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Deep-seated rock slides – engineering geological models

Tiefgründige Rutschungen im Fels – ingenieurgeologische Modelle

Christian Zangerl

University of Natural Resources and Life Sciences, Vienna
Institute of Applied Geology

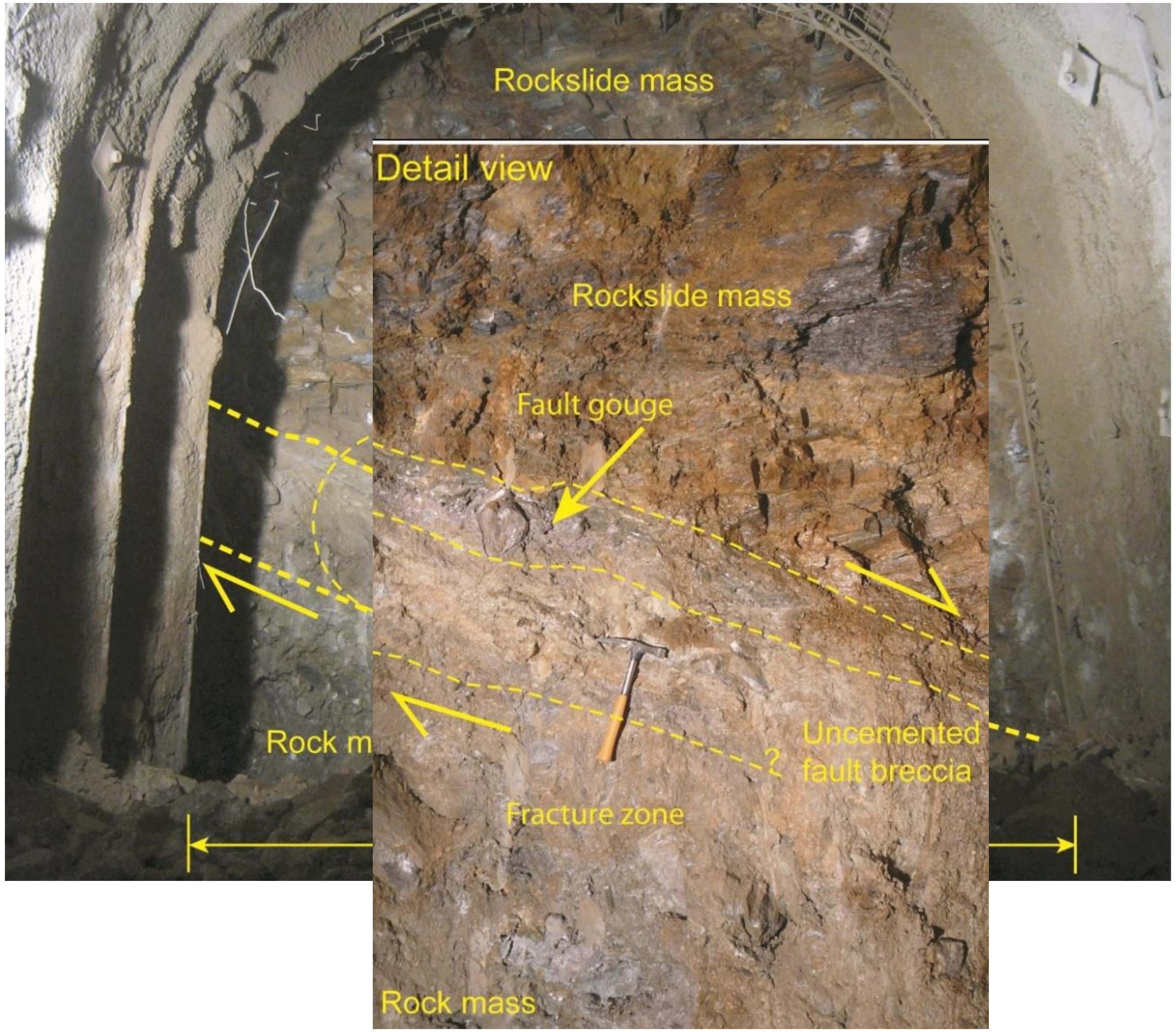
Introduction

- Aim of this presentation is to discuss the impact of the rock slide geometry on slope stability and deformation behaviour.
- Rock slide investigation and hazard assessment mainly focusses on two aspects:
    - the **geological-geometrical situation** and thus the structure and geometry of the slide by applying different in-situ investigation methods
    - the **actual and future activity** by applying monitoring methods

- **Why are we exploring the rock slide geometry and how reliable are our engineering geological models?**

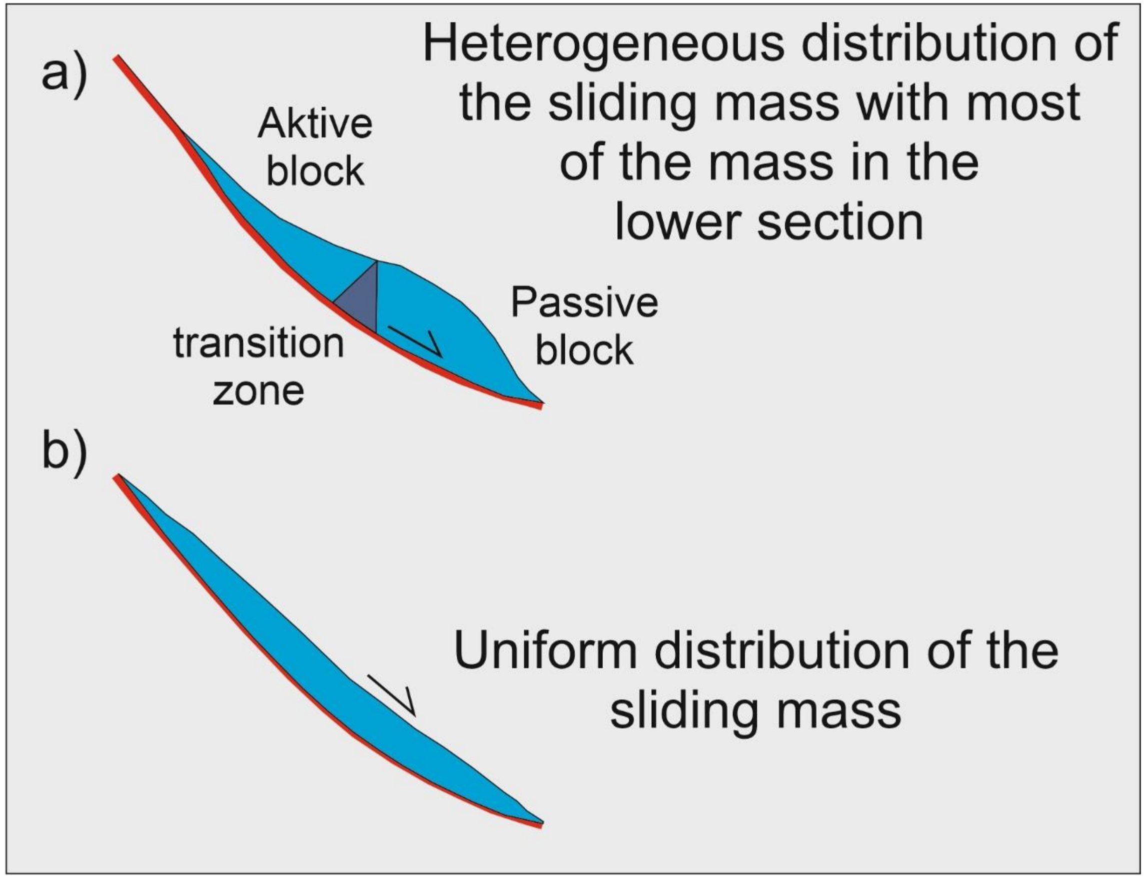
Introduction

- Rock slides are composed of i) the **rock slide mass** or slabs, ii) basal and internal **shear zones** and iii) undeformed **bedrock**.
- Geometry of is controlled by the **lithology** and the **structural inventory** (i.e. foliation, bedding, joints and brittle fault zones).
- **Geological structures** have a crucial influence on i) the initial failure mechanism, ii) the rock slide geometry, iii) the internal deformation behaviour, and iv) the slab formation.
- **Rock slide geometry affects** i) dissection into slabs, ii) internal deformation, iii) in-situ stress condition, iv) stability and deformation characteristics, and v) hydrogeology.

