ANALYSIS OF IMAGE AND DRILLING LOGS FOR FORMATION INSTABILITY UNCERTAINTY ANALYSIS

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STUDENT TECHNICAL CONFERENCE

Introduction

Logging while drilling (LWD) tools are used to gather drilling and formation data during the drilling process of a well. LWD e.g. enables to log resistivity, caliper or pressure data. Azimuthal logs provide images of the borehole wall which can be utilized to detect breakout sections of the wellbore. One challenge with the interpretation of breakouts are the unknown borehole conditions (e.g. pressure) between a bit and an imaging sensor passing a zone of interest ("time window"). To ensure a safe and effective drilling process the borehole pressure has to be within a specified pressure window which is defined by the collapse and fracture pressure.

Objectives

1. Development of a software prototype in the Baker Hughes proprietary software JewelSuite to display and analyze image and drilling logs.
2. Analysis of wellbore stability mechanisms (e.g. borehole breakouts, drilling induced fractures) by utilizing different image logs (e.g. resistivity, density or caliper).
3. Characterization of pressure and temperature variations in the time frame until the imaging sensor reaches the drilled zone of interest→ Correlation to wellbore stability occurrences and relevant parameters (e.g. breakout width).

1) Theoretical background

- Borehole breakouts (Tingay et al., 2008):
  - Occurrence of breakouts when stresses around the borehole are higher than the stress required to generate compressive failure of the borehole wall (Figure 1)
  - Orientation parallel to minimum horizontal stress σ_h
- Drilling induced fractures (DIFs; Tingay et al., 2008):
  - Occur when stresses around a borehole are lower than the tensile strength of the borehole wall (Figure 1)
  - Orientation parallel to maximum horizontal stress σ_H

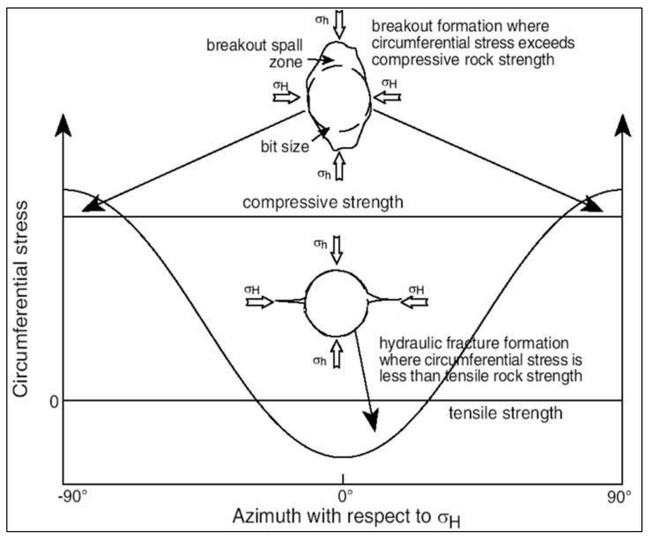
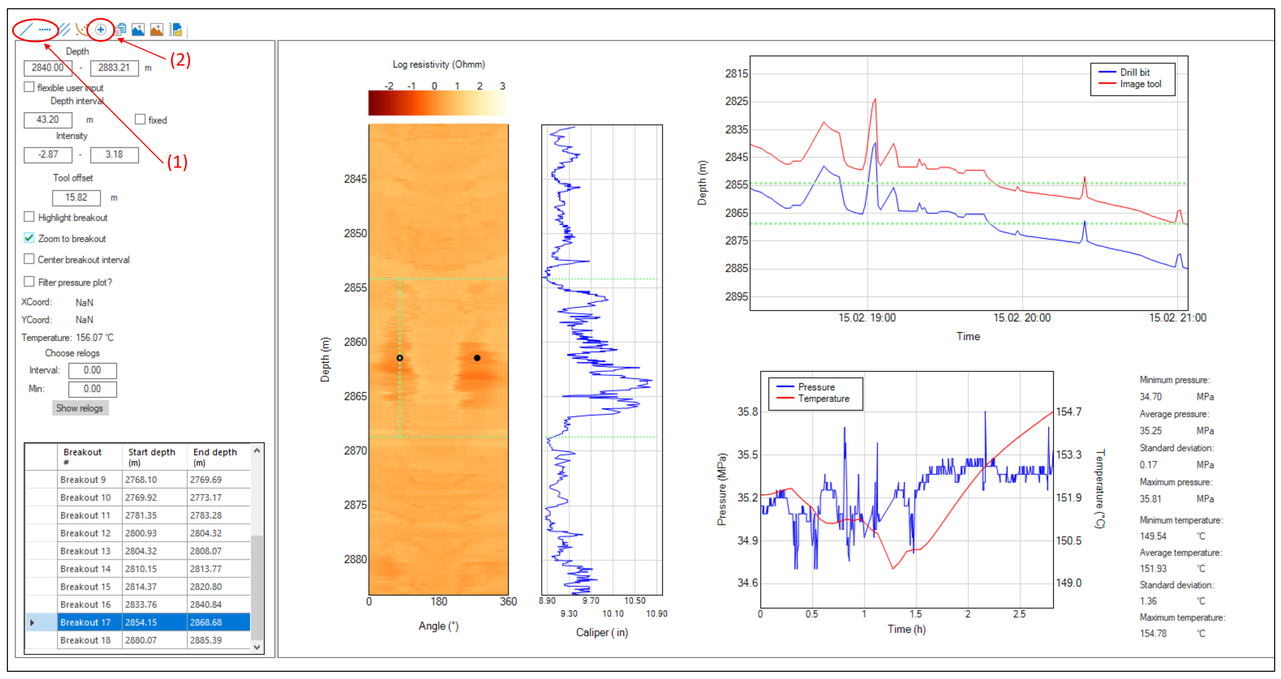


