InterPore 2022- MS05

Microfluidic study of biomass-growth induced changes on hydraulic properties. Investigation of growth characteristics under varying nutrient gas environments.

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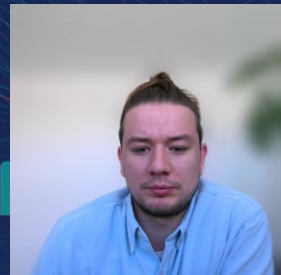
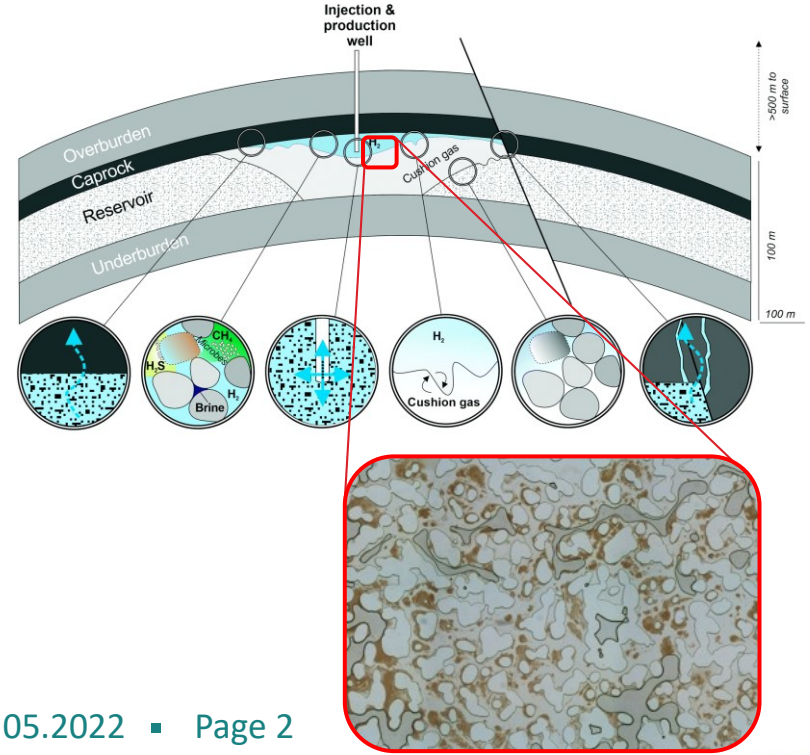
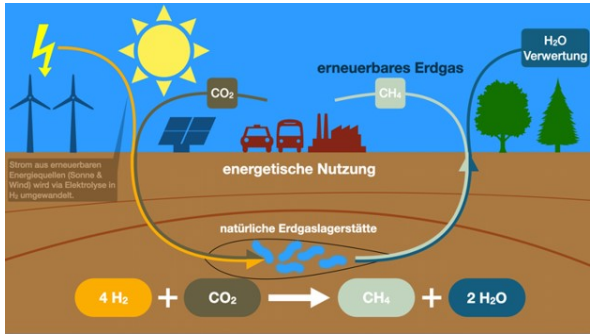
21.05.2022



BioPore-Project

Source: N.Heinemann et al. (2021)





The processes of biomass **accumulation**, **nutrient consumption**, and **growth** change the **hydraulic properties** with time, what are the consequences for **underground hydrogen storage** and **subsurface gas conversion** sites?

Prior Scienta

Transport in Porous Media (2021) 139:579–593
https://doi.org/10.1007/s11242-021-01680-5

Relationship Between Microbial Growth and Hydraulic Properties at the Sub-Pore Scale

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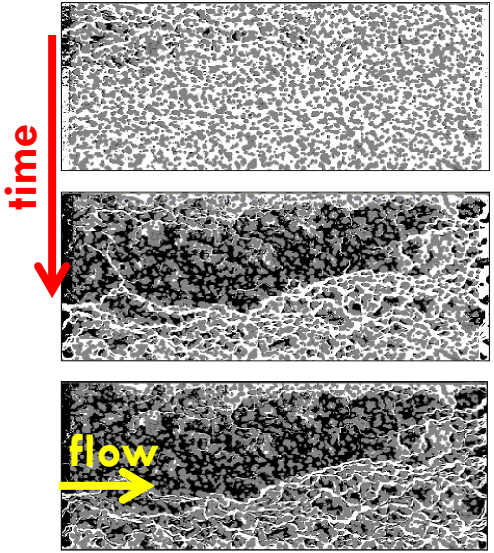
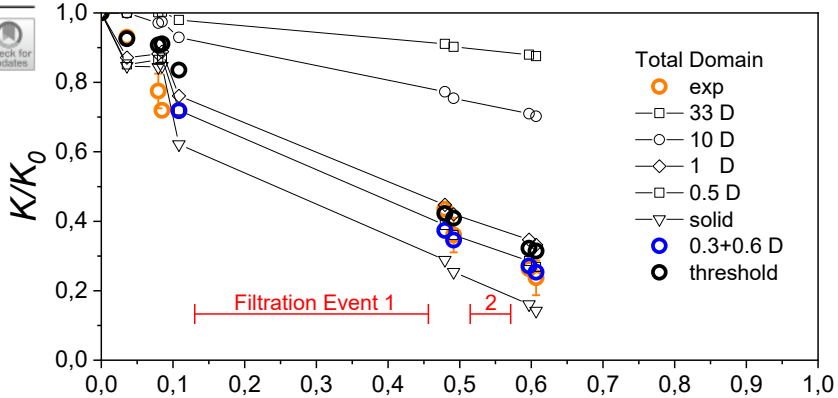
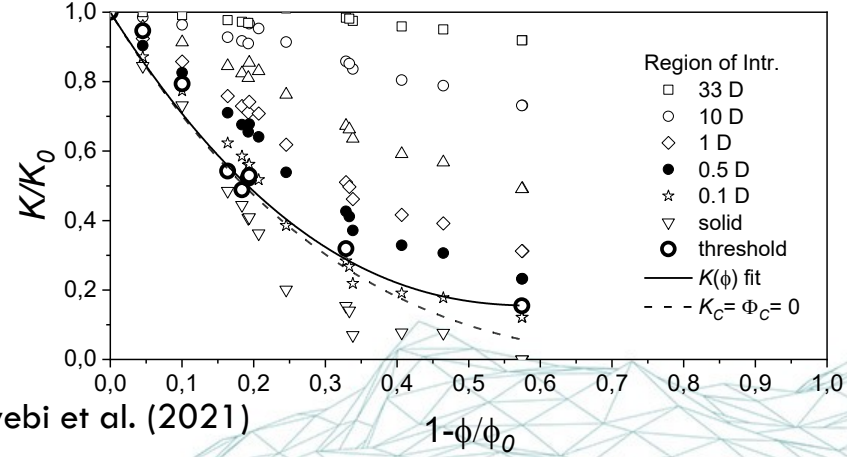






