Analog-based Seal Classification and its Potential Application in Prospect Evaluation

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Abstract

A comprehensive seal classification has been developed using nearly 1000 producing oil and gas reservoirs worldwide. Three end-member seal groups including top seal, updip lateral fault seal and lateral stratigraphic seal, three combination seal groups including top dominated, fault-dominated and stratigraphic dominated, as well as miscellaneous-unconventional seal groups have been defined. Seal surface geometry, depositional system, lithology, thickness, tectonic setting, structural flank dip, reservoir lithology, hydrocarbon column height and percentage of structural closure height filled by hydrocarbon are the key attributes documented for each of the case studies.

The study shows that for the top seal, seal thickness is not a reliable seal efficiency predictor. There is no correlation between the percent fill of a trap and seal thickness. The largest hydrocarbon columns are sustained by evaporite, shale or interlayered seals. Leakage of most underfilled reservoirs was caused by top seal failure, and the most common cause of failure is by tectonic (fault) breaching. Capillary leakage is more common in fields with large productive areas due to lateral facies changes, and in seals formed in coastal depositional systems.

For the updip fault seal, sealing capacity is in part controlled by fault throw. Faults with throw < 15% of the reservoir thickness are non-sealing. Reservoirs with fault throw exceeding reservoir thickness are mostly sealed by juxtaposition. There is a moderate to good correlation between fault throw and hydrocarbon column height, and sealing capacity is better in reservoirs with cross-fault juxtaposition against post-tectonic stratigraphic fills. The majority of reservoirs with updip faults are under-filled. All reservoirs with updip faults and structural flank dips >15o are underfilled. The majority of reservoirs with updip faults in rift basins are also underfilled because of post-rift fault reactivation caused by transpression, inversion, etc.

For the lateral stratigraphic seal, the buoyancy pressure increases towards the updip seal. Stratigraphic sealing mechanisms are capable of retaining large hydrocarbon columns, but because most traps with stratigraphic seals are low-dip, the top seal sustains most of the pressure. The largest columns are retained by facies change seals but most onlap seals hold columns >1000 ft. Although the majority of stratigraphic traps have a low-dip, exceptions are found in high-dip structural traps with a dominant stratigraphic seal. Most reservoirs with stratigraphic seals are filled-to-spill or overfilled.

The combination seals are more complex but share characteristics of the three end-member seal groups. Over half of the reservoirs in the study are sealed by combination seals. Tar, hydrodynamic, hydrostatic-capillary, gas-hydrate and un-fractured shales are the main miscellaneous-unconventional seals.

With the new seal classification scheme, benchmarking of the seal attributes of an exploration prospect against those of the producing reservoirs will reduce the uncertainties of seal evaluation and assist in the estimation of possible sealing capacity and the resulting hydrocarbon column height of the prospect.