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Fluid Substitution in Turbiditic Reservoirs

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Abstract Summary

This study aims to perform fluid substitution in selected wells to analyze and understand the changes in the elastic moduli of rocks resulting from the replacement of pore fluids, enabling a more accurate evaluation of the reservoirs. This substitution will be carried out using functions such as those of Gassmann and Mavko, followed by statistical analyses to highlight the differences in the wells before and after the substitution.

Introduction

Albacora Field, located in the Campos Basin, RJ, was an area discovered in 1984 and recognized for its excellent geological characteristics. The Campos Basin, which extends over approximately 100,000 km² between the northern coast of Rio de Janeiro and the southern coast of Espírito Santo, is one of the most important regions for oil exploration in Brazil. It features a crystalline basement composed of Precambrian gneisses and reservoirs made up of highly productive sedimentary formations.

The reservoirs in the Albacora Field, consisting of turbiditic sandstones from the Carapebus Formation, exhibit high porosity (28%–32%) and permeability (500–8,000 mD), along with both primary and secondary recovery mechanisms such as water injection. These attributes make the area strategically significant for petroleum exploration.

The project's focus is based on Amplitude Versus Offset (AVO) analysis, beginning with fluid substitution, an essential step for evaluating the impact on the physical properties of rocks. The main objective of this study is to present the fluid substitution process in turbiditic reservoirs and the methodologies used to perform it.

Method and/or Theory

Fluid substitution will be performed in the selected reservoirs using Gassmann's equation for wells that contain shear wave velocity (Vs) data. Gassmann's equation is fundamental for modeling the variation in the effective bulk modulus of a porous rock when there is a change in the saturating fluid.

$$K^* = K_d + \frac{\left(1 - \frac{K_d}{K_s}\right)^2}{\frac{\phi}{K_f} + \frac{1-\phi}{K_s} - \frac{K_d}{K_s^2}}$$

Figure 1: General Formula of Gassmann's Equation

The bulk modulus (also known as the volumetric compressibility modulus or incompressibility modulus) is an elastic property of materials that measures their resistance to uniform compression. It is defined as the ratio between the change in pressure applied to a material and the resulting change in volume. The higher the bulk modulus, the more difficult it is to compress the material. Liquids and solids have much higher bulk modulus values, meaning their volume changes very little under pressure. In contrast, highly compressible materials such as gases have low bulk modulus values (K).

For wells without Vs values, the Mavko function is used to perform the calculation based on Vp values. This function takes into account the simultaneous presence of multiple fluids and how they are distributed within the pore space, using adjustable parameters that reflect the saturation geometry and the mechanical behavior of the system. The general form of the function is given by:

$$K_{\text{sat}}(S_w) = K_{\text{dry}} + \frac{(1-f)(K_{\text{sat, gas}} - K_{\text{dry}}) + f(K_{\text{sat, water}} - K_{\text{dry}})}{1 + \alpha(1 - S_w)}$$

Figure 2: General Formula for Mavko's Function

The first step will be fluid substitution in the Oil Sand reservoirs. Next, a Vs adjustment will be performed as a function of Vp, using wells that contain Vs data. In this stage, coefficients will be calculated for each reservoir rock, and subsequently, Vs will be estimated.

