

Experimental investigations of the effects of CO₂/mineral-interactions on seal integrity

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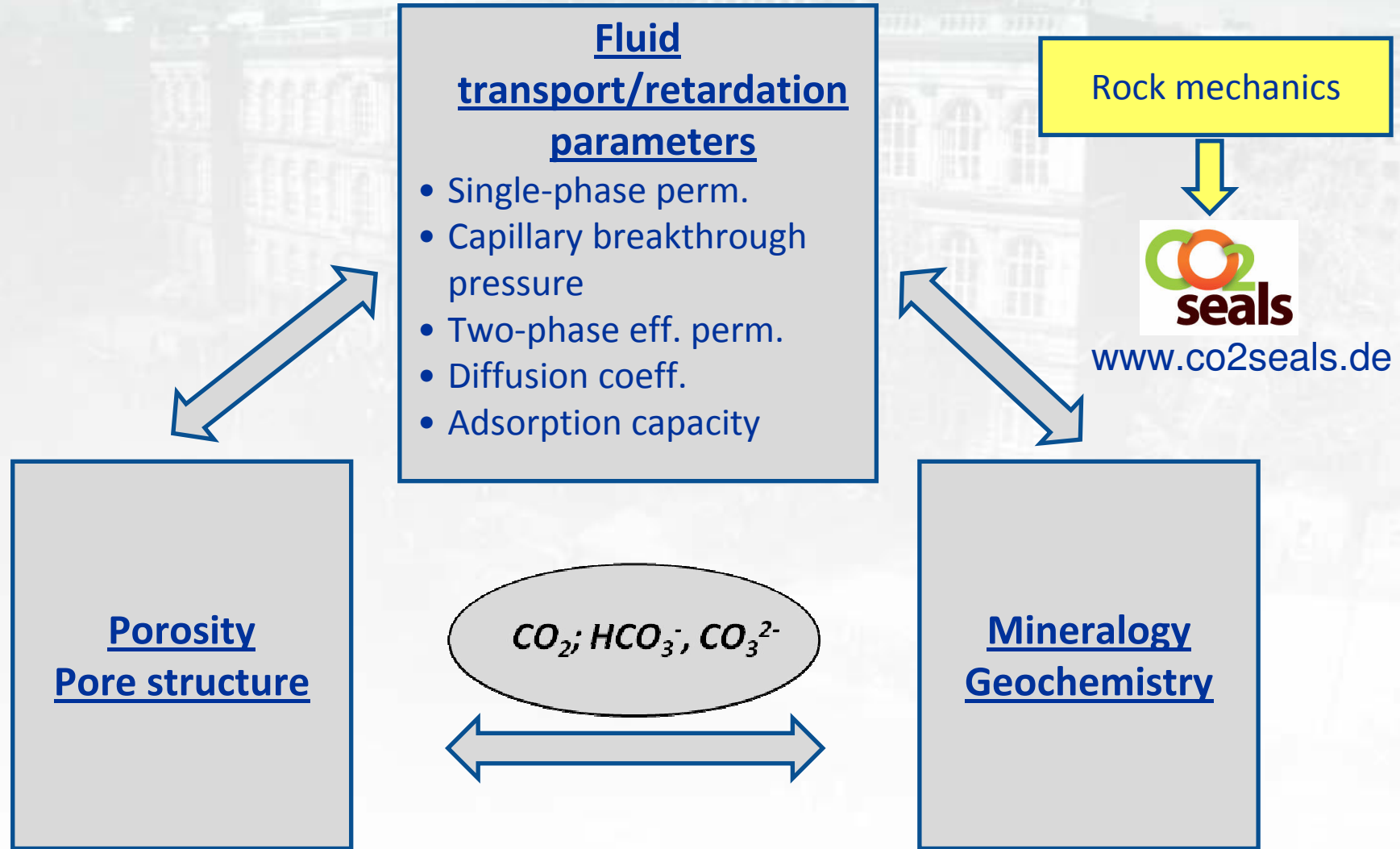
Andreas Busch²

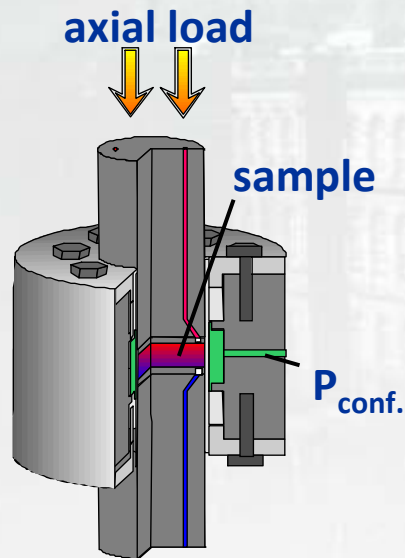
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Multi-purpose high pressure triaxial flow cell:

