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Laboratorium zur Bestimmung von Isotopen in Umwelt und Hydrologie

Using CO_2 for preserving and enhancing the permeability in deep geothermal carbonate aquifers

Eichinger 2016

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Der Geothermiekongress
November 2018, Essen

Bundesministerium für Wirtschaft und Energie
Gefördert durch das Bundesministerium für Wirtschaft und Energie
Koordiniert durch den Projektträger Jülich

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Using CO_2 in deep geothermal carbonate aquifers

LERWTG

Langfristige Verbesserung und **E**rhaltung von **R**eservoir-**W**egsamkeiten in der **T**iefen **G**eothermie“

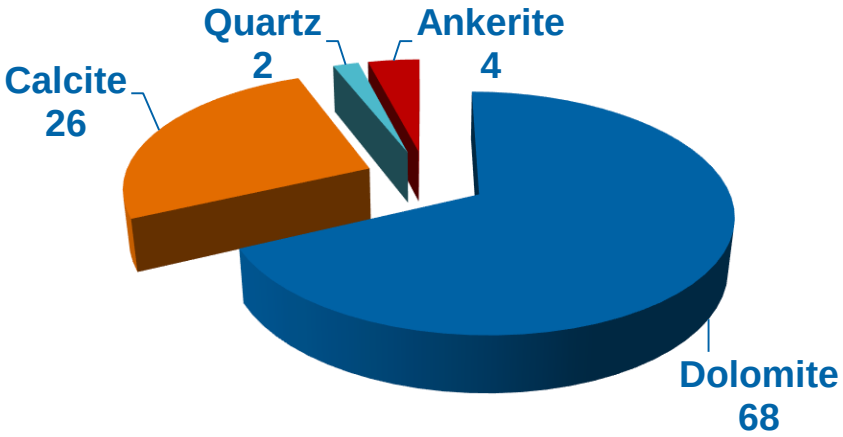
“Long-term improvement and maintenance of reservoir-pathways in deep geothermal energy”

- Continuous or uneven addition of CO_2

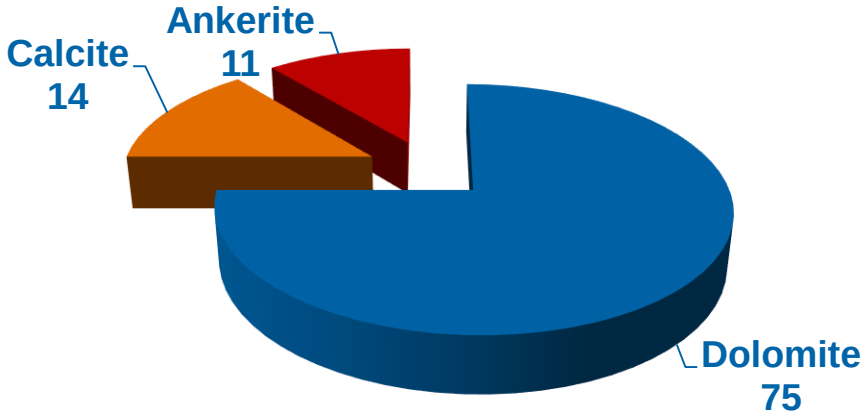
$$CO_2 + H_2O + CaCO_{3(s)} \Leftrightarrow Ca^{2+} + 2\ HCO_3^-$$

- Pilot tests- Bypass system
- Laboratory tests
- Modeling

Sample material description



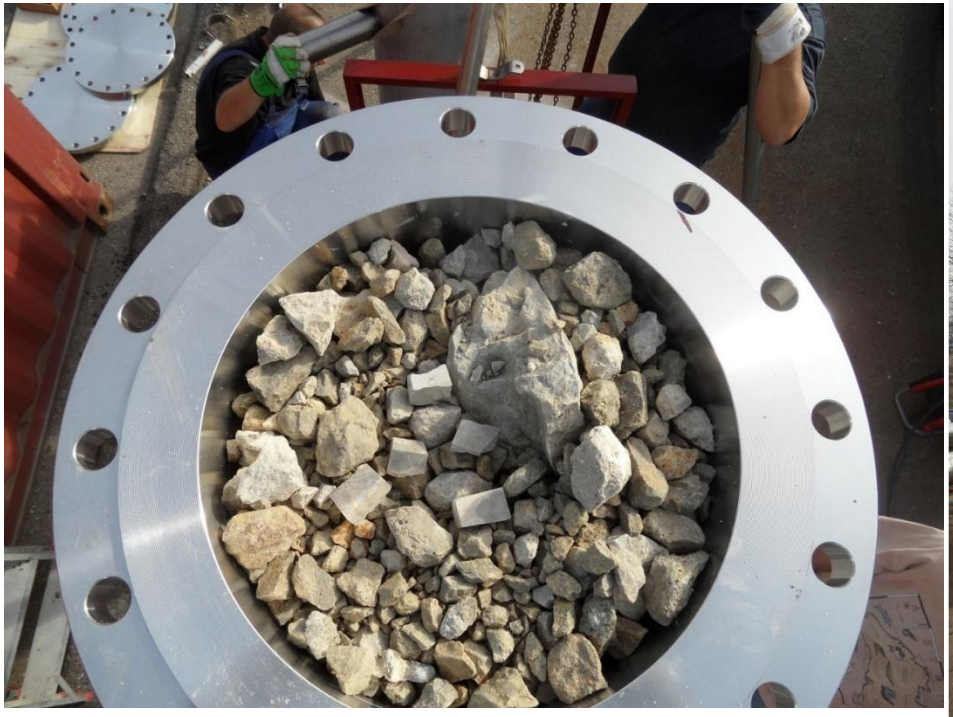
GT1 injection well



GT2a production well

Sample	Dolomite wt%	Calcite wt%	Ankerite wt%	Quartz wt%	Experiment
Analogue A1	96.21	3.41	-	0.39	Batch
Analogue A2	94	5.56	-	0.43	Bypass system
Analogue core B1	96.2	3.3	-	0.5	Batch
Steel casing*	Iron (98.65 wt%), manganese (0.9 wt%), silicon (0.25wt%), chrome (0.2wt%)				Batch

On-site pilot plant (bypass system)



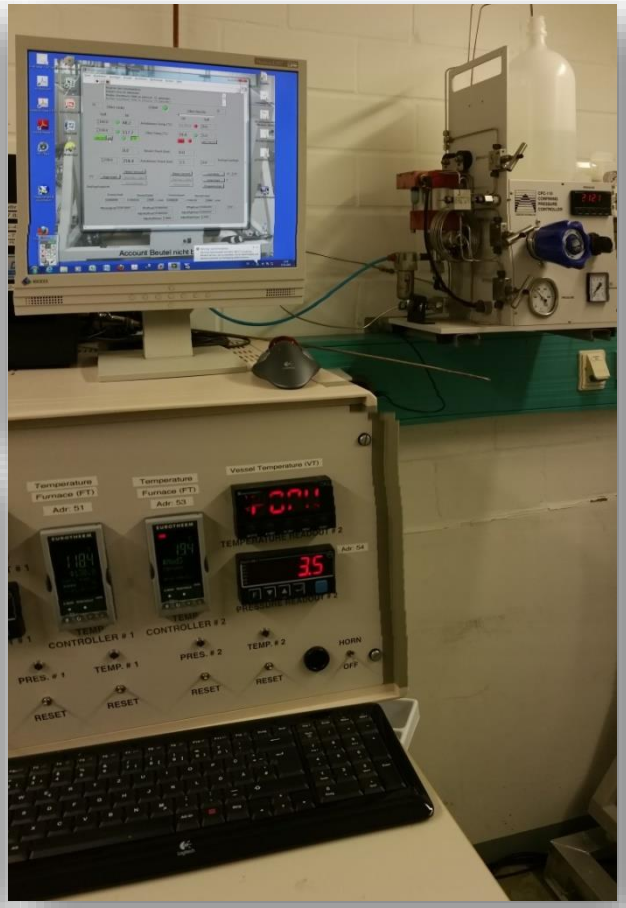
Online: Temperature, Pressure, pH-Conductivity, Redox potential, Oxygen conc.

Weekly Sampling: Major anions and cations, DIC, DOC

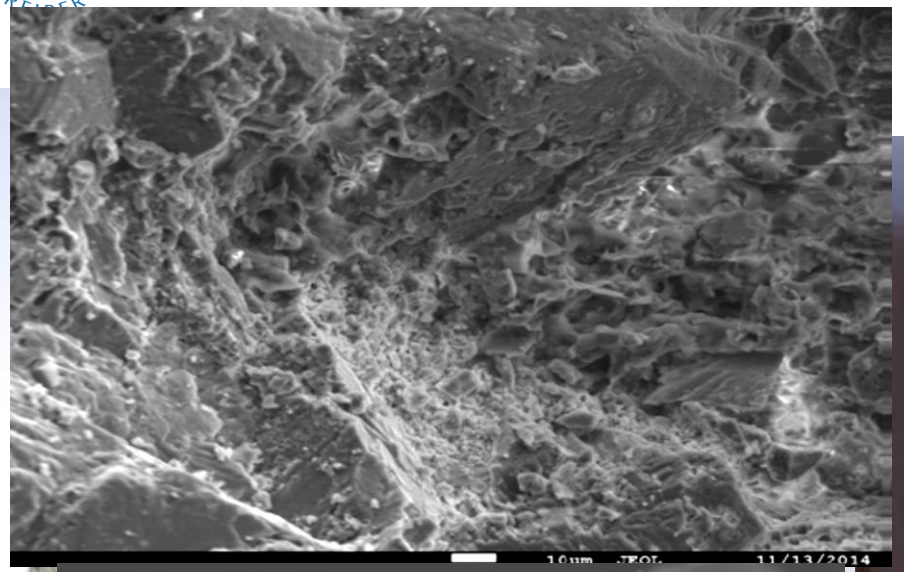
tot. Rock= 1375 kg, avg. 150 mg/l rock => **58 kg (4.2%)** rock dissolved in 6 months

