Interpretation of Induction Logging Data in Horizontal Wells: Physics, Algorithms, and Case Studies

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The High Definition Induction Logging (HDIL) instrument collects data at multiple frequencies and various transmitter-receiver spacings. Conventional focusing and inversion algorithms are designed for vertical and deviated wells to determine invasion profile, to measure resistivity deep in the formation, and to provide high vertical resolution.

In horizontal wells, the objectives are different. In addition to the resistivity distribution in the borehole vicinity, we wish to determine distances to remote cap rocks and water bearing horizons. The vertical resolution (or, more accurately, the resolution along a borehole trajectory) is no longer an important parameter due to the relatively small lateral variation of the formation parameters.

We present a new inversion algorithm for interpreting induction logging data in horizontal wells that consists of three components. First, we determine parameters of the near zone formation using shallow and medium investigation measurements. At this stage, a fast 2D inversion allows us to recover invasion and formation parameters without being affected by remote layers. Second, we correct the deep measurements for the presence of a borehole and invasion using the results of the near zone interpretation. Third, we interpret the corrected deep measurements using a 1D layered inversion to characterize remote layers.

We present a case study for a horizontal well in the North Sea. Successful completion of the well requires distinguishing between low resistive water-flooded zones, with movable water, and an underlying tight layer, that is also low resistive. The developed algorithms allow us to quantitatively estimate the distance to and resistivity of the tight layer and resistivity of the permeable formation. The distance to the tight layer correlates with seismic data.