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A new software tool for 6-arm caliper data

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Introduction

Modern well logging uses 6-arm caliper tools for breakout analysis, thus stress and borehole stability assessment and computation of cementation volume can be performed. However, in comparison to 4-arm caliper data only a few software packages are available for 6-arm caliper log analysis. Breakout analysis based on 6-arm caliper data is more complicated than that of 4-arm caliper data. The major problem is the decentralization of the 6-arm caliper tool in inclined boreholes as well as in breakout sections. Since today, numerous wells are drilled with high well deviations or even horizontally, the risk for decentralization of the logging tool increases. Here, I present the modification of an earlier software tool with the focus on the following

Objectives

1. Solution of the decentralization problem of 6-arm caliper data.
2. Development of a Python-based software tool to display, analyze, process and stack oriented 6-arm caliper data.
3. Testing of the software using data sets of less and highly inclined wells.

1) Visualization of 6-arm caliper data

The data is displayed in different ways (Fig. 1):

- Column 1 shows the uncorrected measurements of all caliper arms with depth. The scattering of the data due to the tool decentralization becomes clear.
- Column 2 shows the azimuth of the first caliper pad, the relative bearing (angle between high side of the hole and the azimuth of the first pad) as well as the hole azimuth. This example displays nearly constant hole azimuth and varying pad 1 azimuth and relative bearing orientations.
- Column 3 displays the deviation of the borehole with depth.

In each diagram a depth interval can be chosen (shaded red), in which the further analyses will be performed.

