



P-311

An Integrated Approach to distinguish and delineate Sub-Unconformity Stratigraphic Pay-sand - A Case Study

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Summary

Analysis of seismic data from various parts of the world indicates that spectral decomposition provides meaningful results for stratigraphic structure interpretation and contributes to enhance drilling success rate. Considering the above fact an integrated approach was made to distinguish & delineate Stratigraphic Sub-Unconformity pay sand packages from the Cauvery Basin of India using spectral decomposition with the help of Kingdom Core Application Software from Seismic Micro Technology (SMT).

Since the instantaneous spectral analysis method uses a wavelet transform technique to produce frequency spectrum of reflection events that are localized in time, thereby an individual target reflection event is spectrally analyzed at its uncontaminated form which can be compared to gas response, observed from the well logs with and without pay. The seismic traces are then decomposed to spot hydrocarbon response within the volume.

In the present study area, an integration of seismic, geology, and data from existing wells, with & without pay were considered and an analogy was drawn to distinguish & delineate further extension of sub-unconformity charged sands. The visualization of the prospective reservoir sand bodies with the help of spectral attributes and the Inversion studies have led to identify the optimum areas for future drilling locations.

This paper summarizes results obtained for identification of sandy reservoir that may have potential gas accumulations in the area of study. The results have been used to define the locations of new exploratory and development wells in order to reduce the risk associated with the search of additional gas reserves in the sub-unconformity clastic sequence in Cauvery Basin.

Introduction

The spectral decomposition of seismic data is the process that transforms seismic amplitudes as a function of space and time to spectral amplitudes as a function of time, frequency and space. Spectral decomposition has been used for a variety of application including layer thickness determination (Partyka et al, 1999), Stratigraphic visualization (Marfurt and Kirlin, 2001) and direct hydrocarbon detection (Satish Sinha et al, 2005). The frequency cubes that result from this process can potentially be used to map variations in bed thickness, geologic discontinuities and differentiation of fluids in the reservoir.

In instantaneous spectral analysis method, each full spectrum reflection can be visualized and analyzed with special emphasis for stratigraphic visualization/variation (Marfurt and Kirlin, 2001). Since, this method does not mix the reflections in time, thus allowing the investigation of reflectivity from individual seismic events. When viewed as a frequency panel movie, the changing contrast becomes very striking.

In the present study an integrated interpretational approach was made to identify the discrete equivalent pay sand lying below sub-unconformity traps in the study area (Fig: 1) of Cauvery Basin of India. In the study area, the juxtaposition of older



Cretaceous against Paleocene across the K/T boundary has brought out highly productive sub-unconformity pay sands. These pay-sands are highly localized, lenticular and deposited dominantly as slumps and debris flows during Santonian-Early Maastrichtian post-rift stage and bisected by series of Normal faults. The main

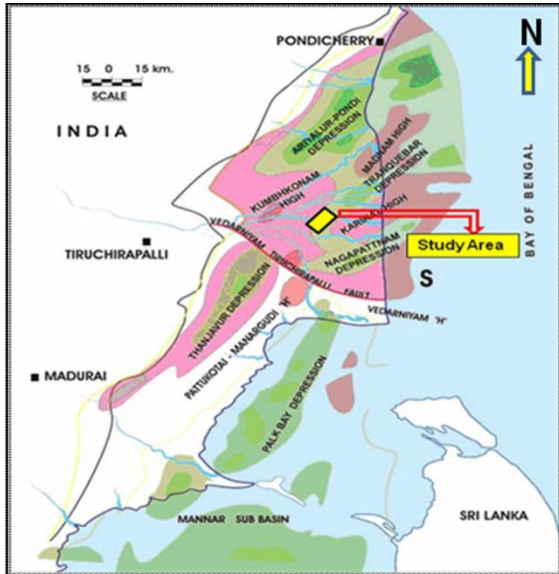


Fig. 1: Study Area within Cauvery Basin

reservoirs in the area of interest are within these post rift sequences. Since the formations are very compact their lithological variations are seismically less resolved, as the sand and shale layer almost shows equal sonic travel time. These sands are well correlated with the spectral amplitude anomalies produced with pay sand from the wells studies & further validated with the Impedance and cross plot analysis. The wells falling in the area have provided us an accurate prior estimation of the impedance background.

