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Structure and Evolution of Diu Arch in Saurashtra shallow water area of Western Offshore Basin India and its importance in hydrocarbon exploration.

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Abstract

Evolution of Diu arch through time and space and its role in controlling distribution of reservoir facies in various depositional units has great bearing on discovery of hydrocarbon accumulations. Understanding of evolution of Diu arch was a challenge due to sparsely spaced G&G data. Recently acquired, processed and interpreted several volumes of 3D seismic data has given the new insights about Diu arch. In western offshore of India, south of Saurashtra Peninsula the shelf has Diu arch in center, Tapti Daman area in the east and Saurashtra low in southwest forming Saurashtra offshore shallow water shelf. Diu arch, located on NNW-SSE trending and SSE plunging basement high is flanked by Saurashtra low in the west and Tapti Daman sector in the east. Monoclinal up dip on the Diu arch with compartmentalized structures formed by EEN-WWS or NW-SE faults ranging from the basement to the Pliocene and at some places to Recent are prominent.

Tertiary sediments from Paleocene to Recent age are present on Diu arch and its surroundings. Thickness maps of the intervals corresponding to Paleocene, Eocene, Early Oligocene, Late Oligocene, E. Miocene and Mid Miocene represent the evolution of the Diu Arch and its surroundings. Paleotectonic study on regional 2D seismic lines passing through Diu arch also reveal that a narrow low running in East West direction separated Diu arch in the north and Mumbai High platform area in the south. This narrow opening was the passage through which east and west basins were connected. Further, during Late Eocene and Early Oligocene the narrow opening separating Diu arch and Mumbai High platform area widened, however the depocenenter remained in the east. The depocenter shiftied towards the west during late oligocene and onwards.The westerly tilt of the basin has been linked with the major geological activity of first major Himalayan orogeny as well as global sea level fall resulting in regressions in the sedimentary basins. The Diu arch plays important role in distribution of late oligocene Daman formation sandstone reservoirs.

The tectonic forces which controlled the basin inversion were responsible for structurisation of Diu arch and surroundings due to generation and orientation of different fault geometries. The regional strike slip fault and associated trans-tensional and trans-pressional faults has generated various small and big (composite) structures. The understanding of genesis of these structures through ages and their relation to peak hydrocarbon generation and migration with areas of good reservoir development will lead to future success of exploration in the area.

Introduction

The Mumbai offshore basin, a passive margin basin on the continental shelf of western India continues into the on-land Cambay basin toward the northeast. On the north, it is bounded by the Saurashtra Peninsula and on the east by the Indian craton. Its southern limit is marked by the east-west trending ridge lying in south of Ratnagiri. **(Fig.-1)**

Hydrocarbon accumulations in Mumbai Offshore generally occur in carbonate reservoirs ranging in age from Middle Eocene to Middle Miocene which are structurally controlled. However stratigraphic / combination plays in Paleocene - Lower Eocene and Oligocene clastic reservoirs are also significant.

Discoveries in the Diu Arch area and Tapti Daman sector in Early Oligocene Limestone and Sandstones have attracted attention in exploration.

Saurashtra arch in the west, Saurashtra low in the southwest, Diu arch in the south and Tapti Daman sector in the south east surround the Saurashtra craton in Saurashtra offshore area. Diu Arch is situated in the central part of the Saurashtra offshore with NNW-SSE trending and SSE plunging basement high. The Diu depression lies in the south and Daman Low in the southeast of Saurashtra offshore.

The Diu Arch laterally dies out in the south **(Fig: 2)**. Two key wells X-1 and X-2 drilled earlier gave discouraging results, However these wells has given valuable information in ascertaining petroleum system in the area. GME process coupled with poor reservoir in Tertiary appears unfavorable conditions for the drilled wells. The low present in the south and southeast of the Diu arch has been proven source potential/kitchen. The lithostratigraphy of the area resembles with Tapti daman area of Mumbai Offshore Basin.

