Capillary Seals and Petroleum Migration: Theory, Observation, Modeling, and Risking

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In the past 30 years, much effort has been put into the understanding of HC generation processes, such as heat flow modeling and kerogen kinetics and the composition of HC generated. There has been much less work on the key factors controlling petroleum migration, and what happens to fluids during migration, and methods for quantifying petroleum charge risk.

Recently we have been studying spatial distribution of petroleum accumulations in structural and stratigraphic context using Trinity 3D and HotSpot, with global datasets that include millions of wells, and thousands of fields from various databases. We observe strong correlation of migration patterns and structural and stratigraphic controlled capillary properties. The data clearly demonstrates the tendency for long distance lateral migration in some systems, and for vertical migration that form stacked reservoirs in others. The patterns also explain how capillary properties exert important controls on gas vs oil distribution, such as proposed by Sales 1997.

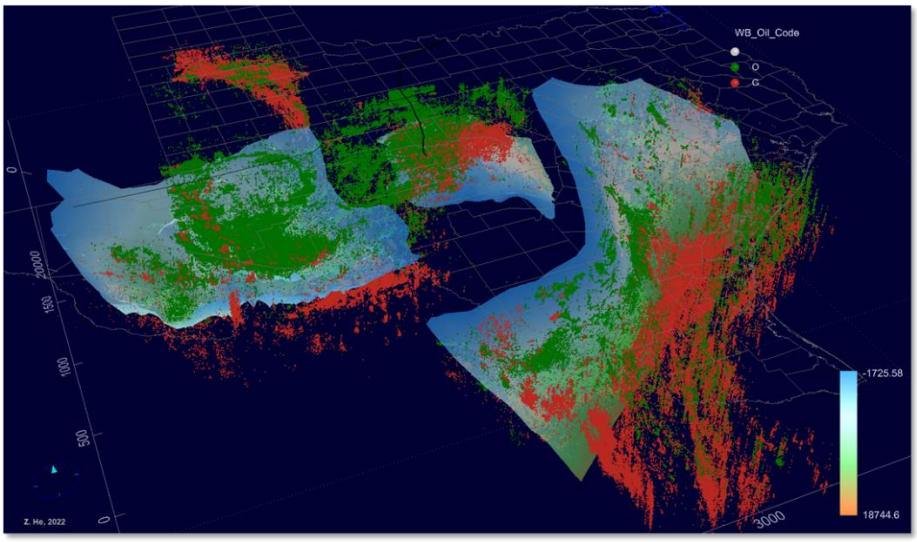

Figure 1 3D distribution of oil and gas in Texas basins. Migration patterns and distribution of oil vs gas are strongly controlled by the different geological settings and associated capillary properties.

In addition, uncertainty analysis of datasets for column heights of petroleum accumulations, association of capillary properties with depositional environments, and phase behavior observed from large PVT and field databases, allowed to develop tools for both probabilistic modeling of petroleum migration, and prediction of fluid phase and properties for prospects.

In this presentation, we will also discuss our findings on migration rates, distances and their controlling factors, concept of migration lag and its control on charge timing, and fluid properties.

Dr. Zhiyong He graduated from the University of South Carolina with a PhD in Geology, with focus on basin modeling and basin analysis. After working as a research geologist at Atlantic Richfield for 10 years, Dr. He Founded ZetaWare, Inc. in 2000 and started a consortium with several oil companies to develop petroleum system analysis and basin modeling software tools with a very different focus: an interactive toolkit for easily integrating various kinds of data, quickly run multiple scenarios, and probabilistically determine various charge related risks and resource volumes. ZetaWare's software suites have been licensed by majority of major oil and gas companies, many independents, and research institutions worldwide.

ZetaWare's Trinity 3D software suite has been used in the discoveries of most of the important giant oil and gas fields since its debut in 2003: Jubilee, Mangala, Leviathan, Johan Sverdrup, Tortue, Orca, SNE/Par, Zohr, Liza, Zama, Dorado, and recently Venus.

In recent years, Dr He has been working with various large petroleum fluids and fields databases using HotSpot, the latest geospatial data analytics tool in Trinity 3D, to study such big datasets in geological context to further understand the geological scale behaviour of petroleum systems and their geological controls.

Based on research with big data in geological context, the spatial variation patterns of bulk petroleum fluid properties (API gravities, GOR, CGR etc.) have led to the new realization that petroleum fluid properties are not only a function of source rock facies, but significant fractionation processes during expulsion and migration under changing PVT conditions. As a result, Dr. He, along with Dr. Andrew Murray, has been advocating a Top-down Petroleum System Analysis method to be the focus on petroleum system analysis. Probabilistic tools have been developed to compliment such workflows.

In addition, the geo-spatial distribution patterns oil and gas fields, both unconventional and conventional, including dry holes, have been linked to the capillary processes that control petroleum migration. This understanding has led to methods to evaluate migration risk for prospects in both mature basins and new ventures.

In the past 20 years, Dr He has taught over 100 training courses in the industry on practical petroleum system analysis.