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Opportunity to Enhance Oil and Gas Production in Mature Basins: A Case Study from D-12 Field, Mumbai Offshore Basin, India

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Abstract

The paper discusses an approach of increasing production in a mature basin by bringing on stream the discovered fields and simultaneously recognising new play potential for further exploration & appraisal.

The case history discussed in this paper is from the D31 cluster located in the Mumbai Offshore Basin, awarded to Antelopus Energy during the DSF-2 bid round in early 2019. D-12 field is part of this cluster, where the D-12-1 well discovered gas and condensate in Ratnagiri limestone reservoir of Miocene age. Though the field was discovered in 1982 by the earlier operator, production from this field was not taken up in view of small size.

AEPL has carried out the detailed subsurface analysis and field development planning work to accelerate the D-12 gas development. Substantial additional gas reserve potential has been recognised in the Ratnagiri pay zone in D-12 field, based on detailed technical work by Antelopus Energy. In addition, integrated analysis has unravelled substantial oil potential in deeper Oligocene and Eocene reservoirs beneath the proven Miocene gas pool.

Together, the field has in-place potential of 235 BCF gas and 400 mmb oil, which will contribute significantly to the oil and gas production in the basin.

The approach discussed in this paper can help recognising additional potential in the mature basins to augment oil and gas production.

Introduction

The Mumbai offshore basin is a prolific petroliferous basin with recoverable volume of 12 bn boe. Several large discoveries viz. Mumbai High, Bassein, Heera, Neelam, South Heera, Mukta, South Tapti etc were made early in the exploration history of the basin, followed by a string of medium to small discoveries.

However, the creaming curve (Fig.1) of Mumbai Basin suggest no significant addition to reserve during last 20 years, due lack of success in establishing new plays in the basin. As a result, the production of oil and gas from the basin has been declining over the years.

Several strategic initiatives have been undertaken by the Government of India to augment the production of Oil & Gas. One of the initiatives is to offer the discovered small fields to other players through competitive bidding process.

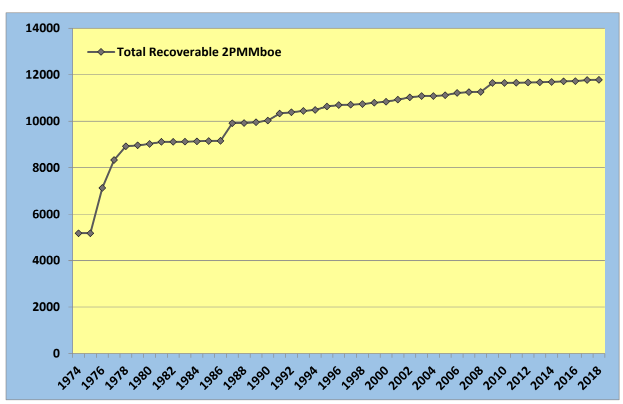

Fig.1: Creaming Curve of Mumbai Basin (modified after Mohapatra, 2018)

Antelopus Energy was awarded the D-31 cluster, during the second Discovered Small Fields (DSF-2) round in early 2019. The D31 cluster (Fig.2) is located in offshore shallow water in the Mumbai Offshore basin in water depth of about 75m to 85m, at a distance ranging from 110 km to 215 Km from Mumbai city. There are 5 discoveries in the D31 contract area viz D-12, D-31, B-192A, BH-70 and BH-67.

