

**DISSESTO IDROGEOLOGICO NELL'ARCO ALPINO E PREALPINO:  
previsione, prevenzione e gestione dell' emergenza**

**MILANO  
28 Settembre 2018**



# IL MONITORAGGIO DELLA FRANA DEL GALLIVAGGIO IN VALCHIAVENNA (SO)

*a cura di:* **Dott. Geol. Luca Dei Cas**  
**ARPA - U.O. Centro Monitoraggio Geologico**

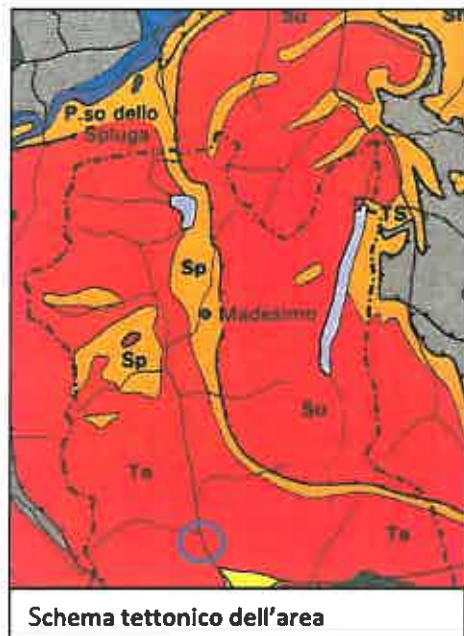


## AREA LOCATION



## GALLIVAGGIO ROCK WALL: GEOLOGY SUMMARY

The monitored area is located in Valle Spluga, in the San Giacomo Filippo district (Sondrio province), and this specific rock wall is directly behind the Sanctuary of Gallivaggio.



This area is inside the Tambò layer which is **constituted by Truzzo granite complex**, and extends from here to Val Bregaglia (Switzerland) along a distance of 27 Km.

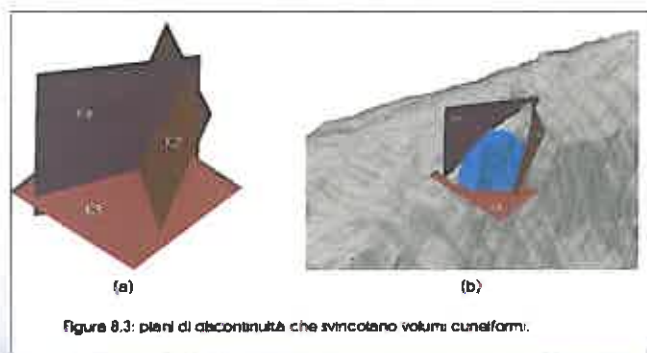


Figure 8.3: piani di discontinuità che svincolano volumi cuneiformi.

The **discontinuity sets**, inside the rock sub vertical cliff, **are very persistent**; their orientation cause rock block instability as you can see on the lateral image.

