Organic Matter Accumulation and Thermal Maturation in the Upper Devonian New Albany Shale of the Illinois Basin

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Abstract

Organic matter (OM) quantity, quality, and thermal maturity are key parameters in source rock evaluation and unconventional shale oil/gas reservoir characterization. Understanding the stratigraphic distribution of OM content and type in black shale successions and its transformation during thermal maturation is of great significance in conventional and unconventional petroleum systems. In this study, multiple techniques including x-ray fluorescence spectroscopy, organic petrography, scanning electron microscope (SEM), and micro-Fourier transform infrared spectroscopy were employed to document the stratigraphic variations of OM content and type, organic maceral transformation during thermal maturation, and associated organic pores development in the Upper Devonian New Albany Shale of the Illinois Basin from early mature (vitrinite reflectance Ro 0.55%) to gas window (Ro 1.42%). OM content and type in the New Albany Shale vary stratigraphically. Relative sea-level fluctuations influence paleoproductivity, clastic supply, bottom-water redox conditions, and their combined control on OM accumulation in the New Albany Shale. Bottom-water redox conditions are one of the controlling factors for OM accumulation in the New Albany Shale. Paleoproductivity and clastic supply exert additional influences on OM accumulation via enrichment or dilution. Oil-prone OM (amorphous OM and alginite) transforms to oil, gas and post-oil bitumen or pyrobitumen during thermal maturation. Amorphous OM and alginite disappear at Ro 0.80 and 0.89%, respectively because of transformation to hydrocarbons and solid bitumen. Terrestrial OM (vitrinite and inertinite) do not change significantly in morphology with increasing thermal maturity. Correlative microscopy (reflected light and SEM) was used to study the influence of thermal maturity and organic maceral type on the development of secondary organic pores. The results show that solid bitumen transformed from oil-prone macerals develops secondary organic nanopores (20−1000 nm) during thermal maturation and that terrestrial organic matte does not develop secondary organic pores, but can host primary cellular pores (0.2–10 μm). Secondary organic nanopores formed in the solid bitumen network, together with the oil wettability of solid bitumen, may facilitate the migration of oil and gas in unconventional shale reservoirs.

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