



United Nations
Educational, Scientific and
Cultural Organization



UNIVERSITÀ
DEGLI STUDI
FIRENZE

• UNESCO Chair on the Prevention and
• Sustainable Management of Geo-Hydrological Hazards,
• University of Florence, Italy

Caratterizzazione e monitoraggio rapidi degli ammassi rocciosi per applicazioni di Protezione Civile

Strumenti innovativi di indagine e di monitoraggio per l'analisi e la
modellazione geologica e geotecnica

Firenze, 19 Giugno 2017

**Giovanni GIGLI, Emanuele INTRIERI,
Stefano MORELLI**



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FIRENZE

DST

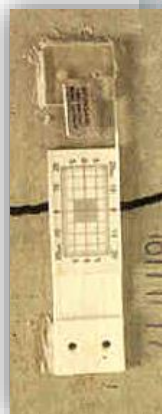
DIPARTIMENTO DI
SCIENZE DELLA TERRA

CENTRO DI COMPETENZA DEL
SERVIZIO NAZIONALE DELLA
PROTEZIONE CIVILE

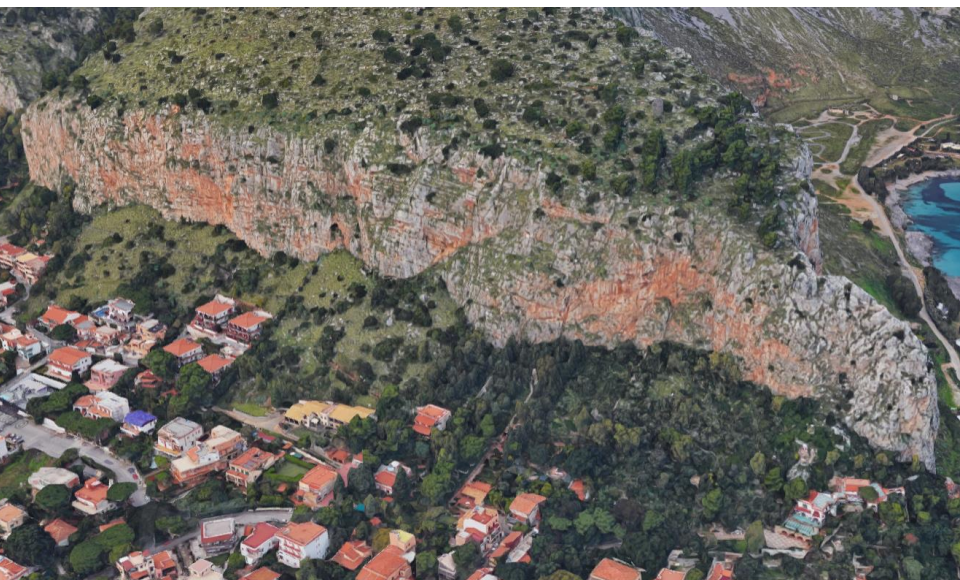


PROTEZIONE CIVILE

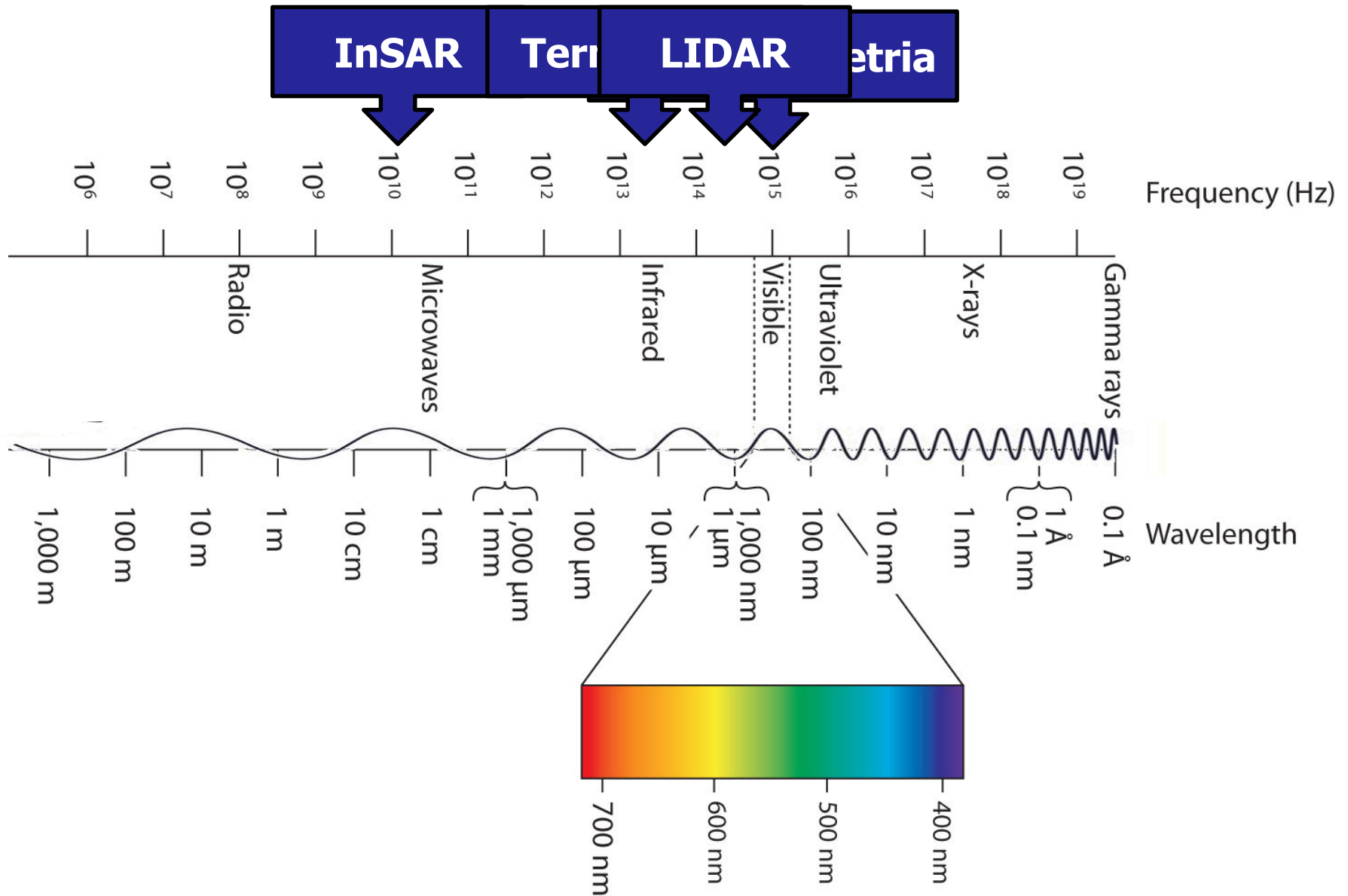
Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile



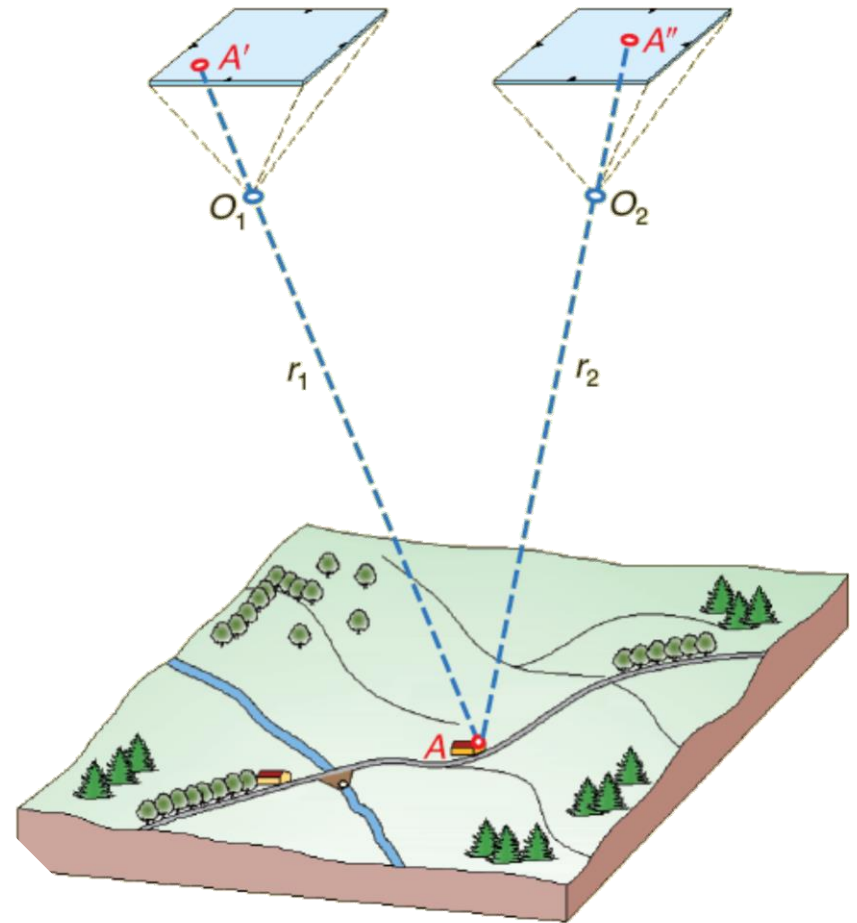
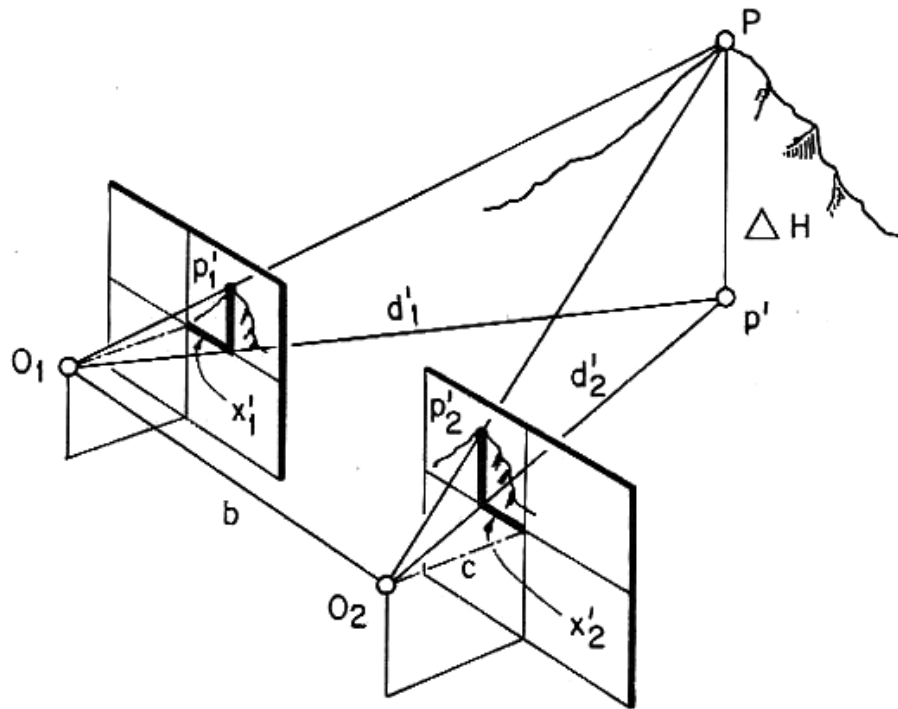
Ammassi rocciosi



Remote sensing



Fotogrammetria



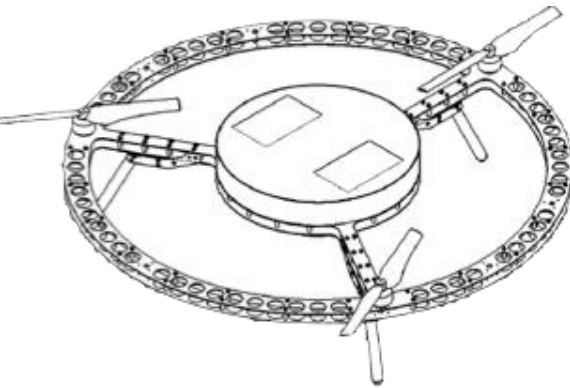
Drone Saturn



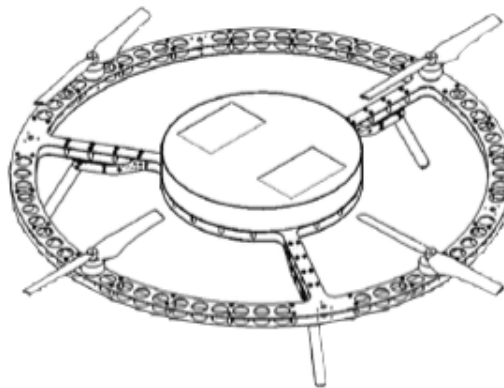
(Rossi, 2013)

Drone Saturn

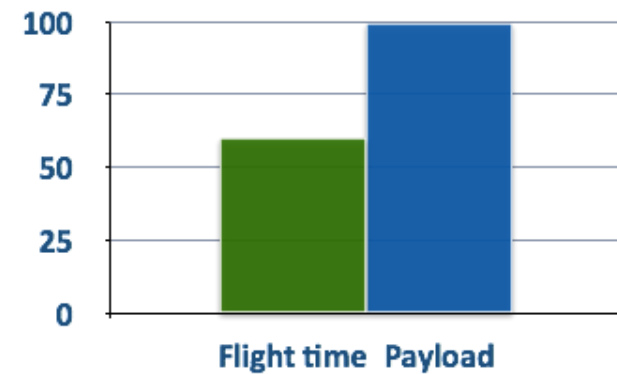
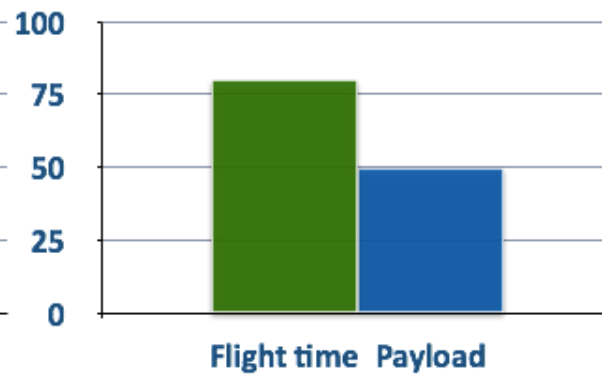
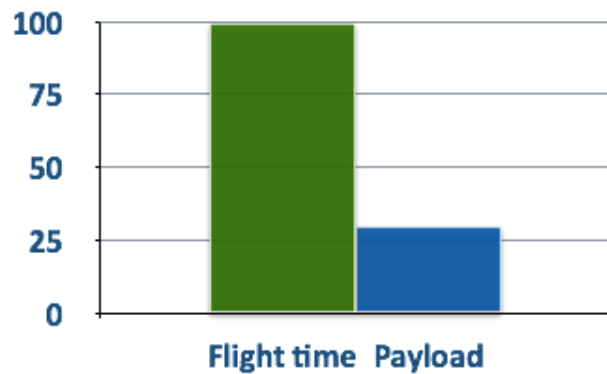
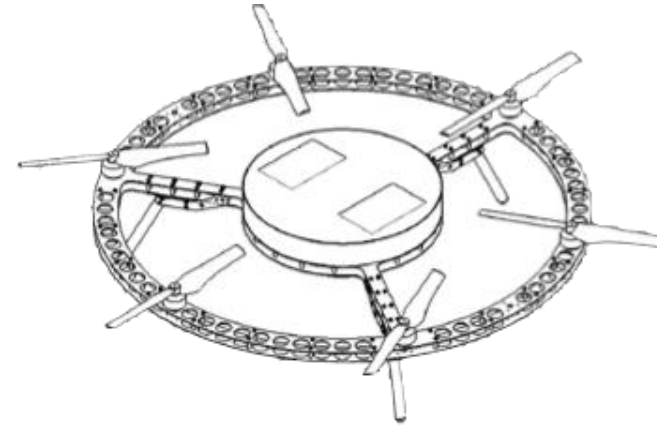
Tricopter



Quadricopter

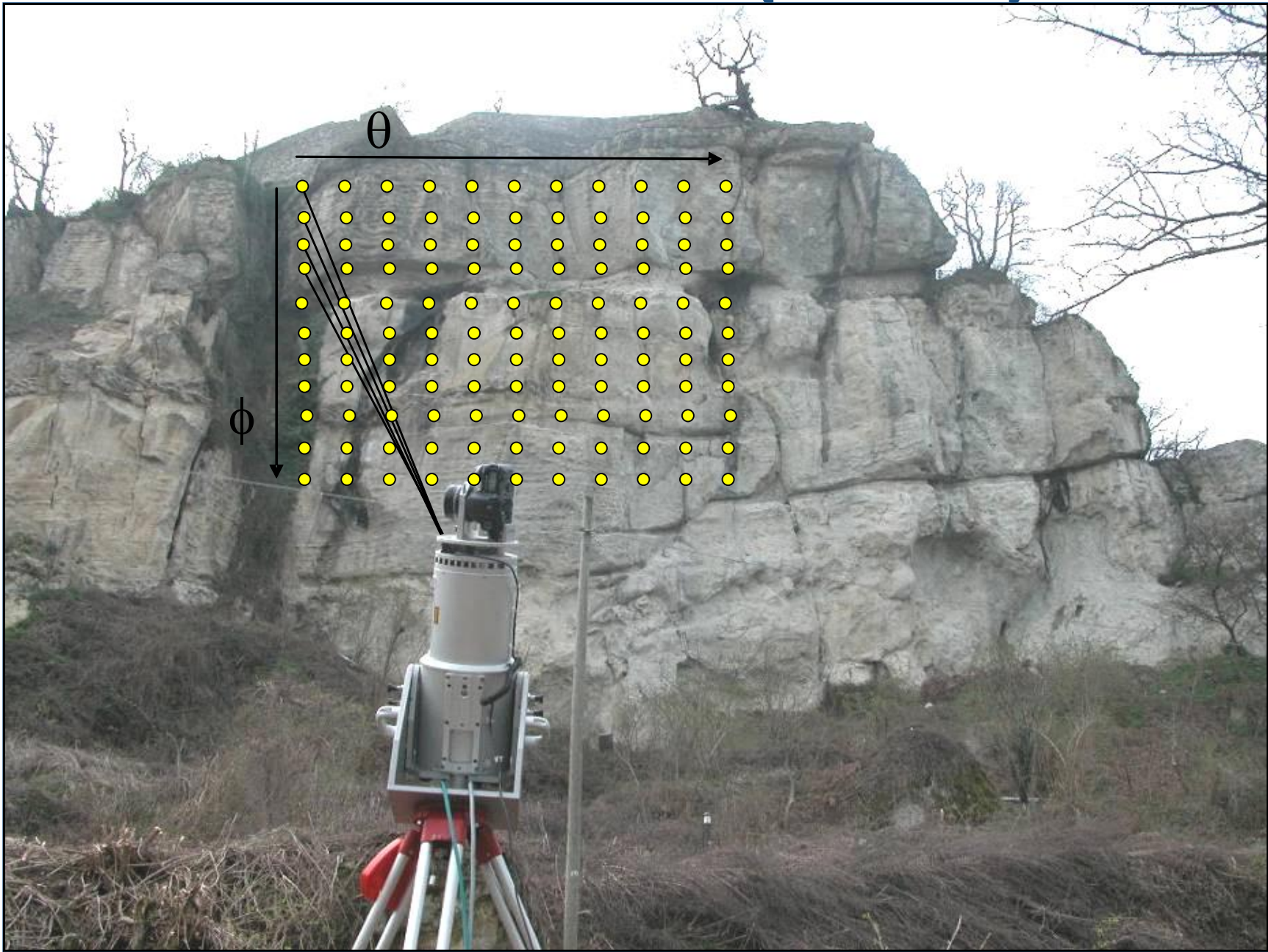


Hexacopter



(Rossi, 2013)

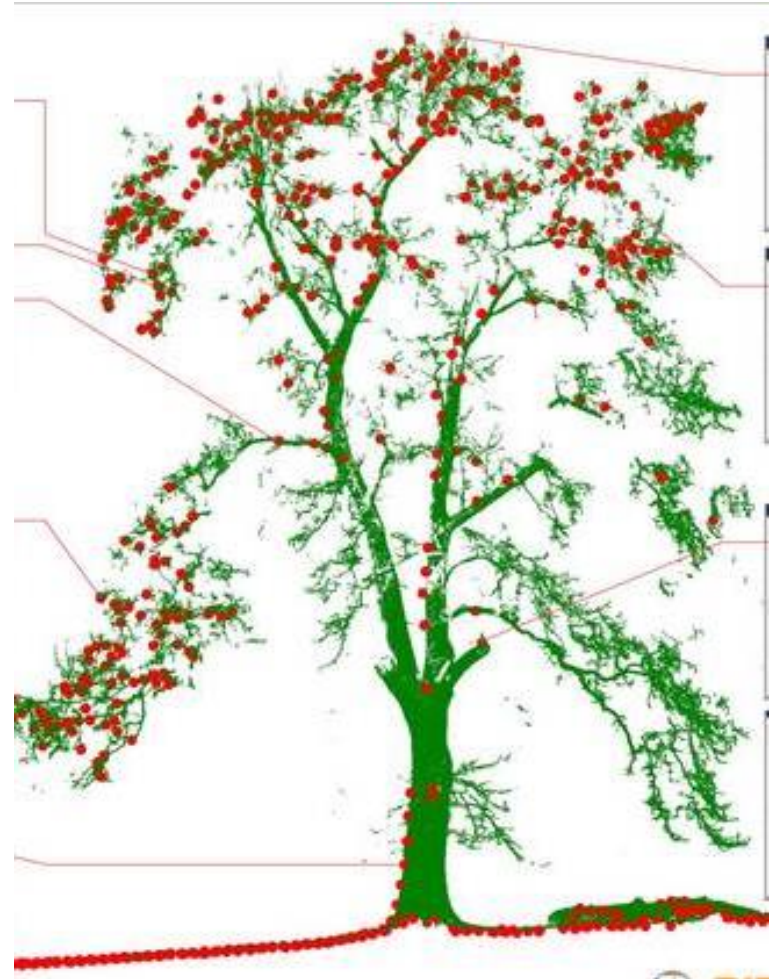
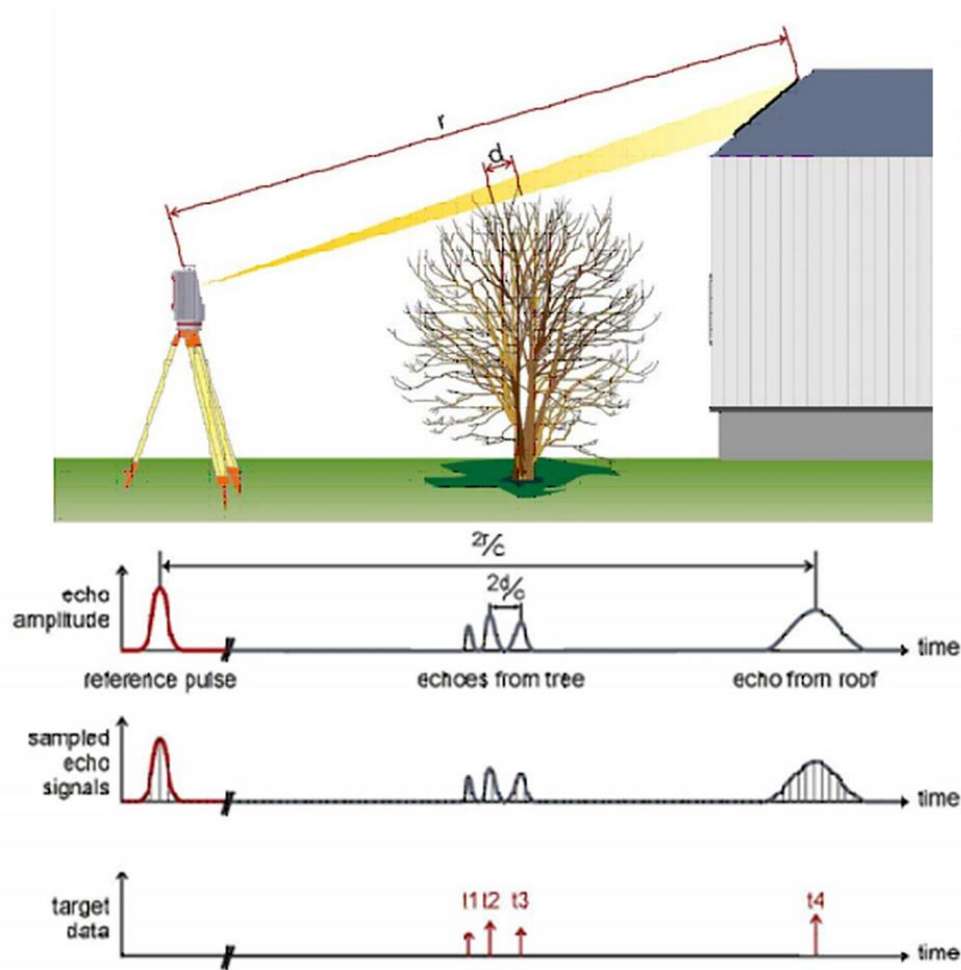
Laser scanner (LIDAR)



