D05

Top Seal Assessment in High Pressure - High Temperature Plays - Evidence from the UK Central Graben

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SUMMARY

The current methodology of predicting top seal integrity in high-pressure/high-temperature (HPHT) plays (Gaarenstoom, et al., 1993) is to assume that the caprock, defined as the low matrix permeability formation immediately overlying the reservoir, is the seal (e.g. the Kimmeridge Clay Formation above older sandstone of the UK Central Graben Mesozoic play fairways).
This study challenges this assumption and proposes the existence within the caprock of a fluid waste zone consisting of a system of fractures cutting from the reservoir up into or even through the caprock and therefore charged with reservoir fluids. Because of the waste zone the caprock cannot seal the underlying reservoir fluids.
Seismic and elastic logs data help identify any fracture waste zone and also any stratigraphic boundary capable of containing it (or arresting its upward propagation).

In many exploration provinces worldwide, top seal presence and integrity is the main exploration risk. Top seal failure increases with depth of burial and fluid pore pressure and as the industry pursues deeper and higher pressure plays top seal risk is deemed to increase in importance.

The current methodology of predicting top seal integrity in high-pressure/high-temperature (HPHT) plays (Gaarenstoom, et al., 1993) is to assume that the caprock, defined as the low matrix permeability formation immediately overlying the reservoir, is the seal (e.g. the Kimmeridge Clay Formation above older sandstone of the UK Central Graben Mesozoic play fairways).

This study challenges this assumption and proposes the existence within the caprock of a fluid waste zone consisting of a system of fractures cutting from the reservoir up into or even through the caprock and therefore charged with reservoir fluids. Because of the waste zone the caprock cannot seal the underlying reservoir fluids (Figure 1). Instead the seal coincides with the fracture waste zone tip point, which occurs at an important stress and stratigraphic boundary. Six case studies documented in this work demonstrate that in the Central Graben the top seal for Jurassic and Triassic HPHT hydrocarbon accumulations lies between the Base Cretaceous Unconformity and the base of the Chalk Group and that the Kimmeridge Clay Formation is not the seal of these prospects. It is proposed here that when it comes to assessing top seal integrity in HPHT plays, for each basin, play fairway area or even for each prospect, the top seal cannot be assumed to occur at some given stratigraphic level but must be identified and defined on the basis of the data at hand for that particular area.

In order to establish a methodology that can be applied to define the top seas in HPHT basins, key data was collected from a number of Mesozoic 4 way dip structures drilled within the UK Central Graben of the North Sea. These are tilted fault blocks with reservoir intervals in their footwall.

The data analysed consisted of: pore pressure measurements (RFT, MDT), formation integrity measurements (LOT, FIT); elastic logs (Sonic and Density), reflection seismic profiles.

The data allow the construction of a detailed structural and stress model for each of the structures (Fig. 1). It is important for this analysis to construct these models through the crest culmination of the studied structure in order to investigate the stress field in the areas most likely to undergo leakage.

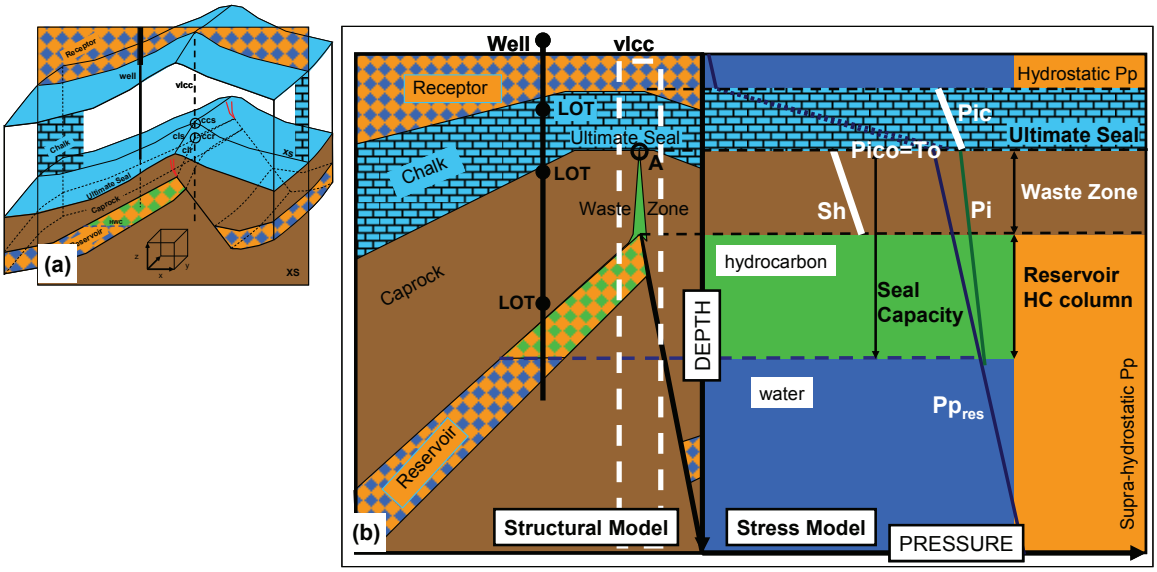

Figure 1 *It is important to construct the 2D structural and stress models through the crest culmination of the structure (a).?: Pic: fracture propagation stress; Pi: Fluid pressure within the waste zone fracture system; Sh: Minimum confining stress; Ppres: Reservoir fluid pressure. Other acronyms: vlcc: vertical line through crest culmination; LOT: Leak off test.*

