DETECTING SEDIMENTARY CYCLES USING VARIATIONAL MODE DECOMPOSITION (VMD) - A CYCLOSTRATIGRAPHIC STUDY IN THE ALBIAN CARBONATE SUCCESSION OF MACAÉ GROUP, CAMPOS BASIN

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ABSTRACT: During the Albian age, large shallow carbonate platform sedimentation began to form along the eastern coast of Brazil. The cyclic depositional pattern is one of the main characteristics of carbonate platforms. The detection of cyclic patterns is a key element of quantitative stratigraphy and involves the investigation of a geological time-series. A detailed cyclostratigraphic characterization of these time series can be achieved by signal decomposition and the investigation of the frequency content by means of spectral analysis. In this study, we applied the Variational Mode Decomposition (VMD) method to access the detailed time-amplitude and -frequency characteristics of the well-log signal. A multiscale analysis of gamma-ray (GR) log was carried out by decomposing the original signal into three components to assess low-, mid-, and high-frequency patterns, allowing to investigate sedimentary cycles and perform cyclostratigraphic analysis in the Albian carbonate succession of the Macaé Group, in southern Campos Basin. Two hierarchical orders of cyclicity were recognized as high- (HFCs) and low-frequency cycles (LFCs). The HFCs were defined by interpreting the cyclicity log, obtained from the VMD-based method, which showed a good correlation with the GR log and clearly reflected the short-term cyclicity characteristics of the formation (meter-scale vertical resolution). The HFC stacking pattern shows an increasing trend of thickening in the Quissamã Formation, indicated by cycles from 5-10m thick at the base and up to 30m thick at the top. A typical asymmetric funnel-shaped pattern was recognized in the upper Quissamã interval, reproducing the dominant shallowing-upward pattern, associated with higher productivity than increasing of accommodation rate on carbonate platform. Toward the top, correlated to the drowning of the platform, the progressive marine transgression reflects the deposition of the Outeiro Formation, marked by a general thinning-upward trend in the cyclic pattern, and inversion of GR log response due to the clay content increase in the system. The different patterns observed in the vertical cyclic succession, as the hemicycles thickness variation, were a key factor in the definition of the LFCs, interpreted in terms of transgressive-regressive (T-R) depositional sequences. Based on the HFC vertical set, we recognized three T-R sequences for the Macaé interval: (1) Lower-Quissamã Transgressive Sequence (TS1), (2) Upper-Quissamã Regressive Sequence (RS2), and (3) Outeiro Transgressive Sequence (TS3). Finally, by analyzing the signal amplitude variation of the distinct frequency components, we could reinforce the interpretation of three-main cyclostratigraphic sequences in the Macaé Group. The abrupt changes in the signal amplitude were used to set cyclostratigraphic boundaries, and useful to delineate the main reservoir interval in the succession. Considering the good lateral continuity of the defined sequences, the LFC distribution was also helpful to establish a regional cyclostratigraphic framework. Our findings suggest that the applied method plays an important role to a semi-automate detection of cyclicity, distinguish hierarchical orders in the occurrence of superimposed cycles, and investigate heterogeneities in the stratigraphic succession, related to the main stratigraphic features and sequence boundaries. The VMD proved to be an effective technique to improve reservoir characterization on a limited dataset scenario (well-log, core and seismic).

KEYWORDS: SEDIMENTARY CYCLICITY, ALBIAN CARBONATES, VARIATIONAL MODE DECOMPOSITION.