



# THE 2016 CENTRAL ITALY EARTHQUAKE (AUGUST 24, Mw 6.2)

**Dr. PANAYOTIS CARYDIS**

PROFESSOR OF EARTHQUAKE  
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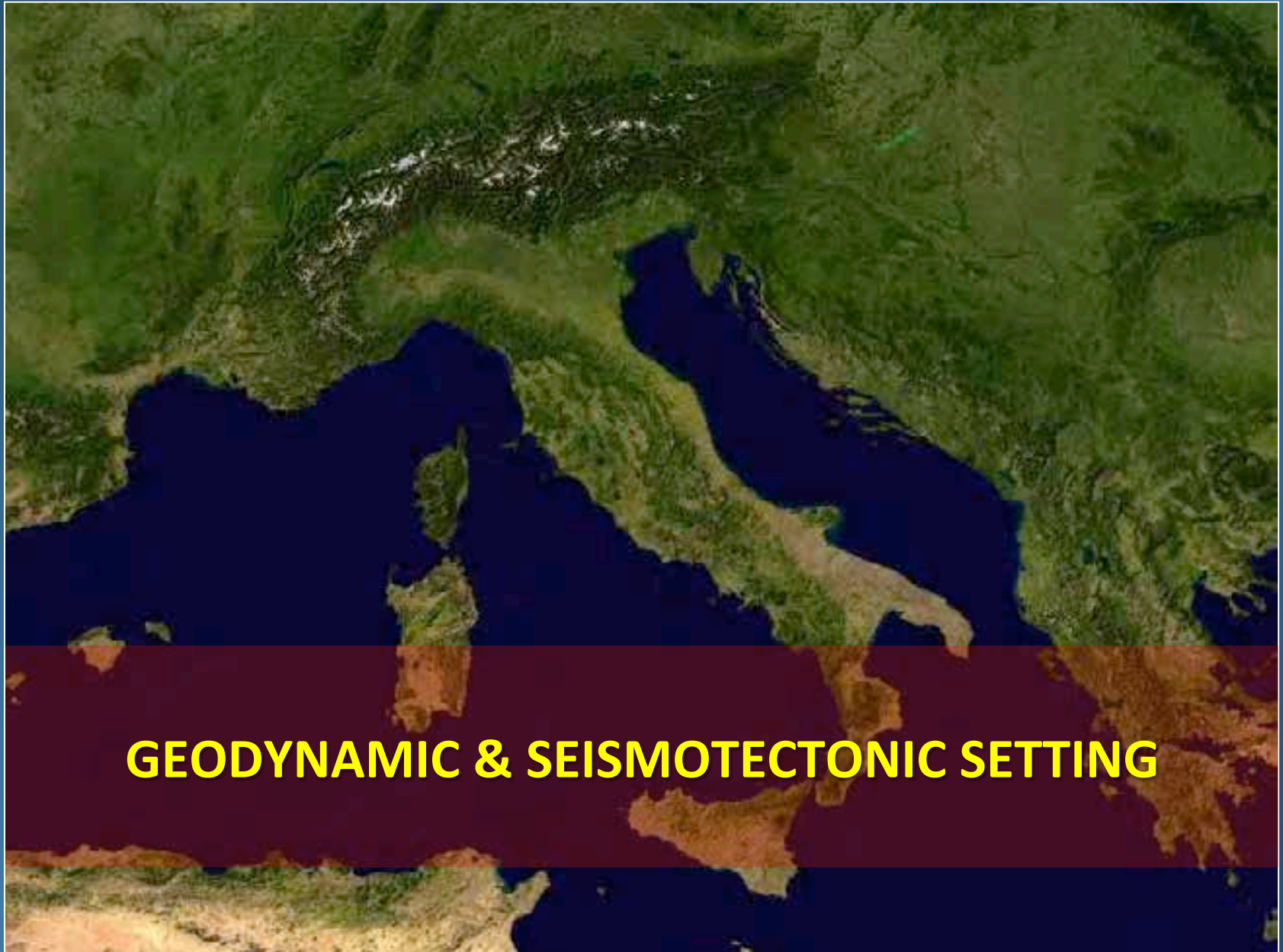
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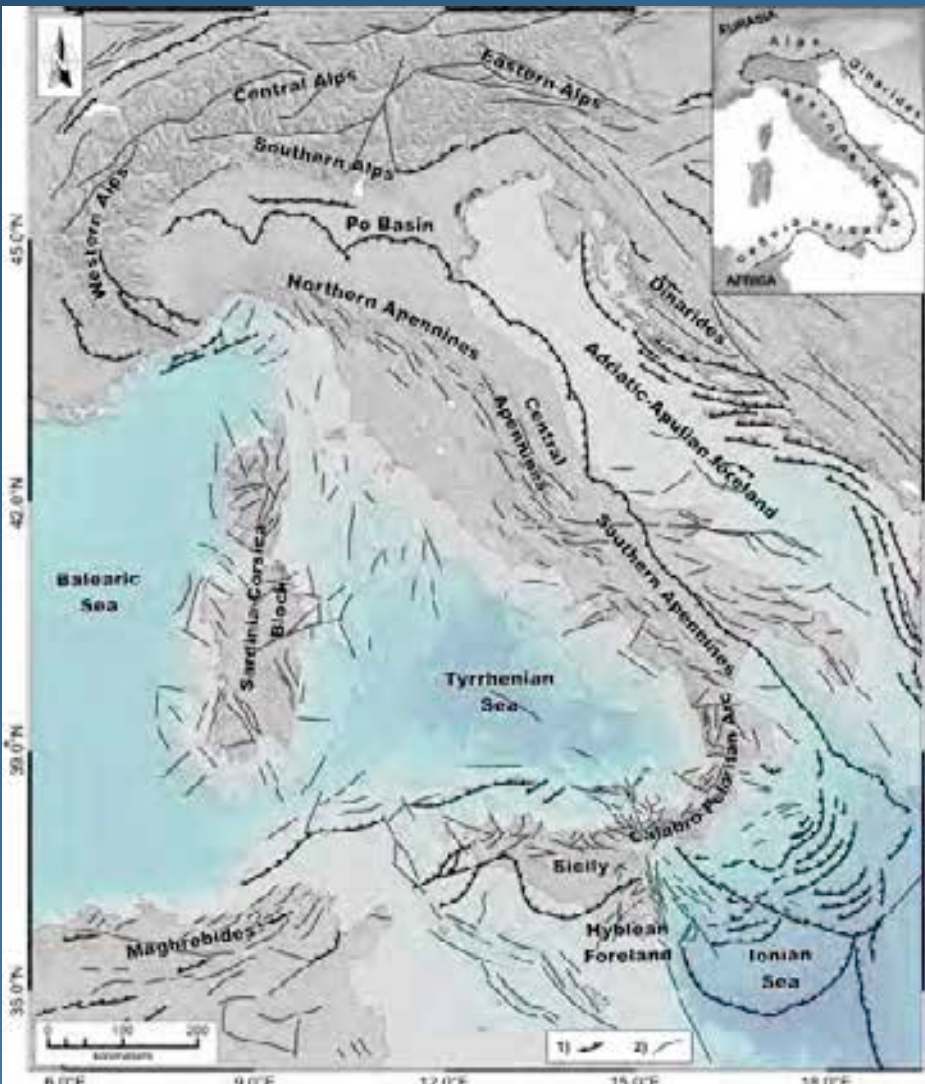




## GEODYNAMIC & SEISMOTECTONIC SETTING



# MAIN TECTONIC LINEAMENTS & MAIN TECTONIC DOMAINS OF ITALY



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



from Galadini et al (2000) Eng. Geol.













## DESTRUCTIVE EARTHQUAKES OF ITALY

Data	Area	Intensità	Magnitudo Mw
08.09.1905	Calabria	X - XI	7.1
23.10.1907	Calabria	IX	5.9
28.12.1908	Stretto di Messina (Calabria, Sicilia)	XI	7.2
07.06.1910	Irpinia (Basilicata)	IX	5.9
27.10.1914	Garfagnana (Toscana)	VII	5.8
13.01.1915	Avezzano (Abruzzo)	XI	7.0
17.05.1916	Mar Adriatico settentrionale	VIII	5.9
16.08.1916	Mar Adriatico settentrionale	VIII	5.9
26.04.1917	Monterchi - Citerna (Toscana - Umbria)	IX - X	5.8
10.11.1918	Appennino forlivese (Emilia Romagna)	VIII	5.8
29.06.1919	Mugello (Toscana)	IX	6.2
07.09.1920	Garfagnana (Toscana)	X	6.5
07.03.1928	Capo Vaticano (Calabria)	VIII	5.9
23.07.1930	Irpinia (Campania)	X	6.7
30.10.1930	Senigallia (Marche)	VIII - IX	5.9
18.10.1936	Bosco Cansiglio (Veneto)	IX	5.9
03.10.1943	Ascolano (Marche)	IX	5.8
21.08.1962	Irpinia (Campania)	IX	6.2
15.01.1968	Valle del Belice (Sicilia)	X	6.1
06.05.1976	Friuli	IX - X	6.4
15.09.1976	Friuli	VIII - IX	5.9
15.04.1978	Golfo di Patti (Sicilia)	VIII	6.1
19.09.1979	Valnenna (Umbria)	VIII - IX	5.9
23.11.1980	Irpinia (Campania, Basilicata)	X	6.9
07.05.1984	Lazio - Abruzzo	VIII	5.9
05.05.1990	Potentino (Basilicata)	VII - VIII	5.8
26.09.1997	Umbria - Marche	IX	6.0
31.10.2002	Molise	VIII - IX	5.8
06.04.2009	Abruzzo	IX - X	6.1*
20.05.2012	Pianura Padana Emiliana (Emilia Romagna)	VIII*	5.8*
29.05.2012			5.6*

\* Dati: [iside.rm.ingv.it](http://iside.rm.ingv.it)

\* Cumulo degli effetti della sequenza

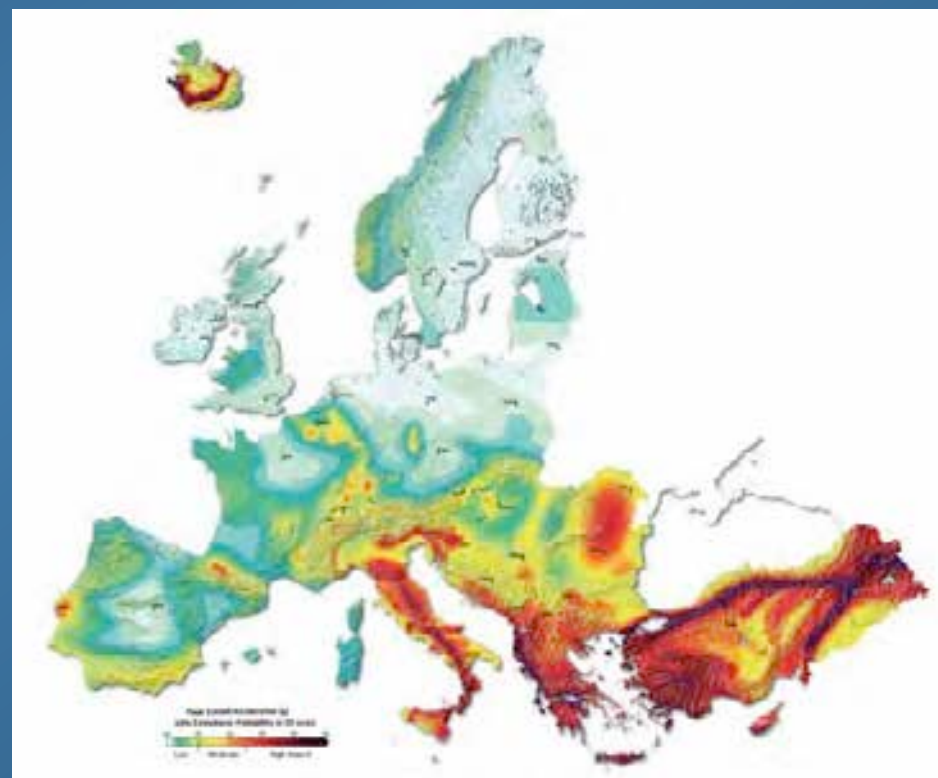
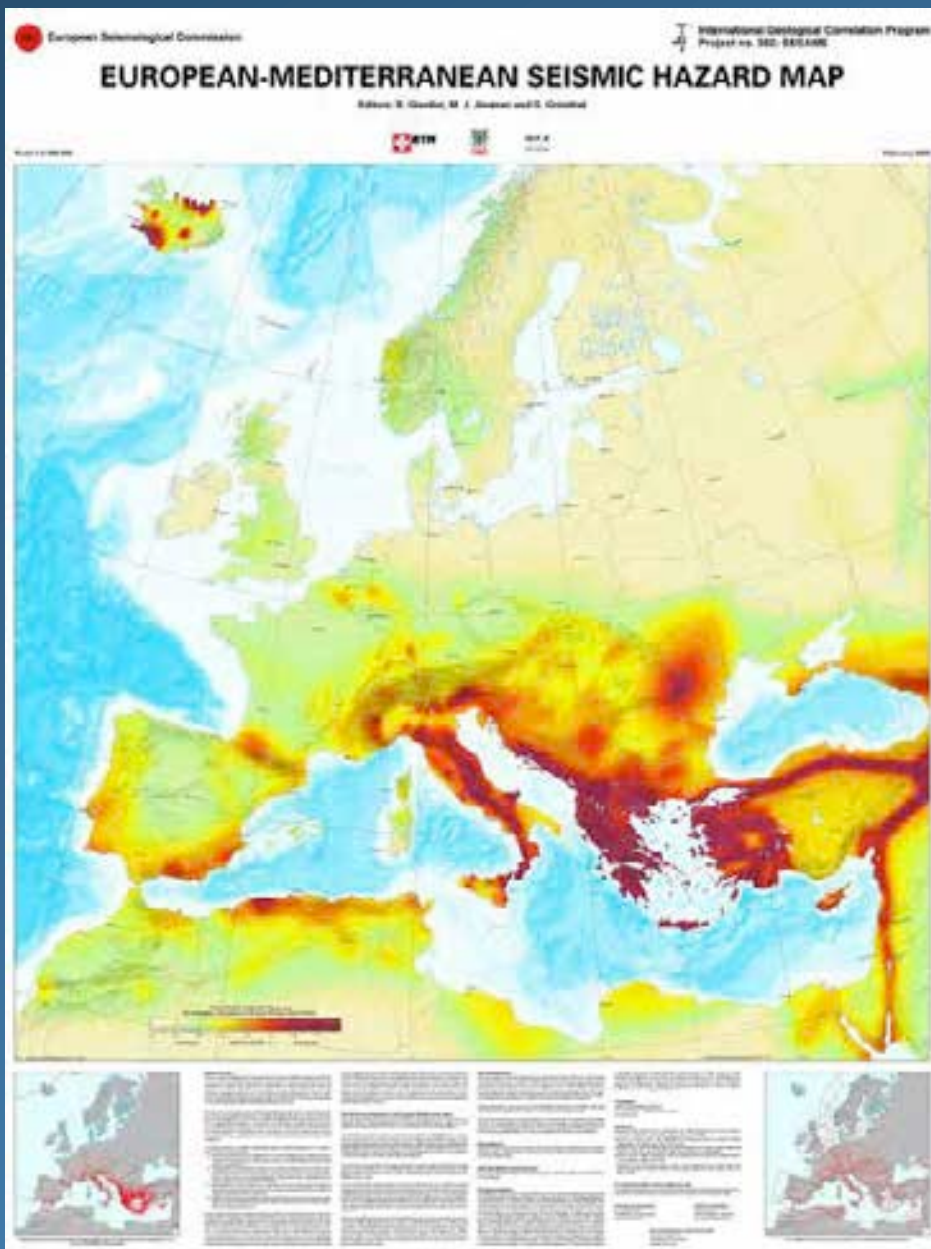








