The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
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2142-12

Advanced Conference on Seismic Risk Mitigation and Sustainable Development

10 - 14 May 2010

The geological evaluation of the seismic hazard in an area

Leonello Serva

Agenzia Nazionale per la Protezione dell'Ambiente
Roma
ITALY

The geological evaluation of the seismic hazard in an area

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Conference on Seismic Risk Mitigation
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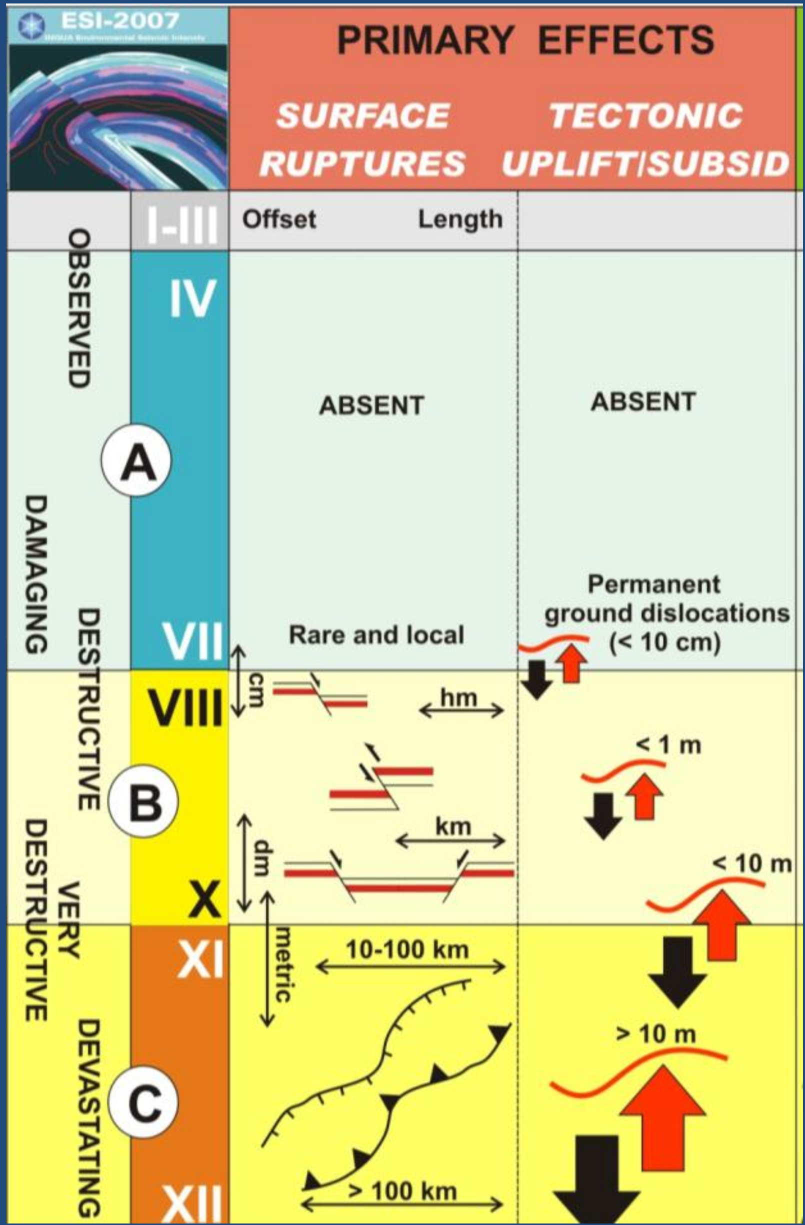
Index

- Earthquakes produces effects on the ground/environment, and this is why the geologists can talk a lot about them
- The goods geologist are able to recognize them
- The good geologists are also able to estimate them and therefore to be very useful for the seismic hazard estimation

PRIMARY EFFECTS



SURFACE FAULTING

1915, January 13, Fucino earthquake, Italy

MAXIMUM DISPLACEMENT

1980, November 23, Irpinia-Basilicata earthquake, Italy

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2009, April 6, L'Aquila earthquake, Italy

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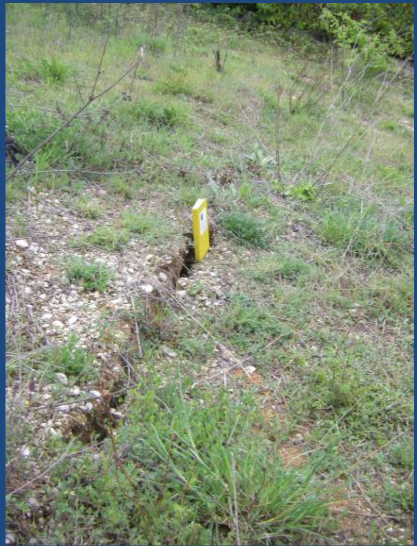
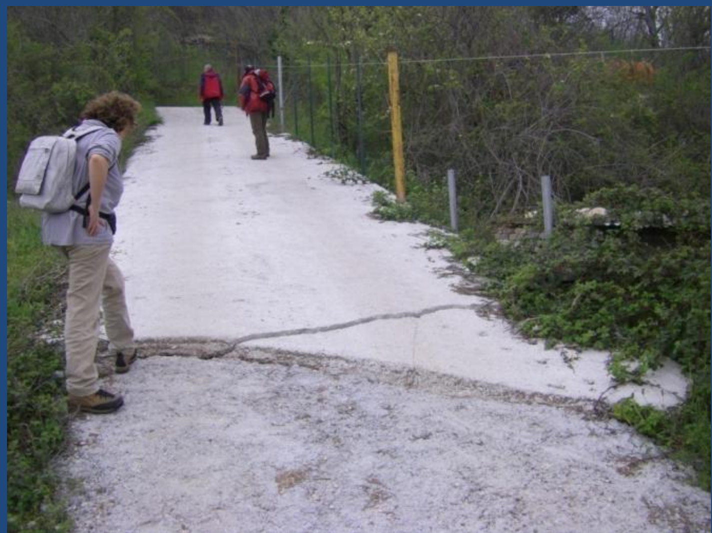
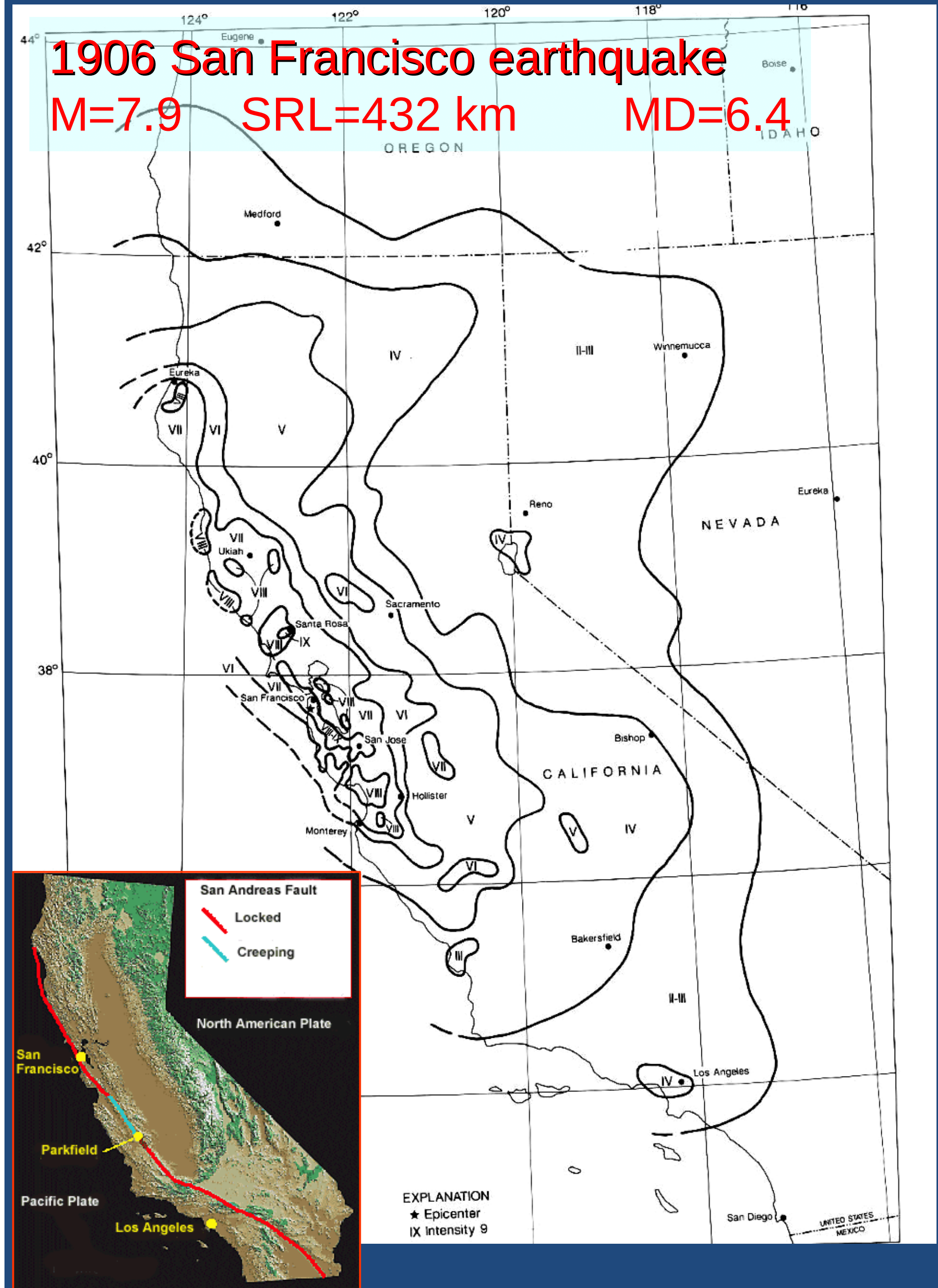




