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First-arrival traveltime tomography of regional-scale seismic-reflection data to image near-surface Quaternary and Tertiary sediments in Northern Switzerland

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Regional-scale seismic-reflection data have usually a limited potential for imaging the shallow (<100 m) subsurface. However, resolving near-surface units is of significant interest for various purposes such as weathering-layer corrections in seismic-reflection processing but also to study Quaternary sediments and their geologic history. In this study, we inverted the first-arrival traveltimes of a recently acquired regional-scale seismic-exploration data set from Northern Switzerland. The overall motivation was to complement the seismic-reflection investigations and to image the shallow subsurface with seismic-refraction tomography. Whereas the surface distribution of the Quaternary and Tertiary sediments is mapped in detail in the investigation area, the highly variable thickness of the Quaternary sediments (up to 150 m) is only constrained at a few borehole locations.

We focused on a ∼9 km long stretch of a 2-D seismic-reflection profile that was acquired with short source and receiver intervals varying between 6 and 12 m. A total of 450'000 traveltimes was picked from mostly Vibroseis and few dynamite data with varying quality due to partly strong sweep-correlation noise and the data were inverted using a regularized inversion scheme. The robustness of the velocity models was assessed based on traveltime residuals, start model and free-parameter variation, and ray coverage.

The final tomograms image the subsurface down to a depth of ∼700 m. Shallow low (< 2000 m/s) seismic velocity zones correlate well with mapped Quaternary sediment units in the valleys. Geological and seismic-velocity information from three boreholes allows to correlate a distinct velocity increase at ∼50 to 100 m depth with the Quaternary-Tertiary sediment interface. Velocity isolines allow tracing the Quaternary-sediment thickness away from the boreholes and significantly aid in updating a pre-existing Quaternary-sediment thickness model.

An extensive about 100 m thick body with very low velocities of around 1000 m/s located on a hill could be identified as only weakly consolidated Tertiary sandstone unit (about 12-20 My old, Upper Marine Molasse and Upper Freshwater Molasse "Glimmersande"). Outcrop and map data confirmed the presence of shallow marine and fluvial sandstones. Comparably low velocities for the same sandstone unit were also observed in a near-by borehole. The unexpected low velocities of the Tertiary sediments, which usually show significantly higher velocities compared to unconsolidated Quaternary sediments, illustrate a potential ambiguity in interpreting seismic velocities in the investigation area.