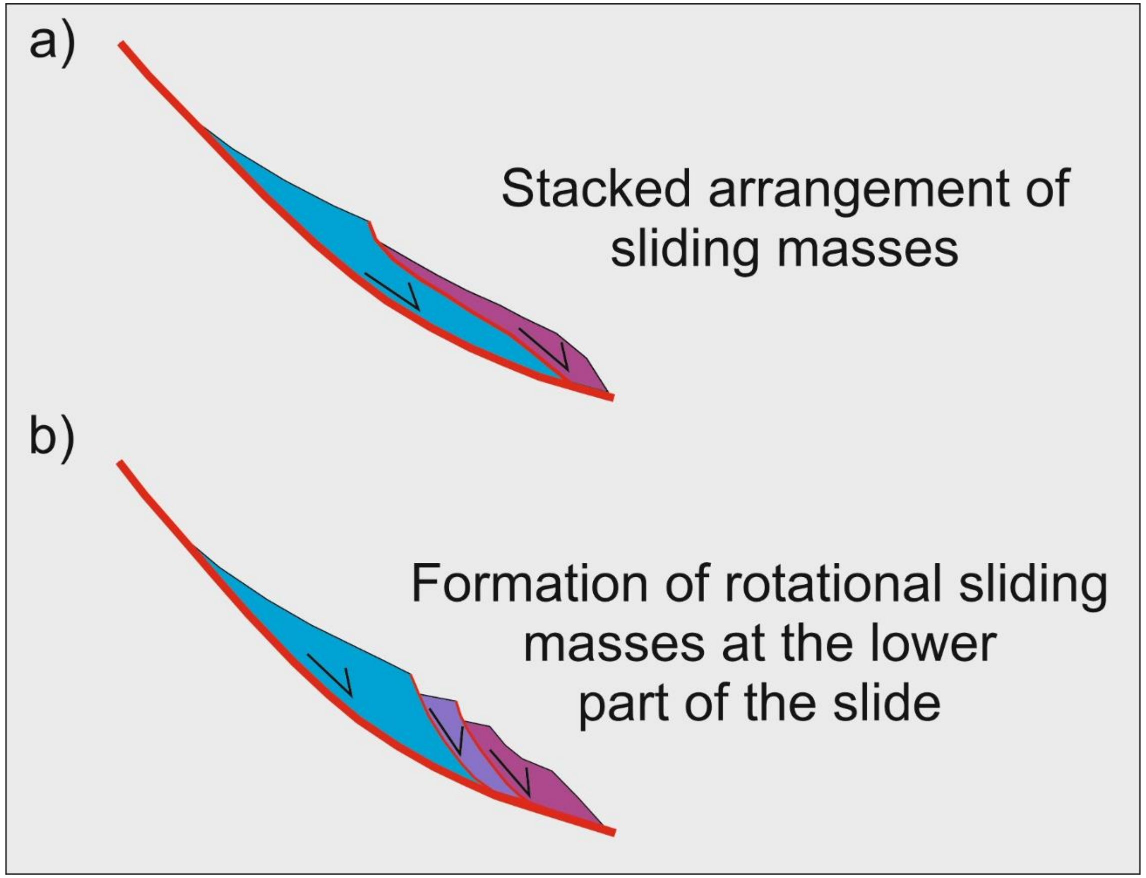


Introduction

Spatial distribution of the sliding mass

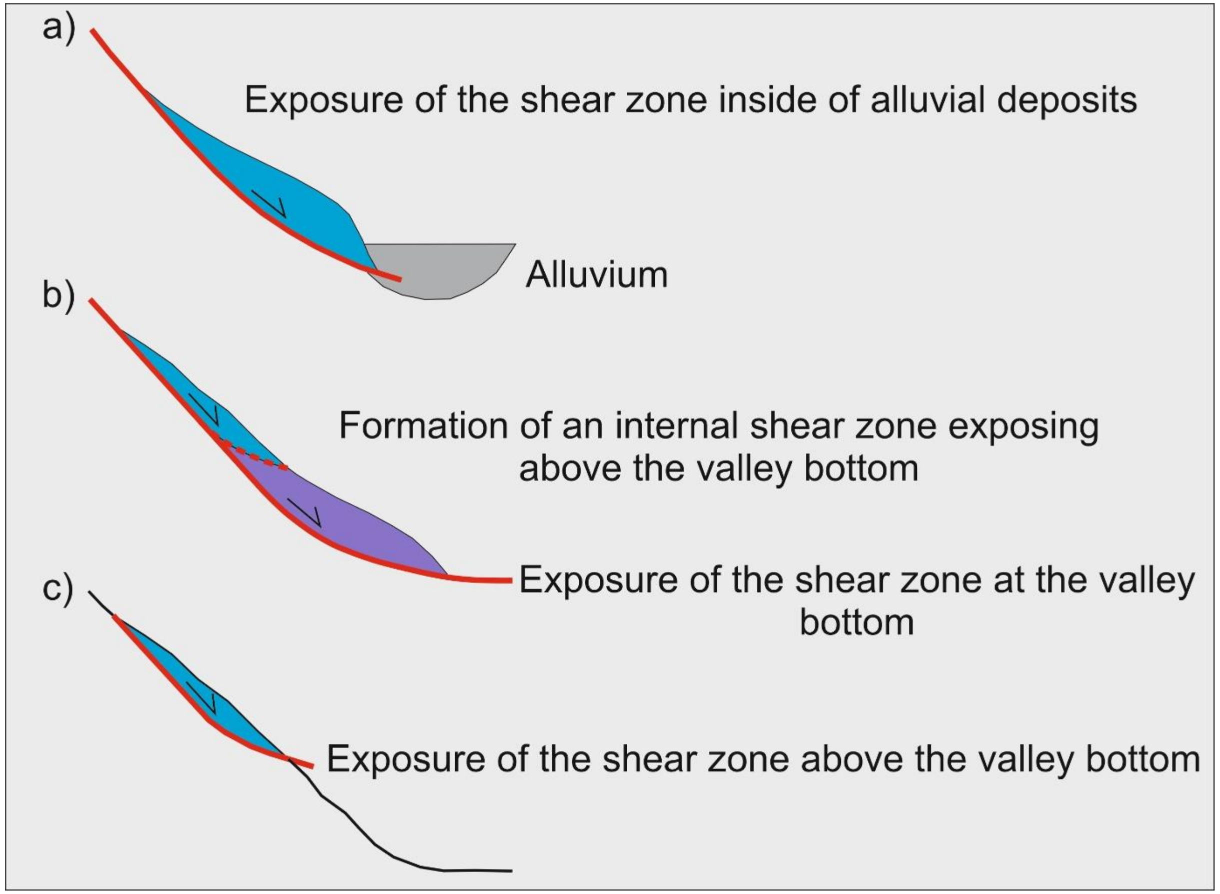


Formation of slabs

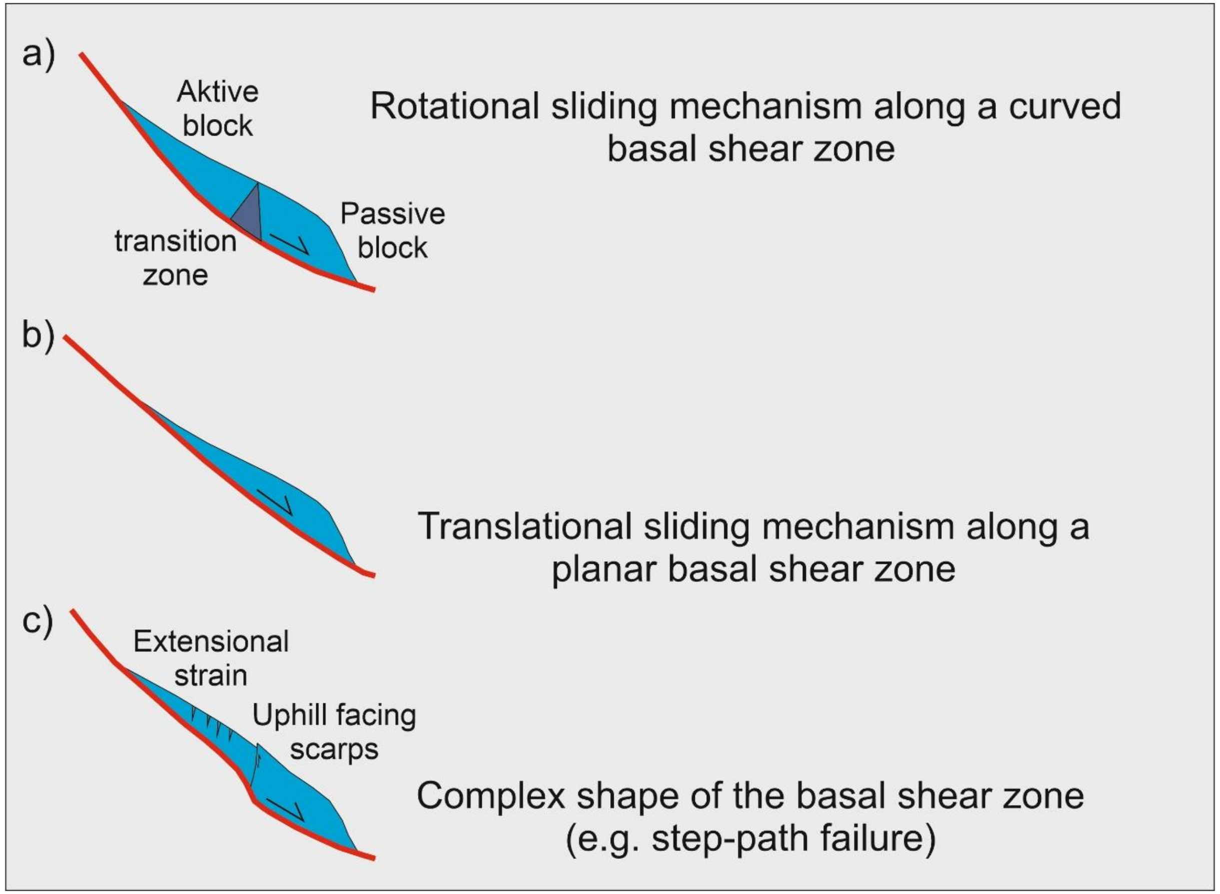


Introduction

Shear zone exposure and debutressing effects

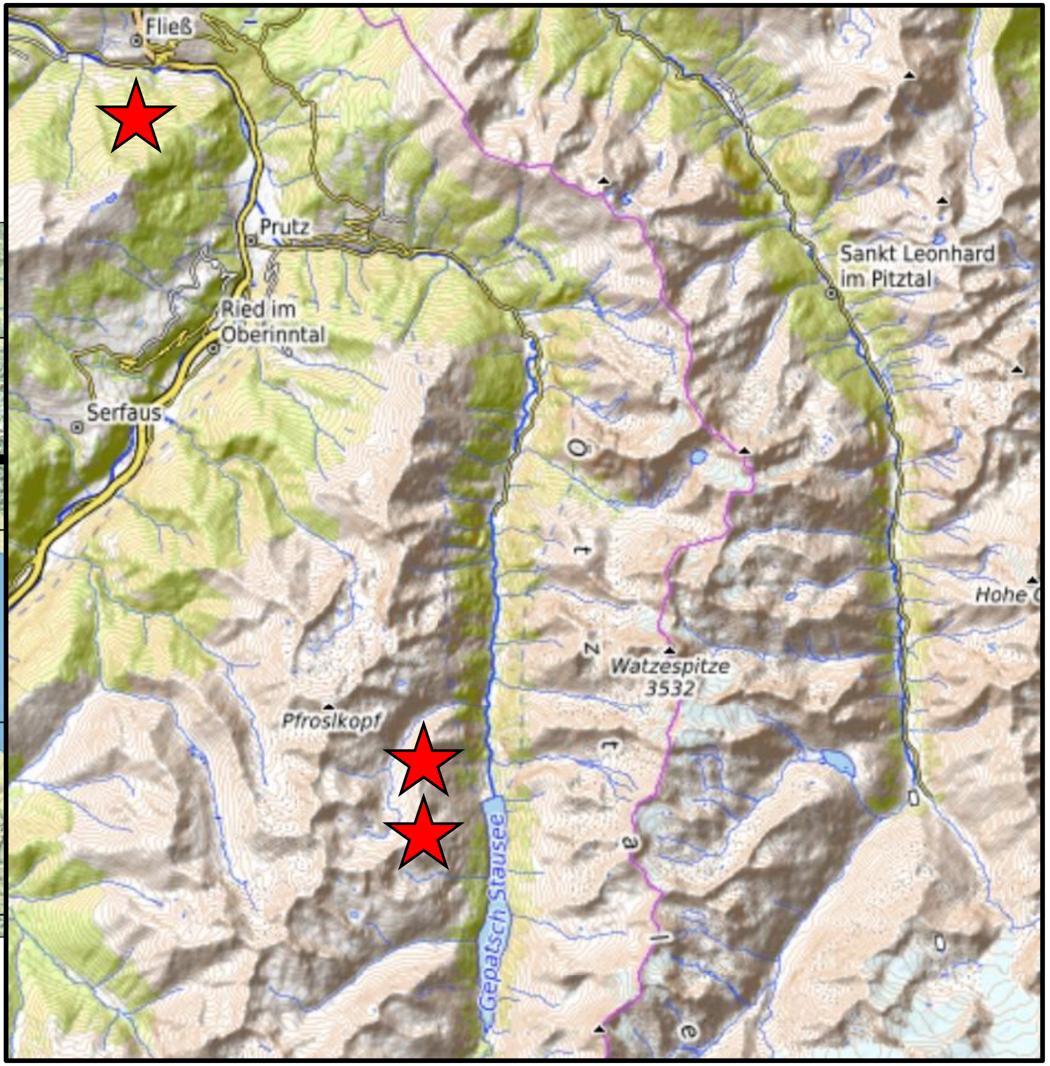


Geometry of the shear zone



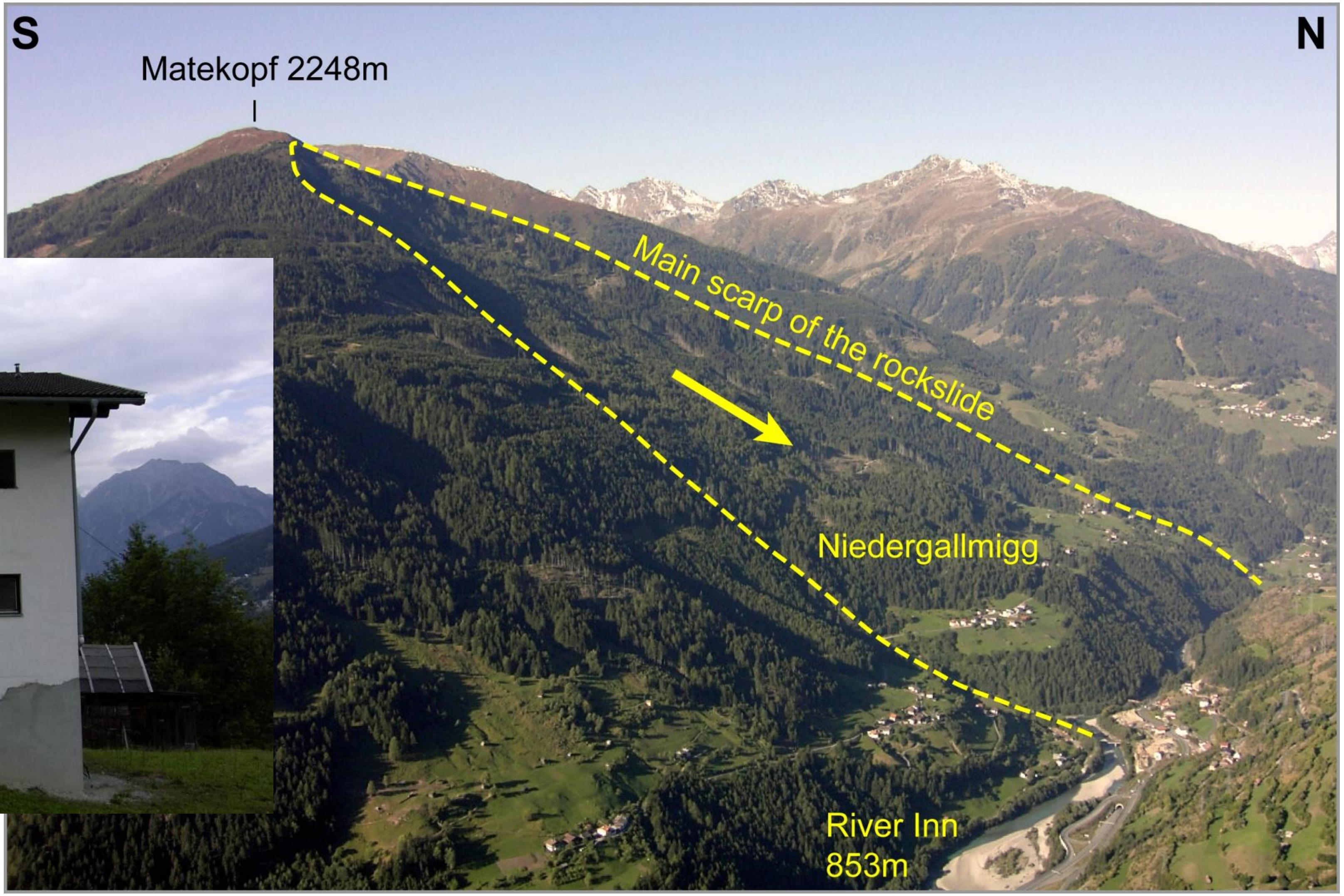
Selected case studies

- Rock slide Niedergallmigg
- Rock slide Kreuzkopf
- Rock slide Hochmais-Atemkopf