2009, April 6, L'Aquila earthquake, Italy

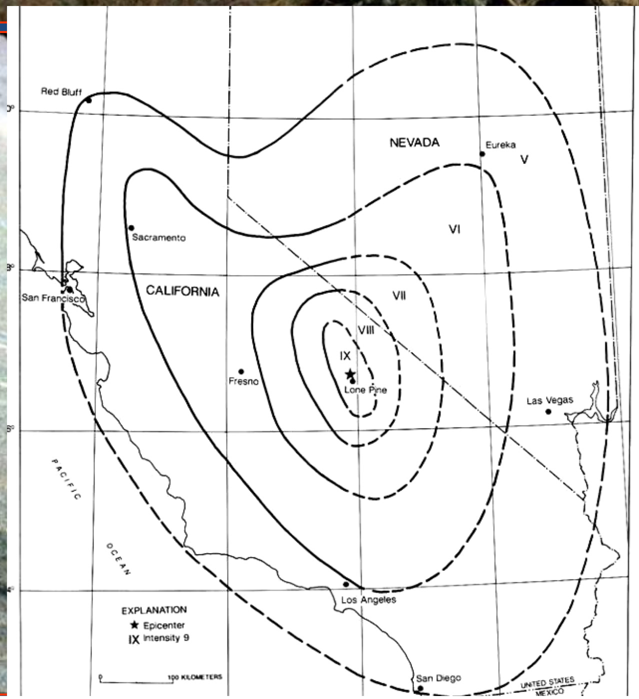
1906 San Francisco earthquake

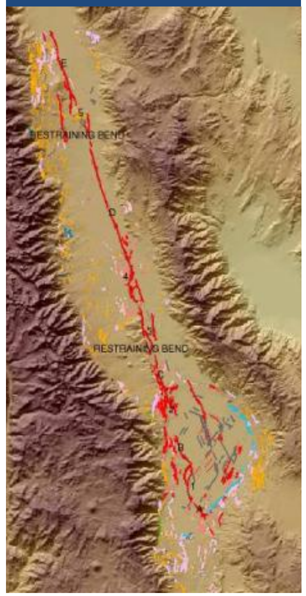
M=7.9 SRL=432 km MD=6.4



26.03.1872 Owens Valley (California, USA)

M=7.6 SRL>110 km MD≥10m





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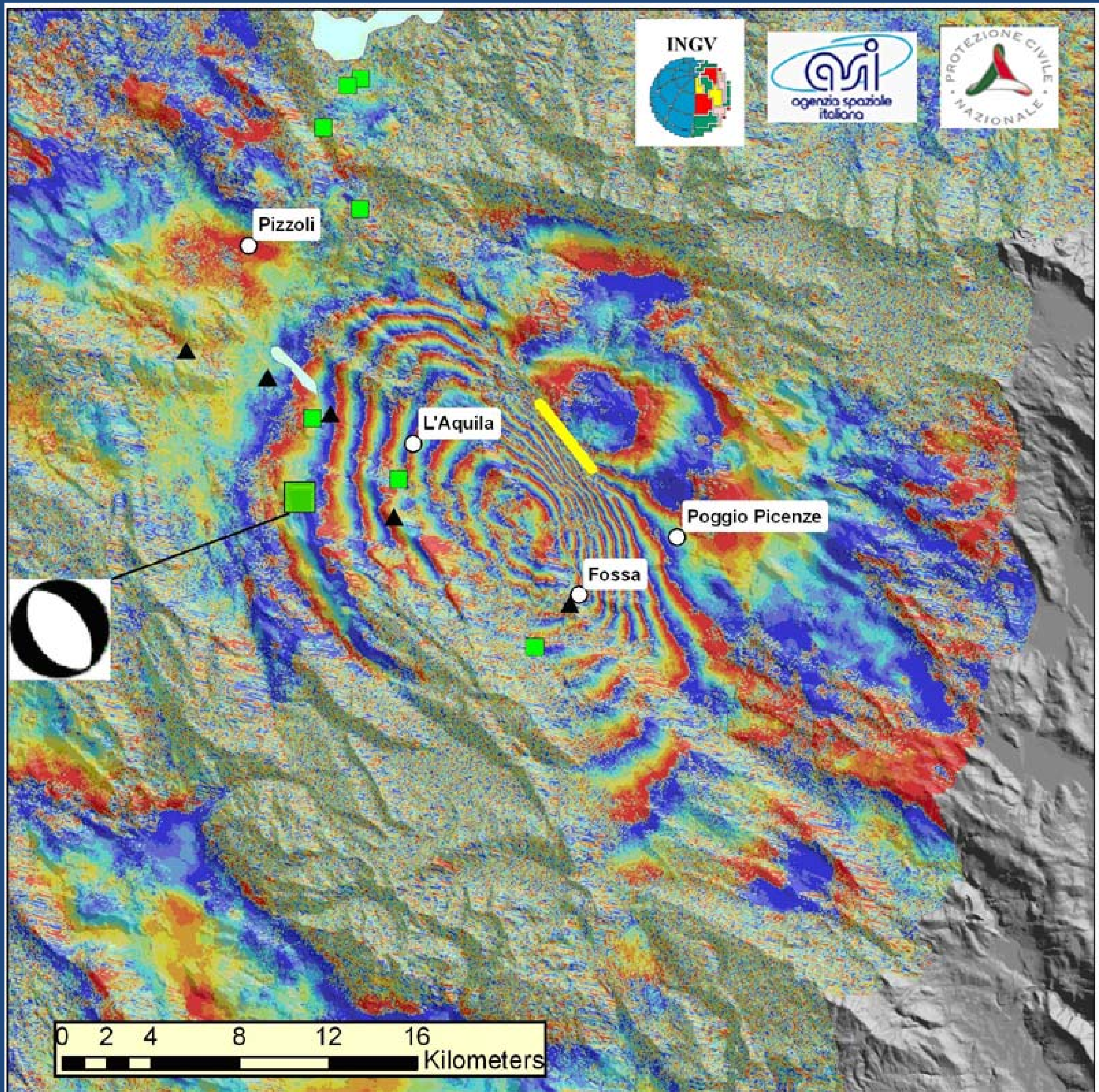
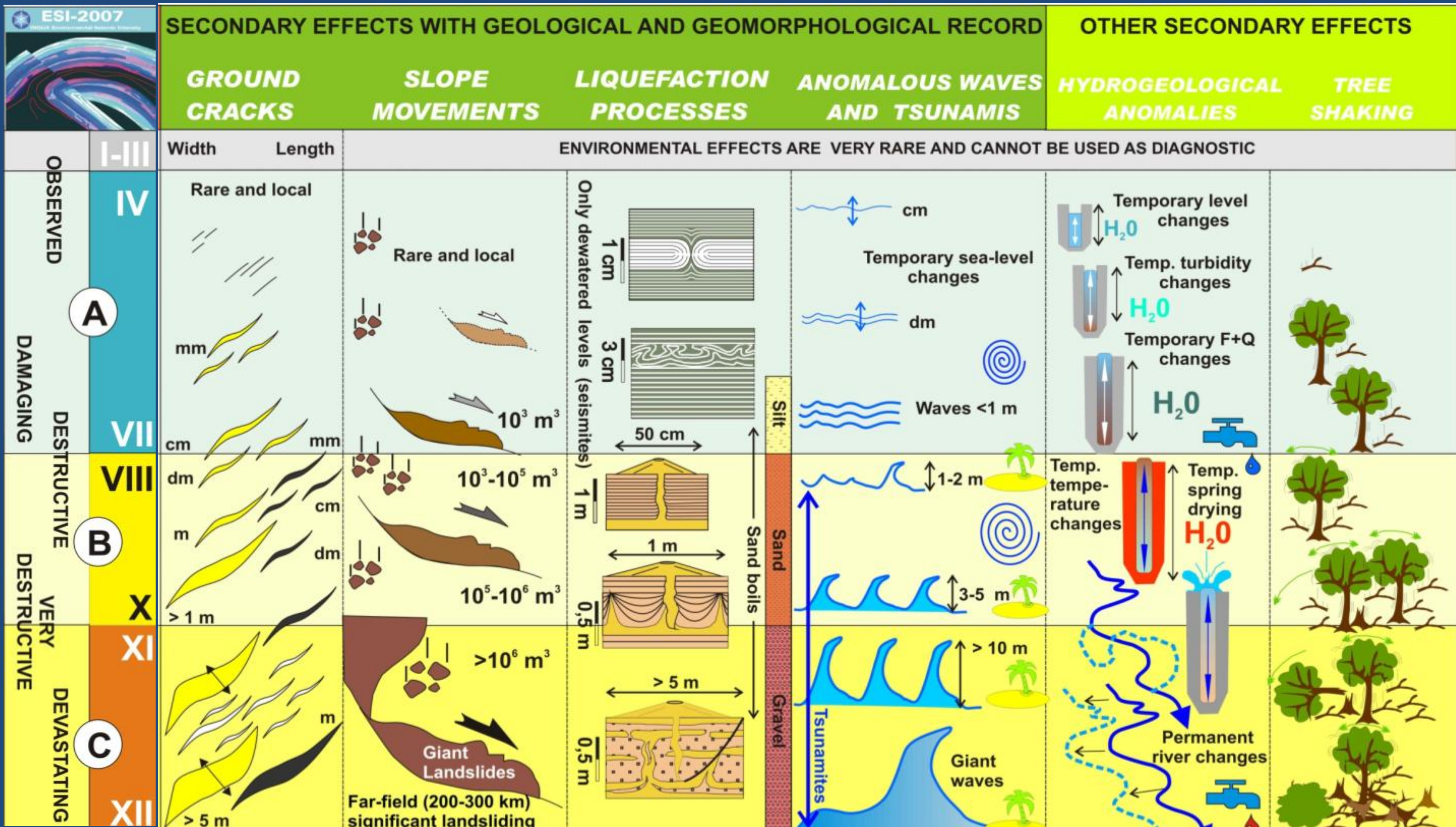


