



Application of inversion and Multi-attribute transform to classify reservoir facies distribution: A case study from Upper Assam Basin

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Summary

Seismic data and well datasets has been integrated to provide an estimate of the sub-surface acoustic property of the study area situated in one of the most prolific Assam-Arakan basin of the Indian subcontinent. Post stack inversion study has been used to integrate Acoustic impedance of the established hydrocarbon bearing sands to derive estimates of the potential distribution of reservoir sands in integration with the computed AI attribute through electrologs. In similar analogy Porosity, Resistivity and V_{shale} volumes through EMERGE study have been generated to delineate the aerial distribution of reservoir sand facies over the 3D volume.

Keywords: Acoustic Impedance through Post-stack inversion and Porosity, Resistivity & V_{shale} volumes through EMERGE study.

Introduction

Assam-Arakan is a shelf-slope-basin situated in NE India and has categorized as category-I basin. So far more than 100 oil and gas fields have been discovered and are lying mostly on the SE slope of the Brahmaputra arch, and almost all the major oil fields lie in a belt bordering the Naga thrust. The important source rock sequences occur within the argillaceous Kopili Formation and in the Coal Shale Unit of the Barail Group. Majority of the oil and gas accumulations has been found in the Tipam Group of Upper Miocene age, Barail Group of Lower Oligocene age and the Langpar and Lakadong formations of Paleocene to Lower Eocene age. Oil also found to occur in fractured granitic basement rock of Precambrian age.

There are three well developed regional cap rocks within the Tertiary sedimentary succession, the lower one, occurring in the Upper Eocene is the argillaceous Kopili formation, the middle one is the Barail Coal-Shale Unit and the upper one, overlying the Tipam Sandstone is the Girujan Clay. Most of the oil accumulations, discovered till date in the Upper Paleocene-Lower Eocene, Oligocene (Barail) and Miocene (Tipam Sandstone) reservoirs, occur in structural combination (fold + fault) traps developed by compressive forces.

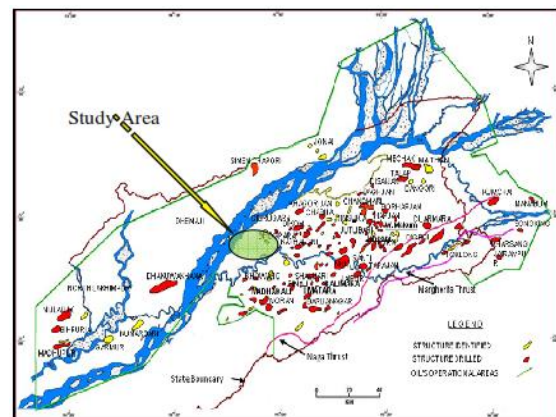


Figure 1: Map showing study area

Data

The study area lies in the prolific Assam-Arakan Basin, adjacent to the major oil fields of Oil India Limited both to the NE and to the south (Figure 1). The 3D volume has been processed at 2ms sample interval having grid geometry of 50m X 25m. The 3D Seismic data has been tied up with electrologs with the help of synthetic seismograms. Seven (7) seismic reflectors (Figure 2) are correlated in the study area. Four (4) numbers of wells have been integrated in the study (Figure 3). However,

the producing and testing results of almost fifteen (15) wells falling in the vicinity of the study area have been incorporated in the study.

