Assessment of a mature hydrocarbon field in SE Czech Republic for a CO_2 storage pilot

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& the CO2-SPICER project team

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NORCE
Norway grants
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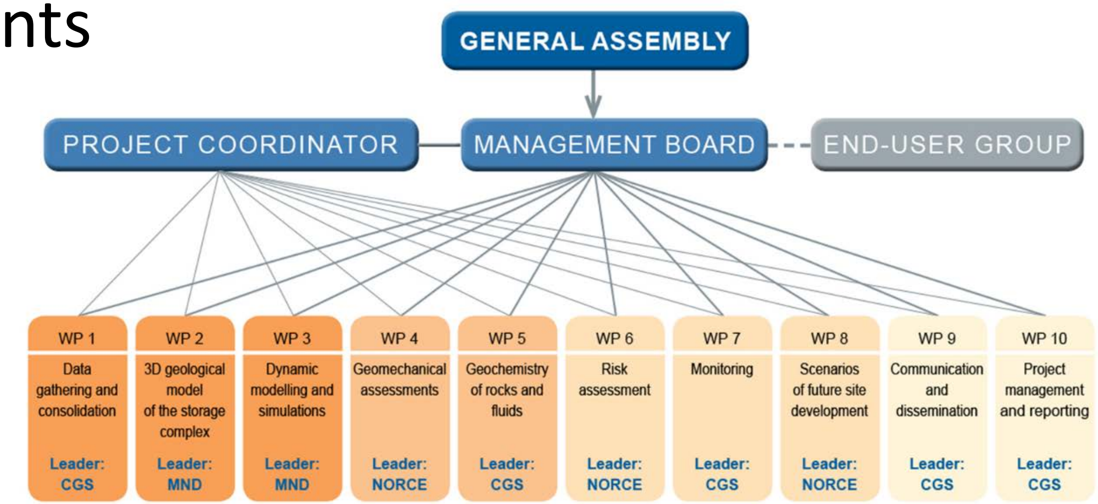
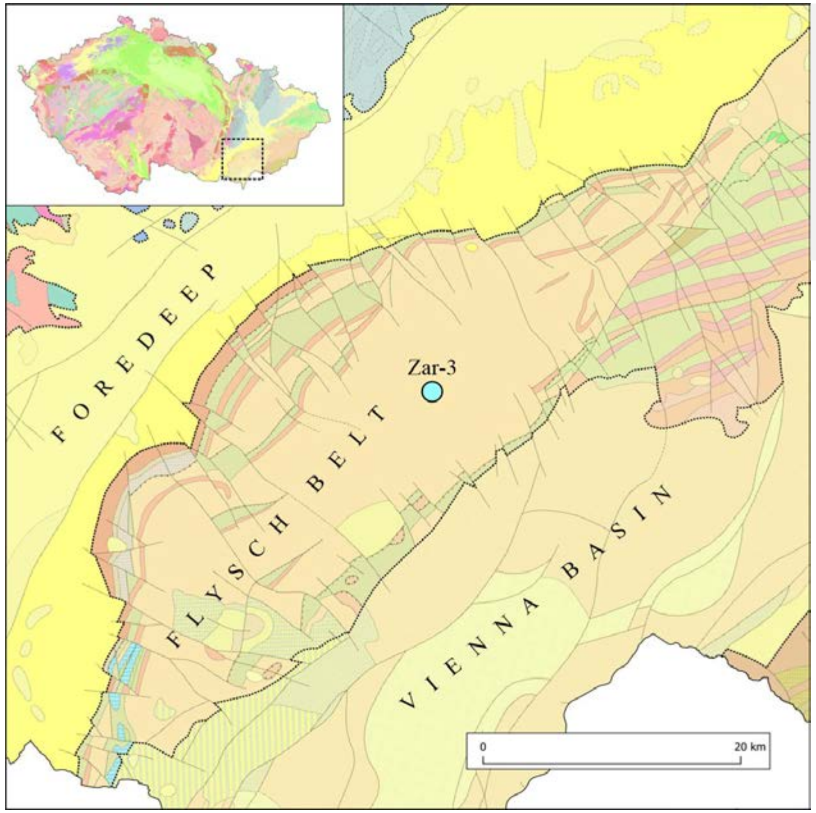
CO2-SPICER project (2020 – 2024)

- Main project objective is to prepare implementation of a CO_2 geological storage pilot project at the mature Zar-3 oil and gas field (achieve implementation-ready stage)
- An important step towards the deployment of the CCS technology in Czechia and C&E Europe
- Workflow follows the requirements of the EU CCS Directive
- 10 Work Packages, 41 Tasks, > 70 team members
- Start 11/2020 – end 4/2024



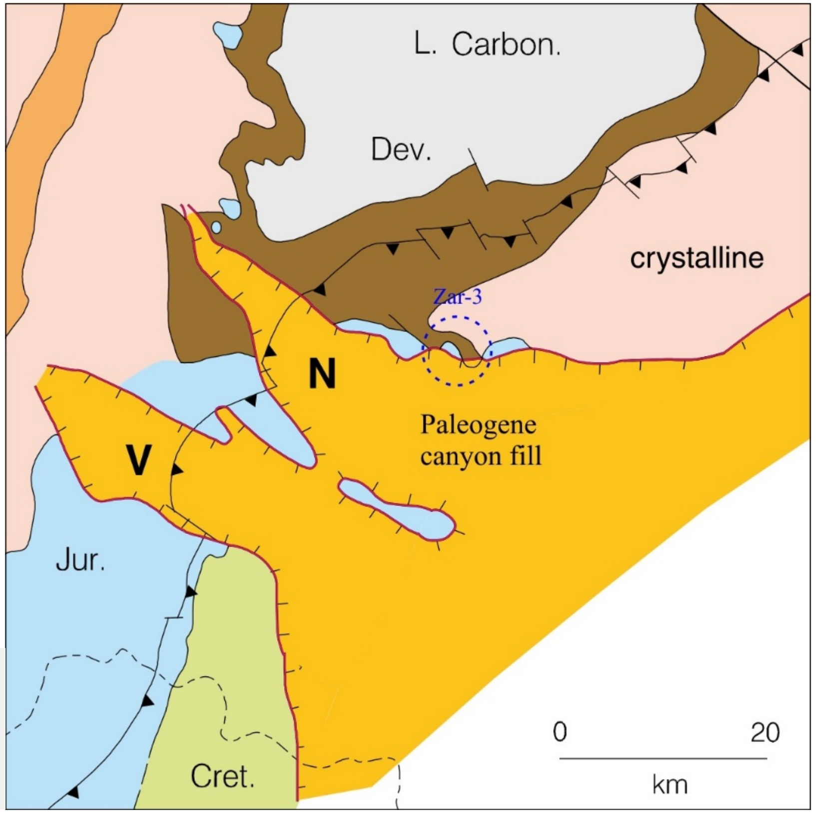
Site location

- Zar-3 field is situated on the NE slope of the Nesvacilka depression, one of two incised canyons on the SE slopes of the Bohemian Massif



Position of Zar-3 site on geological map of the Czech Republic. Source: CGS ArcGIS server map services

