Role of Seismic Attributes to Analyse Thin Shallow Marine Reservoirs – A Case Study

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Summary
Examination of the seismic data indicated a favorable high Amplitude, high Sweetness and high Impedance geobody near the window at the top of L-V. This anomaly has not encountered in any of the nearby wells. It may represent development of a high stand carbonate pack within the regional shale background and hence presents an interesting play opportunity. It is expected to be prospective at Basal Clastics interval apart from L-V level.

One location “A” was proposed and drilled in South West of Mumbai high field to probe the down dip extension of L-V and Basal clastic formation. (arrow in the figure 2)

The high amplitude anomaly at L-V level turned to be a tight carbonate and at the deeper Basal clastic level is indicative of hydrocarbon bearing on the logs.

Introduction
The area under study is covered by 3D seismic data acquired with 12.5m x 12.5 m bin. The Pre-Stack Time Migrated volume was taken up for study under the current interpretation work. Figure 1a (black circle) depicts the geological position of the study area near the Mumbai High and fig 1b showing Mumbai High general starigraphy.

History of exploratory wells and the results explains the interest of the exploration in this study area. Figure 2 indicating the plan view of the wells drilled in the study area. The red color star symbol represents proposed location. Blue represent dry wells and Green represents oil well.

In the North “X”, “Y” wells (N-E) are hydrocarbon bearing in shallow level (L-III), and wells in the southern part of the study area, well “G” has tested oil from Mukta limestone and well “F” south east is gas bearing at Basal Clastic Formation which has been found extended till drilled location well “A”. There are few dry wells too in the vicinity the proposed locations. 

The area under the present study is located in the South West of Mumbai High. The dominant structural trend in this area is the NE-SW trend along which the major faults are aligned and the ENE-WSW trend along which strike slip component is also apparent from lateral displacement of some of the structural highs. The entrapment model envisaged in the current study with structural element playing the major role as the prospects are structural closures. Reservoir facies
character plays a major role in as much that the targeted carbonates are expected to have good porosities at the proposed locations. The prospects are identified with the advantage of 4-way closures.

Figures of 3a and 3b showing an inline NW-SE passing through the proposed location with both uninterpreted and interpreted versions. The red color represents trough and black represents peak. L-V and Basement level have been mapped in time domain. Marked green color correlation line is top of L-V and blue color is top of basement. The high amplitude pack can be seen in the section on top of L-V layer. High structural trends are observable from Bottom Basement to L-V layer with positive relief. This high amplitude anomaly is studied for its prospectivity point of view by considering the advantage of its structural closure behavior encircled in the figures.

Methodology

The Pre-Stack Time data is used for mapping of L-V and Basmenet levels. Seismic attribute analysis was carried out at L-V and basalt clastics level using horizon slices. Mainly Amplitude, Acoustic impedance and Sweetness attribute volumes are studied and established the relationship to find out the prospective areas around the clouser of the strctural maps.

Present Study

Two major seismic markers corresponding to the top of Basement (H5) and L-V correlated with the help of drilled wells and mapped. Time maps corresponding to the above two seismic horizons were prepared. A unified velocity model was prepared for the time volume for depth conversion. Depth maps corresponding to Basement and L-V were prepared. The time and depth maps clearly depict the Westward slope of the Basement level forming successive terraces away from the Bombay High. The structural closures at the Basement level have been extensively probed which yielded mixed results.

Structural map prepared in time domain showing the fault patterns along with the highs and lows at L-V level. Using the time-depth express module (Openworks) suitable velocity model was prepared and converted this time horizons to depth domain. The following figures 4 a & b are depicting both time and depth structure maps. Red color indicates shallow and the green color indicates the deeper level on these maps.

Contours along with the faults are also shown in the figures 4 a&b. Red color lines are fault trends with the structure axis NE-SW and. Proposed location is falling in the structural closure at 1970 m contour level at L-V.