Methodology

In the present study the Spectral decomposition has been used in combination with well data. The workflow shown in (Fig. 2) depicts the combination of well data, seismic-amplitude maps and spectral

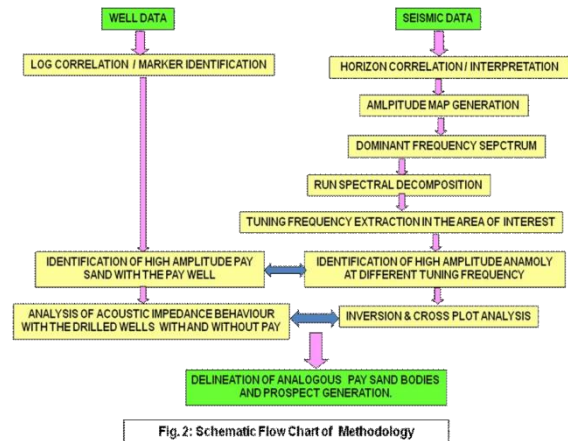
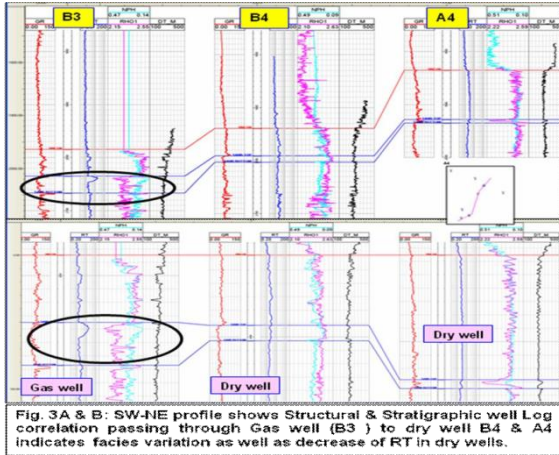


Fig.2: Schematic Flow Chart of Methodology

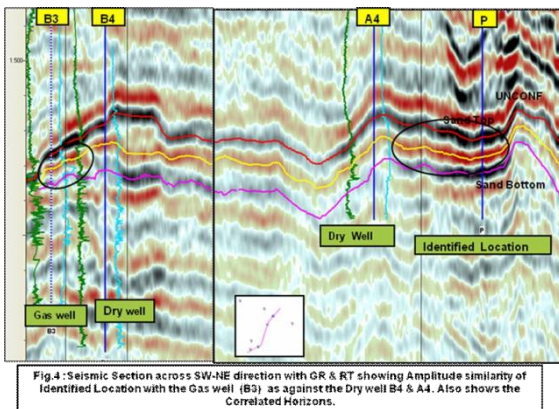
Decomposition results clubbed with Inversion studies & Cross plot analysis. Results derived out of this analysis have been used to identify ideal location ("P") for new well.

Electrolog / Horizon Correlation

A SW-NE profile (Fig. 3A & B) shows Structural & Stratigraphic well log correlation passing through gas well.

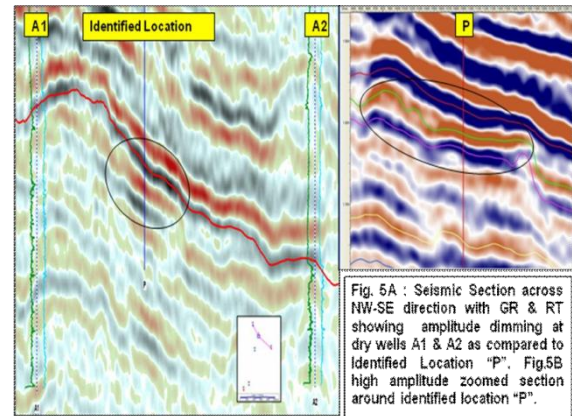


B3 & dry well B4 & A4. The log motifs with lithological markers indicate the presence of B3 equivalent pay sands that has produced gas, has