Cylindrical samples: $\Delta x(\text{max}) = 10\text{-}20$ mm, $\varnothing = 28.5$ and 38 mm

Schloemer & Krooss (1997, 2004)

Hildenbrand et al. (2002, 2004)

Busch et al. (2008)

- permeability
- gas breakthrough (He, CO₂)
- gas diffusion (CO₂)

Mineralogy/Geochemistry

XRD (Rietveld)

Petrophysics

Hg-porosimetry, specific surface area (BET), high-pressure sorption

Reactive and virtually inert samples

- Some samples revealed significant mineralogical changes

- Reaction due to CO₂-treatment
- Reaction mainly controlled by fluid chemistry (K⁺-source)

- Some samples appeared to be mineralogically inert

Petrophysical changes ?

Example 1

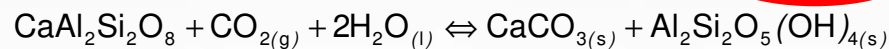
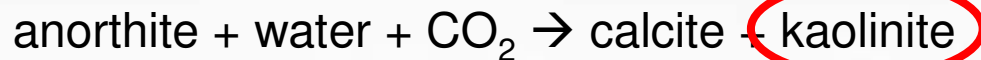
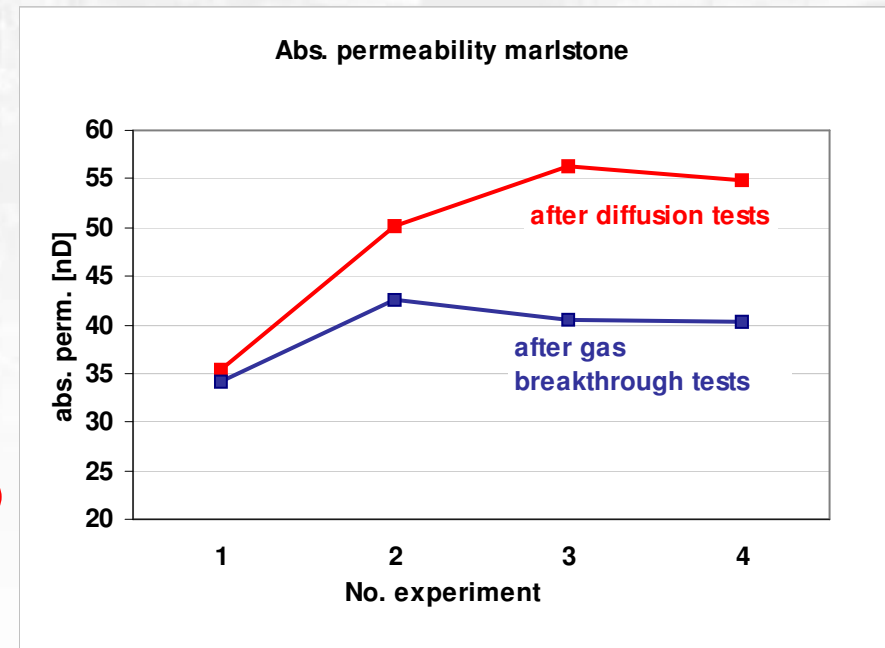
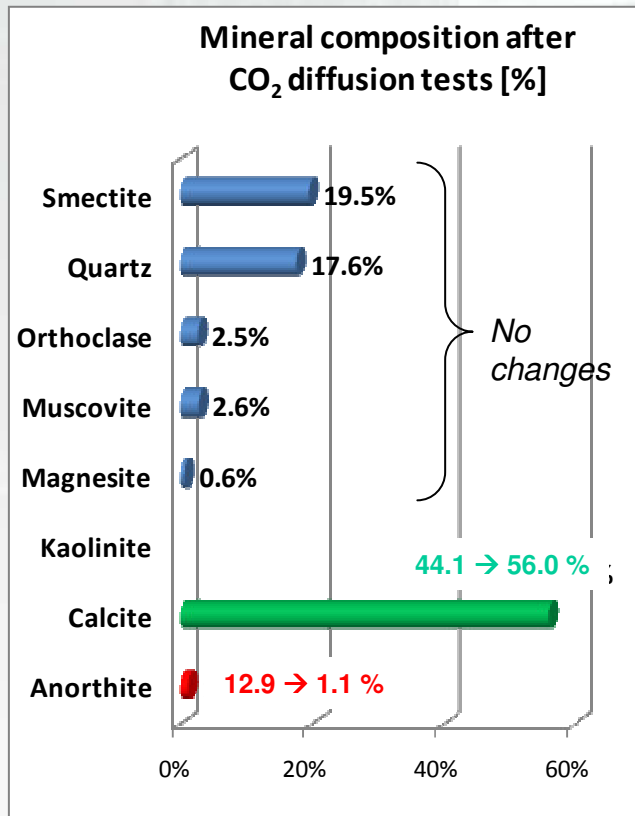
Example 2 & 3

