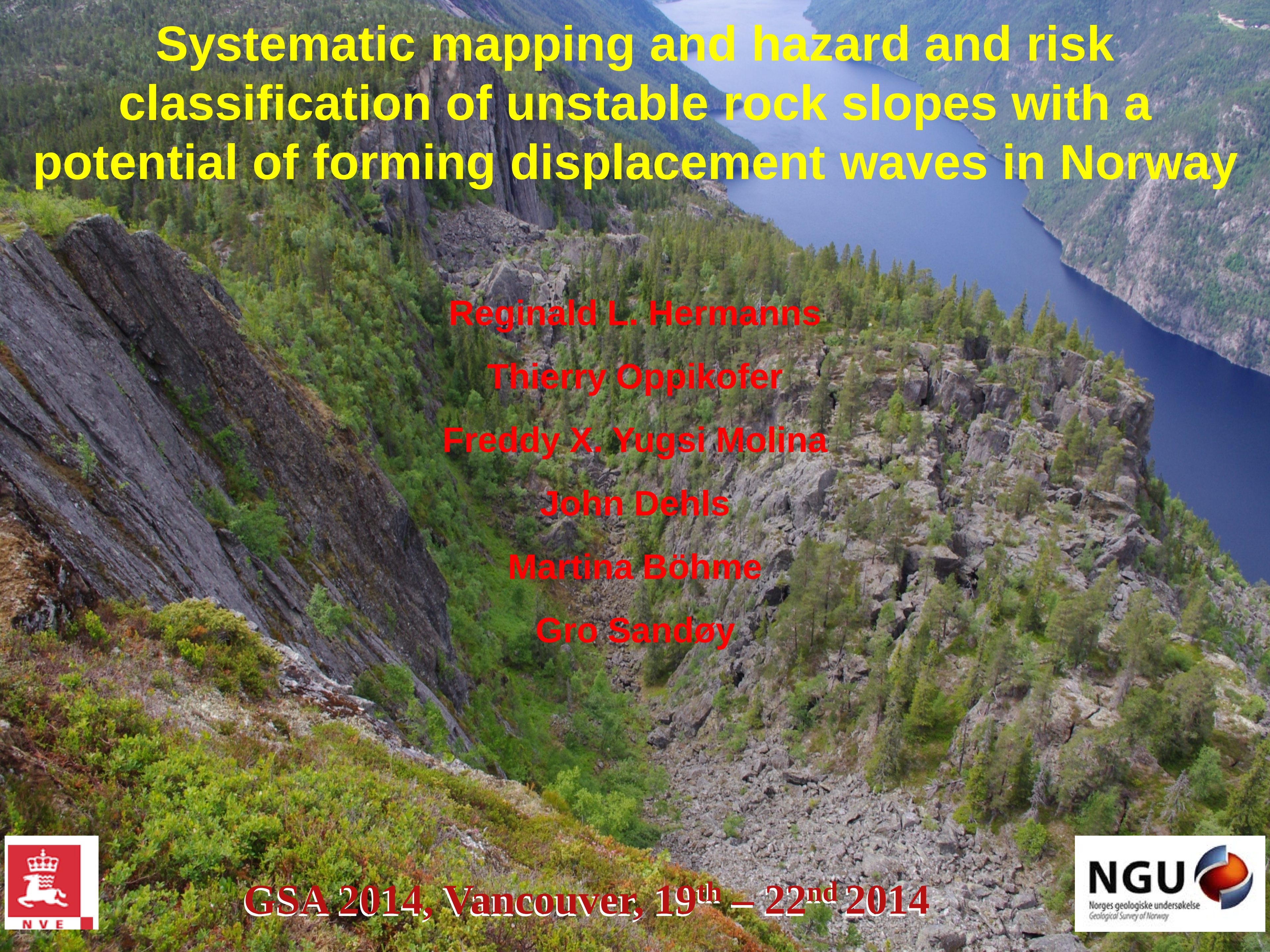
Systematic mapping and hazard and risk classification of unstable rock slopes with a potential of forming displacement waves in Norway



Reginald L. Hermanns

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NVE

GSA 2014, Vancouver, 19th – 22nd 2014

NGU Norges geologiske undersøkelse Geological Survey of Norway

Content

- Historic rock slope failures in Norway triggering displacement waves
- Hazard and risk classification
- Mapping methodology for unstable rock slopes


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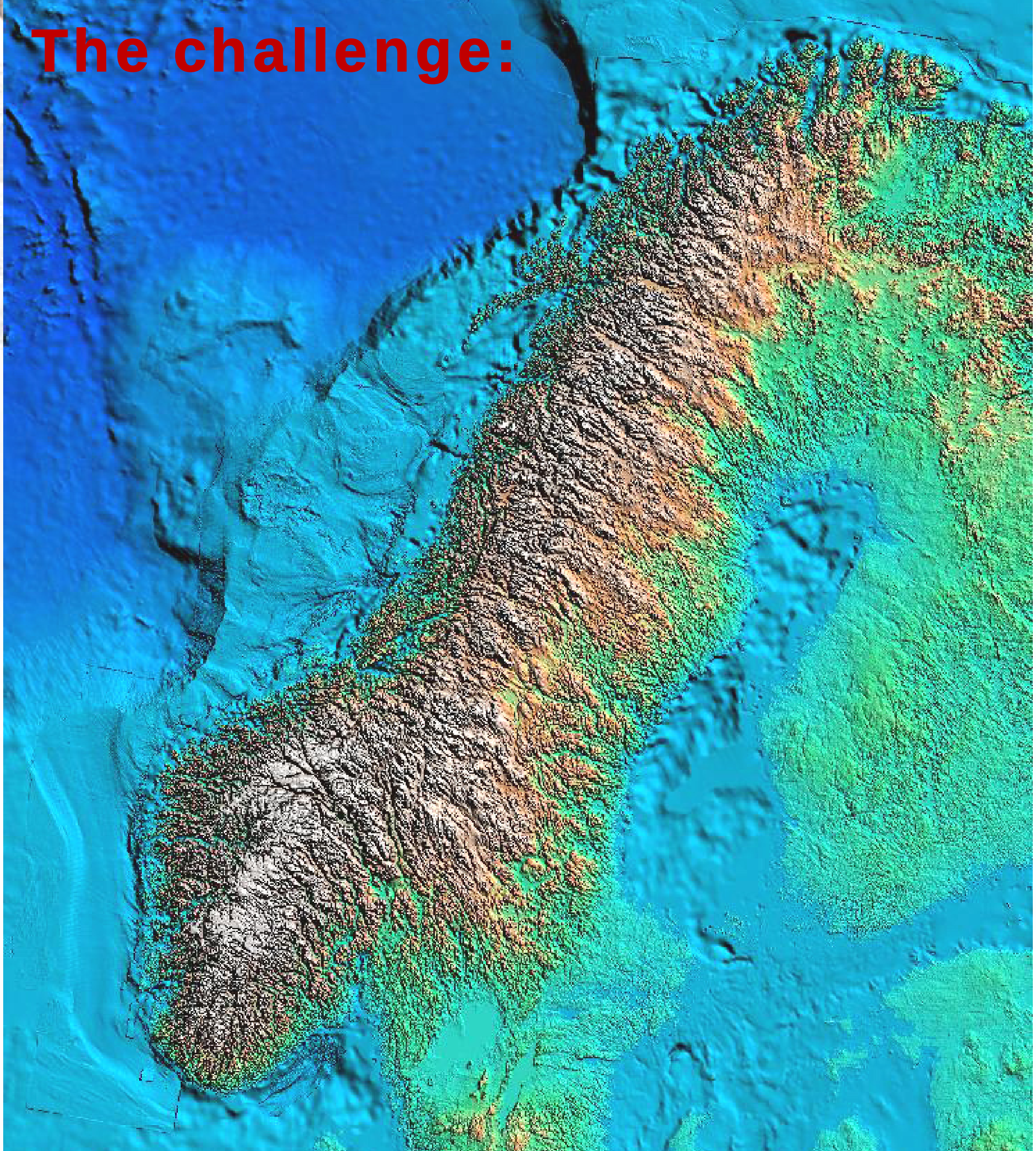
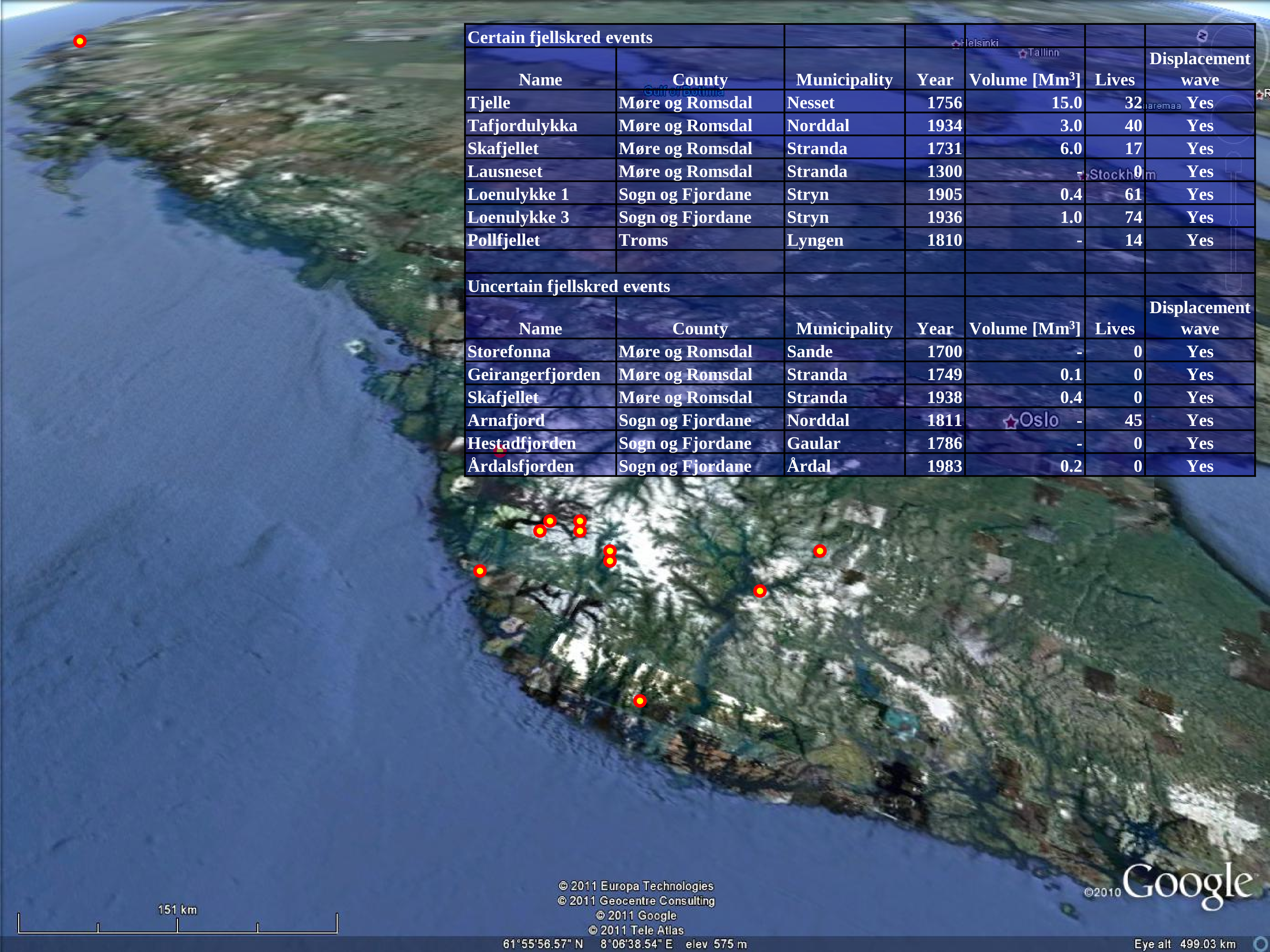
The challenge:



Norway

- 68. largest country on earth
- 7. longest coast line
- coast line > 100.000 km long + lakes

Historic rockslide disasters in Norway



Certain fjellskred events						
Name	County	Municipality	Year	Volume [Mm^3]	Lives	Displacement wave
Tjelle	Møre og Romsdal	Nesset	1756	15.0	32	Yes
Tafjordulykka	Møre og Romsdal	Norddal	1934	3.0	40	Yes
Skafjellet	Møre og Romsdal	Stranda	1731	6.0	17	Yes
Lausneset	Møre og Romsdal	Stranda	1300	-	0	Yes
Loenulykke 1	Sogn og Fjordane	Stryn	1905	0.4	61	Yes
Loenulykke 3	Sogn og Fjordane	Stryn	1936	1.0	74	Yes
Pollfjellet	Troms	Lyngen	1810	-	14	Yes

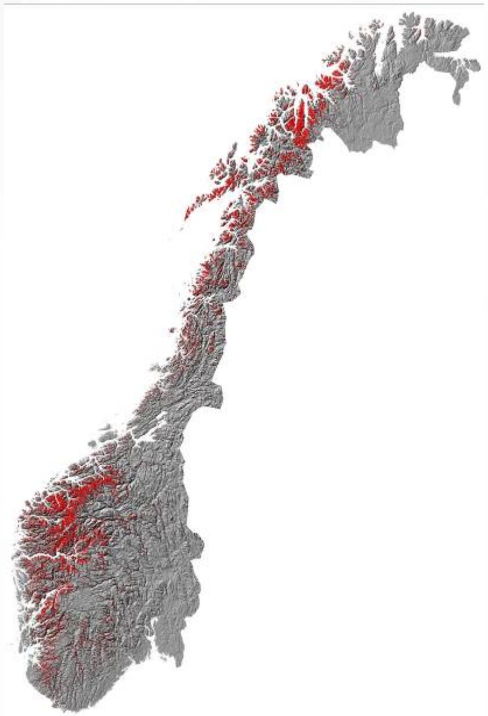
Uncertain fjellskred events						
Name	County	Municipality	Year	Volume [Mm^3]	Lives	Displacement wave
Storefonna	Møre og Romsdal	Sande	1700	-	0	Yes
Geirangerfjorden	Møre og Romsdal	Stranda	1749	0.1	0	Yes
Skafjellet	Møre og Romsdal	Stranda	1938	0.4	0	Yes
Arnafjord	Sogn og Fjordane	Norddal	1811	-	45	Yes
Hestadfjorden	Sogn og Fjordane	Gaular	1786	-	0	Yes
Årdalsfjorden	Sogn og Fjordane	Årdal	1983	0.2	0	Yes

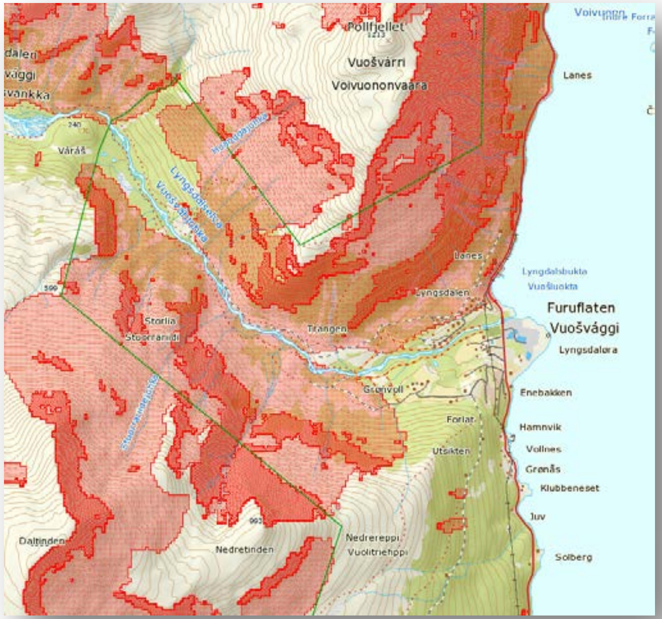
Mapping of unstable rock slopes in Norway

The vision:

- to characterize all unstable rock slopes which can course effects in a distance larger than the shadow angle of rock falls

- 0 loss of life due to large rock slope failures in the next centuries





http://www.skrednett.no/

Assumption:

- Slow deformation indicating slope instability
- Acceleration phase prior to collapse

Hazard and risk classification of unstable rock slopes

” As the likelihood of failure cannot be given quantitatively in hundreds or thousands of years with today's scientific knowledge, the risk analysis is built on a qualitative hazard analysis and a quantitative consequence analysis. ”

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(*****) Norwegian Water and Energy Directorate, Norway
(******) University of Lausanne, Switzerland
(********) ETH Zurich, Switzerland
(********) The county of Møre og Romsdal, Norway

http://www.ngu.no/upload/Publikasjoner/Rapporter/2012/**2012_029**.pdf

Hazard and risk classification of unstable rock slopes

1. Back-scarp	Score	Rel. prob.	Norm. prob.
Not developped	0	0	0.0%
Partly open over length of slide body (few cm to m)	0.5	20	20.0%
Fully open over length of slide body (few cm to m)	1	80	80.0%

2. Potential sliding structures	Score	Rel. prob.	Norm. prob.
No penetrative structures dip out of the slope	0	10	10.0%
Penetrative structures dip on average < 20 degree or steeper than the slope	0.5	80	80.0%
Penetrative structures dip on average > 20 degree and daylight with the slope	1	10	10.0%

3. Lateral release surfaces	Score	Rel. prob.	Norm. prob.
Not developped	0	0	0.0%
Partly developped on 1 side	0.25	0	0.0%
Fully developped or free slope on 1 side or partly developped on 2 sides	0.5	0	0.0%
Fully developped or free slope on 1 side and partly developped on 1 side	0.75	100	100.0%
Fully developped or free slope on 2 sides	1	0	0.0%

4. Kinematic feasibility test	Score	Rel. prob.	Norm. prob.
Kinematik feasibility test does not allow for planar, wedge sliding or toppling	0	0	0.0%
Failure is partly kinematically possible (movement direction is more than ± 30° to slope orientation)	0.5	100	100.0%
Failure is partly kinematically possible (movement direction is more than ± 30° to slope orientation)	0.75	0	0.0%
Failure is partly kinematically possible on persistent discontinuities (movement direction is more than ± 30° to slope orientati	0.75	0	0.0%
Failure is kinematically possible on persistent discontinuities (movement direction is less than ± 30° to slope orientation)	1	0	0.0%