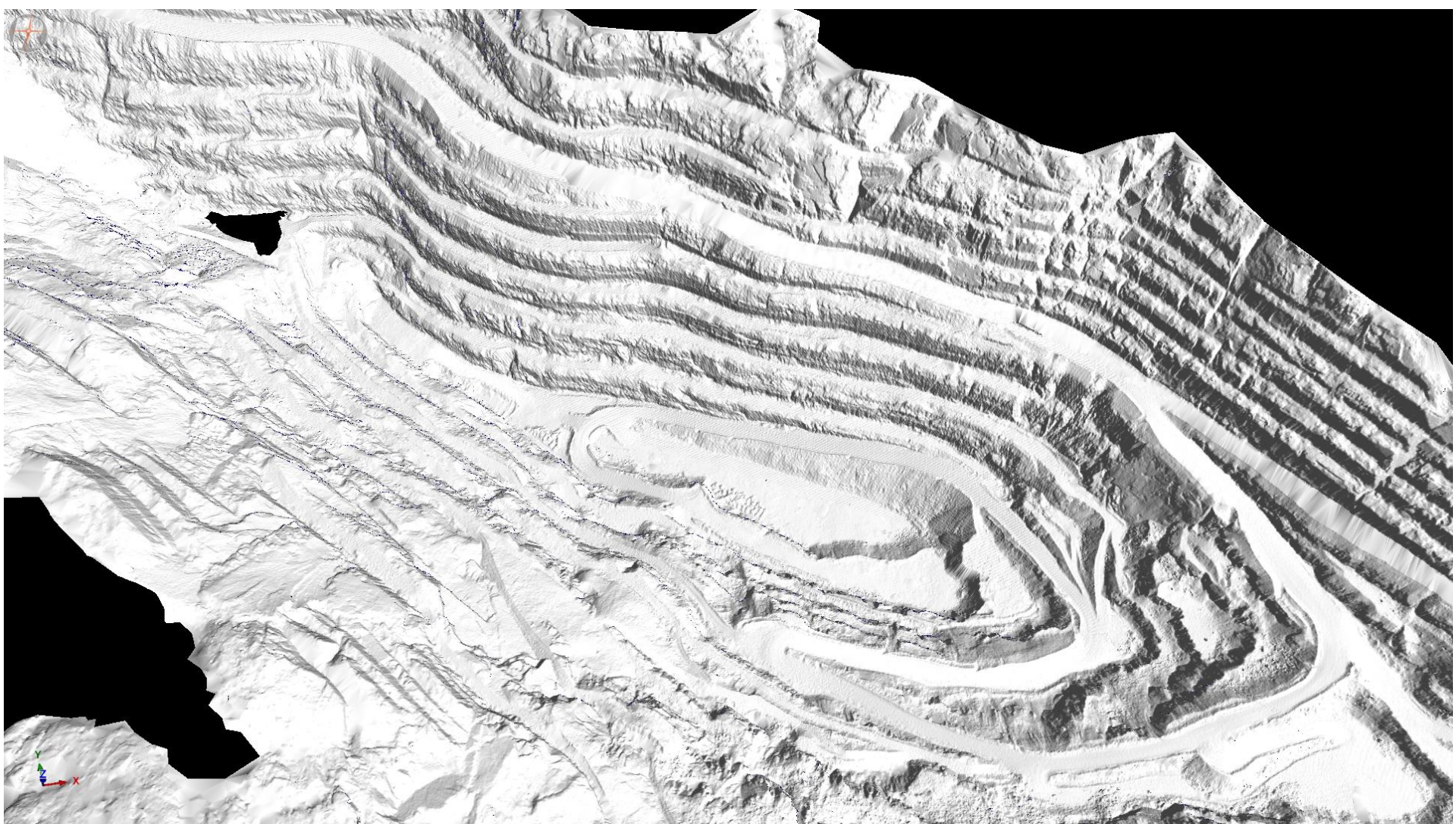
Nuvola di punti



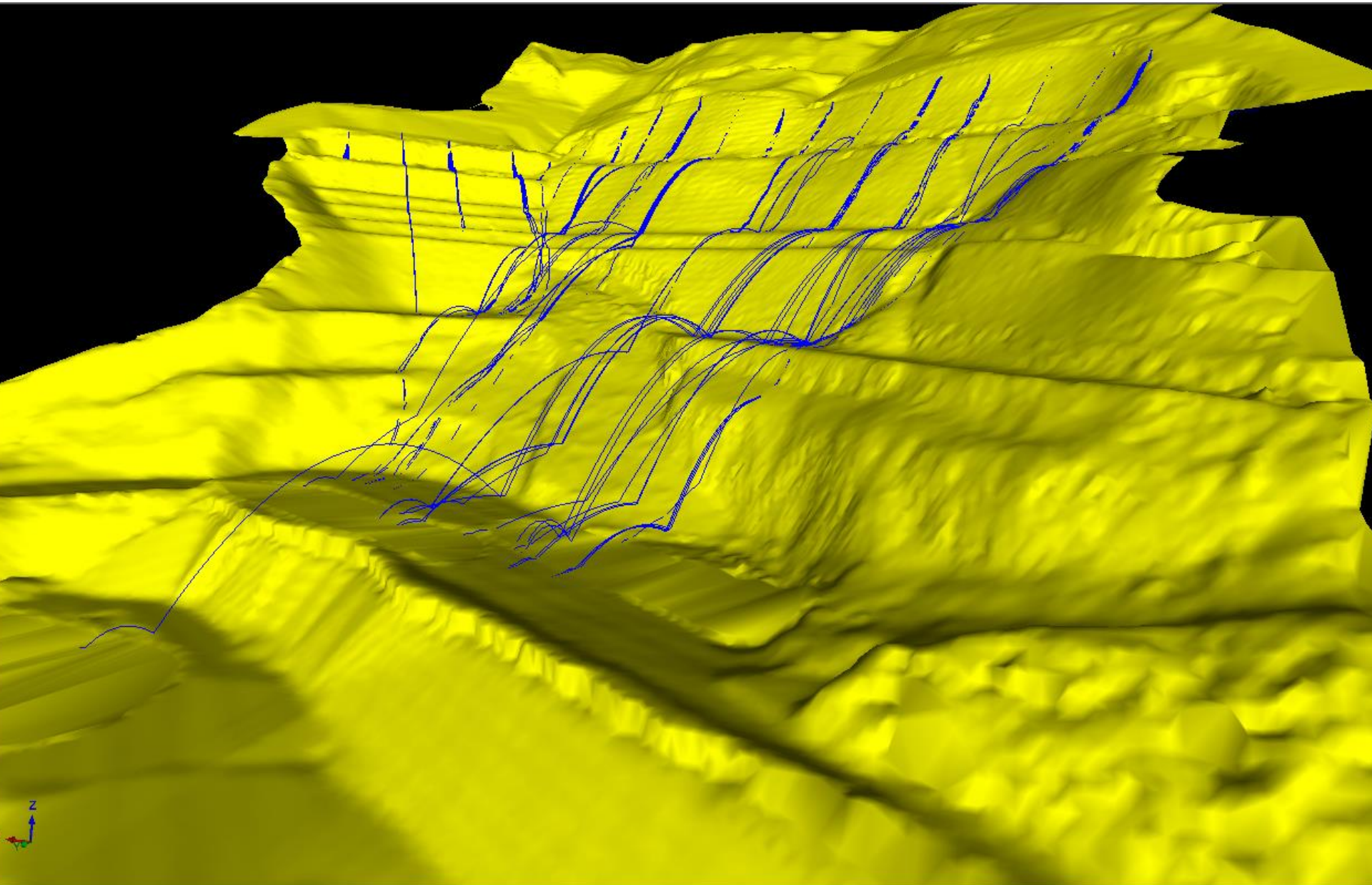
Filtraggio vegetazione



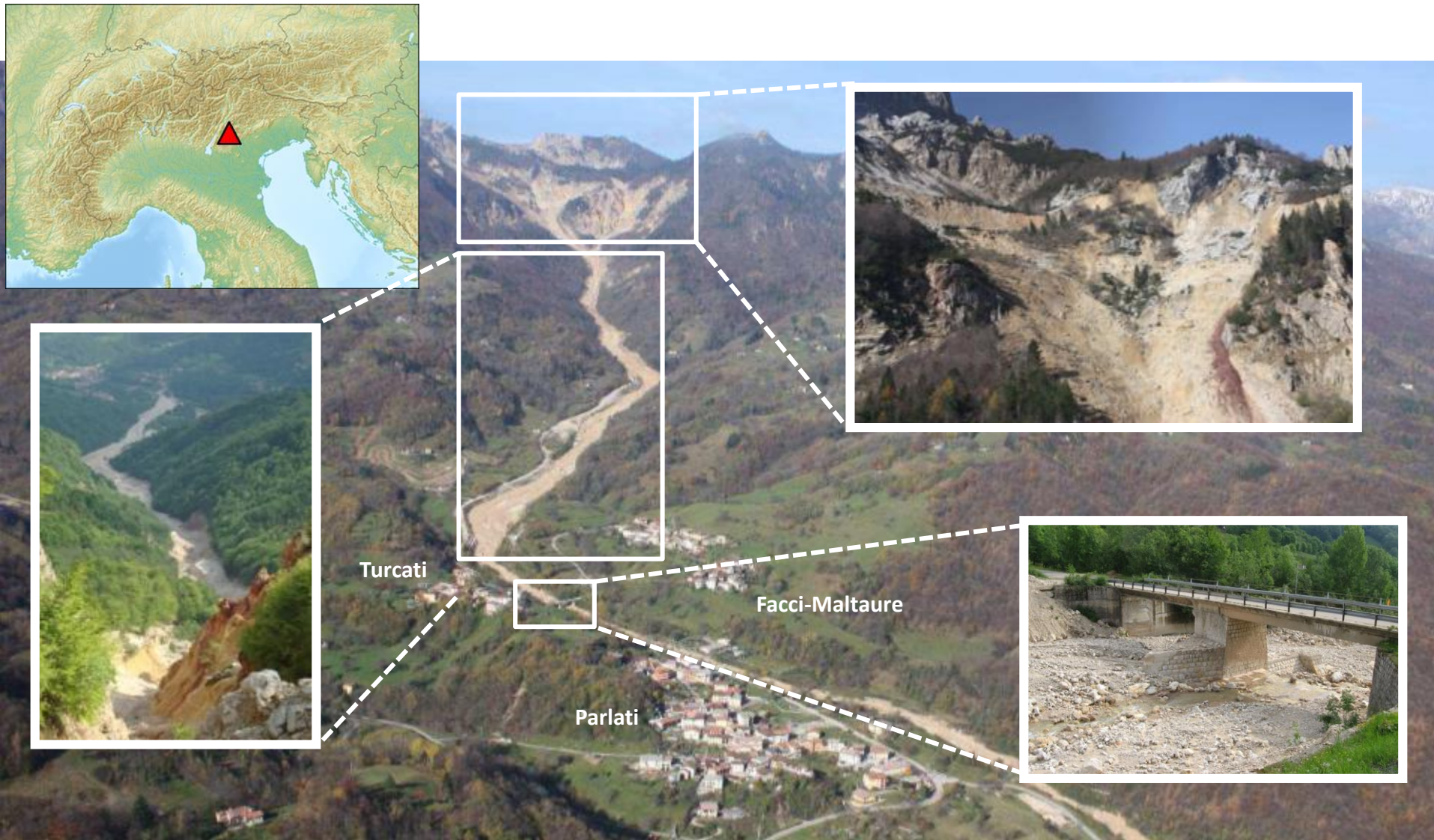
Creazione DEM di dettaglio



Simulazioni caduta massi 3D

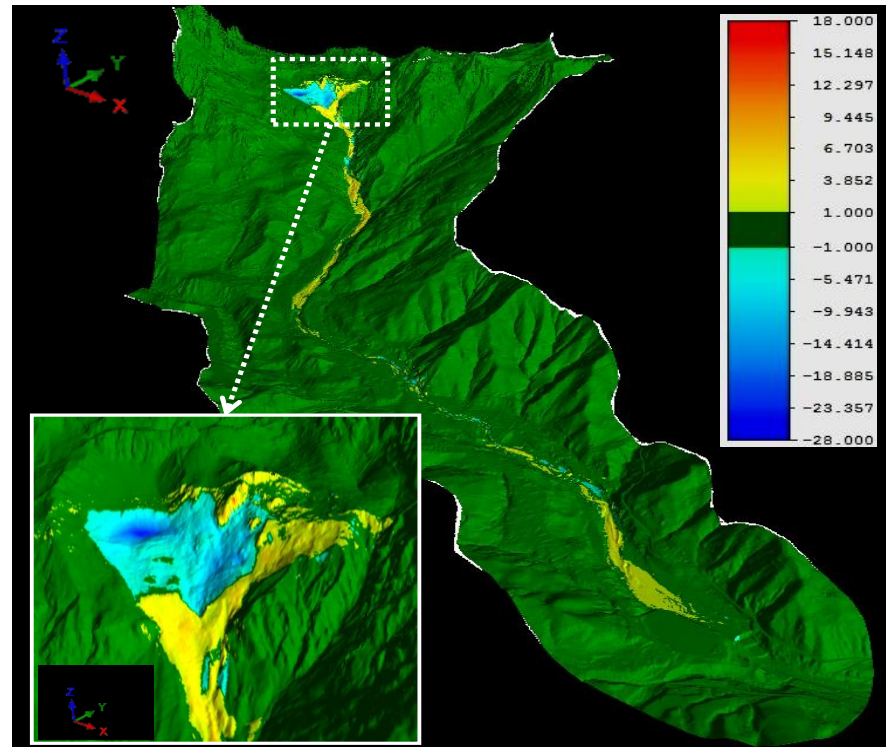
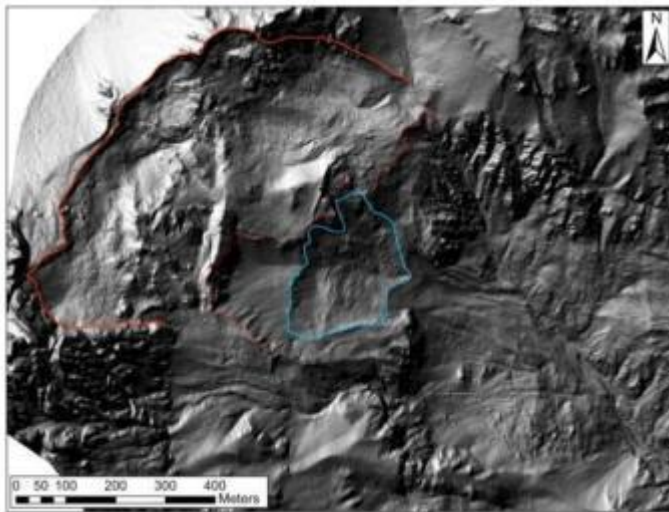
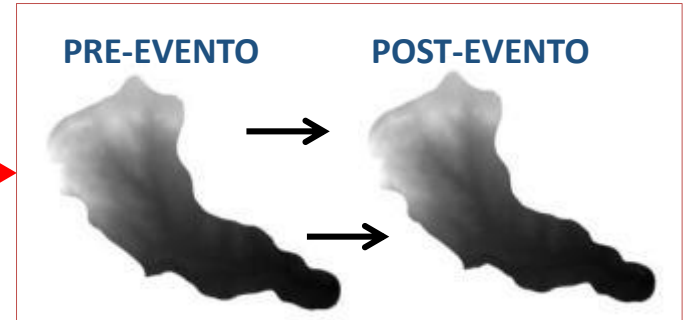
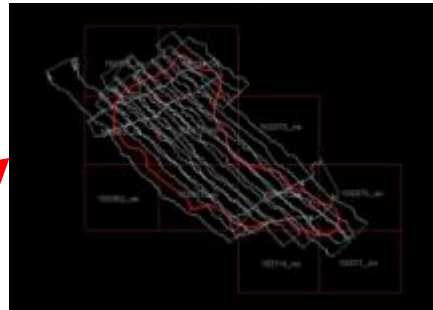
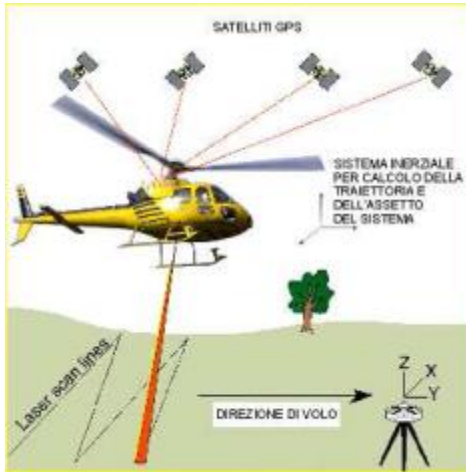


Monte Rotolon

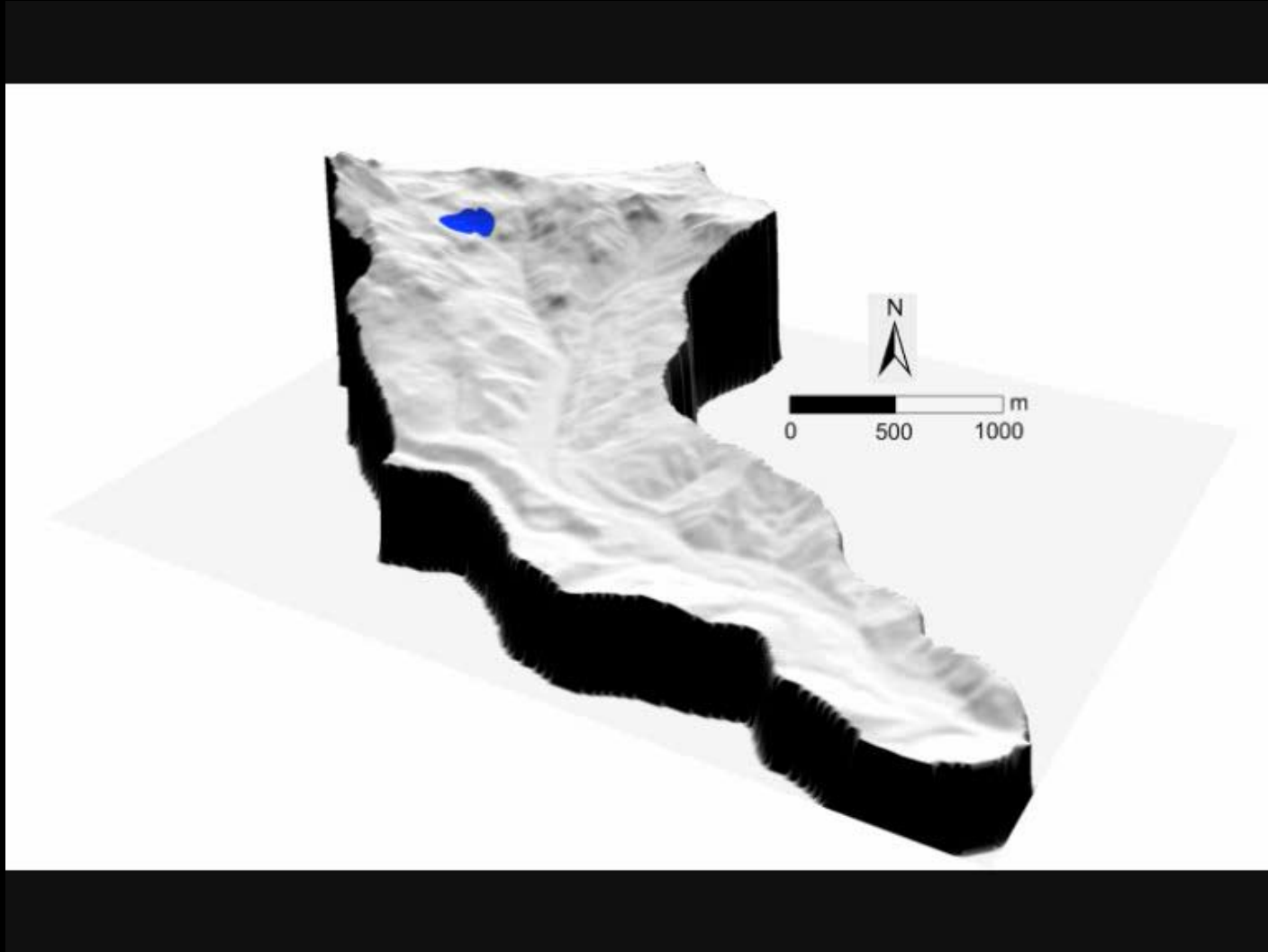


4 Novembre 2010

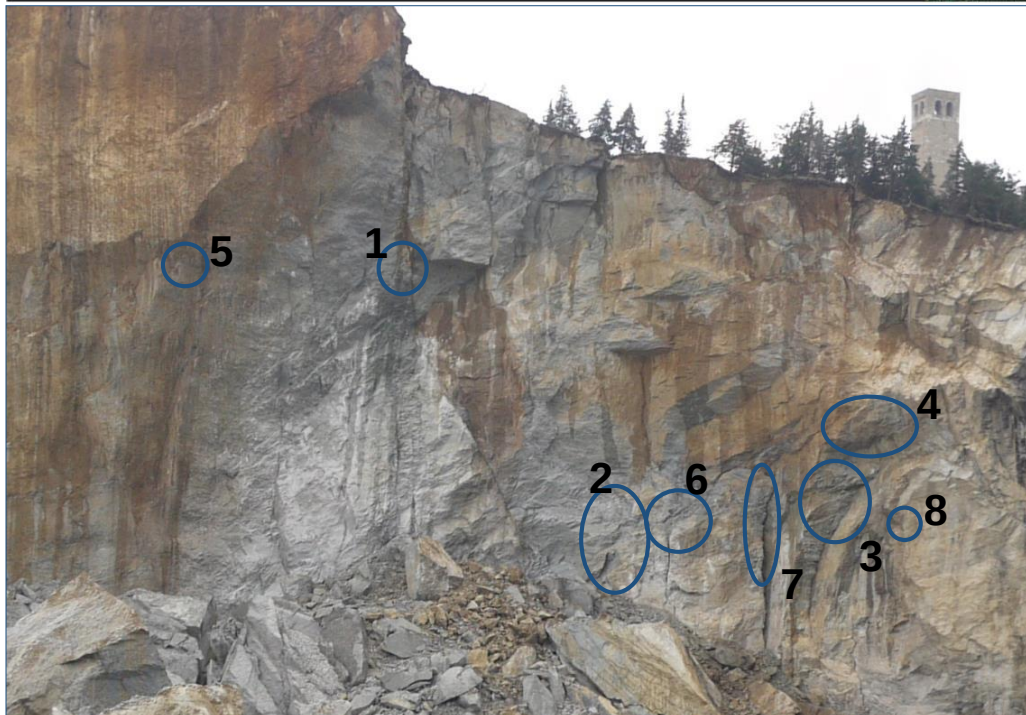
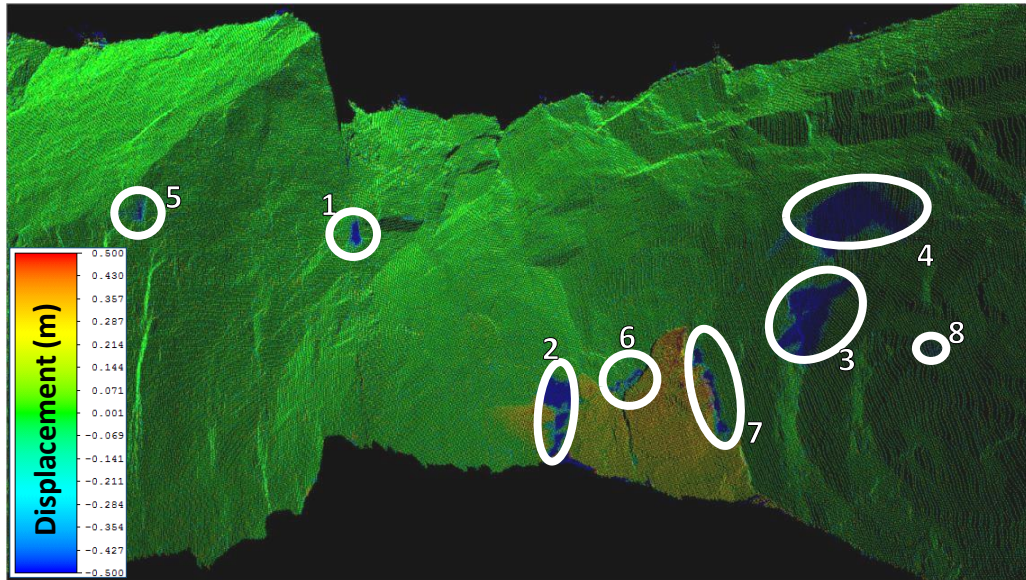
Rilievo LiDAR



Analisi di Runout



Rockfall detection

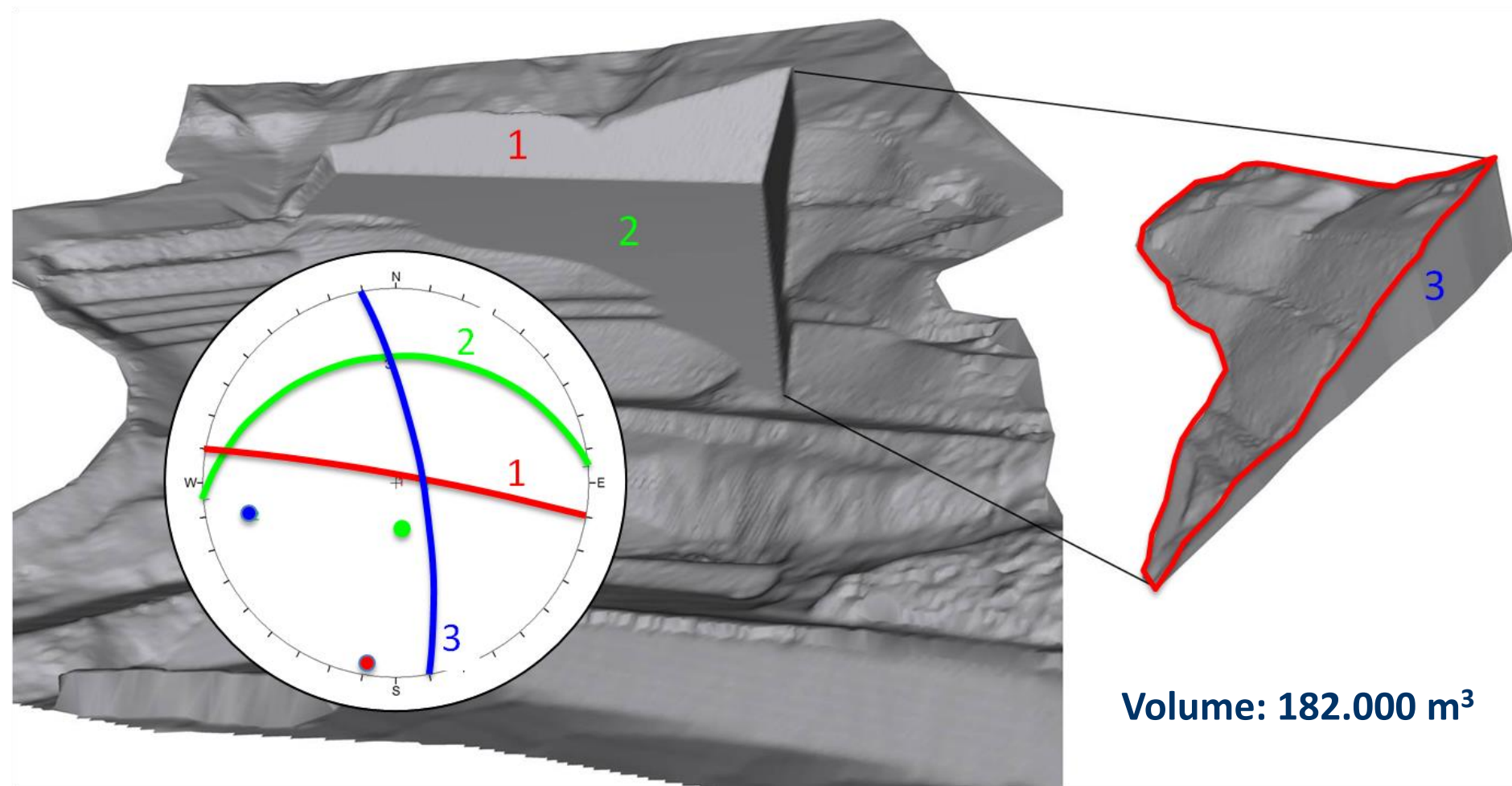


Detached sector	Calculated volume (m ³)	Time interval (2014)
1	10	June 11th – December 18th
2	44	June 11th – December 18th
3	66	June 11th – December 18th
4	94	April 9th - June 11th
5	2	June 11th – December 18th
6	2	June 11th – December 18th
7	1,5	June 11th – December 18th
8	1	June 11th – December 18th

Calcolo magnitudo

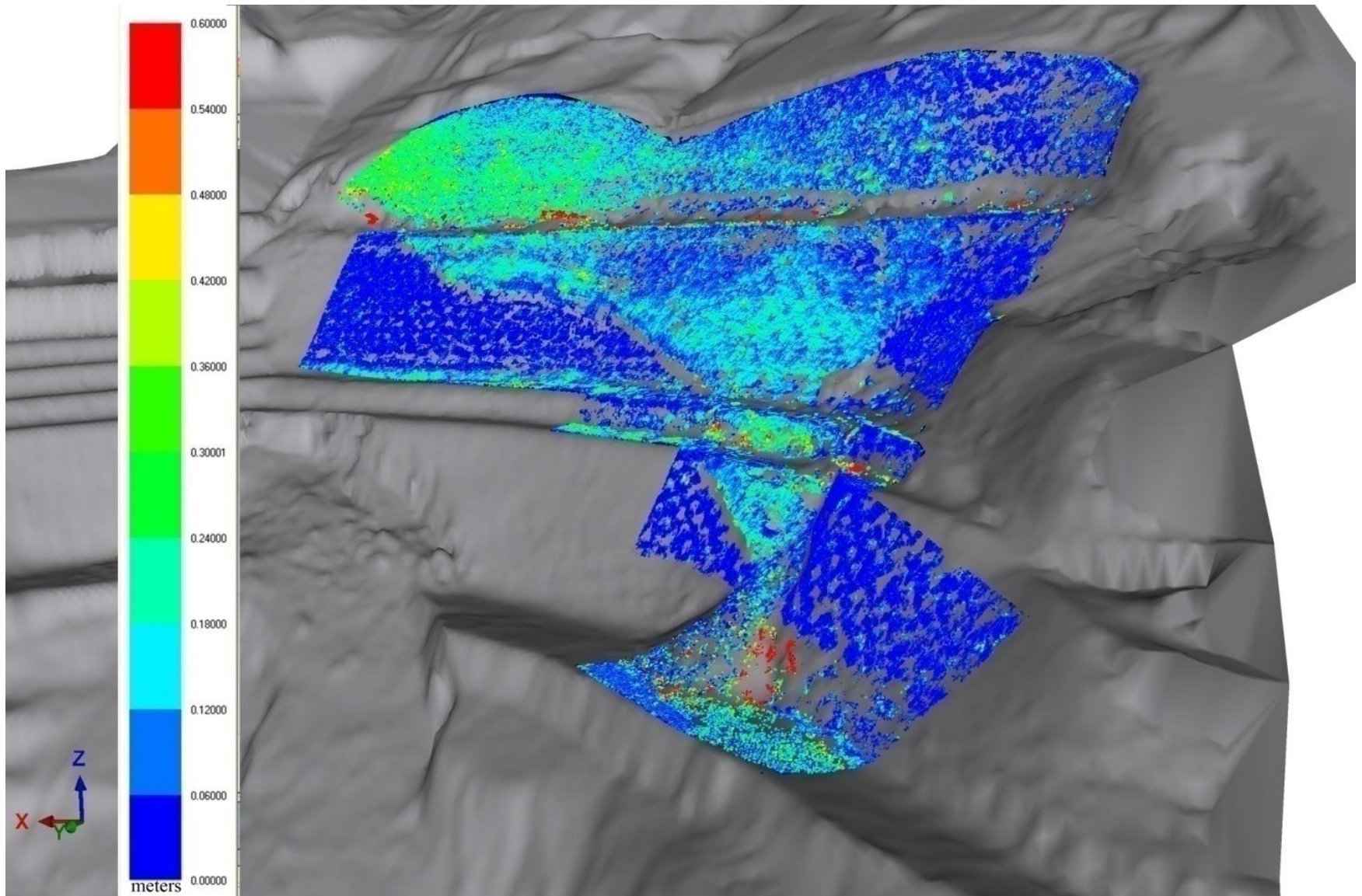


Calcolo magnitudo



(Gigli et al., 2013)

Monitoraggio



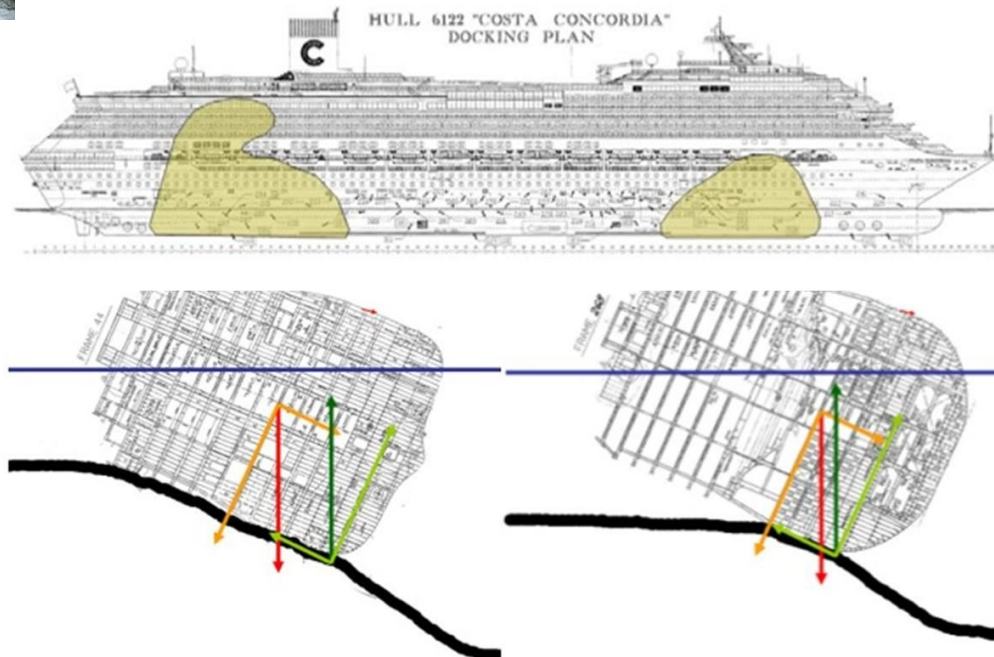
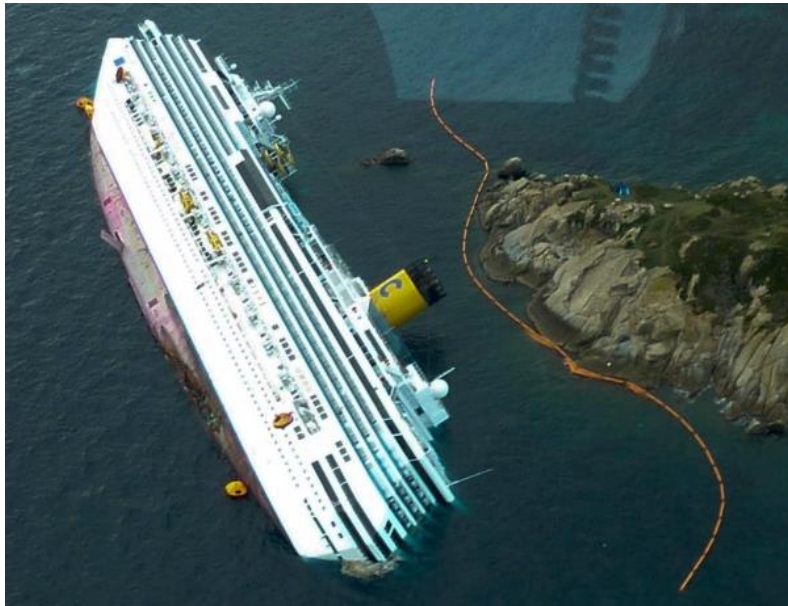
(Gigli et al., 2013)

13 gennaio 2012

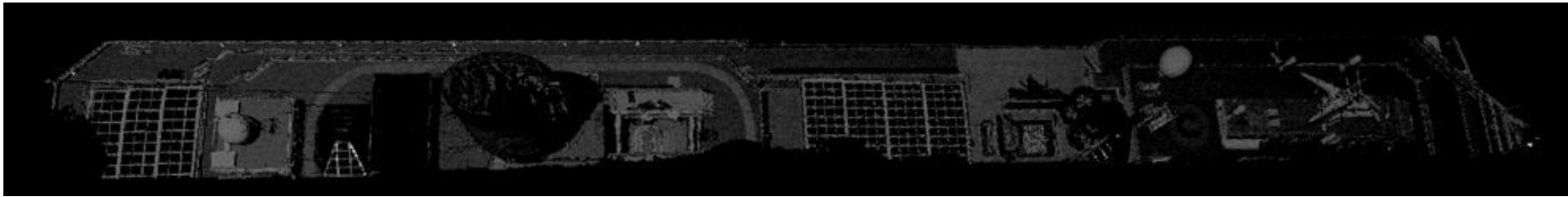


- Gross tonnage 114 500
- Length 290 m
- Passengers 3700
- Crew 1100

32 Casualties



3D Laser scanner



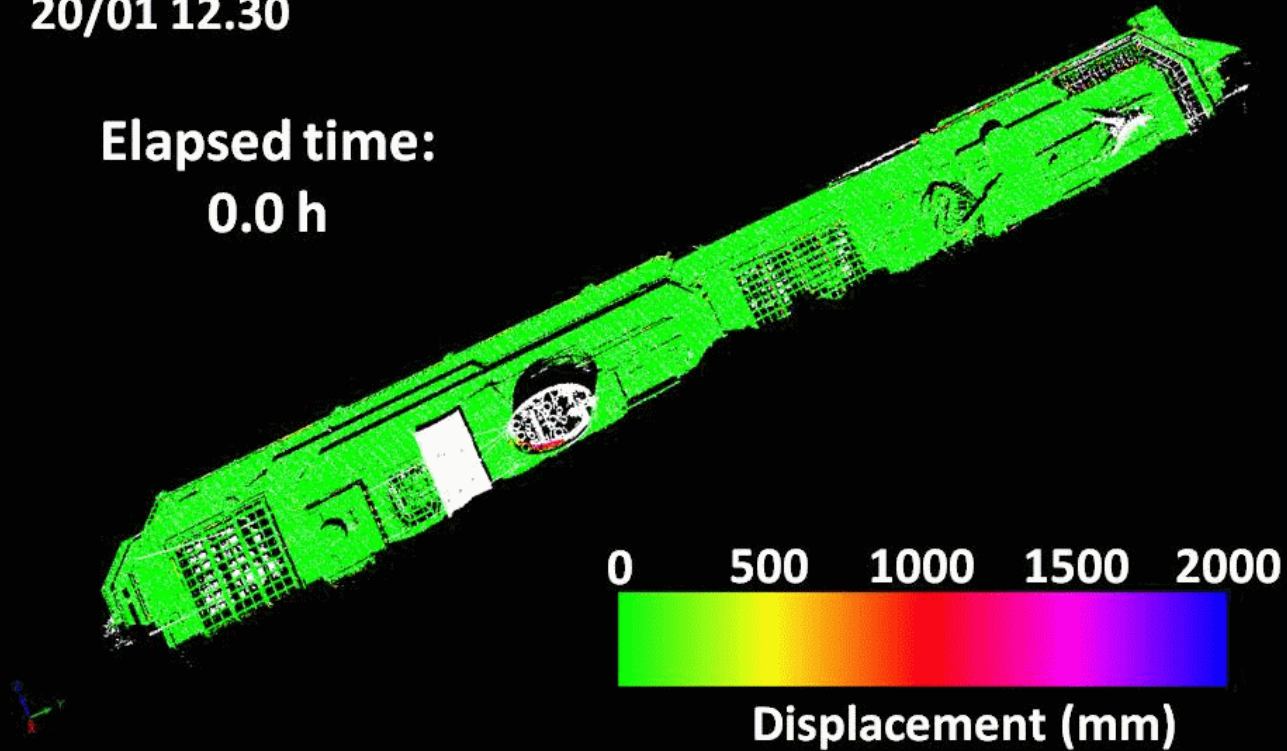
Università degli Studi di Firenze
Dipartimento di Scienze della Terra
CENTRO DI COMPETENZA DEL DIPARTIMENTO DELLA
PROTEZIONE CIVILE - PRESIDENZA DEL CONSIGLIO DEI MINISTRI