## SEISMIC HAZARD IN THE MEDITERRANEAN AND ITALY









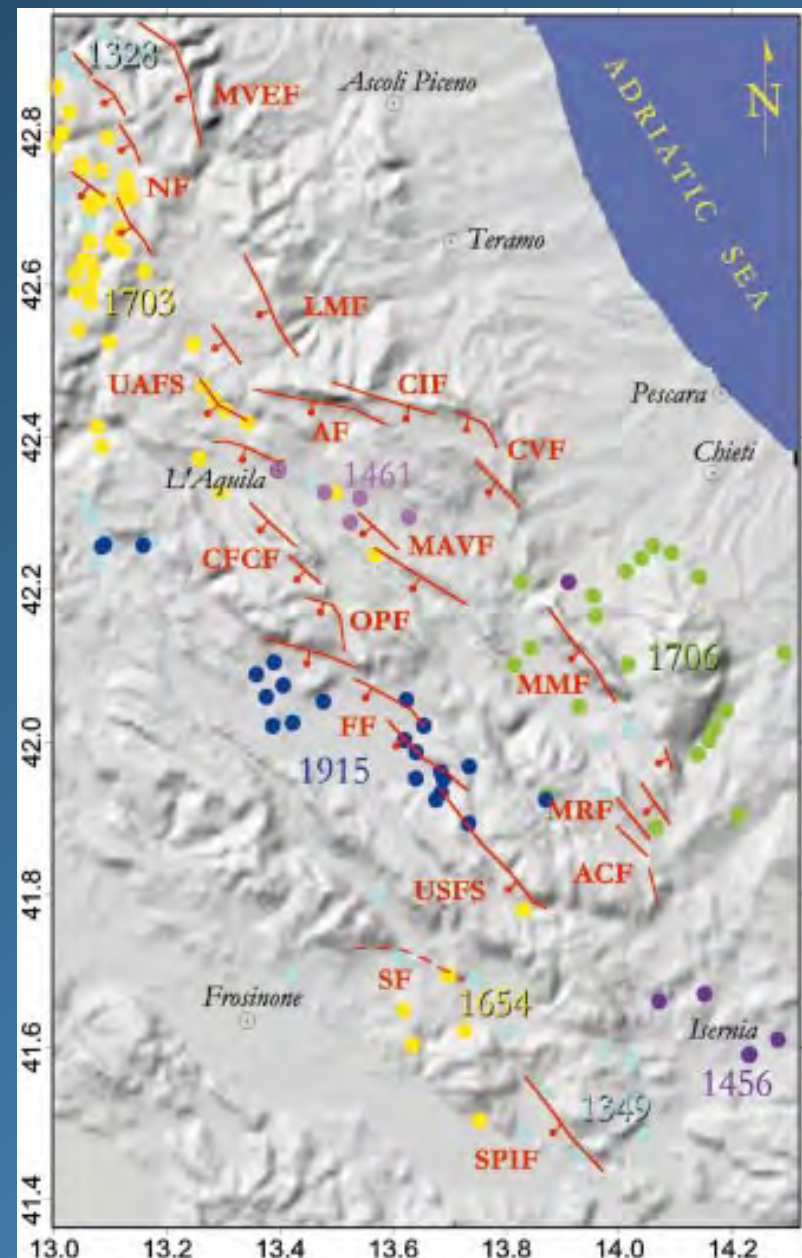


## PRIMARY ACTIVE FAULTS in the Southern Umbria – Abruzzi Apennines and distribution of the highest-intensity datapoints related to major earthquakes ( $M > 6$ )

### MCS INTENSITY DATAPOINTS

- $I = 8/9$  **1328** and **1349** earthquakes
- $I = 9$  **1461**
- $I = 9/10$  **1456, 1654, 1703, 1706**
- $I = 10$  **1915**

*from Galadini and Galli (2000)*







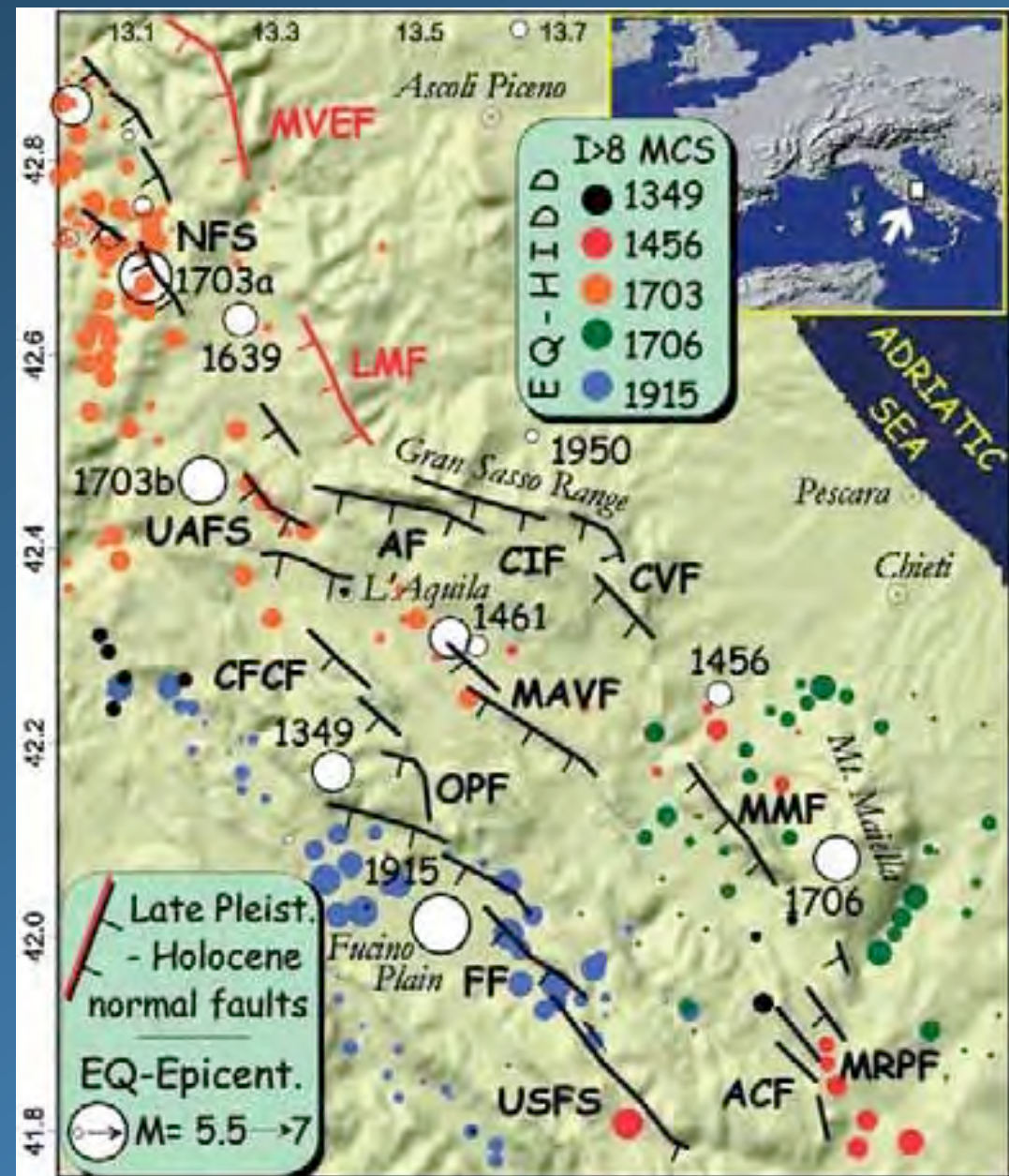
## MAIN NORMAL FAULTS OF THE AREA AFFECTED BY THE CENTRAL ITALY EARTHQUAKE Mw 6.2, 24 AUGUST 2016

