

Project HENRI

19.9.2024

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- **First Slovak Hydrogen IPCEI project– Hy2Tech wave**
- **HENRI – HYDROGEN ENERGY RESERVOIR**
- **HENRY CAVENDISH**



H. Cavendish

- An English natural philosopher, chemist and scientist
- Noted for discovery of Hydrogen
- (1731-1810)



Project goals



Definition of methodology for reservoir assessment



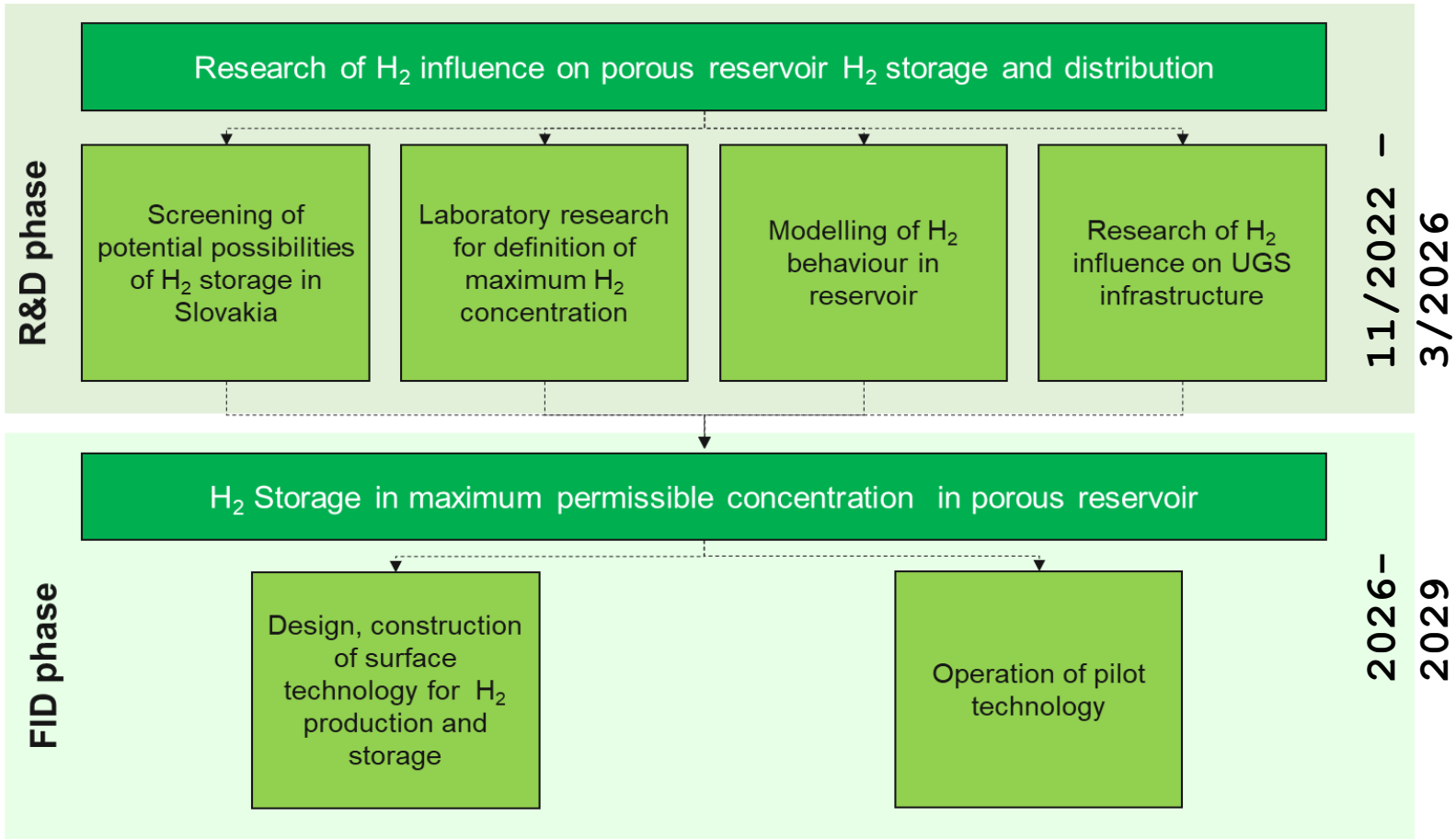
Identification of suitable structure for storing of H₂ in Slovakia



