A07

Integrated Quantitative Seal Assessment for Exploration Projects

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SUMMARY

Today seal evaluations are commonly applied within the industry: during the prospect evaluation process of an exploration project it is essential to predict the probability of the hydrocarbon column height based on seal predictions. The introduction of various quantitative prediction algorithms and related software has opened the way for industry application; however the quality of seal evaluations in exploration projects is still varying from qualitative estimates over inconsistent applications to deterministic capacity estimates. Oversimplification and biased contact scenarios can result in misleading volume predictions and it may have additional negative impact on the prospect chance estimates. To enable consistent prospect evaluation concerning column heights, WINTERSHALL has developed a corporate standard for seal evaluations which is systematically applied to all exploration projects. The methodology integrates top and fault seal workflows resulting in structural related hydrocarbon column heights. Examples from various basins will be used to demonstrate the great potential of integrated quantitative seal assessment (QSA), its limitations in carbonates and the application and integration of QSA in play evaluations. The influence of comparative probabilistic assessment of top and fault seal capacities and proper statistical treatment of seal capacity results play a pivotal role in corporate exploration decision making.

Today seal evaluations are commonly applied within the E&P industry. One key parameter of every volumetric prospect evaluation is the hydrocarbon contact which has to be estimated based on separate evaluations for charge and seal. If charge can be excluded as a limiting factor seal capacity and trap integrity studies have to be performed in order to assign appropriate uncertainty to contact estimates. The introduction of various quantitative prediction algorithms and related software has opened the way for industry application; however the quality of seal evaluations in exploration projects is still varying from qualitative estimates over inconsistent applications to deterministic capacity estimates. Especially in new business exploration projects limited data density and the small available time windows for specialised studies in the overall project time schedule are the main reasons for neglecting these important details. Other methods like widening the distribution for contact estimates e.g. using structural geometry crest and spill can be used to compensate the lack of knowledge about the seals. Figure 1(A) illustrates this valid probabilistic approach on an ideal structural section.

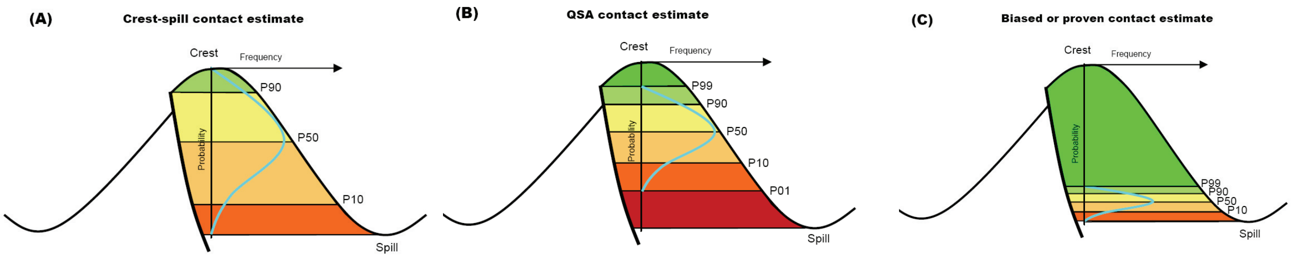

Figure 1 *Ideal 3 way dip fault bounded trap showing probabilistic contact estimates. (A) No specific Quantitative Seal Analysis (QSA) nor data i.e. a well on structure (B) QSA is narrowing uncertainty range (C) Biased estimate without QSA and/or absence of calibration; feasible if confirmed by QSA.*

To optimise the prospect evaluation workflow Wintershall has developed a corporate standard for seal evaluations which is systematically applied to all exploration projects. The methodology integrates top and fault seal workflows resulting in final structure-related hydrocarbon column heights. The approach is a comparative assessment of both top- and fault seal (if any) in terms of capillary breakthrough (membrane leakage cap rock / fault rock) and hydraulic failure of the top seal or (reactivated) fault. If not directly measured, capillary threshold pressures are predicted using state of the art published algorithms. Also overpressures and subsurface stress fields for hydraulic/mechanical fracturing are predicted if no direct measurements are available. An important point for parameterisation of the seal capacity calculations is the burial and tectonic history of the prospect: structural timing and onset of faulting are key parameters for the evaluation. Finally the minimum leak criteria for both the top and fault seals are comparatively evaluated (see Figure 2).