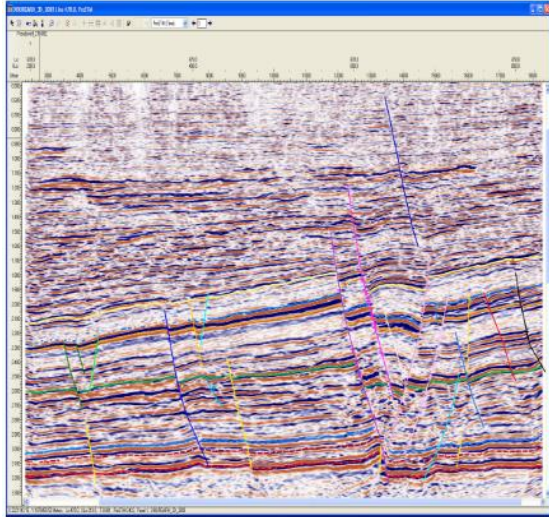


Figure 2: Seismic section and Interpreted Horizon

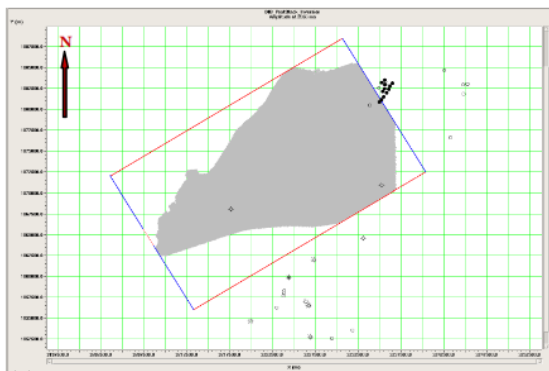


Figure 3: Base Map Showing distribution of wells

Methodology & Work Flow

A series of analysis with electrologs from wells both falling within and in the vicinity of the study area supports the fact that the hydrocarbon bearing sands are at moderate to high acoustic impedance in comparison to the overlying shale. However, the water bearing sands exhibits either low or very high AI value range.

During the crossplots analysis, generated for the AI log, separately for each well, it has been observed that there is an overlap of impedance value range of the hydrocarbon sands with those of water bearing sands and shales. Therefore, in order to eliminate this uncertainty, numbers of reservoir properties (Porosity, Resistivity & V_{shale}) have been analyzed to optimize the restricted conditions for each of the property in order to delineate and separate

the hydrocarbon bearing sands with those of the water bearing sands and shales. The analysis, however suggests that the four reservoir properties taken together may be employed to corroborate the objective to define the hydrocarbon bearing reservoir sands and their aerial distribution over the study area. These properties at all the well locations, under the boundary conditions have found to be in good agreement for both established hydrocarbon and water bearing sands. Therefore, taking the same reservoir properties as base parameters for the delineation of hydrocarbon sands in the study area, the seismic inversion of 3D volume is carried out and acoustic impedance volume is generated using Hampson-Russel software to bring out the Porosity, Resistivity & V_{shale} distribution and litho-facies variation in the study area through multiattribute (EMERGE) study. Spatial and temporal distribution of litho-facies is analyzed within Eocene by extracting Root Mean Square (RMS) of each of the four reservoir properties over the study area.

RMS (Root Mean Square) average of each of the four reservoir properties (Acoustic Impedance, Porosity, Resistivity and V_{shale}) within a window of 8ms within Late Eocene formation is generated. These reservoir property volumes have been generated in the restricted value range optimized during the well log analysis from the established reservoir sands. The window has been confined within the Late Eocene formation in view of impedance offering no anomaly within the Early Eocene, Oligocene or the Miocene formations.

The following workflow has been adopted for the inversion & Multi-attribute (EMERGE) study.

- Importing 3D seismic volume, interpreted horizons, well data, formation tops, TD curves onto HR platform.
- Well data editing and QC.
- Crossplotting logs to identify established hydrocarbon zone (s) and to define cut-off parameters at the target zones for inversion (Acoustic Impedance) & Multiattribute (Porosity, Resistivity & V_{shale}) study.
- Wavelet extraction and Synthetic tie for each well locations separately and to achieve the best correlation between well and seismic in the zone of interest.
- Generate Acoustic Impedance (AI) volume by Inversion.

