Stratigraphic Architecture of the Mississippian Limestone Through Integrated Electrofacies Classification, Hardtner Field Area, Kansas and Oklahoma

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ABSTRACT

The Mississippian Limestone formed through complex structural, stratigraphic, and diagenetic processes involving subsidence, tectonic uplift leading to periodic subaerial exposure, changes in ocean chemistry, variability inherent with carbonate cyclicity, as well as post-depositional alteration. These geologic complexities have led to significant heterogeneity and compartmentalization within Mississippian Mid-Continent reservoirs. In the Hardtner Field area, the Mississippian Limestone is comprised of five main lithologies including tripolitic chert, green shale spiculite, gray shale spiculite, limestone, and shale. A novel log-based approach, termed derivative trend analysis (DTA), is used to identify and correlate depositional cycles, which can be associated with five major stratigraphic zones. In the absence of abundant and complete core data, DTA serves as a rudimentary, yet informative, tool to effectively develop a sequence-stratigraphic framework.

Generation of accurate electrofacies estimations is in many ways essential for effective reservoir characterization. Classifying electrofacies, especially those constrained to core observations, can elucidate key relationships between depositional environments and reservoir properties, as well as provide an improved understanding of the vertical and lateral heterogeneity of the deposits of interest. For this study, three methods of electrofacies classification (including artificial neural network (ANN), kmeans clustering and KNN clustering) are compared and ultimately used to create predictive lithology logs based only on the combined signatures of open-hole digital well logs in non-cored wells. These lithology logs are subsequently integrated with an interpreted stratigraphic framework to generate 3-D reservoir models, which reveal the stratigraphic, lithologic, and petrophysical trends of Mississippian carbonates and cherts in the Hardtner Field area.

Stratigraphic models produced from this study reveal a relatively uniform, flat-lying basal Kinderhookian section, overlain by prograding clinoforms with internally shoaling-upward cycles of limestone, shales, and spiculites deposited during Osagean and Meramecian stages. The sequence is capped by a high-porosity unit comprised mostly of brecciated chert associated with subaerially exposed strata underlying the sub-Pennsylvanian unconformity. Hardtner Field is located on the downthrown block of a major north-south trending fault, where relatively thick intervals of Osagean limestones are overlain by spiculitic units. Towards the south and east, Osagean strata thin significantly and are covered by Meramecian spiculites of the Cowley Formation. The Mississippian section as a whole thins up-dip toward the north, where most of the upper Mississippian is missing from significant erosion. Spatial porosity distributions reveal high reservoir quality deposits associated with regressive phases of 3rd-order cycles, with highest porosity intervals occurring up-section and toward the northeast of the study area.