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Subsurface seismic imaging with a hammer drilling source at an exploration drilling test center in Örebro, Sweden

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1. Introduction

The aim of the study was to inspect if the signals from hammer drilling can be used for seismic imaging of the surrounding rock. If it is possible to look below the bit, the seismic images could be useful for determining when to go from hammer drilling to core drilling. Also, the improved geological models retrieved from the seismic images can be used to guide drilling programs. The test site location in Örebro (south-central Sweden) is situated in Paleoproterozoic bedrock (gneisses and metasediments), similar to the bedrock of many mining districts that are located in crystalline rock.

2. Seismic-while-drilling (SWD) data acquisition

The SWD measurements were performed in August 2020 during the hammer drilling of a 200m deep borehole (Fig 1). The data were recorded at the "I-EDDA-TC" test site (www.iedda.eu/tc) along a W-E oriented line consisting of 45 active 1C vertical geophones with a spacing of 2m and the rig (DB) located approx. in the middle of the profile, near the geophone 17 (Fig 2).
A reference signal, which is usually recorded by the pilot sensor fixed to the top of the drill string to be used to convert geophone recordings to impulsive-like seismic data, was not available. The passive recordings on the surface were thus later in the data processing correlated with the trace from the geophone closest to the rig.

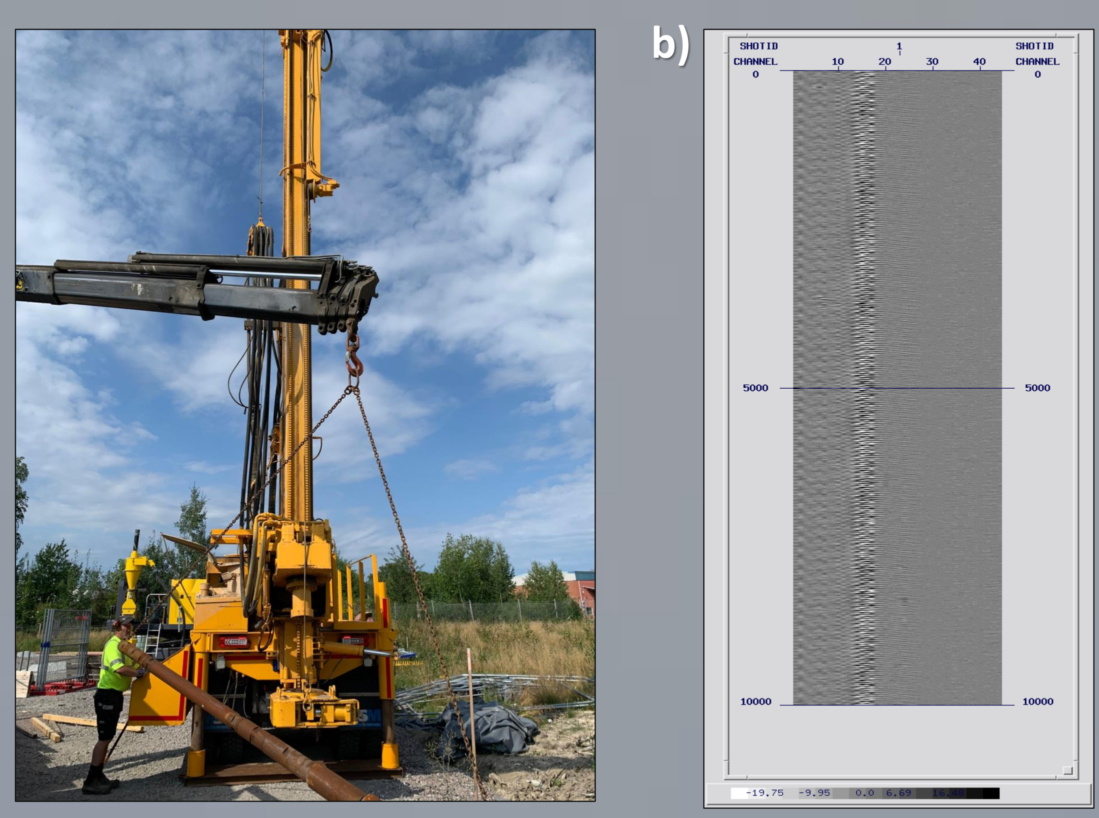

Figure 1. Hammer drilling at the Test Center next to the Epiroc factory in Örebro, Sweden (see Fig 2), Aug 2020 (a); Raw shot gather (b).

Figure 2. The SWD acquisition geometry near the "I-EDDA-TC" site in Örebro, Sweden.

