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# Facies characterization of a seismically thin reservoir using Poisson Impedance

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***Summary***

*This paper discusses about facies characterization of a seismically thin clastic reservoir whose delineation was challenging due to poor seismic resolution and discrete distribution of reservoir geobodies. This study includes AVO analysis and simultaneous inversion. Cross-plot analysis of the well log data provided a priori understanding of attributes to characterize the reservoir. Using the inverted results of P-Impedance (Ip), S- Impedance (Is) and Poisson Impedance (Ip-C*Is), discrimination of reservoir facies was effectively done from background non reservoir facies. Poisson's ratio and density are important in reservoir facies delineation because low values for these parameters tend to be associated with good reservoirs facies (gas- and oil-saturated rocks) as compared to background shale. Poisson Impedance incorporates both Poisson's ratio information and density into a single attribute which has been effective in delineation of reservoir sand.*

***Keywords**: Facies characterization, Cambay Basin*

## Study Area and Geological Background

The study area (between Vatrak and Mahisagar River) lies in Cambay-Tarapur block of Cambay Basin, India (Figure-1). The central part of Cambay-Tarapur block is known as Tarapur depression. Two prominent anticlines occur on rising flanks of Tarapur syncline to the southwest (Cambay structure) and to the southeast (Kathana structure). Lineaments in this block mainly trend in NW-SE direction.

Generalized Stratigraphy of study area is shown in Figure- 2. Organic rich Cambay Shale of Paleocene to Early Eocene age is regional source rock in this basin. Lower Miocene Babaguru formation predominantly composed of sandstone with lesser amount of mudstone, conglomerate and siltstone. Babaguru formation is considered to be fluvial to shallow marine in origin. The comparatively better reservoir facies, corresponding to Miocene Basal Sands (MBS) has been attributed to reworking of these sands by tidal process. A few wells have been drilled in this area encountered hydrocarbon bearing MBS with thickness ranging between 5 - 26 m. Mapping and characterization of this pay sand were challenging using available amplitude data because of poor resolution and discrete nature of the reservoir sand.

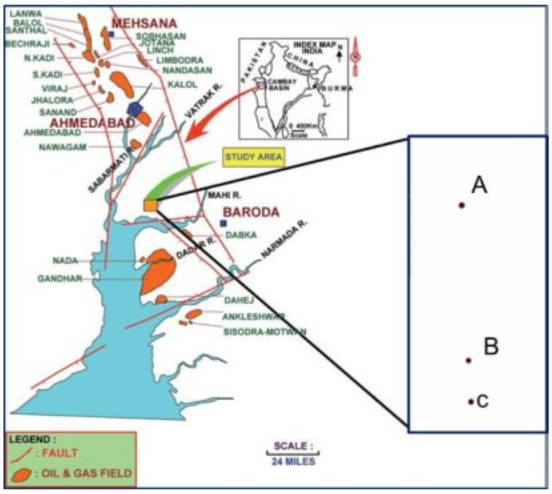


Figure 1. Map of Cambay Basin, showing the study area. Rectangle is 3D area (nearly 100 sq. km) and A, B and C are drilled wells (Bose et al., 2004).

This paper discusses how an integrated approach using the AVO, well data and poisson impedance could effectively map the reservoir facies distribution and delineate the reservoir in consistently with the geological interpretation.

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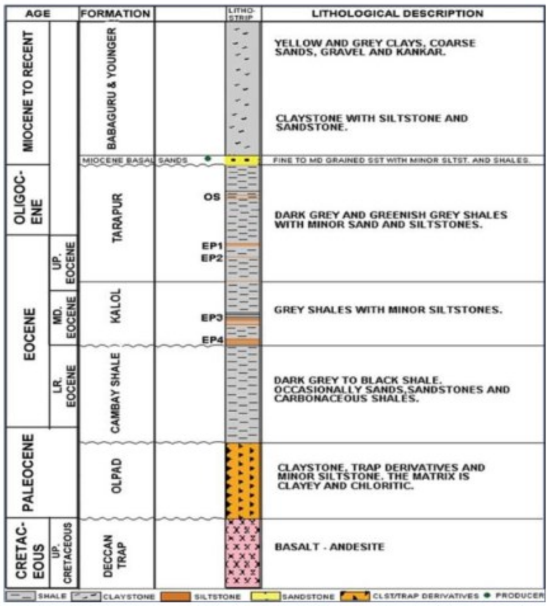


Figure 2. Generalized Stratigraphy of study area. The Miocene Basal Sand is main prolific reservoir in the study area. The Cambay Shale is the main source rock (Bose et al., 2004).