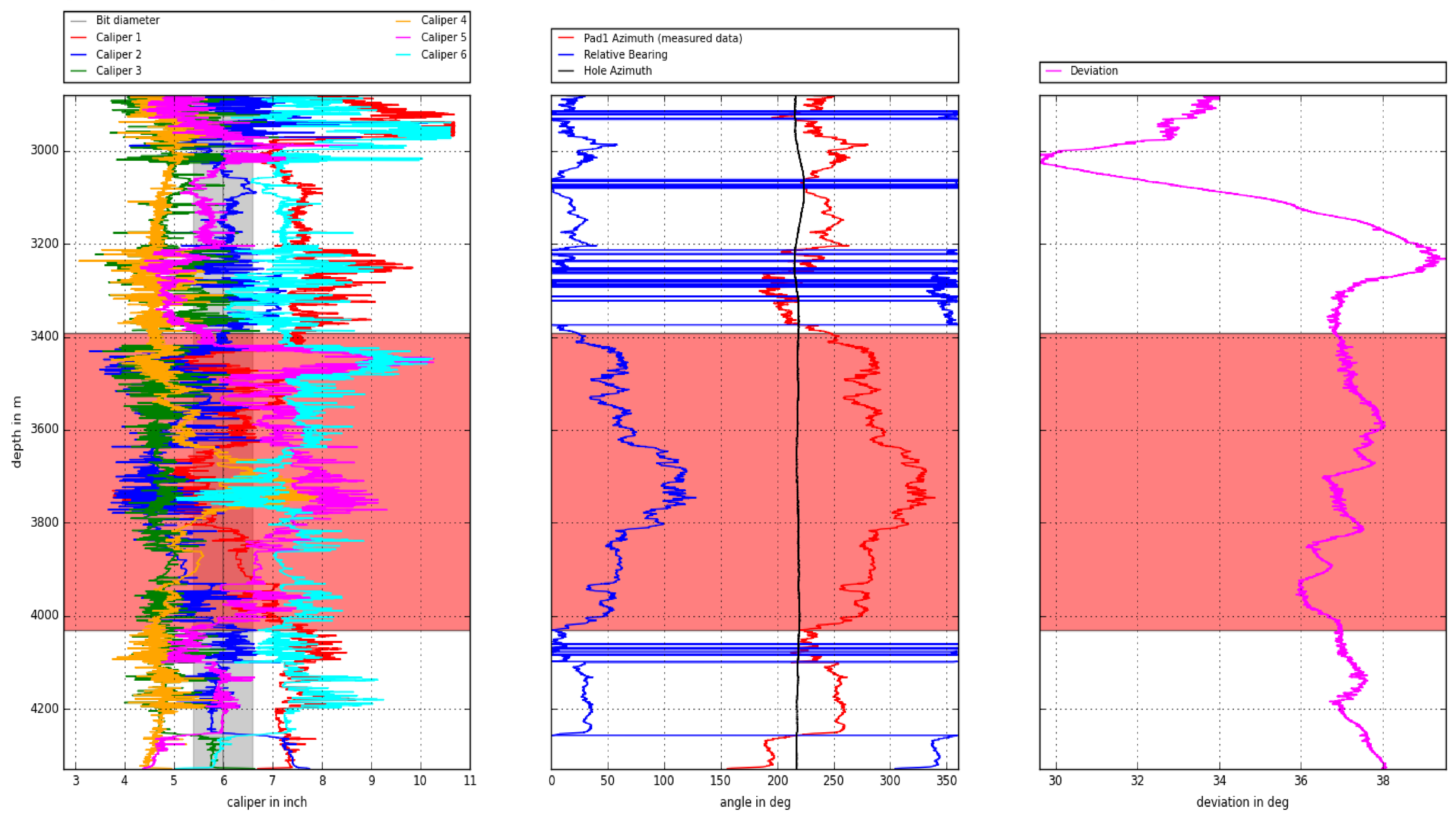


Figure 1: "Main diagrams" tab of the 6-arm caliper software. Red shade: Marked data for following analysis.

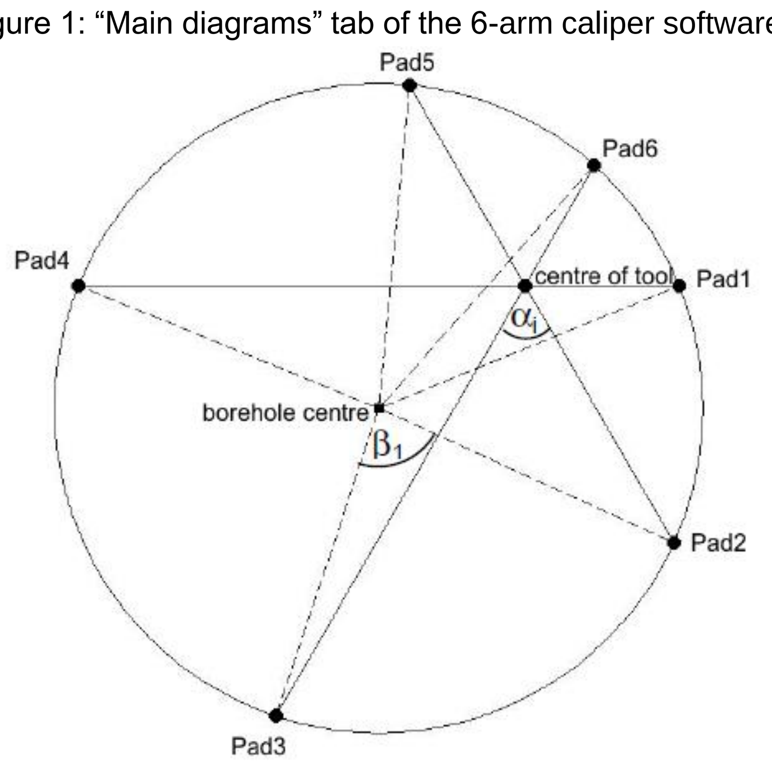


Figure 2: Decentralization of the caliper tool (Wagner, 2003).

2) Causes of tool decentralization

The six arms of the tool open independently and provide 6 radii with angles of 60° between the arms. This leads to decentralization of the tool, especially in inclined boreholes as well as in breakout sections, where the borehole is not circular but exceeds the diameter of the drill bit in direction of the minimum horizontal stress (Fig. 2).

This provides problems to breakout identification if uncorrected data would be used.