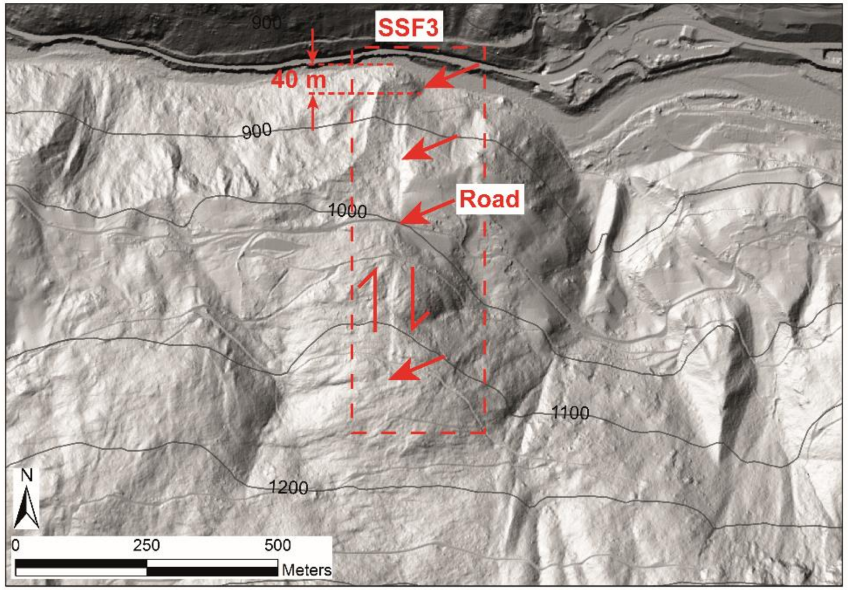
Made with Natural Earth and OpenTopoMap

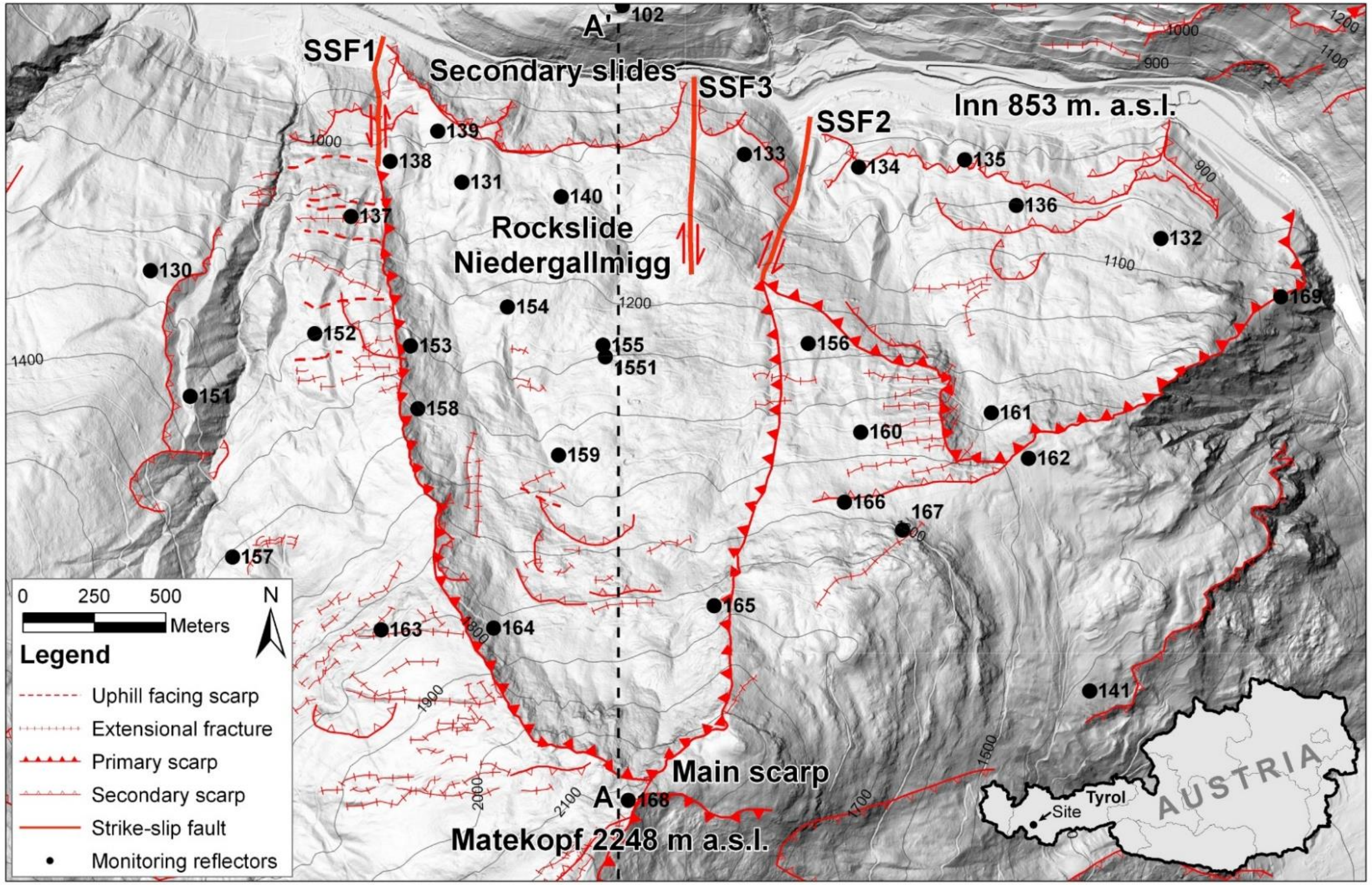
Rock slide Niedergallmigg
Impact of alluvial sediments and secondary slides at the foot of the slope



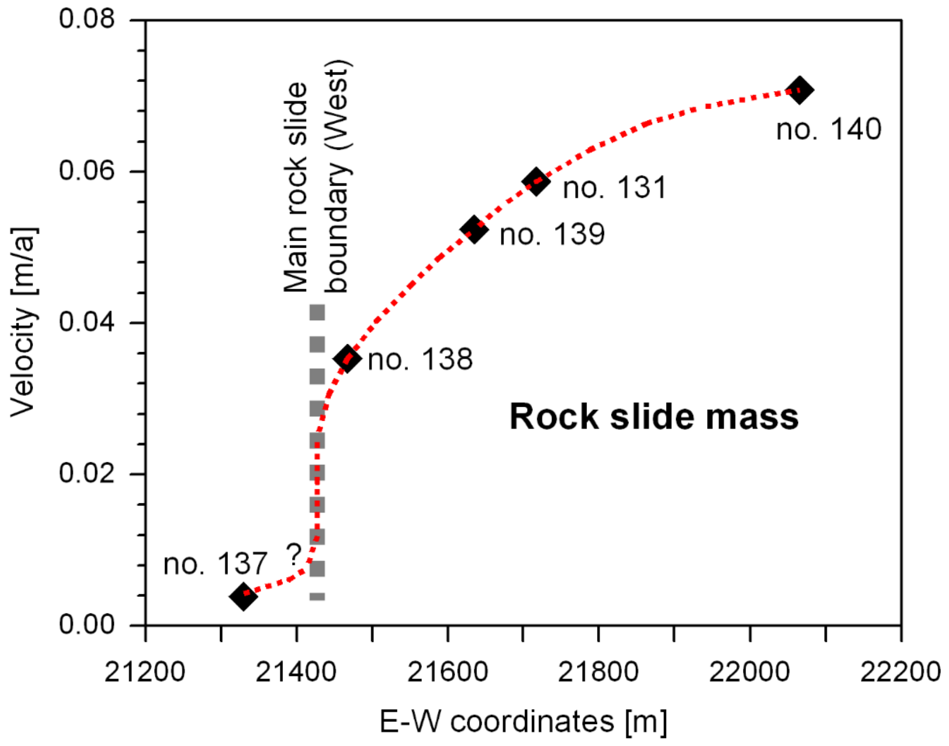
Topographical situation

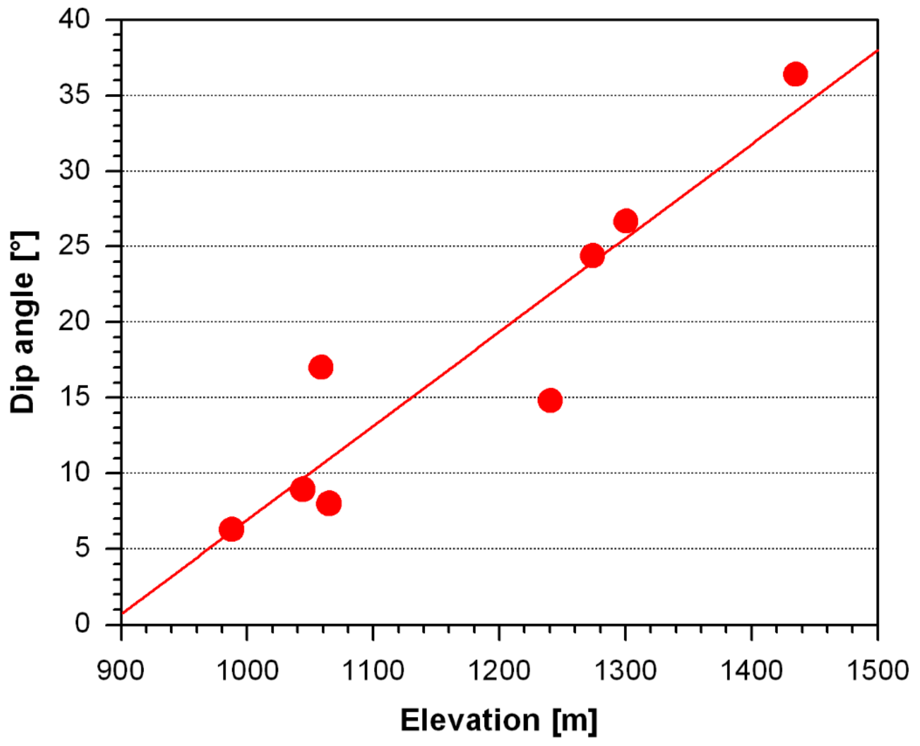
- Paragneisses, schists and phyllites
- Volume 0.43 Mill km^3, thickness up to 300 m
- Average slope inclination 30°
- Primary scarp >200 m
- Offset at the toe ca. 120 m
- Strike-slip faults, Offset 40 m
- Activity 3.5 to 7.8 cm/a