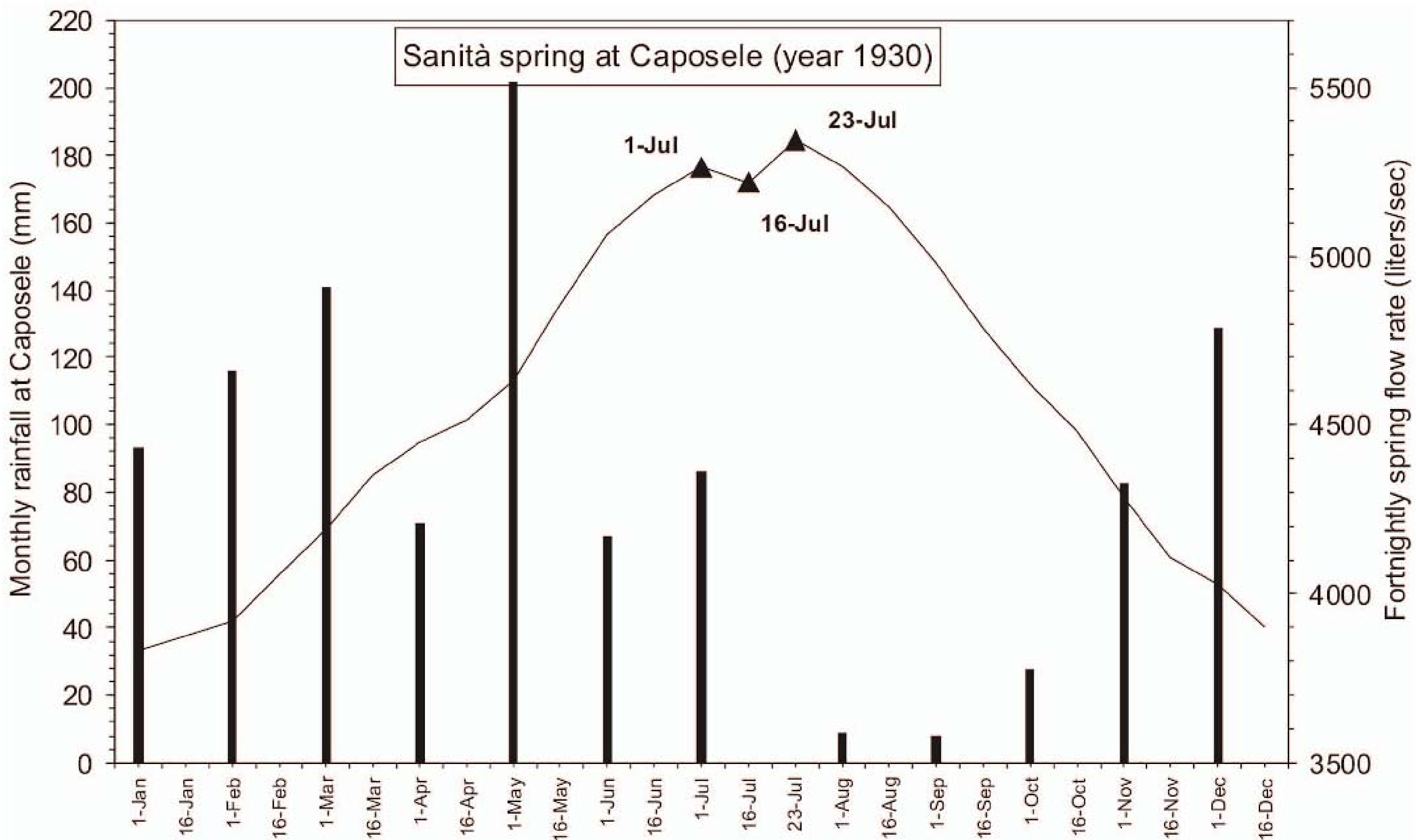
Interferogramma ENVISAT calcolato a partire da una coppia di immagini 1 Febbraio 2009 – 12 Aprile 2009. Il Massimo abbassamento è di circa 25 cm tra L'Aquila e Fossa (ogni frangia corrisponde a circa 2.5 cm).
I quadratini verdi indicano il mainshock e gli aftershocks con Mw > 5; la linea gialla indica la fagliazione superficiale a Paganica; i triangoli marcano la posizione dei caposaldi GPS utilizzati per il confronto con il SAR.

TECTONIC UPLIFT

1811-1812 New Madrid (USA) earthquakes (Mw between 7.2 and 8.3).
Reelfoot Lake, Tennessee, USA.
This lake was formed by coseismic uplift triggered by a blind thrust that caused the inundation of the forested area in foreground.

SECONDARY EFFECTS





1930 Irpinia earthquake: Hydrological anomaly recorded at the Sanità spring, Caposele.

SLOPE MOVEMENTS

January 25, 1999, Armenia, Colombia earthquake (M = 6.1). Seismically induced landslide at Cristales, Cajamarca.

November 23, 1980 Irpinia-Basilicata, Italy earthquake (Ms = 6.9). S. Giorgio La Molara: coseismic reactivation of a landslide

July 12, 2004 Kobarid, Slovenia earthquake (Md = 5.1)
Two small landslides along the Kobarid – Bovec road.

ROCK FALLS

August 6, 2002 Bullas, Spain earthquake (VI MSK; 5.0 mb)

November 24, 2004, Salò, Italy earthquake (Ml 5.2).

2009 April 6th L'Aquila earthquake **Rock fall at Fossa**

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2009 April 6 , L'Aquila earthquake

Rock fall at Stiffe

Rock fall at Bazzano

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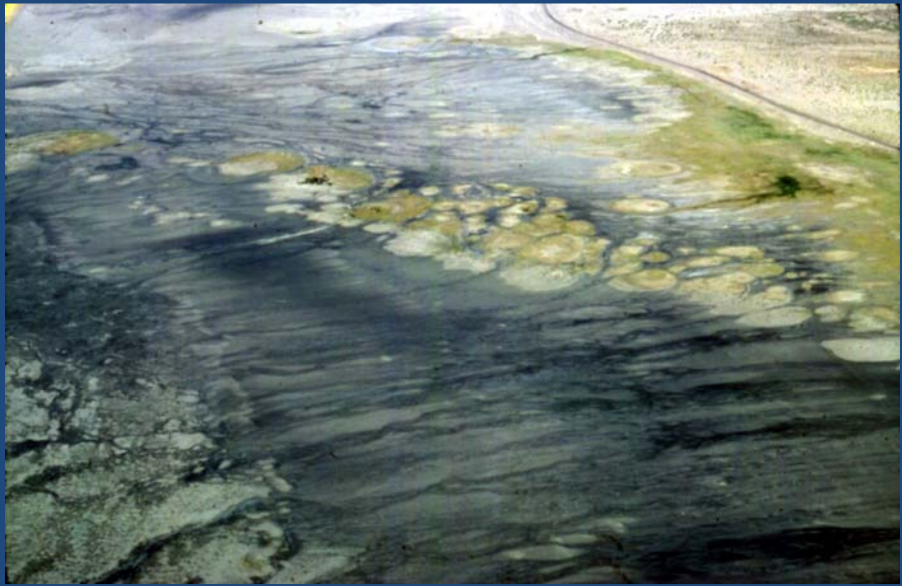
LIQUEFACTIONS

15.01.1968
Ms 5.9 Belice

06.05.1976, Ms 6.5 Friuli



March 3, 1872 Owens Valley, California, USA earthquake (Ms 7.6).
Owens Lake: aligned sand blows in the playa of the lake, dried in 1926.

November 22, 1995 Nuweiba, Sinai, earthquake, (Mw = 7.2).
Gulf of Elat – Aqaba: An about one meter sand blow displaying coarse sand on its surface, suggesting that coarser material might have been ejected during a late liquefaction phase.

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2009 April 6 ,
L'Aquila earthquake

Liquefaction at Vittorito

GROUND COLLAPSES

March 27, 1964 Alaska earthquake (Mw = 9.2).
Collapse pits at Kasilof formed after eruptions of ground water and sand. The pit in the foreground is about one meter in diameter.

August 14, 2003, Lefkada, Ionian Sea, Greece, earthquake (Mw 6.2).
Ground crater opened in the sandy beach of Agios Nikitos.

