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# Seismoelectric effects caused by mesoscopic heterogeneities

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When a seismic wave propagates through a fluid saturated porous medium, it produces a relative motion between the fluid phase and the rock matrix. In the presence of an electric double layer at the fluid-solid interface, this movement introduces a separation of electrical charges which in turn generates a time-varying electrical source current and a resulting distribution of electrical potential. The presence of mesoscopic heterogeneities, that is, heterogeneities having sizes larger than the typical pore size but smaller than the prevailing wavelength, can induce a significant oscillatory fluid flow in response to the propagation of seismic waves. Indeed, the energy dissipation related to this phenomenon is considered to be one of the most common and important seismic attenuation mechanisms operating in the shallow part of the crust. Given that the amount of fluid flow produced by this phenomenon can be significant, a potentially important seismoelectric signal is also expected in such media. However, to the best of the authors' knowledge, the role played by mesoscopic wave-induced fluid flow on seismoelectric phenomenon is so far largely unexplored. In this work, we propose a numerical approach for computing seismoelectric signals related to the presence of mesoscopic heterogeneities. To this end, we consider a two-dimensional representative rock sample containing mesoscopic heterogeneities and apply an oscillatory compression on its top boundary. The solid phase is neither allowed to move on the bottom boundary nor to have horizontal displacements on the lateral boundaries and the fluid is not allowed to flow into or out of the sample. The fluid velocity field is determined by solving the quasi-static poroelastic equations in the space-frequency domain under the governing boundary conditions. Next, the seismoelectric conversion is calculated using the so-called effective electrical excess charge approach, which has been recently developed in streaming potential studies. We illustrate the methodology by analyzing the seismoelectric signals generated by mesoscopic fractures in a homogeneous sandstone sample. For the applied oscillatory compression, we consider a frequency range from 1Hz to 10kHz and an amplitude of 1kPa. For the particular material properties and geometries considered in this analysis, the results clearly show a frequency-dependent response of the seismoelectric signal that is caused by the mesoscopic heterogeneities. The magnitude tends to be negligible at frequencies below $\sim$100Hz. Conversely, at higher frequencies the induced fluid flow between the fractures and the embedding rock matrix becomes fairly important, thus yielding a measurable seismoelectric signal of a few mV. Our results therefore suggest that seismoelectric signals caused by mesoscopic heterogeneities should be explored in more detail. Such efforts should not only include further numerical analysis to better understand the role played by different types of heterogenities, but also well-controlled laboratory investigations.