



Giovedì, 18. Dicembre 2014
Palazzo 1 „Cortile interno“
Piazza Silvius Magnago 1
I-39100 Bozen

Convegno
Fine Progetto SloMove

Monitoraggio di movimenti gravitativi
Esperienze applicative e ricerca nell'arco alpino

INTEGRATION OF DIFFERENT MONITORING TECHNIQUES: THE EXAMPLE OF ROSONE LANDSLIDE (WESTERN ALPS)

Claudia Meisina (*), Alessio Colombo(), Davide Notti (***), &
Francesco Zucca (*)**

claudia.meisina@unipv.it

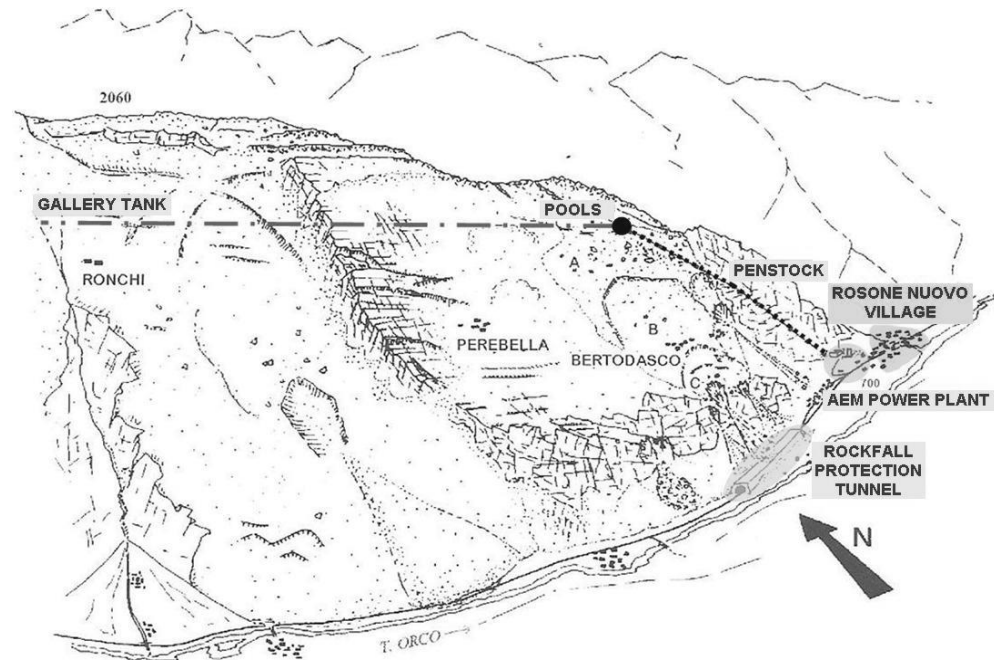
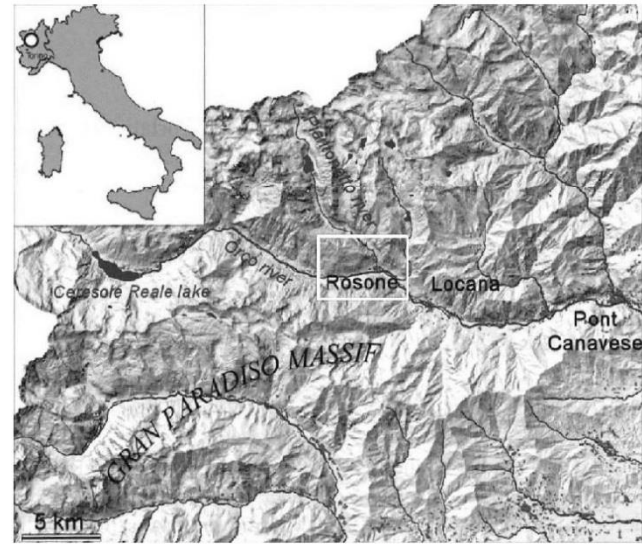


(*) Univ. di Pavia Dipartimento di Scienze della Terra e dell'Ambiente
(**) ARPA - Piemonte - (Italy)
(***) Univ. de Granada Departamento de Geodinamica (Spain)



1. INTRODUCTION

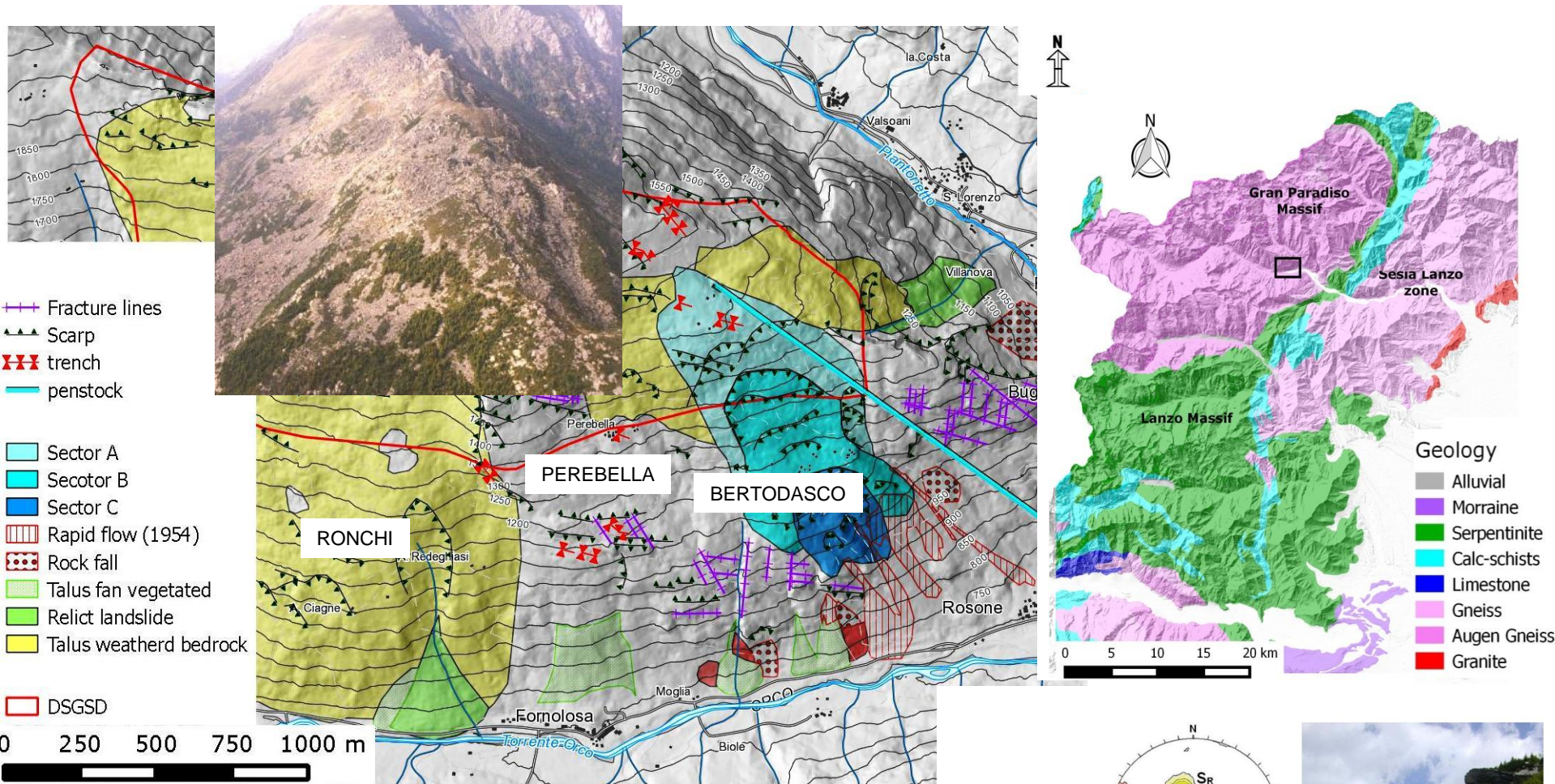
- ✓ The Rosone landslide is located in the Orco Valley (NW Italian Alps). It is a larger deep seated deformation (5,5 km²)
- ✓ The landslide affects the penstock of the near hydroelectric plant.
- ✓ The landslide was well monitored since 60's and it was studied by many authors (Ramasco et al, 1989; Chiriotti, 1997; Forlati et al, 2001; Bonnard et al, 2004; Binet et al, 2007, Pisani et al, 2010; ARPA Piemonte, 2012) that provides to assess the geomechanical, geomorphological and hydrogeological settings and to set up different models to predict the possible evolution and scenarios of risk in case of collapse.
- ✓ It is one of the most studied, modeled and monitored landslide in Piemonte Alps, due to catastrophic consequence of a collapse that may affect the penstock



