Geophysical Research Abstracts
Vol. 18, EGU2016-14507-1, 2016
EGU General Assembly 2016

Quantitative impact of hydrothermal alteration on electrical resistivity in geothermal systems from a joint analysis of laboratory measurements and borehole data in Krafla area, N-E Iceland

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Rock permeability and fluid temperature are the two most decisive factors for a successful geothermal drilling. While those parameters are only measured from drilling, they might be estimated on the basis of their impact on electrical resistivity that might be imaged from surface soundings, for example through TEM (Transient Electro Magnetic) down to one km depth. The electrical conductivity of reservoir rocks is the sum of a volume term depending on fluid parameters and a surface term related to rock alteration. Understanding the link between electrical resistivity and geothermal key parameters requires the knowledge of hydrothermal alteration and its petrophysical signature with the Cation Exchange Capacity (CEC). Fluid-rock interactions related to hydrothermal circulation trigger the precipitation of alteration minerals, which are both witnesses of the temperature at the time of reaction and new paths for the electrical current. Alteration minerals include zeolites, smectites, chlorites, epidotes and amphiboles among which low temperatures parageneses are often the most conductive. The CEC of these mineral phases contributes to account for surface conductivity occuring at the water-rock interface. In cooling geothermal systems, these minerals constitute in petrophysical terms and from surface electrical conduction a memory of the equilibrium phase revealed from electrical probing at all scales.

The qualitative impact of alteration minerals on resistivity structure has been studied over the years in the Icelandic geothermal context. In this work, the CEC impact on pore surfaces electrical conductivity is studied quantitatively at the borehole scale, where several types of volcanic rocks are mixed together, with various degrees of alteration and porosity. Five boreholes located within a few km at the Krafla volcano, Northeast Iceland, constitute the basis for this study. The deepest and reference hole, KJ-18, provides cuttings of rock and logging data down to 2215 m depth; CEC measurements performed on cuttings show. KH-1 and KH-3 have cores and logs in the top 200 m only. Boreholes KH-5 and KH-6 sample cores with higher temperature alteration minerals down to 600 m. Together, these 4 shallow holes cover the diversity of rock types and alterations facies found in KJ-18. The petrophysical calibration obtained from cores will then be upscaled to log data analysis in KJ-18: porosity, formation factor, permeability, acoustic velocity, electrical surface conduction at different temperatures and CEC.

This research is supported by the IMAGE FP7 EC project (Integrated Methods for Advanced Geothermal Exploration, grant agreement No. 608553).