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New Plays in Mature Basins:
A case study from South-West of Mumbai High field

Abstract

Cluster 7 area of Mumbai offshore Basin is a prolific producing field from Oligocene carbonates. Newly acquired Broad Band 3D seismic in the study area has brought out importance of basement spurs and a novel concept wherein integrated comparison of pay level and basement level structural maps were able to explain all wells in the study area resulting in identification of better locales for exploitation and new areas for exploration.

Introduction

The Cluster-7 area is located to the South-West of Mumbai High field in BH-DCS block of Mumbai offshore. The data used for interpretation is part of the newly acquired Broad Band 3D seismic and the area considered for the present study is approximately 1500 Km^2 covering the southern part of the 3D volume with total 58 wells (37 exploratory and 21 development) drilled in the study area (Fig.1).
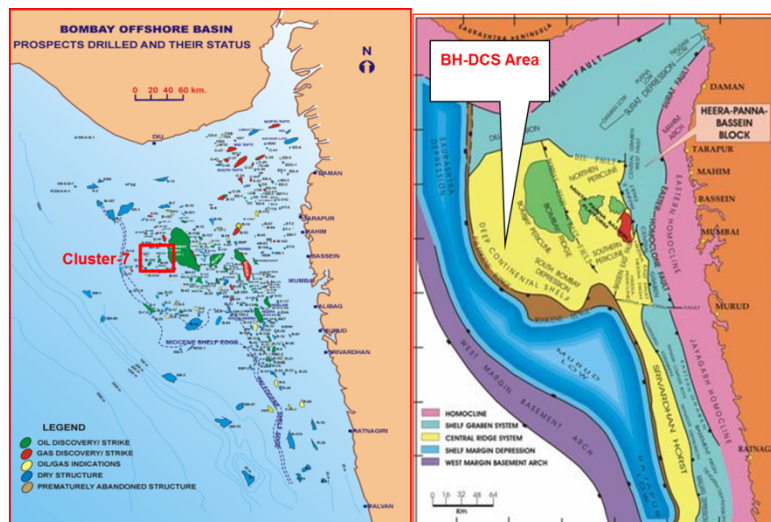

Fig.1: Location of Cluster 7 in prospect map of Mumbai Offshore Basin (Left). Map showing major tectonic divisions in Mumbai Offshore Basin (Right).

Depositional Regime:

Mumbai High along with its western periphery remained a positive area during the rifting episode of the Indian Plate. The first sedimentary sequence i.e. Panna Clastics were deposited over the Basement on the SW part of the study area. This area is marked by Basement spurs, which is granitic/ gneissic in nature. This granitic/ gneissic Basement acted as provenance for the Panna and Basal Clastics formations in the study area. The landward shift of different Paleo-shorelines towards Mumbai High indicates relative rise of sea level under a transgressive setting. This favored the deposition of various limestone units like Devgarh (Early Eocene), Bassein (Mid to Late Eocene) and Mukta (Early Oligocene). However, the clastics system dominated towards the landward side wherein a mixed carbonate siliciclastic system prevailed. Due to oscillations in the sea level, shales were deposited within the Carbonates. The carbonate platform was intervened by subareal exposure and led to the formation of hiatuses and unconformities. This resulted in development of secondary porosity which was preserved in some cases but destroyed on account of secondary mineralization in others. Shallow marine conditions with oscillations persisted from Late Oligocene with the Bombay High being submerged. Carbonates of the Panvel, Bombay and Bandra formations were deposited followed by the finer clastics of the Chinchini Formation (Unpublished report 2016).

Envisaged Hydrocarbon Play:

The area to the west of the main Mumbai High field has been under exploration since the early seventies. After the discovery of Mumbai High field, the initial stage of hydrocarbon exploration in this area was primarily targeted at major structural features which led to the drilling of several structural prospects.