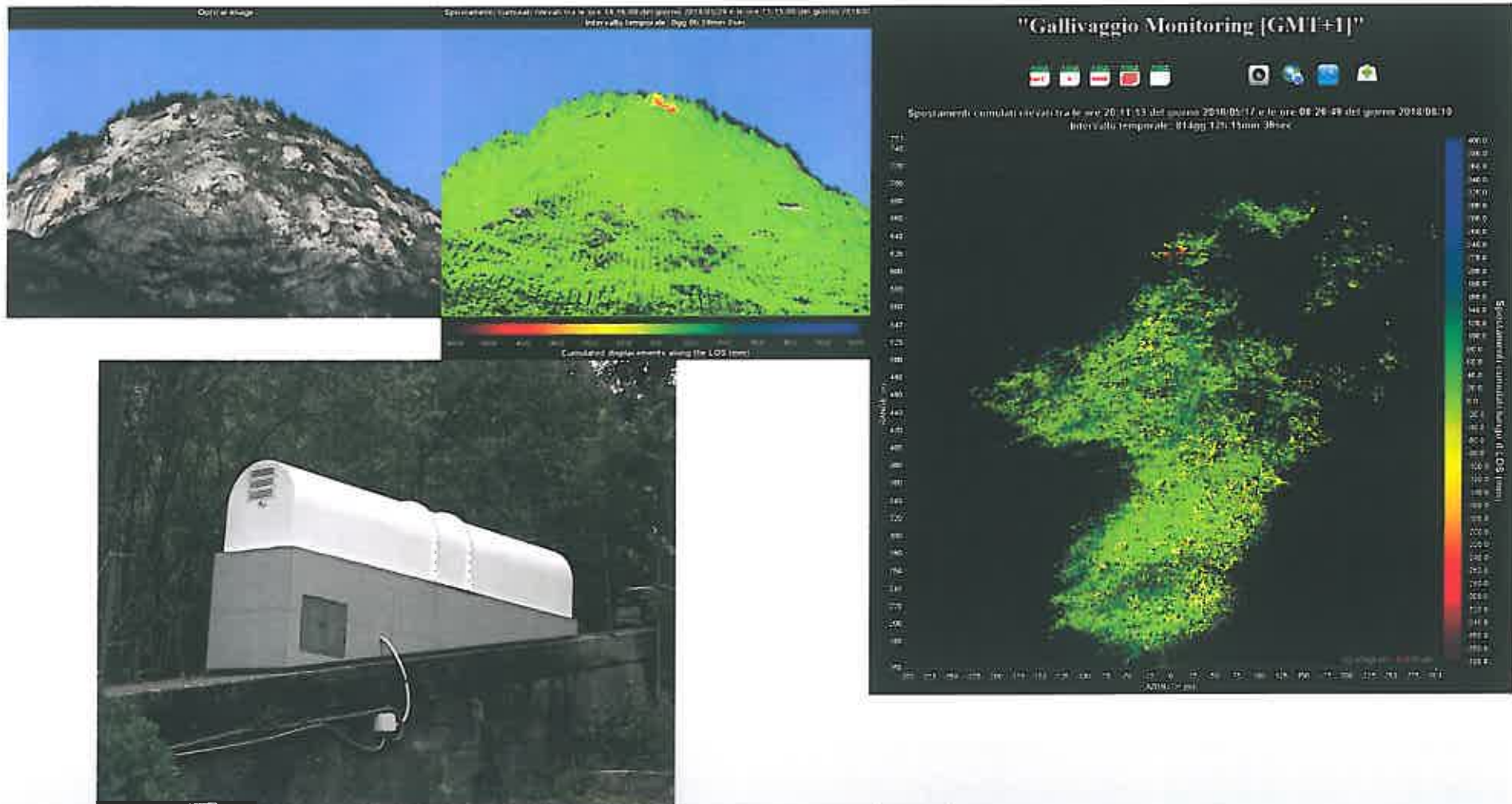
## PROTECTION AGAINST LANDSLIDE

**2008:** rockfall embankment and flexible barriers



## PROTECTION AGAINST LANDSLIDE

### 2011/2012: geological monitoring network

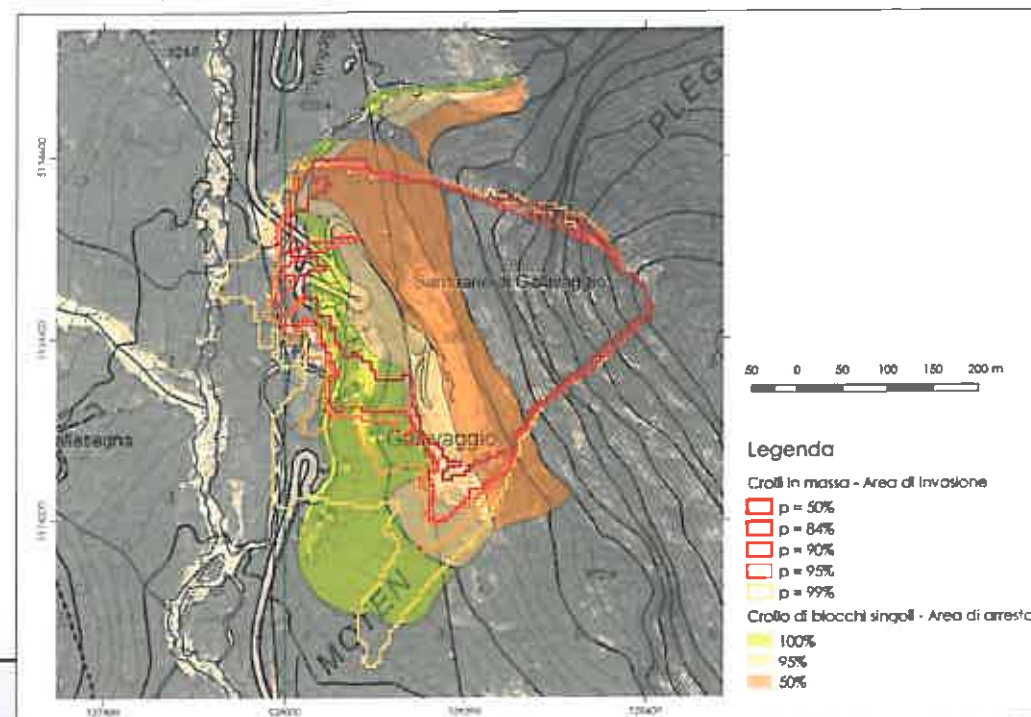


## 2017: GEOTECHNICAL MODEL

In 2017, a study called “**Geotechnical model and discern thresholds of trigger for the Gallivaggio landslide**” showed us different manifestations of rock mass failure.

The different colours lines represent the **area boundary where the landslide could arrive** with changeable probability (function of historical events printed on bibliography).