2. AIMS

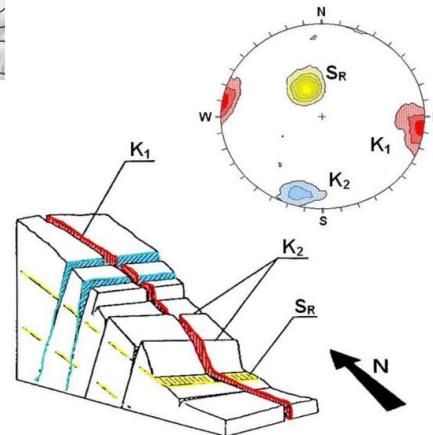
- ❑ to present an example of integration of different monitoring techniques (ground and remote sensing based) in a complex landslide
- ❑ to verify the use and the added value of the SAR satellite Interferometry (PSInSARTM, SqueeSARTM and CRInSARTM) in order to complement the monitoring system

3. GEOLOGICAL SETTINGS

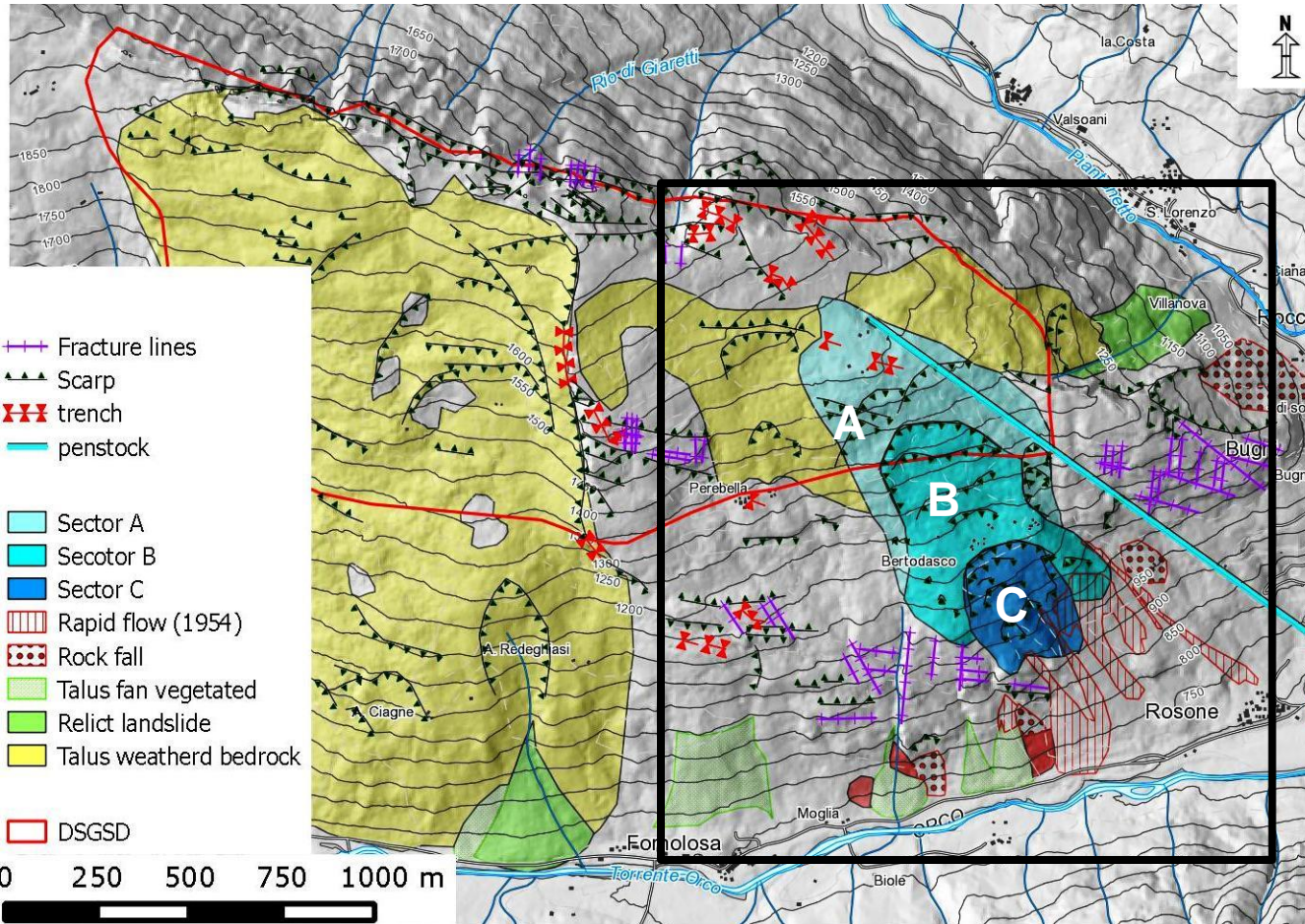


Rosone landslide is located on the Augen Gneiss Complex of Gran Paradiso internal penninic nappe.