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2009 April 6th ,
L’Aquila earthquake

Ground failures ,
Lake Sinizzo

Effects	Intensity MSK	Intensity MCS
-Cracks in saturated soil and/or loose alluvium up to 1 cm,	VI	
- in saturated soil and/or loose alluvium a few cm,	VIII	VIII
- in saturated soil and/or loose alluvium up to 10 cm,	IX	
- in saturated soil and/or loose alluvium a few dm up to one m	X	X
- on road backfills and on natural terrigenous slopes over 10 cm	VII - IX	VIII
- on the dry ground or on asphalted roads	VII – XI	X – XI
-Faults in terrigenous terrains and in rocky terrains	XI - XII	XI
-Liquefaction and or mud volcanoes and/or susidence	IX – X	X – XI
-Landslides in sand or gravel dykes	VII – X	VII
- in terrigenous slopes	VI – XI	X - XI
-Rockfalls	IX – XII	X – XI
-Clouding in the closed water bodies and formation of waves	VII – IX	VII – VIII
-Water bodies new formation	VIII – XII	XII
-Flooding	X – XII	X
-Water level variation of the groundwater level and the flow rate of springs	V - X	VII - X

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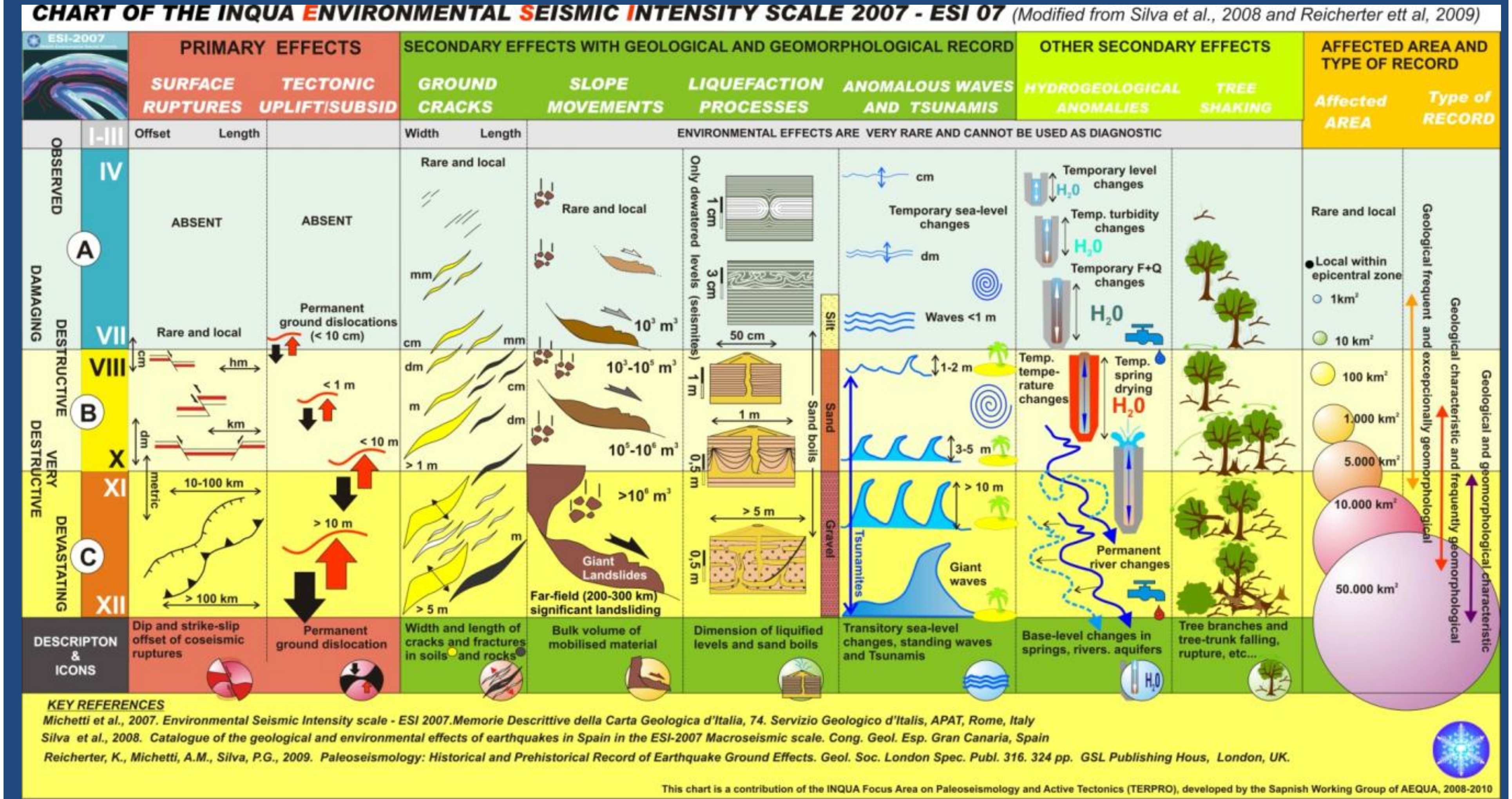

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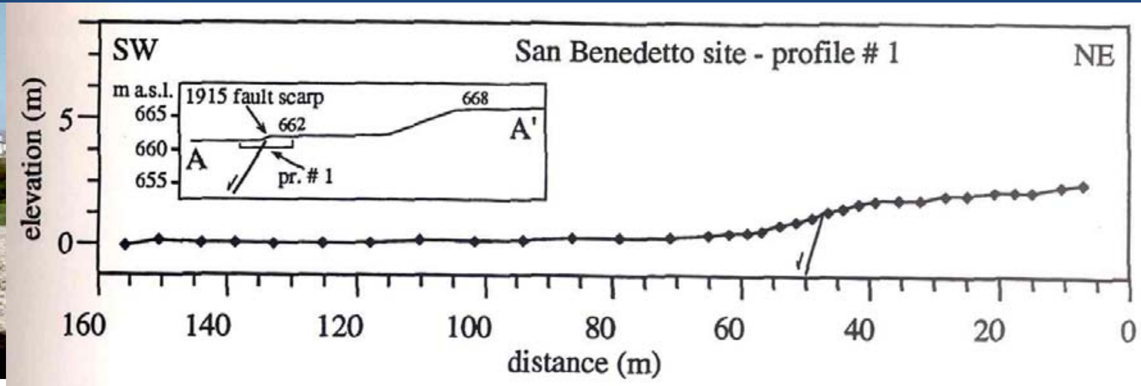
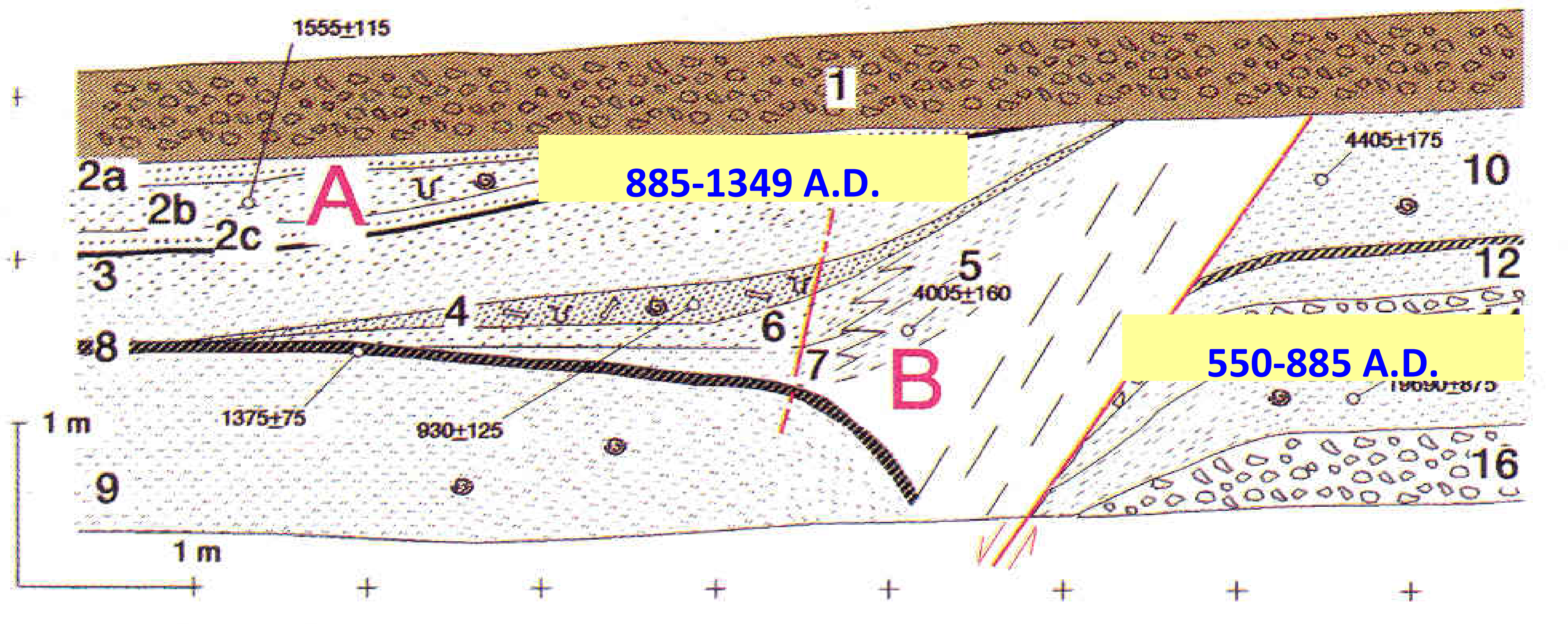
Paleoseismic record in the surroundings of the 1915 Fucino surface faulting

