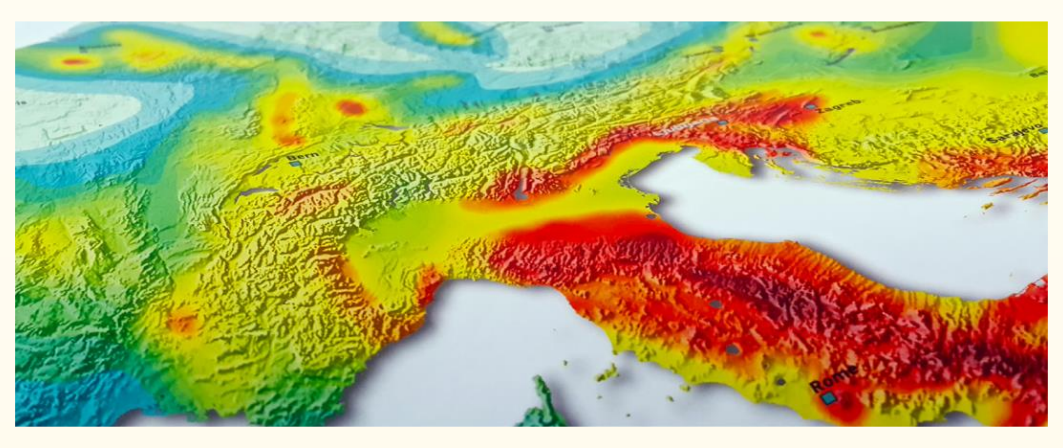

PSHA Workshop
Future directions for probabilistic seismic hazard assessment at a local, national and transnational scale
5 – 7th September 2017, Lenzburg

How much tectonic deformation do we capture by sampling surface fault evidence?

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1. Introduction

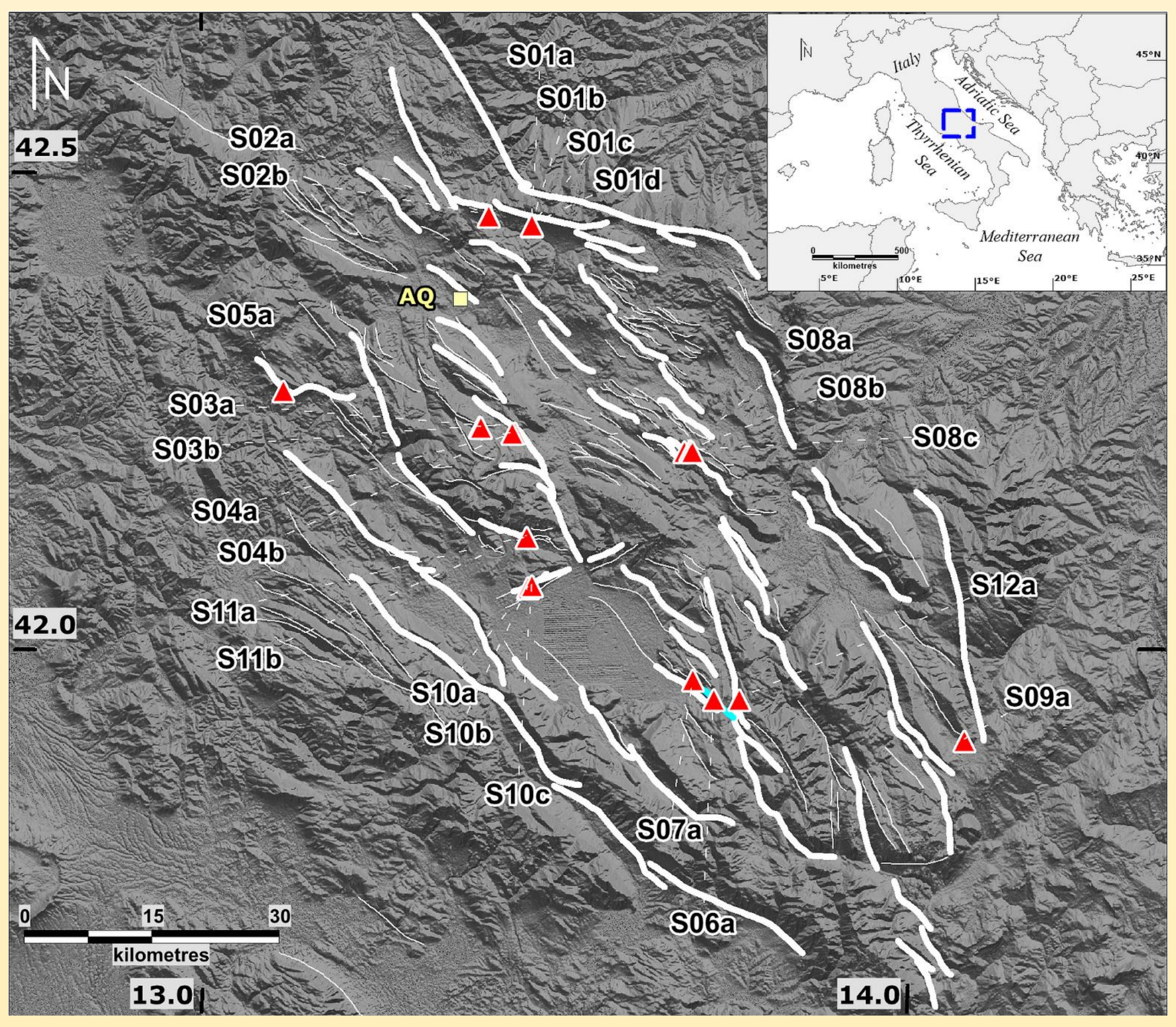
The landscape morphology offers important data on the Earth's deformation timeline, and elements for understanding the geometry of faults and their activity rate. In the case the sampled data derive exclusively from surface or shallow subsurface, however, they may carry with themselves also the effects of other processes. Caution is thus necessary for recognizing and eliminating the non-tectonic components when using such data for seismic hazard purposes. Causes other than primary faulting must be carefully considered in occasions of coseismic surface deformation associated with moderate and strong earthquakes and the same is true when studying the seismogenic fault slip rates in the interseismic period.