Structural settings (foliation) and post glacial evolution



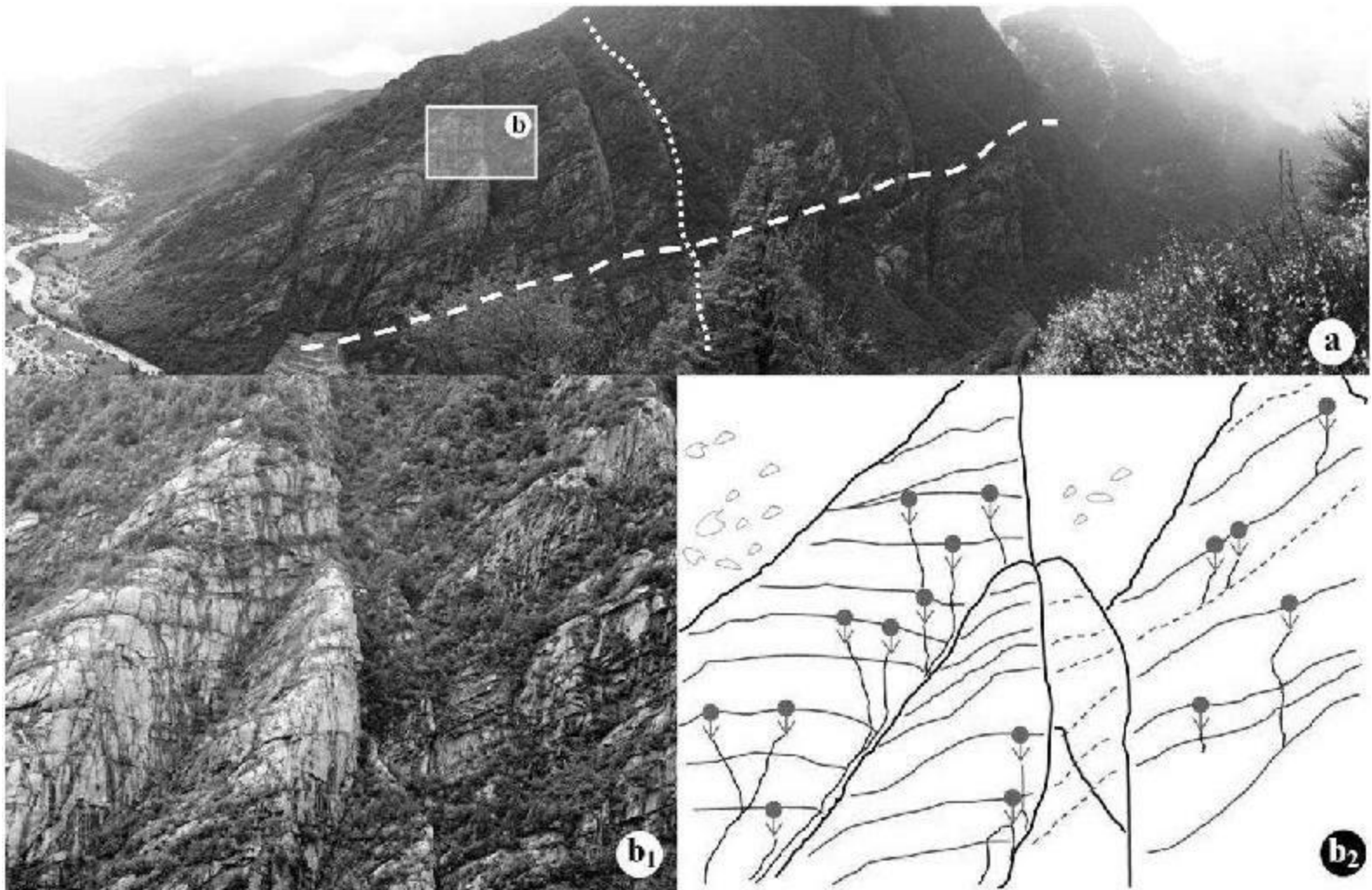
3.1. Morpho-structural Settings



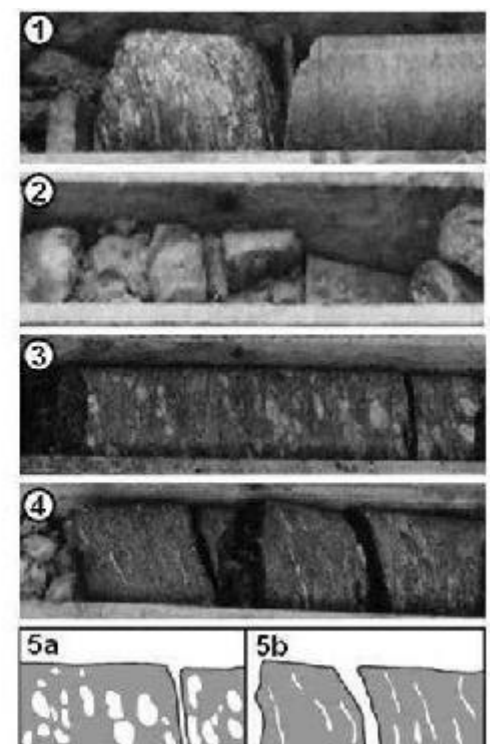
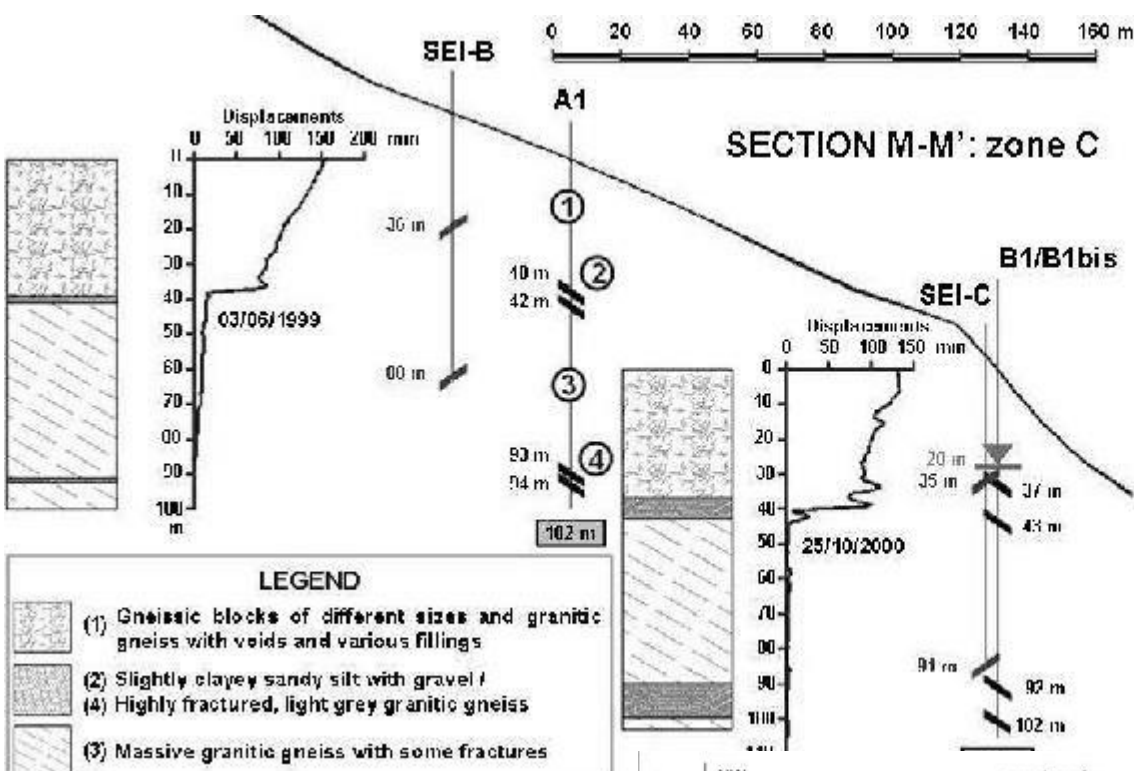
The volume of entire slide = about $2 \cdot 10^7 \text{ m}^3$

- ❖ **Sector A** (0.2 km²): rock mass with few deformations, many trenches and scarps can be detected. The movement is generally weak (up to 10 mm/yr) and sliding surface is between 30 and 75 m.
- ❖ **Sector B** (0.18 km²). The rock mass is rather weathered with completely disarticulated rock block, scarps and the presence of many debris. The sliding surface can be identified 40 / 50 m depth, the type of movement is mainly planar with a rate of movement up to 20 mm/yr
- ❖ **Sector C** (0.08 km²) . it is the most weathered sectors, the rock mass is completely disarticulated. The depth of sliding surface is about 40 / 60 m. The type of movement is mainly roto-translational. This sector is also affected by rock fall and debris flow. In the 1953 a strong reactivation of the movement caused severe damages to Bertodasco village and the inhabitant were evacuated. The movement of this sector is more than 100 mm/yr.

3.2. Hydrogeological Settings

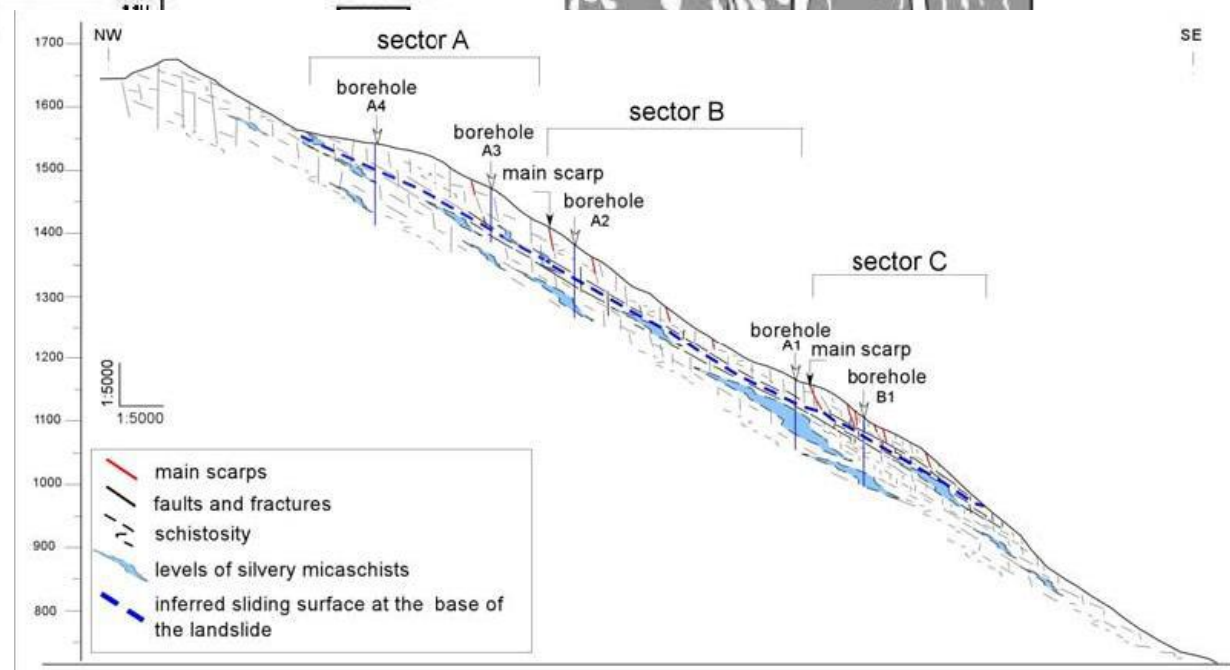


(a) Southern slope of the Orco Valley detailing the main shear bands (dashed line) and the large vertical fracture in NS direction (dotted line), (b1) view of the shear zones, (b2) percolation of water in correspondence of the shear zones.



