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# Modeling techniques for cross-hole seismic monitoring of $CO_2$ injection in a deep saline aquifer

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In this work, we present a modelling technique for a synthetic, yet realistic, 2D cross-hole seismic monitoring experiment for $CO_2$ injection in a deep saline aquifer. We implement a synthetic (2D) geological formation consisting of a sandstone aquifer, with shaly mudstone intrusions, embedded in very low permeability shales. The aquifer has its top at about 800 m b.s.l., is approximately 200 m thick and it extends about 800 m in the horizontal direction.The formation is very heterogenous with respect to all petrophysical and hydrological properties; furthermore, we consider the grains to be a mixture of quartz and clay.

Injection of the $CO_2$ and the propagation of the plume is modelled using STOMP commercial software. The algorithm solves the mass balance equation for wetting and non-wetting phase fluids, as well as for the dissolved salt. It considers advection via Darcy's equation extended to two phase flow and molecular diffusion. Furthermore, dissolution of the $CO_2$ in the brine is considered. We assume the aquifer to be initially in hydrostatic equilibrium and we inject pure $CO_2$ for 2 years. We then compute phase p-wave velocities and quality factor by means of White's mesoscopic theory, which assumes that the partially saturated pore consists of two concentrical spheres; the inner saturated with gas, the outer saturated with brine.

Using this p-wave velocity and quality factor map, we compute synthetic cross-hole seismograms by means of a visco-acoustic modelling code. We perform 80 shots along the left borehole, with a source spacing of 5 metres.

We then pick the first arrivals (direct wave) on the seismograms and we perform a tomographic inversion using cat3d software. We invert for straight rays, updating the velocity model with a SIRT algorithm at each iteration. Due to the mainly horizontal orientation of the velocity anomalies, we select to invert only for rays having an angle lower than 30° with the horizontal direction. The algorithm converged well after 200 iterations; furthermore, the picked and computed velocities fit rather well, with residuals showing a gaussian distribution around 0.

The method looks promising, since the main velocity anomalies are well detected.