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Reservoir Characterization Case Study, Cambay Basin, India

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Summary

The CB/OS-2 Block in the Cambay Basin is located offshore west India in the Gulf of Khambat (Figure 1). The Production Sharing Contract (PSC) was signed in June 1998, between the Government of India and a consortium consisting of ONGC, Tata Petrodyne and Cairn India; Cairn was designated as the operator. The CB/OS-2 block is situated in the Cambay Graben and straddles the transition zone between the Surat Depression and the Western section of the Narmada Rift in the north-west India offshore region, north of Mumbai. The Tarkeshwar and Babaguru Formations form the key reservoir intervals in the area. Exploration and appraisal drilling in the Lakshmi fields encountered HC sands in the lower part of the Tarkeshwar formation of lower Miocene age; as a result these reservoirs are the main targets for development activities. The presence of commercial gas accumulations in the shallow Babaguru formation makes the seismic imaging poor at deeper section (Figure 3). Due to this complex geology and masking of signal it was crucial to delineate the lithology to map the stratigraphic reservoirs in the zone of interest. Integration of rock physics and seismic were used in order to derive a solution to delineate the complex reservoir facies.

Keywords: Reservoir characterization, Cambay Basin, Inversion

Introduction

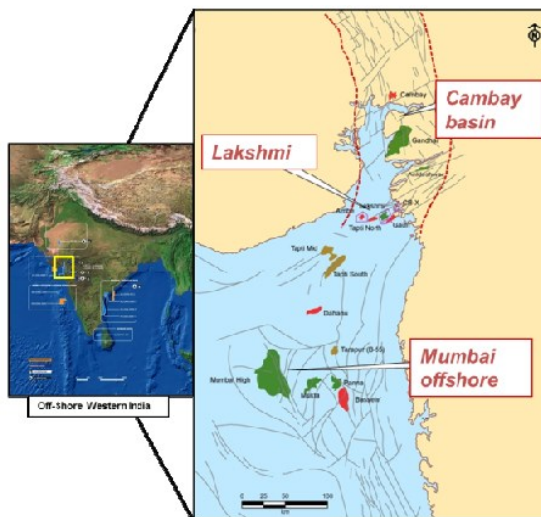


Figure 1: Location map of the block CBOS/2 Block

The CB/OS-2 block is situated in the Cambay Graben and straddles the transition zone between the Surat Depression and the western section of the Narmada Rift in the north-west India offshore region, north of Mumbai.

It is one of a number of local failed rifts with a basin fill of shallow marine clastics that were deposited during Palaeocene to Recent times. The rifts have undergone subsidence, transpression, transtension and partial inversion due to Late Miocene northward movements of the Indian Plate. Structural inversion of the rift sequence occurred during the Miocene and Pliocene, resulting in four-way dip closures which enable hydrocarbon entrapment in the area. Reservoir sands are distributed so that most traps includes some stratigraphic component, with frequent changes in relative sea level resulting in multiple stacked sequence boundaries and flooding surfaces. The main accumulations in CB/OS-2 are the Gauri and Lakshmi (Figure 1) Fields. The present study focuses on the Lakshmi Field. The Tarkeshwar and Babaguru Formations are the main reservoir intervals in the area. Exploration and appraisal drilling in the Lakshmi fields encountered HC sandstones in the lower part of the Tarkeshwar formation of lower Miocene age; as a result these reservoirs are the main targets for development activities. The areal structure of the Gulf of Cambay has most likely not changed significantly since Paleocene times, it is thus possible to establish a tide dominated estuarine environments with highly complex incised valley fills as conceptual sequence stratigraphic



framework of the Lower Tarkeshwar Formation (Sanyal et al., 2012). These reservoirs are deposited as tidal bars, tidal channels, tidal creeks and tidal flats. The primary objective of this reservoir characterisation study was to map those reservoir geometries which were not clearly evident in normal reflectivity data sets due to energy absorption at shallower levels.

Methodology

Rock physics and seismic inversion study was undertaken to integrate seismic, petro-physics and geological data. The study included fluid scenario modelling, depth trends of different acoustic and elastic properties within the zone of interest to underpin the appropriate property that replicates the reservoir character.

