«Ο ρόλος της Γεωλογίας των σεισμών στον προληπτικό σχεδιασμό, στα έργα υποδομής και στην ανάπτυξη καταστροφικών μοντέλων»

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Γεωπονικό Πανεπιστήμιο Αθηνών
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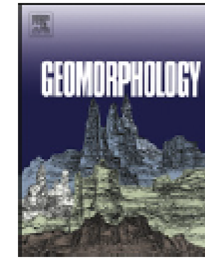


Editorial

Geomorphology of active faulting and seismic hazard assessment: New tools and future challenges

Keywords:
Morphotectonics
ESI 2007
Earthquake environmental effects
LiDAR
GPR

1. Geomorphology of active faults and seismic hazard assessment

Geomorphology is a principal t… Geology and Paleoseismology. How… seismic hazard assessment. There is an emerging tendency and need

the proximity to human habitation rather than the activated structure, thus seriously misplacing the epicentre localities, ii) partial or full destruction of historical chronicles, iii) the low reliability of hypocentral depth estimates for old events (Tinti et al., 1986; Albarello et al., 1995). However, large uncertainties are also evidently portrayed in most countries even for instrumentally recorded epicentres. For example, Fig. 1 shows the epicentre localities retrieved from the historical catalogues and recent papers of the recent 1999 Athens Mw 5.9 earthquake and the 1938 Mw 6.0 Oropos event 40 km north from Athens. It is surprising to note that the uncertainty … of the 1999 moderate and well-… ddition, for the 1938 event the … able earthquake catalogues are

Papanikolaou et al. (2015) Geomorphology

Οι ενόργανοι αλλά και οι ιστορικοί κατάλογοι σεισμικότητας είναι ανεπαρκείς για μια πλήρη και αξιόπιστη απεικόνιση της χωρικής αλλά και χρονικής κατανομής των σεισμών.

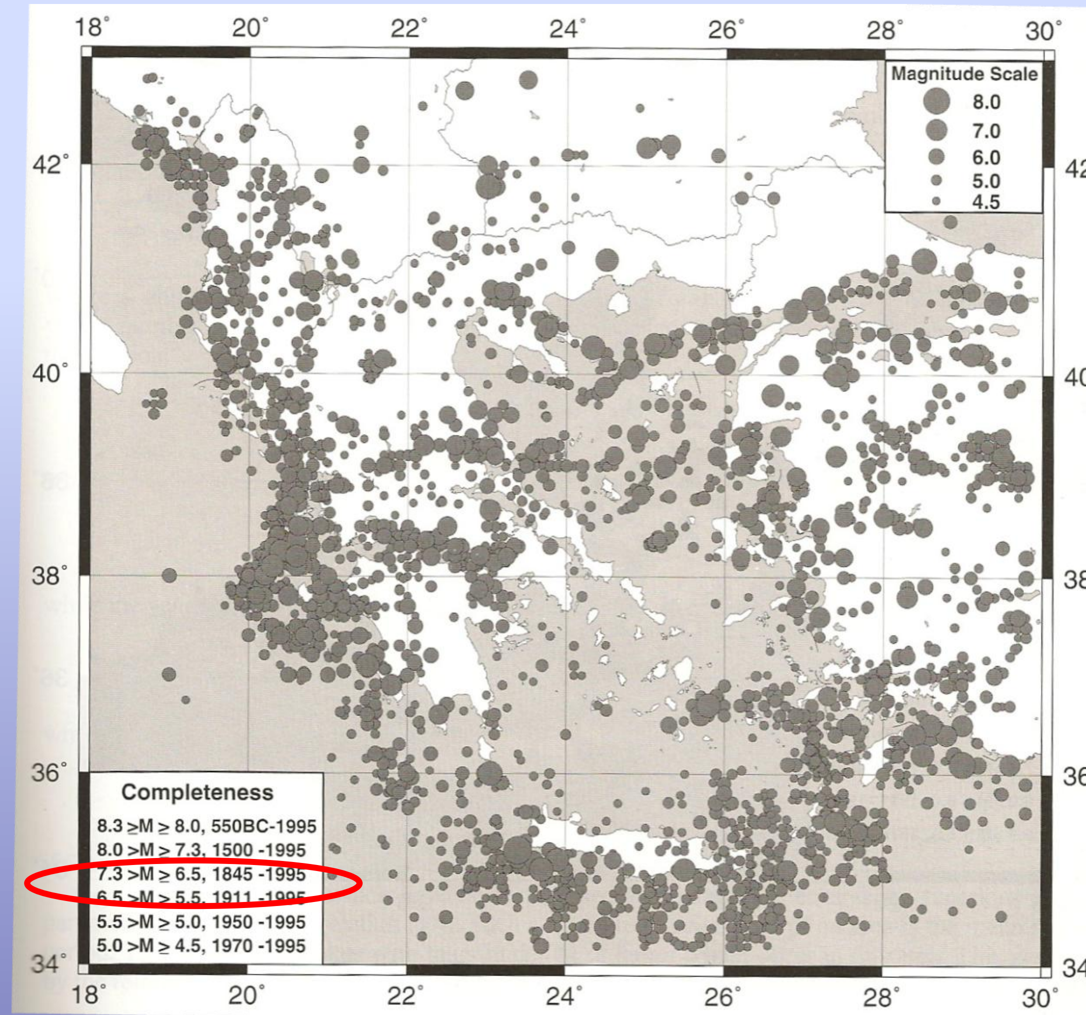
Με λίγα λόγια οι κατάλογοι δεν είναι πλήρεις γιατί

καλύπτουν ένα μικρό χρονικό διάστημα σε σχέση με το χρόνο επανάληψης των σεισμών στα περισσότερα ρήγματα

Distinguish between the time frame covered by the historical record with the completeness period where no events are expected to be missing. The completeness period is a small fraction of the period covered by the historical record, but is important since it is used as input data in the probabilistic seismic hazard assessment

Seismicity of Greece

Despite the long catalogue since 550BC, it is considered complete for events M≥7.3 since 1500 and for M≥6.5 only since 1845



Papazachos et al. (2000)

Classification of tectonic earthquakes *(after Scholz, 2002)*

Type	Slip-rate in mm/yr	Recurrence time in years
I. Interplate	$\nu > 10$	~ 100
II. Intraplate, plate boundary related	$0.1 \leq \nu \leq 10$	100 - 10000
III. Intraplate, midplate	$\nu < 0.1$	> 10000

Οι ιστορικοί κατάλογοι στον Ελλαδικό χώρο θεωρούνται πλήρεις για M>6.5 από το 1845 και για μεγέθη M>7.3 από το 1500 (Papazachos et al. 2000)

Λαμβάνοντας υπ΄ όψιν ότι τα ρήγματα έχουν χρόνους επαναδραστηριοποίησης της τάξης των αρκετών εκατοντάδων μέχρι μερικών χιλιάδων χρόνων, είναι σαφές ότι <u>η πλειοψηφία των ρηγμάτων δεν θα έχει ενεργοποιηθεί στο παραπάνω χρονικό διάστημα που καλύπτεται από τους καταλόγους ιστορικής</u> Σεισμικότητας, <u>**άρα θα απουσιάζουν από το στατιστικό δείγμα**</u>

Country	Magnitude	Completeness period since	Observation period where data are considered complete (in years)
Greece	M ≥ 8.0	550 BC	2564
	M ≥ 7.3	1500	514
	M ≥ 6.5	1845	169
	M ≥ 5.5	1911	103
	M ≥ 5.0	1950	64
	M ≥ 4.5	1970	44
Australia	M ≥ 6.0	1901	113
	M ≥ 5.0	1963	51
	M ≥ 4.0	1975	39
Central Europe (Germany, Austria, The Netherlands, Belgium)	Mw ≥ 5.8	1500	514
USA (San Francisco Bay)	M ≥ 5.5	1850	164
Italy (Central)	Mw ≥ 6.8	1200	814
	Mw ≥ 5.8	1500	514
Italy (southern)	Mw ≥ 6.8	1450	564
	Mw ≥ 5.8	1650	364
Central America (Costa Rica, El Salvador Panama, Nicaragua, Honduras, Guatemala)	Ms ≥ 7.0	1820 Rojas et al. (1993)	194
	Ms > 6.0	1910 Ambraseys and Adams (2001)	104
	Ms > 5.0	1920 Ambraseys and Adams (2001)	94
Iberia (Portugal, Western, Central and Northern Spain)	Mw ≥ 6.8	1300	714
	Mw ≥ 5.8	1800	214
Central & Northern Balkans (Romania, Bulgaria, Serbia)	Mw ≥ 6.8	1650	364
	Mw ≥ 5.8	1850	164
UK	Mw ≥ 5.8	1500	514
	ML ≥ 4.5	1720	294
	ML ≥ 4.0	1830	184

Papanikolaou et al. (2015) Geomorphology

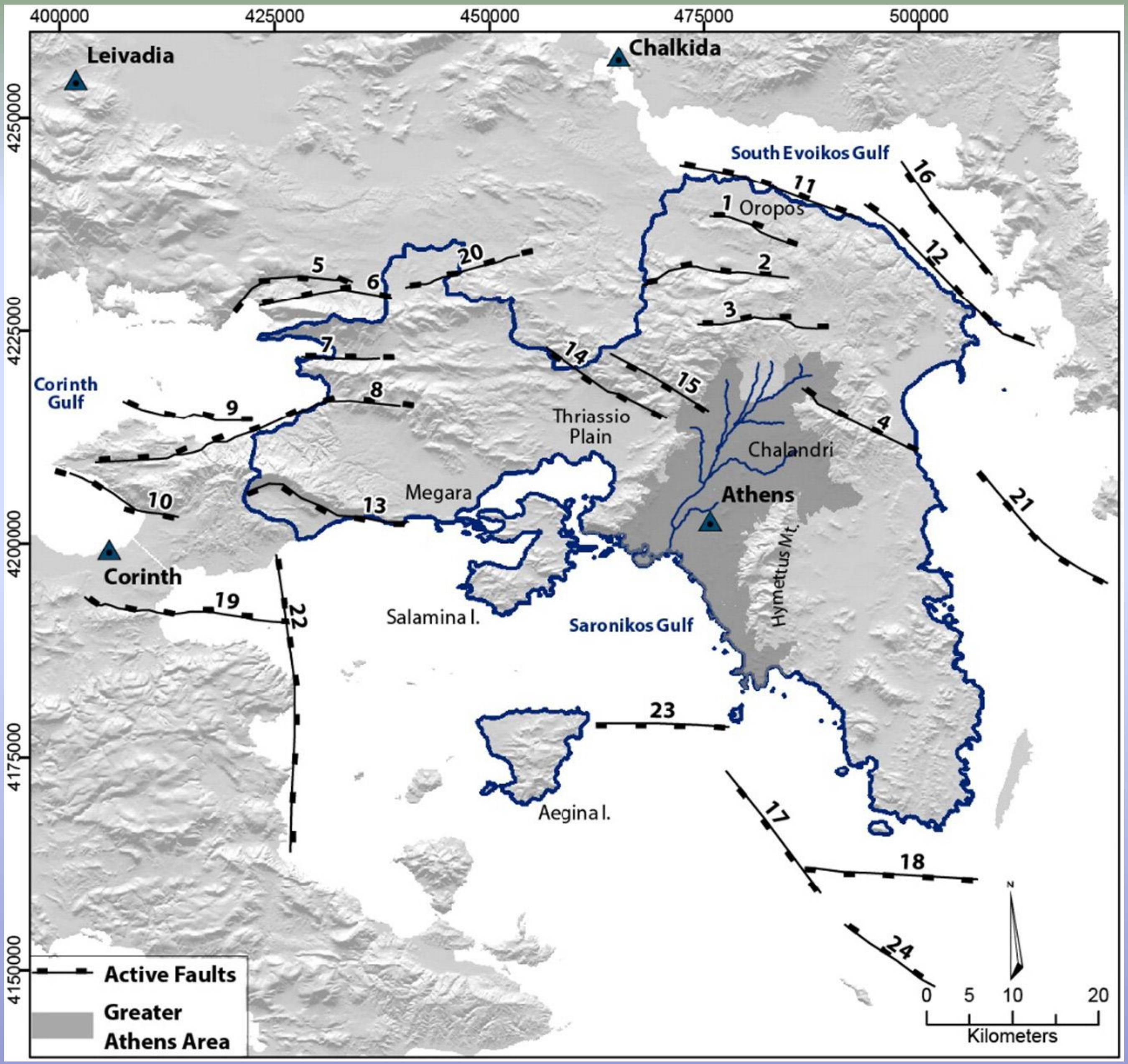
ΠΙΝΑΚΑΣ ΠΛΗΡΟΤΗΤΑΣ ΙΣΤΟΡΙΚΩΝ ΔΕΔΟΜΕΝΩΝ ΓΙΑ ΔΙΑΦΟΡΕΣ ΧΩΡΕΣ

Classification of tectonic earthquakes and recurrence intervals of faults

Type	Slip-rate in mm/yr	Recurrence time in years
I. Interplate	ν > 10	~ 100
II. Intraplate, plate boundary related	0.1≤ν ≤10	100 - 10000
III. Intraplate, midplate	ν < 0.1	> 10000

Scholz (2002)

Historic earthquake catalogues are generally too short compared to the recurrence intervals of particular faults. Therefore, the sample from the historical record is clearly incomplete and a large number of faults would not have been ruptured during the completeness period of the historical record



24 ενεργά ρήγματα στην ευρύτερη περιοχή της Αττικής

4 έχουν ενεργοποιηθεί

ενώ άλλοι 5 σεισμοί δεν μπορούν να ταυτιστούν με ρήγματα

Deligiannakis et al. 2018 Geomorphology

ELSEVIER

Marine Geology

Volume 407, January 2019, Pages 94-110

Active tectonics and seismic hazard in Skyros Basin, North Aegean Sea, Greece

D. Papanikolaou [a], P. Nomikou [a], I. Papanikolaou [b], D. Lampridou [a], G. Rousakis [c], M. Alexandri [c]

Show more

https://doi.org/10.1016/j.margeo.2018.10.001

Highlights

- New bathymetric and seismic data in Skyros Basin, North Aegean Sea
- Oblique opening of the Skyros Basin similar to the North Aegean Basin
- 19 major active faults that can generate M > 6.0 have been mapped for the first time.
- Seismic hazard underestimated, only 3 active faults within the seismic catalogues
- Subsidence of the North Aegean Sea is accelerated since Middle Pleistocene.

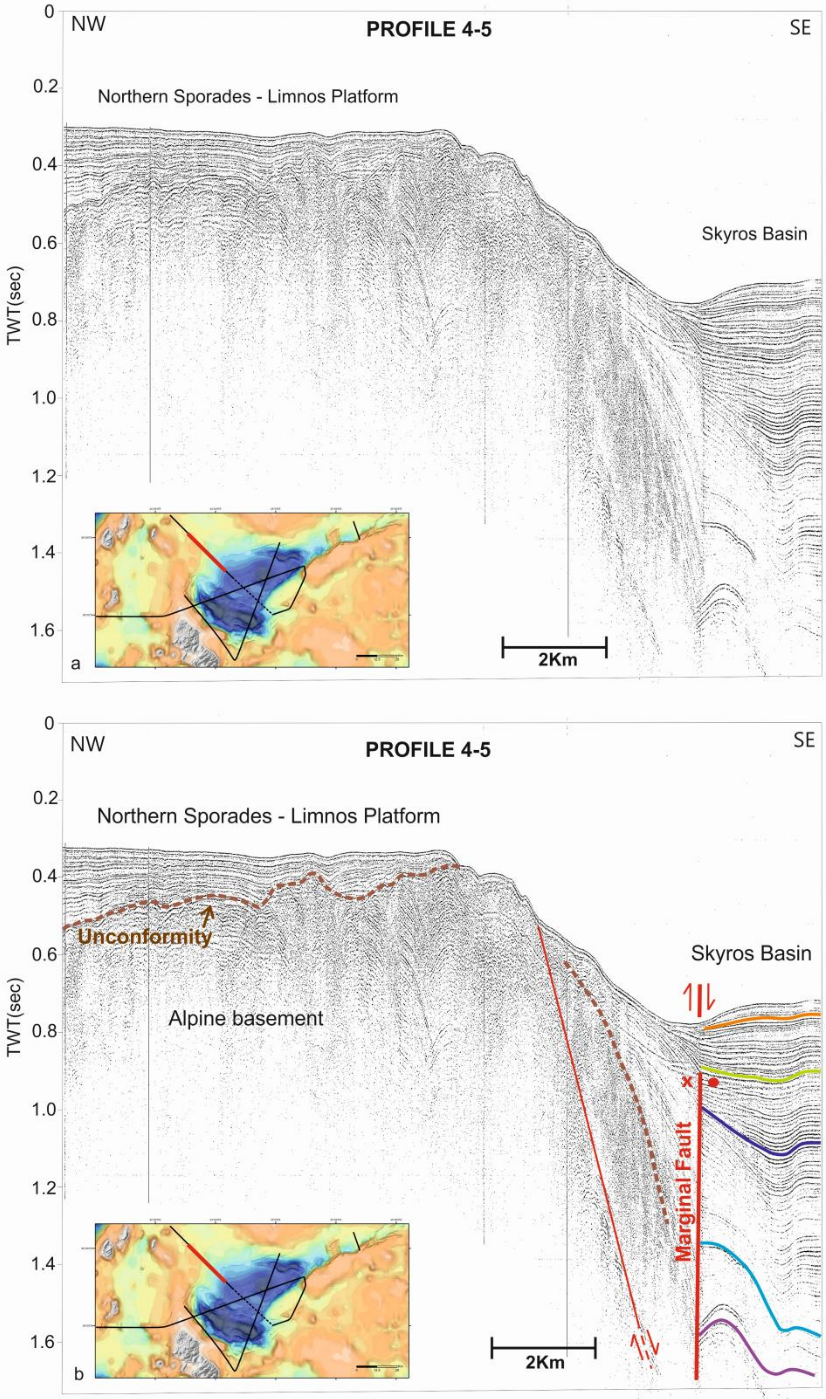


Figure 4

Papanikolaou et al. 2019 Marine Geology

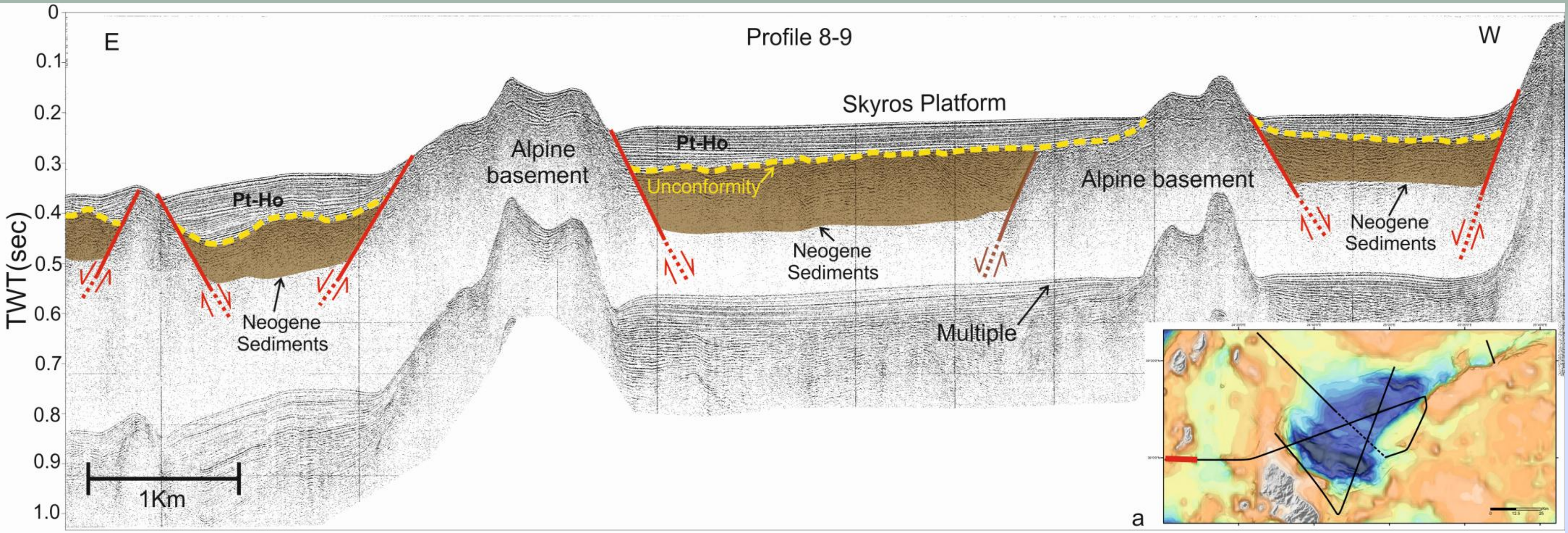


Figure 8

Papanikolaou et al. 2019 Marine Geology

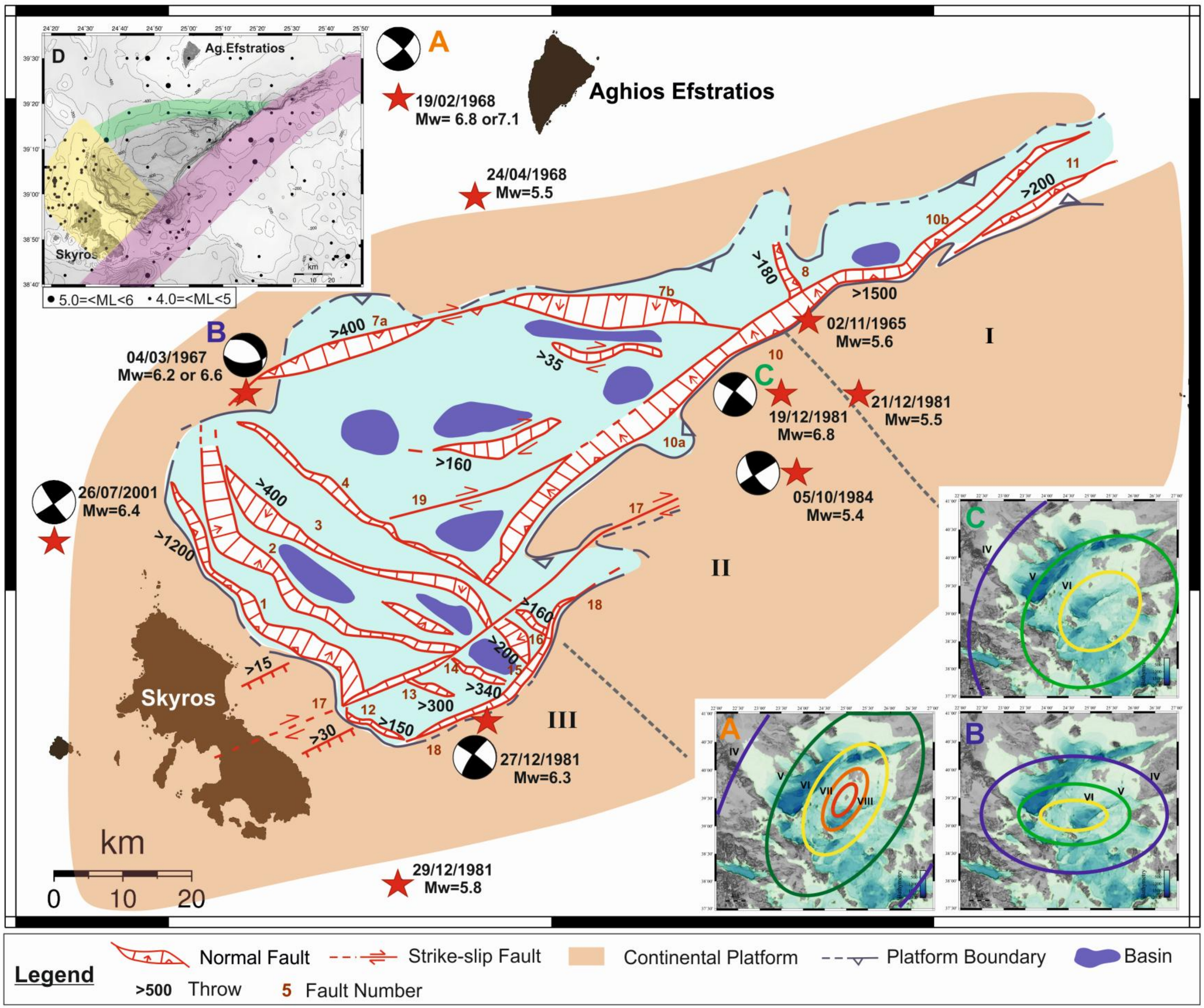


Figure 11

Papanikolaou et al. 2019 Marine Geology

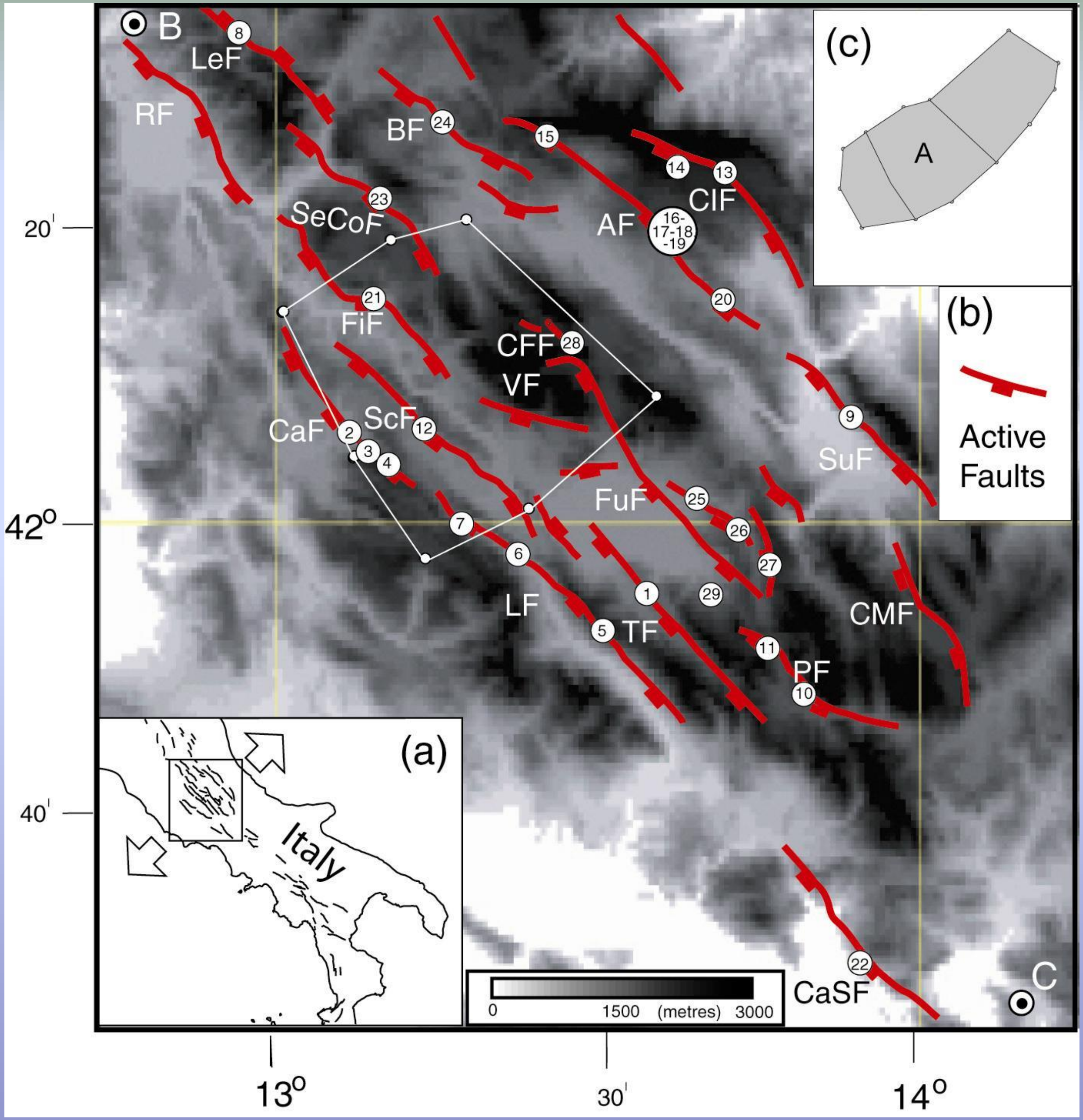
Table 1
Active faults and their seismic potential in Skyros Basin.

Fault no	Length (km)	Strike	SS (Mw) WC	SS (Mw) Wen	NS (Mw) WC	NS (Mw) PC
1	43.5	NW-SE	7.00	6.99	7.02	6.95
2	46.7	NW-SE	7.03	7.01	7.06	6.98
3	45.7	NW-SE	7.02	7.00	7.05	6.97
4	44.5	NW-SE	7.01	6.99	7.04	6.96
5	20.3	WSW-ENE	6.62	6.70	6.59	6.66
6	17.0	E-W	6.54	6.63	6.48	6.59
7	71.0	E-W	7.23	7.17	–	–
7a	31.5	ENE-WSW	6.84	6.86	6.84	6.83
7b	39.5	ESE-WNW	6.95	6.95	6.97	6.92
8	7.8	NNW-SSE	6.16	–	6.04	6.28
9	12.2	NW-SE	6.38	–	6.29	6.46
10	111.2	ENE-WSW	7.45	7.34	–	–
10a	66.4	ENE-WSW	7.20	7.15	–	–
10b	44.8	NE-SW	7.01	7.00	–	–
11	17.7	ENE-WSW	6.56	6.65	6.51	6.60
12	11.4	NW-SE	6.34	6.48	6.26	6.43
13	8.0	NW-SE	6.17	–	6.05	6.29
14	9.1	NW-SE	6.23	–	6.13	6.34
15	8.4	NNW-SSE	6.20	–	6.08	6.31
16	6.5	NW-SE	6.07	–	5.93	6.21
17	48.0	ENE-WSW	7.04	7.02	–	–
18	43.5	ENE-WSW	7.00	6.99	–	–
19	38.8	WSW-ENE	6.94	6.94	–	–

Notes: SS: predominant strike slip rupture, NS: predominant normal slip rupture, WC: Wells and Coppersmith (1994), Wen: Wesnousky (2008) (only for ruptures > 15 km). PC: Pavlides and Caputo (2004).

- we mapped for the first time 19 active faults that can generate earthquakes stronger than M=6.0 (8 of them M>7.0).
- Only 3 of these faults have been ruptured and recorded in the earthquake historical records.
- As a result, seismic hazard is severely underestimated since 16 of the 19 seismic sources were unknown!