5. Morphologic expression of the rupture surface	Score	Rel. prob.	Norm. prob.
No indication on slope morphology	0	75	75.0%
Slope morphology suggests formation of a rupture surface (bulging, concavity-convexity, springs)	0.5	25	25.0%
Continuous rupture surface is suggested by slope morphology and can be mapped out	1	0	0.0%

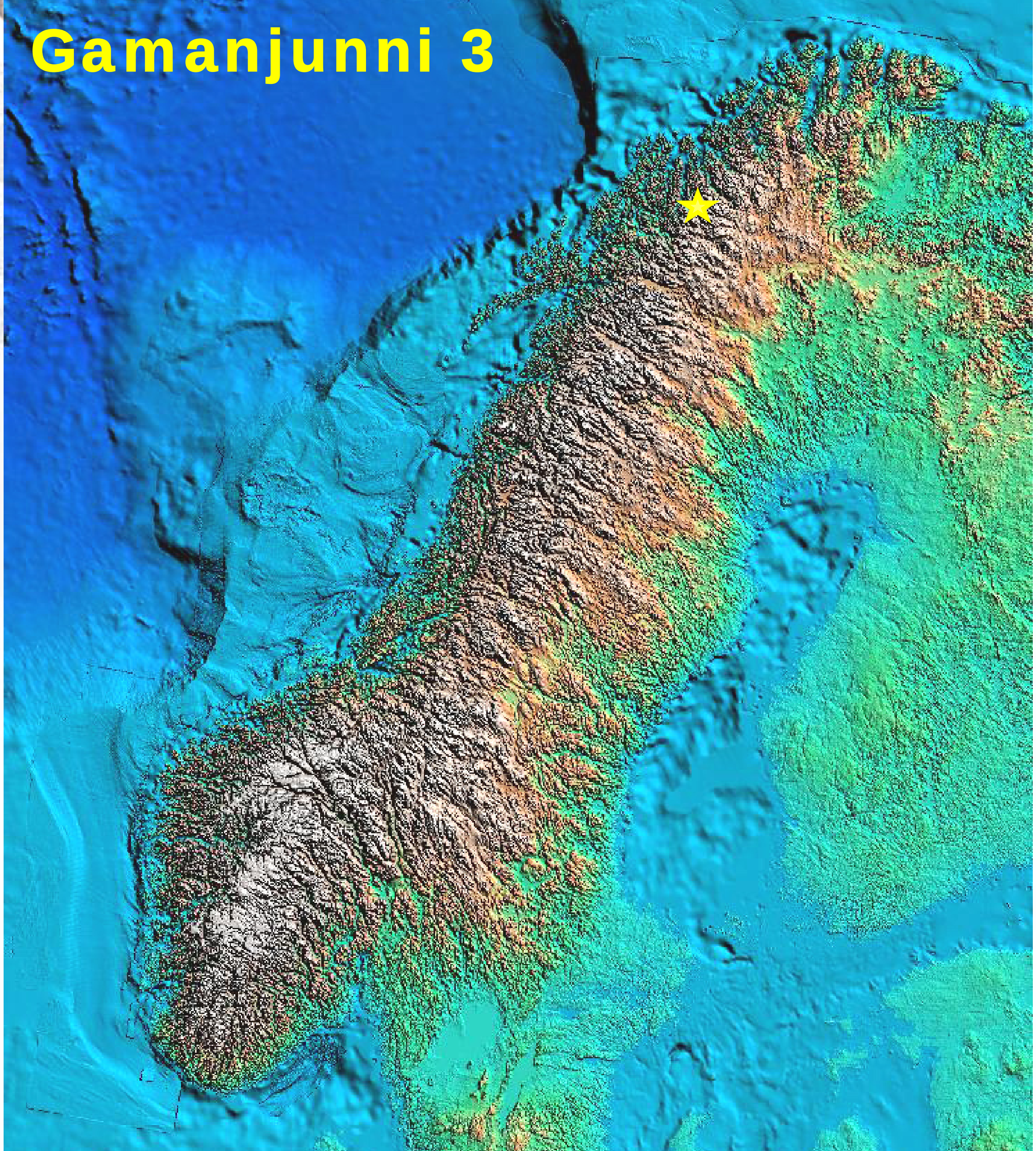
6. Displacement rates	Score	Rel. prob.	Norm. prob.
No significant movement	0	50	50.0%
0.2 - 0.5 cm/year	1	50	50.0%
0.5 - 1 cm/year	2	0	0.0%
1 - 4 cm/year	3		0.0%
4 - 10 cm/year	4		0.0%
> 10 cm/year	5	0	0.0%

7. Acceleration (if velocity is >0.5 cm/yr and <10 cm/yr)	Score	Rel. prob.	Norm. prob.
No acceleration or change in slope deformation	0	0	50.0%
Increase in slope deformation	1	0	50.0%

8. Increase of rock fall activity	Score	Rel. prob.	Norm. prob.
No increase of rock fall activity	0	75	75.0%
Increase of rock fall activity	1	25	25.0%

9. Past events	Score	Rel. prob.	Norm. prob.
No post-glacial events of similar size	0	0	0.0%
One or several events older than 5000 years of similar size	0.5	100	100.0%
One or several events younger than 5000 years of similar size	1	0	0.0%

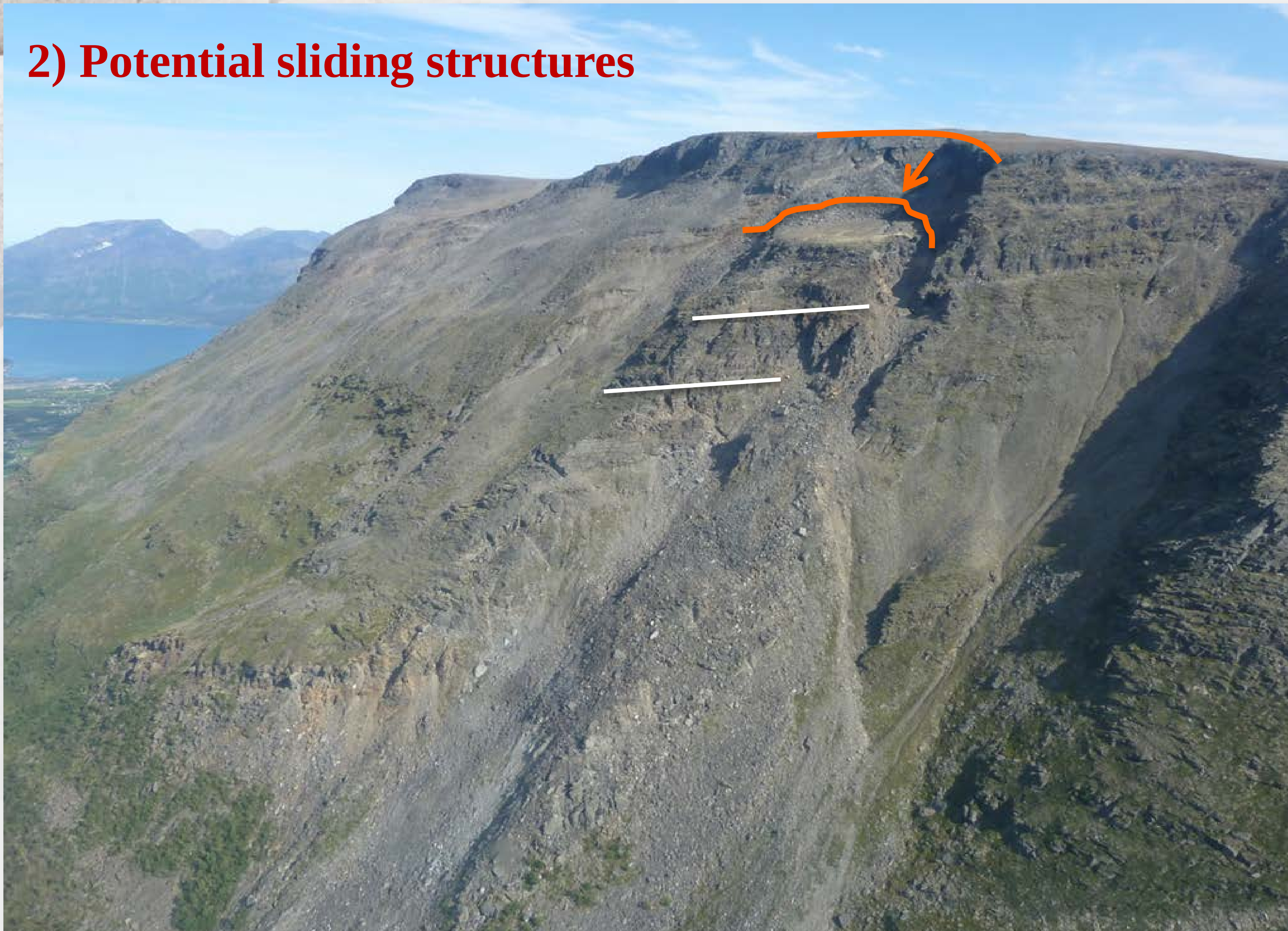
Hermanns et al. 2012, 2013


Gamanjunni 3

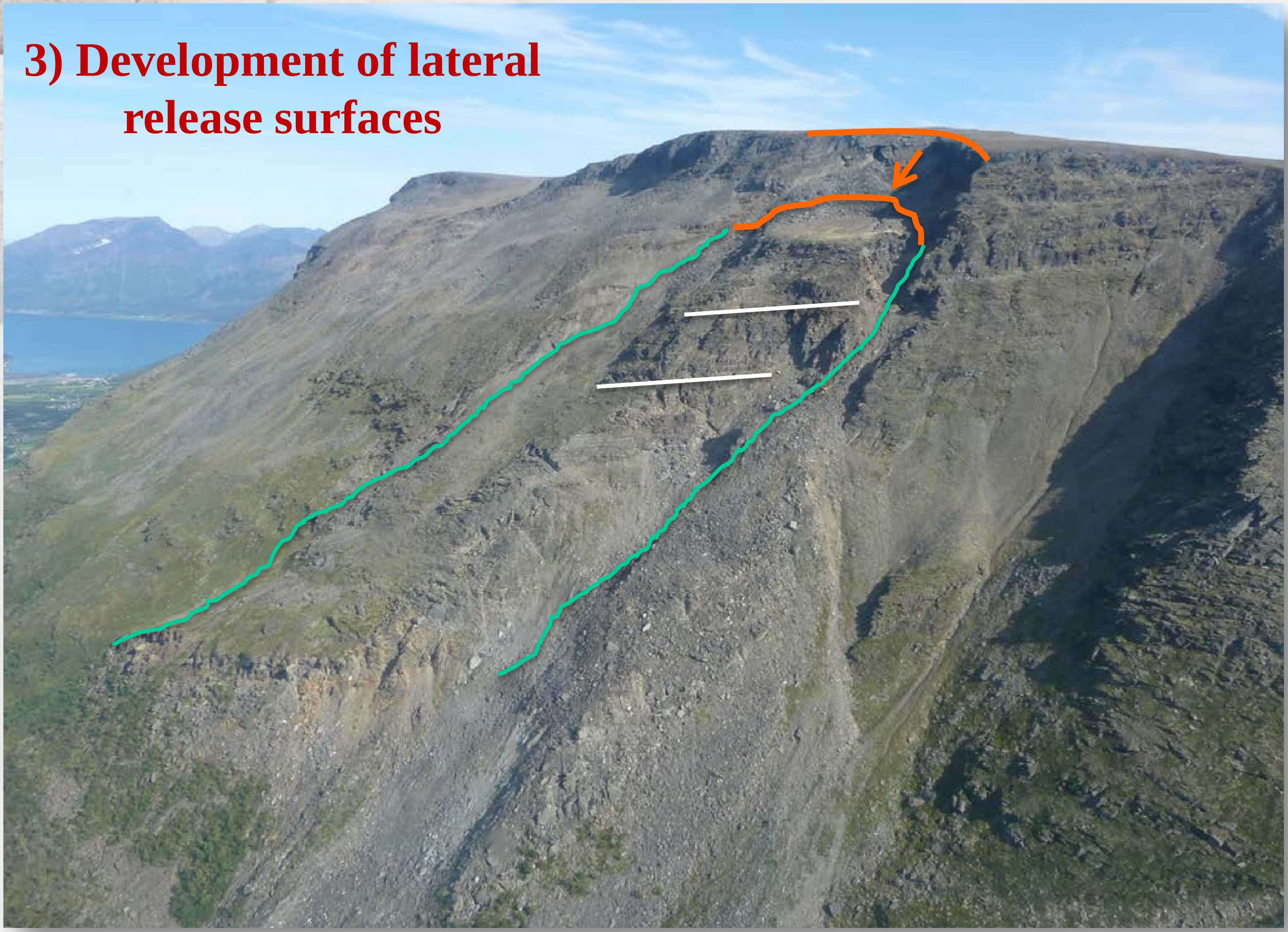
Hazard and risk classification of unstable rock slopes

