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Development of near surface seismic methods for urban and mining applications

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There is a great need to improve our understanding of the geological conditions in the shallow subsurface. Direct observations of the subsurface are cumbersome and expensive, and sometimes impossible. Urban and mining areas are especially challenging due to various sources of noise such as from traffic, buildings, cars, city trains, trams, bridges and high-voltage power-lines. Access is also restricted both in time and space, which requires the equipment to be versatile, fast to set up and pack, and produces the least disruptions. However, if properly designed and implemented, geophysical methods are capable of imaging detailed subsurface structures and can successfully be used to provide crucial information for site characterizations, infrastructure planning, brown- and near-field exploration, and mine planning.

To address some of these issues Uppsala University, in collaboration with a number of public authorities, research organizations and industry partners, has recently developed a prototype broadband (0-800 Hz based on digital sensors) multi-component seismic landstreamer system. The current configuration consists of three segments with twenty 3C-sensors each 2 m apart and an additional segment with twenty 3C-sensors each 4 m apart, giving a total streamer length of 200 m. These four segments can be towed in parallel or in series, which in combination with synchronized wireless and cabled sensors can address a variety of complex near surface problems. The system is especially geared for noisy environments and areas where high-resolution images of the subsurface are needed. The system has little sensitivity to electrical noise and measures sensor tilt, important in rough terrains, so it can immediately be corrected for during the acquisition. Thanks to the digital sensors, the system can also be used for waveform tomography and multi-channel analysis of surface waves (MASW). Both these methods require low frequencies and these are often sacrificed in traditional landstreamers, which are either constructed for refraction and MASW methods or for reflection seismic imaging purposes.

The landstreamer system, assembled in 2013, has so far been tested against planted 10- and 28-Hz coil-based sensors. Two preliminary surveys were performed in 2013, one for imaging the shallow (< 50 m) crystalline basement that controls mineralization at a location in northern Sweden and another one for site characterization at a planned access tunnel in the city of Stockholm. The comparison test showed that the digital sensors on the streamer provided superior results (in terms of resolution and sensitivity to noise) than the planted geophones, suggesting that digital sensors are more suitable for urban and mining applications. In the Stockholm survey, the system was coupled to twelve 3C-digital wireless sensors to cover areas where the access was restricted due to road traffic and existing city infrastructures. The wireless sensors were used to collect data in a passive mode during the survey; these data were later harvested and merged with the active data using GPS time stamps (nanoseconds accuracy). The system thus also allows a combination of active and passive seismic data acquisition if required. Preliminary results for the mining application show successful imaging of the shallow crystalline basement as a high-velocity (> 4000 m/s) media. Clear refracted and reflected arrivals are present in raw shot gathers.

Future efforts will be geared to (i) exploiting information recorded on the horizontal components in order to extract rock mechanic parameters and anisotropy information, (ii) the development and application of a multi-component source to complement the landstreamer system, and (iii) a number of tests at underground sites.

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