Deep learning and geochemical modelling as tools for solute geothermometry

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Motivation

- Solute geothermometry is an economical green field exploration tool to estimate reservoir temperatures from fluid composition
- Geochemical modelling is able to reconstruct in-situ conditions of the reservoir resulting in more precise temperature estimations
- Artificial neural networks are able to learn complex chemical coherences for reservoir temperature estimation

Solute geothermometry

- Solute geothermometry is able to predict the reservoir temperature using the chemical composition of a geothermal fluid
  - 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
  - Method:
    - Element ratios as well as saturation state of mineral phases contain information about the temperature of the reservoir
  - Input:
    - Standard geochemical water analysis of major cations and anions (Na, K, Ca, Mg, Cl, S, C, Si) as well as trace elements (Al, Fe)
    - Sampling parameters of the fluid (temperature, pressure, pH)

MultT_predict

- Minimisation of equilibrium temperature distribution using interdependent optimisation processes

Example of the output of MultT_predict

- Krotscheck and 2D

Conclusion

- Geochemical modelling: Statistically robust and precise temperature estimations via interdependent optimisation processes
- Artificial neural network: Computational efficient geothermometer, capable of handling large amount of data
- High accuracy: Calculated temperatures of both methods match measured in-situ temperatures very well

Statistical evaluation

- MultT_predict:
  - Multicomponent geothermometer with integrated optimisation process
  - Using saturation indices of multiple mineral phases to estimate the reservoir temperature
  - Interdependent parameter adjustment reconstructing equilibrium state of reservoir conditions
  - Converging equilibrium temperatures until a global minimum is reached
  \[ S(T) = \log IAP \frac{K_i(T)}{K_j} \]
  - Equilibrium state for SI = 0
  - IAP: measured ion activity product
  - K_i: mineral solubility product

- Artificial neural network:
  - Minimising cross-entropy losses by adjusting weights within neurons fitting input parameters to the target value

Artificial neural network

- A supervised multilayer perceptron is trained with high-quality data
- Validation and testing of the network minimising the error without overfitting the neural network

Artificial neural geothermometer

- [R^2: 0.970]
- [Training, Testing, Regression]

Publications