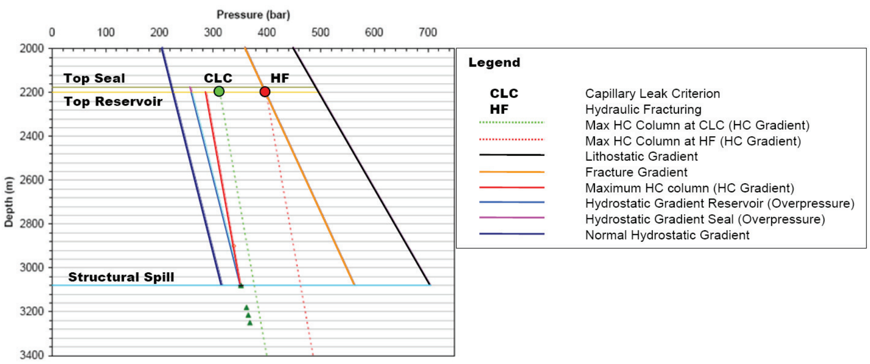

Figure 2 *Pressure depth plot showing the deterministic results of a quantitative top seal assessment. In this example the contact is controlled by the spill point, maximum hydrocarbon column heights for leak criteria Capillary and Hydraulic Leakage are far below the structural spill.*

Capillary leakage through seal rocks has been extensively studied in the past and the physical processes behind capillary leakage are well known. Once the capillary entry pressure for the sealing rock (top seal or fault seal) is predicted or measured uncertainty of column heights decreases considerably. However, the prediction of capillary entry pressures is still a challenge and afflicted with various uncertainties. On the other side the stability or the integrity of the top & fault seal is dependent on rock mechanics. Physical processes and algorithms for a quantitative assessment of mechanical fracturing of rock and its relation to stress and pressures are also known for long times: in principle, column heights are controlled by the pressure and stress field in the subsurface. Major uncertainties apply in case (over)pressures and tectonic stresses are not, or only at regional scale, known.

Despite the very uncertain nature of the top and fault seal input parameters, quantitative seal capacity studies and/or top and fault seal software are very often performed using single deterministic input parameters. However, looking to the complexity of the subsurface, single-value forecasts will hardly ever predict accurate column heights. Key deliverables of a quantitative seal analysis is to narrow uncertainty ranges or mitigate risk. In order to account for these objectives a proper statistical treatment is applied to propagate the uncertainty through the whole calculation. Finally *Monte Carlo* simulations are used to generate specific column height distributions related to the leak criterion respectively (See Figure 3).

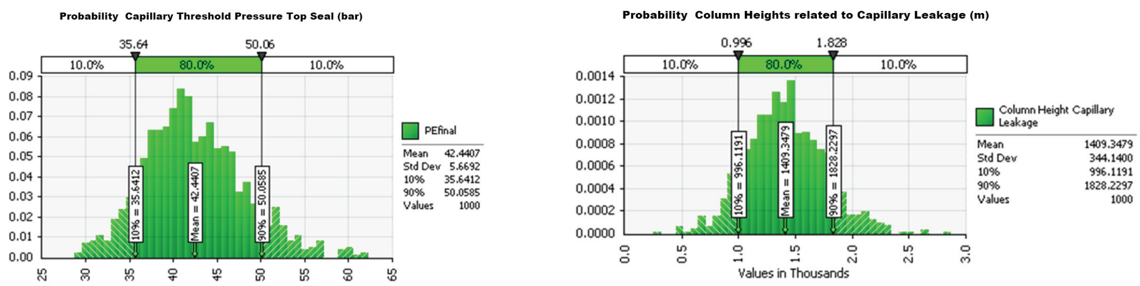

Figure 3 *Histograms showing the predicted distributions for capillary entry pressures (L) and associated column heights (R) on the example of a strong top seal as slightly lognormal distributions.*

The resulting maximum hydrocarbon column height distribution is then used as input for corporate volumetric assessment tools. Since a standardized application of QSA contributes to a more realistic volumetric assessment it finally contributes to a more realistic prospect ranking in the corporate portfolio. Examples from various basins will be used to demonstrate the great potential of integrated quantitative seal assessment, its limitations in carbonates and the application and integration of QSA in play evaluations. The comparative probabilistic assessment of top and fault seal capacity and its impact on play-to-prospect evaluation will be emphasized.