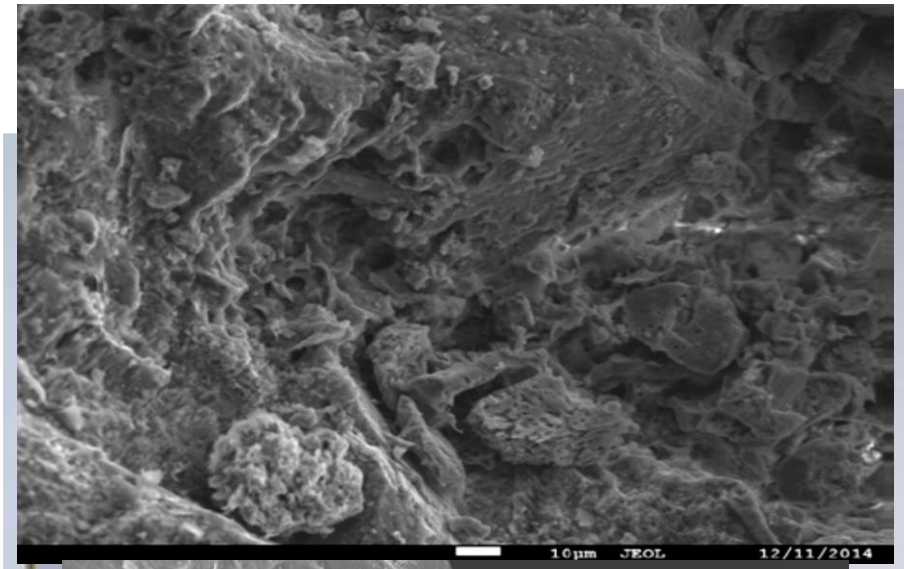
Autoclave 1 TU Bergakademie Freiberg

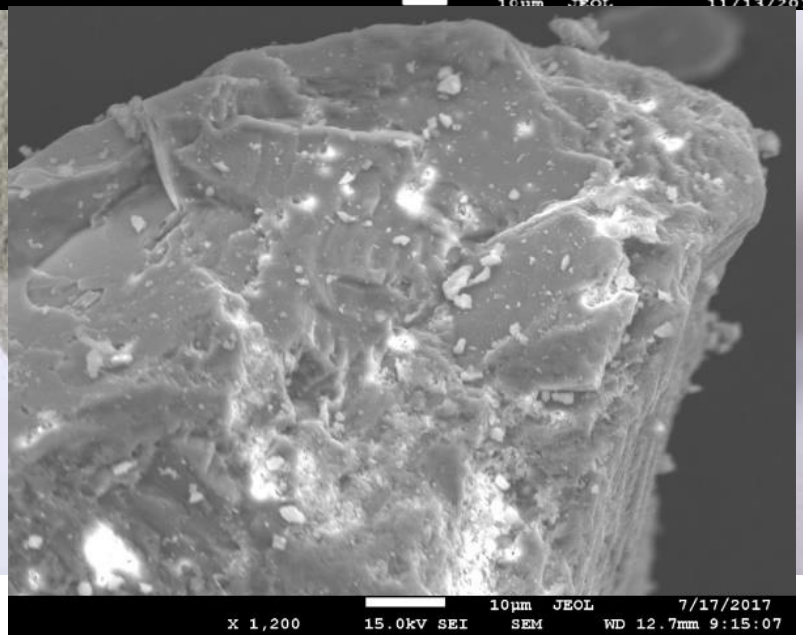
Autoclave 2 GFZ Potsdam

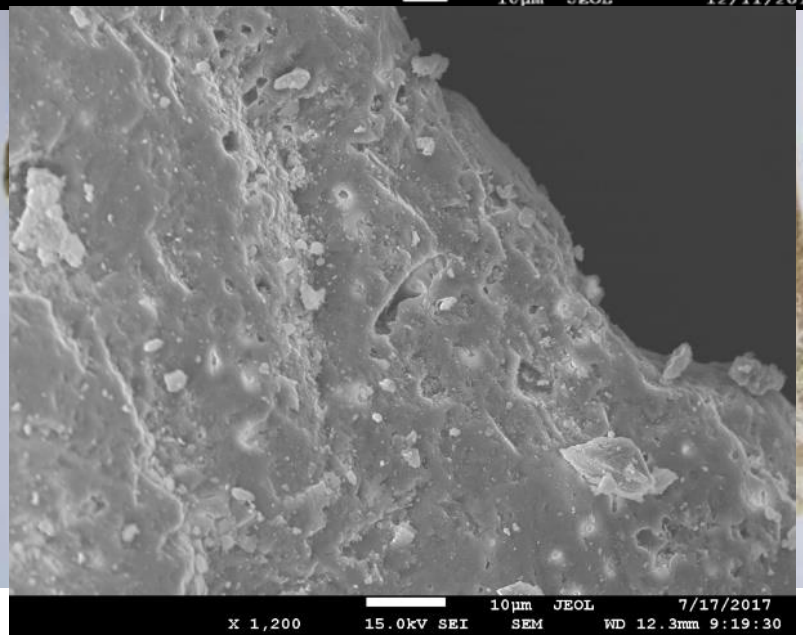


Batch experiment results

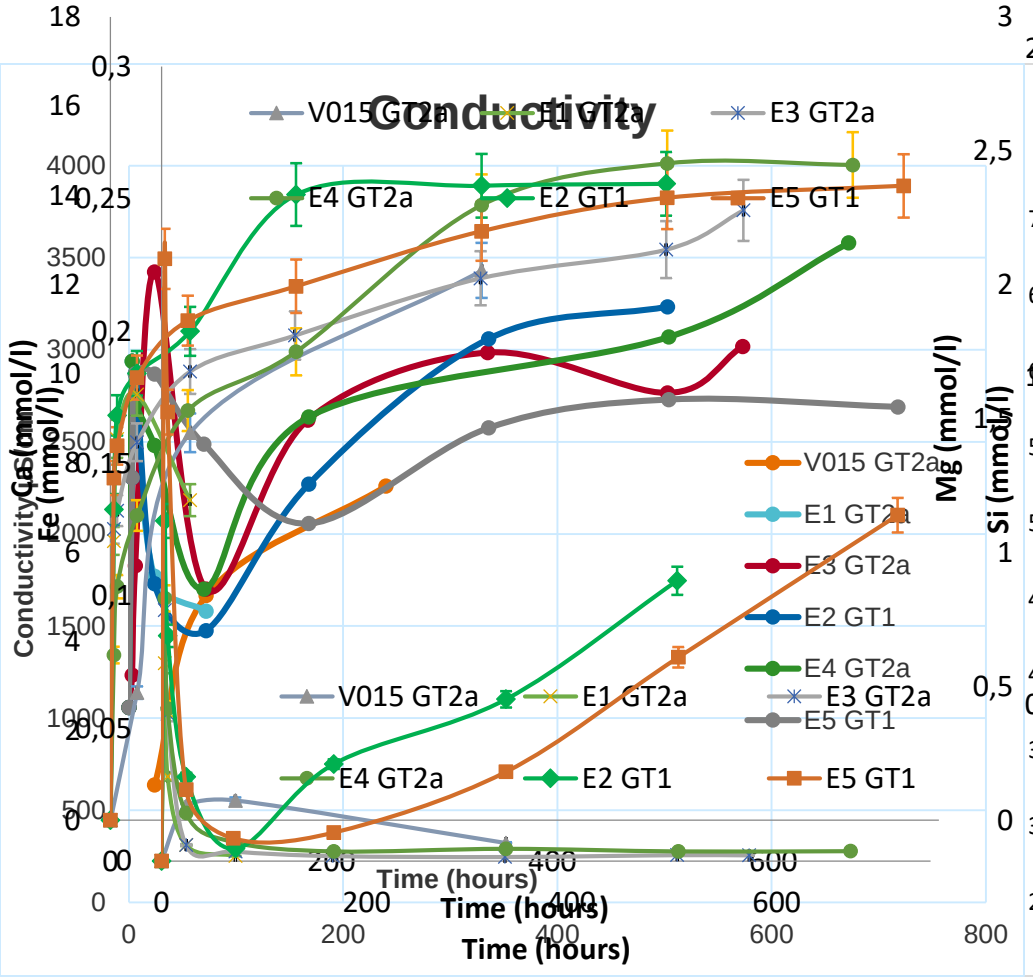


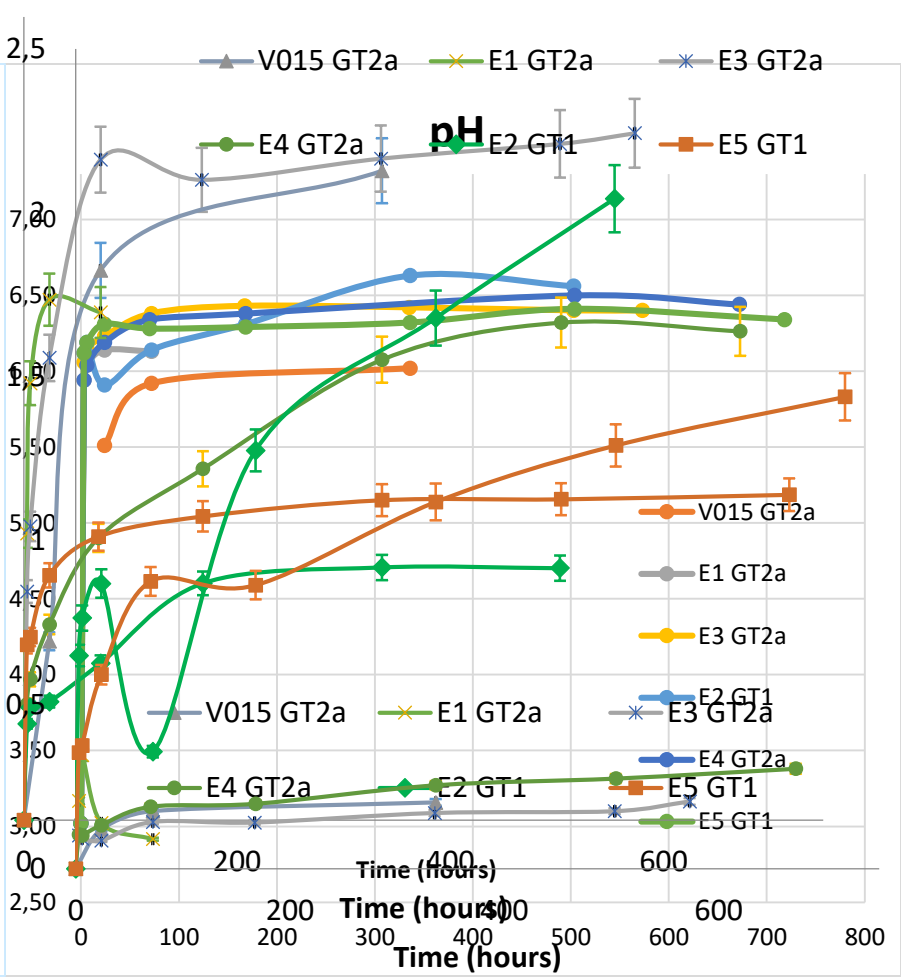