Hazard and risk classification of unstable rock slopes

Hazard and risk classification of unstable rock slopes

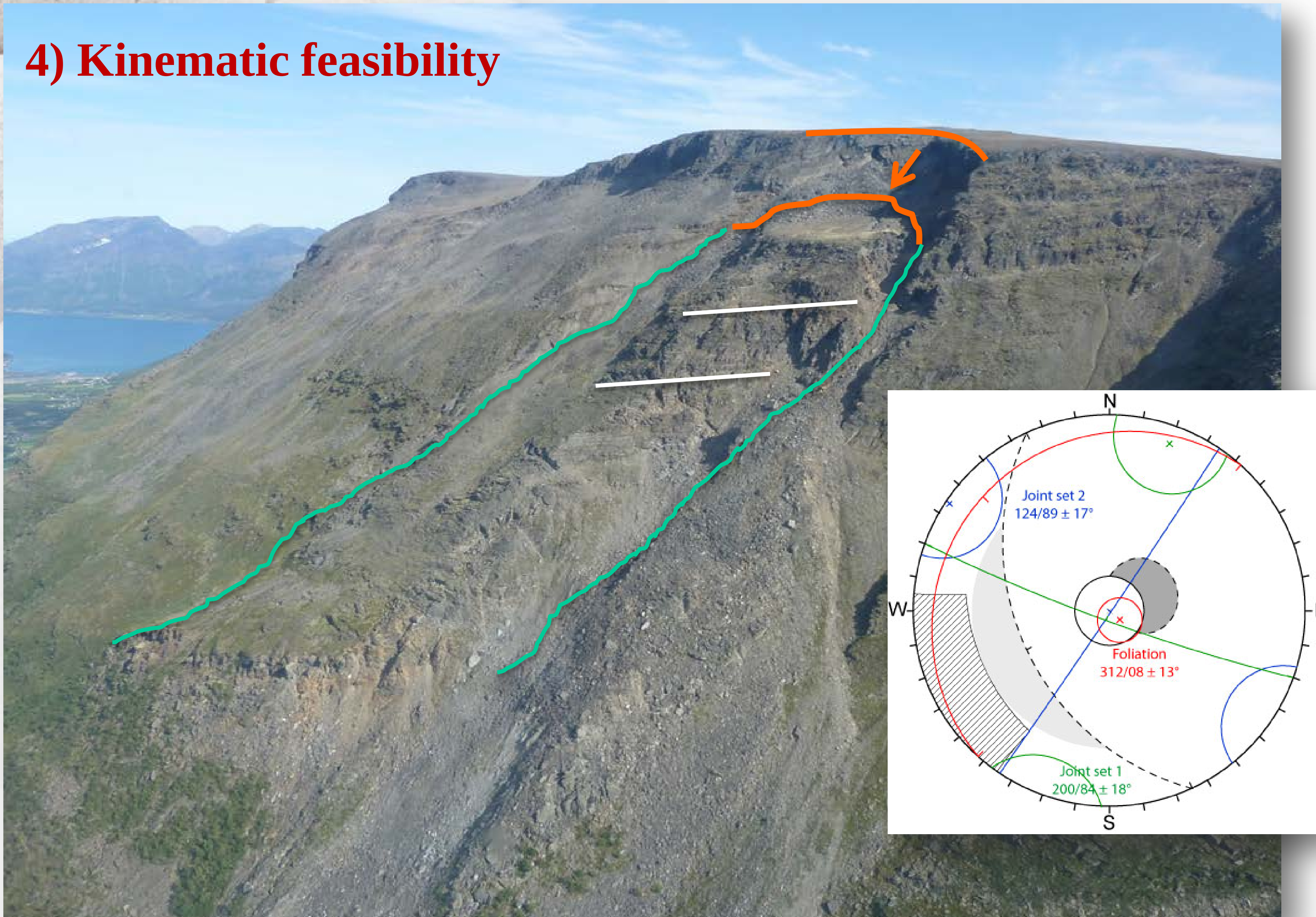


Hazard and risk classification of unstable rock slopes

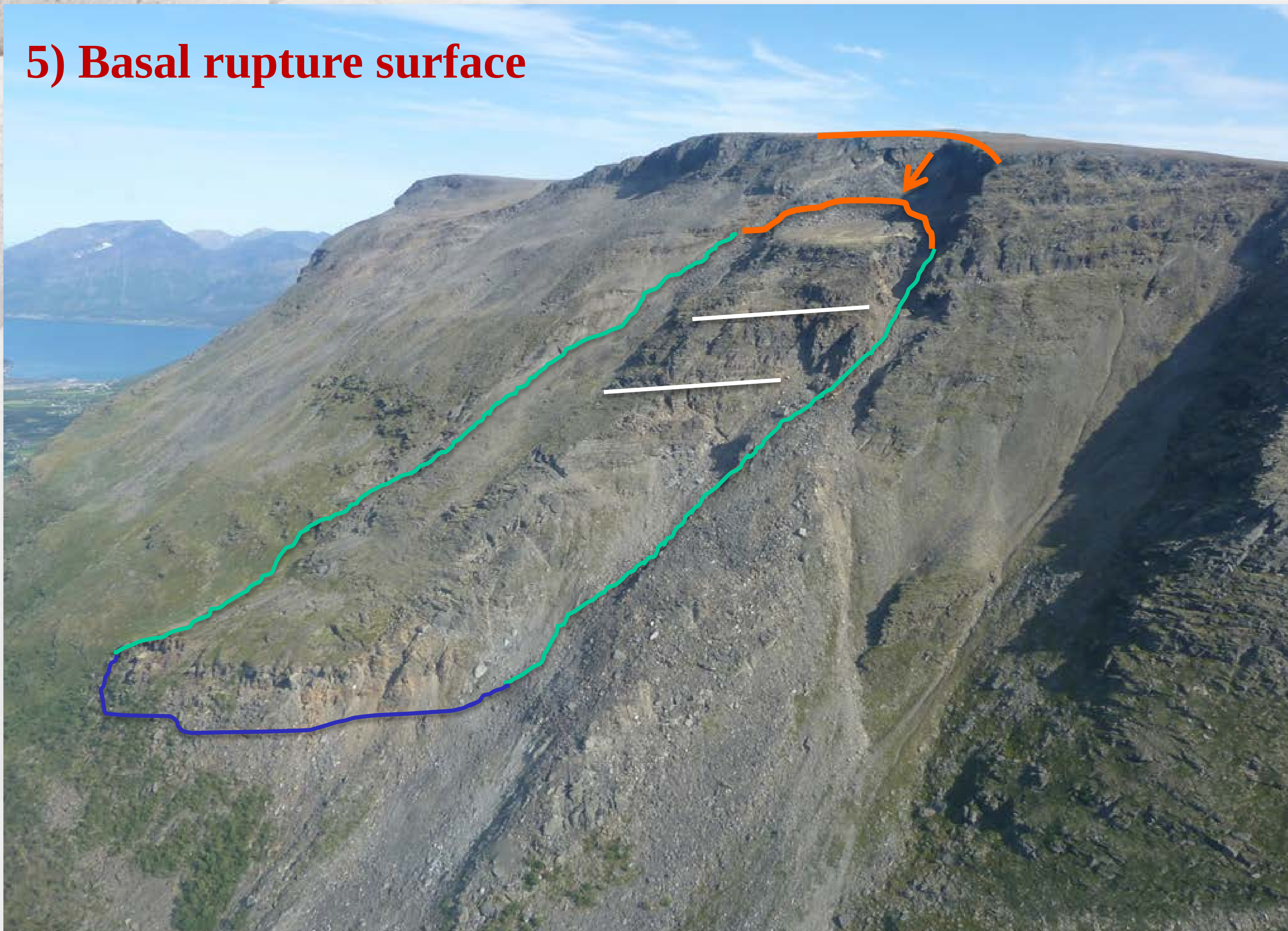


Hazard and risk classification of unstable rock slopes

4) Kinematic feasibility

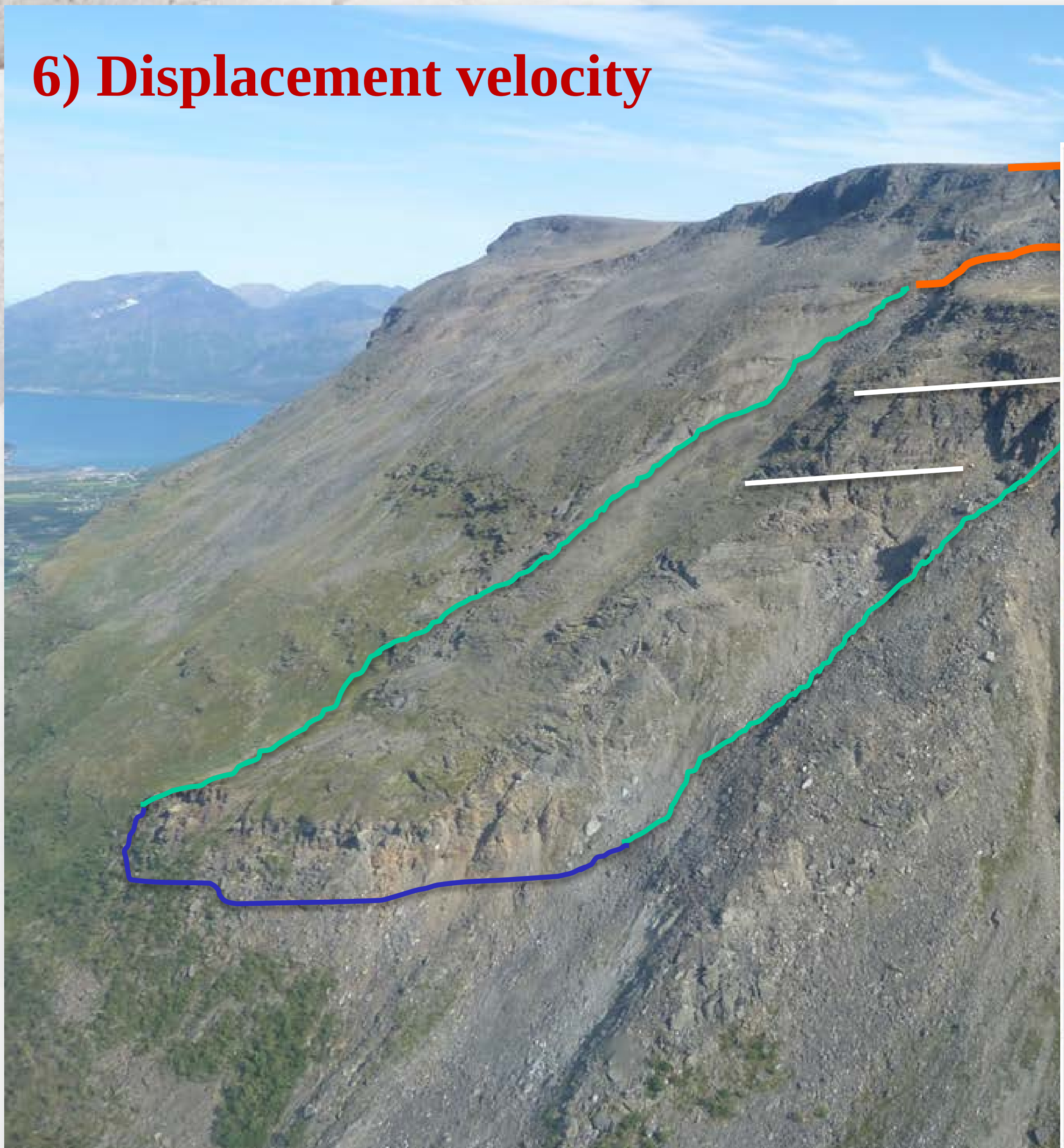


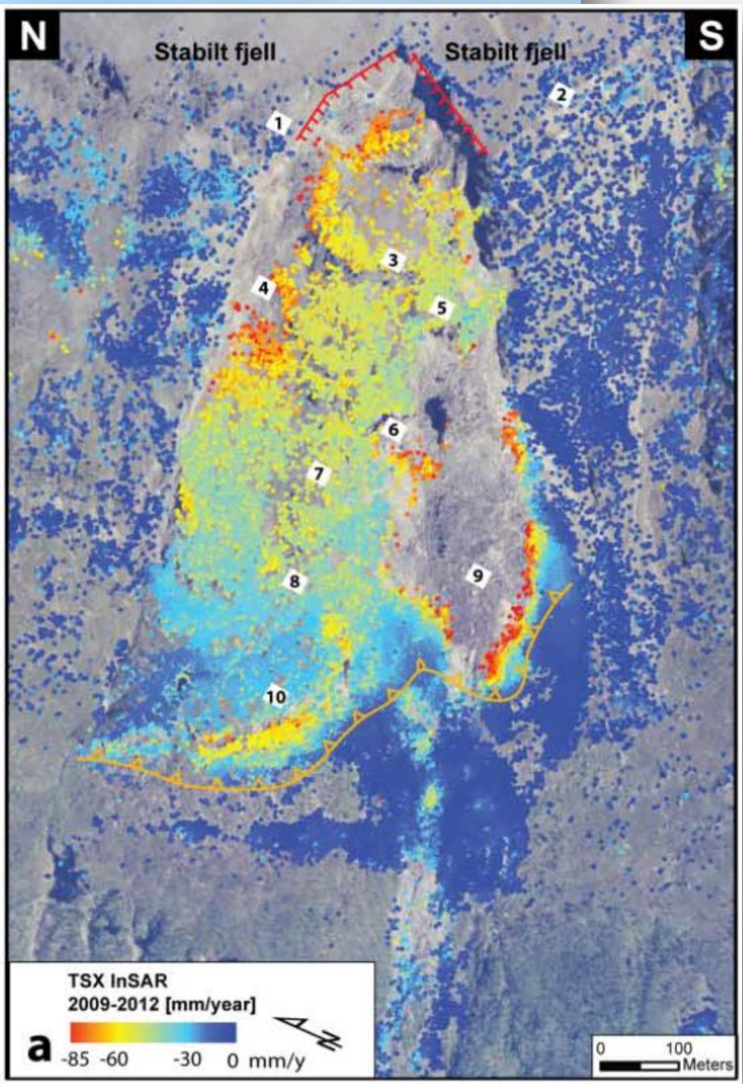
Hazard and risk classification of unstable rock slopes



Hazard and risk classification of unstable rock slopes

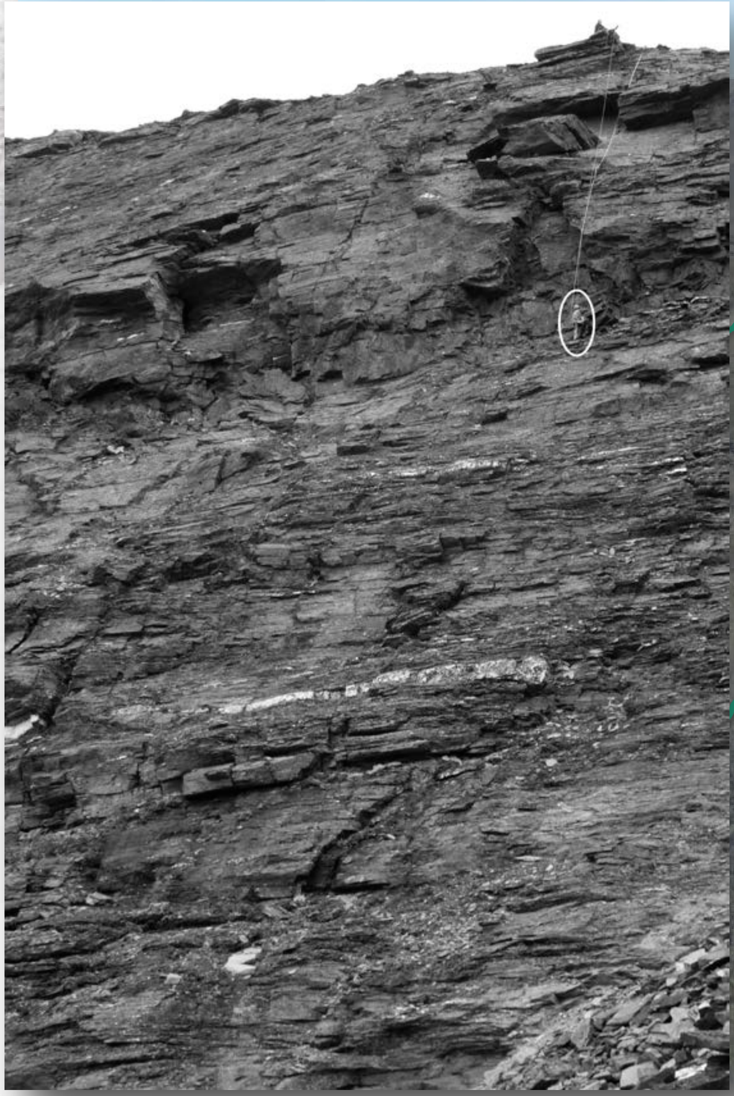
6) Displacement velocity

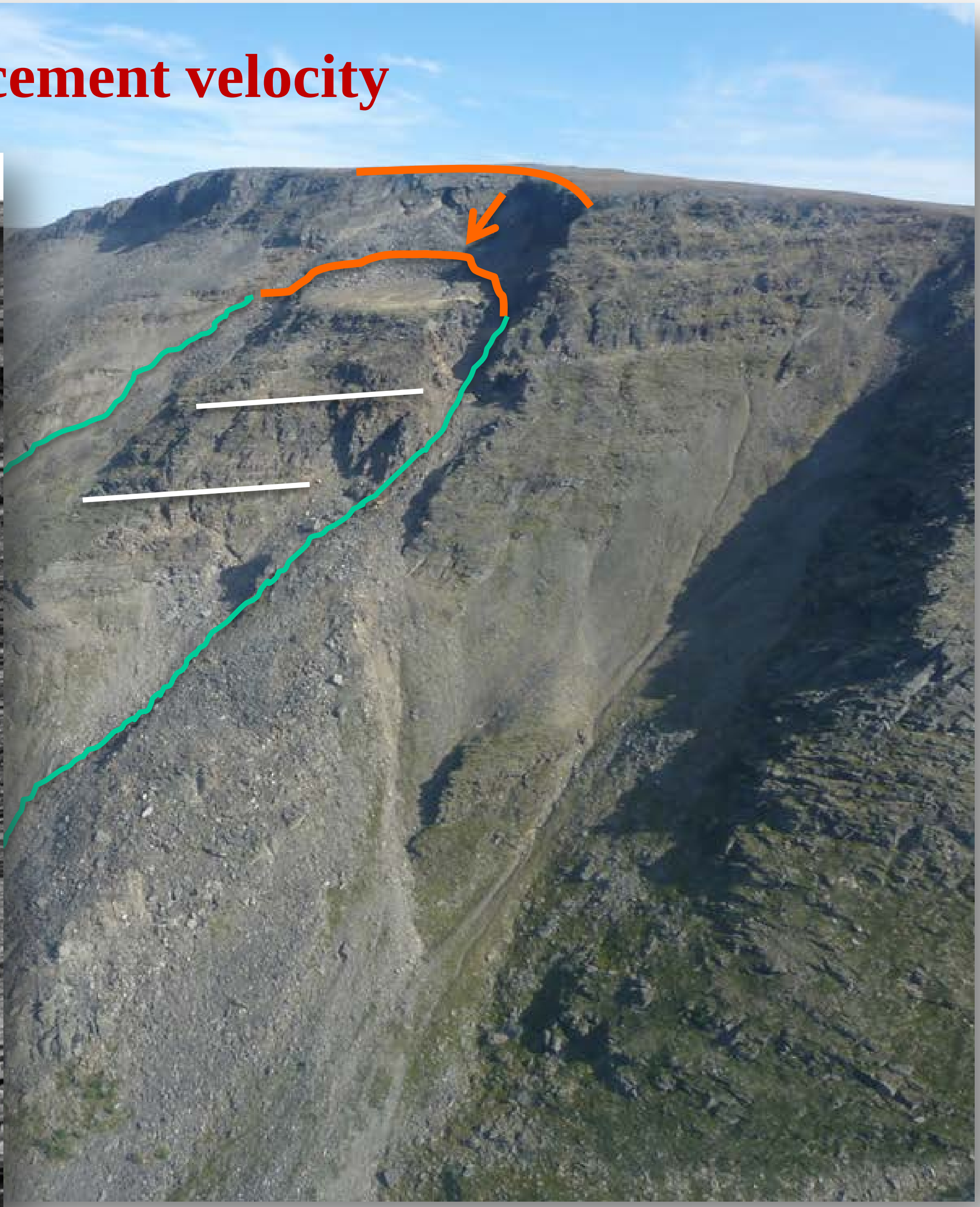




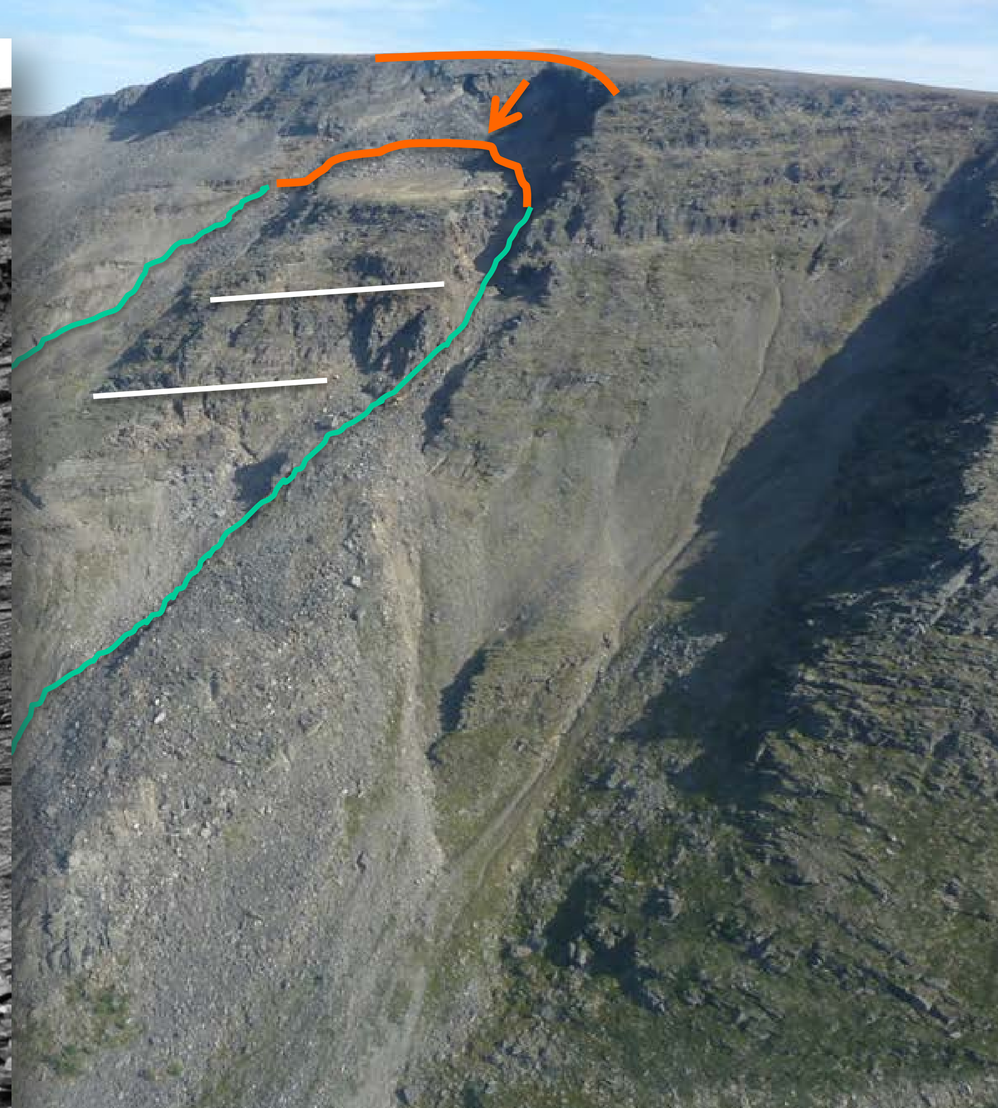
Hazard and risk classification of unstable rock slopes

