Integrated Study for Delineating Mesozoic Sediments Across Gulf of Kutch and its Extension Towards Kutch and Saurashtra Mainland

Kh. Nabakumar[1], Gajendra Singh[2] and Kuldeep Prakash[3]

[1]Geophysics Group, KDMIPE, ONGC, Dehradun, India, [2]Publication Division, KDMIPE, ONGC, Dehradun, India

[3]Knowledge Management, ONGC, Dehradun, India

Nabakumar_Kh@ongc.co.in

Abstract

Mesozoic sediments exposed in Kutch and north eastern part of Saurashtra and findings of drilled well in trap covered area suggests its extension below the trap in Saurashtra and across the Gulf of Kutch. An integrated study of Gravity, MT, DSS and other Geophysical data along with inputs from published literature pertaining to Kutch mainland, Gulf of Kutch, Saurashtra mainland and its adjoining areas is carried out for finding the extension of Mesozoic sediments.

Regional gravity anomaly map prepared by using ONGC vintage land and marine data along with satellite gravity data shows a gravity high in the Gulf of Kutch. Gravity modeling along two profiles across the Gulf reveals the basalt thickness may be more than 2000m. Mesozoic sediments are found to be around 3000m in western part of gulf and thinning towards east. Depth to basement is ~6000m in western part of gulf and it is found to be raised to 2600m in northern coast of Saurashtra within a distance of 44km while the top of basalt is uplifted 520m from offshore to onland within a distance of 11km. This suggest that there is no sharp boundary which may be linked to a fault.

Study of MT data indicates uplifting of the basin towards east and the same is also found from gravity modeling.

Introduction

Mesozoic sediments outcrop in Kutch mainland and north eastern part of Saurashtra area may be expected to continue below trap covered area of Saurashtra and across Gulf of Kutch. Drilled wells at Lodhika and Dhanduka in Saurashtra reveal the existence of Mesozoic sediments below Deccan traps. Earlier, integrated studies carried out by NGRI and ONGC shows possible continuity of Mesozoic sediments across Gulf of Kutch. As no profile was considered connecting the two mainland across the Gulf no geological boundaries were suggested. Considering the geomorphology of Kutch and Saurashtra, it was believed that the Mesozoic sediments exposed in Kutch area have its southern limit somewhere at the Gulf of Kutch and it has been known as North Kathiawar fault (NKF). It has its own importance in understanding the geology of Kutch-Saurashtra region.

The fault is believed to have its extension from western margin of Cambay basin to north western tip of Saurashtra horst having an approximate length a little over 300km. Though the pioneer work draws the fault line in a particular place but later workers draw the fault according to their own concepts. As a result different shape, length and locations of the fault are seen in many published and unpublished academic works. Recent development in satellite altimeter derived gravity anomaly resolution and more ship borne data coverage in marine parts together Mesozoic sediment across the Gulf of Kutch with onland gravity data of Kutch and Saurashtra area the very existence of NKF in Gulf of Kutch become questionable.

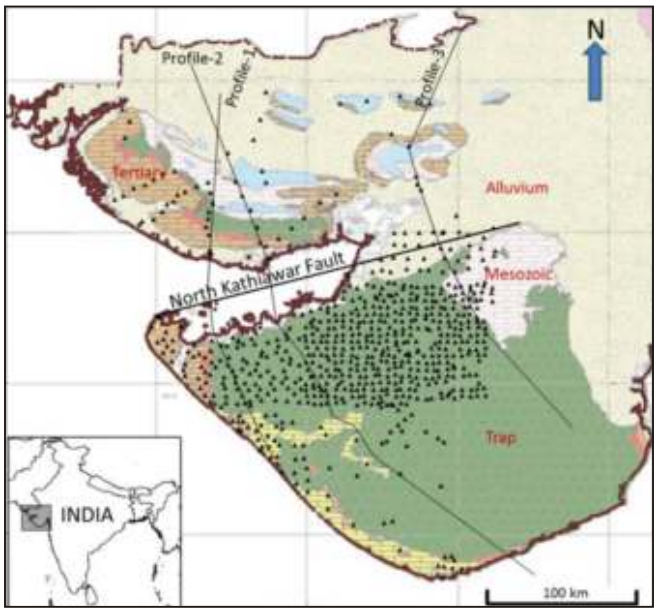

Fig. 1: Location map of study area overlain by geology of the area and available MT stations (black triangles).

Report on Ocean Bottom Seismic and Marine Magneto-telluric data in the Gulf of Kutch suggests existence of thick Mesozoic sediment more than 3.5km below a basaltic trap of 1-2km (RVSONNE_Cruise-report, 2009).

