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RESEARCH FOR GRAND CHALLENGES

Geothermal Energy Systems

Estimating the Static Formation Temperature Using the Drilling and Logging Data of the RN-15/IDDP-2 Well in Iceland

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Background

- The RN-15/IDDP-2 deep geothermal well of the DEEPEGS project at Reykjanes, Iceland, is a demonstration site for EGS geothermal research.
- The RN-15 well with 2.5 km depth is the drilling start point for the IDDP-2 well, which reaches to a final depth of 4,659 m after 168 days' drilling.
- The well was drilled under continuous injection. A complete loss of circulation fluid occurred below 3,200 m.
- The measured temperature at well bottom was 426°C, the fluid pressure 340 bars, which confirmed supercritical reservoir condition.
- Estimation of the static formation temperature around the well is one of the scientific tasks of the project.

Motivation and Objectives

- Temperature logs can be used to estimate the static formation temperature (SFT) and to characterize the fluid loss along the borehole.
- The temperature distribution of the wellbore relies on various factors such as wellbore flow conditions, fluid losses, well layout, heat transfer mechanics, etc.
- The numerical modeling approach offers the capability to investigate the influencing parameters/uncertainties in the interpretation of borehole logging data.
- Questions related to some specific logging conditions in the high-temperature environment, such as whether simple temperature correction methods are still applicable to obtain accurate SFT estimates using non-shut-in data, need to be answered.

Synthetic Simulation Scenarios for the RN-15/IDDP-2 Well

Model setup

- 2D axis-symmetric domain, multiple casings and cementing programs included, injection both into the drill pipe and the annulus
- Mesh dimension 4589 m x 50 m is determined from pre-run tests
- Scenario one: 7 °C cold water injection, Q_1 (15 L/s) in drill pipe, Q_2 (45 L/s) in the annulus for 10 days; then shut-in in the drill pipe (Q_1= 0 L/s), reduced flow in the annulus (Q_2= 0-5 L/s)
- Scenario two: 7 °C cold water injection, total flow rate ($Q_1 + Q_2$) varied between 5-50 L/s; different fluid losses from annulus at 3.35 km depth (0-100%)

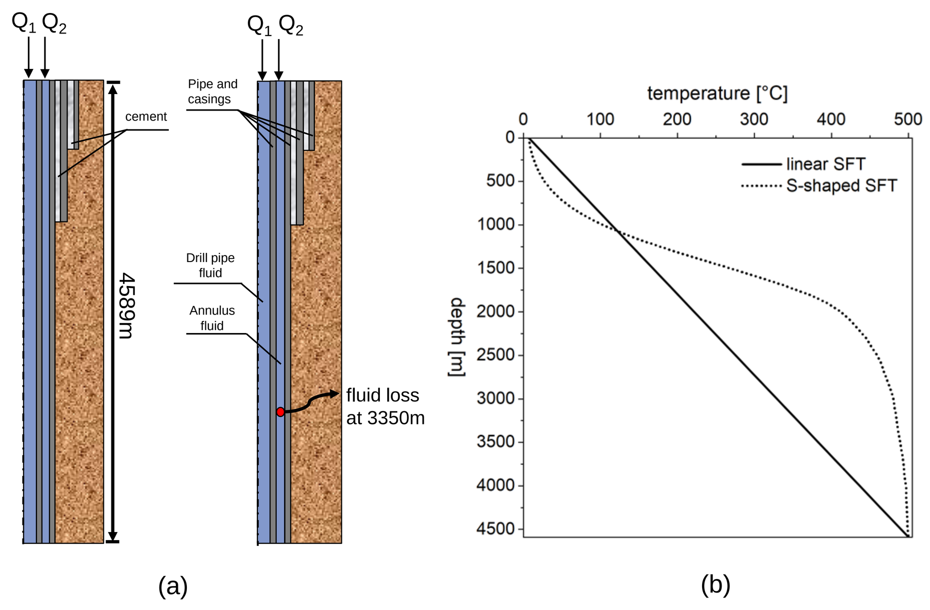

Figure 1: (a) Schematic of two simulated scenarios: co-axial flow without the fluid loss (left), co-axial flow with the fluid loss at 3.35 km depth (right); (b) two static formation temperature profiles assumed for each of the scenarios.

