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Pressure control and conformance management for safe and efficient CO_2 storage – lessons learned in the Pre-ACT project

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Abstract

The three-year (2017-2020) research project Pre-ACT was granted as one of the first three large projects in the Accelerating CCS Technologies (ACT) program (https://act-ccs.eu). Pre-ACT was a collaborative effort between partners from six research institutes and four companies with an active role in CCS. The project ambition was to deliver cutting edge research into the safe storage and monitoring of CO_2, particularly to improve strategies for monitoring and management of the pore pressure distribution within the storage reservoir. Pre-ACT has established methodologies for assessing the conformance of a storage site, relative to its expected performance, through research in five work packages. The primary output is quantitative conformance systems, relying on cost-effective monitoring, and guidelines (protocols) on how to act on a failed conformance test. The protocols are applicable to industrial operators and focus on the main storage-related challenges for accelerated deployment of CCS: capacity, confidence and cost.

We report here on the lessons learned within the project, both in terms of European collaboration between research institutes and industry partners in the new ACT-program, but most of all in terms of the new knowledge and methods related to monitoring and control over large-scale storage projects in the North Sea. In addition, we describe a unique experimental campaign with brine and CO_2 injection at the new ECCSEL Svelvik CO_2 Field Lab and touch upon the importance of communicating research findings to external stakeholders (such as policy makers, regulators, and future CCS project operators).

The project's ambition of providing a quantitative conformance system and guidelines for pressure-driven decision support was achieved through a combination of research and development activities with demonstration of new methods and workflows in a few case studies for potential North Sea storage projects. The R&D focused on

- Pre-injection modelling
- Novel monitoring concepts

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- Conformance verification
- Decision making

Through the work on pre-injection modelling, approaches for assessing how pore pressure builds up and propagates, and for determining the sensitivity of such predictions to various reservoir heterogeneities, were developed. The studies have shown both how to take into account uncertainties in fault properties, reservoir porosity and permeability and how sensitive an injection evolution scenario can be to such uncertainties, see Fig. 1 and (Lothe et al., 2019). The control of pressure via production wells has also been studied, as has been the potential environmental impact of releasing hypersaline water into the water column. This study will allow future cost-benefit appraisal of methodologies for brine disposal (Blackford et al., 2020).

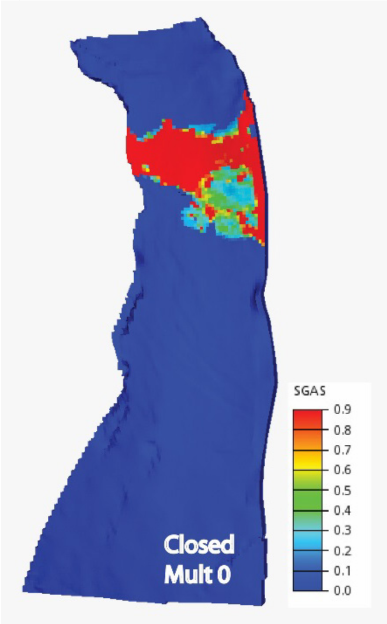

Figure 1: Modelling of CO_2 injection into the Alpha structure. From (Lothe et al., 2019).

The work on novel monitoring concepts has resulted in new methods for discrimination and quantification of pore pressure and CO_2 saturation. A Bayesian rock physics inversion approach for quantification of rock physics parameters including uncertainty has been developed (Dupuy et al., 2019) and a study of a deep neural network approach for rock physics inversion conducted (Weinzierl and Wiese, 2020). In addition, various means of using passive monitoring (based on ambient noise seismic interferometry, local/regional earthquakes, and teleseismics) have been investigated and a combination of those with active monitoring concepts suggested.

To support the developments of new monitoring concepts, in particular related to pressure and saturation quantification, a unique experimental campaign was carried out in 2019 at the new ECCSEL Svelvik CO_2 Field Lab (Fig. 2). To achieve this, three separate experimental phases were performed while acquiring direct pressure measurements and 4D crosshole electrical resistivity and seismic data. During the first phase, brine was injected to build up pressure at reservoir depth without a simultaneous change in CO_2 saturation. In the second phase, CO_2 was injected to achieve a simultaneous change in pressure and saturation. Finally, data was acquired during a trail-off phase in which pressure had normalized, while CO_2 saturation was decaying.

Figure 2: The new ECCSEL Svelvik CO2 Field Lab not far from Oslo, Norway.

Pre-injection modelling scenarios can be compared to observations during monitoring. The agreement (conformance) between predictions and observations provides crucial information on how to proceed with the CO_2 injection operation. This has been a central research topic and the Pre-ACT project has developed strategies for conformance assessment, as well as for assessing value of information potentially needed to verify the conformance of an active storage site (Barros et al. 2018).

Developed methods and workflows have been demonstrated using case studies at Smeaheia outside Norway, Endurance outside UK, and P18 outside the Netherlands. One of the major learnings from the case studies is related to tailoring of conformance tests to a particular site and its geological features. In this respect, the experience of the industrial operators has been very helpful. For the depleted P18 gas field offshore the Netherlands, potential non-conformance could be CO_2 injection problems (due to freezing), pressure deviations (due to gas production) or leakage from boundary faults. For open aquifers, like e.g. Smeaheia, offshore Norway possible non-conformance could be leakage from legacy wells, potentially too low pressure due to depletion from Troll, or migration out of the storage target.

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