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Three-dimensional attenuation imaging of the Irpinia fault zone (Southern Italy): inferences on the fluid storage and earthquake related processes

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The seismic imaging of crustal wave velocity and attenuation provide useful insights into the possible presence and role of fluids in the volume embedding earthquake causative faults. In particular, they allow constraining the range of rock properties such as porosity, consolidation parameter, type of fluid mixing and relative saturation percentage.
Our study is focused on the southern Apennines area that experienced moderate to large earthquakes in the past century, the largest one, the Irpinia MS 6.9 earthquake, occurred on November 23th, 1980.
In this study we propose to integrate velocity and attenuation tomographic images for a comprehensive seismic interpretation of the 1980 Irpinia earthquake fault zone that uses well established rock physical laws to retrieve information about porosity and the type of permeating fluids from seismic attributes.
We performed an attenuation tomographic inversion, which provided 3-D images of the anelastic attenuation properties in terms of body wave quality factors (Qp and Qs). We analyzed a data set of 4801 t*P and 1833 t*S relative to 670 earthquakes with local magnitude $0.1 \leq ML \leq 3.2$. We inverted the t* data for Q following a multiscale strategy, progressively increasing the density of grid points describing the attenuation model. The Qp model shows a slight increase of the values with depth, reaching a value of about 1000 in the central part of the model, at depths between 8 and 12 km. The Qs model shows strong lateral variations along a SW-NE section with a major transition occurring in correspondence with the Ms 6.9, 1980 earthquake rupture. Moreover the Qs model well delineates the transition between the Apulian Carbonate platform and the basement at about 7 km depth with an increase of values from 400 to 1000.
In order to recover the properties of the host rock volume characterized by a set of micro-parameters (porosity, consolidation parameter, permeating fluid type and percentage of fluid saturation), we performed an exhaustive sampling of micro-parameter model space for the prediction of macro-parameters (P and S seismic velocities and attenuation quality factors) resulting from an up-scaling strategy. We focused our rock physics modeling on the volume embedding the Irpinia fault system between 8 and 10 km depth, where the quality factor Qp reaches the largest values and where most of seismicity occurs. We assumed that the simulated rock has a dominant dolomite mineralogical composition, a porosity in the range [1%, 5%], a consolidation parameter Cs in the range [2, 20]. We finally considered the rock pores and fractures filled by a two-phase fluid (brine-CO_2; brine-CH4 and CO_2-CH4). Then we computed the values of the macro-parameters (Vp, Vs and Qp) by varying the relative saturation percentage and compared them to the observed values. We are able to constrain the porosity and consolidation in the range 3%-5% and 6-10, respectively. We interpret these results with the presence of a fracture system, likely saturated with brine-CO_2/CH4 or CO_2-CH4 mixtures and suggest that the triggering mechanism of seismicity at the Irpinia fault zone is strongly controlled by pore fluid pressure changes.