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"Say What We Mean and Mean What We Say": The Unified Upstream Risk Model as a Force for Shared Understanding*

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Abstract

The evaluation of geologic risks associated with plays, prospects, unconventional resources and development and production drill-wells is a fundamental component of the upstream asset evaluation process at ExxonMobil. The results of these analyses determine not only the estimated chance-of success of an opportunity, but also a prediction of the assets' hydrocarbon volume potential.

Geoscience risk models have evolved over many decades of research and application. A new synthesis - the "Unified Upstream Risk Model" - has been developed at ExxonMobil. This initiative has been driven by a desire to promote greater common understanding of assessment terms across the global geoscience and management communities within the company, and to ensure consistent application of risking concepts worldwide.

Without such a unified model, understanding of the definitions of each of the geologic risk factors and their related volumetric products may be inconsistent. Such inconsistencies may potentially lead to confusion, both during the analysis phase, and when communicating results to management and decision-makers. Consequently, it may be difficult to fully comprehend assessment results, and compare them easily between opportunities. The aim of the new "Unified Upstream Risk Model" is to enhance and align appreciation of petroleum systems, and how interpretation thereof translates into risk severity judgments.

When geoscientists and management all share a common understanding of the definitions of the individual geologic risk elements, their products, and the associated volumetric measures presented, investment decision-making are significantly optimized. Each asset under consideration can now be evaluated via a fulsome discussion of its technical merits, without encumbering the discussion with

misunderstandings regarding terminology and descriptors. Furthermore, application of the consistent definitions and principles outlined in the model across the upstream companies ensures that all assets and opportunities worldwide are evaluated on the same numerical basis and can therefore be truly compared, like-with-like, in order to make appropriate investment decisions.

Common Understanding

The essence of a cleanly functioning unified risk model is that it should be adaptable to all types of hydrocarbon resource assessments and applicable in all geologic circumstances. In the modern petroleum industry this includes conventional play and prospect evaluations, production well analyses, and assessments of unconventional or continuous resources such as shale gas, coal-bed methane and oil sands. The risk model presented in this paper – the Unified Upstream Risk Model – achieves this by preserving a consistent risk-element structure for all types of resources, each with a specified definition of the conditions for success and failure, and an inventory of factors that should be considered when evaluating each factor in different resource-type setting.

By ensuring a common understanding of the definitions of each of the risk factors, in all resource-type and geologic settings, both amongst geologists, and between geologists, engineers and managers, much confusion can be avoided. The aim of the Unified Upstream Risk Model is to ensure this clarity exists and to provide unequivocal guidance on the precise definitions of the risk factors. This simplifies discussions both within peer groups and during communication of hydrocarbon volume assessment results to managers and decision-makers.

Risk Factors Through Time

Throughout the history of the petroleum industry different companies and industry bodies have recommended, proposed or adopted the use of different numbers of geologic risk factors when attempting to estimate the probability of hydrocarbons being present at any given drilling location, prospect or play. The essence of all these schemes has been to balance the desire for simplicity and comprehensibility with the demand for maintenance of independence between individual risk elements. This has been, and still is, a somewhat subjective exercise. Different institutions and companies have preferred fewer risk factors, which could therefore cause the risk factors to be interpreted as not fully mutually independent. This has often been done to make the risking process simpler and more tractable. Meanwhile, other organizations have preferred to ensure that all the risk factors are indeed mutually independent, which has resulted in an increased number of risk factors.

ExxonMobil, and its antecedent companies, has experienced the same healthy tension between these competing objectives. Since the 1980s, the company’s risk scheme has been modified several times to address changing business needs. This has resulted in the number of risk factors used in ExxonMobil changing from four, to eight, to seven, and finally to nine, where it now remains, for Exploration assets and Near Field Wildcats, and to 13 for Production wells.

