

Mineral Trapping after CO₂ injection

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reactive transport modelling

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- Angewandte Geologie -

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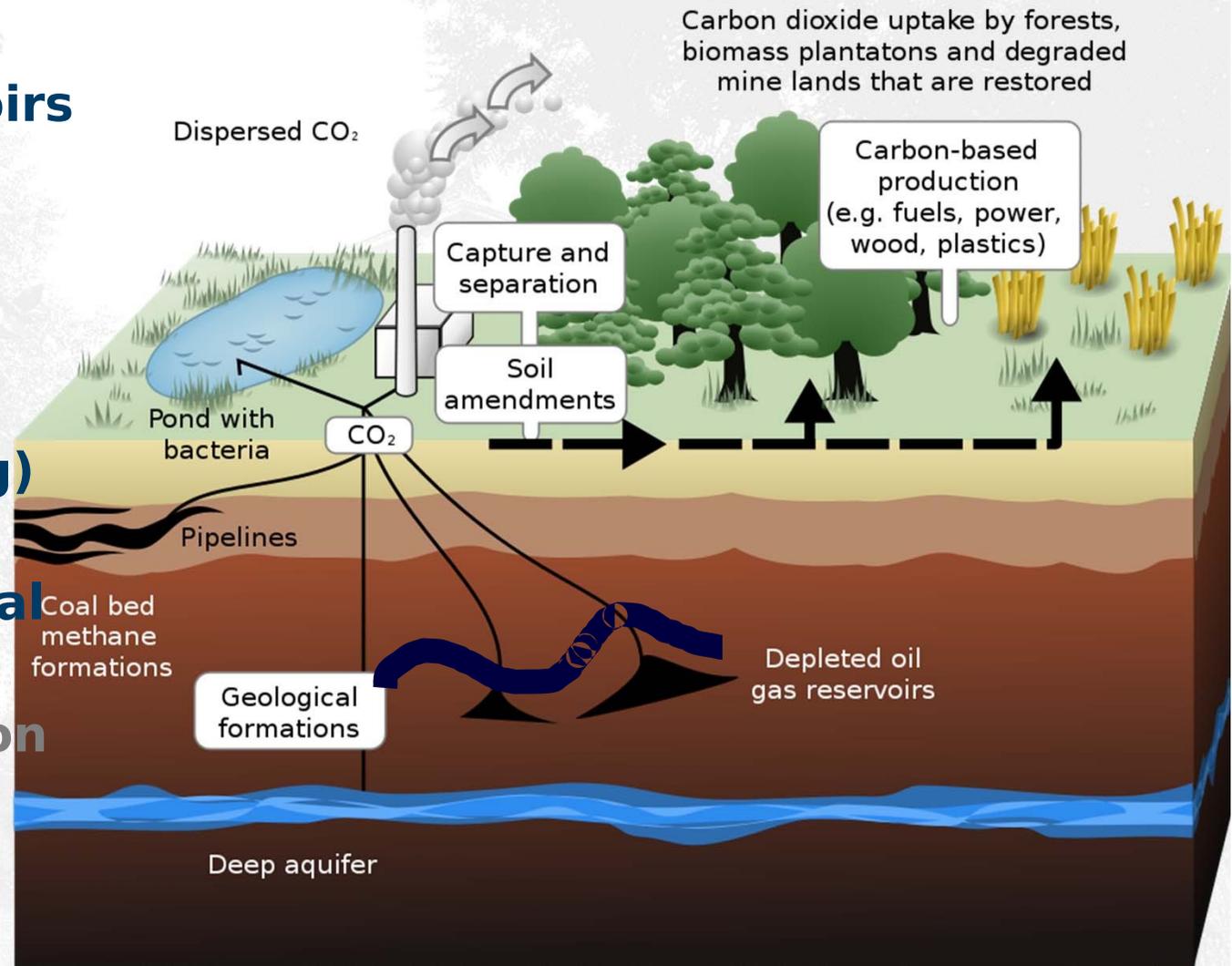
Carbon Capture & Storage (CCS)

