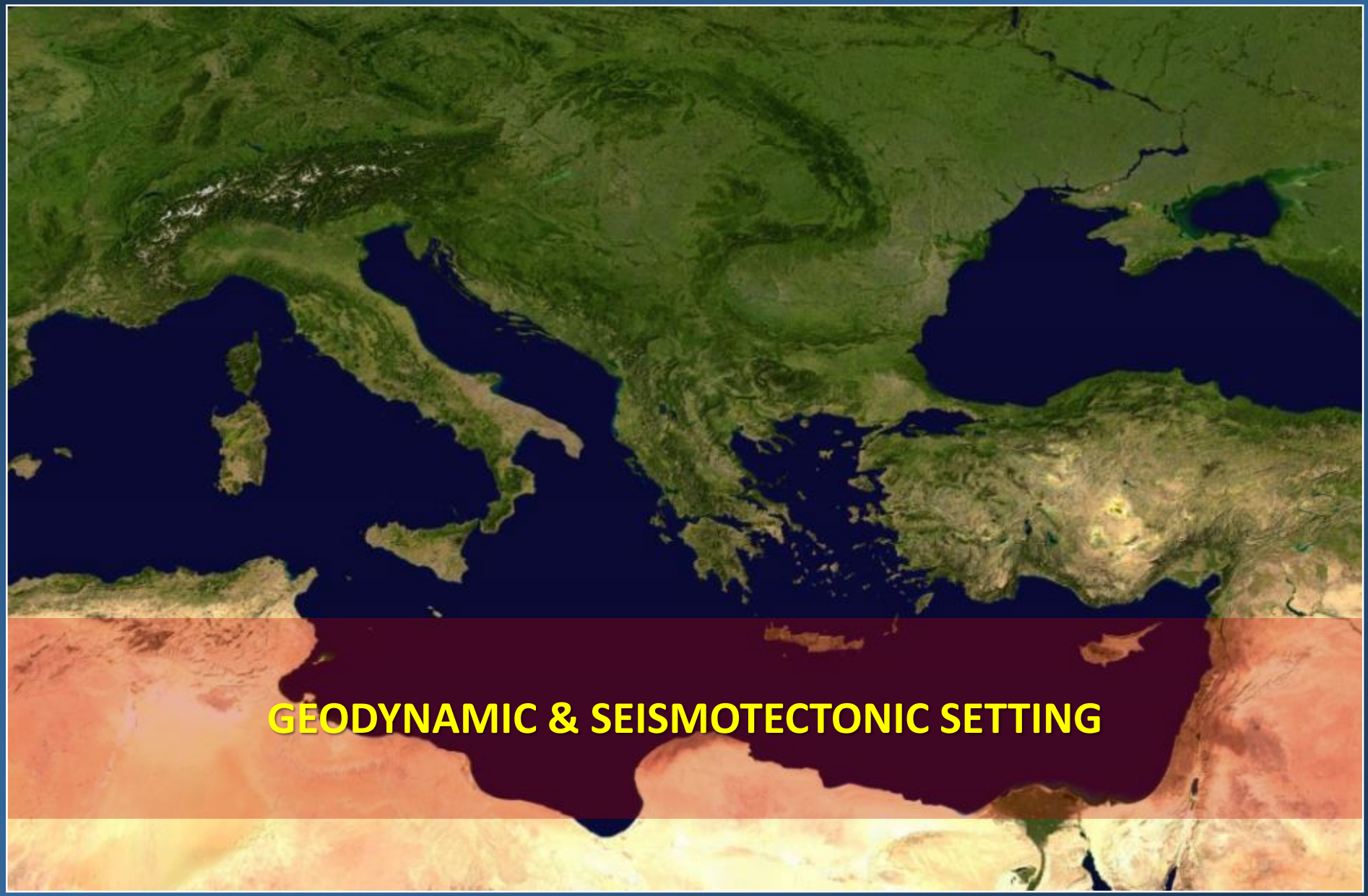
NATIONAL & KAPODISTRIAN UNIVERSITY OF ATHENS
POST GRADUATE PROGRAM
ENVIRONMENTAL, DISASTER AND CRISES MANAGEMENT

**Δρ. ΕΥΘΥΜΗΣ ΛΕΚΚΑΣ**
**ΚΑΘΗΓΗΤΗΣ**
ΔΥΝΑΜΙΚΗΣ ΤΕΚΤΟΝΙΚΗΣ ΕΦΑΡΜΟΣΜΕΝΗΣ ΓΕΩΛΟΓΙΑΣ &
ΔΙΑΧΕΙΡΙΣΗΣ ΦΥΣΙΚΩΝ ΚΑΤΑΣΤΡΟΦΩΝ
**ΠΡΟΕΔΡΟΣ**
ΟΡΓΑΝΙΣΜΟΥ ΑΝΤΙΣΕΙΣΜΙΚΟΥ ΣΧΕΔΙΑΣΜΟΥ & ΠΡΟΣΤΑΣΙΑΣ
**π. ΠΡΟΕΔΡΟΣ**
ΕΛΛΗΝΙΚΗΣ ΓΕΩΛΟΓΙΚΗΣ ΕΤΑΙΡΙΑΣ
**ΔΙΕΥΘΥΝΤΗΣ**
ΠΜΣ ΣΤΡΑΤΙΓΙΚΕΣ ΔΙΑΧΕΙΡΙΣΗΣ ΠΕΡΙΒΑΛΛΟΝΤΟΣ ΚΑΤΑΣΤΡΟΦΩΝ ΚΑΙ ΚΡΙΣΕΩΝ

# ΣΕΙΣΜΙΚΗ ΑΚΟΛΟΥΘΙΑ ΣΤΗΝ ΚΕΝΤΡΙΚΗ ΙΤΑΛΙΑ (ΑΥΓΟΥΣΤΟΥ 2016 ΙΑΝΟΥΑΡΙΟΥ 2017) ΚΑΙ ΑΝΤΙΣΤΟΙΧΙΣΕΙΣ ΜΕ ΤΗΝ ΣΕΙΣΜΙΚΟΤΗΤΑ ΤΟΥ ΕΛΛΗΝΙΚΟΥ ΧΩΡΟΥ

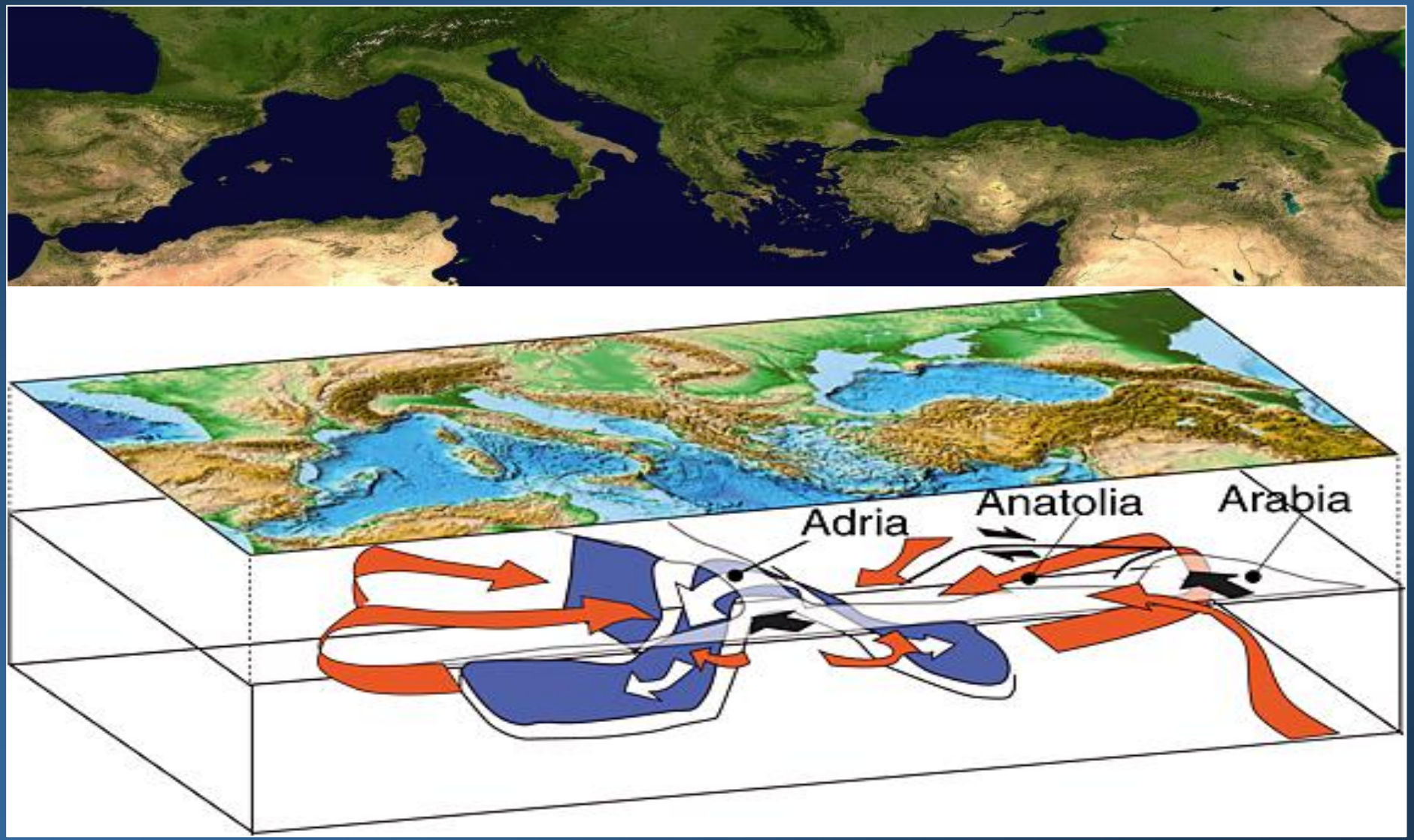
ΑΘΗΝΑ 2017


SABAH
ACI ALLAHIM
EL PAÍS
Newsweek
WHY HAITI MATTERS
BY BARACK OBAMA
star
KIYAMET
KULELERI
THE TIMES
Killer fires ravage Greece
Herald Tribune
EL PAIS
Público
CAOS, SAQUEOS
Y RESCATES
TA NEA
Καταστροφή
BH Magazino
stern
Das unglaubliche Volk
DER SPIEGEL
FUKUSHIMA
Le Point
Quand le destin s'acharne sur les Japonais
La chute d'un géant
855
PLUS: HOW IGNORANT IS AMERICA?
Newsweek
Apocalypse Now
TIME
Haiti's Tragedy
AKŞAM
Sanki kıyame
TIME
The Agony of
KASHMIR

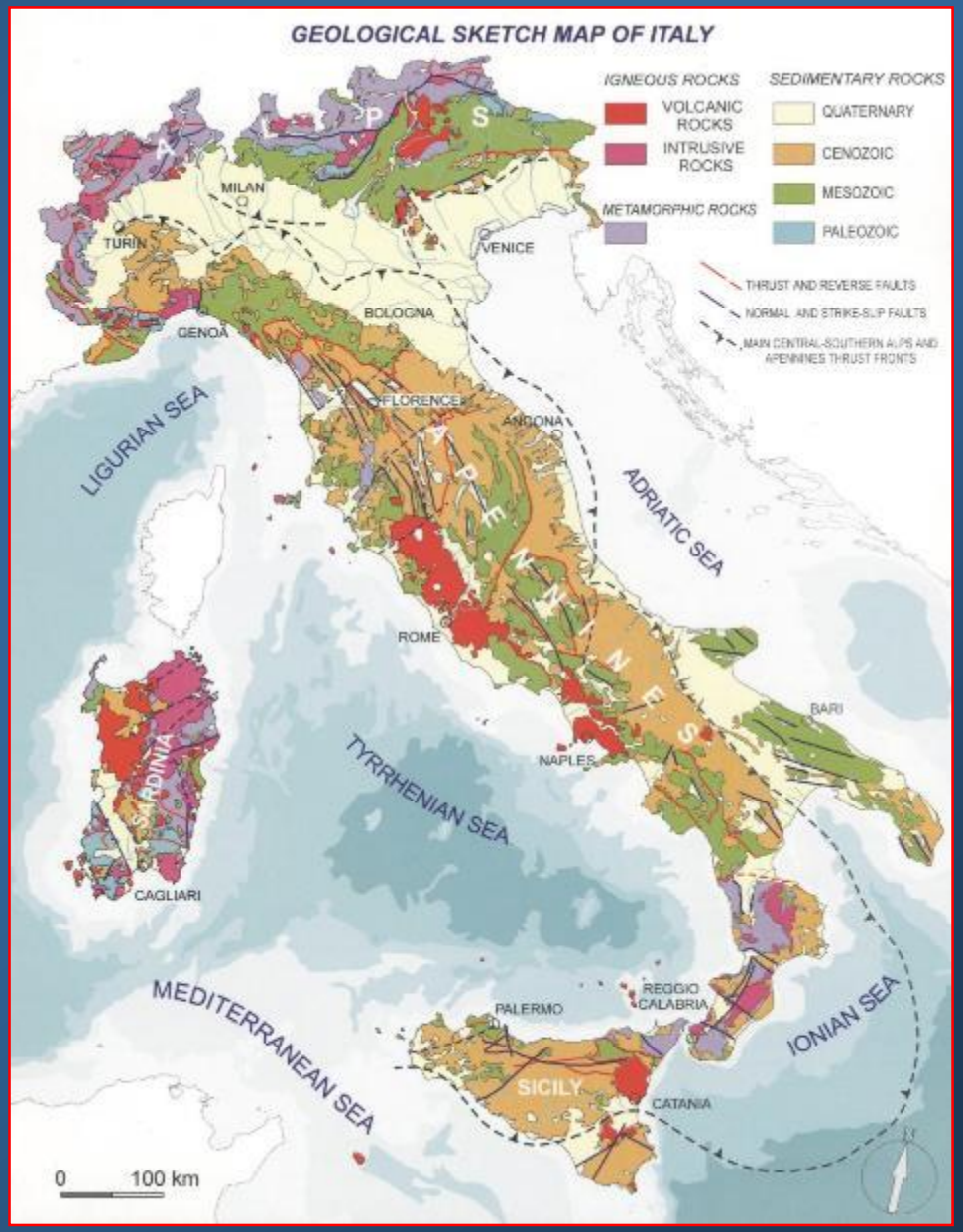


# GEODYNAMIC & SEISMOTECTONIC SETTING

# MANTLE CONVECTION PRESENTLY ACTIVE IN THE MEDITERRANEAN

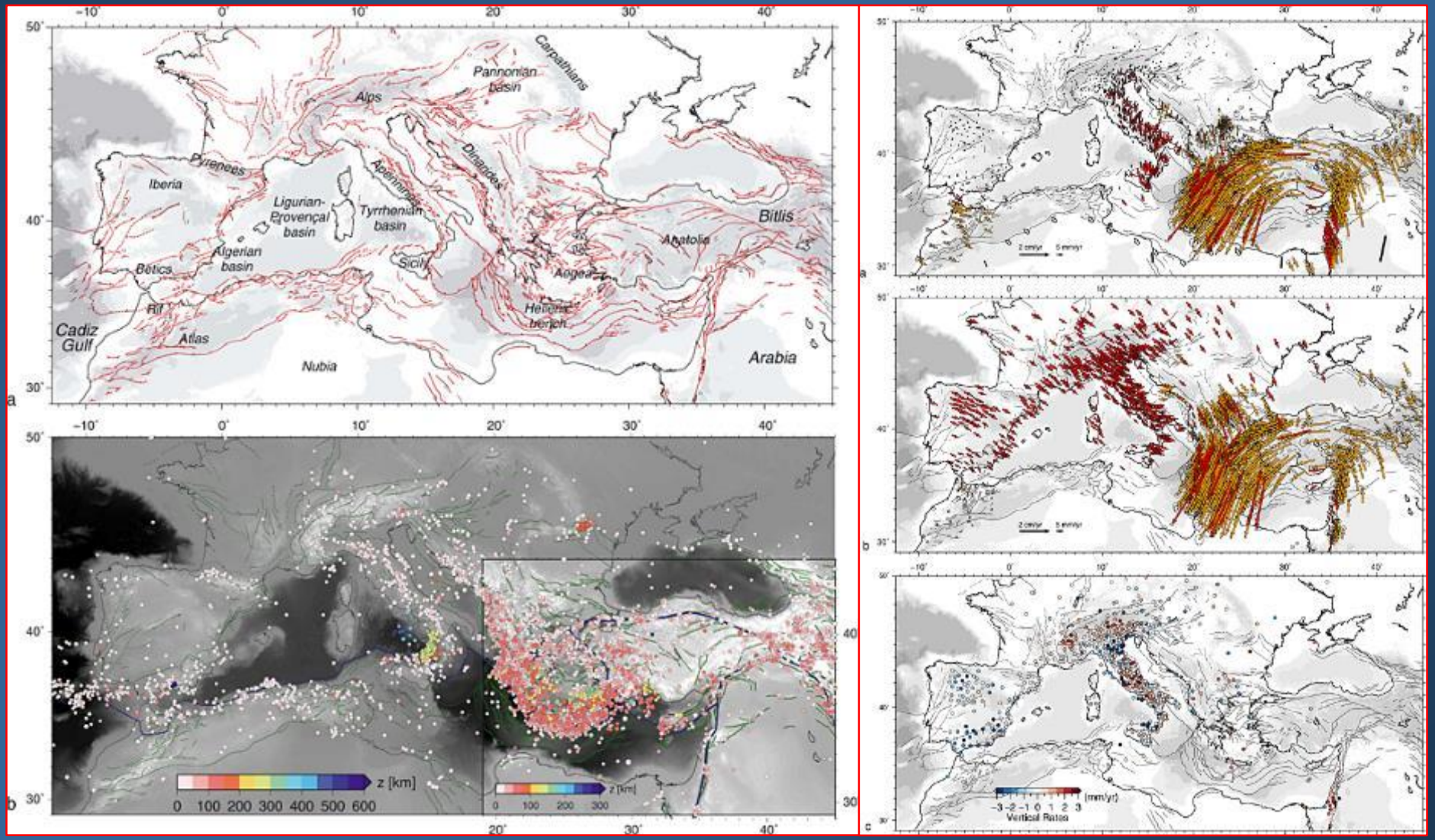


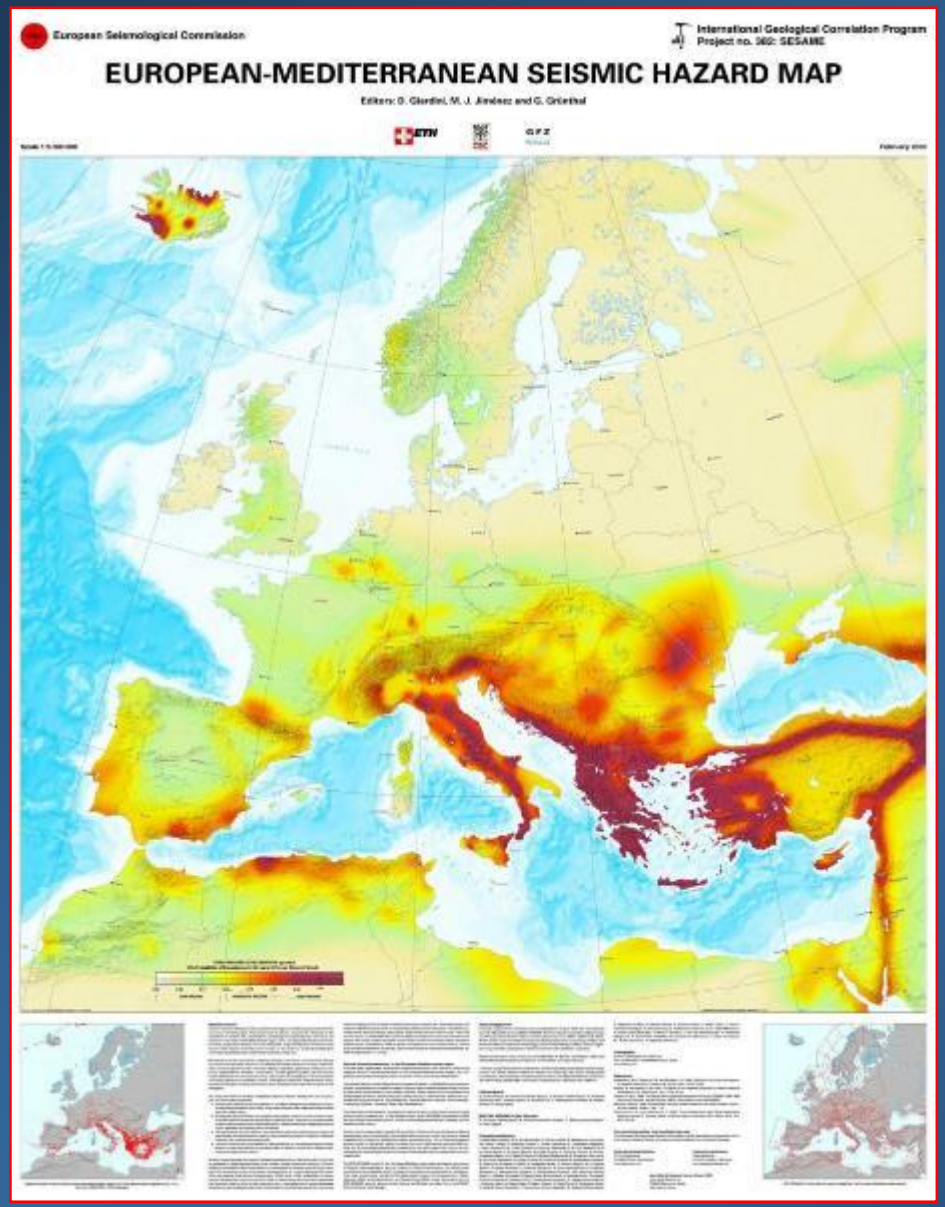

APAT
CARTA GEOLOGICA D'ITALIA


GEOLOGICAL SKETCH MAP OF ITALY
IGNEOUS ROCKS
VOLCANIC ROCKS
INTRUSIVE ROCKS
METAMORPHIC ROCKS
SEDIMENTARY ROCKS
QUATERNARY
CENOZOIC
MESOZOIC
PALEOZOIC
THRUST AND REVERSE FAULTS
NORMAL AND STRIKE-SLIP FAULTS
MAIN CENTRAL-SOUTHERN ALPS AND APENNINES THRUST FRONTS
MILAN
TURIN
VENICE
GENOA
BOLOGNA
FLORENCE
ANCONA
ROME
BARI
NAPLES
CAGLIARI
PALERMO
REGGIO CALABRIA
CATANIA
LIGURIAN SEA
ADRIATIC SEA
TYRRHENIAN SEA
MEDITERRANEAN SEA
IONIAN SEA
SARDINIA
SICILY
0
100 km

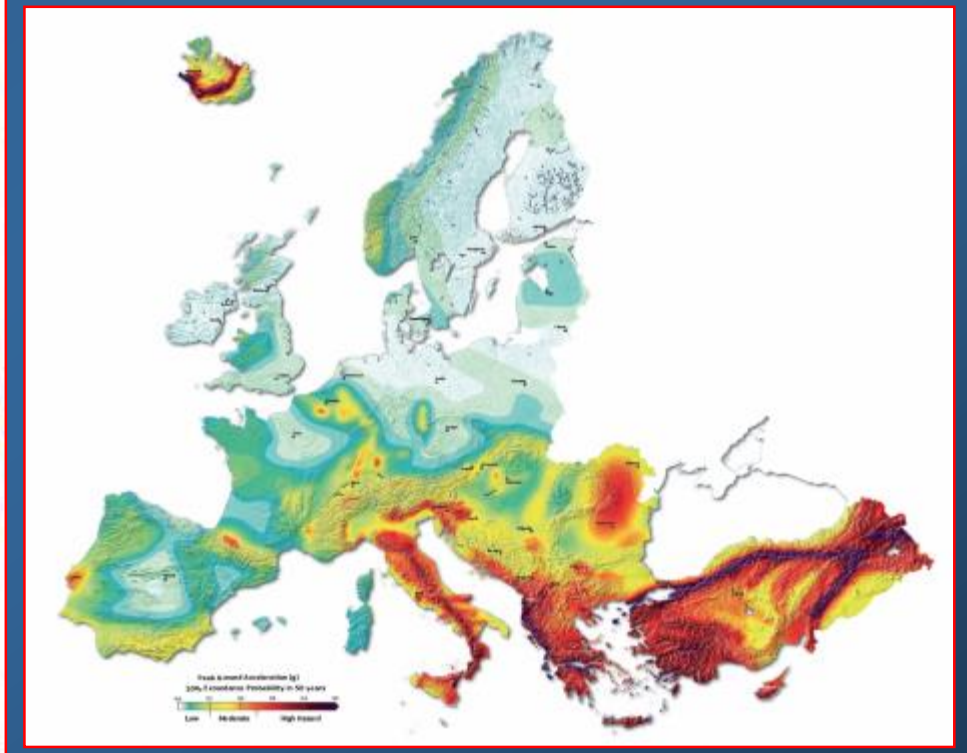
# TECTONIC SEISMIC AND GEODETIC INDICATORS OF LITHOSPHERIC DEFORMATION IN THE MEDITERRANEAN REGION

