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CSM

Research Proposal

Application of Fractals to Modeling and Analysis of Naturally Fractured Unconventional Reservoirs

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Problem Statement

Currently producing nano-porous unconventional reservoirs are characterized by a complex network of fractures

Fractures in unconventional reservoirs display large variations of scale, connectivity, and conductivity

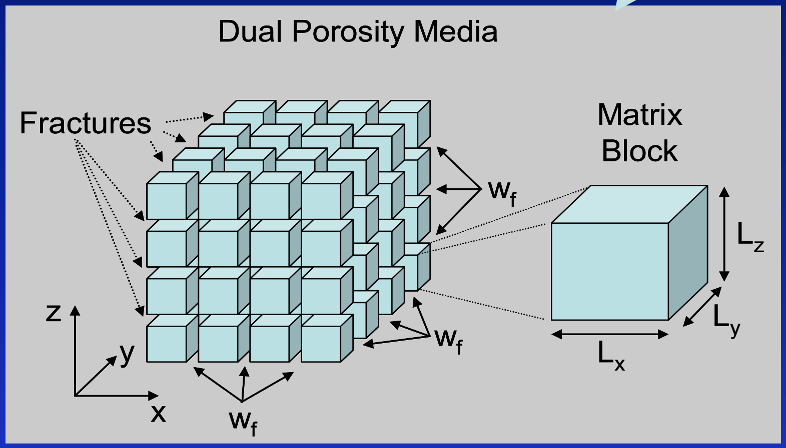
Models currently in use for natural fractures in unconventional reservoirs are either rough approximations or expensive and impractical processes which limit their applicability

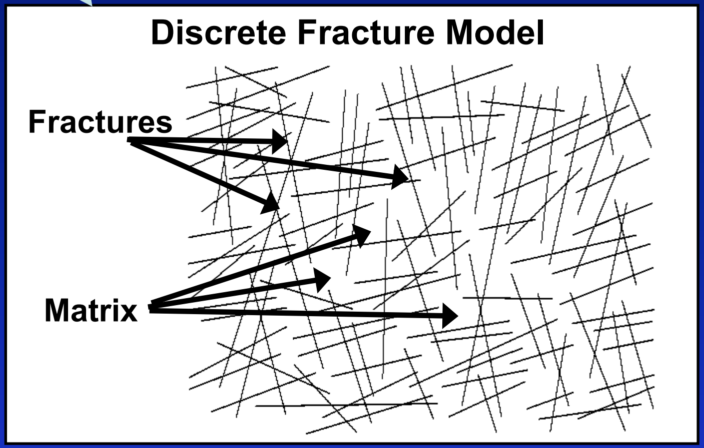
Fractal approach can provide an alternative to more accurately account for the nonuniform distribution of fractures and the presence of fractures at different scales

Importance

Currently producing nano-porous unconventional reservoirs are characterized by a complex network of fractures

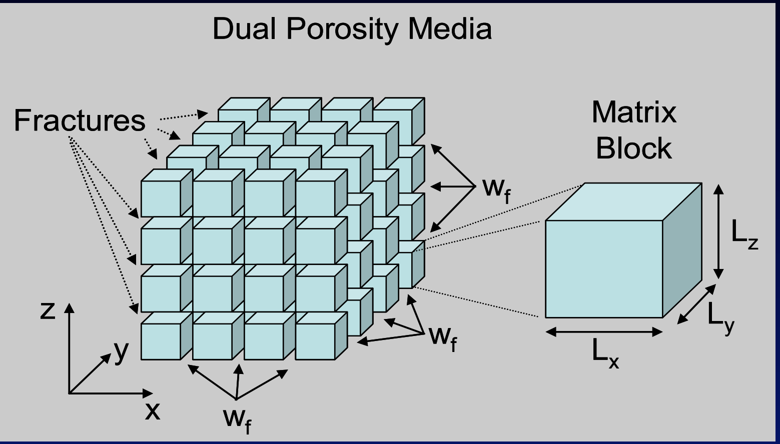
Representation of Fractures in Reservoir Models





Importance

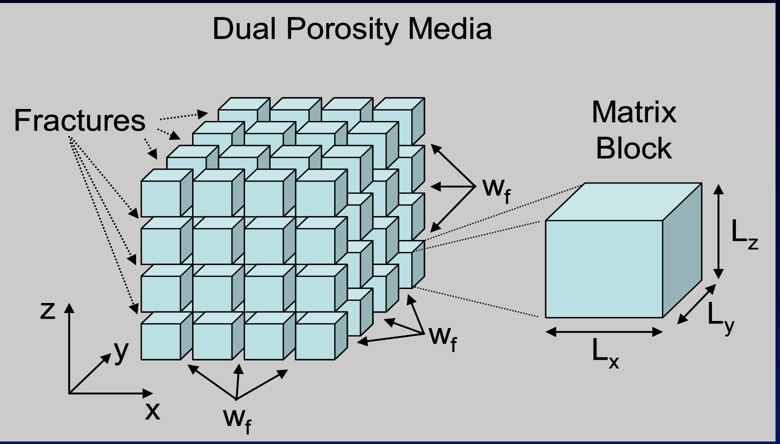
Dual-porosity models are based on the continuity assumption and effective averaging of the naturally fractured medium properties

