MULTIDISCIPLINARY STUDIES OF THE PUIGCERCÓS HISTORICAL LANDSLIDE IN THE CATALAN PYRENEES

GIORGI KHAZARADZE[1*], MARTA GUINAU[1], XABIER BLANCH[1], ANTONIO ABELLÁN[2,3], MAR TAPIA[4], GLORIA FURDADA[1], EMMA SURIÑACH[1,4]

[1] Grup RISKNAT, Institut Geomodels, University of Barcelona, Faculty of Earth Sciences, Department of Earth and Ocean Dynamics, Barcelona, Spain

[2] Institute of Applied Geosciences, School of Earth and Environment, University of Leeds, Leeds, UK

[3] Centre de recherche sur l'environnement alpin (CREALP), Sion, Switzerland

[4] Laboratori d'Estudis Geofísics Eduard Fontserè, Institut d'Estudis Catalans, Barcelona, Spain

* Corresponding author: gkhazar@ub.edu

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Session: NH3.8

Landslide investigation using Remote Sensing and Geophysics

Co-organized by ESSI1/GI6/GM4

Convener: Antonio Abellan

Co-conveners: Janusz Wasowski, Masahiro Chigira, Oriol Monserrat, Jan Burjanek

Wednesday, 6 May 2020, 10:45–12:30, D1826 | EGU2020-7796

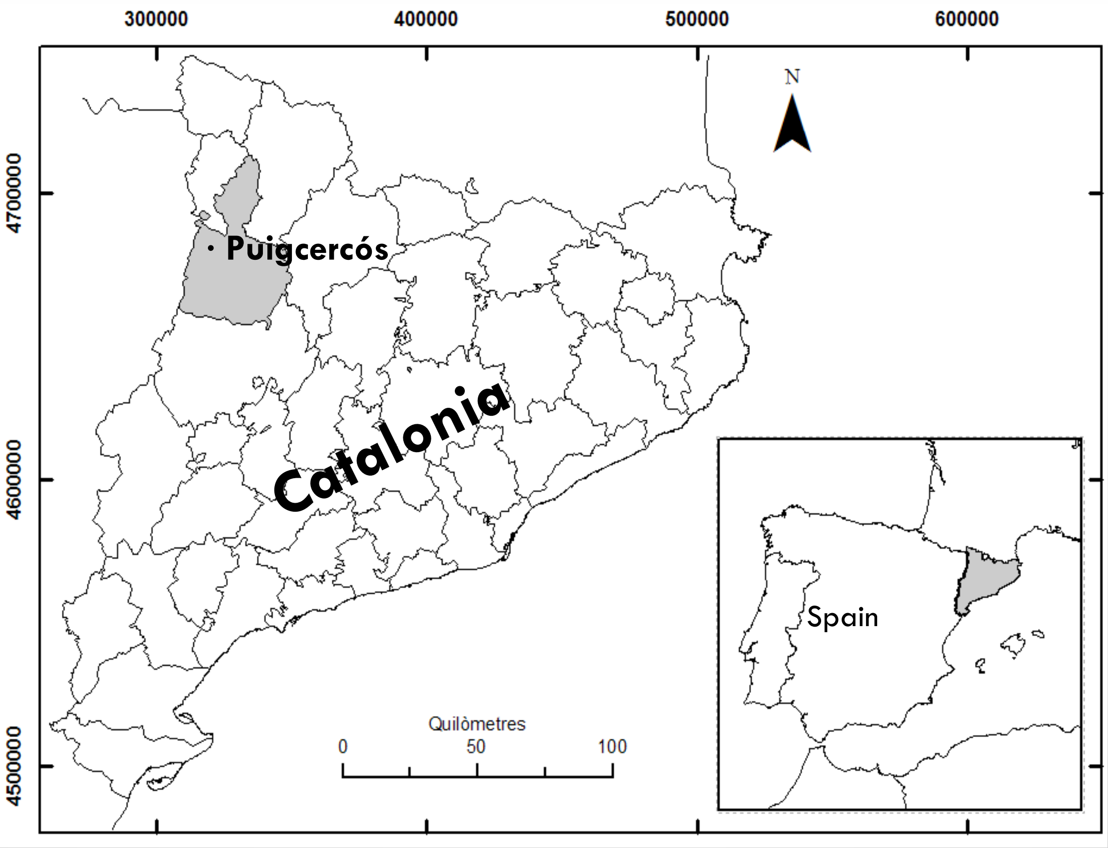
ABSTRACT

More than a century ago, the Puigcercós village located in the region of Pallars Jussà (Catalonia, Spain), suffered a large-scale landslide that occurred on January 13th, 1881. More than 5 million m^3 of sediments and rocks were displaced and a 200 m long and 25 m high rock scarp was formed. Luckily, during the main event, the nearby village was not affected, and due to a prompt evacuation and re-location of the entire village, no casualties were reported. Nevertheless, consequent retreat of the main scarp did destroy the big part of the old village, which confirmed not only the necessity for its relocation, but also gave one of the first clearly described and confirmed examples of a successful geologic risk prevention.

During the last decade, the members of the RISKNAT-UB group have chosen this site to conduct pilot studies of rockfalls and landslides using a multidisciplinary approach. The utilized observational techniques include Terrestrial Laser Scanner (TLS), photogrammetry, GPS, seismic monitoring and geophysical prospecting techniques. The work presented here is an overview of these activities, including the main milestones of the ongoing research. Special emphasis will be given to the use of geodetic techniques for investigating changes on the depositional area of the landslide and around the crown cracks at the upper level of the main scarp. As a result of the GPS observations, for the first time, 130 years after the occurrence of the event, it was possible to observe a continuing geomorphological activity of the depositional zone of this historical landslide.

Currently, the RISKNAT-UB group operates cost-effective, high-resolution and low-cost photogrammetric instruments and seismic continuous records at the site, in order to monitor the evolution of the Puigcercós rock scarp. The correlation of the seismic and the photogrammetric data and intermittently obtained LiDAR images enables us to monitor and characterize frequent rockfalls and premonitory deformations occurring at the site. These observations have allowed quantifying the rate of retreat of the rock scarp at a rate of 10 to 11 cm/yr and a slow motion of the depositional zone up to 6 mm/yr. Since the geologic risk at the study area is not significant, due to the absence of population and/or infrastructures, this site is an ideal natural laboratory for developing new observational techniques, which can be used to develop early warning systems for rockfalls and landslides.

GEOGRAPHIC LOCATION



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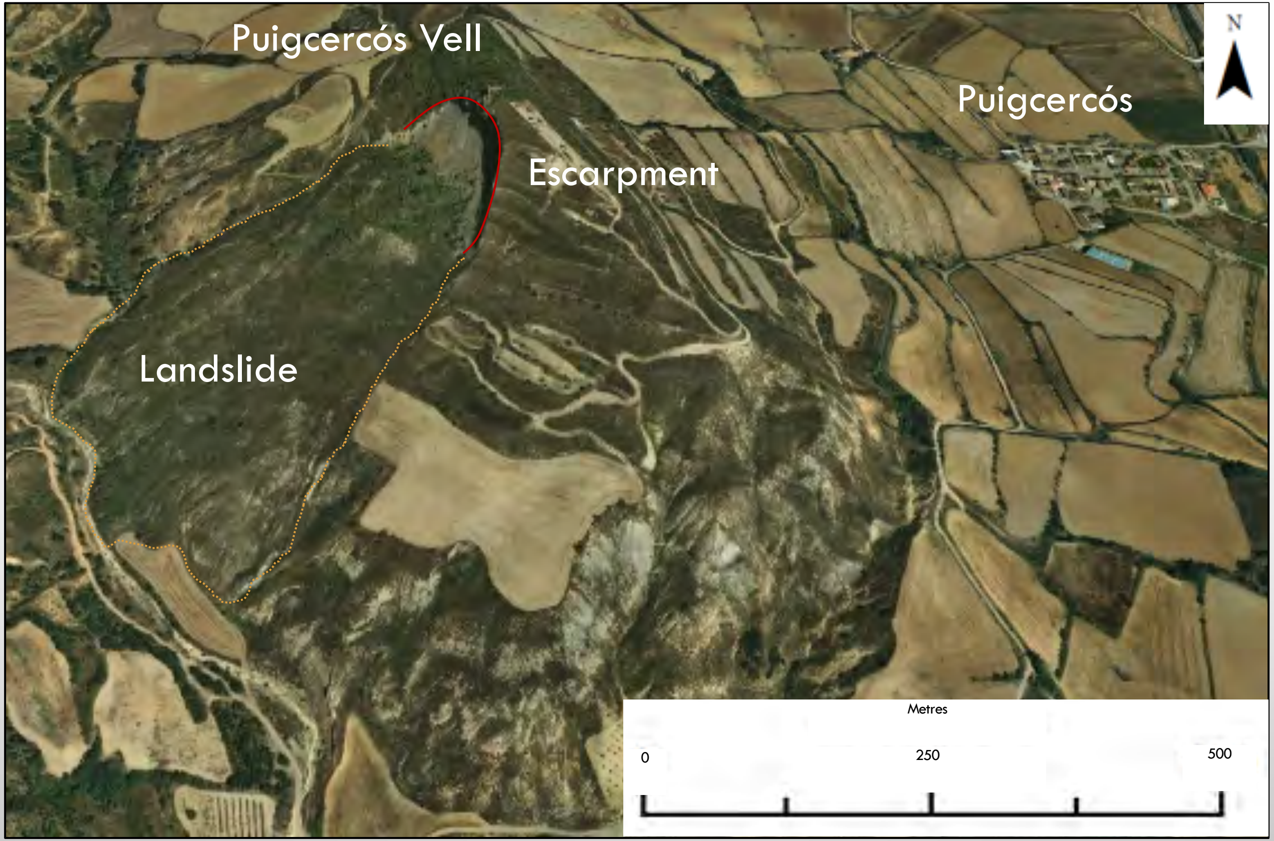
AERIAL PHOTO



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REGIONAL GEOLOGIC CONTEXT

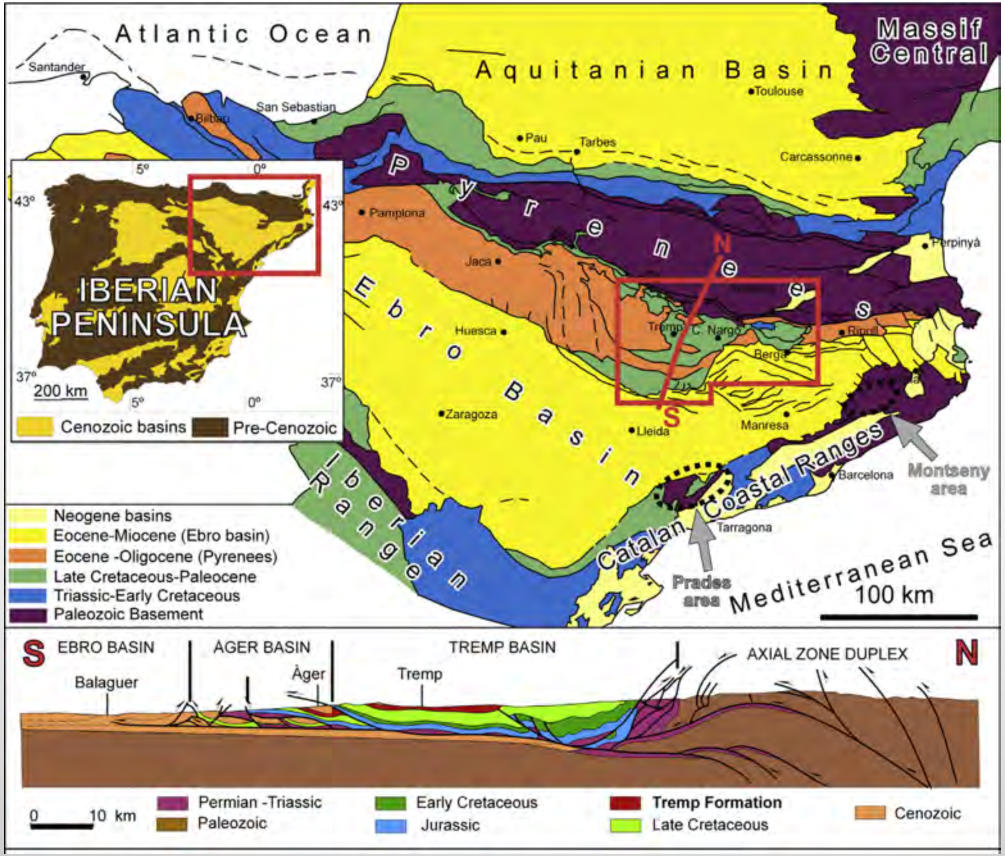
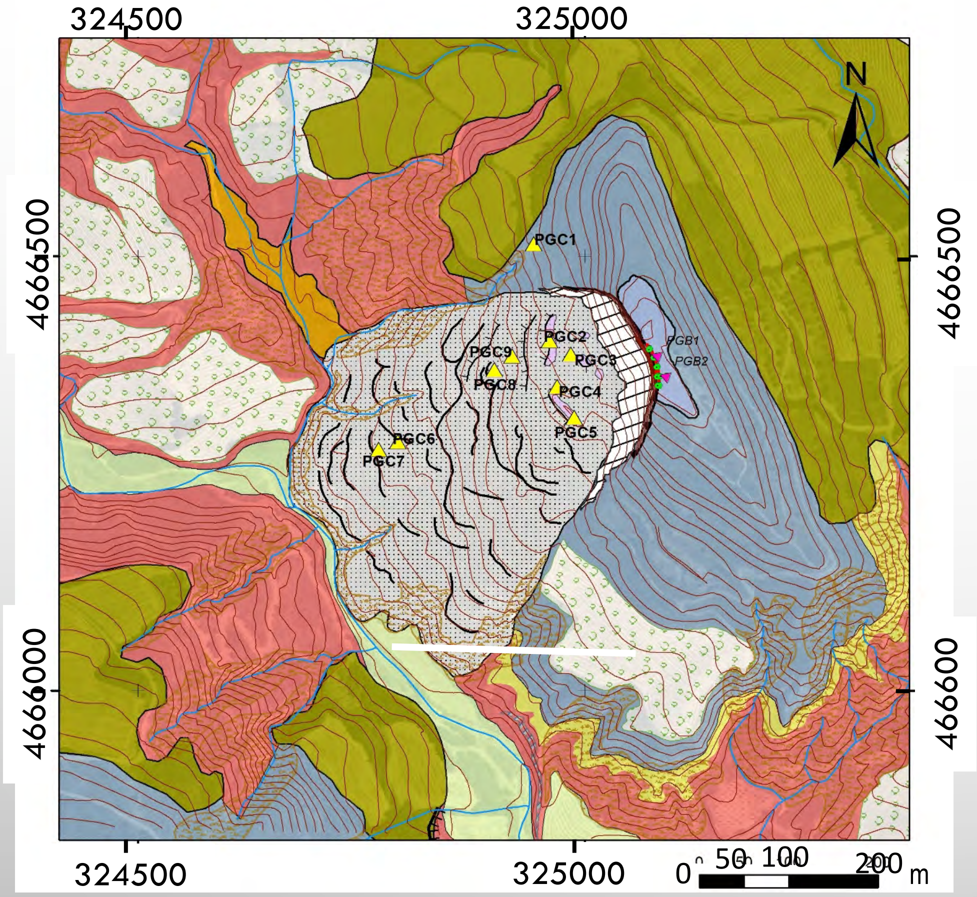


Figure from:
Gómez-Gras et al.
Cretaceous Research
v. 57 (2016)

Cross-section from Muñoz et al., 1992.

