Assessing fault seal risk and fault seal retention capacity in stacked clastic reservoirs

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The prospectivity of structural or combination traps in stacked clastic reservoir settings typical of many of the known hydrocarbon provinces in Southeast Asia such as Baram Delta and Balingian province, often critically hinges on the presence of a working fault side seal. A thorough understanding of the key controls on fault seal risk and retention capacity and from there, a consistent methodology to access these factors across a prospect portfolio, are essential to achieve a balanced prospect ranking and an accurate assessment of prospect success volumes.

Faults in a clastic reservoir typically seal through either one of a combination of the following mechanisms: juxtaposition of reservoir against non-reservoir, the development of impermeable gauge within the fault zone either because of clay smear, mixing of sand and shale in the fault gauge, or through grain size reduction within the fault zone (cataclasis). Fault seals can be breached if pressure buildup exceeds retention capacity or in cases of fault movement post hydrocarbon emplacement. The objective of this paper is demonstrate how stochastic simulation of juxtaposition relationships along faults in combination with reference to literature published data on retention capacity of shaly fault gauges (e.g., Yielding et al., 1997; Yielding, 2002; Freeman et al., 2008) can be used to generate quantitative insights in the relationship between measurable reservoir properties such as net-to-gross ratio and typical thickness of reservoir sands and intervening shales, and the chances of fault seal success as well as the likely retainable hydrocarbon column in a success outcome. Quantitative estimates of the chances of success and the expected range of retention potential can be done for a single reservoir-seal pair, but they can easily be expanded to predictions for a series of stacked reservoirs using binomial distribution theorem. The paper will show how a simple but elegant toolkit incorporating these relationships can be used (Figure 1) to successfully replicate the hydrocarbon distribution of known discoveries (Figure 2, Figure 3) e.g., in Balingian province. A tool like this can be used to assess the fault seal success *Chance Factors*, i.e., the chances of fault seals being able to retain a hydrocarbon fill equal or exceeding the P90 area, in a consistent manner across a prospect portfolio. Whilst the methodology and toolkit described here considers the complete “outcome tree” of success and failure cases, it can also be shown that under certain specific circumstances many of the outcomes have extremely low probability of occurrence. For example, the retention capacity of shaly fault gauge should always be in the range of some 50psi or more even if the net-to-gross ratio is relatively high, which means that failure on Shale Gauge seal is unlikely unless there are significant pressure ramps or the fault re-activates post-hydrocarbon emplacement. By removing the low probability outcomes for specific cases under consideration, we can simplify the “outcome tree” to a set of simple rules that can guide an operator to identify leads prospects with a high chance of fault seal success.

References:

FREEMAN, B., YIELDING, G., NEEDHAM, D.T., BADLEY, M.E. (2008) ‘Fault Seal Prediction: the Gouge Ratio Method’, Geological Society Special Publications’, V. 127: 19-25

YIELDING, G., FREEMAN, B., NEEDHAM, D.T., 1997. Quantitative fault seal predication. AAPG Bulletin, v. 81, No. 6, 897-917

YIELDING, G., 2002. Shale Gauge Ratio – calibration by geohistory. In Koestler, A.G. & Hunsdale, R. (Eds.) ‘Hydrocarbon Seal Quantification’, NPF Special Publication, Elsevier Science, V. 11: 1-15.