*Faccenna et al. (2014)*

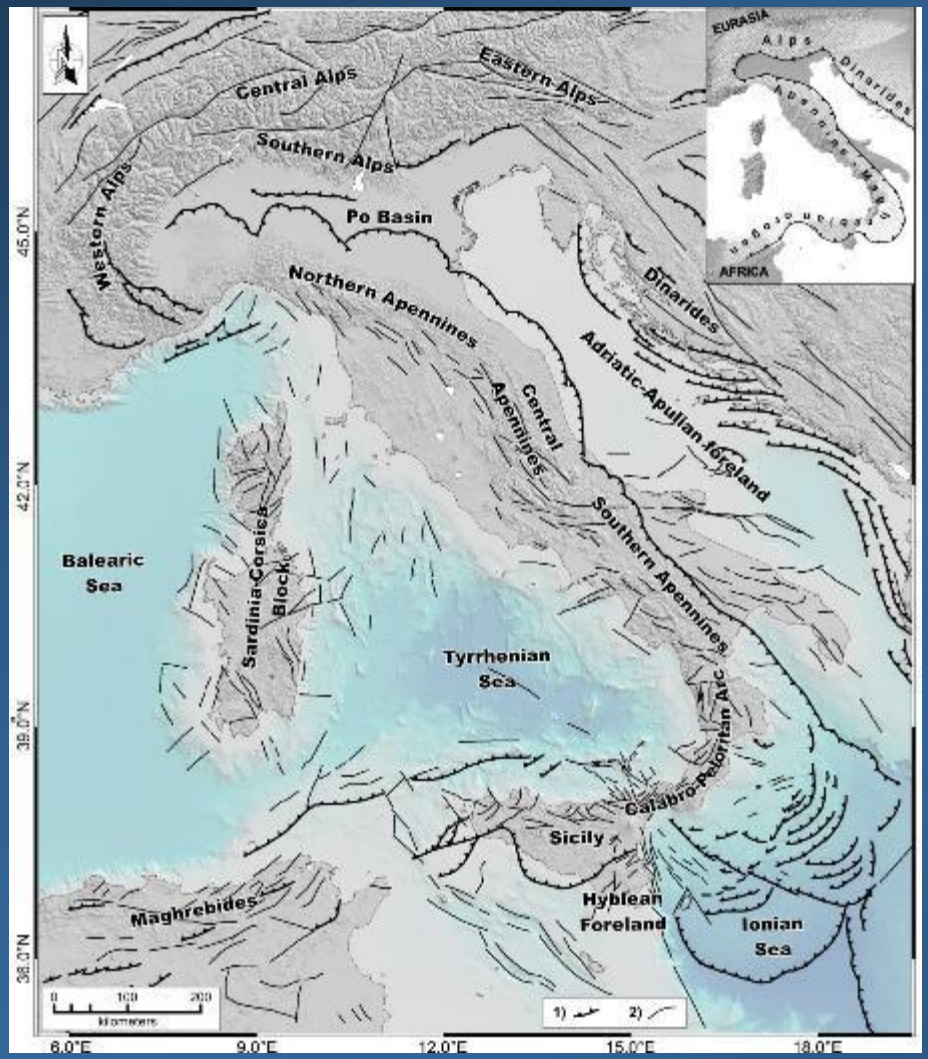


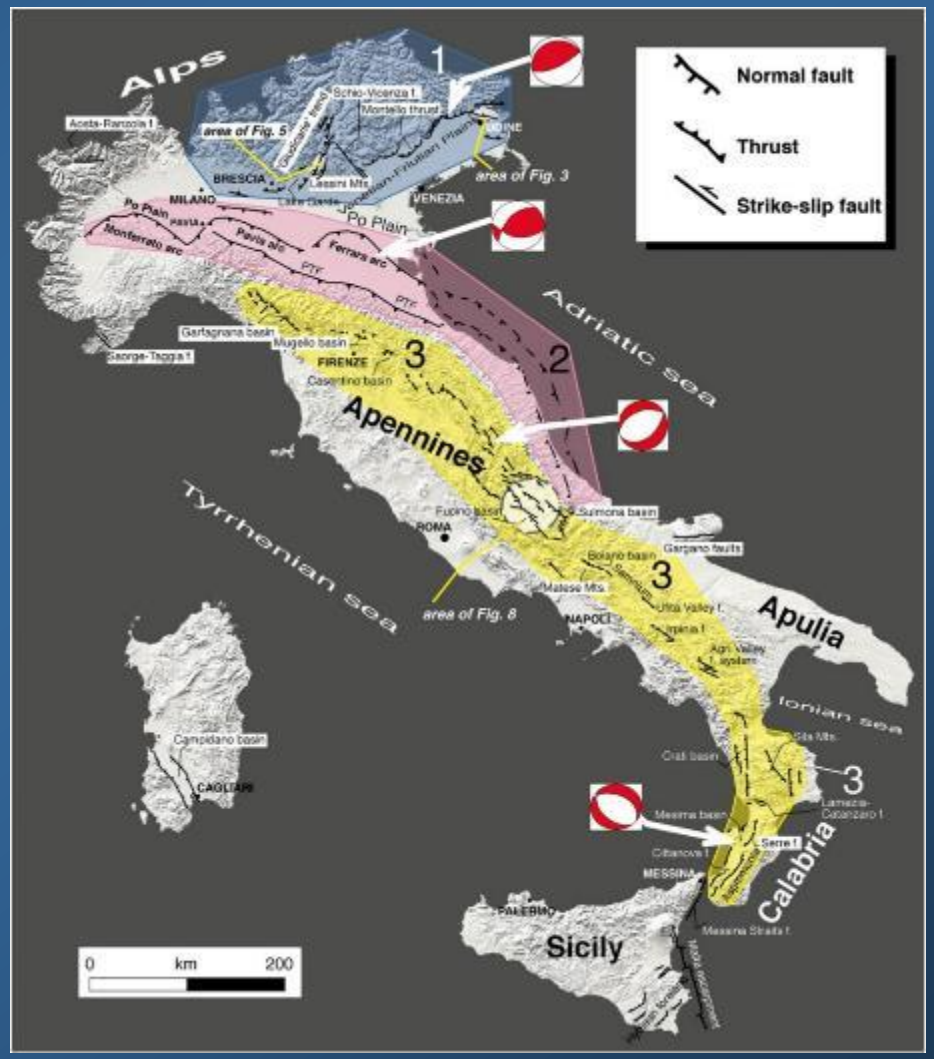



## SEISMIC HAZARD IN THE MEDITERRANEAN



# MAIN TECTONIC LINEAMENTS & MAIN TECTONIC DOMAINS OF ITALY

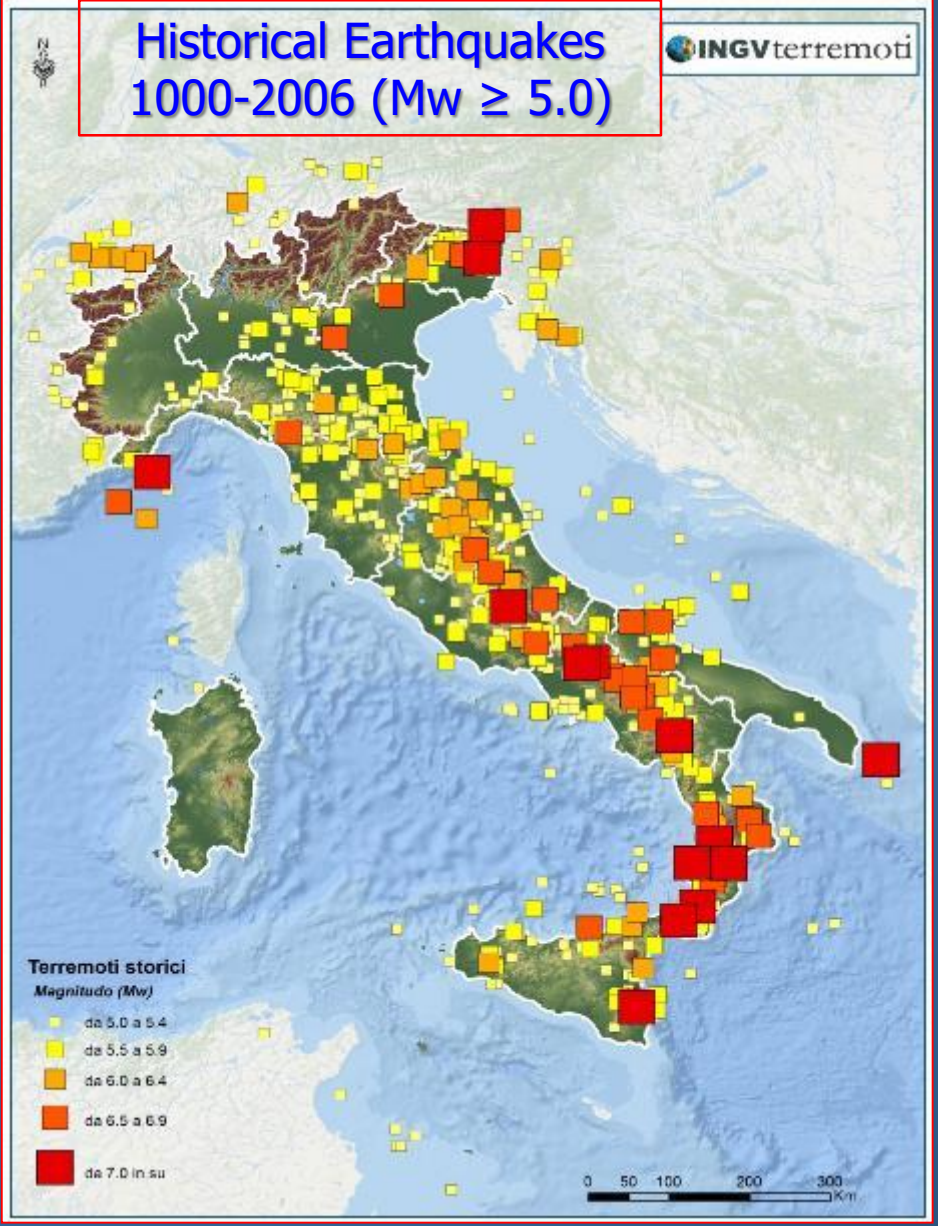


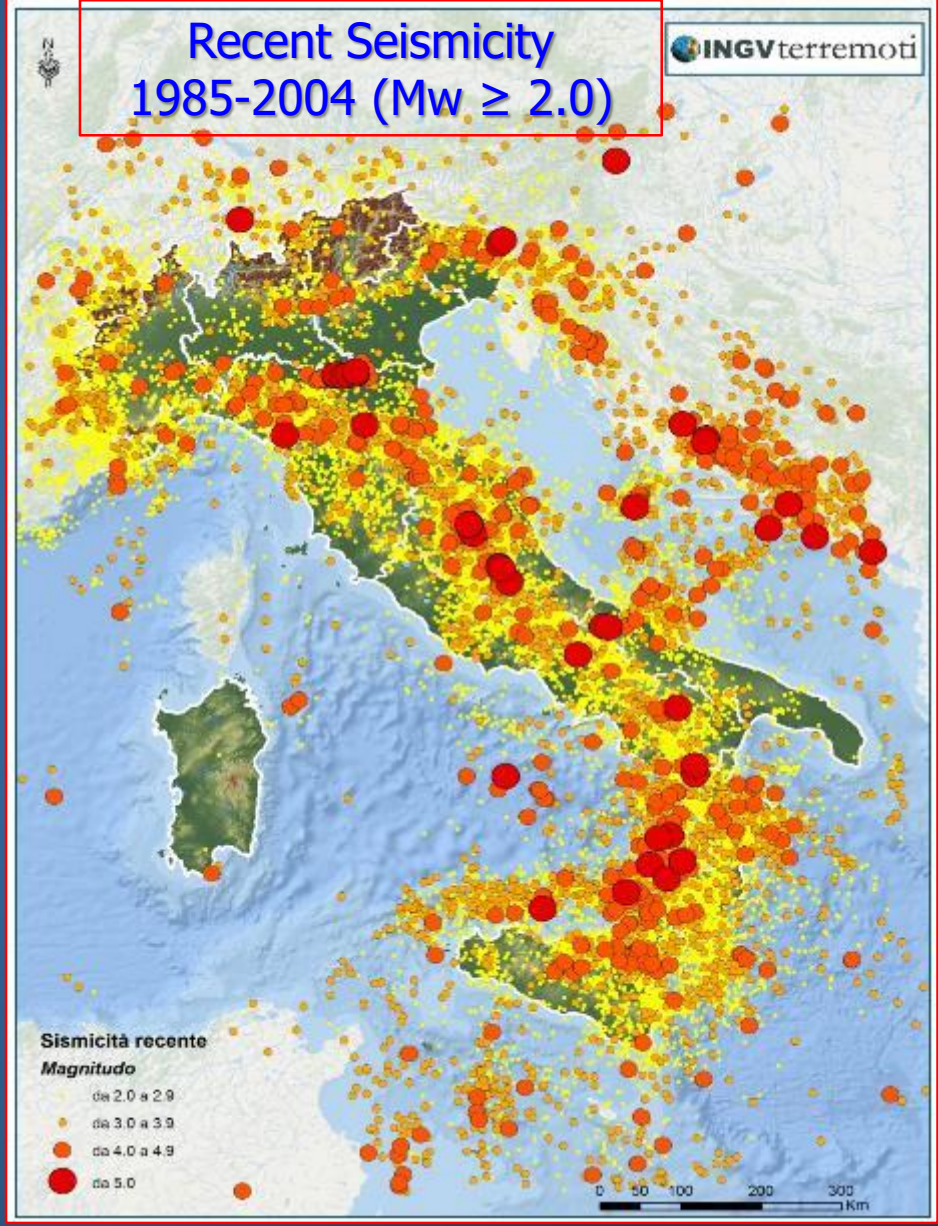

***Palano (2014)*** *Geophys. J. Int.*

***Galadini et al (2000)*** *Eng. Geol.*

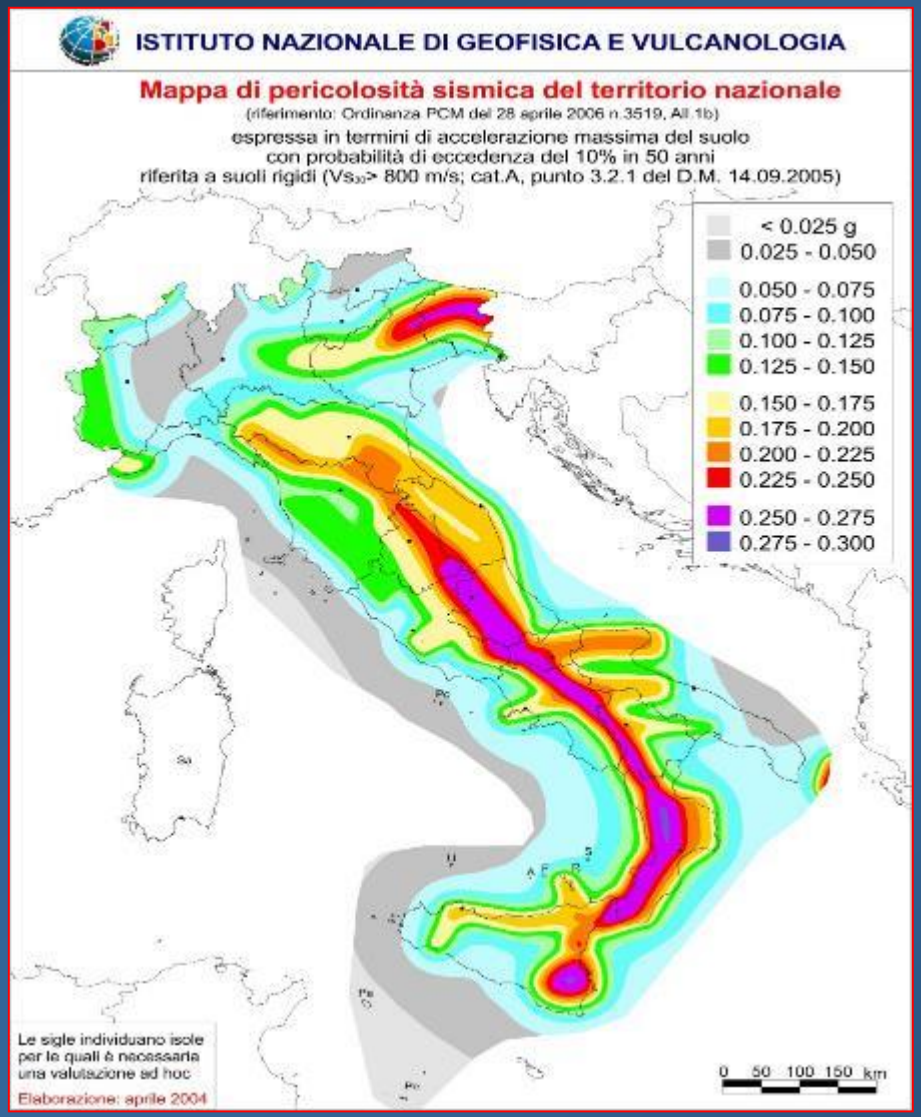
## Historical Earthquakes 1000-2006 (Mw ≥ 5.0)