Example 3

Example 1 – CO₂/rock-interactions

Marlstone (Emscher Marl, before and after CO₂-treatment):

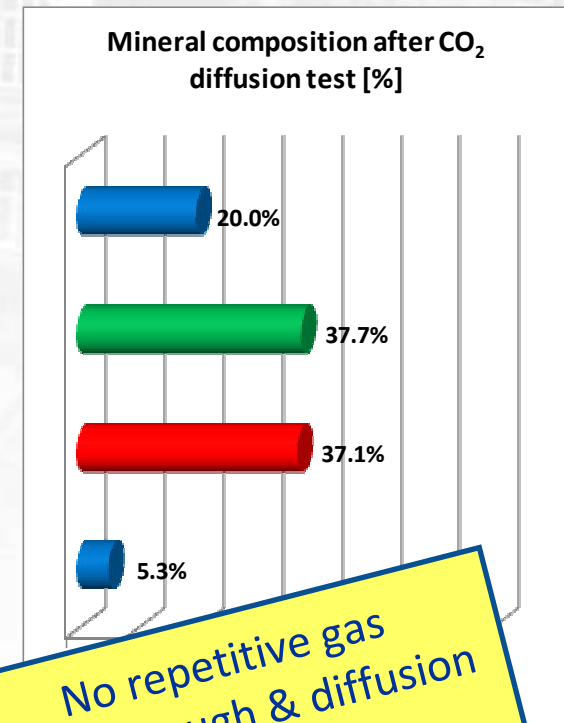
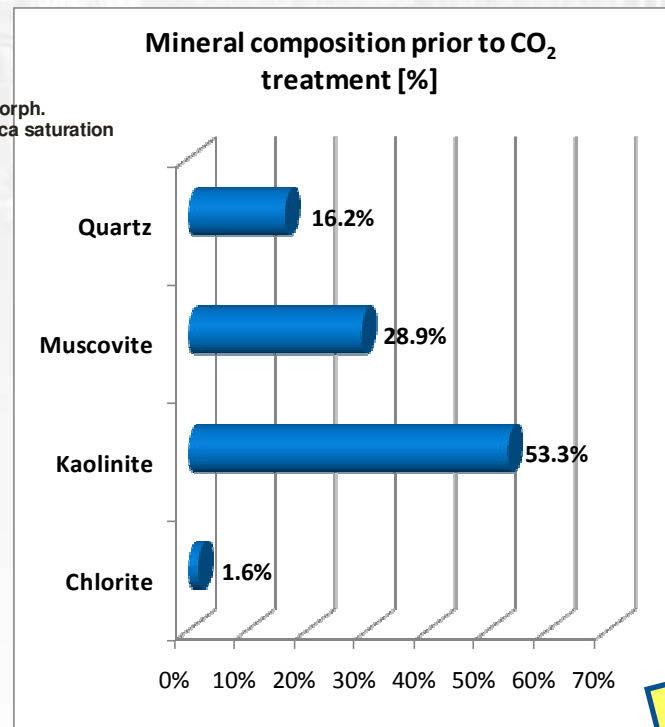
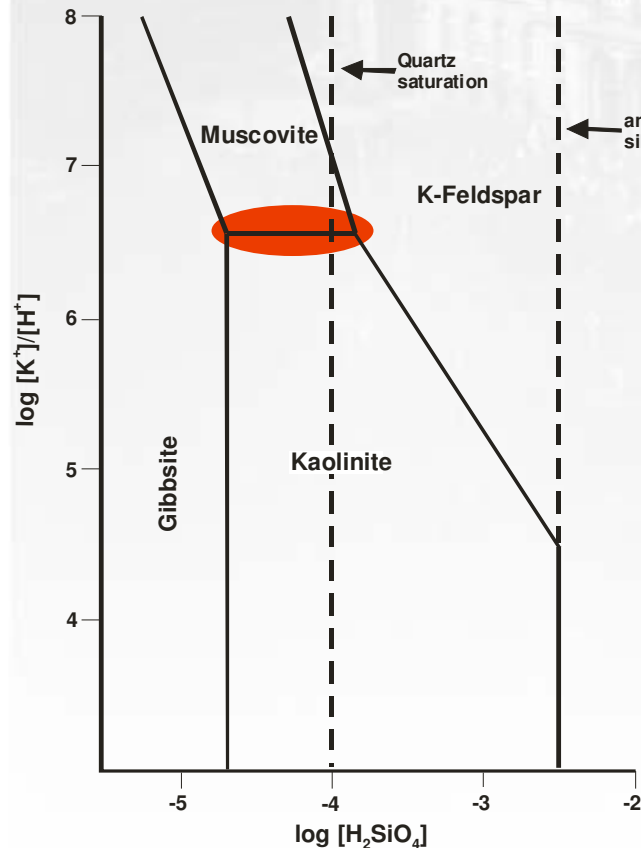
- Decreasing CO₂ snap-off pressure (0.64 - 0.43 MPa)
- Increasing effective gas permeability (1 - 2.9 nD)
- Increasing absolute permeability (34 - 43 nD)
- Increasing diffusion coefficients (7.8·10⁻¹¹ - 12·10⁻¹¹ m²/s)
- Increasing average pore radii (Hg-intrusion, 35 - 40 nm)
- Decreasing BET surface area (21 - 19.8 m²/g)