- Impedance volume imported to the EMERGE platform along with well logs, 3D seismic volume, horizons etc. Porosity, Resistivity & Gamma data from electrologs are integrated with the Acoustic Impedance at the well locations scattered over the 3D volume.
- Multi-attribute study carried out for Late Eocene sands.
- Results from Multi-attribute are then PNN transformed to generate Porosity, Resistivity & V_{shale} volumes.
- Horizon based Impedance, Porosity, Resistivity & V_{shale} slices are generated to analyze their distribution over the 3D area.
- Analysis and Interpretation of the four reservoir properties.

Well log cross plotting, analysis & Interpretation

A comparative study of the reservoir properties viz. Acoustic Impedance (AI), Porosity, Resistivity & V_{shale} have been carried at each of the four well locations taken up in the study. Multiple zones have been defined demarcating the hydrocarbon and water bearing formation at different levels within Late Eocene formation, thus identifying the zone offering the best hydrocarbon possibility in the study area (Figures 4 to 9). Wells (almost 15 wells) nearby study area has also been taken into scrutiny to account for the variation in the above mentioned reservoir properties for both hydrocarbon and water bearing formations. The analysis has also been extended to the sands which are not tested but expected to be hydrocarbon bearing as per the well testing report.

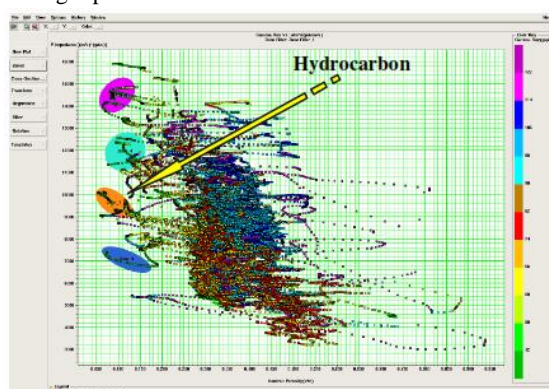


Figure 4: Corssplot between AI & Porosity at well A

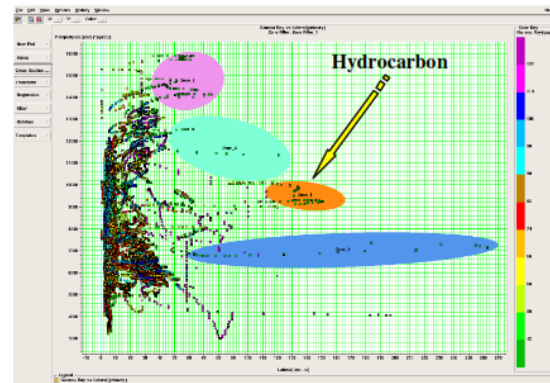


Figure 5: Corssplot between AI & Resistivity at well A

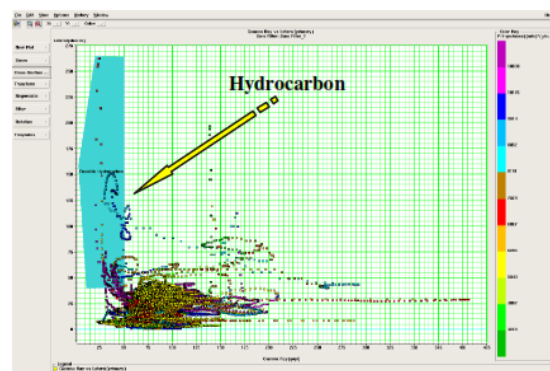


Figure 6: Corssplot between Gamma & Resistivity at well A

The analysis, however suggests that the four reservoir properties taken together may be employed to corroborate the objective to define the hydrocarbon bearing sands over the 3D area. These properties at all the well locations, under the boundary conditions, as discussed above found to be in good agreement for both established hydrocarbon and water bearing sands.