## Work Flow

Input data for this study were PSTM conditioned gather and logs of three wells. The well logs used in this study were as followings.

1) Basic logs (Gamma Ray, Compressional Sonic, Shear Sonic, Density, Resistivity, Neutron Porosity)
2) Computed logs (P-Impedance, S-Impedance, Vp/Vs and Poisson Impedance)
3) Interpreted logs (Total porosity, Saturation, Effective porosity and Clay volume).

The work flow includes Well log analysis and Cross plotting of logs, AVO analysis from well and Seismic (Angle Gather), Creating angle stack from gathers , Seismic Synthetic correlation, Wavelet estimation, Low frequency modeling from well, perform Simultaneous Inversion and Reservoir Characterization from inverted result as shown in Figure-3.

Horizons were mapped using 3D seismic data. The top of Miocene Basal Sand is lower part of Babaguru formation defined as peak and Tarapur top is defined as trough in seismic based on synthetic seismic correlation. These mapped horizons are taken as top and base of the reservoir unit. Seismic section with mapped horizons of MBS Top and Tarapur Top is shown in Figure-4.

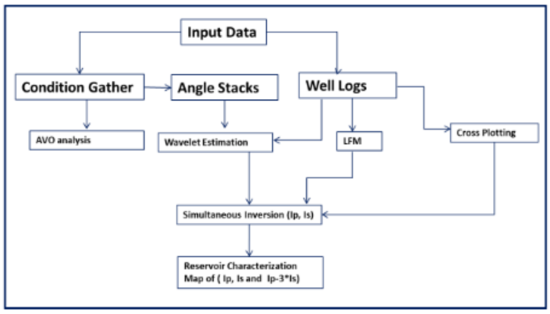


Figure 3. Work flow for current study.

## Well Log Analysis and Cross Plotting

Sample logs from Well-A show log response from Miocene Basal Sand (Figure-5). MBS reservoir shows relatively higher P-wave velocity, higher S-wave velocity. Higher S- Impedance and lower Poisson Impedance (Ip-C*Is) corresponds to low gamma ray as indication of reservoir facies. Here scalar C has been chosen (C=3) by scanning well data at different C values to achieve maximum separation of reservoir sand from shale.

Cross plotting has been performed from well logs (Figure-6). The purpose of this cross plotting was to differentiate reservoir with respect to background shale. MBS reservoir can be characterized by high P-Impedance, high S-Impedance and low Poisson Impedance (Ip-3*Is). The separation in S-Impedance (Is) and Poisson Impedance is found to be more than P-Impedance (Ip) for reservoir than background.

## AVO Analysis

AVO analysis of pre-stack seismic data is useful for fluid and lithology identification. Variations in amplitude with offset are routinely being incorporated into inversion products in order to differentiate lithology and fluids. The P-Impedance and S-Impedance attributes which may be determined with offset ranges up to 30° are in turn regularly cross-plotted to investigate discrimination between differing lithology.

AVO analysis from seismic and well has been carried out (Figure-7). This high impedance sand shows class -1 or class-2p AVO anomaly (amplitude decrease with angle).

Cross over angle for oil bearing reservoir sand is found to be ranging between 35-40 degree. Since this is class-1 sand, it is difficult to discriminate the fluid. Therefore lithology prediction was done by S-Impedance and Poisson Impedance (Ip-3*Is).

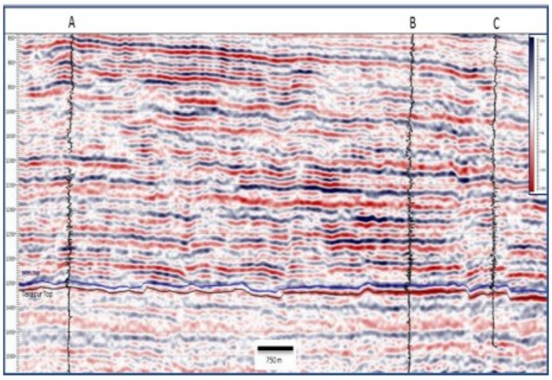



Figure 4. Seismic section passing through wells A-C. Gamma Ray log is displayed at well. The Trough is corresponding to the base of MBS, correlated with the Tarapur Top. The peak is correlated with MBS top.