7) Acceleration of displacement velocity

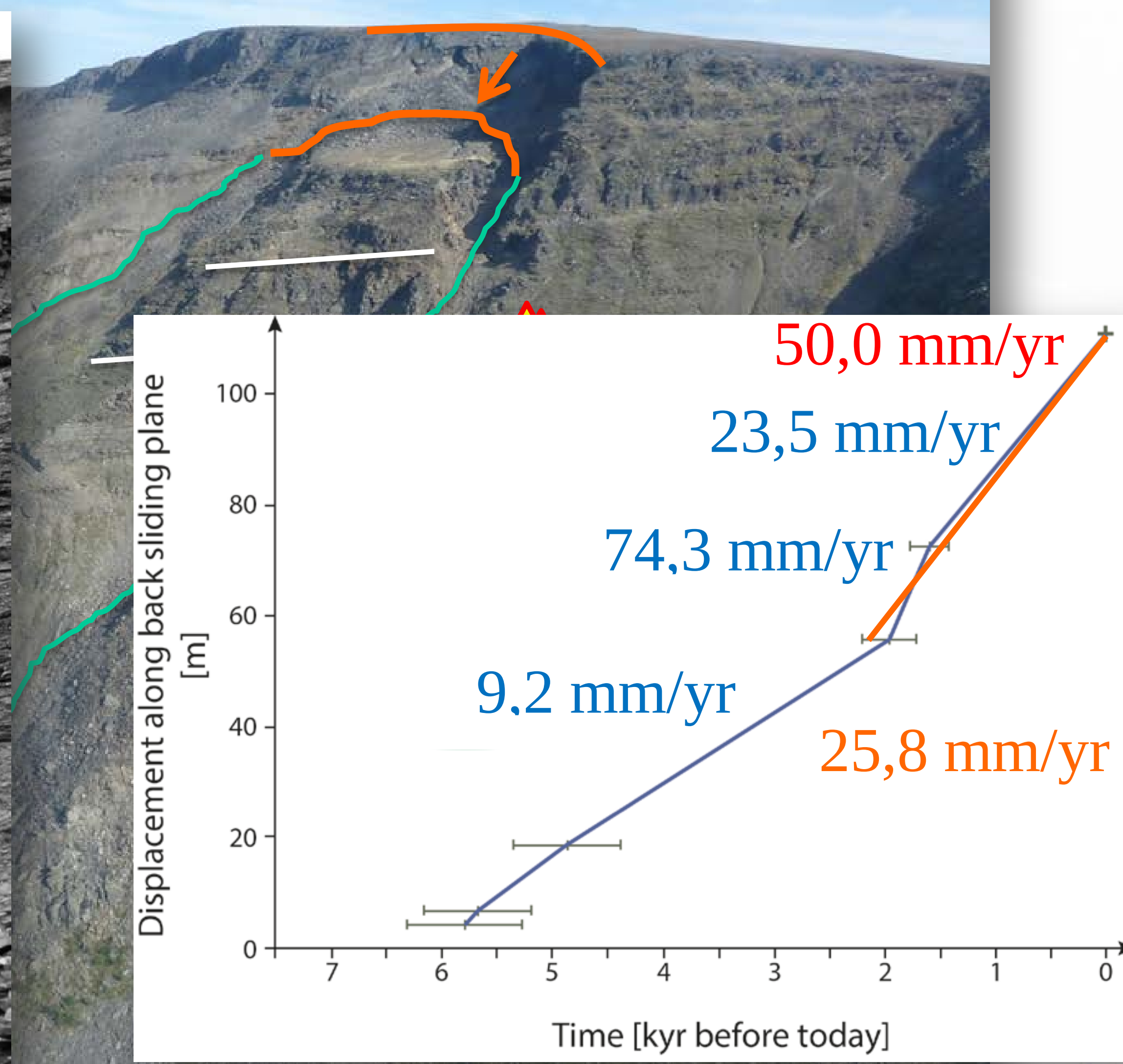




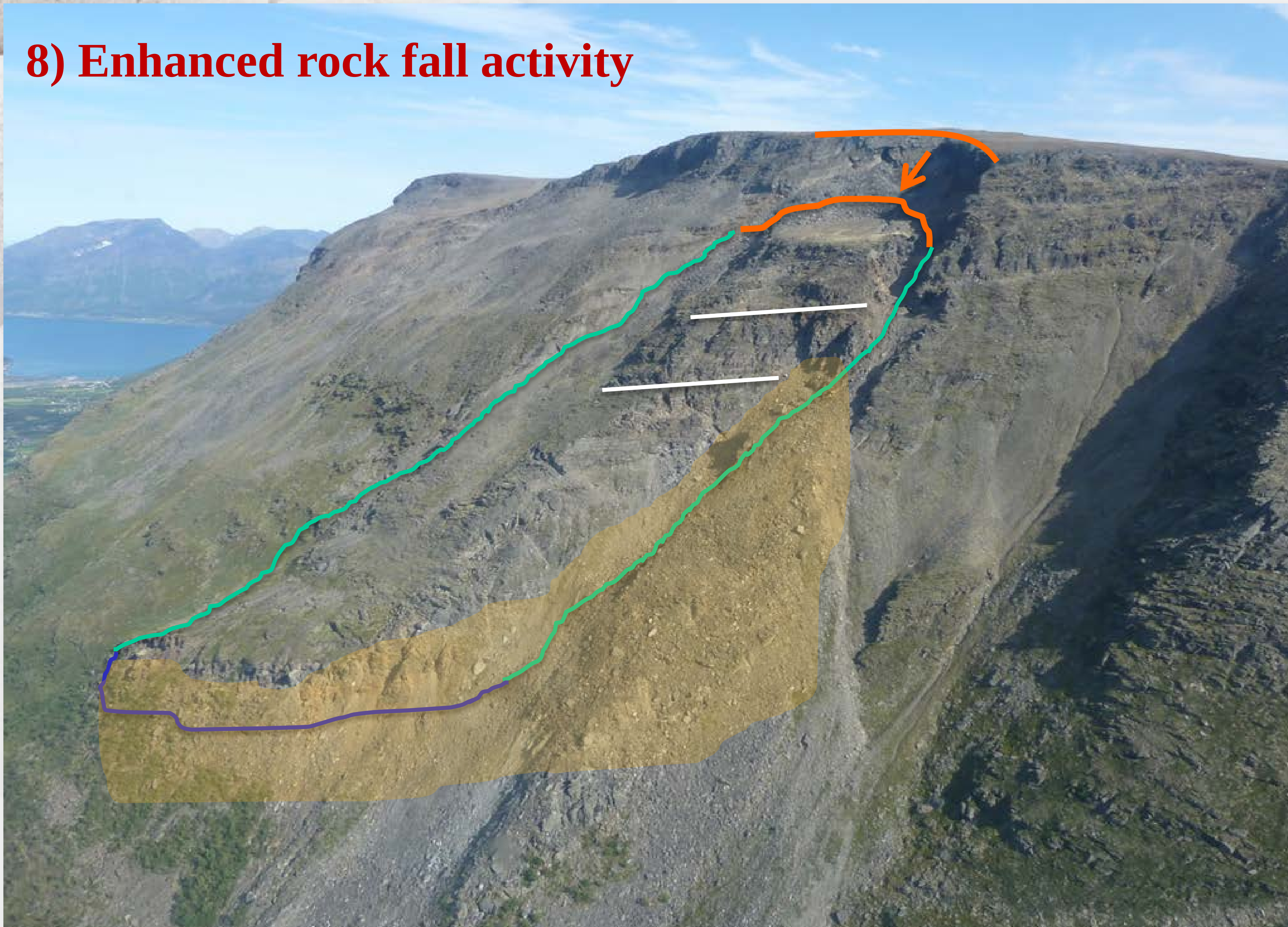
7) Acceleration of displacement velocity



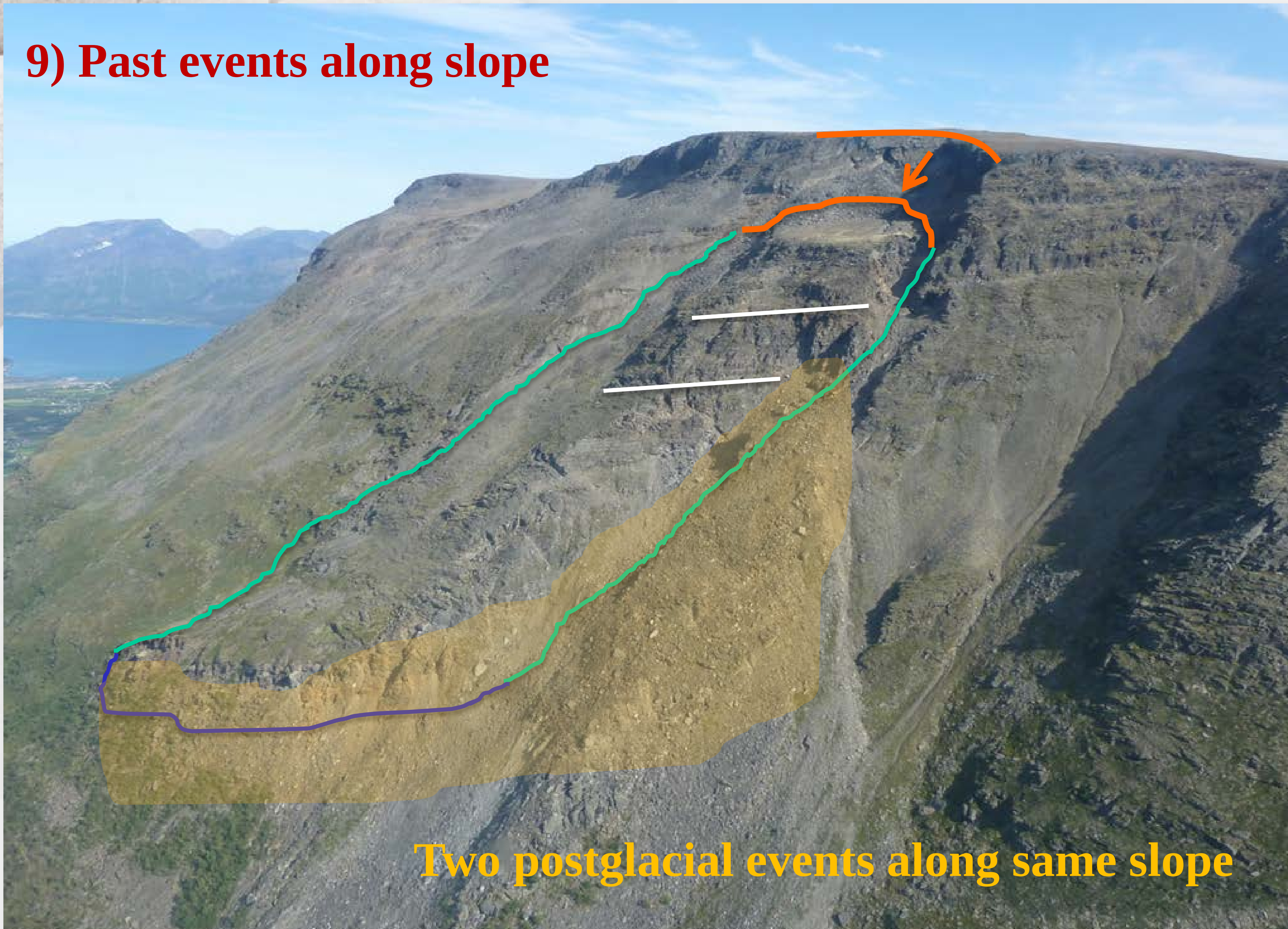
7) Acceleration of displacement velocity



