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The Longyearbyen CO2 Lab Project: Lessons Learned From A Decade Of Characterizing An Unconventional Reservoir-Caprock System

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Summary

The UNIS CO2 Lab has evaluated the subsurface near the local coal-fueled power plant in Longyearbyen, Svalbard, Norway as a possible CO2 storage site. Extensive geological and pressure studies, including eight fully cored slim boreholes have proven a nearly 400 m thick shale dominated unit as an efficient cap rock for buoyant fluids. The underlying 300 m thick fractured and under-pressured heterolithic succession is identified as a potential unconventional reservoir The study concludes that the reservoir exhibits injectivity and storage capacity that are sufficient for the relative small volume of the CO2 emitted from the coal power plant.

Introduction

The Longyearbyen CO_2 Lab was initiated in 2007 with the vision of significantly reducing CO2 emissions in Longyearbyen, the hub of the Norwegian Arctic archipelago of Svalbard. The town obtains its energy from a coal-fuelled power plant utilising locally mined coal. Annual CO_2 emissions from the power plant fluctuate between 60 000 and 80 000 tons and, together with suitable saline aquifers beneath Longyearbyen (Braathen et al. 2012), presented potential storage formations for capturing a significant portion of Longyearbyen's atmospheric emissions this represents a unique opportunity for reducing significant portions of Longyearbyen's atmospheric emissions.

More than 10 years later, CO_2 has still not been injected beneath Longyearbyen despite a dedicated effort focussing on characterizing the reservoir -caprock system (Braathen et al. 2012, Senger et al. 2015, UNIS CO_2 Lab AS 2015). This is primarily due to the cost of establishing a full-scale CO_2 capture facility on the existing power plant, as well as the uncertainty of what Longyearbyen's power supply should be in a low-carbon future. Secondly, the discovery of thermogenic gas in Upper Jurassic shales (i.e. shale gas) at the proposed storage site has led to a major plugging & abandonment (P&A) operation to contain the gas in the subsurface. Nonetheless, the storage site represents a cost-effective onshore location for testing and optimizing the injection and monitoring of CO_2 in unconventional, compartmentalized reservoirs. Storage capacity has been calculated and deemed sufficient considering the emitted volume of CO_2, and fluid injectivity has been confirmed by water injection tests (Senger et al. 2015).

In this contribution, we summarize the key findings of the subsurface characterization efforts focussing on the reservoir-caprock sequence exposed on central Spitsbergen (Fig. 1).

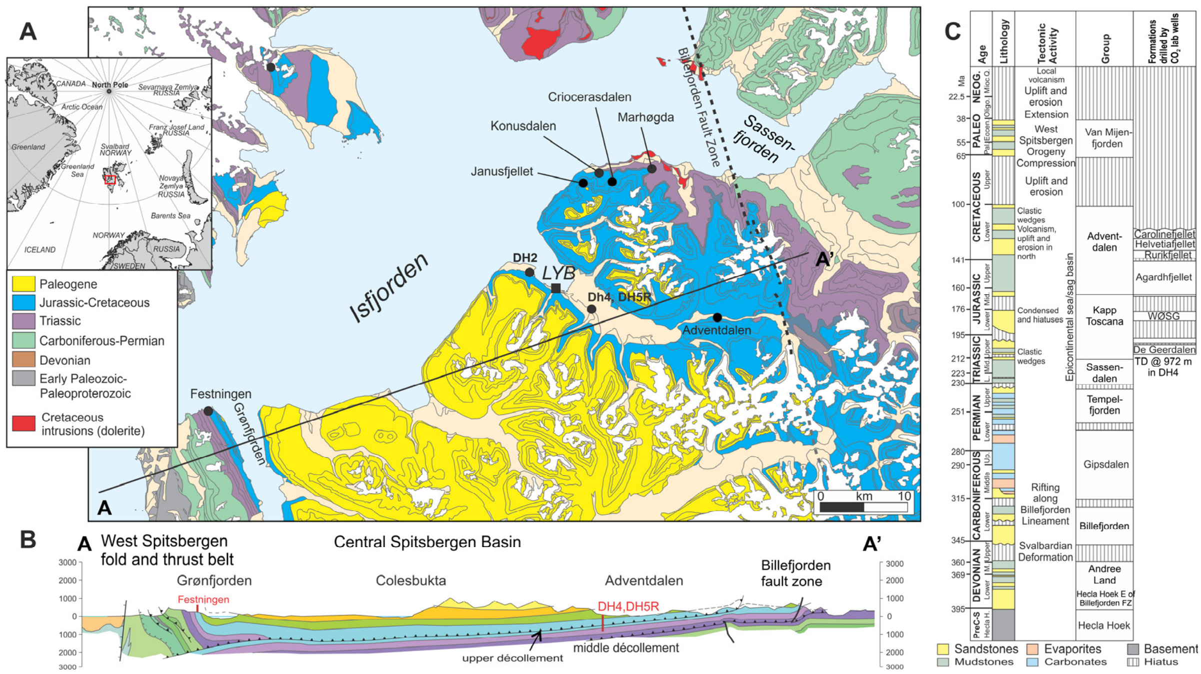

Figure 1 Geological overview of the study area. (A) Geological map illustrating the location of the DH2 and DH5R/DH4 wells and the outcrops at Janusfjellet, Konusdalen, Criocerasdalen and Adventdalen discussed in the text. Digital geological map generously provided by the Norwegian Polar Institute (LYB = Longyearbyen). The inset map shows the location of Svalbard in the North Atlantic. (B) Regional cross-section across the Central Spitsbergen Basin. For location, see Fig. 1A. (C) Regional stratigraphic column highlighting the stratigraphic position of the penetrated formations.

