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Observation of a critically refracted converted SP wave using laser Doppler interferometer

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Laboratory measurements of elastic properties of rocks are important for calibration of seismic data and for corroboration of theoretical models of rocks. The most common way of determining the elastic properties of rock samples in laboratory settings is to estimate the velocities of ultrasonic waves propagating in different directions. The wave velocities are usually obtained from the travel times of waves generated and recorded by ultrasonic piezoelectric transducers. This approach has a large uncertainty associated with shear-wave travel time estimation and separation of differently polarised shear waves, as well as uncertainty as to whether phase or group velocity is measured. The problems are caused by the relatively large size and small number of transducers. One way to address some of these issues is by using laser Doppler interferometer, which records a particle like movement that can serve to separate the waves and to pick the travel times from which the ray velocities cab be estimated reliably, and with a huge data redundancy. In this paper, laser Doppler interferometer is used to record wave propagation in an anisotropic rock sample by measuring three orthogonal components of particle velocity on the sample surface. These measurements allow a clear separation of different wave types. The travel time of these waves are used for estimation of anisotropy parameters of the sample. A key observation is the very strong wave which at small offsets has traveltimes equal to those of the S-wave, but at large offsets travels with a velocity close to that of the P-wave. We interpret this wave as a converted SP wave critically refracted at the free surface. The nature and characteristics of this wave are confirmed by numerical simulations in both isotropic and anisotropic media. These simulations show the same traveltimes as measured in the experiment, but the amplitude of the converted SP wave is much stronger in the measured data. Analysis of this inconsistency is part of the future research, but perhaps one possible explanation is a complex radiation pattern of the source. Such a non-trivial radiation pattern is probably also the reason for the different frequency content in the SH and P-waves compared to the SV and the critically refracted SP wave. Knowledge of the radiation pattern of the source will allow it to be deconvolved from the observed data. Based on our preliminary results, such a deconvolution would also allow us to use semblance as a fitting algorithm, which would eliminate the need to pick the travel times and make the fitting more robust.