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Qualitative and quantitative characterization of transitional shale reservoir: A case study from the Upper Carboniferous Taiyuan shale in eastern uplift of Liaohe Depression, China

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The successful exploration and development of shale gas has triggered upsurge of research in global marine shale. However, more reservoir research of transitional shale is still needed. Transitional shale gas resource accounted one third in China. However, the research about transitional shale is barely seen. The paper took Taiyuan shale in Upper Carboniferous of Liaohe Depression as an example to qualitatively and quantitatively characterize the shale pore structure and the controlling factors for pore development were also discussed.

Eight Taiyuan shale samples were collected for measurements. The total organic carbon (TOC) contents, the thermal maturity, and mineral composition were tested using conventional methods. The porosity was measured with GRI method, the pore size distribution in full scale was conducted with high pressure mercury intrusion and low pressure gas adsorption, the pore types were classified by Focused Iron Beam Scanning Electron Microscopy (FIB-SEM), and the pore connectivity was determined by 3-D reconstruction with Nano-CT.

The results showed that four types of pores including organic matter (OM) pores, interparticle pores (Inter P), intraparticle pores (Intra P) and fractures are developed in the pore system. Among them, intraparticle pores and fractures are well developed, while OM pores and Intra P are only developed in limited areas. Slit-shaped pores were the major pore shape in the pore system and the connectivity of pore-throat system is defined to be moderate which is subordinate to marine shale. The total porosity from GRI ranged between 1.66 and 11.22%, and N2 BET surface area of 6.51-15.06 m2/g. Density functional theory (DFT) based on slit-shaped pores assumption which was used for pore size distribution (PSD) in gas adsorption. Mercury intrusion and gas sorption combination revealed that nanometer-scaled pores were the major pore size, accounting for 87.16% of the pore volume and 99.85% of the surface area. Pore size less than 10 nm was the major contributor for pore volume and surface area, accounting for 70.29% and 97.70%, respectively. The samples also varied in mineralogy, TOC and CH4 sorption capacity. This variety within the samples enables us to study controls on the pore system. By single factor analysis, Clay minerals are positively related to volume and surface area of micropores, mesopores and macropores, which finally controls the free gas (porosity) and adsorbed gas content (surface area). Unlike marine shale, TOC makes little contribution to the development of micropores. Brittle minerals inhibited pore development of Taiyuan mudstone, which verified the influence of clay minerals in pore system.

To sum up, transitional shale is quite different from marine shale in pore structure characteristics as well as controlling factors. The favourable shale gas development area selection criteria and the reservoir evaluation method should be also different from marine shale.

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