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Evaluation of the Drilling and Logging Data of the RN-15/IDDP-2 Well in Iceland for Formation Temperature and Feed Zone Analysis

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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 as well as the fliud loss in 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%)

Simulation results and analysis

Scenario one

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

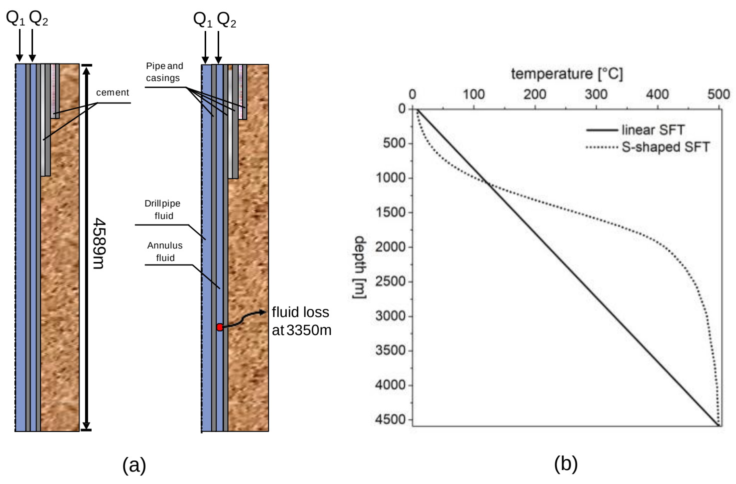

Figure 1: (a) Schematic of two simulated scenarios: co-axial flow without the fluid loss (left), co-axial flow with the fluid loss at 3.35 km depth (right); (b) two static formation temperature profiles assumed for each of the scenarios.

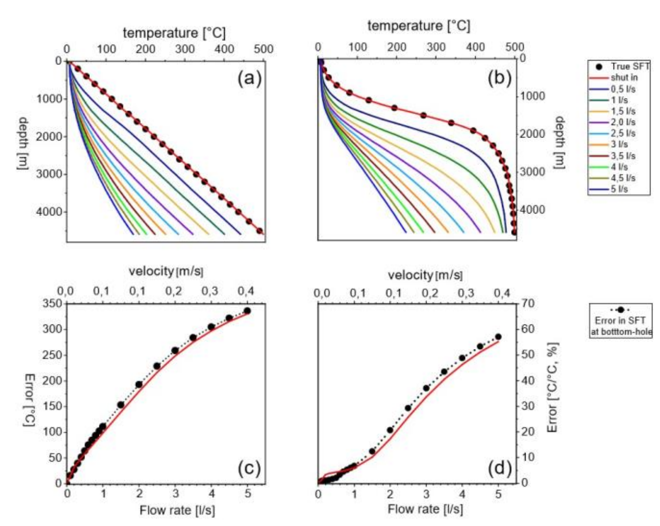

Figure 2: SFT estimates under different flow rates in the annulus during the thermal recovery when assuming (a) a linear SFT profile and (b) S-shaped SFT profile (black dots represent the true SFTs, red lines represent the SFT estimates under real shut-in conditions). (c) Errors in SFT estimates for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

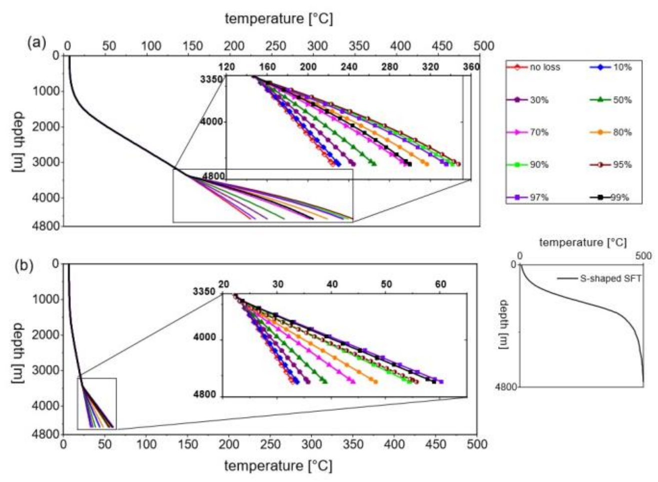

Figure 3. The generated temperature logs for the S-shaped SFT profile case considering different percentages of fluid loss at a depth of 3.35 km. (a) Results for the injection flow rate of 5 L/s. (b) Results for the injection flow rate of 50 L/s.