Based on R&D phase definition the max suitable H₂ storing concentration



Pilot technology for confirmation the research at real condition





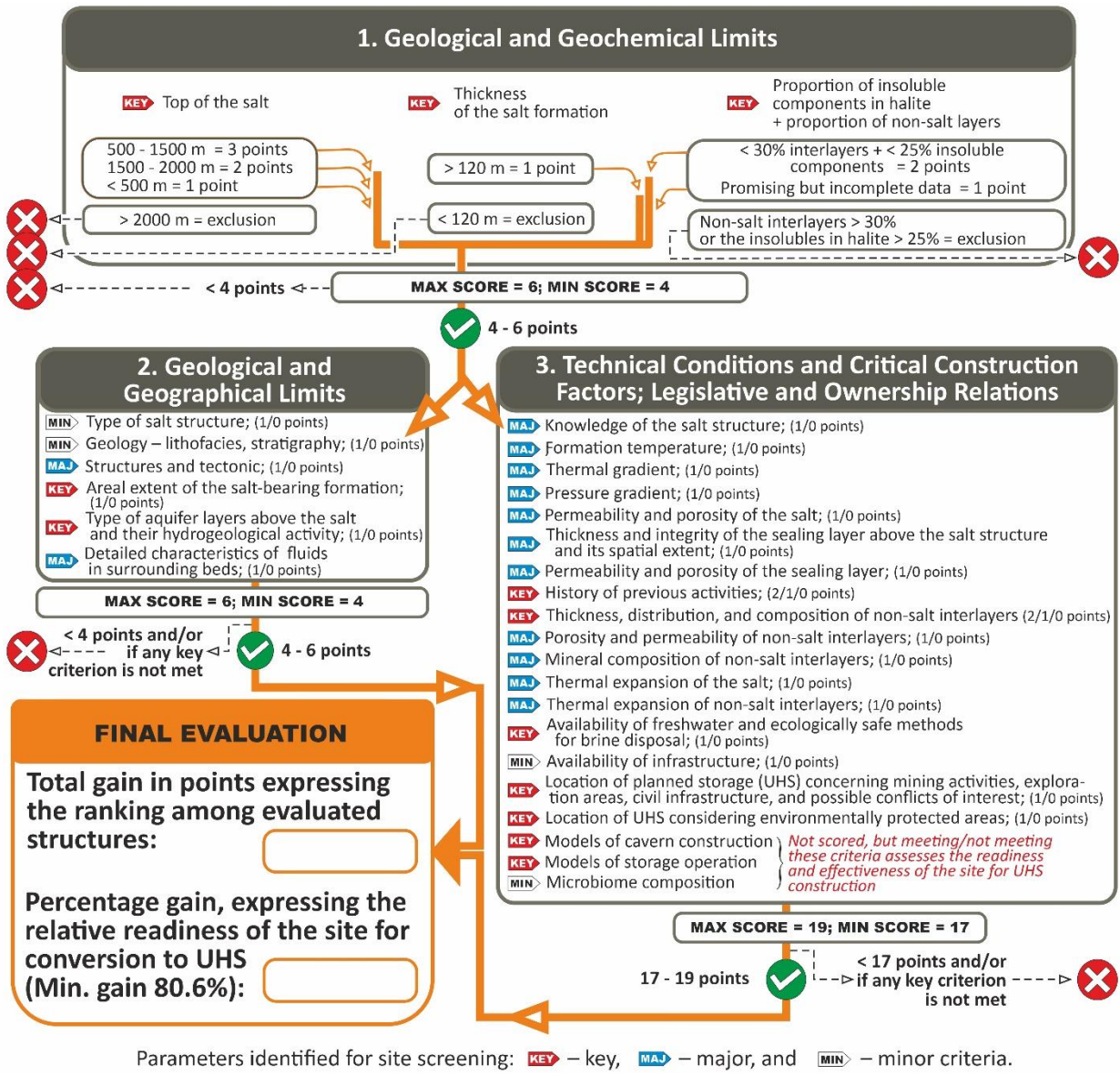
29 conditions are identified within 3 categories

Three weighting factors: key, major and minor
Each criterion is assessed individually (0-1, 0-2, or 0-3 points)

