Insight in Lieu of Truth: an approach to probabilistic fault seal analysis*

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The height of fault-supported hydrocarbon columns is dependent on a number of intrinsic and extrinsic factors. These include fault geometry, fault zone architecture, host and fault rock permeability and fabric, stratigraphic stacking pattern, and hydrocarbon and water densities as well as the overall trap geometry and presence or absence of a hydraulic head. Continuous variation in controlling factors can yield both continuous and discontinuous variation in the resulting trapped columns. Even more than most geologic analyses, faulted column height prediction is an under-constrained task and is thus well suited to a probabilistic approach in which the range of input uncertainty is explored.

However, probabilistic models should complement not substitute for careful analysis of the available data. Often structural analysis is key, as trap geometry is the most important factor and is typically the most constrained by data. Depth structure maps should be made on multiple horizons and the faults should be interpreted in map and section view and linked to the mapped surfaces. From these maps, throw variation can be evaluated systematically to confirm the interpretation integrity and gain insight on possible sub-resolution fault complexity. The relative importance of the other factors varies with geologic history so that factors that dominate in one basin may be insignificant in another.

Once all available data have been in analyzed the remaining uncertainty can be explored in two steps. First is to identify the uncertainty ranges and estimate the impact on column height of the controlling factors. Some factors, such as fault surface and fault zone architecture, have discontinuous impacts on column and thus can only be understood in terms of specific scenarios - e.g. the presence or absence of sand-on-sand windows. Other factors, such as the fluid properties and estimated capillary properties, have a linear or at least continuous impact and can be evaluated by simple error analysis. Second, probabilistic methods can be used to quantify the residual uncertainty of the first-order factors. Second order factors, those that do not contribute significantly to the variance in column height, should be left out of the probabilistic analysis. As Einstein is quoted, “Make everything as simple as possible, but not simpler.” To ensure meaningful results, column heights must be calculated from the geometry and underlying physics for specific deterministic scenarios. Taking care not to interpolate between distinct scenarios, the resulting column heights can then be aggregated and analyzed using standard statistical techniques.

When analyzing the results, keep in mind that, beautiful 3D visualizations not withstanding, models are simplifications of nature and not nature itself. Do not assume the mean result is the best estimate. Rather, use the results to (1) make explicit the uncertain knowledge of controlling parameters and (2) assist in distinguishing independent and dependant parameters, and (3) determine the degree of impact of those parameters on hydrocarbon column height. In short, seek to gain insight, not truth, from the model.