

Bowland Shale Paleoredox: Implications for Prospectivity

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ABSTRACT

The Mississippian Bowland Shale Formation represents a potential unconventional hydrocarbon resource in the UK. Predicting the distribution and type of organic matter (OM) is vitally important for understanding this resource, but is dependent on understanding a variety of processes that operated during deposition and burial. These include understanding sedimentary transport mechanisms, the role of sea level fluctuation and geochemical processes such as reduction and oxidation ('redox') reactions. Comparing sedimentological, palynological and geochemical data from three locations within the Craven Basin (Lancashire, UK) reveals the Bowland Shale to be highly heterogeneous, both in terms of sediment delivery mechanism and type of OM preserved. Palynological and organic geochemical (Rock-Eval pyrolysis, $\delta^{13}\text{C}_{\text{org}}$, n-alkane biomarker) data indicate a variety of marine and terrestrial OM compositions depending on basin position and sea level. Yet inorganic geochemical and organic sulfur analyses suggest that further interpretational refinement is required because the composition of OM is also dependent on redox conditions during deposition. The presence of organic sulfur has implications for understanding the type and timing of hydrocarbon generated. Sea level highstand facies, termed 'marine bands', were deposited under an influx of 'open marine' waters that promoted carbonate export into deeper waters and restricted detrital sediments to proximal positions. High rates of primary production in the water column triggered widespread anoxia, resulting in relatively high total organic carbon content (3 to 5 wt. % TOC). Restricted supply of reactive iron (Fe), however, also promoted development of organic sulfur complexes, so that the composition of OM is considered as 'Type II-S'. Lowering of sea level led to tens of metres of sediment accumulation deposited as storm-derived rip-up clasts and by mass transport processes. Water column redox conditions during early lowstands were anoxic, but progressively became oxic. After three sea level cycles, conditions became fully oxic. Importantly, lowstands were associated with a greater supply of reactive Fe that promoted pyrite formation, rather than organic sulfur, during anoxic conditions. Associated with this process, we hypothesise that the presence of sulfur radicals in these intervals account for a decrease in Rock-Eval T_{max} by ~ 15°C and a decrease in the proportion of pyrolyzable OM.