Forward and Fluid Scenario Modelling

Gassmann Fluid substitution has been performed to create different fluid scenarios in well A (Figure 2). To match the seismic a well derived deterministic wavelet has been used to create the AvO Synthetics. The aim was to study the impact of oil and brine scenarios on the acoustic logs and hence on seismic amplitudes (Figure 2). Oil bearing sands (Figure 2) show class II AvO response which is a characteristic of nearly zero impedance soft sand, whereas the brine sand shows a hard response with an opposite polarity signature compared to the oil bearing sands (Figure 2). As shown in Figure 5, sands in the zone of interest lie on wide spread lines of constant pore space stiffness suggesting that these sands are sensitive to different fluid types (Mavko et al, 1998).

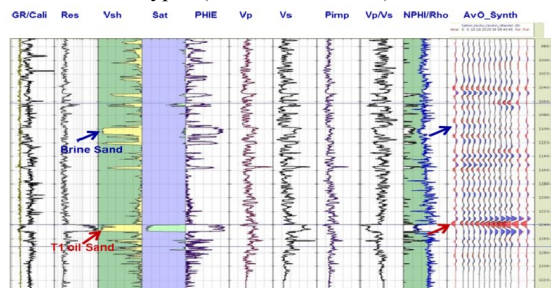


Figure 2: Well composite display showing forward modelling

Lithology and Fluid Discriminations

Vp/Vs depth trends within the zone of interest (Figure 4) shows two distinct end member trends for clean sand and shale. It also depicts that Vp/Vs ratio between 2.1 and 2.3 has substantial amount of overlap between the shaley

sand and shale at the log resolution. However, the Tarkeshwar Formation sandstone shows an excellent Vp/Vs separation from the background shales. Clean hydrocarbon reservoirs having the Vp/Vs values ranging between ~1.50 to 1.85 whereas brine sandstones have Vp/Vs ~1.85 to 2.15

Available database

The database used in this study consists of PSTM NMO corrected offset gathers and well log suits. Offset gathers were taken as an input for seismic. Using the available processed velocities, offset gathers were converted to angles. Subsequently, these traces were simultaneously inverted to determine the Vp/Vs volumes. Vertical wells, having measured shear sonic data sets, were considered initially for the seismic to well ties and for the low frequency model generation. Horizon T2 (Blue horizon in Figure 3) was picked as a key sequence boundary and a 100ms window below that being taken to ensure coverage over the zone of interest, this being key for the structural frame work building. The seismic data sets contains a reasonably high frequency range of between 10 to 80 Hz.; well data is good quality and fit for inversion studies purposes.

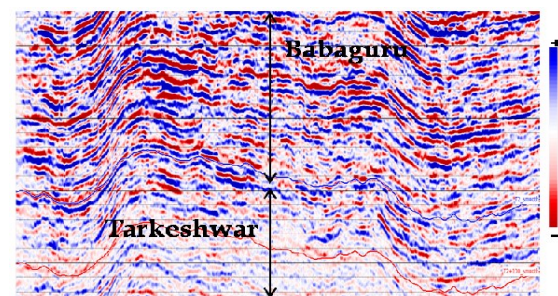


Figure 3: Seismic section showing the amplitude dimming within target (Tarkeshwar) interval

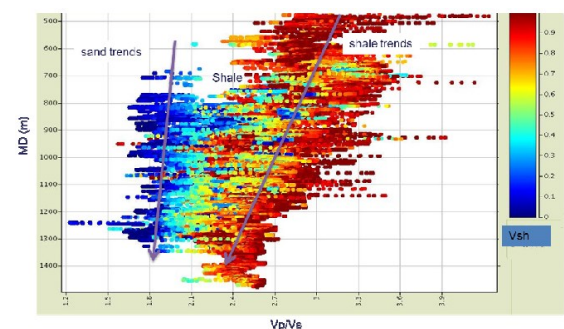


Figure 4: Vp/Vs depth trends (Color Scale Vsh)

