



Summer School “CCS in the High North”

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Introduction

Carbon Capture and Storage (CCS) is one of the major mitigation measures to handle climate change. Even though international organisations agreed on the importance of CCS and the effective Paris Agreement refers to the widely accepted climate scenarios, the technology is not implemented on a large scale beyond pilot projects yet, nor are economic incentives given to foster its deployment. CCS is not a cutting-edge technology, the applied methods are well-known – not only in the oil and gas industry. Buzz words like enhanced oil recovery (EOR) and carbon capture, utilisation and storage (CCUS) stir up hope to realise large-scale projects soon and in an economically viable way.



Figure 1: Students of 2016 at the edge of the world's northernmost swimming pool in the abandoned Russian mining town of Pyramiden (Photo: V. Zuchuat).

The summer school “CCS in the High North” is a collaboration between the **University of Oslo** (UiO), the **Colorado School of Mines** (CSM) in Golden and the **University Centre in Svalbard** (UNIS). It offers a suite of lectures, exercises and geological field work on MSc and PhD level, which are credited with **13 ECTS**. A highly motivated group of international students with diverse backgrounds and specialisations were not only taught, but also engaged themselves in inspiring discussions.

Course Content

Economy, Policies & Risk

- The need for CCS: Physics, history and challenges of global climate change
- Economics and regulations: Incentives, carbon trading, CO₂ utilisation
- Risk Assessment: Monitoring, simulation and liability

Geology & Reservoir

- Trapping mechanisms & storage options: Static vs. dynamic storage
- Geological reservoir characterisation: Field observations and core logging
- Seal properties: Mechanical and chemical compaction, global data collections and experimental studies
- Rock mechanics: Fractures, secondary permeability
- Risk of fault and fracture leakage: Sub-seismic resolution, juxtaposition, smearing

Technology

- Physical and chemical properties of CO₂
- Separation technologies: Chemical absorption, phase change, polymeric membranes
- Enhanced Oil Recovery: Relative permeability & mobility ratio
- Sequestration modelling: Rock & fluid properties, multi-phase flow, initialisation, events/wells

Fieldwork & The Longyearbyen CO₂ Lab

Highlight of the Summer School were three days of fieldwork on the Arctic archipelago of Svalbard. The aim of the field investigations was to identify potential reservoir formations, evaluate and compare them on their ability to safely store CO₂. Beside two promising CO₂ storage formations (see figures 3 and 4), also the targeted units of the Longyearbyen CO₂ Lab were logged in the field close to Deltanesset. Tight sandstones with quartz-overgrowth and pore-filling clay minerals can be observed. Mudstone layers, a thrust décollement and lateral permafrost provide sufficient sealing (compare figure 5). Injection tests show secondary permeability caused by fractures and the sealing ability is proven by high underpressure in the reservoir (Braathen et al., 2012).



Figure 2: Going ashore in Adolfbukta: Survival suits, rifles, redundant communications and an emergency backpack are essential HSE equipment during fieldwork on the Arctic archipelago of Svalbard (Photo: M. Gutierrez).

