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Effect of the water-steam phase transition on electrical rock conductivity

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The effect of the water-steam phase transition on electrical conductivity was experimentally investigated for four specimens of volcanic rocks from Icelandic geothermal reservoirs and one Fontainebleau sandstone sample. The measurements were performed at simulated in-situ conditions: The pore fluid chemistry was chosen to be similar in composition and electrical conductivity to the reservoir fluid; confining pressure, pore pressure, and temperature were controlled. At a temperature of 150°C and constant confining pressure pore fluid was gradually released from the sample by steadily increasing the volume of the pore fluid system. At the vapor pressure this allowed a controlled transformation of liquid water into steam.

In all five experiments the pore fluid vaporized at pressures equal to or below that of the boiling point of free water at the respective temperature. The electrical conductivity of the samples decreased continuously until reaching a distinct minimum at approximately 5 % of its starting value.

The qualitative application of a conductivity model proposed by Roberts et al. (2001) enabled us to interpret the observed concurrent evolution of both electrical conductivity and pore (vapor) pressure with respect to the pore size distribution. An estimate based on the concept of capillarity indicates that virtually all pore size classes became affected by vaporization as conductivity decreased. However, a comparison of the pore volume to the total amount of fluid drained from the sample at the conductivity minimum implies that typically less than 1 % of the liquid mass contained within the (connected) pore space was transformed into vapor until this stage.

Knowing where the liquid-steam transition is located at depth is of relevance for both economic and security reasons. Besides being a fundamental petrophysical investigation, this study was therefore also directed to the question if the water-steam phase transition in geothermal reservoirs could be detected by surface monitoring techniques. Our results present evidence, that depending on the amount of steam in the pore space, electrical monitoring systems should particularly be suitable.

References

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