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Machine Learning-Assisted Enhancing and Optimizing Seismic Interpretation: A Study in the Macabu Formation, Campos Basin

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Abstract

One of the main obstacles faced in traditional reservoir seismic characterization is the integration between well and seismic data, mainly due to the difference in scale between the two datasets. This discrepancy imposes difficulties correlating these two domains, introducing subjectivity and strong dependence on the interpreter's experience and judgment. This work, performed on the characterization of reservoirs in the Macabu Formation, sag phase of the Campos Basin pre-salt, presents a new methodology to overcome this challenge. The proposed workflow offers interpreters quantitative, automated, and data-driven insights that complement geological knowledge and interpreter experience. Machine learning techniques are especially effective in detecting complex and subtle patterns in large volumes of multidimensional data, something that can be difficult to identify solely by visual or traditional interpretative methods. This work demonstrates the application of data analysis and machine learning techniques focusing on the solutions and improvements that these methods may provide complementing traditional seismic interpretation. The workflow was structured in three main steps involving supervised and unsupervised machine learning techniques. In the first step, exploratory analysis and statistical normalization techniques were applied to well data to eliminate redundancies among geophysical logs, highlighting the most relevant information. The selected suite of logs served as input for a supervised classification of electrofacies, conducted with the Multilayer Perceptron (MLP) algorithm. The second step generated an unsupervised classification of seismic facies using the Self-Organizing Maps (SOM) algorithm, known for its ability to cluster high-dimensional data into comprehensible topologies. This step allowed for the automatic identification of different waveform groups, classifying seismic traces from the zone of interest into families with similar characteristics. In the final step, attributes derived from seismic data were extracted and normalized – including the results of the SOM classification, represented by the projections of the classification onto the two axes of the latent space. These attributes were used as input variables in a new classification with MLP, now supervised by the representative electrofacies from the selected wells. The result was a geological facies map coherent with the stratigraphy and the main depositional controls of the area, representing the lateral heterogeneity of the reservoirs in a quantitative and geologically consistent manner. The presented methodology demonstrates how machine learning approaches provide valuable complementary perspectives for reservoir characterization, enhancing traditional methods and improving the understanding of complex subsurface properties.