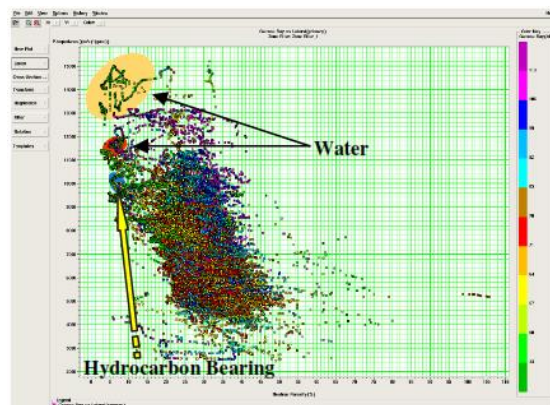


Figure 7: Corssplot between AI & Porosity at well B

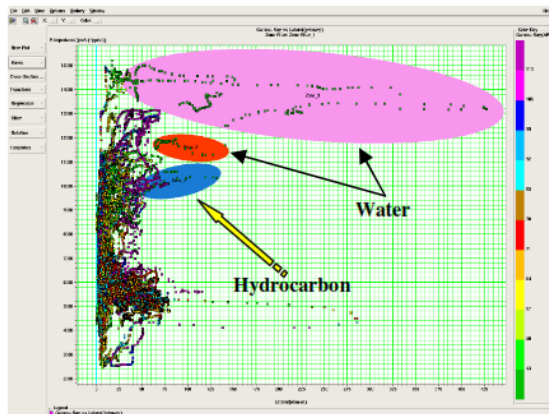


Figure 8: Corssplot between AI & Resistivity at well B

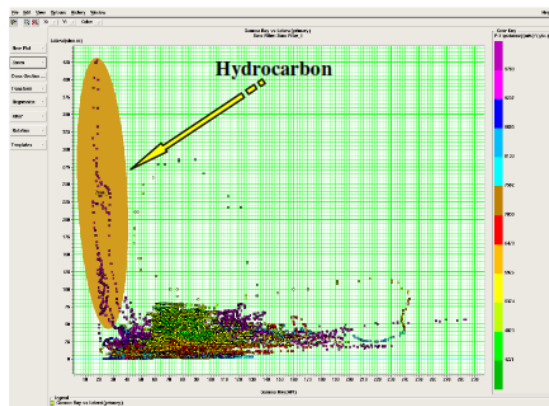


Figure 9: Corssplot between Gamma & Resistivity at well B

On comprehensive analysis of the various sets of crossplots at each of the well locations through AI, Porosity, Resistivity & Natural Gamma logs for both hydrocarbon & water bearing formations it has been concluded that Porosity and Natural Gamma in particular pursue a linear inverse relationship with the AI attribute. However, the resistivity is varying linearly with the acoustic impedance (Figure 4 to 9).

Impedance & Multi-attribute analysis & Interpretation

Attributes derived through Inversion and Multi-attribute are reservoir properties. They are used to better map the extent of the reservoirs and to give a qualitative estimate of reservoir quality. The resulting volumes may be use to predict reservoir properties away from well control.

Geostatistical analysis like Multi-attribute & Probabilistic Neural Network (PNN) through EMERGE study has been carried out for the estimation of the distribution of all the three reservoir properties (Porosity, Resistivity & V_{shale}) particularly within the pay zone in the study area. As per

the well log analysis, pay sand in the study appears to be confined within the sands of Late Eocene formation and as such no anomaly has been observed at any of the Early Eocene, Oligocene or Miocene levels.