2. Case study – exposure of presumably active bedrock fault scarps in central Apennines

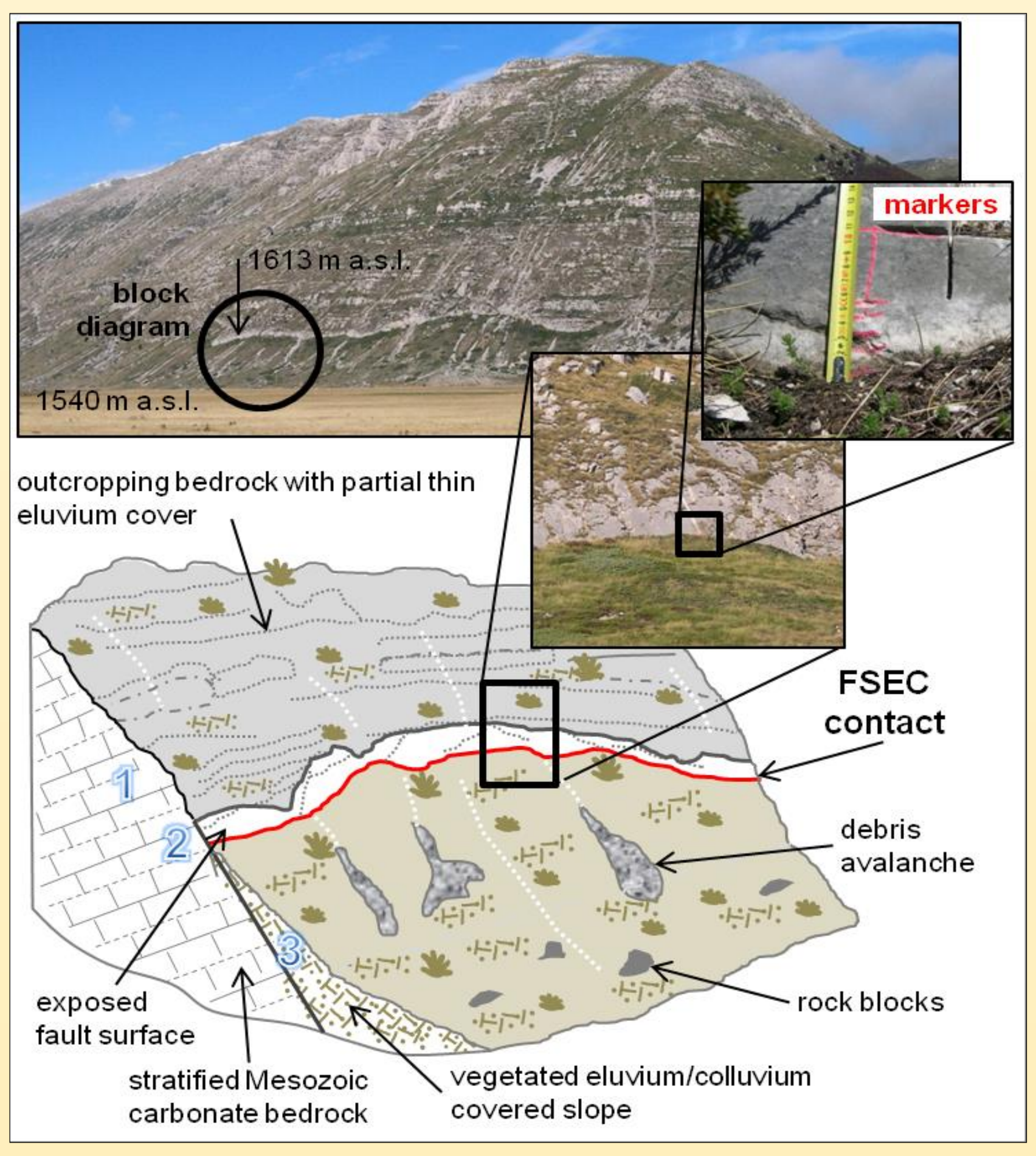
Central Apennines morphology is characterized by the bedrock fault scarps along which the carbonates are in contact with the slope material (FSEC contact). They are exposed at various heights, almost exclusively on the SE flanks of the mountains and their along-strike extent is limited to the length of each individual mountain front. Some of the bedrock fault scarp bearing mountain fronts bound intermountain basins, while others represent a limit of fluvio-glacial valleys and karstic plateaus. These areas are also prone to different types of active landsliding.

The bedrock fault scarp height and the concentration of accumulated cosmogenic nuclides along the scarp height have often been used to calculate the fault slip rates through an assumption that past earthquakes are the only controlling process of their evolution though not having any direct evidence of such a relation.

Study area of the central Apennines with selected measurement points



Geologic conditions along one of the studied bedrock fault scarps



In order to study the processes along 12 different bedrock fault scarps we set up a network of 23 measurement points, where we regularly measured the position of selected markers on the bedrock scarp with respect to the material at its hanging wall contact.

Measurements of berdock scarp exposure through the relative position of the FSEC at the time of each measurement (Kastelic et al., 2017)

3. Results

During a 3.4 year-long observation period we detected either downward or upward movements of the slope deposit with respect to the fault surface between consecutive measurements. During the entire observation period all points, except one, registered a net downward movement in the 2.9 - 25.6 mm/yr range, resulting in the progressive exposure of the fault surface.

During the monitoring period no major earthquakes occurred in the region, demonstrating the measured exposure process is disconnected from seismic activity.