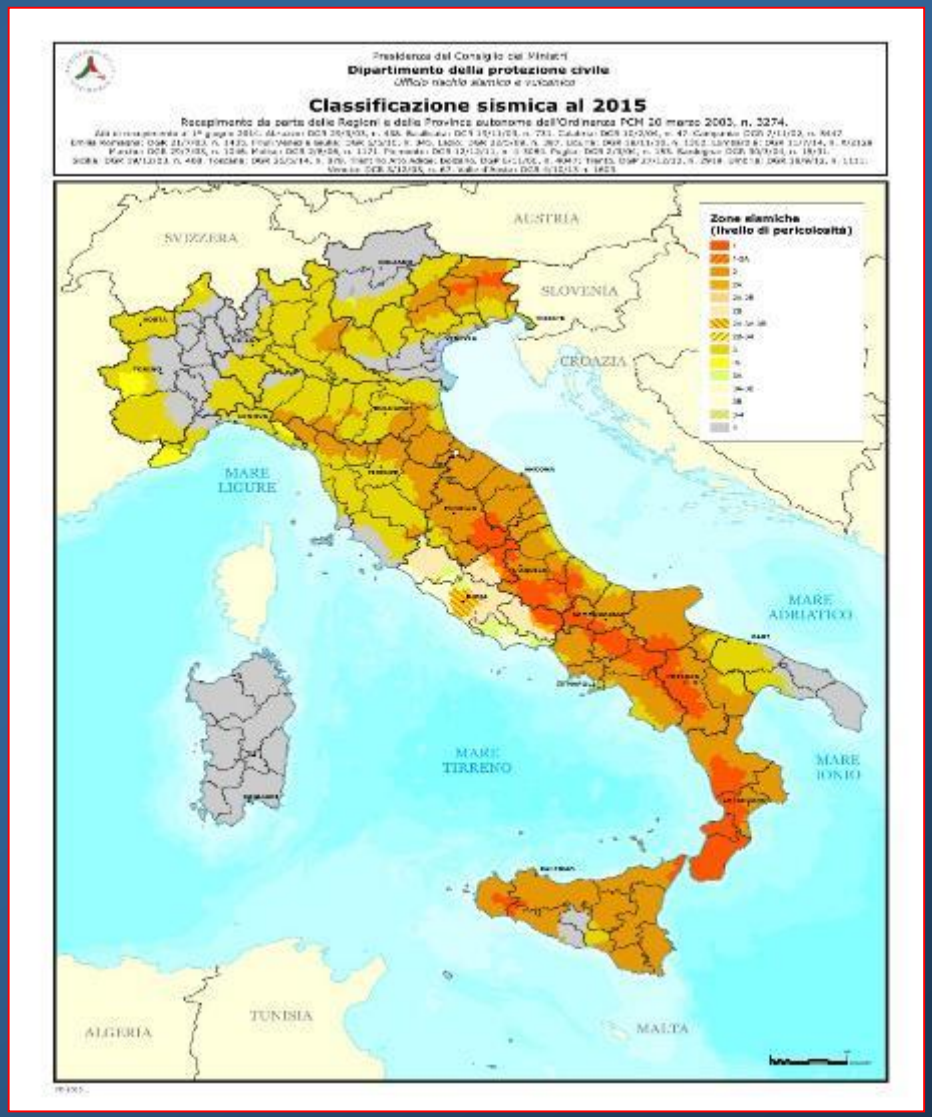


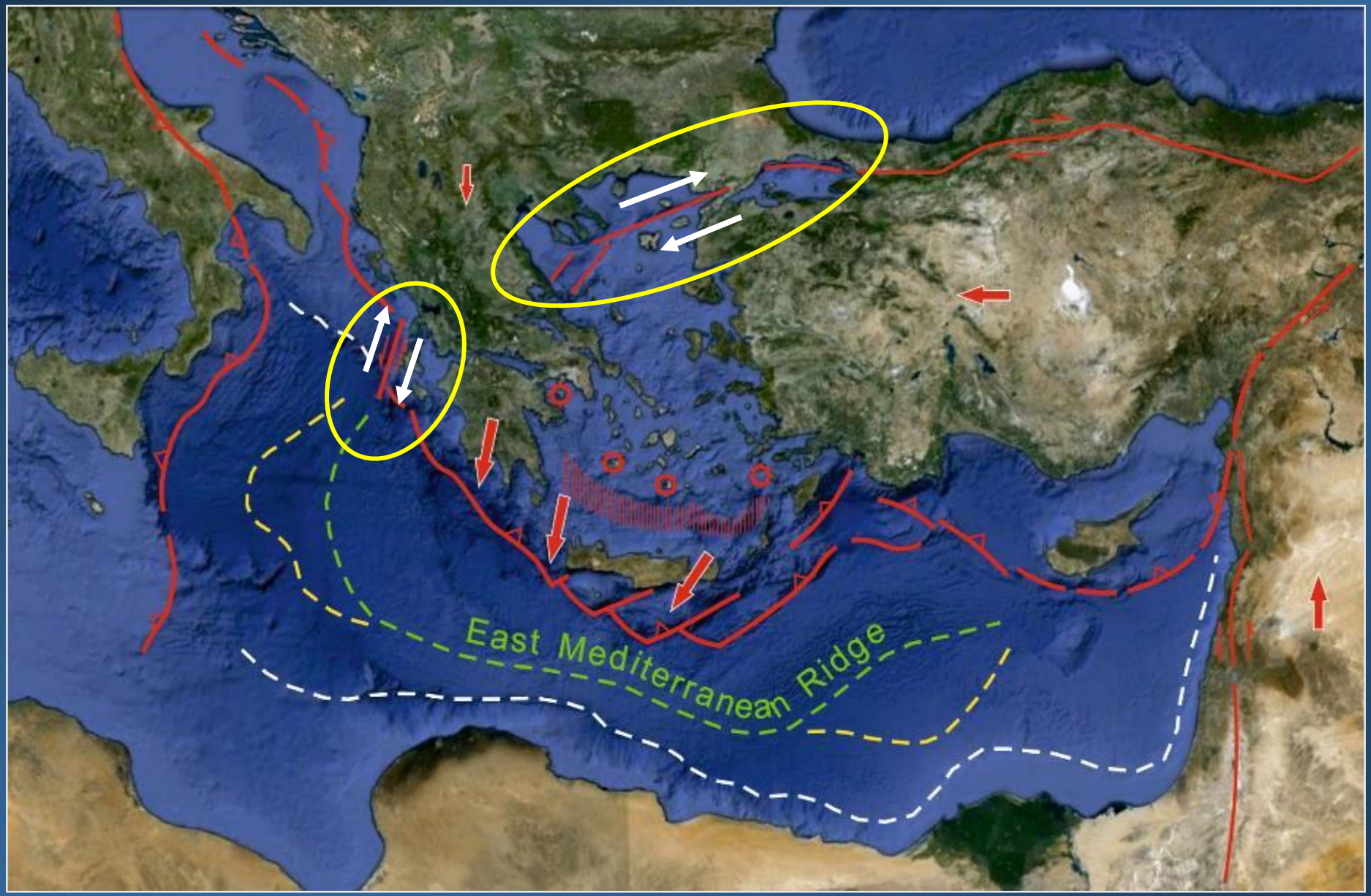

## Recent Seismicity 1985-2004 (Mw ≥ 2.0)



# SEISMIC HAZARD MAP & NATIONAL SEISMIC ZONATION OF ITALY

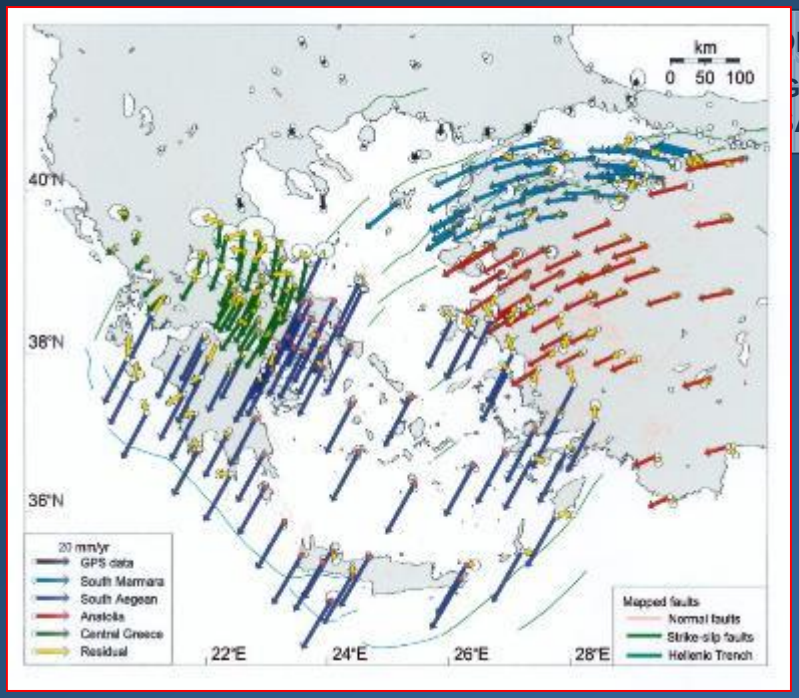


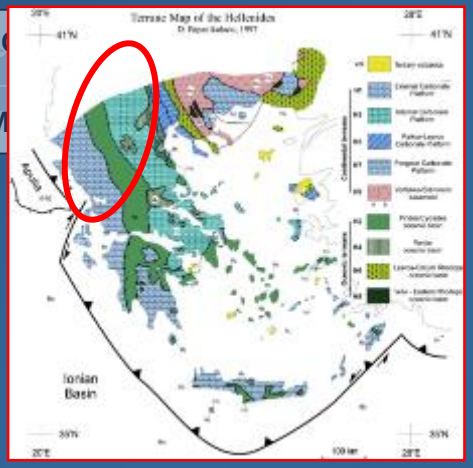



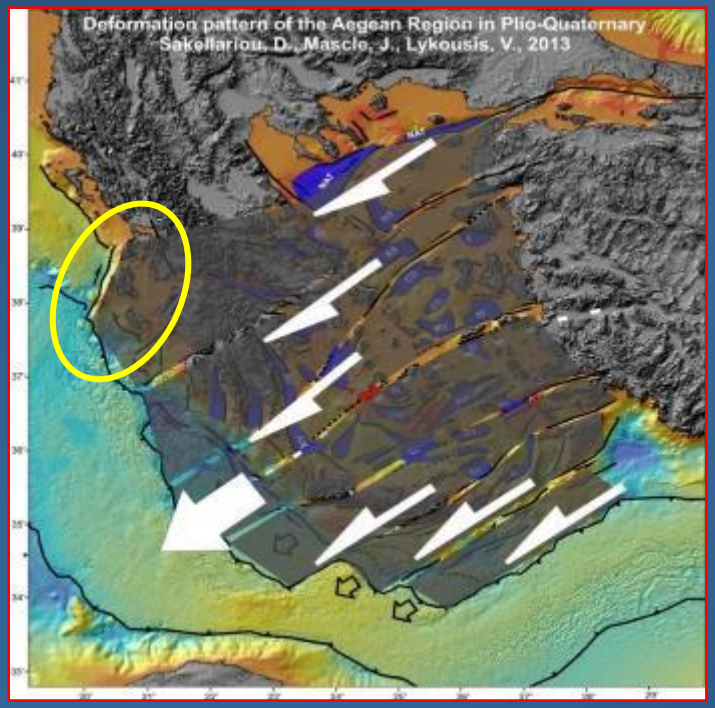


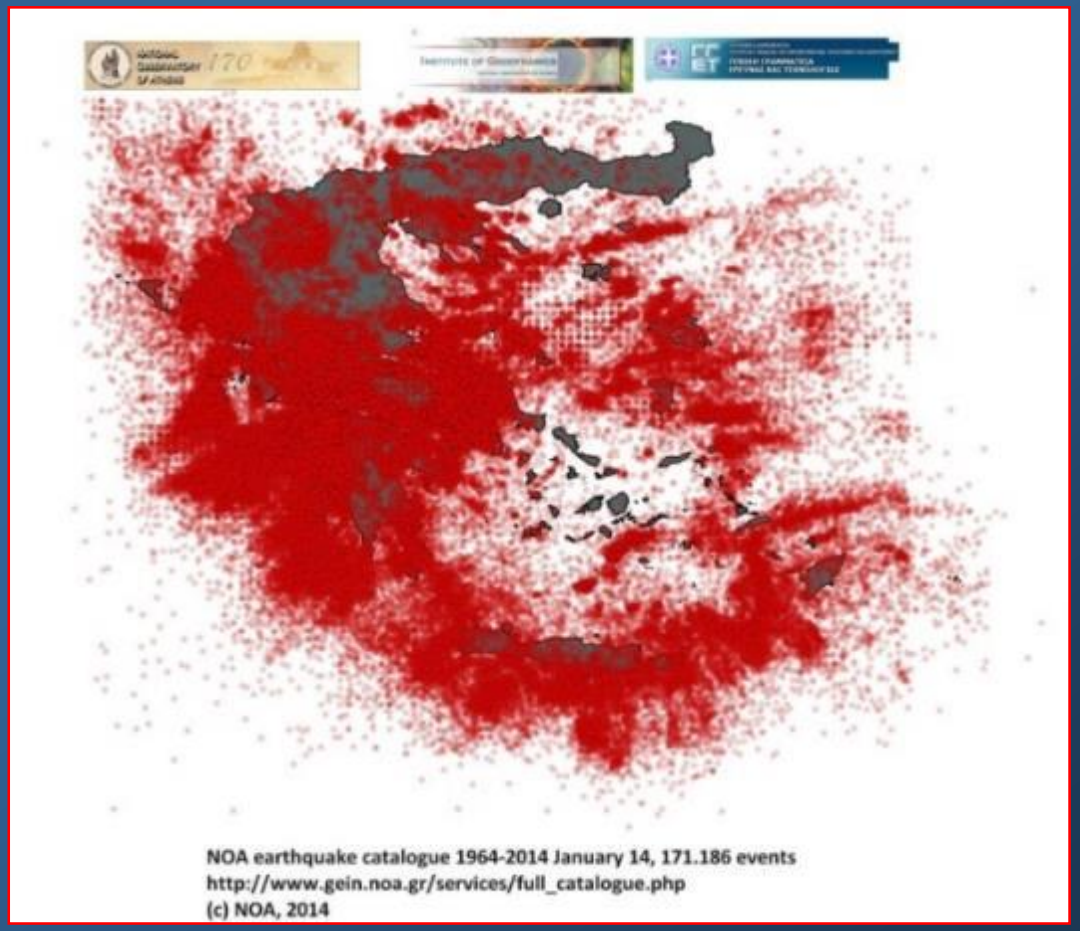

**MAIN TECTONIC ELEMENTS IN THE EASTERN MEDITERRANEAN**
**THE HELLENIC ARC AND TRENCH SYSTEM**

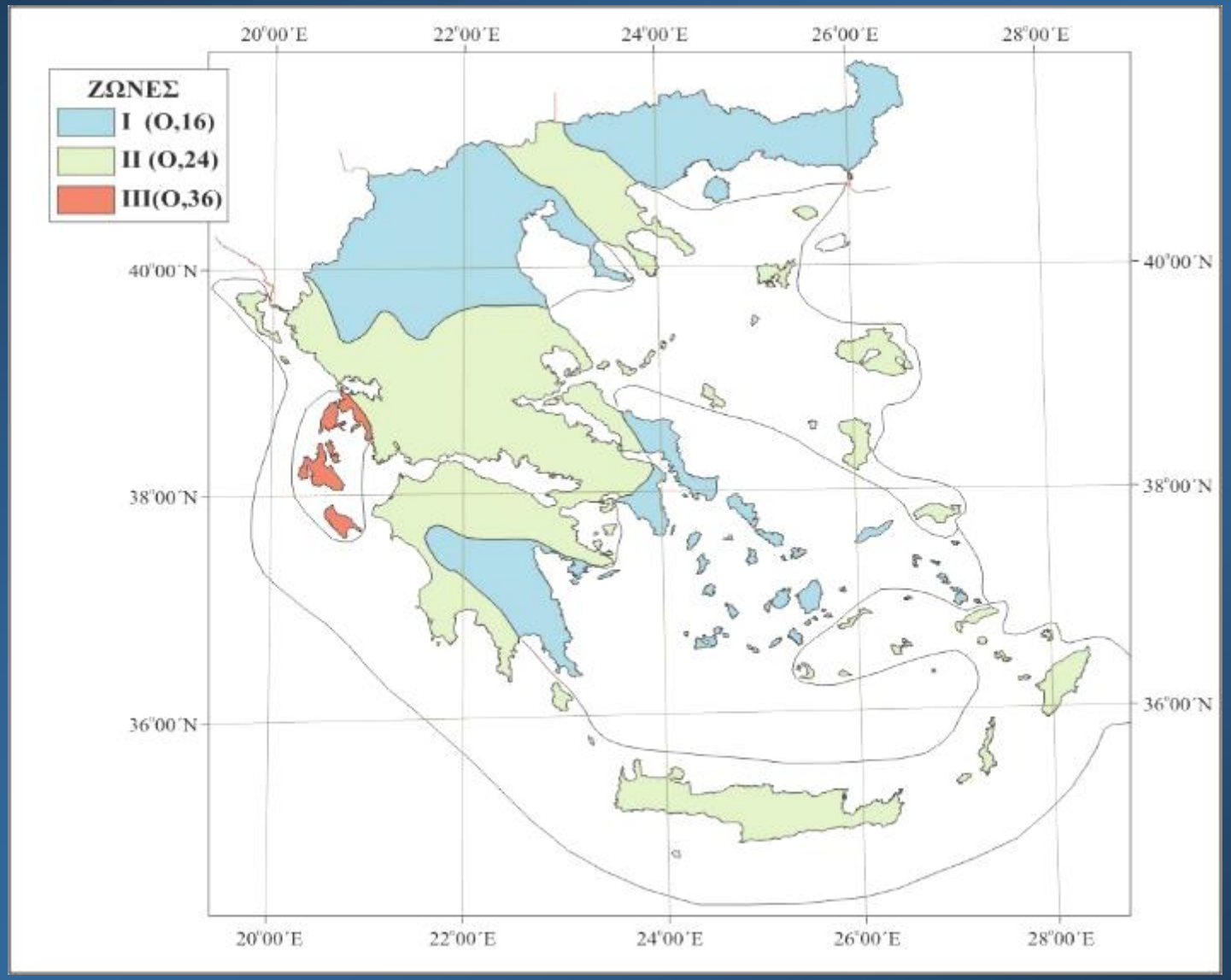
ISTRIAN UNIVERSITY (
GRADUATE PROGRAM
ASTER AND CRISES M



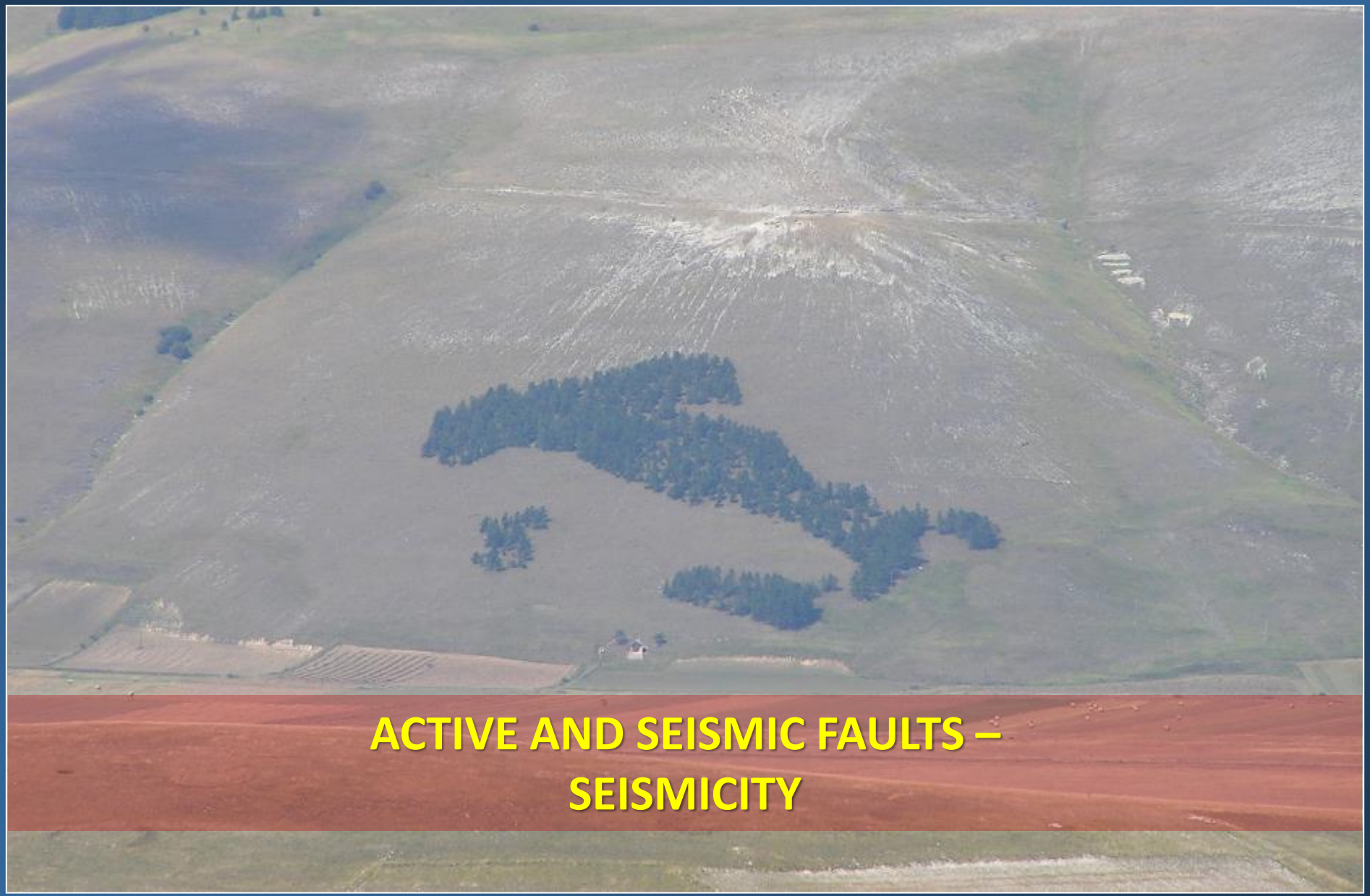



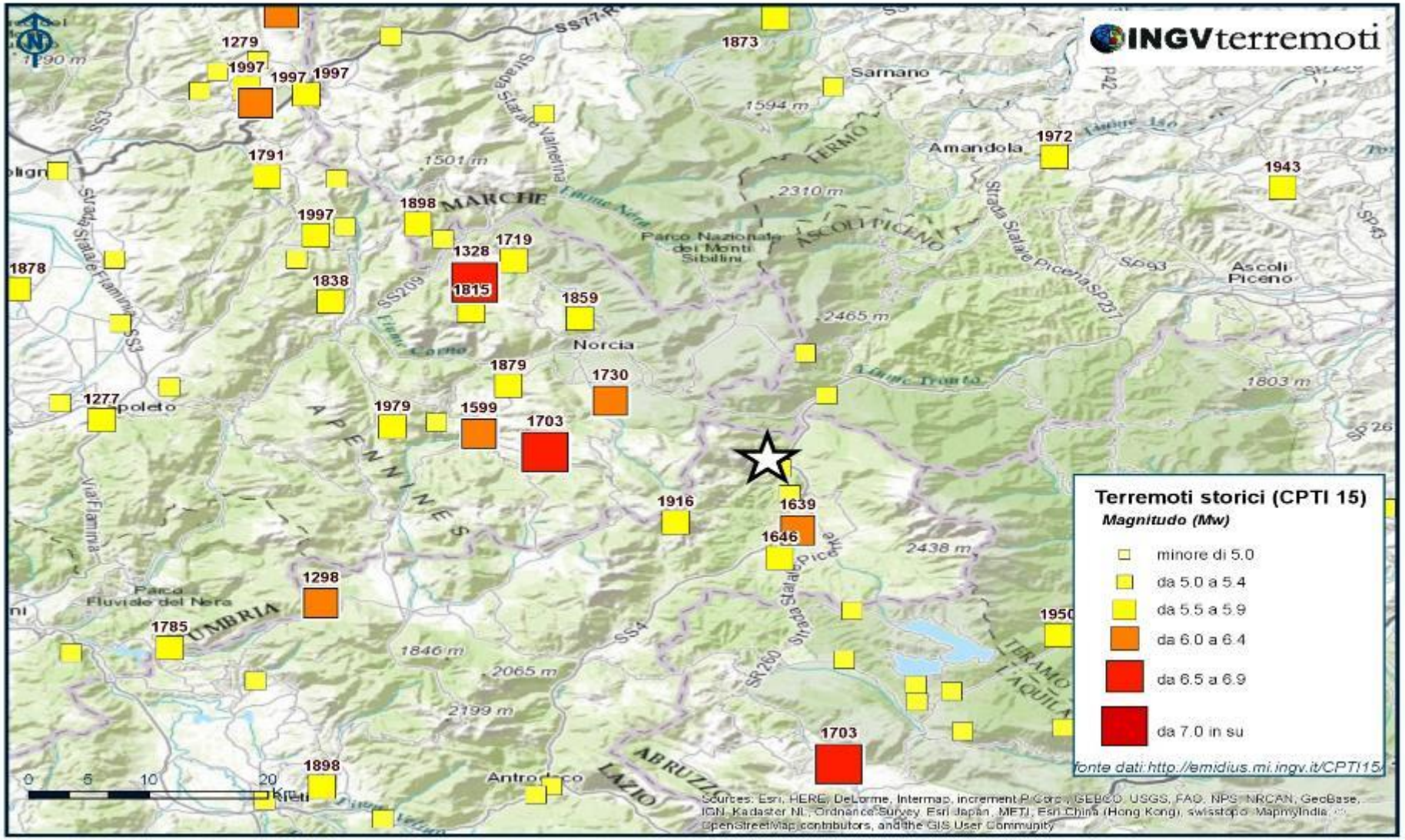


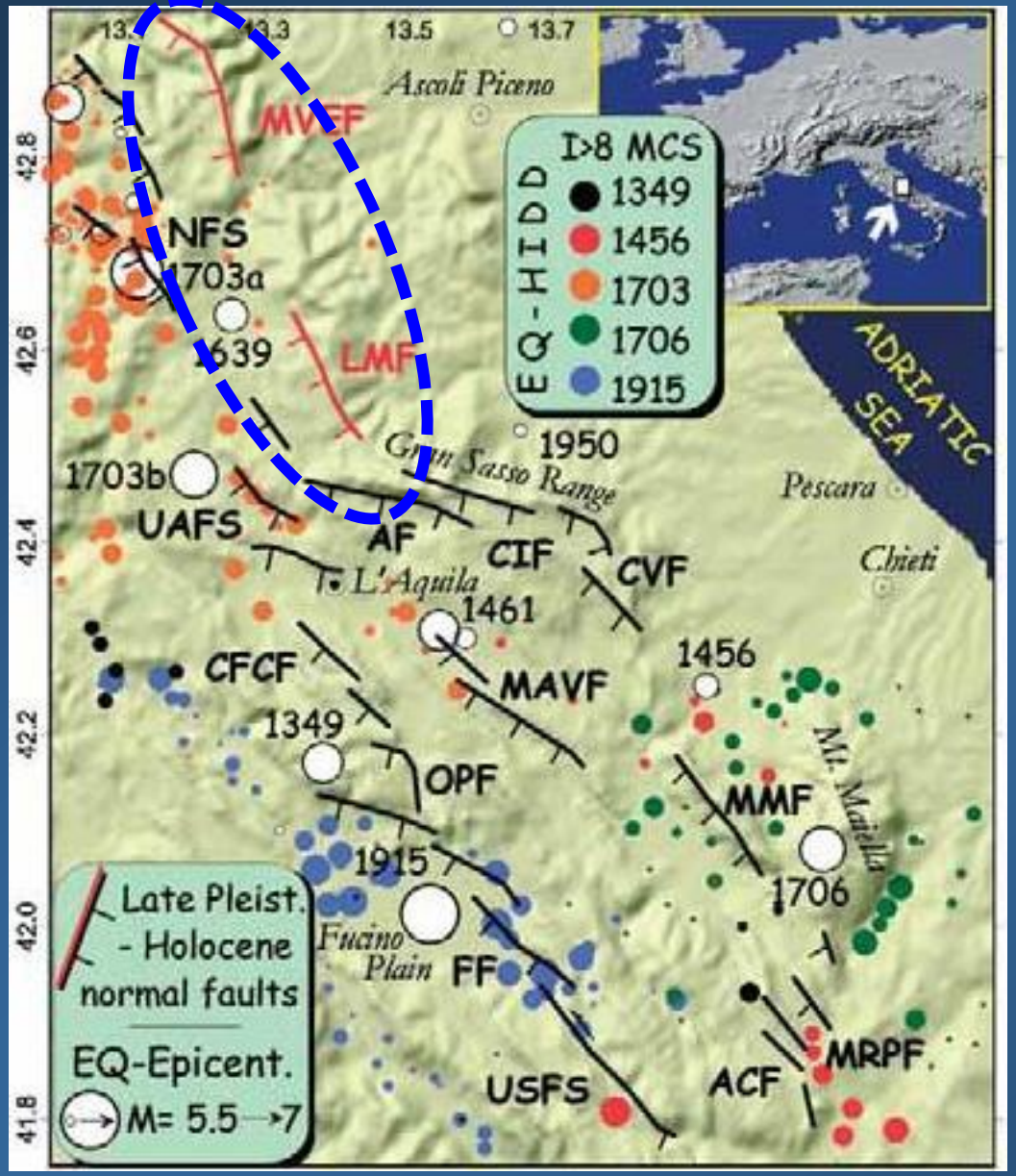

ΧΑΡΤΗΣ ΖΩΝΩΝ ΣΕΙΣΜΙΚΗΣ ΕΠΙΚΙΝΔΥΝΟΤΗΤΑΣ (ΟΑΣΠ, 2003).



# ACTIVE AND SEISMIC FAULTS – SEISMICITY

# HISTORICAL EARTHQUAKES IN UMBRIA, MARCHE & LAZIO REGIONS





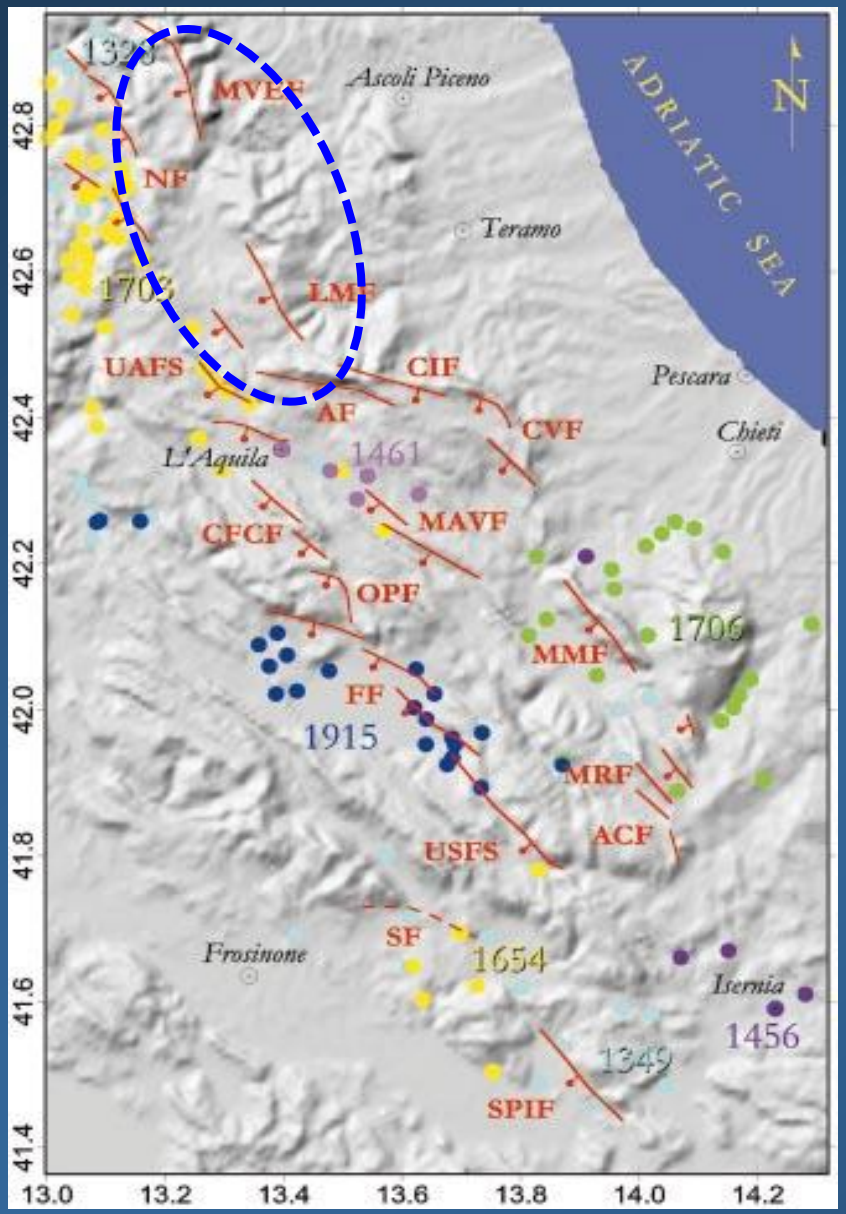

# MAIN NORMAL FAULTS OF THE AREA AFFECTED BY THE CENTRAL ITALY EARTHQUAKE Mw 6.2, 24 AUGUST 2016

## MT. VETTORE FAULT (MVEF)

&

## LAGA MTS FAULT (LMF)

*Galadini and Galli (2000)*



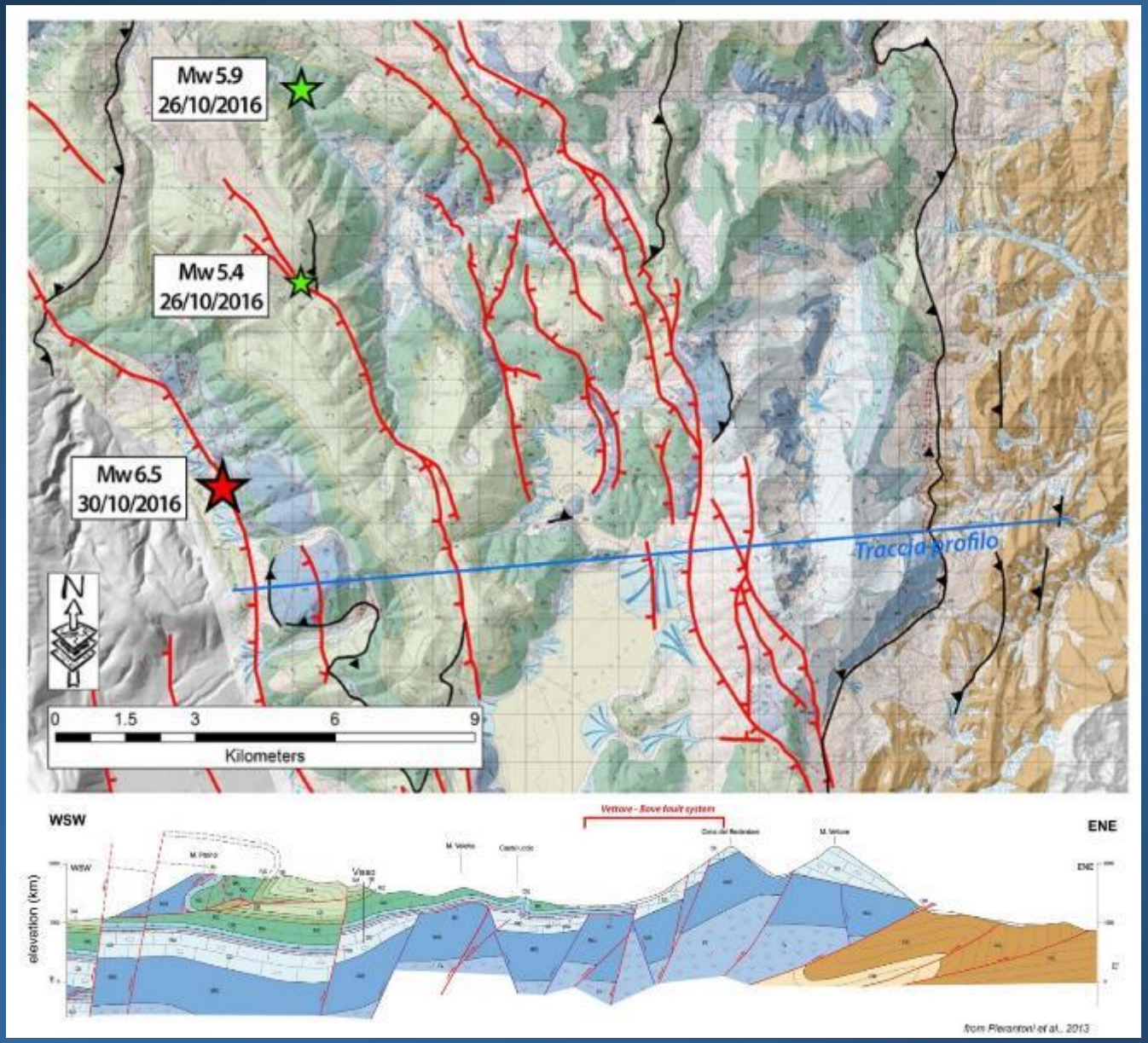

## PRIMARY ACTIVE FAULTS

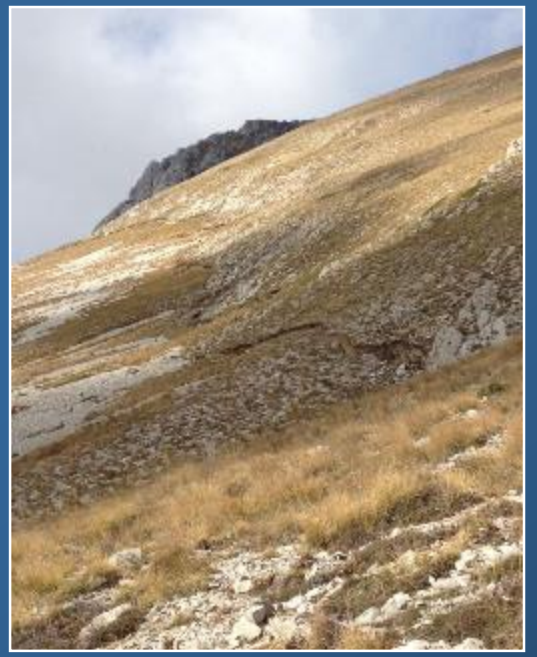
**in the Southern Umbria – Abruzzi Apennines and distribution of the highest-intensity datapoints related to major earthquakes (M > 6)**

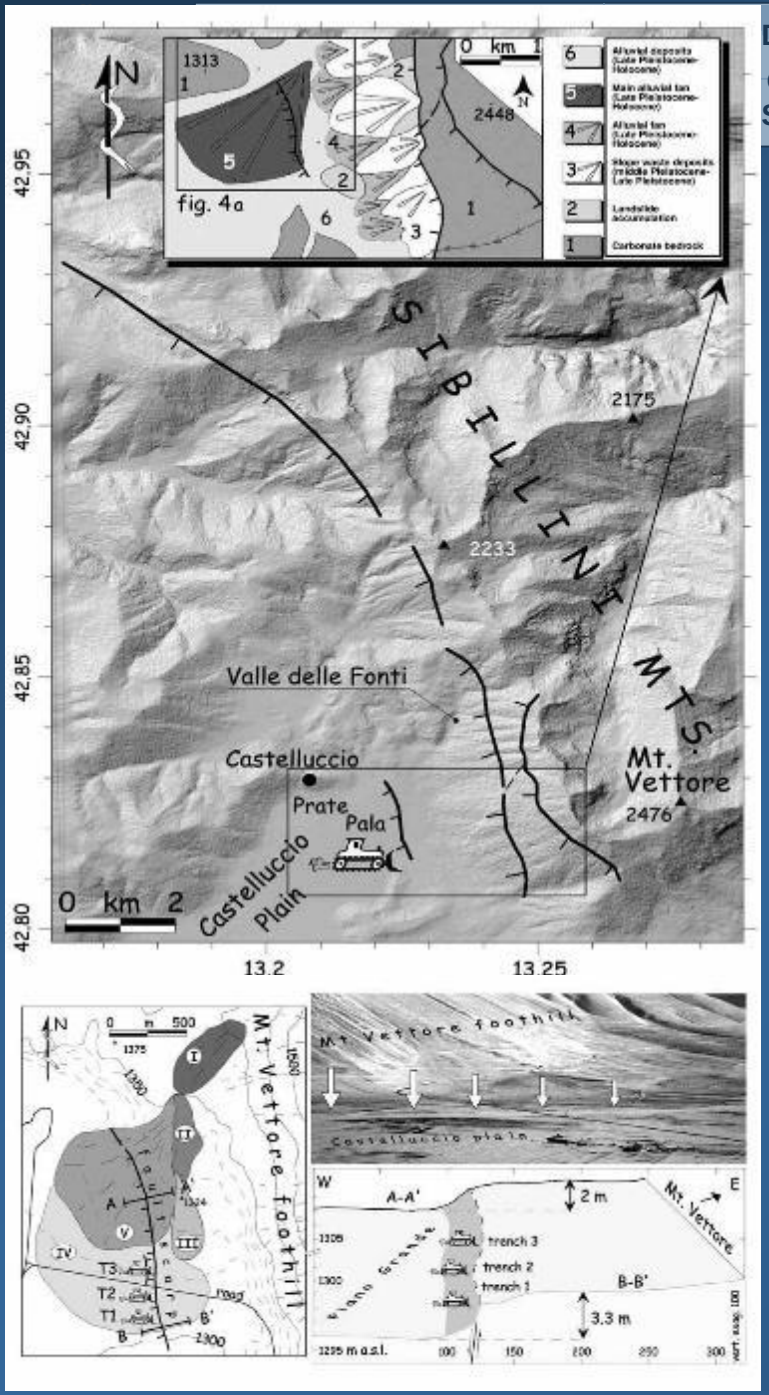
## MCS INTENSITY DATAPOINTS

| | |
|---|---|
| I = VIII/IX | **1328** and **1349** earthquakes |
| I = IX | **1461** |
| I = IX/X | **1456, 1654, 1703, 1706** |
| I = X | **1915** |

*Galadini and Galli (2000)*


Mw 5.9
26/10/2016
Mw 5.4
26/10/2016
Mw 6.5
30/10/2016
Traccia profilo
N
0
1.5
3
6
9
Kilometers
WSW
ENE
elevation (km)
Vettore - Bove fault system
from Pierantoni et al., 2013



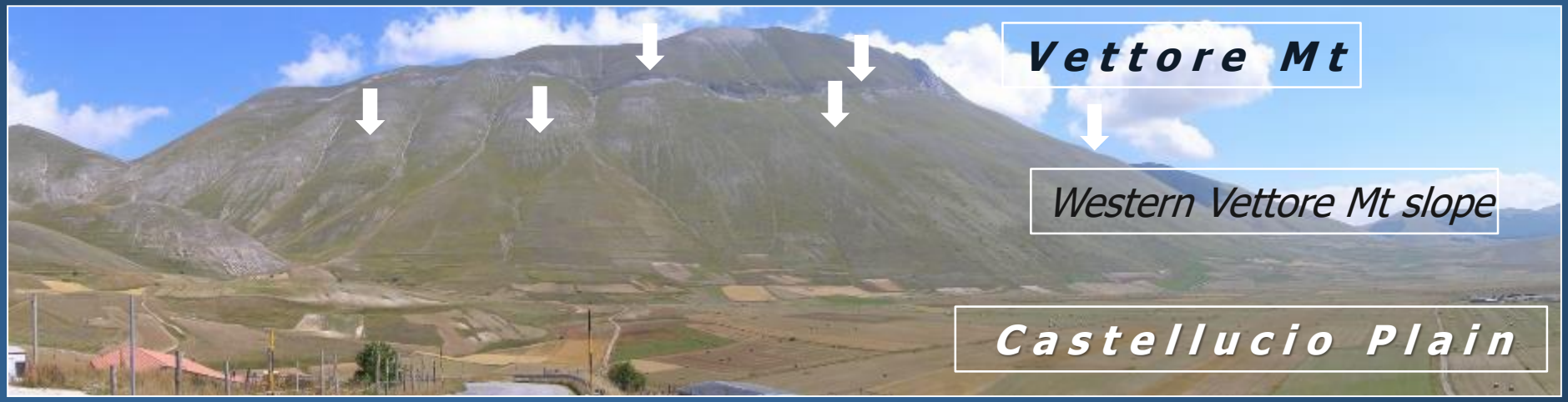



# MT. VETTORE FAULT

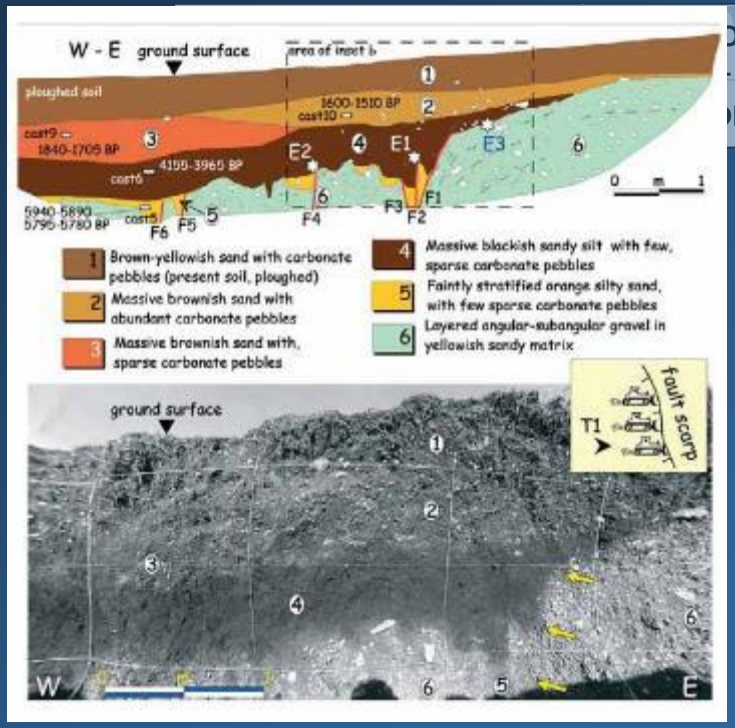
- NNW-SSE to NW-SE trending normal fault
- about 18 km long
- one major intermontane basin formed along the fault, the Castelluccio Plain
- The plain partially filled by an alluvial fan which probably formed between about 23.000 and 3200 years BP
- Two fault splays easily detectable along the Mt. Vettore western slope, since they formed impressive limestone scarps
- Prate Pala scarp (PPs) affects the large Late Pleistocene-Holocene alluvial fan fed from the Valle delle Fonti creek
- PPs, an evidence of displacements affecting recent deposits in the piedmont area

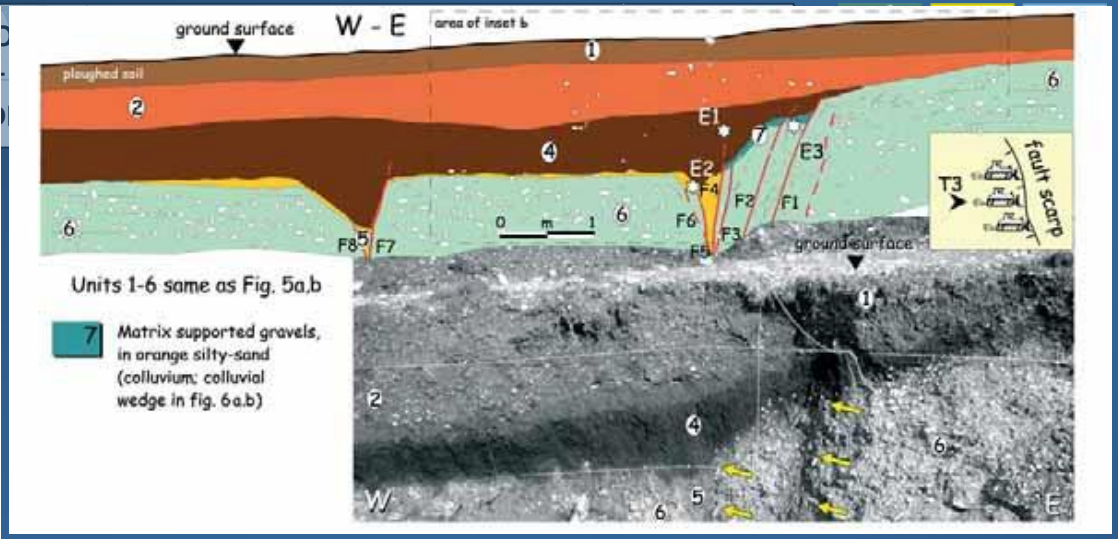
*Galadini and Galli (2003)*

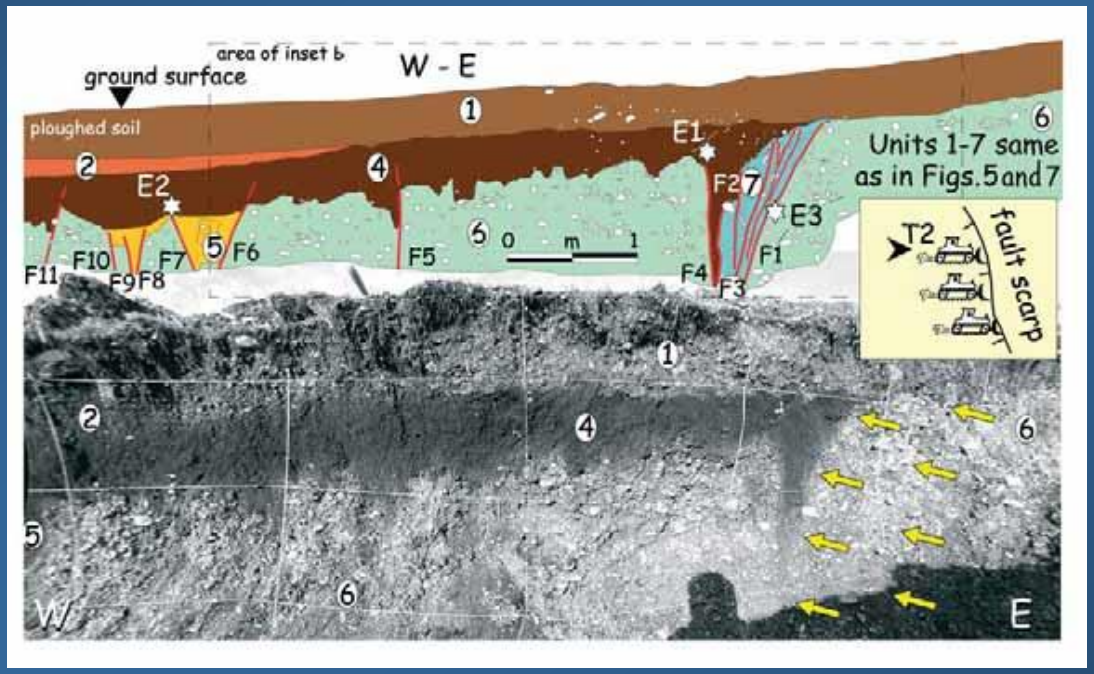

Sibillini Mts
Vettore Mt
Castellucio Plain
Photos taken on 2016.08.26


Vettore Mt
Western Vettore Mt slope
Castellucio Plain


Sibillini Mts
Vettore Mt
Castellucio village




## MT. VETTORE FAULT TRENCHES

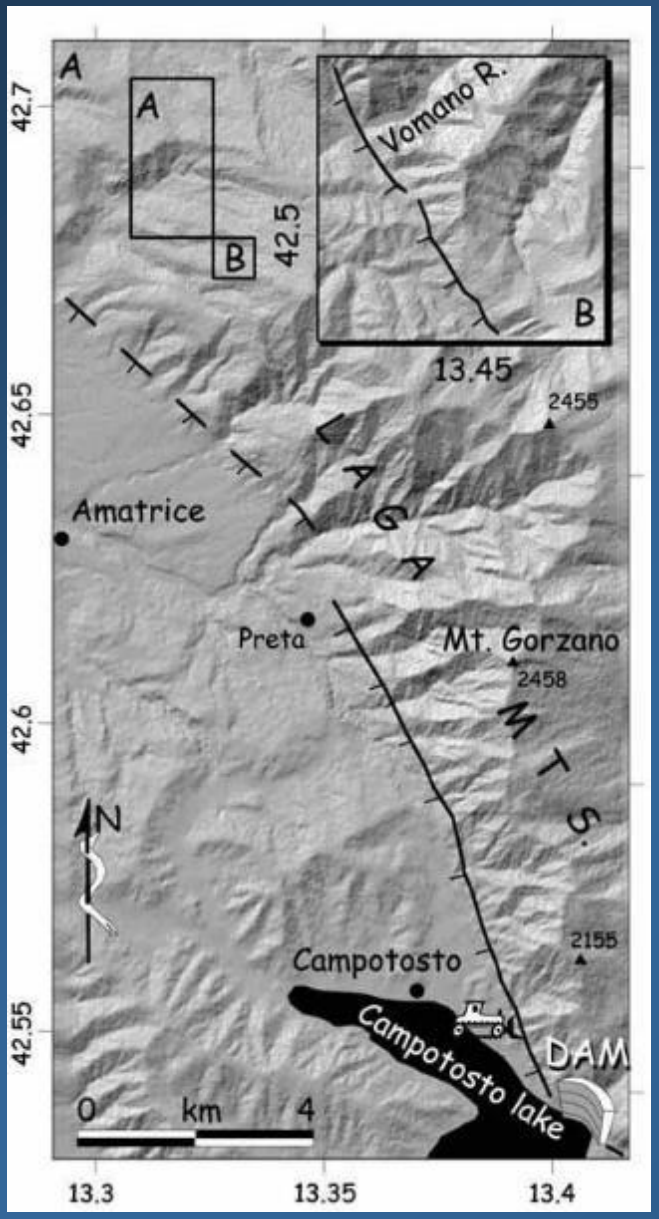
**Three events occurred during the Holocene:**

