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Corrosion Analysis of Geothermal Fluids in Switzerland

Analyse der Korrosion von geothermischen Flüssigkeiten in der Schweiz

SCCER-SoE Annual Conference

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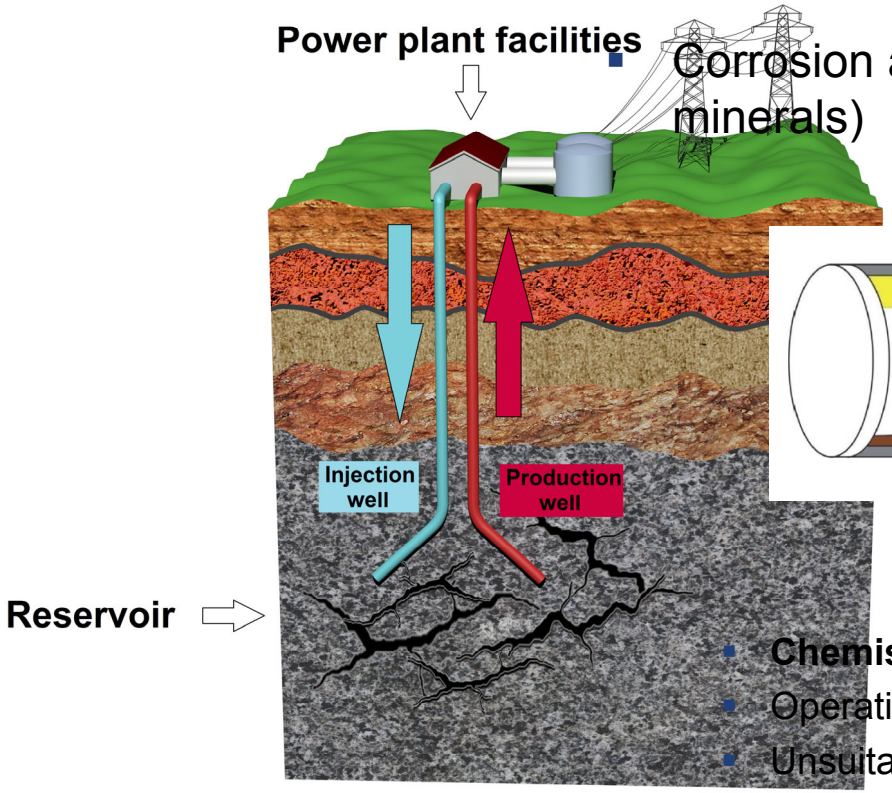
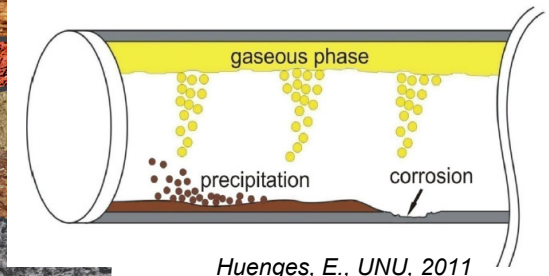
Operational problems in geothermal power plants





Huenges, E., UNU, 2011

- Corrosion and scaling (precipitation of minerals)
- **Chemistry** of geothermal fluids
- Operational **conditions**
- Unsuitable **materials**