**MT. VETTORE FAULT  
(MVEF)**

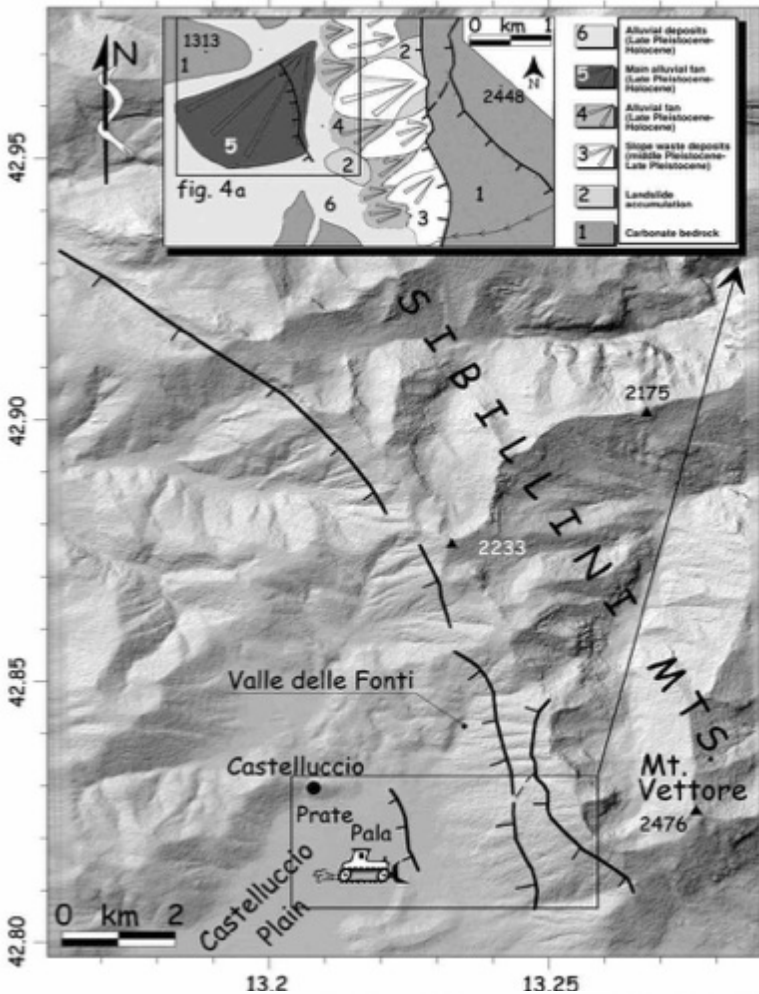
&

**LAGA MTS FAULT  
(LMF)**

*Map from Galadini and Galli (2000)*

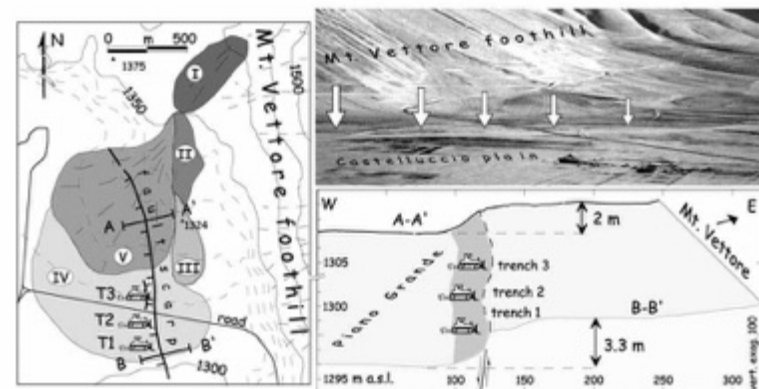






## MT. VETTORE FAULT

- 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

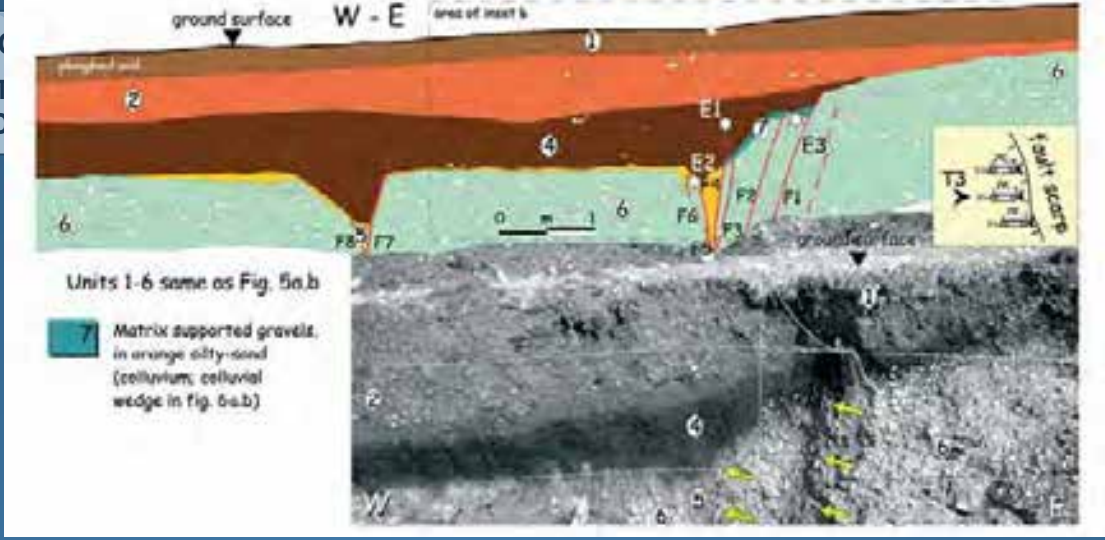
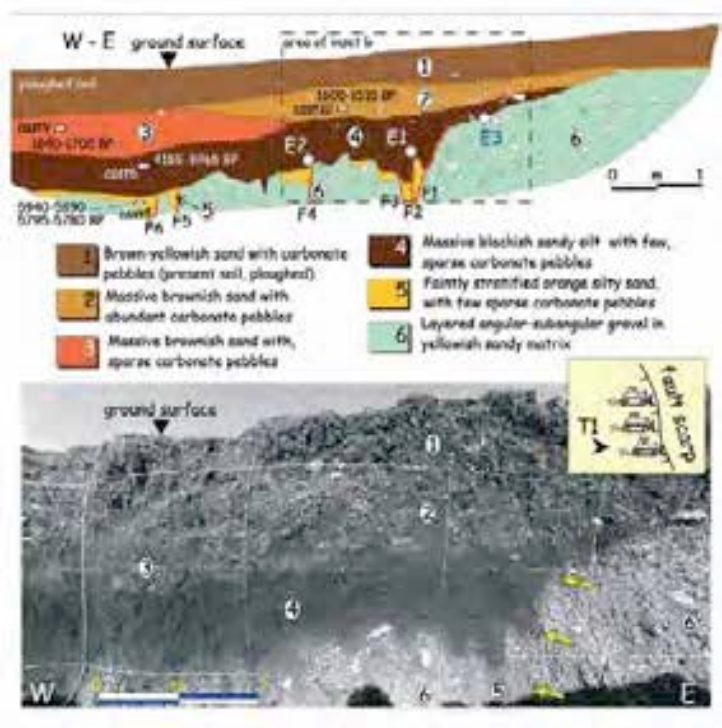


*from Galadini and Galli (2003)*









## MT. VETTORE FAULT TRENCHES

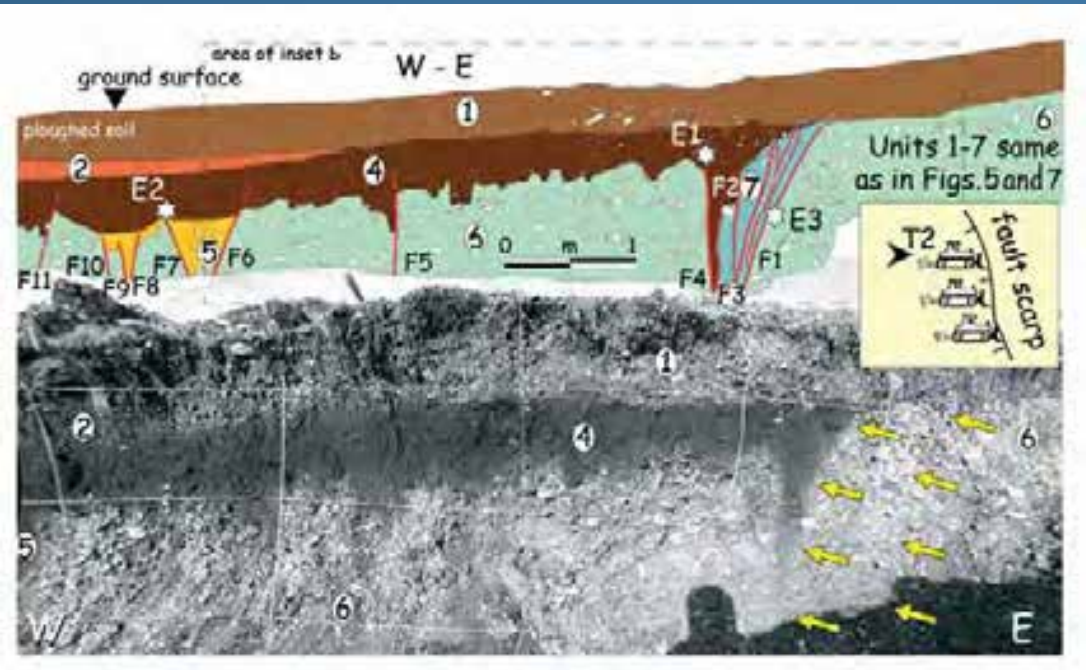
- Three events occurred during the Holocene:

**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

*from Galadini and Galli (2003)*

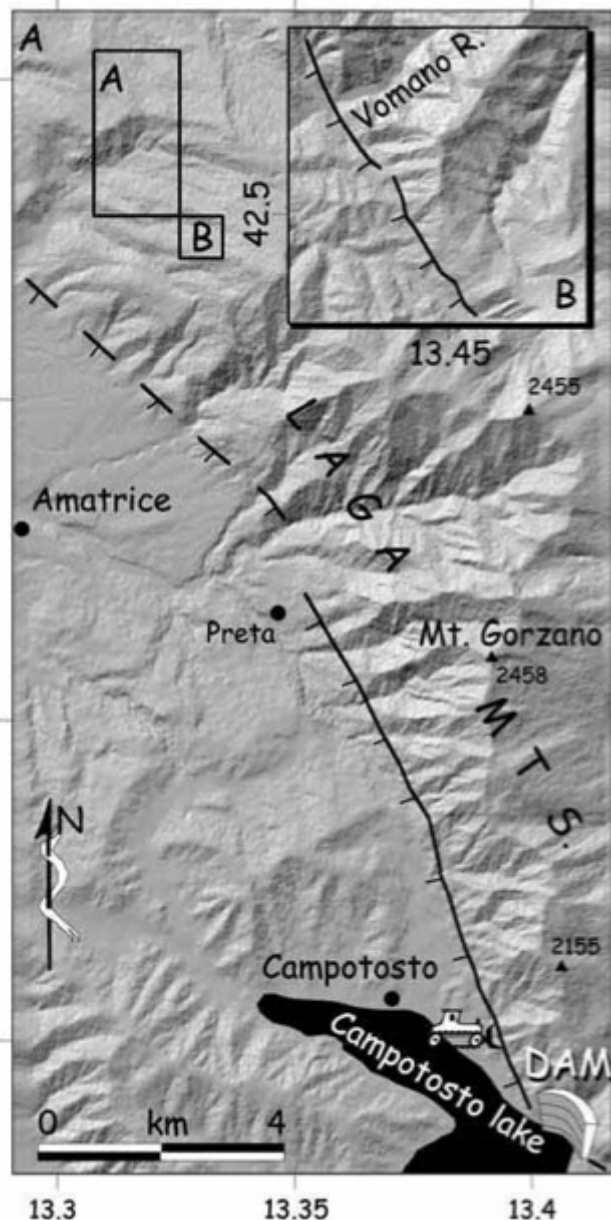






## LAGA MTS FAULT

- 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 heights
- 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



### *Laga Mts fault*



*Photo taken on 2016.08.26*

*Map from Galadini and Galli (2003)*



*Laga Mts*



***Amatrice  
intermontane basin***

*Photos taken on 2016.08.26*

*Northern part of the Amatrice intermontane basin*



***Faete***

***Spelonga***

***Arcuata del  
Tronto***

***Borgo***





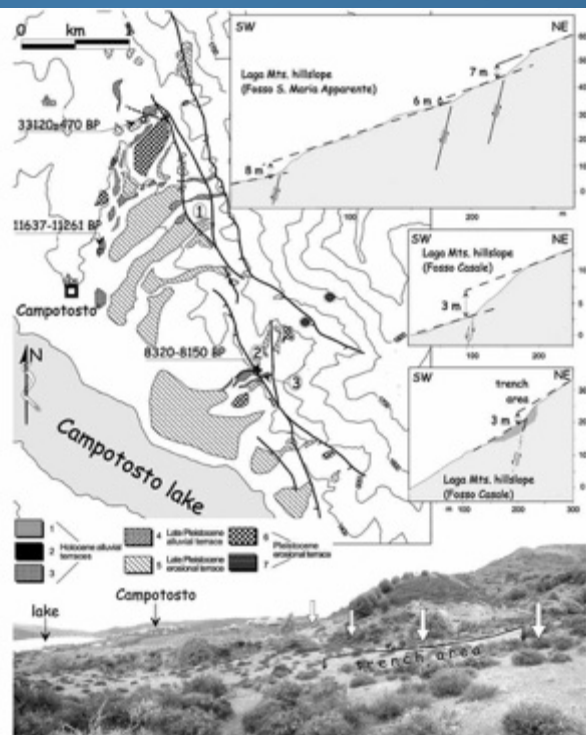
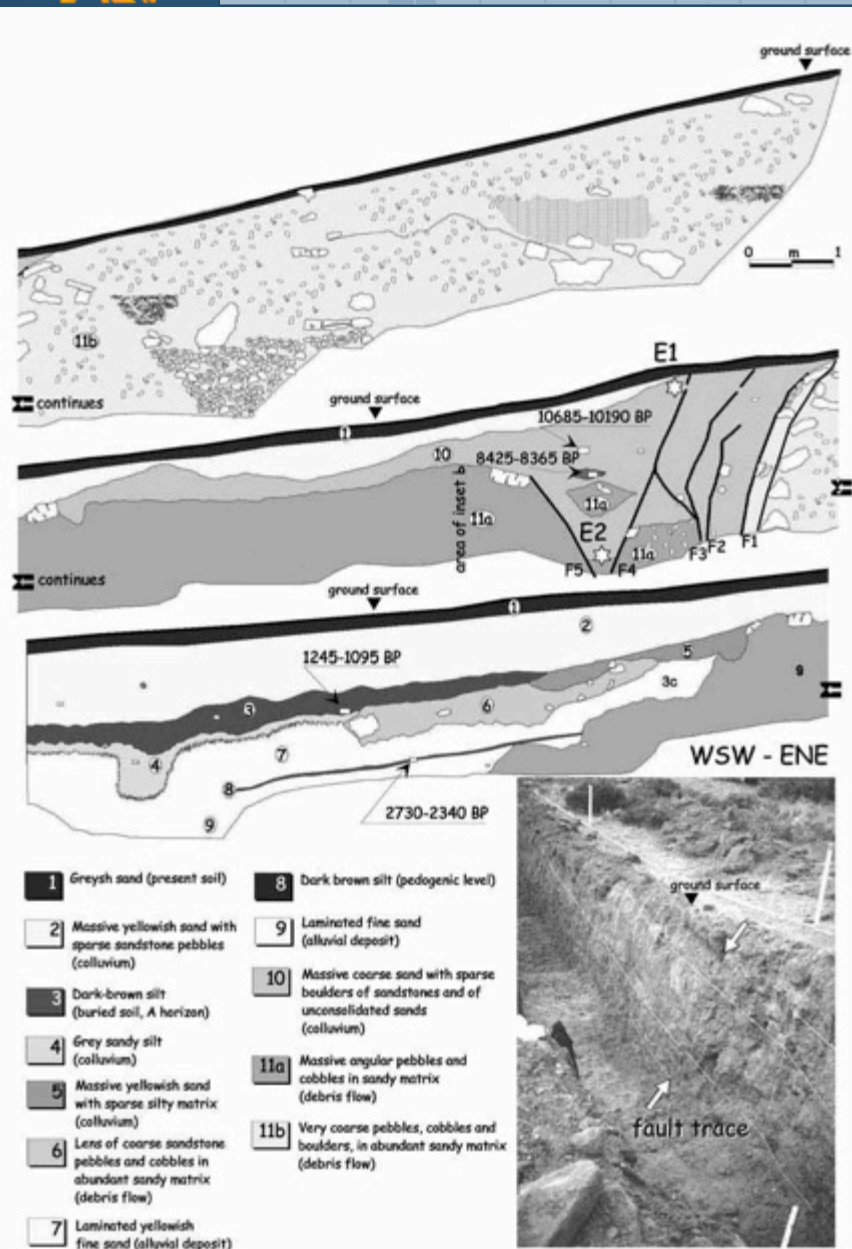
## LAGA MTS FAULT TRENCH

