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Engineering-geological Characterization and Activity Analysis of a deep-seated Rockslide near Laatsch (South Tyrol)

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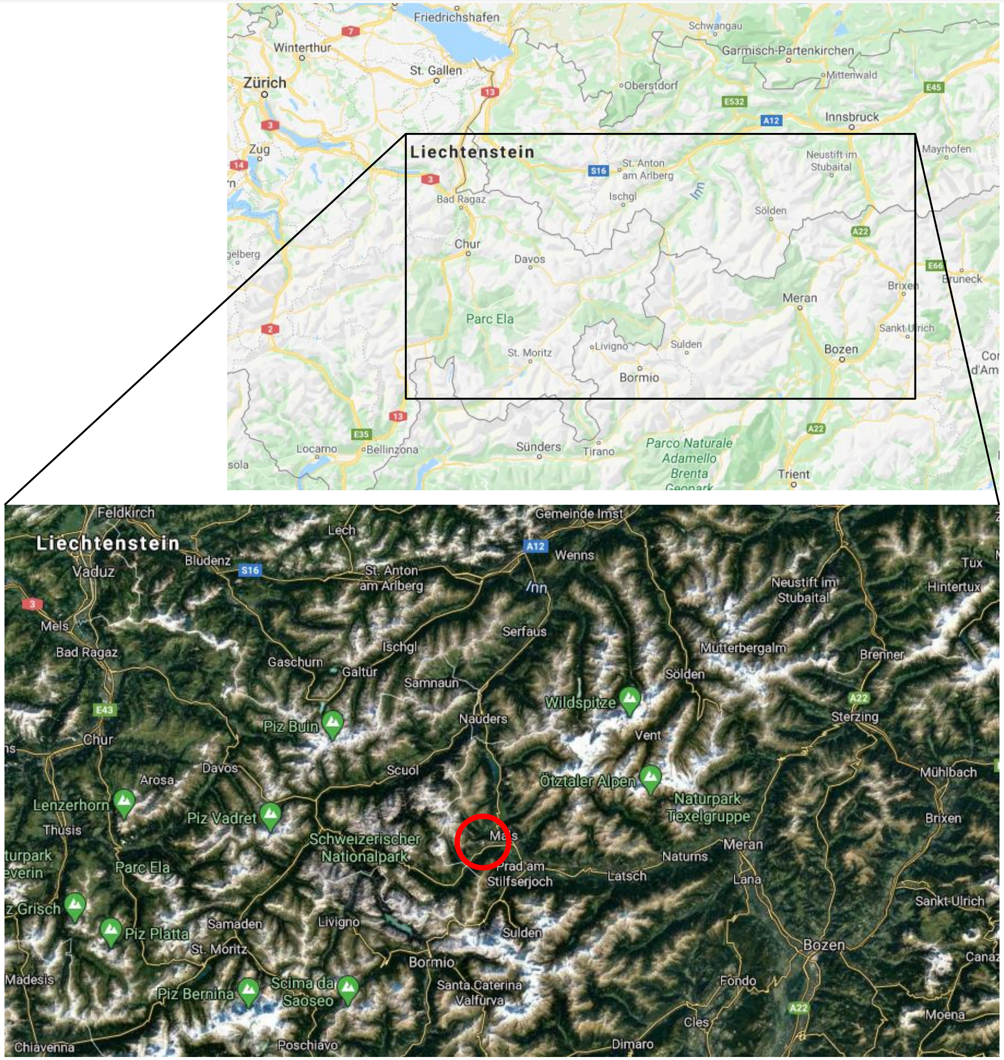
Framework

- Deep-seated rockslides in Alpine areas are common phenomena
- Geological and tectonic conditions enable a disintegration of the rock mass
- Failure process is controlled by structural geology, groundwater flow, permafrost degradation and rock weathering mostly by input of surface water along geological discontinuities
- $\rightarrow$ Extensive slope areas can become unstable

Lateral spreading of mountains in the Kitzbüheler Alps in Salzburg, Austria (Photo from N. Tilch, Geolog. Survey of Austria)

Research Subject

- Deep-seated rockslide at a south-facing mountain slope near Laatsch, Southern Tyrol



Research Subject

- U-shaped valley formed by glaciers, the valley floor is filled with alluvial sediments
- Mountain ridge ca. 2,100 m a.s.l., valley floor at ca.1,000 m a.s.l.
- Slope gradient approx. 30 - 50°
- The rockslide is approx. 400 m wide, approx. 700 m in height at its longest extension, with a slide surface ca. 50 - 100 m deep
- $\rightarrow$ total instable rock volume of approx. 5 - 10 million m³
- Activation of movement in the year ~ 2000, rapid acceleration since 2012

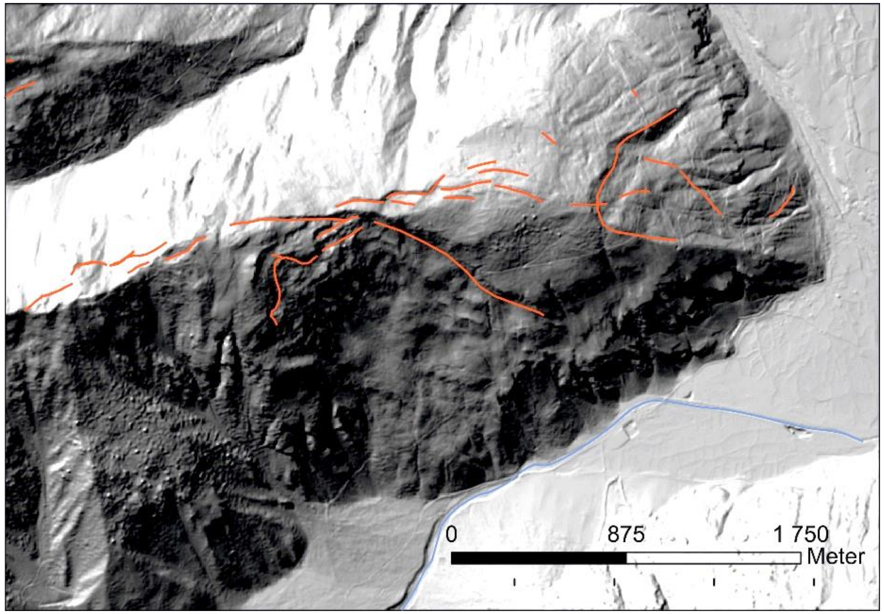
Present Situation & Geomorphological Features