The most prolific oil and gas reservoirs in this field are Late Oligocene carbonates (L-VI layer) (Fig. 2). However, positive results have also been encountered in carbonates of Bassein Formation (Middle to Late Eocene), Mukta Formation (Early Oligocene) and Bombay Formation L-III/L-IV (Mid Miocene). Panna along with the Basal Clastics (Early Eocene to Oligocene) have also yielded positive results.
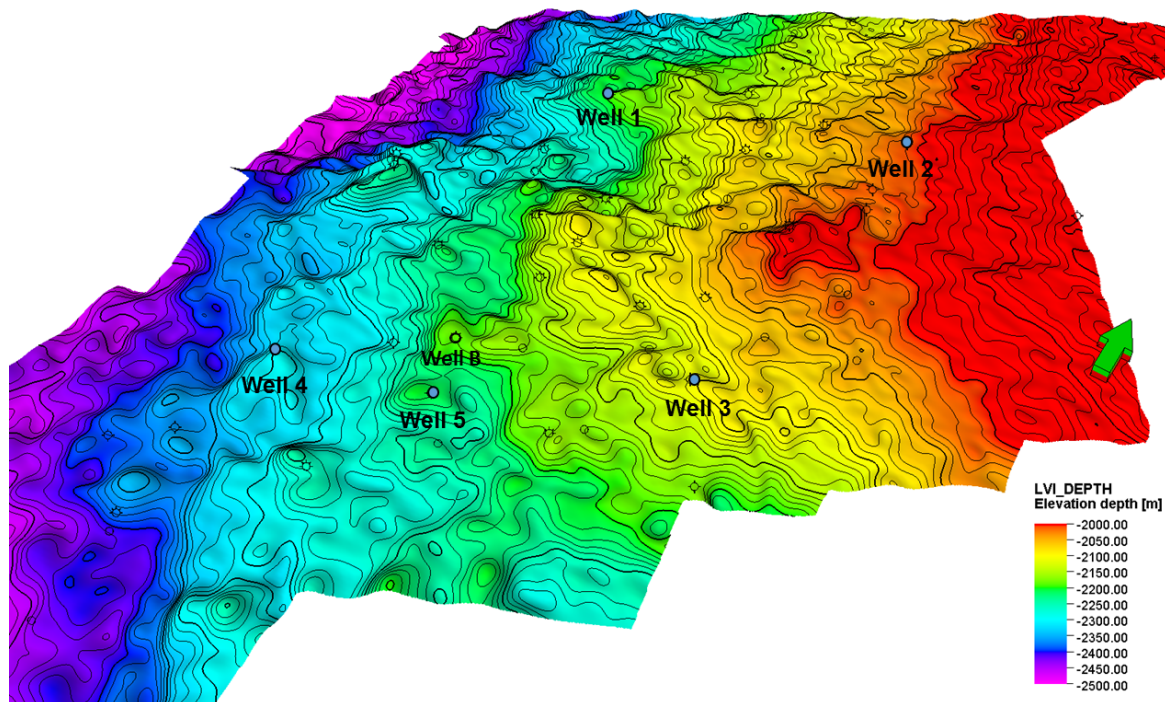

Fig.2: Depth Relief at L-VI top (One of the main reservoirs of this area). There were many wells which went dry in spite of being drilled at structurally favourable positions at reservoir levels (L-VI, Mukta, Bassein top). Examples wells 1-5 plotted in the figure.

The depth relief clearly depicts the westward slope of the Basement level forming successive terraces away from the Bombay High. Spurs radiate outwards from the Basement in the westward, SW and NW directions (Fig.3). The shallower levels mimic the Basement configuration to a certain degree (Fig.4).

With the newly acquired seismic Broad band data of acquisition bin size is 12.5m X 6.25m, the Basement resolution has enhanced significantly and thus brought forward remarkable observation linked with it. The depth relief map of Basement top clearly brings out the structural highs oriented NNW-SSE corresponding with the basin forming Dharwarian trend. These paleo-highs were further reactivated and offset by the Aravalli trend (NE-SW) and youngest Satpura trend oriented (E-W).