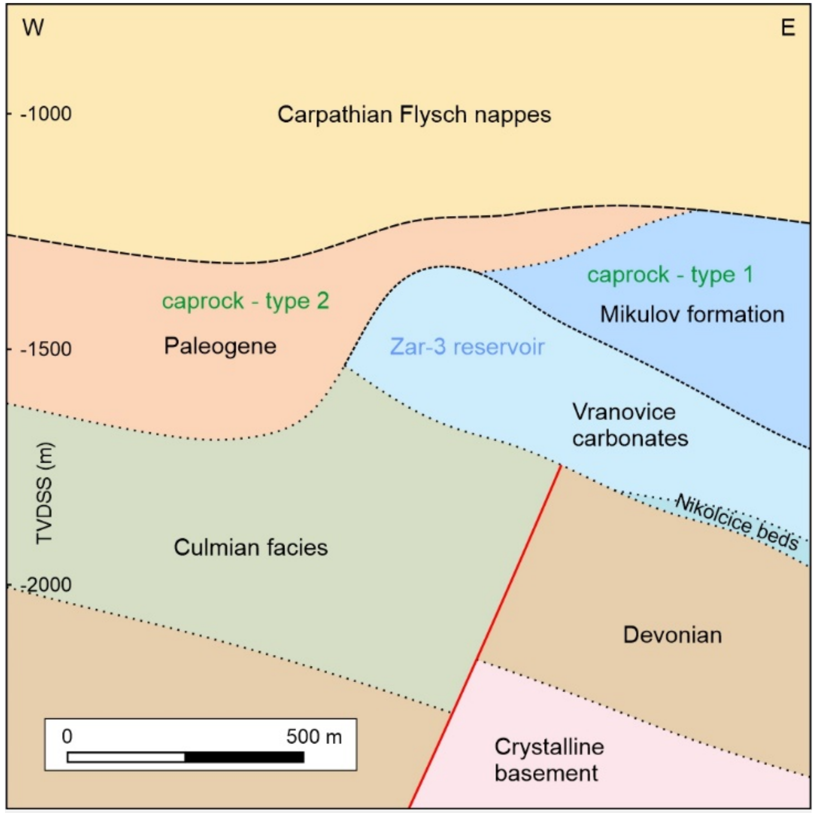
(http://www.geology.cz/extranet/mapy/mapy-online/esri).



Pre-Neogene subcrop map showing the Nesvacilka (N) and Vranovice (V) paleovalleys. Picha et al. (2006).

Basic site geology and field parameters

- Oil field with a gas cap and an active aquifer, discovered in 2001
- Reservoir: Jurassic Vranovice carbonates (porosity: 2 – 20 %, Permeability: 190 – 630 mD)
- Lithology: Dolomites with some limestones and sandstones
- OOIP = 1.2 MMCM, GIIP = 100 MMCM (gas cap) + 77 MMCM
- Caprock: Paleogene pelites and Jurassic Mikulov marls



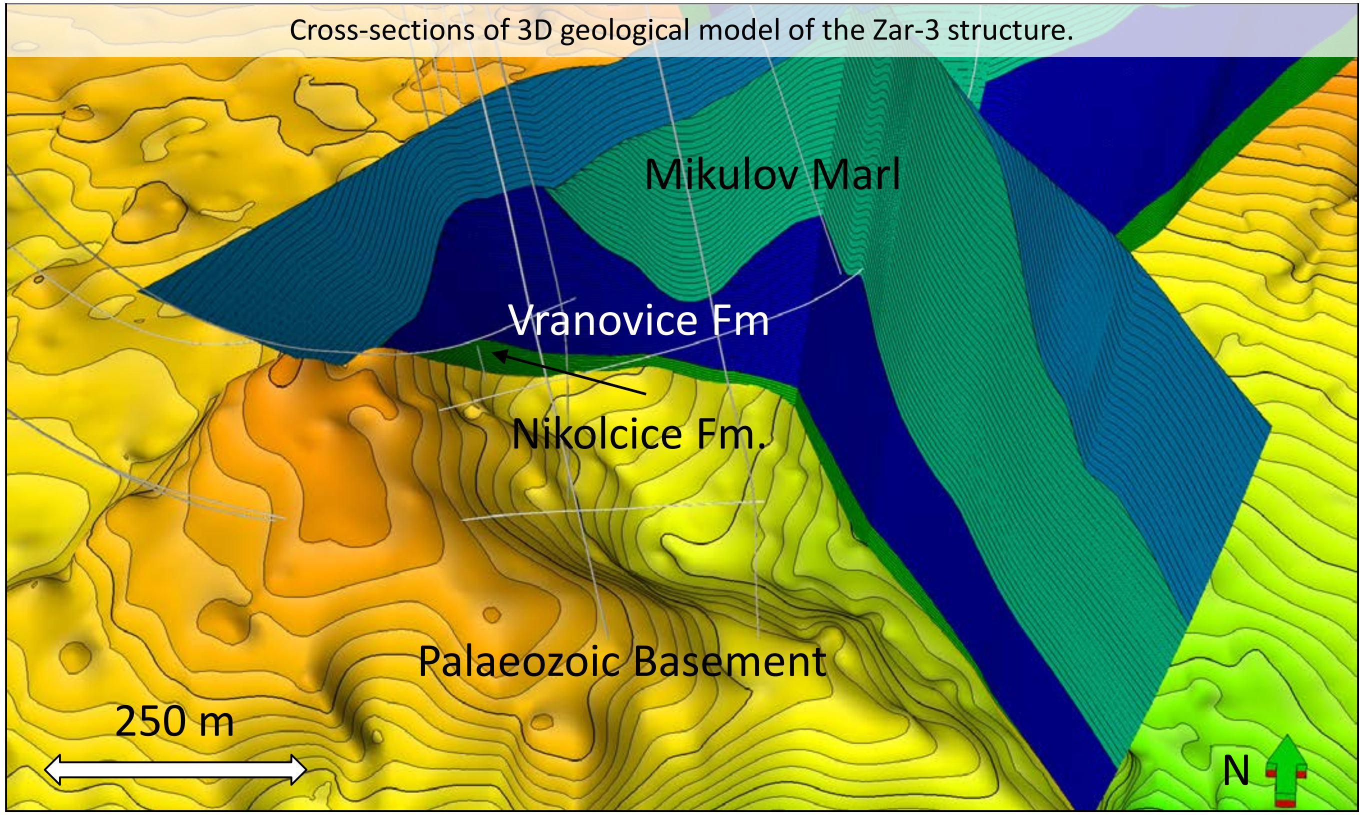
Schematic geological cross-section of W-E direction through the Zar-3 structure.