- Scarps and secondary scarps
- Deep weathering of disintegrated rock mass at fracture surfaces
- Tension cracks
- Individual slabs showing translational movement with minor internal deformation
- Rock fall

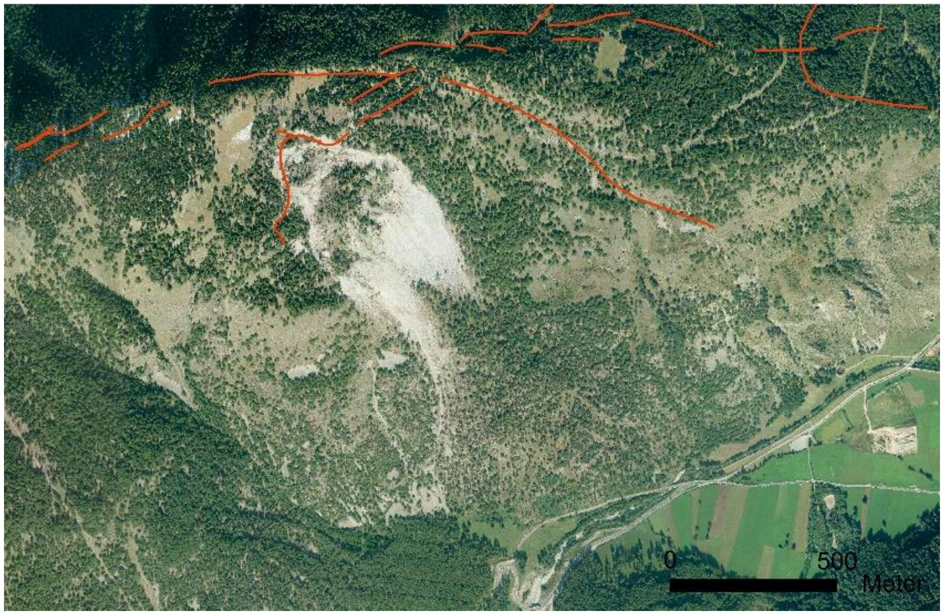
Photograph of rockslide, view to NW (July 2019)

Geomorphological Features: mountain splitting

- Scarps and development of double ridges
- Retrograde destabilisation



Hillshade from airborn laserscanning in 2004



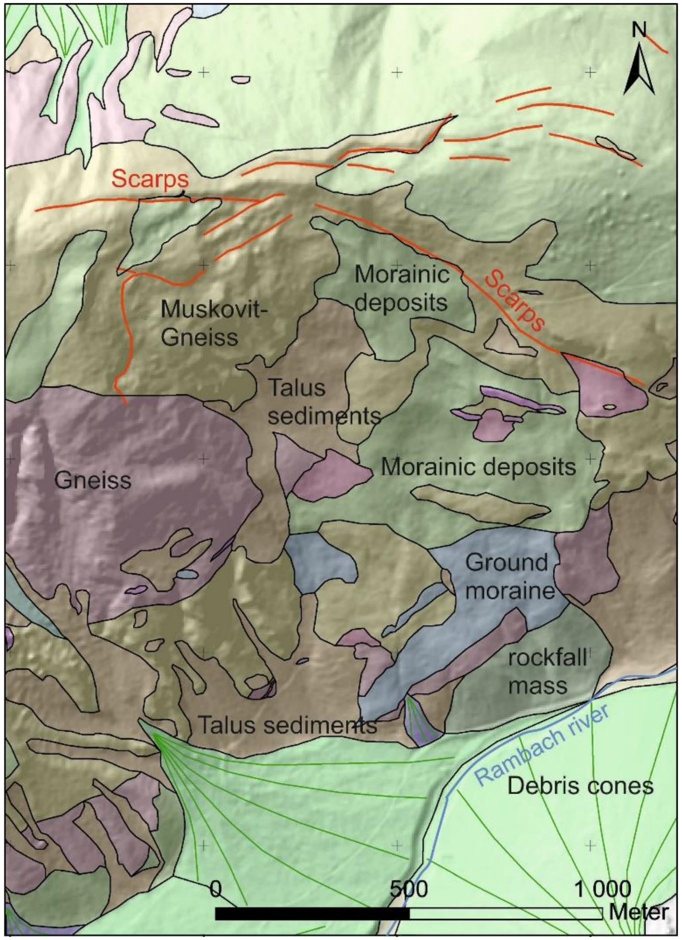
Orthophoto from 2014

Geomorphological Features

- Steep dipping scarps (ca. 70°) and slab development
- Weathering of Gneiss rocks along scarps / pre-existing joints