For past four decades, structural map at these pay levels showed very good and prominent highs but many locations went dry and exploration strategy seemed to be very challenging (Unpublished WCRs). But a new idea changed the course entirely. Same wells when plotted on structural map at basement level, revealed a trend. It was observed that the wells drilled at structural highs/closures of Basement level are HC bearing or the producing wells of the field and encountered porous reservoirs whereas the wells which were drilled on Basement lows/ flanks have been abandoned and dry or have only yielded HC indications at reservoir levels (Fig.5-6). Therefore, at the shallower pay levels like L-VI, Mukta etc., structure is propagated broader w.r.t. the Basement structure, however; the HC entrapment is restricted to the Basement closure only. This model clearly explains entire hydrocarbon habitat of the area particularly for the Oligocene carbonates.
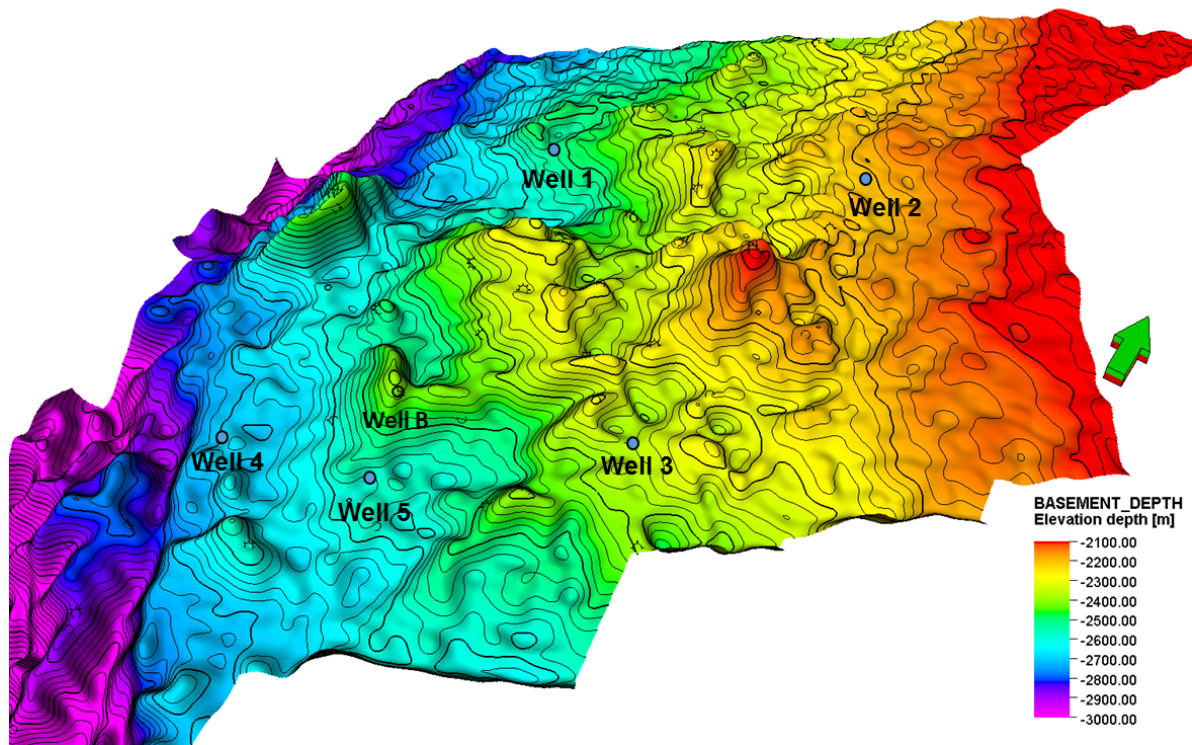
Fig.3: Depth Relief at Basement top. The wells 1-5 which went dry were placed either in lows or at flanks.
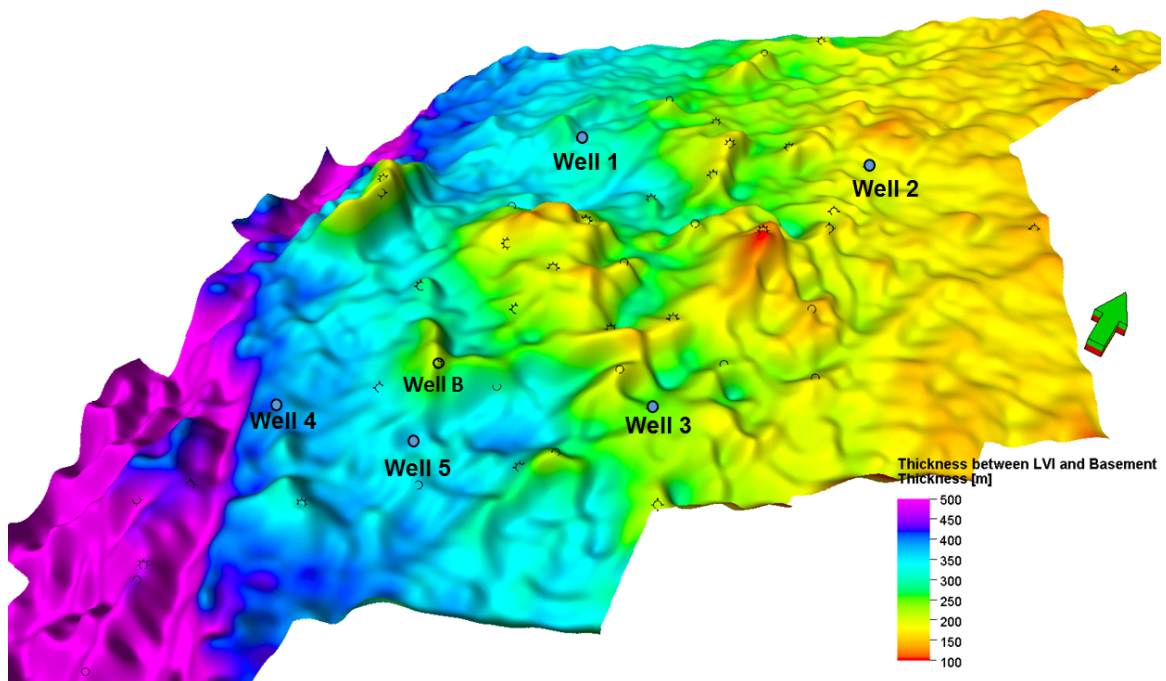