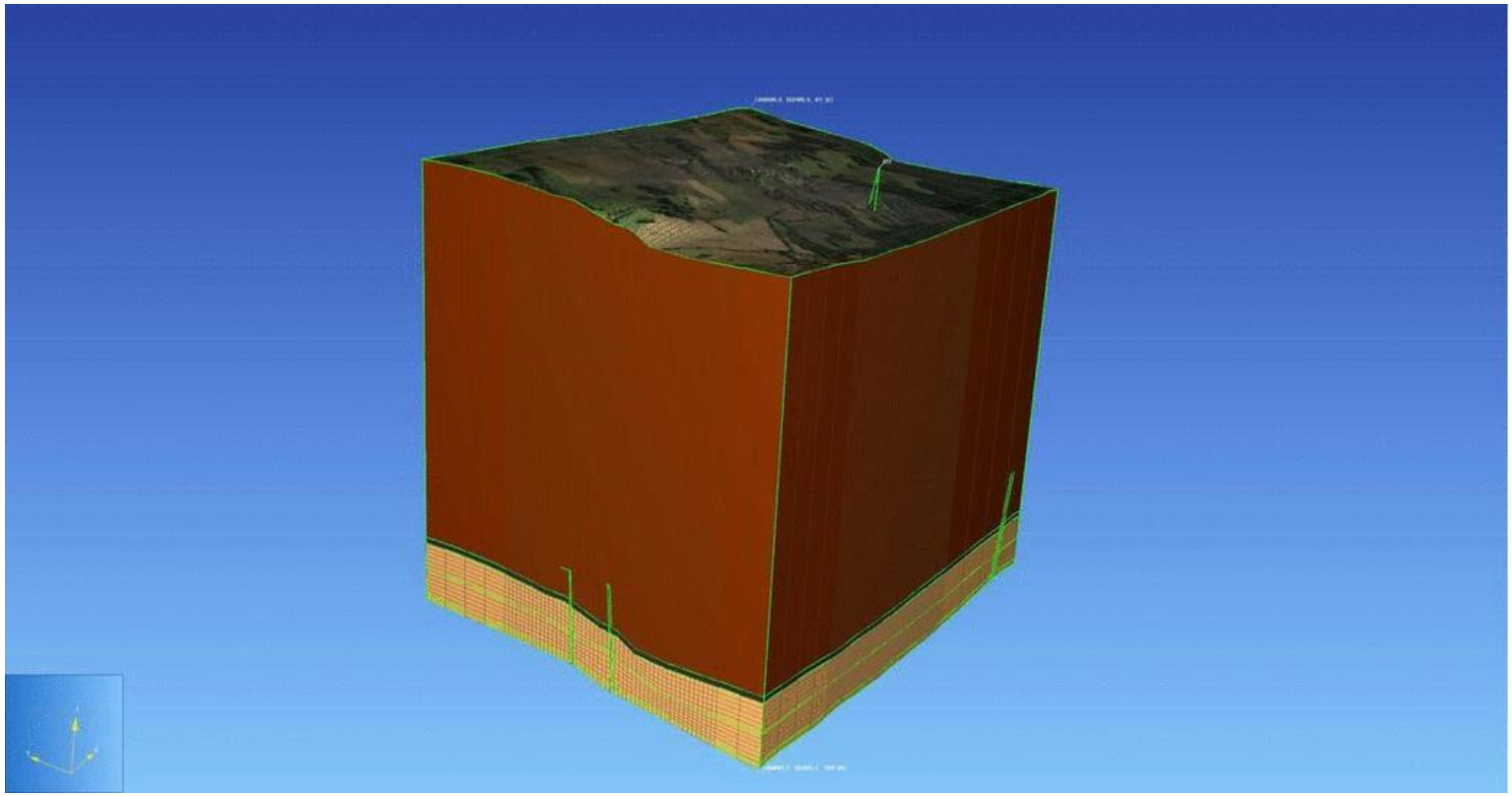


Kinetic experiment results: concentration vs. time





Simulating adding CO_2 to aquifer: model creation

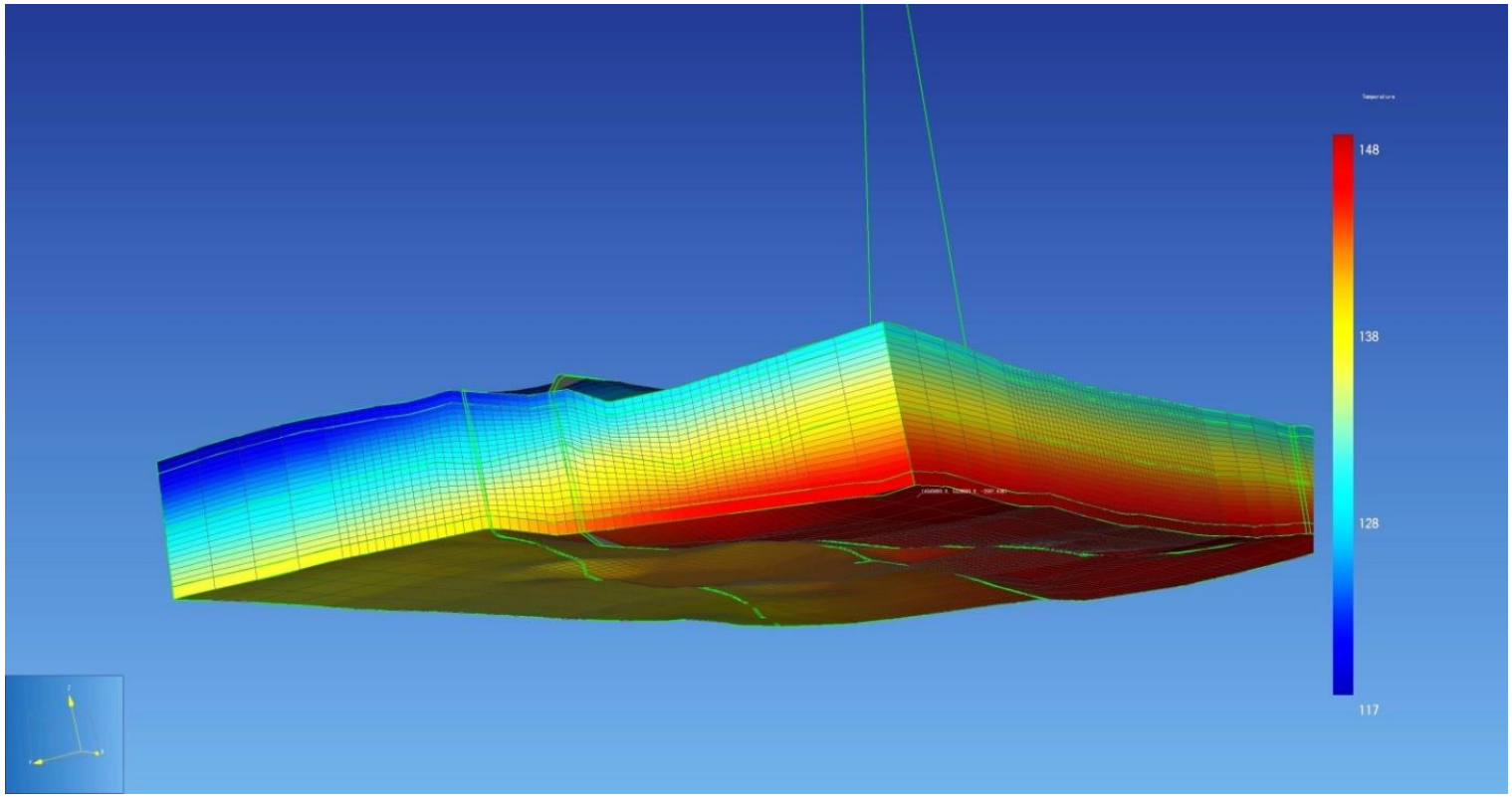


Reservoir depth: -2630m to -3600m

Max Porosity of reservoir: 0.1

Permeabilty range for layers (including faults): 7.9e-16 m^2 to 2.5e-14 m^2