LOCAL GEOLOGIC CONTEXT



Punts GPS

Punts TS i GPS

Punts estaques

Peu de lòbul

Talús d'esbaldregalls

Dipòsit de moviment de massa

Dipòsits col·luvials

Acumulacions

Fractures

Escarpament fluvial

Escarpament principal

Escarpament secundari

Badlands

Reompliment lacustre

Actual llit del riu

Camps de cultiu

Eocè

Calcàries amb alveolines

Margues del Ilerdià

Paleocè *Fàcies Garumnià*

Sediments de coloració groguenca

Sediments de coloració vermellosa

Guix secundari

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SCHEMATIC PROFILE OF THE LANDSLIDE

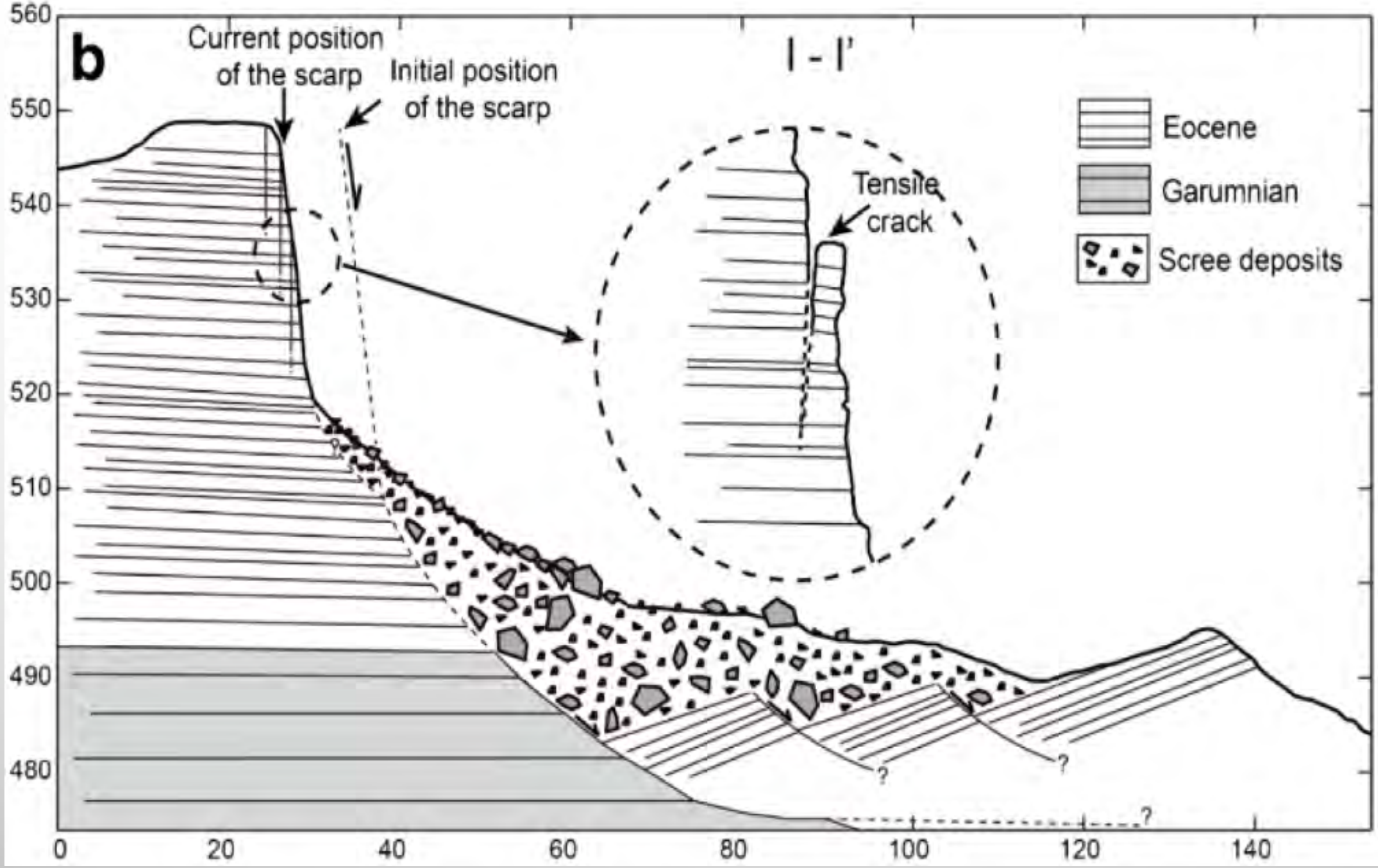

Figure from: Royán et al., Landslides, V. 11-4, 2014.

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A BIT OF HISTORY

941 - First reference to the castro *Poga Circuso*

1012 - Donation of the castle by Ramon Berenguer IV

1365 - Scripture that seems to indicate a different location of the town at this time.

1373 - Earthquake of the Ribagorza

1848 - Emergence of cracks in the SW slope

1857 - First collapse in a period of severe *drought*

1881 - Second sinking, during a day of great *rainfall*

1889 - Third movement, during an episode of *precipitations*

1881 LANDSLIDE

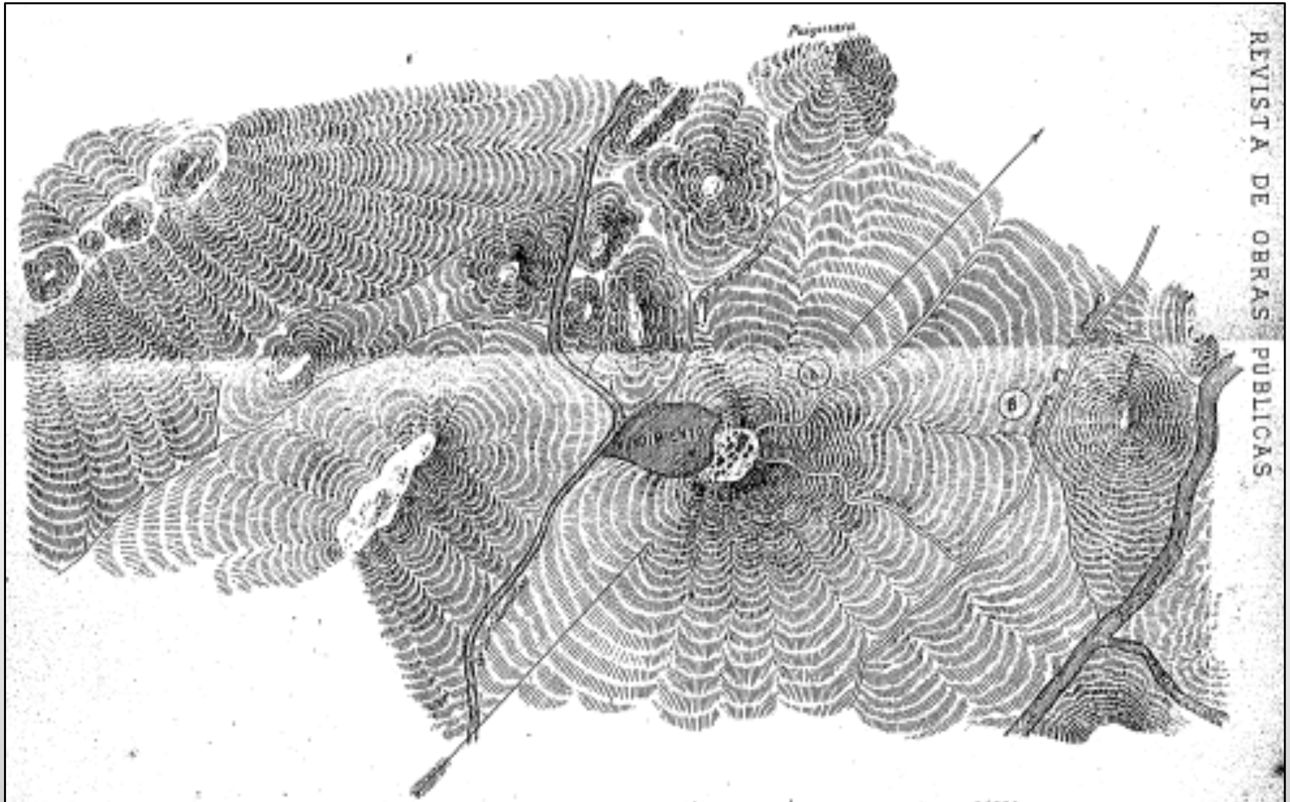


Fig.ª 1.ª CROQUIS DEL TERRENO EN QUE SE HALLA SITUADO PUIGCERCÓS. Escala de 1 por 20000 metros.

Figure from: Corsini, 1881.

CURRENT STUDIES BY THE UB GROUP

Investigations are led by the RISKNAT (*http://www.ub.edu/risknat*) group of the UB, currently under the framework of the PROMONTEC project (CGL2017-84720-R) led by E. Suriñach and G. Furdada.

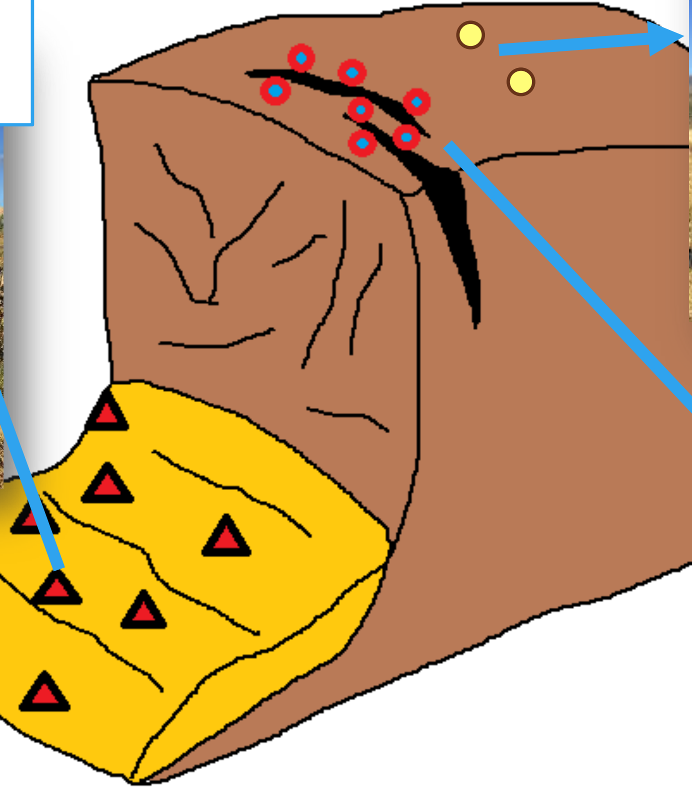
Since 2007 we use the site as natural laboratory to develop and test new methodologies for studying landslides and rock-falls.

The techniques that we use include:

- Terrestrial Lidar
- Time-lapse photography
- Seismic monitoring
- Geodetic monitoring

GEODETIC MONITORING: METHODOLOGY

GPS to monitor the stability



Total Station to monitor the cracks and stability

Tape meter measurements to monitor cracks

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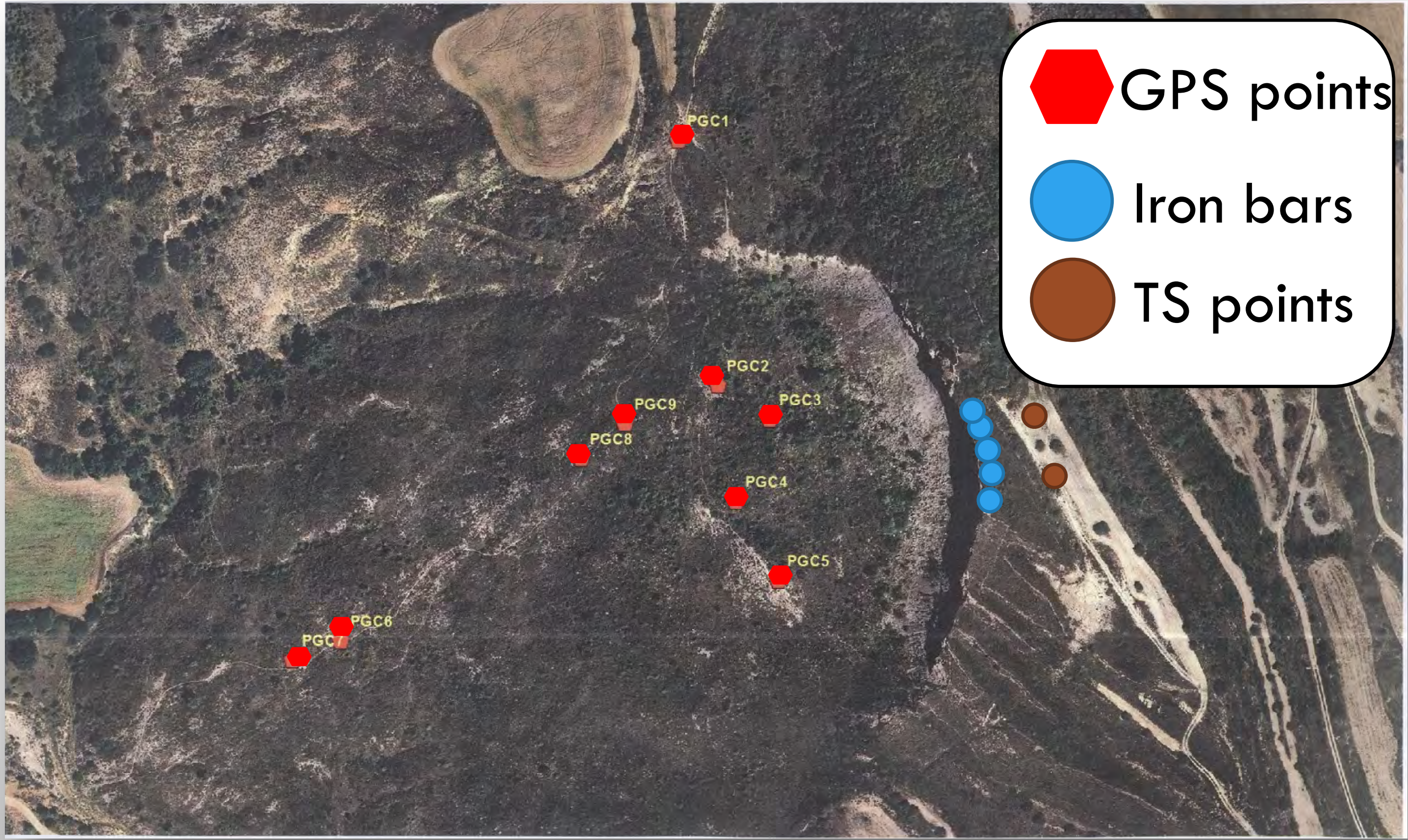
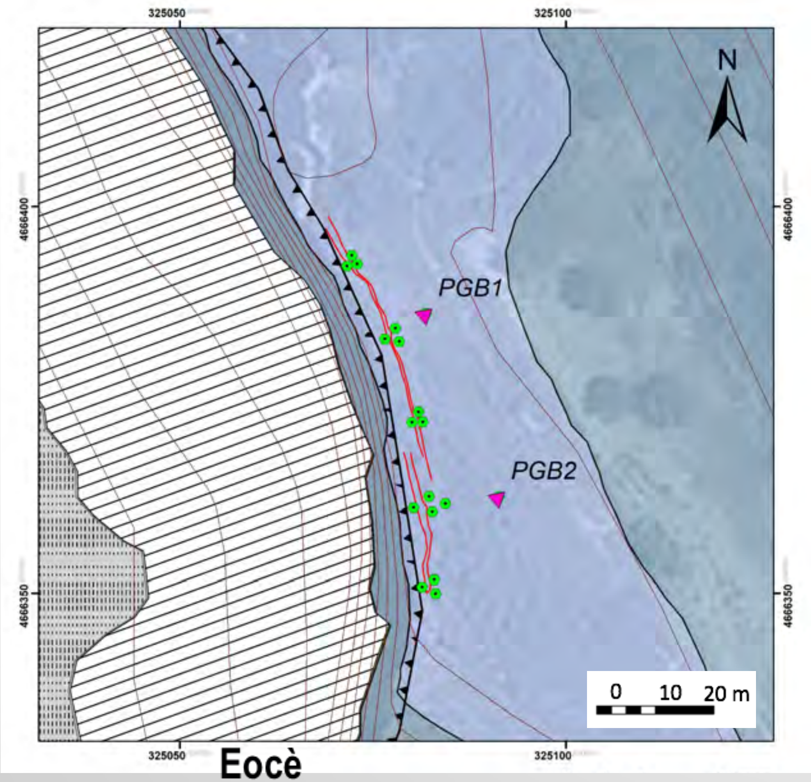
GEODETIC MONITORING NETWORK