Trench investigations along the 1915 Fucino fault scarp





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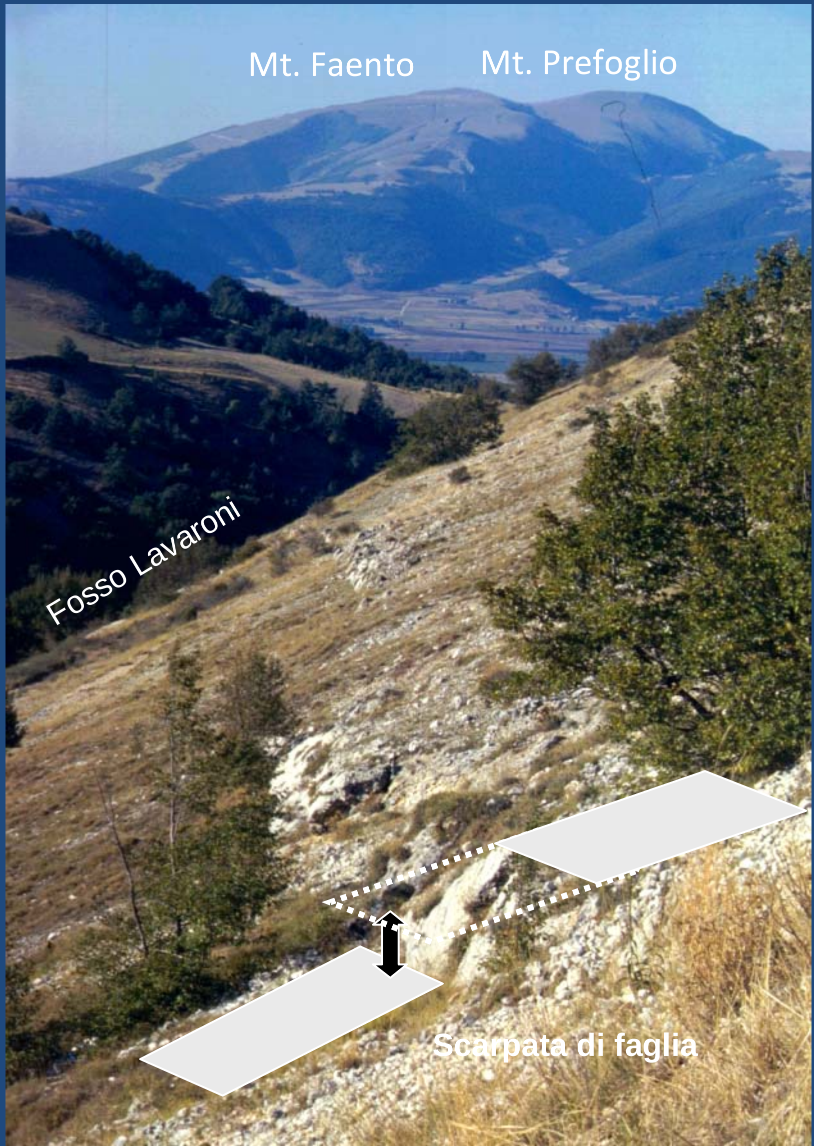
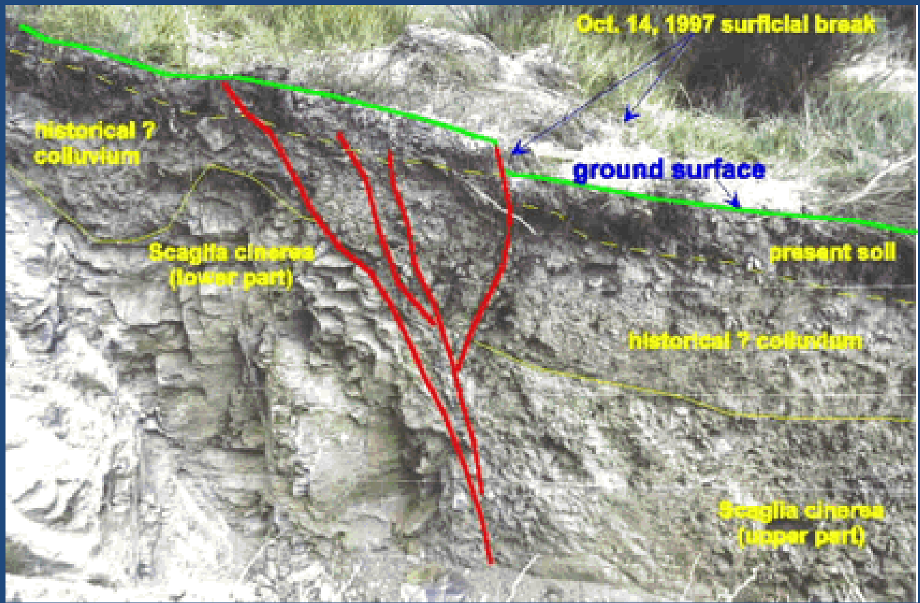
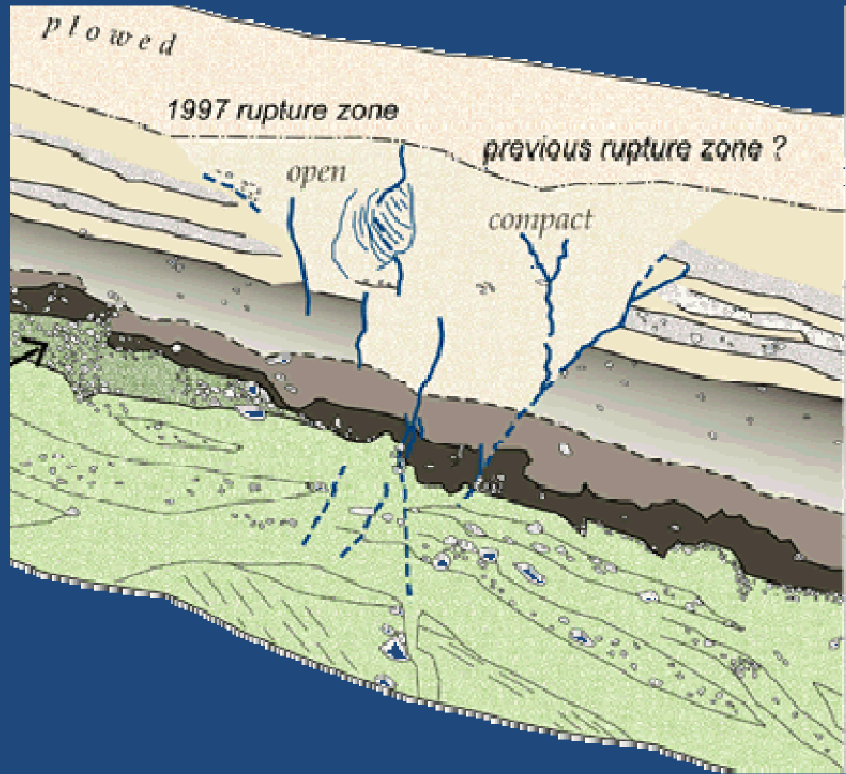
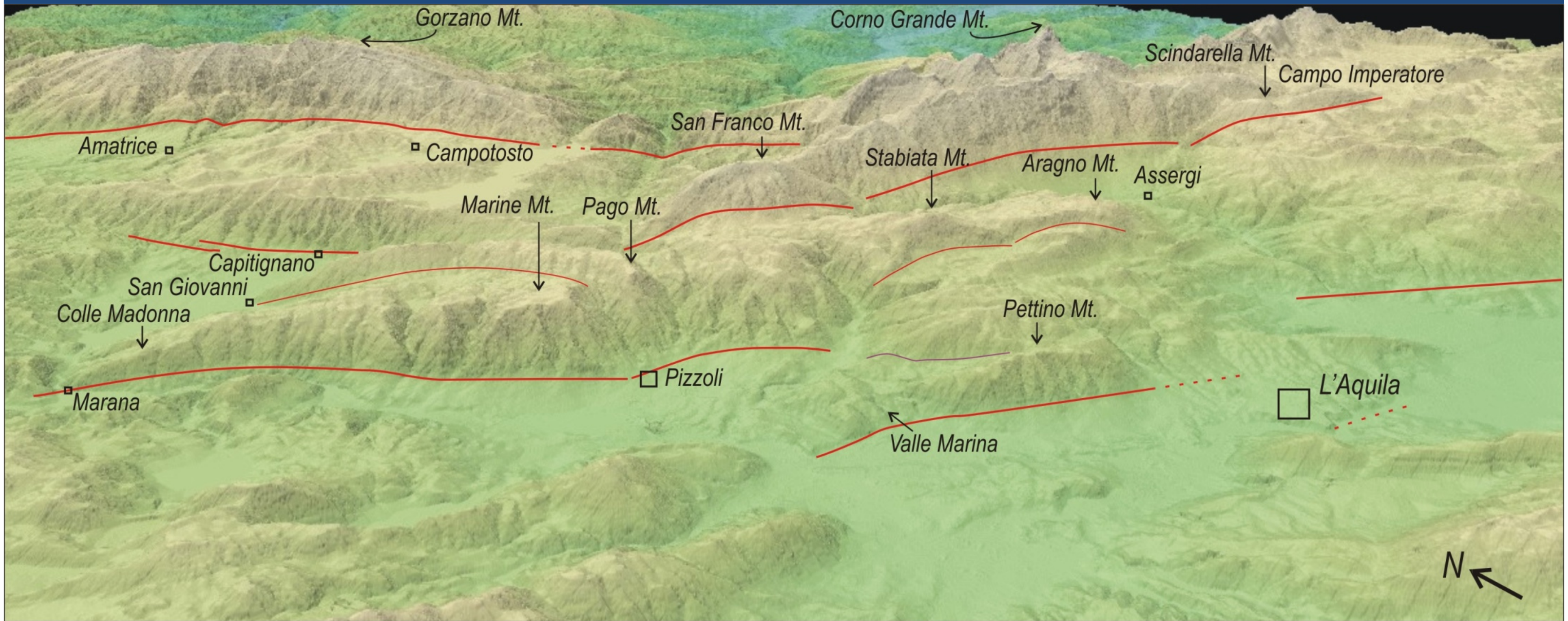


1997, September 26, Colfiorito earthquake, Italy





Trench investigations along the 1997 rupture zone


Gorzano Mt.
Corno Grande Mt.
Scindarella Mt.
Campo Imperatore
San Franco Mt.
Amatrice
Campotosto
Stabiata Mt.
Aragno Mt.
Assergi
Marine Mt.
Pago Mt.
Capitignano
San Giovanni
Colle Madonna
Pettino Mt.
Pizzoli
L'Aquila
Marana
Valle Marina
N

