Pore Structure Characteristics and Its Role to Shale Gas Storage in Organic-Rich Mudstone of the Wufeng-Longmaxi Formation, Sichuan Basin

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Abstract

Organic-rich mudstone of Ordovician-Silurian Wufeng-Longmaxi Formation is the key target for rapid shale gas exploration and development in China. Porosity and pore structure characteristics are important for shale gas storage and its flow. Pore structure characteristics for 32 fresh outcrop shale samples collected from Shuanghe Town, Changning County and 17 core samples collected from the Qianqian 1 core well in southeast Chongqing, Sichuan Basin were investigated by low pressure nitrogen adsorption, nuclear magnetic resonance (NMR) and scanning electron microscopy (SEM) imaging. The main factors controlling pore development and gas accumulation in shales were discussed by integrating total organic carbon (TOC), mineralogy and shale gas content. The porosity measured by nitrogen adsorption method ranges from 4.04%~10.39% with an average of 6.76%, which is greater than the NMR porosity, varying from 2.6% to 6.25% with an average of 4.34% in the mudstones of Wufeng-Longmaxi Formation in Sichuan Basin. The reservoir conditions of gas shales characterized by low porosity and low permeability appear to be mainly affected by nano-sized pores development. Open slit-like and parallel plate structure are major pore types with an average pore diameter of 3.76~12.08nm, and 2~30nm mesopores are dominated. A positive correlation between the BET surface area, micropore volume and mesopore volume with the TOC values reveals that organic matter (OM) pores are primarily composed of mesopores. The size of SEM-visible

pores featured by the clustering of mineral-associated and discrete spongelike OM-hosted pores vary from several to hundreds nanometers but most of them have sizes of less than 50nm. Mineralogical compositions have an important influence on the development and preservation of mudrock pores. The clay-mineral-hosted pores are present in the studied shales, showing that the samples with higher content of clay minerals but similar TOC content have larger specific surface area. Whereas brittle minerals, including carbonate, quartz and so on, are favorable for the preservation of small pores in organic-rich mudstone by forming supporting frame to protect the organic matter filling in it and restraining pore collapse. A positive correlation between the total pore volume, porosity, total gas content and adsorbed gas content with the TOC values reveals that OM richness is the primary control to high shale gas production. Also petrographic evidences from SEM study demonstrated that an abundance of OM-hosted pores might provide principal space for shale gas storage, or path for gas migration. Therefore, OM richness and thickness of the mudstone of Wufeng-Longmaxi Formation are two key factors for shale gas sweet-spot evaluation in the inner of Sichuan Basin where shale gas loss caused by tectonic uplift and faulting is insignificant.