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Paragenesis and Microporosity Evolution in the Lower Carboniferous (Arundian) Bowland Basin Mudstones

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ABSTRACT

The Hodder Mudstone forms the lower section of the Bowland-Hodder Shale, a potential shale-gas play in the UK. The Hodder is an Arundian age, carbonate-rich mudstone. In such carbonate-rich rocks understanding pore characteristics and evolution requires both the identification of pore types related to primary framework of the rock, and those pores that have resulted from diagenetic modification during burial. The latter is due to the high levels of mineralogical instability and chemical reactivity within carbonate-rich sequences. Digital image analysis using SEM, X-ray CT and electron microprobe combined with mineralogical data from XRD, XRF and SEM X-ray based mineral mapping and cathodoluminescence have been utilised for this study. Within the studied samples, there is a complex, nanometre- to millimetre-scale pore system. Micropores (nanometre to micrometer-scale) are associated with organic matter, carbonate, phyllosilicate, silicate and sulphide minerals. The most abundant pores are nanometre-scale interparticle pores within silicate and phyllosilicate grains. These pores are occasionally filled with residual hydrocarbon. Our analysis reveals significant pore modification through spatial alteration of the mineral fraction from mechanical and chemical compaction. Mass exchange from dissolution, precipitation and re-precipitation of carbonates and silica during diagenesis has had significant effect on pore volume. For example, intercrystalline pores within early diagenetic pyrite framboids have been cemented by calcite in bioclastic-rich mudstones, but are well preserved in clay mineral-rich mudstones. During diagenesis, mineral reactions resulting from fluid migration were mediated by both grain texture and mineralogy. The role of mechanical compaction was also significant in preserving primary porosity through the reorientation, fracturing and bending phyllosilicate grains and clay minerals around grains resulting in wedge-shaped interparticle pores. The assessment of paragenesis and relative timing for pore modification is crucial to better understand the role of diagenetic episodes in pore development within mudstone reservoirs.