VISUALISATION OF ROCK ALTERATION PROCESSES IN FRACTURED RESERVOIR ROCKS

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Summary: X-ray micro-tomography was used to visualise and quantify processes related to CO_2 sequestration in fractured reservoir rocks. The study focuses on dissolution/precipitation processes due to acidic flow and the interplay between the fractures and the rock matrix. Furthermore, we studied the real-time evolution of fluid flow in fractures as a function of the normal stress applied to the fracture plane (i.e. confinement), using a triaxial compression cell.

1. INTRODUCTION

In the context of CO_2 sequestration, geomechanical and -chemical processes are able to alter the pore scale structure of reservoir rocks. This is especially the case in the well bore vicinity [1]. These alterations affect the porosity and permeability within the rocks, as well as the chemical balance of the reservoir fluids and the rock matrix. To fully understand what is happening at the pore scale of the system, lab-based experiments are often carried out [2, 3]. The studied processes include dehydration reactions in the area closest to the injection well, while further away from the injection well the injected CO_2 dissolves in the formation fluid, forming an acidified zone with continuing dissolution and precipitation of minerals [1]. It is a highly complex system, which is linked to the pore structure of the rock. In low-permeability rocks, a secondary complexity is added in the form of fractures, which form the primary pathways for fluid flow. In this study, the effect of rock fractures on dissolution/precipitation reactions within reservoir rocks of the Longyearbyen CO_2 Lab is studied, as well as the effect of the burial depth of the reservoir on the fractures and the flow through them. The targeted reservoir, underneath Longyearbyen, Spitsbergen is found at a depth of app. 800 m. The most permeable zones within this reservoir are sandstone and conglomerate rocks with a calcite cement. These sections contain natural fractures which provide the main fluid conductivity.

2. EXPERIMENTAL METHOD

Two different experimental setups were used in this study. In a first set of experiments, the effect of fractures on processes of dissolution and precipitation of minerals was studied. For this, three samples obtained from the main reservoir in the Longyearbyen CO_2 Lab were subjected to an acid fluid in order to investigate the effect of dissolved CO_2 on the rock fabric. In each of the rock plugs, a tensile fracture was induced, in order to ensure the formation of a fracture parallel to the fluid flow. Subsequently, the rock plugs were fully saturated with a 0.17 M NaCl brine, which was pre-equilibrated with the rock to prevent mineral dissolution prior to acid injection. After this, a formic acid solution with a pH of 4 was injected into the fractured plugs. The flow experiments were conducted for a prolonged period of time, in which the progressive dissolution of the calcite cement was followed through micro-CT scans, carried out on the the HECTOR scanner at Ghent University [4]. In a second series of experiments, triaxial tests were conducted on samples of the Longyearbyen CO_2 Lab, as well as on more simple rock types such as the Bentheim sandstone. Triaxial compression experiments were performed at the High Pressure and Temperature

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Laboratory, Utrecht University [5], on ~35 mm by 60-70 mm samples to induce shear fractures at 10 MPa confining pressure and room temperature, i.e. conditions very similar to the in-situ conditions of the Longyearbyen field. After the experiment, sample permeability was measured at different confining pressures, without any remaining differential stress across the sample [6]. In order to understand these results at the cm-scale, similar experiments were carried out on mm-scale (5 mm diameter) rock samples in an in-situ triaxial device, which fits on the Environmental micro-CT system (EMCT) at Ghent University [7].

3. PRELIMINARY RESULTS

In a first series of experiments, in which a fractured rock plug with polished fracture walls was subjected to an acidic fluid, the dissolution of the carbonate cement could clearly be observed (figure 1). The rock matrix dissolved symmetrically around the fracture, which acted as the primary pathway. Although no minerals precipitated during these first tests, differences in dissolution patterns according to changes in fluid flow speed could be noticed. Preliminary results from the Longyearbyen sample deformed at Utrecht University showed the formation of a conjugate set of two shear fractures, which did not cross-cut the sample from top to bottom. Post-experiment permeability showed a two order of magnitude decrease by increasing the confining pressure from 5 to 20 MPa. The details of the role normal stress has on fracture aperture is currently still under investigation. It will be interesting to compare the evolution of the flow patterns in the tensile fractures to those of the shear fracture formed in triaxial compression. The response of the fracture aperture to the applied normal stress on the fracture plane (i.e. through varying the confining pressure) may be very different in both cases, due to the production of fines (fault gouge) and offset along the fracture for the case of shear fractures. Understanding fracture aperture under in-situ stress conditions is important, since most of the data on fracture apertures in the Longyearbyen CO_2 system comes from outcrops, and decompacted cores.

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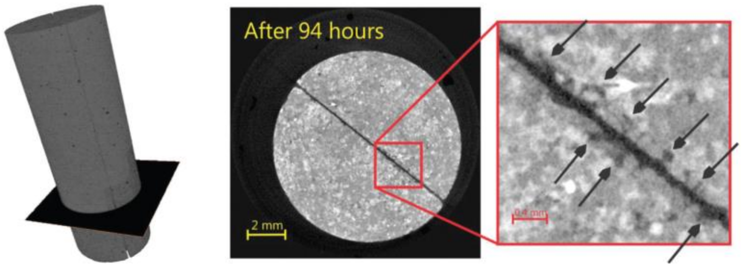

Figure 1: Results of dissolution experiments, using a rock plug with an idealized fracture. Depending on the flow rate of the acidic solution through the fracture, different patterns of dissolution could be observed.