Mapping Vertical and Lateral Diagenetic Heterogeneities In Platform Carbonates With Hyperspectral Imaging — A Case Study Using an Outcrop Analogue of Jurassic Arab - D reservoirs

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Abstract

Diagenetic alteration such as secondary dolomitization cause significant property heterogeneities in reservoirs and pose challenges in reservoir development strategies. Super-k heterogeneities associated with such processes have been reported from super giant reservoirs of Arabia. This study presents a new approach that uses hyperspectral imaging (HSI) to map heterogeneities in dolomite distribution in an outcrop analogue for Arab-D reservoirs found north of Riyadh, KSA.

Sampling of outcrops and drill core are typically performed visually based on the geologist's perception (e.g., dark vs light rock), or by statistical sampling patterns (e.g., grids). Accessibility of cliff faces is another factor that potentially introduces bias. We have employed drone-based HSI to create an unbiased and continuous image of a km-long outcrop cliff to map the vertical and lateral heterogeneity of dolomite geobodies at cm-resolution. Results are furthermore anchored by geochemical data and an HSI scan of a core taken directly behind the outcrop HSI reveals the presence of multiple strata-bound dolomite layers with lateral extent varying from few 10’s of m to several km, with three dolomitizing styles: completely dolomitized horizons, partially dolomitized horizons, and layers with preferential dolomitization of bioturbations. Clumped isotope analyses reveal that dolomites formed at low temperature (30^oC to 50^oC) from fluids of *-0.3‰ to 1.0‰ (Jurassic seawater= -1.0‰)* isotopic composition, indicating dolomitization by slightly evaporated seawater. Preferential dolomitization of grainstone-rich Arab-D strata and grain-rich burrows versus the wackestone/packstone dominated Upper Jubaila Fm suggests preferential flow of dolomitizing fluids along stratabound high-permeability pathways.

The stratabound dolomite shows lateral variation in the degree of dolomitization with increasing offset from side canyons. Fracture analysis performed on the outcrops indicate that side canyons are aligned with a NW-SE regional fracture trend. This alignment suggests flow of dolomitizing fluid occurred through a fracture system at depth. Further investigation is ongoing.

We further classified dolomites by performing Principal Component Analysis (PCA) on short-wave, mid-wave and long-wave infrared hyperspectral data of drill core. The variations evaluated from PCA led to the definition of five different classes of dolomites, representing distinct textural and chemical variability.

This study demonstrates that HSI provides a quick screening method for capturing vertical and lateral heterogeneity and helps in developing an effective sampling strategy to get critical data points that significantly impact interpretation. With appropriate calibration, HSI helps constrain the environment of dolomitization, the flow of dolomitizing fluid and the compositional heterogeneity at cm-scale.