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Extraction of layer-specific seismic velocity in a porous medium through seismic interferometry applied to ultrasonic measurements of CO2 sequestration

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Abstract

Purpose: Time-lapse seismic monitoring constitutes the foundation for most monitoring programmes involving CO_2 storage. When using time-lapse seismics, two major sources of uncertainty in the estimation of changes in the reservoir properties, like saturation and pressure, are the non-repeatability of the source positions and the difficulty to separate the effect of the overburden from that of the changes taking place in a CO_2 reservoir. The goal of this research is to propose a new concept of using non-physical (ghost) reflection events retrieved by seismic interferometry and test this concept through ultrasonic laboratory experiments that mimic realistic CO_2 sequestration in a porous reservoir rock.

Experimental description: Results from two laboratory experiments will be presented. In both experiments, a two-layer sample consisting of a top layer of epoxy, representing the impervious cap rock, and a lower layer of Bentheimer sandstone (porosity ~ 22%, permeability 1.34 Darcy, density 2080 kg/m^3), representing the reservoir rock, is used. In the first experiment, ultrasonic tests using piezoelectric transducers were performed under ambient (room) conditions of temperature and pressure, and water was displaced by ethanol. In the second experiment, elaborate ultrasonic experiments were carried out under controlled (elevated) pressure and temperature conditions mimicking a true CO_2 reservoir where supercritical CO_2 displaced brine. An array of seismic receiver was used to record the ultrasonic reflections from the top and the bottom of the porous layer.

Results and conclusions: Using non-physical (or ghost) reflections retrieved by seismic interferometry, we could successfully estimate the acoustic wave velocity in the porous reservoir and its temporal change associated with changes in pressure and fluid-content in the pores. The estimation of layer-specific wave-velocity, eliminating effectively the effect of the changes occurring in the overburden and that of source irreproducibility, has been possible for the first time. The advantage of using cross-coherence over cross-correlation in the application of seismic interferometry, in order to address velocity changes in a thin reservoir layer, has been established. It was possible to obtain reliable values of the rock-physical properties from the estimated layer-specific acoustic wave velocity obtained by the proposed approach.

Key Words: ultrasonics, interferometry, monitoring, CO_2, CCS, reflections, seismics

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