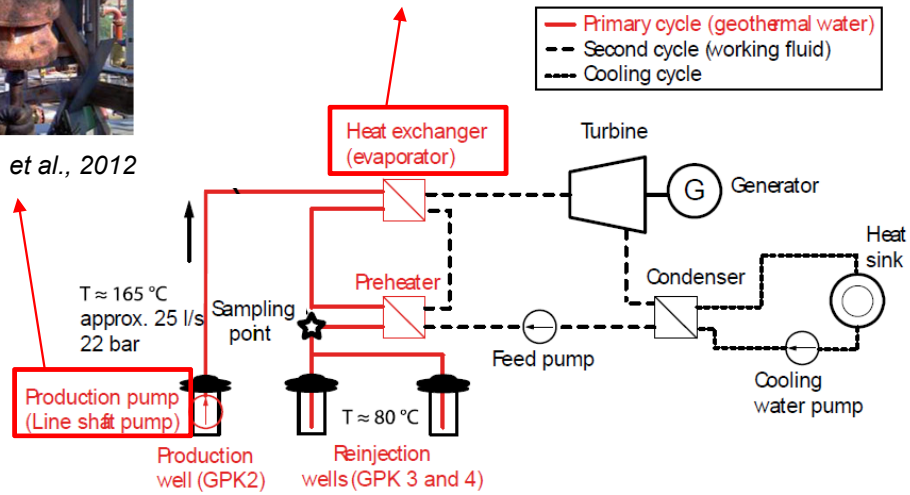
Corrosion in geothermal power plants

- **Attack** that a **material** undergoes when it reacts with the surrounding **environment**

- Technical challenge for the **long-term durability** of metals
  - Loss of cross section, localized damage, etc.
  - Higher maintenance costs

Genter, A. et al., 2012

Scheiber, J. et al., 2013

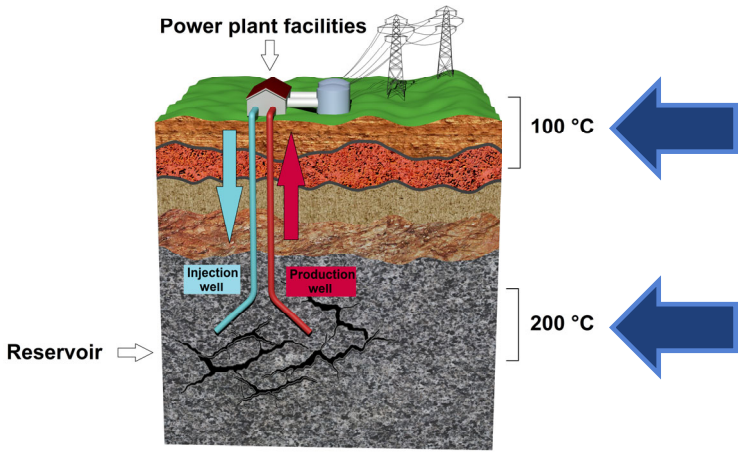


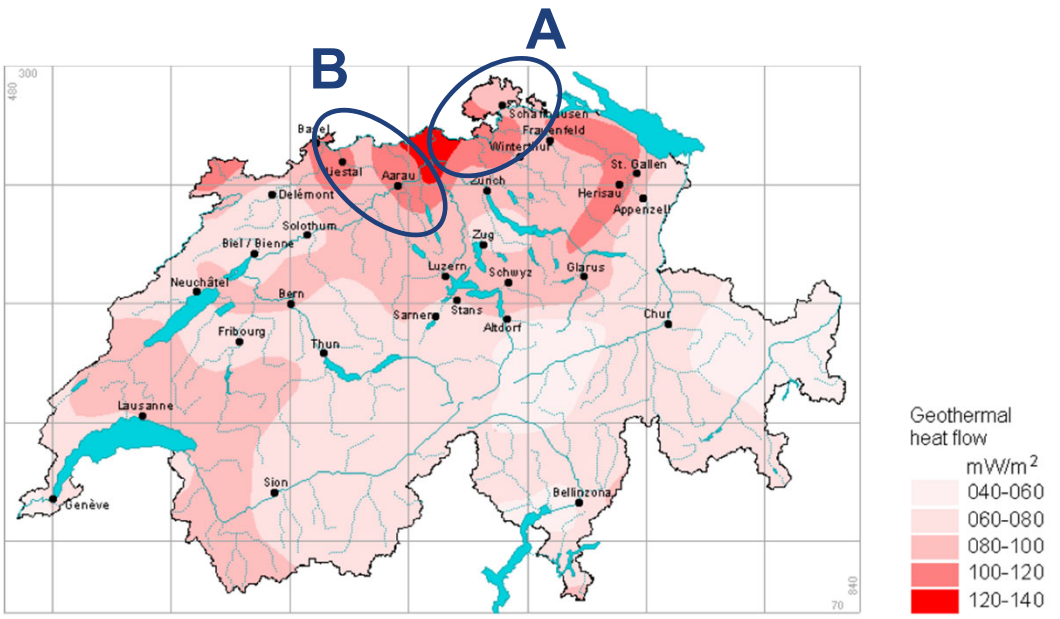
Geothermal power plant at Soultz (binary cycle)