The Geologic Risk Factors

The nine independent geologic risk factors used in the Unified Upstream Risk Model, for exploration opportunity evaluation, are as follows:

- Trap Closure
- Trap Seal
- Reservoir Facies Presence
- Reservoir Quality
- Source Richness
- Source Maturation
- Migration Pathways
- Trap-Migration Timing
- Hydrocarbon Recovery

Each risk factor's chance of adequacy is evaluated against an assessment or geologic Minimum hurdle volume, which is used to define the boundary between success and failure. Within the risk model, each of these factors is defined for each resource type, where appropriate, and illustrated with schematic examples in order to ensure consist understanding and application by geologists across the company. An example of the definition of one of the geologic risk factors, Trap Closure, is illustrated in Figure 1.

Contrasting Resource Types

The efficiency proffered by the Unified Upstream Risk Model is that it addresses all types of hydrocarbon resource currently being evaluated in the oil and gas industry. This includes conventional plays, conventional prospects, production wells, and unconventional/ continuous resources. This diversity of resource type being addressed by a single risk model demands that the conditions for success and failure be clearly defined for each setting. Geologists also need to know what circumstances and observations are pertinent to recognize and make in order to prosecute the evaluation of each risk element.

For the Trap Closure risk element, Figure 2 illustrates how the condition of success for the element is manifested in each resource type. In addition, a "Consider" list is also provided. This list prompts the geologist to make the relevant observations from their data, and to address each of the circumstances and issues pertinent to the risk factor, when making their risking judgments. Some of these factors may not be immediately obvious, particularly if the geologist undertaking the evaluation has not worked extensively with a particular resource-type in the past.

Stratigraphic Traps

Confusion often results when risking stratigraphic traps. Geologists are frequently unclear as to whether particular observations and concepts are relevant to the Trap Closure or the Trap Seal risk element.

It is important to clearly define the difference between the two. Trap Closure pertains to the chance that a geologic configuration will exist in the sub-surface such that at least the geologic Minimum volume of recoverable hydrocarbons can be retained. Examples of these types of configurations include four-way dip closures, three-way fault trap closures, closures against salt domes, sub-unconformity traps and stratigraphic traps. Therefore, a run of dip, if a seal can be invoked, can be considered a valid Trap Closure. The risking of Trap Closure is against the concept of the prospects structural configuration, as interpreted, not against the chance of four or three-way structural closure existing.

Trap Seal, on the other hand, describes the chance that a sealing lithology will exist above, around and/or below the interpreted reservoir such that at least the geologic Minimum volume of recoverable hydrocarbons can be retained. When risking Top Seal, one must address the probability of such a lithologic barrier existing which will prevent hydrocarbons from escaping from the interpreted trap to another location. This is distinctly different from evaluating the probability that a geologic configuration exists that could collect the hydrocarbons.

Figure 3 outlines some examples of distinguishing between the Trap Closure and Trap Seal risk elements when evaluating stratigraphic traps.

Production/Mechanical Risk Factors

One of the enhancements that the Unified Upstream Risk Model provides over existing risk schemes is its capacity to assist with the risking of production wells. Production wells do not have a chance of success of 100%. Indeed the global historic success-rate for production wells is nearer 85%. Some of the failures are owing to unanticipated within-field geologic complexities, such as reservoir pinch-out or erosion, diagenetic issues, or undetected structural complexities.

Production drill-wells differ from exploration wildcats in that they must ultimately produce hydrocarbons, not just prove their existence. Additional risks are present that can cause a production well to fail. Four such elements have been identified for production wells.
They are:

- Drilling and Mechanical
- Completion Mechanical
- Completion Reservoir
- Reservoir Management

Post-set Pipe risk versus Pre-set Pipe risk

Risking a production well is more complex than risking a conventional prospect or play. This is in addition to the introduction of the four extra risk elements. This complexity is introduced because there are two ways in which a production well can fail.

Firstly, a production well may reach TD, but it may be obvious from data acquired at that time, before a decision to complete the well is made, e.g. well logs, that there are no producible hydrocarbons at that location. This is termed pre-set pipe risk. The pre-set pipe chance of success is the probability that, upon cessation of drilling and prior to completion, i.e. in open hole, the reservoir target will appear to contain greater than the minimum volume of hydrocarbons necessary to justify attempting a completion on a money-forward basis.

