High Resolution Microscopic Analysis of Mineral and Organic-matter Components in the Upper Triassic Yanchang Lacustrine Shale Deposits in Southeastern Ordos Basin, China

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ABSTRACT

One of the issues confronting researchers when studying porosity in shales is reconciling the disconnection between indirect and direct pore measurement methodologies. A previously Scanning Electron Microscopy (SEM) examined five select samples of pore systems from the Yanchang petroleum group reservoirs were investigated with this in mind. Samples were about the same maturity Tmax (443-457) with a TOC mg/g range from 86 to 29.4% and Bitumen Ro (%) are very similar at 0.93 to 0.87. N2 adsorption porosity data on these samples suggest there is a large porosity contribution from small pores <10 nm that are not accounted by conventional Field Emission Scanning Electron Microscopic (FESEM). In this study, we investigated this disconnection by leveraging two microscopic methodologies with the potential for nanoscale spatial resolutions: 1. Zeiss Gemini 500 SEM in Low Voltage mode (LVSEM) and 2. JEOL High Resolution Transmission Electron Microscope (TEM). Combining these two microanalysis technologies with CFESEM and N2 absorption we present a more complete picture of the in situ distribution and character of the organic pore networks and associated mineralogical fabric. LVSEM images revealed nano scale features not previously seen on the organic matter surface which enable us to resolve pores sizes from 5nm to microns and their distributions. However, pores less than 5nm in size become increasingly interpretative and hard to quantify. Pores sizes observed appeared to correlate with N2 absorption size distribution data. Observations with low voltage mode and conventional SEM images along with Energy Dispersive spectroscopy (EDS) maps suggest the major contribution to porosity comes from OM generated pores. TEM and STEM -EDS maps provided a unique high resolution three dimensional view of the organic matters' relationship with the mineralogical rock fabric. Graphene-like stacked nanostructures associated with gas/oil maturation window were documented. These structures have been reported as candidates for hydrocarbon trapping and are the possible source for nanoporosity seen in some of the N2 absorption profiles. Deformed clays, bent and delaminated clays, nano-scaled OM and clay mixtures can be clearly imaged with HRTEM. We also observed evidence of pervasive nano scale re-distributed and injected filling of OM into clay minerals matrix assemblage, filling the heterogeneous mineral matrix and fractures compaction and fracture structures. Combining these methodologies greatly improved our understanding of the nanoscale distribution and structure of organic matter pores in these shales and their contribution to porosity and permeability.