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Geological Storage:

- **Supercritical CO_2 in old Oil/Gas reservoirs (pore trapping, residual trapping)**
- **Dissolution of CO_2 in reservoir water/brines (solubility trapping)**
- **Precipitation as Carbonates (mineral trapping)**
- **(Others: Sorption on Coal beds)**
- **(Enhanced oil/gas recovery)**



Data from Heletz reservoir: oilfield (after 1955) site overview

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Lower cretaceous sand layers

High salinity water

~ 1600 m deep

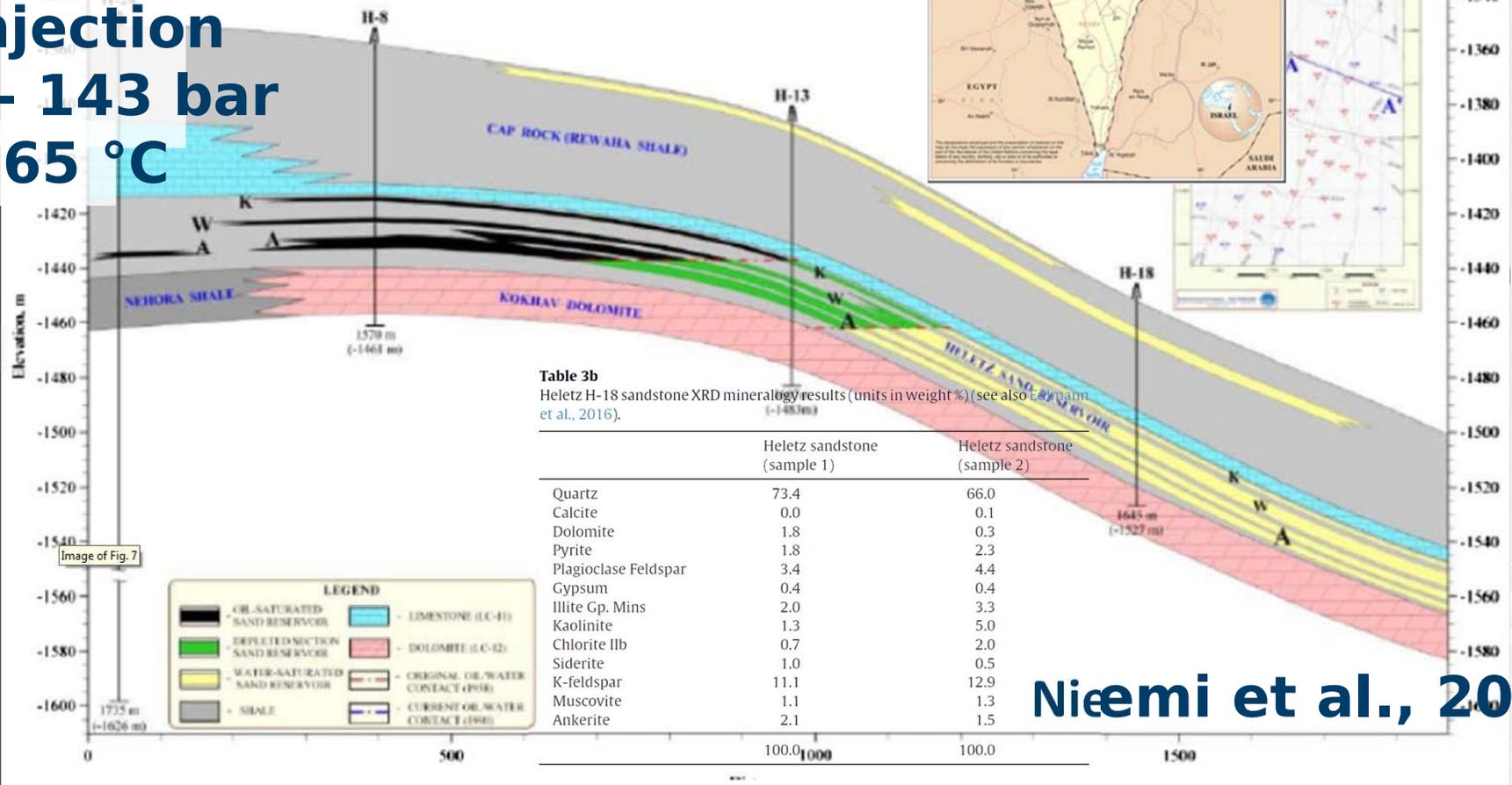
CO₂ injection

132 - 143 bar

61 - 65 °C

GEOLOGICAL CROSS-SECTION
HELETZ-24 - HELETZ-18

Prepared by : M. Gendler
2010



Niemi et al., 2016

Fig. 7. Example geological cross-section A-A crossing the CO₂ investigation area and well H18. Sand layers are indicated with yellow color.

=> what is the potential of mineral trapping?

Carbonate minerals could precipitate: Ca, Mg, Fe: alkaline earths, (Na, Al ?)

Calcite CaCO_3

Aragonite CaCO_3

Dolomite $\text{CaMg}(\text{CO}_3)_2$

Magnesite MgCO_3

Siderite FeCO_3

Ankerite $\text{CaFe}(\text{CO}_3)_2$

Dawsonite $\text{NaAlCO}_3(\text{OH})_2$

Natron (Soda) $\text{Na}_2\text{CO}_3 \cdot 10 \text{H}_2\text{O}$



(wikipedia.org)

Predicting the potential of mineral precipitation:

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Sources of uncertainty:

- **Geochemical databases (e.g. phreeqc, wateq4f, IInI)**
- **Ion activity model: Debye-Hückel/Davies ($I < 0.5$) - Pitzer (salinity!) \rightarrow is most accurate, but has fewest data**
- **Consistency of databases (yet unsolved)**
- **HGC codes - different conceptual approaches**