Secondly, it may appear, at the time the well reaches TD, that hydrocarbons are present to satisfy this money-forward threshold which justifies the attempt at a completion, only to find that when ultimately produced, the well fails to make the minimum volume necessary to have justified the setting of casing and completion of the well. This is termed post-set pipe risk. The post-set pipe chance of success is the probability that the geologic configuration perceived to be adequate at the time that the completion decision and completion was made is ultimately sufficient to recover the minimum volume of hydrocarbons necessary to have justified spending the money to make the completion.

An example of the definition of one of the production risk factors, Reservoir Management, is illustrated in Figure 4, and the definition of the risk factor and the associated “Consider” list are shown in Figure 5.

Conclusions

The evaluation of geologic risks associated with plays, prospects, unconventional resources and development and production drill-wells is a fundamental element of evaluating oil and gas investment opportunities. These judgments drive the business of a petroleum company, establishing the risk hierarchy of opportunities that a company may wish to pursue.

Geologic risk models have evolved over the years, both between and within institutions and companies. However, the essence of an efficient risk model is that it should be easy to understand and apply, and be relevant to all resource-types and geologic settings. The Unified Upstream Risk Model presented in this paper attempts to do this. Its development evolved out of a desire to promote common understanding and application of the geologic risking process across the scientist and management communities within a large integrated oil and gas company.

When geologists and managers share a common understanding of the definitions of the individual geologic risk elements, investment decisions, partially made on the basis of an estimated chance of success of finding commercial quantities of hydrocarbons in the competing opportunities, are enhanced. Each opportunity under consideration can now be evaluated on its technical merits, without encumbering the discussion with misunderstandings regarding terminology.

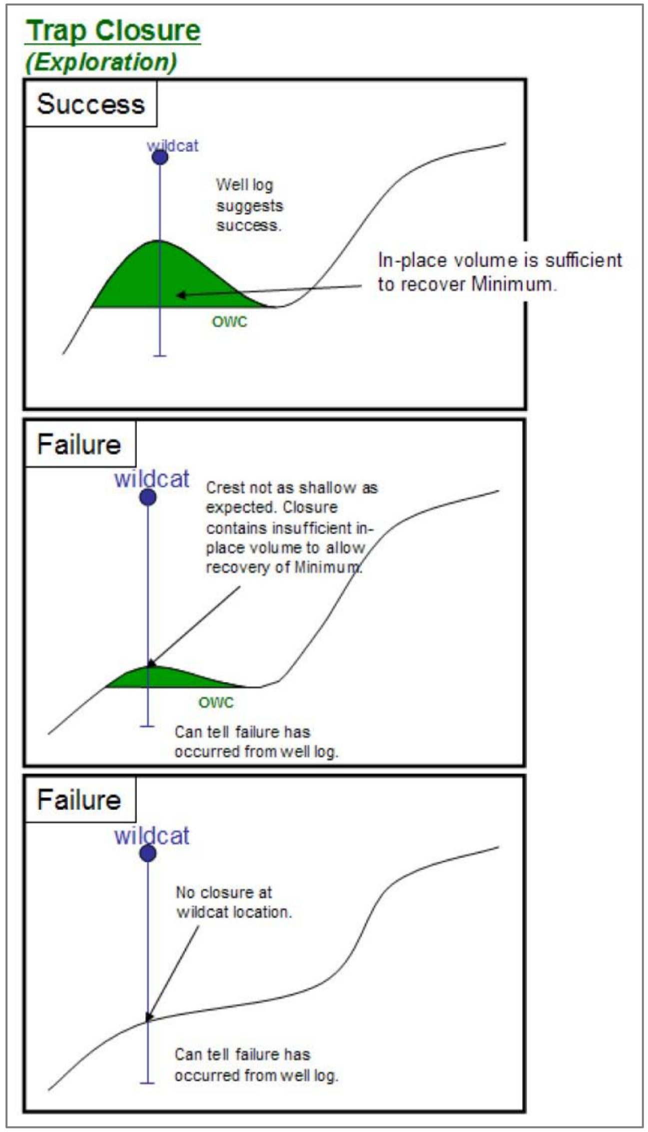

Figure 1: Trap Closure risk element example (exploration setting).

