


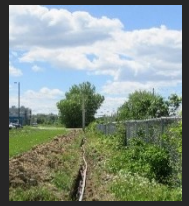

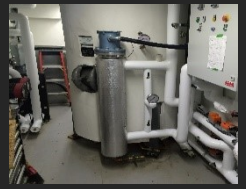


THE IMPACT OF STANDING COLUMN WELL OPERATION ON CARBONATE SCALING

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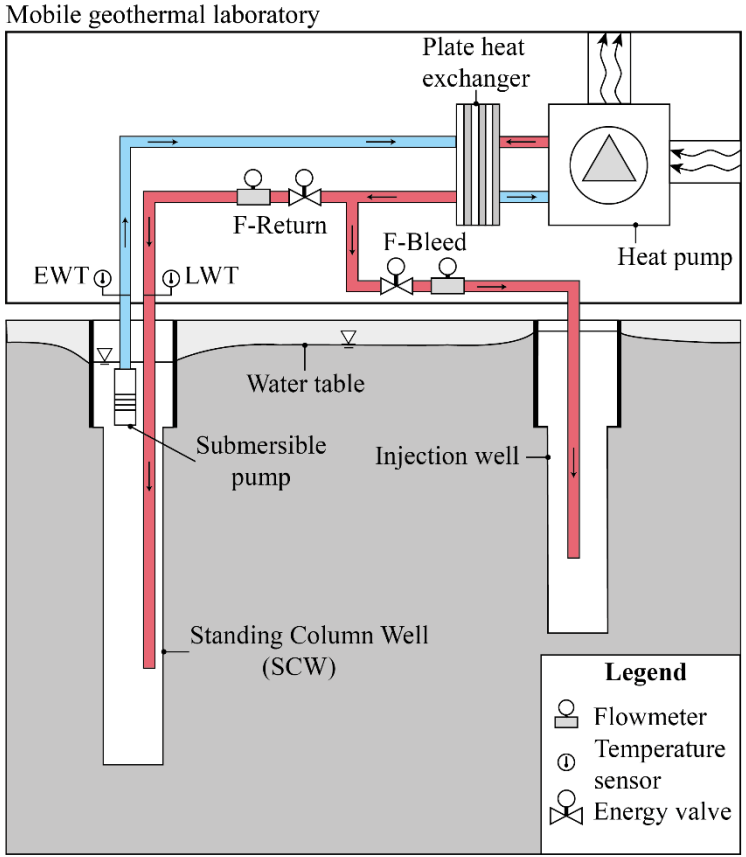
EGU

STANDING COLUMN WELLS



- Standing Column Wells (SCW) demonstrate high heat exchange capacity (Orio et al., 2005) and represent a promising solution to reduce the capital cost compared to classic closed loop, by 49% to 78% (O'Neill et al., 2006).
- In a SCW, groundwater is continuously recirculated in an uncased well, **bringing the water in direct contact with the rock**.
- During peak periods, the SCW can discharge a portion of the outlet water into an injection well. For a fraction of 10% of groundwater flow, it can improve heat transfers by about 2.5 times (Beaudry et al., 2019).
- This technology yields great results in igneous rock, which has limited geochemical reaction (Orio et al., 2005).