(Mundhenk, N., PhD Thesis, 2013)

Swiss geothermal conditions

- DGE roadmap for Switzerland:
  - Enhanced Geothermal Systems
  - Crystalline basement
  - Reservoir temperatures > 150°C
  - Depth of 4-5 km



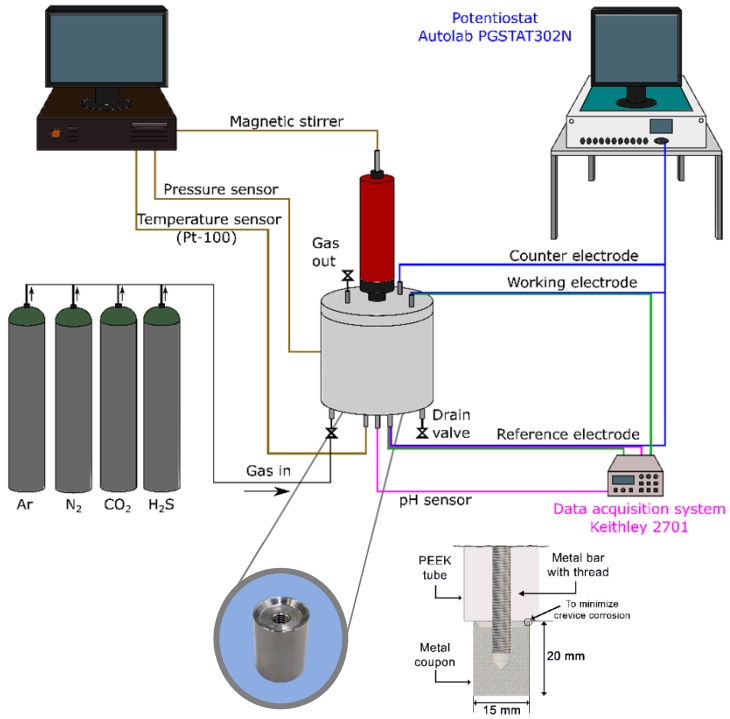


Fluid	pH	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO_3^{-}	SO_4^{2-}	Cl^{-}
A	8.4–9.0	10.0	-	282.8	-	399.8	300.0	-
B	6.5–7.4	250.0	45.0	747.0	35.0	1400.0	900.0	600.0

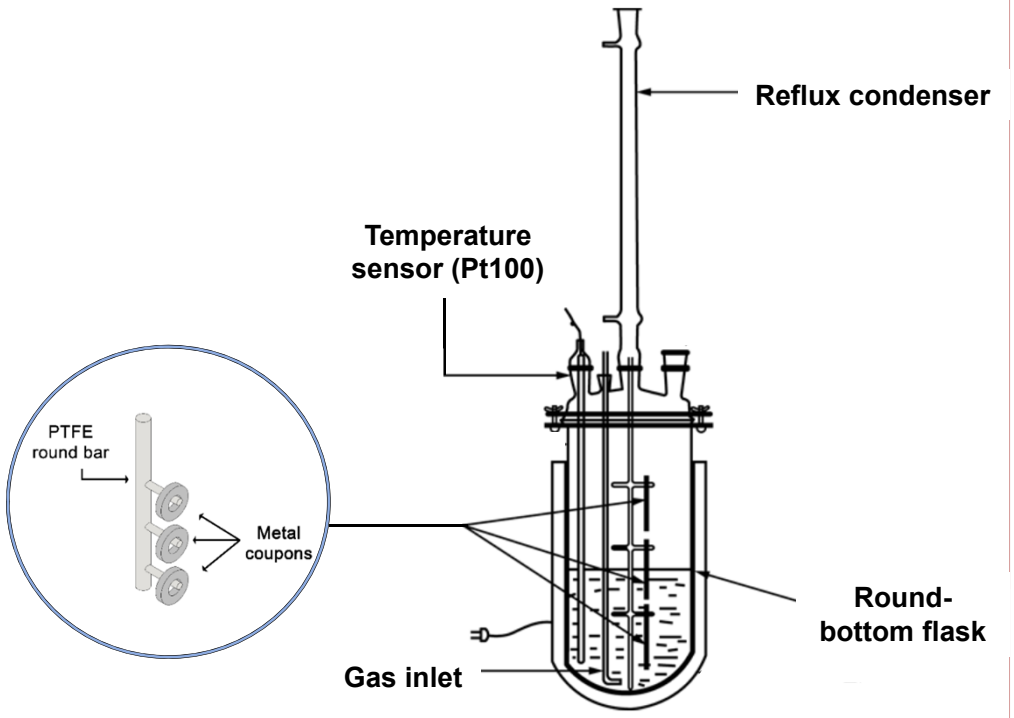
(mg/L)

How to measure corrosion rates in the lab?

