STRUCTURAL GEOLOGY OF LARGE (ANCIENT) ROCKSLIDES - AN INDICATOR FOR A SEISMIC OR CLIMATIC ORIGIN?

Presented by Hans-Balder HAVENITH

Authors: Emilie Lemaire, Anne-Sophie Mreyen, and Hans-Balder Havenith

EGU General Assembly 2020

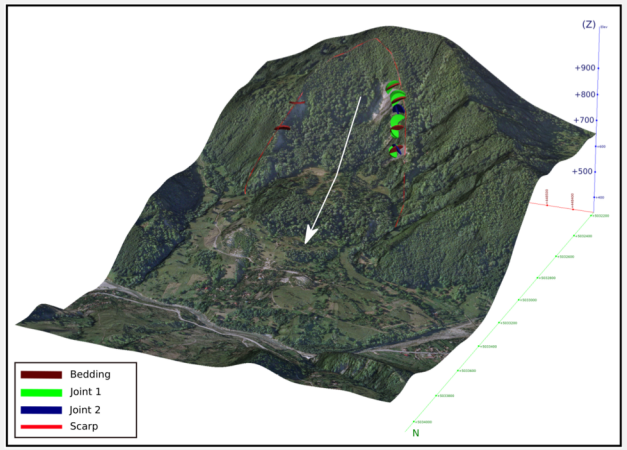
LIÈGE université

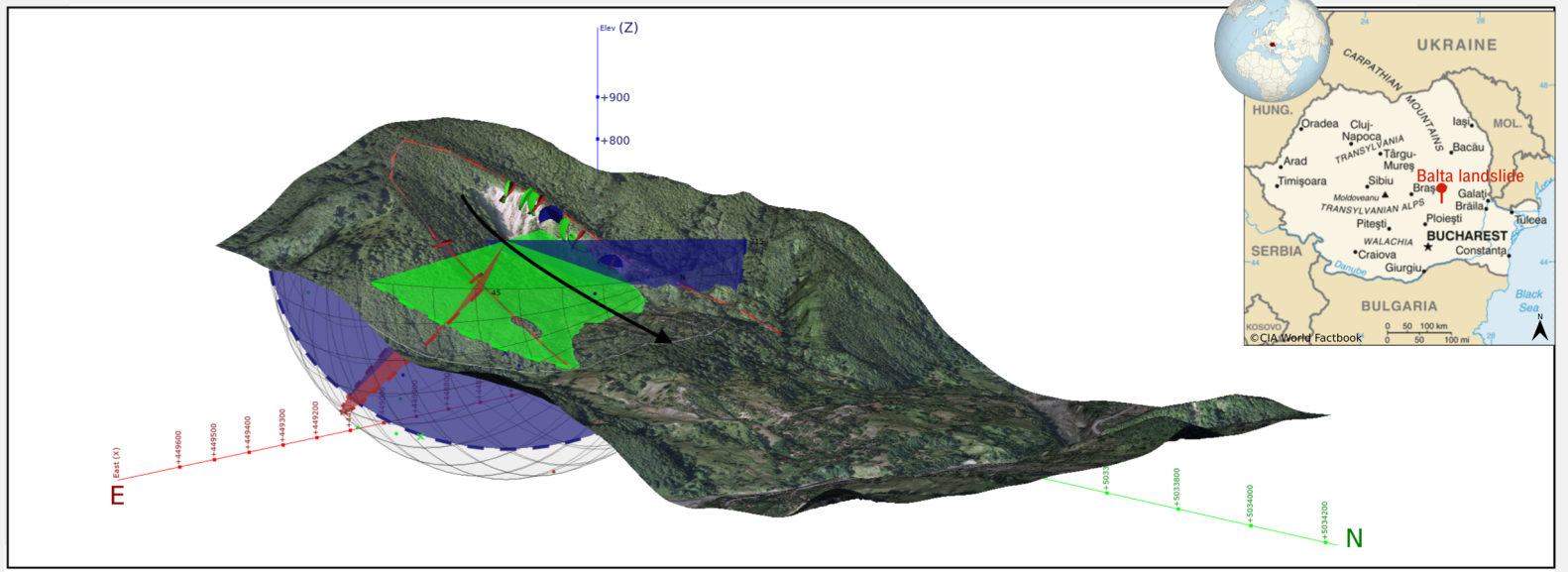
INTRODUCTION

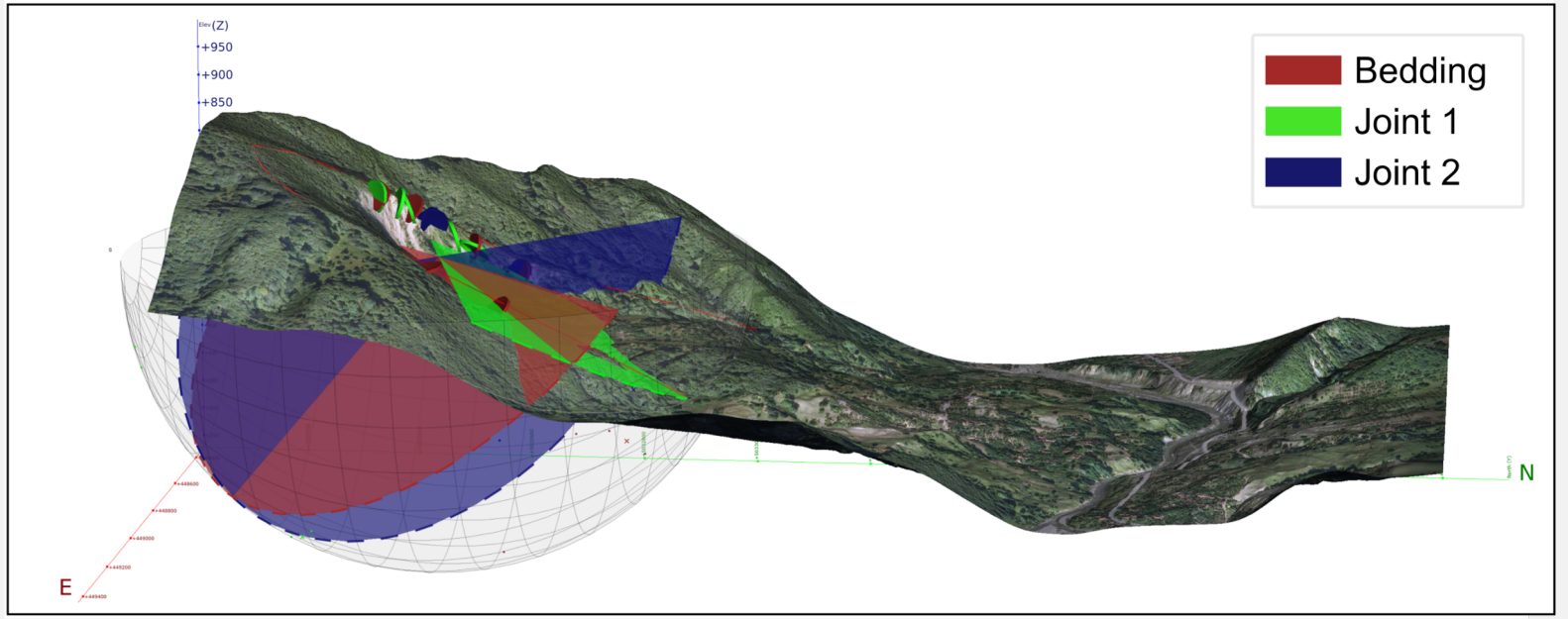
- **Many mountain regions** all over the World are exposed to **rockslide hazards**
- **The origin** of the pre-historic failures is **often unclear**, as they are often the result of processes acting over **longer terms** and of those acting over the **short term**
- **Geological structures**, such as bedding, ductile folds, discontinuities, brittle faults and fractures are **known factors decreasing the stability** of rock slopes
- Focus on the **SE Carpathians** and the **Alps** (examples analysed include the 'Balta' and the 'Tamins' rockslides)

