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Comparative 2D BRT and seismic modeling of CO_2 plumes in deep saline reservoirs

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The multi-disciplinary research project "CO_2 MoPa" (modeling and parameterization of CO_2 storage in deep saline formations for dimensions and risk analysis) deals, among others, with the parameterization of virtual subsurface storage sites to characterize rock properties with modeling of processes related to CCS in deep saline reservoirs. The geophysical task is to estimate the sensitivity and the resolution of reflection seismic and geoelectrical time-lapses in order to determine the propagation of CO_2 within the sediments and the development of the CO_2 reservoir. Compared with seismic, borehole electric resistivity tomography (BRT) has lower resolution, but its permanent installation and continuous monitoring can make it an economical alternative or complement. Seismic and geoelectric applications to quantify changes of intrinsic aquifer properties with time are justified by the lower density and velocity and the higher electric resistivity of CO_2 in comparison to pore brine. We present here modeling results on scenarios with realistic parameters of deep saline formations of the German Basin (candidate for CCS). The study focuses on effects of parameters related to depth (temperature, pressure), petrophysics (salinity, porosity), plume dimensions/saturations and data acquisition, processing and inversions. Both methods show stronger effects with increasing brine salinity, CO_2 reservoir thickness, porosity and CO_2 saturation in the pores. Both methods have a pronounced depth dependence due to the pressure and temperature dependence of the velocities, densities and resistivities of the host rock, brine and CO_2. Increasing depth means also decreasing frequencies of the seismic signal and hence weaker resolution. Because of the expected limited thickness of the CO_2 reservoir, the reflections from its top and bottom will most likely interfere with each other, making it difficult to determine the exact dimensions of the reservoir. In BRT, the resulting resistivity resolution and anomaly magnitudes are inversely proportional to the host salinity and temperatures and directly proportional to CO_2 saturation and reservoir dimensions. The sensitivity of the seismic method to changes in saturation is most pronounced for low CO_2 concentrations while the geoelectric method has a higher sensitivity at high concentrations.

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