Monitoraggio TLS

20/01 12.30

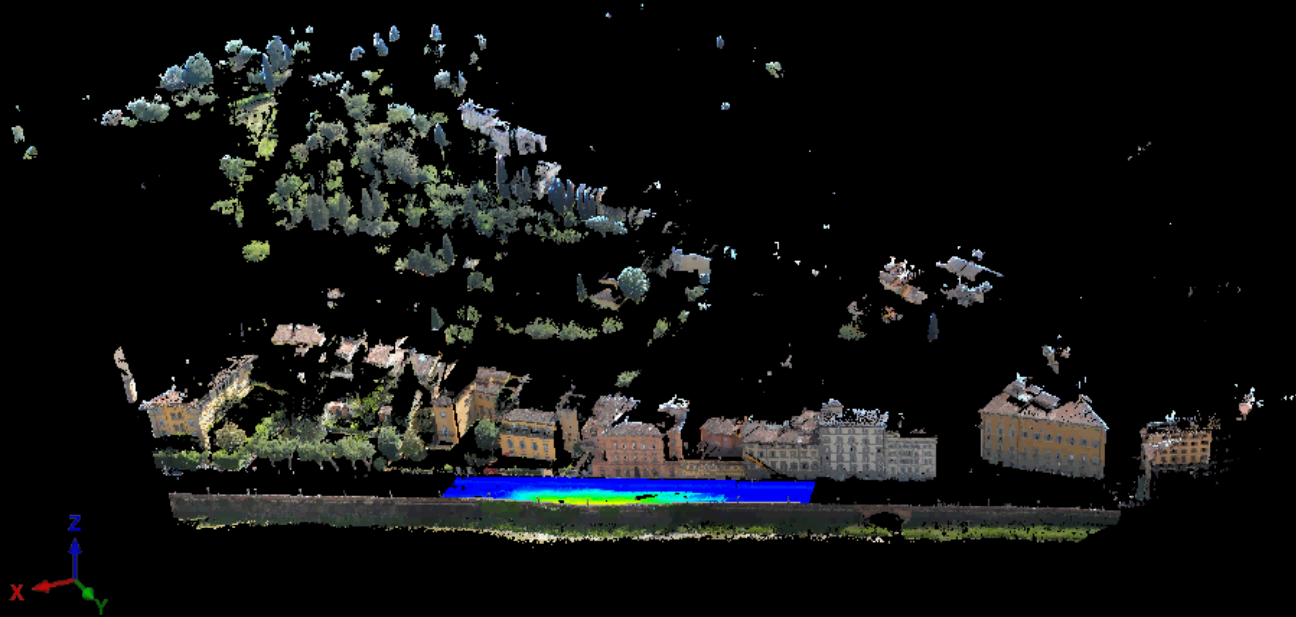
Elapsed time:
0.0 h



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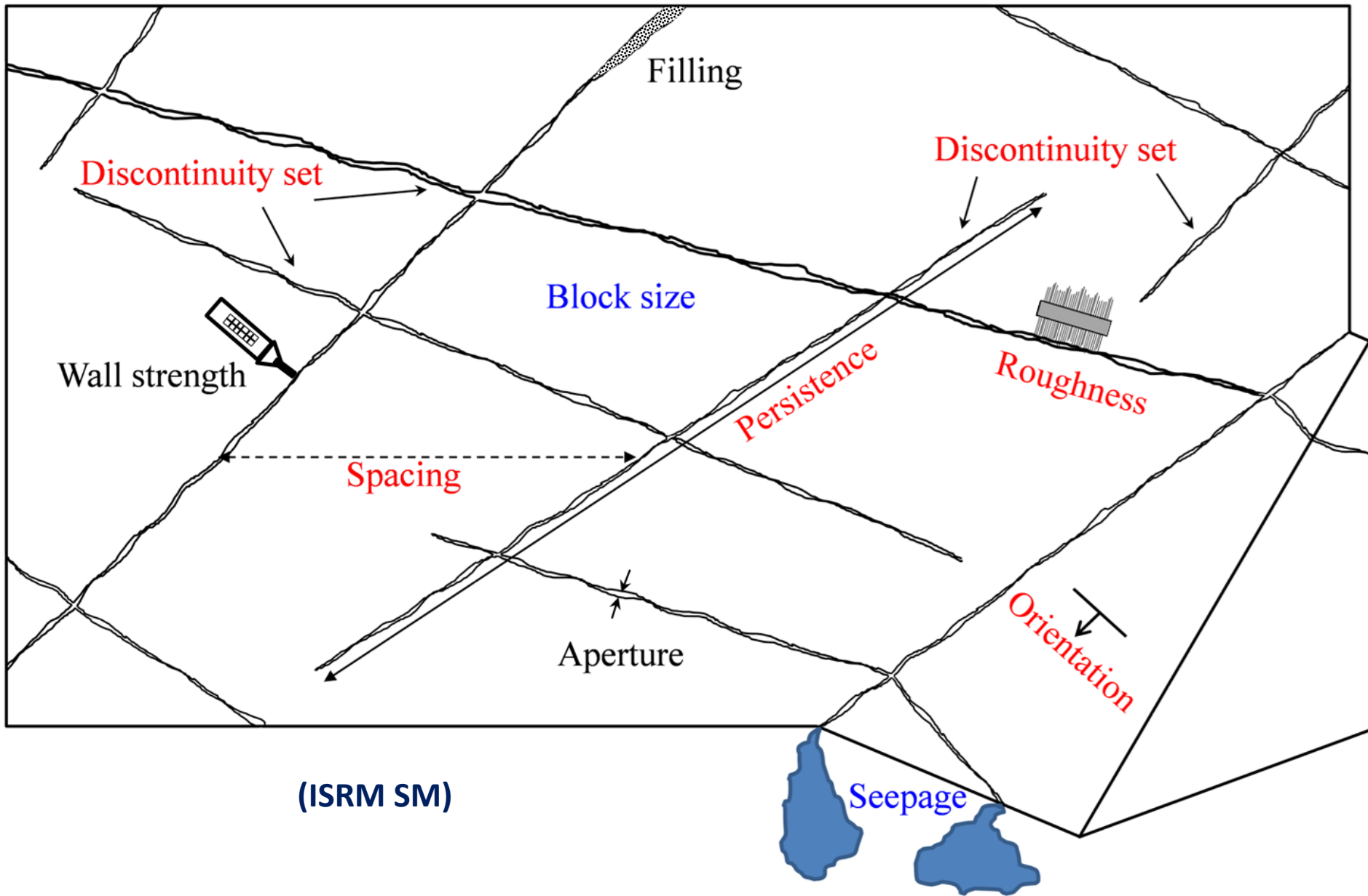


Ricostruzione scenari 3D

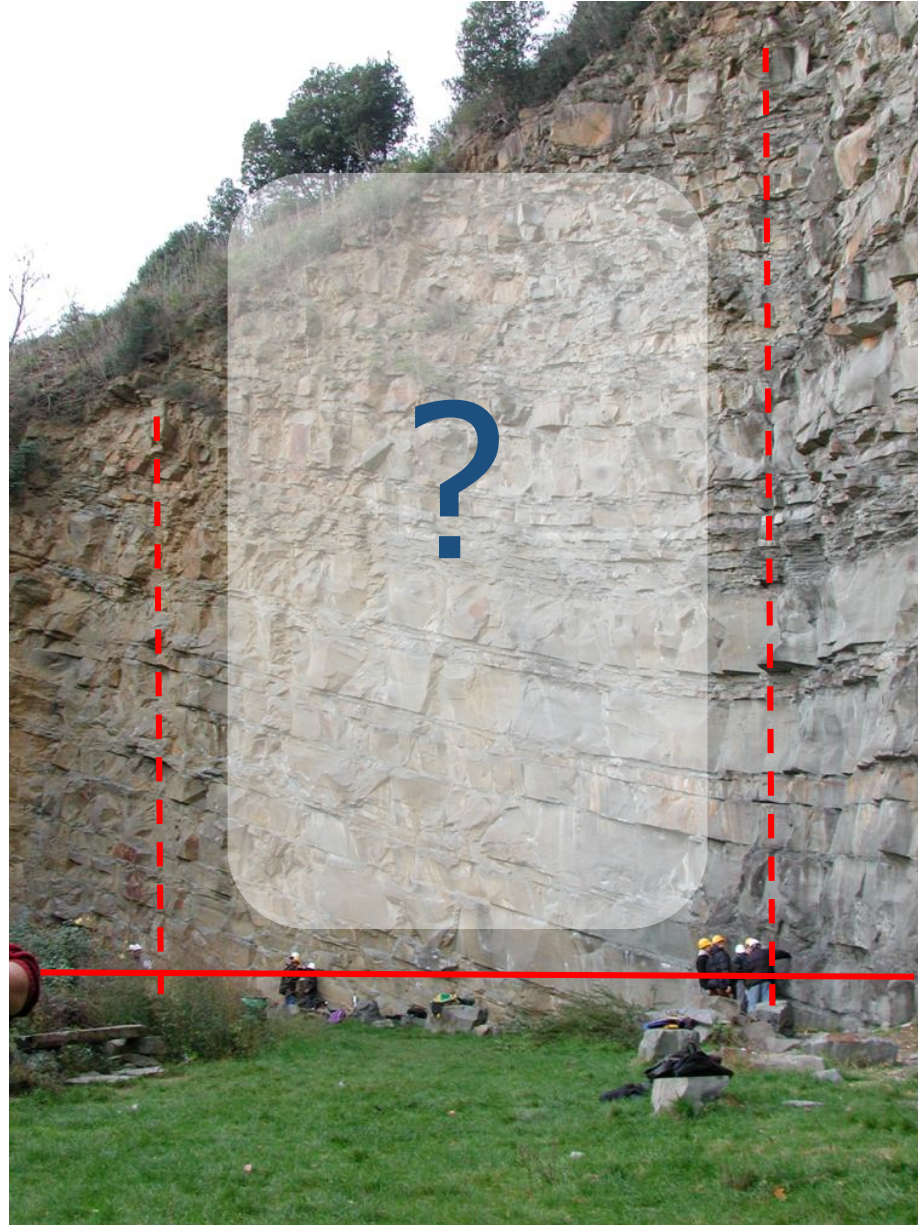


Lungarno Torregiani, 25 maggio 2016

Rilievo geomeccanico



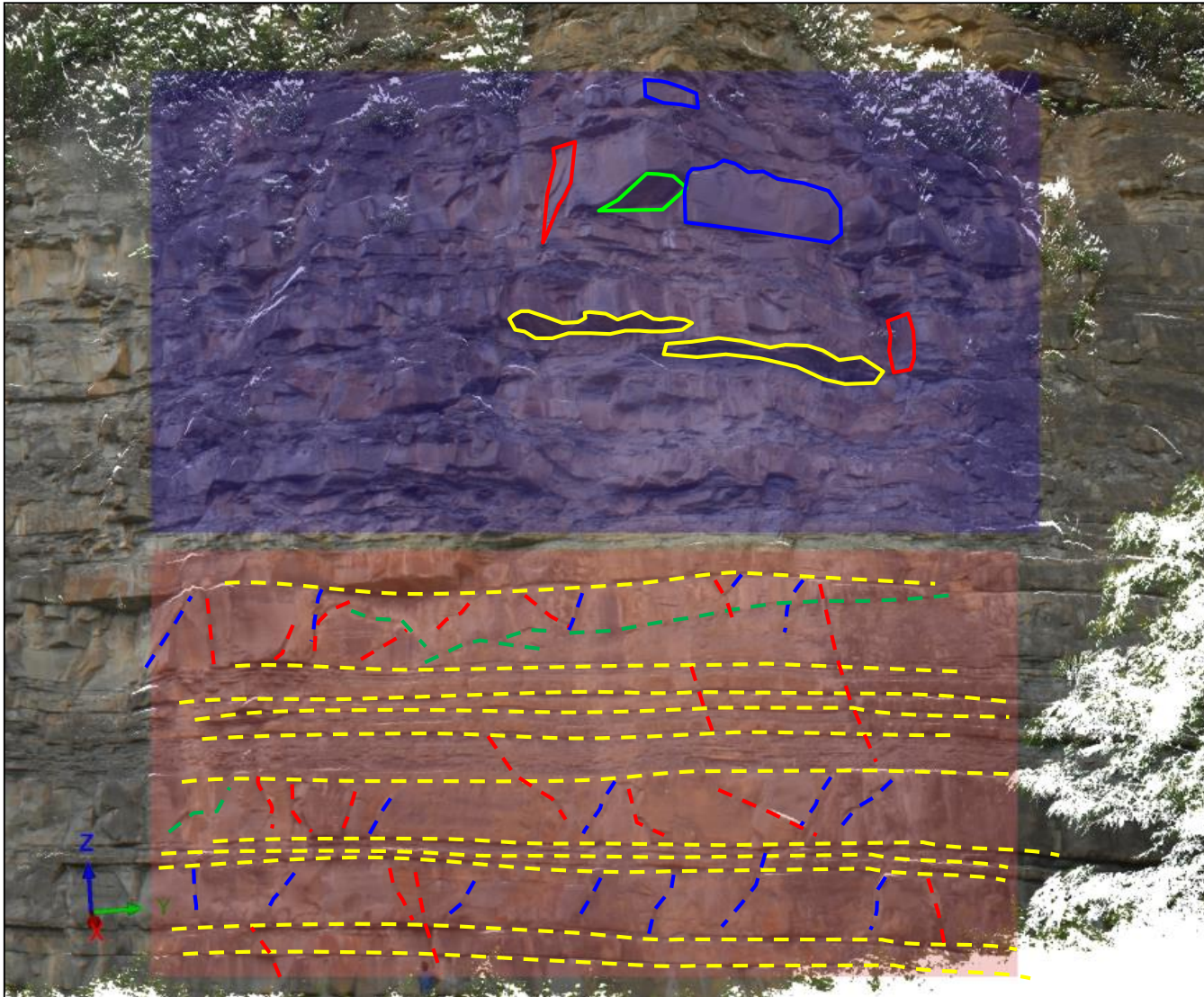
Rilievi tradizionali



DiAna (Discontinuity Analysis)

3D

2D



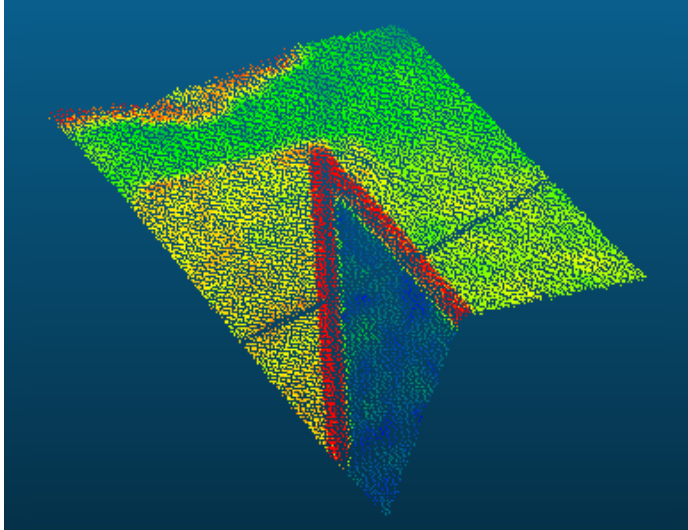
(Gigli and Casagli, 2011)

Individuazione discontinuità

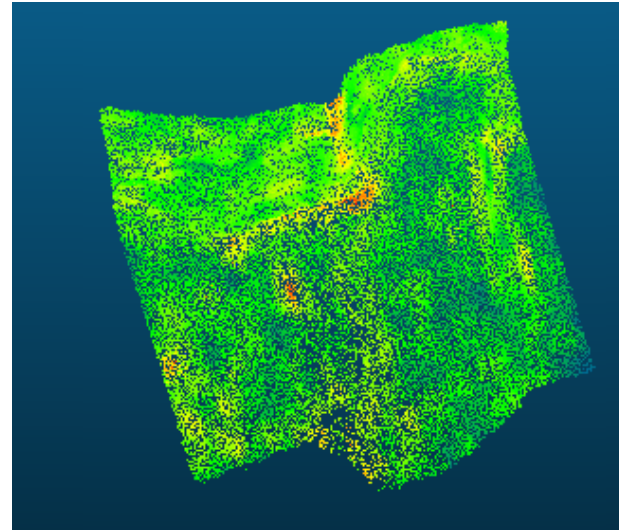
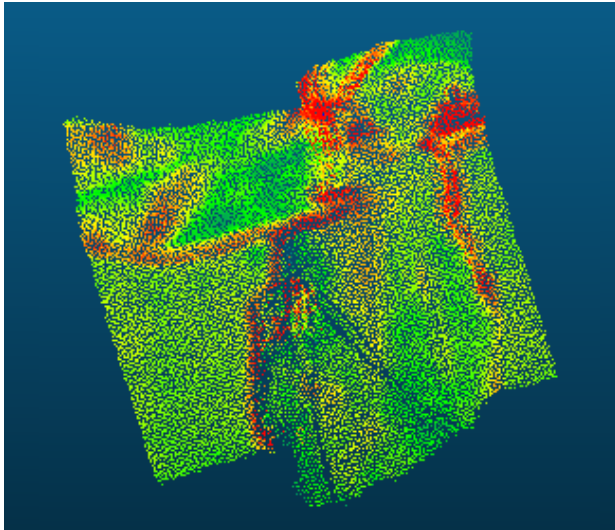
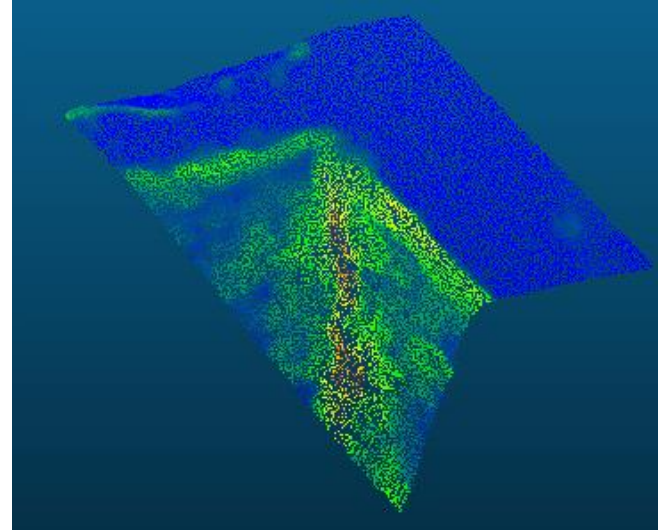


Sharpness

Laser scanner

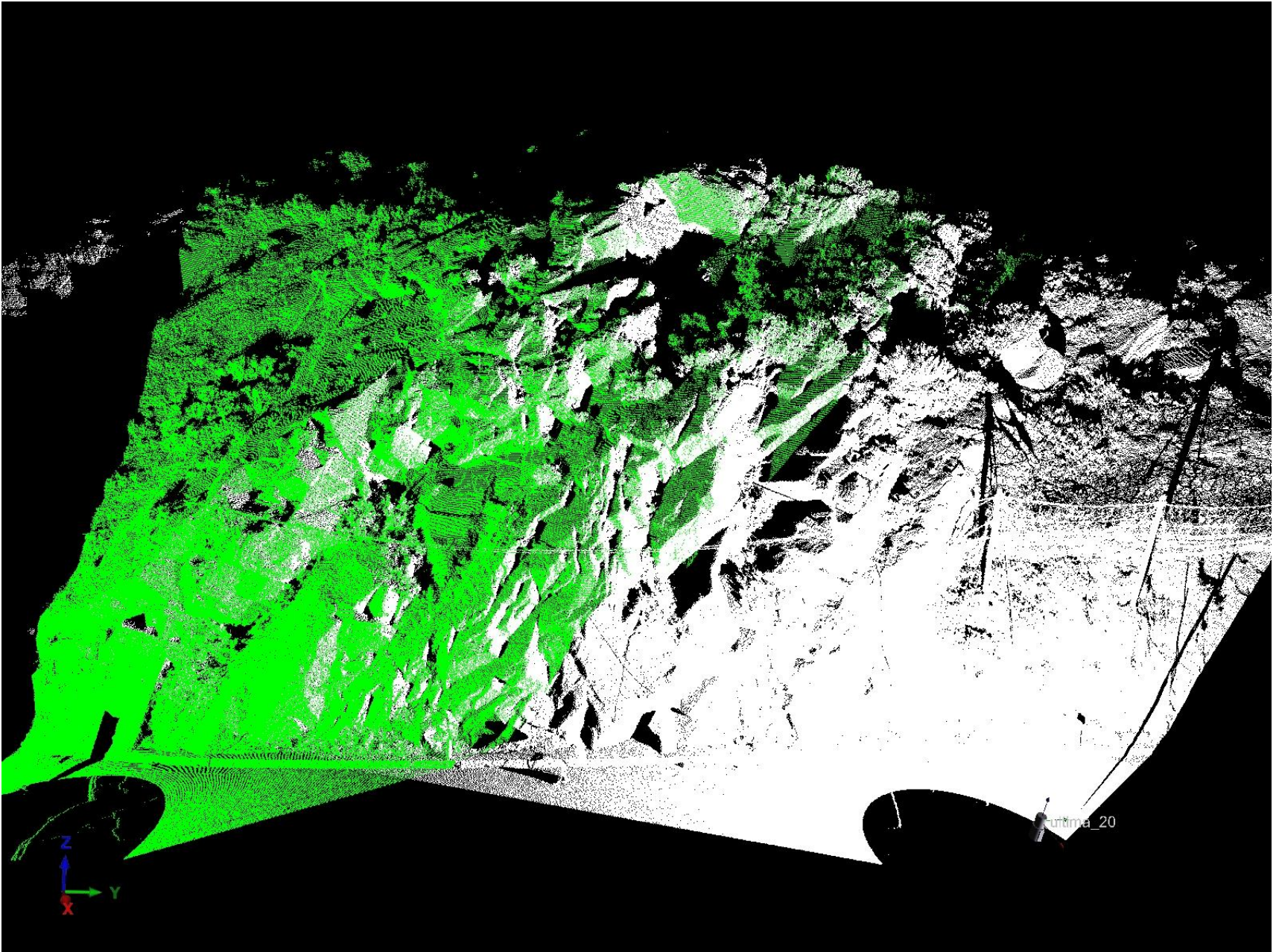


Fotogrammetria



(Giachi, 2017)

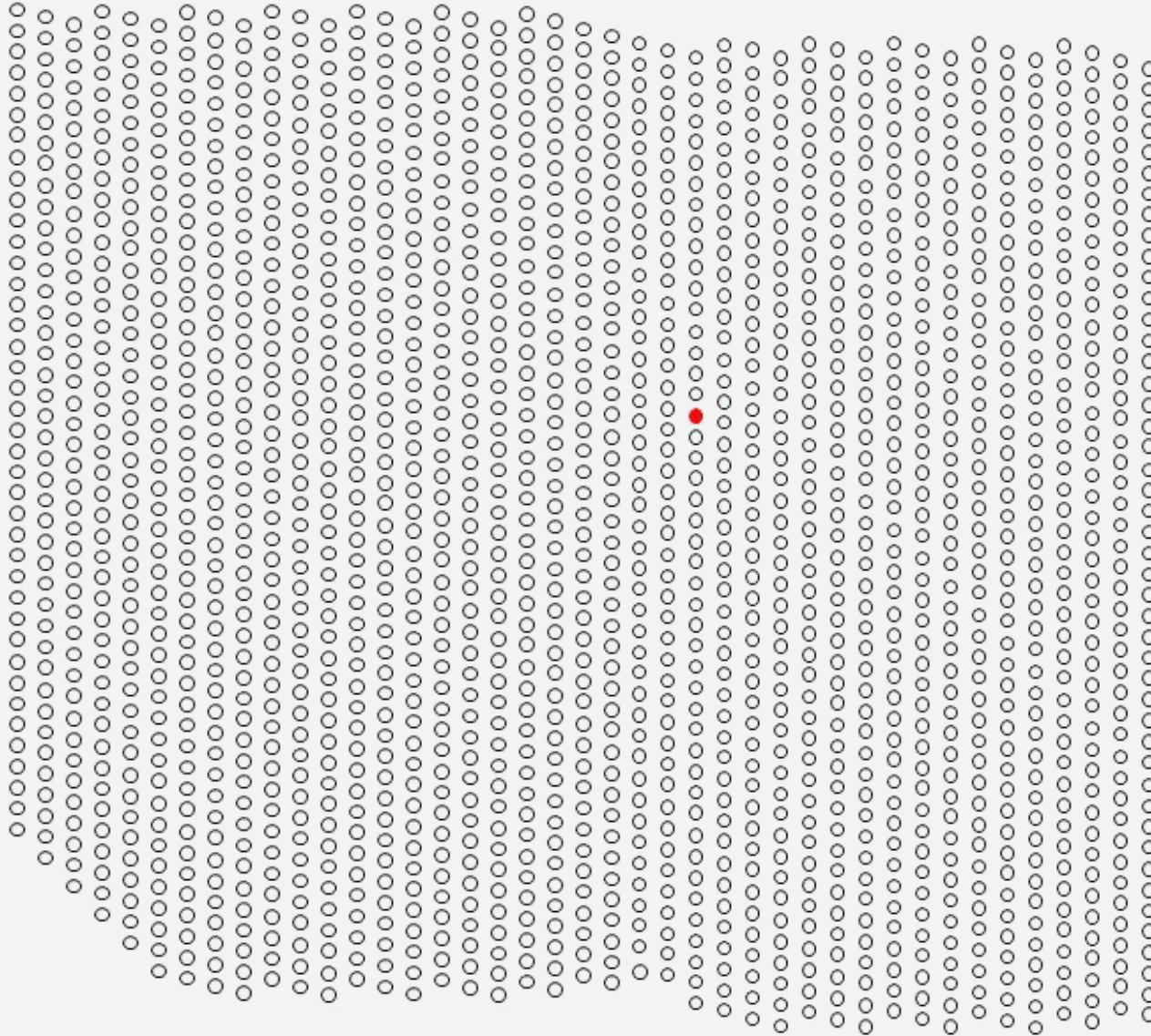
Nuvola “non organizzata”



Nuvola “organizzata”

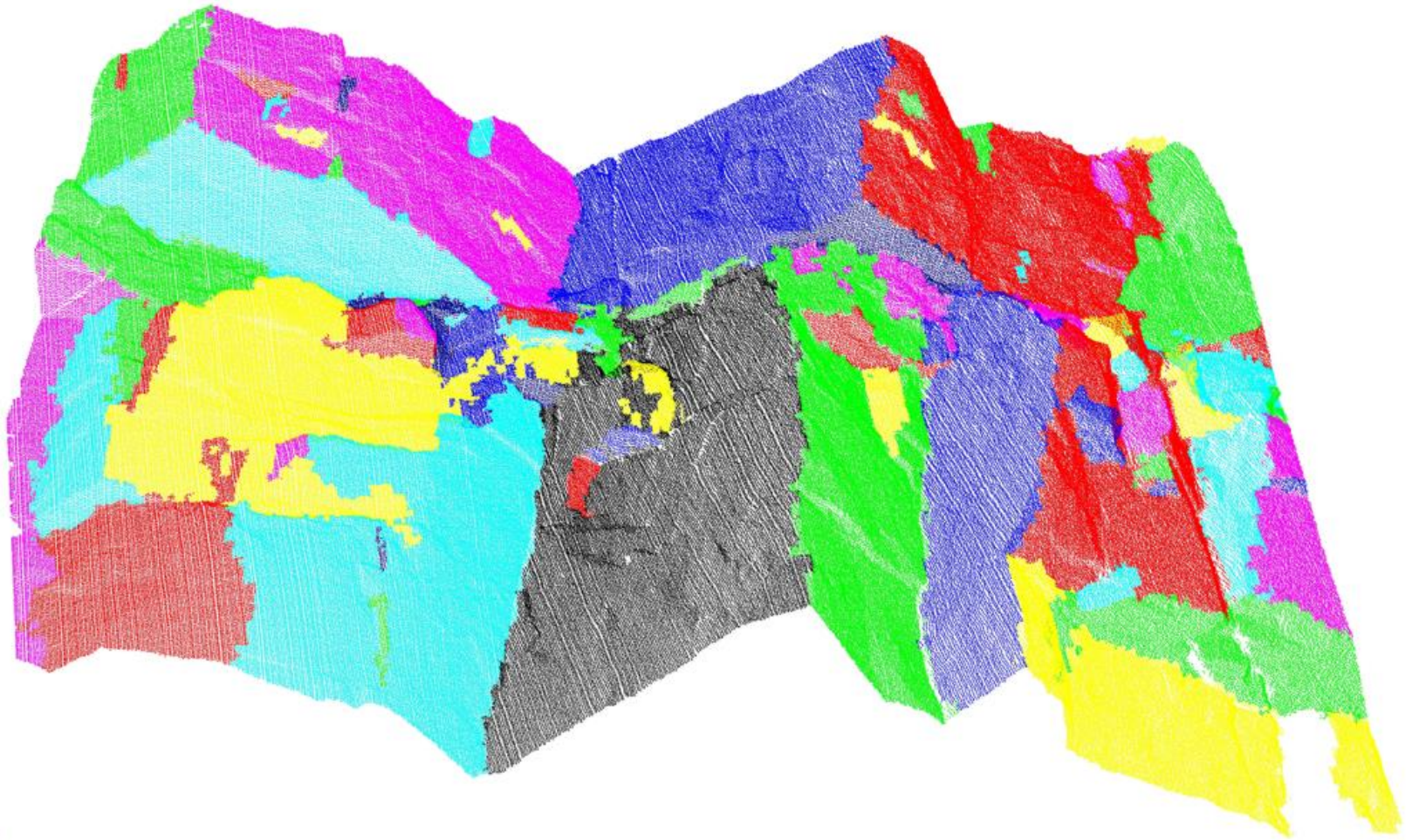


Nuvola “organizzata”