Geological Overview

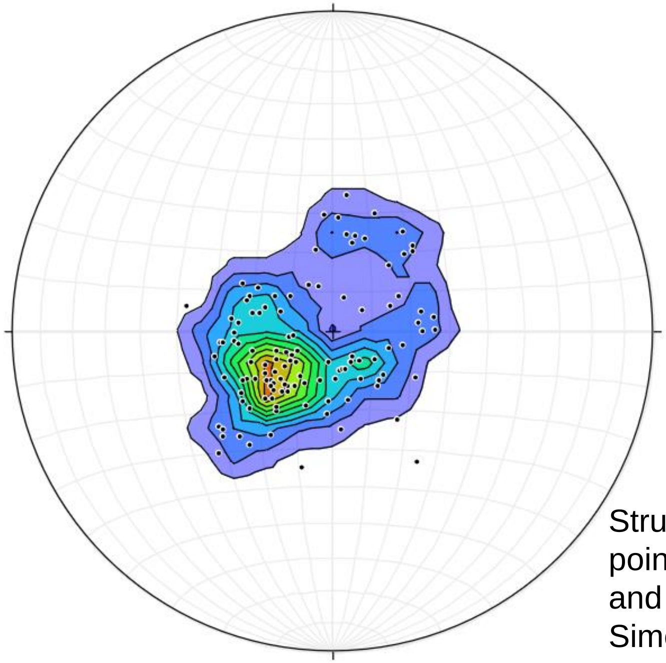
- Geological bedrock consists of foliated metamorphic rocks (mainly orthogneisses), partially covered by talus and glacial sediments
- The foliation dips mainly towards Northeast with a dip of ca. 10-20°
- Major tectonic stress due to its close range to major fault zones generating a dense fracture system
- Two perpendicular steep joint sets could be identified during structural mapping



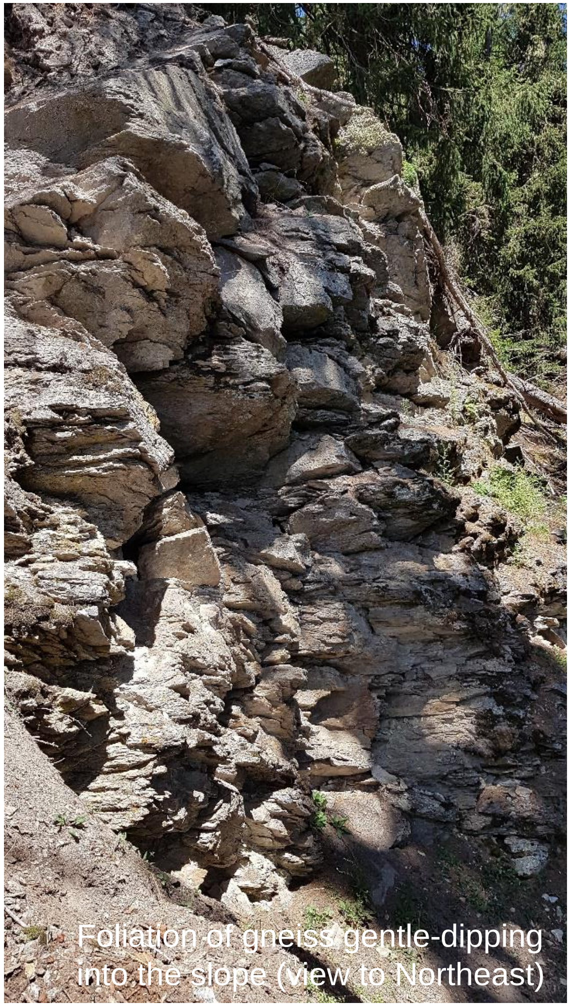
Petrologic map of the investigation area (Property of Office for Geology and building materials testing, Autonomous Province of Bolzano, Italy)

Structural Geology: Foliation

- Gentle-dipping foliation (ca. 20°) to the Northwest
- Foliation dipping towards the slope, therefore not favouring slope failure in terms of sliding

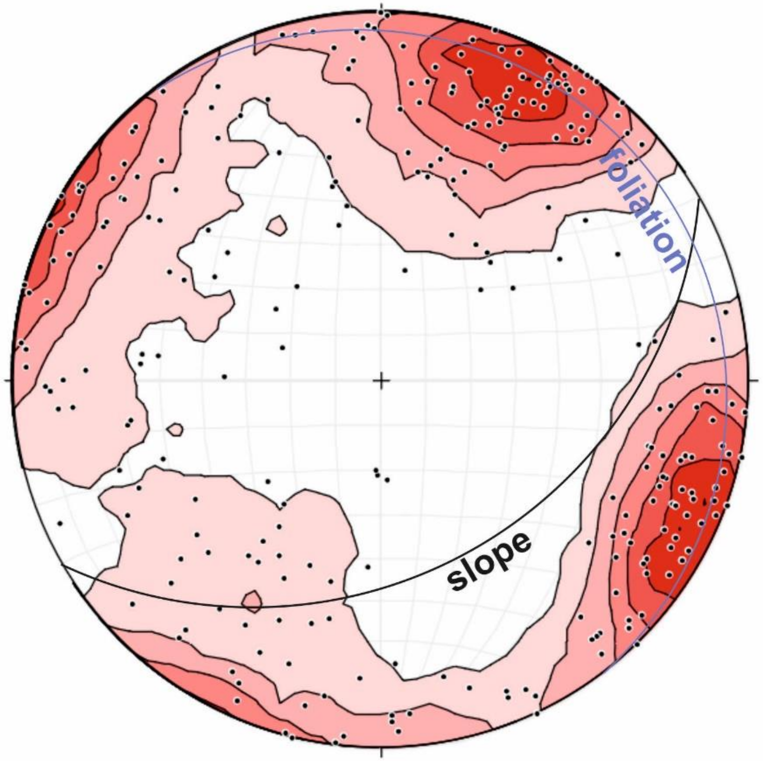


Structural plot: pole points of foliation (Mapping and data processing by Simon Ziernhöld)



