Hysteretic Pressure-Sensitive Permeability and Residual Pressure of Different Types of Rocks

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Abstract

During the production of hydrocarbon, the variation of the effective stress of formation, which depends on the change of fluid pressure (pore pressure) in the pore space, causes the damage of porous media pore structure, leading to permeability hysteresis and residual pressure that affects strongly the permeability of the rock. In this study, several seawater flow porous materials experiments were performed to evaluate the permeability of core plugs with various lithology (clay-free limestones: Indiana and Edward White limestone, clay-rich sandstones: Bandera Brown, Berea Gray, and Castle Get sandstone) under cyclic stress conditions. Specifically, the conducted experiments included: 1) the triaxial and axial hysteretic pressure-sensitive permeabilities; 2) the effect of injection flow rate on the relationship between permeability and effective stress; 3) the effect of the triaxial loading stress under constant fluid pressure on rock permeability; 4) differential pressure history (pressure-hysteresis) and associated residual pressure during cyclic stress processes. During the tests, the variation of effective stress in the range of 300psi to 4200psi was achieved by changing liquid pressure (pore pressure) at constant overlying (confining pressure) /triaxial stress of 4500psi. In addition to the experiments mentioned above, based on the distribution of differential pressure, the residual pressure was proposed to describe the residual resistance in the cores. Moreover, a novel modeling technique was proposed to explain the results of hysteretic pressure-sensitive permeability. Based on the experimental and modeling results, we found that the permeability hysteresis strongly depended on effective stress. Specifically, permeability hysteresis for sandstones and limestones decreased as the effective stress increases. There was a critical value of effective stress for sandstone cores in which permeability hysteresis would disappear when the effective stress is greater than such critical value. For clay-free, low permeability Indiana limestone, a critical value of effective stress has not occurred within the range of effective stress. In addition, permeability of the core plug was related to confining pressure when the liquid pressure in the core was constant and the relationship between permeability and effective stress was obtained with the variation of injection flow rate. The results from the proposed models were consistent with the experimental data. This paper comprehensively studied the effective stress on hysteretic pressure-sensitive permeability and residual pressure of various types of rocks. In addition, the experimental data was modeled by a novel modeling technique proposed in this study. The experimental results are critical to evaluate reservoir permeability and understand the formation protection of different types of reservoirs.