BALTA ROCKSLIDE GEOMODEL

- Bedding: **anti-dip slope**
- Joint 1: **sliding**
- Joint 2: **detachment**

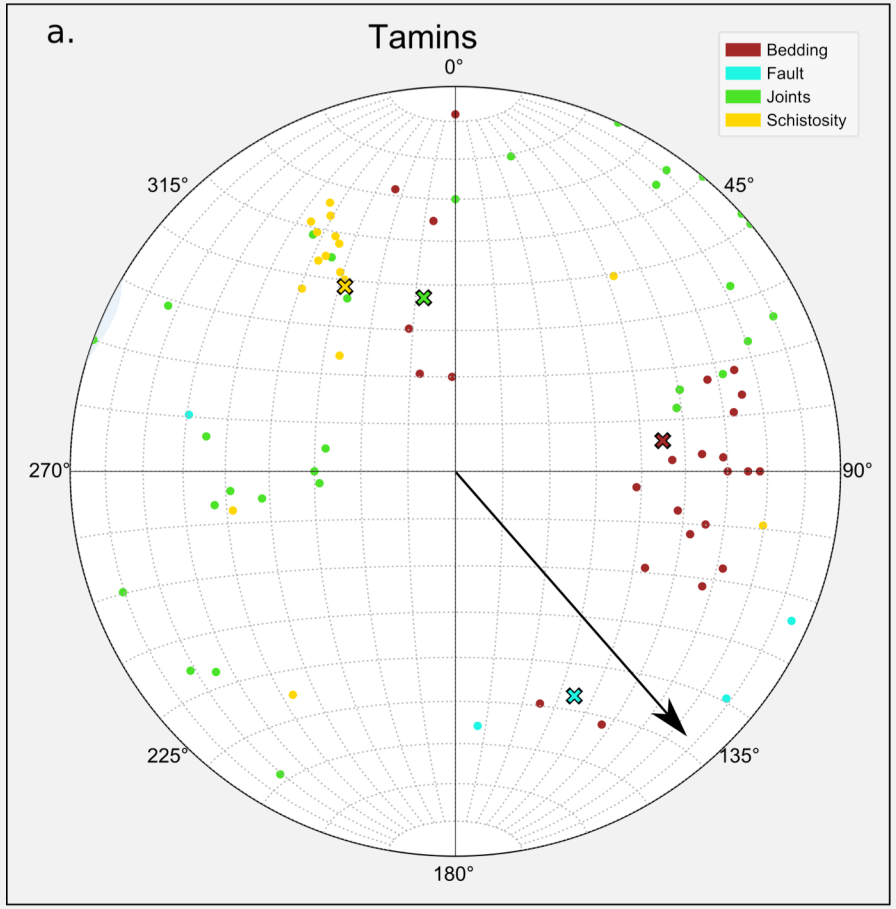


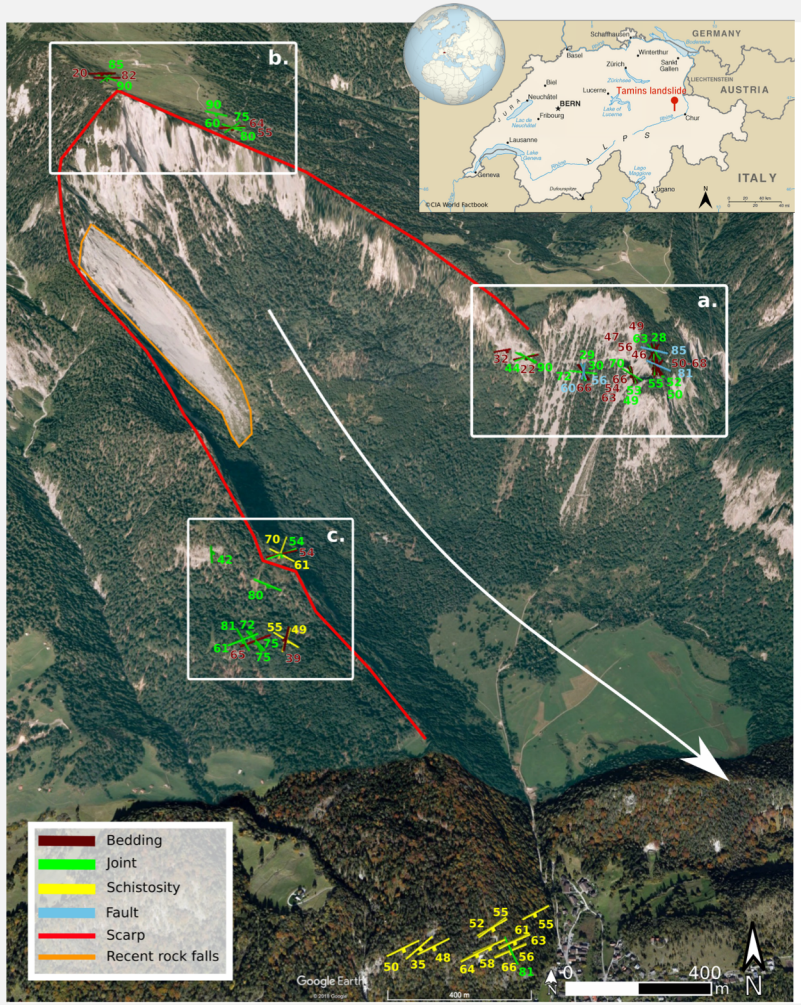


