Combining Seismic and CSEM Data Information to Estimate Fluid Saturation in a Reservoir

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Abstract

This study deals with the fluid saturation estimation in a reservoir using a combination of seismic and controlled-source electromagnetic (CSEM) data. Seismic surveys provide valuable information about the structure and distribution of subsurface rock properties and their pore fluids. One of the products we get from the inversion of seismic data is acoustic impedance (AI). The electromagnetic data have been a useful tool in investigating potential hydrocarbon-bearing formations. The CSEM Inversion techniques yield vertical and horizontal resistivities, which depend on variations in rock layers' electrical resistivity properties.

We proposed a novel approach using a cross-property relation that relates acoustic impedance with electrical resistivity to estimate fluid saturation in a reservoir. This enables combining seismic and electromagnetic (EM/CSEM) information to identify a fluid and quantitatively measure its saturation in a reservoir. The acoustic impedance increases with increasing compaction due to a decrease in porosity. If the pore fluid in a reservoir has an identical density as the in-situ brine, the change in acoustic impedance will be insignificant. On the other hand, if the pore fluid is a low-density hydrocarbon gas or oil, one can expect a noticeable decrease in acoustic impedance. In a hydrocarbon reservoir, the in-situ brine makes the total resistivity of a reservoir very low; however, within the zone where hydrocarbons are accumulated, the overall resistivity of the reservoir increases, making it possible to detect this change using the CSEM method. The resistivity of a hydrocarbon-bearing reservoir depends on the hydrocarbon saturation. The CSEM measurements will have appreciable sensitivity to saturation compared to the seismic velocity, especially in the mid-to-high saturation ranges. Conversely, reducing porosity due to rock compaction also increases total resistivity.

We demonstrated the possibility of isolating the abovementioned effects using wireline log data and acoustic impedance-resistivity models. Our modeling results show potential for monitoring an injected CO_2 plume in terms of extent and saturation using a seismic in combination with time-lapse CSEM data. These results have implications for monitoring oil production - especially with water flooding, hydrocarbon exploration, and freshwater aquifer identification. The CSEM's low resolution and depth uncertainties are some limitations that need to be considered.