Simulation results and analysis

Scenario one

- Temperature measurements of the drill pipe fluid are used to estimate SFT using the Horner-plot method

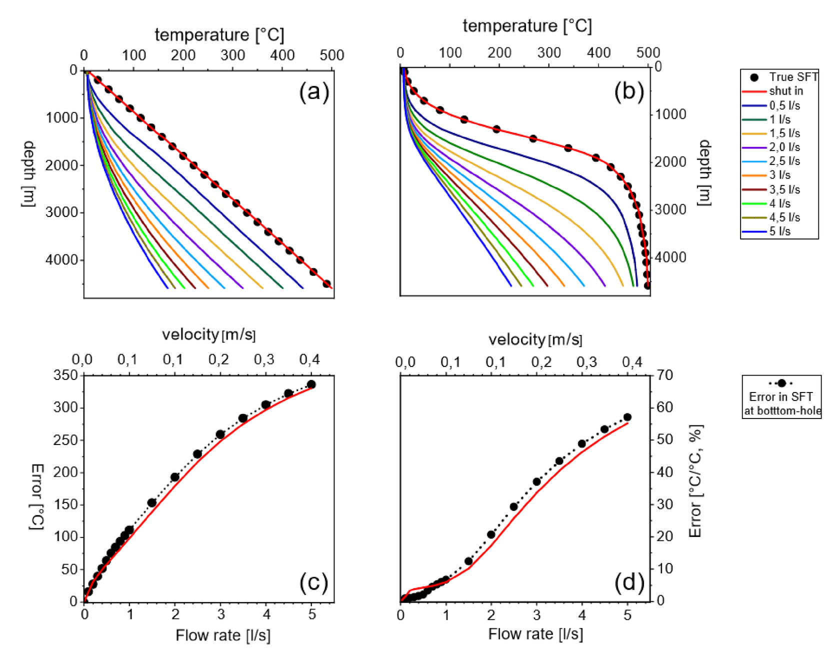

Figure 2: SFT estimates under different flow rates in the annulus during the thermal recovery when assuming (a) a linear SFT profile and (b) S-shaped SFT profile (black dots represent the true SFTs, red lines represent the SFT estimates under real shut-in conditions). (c) Errors in SFT estimates for the linear-shaped SFT profile case. (d) Errors in SFT estimates for the S-shaped SFT profile case.

- Significant under-estimation errors in SFT using non-shut-in temperature even under very low cooling flow rate (24 °C and 74 °C at bottom-hole for a flow rate of 0.7 L/s for the linear- and S-shaped SFT, respectively)

Scenario two

- Non-monotonic relationship between the increase of the temperature gradient and the percentage of fluid loss
- Temperature gradient increase depends on the flow rate, the percentage of fluid loss and the lateral heat transfer between the fluid and the rock formation
- The impact of the flow rate and the lateral heat transfer on the temperature gradient increase can be ignored under low fluid losses (< 30%) or relatively higher flow rates (> 20 L/s)

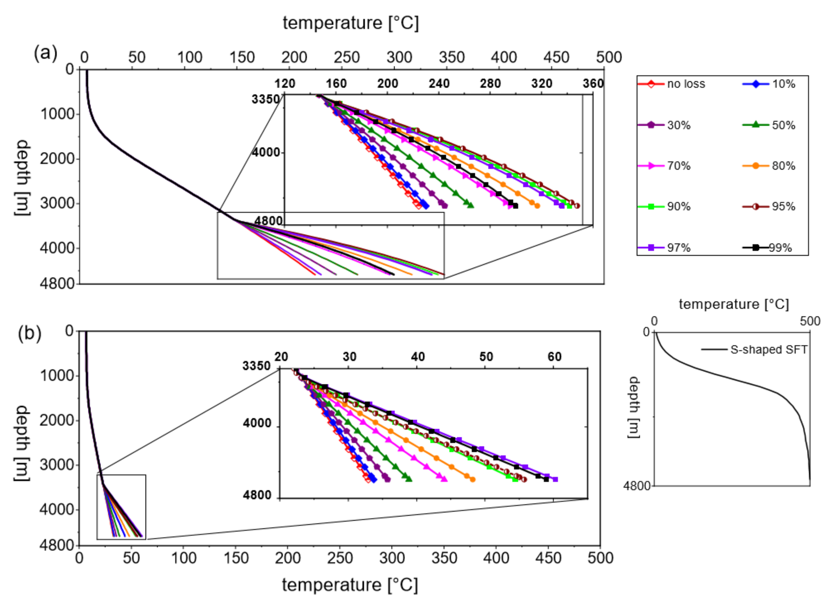

Figure 3. The generated temperature logs for the S-shaped SFT profile case considering different percentages of fluid loss at a depth of 3.35 km. (a) Results for the injection flow rate of 5 L/s. (b) Results for the injection flow rate of 50 L/s.

