EGU21-9230
https://doi.org/10.5194/egusphere-egu21-9230
EGU General Assembly 2021
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Laboratory experiments of water injection coupled with ultrasonic monitoring reveal wave-induced fluid flow in microporous carbonate rock

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Monitoring of fluid movements in the crust is one of the most discussed topics in oil & gas industry as well as in geothermal systems and CO_2 storage, but still remains a challenge. The seismic method is one of the most common ways to detect the fluid migration. However, the use of ultrasonic monitoring at the sample scale in laboratory experiments persists as the most effective way to highlight large scale observations in which the boundary conditions are not well constrained.

To unravel the fluid effect on P-wave and S-wave velocity, we performed mechanical experiments coupled with ultrasonic monitoring on Obourg chalk from Mons basin (Belgium). Water injection tests under critical loading, imbibition tests and evaporation tests provided a full spectrum of observations of fluid-induced wave alteration in term of propagation time and attenuation.

The analysis of these experimental results showed that significant velocity dispersion and attenuation developed through variations in water saturation, and that these processes are linked to the presence of patches of water and air in the pore space.

We used the White's formulation to model the relaxation effects due to spherical pockets of air homogeneously distributed in a water-saturated medium. In this framework, the pressure induced by the passing wave, produces a fluid flow across the water-air boundary with consequent energy loss.

This model reproduces both qualitatively and quantitatively the experimental results observed on the water injection tests. Indeed, it is shown that the progressive water saturation or desaturation of this chalk, generates a shift of the critical frequency (from the undrained relaxed towards unrelaxed regimes) which at some point matches the resonance frequency of the piezoelectric transducers used in the experimental setup (0.5 MHz). This phenomenon allowed us to get a continuous recording of the relaxation processes induced by saturation variations.

The outcomes of this work can significantly improve the actual knowledge on coupled effects of

waves and fluids which is a crucial aspect of fluid monitoring in the context of reservoir evaluation and production.