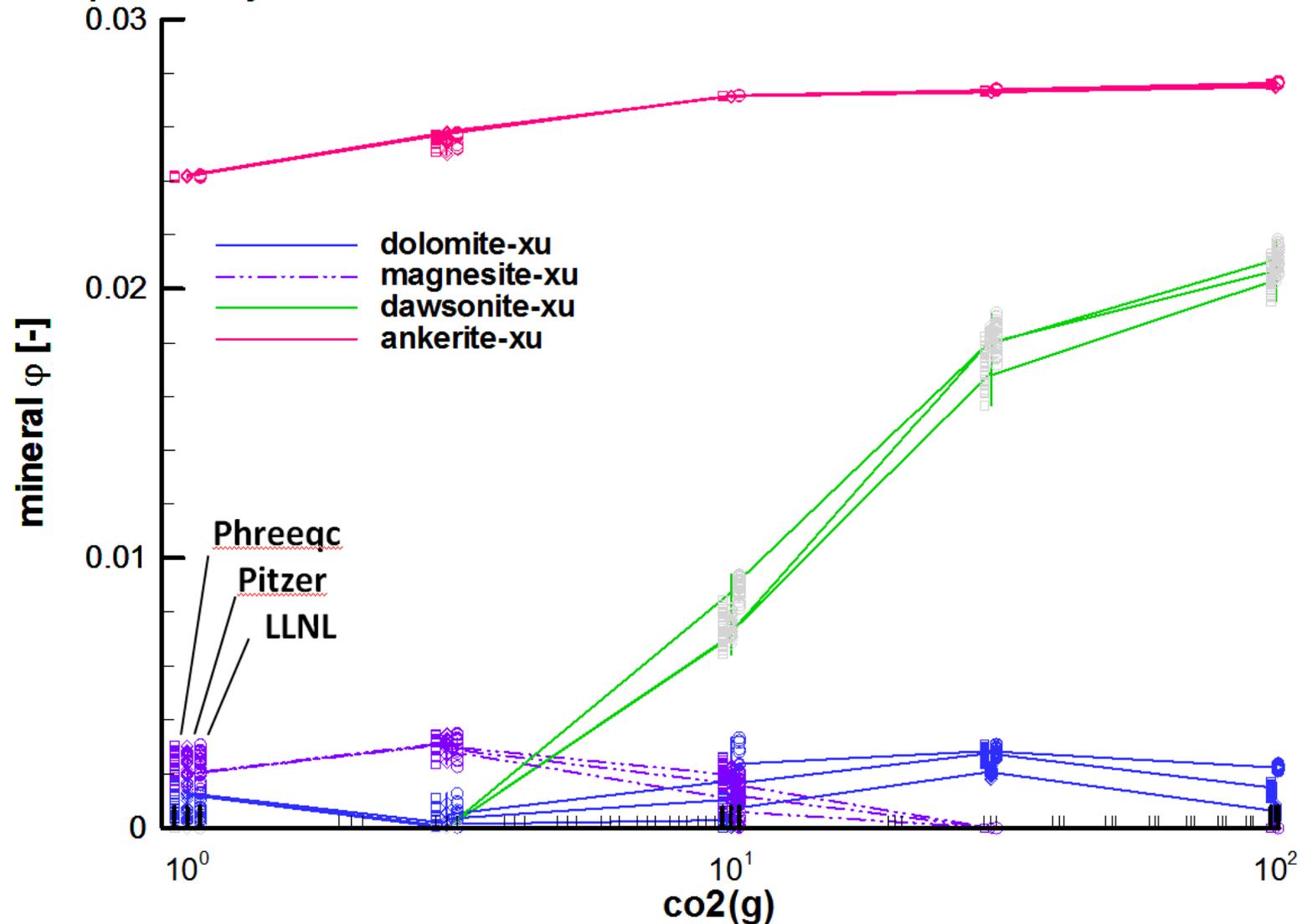
- **Measurement errors**
- **Uncertainty in data (available:
water chem. samples: Gavrielli et al., 1995, Chan et al., 2002, Nie et al., 2003)**

- **f(minerals present) \square usually good measurements/knowledge**
- **f(time) dissol. / precipit. of minerals \square kinetics highly variable**
- **f(pCO₂) \square target variable**

Results: mineral content after 1000 a, based on kinetics publ.



Carbonate mineral volume fraction after CO₂ dissolution,
silicate & carbonate dissolution & precipitation
time elapsed: 1000 years



