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Upper Rhine Graben: Understanding a geothermal fluid system as basis for raw material potential

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

In southwest Germany, the Upper Rhine Graben (URG) represents a reservoir with great geothermal potential. A thermal anomaly accounts for temperatures of about 200 °C, whose gradient ranges between 30 and 120 °C/km. Greatest potentials are exhibited by the Triassic sandstones (~120 °C; Li ~160 mg/L) and Variscan crystalline rocks (~200 °C; Li ~170 mg/L). Data about the reservoir rocks at different depths can be acquired from around 1300 different oil as well as geothermal wells and thermal water wells. It can be used to investigate the origin and properties of the geothermal fluids and to understand the mobilization and transport of elements in the reservoir.

A key process of CRM enrichment in geothermal fluids is the hydrothermal alteration of feldspars and mica of crystalline basement rocks. However, this process appears to be insufficient to attain CRM concentrations measured in geothermal fluids. To analyze the main mechanisms, different fluids from various depths are analyzed in terms of their properties and composition. Recent chemical analyses of the fluids indicate variations in the trace element distribution that are associated with changes in Cl/Br- and Rb/Cs-ratios, and in the stable isotope composition of the water. The comparison of fluid chemistry with the assumed reservoir rock also reveals that the fluids evolve in account of fluid mixing and fluid-rock interaction, and that they contain components consisting of dissolved evaporites, basement brines, and meteoric water. The various proportions of fluid components and intensities of fluid-rock interactions result in different CRM concentrations. The currently developed natural tracer systems, in particular element ratios, help to determine the origin of fluids, their CRM potential and their evolution.