Submission code: 6DVAWK7VQ0

See this and other abstracts on our website: https://home.sbgf.org.br/Pages/resumos.php

Come to Gather: Using AVO Modeling to Understand Seismic Response in Offshore Gas Turbidite Reservoirs

Andrea Damasceno (Petrobras), Matheus Sobreira (Petrobras), Felipe Melo (Geosoftware), Anna Lucia Oliveira (Petrobras)

Come to Gather: Using AVO Modeling to Understand Seismic Response in Offshore Gas Turbidite Reservoirs

Abstract

To investigate the discrepancies between modeled data from a drilled pioneer well and available seismic data, seismic gather modeling and AVO analyses were performed. The methodologies included evaluating seismic responses with variations in frequency content with offset/angle, after fluid replacement modeling, and the presence of intercalations. The modeled data was compared to the real gathers at the well location. Results indicated that the frequency content variation significantly affects the AVO signatures, particularly for intercalated reservoirs. The comparison of modeled gathers under different saturation conditions revealed that the In-situ and gas models closely resemble the real data, validating the modeling inputs. Notably, the presence of intercalations altered the AVO response at the reservoir's top and bottom, influencing the amplitudes at larger angles/offsets.

Introduction

We have identified two gas-saturated reservoir levels in this area of study. These turbidite reservoirs exhibit a total Netpay of 150 meters and an average porosity of 20%. The discovery was primarily based on amplitude variation with offset (AVO) analyses conducted on the available partial stacks.

Comparisons between the modeled data from the pioneer well and the existing seismic data raised questions regarding the discrepancies in the signatures at the top of the reservoirs. Consequently, it became essential to analyze the pre-stack gathers to understand these discrepancies. In this work, we analyze pre-stacks gathers to gain insight into how factors such as frequency content variation between the stacks, fluid presence, and intercalations within the reservoir influenced the seismic amplitudes.

Method

To conduct the analyses, we generated several synthetic seismic gathers and performed AVO analyses, examining the following scenarios:

- Variation in frequency content with offset/angle using angle dependent wavelets.
- Fluid changes in the reservoirs assuming scenarios with 100% brine and 100% gas.
- Presence of intercalations in the reservoir.

The synthetic gathers were computed using the Zoeppritz equations (Dahl and Ursin, 1991) and fluid replacement modeling was used to test fluid hypothesis in the reservoir (Greenberg and Castagna, 1992). The modeled data were compared to real gathers at the well location to validate the models and assess how these factors influenced the AVO signatures. The inputs for the synthetic modeling included elastic well logs and four wavelets estimated from the partial stacks, to ensure enhanced compatibility between modeled and real data. The amplitude analysis was performed inspecting the AVO curve behavior and the intercept and gradient crossplots (Castagna and Swan, 1997) at the top of the reservoir. In this work, we are looking at a Class 2 AVO example, which similar acoustic impedance with the overburden rock (background), but considerable Poisson’s ratio contrast with it.

For the fluid replacement modeling, we used petrophysical logs such as water saturation (Sw), total and effective porosity, and volume of shale (Vsh). In addition, reservoir information such as pressure, rock and fluid data for each reservoir. The Biot-Gassmann equations were employed to replace fluids in intervals with effective porosity greater than 5% and Vsh less than 1%.

Results

The synthetic gathers modeling conducted to evaluate the impact of varying frequency content of the traces with incidence angle on the AVO curves is illustrated in Figure 1. The gathers displayed include: (a) modeling using four wavelets applied to the partial stacks angle ranges, (b) modeling using only the Near stack wavelet, and (c) modeling using the Far stack wavelet. Notable differences can be seen among the gathers. The Near stack wavelet (with higher frequency content) reveals intercalations within the reservoir (highlighted by the red arrow), whereas the Far stack wavelet fails to detect these intercalations. A significant observation post-drilling was that the main anomaly in the Far's data centers in the middle of the reservoir, not at the top, as expected. The Far anomaly is distorted due to reduced seismic frequency content.