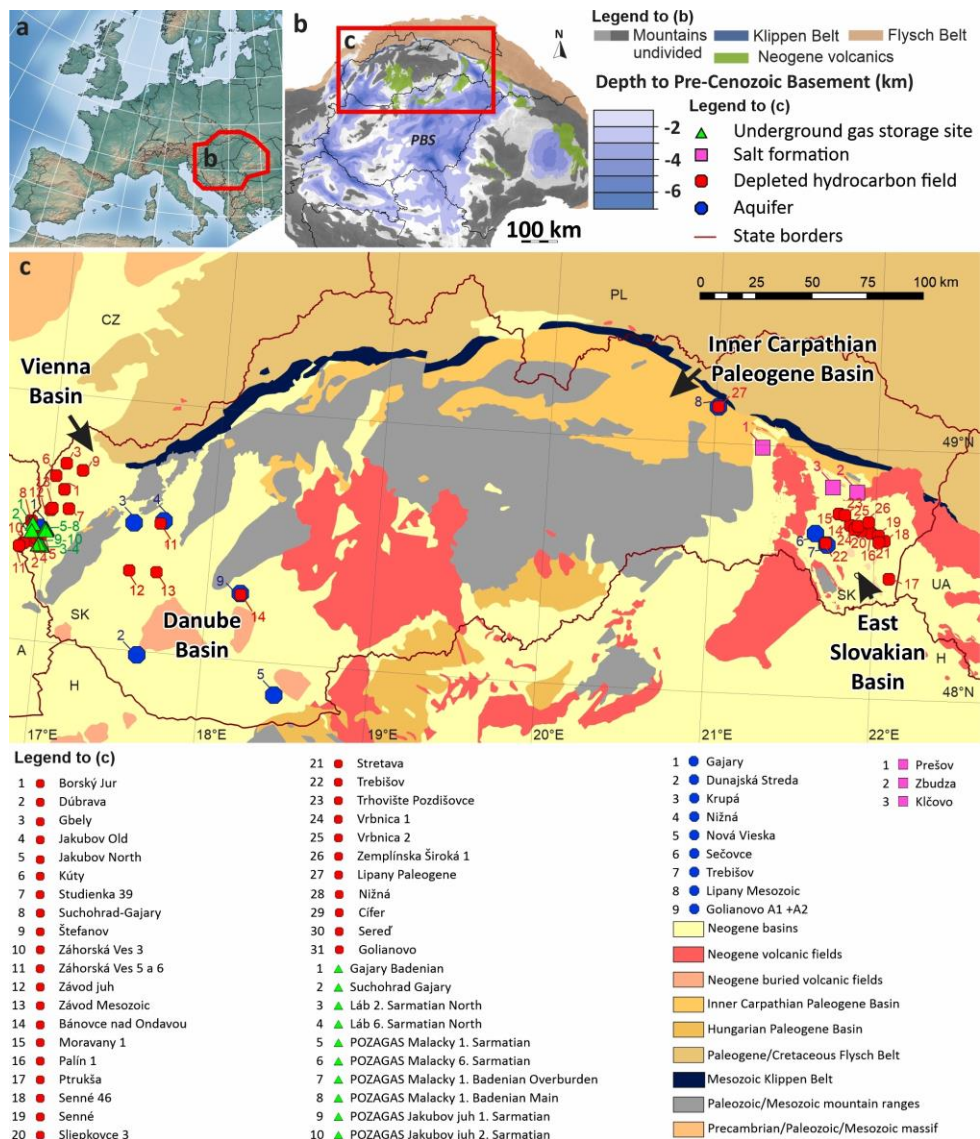
12 key criteria parameters that must be met for a structure to qualify for hydrogen storage. Failure to meet these criteria disqualifies the structure or indicates insufficient data.

13 major and 4 minor criteria parameters are essential for a comprehensive evaluation of the structure, detailing its characteristics and exploration stage.

The minimum gain required for the salt bed to be considered potentially suitable for the construction a cavern and UHS: 80.6 %



Geological map of Slovakia showing the sedimentary basins and structures analyzed in this study (modified from Hók et al., 2014).



Methods: The presented newly developed methodology was introduced

Data: NAFTA a.s. company archive, Geofond - state geological archive, and sci. publications

Assesing of porous structures: **Neogene Vienna, Danube, East Slovakian, and Paleogene Inner Carpathian basins.** The **salt formations** within the **East Slovakian Basin** are evaluated for UHS.