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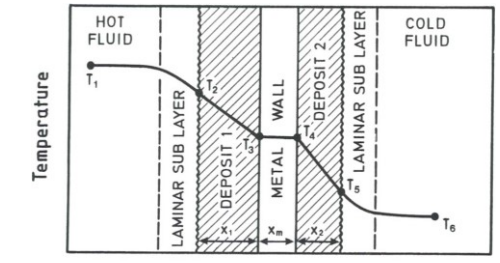
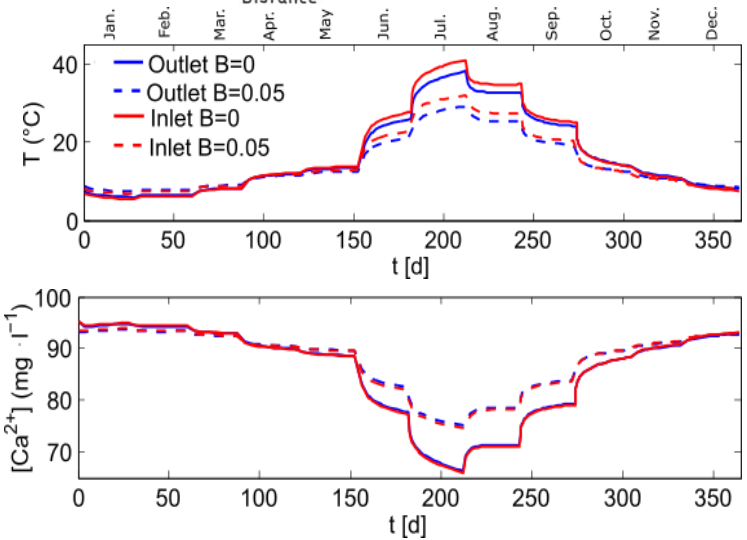
CLOGGING OF STANDING COLUMN WELL



Source : Bott, T. R. (1995). Fouling of heat exchangers. Elsevier.



Source: Eppner, F., Pasquier, P. Baudron, P., 2015. Development of a Thermo-Hydro-Geochemical Model for Low Temperature Geoexchange Applications. COMSOL 2015-Boston.

- The clogging of a geothermal system impacts groundwater flow rate and heat transfer. Indeed, 0.8 mm of scale on the heat exchanger surface results in 19% higher consumption for the heat pump compared to a clean heat exchanger (Rafferty, 2004).
- Geothermal systems are particularly exposed to clogging events. The pumping rate, the variation of temperature and the mixing of water promote several clogging processes which can be physical (Burté, 2018), microbiological (Kim et al., 2017; Lerm et al., 2013) and chemical (Palmer and Cherry 1984; Possemiers et al., 2014).
- Precipitation of calcite is identified as a potential problem when groundwater temperature increases (i.e. when the geothermal system is operated in cooling mode).

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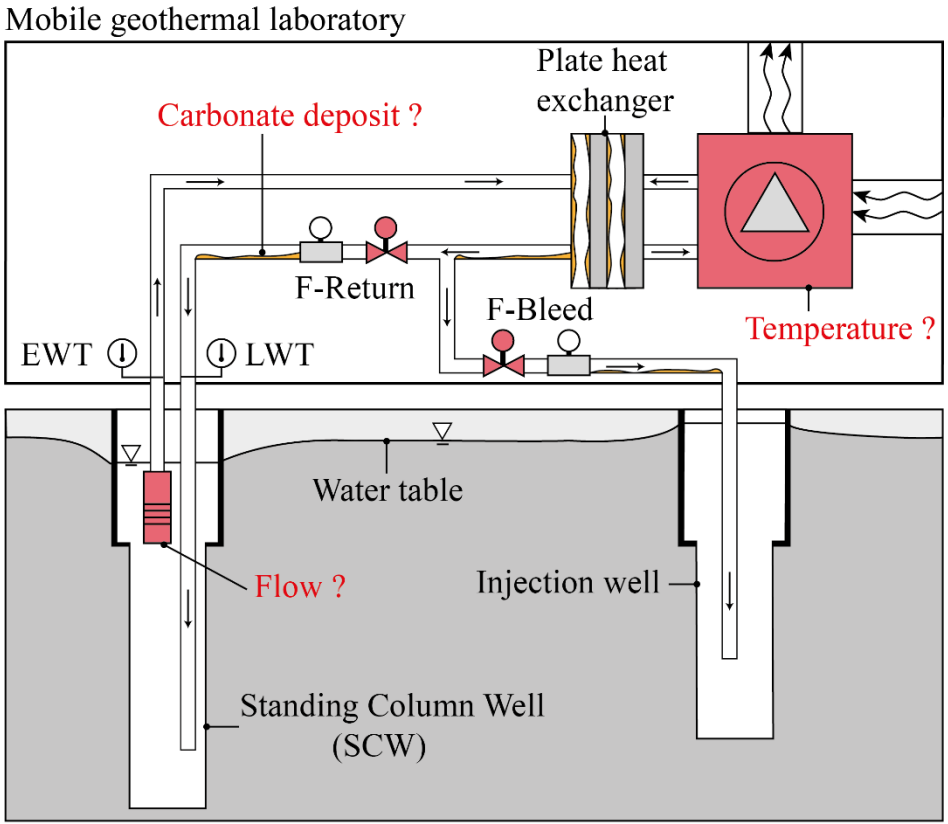
PROBLEMATIC AND OBJECTIVE



