Passive seismic interferometry in XSoDEx experiment in northern Finland

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There is the problem that application of controlled-source seismic exploration is not always possible in nature protected areas. As an alternative, application of passive seismic techniques in such areas can be proposed. In our study we show results of application of passive seismic interferometry for mapping the uppermost crust in the area of active mineral exploration in northern Finland using the data recorded during XSoDEx (eXperiment of SOdankylä Deep Exploration) project. The objectives of the project were to obtain a structural image of the upper crust in the Sodankylä area of Northern Finland in order to achieve a better understanding of the mineral system at depth. Within XSoDEx, a combined seismic reflection and refraction survey was organised by Geological Survey of Finland, University of Oulu, Finland (Oulu Mining School and Sodankylä Geophysical Observatory) and TU Bergakademie Freiberg, Germany. The vibrotrack of TU BAF was used as a source. The experiment was performed during July and August 2017 resulting in an approximately 80 km long seismic profile line. The seismic refraction data were simultaneously recorded by 60 vertical- and 40 three-component wireless autonomous receivers along an extended line around the reflection spread with maximum offsets of around 10 km. During night time, the receivers were recording passive seismic data. Thus the XSoDEx experiment provided a good opportunity to verify results of passive seismic interferometry with controlled-source seismic data, to identify limitations of this technique in areas of generally low level of high-frequency anthropogenic noise and to propose possible improvements of known techniques.

Analysis of the data and theoretical modelling demonstrated that the dominating sources of ambient noise are non-stationary and have different origin in different parts of XSoDEx lines. In addition, the length of passive data for cross-correlation was limited to several hours and the long data recording period is usually considered as one of the main conditions for seismic interferometry applications. In order to obtain reliable Empirical Green Functions (EGF) from such short-term and non-stationary data, we applied a special technique (signal-to-noise ratio stacking). The calculated EGFs were inverted in order to obtain S-wave velocity models along XSoDEx lines down to a depth of several hundreds metres. The obtained results are S-wave seismic velocity models of the upper crust in Northern Finland that agree well with geological data and complement the results of reflection seismic data interpretation.