Example 2 – additional K⁺-source

Carboniferous-shale (from Poland, before and after CO₂-treatment):

- Experiments performed with brine → enhanced K⁺-saturation, formation of muscovite
- k_{abs} increased after CO₂-treatment (0.1 - 0.7 nD)
- Decreasing BET surface area (15.95 - 11.91 m²/g)

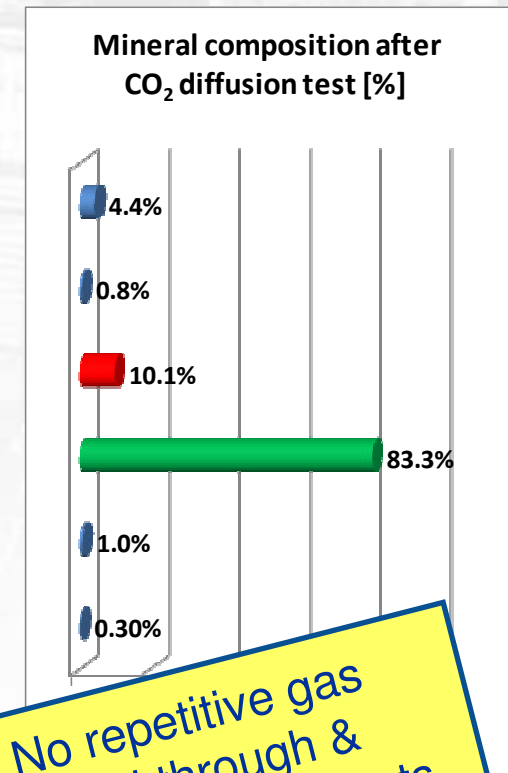
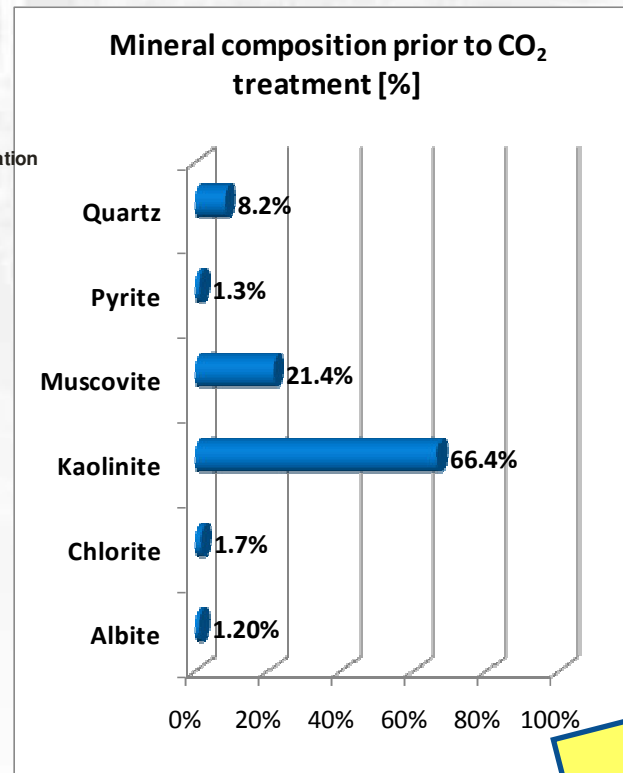
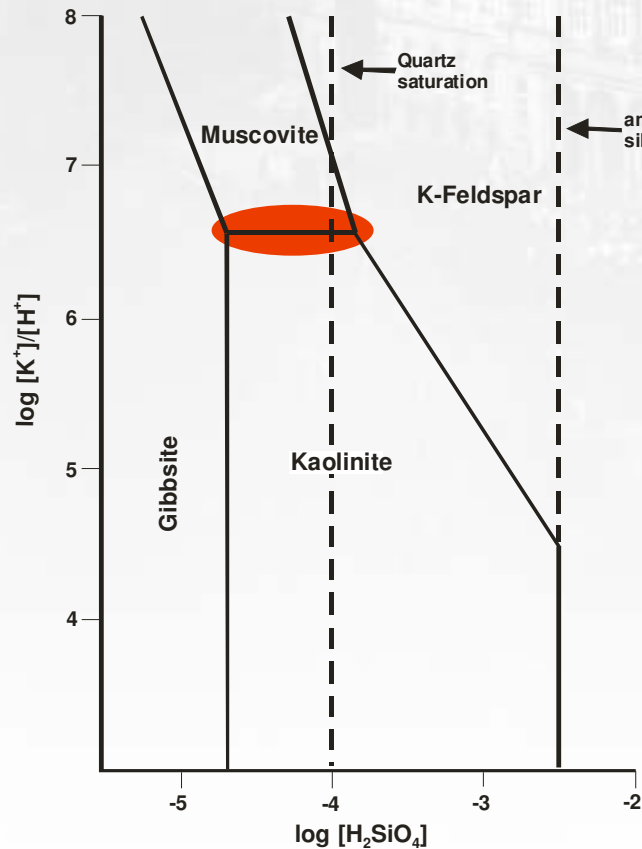


