On wave propagation in a CO_2/Brine-saturated fractured core

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Introduction

A laboratory measurement of acoustic velocity on a vertically-fractured tight sandstone core plug is made, as the brine in the fracture is substituted by liquid CO_2. The core is taken at 772m depth in the De Geerdalen Formation in borehole Dh4, Longyearbyen CO_2 pilot, Svalbard. The natural vertical fracture has 0.5mm average aperture (without any pressurization). The test is performed during a research project led by UNIS CO2 Lab AS (titled *Delineation of an unconventional reservoir in Adventdalen for future CO_2 injection; de-risking and monitoring campaign 2014-2015*). Figure 1 shows the CT image of the core plug and the measured signals when an axial P-wave source and receiver are applied. The source and receiver are placed just above and below the vertical fracture. It is clearly seen that there is a little difference in the recorded waveforms. The first wave arrivals of the two cases (just before and after the liquid CO_2 is injected) are almost the same. At the same time, there is also a small delay in the first peak arrivals of the two cases. In addition, the magnitude is reduced a bit as the brine is substituted by the liquid CO_2. In this study, we investigates the observation more closely by means of a 3D finite-element-based full waveform simulation.

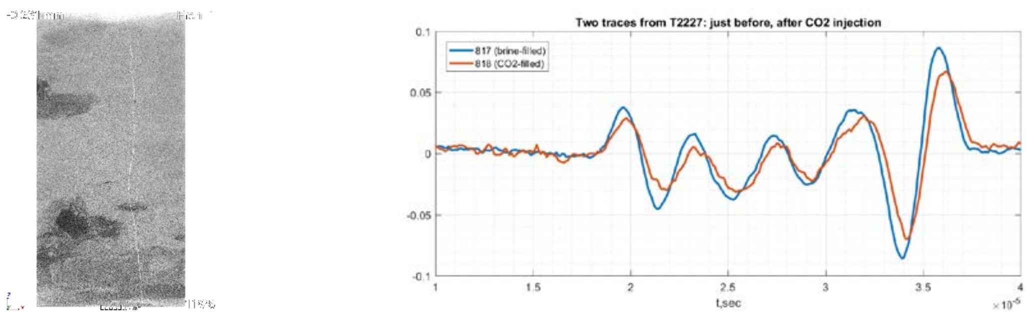

Figure 1: Post-test CT image of the vertically-fractured core of 38.26 mm diameter, 76.03 mm height (left); and the measured signals (right) when the fracture is brine-saturated (trace No. 817, blue) and CO_2-satured (trace No. 818, red).

Methods

In order to generate the synthetic full waveform, we use a commercial finite element (FE) software, named *COMSOL Multiphysics*, and solve the coupled acoustic-seismic wave equations directly in the time domain. The first plot in Figure 2 shows the finite element (FE) model that is built such that it reproduces the laboratory setup as close as possible.

Results and Discussion

The second plot in Figure 2 shows the synthetic waveform that we produce by means of the 3D FE model. The agreement between the measure and synthetic signals are not quite perfect and it is not straightforward to compare them directly data-point by data-point, either. Nevertheless, the simulation result show similar observations to the measured data. We can see that the arrival times for the two cases of brine-filled and CO_2-filled are almost identical in the simulation signals as well. The magnitude for the CO_2-filled case is reduced in comparison to the brine-filled case, whose degree is quite comparable to that of the measured signals.

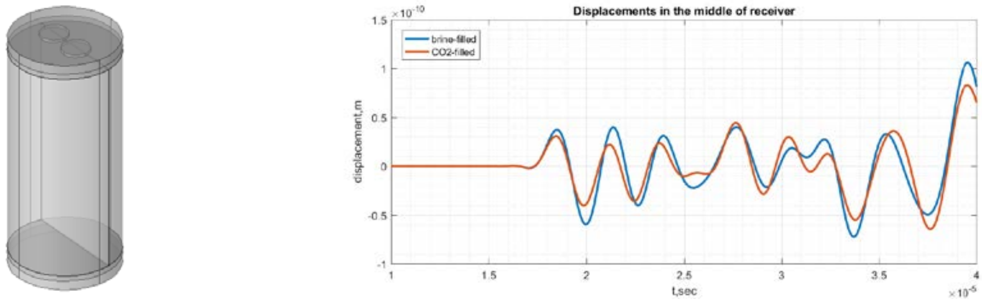

Figure 2: FE model sketch (left) and simulated signals (right) for brine-filled and CO2-filled fractures.

Conclusions

This study attempts to match a 3D FE simulation result with an acoustic signal measured through a tight sandstone core plug, in which a vertical (or axial) fracture exists. The main particular interest is to understand the effect of fluid substitution in the fracture on the velocity measurement. The numerical exercise shows a good potential of increasing our understanding of the measured laboratory data. The simulation exercise will continue in order to produce better agreement with the measured signal. From such investigation, we will be able to explain better the lab data (attenuation, multiples, P/S conversion, boundary conditions in the lab setup, etc.), and suggest more quantitative way of applying the lab data to the field scale.

Acknowledgements

The simulation work was supported by FME-SUCCESS under Grant 193825/S60 from Research Council of Norway. In addition, the laboratory measurement was also partly funded by the UNIS (University Centre in Svalbard) CO2 research laboratory. Finally, we also appreciate the Longyearbyen CO2 storage pilot project for the access to the core sample.