Electrochemical measurements



Gravimetric measurements



Tested material: API L80 (low-alloy steel grade)

How to measure corrosion rates in the lab?

Electrochemical measurements

- Temperature: 100 or 200°C
- Initial deaeration with N_2 gas
- Duration: 5 days at the target temperature

- Open Circuit Potential and pH continuous monitoring with multimeter
- Linear Polarization Resistance with potentiostat:

$$\text{Corrosion rate} = \frac{i_{\text{corr}} \cdot M_{\text{Fe}}}{z \cdot F \cdot \rho_{\text{Fe}}}$$

Gravimetric measurements

- Temperature: 100°C
- Initial deaeration with N_2 gas
- Duration: 30 days

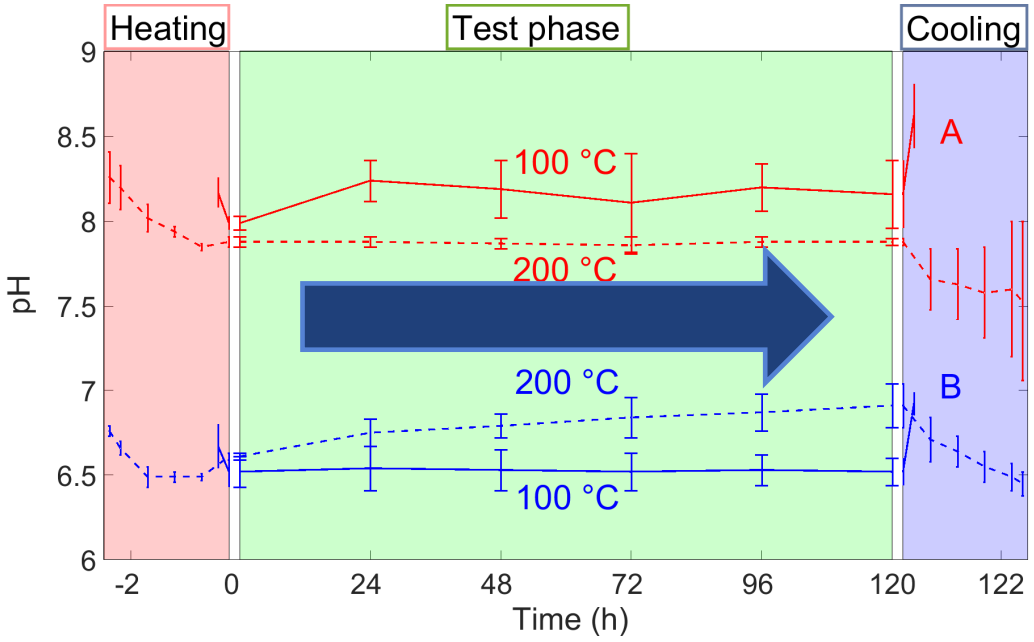
- Weight loss measurements

$$\text{Corrosion rate} = \frac{m_{\text{loss}}}{A \cdot t \cdot \rho_{\text{Fe}}}$$

