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Constraints on fluid flow and circulation depth in a low-temperature geothermal system from environmental tracers

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Numerous low-temperature (~30 to 50 °C) geothermal springs occur in the area surrounding Glenwood Springs, Colorado, USA, and discharge into the Colorado River. The springs are highly saline with total dissolved solids concentrations up to 19,000 mg/L and are a major source of salinity to the Upper Colorado River. To constrain recharge zones and mixing, depth of circulation, and sources of solutes, samples were collected from springs for noble gases, ^{3}H, CFCs, ^{14}C, $\delta^{2}H$, $\delta^{18}O$, $\delta^{34}S$, and $^{87}Sr/^{86}Sr$. Together these tracers can identify physical circulation processes in the geothermal system and quantify mixing between multiple potential end members. Enhanced understanding of the geothermal system will benefit salinity control efforts and will inform spring sustainability planning.

Results for $\delta^{2}H$ and $\delta^{18}O$ indicate that spring discharge is meteoric in origin and has not undergone extensive water-rock reaction, as no shift in $\delta^{18}O$ is observed. These results are consistent with low to moderate reservoir temperatures. Potential spatial patterns in mixing are observed in the $\delta^{2}H$ and $\delta^{18}O$ composition of springs, which is also reflected in spatial temperature variations. Spring waters have terrigenic ^{4}He concentrations three orders of magnitude greater than water in equilibrium with air, and R/R_a values ranging from 0.095 to 0.193 (compared to R/R_a =1 in air equilibrated waters). The high ^{4}He indicates long residence times but quantitative age estimates are complicated by uncertainty in subsurface ^{4}He production. The age of old groundwater discharging from springs is also constrained by ^{14}C, and mixing of young shallow water is indicated by the presence of ^{3}H and CFCs.

When combined with estimates of local geothermal gradients and heat/solute flux from previous studies, groundwater age constraints provide a means to estimate vertical fluid flow and volumetric flux from the geothermal system. Calculated circulation depths are generally shallower than previous estimates which applied simple conceptual models of gravitational-driven flow. Constraints on groundwater age and solute sources also indicate that previously applied conceptual models may not adequately describe the sources of heat and dissolved solids in the geothermal system.