An analysis of the Post stack inverted volume (Figure 10 & 11) and reservoir properties generated through EMERGE study (Figures 12 to 17) throughout the 3D volume, it has been observed that the study area advocates, multiple sands within different levels of Late Eocene formation. The general criteria in terms of AI, Resistivity, V_{shale} and Porosity for a hydrocarbon bearing sands, optimized for the study area appears to satisfy at all the levels of sand, offering convincing reservoir facies development towards the NE. The sand to the SW of the study area though showing limited lateral continuity and offers poor sand development, but however appears interesting. Horizon based study of the above four reservoir properties for the 3D area has been carried out to delineate the possible hydrocarbon bearing sands. The interpretation of the same are discussed below;

Horizon based RMS average Acoustic Impedance of two sands within Late Eocene formation has been generated (Figures 10 & 11). The AI window has been kept within the value range as established for the hydrocarbon bearing sands for the study area. Each of the horizons based acoustic impedance attribute for the two sand levels supports the restricted condition as defined for hydrocarbon bearing sands. Acoustic Impedance extracted at near Top Late Eocene shows favorable facies development over the entire area (Figure 10). However, AI horizon slice extracted from 2nd sand layer appearing at 67ms below Top Late Eocene formation shows encouraging sand facies development to the NW part of the study area (Figure 11). The same sand facies extends to the central part and offers good development and distribution. However, the same deteriorates and shows poor distribution from central part to the SW of the study area (Figure 11).

The SW part shows scattered sand facies. This sand has limited aerial extension and is not continuous but appears persuasive and interesting. The AI for this sand falls well within the narrow range of AI value optimized through the well logs for the hydrocarbon bearing sands for the region. Therefore this proves the sand to be convincing.

