Model Based Shallow Oil/Gas Reservoir Characterisation and Prospectivity Analysis of Miocene Pays, Ankleswar- Kosamba Areas, South Cambay Basin, India.

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Keywords

5D interpolation, braided streams,Constrained/Amalgamated channel,amplitude,attribute

Summary: Discovery of oil/gas pools at shallower depths in Ankleshwar field initially generated lot of interest. However, subsequent exploration efforts targeting the shallow Miocene pays of Babaguru/Tarkeshwar formations have, so far, met with only limited success, because of poor seismic imaging and insufficient understanding of depositional setting and hydrocarbon entrapment mechanism in the area. Hence, to chase existing leads and identify new areas of interest, it is imperative to develop better geological understanding, while being equipped with seismic data of enhanced quality. Seismic data re-processing with focus primarily on shallow data (≤ 1000ms) led to significant improvement in quality, better continuity of events and filling up of data gaps through advance 5D interpolation technique. Mapping of shallow horizons and reservoir characterization with a high degree of confidence was thus made possible, first time in the basin. Litho-facies based depositional modelling and analyses of various seismic attribute studies like amplitude, P-Impedance, seismic facies and spectral decomposition, in conjunction with well behavior were very insightful in understanding sand dispersal patterns and reservoir geometries. Based on G&G interpretation, low impedance-high amplitude- fluvial channel model for Babaguru pays and high impedance-high amplitude-distributary model for Tarkeshwar pays have been proposed and correlated with global analog of such pays. Model has significantly explained the existing fluid distribution pattern and brought out the prospective areas for exploration exploitation.

Introduction: The study area lies to the south of Broach Depression and covers northern part of Narmada-Tapti Block of Cambay basin. Ankleshwar and Kosamba fields, both of which were discovered in the early 1960s, are the two major hydrocarbon producing fields in Narmada block of South Cambay Basin. The middle Eocene Hazad pays have been extensively explored and exploited. However, since the initial discovery of hydrocarbon from the shallower reservoirs within Miocene, namely the Babaguru and Tarkeshwar sands, a lot of interest has been generated. But as the distribution of hydrocarbon in these reservoirs haven't been fully understood as yet, their exploration and exploitation have been largely limited (Fig.1). Reservoir characterization of these sands have been challenging in the absence of good quality seismic data at shallower levels. As an important step to achieve the project objective, post stack data re-processing through 5D interpolation technique was carried at processing division of GEOPIC with focus primarily on shallow data, through which issues like noises, redundant traces and data gaps, that typically afflict shallow data, could be redressed. This led to significant improvement in data quality and better continuity of events, making it possible to map the shallow horizons and to carry out reservoir characterization in a confident manner, perhaps for the first time. Close analysis of well cutting data, electro log signatures, seismic signature and production data have been attempted. Various attribute studies like amplitude analysis, post stack inversion, seismic facies classification and spectral decomposition were carried out to understand the possible linkages between seismic signatures and reservoir character. Analyses of the attributes in conjunction with well behavior have facilitated in understanding sand dispersal patterns, reservoir geometries and bringing out the prospectivity conclusively.

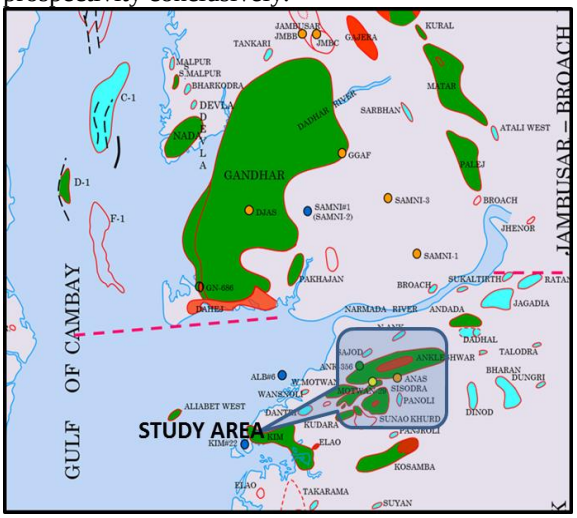

Figure1. Base Map showing the study area.