Deformation measurements

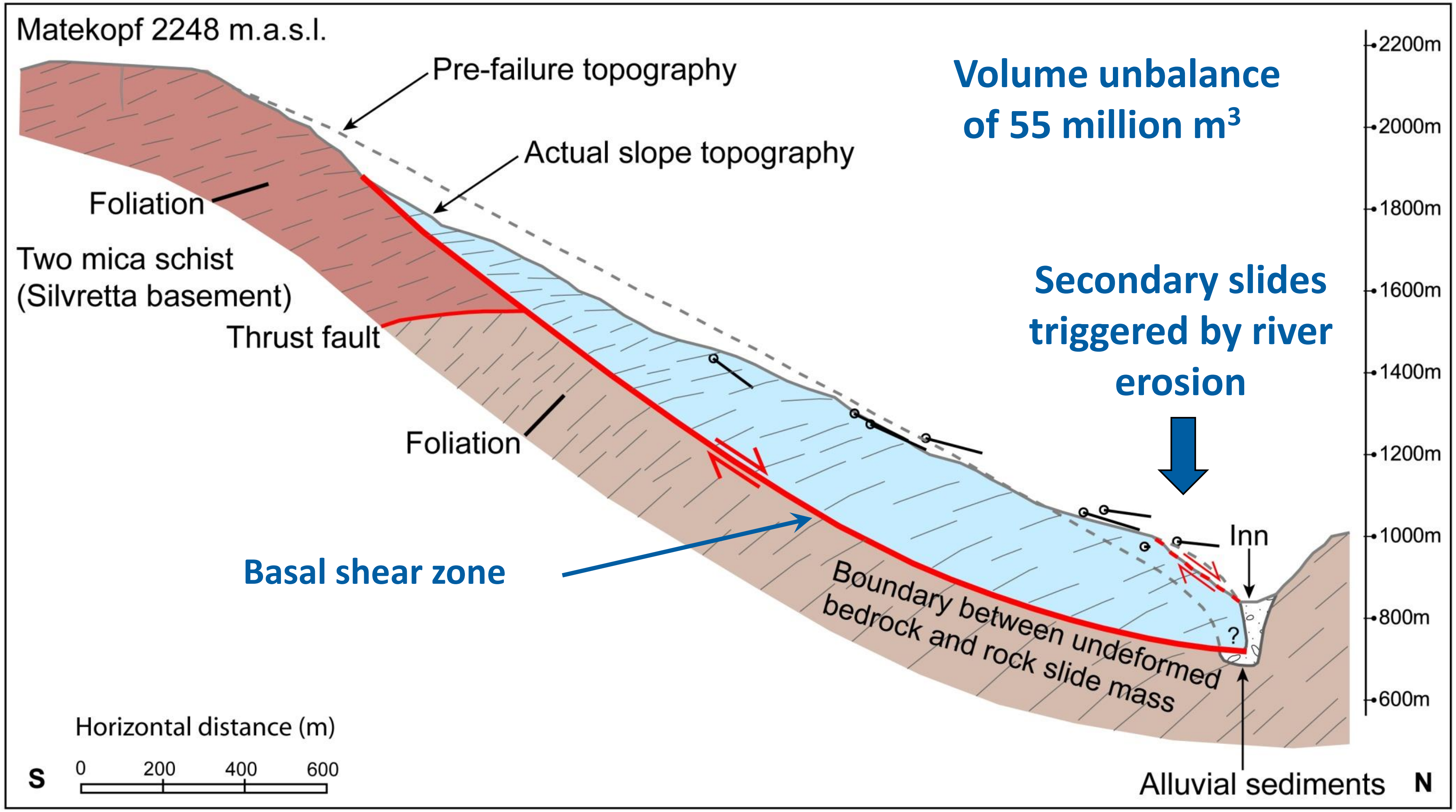




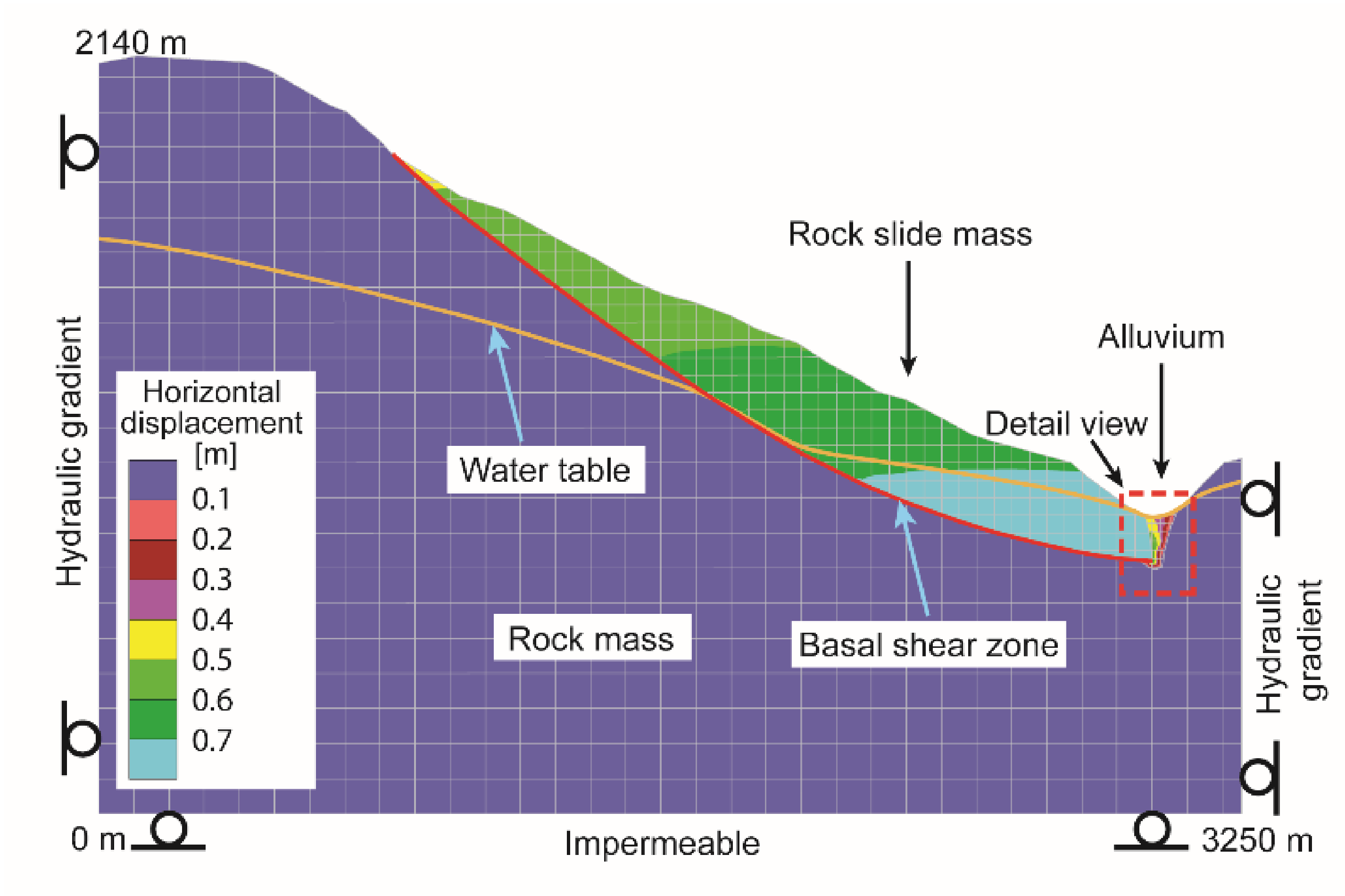
- 3.5 cm/a near the left flank (MP 138)
- 7.1 cm/a within the central part of the slide (MP 140)
- Substantial internal deformation

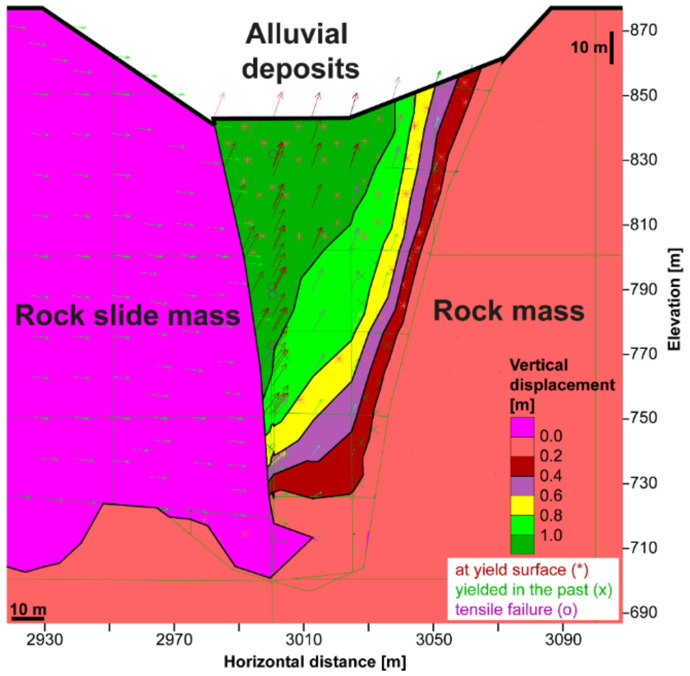
- Dip angle of displacement vectors between 6° and 36°
- Seismic investigation
- Rotational sliding mechanism

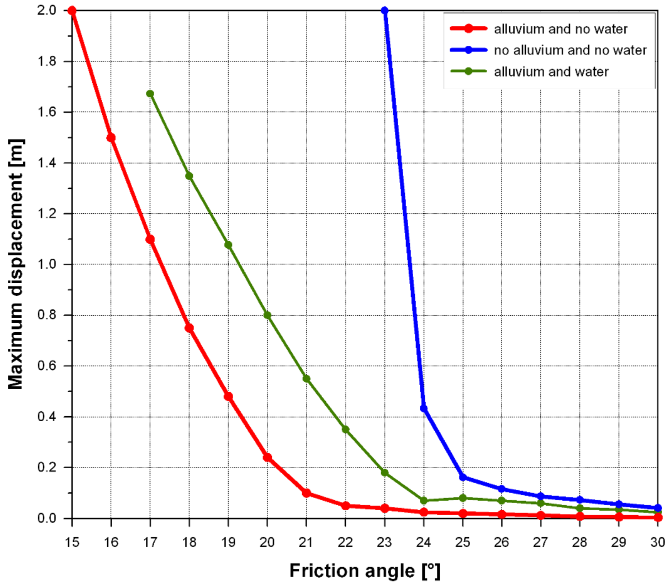
Engineering geological model



Distinct element modelling – impact of alluvial sediments on stability

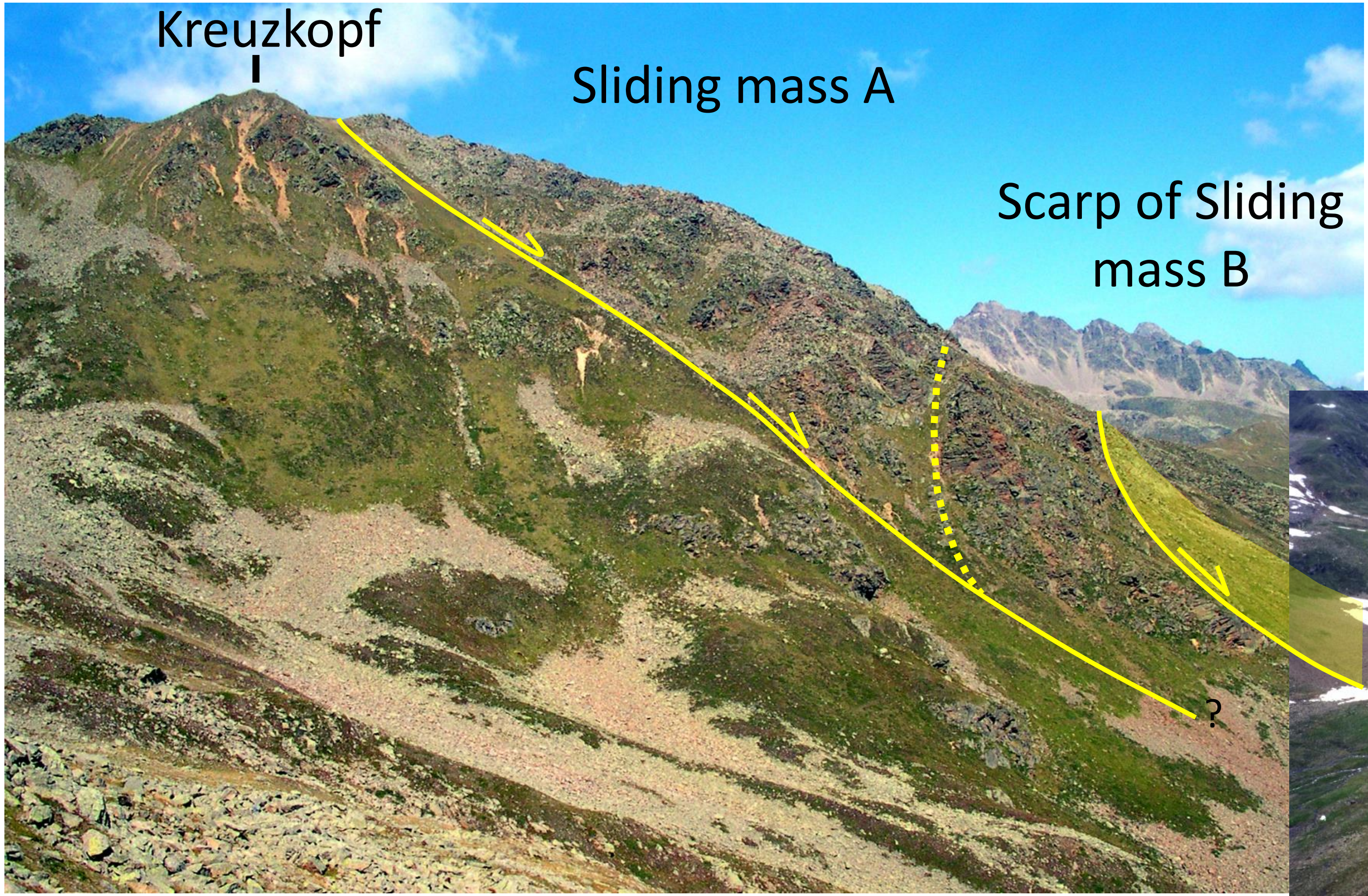






Rock slide Kreuzkopf

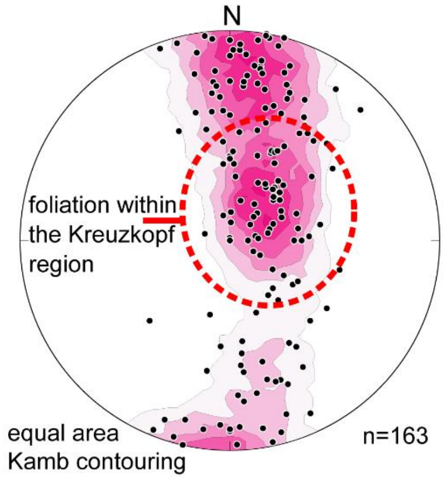
Impact of basal shear zone geometry on internal dissection of the mass



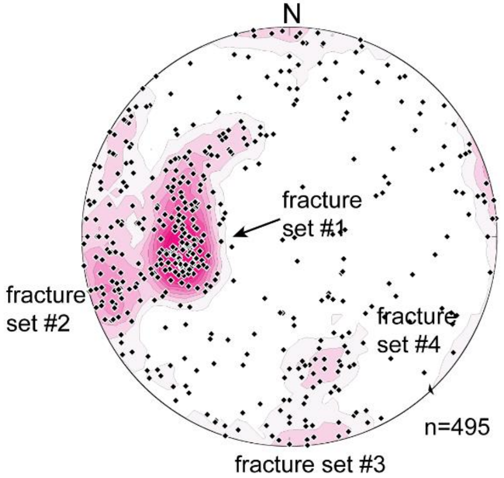
- Paragneissic rock
- Displaced mountain ridge
- Volume 3.2 Mill m^3,
- Thickness up to 50 m
- 2 Slabs A and B
- Scarp slab A 10 m, B >100 m

