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Numerical upscaling of the seismic characteristics of fractured media

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Understanding the effects of fractures in seismic wave propagation, notably with regard to attenuation and velocity dispersion associated with wave-induced fluid pressure diffusion, may provide valuable insights with regard to the mechanical and hydraulic properties of such media. For complex distributions of fractures, these seismic characteristics are difficult to explore through analytical methods. To overcome this limitation, we use numerical upscaling procedures based on the theory of poroelasticity. In these numerical approaches, a homogeneous oscillating displacement or stress field is applied to a subvolume of a heterogeneous poroelastic medium, which via the equivalent complex plane-wave modulus allows for estimating the seismic velocity dispersion and attenuation characteristics of a corresponding dynamic-equivalent viscoelastic medium. The thus inferred seismic characteristics are, however, only meaningful, if the considered sample has at least the size of a representative elementary volume or REV. In analogy to the classical definition for elastic media, we assume an REV to corresponding to the minimum volume for which attenuation and velocity dispersion are independent of the applied boundary conditions. The importance of choosing an adequate REV for estimating the effective seismic characteristics was recently investigated for periodically fractured media. Here, we extend this analysis to media containing randomly distributed parallel fractures. The corresponding media are composed of side-by-side assemblies of fundamental blocks, each containing one randomly positioned horizontal fracture. The fractures themselves are represented as strongly compliant poroelastic features of very high porosity and permeability. The size of the fractures is assumed to lie in the mesoscopic scale range, which implies that they are much larger than the pore size but much smaller than the dominant wavelength. Our results indicate that for an applied homogeneous displacement, boundary condition effects are negligible or, equivalently, that the rate of convergence to the effective properties is very fast for this simple type of fractured media. Conversely, for an applied homogeneous stress the convergence rate is much slower. These findings are largely consistent with those previously obtained for periodic fractured media. If and to what extent these findings can be extended to more complex and more realistic fracture configurations, where the considered subvolumes also need to be representative of the overall statistical properties of the considered fractured media, is a subject of ongoing research.