

A Deep Learning-Aided Method for Precise Identification of Microporosity: A Case Study from the Marine Hydrocarbon Reservoirs in the South China Sea

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Abstract The accurate identification of microporosity is crucial for the characterization of hydrocarbon reservoir permeability and production. Scanning electron microscopy (SEM) is among the limited number of methods available to directly observe the microscopic structure of the hydrocarbon reservoir rocks. Nevertheless, precise segmentation of microscopic pores at different depths in SEM images remains an unsolved challenge, known as the ‘depth-related resolution loss’ problem. Therefore, in this study, a 3D reconstruction technique for regions of interest (ROI) was developed for in-depth pixel analysis and differentiation among various depths of SEM images. The processed SEM images, together with the processing outcomes of this technique, were used as the input database to train a stochastic depth with multi-channel residual pathways (SdstMcrrp) deep learning model programmed in Python to develop a tool for segmenting the microscopic pore spaces in SEM images obtained from the Beibuwan Basin. The more accurate segmentation helped to detect an average of 1.2 times more microporosity in SEM images, accounting for about 1.6 times more pixels and 1.2 times more pore surface area. Finally, the impact of the accurate segmentation on the calculation of permeability, a significant reservoir production property, was investigated using fractal geometry models and sensitivity analysis. The results showed that the obtained permeability values would vary by a factor of 6, which represents a considerable difference. These findings demonstrate that the proposed models can effectively identify features across a wide range of grayscale values in SEM images.

Key words SEM; depth of field; resolution loss; permeability; deep learning; fractal dimension

1 Introduction

With the global extraction of oil and gas resources transitioning from conventional to unconventional, and from shallow to deep reservoirs, numerous scholars have engaged in research on resource extraction under unconventional reservoir conditions, particularly focusing on the

characteristics of reservoir rock porosity (Dong *et al.*, 2022; Liu *et al.*, 2023). The pore space, serving as the conduit for reservoir fluid migration (Golsanami *et al.*, 2015; Wang *et al.*, 2020), plays a crucial role in the extraction of the reservoir fluids, and the proportion of micropores has a particularly significant impact on the extraction efficiency (Wang *et al.*, 2022). Extracting fluid stored in micropores is challenging because the fluid is trapped by capillary forces forming irreducible fluid saturation; that is, an increase in the proportion of micropores

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