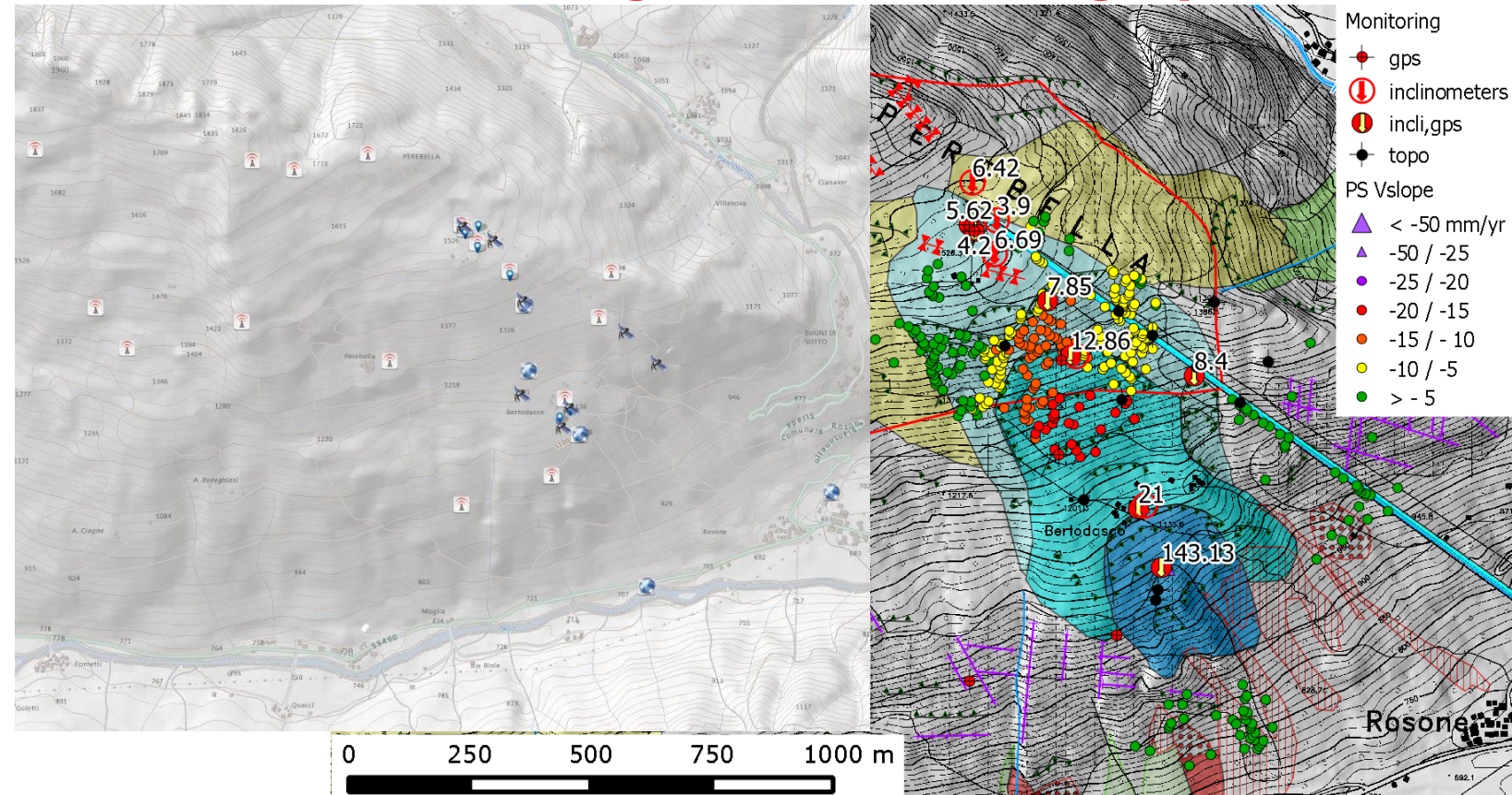
3.3. Geomechanical Settings

- Reflection seismic surveys
- Down holes
- Boreholes (100-120 m)

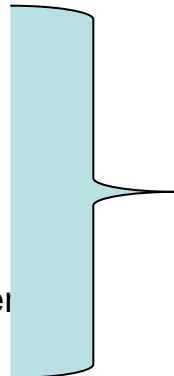


4. MONITORING SYSTEM

4.1. Integrated Monitoring System



- Geomechanical network
 - 10 inclinometers,
 - 11 extensometers
 - 4 piezometers
- Topographical network
 - GPS net
 - 10 optical measurements
- Idrometeorological network



- The landslides monitoring started in the sixties
- The integrated monitoring system designed and installed in 2000,
Aim: real time monitoring for early warning purposes (exceeding of thresholds)



Low and constant movement (no exceeding of thresholds)

4. MONITORING SYSTEM

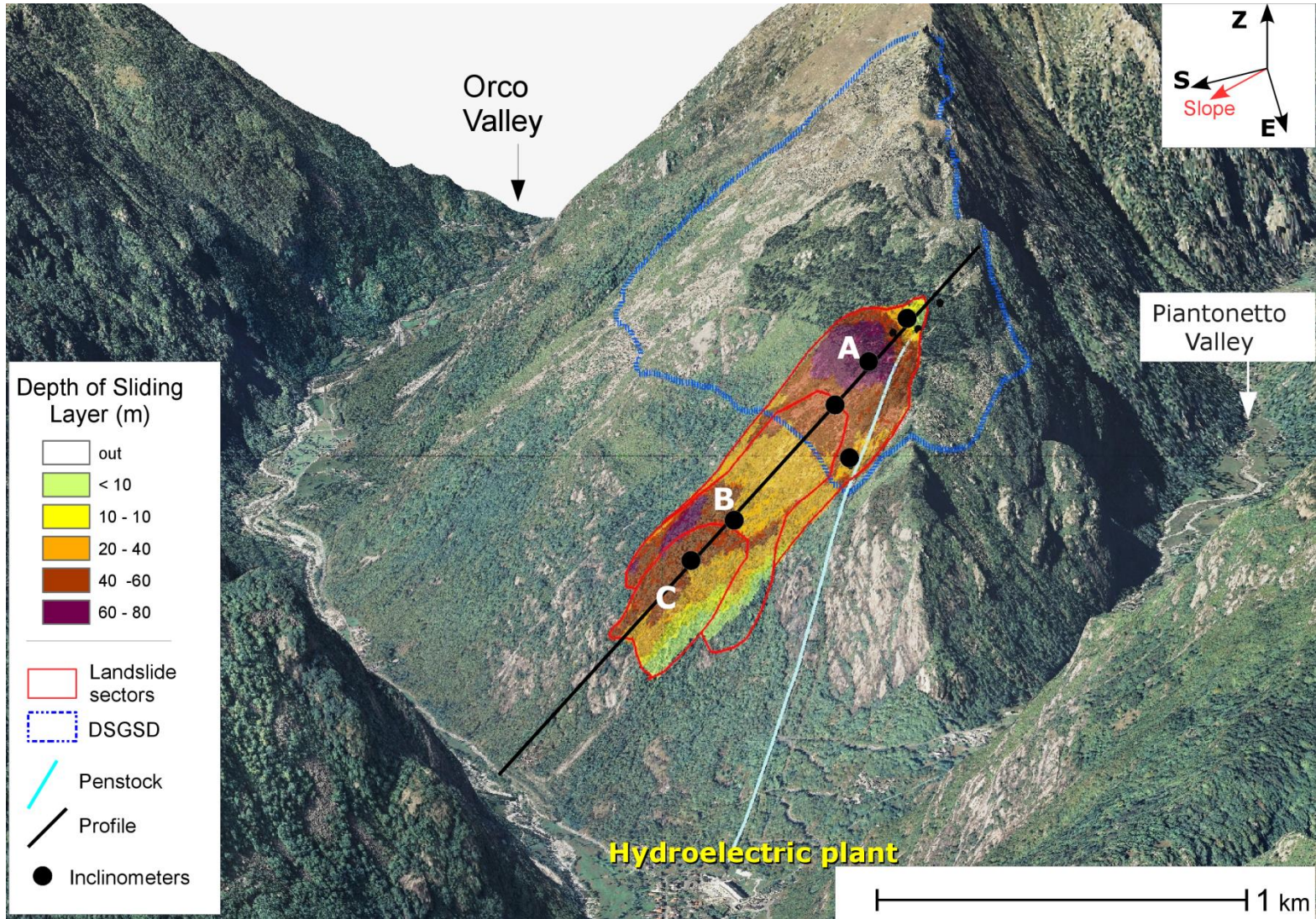
4.2. New Monitoring System

New monitoring system since 2014

- n. 4 **inclinometers with manual reading** (measure of deep movements);
- n. 1 **inclinometers with automated data recording** (continuous measure of the movement along the sliding surface);
- n. 7 **laser distantiometers**;
- n. 24 **GPS with manual reading**;
- n. 5 **GPS stations with continuous measures**;



