The significance of weak layers for submarine slope failure

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Where do submarine landslides initiate?

Hypothesis: Submarine landslides initiate along weak layers, which are embedded within the slope stratigraphy

Main questions: 1. Can we identify prominent layers along which submarine landslides initiate?
2. Where can we find these layers?

Approach: Synthesis of submarine landslide studies, specifically focusing on the role of weak layers in their inception

What causes submarine landslides?

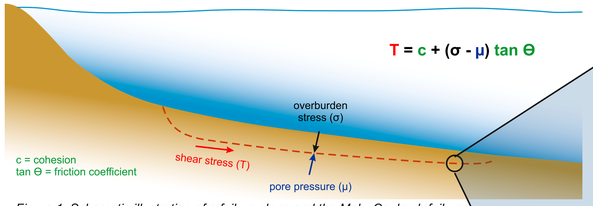


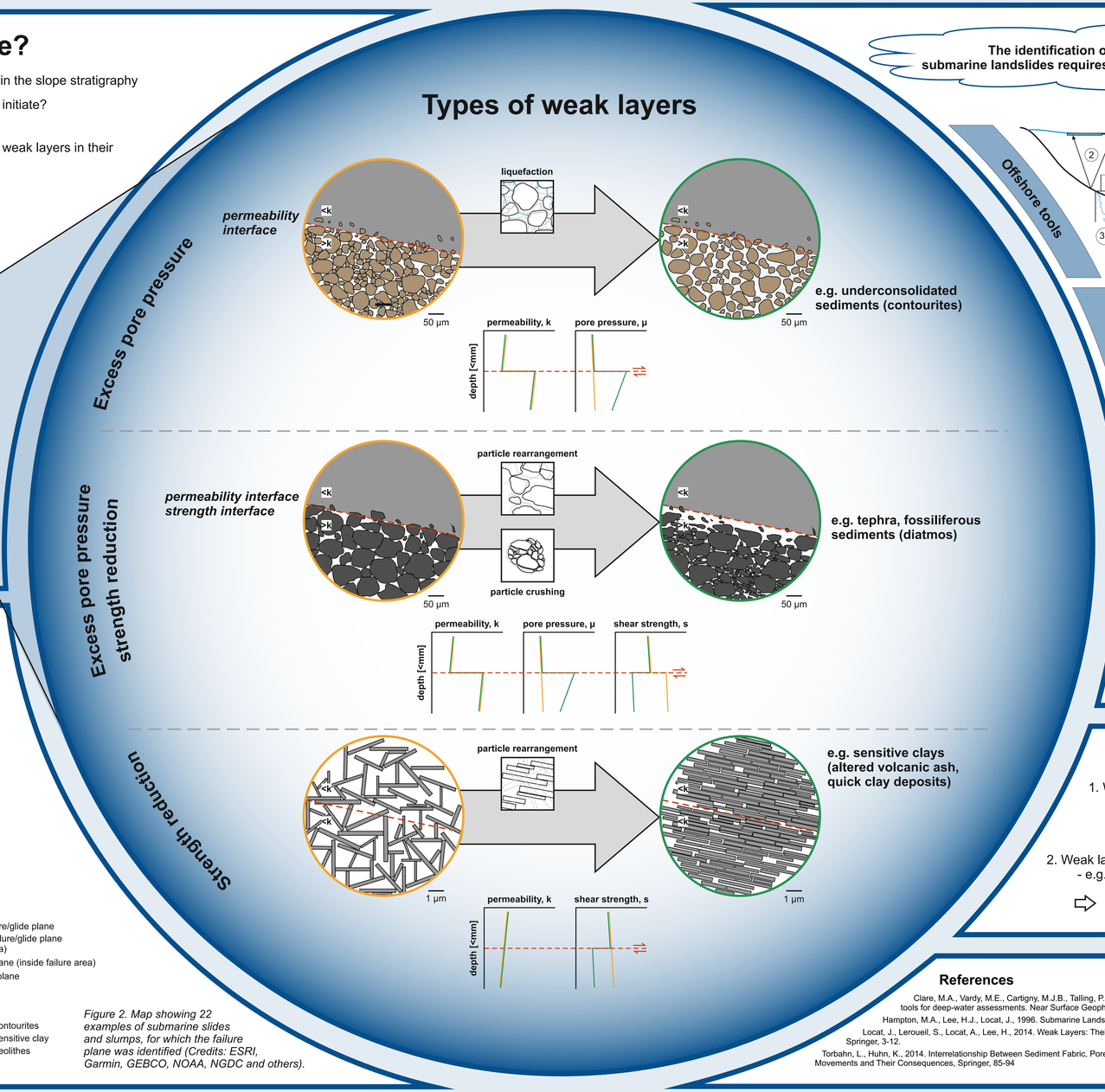
Figure 1. Schematic illustration of a failure plane and the Mohr-Coulomb failure criterion (after Hampton et al., 1996).