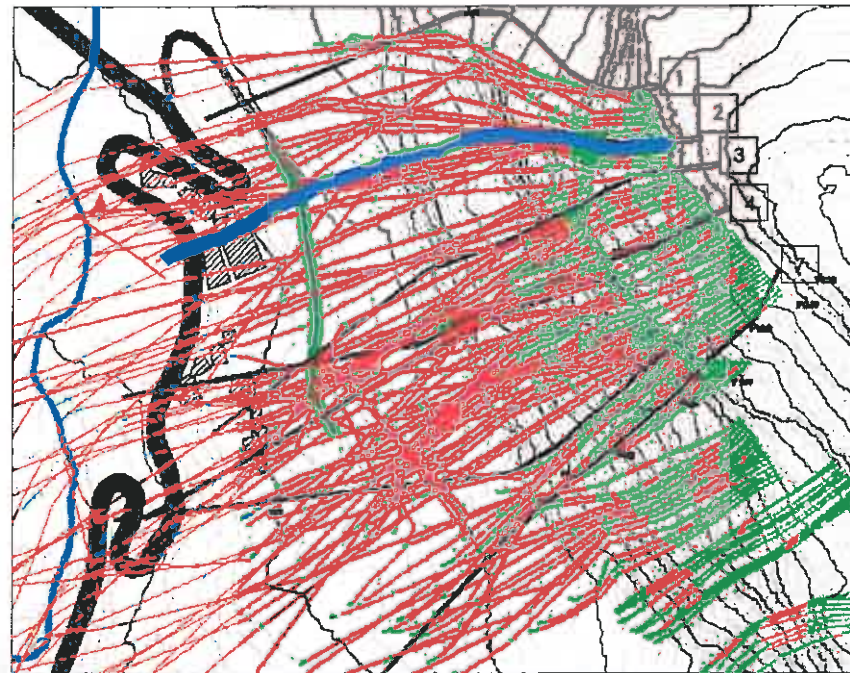
Most of the analysis showed that the infrastructure and cultural heritage (road and Sanctuary) are threatened (the rock mass failure could impact them)



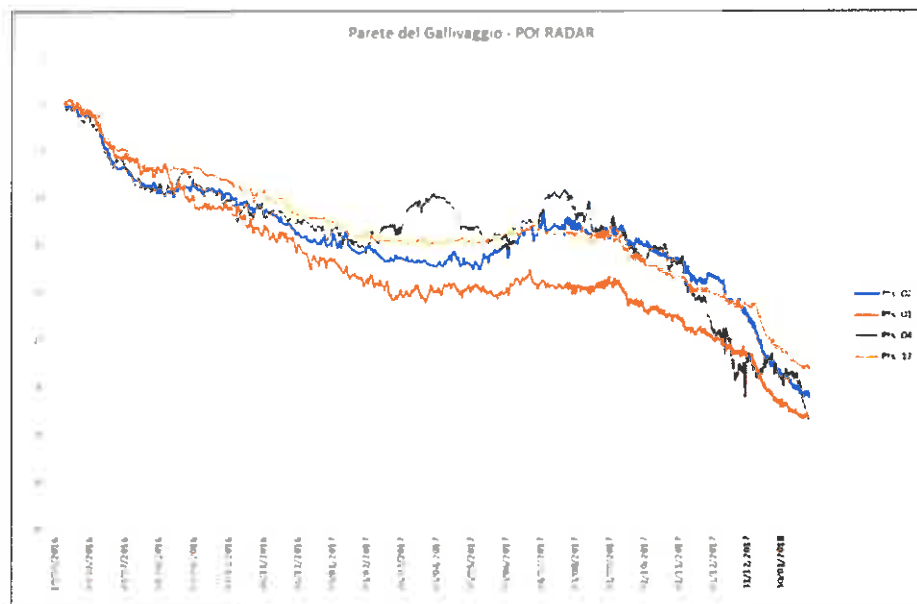
## SINGLE ROCK BLOCK FALLS: JUMP OVER BARRIERS

In the same study, quite an amount of simulation of single rock block falls, (from the upper part of the rock wall) **show us** that from 2% to 7% of these falls would jump over the long embankment and the flexible barriers.

Especially in section 2 the single rock blocks (22%) could arrive on the church or on the road and restaurant !! This situation is **impossible to predict** with monitoring network



During the Autumn of 2017 the data analysis values acquired, enabled us to notify the Lombardy Region Civil Protection of a **dangerous acceleration** of movement in about 460 m<sup>2</sup> of the rock area.



**ARPA** LOMBARDIA  
 Agenzia Regionale per la Protezione dell'Ambiente  
 Settore Tutela dai Rischi Naturali  
 Centro Monitoraggio Geologico

**MONITORAGGIO GEOLOGICO**

**PARETE DEL GALLIVAGGIO**

**NEL TERRITORIO COMUNALE DI**

**SAN GIACOMO FILIPPO (SO)**

**REPORT DI AGGIORNAMENTO**

Redatto	Diret. Geol. Franca Maria Poma	Dicembre 2017
Approvato	Diret. Geol. Luca De Cei	Dicembre 2017

Questo rapporto, redatto con l'indicazione a stampa del numero del foglio responsabile e norma del D.Lgs. 309/93 art. 3 c. 2

In February 2018, we sent another notification in which we informed the Civil Protection about the acceleration showed a doubling of the values compare to the previous ones in Autumn.