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

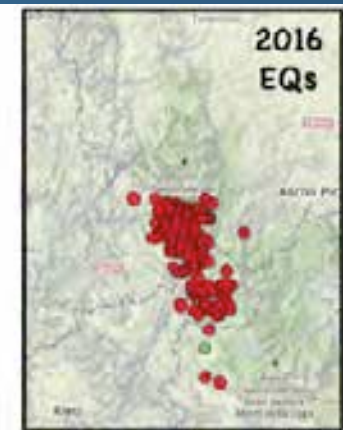
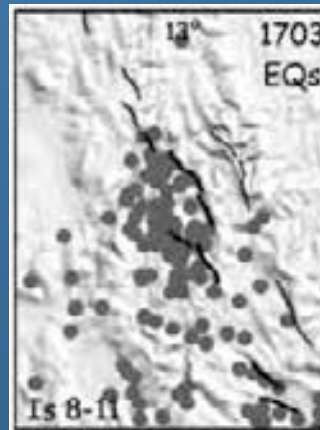
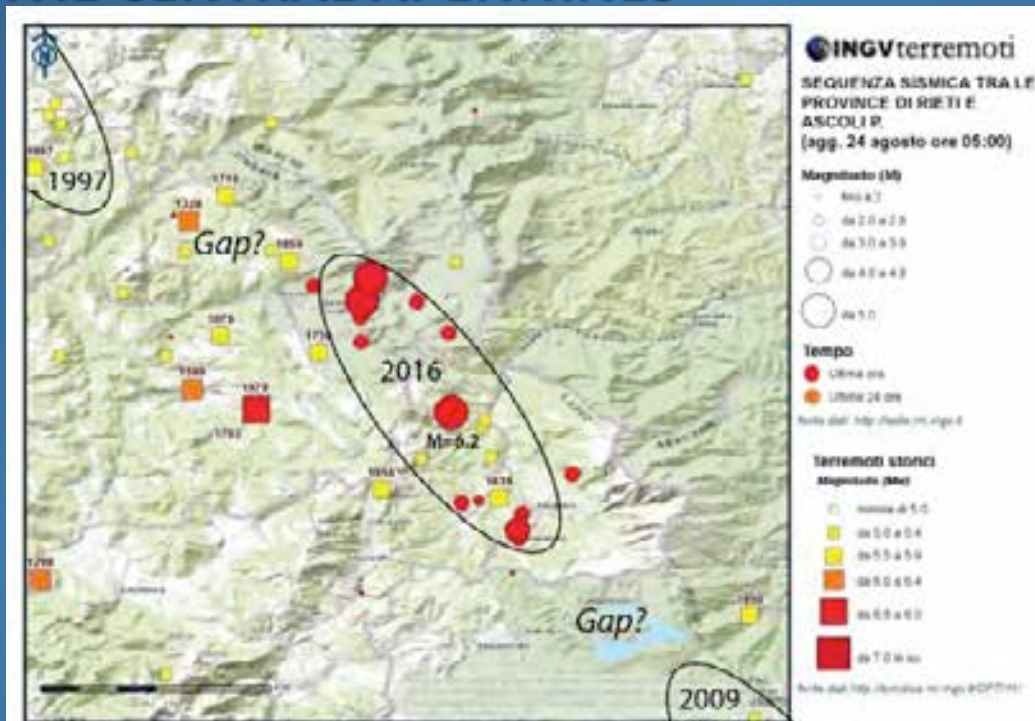
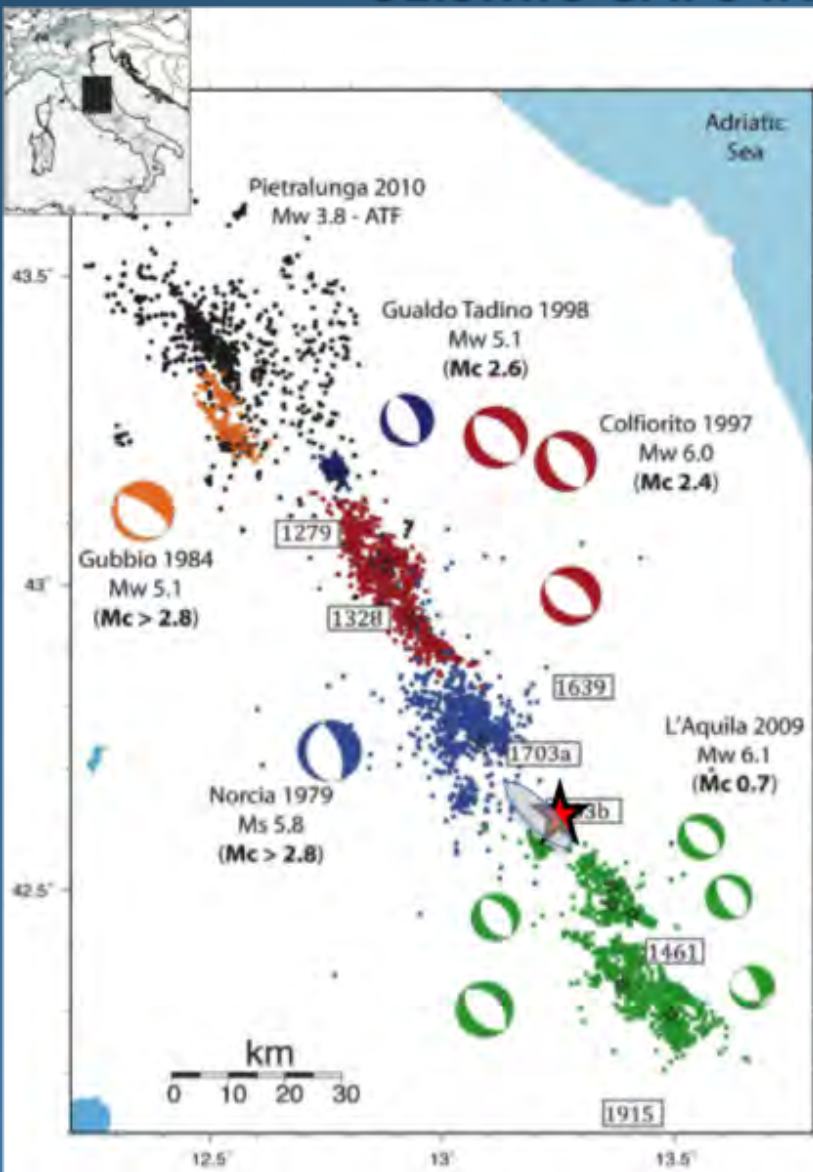
Figures from  
*Galadini and Galli (2003)*