Problematic :

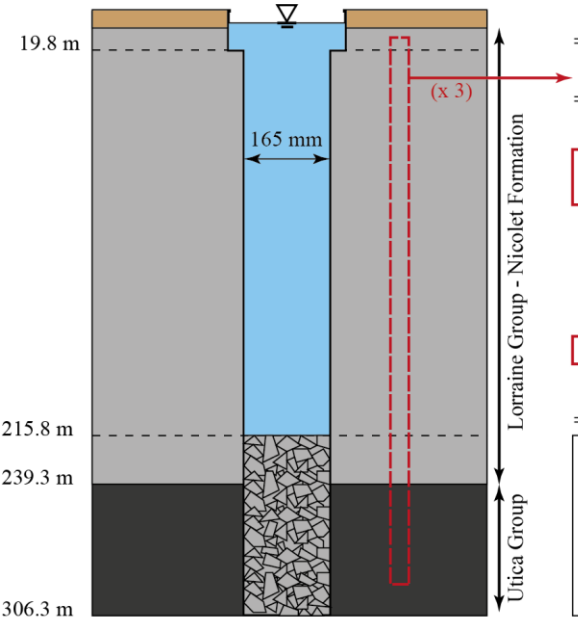
The risk of carbonate scaling is known in the literature to be a hazard during the operation of open-loop systems.

Objective :

To evaluate which operating condition creates the optimal conditions for clogging in standing column well constructed in carbonate aquifer.

EXPERIMENTAL SCW AND PRESENCE OF CARBONATES

Initial rock composition



Stratigraphy adapted form Beaudry et al, 2019

Table 1: Results of geochemical analyze

Elements	Average Value (%)	Standard deviation (n = 3)
SiO_2	51.13	1.24
Al_2O_3	14.02	0.06
CaO	7.79	0.43
MgO	3.02	0.05
Fe_2O_3	6.62	0.08
Na_2O	1.05	0.03
K_2O	2.79	0.08
MnO	0.06	0.00
S	2.62	0.05
Carbon	2.94	0.04
CO_2	7.11	0.21
Total	99.15	0.81

Legend

- Clayey silt
- Mudstone
- Shaly limestone
- Water
- Three random samples

Initial Groundwater composition

Table 2: Groundwater analyze (2016-11-16)

Elements	Value	Unit
Alkalinity total (PNA)	370	mg $CaCO_3$/L
Calcium (Ca)	32.4	mg/L
Magnesium (Mg)	13.0	mg/L
Hardness total	133	mg $CaCO_3$/L
Carbon total	84.9	mg/L
pH	8.1	-

- For this study, a 215.8-m-deep experimental standing column well was monitored over a one-year period using a geothermal mobile laboratory located near Montreal.
- The aquifer is composed primarily of silicates, and its high concentrations in calcium and magnesium make it reactive, since they are the more reactive elements (Appelo and Postma., 2004).
- The initial groundwater composition is also above the recommendations made by Rafferty (2004) to avoid calcium precipitation. This limit is fixed at 80 ppm CaCO3 for hardness.