Geochemical Testing

Investigations:

- Permeability measurements (water and gas)
- Petrographical characterization (Thin section analysis)
- Storage experiments in specific pressure vessel
- Total for 12 months (Sampling after 6 and 12 months)





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Reservoir	Pressure [bar]	Temperature [°C]	Salinity [mg/l]
1	80	40	19 000
2	160	90	16 000
3	200	60	24 000

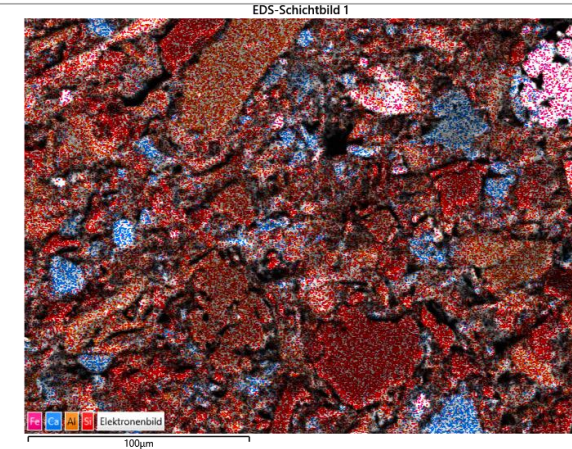
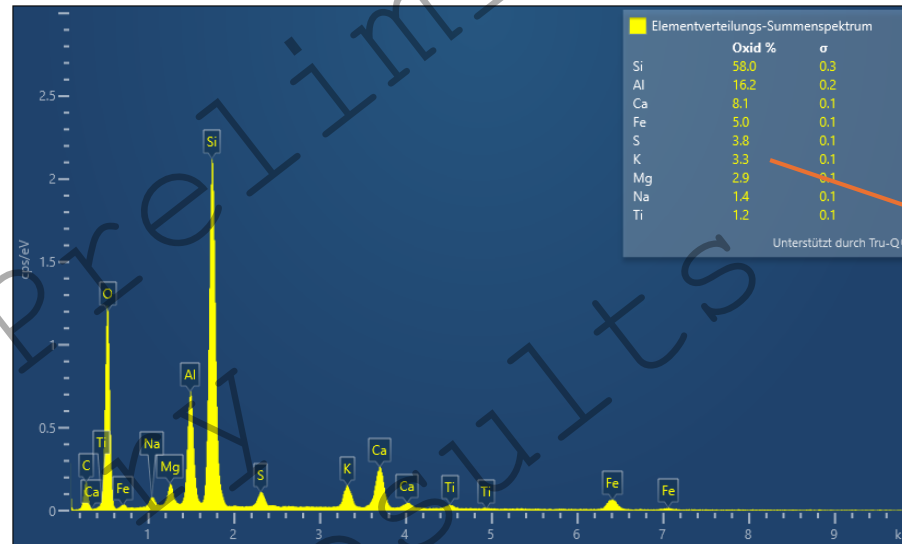
Results:

- First results after 6 months storage 9/2024



Cap Rock Testing

Mineralogy



The elements C, Ca, Ti, Na, Mg, Al, Si, K and Fe were determined in all areas analysed. The most common element is Si with 55-60% (expressed as element oxide), followed by Al (approx. 12-19%) and Ca (approx. 8-11%). Titanium only occurs in proportions <1%.