## ROCK BLOCK FAILURE: APRIL 13TH 2018



## TROUBLES FOR POPULATION



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Con la presente gli abitanti dei Comuni di Campodolcino e Madesimo a seguito delle criticità causate dalla frana in Località Gallivaggio (Comune di San Giacomo Filippo) intendono esprimere le seguenti **URGENTI** esigenze:

1. Apertura della strada e transito sotto la propria responsabilità nei momenti in cui non sono presenti nel cantiere gli operai, in attesa della ragionevole ed indispensabile realizzazione della variante o del ripristino della viabilità ordinaria.
2. Consentire ampliamento del transito dei mezzi di rifornimento delle diverse attività in orari compatibili con le fasce di lavoro e la necessità degli autotrasportatori.
3. Richiesta dello stato di calamità, a causa dei gravi danni economici riportati dai diversi operatori.
4. Creare dei servizi pubblicitari ad hoc dove sia chiarito il punto che la comunità si occupa, nonostante i disagi, quotidianamente delle necessità del territorio, compresa l'ospitalità dei nostri ospiti.

**Questo con lo scopo di evitare ulteriori danni economici già riscontrati nei mesi di Aprile e Maggio e il totale azzeramento della stagione estiva con probabili danni a quella invernale.**



## MAY 11TH 2018: PROTECTION OF CULTURAL HERITAGE



24 MAY 2018

Notice of  
**TRIGGER  
THRESHOLD  
EXCEEDED**  
3mm/24h  
24/05/2018  
ore 08:01



Notice of  
**TRIGGER  
THRESHOLD  
EXCEEDED**  
4mm/24h  
24/05/2018  
ore 20:42



