Simulation and Analysis of a Borehole Transient Electromagnetic Reservoir Monitoring System

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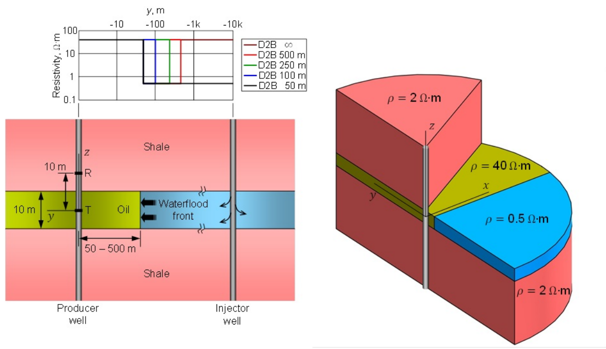
Abstract

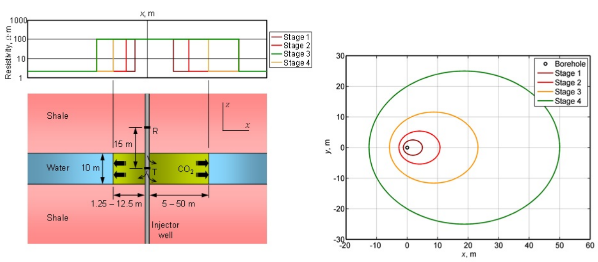
Waterflooding and steam flooding are used worldwide for secondary oil recovery. Recently, carbon dioxide (CO2) flooding has attracted global attention as a means of enhanced oil recovery (EOR) as well as for carbon capture and sequestration (CCS) applications. All these processes cause significant changes over time in the fluid composition of oil reservoirs. In this paper, we demonstrate the feasibility of a borehole transient electromagnetic (TEM) system that can map the fluid dynamics of these processes. This mapping can delineate bypassed pay and yield the extent of flooding. The operator can then use this information to maximize oil recovery efficiency by designing appropriate flooding patterns and controlling the injection rates. We first validate COMSOL Multiphysics simulations for simple one-dimensional layered models with our in-house fast semi-analytical code. Then we use COMSOL Multiphysics to simulate the proposed borehole TEM system in two-dimensional (Figure 1) and three-dimensional (Figure 2) models of waterflooded and CO2 flooded reservoirs. These simulations not only prove the efficacy of this technology in providing deep and azimuthally sensitive measurements (Figure 3), but also help us understand how the TEM diffusion process responds to electrical resistivity contrasts (Figure 4).

Figures used in the abstract



(a) (b)

Figure 1: 2-D model with resistivities showing different stages of waterflooding. T: transmitter, R: receiver, D2B: distance to flood front.



(a) (b)

Figure 2: 3-D model with resistivities showing different stages of CO2 flooding.

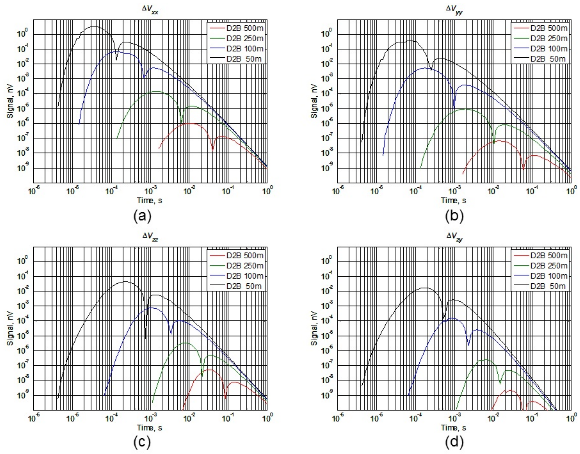


Figure 3: Differential voltage signals measured at the receiver for different stages of the model in Figure 1.

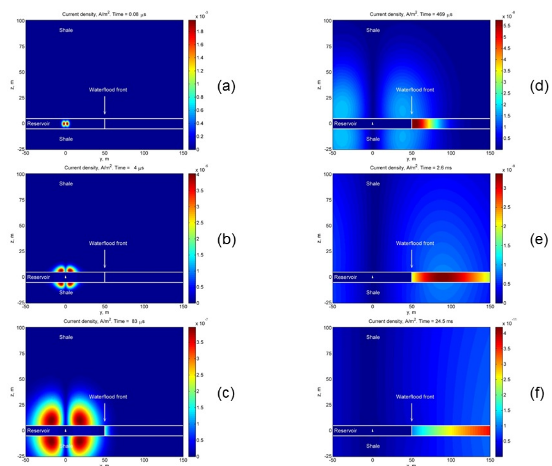


Figure 4: Current density distribution in the formation at different times.