Monitoring concept for a CO_2 migration experiment at the Svelvik CO_2 Field Lab

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ABSTRACT

Introduction

In the frame of the ERA-NET Cofund ACT research project Pre-ACT (Pressure control and conformance management for safe and efficient CO_2 storage), a multiphysical approach for quantitative monitoring of pore pressure and saturation is under investigation. A monitoring concept based on pressure, geoelectric, seismic and gas analysis sensor systems should be tested and evaluated to which degree it could replace expensive repeated 3D seismic surveys for CO_2 migration observation. The practical realisation of a field experiment for studying controlled pressure- and saturation discrimination is in preparation at the Svelvik CO_2 Field Lab. Svelvik as part of the European ECCSEL initiative (Quale et al, 2017), is located on the Svelvik ridge and at the sill of the Drammensfjord 50 km south of Oslo (Norway). Due to its laterally homogeneous unconsolidated sediments, the site offers well constrained conditions for controlled gas/water experiments and forms a suitable analogue for high-permeable sands of storage reservoirs (Bakk et al., 2012). In that way, it bridges the gap between laboratory experiments on core or soil samples and large scale storage reservoirs of true pilot projects. The already started upgrade and site assessment work of the Svelvik CO_2 Field Lab focuses on new monitoring well locations such that a future CO_2 migration test will be captured by geophysical cross-well data (Eliasson et al., 2018). The operational planning has been accompanied by reservoir simulations of injecting CO_2 in a sand-rich sedimentary interval at about 60-m depth, under a clay-rich interval (Grimstad et al. 2018).

Methodological approach

Verification of containment and conformance relies on spatially distributed sensing techniques capable of mapping the temporal evolution of CO_2 migration. In this context, Pre-ACT focuses on the decision making for sparse but reliable monitoring concepts, which provide sufficient meaningful data for a site’s conformance study. For the Svelvik experimental design, the subsurface CO_2 injection has been modelled by a poro-elastic description for the matrix and pores filled with arbitrary water/CO_2 mixtures (Weinzierl et al., 2018). Near surface and appraisal well grain size analysis and appraisal well logging data are used to constrain the elastic properties of an acoustic impedance forward model. Preliminary seismic simulations for a range of plume migration scenarios reveal a weak resolution to determine pressure effects with acoustic methods. This requires further complementary methods, as e.g., electrical resistivity as well as pressure tomography.

Experimental concept

Surface geochemical monitoring

Similar to the Ketzin CO_2 pilot site, a geochemical soil gas system is installed across the test area to observe the soil CO_2 flux from the early beginning of the experiment. The sampling grid consists of seven survey points using LI-8100 automated soil CO_2 flux system (LI-COR Biosciences) and a 10-cm survey accumulation chamber (Zimmer et al., 2011). In addition to the soil CO_2 flux, soil temperature and moisture are also recorded. The data set obtained before the CO_2 injection starts serves as a basis for comparison with all further measurements during the migration test.

Downhole pressure monitoring

Pore pressure is planned to be measured at four different elevations at the aquifers: Two locations above, one inside and one below the injection horizon; the exact levels will be determined based on the lithology found during drilling. The bottom-hole pressure is transferred by capillaries mounted outside the well casing to the surface and transduced there. Compared to common bottom-hole sensor installations, this setup minimizes the required space downhole and increases the resolution and accuracy. Atmospheric pressure is compensated.

Geoelectrical monitoring

All monitoring wells are equipped with permanent electrode arrays of equidistant spacing, comprising 16 electrodes per each borehole and based on spiraglider centralizer design. The downhole installation will be connected with additional electrodes of surface acquisition profiles. This allows an enlargement of the cross-well imaging area and might provide information about preferential pathways.

Distributed Acoustic Sensing

Acoustic data will be recorded on geophones and fiber optic systems in four shallow monitoring boreholes. Both straight and helical fiber will be installed. Pre-installation synthetic modelling is performed to find the optimum wrapping angle of the helical fiber for the different considered applications, i.e. the DAS system is applied to conduct active VSP and cross-well tomography as well as passive seismic. Comparison with the installed conventional geophones will give valuable calibration and thus confidence.

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