3. Data processing and analysis

Different processing steps have been tested to improve the signal to noise ratio. The data were finally processed following the workflow given in Table 1.

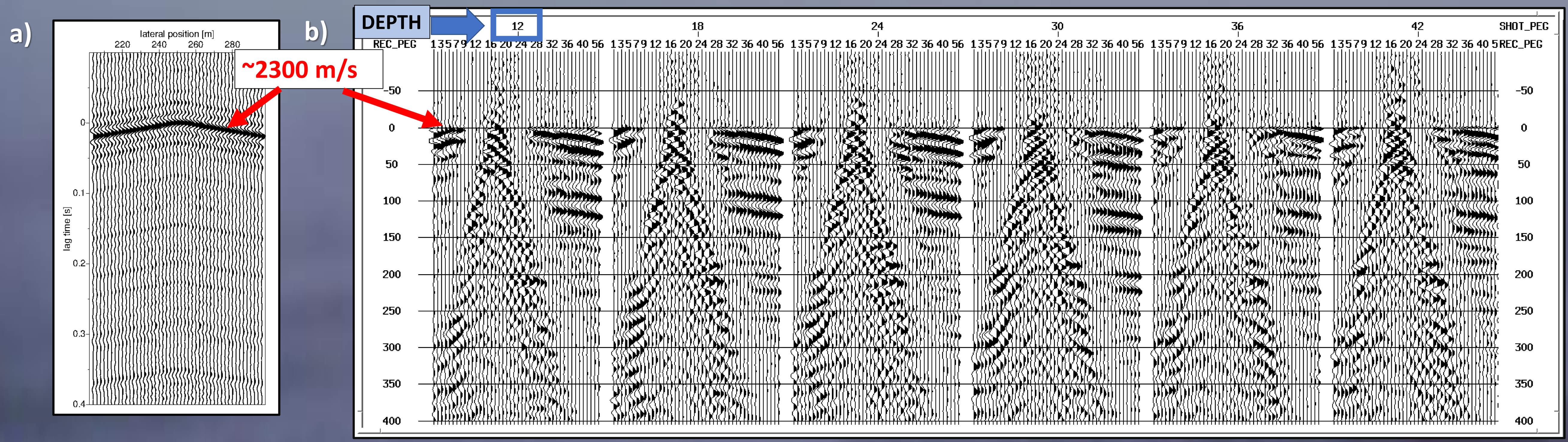

Figure 3. The shot gather of the synthetic data with the source positioned at the 12m depth (a) and the shot gathers of the processed real data generated with the drill-bit source at different depths (b). In the synthetic model, the drill-bit source is represented by 50 random sources. The maximum frequency is 80Hz and the distance between the receivers is 2m. The simple velocity model is retrieved from the active seismic test, i.e. the top layer has the thickness of about 5m and velocity of 2700 m/s; beneath is the bedrock with the velocity of 5500 m/s.

Table 1. The data processing workflow.

Processing workflow

- Read in sgy
- Notch filter: 50 Hz
- Bandpass filter: 20-40-80-100 Hz
- Deconvolution
- Trace balancing and scaling
- FX Deconvolution
- Airwave removal
- Ground roll removal by velocity filtering
- Vertical stacking over the length of a drill pipe (6 m)
- Deconvolution
- FX Deconvolution

