Summary

The project is directed on a problem of general interest for all fluid-related borehole investigations. An interpretation algorithm, already tested in numerous groundwater monitoring wells and shallow boreholes, was adapted for the detection of vertical density-driven flows in the deep boreholes of the ICDP. This Synthetic Convection Log interpretation algorithm enables in-situ detection and identification of free convective, including double-diffusive, flows using state-of-the-art geophysical borehole measurements.

The comprehensive adaptation of the algorithm included several modifications and methodological innovations, like: input unit selection, identification of measurement parameters from the input data, filtering according to measurement precision, implementation of an additional density formula for saline fluids, and automatic choice of the relevant density formula.

The interpretation algorithm computes the essential parameters and instability measures from logs of temperature-mudresistivity probes and compares them to critical thresholds or zones for the onset of density-driven flows. Further required parameters are hydraulic pressure, which is either measured directly or calculated from depth, and the borehole diameter which is either derived from a caliper log or the known casing diameter.

Output is a computer generated, descriptive illustration of the results in form of the SYNCO-Log®. In the sense of a „quick look“ interpretation, the novel log visually divides the fluid column into sections that are characterized by a density-driven flow and sections that are characterized by no density-driven flow. Additionally, it classifies the areas with density-driven flow according to its flow type. Hence, using the SYNCO-Log®, it is possible to differentiate between all forms of density-driven convections that can occur in boreholes: thermal, solutal, thermosolutal (overturning) convection, as well as salt fingers and diffusive convection.

The modified interpretation algorithm SYNCO-Log® confirmed its applicability in deep boreholes (even with large diameter) on the example of measurements from ICDP boreholes. The existence of free convective flows in ICDP boreholes was confirmed.

According to the results, density-driven vertical flow in deep boreholes is notably more intense than in shallow boreholes. Its intensity implies that the induced transport (of heat and mass) is significant.

To support the interpretation of the borehole logs, selected borehole sections were numerically modeled. The modeling results compare well with borehole measurements from ICDP boreholes. The results show: retroaction of the rock formation surrounding the fluid column has an important influence on the intensity of the fluid flow. Higher flow velocities arise, when the fluid column is thermally shielded from the formation, e.g. by a thermally insulating casing.

In high-resolved pressure logs no indication was found that density gradients inducing a vertical flow cause detectable pressure gradients in the fluid column. Incorporating information from pressure logs into the SYNCO-Log® calculation was thus turned down.

Altogether, the SYNCO-Log® is a very important contribution to the improvement and assessment of the quality of special scientific investigations in boreholes. It is a tool to proof, if particular borehole measurements (e.g. for determining heat flow) could be adulterated due to convection and would require special technical equipment to avoid these affects.

The significant results were documented in several publications, presentations, and posters at varying conferences and led to a Ph.D. dissertation.