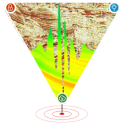




Reservoir Characterization based on Phase Decomposition and its application in Exploration De-risking, Appraisal and Development

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Keywords

Phase Decomposition, AVO, Reservoir Characterization, Prospect De-risking, Exploration, Development

Abstract

A relatively new method of Phase Decomposition (Castagna et al. 2016, Chopra et al. 2023) is critical to for the analysis of lateral changes in thin layers with respect to the contemporary technology and techniques. Phase Decomposition is a novel technique that decomposes a composite seismic signal into different phase components, which can improve reservoir characterization. The technique is particularly useful in those areas where thin-bed interference causes the phase of the input seismic response to differ from the phase of the embedded wavelet in the data. For a zero-phase wavelet in the data and thin low-impedance layers below tuning thickness, the -90° phase component stands out anomalously. A corresponding high-impedance thin layer exhibits a similar $+90^\circ$ phase component response. Furthermore, for thin layers, a change in impedance is best seen on these plus or minus 90° components. By generating a synthetic response with use of well data and a zero-phase wavelet, such observations for thin reservoir layers can be understood with confidence and correlated with real seismic data. The original spatial distribution and lateral extent of amplitude anomalies may vary after phase decomposition, allowing the interpreter to better assess and prioritize target amplitudes and can be effectively used as a direct hydrocarbon indicator (DHI). Thus, combination of output of phase decomposition and AVO modelling will provide a better prospect level de-risking workflow in exploration and development.

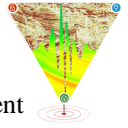
Introduction

This study of Phase Decomposition has been carried out in the Gas bearing Miocene sands of North-East India, represented by alternating sequence of sandstone and shale which are deposited in a tide dominated deltaic to marginal deltaic and marine environment. Impedance of argillaceous units is more than that of arenaceous

units, as observed from the electro logs in the study area and therefore the peaks mostly represent shale and the trough represents sand rich facies in the available SEG Normal polarity seismic volume. In certain cases where thickness of reservoir is more than 50m and have water contact, then peak get represented by the GWC. Lenticular sandstone reservoirs are likely to be sealed vertically and laterally by intercalated shale. In a tidal deltaic environment, pro deltaic shale and shale in interfluvial region provide top and lateral seal. Overpressure zones in Miocene shales due to compaction disequilibrium might have prevented the vertical escape of fluids during burial. Migration is vertical and occurs through basement-rooted faults.

Methodology

In present case study Phase Decomposition was applied on low-impedance hydrocarbon-bearing sands in a clastic section where sand thicknesses vary from the vicinity of tuning to well below tuning. To properly interpret seismic phase changes caused by the introduction of hydrocarbons, it is useful to artificially 'thin' the targets by high-cut filtering the data, thereby increasing the tuning thickness and making more layers seismically thin and eliminating random and incoherent noise data towards the longer tail of high frequencies. Once the seismic thinning is performed, the amplitudes separate into the expected phase components, resulting in a different spatial distribution of mapped amplitudes than on the original seismic data. This technique is called *seismic thinning* and its applications for distinguishing target anomalies have been discussed by Meza et al. (2016) and Barbato et al. (2017). In the study area where multiple stack events were present ranging from ~8 m Thickness to ~ 25 m with dominant frequency of the zone about 25-30 Hz. The seismic to well ties was helpful in delineating the possible and expected response regarding these target sands. Hence, overlooking the frequency dependency of these targets can lead to erroneous interpretations of the results. Further original seismic has a dominant frequency between 40 and 60 Hz. This would be too high to observe the expected anomalous phase



response for these multiple stacked events, which require lower frequency components to provide necessary thin layer condition.

water. This is characterized by the -90° component of Phase Decomposition (Figure 1.b).

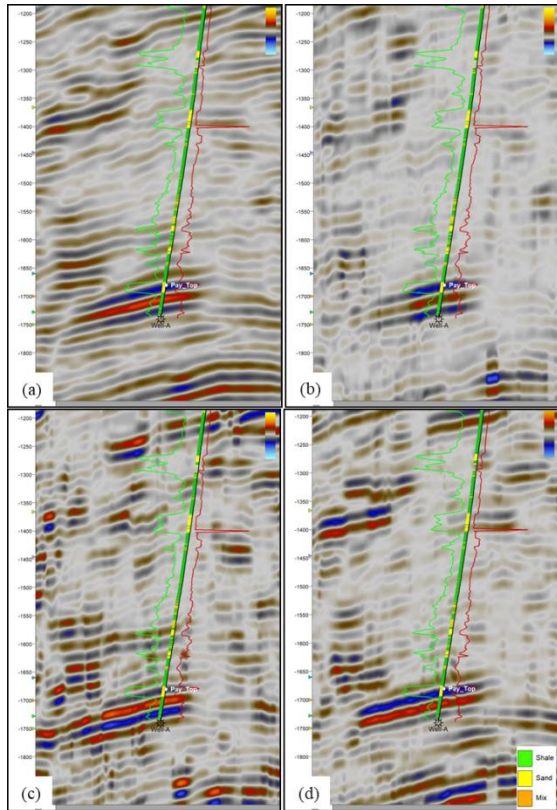


Figure 1: Output of Phase Decomposition (a) SEG Normal Polarity Seismic PSTM (b) 0° Component (c) $+90^\circ$ Component (d) -90° Component

