Abstract

We perform a time-lapse seismic characterization of the Sleipner aquifer due to CO_2 injection and storage. It is essential to built a suitable geological model based on a porous-media constitutive equation. This model considers a poroelastic description of the Utsira formation (a shaly sandstone), based on porosity and clay content, and takes into account the variation of the properties with pore pressure and fluid saturation. Moreover, the model considers the geometrical features of the formations, including the presence of shale seals and fractures. We also model fractal variations of the petrophysical properties. The numerical simulation of the CO_2-brine flow is based on the Black-Oil formulation, which uses the Pressure-Volume-Temperature (PVT) behavior as a simplified thermodynamic model. The corresponding equations are solved using a finite difference IMPES formulation. Then, we compute synthetic seismograms on the basis of the resulting saturation and pore-pressure maps. Wave attenuation and velocity dispersion, caused by heterogeneities formed of gas patches, are described with White's mesoscopic model to obtain an equivalent viscoelastic medium at the macroscale. The wave equation is solved in the space-frequency domain with a finite-element iterative domain decomposition algorithm.

The fluid simulator properly models the CO_2 injection, obtaining accumulations below the mudstone layers as injection proceeds. We are able to identify the time-lapse distribution of CO_2 from the synthetic seismograms, which show the typical pushdown effect.

The proposed methodology constitutes an important tool to monitor the CO_2 plume and analyze storage integrity, providing an early warning in the case any leakage may occur.