Results

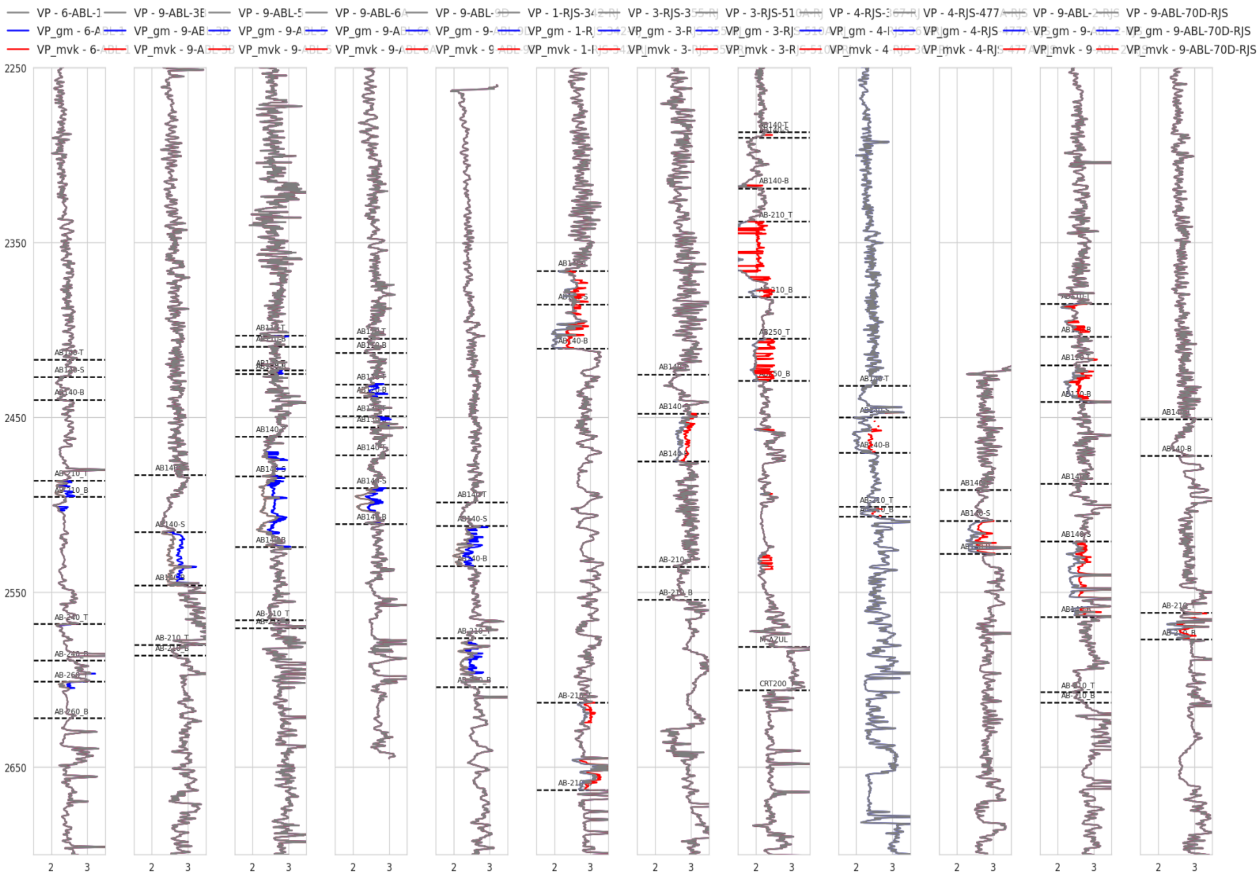

Figure 3: Plot of the wells after fluid substitution, where it is possible to observe the difference in the Vp curve before and after the substitution.

