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Stochastic Trap Analysis and Risking - A Multi-seed Stochastic Approach to Fully 3D (Geocellular-based) Trap Analysis

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SUMMARY

Trap analysis is inherently a three-dimensional problem involving fault geometry, stratigraphy, and seal integrity. The complex interplay of these elements can make it very difficult to understand and visualize the controls on column height – even for a trap analysis expert. Compounding the issue is the uncertainty associated with reservoir distribution, fault offset and seal thickness. Despite the often equivocal nature of the input, fault seal analysis in the industry has historically been done in a deterministic manner with some attempt at varying the stratigraphic model to give low, medium and high cases. Further, the calculation of fault sealing potential has commonly been done on a per fault basis rather than within the greater context of a trap framework. There are, of course, vendor products and practitioners that address column height prediction in an integrated and perhaps stochastic fashion. However, it could be argued that these practices have created a perception that fault seal analysis is a black box affair, which is often perceived as an 'art' rather than a rigorous investigation.

Further, fault seal analysis has traditionally employed workflows that include juxtaposition analysis and/or calculation of column height associated with the capillary entry pressure of fault zone material. The emphasis on the relative importance of shale gouge ratio (SGR) vs juxtaposition, or other controls on column height, varies from one camp to the next. Regardless of which process is applied, quite often any sensitivity analysis of fault seal parameters is disconnected from the original input (interpretation and supporting data) and the uncertainty of the results is difficult to quantify. Commonly, this lack of a feedback to the interpreter, and the inability to establish relevant uncertainty, reduces credibility of the result.

A Shell proprietary toolkit, STAR (Stochastic Trap Analysis and Risking), provides an all-in-one application for addressing critical trap elements by combining container geometry and reservoir distribution with top seal risk and fault sealing potential. Operating on Petrel geologic models, STAR requires only a vshale or net-to-gross property as input. Fault leak can be controlled by juxtaposition, SGR or a hybrid combination of the two. For each model realization, a volume case is generated, along with fault properties (displacement, juxtaposition and SGR), fault spilling cells and contact surfaces.

Fundamental to its design principles, is the ability to visualize and interrogate STAR's output in 3-D. To this end, all STAR objects and properties can be 'touched' in the Petrel canvas. This ability to visually inspect and cross-correlate output within a geologic context (i.e. structural and stratigraphic framework) makes trap analysis more accessible to the non-specialist and specialist alike. Not only does this aid in the understanding of controls on contact distribution, but it also provides a QA/QC feedback loop on framework construction. This facility to simply and interactively investigate the impact of modifying input variables is considered critical to sound trap analysis.

For the Exploration scale, we offer a multi-seed stochastic trap analysis workflow and technology that addresses variations in container geometry, fault throw and stratigraphy. Through the use of geocellular models, the user can perform three-dimensional fault seal analysis while stochastically varying one or more of these customizable parameters. By doing so, sensitivity of results to variations in input can be established and validity of column height distributions can be better assessed (i.e. what makes it a big column versus a small column). As part of this process, mechanical seal capacity and structural spill are reconciled with fault leak to establish column heights on a per container, per segment, per reservoir, and per trial basis. Ultimately, the results are convolved to calculate volume probability distributions.

At the Development and Production stages, when more deterministic models can be employed, STAR can be used for reservoir connectivity analysis. Contact dependencies between fault blocks and reservoir units can be evaluated by tracking reservoir connections and convolving container geometry with fluid pressures (currently in development).

In summary, the STAR technology and associated workflows have broad application across the Upstream workflow. They offer a capacity to work with poorly constrained stratigraphy, at Exploration scale, to increasingly deterministic input as additional control is gained in Development and Production phases. Rather than assessing trap integrity on a map by map basis, the process addresses fault seal analysis, MSC and structural spill point control in a robust and fully 3-D fashion.