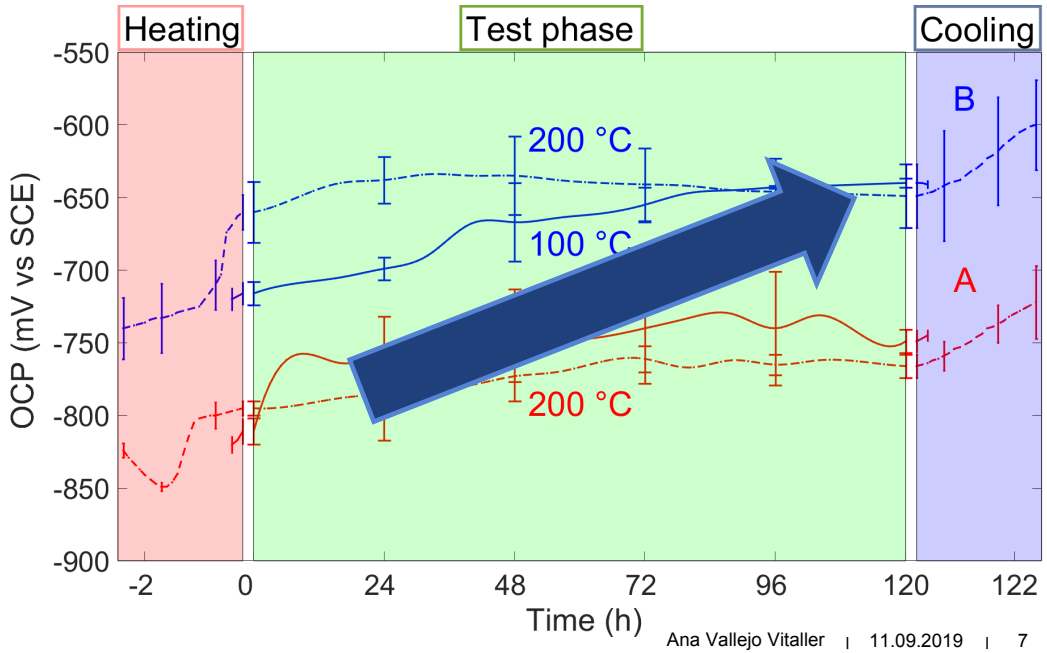
Evolution of pH and Open Circuit Potential (OCP)