Observation of residual base permeability- by structure & permeable biomass

$$\frac{K - K_C}{K_0 - K_C} = \left(\frac{\Phi - \Phi_C}{1 - \Phi_C}\right)^{\tau}$$

N.Hassannayebi et al. (2021)

Methods and Materials

Fig. Microfluidic setup

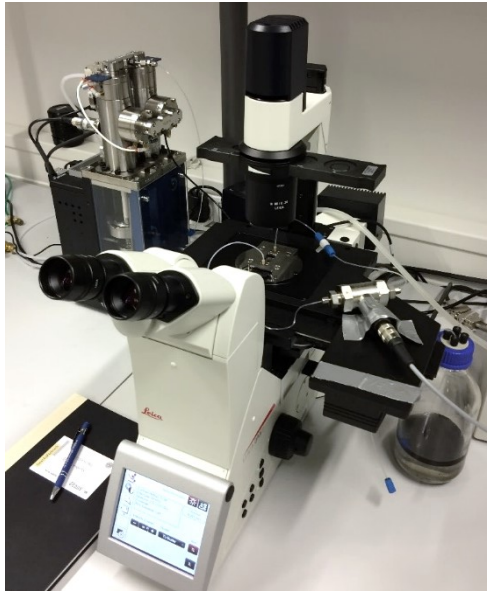
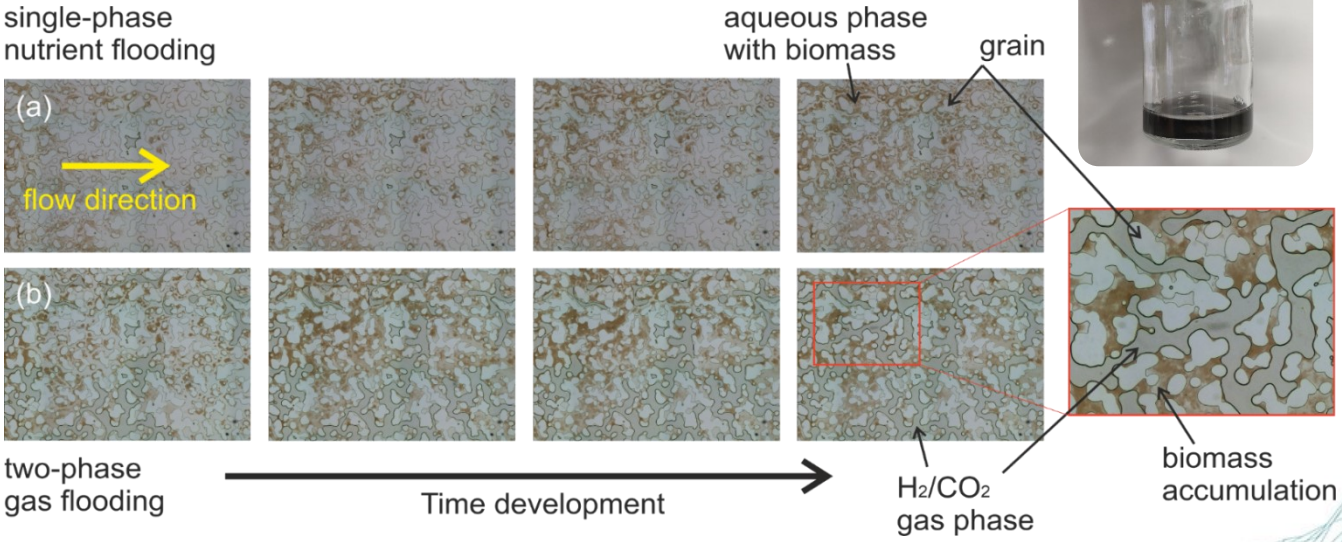
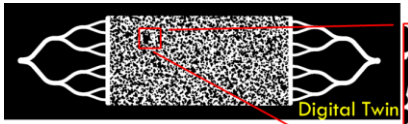