Route «SS  
36» closed  
H24

29 MAY 2018

Last Report sent from  
ARPA LOMBARDIA at  
hour 16:00



## REPORT



EMESSO **MARTEDÌ 29 MAGGIO 2018 ALLE ORE 16.00**

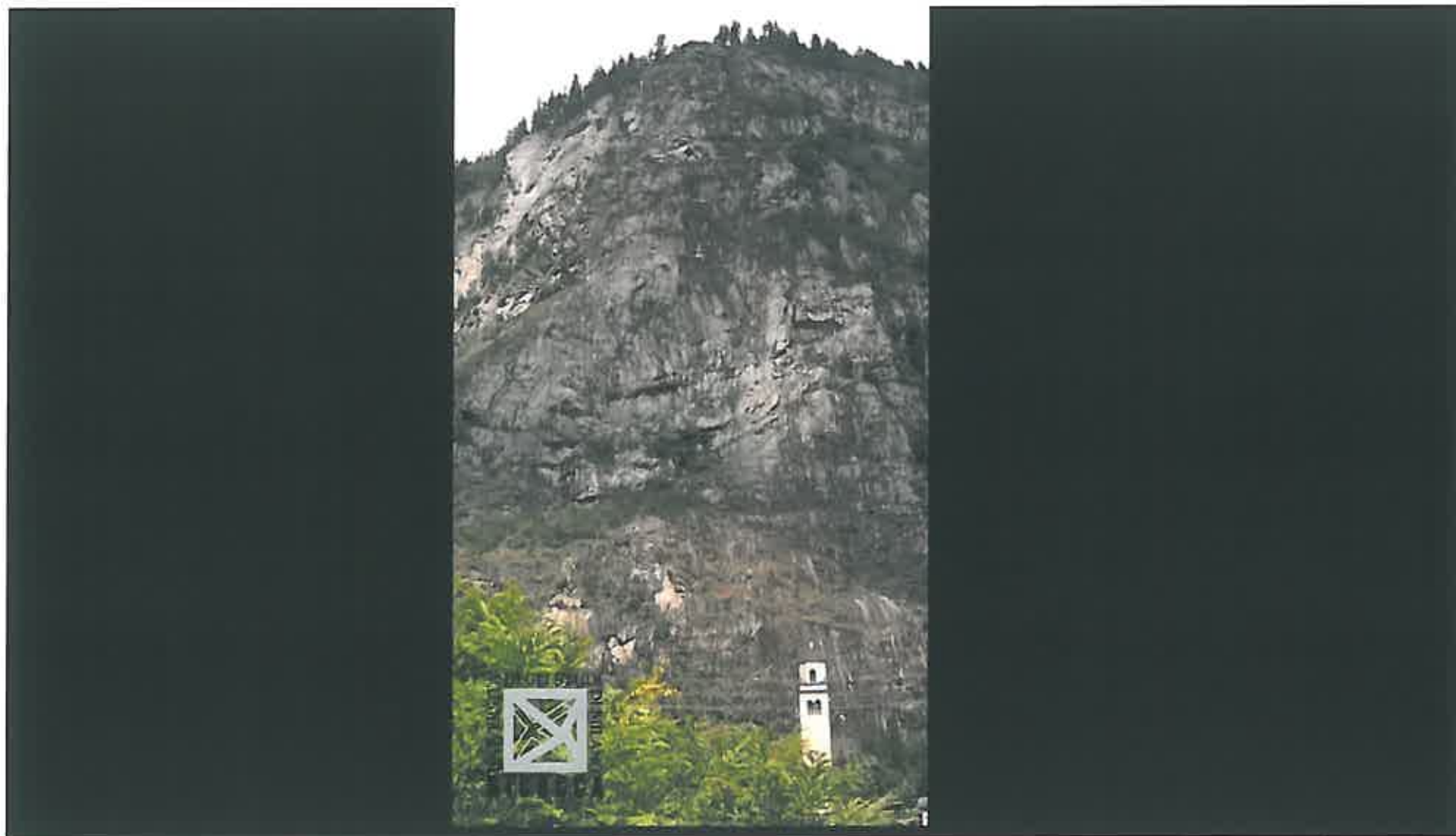
A: REGIONE LOMBARDIA - UNITA' ORGANIZZATIVA PROTEZIONE CIVILE

### Situazione del dissesto

Facendo seguito a quanto precedentemente comunicato si osservano nelle ultime 24 ore velocità dei punti monitorati in ulteriore aumento, con valori che hanno raggiunto un massimo di 107.2 mm/24h, con velocità orarie fra le 15 e le 16 di oggi di circa 2 cm/h. Valori così elevati non erano finora stati osservati sull'ammasso, ed il trend di continua accelerazione indica una situazione di estrema pericolosità ormai prossima al collasso.