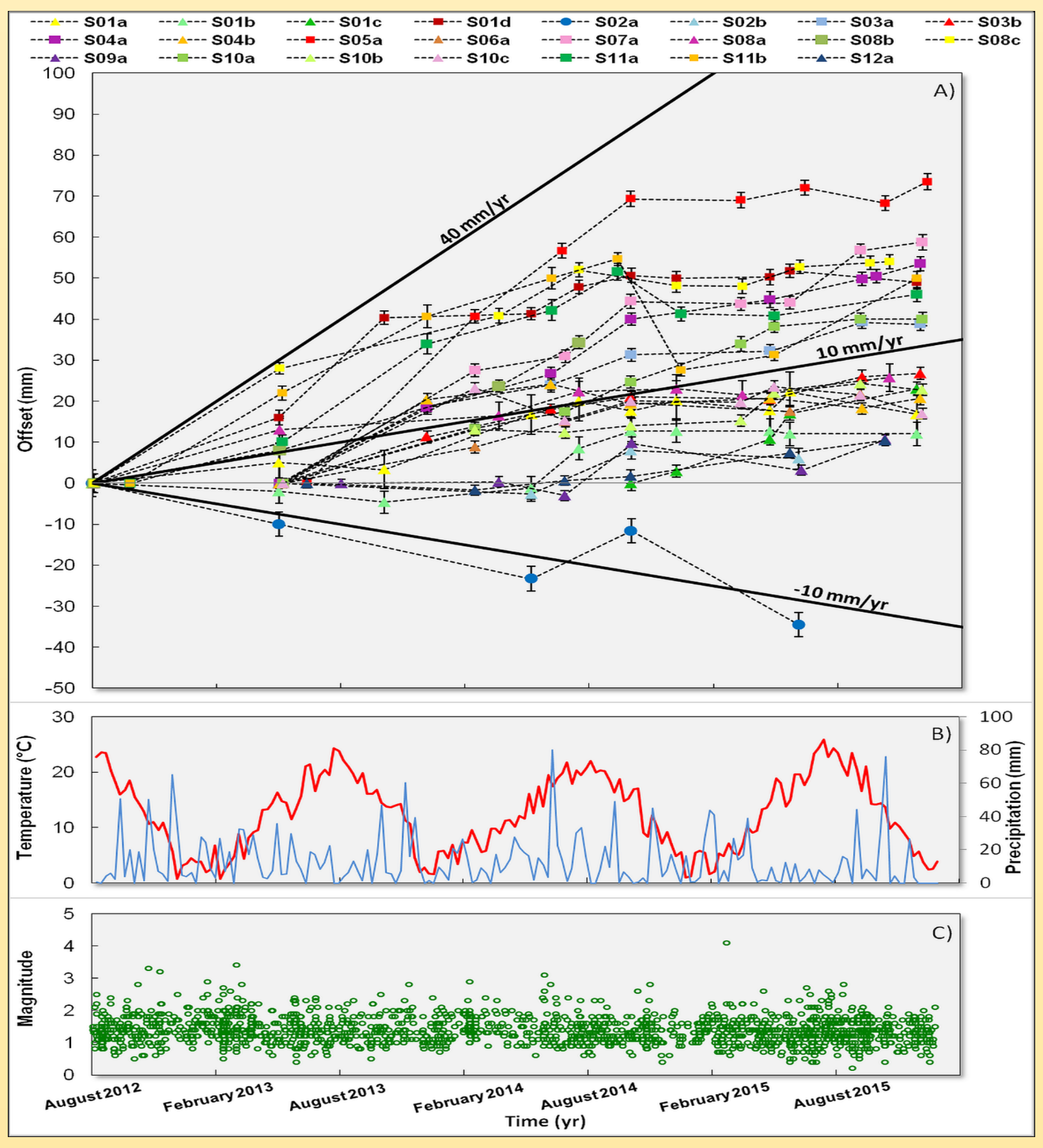
We do however observe a positive correlation between the higher exposure in respect to higher average temperatures, a characteristic typical for erosional processes.

Considering the dependence of the time interval on the (sub)surface processes, we show our exposure rates to be comparable with the slip rates calculated from the data on fault scarp heights and cosmogenic nuclide concentrations.