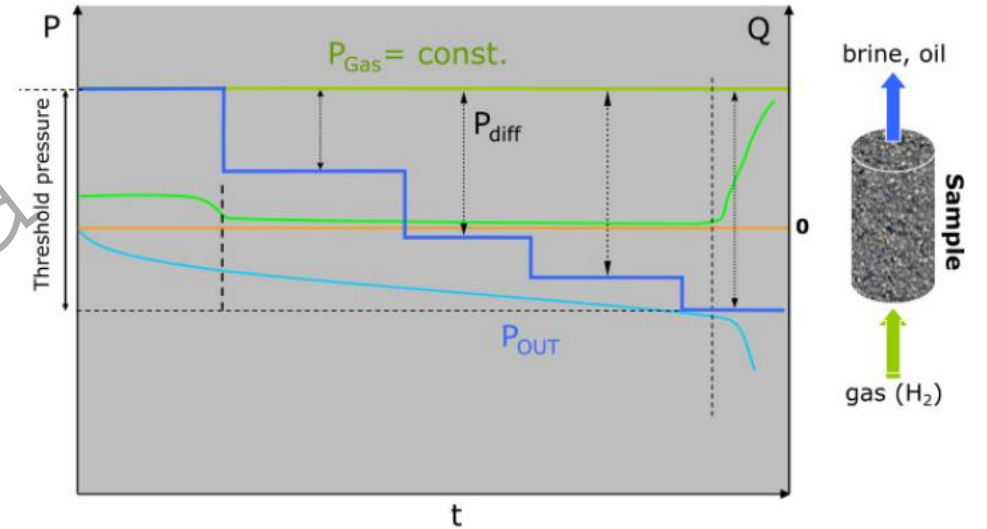


Cap Rock Testing

Capillary threshold pressure

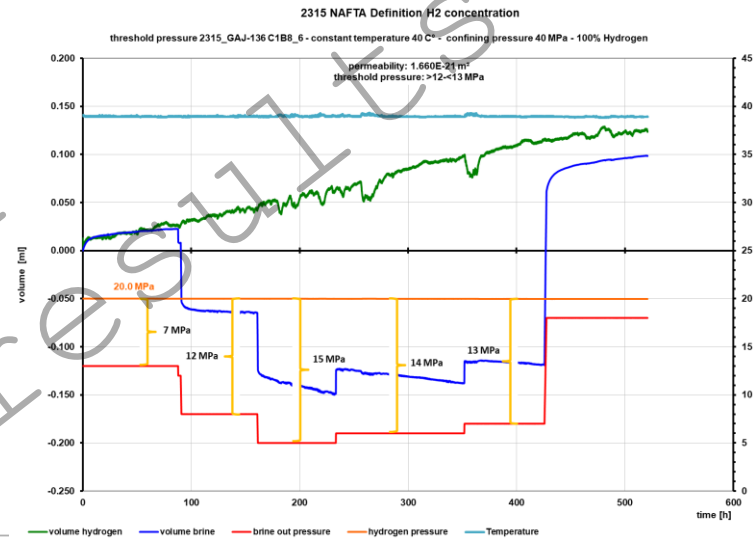
Capillary threshold pressure

- Hydrogen (100%) >12 - <13
- Methane (100%) >11 - <12
- Methane + Hydrogen (2%) >11 - <12
- Methane + Hydrogen (20%) >10 - <11
- Methane + Hydrogen (50%) >10 - <11
- Hydrogen (100%) > 9 - <10



(P: pressure, Q: flow rate, t: time)

Figure 3: Procedure for the static threshold pressure measurement.





Cap Rock Testing

Brine permeability

- Hydrogen (100%)	1.66 E-21 m ²
- Methane (100%)	1.44 E-21 m ²
- Methane + Hydrogen (2%)	1.24 E-21 m ²
- Methane + Hydrogen (20%)	1.31 E-21 m ²
- Methane + Hydrogen (50%)	1.26 E-21 m ²
- Hydrogen (100%)	1.27 E-21 m ²
- Final measurement	1.30 E-21 m ²

