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Basin structure from gravity and magnetic anomalies in the Ramanathapuram sub-basin of 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 profile is taken from Manamudrai to Eruvadi covering a distance of 65 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 profile is interpreted using variable density contrast with depth. From the Bouguer gravity anomaly, the residual anomaly is constructed by graphical method by correlating with well data and subsurface geology. The residual anomaly profiles is interpreted using polygon and prismatic models. The maximum depths to the granitic gneiss basement are obtained as 4.50 km. The regional anomaly is interpreted and observed that Moho rise towards coast. The aeromagnetic anomaly profile is also interpreted for charnockite basement below the granitic gneiss group of rocks using prismatic model.*

Key words*: Cauvery Basin, Gravity anomaly, Variable density contrast, Granitic gneiss basement, Magnetic anomaly, Charnockite Basement, Moho depth.*

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I. INTRODUCTION

The Cauvery basin is located between 9°N-12^{0}N latitudes and 78°30^{1}E to 80°30^{1}E longitudes on the east coast of India and covers 25,000sq. 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. 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). 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 figure. I .The maximum sediment thickness of the basin is estimated to be 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 the gravity and magnetic anomaly maps of Cauvery basin. Verma(1991) has analyzed few gravity profiles in the Cauvery basin. RamBabu and Prasanti Lakshmi (2004) has interpreted aeromagnetic data for the regional structure and tectonics of the Cauvery basin.

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 on the Ramanathapuram sub-basin is presented along the line shown in the tectonic map of Prabhakar and Zutshi (1993)(Figure 2).The gravity anomalies are interpreted with variable density contrast for granitic gneiss basement and the aeromagnetic profile is interpreted for the charnockite basement below the granitic gneiss group of rocks.