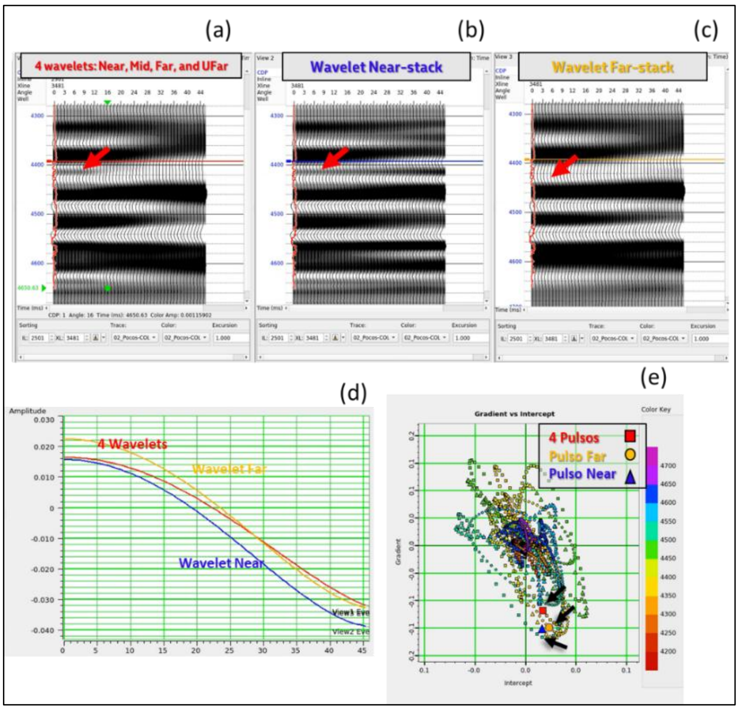

Figure 1: Synthetic gathers and AVO analysis. At the top are shown the synthetic seismic gathers using: (a) four different wavelets per angle range, (b) only the Near wavelet and (c) only the Far wavelet. Below, we show (d) the AVO curve analysis and (e) the crossplot of intercept and gradient curves for the top of the reservoir. The colors in (d) and (e) refer to the same events.

Figure 1 (d) shows a comparison of the AVO curves from all models (a), (b), and (c) at the top of the reservoir. The values of intercept and gradient were derived from fitting the three-term Aki-Richards AVO equation. The AVO curves are parallel but vertically displaced from each other: the gradients of the models using only the Near and Far pulses are similar, while their intercepts differ. The AVO curve that utilizes angle dependent wavelets reflects a combination of the others, showing a gradient modified by frequency content variation across the traces. The graph in (e) is a crossplot of gradient versus intercept for the modeled data, also showing the effect of frequency content variation on the gradient.

We also conducted a comparison (Figure 2) between the real (a) and modeled gathers under three saturation conditions: (b) In-situ, (c) 100% brine, and (d) 100% gas. The original average saturation of the reservoir is 75% gas and 25% water. The synthetic seismic gathers were computed with the same four angle dependent wavelets from the previous test. In the right-hand side of Figure 2, Vsh is superimposed on the lithology well log, with the top and base of the reservoir marked by pink and yellow lines, respectively.

The In-situ modeling gather closely resembles the real gather, validating the modeling inputs. Modeling with 100% Gas also aligns well with the in-situ modeling and the real data, reflecting the high gas saturation characteristic of the reservoir. Figure 2 (e) shows the AVO curves for the models in (b), (c), and (d) and Figure 2 (f) shows the gradient versus intercept crossplot for the reflection at the top of the reservoir (pink horizon). For the water-saturated reservoir, we observe a background response with no AVO anomaly, while the gas-saturated sand (both in-situ and 100% gas) exhibits a class II AVO response with a strong orthogonal deviation from the background line.

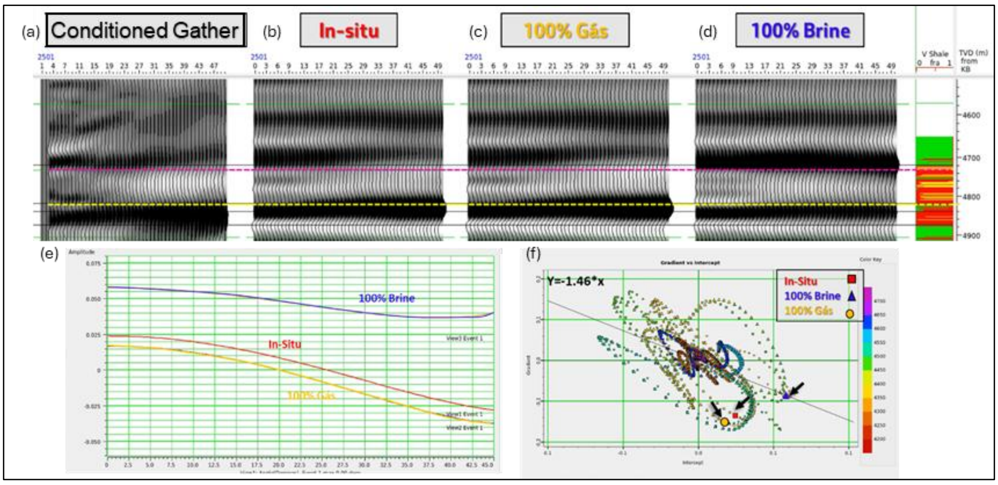

Figure 2: Real gather, synthetic gathers and AVO analysis. At the top is a comparison between the real gather (a) and three synthetic seismic gathers with different reservoir saturation scenarios: (b) In-situ (original saturation), (c) 100% gas and (d) 100% water. (e) AVO analysis and (f) crossplot of the gradient vs. intercept curves for the top of the reservoir for each modeled scenario.