With an aim to find the continuity of Mesozoic sediments gravity modeling of three profiles across the Gulf of Kutch is carried out.

Method

A regional gravity anomaly contour map (fig. 2) is prepared by merging the Bouguer gravity of land part and free air gravity of marine part. The World Gravity Model 2012 (WGM-2012) data is used for neighboring country to have an account on the nature of gravity signatures.

Gravity anomaly in western Saurashtra is dominant with gravity highs due to high density volcanic plugs at east of Porbandar and Girnar hills. In south-eastern part, from Diu to Bhavnagar, three distinct volcanic plugs trending NE-SW appear as a continuous gravity feature. A prominent gravity high feature trending W-SE off the western coast of Saurashtra arising out of Kori- Commorin ridge and Saurashtra arch is seen.

There is an isolated gravity low in the west of Rajkot separated from eastern low by a ridge like gravity high which is believed to be the extension of Delhi Aravali trend. This isolated gravity low is drilled and found Mesozoic sediment of thickness 1.6 km below a basaltic trap of thickness 1.3km. The eastern gravity low has boundary connected to the western margin of Cambay basin where another well was drilled. The well has encountered Mesozoic sediment of 775m below a basaltic trap of 424m.

In Kutch area, known geological features such as Kutch mainland fault (KMF), Wagad ridge (WG), Island fault belt (IFB) and Nagar Parkar ridge (NPR) are co-relatable on this map. KMF is the longest traceable feature on this map extending up to western boundary of India, while the limit of western extension of other features are tapering towards north-east direction. The gravity feature of NPR, which is believed to be northern boundary of Kutch rift basin, is relatively short in length and has a different orientation from other features. Eastern part of NPR is merged with western boundary of Cambay basin and it continues towards north as a part of Cambay basin margin. The western part of NPR bifurcates one towards north-west and other towards west.

Gulf of Kutch area has a prominent gravity high whose northern boundary coincides with southern coastline of Kutch mainland, whereas southern part of this gravity high is seem to be connected well with gravity highs of Saurashtra peninsula. It is very difficult to find any such gravity feature on this map which can be co-relatable with the NKF.

Vertical derivative of gravity anomaly, shown in figure 3, which generally boost up signatures of shallow causatives, brought out many interesting features in both marine and land areas. A number of isolated depressions in trap covered area of Saurashtra are brought out. The Cambay basin margin is depicted with a high gradient. The volcanic plug at the east of Porbandar is having an extension towards east and terminates at Delhi-Aravali extension trend.

The gravity feature of the study area is divided broadly into two parts by Delhi-Aravali extension trend. Gravity features trending NNE-SSW are dominant in east of this trend while NW-SE trending gravity features are common in the west of this trend including the Kutch area.

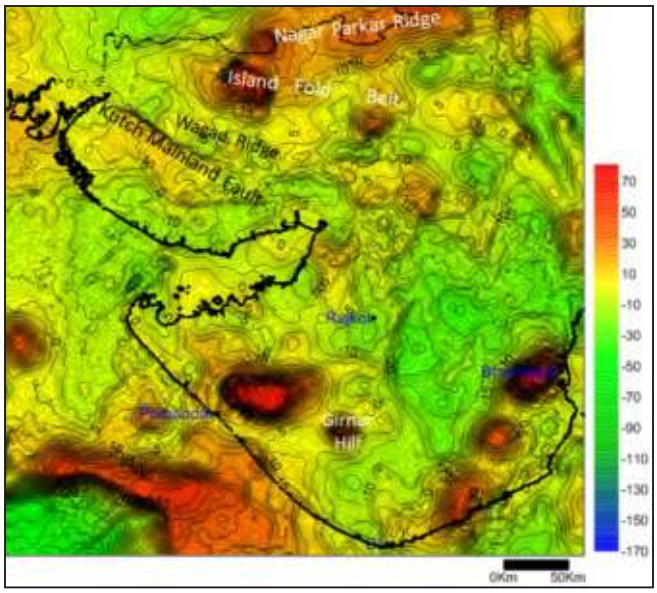

Fig. 2: Gravity anomaly map of study area marked with known features of Kutch mainland.

