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Application of Simultaneous Inversion Method to Predict the Lithology and Fluid Distribution in "X" Field, Malay Basin

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Abstract: Reservoir characterization is one of the most crucial processes in the exploration of hydrocarbons. Thus, having sufficient information such as the lithology and fluid distribution of a reservoir is vital. With the application of Simultaneous Seismic Inversion, we will be able to improve the prediction of the lithology and fluid distribution of the prospect area, as it generates information such as Density (ρ), Lambda-rho (λρ) (Incompressibility), and Mu-rho (μρ) (Rigidity). Real data from the Malay basin were used to show the effectiveness of this method in enhancing the resolution and characterizing the gas sand layer of the prospect.

1. Introduction

Seismic reflection methods have been widely used over the years to locate potential oil and gas reservoirs, as well as providing information on the physical properties of the reservoir rocks. Changes in physical rock properties such as density, results in the change of seismic acoustic impedance, causing a significant effect that could be observed in a high quality seismic data.

Back in the years, reservoir characterization has only been using Acoustic Impedance (P-impedance) seismic data to obtain information. However, this approach is insufficient, since P-impedance seismic data is unable to distinguish the effects between lithology and fluid content. Fortunately, we could overcome this limitation of interpretation by extracting information from the Shear Impedance (S-impedance) seismic data that highlights the fluid content of an area.

This study seeks to demonstrate the application of the Simultaneous Seismic Inversion method on the "X" field which will enhance the prediction of the lithology and fluid distribution in the prospect area. This method estimates the P and S-impedance by inverting each partial angle stack data simultaneously using the extracted wavelet from each angle stack. The inversion results such as Density (ρ), Lambda-rho (λρ) *(Incompressibility)*, and Mu-rho (μρ) *(Rigidity)* are proven to be useful for reservoir characterization of a prospect area.

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2. Methodology

2.1 3D Seismic Data

For this project, the available seismic data are only post-stack angle volumes also known as angle stack. The seismic survey coverage ranges from Inline 980 to 1582 and X-line 2100 to 6090 for each volume. Three angle stacks (post-stack) are used, where each stack represents a different range of angles as shown in Figure 4.13.

a. Near stack (5° - 15°)
b. Mid stack (15° - 30°)
c. Far stack (30° - 45°)

These stacks are loaded separately as post-stack data into the Hampson Russell (HRS) software, before creating pseudo gathers (pre-stack) by extracting a trace from each volume for every offset. In other words, each offset has three different angle traces (15°, 30° and 45°). This seismic loading workflow definitely differs from the conventional workflow of simultaneous inversion, where we create pre-stacks volume from given post-stack volumes.

2.2 Well data

A complete well log data per well is needed before we could proceed with the simultaneous inversion. The essential data required for the inversion workflow are P-wave sonic, S-wave sonic , density and checkshots logs.

2.3 Method

The cross plot approach is being applied on the X-3 well, in order to determine the feasibility of the simultaneous seismic inversion process on the dataset, before proceeding to the full inversion workflow. Figure 4.2 represents the cross plot of Vp/Vs ratio versus P-impedance at the gas sand zone of interest with a colour scale that indicates the gamma ray values. From the cross plot constructed, it can be observed that there is a separation between the points scattered, making it possible to differentiate the gas sand from the brine sand. Therefore, the inversion workflow can be proceed.