The final modeling conducted, illustrated in Figure 3, analyzed the effect of intercalations of shale layers inside the reservoir. We created a blocked model of the reservoir and the background, referencing the average elastic properties of both layers at the real well logs, Figure 3(a). Notably, this simplistic modeling yielded a gather similar to the real one, shown in Figure 2 (a). Figure 3(b) shows a synthetic seismic generated from a model without intercalations and Figure 3(c) shows the synthetic gather generated from the model with intercalations whose elastic well logs are shown in in Figure 3 (a). Like what is seen in real data, intercalations are visible in the Near angles but not in the Far angles. However, intercalations impact the AVO curve at larger angles, as indicated by the dotted purple horizon. The AVO curves displayed in Figure 3(d) also reflect this amplitude difference in the amplitudes of the Far angles due to the presence of the intercalations.

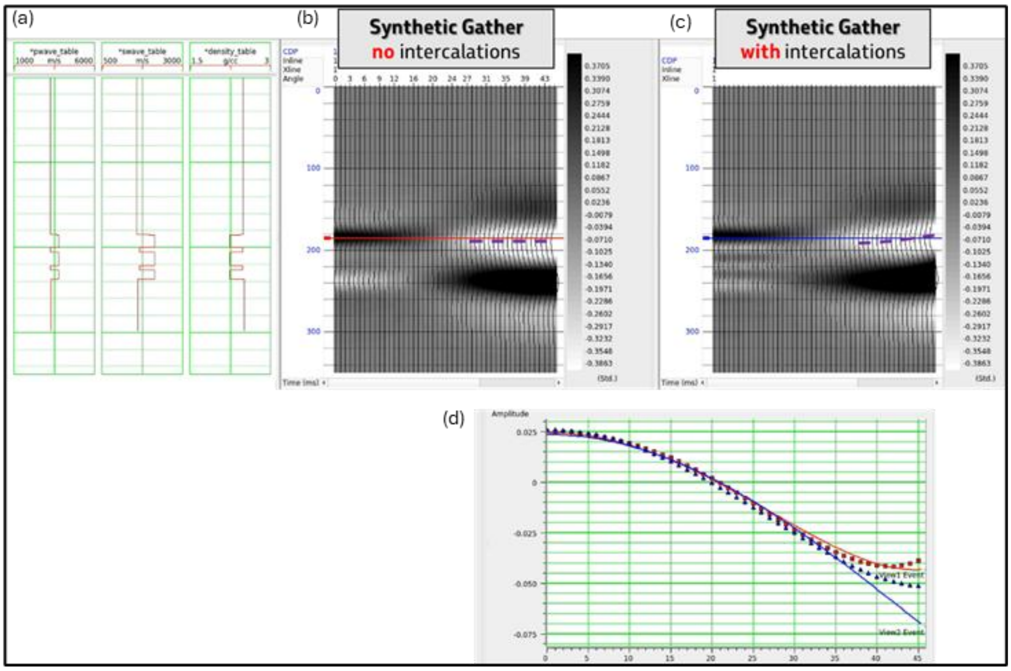

Figure 3: Blocked model. (a) Vp, Vs and density synthetic logs used in seismic modeling considering the intercalations within the reservoir. Synthetic gathers computed from the elastic properties model without (b) and with (c) intercalations. In (d) the AVO curves at the top of the reservoir for each model are shown.

Conclusions

The variation in frequency content between traces significantly influences the AVO signature, particularly in scenarios involving intercalated reservoirs. It is advisable to apply resolution enhancement techniques to the gathers to ensure frequency compatibility of the input data for AVO analysis. The upper reservoir demonstrates strong fluid sensitivity (class II AVO), presenting minimal risk of pitfalls in the AVO when analyzed at the top of the reservoir. The presence of intercalations modifies the AVO response at both the top and bottom of the reservoir, thereby affecting the amplitudes of traces at larger angle/offset and distorting the AVO response of these seismic reflectors. This type of study provides a deeper understanding of the AVO responses of these reservoirs, which will guide the analysis of the seismic response for the next locations to be drilled in this area.

Acknowledgments

We thank Petrobras for authorizing the publication of this work.

References

Castagna, J. P., and Swan, H. W., 1997, Principles of AVO crossplotting: The leading edge, 16(4), 337-344.

Dahl, T., and Ursin, B., 1991, Parameter estimation in a one-dimensional anelastic medium: Journal of Geophysical Research: Solid Earth, 96(B12), 20217-20233.

Greenberg, M. L., and Castagna, J. P., 1992, Shear-wave velocity estimation in porous rocks: theoretical formulation, preliminary verification and applications: Geophysical prospecting, 40(2), 195-209.