Simulating adding CO_2 to aquifer: model creation

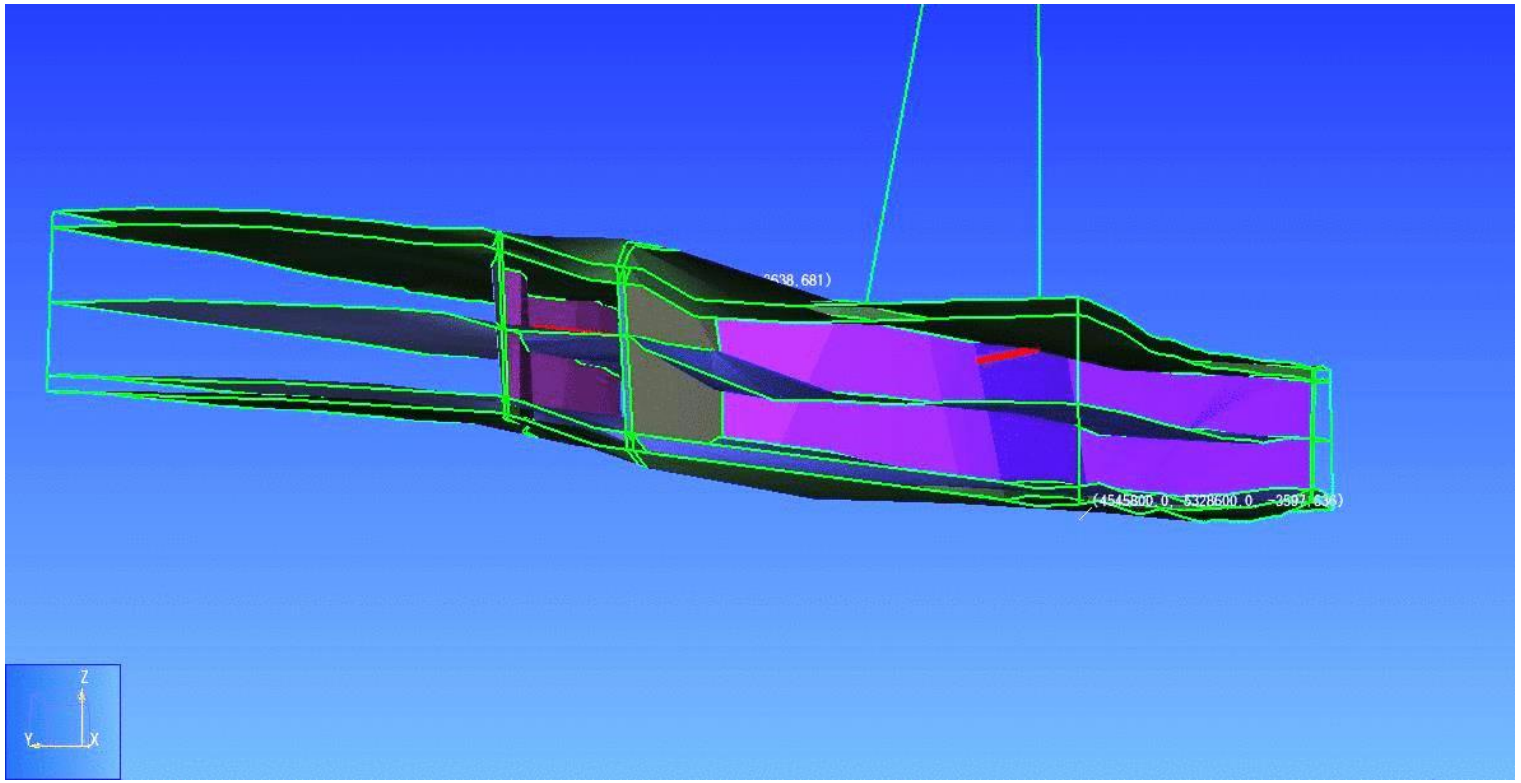


Pressure Range: 29.7 MPa - 37.7 MPa

Temperature Range: 117 °C - 148 °C

10 year run to achieve **initial state**

Simulating adding CO_2 to aquifer: model creation



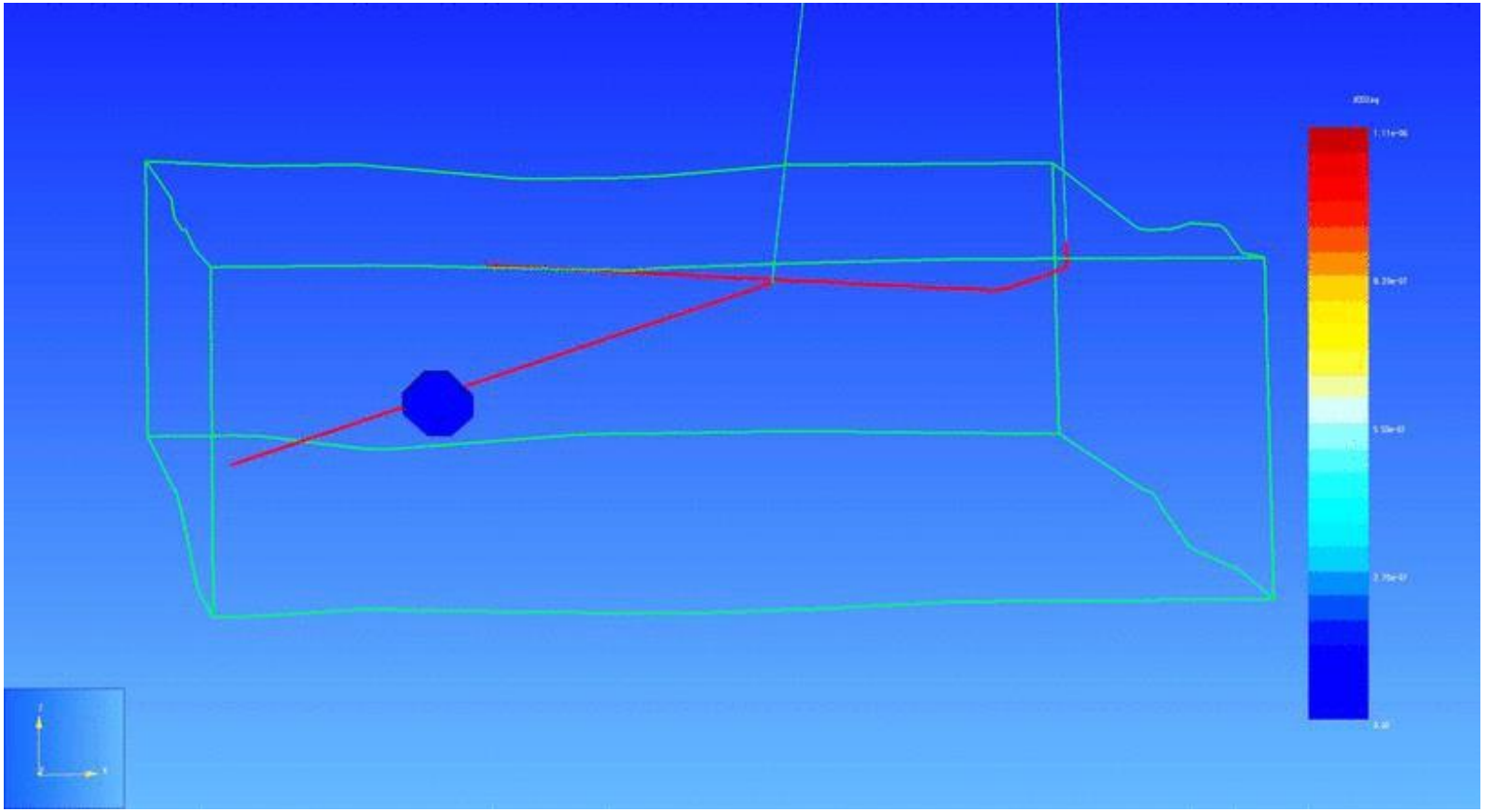
Two inclined wells:

