Focus on Geothermal

Energy for the Weekend

WEBINAR

13 January 2023
14.00 (CET)

Solute Geothermometry - Applications and Development

JOCHEN SCHNEIDER
ENERCHANGE

LARS YSTRÖM

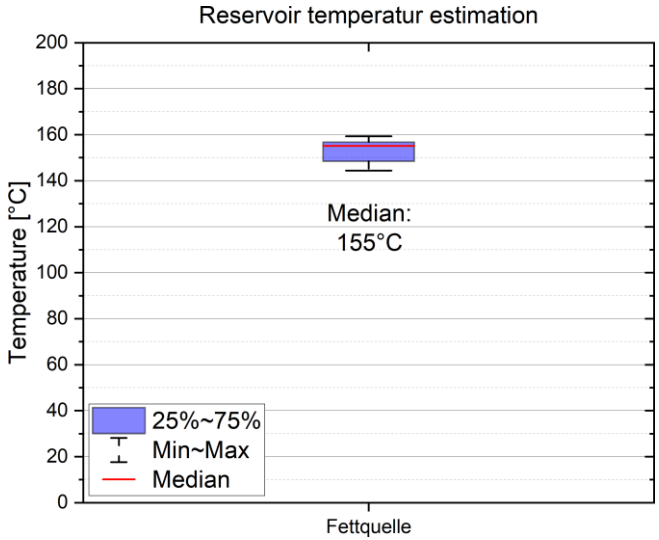
THINK GEOENERGY

ENERCHANGE
agentur für erneuerbare energien

Solute geothermometry

- Solute geothermometry is able to predict the reservoir temperature using the chemical composition of a geothermal fluid
- It is used as a tool for geothermal exploration

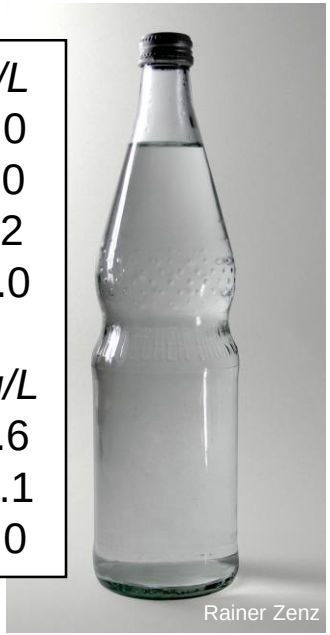
de.wikipedia.org/wiki/Thermalquelle



Basic assumption

- Reservoir mineral composition and the geothermal fluid are in chemical equilibrium
- Temperature-driven rock – water interaction saturates the fluid with elements of the reservoir rock
- The chemical equilibrium is *mostly* preserved while the fluid ascends to the surface

Cations:	*mg/L*
Na^+	20.0
K^+	2.0
Mg^{2+}	18.2
Ca^{2+}	97.0
Anions:	*mg/L*
Cl^-	4.6
SO_4^{2-}	14.1
HCO_3^-	415.0



de.wikipedia.org/wiki/Normbrunnenflasche

Applications

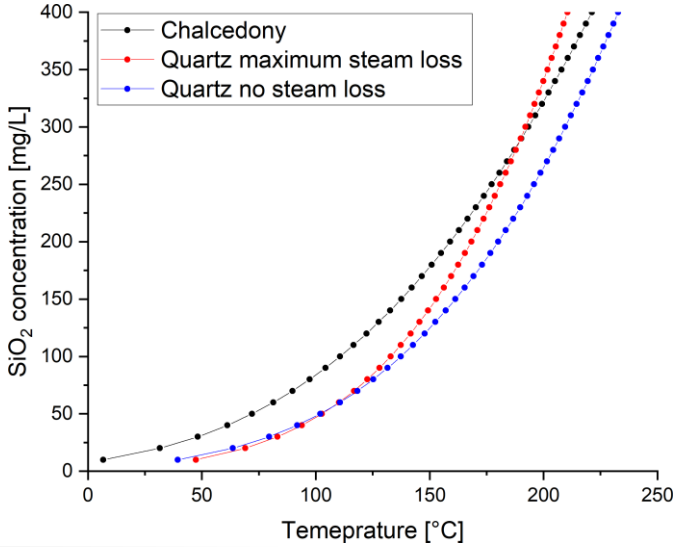
- Conventional geothermometer
- Multicomponent geothermometer
- Artificial neural network geothermometer

