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Deliberate Search for Stratigraphic Traps within Oligocene Sediments of Central Graben in the Western Offshore Basin, India.

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Summary

Western Offshore Basin is the largest petroliferous province situated in the west coast of India. It is a matured basin and most of the structural plays whether big or small, have been identified and drilled. It is felt that the remaining hydrocarbon potential of this basin lies within the stratigraphic traps. The present study attempts to bring out potential stratigraphic traps within the lows and Central Graben was chosen as the best target for exploration of stratigraphic traps.

Standard interpretation workflows like log correlation, well-to-seismic calibration, correlation of horizons and faults, 3-D seismic attribute extraction, spectral decomposition, post stack inversion, 3-D visualization and geobody detection were adopted for the identification of stratigraphic features. From the regional log correlation presence of channel sands within Oligocene sediments towards north were established. Very high amplitude reflections are observed on the vertical seismic sections and these high amplitude attributes forms channel like features on the maps. After integrating all the geological and geophysical data, the study has identified many meandering channels within Oligocene deposits embedded within the thick shale deposits. Analysis of Paleo-structural disposition and provenance of the sediments during the time of deposition supports the presence of coarser clastics within these interpreted channels.

Central Graben is the main depocenter during the Tertiary time and had received more than 6 Km thick siliciclastic and carbonate sediments from south, east and north. Few thin carbonate/sand layers within thick shales are found to be hydrocarbon bearing in this area, which have produced small quantity of hydrocarbon in two drilled wells. To the west and southwest of this low is the platform areas where huge structural traps are proved to be hydrocarbon producers from the carbonate reservoirs. It is an established fact that the Eocene shales have very good source potential and Central Graben is probably the main kitchen which has charged the platform structures. These identified channels with coarser clastics are embedded within the thick shales of Oligocene age. Considering the nature of anomaly, paleostructural disposition, seismic attribute studies, presence of source rocks and seal, stratigraphic entrapment condition favours the accumulation of hydrocarbons within the mapped channel sands.

Introduction

The Western Continental margin of India hosts three major petroliferous basins viz. Kutch–Saurashtra, Western Offshore and Kerala–Konkan basins. The Western Offshore Basin is the largest producing basin and is in the mature stage of exploration. Majority of the structural plays have already been drilled and oil and gas fields are established. In search of yet to find hydrocarbon within the basin, stratigraphic plays have become the main target of exploration in this basin. The present study is primarily focused for identification of stratigraphic traps within the lows especially in the Central Graben.

Fig-1: Location map of the study area

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The area of study covers the northern part of Heera-Panna-Bassein Block and the southern part of Tapti Daman Block within Central Graben (Figure 1). The area is covered by 3-D seismic survey consisting of 1735 Km2 and interpreted to assess the hydrocarbon potential of the study area. Standard interpretation workflows like log correlation, well-to-seismic calibration, correlation of horizons and faults, 3-D seismic attribute extraction, spectral decomposition, post stack inversion, 3-D visualization and geobody detection were adopted for the identification of stratigraphic features. Integrating the geological and geophysiscal data a number of high amplitude channel geometries have been identified and evaluated from the hydrocarbon point of view. Presence of coarser clastics within these channels are predicted on the basis of paleo- structural and provenance analysis.

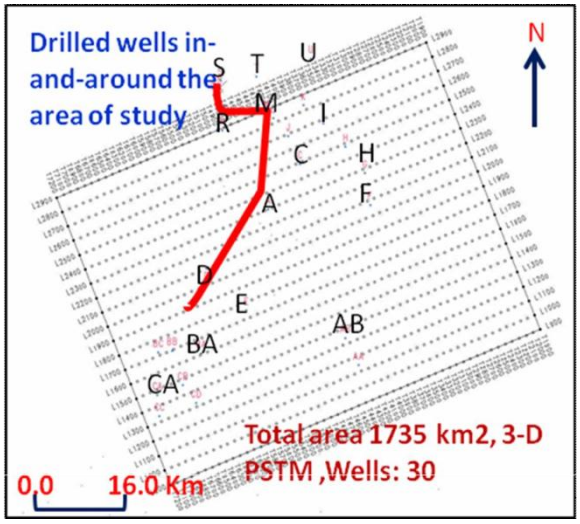

Fig-2: Seismic basemap with the drilled wells in and around the area and the log correlation profile.