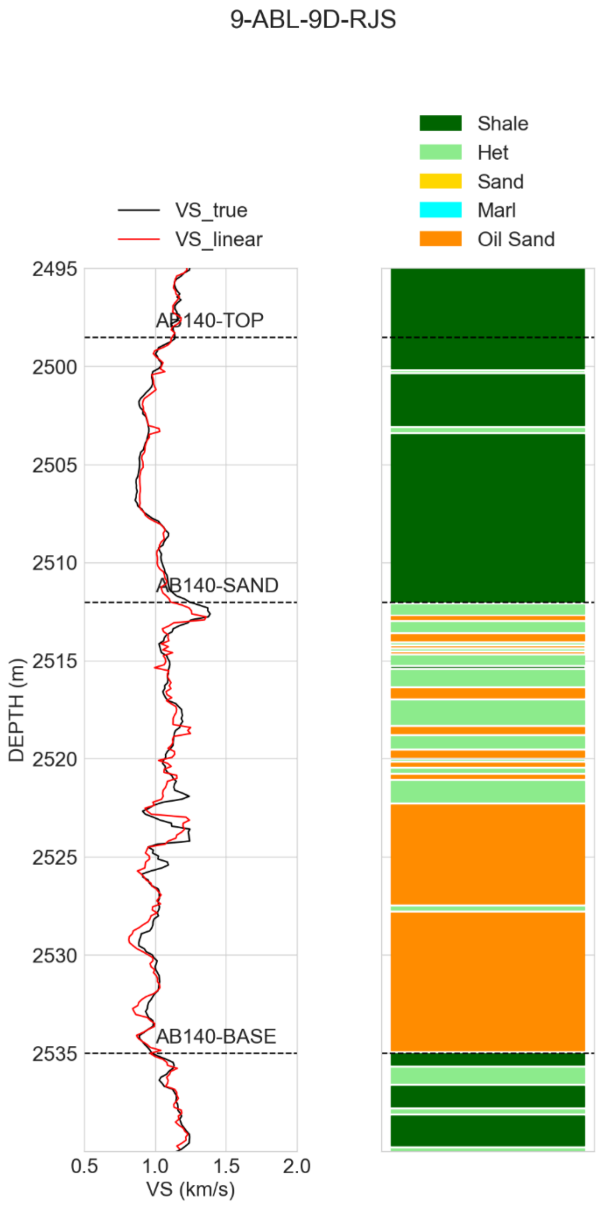

Figure 4: Example of a well using Vs estimation. This estimation is performed by calculating coefficients for each rock type within the reservoirs.

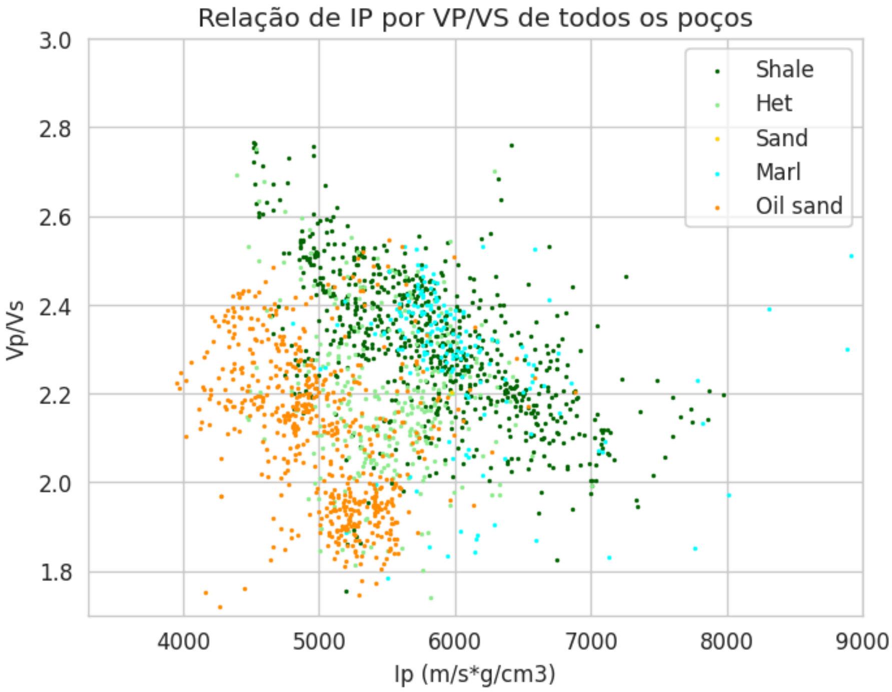

Figure 5: Crossplot using all wells after fluid substitution and Vs estimation.

Conclusions

The applied methods were effective and enabled a better understanding of the study area. A significant presence of heteroliths is evident across all reservoirs. Heteroliths present a challenge in the Albacora Field, as they complicate data interpretation and analysis due to their variable sediment composition and grain size distribution. In the analyzed reservoirs, it is difficult to distinguish heteroliths from other rock types using elastic parameters. This is due to several factors, including the high variability in heterolith composition and porosity, the overlap of elastic parameters, and the influence of porosity on wave propagation. It is also evident that there is not a significant discrepancy between the original and synthetic curves (from substitution and estimation), which results in values that are close to the original ones.

This project is still in development and represents the first stage of the AVO analysis, which is essential for the continuation of the work. It is worth noting that one of the examples used for statistical analysis was the Acoustic Impedance crossplot by Vp/Vs; however, other analyses are also being conducted, such as histograms, residual analysis, and various types of correlations.

Acknowledgments

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