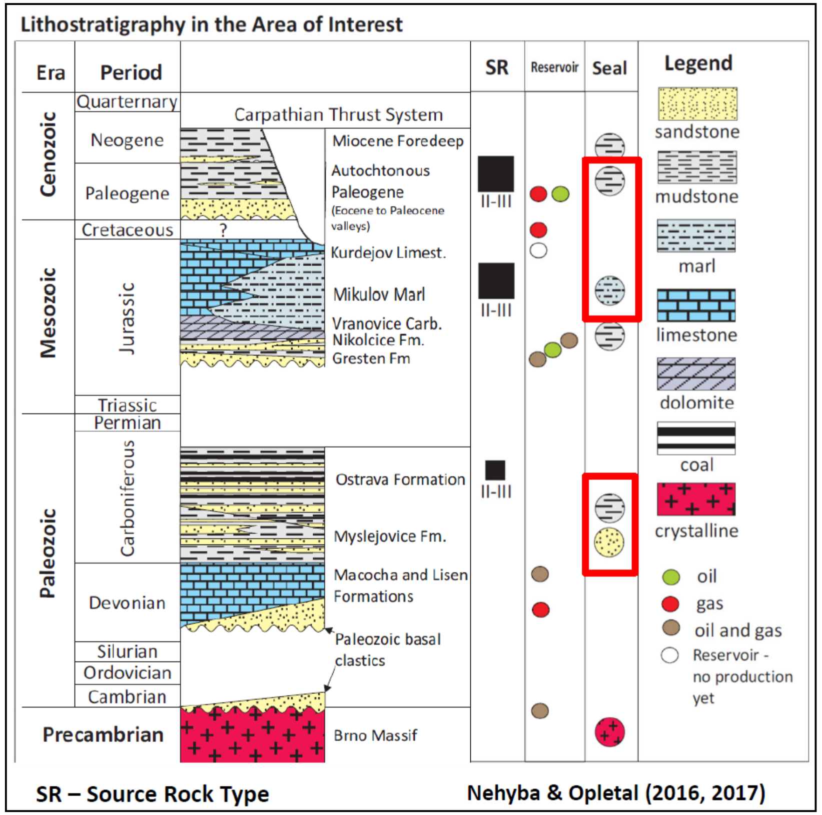
CO2-SPICER project goals

- Construction of a 3D geological model of the storage complex
- Evaluate geomechanical and geochemical properties of the storage complex
- Dynamic modelling and simulation of CO2 injection in the reservoir using various scenarios
- Risk assessment related to CO2 storage on the pilot site
- Preparation of a site monitoring plan
- Evaluation of scenarios for future site development, including design of CO_2 injection facilities

3D geological model – static model

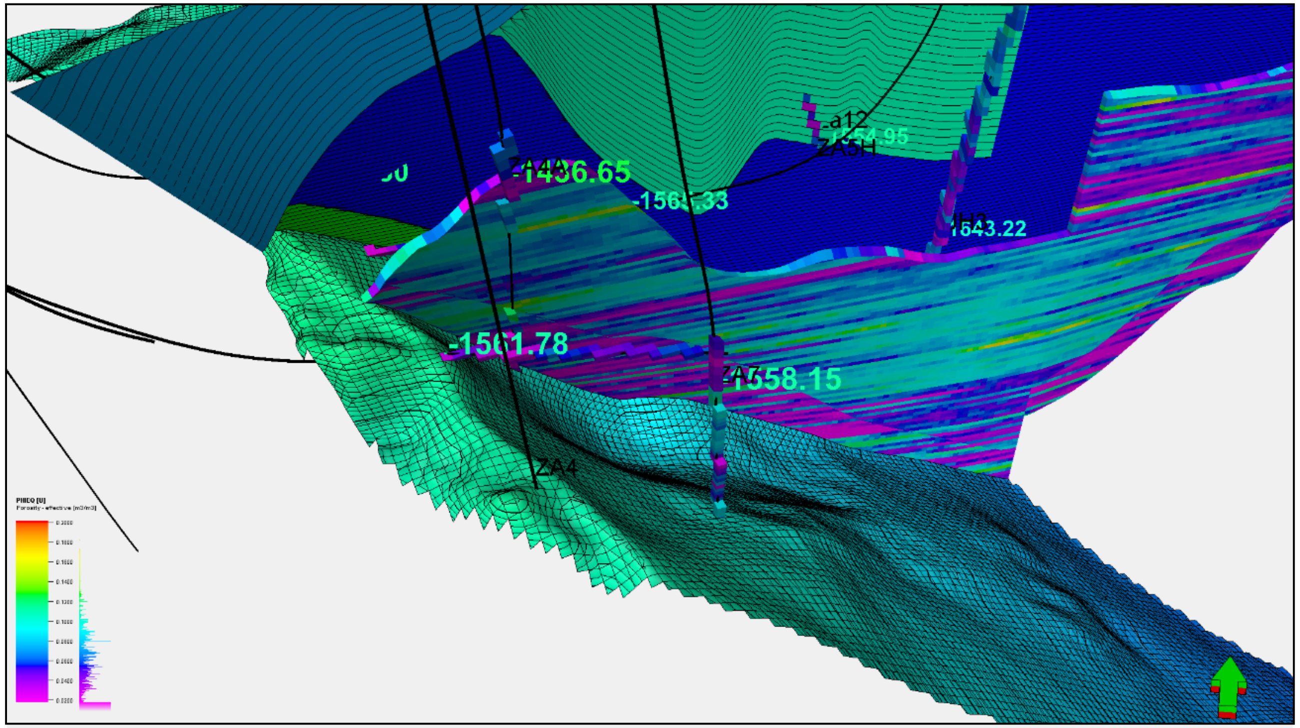
- 3D geological model based on seismic interpretation of horizons and faults and detailed well cores and logs analysis and correlation



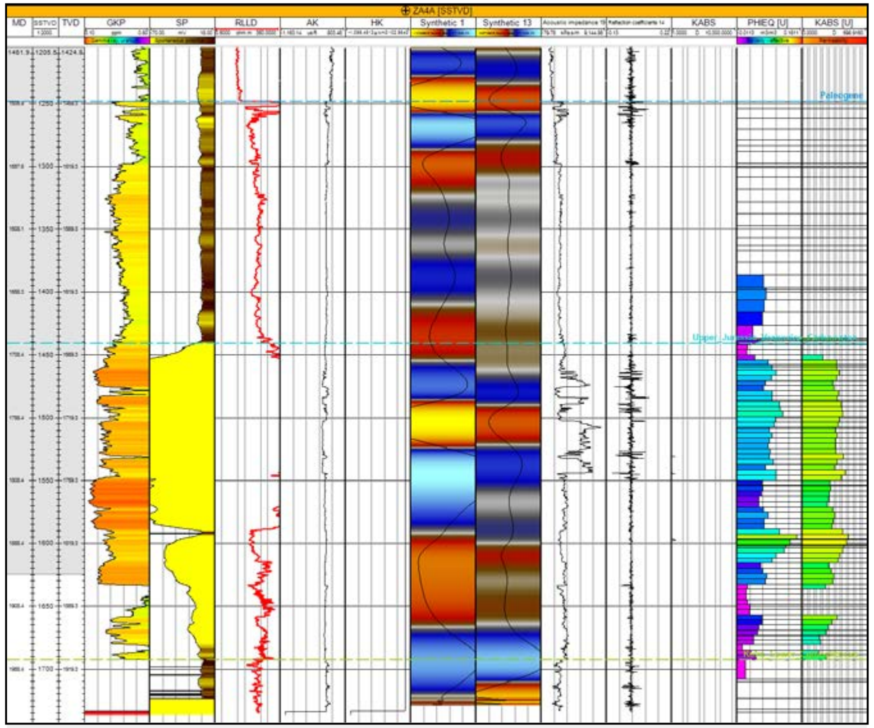


3D geological model – reservoir properties

- Petrophysical properties calculated from the well logs and cores, 3D porosity and permeability distribution added to 3D geological model



The reservoir engineering version of 3D grid with porosity distributions (sub horizontal layering - 10 x 10 m horizontal grid + 1 m thickness of vertical layers).

