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Svelvik CO2 Field Lab: Upgrade And Experimental Campaign

P. Eliasson[1]*, C. Ringstad[1], A. Grimstad[1], M. Jordan[1], A. Romdhane[1]
[1]SINTEF

Summary

A small-scale CO2 field laboratory was established at Svelvik, Norway during 2009-2013. The original intent was to use the field lab for CO2 migration monitoring studies. Findings during the construction of the lab and during the initial experimental campaign indicated that the field lab is better suited for research on monitoring of CO2 storage. The suitability of the field lab for such research was further confirmed in 2013 by feasibility studies based on CO2 injection simulations and sensitivity studies for various geophysical methods. Since 2017, SINTEF is working, within the ECCSEL consortium, on upgrading the field lab with additional monitoring wells, instrumentation for cross-well seismic and ERT, and trenched DAS cables. The upgrade of the lab will be completed in spring 2019, and several new research projects have plans for experiments. The first new experimental campaign will be conducted during 2019 within the Pre-ACT project with the objective to produce field data and develop methods for quantification and discrimination of pressure and saturation changes in the subsurface, caused by CO2 injection.

Introduction

A small-scale CO_2 field laboratory was established in 2009-2013 at Svelvik, Norway, in the SINTEF-coordinated CO2FieldLab[1] project. The test site is currently being upgraded by SINTEF through the ECCSEL (European Carbon Dioxide Capture and Storage Laboratory Infrastructure) consortium. The lab will be available to research projects worldwide when the upgrade is completed in spring 2019.

The test site occupies a non-active part of a sand and gravel quarry, located in a glaciofluvial – glaciomarine environment. It was initially believed that the area contained relatively homogeneous, unconsolidated and highly permeable sand. This would have made the site well suited for testing of monitoring methods aimed at detection of CO_2 leakage. The CO2FieldLab project revealed, however, that heterogeneous (possibly varved) alternating layers of sand, silt and clay existed below 50 m (Mørk et al. 2013). Due to the presence of low permeable clay layers, it was realized that the field lab could also be used for monitoring of storage (laterally migrating or stationary CO_2) by injecting fluids into underlying sediment layers. To exploit those possibilities, the field lab is currently being upgraded with new monitoring wells and monitoring instrumentation. A new experimental campaign will be conducted starting spring 2019, within the Pre-ACT project, with the objective to produce field data and develop methods for quantification and discrimination of pressure and saturation changes in the subsurface, caused by CO_2 injection

Several other projects are considering experiments at Svelvik and the field lab clearly fills a gap between bench laboratory tests and pilots. Due to its size, the controlled environment (known "ground truth"), and the potential of repeatable experiments, the field laboratory will provide excellent possibilities to develop and test technologies required for large-scale CCS applications in a rapid and cost-efficient manner.

Site characterization and first experimental campaign

The site was characterized during 2009 and 2010, starting with the drilling, sampling and logging of a 333 m deep exploration well (Svelvik #1). Core and flow-line samples were analysed. Geophysical data, including resistivity, 2D seismic, and pseudo-3D and 2D ground penetrating radar (GPR) data were acquired. Hydrodynamical, geochemical, and soil gas surveys were also conducted (Bakk et al. 2012).

In 2011, a first experimental campaign was performed, aimed at testing various detection methods for shallow gas migration and leakage from the ground to the atmosphere. In total, 1700 kg of CO_2 was injected at 18 m depth through an inclined well (Barrio et al. 2014). The measured areal variation of gas flux at the surface did not fit the expected migration path to the surface directly above the injection point, but pointed to migration along the dipping layers that could be seen in the GPR data. This also indicated that the dipping layers in the shallower sediments (above 50 m depth) contain zones with low transmissibility to gas flow.

A second well (Svelvik #2) was drilled at the end of the CO2FieldLab project, in 2012, to determine the permeability of a sand layer located at 60–70 m. This layer was one of several sand-rich intervals identified in the log data of Svelvik #1. This layer was particularly interesting due to the presence of a clay-rich interval immediately above. A pumping test established a permeability of about 123 – 170 mD. It was therefore concluded that the sand layer would be suitable for injection experiments.

The test site area and the location of the Svelvik #1 and #2 wells are shown in Figure 1. The area is slightly changed for the upgrade compared to the CO2FieldLab area.

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[1] https://www.sintef.no/Projectweb/co2fieldlab/

