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Assessment of In-Situ Gas Saturation and Permeability From Logs in the Hugoton Field Based on the Physics of Mud-Filtrate Invasion.

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Large discrepancies between the salinity of connate water and drilling mud are responsible for the presence of a prominent low-resistivity annulus in many of the wells drilled in the Hugoton field. This resistivity annulus suppresses the sensitivity of electromagnetic induction tools to quantify in-situ gas saturation. We give a quantitative explanation for the presence of the low-resistivity annulus based on the physics of mud-filtrate invasion.

Simulation of the process of mud-filtrate invasion in the Hugoton field is based on seven basic parameters that define the physical properties of the mud plus knowledge of the overbalance pressure. In addition, the simulation requires basic petrophysical properties such as porosity, permeability, relative permeability, and capillary pressure.

We introduce the inverse problem of mud-filtrate invasion, in which the array induction, bulk density, and neutron logs are provided and one aims at determining the underlying permeability and radial variations of gas saturation away from the borehole wall. A least-squares constrained optimization method is employed to solve the inverse problem. Array induction measurements are simulated in coupled mode with the process of mud-filtrate invasion. Automatic adjustments to permeability and fluid saturation are made until the array induction measurements are matched within the assumed noise level. An extensive analysis is performed of the accuracy and reliability of the inversion when a priori knowledge of mud properties is uncertain. Inversion exercises performed on two key wells that penetrate the Krider and Fort Riley formations, Youngren-J1H and Youngren_J2H, yield accurate and petrophysically-consistent estimates of permeability and in-situ gas saturation.