Structural Geology: Fracture System

- Two sets of very steep dipping joins are present:
    - Set #1 dipping southwest (approx. 205/80) and
    - Set #2 set dipping northeast (approx. 295/85)
- Joint set deeply fragmenting the rock mass
- Predisposing trigger mechanism for rockslide



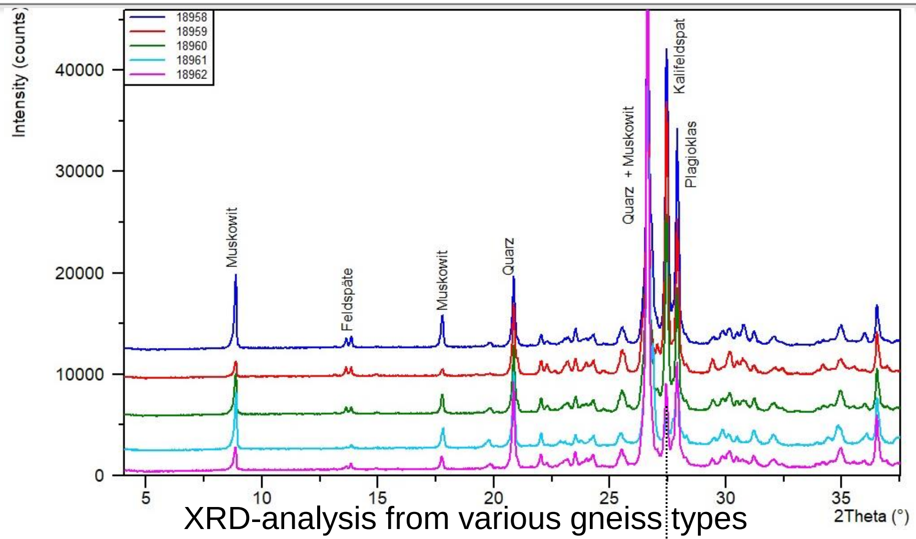
Structural plot: pole points of joints; foliation and slope orientation as great circles
(Mapping and data processing by Simon Ziernhöld)

Geomorphological / Structural Features

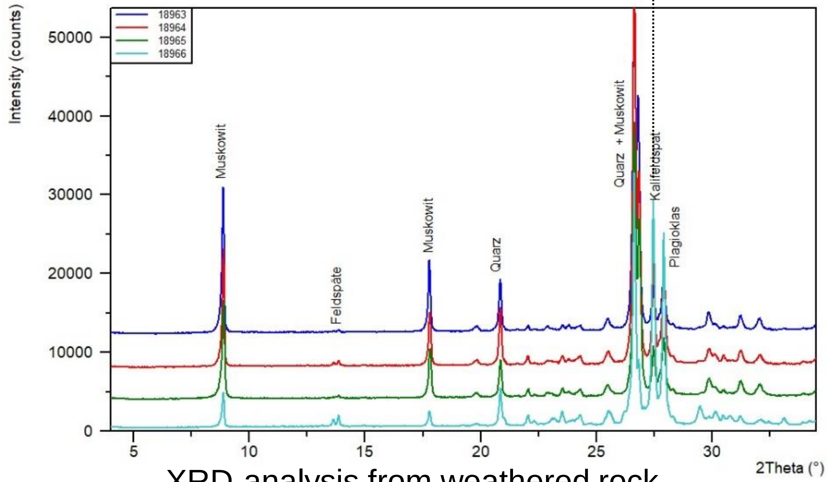
- Fracture fillings from exposed crack / joint surface activated as scarps

XRD Analysis from base and weathered rock

- Various Gneiss types mainly consist of Quartz, Feldspar, Muscovite and Calcite
- At the scarps/weathered joint surfaces, potassium feldspar and plagioclase are reduced, Quartz and Muscovite therefore are dominant
- Thin sections from different Gneiss samples show fine to coarse grained structure; foliation is mainly caused by Muscovite layers; Muscovite-rich shearing planes could also be identified



