Characterizations of a Nano-Scale Pore System and Petrographic Properties of Shale Using Multiple Techniques and their Implications on Gas Storage Capability

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Abstract

It has long been recognized that shale is the source rock of methane, which can be either adsorbed in confined nanopores or stored as free gas in macropores and micro-fractures of shale matrix. Pore, mineral and petrographic properties of shale conjunctionally determine the gas storage and transport properties of gas shale reservoirs. To investigate how these characteristics and pore structure influence the methane adsorption capability of shale formation, a total of forty-nine over-matured shale outcrop samples, thirty samples from Upper Longmaxi Formation and nineteen samples from Lower Longmaxi Formation from southern Sichuan Basin in China, were collected. Multiple techniques, including geochemical and mineralogical measurements, field emission-scanning electron microscopy (FE-SEM), mercury intrusion porosimetry (MIP), low-pressure CO2 and N2 adsorption and high-pressure methane adsorption, were employed to characterize the geo-properties, pore structure and their impacts on methane adsorption capacity under different temperatures. The main findings of this work can be summarized as follows: FE-SEM images show interparticle (InterP), intraparticle (IntraP) and OM pores are the main pore types in the Longmaxi shales. Most of OM pores belong to spongy OM pores due to the over-matured stage for the Longmaxi shales. The Lower Longmaxi shales have more OM pores because they have higher TOC compared to that of the Upper ones. Porosity increases with increasing depth and TOC. The outcrop samples have higher porosity than that of the drilled

core samples. Helium porosity is higher than MIP porosity observed from the outcrop samples. The Lower Longmaxi shales have higher porosity, pore volume and surface area than those of the Upper Longmaxi shales. Although complexity of shale pores and limitation of each technique may cause inconsistence of pore size distribution for some samples, mercury porosimetry and low-pressure N_2/CO_2 adsorption can be used in conjunction to characterize the pore structure of shale with a broad pore size range. Temperature has a distinct negative effect on methane adsorption capacity, where the Lower part of Longmaxi shale has higher thermal effect than the Upper part, which is due to higher TOC content for the Lower Longmaxi shale samples. Both Vs and adsorption heat have positive correlations with surface area. Samples with higher surface area have higher methane adsorption capacity.

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