Oil and Gas accumulation have been established in the platforms to the west and south west and anticlinal structures to the north and northwest. The area has received both siliciclastic and carbonate sedimentation during Tertiary period over the basaltic basement. During Paleocene to Recent period dominantly shales/claystones with minor sandstones and carbonates were deposited within this low. The location map of the area depicting 3-D grid and drilled wells is given in figure 1 and 2.

Tectonic and Geologic setting

The study area covers northern part of Heera-Panna-Bassein tectonic block and southern part of Tapti Daman Block (Figure 1). To the north of this area, two major lows are situated i.e., Navasari low and Daman low. To the west Bombay high and Mukta field, to the south and south west Panna and Bassein fields and to the east lies the Eastern Homocline and the Deccan trap outcrops. The NNE-SSW trending major low i.e., Central Graben is situated in the central part of the area. The major tectonic elements are the NNE-SSW, NW-SE and WNW-ESE, NE-SW trending faults which dissect the area forming highs and lows. The Central Graben is the major depocenter which has accommodated more than 6 Kms of sediments within the study area.

Stratigraphic Framework

The area has received a huge sedimentary accumulation starting from Paleocene to Recent. Panna Formation is the oldest sequence overlying the basaltic basement followed by deposition of Mid Eocene to Recent sediments consisting of Belapur, Diu, Mahuva, Daman, Mahim, Tapti, and Chinchini Formations. The generalized stratigraphic succession is shown in figure 3. This paper is focused mainly on Oligocene Mahuva and Daman Formation. Mahuva Formation is subdivided into two units; the lower unit is represented mainly by thick monotonous shale with occasional development of limestone. The upper unit is represented by thick shale with interbeded sandstone, siltstone and limestone. The Mahuva Formation is unconformably overlain by Daman Formation of Upper Oligocene age and consists of mainly shale, sandstone and siltstone (Zutshi etal, 1993).

AGE	FORMATION	EXPECTED LITH	H/C	DESCRIPTION	ENVIRONMENT OF DEPOSITION
MID. MIOCENE TO RECENT	TAPTI & CHINCHINI			Clay stone, Shale with thin streaks of siltstone.	Tidal Shallow Marine
LOWER MIOCENE	MAHIM			Mainly Shale with thin streaks of siltstone	Tidal- Deltaic
UPP. OLIGOCENE	DAMAN		☆	Shale,Siltstone and sandstone	Tidal- Deltaic
LR. OLIGOCENE	MAHUVA Lower		☆	Mainly Shale with siltstone ,sandstone & limestone streaks	Shallow Marine
	MAHUVA Upper			Mainly Shale with limestone streaks	Shallow Marine
MID-UPPER EOCENE	DIU		☆	Mainly Shale with limestone streaks	Shallow Maine
	BELAPUR				
PALEOCENE TO LOWER EOCENE	PANNA		☆	Mainly Shale with sandstone streaks	Fluvial to shallow marine
CRETACEOUS	TRAP/BASEMENT			Deccan traps	

Fig-3: Generalized Stratigraphy of the study area.

Data interpretation and analysis

Data used in this study comprised of 3-D seismic volume of around 1735 Km2 with a bin size 25X12.5 m. The record length of raw data is 6s with 2 ms sample interval. Wire-line logs and stratigraphic tops are available from 30 wells drilled in and around the area. Well data include nine stratigraphic tops, time-depth tables and various wire-line logs (spontaneous potential, gamma ray, resistivity, acoustic, neutron porosity, and density). Well data like cutting samples, core samples, initial testing results, sedimentogical, geochemical and paleontological reports were also available for study.

Horizon correlation and mapping

The seismic reflections within the entire stratigraphic sequence in the area are characterized by moderate to high amplitude and good continuity. The individual log signatures can also be easily correlated across the area. The structural framework was reconstructed for entire sequence by correlating 11 horizons. Most fundamental and basic approach was adopted for understanding vertico lateral distribution of the stratigraphic units in the study area as given below.