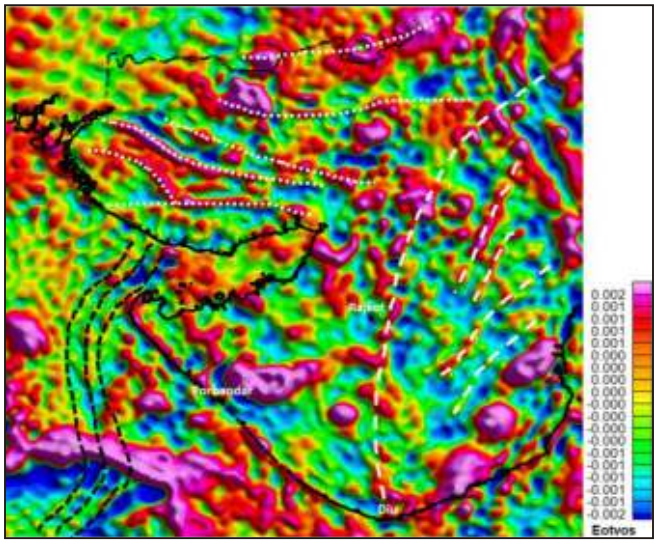

Fig. 3: First vertical derivative map. NNE-SSW (dashed line) trending gravity features in the eastern part of Saurashtra, E-W and NWW-E (stars) trending gravity features in Kutch mainland. Gravity features shown by black dashed line in western marine part of Saurashtra may belongs to median high.

In the offshore part, a chain of high gradient resembling a ridge like gravity features (shown in black dashed lines) starting just south of Katrol hill fault extending to abyssal plain in South Western corner of study area, may be a part of median high. Though it is not clear in Saurashtra arch area, merits attention for better understanding.

According to theory, the negative gradient of vertical derivative in the Saurashtra area may be arise of low density Mesozoic sediment below the trap. But lower density granitic material of basement undelaying basaltic trap directly may also reproduce negative gradient which makes illusive in the interpretation of gravity data in trap covered area.

Three gravity profiles falling along MT stations as shown in figure1 of which two are across the Gulf of Kutch and one only on land part are considered for further study. The aim is to find the extension of outcrops in Kutch mainland across Gulf of Kutch and to Saurashtra.

Profile-1 starts from IFB in northern part of Kutch mainland and ends at west coast of Saurashtra. The MT data pseudo section of resistivity and phase both for TE and TM are shown in figure 5. Low resistivity at the beginning of profile, falling near Rann of Kutch and at the end of profile in Saurashtra west coast, may be because of the influence of saline water. Both TE and TM show high resistivity in the northern part of Saurashtra which may arise because of higher resistivity trap at the surface. Though TE shows lower resistivity continuity from Saurashtra to Gulf of Kutch, TM shows continuity of higher resistivity from Saurashtra to southern coast of Kutch.

1D-Occam inversion for all the MT stations of these profiles are carried out and after gridding a resistivity section of profile-1 is prepared and shown in figure 6. Though data gap is very large the section seems to reproduce the geology and interpretation is attempted. It is very difficult to infer exact depth of tertiary sediments in Gulf of Kutch, as these sediments are infested with brine. However, a maximum thickness of ~1000m may be expected in Gulf area and around 600m towards end of the profile. Depth to basement is varying between 2500m to 3500m in Kutch and 1500m to 3000m in Saurashtra part.

Depth to basement is uncertain in Gulf of Kutch due to large data gap, but based on the inversion it may be expected more than 4000m. Continuity of basaltic trap can be clearly mapped along this profile. Mesozoic sediments are wedging towards the end of the profile. Using the findings of MT inversion result gravity modeling along this profile is attempted.

No seismic data is available in these profiles for constraining the shallow horizons. The parts of the profile, lying over Kutch mainland are constrained with MT data and in Saurashtra with MT, DSS and other G&G data. In Gulf of Kutch information obtained from published report of OBS and Marine magneto telluric data is used for constraining the basalt, tertiary and Mesozoic sediments.

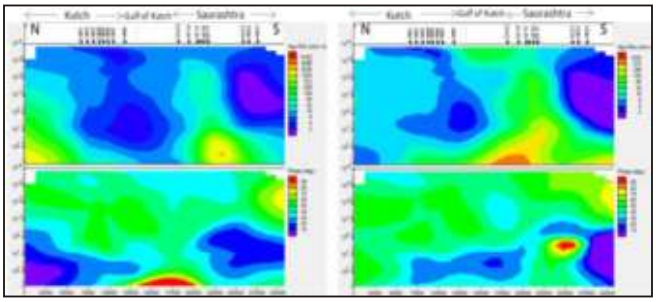

Fig. 4: TE-TM pseudo section of profile-1.