Present study is the result of integration of the 2D and 3D seismic data, Well log correlations, and interpretation of other Geoscientific data. The area under study is Saurashtra offshore in the South and South East. **(Fig:2)**.

Tectonic setting and Structural framework

Basement controlled NW-SE (Dharwarian trend) to NS (Delhi trend) trending faults split the entire shelf area in longitudinal stripes. This has resulted in a horst-graben morphology which guided sedimentation in the basin throughout the Tertiary period up to Middle Miocene.

Five mega tectonic elements; viz. Eastern Homocline, Graben system, Central Ridge System, Shelf Margin Depression and West Margin Basement Arch **(Fig:3).** Each element is bounded by normal faults. Tectonics is primarily guided by major basement lineaments. The 'highs' are dissected by NE-SW cross trends. The most prominent among basement highs over Mumbai platform is the 'Mumbai High'.

In the North and North East of Mumbai high Diu arch, Dahanu structure, Saurashtra low, Surat depression, Daman low and Navasari lows have various Inversion structures formed due to transpressional and transtensional forces of strike slip movements.

Stratigraphy and Depositional Setting

Mumbai Offshore basin is limited by the exposures of Deccan Trap in the east. A thin veneer of Neogene and Quaternary limestone, marl and clay form the outcrops along the coastal belt of Saurashtra Peninsula in the north. The subsurface sedimentary section ranges in age from Paleocene to Holocene and overlies non-conformably the Deccan Trap / Granitic / Metamorphic basement. Deccan Trap represents the basin floor geology with a few granitic/metamorphic inliers. Seismic sections and Cretaceous exposures in Wadhawan and Dhrangadhara areas of Saurashtra block reveal the presence of a sub Deccan Trap Mesozoic basin. The lithostratigraphy of the basin is shown in **Fig:4**

Significant Geologic and Tectonic Events

"Crustal scale" tectonic events affecting the passive margin in the study area include:

1. Long period of stable emergent craton from Pre-Cambrian to early Mesozoic. Initial rifting and separation of India from Africa in the mid-Jurassic.
2. Continued rifting, separation of Madagascar from west India in the mid-Cretaceous.
3. Northward drift of western India over a mantle plume at K/T boundary.
4. Outpouring of Deccan Trap flood basalts over a large area between 66 and 65 Ma.

5. Last major rift as Seychelles moves away from western India in the Early Tertiary. Deposition of Paleocene-Eocene source rocks in accommodation caused by rifting.
6. Continued igneous activity along southward moving track of hotspot. Thermal cooling and subsidence after rifting event & movement away from plume.
7. Localized wrench tectonics and intrusive & extrusive igneous activity in the Eocene.
8. Initial contact of Indo-Australian and Eurasian plate in mid-Eocene.
9. Significant subduction and first major Himalayan orogenic event in mid-Oligocene.
10. Extension & block faulting in some areas of western Indian margin in Late Paleogene.
11. Thermal-isostatic subsidence of margin appears to accelerate around mid-Miocene.

G &G data observations and analysis

Time thickness map Trap top (Paleocene) to H4 (Panna top/Early Eocene) indicates that the Diu arch area and Mumbai High were connected to each other during this period. However a narrow low running in East-West direction separated Diu arch in the north and Mumbai High area in the south. East and South east being major depocentres had more thickness **(Fig:5)**. Time thickness map of H4 (Panna top/Early Eocene) to Mahuva top (Early Oligocene top) indicates that the main low / depocentres remained in the east and south east but the narrow opening separating Diu arch and Mumbai High widened with the NW-SE orientation of the Diu arch (**Fig: 6).** The present shape of the Diu Arch was initiated during this period.

Time thickness map between Mahuva top (Early Oligocene top) to Daman top (Late Oligocene top) of Late Oligocene period indicates that the main low in the east and south east has undergone basin inversion. The westerly tilt of the basin has been linked to the major geological activity of first major Himalayan orogeny as well global sea level fall. The opening separating Diu arch and Mumbai High widened further and increases sedimentation in the western part and its connectivity to the eastern part became through the open sea (**Fig: 7**).The channel bar complexes in the proximity of the Diu arch during this period are well established.