either been pinched out or the arenaceous facies has changed into the argillaceous facies at B4 and A4 level. The top of the Unconformity boundary is prominently marked by clear shift in SP, RT, Density- Porosity and Sonic base lines. The significant increase of RT value in gas well as compared to dry well can be easily distinguished. Seismically, the Unconformity boundary has been correlated taking compression as positive represented by peak (blue). Based on the synthetics generated from the log curve the seismic events corresponding

to Unconformity, Sand Top & Sand Bottom were correlated. An arbitrary SW-NE seismic profile (Fig 4) have shown correlated horizons with GR & RT shift at Gas well (B3) as against the dry well B4 & A4. The amplitude similarity of the identified



location with drilled Gas well B3 is quite evident. This clearly infers that how lateral variation of amplitude has taken place along the pay zone of gas well as well as dry wells.

Another profile (Fig. 5A) was generated along NW-SE with GR & RT signature again depicting high amplitude anomalies around the proposed location as against the dry well A1 & A2. Fig 5B represents the zoomed section of the proposed location with high amplitude burst.

Amplitude Map

The RMS amplitude maps were extracted in the area of interest to determine the stratigraphic area of interest and used as a base map. The seismic reflections are found prominent in areas where arenaceous facies are better developed as an interbed within shale. Fig.6 depicts the good RMS amplitude anomaly around the identified location "P" with its higher structural disposition and showing

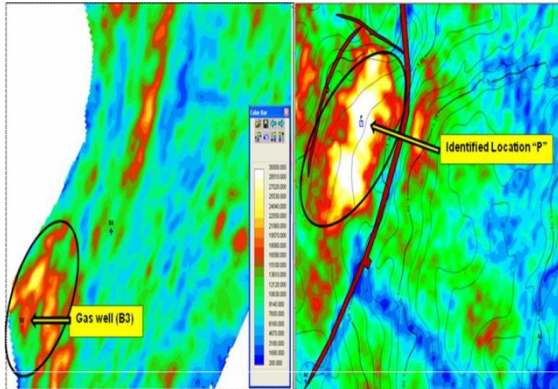


Fig. 6 Amplitude anomaly around Identified Location with Structural Disposition

good correlation with the drilled gas well B3 in the area of study. But it is difficult to conclude hydrocarbon occurrences based on the amplitude contrast only. The amplitude anomaly around the "P" clearly indicates the high trend and is interpreted to be caused by the increased sand dispersal pattern which has further led us to study the spectral response to enhance our confidence.

Spectral Analysis Results

The identification of tuning (highest normalized amplitude) from the reflection amplitudes associated with the top and bottom of a layer is the fundamental concept used in interpreting spectral decomposition.

The envelope sub-band output option is used to identify the highest amplitudes which may denote tuning at specific frequencies. The dominant frequency band (Fig.7) between 08-35Hz was considered for slice generation and estimation of tuning frequency. Spectral sub-bands that lie outside or partially outside the frequency spectrum of the original data, will give inaccurate measurements of tuning, especially at the lower end of the frequency spectrum.

The seismic horizon Sand top-Sand bottom was used to select a window of the data around the event of interest for spectral decomposition and generated