**E1**: between 4155-3965 yrs BP and the 6th-7th century AD

**E2**: between 5940-5890 / 5795-5780 yrs BP and 4155-3965 yrs BP

**E3**: related to events occurred between 18.000-12.000 yrs BP and 5940-5890 / 5795-5780 yrs BP

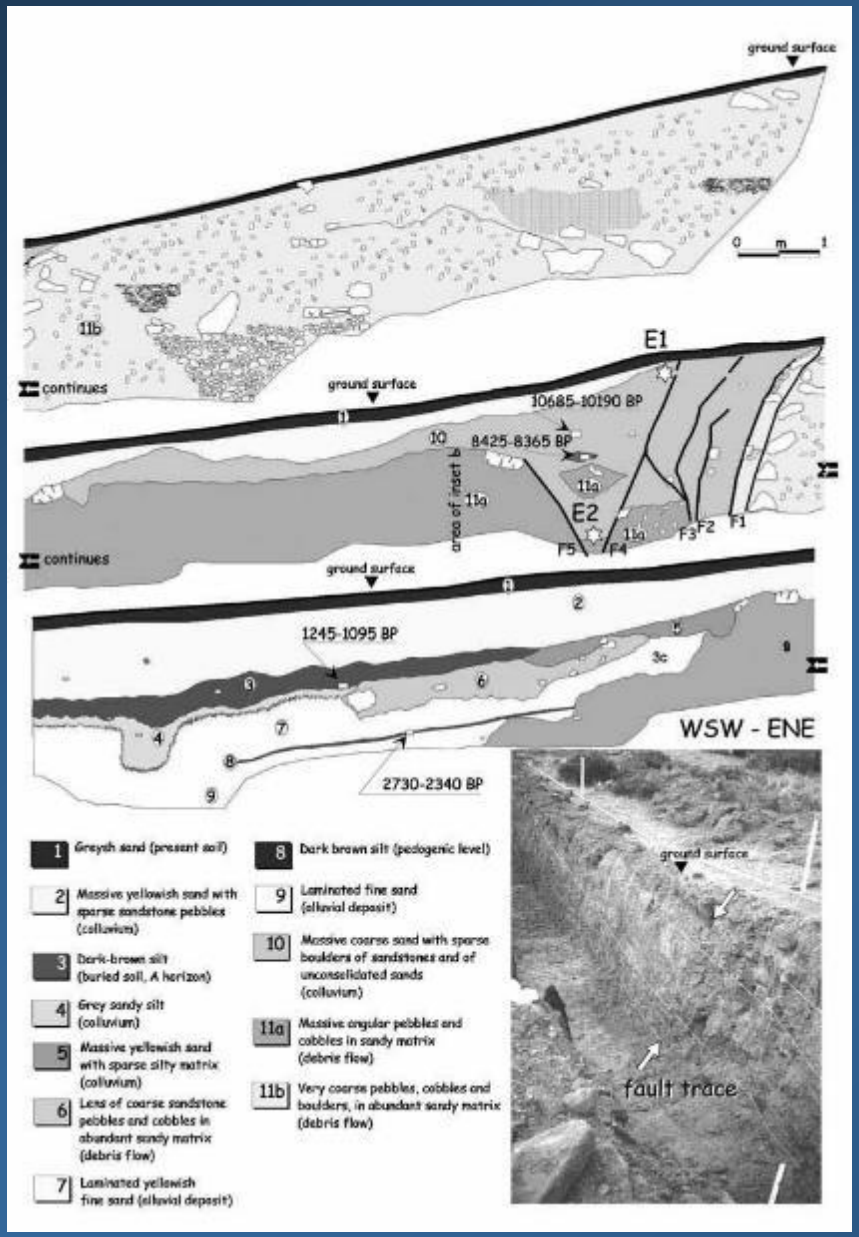
*Galadini and Galli (2003)*




# LAGA MTS FAULT

- NW-SE-trending normal fault
- 30 km long and bounds two intermontane basins: Amatrice and Campotosto basins, located along the northern and southern portions of the fault, respectively
- the fault is made of three parallel splays affecting the Laga Mts. SW slope at different height
- Evidence of recent activity represented by fault scarps on the arenaceous bedrock and deposits related to terraces which formed along the incisions perpendicular to the slope
- Some scarps detected on Holocene terraces


Galadini and Galli (2003)



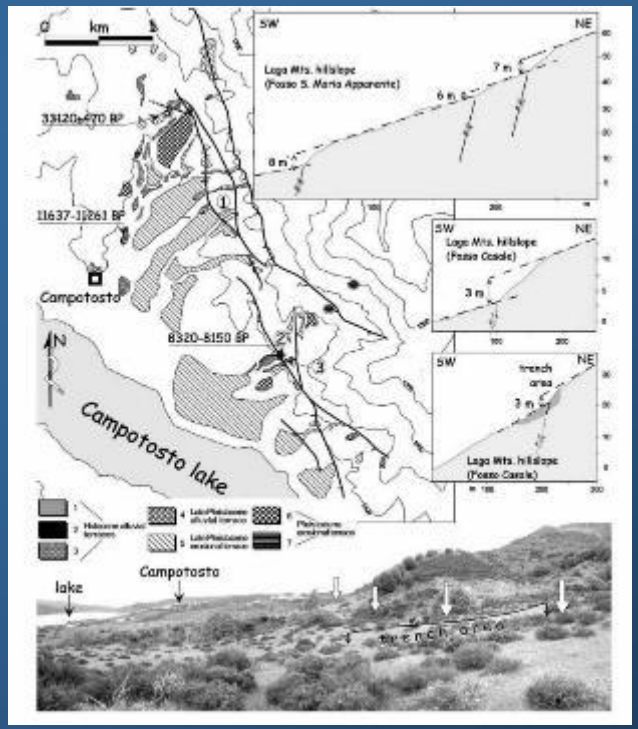

# LAGA MTS FAULT TRENCH

Two displacement events recognized based on the trench:

**E1**: E1 occurred after 8425-8365 yrs BP

**E2**: E2 occurred at about 8425-8365 yrs BP

**Galadini and Galli (2003)**



*Data from*
***Galadini and Galli (2000, 2003)***

## VETTORE MTS FAULT

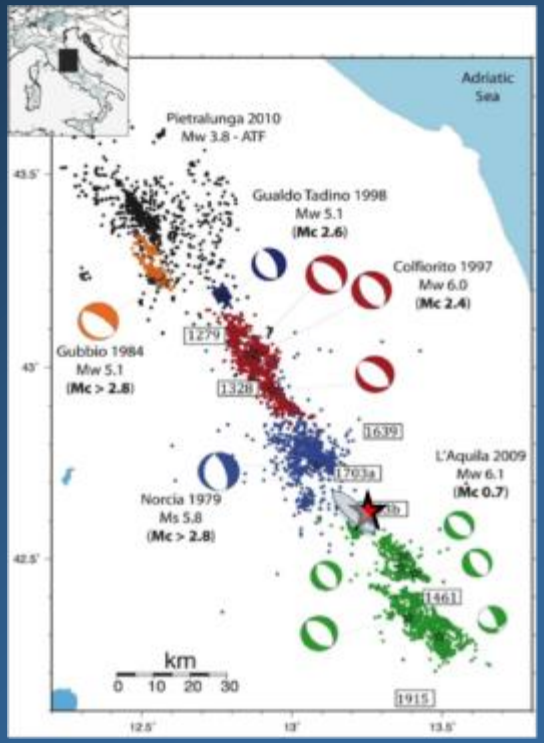
- repeated Holocene activation
- a minimum vertical slip rate ranging between 0.11 and 0.62 mm/yr for the Prate Pala scarp (Mt. Vettore fault)
- a paleoseismologically inferred minimum elapsed time of 1300-1500 years defined for the Mt. Vettore fault
- a maximum recurrence interval of 4690-4490 years for surface faulting events along the Mt. Vettore Fault

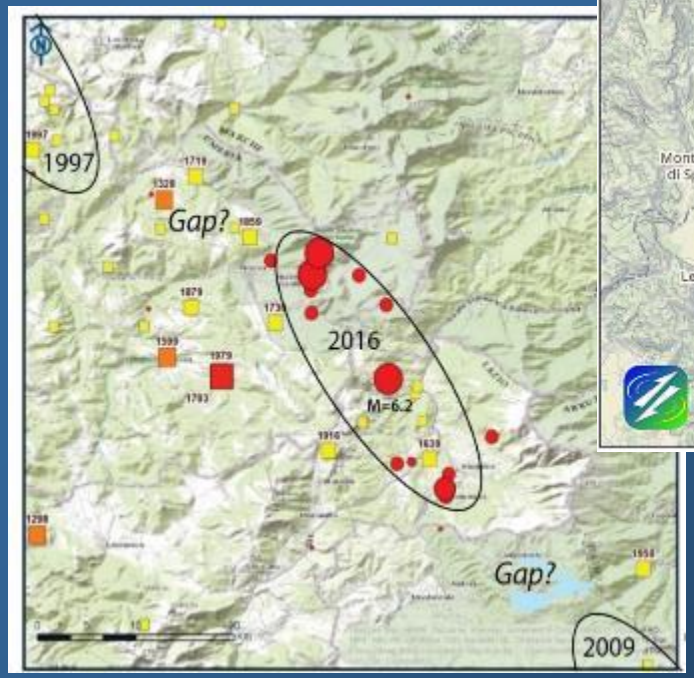
## LAGA MTS FAULT

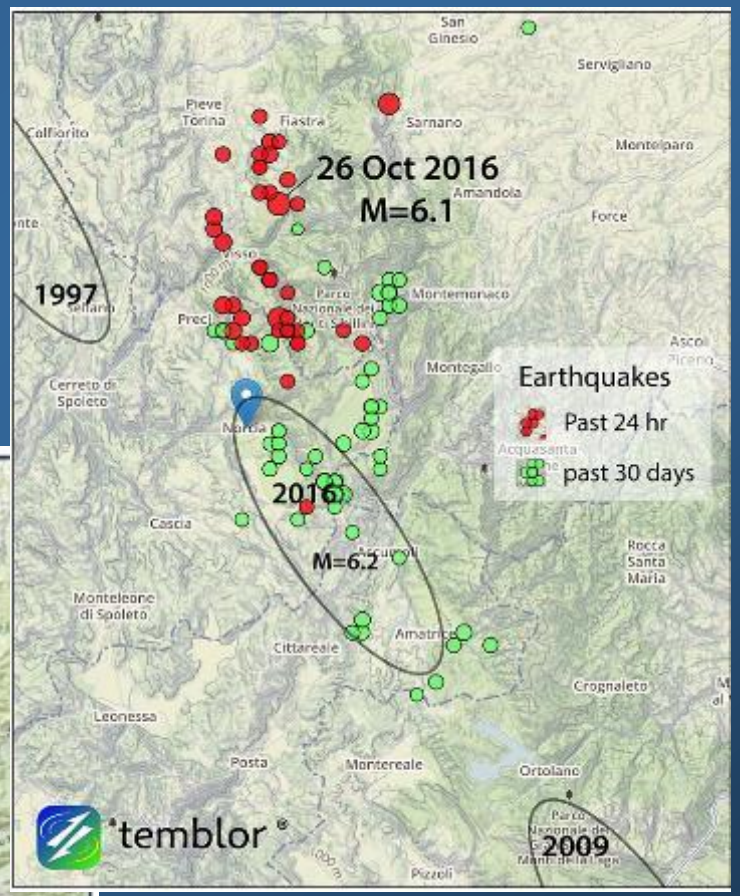
- repeated Holocene activation
- minimum vertical slip rate of 0.12 mm/yr for the Laga Mts fault
- minimum elapsed time (eight centuries) for the Laga Mts. fault
- a maximum time span between the two events of Laga Mts fault of 7570 years

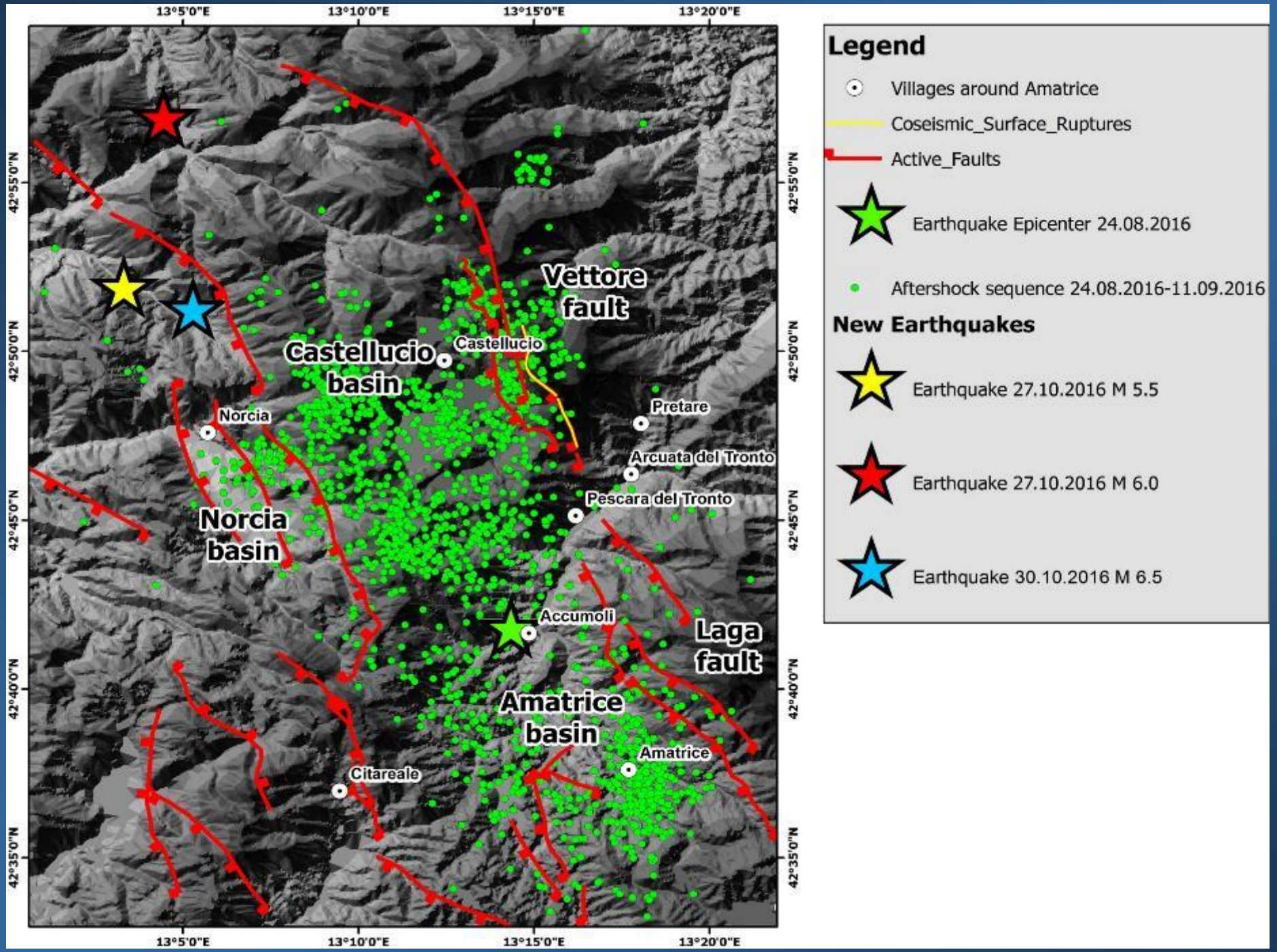
**Silent faults during at least the past eight centuries until**
**the 24 August 2016 earthquake**

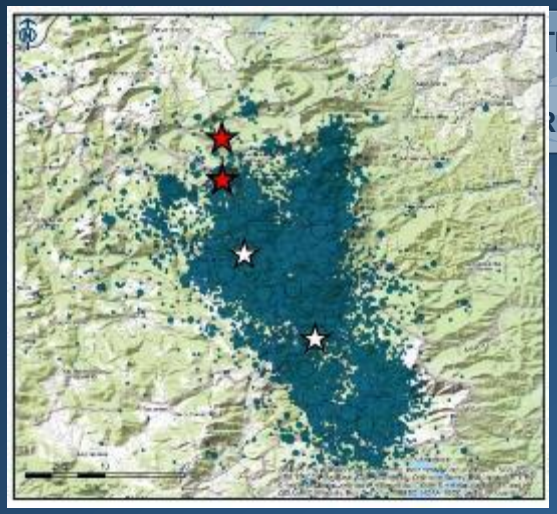
# SEISMIC GAPS IN THE CENTRAL APENNINES

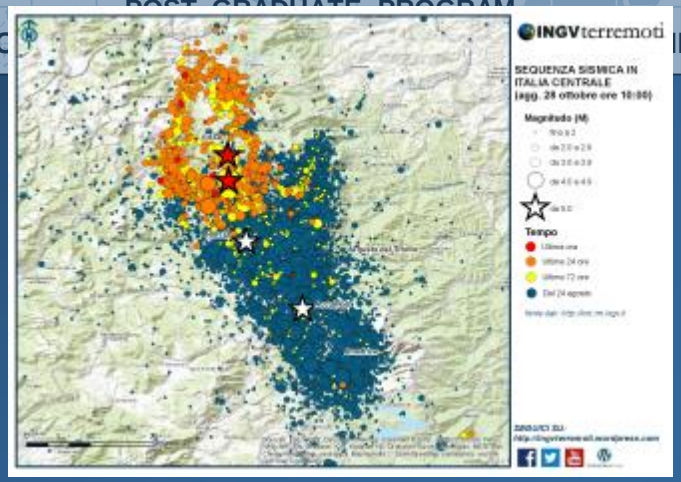


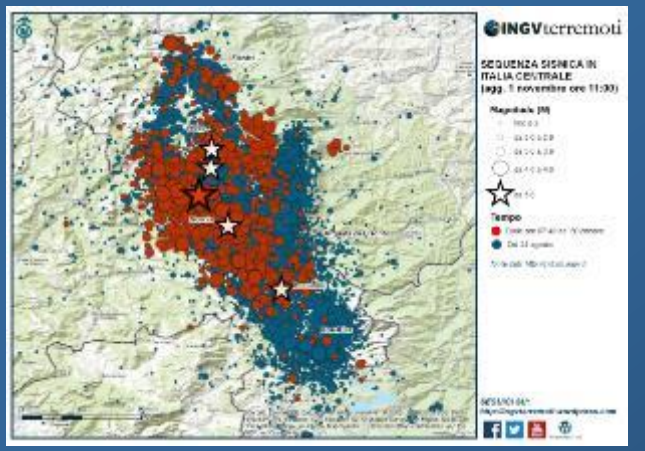



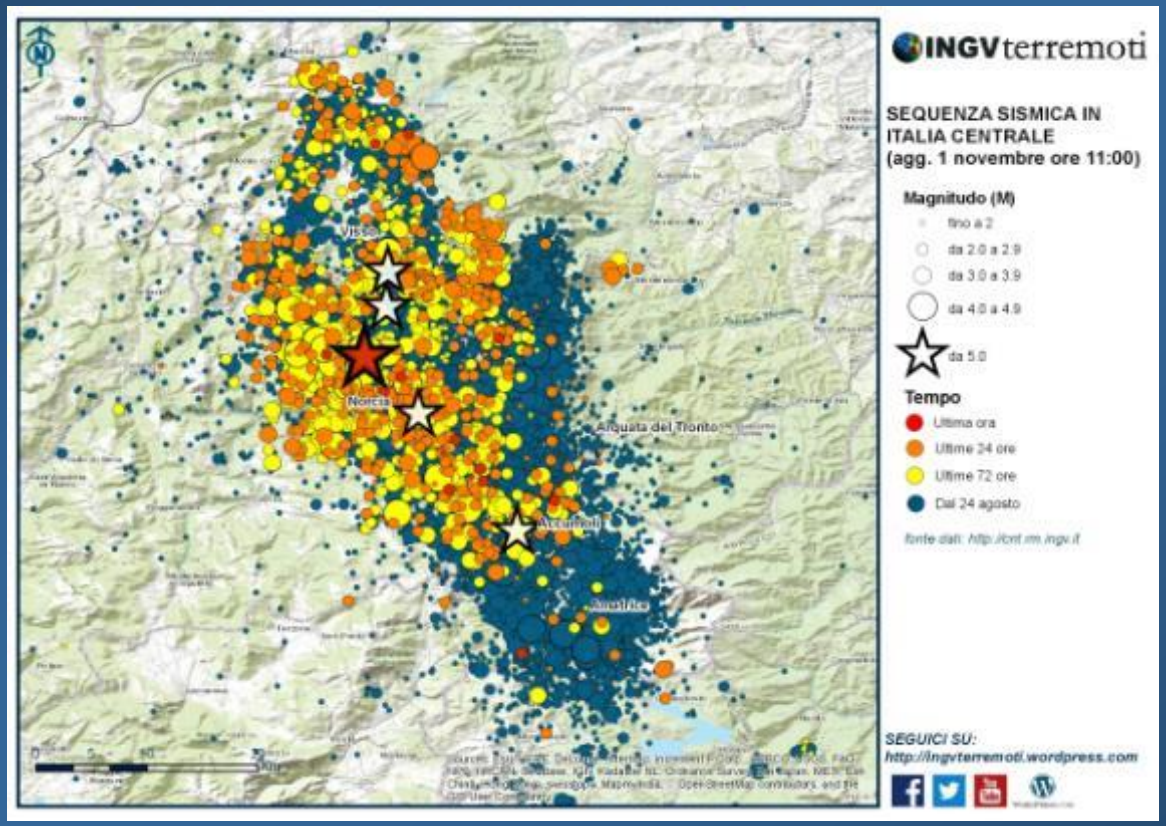



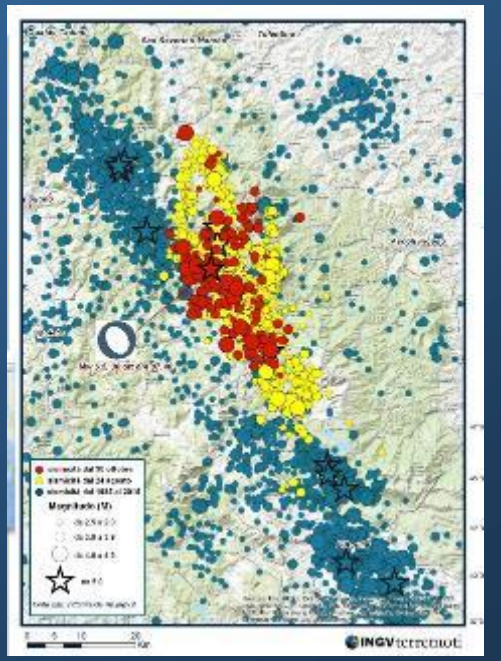

13°5'0"E
13°10'0"E
13°15'0"E
13°20'0"E
42°55'0"N
42°50'0"N
42°45'0"N
42°40'0"N
42°35'0"N
Vettore fault
Castellucio basin
Castellucio
Norcia
Norcia basin
Pretare
Arcuata del Tronto
Pescara del Tronto
Accumoli
Laga fault
Amatrice basin
Amatrice
Citareale
Legend
Villages around Amatrice
Coseismic_Surface_Ruptures
Active_Faults
Earthquake Epicenter 24.08.2016
Aftershock sequence 24.08.2016-11.09.2016
New Earthquakes
Earthquake 27.10.2016 M 5.5
Earthquake 27.10.2016 M 6.0
Earthquake 30.10.2016 M 6.5

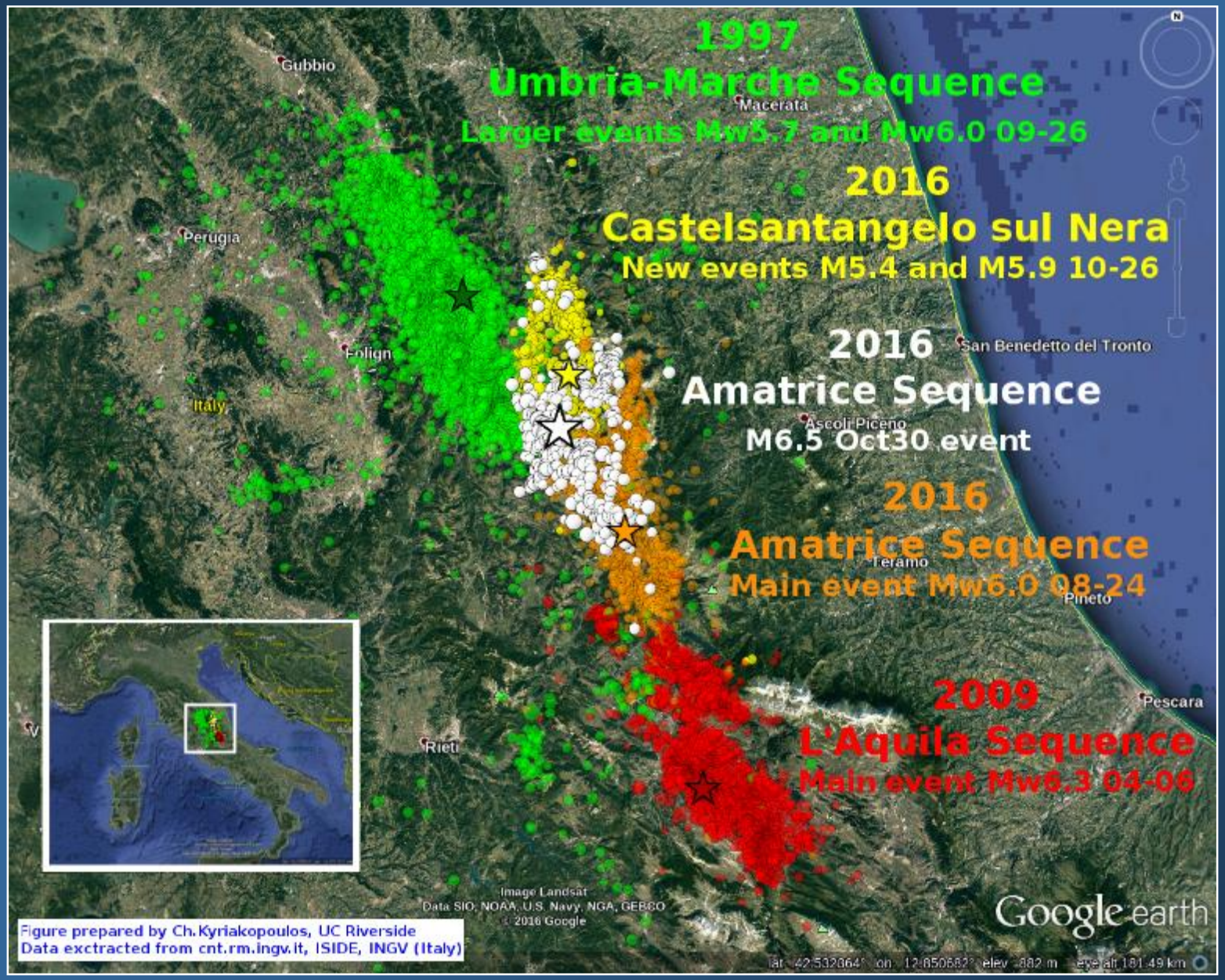



INGVterremoti
SEQUENZA SISMICA IN ITALIA CENTRALE
(agg. 28 ottobre ore 10:00)
Magnitudo (M)
Tempo


INGVterremoti
SEQUENZA SISMICA IN ITALIA CENTRALE
(agg. 1 novembre ore 11:00)


INGVterremoti
SEQUENZA SISMICA IN ITALIA CENTRALE
(agg. 1 novembre ore 11:00)
Magnitudo (M)
fino a 2
da 2.0 a 2.9
da 3.0 a 3.9
da 4.0 a 4.9
da 5.0
Tempo
Ultima ora
Ultime 24 ore
Ultime 72 ore
Dal 24 agosto
fonte dati: http://cnt.rm.ingv.it
SEGUICI SU:
http://ingvterremoti.wordpress.com
Norcia
Arquata del Tronto
Accumoli
Amatrice


INGVterremoti


1997
Umbria-Marche Sequence
Larger events Mw5.7 and Mw6.0 09-26
2016
Castelsantangelo sul Nera
New events M5.4 and M5.9 10-26
2016
Amatrice Sequence
M6,5 Oct30 event
2016
Amatrice Sequence
Main event Mw6.0 08-24
2009
L'Aquila Sequence
Main event Mw6.3 04-06
Gubbio
Macerata
Perugia
Foligno
Italy
San Benedetto del Tronto
Ascoli Piceno
Teramo
Pineto
Pescara
Rieti
Image Landsat
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
© 2016 Google
Google earth
Figure prepared by Ch.Kyriakopoulos, UC Riverside
Data exctracted from cnt.rm.ingv.it, ISIDE, INGV (Italy)