The chance that a geologic configuration will exist in the sub-surface such that the……

- *Play*: …..prospect could potentially contain at least the Minimum volume of recoverable hydrocarbons, i.e. the Large Field Minimum (LFM).
- *Prospect*: …..segment could potentially contain at least the Minimum volume of recoverable hydrocarbons, i.e. the segment Assessment Minimum.
- *Well Target*: …..target could potentially contain a volume of hydrocarbons associated with an economic success on a money forward basis. (Pre-set pipe & Post-set pipe|Pre-set pipe)
- *Continuous* ("unconventional"): …..assessment polygon could potentially contain sufficient resource density for a well to produce at least a Minimum volume of recoverable hydrocarbons.

Consider:

- *closure height, closure area, up-dip pinchout (strat trap)*
- *trap geometry,*
- *tectonic domain,*
- *structural style,*
- *velocity control,*
- *seismic coverage,*
- *seismic quality,*
- *post-charge deformation,*
- *valid tests of similar trap configurations.*

Figure 2: Trap Closure risk element definitions.

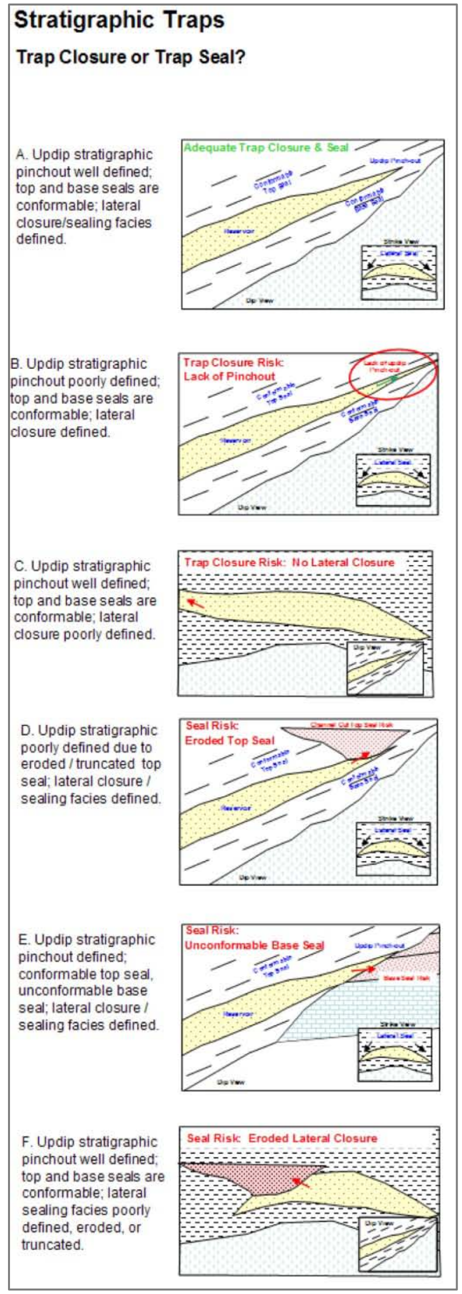

Figure 3: Stratigraphic traps: Trap Closure or Trap Seal?

