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NEW WORKFLOWS FOR PROBABILISTIC CHARGE RISK ANALYSIS

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Recent developments in 3D petroleum systems analysis include fast Monte Carlo based simulations of volumes of oil and gas expelled from source rocks within the fetch areas of specific prospects. Migration losses and timing of trap formation may be risked at the same time. These results can be used to help construct oil-in-place probability distributions and to directly estimate probability of charge.

A typical charge analysis workflow involves defining a prospect with a polygon on the reservoir surface, then analyzing migration flow paths to delineate a fetch area for that prospect, and finally calculating the volumes of oil and gas that were expelled from the source rock through time within that fetch area (Figure 1). Such a result is known as a "fetch history" (Figure 2). A deterministic approach to charge prediction would stop at this stage, yielding a precise—but perhaps not very accurate—predicted volume. The problem is that the volumes obtained in a single fetch history calculation rely on many variables and the implicit assumption that they are well estimated or accurately calculated is usually not justified. Variables such as the thickness, richness and kinetic type of the source rock, its depth and temperature history, and migration losses are typically poorly constrained, whether they are input directly by the user or calculated during the simulation.

We address this problem by taking a probabilistic approach to fetch history and charge volume prediction. We build probability distributions to capture the uncertainty of key variables. Then, instead of running the fetch history one time using best estimates of each variable, we run it thousands of times and each simulation randomly pulls values for each variable according to the distributions the user has constructed. The results feature plots such as probability distributions of oil and gas charge volumes (Figure 3).

There are barriers to incorporating Monte Carlo approaches to charge volume prediction in a way that is practical and useful for real-world exploration projects. First, the simulation of burial, thermal, and generation/expulsion history in the fetch area, and of migration to the trap, needs to be fast enough that it is practical to repeat thousands of times without sacrificing stratigraphic resolution. In fact the ideal simulator should be essentially interactive, so that the implications of different geological assumptions can be immediately assessed. This is not the case with most 3D basin simulators which tend to be slow when run with full seismic resolution and are never interactive. On the other hand it is highly desirable that the simulator be integrated with the maps and burial, thermal and generation calculations since the probability distributions of some variables are best built on the fly as the fetch history is being calculated.

Anadarko and other exploration companies have participated for several years in a research consortium to develop an application called Trinity. It has become the primary tool at Anadarko for building comprehensive multi-dimensional models of petroleum systems and is used for most large frontier exploration projects where charge is perceived as a sensitive risk. Trinity is an example of a *map-based* 3D tool, meaning that each model is built around a stratigraphic framework comprising maps of chrono-stratigraphic surfaces. Temperature and pressure relationships are added to the model along with source-rock characteristics such as kinetic type and richness and maps of facies distributions that control migration properties. All of these parameters may vary spatially and temporally and these variations are also described with maps. The simulations of the petroleum system are interactive, and they include temperature, pressure, paleo-structure and maturity through time as well as migration flow path simulations and phase behavior within traps.

Trinity Monte Carlo simulations are very fast: thousands of simulations can normally be done within a few minutes on an ordinary PC (grid-cell size and the size of the fetch area affect the time required). Built-in plots are then generated showing frequency distributions of charge volume bins, cumulative probability graphs that indicate key probability values and means for both oil and gas (Figure 3), and tornado plots to assess the relative sensitivity of the results to each risked variable. The probability of charge is essentially the probability at which charge volumes exceed zero. The variables that are riskable in the current version of Trinity are: source rock (SR) depth, SR thickness, hydrogen index, TOC, generation kinetics, size of fetch area, thermal gradient, timing of trap formation (structuring or seal formation), and oil and gas migration losses. Since many of these quantities are calculated on the fly by the model, and also vary over the fetch area, the actual distribution of values is also constructed on the fly and the user's input is relative. For example, source rock depth: the user does not put in an absolute value for P50 and P90 in the case of a normal distribution, but rather uses proxy numbers and Trinity will obtain the real P50 number from the map value at each grid cell and build an appropriate distribution.

Examples will be shown in this presentation of recent international projects in which this tool has been used along with some simple hypothetical examples to illustrate the concepts and workflow.