- **GT1:** Injection well, **GT2a:** Production well

Injection rate: 99 Kg/s

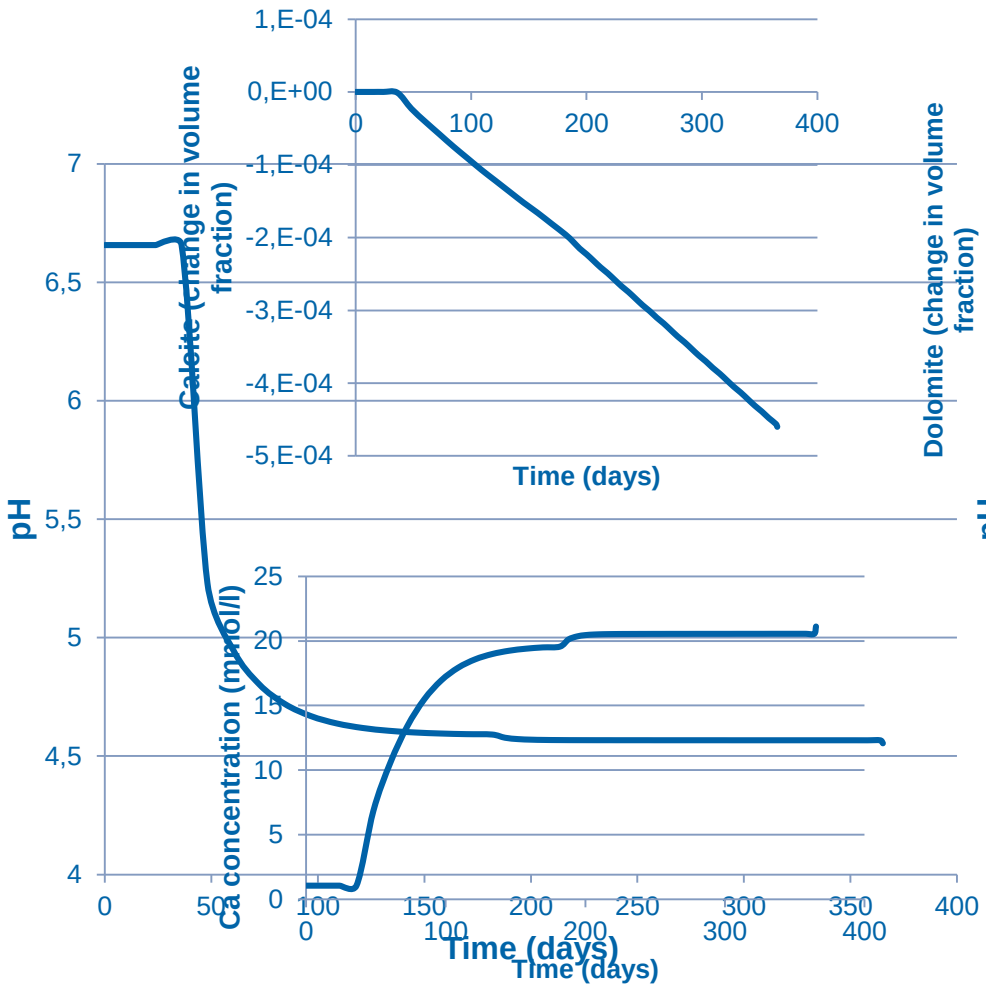
Production rate: 99 Kg/s

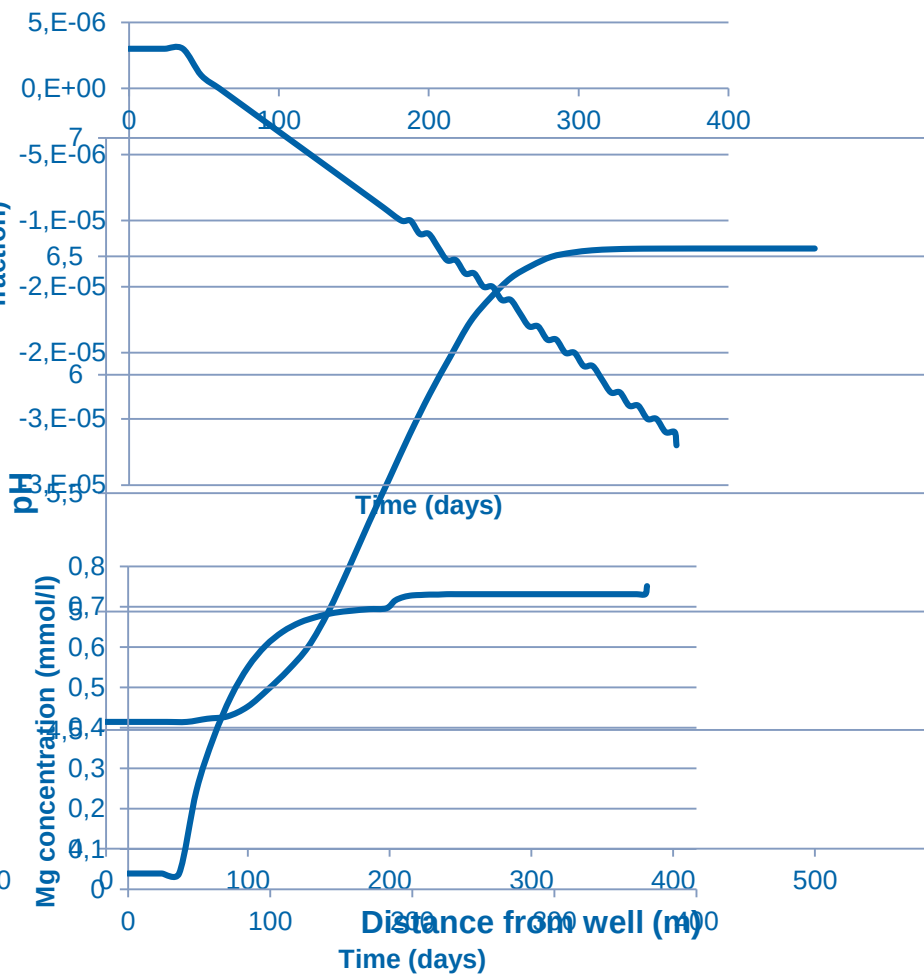
Simulating adding CO_2 to aquifer: reactive model



CO_2 partial pressure during 1 year injection

Simulating adding CO_2 to aquifer: model results





Summary and Conclusions

- Enhance pathways and prevent precipitation
- CO_2 can be adapted to achieve a preferred enhancement
- CO_2 Capture, Storage and Utilization by-effect 14000 tons/year. No additional energy required.
- Above-ground energy production is not interrupted by CO_2 addition
- Bypass system well suited for flexible boundary condition simulation
- Develop reliable models/ use for similar sites with similar minerology and heterogeneity

