# *Laboratory and modelling investigations of potential geochemical reactions upon seasonal heat storage in Danish geothermal reservoirs*

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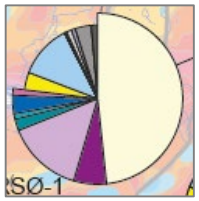
# Heat storage in the deep subsurface

- Seasonal storage of excess heat in hot deep aquifers is considered to optimize the usage of commonly available energy sources.
- A major concern regarding heat storage in hot deep aquifers is that the heat may permanently damage the aquifer making extraction of further geothermal energy unfeasible.
- The **objective** of this study is to investigate possible chemical effects of introducing heated formation water into two potential Danish geothermal reservoirs (Gassum and Bunter Sandstone formations).
- Method:
  - Combination of ***core flooding*** experiments, ***petrografic analysis*** and ***geochemical modelling*** using PHREEQC and the Thermoddem database.
  - Core material flooded with synthetic formation water.
  - Experiments performed at reservoir conditions and elevated temperatures up to 150$^{o}$C.

# Sample material

## Gassum (Farsø)

Mineralogy



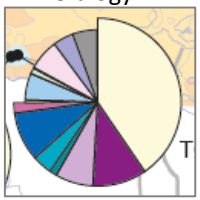

Weibel et al. 2020

No calcite observed in the tested specimen

Depth: 2875 m
Res. temp: 80 °C
Porosity: 15.7 %
Permeability: 86 mD

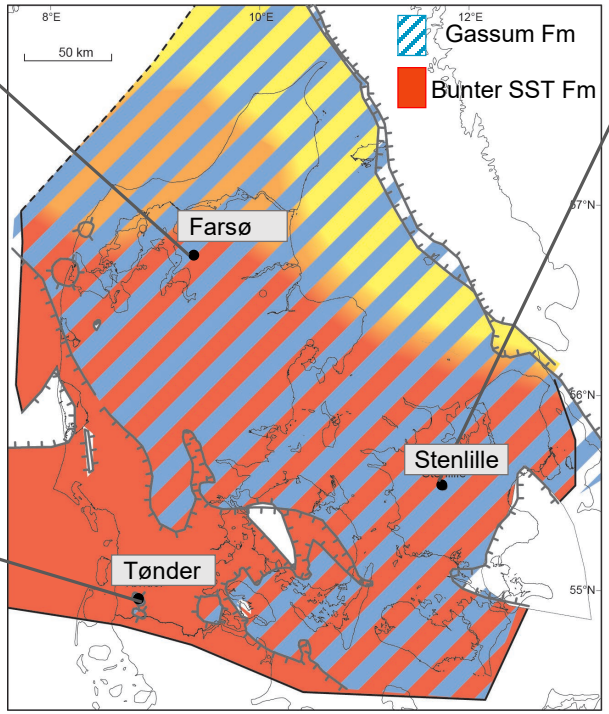
## Bunter (Tønder)

Mineralogy



Weibel et al. 2020

Depth: 1654.7 m
Res. temp: 75 °C
Porosity: 28.2 %
Permeability: 251 mD

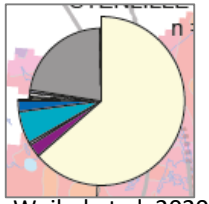



(Modified from Weibel et. al., 2017)

The calcium carbonate-containing Bunter Sandstone formation is flooded with Ca-depleted synthetic formation water to avoid loss of injectivity by calcium carbonate scaling at elevated temperatures.

