



## Monitoring reactive flow in geothermal settings: A petro- and fluid physical approach

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Water-rock interactions and other mineral reactions, such as dehydration processes, have a fundamental impact on structural properties of a rock formation, such as porosity and pore connectivity, and are thus highly relevant for transport and storage processes in crustal settings. Fluid-rock interactions at greater depths under higher pressure and temperature conditions are inaccessible to direct observation. However, the breakdown of minerals as well as the formation of new ones changes the availability of charge carriers in the pore fluid, especially at elevated temperature. The availability of charge carriers and their mobility determine the electrical rock properties besides the pore structure. Studies on electrical properties of rock under controlled laboratory conditions may help to increase our understanding of these processes. The purpose of this study is to examine under which circumstances physical properties of rocks and pore fluids can be used as monitoring tools for fluid-related processes in high-temperature environments. We have performed reactive flow experiments on water-rock systems of various fluid to rock ratios at flow rates ranging from 0.02 – 0.00002 ml/min and pT conditions of unconventional high-enthalpy geothermal reservoirs ( $T > 350^{\circ}\text{C}$ ,  $p_{\text{fluid}} = 25\text{ MPa}$ ). Hydraulic and electrical properties were determined on low to medium porous rocks. Additionally, the electrical properties of highly reactive systems were measured, where water was circulated around a rock core. The measurements were supplemented by a number of additional tests, comprising microstructural investigations as well as the chemical analysis of fluid samples, which were taken at every temperature step. At low temperature ( $< 200^{\circ}\text{C}$ ), both physical and chemical data show only slight fluid-rock interactions, whereas above  $200^{\circ}\text{C}$ , continuously increasing Si concentrations in the fluid samples indicate a beginning mineral dissolution. In porous samples with high initial fluid-rock contact area this process is detectable as decreasing electrical formation factor. At near-critical conditions Si dissolution is going to accelerate and also Al is more intensively mobilized. In highly permeable systems, the release of charge carriers to the formation fluid is accompanied by a steep increase in electrical fluid conductivity by factor 7 within seconds. This points to an extensive and spontaneous increase in rock solubility. However, at supercritical conditions conductivities did not remain steady and the electrical properties of porous supercritical fluid-rock systems are characterized by a fluctuation of conductivities over a wide range. This indicates a dynamic interplay of the competing processes of mineral dissolution and new mineral formation, which are also evident from complementary micro-structural investigations as well as chemical analyses of the percolated fluids. From SEM analyses it is apparent that the alteration of the solid material is most effective where fresh fluid is continuously flowing around the solid, while stagnant fluids in low permeable samples led to a much less pervasive alteration of the solid. In consequence, resistivity contrasts are too low, to be detectable. However, the release of additional water due to dehydration reactions can cause strong changes in electrical resistivity, especially in stagnant low permeability systems.