CROWN CRACK MONITORING



Punts TS i GPS

Punts estaques

Fractur
es

Escarpament
principal

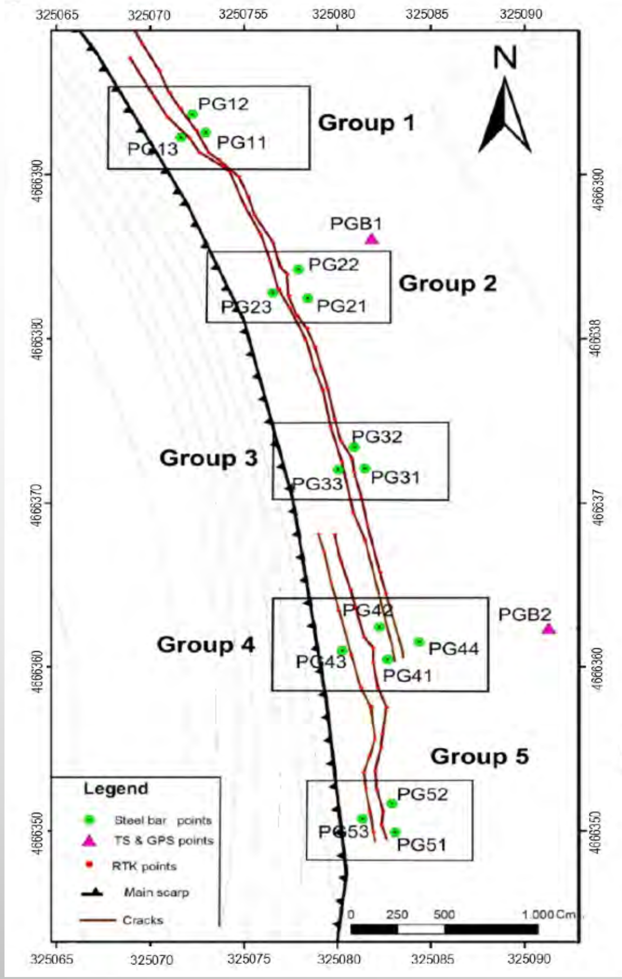
Talús
d'esbaldregalls

Eocè

Calcàries amb alveolines

Margues del Ilerdià

CROWN CRACK MONITORING



- Steel bar points
- TS & GPS points
- Cracks
- Main scarp
- RTK points

CROWN CRACK MONITORING

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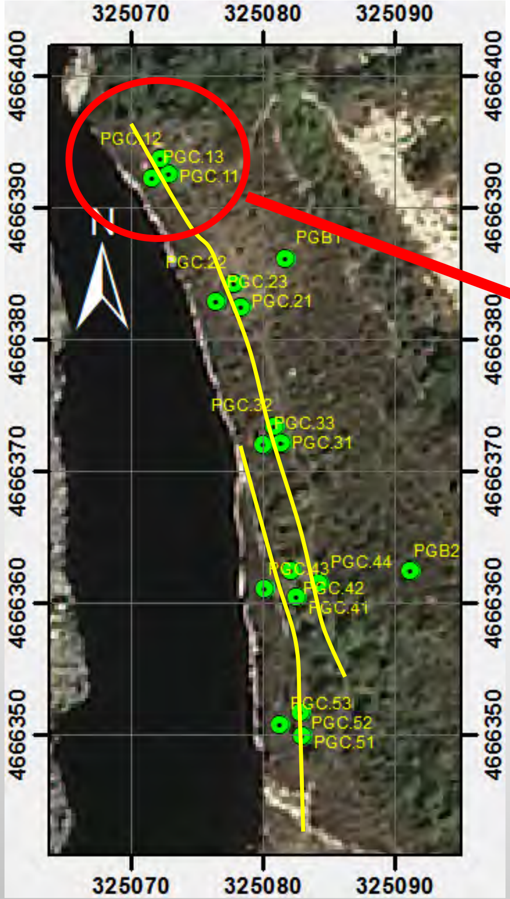
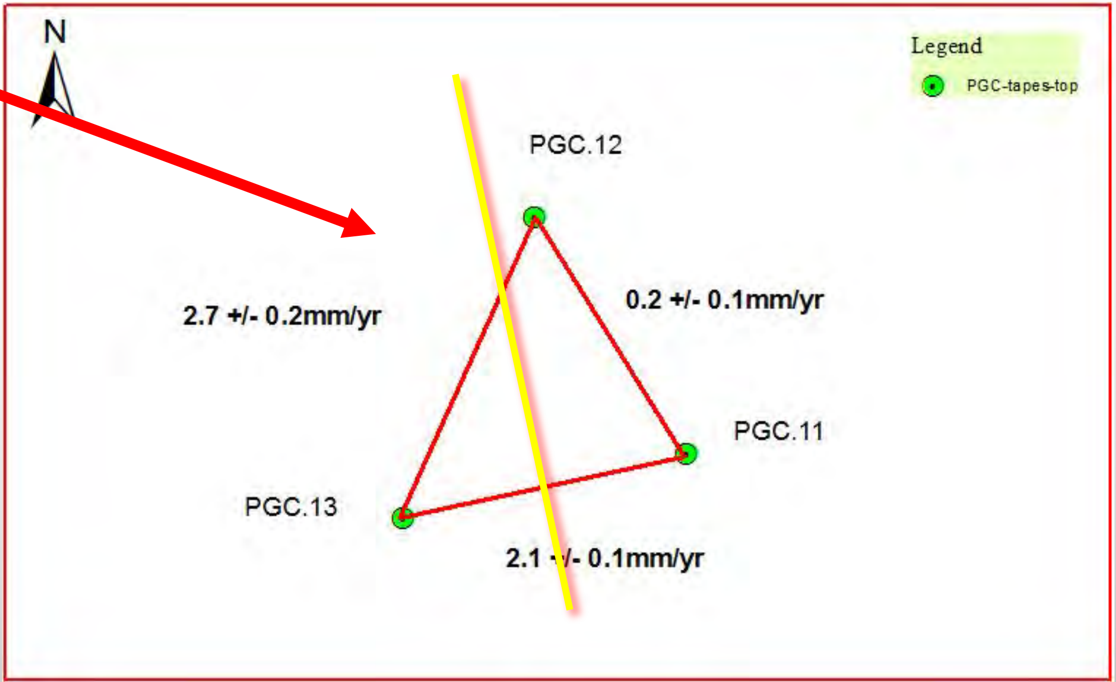
CROWN CRACK MONITORING: GROUP 1



Extension of 2.7 to 2.1 mm/yr



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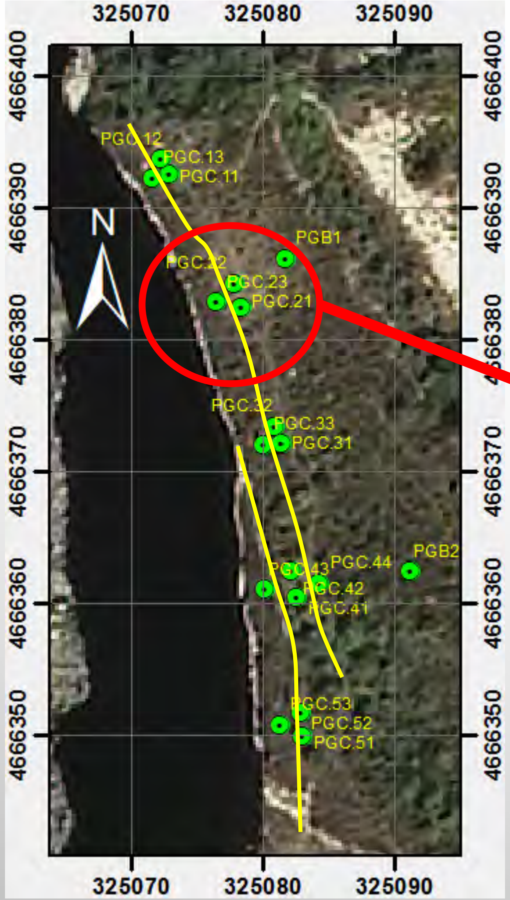
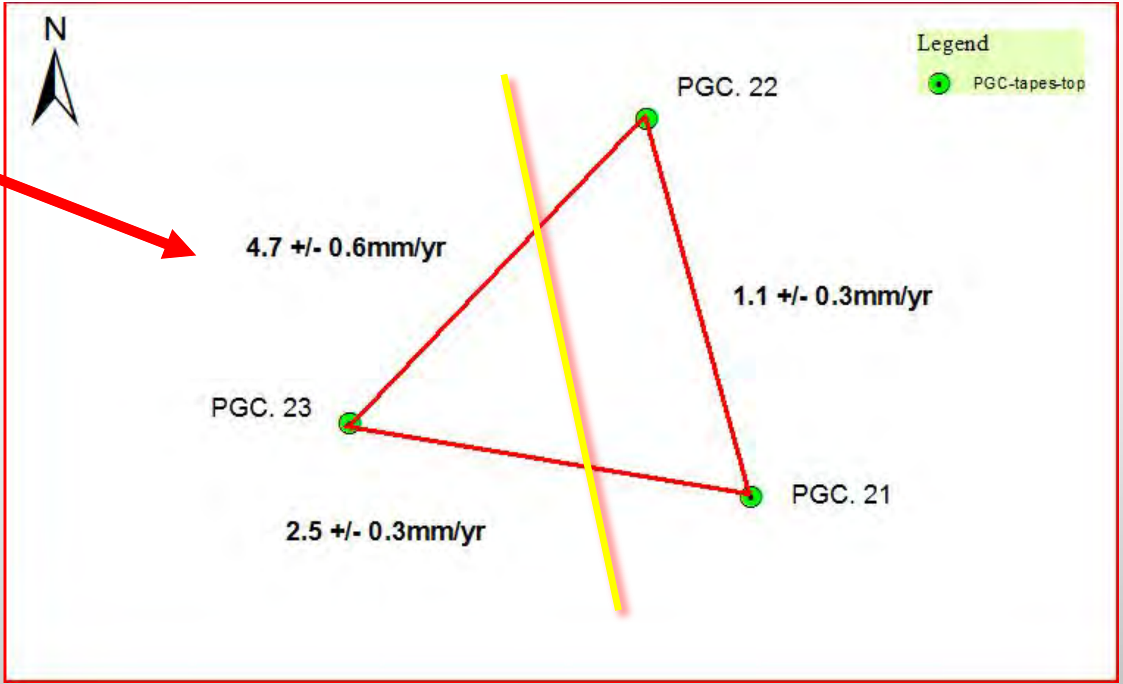
CROWN CRACK MONITORING: GROUP 2



Extension of 4.7 to 2.5 mm/yr



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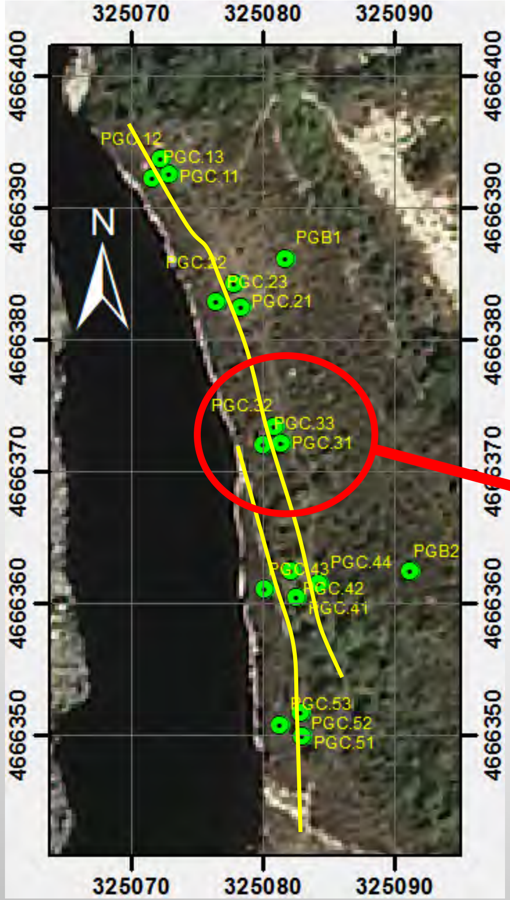
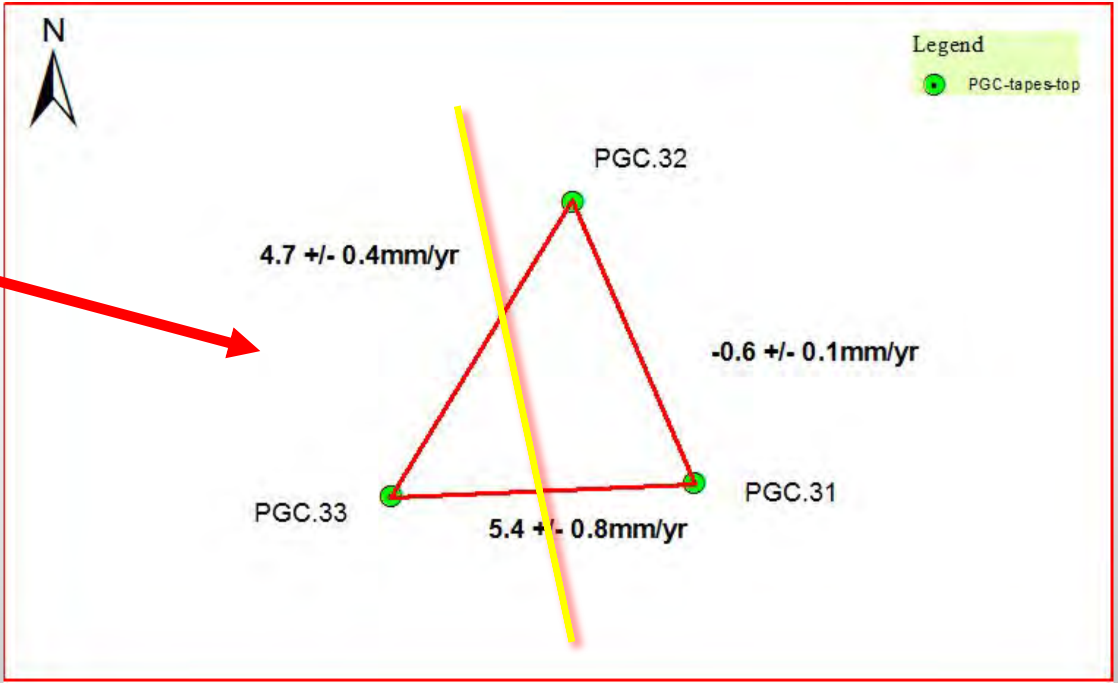
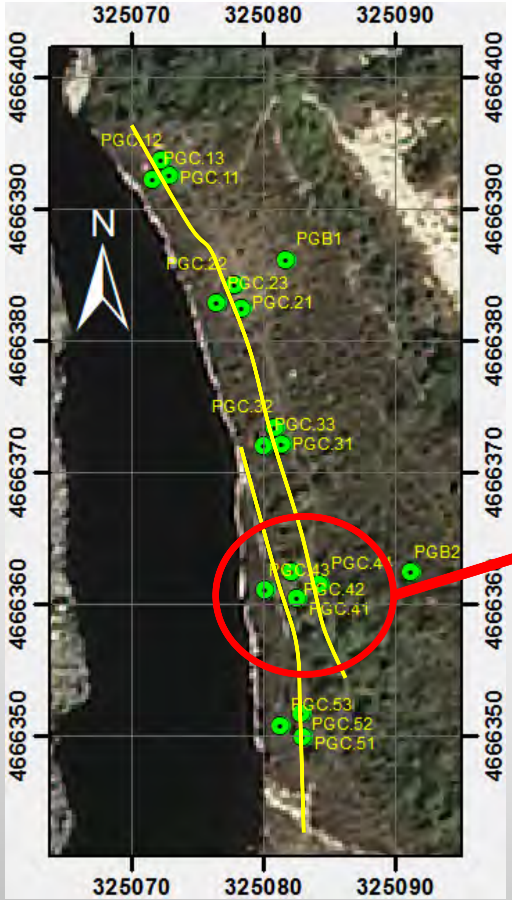
CROWN CRACK MONITORING: GROUP 3