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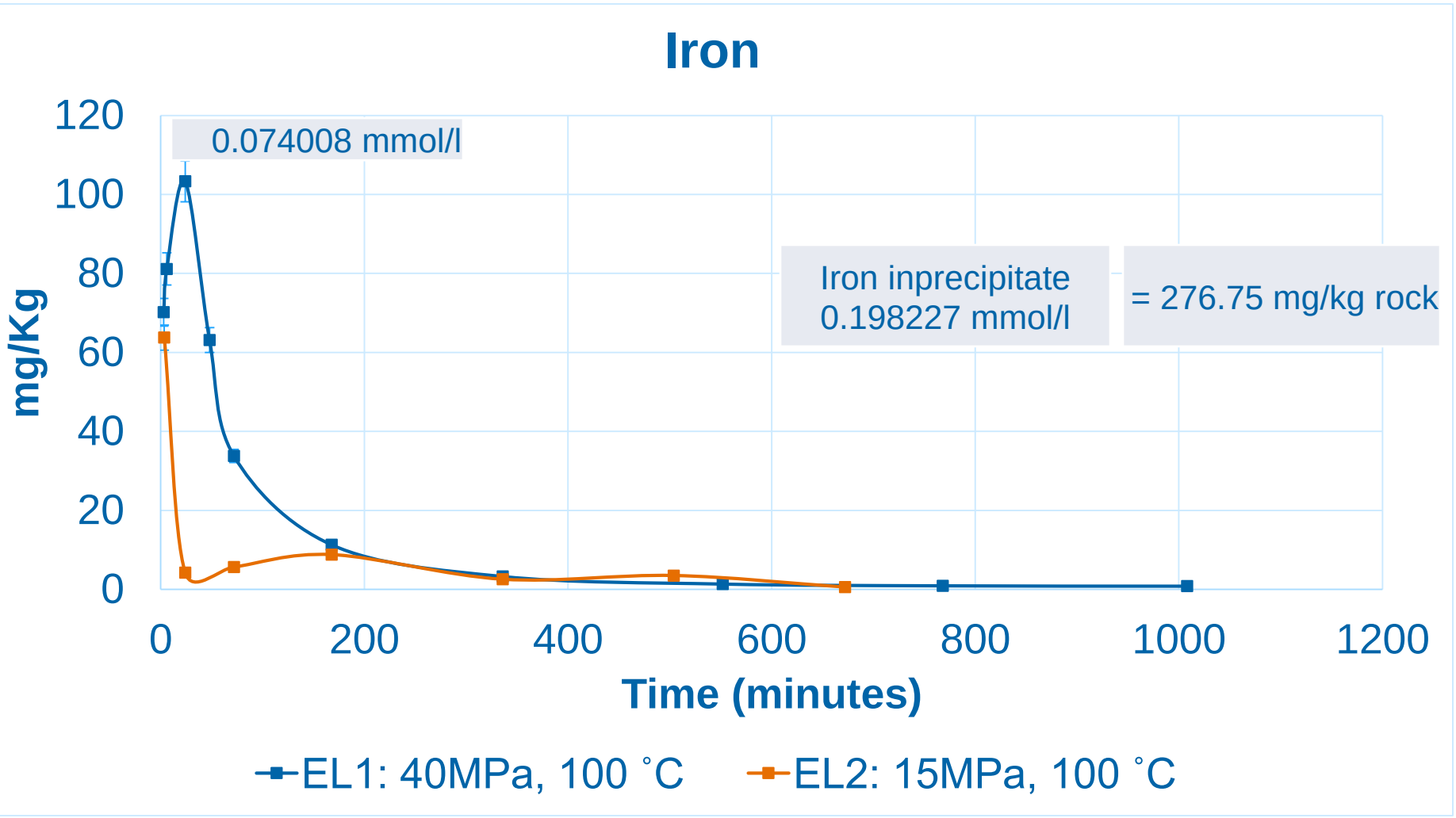
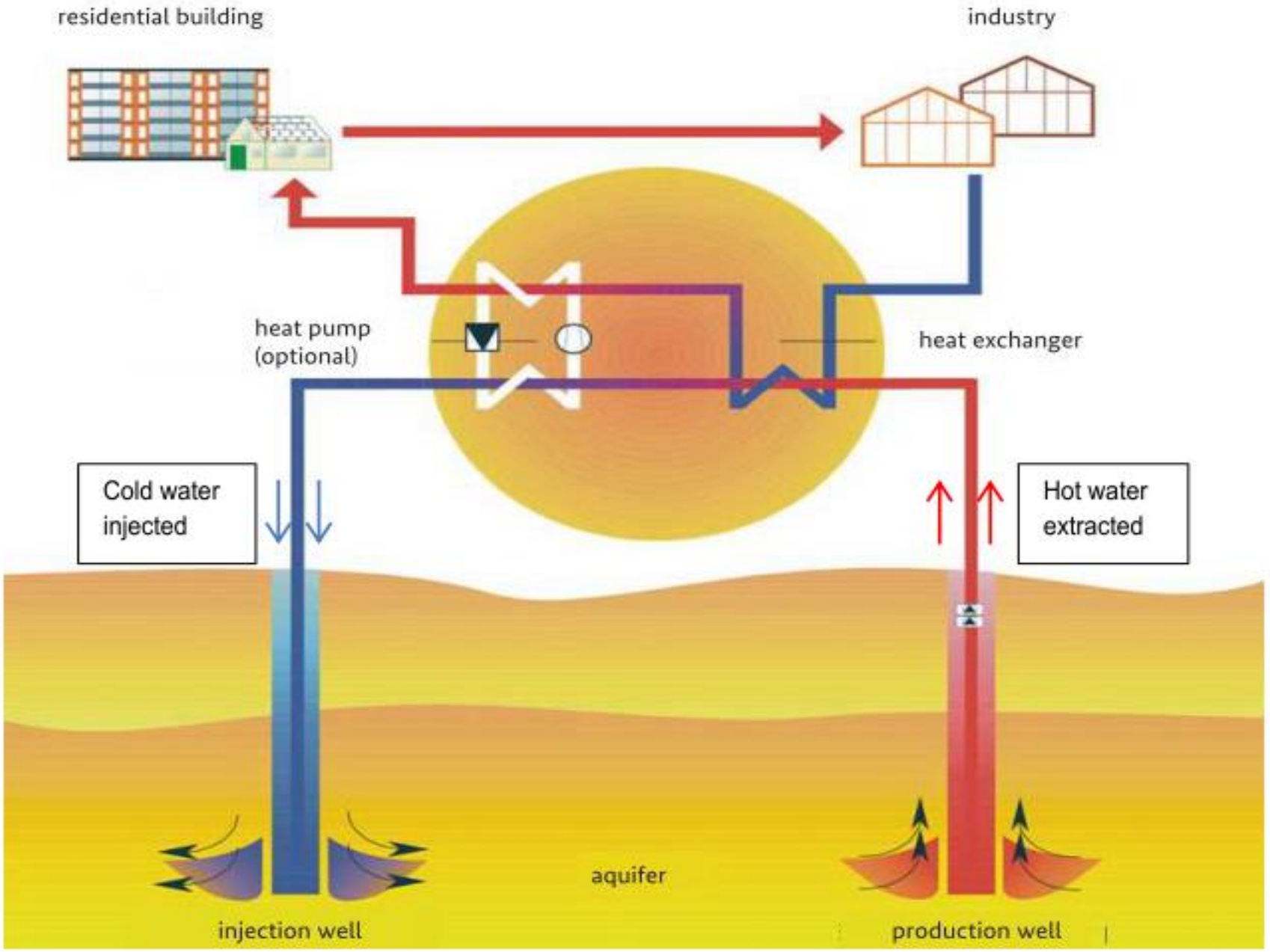
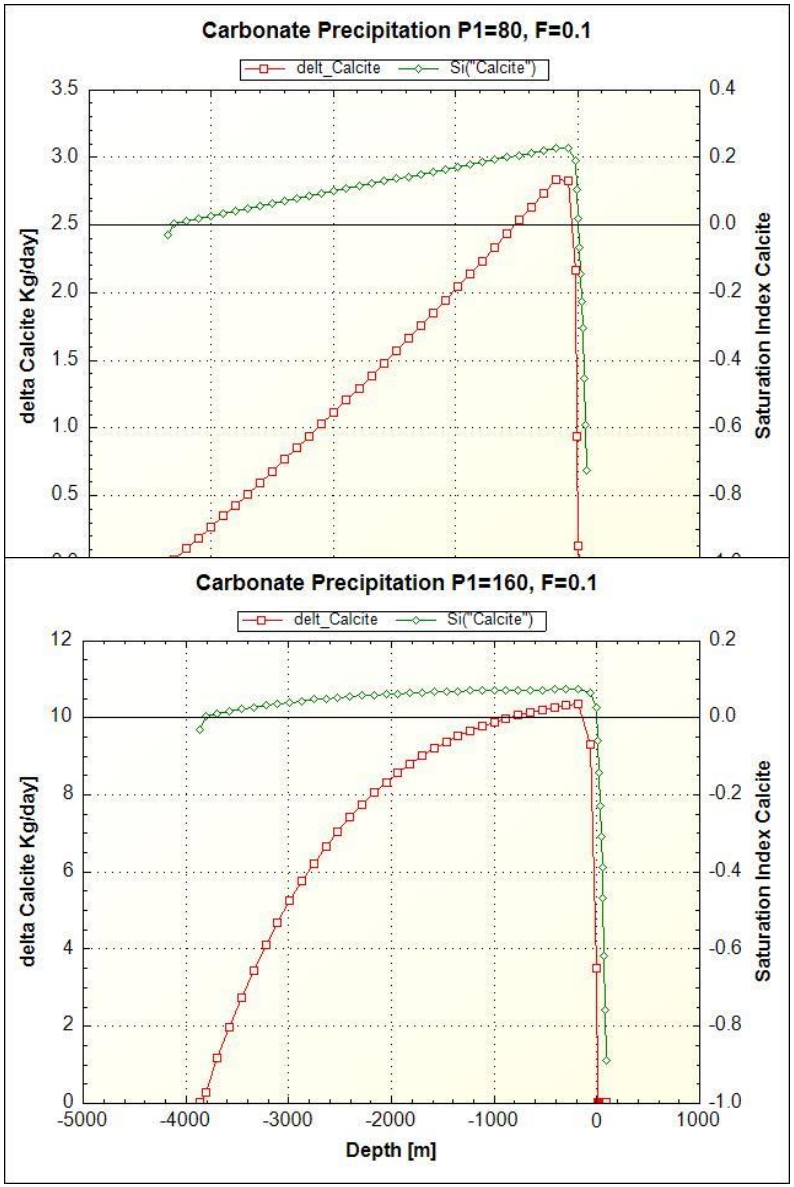
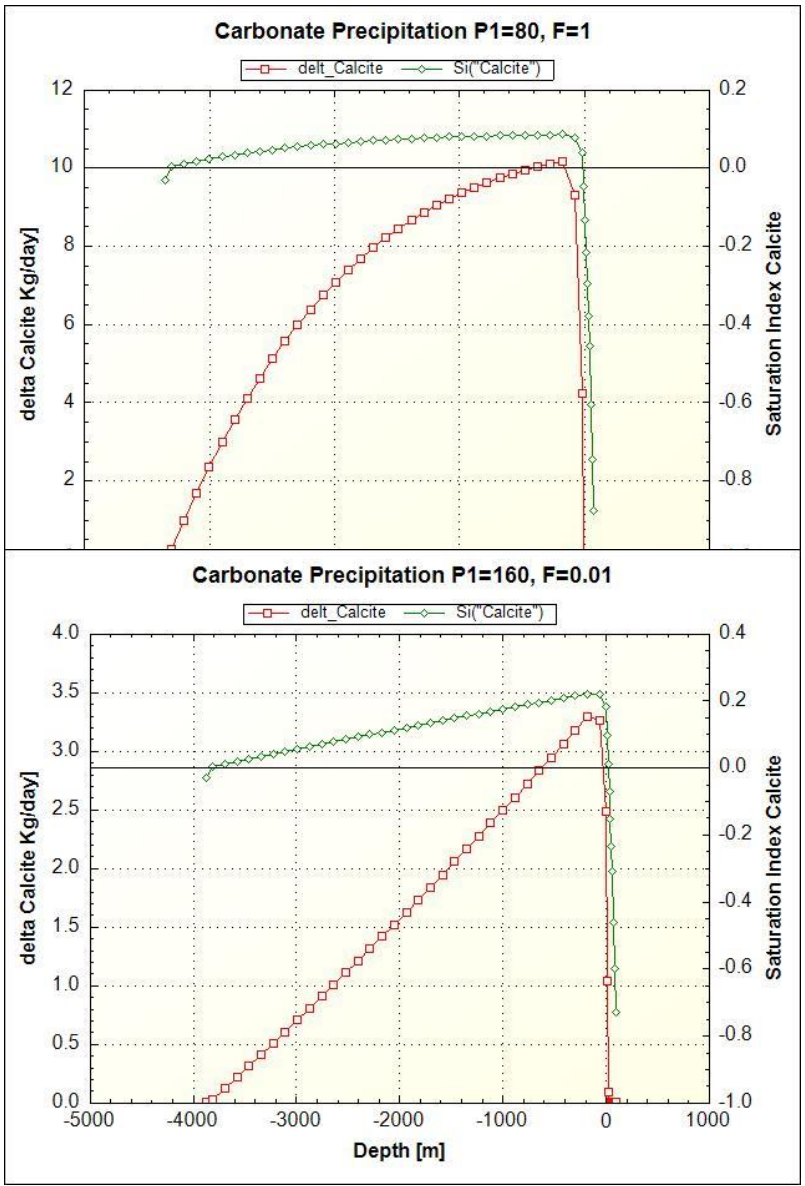

Iron
120
100
80
60
40
20
0
mg/Kg
0.074008 mmol/l
Iron inprecipitate
0.198227 mmol/l
= 276.75 mg/kg rock
0
200
400
600
800
1000
1200
Time (minutes)
EL1: 40MPa, 100 ˚C
EL2: 15MPa, 100 ˚C


residential building
industry
heat pump
(optional)
heat exchanger
Cold water
injected
Hot water
extracted
aquifer
injection well
production well

