Gravity and Magnetic Surveys and Interpretation with Variable Density in the Tanjavur Sub-Basin, South of Cauvery Basin, India

M. Jyothi Prakash[1], T. Annapurna[2], D. Bhaskara Rao[3]

[1]Andhra University, Geophysics Department
Email: *prakashmyneni[at]rediffmail.com*

[2]Andhra University, Geophysics Department
Email: *anuradhaprasad369[at]gmail.com*

[3]Andhra University, Geophysics Department
Email: *dommeti49[at]gmail.com*

Abstract: ***The gravity and magnetic data along the profile across the southern part of the Cauvery basin of India have been collected and the data is interpreted with variable density contract in order to deduce the structure of the sedimentary basin. The profile is taken from Nattarsankotai to Nayattapathi 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 profile is interpreted using polygon and prismatic models. The maximum depths to the granitic gneiss basement is obtained as 11 km. These studies are useful to nearby refine the subsurface geological studies. 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.***

Keywords: Cauvery Basin, Gravity anomaly, Variable density contrast, Bott's method, Granitic gneiss basement, Magnetic anomaly, Charnockite Basement, Tanjavur sub - basin, Moho Depth

1. Introduction

The Cauvery basin is located between 9^{o}N - 12^{0}N latitudes and $78^{o}30^{1}$E to $80^{o}30^{1}$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 useful information about the stratigraphy and density of the formations with depth.

The Cauvery basin is for the most part covered by Holocene deposits. 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[4] 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 Tanjavur 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.

