EGU24-20377, updated on 06 Oct 2024
https://doi.org/10.5194/egusphere-egu24-20377
EGU General Assembly 2024

High-resolution crosshole seismic imaging of glacial sediments by full-waveform inversion

Sarah Beraus[1,2], Daniel Köhn[3], Thomas Burschil[4], Hermann Buness[2], Thomas Bohlen[5], and Gerald Gabriel[1,2]
[1]Leibniz Institute for Applied Geophysics, Hannover, Germany (sarah.beraus@leibniz-liag.de)
[2]Institute of Geology, Leibniz University Hannover, Hannover, Germany
[3]Institute for Geosciences, Christian-Albrechts-University Kiel, Kiel, Germany
[4]Federal Institute for Geosciences and Natural Resources, Hannover, Germany
[5]Geophysical Institute, Karlsruhe Institute of Technology, Karlsruhe, Germany

During the Quaternary, glaciers shaped the Alpine region by excavating deep valleys and refilling them with the sediments that they transported. One such overdeepened valley is the Tannwald Basin (ICDP site 5068_1), which was created by the Rhine Glacier in what is thought to have been several glaciations. The sediments found in such valleys thus provide climate archives and tell us about the landscape evolution if we understand the sedimentation processes that took place.

To study these glacial sediments in terms of their small-scale structure and deposition, we acquired P- and S-wave seismic crosshole data using high-frequency borehole sources. While the pressure field was recorded by a 24-station hydrophone array, the S-waves excited by horizontally and vertically polarizing sources, respectively, were recorded by an 8-station 3C geophone string.

Since the S-wave data is quite complex, we directly apply elastic mono-parameter full-waveform inversion (FWI). This mitigates the phase misidentification problem in deriving an S-wave model from phase picks. In preparation for the inversion, we rotate the data into a ray-based coordinate system so that the SV-wave dominates on the vertical component and the SH- wave dominates the horizontal component. We then invert the vertical component of the SV-dataset and the transverse component of the SH-dataset using the appropriate parameterization. We apply a global correlation norm and preconditioning to ensure proper and fast converge of the inversion. In addition, we use the multistage approach to deal with the non-linearity of the problem. Anisotropic Gaussian filtering of the gradients as a function of the S-wave wavelength at higher frequency stages pushes the vertical resolution of our model below 1 m. This represents a significant improvement over surface seismic and traveltime tomography methods. A comparison with the lithology known for one of the boreholes shows an impressive correlation. Thus, our approach can bridge the gap between traditional surface seismic imaging and borehole methods.

In future research, we will repeat this approach for the SH-dataset. In the case of structural similarity, but a systematic difference in the S-wave velocities, this will provide us with evidence of seismic anisotropy, which will then need to be further characterized and quantified. From this, we will be able to infer the sedimentation processes that will help us to understand the evolution of the Alpine landscape. Eventually, FWI of the P-wave data will provide a more comprehensive, high-resolution image of the subsurface at the drill site.