A multi-scaled approach towards weak layer characterisation, the AFEN submarine landslide complex (UK)

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Submarine landslides are common on continental slopes worldwide. They can pose a hazard to seafloor infrastructure and may generate tsunamis that can cause substantial coastal damage and loss of life. Despite their importance, it is still unclear what governs the depth at which submarine landslides initiate. Two key controlling mechanisms have been proposed. The first is the generation of excess pore pressures (i.e. above hydrostatic pressure) at subsurface permeability interfaces. This rise in pore pressure reduces the vertical effective stress, which in turn decreases the shear strength of the sediment and reduces slope stability. The second is the presence of mechanically weak layers within the stratigraphy. Such interfaces of contrasting strength can be a focal zone for shearing, and hence enhance the formation of a basal failure plane. Although understanding permeability interfaces and/or weak layers is key to understanding how submarine landslides initiate, little is known about their composition and nature because the slide movement usually removes or remoulds them. There is thus a pressing need to sample, test and characterise zones of such mechanical contrast.

Here, we present a detailed characterisation of a weak layer based on core material from the AFEN (Atlantic Frontier Environmental Network) submarine landslide complex. The AFEN slide is a four-stage retrogressive landslide, located offshore the Shetland Islands (UK), which lies on a slope between 0.7 and 2.5°. This study places detailed constraints on the main weak layer of the AFEN submarine landslide complex. The setting provides a unique opportunity to identify and characterise the weak layer, because cores seem to have penetrated both the upper glide plane and the main failure plane traced in the undisturbed sedimentary sequence. Here we use multiple scales of data to delineate and characterise the weak layer, ranging from seismic profiles, non-destructive core scanning (MSCL), geochemical (XRF) data, as well as grain size analysis and geotechnical tests, including undrained shear tests and water content measurements. We use micro-CT scans to image grain-scale structures, which are coupled with direct shear and oedometer tests, to explain the geomechanical behaviour of the weak layer. We assume that the weak layer of the AFEN slide coincides with a prominent sand layer, embedded between clayey layers. We observe a sharp increase in water content, and a decrease in bulk density and undrained shear strength at the interface between this sand layer and the underlying clayey layer. This detailed study of a weak layer that spans from continental slope to grain-scale provides new insights into the important role of these geomechanical interfaces.