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Electrical conductivity of Icelandic deep geothermal reservoirs: insight from HT-HP laboratory experiments

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Although the Icelandic geothermal system has been intensively investigated over the years, targeting increasingly deeper reservoirs (i.e. under supercritical conditions) requires a good knowledge of the behaviour of physical properties of the host rock in order to better interpret large scale geophysical observations. In particular, the interpretation of deep electrical soundings remains controversial as only few studies have investigated the influence of altered minerals and pore fluid properties on electrical properties of rocks at high temperature and pressure.

In this study, we investigate the electrical conductivity of drilled samples from different Icelandic geothermal fields at elevated temperature, confining pressure and pore pressure conditions (100°C < T < 600°C, confining pressure up to 100 MPa and pore pressure up to 35 MPa). The investigated rocks are composed of hyaloclastites, dolerites and basalts taken from depths of about 800 m for the hyaloclastites, to almost 2500 m for the dolerites. They display different porosity structures, from vuggy and intra-granular to micro-cracked porosities, and have been hydrothermally altered in the chlorite to amphibolite facies.

Electrical conductivity measurements are first determined at ambient conditions as a function of pore fluid conductivity in order to establish their relationships with lithology and pore space topology, prior to the high pressure and temperature measurements. Cementation factor varies from 1.5 for the dolerites to 2.83 for the basalt, reflecting changes in the shape of the conductive channels. The surface conductivities, measured at very low fluid conductivity, increases with the porosity and is correlated with the cation exchange capacity.
At high pressure and temperature, we used the two guard-ring electrodes system. Measurements have been performed in dry and saturated conditions as a function of temperature and pore pressure. The supercritical conditions have been investigated and temperature cycles have been performed systematically. Dry electrical conductivity measurements show for most of the samples irreversible changes when temperatures exceed 500°C. These changes are interpreted as destabilization/dehydration of alteration minerals that could lead to the presence of a conductive fluid phase in the samples. Very low and high salinity (NaCl) electrical conductivity measurements have been performed as a function of temperature. At supercritical conditions, electrical conductivity at low salinity is not pore pressure dependent and surface conduction is preponderant. At saturated conditions, the rock's electrical conductivity increases linearly (as a function of T-1) until 350°C. Above 350°C, the conductivity decreases. All rock types exhibit the same increasing rate.

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