Injection-triggered flow pathway occlusion in geothermal operations in Klaipeda

Maren Brehme

Klaipeda: site location

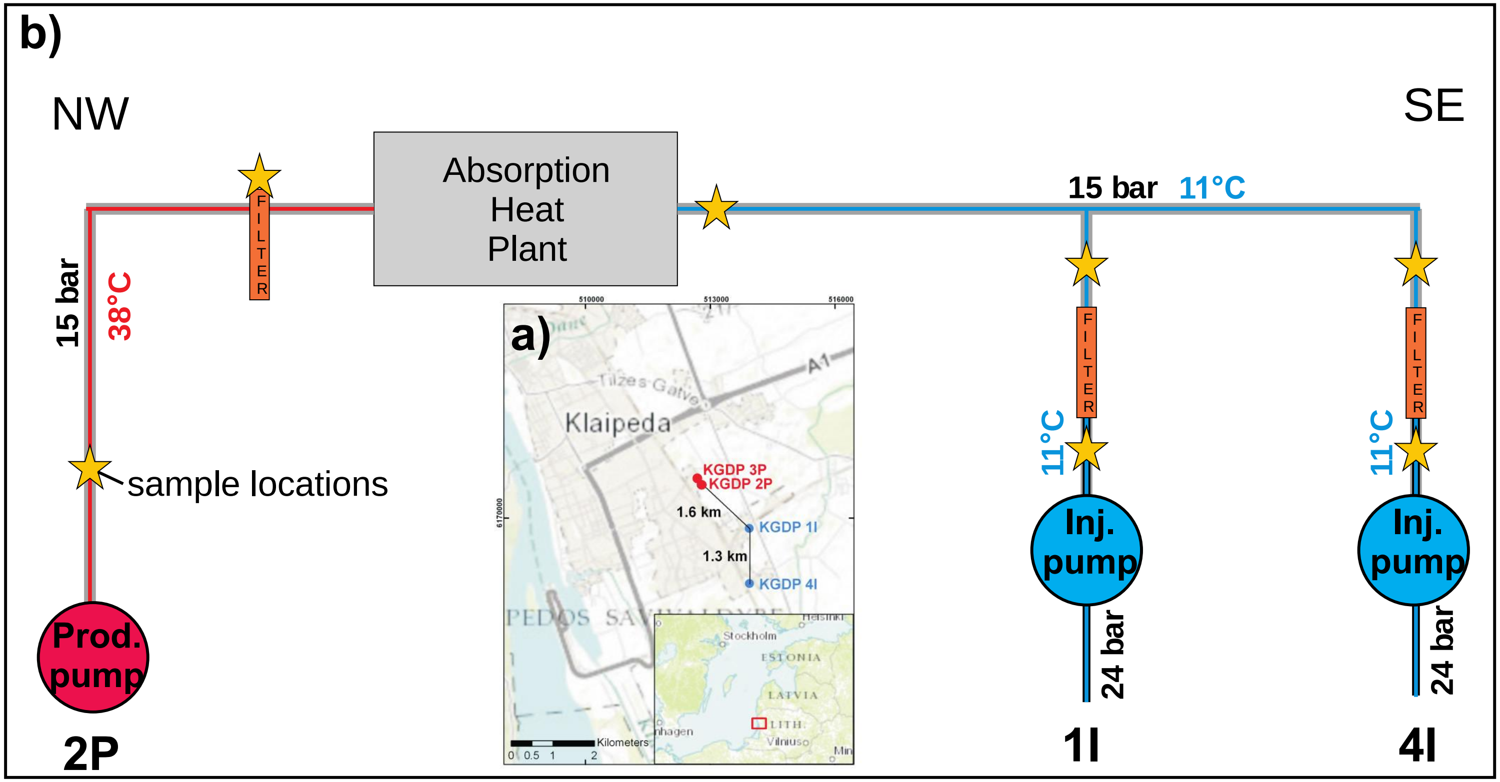
Klaipeda old town

Geothermal plant

Courland Lagoon

Injection well