Fig.4: Isopach thickness (color bar) between L-VI and Basement superimposed on a Basement relief surface. The Basement High positions remained elevated up to the L-VI level as shown by the warm colors denoting the lower thickness values.
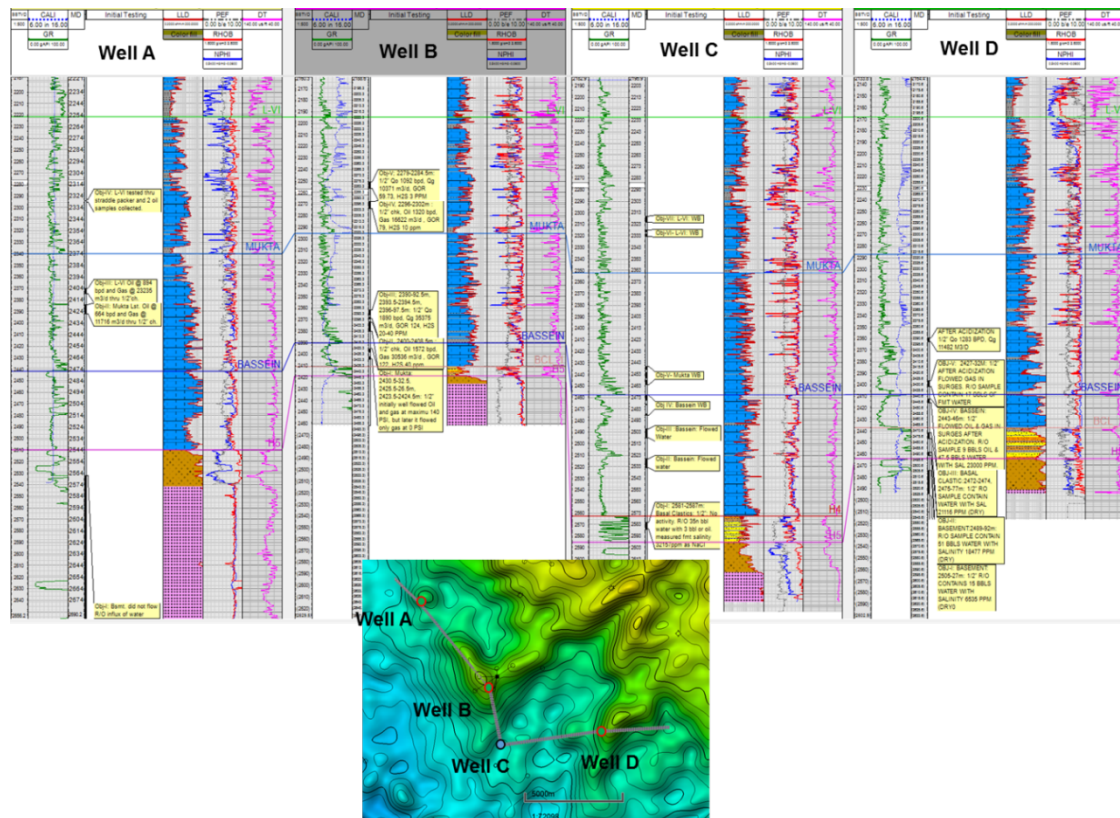
Fig.5: Well Correlation along wells A- D (Well C is the well denoted as well 5 on the previous maps) flattened at L-VI top
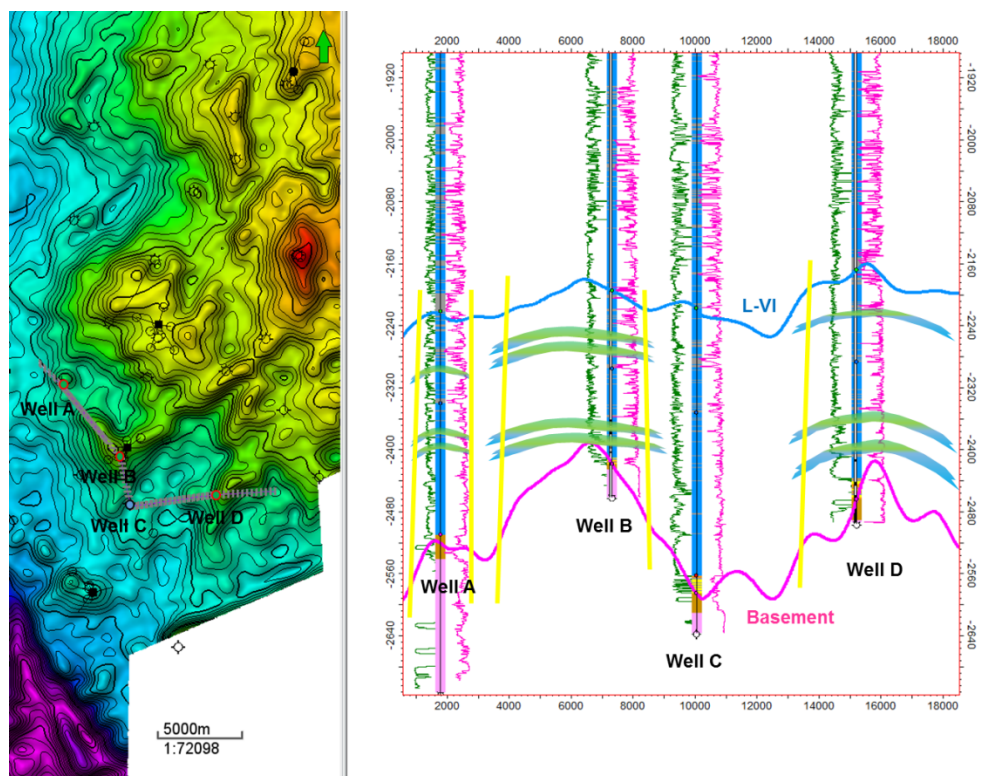