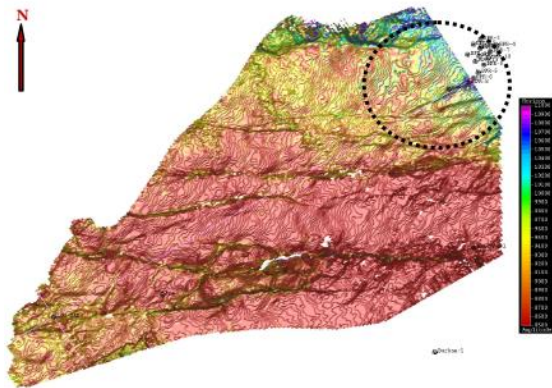


Figure 10: AI slice near Top Late Eocene

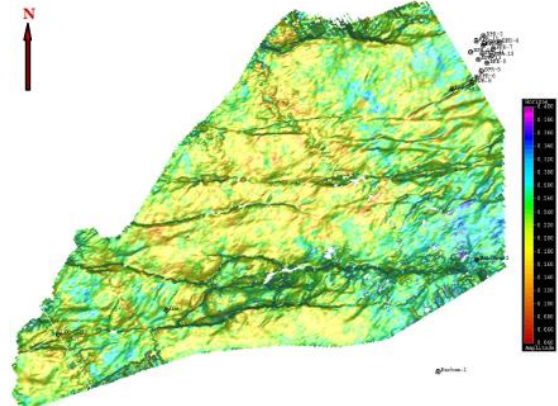


Figure 12: Porosity slice near Top Late Eocene

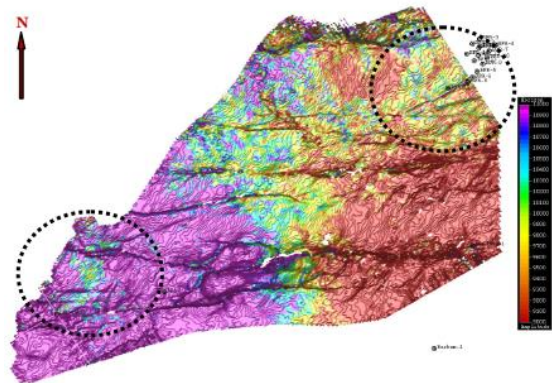


Figure 11: AI slice 67ms below Top Late Eocene

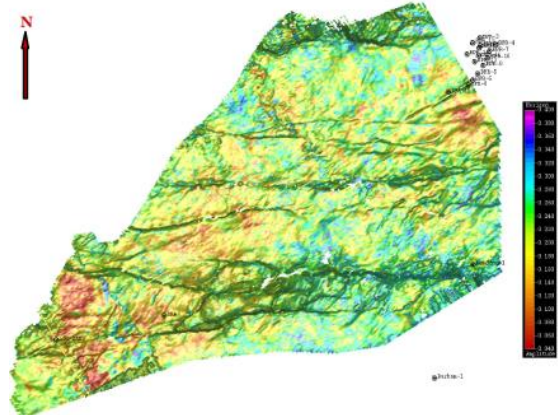


Figure 13: Porosity slice 67ms below Top Late Eocene

Horizon based RMS average computed Porosity of the same two sands (Figure 12 & 13) have been generated and the analysis & interpretation has been carried out within the window as defined for the hydrocarbon bearing sands for the study area. Both the sands agree with the restricted boundary condition. Moreover, the computed porosity distribution is discontinuous and indicates moderate development in and around SW of the study area for the 2nd sand appearing 67ms below Top Late Eocene formation. Corroborating the acoustic impedance with the computed porosity, it may be inferred that sands show convincing development towards the NE of the study area for both the sand levels.

Horizon based RMS average computed Resistivity of the sands (Figure 14 & 15) discussed within Late Eocene formation has been generated. The analysis & interpretation window has been confined by keeping resistivity value within the range as optimized through electrolog from the established hydrocarbon bearing sands. It has been found through the above analysis that both the sands agree with the restricted boundary condition and are lying well above 75 Ω m to as high as 300 Ω m and thus appears promising. Interestingly the sand at both the levels towards the SW of the study area shows very high value of resistivity (Figures 14 & 15). This is however, very high than the reservoir sands to the NW of the study area. High resistivity is in general associated with hydrocarbon accumulation. Therefore, taking the above reservoir properties viz. AI (Figures 10 & 11), Porosity (Figures 12 & 13) and Resistivity distribution (Figures 14 & 15) the sands to the SW appears convincing. On the basis of the above discussed properties the central part of the study area does not offer encouraging results.

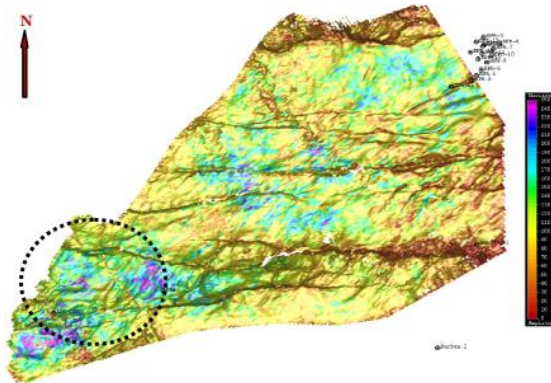


Figure 14: Resistivity slice near Top Late Eocene

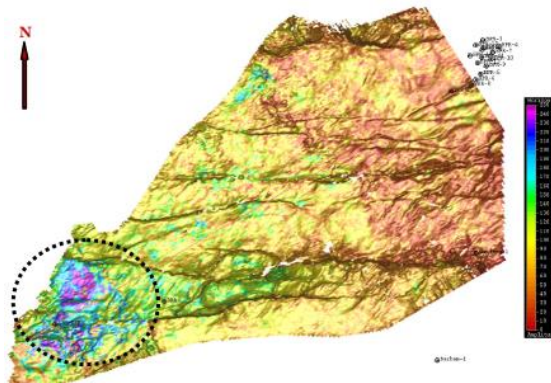


Figure 15: Resistivity slice 67ms below Top Late Eocene

Horizon based RMS average computed V_{shale} map near Top Late Eocene formation is slightly towards the higher side (Figure 16) may depicting the clay contamination in the sands (shaly sand). This is equally support by the electrologs information from the reservoir sands to the NE of the study area.

