Evaluating SVD Domain Waveform Clustering: Insights from Deepwater Ceará Basin, Brazilian Equatorial Margin

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Abstract

The analysis of seismic facies plays a fundamental role in understanding the distribution of physical, structural, and fluid properties both in reservoir standpoint and from an exploratory perspective. Supervised or unsupervised, numerous machine learning algorithms are emerging as alternatives to perform pattern recognition to characterize a region of interest. The waveform clustering approach analyzes aspects such as amplitude, phase, and frequency of the signal to extract information from seismic data based on certain premises. In this work, a series of experiments were conducted to evaluate the performance of the Self-Organizing Maps (SOM) algorithm on seismic data in the SVD domain and to understand the advantages and disadvantages of clustering waveforms on a minimum-phase version of seismic signatures. Synthetic data, constructed from convolutional modeling and simulating the seismic response of a fluvial environment whose geometric properties are not explicitly imposed but incorporated into the model through their influence on the variation of migration rates, were used for this study. Additionally, the methodology was applied to 3D seismic data from the deepwater Ceará Basin, located on the Brazilian Equatorial Margin, to characterize the facies distribution of a turbiditic system with proximal confined channels and distal unconfined basin floor fan where the turbiditic lobes are located. The experiments on synthetic data indicate the robustness of the clustering performed on SVD domain, showing results similar to or even superior to the traditional approach, especially when the signal-to-noise ratio of the data worsens. In real data, in the absence of well data, the unsupervised algorithm proved efficient in segmenting seismic signatures extracted from a symmetric time window (± 20 ms) over a previously mapped horizon associated with the turbidite base. The interpretation of the label distribution obtained from training the model in the SVD domain allowed identifying regions with beds lateral thinning, intervals with intercalations between sands and shales, tilted beds in the depositional slope, and moderate to high amplitude anomalies in intervals associated with sandstones. The results were compared to the RMS amplitude map extracted from the same time window, and the enrichment of facies details generated by waveform clustering was notable, as the amplitude map presents sudden and non-geological changes in some regions.