An Integrated Sedimentological, Geochemical and Rock Mechanical Facies Classification for the Evaporite Facies of the Hith and Arab Formation (Saudi Arabia) - Implications for Seal Integrity

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Abstract

The most extensive Mesozoic seals of Saudi Arabia, the Hith and Arab evaporites are generally believed to be highly effective because they have held hydrocarbons in place over many millions of years. Yet, they are nonetheless known to have lost their seal integrity locally (e.g., in Bahrain and Qatar) – in particular along persistent fracture zones. Predicting zones for seal bypass and associated risk levels in these formations is crucial for the safe storage of geofluids such as CO2 or H2. To study relevant in situ processes and quantify failure risks we obtained a fully cored section through these formations. We analyze and study this core to identify sedimentary facies, constrain geochemical, and determine rock mechanical properties. The integration of the results enables us to build a robust and adequate evaporite facies classification.

The Hith and Arab formations consist of evaporites (gypsum, anhydrite, halite), carbonates, dolomites and marly intervals. Our focus is in particular on the evaporite intervals, to characterize their chemical composition, reactivity with previously non-resident fluid phases (e.g., super-critical CO2), sedimentological bedding type, thickness and vertical distribution and to correlate this with rock-mechanical properties (e.g., compressive rock strength, elastic moduli and more) in order to evaluate variations that might translate into a seal capacity risk matrix.

The well reaches the Arab C carbonates and the dataset is complemented by fieldwork on Arab D reservoir outcrops 30 km west from the well location. Thus, this dataset provides an important 1D control point for the Arab A-B-C and Hith formation cycles south-east of Riyadh and enables a regional well log correlation from this well location to subsurface information derived from wells in Saudi Arabia’s Eastern Province. What we observe from the core in our well are three cycles of shoaling upwards carbonates from a more marine base to a restricted marine base and evaporite deposition. Geochemical analysis based on XRF and XRD data derived from the core help to accurately establish mineralogical composition. Compressive rock strength profiles were derived along the entire core interval using scratch testing technology. We perform an anhydrite facies classification based on core description, thin section analyses and the XRD/XRF results. A comparison between the facies classification and their wireline log signature and rock strength values contribute to an integrated evaluation of seal capacity.

The top half of the core is comprised of the lower Cretaceous Sulaiy limestones and Manifa reservoir. The lower half contains 78m of the Hith and 115m of the Arab A-B-C formation cycles. The core shows that the evaporite facies of the Hith and Arab formations are highly varied. Some of the main evaporite facies types that can be observed are the following: nodular anhydrite (with nodules either touching or separated),

massive anhydrite (lacking internal structure) and laminated anhydrite. The evaporites often have thin (cm- to mm-scale) dolomite layers that separate layers of anhydrite or gypsum or is found in-between the nodules.

Massive evaporite with homogenous composition and very little (to none) dolomite between the anhydrite nodules has higher rock strength and may pose lower risk for seal by-pass. However, such correlations are still under investigation. Nonetheless, this study provides important insights for a regional evaluation of seal integrity.