The errors between the residual and calculated anomalies in both the methods are below ±0.1 mgals. The maximum and minimum depths over the basins and ridges are the interpreted depths are nearly coinciding with the depths given by Prabhkar and Zutshi (1993). The regional is interpreted for Moho depths. For this, the normal Moho value outside the basin is taken as 42km from Kaila et al (1990) and the regional anomaly is obtained by removing a constant value of -25mgals from the regional and a density contrast of +0.6 gm/cc is assumed between the upper mantle and crust. The depths to Moho are deduced from the regional anomaly by Bott's method and the Moho rise is plotted at the bottom of Fig.1 and the Moho is identified at 34.0 km depth near the coast to 42 km on land border of the basin in NW.

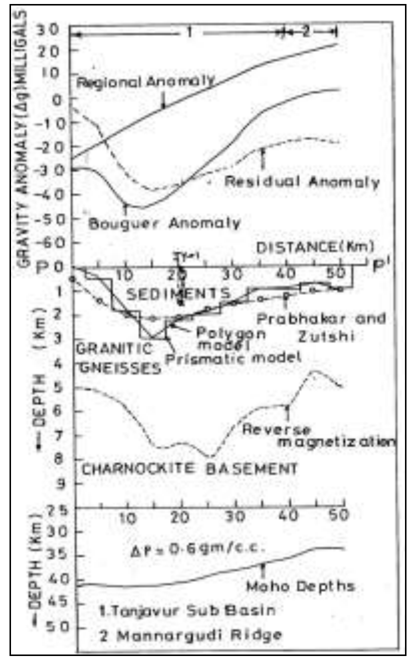

Figure 1. Interpretation of gravity anomaly profile along PP'

Magnetic profile along PP'

The magnetic data for the profile PP' is taken from two topo sheets (58J and 58K).To construct the profile, the observed stations are placed on topo sheets of the magnetic anomaly map and a mean straight line is drawn. The points of intersection of the magnetic contours with the straight line are noted and these values are plotted against the distance .This aeromagnetic data was collected in the year 1983 and diurnal corrections were made before contouring the data. IGRF corrections made to this data using 1985 coefficients as and the magnetic anomaly profile is constructed. The length of the magnetic anomaly profile is 50 km and is sampled at 5 km interval. The magnetic anomalies vary from 36ηT to 164ηT. The anomalies are interpreted for magnetic basement structure below granitic gneisses using prism model. The profile is interpreted by taking the mean depth of the basement at 5.0 km and constraining the depths to upper and lower limits of the basement as 2.0 km and 8.0 km respectively. The FORTRAN computer program TMAG2DIN to interpret the profiles is taken from Radhakrishna Murthy (1998). The program is based on the Marquadt algorithm and this seeks the minimum of the objective function defined by the sum of the squares of the differences between the observed and calculated anomalies. A linear order regional, viz; Ax+B, is assumed along this profile and the coefficients A and B are estimated by the computer. The profile is interpreted for different magnetizations angles (Φ)+18,-18 and intensity of magnetizations (J) 450.The average value for the total field (F)39780 , inclination (i)4.0 and declination (d)0.0 along this profile and the measured angle between the strike and magnetic north (α)22. Based on this data, the magnetization angle Φ is calculated to be 11.00°. But by trial and error, the best fit of the anomalies for Φ and J. The values of the objective function, lamda (ג), regional at the origin (A), regional gradient (B) and the no.of iterations executed for normal as well as reverse magnetization. Here the objective function for normal magnetization is 3.46 and that of reverse magnetization is 18.51. The residual anomaly after removing the regional from the observed anomaly is plotted in the figure 2. The differences between the residual and the calculated anomalies are negligible as shown in the figure 2. The interpretations of the depths for normal and reverse magnetizations for charnockite basement. The depths for these two interpretations are not much different. As the average susceptibility of the granitic gneisses is of the order of $10*10^{-6}$cgs units and that of charnockite is $2000*10^{-6}$cgs units, granitic gneiss basement cannot explain the observed magnetic anomalies. The modeling results place the charnockite basement 0 to 8 km below the granitic gneiss basement along this profile. The existence of charnockite basement below granitic gneisses was also noted by Narayaswamy (1975).