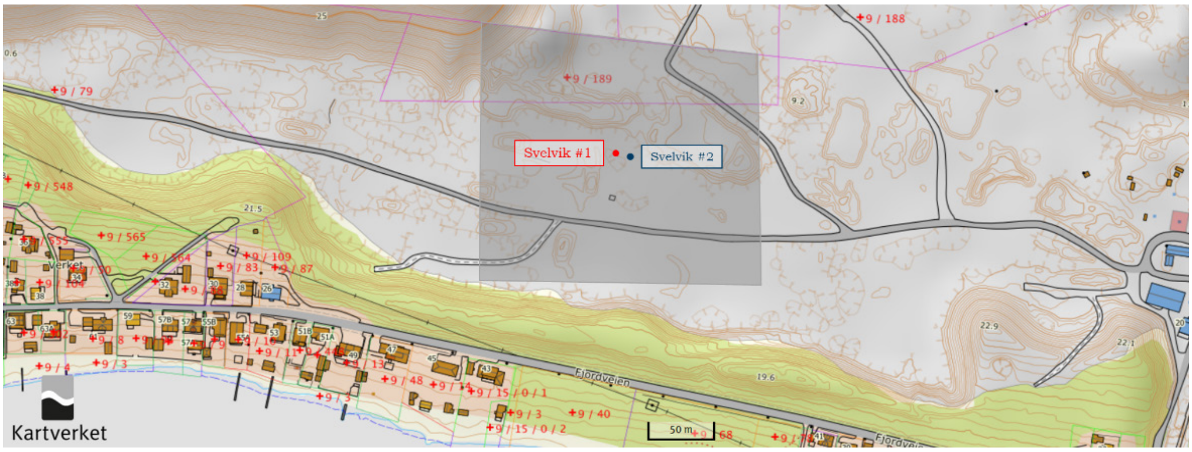

Figure 1 *Schematic drawing of the test site area at Svelvik (in grey), together with the location of Svelvik #1 (red dot) and Svelvik #2 (blue dot).*

Feasibility study: Monitoring of CO_2 storage

Based on the initial site characterization and further information obtained during the experimental campaign, new investigations were initiated in 2013. Notably, the feasibility of geophysical monitoring of gas injection into the sand layer at 65 m depth was studied numerically (Querendez et al. 2014). To build a framework for the feasibility study, existing site characterization data was compiled into a new, more comprehensive, 3D digital geomodel. Information from well log data, reprocessing of the 2D seismic and available prior geological knowledge about the site were included to better capture the complexity of the site, see Figure 2.

The likely gas saturation distribution from a gas injection scenario was simulated. Realistic reservoir conditions (10 °C and 6 bar) were used, and the injection rate (50 Sm^3/day, low enough not to risk fracturing of the seal) was maintained for up to 9 weeks. Several intermediate saturation distributions were investigated for detectability by geophysical methods. Gassmann's equation and Archie's law were used to derive elastic and resistivity models of the subsurface for each saturation distribution, and synthetic geophysical monitoring data was generated using SINTEF's in-house modelling tools for seismic, EM, and gravity.

The synthetic seismic data was inverted using a few different scenarios (perfect baseline vs. smoothed baseline and velocity model with or without diffractors). The inversion did not seem to depend critically on a perfect baseline, even though this helped to improve the result. The plume was in both cases clearly detectable. However, the presence of shallow diffractors in the weathered zone had a clear negative effect on the inversion results and the plume may not be possible to detect.

Inversion of synthetic EM and gravity data was also carried out. As for the seismic data, the plume seemed to be detectable under ideal circumstances. However, the results suggested that combinations with other acquisition configurations (VSP and cross-well) should be evaluated for improved monitoring performance.

Upgrade and new instrumentation

An upgrade to prepare the field lab for new types of experiments was initiated in 2017. The upgrade will convert Svelvik #2 to an injection well, enabling both water and CO_2 injections. It will be instrumented with sensors for monitoring of pressure, temperature and CO_2 concentrations.

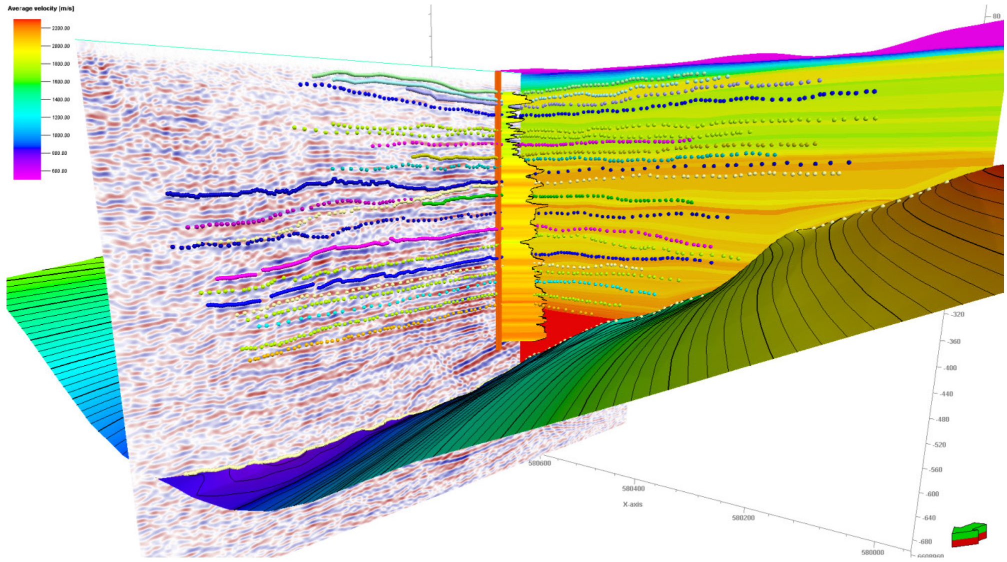

Figure 2 *Petrel snapshot of the 65 m deep geomodel. Seismic interpretation is done on the depth migrated images of reprocessed 2D seismic lines.*

