The Application of Machine Learning for Automatic Carbonate Facies Interpretation in Outcrops - An Example from the Jurassic Hanifa Fm., Saudi Arabia

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Abstract

Carbonate reservoirs are inherently heterogeneous and complex driven largely by depositional and diagenetic processes. Outcrop studies provide an insight into carbonate facies distribution leading to sub-seismic inter-well scale heterogeneities. The drone imaginary technique is commonly used to efficiently capture large-scale outcrop data. However, facies interpretation from digital outcrop images consumes a lot of time and can be very subjective depending on captured image resolution and geologist experience. This study presents a machine learning application using a Generative Adversarial Network (GAN) to identify carbonate facies from digital outcrop data of the Hanifa Formation. Outcrops are located in the Tuwaiq Mountain escarpment south of Riyadh in Wadi Birk and expose shallow water deposits composed of coral stromatoporoid build-ups and associated flank and inter-build-up sediments. We prepare training set images taken from approximately one kilometer of outcrop images and associated facies interpretation. Both training images and interpreted facies are cropped into a square shape covering 29 x 29m (512x512 pixels) providing a resolution of 5 x 5 cm per pixel. The GAN algorithm learns the correlation of these paired images and iterates this learning process 500 times until it reaches a consistent outcome. We also select three outcrop photos as blind-test images to assess the capability of this network. The trained network has been used to automatically interpret another 1.5 km long outcrop section of the Jurassic Hanifa Formation. The result shows the image correlation between carbonate facies derived from the GAN method and pre-defined facies interpretation by geologists is 83%-89%. Stromatoporoid coral build-ups and associated muddy and grainy flank facies surrounding the mound are successfully identified. These stromatoporoid coral build-ups are distributed patchily along the outcrop with sizes ranging between 2 to 66 m wide and 1 to 10 m tall. Importantly, non-geology features including fallen rocks from erosion are also recognized correctly as scree rocks. This study provides a centimeter-scale insight into carbonate facies heterogeneity that illuminates the blind spot between well data and seismic. The facies distribution obtained from this study can be used as guidance for geological interpretation of seismic and well data, and 3D reservoir modeling providing an improved understanding of reservoir connectivity.