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Structural and Porosity Characterization Based on Borehole Image Logs and NMR in the Iracema Area, Santos Basin, Brazil

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Introduction

With the announcement of the pre-salt discovery, the Santos Basin became essential to national petroleum exploration after exponentially increasing its hydrocarbon potential by incorporating estimated reserves hosted in Aptian-age carbonate reservoirs. These carbonate rocks exhibit a complex pore system, resulting in high heterogeneity in permeability patterns, making reservoir modeling a major challenge. Additionally, recent studies highlight the presence of fractures and their role in fluid percolation during diagenetic processes, as well as their contribution to forming reservoirs with excessive permeability. Borehole image log (BHI) is an extremely useful tool for structural and geomechanical analysis and it contributes to the analysis of fluid properties and their behavior concerning porosity, permeability, and reservoir fracturing. In this context, this research aims to characterize structures such as fractures and vugs and identify fracturing episodes affecting the reservoir in the Barra Velha Formation within the Iracema area, in the northwestern portion of the Tupi field. Furthermore, combined with nuclear magnetic resonance (NMR) data, this study seeks to identify the influence of these structures on porosity control.

Method and/or Theory

The methods include structural and porosity analyses in a well located in the Iracema area. Structural features were described using acoustic borehole image logs and classified as natural or induced. Four natural structures were identified: bedding planes, low-amplitude fractures (unfilled), mixed fractures (partially filled), and high-amplitude fractures (fully filled), based on waveform responses. Induced features, limited to borehole breakouts in this study, refer to structures generated during drilling process. The well was zoned by bedding orientation. The P10 method was used to calculate fractures per meter. A stress analysis was also performed through breakout interpretation. Finally, porosity was assessed by comparing total porosity from NMR with vug volume estimated from BHI, aiming to characterize the relationship between matrix and nonmatrix porosity.

Results and Conclusions

The well was divided into four zones. Shifts in bedding attitude between zones may result from tilting events, creating local intraformational unconformities. Mixed and high-amplitude fractures revealed two main families: NW-SE (aligned with regional lineaments) and NE-SW (consistent with the current stress field, as analyzed through borehole breakouts). In contrast, low-amplitude fractures showed a single dominant set, also NE-SW oriented. These low-amplitude fractures occur across all zones and were interpreted as late-stage tectonic features. The well shows a complex and heterogeneous porosity distribution, with some zones dominated by nonmatrix porosity and others by matrix porosity. The highest vug volumes are linked to depths with high low-amplitude fracture density, coinciding with breccias and travertine/tufa lithotypes. While tectonic structures play a key role in enhancing nonmatrix porosity, high-porosity zones were also found in areas with low fracture density or lacking typical carbonate porosity-enhancing features such as karst. Thus, porosity estimation requires integrating multiple parameters. Understanding the region's fracturing episodes and their relationship with porosity contributes to discussions on fluid migration and carbonate reservoir formation in the basin. The results offer insights valuable for both hydrocarbon prospecting and reservoir exploitation.