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Please fill in your manuscript title.	Machine Learning for Carbonate Diagenetic Facies Classification Based on Nmr and Image Logs: A Field Case from The Arbuckle Formation, Kansas

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Abstract

Objectives/Scope:
This paper introduces a novel petrophysical workflow that utilizes convolutional neural networks (CNN) to classify carbonate diagenetic facies (DF) from a combination of core and logs. We focus on extracting various diagenetic features such as vugs and fractures from NMR and image logs. A field case using public data from the Arbuckle formation in Kansas will be presented to illustrate the new method.

Methods, Procedures, Process:
First, DF are identified and labeled in cored intervals by geologists using detailed core description. The labeled DF from core are then used to supervise deep learning algorithms (CNNs) to recognize the well-log responses of various DF. For example, NMR logs typically show abnormally large macro-porosity associated with vuggy facies while high-resolution image logs are capable of visualizing diagenetic features such as fractures and vugs directly. Once the deep learning algorithms achieve a reasonable correlation in the cored intervals between the core- and log- based classifications, the algorithms are then applied to un-cored intervals and wells for extended DF classification.

Results, Observations, Conclusions:
CNNs are proven to be effective for classifying carbonate diagenetic facies from both wave-form and image-based well-logs. In this field case, we conducted rigorous quality control on several hundred feet of core and over 1,000 feet of log data acquired from a key well penetrating the Arbuckle formation in Kansas. Using a combination of well logs, CNNs were trained to predict a vertical diagenetic facies profile of reasonable accuracy when compared to the manual core-based classification. We use cross-validation and blind tests to verify the results. More importantly, this approach represents a significant improvement in workflow efficiency by reducing the classification time for a typical well to only a few minutes. In addition, the systematic and automatic DF classification workflow is based on quantitative feature extraction from multiple logs which is not biased by human subjectivity. Therefore, it can generate consistent and un-biased DF classification in multiple wells in a field.

Novel/Additive Information:
The use of deep learning for DF classification is a promising approach to improve both efficiency and accuracy of diagenetic facies predictions across large, complex and multi-scale datasets. Machine-assisted DF workflows can recognize and extract diagenetic features with much less subjectivity, ensuring a consistent and un-biased DF classification which is a key input for building accurate reservoir models.