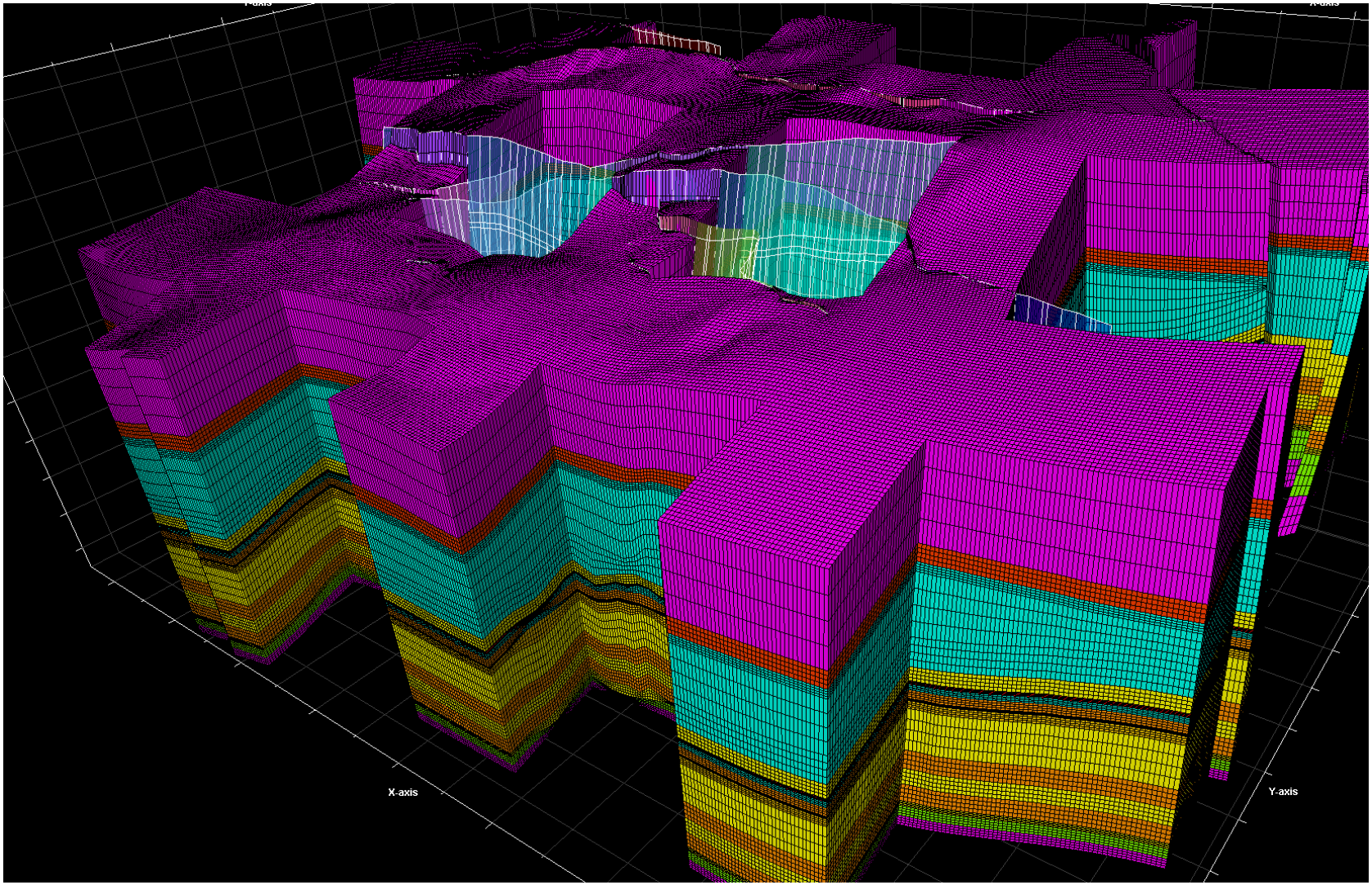
Using CO_2 in deep geothermal carbonate aquifers (LERWTG)

$$R = k_1 a_{H+} + k_2 a_{H2}\,CO_3 + k_3 a_{H2O} - k_4 a_{Ca2+}\, a_{HCO3-}$$ PWP Equation



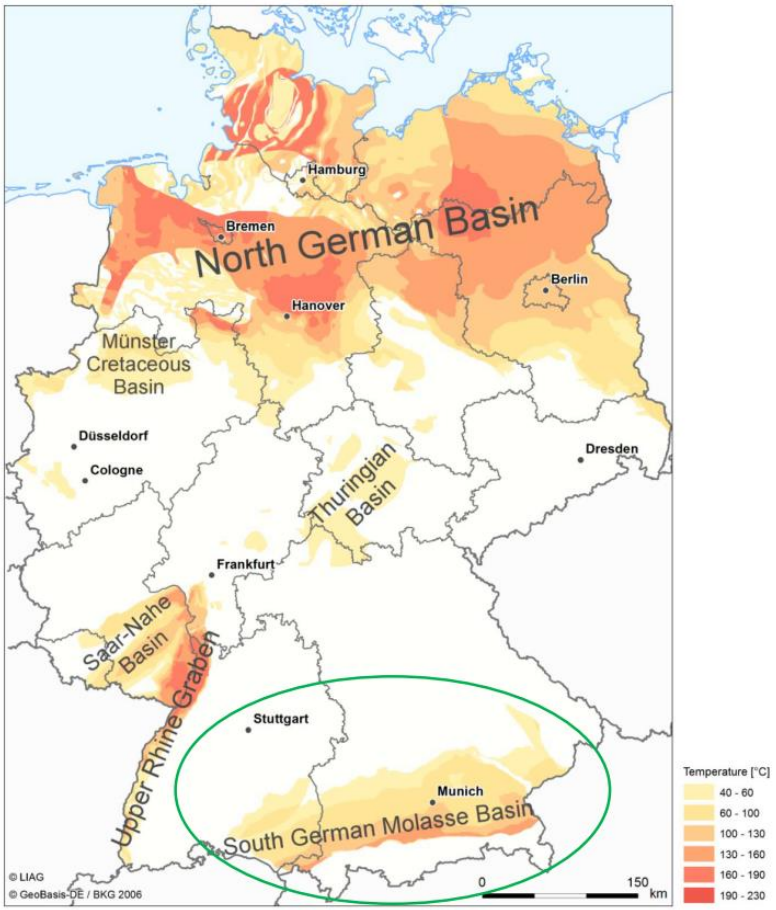


Using CO_2 in deep geothermal carbonate aquifers (LERWTG)

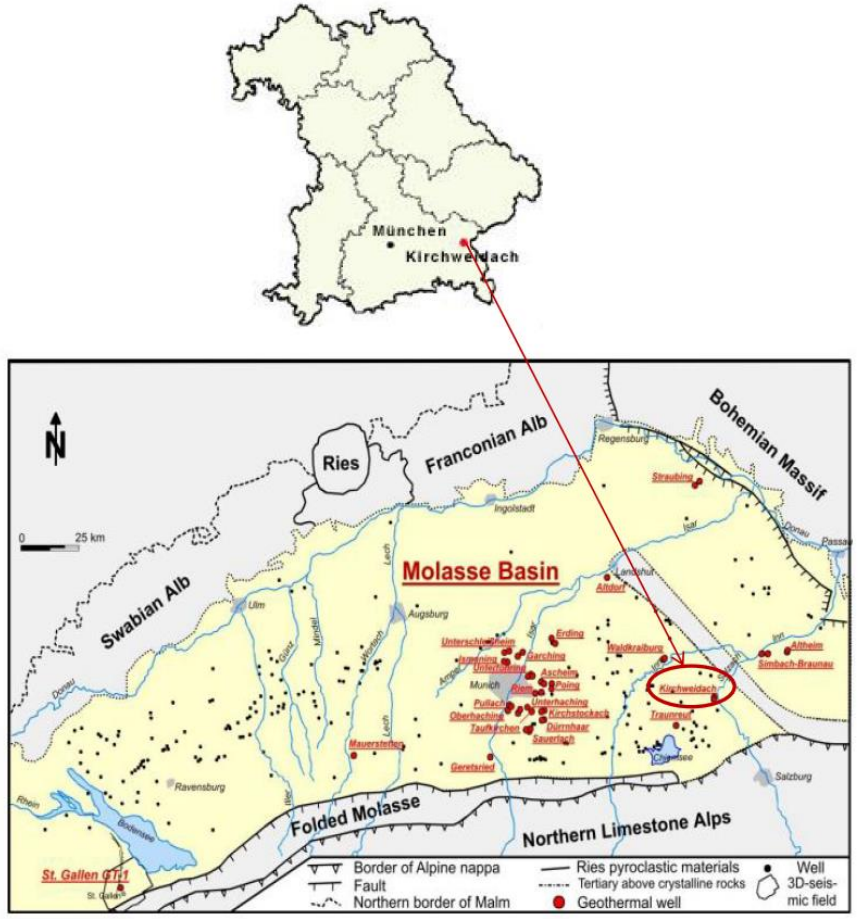


Eclipse model

Enhancing geothermal wells and reservoirs by using CO_2 (LERWTG)



Major geothermal sites in Germany
(modified after Agemar et al. 2014)



Geothermal well distribution in the Molasse Basin
(Geoenergie Bayern GmbH 2015 and Wolfgramm et al. 2015)