Well A has produced gaseous hydrocarbon from the pay sand at 1680ms. A bright spot anomaly is observed on the PSTM Seismic at the pay level. Applying Phase Decomposition technique has validated the presence of the hydrocarbon at pay level as the -90° phase component stands out anomalously (Figure 1).

Dipping bright spot amplitude anomalies may exhibit a GSC or a GWC. If the idea of the probable GWC is envisaged, well in advance, the probability of exploration and development increases significantly. Brine saturated sands at the down-dip of a GWC bearing bright anomaly would be exhibiting higher impedance than its gas bearing counterpart at the shallower. This effect is characterized by Phase Decomp. The 0° and -90° component deciphers the gas bearing part, whereas the brine charged sand is characterized by 90° and 180° components. This is evident from the Figure 2 where Well-B is gas bearing, whereas the Well-C, drilled in the same amplitude anomaly has produce

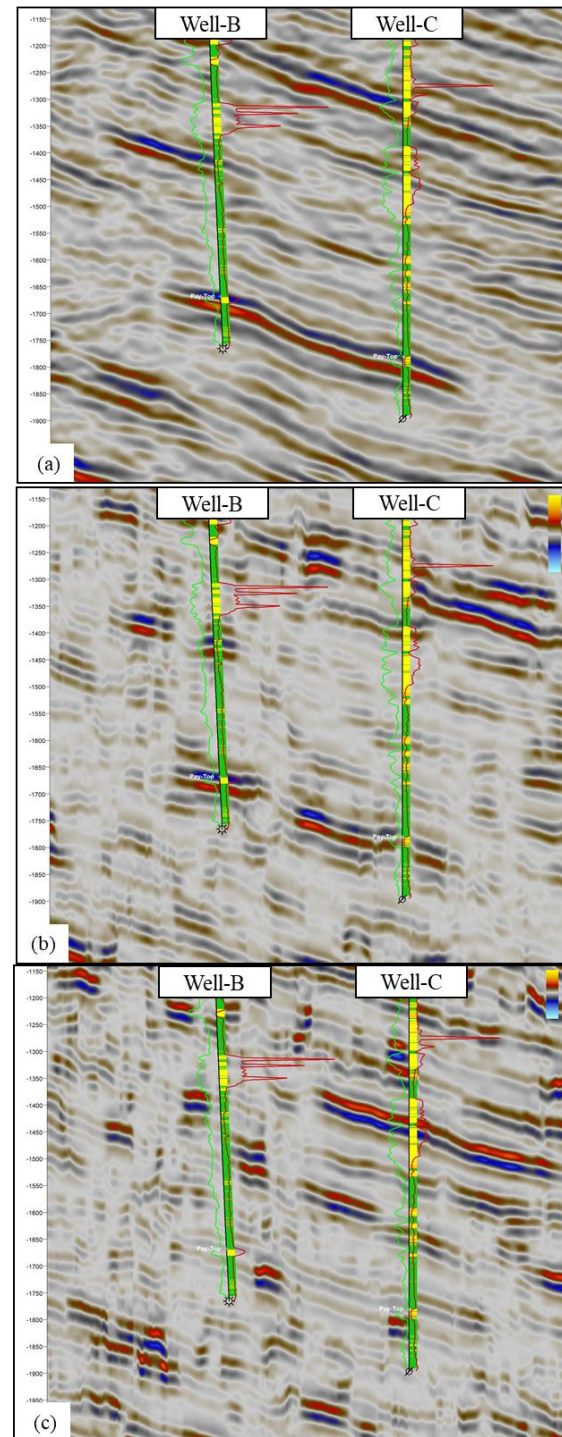
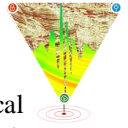


Figure 2: Well B (Gas) and Well C (Water) has been drilled on the same Bright Spot Seismic Amplitude Anomaly. (a) PSTM seismic section across both the wells (b) -90° component of Phase Decomposition (c) $+90^\circ$ Component of Phase Decomposition

A comparative study (Figure 3) of the Seismic Amplitude Strength attribute extracted at the top of the reservoir (Window ± 6 ms) from PSTM Seismic volume and -90° component of Phase



Decomposition demonstrates that Phase Decomposition aids in delineation of the probable extent of the pay in a reservoir, characterized (Figure 3.c) by most negative values.