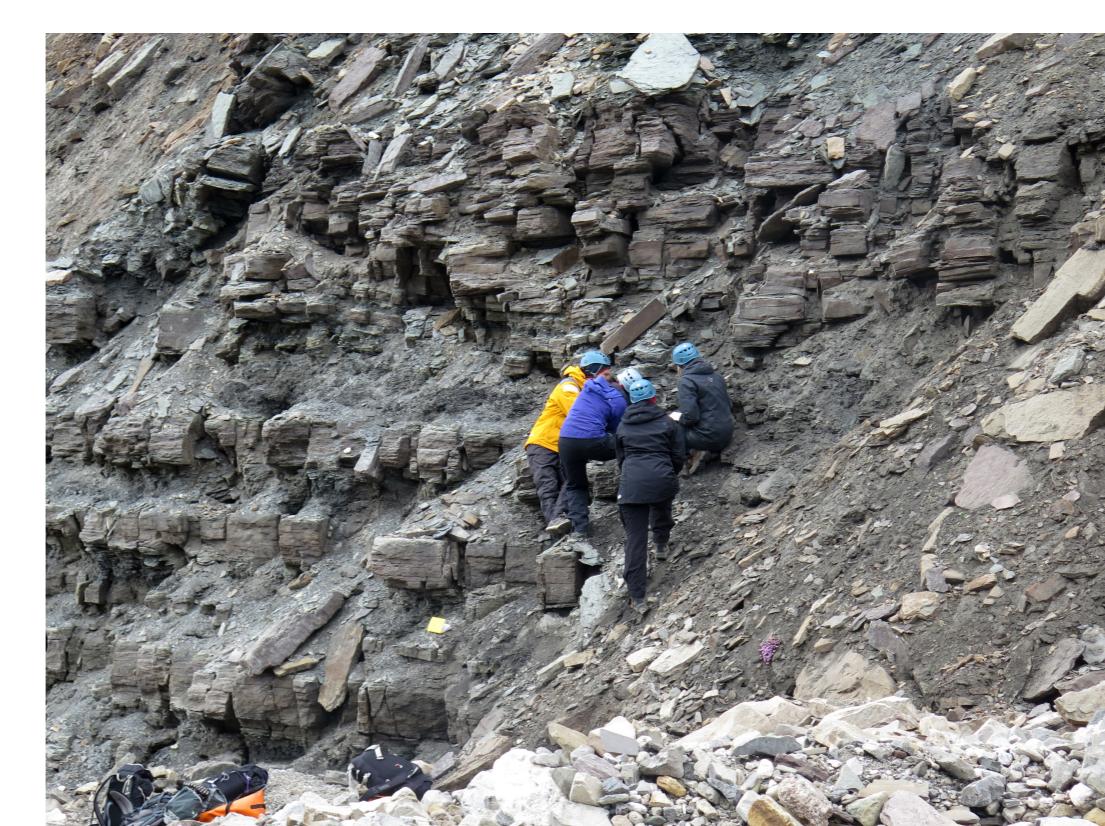


Figure 3: Exposed sandstones of the Carboniferous Ebbadalen Formation north of Adolfbukta. Seven distinctive coarsening-up sequences of thick beds alternating with silty layers are expected to provide high horizontal permeability (Photo: M. Gutierrez).



Figure 4: Permian limestone beds of the Gipshukten and Kapp Starostin Formations are found at Skansbukta. Bioturbation structures filled with evaporitic material could provide secondary porosity. The picture shows cross-bedding in upper layers (Photo: M. Gutierrez).

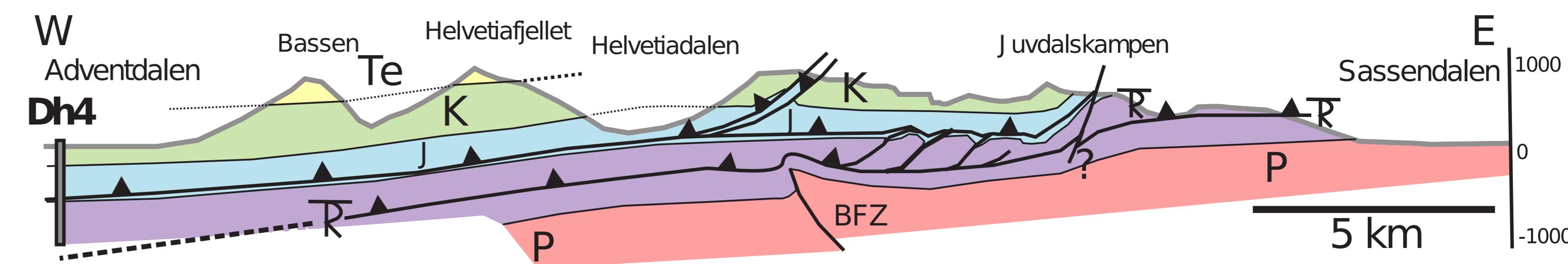


Figure 5: Cross section of the targeted storage formation (Upper Triassic–Middle Jurassic sandstones of the Kapp Toscana Group), the overlying seal (Jurassic mudstones of the Agardfjellet Formation) and the prominent thrust décollement which is providing an additional seal. The indicated well Dh4 in the west is part of the Longyearbyen CO₂ Lab, the logging took place in the east where the layers are outcropping. Modified from Braathen et al. (2012).