Geological setting: Geology of the area is fairly well known with more than 550 wells drilled in Ankleshwar field and adjacent areas. Structural set up of the area includes east-west trending highs of Ankleswar and Kosamba separated by Sisodra low (Fig.2). Ankleshwar field forms a part of the northern-most Narmada-Tapti block, bounded by Narmada River in north and Tapti River in south, i.e. two fault zones parallel to Satpura trend.

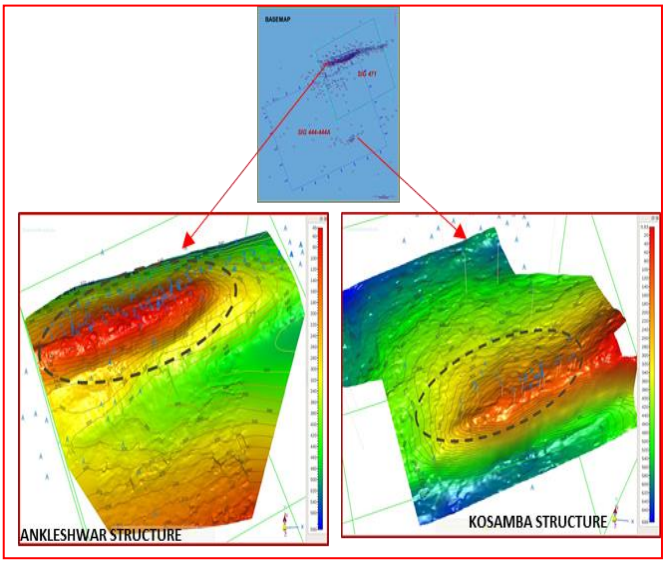

Figure 2. Map of study area showing the Ankleshwar and Kosamba field.

Ankleshwar field is separated from nearby Sisosdra field in south by the main Ankleshwar Reverse Fault. South of Sisodra low is Kosamba field which is doubly plunging anticline and is limited by NE-SW trending Kosamba reverse fault. The field is divided into eastern and western parts by NNE-SSW trending fault. The average depth of the hydrocarbon producing layers is in the range of 300-1600m. The synrift faults were reactivated in post Mid Miocene forming the present structural disposition of the area (Fig.3).

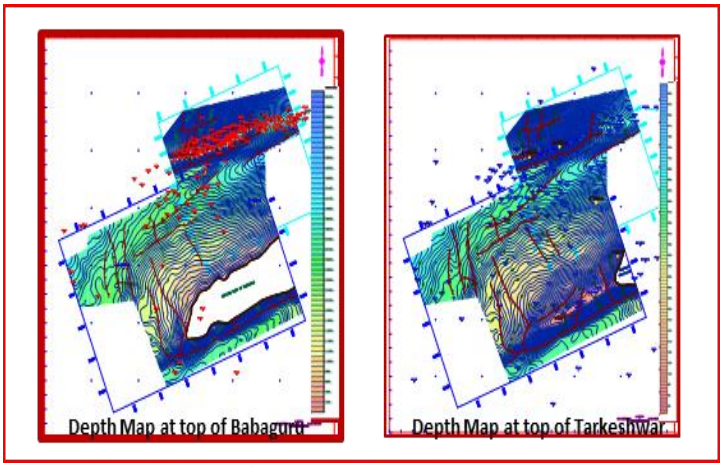

Figure 3 Depth Map at top of Babaguru and Tarkeshwar

Generalised Stratigraphy: The sequences of study area are in conformity with regional stratigraphy of Cambay Basin.
The synrift sequence of Olpad (Paleocene) is the oldest sequence deposited unconformably above Deccan Trap (Late Cretaceous) in the area with a complex lithology association. Cambay shale of Paleocene/early Eocene age unconformably overlies the Olpad section of Paleocene age. The reservoirs within Cambay shale are siltstones / fine sandstone. Cambay shale is overlain by Ankleswar Formation. Hydrocarbon bearing Ankleswar & Kosamba pay sands are within Hazad Member of Ankleswar Formation of Middle Eocene age and are well developed in the area which in turn overlain by Oligocene sequence of Dadhar Formation. Objective of present study, Miocene sequence is the youngest sequence which are gas bearing within Tarakeswar and oil & gas bearing in Babaguru formation (Fig.4).