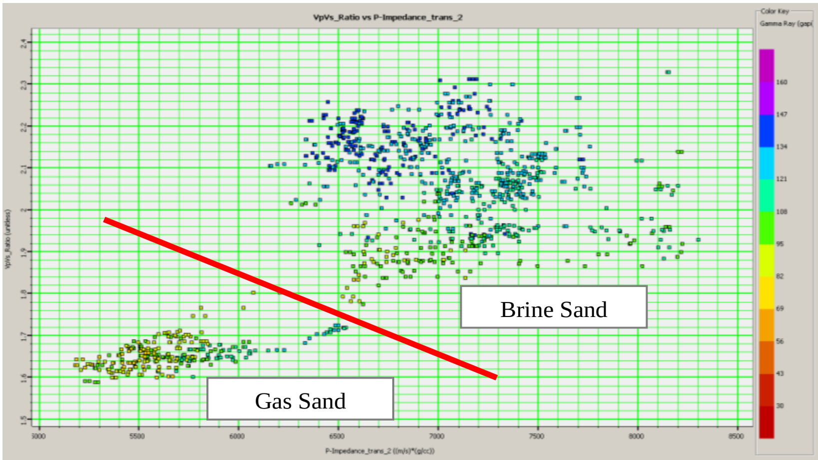

Figure 2.1 Cross plot of Vp/Vs ratio against P-impedance

For a pre-stack data, it is highly expected that the high frequency energy of the seismic data would experience a continuous loss as it moves from the near to the far offset. Thus, each trace of the CDP gather would have a different wavelet representation. However, it is believed that extracting a wavelet for every 15 degrees of incident angle is adequate to be used for the inversion process, instead of extracting for each offset, which is not practical yet time consuming.

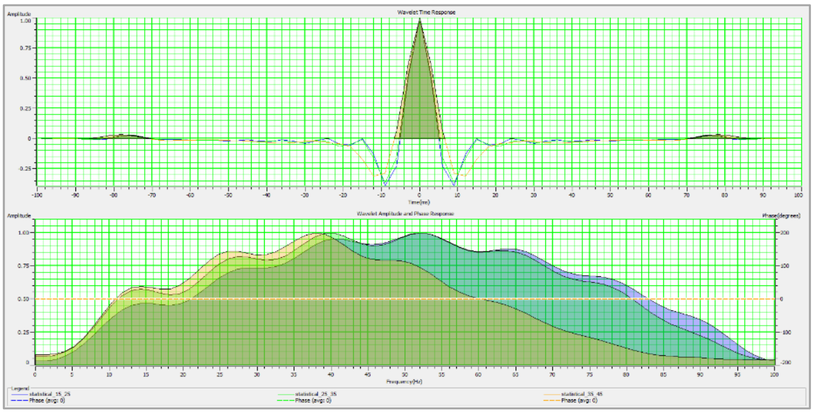

Figure 2.2 Extraction of Statistical wavelet

Synthetic traces are the ultimate key in the well-tie process, where well data are linked to the seismic data. In the process of creating synthetic traces, a bandpass filter is applied to the well log curves, in order to obtain the same frequency range as the seismic data. A filter with a low pass of 0Hz and a high pass of 50 Hz applied to the log curves, permits us to observe how well the inversion has worked within the seismic band, since the end result of inversion are expected to be in that particular range of frequency.

When both wavelet and the low frequency model have been obtained, the convolution process is carried out and applied to the volume. As a result, three volumes is generated namely, inverted P-impedance (Zp), inverted S-impedance (Zs) and density.

The inversion workflow continues by transforming the output volumes into Lambda-rho, Mu-rho and Vp/Vs volumes. The Lambda-mu-rho approach was proposed by Goodway et al. in 1997, where he introduced the Lame parameters (λ and μ) and density ρ as the core parameters of the Simultaneous Inversion new approach.

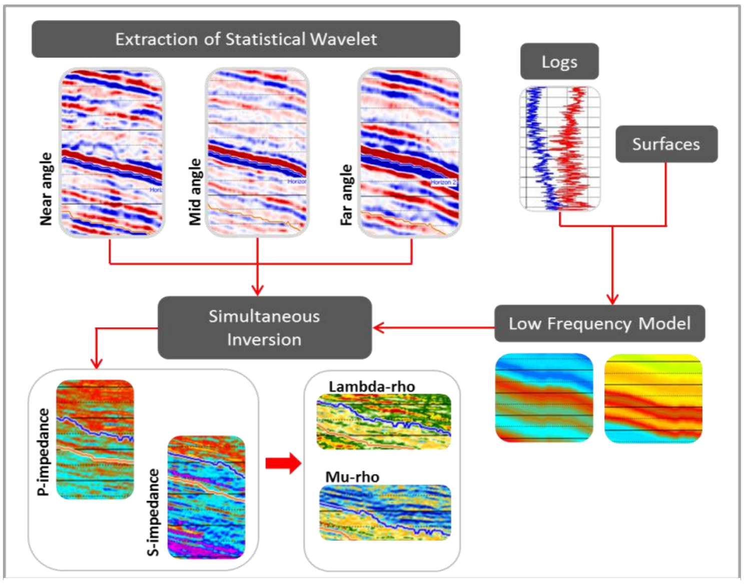

Figure 2.3 The Simultaneous Inversion Workflow. (Edited from Jason, CGG).