XRD-analysis from various gneiss types

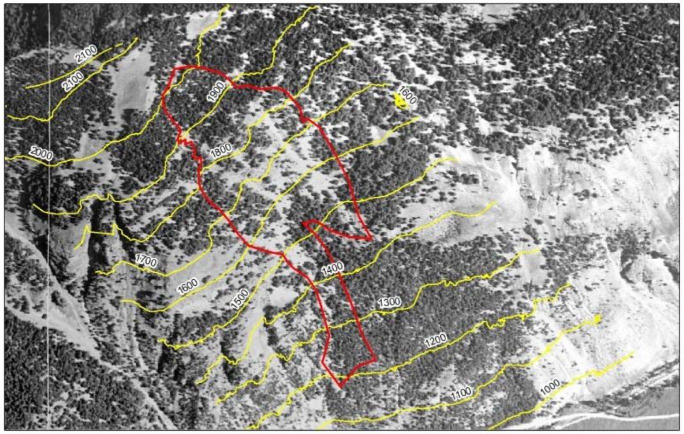


XRD-analysis from weathered rock
Analysis by BOKU Vienna, Karin Wriessnig

Movement Time Series

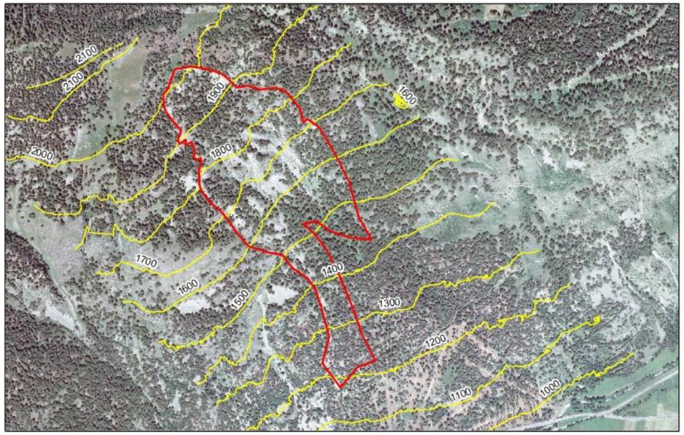
Orthophoto 1945

Kilometer
0 0,1 0,2 0,4 0,6
N



Orthophoto 2011

Kilometer
0 0,1 0,2 0,4 0,6
N



Orthophoto 2000

Kilometer
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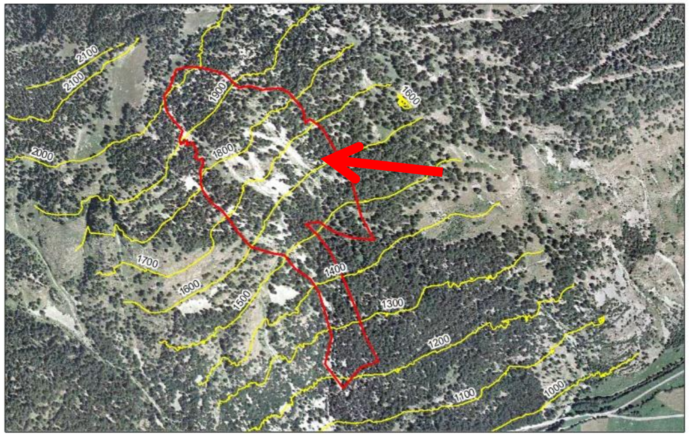
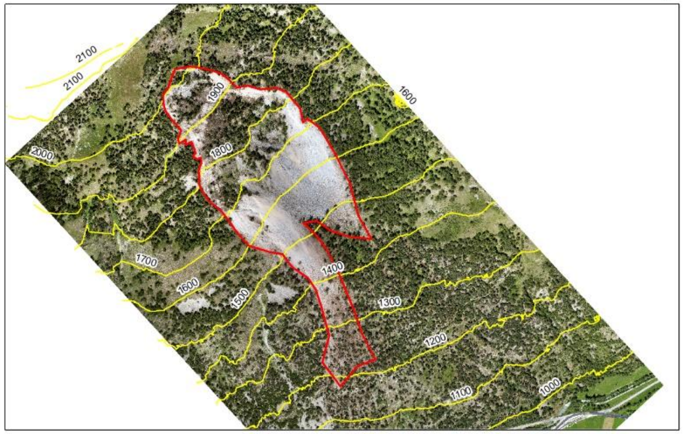


Orthophoto 2014

Kilometer
0 0,1 0,2 0,4 0,6
N

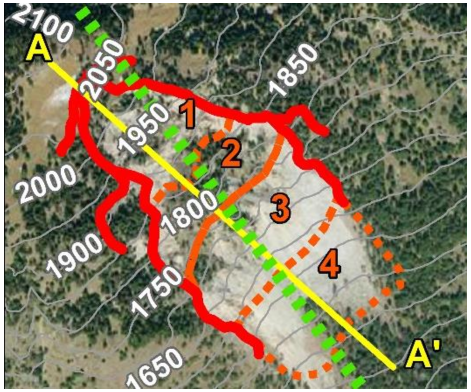


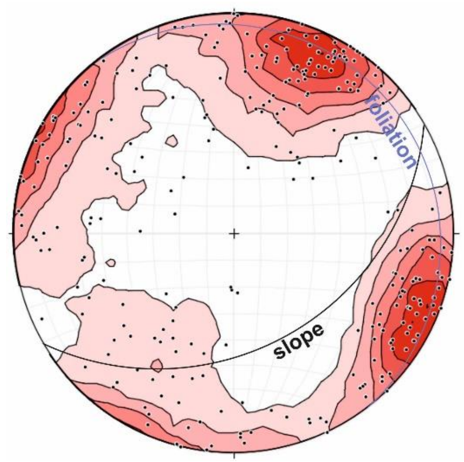
Kinematics Characterization – sub-areas

- Since several years, the highly active rockslide shows displacements of several metres per year
- In 2014, the road SS41 was relocated over a length of ca. 800 m to the other side of the Rambach due to ongoing rock fall events
- Destabilization of a large area at the mountain ridge → primary and secondary scarps, tension cracks, up-hill facing scarps and development of a double ridge
- Scarps deviding the rockslide into different slabs

Kinematics Characterization – sub-areas

- The rockslide can be divided into different slabs of varying activity
- Deformation rates of slabs between ca. 0.2 to 0.3 m per month in the years 2018 and 2019
- Higher activity during summer (because of snow melting?)
- Translational movement behavior with minor internal deformation
- Rotational kinematics along polygonal slip surfaces
- Slip surfaces developed from pre-existing steeply dipping joint surfaces