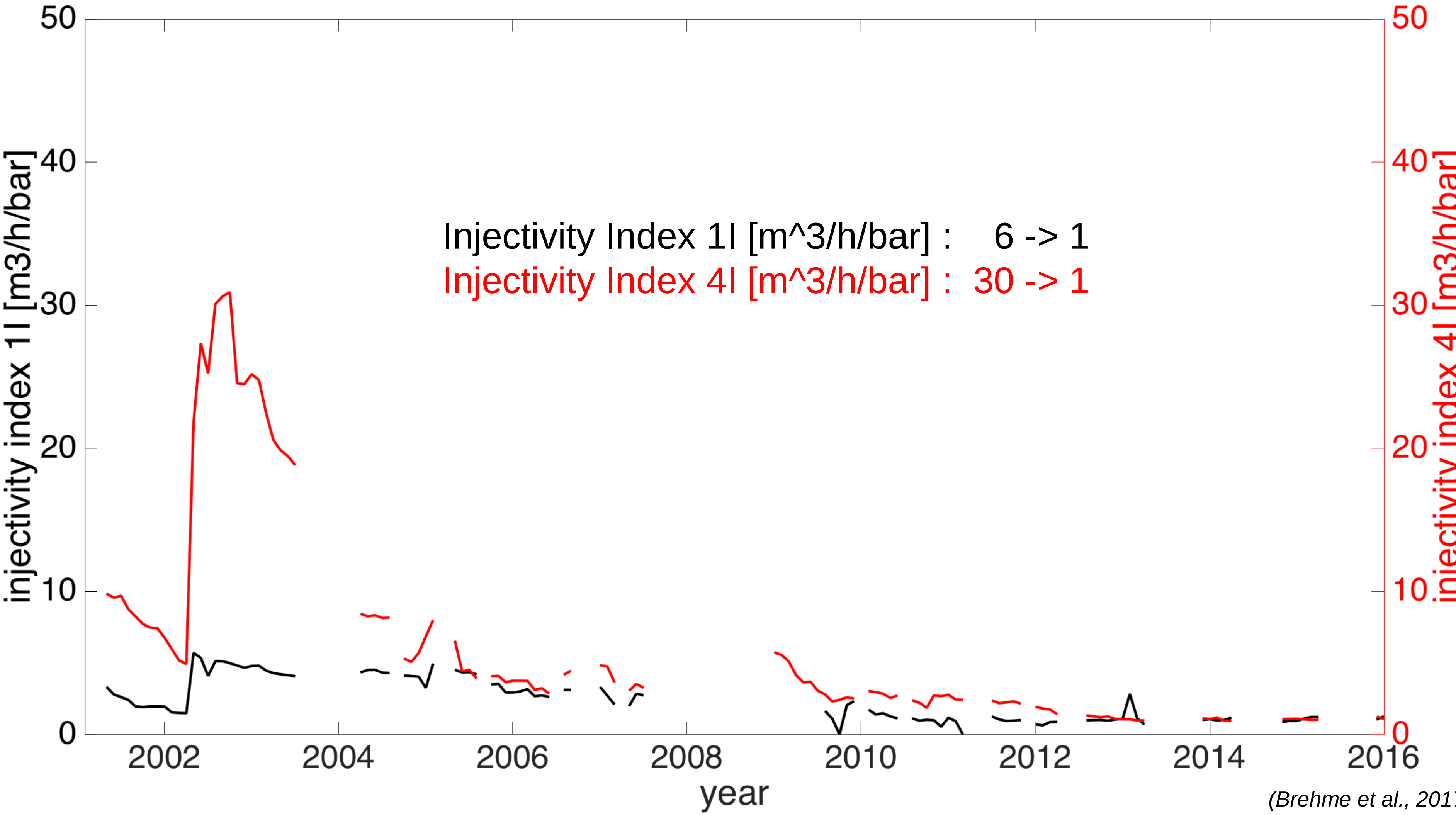
Geothermal cycle set-up




GEOTERMINIS
VANDUO

Thermal gradient: 38-40° C
Depth of wells: ~1130 m below surface
Reservoir depth: 980-1129 m below surface
Reservoir pressure: 104 bar
Static water level: 31 m below surface

