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Improving Carbonate Reservoir Models with Digital Outcrop Modeling - An Example from the Cretaceous Natih Formation, Sultanate of Oman

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SUMMARY

In order to ground-truth and quantify both the external and internal make up of geobodies, outcrop analogues for the Natih Formation of Oman were used. By deploying a digital outcrop modelling workflow, geobodies observed in outcrop can be quantified efficiently and effectively. The main objective of the study was to develop recommendations and guidelines on ways to incorporate these type of geobodies into static and dynamic models. Furthermore, the digital outcrop models will be presented as virtual reality (VR) training datasets spanning resolutions ranging from sector-scale to thin section-scale.

Commonly, interiors of Middle East carbonate platforms are stratigraphically correlated in a layer-cake fashion making the assumption that the platform interior was represented by flat, extensive and undifferentiated shallow-water environments creating wide, laterally continuous facies belts. However, high-resolution, 3-D seismic data from the subsurface of Oman of Cretaceous epeiric platform carbonates reveals a complicated internal stratigraphic architecture, comprising depositional geometries such as platform incisions and clinoforms. The internal spatial complexity, facies heterogeneities and reservoir property distribution of these architectures remains unknown. In order to ground-truth and quantify both the external and internal make up of these geobodies, outcrop analogues can be used. In Jabal Madmar in Oman, these geobodies were recognized in outcrops of the Natih Formation. The outcrops are exposed along several canyons that cut deeply into an anticline structure and as such provide pseudo 3-D exposures.

A reservoir model should be robust for predicting responses to IOR and EOR processes. For that reason it should adequately account for critical embedded geologic heterogeneities and geobodies. One of the most reliable sources of information on heterogeneities comes from outcrops because it allows examining geological variability at all scales. By deploying a digital outcrop modelling workflow, geobodies observed in outcrop can be quantified efficiently and effectively. In essence, outcrop-based geologic features are spatially positioned and recorded with digital mapping and surveying techniques – in our case high-resolution GPS and lidar – in 3-D and on scales ranging from centimetre (hand specimen observations) to kilometre (mountain range observations). The large amount of collected data is assimilated, visualized, and modelled to create a digital outcrop model (DOM), which delivers numerical data on matrix heterogeneity and structural overprint.

In Jabal Madmar, the first type of geobody is a seismic-scale incision (depth of 15 m and width of c. 600 m) that was formed during a relative fall in sea level. Dolomitized wackestone facies infilling the incision indicate that diagenesis played a role in defining the reservoir properties of the incision. The second type of geobody is recognised by hectometre-scale (100 m long) medium-angle to high-angle (1–50°) stratal surfaces bounding clinoform sets that are observed within grainstone shoal complexes. The clinoforms are characterised by complex internal architectures and lithological and diagenetic changes.

The main objective of the study was to develop recommendations and guidelines on ways to incorporate these type of geobodies into static and dynamic models. Special attention was given for modelling clinoforms in Petrel™. Although upscaling will need considerable attention, complex and high-resolution clinoform models must be considered in reservoir modelling workflows in order to correctly derive static and dynamic rock properties for input into a full-field model. Besides direct subsurface applications, the digital outcrop models can be presented as virtual reality (VR) training datasets spanning resolutions ranging from sector-scale to thin section-scale.