Papanikolaou et al. 2019 Marine Geology

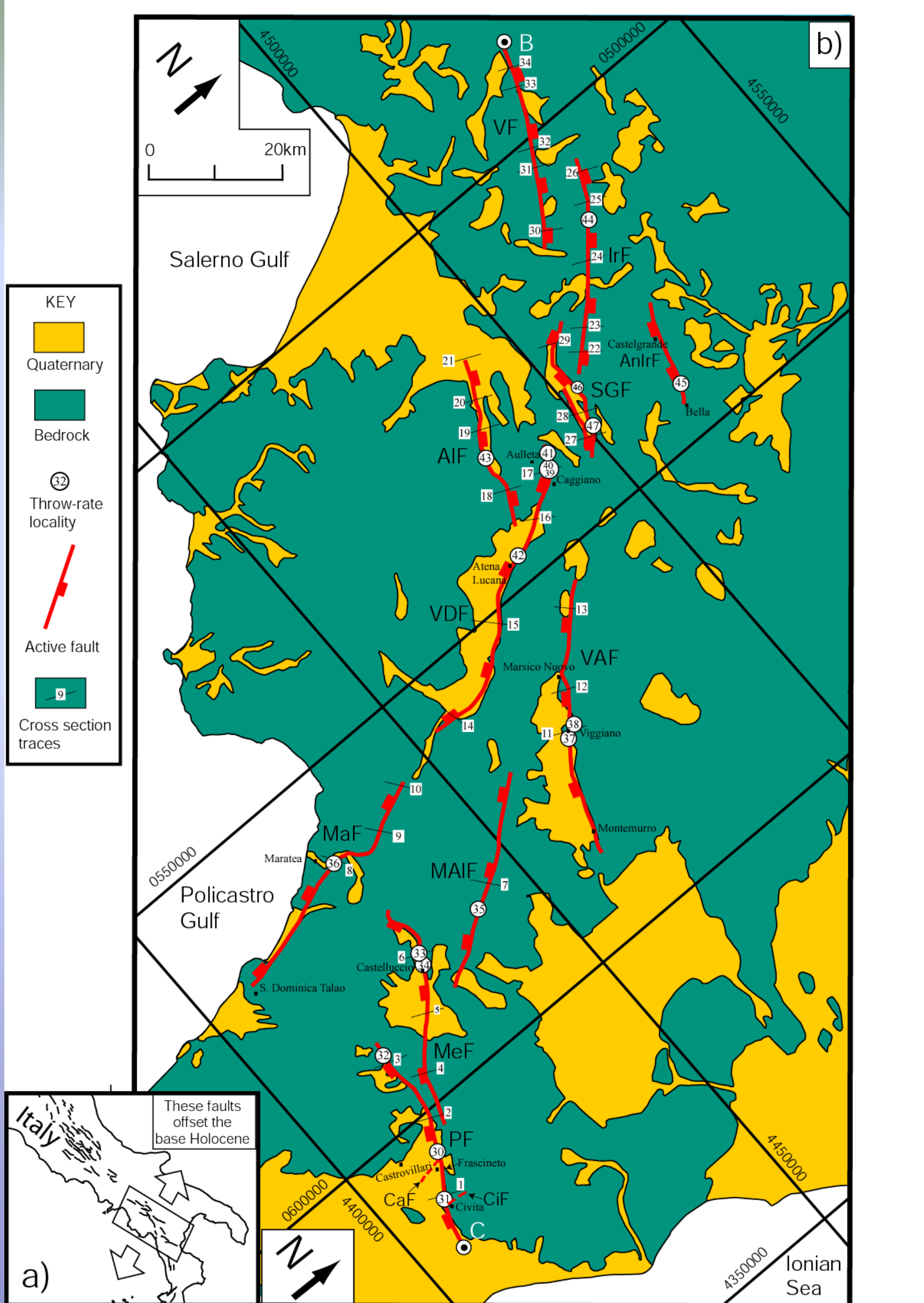


Κεντρικά Απέννινα

17 Ενεργά ρήγματα

3 ρήγματα ενεργοποιήθηκαν σε ιστορικούς σεισμούς και άλλοι 5 μεγάλοι ιστορικά καταγεγραμμένοι σεισμοί δεν έχουν ταυτοποιηθεί

Papanikolaou et al. (2005) Tectonophysics



Νότια Απέννινα

10 Ενεργά ρήγματα

4 ρήγματα ενεργοποιήθηκαν σε ιστορικούς σεισμούς

Papanikolaou and Roberts (2017) Journal of Structural Geology

Οι ενόργανοι αλλά και οι ιστορικοί κατάλογοι σεισμικότητας είναι ανεπαρκείς για μια πλήρη και αξιόπιστη απεικόνιση της χωρικής αλλά και χρονικής κατανομής των σεισμών.

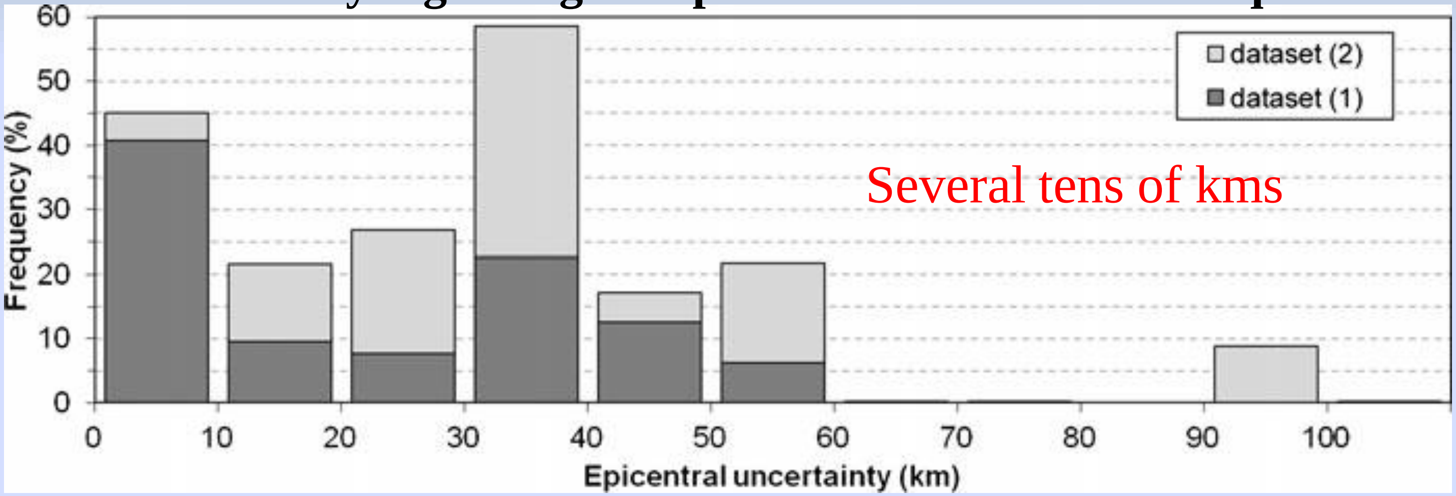
Με λίγα λόγια οι κατάλογοι δεν είναι πλήρεις γιατί

καλύπτουν ένα μικρό χρονικό διάστημα σε σχέση με το χρόνο επανάληψης των σεισμών στην μεγάλη πλειοψηφία των ρηγμάτων

Χαρακτηρίζονται από μεγάλες αβεβαιότητες σχετικά με τα επίκεντρα αλλά και τα μεγέθη ιστορικών σεισμών

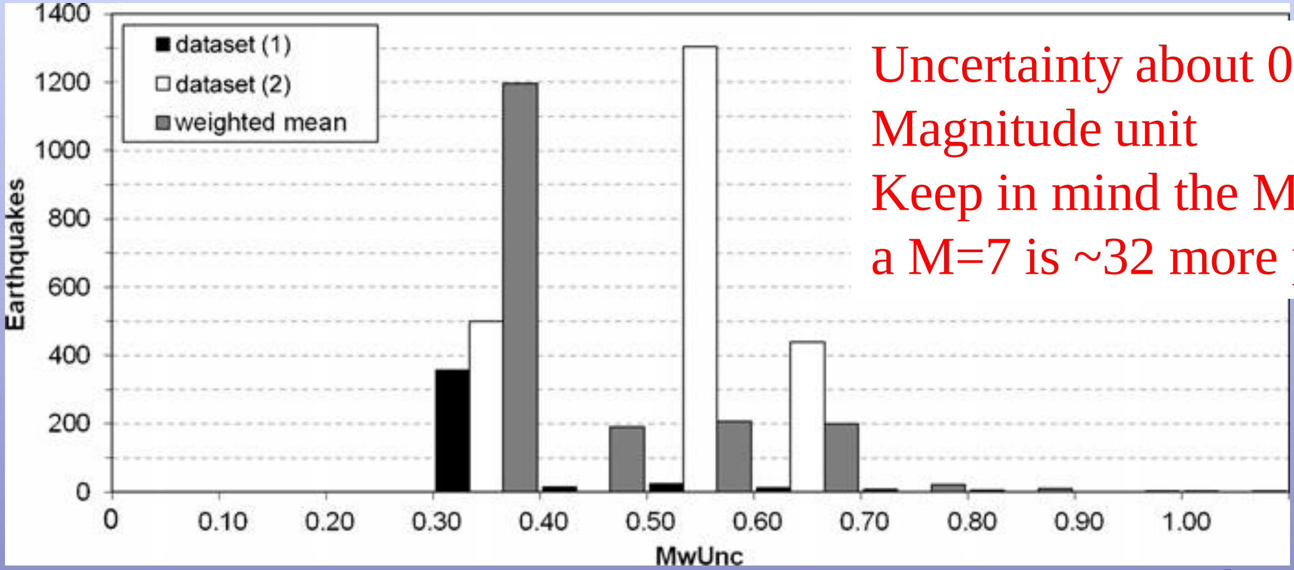
European Seismic Historical Catalogue 1000–1899 & implied uncertainties

Uncertainty regarding the epicenter of historical earthquakes



Several tens of kms

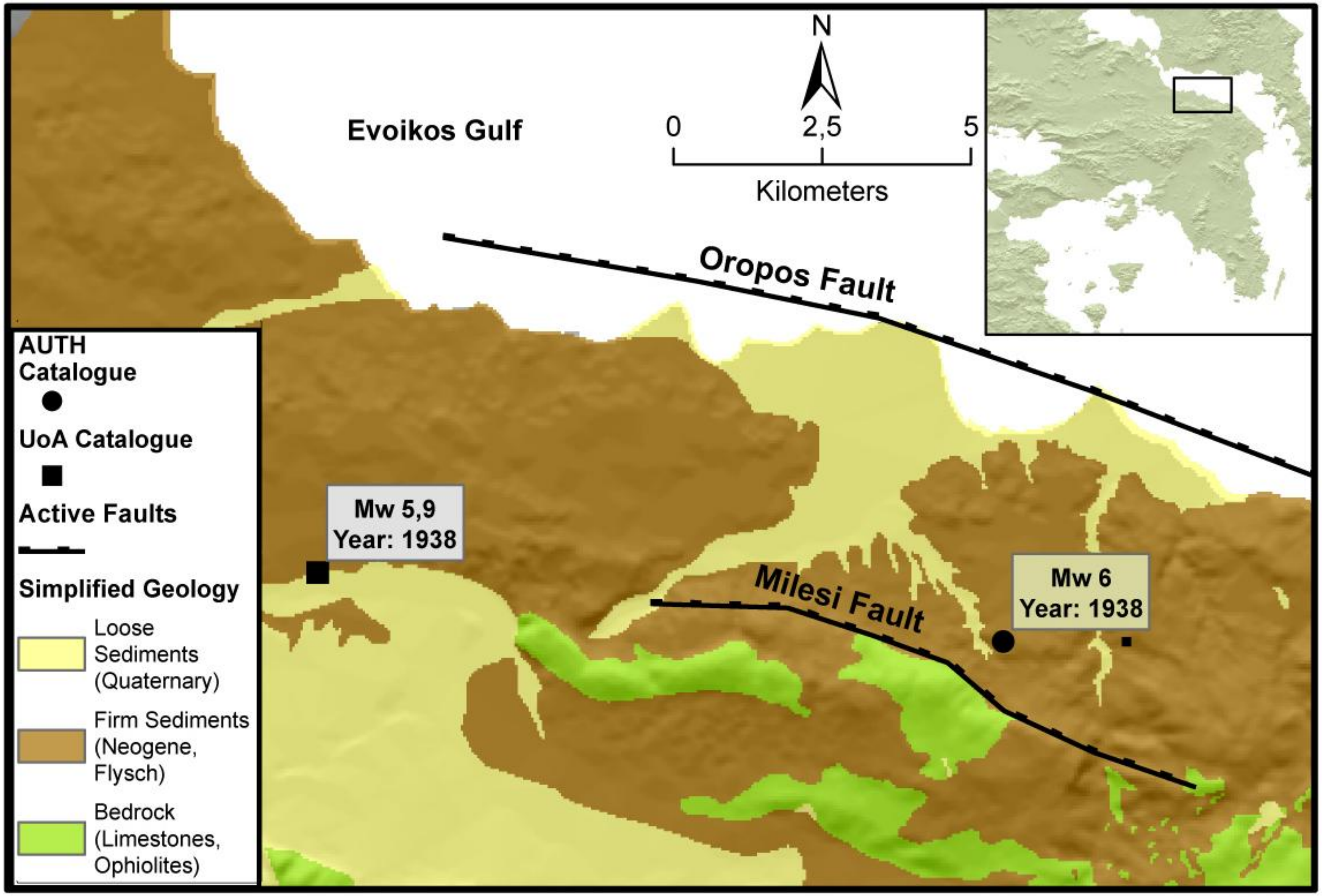
Uncertainty regarding the estimated Magnitude Mw of historical events



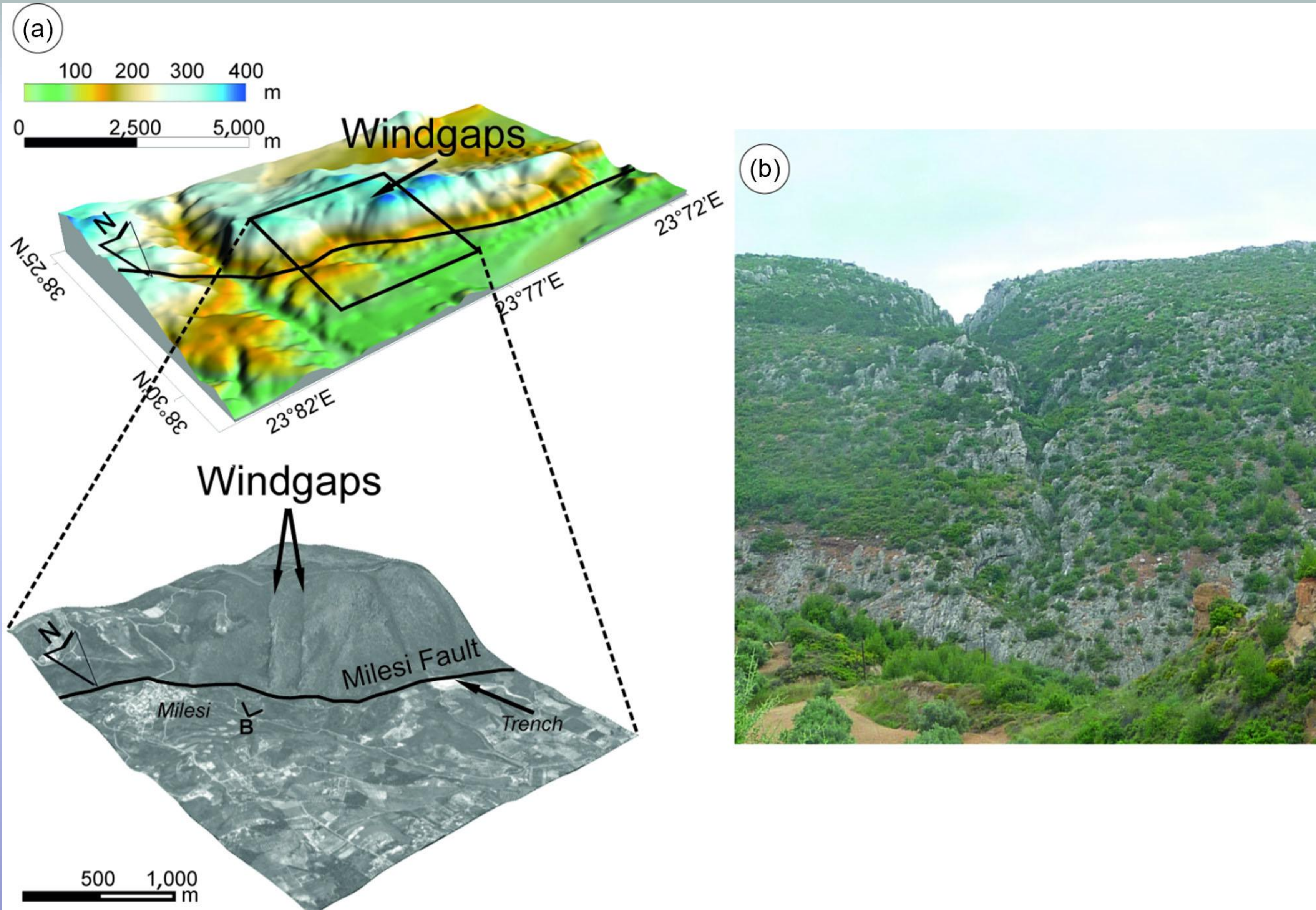
Uncertainty about 0.5 ± 0.2 of a Magnitude unit

Keep in mind the Mw scale Is logarithmic a M=7 is ~32 more powerful than a M=6

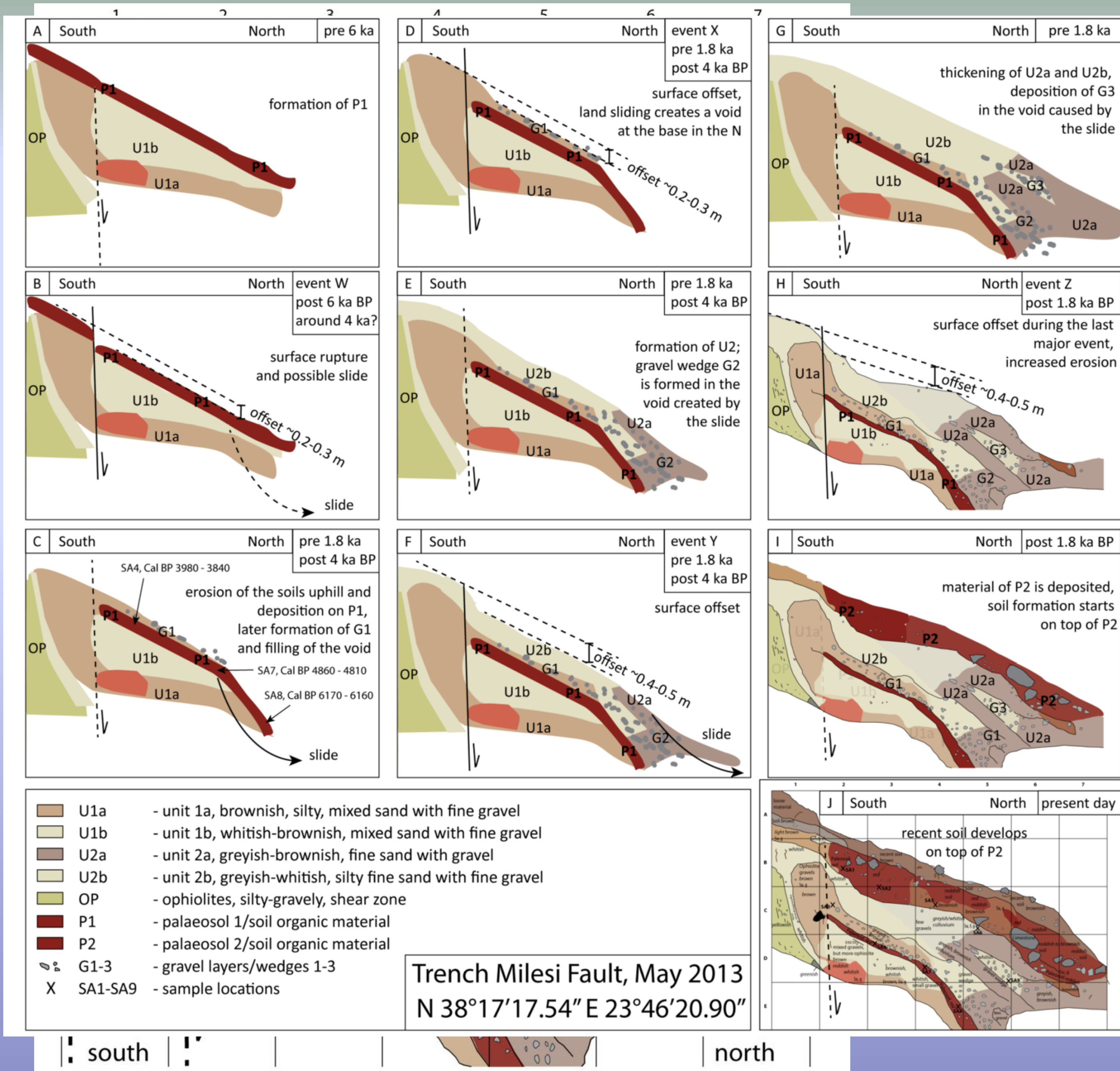
Stucchi et al. 2013 J. Seismology



Papanikolaou et al. (2015) Geomorphology



Grutzner et al.2016 Geophysical Journal International

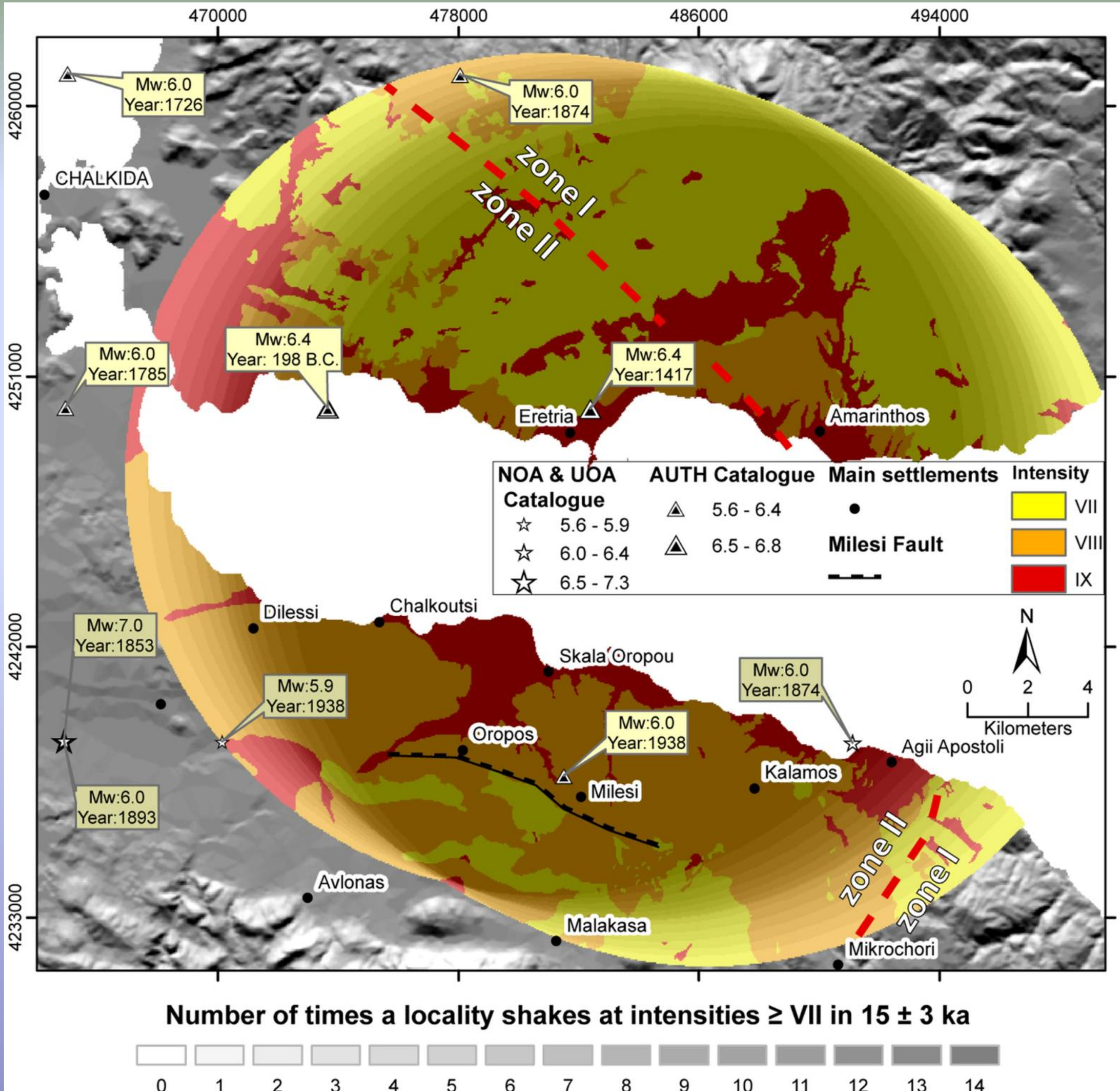


Τέσσερις παλαιοσεισμοί τα τελευταία 6 χιλιάδες χρόνια

Ρυθμός ολίσθησης 0.3mm/yr

Ο σεισμός του 1938 δεν ενεργοποίησε το Ρήγμα του Μηλεσίου

Grutzner et al.2016 Geophysical Journal International



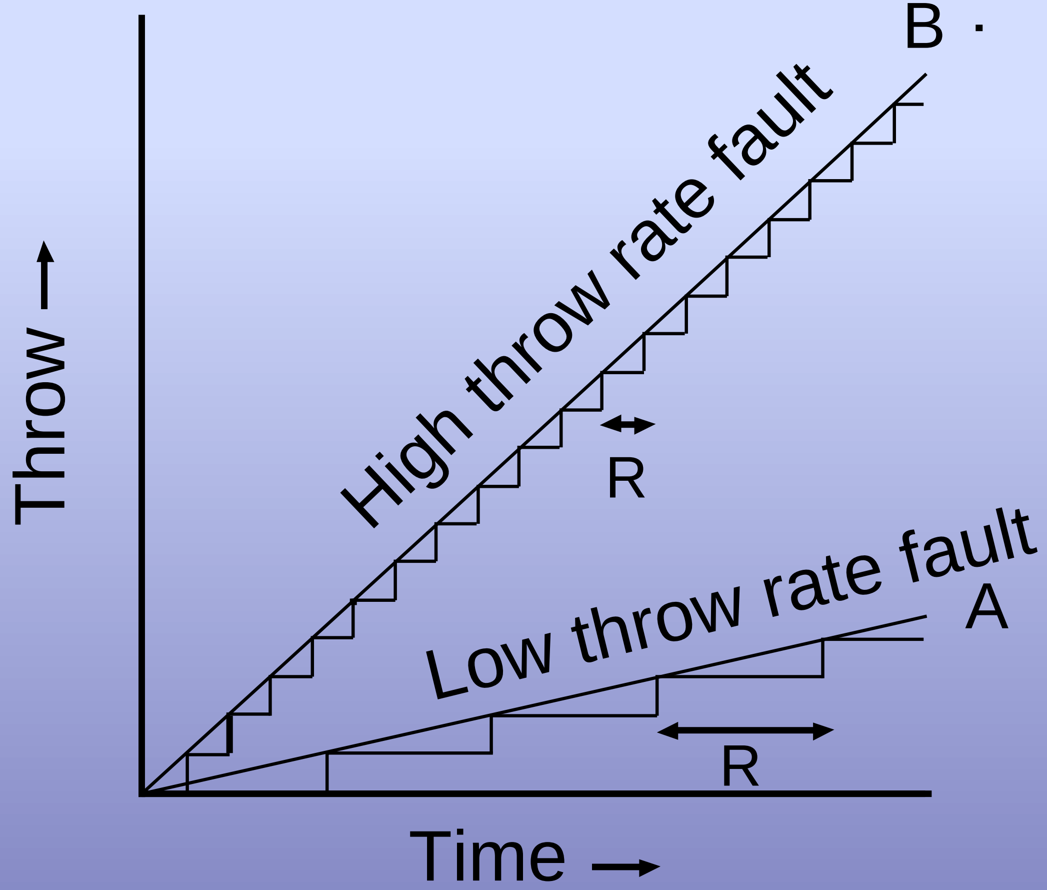
Ρυθμός Επανάληψης M~6.2
1000-1500 χρόνια

Δεν υπάρχει διαφοροποίηση μεταξύ Αμαρυνθου και Ερέτριας ως προς τον σεισμικό κίνδυνο παρ΄ όλα αυτά ανήκουν σε διαφορετικές ζώνες με βάση των ΕΑΚ

Grutzner et al.2016 Geophysical Journal International

Slip-rates and Recurrence Intervals
Ρυθμοί Ολίσθησης και Επαναληψιμότητα

1mm/yr είναι ρυθμός ολίσθησης ενός ρήγματος που προκάλεσε ολίσθηση 1m σε χρονικό διάστημα 1000 ετών



Slip-rates

Ρυθμοί Ολίσθησης

Aver. Recurrence Intervals

Μέσοι Ρυθμοί Επαναδραστηριοποίησης

LiDAR

Create a DEM and high- spatial resolution maps,

Visualize bare earth by extracting vegetation with filters

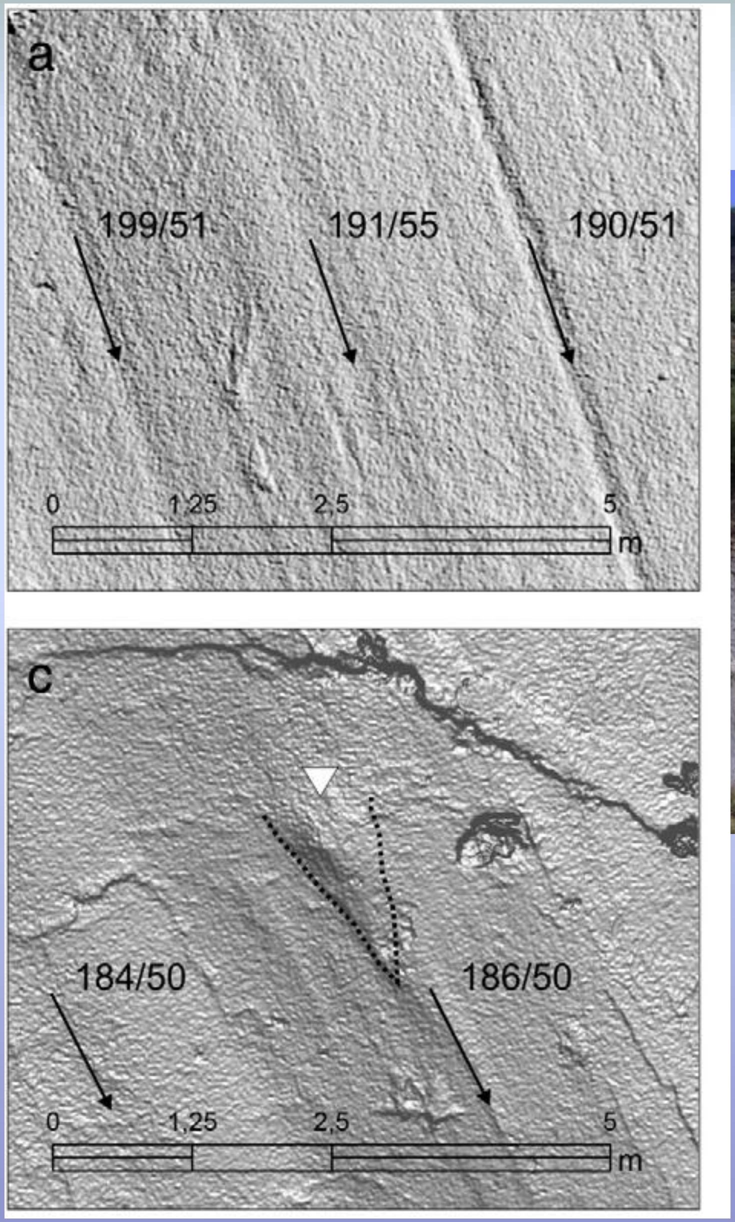
Measuring tectonic features (e.g. striations, postglacial scarps)

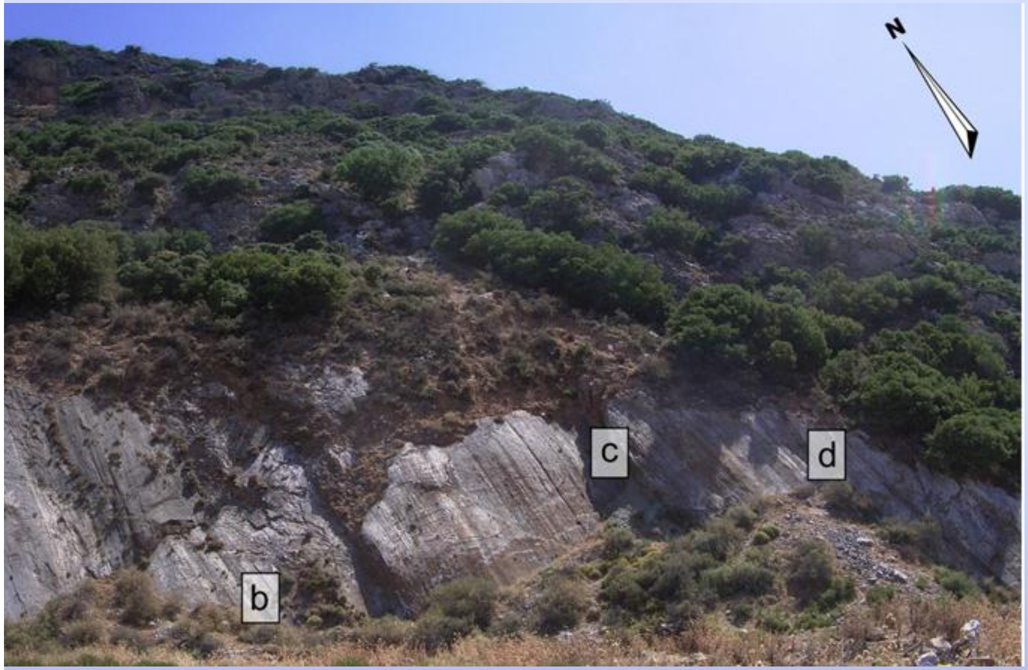
Monitoring (e.g. afterslip, landslides),

Trace paleoshorelines/notches

Roughness analysis on fault planes for searching paleoearthquakes!