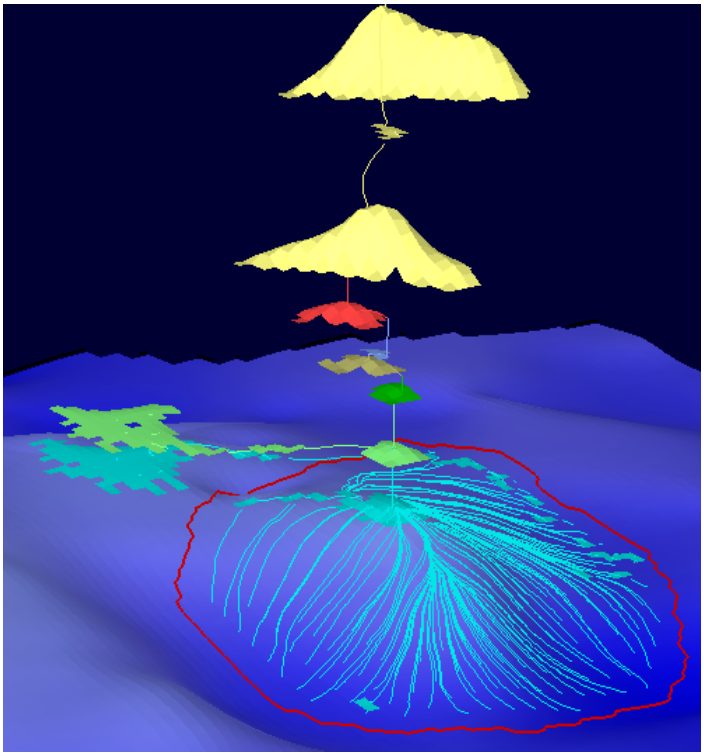

Figure 1. Several predicted hydrocarbon accumulations (colored blobs) in 3D space that share a common fetch area. For simplicity, only the source rock layer (blue) is shown. The fetch area is outlined in red.