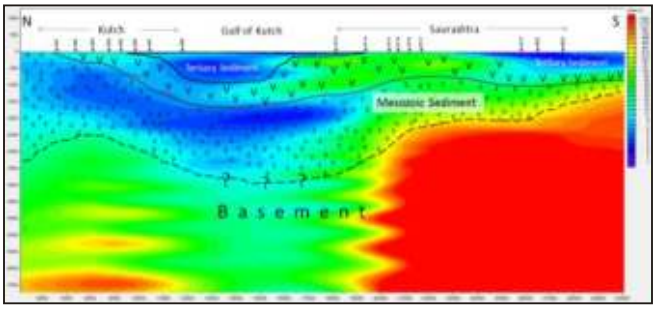

Fig. 5: 1D Occam-inversion section of profile-1.

Inputs difficult to incorporate such as surface heterogeneity are ignored. The basalt is not weathered uniformly everywhere and considering only one density for all the basalt covered area may not be justifiable but keeping in view of regional nature of the study it may be accepted. High amplitude gravity fluctuations arisen out of known volcanic plugs etc. are put for producing only the amplitude, its actual size and extent is not given any weightage.

Most of the studies till today are confined to land parts of Kutch and Saurashtra areas and done separately. North-South profile connecting both Kutch and Saurashtra is not available. Studies based on well and exposed geological data suggested a boundary between Mesozoic sediments viz. Cretaceous and Jurassic in Kutch area. But no such boundary was set in Saurashtra area. Therefore, a single average density is used in gravity modelling for Mesozoic sediments. In order to produce the boundary due to geological contacts, isolated body masses are placed.

Gravity modeling (Fig. 6) shows depth to moho is approximately 40 km in northern part of Kutch and below Saurashtra landmass. Depth to moho is rising upto 32 km over Gulf of Kutch. In comparision to other profiles moho is found to be more undulating along this profile. This may be due to the beginning of profile near Nagar Parkar ridge where a deeper moho could be expected. Moho is rising to compensate less dense water at the mouth of Gulf of Kutch and then going down below Saurashtra landmass beyond which ultimately rises because of Arabian sea. Zoom version of this profile is shown in figure 6a.

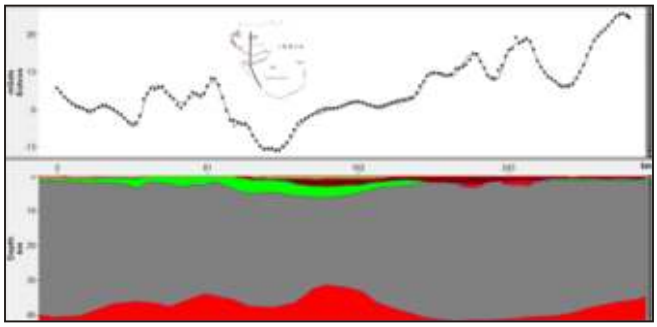

Fig. 6: Gravity modelling of profile-1.

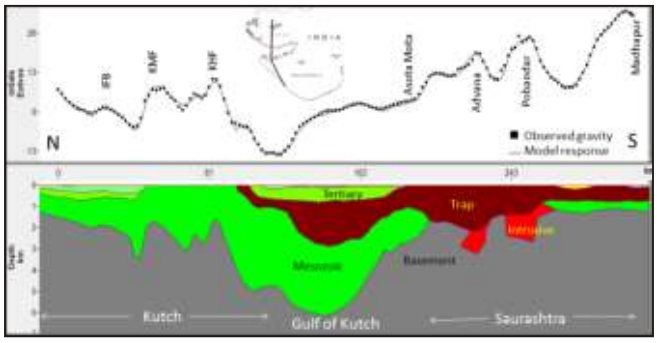

Fig. 6a: Gravity modelling of profile-1.

Maximum tertiary sediments upto 750m may be expected at Gulf of Kutch which ower than anticipated by MT inversion. The gravity high over Gulf of Kutch (fig.2.) can be explained in two ways the first is the thickening of basalt from ~400m near Mundra to 2100m in Gulf of Kutch part and the second is the rised mantle. Gravity modeling reveals the depth to basement in marine part is upto 6000m. More than 3000m of mesozoic sediments are expected in this area. A rise of basement from 6000m to 2600m towrads the northern part of Saurashtra is observed within a distance of 44km. While the top of basalt is rising from 520m in Gulf of Kutch to surface in Saurashtra within a horizontal distance of 11km. Therefore, there is no sharp boundary which may be linked to a fault in and around the gulf area. Moreover the mesozoic sediments exposed in the Kutch mainland is continued towatrds south below the deccan traps of Saurastra area.

Gravity modeling along profile 2 is shown in figure 7. It shows maximum thickness of tertiary sediments ~ 550m in Gulf part. Basalt thickness is increasing towards Gulf to a maximum of ~2300m from either side. Basement rises from 4500m to 1900m to the north of Saurashtra within a distance of 36km. Mesozoic sediment thickness may be expected up to 2000m. In this profile also gravity modelling does not show any sharp boundary which may refer as a fault in the Gulf of Kutch area instead there is gradual thickening of tertiary sediments from northern Saurashtra coast to southern Kutch coast.