Fig. M.formicicum serum bottle





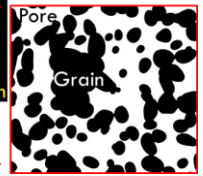
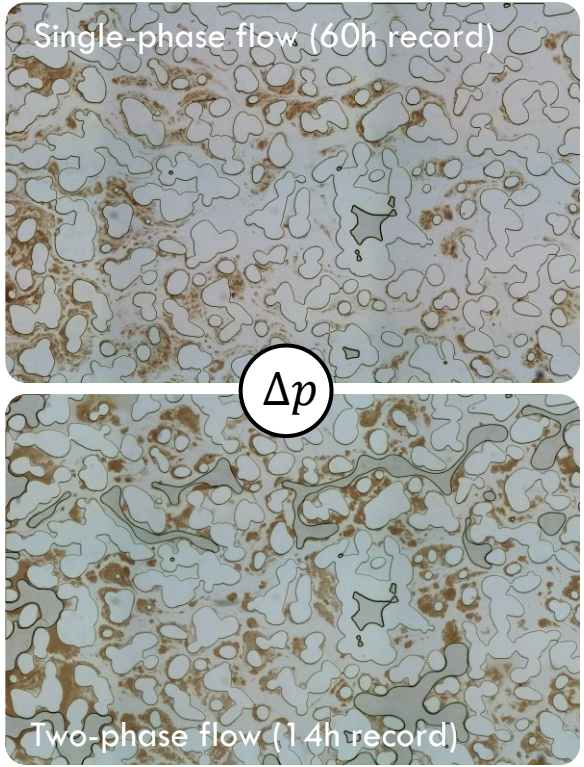
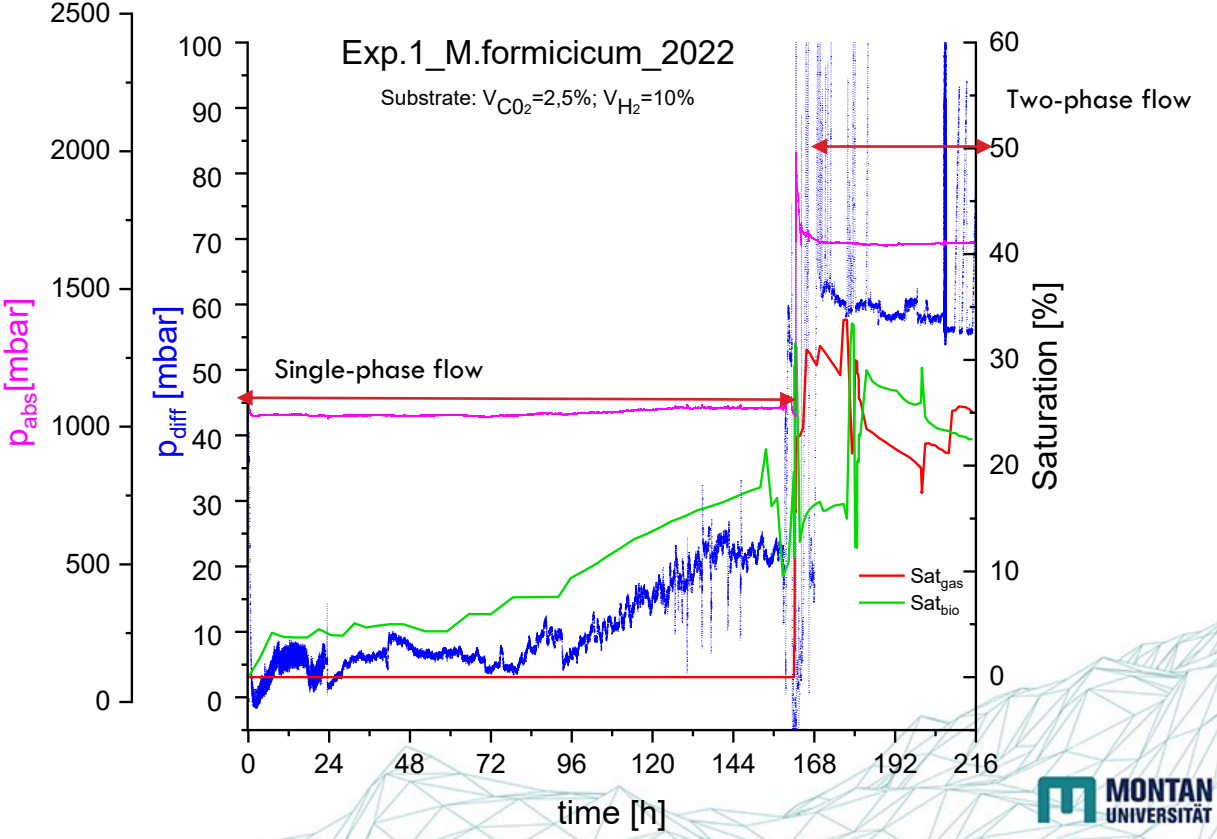


