High Impedance shales of Daman formation towards east of Diu arch in Saurashtra offshore: their role in hydrocarbon exploration and exploitation.

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Abstract: Amplitude anomalies have been the significant tool for exploration of hydrocarbon as bright spot/DHI for many years for the Geoscientists. This has proved to be important in some places and in some formations whereas it has failed at some places. Since it is one of the quick look interpretation skills, it is still adopted by Geoscientists for obtaining confidence. However validation of the anomalies is done through different petro physical analysis. Tapti Daman sector in the Western offshore basin has been explored widely based on the amplitude anomaly analysis. Success and failures both have been observed from this sector of the basin. Late Oligocene Daman formation has been explored in this basin from 2D seismic data to 3D seismic data. The amplitude anomalies which failed for the upper part of Daman formation has proved successful for lower part. The Western part of Tapti Daman sector covering part of Diu Arch has been explored widely based on the amplitude driven exploration. High amplitude anomalies depicting presence of thick channel sand proved to be water bearing after drilling. The shales within the Daman formation are low impedance shales and water bearing sands are high impedance sandstones. In this paper an attempt has been made to analyze the lithology and their respective impedance in the western part of Tapti daman sector on the eastern flank of the Diu arch. The lower part of Daman formation having thick net gas bearing sand of 15-18m has been explored which has no impact on amplitude anomaly whereas in upper part of Daman formation high amplitude anomaly corresponding to the channel sand has been found water bearing. Cross plots of the logs have been attempted and the shales of the area are analyzed in finer detail. It has been found that the shales are dominantly silty in nature, thus reducing fissility. Sandstones are also silty in nature and found to be unconsolidated at some places, hence posing problem of sand incursion in well testing and well completion. The analysis of the impedance of the lithology and pay sands from logs is then compared with seismic data. The analysis suggests that the shales in the lower part of Daman formation are predominantly high impedance shales having impedance values close to that of Gas bearing sands. Thus it becomes difficult to differentiate between the Gas bearing sands and shales. The shales in the upper part of Daman formation are clean and devoid of silt, hence having lower impedance values.

Keywords: Shale, impedance, Clastic reservoirs , Crossplots of the logs, Stratigraphic / Combination, Plays, Carbonates

Introduction

The Mumbai offshore basin, a passive margin basin on the continental shelf of western India continues into the on-land Cambay basin towards 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 south of Ratnagiri.

Hydrocarbon accumulations 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. The area under study covers part of south-eastern sub-basin of Saurashtra offshore towards south of Saurashtra craton (Fig: 1).

Present study is the result of interpretation of the 3D seismic data and Well log caliberations and integration of laboratory studies in the interpretation.

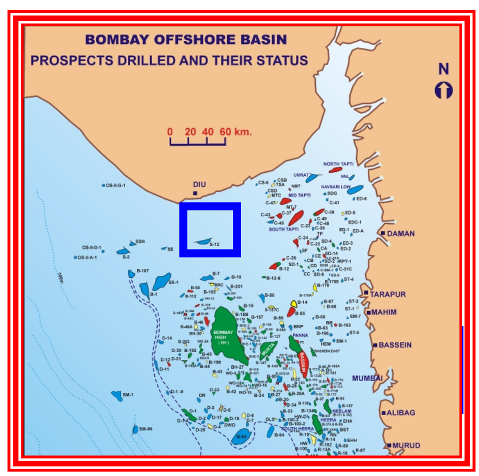

Fig. 1: Location Map

The area under study lies to the east of Diu Arch in Saurashtra offshore area (Fig: 2). An attempt has been made to analyze the available geoscientific data and bring out the responses of various lithologies with its characteristic fluid within Daman formation in the area. The study will help to efficiently differentiate & identify the varied lithology encountered along with its fluid content for better exploration of Daman formation in the area.