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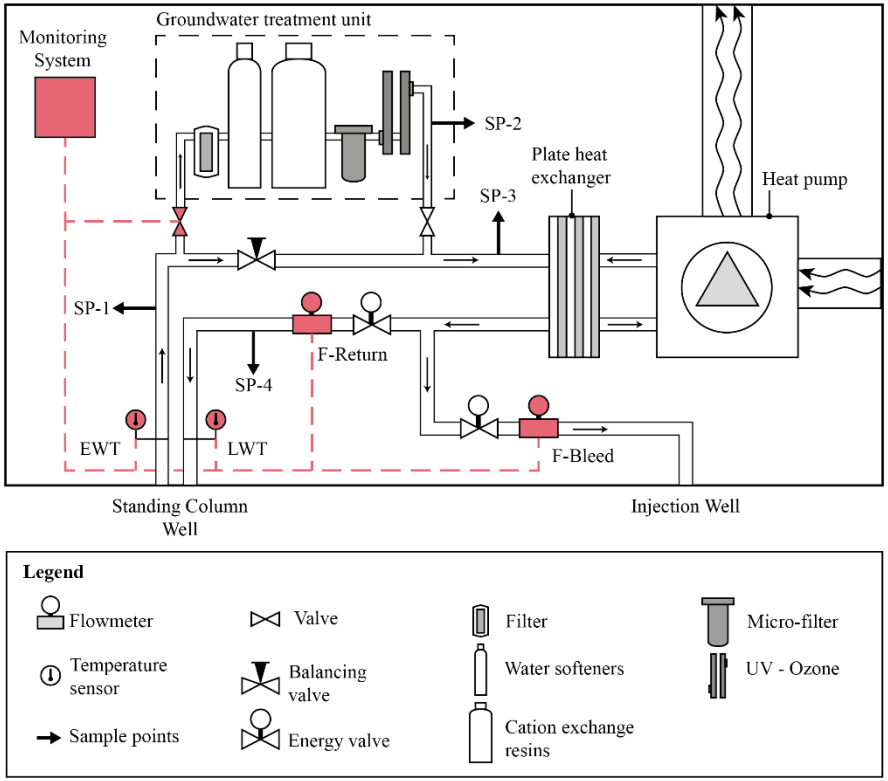
EXPERIMENTAL SCW AND GEOTHERMAL LABORATORY

Mobile geothermal laboratory



Mobile geothermal laboratory

- In operation since 2016
- This study takes place between January 2018 and October 2018 (1 year)
- 51 groundwater samples
- 1 advanced monitoring system (flow, temperature)
- 4 sample points
- 1 solid deposit sample scheduled for the end of this study

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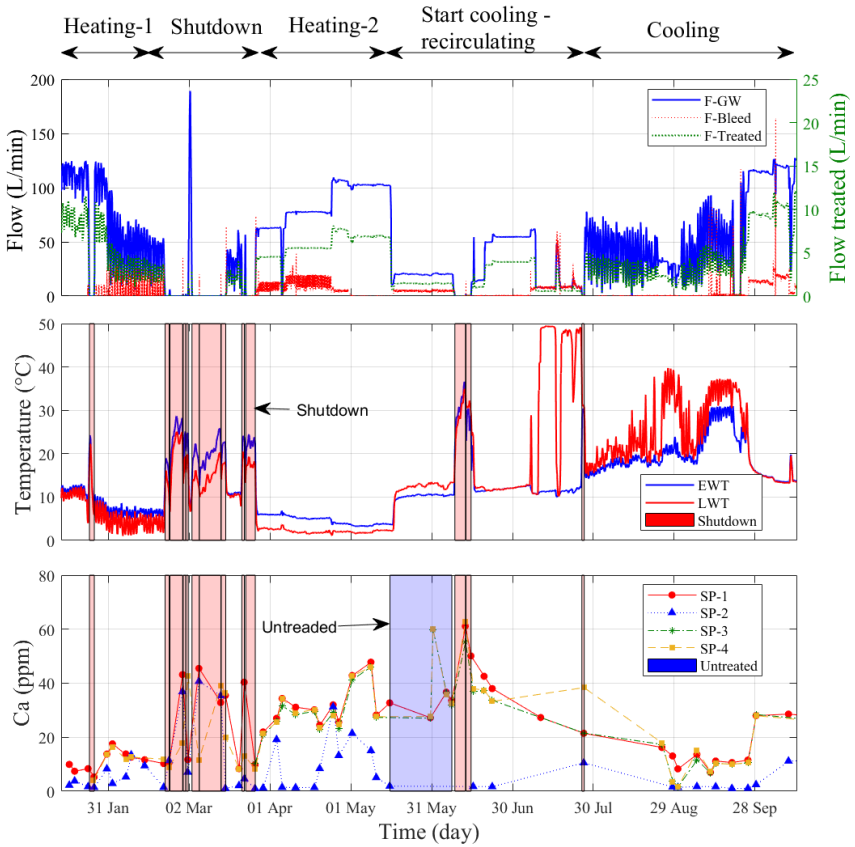
OPERATION – VARIABLES FOR STEPWISE REGRESSION



