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Analytical Analysis of Layer Spreading in the CO2 Plume at Sleipner

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SUMMARY

At the Sleipner field, CO2 is removed from natural gas extracted at the Sleipner East field and pumped into the Utsira sandstone. The time-lapse seismic reflection profiles across the injection site show the CO2 plume as a series of bright reflective layers.
Combining analytical solutions of flow with observations from the extensive seismic reflection data has provided understanding of the CO2 migration. For a buoyant flow in porous medium, show that if the net input flux remains constant, radius will increase with the square root of time and the height of the flow will increase from the nose of the current to the centre. Accumulations of CO2 in layers at Sleipner exhibit this behaviour over the first six years of injection.
The CO2 plume has been mapped on subsequent seismic surveys.
After 2004 the growth of the accumulations of CO2 varies throughout the plume. Layers higher in the plume continue to exhibit a linear relationship between radius squared and time indicating no change in net input flux. The area of the lower layers decreases at a similar rate to the initial growth and to a first approximation this may indicate a net output flux, however the reflectivity of the lower horizons is also reduced significantly.
The reflectivity of the plume varies both spatially and temporally.
Quantifying the reduction of CO2 from layers which exhibit a decrease in area and amplitude will only be possible if the decrease due to imaging processes is known and understood. Reduction in reflectivity or seismic amplitude can be caused by: 1) Lateral velocity variations. 2) Transmission loss at reflective interfaces, which increasingly becomes a problem as the reflectivity of the layers increases with greater amounts of CO2. 3) Increased amounts of intra-layer CO2 at low saturations results in intrinsic attenuation and lower reflection coefficients.
The total area of the layers of CO2 is no longer increasing at the same rate as injection of CO2. The CO2 that does not appear present in the high saturation layers is either, a)dissolved in the brine, b)present as low saturations, diffuse CO2 , or c)present in the high saturation layers and the decreased reflectivity is an artefact of the imaging. It is most likely to be a combination of all three and this ongoing research endeavors to investigate this.