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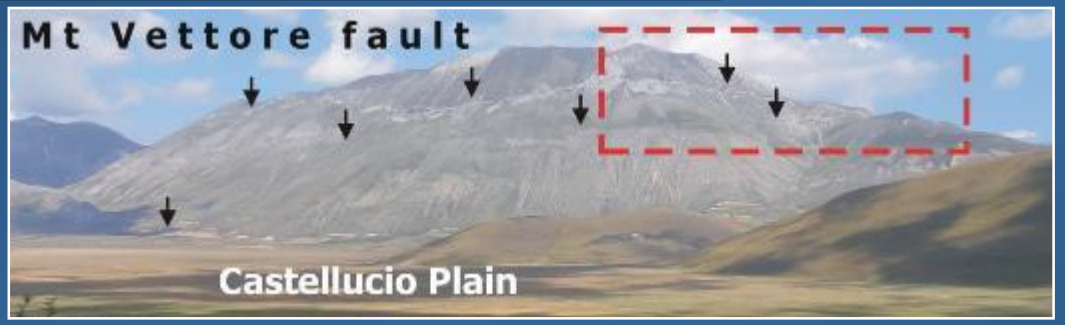
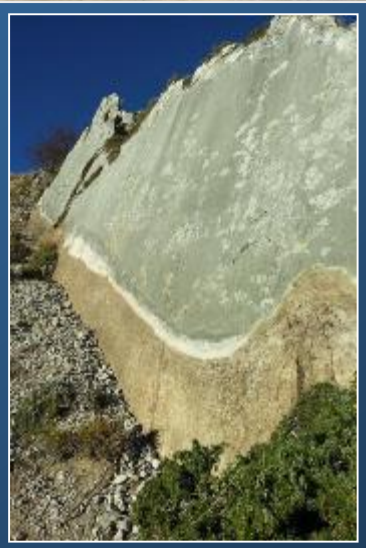
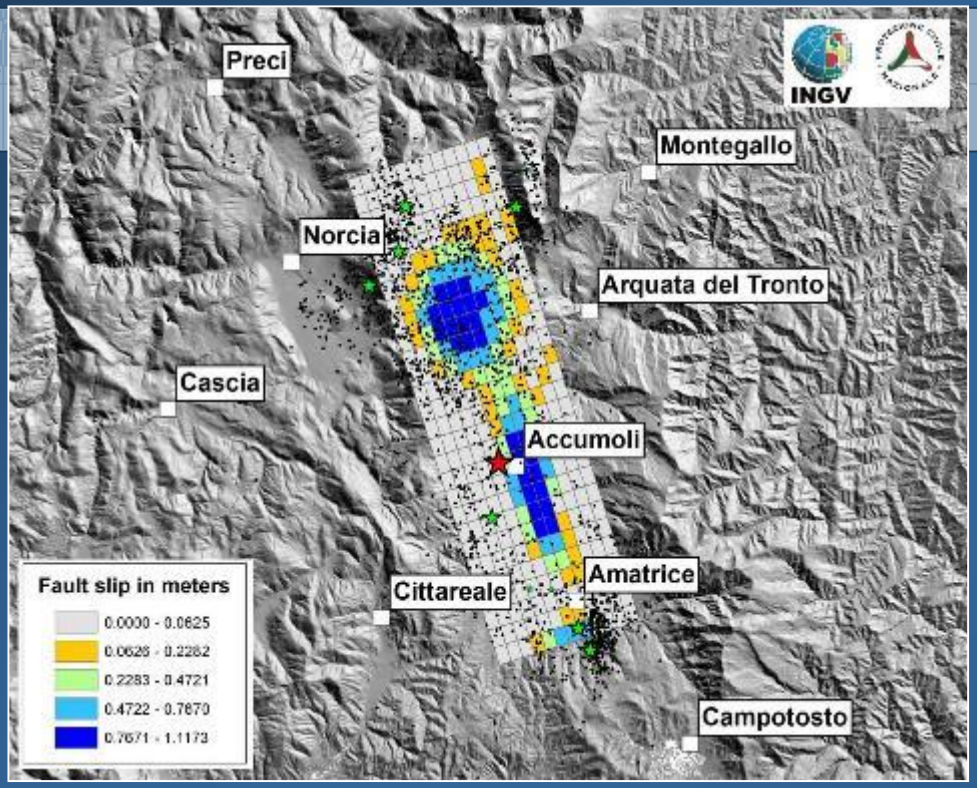
ENVIRONMENTAL, DISASTER AND CRISES MANAGEMENT

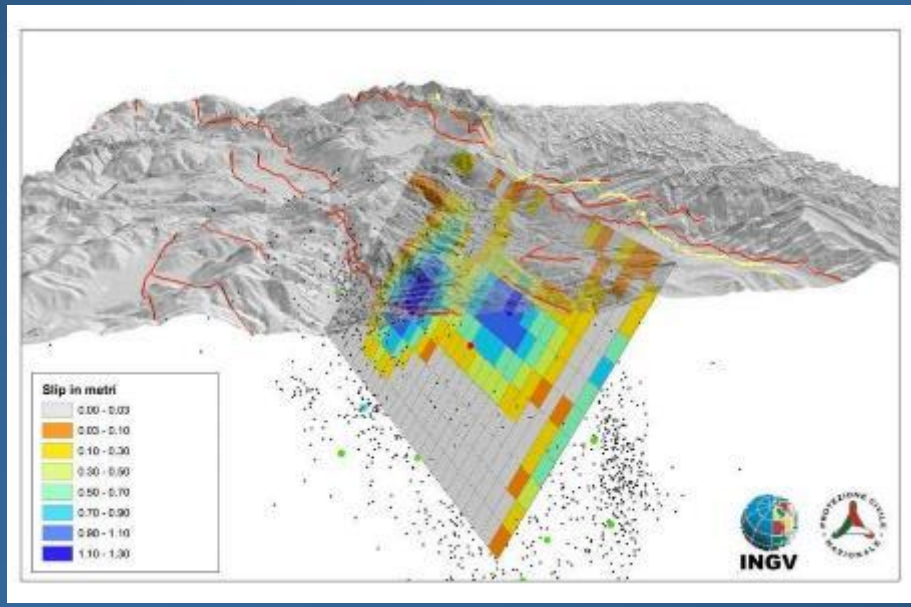
# COSEISMIC SURFACE RUPTURES ALONG THE VETTORE MT FAULT

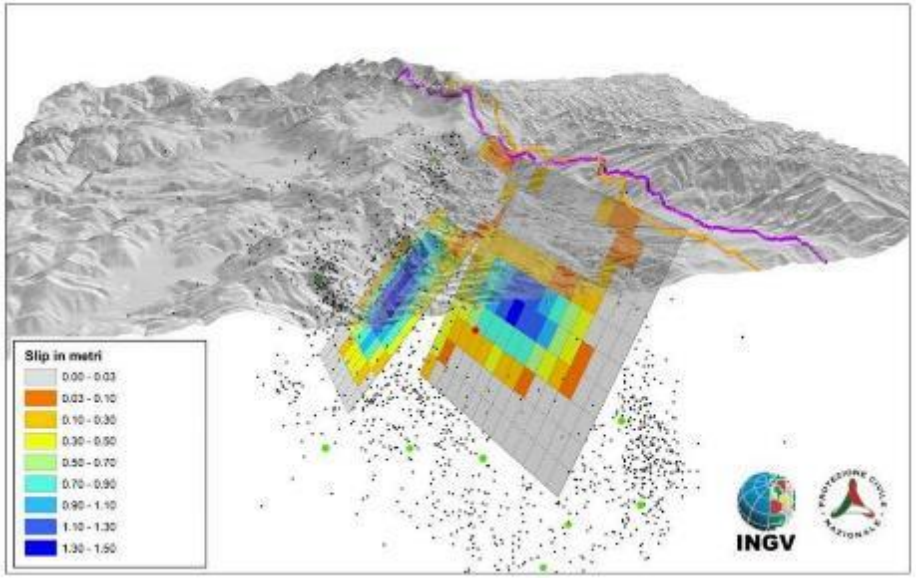





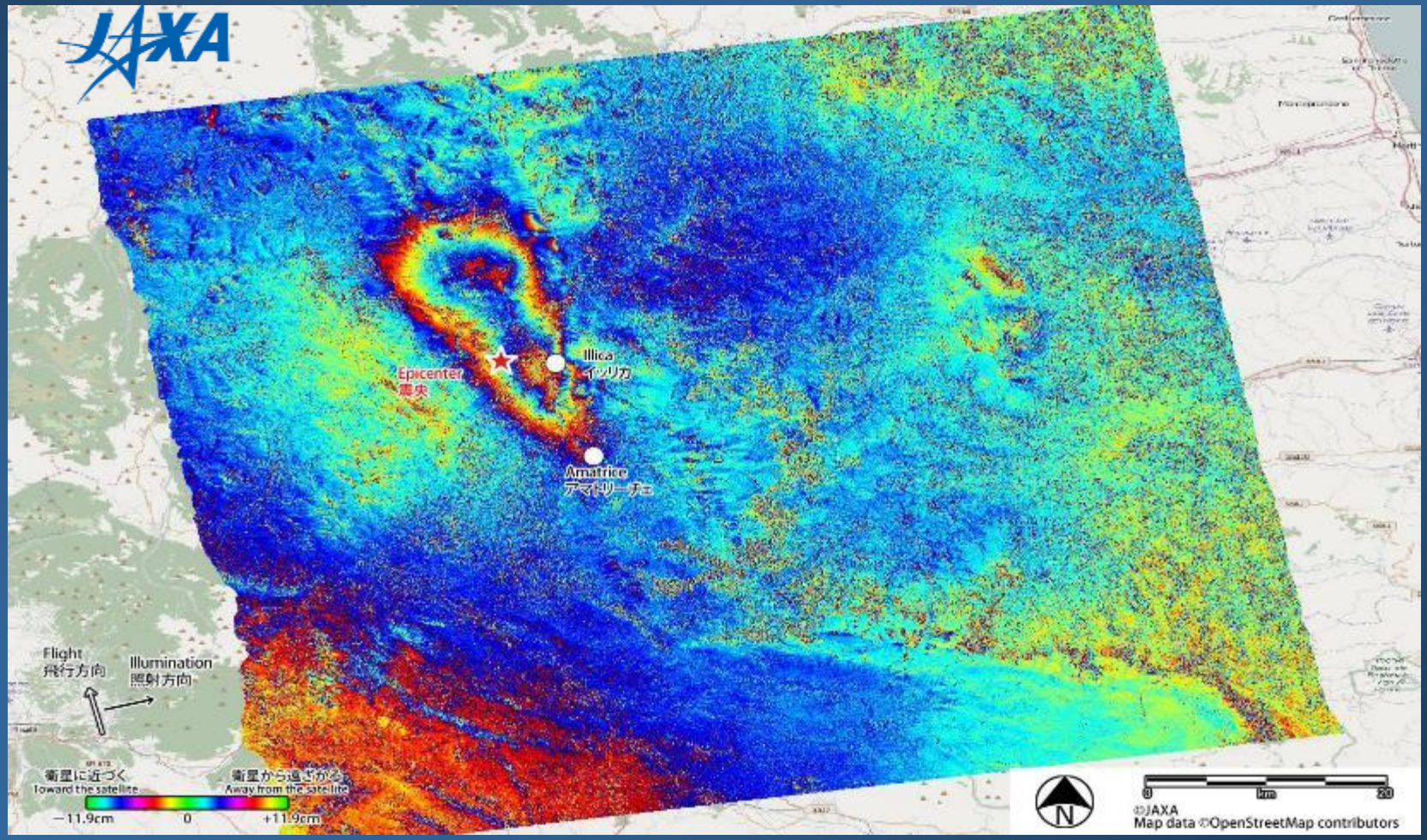



Preci
Montegallo
Norcia
Arquata del Tronto
Cascia
Accumoli
Amatrice
Cittareale
Campotosto
INGV
Fault slip in meters
0.0000 - 0.0625
0.0626 - 0.2282
0.2283 - 0.4721
0.4722 - 0.7670
0.7671 - 1.1173

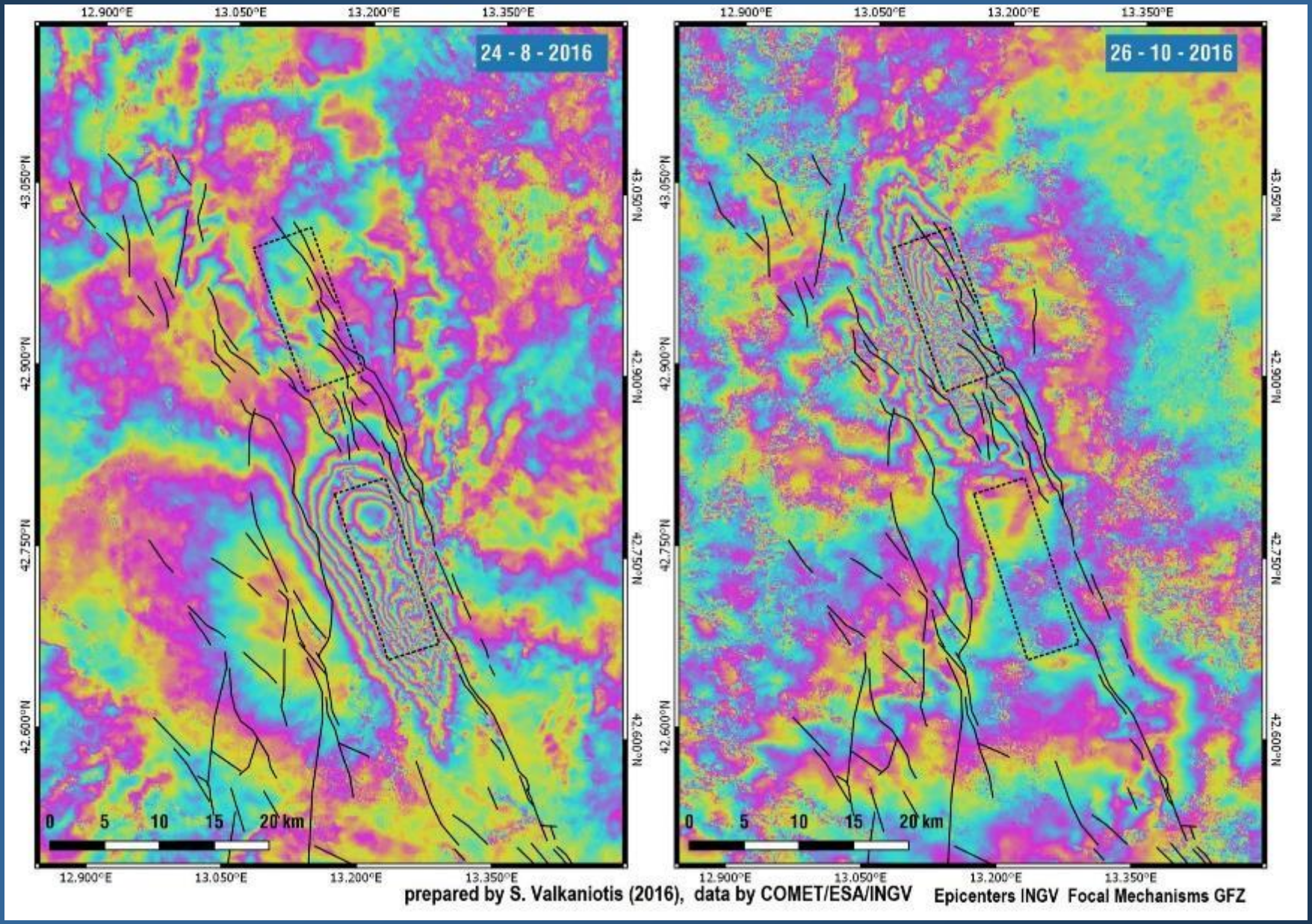

Slip in metri
INGV


Slip in metri
INGV

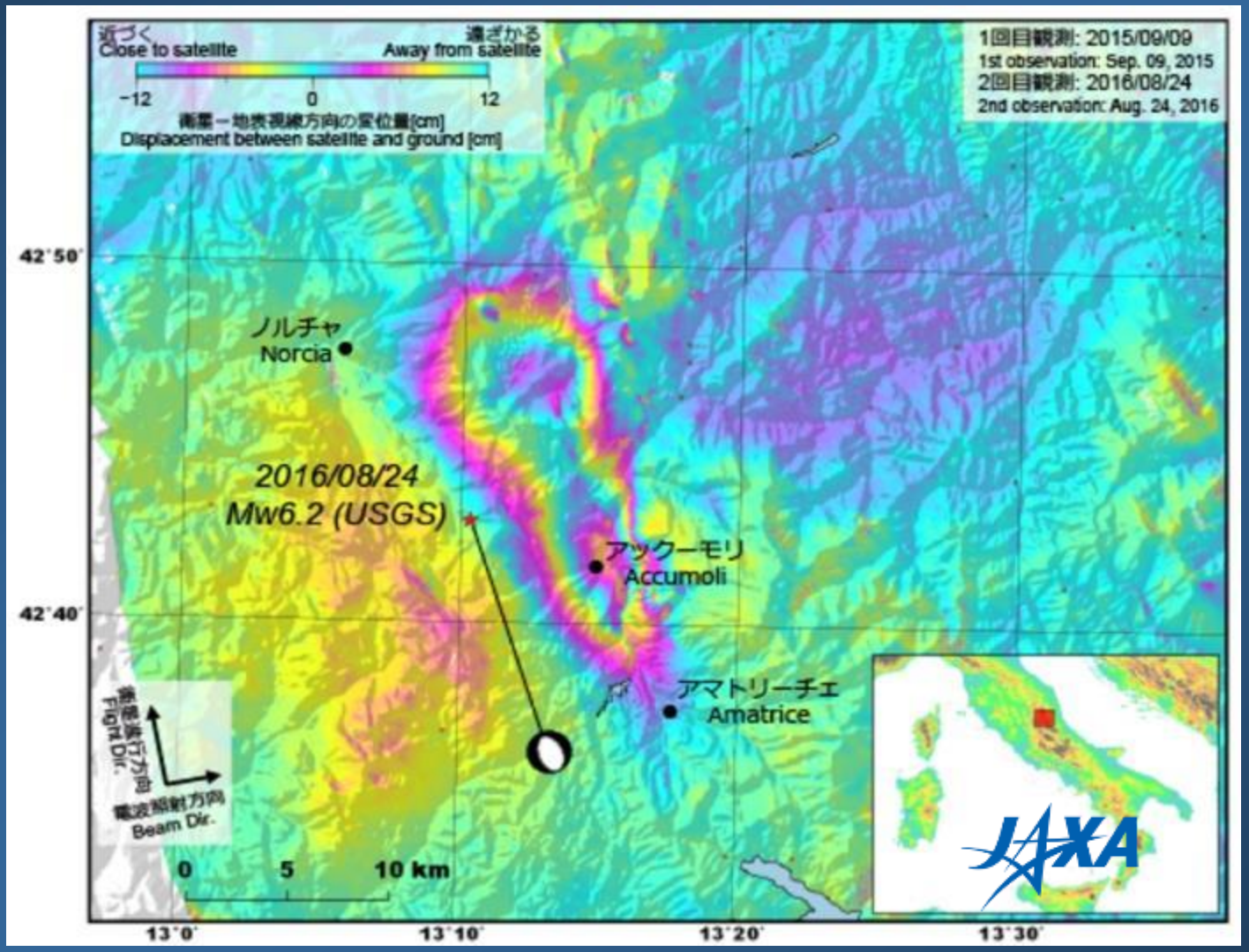
# DIFFERENTIAL INTERFEROMETRY (DINSAR) RESULT USING THE ALOS-2 PALSAR-2 DATA ACQUIRED BEFORE (2015.09.09; UTC) AND AFTER (2016.08.24; UTC) EARTHQUAKE




http://www.eorc.jaxa.jp/ALOS-2/en/new/20160825_ita-eq/l_dis_infe60825_fig2.jpg

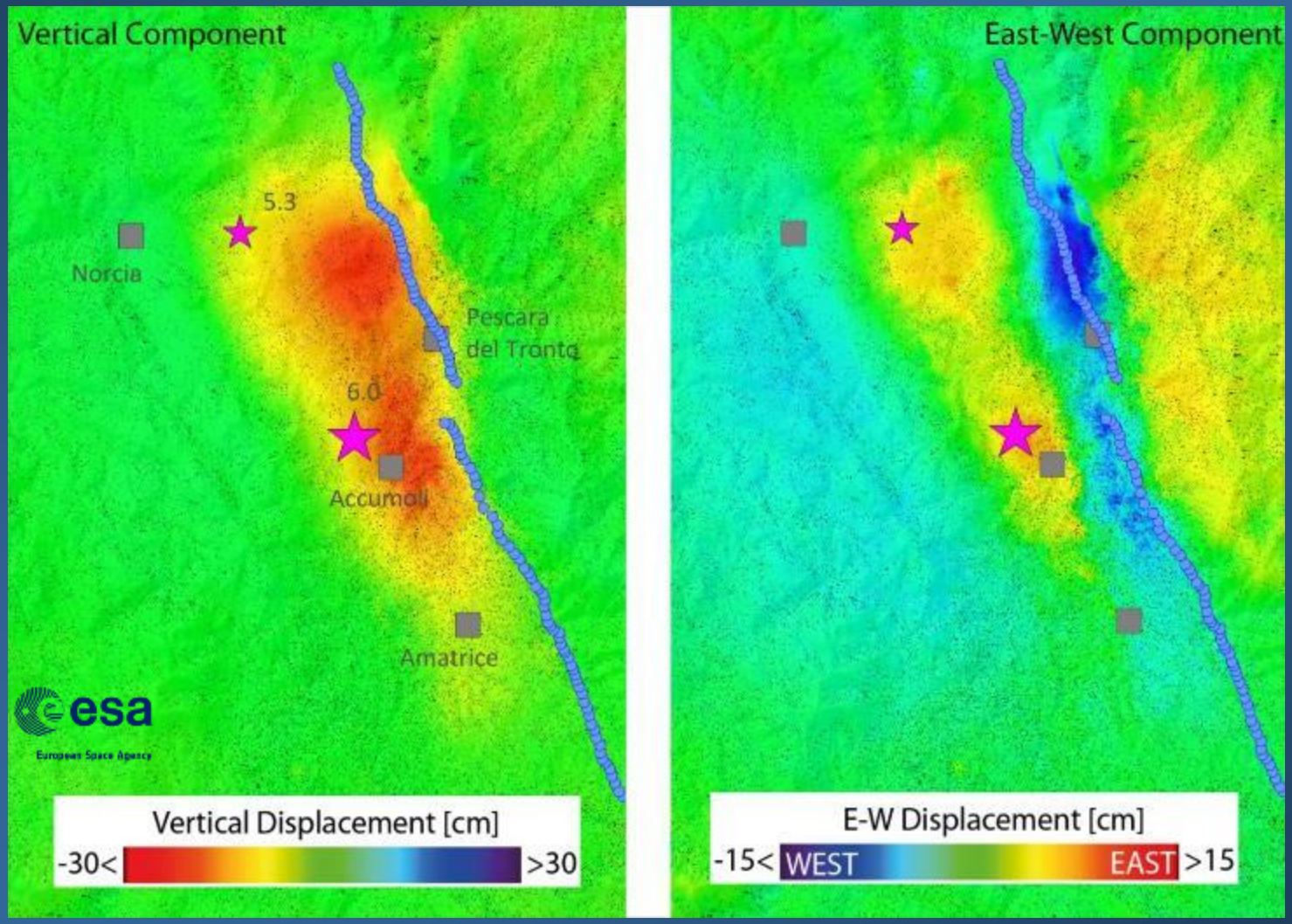

24 - 8 - 2016
26 - 10 - 2016
12.900°E
13.050°E
13.200°E
13.350°E
43.050°N
42.900°N
42.750°N
42.600°N
0 5 10 15 20 km
prepared by S. Valkaniotis (2016), data by COMET/ESA/INGV
Epicenters INGV Focal Mechanisms GFZ

# GROUND DEFORMATION CAUSED BY THE EARTHQUAKE



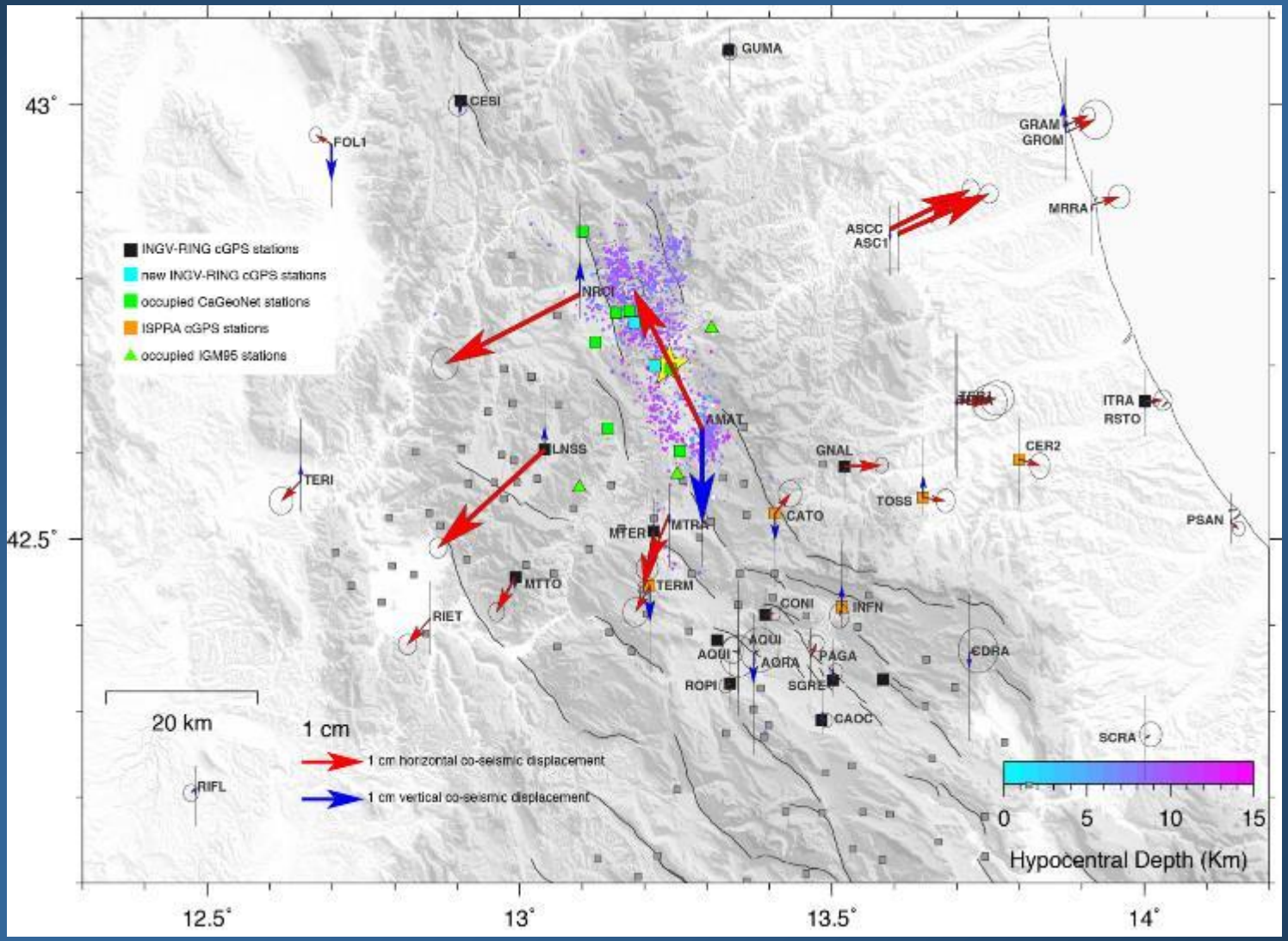

Japan Aerospace Exploration Agency - http://global.jaxa.jp/

# GROUND DISPLACEMENT FROM CENTRAL ITALY EARTHQUAKE

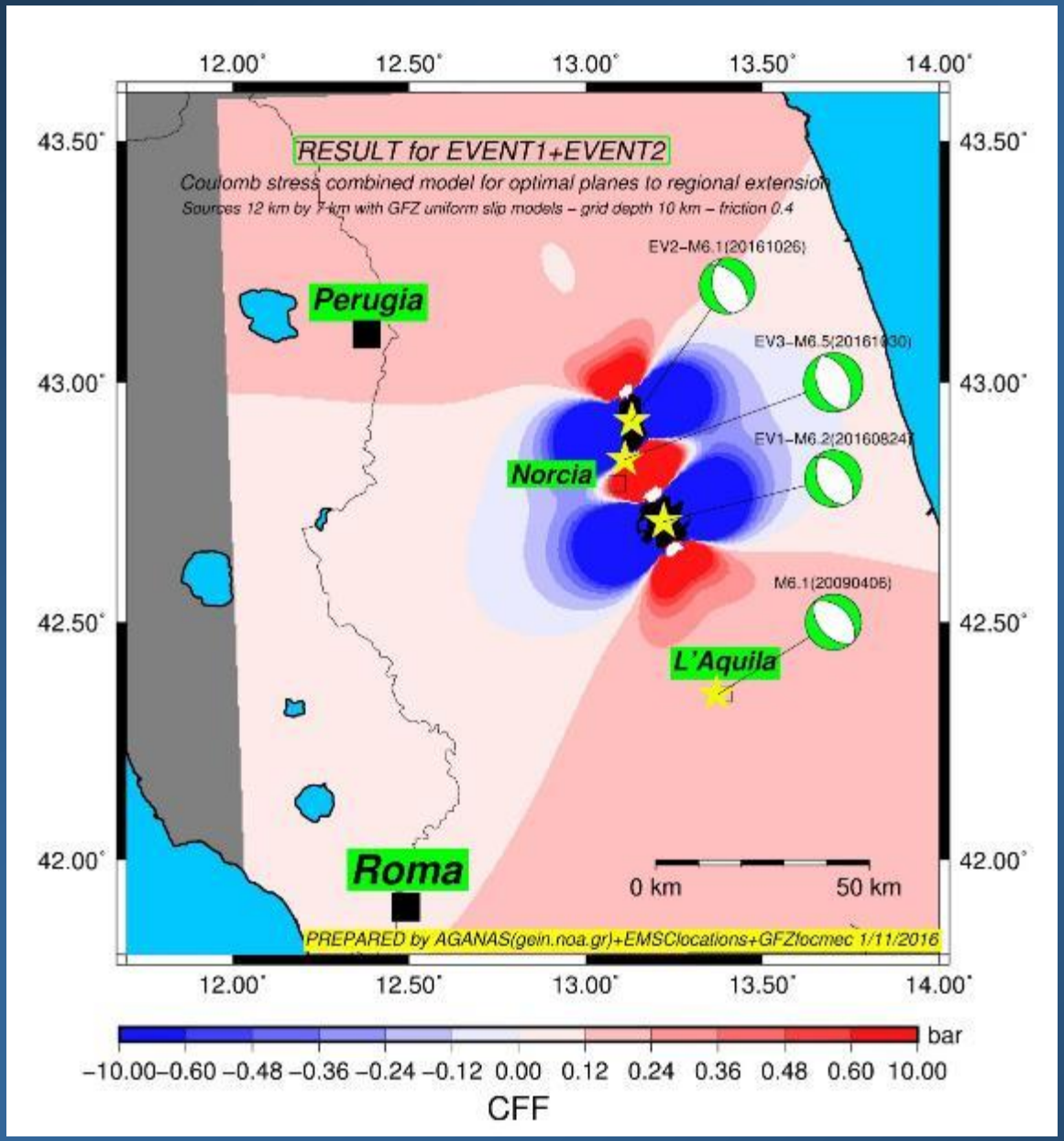


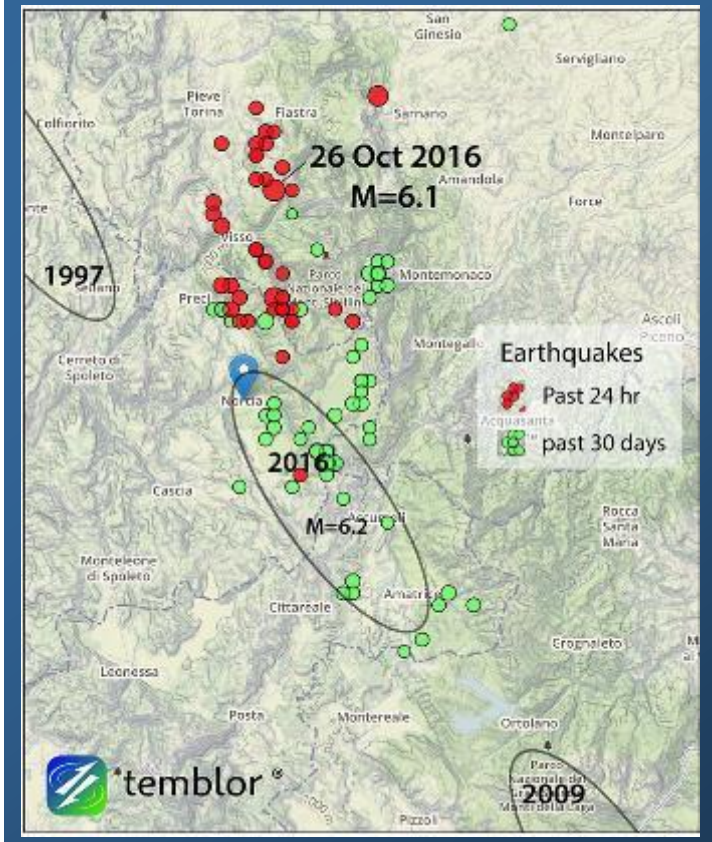

http://www.esa.int/spaceinimages/Images/2016/08/Ground_displacement_from_Italy_s_earthquake