Fig. Micromodel

Experiment: M.formicicum_2022

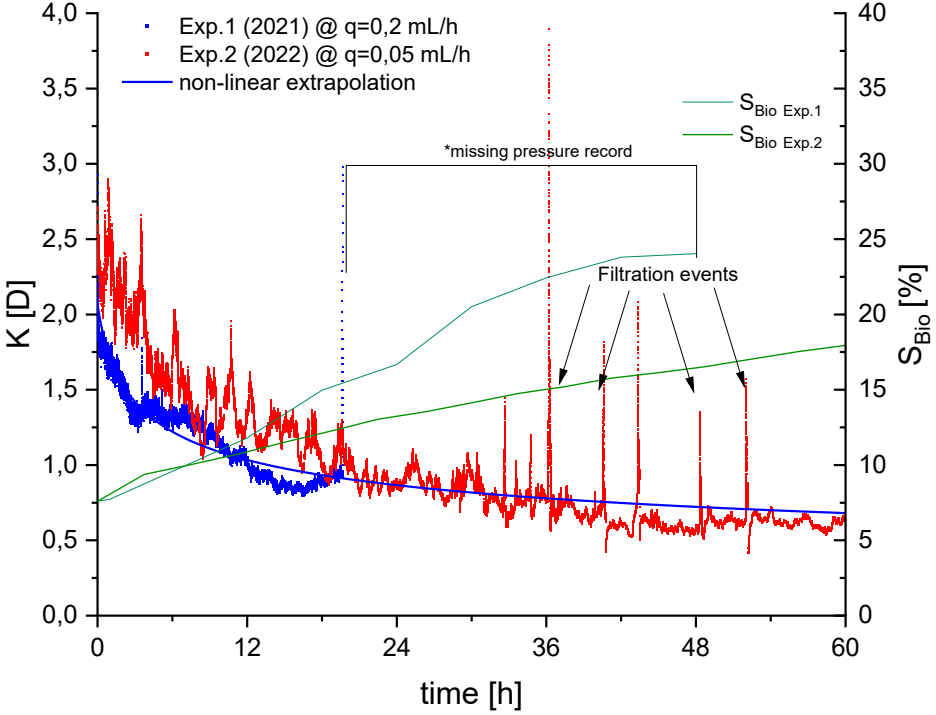
Response summary

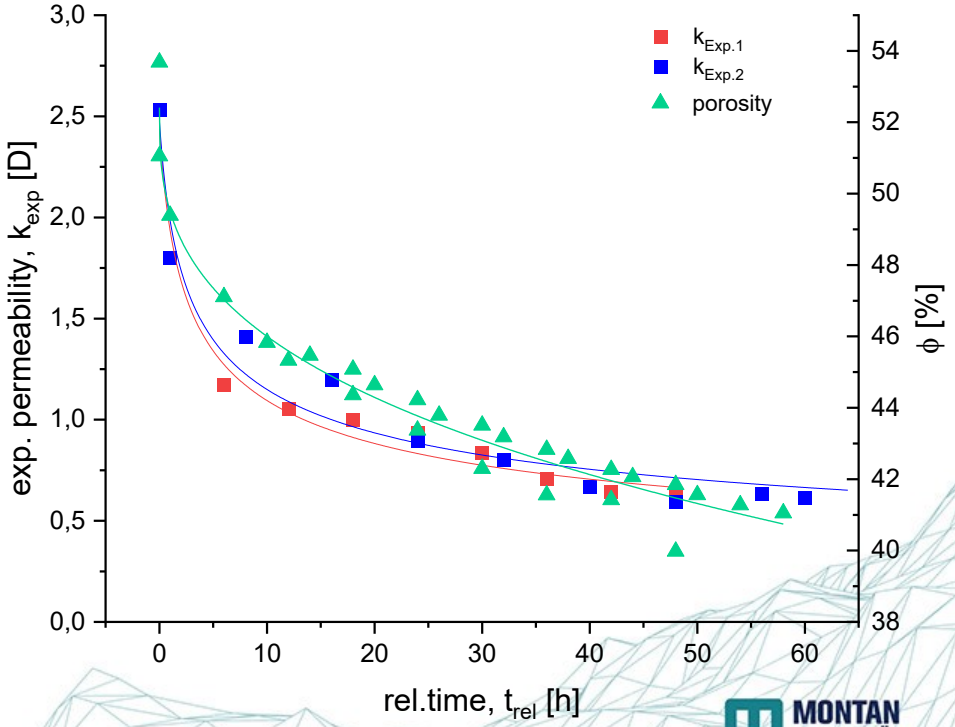




Biomass and permeability evolution

Single-phase flow

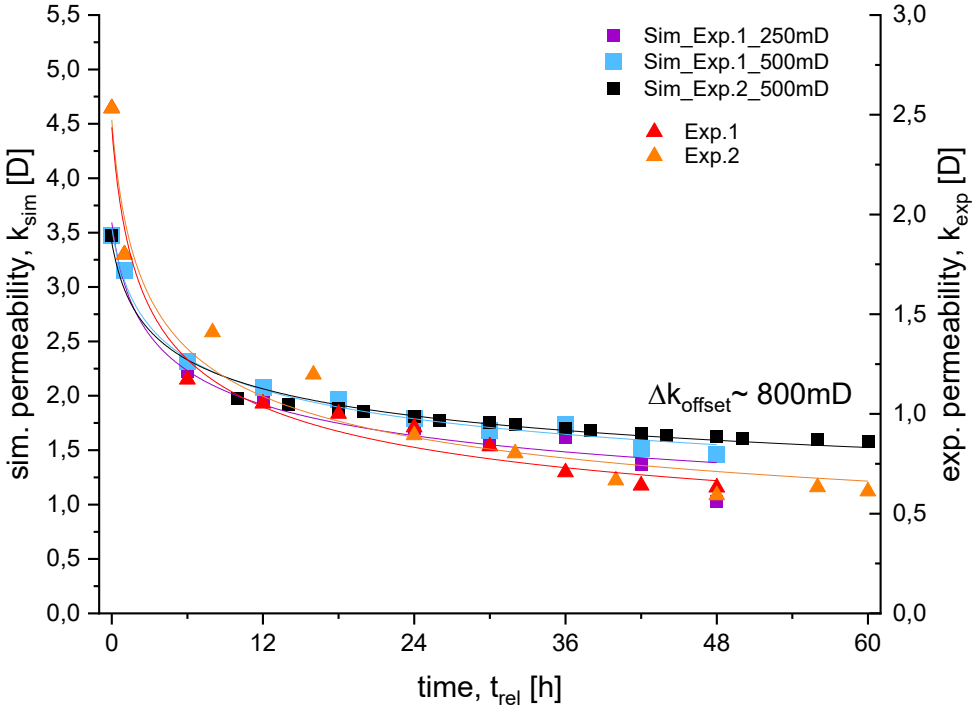




Experimental data and simulation results

Single-phase flow

Offset corrected-discrepancy between experiment and simulation



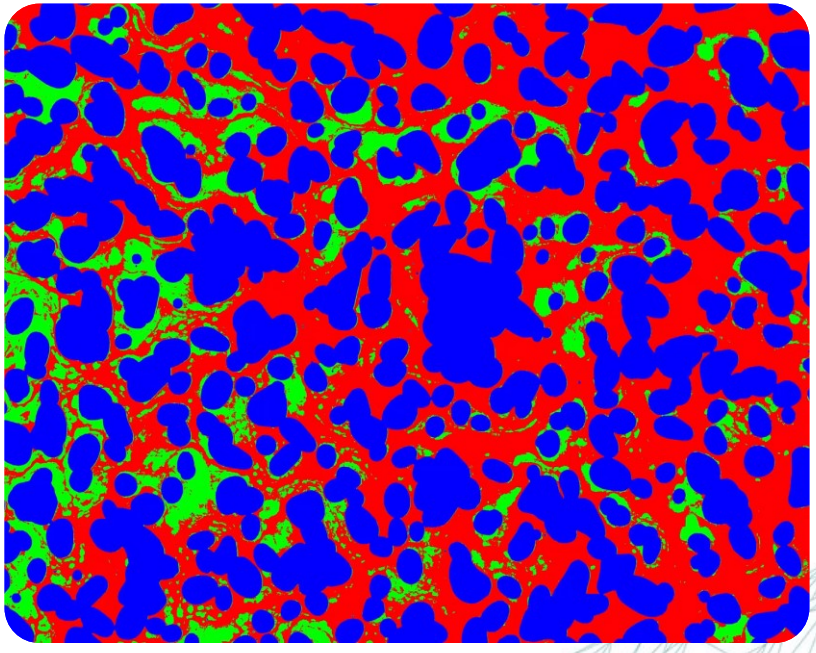
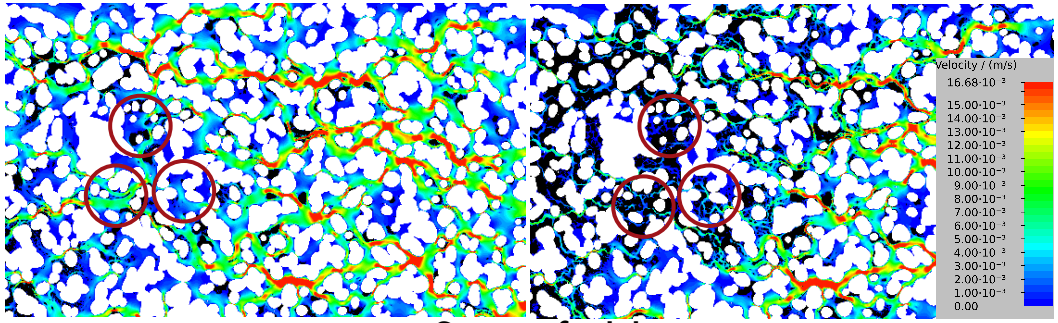