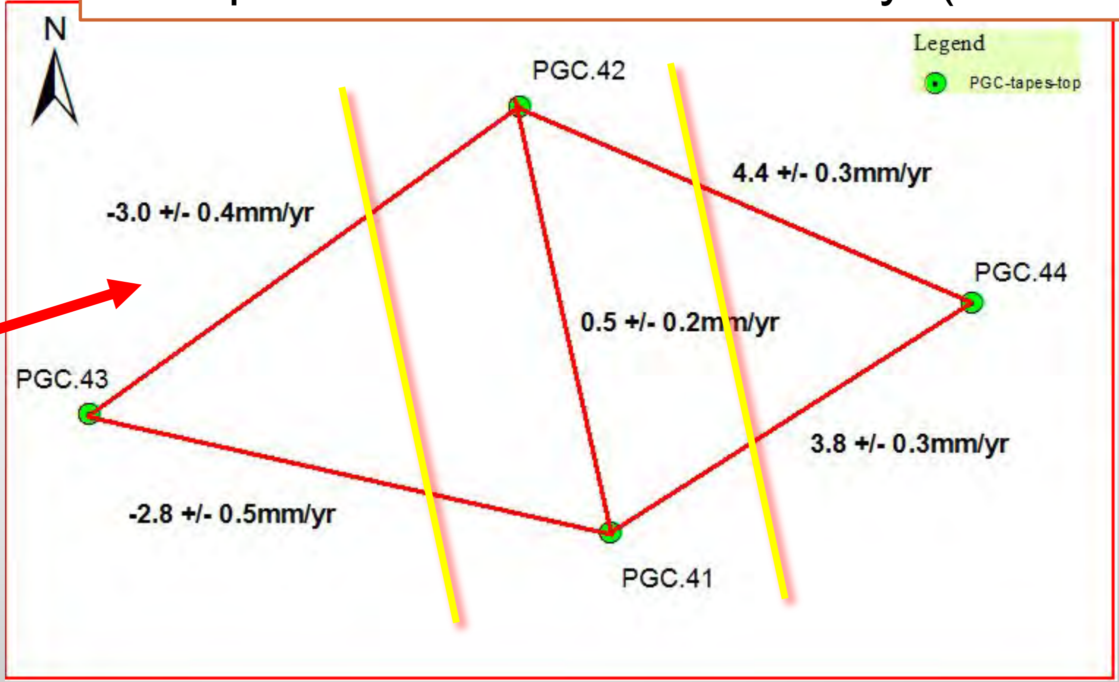
Extension of 4.7 to 5.4 mm/yr



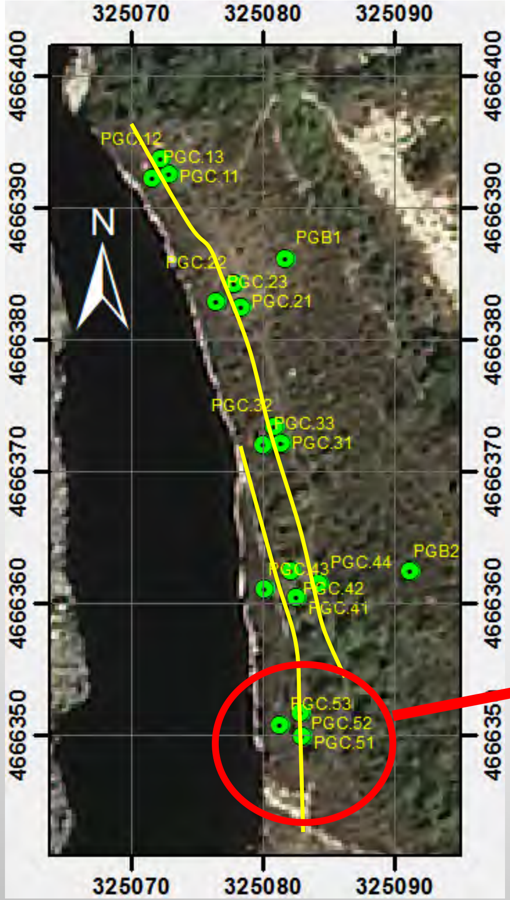
CROWN CRACK MONITORING: GROUP 4



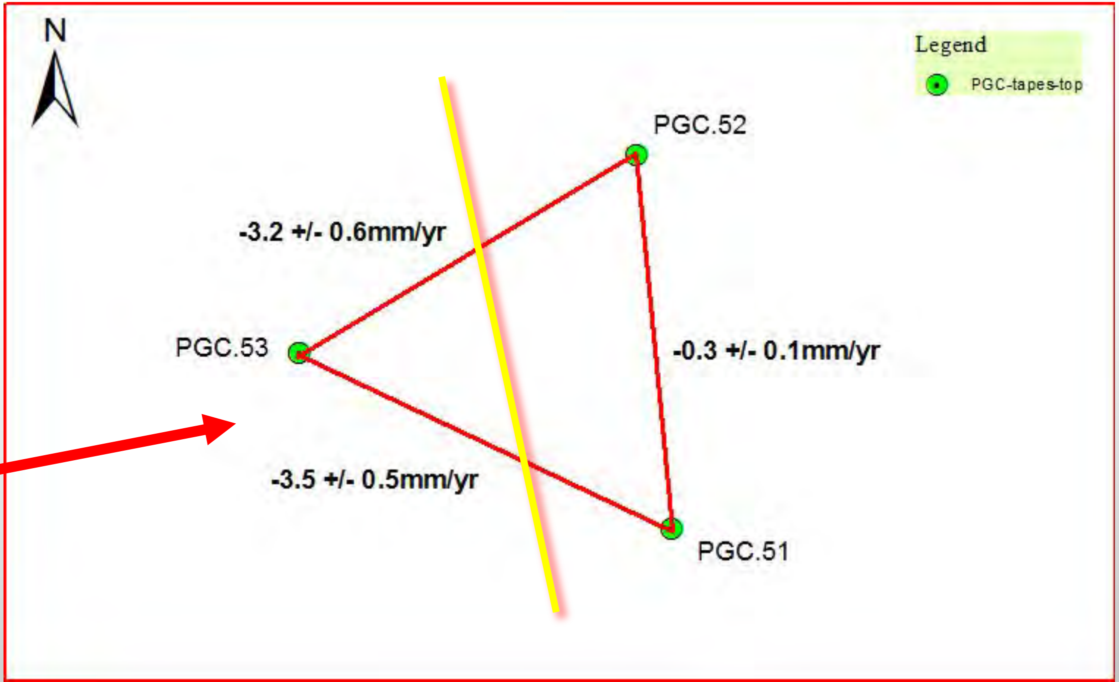
Extension of 4.4 to 3.8 mm/yr (inner crack)
and
Compression of -3.0 to -2.8 mm/yr (outer crack)



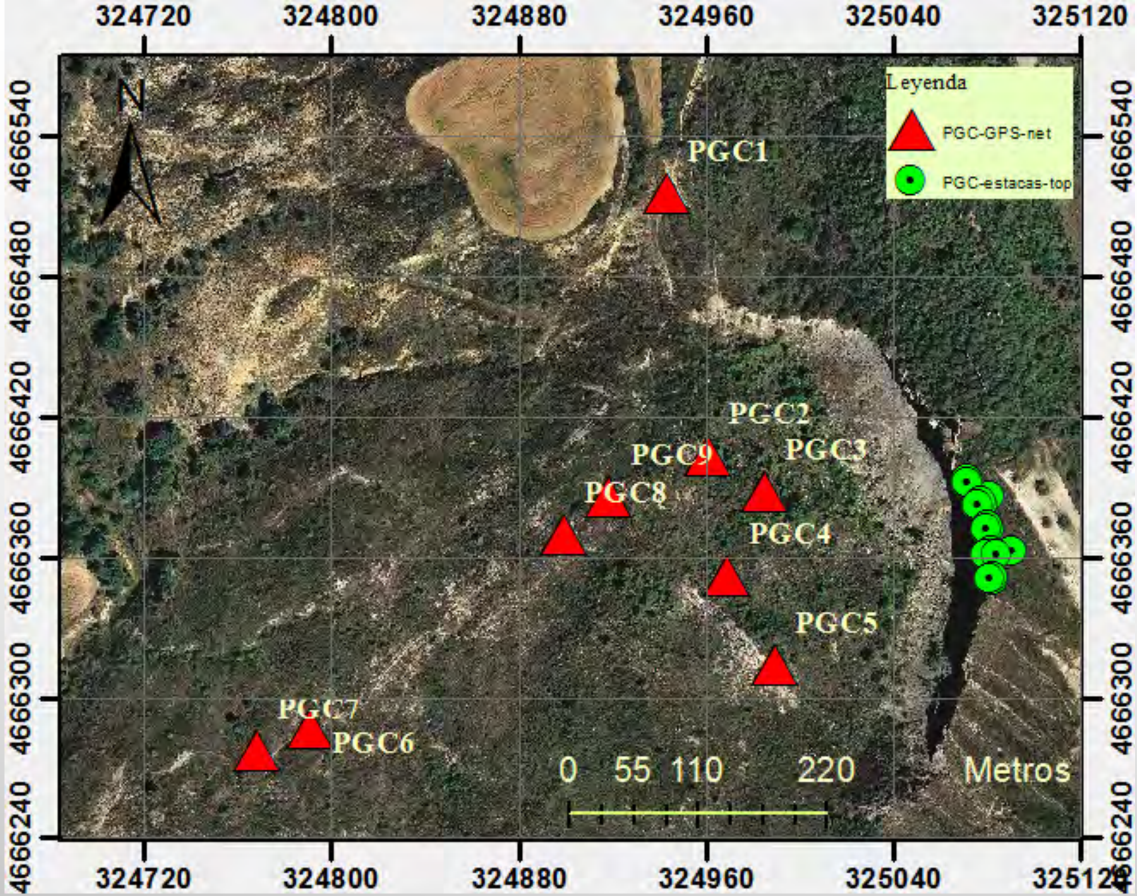
CROWN CRACK MONITORING: GROUP 5



Compression of -3.2 to -3.5 mm/yr



GEODETIC MONITORING NETWORK: DEPOSITIONAL AREA

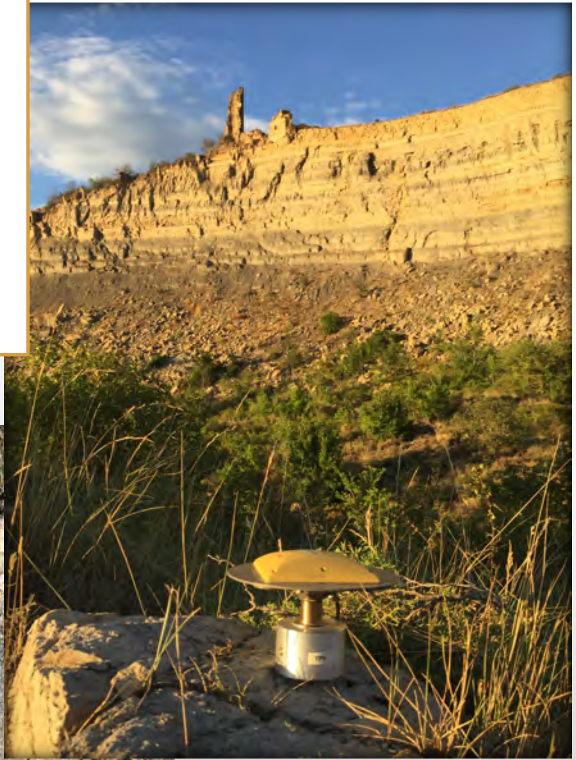


In July 2015, a network of 11 geodetic points were established:
9 points in the part of the depositional area (PGC1-9)

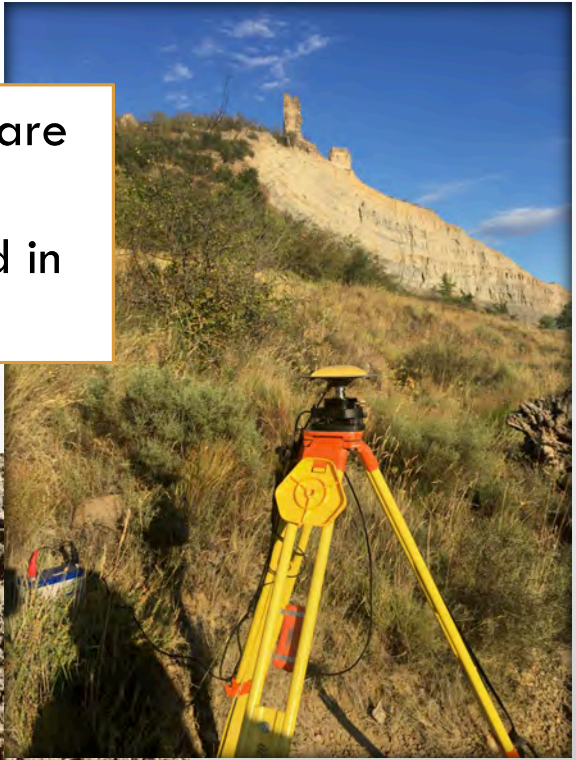
2 points on the interior side of the top (PGB-1-2)

GPS MONITORING
DEPOSITIONAL AREA (PGC1-9)

6 of these points (PGC4 to PGC9) are 5/8 inch nuts cemented into the rock



3 points are nails anchored in the rock



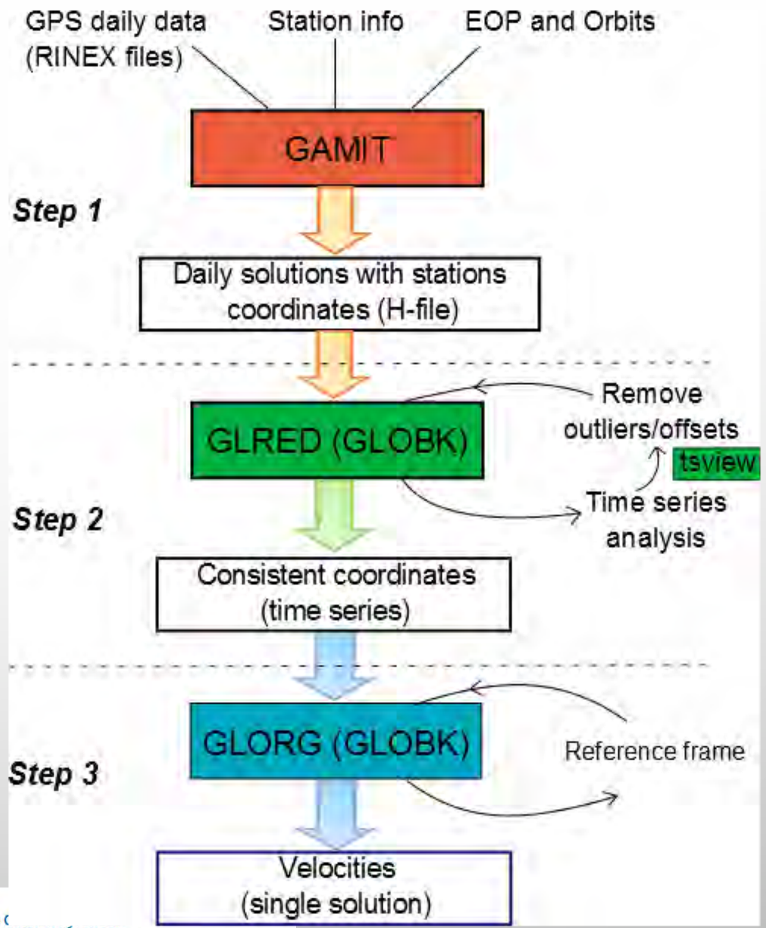
GPS DATA ANALYSIS

Software: GAMIT/GLOBK from MIT

Strategy: Network mode

CGPS Stations Analyzed: AVEL BELL CSOS ESCO GRAU LLIV SONA SORG TLSE YEBE

Reference Frame: ITRF2014 and later fixed station **PGC1**



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GPS CAMPAIGNS: 2014 TO 2019

#	Name	Longitude	Latitude	# Obs. Days	Duration years
1	AVEL	0.7505	41.8816	2167	6.0
2	BELL	1.4011	41.5996	2183	6.0
3	CSOS	0.4856	42.5119	2142	6.0
4	ESCO	0.9757	42.6936	2097	6.0
5	GRAU	0.3407	42.1915	2019	6.0
6	LLIV	1.9731	42.4781	2182	6.0
7	SONA	1.5168	41.9922	2167	6.0
8	SORG	1.1328	42.3745	2178	6.0
9	TLSE	1.4809	43.5607	1656	4.8
10	YEBE	356.9114	40.5249	2166	6.0
1	PGB1	0.8837	42.1301	8	4.0
2	PGB2	0.8838	42.1299	9	4.0
3	PGC1	0.8819	42.1312	16	4.6
4	PGC2	0.8822	42.1302	8	4.4
5	PGC3	0.8825	42.1301	9	4.1
6	PGC4	0.8823	42.1297	8	2.9
7	PGC5	0.8825	42.1294	10	2.9
8	PGC6	0.8802	42.1291	11	3.3
9	PGC7	0.8799	42.1290	8	4.4
10	PGC8	0.8814	42.1299	9	2.9
11	PGC9	0.8817	42.1300	8	2.9