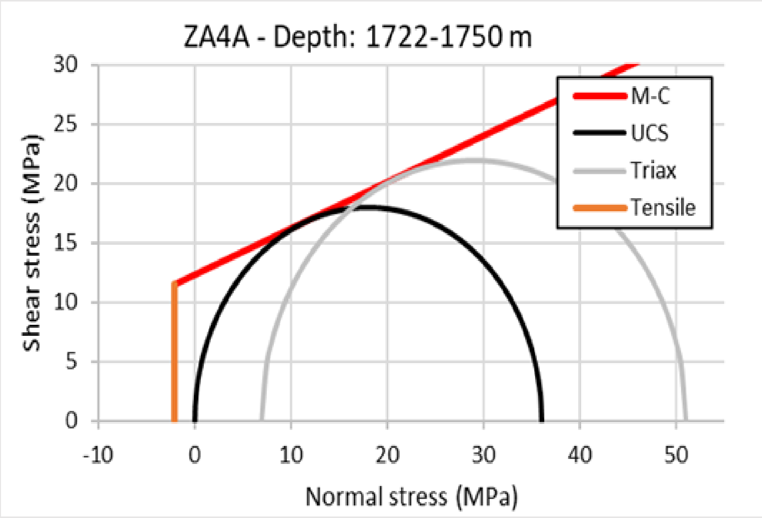


Well ZA4A - depths, well logs and upscaled values of porosity (PHIEQ) and permeability (KABS).

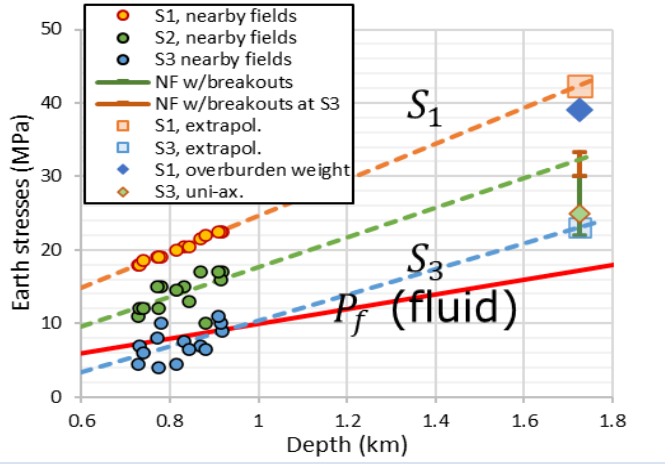
Geomechanical evaluation

- Purpose: Evaluate geomechanical consequences of re-pressurzation and cooling. Ensure the injected CO2 remains underground.
- Combine geomechanical test results and earth stress estimates to evaluate stability

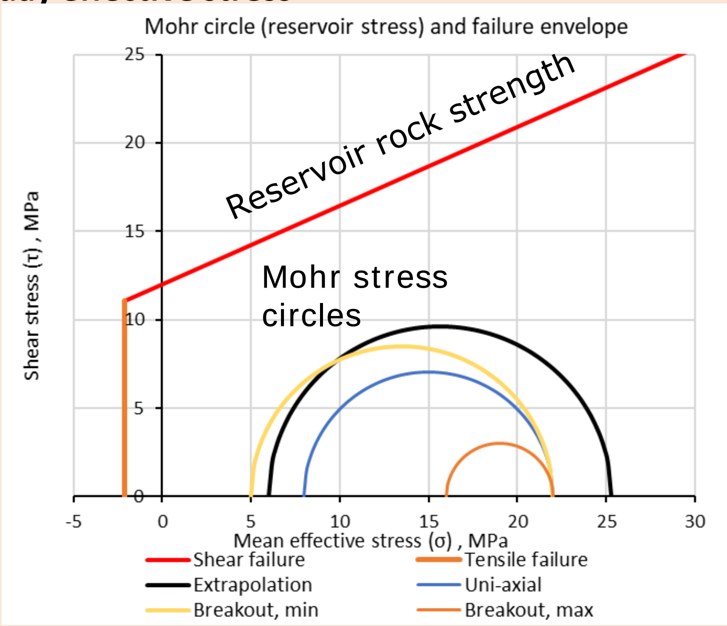
Rock strength ($\tau\sigma$-space):
- UCS and triaxial test → MC envelope
- Brazilian tests for tensile strength



Field stress evaluation (three techniques):
a) Extrapolation of nearby field stresses
b) Weight of overburden (S_1), and from uni-axial strain (S_3)
c) Break-out analysis for S_1 and S_3.

