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Numerical analysis of anisotropic seismic attenuation and velocity dispersion in fractured media.

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Fractures are present in most geological formations and they tend to dominate not only their mechanical but also, and in particular, their hydraulic properties. For these reasons, the detection and characterization of fractures constitutes a subject of great interest in several fields of Earth sciences, such as groundwater and contaminant hydrology, CO_2 sequestration as well as geothermal and fossil energy exploration and production, among many others. Seismic attenuation has been recognized as a key attribute for this purpose, as both laboratory and field experiments indicate that the presence of fractures usually produces very significant attenuation and that this attribute tends to systematically increase with increasing fracture density. In the absence of fracture connectivity, this energy loss is generally considered to be primarily due to fluid flow between the fractures and the embedding porous matrix. That is, due to the very significant compressibility contrast between fractures and the embedding porous matrix, the propagation of seismic waves can generate a strong fluid pressure gradient and associated fluid flow between the two domains, which in turn generates energy dissipation. Due to the typical geometrical characteristics of fractures, the associated attenuation and velocity dispersion must be expected to be strongly anisotropic. In this work, we seek to explore the main characteristics of anisotropic seismic attenuation and velocity dispersion due to fluid flow between mesoscopic fractures and the embedding matrix. To this end, we apply numerical oscillatory compressibility and shear tests based on the quasi-static poro-elastic equations on two-dimensional synthetic rock samples containing representative mesoscopic fractures. Assuming that the considered rock sample can be effectively represented by a homogeneous transversely isotropic viscoelastic medium, such tests allow us to compute the corresponding complex-valued and frequency-dependent elements of the stiffness matrix. Finally, we perform an exhaustive sensitivity analysis to determine the role played by different properties of fractured porous rocks with regards to this energy dissipation mechanism as a function of the direction of seismic wave propagation.