- Understanding the regional tectonics and prevailing basement configuration vis-à-vis perceived paleo drainage systems during deposition of the sediments from published and unpublished literatures.
- Mapping of tops as Basement, Paleocene (Synrift), Panna, Belapur, Diu (Bassein), Mukta (Lower Mahuva), Heera (Mahuva), Alibagh (Daman), Bombay and Mahim. Additional horizon "Within Daman" in Daman Formation, (Figure 4).
- Understanding the paleostructures from isochronopach maps of different units within it.
- Identification of reservoir facies within Panna, Mahuava and Daman from different seismic attributes as well as facies analysis.

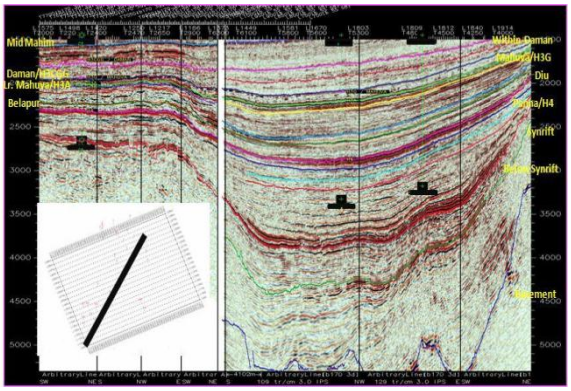

Fig-4: NE-SW arbitrary line passing through the Well CE and E showing correlated horizons and other features.

Log facies mapping

Macro/micro level electrolog facies analysis was done along seven log profiles for inferring the associated lithofacies changes in and around the area. Panna Formation is mainly shales with layers of Sandstones, siltstone and coal. Belapur is mainly a limestone layer whereas the Diu (Time equivalent of Bassein) is dominantly shale/claystone with thin limestones streaks in the lows and thick monotonous limestone in the platform areas. The Early Oligocene Mahuva Formation is dominantly a shale/claystone unit and divided into two subunits. The Lower Mahuva unit is predominantly shales with thin limestone streaks. In Upper Mahuva unit silty-sandstones/siltstones are also observed along with limestone streaks within predominantly shaly sequence. The Upper Oligocene Daman Formation is a Sand/Siltstone and Shale alternations with increase in sand towards north (Figure 5).

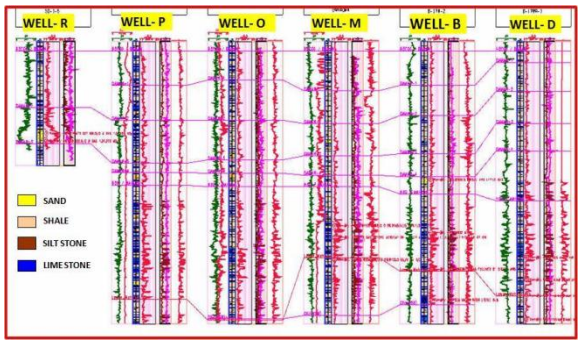

Fig-5: Electrolog correlation along well R, P, O, M, B and D The profile is Flattened at DamanTop. The correlation profile is shown in the figure 2.

Seismic Attributes Study

The mapped sedimentary column was analysed by extracting seismic attributes within sequences and within time windows with reference to mapped horizons, computing horizon slices of attributes and seismic trace data. 3-D visualization, seismic inversion, spectral decomposition and geobody detection, were attempted to understand the spatial and temporal distribution of the facies and identification of the stratigraphic features within the identified intervals.

Identification of Stratigraphic features

Sand filled channels, point bars within Lower Oligocene Mahuva Formation

Within Mahuva Formation at top of Lower Mahuva reflector, meandering channel (Point bar) like features are mapped from high amplitude anomaly (Figure 6). This channel is very distinct on seismic sections.