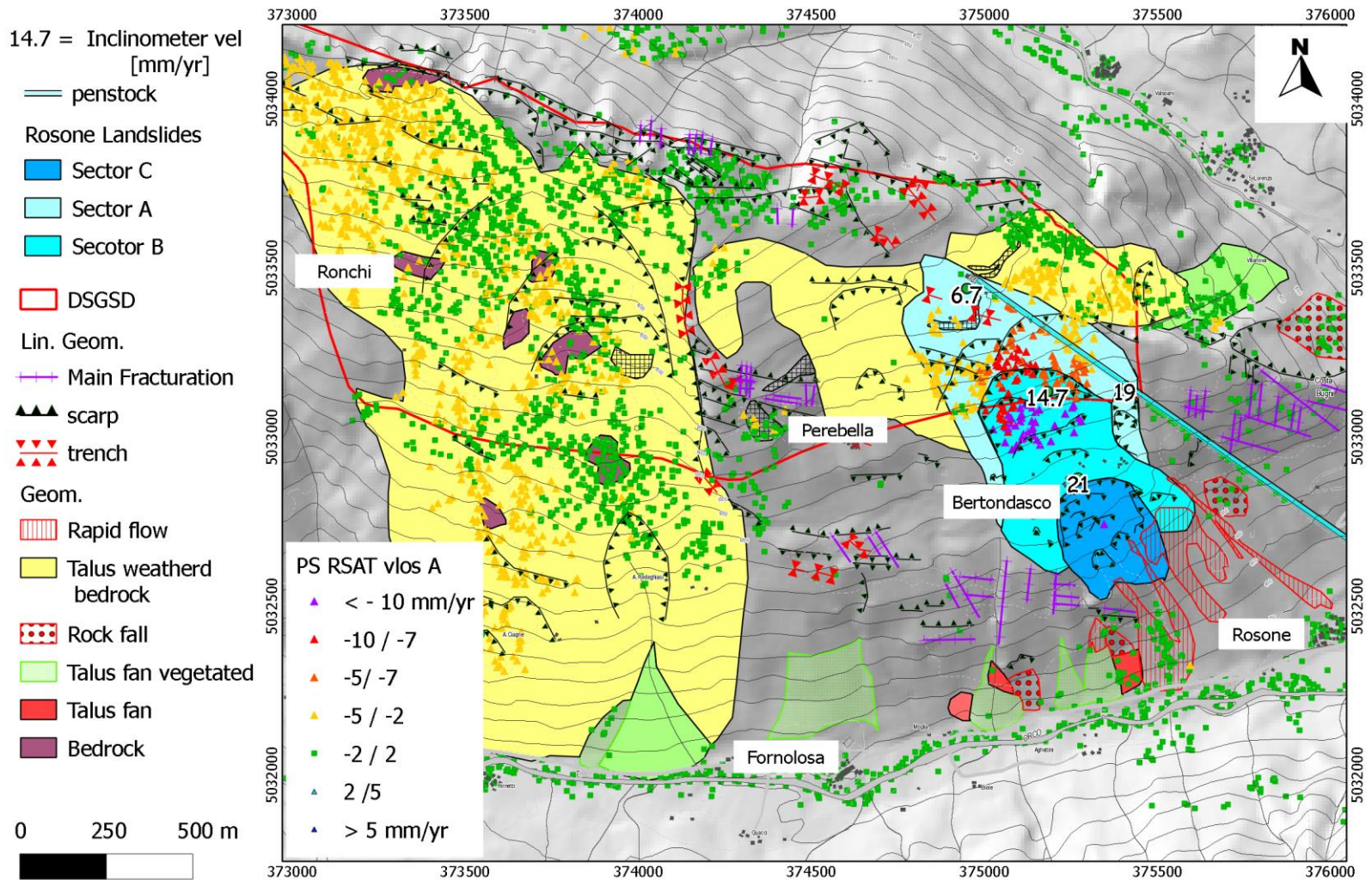
monitoring system for knowledge purposes



Landslide 3D model

4.3. SAR satellite data

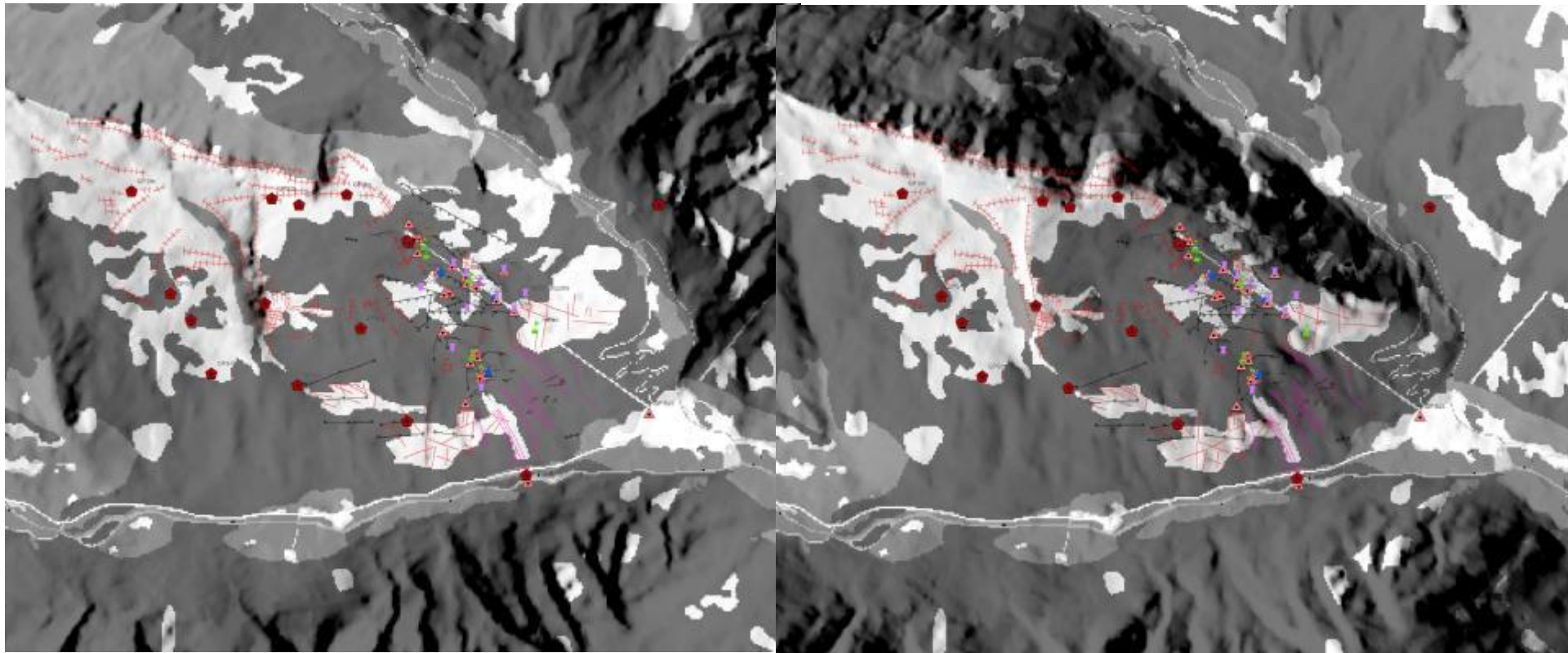
- ERS 1-2 data (1992-2001) elaborated with PSInSAR™ (TRE)
- Radarsat data (2003-2009) elaborated with SqueeSAR™ (TRE)



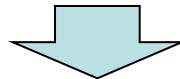
Is the Rosone landslide suitable for a SAR interferometric analysis?

