New Method for Quantitative Classification of Pore and Porosity of Organic-Rich Shale Using Digital Image Processing

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Abstract

Pore type, structure, and distribution vary from micro- to nano-meter scale in organic-rich shale. Different pore types have different functions in gas storage and fluid migration in shale, leading a great difficulty in pore network modeling and shale reservoir evaluation. A decade of extensive studies have identified and classified various pore types, though most of them were descriptive. In order to better relate pore to reservoir properties, quantitative classification of pore and porosity is essential, which is much more challenging. Many efforts have been made to successfully characterize shale pore type and structure, by applying a series of quantitative fluid-injection methods, i.e., low-pressure N2 and CO2 gas adsorption, and high-resolution imaging techniques, i.e., field emission scanning electron microscopy (FE-SEM). However, every technique has its own limits. The fluid-injection techniques all rely on models to infer pore structure, and cannot provide direct evidence for pore morphology and spatial distribution. They are thus impossible to reveal the characteristics of different pore systems, separately. As for imaging methods, it is highly dependent on the selection of imaging region and resolution in order to accurately quantify pore nature. The inherent conflict between an increase in image resolution versus a decrease in field of view has posed a great challenge to characterize pore structure representatively. Although several digital image processing technologies have been applied to segment different pore types from matrix, capturing the quantitative pore data within a sequence of SEM-images is still time- and cost-consuming. In this study, high-resolution FE-SEM with the Atlas software was applied to provide

pore images in a large field-of-view. These digital images were then automatically processed, which separately segmented pore into OM-pore and mineral-pore by using an in-house developed proprietary algorithm and automated segmentation routine. A series of pore structural parameters, i.e., pore area and pore diameter, and the porosity or proportion of different pore types were thus measured and calculated from the segmented-images. Given shale properties varying at multi-scales, this study was designed to quantify pore heterogeneity of different lithofacies within the Longmaxi shale, in Sichuan basin. The more specific objectives of this research are to 1) quantitatively characterize pore types, pore structures and distributions within different shale rocks in a representative way, 2) analyze the respective contributions of mineral-pores and OM-pores to total porosity in different shales, and 3) figure out the link between microscale pore heterogeneity and shale reservoir quality.