## LANDSLIDE CROWN





## THE INFRASTRUCTURES AND CULTURAL HERITAGE AFTER THE COLLAPSE

### BELL TOWER





## THE INFRASTRUCTURES AND CULTURAL HERITAGE AFTER THE COLLAPSE

### THE CHURCH



## THE INFRASTRUCTURES AND CULTURAL HERITAGE AFTER THE COLLAPSE

### SANCTUARY SQUARE



## THE INFRASTRUCTURES AND CULTURAL HERITAGE AFTER THE COLLAPSE

### BEHIND THE SANCTUARY



## THE INFRASTRUCTURES AND CULTURAL HERITAGE AFTER THE COLLAPSE

### ROKFAH EMBANKMENT AND PLANTS

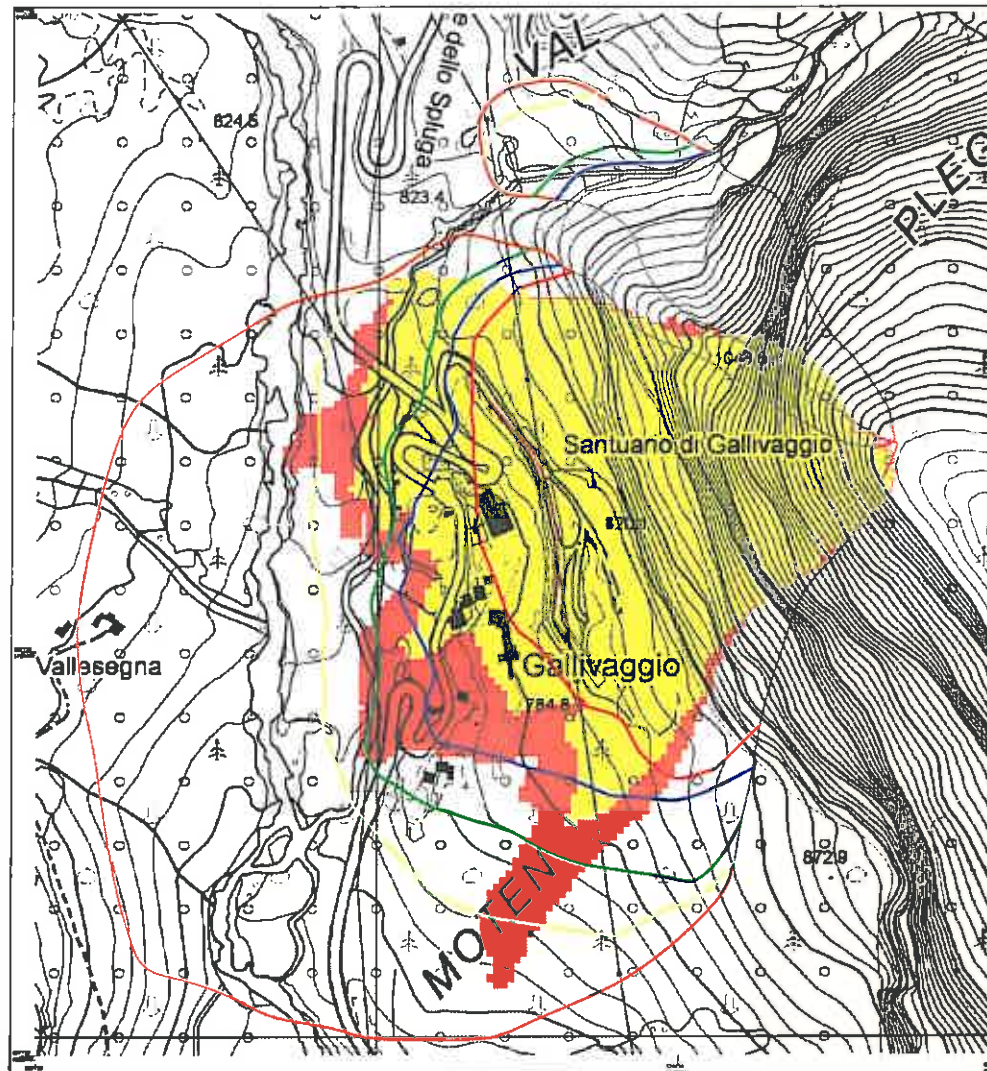


## THE INFRASTRUCTURES AND CULTURAL HERITAGE AFTER THE COLLAPSE













### ROAD



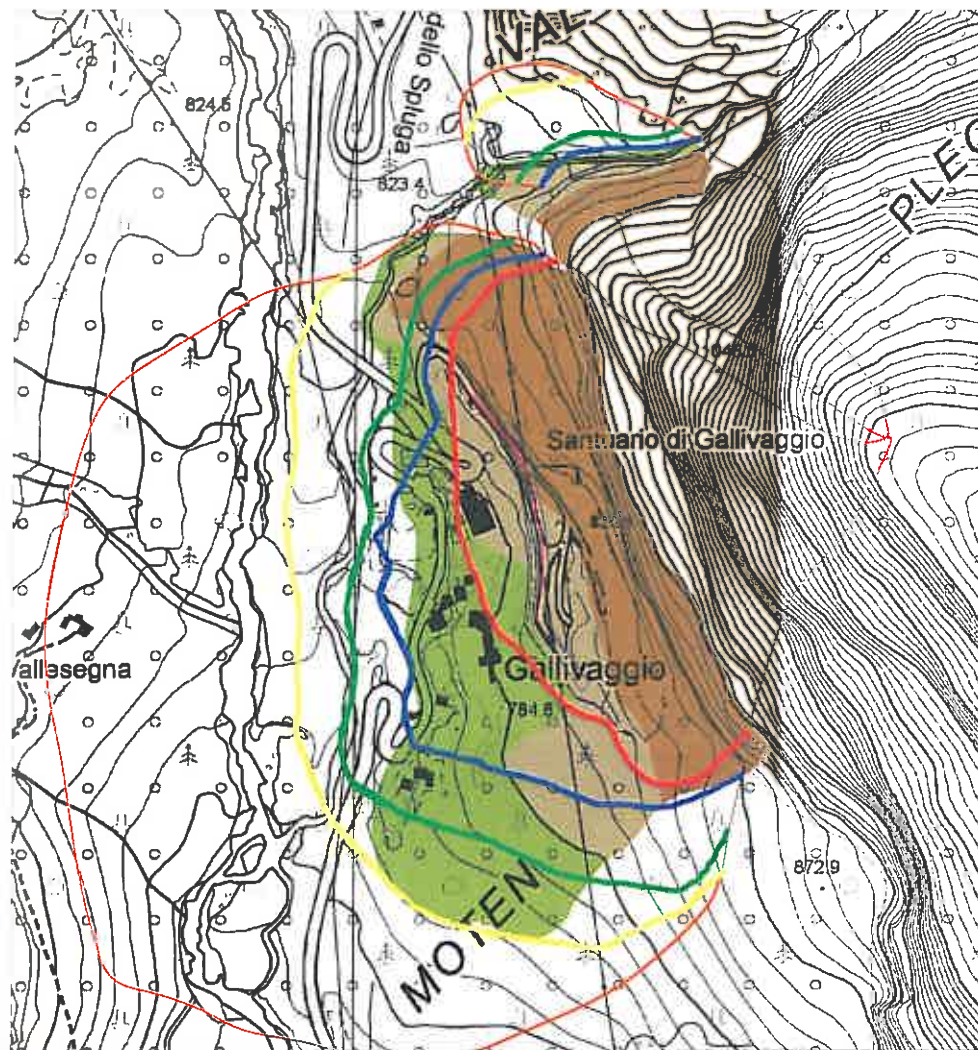
## ROCK MASS FAILURE
















### LEGEND (areal distribution of the deposit)

-  Landslide crown
-  Boundary line rock blocks fallen ( $b > 0,5 \text{ m}^3$ )
-  Boundary line r. blocks fallen ( $0,5 \text{ m}^3 > b > 0,05 \text{ m}^3$ )
-  Boundary line r. b. fallen ( $0,05 \text{ m}^3 > b > 0,005 \text{ m}^3$ )
-  Boundary line r. blocks fallen ( $b < 0,005 \text{ m}^3$ )
-  Boundary line fine grain debris
-  Boundary line of lateral debris fallen
-  Flexible barriers razed
-  Flexible barriers not razed
-  Embankment
-  Rock mass failure: covered area 95% probability (Cancelli engineering study 2017)
-  Rock mass failure: covered area 99% probability (Cancelli engineering study 2017)