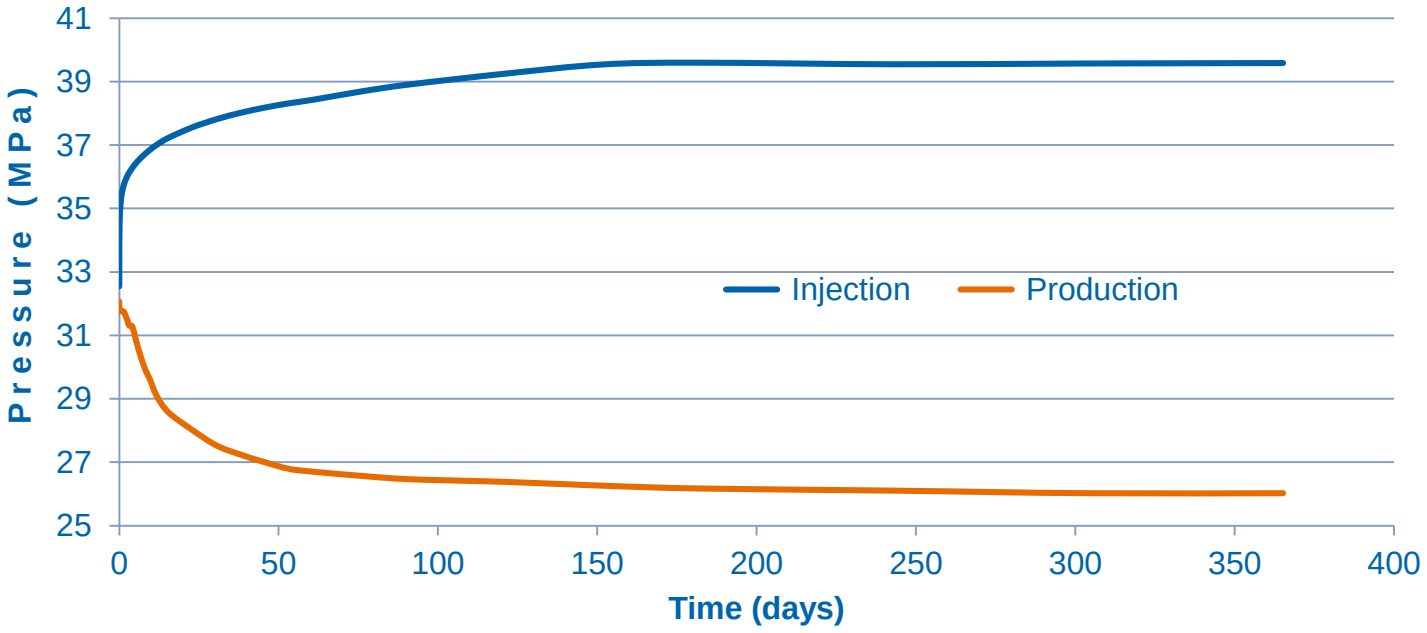
Enhancing geothermal wells and reservoirs by using CO_2 (LERWTG)

Calcite and dolomite mass balance

		vF1	F1	F2	F3	F4	F5
Average calcium concentration	(mg/l)	25	115.5	153.2	167.1	175.8	178.6
Increase of calcium content	(mg/l)	0	90.5	37.7	13.9	8.7	2.8
Increase in % of total increase	%	0	59%	25%	9%	6%	2%
Calcite dissolution	(kg)	0	35.4	14.7	5.4	3.4	1.1
Average magnesium concentration	(mg/l)	4	45.8	58.5	59.2	60.6	60.5
Increase of magnesium content	(mg/l)	41.8	12.7	0.7	1.4	-0.1	41.8
Increase in % of total increase	%	0	74%	22%	1%	2%	0%
Dolomite dissolution	(kg)	0	21.8	6.6	0.4	0.7	-0.1
Rock mass before experiment	(kg)		279	280	270	278	275
Dissolved mass	Wt.%		20	7.6	2.1	1.5	0.4

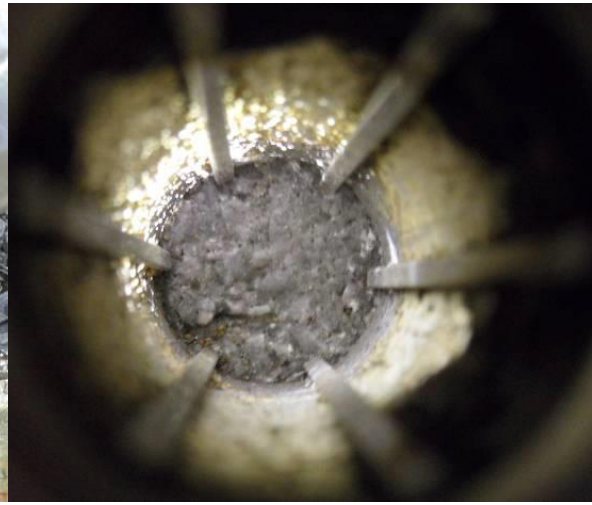
Enhancing geothermal wells and reservoirs by using CO_2 (LERWTG)

	Static pressure (MPa)	Pumping test pressure 105 l/s (MPa)	Temperature (°C) before pumping test	Temperature (°C) after pumping test
GT1 (injection well) – measured depth 3470 m TVD	32.56	39.53	125	124
GT2a (production well) – measured depth 3421 m TVD	32.06	26.03	126	128



Injection and Production well pressure after 1 year injection

Using CO_2 in deep geothermal carbonate aquifers



Eichinger 2016

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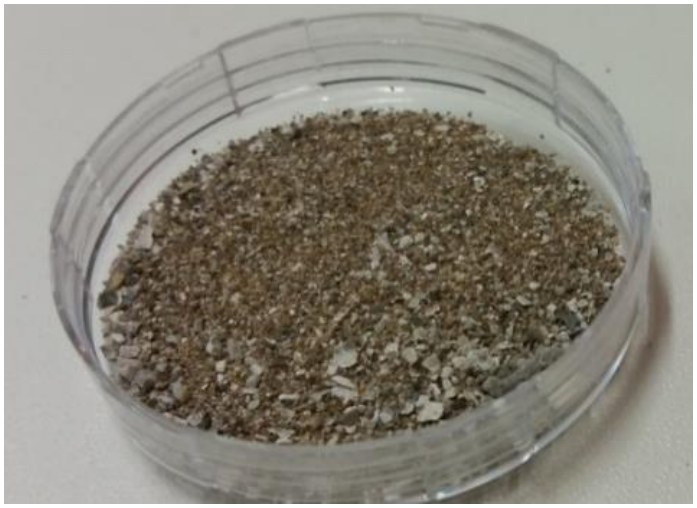
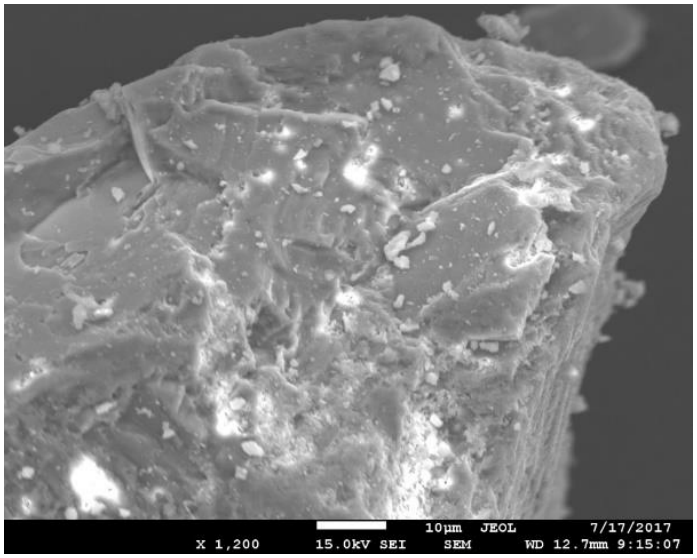
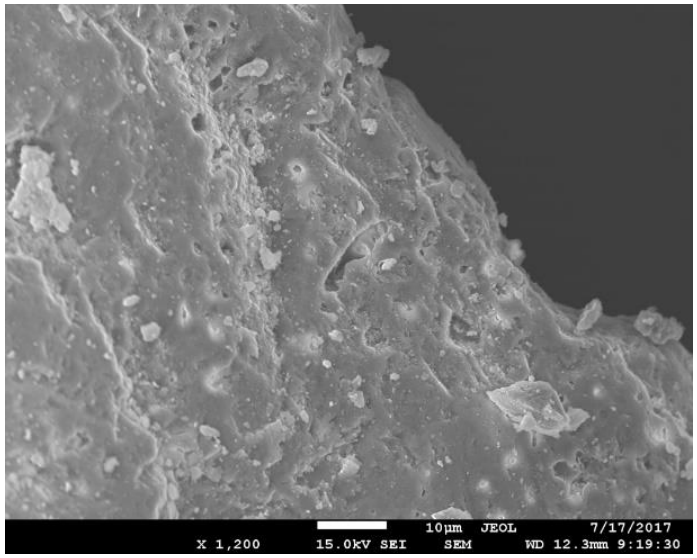
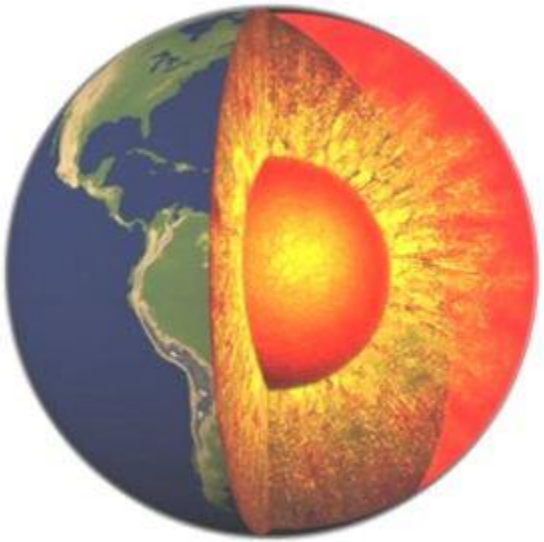






Using CO_2 in deep geothermal carbonate aquifers

- Actual pilot CO_2 realization
- Different pCO_2 ratios to achieve a preferred enhancement



http://www.waterionizermachinereviews.com

Using CO_2 in deep geothermal carbonate aquifers