## Inversion and reservoir Characterization

Seismic to well calibration is the first step for interpreting the seismic data using log properties (Figure-8). Determination of the phase of seismic data is critical to define reservoir top and bottom in seismic. However achieving zero phase seismic is always difficult. Seismic Synthetic correlation has been performed at all well locations. Wavelet is estimated at well locations from each angle stack (near, mid and far angle stack). Average wavelet for each angle stack is taken for simultaneous inversion.

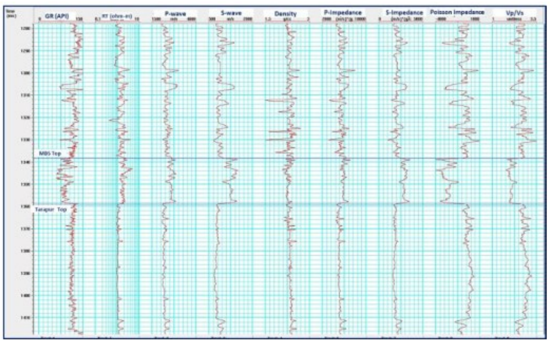
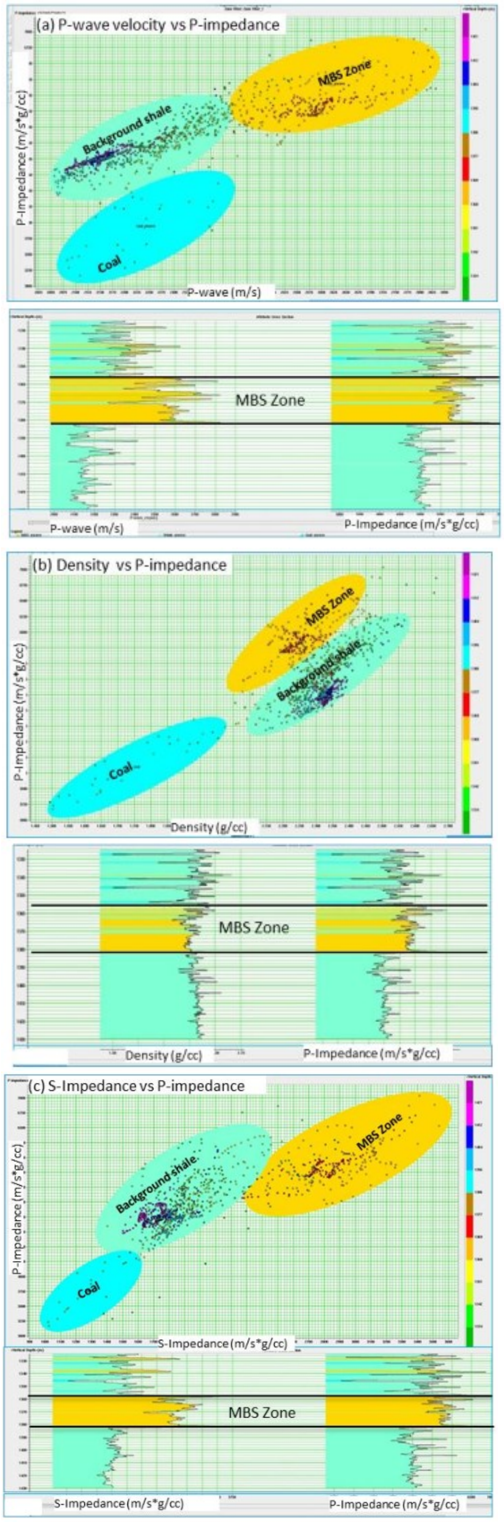


Figure 5. Log of well–A shows response for Miocene basal sand : from left to right are gamma ray (GR) Resistivity (RT), P-wave velocity, S-wave velocity, density and computed logs: P-Impedance(Ip), S- Impedance (Is), Poisson Impedance (Ip-3*Is) and Vp/Vs.