Fig.6: Geological Cross-section along wells A-D with HC pools. Well C was tested water bearing at various reservoir levels.
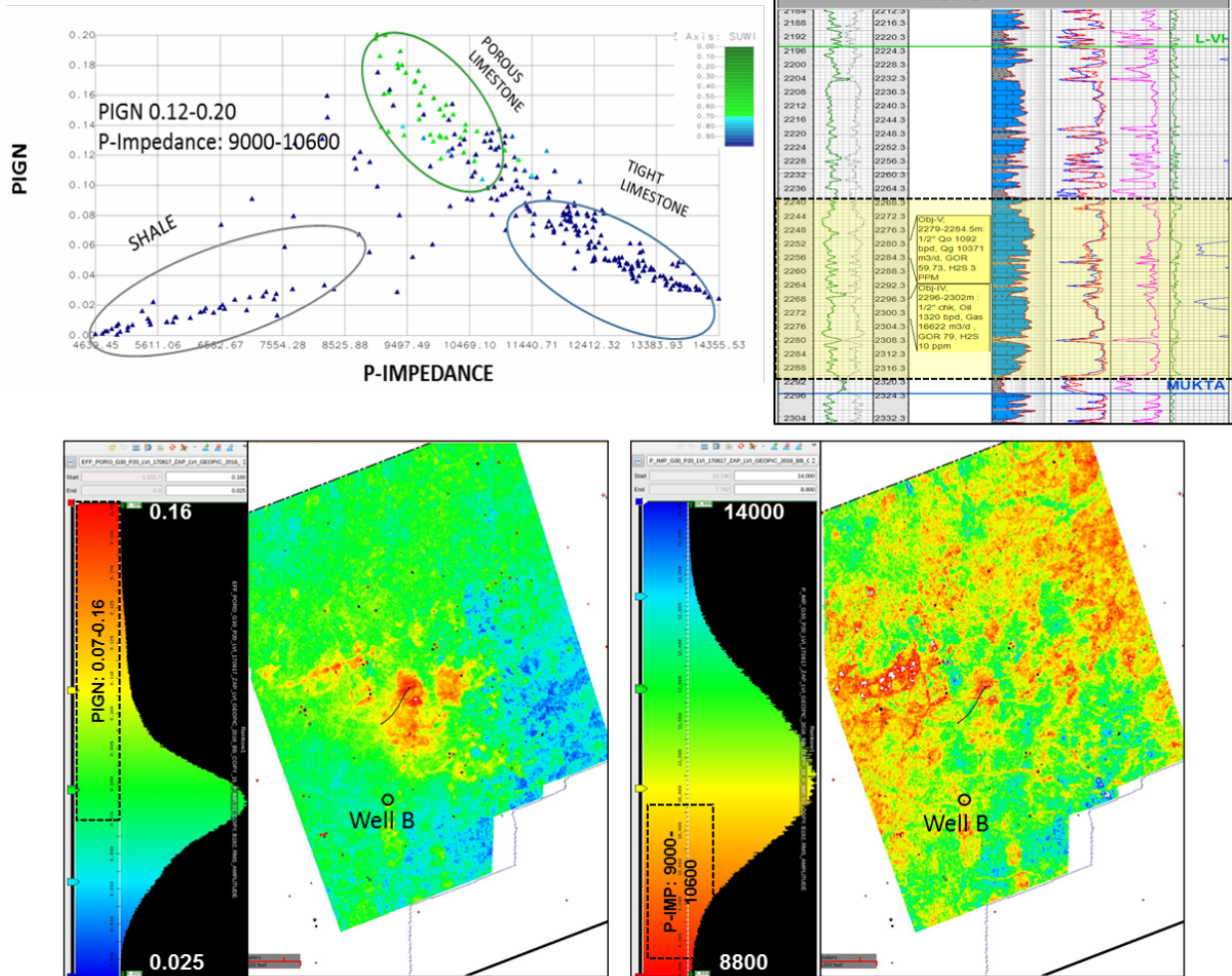
Fig.7: PIGN vs. P-Imp derived P-Imp range (9000-10600) of a producing well B from cross plot analysis and corresponding PIGN and P-Imp slices for the pay window (L-VI offset 30 P20 ms) showing good facies development in concordance with the structurally favourable positions.
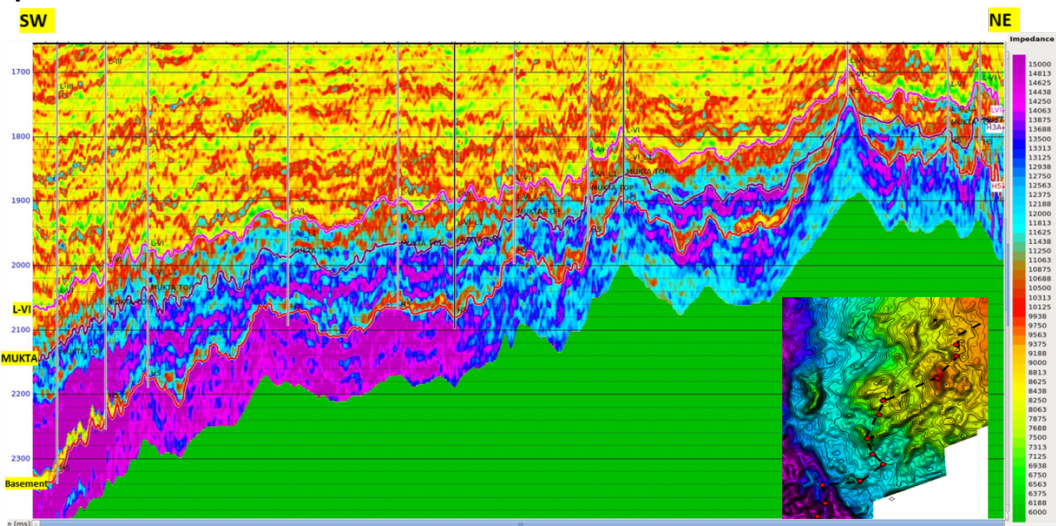