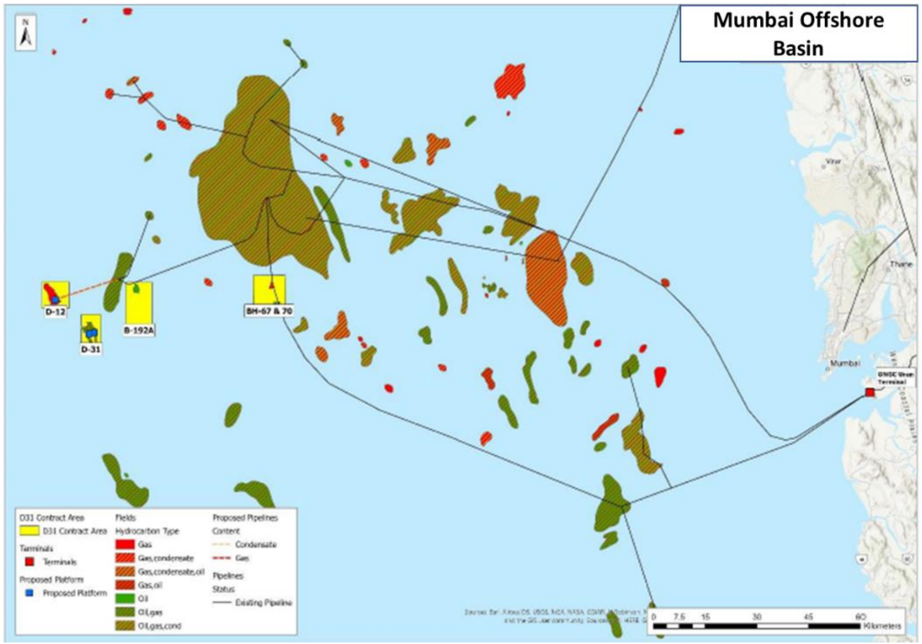

Fig.2: Location Map of D-31 Cluster, Mumbai Offshore basin

Stratigraphic Framework

The Mumbai Offshore basin is a peri-cratonic basin, with individual rift grabens forming sub-basins. This basin hosts thick pile of sediments, ranging in age from Paleocene to Recent.

The study area, D-12 field is situated in the Deep Continental Shelf (DCS) area. The general stratigraphy of the Mumbai Basin is given in Fig.3.

In this area, the Late Paleocene to Early Eocene time signifies the early syn-rift stage & is represented by clastics contributed by the then existing paleo-highs, essentially in continental to fluvial environment (Panna Formation). It is overlain by grey to dark grey shales with thin sands representing the first marine transgression into the basin. Presence of carbonaceous shale and coal at a few places suggest localized restricted conditions.

During Middle to Late Eocene, after a period of peneplanation, the basin witnessed a major transgression. Extensive carbonate sedimentation of Bassein Formation occurred in the shallow shelf area.

During Early Oligocene, the DCS area experienced generally shallower water depths and shale interbeds within limestone becoming more frequent. End of Early Oligocene also witnessed initiation of the westerly tilt of the basin.

The carbonate reservoirs within Early Oligocene (Mukta Formation) host significant amounts of hydrocarbons. Close of Early Oligocene is marked by an unconformity.

A few brief spells of transgression followed by continuous eustatic rise in sea level up to Middle Miocene led to formation of shelfal carbonate banks (Ratnagiri formation). A thick shale of Chinchini formation overlies the Ratnagiri carbonate providing a regional cap.

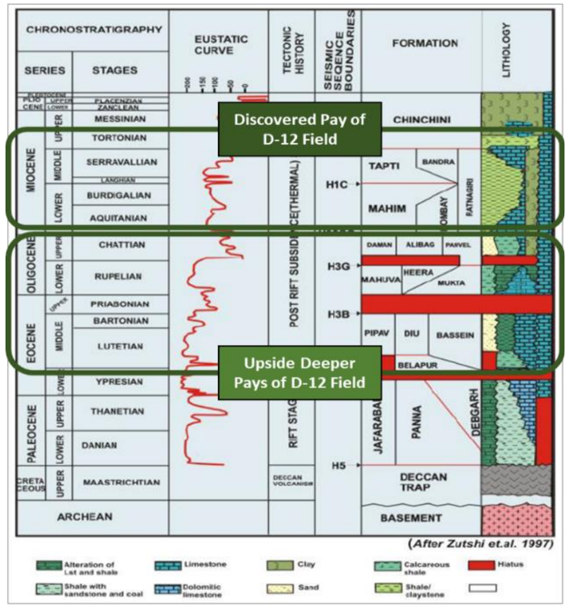

Fig.3: Generalized stratigraphy of Mumbai Offshore Basin (modified after Zutshi et. al. 1997).

Reservoir Characterization and Development planning of Miocene Pay in D-12 field

The lithological association of Ratnagiri formation in D-12 field comprises of limestone with few streaks of shale. The limestone microfacies mostly range from foraminiferal wackestone to packstone, deposited under shallow inner shelf environment. The limestones are argillaceous, fossiliferous, biomicritic, grey to dark grey in nature. In some places, the limestone is hard and compact with microcrystalline in nature. From the core analysis of this reservoir, it is observed that the porosity is mainly moldic and solution vugs or channels.

The D-12 field is manifested by a three-way anticline closure bounded by two faults, one trending SW-NE forming the south bounding fault and the second NW-SE trending, forming the east bounding fault (Fig.5). RMS amplitude attribute analysis of the Ratnagiri (H1A) horizon displays amplitude dimming (Fig. 4) that broadly conforms to structure (Fig. 5). The D-12-1 well has been drilled in the flank of this structure, which indicates a 63m of gross hydrocarbon bearing section to the crest of the structure.