LiDAR applications

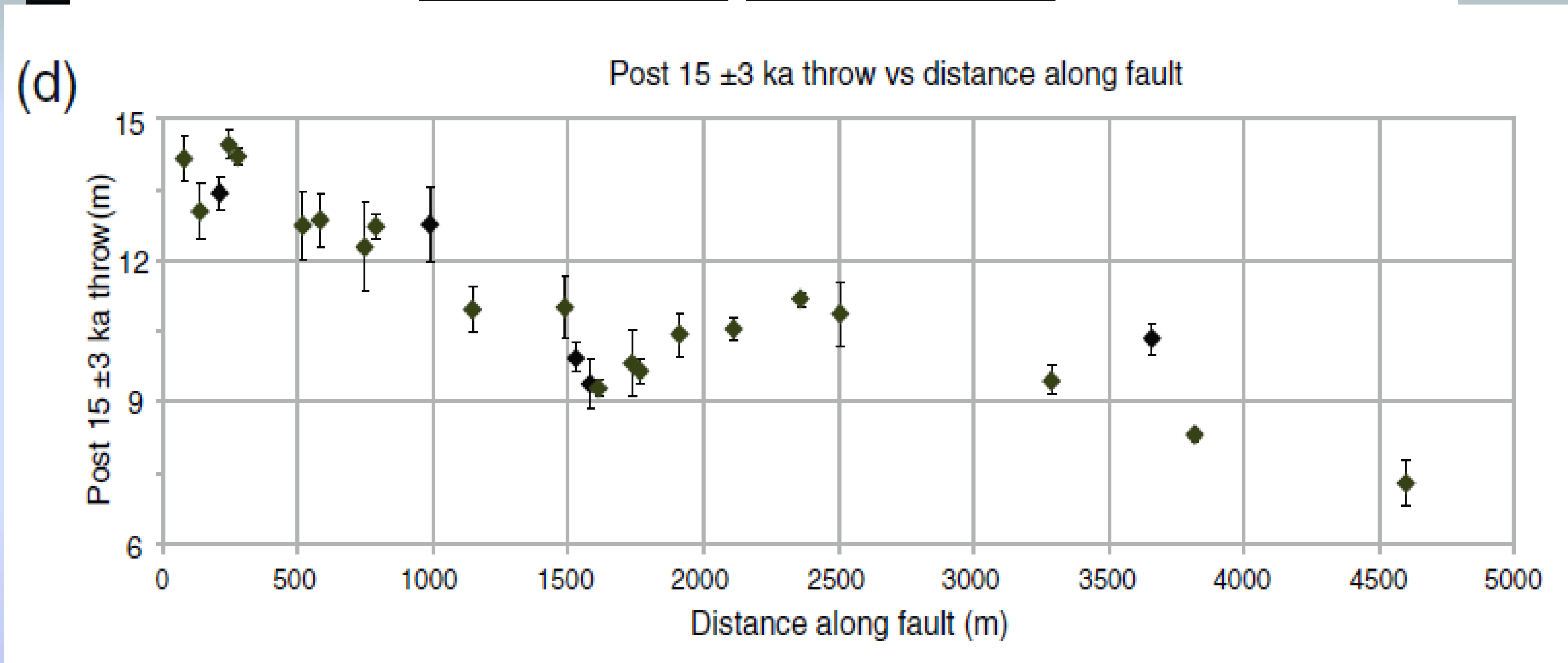




Extracting striations from the fault plane
Spili fault Crete

Wiatr et al. (2013) Tectonophysics

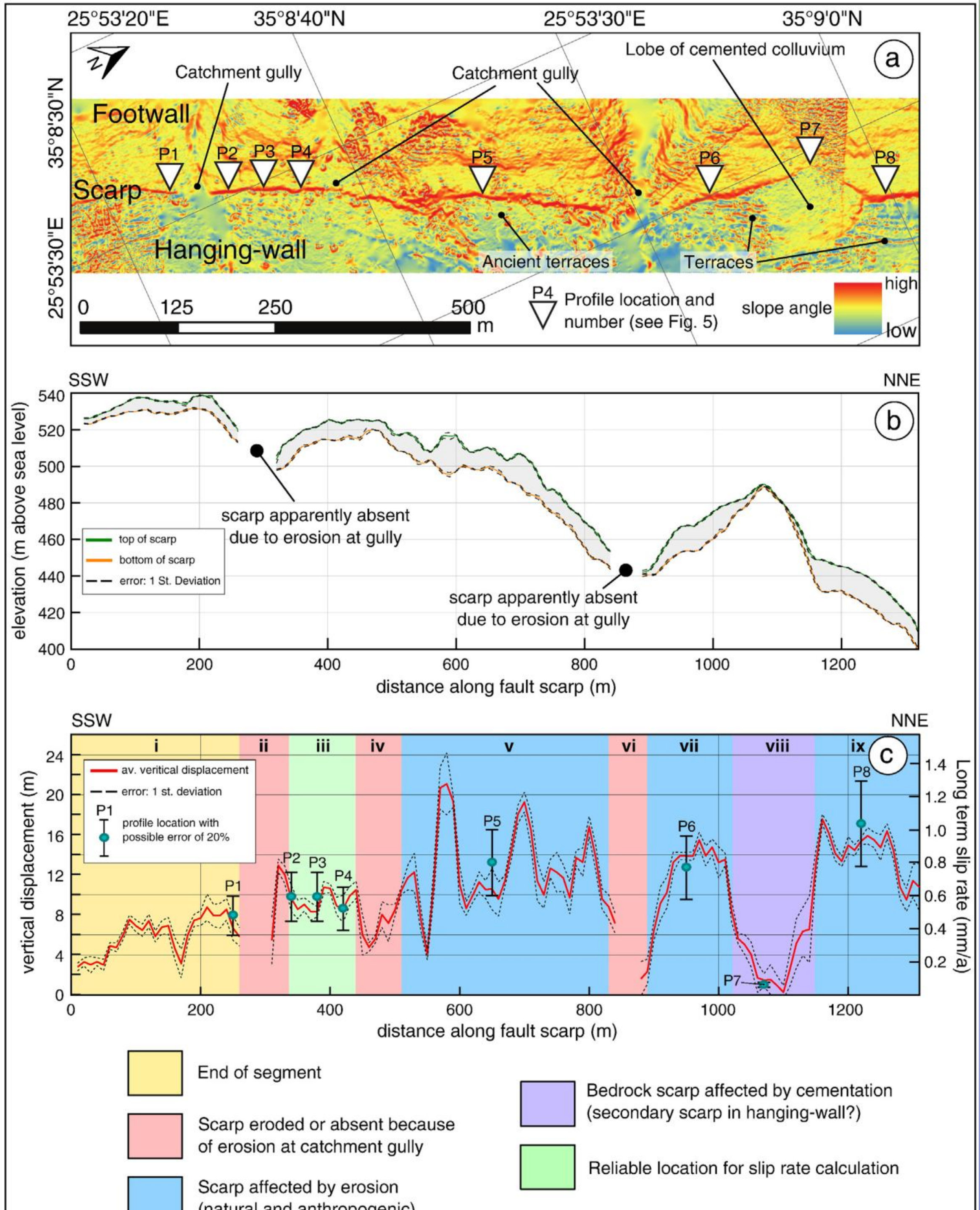
LiDAR applications



Campo Felice fault
Abruzzo

Measuring fault strike, fault dip and the post glacial throw over 5km

Wilkinson et al. 2015 Geomorphology

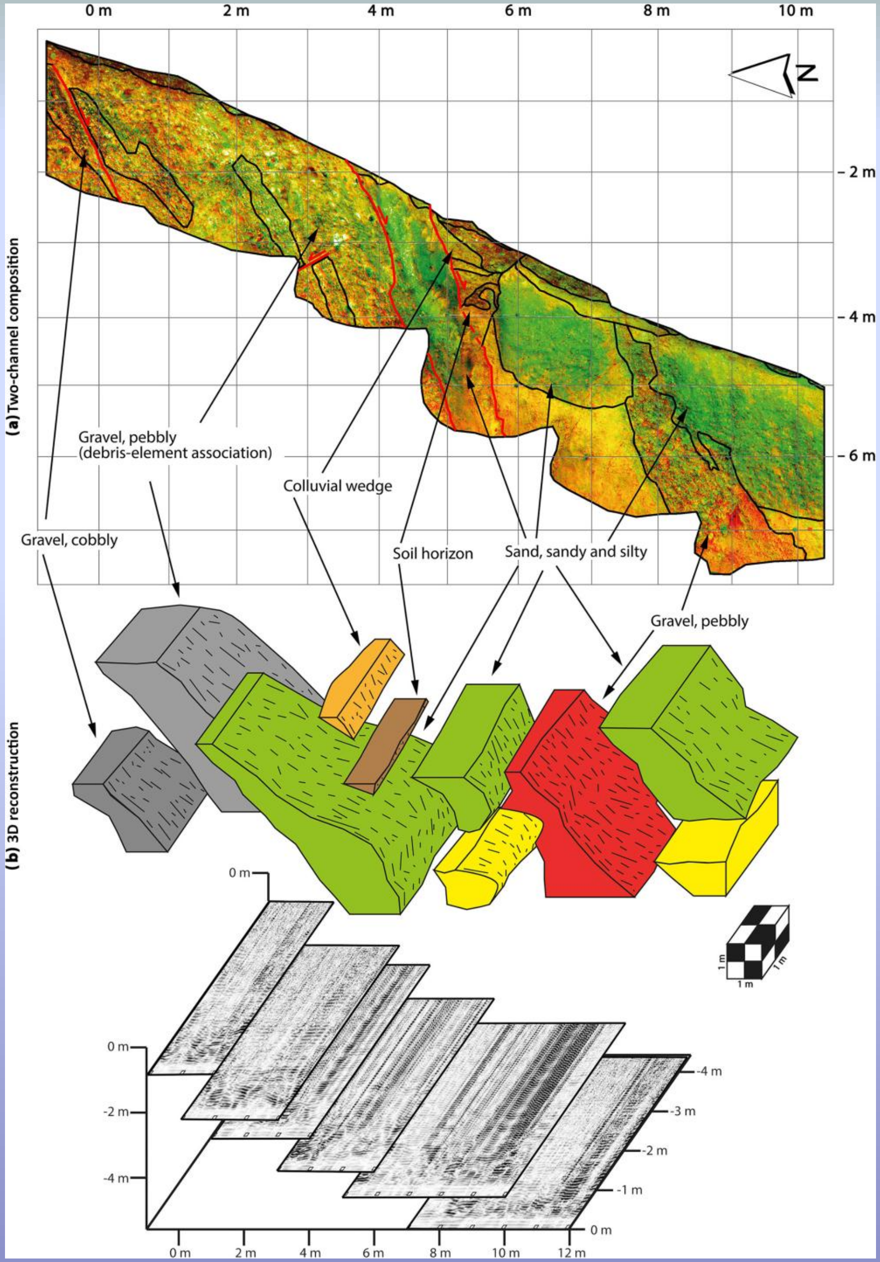


A mean postglacial scarp height of 9.4 m.

A slip rate of
0.69 ± 0.15 mm/yr

Mason et al. (2016) Tectonophysics

LiDAR applications



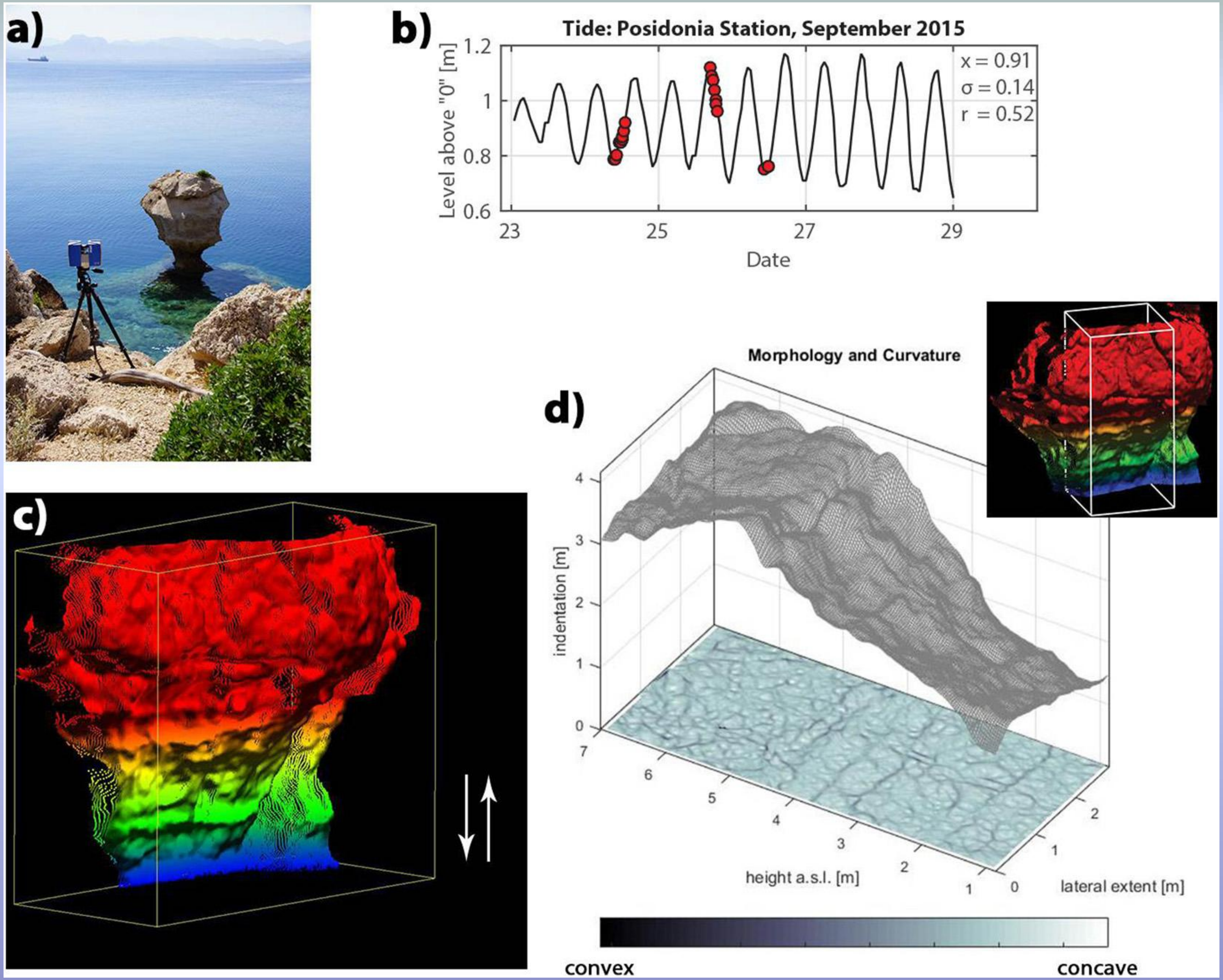
LiDAR multispectral analysis shows that distinct layers can be identified in a trench

Combining LiDAR and GPR for 3-D visualisation of palaeoseismic trench stratigraphy

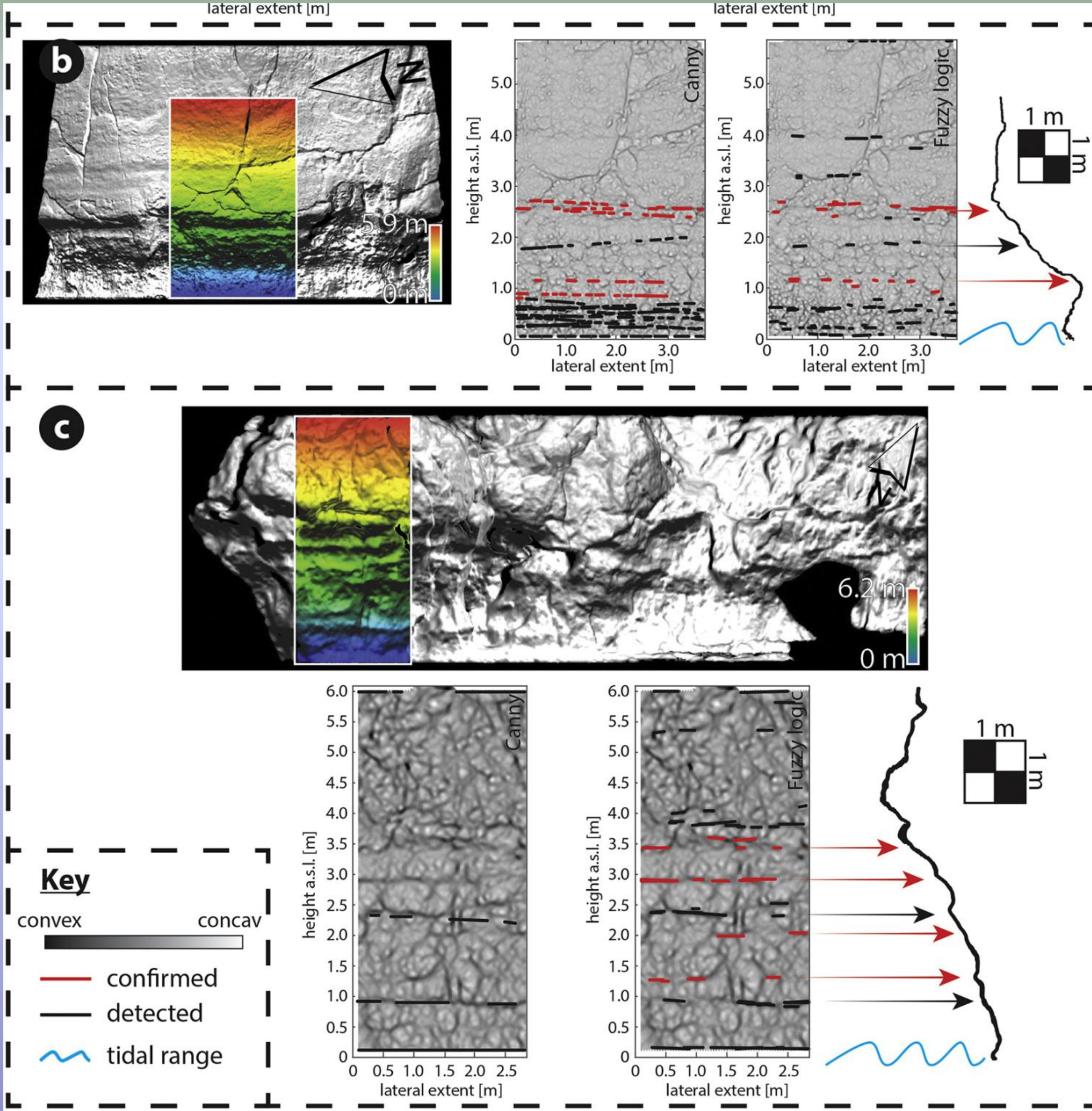
Kapareli Fault Corinth

Schneiderwind et al. 2016 Solid Earth

LiDAR notches



Schneiderwind et al. 2017 Geomorphology



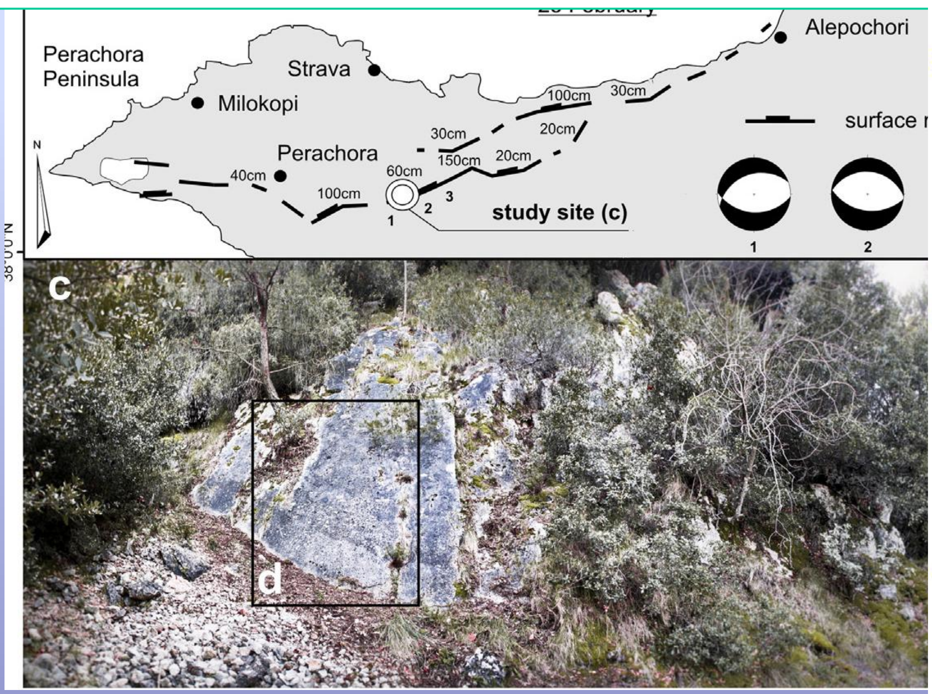
3D TLS offers high-resolution by recognizing undiscovered notches or features corresponding to multiple notches.

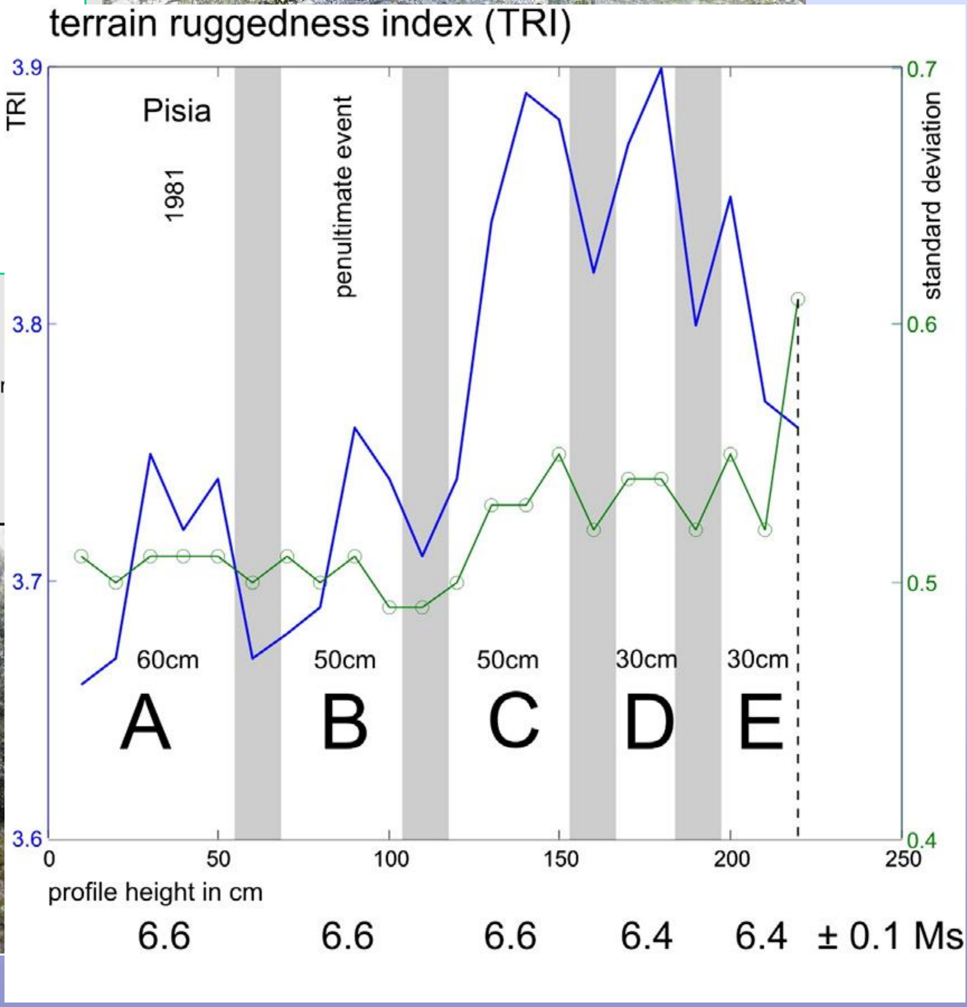
Schneiderwind et al. 2017 Geomorphology

LiDAR applications

t-LiDAR backscatter behaviour and roughness along the fault plane

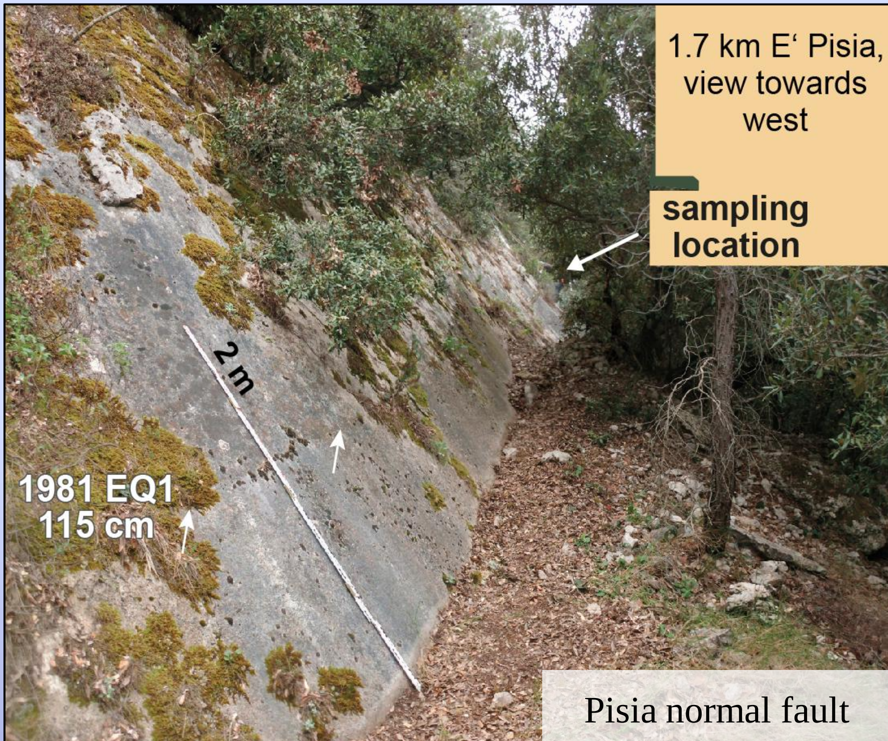
Extraction of paleoevents
Pisia fault Corinth