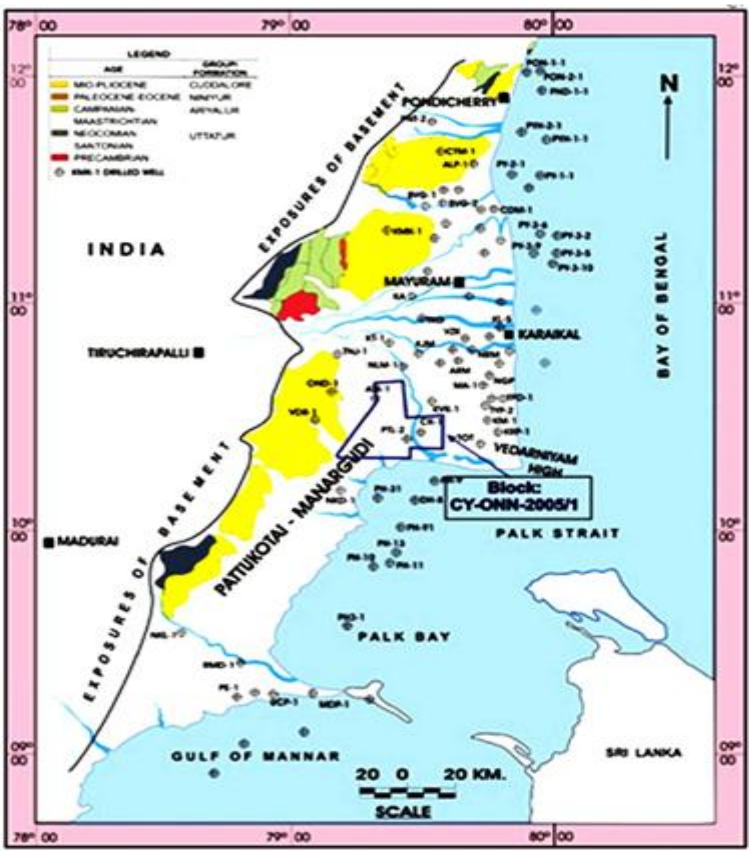

Figure 1: Geology map of the Cauvery basin

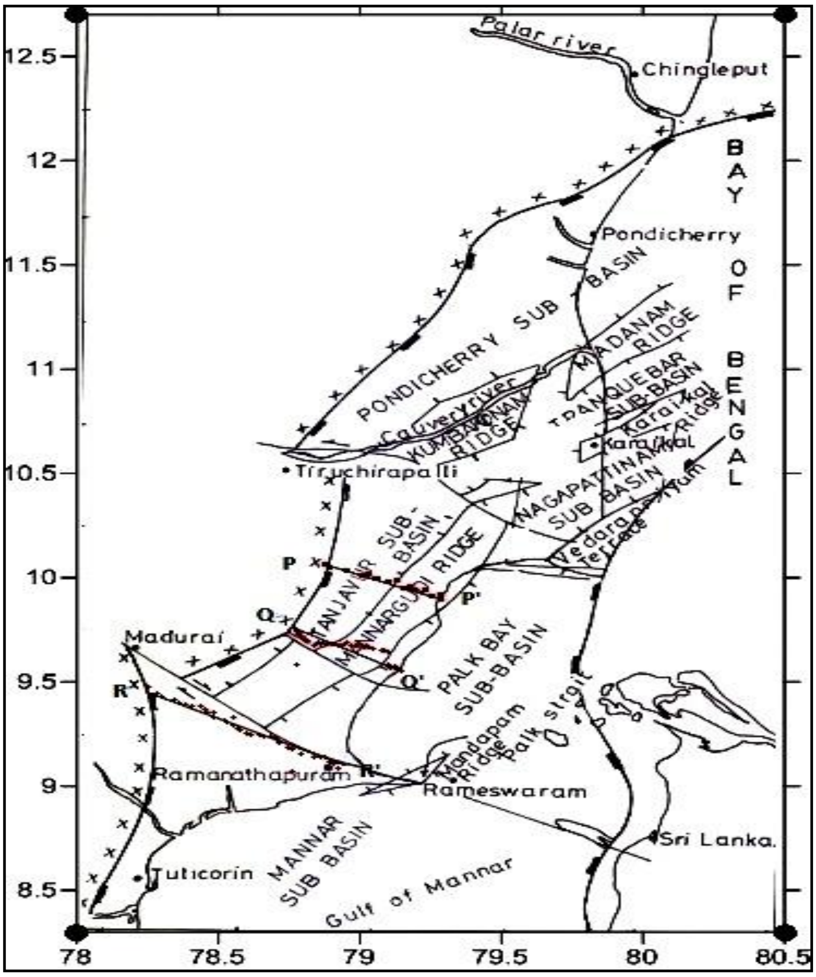

Figure 2: Tectonic elements of Cauvery basin (after Prabhakar and Zutshi, 1993)

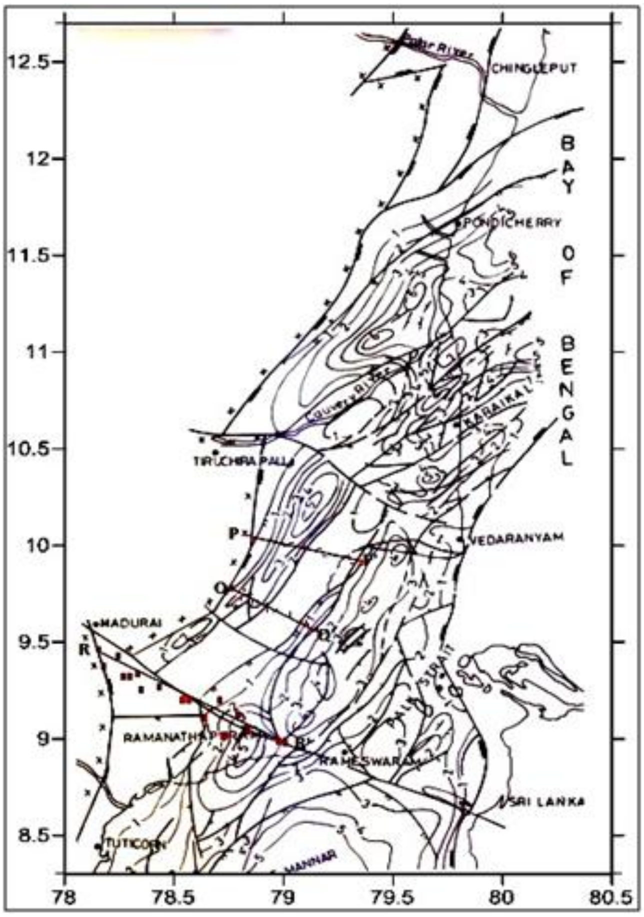

Figure 3: Basement configuration map of Cauvery basin (after Prabhakar and Zutshi, 1993).

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 southern part of the Cauvery basin in this paper we discuss QQ^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 QQ^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 Figure 2. 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[7], 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. 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.