The well D-12-1 produced 4.8 MMscfd gas and 440 bcpd condensate through ½" choke from Ratnagiri Limestone. Detailed petrophysical analysis has been carried out and well testing data of D-12-1 well was analysed. Based on all the available information (testing, core analysis, gas shows and petrophysical interpretation) a GWC is interpreted at 1535m TVDSS depth (Fig.6). As can be seen in figure, the hydrocarbon saturation is much lower in the interval 1529m to 1535m, hence the top transition zone is marked at 1529m TVDSS, which is also evident from the well testing result of the first perforation interval.

For development planning purpose, integrated static geocellular model and dynamic simulation has been carried out. The hydrocarbon pore volume map at the Ratnagiri pay is shown in Fig 7. The re-interpretation of seismic data, petrophysical analysis and static geocellular modelling indicated significantly higher gas in place than previous estimate.

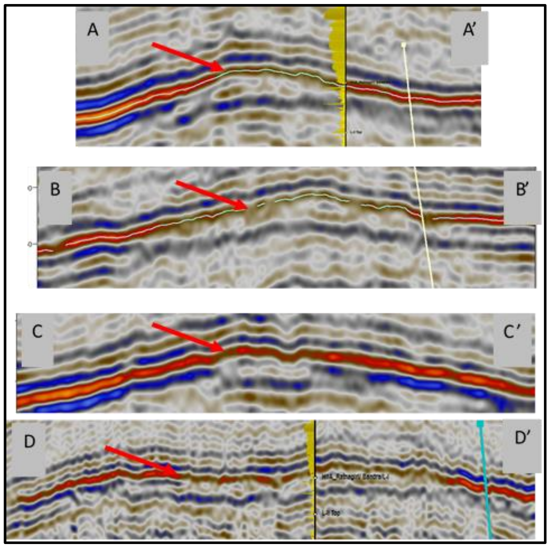

Fig.4: Low amplitude anomaly in the seismic section at Ratnagiri reservoir zone indicating presence of gas

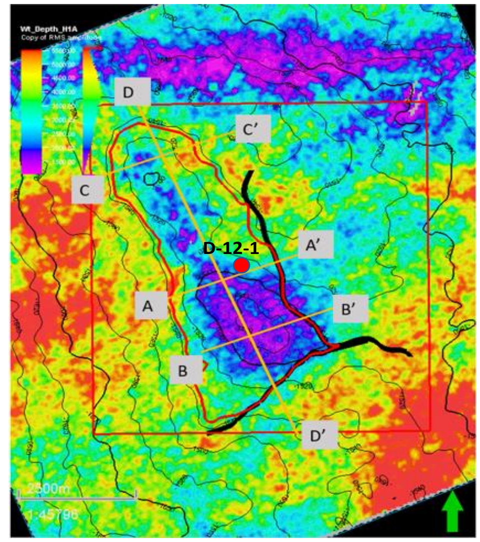

Fig.5: Low amplitude anomaly broadly confirming the structure at reservoir level

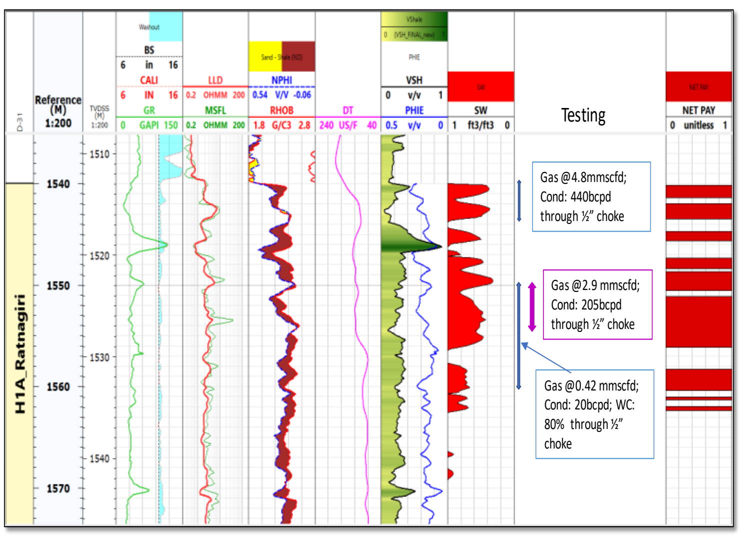

Fig.6: Petrophysical interpretation & well testing information of D-12-1 well in Ratnagiri pay