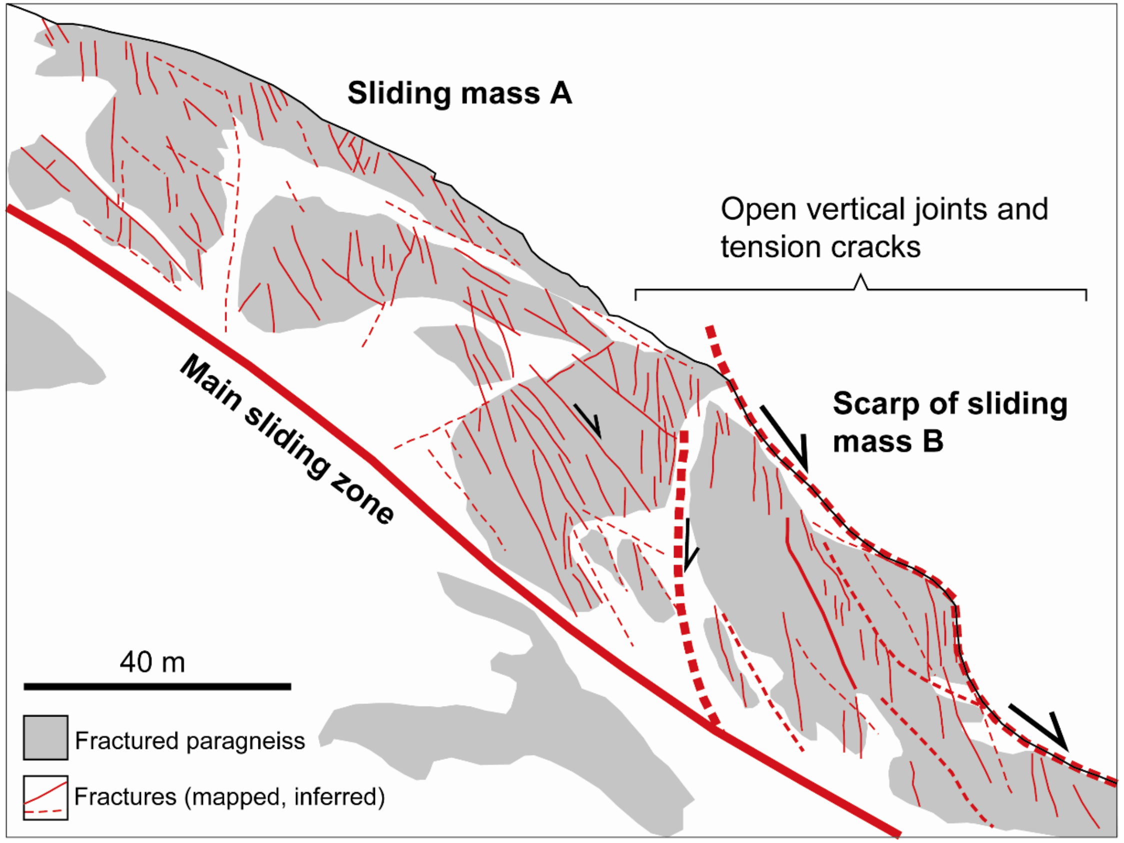
Structural inventory

Paragneiss: foliation planes

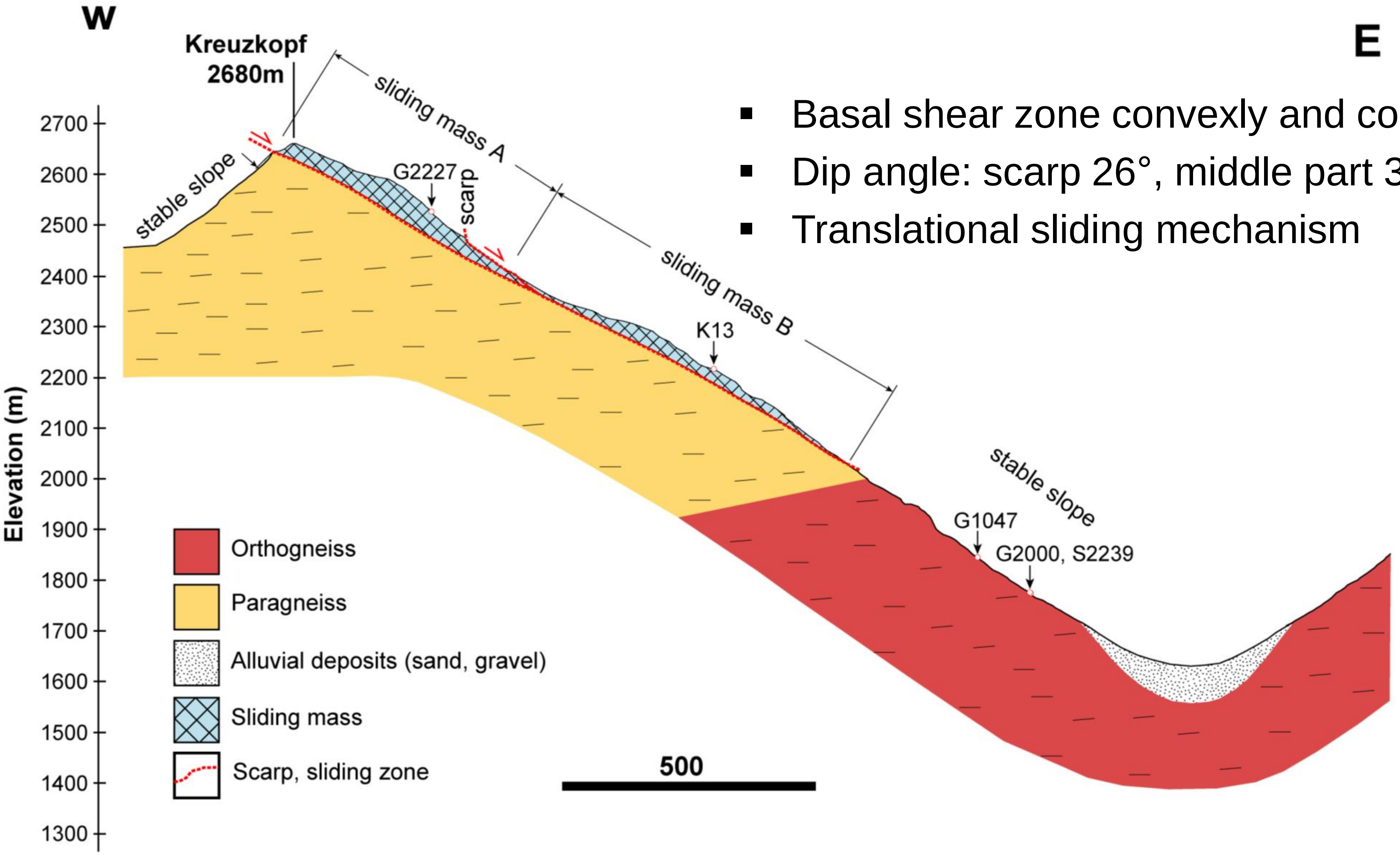


Paragneiss: meso-scale fractures



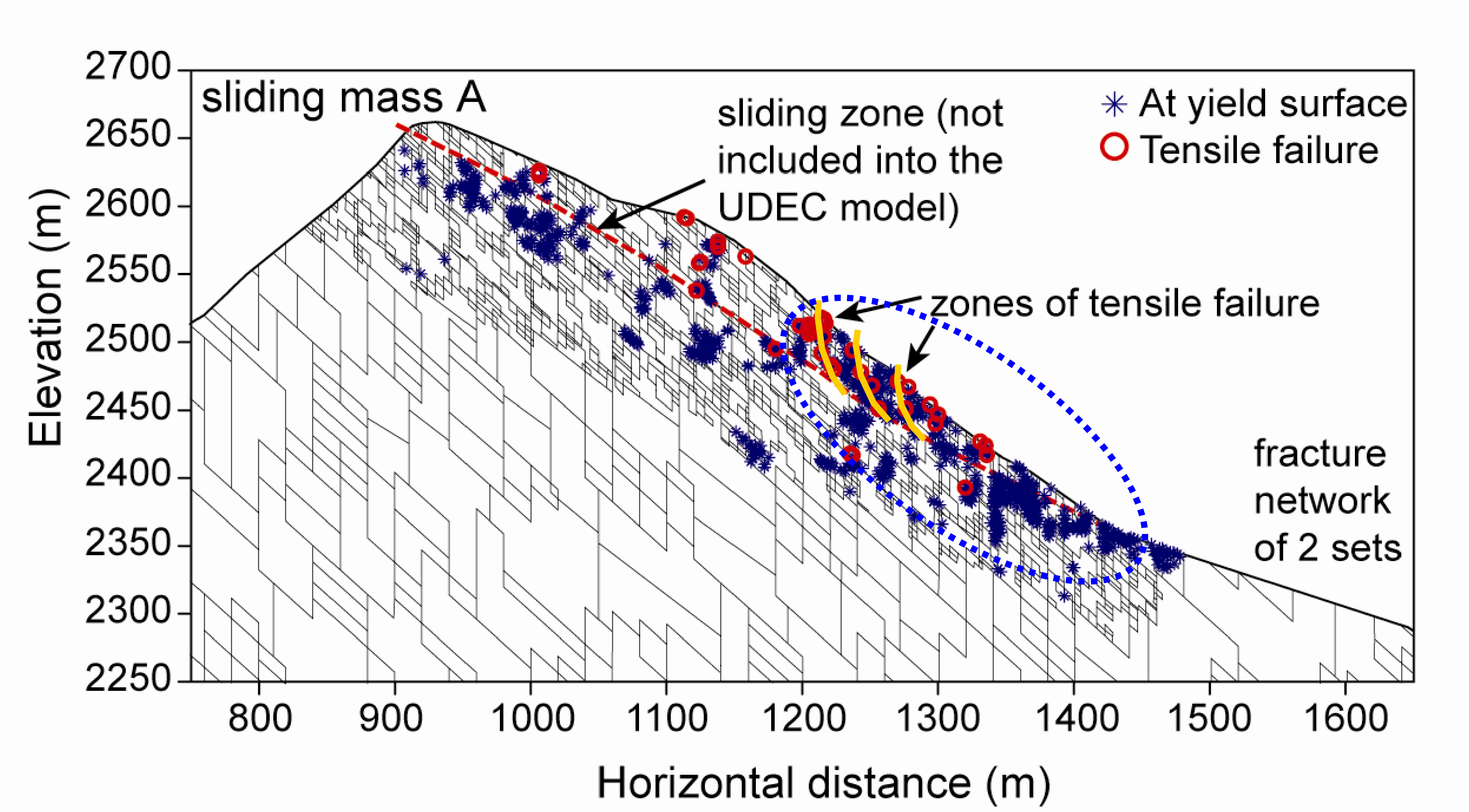


Engineering geological model

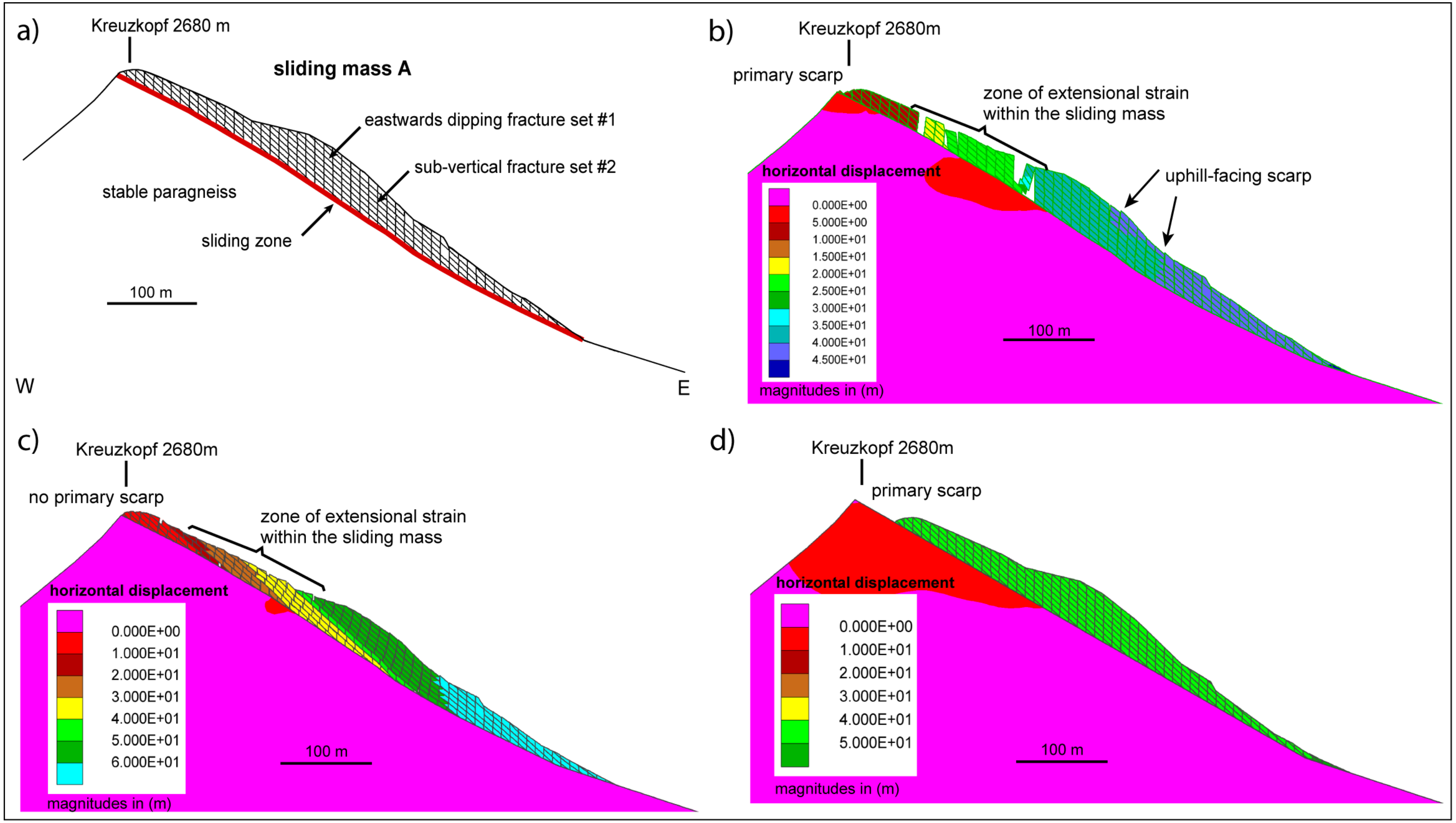


- Basal shear zone convexly and concavely curved
- Dip angle: scarp 26°, middle part 37°, lower part 26°
- Translational sliding mechanism