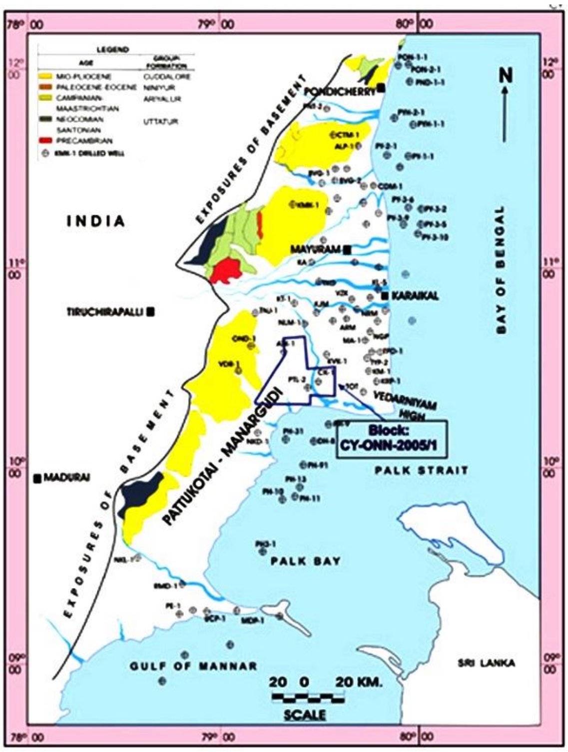

Fig.1. Geology map of the Cauvery basin

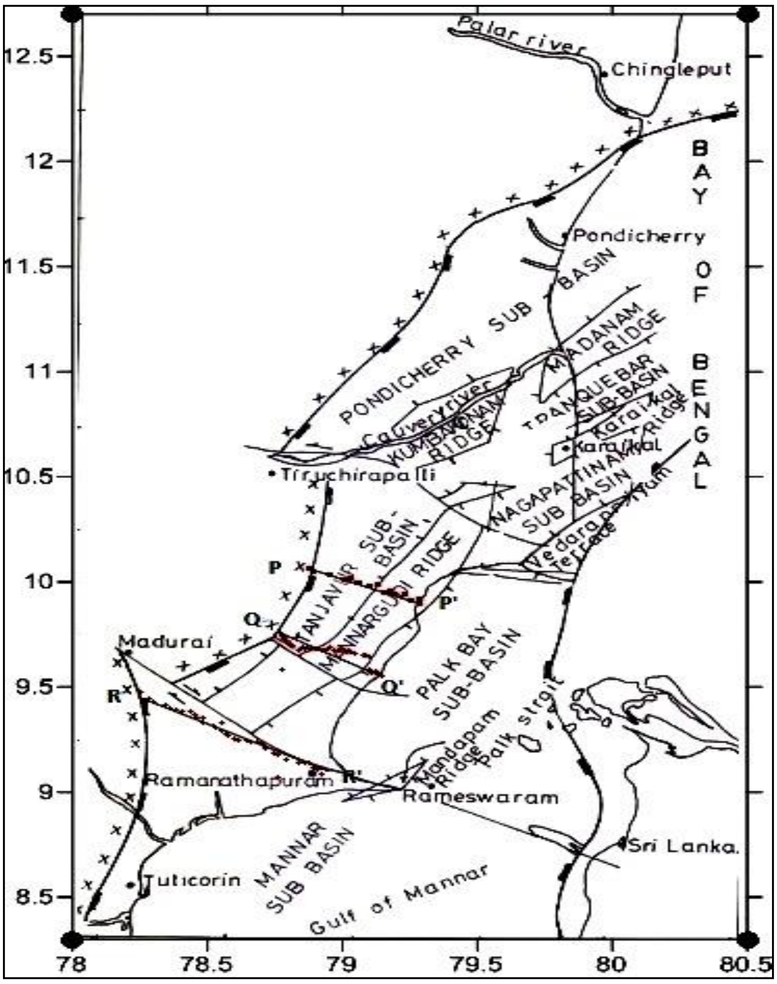

Fig.2.Tectonic elements of Cauvery basin (after Prabhakar and Zutshi,1993).

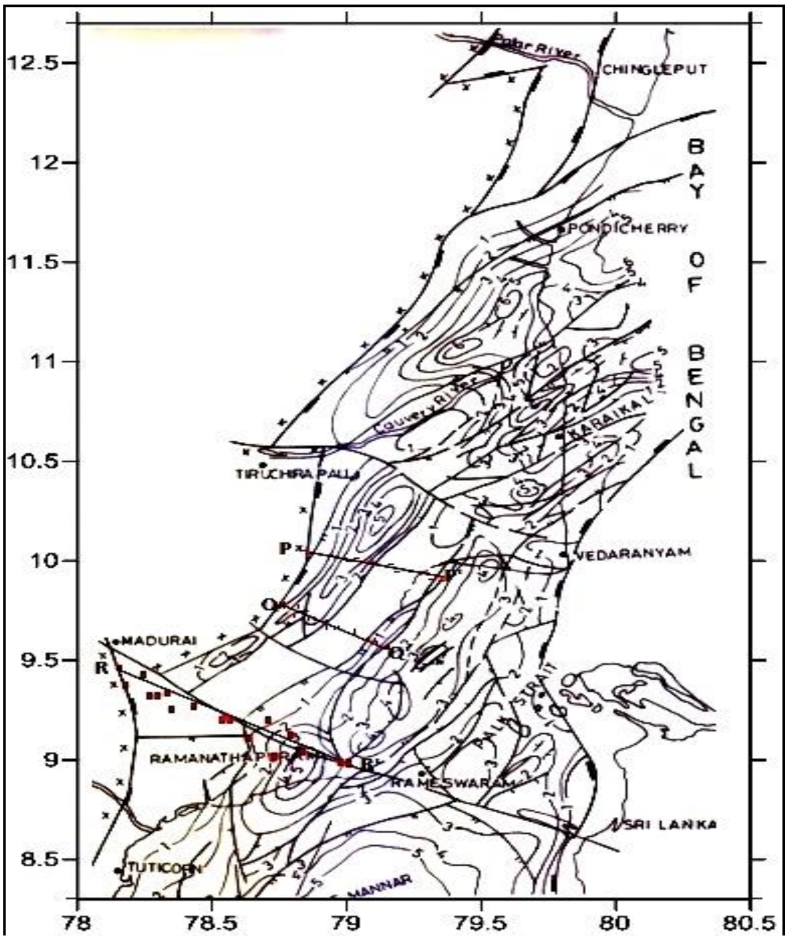

Fig.3.Basement configuration map of Cauvery basin (after Prabhakar and Zutshi,1993).

