Geophysical Research Abstracts
Vol. 20, EGU2018-16256, 2018
EGU General Assembly 2018
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Impact of seismic wave scattering on the seismoelectric response of fractures

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When a seismic wave propagates through a fluid-saturated porous rock containing fractures, it produces fluid pressure gradients between the more compliant fractures and the stiffer embedding background. Consequently, fluid flows until the pressure equilibrates. This phenomenon, commonly referred to as wave-induced fluid flow (WIFF), can produce measurable seismoelectric signals of the interface type due to the conversion of mechanical into electromagnetic energy. Biot's theory of poroelasticity is the adequate framework for predicting WIFF effects. In the context of this theory, the interface response of fluid-saturated rock samples containing fractures has been recently studied by computing the electrical potential distribution in the sample when subjected to a numerical oscillatory compressibility test. This test can be interpreted as the action of a propagating P-wave under the assumption that the size of the sample is much smaller than the seismic wavelength. Imposing appropriate boundary conditions, the electrical potential distribution can be retrieved from the relative fluid velocity fields as a function of the frequency of the oscillatory compression. This approach allows for considering realistic fracture distributions, which are generally not amenable to analytical methods and computationally demanding through direct simulations of seismic wave propagation. However, the approach is not valid at frequencies at which seismic wave scattering effects arise. In this scenario, the relative fluid velocity distribution is given by the contributions associated with all the wave modes scattered from the fractures. In order to shed some light on the importance of these effects on the seismoelectric interface signal, in this work, we solve the full poroelastic equations of wave propagation for a thin-layer model. In this model, the fracture is represented by a very thin, porous, and compliant layer embedded between two identical halfspaces. We consider an incident plane P- or S-wave and assume that the energy of the incident wave is split into two compressional waves (fast and slow) and one shear wave at each side of the fracture interfaces. The relative fluid velocity fields associated with the different wave modes are computed as functions of frequency and incidence angle. Then, we model the interface response of the fracture and explore the relative contributions of the different wave modes. Moreover, we assess the importance of Biot's global flow effects, which are generally neglected in the numerical oscillatory tests.