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Mapping near surface-elastic parameters of Quaternary sediments using multicomponent seismic techniques

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The geophysical characterization of Quaternary sediments is of particular interest, for example, in the assessment of groundwater reserves, engineering applications, and climate history reconstruction. Furthermore, the Quaternary sediment cover can pose a problem for seismic-reflection investigations because its presence can lead to distortions in the deep exploration-seismic image. Reliable estimates of the Quaternary sediment elastic parameters are often necessary to correct for these distortions.

Multicomponent seismic data analysis provides advantages for the quantitative estimation of elastic parameters compared to analyses of conventional 1-component data. By using multiple source and receiver orientations, the polarization of incoming waves can be determined due to the fact that the complete vector wavefield is recorded. This alleviates a successful identification and separation of the incoming modes (P-wave, S-wave and surface waves), which is a prerequisite for a proper reconstruction of the near-surface elastic parameters. Furthermore, both reliable P- and S-wave velocities and, hence, the Poisson's ratio can be obtained from multicomponent analysis. This information enhances the geological interpretation of geophysical datasets.

A high-resolution multicomponent seismic dataset was acquired over a Quaternary valley in Neuhausen, Switzerland. In order to generate simultaneously P- and S-waves with different polarizations, a sledgehammer source striking a prism from four different directions was employed resulting in records with different polarity. By subtracting records with opposite polarity and rotating of the sources and receivers into a radial-transverse coordinate system, effective wavefield separation was achieved. On these separated P- and S-wave records, the arrival times of refracted waves of the two modes could be readily identified. A hodogram analysis ensured the reliability of this mode identification process. The picked first-arrival traveltimes of both P- and S-waves were then separately inverted for P- and S-wave velocities.

The general velocity structure on the resulting high-resolution tomograms looks similar for both P- and S-wave velocities with an average Vp/Vs velocity ratio of around 2. A clear Vp/Vs-ratio anomaly (values of up to 3) can be observed at the lowest topography point along the profile at a depth of about 15 meters. In this zone, the P-wave velocity increases while the S-wave velocity remains constant. Since P-wave velocities are significantly more affected by the water content compared to S-wave velocities, the observed anomaly can possibly be explained by increased water content in this region. This interpretation is supported by the electrical-resistivity tomography results that show a low resistivity zone at the same location.