Conventional geothermometer

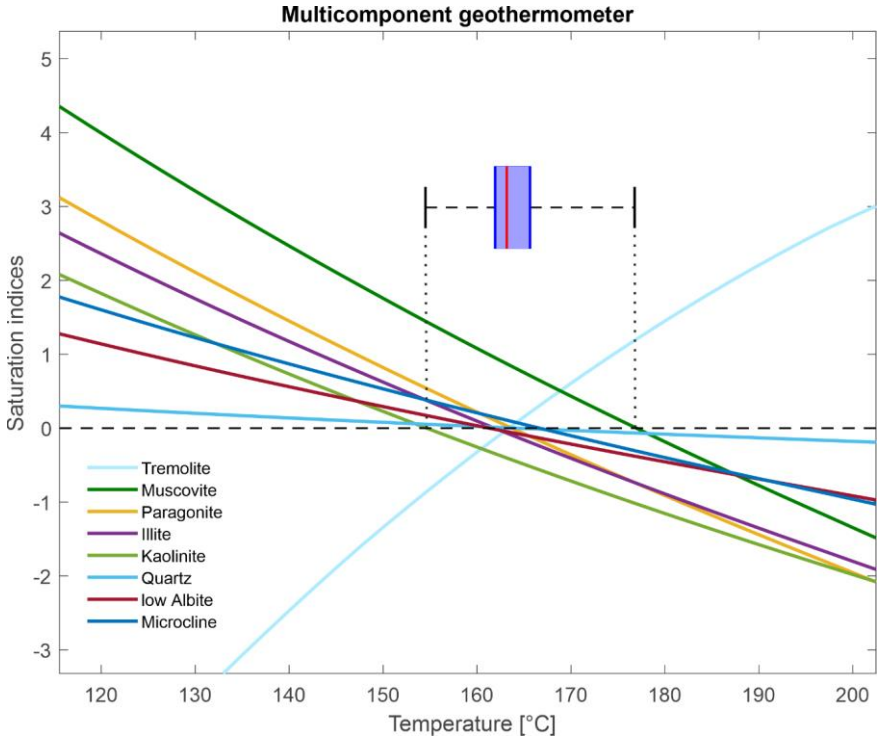
- Based on element concentration and ratios
- Easy to use
- Partially high errors and uncertainties

Geothermometer	Equation
Quartz – no steam loss	$t°C = \frac{1309}{5.19 - \log SiO_2} - 273$
Quartz – maximum steam loss	$t°C = \frac{1522}{5.75 - \log SiO_2} - 273$
Chalcedony	$t°C = \frac{1032}{4.69 - \log SiO_2} - 273$
Na-K (Fournier)	$t°C = \frac{1217}{\log (Na/K) + 1.483} - 273$
Na-K (Truesdell)	$t°C = \frac{885.6}{\log (Na/K) + 0.8573} - 273$
Na-K-Ca	$t°C = \frac{1647}{\log (Na/K) + \beta[\log(\sqrt{Ca}/Na) + 2.06] + 2.47} - 273$
	$\beta = 4/3$ for $t < 100°C$; $= 1/3$ for $t > 100°C$