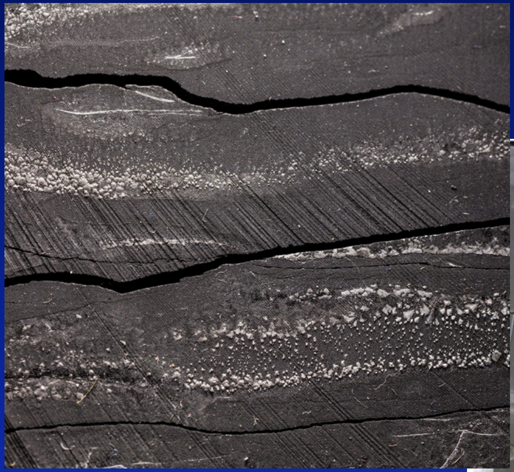


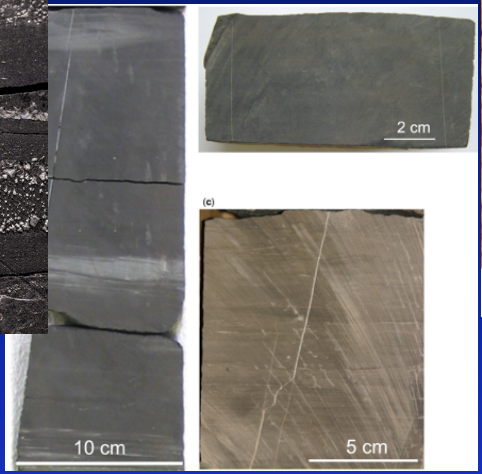
Dual porosity models are appropriate for systems where a repeated pattern of continuous fractures can be distributed to the entire flow domain

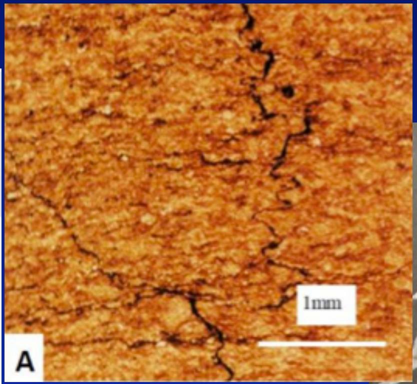
Importance

Considering the large variations of scale, connectivity, and conductivity of fractures in shale, dual-porosity assumption is only a first order approximation

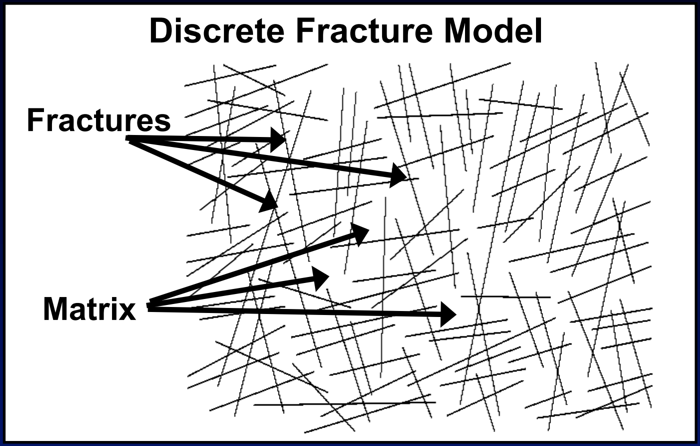








Importance



In discrete fracture network (DFN) models, it is possible to consider the details and distribution of individual fracture properties

However, DFN models require extensive characterization studies and also lead to computationally inefficient models