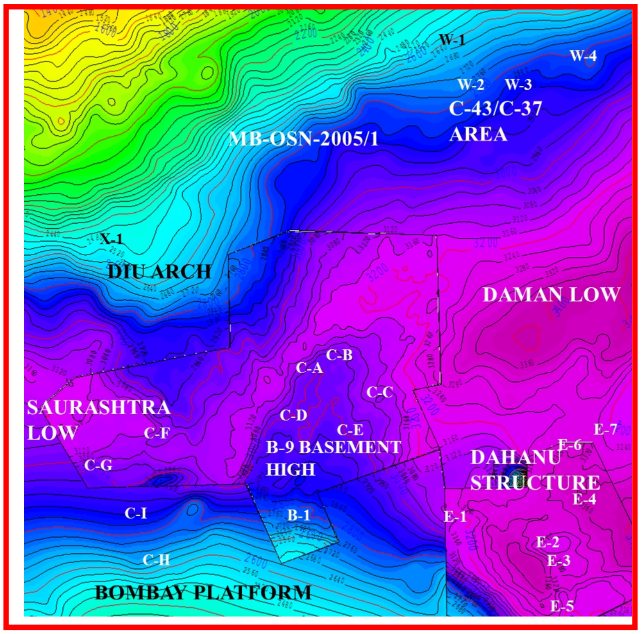

Fig. 2: Time relief map on top of Panna formation

Tectonic setting and Structural framework

Basement controlled NW-SE (Dharwarian trend) to N-S(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.

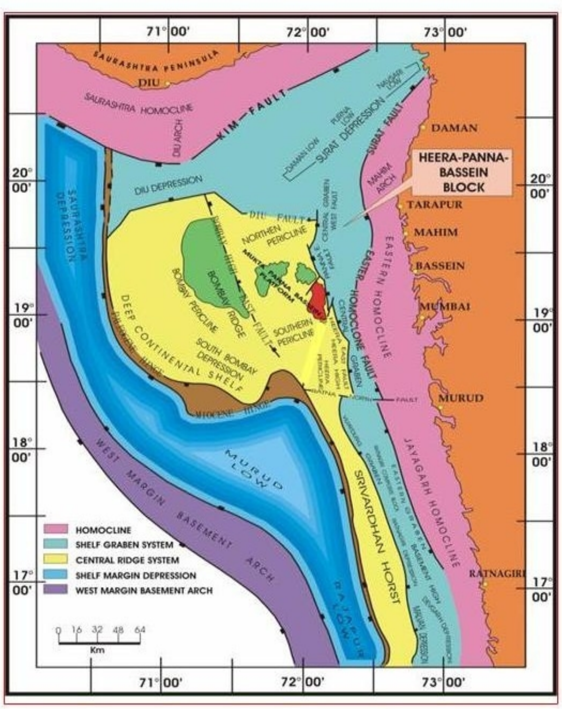

Fig. 3: Structural elements of Mumbai offshore Basin

Five mega tectonic elements; viz. Eastern Homocline, Graben system, Central Ridge System, Shelf Margin Depression and West Margin Basement Arch define the tectonic setup of the Mumbai offshore basin. Each element is bounded by normal faults (Fig: 3).

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.