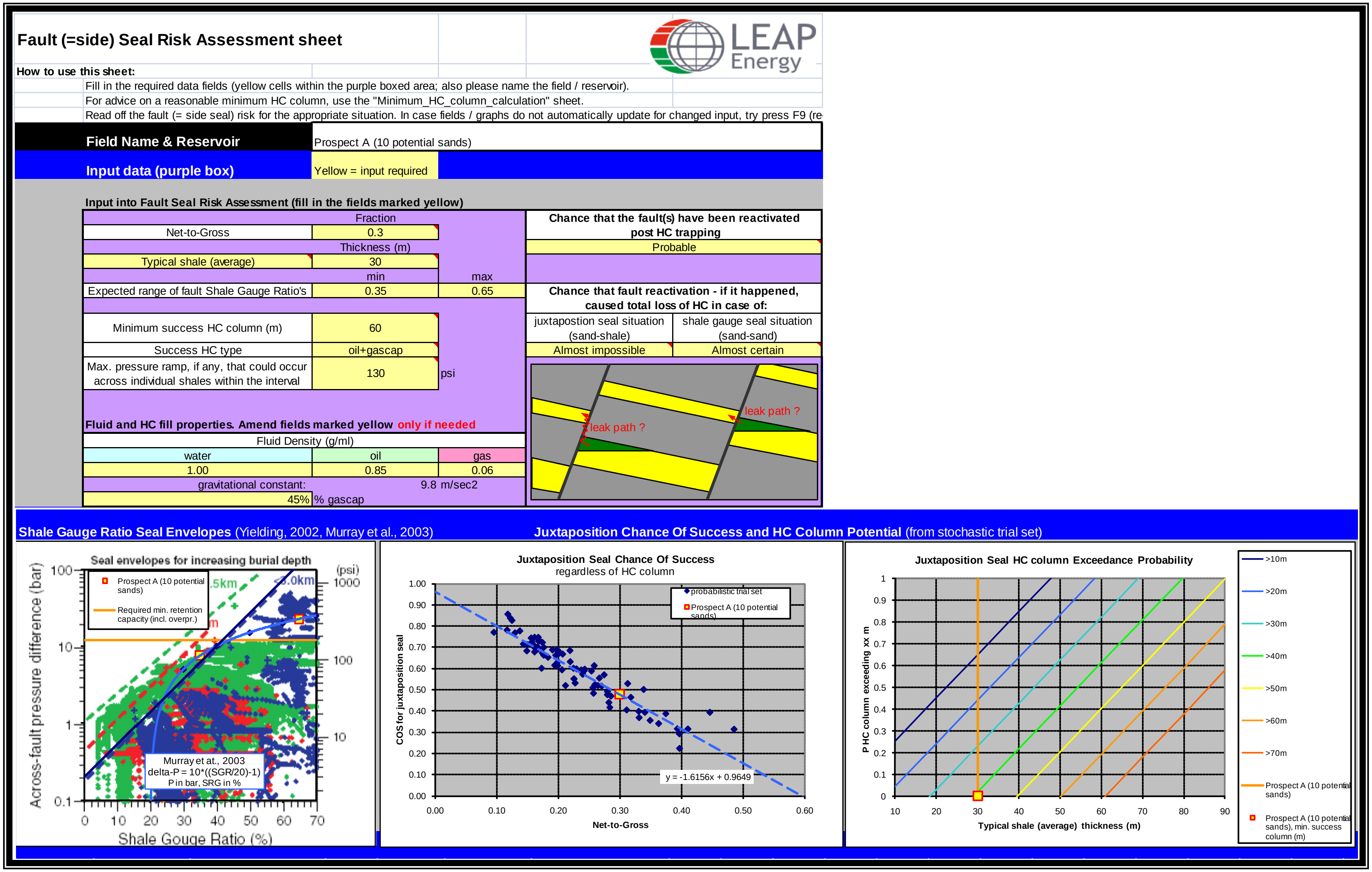

Figure 1. Example of use of our faultseal risk assessment toolkit on Prospect A, offshore Sarawak. Top portion shows the input data; bottom part of the figure illustrate some of the chance factor estimates for specific seal mechanisms.