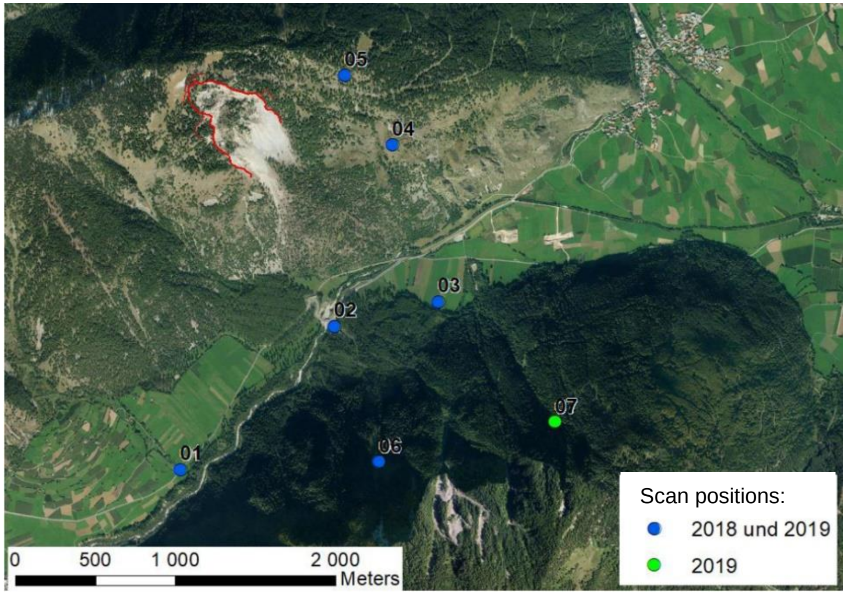




Pole points of joints:
two joint sets

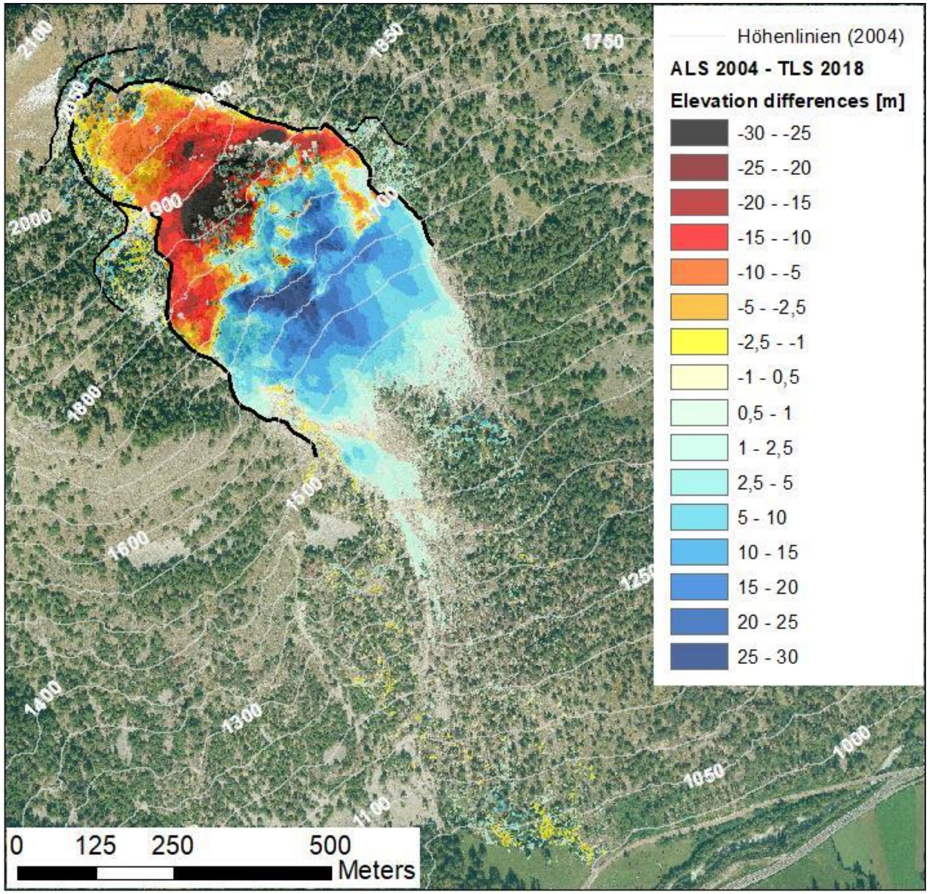
Displacement – Laserscanning measurements

- Terrain model data analysis (TLS, ALS, Photogrammetry)
- Laserscanning measurements from various scan positions
- Displacement calculation in different time periods



Displacement – Laserscanning measurements

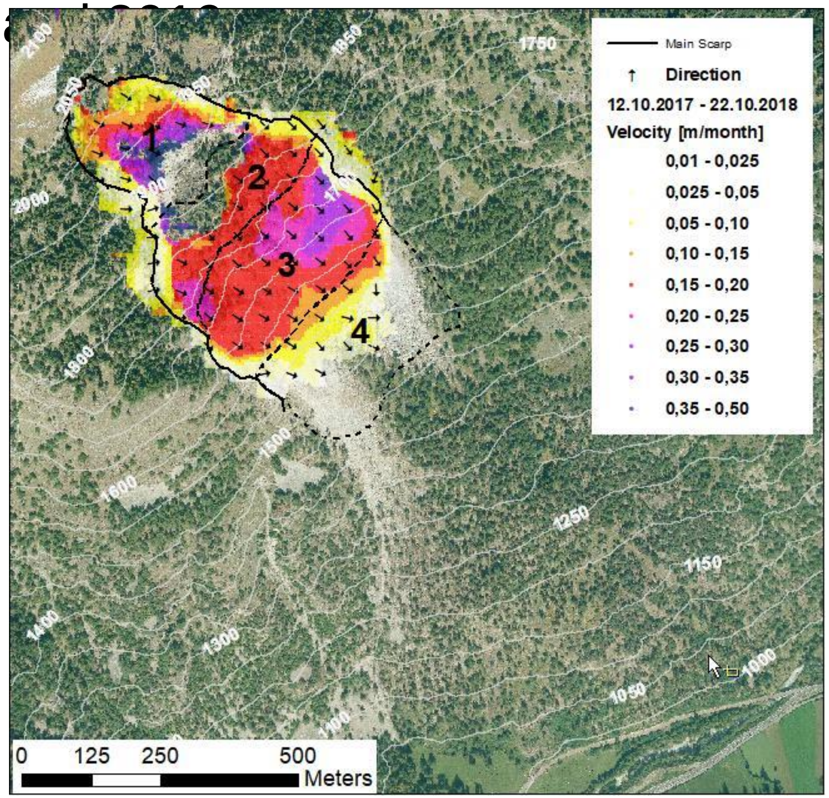
- Terrain model data analysis
- Laserscanning measurements
- Example: Elevation difference between 2004 (ALS) to 2018 (TLS)
- Mass transport from upper steep slope area to areas of lower slope angle