No repetitive gas breakthrough & diffusion experiments

Example 3 – K⁺-undersaturation

North-Sea shale (S08, before and after CO₂-treatment):

- Experiments performed with tap water → K⁺ undersaturation, transformation of muscovite into kaolinite
- Increasing average pore radii (Hg-intrusion, 7.64 - 8.72 nm)



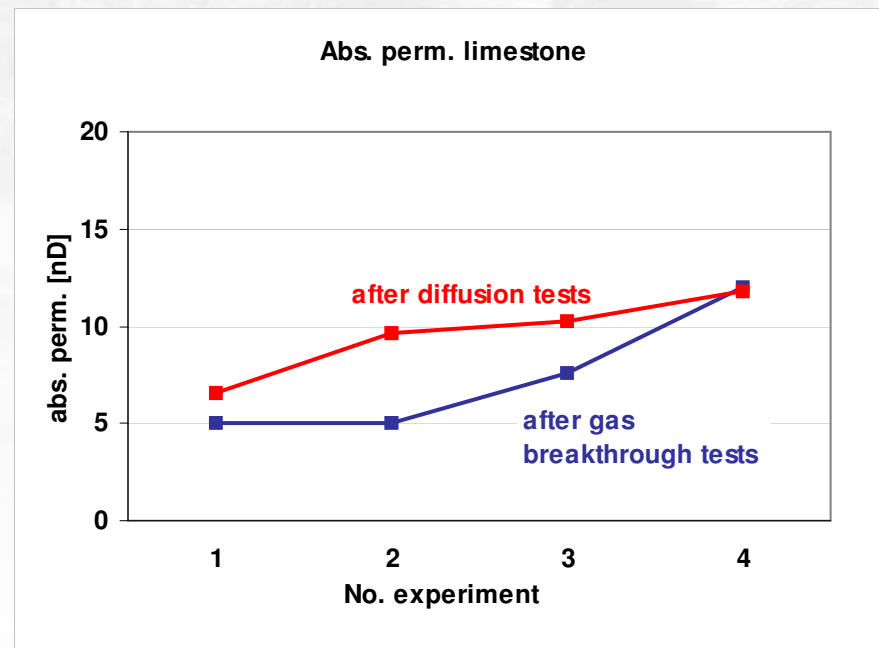
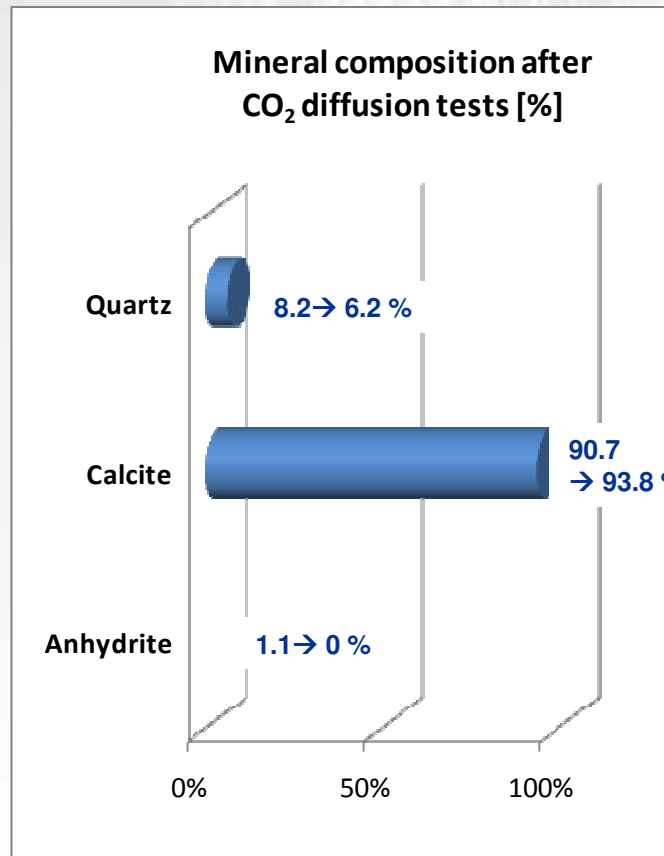
No repetitive gas breakthrough & diffusion experiments

