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Methods of Estimating Fracture Density (P_{32}) and Size from an Image Log in the Horizontal Cardium Well, Persist Oil Stolberg 10-11-42-15, in the Alberta Foothills.

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Berg (2019) published methods for calculating fracture density (P_{32}) and size from image logs and cores. A later document (Berg 2019a) describes a method for calculation of connectivity based on equations derived in the former paper. The methods described below use the relationships for rectangular fractures from Berg (2019). These methods were specifically derived for bed-bounded, opening-mode fractures.

The basic equation for the new methods was derived using simulations from a discrete fracture network (DFN) program. This equation calculates fracture density (P_{32}) using fracture orientation and size, and borehole diameter. Fractures are considered to be rectangular and planar. The equation is applied by calculating a correction factor for each fracture and then dividing the sum of the correction factors by the interval length. There are two methods for determining size: 1) In the enclosed-length method, the borehole-enclosed fracture-edge lengths and borehole-enclosed fracture areas are used to estimate average fracture size. 2) In the density-compare method, P_{32} is first calculated directly by dividing the total borehole-enclosed fracture area by the borehole volume. The equation is then applied repeatedly to the fractures within the interval, varying fracture size until the equation-calculated P_{32} matches the directly-calculated P_{32}. Both methods have been verified using the DFN model. Fracture connectivity index is calculated using the number of fracture intersections divided by the number of whole fractures. The number of whole fractures is calculated by dividing the borehole-enclosed fracture area by the product of fracture height and length. Figure 1.

The well under study is a Cardium Formation horizontal well in the Alberta foothills, Canada, the Persist Oil Stolberg 10-11-42-15. It was drilled NW along strike in a well-developed detachment fold with a late-stage fault cutting the NE limb. Fold and HW vergence is to the NE. Dip is 60° SW. At this location, the Cardium is a 125m thick, complex interval of five coarsening-upward sequences that were deposited in a ramp setting on the western side of the Western Canada foreland basin. The net pay is distributed over about a 20m interval in the lower of two prospective sandy units. The Stolberg field has 33 producing horizontal Cardium wells. The wells have horizontal legs of between 500 to 1000m and have an initial production of 400 to 800 bbls per day.

In the entire 503m Cardium interval, there were 1547 fractures with an overall fracture density of 2.15m^{-1}, equivalent to an average fracture spacing of 0.466m. Average fracture height and length were 0.320m and 1.019m, respectively. The connectivity index averaged 5.33, well above the percolation threshold of 2.0. The enclosed-lengths method yielded height and length values about 5% higher than the density-compare method, while the connectivity was about 11% higher. When calculated in 100m intervals, average fracture height varied from 0.289m to 0.373m, average fracture length varied from 0.910m to 1.50m, and connectivity varied from 2.57

to 7.76. P_{32} varied from 0.951m^{-1} to 4.17m^{-1} (average spacing of 1.05m to 0.240m, respectively). The large P_{32} range is mostly from shale and poor-data intervals.