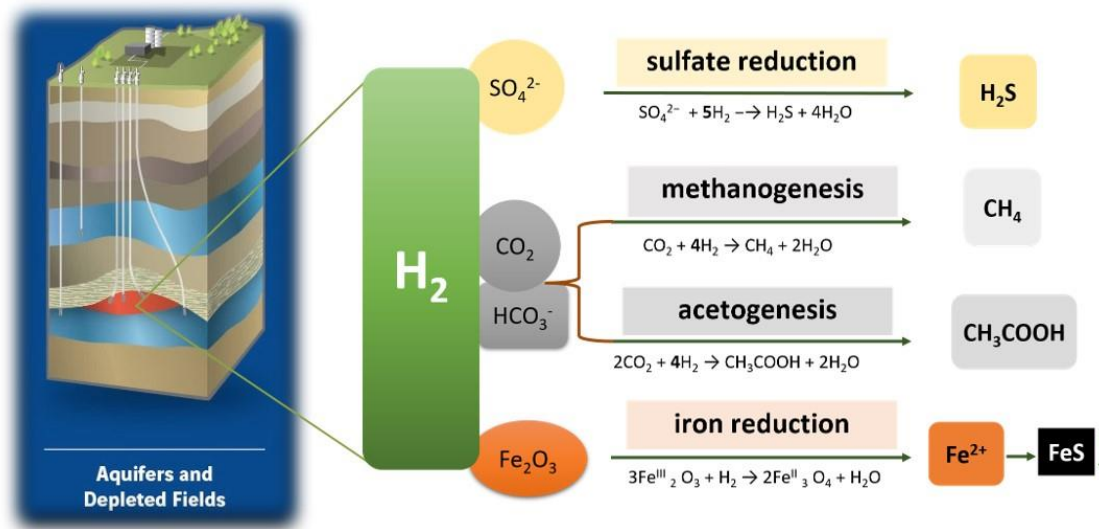


- The steady-state permeability can be determined by applying a differential pressure onto the specimen.
- The system has to equilibrate until a stationary pressure gradient inside the specimen is reached
- If equilibration is reached, the injection rate equals the output flow rate and all parameters are constant over time.
- A characteristic property of caprock samples is the very **low permeability** ($\sim 10^{-20}$ to 10^{-22} m²)
- From the fluid flow, the permeability can be calculated by applying Darcy's law for flow in porous media (Darcy 1856).



Microbiology

- Living microorganisms have been found in various underground structures in previous studies
- Hydrogen is a very good energy source for many anaerobic processes





Identification of physiological microorganism groups with selective cultivation methods



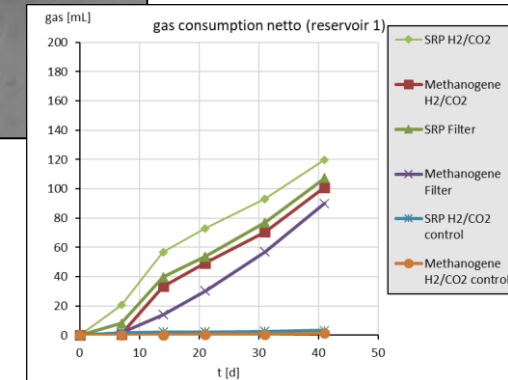
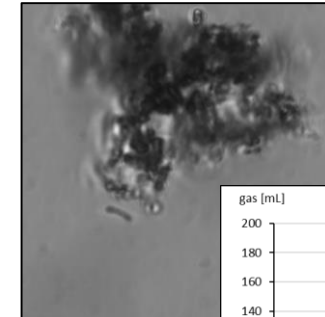
Original reservoir sample



Different cultivation methods



Evaluation of cell growth and activity





Identification of microbial population with molecular biological methods



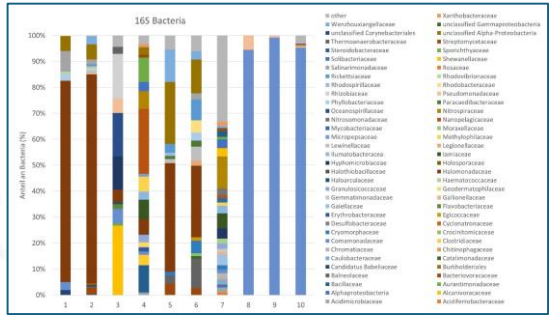
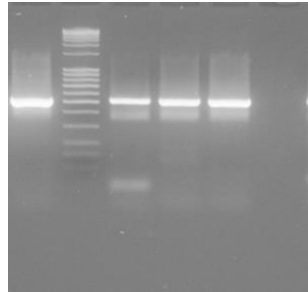
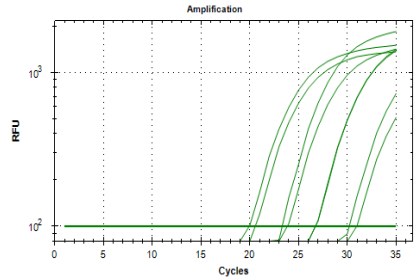
Original reservoir sample