# SEISMIC GAPS IN THE CENTRAL APENNINES







## VETTORE MTS FAULT

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

- 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**



***Vettore Mt***



*Western Vettore Mt slope*

***Castelluccio Plain***

**COSEISMIC SURFACE RUPTURES ALONG  
THE VETTORE MT FAULT**







# COSEISMIC SURFACE RUPTURES ALONG THE VETTORE MT FAULT



*from field reconnaissance conducted by INGV*



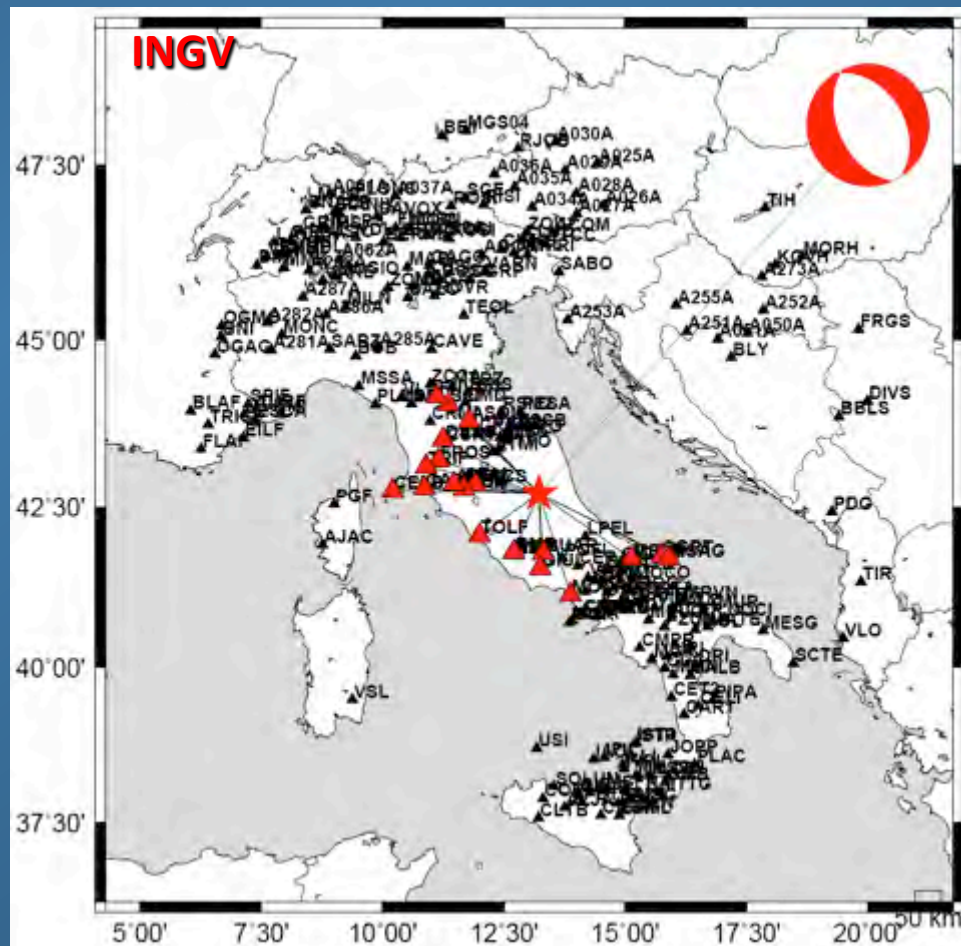


**INSTRUMENTAL DATA  
OF THE CENTRAL ITALY EARTHQUAKE  
Mw 6.2 24 AUGUST 2016**





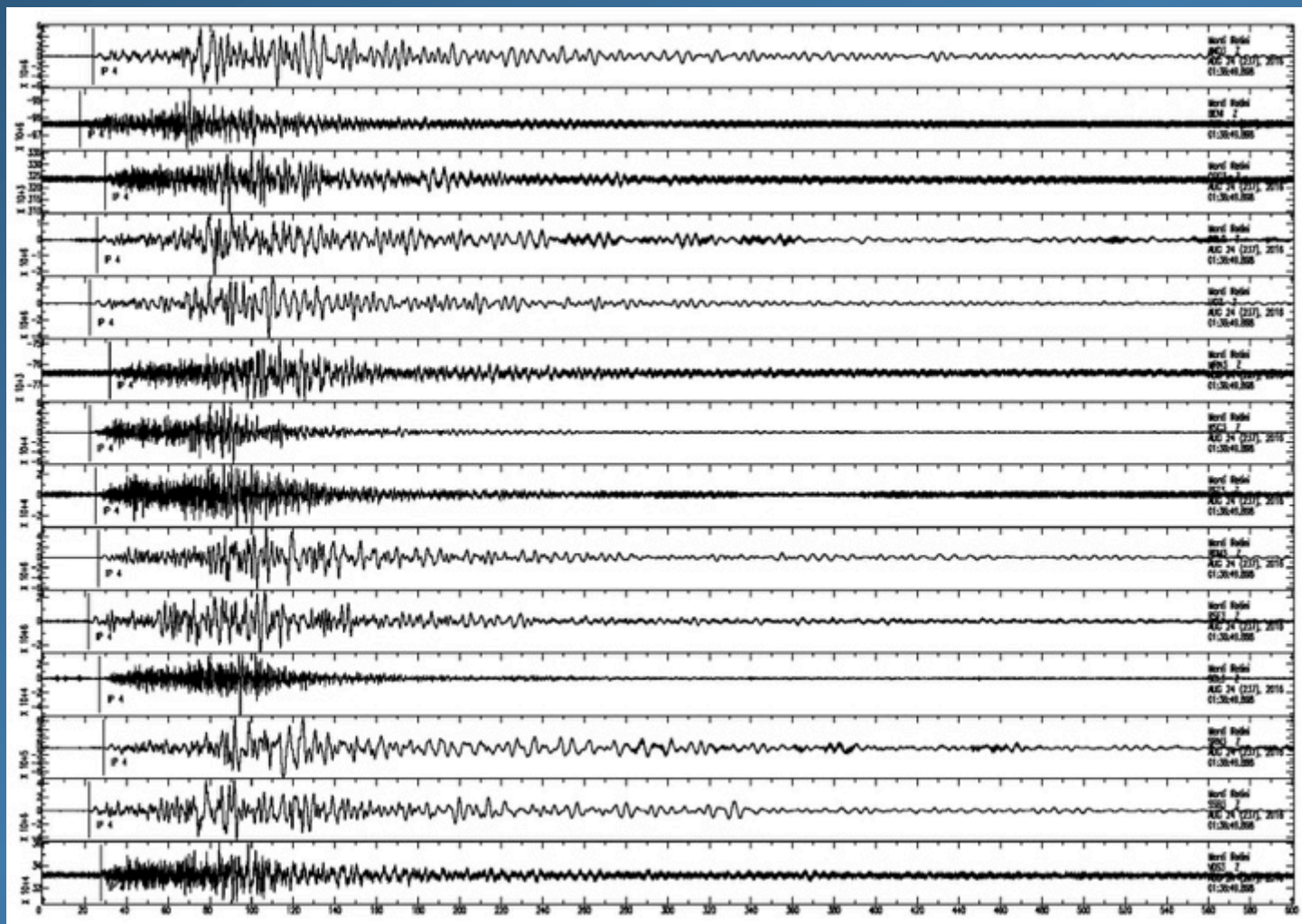
# CENTRAL ITALY EARTHQUAKE Mw 6.2, 24 AUGUST 2016 MOMENT TENSORS SOLUTIONS





# WAVEFORMS

## VERTICAL COMPONENT OF ACCELEROMETERS FROM ISNET

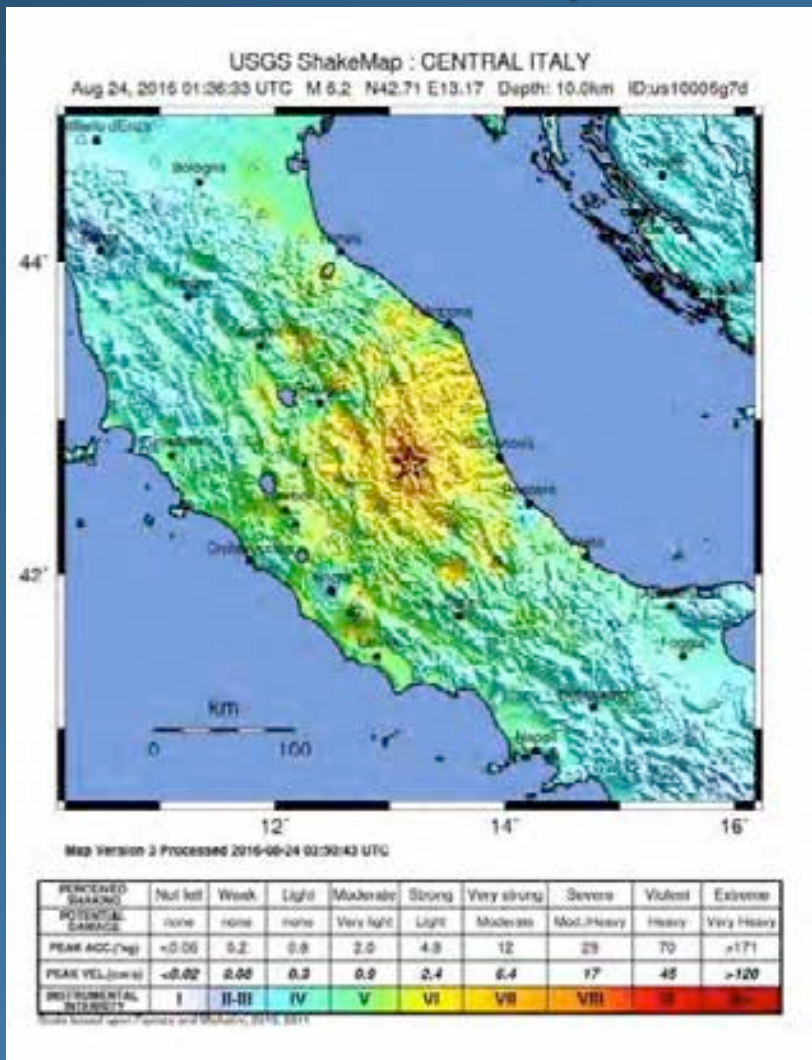




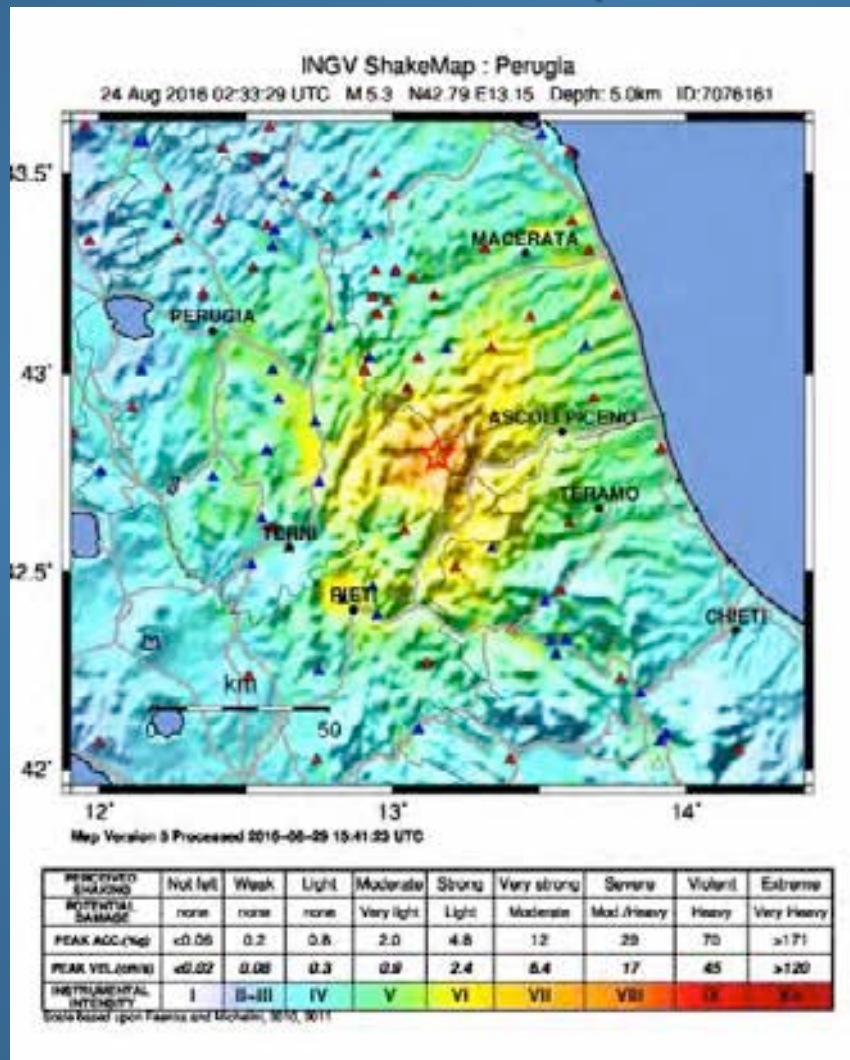


## USGS ShakeMap

## INGV ShakeMap



<http://earthquake.usgs.gov/earthquakes/eventpage/>



<http://shakemap.rm.ingv.it/shake/7073641/intensity.html>



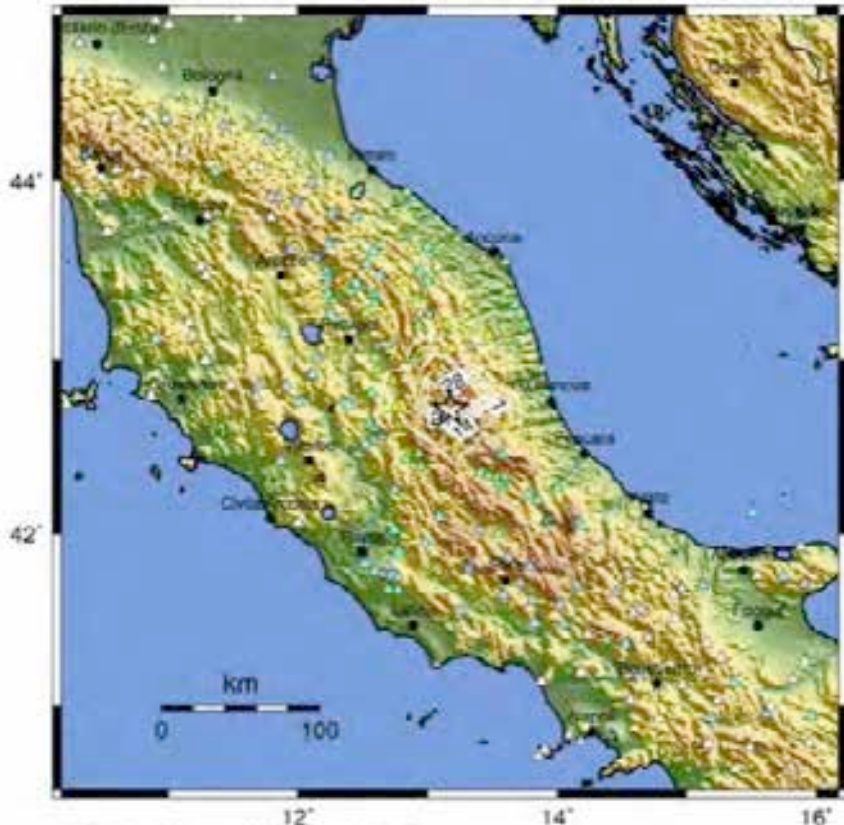


## USGS Peak Acceleration Map

## USGS Peak Velocity Map

USGS Peak Accel. Map (in %g) : CENTRAL ITALY

Aug 24, 2016 01:36:33 UTC M 6.2 N42.71 E13.17 Depth: 10.0km IDus10006g7d



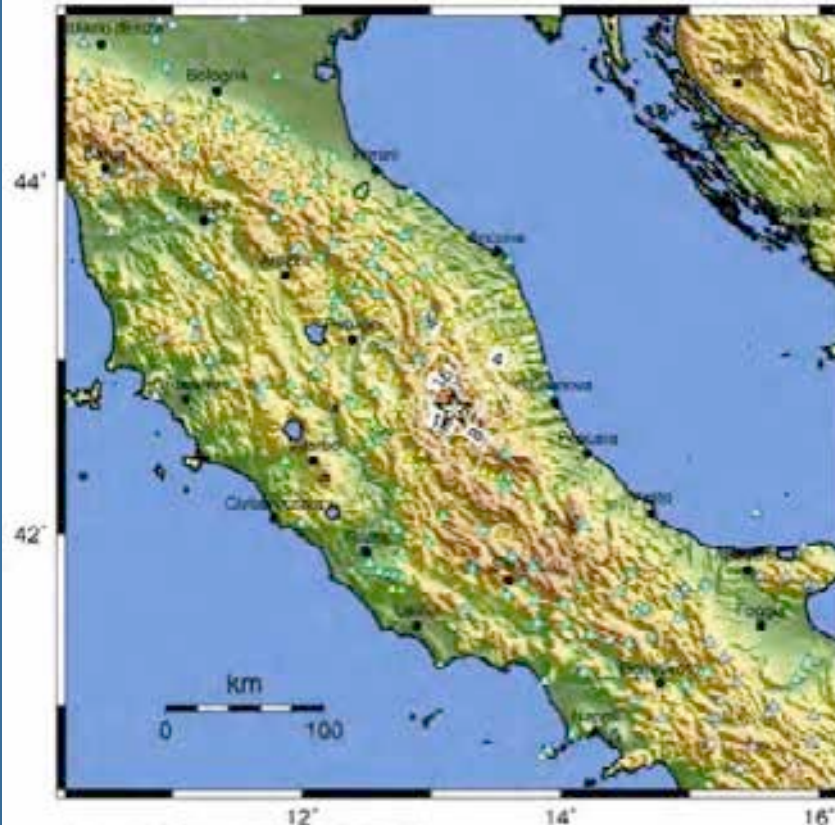
Map Version 3 Processed 2016-08-24 03:50:43 UTC

PEAK ACC (%g)	<0.06	0.2	0.8	2.0	4.8	12	29	70	>171
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X