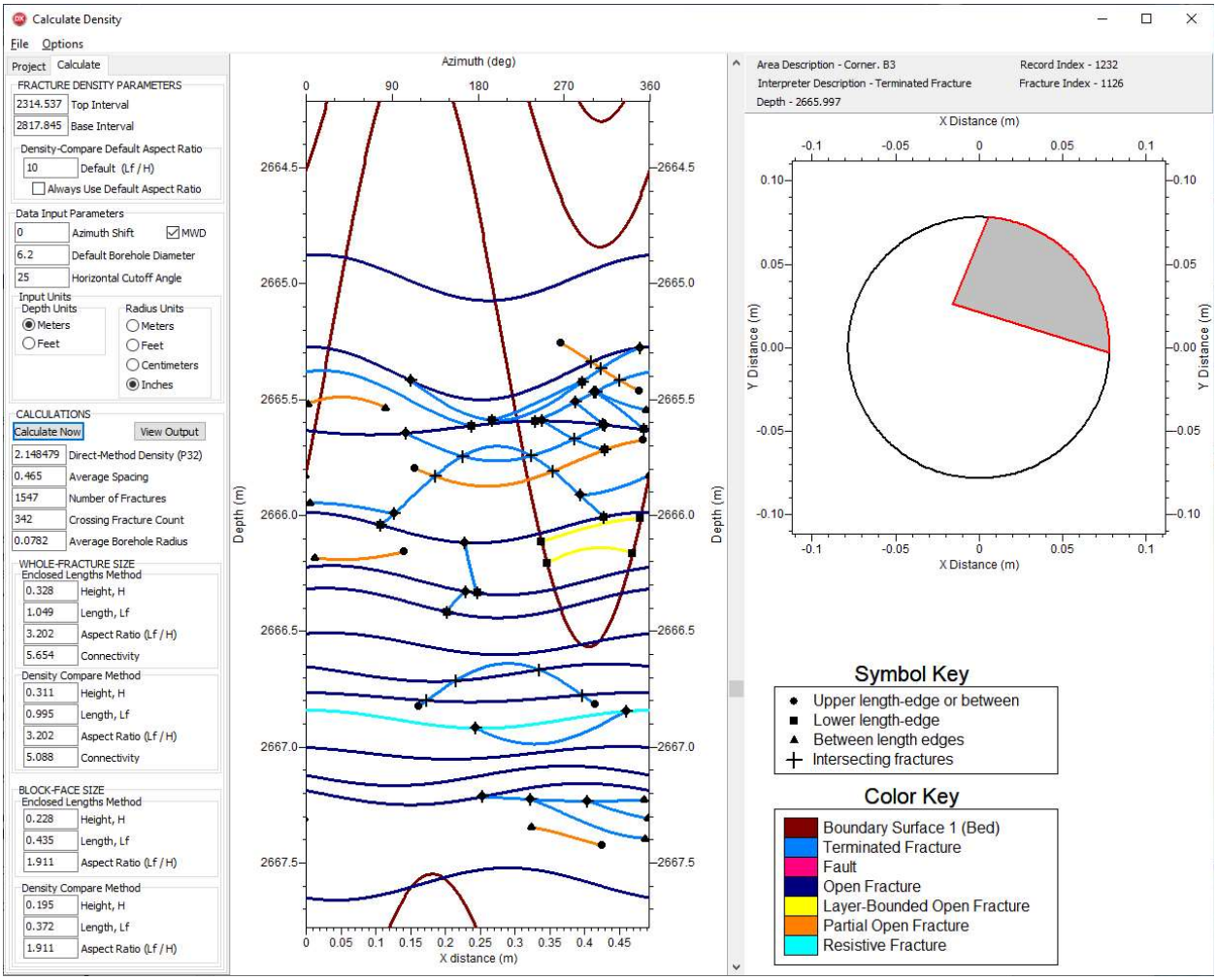

Figure 1. Plot showing calculations on the left-hand control panel, fracture and bed traces on the middle panel, and a down-borehole view on the upper right. The middle panel shows the interpretation from the image log along with symbols that the program uses to help classify traces. Specifically, those symbols are used for finding the fracture area and connectivity. The symbol key on the middle right shows the trace classification, and the color key below it shows the colors defined by the image-log interpreter. On the upper right is a down-borehole view of the part of the part of the fracture inside of the borehole. The fracture shown is a corner or B3 intersection type as described in Berg (2019). On the middle panel, it is the short, blue fracture on the middle left-hand side at 2665.997m.

References

C. R. Berg, 2019, Methods for Estimating Fracture Abundance and Size from Borehole Observations, SPE Reservoir Evaluation & Engineering Journal, 29, 1399-1425, SPE 195583, https://doi.org/10.2118/195583-PA.

Berg, C. R., 2019a, Calculation of Fracture Connectivity, ResDip Systems internal report.