Electrochemical measurements

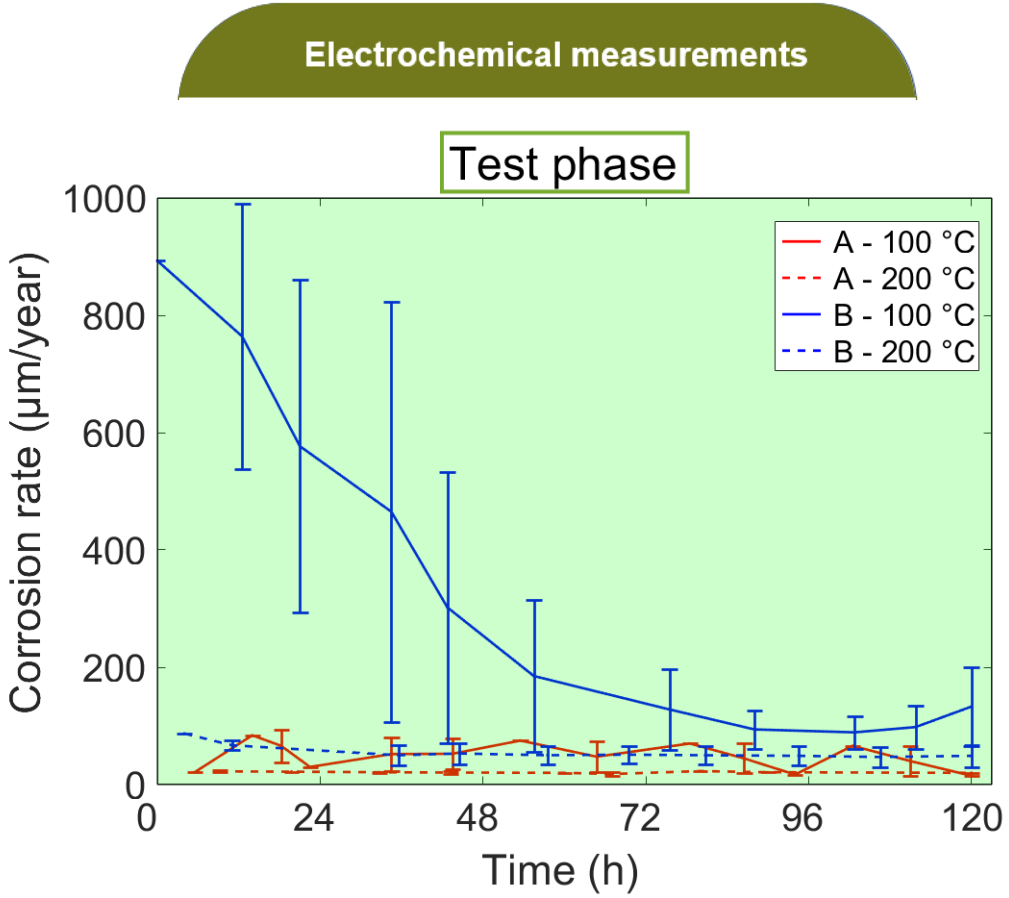
pH



OCP



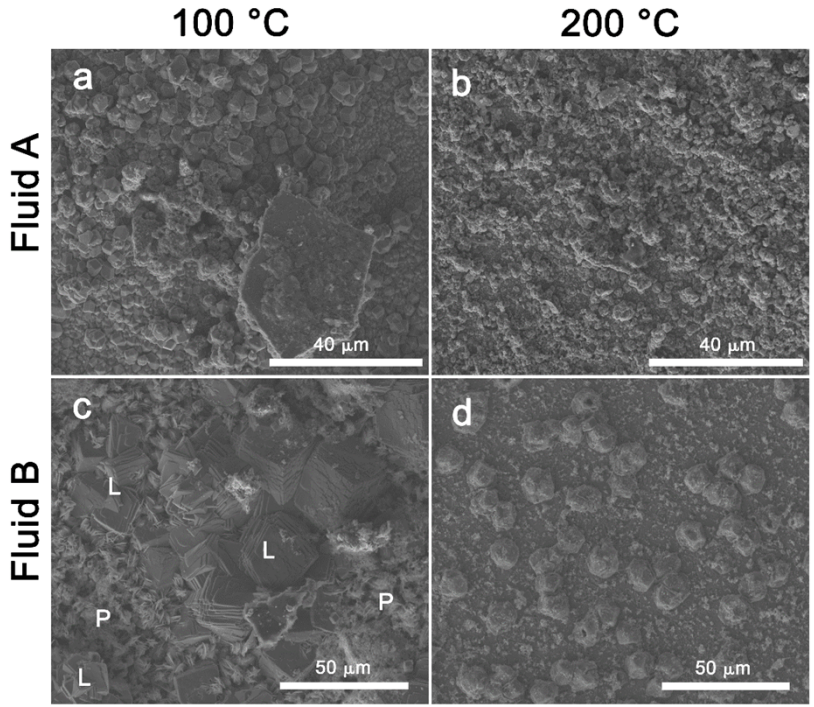
Corrosion rates



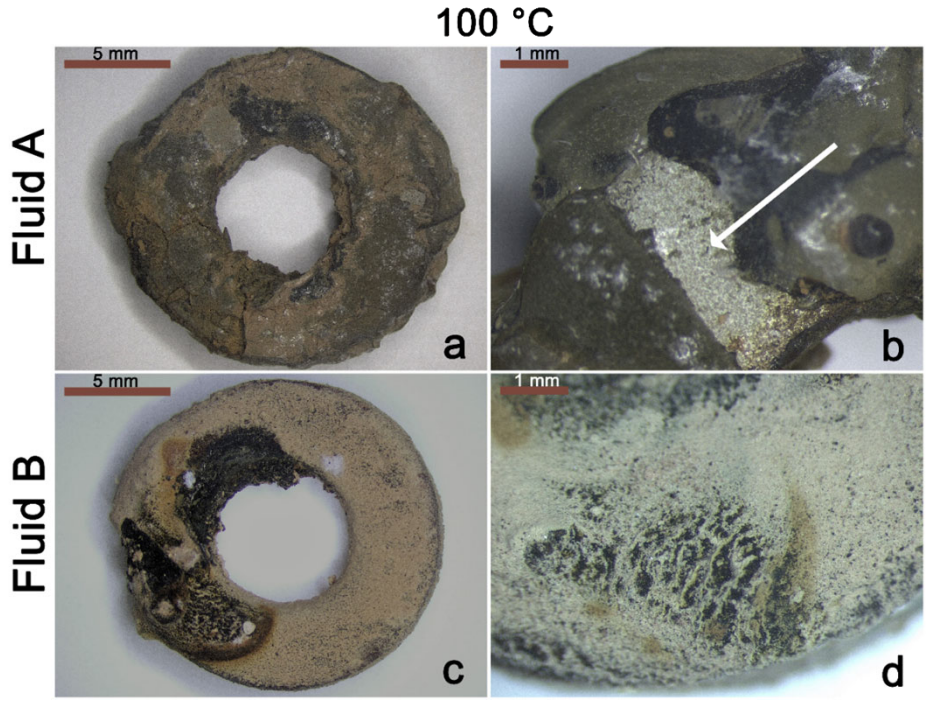
Temperature	Fluid	Corrosion Rate (µm/year)	
		Gravimetric Tests	Electrochemical Tests
100 °C	A	92 ± 22	48 ± 11
	B	245 ± 43	308 ± 136
200 °C	A	-	19 ± 1
	B	-	52 ± 14