Figure 1: Schematic cross-sections of borehole breakout and DIF (Hillis and Reynolds, 2000)

2) Software development

- Basis for development: Previously developed MATLAB prototype
- Programming language: C# (development environment: Microsoft Visual Studio)
- Major challenge: Visualization of image log data (no implementation in the JewelSuite framework available) → pixel-by-pixel realization
- Design: Figure 2 shows the main graphical user interface of the software divided into:
  - Left Panel: multiple user controls to manipulate the displayed data in the plots
  - Right Panel: plots for image, caliper, bit and image tool depth as well as time based pressure and temperature data
- Extras: relogs of image data, information about picked borehole instability occurrences



Breakout #	Start depth (m)	End depth (m)
Breakout 9	2768.10	2769.69
Breakout 10	2769.92	2773.17
Breakout 11	2781.35	2783.28
Breakout 12	2800.93	2804.32
Breakout 13	2804.32	2808.07
Breakout 14	2810.15	2813.77
Breakout 15	2814.37	2820.80
Breakout 16	2833.76	2840.84
Breakout 17	2854.15	2868.68
Breakout 18	2880.07	2885.39

Figure 2: Display of developed JewelSuite software prototype showing a picked breakout section (between green horizontal lines)

3) Analysis of image logs

- Image log types which are used: Resistivity, density and caliper
- Characteristics of borehole breakouts and DIFs in image logs (Tingay et al., 2008):
  - Borehole breakouts (generally broad and parallel zones, separated by 180°):
    - Resistivity image: Lower resistivity reading due to higher conductance of mud
    - Density image: Lower density reading
    - Caliper image: Increased caliper reading
  - DIFs (generally narrow, sharply defined features):
    - Resistivity image: Lower resistivity reading due to mud invasion into fractures
    - Density image: Sometimes visible as narrow low-density axial-parallel features
    - Caliper image: Difficult to identify due to missing borehole enlargement
- Picking of borehole stability features using different tools of the software (first red arrow in Figure 2) → All other plots are updated accordingly
- Relogs of image data can be used to determine time-based changes on the borehole instability features (e.g. breakouts, Figure 3)
- Further information of picked features can be displayed optionally in a separate view (second red arrow in Figure 2)

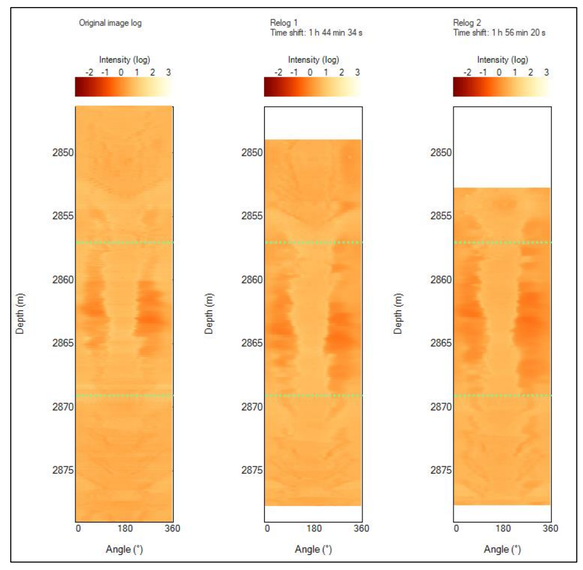


Figure 3: Time-based relog image analysis showing increase of breakout width and length over time

4) Characterization of pressure and temperature variations

→ Analysis of pressure and temperature differences during the time window, pattern analysis, usage of statistical methods

→ Analysis of drilling operation influences during time since drilled on e.g. breakout width