3) Detection of tool decentralization

Two algorithms are used to centralize the caliper data (Wagner, 2003). The chord approach exploits the geometrical relation between different chords of a circle to approximate the accurate caliper position within the borehole. The second algorithm fits an ellipse to the borehole shape, and thus can estimate the caliper tool position.

The new software includes a tool to identify possible key seat effects, which could be misinterpreted as breakouts (Fig. 3).

Since key seats also have an opening angle, we consider an orientation limit range (normally +/- 10°) as being potentially critical. This means that a key seat is possible if one of the caliper arms lies between the two red lines in Fig. 3.

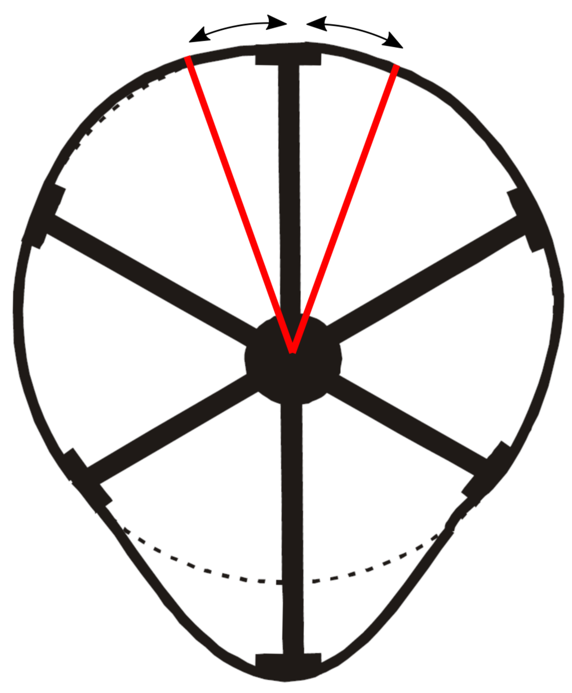


Figure 3: Sketch of a borehole cross section with a so-called key seat. In inclined boreholes there is the risk of one-sided abrasive wear of the borehole wall: key seats. The sketch displays the geometrical relation to 6-arm caliper data. Due to gravity drill pipe wear (key seats) occurs mostly on the low side of the hole, this means that the azimuth of one of the caliper arms is opposite to the hole azimuth. The hole azimuth is the angle between the projection of the well bore trajectory and true north, measured clockwise from north.

4) Breakout analysis

The contour plots show the raw data as well as corrected or centralized data of both approaches (Fig. 4). It can be clearly seen that both algorithms yield improved centralization of the caliper data compared to the measured raw data.

The results of the two approaches are predominantly equal. It is becoming clear that in both approaches caliper 2 and 5 deviate from the borehole shape (shaded grey) which indicates a breakout in this orientation.

Three plots with depth are located below the polar plots. The uppermost plot shows the measured and corrected azimuth of the first caliper, the hole azimuth and the deviation of the borehole. In the middle plot the raw caliper data (equivalent to the leftmost plot in Fig. 1) is shown. In the lowermost plot the corrected data (using the ellipse algorithm) is displayed, the red dots indicate potential key seats.

In each of the three plots a depth interval can be chosen for further breakout analysis (shaded red). Breakouts can be picked in the contour plots of chord and ellipse approach. The picked interval is visualized by two black lines which span an angle that contains the chosen data. The selected data is added to the breakout log.