# COSEISMIC DISPLACEMENTS FOR THE 2016 CENTRAL ITALY EARTHQUAKE ESTIMATED FROM CONTINUOUS GPS STATIONS




http://ring.gm.ingv.it/


RESULT for EVENT1+EVENT2
Coulomb stress combined model for optimal planes to regional extension
Sources 12 km by 7 km with GFZ uniform slip models – grid depth 10 km – friction 0.4
EV2–M6.1(20161026)
EV3–M6.5(20161030)
EV1–M6.2(20160824)
M6.1(20090406)
Perugia
Norcia
L'Aquila
Roma
0 km
50 km
PREPARED by AGANAS(gein.noa.gr)+EMSClocations+GFZlocmec 1/11/2016
12.00°
12.50°
13.00°
13.50°
14.00°
43.50°
43.00°
42.50°
42.00°
bar
−10.00 −0.60 −0.48 −0.36 −0.24 −0.12 0.00 0.12 0.24 0.36 0.48 0.60 10.00
CFF


26 Oct 2016
M=6.1
1997
2016
M=6.2
2009
Earthquakes
Past 24 hr
past 30 days
temblor

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PROFESSOR OF
DYNAMIC TECTONIC APPLIED GEOLOGY &
NATURAL DISASTER MANAGEMENT

PRESIDENT OF THE
EARTHQUAKE PLANNING &
PROTECTION ORGANIZATION

PRESIDENT OF THE
GEOLOGICAL SOCIETY OF GREECE

SPYRIDON MAVROULIS
GEOLOGIST MSC
PHD CANDIDATE

# THE EARTHQUAKES (Mw 6.0) OF 26 JAN & 3 FEB 2014
## A GEODYNAMIC EPISODE IN THE EVOLUTION OF KEFALONIA ISLAND

ARGOSTOLI 2014

# HISTORIC EARTHQUAKE SEQUENCES WITH TWO STRONG EVENTS

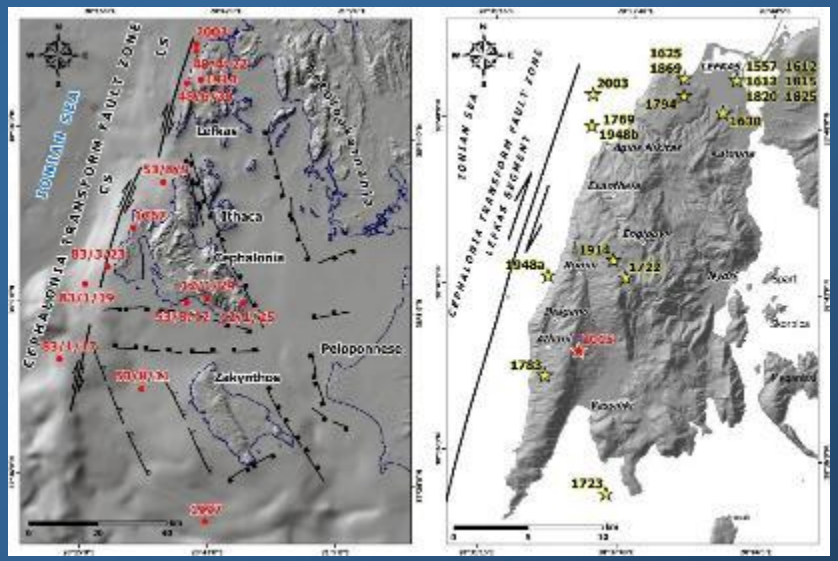
- **1513 – 18, 19 September**
  Sanudo, M. (1886), Μανούσακας, Μ.**Ι.** (1967)
- **1767 – 11, 22 July**
  Ζώης, Λ.Χ. (1893), Κατράμης, Ν. (1880), Κονόμος, Ντ. (1970), Τσιτσέλης, Η. (1960), Kouskouna, V. et al (1993), Makropoulos, K. & Kouskouna, V. (1994)
- **1791 – 22, 23 October, 2 November**
  Ζώης, Λ.Χ. (1893), Κατραμής, Ν. (1880), Κολυβά, Μ. (1997), Χιώτης, Π. (1886), Barbiani (1863), Saint Sauverur (1800)
- **1820 – 17, 29 December**
  Ζώης, Λ.Χ. (1893), Ζώρας, Γ. (1973), Κονόμος, Ντ. (1970), Παπανικολάου-Κρίνστενσεν, Α. (1993), Τσιτσέλης, Η. (1960), Χιώτης, Π. (1886), Barbiani (1863),
- **1840 – 18, 30 October**
  Ζώης, Λ.Χ. (1893), Κολυβά, Μ. (1997), Κονόμος, Ν. (1970), Ρώμας, Δ. (1973), Χιώτης, Π., (1886), Barbiani (1863), Montessus de Ballore, F. (1900)
- **1872 – 10, 25 October**
  Χιώτης, Π. (1886)
- **1886 – 15, 27 August**
  Ζώης, Λ.Χ. (1893), Χιώτης, Π. (1886), Montessus de Ballore, F. (1900)
- **1893 – 19, 31 January**
  Ζώης, Λ.Χ. (1893), Issel, A. & Agamennone, G. (1894), Issel, A. (1893). Montessus de Ballore, F. (1990)

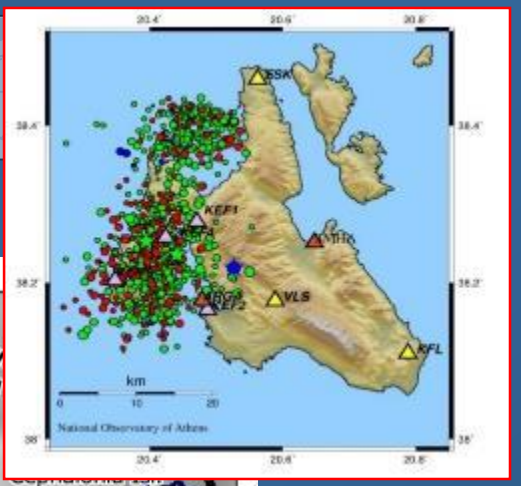
- **1953 – 9, 11, 12 August**
  **9 August, M 6.4  11 August, M 6.8  12 August, M 7.2**

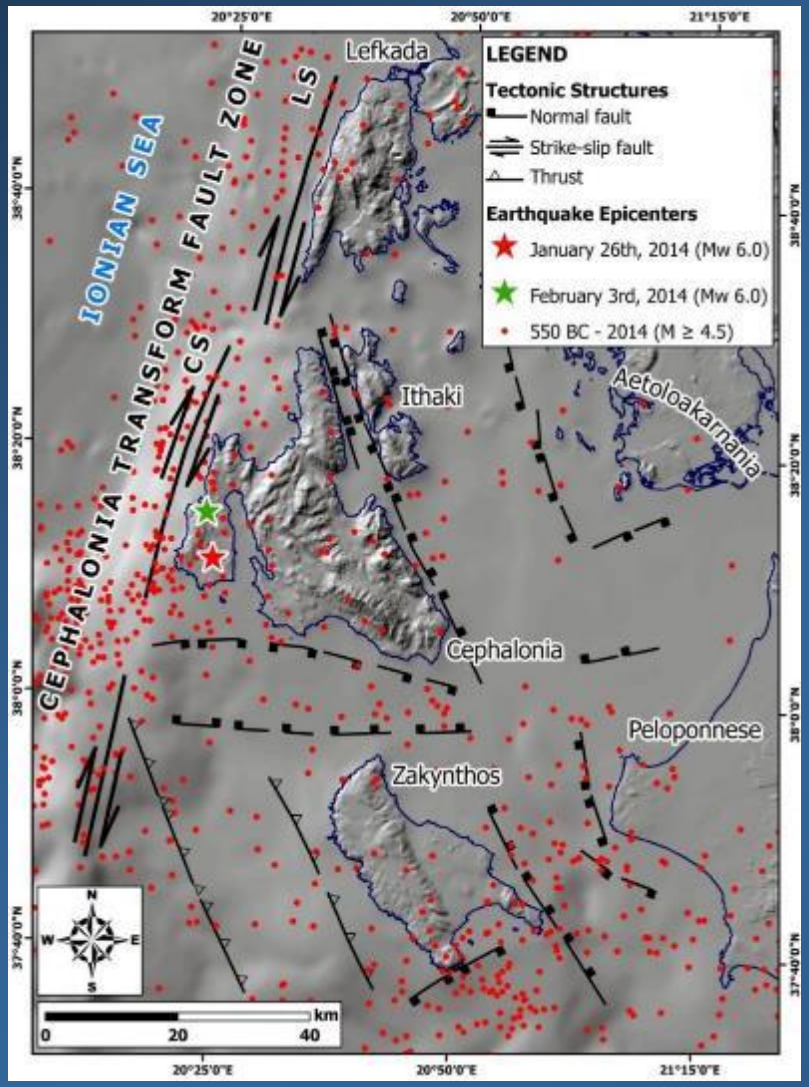
**Lekkas et al. (1997)**

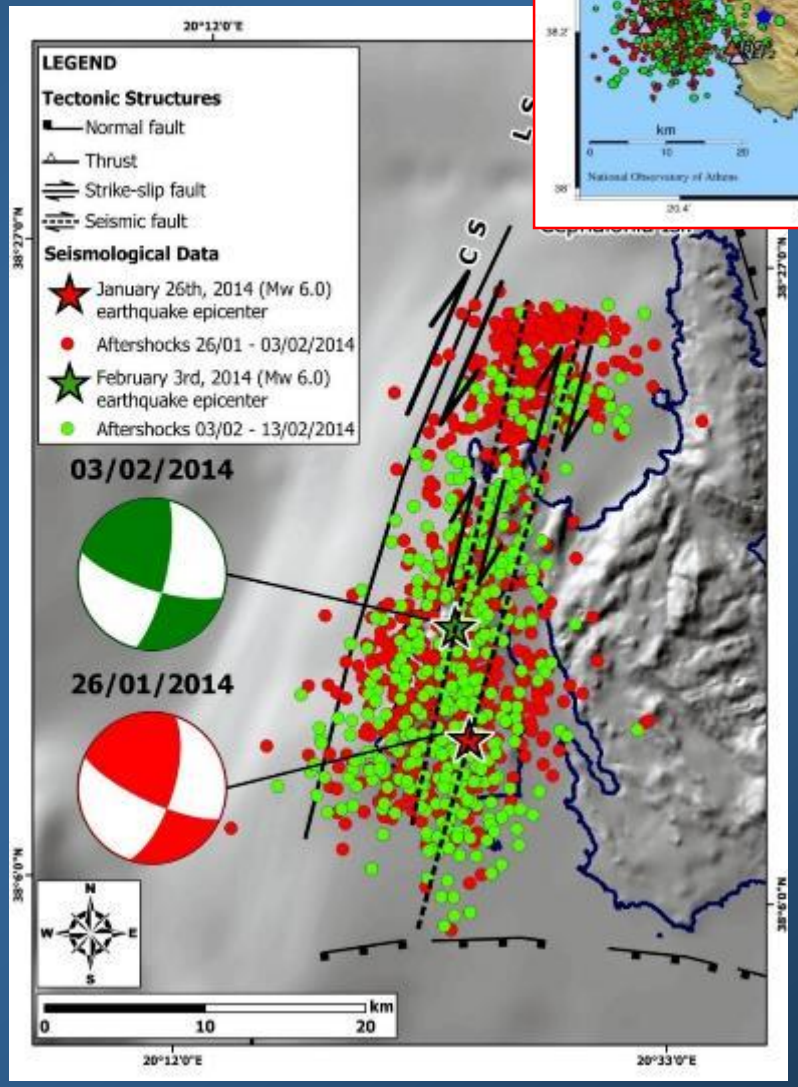
# HISTORIC AND INSTRUMENTAL EARTHQUAKES IN LEFKAS ISLAND

| | | | |
|---|---|---|---|
| 1557 | | M = 6.2 | Imax = 8 |
| 1612 – May 26 | | M = 6.3 | Imax = 8-10 |
| 1613 – October 2 | | M = 6.3 | Imax = 8-10 |
| 1625 – June 18 | | M = 6.5 | Imax = 9-10 |
| 1630 – July 2 | | M = 6.4 | Imax = 9-10 |
| 1704 – November 22 | M = 6.4 | Imax = 9-10 | |
| 1722 – June 5 | | M = 6.3 | Imax = 8-9 |
| 1723 – February 22 | | M = 6.5 | Imax = 8-9 |
| 1769 – October 12 | M = 6.4 | Imax = 9-10 | |
| 1783 – March 23 | | M = 6.6 | Imax = 10 |
| 1815 | | M = 6.3 | Imax = 8-9 |
| 1820 – February 21 | | M = 6.6 | Imax = 8-9 |
| 1825 – January 1 | | M = 6.7 | Imax = 9-10 |
| 1869 – December 28 | M = 6.7 | Imax = 10 | |
| 1914 – November 27 | M = 6.3 | Imax = 9 | |
| 1948 – April 22 | | M = 6.5 | Imax = 9 |
| June 30 | | M = 6.4 | Imax = 10 |
| 2003 – August 14 | | M = 6.2 | Imax = 8 |



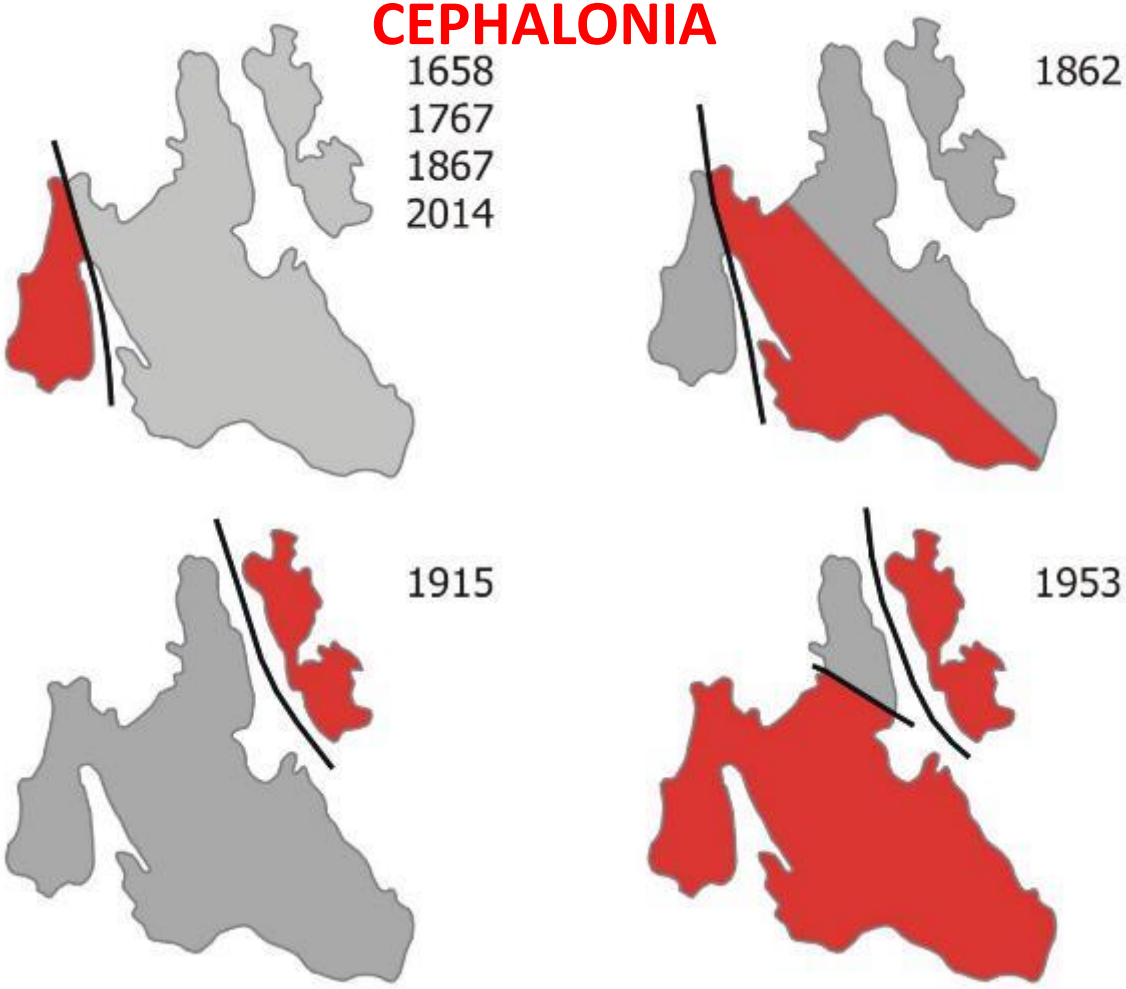


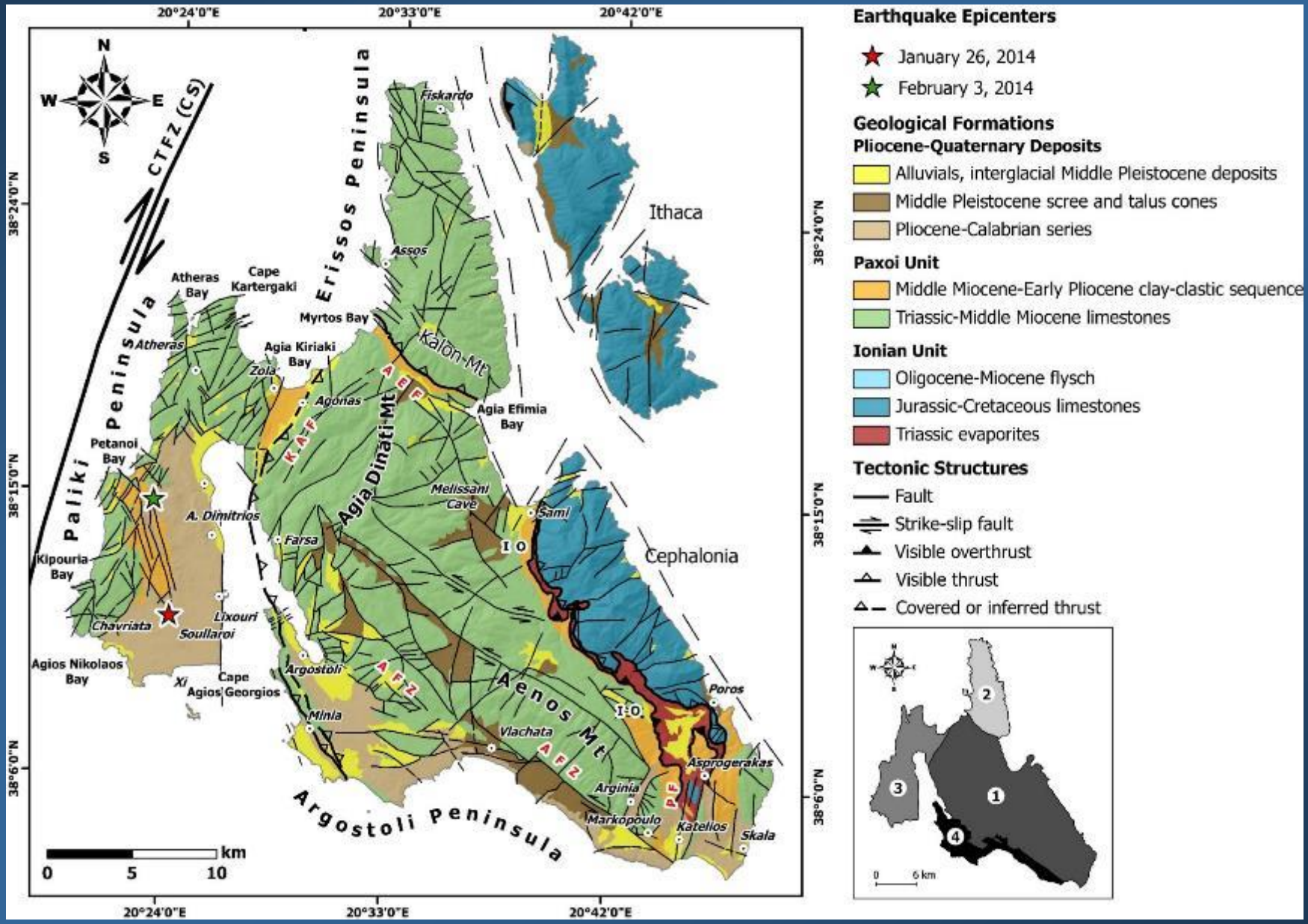




Lekkas and Mavroulis (2015)

# MAXIMUM SEISMIC INTENSITIES FOR HISTORIC AND RECENT EARTHQUAKES IN CEPHALONIA






**Earthquake Epicenters**

- January 26, 2014
- February 3, 2014

**Geological Formations**

**Pliocene-Quaternary Deposits**

- Alluvials, interglacial Middle Pleistocene deposits
- Middle Pleistocene scree and talus cones
- Pliocene-Calabrian series

**Paxoi Unit**

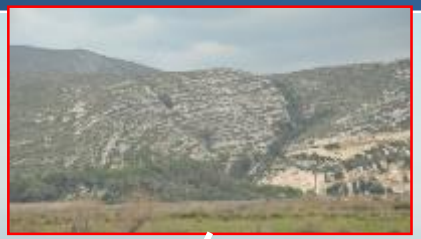
- Middle Miocene-Early Pliocene clay-clastic sequence
- Triassic-Middle Miocene limestones

**Ionian Unit**

- Oligocene-Miocene flysch
- Jurassic-Cretaceous limestones
- Triassic evaporites

**Tectonic Structures**

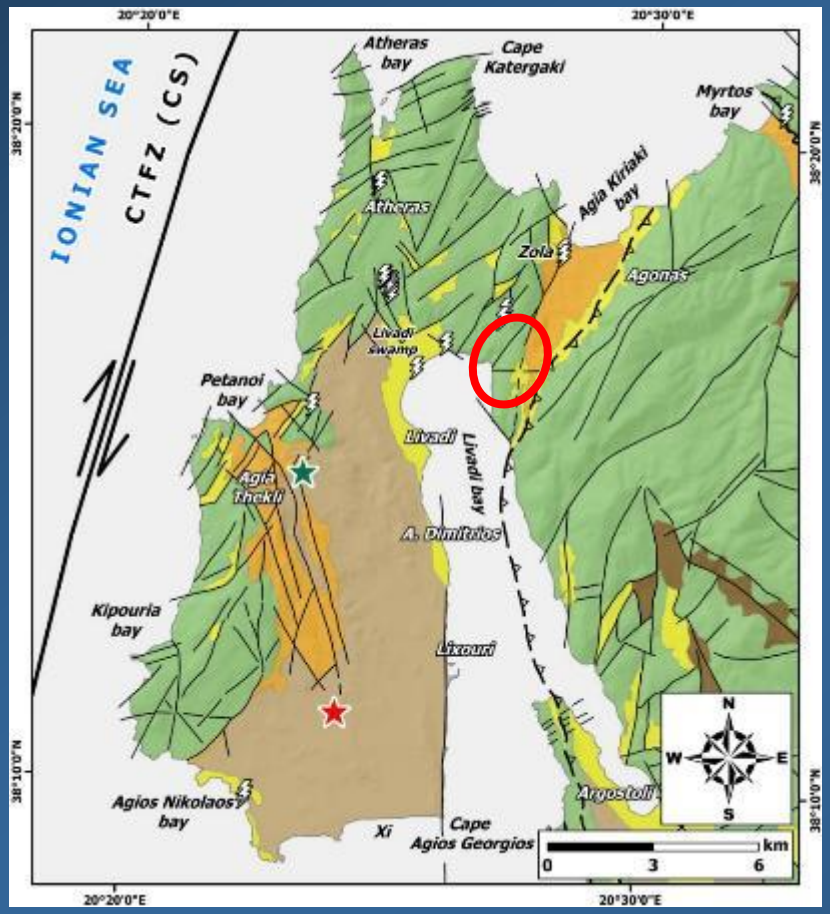
- Fault
- Strike-slip fault
- Visible overthrust
- Visible thrust
- Covered or inferred thrust



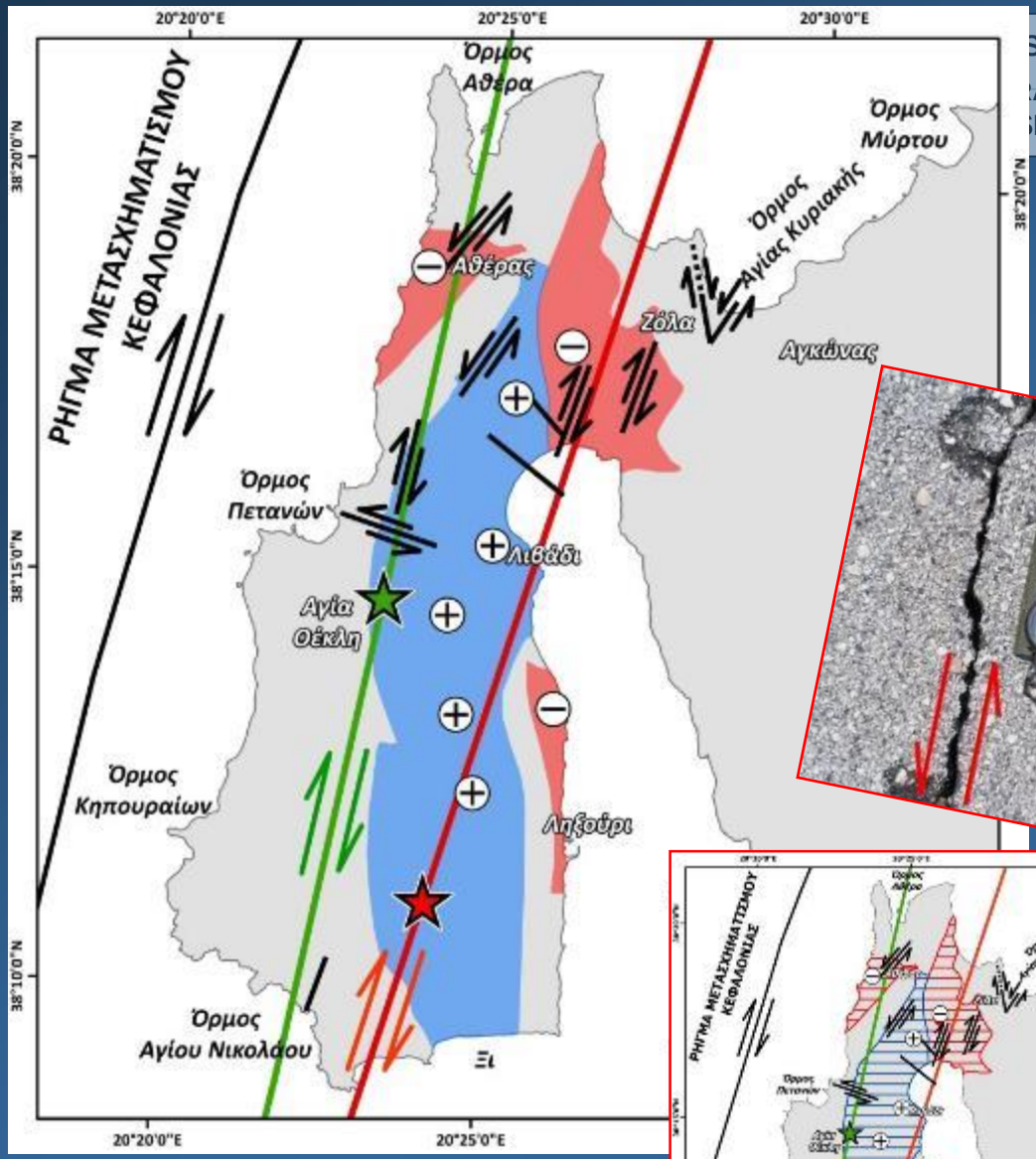
SURFACE FRACTURES , N 025° W
EQ Mw 6.0 FEBR 3 2014

ACTIVE FAULT, N 20° E
EQ Mw 6.0 . JAN 26 2014

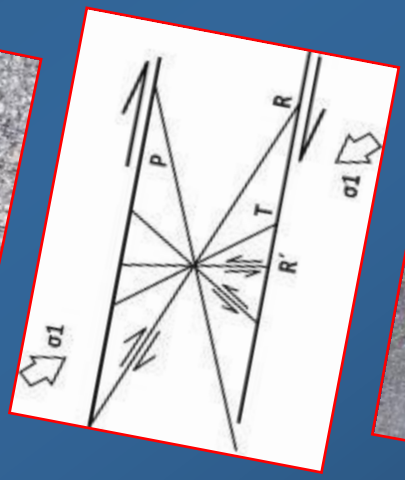
# Surface ruptures in the broader Livadi swamp area observed during 1st earthquake

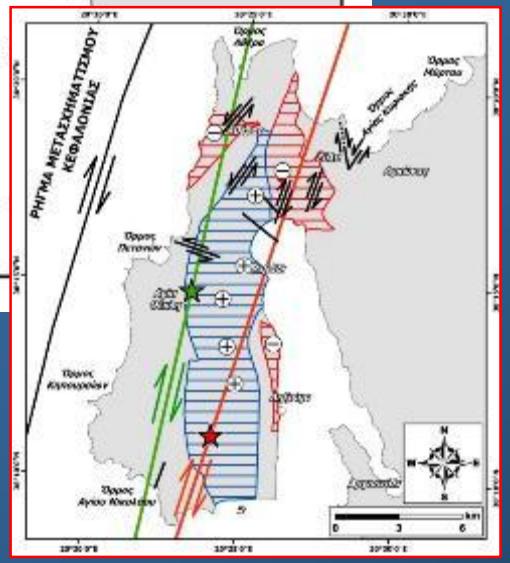


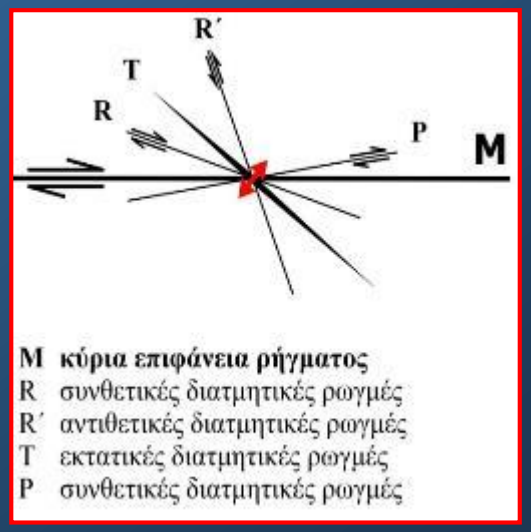

Lekkas and Mavroulis (2015)