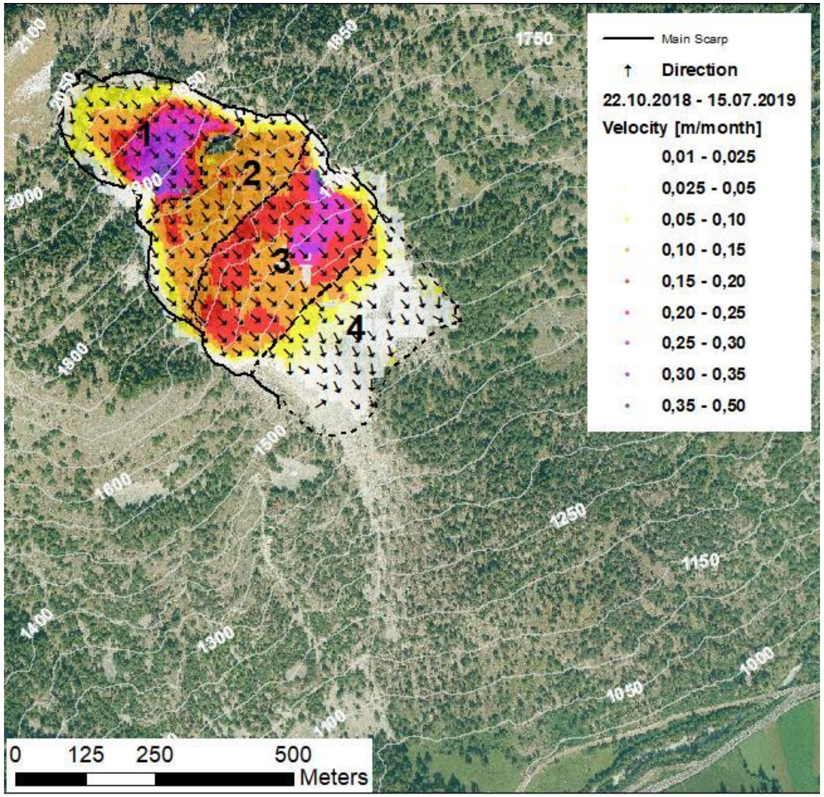
Difference in height from 2004 (ALS) to 2018 (TLS); Analysis by Christine Fey

Displacement – Laserscanning measurements

- Recent changes: average horizontal displacements between 2017 and 2019



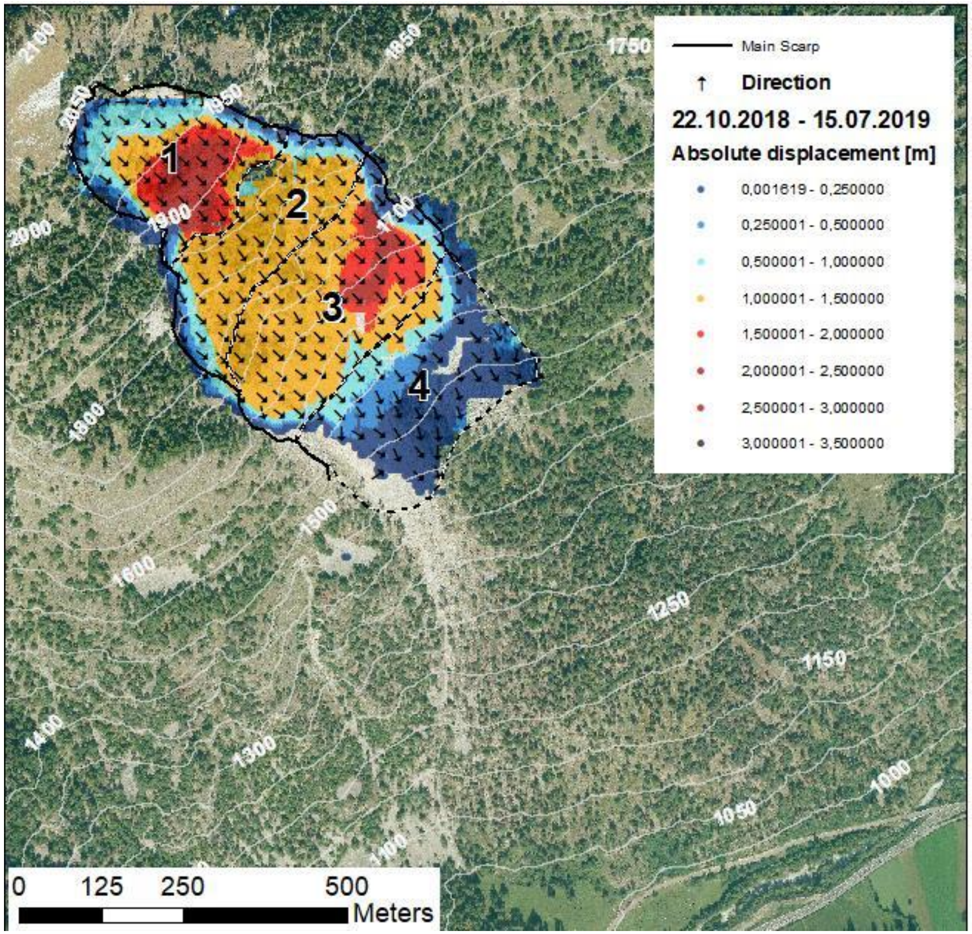
Average horizontal displacements (meters per month) from TLS-measurements between October 2017 and October 2018; Analysis by Christine Fey