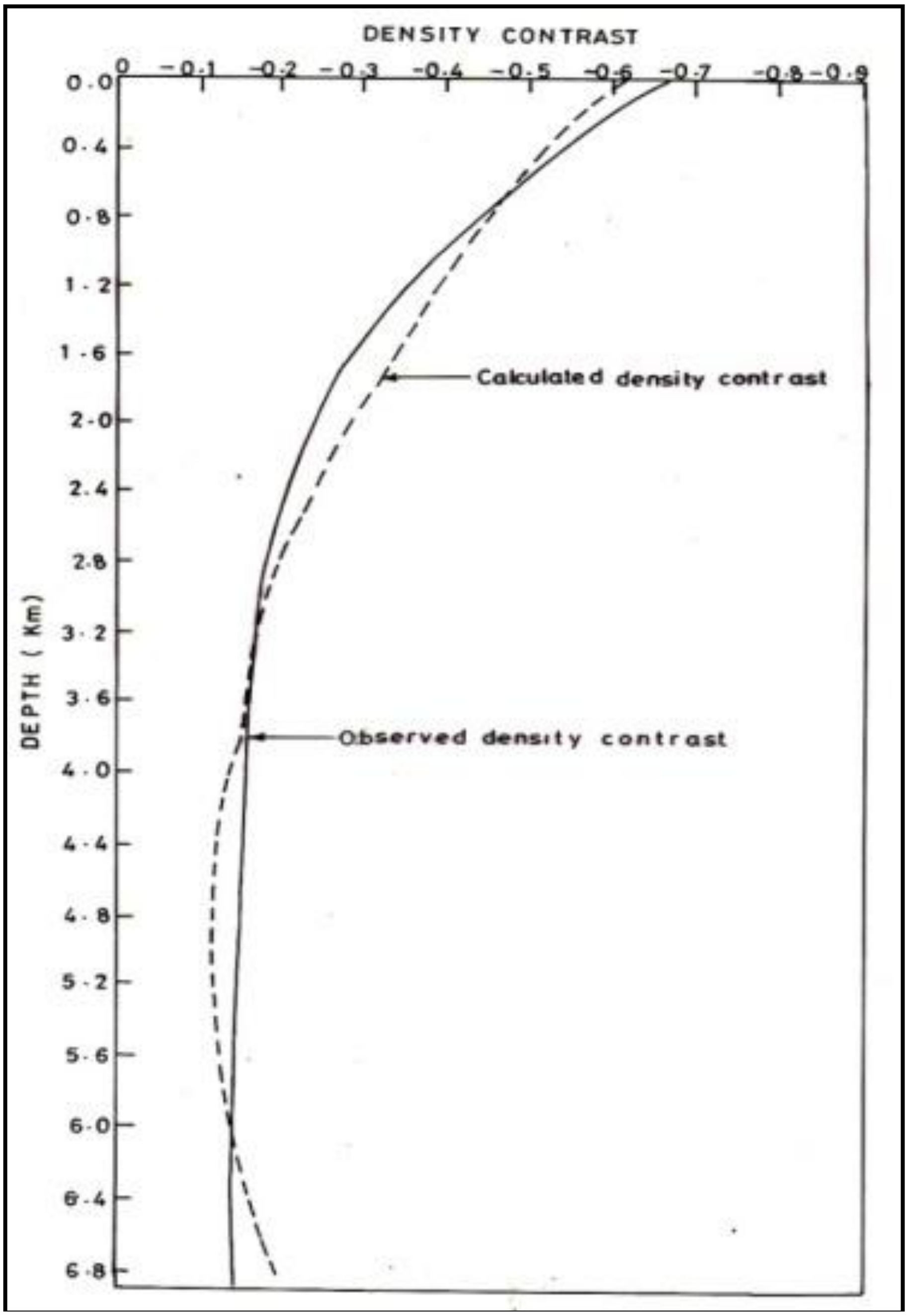

Figure 4: Variation of density contrast with depth

Interpretation

The gravity profile is interpreted with quadratic density function by methods described by BhaskaraRao and Radhakrishna[8] 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[9] Murthy (1998) for interpretation of magnetic anomalies

Gravity Profile along QQ'

