Geophysical Research Abstracts
Vol. 21, EGU2019-2051, 2019
EGU General Assembly 2019

Seismic envelopes at laboratory sample scale from rock physics measurements

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Fracture- and fluid-induced heterogeneities in rocks generate scattering sources that attenuate direct-wave seismic energy. This scattered energy is recorded later in seismograms and is measurable as coda envelopes, which hold information about fracture networks and fluid content in the rock. Seismic coda analysis has the potential to provide useful information about fracture systems and fluid-flow process, while coda imaging is currently a state-of-art technique in highly heterogeneous media.

These techniques have already been applied at field scale (10^1-10^3 m) to characterize lithospheric and volcanic settings; however, the connection between smaller scale rock physics (10^{-3}-10^{-1} m) and seismic scattering parameters is still unclear. In this study, we developed computational tools that use rock physics observations to model seismic envelopes at core plug scale (mm-cm) in the laboratory. We use field-dependent qualitative measurements of seismic heterogeneity, like fracturing, porosity and saturation, as inputs for constructing synthetic coda envelopes. The computational framework applied is radiative transfer theory (RTT), which allows us to compute envelopes that are comparable with experimental data.

The synthetic envelopes are computed using stochastic parameters and follow a Born approximation. We use as input an analysis of the statistical distribution of fractures previously estimated in a sandstone core plug, deformed with a confining pressure of 35 MPa and pore fluid pressure of 10 MPa. The results can be up-scaled to model seismic attenuation observations at field scale; the outcomes provide a novel and useful approach for quantifying fractures network and saturation directly from seismic coda analysis.