Exposure rates for the 23 MSs during the 2012-2015 observation period

Site ID	Fault Name	Fault classification	Cum. Offset ± Unc. at k=2 (mm)	ER ± Unc. at k=2 (mm/yr)	R^2	F_{obs}/F_{crit}	ER over 10^4 years [mm/yr]	Slip rate [mm/yr]
S01a	Assergi east	Po / Pr	16.8 ± 4.8	6.8 ± 1.3	0.74	4.3	1.5	0.2 ± <0.2
S01b	Assergi east	Po / Pr	12-0 ± 2.8	5.8 ± 0.8	0.65	2.8	1.3	0.2 ± <0.2
S01c	Assergi east	Po / Pr	23-0 ± 1.7	21.0 ± 1.9	0.95	6.6	3.9	0.2 ± <0.2
S01d	Assergi east	Po / Pr	51.8 ± 1.7	15.4 ± 0.5	0.79	5.8	3.5	0.2 ± <0.2
†S02a	Assergi west	VP / Pr	-34.5 ± 2.9	-10.2± 1.1	0.56	0.4	-2.3	0.2 ± <0.2
†S02b	Assergi west	VP / Pr	6 ± 2.6	3.6 ± 0.4	0.40	<0.1	0.8	
S03a	Campo Felice west	Po / S	38.8 ± 1.4	13.9 ± 0.6	0.91	7.3	3	
S03b	Campo Felice west	Po / S	26.8 ± 1.4	9.4 ± 0.6	0.90	6.7	2	
S04a	Campo Felice east	VP / Pr	53.5 ± 1.7	19.8 ± 0.6	0.87	115.5	4.3	0.17 1.0
†S04b	Campo Felice east	VP / Pr	20.8 ± 1.7	5.0 ± 0.6	0.34	0.4	1.1	0.17 1.0
S05a	Fiamignano	VP / Pr	73.5 ± 1.9	25.6 ± 0.9	0.77	3.3	5.5	0.83 ± <0.2 1.27 ± 0.4
S06a	Serrone anthitetic	not mapped as fault	21.8 ± 1.4	8.9 ± 0.7	0.86	20.5	1.9	
S07a	Fucino high	Po / S	58.8 ± 1.9	21.2 ± 0.6	0.93	13.5	4.6	
S08a	Aterno valley	P / Pr	25.8 ± 3.4	7.6 ± 1.1	0.88	5.9	1.7	0.3 ± <0.2
°S08b	Aterno valley	P / Pr	10.7 ± 1.2	4.5 ± 0.6	0.43	0.4	0.9	0.3 ± <0.2
S08c	Aterno valley	P / Pr	54.0 ± 1.7	15.0 ± 0.4	0.85	7.27	3.4	0.3 ± <0.2
†S09a	Pizzalto	P / S	3.2 ± 1.3	2.9 ± 0.8	0.62	<0.1	0.6	1.4
S10a	Tre Monti	VP / Pr	40.0 ± 17	17.0 ± 0.6	0.96	32.2	3.7	0.16 ; 0.2 0.43 ± <0.1
S10b	Tre Monti	VP / Pr	22.8 ± 1.4	8.7 ± 0.6	0.90	8.8	1.9	0.16 ; 0.2 0.43 ± <0.1
†S10c	Tre Monti	VP / Pr	17.0 ± 1.3	5.7 ± 0.6	0.41	0.7	1.2	0.16 ; 0.2 0.43 ± <0.1
S11a	Magnola	VP / Pr	46.0 ± 1.7	13.2 ± 0.5	0.60	1.8	3	0.23 ; 1.3 1.0 ± <0.1
S11b	Magnola	VP / Pr	50.0 ± 1.6	13.9 ± 0.5	0.63	1.8	3.1	0.23 ; 1.3 1.0 ± <0.1
S12a	Valle Giovenco	P / Pr	10.4 ± 1.3	4.5 ± 0.6	0.70	1.7	1	0.27 ± <0.2 0.5

Central Apennines berdock fault exposure rates during the 2012-2015 observation period

