AAPG/SPE/SEG HEDBERG CONFERENCE
"ENHANCED GEOTHERMAL SYSTEMS"
MARCH 14-18, 2011 – NAPA, CALIFORNIA

Tracing Injection Fluids in Engineered Geothermal Systems

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The reinjection of produced fluids is important in the management of Engineered Geothermal Systems (EGS), since it provides a mechanism for maintaining reservoir pressures while allowing for the disposal of a toxic byproduct. Tracers are essential to the proper location of injection wells since they are the only known tool for characterizing the flow patterns of recirculated fluids. If injection wells are placed too close to production wells, then reinjected fluids do not have sufficient residence time to extract heat from the reservoir. If injection wells are placed too far from production wells, then the reservoir risks unacceptable pressure loss.

Several thermally stable compounds from a family of very detectable fluorescent organic compounds (the naphthalene sulfonates) were characterized and found to be effective geothermal tracers. Through batch-autoclave reactions, their pseudo-first-order decay-rate constants were determined using an Arrhenius model. An HPLC method was developed that allows for the laboratory determination of concentrations in the mid parts-per-trillion range. Field experiments in geothermal and EGS reservoirs throughout the world served to verify the laboratory findings.

Whereas the naphthalene sulfonates were shown to be effective conservative tracers for use in geothermal reservoirs, other studies at our laboratory focused on identifying reactive tracers that can be used to constrain fracture surface area, which is the effective area for heat extraction. This is especially important for EGS wells, since reactive tracers can be used to measure fracture surface area immediately after drilling and while the stimulation pumps are still on site. The desired 'reactive' properties of these tracers are diffusivity, reversible sorptivity, and thermal decay kinetics. Laboratory flow-reactor experiments served to identify candidate compounds for use as reversibly sorbing tracers. Likewise, numerical modeling studies indicate that a geothermal tracer with known decay kinetics can serve to constrain near-wellbore fracture surface area in single well injection/backflow (SWIW) experiments. Field experiments in EGS and geothermal reservoirs designed to test the performance of these reactive tracers for characterizing fracture surface areas are discussed.

Colloidal nanocrystals (quantum dots) are an emerging class of materials that show promise for use as EGS and geothermal tracers. These are semiconductor particles that fluoresce as a function of particle size. Laboratory experimentation has demonstrated that these thermally stable water-soluble particles can serve as conservative tracers for geothermal applications. Likewise, their surfaces can be modified to be reversibly sorptive and their diameters can be modified to allow for large contrasts in diffusivity. Recent laboratory developments resulted in significant increases in yield and production volume and a large increase in thermal stability.