The Time thickness map of Daman top (Late Oligocene top) to H2B (Early Miocene top) of Early Miocene period show continuity of the thickness trend of Late Oligocene period **(Fig: 8**).Time thickness H2B (Early Miocene top) to H1A (Mid Miocene top) indicate the thickness of sediments Mid Miocene **(Fig: 9**). The thickness trend as observed in this map having the present coast trend indicate accomodation of sediments during this period with basin pattern transformed earlier.

The 2D seismic section passing though East and West of Diu arch displays various features which explain Basin configuration as well as as well as structural styles observed (**Fig: 10**)**.** In the East the sesmic section clearly depicts the low below Early oligocene period.The thickness of sediments in the east are more than west below Early oligocene horizons. The positive basin inversion has made the situation reverse in the Late oligocene and above sections. In the west of of sesmic section a fault forming the flower structure has been observed. This fault lies in the southwestern part of Diu Arch and in the west of this fault the thickness of late sediments from oligocene to recent has increased.

Generation Migration and Entrapment

The geochemical analysis for the Mid-Late Eocene and Oligocene sections in well X1 on the centre of Diu arch have TOC values for Mid Eocene, Late Eocene and Early Oligocene as 1.62%, 1.16% and 1.25% respectively. Tmax values are 337, 327 and 328 respectively. S2 values are 0.58, 1.21 and 1.55. These values are higher than expected indicating possibility of contamination of samples. Maturity-wise, none of the formations appear to have entered the oil window. It can be concluded that the source rock around the well has poor hydrocarbon potential.

The Geochemical studies of the nearby well W4 in the flank of Diu arch indicate that Panna Formation with mainly Type -III organic matter is the dominant source rock unit in the Daman low and other lows in this part of the basin. The TOC and Tmax data shows that the Panna sediments are mature with good source rock characters.Ro values in the drilled well samples indicate top of Oil windows between 2500-2900m in this area. The studies on burial history and geothermal gradient suggest that Late Miocene as the period of peak generation and peak migration could be during late Miocene to Pliocene.

The reservoir facies in the vicinity of Diu Arch vary from Paleogene carbonates in the west to Oligocene sands and carbonate bands in the East and North East. On Diu Arch, basalts/ weathered basalts and Trap wash are also possible reservoir rocks. During the Paleocene-Eocene times the western side of the block witnessed mainly carbonate growth/ sedimentation/ development with frequent ceasing of carbonate activity and deposition of fine clastics – shale/ calcareous shale. The carbonate sedimentation slowed during the Late Eocene to Oligocene period and the sedimentary sequence is mainly shales/ calcareous shales with limestone bands.

Conclusion:

The observations and analysis of G&G and other data following conclusions can be made:

1. The westerly tilt of the basin during late oligocene has been linked to the major geological activity of first major Himalayan orogeny as well as global sea level fall. Thickness maps prepared between different time units has clearly brought out the timing of Evolution of Diu Arch.
2. The structural styles related to basin inversion and flower structures have established their relavance in hydrocarbon exploration.The strike slip faults related to transtensional and transpressional forces form various structures which are suitable for structural as well as stratistructural entrapment.
3. The studies indicate that the Diu arch is not having sufficient source potential to generate hydrocarbon. However the hydrocarbon generated in nearby lows may move to Diu arch and proximal areas.
4. The limestones of Paleocene, Eocene and Early oligocene formations have poor reservoir condition. The limestones deposited during above periods are hard and compact and thus they form tight reservoirs. Occasionaly in early oligocene limestones some porosity pods has been observed.
5. The channel bar complexes in and around the Diu arch area during late oligocene period are well established.

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References

1. Biswas, S.K. 1982. Rift Basins in Western Margin of India and their Hydrocarbon Prospects with Special Reference to Kutch Basin. AAPG Bull., v. 66, no. 10, pp. 1497-1513.