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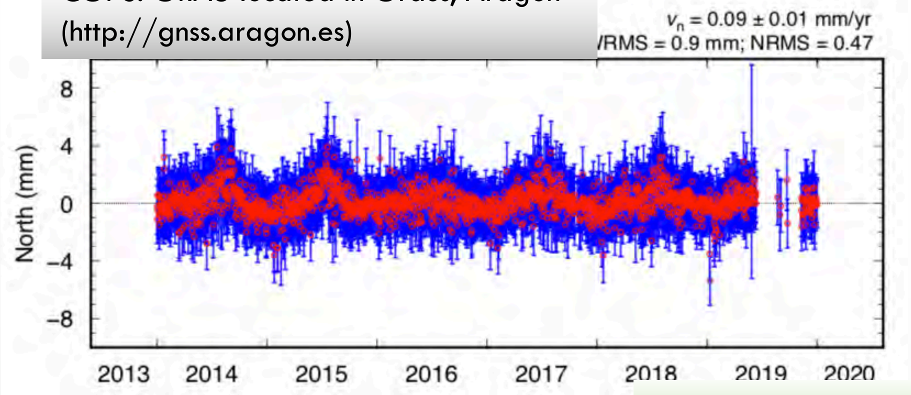
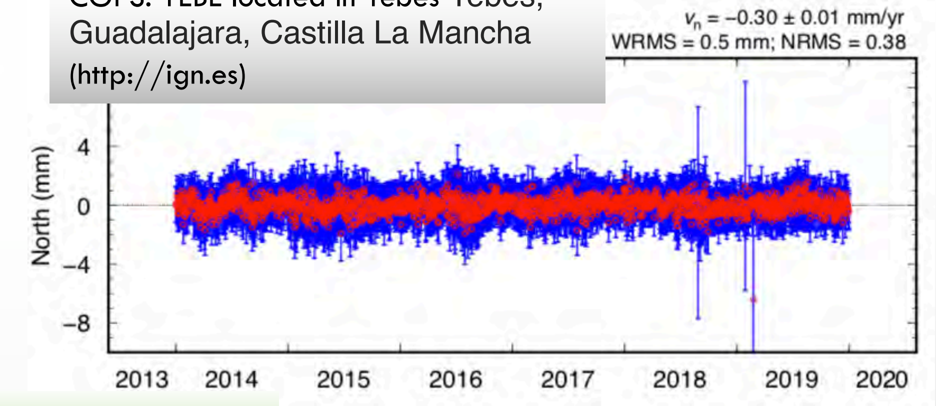
GPS TIME-SERIES

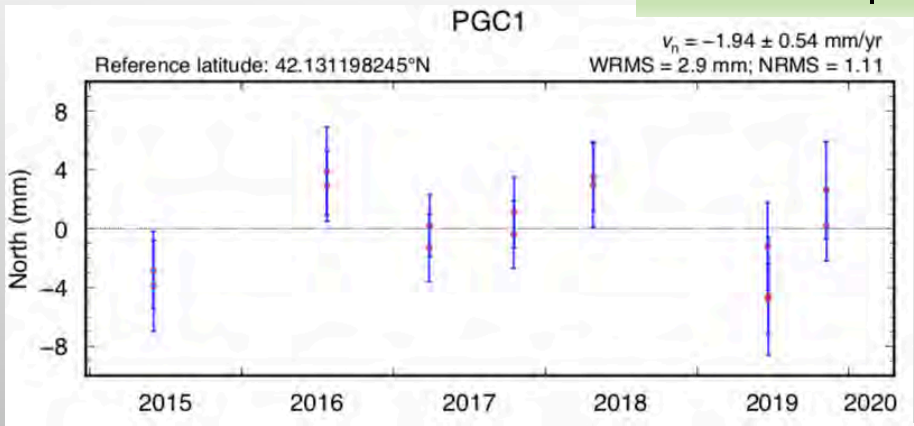
CGPS: GRAU located in Graus, Aragon (http://gnss.aragon.es)

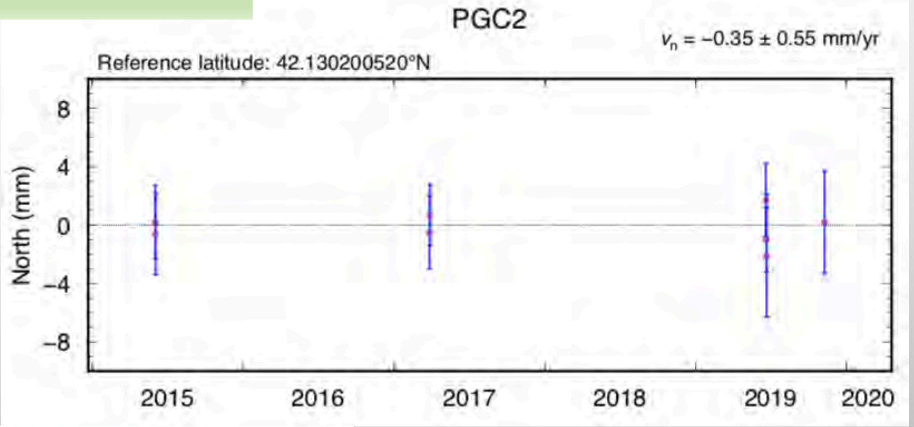


CGPS: YEBE located in Yebes Yebes, Guadalajara, Castilla La Mancha (http://ign.es)

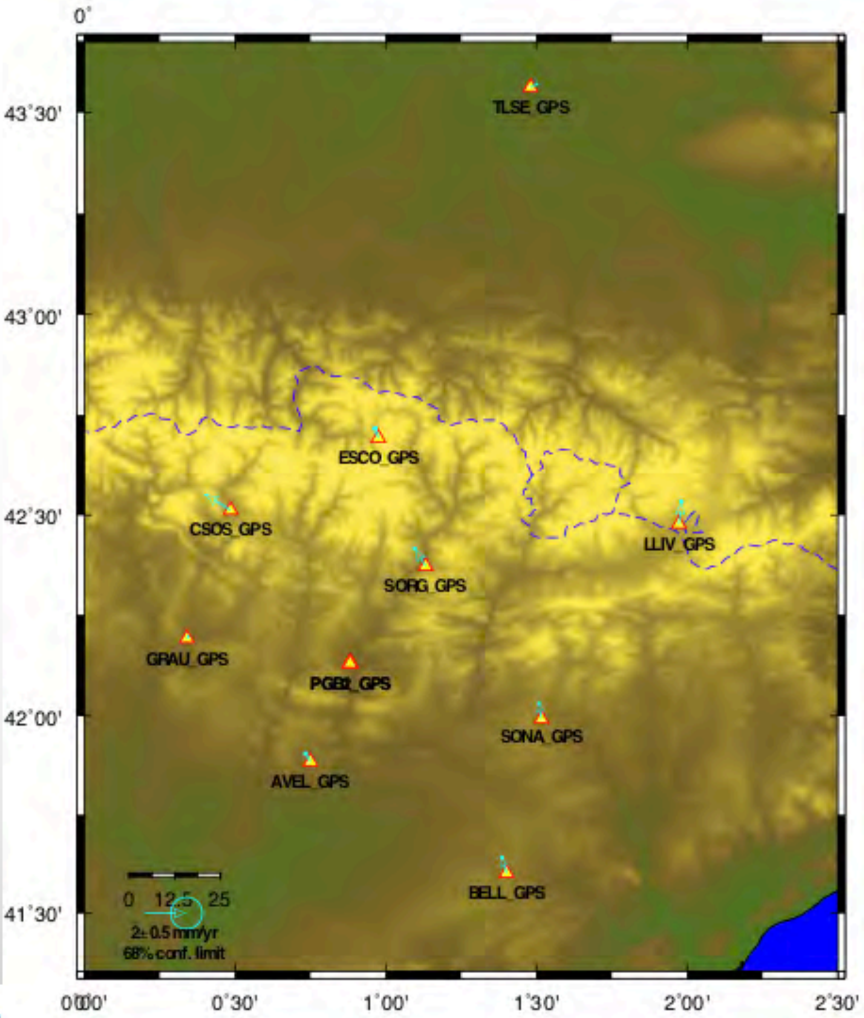


SGPS: depostional area



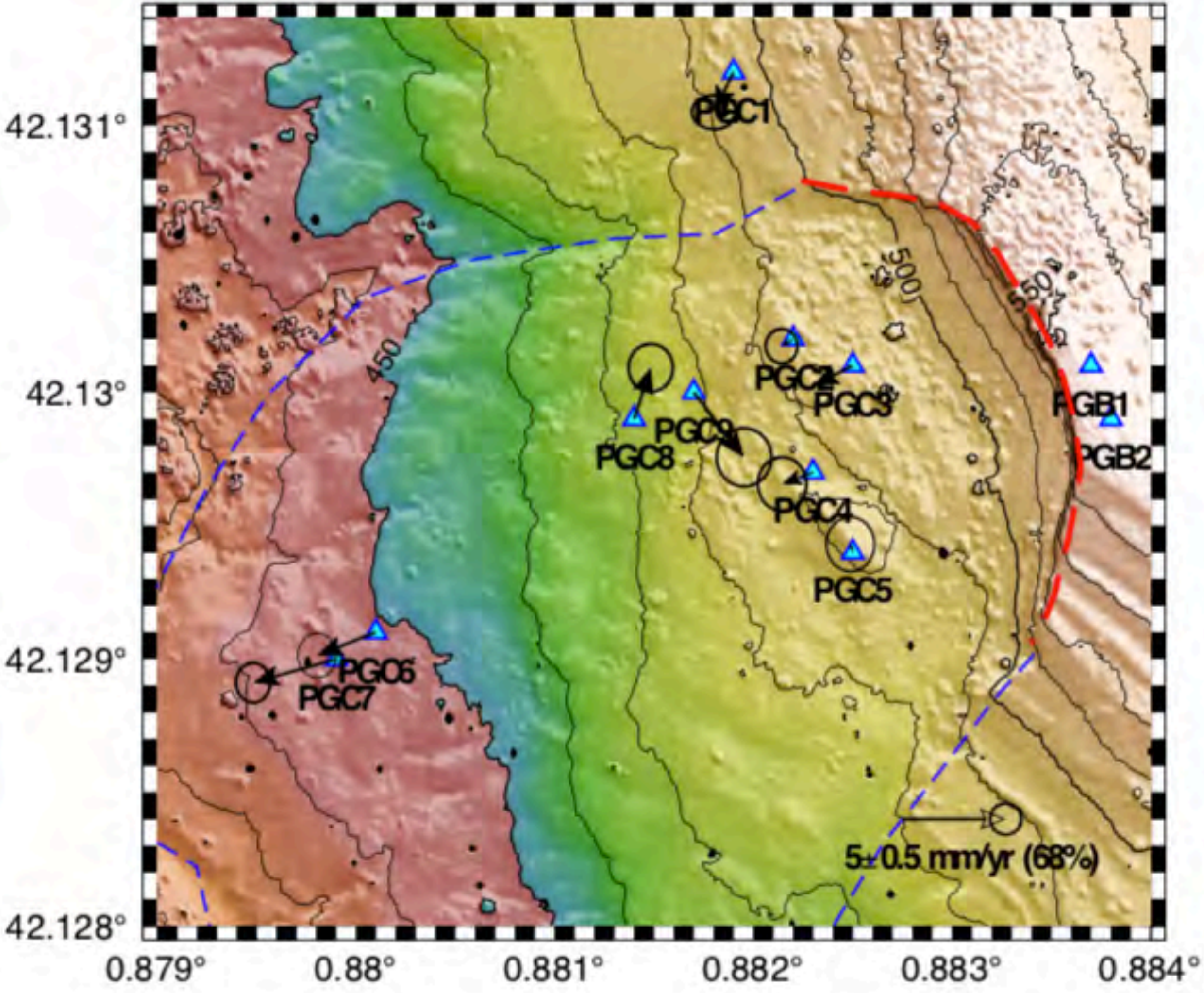


GPS VELOCITIES: CONTINUOUS GPS (CGPS) REFERENCE SITES

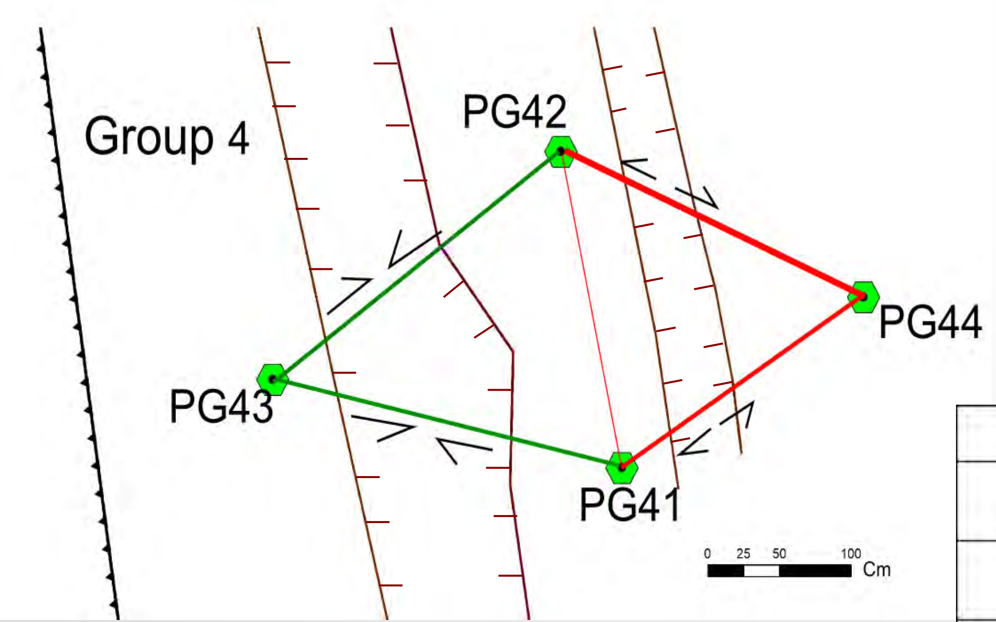


GPS VELOCITIES

Eurasia
fixed
reference
frame



DISCUSSION: CRACKS AT THE CROWN



PG41-43	-2,5+/- 0,4 mm/yr
PG43-42	-2,8+/- 0,3 mm/yr
PG41-42	0,5+/- 0,2 mm/yr
PG41-44	3,6+/- 0,3 mm/yr
PG42-44	4,3+/- 0,3 mm/yr

