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Impacts of quantitative seismic interpretation on the geological modeling of porosity and permeability in silica-rich carbonate reservoirs

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Introduction

Lacustrine carbonates, especially the ones which comprise the pre-salt reservoirs, experience extreme diagenetic processes. These events significantly alter porosity and permeability, therefore acting optimization of the production. The acquisition of Ocean Bottom Nodes (OBN) and least-squares reserve-time migration (LSRTM) led to a paradigm shift in the Buzios field, mainly related to the confidence in the amplitude in the pre-salt deposits which caused stability in the compressional-to-shear velocity ratio estimated by the seismic inversion. Rock physics demonstrates that the increase in silicification intensity decreases the Vp/Vs, stating that this elastic property is a proxy for the identification of the silica-rich facies. The reason for this behavior has a geological explanation: the contact of calcite-dominated host rocks percolated by highly silica-rich hypogenic fluid engenders a diagenetic process whereby occurs the replacement of the calcite mineral by silica mineral. As silica presents relatively low Vp/Vs in comparison to the carbonate reservoirs, this activity reduces the Vp/Vs with respect to the background media. Therefore, we make use of the seismic-derived Vp/Vs volume for the recognition of silicification in subsurface. The procedure follows the geophysical and geological concepts which stipulate that low Vp/Vs geobodies close to hydrothermal fluid conduits, particularly faults and fractured intervals, are strong prospects for presence of silica in this lacustric carbonate. These geobodies provide, in the geological model, the distribution and geometry of the karstified bodies and, consequently, the porosity and permeability thereof.

Method

The methodology can be simplified by the following steps: i) perform the rock physics diagnosis to understand the elastic property behavior of silicification in carbonate rocks; ii) the sparse-spike seismic inversion of angle-stacked volumes allows for the three dimensional estimation of elastic property volumes; iii) track low Vp/Vs geobodies close to conduits of silica-rich hypogenic fluid, where are the most plausible locations of silicified host rocks; iv) select these geobodies tying them to well information and conceptual knowledge; v) combine them with high-resolution stratigraphy to delineate the geometry of karst; v) guide porosity and permeability distribution in the karstified rocks .

Results and Conclusions

In this work, we delve into a novel methodology and fundamental concepts behind the seismic identification of silicified rocks and its impact on geological modeling of porosity and permeability in pre-salt carbonates. The results of acquisition and processing data of OBN deliver confident amplitudes which enable us to extract more information from the quantitative seismic interpretation and expand its application to geological modeling. Stable Vp/Vs volumes proved to be the proxy for the interpretation of silicification in pre-salt reservoirs. Geobodies of low Vp/Vs provide the geometry of silicified bodies, therefore, tracking the karstification in carbonate rocks. The procedure directly impacts the estimation of porosity and permeability in the modeling stage. The insights of this research contribute to refining reservoir management strategies and enhancing production optimization initiatives in similar geological settings.