Decision-making under uncertainty – case study from a Czech Republic CO2 storage

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Large-scale projects involve a multitude of assessments and analyses, encompassing a wide range of data, judgments, assumptions, limitations, simplifications, and uncertainty. CO2 storage pilot projects are an example of such types of a project, involving complex assessments of the storage structure and its capacity and boundary conditions, how properties will change when exposed to CO2 on both short- and long term, and risks that may arise concerning the site storage integrity. The objective of the assessments and analyses is to ultimately serve as input to a decision-making context. This decision information however needs to be simplified into a manageable and processable amount for it to be useful, but without losing vital elements, whether these are constraints, simplifications, or project risks. This paper seeks to examine challenges related to analyzing, evaluating, and communicating uncertain data, using geomechanical risk evaluations from a Czech Republic CO2 storage site as a case study, and suggests some paths towards better informed decisions under uncertainty.

CO2-SPICER at a glance

The main objective is to prepare a CO2 geological storage pilot in Zar-3, a mature oil & gas field in the Czech Republic. This is needed to kick-start deployment of onshore CCS technology in Central & Eastern Europe. The project is led by CGS with partners NORCE, MND and VSB, and features 10 WP's, 41 tasks and 70+ team members. The main tasks and risk assessments include:

TASKS

- Data gathering and consolidation
- 3D geological model of storage complex
- Dynamic modelling and simulations
- Geomechanical assessments
- Geochemistry of rocks and fluids
- Risk assessment
- Monitoring
- Scenarios of future site development
- Communication and dissemination
- Project management and reporting

RISK ASSESSMENTS

- Fault and fracture assessment
- Spill point assessment
- Caprock assessment
- *Geomechanical risk assessment*
- *Wellbore seepage assessment*
- Seepage dispersion analysis
- Impact assessment
- Risk evaluation

Example case: Geomechanical risk

No faults nor weak planes crossing the reservoir were interpreted from geophysical data . Thus, mechanical stability is performed by evaluating the rock strength itself when combined with estimated in-situ stresses.

- Rock strength (Brazilian, UCS and 3ax tests) was determined for all rocks represented in the storage complex. The reservoir rocks were weaker than the overburden rocks.
- Deviatoric stress ($q = s_1 - s_3$) and mean effective stress ($p' = \frac{s_1+s_3}{2} - \alpha P_f$) were estimated (not measured). Upper and lower limits bounded probability density functions (PDFs).
- Increased pore pressure → reduces p'. Temperature affects side stress s_3 while s_1 remains constant. Lowered temperature both increase q and reduce p'. Thermoelastic coupling estimated from measurements.
- Drawing from PDFs the number of unstable events for each pore pressure and temperature in qp-plots.
- The geomechanical safe operation envelope impacts the subsequent operational decision alternatives in all project stages.