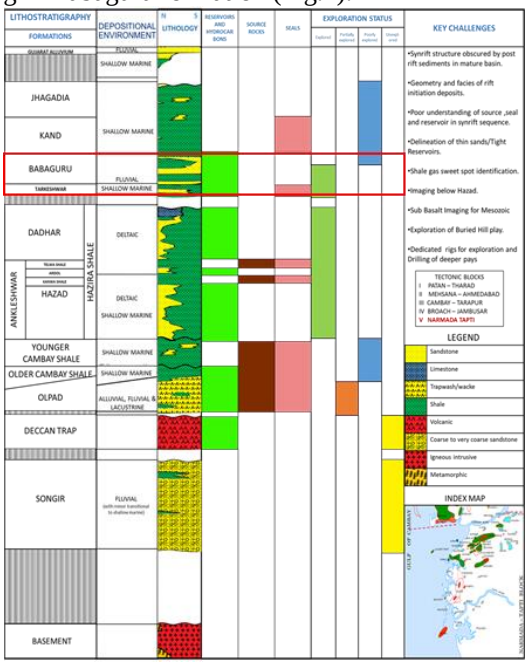

Figure 4. Generalised Stratigraphy

Present Study:

Seismic Data re-processing: The seismic data used for study spans an area of ~ 380 SKM, covering the main fields of Ankleshwar and Kosamba, besides the adjacent satellite fields of Sajod, Motwan, Sisodra and Elao. Being originally acquired and processed for Hazad and deeper levels, acquisition foot prints and random noise are very pronounced at the near surface and ultra-shallow levels. Moreover, data gaps are also present in several zones for the shallow portion. Re-processing of the data with focus on shallow portion (0-1000ms) led to significant improvement of data quality and better continuity of events. 5D interpolation technique formed the cornerstone of the processing workflow through which removal of noises and redundant traces, as also filling of data gaps could be successfully achieved by offset regularisation. Simultaneous interpolation in all five seismic data dimensions (inline, cross

line, offset, azimuth and frequency) through Fourier reconstruction using matching pursuit algorithm was largely successful in predicting missing data with correct amplitude and phase variations(Fig.5&6) .

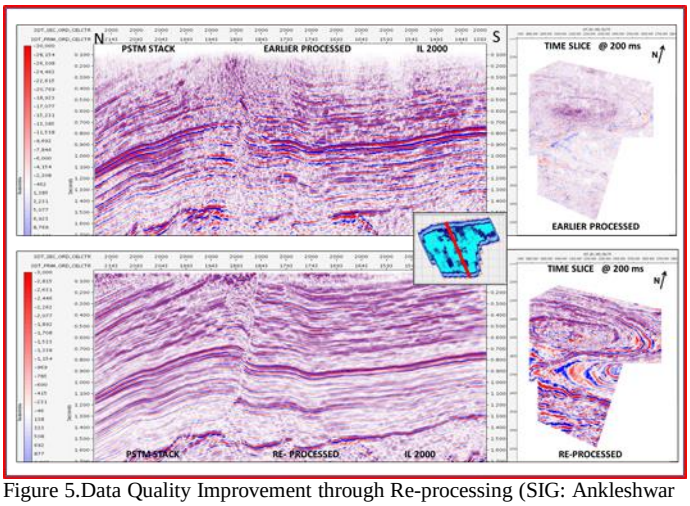

Figure 5.Data Quality Improvement through Re-processing (SIG: Ankleshwar area)

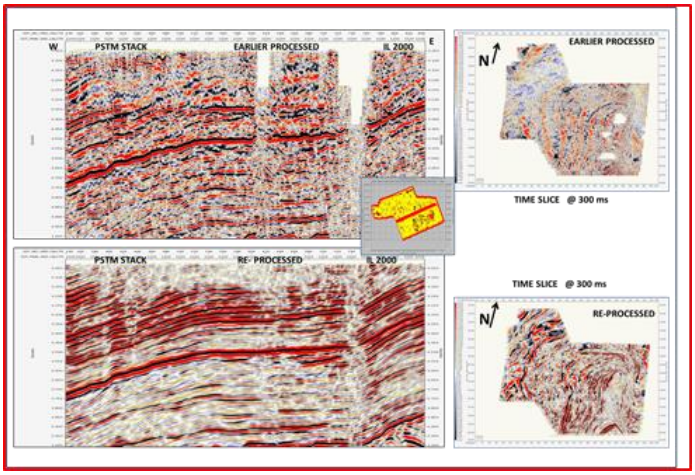

Figure 6 . Data Quality Improvement through Re-processing (SIG: Kosamba area)

Electrolog Correlation: Data of ~150 wells (both exploratory and development) in the area, logged in the shallow Miocene formations, were used in the study. Log data of several wells were conditioned for better reliability and interpretability. Multi mineral processing of drilled formations were carried out for 10 wells. These data were analysed for understanding the vertical and lateral disposition of litho-facies in the zone of interest. Babaguru formation is divisible in to eight units while Tarkeshwar formation has seven units (Fig.7).

