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Impacts of mineralogy on micro-scale pore structure and fluid flow capacity of deeply buried sandstone reservoirs

Juncheng Qiao[1,2], Jianhui Zeng[1,2], and Xiao Feng[1,2]
[1]China university of Petroleum (Beijing), College of Geosciences, China (webmaster@cup.edu.cn)
[2]State Key Laboratory of Petroleum Resources and Prospecting, China University of Petroleum, Beijing 102249, P. R. China (prp@cup.edu.cn)

Hydrocarbon exploration is extending from the shallowly buried to deeply buried strata with increasing demands for fossil fuels. The variable storage and percolation capacities that intrinsically depend on the pore geometry restrict the hydrocarbon recovery and displacement efficiency and trigger studies on the micro-scale pore structure, fluid flow capacity, and their controlling factors. Minerals within sandstone are the results of the coupling control of depositional factors and diagenetic alternations, which determine the microscopic pore geometry and subsequently affect the fluid flow capacity. In order to investigate the impacts of mineralogy on the pore structure and fluid flow capacity, integrated analyses including porosity and permeability measurements, casting thin section (CTS), scanning electron microscopy (SEM), pressure-controlled mercury porosimetry (PCP), rate-controlled mercury porosimetry (RCP), nuclear magnetic resonance (NMR), and X-ray diffraction (XRD) are conducted on the deeply buried sandstone samples in the Jurassic Sangonghe Formation of the Junggar Basin. Microscopic pore structure is characterized by the combination of SEM, CTS, PCP, and RCP and fractal theory. Fluid flow capacity is evaluated by the innovative application of film bound water model in NMR and mineralogy is quantitatively measured by XRD. The results indicate that the deeply buried sandstone is rich in quartz (54.2%), feldspar (25.1%), and clay (14.2%), with dominant kaolinite (5.04%) and chlorite (5.38%) cementation. The reservoir has a wide pore-throat diameter distribution with three peaks in the ranges 0.01–1, 10–80, and 200–1000 μm. Pores are tri-fractal and can be divided into micropores, mesopores, and macropores, with average porosity contributions of 50.11, 21.83, and 28.04%, respectively. The movable porosity of deeply buried sandstone ranges from 1.75 to 8.24%, primarily contributed by intergranular (avg. 2.34%) and intragranular pores (avg. 2.56%). Most of the fluids are movable in intergranular pores but are irreducible in intragranular pores. Correlation analyses between mineralogy and pore structure suggest that quartz provides preservation to intergranular porosity, which increases pore size and macropores porosity and reduces heterogeneity of the pore system. The influence of feldspar reverses and becomes poor owing to the simultaneous clay precipitation and complex roles of feldspar dissolution in microporosity. Chlorite, kaolinite, and illite, all act as destructions to intergranular porosity. They enhance the mesopores and micropores porosities, reduce the pore size, and increase the microscopic heterogeneities of the macropores, micropores, and whole pore system. The relationships between mineralogy and fluid flow capacity indicate that quartz is favorable for the fluid flow capacity, but feldspar and clay play negative roles. The reversed impacts of quartz and feldspar lay in their opposite controls on pore size. However, both pore size and hydrophilia should be taken into account when considering the effects of clay minerals. These negative effects are associated with types, contents, and hydrophilic degrees of clay minerals, in which I/S and illite exhibit the strongest negative impacts. The fluid flow in the intergranular and intragranular pores is generally enhanced by higher quartz content, but reduced by higher clay content. Irreducible fluids in the intergranular and intragranular pores are determined by chlorite and kaolinite contents, respectively.