Gravity Modeling of Kutch Offshore Basin

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ABSTRACT: Integration of land and marine gravity-magnetic data from the Kutch offshore and onland has been used to study prospectivity of Pre-Oligocene and Mesozoic sediments, likely distribution and thickness of traps and subtrappean sediments and also to understand the structure and tectonics of the area. A broad gravity low characterizing the sedimentary basin have been observed over the inner shelf platform area of Kutch offshore which has its extension in Kutch and Saurashtra onshore areas. Gravity modeling has been attempted along selected profiles connecting drilled wells to bring out density model for the basin, constraining the model from borehole information and observed gravity anomalies. The same density model of the basin was extended inside the gravity low depicting the Mesozoic basin. The modeling study reveals presence of thick porous sedimentary layer of about 2.0 to 3.0 Km thick below trap in the area of gravity low. Thus the gravity modeling study has confirmed that the Mesozoic basin with large areal extent exists in Kutch offshore, which has got its extension in Kutch and Saurashtra coastal areas. This prospective Mesozoic basin has been identified by a broad gravity low exhibiting mass deficient zone employing lowering of density. The ‘Prospective Cretaceous Fairway’ mapped by TOTAL CFP 1990 on the basis of probable southern extension of producing oil and gas fields of Lower Goru sands of Early Cretaceous of Sindh Province of Pakistan engulfs the gravity low area (Bordenave, 1990).

INTRODUCTION

The offshore block of Kutch basin, the study area, is bounded by Saurashtra arch to the south, Indus basin of Pakistan to the north, Arabian Sea to the west and Kutch onland to the east. The Kutch offshore basin is a southwestern extension of onland Kutch basin in the Arabian Sea covering an area of about 28000 sq.km. upto 200 m bathymetry. The Kutch onland basin is characterized by a rugged topography exposing Jurassic and Cretaceous rocks amidst the vast plains of alluvium covered Rann. This basin extends into the offshore with a wide shelf platform.

In most of the wells drilled in Kutch offshore the Mesozoic sequence below Deccan traps has been encountered but none have penetrated up to the basement. The lithological and density information of some of these wells has been constrained for the purpose of gravity modeling.

Considerable amount of seismic reflection data has been acquired in Kutch offshore. Few key seismic sections of the area have been examined; the reflections below trap and top of basement are not identifiable.

The present study was undertaken with the objective of understanding prospectivity of Pre-Oligocene and Mesozoic sediments, likely distribution and thickness of traps and subtrappean sediments and also to understand the structure and tectonics of the area.

METHODOLOGY

Composite gravity anomaly map of Kutch-Saurashtra onshore and offshore has been used to find the regional structural trend and its continuation from onland to offshore. All data could not be converted to single data set as different data sets are with different gravity base and of different type as offshore-onland parts and bouguer and free air anomalies are involved. Qualitative and quantitative analysis of gravity and magnetic data have been done. From qualitative analysis fault, high-low trend and amplitude of the anomalies were identified. These geophysical signatures were translated into geological features. Spectral analysis of gravity data has been used to estimate basement depth. A geological model for the area was conceived on the basis of geology and well data. 2-D modeling algorithm of Talwani et al (1959) has been used to compute gravity response of the model. Gravity modeling was attempted along a profile connecting drilled wells in the Kutch offshore after putting constraints from well data and same approach was extended along another profile joining Suthri-1 well in Kutch onland.

QUALITATIVE ANALYSIS OF GRAVITY DATA

The composite gravity anomaly map has been used to study the continuation of tectonic features and lineament trend from Kutch-Saurashtra onland to Kutch offshore. The bathymetry follows the coastline trend and gradually increases across a NW-SE line. There is a little variation in bathymetry
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in the area. In the bouguer anomaly map of Kutch offshore there is one prominent gravity high circular closure west of Dwarka having maximum contour value of 58 mgal, relief of about 30 mgal and areal extent of about 2000 sq km. The contour exhibits a sharp gradient of about 2 mgal/km from all sides reflecting the presence of faults. Approximate depth estimates of causative of this gravity anomaly can be obtained by making use of the well-known thumb rule of half-width method. The depth of causative for this anomaly works out to be about 11 km for horizontal cylinder and 14 km for spherical body. As these depths belong to the centre of causative the expected depths to the top of causative should be less than above estimates. This gravity high lies well within the shelf basin east of 200-m bathymetry line representing shelf break. The gravity high may be associated with some volcanic pipe of high-density rock. This may be correlated with the gravity highs observed in Saurashtra onland (like Rajula, Palitana and Vallabipur-Sihore in the southeast part and Osham, Barda and Alech towards west). The general trend of the anomaly in the basin is NNW-SSE following the coast line trend without having much influence of Gulf of Kutch trend. In the free-air anomaly map of Kutch offshore the shelf basin is marked by a broad gravity low which extends in coastal area of Kutch onland towards Jakhau and Suthri and also extends into Saurashtra onland towards Okha, Jamnagar area. Taking into account the lead provided by integrated geophysical study in Saurashtra onshore in Jamnagar and Dwarka areas of having appreciable Mesozoic thickness, the same could be expected in the entire gravity low area of Kutch offshore basin which represents the main Mesozoic basin and extends into coastal area of Saurashtra and Kutch onland.