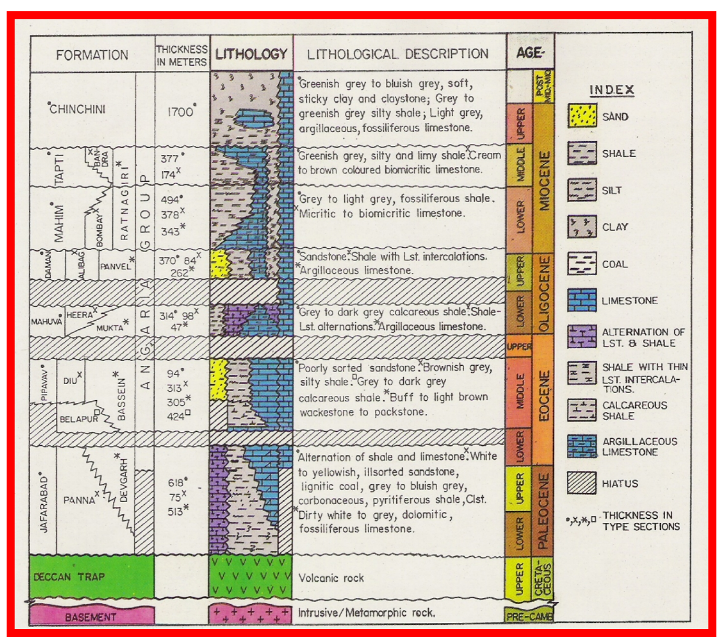

Fig. 4: Lithostratigraphy of Mumbai Offshore Basin

During different stratigraphic units the geologic events, sea level changes and geochronology has been depicted in (Fig: 5).

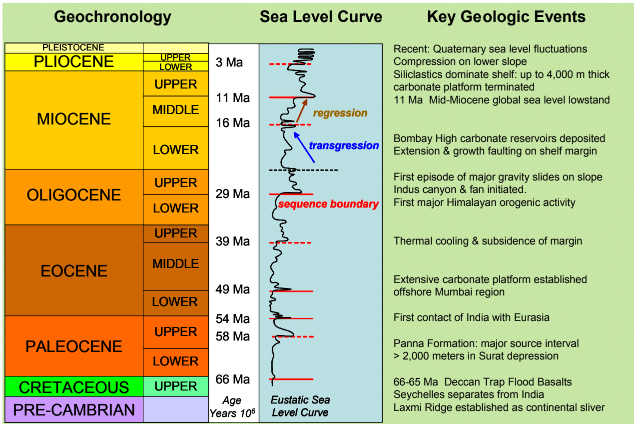

Fig. 5: Geo-chronological chart, Sea Level Curve and Key Geologic Events

G &G data observations and analysis

1: Seismic data showing the high amplitude anomaly. The amplitude attribute indicating presence of channel sand in the upper part of Daman formation were explored in some of the wells. These anomalies proved to be water bearing thick channel sand in C-37 area(Fig: 6).

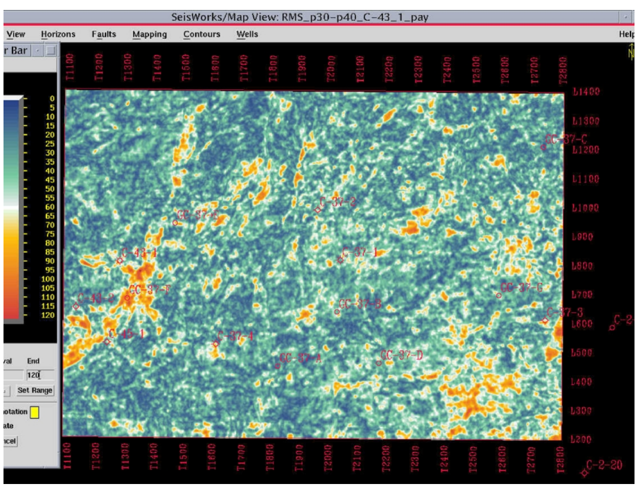

Fig. 6: Horizon slice of 3D seismic data indicating High Amlitude anomaly as channel sand.

2: Seismic amplitude anomaly in upper daman formation of another seismic close to the above 3D seismic has also indicated presence of similar channel sands (Fig: 7) however these channel sands were validated by AVO analysis. In AVO analysis these amplitude anomalies turned out to be Class-III anomaly suggesting absence of hydrocarbon (AVO Analysis report).