Limited Information & Seal Uncertainty

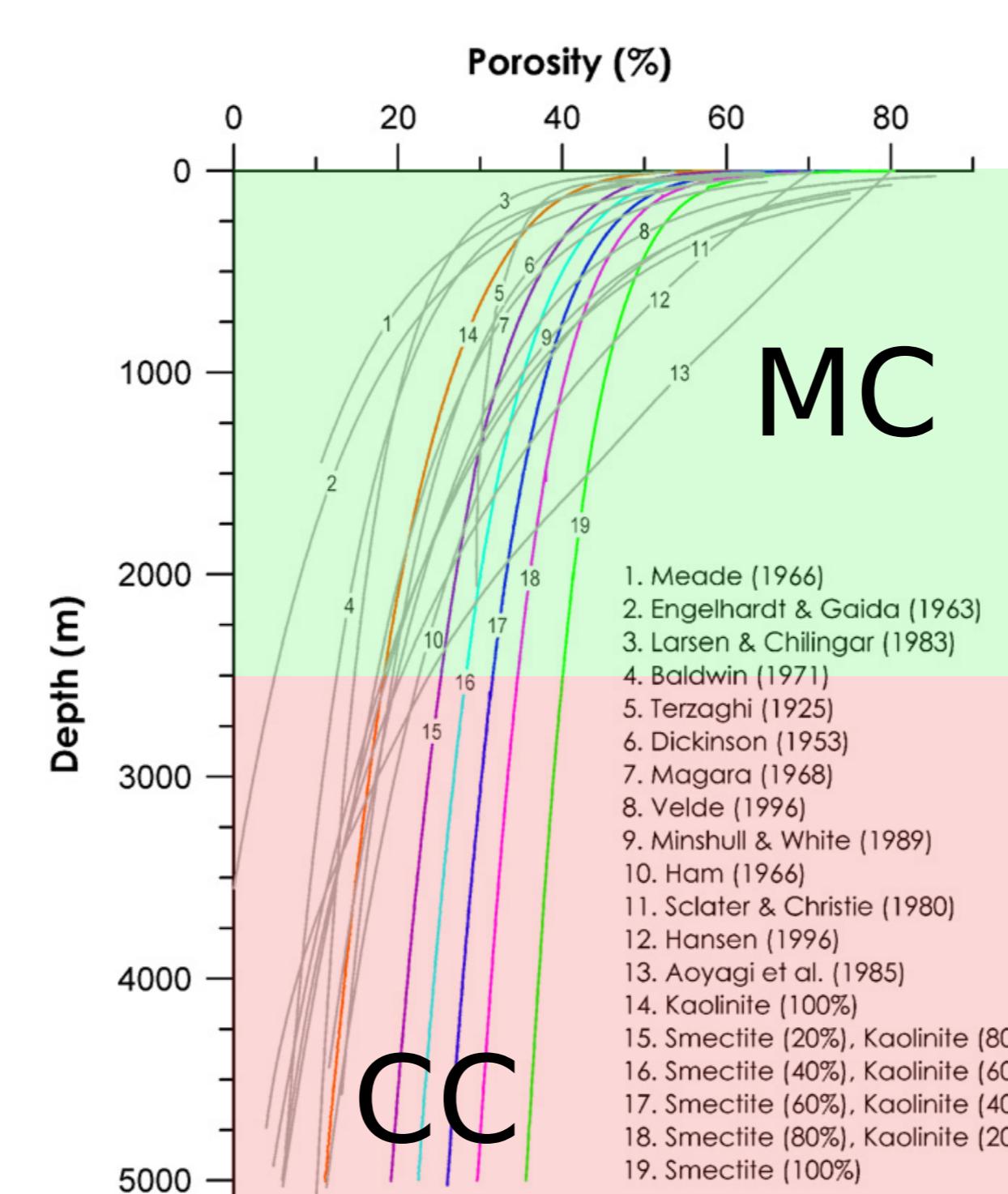


Figure 6: Comparison of porosity-depth trend studies and experimental results for shales and argillaceous sediments. While for E&P projects the seal integrity is proven by the abundance of hydrocarbons, for CO₂ storage it remains uncertain. Controlling factors are clay mineral and pore fluid composition, grain sizes, pore pressure and the influence of mechanical (MC) and chemical compaction (CC). Because core sampling of seal layers is expensive, experimental studies and global databases might be auxiliary. Still, extrapolation of experimental results has limited validity for natural anisotropy and the influence of chemical compaction (Mondol et al., 2007).

