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Calibrating Seal Risk Against Global Analogues and Observations: Where Does the Middle East Fit?

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Abstract

Seal succeed or fail by five main mechanisms, which can be listed as follows:

1. Areal discontinuity of the rock type proposed as the seal, over a structure or fairway, termed ‘Seal Distribution’ in this paper.
2. Excess pressure due to the development of a hydrocarbon column exceeding membrane capacity of the seal, termed ‘Seal Capacity’ in this paper
3. Tectonic fracturing of the seal, termed ‘Seal Integrity’ in this paper
4. Displacement of the seal by faulting, termed ‘Seal Displacement’ in this paper
5. Hydraulic fracturing of the seal, termed ‘Seal Hydraulic Fracturing’ in this paper

Seal Distribution is clearly analysed by facies and depositional environment mapping. Seal varies with lithology and grain size. Seal Integrity is dependent on a relationship between the seals ductility (i.e. lithology) and the tectonic strain imposed on it (i.e. tectonic regime). Seal Displacement is dependent on a relationship between the seal thickness and the displacement on faults, while hydraulic fracturing is dependent on a highly overpressured regime. The chance of a seal being successful is the product of the risk of all possible leakage processes. This may well vary between partial fill and full to spill cases. Quantification of each process, and therefore of the each of the risks involved, is hazardous and it is key therefore to calibrate to field analogues.

Seal Capacity and Seal Integrity are both lithology dependant and it is possible to rank potential seal lithologies by a combination of analysis, theoretical prediction and analogue observation, with evaporites providing the lowest risk seals follower by organic shales, then mudrocks in increasing grain size, then argillaceous carbonates. Seal Integrity and Seal Displacement are also dependant on the tectonic regime, which together with the age of the petroleum system, can be seen to impose constraints on the spectrum of lithologies that act as effective seals in a basin. Relatively few regional seals (and often mainly evaporites) are seen in old petroleum systems and thrust belts, whereas a wider range of seal types are seen in active petroleum systems and more quiescent tectonic settings. In some cases, the rate of hydrocarbon charge seems to exceed the rate of leakage through seals, expanding the range of sealing lithologies and models.

The availability of high quality, ductile and continuous regional seals is arguably the main factor controlling the high petroleum productivity of the Middle East. Key factors include the abundance of ductile evaporites and anhydritic shales, together with the availability of clastic shale

seals in some regions, all lithologies with high Seal Capacity. Carbonate seals trap a smaller proportion of petroleum but are unusually effective compared to other parts of the world. In the Arabian Basin, relatively thin seals are seen to work as regional seals (e.g. basal Sudair/Aghar Shale seal), which suggests few faults and low fault displacements, indicating Seal Displacement is rarely an issue. In the Zagros, the range and number of seals are diminished, but are still wider than seen in any other 'thrust belt'.

Because seals exert such an important influence on the Middle East petroleum systems, there is a strong argument for focussing play fairway/common risk segment mapping on seal rather than reservoir levels, particularly as in some cases, different reservoirs underlie the key seals. A methodology for such mapping is outlined, considering each potential seal leakage mechanism and tying to analogue observations where available. This is demonstrated for a series of seals in northern Iraq, where the most important considerations appear to be Seal Distribution and Seal Integrity, and where few pools are full to their structural spill points.