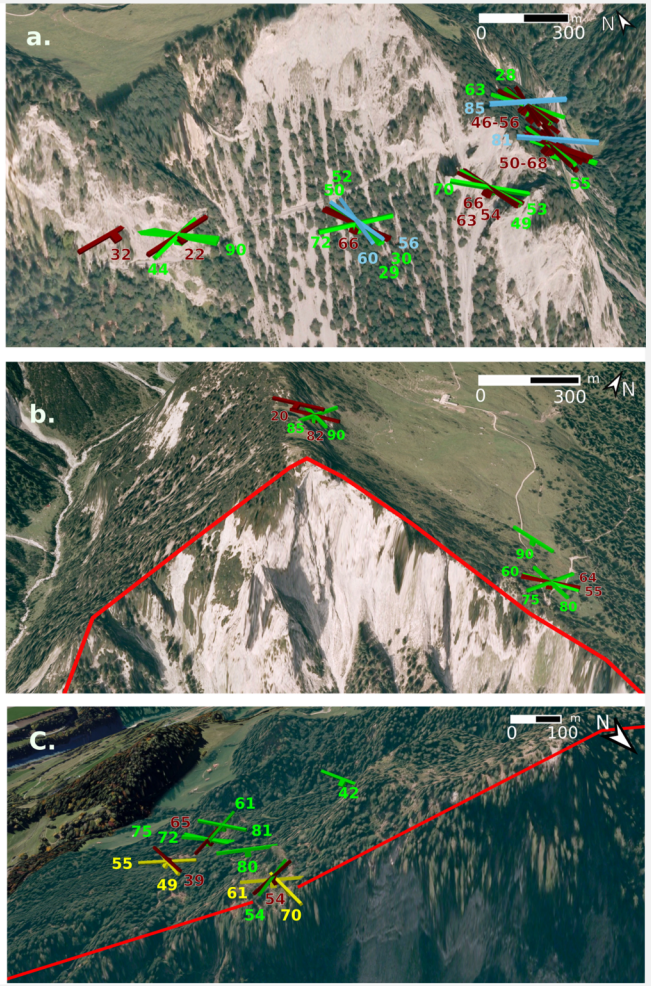


TAMINS ROCKSLIDE GEOMODEL

- The Tamins rockslide





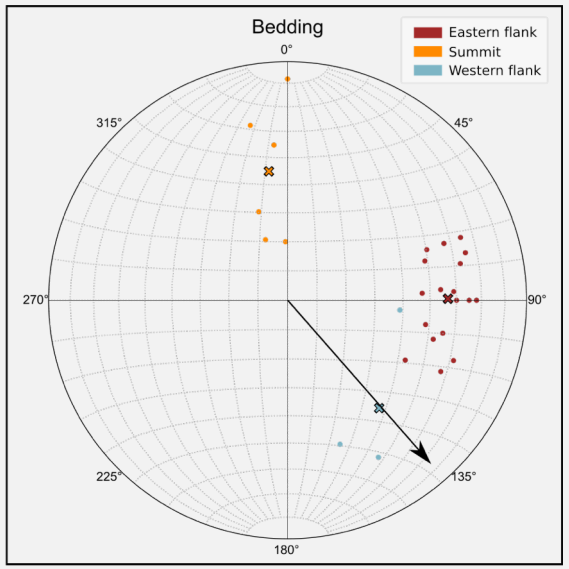


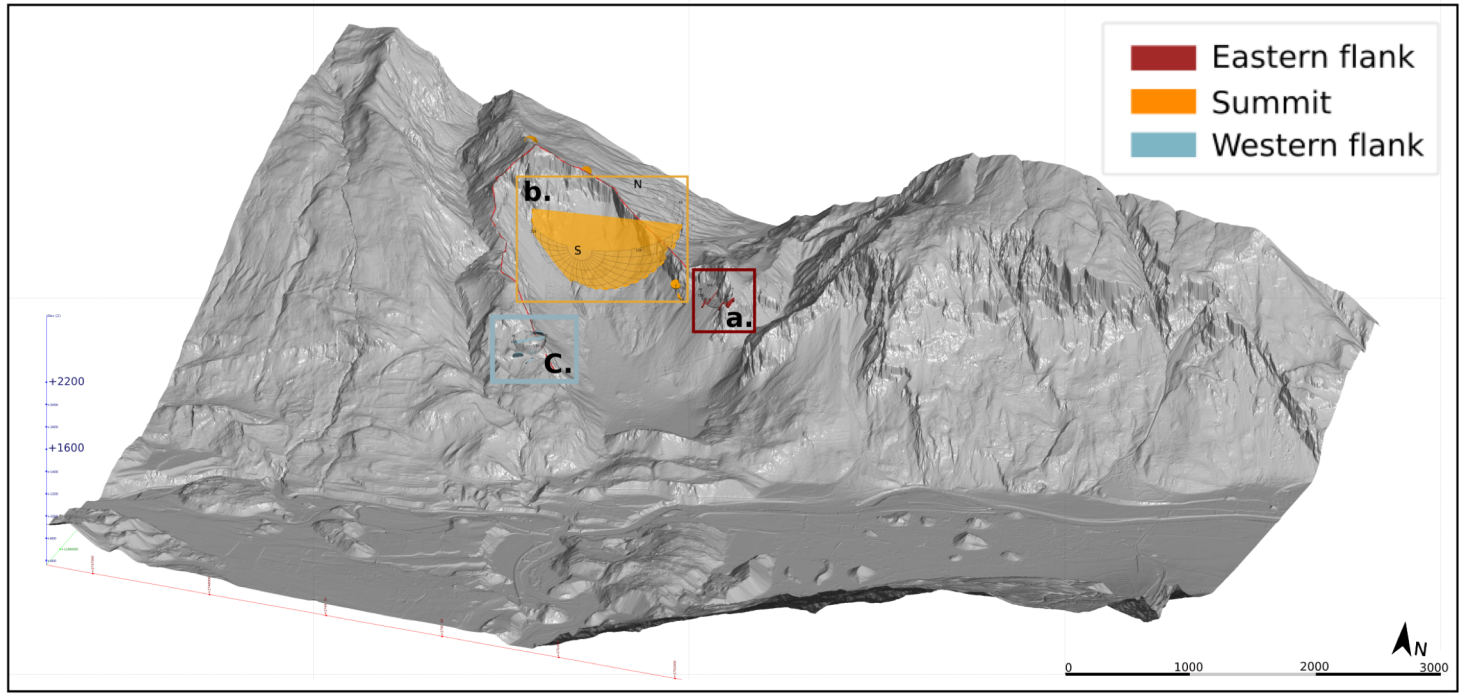
→ Direction of the slide