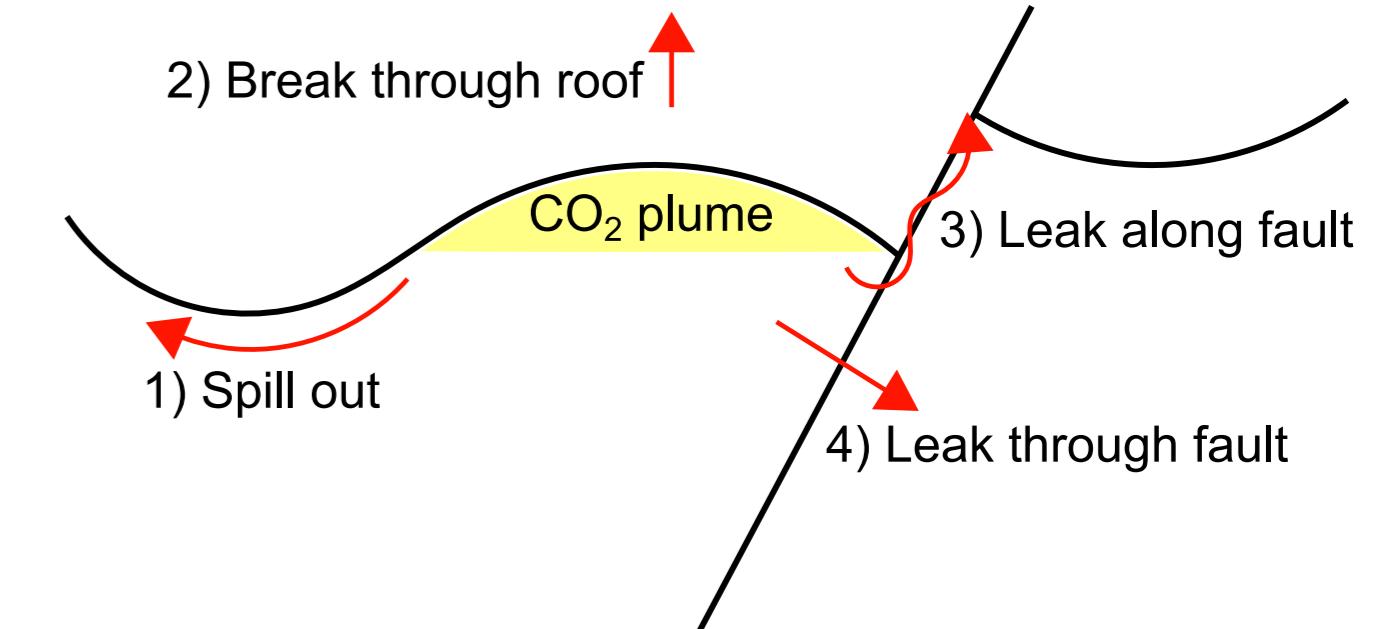


Figure 7: Different leakage scenarios for a CO₂ storage project which are subject to uncertainty. To prevent a spill out of the storage formation (1), the storage capacity must be estimated. A break of CO₂ through the formation's roof (2) depends on seal properties and knowledge of fracture pressures (see figure 6). Evaluation of leakage along (3) or through (4) a fault requires the analysis of juxtaposition and smearing. Sub-seismic faults represent an additional risk. Still, the highest risk of leakage exists in close proximity to wells (Figure based on lecture notes, lecture by K. Indrevær & A. Braathen, 15.6.2017).

Outlook & Motivation

Marco studies **Georesources Management** in Aachen. During his various stays in Norway – two semesters in Stavanger and summer courses in Oslo and Longyearbyen – he became passionate about **risk** and **decision analysis**. Currently he is writing his master thesis in the field of **geologic modelling and uncertainty quantification** in exploration. His focus will be on the application of a **value of information (VOI)** approach. A specific project to test assumptions and models would be beneficial. The high potential of future **CO₂ storage projects** provides a suitable case for application. The mentioned methods are believed to contribute to urgently needed **cost reduction** and **risk management** of CCS projects.



References

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- Mondol, N. H., Bjørlykke, K., Jahren, J., and Høeg, K. (2007). Experimental mechanical compaction of clay mineral aggregates—Changes in physical properties of mudstones during burial. *Marine and Petroleum Geology*, 24(5):289–311.