Litho-facies Analysis &Depositional Model: Depositional model and sand dispersal pattern were inferred by integrating log motifs, drilled cutting data and seismic attributes for Babaguru and Tarkeshwar sands. The Babaguru sands are deposited as braided streams under fluvial environment. It constitute of two major sequences. The thick lower multi-storied sand constitutes of amalgamated channel system and upper hydrocarbon bearing sands are part of isolated constrained channel systems which is embedded in flood plain clays. These are also associated with thicker/thinner leeves. In sequence stratigraphy terminology. The thinner upper sands are part of high accommodation system tract (HAST) and lower thicker sands are part of low accommodation system tract (LAST) with widespread thick multi-storied amalgamated channels (Fig.7).

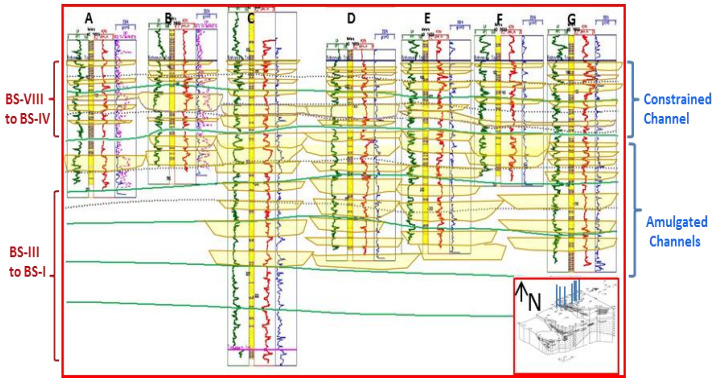

Figure 7. Deposition model of Babaguru sands

Amplitude Attribute Analysis: Bright amplitude anomalies associated with frequency dilations have been observed in the zone of interest, in form of channel morphologies and point bars, sporadically distributed elsewhere in the area. However, due to presence of large number of individual sand units, both within Babguru and Tarkeshwar and their varying thicknesses, both vertically and laterally, designing optimal windows for extraction of attributes was a challenging task. Seismic attributes like RMS, AAA, Instantaneous Frequency and Sweetness etc. were extracted against stratal slices, made for the purpose, with each thought to depict a particular sand sub-unit to a reasonable level of approximation. The clastic dispersal pattern and depositional trends for the various sand units were inferred from the attributes (Fig.8).

