Sequence stratigraphy boundary delineation based on adaptive seismic decomposition

Fangyu Li[1], Rui Zhai[1], Jie Qi[1], Bo Zhang[2], Kurt J. Marfurt[1]
1, University of Oklahoma; 2, University of Alabama.

While sequence stratigraphic boundaries are commonly observed and mapped on vertical slices through amplitude volumes, they are often masked by noise and artifacts from seismic acquisition and processing. "Signal decomposition" techniques can reveal hidden features in the seismic data. Traditionally, most seismic decomposition methods have been constrained by interpreter parameters such as spectral components. However, the subsurface has been built over geologic time through deposition, deformation, erosion, and diagenesis, which can lead to a between the "actual" features and human defined expressions. For this reason, a data-driven decomposition such as used in the SETI project might be more appropriate than an interpreter-defined decomposition method using predefined parameters.

In this work, we apply a data-adaptive signal decomposition method named variational mode decomposition (VMD) on both synthetic and 3D field data with the objective of mapping sequence boundaries. Unlike time domain decomposition methods, the VMD decomposes seismic signal in the frequency domain, which makes it more robust and optimal. Without any priori knowledge, it separates the intrinsic frequency components buried in the data based on their spectral responses. Though it doesn't enhance high frequencies, the VMD improves the ability to recognize stratigraphic boundaries on different components by suppressing interference from other less representative components,

In the synthetic examples, we build four deposition cycle models: normal, inverse, inverse-normal, and normal-inverse models. At every case, the gamma ray trend associated with seismic section can be expressed theoretically. The first intrinsic mode functions (IMF-1) calculated using VMD exhibits the pattern of gamma ray curve. In order to validate this observation, we examine gamma ray logs acquired through Marble Falls limestone in Fort Worth Basin and find a high correlation with IMF-1 computed from the seismic data. To determine if these correlations are general, we compute IMFs from seismic data volume acquired over a clastic delta in the Dutch Sector of the North Sea. Because of the data quality, the sequence boundaries of the delta facies are not very clear on the seismic amplitude data. In contrast, the different IMFs from VMD highlight onlaps, toplaps, downlaps and flooding surfaces more clearly, as well as the transgression and regression features. From the examples, VMD shows promises in seismic stratigraphy interpretation and potentials for assisting facies analysis.