(Full, Near, Mid and Far) and the geological settings in which phase decomposition is applied. As depicted in Figure 4, we applied Phase decomposition on Full Stack Seismic (Zero Phase). Later the results from phase components 0°, -90°, and +90° were used for analysis.

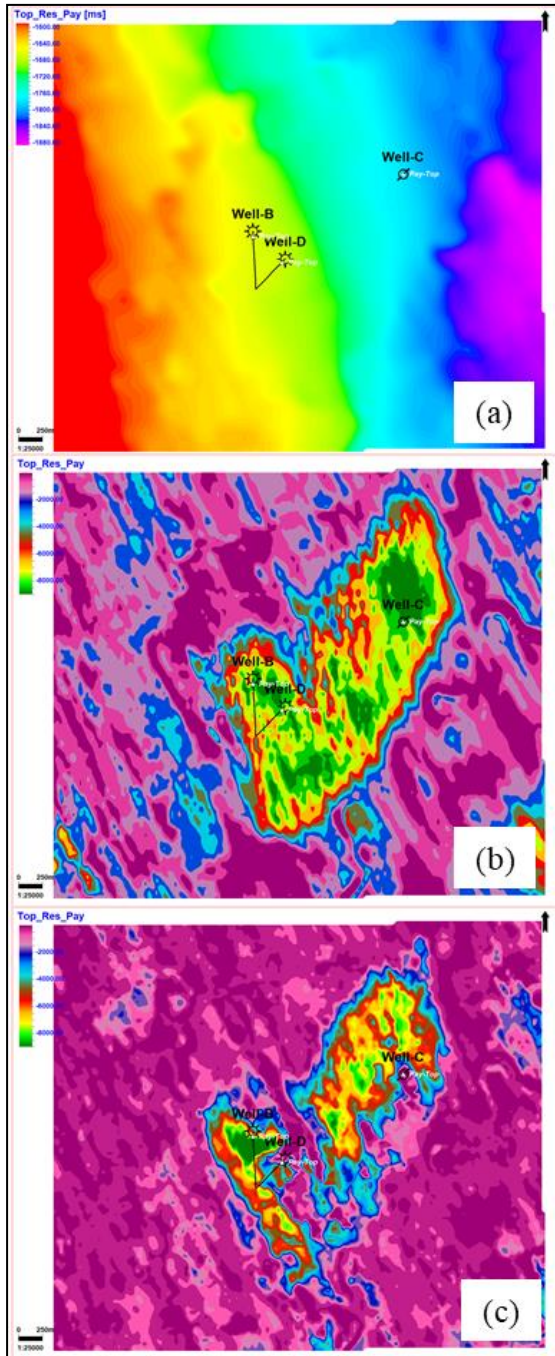


Figure 3: (a) TWT Map at the Top of the Reservoir Sand (b) Amplitude Value extracted at the top of the reservoir from SEG Normal Polarity Seismic PSTM Volume (c) Amplitude Value extracted at the top of the reservoir from -90° component of Phase Decomposition

Figure 4 shows the generic workflow procedure applied in the present case study. It may vary slightly from interpreter and interpreter and depending on the type of stacked seismic data

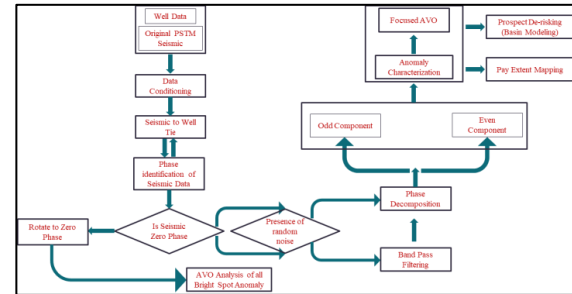


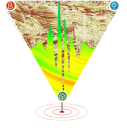
Figure 4: Phase Decomposition aided Workflow for Prospect De-risking.

Conclusions

With the presence of multiple contemporary tools and techniques for thin bed detection and reservoir anomaly characterization, Phase Decomposition can be considered as a relatively new and unique way of discerning the Hydrocarbon effect. It will be quite a useful process to apply before a focused AVO and Inversion study on the seismic data which are band limited and further can solve the challenges for fields across the world where the production is seen and is expected from thin reservoirs. For seismic events above and in the vicinity of tuning, artificial “thinning” can be achieved by simple high-cut filtering. Thin low-impedance gas bearing sands can be identified in the odd component when the stated events are well below seismic resolution. Removing high frequencies via bandpass filtering allows us to thin layers that are otherwise resolved, achieving an optimal illumination frequency. The Phase Decomposition do not need well data, but it can be used in the identification of seismic phase using seismic to well ties and later for calibration of results which increases the percentage of certainty and better interpretations of reservoir anomaly.

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