Electrical conductance of pore water in a sandstone at low water saturation

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In rocks with pores partially filled with water and air, different physicochemical properties than the water-saturated states occur affecting various material transport and chemical reactions. Electrical properties of rocks are known to depend on degrees of water saturation and pore structures. Electrical conduction in rocks is considered to be composed of conductions in bulk pore water and electrical double layer at mineral/water interface at high water saturation. At low water saturation, when water in rock pore loses electrical conduction connectivity, water film is still percolating all over the pore space conducting electricity.

In this study, to investigate electrical conduction down to low degrees of water saturation (S_w), electrical conductance was measured on a Berea sandstone (main mineral composition: quartz, porosity 25%) initialy saturated with pure water upon natural drying for decreasing water saturation degree. For lower water saturation than $S_w = 0.03$, dry air was flowed in the sytem to attain until $S_w = 0.001$. Since electrical properties of rocks are known to depend mainly on conduction of electrical double layer in water film at low water saturation, surface conductivity was calculated with the measured electrical conductance values. The obtained surface conductivity is mostly constant for higher water saturation $S_w > 0.2$. However, the surface conductivity for $S_w < 0.2$ (water film thickness $h < 20$ nm) decreases with decreasing degree of water saturation, indicating changes in the structure of electrical double layer in water film.

In order to understand the surface conductivity, we first calculated the distribution of dissolved ions at quartz/water interface using triple-layer model (TLM). Then, we estimated the surface conductivity by summing the following three contributions: conductivity of ions in diffuse layer; conductivity of ions absorbed in Stern layer; and proton transfer at surface silanol group (>Si-OH).

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