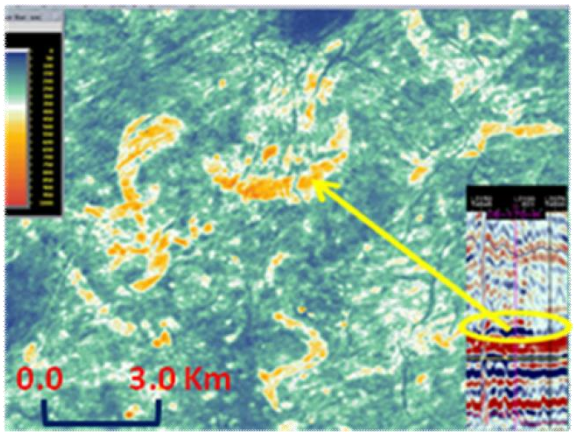

Fig-6: Maximum Positive Amplitude within 20-50ms above Lower Mahuva showing the Meander Channel & Point Bars.

High positive amplitude may be generated from carbonate-clastics (sands and/or shales) interface. However, characteristic meandering geometry and point bar favour coarser clastics (sandstone). Occurrence of sandstone layers over the Lower-Mahuva shales are known in nearby drilled wells towards north (Figure 5). Thus, relatively wider channel is envisaged to be filled with good reservoir sands and forming stratigraphic traps.

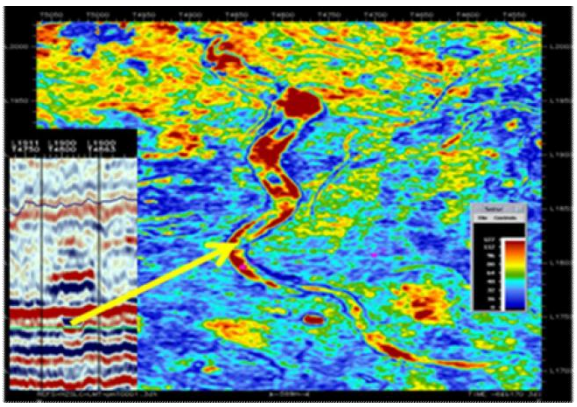

Fig-7: Horizon slice at 6 ms above Lower Mahuva top showing the meander channels.

Another channel manifested by high amplitude anomaly at the top of lower-Mahuva reflector (Figure 7), mapped from the horizon slice of reflection strength taken at 6 ms above Lower-Mahuva Top. Log interpretation of well M around Lower-Mahuva top surface shows that thin sandstones are embedded in relatively thicker limestone. Sandstones have lower impedance than limestone and under favourable

conditions (thicker layer or higher frequency) limestone/sandstone interface (high to low impedance) may generate high positive reflection as seen in this case. Using this analogy and channel like geometry, it is inferred that mapped high amplitude channel-like anomaly is generated from limestone-sandstone interface.

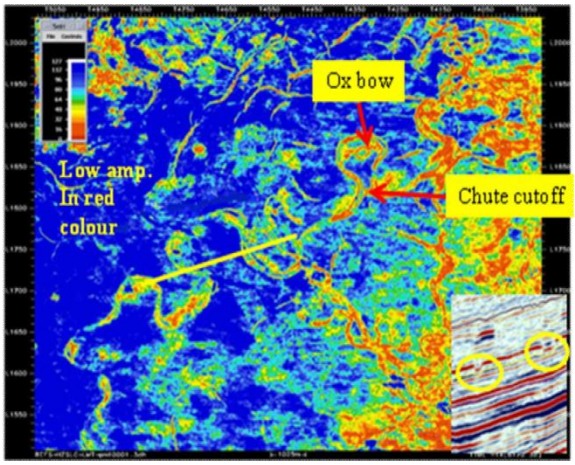

Fig-8: Horizon Slice at 20 ms above the Lower Mahuva showing the meander channels with ox-bow, chute cutoff and river capture.

Another channel system is identified by low amplitude anomaly at the top of Lower-Mahuva reflector, mapped from the horizon slice of reflection strength taken at 20 ms above Lower-Mahuva Top (Figure 8). This anomaly exhibits meandering channel geometry along with chute-cut-off, river capture and ox-bow features. Reservoir quality rocks are expected to be filled within this channel.

