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The importance of borehole image logs in evaluating carbonates in the subsurface: insights from the Brazil Pre-Salt

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Borehole image (BHI) logs are an essential dataset for characterizing carbonate reservoirs in the subsurface. BHI logs measure petrophysical rock properties to generate a high resolution image of the borehole wall. In the absence of core, BHI logs provide a way to interpret the presence of structural, diagenetic, and sedimentary features. As with any other remote sensing technique, there is an inherent uncertainty on the interpretation of some features. However, where core and BHI logs overlap, there is an opportunity to calibrate our interpretations. Calibrated BHI logs can be integrated with dynamic data (e.g., well tests and drilling losses) to gain insights into the permeability structure of a carbonate reservoir.

In the pre-salt Cretaceous reservoirs of the Santos and Campos Basins, offshore Brazil, image logs are consistently acquired on all wells as part of the routine data collection program. In this work, we validated BHI interpretations against core and compared and contrasted with wireline logs to identify reproducible log signatures. These calibrations were performed for facies, structural, and dissolution features.

Using core as a ground truth and guided by wireline log responses (PEF, GR, PHIT), we have developed a BHI log facies scheme to assign rock types and reservoir quality in intervals where there is no available core control. This facies scheme also allows us to define stratigraphic stacking patterns that are inputs for regional correlations as well as building reservoir models. Using image logs, we identify the various core-calibrated facies types through stratigraphic sections penetrated by the borehole, predicting rock types and expected reservoir quality in wells where collection of core is not possible. Facies interpretations are complemented with a BHI log non-matrix interpretation, which includes picking sinusoidal features that correspond to natural fractures, and identifying open dissolution features including touching vugs, voids and caves. This interpretation also relies on a detailed calibration with core data so that artifacts and stress related features can be appropriately filtered out.

The power of image logs comes from integrating the static interpretations with dynamic data, where available, so we can develop predictive concepts and define sound reservoir property ranges. Losses while drilling are indicative of open features with associated excess permeability, and are mostly attributed to natural fractures and meter-scale caves. Well tests in combination with production logs provide the means to reallocate permeability to the different interpreted features. Our observations suggest that the presence of excess permeability from structural and dissolutional features can have several orders of magnitude greater permeability than the background matrix. The result is a highly heterogeneous reservoir architecture where fractures, caves and touching vugs, when present, dominate flow and overall well performance. The robust dataset gleaned from BHI logs allows for an encompassing characterization of the subsurface that aids in identifying reservoir properties, constructing local and regional stratigraphic frameworks, calculating in-place volumes, extrapolating connectivity and dynamic performance, and informing wellbore failure and design.