Scale based upon Franco and Mulhens, 2012, 2011

USGS Peak Velocity Map (in cm/s) : CENTRAL ITALY

Aug 24, 2016 01:36:33 UTC M 6.2 N42.71 E13.17 Depth: 10.0km IDus10006g7d



Map Version 3 Processed 2016-08-24 03:50:43 UTC

PEAK VEL (cm/s)	<0.02	0.08	0.3	0.9	2.4	6.4	17	45	>120
INSTRUMENTAL INTENSITY	I	II-III	IV	V	VI	VII	VIII	IX	X

Scale based upon Franco and Mulhens, 2012, 2011





## INGV Peak Acceleration Map

## INGV Peak Velocity Map

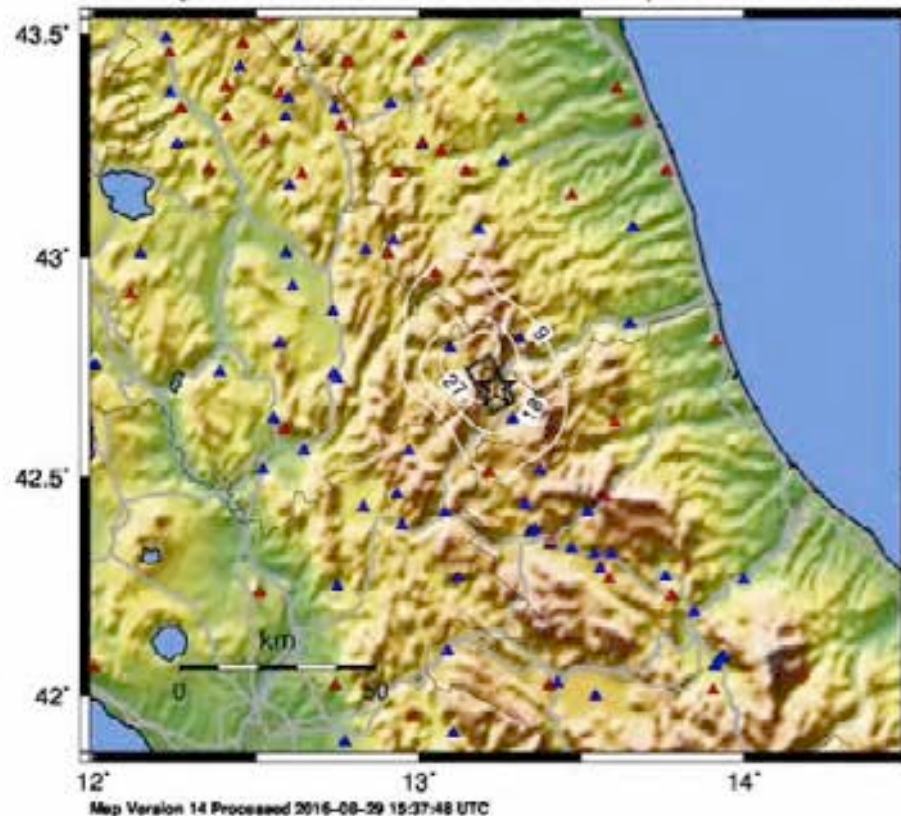
INGV Peak Accel. Map (in %g) : Rieti

24 Aug 2016 01:38:32 UTC M 6.0 N42.70 E13.24 Depth: 4.2km ID:7073641



INGV Peak Velocity Map (in cm/s) : Rieti

24 Aug 2016 01:38:32 UTC M 6.0 N42.70 E13.24 Depth: 4.2km ID:7073641



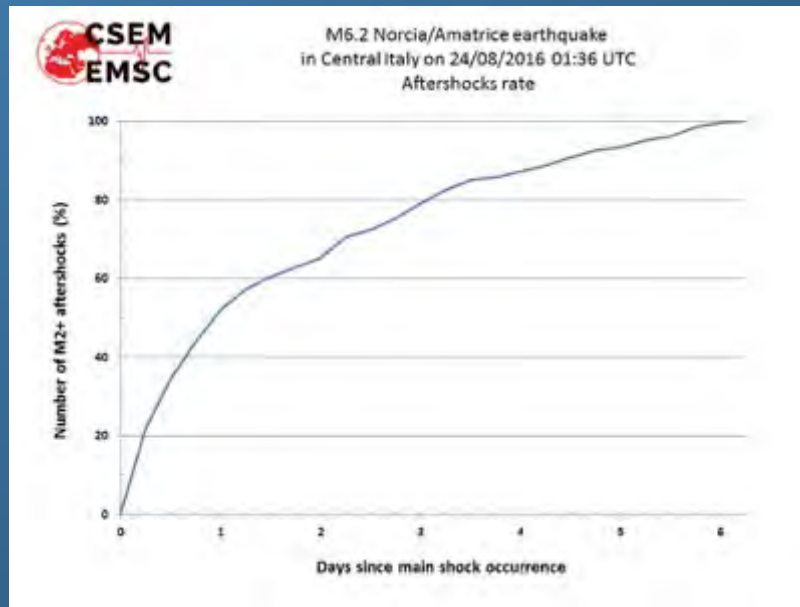
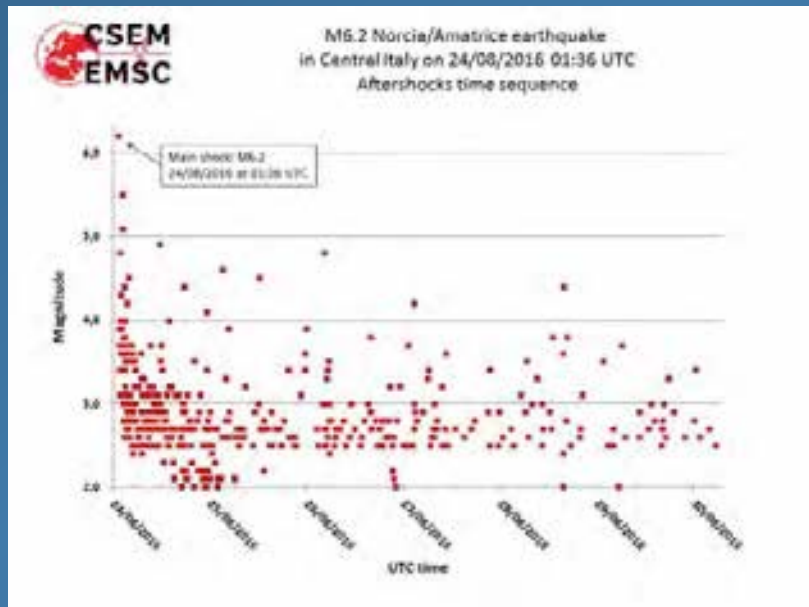
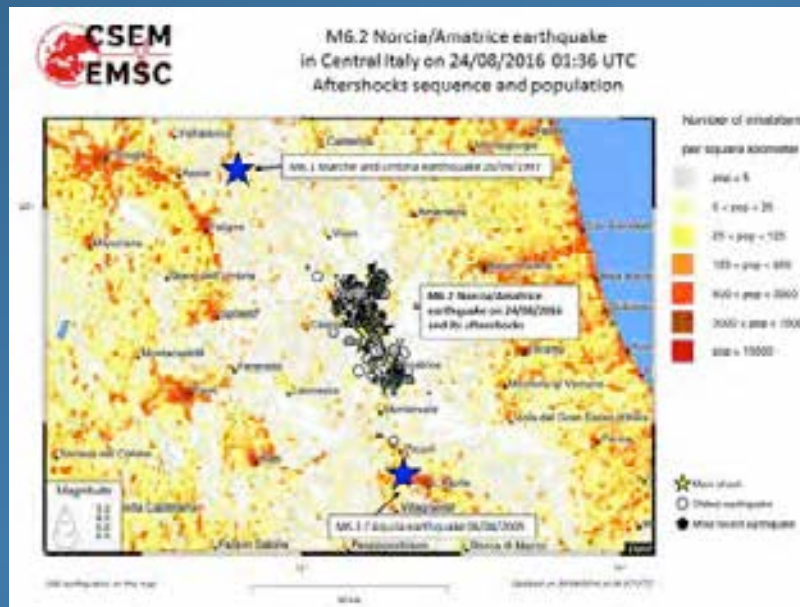
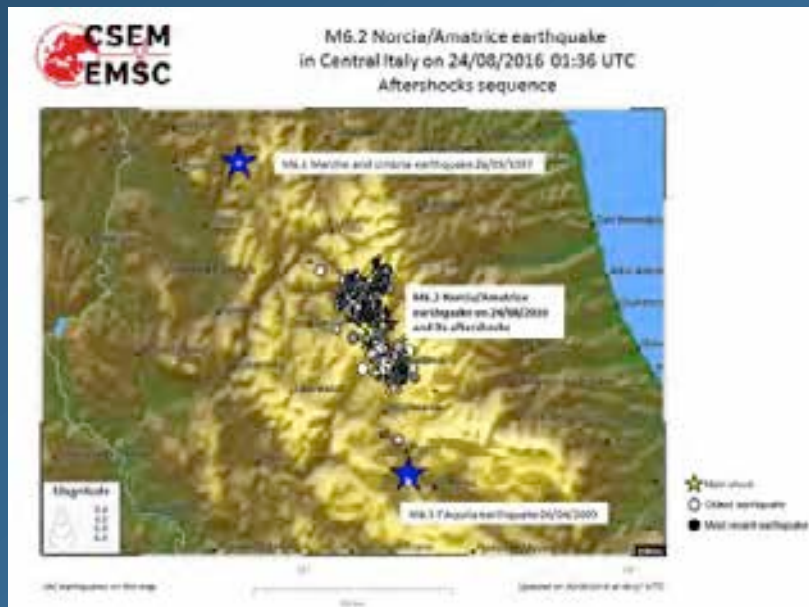
<http://shakemap.rm.ingv.it/shake/7073641/pga.html>

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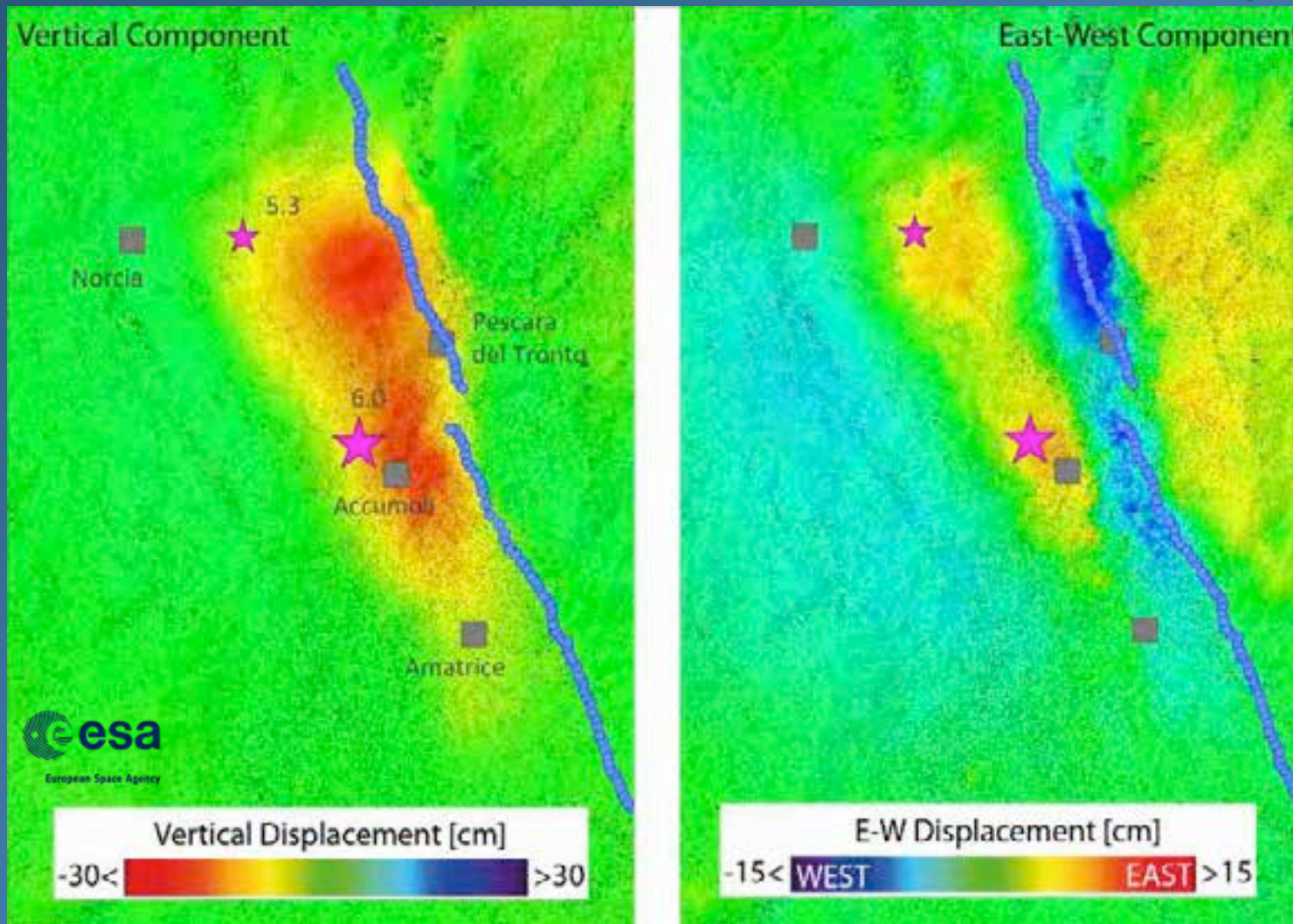