Paleoseismic record in the surroundings of the 2009 L’Aquila surface faulting

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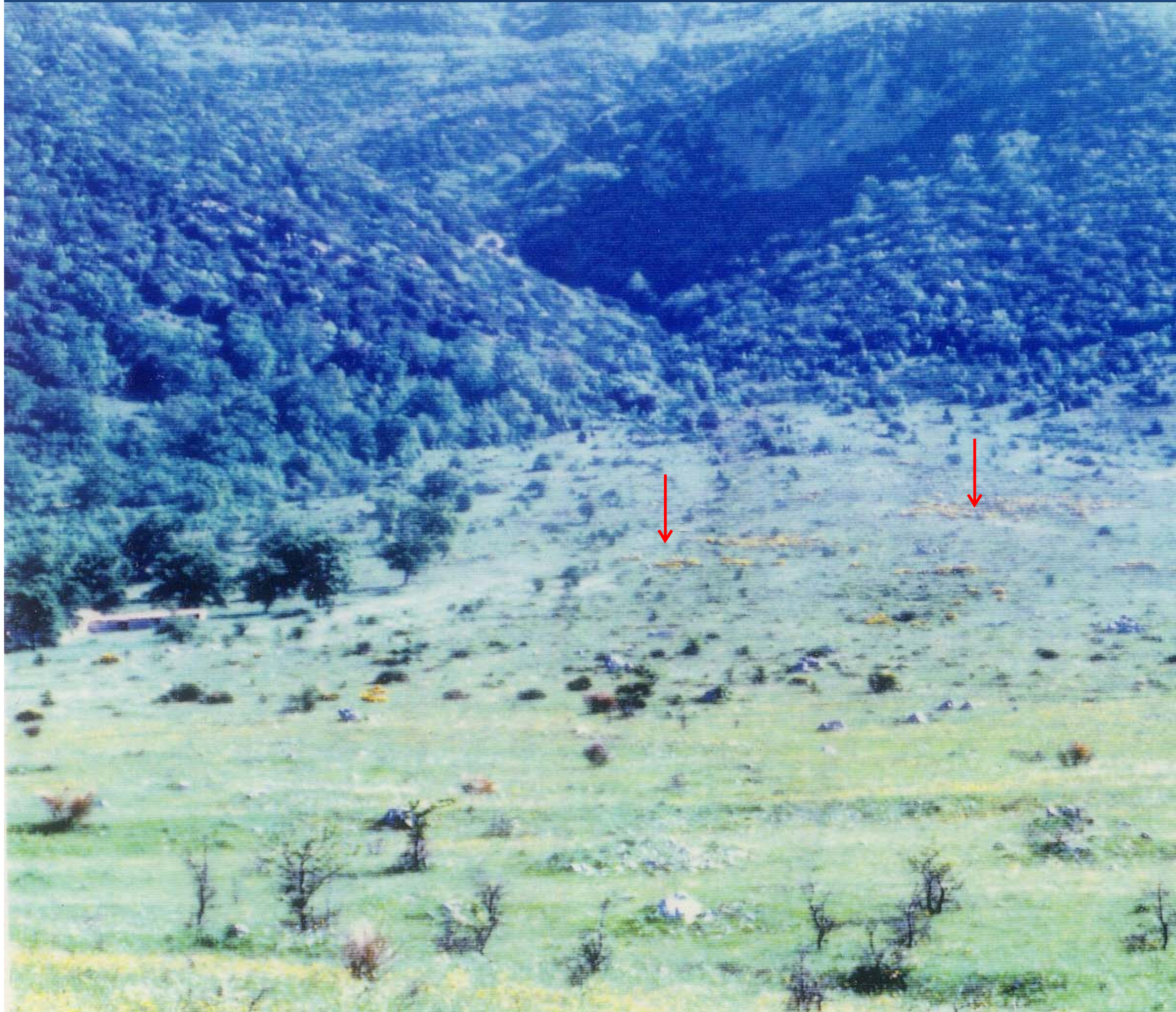
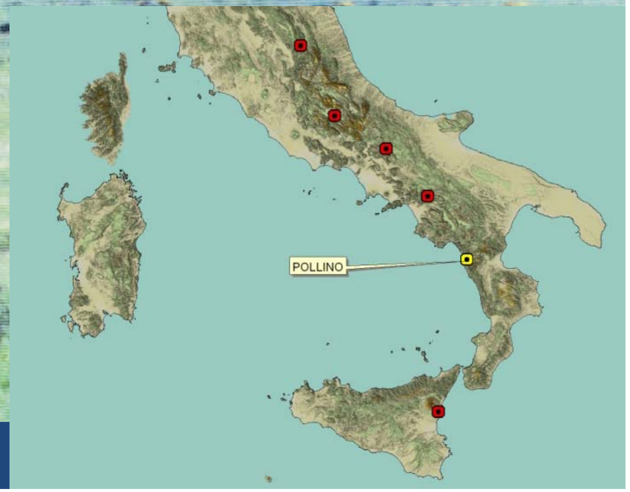
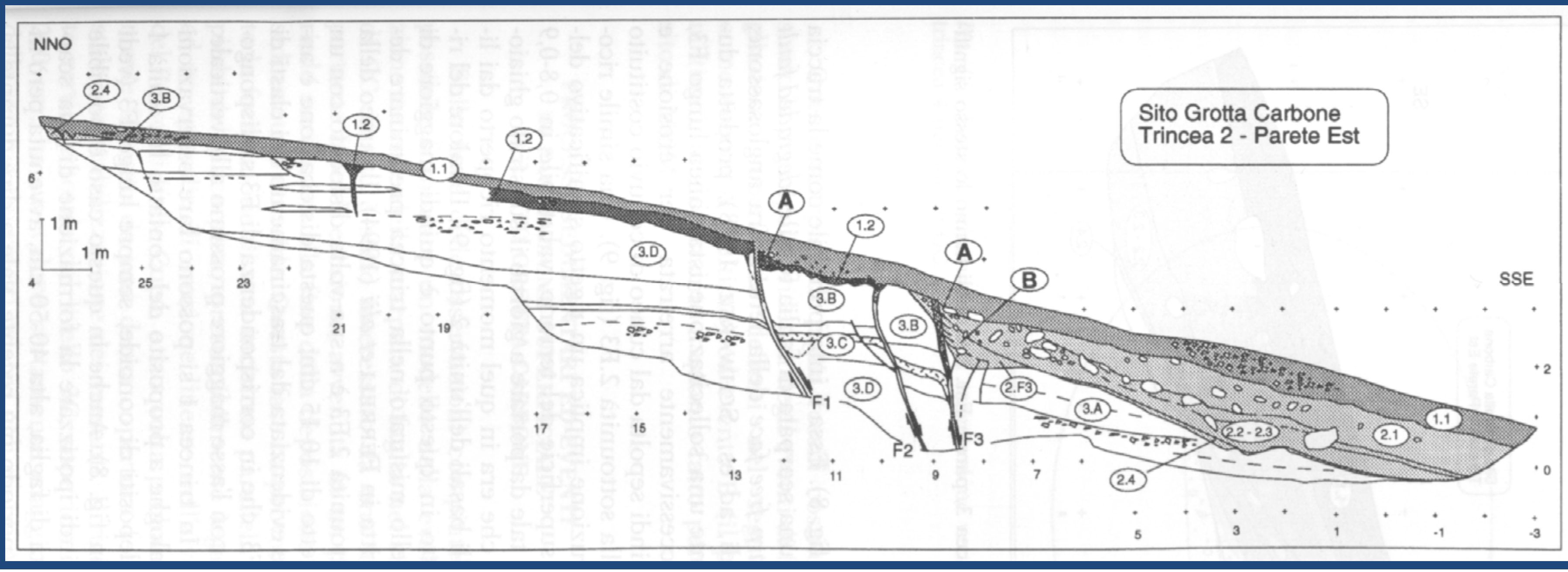




