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Prediction of Facies & Reservoir Properties in Carbonate Reservoir through Geo-body Modelling: Mumbai Offshore Case Study

S. Gorain[1*], A. Kumar[1], L. Reddy[1]

[1] Directorate General of Hydrocarbons*

Summary

The study area is located on a westerly dipping gentle homoclinal part of Mumbai High-Deep Continental Shelf and has a full coverage of 3D seismic data. Eight exploratory wells have been drilled out of which five wells proved to be oil-bearing with three pays. These pays lie within Oligocene limestone. The crestal well is enigmatic and is characterized by the absence of hydrocarbons.

Geo-body modelling approach has been adopted to characterize the reservoir variability and facies architecture. Two reflectors within the reservoir zones were mapped and window-based 3D-RMS attributes were generated. Based on the integration of seismic attributes with petrophysical studies, three geo-bodies had been extracted within the pay sequences. The extracted geo-bodies were modelled geo-statistically with a proper calibration with seismic attributes and petrophysical properties.

This integrated approach of geo-body extraction and geostatistical modelling is very effective in delineating facies architecture and reservoir heterogeneity. Both seismic and well inputs are efficiently collated to characterize the reservoir. Seismic attribute analysis helped in geo-body extraction and bring the facies architecture and geostatistical modelling helps in exhibiting the heterogeneity. The present study helped in understanding the facies architecture and prediction of reservoir properties within the study area and its potential.

Introduction

Carbonate reservoirs are estimated to hold more than 60% of the world's oil and 40% of the world's gas reserves (Montaron, 2008), so their significance is substantial. However, the influence of their complex features creates significant challenges in the prediction of facies architecture and reservoir properties (Lucia et al. 2003). The study area is in the westerly dipping gentle homo-clinal part of the Mumbai High-Deep Continental Shelf (DCS) in the Mumbai Offshore Basin, India. The area is well explored and found to be promising from the hydrocarbon point of view. The first discovery well (D-1) established the presence of hydrocarbon in Oligocene Carbonate within Panvel & Mukta Formations (Dotiwala et al. 2012). The second most recent well (D-8) encountered very poor reservoir rocks with no hydrocarbons shows though it was drilled at the crest of the antiformal structure. This peculiar behavior of the wells were studied and built the geological model based on geo-body analysis to explain the reservoir properties within the study area and its prospectivity.

Methodology

An integrated approach had been adopted to build the geological model. Two seismic reflectors within the reservoir zones were mapped and the root mean square amplitude attribute is extracted within the proportionate slices with an opacity control to filter out the extremes. Window-based 3D seismic root mean square amplitude attributes were generated within the reservoir based on 3D seismic attribute analysis. Based on opacity control three, 3D geo-bodies have been extracted using surface probe taking sufficient thickness along the three pays.

Facies Modelling

Geo-bodies extracted in the time domain are converted to the depth domain using the VSP velocities in the available wells. A structural grid size of 100m x 100m x 5 m is considered for property modeling. Based on the log signature the reservoir and the non-reservoir part of the three pays were demarcated at the well locations and a discrete facies log was generated. This facies log is upscaled in the structural grid. A good correlation was found between the RMS distribution and the reservoir facies at the well location. Using the correlation upscaled facies logs were populated geo-statistically in the structural grid and facies modeling was performed. Figure 1 shows the facies distribution within the structural grid for all the three pays and it depicts that areas near dry wells (D-8, D-4, and D-7) have distinct non-reservoir facies.

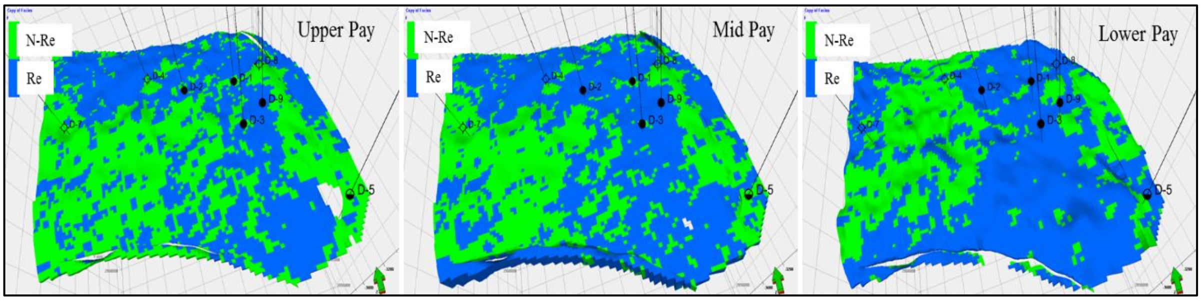

Figure 1 *Facies distribution along the three pays (Upper pay, Mid Pay, and Lower Pay).*

