Virtual Outcrop “Behind-the-Outcrop” of the Hanifa Reservoir Analog: Blending Near-Surface Acoustic Impedance Data with Drone-Based Outcrop Imageries

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Abstract

Outcrop analogs play a central role in understanding sub-seismic interwell depositional facies heterogeneity of the subsurface reservoir. Contemporary outcrop geologists typically utilize drone-based digital outcrop models to interpret outcrop facies. However, they rarely employ near-surface seismic data to extend the dimensionality of an outcrop in 3D space due to the limited vertical resolution and unfamiliarity of seeing seismic signals as a proxy of rocks. This study implements an artificial intelligence-driven methodology that blends drone-based outcrop imageries of the Hanifa reservoir analog with near-surface seismic data, resulting in a virtual outcrop “behind-the-outcrop” model. We interpret the depositional facies from a four km-long drone-based outcrop photo-mosaic from the Hanifa reservoir, Wadi Birk, Saudi Arabia. Using lab-measured properties and outcrop interpretation, we perform forward modeling and calculate the bandlimited acoustic impedance of the outcrop facies using colored inversion. We pair the synthetic bandlimited acoustic impedance with outcrop facies and train them using the conditional generative adversarial network. Similarly, we pair the outcrop facies with outcrop photos and train them using a similar method. Finally, we chain the two trained networks and apply them to the ~600 m-long seismic-derived acoustic impedance data acquired just behind the outcrop. The result translates bandlimited acoustic impedance images into a pseudo-high-resolution virtual outcrop “behind-the-outcrop” model. This model successfully resolves sub-seismic stratigraphic features of the Hanifa reservoir analog, such as the intricate downlap and onlap stratal termination at tens of centimeter-scale and the outline of buildup facies which are otherwise unresolvable in the seismic data. This study potentially expanded further by transferring the learning process and constructing a virtual outcrop in the reservoir using subsurface seismic data.