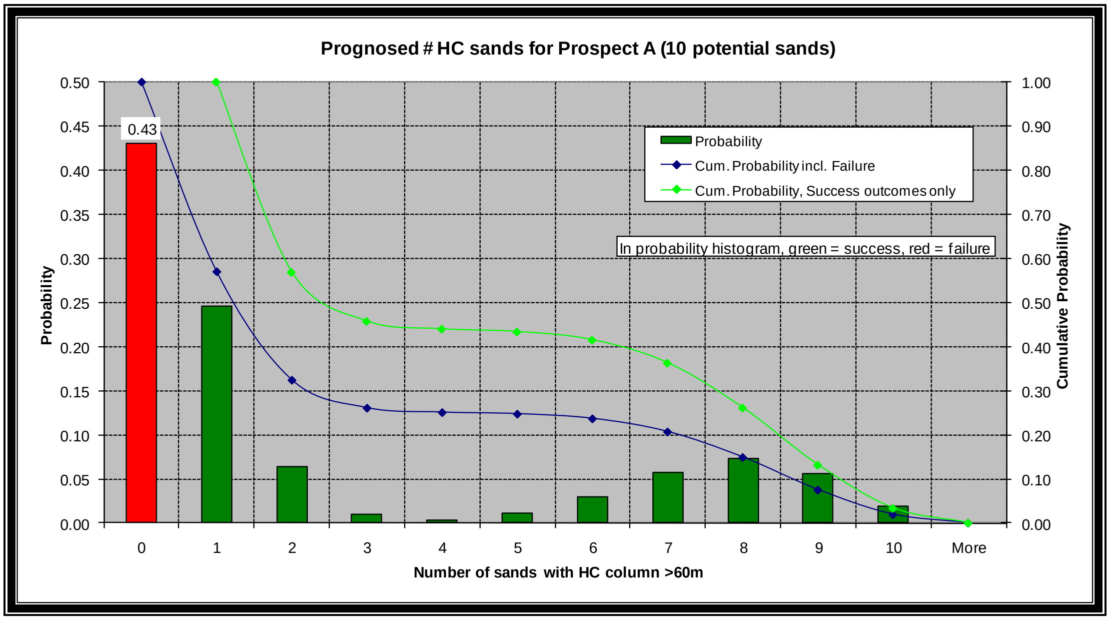

Figure 2. Fault seal Chance Of Success (COS) prediction for Field A, for an aggregate of 10 potential reservoir zones. This simulation of fault seal success considers all possible seal mechanisms and aggregates the individual chance factors. Simulated fault seal results compare well with the findings in fields nearby to Prospect A where only 10 to 40% of the sands have significant HC fill (column length >60m).

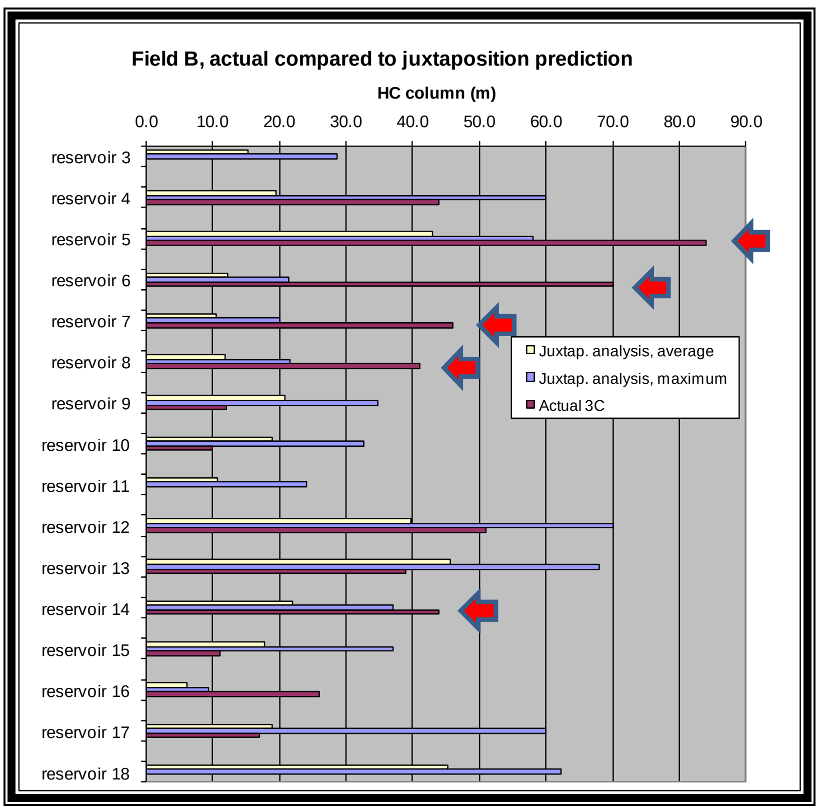

Figure 3. Predicted potential for juxtaposition seal for Field B, compared to actual well results. Note that the trends in predicted column height match the actually observed HC columns fairly well, suggesting juxtaposition seal is one of the key sealing mechanisms in Field B. The red arrows mark reservoirs where other seal mechanisms (e.g., shale fault gauge) may play a role as actual HC columns are significantly beyond the estimated juxtaposition seal retention capacity.