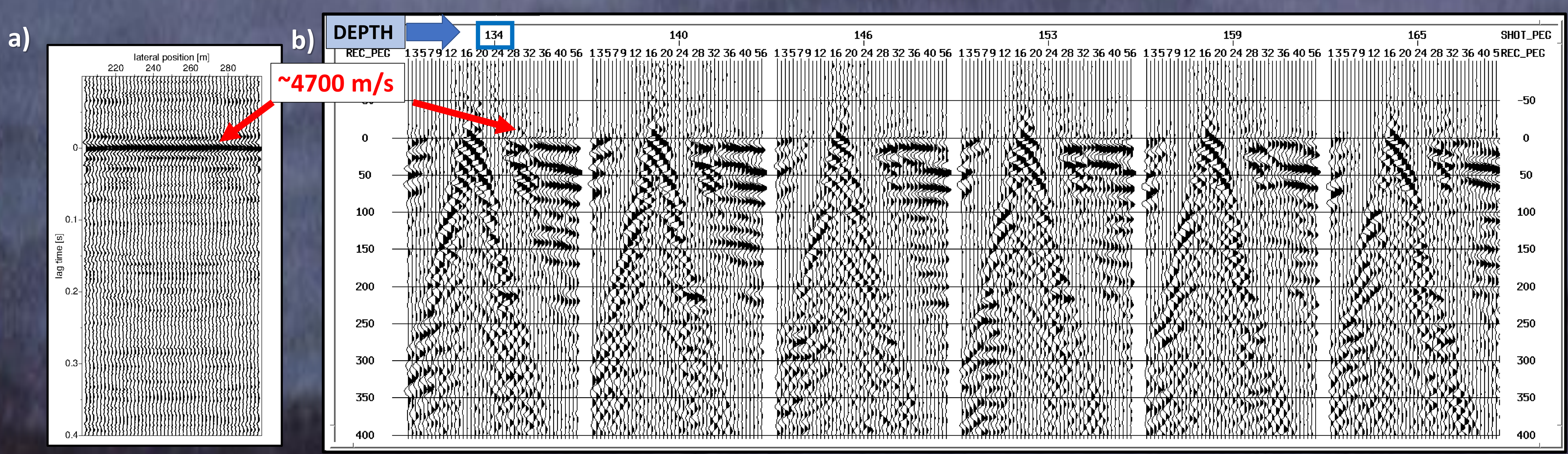

Figure 4. Same as in Fig 3, but for the drill-bit depth of 134m in the synthetic data set (a) and of 134– 165 m in the real data (b).

4. Comparison with the active seismic test and Conclusions

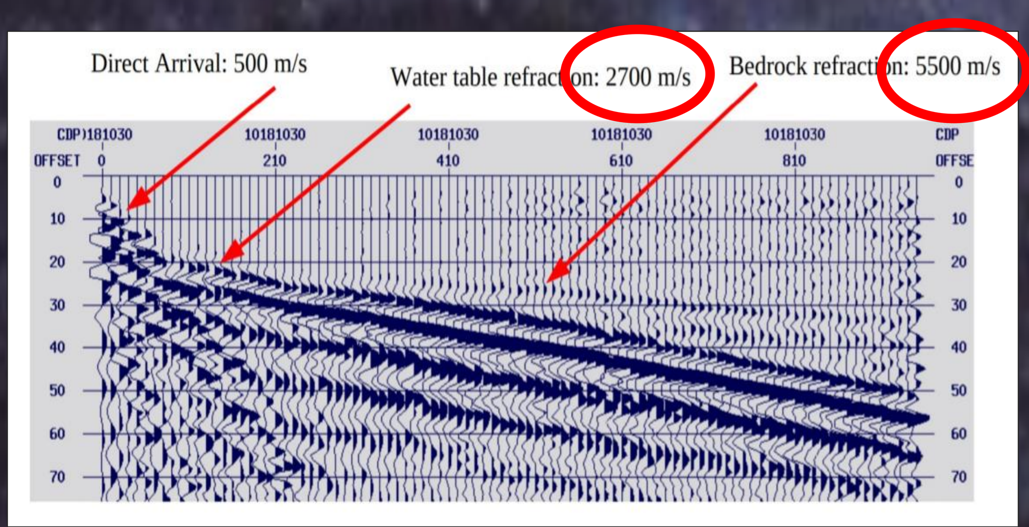

Figure 5. Active seismic test at the site: The direct arrival has a velocity corresponding to dry glacial sediments. The first refractor has a velocity corresponding to water saturated glacial moraine. The weak refraction at offsets greater than about 25 m is from the bedrock surface (offsets are in dm) (Juhlin et al., 2019).

- The data generated with the drill-bit (Figs 3 and 4) show an agreement with the active seismic data (Fig 5). The refractor corresponding to water saturated glacial moraine (Fig 5) is well imaged. However, the bedrock refractor has not been observed, most likely due to the insufficient offset in the SWD data set and lower frequency content.
- Based on the interpretation of the active seismic data, the strong linear noise with the velocity of about 250 m/s is the ground roll. However, present is also a strong level of noise generated by the rig.
- The strong contamination by the rig noise, more significant in cases with smaller offset data, and the lack of a pilot signal may have also significantly impacted the quality of the seismic signal.
- The lack of clear reflections in the active seismic data indicate that there are no detectable changes in the bedrock lithology, which further hinders the assessment of the seismic signal generated with the hammer drilling.

References

Juhlin, C., Almqvist, B.S.G., Buske, S., Ivandic, M., Linden, C., 2019. Innovative Exploration Drilling and Data Acquisition Test Center: First Geophysical Site Survey, AGU 2019.

Acknowledgements

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