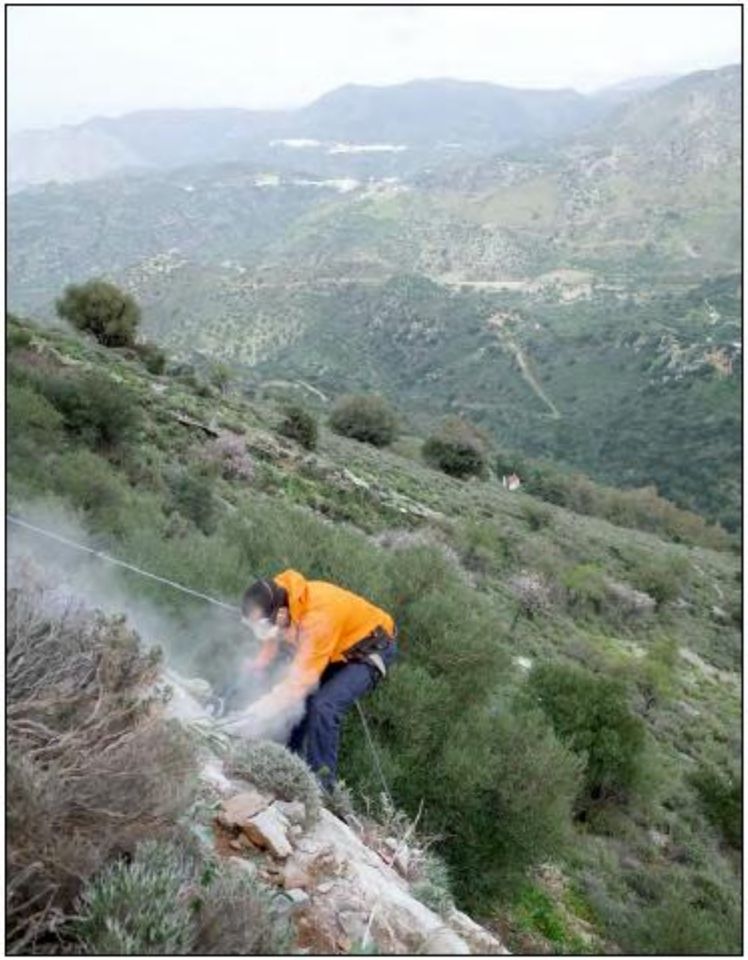
Wiatr et al. 2015 Geomorphology

Bedrock fault scarps

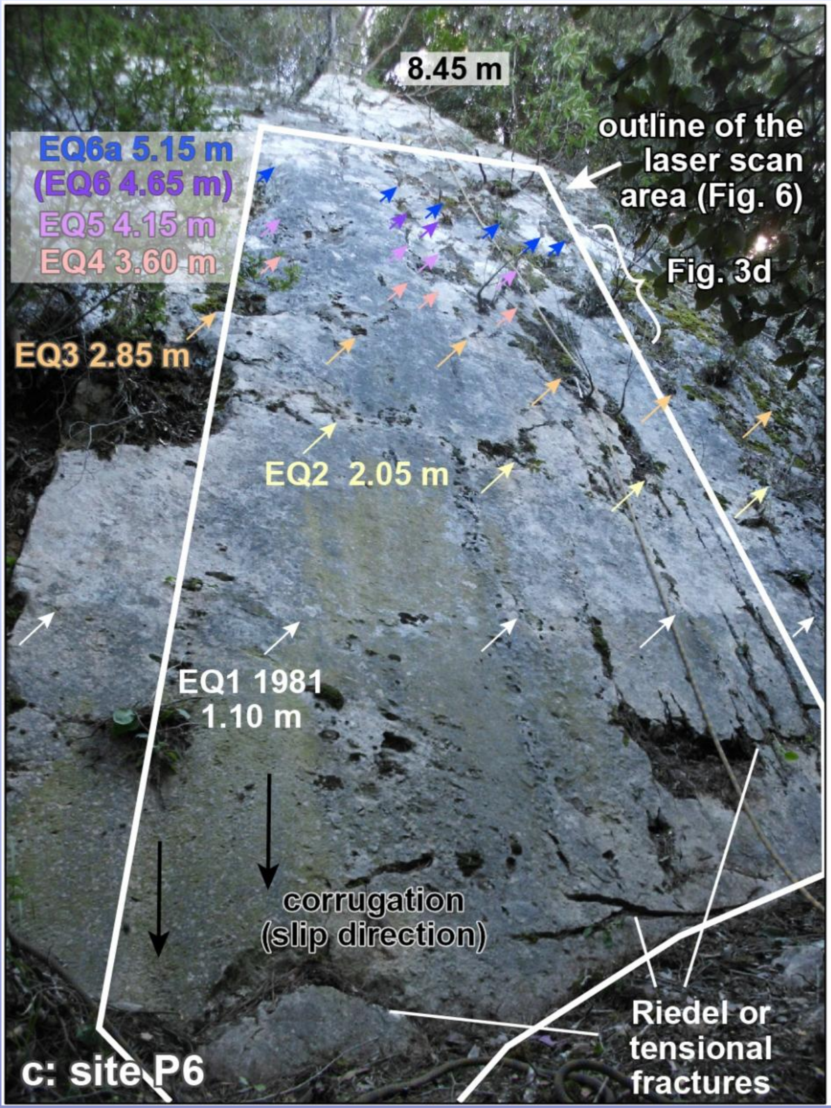


Uplift by cumulative earthquakes

Cosmogenic ^{36}Cl exposure dating

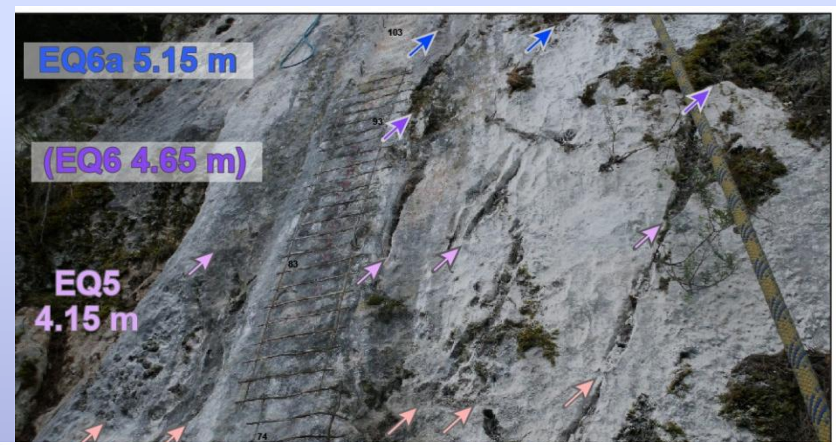


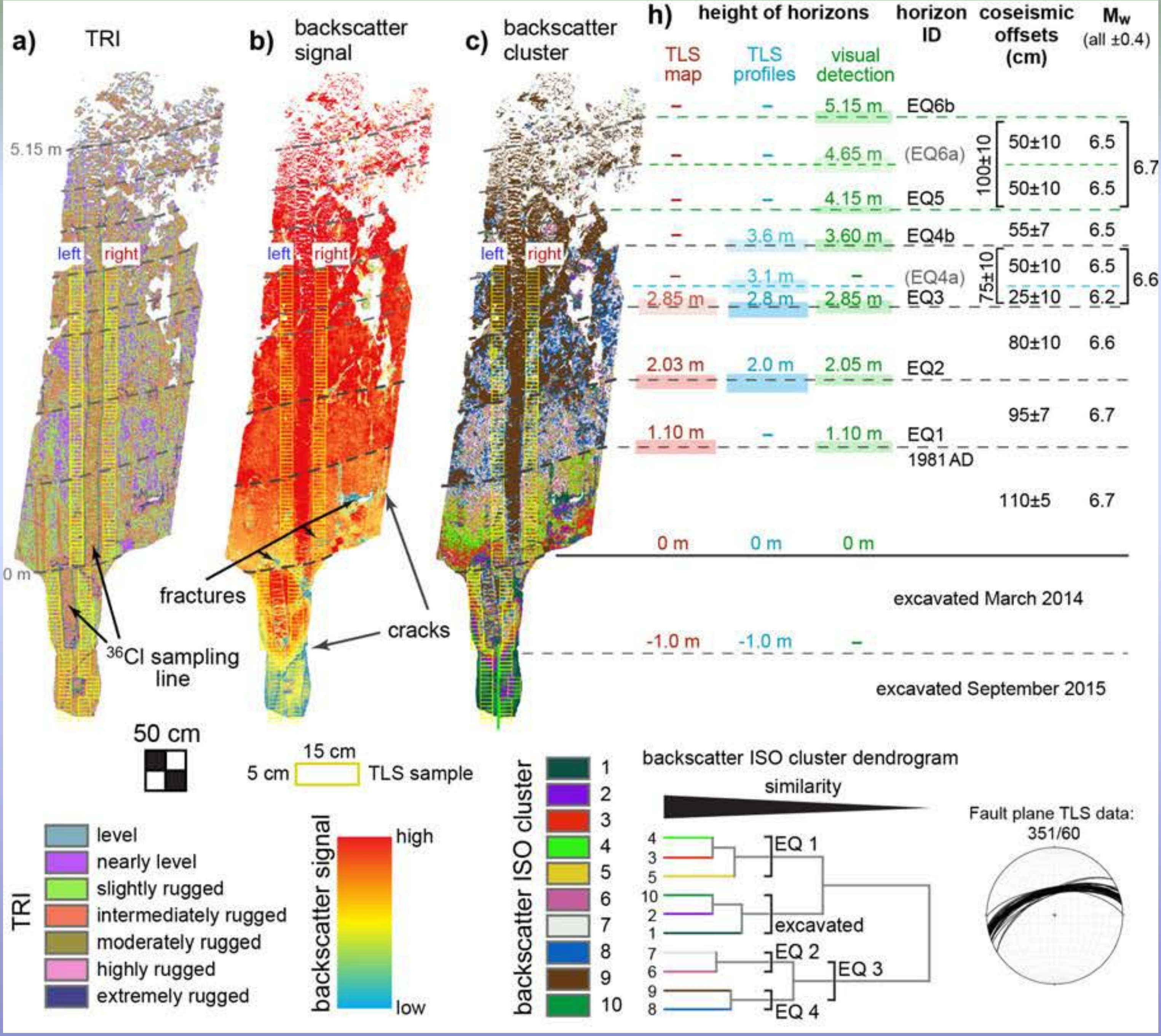
Indicators of past slip events



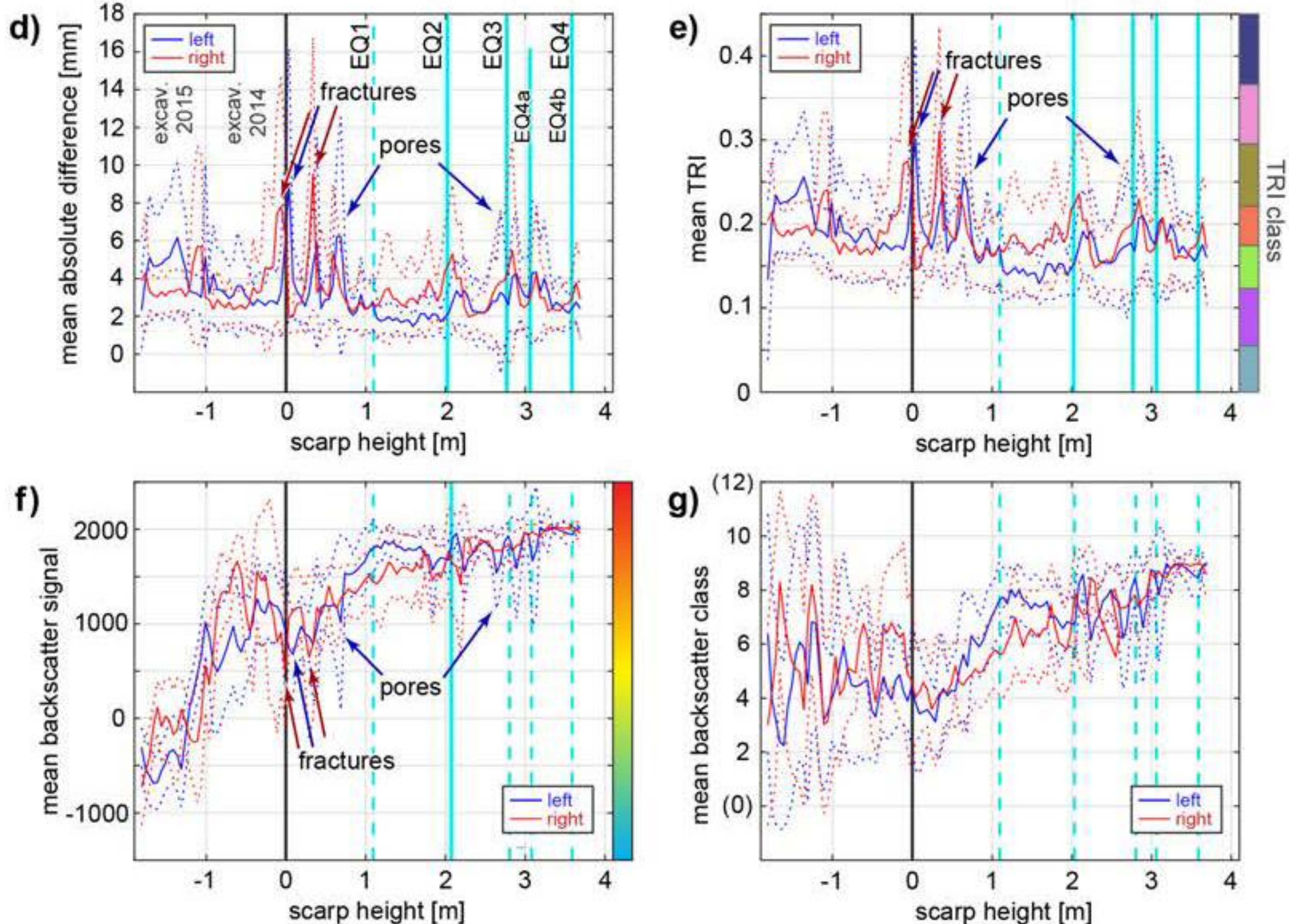
Criteria for earthquake horizons:

- colour contrast
- lichen growth
- pitting areas
- termination of solution flutes



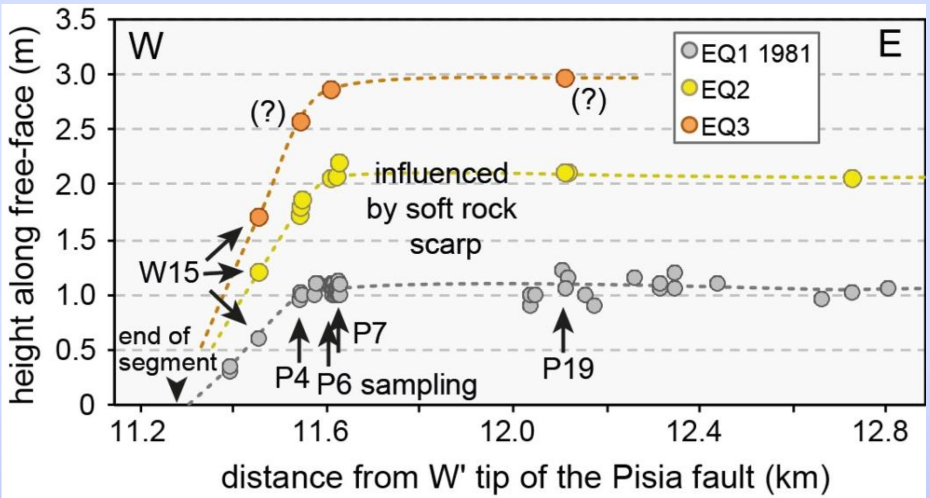


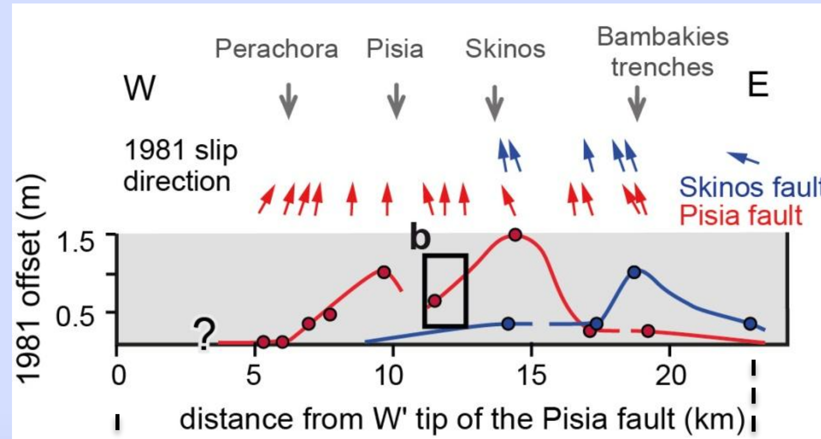
Mechernich et al. 2018 JGR



Mechernich et al. 2018JGR

EQ horizon mapping along strike



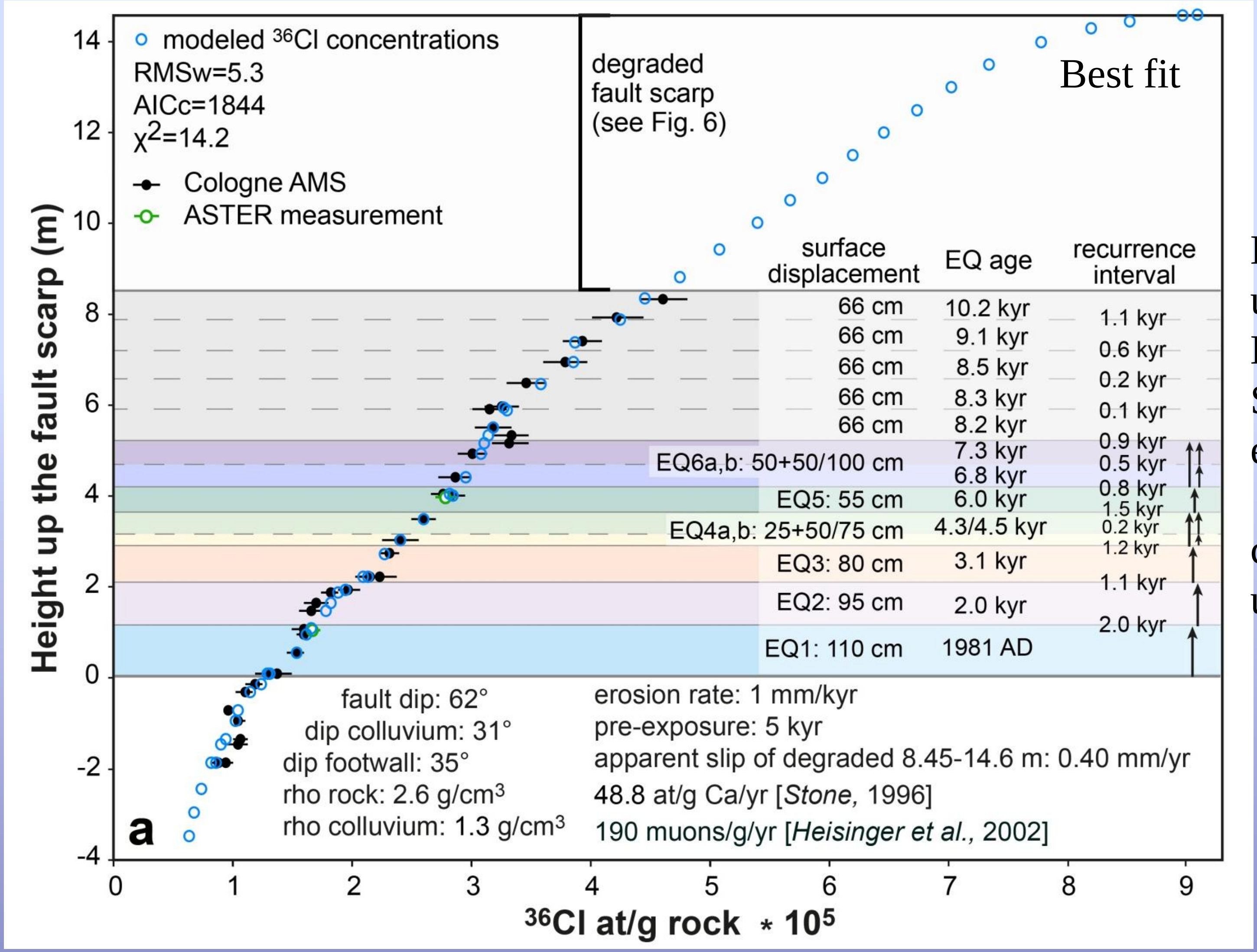


after Jackson et al. (1982)

=> Representative offset along
fault strike
=> More detailed than 1981 mapping
=> Chosen site P6 for dating

Mechernich et al. 2018JGR

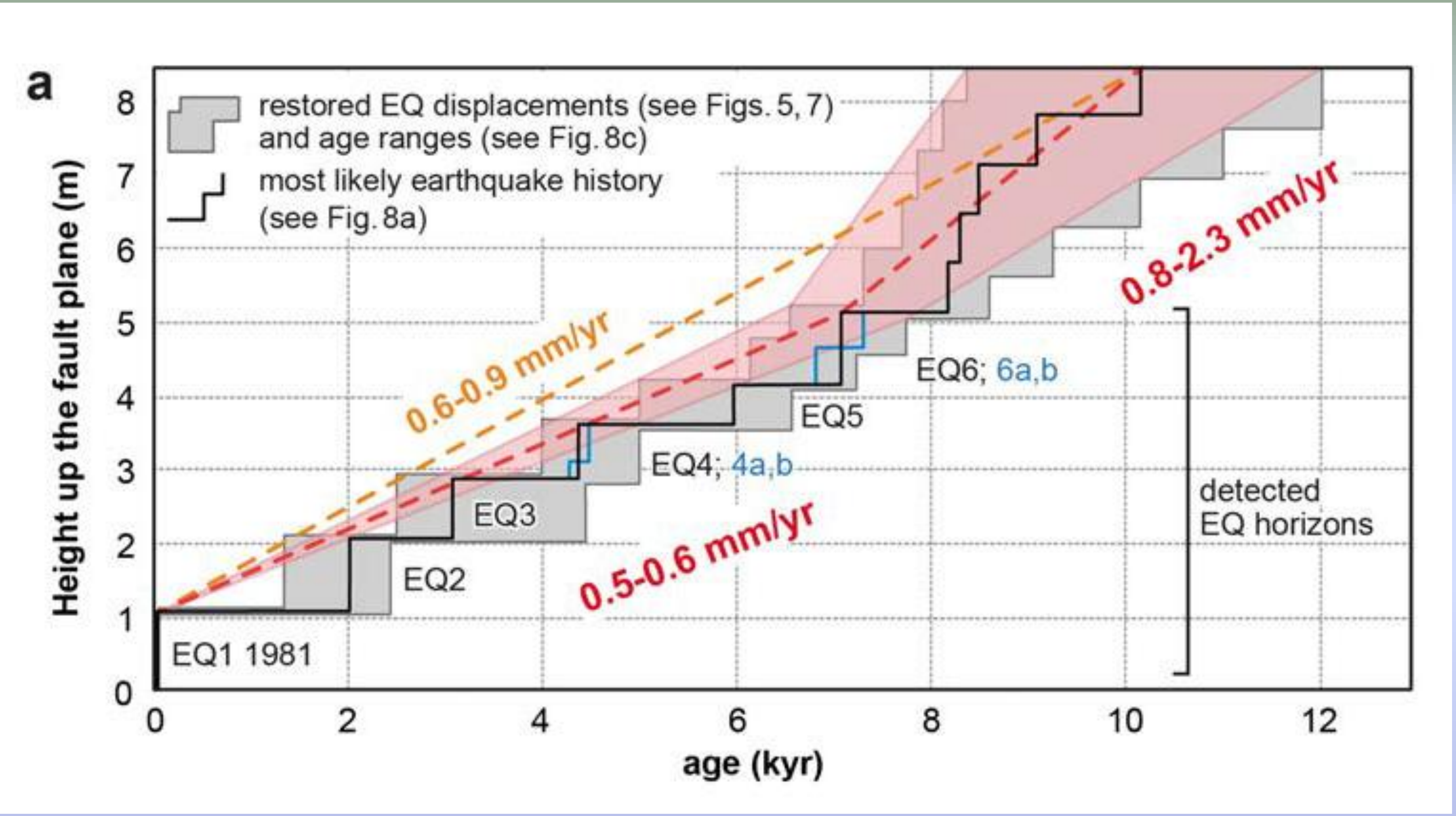
^{36}Cl: earthquake ages and slip rate



Modeling using the Matlab code of Schlagenhauf et al. (2010)

ca ±1 kyr age uncertainty

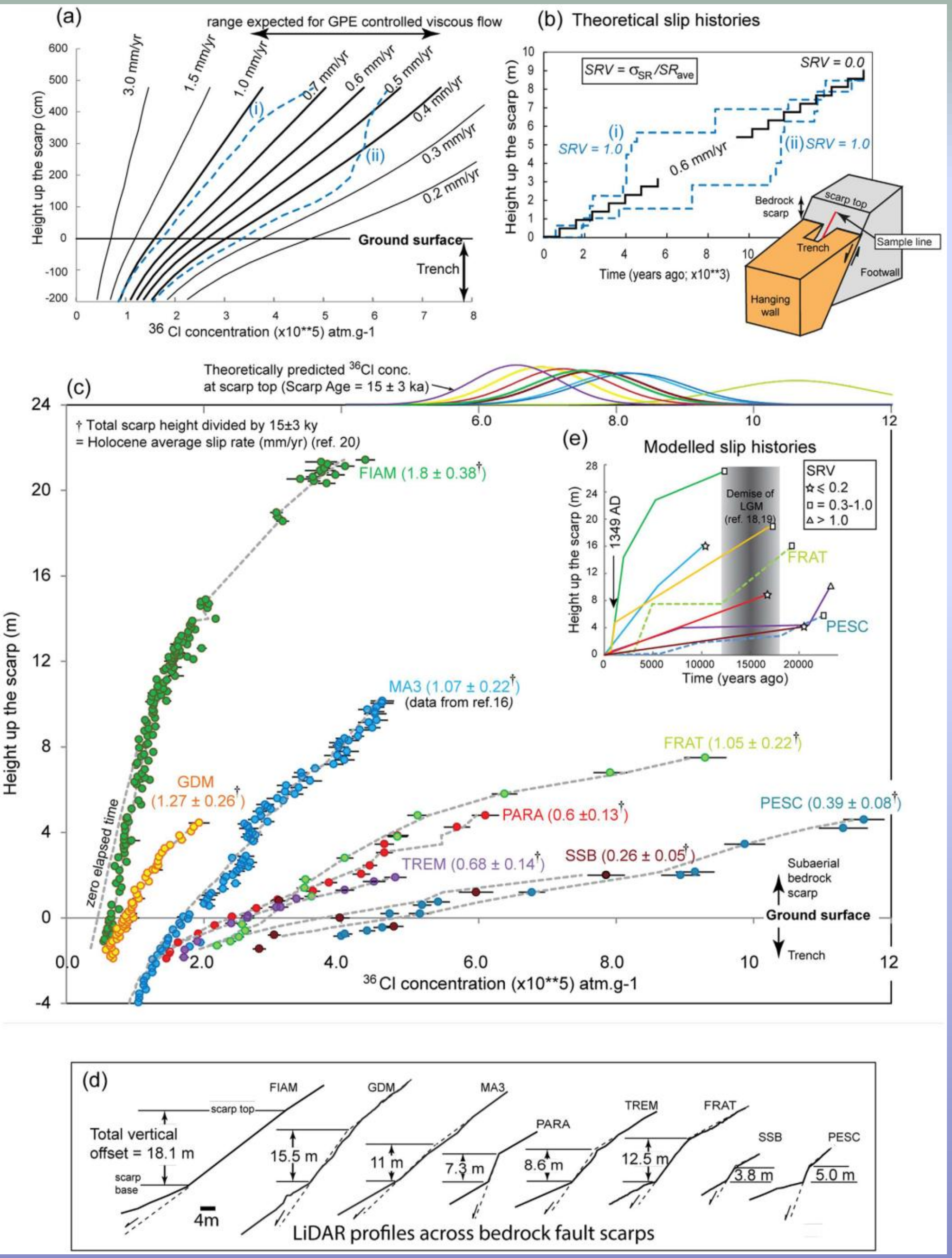
Mechernich et al. 2018JGR



Αποκρυπτογραφήθηκαν τα τελευταία 6 σεισμικά γεγονότα που προκάλεσαν μετατοπίσεις από 25-110 cm (Mw 6.2-6.7) τα τελευταία 7.3 ± 0.7 kyr

Ο ρυθμός ολίσθησης επιβραδύνθηκε από 0.8-2.3 mm/yr στις αρχές του Ολοκαίνου στα 0.5-0.6 mm/yr στο μέσο και ανώτερο Ολόκαινο

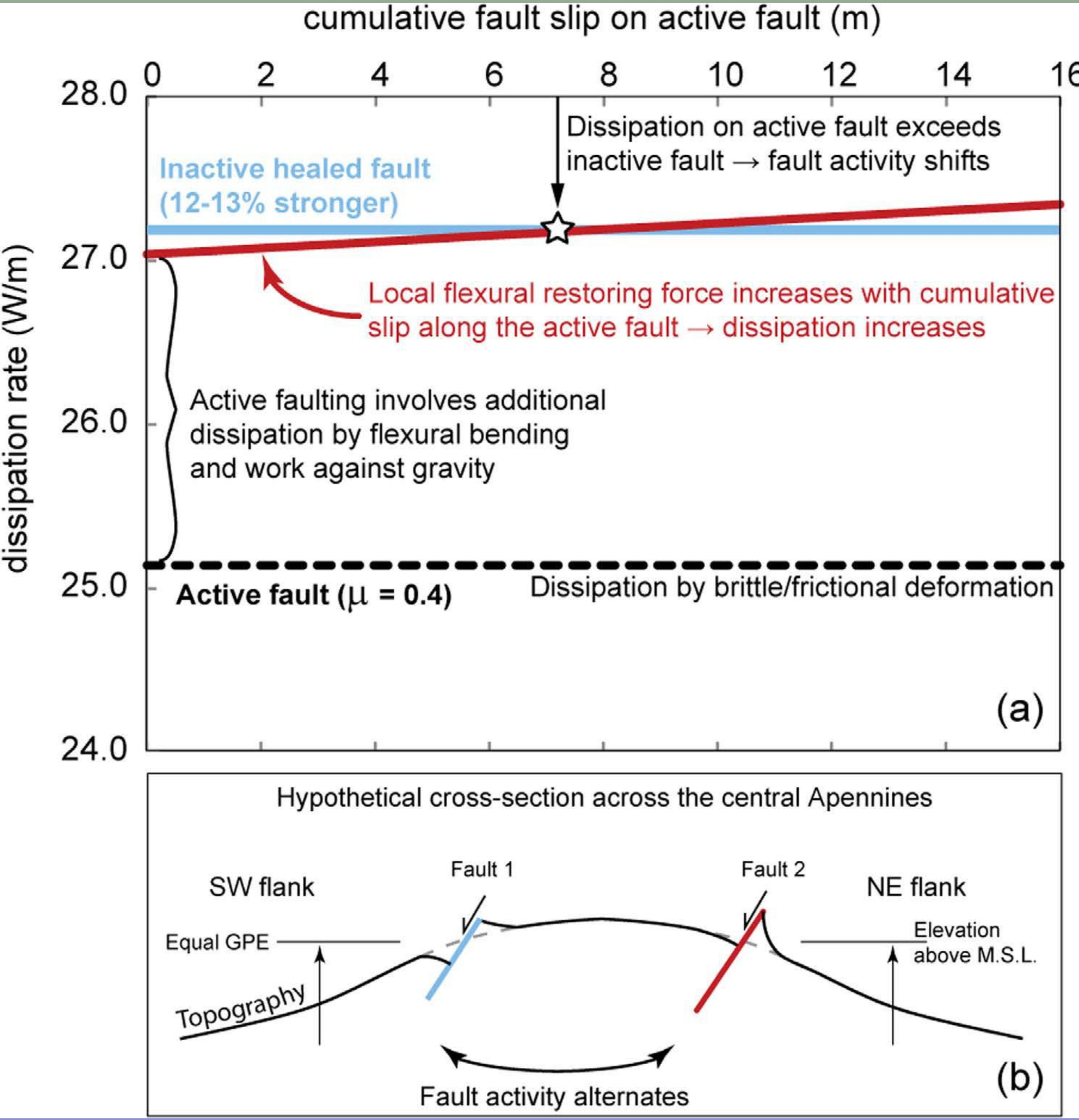
Mechernich et al. 2018 JGR



Cosmogenic Isotope dating

Earthquake hazard from cosmogenic ^{36}Cl exposure dating of elapsed time and Coulomb stress transfer in central Apennines (NERC, UK)