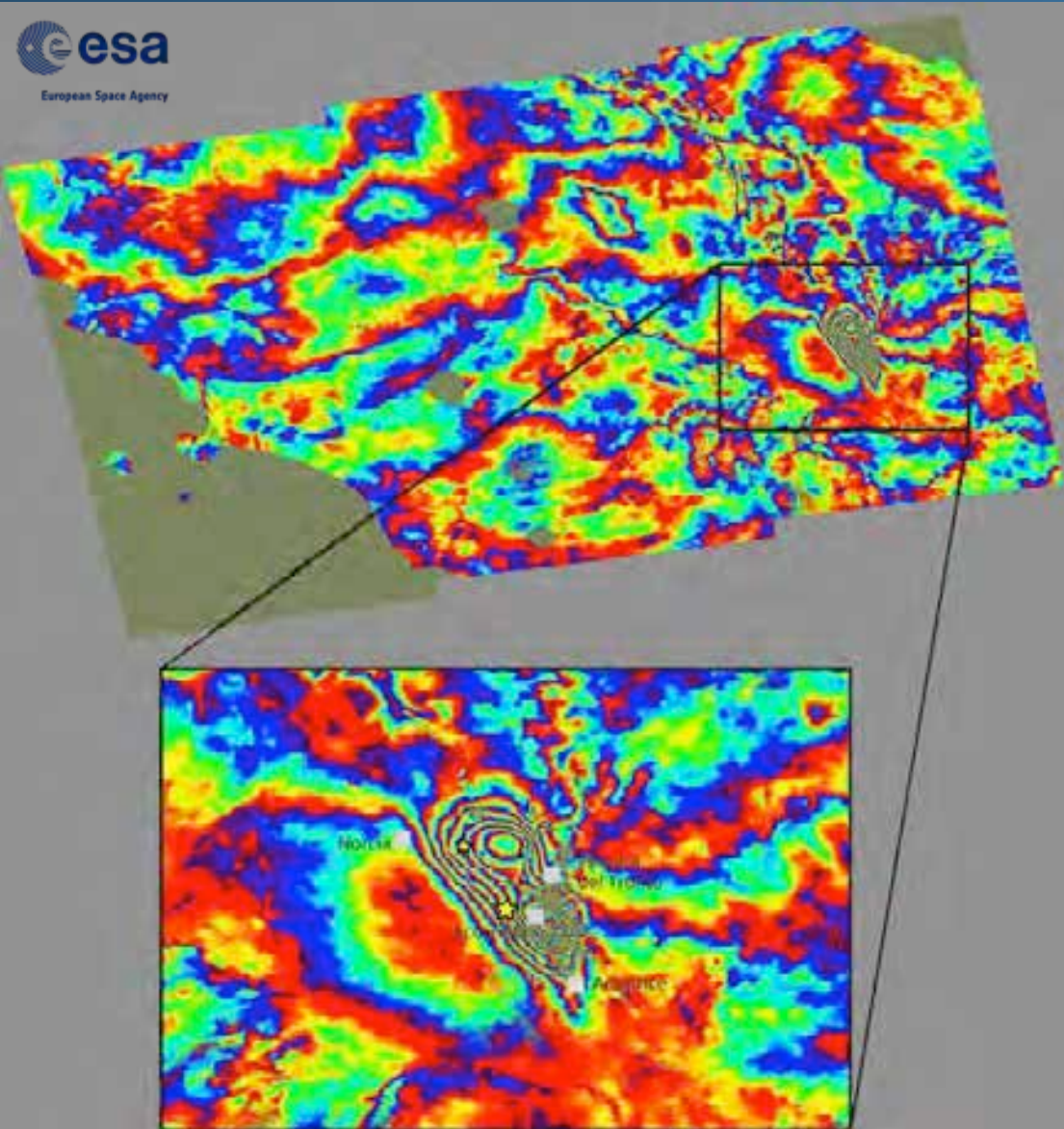


## GROUND DISPLACEMENT FROM CENTRAL ITALY EARTHQUAKE



[http://www.esa.int/spaceinimages/Images/2016/08/Ground\\_displacement\\_from\\_Italy\\_s\\_earthquake](http://www.esa.int/spaceinimages/Images/2016/08/Ground_displacement_from_Italy_s_earthquake)





## Central Italy Earthquake Deformation

Combination of Sentinel-1 radar acquisitions over central Italy from before (15.08.2016) and after (27.08.2016) the earthquake

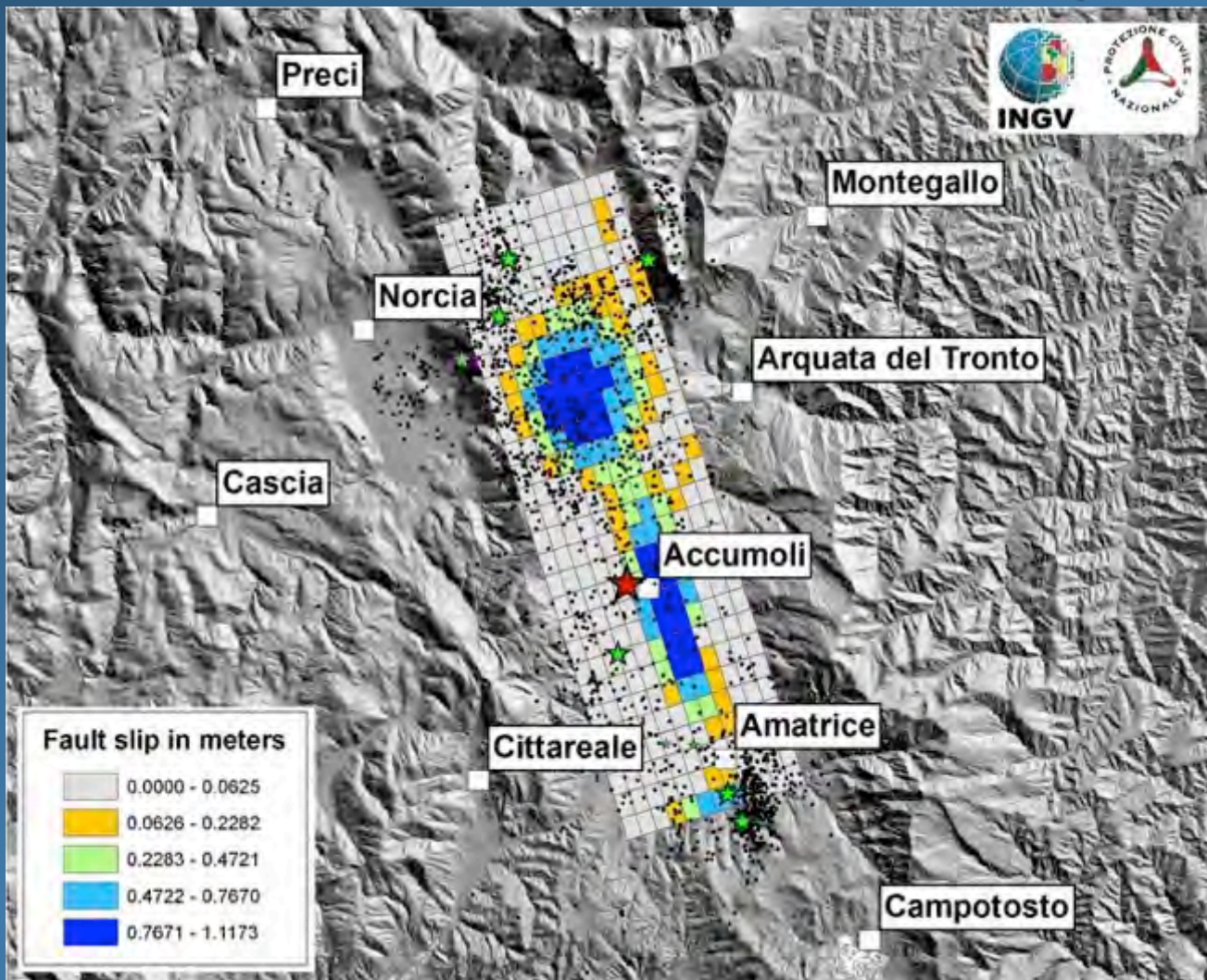


'Interferogram' showing ground deformation caused by the 24 August earthquake





## SOURCE FAULT OF CENTRAL ITALY EARTHQUAKE

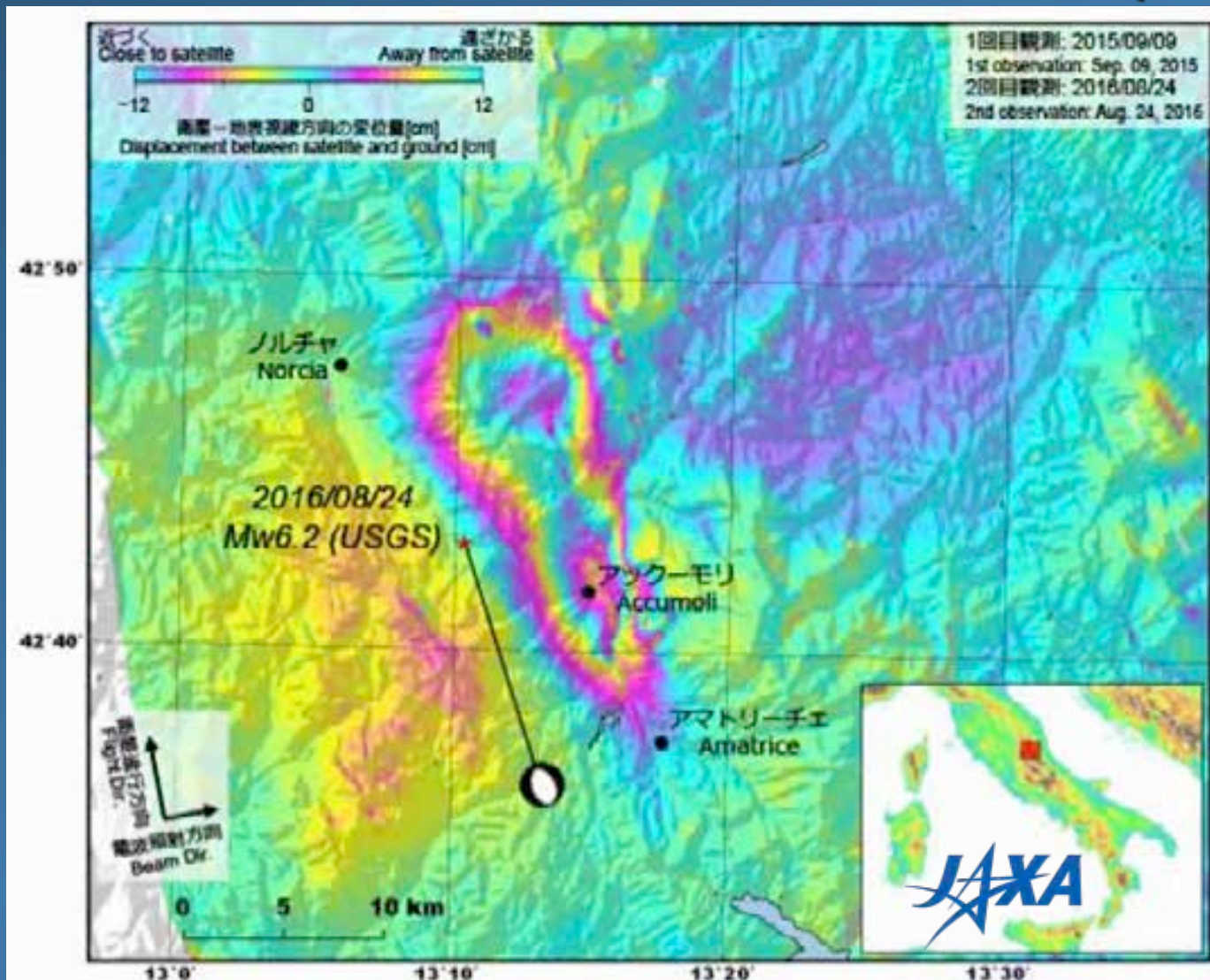


[http://www.esa.int/spaceinimages/Images/2016/08/  
Source\\_fault\\_of\\_Italy\\_s\\_earthquake](http://www.esa.int/spaceinimages/Images/2016/08/Source_fault_of_Italy_s_earthquake)





