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Petroleum Geochemistry and Mudstone Diagenesis of the Woodford Shale, Anadarko Basin, USA – An Integrated Approach

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Speaker: Christopher Laughrey,

ABSTRACT:

We undertook an integrated organic geochemical and petrologic study of the Upper Devonian-Lower Mississippian Woodford Shale on cores recovered from thermally mature and liquids-rich mudstone reservoirs in the Anadarko basin of south-central Oklahoma, USA. The purpose of the work was to identify the critical mechanisms that control oil and natural gas generation, expulsion, migration, and retention in an active petroleum source rock that is also a producing unconventional reservoir.

We identified five microfacies in the Woodford Shale; 1) siliceous mudstone; 2) silicified mudstone; 3) chert and argillaceous chert; 4) argillaceous, siliceous dolostone; and 5) phosphatic mudstone. All of these microfacies exceed the minimum TOC and S2 threshold values for effective petroleum source rocks. The original HI values, calculated from visual kerogen data, indicate oil-prone organic matter in the rocks. Thermal maturity approximates the boundary between low-volatile and high-volatile liquid generation. Maximum burial temperatures were between 124 to 134°C. Sixty to 75 % of the petroleum generation process is complete and expulsion efficiency was 61 to 83 %. Plots of oil crossover effect and oil saturation indices denote Woodford Shale intervals that retained adequate volumes of hydrocarbons for commercial petroleum production.

Reservoir quality in these productive intervals is controlled by the diagenetic fabric of the mudstones. Mineral matrix porosity was reduced by compaction, quartz cementation, and bitumen expulsion from kerogen during deeper burial. However, significant mineral matrix porosity was initially preserved in microfacies that underwent early quartz cementation, and relatively larger amounts of pre-oil bitumen filled these spaces prior to the onset of petroleum generation and organic-matter porosity formation. Organic-matter porosity now comprises greater than 99 % of the observed pore volume, and occurs within an extensive and well-connected post-oil solid bitumen network which serves as a major petroleum migration path.

Speaker Biography:

Christopher D. Laughrey is a Senior Petroleum Systems Analyst with Weatherford Laboratories' Geochemical Interpretive Services (OilTracers) Group. His forty years of professional

experience is international in scope with specializations in isotope and petroleum geochemistry, production monitoring and allocation of petroleum and water, clastic and carbonate reservoir petrology, basin analysis, and geophysical log interpretation. Christopher consults for private industry working on integrated interpretive projects, teaches workshops on both unconventional and conventional reservoir geology and geochemistry, and collaborates with other Weatherford scientists on research and business development efforts within the company. Prior to joining the OilTracers group in 2016, Christopher worked for a year with the Dolan Integration Group in Boulder, Colorado, and for five years as a Senior Geosciences Advisor for Weatherford Laboratories in Golden, Colorado. At Weatherford, he focused on unconventional resources in various Rocky Mountain basins, the Anadarko and Arkoma basins, and the Appalachians. He also completed projects in various other basins in the United States, Canada, Australia, China, Argentina, Colombia, the Middle East, Russia, and new plays in the UK. He was involved in Weatherford Laboratories' research and development efforts in quantitative natural gas isotope applications in the petroleum geosciences, high-resolution SEM imaging and 3-D modeling of low-permeability fine- grained clastic and carbonate reservoirs with an emphasis on the evolution of organic and inorganic pore systems, biomarker applications in petroleum resource systems, and high-temperature programmed pyrolysis of organic matter in unconventional shale-gas and tight-oil reservoirs. Christopher has conducted numerous professional workshops in applied shale petrology, petroleum geochemistry, sequence stratigraphy, and carbonate petroleum reservoirs for the Petroleum Technology Transfer Council, AAPG, SPE, and numerous oil and gas companies including Cabot, Chevron, Colombian Petroleum Institute, El Paso, ExxonMobil, Hess, Petro China, Repsol, Shell, and Talisman. In 2008 and 2009, Christopher conducted Carbonate Petroleum Reservoir workshops and field seminars for Petro China through Geologic Mapping and Resource Evaluation (GMRE), Inc.in State College, Pennsylvania. From 1980 through 2009, Christopher worked as an industry consultant, and as a Senior Geological Scientist for the Pennsylvania Geological Survey where he conducted applied research in tight-gas sands, fractured carbonate reservoirs, applied sequence stratigraphy, shale petrology, source rock geochemistry of the Marcellus and Utica shales, and natural gas isotope geochemistry throughout the Appalachian basin. Christopher taught graduate courses in sandstone and carbonate petrology and undergraduate geochemistry at his alma mater, The University of Pittsburgh. He is the author or coauthor of forty technical papers and books on the application of integrated geochemistry, petrology, and stratigraphy to petroleum exploration and production, and on the applications of isotope geochemistry to the mitigation of stray natural gas environmental problems. Christopher began his career in 1977 as a geologist and geophysical analyst for the Marine Seismic Exploration Department at the Western Geophysical Company (now Western Geco) in Houston, Texas.

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