Chemical and isotopic geothermometers applied to deep geothermal brines from the Upper Rhine Graben

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Several geothermal projects are being developed in fractured deep areas of the Upper Rhine Graben to extract high-temperature fluids (≥ 150°C) for electricity and/or heat production. In 2016, several deep native brines from oil and geothermal fields were studied in this area [1]. Among these brines, most of the geothermal saline waters were collected from deep wells (from 2850 to 5000 m) penetrating the granite basement underlying the sedimentary cover, only drilled in four sites (Soultz-sous-Forêts and Rittershoffen in France; Landau and Insheim in Germany). These Na-Cl geothermal brines indicate similar chemical and isotopic characteristics with TDS values ranging from 99 to 107 g/l and pH values close to 5, suggesting common processes of seawater evaporation, halite dissolution, fluid mixing between deep and meteoric waters as well as of water-rock interaction at relatively high temperatures (enrichment in K, Ca, Si, Li, Rb, Cs, As, Sr, Mn, Ba and metals; depletion in Mg, SO_4, B).

This communication discusses the use of classical geothermometers and the development of new thermometric relations as Na-Rb, Na-Cs and K-Sr (thanks to the European FP7-IMAGE project), in order to estimate the temperature of deep reservoirs in such geological environments. For the geothermal brines from the deep granite reservoirs, most of the geothermometers indicate concordant temperatures close to 225°C ± 25°C, whereas the maximum temperature so far measured on site is 200°C. For the other native brines, the temperatures estimated using most of these geothermometers are lower. Calculations of aqueous speciation and mineral saturation indices done for the Soultz native brine suggest that the deep geothermal saline waters discharged from the granite reservoirs are close to equilibrium with respect to albite, K-feldspar, quartz, calcite, dolomite, $CaSO_4{:}0.5H_2O$ (β), barite, fluorite, pyrite, Mg-illite, and smectites at 200-230°C and a P_{CO2} close to 6 bar. These calculations are in good agreement with the geothermometric estimations and also allow explaining the observed barite precipitation when these hot deep brines are considerably cooled (< 100°C).

[1] Sanjuan B., Millot R., Innocent Ch., Dezayes Ch., Scheiber J., Brach M. (2016) *Chemical Geology*, **428**, 27-47.