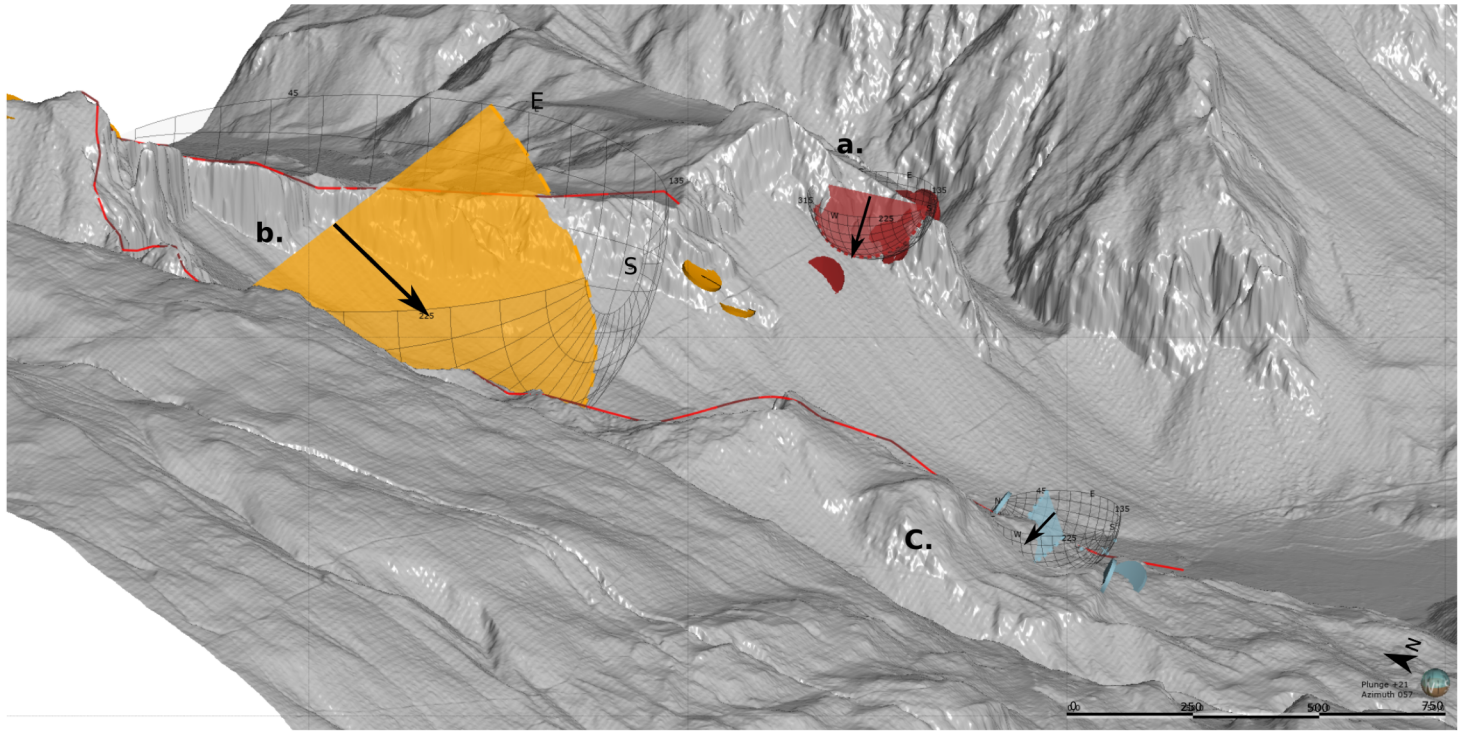
- The Tamins rockslide

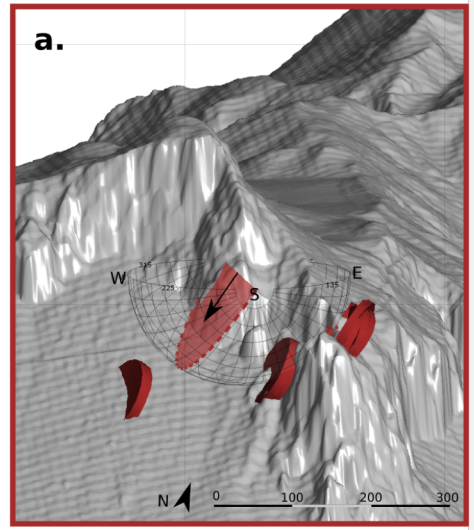
→ Bedding

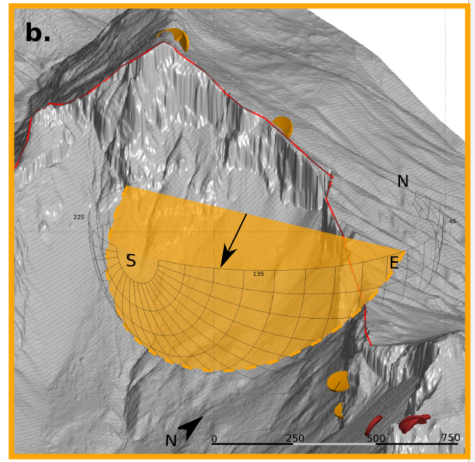
- (a) Eastern flank: W
- (b) Summit: S
- (c) Western flank: NW