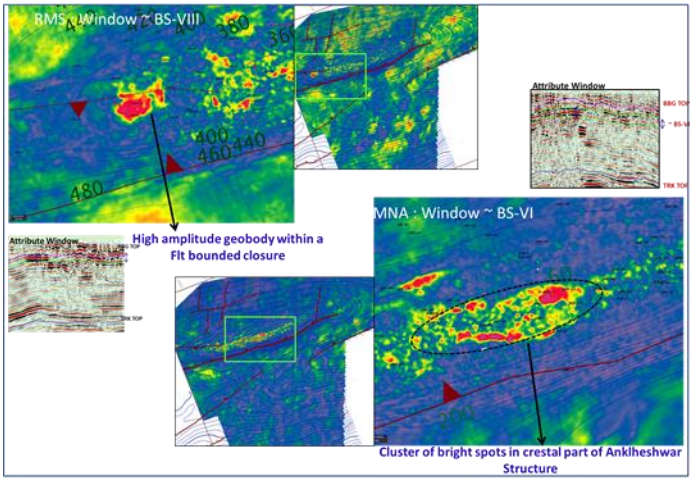

Figure 8. Amplitude attribute analysis –Babaguru formation

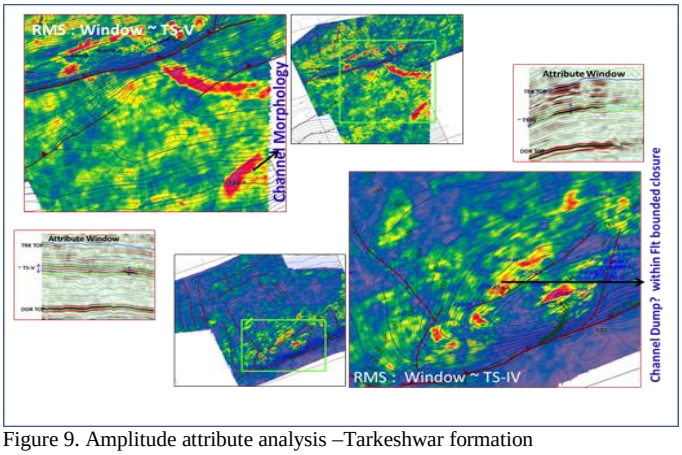

Figure 9. Amplitude attribute analysis –Tarkeshwar formation

These events have been calibrated with well data and are correlatable with the shallow Miocene pays sands in the area. Based on the seismic signatures of hydrocarbon bearing wells and analog from Netherlands offshore field for shallow gas seismic characterization, the bright amplitude anomaly and frequency attenuation have been attributed to the presence of gas (Fig.10&11). Likely hydrocarbon prospects were identified, which were firmed up further on the basis of additional studies enumerated below.

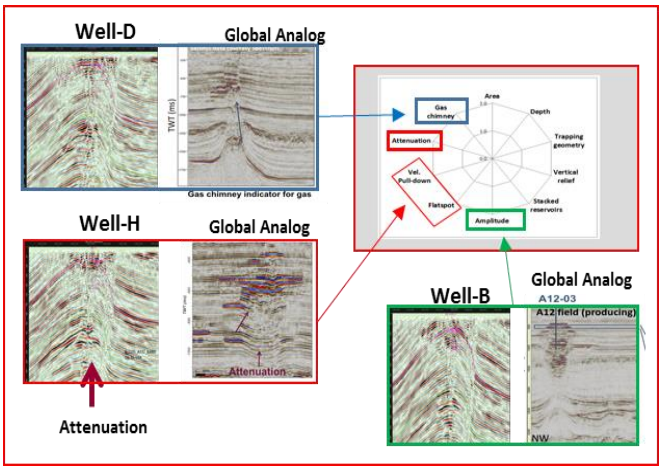

Figure 10. Global Analog and the study area showing seismic characteristic of shallow gas.

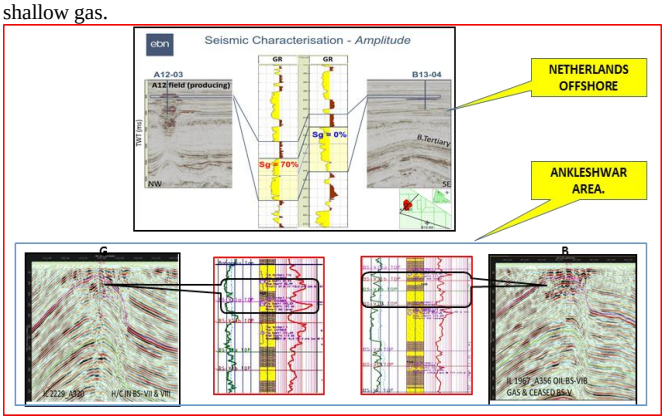

Figure 11. Global Analog and the study area showing log and seismic characteristic of shallow gas.

Seismic Facies Analysis: Reservoir characterization approach, using seismic pattern recognition methodology, based on principal component analysis and 3D multi-attributes based classification, was attempted, through which some discernible geometrical pattern could be brought out, which, in turn, helped in enhancing the confidence on geological model building. Five seismic attributes were used for the classification (Full stack, Instantaneous Frequency, Continuity, Energy and Signal Envelope) to establish which one or combination could bring the more appropriate and objective discrimination for describing rocks and fluid properties in the reservoir. The vertical and lateral disposition of the seis-facies classes corresponding to the pay intervals in tested wells could largely explain the facies association with good reservoirs and proved insightful in identifying zones of interest for exploration, along with other studies (Fig.12).