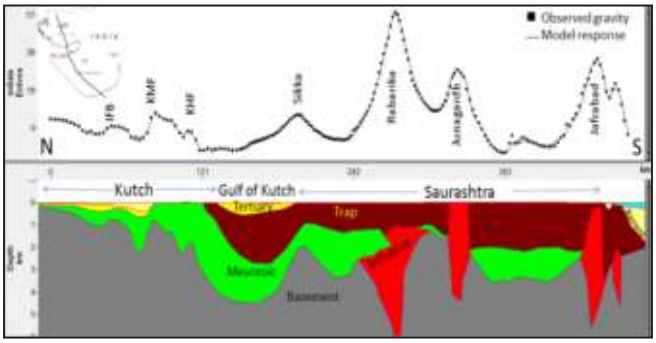

Fig. 7: Gravity modelling of profile-2.

Profile-3 starts from the south of Nagar Parkar ridge in northern Kutch and extends upto volcanic plug near Bhavnagar. Gravity modelling along this profile is shown in figure 8. The gravity high at the beginning of profile in northern part of Kutch is explained by two components viz. first is shallow basement depth and second is the high density mass intrusion in the crust, which justifies the gravity high in Nagar Parkar ridge. Depth to basement in this profile is varying from 200m to 3700m in Kutch part while it is fluctuating between 600m to 2700m in Saurashtra part. In comparison to other two profiles Deccan trap is very thin along this profile, thinnest may be around 200m and thickest ~450m. Mesozoic sediment may be expected 2400m thick in Saurashtra area.

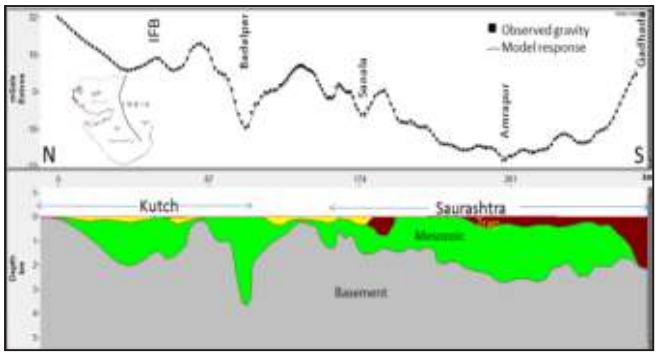

Fig. 8: Gravity modelling of profile-3.

From these studies it can be concluded that there is no support for any kind of sudden change in geology in northern Saurashtra, southern Kutch and Gulf of Kutch area.

Conclusions

Mesozoic sediments exposed in Kutch mainland has extension across Gulf of Kutch and Saurashtra peninsula.

There is no distinct geophysical boundary which can be referred as North Kathiawar Fault.

As there is Deccan basalt in northern part of Saurashtra and Tertiary sediment to the south of Kutch, geomorphological change is expected in the Gulf of Kutch but no distinctive signature is seen on gravity anomaly map.

Acknowledgements

Authors expressed gratitude to A.K. Dwivedi, Director (E) for his kind permission to present this paper. Sincere thanks are due to Dr. D.N. Singh, HOI-KDMIPE for his guidance. The suggestions and directives of Head Geophysics are respectfully acknowledged. All the members of Geophysics group are highly acknowledged for their kind co-operation.

Views and opinions expressed in this paper are of authors only, not of ONGC.

References

D. Rai and P.P. Gupta, Geophysics Group, KDMIPE, 1999, Gravity Modelling of Kutch Offshore Basin.

K.L. Kaila, H.C. Tewari and K.M. Tripathi, NGRI, Hyderbad, 1979, Technical report on Deep seismic sounding studies along Navibandar-Amreli profile.

Report on Integrated Geophysical Studies for hydrocarbon exploration Saurashtra, India, NGRI Hyderabad, 1998.

Report on Integrated Geophysical Studies for Hydrocarbon Exploration Kutch, India, NGRI, Hyderabad, 2000.

RVSONNE_Cruise-report on Marine Seismic and Marine Magneto-telluric survey in Gulf of Kutch region, 2009.

S. Rangarajan, Geophysics Group, KDMIPE, 1995, Reinterpretation of MT data of Saurashtra.

Unpublished report on Integrated studies for hydrocarbon prospect evaluation of Mesozoic sediments in Kutch basin, KDMIPE, 2002.