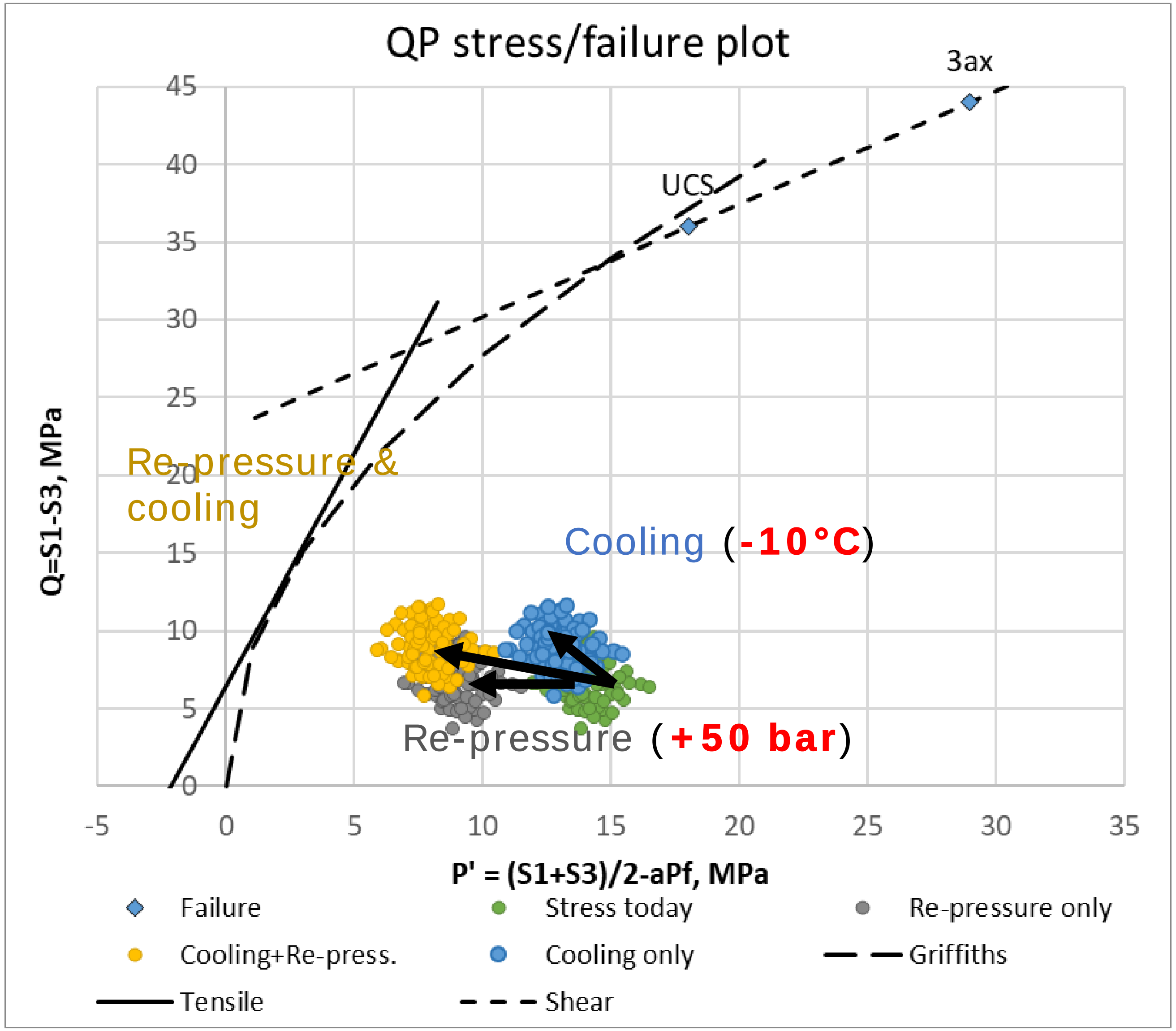


Combined reservoir failure and current day effective stress



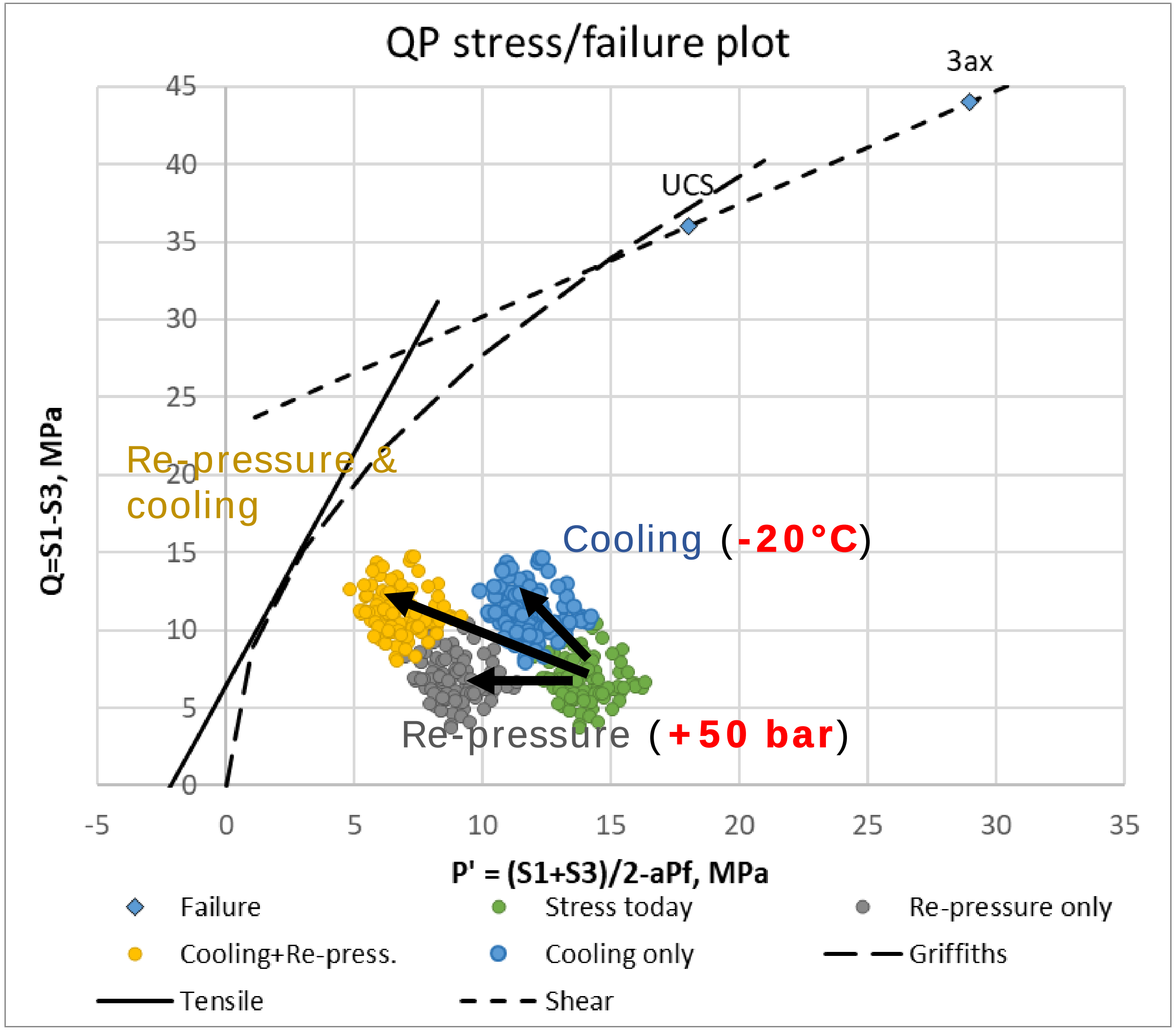
Impact of re-pressurization and cooling (*qp*-plot) – Example 1

- Increased pore pressure reduce mean effective stress:
$$p' = (S_1 + S_2)/2 - aP_f$$
- Cooling (ΔT) at constant overburden and uni-axial strain reduces S_3. Measure all input parameters on rock samples: Biot coefficient α, bulk stiffness K, and thermal expansion coefficient β, and Poisson ratio ν.
- Estimate change in stress from cooling:
$$\Delta S_3 = \frac{K\beta}{1-\nu}\Delta T$$
- Use the uncertainty in Earth stress estimate and plot range of stresses (one dot for each stress case).



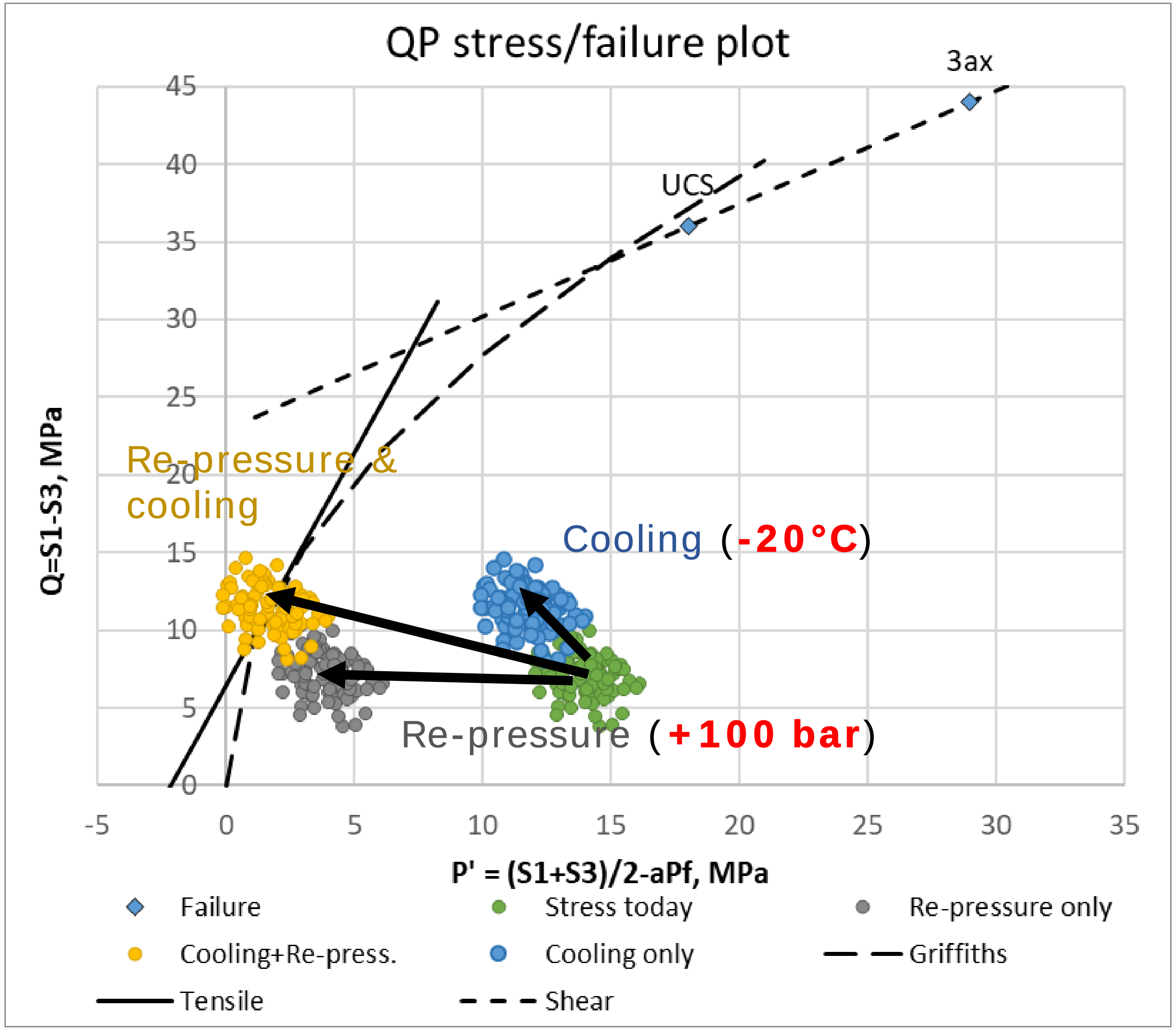
Impact of re-pressurization and cooling (*qp*-plot) – Example 2