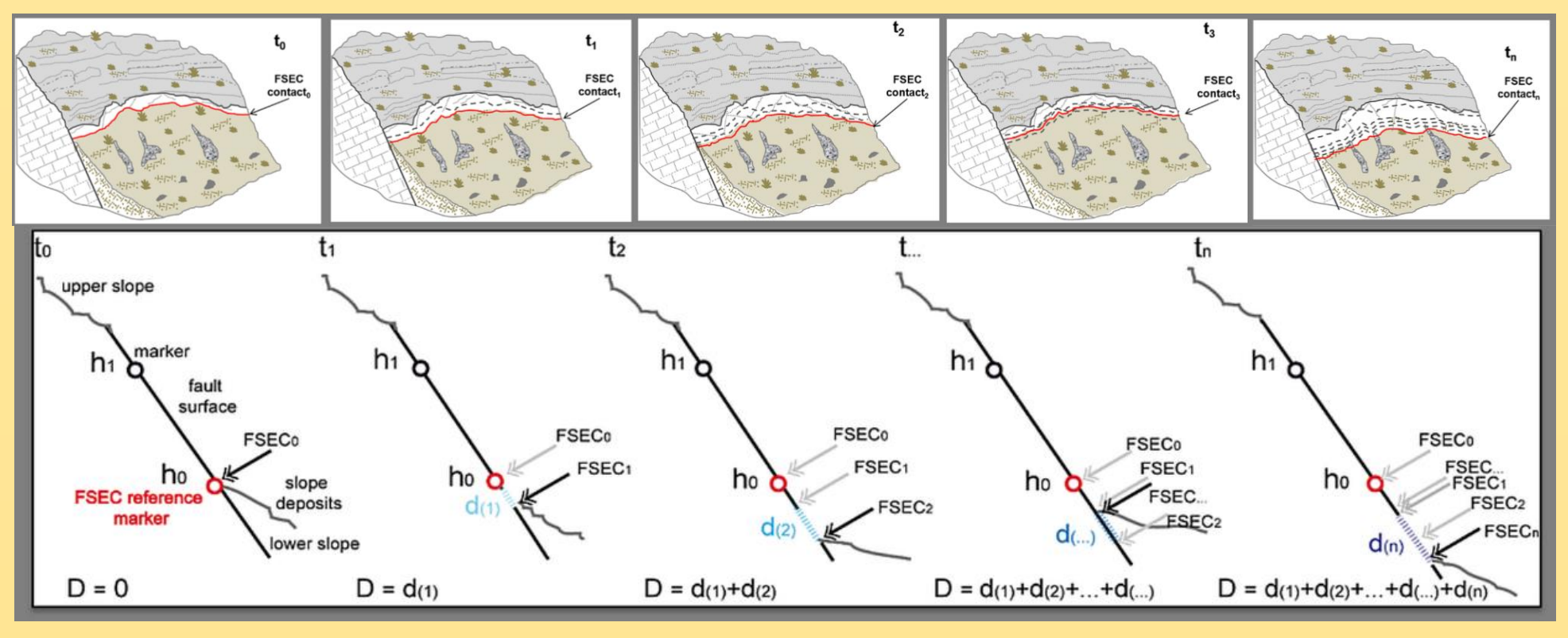


4. Conclusions and further investigations

The landscape morphology offers important data on the Earth's deformation timeline, and elements for understanding the geometry of faults and their activity rate. In the case the sampled data derive exclusively from surface or shallow subsurface, however, they may carry with themselves also the effects of other processes.

