Pore Structure and Fluid Distribution of Tight Sandstone Using the Combined Application of Scanning Electron Microscopy (SEM), Mercury Injection Capillary Pressure (MICP) and X-Ray Micro-Computed Tomography (CT)

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Abstract

Tight reservoirs contain considerable hydrocarbon resources, which are regarded as important complement of conventional resources. In this study, the pore microstructure was comprehensively revealed by the simultaneous use of SEM, MICP and micro-CT, whereas pore-scaled fluid distribution was visualized in a series of in-situ multiphase flow experiments by using an apparatus equipped with micro-CT and a special X-ray transparent core holder. Pores were identified as interparticle and intraparticle pores, and these pores presented complex morphology. Intraparticle pores were prevailing in the sample, which were the dominant contributor of surface area for pores smaller than 1μm. Interparticle pores, ranging from 0.18 μm to 22 μm, contributed considerably to pore volume with minor quantity. Pore network was featured by large pore throat ratio, which had a significant effect on fluid flow. High ratio of injection to extrusion mercury volume (98.34%) indicated a large hysteresis, demonstrating a great amount of fluid was stuck in pore bodies commonly connected by narrow throats. The permeability contribution curve suggested that the flow potential of tight reservoir was dominantly controlled by the pore-throats with a diameter large than 2 μm. Based on shape factor and Euler number, the

configuration of oil clusters in the pore space were identified as singlet, multiple, branched and network. Singlet oil clusters were prevailing in the porous media, and oil phase was gradually becoming continue with the increase of injection pressure. The size of oil clusters ranged over five orders of magnitude (10 ~ 106 μm^3), which followed a power-law distribution. Compared with the stage of low injection pressure, exponent τ decreased as small-sized oil clusters converged into medium-sized oil clusters. However, τ increased under a higher injection pressure, indicating more water was replaced by oil and singlet clusters were formed. This was also suggested by the gradual increase of oil saturation. Capillary pressure was the key element to control fluid distribution in the tight reservoirs, which was associated with pore microstructure. The high proportion of nano-scaled intraparticle pores and large pore-throat ratio were favorable for forming singlet oil clusters. The positive correlation existed between external driving force and oil saturation, suggesting external driving force increased differential pressure between oil and water to break through smaller pore-throat.