Applicability and performance of seismic sources in clay

Britta Wawerzinek¹, Stefan Lüth¹, Roman Esefelder¹,², Rüdiger Giese¹, and Charlotte M. Krawczyk¹,²
¹GFZ German Research Centre for Geosciences, Potsdam, Germany (britta.wawerzinek@gfz-potsdam.de)
²Technical University Berlin, Germany

Since clay formations are heterogeneous and anisotropic, their seismic characterization at the meso scale is challenging. To tackle this problem, experiments using different seismic sources were undertaken in the Mont Terri Underground Rock Laboratory (URL). The first experiment was carried out using impact and vibroseis sources which were particularly designed for seismic exploration in the underground. The second experiment was conducted using an ELVIS vibration source (Polom et al. 2011) which was mainly designed for near-surface investigations on roads or in open terrain.

The first experiment focused on the applicability and performance of the modular underground system (Borm & Giese 2003) in clay. It demonstrates the successful application of impact and vibroseis source in Opalinus clay. The impact source generates signals with high signal-to-noise ratios and strong lower frequencies (above 100 Hz). Due to that, the impact source is preferred for applications at large offsets. In contrast the vibroseis source has more control of the frequency generation and is able to excite higher frequencies (up to 12 kHz) than the impact source. Therefore, the vibroseis source is preferred for high-resolution applications at near offsets.

Both sources are also suitable for clay characterization and reflection imaging. Travel time analyses resulted in average P- and S-wave velocities that show a clear azimuthal dependence. The carbonate-rich sandy and the sandy facies are characterized by faster velocities than the shaly facies which is stronger anisotropic than the sandy facies. Our findings are in good agreement with seismic velocities and anisotropy determined by Schuster et al. (2017), Popp & Salzer (2007) and Siegesmund et al. (2014). Although the sparse acquisition geometry was not optimal for reflection imaging of the geological conditions around the URL, later arriving shear wave reflections could be extracted from the impact data. A 3D migration focuses these reflections at a distance of ~50 m at the transition from the lower sandy facies to the upper shaly facies.

The second experiment of our pilot survey focused on seismic reflection measurements using near-surface equipment to evaluate its applicability in URLs. Since the ELVIS source was combined with the 3-C geophones of the main experiment, the acquisition geometry was not optimal to image settings beneath the URL. The acquired ELVIS data were dominated by strong surface waves. After their removal, surface wave reflections appeared which mainly map the structural elements of the URL. The test measurements confirmed a general applicability of ELVIS in the tunnel, however it also indicates the need to improve the acquisition geometry.