For any particular structure these two models show the relationship between confining stresses and fluid pressure. From the seismic and elastic logs data it is possible to identify any fracture waste zone and also any stratigraphic boundary capable of containing it (*or* arresting its upward propagation).
With this dataset at hand the seal integrity (fluid pressure which the top seal can withstand) and seal capacity (hydrocarbon column that could be trapped in the prospect) can be determined.
The accepted method (Gaarenstoom, et al., 1993) takes the minimum stress at top reservoir as the top seal integrity. However with this assumption it cannot differentiate between stable (intact) and unstable (breached) top seals (Fig. 2e). In the current study the seal integrity is taken to be the fracture propagation stress (Pic in Figs. 1b and 2f) at the waste zone tip point. Using this model,) hydrocarbon charged and water filled reservoirs can be differentiated (Fig. 2f).
An important conclusion of this study is that the top seal of these accumulations is located at the waste zone tip point and that the shorter the waste zone the higher the chance of finding hydrocarbons in the reservoir (Fig. 2d). In any play fairway, knowledge of the waste zone thickness can be therefore easily translated into a top seal risk factor.

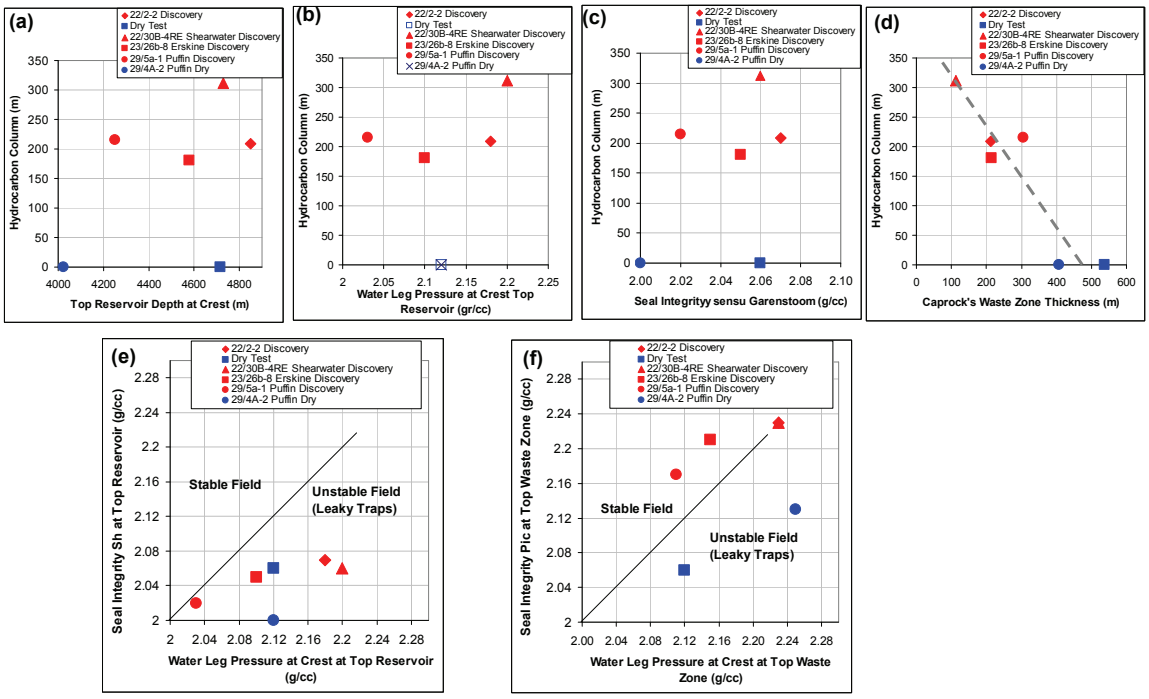

Figure 2 *Evidence from 6 case studies demonstrating that waste zone thickness controls top seal integrity and capacity.*

A number of prospects held in the portfolios of several North Sea operators could be re-evaluated using this technique, which may also provide insights into the seal integrity of other HPHT provinces worldwide.

References

Gaarenstoom, L., Tromp, R.A.J., De Jong, M.C. & Brandeburg, A.M., 1993. Overpressures in the Central North Sea: implications for trap integrity and drilling safety. In Parker, J.R. (ed.), *Petroleum Geology of North-West Europe*: Proceedings of the 4th Conference. Geological Society, London 1305-1313.