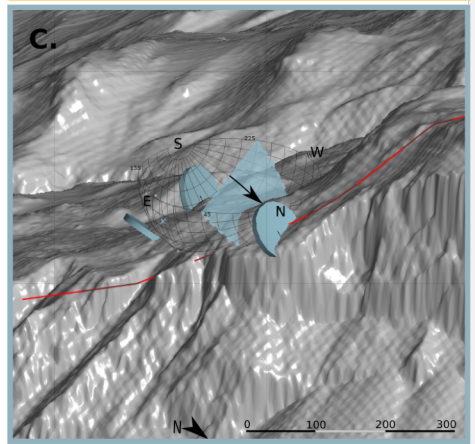








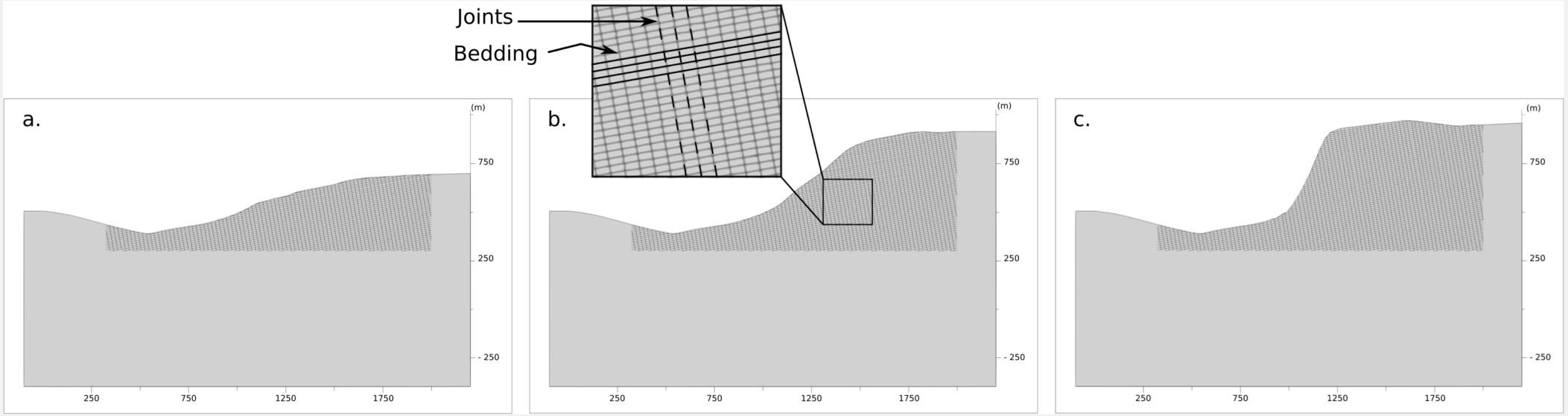




2D NUMERICAL MODELLING OF STATIC AND DYNAMIC DEFORMATION

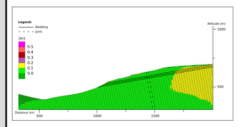
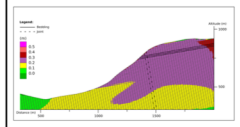
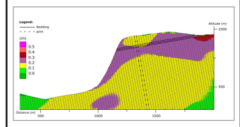
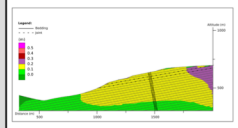
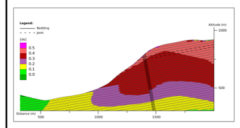
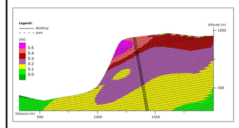
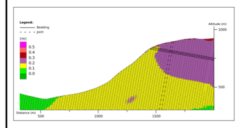
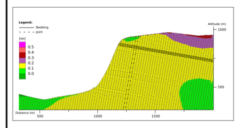
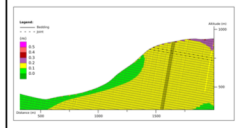
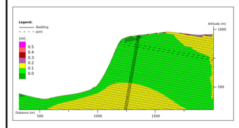
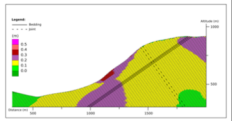
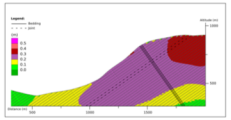
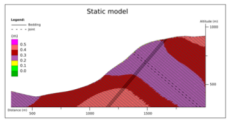
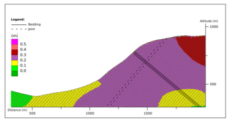
Slope	Φ bfricr/jfricr (°)	Cohesion bcohr/jcohr (kPa)
Gentle ~15°	30 20/25	100 0/50
Medium = Balta ~ 35°	35 25/30	200 100/150
Steep ~70°	45 35/40	1000 300/500

Slope	Bedding dip (°) variants	Joint dip (°) variants
Gentle ~15°	10 / -80	-80 / 10
Medium = Balta ~ 35°	10/-10/ 80/ -80/ 35 / -40 / 50 / -55	-80 / 80 / -10 / 10 -55 / 50 / -40 / 35
Steep ~70°	10 / -10 / 80 / -80	-80 / 80 / -10 / 10



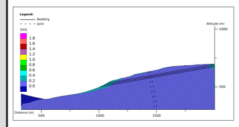
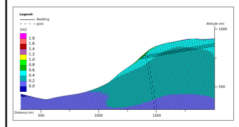
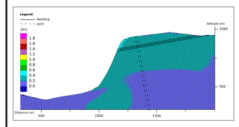
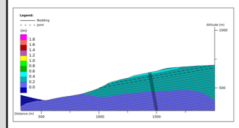
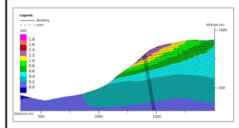
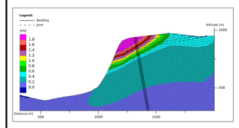
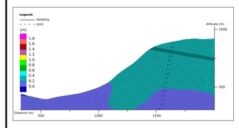
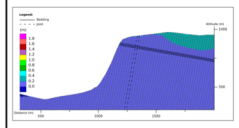
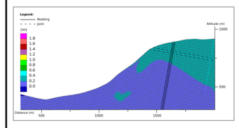
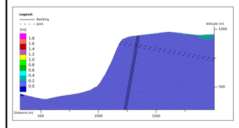
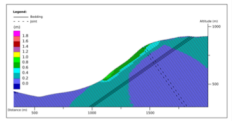
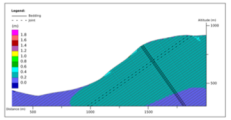
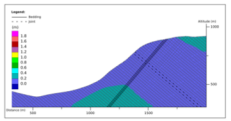
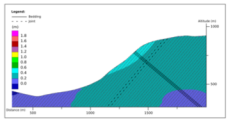
2D NUMERICAL MODELLING OF STATIC AND DYNAMIC DEFORMATION

STATIC MODELS

	Gentle slope	Middle slope	Steep slope
Structure 1: b= 10° dip j= 80° anti-dip			
Structure 2: b= 80° anti-dip j= 10° dip			
Structure 3: b= 10° anti-dip j= 80° dip	Not studied		
Structure 4: b= 80° dip j= 10° anti-dip	Not studied		
Structure 5: b= 35° dip j= 55° anti-dip	Not studied		Not studied
Structure 6: b= 55° anti-dip j= 35° dip	Not studied		Not studied
Structure 7: b= 50° dip j= 40° anti-dip	Not studied		Not studied
Structure 8: b= 40° anti-dip j= 50° dip	Not studied		Not studied