Data and methods

The project has drilled, fully cored and partially wireline-logged 8 slim-hole boreholes (Fig. 2). In addition, 2D seismic data was collected onshore and integrated with pre-existing onshore and offshore

2D seismic data (Bælum et al. 2012, Anell et al. 2014). Fieldwork was conducted at nearby locations to characterize the stratigraphic, facies and structural architecture (Ogata et al. 2014, Koevoets et al. 2018, Mulrooney et al. in press, Rismyhr et al. in press).

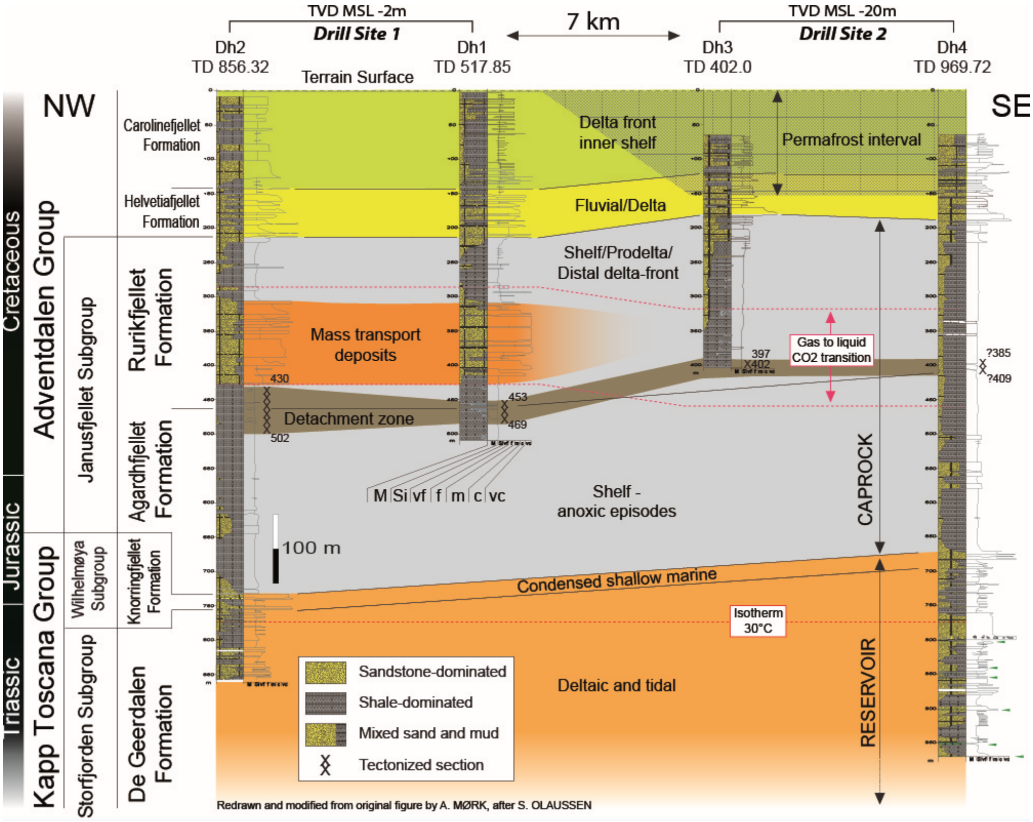

***Figure 2** Summary of the stratigraphy penetrated by four of eight the wellbores drilled by the Longyearbyen CO_2 Lab project.*

Results

An unconventional reservoir

The targeted heterolithic siliciclastic reservoir unit was encountered at approx. 670 m depth at the potential injection site in Adventdalen was found to be severely under-pressured (at least 35 bar), tight reservoir with natural fractures contributing significantly to permeability. The upper part of the reservoir, the Norian–Aalenian Wilhelmøya Subgroup, encompasses a relatively thin (15–24 m) compartmentalized siliciclastic succession of mudstones, sandstones and conglomerates (Fig. 3) (Rismyhr et al. in press). Structural and sedimentological heterogeneities may contribute to the compartmentalization, evident by the lack cross-well flow of relatively short distance between borehole DH7A and DH5R, only 50 m apart, during a water injection testing. A nearly 300 m thick upper Triassic succession with a sandstone-shale ratio of 0.25 to 0.30 is regarded as the lower aquifer. In spite of the very low matrix permeability, i.e. best values of 0.1-0.2 mD in the lower aquifer, fractures provide reasonable injectivity and storage capacity.