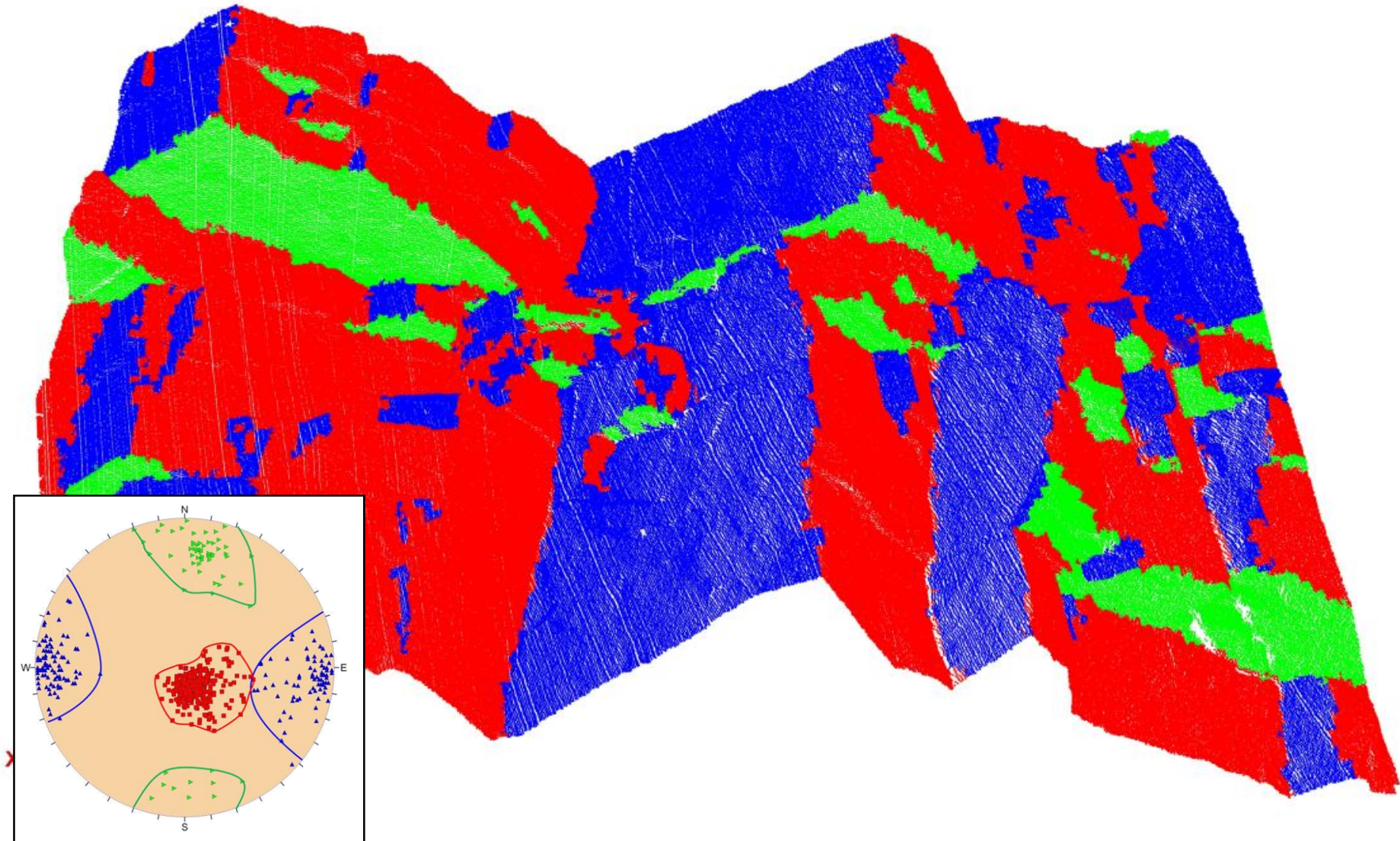


Parametro di input
1) $\sigma_{\max}(m)$

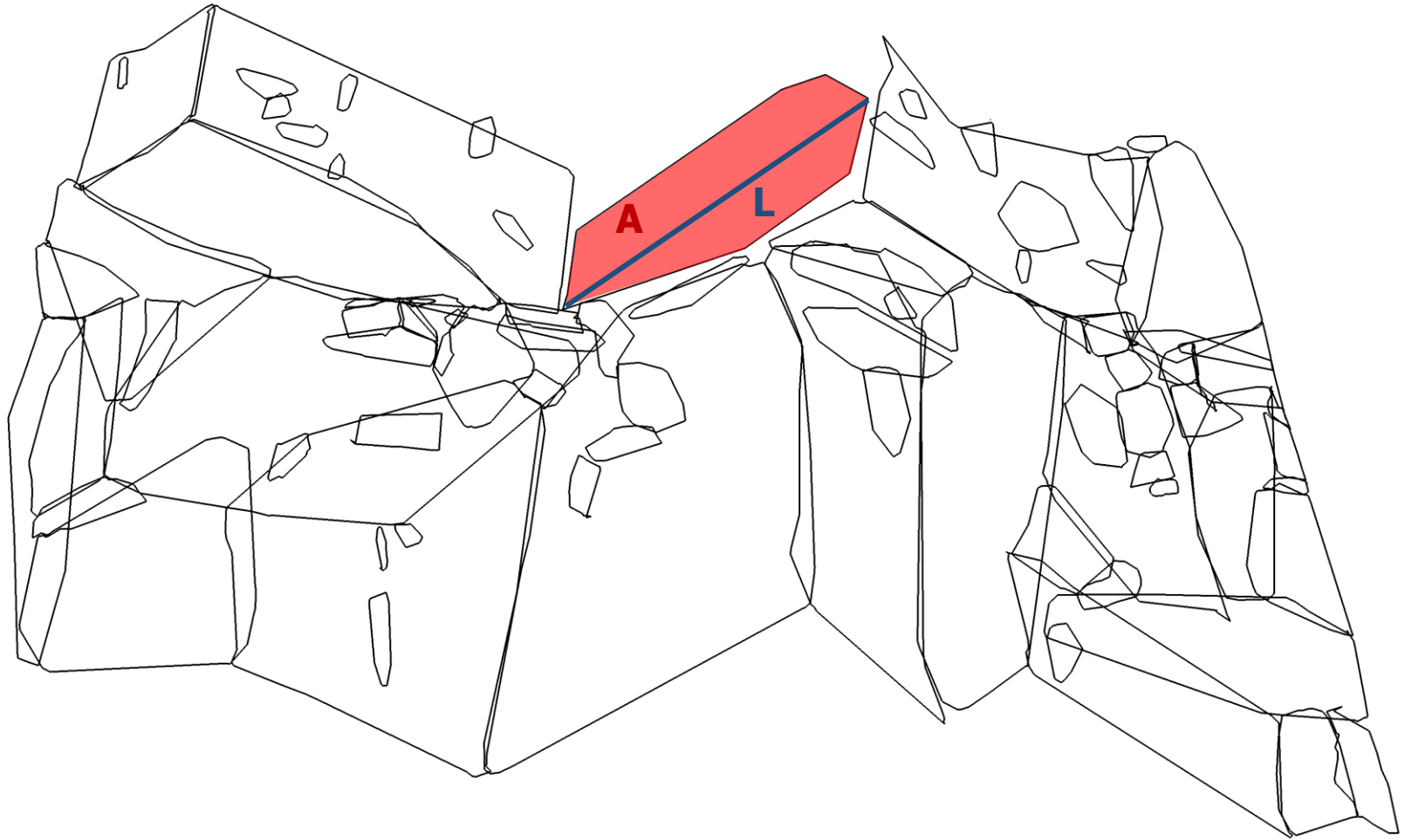
Orientazione joints



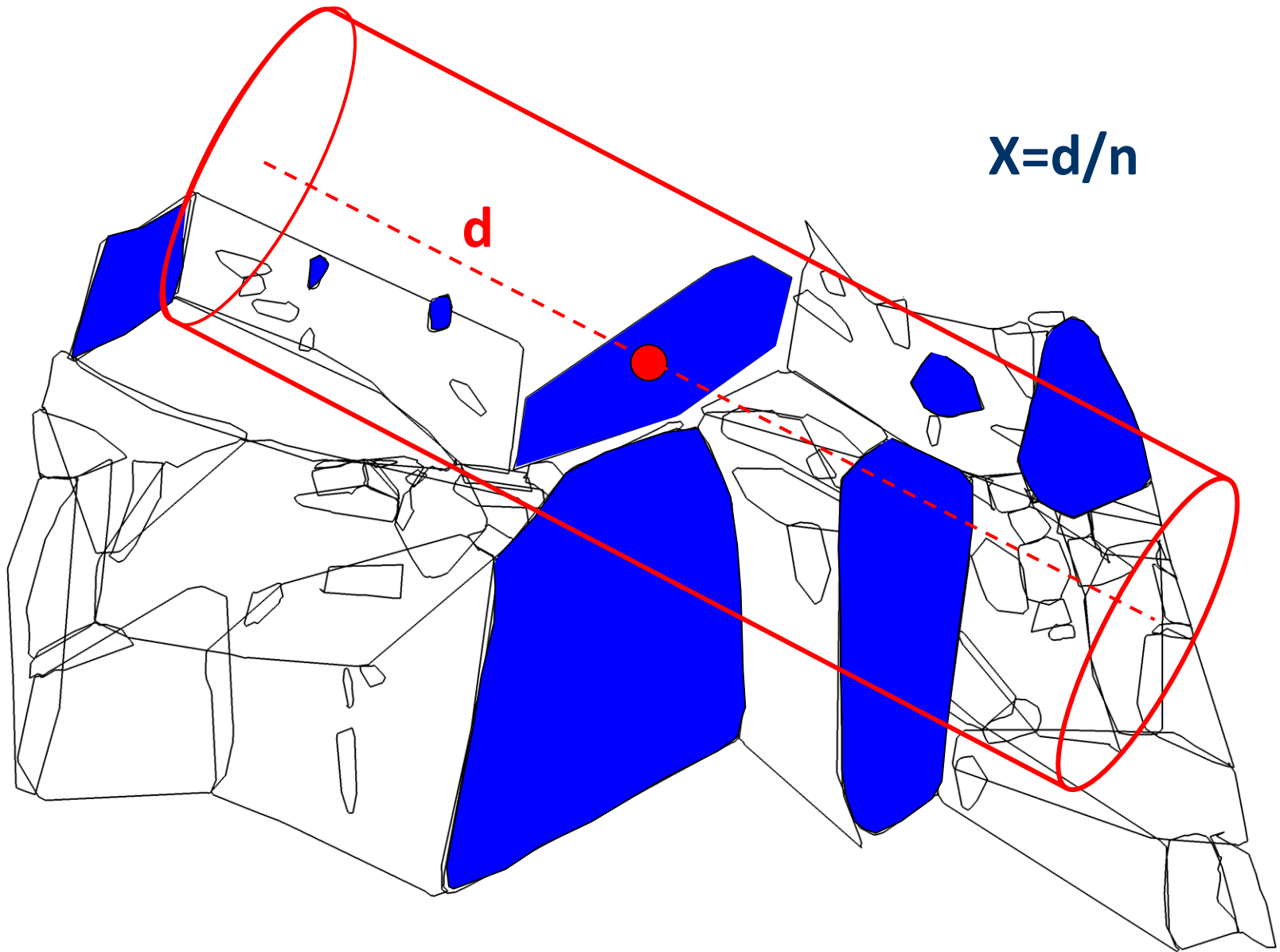
Famiglie di discontinuità



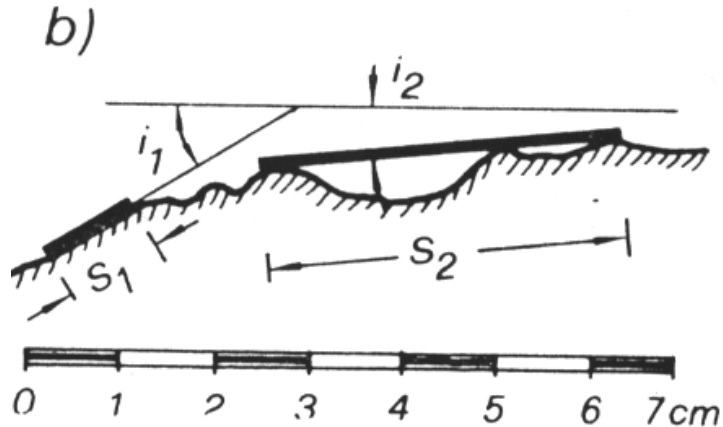
Persistenza



Spaziatura



Rugosità

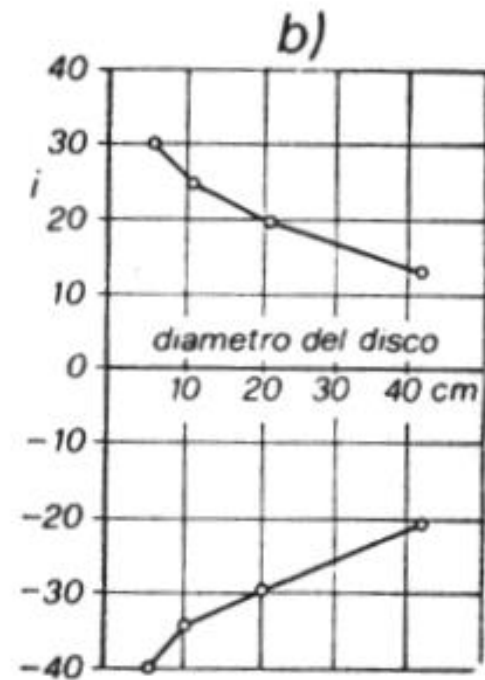
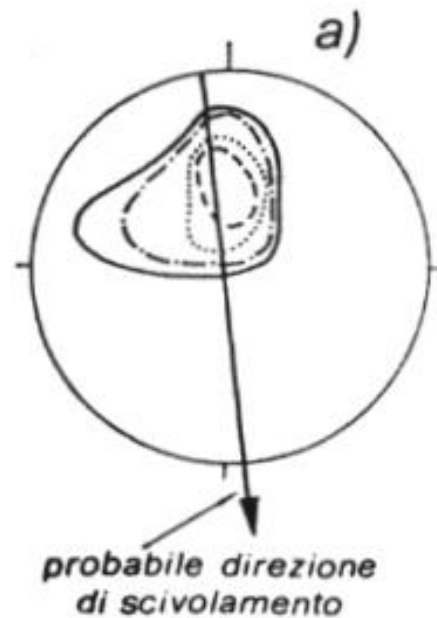


simbolo	ϕ disco cm	n° minimo di misure
—	5,5	100
- - - -	11	75
.....	21	50
- - - -	42	25

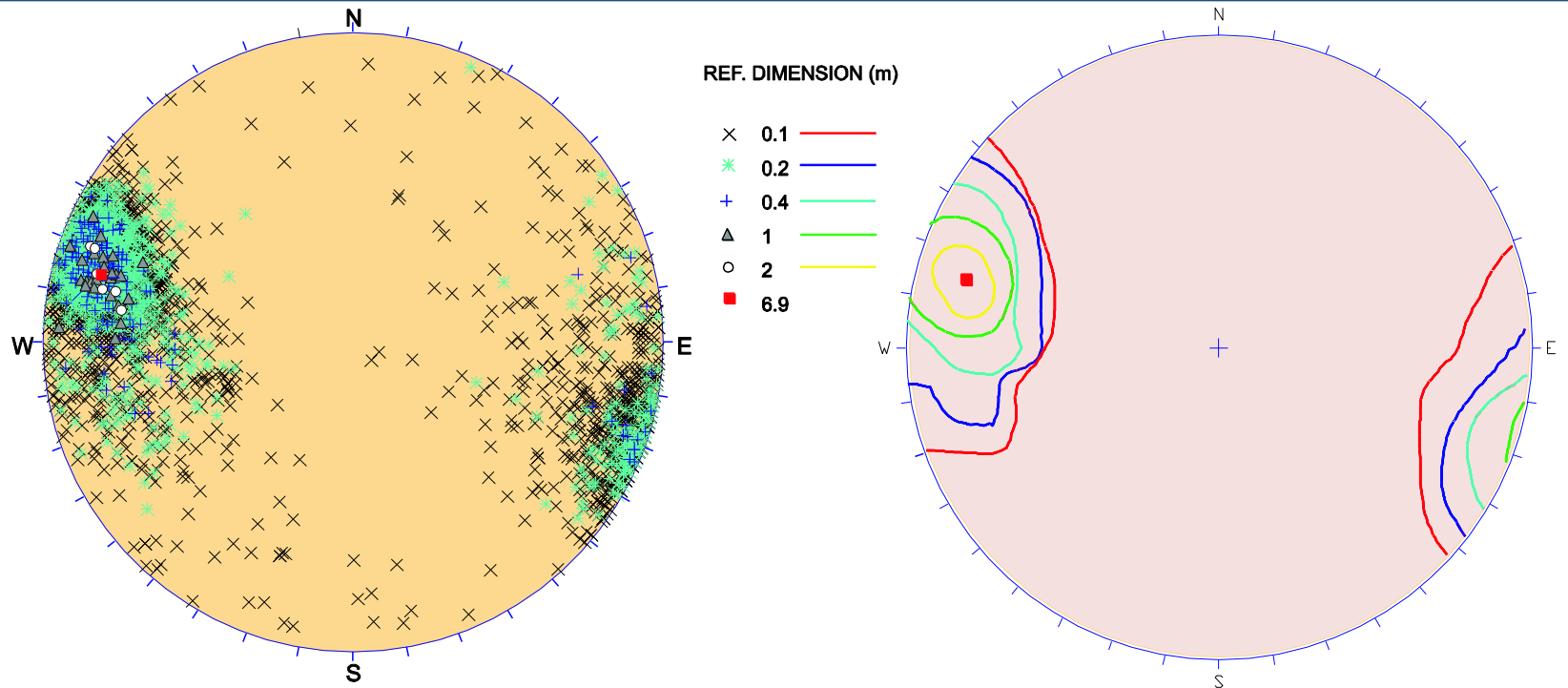
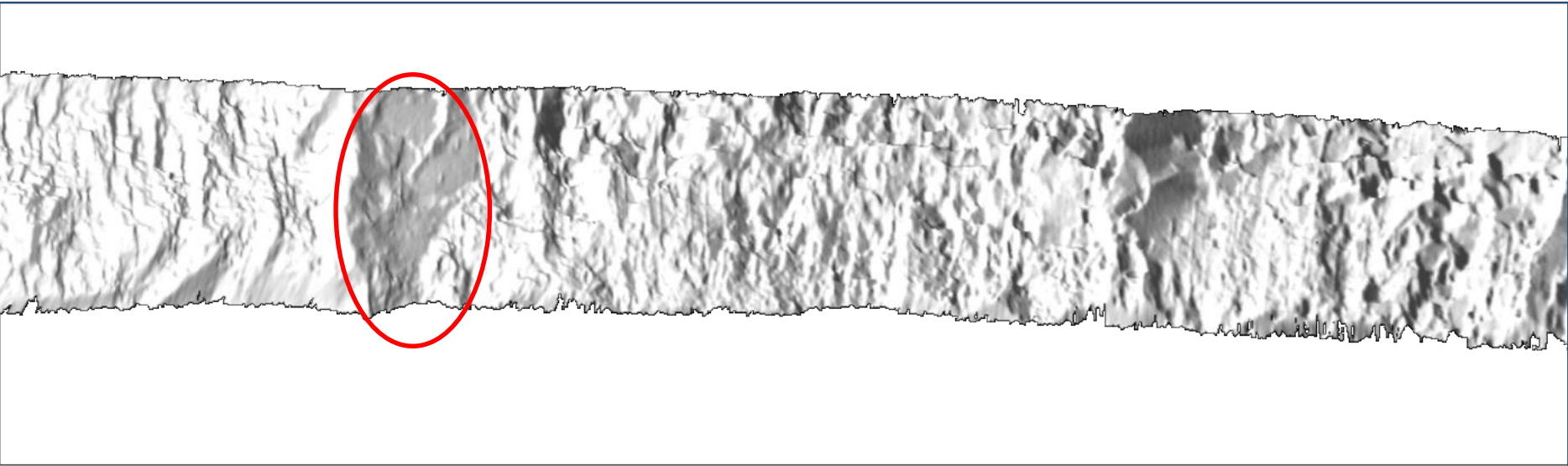
Misura tridimensionale della
rugosità

Si determina l'angolo i di
inclinazione medio delle asperità
in funzione dell'orientazione

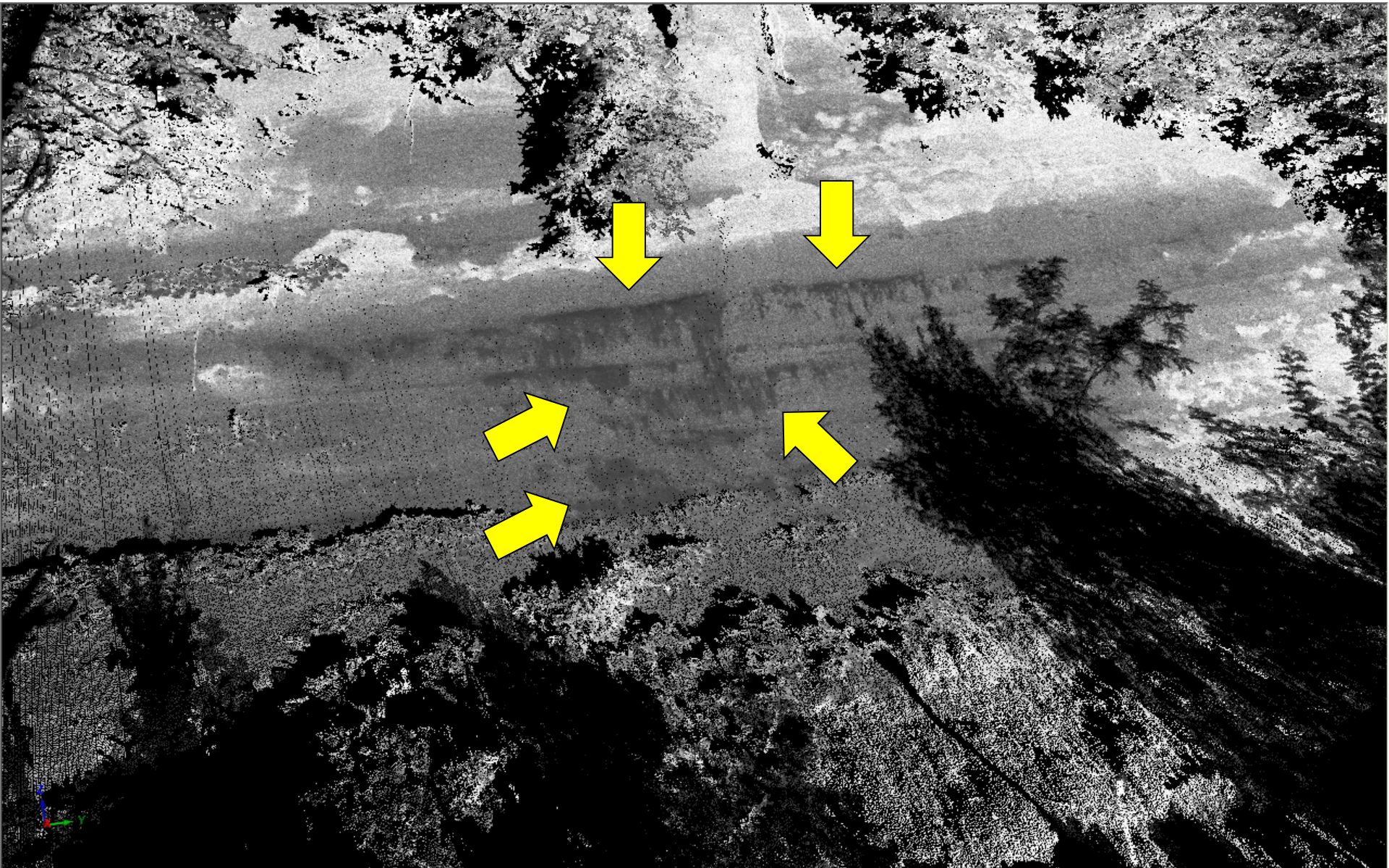
(ISRM, 1978)



Rugosità



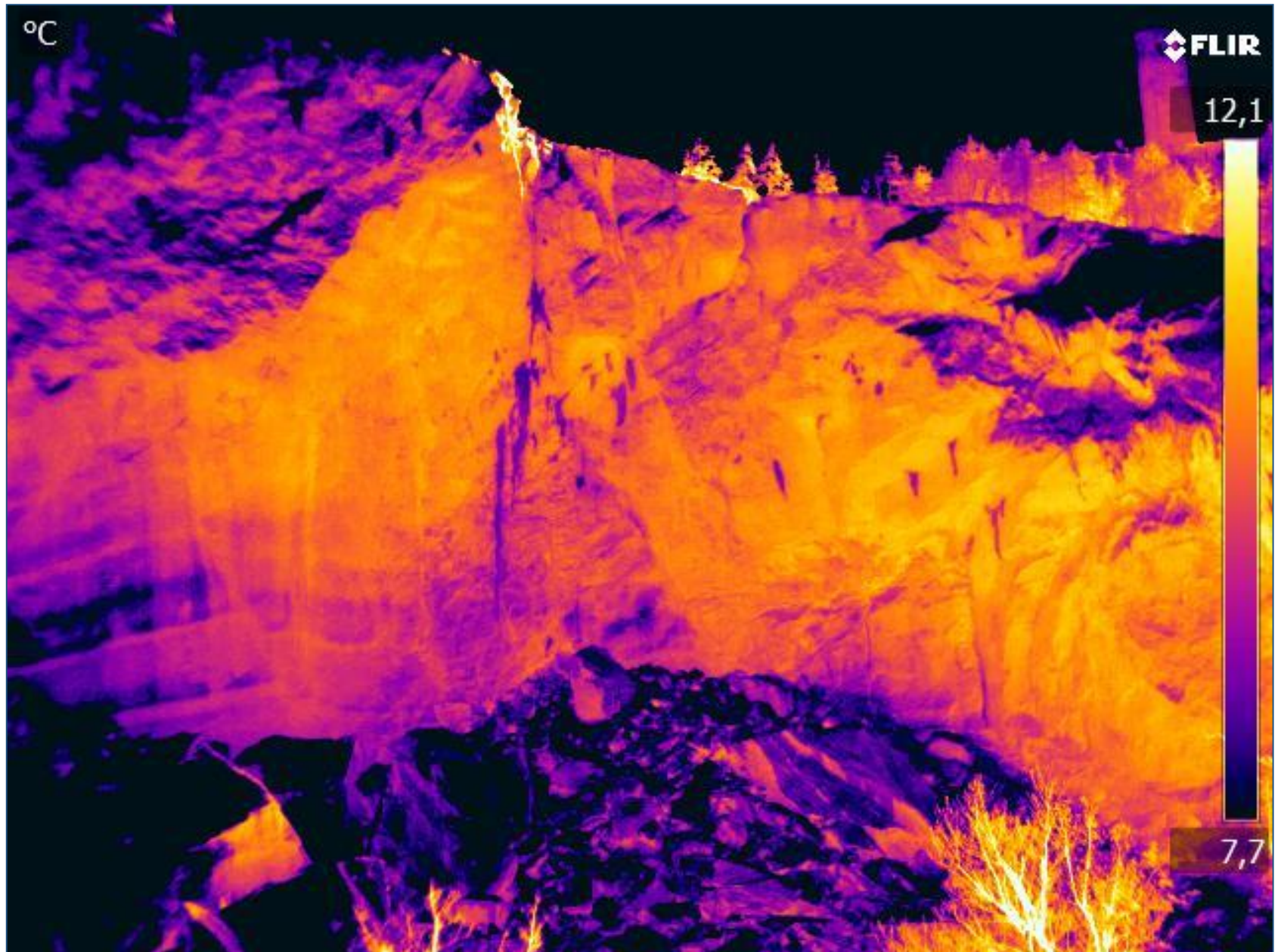
Filtrazione



Termografia ad infrarossi



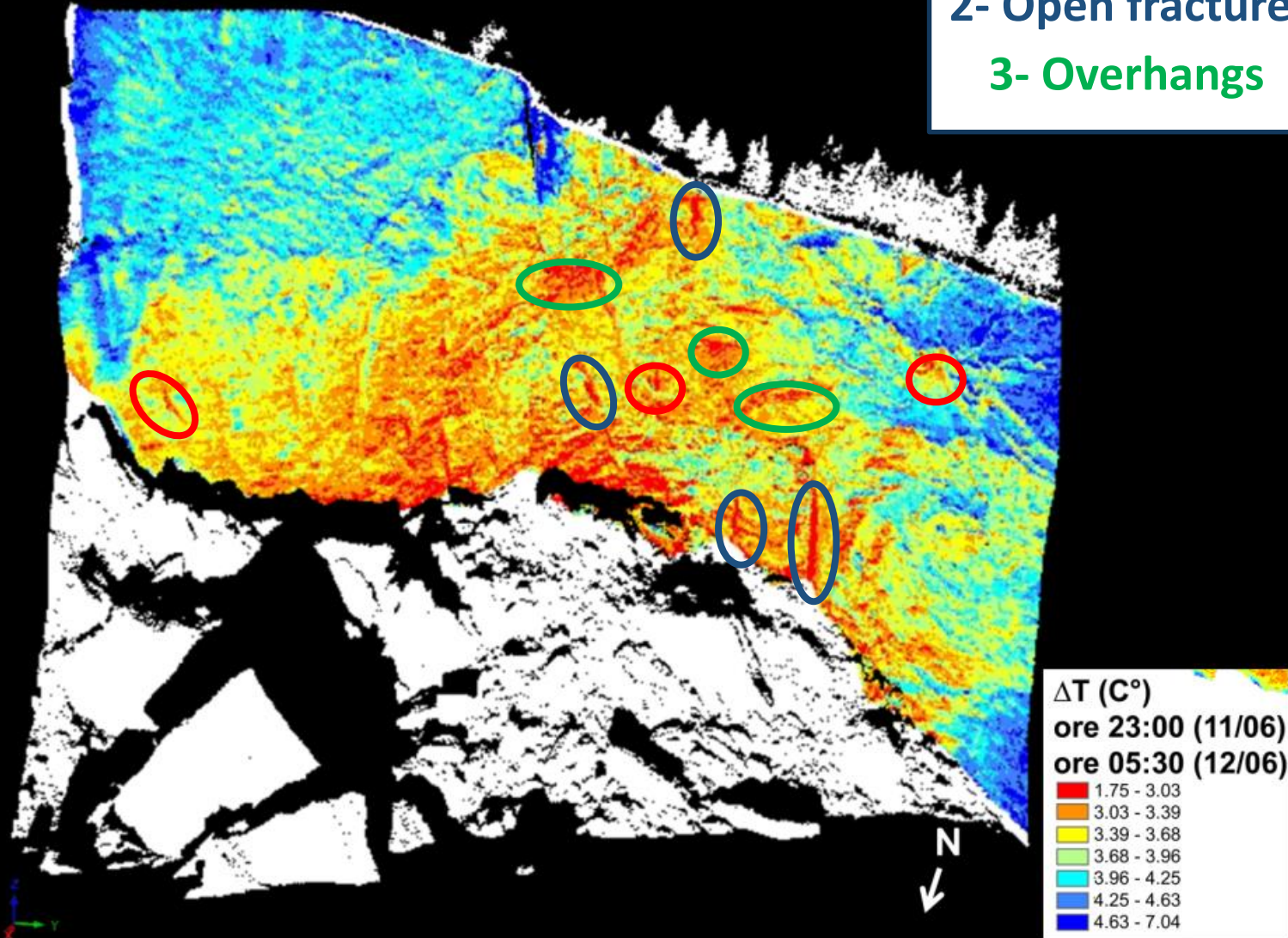
Filtrazione



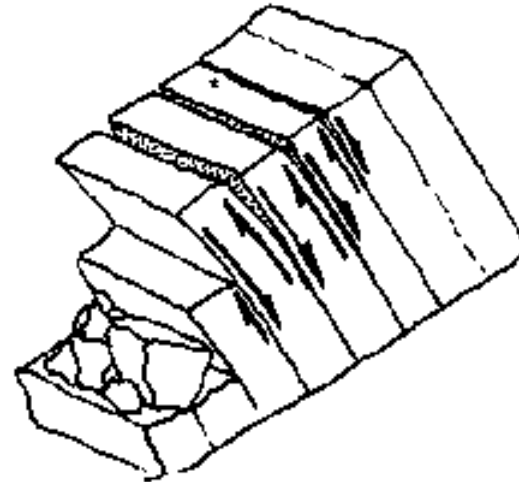
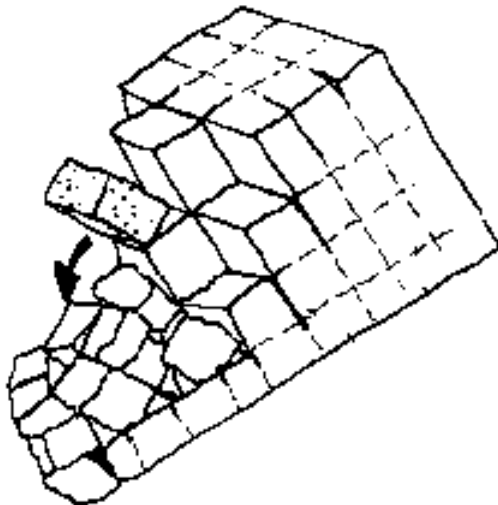
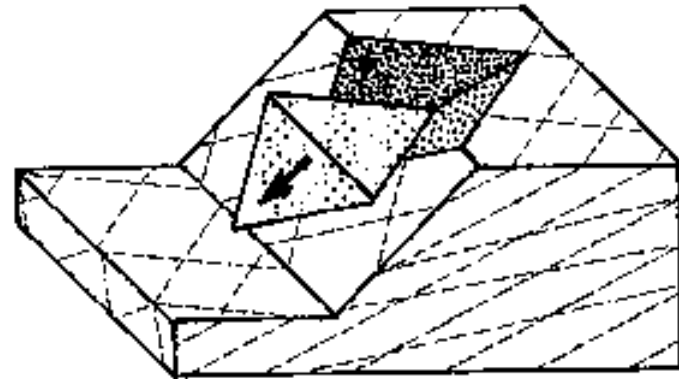
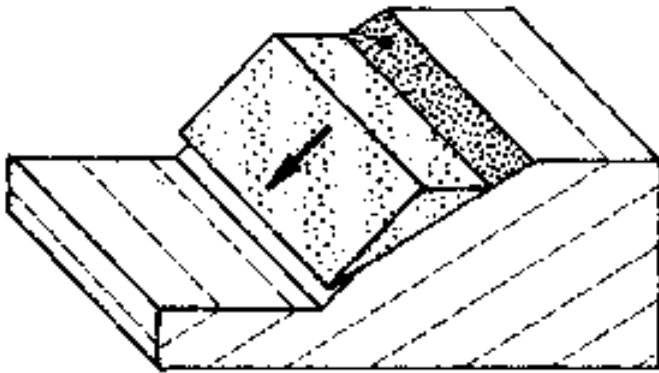
Mappa differenziale (3D)

(Frodella et al., 2016)

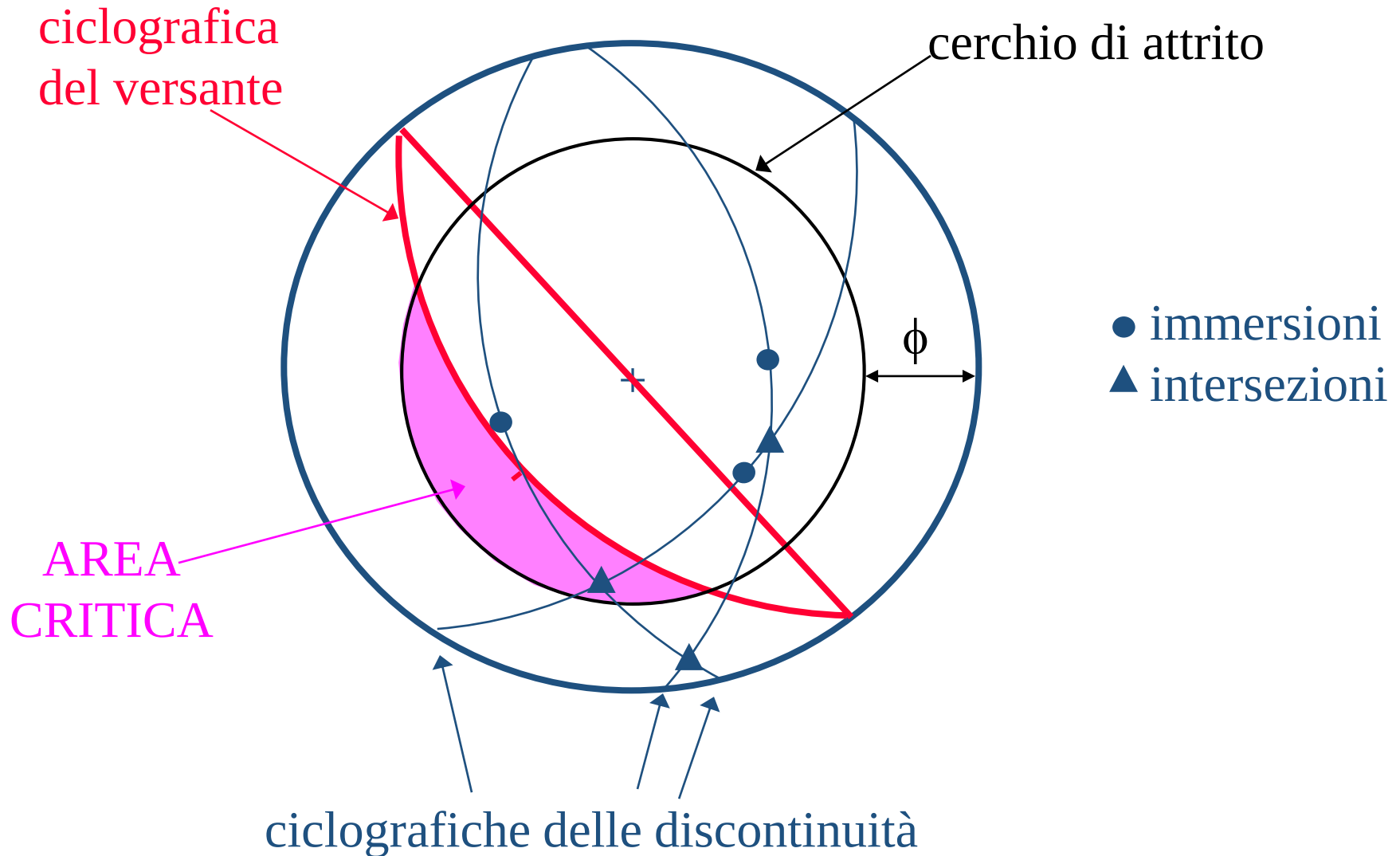
- 1- Niches
- 2- Open fractures
- 3- Overhangs