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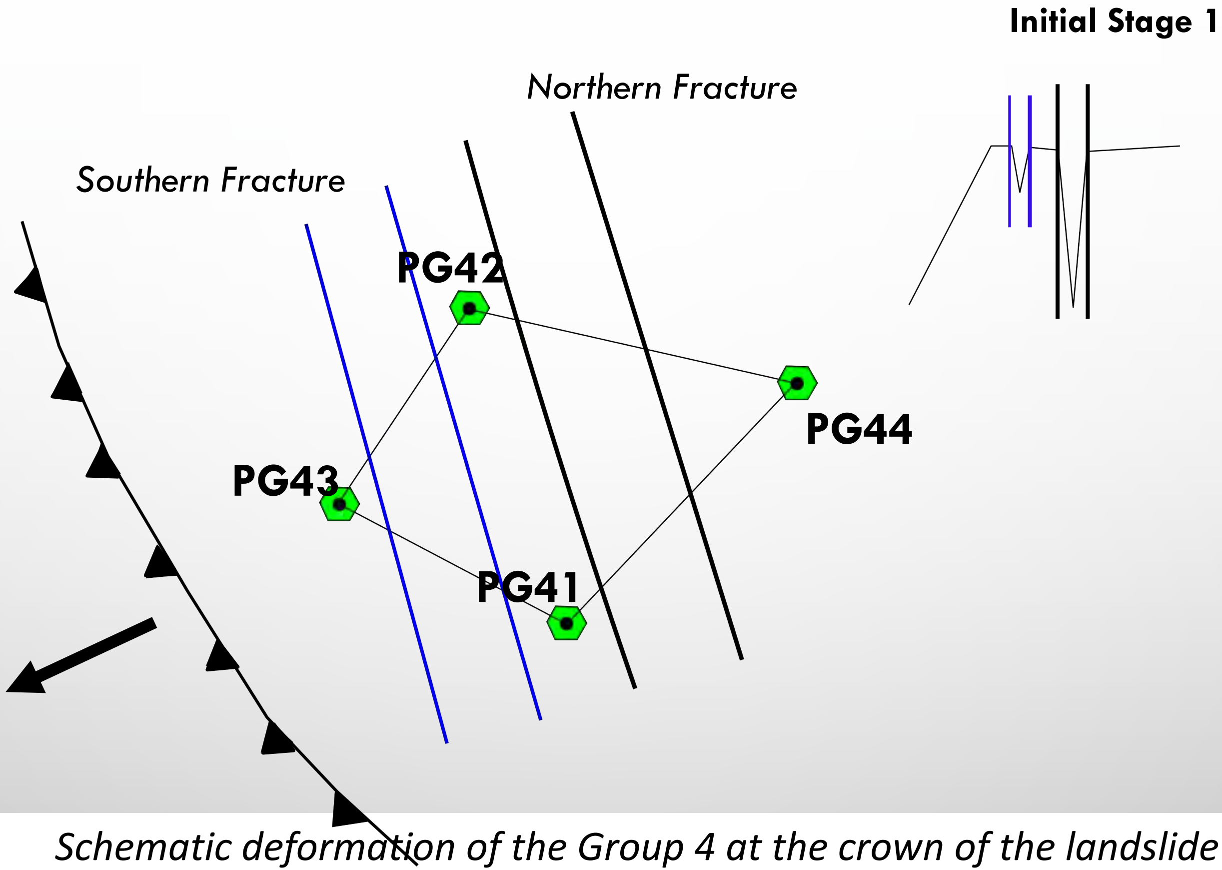
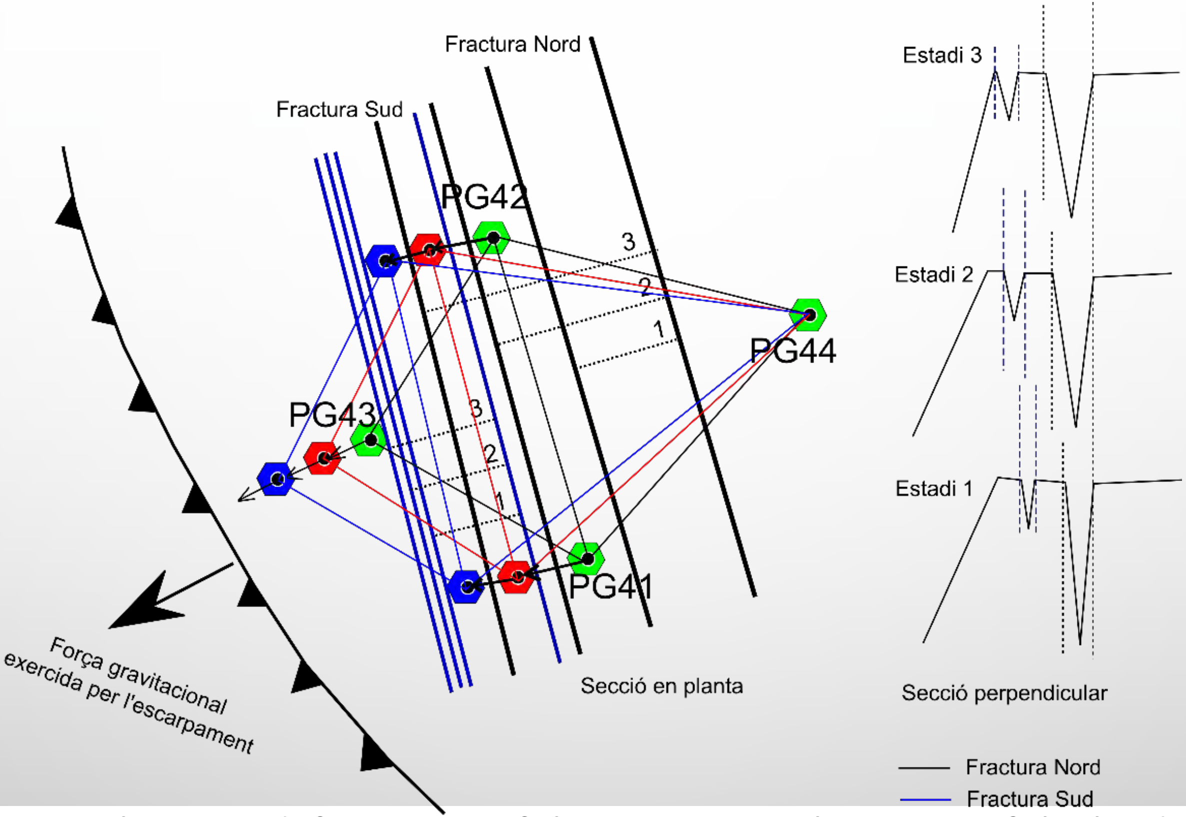
DISCUSSION: CRACKS AT THE CROWN



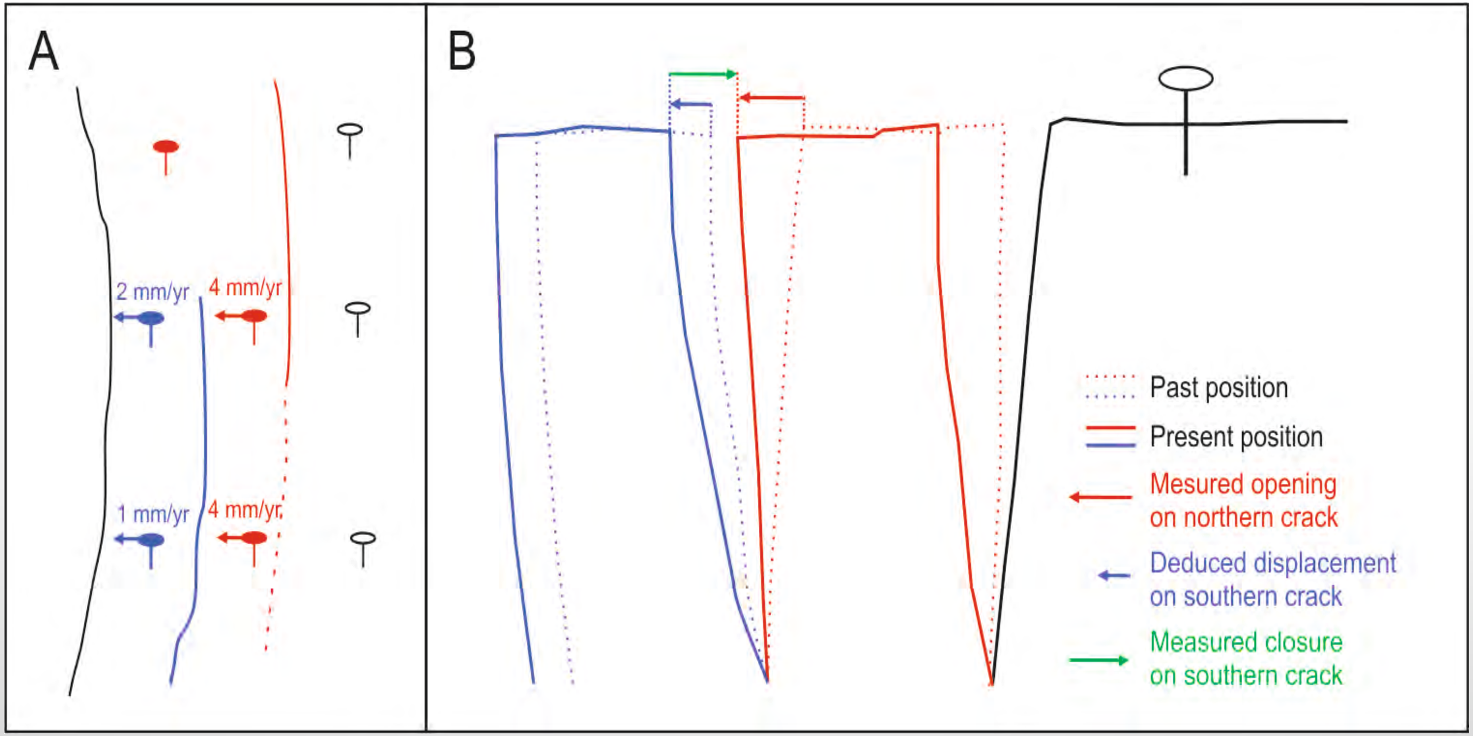
Schematic deformation of the Group 4 at the crown of the landslide

DISCUSSION: CRACKS AT THE CROWN



Schematic deformation of the Group 4 at the crown of the landslide

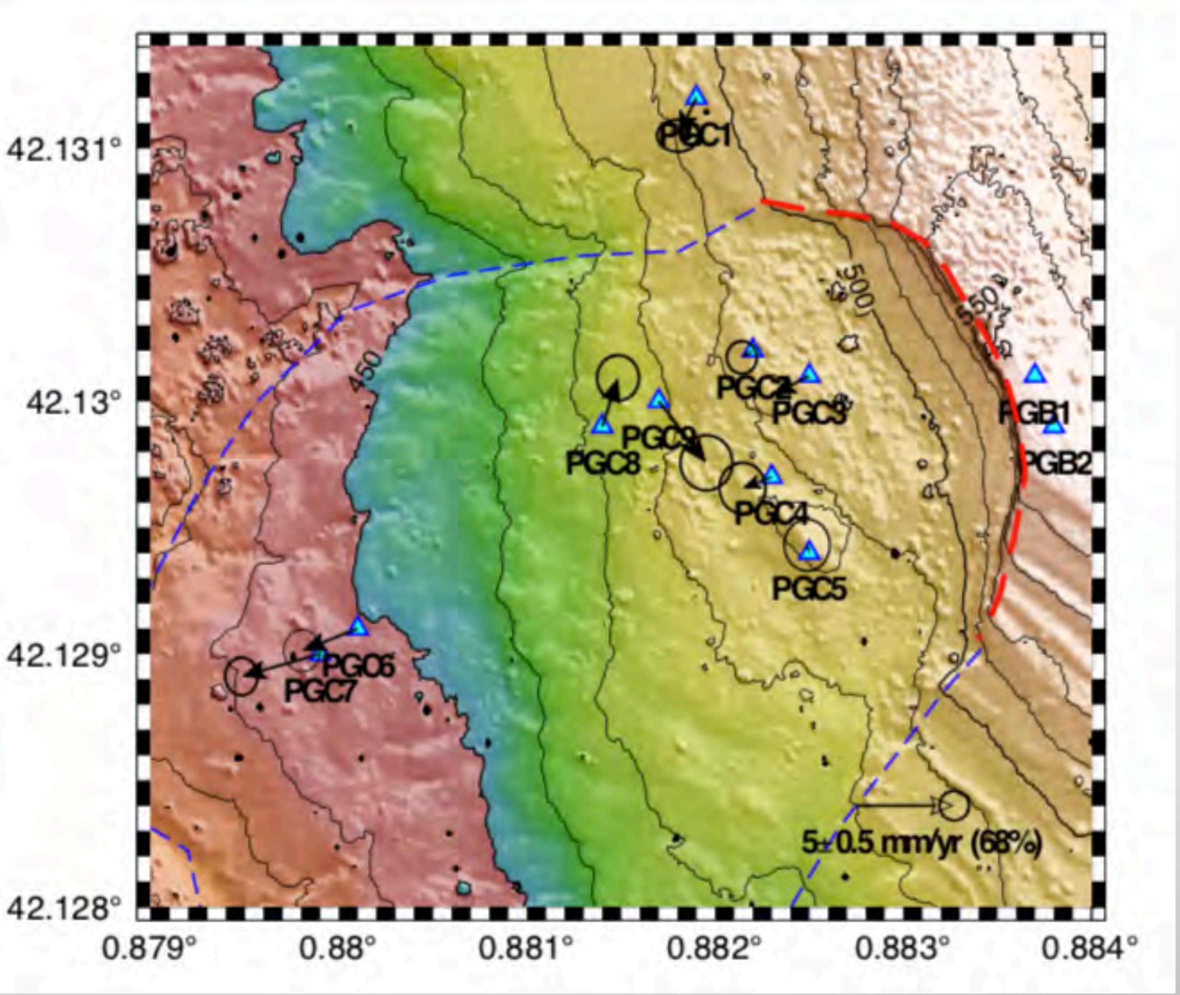
DISCUSSION: CRACKS AT THE CROWN



Simplified model of the behaviour of the crown cracks. Nail symbols indicate a stable (or fixed) points.

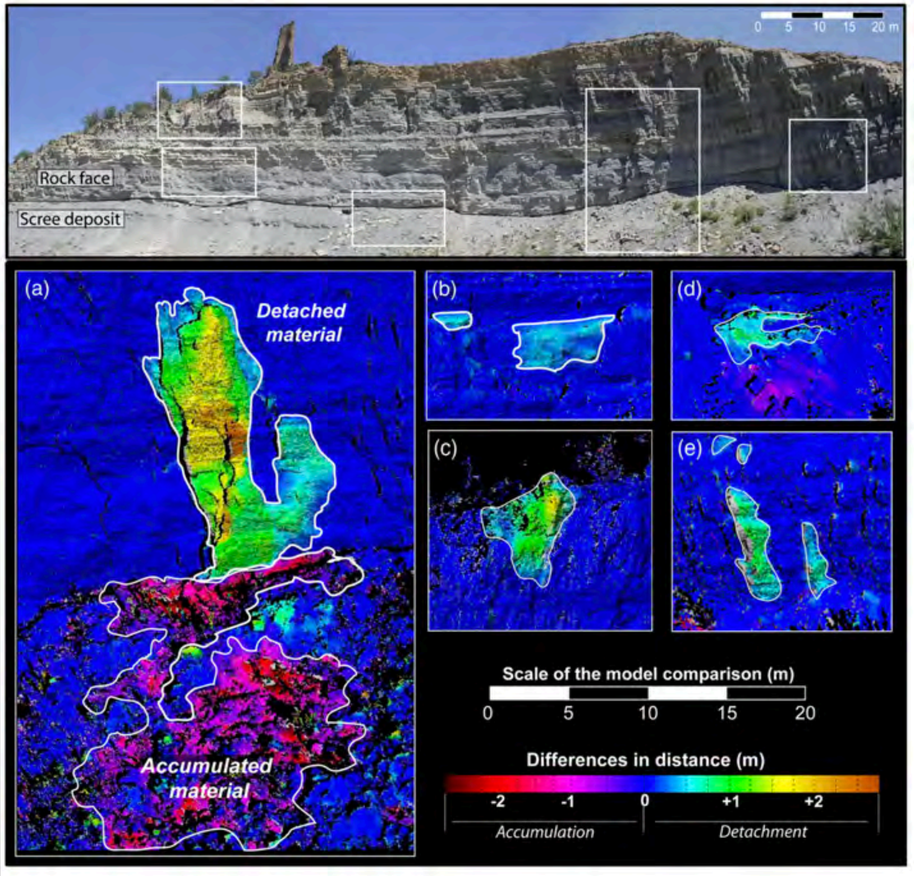
A) Map view; B) Cross-section.