Fig. Segmented view of Experiment 2 (60h record a‘ 4h capture)

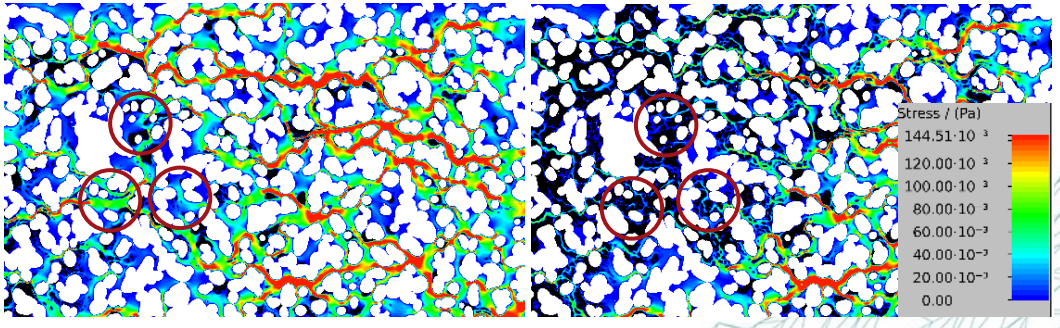
Way forward

- REV dependencies
- Reasons for offset between numerical and experimental results → improvement of sim. methods
- **Evaluation of two-phase experiments →**
  - **Effective gas permeability, f(t)**
  - **Growth characteristics**
- **Evaluation of reactive system →**
  - **Gas chromatography**
  - **Controlling parameters (Pe, Da)**
- **Impact of velocity and shear rates**
- Multiscale experiments – rock samples →
  - Link to associated research
- Iteration towards injectivity, conversion, and storage shortcomings

Velocity field



Stress field



time

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- Saeid Sadeghnejad
- Michael Kersten

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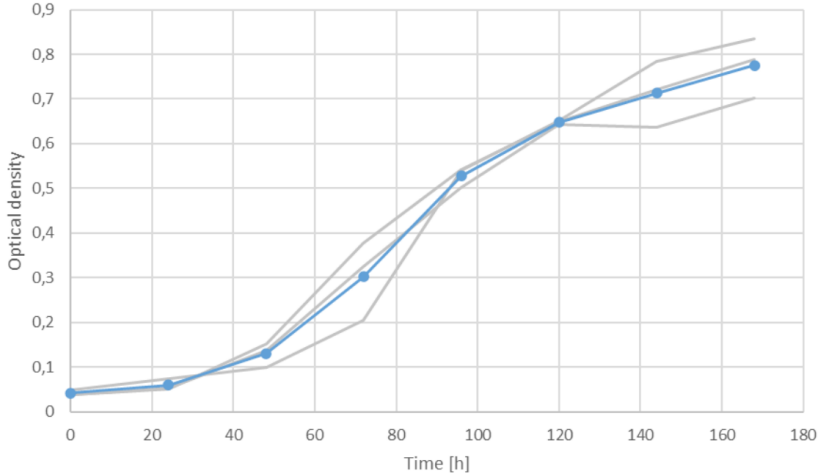
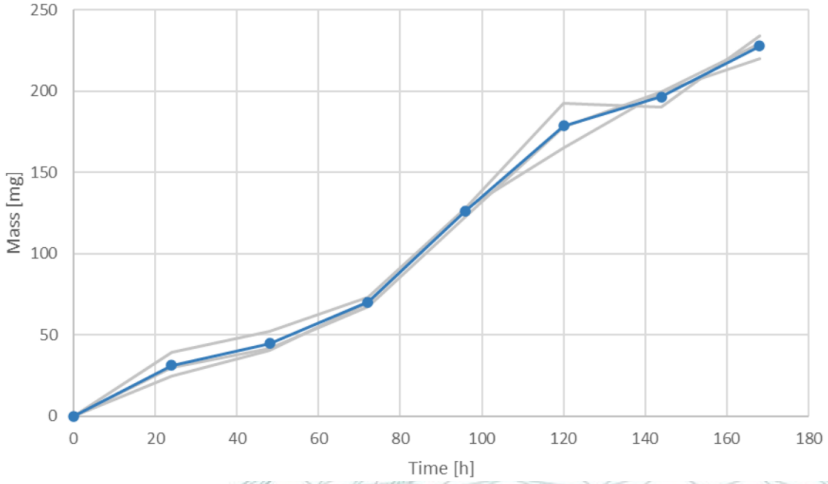
Backup

- **Growth rate**



- **MER**



Phase 1.

DEPARTMENT PETROLEUM ENGINEERING

Static growth rate and methane evolution rate determination

- Microbes maturity before injection (optical density)

$$4H_2(g) + CO_2(g) \rightarrow CH_4(g) + 2H_2O(l) \quad \rightarrow \quad \Delta H_R^0 = -253 \; {}^{kJ}/_{mol_{CH_4}}$$

$$\mu = \frac{\ln OD_i - \ln OD_{i-1}}{t_i - t_{i-1}}$$

$$n_{CH_4} = \frac{\Delta m}{M_{H2O} * 2}$$

$$MER = \frac{\Delta n_{CH4}}{\Delta t * V}$$

Micromodel saturation with bacterial suspension

- Multi-rate k [exp]
  - HM in GeoDict [sim]
  - Permeability evolution[sim]
- Time laps-Imaging
  - porosity reduction[exp|sim]
  - biomass increase [exp|sim]

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Phase 2.