Trench investigations along the Pollino fault scarp



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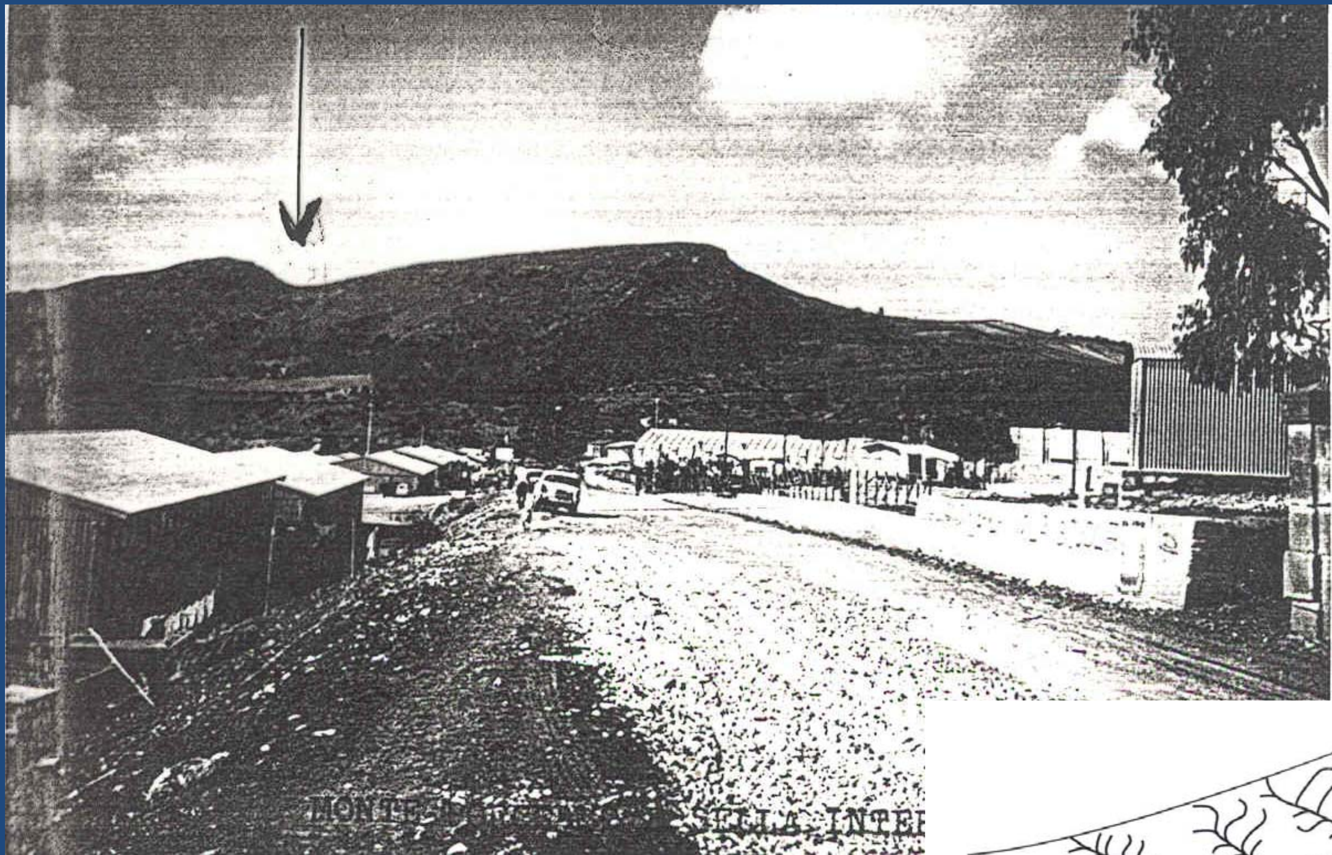
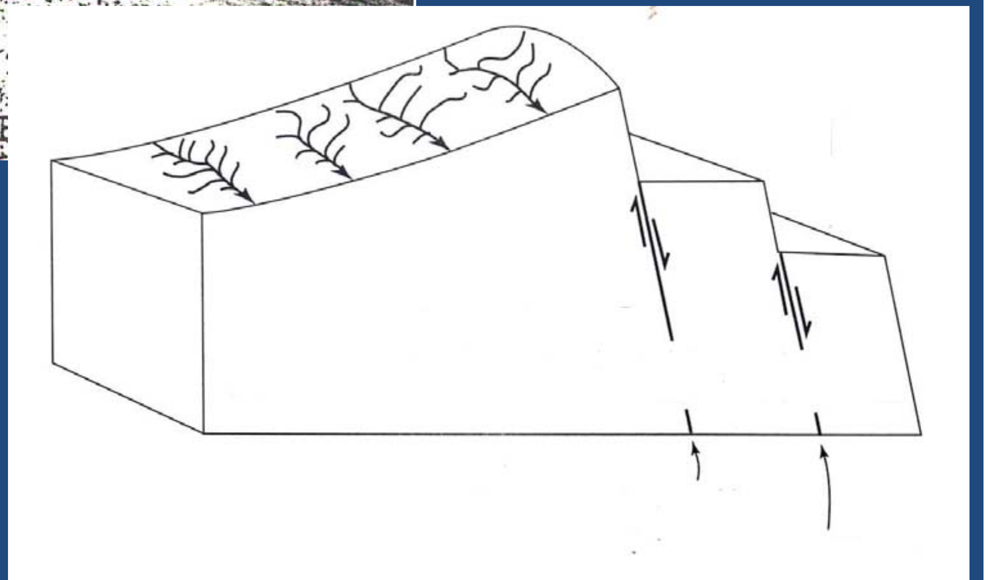
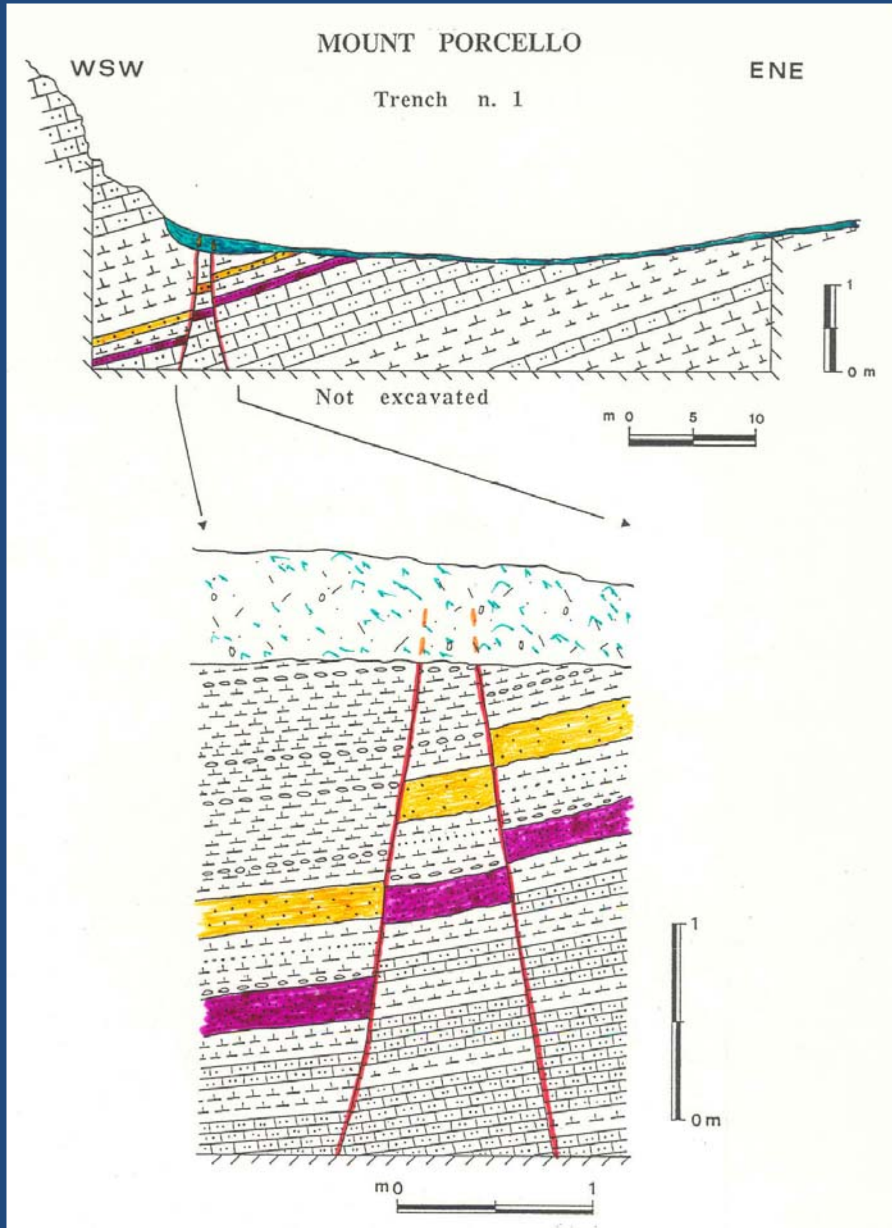
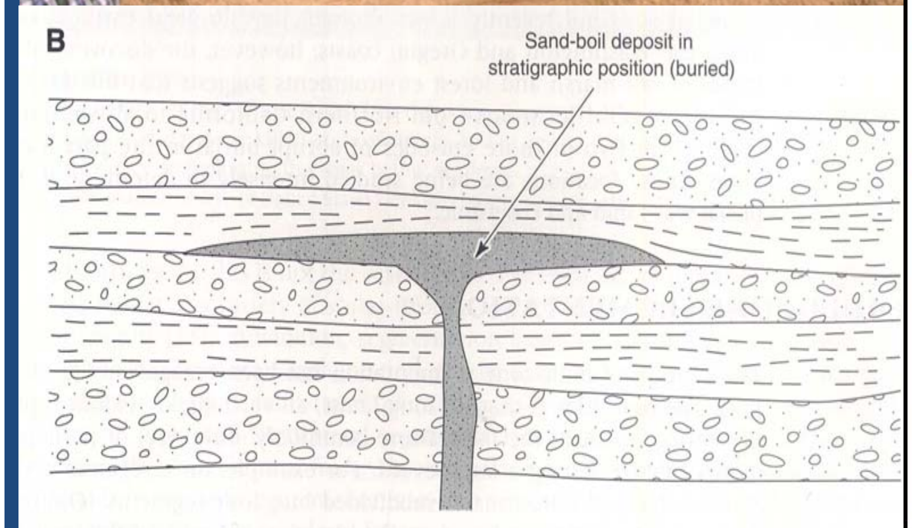
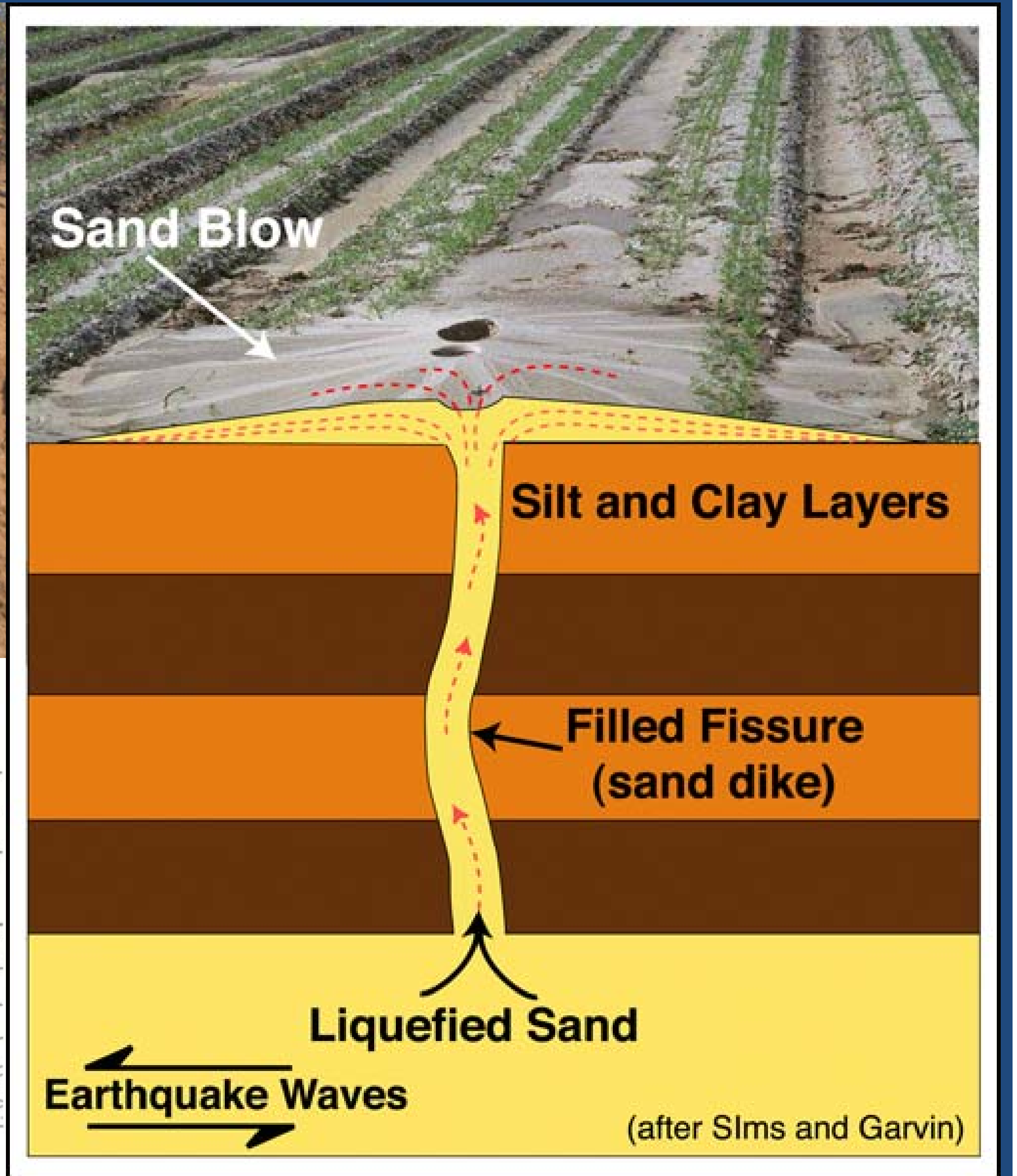





