THERMAL MATURITY-ADJUSTED LOG INTERPRETATION (TMALI) IN ORGANIC SHALES

Abstract:

Petrophysical analysis of downhole logs requires accurate knowledge of matrix properties, commonly referred to as matrix adjustments. In organic-rich shale, the presence of abundant kerogen (solid and insoluble sedimentary organic matter) has a disproportionate impact on matrix properties because kerogen is compositionally distinct from all inorganic minerals that comprise the remainder of the solid matrix. As a consequence, matrix properties can be highly sensitive to kerogen properties. Moreover, the response of many downhole logs to kerogen is similar to their response to fluids. Relevant kerogen properties must be accurately known to separate tool responses to kerogen (in the matrix volume) and fluids (in the pore volume), to arrive at accurate volumetric interpretations. Unfortunately, relevant petrophysical properties of kerogen are poorly known in general and nearly always unknown in the formation of interest.

A robust method of “thermal maturity-adjusted log interpretation” replaces these unknown or assumed kerogen properties with a consistent set of relevant properties specifically optimized for the organic shale of interest, derived from only a single estimate of thermal maturity of the kerogen. The method is founded on the study of more than 50 kerogens spanning eight major oil- and gas-producing sedimentary basins, 300 Ma of depositional age, and thermal maturity from immature to dry gas (vitrinite reflectance, R_o, ranges from 0.5 to 4%). The determined kerogen properties include measured chemical (C, H, N, S, O) composition and skeletal (grain) density, as well as computed nuclear properties of apparent log density, hydrogen index, thermal- and epithermal-neutron porosities, macroscopic thermal-neutron capture cross section, macroscopic fast-neutron elastic scattering cross section, and photoelectric factor. For kerogens relevant to the petroleum industry (i.e., type II kerogen with thermal maturity ranging from early oil to dry gas), it is demonstrated that petrophysical properties are controlled mainly by thermal maturity, with no observable differences between sedimentary basins. As a result, universal curves are established relating kerogen properties to thermal maturity of the kerogen, and the curves apply equally well in all studied shale plays. Sensitivity calculations and field examples demonstrate the importance of using a consistent set of accurate kerogen properties in downhole log analysis. Thermal maturity-adjusted log interpretation provides a robust estimate of these properties, enabling more accurate and confident interpretation of porosity, saturation, and hydrocarbon in place in organic-rich shales.

Bio:

Paul Craddock is a Senior Research Scientist in the Applied Math & Data Analytics Department at Schlumberger-Doll Research Center in Cambridge, Massachusetts. His research addresses oilfield petrophysics and formation evaluation using nuclear, X-ray, infrared spectroscopy, and most recently machine-learning methods. He has developed methods to: derive saturation from spectroscopy logs in conventional reservoirs; indicate zones for favorable well placement and production in shale (RPI); combine cuttings and logs for enhanced petrophysics in data-poor shale wells (DRIFTS); and optimize kerogen properties for global shale log evaluation (TMALI). He received a PhD in chemical oceanography from Massachusetts Institute of Technology/ Woods Hole Oceanographic Institution. Paul is a member of SPWLA and SPE, current President of the Boston Chapter, and twice a Distinguished Speaker for SPWLA .