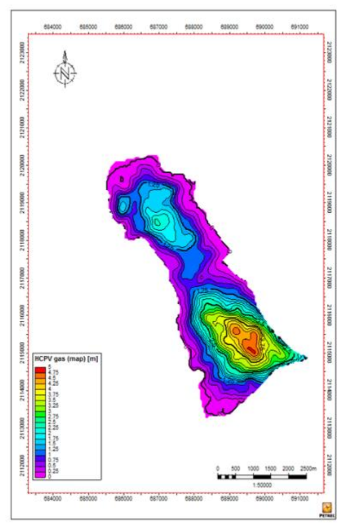

Fig.7: Hydrocarbon Pore Volume (HCPV) map at Ratnagiri level

The dynamic simulation model determines the optimal field development strategy to develop this reservoir. Considering the presence of bottom water, controlling the rate of water movement due to well drawdown is very important to maximize ultimate recovery. At the same time, drilling wells with high deliverability is also required to make the development commercially attractive. High angle development wells have been planned to achieve higher reservoir contact for high initial rates that also helps delaying the possible water coning effects. These wells are planned to be drilled with high performance water-based mud system; acid stimulation is also planned prior to start of production which would help reduce any drilling induced damage, as well as increase well productivity.

The shallow water depth and location near to existing facilities will lead to a cost-effective development strategy for the D-12 field. The Production facilities will consist of well-heads, flowlines, production manifold and process equipment (separation, condensate handling, produced water treatment, gas compression, gas dehydration, condensate storages, utilities, fire water and flare system).

The detailed techno-economic analysis has been carried out incorporating surface facilities, pipeline, tie-in and commercial arrangements. The D-12 gas development is a commercially robust project and this integrated study helped to accelerate monetization of the discovered field.

Reservoir Characterization & Upside Potential of Deeper Pays

In addition to the development planning for the discovered Miocene pool (Ratnagiri formation) in D-12 field, a comprehensive review of the potential for deeper pays (i.e. Panvel, Mukta, Bassein, Panna and Basement) has been carried out. The seismic interpretation and mapping indicated a fault bounded structural high in the deeper pay zones. The D-12-1 well was drilled in the flank of the structure (Fig.8).

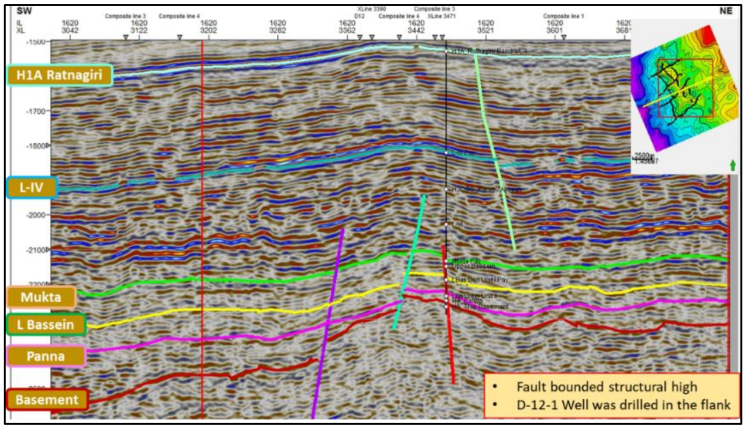

Fig.8: Seismic Section along the D-12-1 showing structural configuration of deeper reservoirs

The production testing in the deeper pays were inconclusive, considering the well's drilling history and low perforation density charges (4 SPF) with overbalance condition during testing. The wellbore was also damaged due to stuck pipe and complicated well operations, leading to high skin.

During reservoir characterization studies, it was also noted that dolomites are present in the deeper pays. The petrophysical analysis was carried using mix of dolomite and calcite matrix, which enhanced the hydrocarbon saturation in the deeper reservoirs.

The gas shows, fluorescence observed in cuttings and petrophysical analysis indicate hydrocarbon bearing reservoirs in the deeper zones in D-12-1 well (Fig 9). Reservoir pressure and STHP data analysis also infers possible hydrocarbon influx in the well bore while testing.