ASCE

DESCE

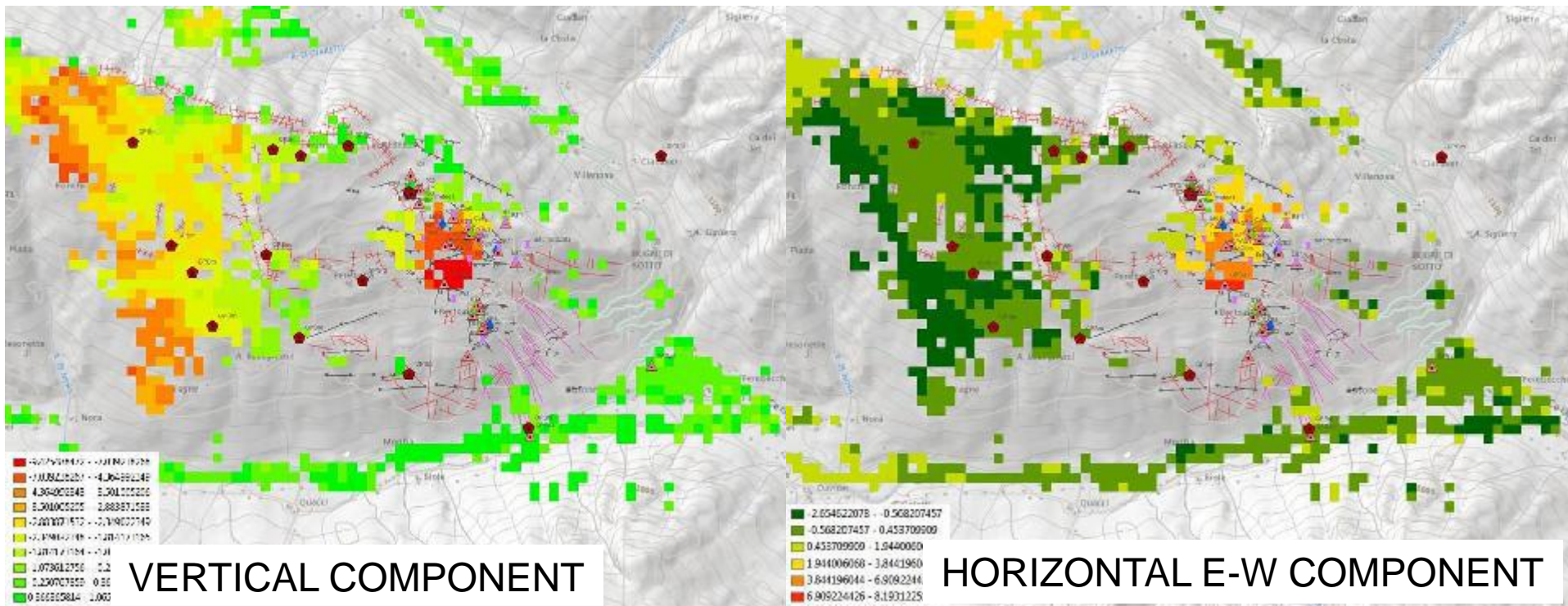


Prediction of the PSI distribution through the CR-Index .
White areas: probability up to 90% to find PSI



The C area is not suitable for a PSI processing

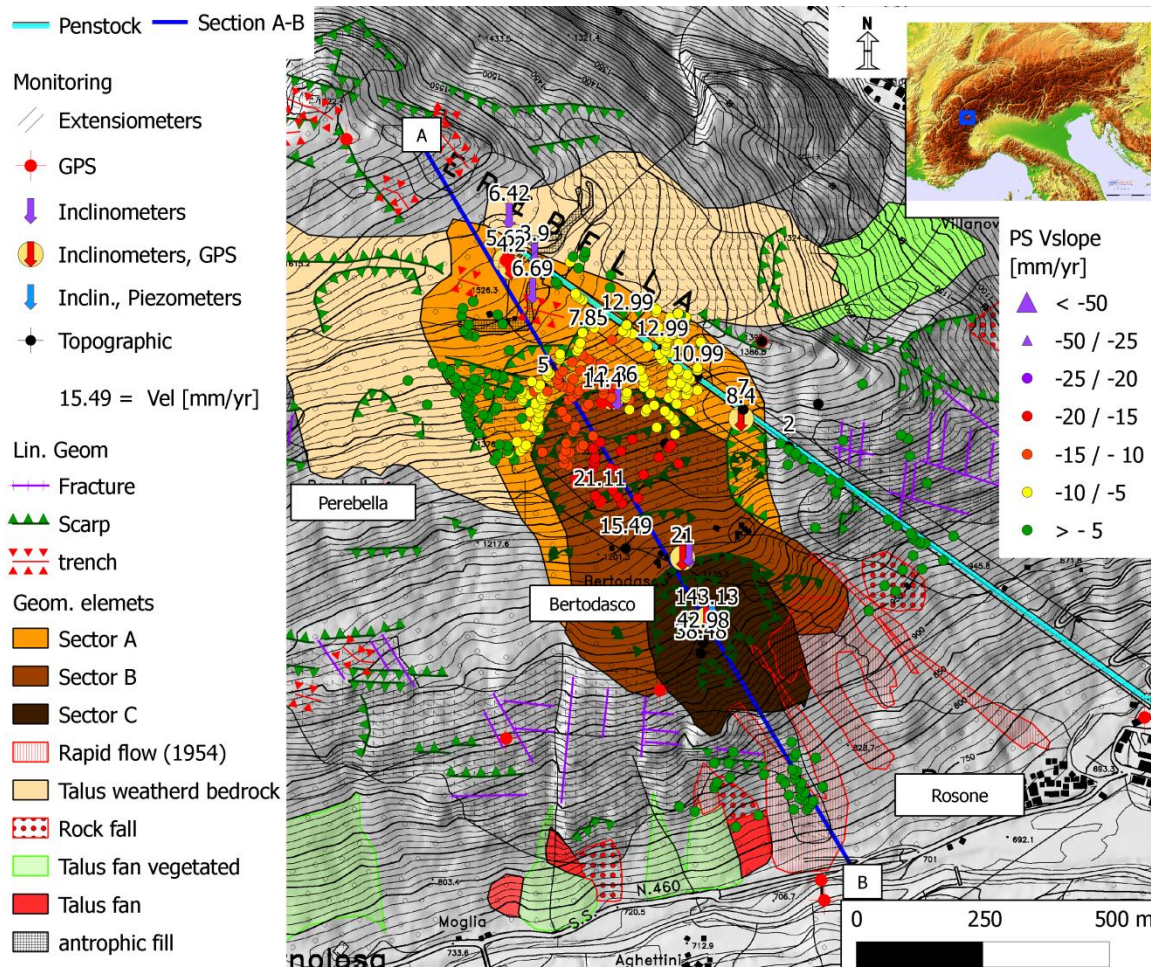
- ✓ The combination of ascending and descending geometries allowed to resolve the vertical and E-W component of the movement



Under the assumption of the small contribution of N–S horizontal motion, the availability of two geometries (ascending and descending) allows the E–W (VEL_{EW}) and vertical (VEL_{VERT}) velocity components to be resolved.

The results (up to 6 mm/yr toward East, and 10 mm/yr to down) are in a very good agreement with the other monitoring instruments

✓ The projection of the velocity of PS data V_{SLOPE} was made on the mean dip direction schistosity of the rock mass



The PSI analysis is possible only in the sector A and B:

- The sector A presents weak movements (5 mm/yr) in the eastern part and moderate movements (up to 10 mm/yr)

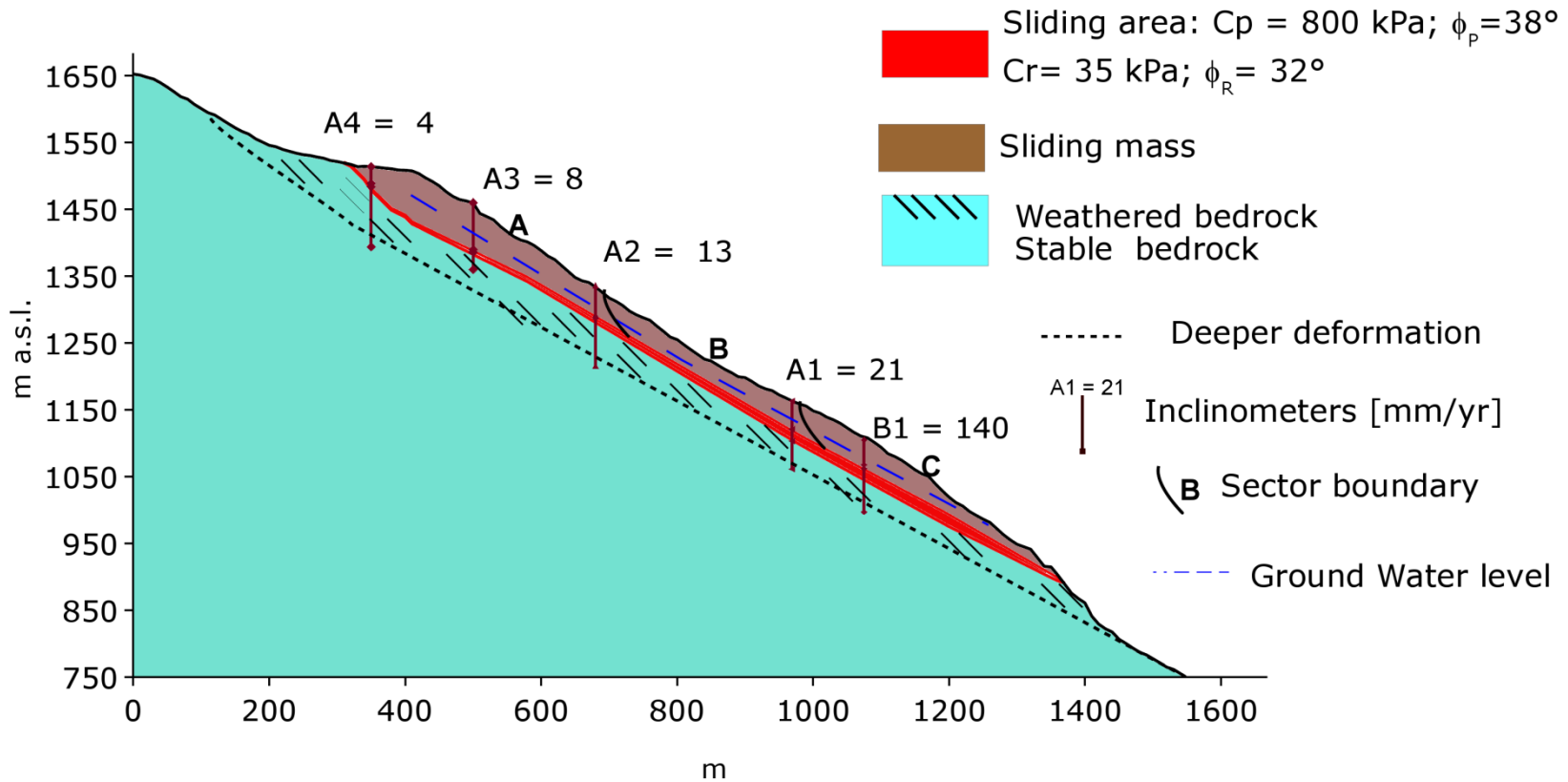
- The sector B is characterized by moderate movements from 10 to 20 mm/yr. It is possible to see that a scarp borders a sub-sector with major movement.