Anomaly within Mahuva (Mahuva Carbonate buildup)

A carbonate buildup like body is interpreted from seismic reflection configuration and reflectivity changes above Lower Mahuva reflector (Figure 9). On horizon slice taken at 72 ms above Lower Mahuva Top (Figure 9 inset), the identified body is having NW-SE trend. Impedance section overlaid on seismic trace shows the possible Carbonate buildup enclosed by relatively high impedance layers at top and bottom. Within the body, relatively low impedance indicating possible development of better porosity. This Carbonate buildup may form good strati-structural prospect due to availability of deep rooted fault in the east (charging through fault).

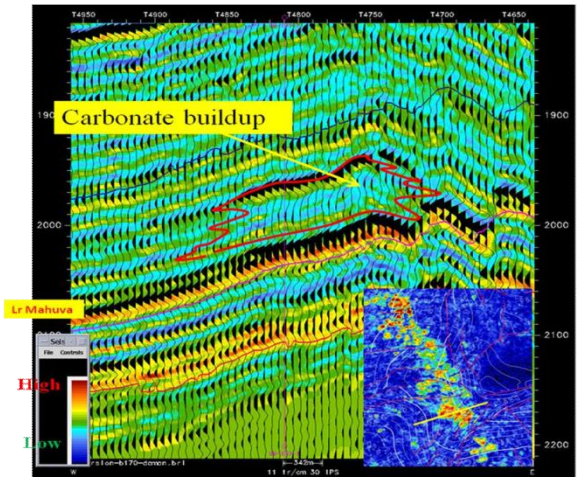

Fig-9: Impedance section overlaid with seismic trace. The inset map shows Horizon slice 72 ms above Lower Mahuva Top.

Sand filled Channel within Upper Oligocene Daman Formation

Within Daman Formation stacked amplitude (Figure 10) anomalies are observed in vertical section. To map them a reflector named as "Within-Daman" was correlated. Over "Within-Daman" reflector, high amplitude anomalies organized in channel-like features (Figure 11) were mapped. The channel feature has also been brought out in the horizon slice taken at 20 ms above the reflector "Within Daman". Impedance map within 60 ms above "Within Daman" shows the low impedance sands within the channel. High amplitudes associated with relatively lower impedance are known hydrocarbon bearing sands in nearby area (Well R, 2699-2719, 2725-27 m, oil @389 BPD, gas@120272 m3/d)). The Isochronopach map between Mahuva Top and Daman Top shows the gradient for channel entry from the north (Figure 12).

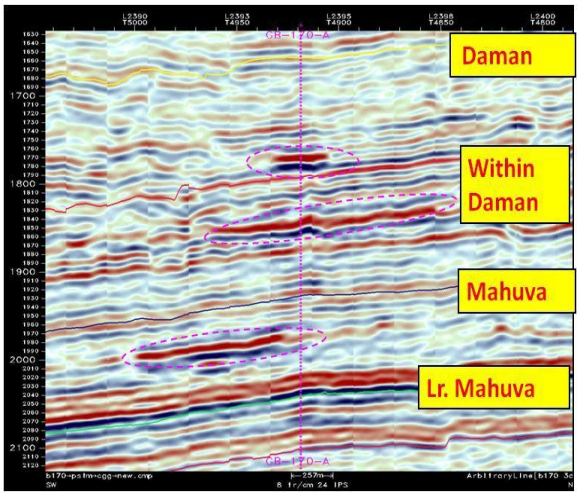

Fig-10: Seismic section showing the vertically stacked amplitude anomaly within Daman Formation

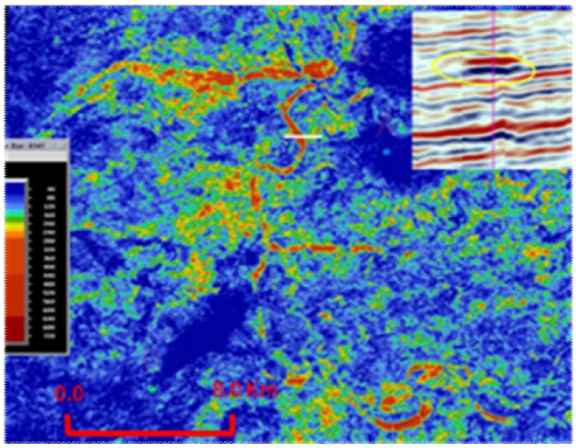

Fig-11: RMS Amp within -12 to -32 ms window w.r.t. within-Daman Reflector. High amplitude channels are mapped within Daman Formation from horizon slices and window attributes. Similar anomalies are hydrocarbon producer in near by area.