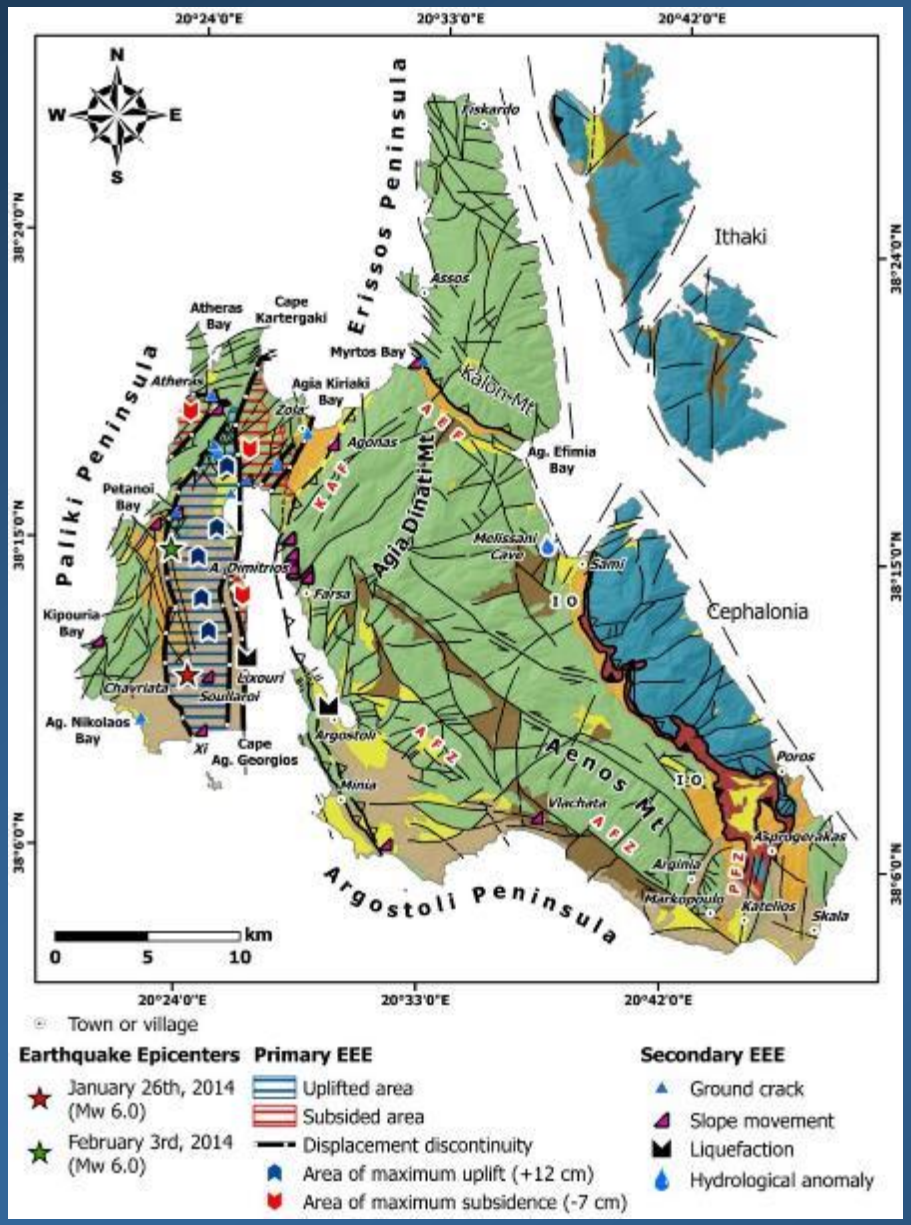


20°20'0"E
20°25'0"E
20°30'0"E
38°20'0"N
38°15'0"N
38°10'0"N
ΡΗΓΜΑ ΜΕΤΑΣΧΗΜΑΤΙΣΜΟΥ ΚΕΦΑΛΟΝΙΑΣ
Όρμος Αθέρα
Όρμος Μύρτου
Όρμος Αγίας Κυριακής
Αθέρας
Ζόλα
Αγκώνας
Όρμος Πετανών
Λιβάδι
Αγία Οξέλη
Όρμος Κηπουραίων
Λιξούρι
Όρμος Αγίου Νικολάου
Ξι

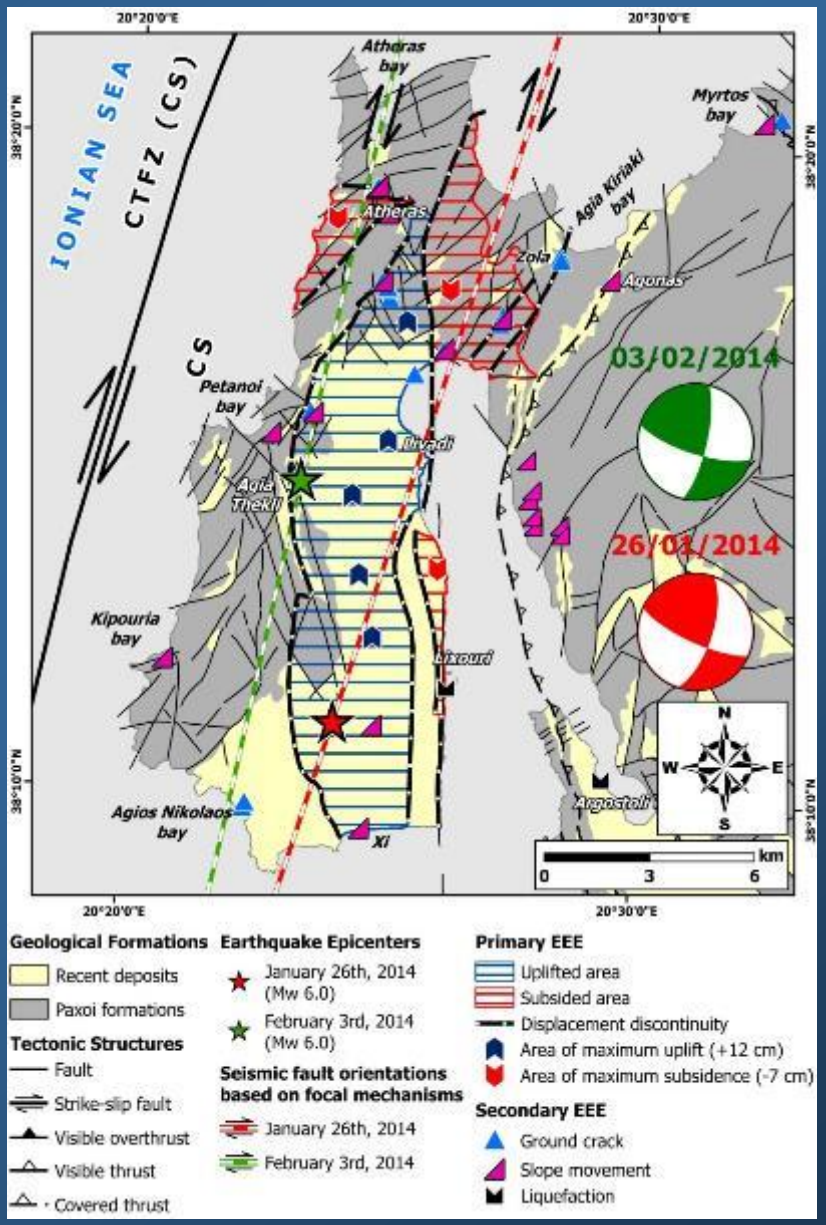


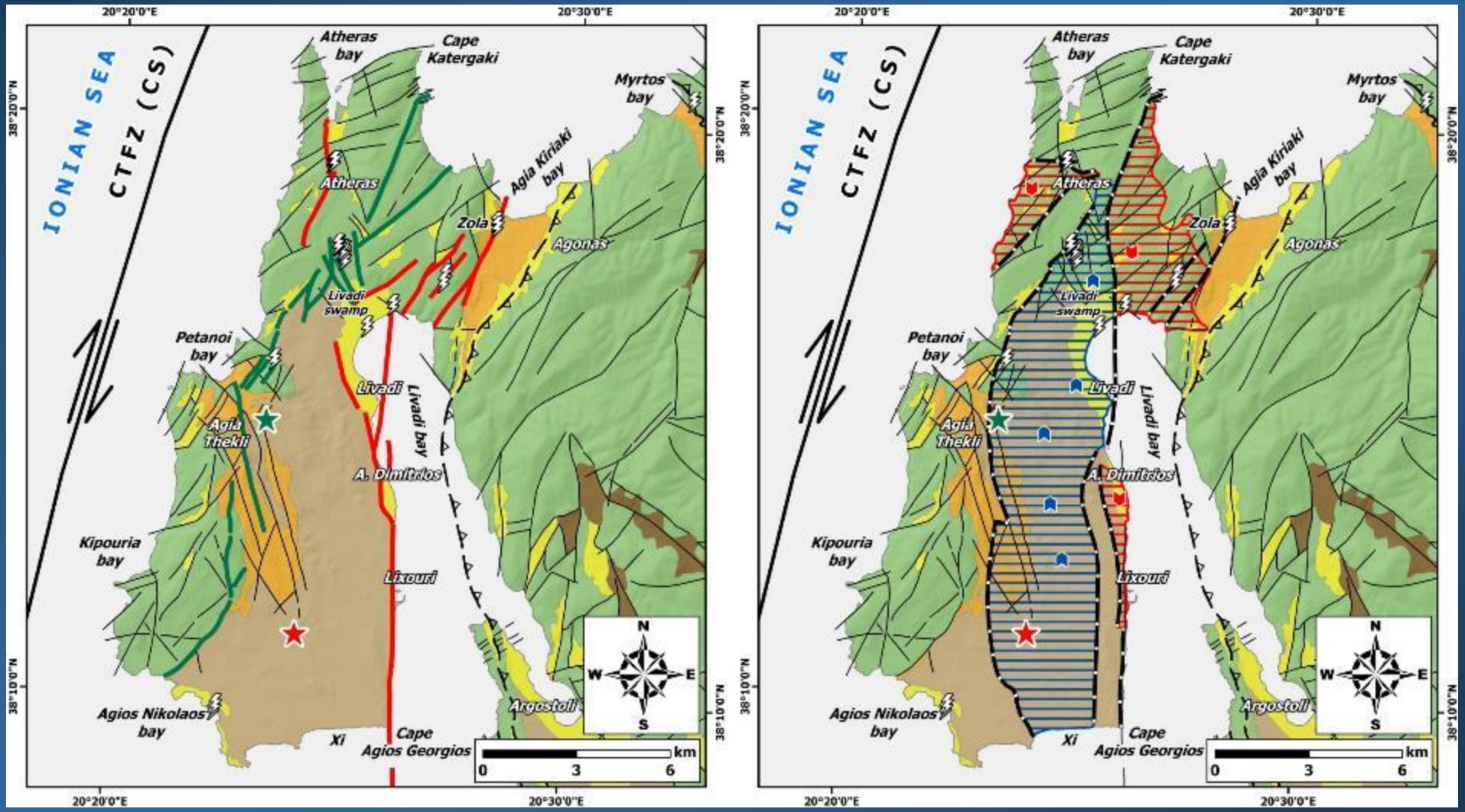

P
R
T
R΄
σ1
σ1

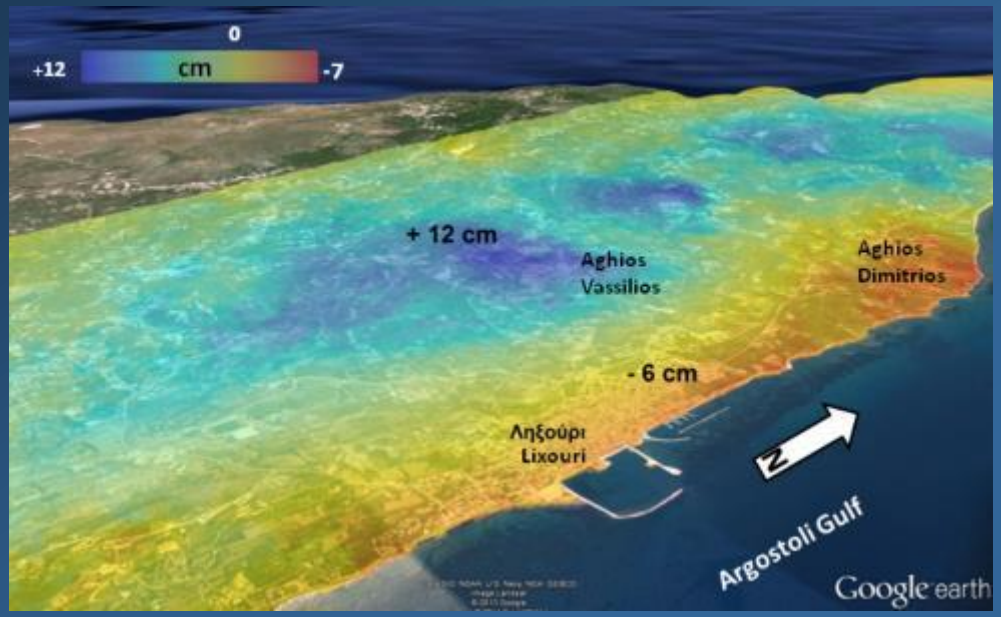



R΄
T
R
P
M
M κύρια επιφάνεια ρήγματος
R συνθετικές διατμητικές ρωγμές
R΄ αντιθετικές διατμητικές ρωγμές
T εκτατικές διατμητικές ρωγμές
P συνθετικές διατμητικές ρωγμές


20°24'0"E
20°33'0"E
20°42'0"E
38°24'0"N
38°15'0"N
38°6'0"N
N
W
E
S
Ithaki
Cephalonia
Paliki Peninsula
Erissos Peninsula
Argostoli Peninsula
Aenos Mt
Ainos Mt
Agia Dinati Mt
Kalon Mt
Fiskardo
Assos
Atheras Bay
Cape Kartergaki
Atheras
Myrtos Bay
Agia Kiriaki Bay
Zola
Agonas
Ag. Efimia Bay
Petanoi Bay
A. Dimitrios
Farsa
Sami
Melissani Cave
Kipouria Bay
Chavriata
Lixouri
Soulliaroi
Ag. Nikolaos Bay
Xi
Cape Ag. Georgios
Argostoli
Minia
Vlachata
Poros
Asprogerakas
Arginia
Markopoulo
Katelios
Skala
AFZ
PFZ
KAFZ
km
0
5
10
Town or village
Earthquake Epicenters
January 26th, 2014 (Mw 6.0)
February 3rd, 2014 (Mw 6.0)
Primary EEE
Uplifted area
Subsided area
Displacement discontinuity
Area of maximum uplift (+12 cm)
Area of maximum subsidence (-7 cm)
Secondary EEE
Ground crack
Slope movement
Liquefaction
Hydrological anomaly

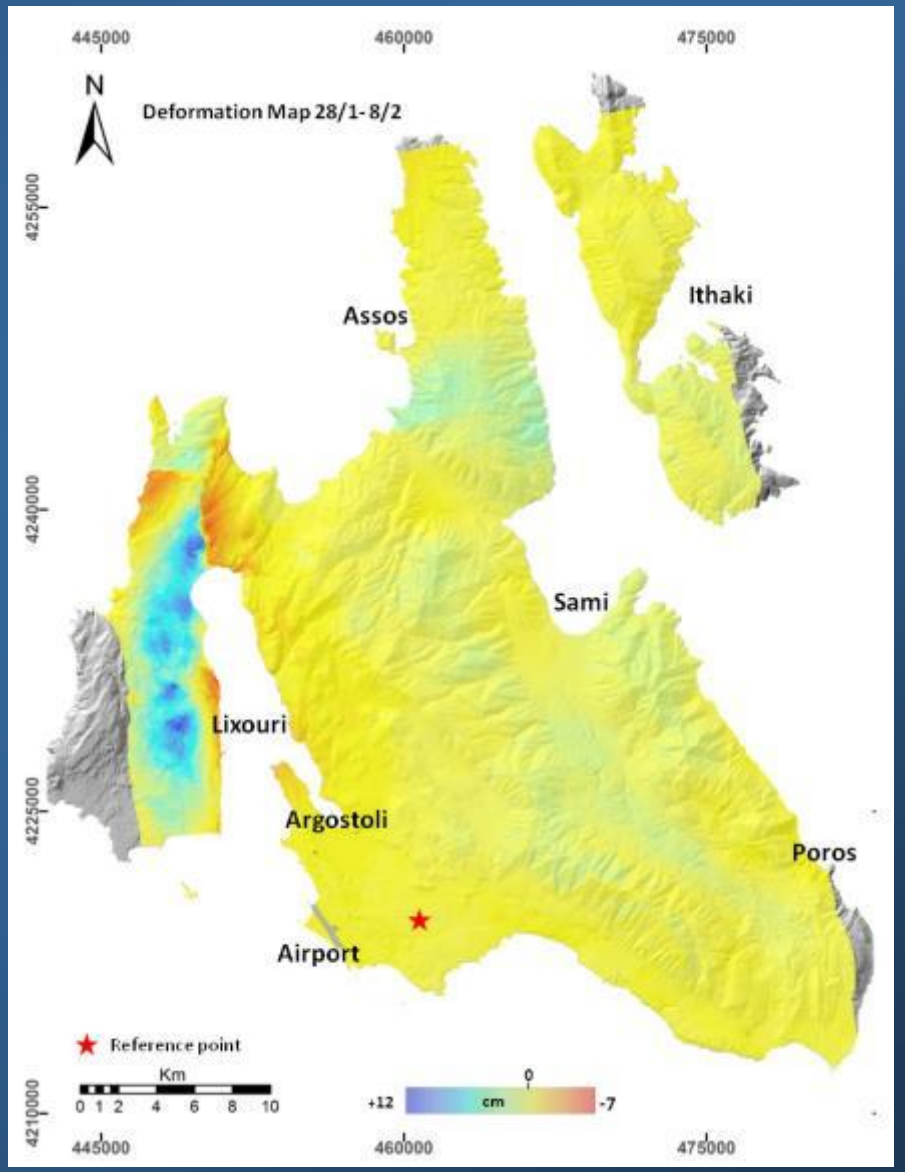

20°20'0"E
20°30'0"E
38°20'0"N
38°10'0"N
IONIAN SEA
CTFZ (CS)
CS
Atheras bay
Myrtos bay
Agia Kiriaki bay
Atheras
Zola
Agonas
Petanoi bay
Ilivadi
Agia Triada
Kipouria bay
Lixouri
Agios Nikolaos bay
Xi
Argostoli
03/02/2014
26/01/2014
N
W
E
S
km
0
3
6
Geological Formations
Recent deposits
Paxoi formations
Tectonic Structures
Fault
Strike-slip fault
Visible overthrust
Visible thrust
Covered thrust
Earthquake Epicenters
January 26th, 2014 (Mw 6.0)
February 3rd, 2014 (Mw 6.0)
Seismic fault orientations based on focal mechanisms
January 26th, 2014
February 3rd, 2014
Primary EEE
Uplifted area
Subsided area
Displacement discontinuity
Area of maximum uplift (+12 cm)
Area of maximum subsidence (-7 cm)
Secondary EEE
Ground crack
Slope movement
Liquefaction


IONIAN SEA
CTFZ (CS)
Atheras bay
Cape Katergaki
Myrtos bay
Atheras
Agia Kiriaki bay
Zola
Agonas
Livadi swamp
Petanoi bay
Livadi
Livadi bay
Agia Thekli
A. Dimitrios
Kipouria bay
Lixouri
Agios Nikolaos bay
Xi
Cape Agios Georgios
Argostoli
N
W
E
S
km
0
3
6
20°20'0"E
20°30'0"E
38°20'0"N
38°10'0"N




# SURFACE DEFORMATION MEASUREMENTS FROM HIGH RESOLUTION INSAR

*by Parcharidis et al. (2014)*



NATIONAL & KAPODISTRIAN UNIVERSITY OF ATHENS
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Dr. EFTHYMIS LEKKAS
PROFESSOR OF
DYNAMIC TECTONIC APPLIED GEOLOGY &
NATURAL DISASTER MANAGEMENT

PRESIDENT OF THE
EARTHQUAKE PLANNING &
PROTECTION ORGANIZATION

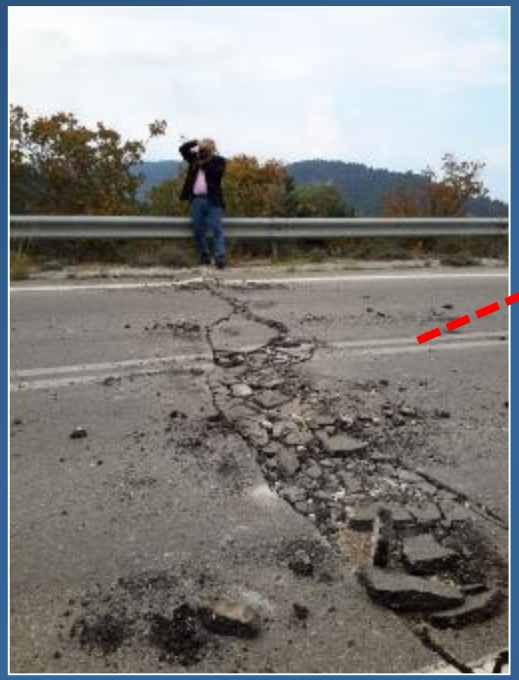
PRESIDENT OF THE
GEOLOGICAL SOCIETY OF GREECE

PRESIDENT OF THE S C OF KEDE

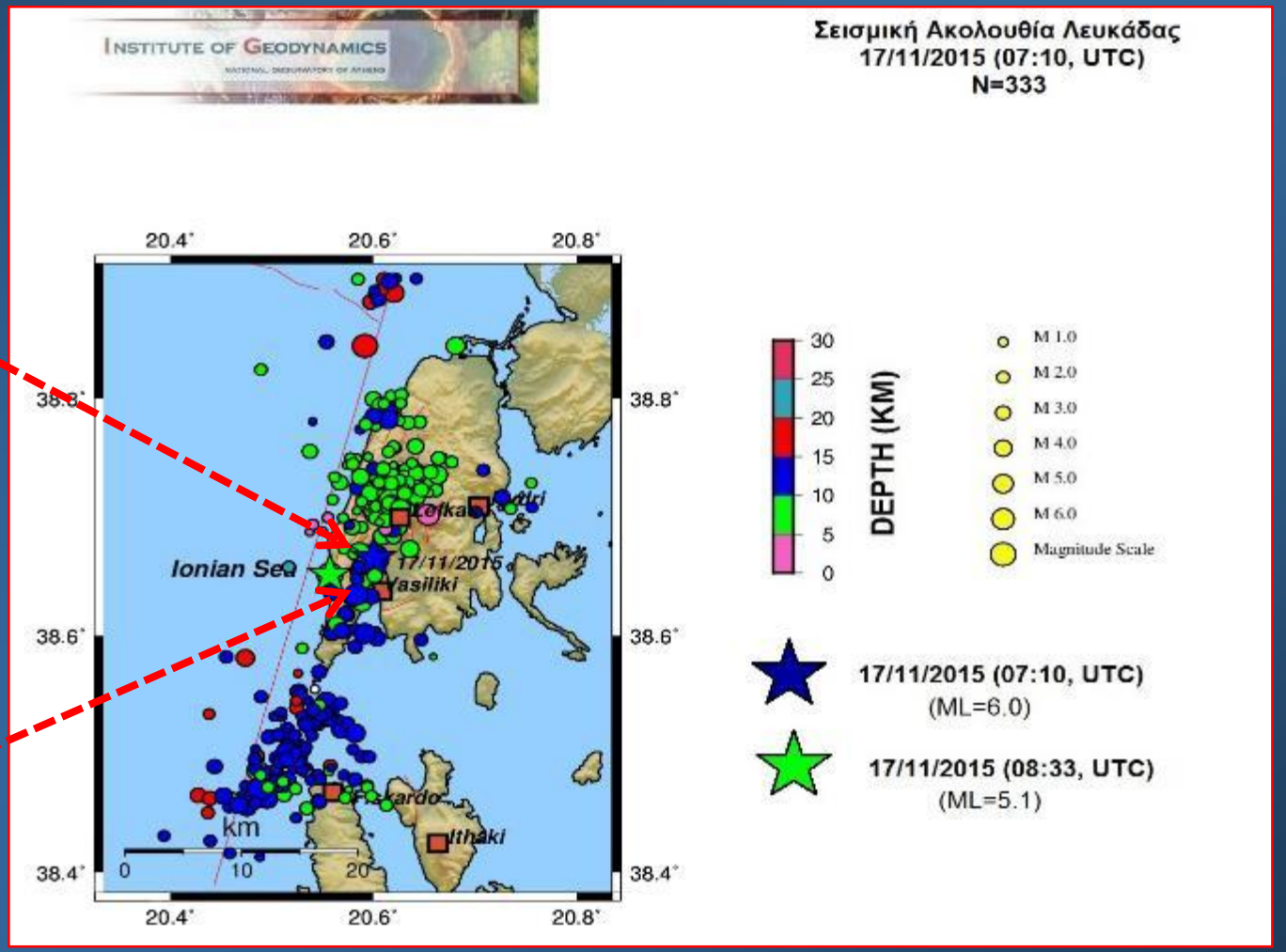
# THE 2015 LEFKAS EARTHQUAKE (NOVEMBER 17, Mw 6.4)

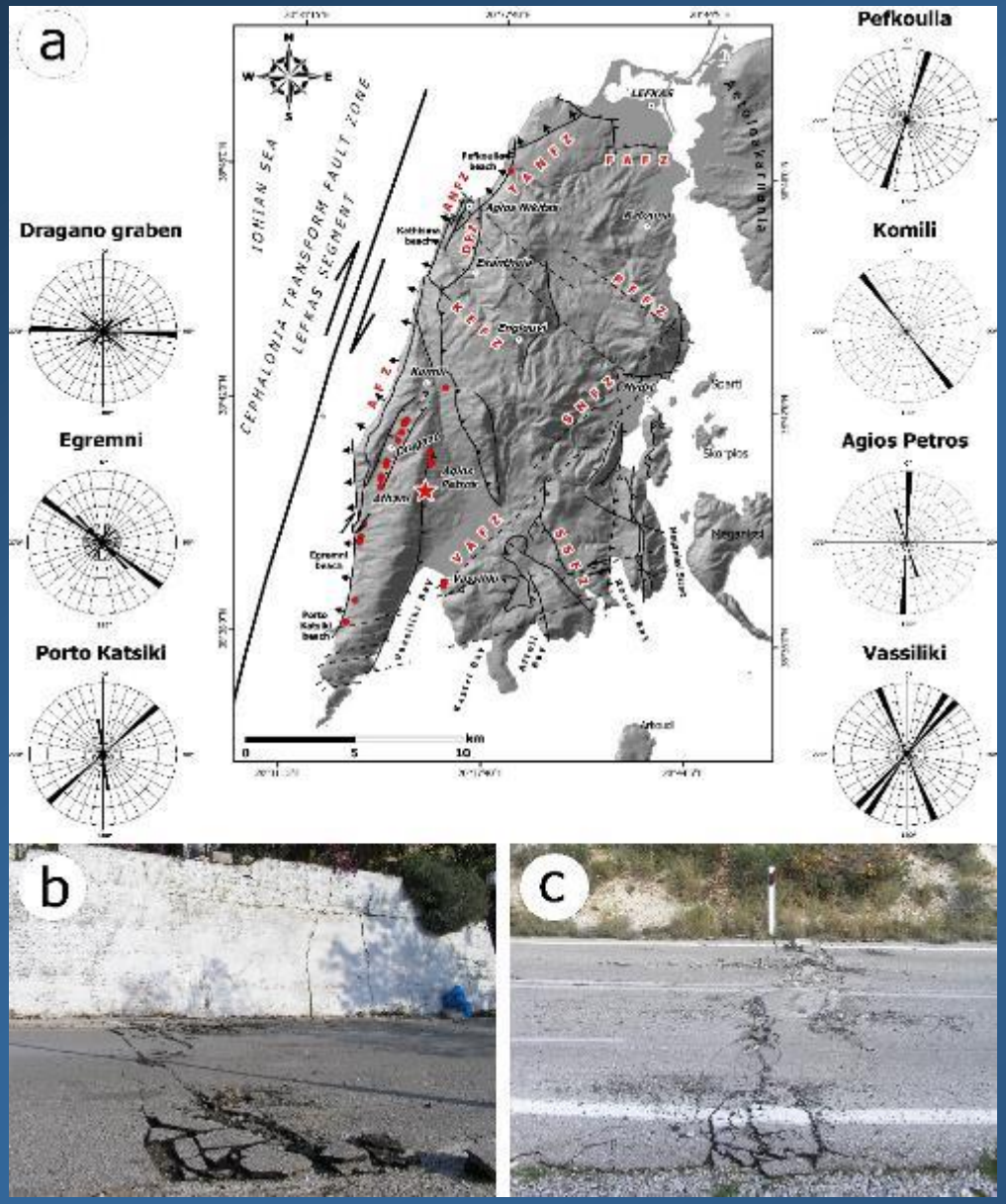
## A GEODYNAMIC EPISODE IN THE EVOLUTION OF IONIAN SEA

