Image-Based Pore Structure Characterization and Pore-Scale Fluid Flow Simulation of Eocene Beach-Bar Sandstones in the Western Slope of Dongying Depression, Eastern China

Ya Wang[1], Shaochun Yang[2], Yifan Zhang[1], Yan Lu[2]
[1]School of Geosciences, China University of Petroleum; [2]China University of Petroleum

Abstract

The understanding and management of oil and gas recovery depend critically on quantifying microscopic pore structure features and how fluid flow through tortuous pore systems. Here an integrated approach based primarily on image processing combined with MICP tests was served to investigate the geometrical and topological features of pore spaces and single-phase flow behavior in porous media. The pore spaces were extracted by segmenting 3D images (X-CT) and 2D images (thin sections and SEM) based on grayscale threshold or color threshold, and watershed algorithms was implemented to explicitly identify pores and throats. In addition, the connected and isolated pore spaces were distinguished according to whether connected paths can be generated in Y-axis direction, and single-phase flow simulation was performed using pore network models and traditional CFD methods respectively. Results show that the isolated pore spaces occur extensively scattered within the beach-bar sandstones, conversely the connected pore spaces are spatially concentrated. In 3D representation of pore spaces, 82.64% of isolated pore spaces are dead end pores, while 73.95% of the connected pore spaces are connected by at least two throats. Smaller shape factors and network tortuosity of connected pore spaces can be obtained, which indicate more irregular shapes and less curved paths for connected pore spaces. Pore and throat size distribution has been shown to determine pore structures and reservoir quality. The 3D

images can provide broadly information about pore and throat size, but the limitation is that not all pores are captured in one single imaging experiments, due to finite resolution and sample volume of the experiments. The 2D images of different resolutions allow to capture geometrical features of pore spaces in different scales, but they cannot effectively reflect the realistic topology characters of pore spaces, i.e. the connectivity of pore spaces (2D) is significantly poorer than their real connectivity and it is substantially difficult to find connected paths in 2D images. Solving single-phase transport properties using pore network models is numerically efficient, which attempt to simply the pore geometries while retain pore topology features. Good positive correlation between coordination number and pore radius could be found in pore network model, which means that larger pores are more likely to be connected by throats and emerge better pore connectivity. The throat radius records a good positive correlation with fluid flow rate, which is consistent with the results of MICP tests, that is, a small number of large throats in low-permeability sandstones contribute the vast majority of permeability. The simulation results of CFD methods also show that the large pore throats in the sandstone constitute the dominant seepage paths.