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Upper Rhine Graben: Using isotopes and trace elements to understand a thermal fluid system as basis for raw material potential

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In the context of the energy and mobility transition, operators of geothermal power plants and associated industries spotlight the potential to combine production of sustainable energy with the extraction of critical and strategic raw materials (CRM, SRM) from geothermal fluids (e.g., Li). Sustainable extraction of CRM/SRM requires a comprehensive understanding of the geothermal fluid system, including fluid sources and migration pathways.

In southwest Germany, the Upper Rhine Graben (URG) represents a reservoir for Li extraction from geothermal fluids. Collected data from (geo)thermal waters and springs can be used to investigate the origin and properties of the geothermal fluids and to understand the mobilization and transport of elements, like Li, in the reservoir.

A key process of CRM/SRM enrichment in geothermal fluids is water-rock interaction (WRI) within a variety of reservoirs, as mixing between different water horizons is a major part of the fluid evolution. Furthermore, the various proportions of fluid components and intensities of WRI could result in different CRM/SRM concentrations. To better interpret these pathways, fluids at various depths were analyzed for major and trace element composition, as well as for stable and radiogenic isotopes. Results show variations in the trace element distribution, including notable changes in Cl/Br (~100 S-URG, ~1000 N-URG) and Rb/Cs ratios (1-20), as well as changes in the stable isotope (O, H, S) composition of the waters. The results are interpreted as influence from groundwater input into the system, as well as WRI. To further substantiate the results from trace element and stable isotope analyses, we applied 87Sr/86Sr as a conservative tracer to the system to better differentiate between reservoirs.

The 87Sr/86Sr results support the trace element and stable isotope analyses, indicating characteristic WRI and mixing in a multi-component system. At least three endmember components have been identified and include: (1) local groundwater (87Sr/86Sr ~0.7085), (2) brines in contact with granitic (basement) rocks (87Sr/86Sr ~0.7182), and (3) dissolved evaporites and carbonates (87Sr/86Sr ~0.7091). These preliminary results demonstrate that multi-proxy natural tracers employed in the URG are useful to discern between fluid sources and flow paths, and the potential to trace CRM/SRM enrichment in the subsurface.