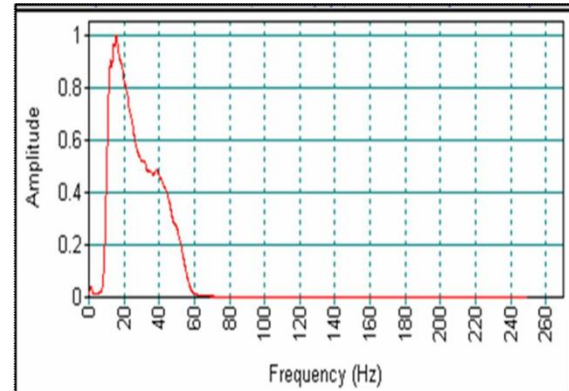


Fig. 7 Dominant Frequency Band 15-35Hz

a series of amplitude maps at different frequencies. Six spectrally decomposed amplitude slices were generated from the frequency cubes on the pay horizons Sand top-Sand Bottom. The tuning slices for the identified location were generated at 10, 13, 17, 22, 28 & 37Hz. The high amplitude anomaly was observed at 17, 22 & 28Hz (Fig.8) suggesting better reservoir facies and clear affinity with the sand facies of pay well (B3). The amplitude dimming was observed at 10, 13 & 37Hz showing background frequency response indicating that arenaceous facies has changed to argillaceous facies.

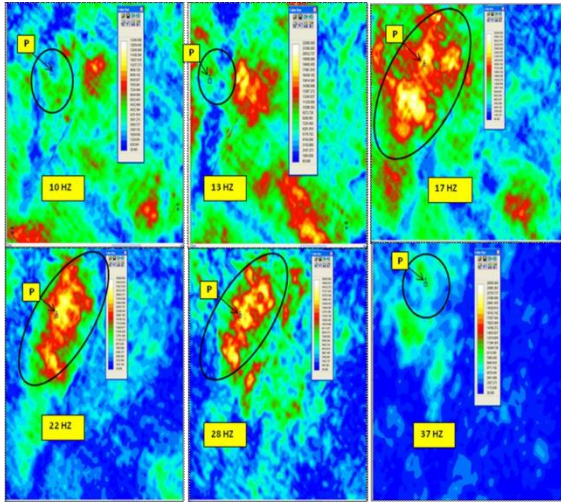


Fig. 8: Spectral Decomposition tuning showing high amplitude anomaly at 17Hz, 22Hz, & 28 Hz, while the Amplitude Dimming at 10Hz, 17Hz & 37Hz around Identified Location "P"

Rock Physics Analysis and Inversion Study

Seismic Inversion converts the interface property of geological boundaries (lithology change) and the main reservoir into layer property. This is done by the inversion of the seismic cube into an Acoustic Impedance cube. Model based inversion was carried out in this particular case.

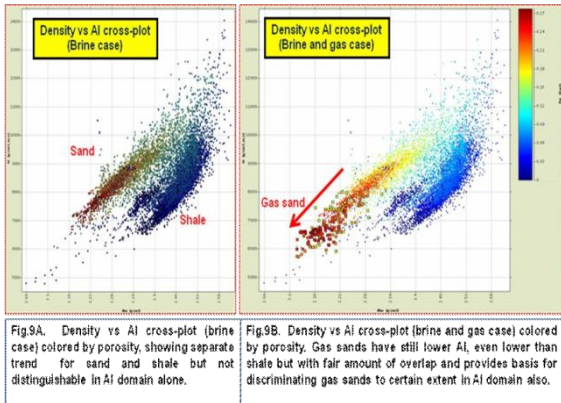


Fig.9A. Density vs AI cross-plot (brine case) colored by porosity, showing separate trend for sand and shale but not distinguishable in AI domain alone.
 Fig.9B. Density vs AI cross-plot (brine and gas case) colored by porosity. Gas sands have still lower AI, even lower than shale but with fair amount of overlap and provides basis for discriminating gas sands to certain extent in AI domain also.

The Elastic properties such as velocity, density, impedance and V_p/V_s ratio plays an important role in reservoir characterization, as they are related

to the reservoir properties. To analyze these elastic properties, rock physics knowledge is a bridge that links the elastic properties to the reservoir properties such as water saturation, porosity and shale volume.