2. Brown, L.F. Jr., Loucks, R.G., Trevino, R.H. and Hammes,U. 2004. Understanding Growth-Faulted Intraslope Basins by applying Sequence Stratigraphic Principles: examples from south Texas Oligocene Frio Formation. AAPG Bull., v. 88, no. 11, pp. 1501-1522.

3. Chowdhary, L.R. 1975. Reversal of Basement-Block Motions in Cambay Basin, India and its Importance in Petroleum Exploration. AAPG Bull., v. 59, no. 1, pp. 85-96

4. Dare, A. 1997. Foraminiferal modeling of relative sea level change in the Oligocene to Pliocene of Bombay Offshore. KDMIPE Report No. GR103, C.14, May 1997.

5. Pandey J.P., Singh K.R.K, Singh M, Kalairasan T and Marathe U. G. Late Oligocene Sandstone reservoirs of Saurashtra Offshore: significance of their deposition – An Integrated study resulting regional clastic model.

6. Singh K.R.K, Pandey J.P, Singh M, Kalairasan T and Marathe U. G. Early Oligocene limestone deposits of Saurashtra Offshore, Mumbai High platform northern flank and Tapti Daman Area – A regional carbonate model.

7.

8. Nair, K.M., Singh, N.K., Ram J., Gavarshetty, C.P. & Muraleekrishanan, B. 1992. Stratigraphy and Sedimentation of Bombay Offshore Basin. Journal of Geological Society of India, Vol. 40, pp 415-442.

9. Roychoudhury, S.C and Deshpande, S.V. 1982. Regional Distribution of Carbonate Facies, Bombay Offshore Region, India. AAPG Bull., v. 66, no. 10, pp. 1483-1496.

10. Rao, R.P. and Talukdar, S.N. 1980. Petroleum Geology of Bombay High Field, India. AAPG Bull., pp. 487-506

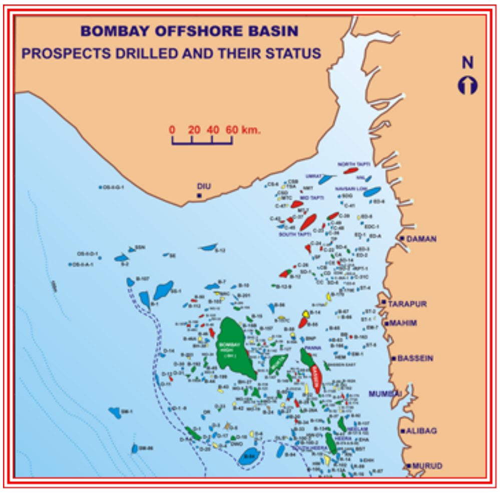


Fig. 1: Location Map

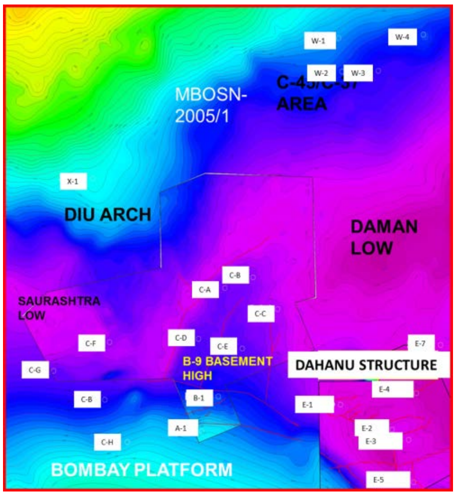


Fig. 2: 2D-3D seismic data based Regional Time relief map on top of Panna formation (Early Eocene)

