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Shear-wave reflection imaging using a MEMS-based 3C landstreamer and a vertical impact source – an esker study in SW Finland

Bojan Brodic (1), Alireza Malehmir (1), Georgiana Maries (1), Elina Ahokangas (2), Joni Mäkinen (2), and Antti Pasanen (3)

(1) Uppsala University, Uppsala, Sweden (bojan.brodic@geo.uu.se; alireza.malehmir@geo.uu.se; georgiana.maries@geo.uu.se), (2) University of Turku, Department of Geography and Geology, Turku, Finland (eliaho@utu.fi; jonmak@utu.fi), (3) Geological Survey of Finland, Espoo, Finland (antti.pasanen@gtk.fi)

Higher resolution of S-wave seismic data compared to the P-wave ones are attractive for the researches working with the seismic methods. This is particularly true for near-surface applications due to significantly lower shear-wave velocities of unconsolidated sediments. Shear-wave imaging, however, poses certain restrictions on both source and receiver selections and also processing strategies. With three component (3C) seismic receivers becoming more affordable and used, shear-wave imaging from vertical sources is attracting more attention for near-surface applications. Theoretically, a vertical impact source will always excite both P- and S-waves although the excited S-waves are radially polarized (SV). There is an exchange of seismic energy between the vertical and radial component of the seismic wavefield. Additionally, it is theoretically accepted that there is no energy conversion or exchange from vertical into the transverse (or SH) component of the seismic wavefield, and the SH-waves can only be generated using SH sources.

With the objectives of imaging esker structure (glacial sediments), water table and depth to bedrock, we conducted a seismic survey in Virttaankangas, in southwestern Finland. A bobcat-mounted vertical drop hammer (500 kg) was used as the seismic source. To obtain better source coupling, a $75\times75\times1.5$ cm steel plate was mounted at the bottom of the hammer casing and all the hits made on this plate after placing it firmly on the ground at every shot point. For the data recording, we used a state-of-the-art comprising of 100 units, 240 m-long, 3C MEMS (micro electro-mechanical system) based seismic landstreamer developed at Uppsala University. Although the focus of the study was on the vertical component data, careful inspection of the transverse (SH) component of the raw data revealed clear shear wave reflections (normal moveout velocities ranging from 280-350 m/s at 50 m depth) on several shot gathers. This indicated potential for their analysis, hence shear-wave reflection imaging was carried out. Results show an excellent correspondence between the drilled depth to bedrock and the one independently obtained using P-wave first arrivals traveltime tomography with a reflection imaged on the stacked section of the SH component data. Aside from this reflection that follows the undulating bedrock topography, additional reflections are also observed on the stacked section that might be related to the sedimentary structures at the site. The section shows much finer resolution compared to the P-wave stacked section processed independently and reported earlier this year.

This study illustrates the importance of 3C data recording and shows the potential of the landstreamer in imaging shallow subsurface using both P- and SH-waves generated from a vertical impact source. Whether the strong SH-wave energy observed is generated immediately at the source-ground contact, possible sliding of the base plate on which the impacts were made, an effect of near-surface heterogeneities or other factors remains to be carefully investigated.

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