Hazard and risk classification of unstable rock slopes

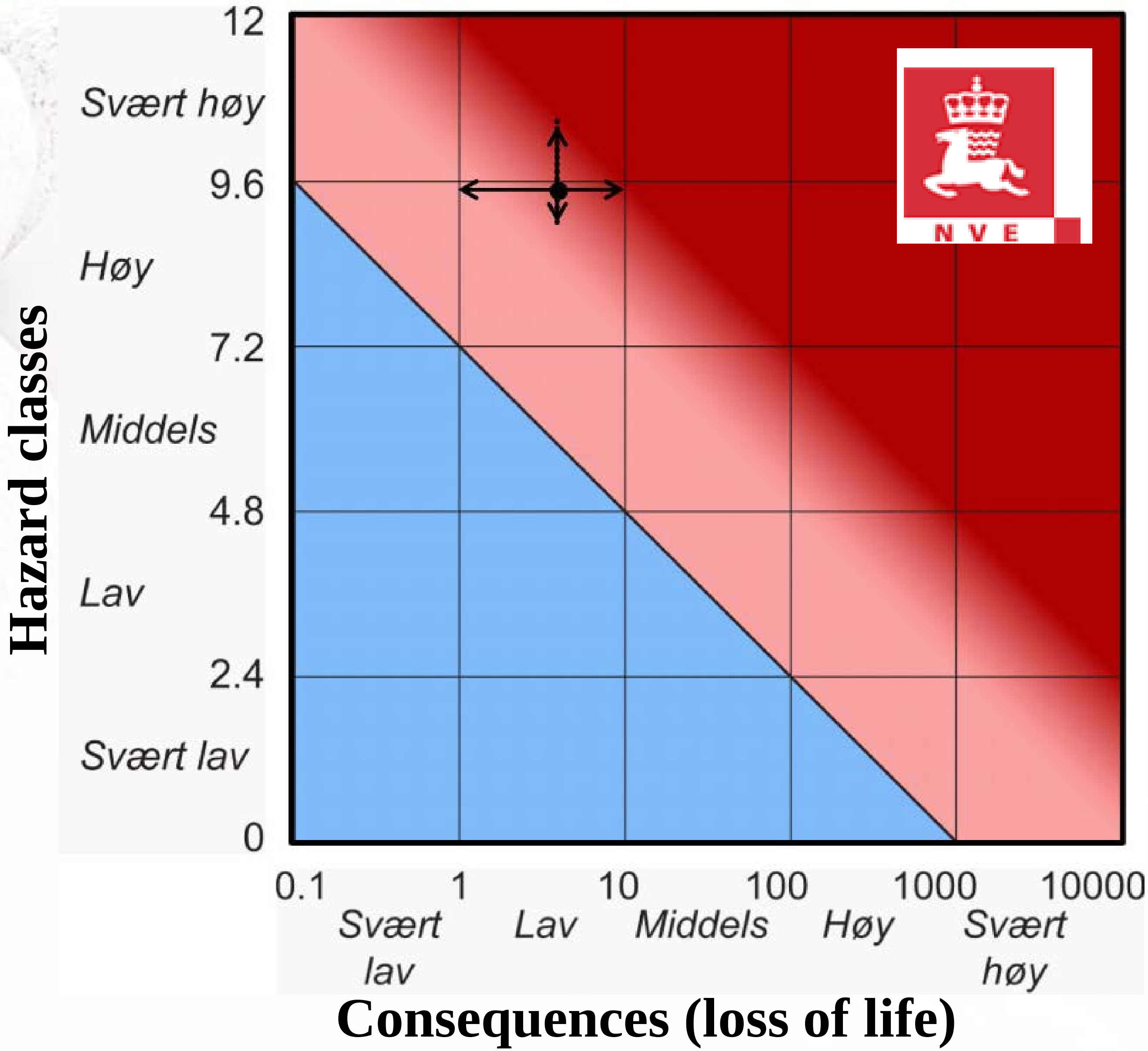


Hazard and risk classification of unstable rock slopes

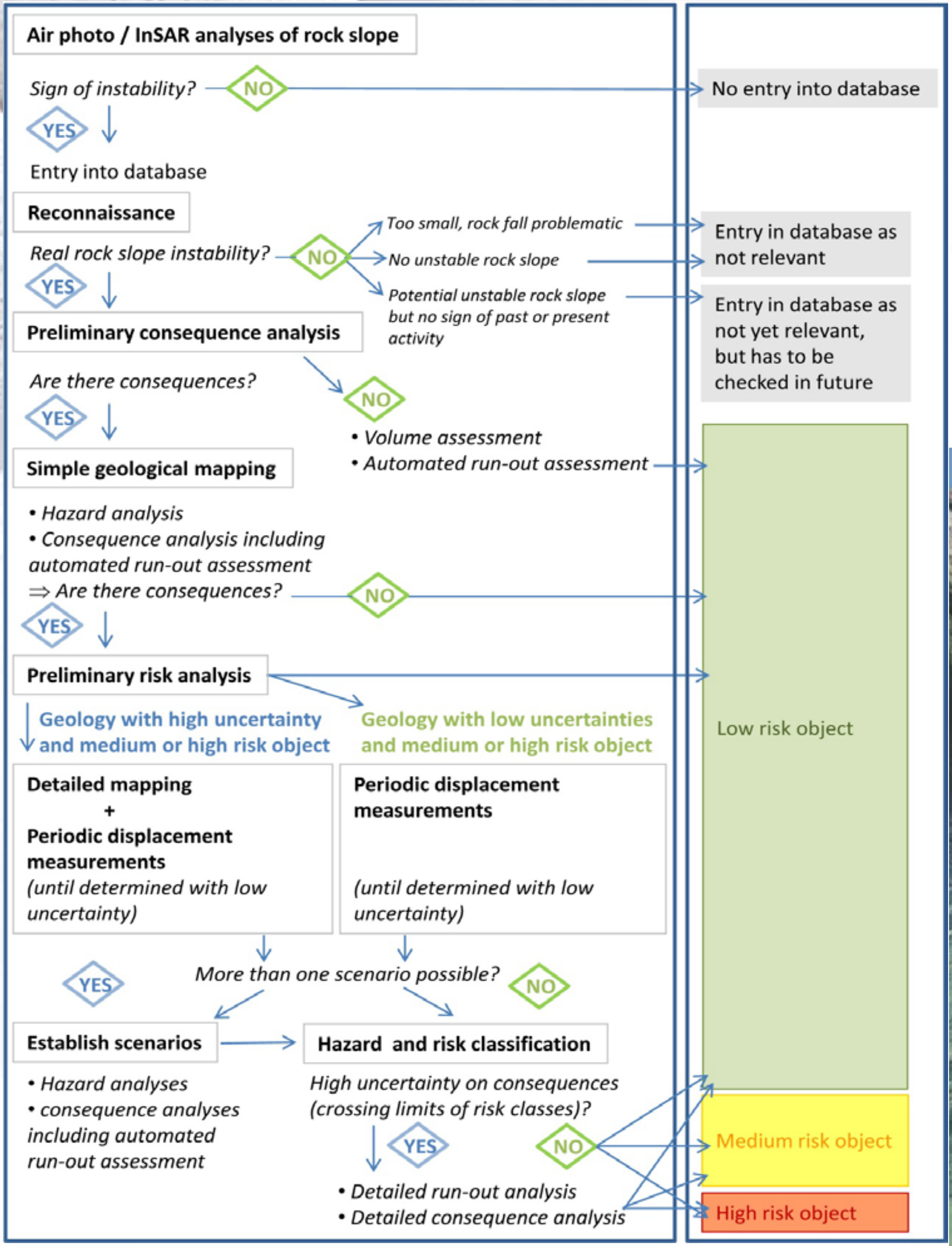


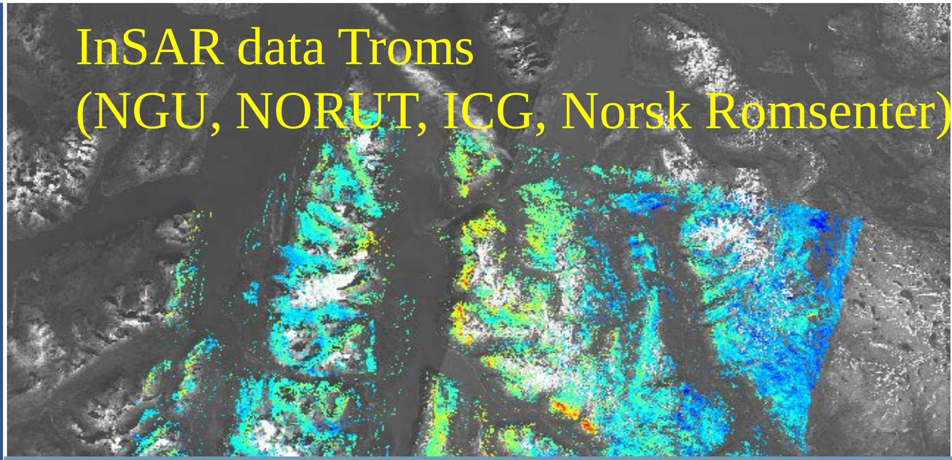
Hazard and risk classification of unstable rock slopes

Risk matrix Gamanjunni 3



Mapping methodology for unstable rock slopes





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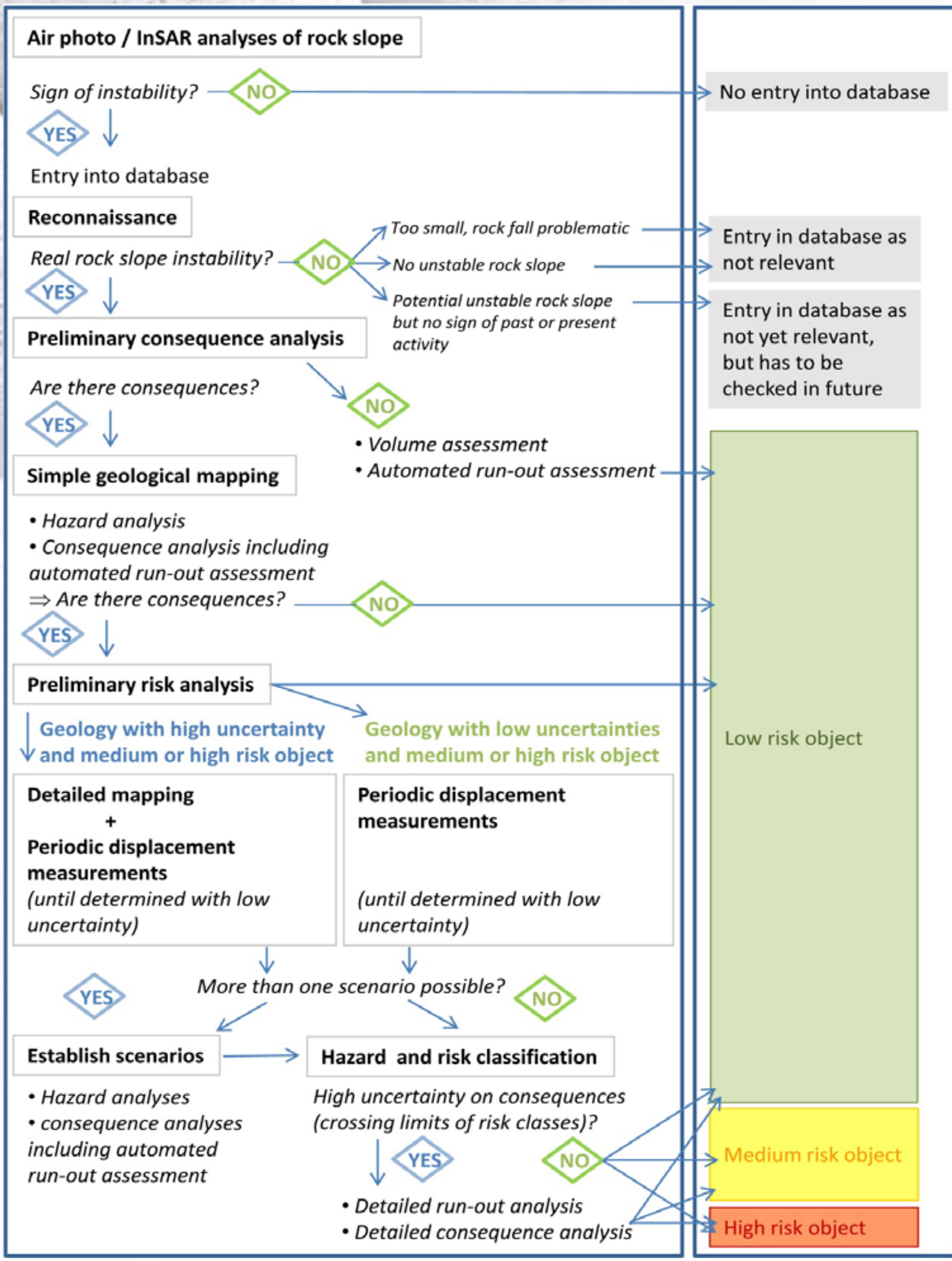

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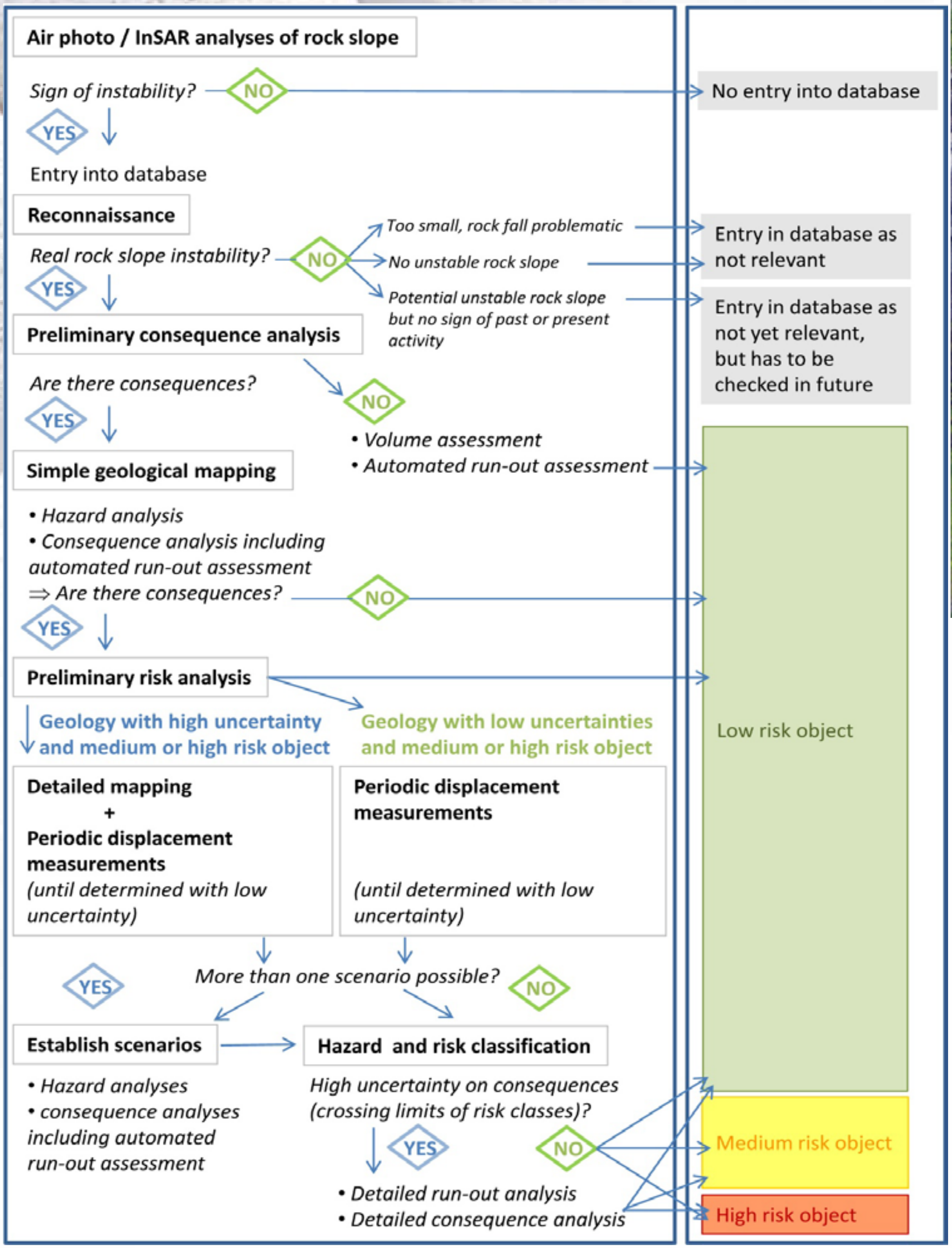

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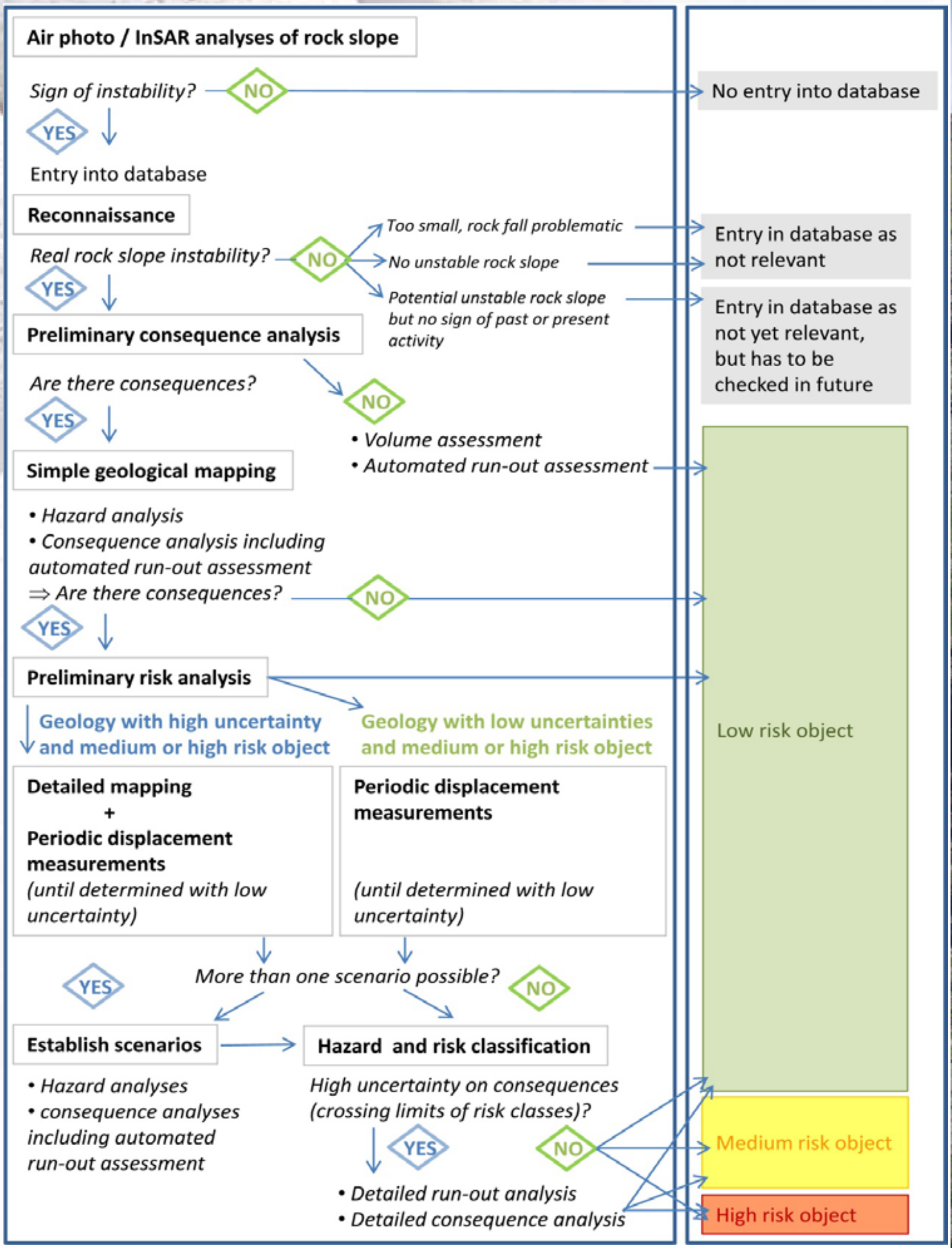