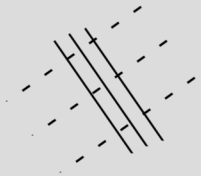
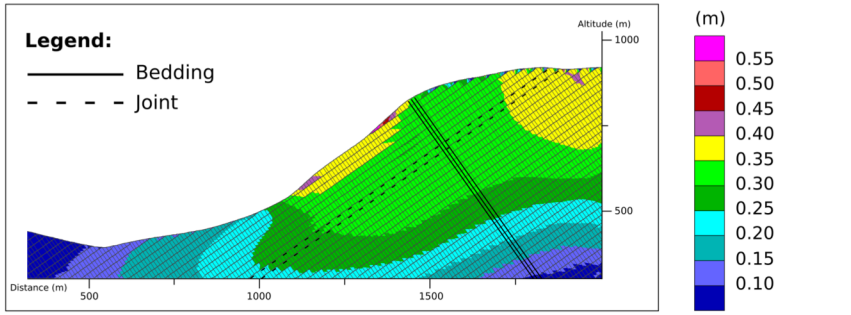
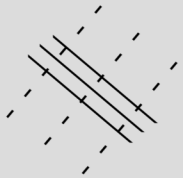
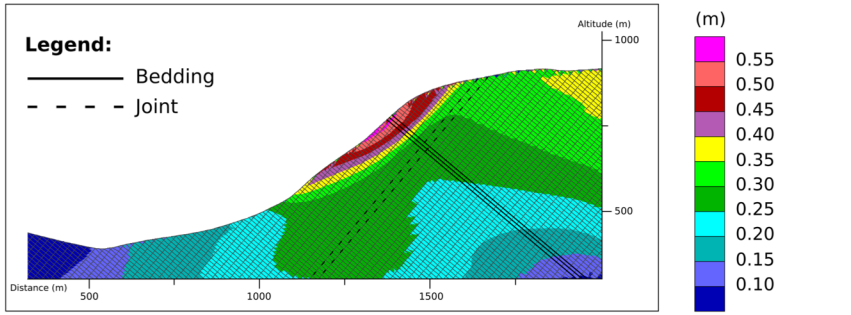
Legend:
Bedding
Joint
(m)
0.5
0.4
0.3
0.2
0.1
0.0

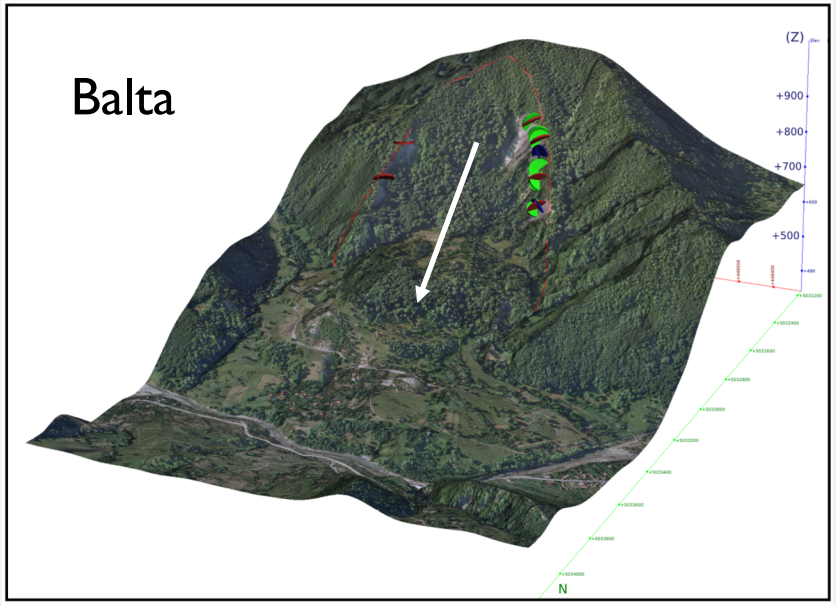
DYNAMIC MODELS

	Gentle slope	Middle slope	Steep slope
Structure 1: b= 10° dip j= 80° anti-dip			
Structure 2: b= 80° anti-dip j= 10° dip			
Structure 3: b= 10° anti-dip j= 80° dip	Not studied		
Structure 4: b= 80° dip j= 10° anti-dip	Not studied		
Structure 5: b= 35° dip j= 55° anti-dip	Not studied		Not studied
Structure 6: b= 55° anti-dip j= 35° dip	Not studied		Not studied
Structure 7: b= 50° dip j= 40° anti-dip	Not studied		Not studied
Structure 8: b= 40° anti-dip j= 50° dip	Not studied		Not studied