- Increased pore pressure reduce mean effective stress:
$$p' = (S_1 + S_2)/2 - aP_f$$
- Cooling (ΔT) at constant overburden and uni-axial strain reduces S_3. Measure all input parameters on rock samples: Biot coefficient α, bulk stiffness K, and thermal expansion coefficient β, and Poisson ratio ν.
- Estimate change in stress from cooling:
$$\Delta S_3 = \frac{K\beta}{1-\nu}\Delta T$$
- Use the uncertainty in Earth stress estimate and plot range of stresses (one dot for each stress case).



Impact of re-pressurization and cooling (qp-plot) – Example 3

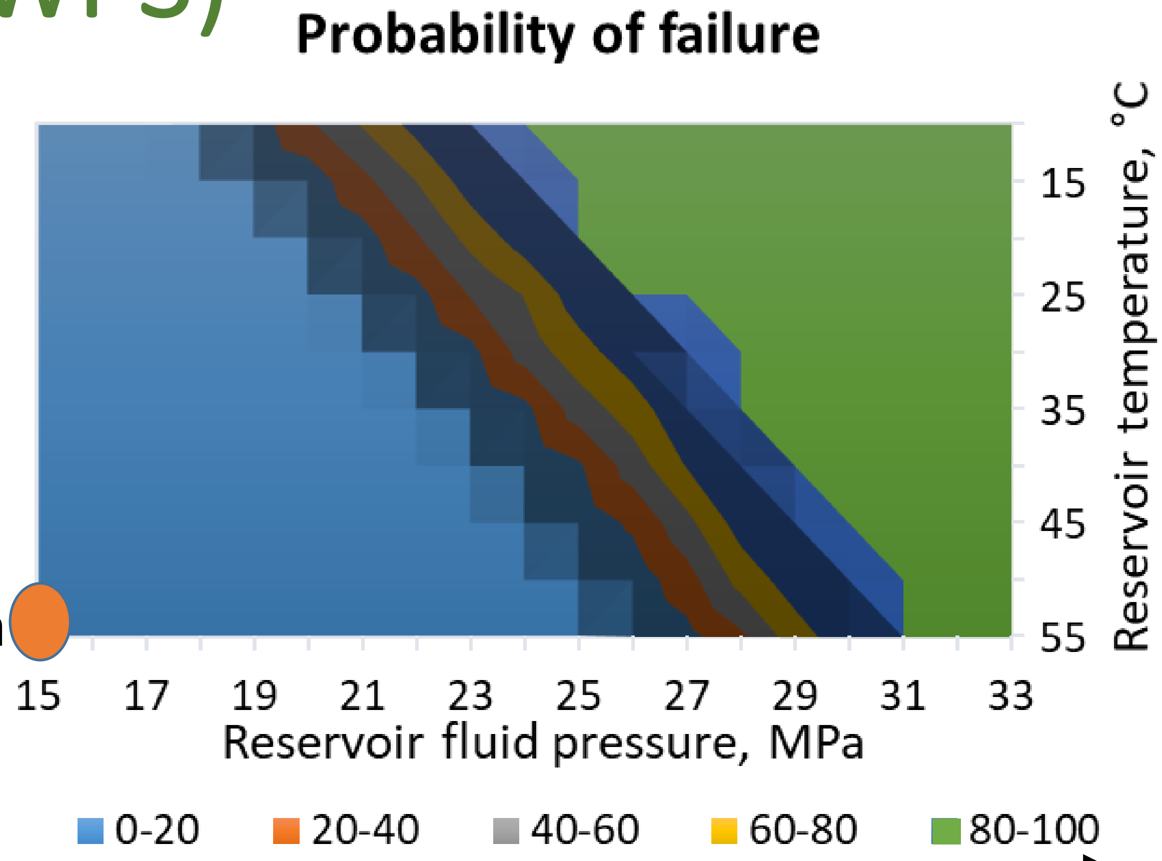
- Increased pore pressure reduce mean effective stress:
$$p' = (S_1 + S_2)/2 - aP_f$$
- Cooling (ΔT) at constant overburden and uni-axial strain reduces S_3. Measure all input parameters on rock samples: Biot coefficient α, bulk stiffness K, and thermal expansion coefficient β, and Poisson ratio ν.
- Estimate change in stress from cooling:
$$\Delta S_3 = \frac{K\beta}{1-\nu}\Delta T$$
- Use the uncertainty in Earth stress estimate and plot range of stresses (one dot for each stress case).



Phase diagram: Probability of failure for varying reservoir pressure and temperature (hand-over to WP3)

Evaluate 200 scenarios via 10 reservoir temperature and 20 pressures steps.