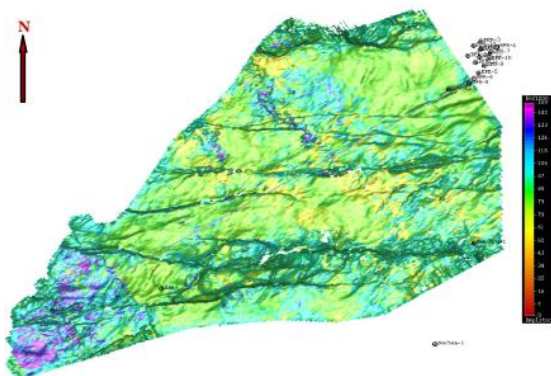


Figure 16: V_{shale} slice near Top Late Eocene

The 2nd sand on the other hand appears cleaner where the

value is relatively low (Figures 17). Moreover, the V_{shale} distribution at 67ms below top Late Eocene offers good clean sand in comparison to the sand at near Top Late Eocene and appears promising both to the NE and to the SW part of the study area. It is to be further noted that, the V_{shale} computed using the inverted volume shows the overall distribution lying in the moderate value range.

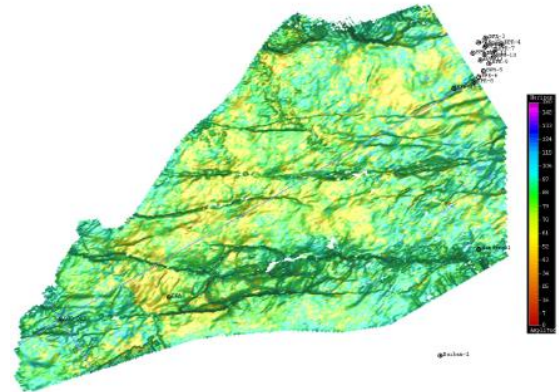


Figure 17: V_{shale} slice 67ms below Top Late Eocene

Conclusion

Inversion study and Multi-attribute analysis carried out using Hampson-Russel software has helped to closely understand the distribution of reservoir properties viz. Impedance, Porosity, Resistivity and V_{shale} within the study area.

Horizon based RMS average acoustic impedance maps conclusively indicate good reservoir facies development which is equally supported by the producing field in the NE of the study area. The impedance value deteriorates and reservoir facies offers confined and discrete aerial distribution to the SW of the study area.

Each of the three computed reservoir properties viz. Porosity, Resistivity & V_{shale} distribution derived through EMERGE study indicates convincing sand development and distribution and falls in agreement as per the well log information of the established hydrocarbon bearing sands to the NE part of the study area. Alike impedance, the computed reservoir properties bears the same resemblance from fair to moderate sand facies development and confined distribution to the SW, however the potential of the sand may not be ruled out.

SW part of the study area is towards the downdip side; however significant anomaly may be seen at both the sand levels within the Late Eocene formation. Except V_{shale} slices (Figures 16 & 17) rest of the three derived



reservoir properties shows the sands to the SW appears convincing, however the central part of the study area does not offer encouraging results.

Integrating, computed Porosity Resistivity and V_{shale} with the AI volume, it may be seen that the intermediate impedance range optimized through well log analysis for the established hydrocarbon bearing sands equally supported by the fair to moderate Porosity (=16%), moderate to high Resistivity (=100 Ω m) and low V_{shale} distribution within the Late Eocene level.

Selection of right known reservoir property which best represents the desired properties (Impedance, Porosity, Resistivity and V_{shale}) through the judicious use of cross plotting technique.

The resolution of the inversion study is limited by the highest usable frequency available in the seismic data. Inversion increases the temporal resolution but for very deep prospects, limitations are inevitable.

Seismic data quality, dept of investigation, vertical resolution, well log data quality, well distribution over the study area, thickness of sand bodies, well to seismic tie etc possibly are the most crucial ingredients in any inversion study on which the outcome significantly depends on.

The accuracy of any statistical analysis tends to deteriorate away from the control points; therefore even distribution of optimum number of wells are crucial.

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