Geophysical Monitoring of Changes to the Subsurface Caused by Fluid Injection

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ABSTRACT

As fluid is injected into the subsurface from a borehole during various industrial applications, geophysical properties such as seismic velocities and electrical conductivity are altered which leaves open the possibility of using time-lapse seismic and electrical surveys to monitor where the injected fluids go and what they do to the subsurface. Material properties are changing by three dominant mechanisms: (1) in situ fluid of one type is being replaced by invading fluid of a different type; (2) changing stress and pore pressure are causing pre-existing fractures to either close or open which alters the elastic moduli and the transport properties of the rocks; and (3) new cracks and/or fractures are created once thresholds are reached which further alters the elastic moduli and transport properties. Over longer time periods, chemical alterations of the rocks may occur but we do not focus on such alterations at this time. For the last 18 months, our geophysics group at LBNL has been tasked with determining ways to model the above processes and to formulate the inverse problem for obtaining the initial stress-state and material properties that held prior to the start of injection using time-lapse geophysical data. In this talk, I will present some of the approaches and models we have been developing. I will review models for how the elastic moduli and transport properties of rocks change with evolving stress and fluid pressure. Such models will be used in new finite-difference simulations to show by how much geophysical properties and geophysical signals are altered by a simulated brine injection process. In formulating the inverse problem for the initial conditions, it is important to be able to calculate how the fluid injection is altering the subsurface including the geophysical properties. The two principal remaining challenges that the hydro-geological and geophysical communities have not yet properly resolved is how to forward model immiscible invasion and how to allow new damage in the form of cracks and fractures to arrive in the subsurface and alter the properties. New approaches for tackling these two challenges will be presented as time permits.