

## Understanding physical rock properties and their relation to fluid-rock interactions under supercritical conditions

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The electrical conductivity of rocks is, in addition to lithological factors (mineralogy, porosity) and physical parameters (temperature, pressure) sensitive to the nature of pore fluids (phase, salinity), and thus may be an indicative measure for fluid-rock interactions. Especially near the critical point, which is at 374.21° C and 22.12 MPa for pure water, the physico-chemical properties of aqueous fluids change dramatically and mass transfer and diffusion-controlled chemical reactivity are enhanced, which in turn leads to the formation of element depletion/ enrichment patterns or cause mineral dissolution. At the same time, the reduction of the dielectric constant of water promotes ion association and consequently mineral precipitation. All this cause changes in the electrical conductivity of geothermal fluids and may have considerable effects on the porosity and hydraulic properties of the rocks with which they are in contact. In order to study the impact of fluid-rock interactions on the physical properties of fluids and rocks in near- and supercritical geological settings in more detail, in the framework of the EU-funded project “IMAGE” (Integrated Methods for Advanced Geothermal Exploration) hydraulic and electrical properties of rock cores from different active and exhumed geothermal areas on Iceland were measured up to supercritical conditions ( $T_{max} = 380^{\circ} \text{C}$ ,  $p_{fluid} = 23 \text{ MPa}$ ) during long-term (2-3 weeks) flow-through experiments in an internally heated gas pressure vessel at a maximum confining pressure of 42 MPa. In a second flow-through facility both the intrinsic T-dependent electrical fluid properties as well as the effect of mineral dissolution/ precipitation on the fluid conductivity were measured for increasing temperatures in a range of 24 – 422° C at a constant fluid pressure of 31 MPa. Petro- and fluid physical 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 level.

Both physical and chemical data indicate only slight fluid-rock interactions at  $T < 250^{\circ} \text{C}$  and the increase in bulk conductivity is most probably dominated by a T-dependence of the surface conductance. At higher temperatures, the decreasing fluid density causes the decrease of dielectric constant, which in turn leads to the precipitation of minerals due to a promoted association between oppositely charged ions. This is intensified at the critical point, indicated by a sharp decrease in conductivity, when regarding pure fluids. The opposite was observed in experiments, where fluid–solid interaction was allowed. In this case, the conductivity of the bulk system has increased within seconds nearly by factor 7. This points to a massive release of charge carriers due to an extensive and spontaneous increase in rock solubility, what counterbalances the effect of mineral precipitation. Moreover, the permanent oscillation of conductivities at supercritical conditions may indicate a dynamic interplay of ion depletion by mineral precipitation and the input of new charge carriers due to mineral dissolution. Regarding the permeability we can resolve the influence of mineral precipitation only, which is indicated by a decrease in rock permeability by about 5 % after the sample was exposed to supercritical conditions for 4 hours.

Especially, for Si a continuous increase of ion concentration in the fluid samples is revealed for increasing temperatures, indicating a beginning mineral dissolution above 150° C. At near-critical conditions also Al and Pb as well as the rare earth elements (REE) are more intensively dissolved. 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 led to a much less pervasive alteration of the material. In this case, solid dissolution seems to slow down considerably or even comes to an end, what can be explained by the adjustment of a chemical equilibrium and the stabilisation of the reaction front.