Micromodel pressurization

Substrate in pressure equilibrium

- **Drainage** by liquid phase suction
  - Vindum-Pump at constant pressure operation
  - Saturation determination after Bt (Swir)
  - Critical Nc for desaturation of wetting phase
- **Imbibition**
  - Residual gas saturation as f(Nc)
    - Displacement/dissolution of substrate
    - Gas trapping by snap-off (diffusive dissolution as f (Nc,p)

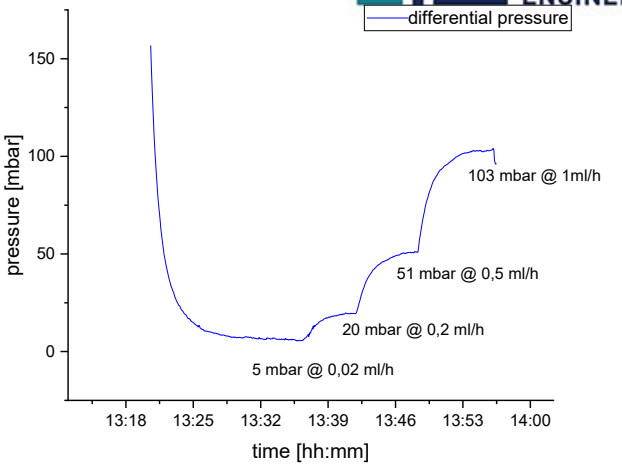
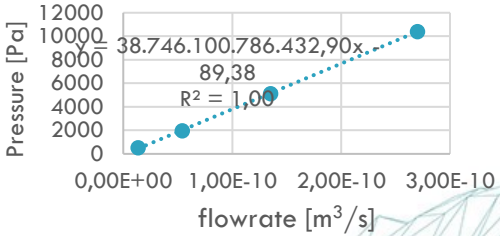
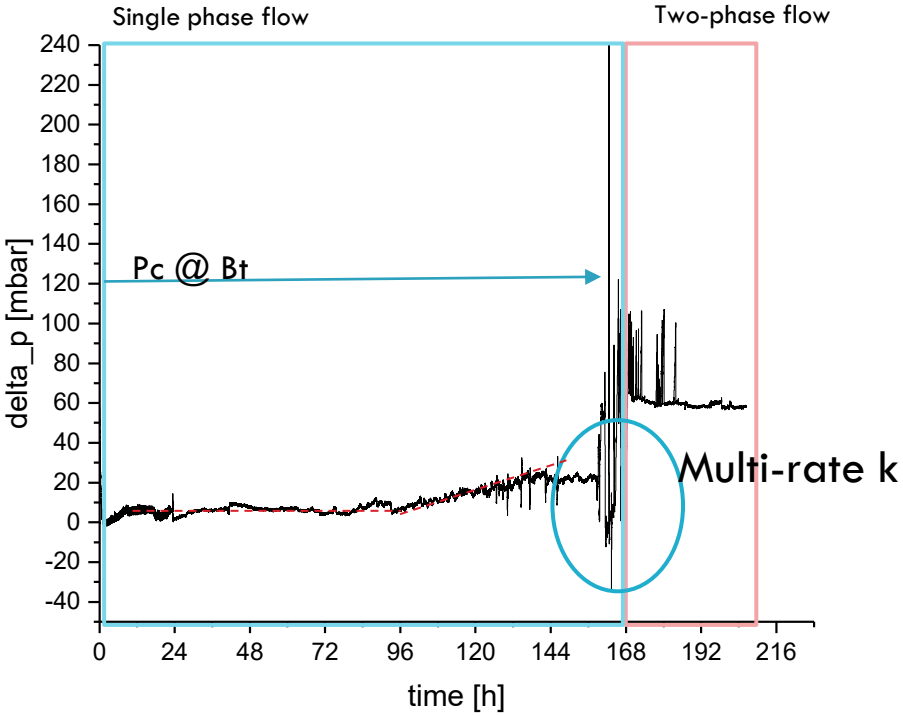