Fig.8: P-Imp section showing westward dip and gradual thinning towards East of L-VI below sequence.

Facies Characterization:

Different pre-stack attribute volumes viz. P-Impedance, S-Impedance, Effective Porosity (PIGN), Vp/Vs, Density etc. were studied. Well based cross plots between PIGN and P-Impedance for the producing well "B" with saturation in Z axis was generated to analyze the facies and hydrocarbon spatial distribution in the field for the L-VI pay window (Fig. 7).

The PIGN and P-Impedance slices taken for the pay window were able to differentiate porous facies developed at structural highs/ closures from the tight facies encountered at paleo-lows. The effective porosity volume was not able to discriminate the ranges captured in the well based cross-plots as the values were < 0.11, however the trend does indicate that there is lowering in effective porosity eastwards towards the western periphery of Mumbai High field. In the same direction, the Oligocene carbonates are gradually thinning (Fig.8) and becoming more argillaceous with poor porosity due to undistinguishable structural closures at Basement level.

Conclusion:

Thus, the present model with the help of high resolution Broadband seismic data clearly brings out:

- The significance of prominent Basement highs/ paleo-highs in carbonate dominated setting even when these highs have been submerged is brought out. Therefore, for carbonate reservoirs that broadly follow basement trend, use of structural map at pay level in stand alone is not recommended and should be validated with the basement level highs as well.
- The shallower pay levels like L-VI, Mukta etc., structure is propagated broader w.r.t. the Basement structure, however; the HC entrapment is restricted to the Basement closure only.
- Reservoir facies characteristics also play a major role and are found to be better developed in the structural high areas. These Basement paleo-highs witnessed better carbonate platform growth resulting in porous reservoir fairways in comparison to the adjoining lows which were locales of deposition of low energy facies.
- Basement level spurs are undistinguishable as we further move eastwards and facies wise the Oligocene carbonates become more argillaceous and less porous in that direction.

Thus, in Cluster-7 area with exploration history of four decades, this concept not only explains status of all drilled wells but also brings forward significant areas along the distinct Basement high trends with better reservoir development which is yet to be assessed for the multiple prospective reservoir units present here.

Acknowledgement

References

- Unpublished WCR and Lab Reports, ONGC
- Reservoir Characterization of L-III, Panvel, Mukta and Bassein Formations of Cluster-7 (B-192, B-45, WO-24) area integrating 3D Seismic (Broad Band Data) and Well Data, Western Offshore Basin, Mumbai, 2016, Unpublished Report, GEOPIC, ONGC Dehradun