Analisi cinematica



Analisi cinematica

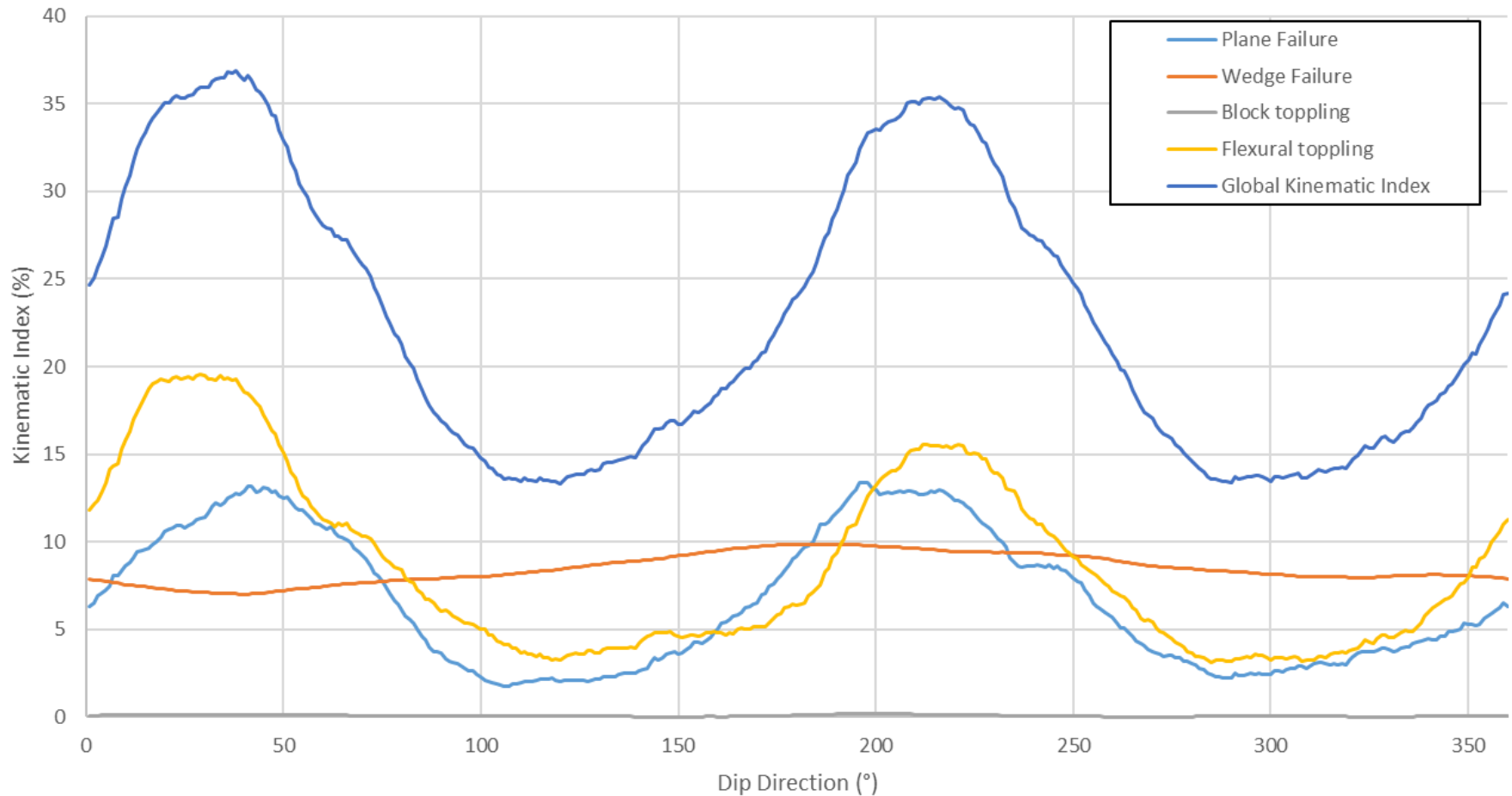


Progettazione scavo a cielo aperto



Analisi cinematica ad Azimut variabile

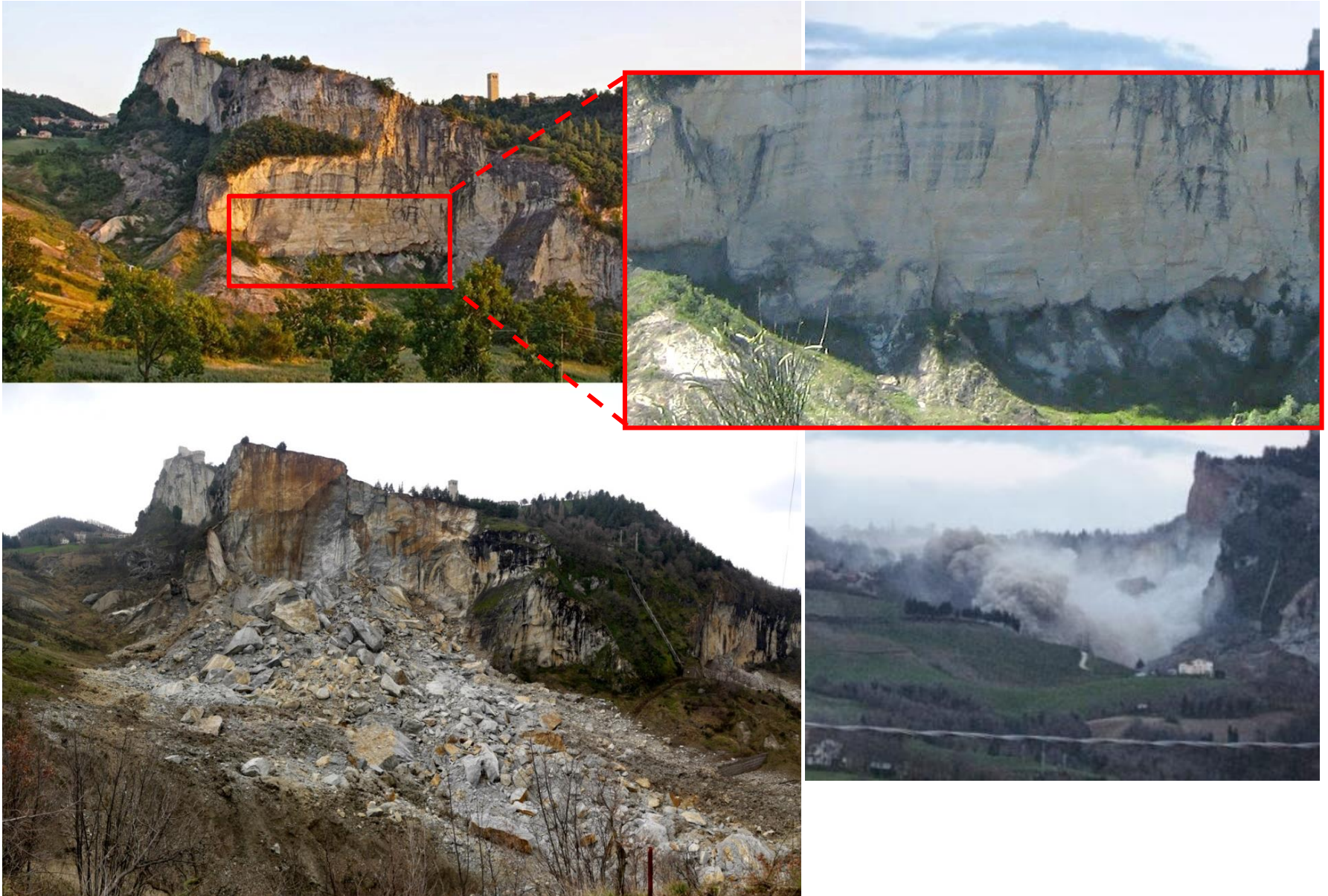
SLOPE: 80° AZIMUTH: VARIABLE



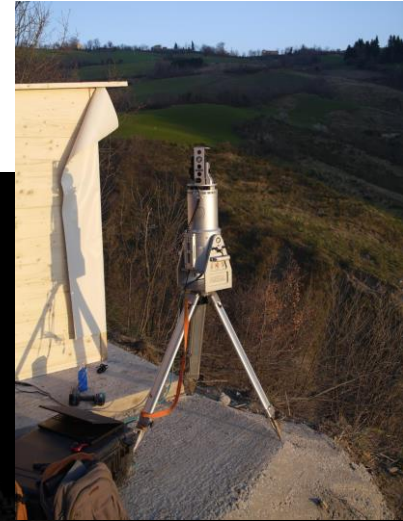
San Leo (Rn)



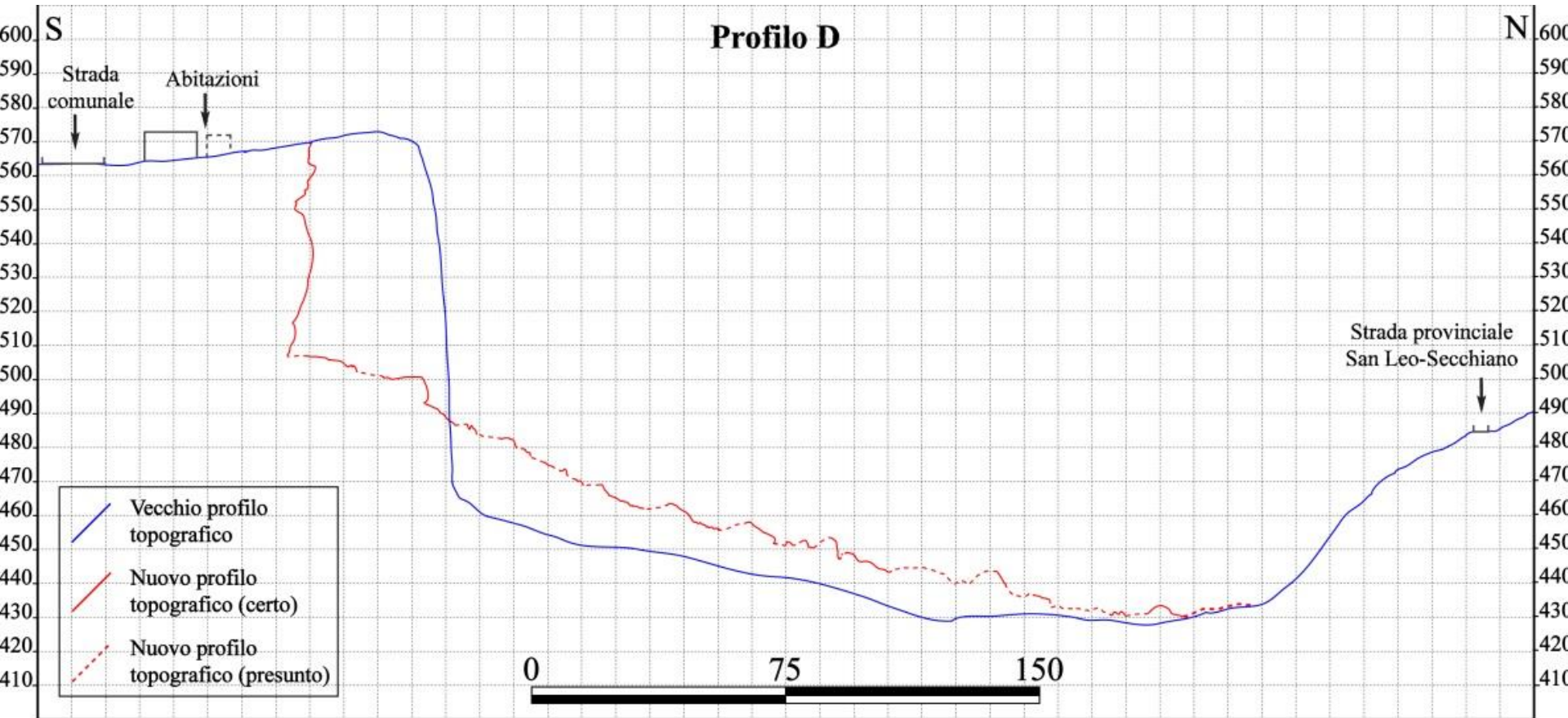
27 febbraio 2014



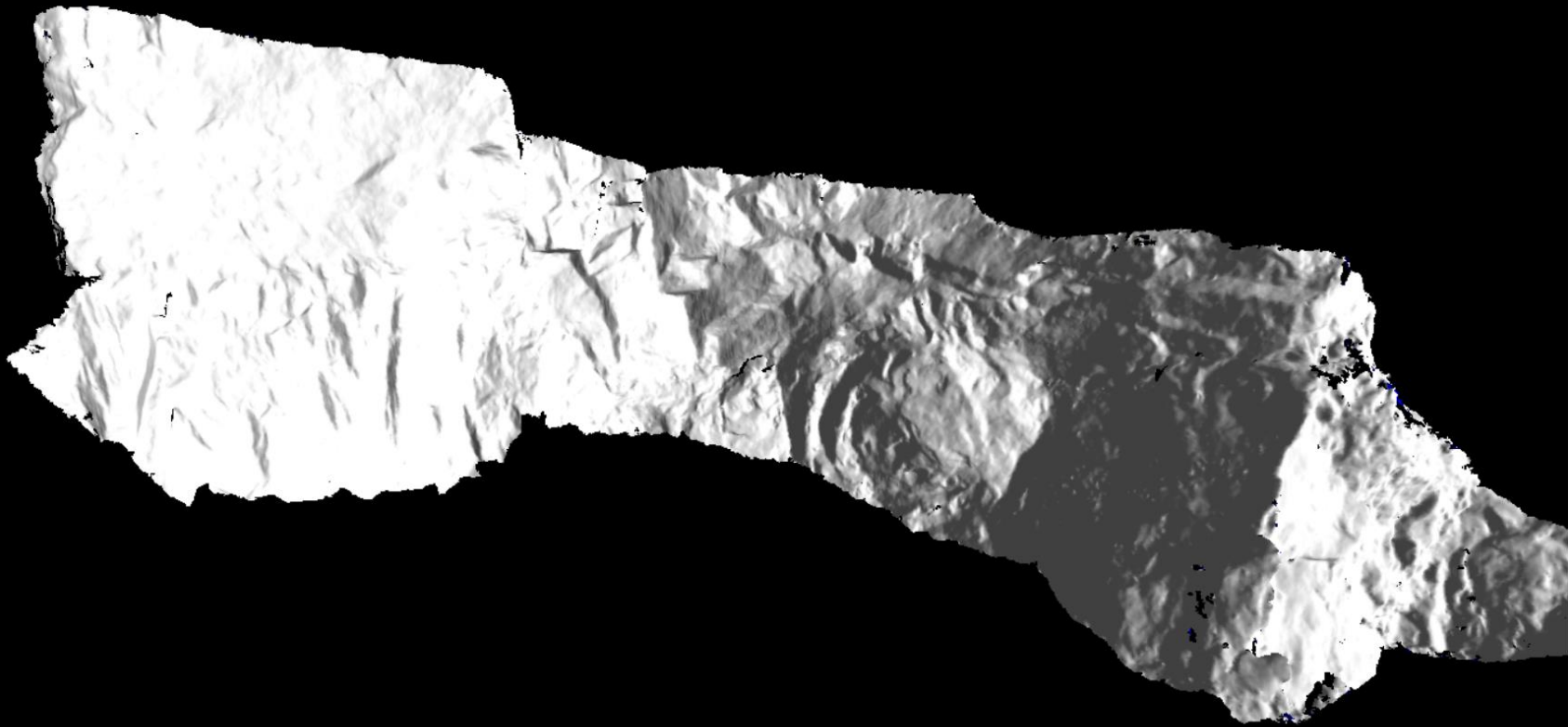
Rilievo Lidar



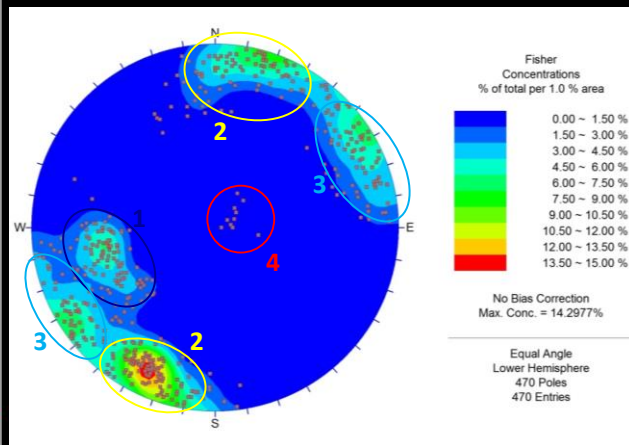
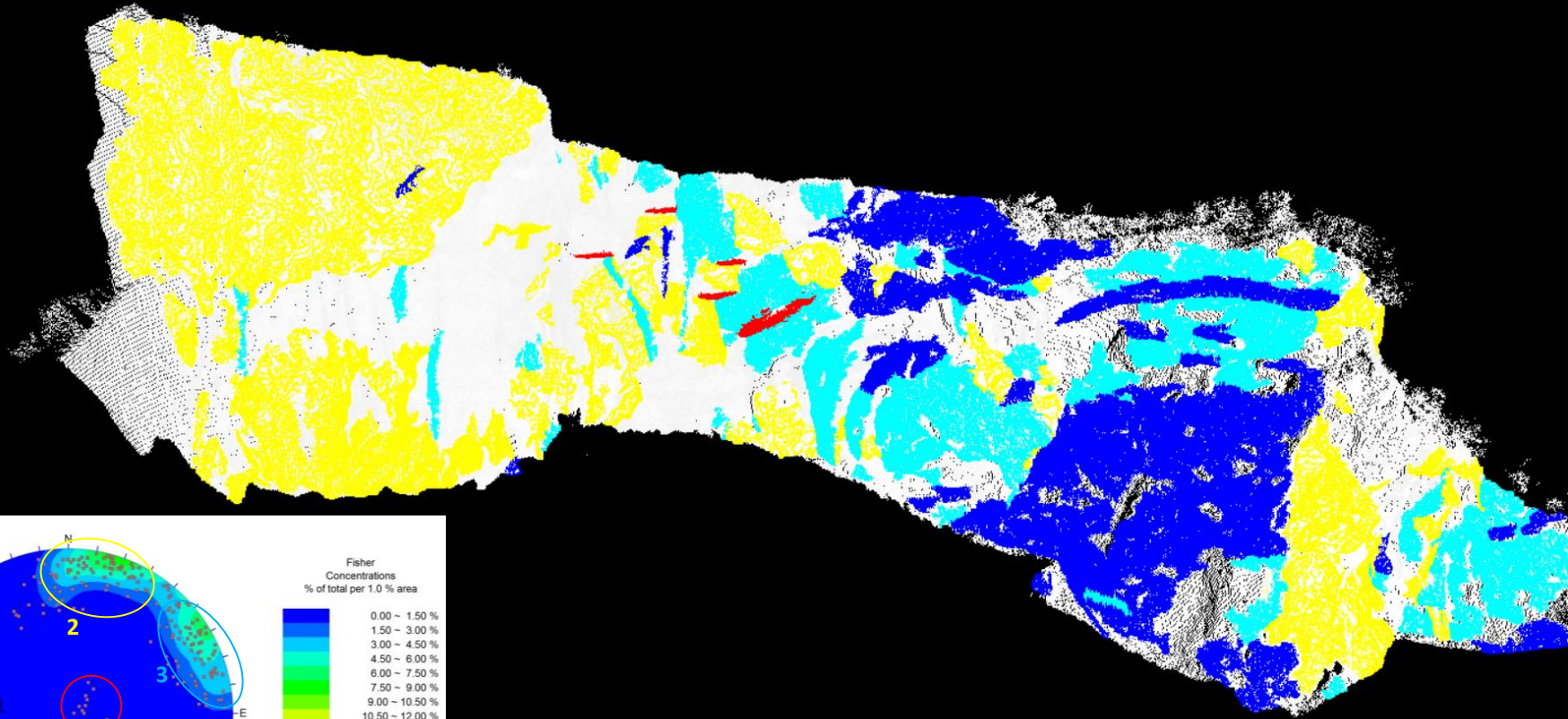
Spessore distacco



