Rock properties conducive to seismo-electric and electrokinetic effects

Valeriya Hallbauer-Zadorozhnaya

Irkutsk National Research Technical University/ Irkutsk, Russia

The seismo-electric effect and the effect of induced polarization of the electro-osmotic type are electrokinetic phenomena. The theoretical conceptions of both effects are based on the Helmholtz-Smoluchowski equations applied to streaming potentials and electro-osmosis. However, electrokinetic phenomena of significant amplitude do not occur in every rock type. Taking into account the mathematical concepts of M. Biot in the wave equation, the movement of a liquid relative to a solid matrix for slow seismic waves and the problem of R.N. Chandler on transient pressure inside a pore, the amplitude of seismo-electric effects in porous rocks was calculated.

Based on F. Gassman's classification of the relationship between the components of rocks, on distinguishing rocks with perfect, imperfect and absent relationships between they phases (solid and fluid). It has been shown that in rocks with absent relationship between the components (the fluid circulates freely in the pore space and the pores are well connected to each other, wide pores) and in rocks with perfect relationship (thin pores in which the movement of pore moisture in the pores does not occur), electrokinetic phenomena are suppressed. In nature, however, there are many types of rocks containing liquid and gas components in volumes that significantly affect their elasticity with less strong interfacial bonds. Due to the difference in the elastic properties of the liquid and the skeleton, under the influence of elastic deformations, the solid and liquid components will move relative to each other, and these movements are interconnected. Changes in pressure in the skeleton will determine changes in pressure in the pores. We will consider these sediments as "sediments with an imperfect relationship between components".

The results of our research are as following:

1. Applying the wave equation and using the mathematical concepts of M.A.Biot (1959) on the movement of a liquid relative to a solid matrix for slow seismic waves and implementing the approach of R.N. Chandler (1971) on transient pressure inside a pore, the amplitude of the seismoelectric effect in porous rocks was calculated.
2. The amplitudes of the seismoelectric effect were calculated for rocks with perfect, imperfect and absent connections between the liquid (in the pores) and the solid components of the rock matrix.
3. It has been shown that the seismoelectric effect can only occur in rocks with an imperfect relationship between the above components, where, under the influence of a pressure gradient, the fluid in the pores begins to move relative to the solid components. This effect occurs in rocks with medium to high fluid movement permeability (sediments with low, medium and, partly, high permeability except for clays).
4. An electrokinetic effect of the electro-osmotic type occurs in rocks with imperfect liquid connections between pores with radii of 5·10-6 to $1 \cdot 10^{-4}$ m, which also corresponds to weakly, moderately and highly permeable rocks. Calculations have shown that the effects of induced polarization effect distorted TEM signals can only be detected where a decay constant of the induced polarization occurs in $\tau \sim 1\mu c \div n$ ·мс. range.

References

1. Biot, M. Theory of propagation of elastic waves in a fluid-saturated porous solid. Low frequency ranges / J. Acoust. Soc. Am. 1956. Vol. 28. 168–178.

2. Chandler R.N. Transient streaming potential measurements on fluid-saturated pore structures: An experimental verification of Biot’s slow wave in quasi-static limit / J. Acoust. Soc. Am. 1981. №70(1), 116–121.