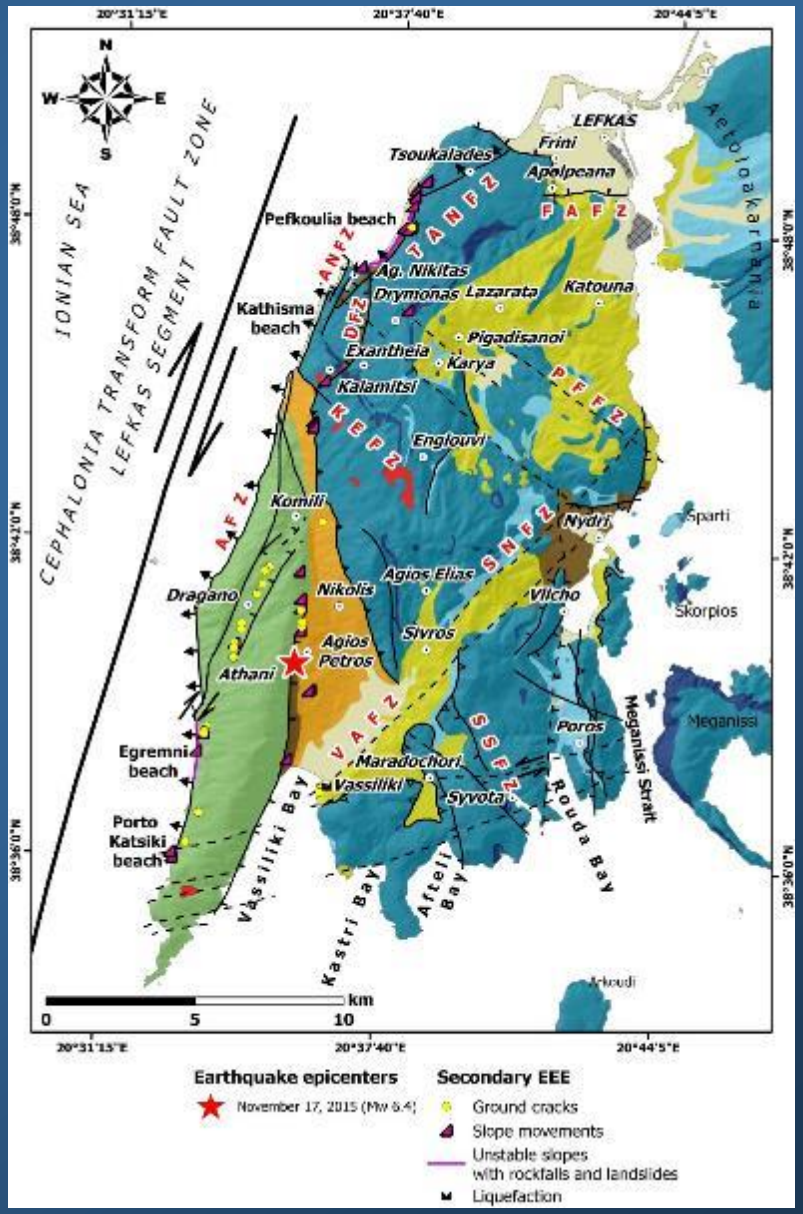
LEFKAS 2015

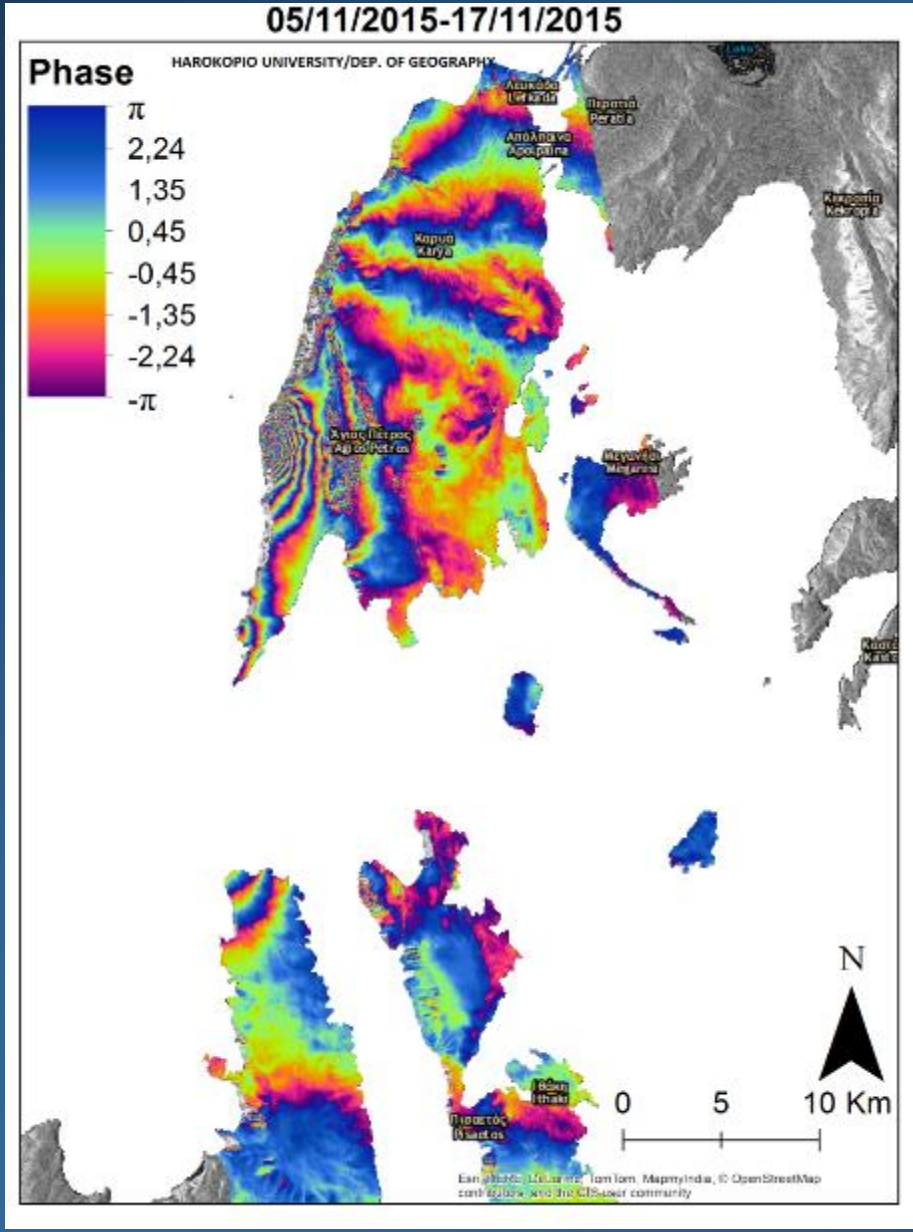


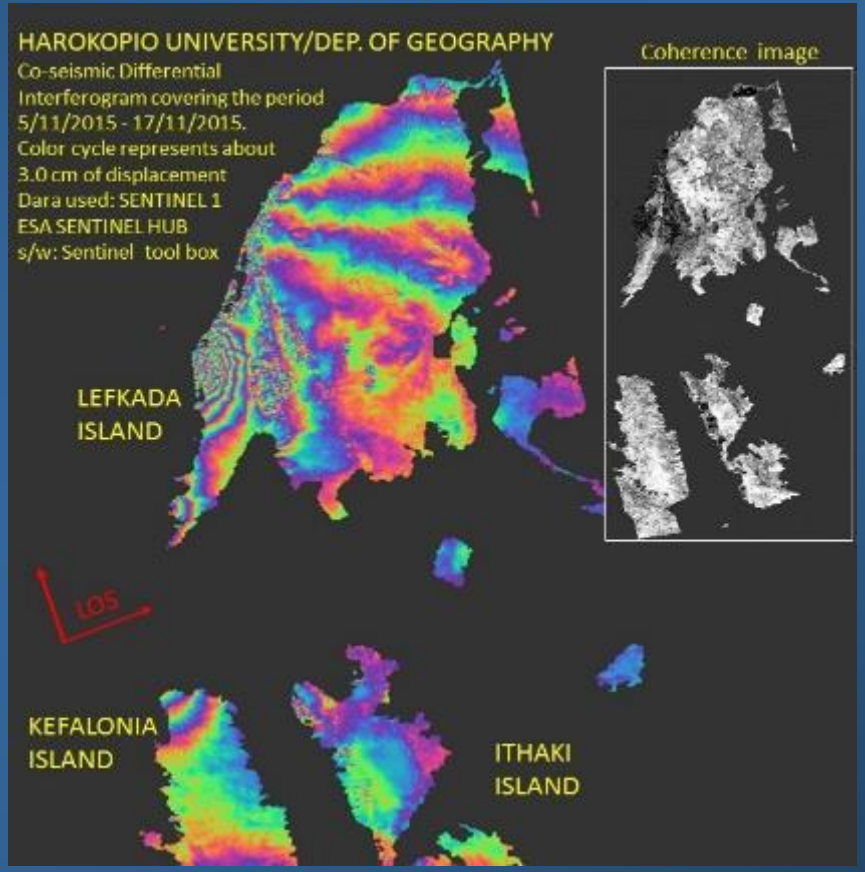
INSTITUTE OF GEODYNAMICS




a
Dragano graben
Egremni
Porto Katsiki
Pefkoulia
Komili
Agios Petros
Vassiliki
IONIAN SEA
CEPHALONIA TRANSFORM FAULT ZONE
LEFKAS SEGMENT
LEFKAS
Aetoloakarnania
Skorpios
Meganisi
km
0
5
10
b
c

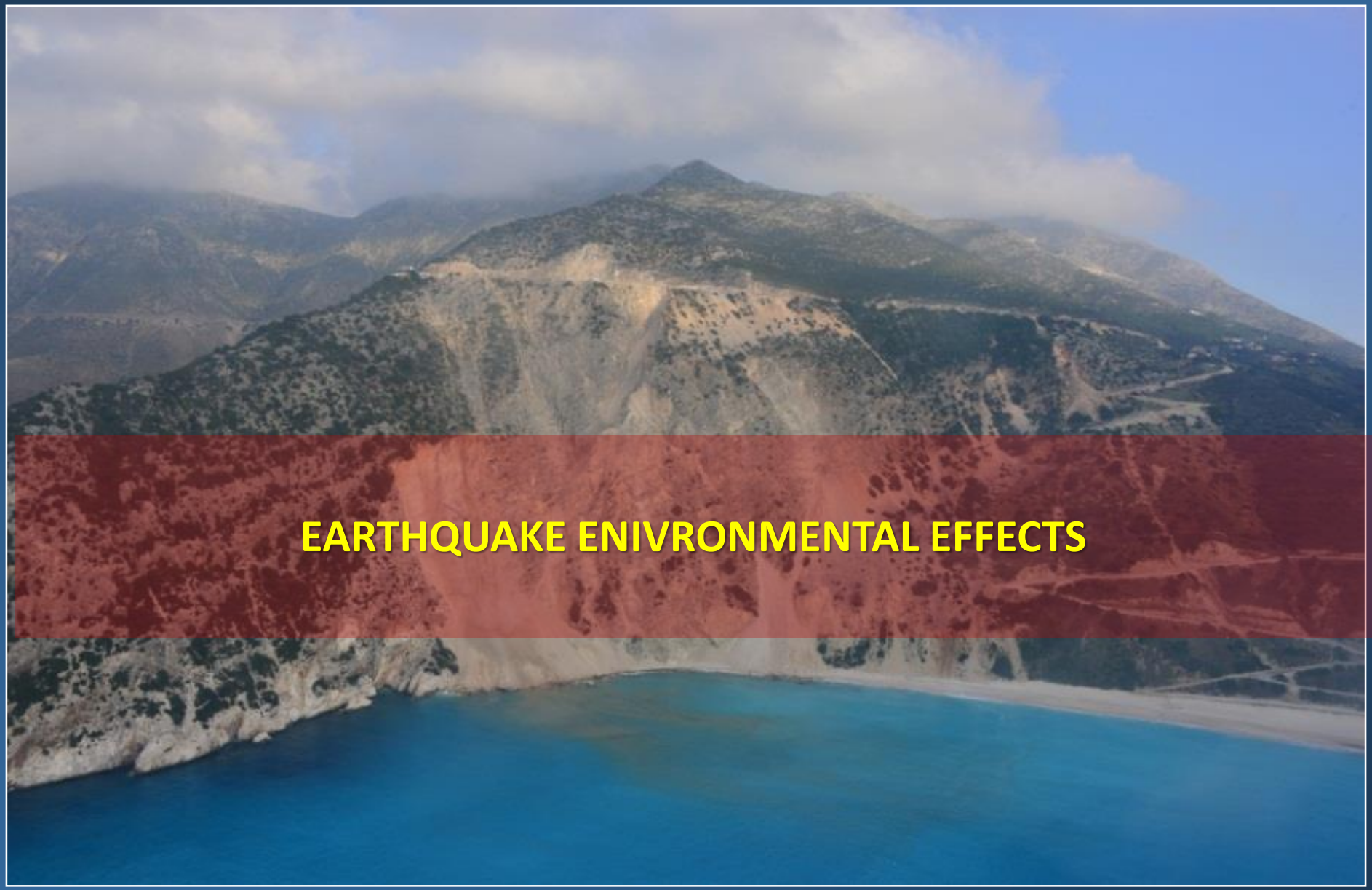

IONIAN SEA
CEPHALONIA TRANSFORM FAULT ZONE
LEFKAS SEGMENT
LEFKAS
Tsoukalades
Frini
Apolpeana
Pefkoulia beach
Ag. Nikitas
Drymonas
Lazarata
Katouna
Kathisma beach
Pigadisanoi
Exartheia
Karya
Kalamitsi
Englouvi
Komili
Nydri
Sparti
Agios Elias
Nikolis
Vlicho
Dragano
Skorpios
Sivros
Agios Petros
Athani
Poros
Meganissi
Egremni beach
Maradochori
Vassiliki
Syvota
Porto Katsiki beach
Vassiliki Bay
Kastri Bay
Afteli Bay
Rouda Bay
Meganissi Strait
Aetoloakarnania
km
0
5
10
Earthquake epicenters
November 17, 2015 (Mw 6.4)
Secondary EEE
Ground cracks
Slope movements
Unstable slopes with rockfalls and landslides
Liquefaction




**COSEISMIC DIFFERENTIAL INTERFEROGRAM (5.11-17.11.2015)**

**SURFACE DEFORMATION MEASUREMENTS**



# EARTHQUAKE ENIVRONMENTAL EFFECTS

**2014 CEPHALONIA EARTHQUAKES**
**MYRTOS COASTAL AREA**

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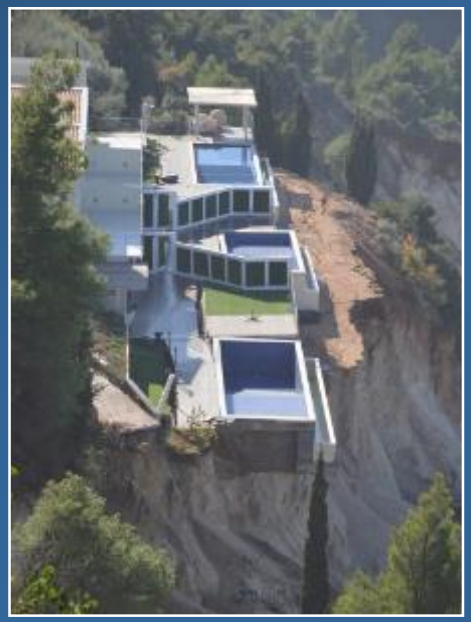
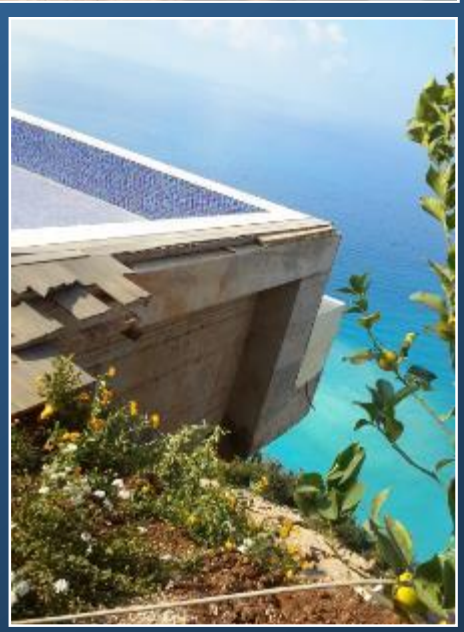
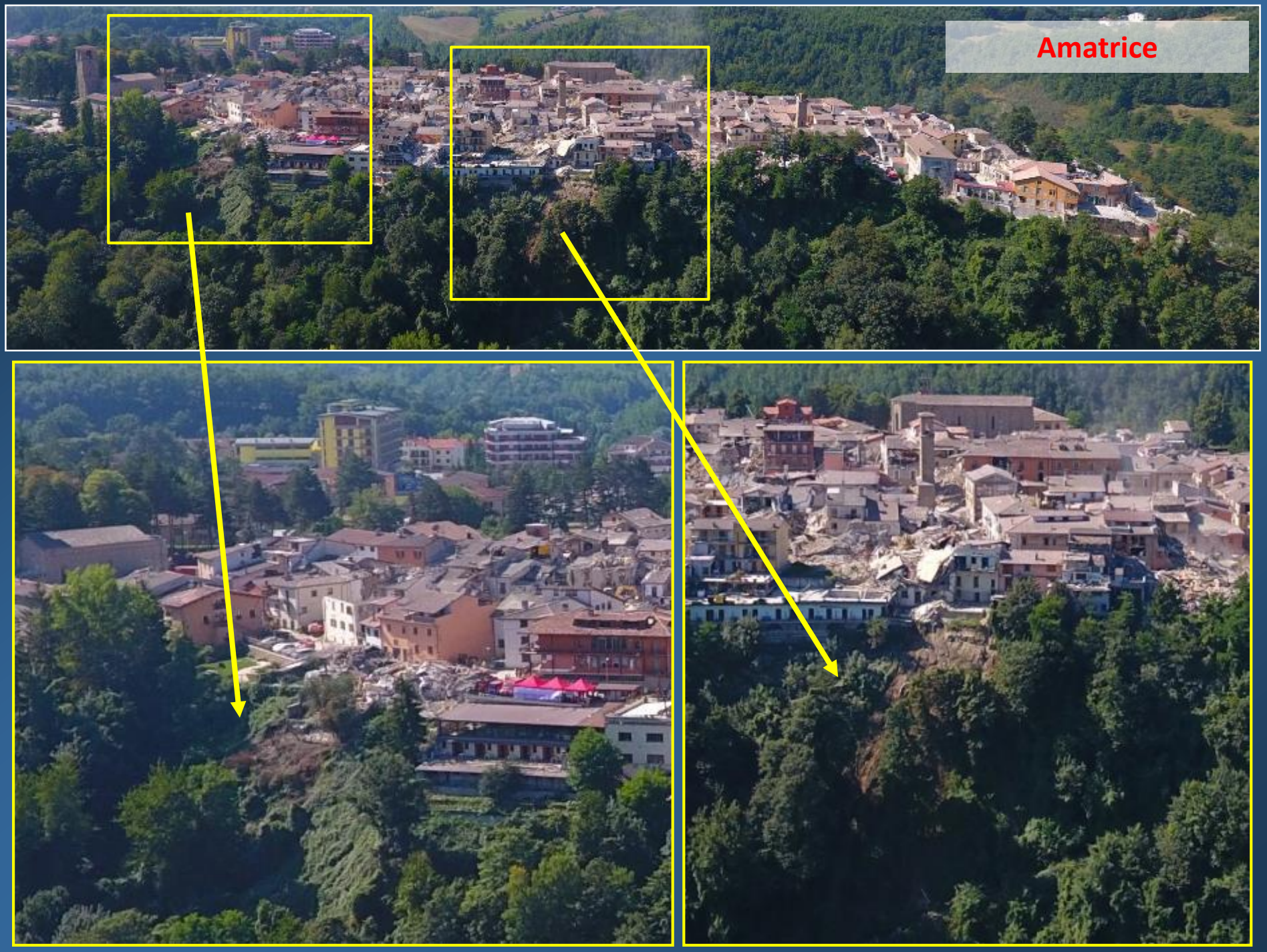
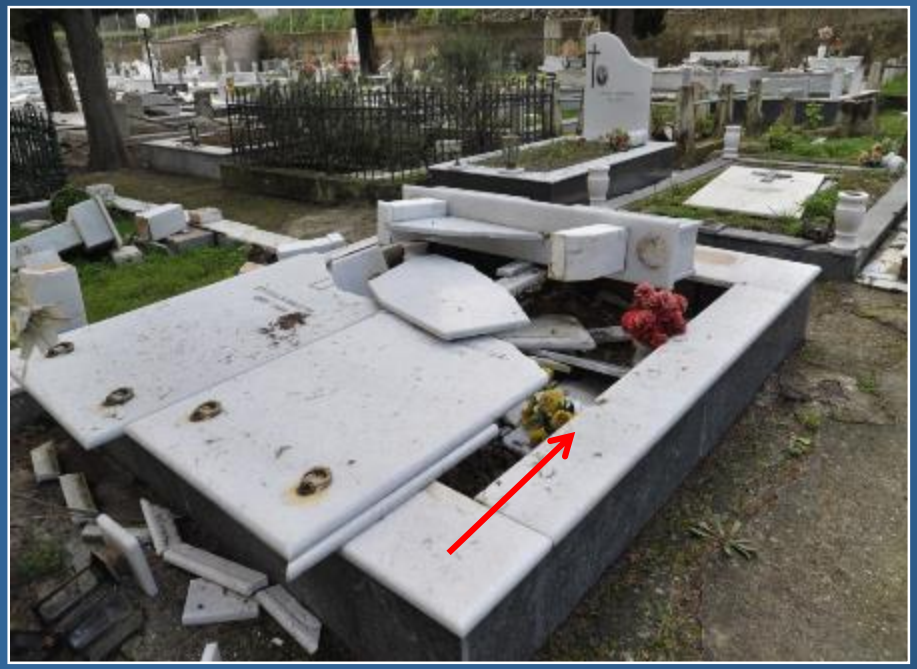


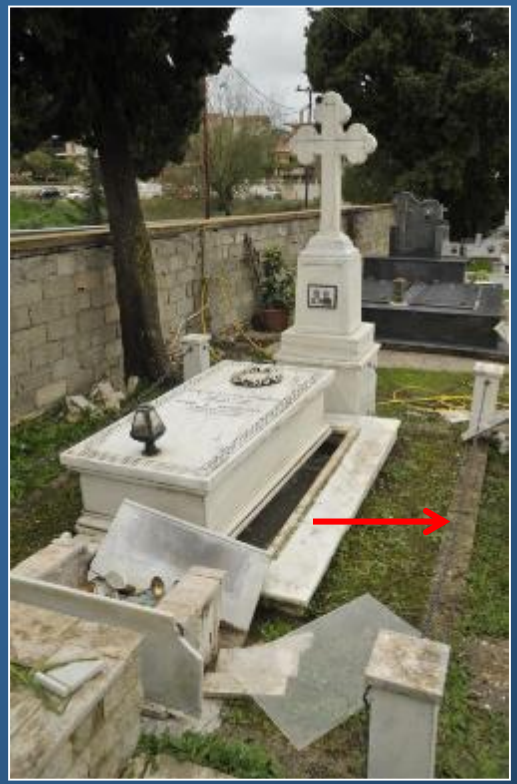



ΠΡΟΣΟΧΗ!
ΚΙΝΔΥΝΟΣ ΛΟΓΩ
ΠΤΩΣΗΣ ΒΡΑΧΩΝ
ATTENTION!
DANGER DUE TO
FALLING ROCKS


Amatrice

# BUILDING DAMAGE






ΠΕΤΡΙΤΣΕΙΟ
ΓΥΜΝΑΣΙΟ ΛΙΘΟΥΡΙΟΥ











*Photos taken on 25 August before a 4.3 aftershock*

AMATRICE

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A.U.S.L. RIETI
Ospedale F. Grifoni


AMATRICE

# AMATRICE

*Photos taken on 2016.08.26*

AMATRICE

*Photo taken on 2016.08.25 before an Mw 4.3 aftershock*

*Photo taken on 2016.08.25 during an Mw 4.3 aftershock*

*Photo taken on 2016.08.26 after an Mw 4.8 aftershock*




*P. Carydis*
*unpublished*


REGOLI ROMANO
BELFIORI CARLO

R/C BUILDINGS

# R/C BUILDING

# R/C BUILDING

# R/C BUILDINGS




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# R/C BUILDINGS




**Geological formations**

**Pliocene-Quaternary Deposits**

- Alluvials, interglacial Middle Pleistocene deposits
- Middle Pleistocene scree and talus cones
- Pliocene-Calabrian sequence

**Paxoi Unit**

- Middle Miocene-Early Pliocene clay-clastic sequence
- Triassic-Middle Miocene limestones

**Earthquake epicentres**

- January 26th, 2014
- February 3rd, 2014

**Ruptured fault zones**

- Fault zone ruptured during 1st earthquake
- Fault zone ruptured during 2nd earthquake

**Tectonic structures**

- Fault
- Strike-slip fault
- Visible thrust
- Covered thrust

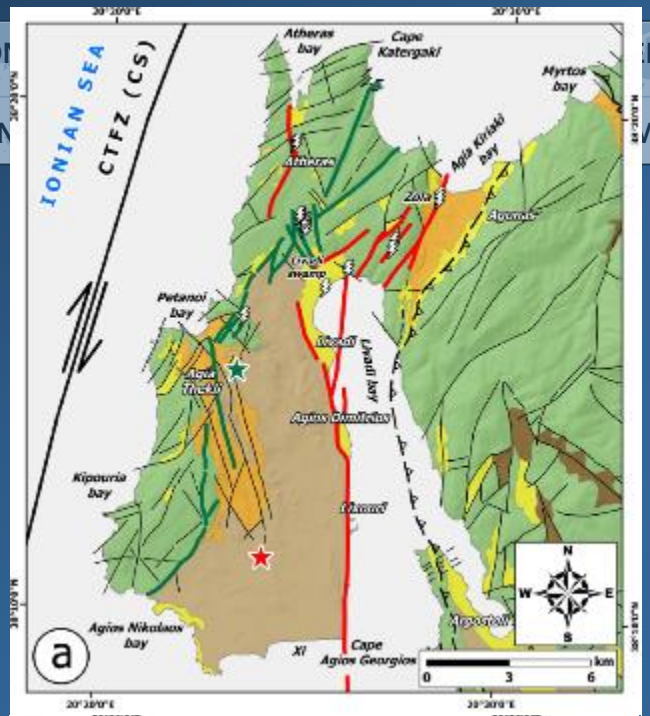
**Earthquake environmental effects**

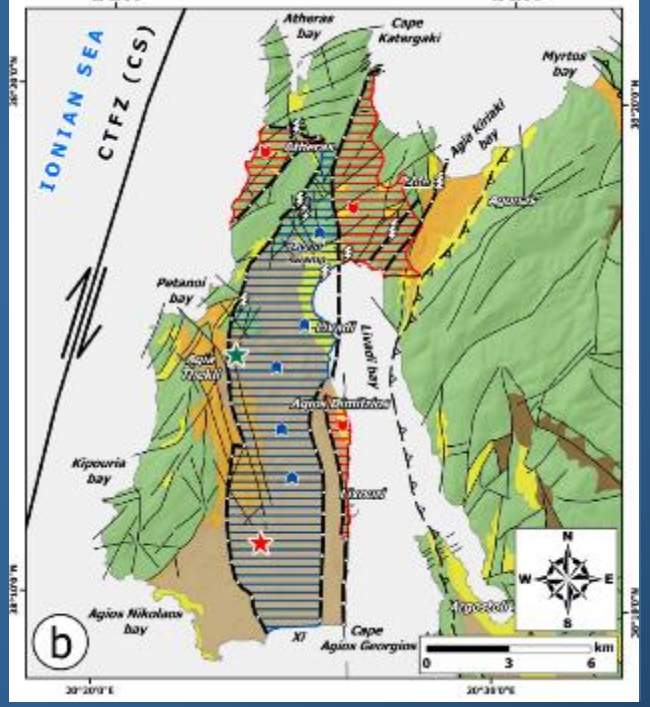
- Surface ruptures

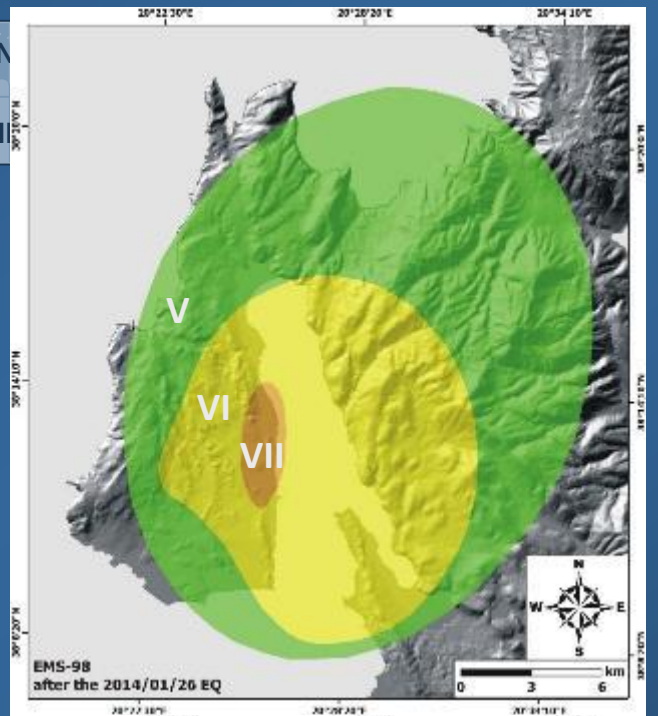
**Data derived from already published DInSAR analysis results**

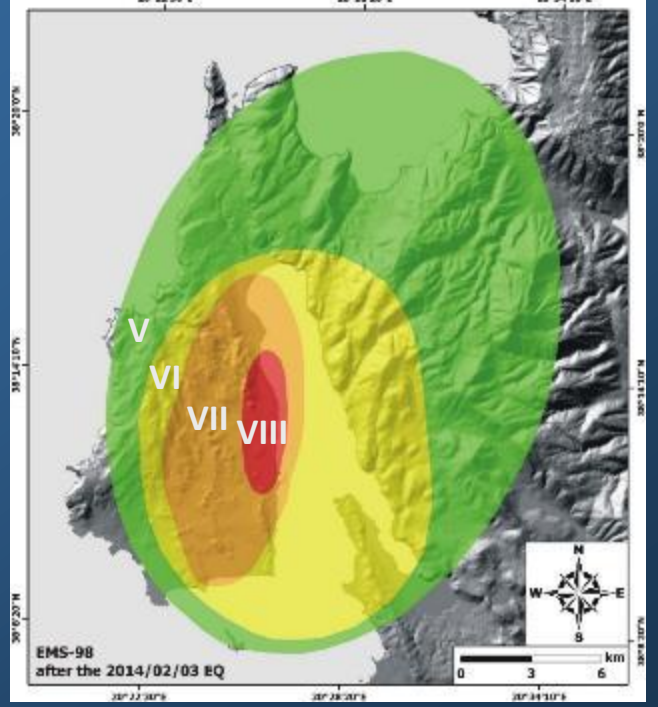
- Uplifted area
- Area of maximum uplift (+12 cm)
- Displacement discontinuity
- Subsided area
- Area of maximum subsidence (-7 cm)

*modified from Lekkas and Mavroulis (2016)*



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# EMERGENCY RESPONSE AND CIVIL PROTECTION

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VIGILI DEL FUOCO


CROCE ROSSA ITALIANA

NATIONAL & KAPODISTRIAN UNIVERSITY OF ATHENS
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**Δρ. ΕΥΘΥΜΗΣ ΛΕΚΚΑΣ**
**ΚΑΘΗΓΗΤΗΣ**
ΔΥΝΑΜΙΚΗΣ ΤΕΚΤΟΝΙΚΗΣ ΕΦΑΡΜΟΣΜΕΝΗΣ ΓΕΩΛΟΓΙΑΣ &
ΔΙΑΧΕΙΡΙΣΗΣ ΦΥΣΙΚΩΝ ΚΑΤΑΣΤΡΟΦΩΝ
**ΠΡΟΕΔΡΟΣ**
ΟΡΓΑΝΙΣΜΟΥ ΑΝΤΙΣΕΙΣΜΙΚΟΥ ΣΧΕΔΙΑΣΜΟΥ & ΠΡΟΣΤΑΣΙΑΣ
**π. ΠΡΟΕΔΡΟΣ**
ΕΛΛΗΝΙΚΗΣ ΓΕΩΛΟΓΙΚΗΣ ΕΤΑΙΡΙΑΣ
**ΔΙΕΥΘΥΝΤΗΣ**
ΠΜΣ ΣΤΡΑΤΙΓΙΚΕΣ ΔΙΑΧΕΙΡΙΣΗΣ ΠΕΡΙΒΑΛΛΟΝΤΟΣ ΚΑΤΑΣΤΡΟΦΩΝ ΚΑΙ ΚΡΙΣΕΩΝ

# ΣΕΙΣΜΙΚΗ ΑΚΟΛΟΥΘΙΑ ΣΤΗΝ ΚΕΝΤΡΙΚΗ ΙΤΑΛΙΑ (ΑΥΓΟΥΣΤΟΥ 2016 ΙΑΝΟΥΑΡΙΟΥ 2017) ΚΑΙ ΑΝΤΙΣΤΟΙΧΙΣΕΙΣ ΜΕ ΤΗΝ ΣΕΙΣΜΙΚΟΤΗΤΑ ΤΟΥ ΕΛΛΗΝΙΚΟΥ ΧΩΡΟΥ

ΑΘΗΝΑ 2017