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Refraction and reflection seismic investigations for geological energy-storage site characterization: Dalby (Tornquist Zone), southwest Sweden

Alireza Malehmir (1), Bo Bergman (2,3), Benjamin Andersson (4), Robert Sturk (4), and Mattis Johansson (2)

(1) Uppsala University, Dept. of Earth Sciences, Uppsala, Sweden (alireza.malehmir@geo.uu.se), (2) Sweco Environment AB, Malmö, Sweden, (3) WSP (presently), Malmö, Sweden (bo.bergman@wspgroup.se), (4) Skanska Sverige AB, Malmö, Sweden (benjamin.b.andersson@skanska.se; robert.sturk@skanska.se)

Three high-resolution, 5 m shot and receiver spacing using 141-172 receivers, refraction and reflection seismic profiles for the planning of a major underground energy-storage site near the town of Dalby-Lund within the Scania Tornquist suture zone in southwest of Sweden were acquired during August 2015. The site is situated ca. 1 km north of the RFZ (Romeleåsen fault and flexure zone) with a complex geologic and tectonic history. Near vertical dikes are observed from several quarries in the area crosscutting granitic-gneissic-amphibiotic rocks and form clear magnetic lineaments. These dikes likely have also acted as surfaces on which further faulting have occurred. Although a major high-speed and traffic road runs in the middle of the study area, the seismic data show excellent quality particularly for the data along two profiles (profiles 2 and 3) perpendicular to the road, and slightly noisy, due to high wind, for the data along a profile (profile 4) parallel to the road. A bobcat-mounted drop hammer (500 kg) was used to generate the seismic signal. To provide continuity from one side of the road to another, 51 wireless recorders connected to 10 Hz geophones and operating in an autonomous mode were used. GPS times of the source impacts were used to extract the data from the wireless recorders and then merged with the data from the cabled recorders (also 10 Hz geophones). Three shot records per source position were generated and vertically stacked to improve the signal-to-noise ratio.

First arrivals are clear in most shot gathers allowing them to be used for traditional refraction seismic data analysis and also for more advanced traveltime tomography. The velocity models obtained through traveltime tomography clearly depict bedrock surface and its undulations and in many places show good correlation with the boreholes recently drilled in the area. At places where bedrock is intersected at greater depths than usual, for example 25 m at one place, depression-looking bedrock is clearly observed in the tomograms suggesting the possibility of weakness zones (likely highly fractured and/or weathered) in the bedrock.

Signs of reflections in the raw shot gathers were encouraging and motivated to process the reflection component of the data for the purpose of subsurface imaging. Several northeast dipping, about 60-65 degree, reflections were imaged down to 400 m depth thanks to the close shot and receiver spacing strategy of the data acquisition. These reflections often show coherent character but at occasions are discontinuous and have different appearances. Reflections along profile 4 have for example different characters, shorter and more gently dipping, compared to those observed in profiles 2 and 3 suggesting that the main dip favors the orientation of profiles 2 and 3. The origins of the reflections are unclear ranging from amphibolite sheets to diabase dykes within the gneissic rocks, and each of this implies a different geological scenario (when compared with the geological data from a nearby quarry north of the study area) at where the site will be developed. Future studies should aim at understanding the cause of the reflections, constraining their locations at depth, and if they play any major role for the planning of the underground facilities. This study however illustrates the potential of the combined refraction and reflection imaging for these types of projects. For future developments of the site however a full 3D seismic survey can highly be useful.

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