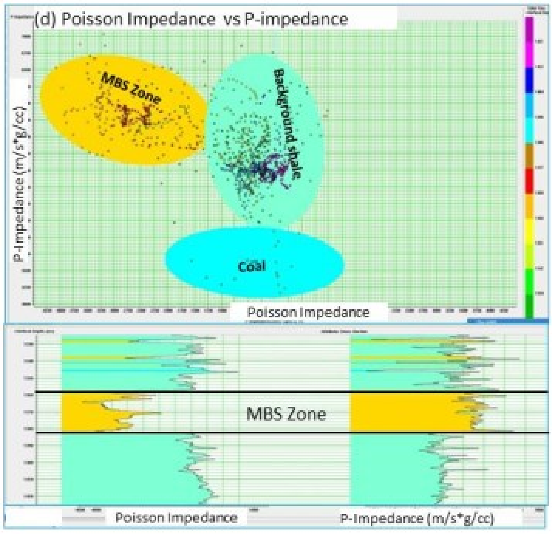



Figure 6. Different Cross Plots (a) Plot between P-wave velocity versus P- Impedance (b) Density versus P-Impedance (c) S- Impedance versus P-Impedance (d) Ip-3*Is versus P-Impedance, Where Ip is P-impedance and Is is S-Impedance . These sands can be better differentiated in S-Impedance and Poisson Impedance (Ip-3*Is).

The seismic data lacks low frequency information so we need the low frequency to determine the trend of the inversion. Low frequency modeling (LFM) has been carried out using well logs and interpreted horizons.

Number of partial stacks (Near, Mid and Far) used for simultaneous inversion is based on a compromise of stability of inversion parameters, interpretation, and wavelets. Simultaneous Inversion estimates elastic parameter volumes (some combination of P-Velocity, S-Velocity and Density) by using the information contained in multiple input seismic volumes (either partial angle stacks or partial offset stacks). The process is accomplished in three steps: Elastic parameter contrasts are estimated which create synthetics, which simultaneously honour all of the input seismic stacks. The elastic parameter contrasts are integrated to create elastic parameter volumes. The elastic parameters are optimized by modifying the low frequency trends and enforcing compliance with any additional constraints.

Seismically we can determine P-Impedance (Ip) and S-Impedance (Is) through inversion. An interesting relation between these two seismic attributes is Poisson Impedance (Ip-C*Is), which describes a rotation of the Ip-Is data to obtain lithofluid discrimination, while the "C" term optimizes this rotation (Quakenbush et al. 2006).

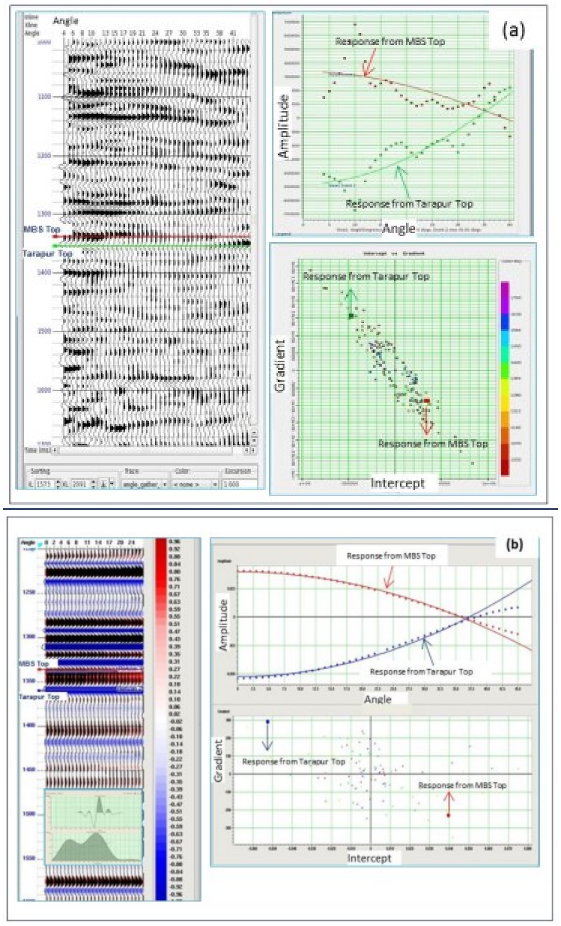



Figure 7. AVO analysis (a) AVO analysis from seismic (b) AVO analysis from well, both show class -1 behavior i.e amplitude decrease with angle. Cross over angle is nearly 35 degree from both seismic and well. Cross plot between intercept versus gradient shows position of MBS top and Tarapur top.