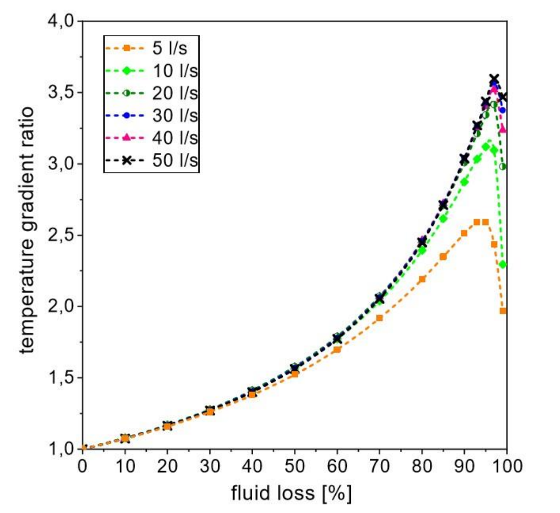

Figure 4: The ratio of temperature gradient below the fluid loss zone (3.35 km depth) to the gradient above the fluid loss zone versus the percentage of fluid loss (S-shaped SFT profile is assumed).

Simulations Using Real Drilling Data for Formation Temperature and Feed Zone Analysis

- Temperature log simulated using integrated drilling data such as injection flow rate, logging speed, static formation temperature (prior-know until 2.5 km) (Figure 5)
- The change of well depth tiwth time below 2.5 km is modelled according to the drilling progress report
- Major fluid loss zones at 3400m, 4200m, 4375m are considered in the model

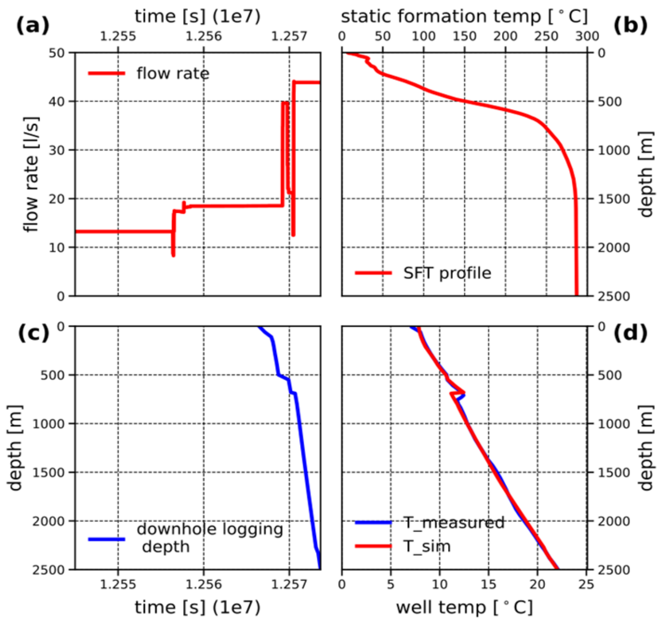

Figure 5: Illustration of the input data and results of a standard wellbore simulation. (a) Long-term injection flow rate history (visualized only for 6 hours before the logging and during the logging); (b) static formation temperature profile until 2.5 km depth provided by the Iceland Geosurvey; (c) changing of the downhole logging tool position with time; (d) simulated temperature profile (red line) and measured temperature profile (blue line).

- The SFT profile and the fluid loss amount at these feed zones are estimated using grid search method by fitting the temperature log
- Results of two-layer inversion

  2.5–4.2 km: ~125°C/km

  4.2–4.5 km: ~66°C/km

  SFT at 4.5 km reaches 520°C
- The most significant fluid loss at 3.4 km is 90%, cumulated loss ratio at 4.2 km and 4.375 km are 93% and 98%, respectively.

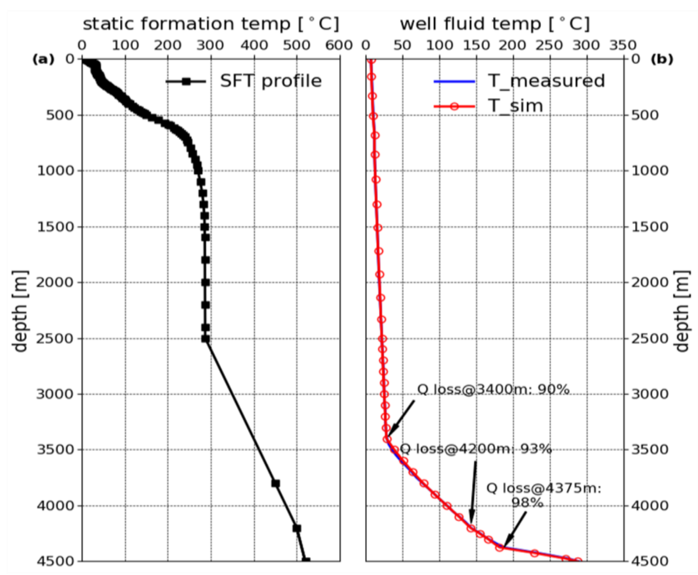

Figure 6: (a) SFT profile estimated well RN-15/IDDP-2/DEEPEGS using temperature log of January 3rd, 2017. (b) temperature measurementuntil 4500m around ents (blue line) and simulated fluid temperature (red circles) with fluid loss (ratio of total fluid loss to the total injection flow rate Q in percentage) marked at the corresponding feed zones.

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