Example 4 - No mineralogical changes

→ Reorganisation of pore system

Limestone, D5 (before - after CO₂-treatment)

- Decreasing snap-off pressure
 - $P_c(\text{CO}_2)$: 0.74 - 0.41 MPa
 - $P_c(\text{He})$: 1.81 - 0.62 MPa
- Increasing effective CO₂ and He permeability
 - $k_{\text{eff}}(\text{CO}_2)$: 0.4 - 0.8 nD
 - $k_{\text{eff}}(\text{He})$: 0.1 - 0.7 nD
- Increasing absolute permeability (7 - 12 nD)
- Small decrease in BET surface area (3.76 - 3.64 m²/g)



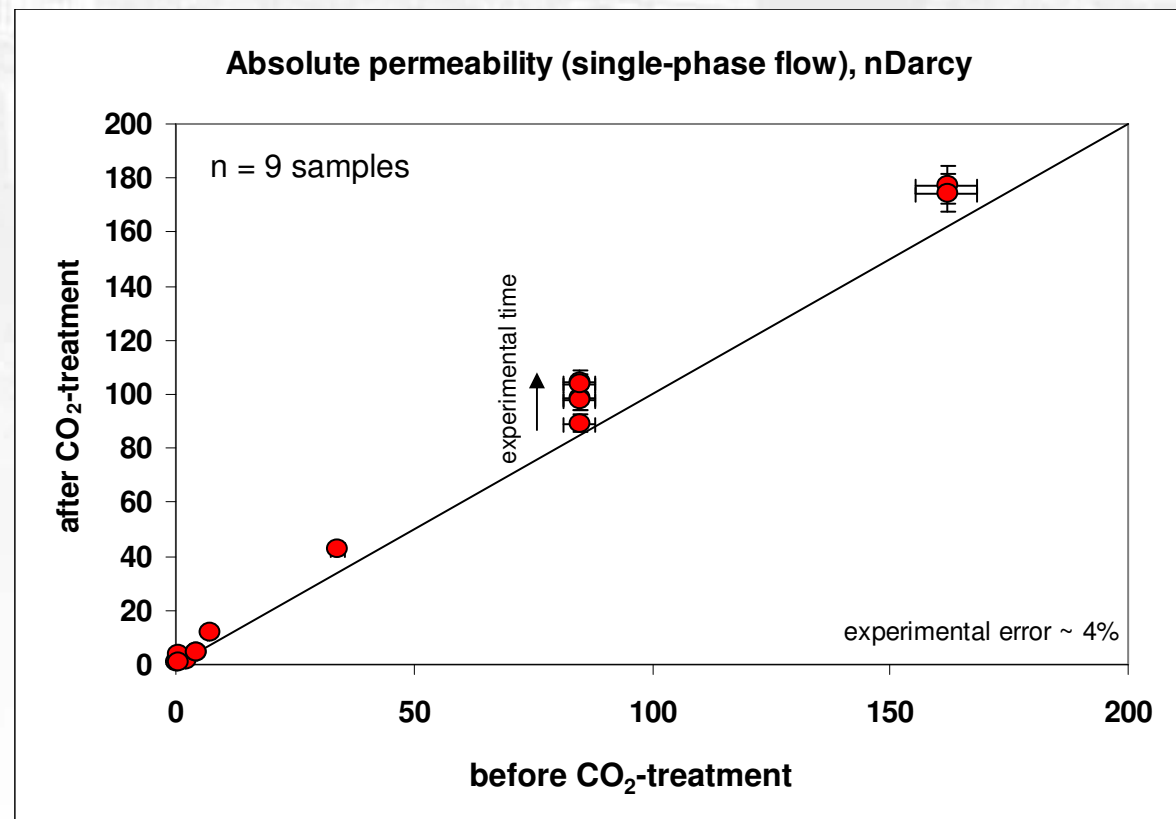
Trends ?