Kharaka & Marnier 1989



Multicomponent geothermometry



- Using multiple mineral phases as geothermometer
- Plotting the saturation curves of minerals against temperature
- Temperature estimation is given when mineral phase is in equilibrium (*SI* = 0; intersecting dashed line)

$$SI(T) = log\left(\frac{IAP}{K(T)}\right)$$

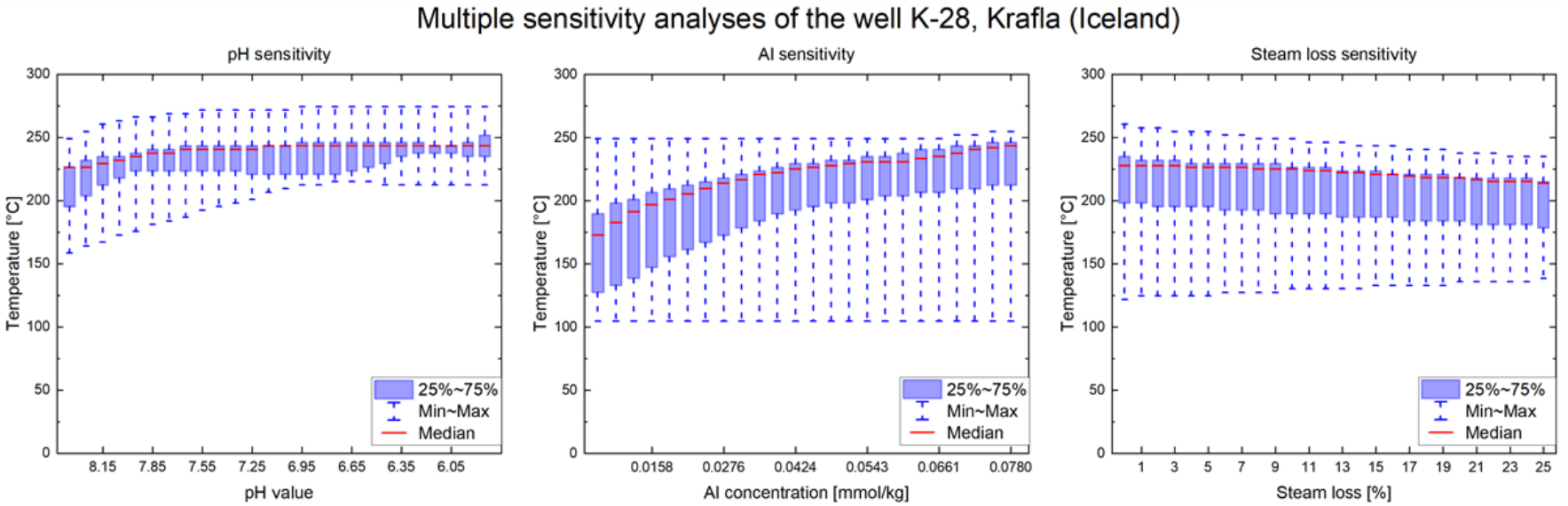
SI = saturation index, *T* = temperature, *IAP* = ion activity product, *K* = thermodynamic equilibrium constant

Multicomponent geothermometry

- Statistically more robust and precise than conventional geothermometer
- Uncertainties: Reservoir mineralogy and secondary processes
- Fluid is vulnerable to secondary processes while ascending to the surface, disturbing the equilibria of mineral phases
  - Boiling or phase segregation
  - Mixing or dilution
  - Precipitation of mineral phases

