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Minerals Dissolution Effect on the Mechanical Properties of Synthetic Carbonate Rocks

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Injection of CO_2 and water in saline aquifers or oil reservoirs causes changes of pressure, saturation and concentrations that affect the state of stress and promote chemical reactions in the host rock, resulting in porosity and permeability variations. It is therefore a coupled hydro-mechanical and chemical (HMC) problem. Numerical simulation of multiphase and multicomponent flow of CO_2, oil and water with mechanical coupling allows realistic modeling of the reservoir and cap rocks. Carbonate reservoirs are geological formations composed mainly of minerals such as calcite and dolomite which can dissolve or precipitate in the medium when injecting a fluid of chemical composition and temperature different from those of the fluids initially contained in the rock. Water-weakening due to matrix acidification of carbonates is a well-known phenomenon that can be modeled by including mineral concentrations as state variables in the stress-strain behavior of the material.

The objective of this work is to characterize synthetic carbonate rocks through microtomography and petrography techniques, focusing on a comparative analysis before and after load application and degradation with a reactive fluid [1]. The synthetic rocks were subjected to physical characterization (mineralogy, computed tomography and porosity) and mechanical characterization (uniaxial compressive strength and Brazilian tests) before and after the dissolution process. The petrographic analysis verified an increase in both intergranular and intragranular porosities after dissolution. The microtomography analysis quantified the maximum increase in porosity, from 11.8% to 41.3% in the two-dimensional analysis and 31.6% to 52% in the three-dimensional analysis of the porous structures. Furthermore, the pores were quantified according to their area, and data was obtained on the orientation of the pores, providing insight into the preferred paths of fluid flow. It was also observed that the microtomography technique was an effective tool for characterizing fractures in the samples before and after dissolution [1].

Dissolution tests were also performed in a modified oedometer cell adapted to measure horizontal stress. The dissolution phase was conducted using water and an acid solution to evaluate the influence of the pH on the mechanical behaviour of the samples. When the sample in the oedometric cell is exposed to an acid solution under constant vertical load of 400kPa, vertical displacement takes place (volume decrease of the sample) and horizontal stress increases (Figure 1). The synthetic rock used in this experiment is mainly composed by calcite, with small additions of calcium hydroxide, and the reactive fluid is water acidified with acetic acid (with 10% concentration). This material is manufactured in laboratory in order to have greater control of its constituents and reproducibility of experimental results. During the acidification phase of the experiment, the sample was subjected to an acid flow with a pressure differential of 12kPa for 7h. The behavior in Figure 1 was also observed by [2] and [3]. The model for degradation of carbonatic soft rocks proposed by [2] was implemented in a finite element code capable of performing coupled THMC analyzes in porous media [4]. This model is based on the Critical State Theory with the introduction of a bonding variable that controls the size of the yield surface by modifying the tensile strength and the pre-consolidation stress of the material. In Figure 1 it is also possible to see that the HMC coupled simulation of the oedometric test was able to reproduce the experimental results in terms of volumetric strain and horizontal stress. In Figure 2 tomographic images of the synthetic carbonate rock before and after exposure to the acid solution in an oedometric cell under constant vertical load are presented. Such analyses are crucial for the injection of reactive fluids,

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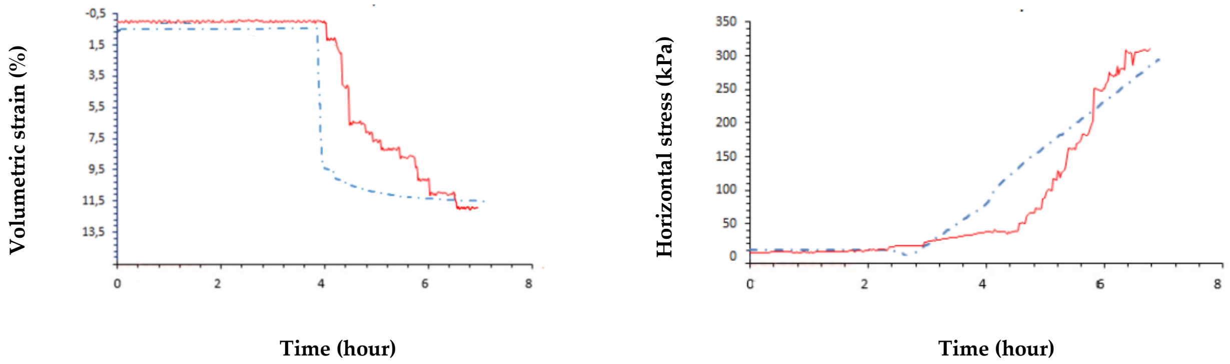
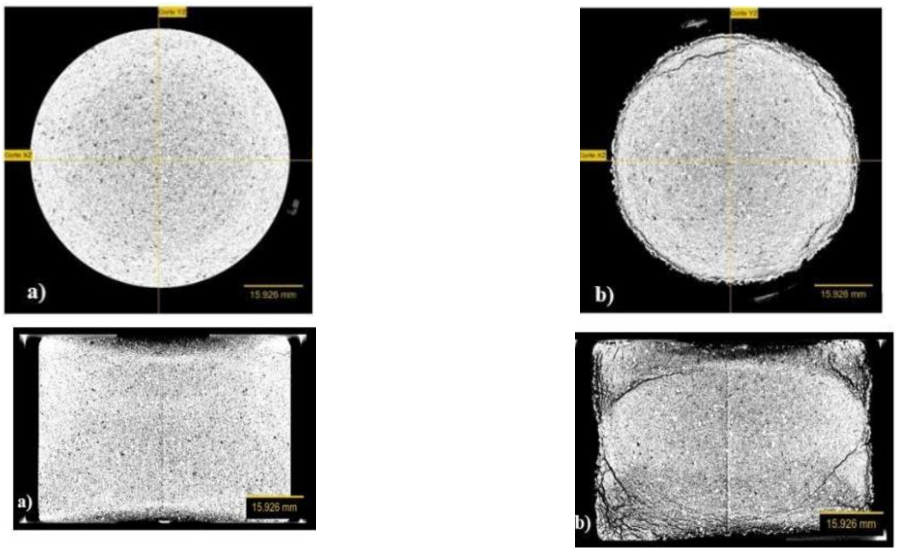
such as CO_2, at high depths. Dissolution of minerals will affect not only the porosity and permeability of the reservoir rock but also, possibly, the stress state in the vicinity of the injection well.



(a) (b)

Figure 1: Evolution of volumetric strain (a) and horizontal stress (b) during the acidification phase (at constant vertical stress) of a synthetic carbonate sample under oedometric conditions.



(a) (b)

Figure 2: Tomographic images of the synthetic carbonate rock before (a) and after (b) exposure to the acid solution in an oedometric cell under constant vertical load.

Contributor statement

Katia Galindo: Methodology, Investigation, Software, Experiments, Writing. Leonardo Guimarães: Conceptualization, Investigation, Supervision, Funding acquisition, Writing. Cecília Lins: Conceptualization, Investigation, Supervision, Writing. Analice Lima: Conceptualization, Investigation, Resources, Writing.

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