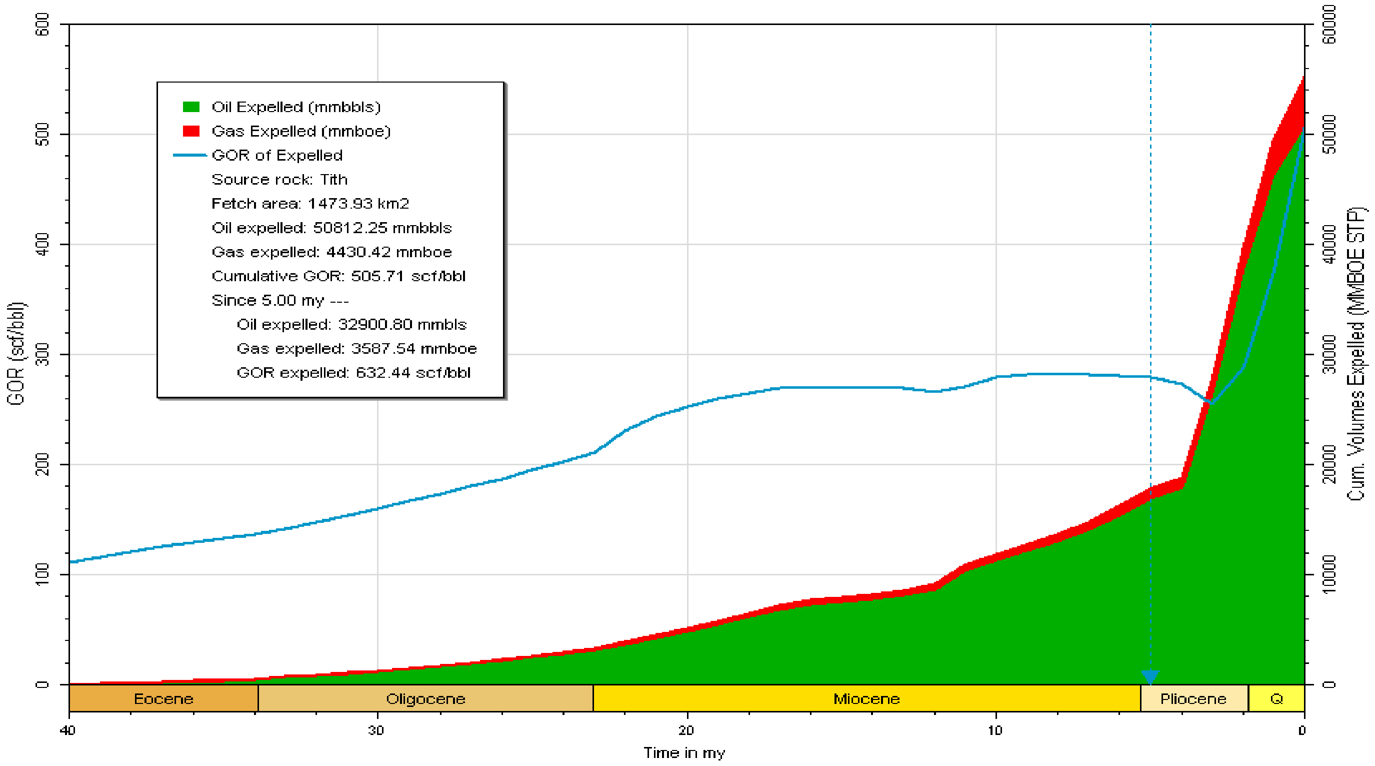

Figure 2. Fetch history calculation for fetch area of Fig. 1.

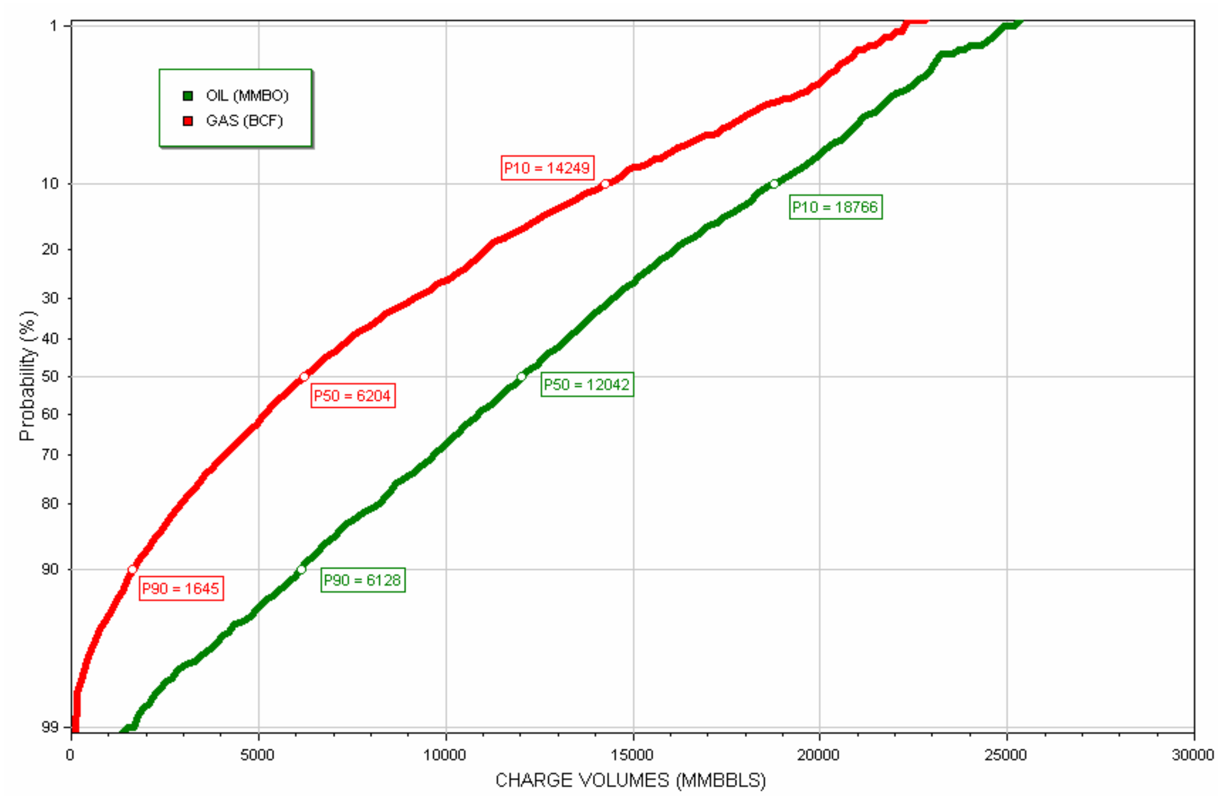

Figure 3. Cumulative probability graph of volumes expelled for a large (play-size) fetch area full of rich, mature source rock.