Distinct element modelling of the initial failure process

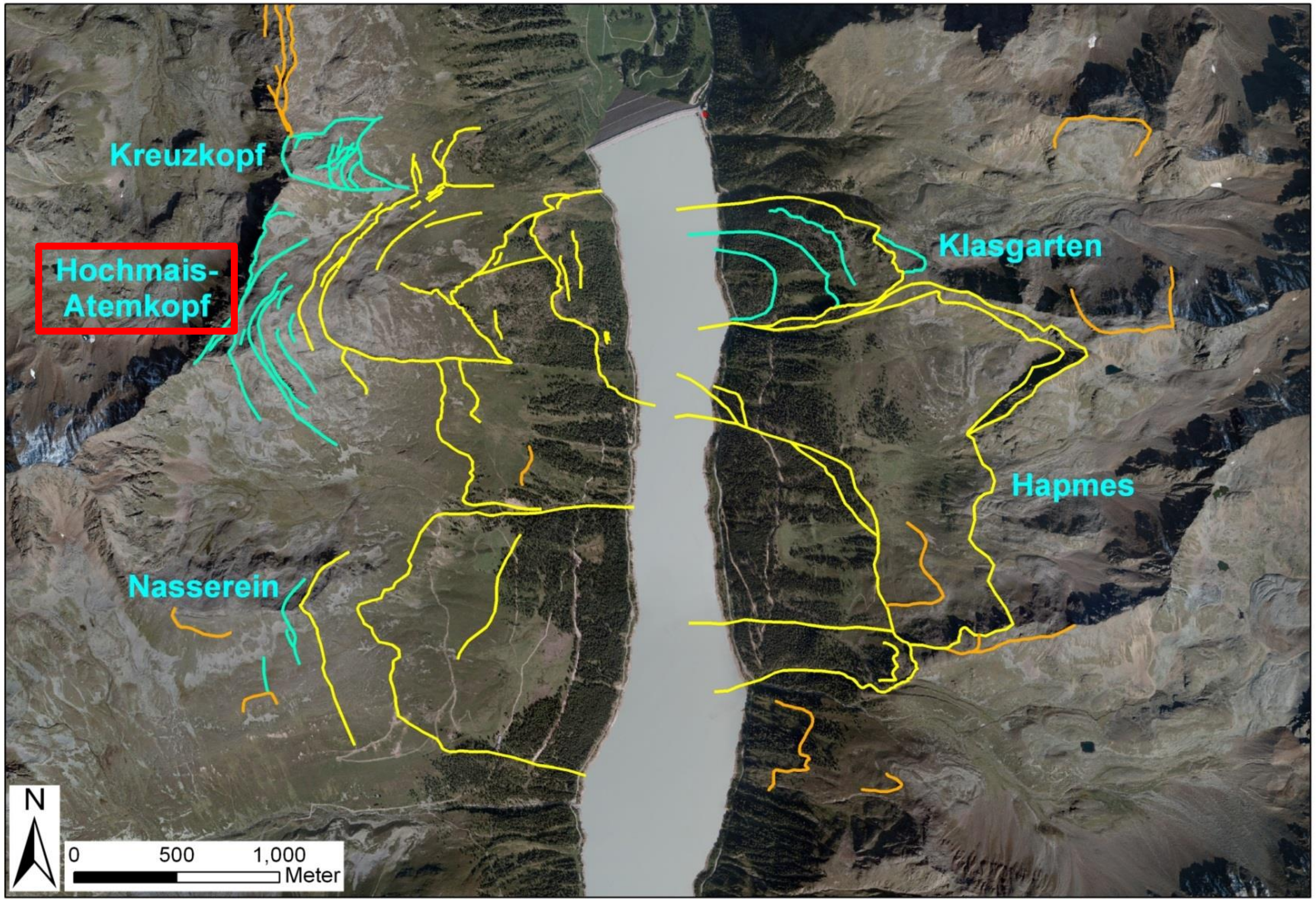


Distinct element modelling of the sliding process



Rock slide Hochmais-Atemkopf

Formation of slabs

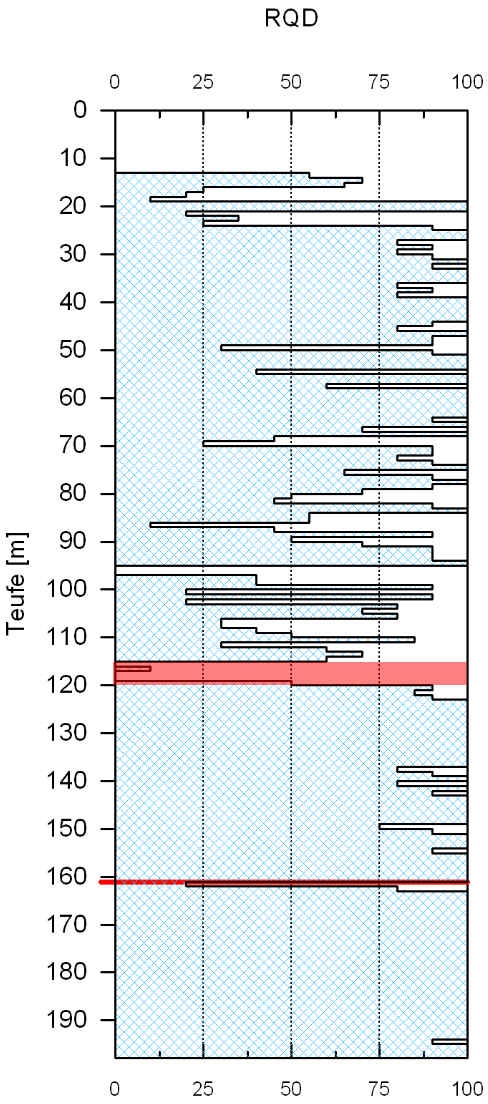


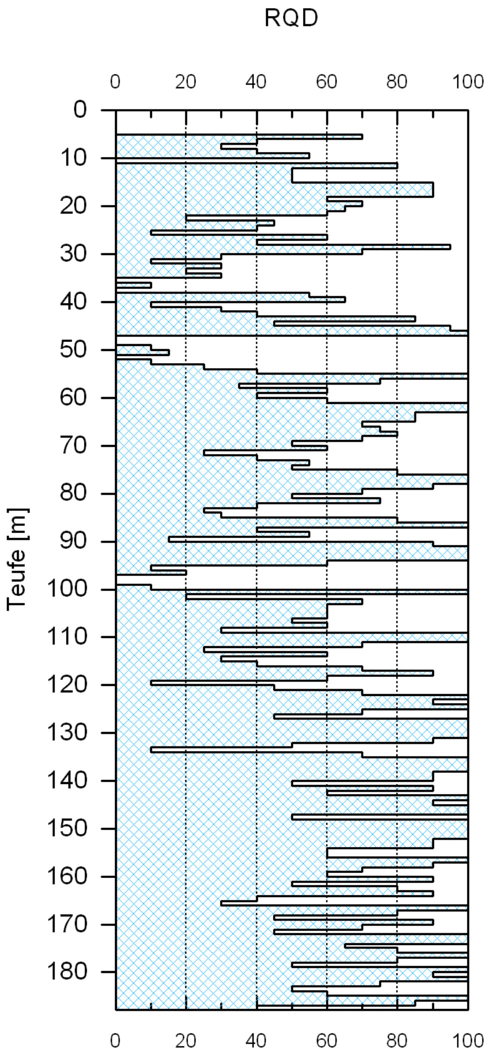
In-situ investigation - drillings