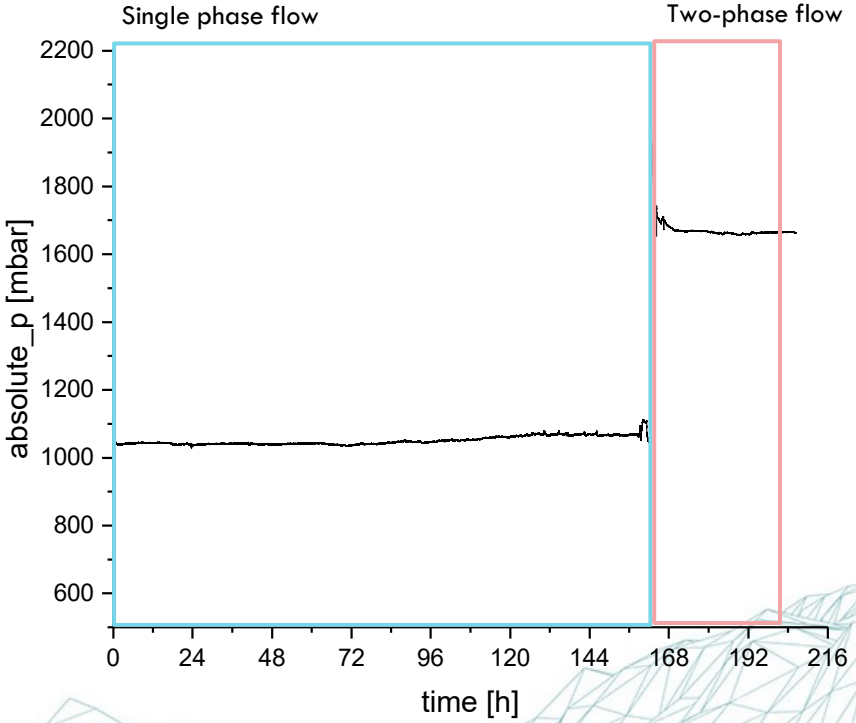
Fig.Multi-K permeability determination



k=2,61 D

Experimental pressure records





Time development of hydraulic properties

Single-phase flow

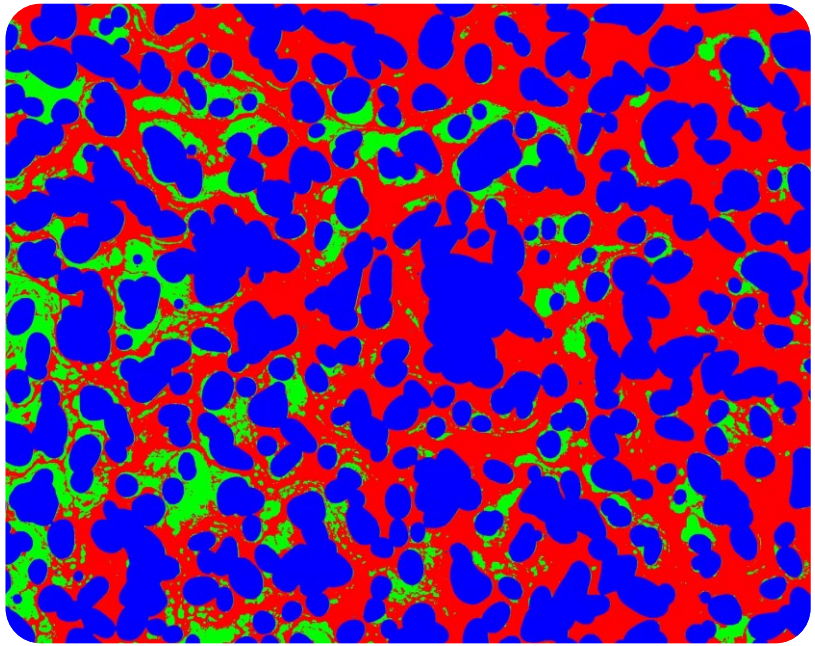
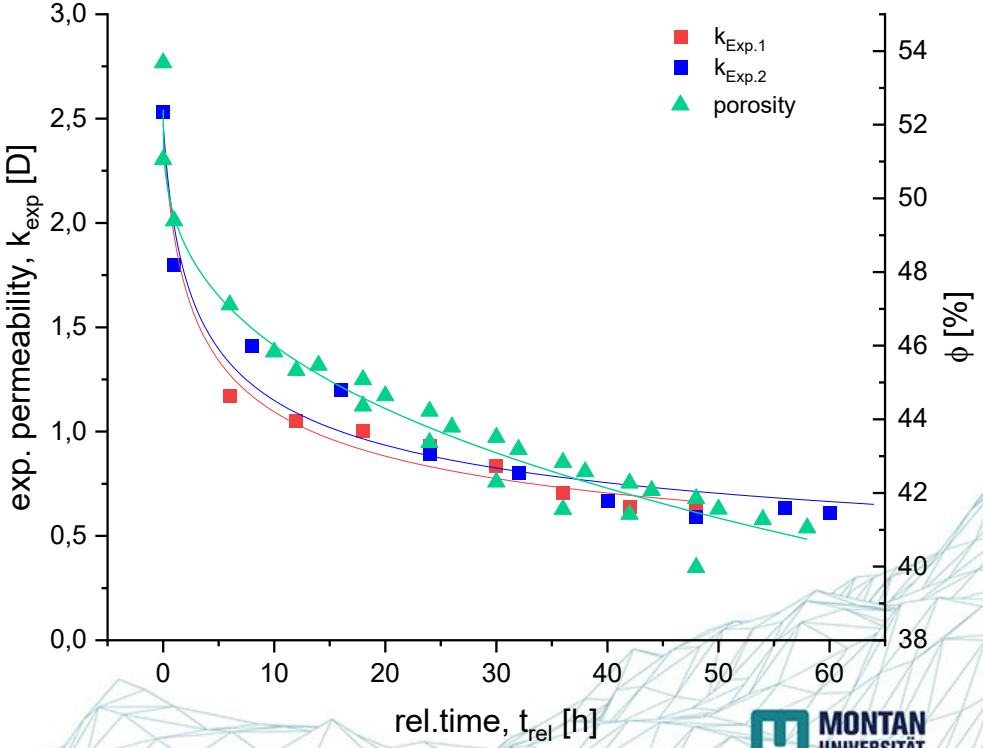
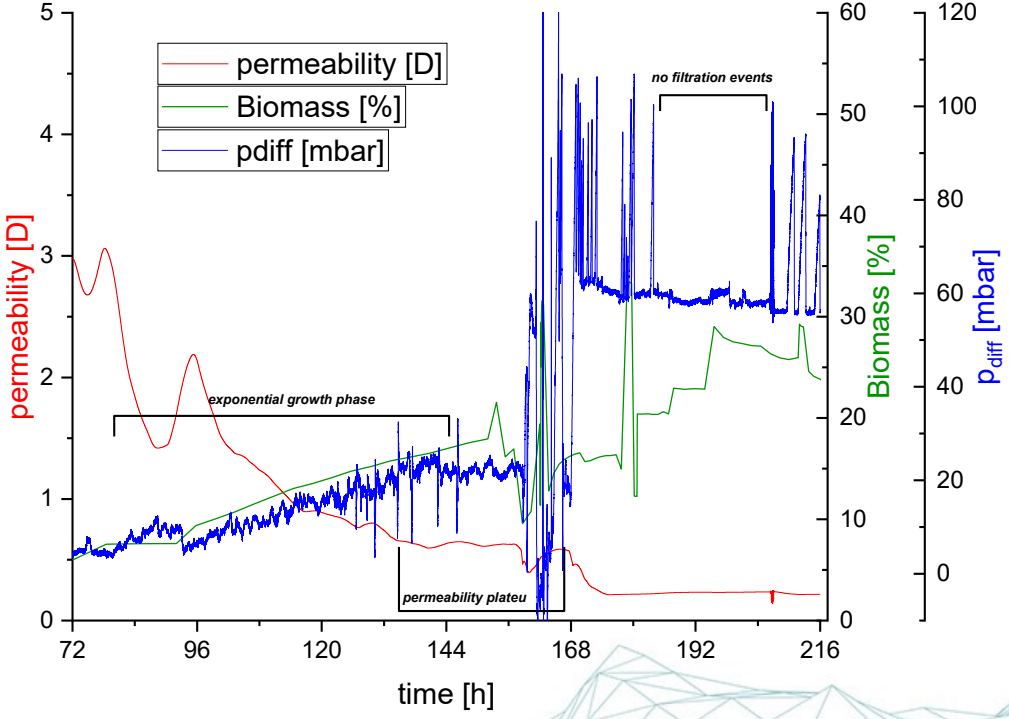


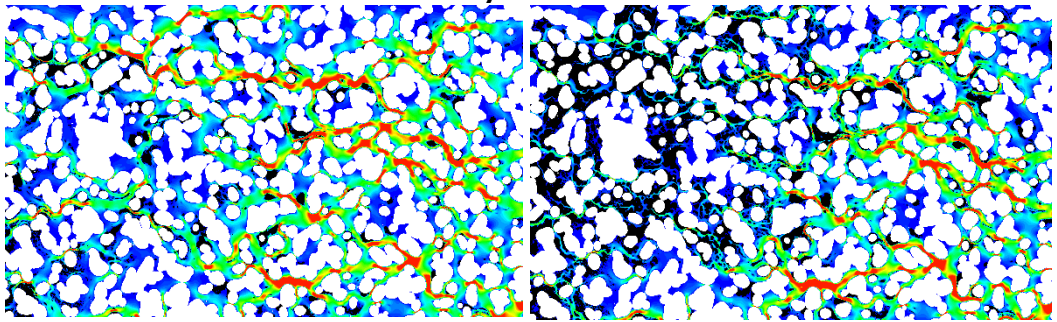
Fig. Segmented view of Experiment 2 (60h record a‘ 4h capture)