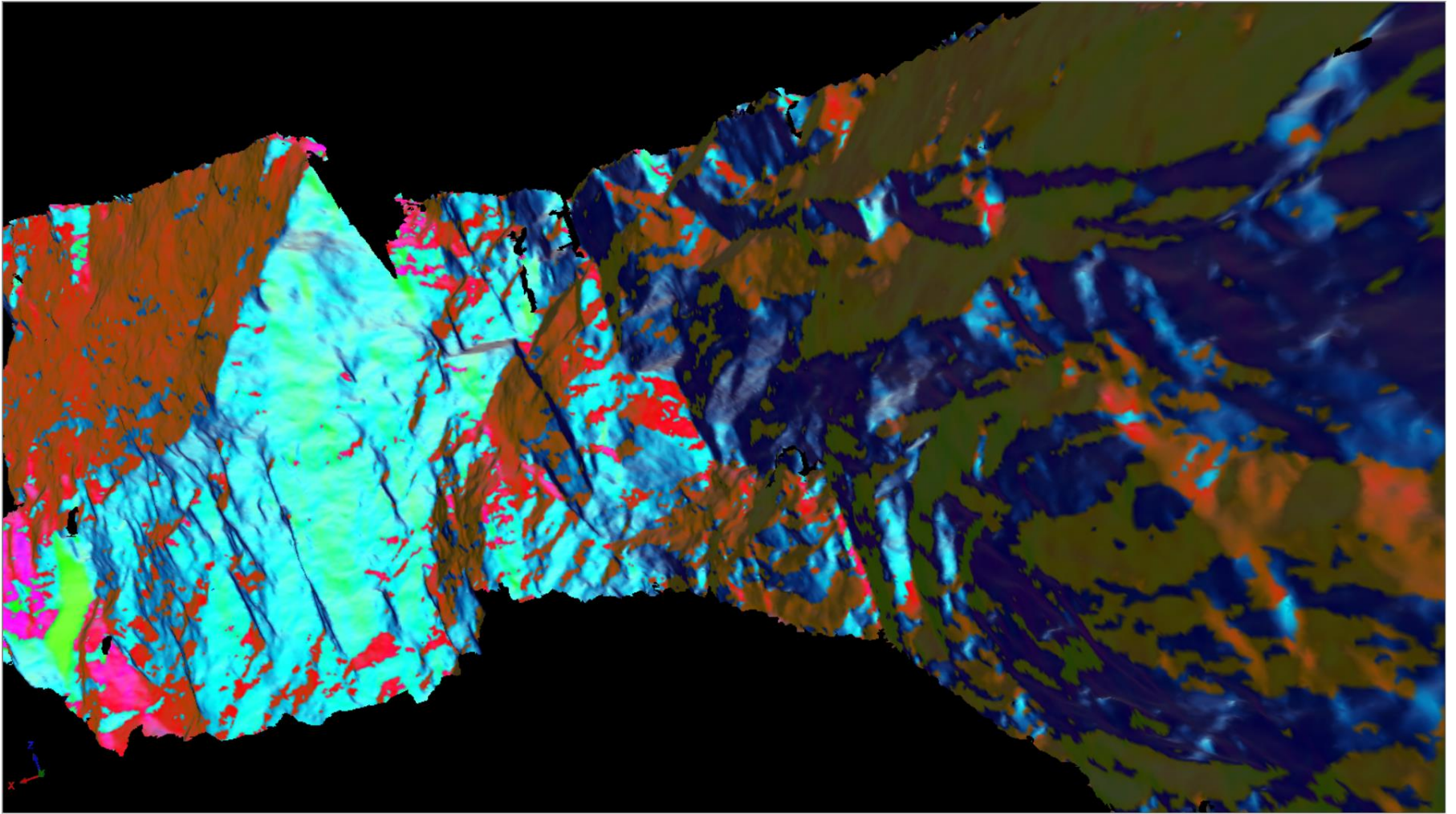
MESH



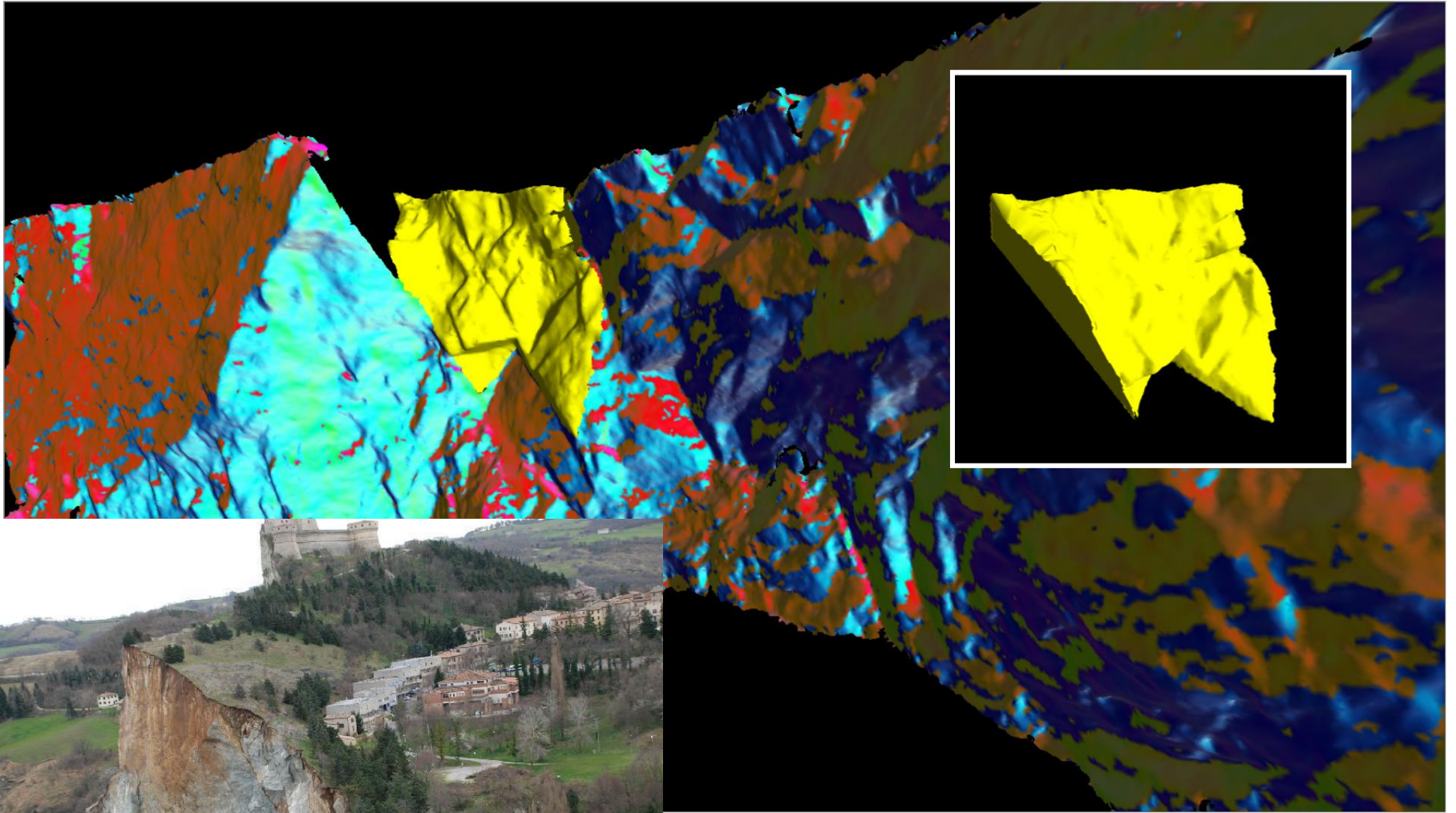
Famiglie di discontinuità



Cuneo centrale

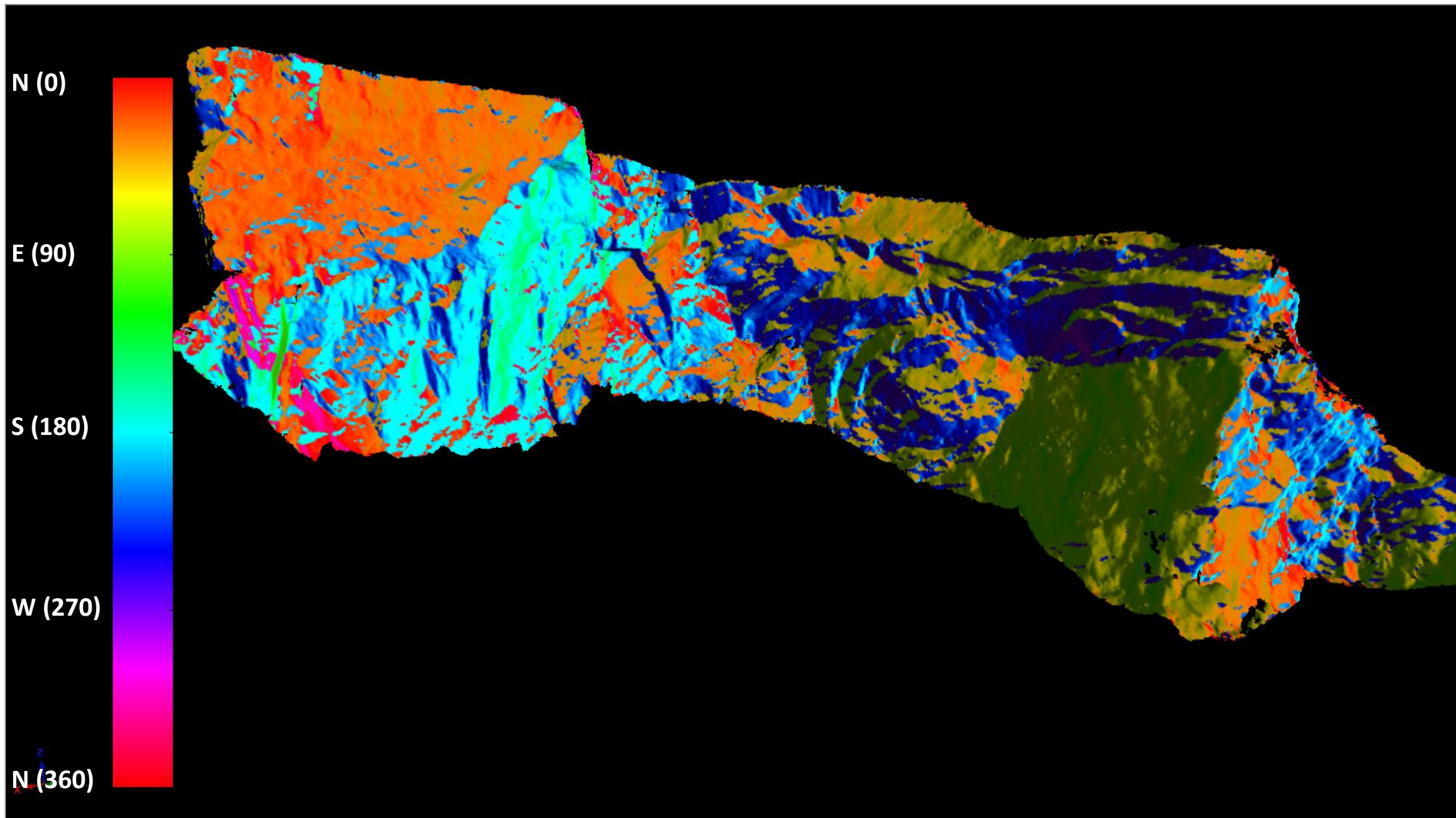


Cuneo centrale

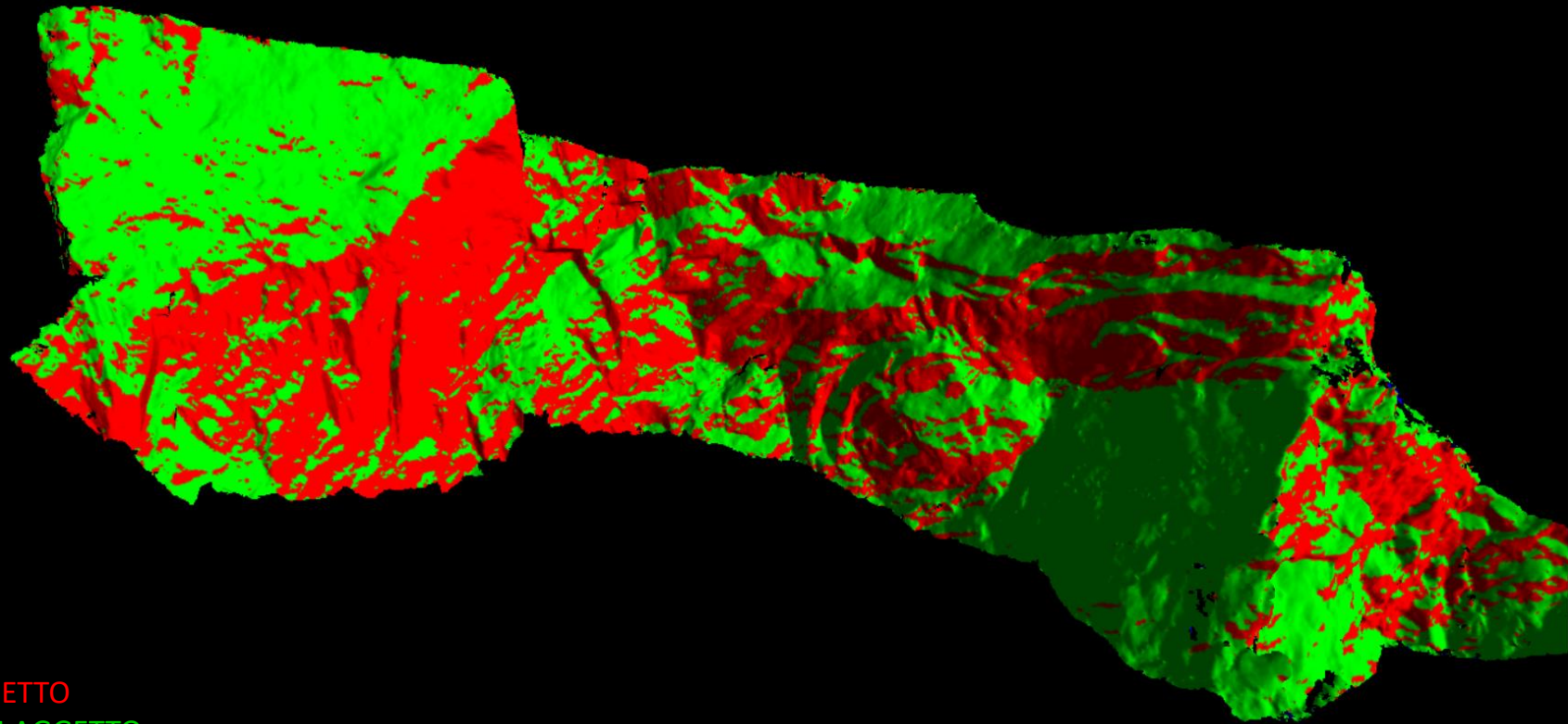


Volume: 4040 m³

Dip Direction



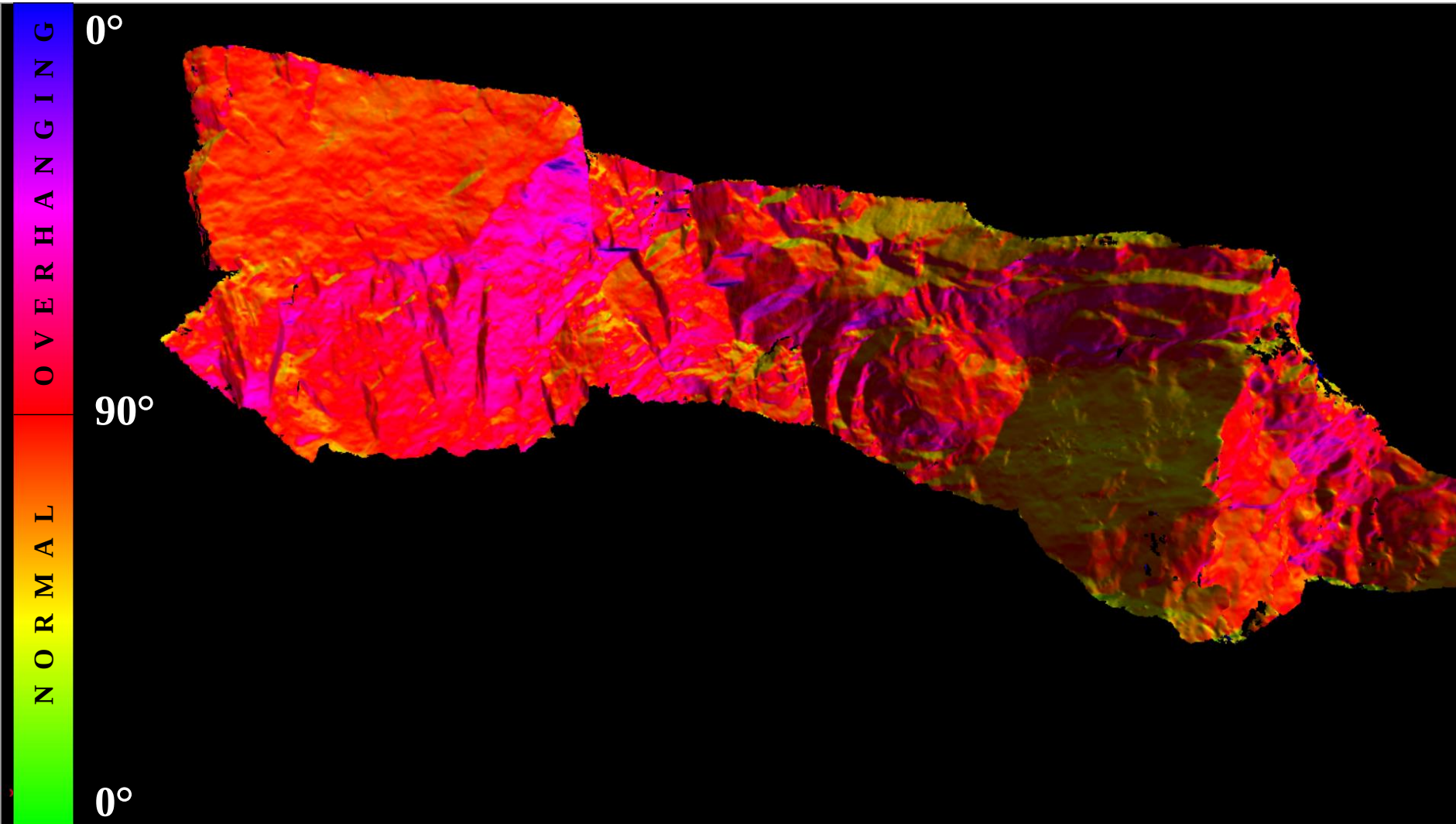
Settori in oggetto



AGGETTO
NON AGGETTO



Dip



Analisi cinematica 3D

(Gigli e Lombardi, in prep.)

dip direction of the slope

envelope of the plane normals

pole orientation variability

free fall area for overhanging slope

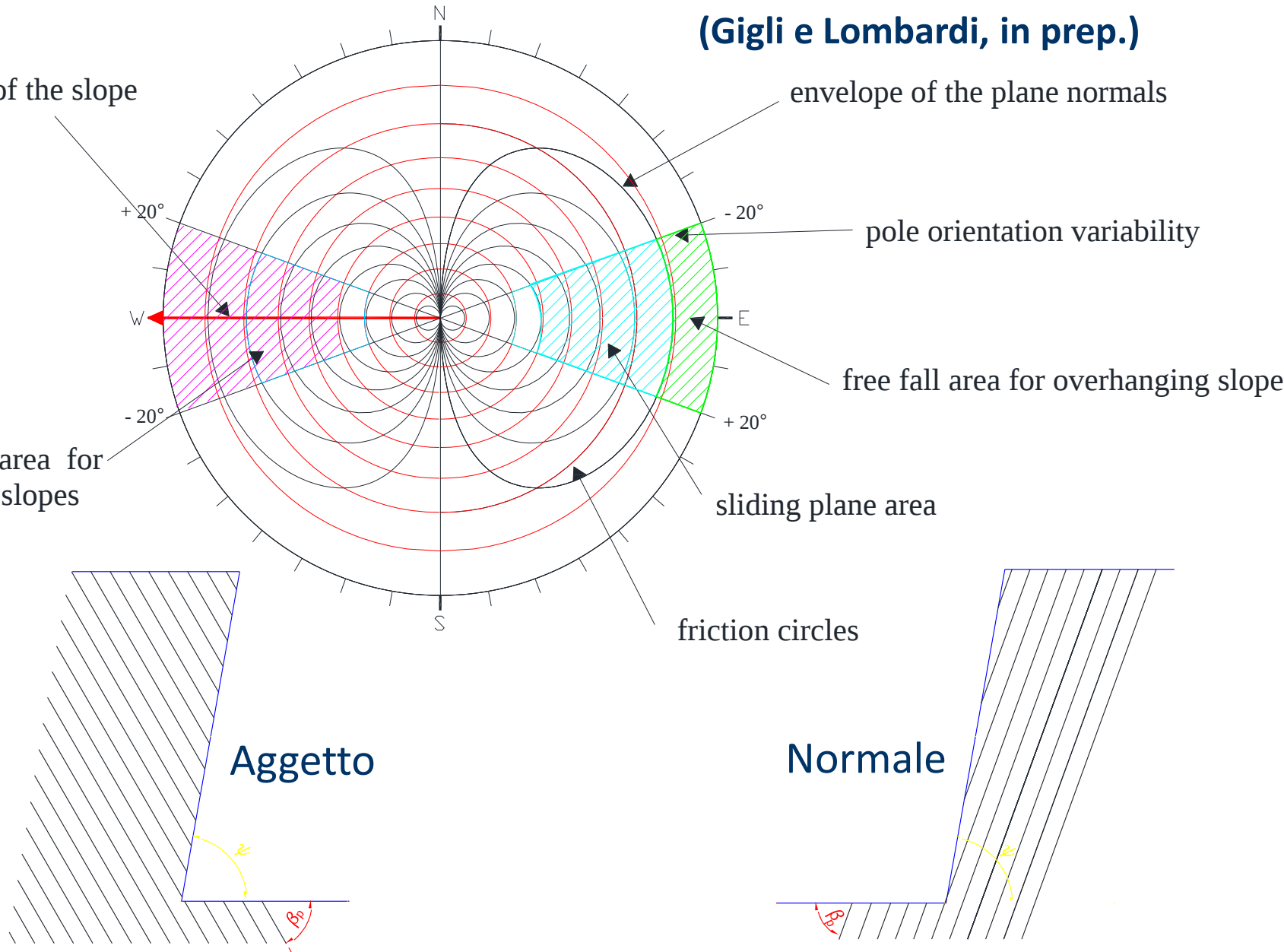
sliding plane area for overhanging slopes

sliding plane area

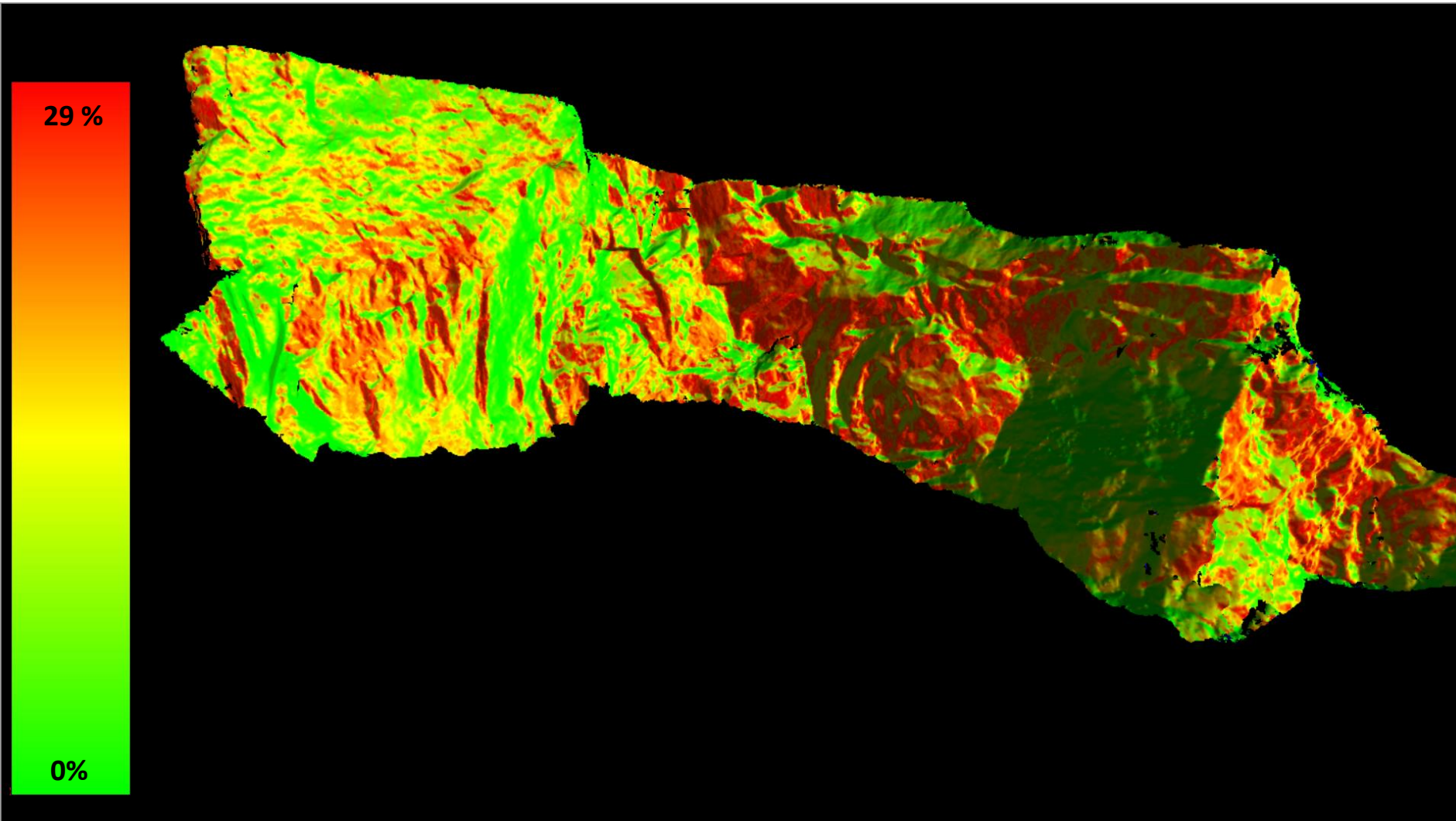
friction circles

Aggetto

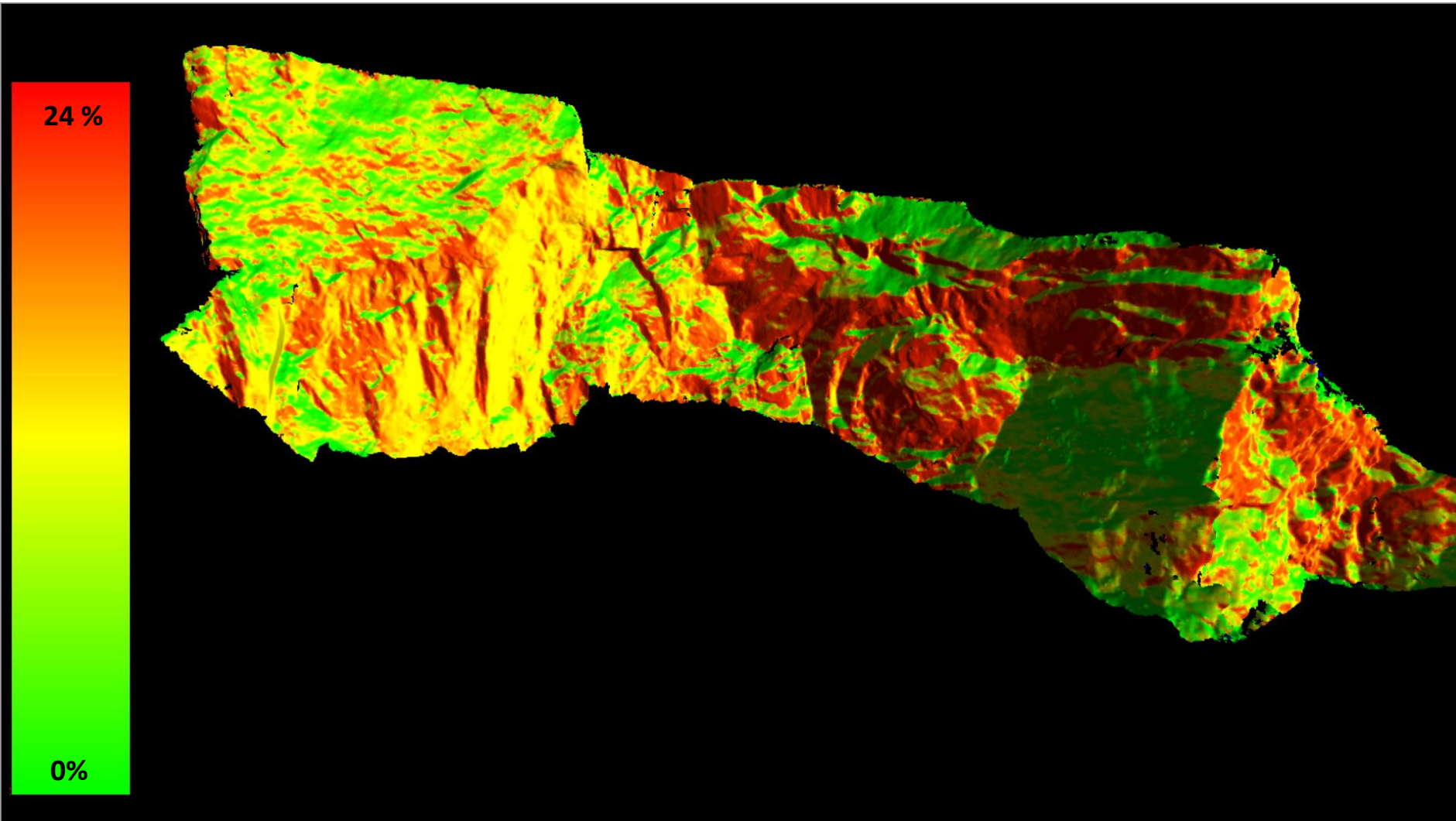
Normale



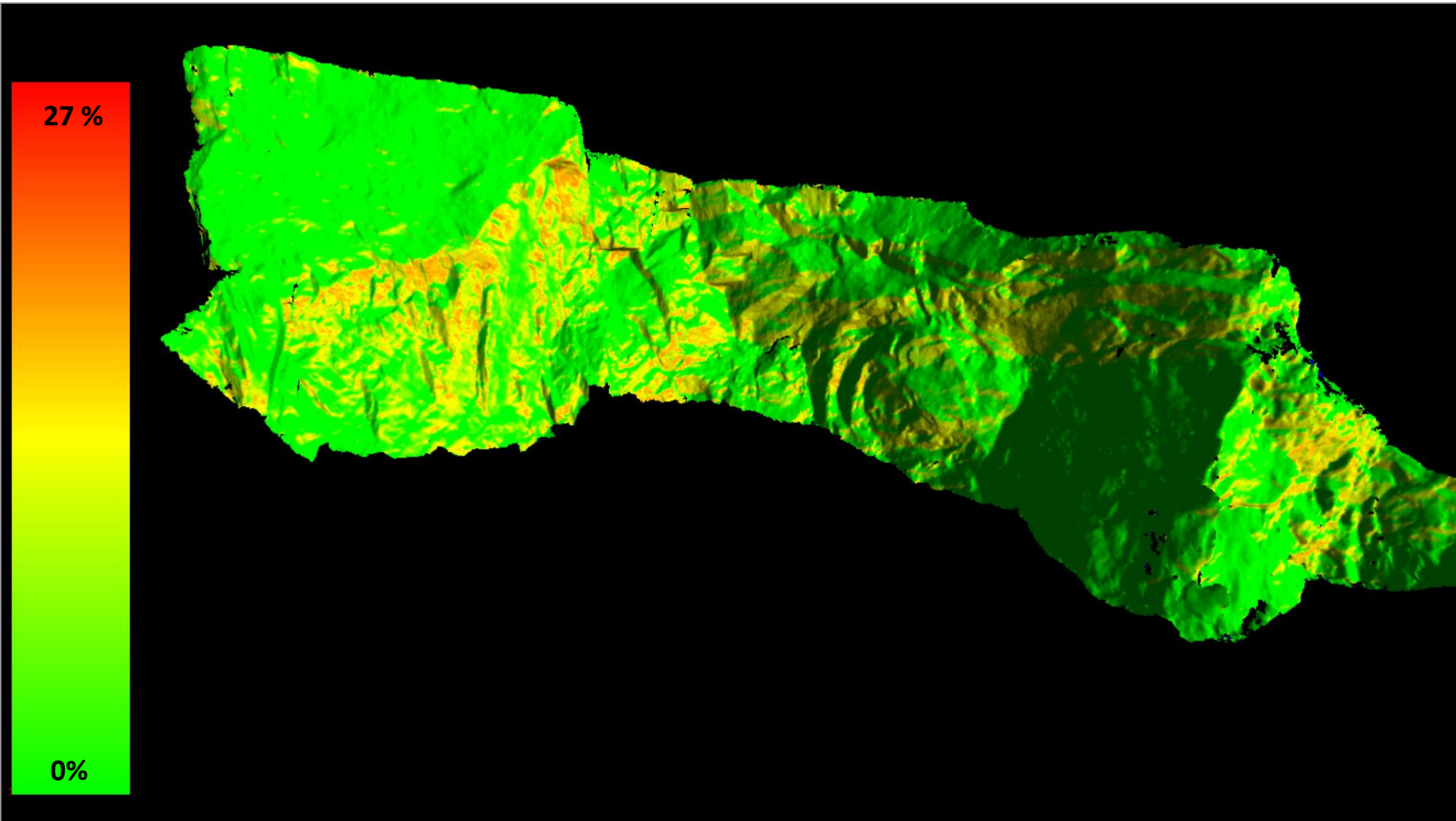
Scivolamento planare



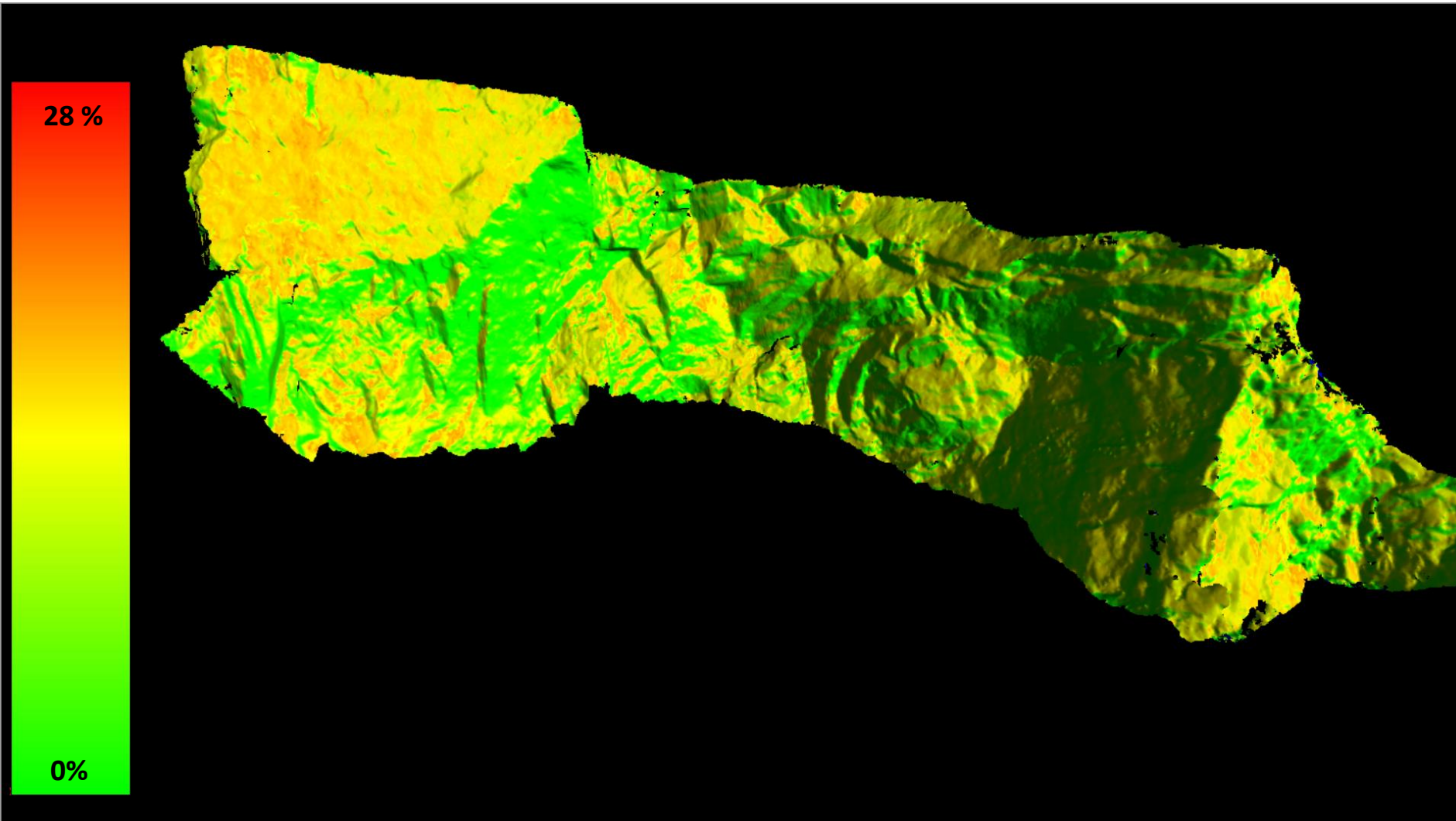
Scivolamento di cunei



Caduta libera

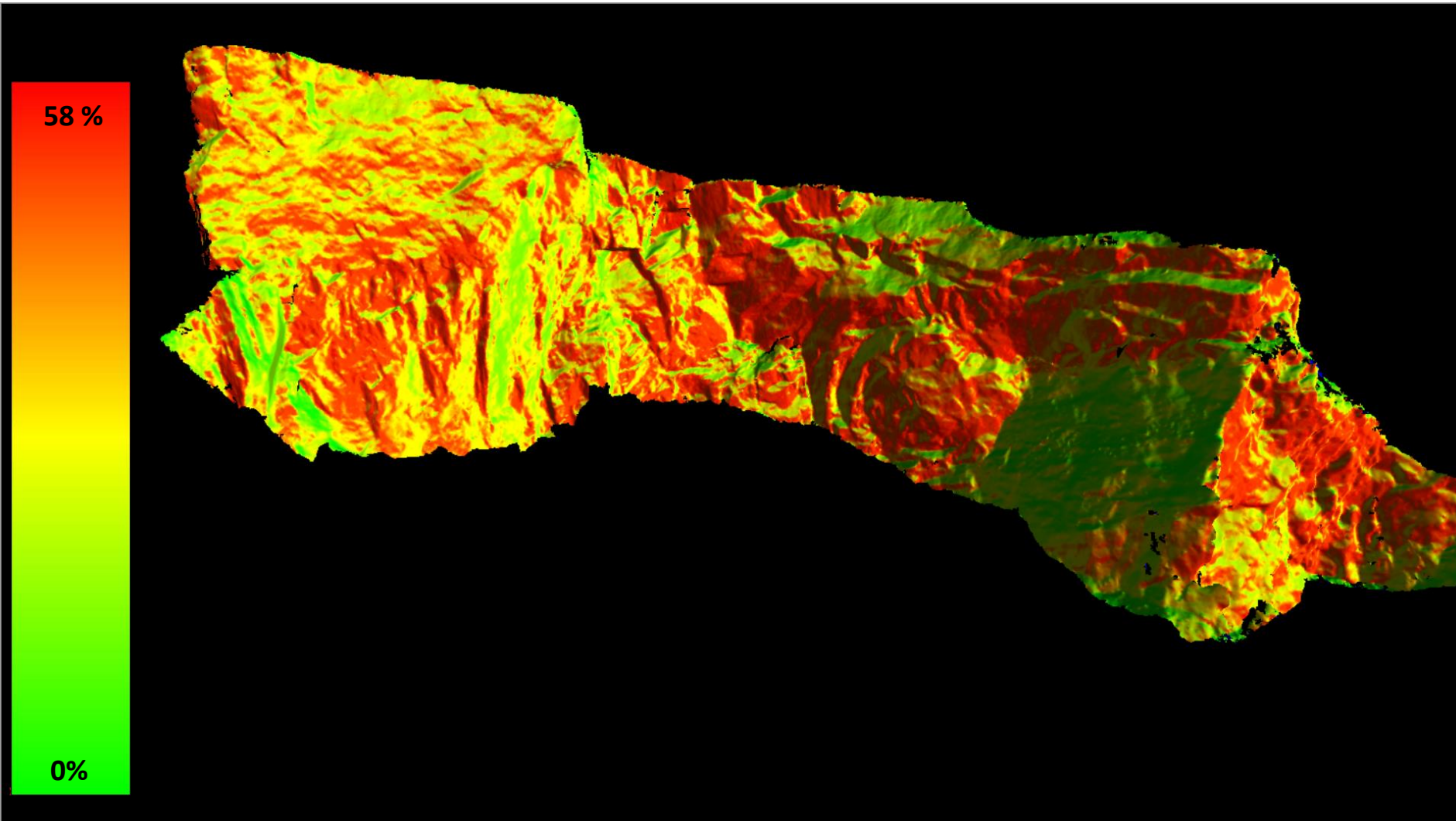


Toppling

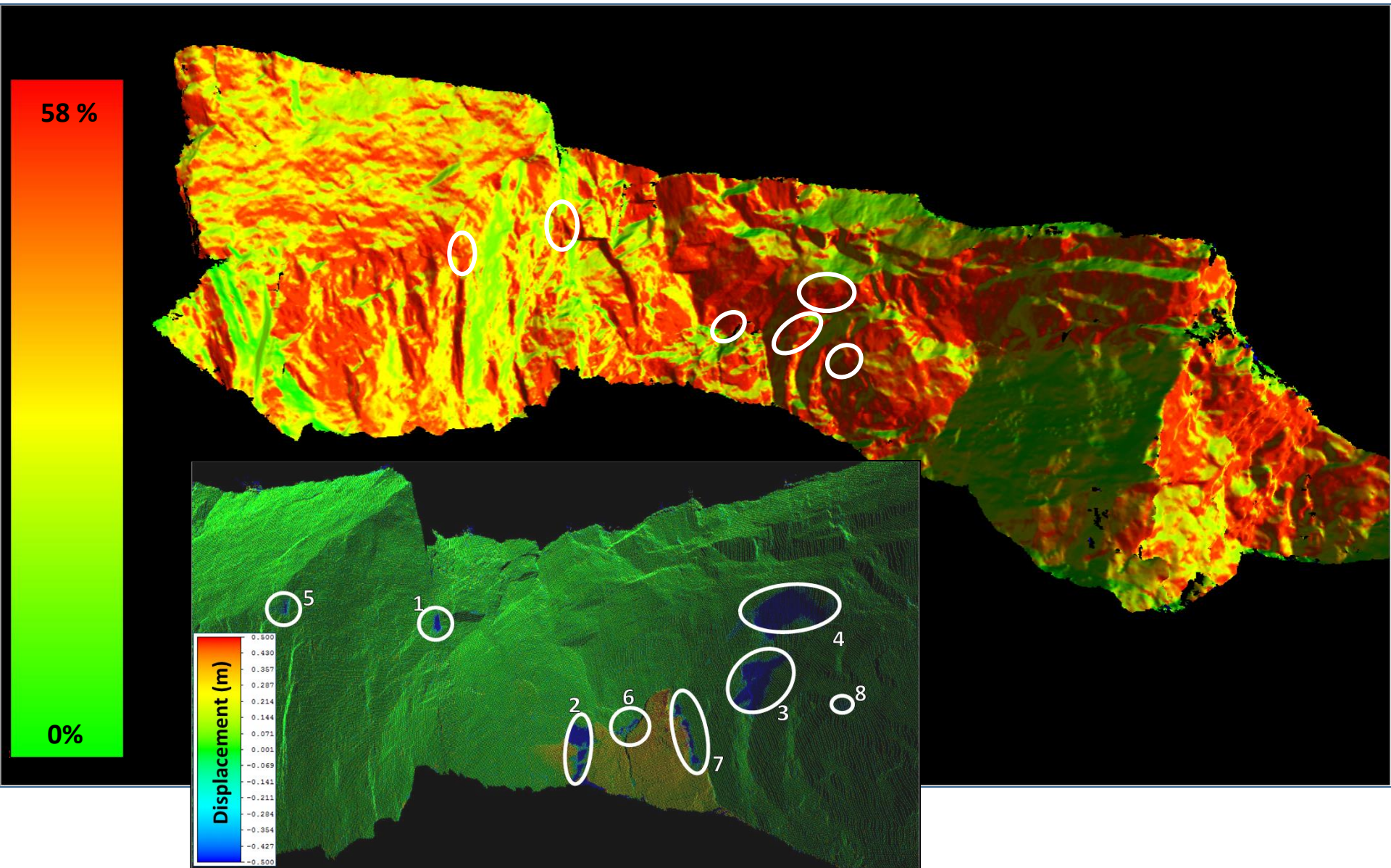


Global Kinematic Index

(Gigli e Lombardi, in prep.)