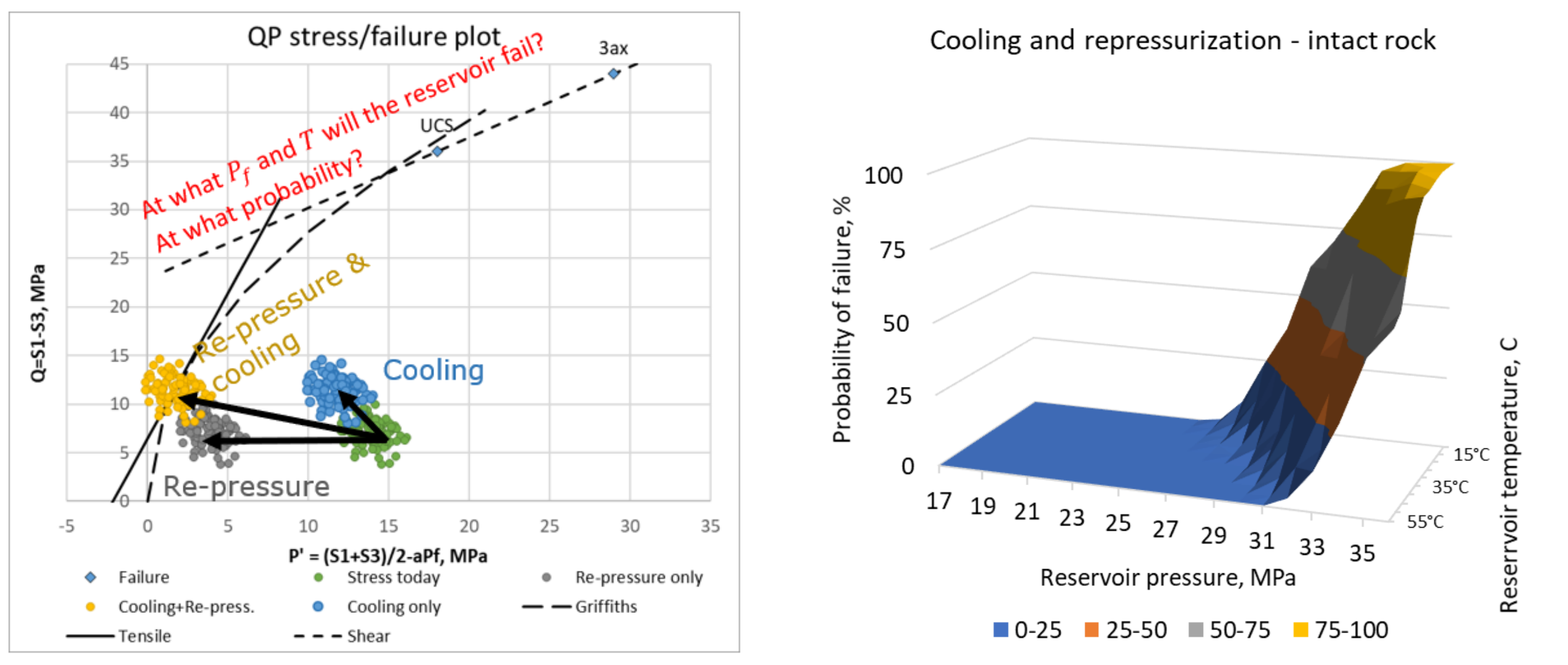

Figure 1: Stress changes in qp-plots from initial to cooling, repressured and combined states. Number of rock failure cases are estimated when surpassing the measured failure lines may occur (Nermoen, et al., 2023). Right: Number of unstable cases as function of reservoir temperature and pore pressure.

Risk assessment & decision making processes

Risk identification must clarify the main storage integrity risks based on as much available data as possible, acknowledging key assumptions and limitations.
Risk analyses, including geomechanical stability and wellbore integrity, must embed uncertainties as part quantitative assessment to highlight as many plausible scenarios as possible.
Risk evaluation must contextualize main leakage scenarios in terms of likelihood and exposure for humans, animals, flora, fauna, water sources, society, infrastructure.
Decision analysis must not only consider the main findings of the risk assessment, but also account for influencing factors when establishing the decision foundation
Final Investment Decision may ultimately be to approve or terminate the project but could also require re-investigating risk assessments and other key factors based on additional or updated information before a final decision is made.
Risk assessments and decision analyses are mutually dependent and iterative processes, and are subject to changes in information, uncertainty, and influencing factors