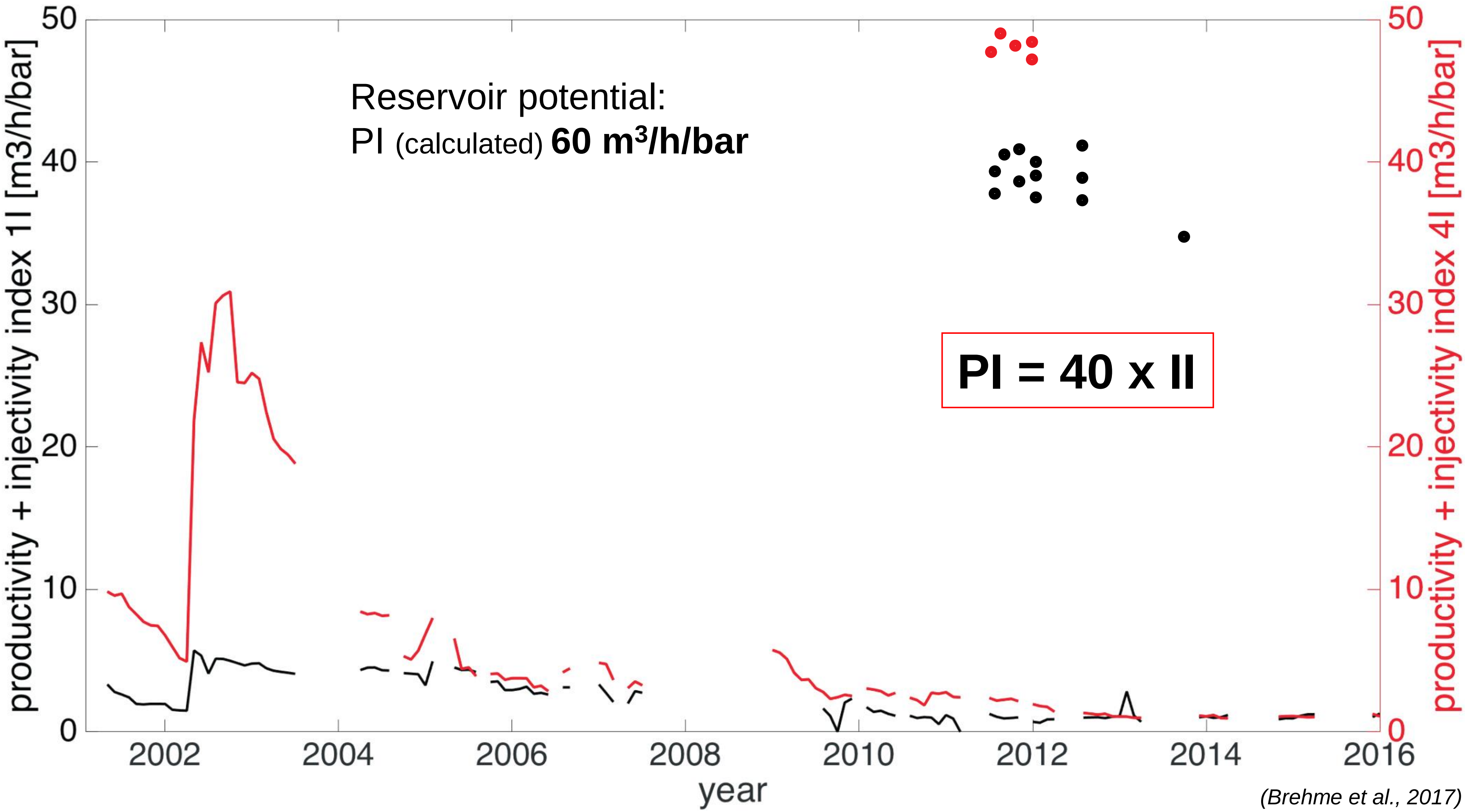
Injection history



(Brehme et al., 2017)

Continuous decrease of injectivity

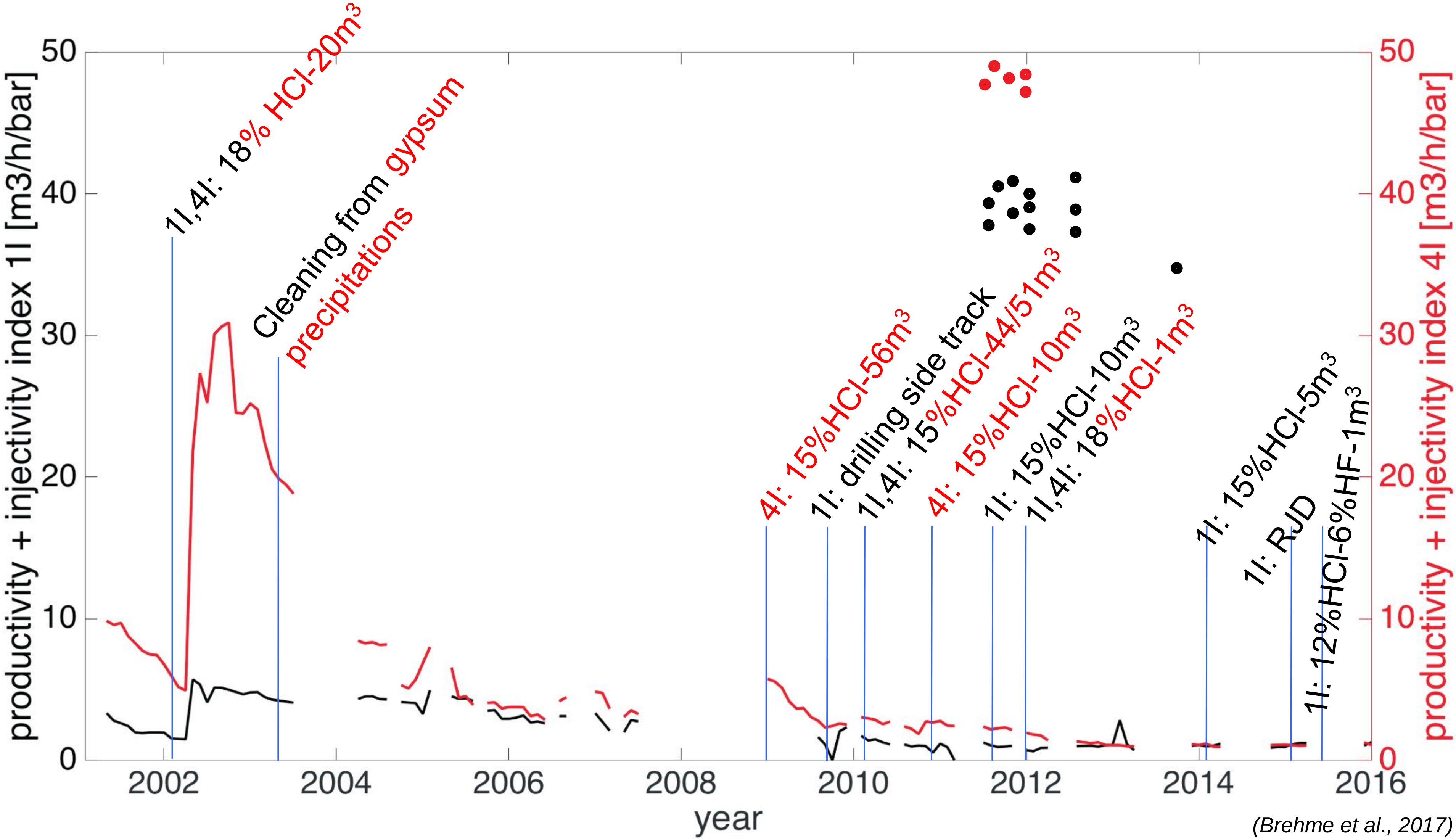
Injectivity/Productivity



(Brehme et al., 2017)