- **Increasing absolute permeability**
- **Increasing effective permeability to the gas phase**
- **Increasing diffusion coefficients**
- **Decreasing capillary pressure (here: snap-off pressure)**
 - **Increasing mean pore radius ?**
- **Decreasing adsorption capacity (reactivity)**
 - **Decreasing specific surface area ?**

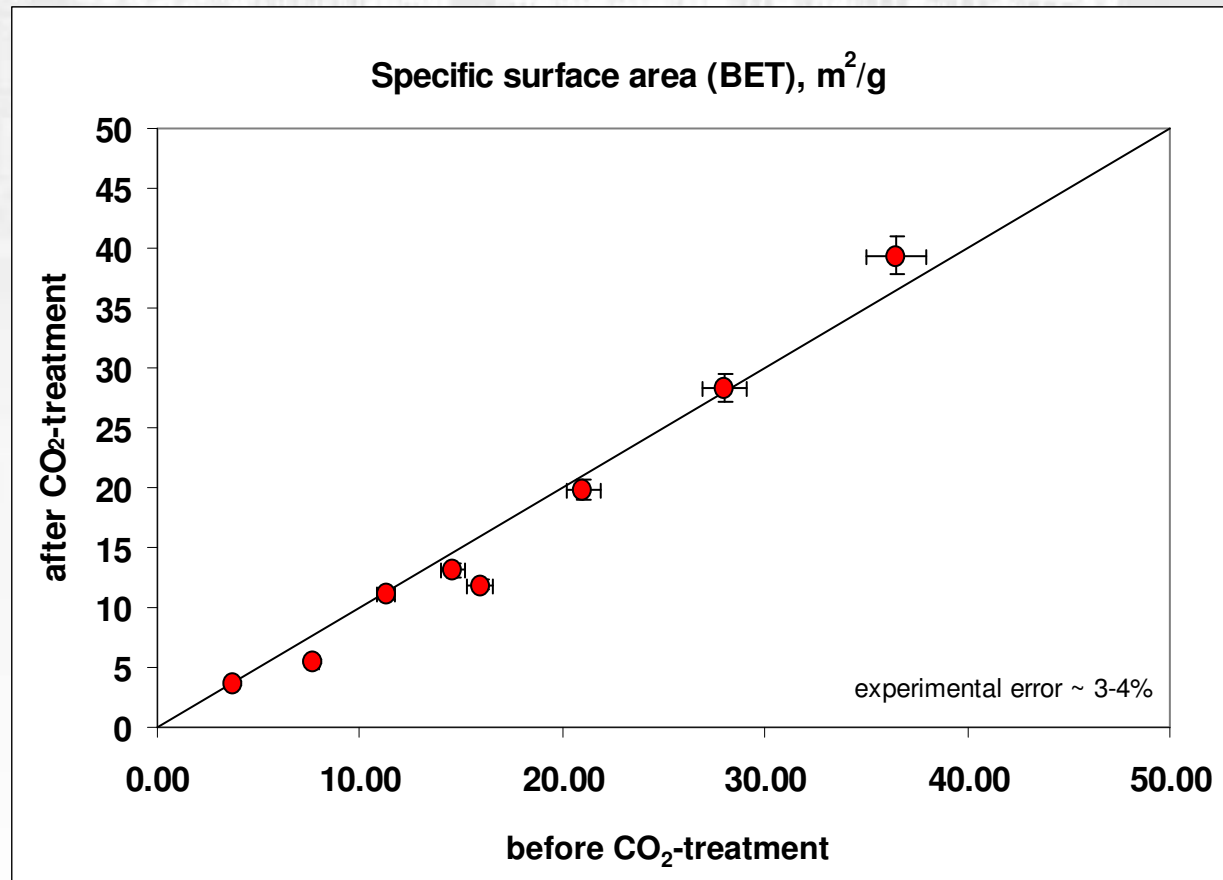
Pore size distribution → fluid flow

- Samples with increasing average pore size (APR) after CO₂-treatment show
 - Increasing permeability
 - Decreasing capillary sealing efficiency
- Only **one sample showed decreasing abs. perm. values** (L 1114) → no changes in pore radius distribution

	APR [nm]		
	raw	post CO ₂	rel. sc. (%)
Emscher	35	40	15
EST 25593	7.1	8.2	14
L 930	10	8.1	20
L 1114	4	4	0.25
S08	7.6	8.7	13