Validazione analisi cinematica



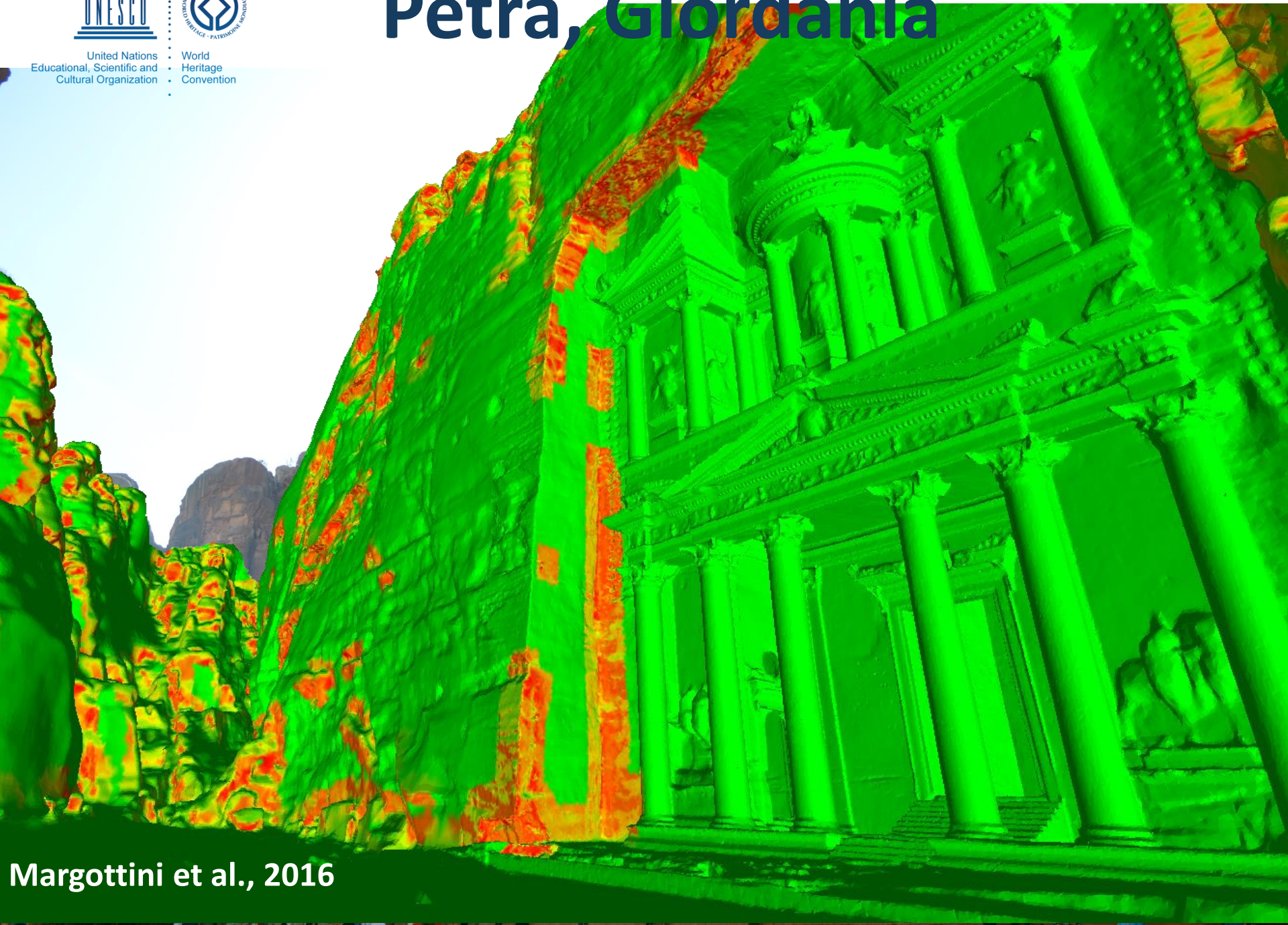


United Nations
Educational, Scientific and
Cultural Organization



World
Heritage
Convention

Petra, Giordania



Margottini et al., 2016

Crollo di una parete rocciosa negli scavi di Petra. Illeso il segretario del Comune Marini

Scritto da Super User. Pubblicato in [Territorio](#)

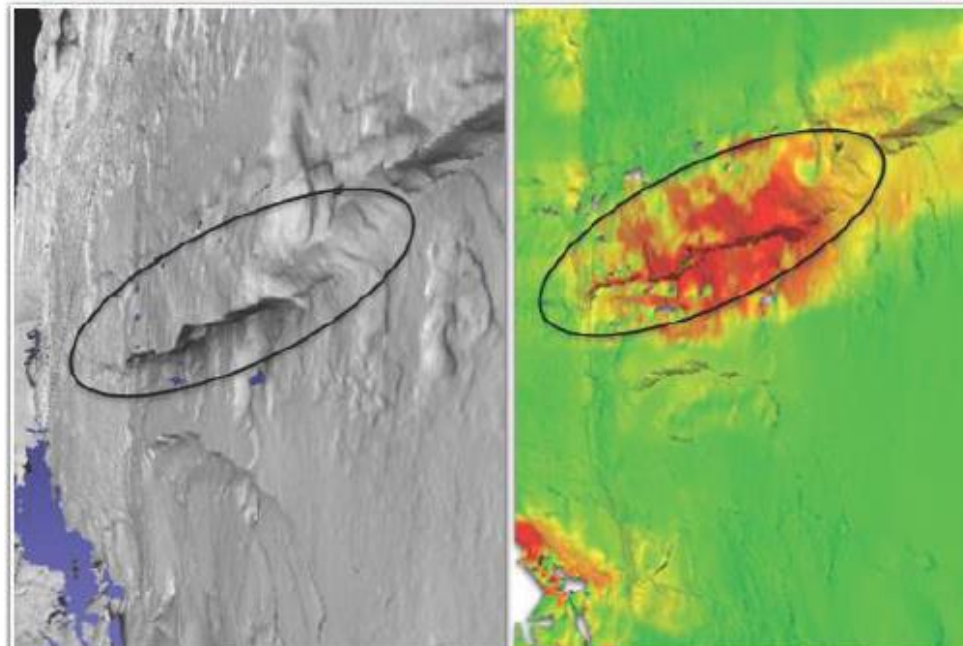


Tragedia sfiorata

Il viaggio in Giordania di una comitiva di bergamaschi poteva trasformarsi in tragedia. A pochi metri da loro una delle pareti rocciose degli scavi di Petra cede.



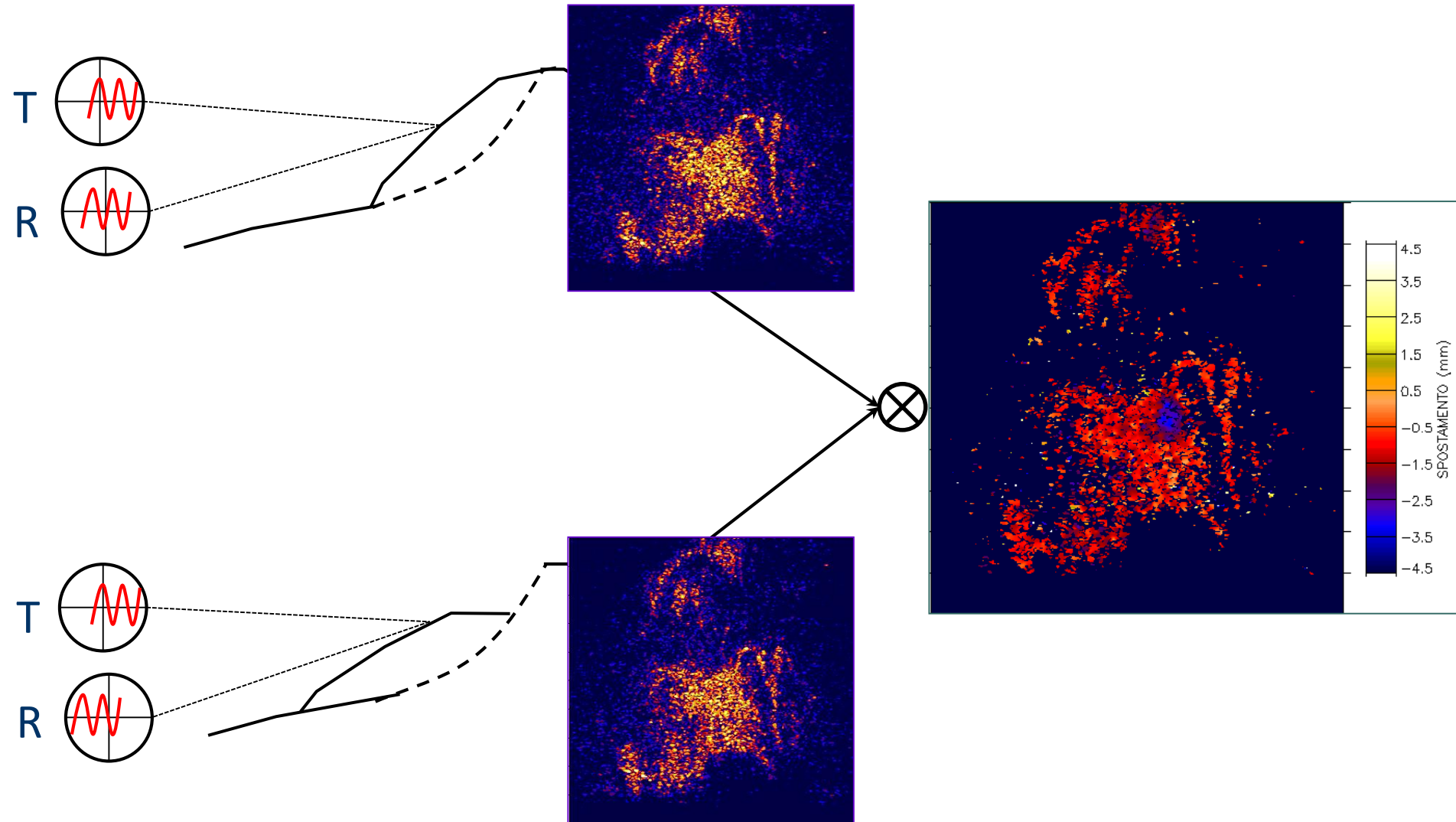
Giordania. A maggio nel siq di Petra è caduto un masso di 10 tonnellate: l'evento era stato previsto da un algoritmo ideato all'università di Firenze



Slope Stability Radar

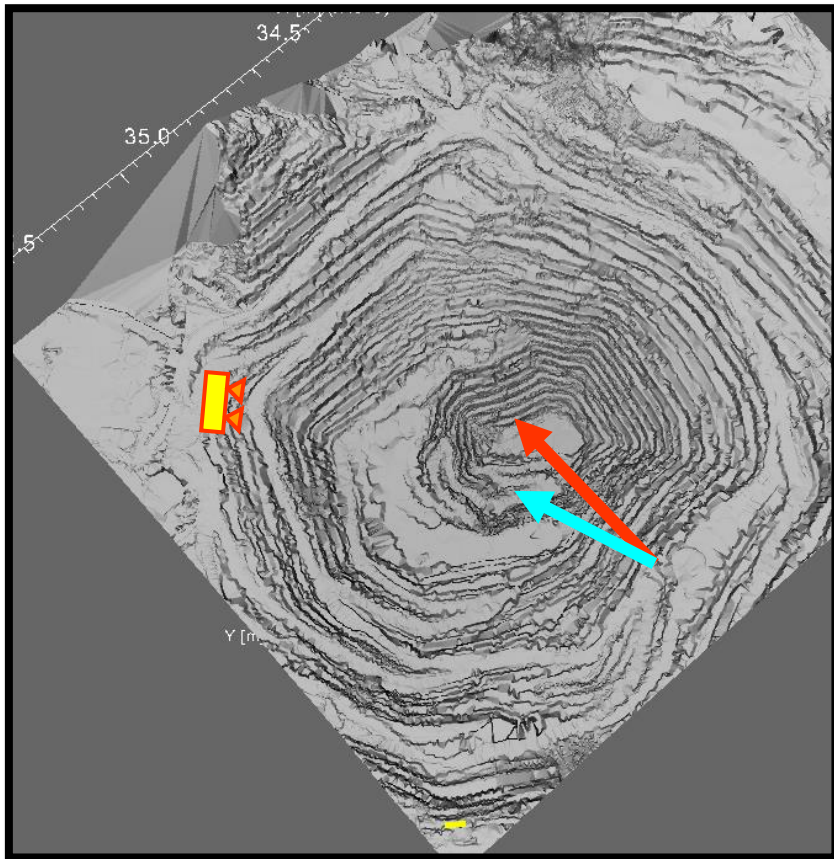


GB InSAR

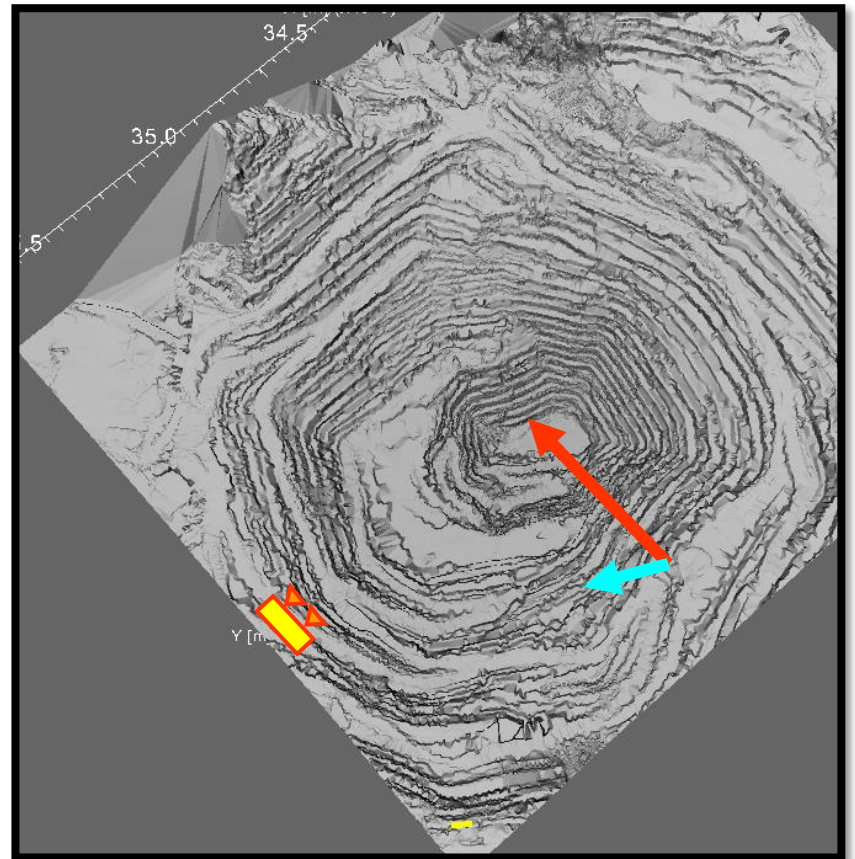


Linea di vista (LOS)