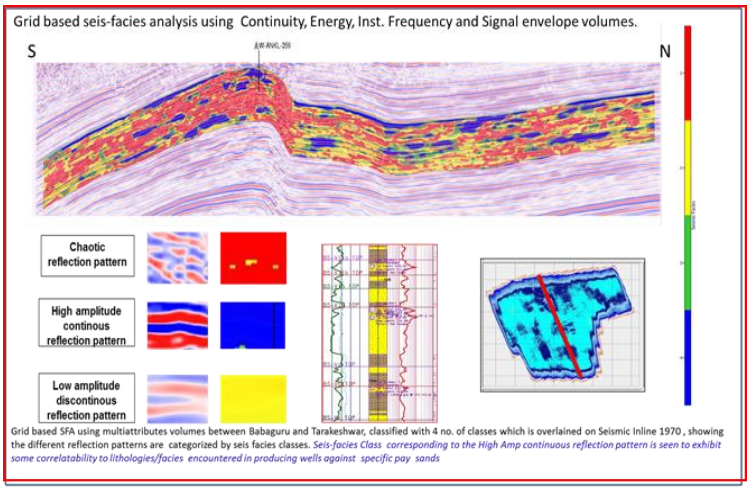

Figure 12. Ssei-facies analysis: Grid based.

Post Stack Inversion: Post Stack Inversion was carried out to characterize thin pay sands within Babaguru & Tarkeshwar formations and to decipher their most probable distribution. Rock physics analysis indicate that for Babaguru level, most of the hydrocarbon wells show low impedance, while for Tarkeshwar level, the hydrocarbon bearing zones are seen to be associated with higher impedance values. In the absence of shear sonic log in the study area, Pre-stack Inversion could not be attempted. 22 wells were used in the study for building the Low Frequency Model (LFM), using the inverse distance square method for interpolation. Reasonable well to seismic tie with satisfactory correlation of 60-65% could be achieved in the zone of interest. Model based inversion was then run using the input seismic, multi-well wavelet and LFM. Comparison of inverted results with actual well logs (filtered to seismic band) showed reasonable match at well locations confirming the validity of the inversion output. Correlation between P-imp, Amplitude and fluid for Babaguru was sought to be established by comparison of GR & Resitivity logs at key tested wells with P-imp & RMS logs extracted from the seismic at corresponding positions (Fig-13). For as many as

70-75 % of the wells considered in the study, it could be established that hydrocarbon bearing zones were associated with low P-imp (< 4000 m/s * g/m3) and moderate to high RMS amplitudes. A similar excercise was also carried out for Tarkeshwar Sands in Kosamaba area, wherein through callibration well KOS-A (gas producer), it was established that hydrocarbon (gas) association is likely with high amplitude and high P-imp (> 5000 m/s * g/m3) (Fig.14&15).

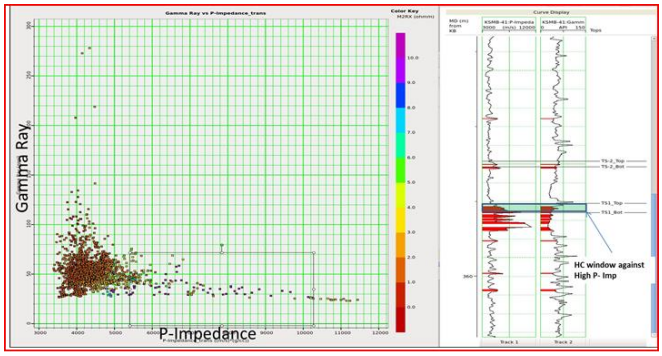

Figure 13. Cross Plot of Gamma Ray vs P-impedance (Colored with Resistivity)