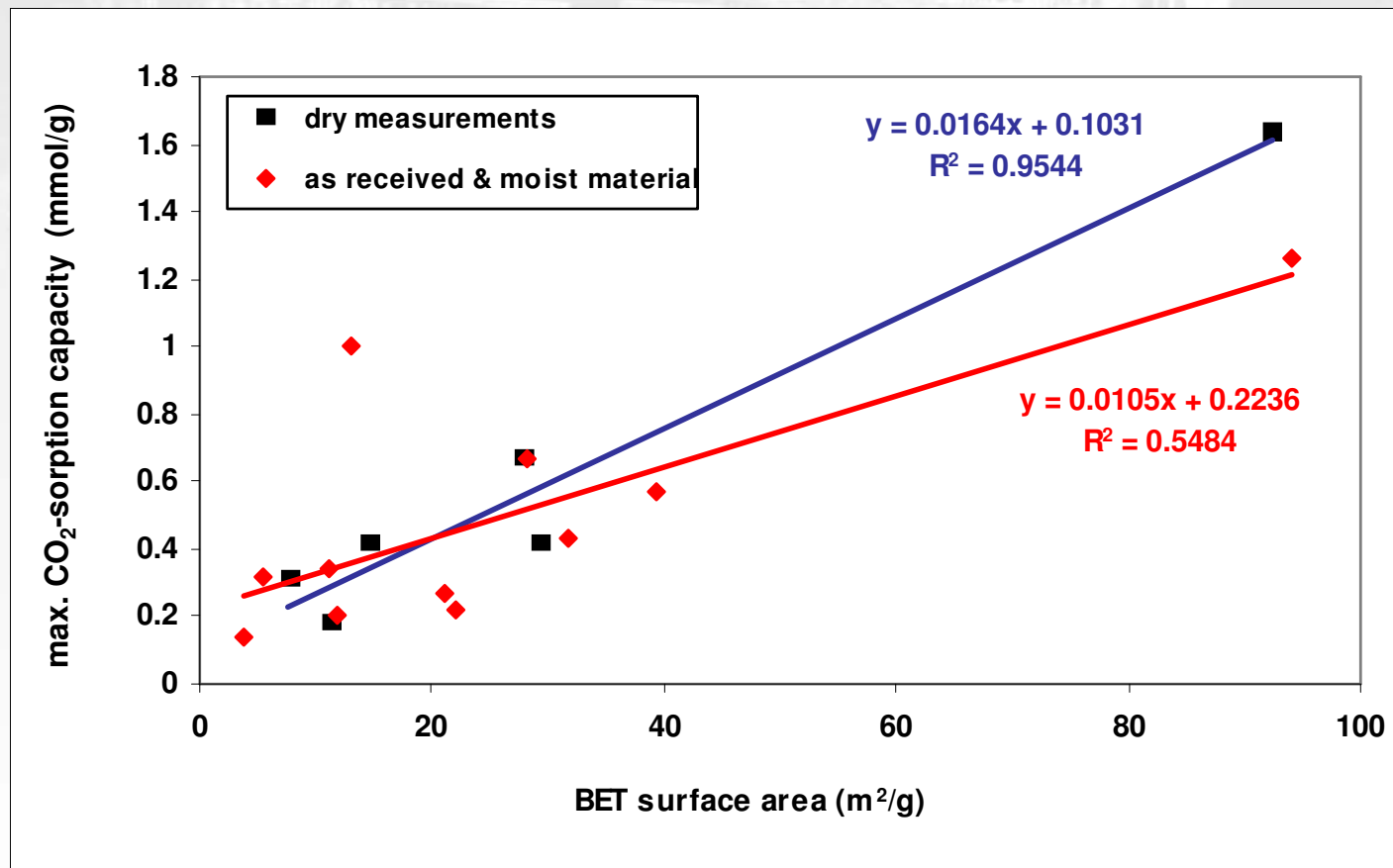


→ no clear difference before and after CO₂-treatment



BET surface area → adsorption capacity

- Strong influence of water content on “adsorption” capacity; to our knowledge high water content should reduce adsorption capacity
- Scatter due to varying water contents
→ Further investigations in the ongoing **CO2Seals** project



- **Summary of observations collected during several CO₂-related projects (> 2001)**
 - Ongoing project: “CO2Seals” www.co2seals.de (→ poster)
- **Changes in petrophysical rock properties after CO₂ exposure**
 - **Increasing pore size**
 - Increasing absolute permeability
 - Increasing effective permeability to the gas phase
 - Decreasing capillary pressure
 - **Decreasing surface area (BET)**
 - Decreasing adsorption capacity (reactivity) → no clear trend so far
- **Changes depend on rock type / mineralogical composition and have to be determined individually**

Thank you !