Very high productivity in the same wells

Reservoir stimulation history

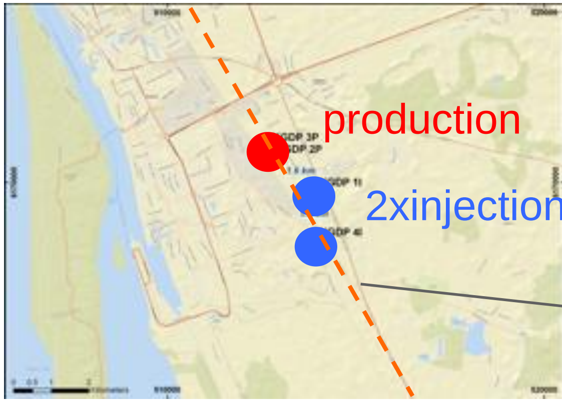


(Brehme et al., 2017)

Reservoir stimulations with low effectivity

Physical processes

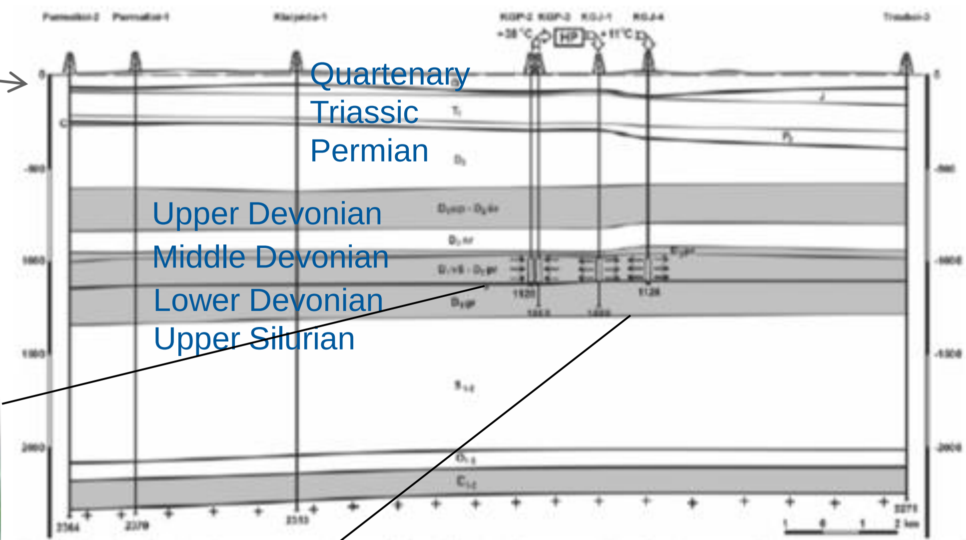
Geological set-up



production
100m3/h

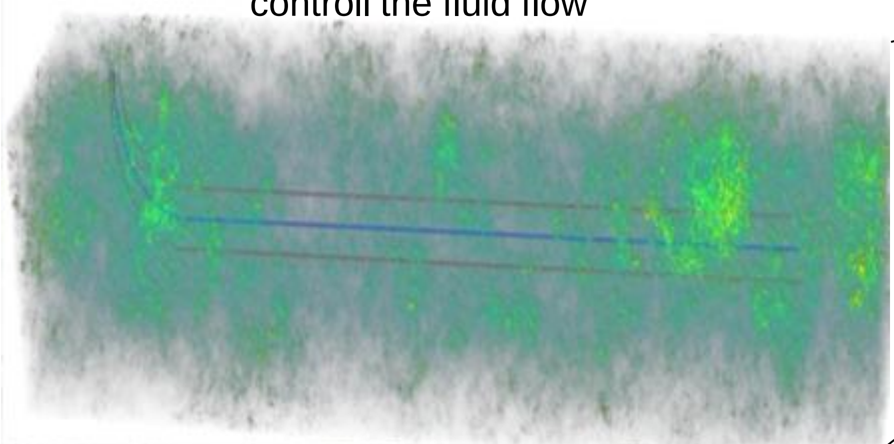
injection
2x50m3/h

15% of would could be produced



(Sliaupa, 2016)

Pore-connectivities on grain scale
controll the fluid flow



(Leary, 2016)

Reservoir:
Lower Devonian sandstones
highly porous (25%) with calcite matrix
interbedded with clay- and siltstones

Reservoir rock properties

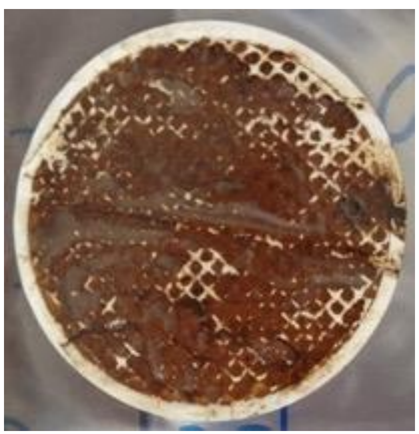
claystone

sandstone

Porosity measurements: 26.1%
85% of pores have a size of 3-40µm

Permeability of 2-4 Darcy (2-4*E^{-12} m2)