Filtration, DNA extraction



qPCR, Microbiome-Analysis

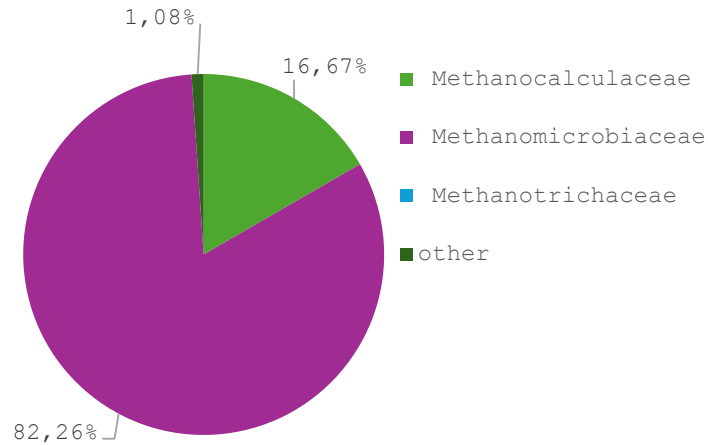




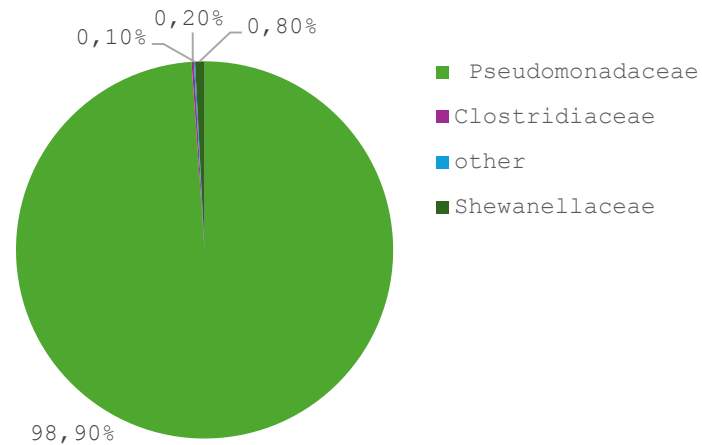
Microbiome Analysis- Reservoir 1



Archaea



Bacteria



Archaea:

- ❖ Hydrogenotrophic methanogens
- ❖ Families: Methanocalculaceae and Methanomicrobiaceae

Bacteria:

- ❖ Family: Pseudomonadaceae
 - Widespread environmental bacteria
 - Denitrification
 - acetate production with H₂
 - biofilm formation
- ❖ Families: Clostridiaceae and Shewanellaceae
 - some are SRB



Hydrogen stimulation tests at ambient pressure and high pressure



Ambient pressure tests

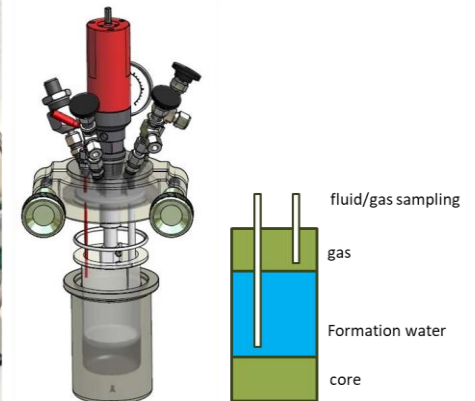
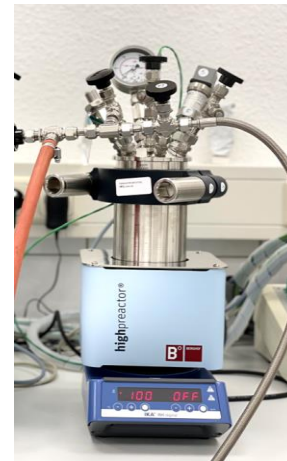
Hydrogen-concentration	0; 5; 15; 50; 100%
pressure	2 bar



Formation water
Core
cultures from reservoir 1
Different hydrogen concentrations
Measurement of gas consumption and gas composition during test period

