Seismic response of fractures and induced anisotropy in poroelastic media

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ABSTRACT

A planar fracture embedded in a fluid-saturated poroelastic – Biot - medium can be modeled either as a extremely thin, highly permeable and compliant porous layer or employing suitable boundary conditions. A Biot medium containing a dense set of aligned fractures behaves as an effective transversely isotropic and viscoelastic (TIV) medium when the average fracture distance is much smaller than the predominant wavelength of the traveling waves. This leads to frequency and angular variations of velocity and attenuation of seismic waves. P-waves traveling in this type of medium induce fluid-pressure gradients at fractures and mesoscopic-scale heterogeneities, generating fluid flow and slow (diffusion) Biot waves, causing attenuation and dispersion of the fast modes (mesoscopic loss). A poroelastic medium with embedded aligned fractures exhibits significant attenuation and dispersion effects due to this mechanism, which can properly be represented at the macroscale with an equivalent TIV medium. In this presentation, we apply a set of compressibility and shear harmonic finite-element (FE) experiments on representative samples of fractured highly heterogeneous Biot media to determine the five complex and frequency dependent stiffnesses characterizing the equivalent TIV medium at the macroscale. The FE experiments consider brine or patchy brine-CO_2 saturated samples and a brine saturated sample with an heterogeneous (fractal) skeleton with fractures. We show that fractures induces strong seismic velocity and Q anisotropy, both for qP and qSV waves, enhanced either by patchy saturation or frame heterogeneity. Finally we illustrate the propagation of waves at the macroscale for the case of horizontal and vertical aligned fractures employing the equivalent media determined at the mesoscale.