Average horizontal displacements (meters per month) from TLS-measurements between October 2018 and July 2019; Analysis by Christine Fey

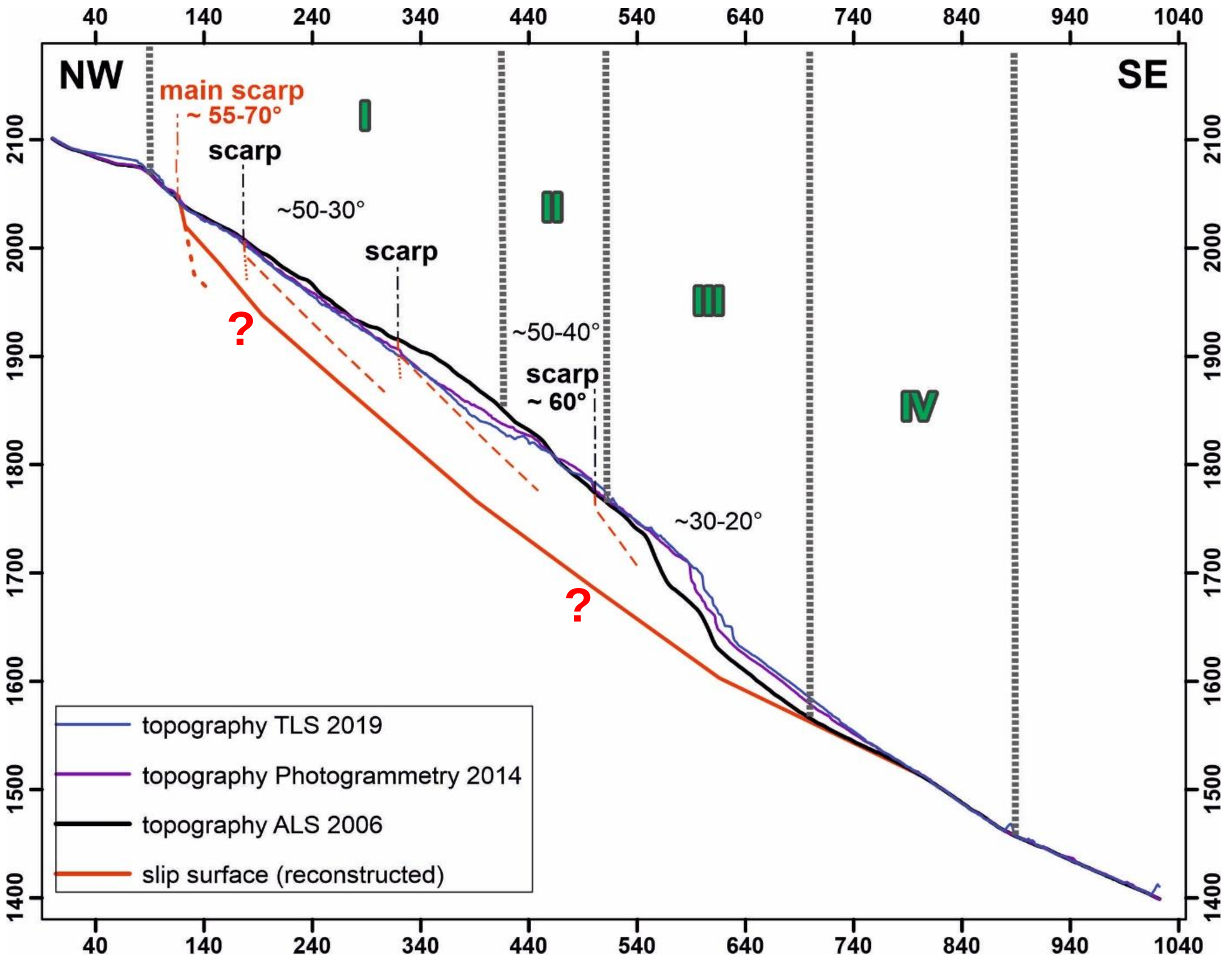
Displacement – Laserscanning measurements

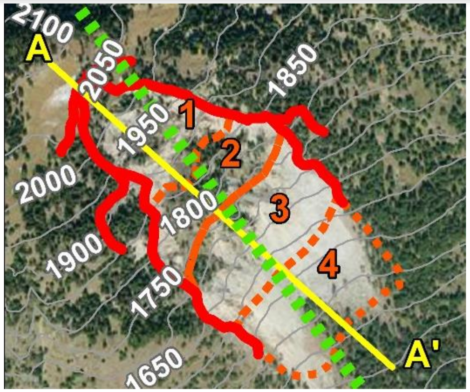
- Recent changes: absolute horizontal displacements between 2018 and 2019
- Displacement up to ca. 3 m (red colour) in upper and middle section



Absolute horizontal displacements (meters) from TLS-measurements between October 2017 and July 2019; Analysis by Christine Fey

Cross Section – preliminary interpretation





- Multiple scarps from Orthophoto and field investigation
- Individual sub-areas with varying deformation rates identified by Laserscanning

Cross section interpretation on the basis of terrain model and field investigation (Christina Rechberger)

Summary & Outlook

- Classic example for deep-seated rockslide in alpine area
- Two joint sets disintegrate rock mass
- Deep weathering along joints cause destabilization of slope
- Development of scarps, double ridges
- Displacement analysis via Terrestrial Laserscanning shows various areas of different displacement rates

Outlook:

- Further investigations in the field (detailed structural geological mapping) and lab (thin section analysis)
- Modelling of the rockslide