Cowie et al. 2017 Nature Scientific Reports



The 36Cl data reveal that

individual faults accumulate meters of displacement rapidly over several thousand years, separated by similar length time intervals when slip-rates are much lower,

and activity shifts between faults across strike

Cowie et al. 2017 Nature Scientific Reports

ESI 2007 (Environmental Seismic Intensity)

ELSEVIER

Quaternary International

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

Uncertainty in intensity assignment and attenuation relationships: How seismic hazard maps can benefit from the implementation of the Environmental Seismic Intensity scale (ESI 2007)

Ioannis D. Papanikolaou [a,b,*]

Quaternary International 451 (2017) 37–55

Contents lists available at ScienceDirect

Quaternary International

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

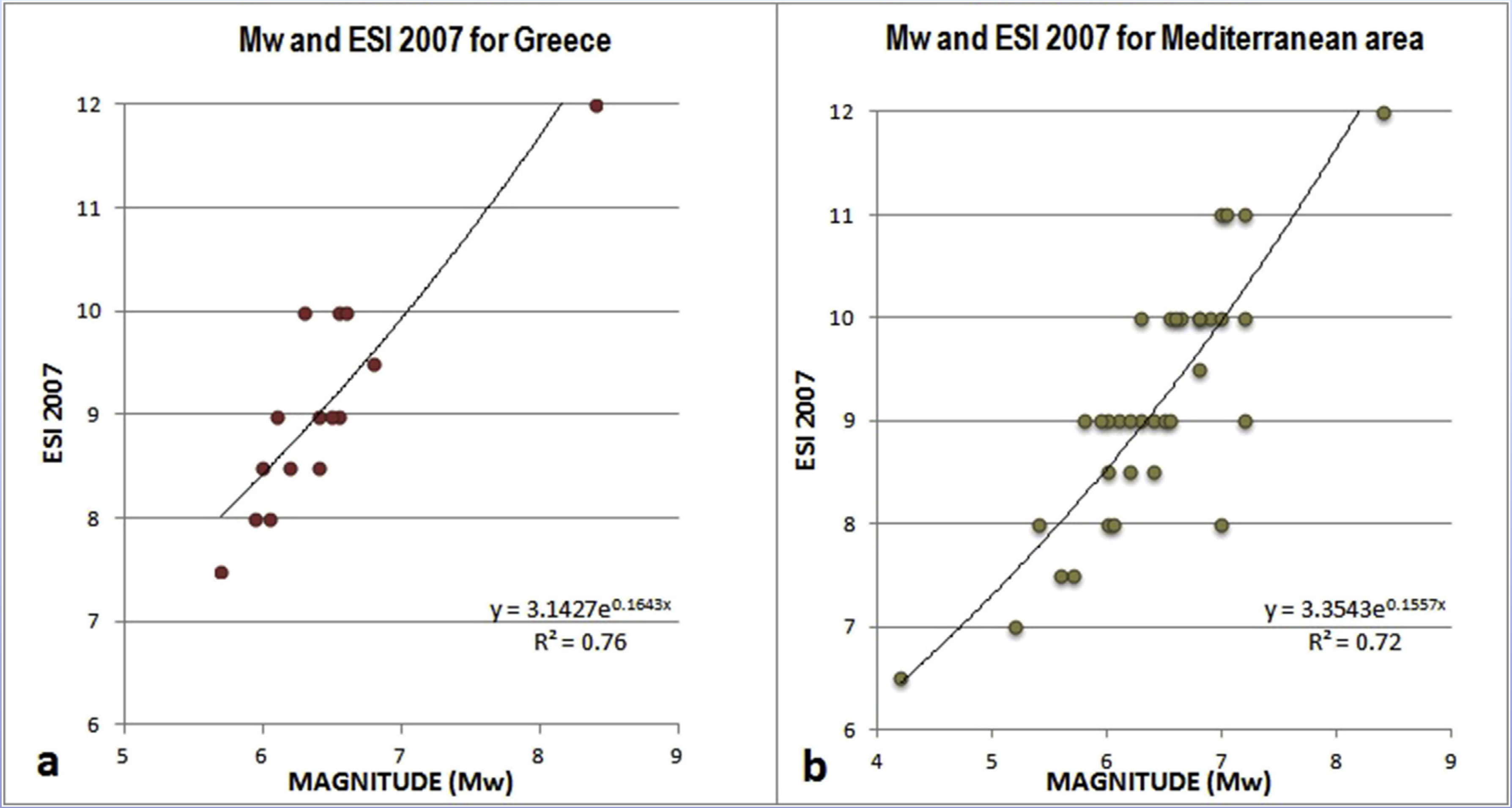
The Environmental Seismic Intensity Scale (ESI 2007) in Greece, addition of new events and its relationship with magnitude in Greece and the Mediterranean; preliminary attenuation relationships

CrossMark

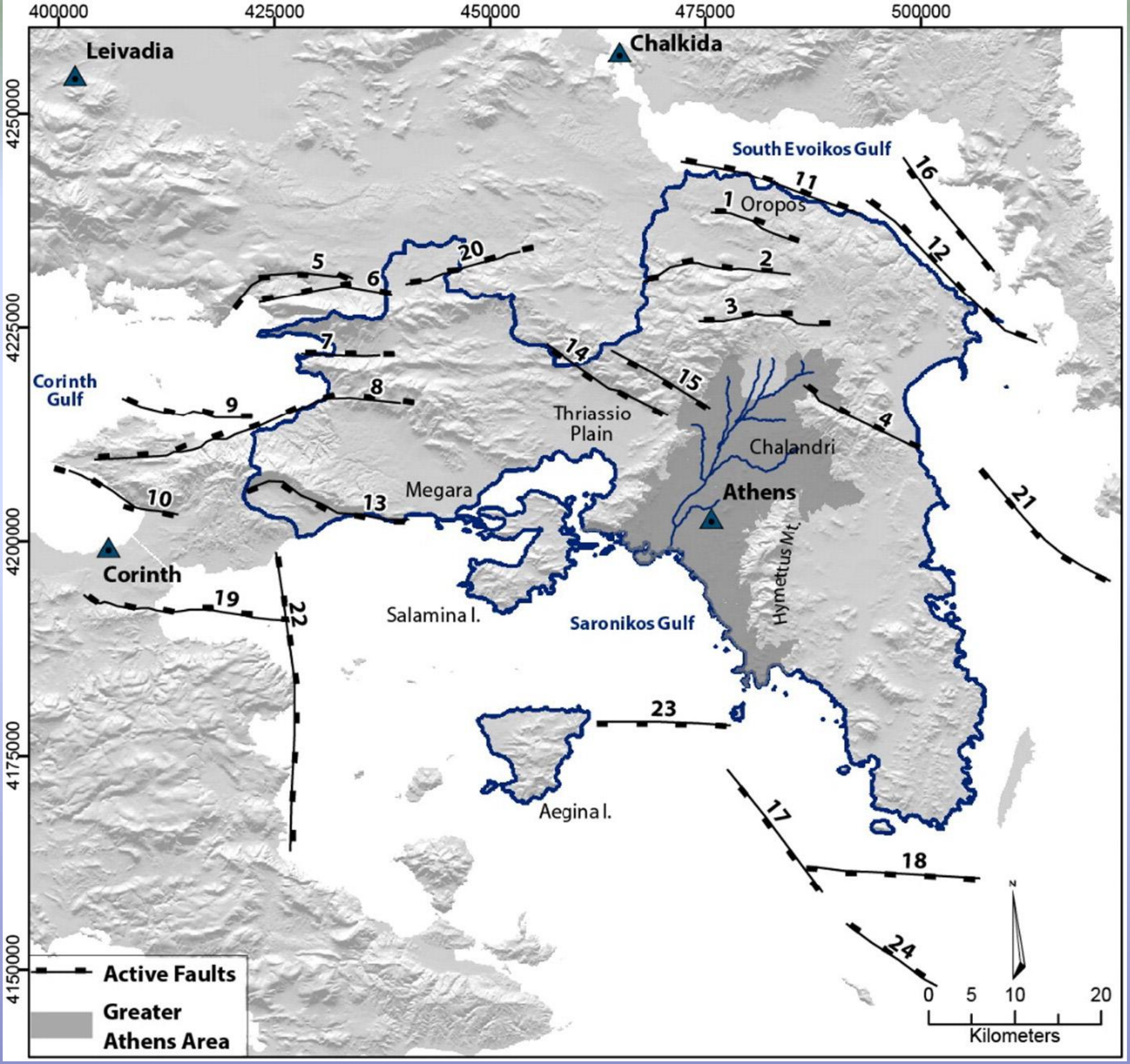
Ioannis Papanikolaou [a,*], Maria Melaki [a,b]

ESI 2007 (Environmental Seismic Intensity)

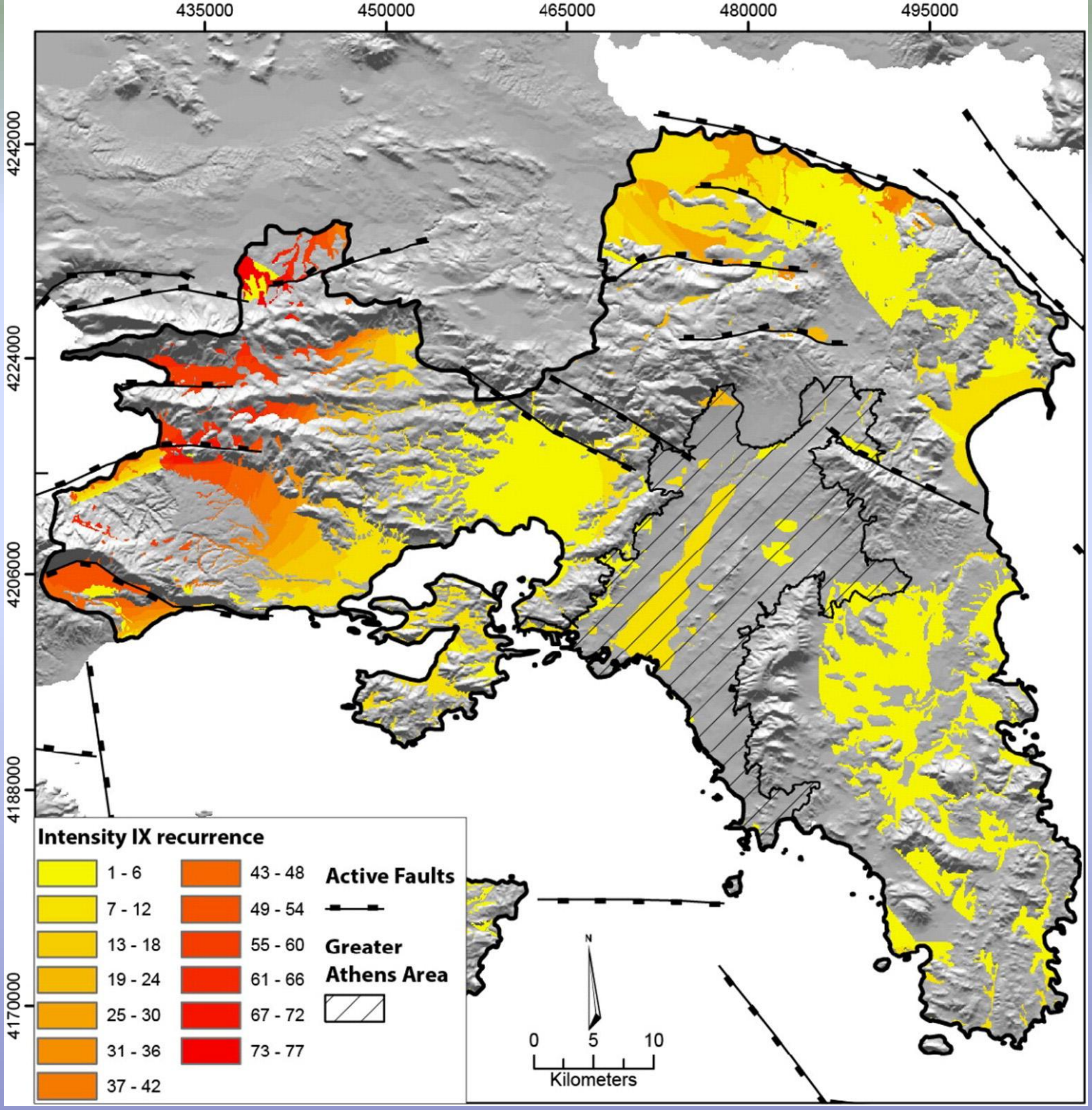
Οι πρώτες σχέσεις μεταξύ του μεγέθους του σεισμού και της έντασης ESI 2007 σε Ελλάδα και Μεσόγειο



Papanikolaou and Melaki 2017 Quanternary International



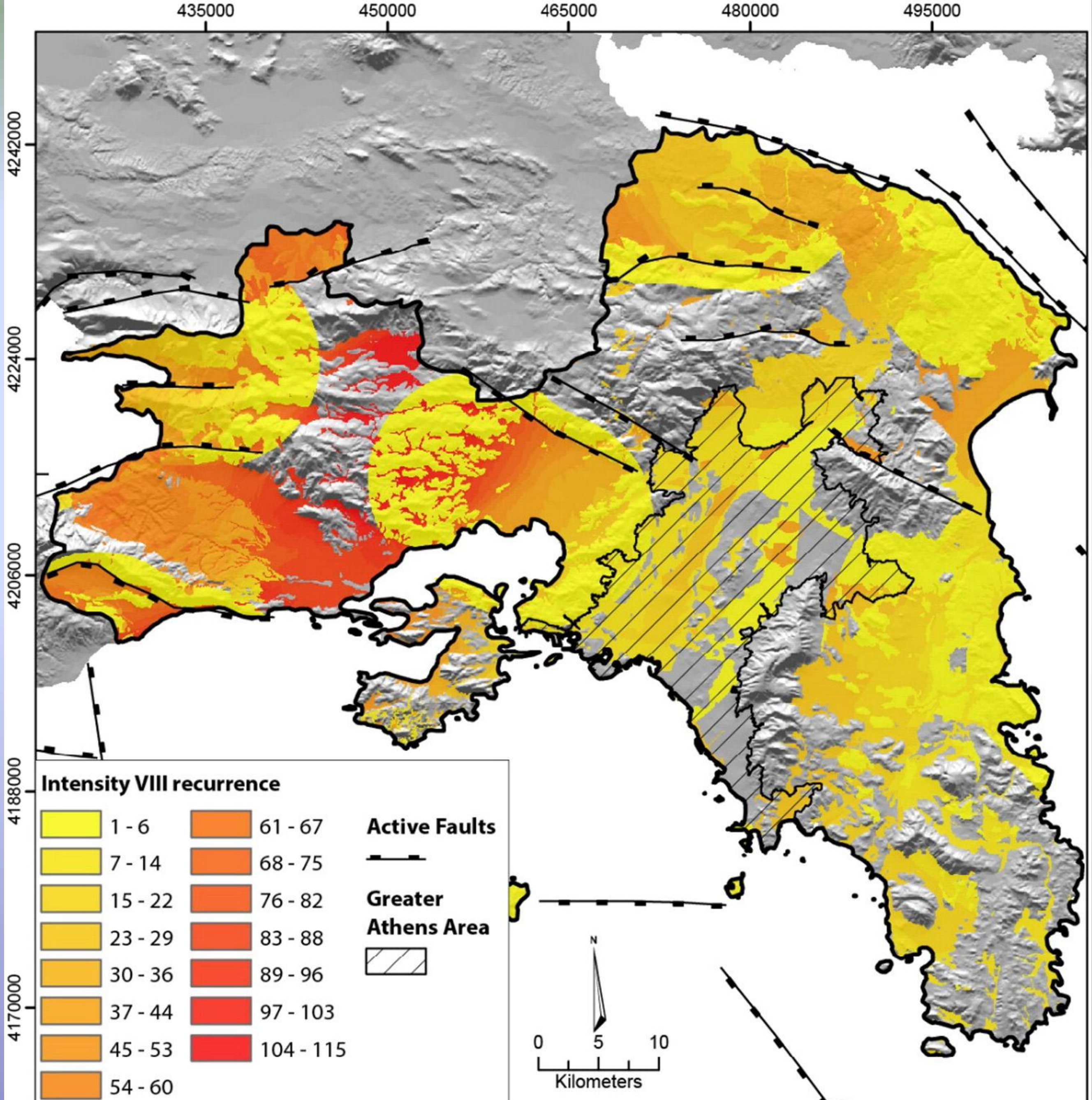
Deligiannakis et al. 2018 Geomorphology



77 φορές **ένταση IX** και
29 φορές **ένταση X** στην περιοχή των Αλκυονίδων

περίοδος επανάληψης
**(195 χρόνια ένταση IX
517 χρόνια ένταση X)**

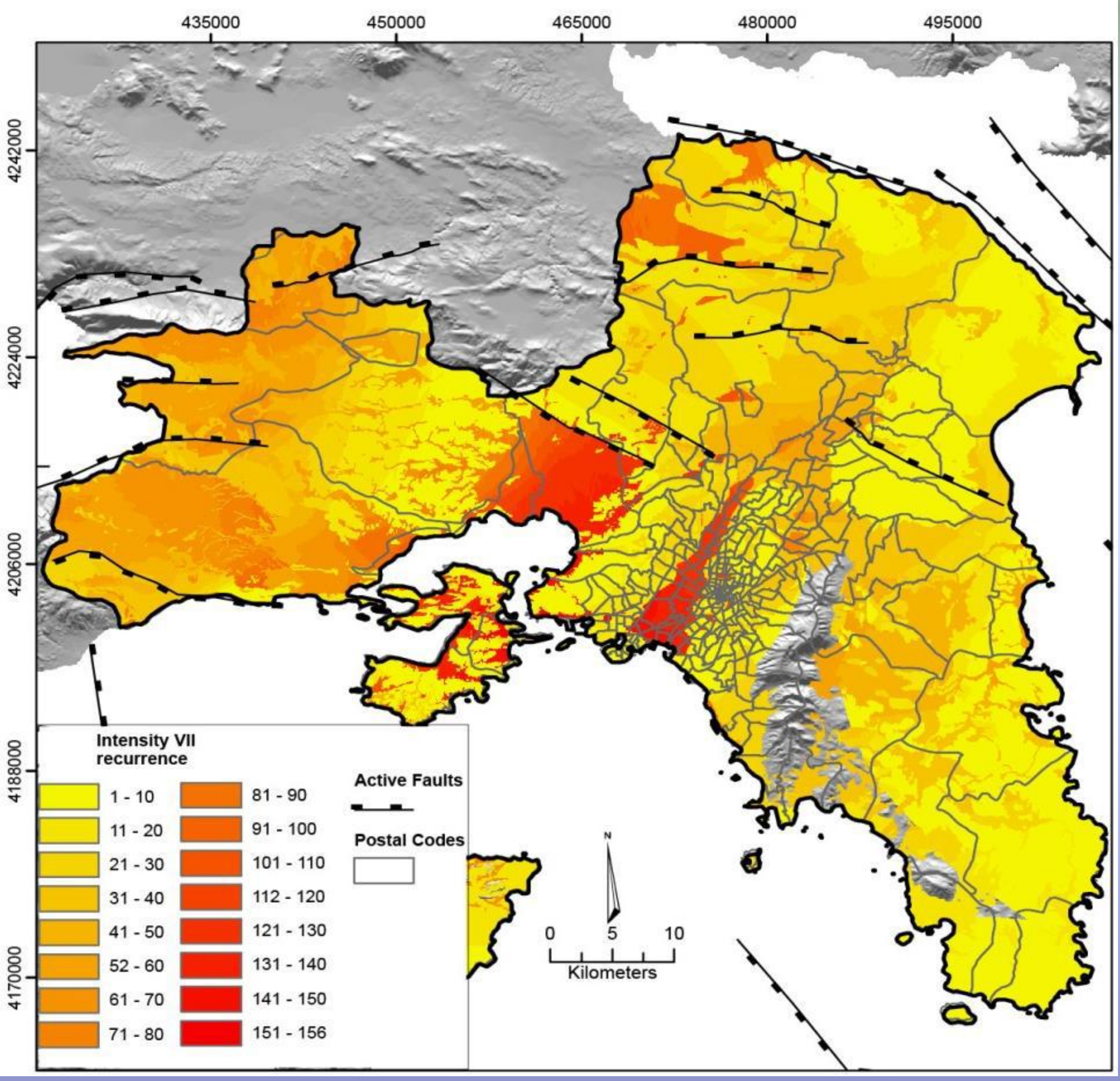
Deligiannakis et al. 2018 Geomorphology



115φορές **ένταση VIII** στην περιοχή της Δυτικής Αττικής

περίοδος επανάληψης **(130 χρόνια ένταση VIII)**

Deligiannakis et al. 2018 Geomorphology



156 φορές **ένταση VII** στα 15.000 χρόνια, περίοδο επανάληψης **96 ετών για το κέντρο του Λεκανοπεδίου**

Deligiannakis et al. 2018 Geomorphology

Earthquake CAT Risk model for the Region of Attica, Greece, based on a fault specific hazard module

Georgios Deligiannakis [1]

Ioannis D. Papanikolaou **[1]**

Alexandros Zimbidis [2]

Iraklis Kakouris [3]

(1) Mineralogy-Geology Laboratory, Department of Natural Resources Development and Agricultural Engineering, Agricultural University of Athens

(2) Department of Statistics, Athens University of Economics and Business

(3) Prudential Actuarial Solutions Ltd

Synthetic stochastic model description

Hazard module

Future seismic events stochastic simulation

- Fault Specific modeling
- Historic Earthquake Catalogues

Stochastic or deterministic attenuation relationships model

- Attenuation Relationships

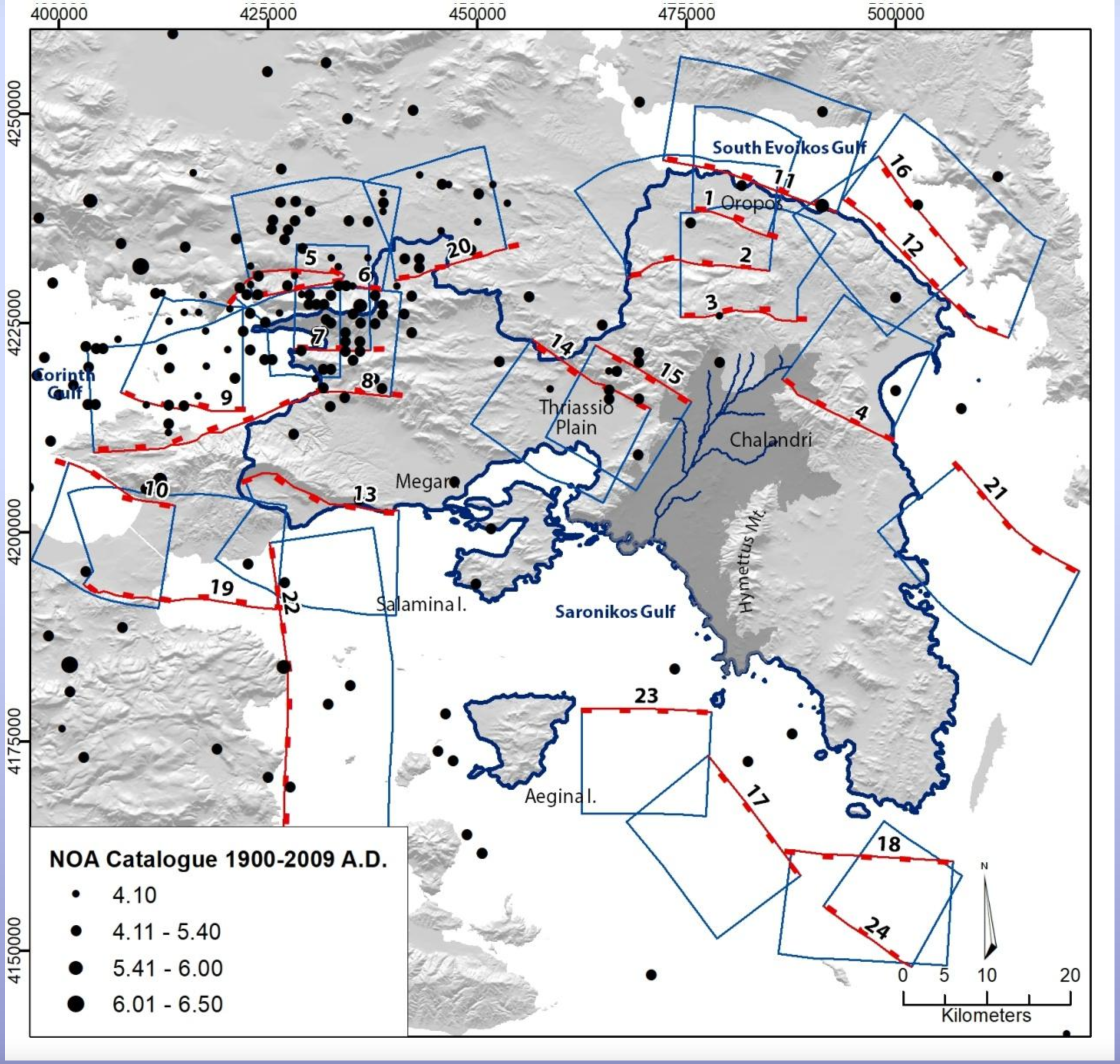
Surface Geology

- Amplification – attenuation of seismic intensity
- Detailed geological maps

Synthetic stochastic model description

Instrumental and historical earthquakes record modeling

- Different earthquake catalogues (NOA-UOA post 1900 and AUTH in pre-1900)
- Events with M>6.0 laying on the active faults hanging walls are rejected
- <u>Only 4 faults can be related to historic or recent events</u>
- Combination with the fault specific model results
- **Final catalogue with historic, instrumental and fault specific epicenters**



Synthetic stochastic model description

Stochastic earthquake modeling

- Stochastic simulation of the **future events** based on the new epicenters database.
- Attica is split in a 1 km x 1km grid

Inside each cell the λ parameters of the random variable of the epicenters number per year are calculated (Poisson distribution)

1

Latitude	Longitude 18	19	20	21	22	23	24	25	26	27	28	29	30
42	0,15	0,57	0,10	0,10	0,02	0,08	0,09	0,11	0,06	0,00	0,01	0,00	0,00
41	0,01	1,07	1,06	0,08	0,1								
40	0,00	0,97	0,59	1,13	0,2								
39	0,08	0,21	1,55	0,79	1,1								
38	0,00	0,17	4,32	2,01	2,0								
37	0,00	0,50	3,66	2,39	0,6								
36	0,00	0,03	0,14	1,65	0,7								
35	0,00	0,00	0,05	0,67	1,0								
34	0,00	0,00	0,02	0,04	0,5								
33	0,00	0,00	0,00	0,01	0,0								

Latitude	Longitude 20	20,1	20,2	20,3	20,4	20,5	20,6	20,7	20,8	20,9
38	0,030	0,045	0,032	0,008	0,008	0,015	0,006	0,002	0,015	0,008
38,1	0,019	0,070	0,038	0,034	0,006	0,008	0,015	0,008	0,008	0,002
38,2	0,002	0,028	0,028	0,017	0,019	0,015	0,011	0,013	0,006	0,004
38,3	0,004	0,006	0,008	0,032	0,017	0,006	0,000	0,006	0,068	0,004
38,4	0,004	0,000	0,006	0,025	0,008	0,002	0,002	0,000	0,006	0,000
38,5	0,000	0,000	0,002	0,015	0,004	0,017	0,002	0,000	0,002	0,002
38,6	0,000	0,002	0,006	0,004	0,021	0,002	0,002	0,000	0,000	0,002
38,7	0,000	0,002	0,002	0,006	0,015	0,017	0,002	0,004	0,006	0,004
38,8	0,000	0,000	0,000	0,004	0,008	0,017	0,017	0,004	0,015	0,006
38,9	0,000	0,000	0,004	0,006	0,004	0,028	0,000	0,002	0,004	0,004

Each cell is attributed to a percentage, representing the probability of earthquake occurrence, following a two-dimensional beta and polynomial distribution

2

Synthetic stochastic model description

Stochastic earthquake modeling

- Stochastic simulation of the **future events** based on the new epicenters database.
- Attica is split in a 1 km x 1km grid
- **Focal depth:**
  Bivariate variable distribution
- **Magnitude:**
  Beta distribution (commonly used by vendors)

Latitude \ Longitude	20	20,1	20,2	20,3	20,4	20,5	20,6	20,7	20,8	20,9
38	0,030	0,045	0,032	0,008	0,008	0,015	0,006	0,002	0,015	0,008
38,1	0,019	0,070	0,038	0,034	0,006	0,008	0,015	0,008	0,008	0,002
38,2	0,002	0,028	0,028	0,017	0,019	0,015	0,011	0,013	0,006	0,004
38,3	0,004	0,006	0,008	0,032	0,017	0,006	0,000	0,006	0,068	0,004
38,4	0,004	0,000	0,006	0,025	0,008	0,002	0,002	0,000	0,006	0,000
38,5	0,000	0,000	0,002	0,015	0,004	0,017	0,002	0,000	0,002	0,002
38,6	0,000	0,002	0,006	0,004	0,021	0,002	0,002	0,000	0,000	0,002
38,7	0,000	0,002	0,002	0,006	0,015	0,017	0,002	0,004	0,006	0,004
38,8	0,000	0,000	0,000	0,004	0,008	0,017	0,017	0,004	0,015	0,006
38,9	0,000	0,000	0,004	0,006	0,004	0,028	0,000	0,002	0,004	0,004