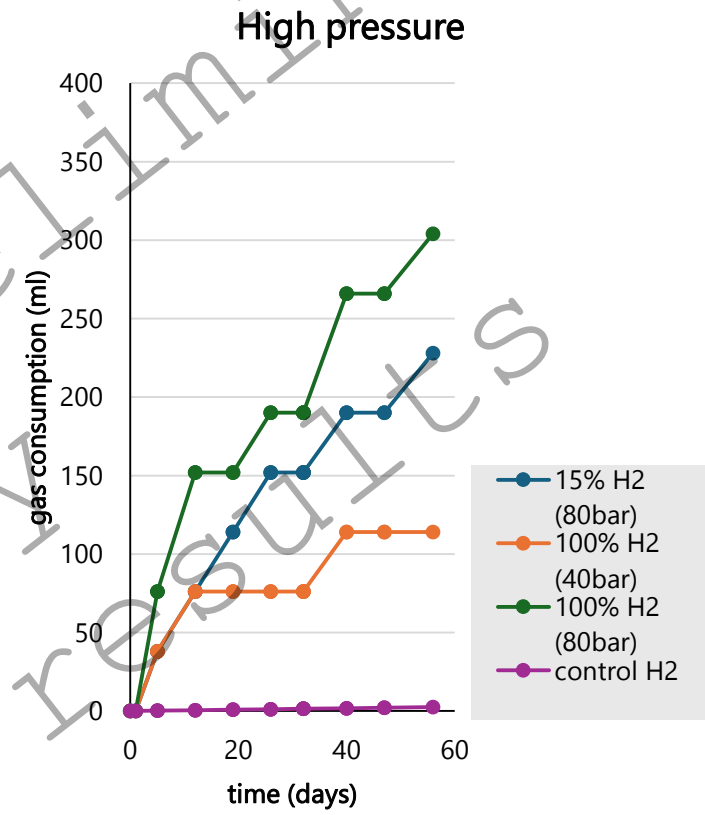
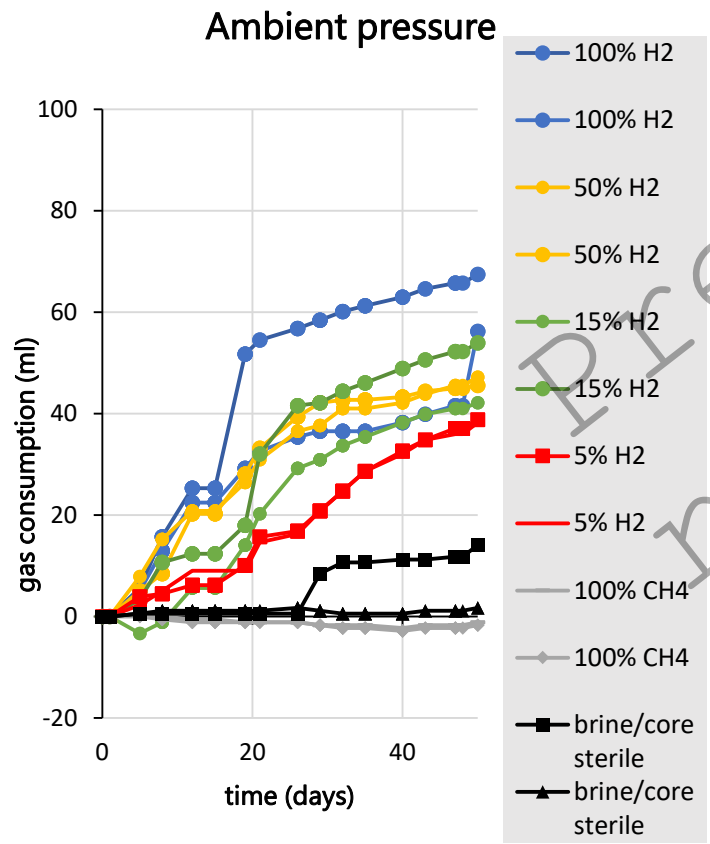
High pressure tests

Hydrogen-concentration	15% and 100%
pressure	40 and 80 bar





Gas consumption at ambient pressure and high pressure- Reservoir 1



Reservoir microorganisms consume gas under ambient and high pressure at all tested hydrogen concentrations

Gas consumption rate was influenced by hydrogen concentration and pressure



Material testing

- Tests are ongoing
- Partners: TUKE, MontanUniversität Leoben, Institute de la Corrosion
- Results in 2025



Next step of the project

- 1) Completion of laboratory experiments and interpretation of measured data
- 2) Processing of a complex model of the reservoir
- 3) Preparation of engineering study and documentation for Second phase of the project
- 4) Preparation of the study for Hydrogen purification
- 5) **Completion of the project first phase**





Preliminary results from the Cap rock testing are very optimistic, other tests are still ongoing.