LoS Favorevole



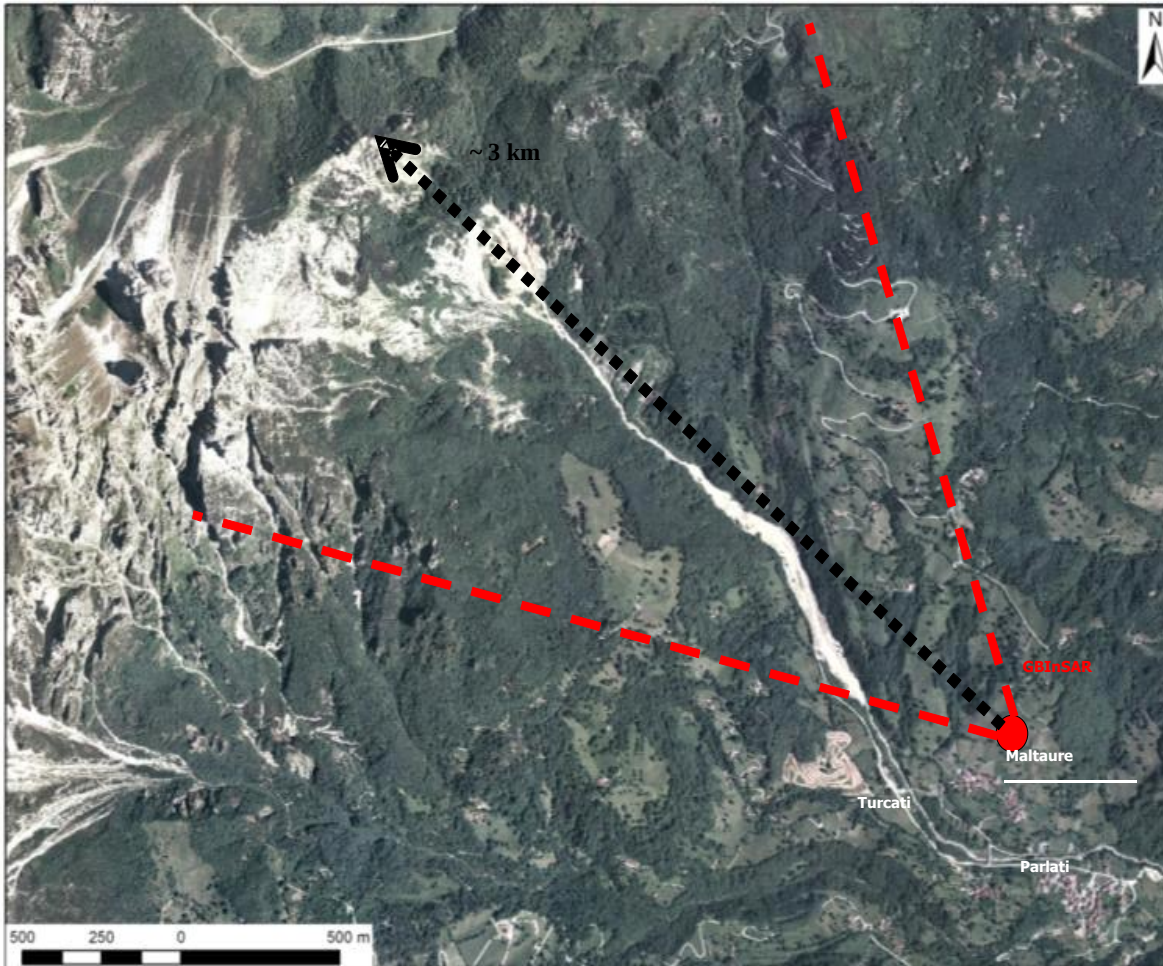
LoS Sfavorevole



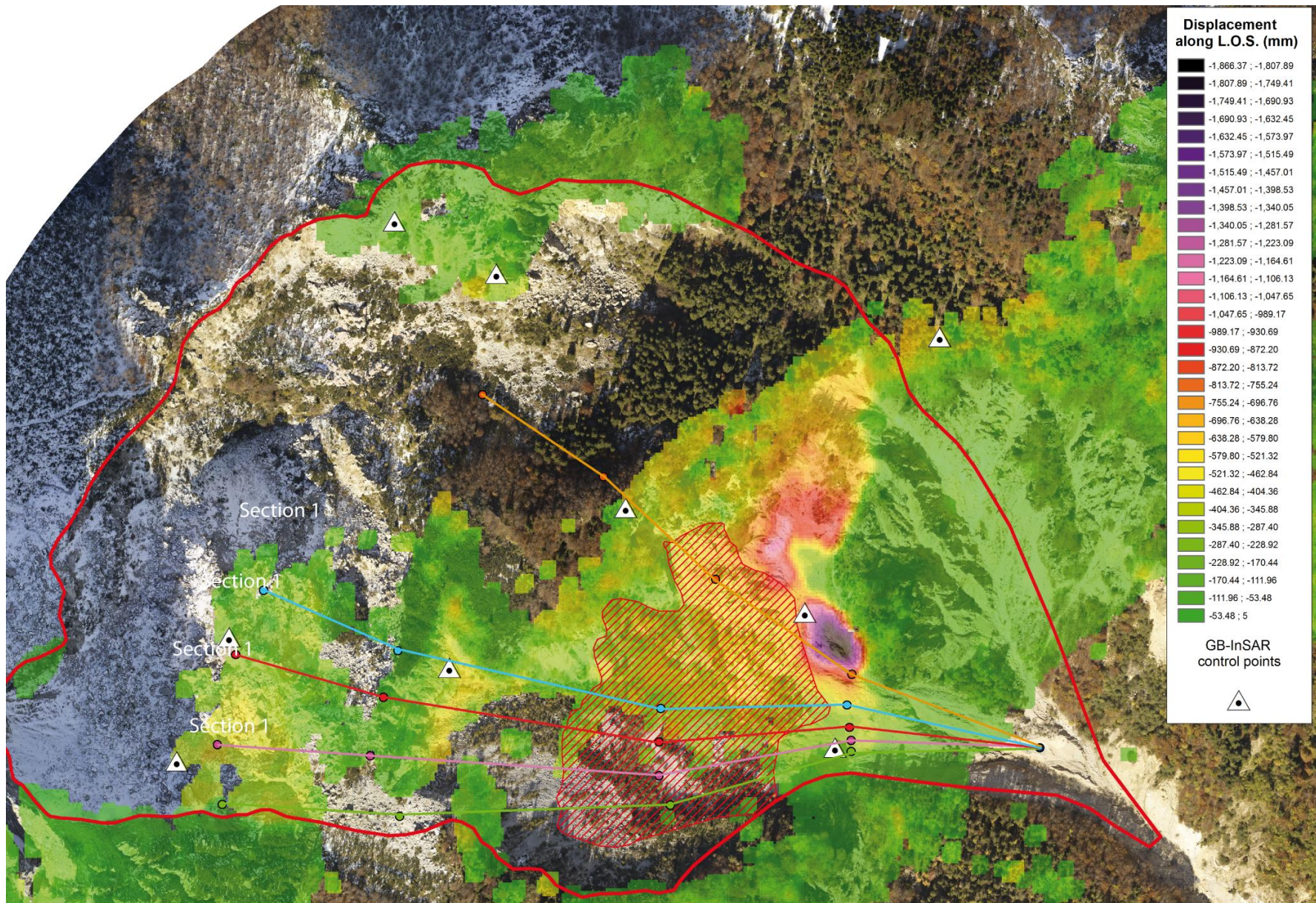
Frana del Rotolon



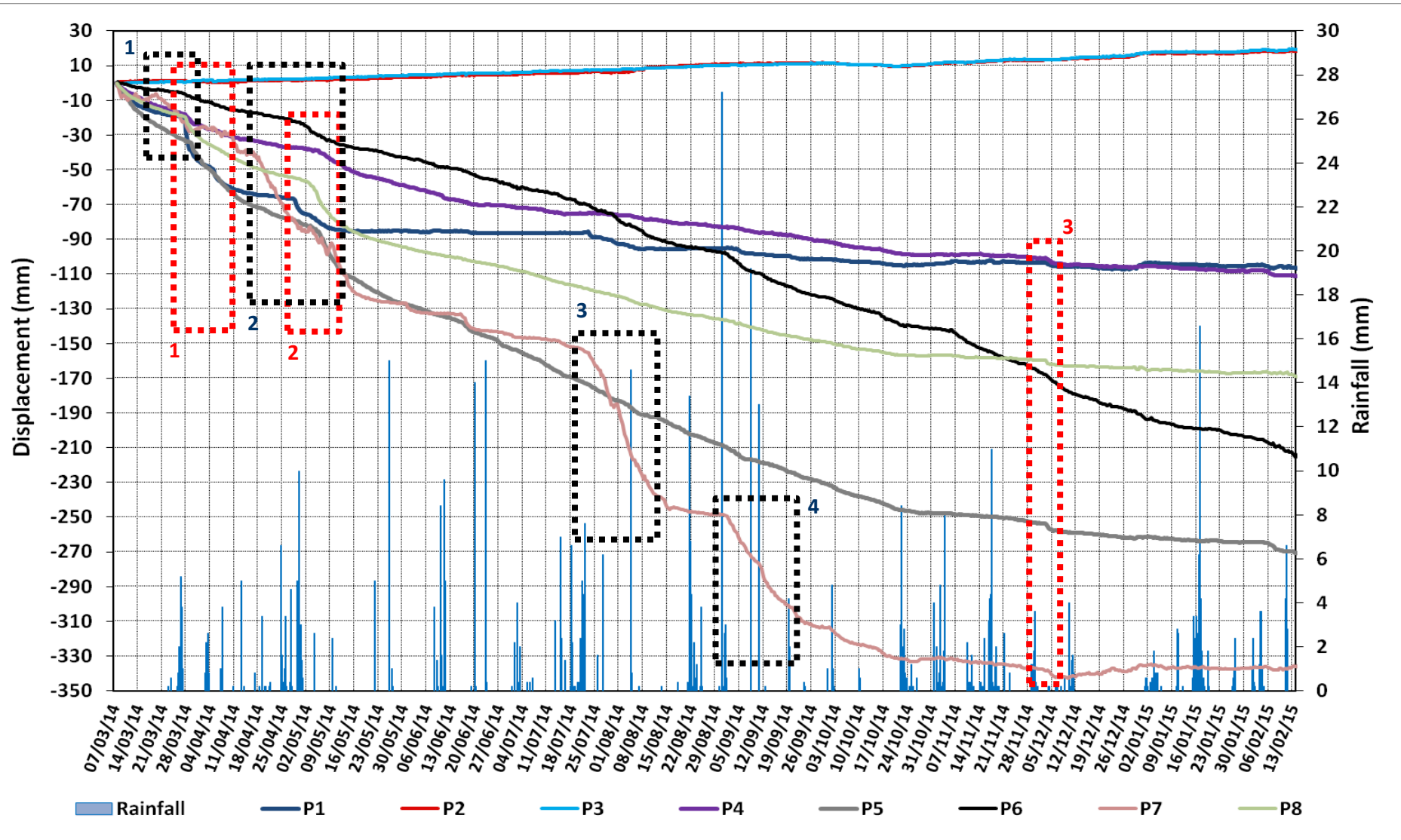
Monitoraggio GB-InSAR



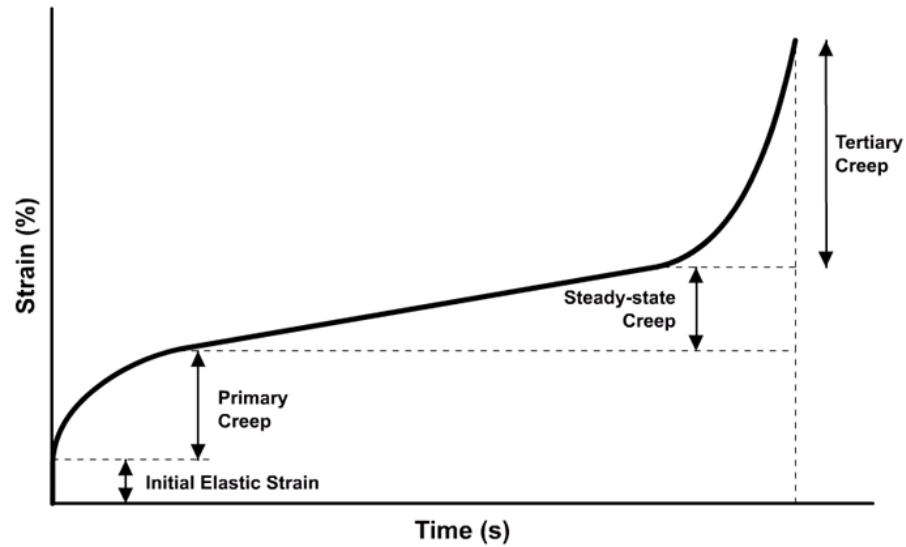
Spostamenti cumulati



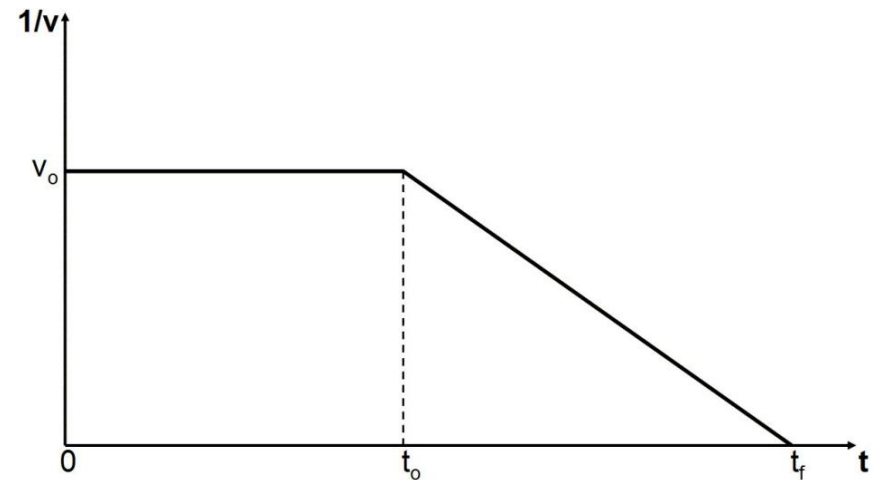
Serie temporali di spostamento



Failure forecast



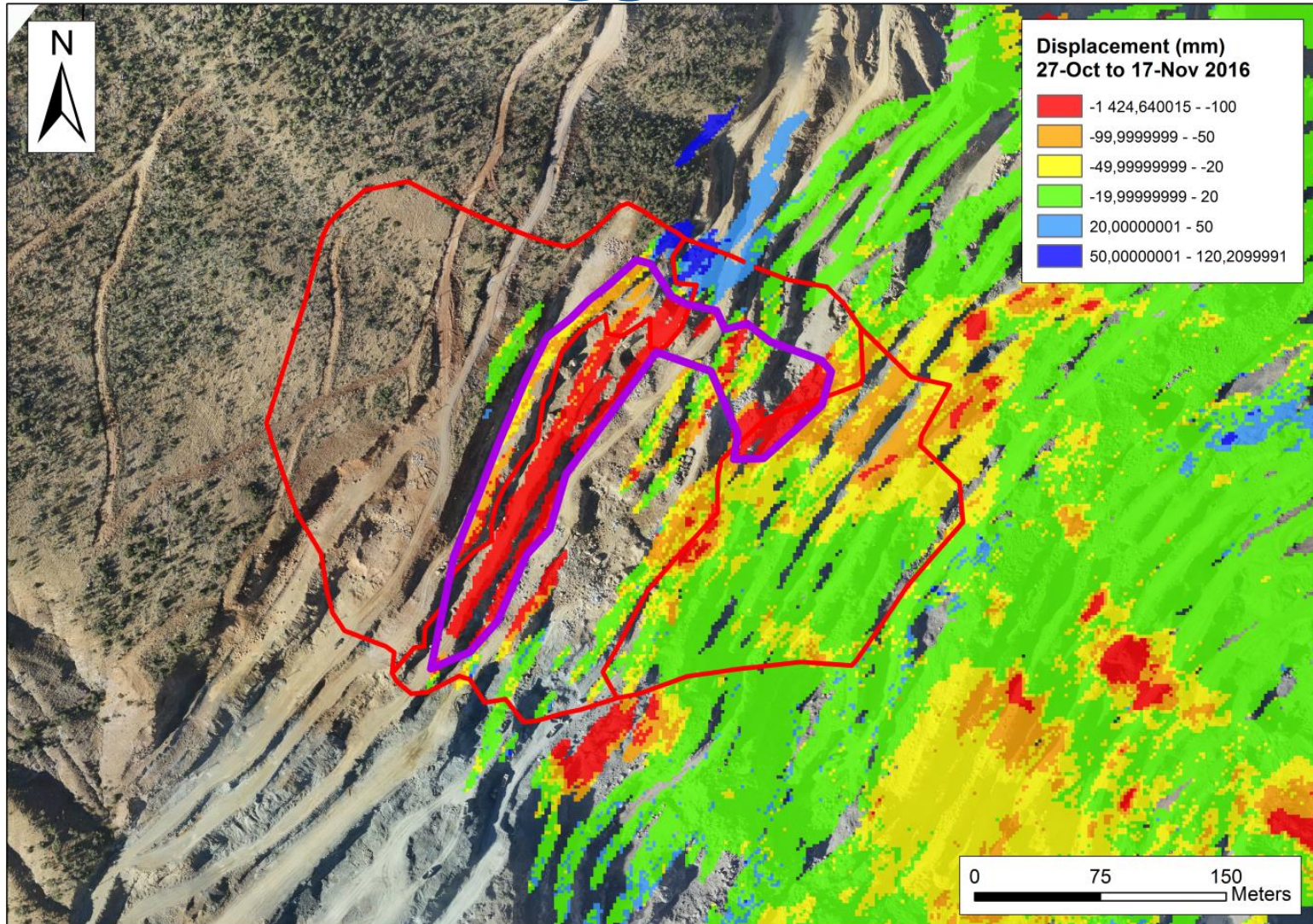
Saito, 1969
Fukuzono, 1985
Voight, 1988



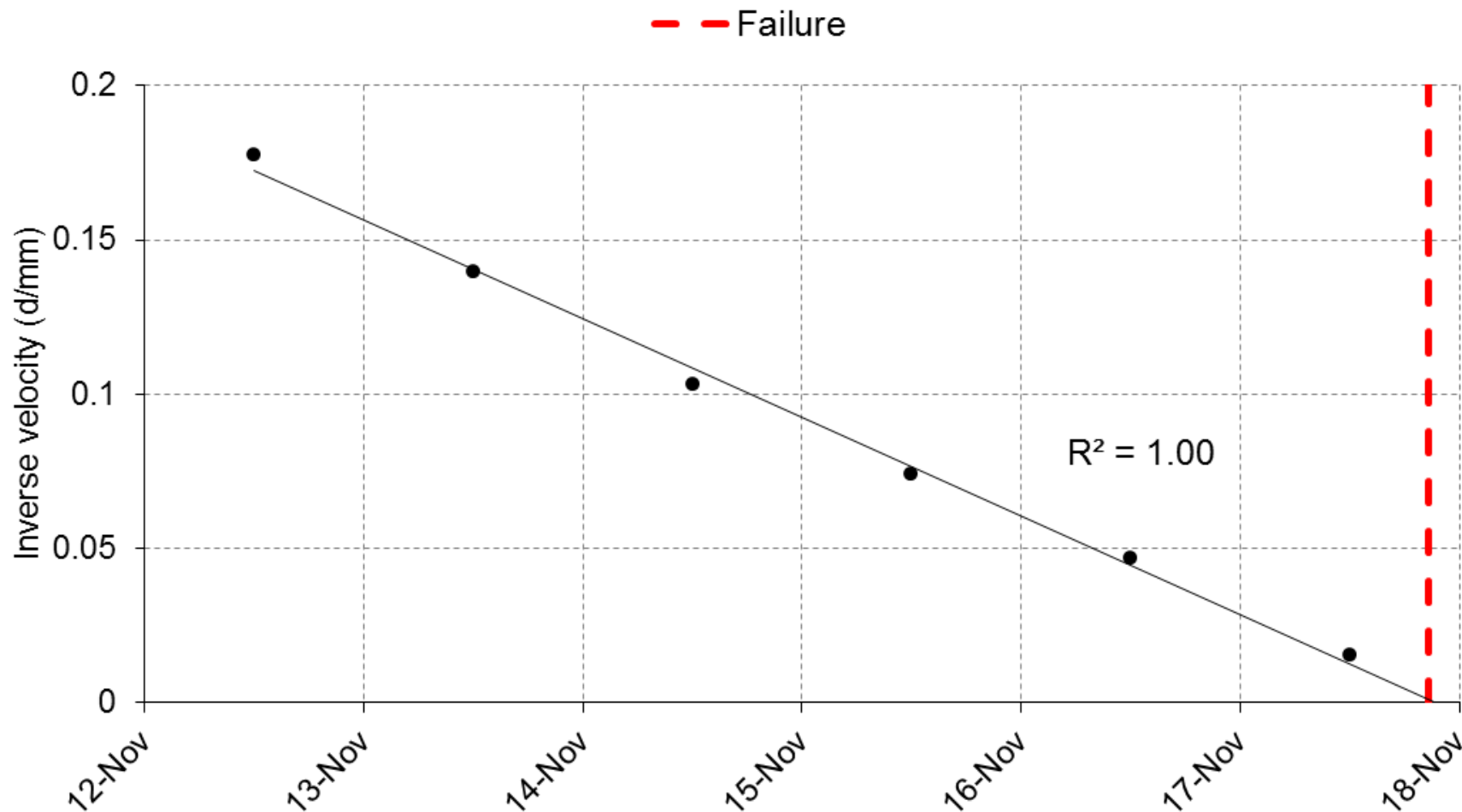
Miniera a cielo aperto di rame



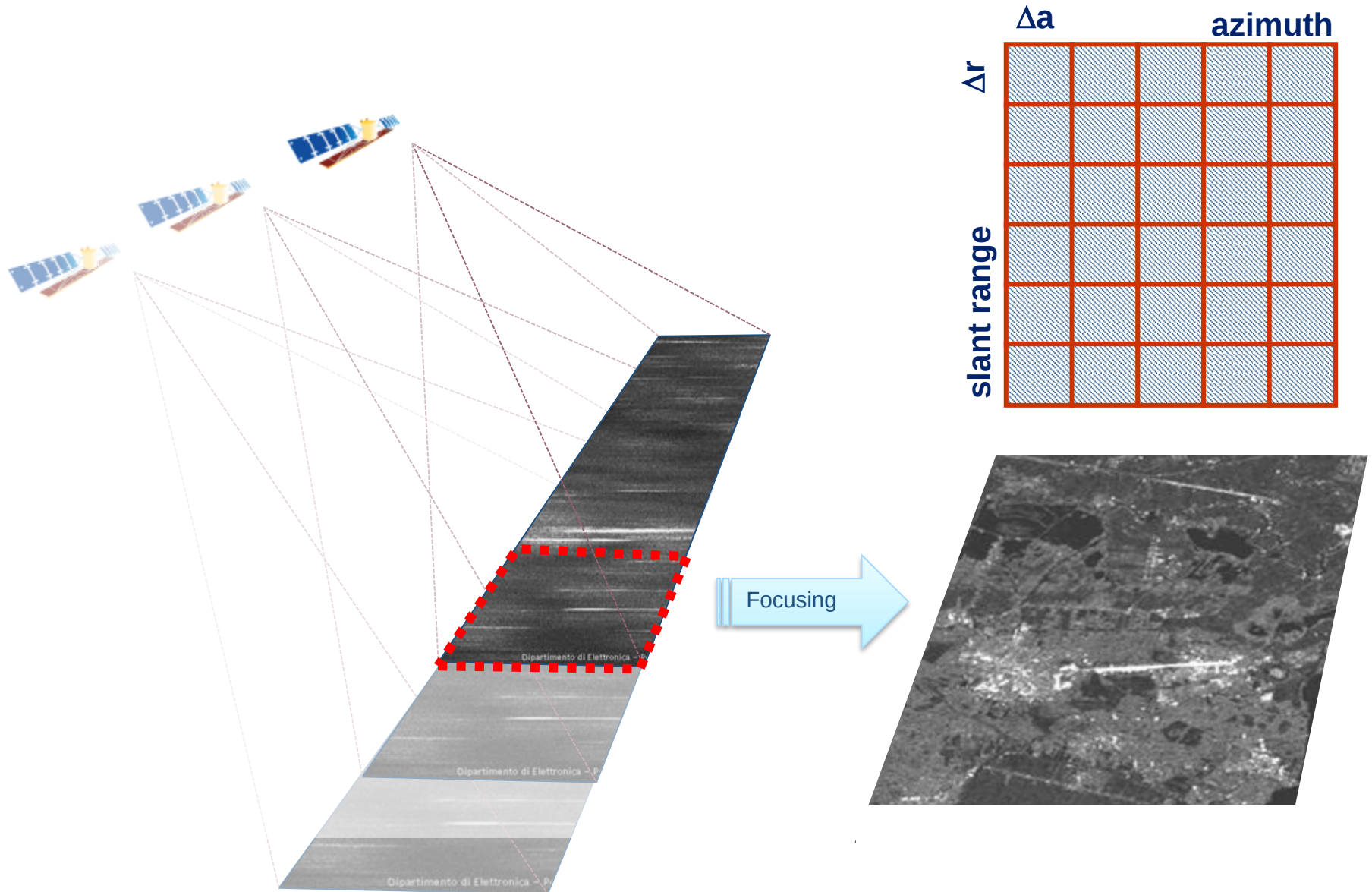
Monitoraggio GB-InSAR



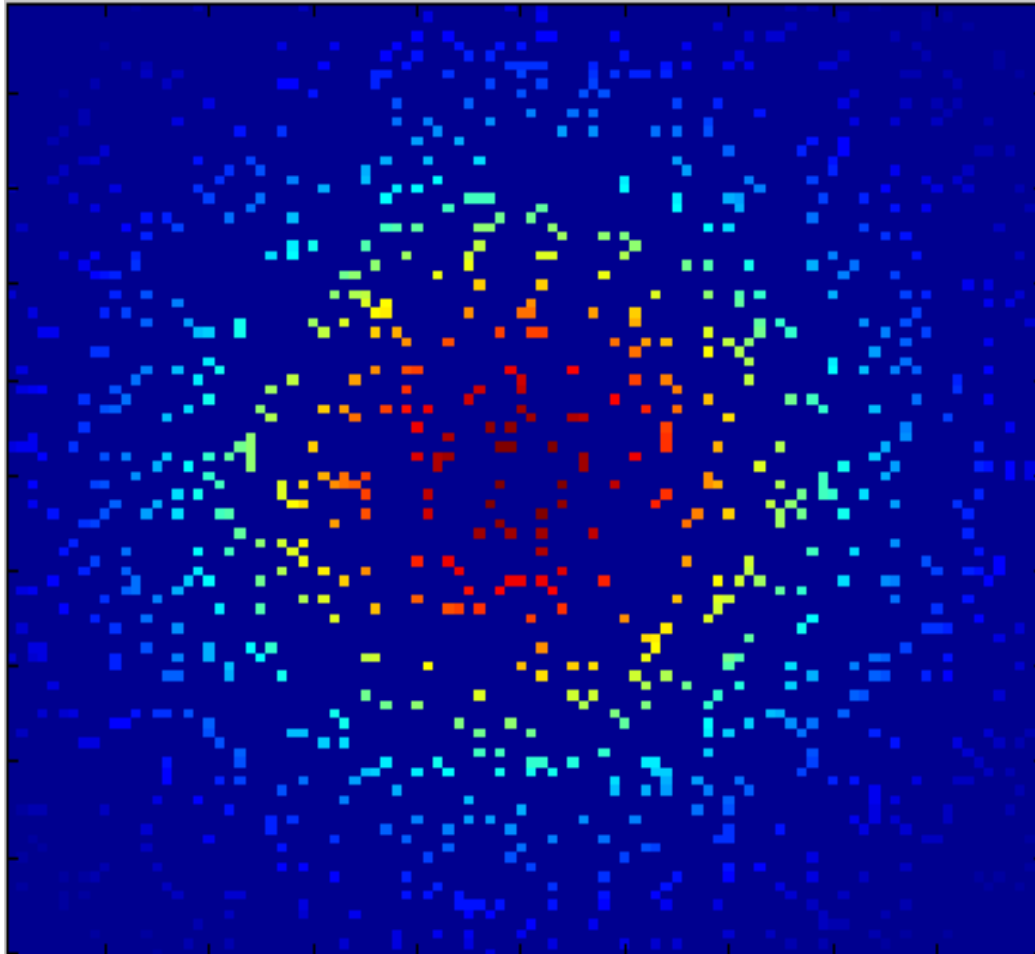
Previsione collasso



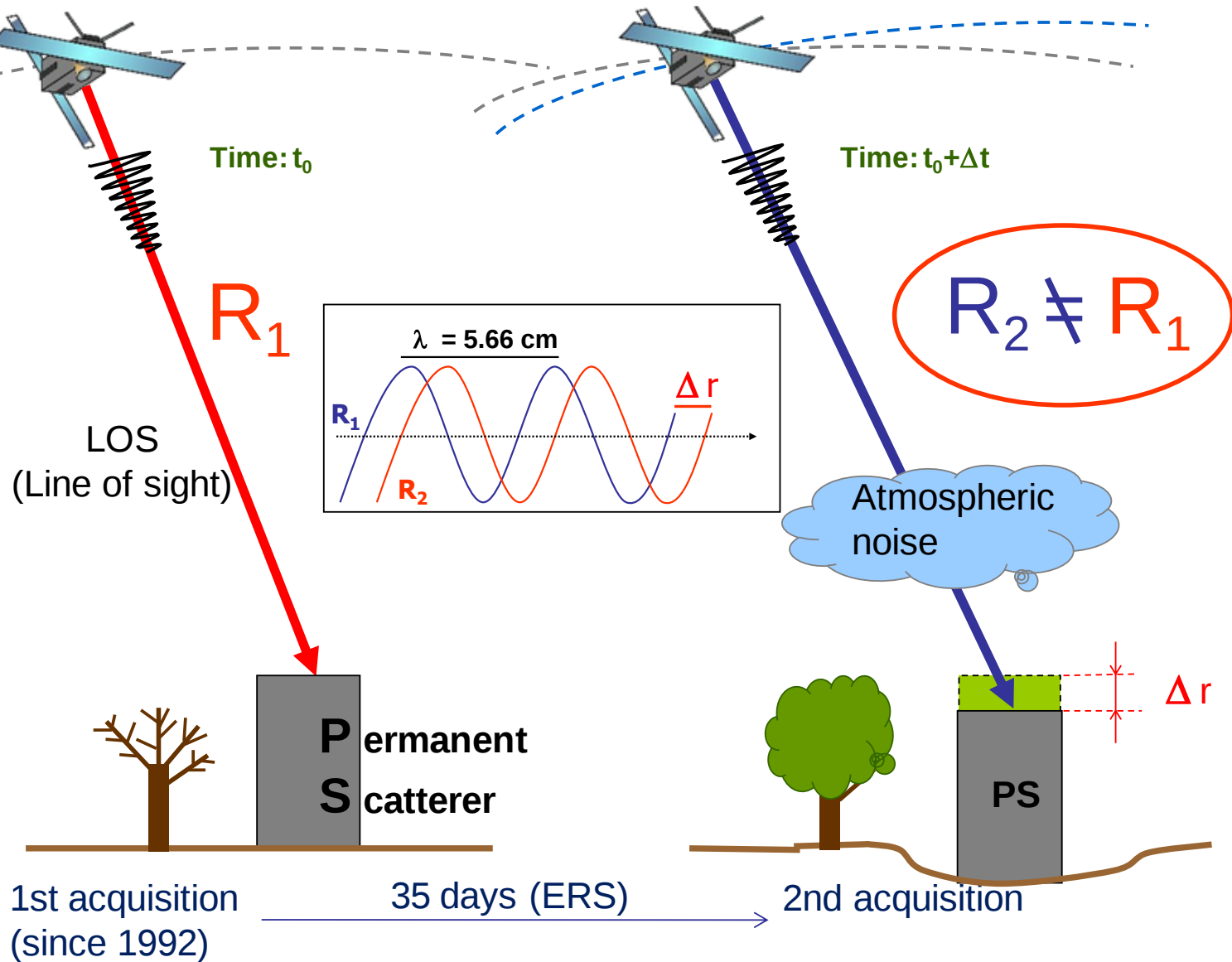
Satellite Synthetic Aperture Radar



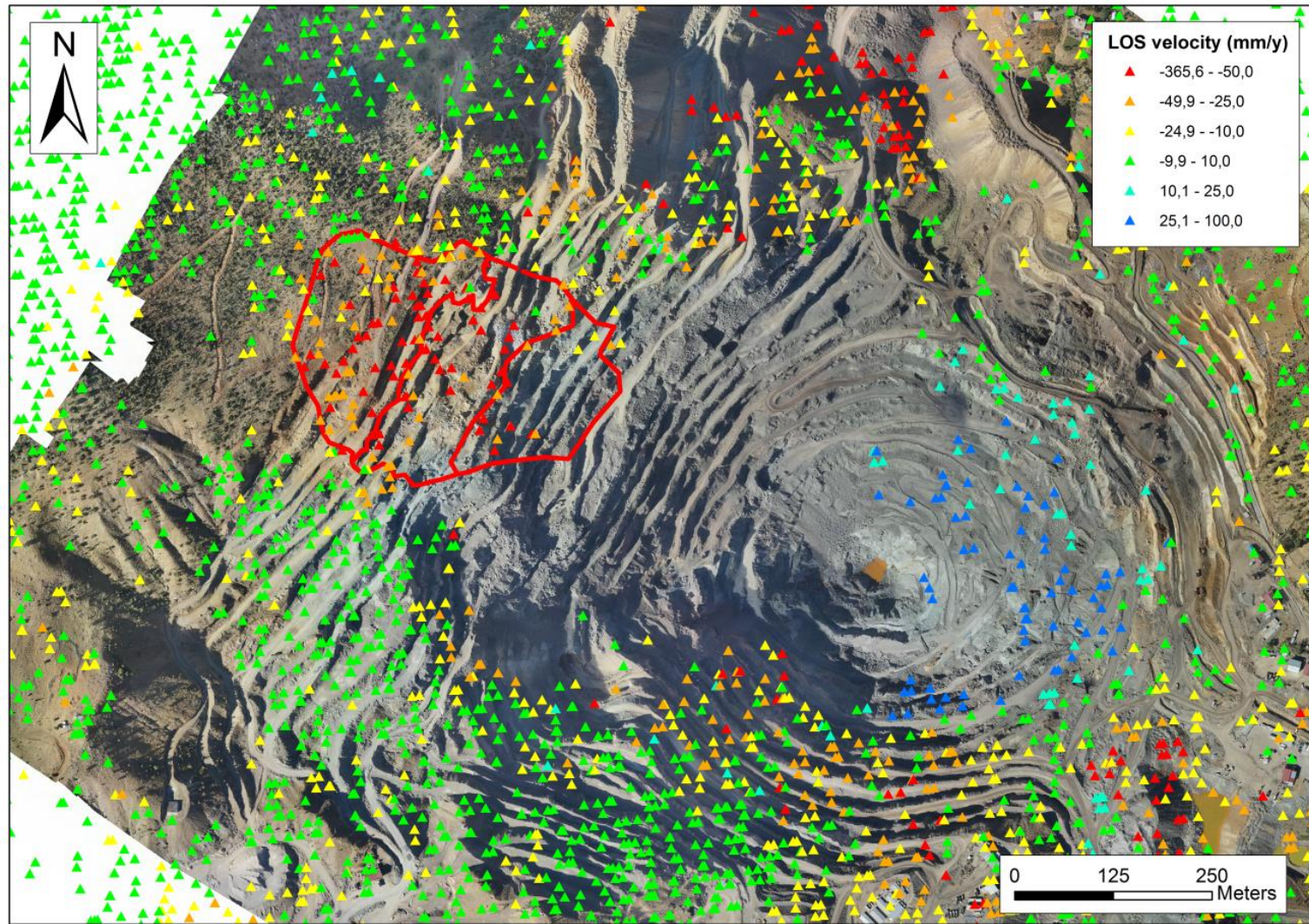
Advanced PSI techniques



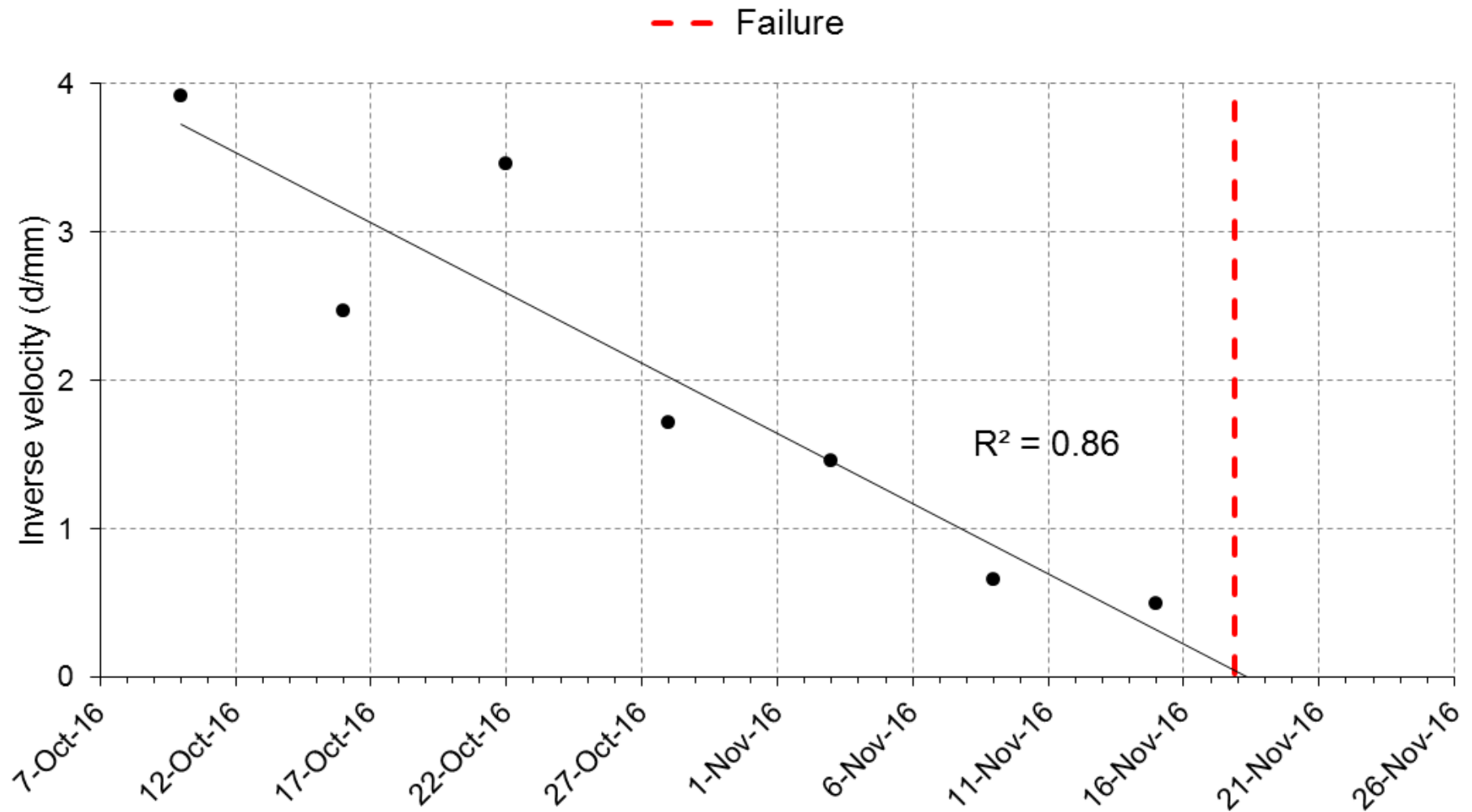
Tecnica PSInSAR



Monitoraggio PS-INSAR



Previsione collasso



Monitoraggio radar satellitare



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SCIENZE DELLA TERRA



Regione Toscana



PROTEZIONE CIVILE

Presidenza del Consiglio dei Ministri
Dipartimento della Protezione Civile

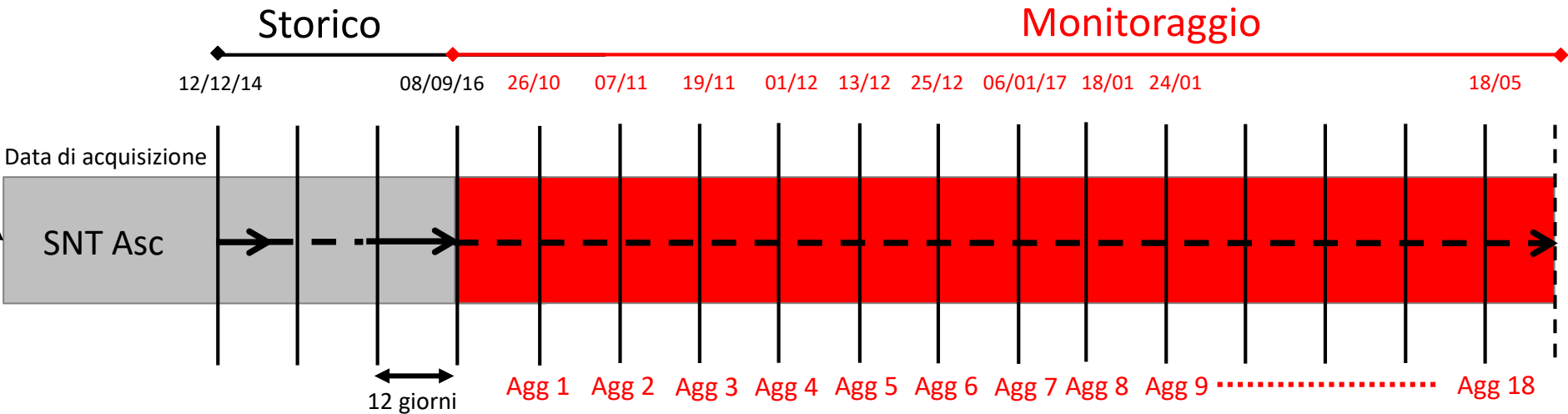
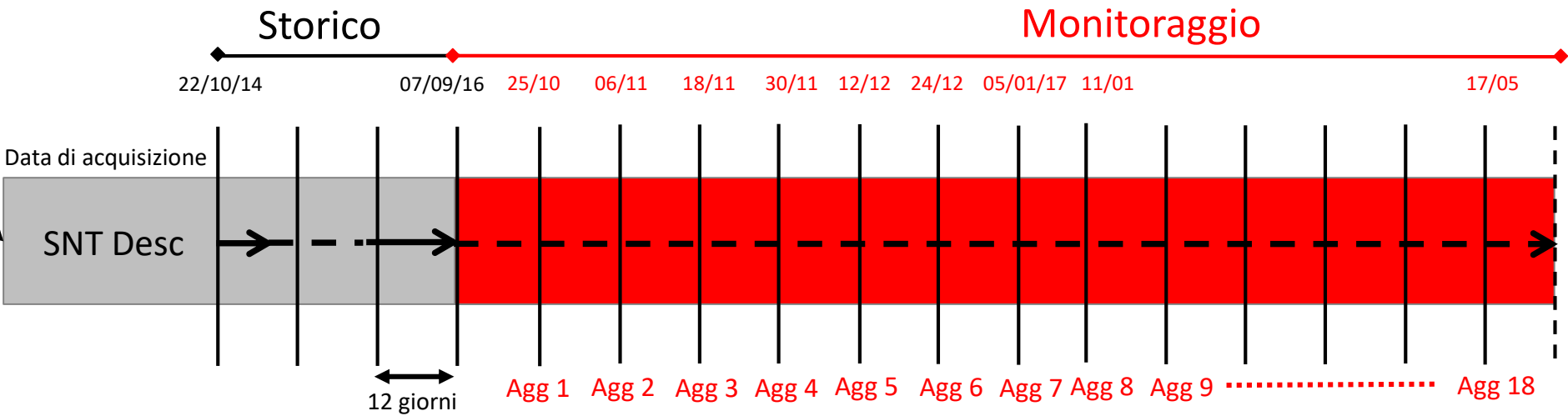


CONSORZIO

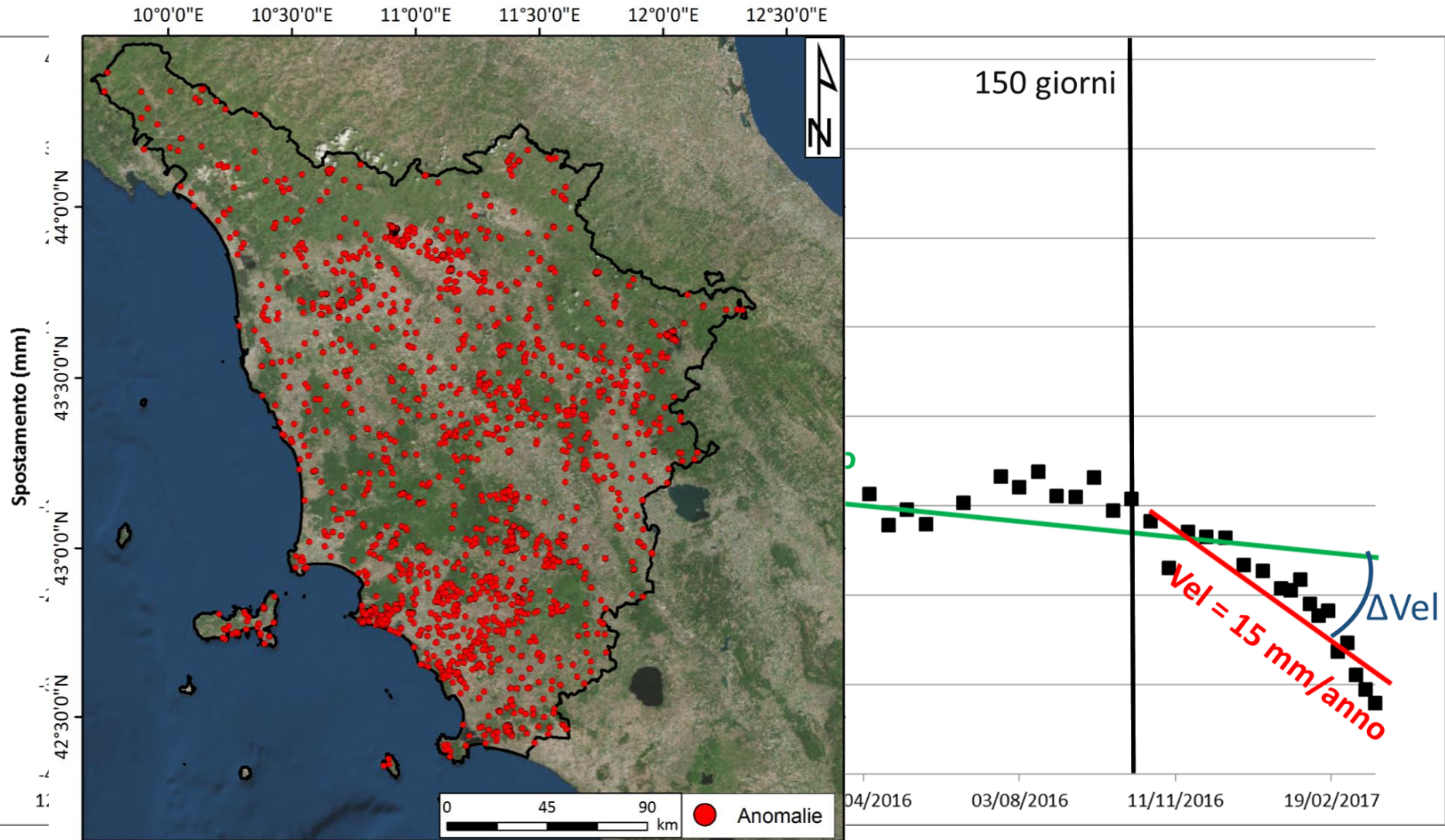
LaMMA



Piano di monitoraggio PS monitoring

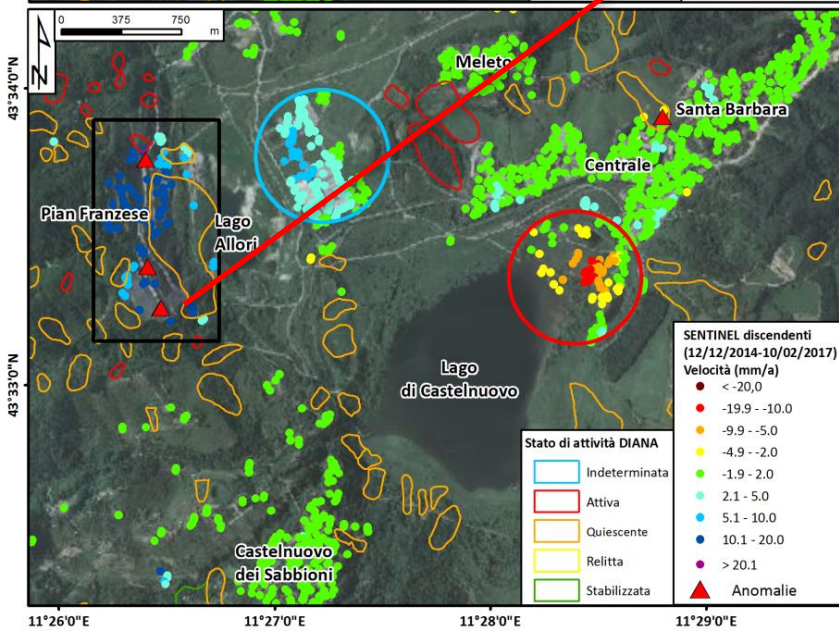
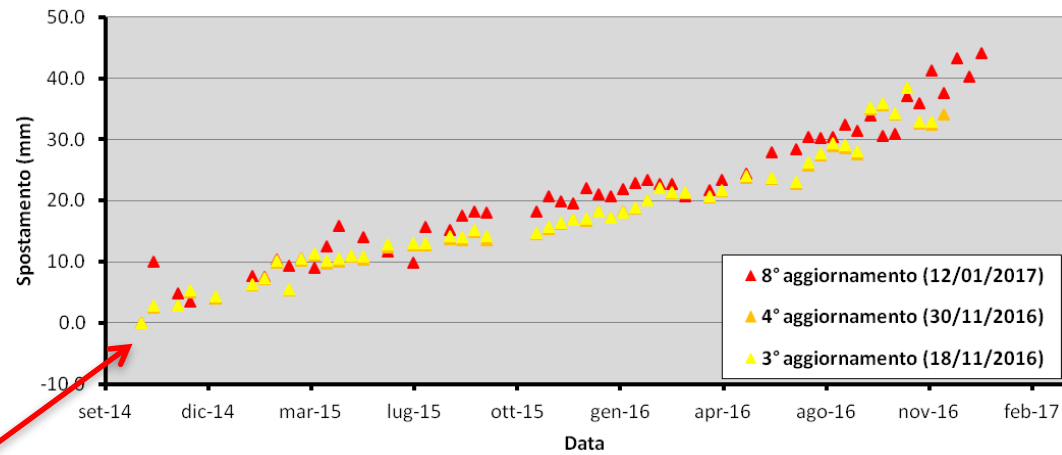
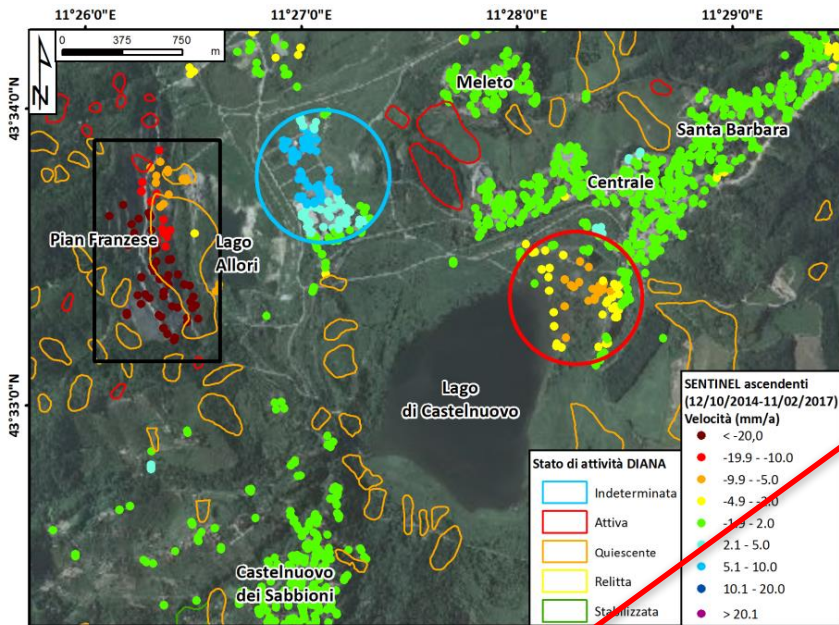


Anomalia



Variazione (ΔVel) > 10 mm/anno all'interno degli ultimi 150 giorni

Cavriglia (AR)



GRAZIE PER L'ATTENZIONE



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