Fractals, Vol. 27, No. 1 (2019) 1902001 (3 pages)
© The Author(s)
DOI: 10.1142/S0218348X19020018

Editorial

AN INTRODUCTION TO FRACTAL-BASED APPROACHES IN UNCONVENTIONAL RESERVOIRS — PART II

JIANCHAO CAI,[*,‖] LIEHUI ZHANG,[†] YANG JU,[‡]
GIORGIO PIA[§] and ZHIEN ZHANG[¶]
[*]*Institute of Geophysics and Geomatics*
China University of Geosciences, Wuhan 430074, P. R. China
[†]*State Key Laboratory of Oil*
and Gas Reservoir Geology and Exploitation, Southwest Petroleum University
Chengdu, Sichuan 610500, P. R. China
[‡]*State Key Laboratory of Coal Resources*
and Safe Mining, China University of Mining & Technology
Beijing 100083, P. R. China
[§]*Dipartimento di Ingegneria Meccanica*
Chimica e dei Materiali, Università Degli Studi di Cagliari
Piazza d'Armi, 09123 Cagliari, Italy
[¶]*William G. Lowrie Department of Chemical and Biomolecular Engineering*
The Ohio State University, Columbus, OH 43210, USA
[‖]*caijc@cug.edu.cn*

Received February 16, 2019
Accepted February 19, 2019
Published March 8, 2019

In recent years, unconventional oil and gas reservoirs have attracted a great deal of attention including the theoretical, numerical and experimental aspects (also see the first part of this issue published in the second issue of 2018 in *Fractals*). Due to the complex geological condition and micro and

[‖]Corresponding author.

nanoscale properties of pore structures, unconventional oil and gas reservoirs face many challenges in their characterization, evaluation and exploitation. Natural rocks with complex pore microstructures are usually fractals, their heterogeneity and complexity at different scales can be effectively evaluated and fractal theory has been successfully used in unconventional reservoirs especially in recent years.

Fifteen articles are included in this special issue, including many aspects in fractal-based approaches applied in unconventional oil and gas formations.

An analytical model for the spontaneous imbibition within a fracture with rough fractal surface is derived in the paper "Spontaneous imbibition of a wetting fluid into a fracture with opposing fractal surfaces: Theory and experimental validation" by Brabazon *et al.* (*Fractals*, 2019(1): 1940001). This model takes the contact angle of a fluid on a rough fractal surface into account and is tested by fitting it to experimental data. The estimated surface fractal dimension ranges from 2.04 to 2.45, with a median of 2.24, which are significantly greater than two, and confirms the fractal nature of fracture surfaces.

In the paper "A geometrical aperture–width relationship for rock fractures" by Ghanbarian *et al.* (*Fractals*, 2019(1): 1940002), a first-order linear approximation of the relationship between fracture aperture and its width is shown by invoking concepts of fractal geometry. This paper discusses the limitations of the proposed model, and its potential applications to the prediction of flow and transport in fractures.

The paper "Compressive strength of fractal-textured foamed concrete" by Chen and Xu (*Fractals*, 2019(1): 1940003) derives a theoretical relation for the compressive strength relating to porosity based on the fractal model for foamed concrete. The proposed relation has a simple formulation and employs the fractal dimension of porous structure in foamed concrete.

A multi-linear fractal model considering imbibition for multiple fractured horizontal wells in tight oil reservoirs is established based on fractal theory and semi-analytical method in the paper "A multi-linear fractal model for pressure transient analysis of multiple fractured horizontal wells in tight oil reservoirs including imbibition" by Wang *et al.* (*Fractals*, 2019(1): 1940004). In their model, fractal theory is used to describe the heterogeneous, complex fracture network. The results show that the fractal dimension of fracture system is negatively correlated with porosity and permeability.

In the paper titled "Overall PSD and fractal characteristics of tight oil reservoirs: A case study of Lucaogou formation in Junggar Basin, China" by Wang *et al.* (*Fractals*, 2019(1): 1940005), the overall pore size distribution of Lucaogou tight oil reservoir is obtained by using the combination of rate-controlled mercury injection and pressure-controlled mercury injection (PMI). Based on the PMI data, the fractal characteristics of different tight reservoirs are compared and analyzed.

In the paper "Pore structure characterization for a continental lacustrine shale parasequence based on fractal theory", Zhang *et al.* (*Fractals*, 2019(1): 1940006) investigate the variations of the internal pore structure characteristics of the selected shale outcrop by applying fractal theory. It is found that fractal dimensions calculated by the imaging method and the Frenkel–Halsey–Hill (FHH) method are the same in the profile, indicating an upward increasing trend in each parasequence, but as a result of different phenomena.