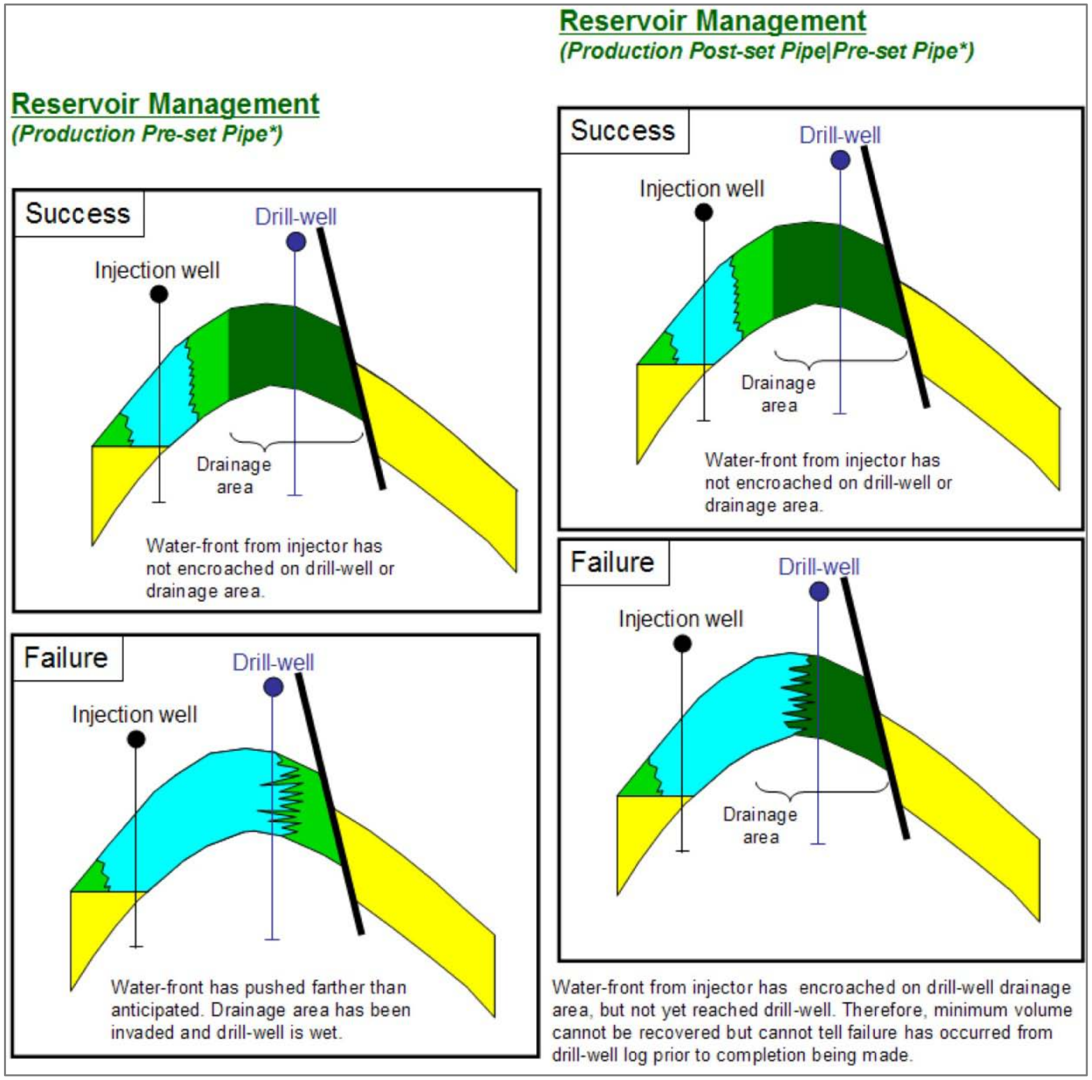

Figure 4: Reservoir Management risk element example (production setting).

The chance that previous hydrocarbon production or management activities within or affecting the reservoir comprising the target will not prevent ……

- *Play*: …..N/A
- *Prospect*: …..N/A
- *Well Target*:…..the minimum volume of recoverable hydrocarbons necessary to justify the completion to be produced. (Pre-set pipe & Post-set pipe|Pre-set pipe)
- *Continuous* ("unconventional"): …..N/A

Consider:

- *water-front encroachment,*
- *production/injection-induced hydrocarbon phase replacement,*
- *production-induced contact tilting,*
- *pressure depletion,*
- *early water or gas breakthrough,*
- *misleading formation evaluation at the time of the completion decision,*
- *early onset of gas exsolution or condensate drop-out,*
- *condensate banking.*

Figure 5: Reservoir Management risk element definitions.