II. MATERIAL AND METHODS

GRAVITY AND MAGNETIC SURVEYS

The gravity, magnetic and DGPS(Differential Global Position System) observations are made along this profile across the various tectonic features (Prabhakar and Zutshi, 1993) in the northern part of the Cauvery basin in this paper we this discuss RR^1 profile only as shown in Fig.2 and basement configuration map Fig.3, 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 Bougher 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 2.0 gm/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,58Land 58H covering the total Cauvery basin on land from GSI are procured and anomaly data is taken along this profile. 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.

MAGNETIC CORRECTIONS

DIURNAL CORRECTION

The aeromagnetic data was already corrected for diurnal correction while the magnetic contour maps were prepared and hence no additional diurnal corrections are made here.

IGRF CORRECTION

The International Geomagnetic Reference Field (IGRF) is a mathematical model of the normal magnetic field of the earth. This model is a function of data, location and elevation, and the model is updated every five years based on magnetic observations from base stations located throughout the world. Once updated, the model is termed the Definitive Geomagnetic Reference Field (DGRF).The magnetic anomalies in the survey can be corrected for the IGRF by subtracting the IGRF model values at each point in the survey. The aeromagnetic data was collected in the year 1983 in the Cauvery basin. IGRF corrections are made to the data along this profile RR^1 using IGRF coefficients of 1985 as the data collected in the year 1983. By removing the normal variations of magnetic field from the observed aeromagnetic anomalies, we get the total field magnetic anomalies.

VARIATION OF DENSITY CONTRAST WITH DEPTH

The density data with depth from 26 wells in the Cauvery basin, drilled by ONGC, have been collected. The granitic gneiss basement is assumed to be having an average density of 2.7gm/cc. This value is subtracted from the well densities to obtain the density contrast with depth in the basin. After plotting these values against depth, a mean curve representing the variation of density contrast with depth has been drawn and shown in Fig.4.The well log density is available up to a depth of 4.5km. However, the curve is extended up to a depth of 6.8km as the maximum depths deduced from the gravity anomalies are around this value. The density contrast is about –0.67gm/cc at the surface and falls to –0.18gm/cc at 6.0 km depth. The decrease of density contrast is due to compaction, age etc. of the sedimentary strata. Hence, the interpretation of the gravity anomalies cannot be carried out with the assumption of a constant density contrast. The variation of density contrast with depth is approximated to a quadratic function (BhaskaraRao, 1986) such as $\Delta\rho(z) = a_0+a_1z+a_2z^2$, where a_0, a_1, a_2 are the constants to be found. Accordingly, the variation of density contrast is fitted to a quadratic function and the coefficients are solved by the least squares method. The values of the coefficients so obtained for a_0, a_1, a_2 are --0.60012, 0.19931 and -0.02039 respectively.