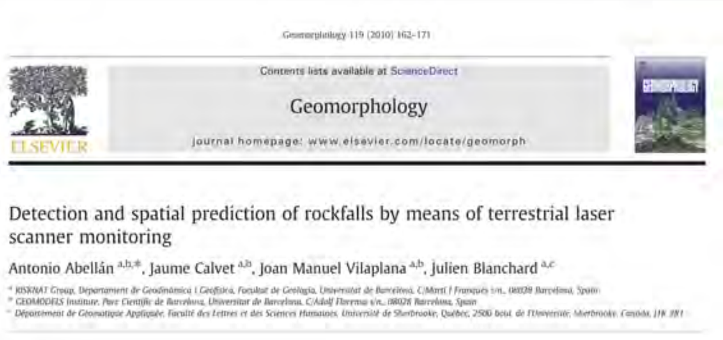
DISCUSSION: DEPOSITIONAL ZONE



TERRESTRIAL LIDAR

TERRESTRIAL LIDAR




Geomorphology 119 (2010) 162–171

Contents lists available at ScienceDirect

Geomorphology

journal homepage: www.elsevier.com/locate/geomorph

ELSEVIER

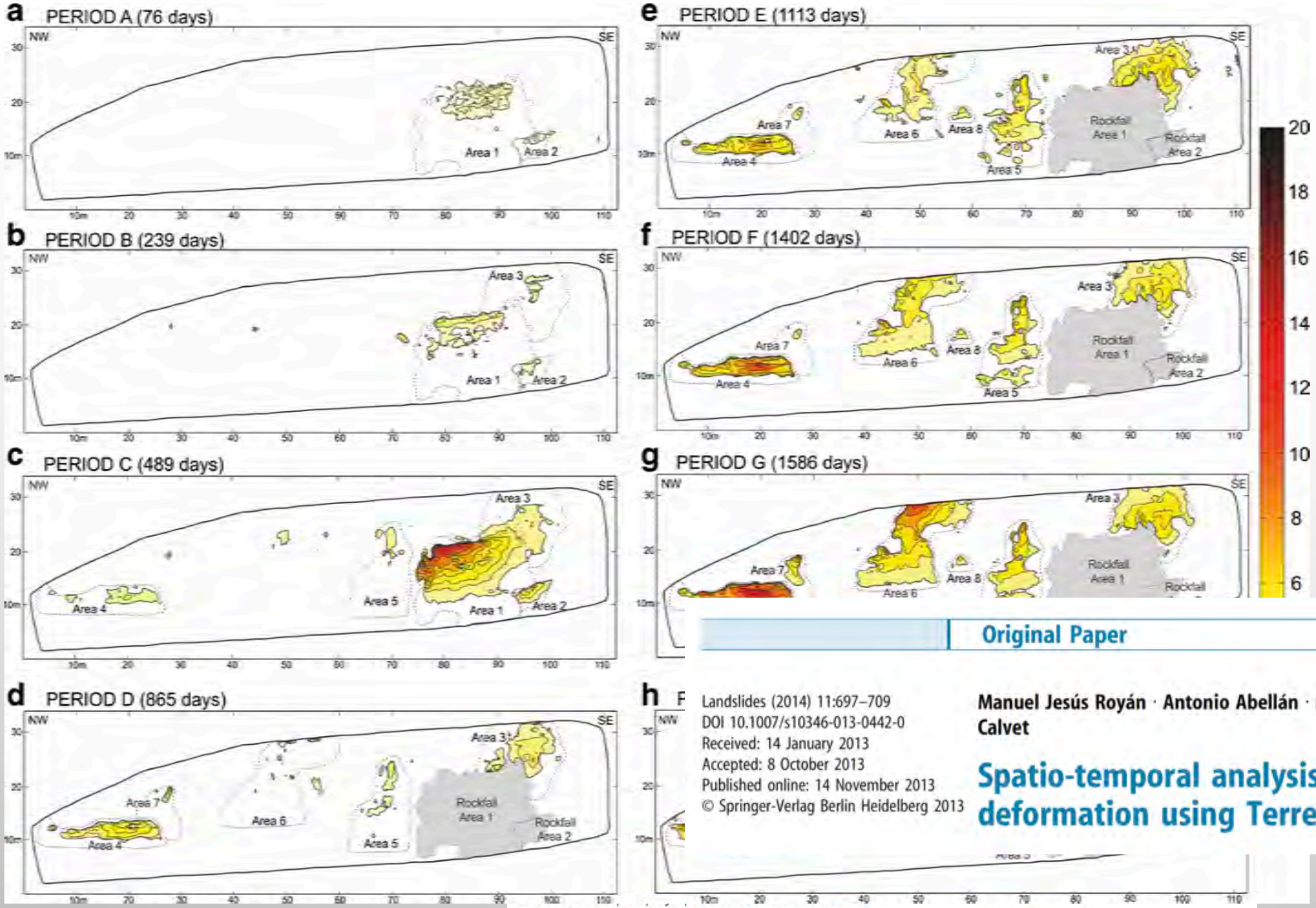
Detection and spatial prediction of rockfalls by means of terrestrial laser scanner monitoring

Antonio Abellán [a,b,*], Jaume Calvet [a,b], Joan Manuel Vilaplana [a,b], Julien Blanchard [a,c]

[a] RISKNAT Group, Departament de Geodinàmica i Geofísica, Facultat de Geologia, Universitat de Barcelona, C/Martí i Franquès s/n., 08028 Barcelona, Spain
[b] GEOMODELS Institute, Parc Científic de Barcelona, Universitat de Barcelona, C/Adolf Florensa s/n., 08028 Barcelona, Spain
[c] Département de Géomatique Appliquée, Faculté des Lettres et des Sciences Humaines, Université de Sherbrooke, Québec, 2500 boul. de l'Université, Sherbrooke, Canada, J1K 2R1

Puigcercós landslide, Catalonia, Spain

TERRESTRIAL LIDAR



Original Paper

Landslides (2014) 11:697–709
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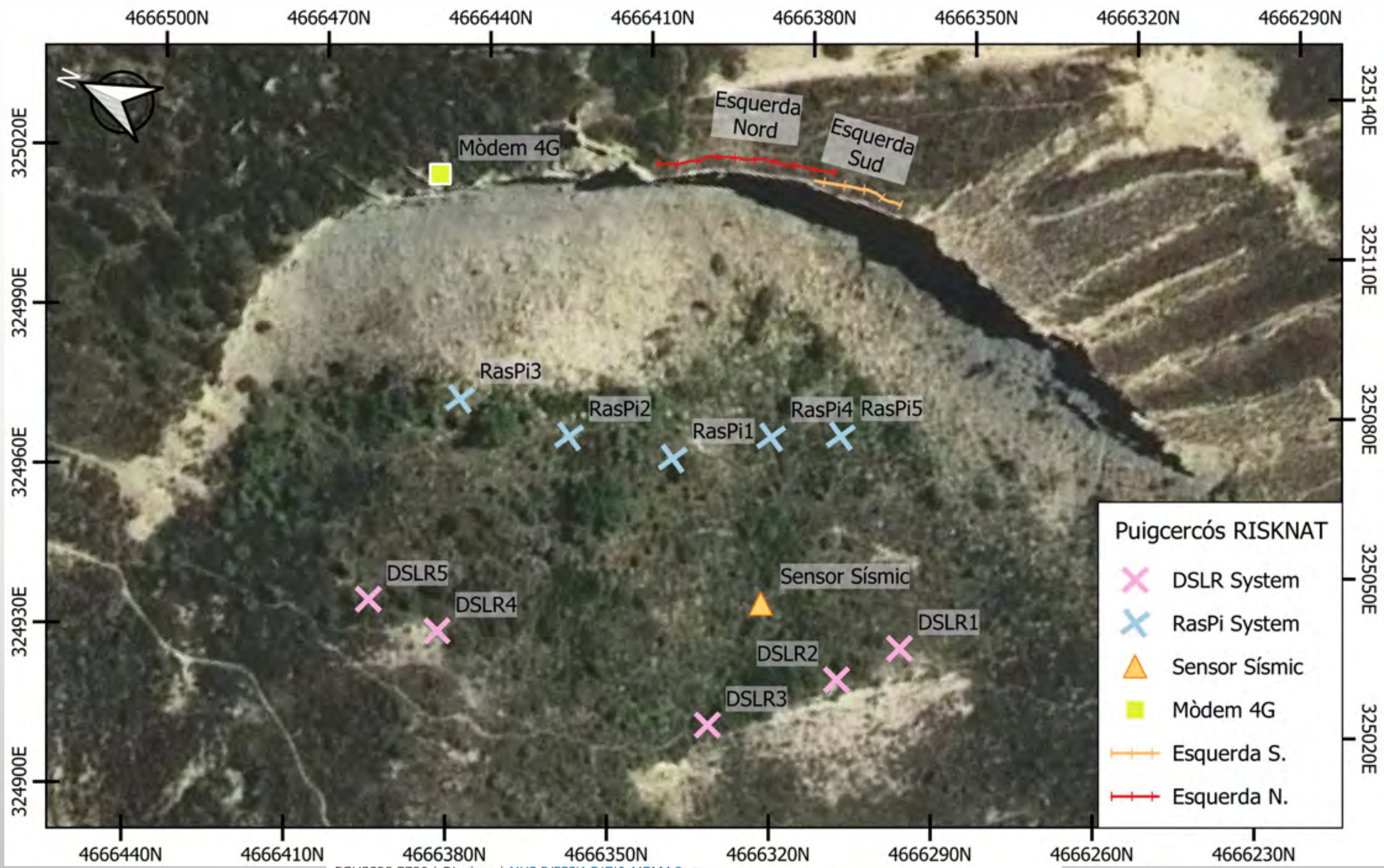
Manuel Jesús Royán · Antonio Abellán · Michel Jaboyedoff · Joan Manuel Vilaplana · Jaume Calvet

Spatio-temporal analysis of rockfall pre-failure deformation using Terrestrial LiDAR

Puigcercós landslide, Catalonia, Spain

TIME-LAPSE PHOTOGRAMMETRY

RasPI and HRCam Photogrammetry Systems



Puigcercós landslide, Catalonia, Spain

Time-lapse photogrammetry: RasPi System

Blanch, X., Abellán, A., & Guinau, M. (2019). Rockfall monitoring at a high-temporal rate using cost-effective photogrammetric systems. *Geophysical Research Abstracts*, *21*, EGU2019-11591–11592.

remote sensing

MDPI

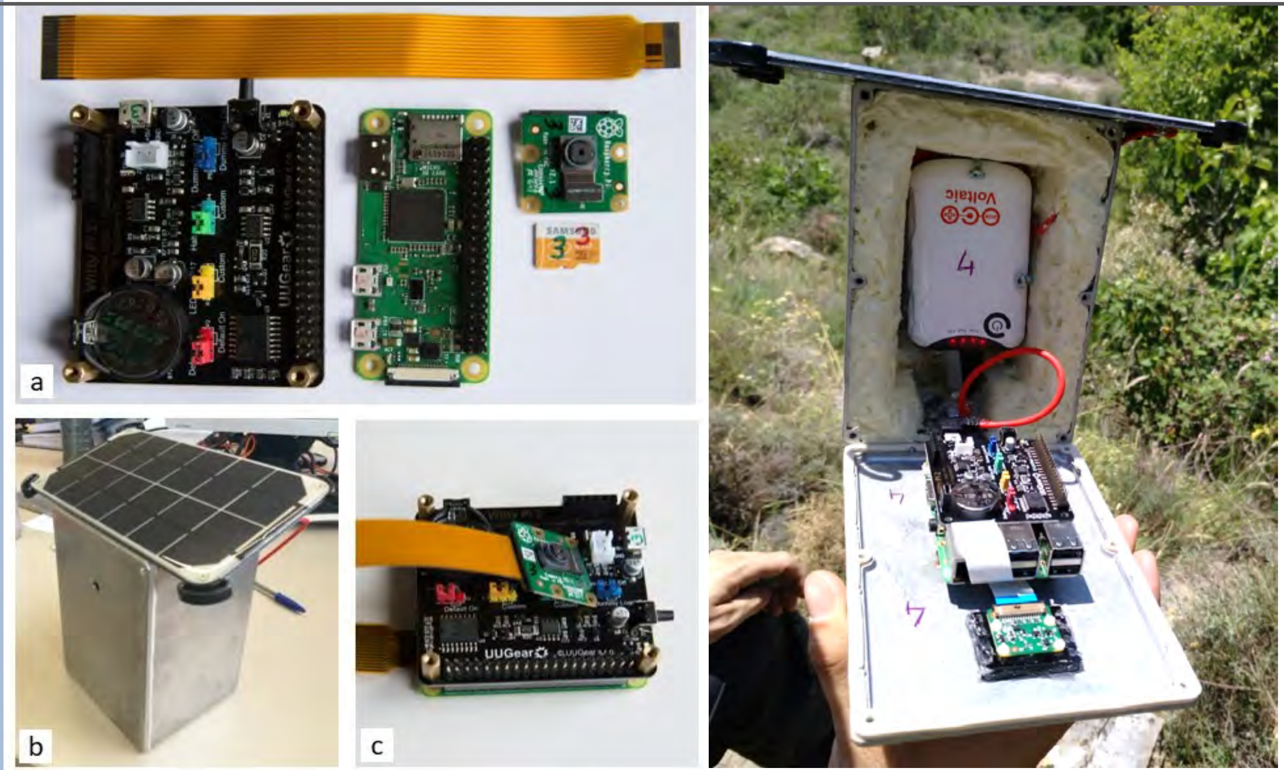
Article

Point Cloud Stacking: A Workflow to Enhance 3D Monitoring Capabilities Using Time-Lapse Cameras

Xabier Blanch [1,*], Antonio Abellan [2,3] and Marta Guinau [1]

RasPi System: Hardware

- **Non-commercial** solution
- Based on **Raspberry system**
- Camera Module V2
- WittyPi RTC shield
- **Low-cost** configuration
- **Sufficient** image quality



Blanch, X., Abellan, A., Guinau, M., 2020. Point Cloud Stacking: A Workflow to Enhance 3D Monitoring Capabilities Using Time-Lapse Cameras. Remote Sens. https://doi.org/10.3390/rs12081240

RasPI: setup

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Multidisciplinary studies of the Puigcercós historical landslide in the Catalan Pyrenees

Puigcercós landslide, Catalonia, Spain

Giorgi Khazaradze, Marta Guinau, Xabier Blanch, Antonio Abellán, Mar Tapia, Gloria Furdada, and Emma Suriñach

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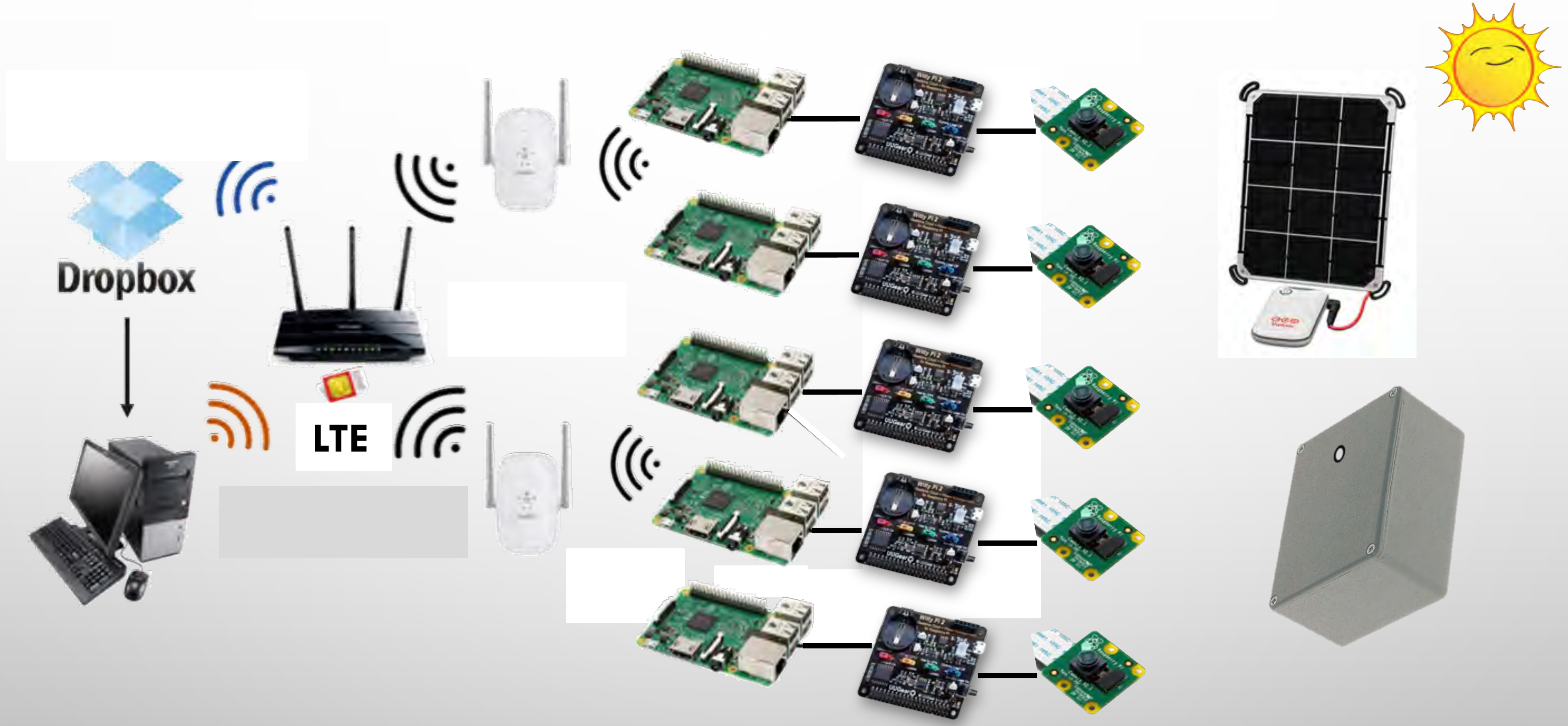
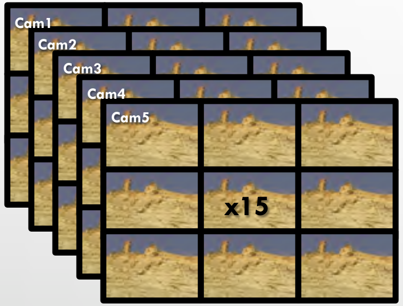
RasPi System: Setup scheme