Weak layer concept

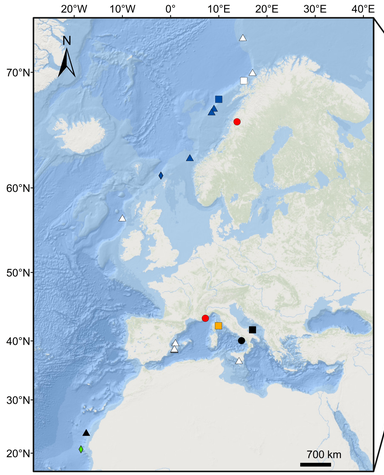
Weak sediment layers within the slope stratigraphy that have a strength lower than the surrounding units and provide a potential focus for the formation of a failure plane (Locat et al., 2014)

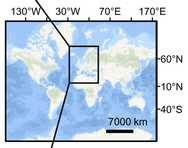
3 types of weak layers:
- excess pore pressure
- excess pore pressure + strength reduction
- strength reduction

Types of weak layers



Case studies





Availability of cores
- △ no cores penetrating failure/glide plane
- ○ cores penetrating both failure/glide plane (inside/outside failure area)
- ◊ cores penetrating glide plane (inside failure area)
- □ cores penetrating failure plane (outside failure area)

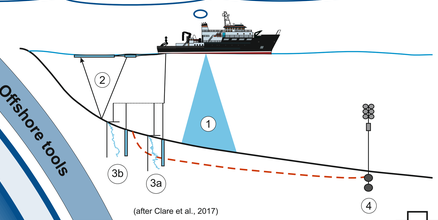
Weak layer
- no information
- tephra
- diatoms
- contourites
- sensitive clay
- zeolithes

Figure 2. Map showing 22 examples of submarine slides and slumps, for which the failure plane was identified (Credits: ESRI, Garmin, GEBCO, NOAA, NGDC and others).

Multi-disciplinary research

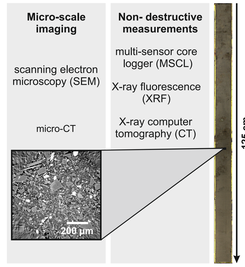
The identification of the weak layers of submarine landslides requires a multi-disciplinary approach

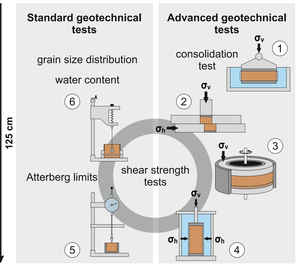
Offshore tools



1. seafloor mapping (e.g. bathymetry)
2. subsurface surveys
3a. core and insitu testing (inside failure area)
3b. core and insitu testing (outside failure area)
4. long-term monitoring

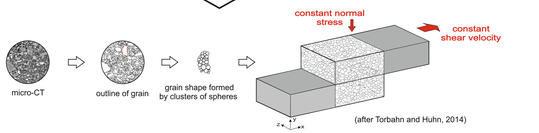
Laboratory tests





1. oedometer test
2. direct simple shear (DSS) test
3. ring shear test
4. triaxial test
5. fall cone penetration test
6. vane shear test

Numerical models



Conclusions

1. Weak layers can involve various sediment types and failure processes. However,
   - the weak layer (if identifyable) does not have to be the failure plane
   - there is a lack of detailed case studies focusing on the weak layer/failure plane
   - failure planes likely form along permeability and strength interfaces related to weak layers

2. Weak layers can be found worldwide in a variety of environments
   - e.g. fjords - sensitive clay deposits, contour currents - contourite deposits, volcanoes - tephra

⇨ The identification of the failure plane requires a multi-disciplinary approach

References

Clare, M.A., Vardy, M.E., Cartigny, M.J.B., Talling, P.J., Himsworth, M.D., Dix, J.D., Harris, J.M., Whitehouse, R.J.S., Belal, M., 2017. Direct monitoring of active geoharzards: emerging geophysical tools for deep-water assessments. Near Surface Geophysics, 15: 427-444. Doi: 10.3997/1873-0604.2017033.

Hampton, M.A., Lee, H.J., Locat, J., 1996. Submarine Landslides. Reviews of Geophysics, 34: 35-59. Doi: 10.1029/95rg03287.

Locat, J., Lerouell, S., Locat, A., Lee, H., 2014. Weak Layers: Their Definition and Classification from a Geotechnical Perspective. In: Krastel et al. (Eds.) Submarine Mass Movements and Their Consequences, Springer, 3-12.

Torbahn, L., Huhn, K., 2014. Interrelationship Between Sediment Fabric, Pore Volume Variations as Indicator for Pore Pressure Changes, and Sediment Shear Strength. In: Krastel et al. (Eds.) Submarine Mass Movements and Their Consequences, Springer, 85-94

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