Establishing Proper Calibration of DeltaLogR in Heterogeneous Mudstone Units and the Implications for Assessing Source and Reservoir Quality in Marine Shale Systems

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Abstract

DeltaLogR (DLogR) is a petrophysical method for evaluating the organic richness of marine mudstone from well logs. It has been applied to evaluations of source rock quality in petroleum systems and regional evaluations of carbon burial related to paleoclimate events. However, DLogR was devised under an assumption that mudstones are homogenous in composition and structure. Attempts to apply this method to heterogeneous mudstones have yielded poor results when compared to measured organic content. To obtain useful results, it is critical to establish a proper baseline given the varied composition of both the organic-rich and organic-lean intervals in highly heterogeneous lithologies. In this study, we evaluated the DLogR response of thermally immature Cenomanian – Turonian calcareous mudstones from two cored wells in the Western Interior Seaway and a cored well of the Late Devonian siliceous mudstone in the Appalachian Basin that is thermally mature (dry gas window). For each well, detailed lithologic descriptions were incorporated with high resolution geochemical data, including total organic carbon (TOC), mineralogy, programmed pyrolysis, and major and trace element concentrations. Incorporation of detailed sedimentologic descriptions with geochemistry allows for the comparison of the varied lithofacies in both organic-rich and organic-lean intervals within each core. The wireline logs utilized in the DLogR calculations and screening include gamma ray, deep resistivity, sonic, and bulk density. Establishing a baseline representative of the study interval is key, as all logs involved in DLogR vary with changing composition. In each of the cored wells, multiple facies were tested as potential baselines for DLogR analysis. Because of the heterogeneous nature of both the organic-rich and organic-lean intervals, it was determined that multiple baseline units were needed to calibrate the entire stratigraphic interval. It is also noted that not every organic-lean facies can serve as a baseline and that, in some instances such facies result in a false positive DLogR response. Cemented lithologies result in resistivity increasing relative to the chosen porosity log generating a positive DLogR response that is not related to organic enrichment. Proper baselines were established by identifying intervals at least 1 m thickness with minimal separation between the resistivity and porosity logs, where geochemical data demonstrates composition similar to the study interval. Utilization of a gamma ray minimum enables identification of lithologic units where separation of the resistivity and porosity logs may be representative of a highly cemented lithology rather than an organic-rich unit. Our results show that careful application of DLogR improves TOC estimates within heterogeneous lithologies, providing valuable information regarding the distribution of quality source and reservoir facies.