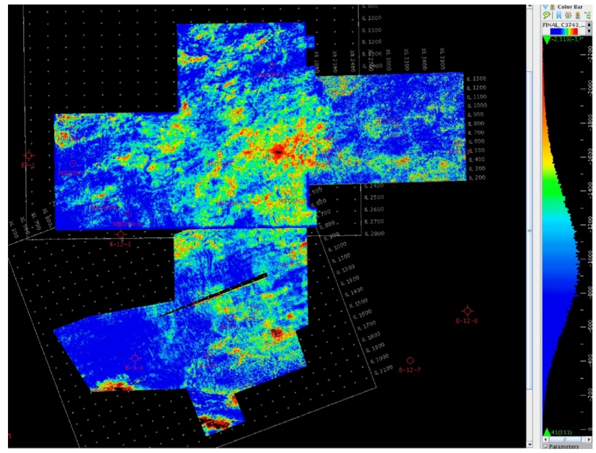

Fig. 7: 3D Seismic line showing High Amplitude Anomaly

3: Log correlation of 4 wells A, B, C and D was attempted. Clean shale corresponding to Maximum flooding surface and flooding surfaces were correlated in all the 4 wells. The sandstones and limestones genetically related to each other were correlated with sequence stratigraphic approach. Progradation of Sands from North East to Southwest direction has been clearly brought out. Water bearing sand and gas bearing sand genetically related to each other have been marked (Fig: 8). Between clean sandstones and clean shales there is abundant presence of shaly sandstones, silty sandstones , silty shales and siltstone. The differentiation of these lithologies has been clearly demonstrated on the logs. However the impact of the lithological variations on seismic data has a great bearing on understanding their petrophysical relation in one dimension and lateral changes in two dimensions.

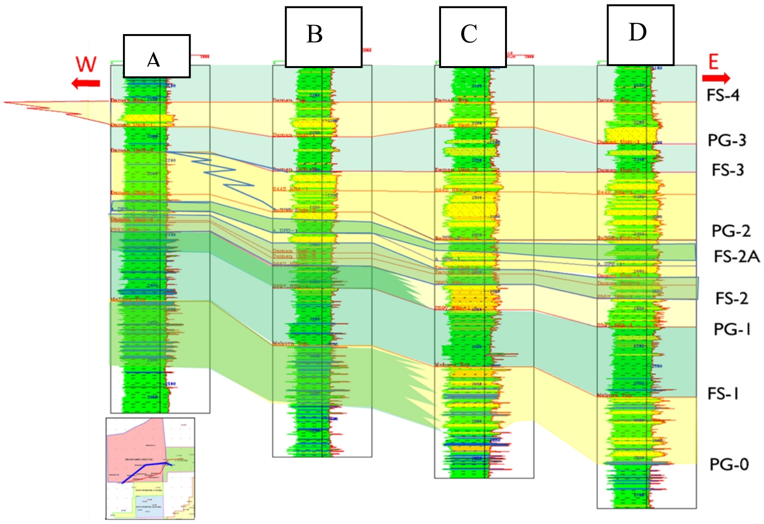

Fig 8: Log correlation along dip direction with sequence stratigraphic approach

4: Crossplots of GR and Impedance against clean shale for understanding the nature of impedance in clean shale encountered in the wells A, B, C and D has been attempted. The clean shales are having low impedance & high GR values and are marked as Flooding surfaces. As depicted by cross plots the Clean Shales belonging to Upper Mahuva, Lower Daman and Upper Daman formation have similar impedance values (Fig: 9).

