A New Approach to Automated Well-Log Correlation in Three Dimensions: Examples from the Permian Basin, Texas

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Abstract

Correlation of geophysical well logs is one of the most important - and most time-consuming - tasks that applied geoscientists perform on a daily basis. In many onshore and shallow-water settings, it is common that hundreds or thousands of wells have to be correlated. With such large datasets, humans are unable to take advantage of all the stratigraphic information that a dense set of well logs holds. Using the dynamic time warping (DTW) algorithm, automated correlation of two wells is a fairly simple task. This approach can also be used to correlate a large number of wells along a single path. However, errors accumulate along a single path and loops cannot be easily closed.To address this problem and create a three-dimensionally consistent correlation framework, we use a Python implementation of the Wheeler and Hale (2014) approach, which is based on the idea of stretching-and-squeezing all logs into a chronostratigraphic diagram that has relative geologic time (RGT) on its y-axis. The depth shifts needed for the RGT transformation are computed by translating the outputs of a large number of pairwise DTW correlations into a least-squares optimization problem that is solved through the conjugate gradient method. The resulting chronostratigraphic diagram provides an overview of the stratigraphy and its variability. To create geologically intuitive well-log cross sections, we use a multi-scale blocking method that relies on the continuous wavelet transform to identify stratigraphic units of a certain scale in one well and then propagate these boundaries to all the other wells.We demonstrate the usefulness of this approach on two datasets with hundreds of wells from the Permian Basin, West Texas. Single-

panel correlations that rely on a small number of well pairs show significant differences when compared to the global correlation result; and, despite their geologically reasonable appearance, they contradict each other and are strongly dependent on lithologies. In contrast, the RGT approach is not a simple lithologic correlation, as the global optimization often places different types of rocks into the same time-stratigraphic unit. Linear channel bodies in the deepwater Spraberry Formation are easily detected and clearly highlighted in maps and cross sections. These results suggest that our methodology is robust enough for mapping subtle stratigraphic details, previously considered feasible only through manual interpretation.