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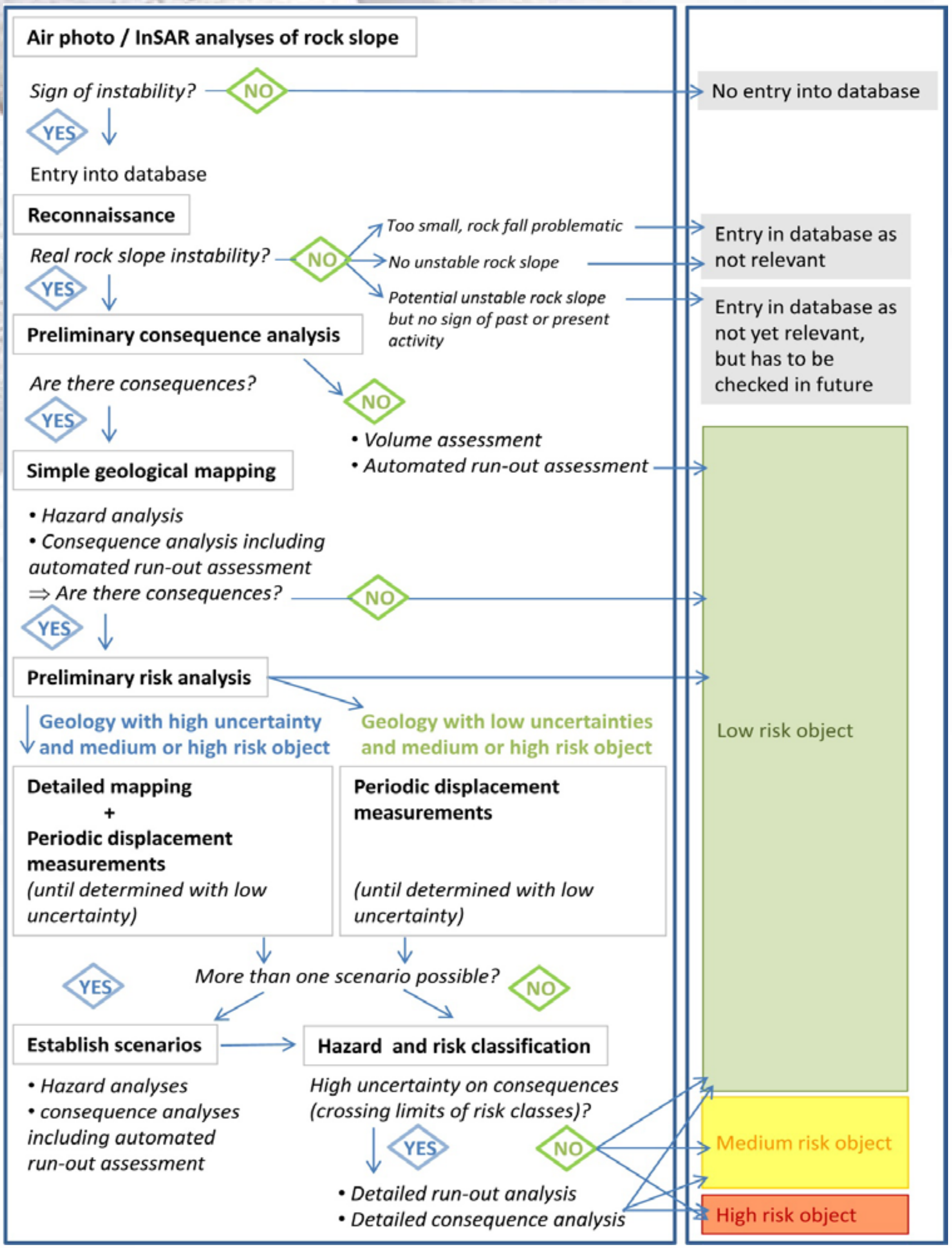
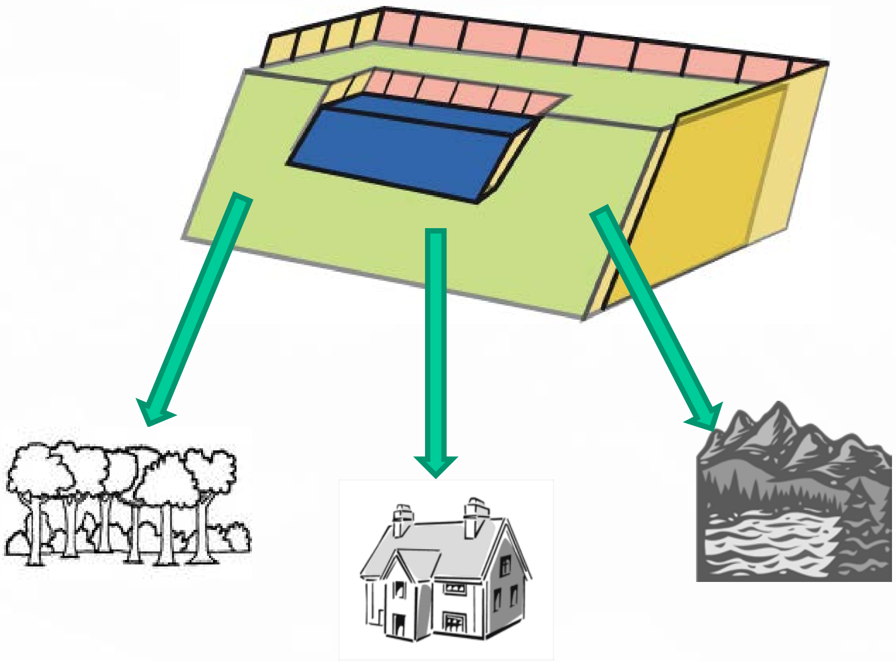
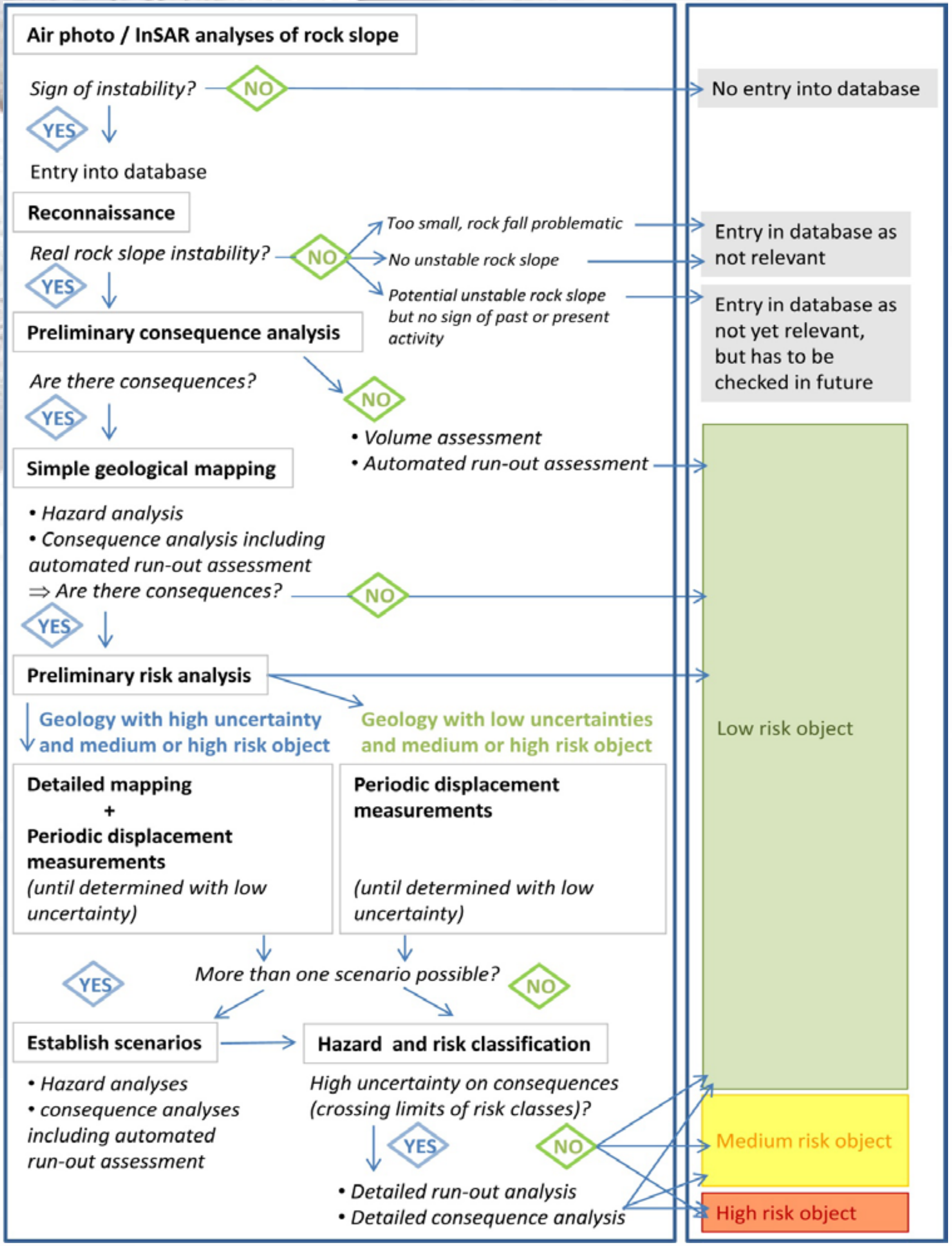
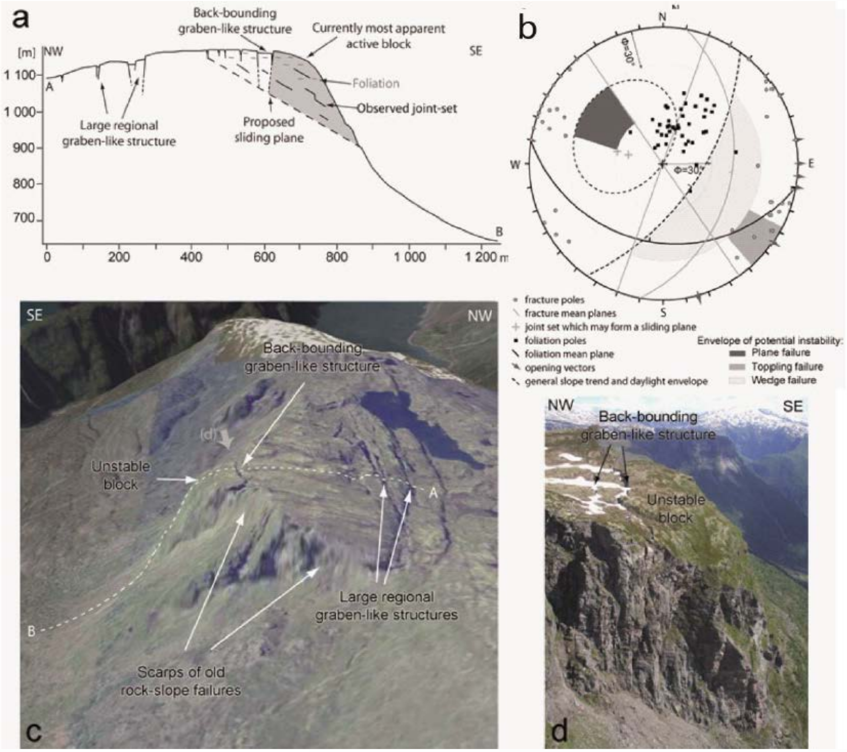




Mapping methodology for unstable rock slopes





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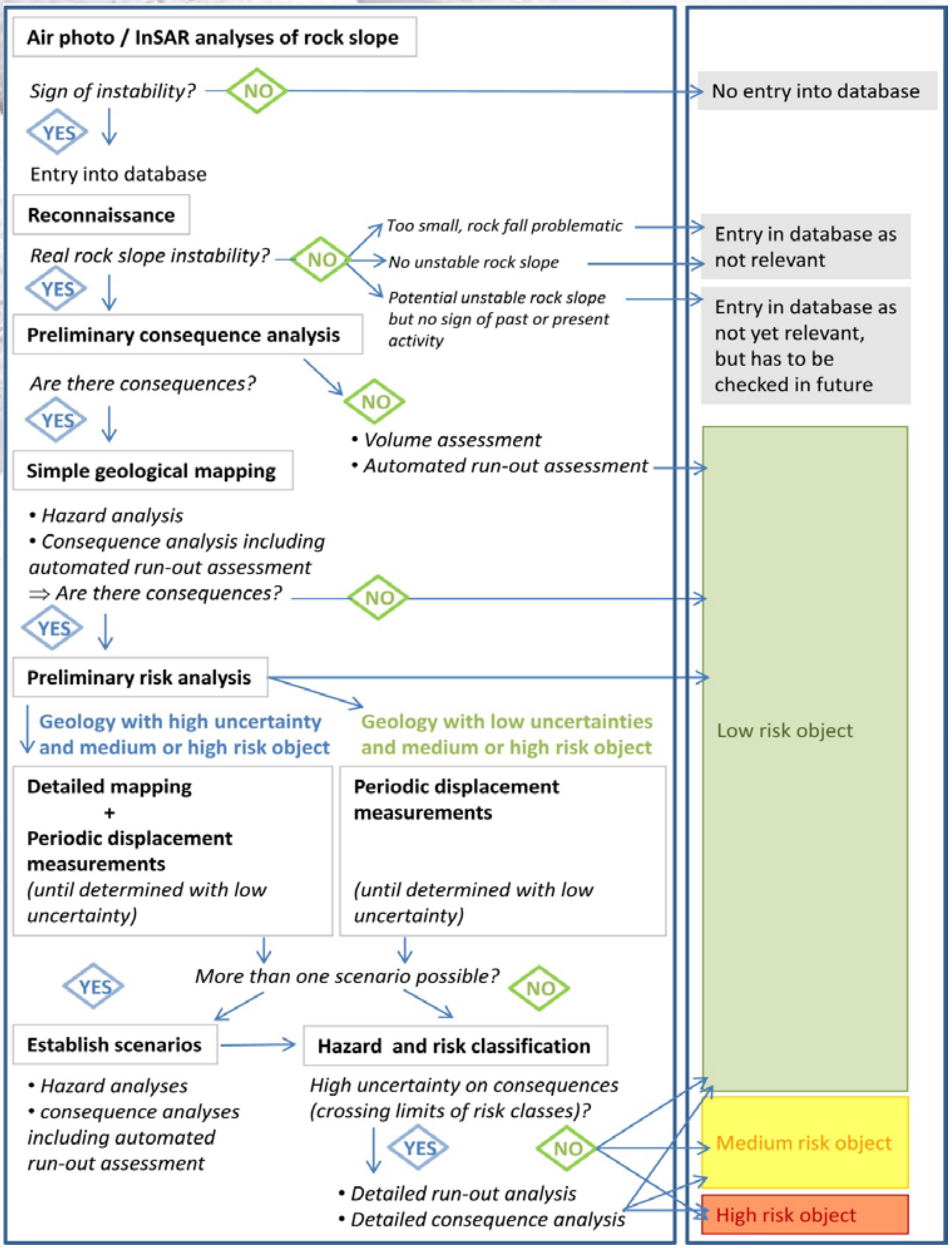
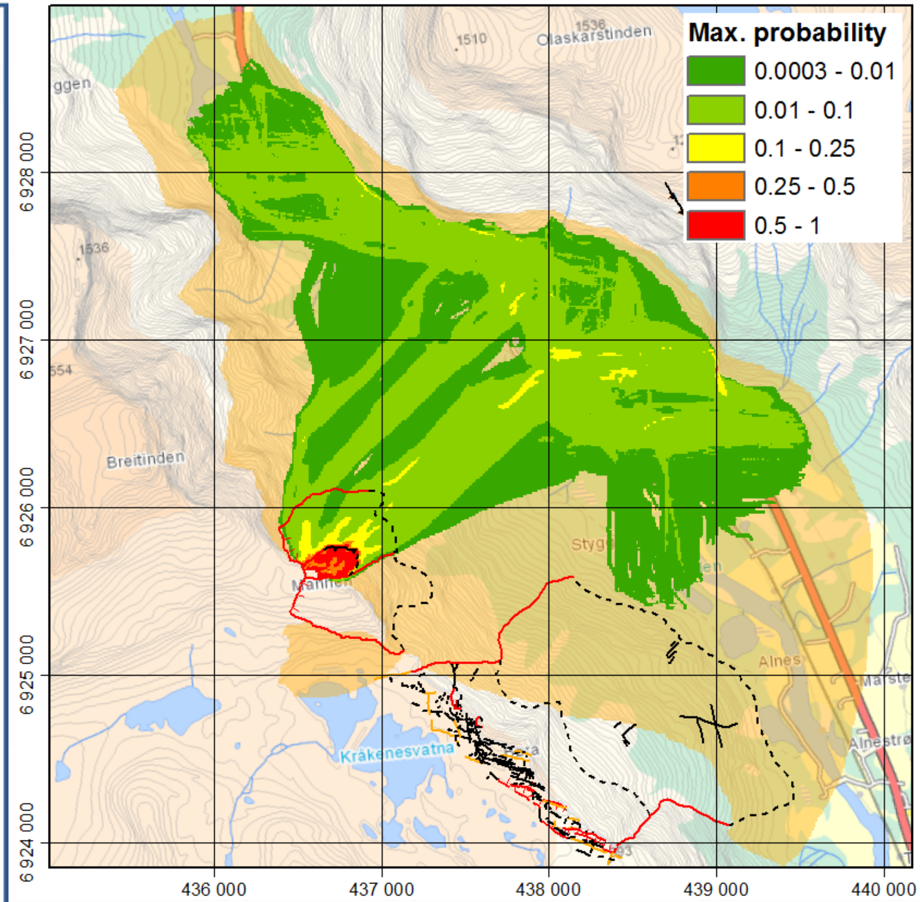
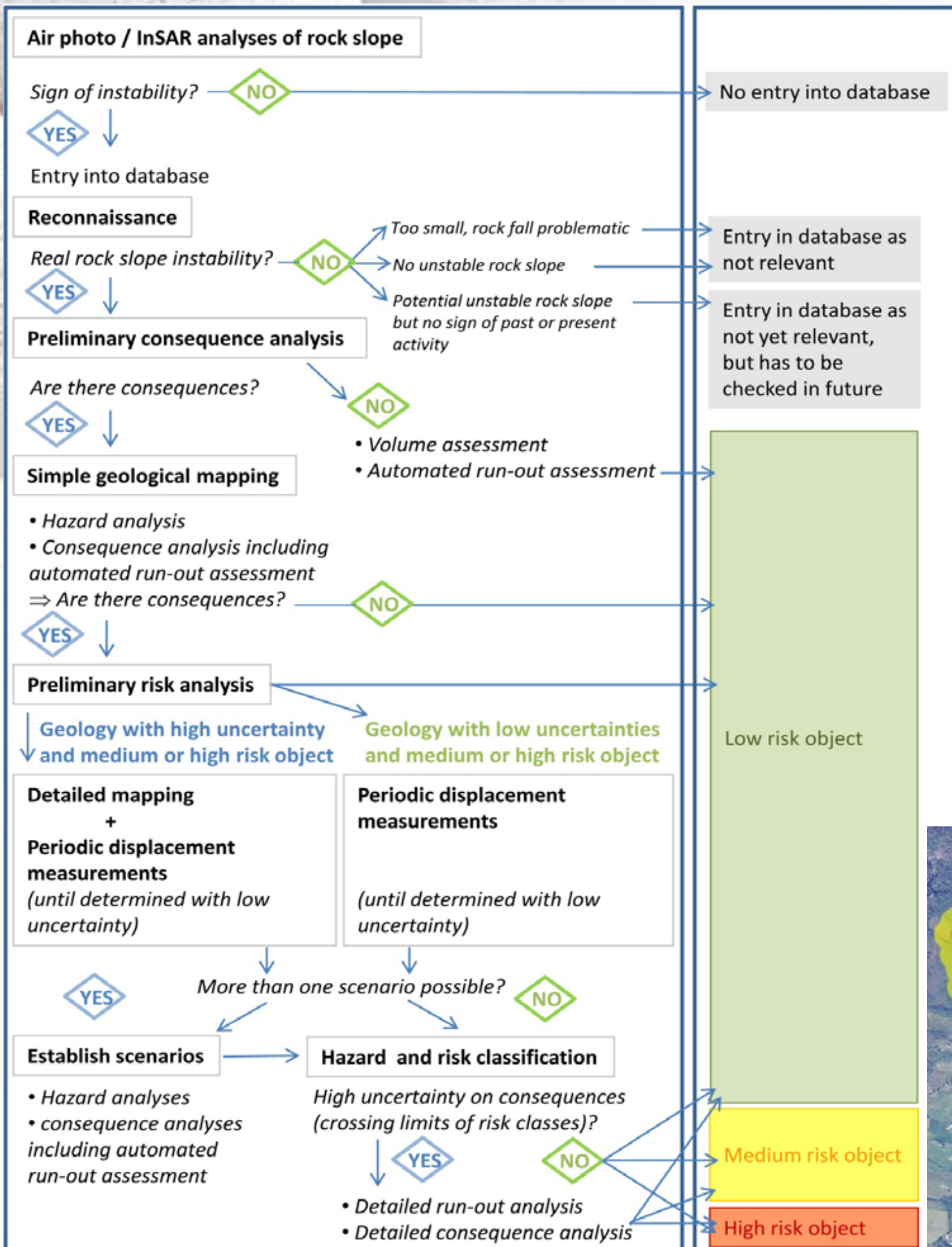
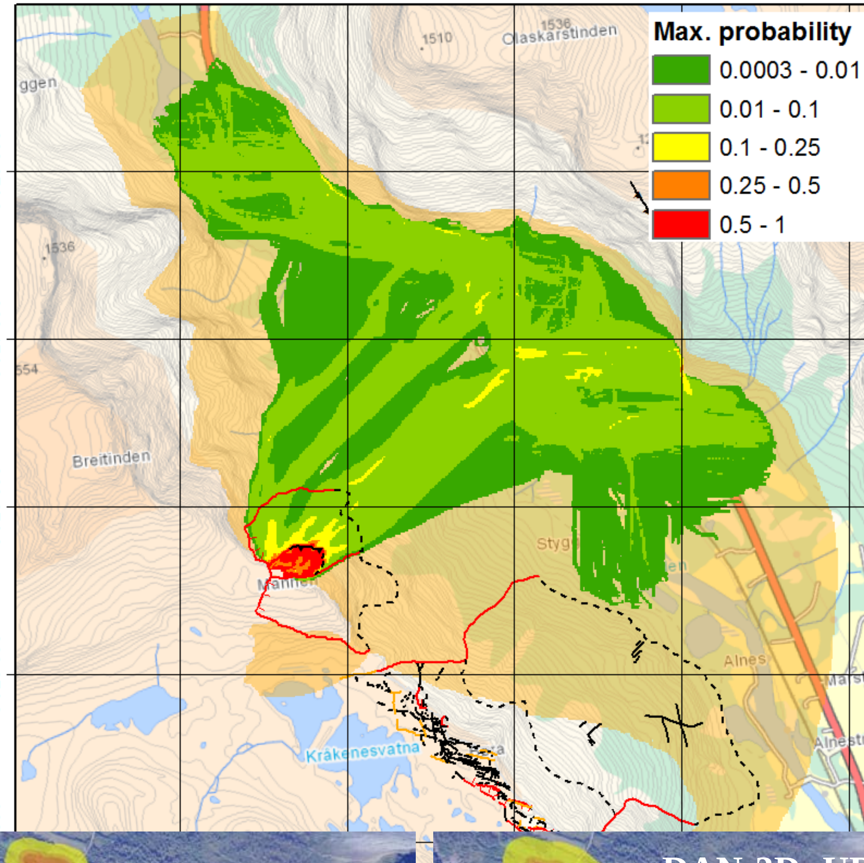