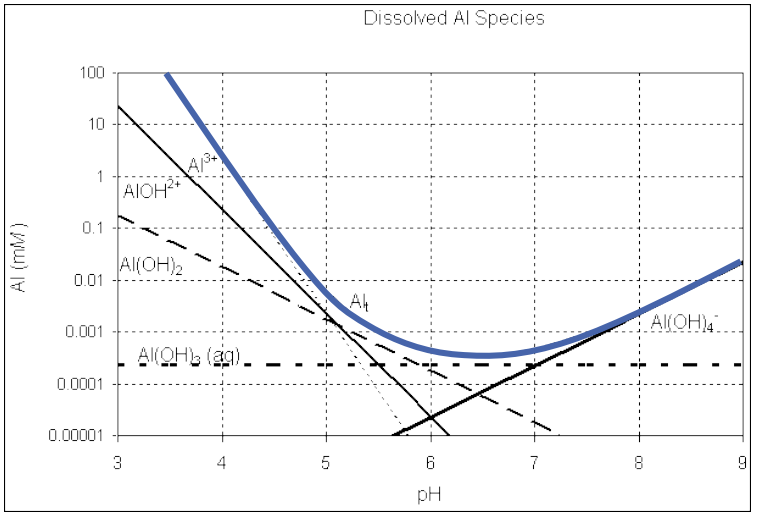
Uncertainties

- Performing sensitivity analyses to reconstruct reservoir conditions



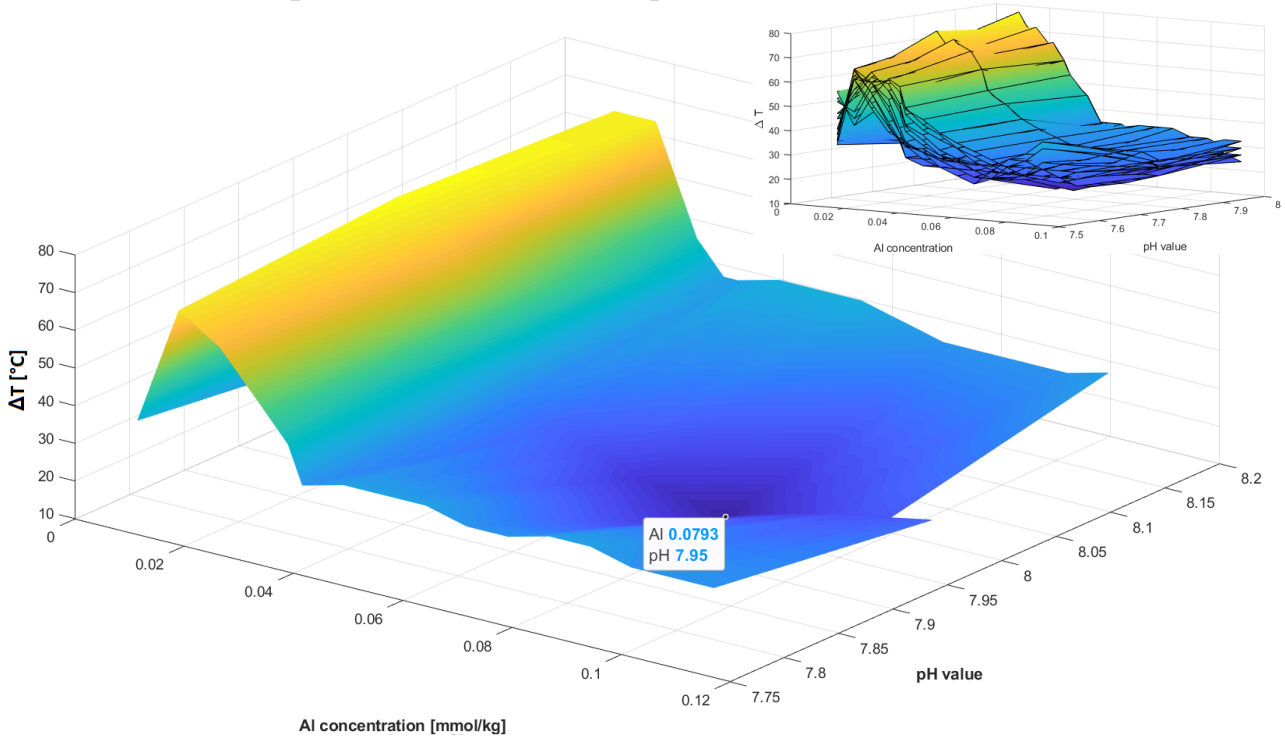
Sensitive parameters

- pH value:
  - Uncertainties due to CO_2 and H_2S buffering, temperature dependence, steam loss, and measuring errors (field / laboratory)
- Aluminium concentration:
  - Uncertainties due to pH changes, forming and precipitation of aluminium complexes, fluid sampling (filter), measurement close to detection limit
- Steam loss / dilution:
  - Uncertainties due to overall element concentration errors



