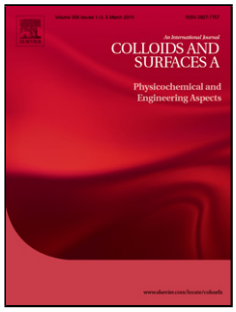

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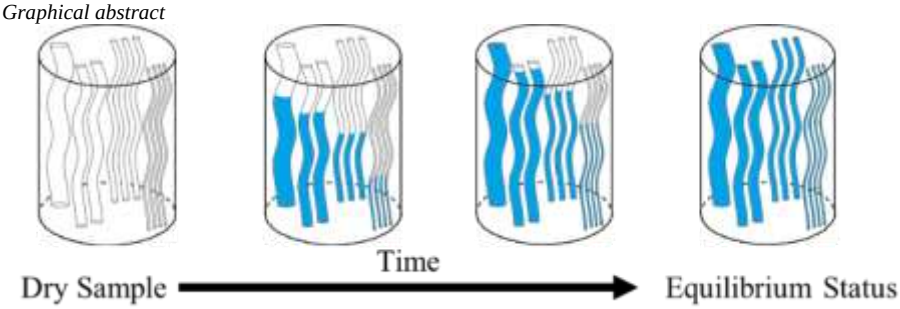
A Modified Model for Spontaneous Imbibition of Wetting Phase into Fractal Porous Media

Yue Shi, Mahmood Reza Yassin, and Hassan Dehghanpour*

Department of Civil and Environmental Engineering, School of Mining and Petroleum Engineering, University of Alberta, Edmonton, Alberta T6G 2W2, Canada

**Corresponding author (dehghanpour@ualberta.ca)*

Graphical abstract



Abstract

Fractal theory has been applied to characterize complex pore structure of sedimentary rocks and to model fluid flow through porous media. In recent years, several analytical models have been developed to simulate spontaneous imbibition of wetting phase into porous media with fractal geometry. In previous studies, spontaneous imbibition of wetting phase is considered as a piston-like displacement phenomenon which leads to similar rates of imbibition in capillaries with different diameters. However, imbibition rate of wetting phase is positively proportional to the square root of pore diameter based on Lucas-Washburn equation. Therefore, we should expect faster imbibition of wetting phase in larger capillaries compared with smaller capillaries.

In this paper, we extend the previous model by assuming non-piston-like imbibition in capillaries with different diameters. In our model, first the larger capillaries are filled by wetting phase, followed by smaller capillaries. We develop an analytical equation without considering hydrostatic pressure and a semi-analytical equation with considering hydrostatic pressure. We can apply actual boundary conditions in the proposed model, while the previous piston-like models are only valid before the wetting phase reaches the top of the porous media in co-current spontaneous imbibition test. Moreover, the proposed model can be used to determine the minimum pore diameter of rock sample according to the equilibrium time in spontaneous imbibition tests.

Keywords: spontaneous imbibition; fractal theory; capillary pressure; pore size distribution

Nomenclature

A_f	Cross-sectional area of rock sample, L^2
A_P	Total pore area in the cross section of rock sample, L^2
A_{Pu}	Cross-sectional area of unit cell, L^2
D	Pore diameter, L
D_C	Critical diameter of the capillaries just filled by liquid, L
D^*	The wetting phase in the capillaries larger than D^* cannot reach top of the capillaries, L
D_f	Pore fractal dimension
D_{max}	Maximum pore diameter, L
D_{min}	Minimum pore diameter, L
D_s	Characteristic diameter of particles, L
$f(D)$	Fractional number of pores
g	Gravitational acceleration, Lt^{-2}
H	Height of the rock sample, L