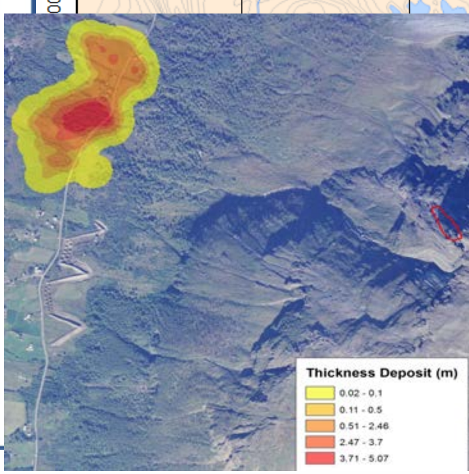


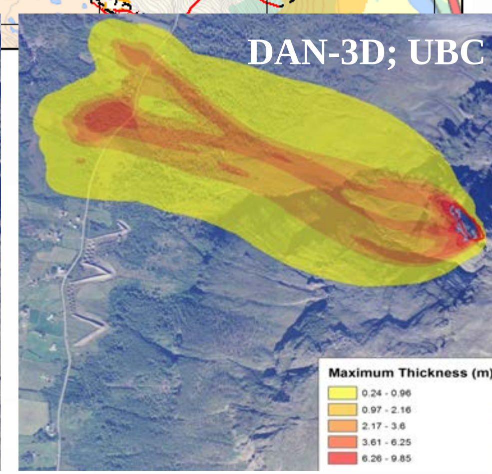
Flow-R, University of Lausanne

Mapping methodology for unstable rock slopes

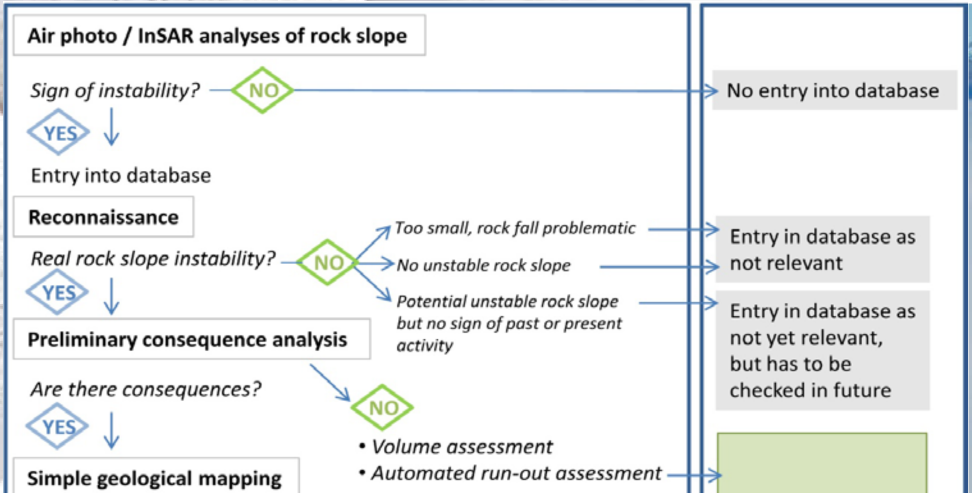


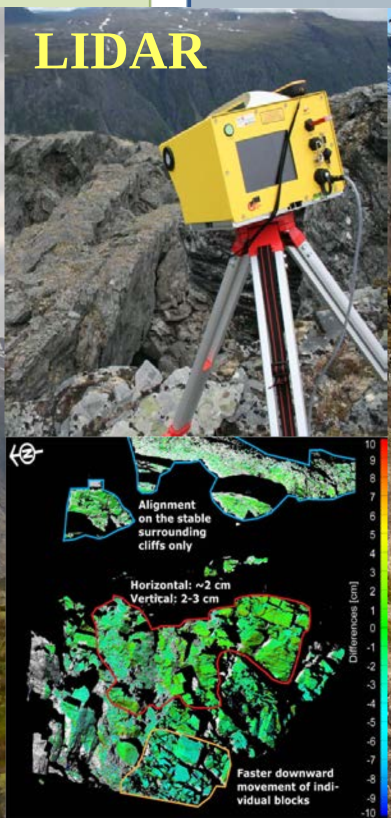


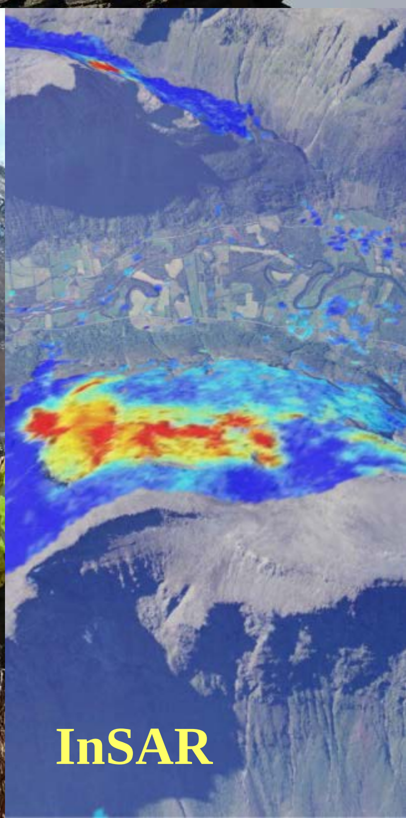




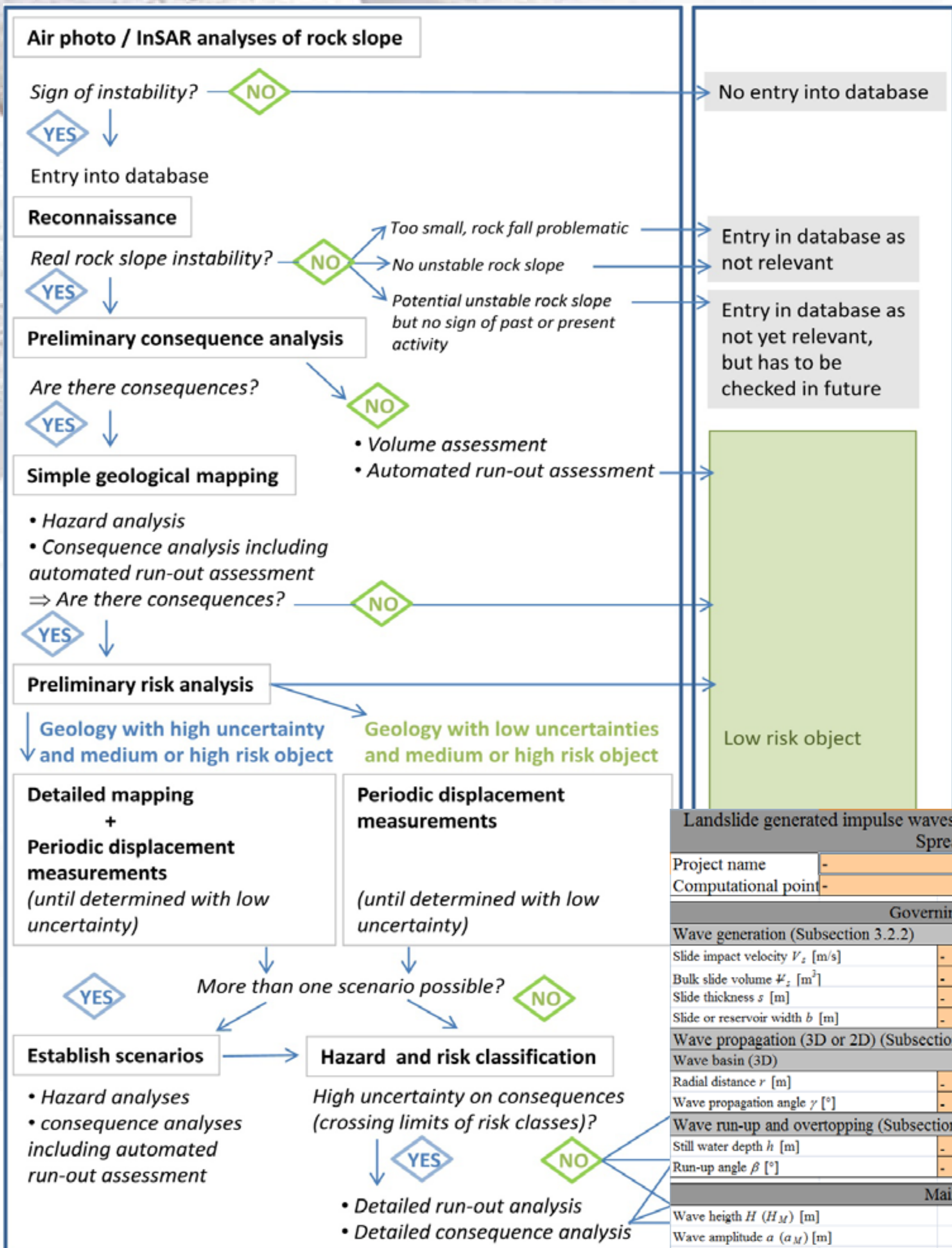
Mapping methodology for unstable rock slopes