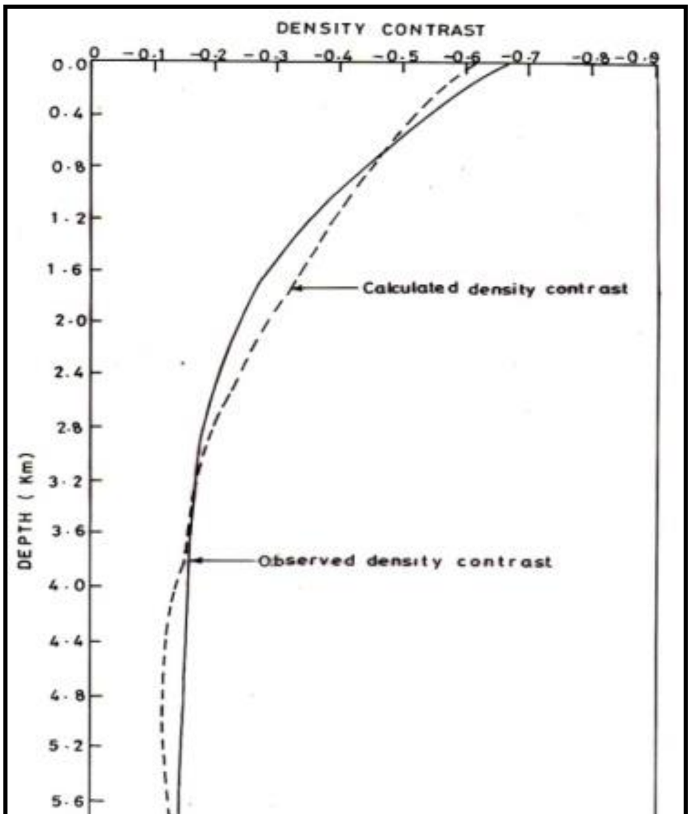

Fig.4.Variation of density contrast with depth of Cauvery basin.

INTERPRETATION:

The gravity profile is interpreted with quadratic density function by the methods described by BhaskaraRao and Radhakrishna Murthy (1986) using polygon model and BhaskaraRao (1986) using prismatic model. The aeromagnetic anomalies are interpreted for charnockite basement below the granitic gneiss group of rocks assuming prism model. The computer program **TMAG2DIN** is taken from Radhakrishna Murthy (1998) for interpretation of magnetic anomalies.

GRAVITY PROFILE ALONG RR'

The profile RR' runs from Manamudrai(Latitude 9°43'01.4901"N and Longitude 78°28'49.54001"E) to Eruvadi (Latitude 9°21'57.58161"N and Longitude 78°43'08.81019 "E) covering a distance of 65 km and 38 stations are established along this profile (Fig. 5).The data is collected for two days from 24/03/2007 to 25/03/2007.This profile passes across the Ramanathapuram sub basin.An auxiliary base station is established at Manamadhuri (land mark of Railway station) for this profile on 24-03-2007 and the gravity value at this place is 978180.6207 mgals. The elevation above msl, latitude and longitude at this base are 67.06 m, 9°43'01.4901"N and 78°28'49.54001"E respectively.18 gravity stations are established along this profile on 24-03-2007 using this auxiliary base. For the next day survey on 25-03-2007, another auxiliary base station at Manamudrai (land mark Railway station) is used, and the gravity value here is 978180.6207 mgals. The elevation above msl, latitude and longitude at this base are 67.06 m, 9°43'01.4901"N and 78°28'49.54001"E respectively. 20 gravity stations are established along RR' profile on 25-03-2007 using this auxiliary base station.The minimum Bouguer gravity anomaly over the basin is given in Table 1.The profile is passing through one ONGC well which was drilled up to a depth of 2200.50 meters (RJ-1,Latitude 9°06'03.13"N and Longitude 78°35'20.110"E) and this did not reach granitic gneiss basement, and is plotted as dotted lines as shown in Fig. 5.The basement depths, based on sub-surface geology (Prabhakar and Zutshi , 1993), are plotted as dotted curve. Based on this data, the regional is assumed as a smooth curve as shown in the figure5. The regional is -43 mGals at the origin and continuously increasing reaching a maximum of+1 mGals towards SE near the coast. The minimum and maximum residual anomaly on the basins is given in Table.1.The residual anomaly is interpreted with quadratic density function using polygon and prismatic models. 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. 5. The maximum depth over the basin is given in Table 1.The interpreted depths are nearly coinciding with the depths given by Prabhakar and Zutshi (1993) and drilled depths. However, the depths obtained by gravity methods are more than the depths given by Prabhakar and Zutshi (1993) between 30 to 55 km distances along this profile. The regional is interpreted for Moho depths. For this, the regional anomaly is obtained by removing a constant value of -43 mGals from the regional. The Moho depths are plotted at the bottom .It is observed that the Moho depths are decreasing towards the coast.

