Summary

Due to the increasing global demand in raw materials, the need for cost-effective and environmentally friendly seismic methods, tailored to mineral exploration, emerges. Smart Exploration is a project funded by the EU's Horizon 2020 research and innovation programme, with the aim of developing cost-effective and environmentally friendly geophysical tools and methods for mineral exploration.

The current thesis has been supported by the project to address one of the key steps of the seismic processing workflow, the estimation of the shallow velocity model, which is essential to accurately image the deeper exploration targets through static corrections, to facilitate mine-planning and safety evaluation and to assist geological-model building.

We propose the use of seismic surface-waves (SW) which are highly sensitive to the near-surface properties and contain high energy. Moreover, the high seismic velocities (long SW wavelengths) of hard rock, often encountered at mining sites, provide the opportunity to exploit SW methods also for deeper investigations. Nevertheless, due to the complexity of the hard-rock geology, seismic data are noisy and narrow-banded and, SW methods, are rarely applied.

Our target is to show that not only SW can be used in hard rock, but also that this can be done in an efficient way and with valuable outcomes. We developed a series of novel methodological tools, forming a framework for a data-driven way of processing the data, towards a fast site assessment and easy application of sophisticated analysis methods.

Our contribution includes a fast and computationally efficient method for the estimation of statics, based multichannel SW analysis and including mostly simple data transforms, which overcomes the common challenge of sharp lateral variations. A statics-estimation method, based on SW tomography, which can provide high-resolution results and is applicable to any kind of acquisition geometry. An automatic processing tool to extract a large number of dispersion curves in a reliable, fast and efficient manner and a novel, data-driven approach to optimize the selection of the processing parameters, without the need of any ad-hoc, user-based decisions.

To efficiently analyze passive-source data, we developed an automatic data-driven pre-processing tool, which isolates the portions of the records which contain

useful SW information and estimates the SW direction of propagation, facilitating the DC extraction. To retrieve high-resolution inverted models in a wide depth range, we implemented a scheme to jointly invert active- and passive-source DCs. Finally, a method to extract high-quality body waves from passive-source data and use them for reflection interferometry has been optimized and tested for mineral-exploration.

The methods have been applied to synthetic data and to real 2D/3D datasets, acquired for seismic reflection or specifically acquired for active and passive SW analysis, at two brown-field areas: the iron-oxide mining site of Ludvika, in Sweden, belonging to one of the country's most significant mineral districts, known for its high-quality deposits, and to the apatite-mining site of Siilinjärvi in Finland, the only operating mine producing phosphorus within the EU.

The results have been validated through comparison with independently derived information and have been used to increase the existing knowledge on the available ore deposits and support the mine planning and development. The estimated statics have been applied to stacked sections and assisted the delineation of the exploration targets at depth. Our models provided information on possible shallow-weakness zones and were used to constrain and extend geological models, providing descriptions of the shallow portions of the mineralized bodies.