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Application of full-waveform inversion to characterize quick-clay landslide site in southwest Sweden.

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Landslides are one of the most commonly occurring natural disasters. Society of Exploration Geophysics (SEG) through its Geoscientists Without Borders (GWB) program sponsored a multidisciplinary project to study quick clay landslides in Sweden. Extensive geophysical survey was conducted over a landslide scar near the river Göta in southwest Sweden. Here, we present the application of full-waveform inversion/tomography (FWT) to seismic profiles that cross the scar.

Quick clay could be defined as a clay whose structure collapses completely at remoulding and whose shear strength is thereby reduced almost to zero. Quick clay landslides occur in an unpredictable manner and can affect large areas. A mass of quick clay undergoing sufficient stress (i.e. from excessive rainfall) rapidly liquefies and flows easily even at low slope angles - usually the slope of the bedrock under the clay deposits is more important than the actual slope of the local terrain.

Recognition of the geometry and physical properties of clay layers and the underlying bedrock is crucial to understanding the mechanism of a landslide. The sediments in the area have formed thin ($\sim$10m) layers of clays and coarse-grain materials. In order to correctly identify them, we need a method that provides high-resolution models, that is why we decided to use FWT. It offers an unprecedented improvement in seismic imaging and thus allows delineating the layering within the sediments. However, FWT not only is demanding in terms of input data, but also offers a challenge when applied in near-surface environment, e.g because of large velocity contrasts.

The lines presented here are several hundred meters long, according to the standard checkerboard tests the imaging is accurate up to 40-60 m below the surface. Data was acquired using vertical-component 28-Hz geophones, placed every 2-4 m. The seismic signal is generated either with small amounts of explosives fired in 0.5-1 m deep boreholes, or an accelerated weight-drop, depending on the line. The shot spacing was 2-12 m.

We run early-arrival frequency-domain FWT using implementation of Sourbier et al. (2009). Data preprocessing consisted of: trace editing, spectral equalisation, trace muting, 3D-2D correction and time damping. Inversion was performed for frequencies between 27.5 Hz and 43.1 Hz. The starting frequency is relatively high, but little consistent signal was detected below (attributed to the effect of damping of the geophones).

The FWT results were validated with a series of extensive procedures: (1) examination of the data fit in the frequency domain; (2) a posteriori source signature estimation; (3) time domain finite difference synthetic modelling; (4) comparison of 1D velocity profiles at the intersection of the seismic lines; (5) comparison with data from other surveys: electrical resistivity tomography, cone penetration tests. We have also performed the pre-stack depth migration (PSDM) of the reflection seismic data using velocity models obtained from FWT. The resulting images show good correspondence with our velocity models, especially in the area of the layering within the sediments and at the boundary with the high velocity granitic bedrock. Flatness of the common-image gathers from PSDM indicates that FWT-derived velocity models are superior to those derived by first-arrival tomography.