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Image-Based Rock Typing Using Specific Surface and Iterative Convolution-Thresholding Method

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Abstract. Image-based rock typing (IBRT) is an effective way to understand the pore scale heterogeneity of the reservoir samples. IBRT is aimed at segmenting a rock sample's image into different regions where each region represents a homogeneous porous medium, also known as rock type. Currently, the phase-field rock typing method has attracted more attention due to its impressive performance in classifying the heterogeneous rock images with highly irregular pore structures. In this paper, a modified specific surface CV (SSCV) model is proposed to realize the IBRT. In the SSCV model, the specific surface of a pixel is calculated within a given size neighborhood to distinguish different rock types, and the iterative convolution-thresholding method (ICTM) is applied as the classifier. Compared to the LHFCV method, an existing phase-field rock typing method, the proposed SSCV is capable of processing the images with more than two rock types and can be solved by ICTM which has higher computational efficiency. The proposed SSCV method has demonstrated remarkable performance in the segmentation of various images of both synthetic and natural rock samples.

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1 Introduction

The image-based rock typing is a crucial step for understanding the reservoir heterogeneity at the pore scale [13]. Nowadays, an IBRT task can be classified as a pattern recognition problem or a texture segmentation problem [3, 14]. The pattern-recognition-related rock typing (PRRT) is carried out to solve some problems like identifying lithofacies [24], reservoir zone [15], or Dunham textures [18]. In this case, the input is a rock sample image, and the output is a label that denotes the class of this sample. The texture-segmentation-related rock typing (TSRT) focuses on identifying the spatial distribution of various rock types in available images. In this study, we focus on the TSRT.

The TSRT is a typical texture classification problem [3, 14]. A general workflow of solving the texture classification problem contains two procedures including: extracting texture features and selecting proper classifier [17, 32]. Feature extraction step is carried out to organize a feature vector that consists of several structural descriptors for each specimen. Then a proper classifier (e.g., GMM, SVM, and random forest) is selected to categorize these specimens. From the perspective of feature extraction, TSRT can be further classified as object-based rock typing and pixel-based rock typing. In pixel-based rock typing, each image pixel is treated as a specimen. While in object-based rock typing, the target objects (e.g., grains or pores) need to be identified and separated firstly, and then the geometry descriptors of each object can be organized as its corresponding feature vector [32]. Pixel-based rock typing identifies each pixel's rock type, while the object-based rock typing identifies each object's category. An image object is a combination of a group of pixels/voxels with specific geometric features [9].

More literature about the TSRT is reviewed as follows. Ismail *et al.* [11] applied regional Minkowski functionals as structure descriptors and a multi-variate Gaussian mixture model (MGMM) [35] as a classifier to realize the sandstone pore structure rock typing. The Minkowski functionals consist of volume, surface area, mean curvature, and total curvature which are always treated as basic integral geometric measurements to quantitatively describe porous media [30]. The Minkowski functionals are sensitive to spatial support (filter window size) [4]. An insufficient window size will lead to an increase in contrast in one rock type, while a large regional support window will result in computational expense. To