Cap rock

The caprock comprises a shale-dominated succession comprising the Upper Jurassic–Lower Cretaceous Agardhfjellet Formation (Senger et al. 2016, Koevoets et al. 2018,) and the overlying Rurikfjellet Formation (Grundvåg et al. 2017). A regional decollement zone is present at the interface between the two formations and coincides with a major pressure barrier. Top seal integrity is confirmed by the presence of slightly over pressured overburden an under-pressured reservoir units.

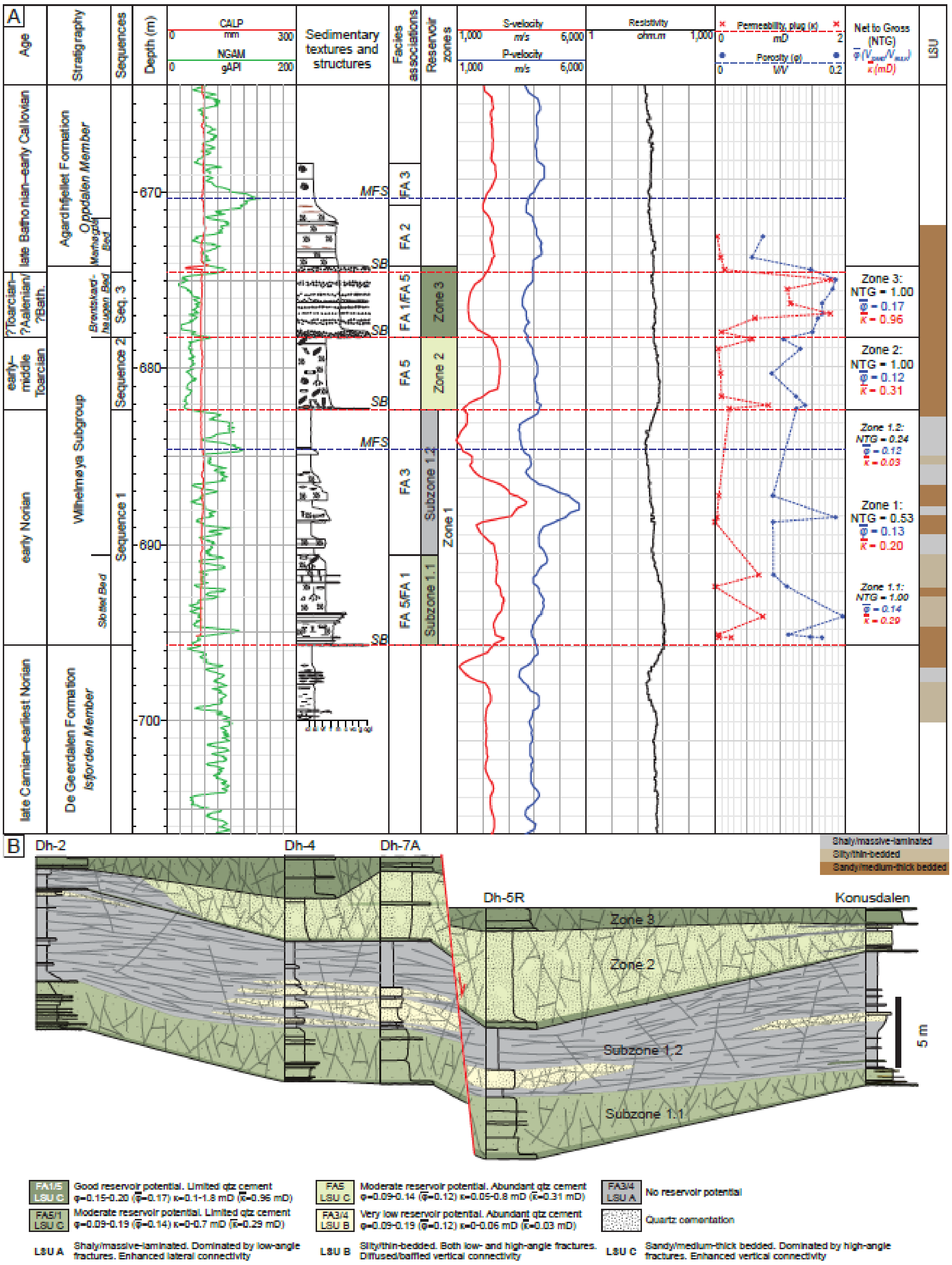

Figure 3 *Schematic illustration of the distribution of different reservoir zones in the Wilhelmøya Subgroup. A fault of approx. 5 m displacement is shown offsetting the reservoir between DH7A and DH5R. Distance between sections is not to scale. Figure from Mulrooney et al. (in press).*

Conclusions

Through an integrated study of a reservoir-cap rock system onshore Svalbard we conclude that:

- The best reservoir properties are documented in the upper aquifer, the Wilhelmøya Subgroup and represent a viable CO_2 storage reservoir with confirmed storage capacity and injectivity.
- The lack of interference during water injection tests how limited lateral pressure communication within the reservoir, and the presence of barriers to flow.
- Additional storage volume occurs in the lower aquifer due to an extensive natural fracture network which contributes to fluid injectivity and storage potential.

Acknowledgements
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