Mass balance over time: total mineral trapping

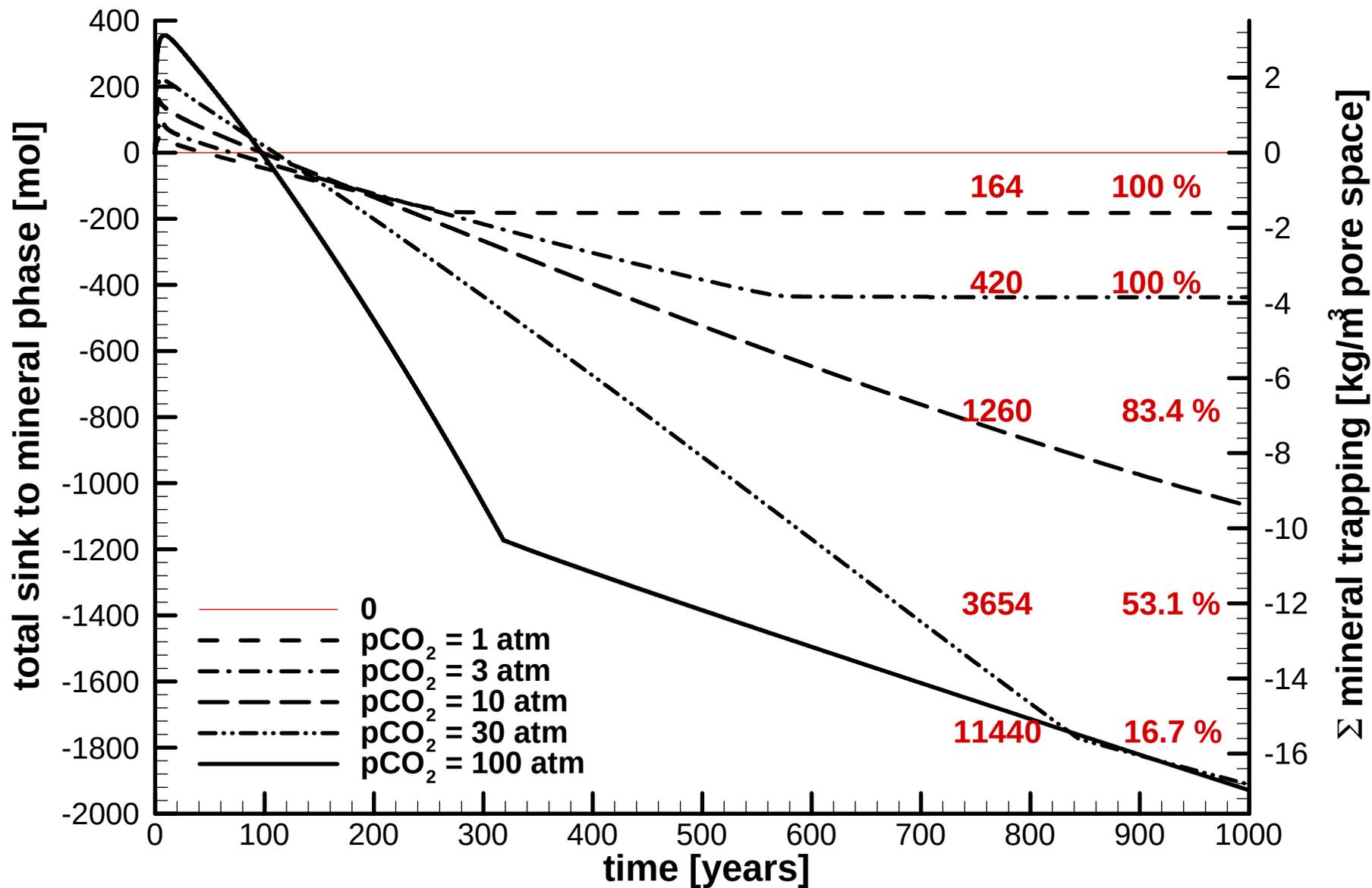
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Frame 001 | 17 Dec 2019 | dataset co2press | dataset co2press | dataset co2press | dataset co2press | dataset co2press

mass balance for component co3-2 - reactive transport

total inj.

% mineralized



Sensitivity of salinity onto final mineral vol%

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$$S = \frac{df/f}{dp/p} = \frac{df}{dp} \cdot \frac{p}{f}$$

