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Advances and Perspectives on Stratigraphic Trap Exploration-Making the Subtle Trap Obvious

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ABSTRACT

Stratigraphic trap exploration principles have been established for nearly 80 years since first being classified by A. I. Levorsen in 1936. Advances in understanding of the wide variety of traps accelerated in the 1950's and 70's, including hydrodynamic and pore-throat capillary traps. In 1977, a step change occurred when AAPG and Exxon geoscientists released their classic papers on seismic stratigraphy. Over the ensuing decades, sequence stratigraphic models and nomenclature have proliferated. There remains, however, the fundamental need to integrate seismic, wells, cores, logs, petrophysics and biostratigraphy to map chronostratigraphic packages and recognize new traps. Creaming curves of giant field discoveries show that a significant step-change in stratigraphic and combination traps discoveries has occurred since early 2000, driven largely by 3D seismic imaging. The objective is not to look for a subtle trap, but to make the subtle trap obvious.

Stratigraphic and combination traps comprise 15-20% of the 2.8+ trillion barrels of recoverable oil contained in giant traps (>500 mmboe), despite the dominance of the absolute numbers of stratigraphic traps over structural traps in many basins. The smaller proportion of reserves is due primarily to a lack of significant numbers of stacked pay zones common to fault and anticlinal traps.

Trap volume, if not charge limited, is controlled by the weakest seal. While only top seals are needed in -way closures, additional lateral and bottom seals are needed in all other traps, increasing risk. Seal recognition from seismic, wells and test data is thus critical. Fluid Inclusion Stratigraphy (FIS) is an additional tool, offering a unique ability to detect seals, migration pathways and fluid phase. Seal edges are also commonly diffuse, with waste zones up dip of commercial reservoirs. How many dry holes containing tight reservoirs with hydrocarbon saturation demonstrating a column are actually within waste zones and either lateral or up dip of commercial accumulations?

Large stratigraphic traps are favored by low structural tip and are often drilled through and unrecognized until years later, particularly in waste zones. These traps are recognized by careful analysis of oil and gas shows, rock petrophysics, pay behind pipe or even wells within closed structures, where hydrocarbons occur below spill point. Recent discoveries in Russia (2007) and the Alaska North Slope (2016) provide examples.

Turbidite fans, slope channels and carbonate buildups dominate recent giant stratigraphic discoveries. In addition, seismic DHI's, particularly in offshore Tertiary strata, have driven much of this success. Shelf edge 'clinoform' plays associated with prograding clastic and carbonate

margins are also significant. Recent carbonate reef plays such as Zohr in Egypt (2016), illustrate that even some large, obvious traps are overlooked by many oil companies.

Advances in seismic acquisition and imaging have substantially improved mapping reservoir temporal and spatial distributions. Examples from offshore East Africa and Brazil demonstrate the need to view large-scale variation in depositional systems across a basin and how it is possible to predict depositional facies, geometries and connectivity.

Seismic inversion, the use of semblance data, and seismic wavelet classification go beyond simple amplitude maps and help define the distribution of reservoir-prone facies. The challenge is to extract enough data at a wavelet scale to make large, subtle stratigraphic traps obvious. All geoscientists need to think in terms of scale when working with seismic data. Amplitude extractions over 50-200 milliseconds of data, for instance, often cover hundreds of meters of section, far too coarse to visualize individual sequences.

Advances in petroleum systems migration modeling software also provides new ways to visualize potential traps. Conversion of paleogeographic maps or seismic reservoir images to reservoir-seal pairs expressed in displacement pressure differences or meters of column height for a given fluid phase can reveal multiple potential stratigraphic traps along a migration pathway. Hydrodynamic trapping can also be readily modeled, not only in shallow meteoric strata, but in deep, over-pressured basins. A number of giant fields with tilted oil-water contacts have been found or recognized in deep basins in the last decade, caused by upward flow of water from de-compacted shales. How many dry or uncommercial wells at the crests of large structures are dismissed as charge-limited, rather than tilted?

The tools needed to find economic stratigraphic traps remain, first and foremost, the belief that such traps exist. Integration of full ranges of subsurface data reduces risk, but also requires an awareness of the breadth of potential trap types, something gained only with experience and training. Increasingly, successes have belonged to smaller companies and independents, with experienced staff willing to take a new look at old areas or new plays in frontier areas.

For those that learn to do this well, the future is bright.