The upgrade includes further drilling and completion of four vertical monitoring wells, approximately 100 m deep and equipped with fiberglass casings. Fibre-optic cables for seismic monitoring (both straight and helical DAS cables) and temperature measurements (DTS) will be installed permanently behind casing in addition to electrical resistivity tomography (ERT) electrodes and cables to enable cross-well measurements. In addition, downhole sensors for measurements of pressure, CO_2 concentration and salinity will be installed. The monitoring wells will cover a square area of about 100 x 100 m with the injection well in the centre. Cross-well monitoring will therefore be able to intersect the CO_2 plume, whatever the direction it may propagate. Fibre-optic DAS cables will also be installed in trenches at the surface, enabling surface seismic measurements.

The interior of the monitoring wells will be available for non-permanent monitoring equipment. For instance, seismic P- and S-wave borehole sources may be used together with 3C borehole receivers, creating high resolution seismic cross-well data sets. The colocation of conventional seismic receivers and DAS cables will provide additional opportunities for the development and testing of fibre-optic cables and processing techniques for this type of data.

The Pre-ACT project and new experimental campaign

Pre-ACT is a 3-year (2017-2020) research project involving partners SINTEF (coordinator), NORSAR, BGS, PML, TNO, and GFZ. The project is funded by the ACT program and four industry partners (Equinor, Shell, Total, and TAQA). The objective of Pre-ACT is to equip operators and regulators with pressure-driven decision support protocols that enable them to establish a safe and efficient monitoring system and to assess quantitatively site conformance.

One task in the project deals with development and testing of a novel geophysical method for quantification and discrimination of saturation and pressure changes caused by CO_2 injection. Those studies will partly be performed using data from a new experimental campaign at the Svelvik field lab. As soon as the upgrade of the field lab is completed in spring 2019, the experimental work as part of Pre-ACT will be initiated and run for around six months. The cross-well seismic and electric setup, complemented by seismic 2D data, will be used to monitor the CO_2 injection in which pressure will first be built up without a CO_2 saturation change by injecting formation water. In a second step, after pressure has fallen to normal, CO_2 will be injected to induce a simultaneous pressure and saturation increase. This second step will be cycled and the acquired geophysical data will be used to test an approach for quantitative pore pressure monitoring (Eliasson et al., to be published in International Journal of Greenhouse Gas Control).

The use of multiparameter seismic methods in combination with other geophysical observables (resistivity, gravity) will be investigated. Based on relevant rock physics models, the integration will be carried out using SINTEF's waveform and rock physics inversion tools in a time-lapse mode. Owing to a Bayesian formulation, this will allow quantification of pore pressure and saturation, including uncertainty. The developed approach will provide essential input for pressure management and qualified decision making during CO_2 injection.

Conclusions

A small-scale CO_2 field laboratory was established at Svelvik, Norway during 2009-2013. The original intent was to use the field lab for CO_2 migration monitoring studies. Findings during the construction of the lab and during the initial experimental campaign indicated that the field lab is better suited for research on monitoring of CO_2 storage. The suitability of the field lab for such research was further confirmed in 2013 by feasibility studies based on CO_2 injection simulations and sensitivity studies for various geophysical methods. Since 2017, SINTEF is working on upgrading the field lab with additional monitoring wells, instrumentation for cross-well seismic and ERT, and trenched DAS cables. The upgrade of the lab will be completed in spring 2019, and several new research projects have plans for experiments. The first new experimental campaign will be conducted during 2019 within the Pre-ACT project with the objective to produce field data and develop methods for quantification and discrimination of pressure and saturation changes in the subsurface, caused by CO_2 injection.

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References

Bakk, A., Girard, J-F., Lindeberg, E., Aker, E., Wertz, F., Buddensiek, M., Barrio, M. and Jones, D. [2012] CO2 field lab at svelvik ridge: site suitability. Energy Procedia, 23, pp.306-312.

Barrio, M., Bakk, A., Grimstad, A.-A., Querendez, E., Jones, D.G., Kuras, O., Gal, F., Girard, J.-F., Pezard, P., Depraz, L., Baudin, E., Børresen, M.H. and Sønneland, L. [2014] CO2 Migration Monitoring Methodology in the Shallow Subsurface: Lessons Learned From the CO2FIELDLAB Project. Energy Procedia 51, 65 – 74.

Mørk, A., Barrio, M., Buddensiek, M., Grimstad, A.-A., Lindeberg, E., Bakk, A., Rendall, H., and Ruden, F. [2013] CO2FieldLab: Field experience with monitoring and safety assessment of CO2 migration in shallow subsurface. NGF Abstracts and Proceedings, no. 1, 2013.

Querendez, E., Romdhane, A., Jordan, M., Eliasson, P. and Grimstad, A.A., 2014, May. Geophysical monitoring of near surface CO2 injection at Svelvik-Learnings from the CO2FieldLab experiments. In EGU General Assembly Conference Abstracts (Vol. 16).