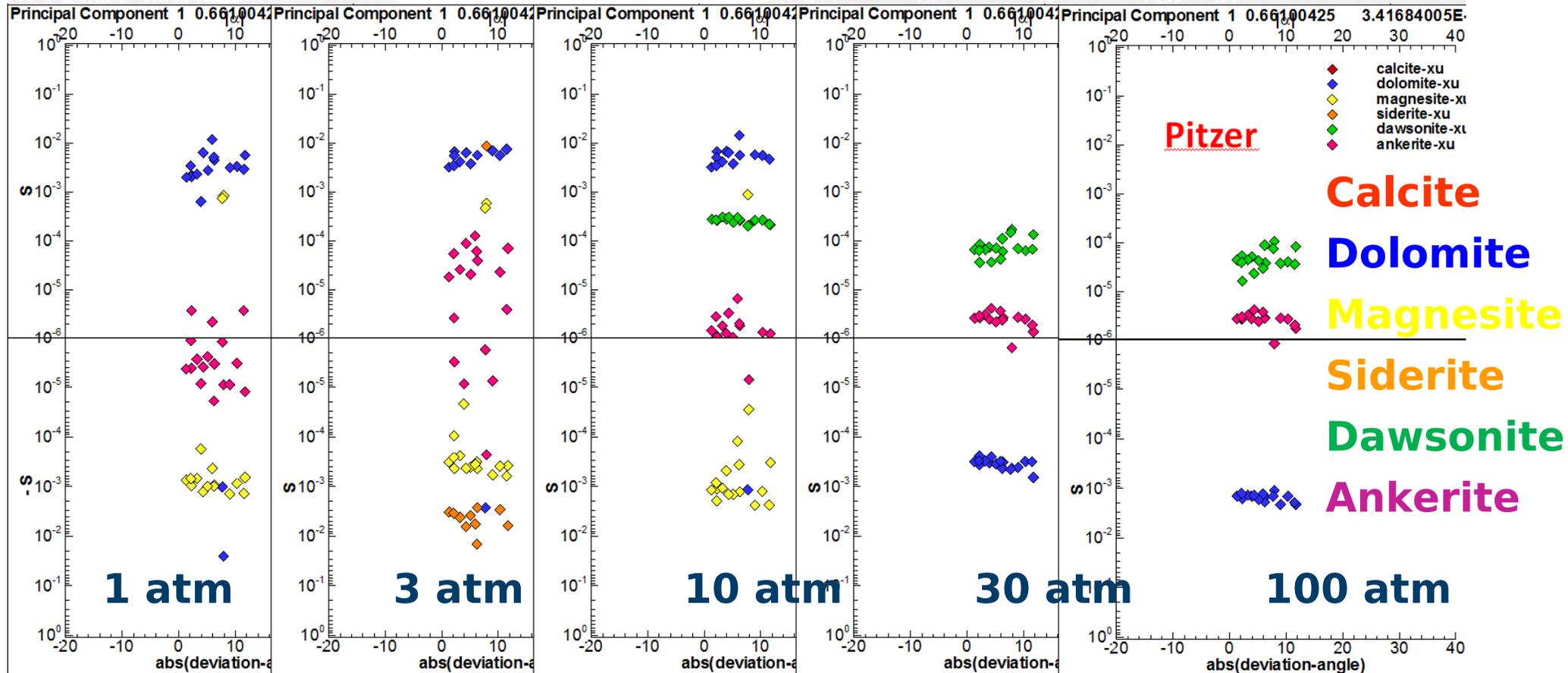


Fig. 10. Sensitivity coefficients of carbonate minerals depending on time elapsed 1000 years, at 1, 3, 10, 30 and 100 atm, using Pitzer ion activity correction.

Conclusions & Outlook: mineral trapping & uncertainty

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CQ mineral trapping

- Pressure dependent HGC available in 3-D model
- Most important minerals at Heletz site:
Ankerite > Dolomite > Magnesite (Siderite, Calcite)
Dawsonite: at low silicate dissolution; long-term stability?
- Storage potential at Heletz (1000 a) $\sim 10^3$ pore space +/-???
- Strong influence of silicate dissolution
- Ion activity model is influential
- Uncertainty of dbs & data is in the same order of magnitude
- Consistency of databases (Phreeqc manual, Parkhurst & Appelo, 2013):
cumbersome? → Application of machine learning approaches?
- Uncertainty Sobol index methods (Ceriotti et al., 2017)
- Consequences on flow and transport properties?
 - Avoid oxygen intrusion, when Pyrite is present!

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