Based on the multifractal spectrum and matching pursuit, a novel audio magnetotelluric signal–noise identification and separation methods are proposed by Li *et al.* in the paper "Audio magnetotelluric signal–noise identification and separation based on multifractal spectrum and matching pursuit" (*Fractals*, 2019(1): 1940007). They extract two sets of multifractal spectrum characteristic from magnetotelluric time-series data to analyze the singularity and use a support vector machine approach to learn the multifractal spectrum characteristics in a sample's library.

The paper "A fractal discrete fracture network model for history matching of naturally fractured reservoirs" by Zhang *et al.* (*Fractals*, 2019(1): 1940008) presents an integrated history matching method based on fractal discrete fracture network model for naturally fractured reservoirs. A fractal discrete fracture network model is used as the geological simulation model to predict the distribution of fractures in naturally fractured reservoirs with multi-scale complex fracture network and to reduce the inversion parameters.

In the paper "Fractal characterization of silty beds/laminae and its implications for the prediction of shale oil reservoirs in Qingshankou Formation of northern Songliao Basin, Northeast China", Liu *et al.* (*Fractals*, 2019(1): 1940009) establish a distribution model of silty beds/laminae by using fractal method. They find that the silty beds/laminae have the uniform fractal characteristics in the decimeter, centimeter, and millimeter levels, and the fractal dimension keeps the scale invariance. This work also indicates that the fractal-based number–size model is an effective method to estimate the parameters of the silty laminae.

The one-dimensional modified Korteweg–de Vries equation defined on a Cantor set involving the local fractional derivative is investigated in the paper entitled "Exact traveling-wave solutions for one-dimensional modified Korteweg–de Vries equation defined on Cantor sets" by Gao *et al.* (*Fractals*, 2017(1): 1940010). The nondifferentiable traveling-wave solutions are discussed in detail with the aid of fractal traveling-wave transformation technology.

The paper "Investigation of fractal characteristics and methane adsorption capacity of the Upper Triassic lacustrine shale in the Sichuan Basin, Southwest China", by Chen *et al.* (*Fractals*, 2019(1): 1940011) performs fractal analysis of nine shale samples collected from the fifth member of Upper Triassic Xujiahe Formation. The pore surface and pore structure fractal dimensions are obtained by using FHH equation. In addition, the effects of fractal dimensions on methane adsorption capacity are discussed.

The paper "A unified fractal model for permeability coefficient of unsaturated soil" by Tao *et al.* (*Fractals*, 2019(1): 1940012) derives a fractal-form of soil–water characteristic curve from fractal theory and then presents a unified fractal model of relative permeability coefficient for unsaturated soil to address the issue that the existing models are greatly restricted in their practical applications. The proposed unified fractal model included only two parameters, i.e. fractal dimension and air-entry value.

The paper "Investigation of dynamic texture and flow characteristics of foam transport in porous media based on fractal theory" by Wang *et al.* (*Fractals*, 2019(1): 1940013) aims to describe the structure of dynamic foam and explore a quantitative description method for foam fluid. The fractal characteristics of foam in porous media are verified and combined with foam microdisplacement experiment, and the fractal rule of foam is found. The relationship between fractal dimension and pressure is also discussed in this paper.

Fractal features of nanoscale pores and the implication on methane adsorption capacity of shale are investigated in "Fractal characteristics of nanoscale pores in shale and its implications on methane adsorption capacity" by Liu *et al.* (*Fractals*, 2019(1): 1940014). All 12 shale samples have obvious fractal features and all the fractal curves can be divided into two segments. Since organic matter is rich in pores and has relatively large fractal dimension values, methane adsorption capacity of shale samples increases with the increasing total organic carbon contents. Larger fractal dimensions indicate rougher pore surfaces and could form more small-scale organic pores.

To obtain three-dimensional digital rocks reflecting the properties of fractured reservoirs, the paper "Effect of fractal fractures on permeability in three-dimensional digital rocks" by Lv *et al.* (*Fractals*, 2019(1): 1940015) generates discrete fracture networks by stochastic modeling based on fractal theory. It is found that the relation of the permeability of fractured rock and fractal dimension of fracture centers/length is exponential.

These papers in this special issue further provide a diverse overview of fractal-based approaches applied in unconventional reservoirs, which cover several topics of fractal characterization of pore (throat) structure and its influences on the physical properties of unconventional rocks, fractal characteristics of fracture network and the relationship between characteristic parameters, porous flow and gas adsorption mechanisms. However, more innovative and in-depth researches on fractal-based approaches in unconventional reservoirs still need to be further carried out.