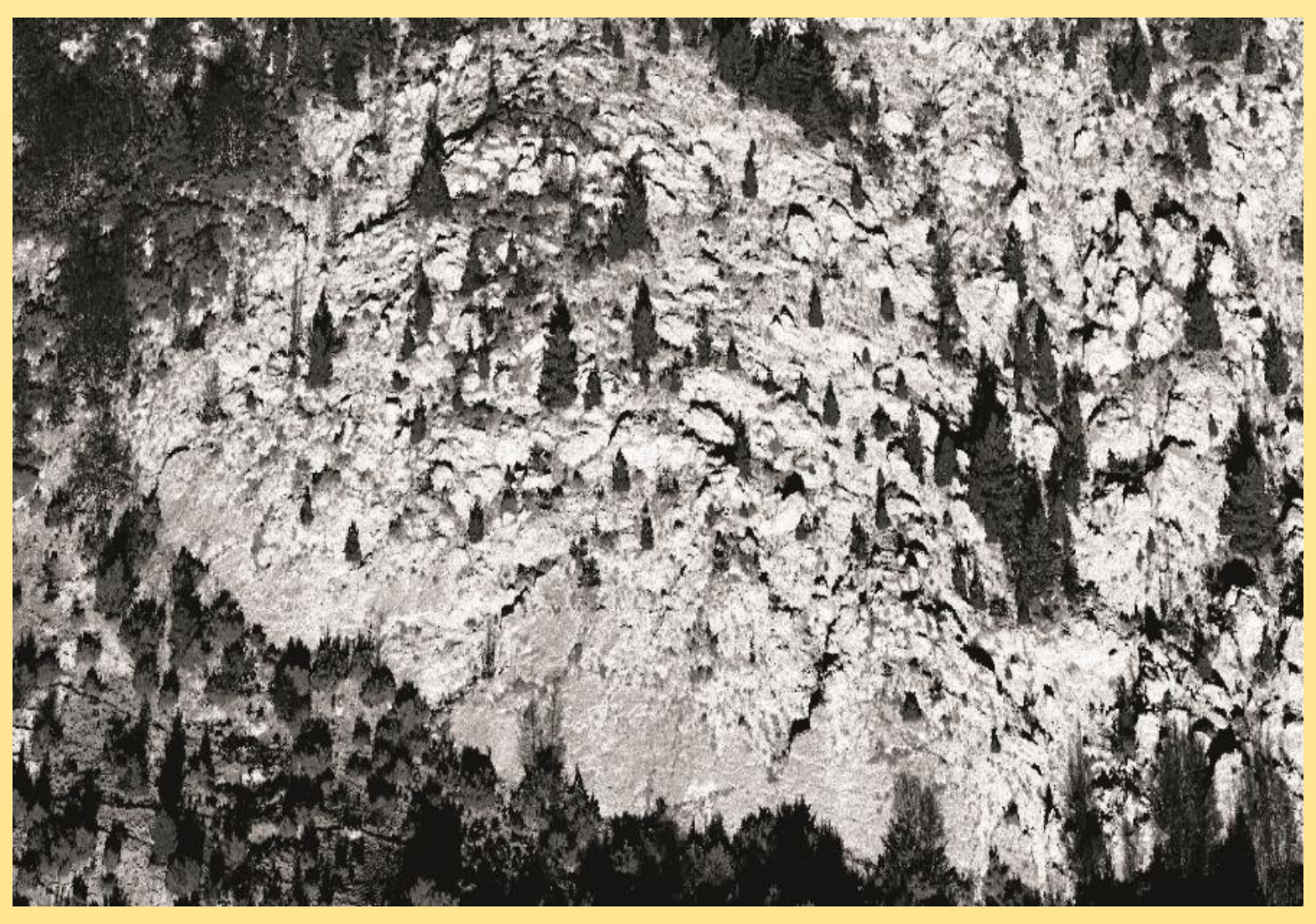
Caution is thus necessary for recognizing and eliminating the non-tectonic components when using such data for seismic hazard purposes.

Interpretive sketch model of the fault surface - eluvium/colluvium contact evolution depicting incremental [d] and cumulative [D] offset over a given time period [t_0 to t_n]. The dashed lines represent the free face formed between successive surveys. Note that we monitor the lower edge of the exposed fault surface, i.e. its contact with the hanging-wall material.