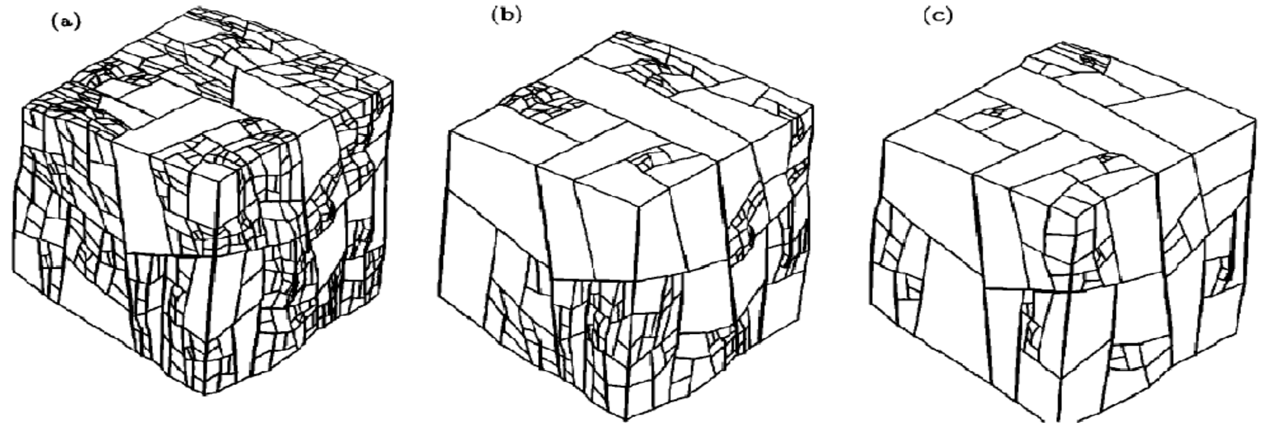
In general, the level of details that can be incorporated by the DFN model is limited by the capabilities of the flow model which will use the DFN model

From a practical perspective, DFN models are not well suited for routine engineering applications

Importance

Considering the shortcomings of the traditional modeling options for fractures in unconventional reservoirs, there is a need to search for alternatives

Fractal approach has been used to account for the nonuniform properties of fractures; however, it has not been commonly used for unconventional reservoirs



Three examples of three-dimensional (3-D) networks created by an initial fracture in a hexahedral medium and fractal dimension of (a) 2.78, (b) 2.65, and (c) 2.48.

(Acuna and Yortsos, 1995)

Literature Review

Sahimi and Yortsos (1970), Chang and Yortsos (1990), Beier et al. (1990) and Acuna et al. (1995)

They defined fracture properties as fractals; e.g.,

$$k(r) \propto r^{d_f - d - d_w + 2} \qquad \phi(r) \propto r^{d_f - d}$$

In general, their approach uses fractals to define the relation of the fracture properties to the space variable and implements it in the diffusion equation

$$D(x) = D_f x^{-\theta} \qquad \frac{\partial C}{\partial t} = \frac{\partial}{\partial x}\left(D_f x^{-\theta} \frac{\partial C}{\partial x} \right)$$

Literature Review

Flamenco-Lopez and Camacho (2003), Camacho et al. (2008) & Camacho et al. (2011)

Followed a similar approach to Sahimi and Yortsos and Chang and Yortsos

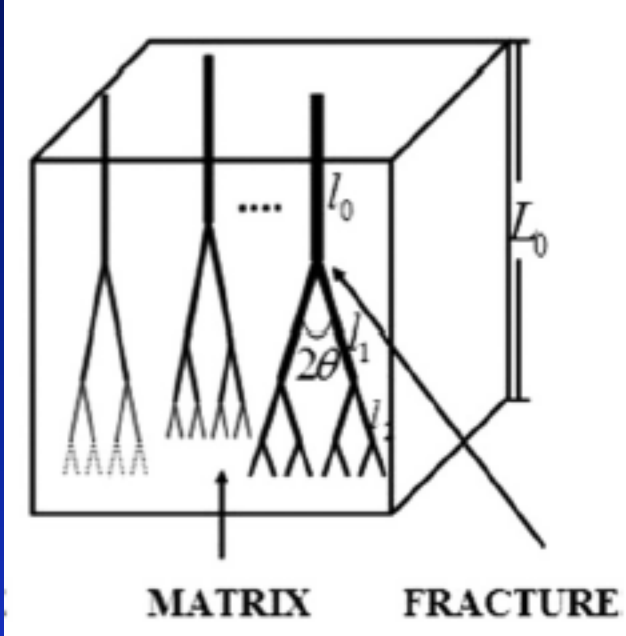
They incorporated the fractal derivatives of time also

They demonstrated applications to the analysis of production data from naturally fractured reservoirs, interference testing, etc.

Literature Review

Zheng and Yu (2011)

They investigated the gas permeability through porous matrix including a randomly distributed fractal-like tree network of fractures



Assumption of a specific fracture-network geometry limits the general use of this model

Scope of Research

- Modeling pore scale heterogeneity with fractals
- Fractal description of naturally fractured unconventional reservoirs
- Application of the models to data analysis from unconventional reservoirs

Method of Research

- Analytical and semi-analytical modeling
- Implementation of existing approaches to nano-porous, unconventional reservoirs
- Demonstration of applicability and improvement in results by simulated and field examples

Approach

- Analytical and numerical modeling of fractal reservoirs
- Use of data for the estimation of fractal properties of unconventional reservoirs
- Determine the shortcomings of the models and the available data