The profile QQ' runs from Nattarsankotai (Latitude 9°58'41.74454"N and Longitude 78°38'03.67508"E) to Nayattapathi (Latitude 9°37'46.96189"N and Longitude 78°57'28.61142"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 22/03/2007 to 23/03/2007. This profile passes across the Tanjavur sub - basin and Mannargudi ridge (Fig.2), and the Bouguer anomalies are drawn in (Fig.5). These tectonic features are reflected in the Bouguer and residual anomaly profiles. One of the auxiliary base station is established at Nattrasankottai (land mark Railway station) for this profile on 22 - 03 - 2007 and the gravity value at this place is 978193.6016 mGals. The elevation above msl, latitude and longitude at this base are 88.39 m, 9°58'41.74454"N and 78°38'03.67508"E respectively.20 gravity stations are established along this profile 22 - 03 - 2007 using this auxiliary base. For the next day survey on 23 - 03 - 2007, another auxiliary base station at Nattrasankottai (land mark Railway station) is used, and the gravity value here is 978193.6016 mgals. The elevation above msl, latitude and longitude at this base are 88.39m, 9°58'41.74454"N and Longitude 78°38'03.67508"E respectively.18 gravity stations are established along QQ' profile on 23 - 03 - 2007 using this auxiliary base station.

The minimum and maximum Bouguer gravity anomalies over the basins and ridges are given in Table 1. The profile is passing through one ONGC well which was drilled upto a depth of 2500.00 meters (MIAA - 1, Latitude 9°.35'52.16"N and Longitude 79°52'02.3"E) and did not reach granitic gneiss basement, and are plotted as dotted lines in Fig.5. The basement depths based on sub - surface geology (Prabhakar and Zutshi, 1993) are plotted as dotted curve. Based on this data and using gravity modeling, the regional is assumed as a smooth curve as shown in the figure. The regional is - 40 mgals at the origin and continuously increases reaching a maximum of 15 mGals at 65 km distance from the land border of the Cauvery basin. The regional is subtracted from the Bouguer anomaly and the residual is plotted as shown in the figure 5. The minimum and maximum residual anomalies on the basins and ridges are 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 errors between the residual and calculated anomalies are below +0.2 mgals in both the cases. The maximum and minimum depths over the basins and ridges are given in Table 1. The interpreted depths are nearly coinciding with the depths given by Prabhakar and Zutshi. However, in the SE part of the profile and near the coast the depths obtained by gravity methods are very high reaching about 11.0 km, where the depths given by Prabhakar and Zutshi (1993) are of the order of 1.5 km. The regional is interpreted as undulations in Moho depths. For this, a constant value of - 40 mgals is subtracted from the regional. The Moho is plotted at the bottom of Fig.5 and it shows that Moho reaches 33.0 km towards SE near the coast.