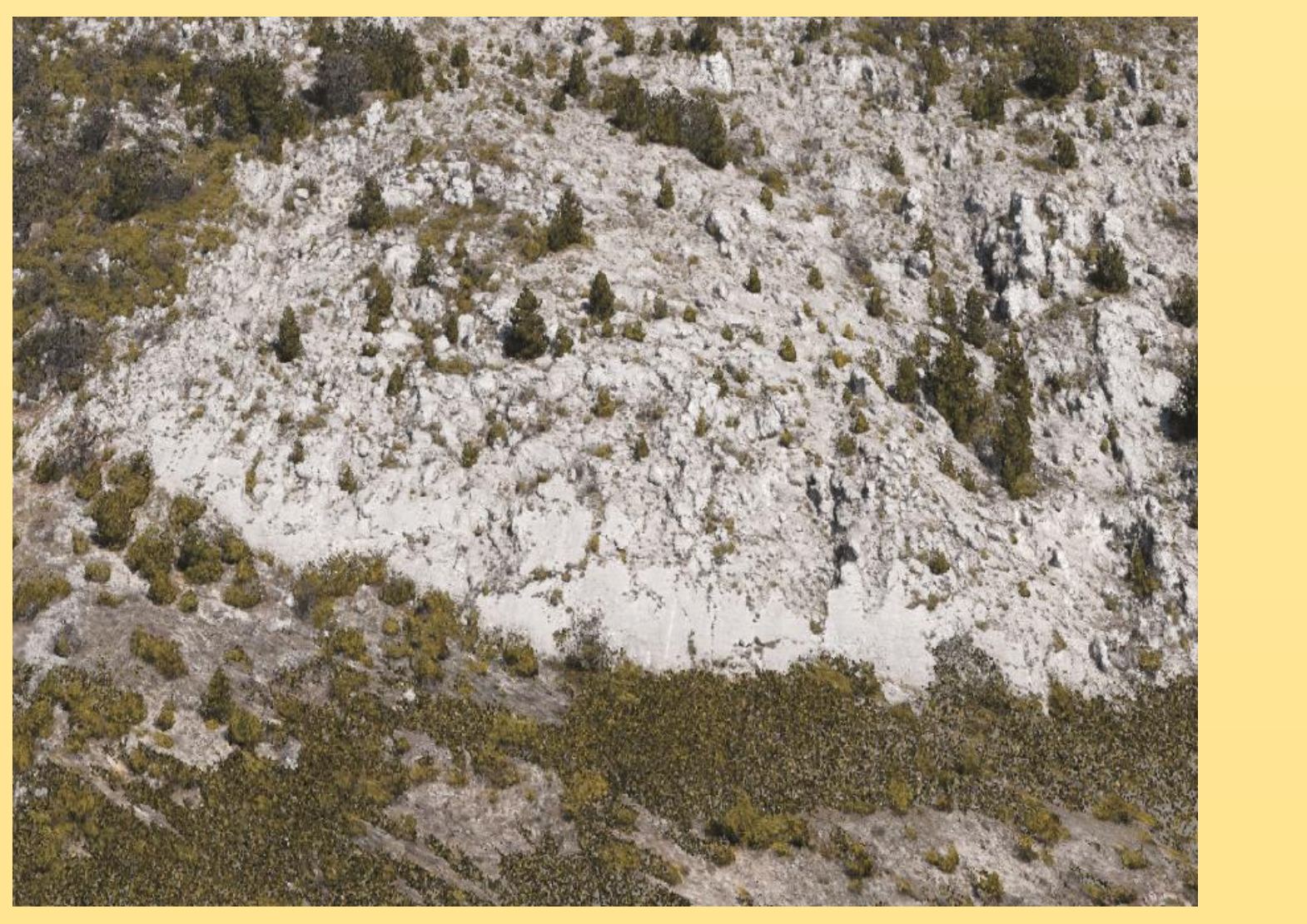


We are implementing the measurement at singular points along a bedrock fault scarp with measurement techniques capable of sampling much larger continuous area with enough resolution to detect the various cm/yr to mm/yr velocities. Such results will help us in quantifying the exposure process along different parts of the scarps and throughout the hanging wall block.

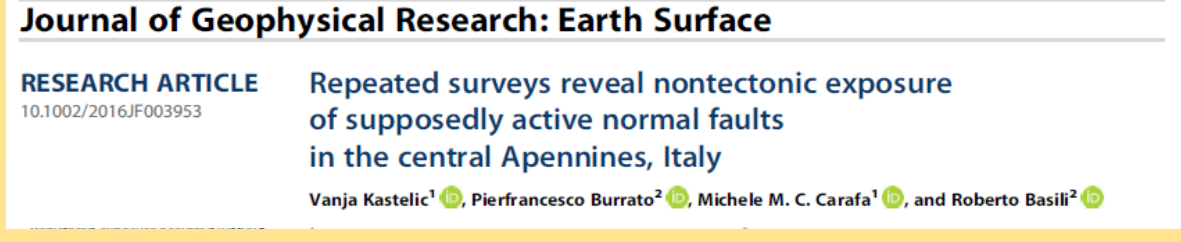
Terrestrial Laser Scan - TLS



Structure from Motion – SfM photo gravimetry



References



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Journal of Geophysical Research: Earth Surface
RESEARCH ARTICLE
10.1002/2016JF003953
Repeated surveys reveal nontectonic exposure of supposedly active normal faults in the central Apennines, Italy
Vanja Kastelic[1], Pierfrancesco Burrato[2], Michele M. C. Carafa[1], and Roberto Basili[2]

Kastelic et al.. 2017, JGR-ES

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Along faults in the Central Apennine Mountains, weather and landslides may cause rock exposure that is mistakenly attributed to earthquakes.
SOURCE: Journal of Geophysical Research: Earth Surface

Stanley, S., 2017, Eos, 98,https://doi.org/10.1029/2017EO073171. Published on 16 May 2017