5) Results of exemplary application

- Raw pressure and temperature data are superimposed by drilling effects and parameter gradients over depth (left part of Figure 4) → Correction / normalization is necessary (especially for pressure data)
- Occurrence of pressure spikes during downward movement of bit through already drilled depths (right part of Figure 4) → pressure increase may cause/enhance DIFs
- Temperature responses more slowly to breakouts and artificial influences

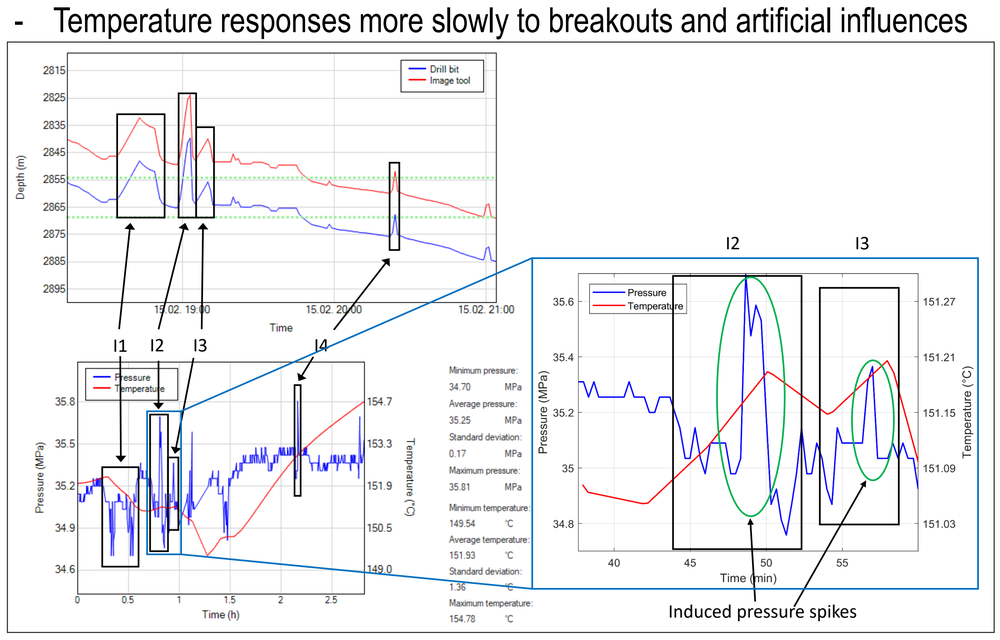
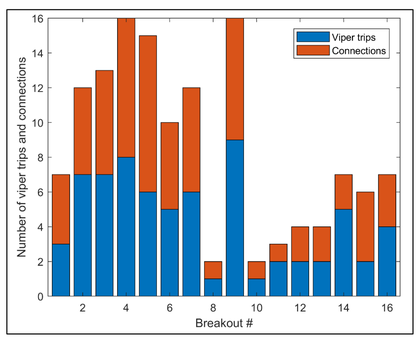


Figure 4: Top Left: Bit and image tool depth over time
Bottom Left: Pressure & temperature data of the chosen breakout interval. Pressure and temperature data show superimposition of gradients over depth and drilling effects (black rectangles).
Right: Detailed view on two pressure spikes (highlighted in green) which have probably been caused by drilling operations.



- Pressure reductions visible in Figure 4 can not solely be explained by hydrostatic pressure reduction due to bit movement →Additional explanation needed
- Figure 5 shows that breakout intervals of the exemplary well always contain viper trips

→The breakouts in the well seem to be associated with drilling operations (at least 82 % of all viper trips of the well occur during a breakout interval)

Figure 5: Number of viper trips (blue) and connections (red) during each breakout interval of the exemplary well

6) Planned further development

- Correction / normalization of pressure and temperature data
- Determination of causal relationship between breakout intervals and viper trips
- Consideration of additional drilling logs (e.g. ROP) and supplementary image logs (e.g. PE)
- Observation of relog sections to investigate time-dependent changes of breakout sections
- Calculation of pressure window (between collapse and fracture pressure)
- Calibration of stress model around boreholes (including sensitivity analysis of pressure gradients) based on preceding results and the calculation of an initial stress field

→ Adjustment of pressure window (crucial for correct determination of mud pressure for drilling)

Conclusion

- Successful development of JewelSuite prototype to display and analyze image and other drilling logs with regards to borehole stability analysis
- Investigation of pressure and temperature changes during the "time window" between bit and image tool using an exemplary well

→ Influence of drilling operations on especially pressure during the investigated breakout intervals

→ Breakouts may be associated with drilling operations (e.g. viper trips)

References

M.Tingay, J. Reinecker, B. Müller (2008): Borehole breakout and drilling-induced fracture analysis from image logs, World Stress Map Project – guidelines: Image Logs, Helmholtz Vent. Potsdam, GFZ.

R.R. Hillis and S.D. Reynolds (2000): The Australian Stress Map, J. Geol. Soc. London, 157, 915-921.

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