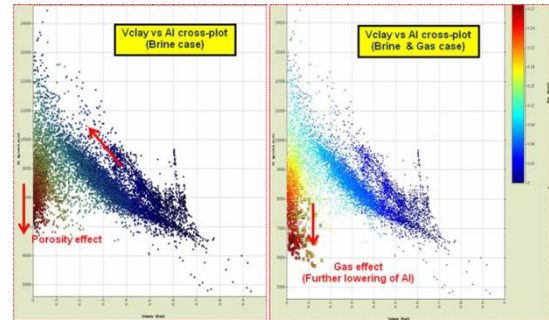


Fig.10A. V clay vs AI cross-plot (brine case) colored by porosity, showing increasing trend in AI with decreasing clay content. Although effect of porosity in lowering of AI is evident, sand-shale distinction based on AI values is not possible
 Fig.10B. V clay vs AI cross-plot (brine and gas case) colored by porosity, showing increasing trend in AI with decreasing clay content. In addition to porosity effect in lowering AI, further decrease in AI is evident in case of gas saturated sands.

A rock physics template is built from the inverted elastic properties to aide the interpretation. Using this we can estimate the lithology and fluid content of unexplored areas if that has the same geological depositional environment as that of explored area. The final result shows that the lithology and fluid content can be efficiently interpreted for our target reservoir using the inverted elastic properties plotted against rock physics template.

In the present study, post stack 3-D seismic volume was inverted for P-impedance volume. The cross

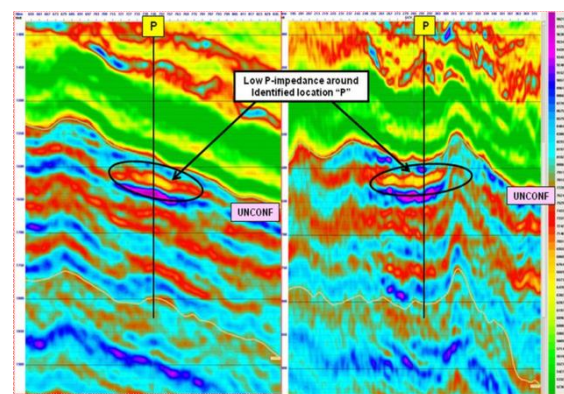


Fig.11A. Lowering of P-impedance along inline & Crossline passing through identified location "P"



plot analysis of Density versus P-impedance, (Fig. 9A&B) and Vclay versus P-impedance (Fig. 10A&B) was carried out using all the wells drilled in the study area. The results have shown that the gas saturated

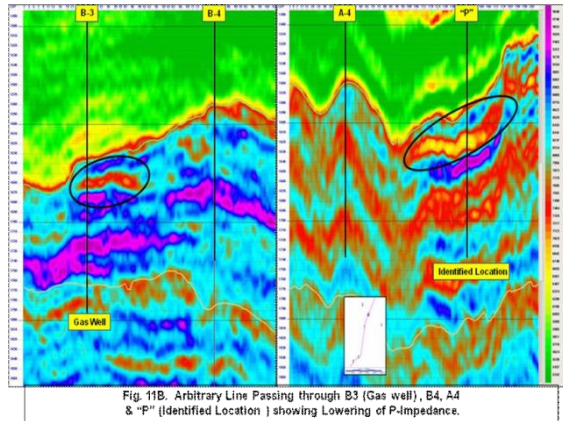


Fig. 11B. Arbitrary Line Passing through B3 (Gas well), B4, A4 & "P" (Identified Location) showing Lowering of P-impedance.

clean sands have lower impedance than that of shale and brine sand. Based on this analysis low Impedance locale was targeted in P-impedance volume and compared with the Gas bearing well (B3) to firm up the drillable prospect. (Fig 11A &B) These low impedance locale was a corroborated with RMS amplitude and Spectral decomposition results mentioned above.

Conclusion

Discrete high amplitude anomalies have been observed in the prospective gas prone area and used as a lead for further analysis through spectral decomposition studies. By viewing frequency slices as movie, subtle changes in frequency become dynamically visible.

Results of Post-Stack Seismic Inversion indicate lowering of impedance at the locales which are comparable with the nearby Gas bearing well (B3). Integrating the results of log studies, RMS Amplitude, Spectral Decomposition and Inversion

studies have resulted in identification of suitable locales for future exploration.

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