Exploring links between resistivity and thermal maturity in organic-rich shales

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The petrophysical signature of organic-rich shale is determined by their mineral and organic matter assemblage and the nature and distribution of fluids. Electrical resistivity has been widely used as an effective proxy for detection of organic matter and hydrocarbons in shales. Up to thermal maturities within the oil window, the so-called delta log R method (Passey et al., 1990) is used to estimate organic richness of potential source rocks from the sonic and the resistivity wireline log curves. However, at higher thermal maturities, the sediments undergo chemical and structural reorganization involving loss of hydrogen and oxygen and aromatization of the organic component leading to a dramatic decrease in its electrical resistivity. This influence, especially at thermal maturities consistent with and beyond the gas generation window is not accounted for in petrophysical log interpretation and the petrophysical properties of over-mature shales are poorly documented in the literature.

We show examples of hydrocarbon prospective shales characterized by low electrical resistivity of the organic-rich sections and through an integrated petrophysical, petrological, and nanoanalytical approach we show that the anomalous conductivity is related to a conductive, connected network of partially graphitised bitumen and not to commonly assumed accessory conductive minerals such as pyrite. This interpretation is verified by several case studies on prospective organic-rich shales that have been exposed to high thermal maturation induced by either deep burial conditions (Appalachian Basin, USA; Sichuan Basin, China), or contact metamorphism (Beetaloo Basin, Australia).

Importantly, these results can help better define prospective areas of hydrocarbon accumulation in sedimentary basins as well as potentially identify false positives in the geophysical signature of mineralization under cover.

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References

Passey, Q. R., S. Creaney, J. B. Kulla, F. J. Moretti, and J. D. Stroud, 1990, A practical model for organic richness from porosity and resistivity logs: AAPG Bulletin, 74, no. 12, 1777–1794.