

Exploration for blind geothermal systems: Chemical tracers of thermal waters applied to shallow groundwaters

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Orogenic geothermal systems result from topography-driven, deep circulation of meteoric water through fractured crystalline basement, followed by fast upflow of the heated water along spatially restricted subvertical conduits in fault zones. Such orogenic systems are responsible for the 15 thermal water occurrences in and near the inner Alpine Rhône Valley (Switzerland) which discharge at temperatures up to 65 °C. Due to the abundance of deep-reaching faults, it can be assumed that there are also an unknown number of blind geothermal systems, i.e., systems hidden below Quaternary cover without surface manifestations such as warm springs. Our ongoing project aims to identify areas where such blind systems are most (and least) likely to exist within the Rhône Valley by creating probability maps as a basis for future exploration.

We first evaluated the chemical composition of a number of several known thermal water occurrences. Elevated contents of ⁴He show that all thermal waters represent a deep thermal component mixed with shallower cold groundwaters. By numerically unmixing the two end-members and applying principal component analysis to both, the following tracers were identified as fingerprints of water-rock interactions with deep basement rocks: Na, K, Cl, SO₄, Si, Li and F.

In a second step, we evaluated the concentrations of the main ion tracers (Na, K, Cl, SO₄) in shallow groundwaters across the Rhône Valley. Taking into account geogenic background values, we identified sites with anomalously high concentrations of two or more tracers. Such geochemical anomalies are most abundant close to the sides of the Rhone Valley where the Quaternary infill is thinnest and in areas where brittle structures (i.e., faults) cause localised enhanced permeability due to fracturing and dilation.

In a third step, we carried out an additional sampling campaign for the most promising region with much higher spatial resolution. Anomalously high concentrations of Si, Li, and ⁴He as well as highly negative $\delta^{18}\text{O}$ values clearly confirmed the presence of a blind geothermal system. Our results thus demonstrate the high potential of the chosen approach in the exploration of hidden thermal systems in the Alpine realm and potentially even further afield (e.g. foreland basins).