QUALITATIVE ANALYSIS OF MAGNETIC DATA

Magnetic anomaly map also is available in two different sets. A part of first map has been composited with second to have complete map for the basin. There is a shift of about 400 gamma in the two anomaly maps as base value difference but the general trend matches well. Furthermore the contour interval is also different. The magnetic anomaly exhibits long wavelength anomalies representing deeper causatives (basement) except the area on the mouth of Gulf of Kutch which shows high frequency and short wavelength anomaly representing shallow causatives. The long wavelength anomaly also exhibits sparse contour belts indicating character of sedimentary basin. The area of broad gravity high observed in bouguer anomaly map has been marked by a high and low in magnetic intensity map reflecting bipolar character of the anomaly at our latitude. Thumb rule depth estimates for this anomaly is of the order of 6 to 12 km. Magnetic anomaly contours of Kutch offshore basin as discussed by Rai et al (1994) in general shows WNW-ESE to E-W orientation. The high frequency anomalies are observed all along the coast indicating presence of shallow causative. The most obvious tectonic element observed in gravity anomaly map i.e., Saurashtra arch has got magnetic signature also as it is marked by high trend in magnetic anomaly.

QUANTITATIVE INTERPRETATION OF GRAVITY DATA

Power spectrum of the potential field anomaly would reflect the sub-surface discontinuities of the density distribution or magnetic character. Such discontinuities can be identified by the distinct nature of different sets of frequencies, the amplitudes of which follow different linear trends. In case of gravity anomaly each linear trend defines a discontinuity in the density distribution about which masses producing the gravity anomalies are distributed. Spectral analysis of gravity data indicates two causative depths one at 5 km and other at 13 km. These depths can be attributed to basement depth and Conrad discontinuity respectively.

THE GEOLOGICAL MODEL

Using the results of basement depth from spectral analysis and available drilled well data a tentative geological model for the Kutch offshore along a profile joining wells KD-1, GK-22C-1, SP-1-1 and GK-29A-1 was constructed. Here the thickness and average density of different column were based on the drilled well information except the thickness of deepest column above basement. For the convenience of modeling, the various sedimentary layers have been taken as one unit since no significant difference in the density of the layers was noticed. A prospective porous sedimentary layer was observed in different logs with density of 2.3 gm/cc below Deccan Trap. A tight limestone layer below Deccan Trap with density 2.6 gm/cc was observed in KD-1 well and has been considered for modeling. Since the thickness of the Deccan trap layer is very less and it is weathered so it has been considered along with sediments as density layer of 2.4 gm/cc for modeling. The water column was also considered in the modeling with density layer of 1.03 gm/cc though the thickness of water layer is very less and it shows variation of about 5 to 10 m only. The basement density has been considered as 2.67 gm/cc and the gravity response of the model
was computed using 2-D modeling technique of Talwani et al. (1959) and was constrained with the observed gravity response (Fig.1). Here the regional was considered as flat and hence no correction was made in the observed value and the same has been considered as residual. The final model along the above mentioned profile whose response fitted well with the observed data and is compatible with the tentative model of the basin matches well with the preliminary interpretation result of integrated geophysical work in Kutch onland by NGRI, Hyderabad. The same approach was extended along another profile joining wells GK-1-1, GK-22C-1, SP-1-1, GK-29A-1 and Suthri-1 (onshore well) with Known lithostratigraphy (Zutshi et al. 1993) from the wells and its response matches well with the observed data (Fig.2).

**DISCUSSION**

Recently acquired integrated geophysical data of Saurashtra onland has indicated presence of considerable Mesozoic sediments in Dwarka and Jamnagar area. Actual observation of the composite gravity anomaly map of Kutch and Saurashtra offshore-onland reveals that the gravity low represents a broad basin in Kutch offshore. The well GK-22C-1 within the gravity low area has already established presence of commercial gas in thick Mesozoic column of Bhuj formation. This gravity low has its extension in coastal area of Kutch and Dwarka and Jamnagar area of Saurashtra as discussed earlier. The gravity low is bounded from west by gravity high representing limestone ridge of high-density layer.
below trap. In the northeast it is again bounded by gravity high in Kutch onland showing shallowing of the basin. In the Saurashtra onland it is bounded by gravity highs observed near Osham, Barla and Alech towards western part of Saurashtra. We believe that the gravity low area of Kutch offshore represents the main Mesozoic basin which has its extension in Kutch and Saurashtra onland area. To thoroughly explore the hydrocarbon prospect of this Mesozoic basin drilling of at least one parametric well up to basement is recommended so that clear basement picture of the basin can be visualized. The ‘Prospective Cretaceous Fairway’ mapped by TOTAL CFP 1990 on the basis of probable southern extension of producing oil and gas fields of lower Goru sands of Early Cretaceous of Sindh Province of Pakistan en-gulfs the gravity low area (Bordenave, 1990).

The proposed density model of the basin along two profiles joining different wells in Kutch offshore has got support from interpretation result of integrated geophysical work carried out in Kutch onland by NGRI. Gravity modeling has suggested presence of prospective low-density porous sedimentary layer below trap. Further it has established presence of compact thick layer of limestone below Deccan Trap in northwest part near well KD-1.

The basement depth in the gravity model is based on spectral analysis results of gravity data only because none of
the offshore well in the basin has penetrated up to basement. Further the seismic reflection data does not show clear picture below high velocity layer of trap. The all other density columns are known from the well data near well column only.

Thus the gravity modeling study has confirmed that the Mesozoic basin with large areal extent exists in Kutch offshore, which has got its extension in Kutch and Saurashtra coastal areas. This prospective Mesozoic basin has been identified by a broad gravity low exhibiting mass deficient zone employing lowering of density.

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