- The sector C does not have significant PS data. The GPS and optical measurements show a velocity from 45 up to 130 mm/yr.

Direction of the movement: SE-SSE; $V_{\text{LOS}} / V_{\text{SLOPE}} = 0.65$

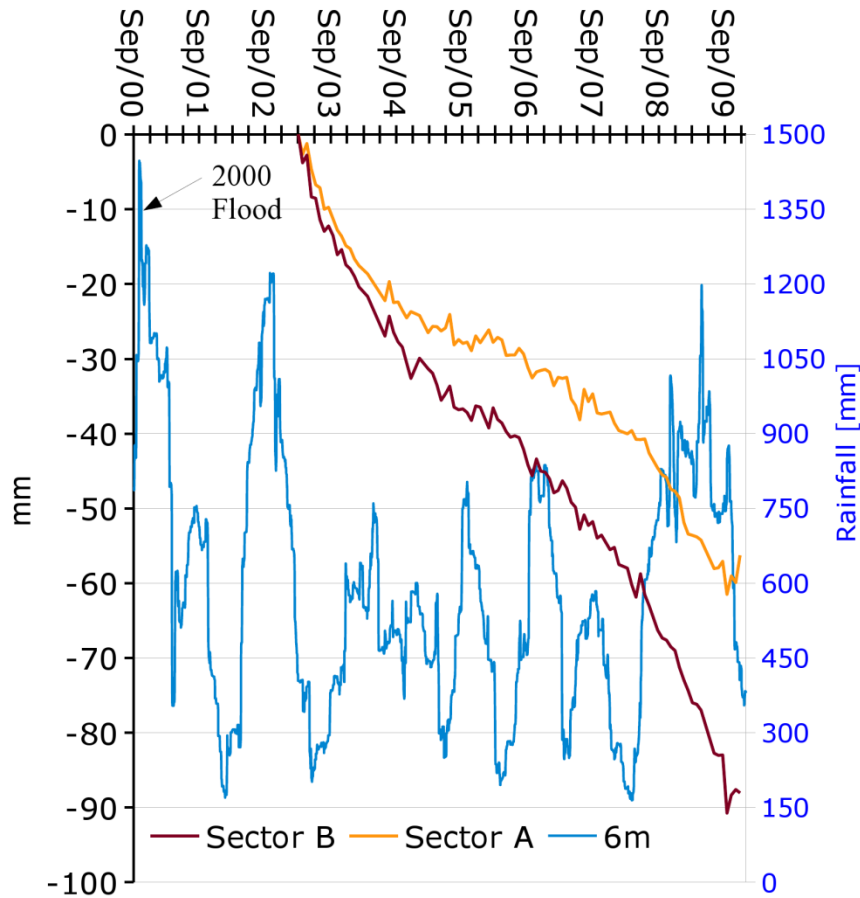
ASCENDING GEOMETRIES CAN DETECT THE 60% OF THE REAL MOVEMENT

✓ Velocity registered by the different monitoring systems



Landslide sector	Velocity mm/yr			
	GPS	Optical	Inclin.	PS Data
A (a1 - a2)	12	5	< 10	4 a1 - 10 a2
B (b1 - b2)	20	15	10 - 30	8 b1 - 20 b2
C	45	38 - 43	n/a	n/a
Period of analysis	2001-2011	2001-2011	1991-2008	2003-2009

PS Time series (2003-2009 *RADARSAT* descending data) of the sectors A and B compared with 6 months (6m) cumulated rainfall (2000-2009)



The TS show a weak change in the trend

- Slow movement in the period 2005-2008 may be related to dry period;
- No critical events during PS monitoring (2003-2009)

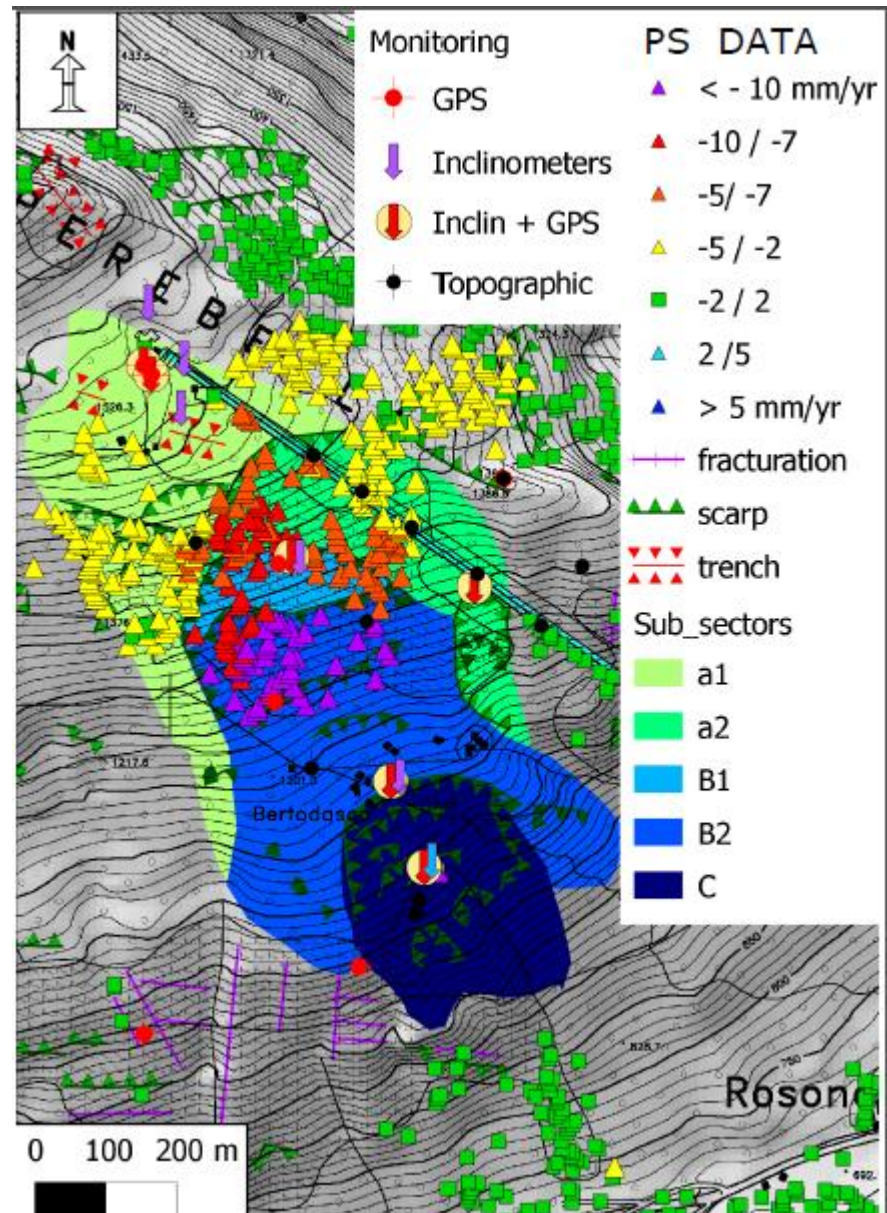
The added values of PS Data:

