Review of the Permian–Triassic Gas Play in the Arabian Gulf Region

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Significant amounts of non-associated gas reserves are proven from the Permian–Triassic Khuff-Dalan play across the Arabian Gulf region (Figure 1). This play is part of the Paleozoic petroleum system that is mainly sourced by the base Qusaiba hot shale of the Silurian Qalibah Formation. It is sealed by the Triassic Sudair-Aghar shales (Figure 2) and trapped in high relief, north-trending anticlines or salt domes.

The Khuff formation was deposited on a broad shallow marine restricted shelf across the Arabian Platform (Figure 3) and consists of interbedded carbonates and evaporites. Four reservoirs, named Khuff-A, B, C and D in descending order (Figure 4), are present within the carbonates and their porosity ranges between 3% and 12%. The Khuff reservoirs tend to thicken with improved development toward the east.

Several long N-trending folds were initiated during the Permian–Triassic across the Arabian Plate (Faqira, et al., 2004). These folds, together with salt-cored structures, played a significant role in reservoir development through diagenetic processes. Better reservoir development and communication occurs in the salt dome structures, whereas the anticlinal trends tend to have less reservoir development and no communication across the various Khuff reservoirs.

The hydrocarbon gases of the Khuff reservoirs were sourced from the base Qusaiba *hot shale* of the Silurian Qalibah Formation. The distribution of these rocks across the Arabian Plate has been influenced by the mid-Carboniferous Hercynian unconformity, in which the Silurian source rocks are preserved in the mid-Carboniferous basins and eroded from the intervening arches (Figure 5).

Hydrocarbon migration is the most critical element of the Khuff play. We believe that this migration requires faults with sufficient throw or high intensity fractures to connect the base Qusaiba hot shale source rocks to the Khuff reservoirs (Figures 6 and 7). The Khuff hydrocarbons accumulate in either long north-trending basement-cored high relief forced fold structures controlled by deep-seated faults or salt domes. Afifi (2010) believes that the hydrocarbon migration is attributed to the breaching of thick shale/carbonate/anhydrite seals at the base of the Khuff Formation by faults that propagated upwards into the Khuff during the initial development of high-relief salt domes, followed by migration up dip on fill and spill bases.

The quality of the Khuff gas varies with depth in response to increased reservoir temperature. The non-hydrocarbon gas components found are usually H₂S, CO₂ and N₂. The H₂S is generated in the Khuff reservoirs following a reaction between the hydrocarbons and anhydrites. Geochemistry and petrography have confirmed that H₂S in the Khuff reservoirs is due to thermo-chemical sulphate reduction (TSR), in which anhydrite is replaced by calcite and sulfur.

References

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Figure 1: Arabian Plate map with Permian–Triassic gas fields.

Figure 2: Paleozoic stratigraphy of the Arabian Basin (Pollastro, 2003).

Figure 3: Simplified Khuff depositional model (Faqira et al., 2009a).

Figure 4: Permian–Triassic Khuff stratigraphy (Alsharhan, 2006).

Figure 5: Silurian source rock distribution (Faqira et al., 2009b).

Figure 6: Hydrocarbon migration in salt structures.

Figure 7: Hydrocarbon migration in basement-cored structures.