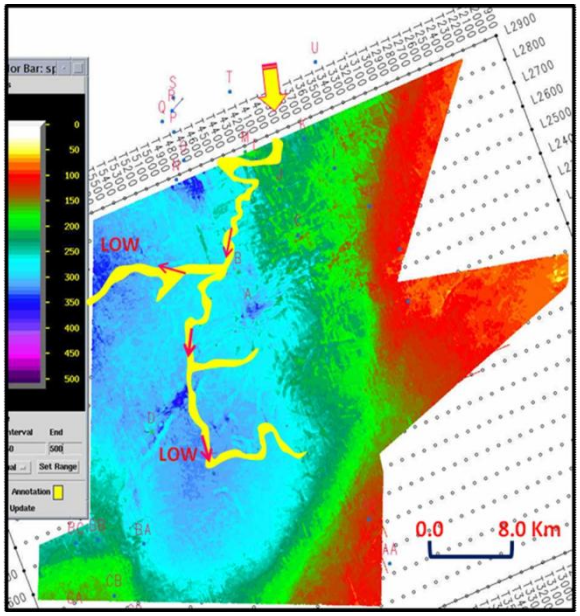

Fig-12: Isochronopach between Mahuva Top and Daman Top. Channels interpreted from seismic attributes and possible flow direction are overlaid

Petroleum System

Commercial accumulation of oil and gas has been established in Heera-Panna-Bassein sector with major producing fields like B55, Bassein, Heera, Panna etc. Hydrocarbons are also established in Tapti Daman area to the north. Within Central Graben presence of hydrocarbon is already established in some of the drilled wells. Presence of gas chimneys in the seismic section establishes the presence of active petroleum system in this area.

Source Rocks

Main source rocks in the Western Offshore Basin are in the Paleocene to Eocene sequence (Panna Formation) and consist of shales and coals of continental to paralic origin. Marginal potential source rocks might exist in the Upper Oligocene to Miocene section. Oligocene rocks are richer in organic matter than the overlying Miocene rocks. Burial history curves constructed for the Surat Depression and the Central Graben indicate that Paleocene-Eocene sediments have reached peak generation potential for Type-III kerogen.

Maturation

Synthesis of thermal maturity parameters reveals that the sediments of Panna Formation attained adequate thermal maturity for commercial generation of hydrocarbons in the area. High geothermal gradients have compensated for a modest overburden which is provided by the Middle Eocene to Middle Miocene age sediments in the Surat Sub-basin and the Lower Oligocene to Recent fill in the Central Graben. Oil generation is reported to be from Late Early Miocene time and is also in the process of active generation till recent times.

Reservoirs

Oligocene sandstones, siltstones and limestones of the Mahuva Formation and Daman Formations deposited in the identified channels and reefal builups are expected to be good reservoirs for hosting hydrocarbon. Similar channels in the north are good reservoirs and is hydrocarbon bearing.

Seals

The identified channels are enclosed within thick shales which act as both vertical and lateral seals. The limestone of reefal build ups are expected to have embedded within the thick Oligocene shales. Middle Miocene to Holocene shales of Chinchini Formation constitutes the most widespread regional seal facies in the basin.

Conclusions

Integrated evaluation of 3D seismic data has brought out many high amplitude channel features and reefal buildups within Oligocene sequences. Additional studies like spectral decomposition, post stack inversion, 3-D visualization and geobody detection, were adopted for further conforming the identified stratigraphic features.

Central Graben is the main depositional low and a proved kitchen for the hydrocarbon accumulation in the surrounding areas. These stratigraphic features located within the main kitchen and associated with excellent vertical and lateral seals like clays and shales favours the stratigraphic entrapment for hydrocarbon accumulation in this low. Thus, deliberate search for stratigraphic features in Central Graben may provide fruitful results.

Acknowledgements

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