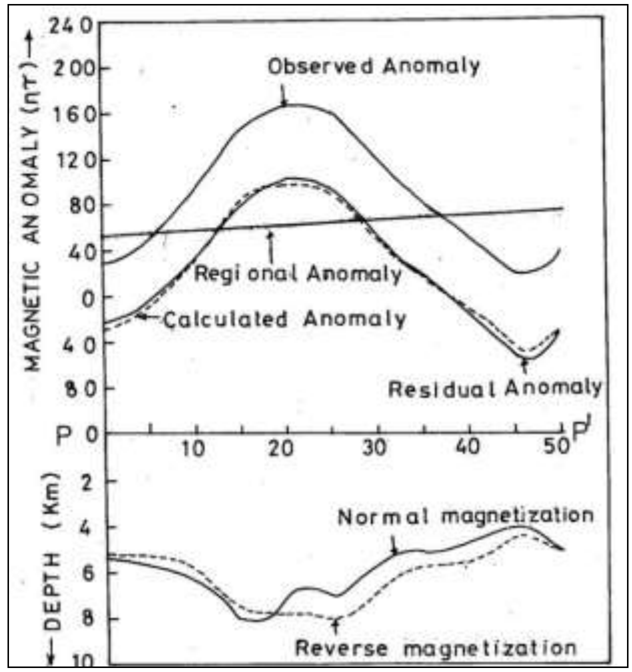

Figure 2. Interpretation of total field magnetic anomaly profile along PP'

3. RESULTS AND DISCUSSION.

The gravity and magnetic surveys have been carried out along profile laid perpendicular to various tectonic features, approximately at 30 km interval, in the southern part of the Cauvery basin. The subsurface geology and information available from the boreholes along these profiles are used to estimate the regional in the case of gravity anomalies. The residual gravity anomalies are interpreted for the thickness of the sediments in the basins and on ridges using variable density contrast. The density data obtained from various boreholes drilled in connection with oil and natural gas exploration is used to estimate variable density contrast, which is approximated by a quadratic function. The gravity anomalies are interpreted with polygon model (BhaskaraRao and Radhakrishna Murthy 1986) and also with prismatic model (BhaskaraRao, 1986), and the depths are plotted and these are nearly the same for both the methods: The basement for the sedimentary fill is the granitic gneiss group of rocks. The maximum depths obtained in the Tanjavur sub-basin is 3.0 km along PP' profile. The regional anomaly is interpreted for Moho depths and it is rising towards coast along these profiles. The Moho depth outside the basin is taken as 42 km and the Moho depths near the coast are obtained as 34.0 km for the PP'. The gravity studies clearly brought out the structure of the sedimentary basin along the profile and supplement the geological studies. The aeromagnetic anomalies along these three profiles are also interpreted as a basement structure below the sediments. The magnetic basements do not coincide with the gravity basements. The depths obtained for chornackite basement for normal and reverse magnetizations are nearly the same. The best fit for the observed magnetic anomalies is obtained for chornackite basement structure0 to 8 km below the granitic gneiss basement. The values of magnetizations angle and intensity of magnetization show that the anomalies are caused by remanent magnetization. There is no correlation between the basements obtained by gravity and magnetic methods. A close fit with the observed magnetic anomalies is obtained for reverse magnetization. However, the charnockite basement structure for normal and reverse magnetizations are not much different. The interpretation of magnetic anomalies clearly brought out the existence of charnockite basement below the granitic gneiss basement. The observed magnetic anomalies can be best explained with the intensity of magnetizations 450 gammas for PP'. The modeling results for various profiles place the chornackite basement at 0 to 8km below the granitic basement.

4. CONCLUSIONS.

The profile PP' runs from Karikudi to Embale covering a distance of 50 km. This profile passes across the Tanjavur sub-basin and Mannargudi ridge.The residual anomaly is interpreted with quadratic density function using polygon and prismatic models. The depths obtained by gravity methods on the Tanjavur sub basin and Mannargudi ridge are 1.8 km, and 0.7 km respectively. The interpreted depths are nearly coinciding with the depths given by Prabhakar and Zutshi (1993) and drilled depths. The regional gravity anomalies are interpreted for Moho depths. The Moho is identified at 34.0 km depth near the coast to 42 km on land border of the basin in NW. The magnetic anomaly profile is interpreted with different intensity of magnetizations (J) and dips (Φ) for charnockite basement. There is no correlation between the basements obtained by the gravity and magnetic methods. The observed magnetic anomalies can be best explained with the intensity of magnetization of 450 gammas and dips of ±18.0 degrees. The objective functions for normal and reverse magnetizations are 3.46 and 18.51 respectively.

5. ACKNOWLEDGEMENTS

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