Surface analysis

Scanning Electron Microscopy (SEM)

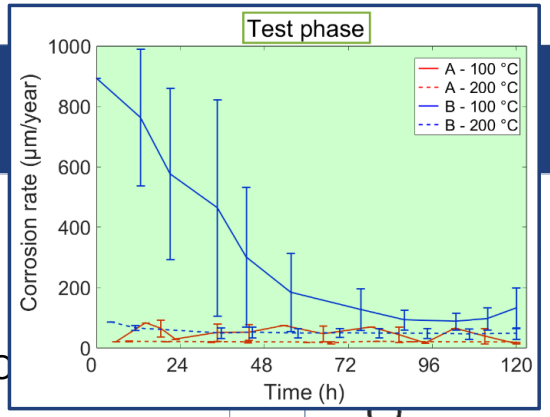


Stereomicroscopy

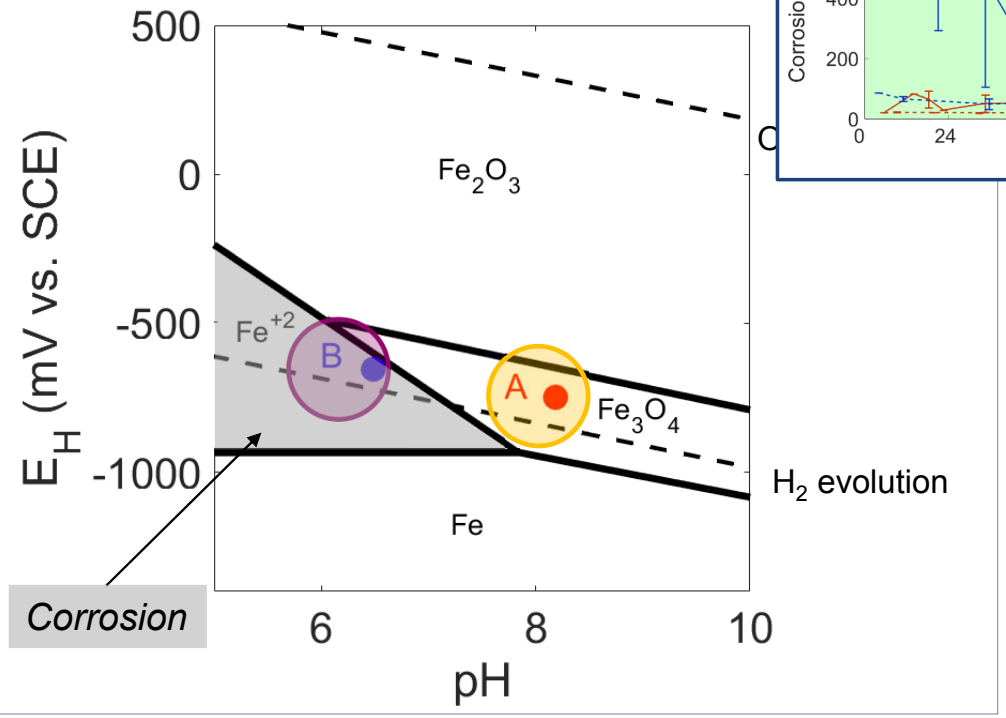


Main corrosion products (X-ray diffraction analysis): magnetite (Fe_3O_4) and hematite (Fe_2O_3)