Current day condition

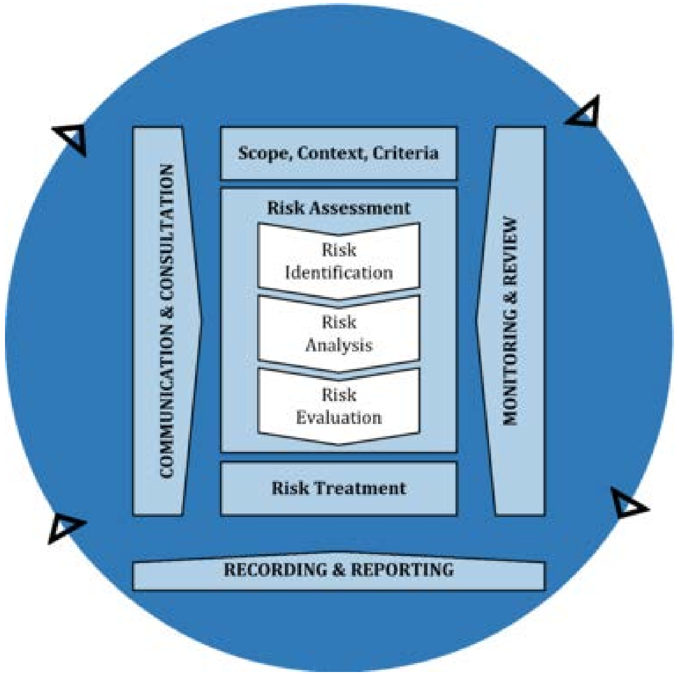


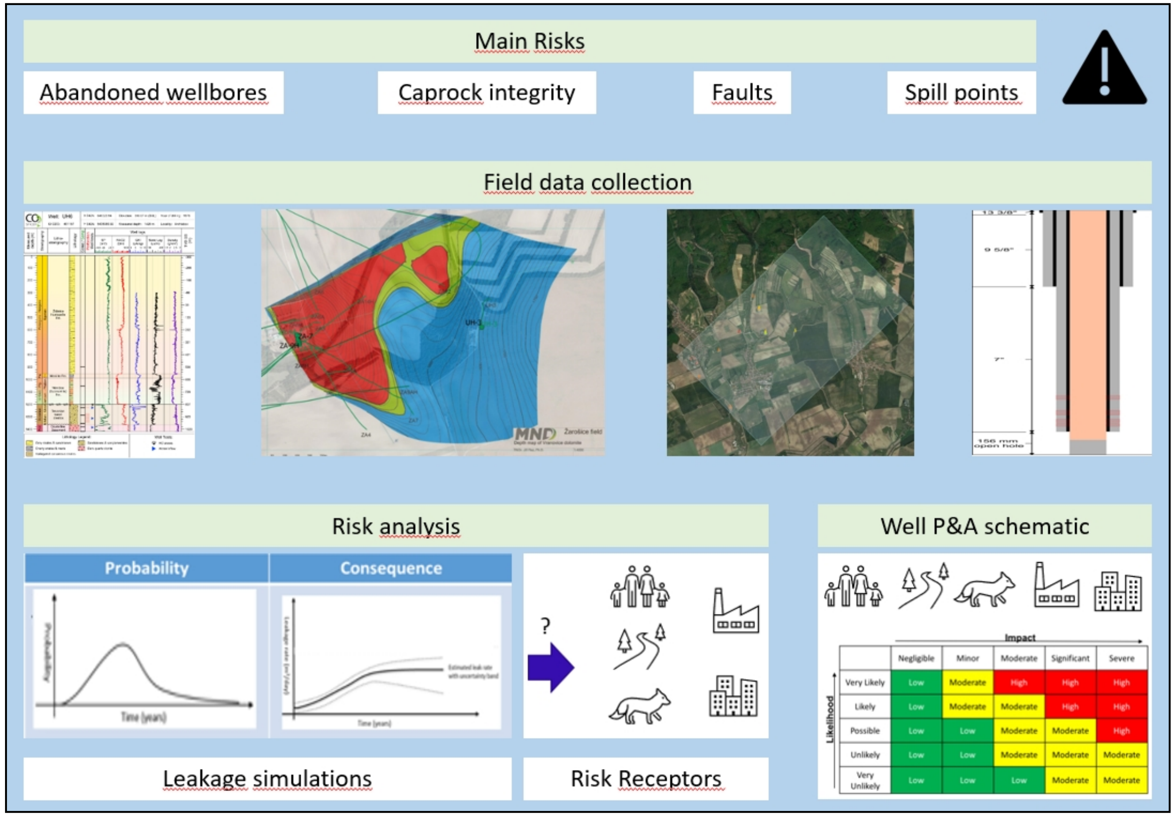
Safe

Un-safe

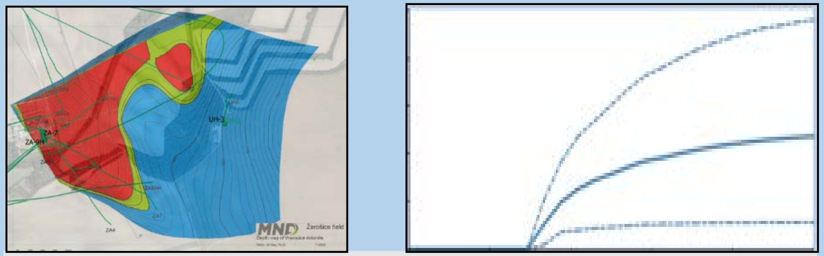
Risk assessment

- Collected data will be used to simulate leakage through abandoned wellbores, caprock, faults and spill points, next step will address the risk to various receptors

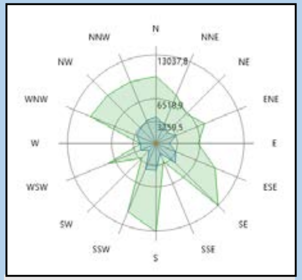




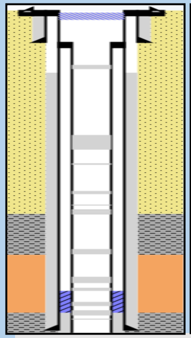
Risk assessment – simulation of abandoned wellbores



Geology and pressure development



Site wind data

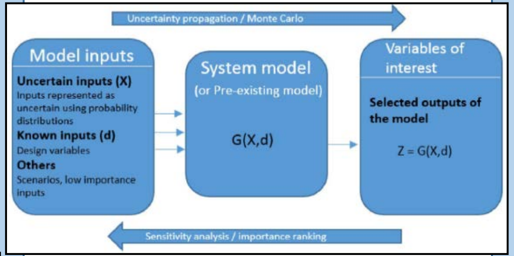


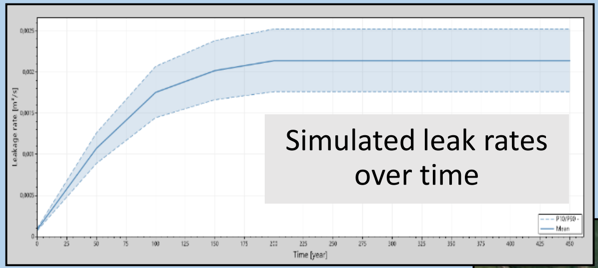
43,7	49,5	63,7	39,4	9,9	48,2	43,0	34,2	44,4	6,8
28,2	28,0	49,0	27,6	33,0	31,4	53,5	16,8	44,4	37,3
16,2	37,9	15,4	29,4	51,7	43,8	21,9	22,7	50,8	38,0
14,9	30,3	32,7	34,9	45,1	20,6	46,8	23,3	6,5	19,5
48,5	47,7	14,2	41,6	30,8	18,9	53,7	18,7	56,1	15,0
41,7	29,6	12,8	33,8	20,2	53,1	59,0	24,4	36,9	18,4
20,0	32,7	35,1	21,2	49,6	19,5	32,9	38,1	19,4	14,3
39,9	7,4	36,3	37,5	48,1	7,8	41,1	32,2	17,5	14,8
6,4	57,5	56,2	46,9	44,7	30,8	34,3	19,3	8,9	22,3
16,4	32,9	50,9	23,2	60,7	18,9	9,0	21,6	16,4	32,3

