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Optimising Mature heavy-oil Field Development: A Multiscale Flow Unit and Reservoir Quality Approach in the onshore Potiguar Basin, Brazil

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Introduction

This study integrates geological/geophysical, petrographic/diagenetic, and petrophysical data to individualise rocks with different flow capacities in the Alto do Rodrigues (ARG) Field, a producing heavy-oil field in the onshore Potiguar Basin, NE, Brazil. Petrophysical rock typing is critical in managing hydrocarbon oil fields, especially in mature fields where additional recovery depends on suitable technologies and reservoir management strategies. This work aims to characterise and classify reservoir rocks into distinct flow units, upscale this characterisation from well to reservoir scale, develop and validate a quantitative Reservoir Quality Index (RQI) correlated with actual field production data, and quantify the impact of steam injection on well productivity using the developed RQI.

Method and/or Theory

The study used information from over 800 vertical wells, 19 with rock data, and petrophysical analysis, with seven wells providing most of the data due to the greater thickness of recovered cores. A multiscale approach was implemented, starting with micro-scale thin section analysis to identify clay minerals that can obstruct pore throats. The study of cores in different field portions characterised the depositional systems and quantified factors influencing oil entry into the reservoir. Based on determining the effective pore throat radius from capillary pressure curves, we used Winland's and Pittman's classical methodologies to better understand the petrophysical features controlling productivity. A Reservoir Quality Index (RQI) was developed to quantify the production capacity of the rocks. The rock-profile correlation was used to build geological models for the oil-bearing sedimentary formations.

Results and Conclusions

The multiscale analysis allowed the characterisation and classification of the ARG Field fluvial reservoirs into four distinct flow units (Mega pore, Macro pore, Meso pore, and Micro pore) based on the rocks' pore throat sizes. These flow units are primarily related to the textural characteristics of the rocks and, to a lesser extent, to diagenetic effects. Oil in the ARG field was found to preferentially enter reservoirs with pore throat radii above 3 µm, resulting in static cut-off values of $\phi \geq 12\%$ and $K \geq 30$ mD. The developed Reservoir Quality Index (RQI) showed a direct relationship with well productivity under cold production ($R^2=0.9578$) and after steam injection ($R^2=0.8103$). After the first steam injection cycle, the minimum accumulated production was almost three times the cold production values. The RQI map allowed for the identification and evaluation of the best field areas for well densification and continuous steam injection projects. The results can be applied to various reservoir management activities, including ranking wells for steam injection, providing quantitative constraints for new drilling projects, and understanding flow barriers and steam pathways.