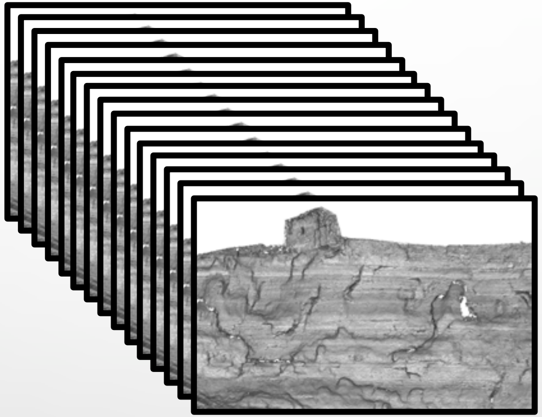
RasPi System: Methodology – 3 STEPS

- **Increase** 3D model quality – Image **redundancy** – Iterative process with **different** approximate solutions



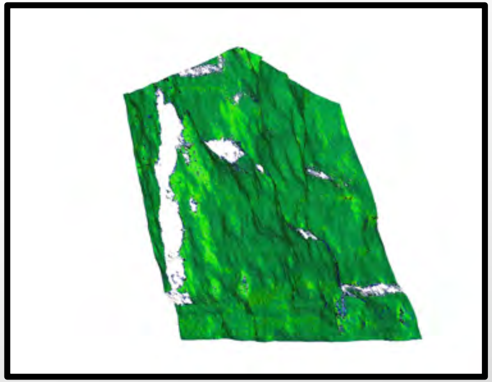
15 simultaneous photos from each camera

[1]



15 Points Clouds (Agisoft Metashape)

[2]



1 Dense Point Cloud

[3]

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RasPi System: examples

- 5 Photogrammetric modules
  Raspberry Pi 3B
  Camera RasPi v2 (8mpx)
  WittyPi 2

- 60/80 meters (RasPi – Cliff)

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RasPi System: results

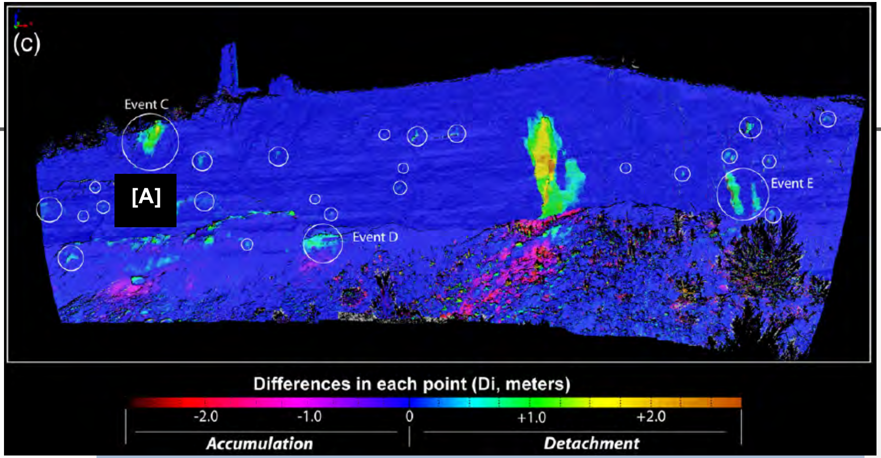
- **Rockfall monitoring** and magnitude - frequency analysis

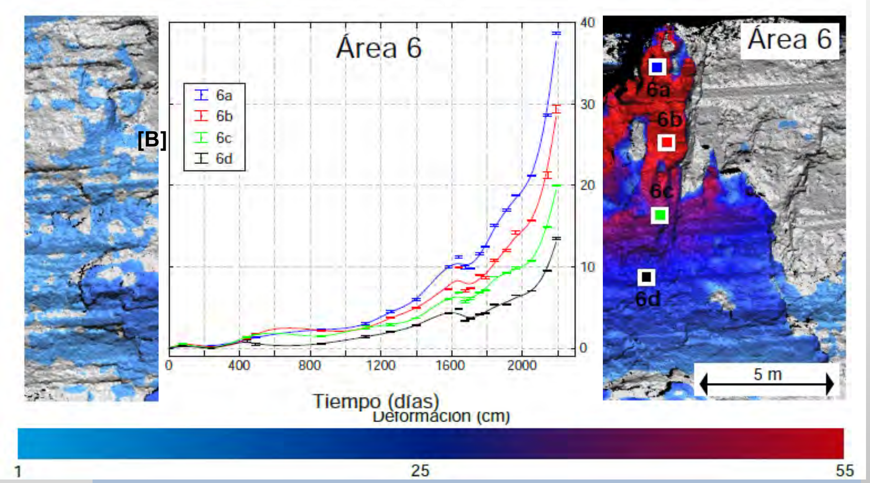
- **Prefailure deformation** analysis (study of the accelerations)

Cost-effective system

- **High temporal rate**

- **Real-time:** data transfer and remote processing





[A] A. Abellan 2010 [B] M. Royan 2015

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Time-lapse photogrammetry: HRCam

Quintero-Montaño, E. M. (2019). Análisis de límites de detección y cálculo de volumen de desprendimientos en escarpes rocosos mediante datos LiDAR y fotogramétricos Especialidad : Riesgos Geológicos. Universitat de Barcelona.

TFM dirigido por Blanch, X., & Guinau, M. (UB)

HRCam System: examples

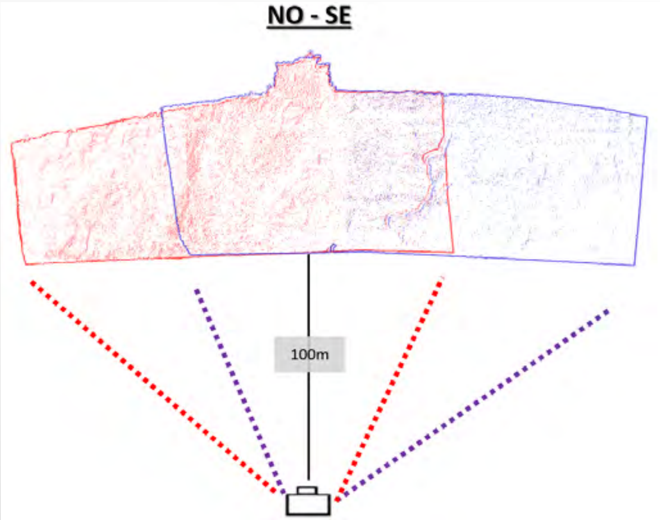
- 3 Photogrammetric modules
  Sony A7r II – FF: 42 Mpx
  Lens: 35mm - f7.1

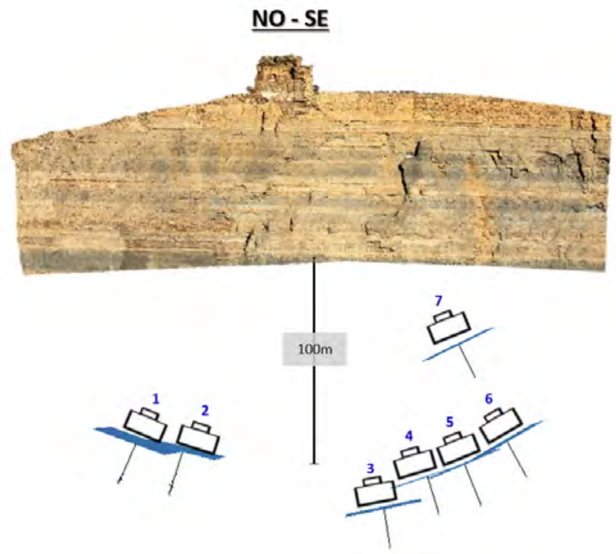
- 2 Photogrammetric modules
  Canon EOS 77D - APSC: 24Mpx
  Lens: 24mm (38 eq) - f7.1

- 100/120 meters (HRCam – Cliff)

HRCam photogrammetry: Methodology

Instrumento	Año: 2018		Año: 2019		Ventana temporal
	Fecha	Datos	Fecha	Datos	
LiDAR	17 de Mayo	2 escaneos	05 de Febrero	2 escaneos	9 meses
Nikon	05 de Marzo	7 fotografías	05 de Febrero	7 fotografías	11 meses
Sony	26 de Octubre	7 fotografías	05 de Febrero	7 fotografías	4 meses





Posiciones de los instrumentos de adquisición de datos.

SEISMIC MONITORING

SEISMIC MONITORING

Main objective:

To identify and characterize rock falls:

- FIRST PHASE HELPED BY PHOTOGRAPHS
- SECOND PHASE FOR INDEPENDENT MONITORING

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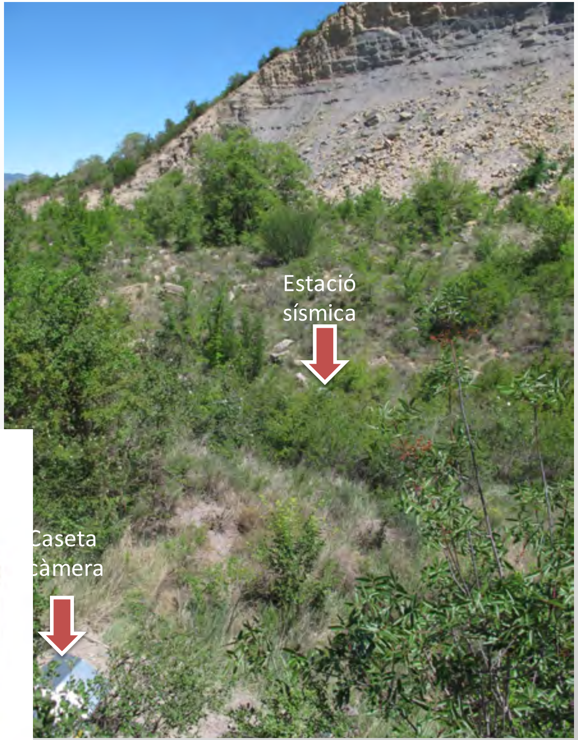
SEISMIC MONITORING



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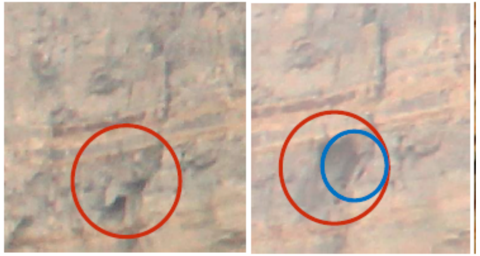
SEISMIC MONITORING

1) Rock-fall identification using photographs. Time intervals. (Time resolution: some hours)

2) Rock-fall identification in the seismic signal (Time resolution: exact time)

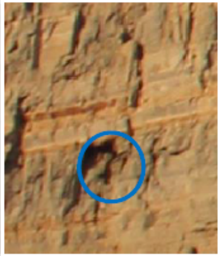
3) Rock-fall seismic characterization



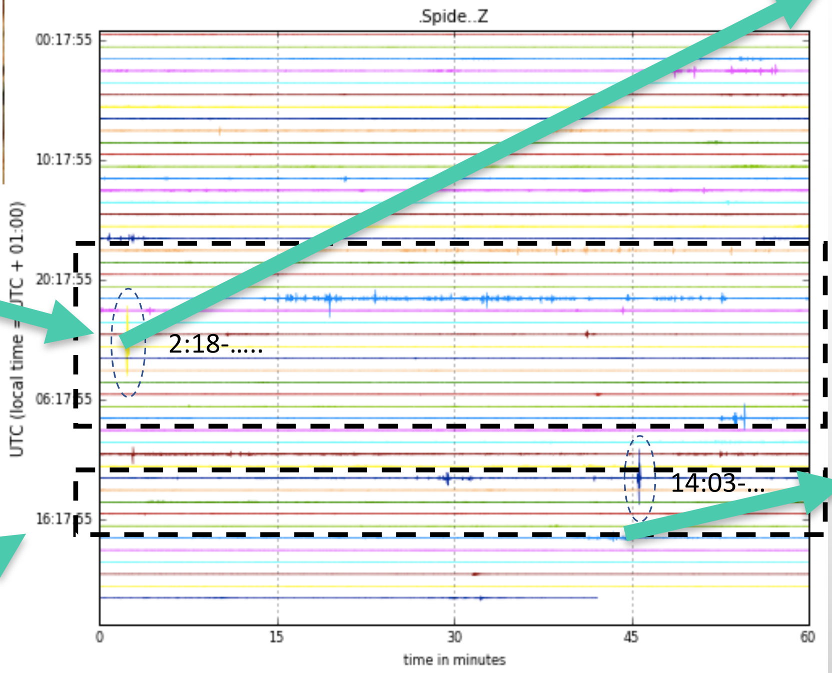
30/08/17 17:28h

31/08/17 09:28h

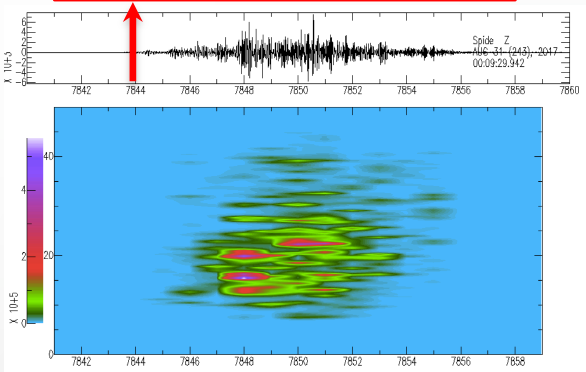
Rock 1
Aug30, 2017 17:28
Aug31, 2017 09:28



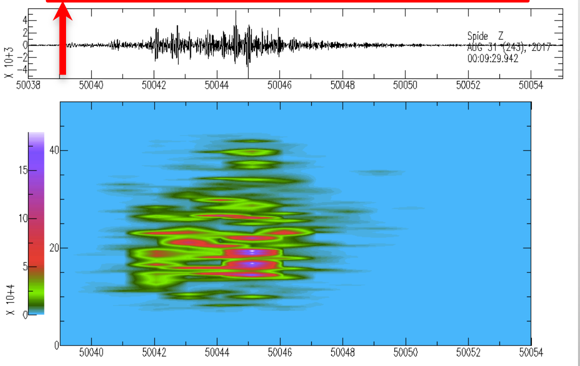
Rock 2
Aug31, 2017 13:28 - 17:28



AUG 31 (243), 2017 02:20:13.403



AUG 31 (243), 2017 14:03:28.977



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CONCLUSIONS 1

- The Puigcercós landslide continues to be **active**
- Apart from the frequent rockfalls at the scarp, the **cracks** at the crown of the scarp are **deforming**, showing an interesting pattern of simultaneous compression and extension, reaching half a cm/year.
- The body of the century old landslide is also **active**, although its deformation rates are slow. We hypothesize that the westerly motion of the lower group of the GPS sites are due to shallow creep, driven by gravitational forces.

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CONCLUSIONS 2

The correlation of the seismic and the photogrammetric data and intermittently obtained LiDAR images enables us to **monitor** and **characterize** frequent rockfalls and premonitory deformations occurring at the site.

These observations have allowed **quantifying** the rate of retreat of the rock scarp (10 to 11 cm/yr) and a slow motion of the depositional zone up to 5 mm/yr.

Since the geologic risk at the study area is not significant, due to the absence of population and/or infrastructures, this site is an **ideal natural laboratory** for developing new observational techniques, which can be used to develop early warning systems for rockfalls and landslides.

ACKNOWLEDGMENTS

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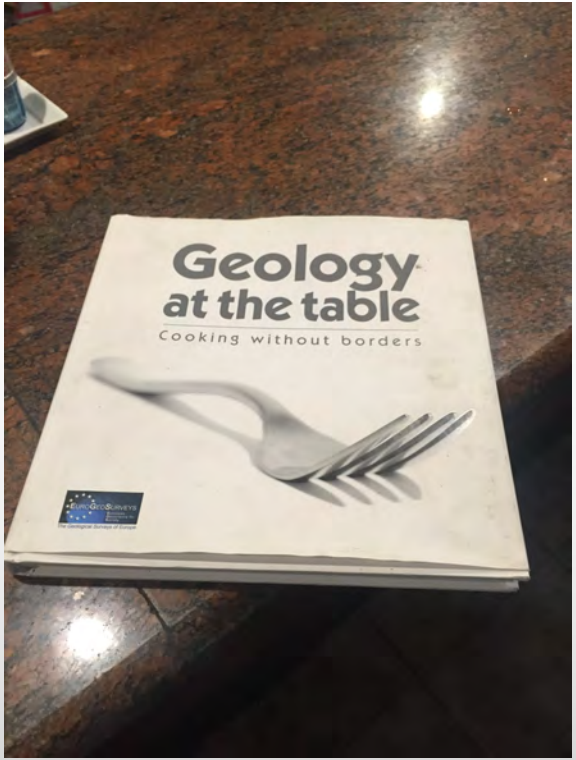
We are also thankful to UNESCO Global Geopark [Conca de Tremp-Montsec] for their support.

THANKS TO ALL



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