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Seismic facies predictions by unsupervised machine learning method: a study in the Upper Cretaceous of the Ceara Basin

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Introduction

Through machine learning techniques, seismic interpretation processes have been reduced and enhanced, allowing for the visualization of complex and subtle geological features. This occurs because the algorithms of machine learning techniques operate on data autonomously and in a logically distinct manner compared to methods normally used by interpreters, enabling the highlighting of patterns and internal relationships that are not always visible to the human eye. In this regard, the unsupervised machine learning method is a useful approach for areas that are still little-studied, underexplored, or have sparse data. In this context, the present work proposes to analyze the Cenomanian to Turonian deep-water environment of the Ceará Basin, Brazilian Equatorial Margin (BEM), with the objective of performing seismic facies prediction to characterize possible reservoirs present in the region, their geological controls, and to validate efficient workflows for seismic interpretation in complex regions, including the voluminous presence of igneous rocks, intense faulting, and complex submarine channel evolution.

Method and/or Theory

For the development of the present study, four exploratory wells drilled in deep waters were selected, including lithostratigraphic and biostratigraphic data, and a depth-migrated seismic volume covering approximately 2.200 km², provided by TGS. From the well-to-seismic integration, the Cenomanian and Turonian horizons were identified and mapped throughout the area. Subsequently, the relationship between the seismic data amplitude and various seismic attributes was analyzed using the Principal Component Analysis (PCA) method to select the attributes with the highest correlation. The Sobel Filter, GLCM Entropy, RMS Amplitude, and frequency filtered at 25Hz and 35Hz were ultimately selected. For seismic facies prediction, the selected attributes were clustered using the Self-Organizing Maps (SOM) method, making it possible to individualize 64 neurons, which were grouped in this work into 5 groups, numerically labeled from 1 to 5.

Results and Conclusions

From the results obtained, it was possible to identify in the Cenomanian, sinuous and strongly confined channels, without the presence of fans, avulsions, or marginal levees, apparently developed in a transgressive systems tract. In addition, it was also possible to highlight N-S oriented faults, more expressive throughout the entire area, and NE-SW faults, limited to the center of the study area, with these being associated with the accommodation event of the drift and rift layers, respectively. In general, facies 03 are more expressive in the center of the channels and can be associated with conglomerate and sandstone lag deposits, while facies 01 are concentrated on the margins, with apparent lesser lateral continuity. The Turonian is characterized by the absence of expressive channels; however, N-S faults can be identified, and facies 01 and 02 are predominant in almost the entire study area. Recently drilled exploratory wells in deep waters indicate the presence of expressive sandy layers in the Turonian; based on the distribution of seismic facies, it is possible that the occurrence of contourites is associated with these sandy deposits. From the analyses carried out in this study, it was possible to cluster seismic facies with potential for good reservoirs, reducing uncertainties associated with exploration and proving the efficiency of combining multi-attributes and machine learning techniques for geologically complex deep-water areas.