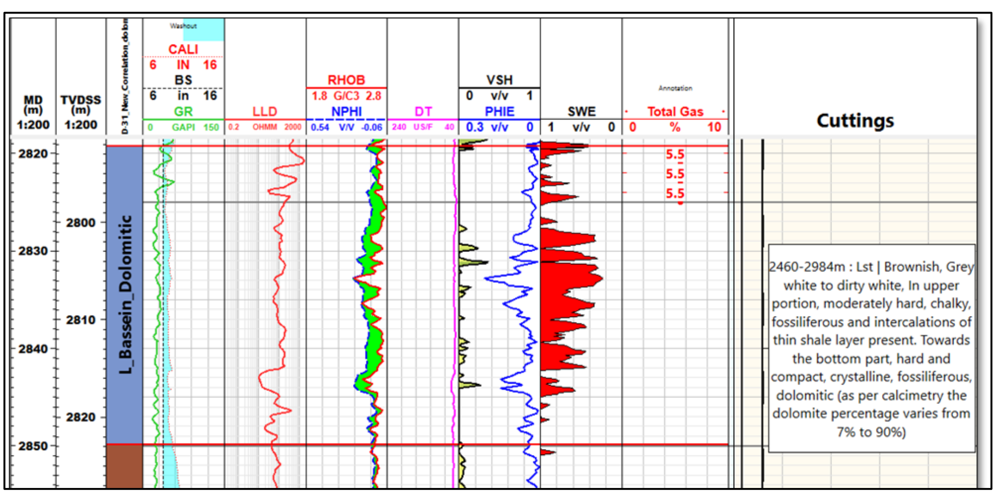

Fig.9: Petrophysical interpretation of D-12-1 well in Lower Bassein pay

The mapping of the reservoir zones indicated a fault bounded structural high in the deeper pay zones where, D-12-1 well was drilled in the flank of the structure (Fig. 10)

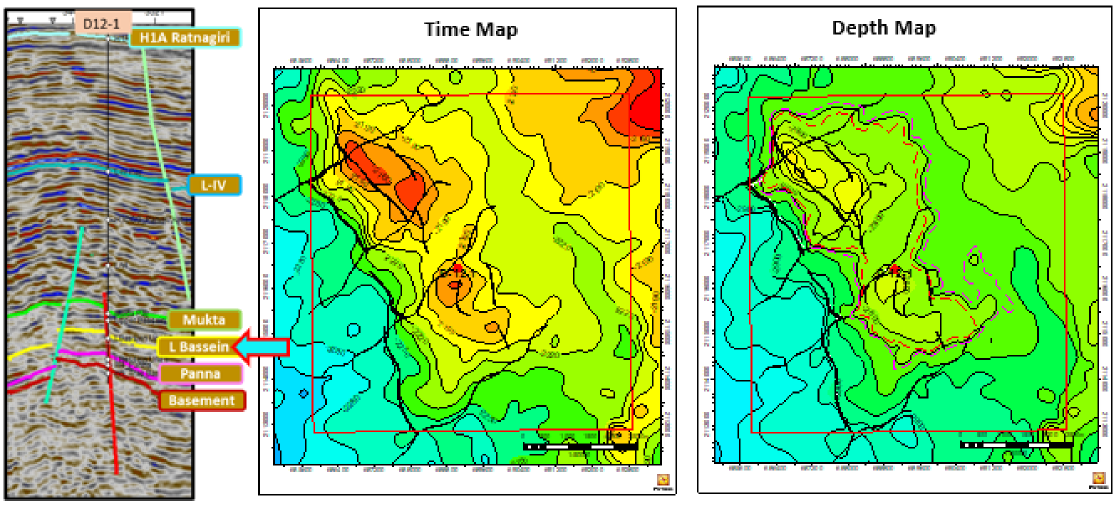

Fig.10: Time & Depth structure map of Lower Bassein pay

The integrated analysis suggests significant oil in-place in the deeper zones, to the tune of 400 mmb.

In D-12 field, with optimal well design, well testing methods and well activation strategy could unlock a large hydrocarbon pool in this mature basin, with best in class near field exploration opportunity. In case of success in the exploration well, the discovery can be quickly monetised along with the Miocene gas development.

Conclusion

The mature basins in India have significant unrealised potential both in the yet-to-produce fields and establishing opportunities in new plays. An integrated approach collating all the available geoscientific data can lead to enhancing the reserves and resource base to establish additional production potential. D-12 field in Mumbai Offshore basin is one such example, which was initially considered to be small and sub-economic gas field. The geoscientific data integration by Antelopus Energy has aided in better reservoir description and multi fold increase in reserves of the discovered Miocene pool. In addition, re-interpretation of 3D seismic data and integration with revised petrophysics analysis and reservoir engineering information have led to recognising upside potential in deeper zones with significant resource base.

Such integrated approach can lead to significant reserve addition in the Mature basins, augmenting oil and gas production in the Country.

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