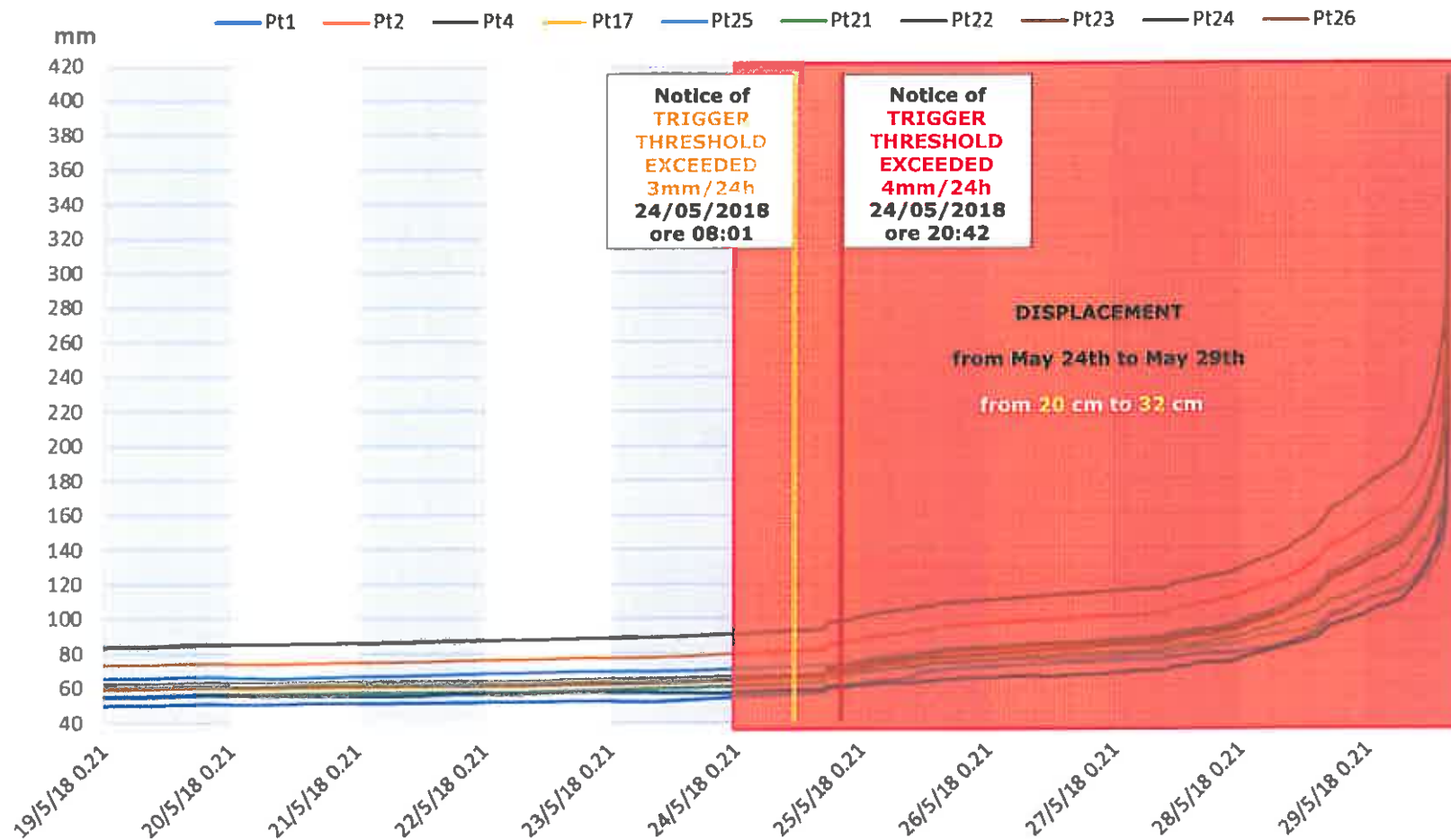
## SINGLE ROCK BLOCK FALLS



### LEGEND (areal distribution of the deposit)

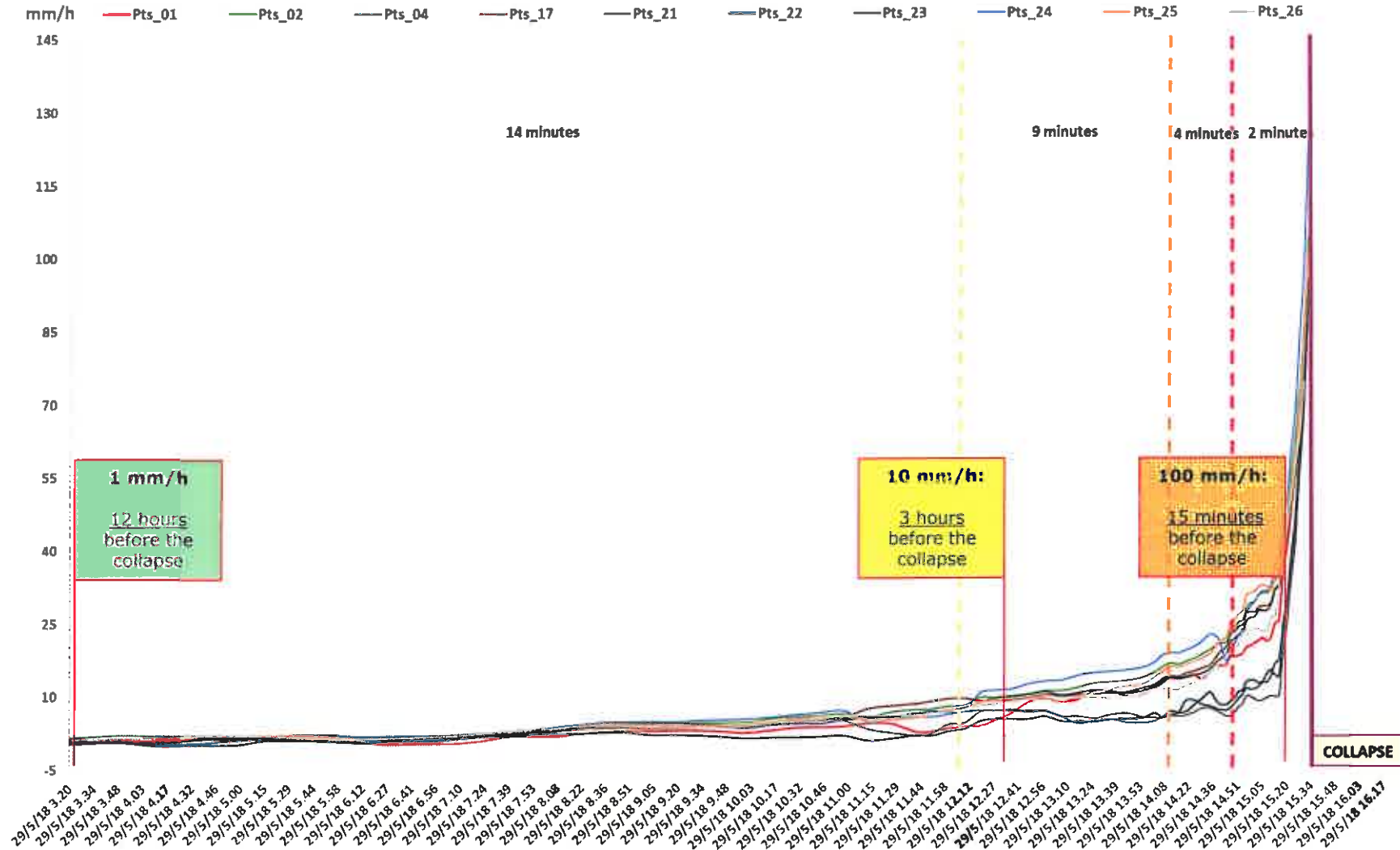
-  Landslide crown
-  Boundary line rock blocks fallen ( $b > 0,5 \text{ m}^3$ )
-  Boundary line rock blocks fallen  $0,5 \text{ m}^3 > b > 0,05 \text{ m}^3$
-  Boundary line rock blocks fallen ( $0,05 \text{ m}^3 > b > 0,005 \text{ m}^3$ )
-  Boundary line rock blocks fallen ( $b > 0,005 \text{ m}^3$ )
-  Boundary line fine grain debris
-  Boundary line of lateral debris fallen
-  Flexible barriers razed
-  Flexible barriers not razed
-  Embankment
-  Single rock block failed: covered area 50% probability (Cancelli engineering study 2017)
-  Single rock block failed: covered area 95% probability (Cancelli engineering inside 2017)
-  Single rock block failed: covered area 100% probability (Cancelli engineering study 2017)

### Gallivaggio Radar points Displacements from May 19th to May 29th





Gallivaggio radar points - velocity hourly (last 12 hours before the collapse )



## CONCLUSION 1 / 2

**Possibility of forecast rock mass failure**: Gallivaggio landslide represents an example of a forecast failure of about 5000 mc rock.

**Efficacy of the monitoring network**: the performance of the network gives us data values to identify vast movement areas and permit us to see gradual movement (0,03 mm/d) and then to monitoring movement close to any failure. It isn't effective for single rock block falls.

**The collection of important data values**: the collection of data values, from the start of acceleration to the time of rock mass failure, permitted us to have all acceleration data values (0,1 mm/h 6 day from failure, 1 mm/h 40 hour from failure, 10 mm/h 3 hour from failure, 100 mm/h 15 minutes before failure).

**Good performance of geotechnical modelling** : the scenarios of rock mass failure and single rock block failure had a good realistic overlapping.

## CONCLUSION 2/2

**Carried out monitoring**: first notice (December 2017 and February 2018) then trigger threshold exceeded notice (May 24th 2018) and the last notice close to failure (May 29th, hour 4 p.m.).

**In May 2018, monitoring was the only activity to guarantee human safety and protection of cultural heritage**: with evacuation, the SS 36 route closed, removal of sacred paintings and gold sacred cups before the failure.

**Cost**: the setting up and implementation of the geological monitoring network in Gallivaggio cost much less than the cost of protective mechanisms which would have been necessary.

**THANK YOU FOR YOUR ATTENTION !!**