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Variation of the property model for 4D reservoir monitoring simulation

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Introduction

Simulating the effects of hydrocarbon production on the elastic properties of rocks is essential for reservoir characterization, enabling the monitoring of fluid saturation, migration flow, and pressure variations. In carbonate reservoirs, heterogeneity and low pore connectivity lead to non-linear responses to these changes, posing challenges to the application of Gassmann's equation. This study allows the identification of variations in P- and S-wave velocities and bulk density within Brazilian Pre-salt carbonate reservoirs. These results make it possible to monitor different production scenarios, including increases in gas and water saturation, as well as both increases and decreases in reservoir pressure, contributing to production optimization.

Method and/or Theory

The study began with the mapping of seismic horizons—specifically the base of the salt and the reservoir—defining the area of interest for analyzing pressure and fluid changes. A 20-meter grid enabled seismic amplitude correlation and structural interpretation. Geophysical logs (Caliper, Gamma Ray, and Resistivity) were interpreted to characterize lithologies and fluids, followed by quality control using composite logs and well data. Predominantly calcitic and dolomitic lithologies were then analyzed to define petrophysical and mechanical properties. Using Voigt-Reuss-Hill averages, we calculated the matrix moduli and density. Fluid properties were incorporated to estimate saturated and dry rock properties via Gassmann's equation. Finally, pressure variations were simulated to determine updated elastic parameters in a monitoring scenario.

Results/Conclusions

This section evaluates the impact of pore pressure and fluid saturation changes on the elastic properties of carbonate rocks by simulating different stages of hydrocarbon production. The Base scenario represents initial conditions with high oil saturation, while the Monitor scenario reflects advanced production, marked by increased gas saturation and reduced pore pressure. These changes result in elastic variations—manifesting as velocity increases (hardening) and decreases (softening)—notably at the base and top of the reservoir. Gassmann's equation proved effective in capturing these effects, with variations in P- and S-wave velocities and density revealing the heterogeneous behavior of Pre-salt carbonate systems. The study highlights scenario simulation as a strategic tool for reservoir monitoring and decision-making, especially in 4D seismic applications. It also emphasizes the need for methodological refinement through updated petrophysical data and improved property propagation between wells to build robust two-dimensional models.