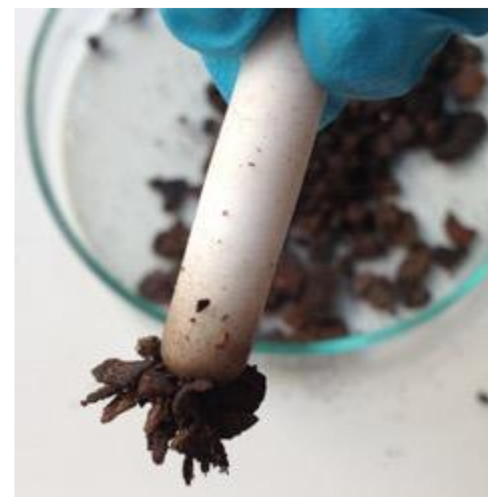
Filter residual - types



- **Filter residual:**

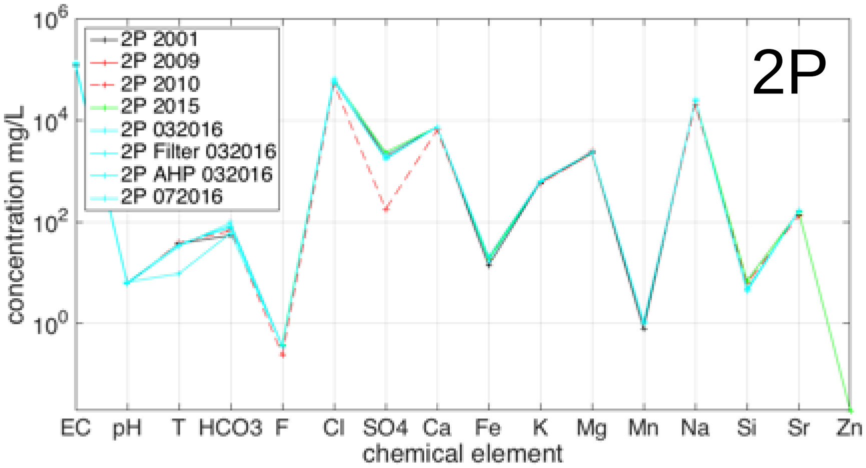
Sand/particles from reservoir (middle-fine sand + clay Reservoir rock)

Magnetic corrosion material (Pipe)



Chemical processes

Hydrochemistry



HCO3, Fe, Mn increased
Si decreased

Average water composition

pH	Sal. [g/l]	Cl [mg/l]	HCO3 [mg/l]	SO4 [mg/l]	Na [mg/l]	Ca [mg/l]	Mg [mg/l]
6.5	125	56498	85	1733	24299	7558	2375

