CERAMAH TEKNIK TECHNICAL TALK

Possible Oil Accumulation with Convex-shaped OWC under Abnormally High Pressure Condition; Example from Offshore Sabah, Malaysia

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The cap, or seal, of an oil reservoir does not have limitless sealing capacity – exert enough of a pressure differential across the seal and it will begin to leak fluids. The point at which leakage takes place depends on several things – mainly the lithology of the seal rock, but also the nature of the fluid contained within the trap. The behavior of the seal can be modeled using capillary pressure theory, finer grain sizes result in higher sealing capacity. Sealing capacity is expressed in terms of the column height of fluid capable of being trapped without leakage. It can further be expressed using the conceptual "Equivalent Grain Size" – the smaller the EGS, the higher the sealing capacity. Leakage always occurs at the very top of the trap, since this is where the pressure differential across the seal is greatest.

Gas leaks more readily than oil since its buoyancy (the difference in density between it and the oilfield brine underneath it) is much greater, which makes the pressure differential across the seal greater for a given column height. A seal that is capable of supporting a tall oil column would only be capable of supporting a much shorter column of gas.

The nature of the fluid contained in a trap may depend on the sealing capacity of the cap rock. Since oil is more desirable than gas, a seal that leaks gas is actually more desirable than one that does not, since it allows oil to replace the gas that leaks from the top of the trap. A stronger seal would result in a trap containing far more gas, since the gas would prevent oil from entering the trap (if the oil were the later charge) or would displace oil (if gas were the later charge, which is usually the case). If the seal can support a column of fluids greater than the height between the top of the trap and the spill point, then the trap is a "spill point limited" one and would tend to contain gas. If it cannot, then the trap is "capillary limited" and would be more likely to contain oil. One might also have traps that are intermediate – the spill point is below the supportable column height for oil, but above that for gas (oil will spill if enough is put into the trap, but gas will leak through the seal before the trap fills to the spill point).

An interesting observation is that, in offshore Sarawak, there exist nested and adjacent traps where the gas in each trap contains different amounts of CO_2. Dr. Nakayama thinks that this may be due to different sealing capacities for each of the seals – spill point limited traps contain less CO_2, while capillary limited traps contain more CO_2. This can be explained if the hydrocarbon gas charge were earlier and distinct from the CO_2 charge. CO_2 is denser than hydrocarbon gas, so when it is introduced into a spill point limited trap containing hydrocarbon gas, it will not be able to displace the hydrocarbon gas. However, if it is introduced into a capillary limited trap containing hydrocarbon gas, the added pressure would induce some of the resident charge to leak out the top. The resulting mixture would have a taller column height than before, because the mixture, being denser, would have less buoyancy than the original hydrocarbon gas and thus a taller column would be supported by the seal.

Nested or stacked traps are common in areas with layercake stratigraphy, such as offshore Sabah. Where traps are separated by large vertical distances (i.e. large thicknesses of seal rock), or if the intervening seals have high sealing capacity, they operate independently (independent mode), where lower traps have oil-water contacts below the oil-water contacts of the higher traps. In contrast, nested traps with thin (or weak) layers of seal rock in between them operate in "Matryoshka mode" (after the Russian dolls which nest within one another), with a common oil-water contact level. This is due to the capacity of the topmost seal being the limiting one – gas leaking through the lower seals accumulates in the upper levels until the pressure across the seals reach equilibrium.

It should not be possible to have nested traps where the lower traps have oil-water contacts above the oil-water contacts of the upper traps. However, this is exactly was was found in certain nested traps offshore Sabah. Dr. Nakayama thinks that the only way to account for this would be if the lower traps had abnormally high pressures compared to the higher traps. If one uses the depth of the oil water contact encountered in wells drilled into the crest of the structure for volumetric calculations of hydrocarbons in place, then these calculations will result in underestimates, since there will be oil below the observed oil-water contact on the flanks of the structure. Such situations can be recognized by pressure-depth gradients higher the expected hydrostatic gradient hydrocarbons.

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