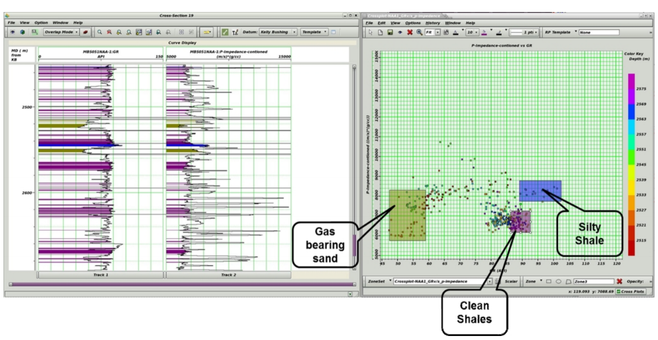

Fig. 9: Impedance against clean shales

5: Crossplots of GR and Impedance against water bearing sands for understanding impedance of Water bearing sand in the wells A, B, C and D has been attempted. This has been done in two parts. The cross plots for upper and lower Daman sandstones has been done separately. The upper daman water bearing sand have high impedance values and range from 7000 to 8000 (Fig. 10). As depicted by cross plots the Water bearing sand belonging to Upper Daman section corresponds to Tidal channel and Bar complex having higher impedance.

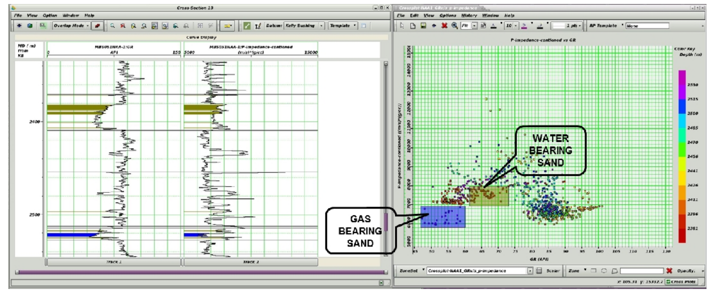

Fig. 10: Impedance against Water Bearing & Gas Bearing Sands in Upper Daman Section

The higher impedance of these water bearing sands against the low impedance Flooding surface clean shales generates a high amplitude anomaly in seismic data. Lower Daman water bearing sands also have high impedance but they are encased in silty shales and siltstones spatially and temporaly. This association of lithology does not have an impact on seismic amplitude changes thus these donot generate amplitude anomalies (Fig: 11).

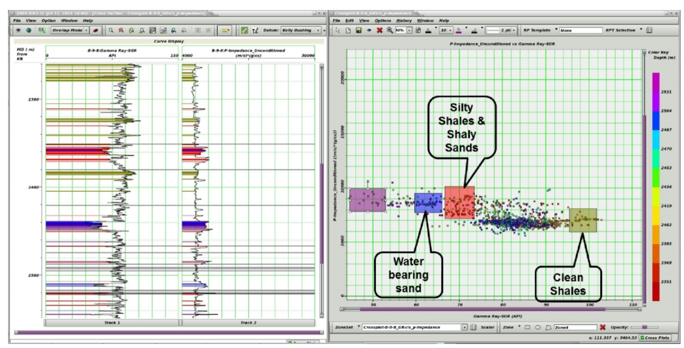

Fig. 11: Impedance against Water bearing sands, Silty Shales & Shaly Sands of Lower Daman Section

6: Crossplots of GR and Impedance against silty shale and shaly sand are having high impedance value (Fig:11). The relation of these silty shales to clean sands and clean shales generate different amplitudes depending on the relative impedances. The impedance of these silty shales and shaly sands are high thus it makes difficult to differentiate between water bearing sand and silty shales.

7: Crossplots of GR and Impedance against silty Gas bearing sand suggest lowering of impedance compared to water bearing sands. The impedance of these gas bearing sands are however not as low which can differentiate the water bearing and Gas bearing sands (Fig:12). Under these circumstances it becomes difficult to delineate these sands spatially and temporaly.