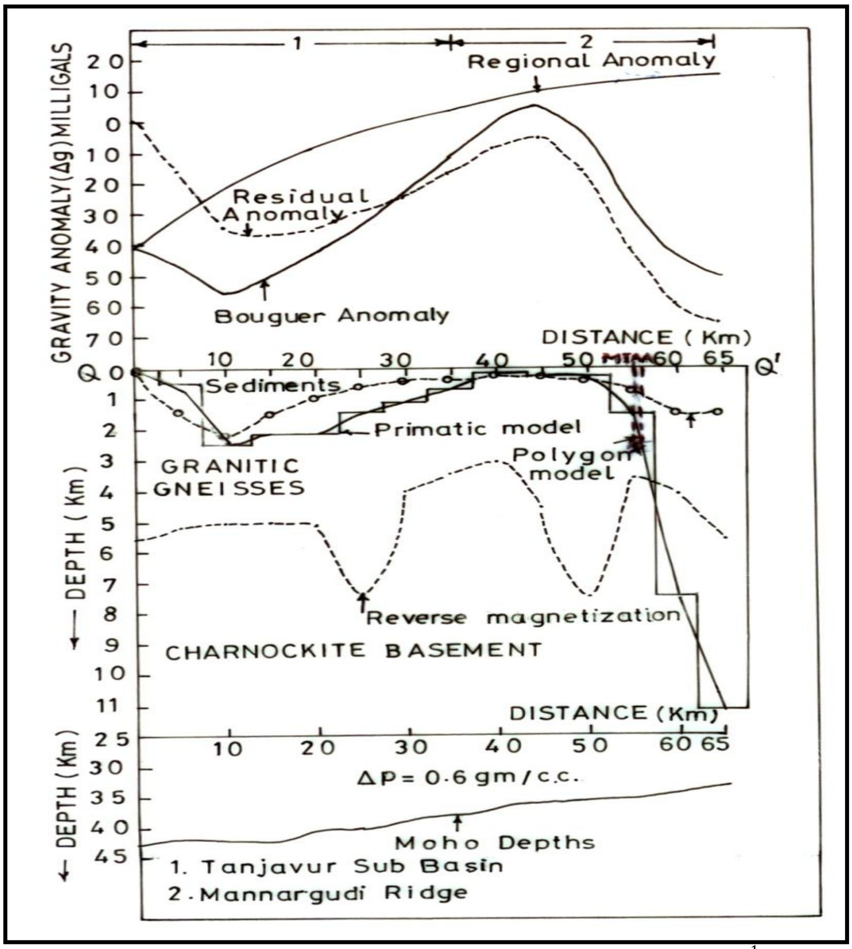

Figure 5: Interpretation of gravity anomaly profile along QQ^1

Magnetic profile along QQ^1

The magnetic data for the profile QQ^1 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 - 28ɳT to 160 ɳT along this profile (Fig.6). The anomalies are interpreted for magnetic basement below granitic gneisses using prism models. After several trials the profile is interpreted by taking the mean depth of the basement at 5.5 km and constraining the depths to upper and lower limits of the basement as 2.0 km and 8.0 km respectively. 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 magnetization angles (Φ) and intensity of magnetizations (J). The results of interpretation of the magnetic profile $QQ^1$are given in Table 2. Based on this data, the magnetization angle Φ is calculated to be 7.88 degrees. But by trial and error, the best fit of the anomalies for Φ and J are given in Table 2. 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 magnetizations are

ISSN: 2319-7064
SJIF (2022): 7.942

also tabulated in Table 2. The interpretation of the depths for normal and reverse magnetization is shown in Fig. 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. The observed and the best fitting anomaly for reverse magnetization are also shown in Fig.6. Here the objective function for normal magnetization is 0.00 and that of reverse magnetization is 9.71. 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 6. 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 7.5 km below the granitic gneiss basement along this profile.

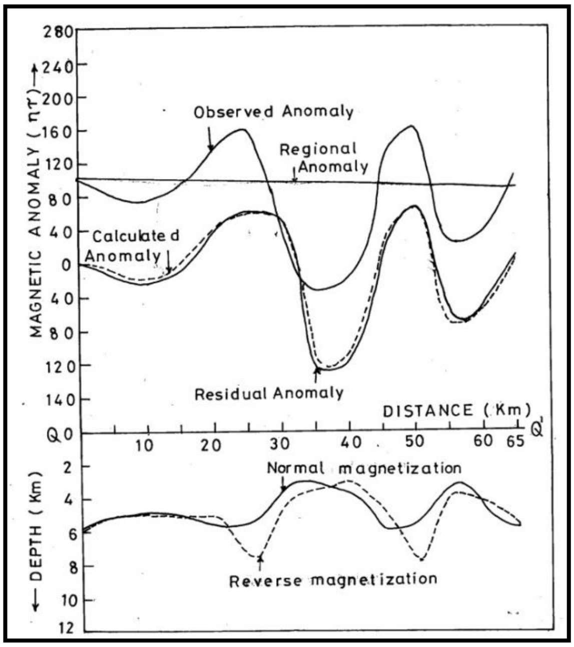

Figure 6: Interpretation of total field magnetic anomaly profile along QQ^1

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

Profile	Type of anomaly/ Depths	Tanjurvur sub- basin	Mannarggudi ridge
QQ^1	Bouguer (mgl)	- 55.0	+5.0
QQ^1	Residual (mgl)	- 34.0	- 5.0
QQ^1	Depths (km)	2.5	0.3

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
QQ^1	Normal	3900	3.6	27	7.88	+18.0	450	79.3	0.6	0.00	3rd
QQ^1	Reverse	3900	3.6	27	7.88	- 18.0	450	99.8	- 0.1	0.00	2nd

2. Results and Discussion

The gravity and magnetic surveys have been carried out along QQ^1 profile laid perpendicular to various tectonic features, in the Tanjavur 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 and on ridge 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 regional anomaly is interpreted for Moho depths and it is rising towards coast along this profile. The Moho depth outside the basin is taken as 42 km and the Moho depth near the coast is obtained as 34.0 km for the QQ^1 profile. The gravity studies clearly brought out the structure of the sedimentary basin along this profile and supplement the geological studies.

