An Integrated Workflow to Assess, Process, and Interpret Photogrammetry, Sedimentology, and Geophysical Data for Three-Dimensional Carbonate Outcrop Investigation of the Late Jurassic Stromatoporoid/Coral Buildup

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Abstract

The sub-seismic stromatoporoid/coral buildup of the Hanifa Formation is one of Arabia's most heterogeneous reservoir facies. Deciphering the 3D meter-scale morphological architecture and distribution of this facies requires an outcrop-scale investigation. However, two-dimensional outcrops are insufficient to decipher the three-dimensional geobody of the stromatoporoid/coral buildups. Therefore, a 3D outcrop depositional facies investigation requires a comprehensive integration with "behind-the-outcrop" geophysical data. This study proposes a comprehensive methodology to assess, process, and interpret photogrammetry, sedimentology, ground penetrating radar (GPR), and seismic datasets based on the outcrop depositional facies framework. The methodology was tested and applied to map the 3D morphology of the stromatoporoid-coral buildups in the Late-Jurassic Hanifa reservoir analog at Wadi Birk, Saudi Arabia. Datasets acquired include 1.2 km2 drone imageries; measured sections; 8 km-long networks of 2D GPR, three grids of 3D GPR (60 m x 50 m; 50 m x 20 m; 55 m x 40 m); 640 m-long 2D seismic profile; and a 50-m long core. A digital outcrop model (DOM) is constructed from drone imageries. Outcrop measured sections are utilized to calibrate and interpret the DOM. Laboratory-scale dielectric permittivity, acoustic velocity, and bulk density are measured to assess the geophysical properties of the stromatoporoid/coral buildup facies. DOM-based GPR and seismic models are employed to assess the geophysical responses and formulate processing flows that accentuate anomalies from the stromatoporoid/coral facies. Integrated outcrop and "behind-the-outcrop" data allow the measurements of buildups morphology in 3D. The buildups are 3D pseudo-ellipsoid with an average long and short axis length of ~36 m and ~11 m, respectively. The average thickness of the buildup is ~2.6 m with ~N335E orientation. 2D Outcrop-only measurements would only allow for tallying the apparent length and thickness of the buildup biased by outcrop orientation. These results exemplified the importance of geological and near-surface geophysical data integration in outcrop studies.