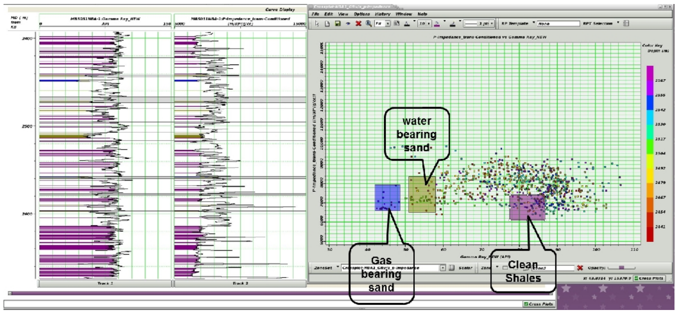

Fig. 12: Impedance against Silty Gas Bearing Sand, Water bearing sand & Clean shales

8: Crossplots of GR and Impedance against two distinct gas producing sands of well A shows a slight difference in their impedance values. The deeper sand-1 has a pore pressure of Hydrostatic + 10% causing more compaction of the sand resulting in higher impedance values (7000-8000) as compared to shallower sand-2 which is less compacted due to near hydrostatic pore pressure having lower impedance values (5900-6900) (Fig: 13). The interesting fact is that the flow rates and FTHP of deeper sand-1 are higher than that of shallower sand-2.

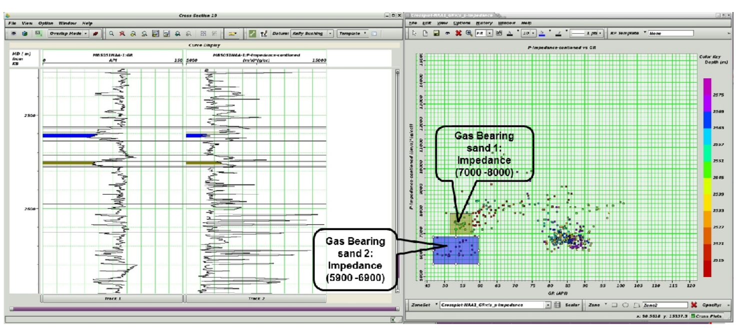

Fig. 13: Comparison of impedance between two different gas bearing sands

9: Side wall core and conventional cores cut in theses sandstones were investigated in detail in Regional Geological Laboratory Panvel. The sandstones are milky white, transparent to transluscent, fine to medium grained, occassinaly coarse grained, moderately to well sorted, with polycrystalline quartz grains. The quartz arenite comprising of fine to medium grained lithclasts, Occassionally coarse grained, subangular to sub rounded, polycrystalline quartz have poor sorting. The matrix is argillaceous.

Conclusions:

1. The Western part of Tapti Daman sector covering part of Diu Arch has been explored widely based on the amplitude driven exploration. High Amplitude anomalies depicting presence of thick channel sand proved to be water bearing after drilling. The understanding of these amplitude anomalies has been judgemental and biased.
2. The shales within the Daman formation are taken as low impedance shales and water bearing sands as high impedance sandstones. An attempt has been made to analysis the lithology and their impedance in the western part of Tapti Daman sector on the eastern flank of the Diu arch.
3. In the western part of Tapti Daman sector and in the eastern flank of Diu Arch, the lower part of Daman formation having thick net gas bearing sand of 15-18m has been explored which has no impact on amplitude anomaly whereas in upper part of Daman formation, high amplitude anomaly corresponding to the channel sand has been found water bearing. Cross plot of the logs has been attempted and the shales of the area are analysed in finer detail. It has been found that the shales are dominantly silty in nature thus resulting in loss of fissility.
4. Sandstones are also silty in nature and at some places are found to be unconsolidated, causing sand incursion problem during well testing and well completion. The analysis of the impedance response of the lithology from log is then compared with seismic data. The analysis suggests that the shales in the lower part of Daman formation are predominantly high impedance shales which are close to Silty Gas bearing sands. Thus it becomes difficult to delineate & differentiate the Gas bearing sands and shales. The shales in the upper part of Daman formation are clean and devoid of silty matter thus lowering the impedance of the shale. Validation of windowed attributes by AVO analysis and other advanced seismic methods are done.

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REFERENCES:

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.

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.

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

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.

Hoves J.V.C., 2005. Evaluation of Petroleum Geology of Western Offshore Shelf block.

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.

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.

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.

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