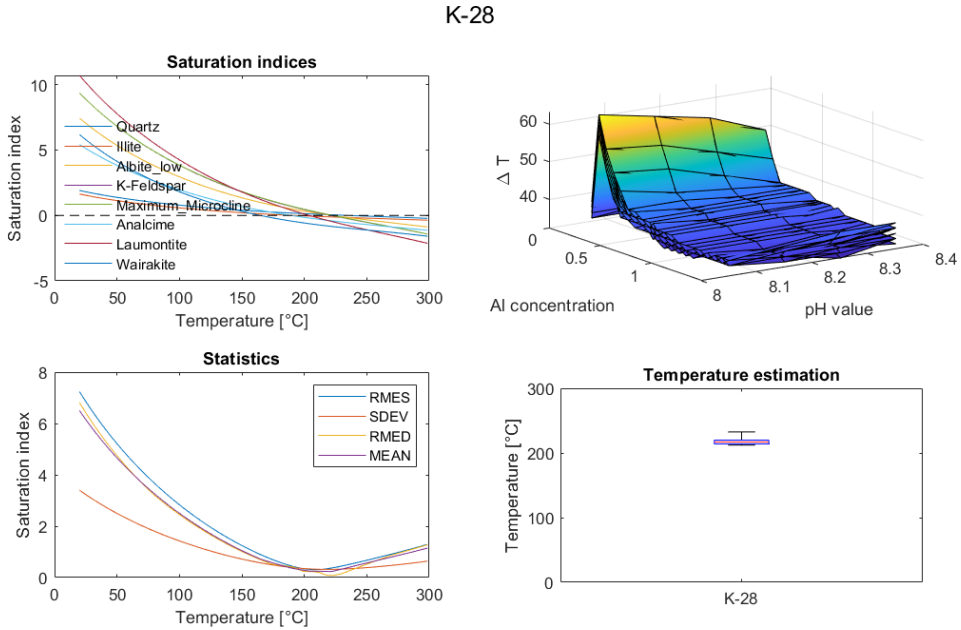
Driscoll & Schecher 1990

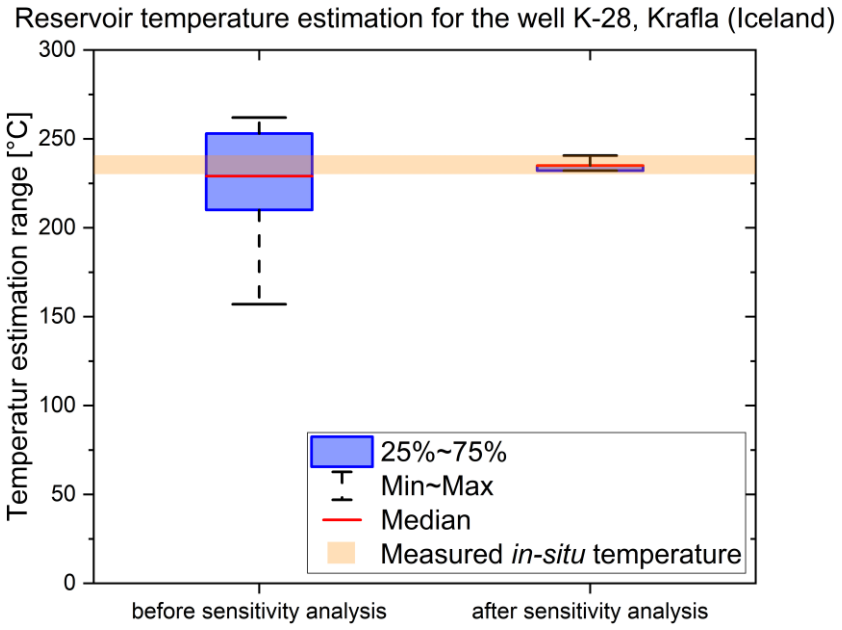
Interdependent optimisation process



- Global minimum: Al concentration 0.079 mmol/kg, pH 7.95, and 14% steam loss

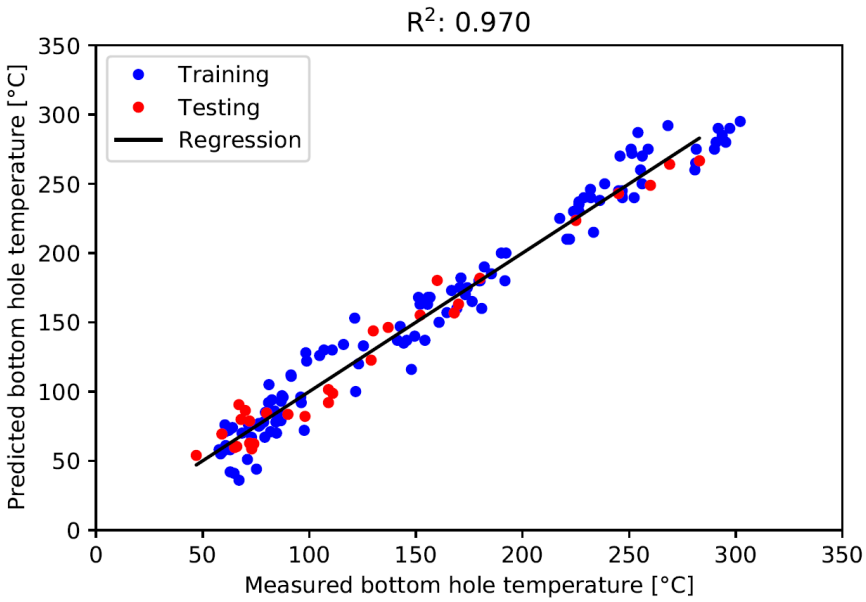
Result given by MulT_predict

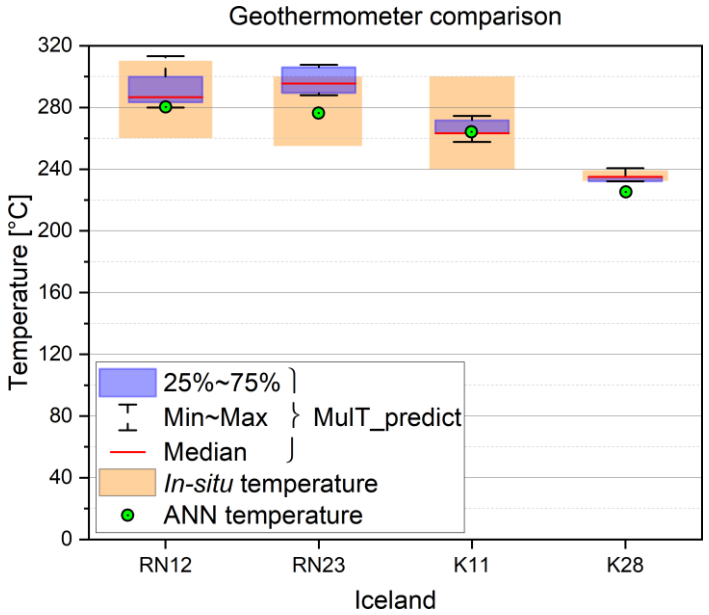




Artificial neural network geothermometer

- A supervised multilayer perceptron, which is trained with high-quality data
- Validation and testing of the network to minimise the error





Sum up

- Conventional geothermometer
  - Simple element concentration and ratios but partially high errors due to uncertainties
- Multicomponent geothermometer
  - More robust and precise by using mineral saturation indices but prone to secondary processes (sensitive parameters), which can be optimised
- Artificial neural network geothermometer
  - Computational efficient and precise but needs large amount of high-quality data