Average gas composition

N2	CO2	CH4	H2S
80.1%	19.8%	0.024%	0.0005%

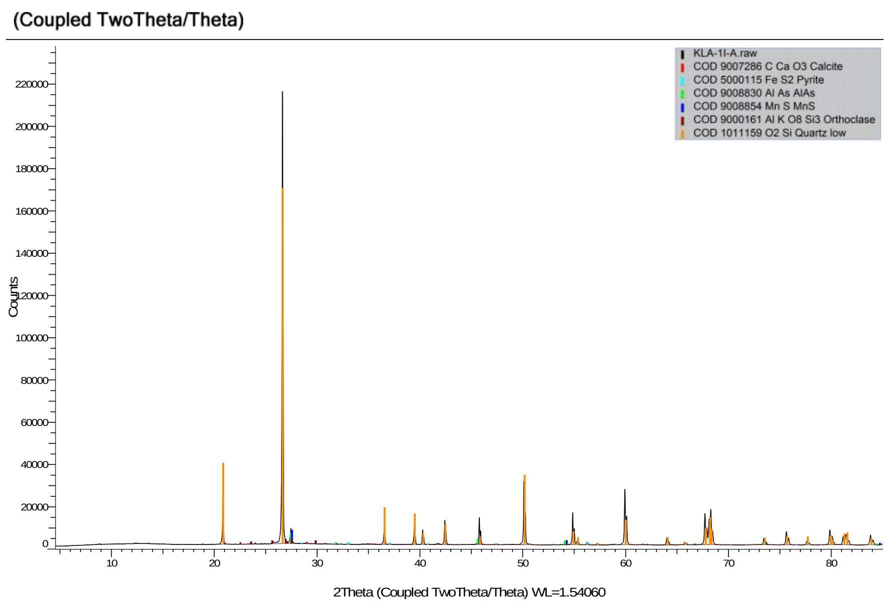
Geochemistry – Reservoir rock

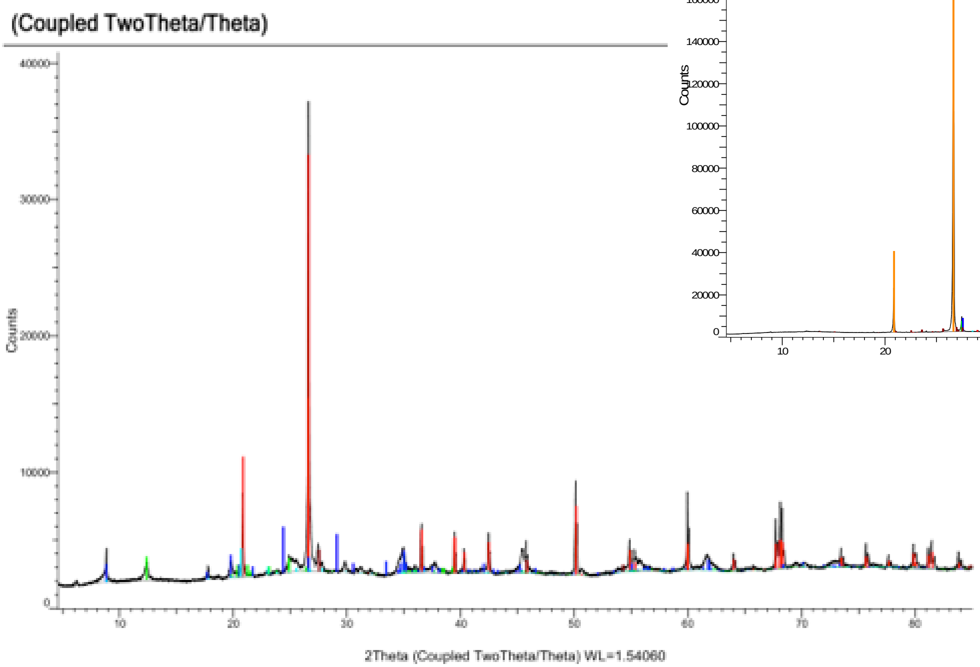
Major components

- Quartz
- Calcite
- Dolomite
- Orthoclase
- MnS
- Pyrite

Minor components

- Biotite
- Muscovite
- Kaolinite
- Illite
- Chlorite





Geohydrochemistry

- **Saturation modeling**

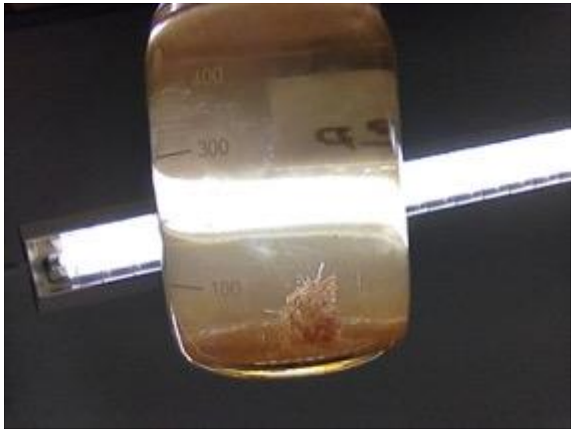
- 2P rock EQ
  - Anhydrite 0.56
  - Barite 0.42
  - Celestite 0.7
  - Goethite 4.9
  - Gypsum 0.64
  - Hematite 11.9
  - Sphalerite 0.65
  - Talc 1.66

- 1I rock EQ acid injection
  - Anhydrite 0.38
  - Barite **0.64**
  - Celestite 0.59
  - Goethite **5.34**
  - Gypsum 0.56
  - Hematite **12.66**
  - Sphalerite **1.4**
  - Talc **1.78**

- $CaSO_4$
- $BaSO_4$
- $SrSO_4$
- FeOOH
- $CaSO_4:2H_2O$
- Fe_2O_3
- ZnS
- $Mg_3Si_4O_{10}(OH)_2$

Water in equ. with reservoir rock

Water in equ. with reservoir rock and treated with HCl



Biological processes

Microbiological studies

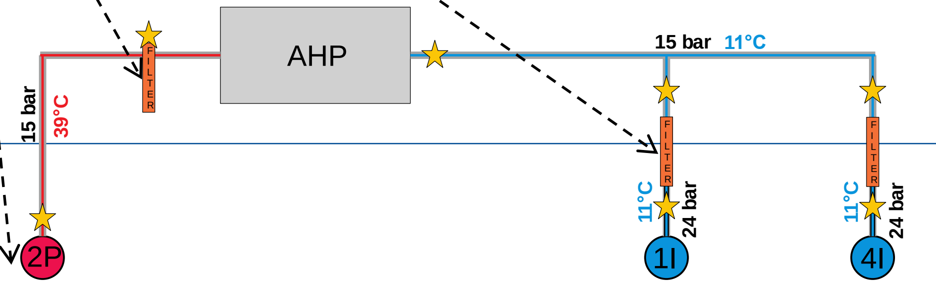
- Cell counts:
  - production site ($5.5*10^7$ cells/l) 2008
  - injection site ($3.2*10^7$ cells/l) 2008
  - production site ($3.04*10^5$ cells/ml) 2016
  - injection site ($8.58*10^5$ cells/ml) 2016

Aberdeen and Blaichem Ltd (2008)

- Amount of Archaea is the same at production and injection site
- Amount of sulfate-reducing bacteria is higher at production site