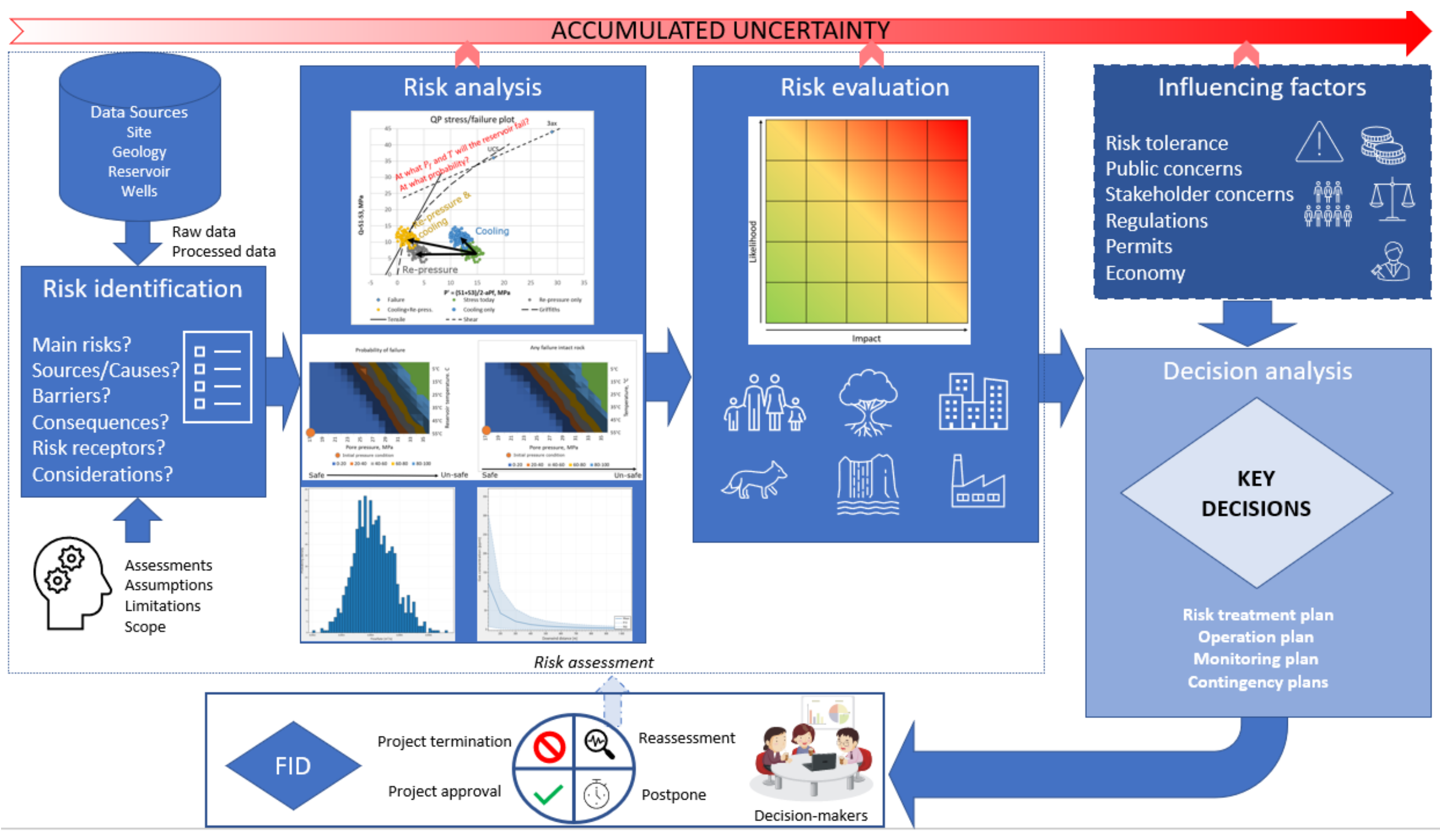

Figure 2: Risk assessment process, consisting of identification, analysis and evaluations of risk. Each step depends on its preceding ones and aggregates uncertainty (and complexity).

- The quality of decisions depends on the understanding and communication of key uncertainties and the basis from which risk assessments are derived.
- Of key importance is the active participation of stakeholders, analysts and technical personnel, embracing the principle of shared responsibility.
- Geomechanical risks and risk acceptance criteria are used to define injection rate and overall storage capacity – this is important for the entire value chain!
- The decision process is non-linear, as both risk identification, risk analysis and evaluation are inter-dependent, and may be re-done if new information becomes available.
- Decision-making processes play a vital role in the maturation of project ideas toward a final investment decision
- When all relevant risk factors are evaluated they need to be matched to the external factors for key decisions to be made.

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