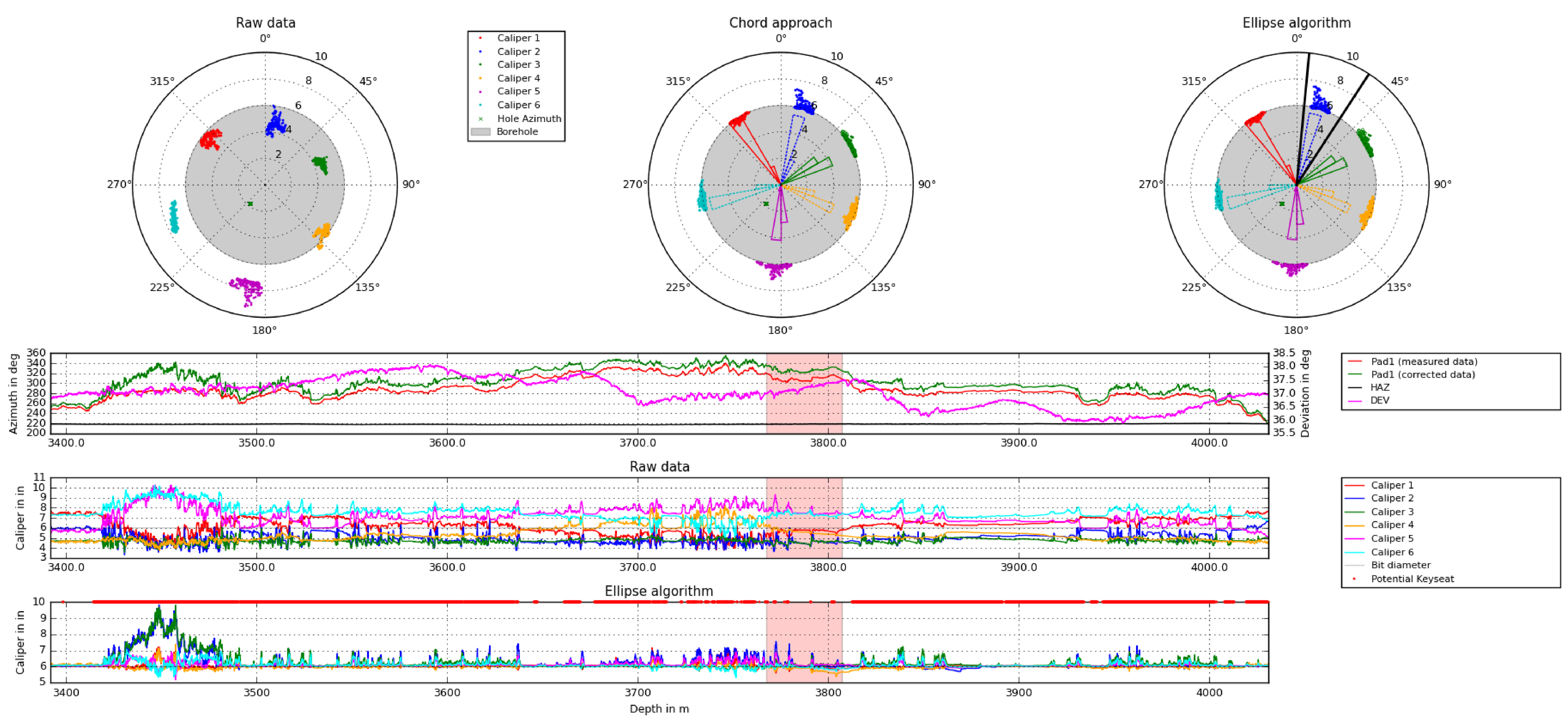
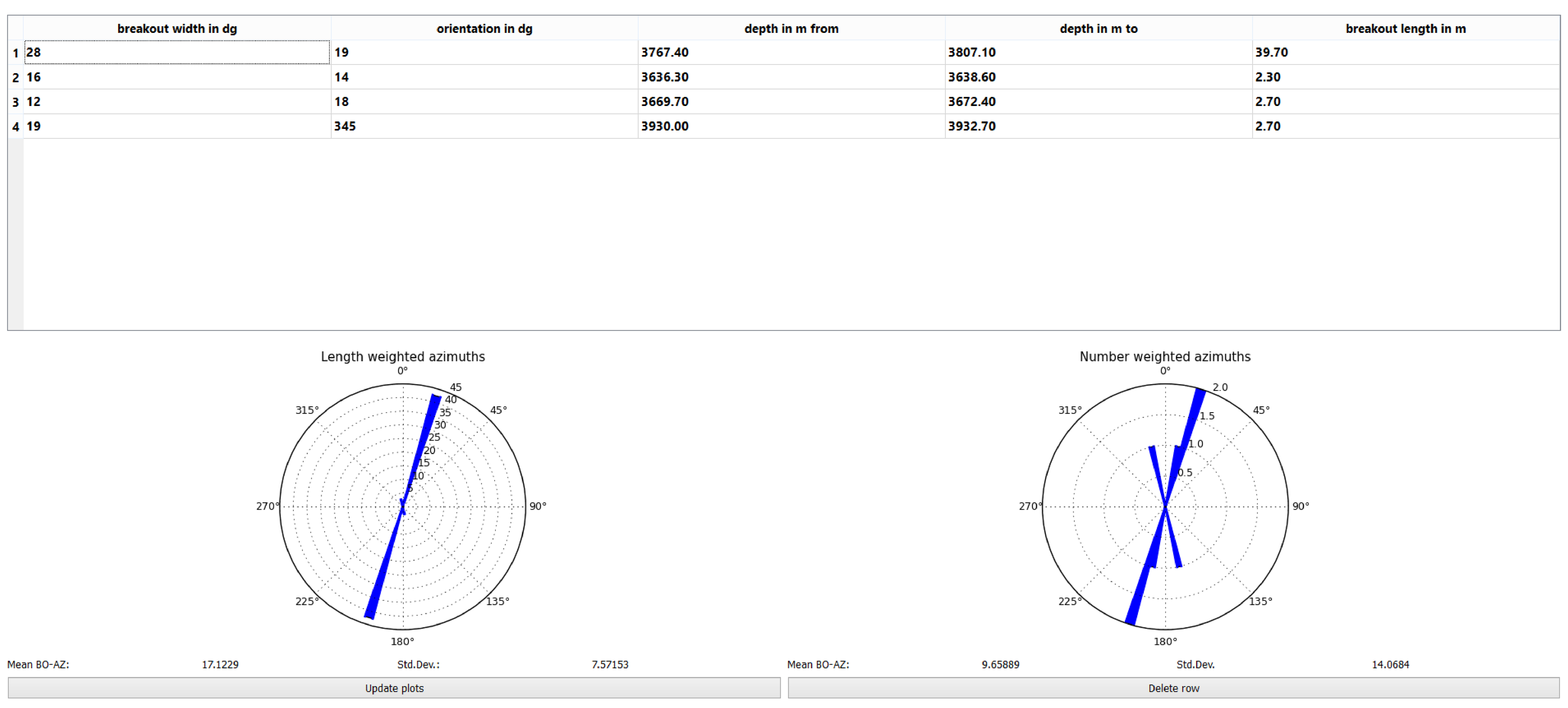