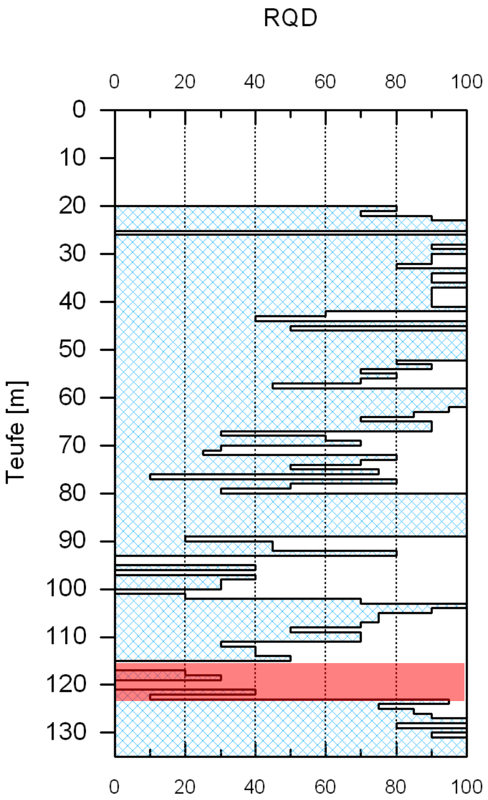
- Core logging
- RQD

112-116 m

136-140 m

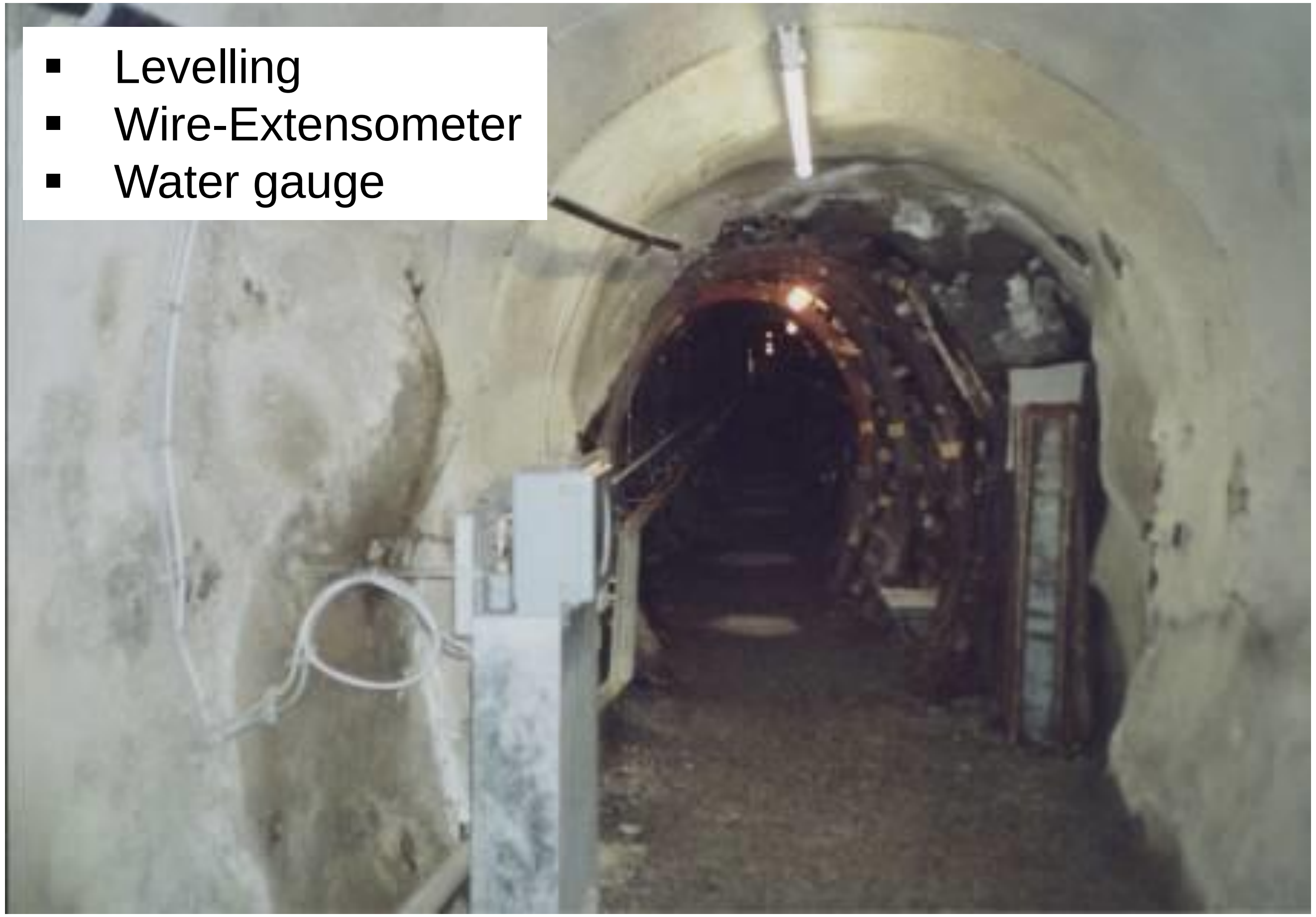


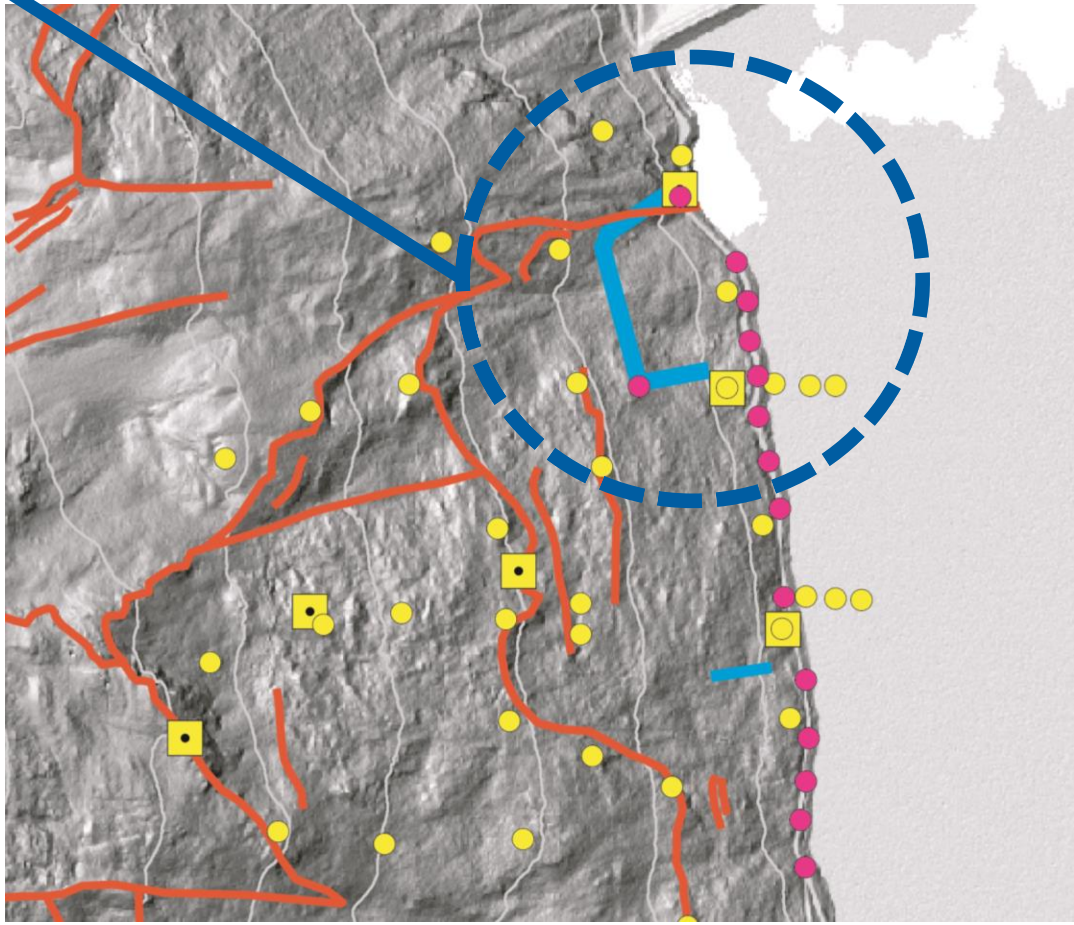




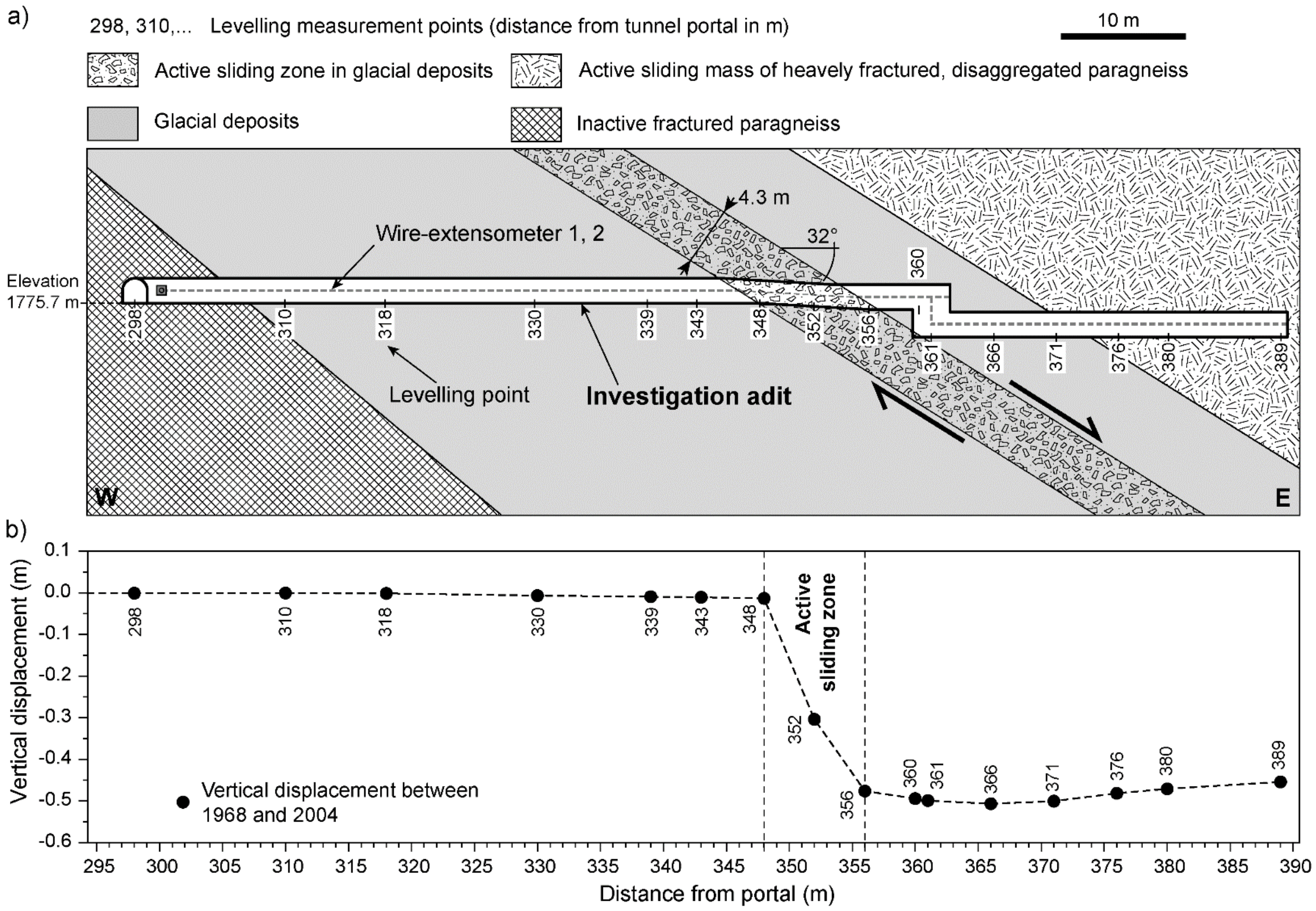
In-situ investigation - drifts

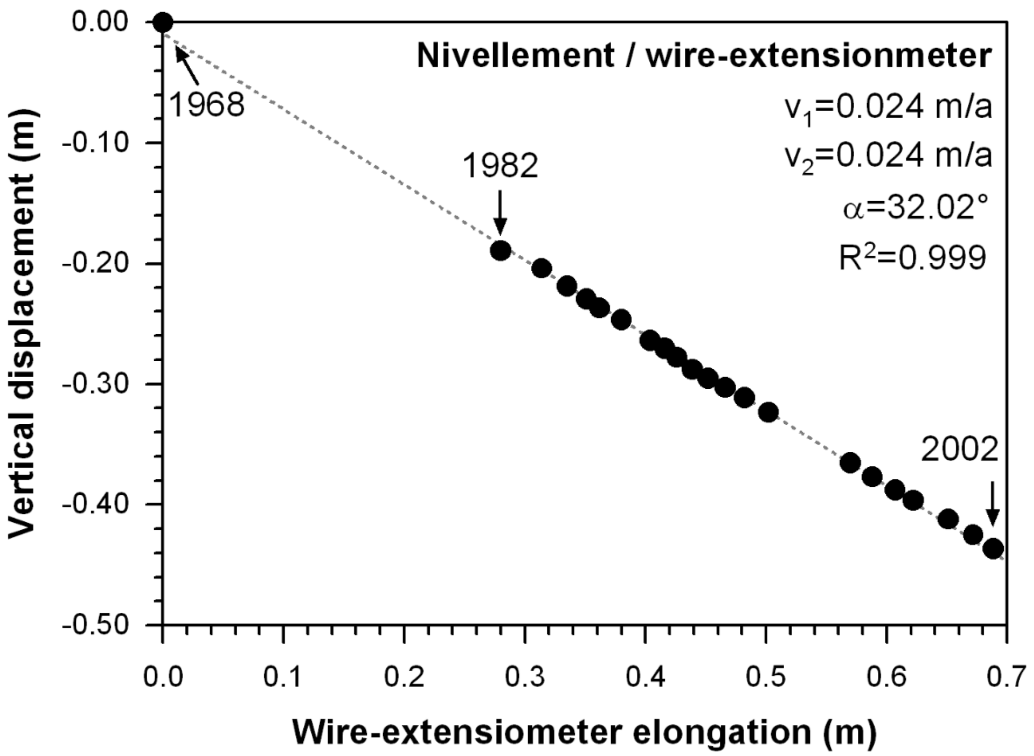
- Levelling
- Wire-Extensometer
- Water gauge



