High Fidelity Reservoir Model from Integrated 3-D Photogrammetry, Core, and Geophysical Data of the Late Jurassic Hanifa Formation, Saudi Arabia

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Abstract

Inter-well depositional heterogeneity is a key geologic factor behind uneven fluid advance in the tertiary recovery of carbonate reservoirs. Understanding spatial distribution of depositional facies is hence critical in order to develop optimum strategy for improving ultimate recovery. Subsurface datasets are limited in both resolution and data density to resolve this level of heterogeneity. Outcrop analogue is commonly used to provide a statistical insight and resolve these inter-well facies heterogeneity. While most outcrop analogue studies rely only on 2D data, this study aims on building a high-fidelity carbonate reservoir model based on 3D outcrop drone photogrammetry paired with core and geophysical data. Wadi Birk is located in Saudi Arabia and exposes 160 m of Oxfordian-Kimmeridgian section of the Hanifa Formation. The top 50 m is stratigraphically equivalent to Hanifa reservoir in the subsurface and in many respects analogous to the upper part of Arab-D reservoirs in Saudi Arabia. This outcrop provides an excellent analogue to resolve meter-scale inter-well facies heterogeneity commonly found in shallow water lagoonal carbonate reservoirs. Data acquired from the outcrop includes a 16 km^2 drone photogrammetry, a total of 300 m measured sections and gamma ray data from 9 different locations, 150 thin sections and 120 hand samples. The geophysical data consists of 8 km-long networks of 50 MHz and 100 MHz 2D Ground Penetrating Radar (GPR) as well as 2 km of 2D seismic. Three 50 m long cores were drilled behind the outcrop, intersecting both seismic and GPR lines. Plugs from

hand samples and core were drilled and measured for their dielectric constant, p-wave velocities and densities in order to perform well-to-GPR and seismic ties. These ties were then used to better constrain geophysical interpretations. Our data show that the lower part of the Upper Hanifa Formation consists of parallel-bedded bioturbated mudstone/wackstone intercalated with intraclasts-skeletal-peloidal grainstone/rudstone layers. This architecture is confirmed by seismic image as a continuous parallel reflection event. The upper part of the Upper Hanifa Formation consists of a complex assembly of stromatoporoid/coral reefs and oncoid shoals (SCROS). The SCROS is expressed in radargram by tabular-chaotic to bulbous buildup-like features with well-defined stratal termination. Large complexes tend to be more pseudo-ellipsoid (30-40 m long axis and 5-10 m short axis) while smaller complexes tend to be more circular (< 5 m). These complexes seem to form larger clusters, potentially indicating larger areal heterogeneities. 3D outcrop analogue facies model of Upper Hanifa Formation was built based on these insights. This model can be used as an input to build static model and dynamic simulation to assess for the best development strategy and improve ultimate recovery in Hanifa-like shallow lagoonal reservoirs.