1. **Validation of monitoring:** The velocity the same for different systems
2. **High Spatial density measure** in the sectors **A** and **B** allows division:
sub-sectors A1/A2 – B1/B2

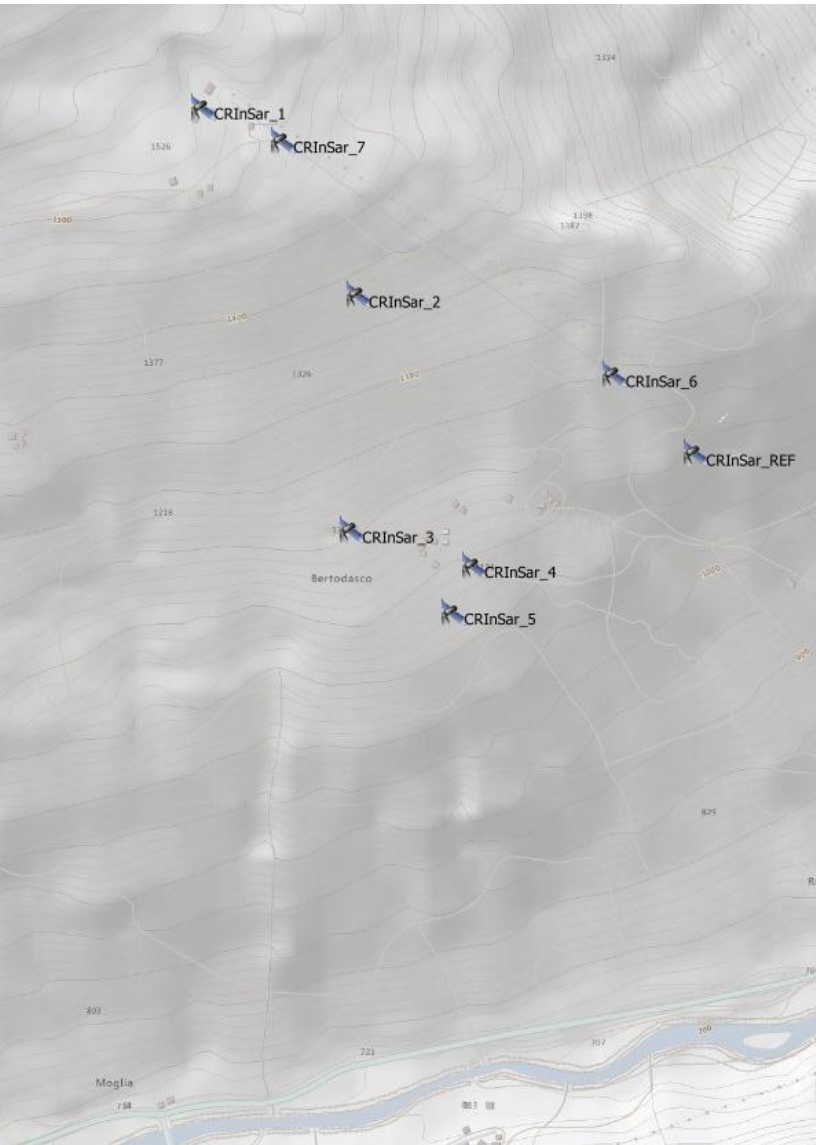
3. **High Temporal density of measure:** 24 days from 2003-2009

Future:

Corner Reflectors and high resolution satellite (Cosmo-SkyMed) **will replace many traditional instruments** (now broken..) especially in the sectors A-B



4.3. CORNER REFLECTOR



□n. 8 **Corner Reflector** for the application of Corner Reflector Interferometric SAR (CR-InSAR) technique;

PUNTO DI MISURA	Nome	CRInSAR3		
	Posizionato da	Tele-Rilevamento Europa T.R.E. s.r.l.	Data	22/10/2014
DESCRIZIONE	Il punto di misura è stato materializzato utilizzando un affioramento roccioso pre-esistente.			
COORDINATE	Northing [m]	Easting [m]	Quota ellissoidica [m]	
WGS84-UTM32N	5032894,61	375145,803	1256,547	

IDENTIFICAZIONE FOTOGRAFICA



GPS SURVEY GENERAL INFORMATION

DEVICE TYPE	OPER. MODE	REC. PER.
Vector G2 GPS Compass	Static	15'

ESTIMATED ACCURACY [m]

X/LON	1 σ	0,047
Y/LAT	1 σ	0,129
Elevation	1 σ	0,137

NOTE

Si consiglia una verifica della visibilità in relazione alla presenza di alberi sul lato ovest del riflettore (possibile impedimento in geometria ascendente).

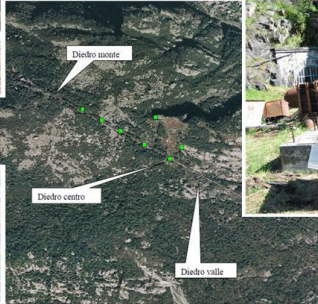
4.3. CORNER REFLECTOR



Diedro monte



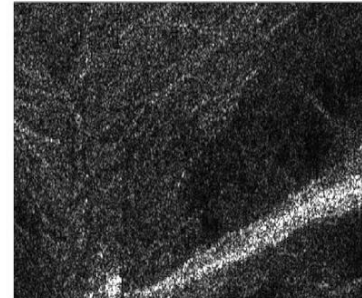
Diedro centro



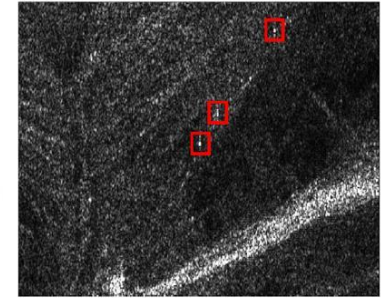
Diedro valle



Prima



Dopo



treuropa.com

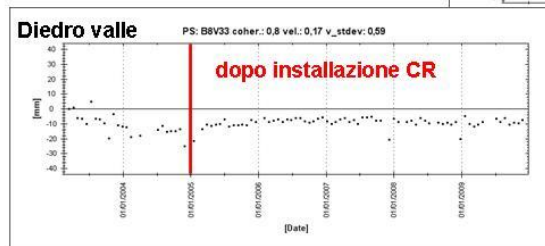
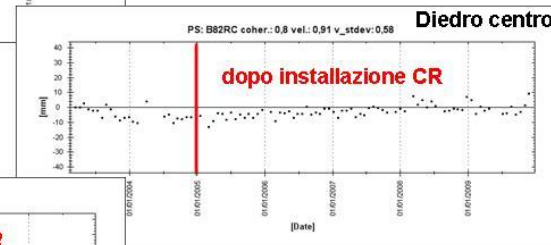
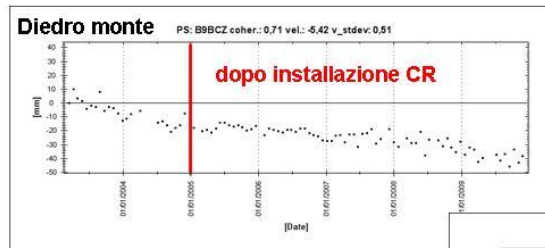
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5. CONCLUSIONS

- The Rosone landslide is a **complex phenomenon**, the different sectors **have kinematic mechanisms and evolutionary trends very different**, even within the same sector can be identified areas with different behaviors. Particularly in the C area can be difficult to discriminate, through monitoring systems, the behavior of the deep landslide by some local situations and surface instability.
- The use of **different types of monitoring** (deep and surface, ground based and remote sensing) is dictated by the need to compensate and / or test the limits in each method and integrate their results.
- **The Interferometric SAR data confirm** the already dense and heterogeneous **monitoring system network** and the other geological-geomorphological evidences
- The Interferometric SAR techniques have the **potential to improve the knowledge about the spatial distribution and temporal evolution of ground movements**.
- Due to the benefits in density and for the easiness in data acquisition and storage over large areas, it was decided to **integrate and largely replace the old monitoring system with a regular Interferometric SAR techniques analysis SqueeSAR and CR-InSAR** (every 2 years) through Cosmo-SkyMed data in order to follow the evolution of the phenomenon for civil protection purposes.
- The good amount of data available on this deformation will allow to well define the geometry of the deformation (e.g. three dimensional model)

A scenic mountain landscape featuring a steep, rocky slope on the left side, covered with patches of green vegetation and scattered rocks. The background shows a rugged mountain peak under a clear sky. A semi-transparent text box is overlaid in the center of the image.

Thanks for your attention !