Property Modelling

Through conventional petrophysical analysis porosity and water saturation were estimated at the wells. Porosity and water saturation logs were upscaled and populated in the reservoir facies through geo-statically analysis (Kriging Interpolation). In the non-reservoir segment of the facies model, zero porosity and 100% water saturation were assigned during geo-statistical distribution.

Instead of taking a cut off on porosity/water saturation, net to gross facies across the geo-bodies has been derived using the following relation considering the reservoir heterogeneity-

NTG=Porosity value of the cell/Maximum porosity observed in the geo-bodies

This normalization helps in reducing weightages of poorer facies within each geo-body and volumetric estimates are more realistic in this case. As the NTG is just the normalization of the porosity model the trend of the net to gross is similar to porosity distribution.

Grid base hydrocarbon in-place was estimated using inputs from porosity, water saturation, and net to gross models as described above. The contacts and volume expansion factor (Bo) were considered based on the available information. Various maps of STOIIP distribution pay-wise in the field are shown in Figure 2.

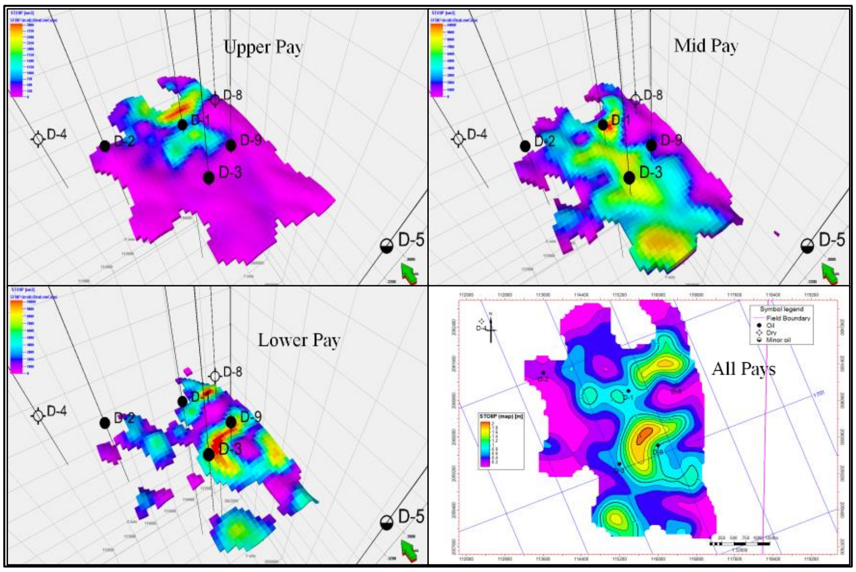

Figure 2 *Hydrocarbon in-place distribution along the three pays along with a composite distribution.*

It was found that due to the absence of reservoir facies and good petrophysical properties the well D-8 was dry whereas well D-2, D-4, and D-7 were below the contacts. It also indicated that though the wells D-9 and D-3 were above the contacts at upper pay but due to poor petrophysical properties, these wells had no hydrocarbon at this pay. The hydrocarbon distribution pattern within the study area indicates that the reservoir is highly heterogeneous and can have additional potential for future exploration.

Conclusions

This integrated approach of geo-body extraction and geostatistical modeling is very effective in delineating facies architecture and reservoir heterogeneity. In this approach, both seismic and well inputs are efficiently collated to characterize the reservoir. Seismic attribute analysis helped in geo-body extraction and bring the facies architecture and geostatistical modeling helps in exhibiting the heterogeneity. The proposed approach explains why some wells are dry and some are productive and can also able to delineate the additional potential.

References

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