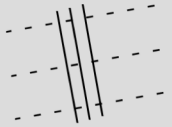
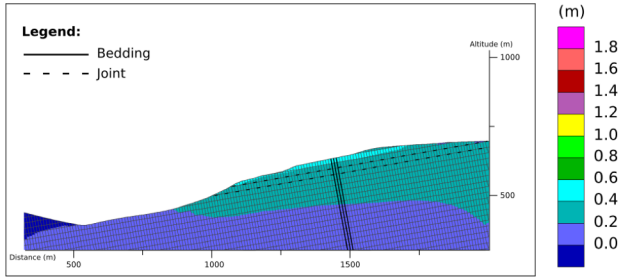
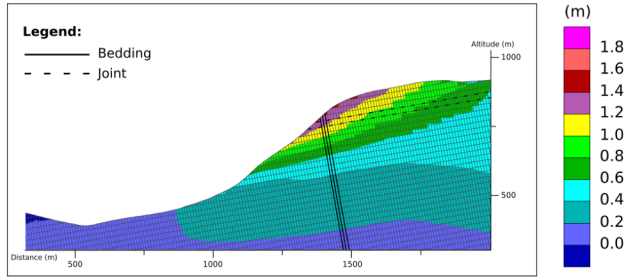
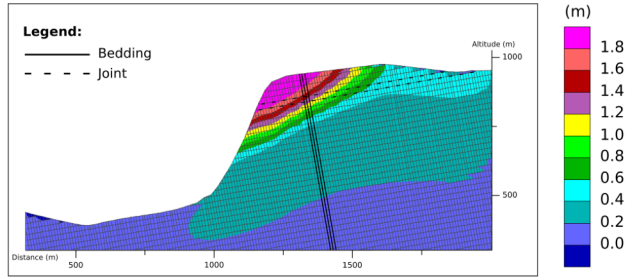
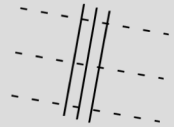
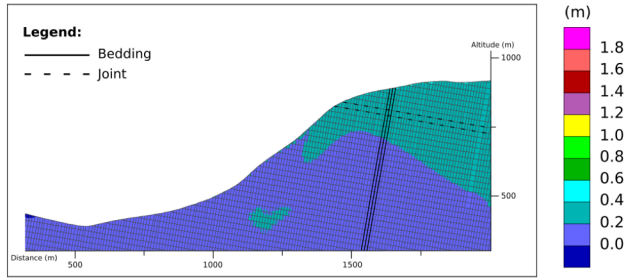
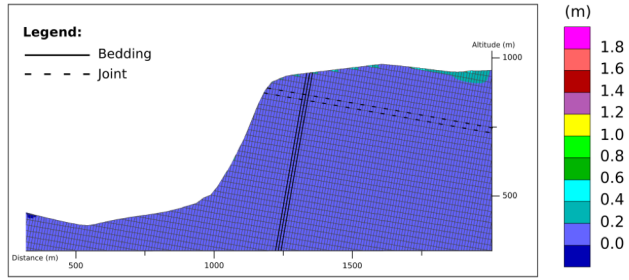
Legend:
Bedding
Joint
(m)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0

2D NUMERICAL MODELLING OF STATIC AND DYNAMIC DEFORMATION

	Medium slope (Dynamic models)
Rock material	φ= 35°
	coh= 0.20 MPa
Joints	φ= 35° --> φres= 30°
	coh= 0.20 MPa --> cohres= 0.15 MPa
Bedding	φ= 35° --> φres= 25°
	coh= 0.20 MPa --> cohres= 0.10 MPa
Structure 6: b= 55° anti-dip j= 35° dip 	 *Dynamic displacements (0-0.55 m)*
Structure 8: b= 40° anti-dip j= 50° dip 	 *Dynamic displacements (0-0.55 m)*



2D NUMERICAL MODELLING OF STATIC AND DYNAMIC DEFORMATION

	Dynamic models		
	Gentle slope	Medium slope	Steep slope
Rock material	φ= 30° coh= 0.10 MPa	φ= 35° coh= 0.20 MPa	φ= 45° coh= 1.0 MPa
Joints	φ= 30° --> φres= 25° coh= 0.10 MPa --> cohres= 0.05 MPa	φ= 35° --> φres= 30° coh= 0.20 MPa --> cohres= 0.15 MPa	φ= 45° --> φres= 40° coh= 1.0 MPa --> cohres= 0.50 MPa
Bedding	φ= 30° --> φres= 20° coh= 0.10 MPa --> cohres= 0.00 MPa	φ= 35° --> φres= 25° coh= 0.20 MPa --> cohres= 0.10 MPa	φ= 45° --> φres= 35° coh= 1.0 MPa --> cohres= 0.30 MPa
Structure 2: b= 80° anti-dip j= 10° dip 	 *Dynamic displacements (0-0.4 m)*	 *Dynamic displacements (0-1.4 m)*	 *Dynamic displacements (0-1.8 m)*
Structure 4: b= 80° dip j= 10° anti-dip 	Not studied	 *Dynamic displacements (0-0.2 m)*	 *Dynamic displacements (0-0.2 m)*

CONCLUSIONS

- Some rock structures can have a **strong influence** on **slope stability** and may be more or less susceptible to seismically induced failures.

- The **Balta rockslide** in Romania, is the prime example of ancient massive slope failure, which **origin is unknown** but for which a **seismic origin is very likely .**

- For the **Tamins rockslide** source zone, a mixed situation was found, so with an origin that is the closest to the glacier retreat and related **debuttressing effects**, **a possible seismic influence** cannot be easily proved.

- **Static and dynamic numerical 2D models** confirm that the **medium slope** case with **anti-dip slope bedding** structure (closest to the 'Balta model') is **stable** after gravitational loading and **only minor deformation** occurs for the applied seismic load (~0.4g).

- The **most unstable** rock structure surprisingly appeared to be the one with an **80° anti-dip slope bedding** orientation.

THANK YOU FOR YOUR ATTENTION