## GROUND DEFORMATION CAUSED BY THE EARTHQUAKE

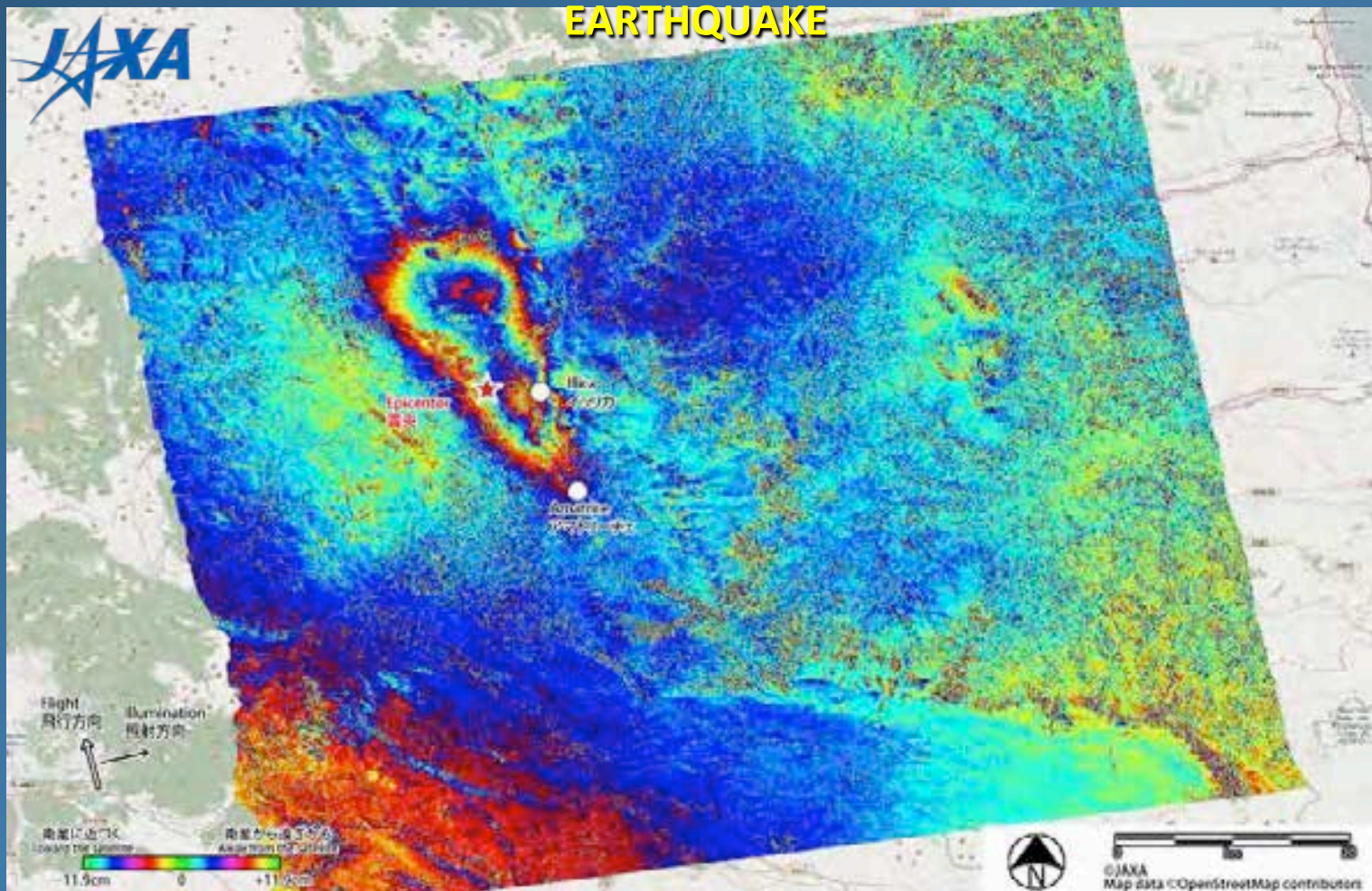






# DIFFERENTIAL INTERFEROMETRY (DINSAR) RESULT USING THE ALOS-2 PALSAR-2 DATA ACQUIRED BEFORE (2015.09.09; UTC) AND AFTER (2016.08.24; UTC)

## EARTHQUAKE











**SECONDARY EARTHQUAKE ENVIRONMENTAL EFFECTS  
INDUCED BY THE CENTRAL ITALY EARTHQUAKE  
Mw 6.2 24 AUGUST 2016**



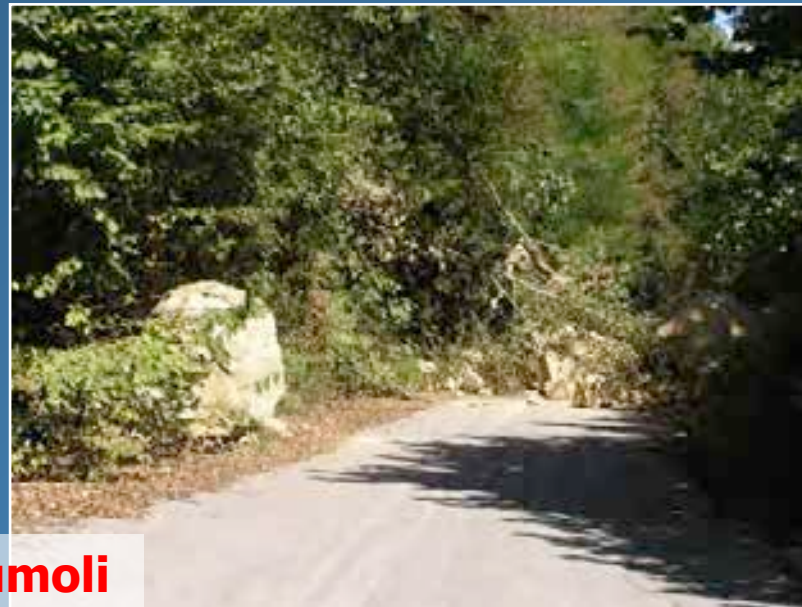


**Accumoli**

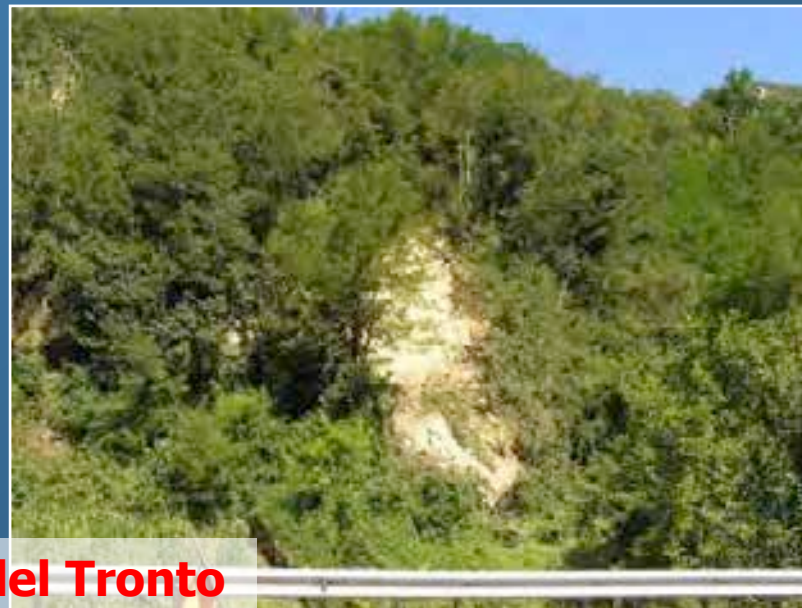




**Accumoli**



**Pescara del Tronto**







**Pescara del Tronto**



# Pescara del Tronto





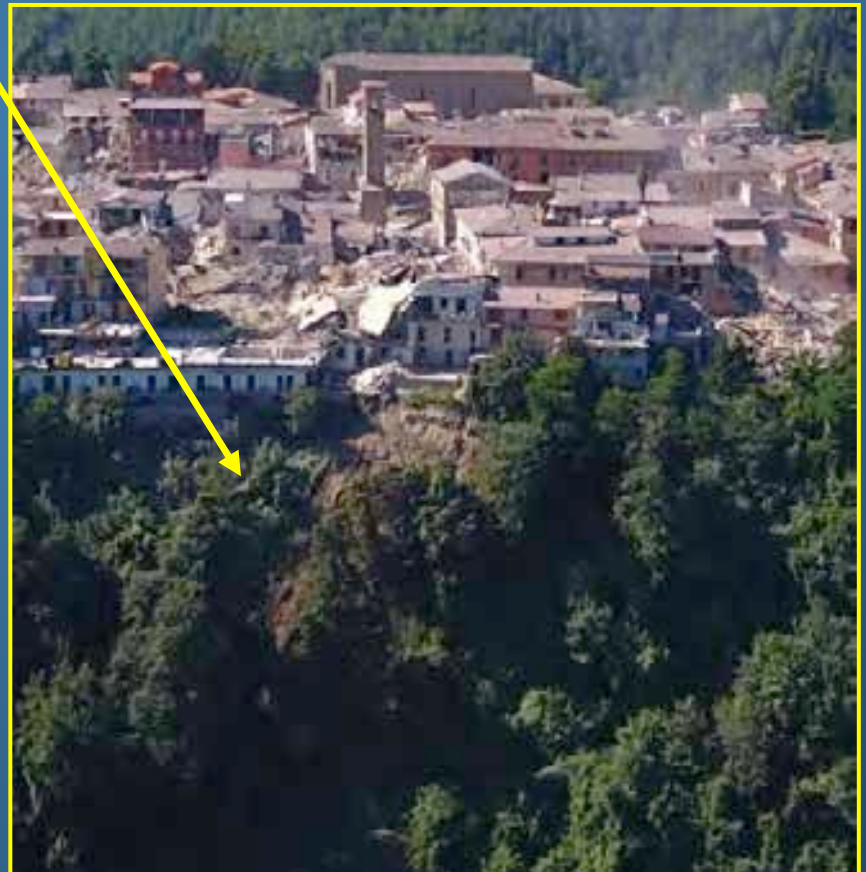


**Pescara del Tronto**





# Amatrice







**BUILDING DAMAGE  
INDUCED BY THE CENTRAL ITALY EARTHQUAKE  
Mw 6.2 24 AUGUST 2016**



# AMATRICE



*Photos taken on 2016.08.26*





***Photos taken on 2016.08.25 before the Mw 4.3 aftershock of 2016.08.25 and the Mw 4.8 aftershock 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*





*Photos taken on 25 August before a 4.3 aftershock*

**AMATRICE**



*Photos taken on 25 August before a 4.3 aftershock*



**AMATRICE**





*Photos taken on 25 August  
before a 4.3 aftershock*



## AMATRICE







## AMATRICE

*Photos taken on 25 August  
before (1), during (2) and after (3, 4) a 4.3 aftershock*





## ACCUMOLI





*Photo taken on 2016.08.27 after two aftershocks with Mw 4.3 and 4.8 respectively*



**PESCARA DEL TRONTO**



**BORGO**



*Photos taken on 2016.08.27*





NATIONAL & REGIONAL  
PROTECTION  
ENVIRONMENTAL

PRETARE

(Fraz. di Arquata del T.)



*Photos taken on  
2016.08.27*





# ARCUATA DEL TRONTO



*Photos taken on 2016.08.27*



SALETTA







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











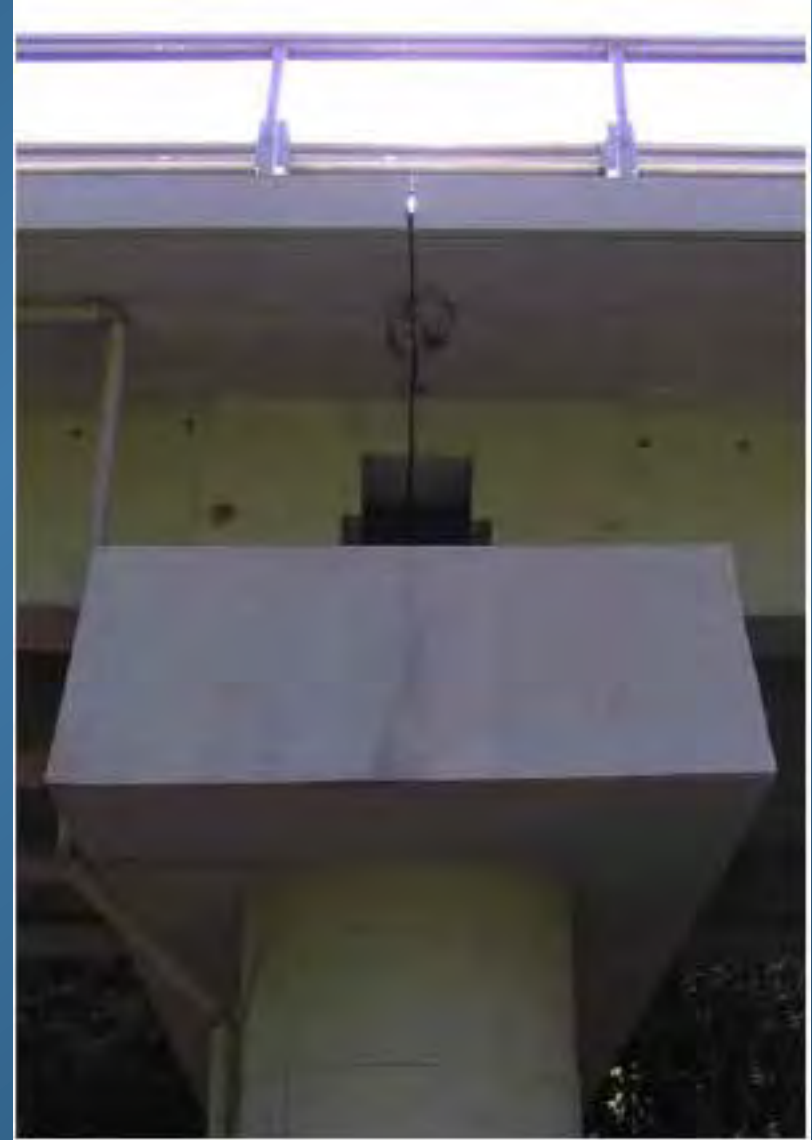
**NORCIA**







## DAMAGE TO BRIDGES







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







**EMERGENCY RESPONSE  
AFTER THE CENTRAL ITALY EARTHQUAKE  
Mw 6.2 24 AUGUST 2016**





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







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ENVIRONMENTAL, DISASTER AND CRISIS MANAGEMENT











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**PROTEZIONE CIVILE**

Presidenza del Consiglio dei Ministri  
Dipartimento della Protezione Civile

# TERREMOTO CENTRO ITALIA

# SMS solidale al 45500



**PROTEZIONE CIVILE**

Presidenza del Consiglio dei Ministri  
Dipartimento della Protezione Civile

# TERREMOTO CENTRO ITALIA

PER INVIARE OFFERTE DI BENI E SERVIZI

[sismarieti@regione.lazio.it](mailto:sismarieti@regione.lazio.it)

[prot.civ@regione.marche.it](mailto:prot.civ@regione.marche.it)





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