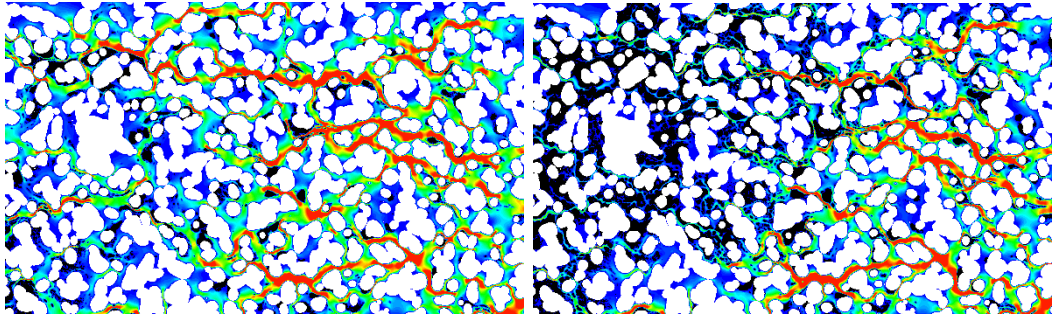
Biomass and nutrient gas interaction



Velocity field



Stress field



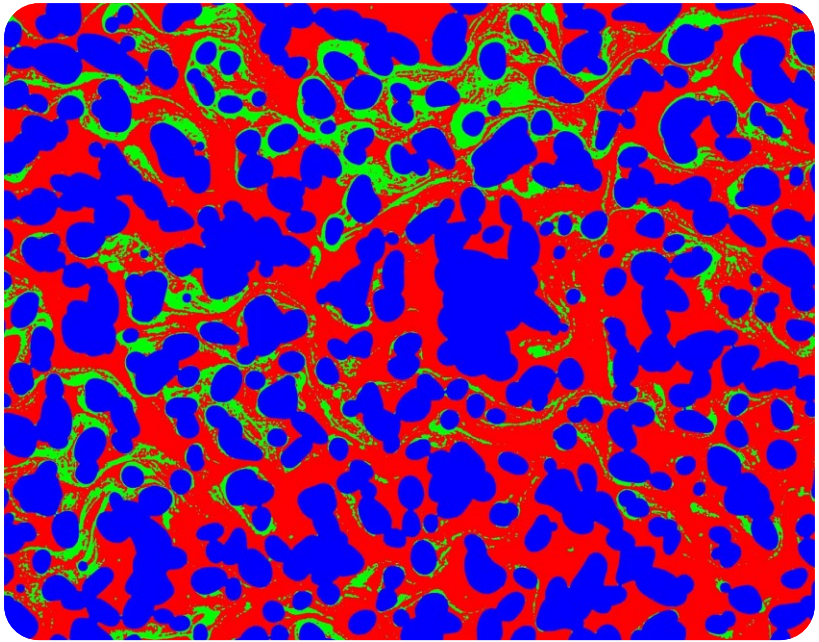
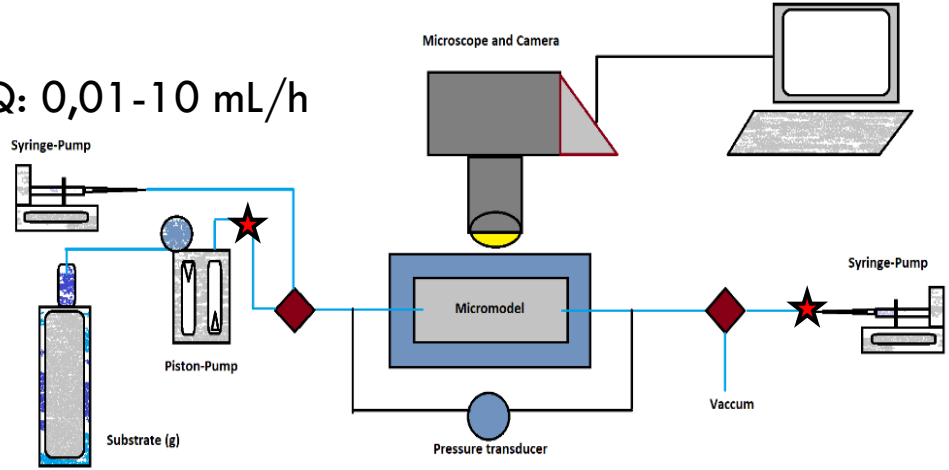


Fig. Segmented view of Experiment 1 (48h record)

Materials and samples

-*wide range pressure applications*-

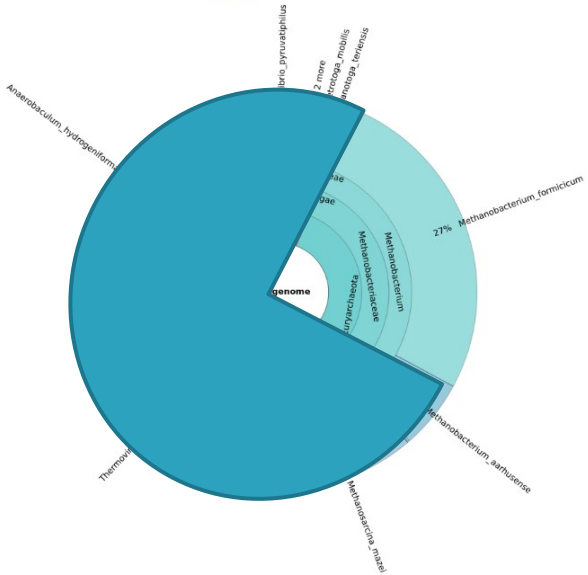
Q: 0,01-10 mL/h



p =1-30bar

Max.

Δp =3bar



Microbes abundance Lehen-field

Synthetic brine with M.formicium