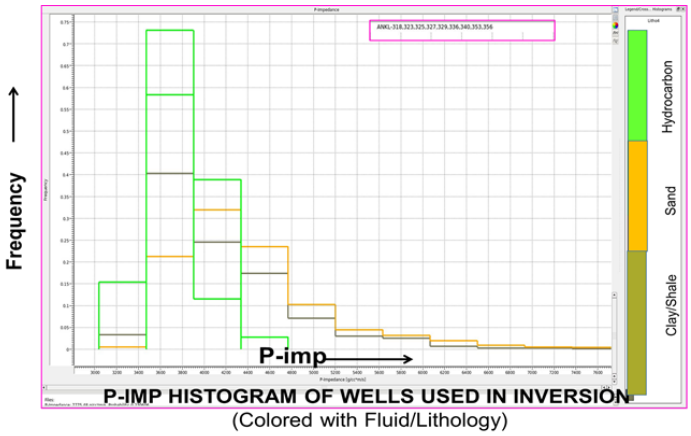

Figure 14. P – Impedence Histogram of wells

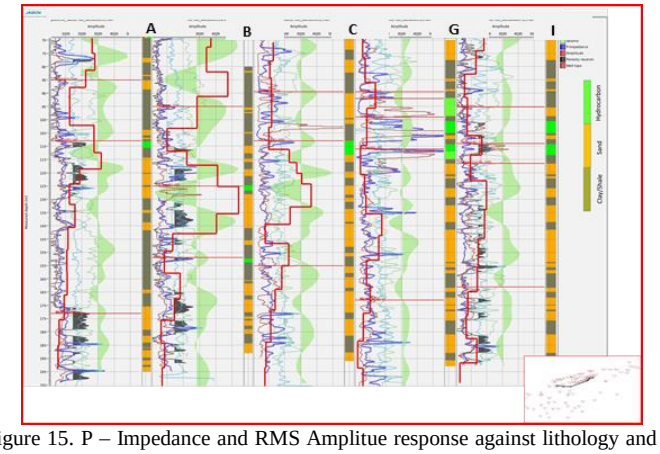

Figure 15. P – Impedance and RMS Amplitue response against lithology and Hydrocarbon pays

Results and Discussion: An integrated approach has been attempted to predict reservoir model on the basis of lithofacies and seismic attribute studies. From the above analyses, it is clear that hydrocarbon locales are likely to be associated with high amplitudes/attenuated frequencies and low P-imp (< 4000 m/s * g/m3) for Babaguru, whereas for Tarkeshwar, the P-imp is moderate to high (> 5000 m/s * g/m3). Applying the aforementioned cut-offs of P-imp, two sets of geobodies were extracted to decipher prospective zones for Babaguru and Tarkeshwar pays. The spread of geobodies, thus obtained, could largely explain (~ 70 – 75%) the tested hydrocarbon wells and those lying within the estimated limits (Fig.16&17). Based on G&G integration, low impedance-high amplitude, fluvial channel model for Babaguru sands and high impedance-high amplitude, distributary model for Tarkeshwar sands have been envisaged. The study could bring out a better understanding of the reservoir/ fluid distribution and enabled identification of prospective locales for exploration.

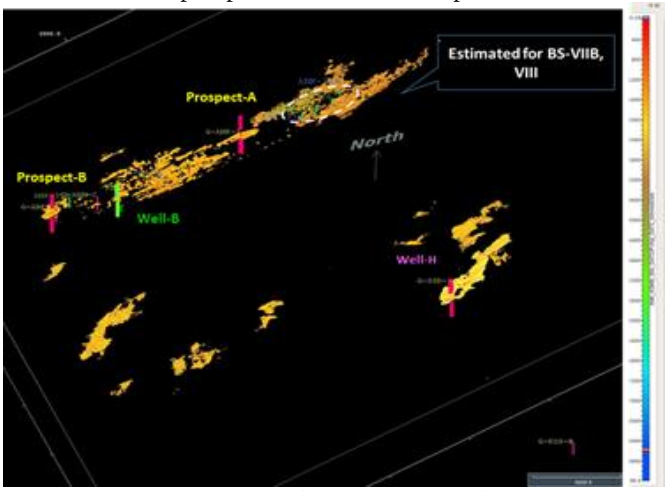

Figure 16. 3D Perspective view of areal distribution of Geo-bodies extracted against Low P-imp values (< 4000 m/cm3* m/sec) of Babaguru sands