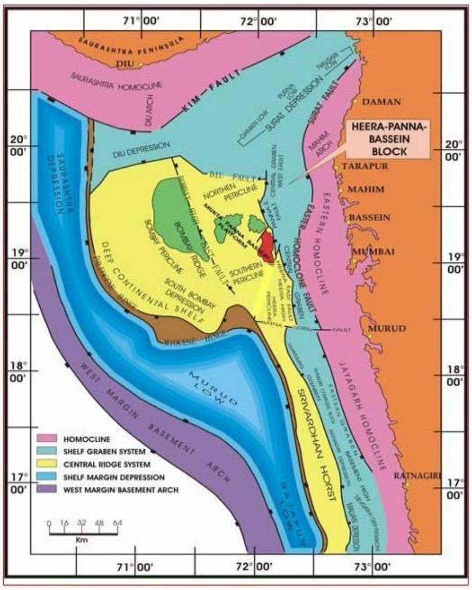
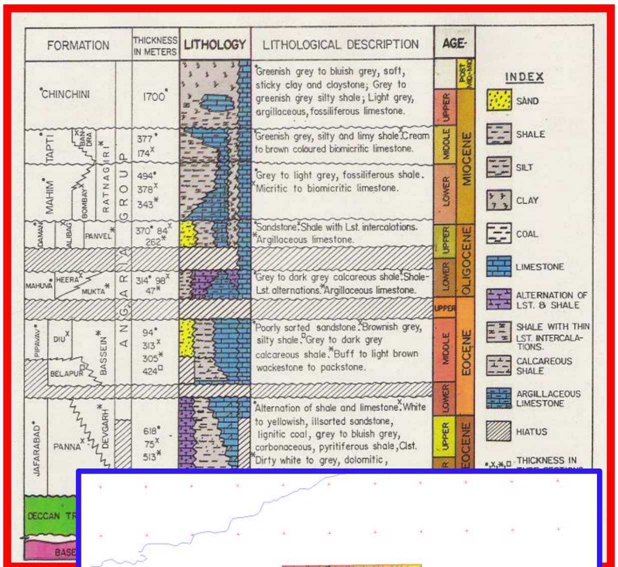
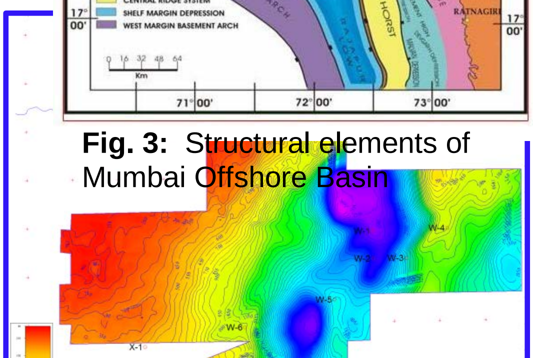
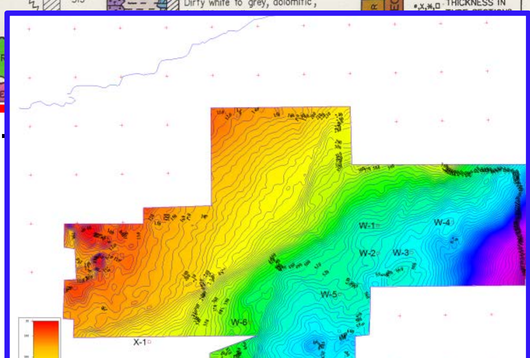


Fig. 3: Structural elements of Mumbai Offshore Basin







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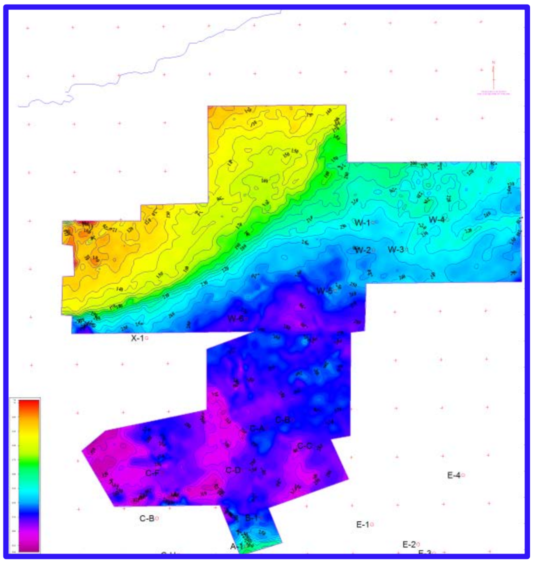