The aeromagnetic anomalies along this profile are also interpreted as abasement 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 8 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 observed magnetic anomalies can be best explained with the intensity of magnetization of 450 gammas for the QQ[1] profile.

3. Conclusions

The profile QQ' runs from Nattarsankotai to Nayattapathi covering a distance of 65 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 2.5 km and 0.3 km respectively. The interpreted depths are nearly coinciding with the depths given by Prabhakar and Zutshi. However, in the SE part of the profile and near the coast the depths obtained by gravity methods are very high reaching about 11.0 km, where the depths given by Prabhakar and Zutshi (1993) are of the order of 1.5 km. The regional gravity anomalies are interpreted for Moho depths. Moho reaches a depth of 33.0 km towards SE near the coast.

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 0.00 and 9.71 respectively.

Acknowledgement
A part of this work was carried out during the DST project (2005 - 2009) "Crustal structure, regional tectonics and evolution of K - G and Cauvery basins from gravity and magnetic surveys and modeling" and the financial support received from the DST is gratefully acknowledged. We thank the Director (Exploration), O. N. G. C. for giving permission to use well log density data and seismic data.

References

[1] Avasthi, D. N., V. V. Raju, and B. Y. Kashethiyar, 1977, A case history of geophysicalsurveys for oil in the Cauvery basin: In: Geophysical case histories of India (Ed. V. L. S. Bhimasankaram), Vol.1, p.57 - 77, Assoc. Expl. Geophysics. India
[2] BhaskaraRao, D.1986 Modelling of sedimentary basins from gravity anomalieswith variable density contrast. Geophys. J. R. Astrs. Soc. (U. K), v.84, pp.207 - 212.
[3] BhaskaraRao, D., and I. V Radhakrishna Murthy, 1986, Gravity anomalies of two dimensional bodies of irregular cross - section with variable density contrast. Bolletino Di GeofisicaTeorica ED applicata (Italy), V. XXVIII, N.109, pp.41 - 47.
[4] Kumar, S. P., 1993, Geology and hydrocarbon prospects of Krishna - Godavari and Cauvery basins, Petroleum Asia Journal, V.6, p.57 - 65.
[5] Prabhakar, K. N., and P. L, Zutshi, 1993, Evolution of southern part of Indian East Coast basins, J. G. S. I, V.41, P.215 - 230.
[6] Rangaraju, M. K., A. Agrawal., and K. N Prabhakar, 1993, Tectono - Stratigraphy, Structural Styles, Evolutionary Model and Hydrocarbon Habital, Cauvery and Palar Basins. Proc. Second Seminar on Petroliferous Basins of India. Vol.1. pp.371 - 388.
[7] Radhakrishna Murthy, I. V.1998 Gravity and magnetic interpretation in exploration geophysics, Geol. Soc. India, Mem.40 pp.298 - 305.
[8] Ram Babu, H. V., and M. Prasanti Lakshmi, 2004, A Reappraisal of The Structure And Tectonics of The Cauvery basin (India) From Aeromagnetic And Gravity, 5th Conference &Exposition on Petroleum geophysics, Hyderabad - 2004, India pp19 - 23.
[9] Verma, R. K., 1991. Geodynamics of Indian Peninsula and the Indian Plate margin. Oxford and IBH publishing Co. Pvt Ltd, pp: 76 - 83.

Author Profile

Dr. M. Jyothi Prakash was born in 1964. In 1986 he was completed his post graduation (M. Sc) in Marine Geophysics at Andhra University, Visakhapatnam, India. He was awarded Junior Research Fellow (JRF) in the year 1987 by the University Grants Commission (UGC) and Senior Research Fellow (SRF) in the year 1989 by Council of Scientific and Industrial Research (CSIR), New Delhi. He was awarded doctorate degree in the year 1992 by Andhra University, Visakhapatnam, India. He was also awarded Research Associate (RA) in the year 1993 by CSIR, New Delhi. Dr. M. J. Prakash was joined as a faculty in the department of Geophysics, Andhra University, Visakhapatnam in the year 2005 and continuing his teaching and research in the field of Geophysics.