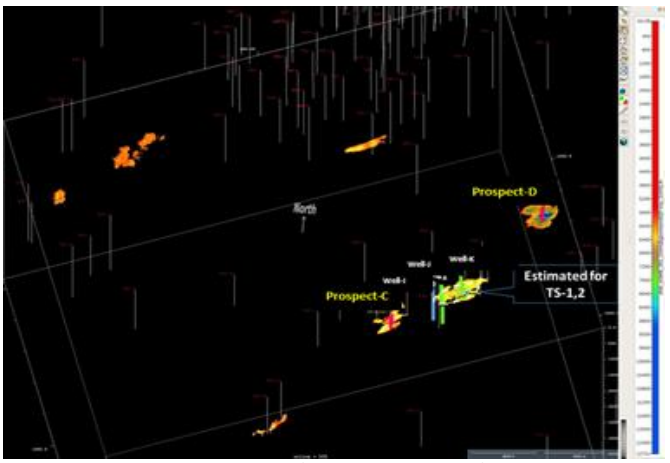

Figure 17. 3D Perspective view of areal distribution of Geo-bodies extracted against Higher P-imp values (> 5500 m/cm3 * m/sec) of Tarkeshwar sands

Conclusion: A systematic work flow from data quality enhancement to prospect generation was followed taking clue from global case study for such pays. Re-processing of the data with focus on shallow portion (0-1000ms) led to significant improvement of data quality through advance technique in random attenuation & coherent noise attenuation & 5D interpolation. Depositional model and sand dispersal pattern were inferred by integrating log motifs, drilled cutting data and seismic attributes for Babaguru and Tarkeshwar sands. It is inferred that Babaguru sands are deposited as braided streams under fluvial environment. It constitute of two major sequences. The thick lower multi-storied sand constitutes of amalgamated channel system which is part of low accommodation system tract (LAST) and upper hydrocarbon bearing sands constituting isolated constrained channel systems which are part of high accommodation system tract (HAST) embedded in flood plain clays. Most of the hydrocarbons are found in the upper sequence of constrained channels. Amplitude-Impedance-fluid distribution relationship has been established and convincing exploration model for Babaguru & Tarkeshwar formation has been proposed. Impedance and attributes study shows that Babaguru pays are having lower impedance (<4000 g/cm3*m/sec) and higher RMS amplitude while Tarkeshwar sands show higher impedance (>5000 g/cm3 * m/sec) and high amplitude corroborating with hydrocarbon bearing wells in the area. Data integration and analysis have led to constrained channel, low impedance - high amplitude model for Babaguru and distributary channel, high impedance -high amplitude model for Tarkeshwar formation (Fig.18&19).The study has brought out a better understanding of the reservoir/ fluid distribution and enabled identification of prospective locales for exploration.

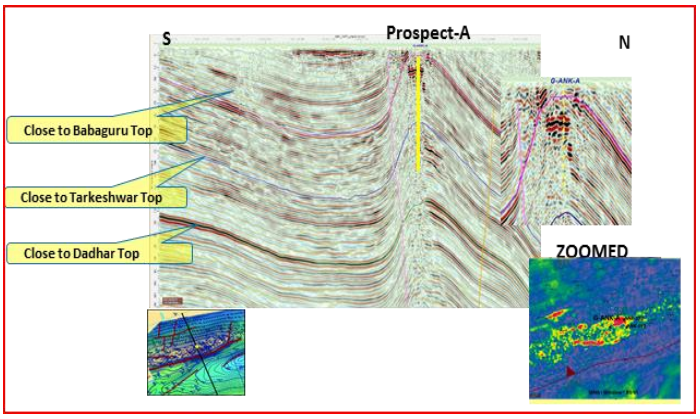

Figure 18. Inline Passing through Prospect-A

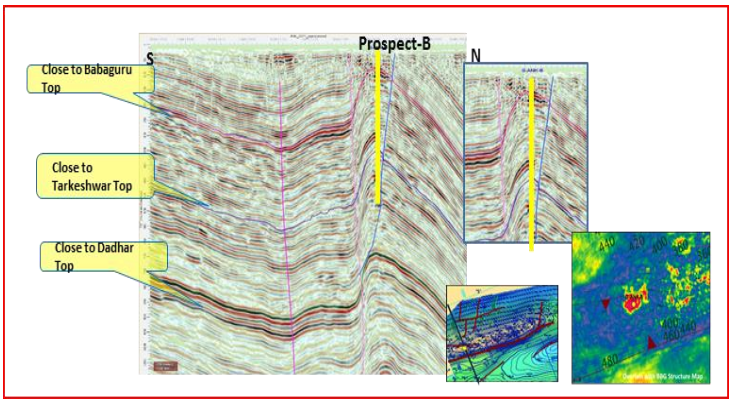

Figure 19. Inline Passing through Prospect-B

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