## Gassum (Stenlille)

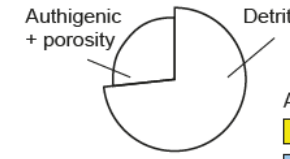
Mineralogy



Weibel et al. 2020

Depth: 1539.5 m
Res. temp: 50 °C
Porosity: 29.1 %
Permeability: 195 mD

Legend mineralogy



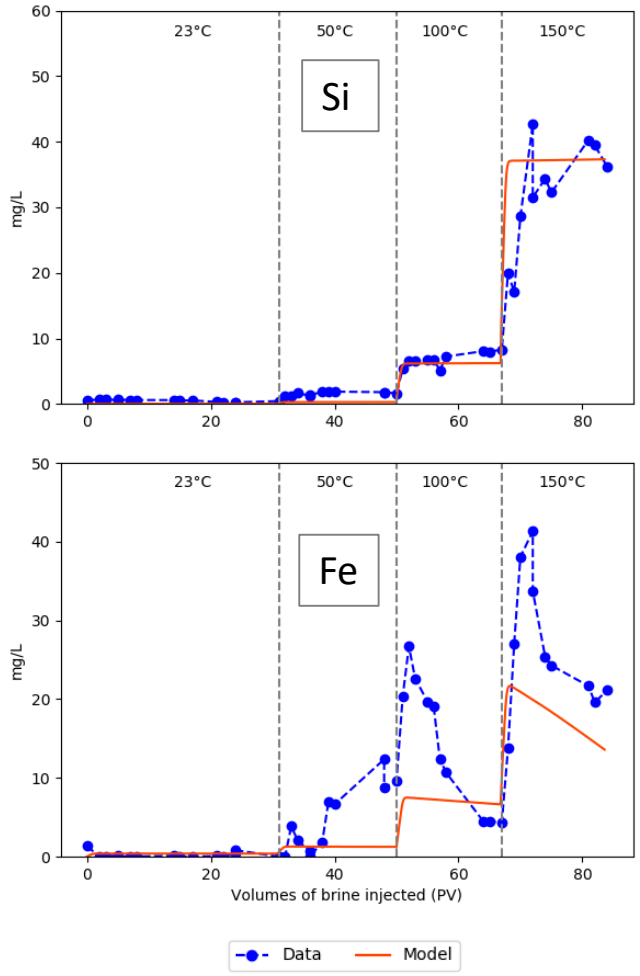

DETRITAL MINERALS
- Quartz
- K-feldspar
- Albite, plagioclase
- Mica
- Clays
- Rock fragments + ooids
- Heavy minerals

AUTHIGENIC MINERALS
- Quartz
- Calcite, dolomite, ankerite
- Siderite
- Illitic clays
- Kaolinite
- Anhydrite
- Others
- Porosity, primary
- Porosity, secondary

# Results

## Gassum Formation (Stenlille)

### Flooded with synthetic formation water




(Holmslykke et al, 2017)

<u>Heat induces:</u>

- The naturally occurring conversion of albite to kaolinite at 100°C. This process ceases at 150°C
- Dissolution of quartz
- Dissolution of siderite

- Insignificant amounts of siderite, albite and quartz dissolves.
- Formation of kaolinite may increase the formation damaging potential of the reservoir. However, only small amounts are precipitated

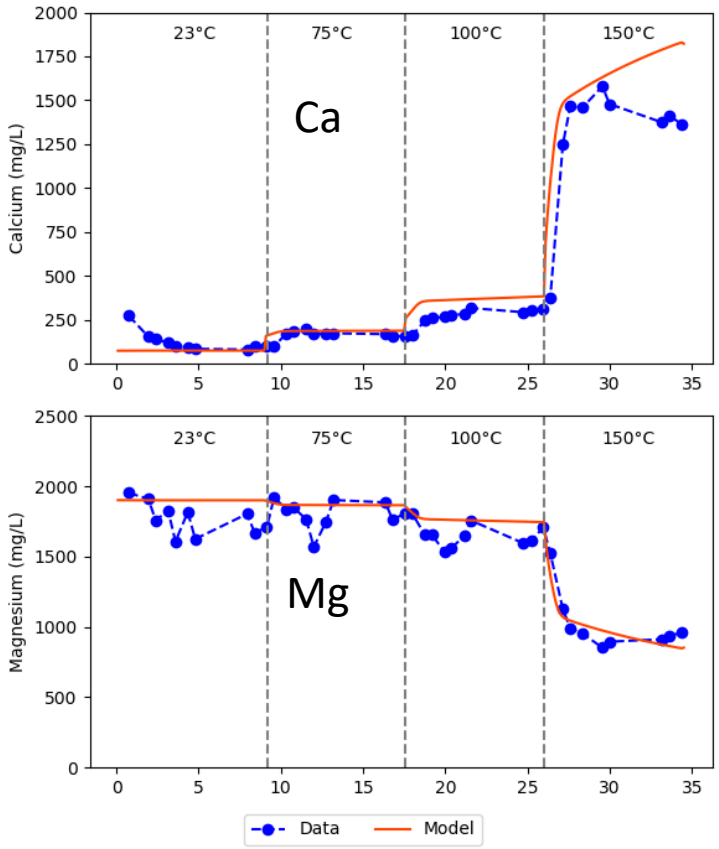
⇨ Potential dissolution/precipitation induced by injection of heated formation water are not likely to damage the reservoir.

Similar results are found when flooding core material from Gassum Formation (Farsø) with synthetic formation water

# Results

## Bunter Sandstone Formation (Tønder)

Flooded with Ca-depleted brine to avoid carbonate scaling upon heating




- Increase in concentration of Si and Ba due to reactions with silicates and barite
- Reactions are of minor importance and are not expected to damage the formation
- At temperatures >75°C, dolomitisation is observed:

$$2CaCO_{3(s)} + Mg^{2+}_{(aq)} \rightarrow CaMg(CO_3)_{2(s)} + Ca^{2+}_{(aq)}$$

- Significant part of cementing calcite dissolved during the experiment and core material disintegrated.

⇨ Means for avoiding calcium carbonate precipitation during heat storage should be chosen with caution to minimise possible reservoir damaging side effects.

# Conclusions

Injection of heated formation water may induce:

- Increased concentrations of particularly Si, Fe and Ba

  ⇨ Special care should be taken to prevent re-precipitation of Si, Fe and Ba upon cooling of the formation water.

- When injecting heated formation water, mineral dissolution/precipitation reactions are not expected to damage the reservoir.

- However, when flooding a calcite cemented sandstone with Ca-depleted formation water, dissolution of calcite may reduce the mechanical strength of the sandstone.

  ⇨ Means for avoiding calcium carbonate precipitation during heat storage should be chosen with caution to minimise possible reservoir damaging side effects.