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3. Result and Discussion

Pre Inversion Analysis acts as a platform for geophysicists to test a variety of inversion parameters on a selected well before applying to the seismic volume. It permits us to measure the success of the inversion, as well as to analyse different possible outcomes resulting from different parameters

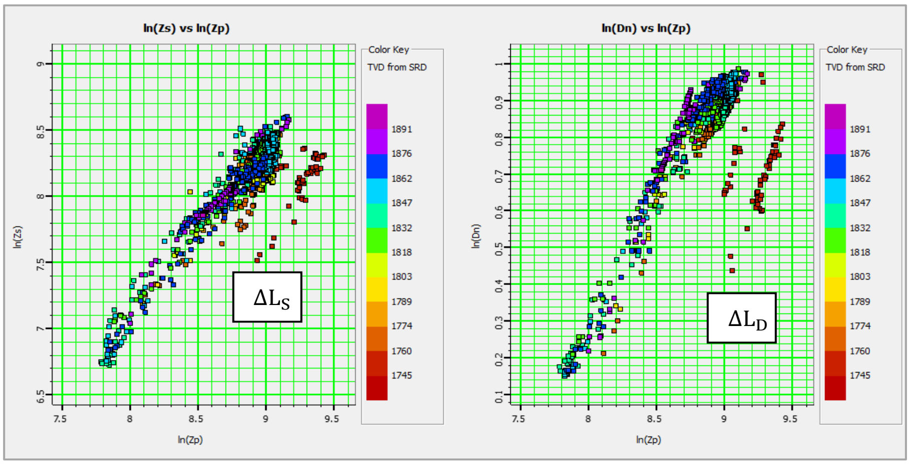
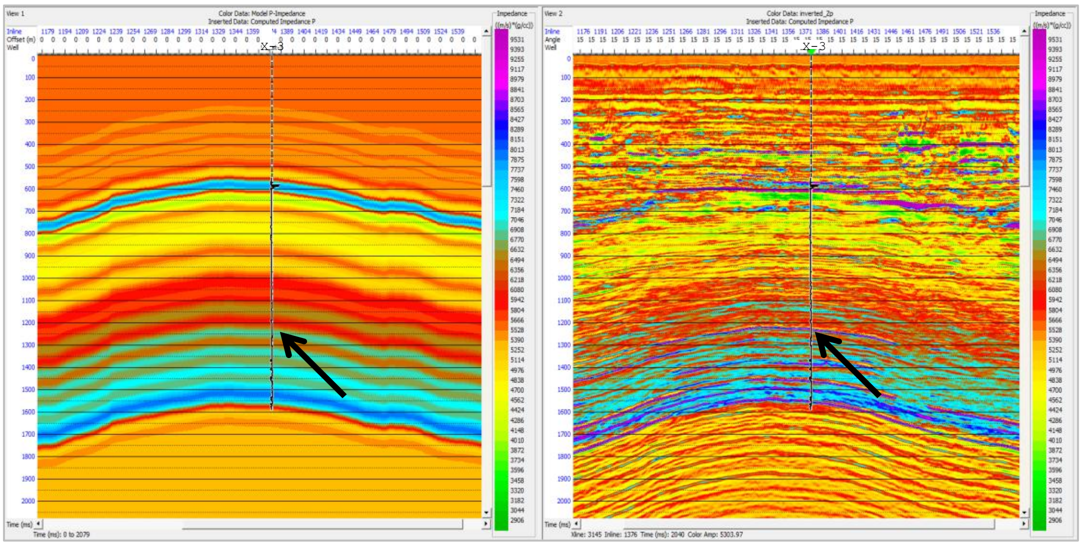


Figure 3.1 Cross plot Inversion analysis at wells.