Figure 4: "Contour Plot" tab of the 6-arm caliper software.

Fig. 5 shows the "Breakout Log" tab of our caliper software. The table contains information about selected breakouts: The width and orientation in degrees and the depth interval and breakout length in meters. The selected breakouts are visualized in two polar plots (weighted by length and number). It can be clearly seen that the preferred breakout orientation is NNE-SSW.



	breakout width in dg	orientation in dg	depth in m from	depth in m to	breakout length in m
1	28	19	3767.40	3807.10	39.70
2	16	14	3636.30	3638.60	2.30
3	12	18	3669.70	3672.40	2.70
4	19	345	3930.00	3932.70	2.70

Figure 5: "Breakout Log" tab of the 6-arm caliper software.

Conclusion

The solution of tool decentralization was successfully implemented in our Python-based software tool. Both algorithms provide effective results which can be used for breakout analysis of 6-arm caliper data. Our software can be used to identify breakout sections on either less or highly inclined well data. Thus, the tool improves the stress analysis from borehole breakout analysis using 6-arm caliper logs.

References:

Mardia, K. V. & Jupp, P. E. (2009): Directional statistics. John Wiley & Sons.
Wagner, D. (2003): Contemporary Tectonic Stress – Derived From Oriented 6-arm Caliper Logs. Diploma thesis, Karlsruhe.