A numerical investigation on seismic waves for an anisotropic fault zone

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We examine the effects of anisotropy on the seismic wavefield in a fault zone by analyzing the synthetic seismograms for a fault zone model and a variety of seismic wave sources. The fault zone is modeled by a homogeneous vertical layer of transverse isotropy sandwiched between isotropic half-spaces (host rocks), which is induced by aligned cracks. The symmetry axis of the transverse isotropy is horizontal and perpendicular to the fault zone strike. We calculate the synthetic seismograms for this anisotropic fault zone model using a semi-analytical method, the reflectivity method.

The synthetic seismograms near the fault zone show a later phase arriving after the main shear-wave in the horizontal component perpendicular to the strike of the fault zone. It is the slow shear-wave qS2 and its reverberation. The amplitude of this phase and the time delay from the main shear-wave arrival are proportional to the degree of anisotropy, which suggests that observing such phase in field measurements may imply the presence of an anisotropic fault zone.

In general the fault zone is composed of the highly damaged region and the undeformed host rock region. The high damage usually causes the velocity reduction of the fault zone material due to intense fracturing, brecciation, liquid-saturation and possibly high pore-fluid pressure. This strong heterogeneity sometimes raises a problem on measuring shear-wave splitting parameters (the polarization direction of the fast shear-wave and the time delay of the arrival of the slow shear-wave): the cross-correlation or some other similar methods such as the linearity techniques cannot extract the splitting parameters. We here perform the extraction of the shear-wave splitting parameters by applying the cross-correlation method to the synthetic seismograms in order to investigate which source type and station location would be more appropriate to estimate them correctly.

As results, for a strike-slip source, the synthetic seismograms show that the wavefield is more affected by the velocity structure than by the degree of anisotropy, which makes it difficult to estimate the shear-wave splitting parameters. However, the polarization direction can be detected, when the fault zone has large crack density, for strike-slip fault, normal-fault, and dip-slip sources located outside the fault zone with the strike of 45 degrees, and for normal-fault source with the strike parallel to the fault zone. Also for normal-fault and dip-slip sources located inside the fault zone with the strike of 45 degrees against the fault zone, it can be detected. The time delay is not obtained correctly because at stations and/or sources located outside the fault zone the propagation distance in anisotropy is too short to affect the waveform and inside the fault zone the effects of the velocity structure is dominant compared with the effects of the anisotropy. These results suggest that the determination of the anisotropic properties in the fault zone would require an appropriate station deployment and the source type information.