Enhanced Reservoir Monitoring using Coupled Electromagnetics and Flow Modeling

Introduction

Remote time lapse monitoring of reservoirs can provide valuable information to meet production goals. Remote monitoring requires technology that can detect movement and changes in the reservoir during production and flooding events. In this case study, we demonstrate how an injection event can be modeled and monitored using flow simulation software and electromagnetic data. First the injection event is simulated to predict the fluid flow. This information is then used as a constraint when inverting the collected geophysical data. The combination of flow simulation and electromagnetic data inversion provides an enhanced monitoring technique for reservoir characterization.

Survey Goals and Design

Computational Geosciences Inc. (CGI) can determine the best electromagnetic method and survey geometry to meet your reservoir monitoring needs based on the geologic setting, reservoir simulation, local infrastructure, and logistical/cost considerations. Synthetic flow and EM modeling studies can be performed that integrate geologic and reservoir characteristics in order to validate the survey design before conducting data acquisition. Completing modeling studies before data is acquired ensures that the optimal geophysical survey will be performed thereby reducing the risk of wasting resources and failing to achieve the project goals. In the following example, CGI constructed a synthetic conductivity and hydro-geological model of a reservoir. The model (see figure 1) contained a resistive permeable reservoir embedded in several layers of less permeable and more conductive sediments. An injection event was modeled using proprietary flow simulation software and monitored using data computed at downhole electromagnetic transmitters and receivers.

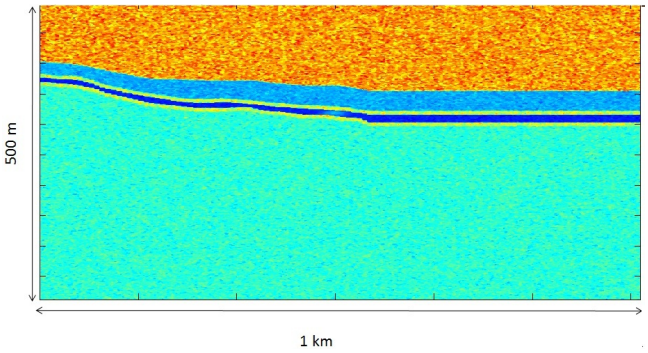

Figure 1: Synthetic reservoir model consisting of a thin reservoir between impermeable layers. The conductivity structure consisted of a resistive reservoir embedded in a conductive layered background.

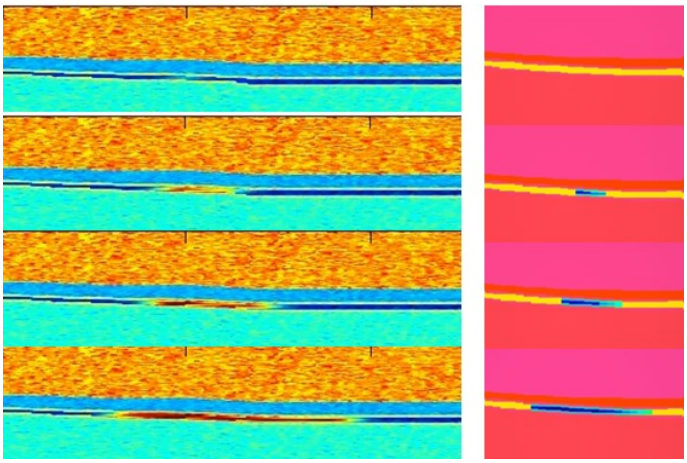

Figure 2: **Left:** Time lapse images of the injection event into the reservoir. **Right:** Inverted conductivity model mapping the injection event at various time steps during the injection

Flow Modeling

Based on the 3D reservoir model and typical injection parameters, an injection event was modeled using proprietary flow simulation code. The code simulates multiphase flow in porous media and is based on a fully implicit solution of the pressure saturation formulation. The code can simulate any fluid flow, such as water, CO2 and/or oil, within the reservoir given an injection rate and hydraulic parameters. A few time lapse images of the injection into the reservoir can be seen in figure 2.

EM Modeling

While geophysical data can be inverted on their own, due to the non-uniqueness of the problem, adding additional information to the inversion can greatly improve results. To enhance the inversion model, the outputs of the flow simulation software are used as constraints for the electromagnetic inversions. Once the constraint model has been constructed, the data are then inverted in 3D. The changes in the inverted conductivity models image the injection event over time. The final product is a remote monitoring system for reservoirs and injection events that can help meet production goals.

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