## Result and Discussion

P-Impedance and S-Impedance sections with interpreted horizons (MBS top and Tarapur Top) and GR are over laid at well location are shown in Figure-9. MBS zone is characterized by high P-Impedance and S-Impedance.

Mean Attributes (P-Impedance, S-Impedance and Poisson Impedance) between Miocene Basal Sand (MBS) Top and Tarapur Top are extracted (Figure-10). These attribute maps show distribution of tidal channel and tidal sand bars. These attribute maps have clearly brought out the reservoir geometry and also revealed additional sands and the enlargement of the sands lobes towards the southeast. These southeast trending sand bars are mostly channel deposits with possible tidal influence from south east. High P-Impedance, high S-Impedance and low Poisson Impedance are corresponding to reservoir facies and low P- Impedance, S-Impedance and high Poisson Impedance are corresponding to non reservoir facies.

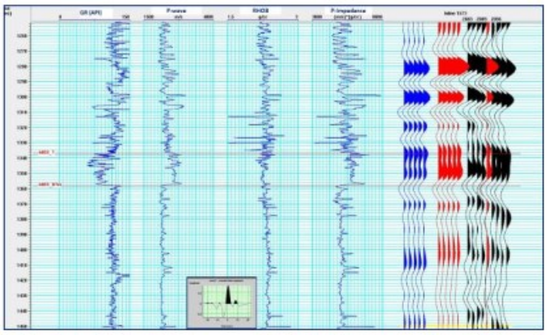


Figure 8. Calibration between well logs, synthetic, and seismic at well-A. Synthetic traces (blue color) are generated from well logs and it is compared with seismic data. The correlation for synthetic and seismic is 84 %. Composite trace (red) was extracted by averaging nearby trace at well location.

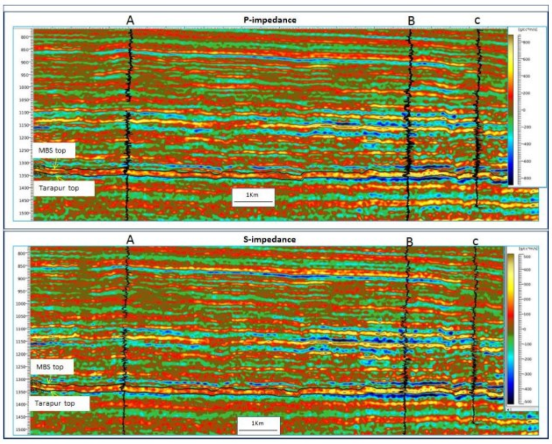



Figure 9. Impedance Section passing through three wells A, B and C. Gamma ray log are superimposed at the wells (a) P-Impedance section (b) S-Impedance section. Horizons of MBS top and Tarapur top are also overlaid on it.

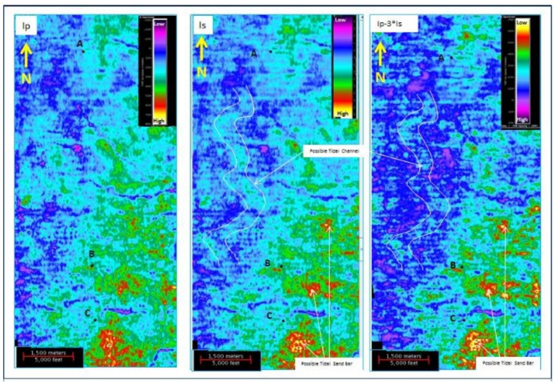



Figure 10. Map of Mean P-Impedance (Ip), S-Impedance (Is) and Poisson Impedance (Ip-3*Is) for MBS reservoir shows possible sand distribution. These sand are better discriminated in Is and Ip-3*Is map.

## Conclusion

From integrated study of well log analysis, AVO analysis and inverted impedance volumes reservoir facies are effectively discriminated from non-reservoir facies. Tidal sands in the study area are characterized by high P-Impedance, high S-Impedance and low Poisson Impedance. Poisson Impedance which is combination of both Poisson ratio and density gives better separation for reservoir facies. This class-1 or class-2p high impedance sand shows peak to trough crossover at higher angle (35 to 40 degree).

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