- This figure presents the operating parameters and the calcium concentrations of water. It presents the major variables used by the stepwise regression performed between the operational parameter and the groundwater calcium concentration (*SP-1*).
- The monitoring system logs the bleeding water flow (*red line*), the total flow (*blue line*) and the treated water flow (*green line*).
- The red boxes represent the periods where the geothermal system was offline. The downtime is used as a variable in the stepwise regression.
- The temperatures LWT and EWT are recorded for each sampling.
- A new variable is created to represent the three modes linked to temperature (the “heating mode”, the “recirculating mode” and the “cooling mode”).

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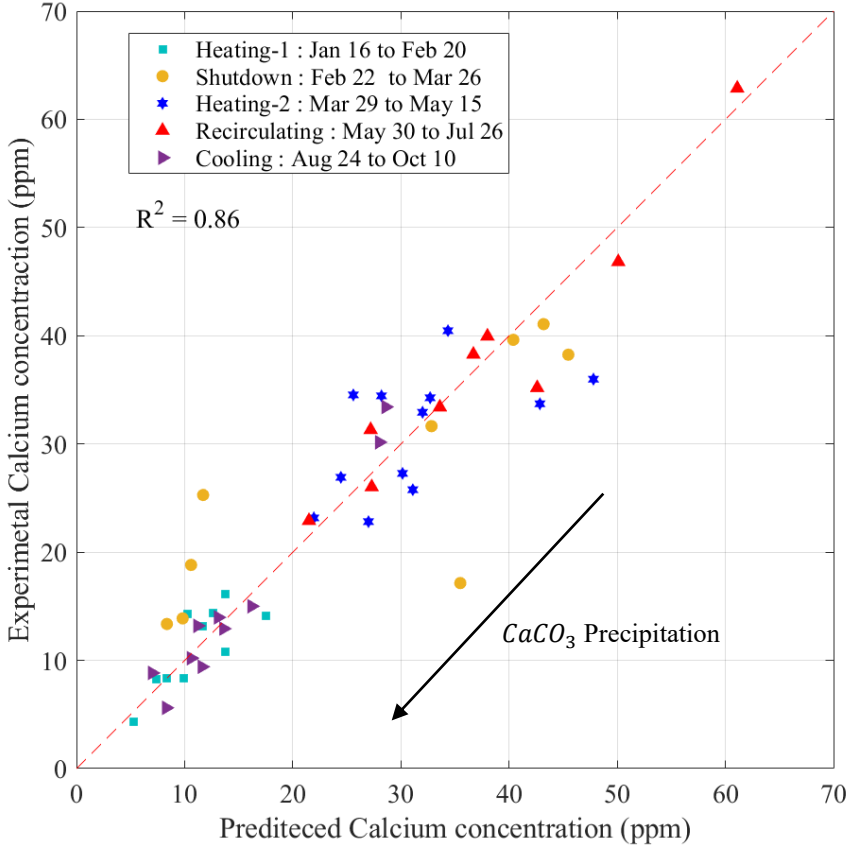
STEPWISE REGRESSION



- The regression found 10 operating variables explaining the calcium concentration, with a correlation factor of 0.86.