CNS in solids

Name	% N	% C	% S
KLA_1I Filter	0.30	3.26	9.85
KLA_2P Filter	0.06	0.72	1.73
KLA_1I Core	0.00	0.05	0.64



Interaction

Processes causing injectivity decline

Dissolution of minerals by flow/time + acidization -> small particles in water

Fines migration

Supersaturation of minerals + acidization -> new minerals forming

Precipitation

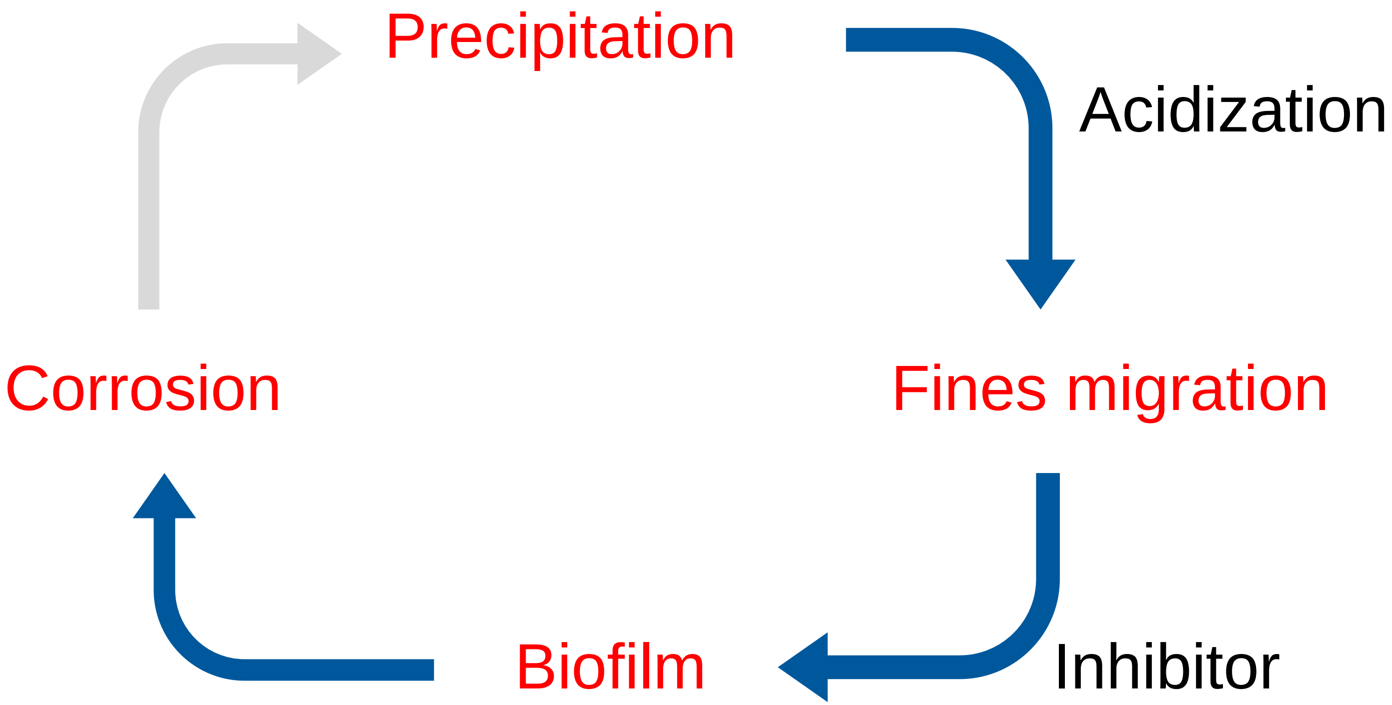
Gypsum inhibitor + leaching of surface filters -> microbial cell amount increase

Biofilm

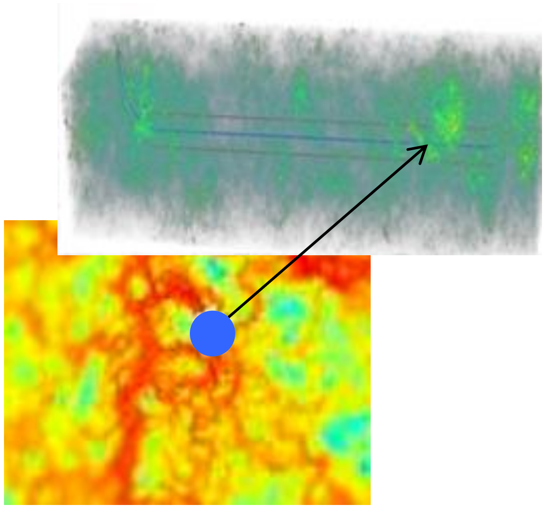
Corrosion + acidization -> increase in Fe and Mn concentration

