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Petroleum & Petrochemical Engineering Journal
ISSN: 2578-4846

Modelling Supercritical CO_2 Migration and Storage in Fractured Reservoirs

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Editorial

Volume 7 Issue 1

Received Date: January 31, 2023

Published Date: February 13, 2023

DOI: 10.23880/ppej-16000334

Editorial

Fracture networks exist at a wide range of scale in the earth crust and strongly influence the hydraulic behaviour of rocks, providing either pathways or barriers for fluid flow. Many oil, gas, geothermal and water supply reservoirs form in fractured rocks [1]. The main challenge is the application of numerical models that account for the fracture network geometries and the equations that govern the physical processes in fractured reservoirs in order to help with reservoir management decision to ensure safe and efficient operations.

Typically, fracture systems are characterized using outcrops through the measurement of several parameters (e.g., length, aperture, spacing) in one or two dimensions [2], that are used to generate statistical 3D discrete fracture network models (DFNs), models [3]. These parameters vary according to the tectonic settings, the lithologies, the thickness of the beds and the presence of fluids [4]. The study of the outcrop analogues is fundamental to understand the distribution of the fractures in depth in the reservoirs [5]. Usually, the workflow adopted to model fractured reservoirs consists of characterization and modeling of a three-dimensional fracture system through the use of Discrete Fracture Network (DFN) models [6] and upscaling of the network properties in an Equivalent Continuum Model (ECM) at reservoir scales [7,8]. The ECM is a geo-cellular model with average value of permeability and porosity for each cell that allows the simulation of fluid flow. This simulation is usually based on dual porosity/dual permeability models, composed by two continuum media that represent matrix and fractures [9]. This approach, although useful and widely used in many studies, has a large gap, i.e., the representation of fractures as single, distinct, and discrete objects, can individually affect migration of fluids that is strongly influenced by the geometric characteristics of each individual fracture, e.g., aperture and connectivity.

We briefly introduce a new methodology to simulate multi-phase fluid flow in fracture networks (Figure 1) and to estimate the amount of CO_2 that can be stored in the system. Our method uses only a discrete fracture network approach, able to catch the geometry and connectivity of the fracture networks, that is usually lost in the upscaling procedures commonly adopted in the modeling of fractured reservoirs.

The biggest challenge in a fractured reservoir flow simulation is combining the petrophysical properties of the rocks and the hydraulic properties of the fractures. Since the studies about fractured reservoirs highlight that fractures play a primary role in the migration and transport of the fluids [10,11], modeling the interplay between fracture network properties (e.g., connectivity) and fluid migration is indeed necessary. Recently Hyman, et al. [12] applied a DFN approach to characterize the impact of fractured caprock heterogeneity to the injection of supercritical CO_2, demonstrating how network structure plays a key role in controlling the displacement of water by $scCO_2$.

We used a similar approach to simulate fluid flow in a fractured reservoir, in order to quantify the effective contribution of fracture networks geometry and connectivity to the CO_2 migration and reservoir storage capacity [13,14], reflecting a range of variability in fracture network characteristics (e.g., number of fractures, stress field). The geometry of the fracture networks was modelled with the dfnWorks suite [15], while supercritical CO_2 flow simulation were performed using FEHM, a "Finite Element Heat and Mass" code [16], a simulator, based on a multiphase flow and thermal approach. Our results suggest a direct relationship between the fracture intensity, geometry and the volume of fluids stored in the reservoir.

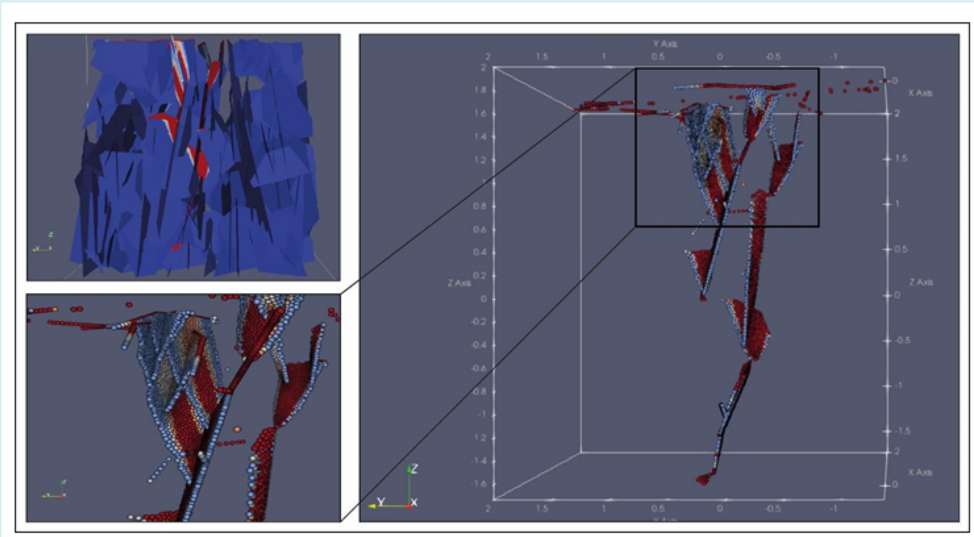

Figure 1: Fluid particle tracking inside a reservoir fractured model. The red-blue scale bar refers to the fluid saturation.

This method allows to model fractured systems at reservoir scale, in a variety of geological settings, using exclusively a DFN approach. The results confirm that it is possible to explicitly simulate the effective contribution of fractures to fluid migration and transport and to estimate fluid storage volumes in a fractured reservoir.

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