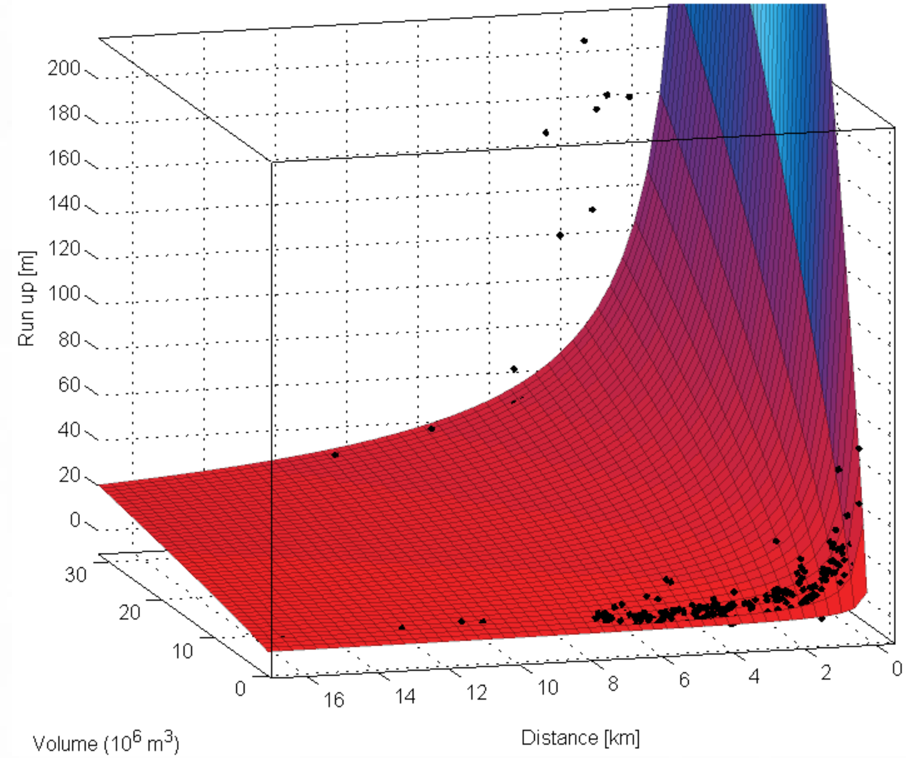




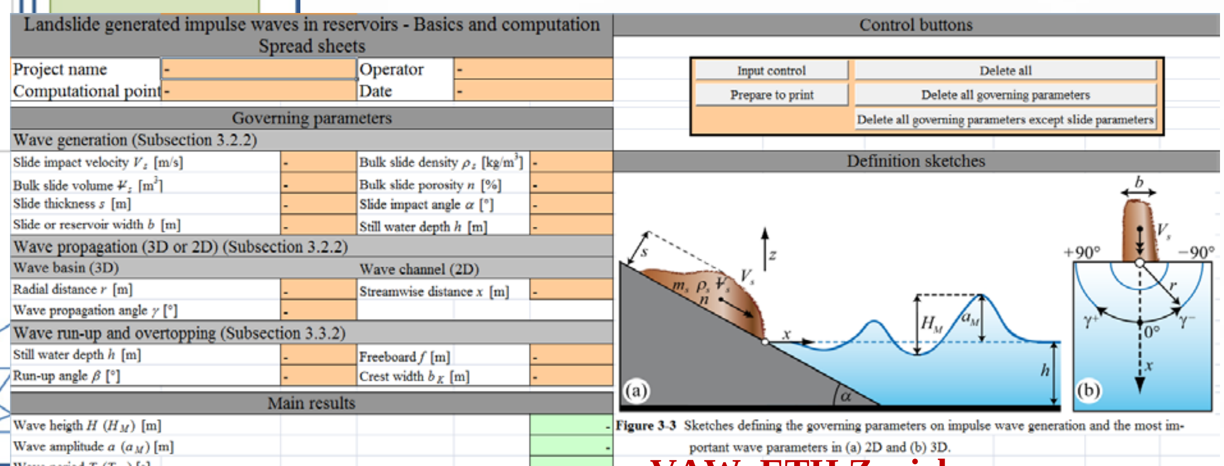


Mapping methodology for unstable rock slopes



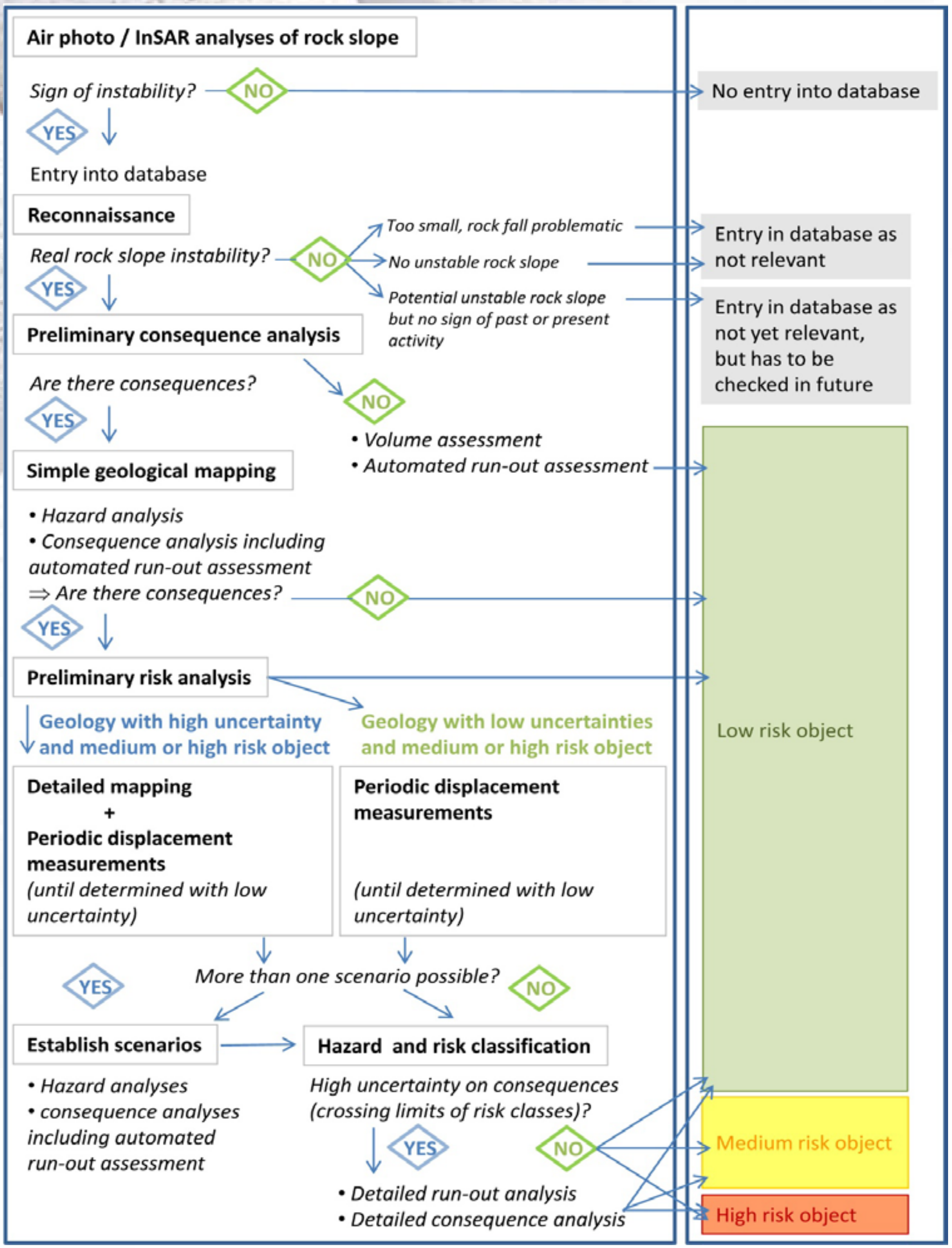


Roberts et al. 2014



VAW, ETH Zurich

Mapping methodology for unstable rock slopes



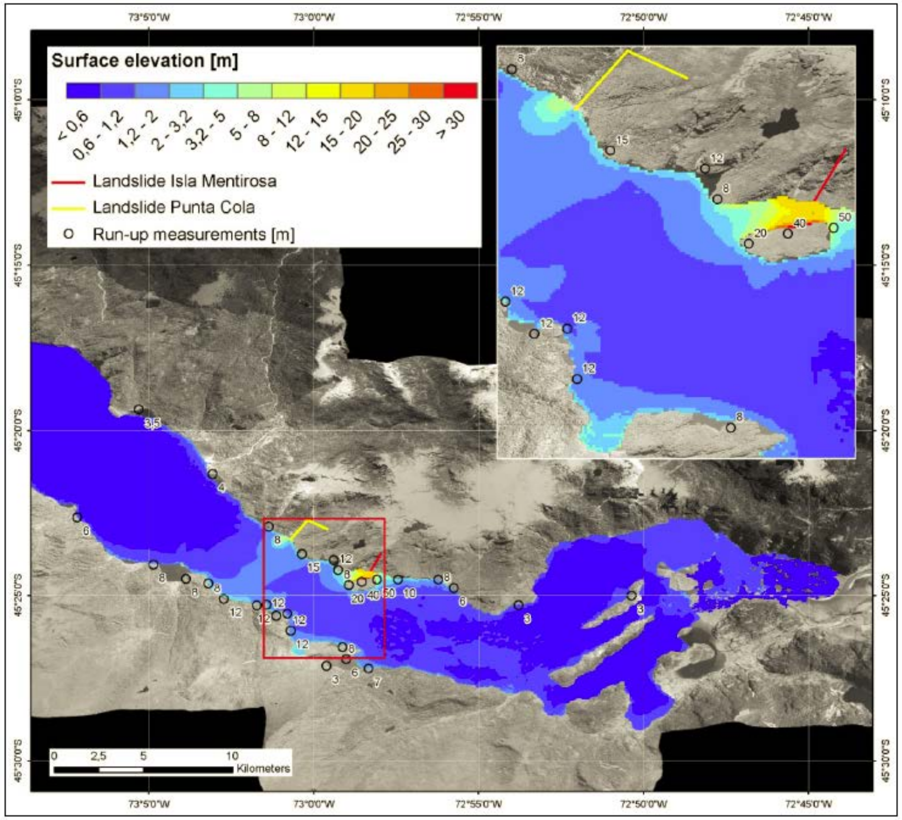


Figure 11: Modelled maximum surface elevation and comparison to measured run-up values.

Mapping methodology for unstable rock slopes

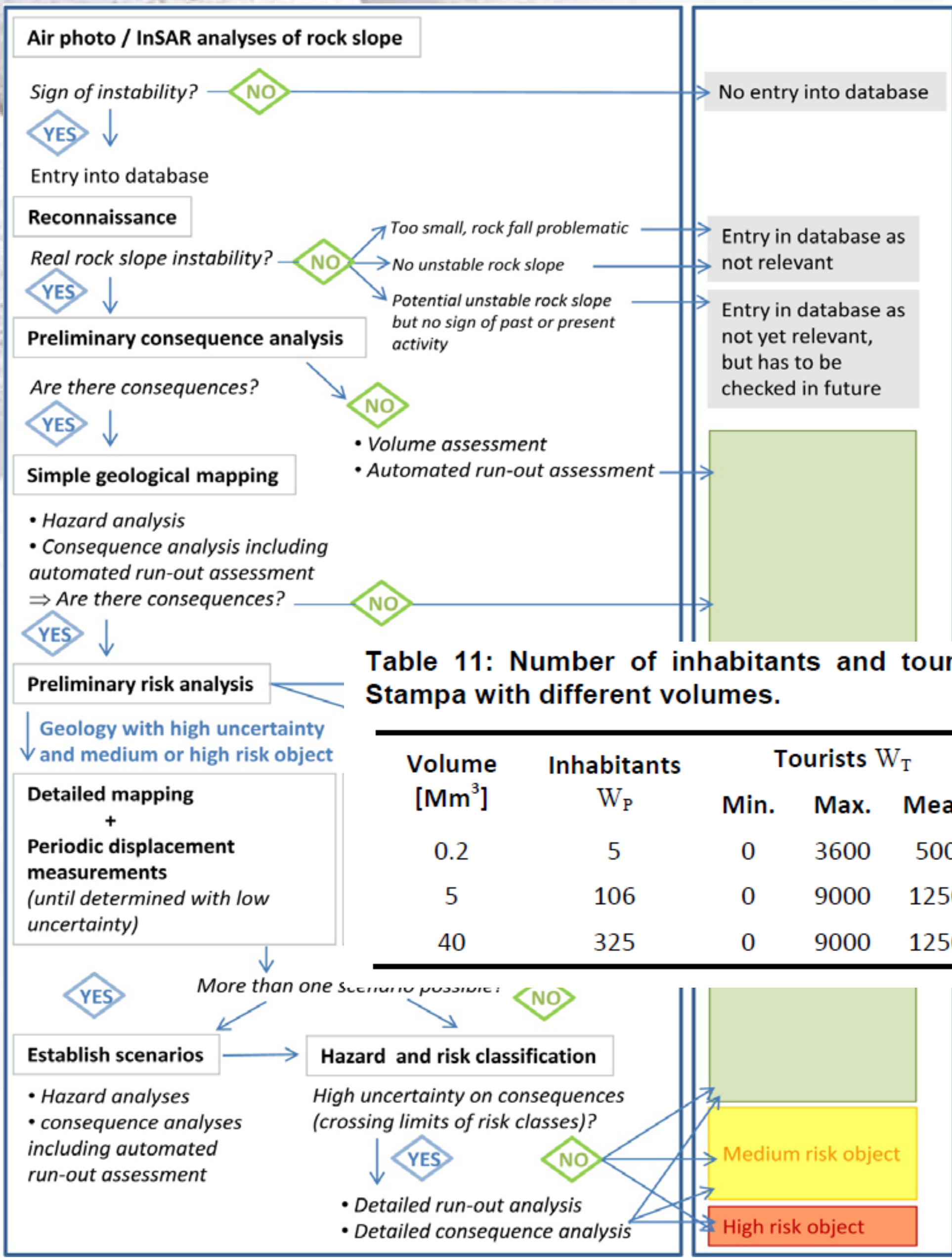
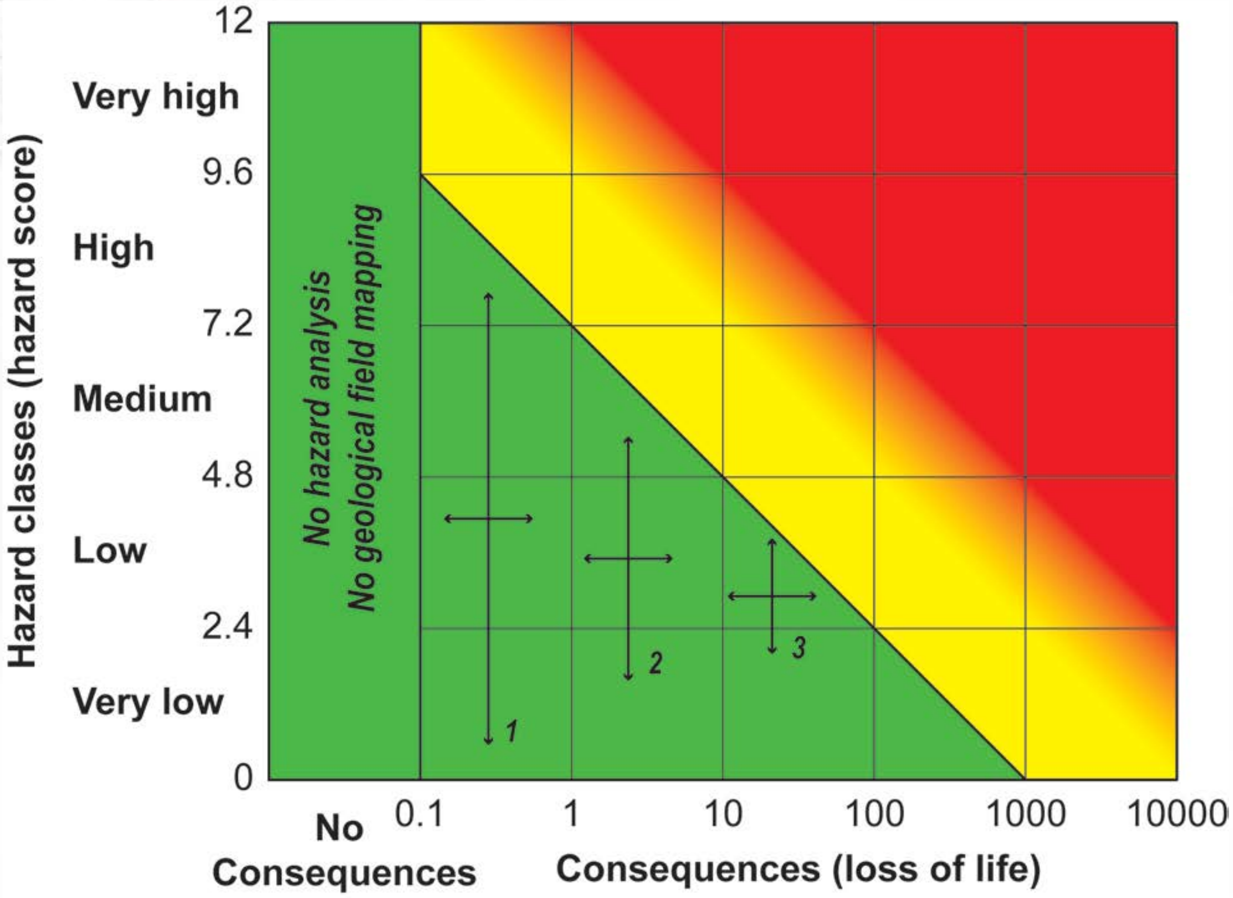


Table 11: Number of inhabitants and tourists exposed to displacement waves created by rockslides from Stampa with different volumes.

Volume [Mm³]	Inhabitants W_P	Tourists W_T			Total exposed persons, W_{TOT}			Potential life loss		
		Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
0.2	5	0	3600	500	5	1805	130	4	1264	91
5	106	0	9000	1250	106	4606	419	74	3224	293
40	325	0	9000	1250	325	4825	638	228	3378	446

Mapping methodology for unstable rock slopes



Mapping methodology for unstable rock slopes

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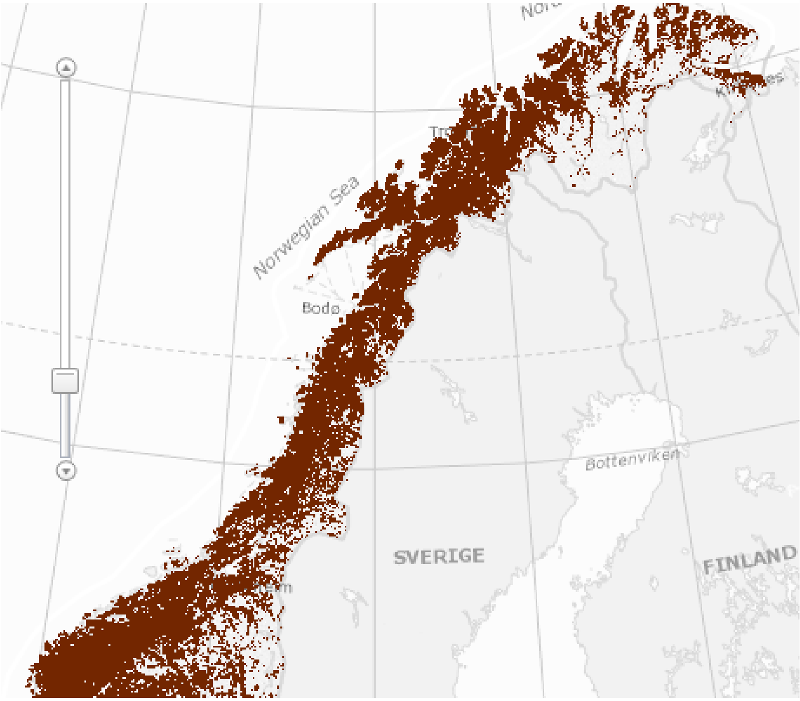


Landsdekkende aktsomhetskart for jord- og flomskred

15.05.2014 08:36:00

NVE publiserer aktsomhetskart for jord- og flomskred. Aktsomhetskartet viser områder med potensiell fare for jord- og flomskred. Kartet gir kommunene et godt grunnlag for en første vurdering av skredfare.

Faresonekart skred for Loppa kommune

05.05.2014 08:30:00

Mandag 5. mai overleverte Norges vassdrags- og energidirektorat (NVE) faresonekart for skred til Loppa kommune.

Faginformasjon | Nyttige lenker | Om dataene | Nedlastning / WMS

Norges vassdrags- og energidirektorat

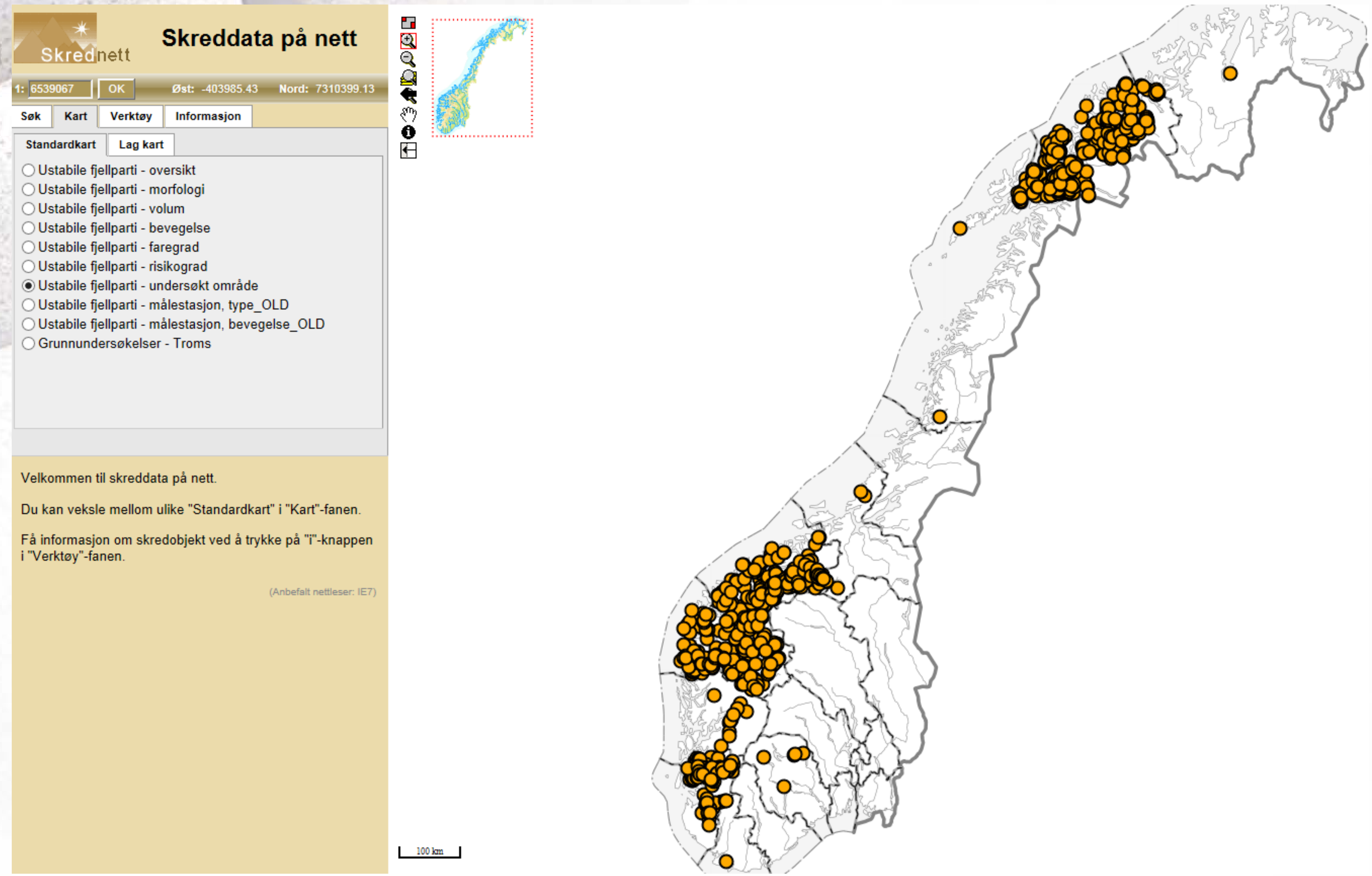
NVE

NGU Norges geologiske undersøkelse

Statens vegvesen   Jernbaneverket   Forsvarets militærgeografiske tjeneste

http://www.skrednett.no/

Mapping methodology for unstable rock slopes



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Thank you for your attention

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Reginald.Hermanns@NGU.NO