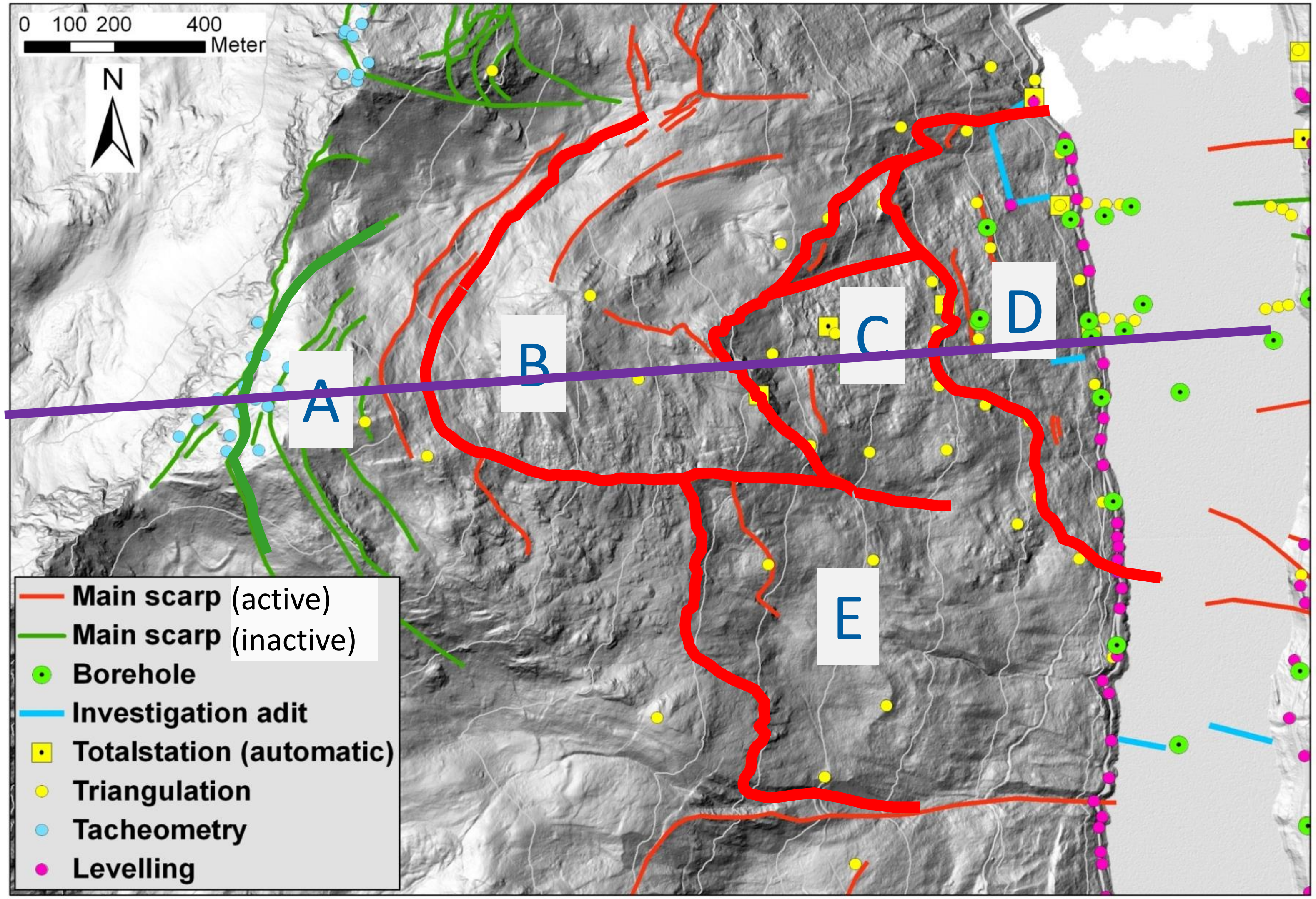


In-situ investigation - drifts



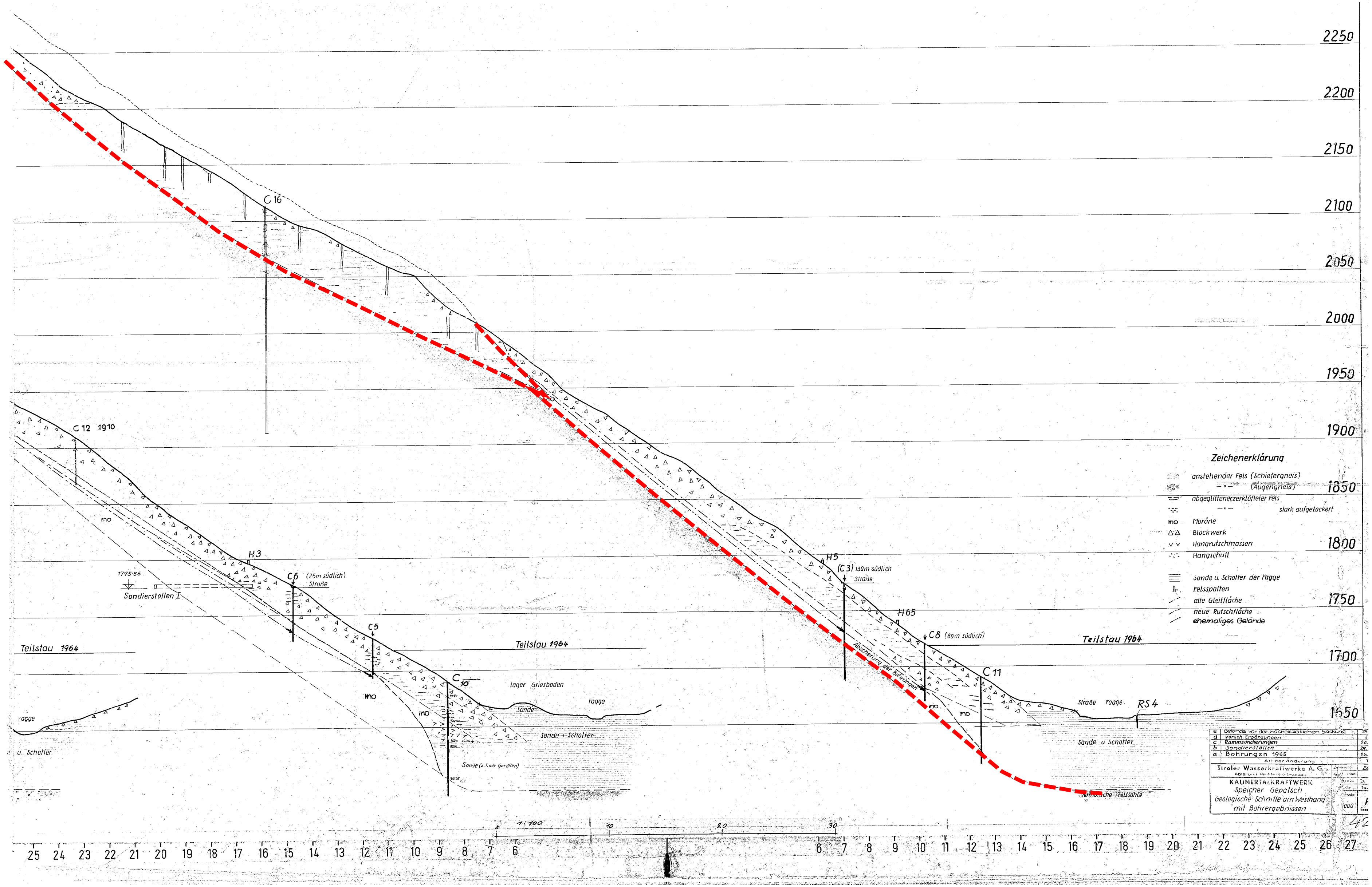


Engineering geological model

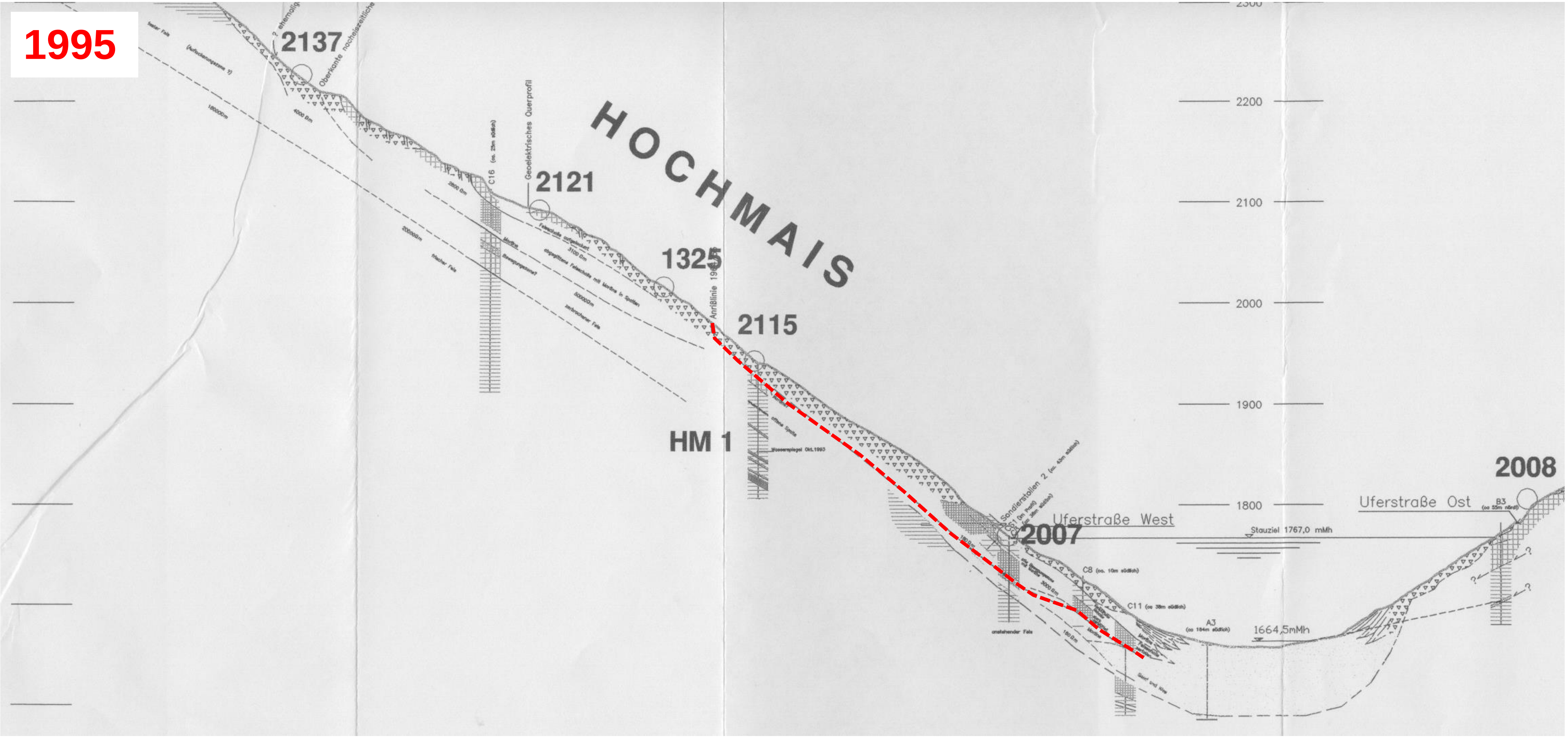


Engineering geological model

1964

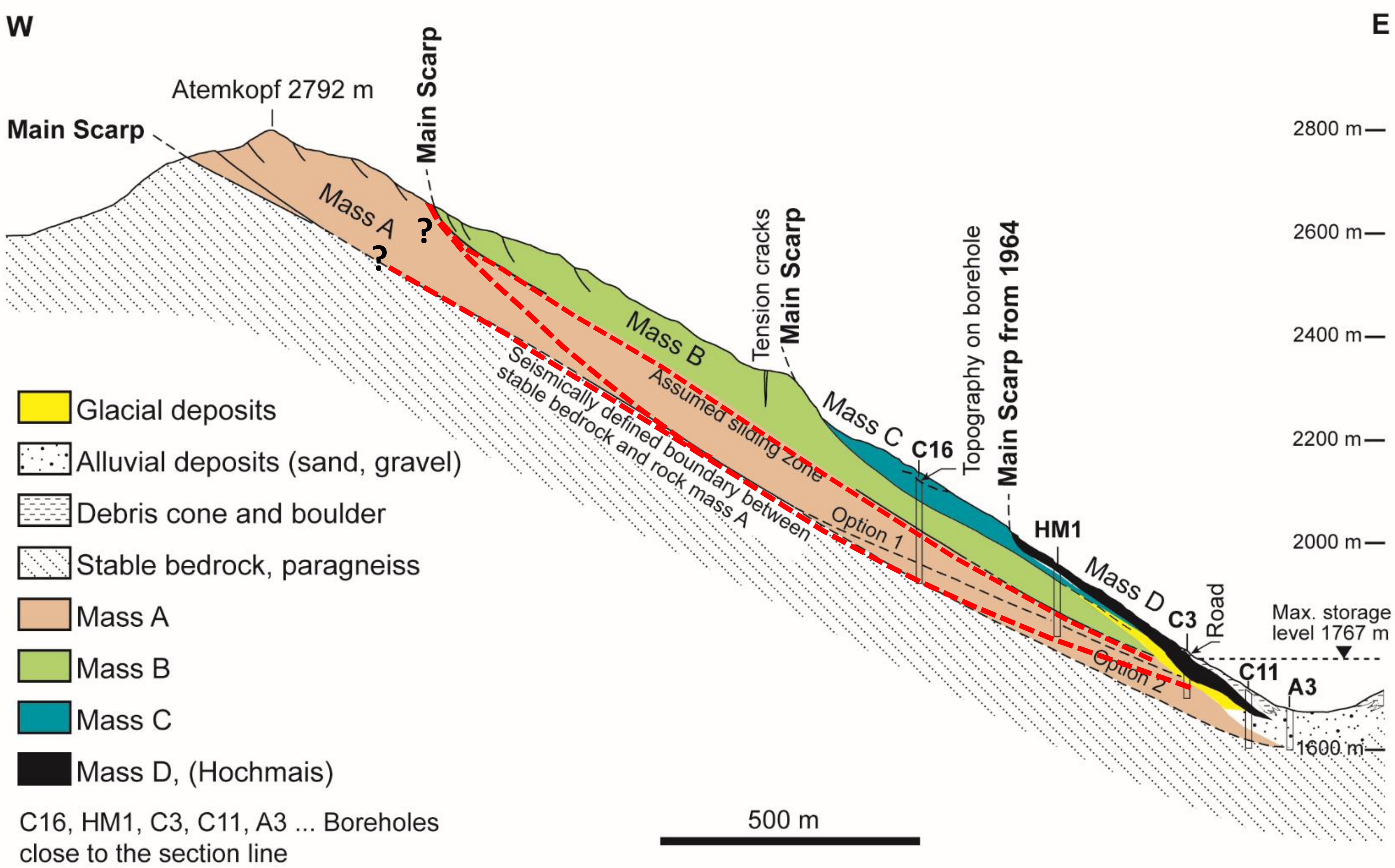


Engineering geological model



Engineering geological model

2010
2020



Implications and conclusions

- Reliable geologic models are necessary for hazard assessment because geometry and structure affect deformation behavior of the rock slide and its stability.
- Deep-seated rock slides are highly complex, and even drillings and investigation drifts associated with displacement measurements do not tell us the full story, especially in 3D. We have to deal with models!
- Pre-existing geological structures have a crucial influence on i) the initial failure mechanism, ii) the characteristic of the rock slide geometry, iii) the internal deformation behaviour, and iv) the slab formation.
- Numerical models (e.g. discrete element methods) able to simulate large displacements and block interactions are very helpful to better understand deformation mechanisms.

References

- Zangerl, C., Prager C. (2008): Influence of geological structures on failure initiation, internal deformation and kinematics of rock slides. 42nd U.S. Rock Mechanics Symposium and 2nd U.S.-Canada Rock Mechanics Symposium, San Francisco, June 2008, 13 pp.
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- Zangerl, C., Chwatal, W., Kirschner, H. (2015): Formation processes, geomechanical characterisation and buttressing effects at the toe of deep-seated rock slides in foliated metamorphic rock. Geomorphology, 243, 51-64.

Thank you - questions!