The prospect is bounded by a NNE-SSW & NW-SE trending faults. This prospect is located structurally down dip to the main Bombay High field as independent closure. Pays are developed at deeper
level and L-V level, having better reservoir facies as indicated by the impedance maps and sections passing through the proposed location.

Structural aspects at Basement level

Structure maps at basement level both in time domain and depth domain are prepared and placed in the figure: 5a & 5b. The color scheme adopted is red indicates shallow and green indicates deeper level in the both maps. Proposed location is falling in the structural closure at 2150 m contour level at L-V.

Basal clastics formation which rests above the basement level cannot be resolved on seismic for horizon correlations. However the basement horizon is used to evolve the attributes by using the horizon slice techniques at basal clastics level to understand and study the reservoir facies information.

Seismic Attribute analyses carried out in the current studies includes generation of RMS volume, Impedance volume and Sweetness volumes. These attributes are used for prospectivity analysis near the above identified structural closure areas in the high amplidue anomaly zone both at L-V level and above Basement level.

P wave Inversion with correlated horizons of shallow level to deeper level has been carried out using Hampson-Russel software. The seismic data pertaining to this area along with log data of the wells falling in the area were conditioned and used them for the inversion process.

Prospective analysis at L-V level
Figure 6 shows the horizon slices of 10 ms window from -25ms to -35ms above L-V, using the (a) Impedance, (b) RMS, (c) Sweetness and (d) Instantaneous Frequency volumes. As shown in the color legend, yellow color indicates low value and blue indicates higher value of respective attribute.

High amplitude - Low Frequency response in this interval and development of NS trending Sweetness anomaly observed at the proposed location. These seismic attributes infer likely development of good reservoir facies at the proposed location.

Prospective Analysis of Basal clastics level

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Prospective Analysis of Basal clastics level

Horizon slices above basement reflector with a window of 25ms from 0ms to -25ms studied. Similar attributes Impedance, Frequency, RMS and Sweetness volumes were used to study the facies within this horizon slice window. They also shown similar type L-V anomaly of High Amplitude, Low Frequency along with Sweetness at the proposed location at basal clastics level.

Figure 7 is showing the seismic responses of RMS and trough amplitudes. In this figure yellow color represents lower amplitude value and green represents higher values.

From this study, it is envisaged that the area at the proposed location is favorable for good reservoir facies development at this basal clastics level also.

Drilling results

In view of the above seismic study one location proposed as mentioned in the figure 2 at ‘A’ as an exploratory well and drilled up to depth 2133 m. Based on interpretation expected tops of LV and Basement were 1900m and 2120m respectively. After drilling found that LV at 1891m & basement at 2080m depth with a deviation of 9m at LV level from seismic top which is of tight carbonate and 40m at basement level which is of granitic in nature.

Detailed Log Interpretation & Testing Results

Figure 8a shows inline passing through the drilled well with GR log super imposed over it. The high amplitude anomaly is corresponding to depth range 1850-1880 m in log shown in Fig: 8b, above the LV top.

Cutting data corresponding to this depth range shows presence of limestone with a low porosity and high density. This interval has not tested because log data not shown any HC indication.
Basal clastic zone is falling in the range from 2068 - 2080 m. Gross lithology is Sandstone, Siltstone and Shale. The density range is 2.3-2.6 g/cm³ and porosity is of range 12-18% in this zone Fig 9. Zone 2071m to 2079.5m with a thickness of 8.5m has been tested. During production testing of this zone of interest shown Gas @12273 m³/day, water @ 524 BPD with trace of oil at FTHP-240 psi and FTHT-91°F through 32/64".

**Conclusion**

It is concluded that the high amplitude zones are prospective provided they are subjective to the secondary diogenesis effects which are responsive of the development of secondary porosity in the shallow marine carbonates. The L-V level is less porous looks to be tighter carbonate facies. However the basal clastics zone is shown the hydrocarbons.

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