Well design and assessment of possible microannuli apertures

P&A Leakage Calculator

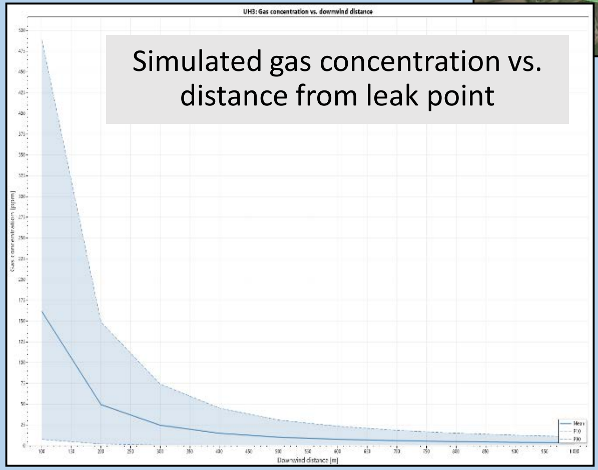
NORCE Norwegian Research Center





Simulated leak rates over time

Simulated gas concentration vs. distance from leak point



Simulated gas concentration vs. distance from leak point

Monitoring

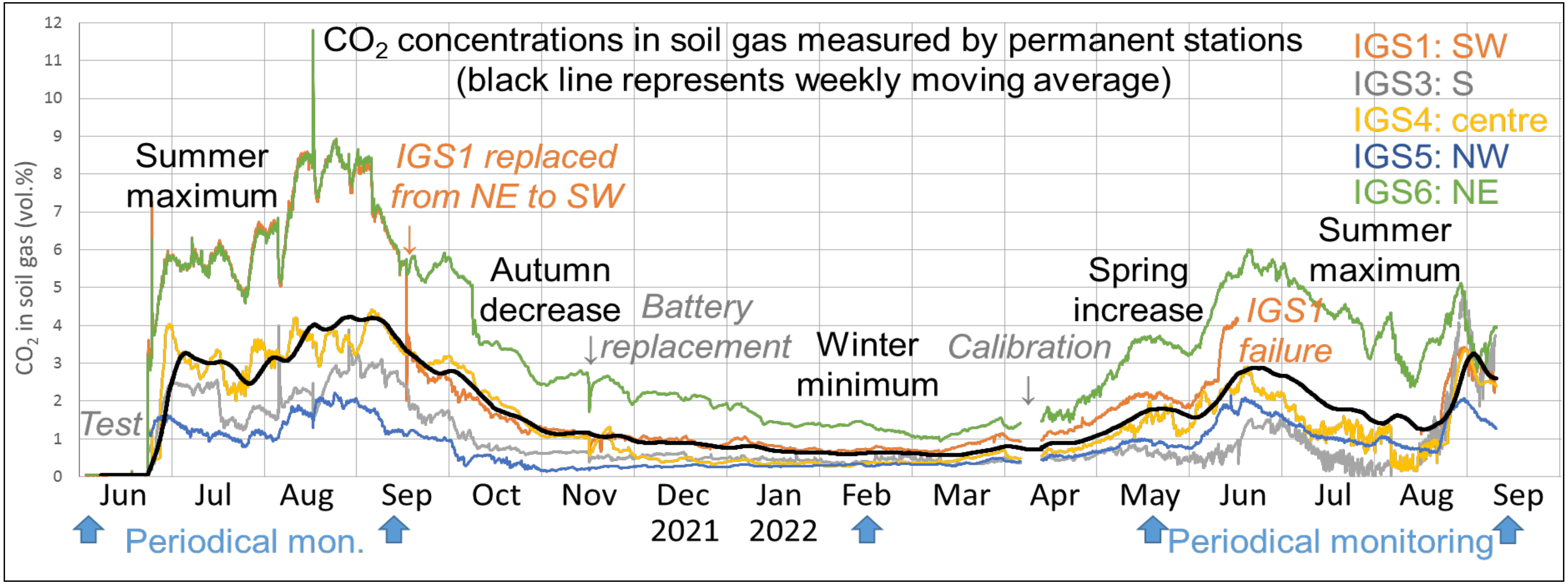
- The main objective: to prepare a storage site monitoring plan
- since Aug 2021, planned to Aug 2022, prolonged to summer 2023 + six temporal stations (November 2021 + May 2022)



Examples of different monitoring techniques: atmogeochemical, seismic and groundwater monitoring

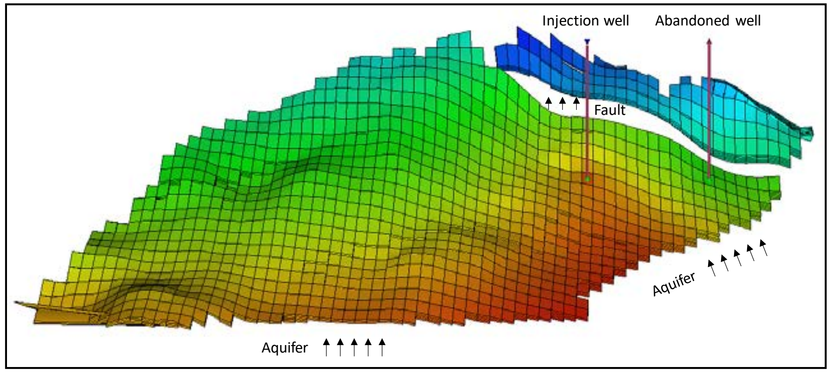
Monitoring – atmogeochemical monitoring

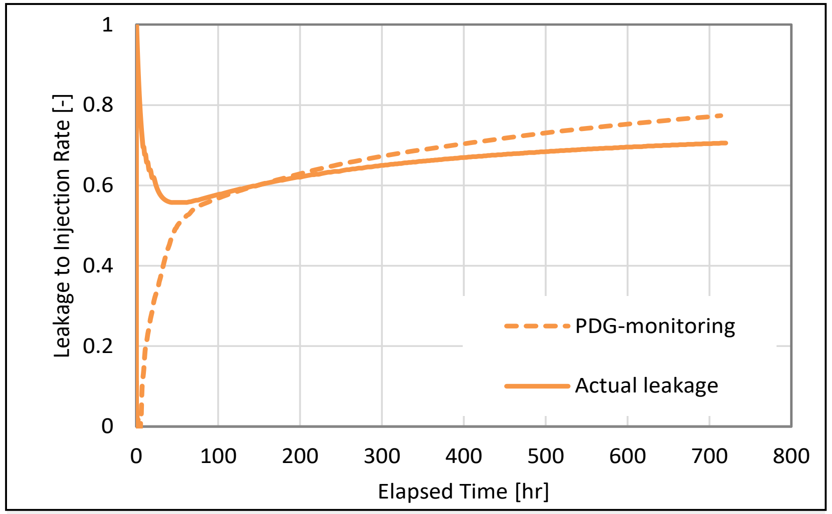
- Continuous monitoring: 5 permanent IGS stations, every single hour; data will be interpreted and correlated with weather conditions



Monitoring – reservoir containment

- A technology for reservoir containment monitoring progressed in EU H2020 ENOS project to be evaluated for use in Zar-3 pilot
  - Novelty: Time-lapse pressure responses in active injection wells are used to monitor leakage in nearby legacy wells and faults (in addition to injection performance)
  - Equipment: Permanent Downhole Gauges (PDG). One gauge already installed in observation well for baseline survey
  - Zar-3 scope: Leakage detection possibility (legacy wells) and optimal location of PDGs to be evaluated with reservoir simulations





Simulation results of fault leakage monitoring with PDGs from EU H2020 ENOS project [https://doi.org/10.3997/2214-4609.201802990]

Site development scenarios

- Basic pilot scenario – tens of kt CO_2 (100,000 t limit)
- Full-scale structure utilization – adjusted to expected CO_2 delivery

WHERE TO GET THE CO_2 FROM?

- Original plans based on Russian gas failed
- New plans under discussion – DACCS, part of larger cluster

WHAT TO DO WITH THE REMAINING HYDROCARBONS?

- The gas cap still in place + the remaining oil in the oil zone
- Transition from production to storage regulatory unclear
- Any CO_2-EOR disqualifies the project from public funding

Acknowledgement

The CO2-SPICER project benefits from a € 2.32 mil. grant from Norway and Technology Agency of the Czech Republic.

PROJECT PARTNERS

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