Each cell is attributed to a percentage, representing the probability of earthquake occurrence, following a two-dimensional beta and polynomial distribution

2

Synthetic stochastic model description

Hazard module

Future seismic events stochastic simulation

- Fault Specific modeling
- Historic Earthquake Catalogues

Attenuation relationships model

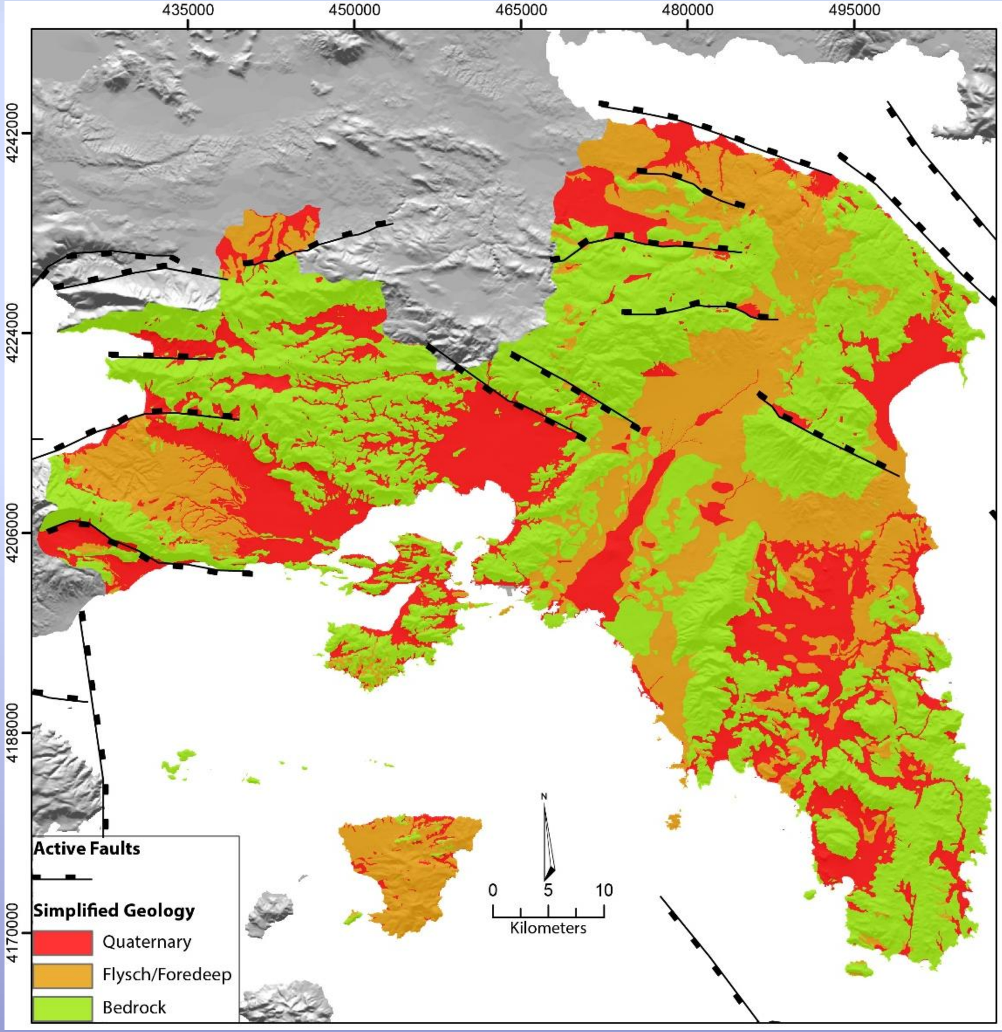
- Attenuation Relationships

Surface Geology

- Amplification attenuation of seismic intensity
- Detailed geological maps

Synthetic stochastic model description

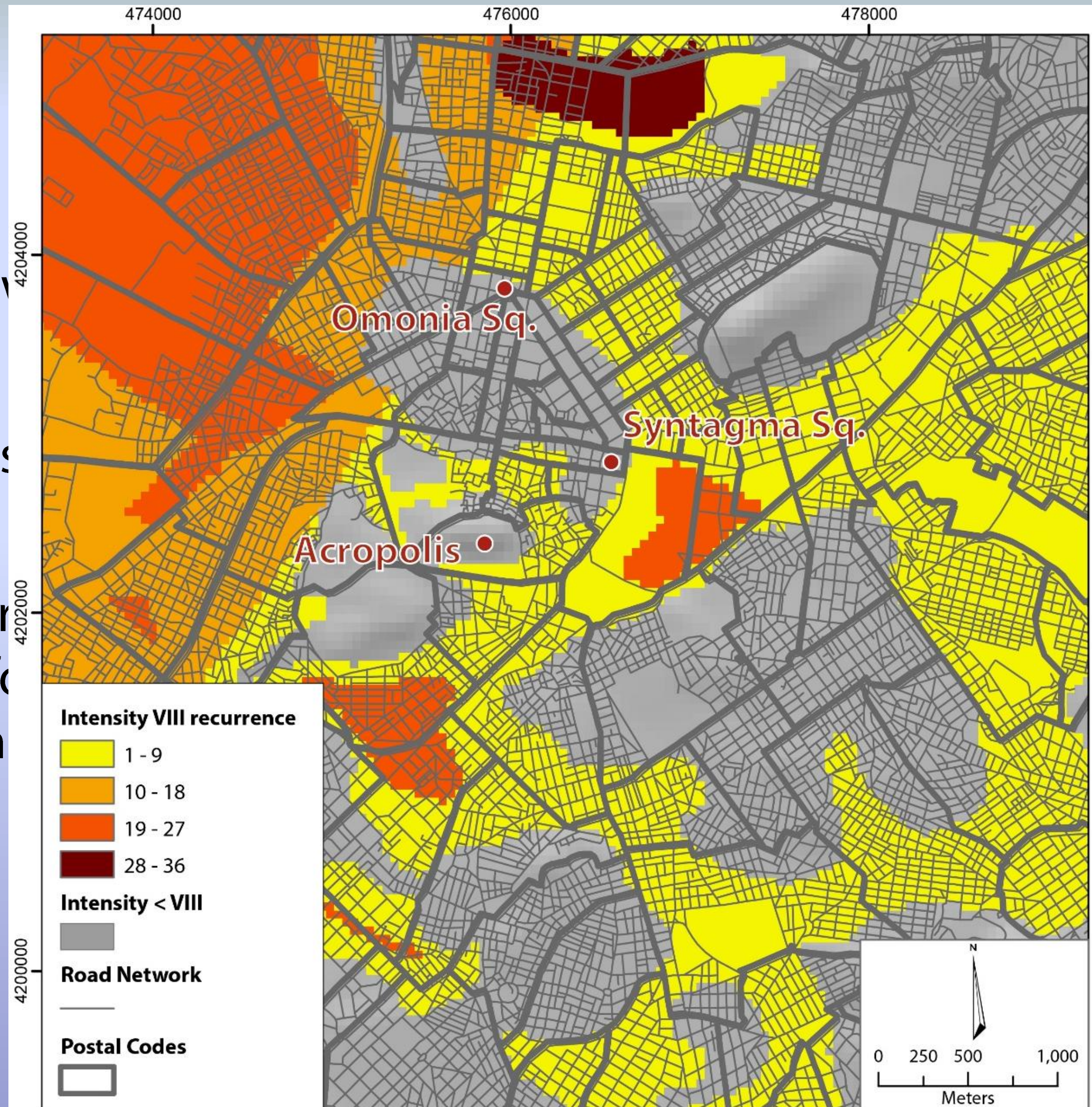
Hazard module

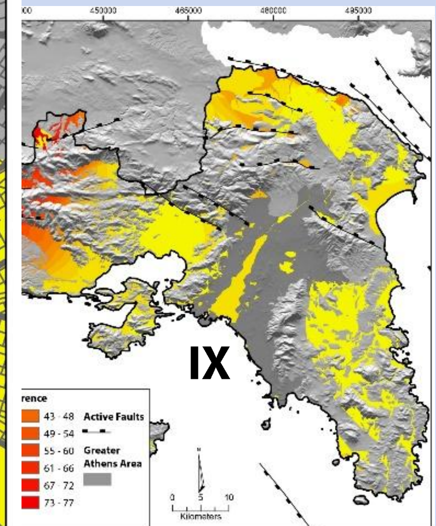


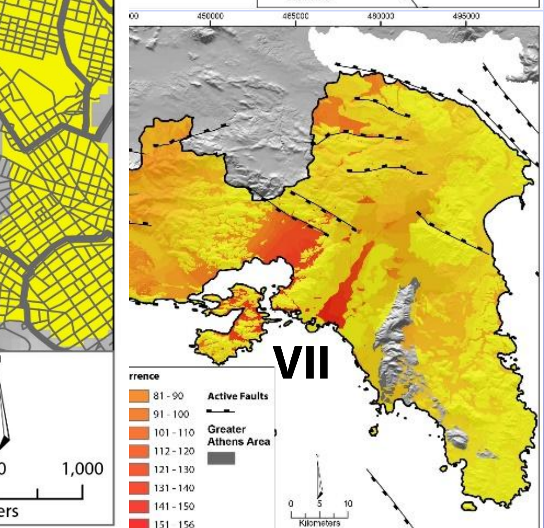
Subsoil	Average change in intensity
Mesozoic or Tertiary limestone, schists, gneisses, marbles and granites	-1
Flysch/foredeep deposits	0
Quaternary deposits	+1

Synthetic stochastic model description

- Intensities VII, V
- 24 active faults
- 4 high spatial r
hazard maps fo
showing inten
recurrence







Synthetic stochastic model description

Vulnerability module

Vulnerability tables – Vulnerability curves

- Building and building contents

- Average value of the expected damage

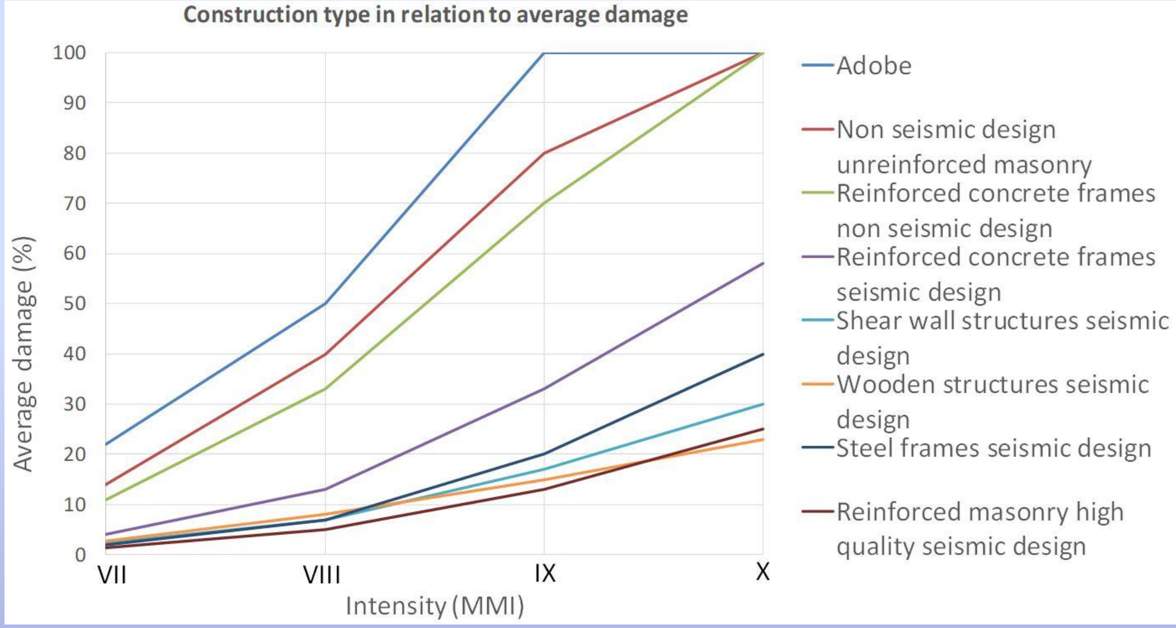
- They depend on:
  - Seismic intensity (hazard module)
  - Building characteristics (exposure data)

- Based on seismic intensity scales (e.g. MMI) or ground motion characteristics (e.g. PGA, SA, etc)

Synthetic stochastic model description

Vulnerability module

- Existing tables (e.g. Sauter & Shah, 1978; Degg, 1992), modified by already published vulnerability curves and tables (e.g. Kappos et al., 1998; Kappos et al., 2006; Kappos & Panagopoulos, 2009).



Exposure data

Portfolio characteristics

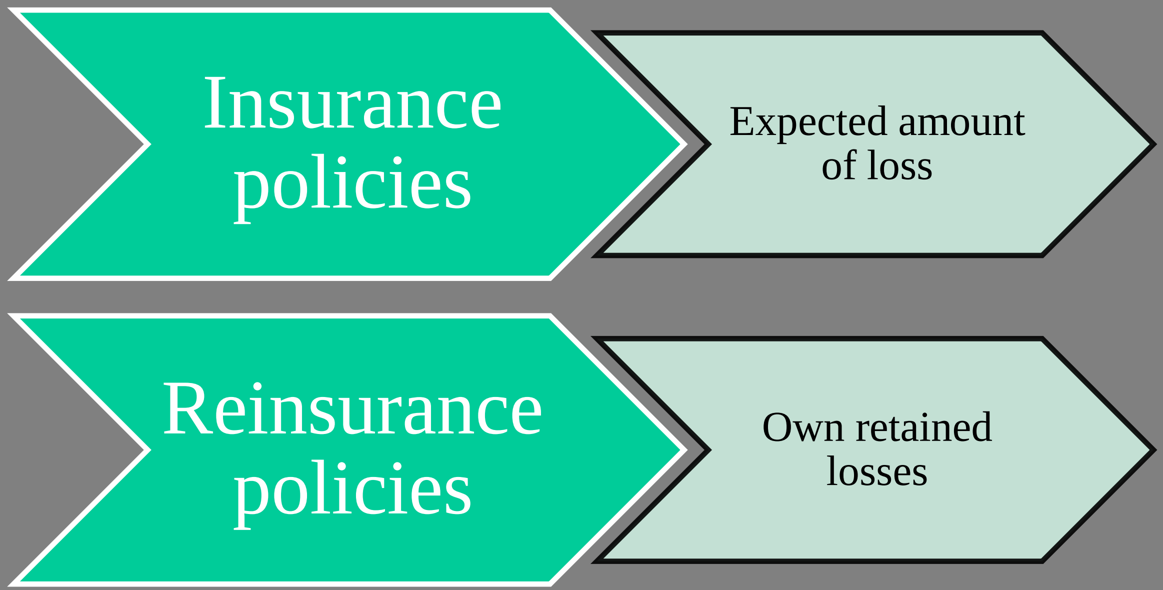
Basic assumptions for blank records:

- Construction type
- Building age
- Number of floors

Building Characteristics							
Policy Serial No.	Postal Code	Construction Value	Insured Value	Construction Type	Building Age	Number of floors	Use of Property
1	10431						
2	10431						
…	…						
n	85900						

Financial Module

Total loss for each insured property



Total loss for insured portfolio

Synthetic stochastic model description

Financial module

Objective

To specify the required capital ***K***, in order to ensure that the insurance company will be able to meet its obligations over the following year, with a probability of at least **99.5%**.

Resolving method

Portfolio: we assume ***n*** buildings and that X_i is a random variable, representing the amount of the annual own retained loss for the i_{th} building, where $i=1,2,\ldots,n$.

then

The total annual own retained loss amount : ***S***

$$S = X_1 + X_2 + \cdots X_n$$

The Solvency II requirement is typically described by the following equation:

$$\Pr[S < K] = 99.5\%$$

Synthetic stochastic model description

Financial module

Simulation techniques for the random variable *S* distribution:

We develop a synthetic stochastic model that reproduces a large number (e.g. N, where N=10,000) of different values for the random variable ***S*** (e.g. S_1, S_2,...$S_{9,999}$, $S_{10,000}$)

Events table

1st option

- Sorting of $S_{(1)}, S_{(2)}, \dots S_{(9.999)}, S_{(10.000)}$ in descending order
- Select the number $\boldsymbol{\omega}$ arranged value, where

$$\boldsymbol{\omega = N \times 0.05}$$

- calculate capital ***K*** based on the corresponding value from the sorted random variables ***S***, that is,

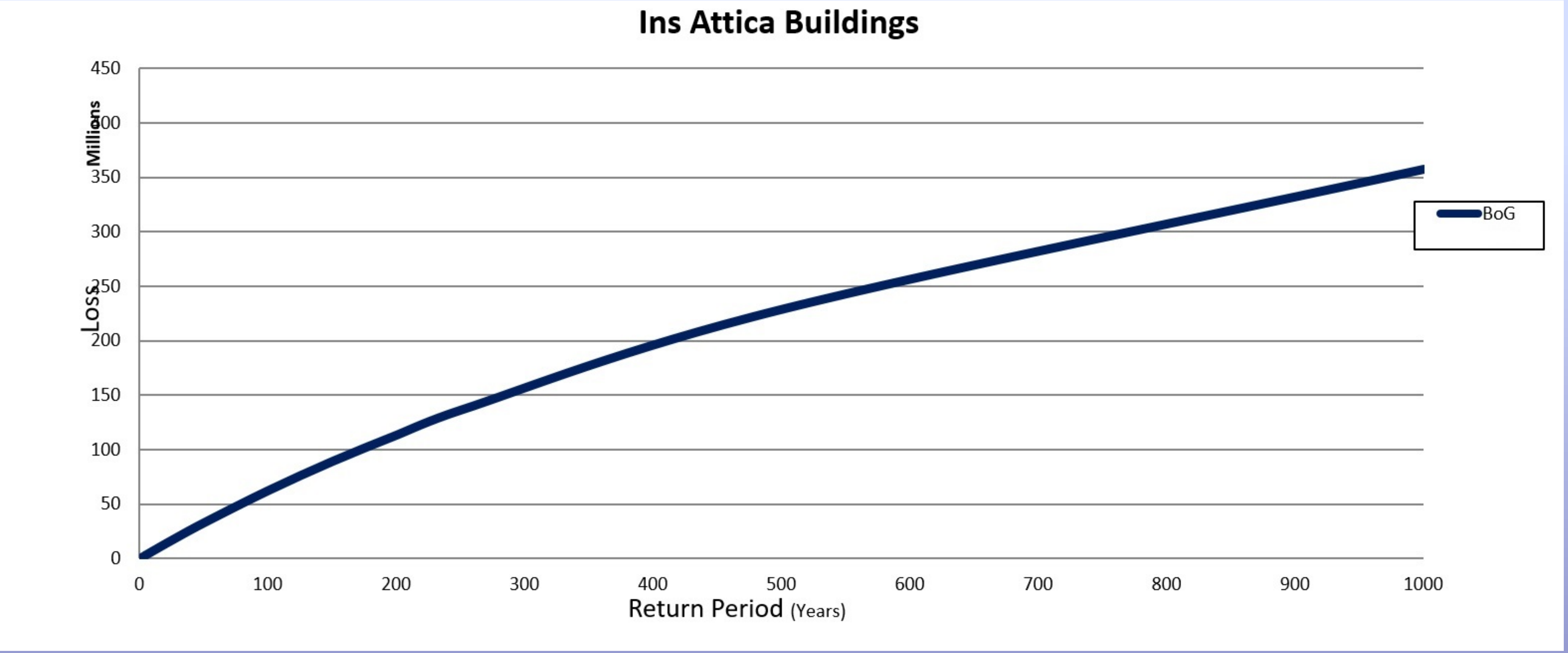
$$\boldsymbol{K = S_{(\omega)}}$$

2nd option

- A theoretical distribution is fitted to the initial sample of the random variable ***S***, (S_1, S_2, ... $S_{9,999}$, $S_{10,000}$)
- We calculate the capital ***K*** using the mathematical formula of the corresponding cumulative distribution or cumulative probabilities tables, so that:

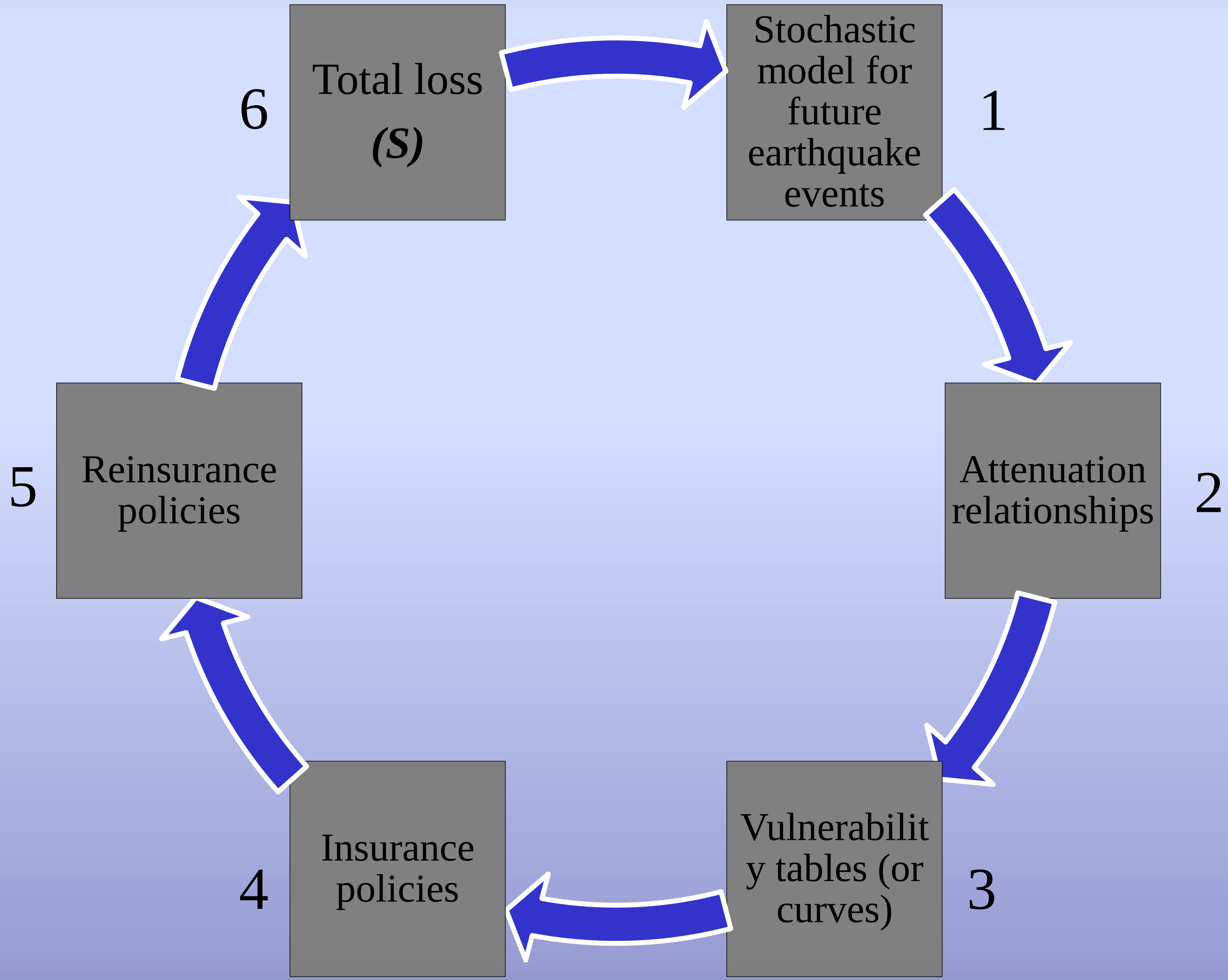
$$\mathbf{Pr}[\boldsymbol{S < K}] = \mathbf{99.5\%}$$

Η καμπύλη EP (*Exceedance Probability*) επικοινωνεί την πιθανότητα υπέρβασης κάθε οικονομικής ζημιάς στο χρόνο

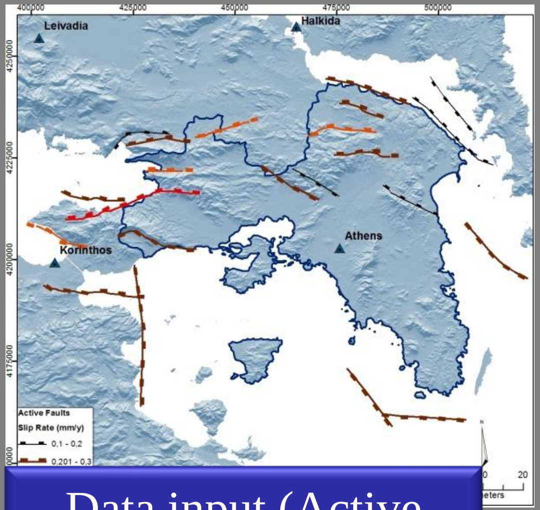


Synthetic stochastic model description

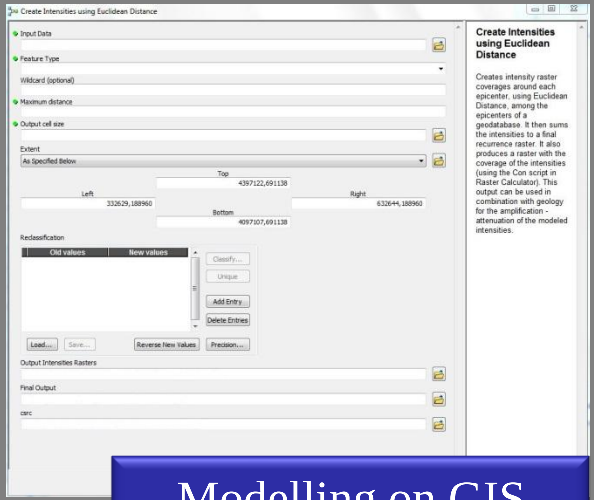
Overall process per event



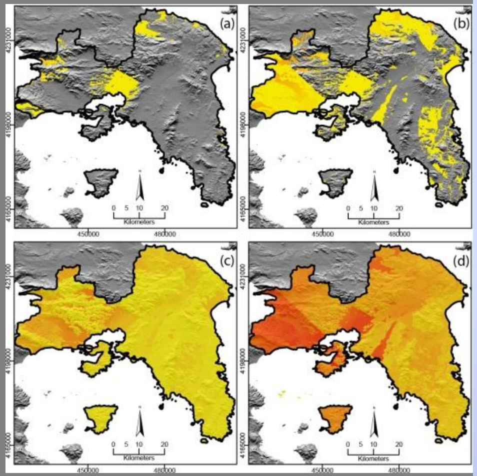
Workflow



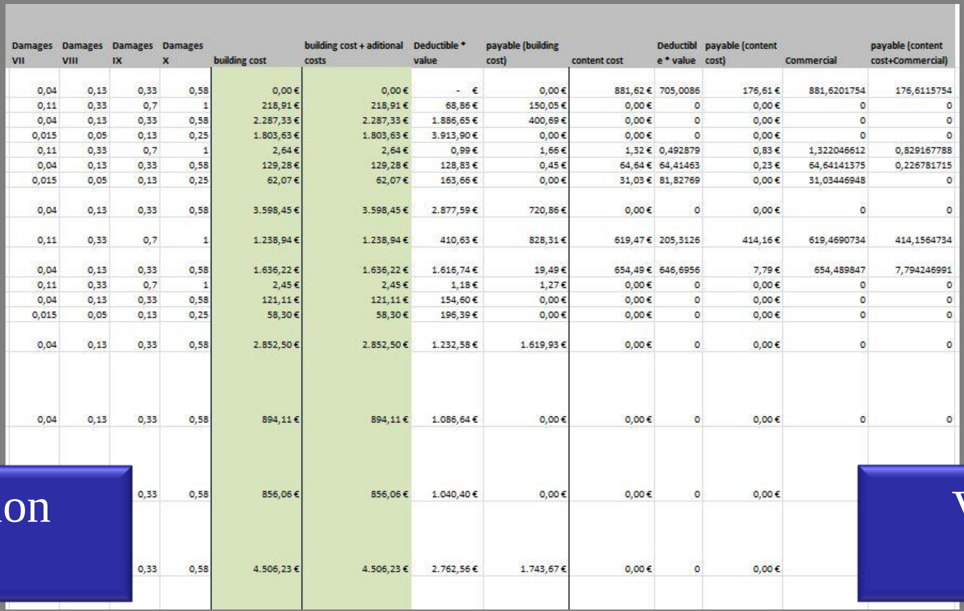
Data input (Active faults+ Catalogues)



Modelling on GIS environment



Vulnerability + Exposure



Damages VII	Damages VIII	Damages IX	Damages X	building cost	building cost + aditional costs	Deductible * value	payable (building cost)	content cost	Deductible * value	payable (content cost)	Commercial	payable (content cost+Commercial)
0,04	0,13	0,33	0,58	0,00 €	0,00 €	- €	0,00 €	881,62 €	705,0086	176,61 €	881,6201754	176,6115754
0,11	0,33	0,7	1	218,91 €	218,91 €	68,86 €	150,05 €	0,00 €	0	0,00 €	0	0
0,04	0,13	0,33	0,58	2.287,33 €	2.287,33 €	1.886,65 €	400,69 €	0,00 €	0	0,00 €	0	0
0,015	0,05	0,13	0,25	1.803,63 €	1.803,63 €	3.913,90 €	0,00 €	0,00 €	0	0,00 €	0	0
0,11	0,33	0,7	1	2,64 €	2,64 €	0,99 €	1,66 €	1,32 €	0,492879	0,83 €	1,322046612	0,829167788
0,04	0,13	0,33	0,58	129,28 €	129,28 €	128,83 €	0,45 €	64,64 €	64,41463	0,23 €	64,64141375	0,226781715
0,015	0,05	0,13	0,25	62,07 €	62,07 €	163,66 €	0,00 €	31,03 €	81,82769	0,00 €	31,03446948	0
0,04	0,13	0,33	0,58	3.598,45 €	3.598,45 €	2.877,59 €	720,86 €	0,00 €	0	0,00 €	0	0
0,11	0,33	0,7	1	1.238,94 €	1.238,94 €	410,63 €	828,31 €	619,47 €	205,3126	414,16 €	619,4690734	414,1564734
0,04	0,13	0,33	0,58	1.636,22 €	1.636,22 €	1.616,74 €	19,49 €	654,49 €	646,6956	7,79 €	654,489847	7,794246991
0,11	0,33	0,7	1	2,45 €	2,45 €	1,18 €	1,27 €	0,00 €	0	0,00 €	0	0
0,04	0,13	0,33	0,58	121,11 €	121,11 €	154,60 €	0,00 €	0,00 €	0	0,00 €	0	0
0,015	0,05	0,13	0,25	58,30 €	58,30 €	196,39 €	0,00 €	0,00 €	0	0,00 €	0	0
0,04	0,13	0,33	0,58	2.852,50 €	2.852,50 €	1.232,58 €	1.619,93 €	0,00 €	0	0,00 €	0	0
0,04	0,13	0,33	0,58	894,11 €	894,11 €	1.086,64 €	0,00 €	0,00 €	0	0,00 €	0	0
		0,33	0,58	856,06 €	856,06 €	1.040,40 €	0,00 €	0,00 €	0	0,00 €		
		0,33	0,58	4.506,23 €	4.506,23 €	2.762,56 €	1.743,67 €	0,00 €	0	0,00 €		

