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Formation Evaluation of High-Angle and Horizontal (HA/HZ) Well: 1990s' Issues, 2000s'Learnings, and 2010s' Directions

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The 1990s can be seen retrospectively as "the decade of the horizontal well," because it was during this period that sharper seismic imaging, new drilling technology and reliable geosteering were recognized as leading to increased hydrocarbon production from extended-reach wells with correspondingly lower unit costs. Subsequent advances in logging-while-drilling and in the deployment of wireline tools in the 2000s have allowed horizontal-well data broadly to match vertical-well databases in terms of the achievable range of along-hole measurements. However, tool environmental corrections in horizontal wells are more complex, particularly because of the 3D manifestations of differential invasion (of water-base mud filtrate) and of formation heterogeneity. The technological advances in data acquisition have widened still further the gap between our ability to measure along hole and our ability to interpret the resulting log data. Indeed, even with current logging technology, it may not be possible to evaluate accurately some of the parameters we wish to quantify. The interpretation of environmentally-corrected, horizontal-well logs can be far more difficult than for corresponding logs in vertical or even relatively high-angle wells. The situation is compounded by dipping beds and by undulating well trajectories. An overriding issue is the nature and scale of formation anisotropy, especially that which relates to formation resistivity.

After having introduced industry-recognized issues related to formation evaluation in high-angle/ horizontal (HA/HZ) wells, this paper reviews current academic and industry research efforts to develop methods for faster modeling and inversion of tool response in more complex geometries and more realistic formations. A workflow that combines azimuthal nuclear and scalar resisistivity logging-while-drilling (LWD) logs to construct a common subsurface model is illustrated. Data include standard LWD triple-combo logs of wells with an apparent dip ranging from 80 to 90 degrees. By comparing properties estimated in cored near offset vertical wells, results for HA/HZ wells show improved resolution and estimation of formation layer petrophysical properties, and thus, more accurate estimates of reserves in place compared to those estimated from original field logs.