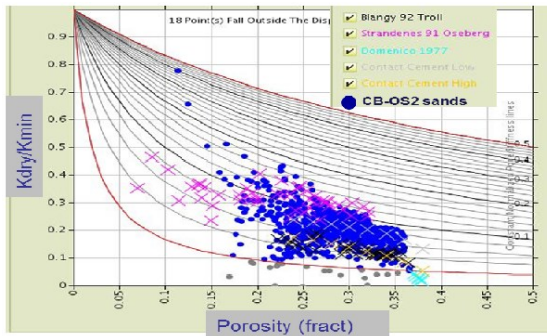


Figure 5: Kdry/Kmin Vs Porosity

Wavelet Extraction and Well correlation

Initial studies suggested that the seismic is of a non-zero phase character. Available corridor stack were used to understand the phase character of the seismic. Due to inconsistent gas masking in the shallower zone, it was not possible to determine a single derivation throughout the zone of interest to make the wavelet zero phase, so it was decided to go ahead with a deterministically derived wavelet for near and far datasets which are almost consistent throughout the field. A previous QI pilot study which was undertaken by a third party consultancy also suggested a minimum phase wavelet albeit concluded that lithology or fluid discrimination would be difficult to be determined for these reservoirs. Taking cognisance of the earlier studies, it was proposed to use a shorter wavelet with 80ms length and targeted seismic to well ties within 250ms window at reservoir. Wells with measured shear sonic were used for wavelet extraction and well ties. This leads to a high degree of average well correlation of 70 to 75% within the zone of interest compared to 55% during previous studies.

Results

The inversion results show a good match with the log data (Figure 7a). Results are consistent with the rock physics study and will help to delineate the reservoir facies versus non-reservoir facies distribution. The HC bearing lower Tarkeshwar sands are delineated in Vp/Vs data sets (Figure 8 and 9). As observed during the feasibility study, gas sands have the lowest Vp/Vs ratio, followed by oil sands and lastly the shale lithologies. Furthermore the Vp/Vs ratio of brine sands are slightly higher than oil sands. Figure 4, highlights this, having a Vp/Vs ratio below ~ 2.15 being classified as clean sands ; Vp/Vs ratio between 2.15 and 2.3 shows overlap between

the shaly sands and shale lithologies, whereas any value greater than 2.3 indicates shales.

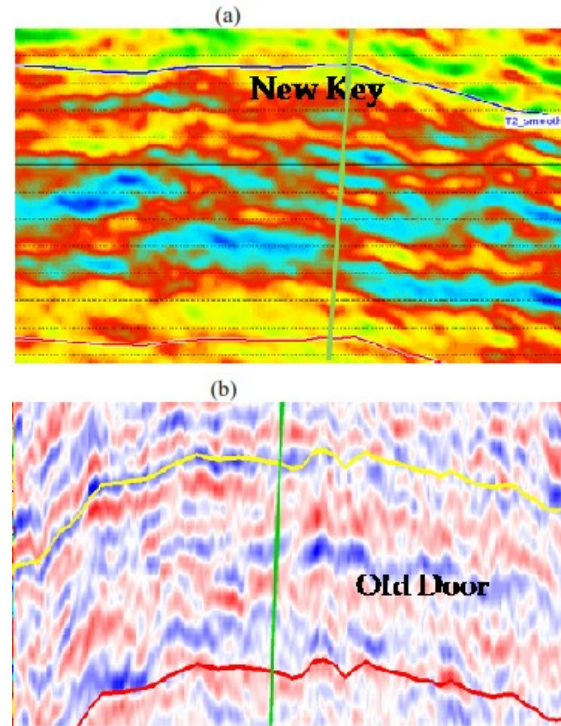
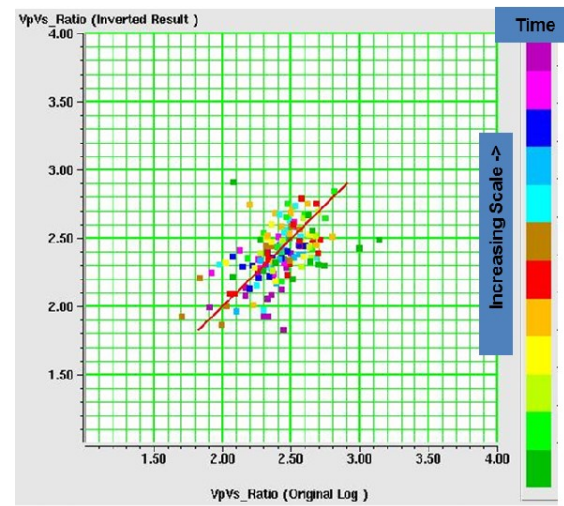