Both cross plot of $\ln Z_S$ vs $\ln Z_P$, and $\ln \rho$ vs $\ln Z_P$, could be consider as having a directly proportional trend which suggests that the inversion workflow is accurate and no shifting will be needed.

Apart from the direction of the trend, the plotted points do give other insights too. In Figure 3.1, we could observe that each case has two trend lines being plot. The line with the most plotted data would represent the best fit line, while the deviation of data away from this straight line, are believed to be fluid anomalies, ΔL_S and ΔL_D.



Low Frequency P-impedance model Inverted Zp model

Figure 3.2 Comparison between the P-impedance and the Inverted Zp model at X-3.

Once the inversion is applied to the volume, we could evaluate that the inversion results have a better image with clearer and more accurate impedance model. The arrows in Figure 4.24 showing the clear separation of top gas sand (higher impedance - purple) in the inverted Zp model compared to the P-impedance model.

Lambda-rho and mu-rho are indeed powerful attributes in characterizing a reservoir. Lambda-rho which is sensitive to the pore fluids, shows a smaller thickness in Figure 3.3 compared to the Mu-rho in Figure 3.4 . Since mu-rho is only sensitive to the rock matrix, thus its responses characterize the rigidity of the gas sand layer, rather than the pore fluid content. Meanwhile the Lambda-rho gives the distribution in pore fluid within the gas sand layer. By integrating the information, we would be able to predict the actual condition of the gas sand layer, directly reduces the risk of drilling a dry well **.**

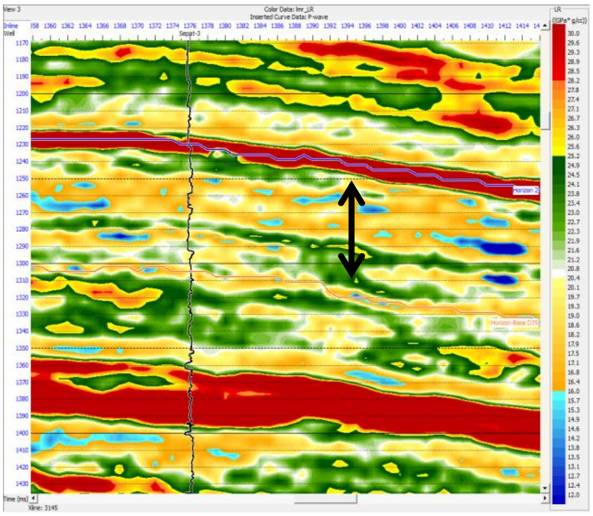


Figure 3.3 Lambda-Rho Volume at X-3.

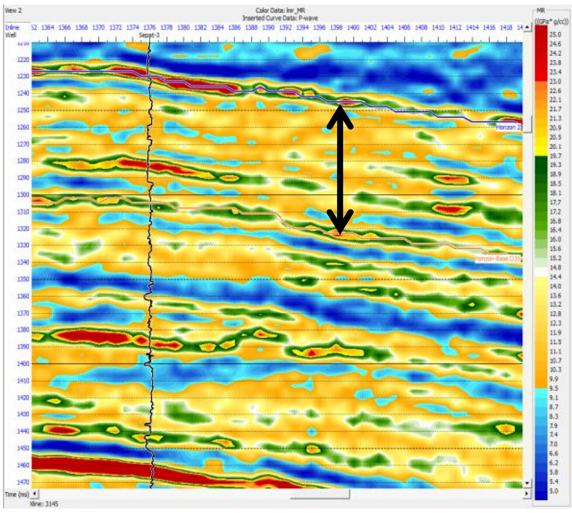


Figure 3.4 Mu-Rho Volume at X-3.

4. Conclusions

We have demonstrated that the Simultaneous Seismic Inversion is indeed a powerful tool in predicting the lithology and fluid distribution in the "X" field gas sand layer. The resolution achieved through this inversion allows us to characterize a reservoir better, especially by applying the Lambda-mu-rho analysis onto the inversion volumes.

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