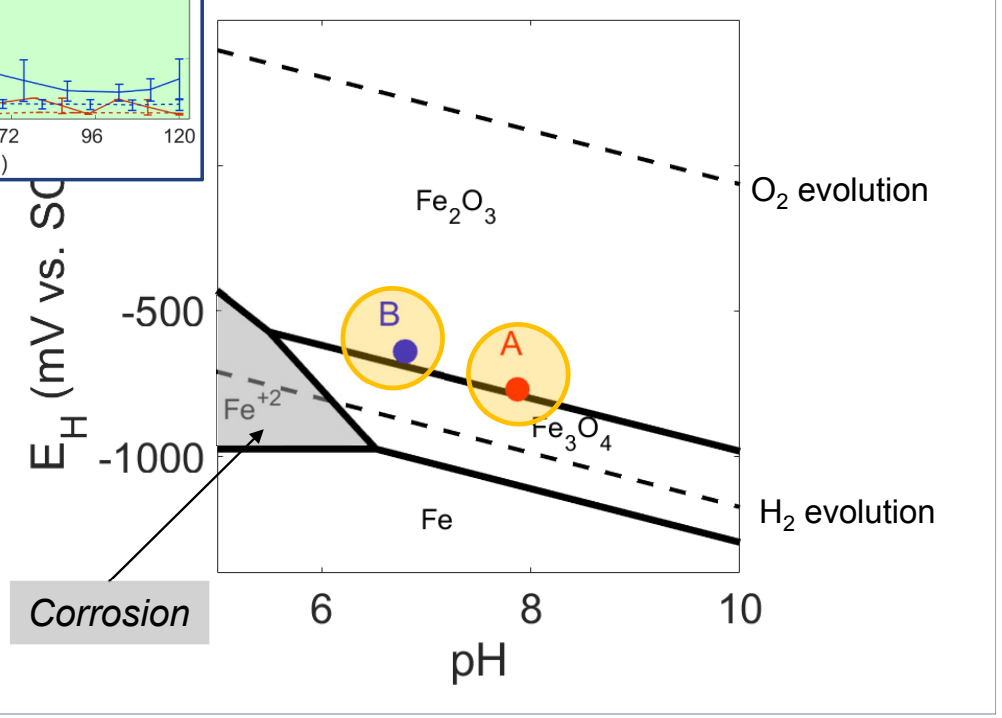
Pourbaix diagrams for iron at 10^{-6} m



100 °C

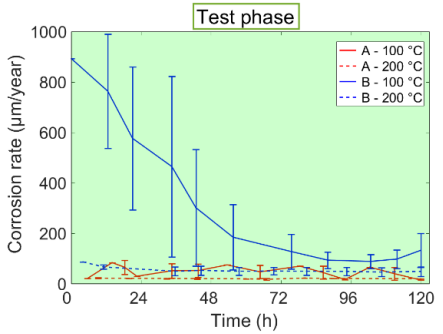


200 °C

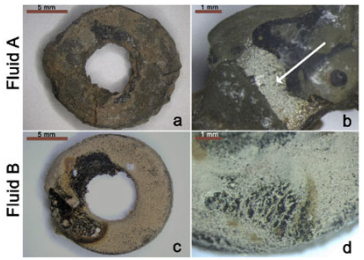


Conclusions

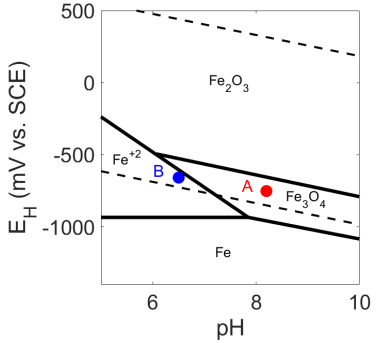
- In deep geothermal systems, the high corrosivity of the fluids limit the applicability of many metals



- In Switzerland, low-alloyed steels show high corrosion resistance under conditions such as in the wells (200°C)
  - However, conditions might change over time: chemistry, reservoir temperature, …



- However, they show low corrosion resistance in contact with geothermal fluids:
  - …of neutral pH and chlorides (B)
  - …at temperatures of 100°C (heat exchanger, production pump, etc.)



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Vielen Dank für Ihre Aufmerksamkeit!