Figure 6: (a) Inverted Vp/Vs profile along a well trajectory (light blue: sand facies); (b) Full offset seismic



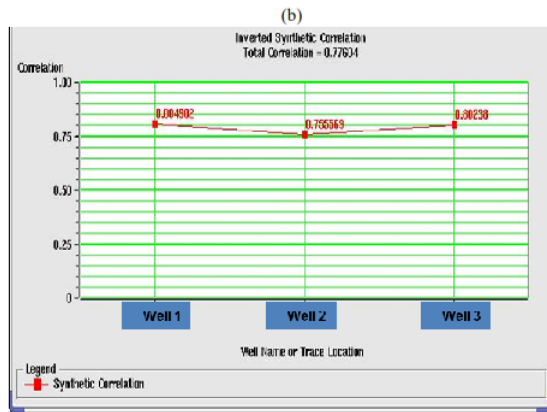


Figure 7: (a) Vp/Vs (log) Vs Vp/Vs (inverted); (b) Inverted Synthetic Versus Seismic correlation

Ongoing evaluation of the reservoir characterisation study in the CB/OS-2, has delineated several regions of analogous Vp/Vs ratio zones, which are considered to be oil bearing. This is indicative of upside potential remaining within the field and will be the subject of further studies.

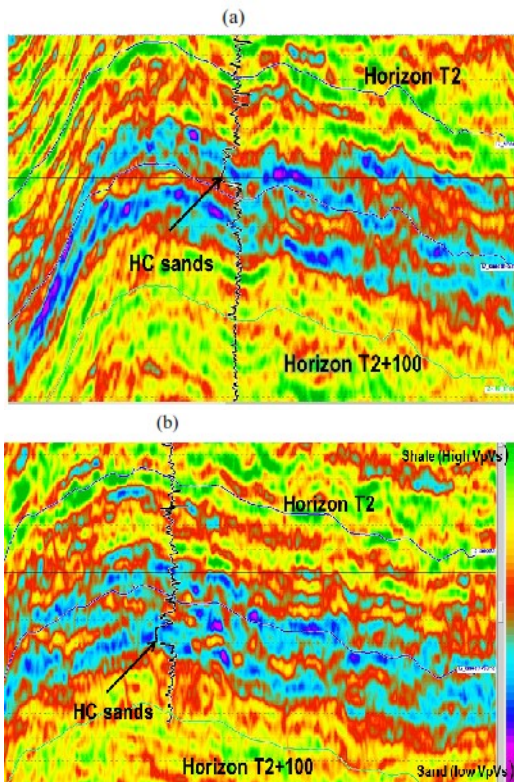


Figure 8: (a) Vp/Vs Profile passing through well1 (Inserted log Gamma); (b) Vp/Vs profile passing through first appraisal well.

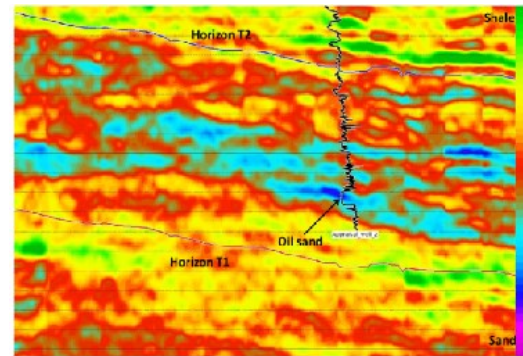


Figure 9: Vp/Vs Profile passing through second appraisal well (Inserted log Gamma)

Conclusions

Lower Tarkeshwar reservoirs are sensitive to fluid change. Hence, Vp/Vs is a good discriminator of the lithology. Ongoing appraisal drilling is demonstrating the reliability of the inversion model (Figure 9). This will reduce the sub-surface uncertainties and aid in the further development campaign to optimise development well locations and extend field life.

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