New Asphaltene Nanoscience and Its Impact on Reservoir Characterization

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This seminar will begin at 12:30 p.m. Pizza will be served at noon.

Abstract: Crude oils consist of gases, liquids and solids, the asphaltenes. The gas and liquid constituents of crude oil are chemically well understood and their theoretical frame work can be satisfactorily treated by cubic equations of state. In contrast, the asphaltene have been grossly misunderstood precluding any theoretical treatment of asphaltene gradients in reservoirs. In recent years, asphaltene science has undergone a renaissance with many of the advances being subsumed in the “Yen-Mullins model which consists of asphaltene molecules, nanoaggregates and clusters of nanoaggregates. Various molecular diffusion and mass spectral measurements show that asphaltene molecular weights are ~750 (range 500-1000) Daltons. Molecular diffusion measurements originally established the predominance of (but not limited to) one polycyclic aromatic hydrocarbon (PAH) per molecule, now strongly supported by laser mass spectral studies. Recent, ultrahigh resolution molecular imaging supports this key finding. This molecular architecture yields nanoaggregates with <10 aggregation number as proven by recent laser mass spectroscopy results. High-Q ultrasonic studies were first to show that asphaltene nanoaggregates form at 10-4 mass fraction. SANS and SAXS studies confirm these small asphaltene nanoaggregates as well as clusters of nanoaggregates; DC-conductivity studies support all these findings of the size and aggregation concentration. Clusters of nanoaggregates form at ~10-3 mass fraction as shown by a flocculation kinetics and other measurements. Moreover, in a recent breakthrough oil-water interfacial science along with asphaltene molecular orientation studies in Langmuir-Blodgett films prove consistency with the Yen-Mullins model providing a way forward to investigate more challenging interfacial concerns.

With this nanoscience, the ‘gravity’ term (in Newton’s 2nd law; F=mg) is understood enabling our group to develop the industry’s first equation of state for asphaltene gradients, the Flory-Huggins-Zuo (FHZ) EoS. This new science is being linked with new measurement technology Downhole Fluid Analysis to address reservoir complexities to optimize oil production. This new FHZ EoS has found enormous application in oil reservoirs accounting for asphaltene gradients in widely ranging fluids from condensate to heavy oil. Application of the FHZ EoS to a complex oil column is established over a lateral distance of 100 kilometers. Equilibration of reservoir fluids indicates reservoir flow continuity as proven is many case studies (a billion dollar concern in deepwater). Stair-step, disequilibrium asphaltene distributions portend reservoir compartmentalization, which can destroy reservoir economic value. New case studies show nonequilibrated asphaltene gradients are associated with baffles to fluid flow which can decrease production rates by 10x. Other transients (in geologic time) accurately modeled by the FHZ EoS include a reservoir undergoing diffusion and biodegradation for 50 million years is now accurately modeled with the FHZ EoS coupled with a diffusion term. Several mechanisms of tar mat formation are now resolved addressing a long-standing enigma in the oil industry. The combination of new asphaltene science new downhole measurement technology is producing an explosion of applications.

Bio: Dr. Oliver C. Mullins is a Science Advisor in Schlumberger. He is the primary originator of Downhole Fluid Analysis (DFA) in well logging. Dr. Mullins also leads an active research group in petroleum science leading to the Yen-Mullins model of asphaltenes and the FHZ EoS. His current interests include utilizing the new DFA technology and new asphaltene science to perform novel reservoir evaluation. He has won several awards including the SPWLA Gold Medal for Technical Achievement. He authored the award-winning book The Physics of Reservoir Fluids; Discovery through Downhole Fluid Analysis and has been Distinguished Lecturer 5 times for SPWLA and SPE. He has coedited 3 books and coauthored 13 chapters on asphaltenes and related topics. He has coauthored 230 publications, ~½ on petroleum science, ~½ on applications, and has
coinvented 96 allowed US patents. He has accumulated >10,000 citations on Google Scholar. He is Editor of Petrophysics, Fellow of two professional societies and is Adjunct Professor of Petroleum Engineering at Texas A&M University.