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A Circuit Model for the Measurement of the Streaming Potential in a Rock Sample

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Streaming potential is usually defined under the assumption that the rock sample under consideration is not connected electrically to any external circuit. In this study we investigate experimentally the effect of the external circuit on the measurement of the streaming potential.

Cations usually dominate anions in the diffuse layer in the pore canals in a fluid-saturated porous sandstone sample. When a pressure difference is applied to the sample, fluid flows in the pores and causing a convective current due to the cation-dominate motion. With the separation of opposite ions at the two ends, a streaming potential occurs, and results in a conductive current. Those two current will be opposite and equal in value so that the streaming potential does not change.

But in any experimental measurement of the streaming potential, the rock sample is not isolated in the circuit. An external circuit is necessary for the measurement of the potential difference at the ends of the sample. This external circuit will divert the flow of charges. This study investigates the effect of the external circuit on the convective current and conductive current in the pores by experiments, and gives an equivalent circuit model for the two currents.

We connect an external resistance R_{ext} to the ends of the fluid-saturated rock sample, and measure the potential difference at the ends of the sample . The impedance of the fluid-saturated rock sample Z_{rock} is definite under a given salinity and can be separately measured. The circuit is governed by the following equations,

$$U_{rock} = Z_{rock} I_{cond}, \tag{1}$$

$$U_{rock} = R_{ext} I_{ext}, \tag{2}$$

$$I_{conv} + I_{cond} + I_{ext} = 0, \tag{3}$$

where I_{conv} is the convective current, I_{cond} is the conductive current, I_{ext} is the external current and U_{rock} is the potential difference at the ends of the rock sample.

From the above three equations, we get

$$I_{conv} = \frac{-U_{rock}\left(Z_{rock} + R_{ext}\right)}{Z_{rock} R_{ext}} \quad . \tag{4}$$

We repeated the measurement under different external resistance R_{ext}. The computed convective current changes slightly. Thus we conclude that the measurement circuit does not change the convective current, although it changes the conductive current. So the convective current behaves as a constant current source. This conclusion is in consistence with the electrokinetic model, in which the convection current is caused by the cation-dominated fluid flow under pressure difference. We notice that the measured streaming potential is smaller than that without measuring circuit connected to it, unless the external resistance R_{ext} is orders higher than the resistance of the rock.

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