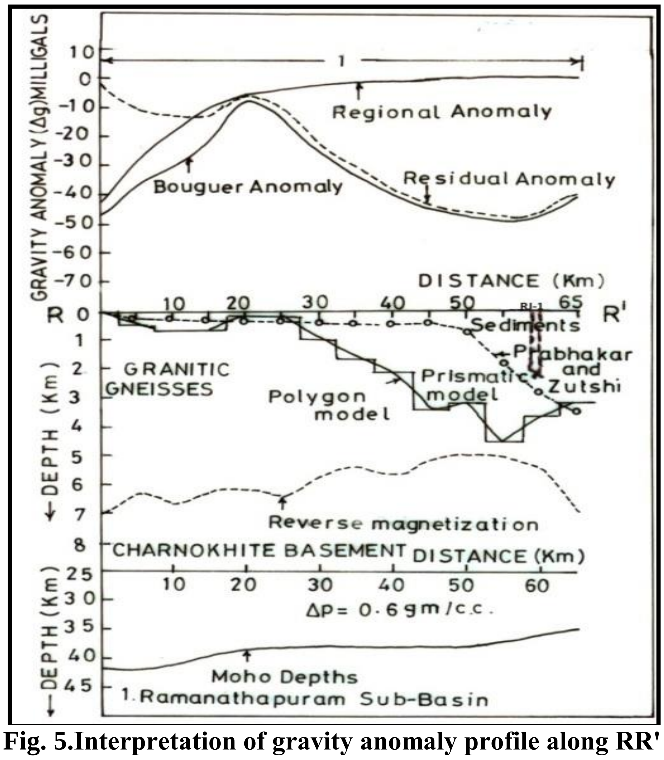

Fig. 5.Interpretation of gravity anomaly profile along RR'

MAGNETIC PROFILE ALONG RR'

The magnetic data for the profile RR' is taken from the topo sheet 58K. This data was collected in the year 1983. IGRF corrections are made to this data using 1985 coefficients and the magnetic anomaly profile is constructed. The length of the magnetic anomaly profile is 65 km and is sampled at 5 km interval. The magnetic anomalies vary from 20ηT to 180 ηT. The anomalies are interpreted for magnetic basement structure below granitic gneiss basement using prism models. The profile is interpreted by taking the mean depth of the basement at 7.0 km and constraining the depths to upper and lower limits of the basement as 2.0 km and 9.0 km respectively. A linear order regional is assumed along this profile. The profile is interpreted for different magnetization angles (Φ) and intensity of magnetizations (J). The results of interpretation of the magnetic profile RR' for normal and reverse magnetization are given in Table 2. The interpretation of the depths for normal and reverse magnetization is shown in Fig.6. These two are nearly the same. The magnetic basement for reverse magnetization is presented in Fig.6.There is no correlation between the basements obtained by gravity and magnetic methods. Here the objective function for normal magnetization is 0.08 and that for reverse magnetization is 0.21.The observed and the best fitting anomalies for reverse magnetization are also shown in Fig. 6. For the reverse magnetization, the linear order regional is as shown in the figure. The residual anomaly after removing the regional from the observed anomaly is plotted in the figure. The differences between the residual and the calculated anomalies are negligible as shown in the figure 6. The charnockite basement depths for the reverse magnetization are from 0 to 7.0 km below the granitic gneiss basement along this profile.