Loss calculation

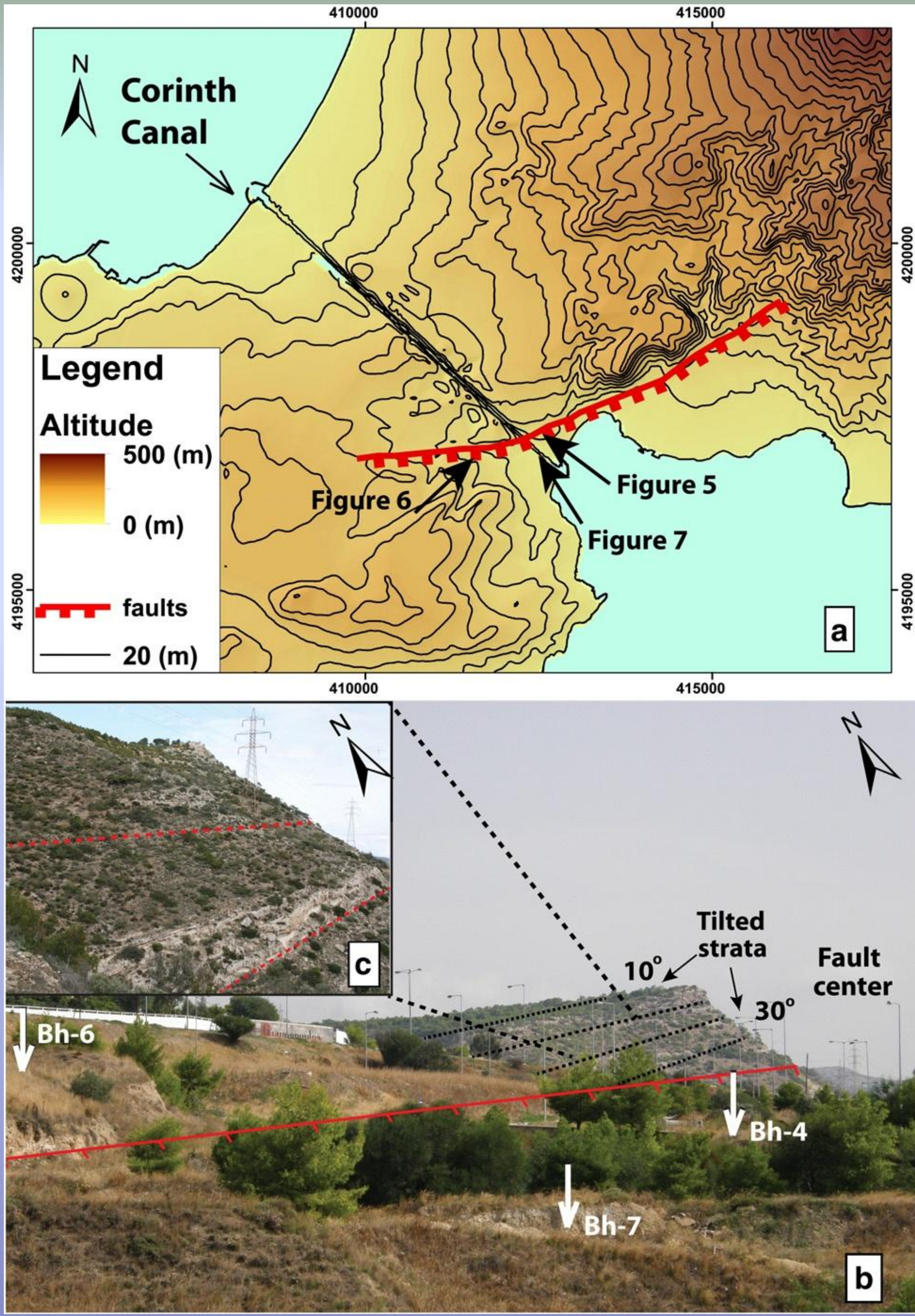
Discussion

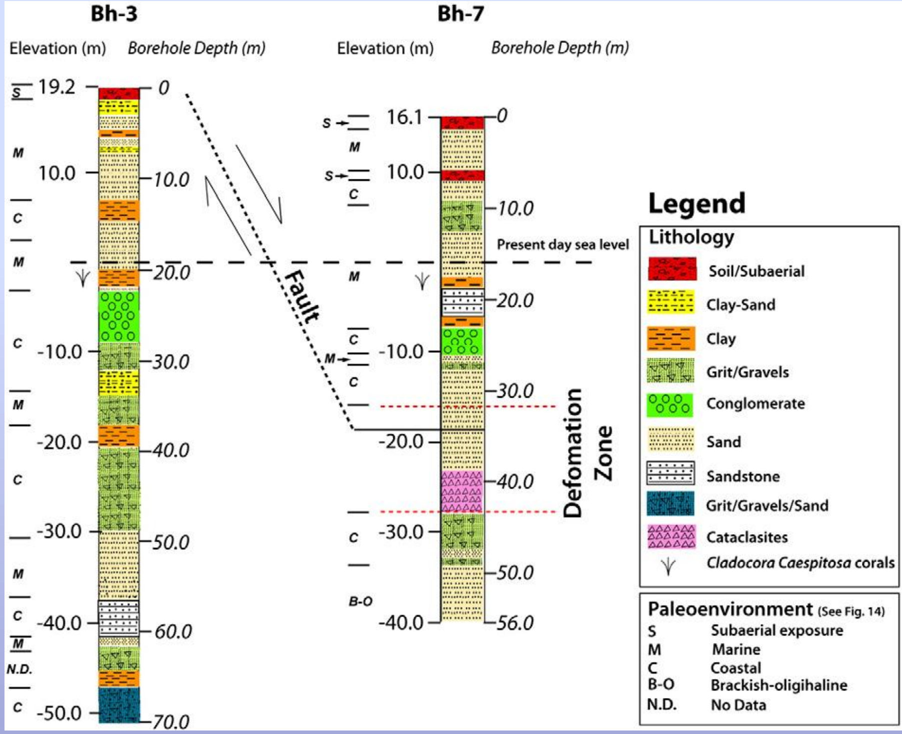
Test with EIOPA's Standard Formula

- Test conducted for each CRESTA zone of Attica (first 2 Postal Code digits)
- Comparison of SCR calculations for both methods

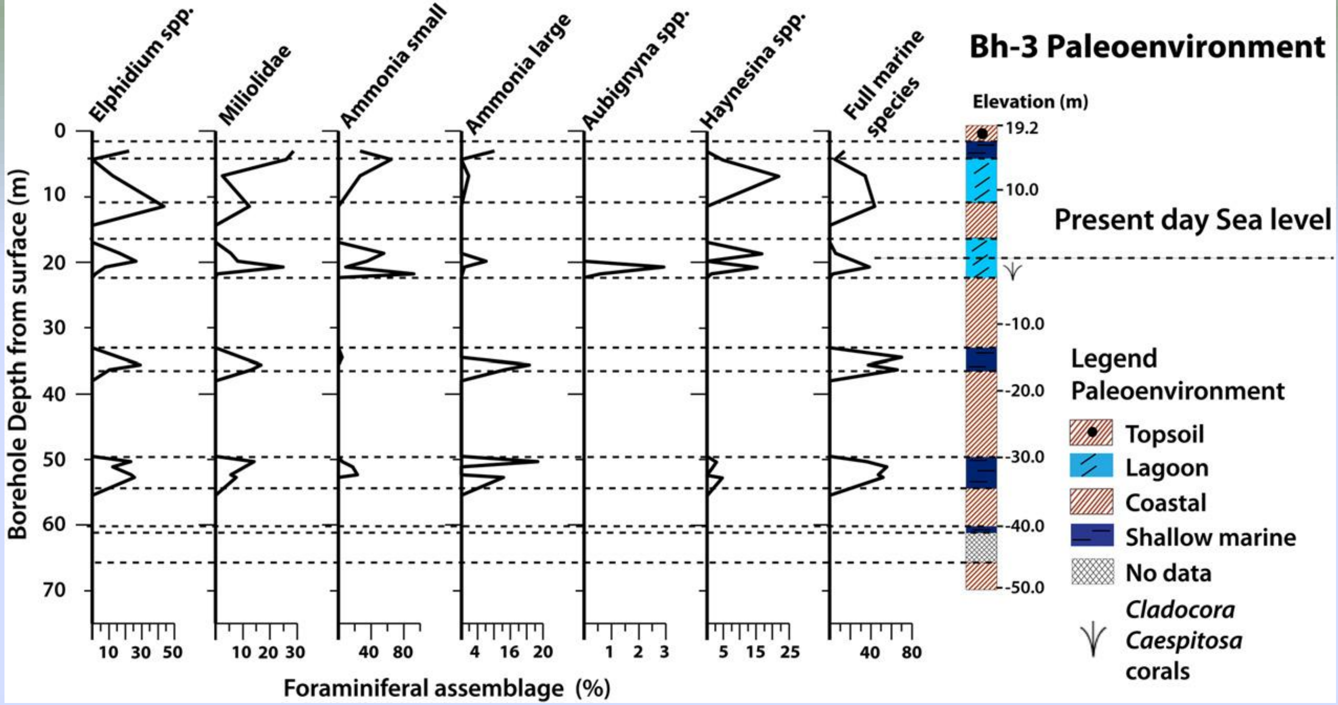
Cresta Zones	EQ Model	SF	EQ Model vs SF
10	105,001,002.52 €	87,906,833.19 €	-19%
11	88,814,524.13 €	113,844,132.52 €	22%
12	60,514,798.39 €	67,062,518.50 €	10%
13	98,882,903.62 €	165,027,418.95 €	40%
14	133,530,321.75 €	311,892,996.11 €	57%
15	183,199,273.47 €	188,617,594.92 €	3%
16	65,528,377.75 €	43,926,033.97 €	-49%
17	106,461,433.82 €	129,274,302.00 €	18%
18	164,988,844.74 €	207,146,262.87 €	20%
19	306,192,171.01 €	251,562,112.28 €	-22%

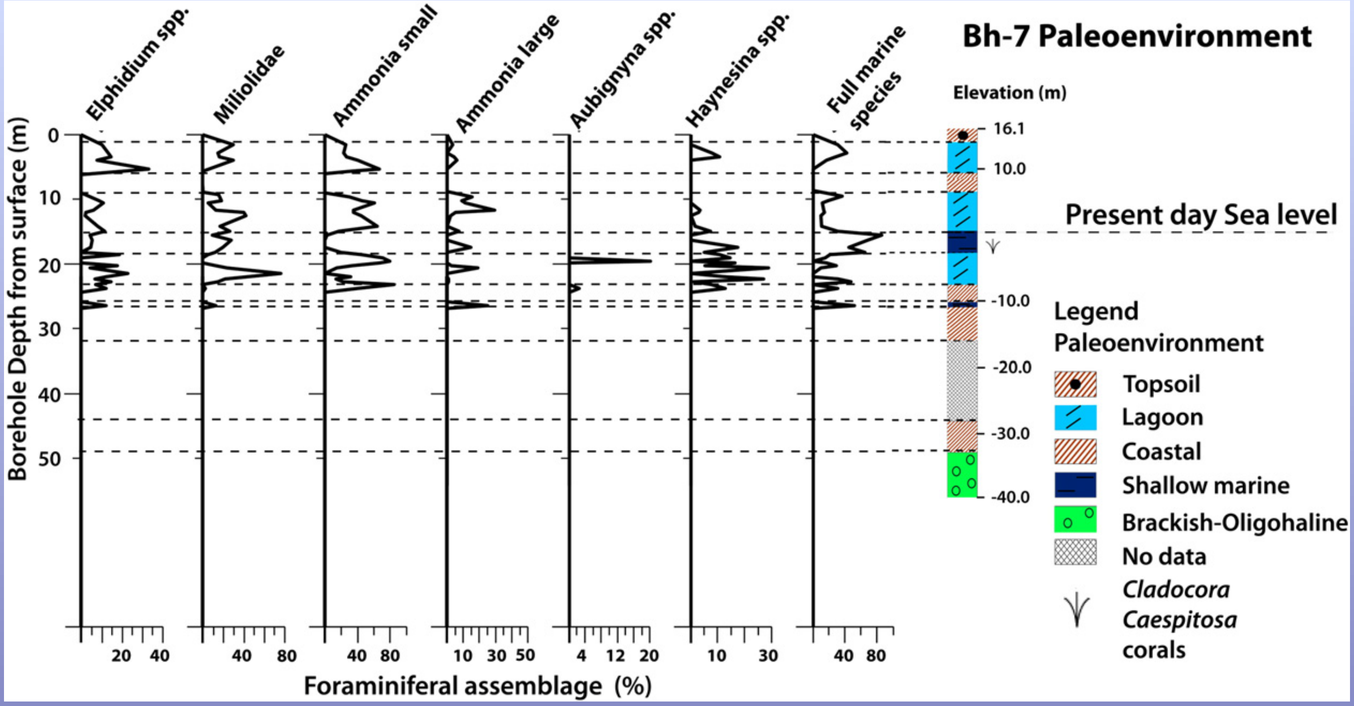
Αγωγός Αγ. Θεοδώρων – Μεγαλόπολης
Ρήγμα στον Ισθμό
Μελέτη με γεωτρήσεις

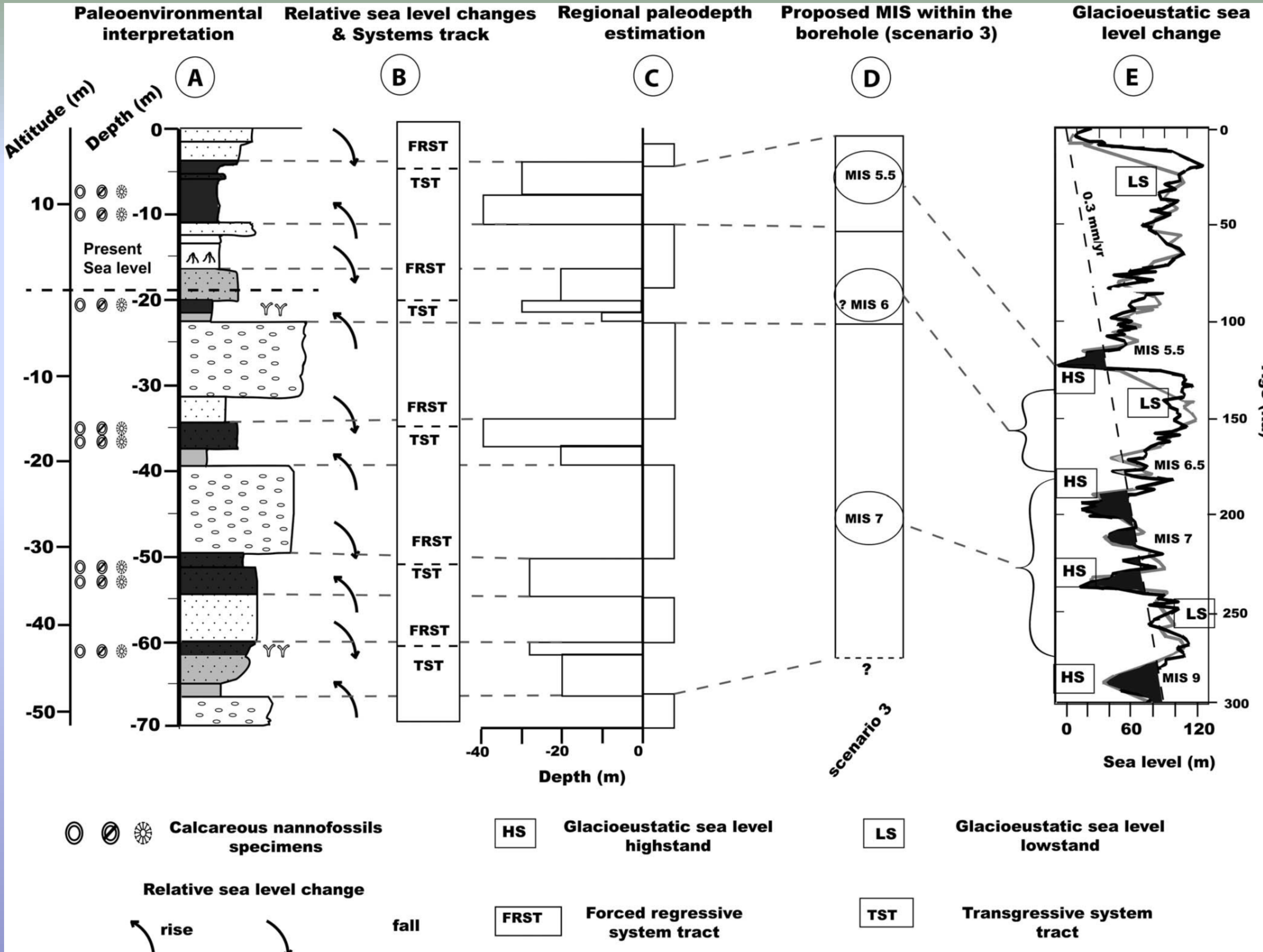




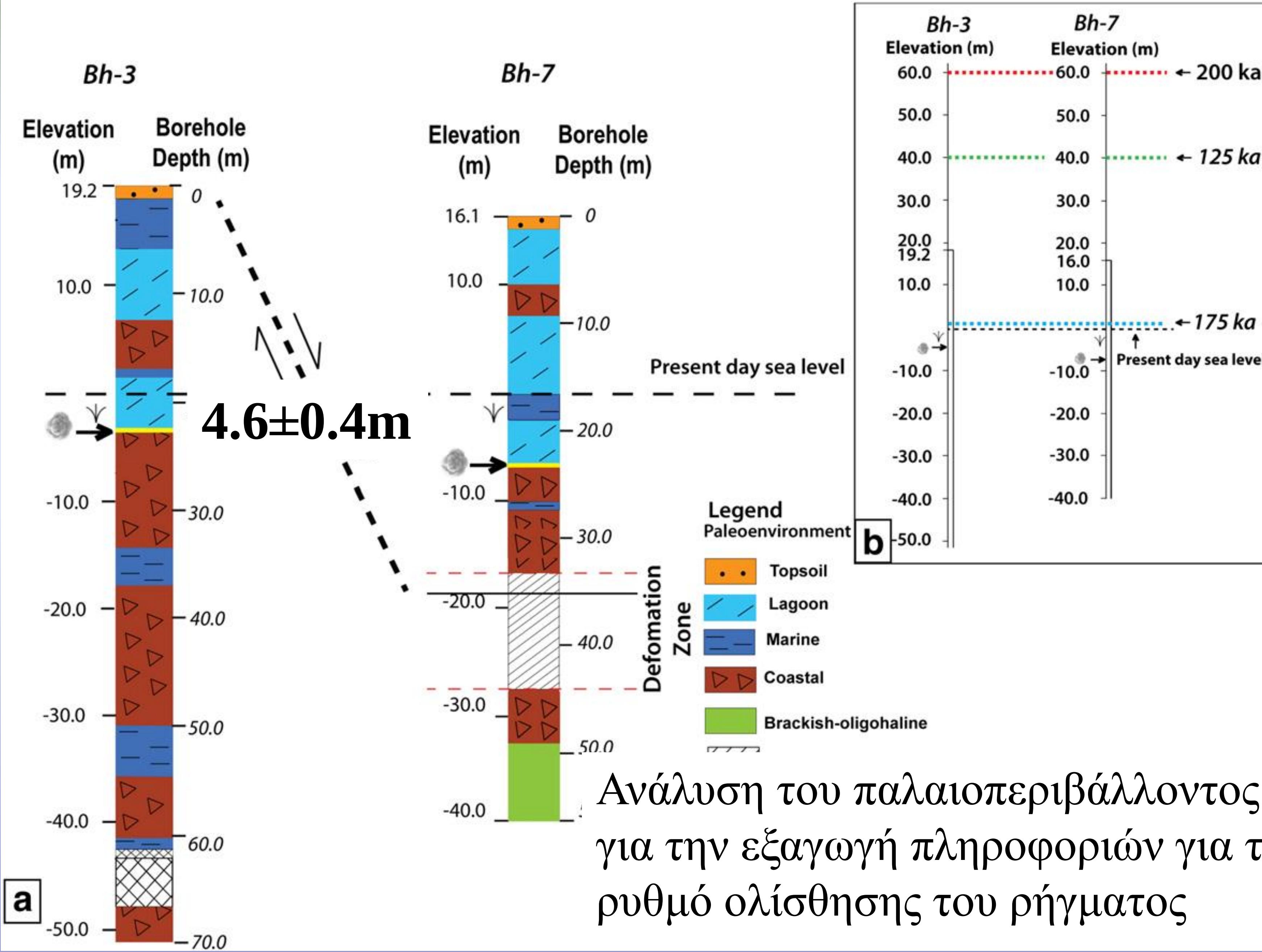
Papanikolaou et al. 2015 Geomorphology


Bh-3 Paleoenvironment
Elphidium spp.
Miliolidae
Ammonia small
Ammonia large
Aubignyna spp.
Haynesina spp.
Full marine species
Borehole Depth from surface (m)
Foraminiferal assemblage (%)
Elevation (m)
Present day Sea level
Legend
Paleoenvironment
Topsoil
Lagoon
Coastal
Shallow marine
No data
Cladocora Caespitosa corals


Bh-7 Paleoenvironment
Elphidium spp.
Miliolidae
Ammonia small
Ammonia large
Aubignyna spp.
Haynesina spp.
Full marine species
Borehole Depth from surface (m)
Foraminiferal assemblage (%)
Elevation (m)
Present day Sea level
Legend
Paleoenvironment
Topsoil
Lagoon
Coastal
Shallow marine
Brackish-Oligohaline
No data
Cladocora Caespitosa corals



Pallikarakis et al. (2018) JCR

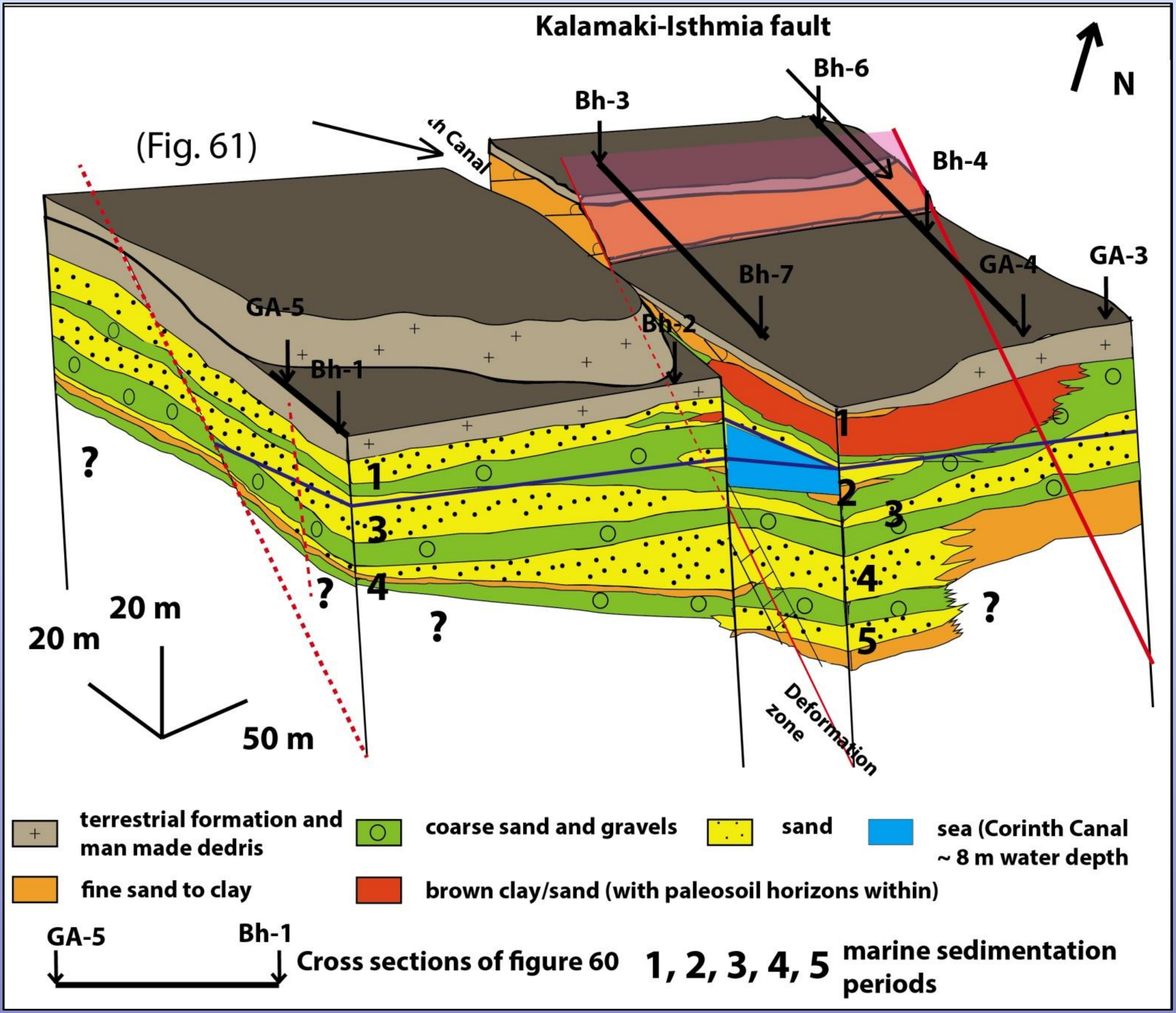


Ανάλυση του παλαιοπεριβάλλοντος για την εξαγωγή πληροφοριών για τον ρυθμό ολίσθησης του ρήγματος

Papanikolaou et al. 2015 Geomorphology

Multidisciplinary Studies

3D visualization and paleoenvironmental interpretation



3D sketch of the study area based on the boreholes description.