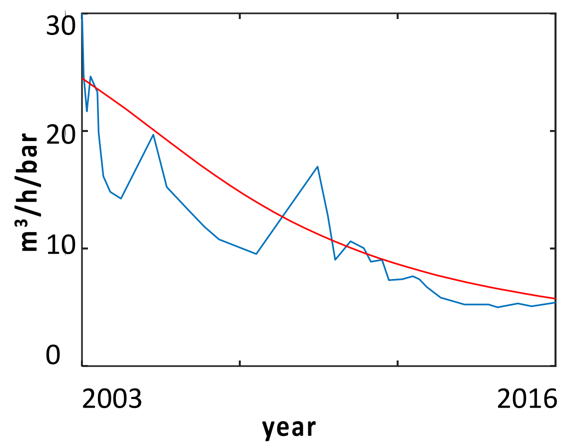
Corrosion plates

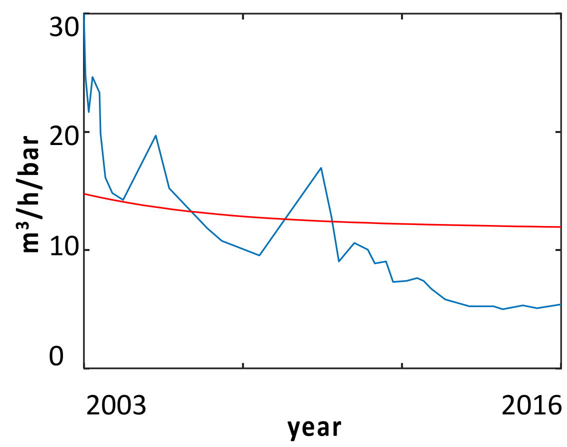
Processes causing injectivity decline and what to do?

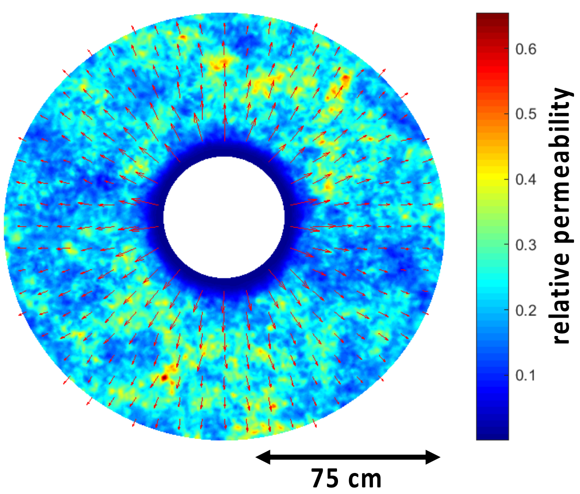


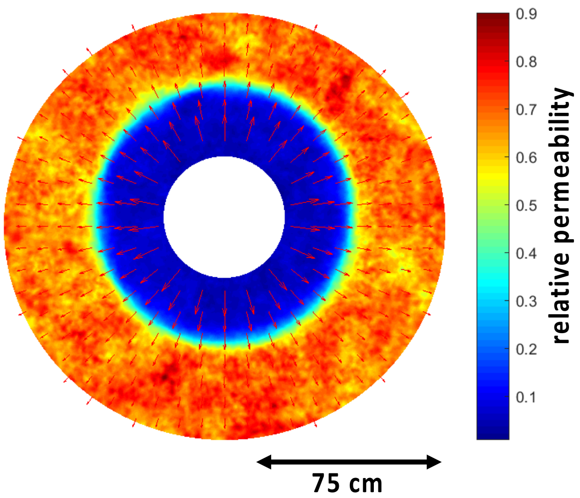
Processes causing injectivity decline





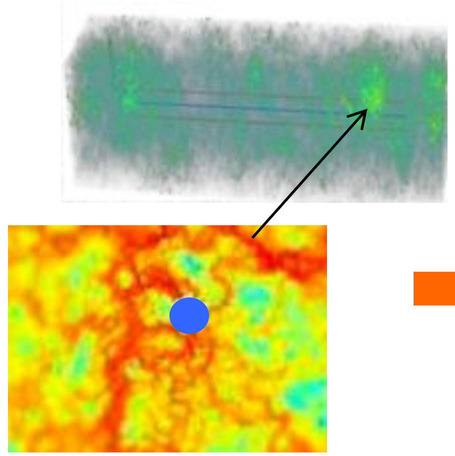


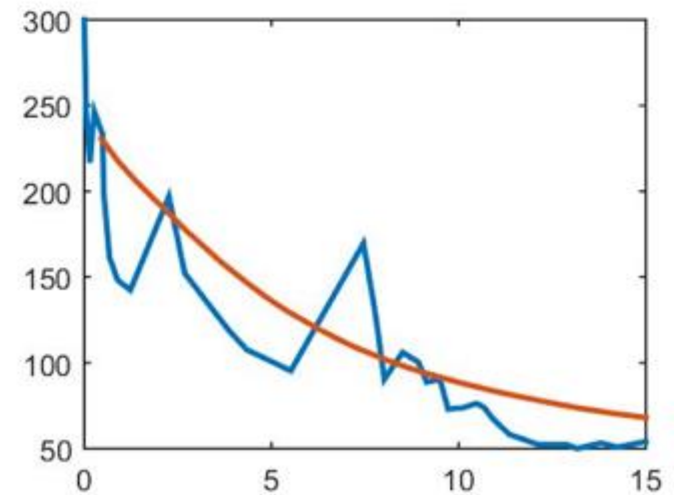




Processes causing injectivity decline

Fines migration
Precipitation
Biofilm
Corrosion plates





Thank you for your attention!

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