The most significant operating variables :

- The pumping groundwater flow has the most impact on groundwater calcium concentration.
- The LWT also influences the calcium concentration. This result is in agreement with the simulation performed by Eppner et al. (2016). Moreover, the transition from recirculation to cooling leads to precipitation of calcium.
- The downtime has a strong impact on the calcium concentration.

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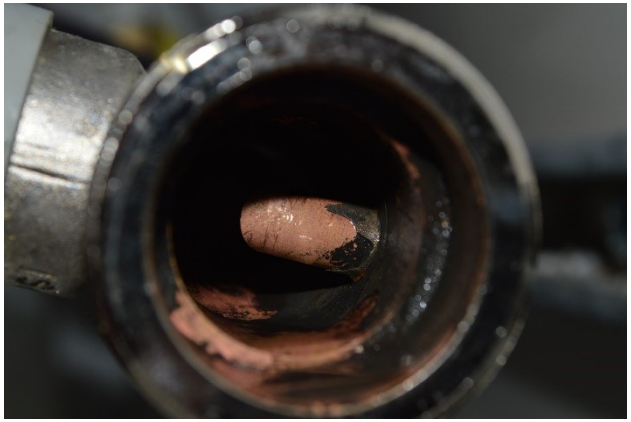
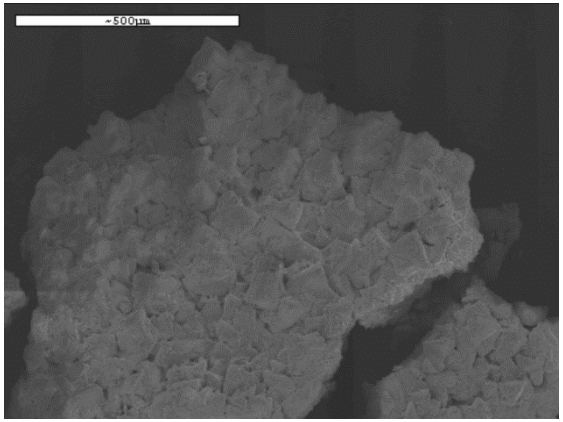
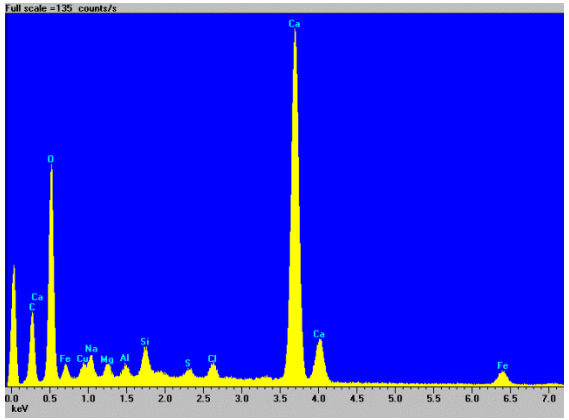
RESULTS AND DISCUSSION







- After two years of operation, two flow sensors were cleaned. The deposit observed is black, solid and reacts with nitric acid.
- The results show that the concentrations in calcium, oxygen and carbon are highest in the deposit.
- This chemical composition and the mineral structure indicate a deposit composed of calcite. The X-ray had a score of 81 for the calcite.
- Nevertheless, the effect of the scaling on the system's operation was limited to the flowmeters.

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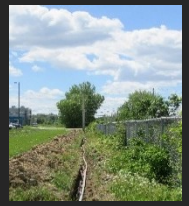
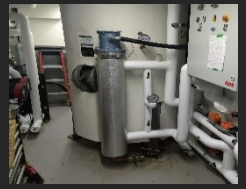
CONCLUSION

- This study explored the impacts of standing column well operation on the stability of calcite. These impacts are limited to the precipitation of calcite in the flowmeters.

- Future works will focus on the impacts of these deposits on thermal exchanges, on finding a way to avoid their formation through the use of a water treatment system and on strategies to limit the impacts of system downtimes.



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