Fig 7: Time thickness Map (Daman top- Mahuva top)

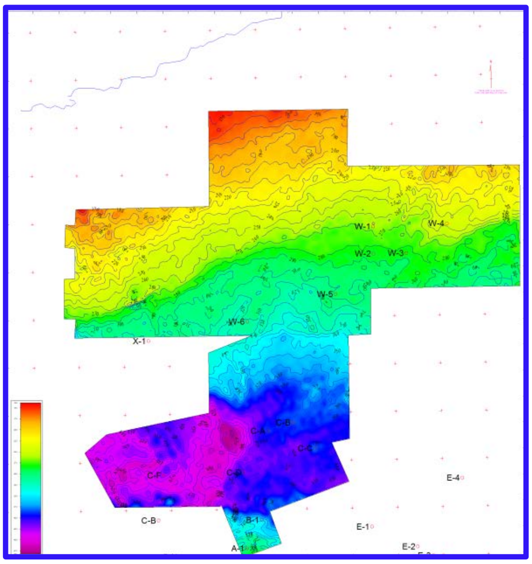

Fig 8: Time thickness Map (Daman top – H2B)

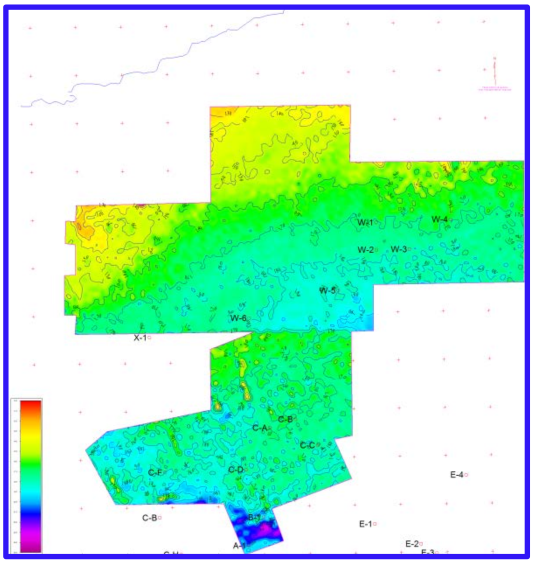

Fig 9: Time thickness Map (H2B-H1A)

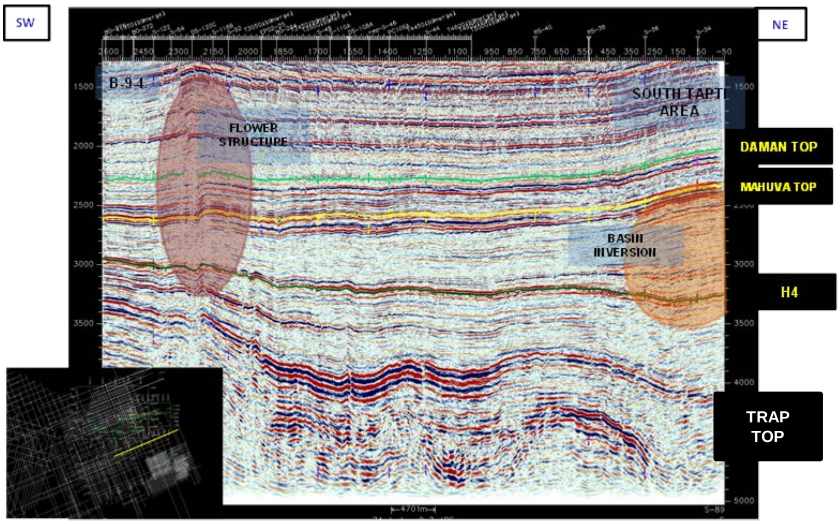

Fig 10: Time thickness Map (Mahuva top - H4)