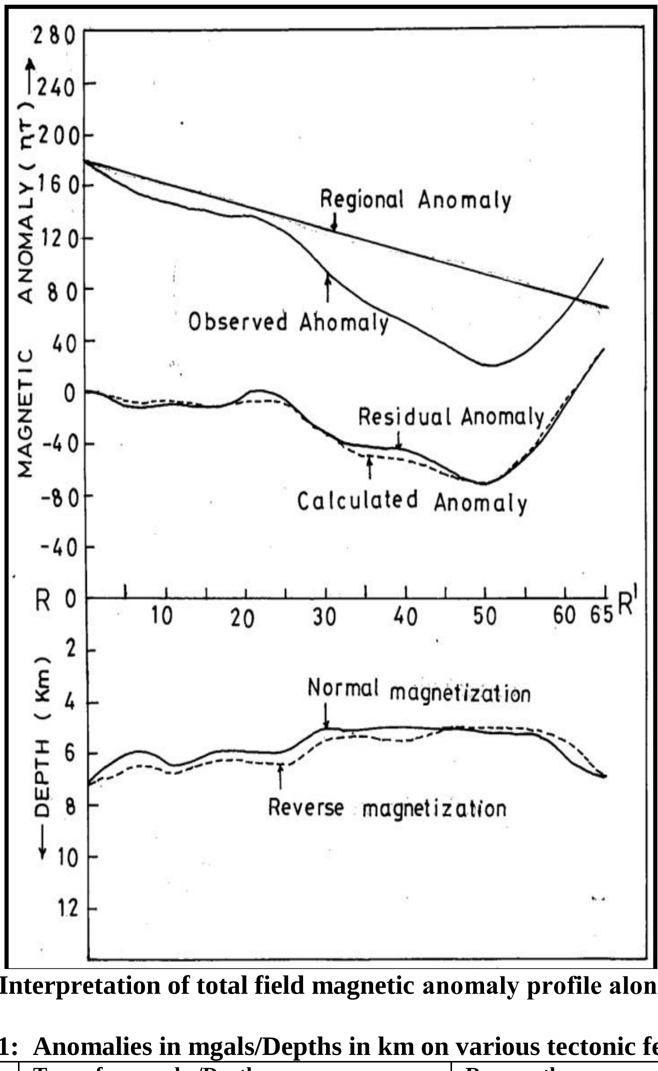

Fig.6.Interpretation of total field magnetic anomaly profile along RR'

Table-1: Anomalies in mgals/Depths in km on various tectonic features

Profile	Type of anomaly /Depths	Ramanathapuram sub-basin
RR'	**Bouguer(mgl)**	**-49.0**
RR'	**Residual(mgl)**	**-48.0**
RR'	**Depths(km)**	**4.50**

Table.2 .Results of magnetic interpretation

Profile	Magnetization	Average value of total field(F)	Average value of inclination (i)	Angle between strike and magnetic north(α)	Calculated magnetization angle (Φ)	Assumed magnetization angle for best fit (Φ)	Assumed value of intensity of magnetization for best fit (J) in gammas	Regional at the origin (A)	Regional gradient (B)	Damping factor (λ)	Iterations carried out	Objective function
RR'	Normal	38850	3.28	31	6.34	+18.0	380	150.3	-0.8	0.00	2nd	0.08
RR'	Reverse	38850	3.28	31	6.34	-18.0	380	176.4	-1.7	0.00	2nd	0.21

III. RESULTS AND CONCLUSIONS

The gravity and magnetic surveys have been carried out along RR^1profile laid perpendicular to various tectonic features, approximately at 30 km interval, in the Ramanathpuram sub-basin of Cauvery basin. The subsurface geology and information available from the boreholes along this profile 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 basin 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 depth obtained in the Ramanathapuram sub-basin is 4.5 km along RR' profile. The regional anomaly is interpreted for Moho depths and it is rising towards coast along this profile. The interpreted depths are nearly coinciding with the depths given by Prabhakar and Zutshi (1993) and drilled depths. However, the depths obtained by gravity methods are more than the depths given by Prabhakar and Zutshi (1993) between 30 to 55 km distances along this profile. It is observed that the Moho depths are decreasing towards the coast.

The aeromagnetic anomalies along this profile are also interpreted as a basement structure below the sediments. The magnetic basement do not coincide with the gravity basement. The depths obtained for charnockite basement for normal and reverse polarization are nearly the same. The best fit for the observed magnetic anomalies is obtained for charnockite basement structure at 0 to 9 km below the granitic gneiss basement. The values of polarization angle and intensity of magnetization show that the anomalies are caused by remanent magnetization. The magnetic basement topography for this profile follows the granitic gneiss basement to some extent. A close fit with the observed magnetic anomalies is obtained for reverse polarization. However, the charnockite basement structure for normal and reverse polarizations are not much different. The interpretation of magnetic anomalies clearly brought out the existence of charnockite basement below the granitic gneiss basement.

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 380 gammas and dips of ±18.0 degrees. The objective functions for normal and reverse magnetizations are 0.08 and 0.21 respectively.

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