Numbers 1-5 show the correlation among the sediments described at the 3-D sketch with the borehole Bh-3

Pallikarakis et al. (2018)

Paleoseismic Trenching and Evaluation of the Symvoli – Fotolivos and Tholos – Nea Zichni Fault zones in Northern Greece

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James Hengesh [(2)], Pavlos Dafnis [(3)], Anestis Panagopoulos [(3)],
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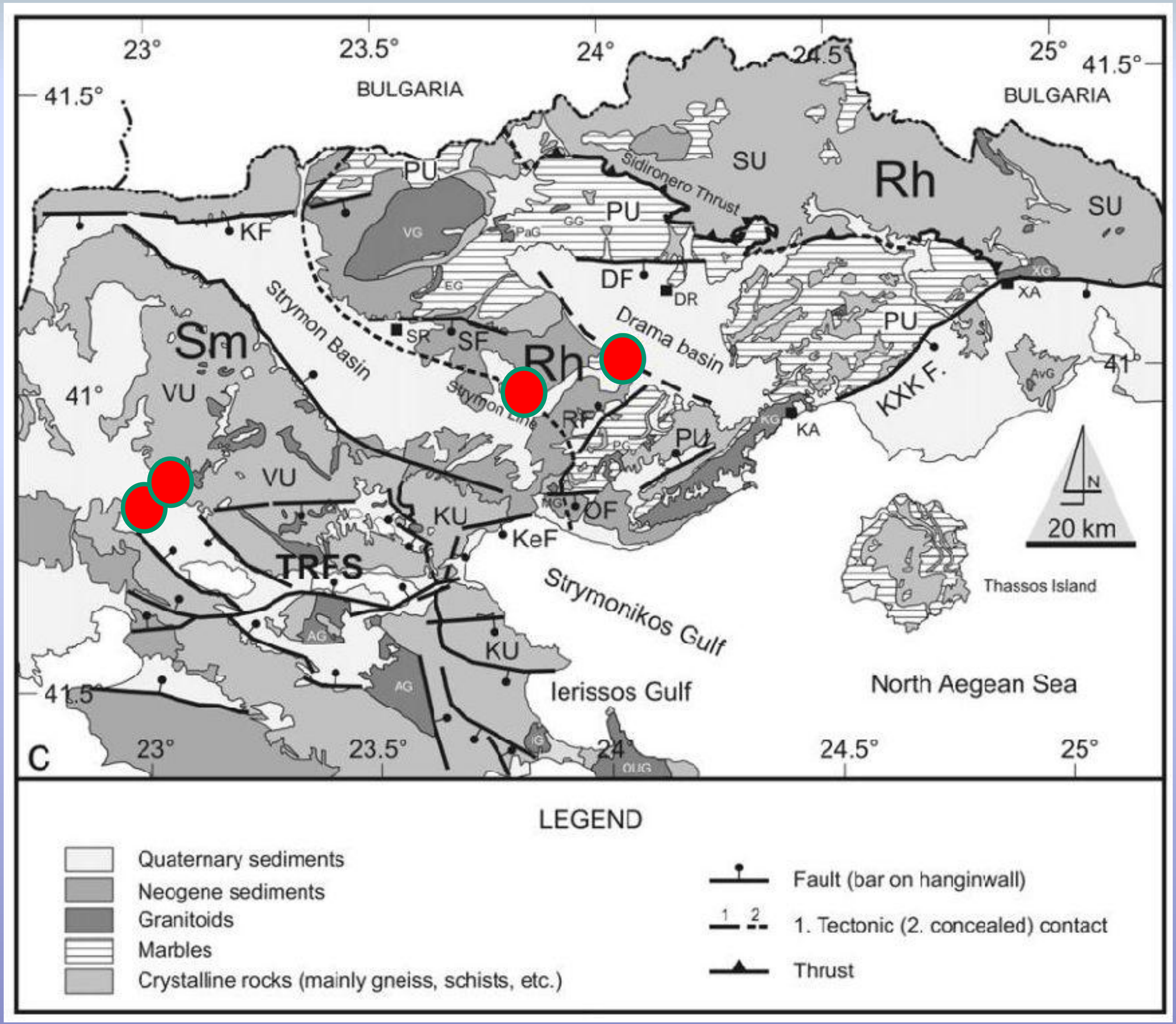
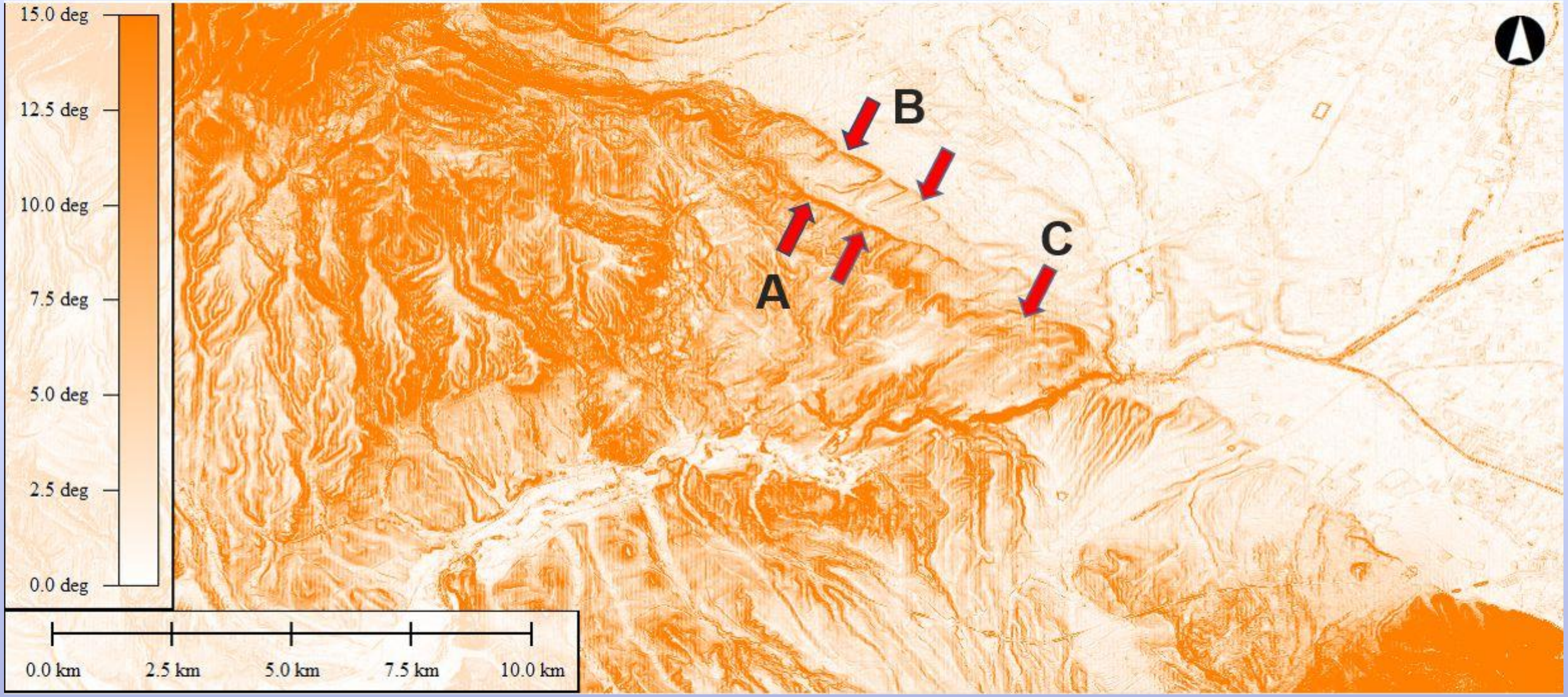
(1) Mineralogy-Geology Laboratory, Section of Geological Sciences, Department of Natural Resources and Agricultural Engineering, Agricultural University of Athens
(2) Interface Geohazard Consulting LLC, USA
(3) Geoskopio SA – EDAFOMICHANIKI GROUP, Greece
(4) Edafos Engineering Consultants SA, Greece

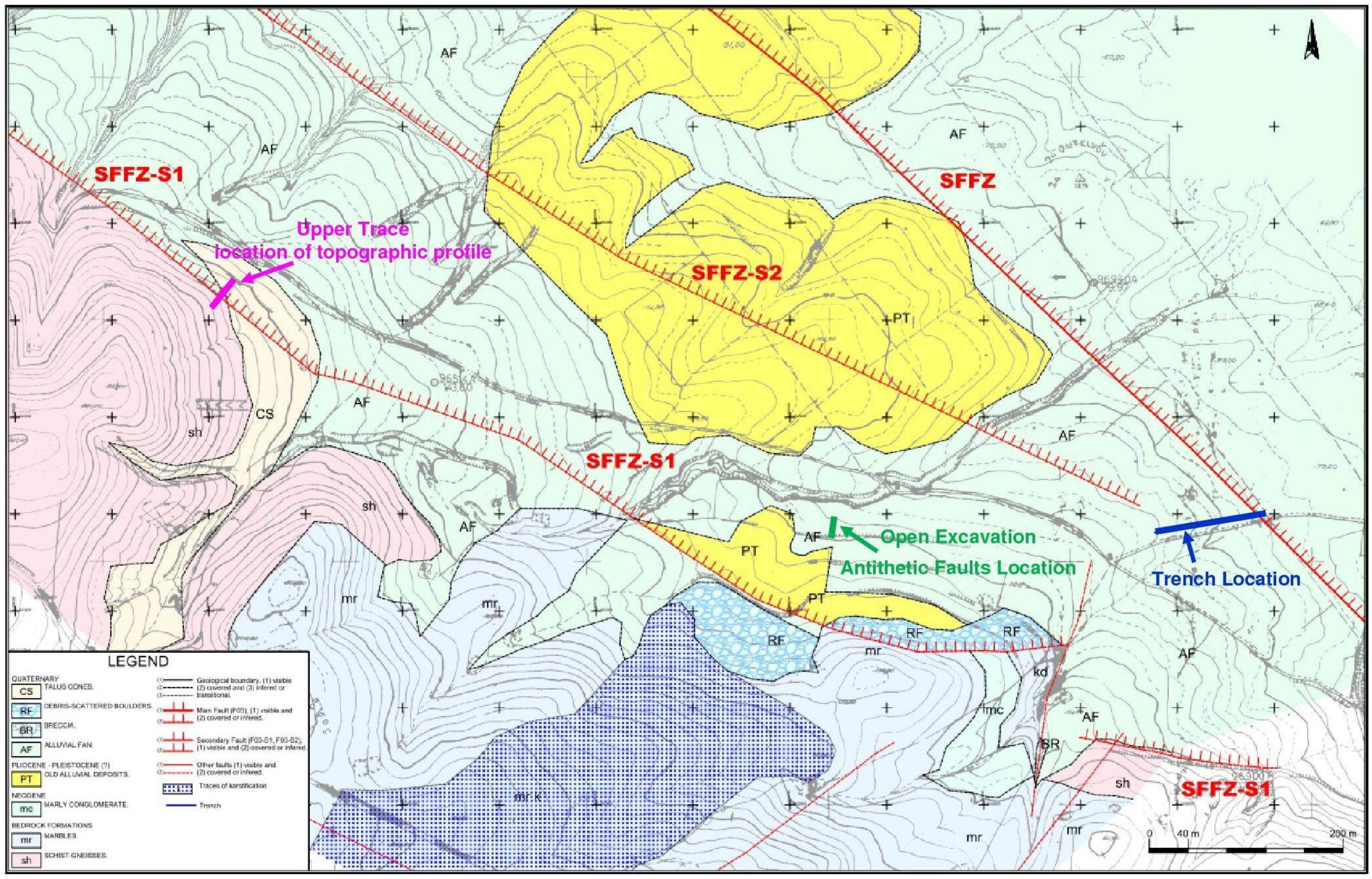


Sites examined in this study

Tranos 2011



Slope map of the wider study area.
The three topographic anomalies are clearly identified

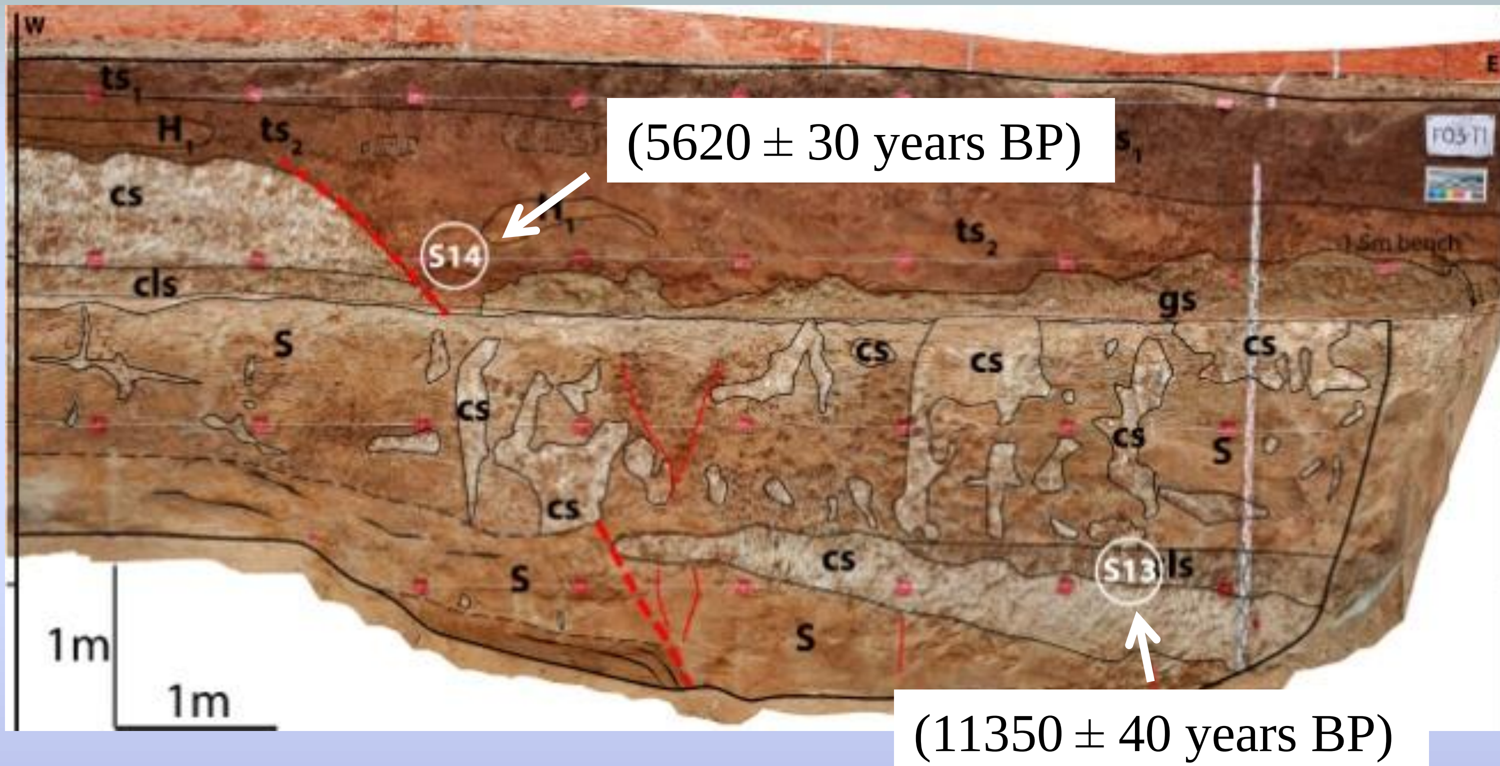


The fault dips towards the NE (045°)

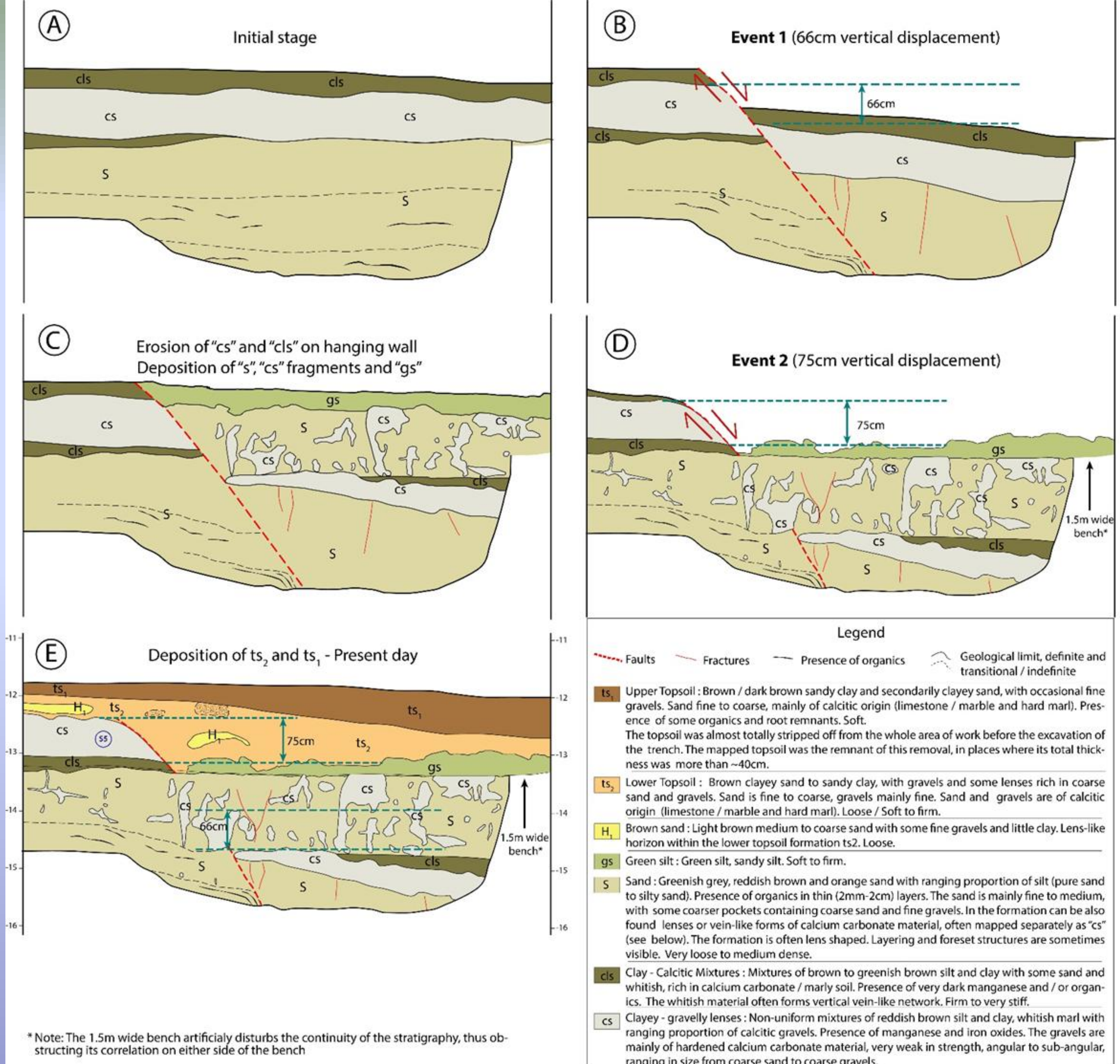
Westward view of the 221m long trench.

Photogrammetry combined with a Base and Rover GPS

- Installation of grid (1X1m)
- 430 images, with at least 70% side overlap and nearly 90% vertical overlap.
- 72 evenly distributed points on the preinstalled grid were used as ground control points (GCPs) and were accurately measured by a Base & Rover GPS
- The image dataset was then photogrammetrically processed in order to create a sparse point cloud, a dense point cloud, a mesh and a texture for the entire trench wall model.
- The final products were 2 high resolution orthomosaics,
    - one for the whole length of the trench with 3mm pixel size and
    - one for the 18m long active fault area with 1mm pixel size

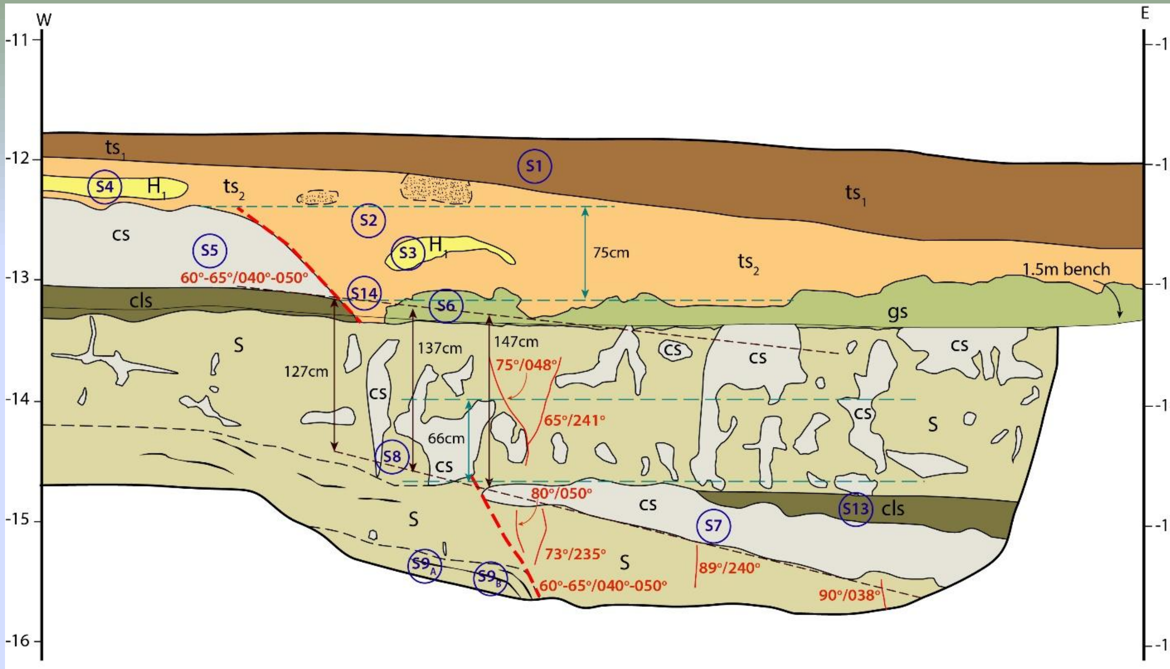


Interpretation on the photomosaic depicting all major boundaries and trench stratigraphy



Retrodeformation and graphic reconstruction

Final Trench mapping and legend



- Presence of organics
- Geological limit, definite and transitional / indefinite
- Fractures / Faults
- 80°/050° Measured dip and dip direction of geological surfaces
- S2 Sample locations
- 1.5m wide bench
- Preferred displacement scenario
- Conservative displacement scenario

ts1 Upper Topsoil : Brown / dark brown sandy clay and secondarily clayey sand, with occasional fine gravels. Sand fine to coarse, mainly of calcitic origin (limestone / marble and hard marl). Presence of some organics and root remnants. Soft. The topsoil was almost totally stripped off from the whole area of work before the excavation of the trench. The mapped topsoil was the remnant of this removal, in places where its total thickness was more than ~40cm.

ts2 Lower Topsoil : Brown clayey sand to sandy clay, with gravels and some lenses rich in coarse sand and gravels. Sand is fine to coarse, gravels mainly fine. Sand and gravels are of calcitic origin (limestone / marble and hard marl). Loose / Soft to firm.

H1 Brown sand : Light brown medium to coarse sand with some fine gravels and little clay. Lens-like horizon within the lower topsoil formation ts2. Loose.

gs Green silt : Green silt, sandy silt. Soft to firm

S Sand : Greenish grey, reddish brown and orange sand with ranging proportion of silt (pure sand to silty sand). Presence of organics in thin (2mm-2cm) layers. The sand is mainly fine to medium, with some coarser pockets containing coarse sand and fine gravels. In the formation can be also found lenses or vein-like forms of calcium carbonate material, often mapped separately as "cs" (see below). The formation is often lens shaped. Layering and foreset structures are sometimes visible. Very loose to medium dense.

cls Clay - Calcitic Mixtures : Mixtures of brown to greenish brown silt and clay with some sand and whitish, rich in calcium carbonate / marly soil. Presence of very dark manganese and / or organics. The whitish material often forms vertical vein-like network. Firm to very stiff.

cs Clayey - gravelly lenses : Non-uniform mixtures of reddish brown silt and clay, whitish marl with ranging proportion of calcitic gravels. Presence of manganese and iron oxides. The gravels are mainly of hardened calcium carbonate material, very weak in strength, angular to sub-angular, ranging in size from coarse sand to coarse gravels.

The preferred displacement scenario suggests two events with vertical displacements of 66 cm (penultimate event 11350±40 BP) and 75 cm (most recent event ~5620 ± 30 years ago), implying an approximate 0.12 mm/yr throw-rate and 0.14 mm/yr slip-rate, respectively

Conclusions

- The Symvoli – Fotolivos Fault Zone (SFFZ) has a segment length of **32 km,** impacts on the landscape and has been traced in the trench.

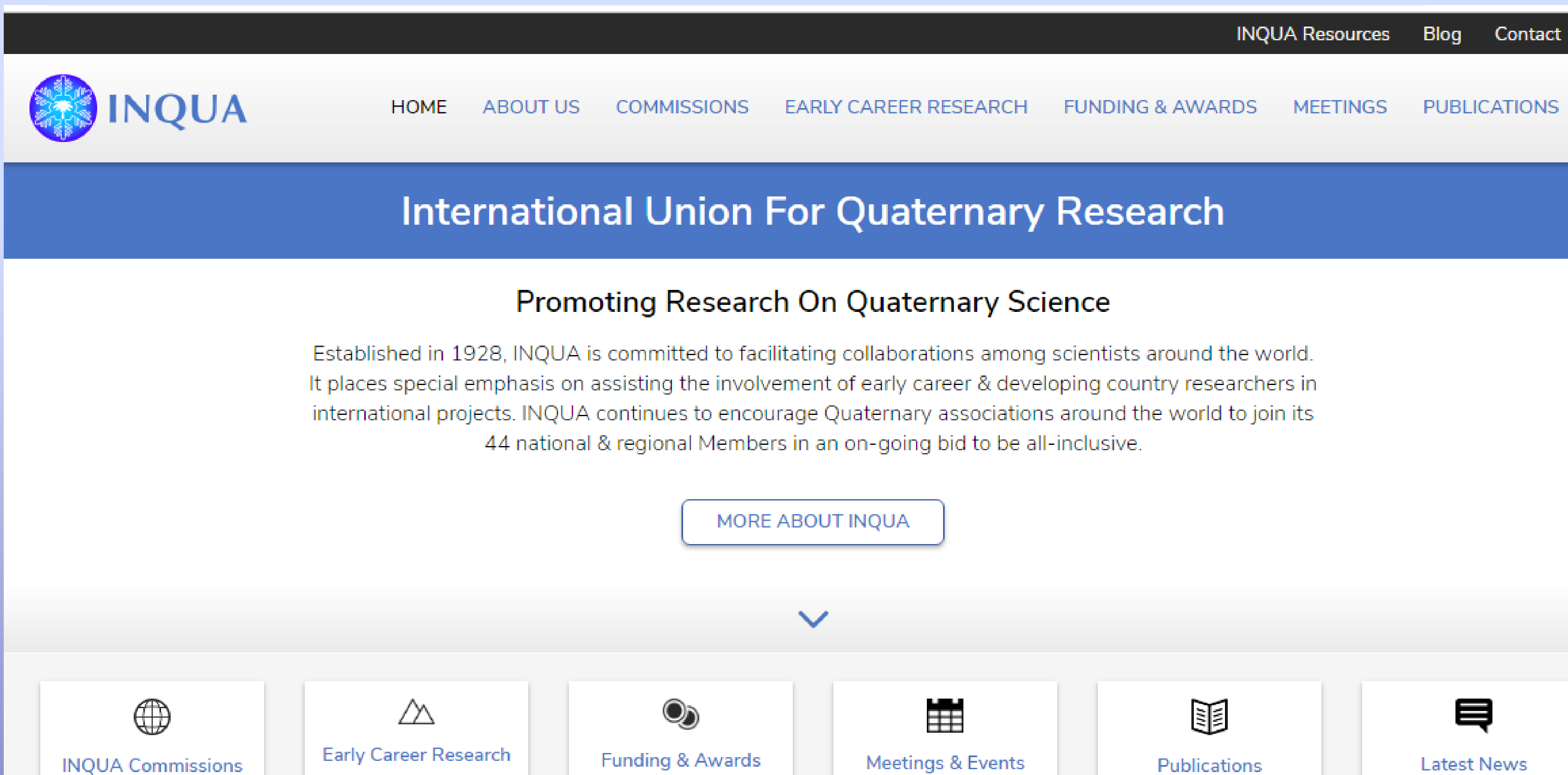
- The preferred displacement scenario suggests **two events** with vertical displacements **of 66 cm** (penultimate event **11350±40 yrs BP**) and **75 cm** (most recent event ~**5620 ± 30 yrs BP**), implying a <u>0.12 mm/yr throw-rate and 0.14 mm/yr slip-rate</u>, respectively, with <u>earthquake recurrence intervals on the order of 5700 yrs.</u>

- **No major historical or instrumental earthquakes** can be correlated with this fault and this might be due to its long recurrence interval

International Union for Quaternary Science (INQUA)
Διεθνής Ενωση για την Ερευνα του Τεταρτογενούς

(established in 1928)

encourage, facilitate and coordinate the research of Quaternary scientists in all disciplines



International Focus Group

Earthquake Geology and Seismic Hazards

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INQUA IFG 1618F EGSHaz (Earthquake Geology and Seismic Hazards)

The main scope of the EGSHaz IFG is the understanding of past earthquakes and future seismic risks using Quaternary geology. This includes multiple disciplines that contribute to understanding Quaternary earthquake activity, such as palaeoseismology, active tectonics and neotectonic studies, tectonic geomorphology, archaeoseismology, and seismology. IFG EGSHaz promotes interdisciplinary approaches and multi-proxy studies to comprehensively understand the effects that seismic events have on society and on the environment and to improve seismic hazard assessment. This is done in part by co-operation with other IFGs, especially those that work on Quaternary dating methods, Quaternary stratigraphy and soil science, and liaisons with a broader spectrum of Quaternary researchers. The activity of the IFG is focused on the study of coseismic environmental effects and their integral expression in the Quaternary record. Recent progresses in the field of paleoseismology have clearly shown that earthquake effects on natural environment are more strictly related to the earthquake magnitude than effects on humans and manmade structures.

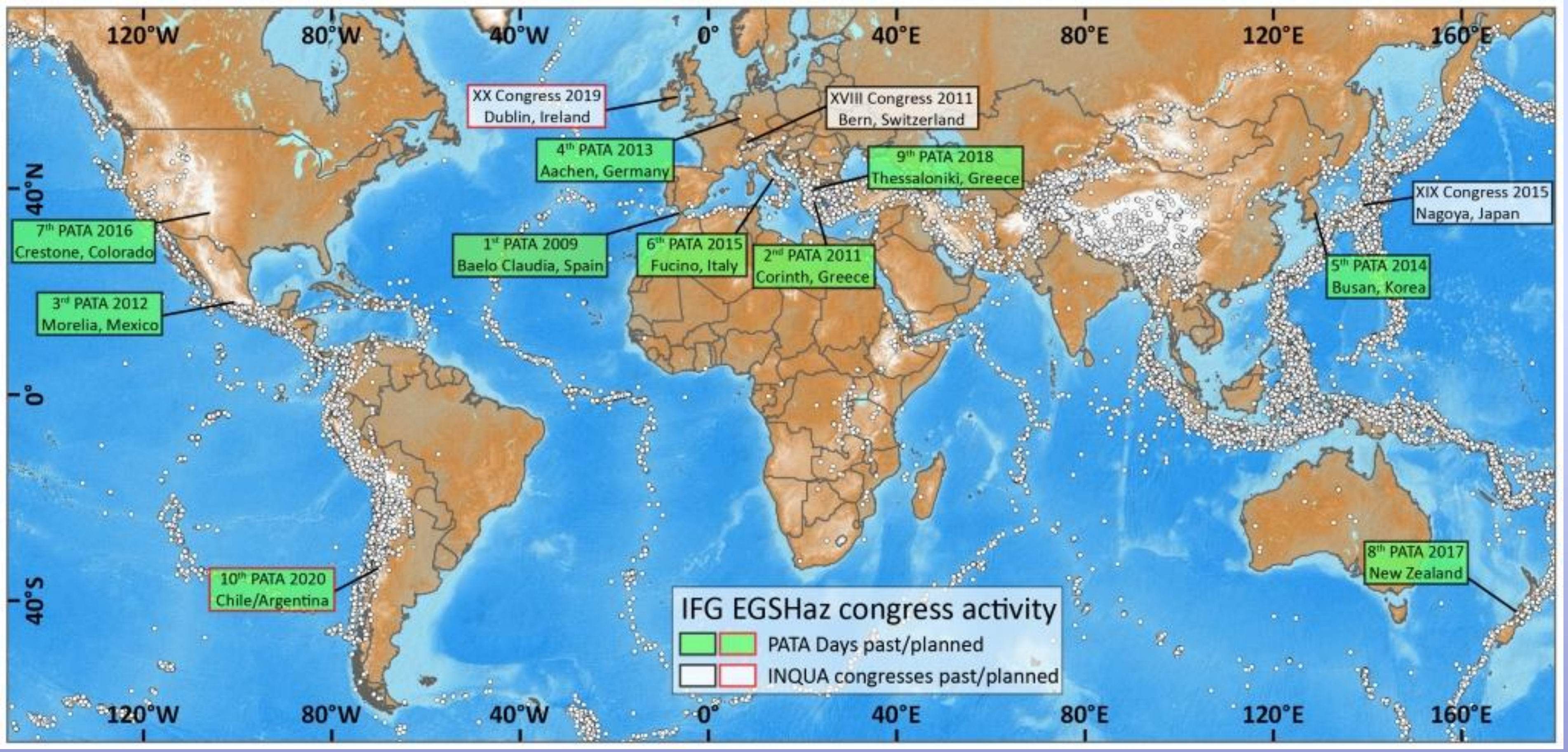
Leaders: Ioannis Papanikolaou (Greece); Petra Štěpančíková (Czech Republic); Christoph Grützner (Germany)

Contact: Dr I. Papanikolaou (i.pap@aua.gr)

Website link: http://www.earthquakegeology.com

http://www.earthquakegeology.com/

Meetings of the International Focus Group



INQUA summer school on active tectonics and tectonic geomorphology,

24 September - 27 September 2019
Prague, Czech Academy of Sciences

The summer school mainly MSc./PhD students