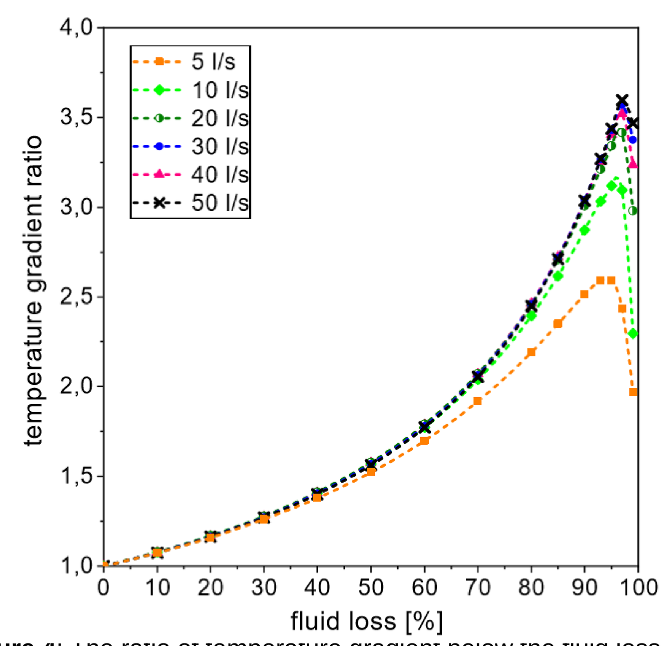

Figure 4: The ratio of temperature gradient below the fluid loss zone (3.35 km depth) to the gradient above the fluid loss zone versus the percentage of fluid loss (S-shaped SFT profile is assumed).

Simulations Using Real Drilling Data

- Temperature log simulation using integrated drilling data such as injection flow rate, logging speed, static formation temperature (estimated and provided by ISOR)
- The simulated fluid temperature profile is compared with data from one temperature log, which lasted two hours (Figure 5)
- The compensation between the measured and simulated temperature log varies along the well depth which may due to several uncertainties (rock heat conductivity, heat capacity, SFT, etc.)

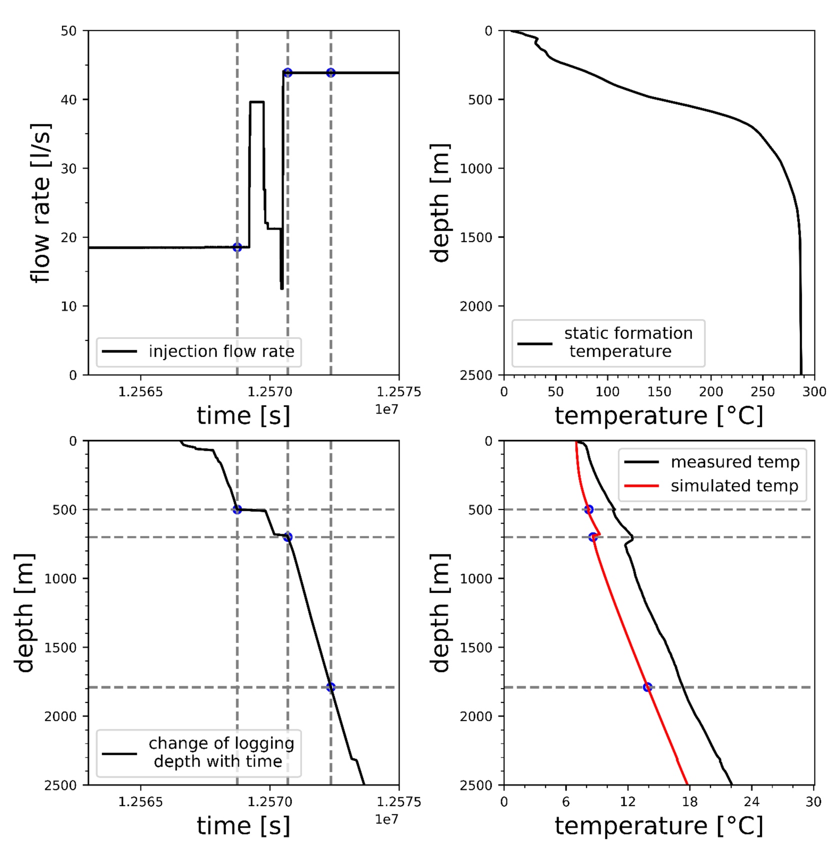

Figure 5: Input data and simulation results: flow variation with time before and during the logging (upper left); static formation temperature profile until 2.5 km depth (upper right); change of the logging depth with time (lower left). Comparison of the logged temperature and the simulated temperature along the well depth (lower right).

Conclusions and Perspective

- Applying simple temperature correction methods on the non-shut-in temperature data could lead to large errors for SFT estimation for the RN-15/IDDP-2 well even at very low injection flow rates.
- The percentage of fluid loss can be unambiguously quantified from temperature logs when it is below 70%.
- The simulation of temperature logs of the RN-15/IDDP-2 well using real drilling data can be a good test example to demonstrate the capability of the numerical tool to account for complex logging conditions, e.g., varying flow, changing logging speed, etc.
- Work is underway to use three dynamic temperature logs together to constrain the far-field formation temperature.

Acknowledgements

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