MOUNT PORCELLO
WSW
ENE
Trench n. 1
Not excavated
m 0 5 10
1
0 m
m 0 1

Geological record of paleoliquefaction





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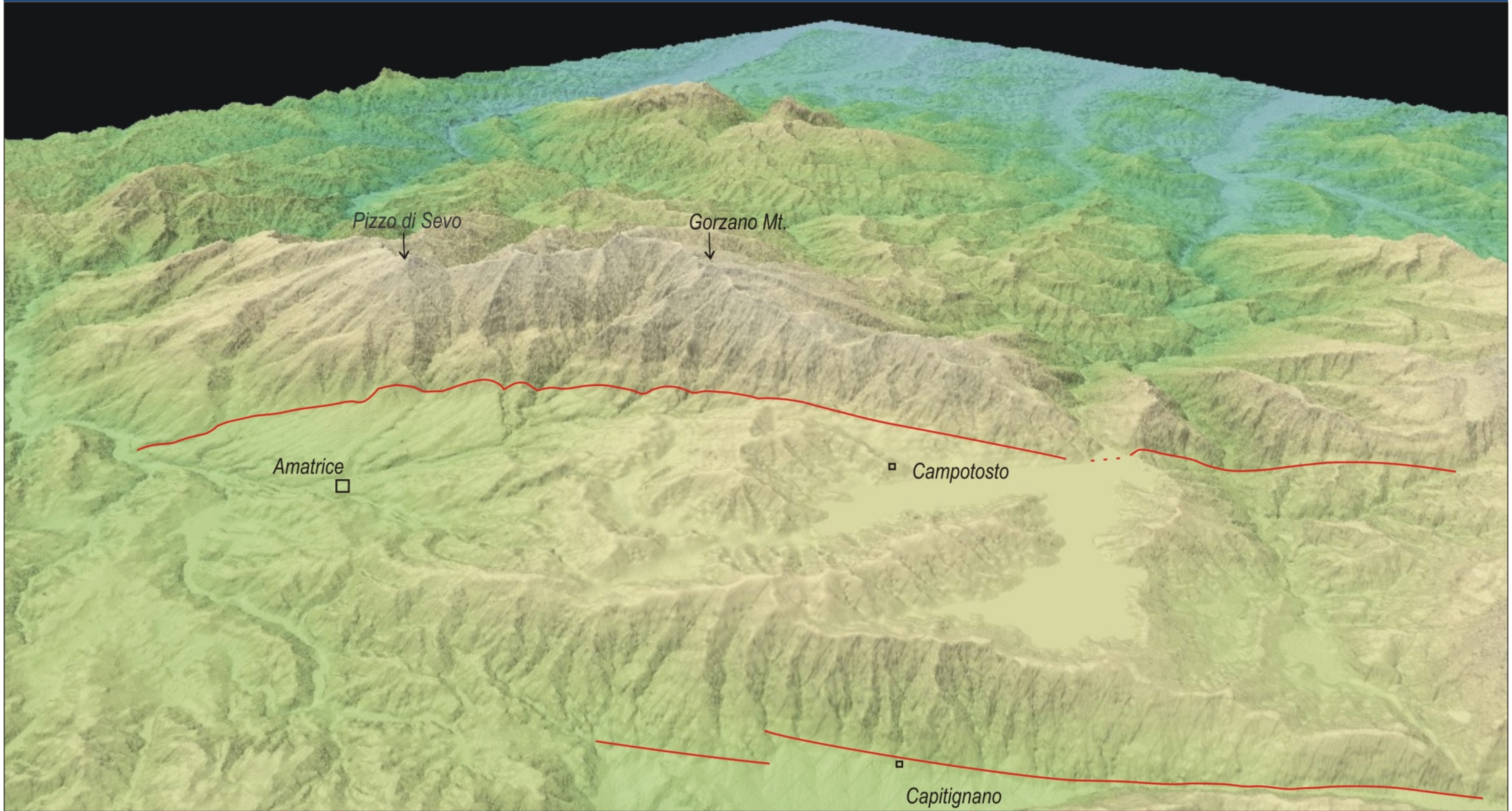
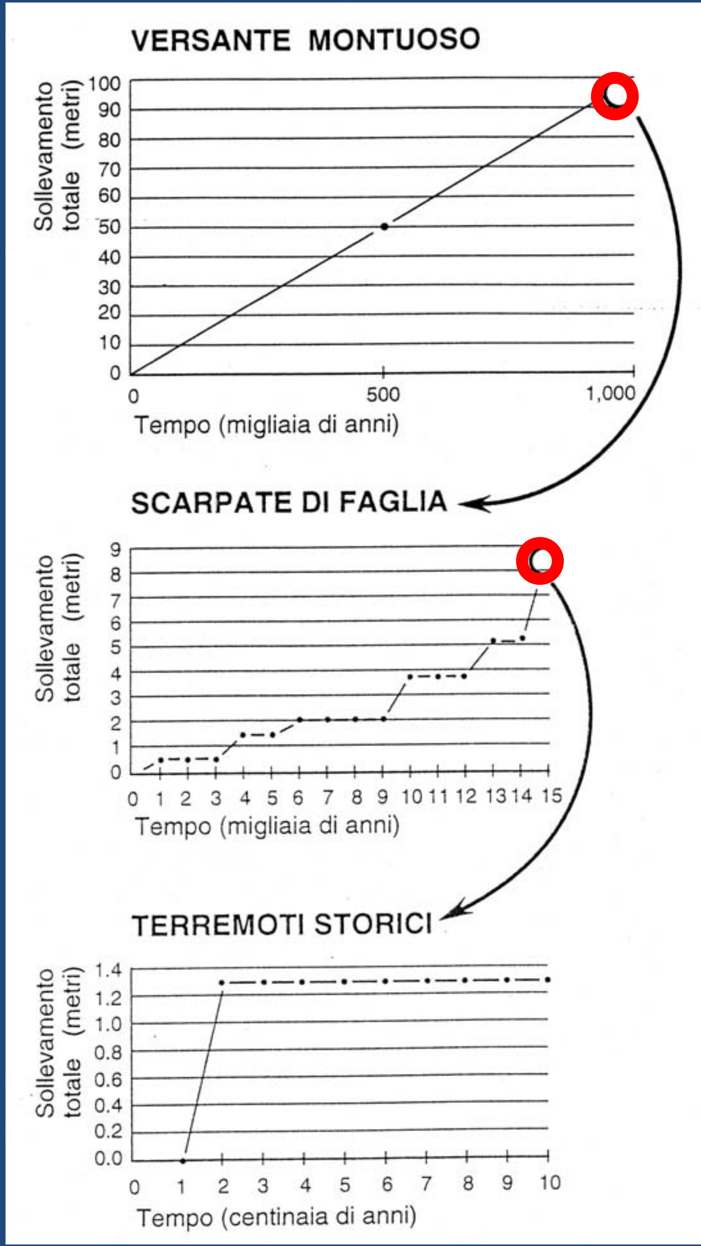
Landforms resulting by repeated surface faulting events over a geological time interval



LANDSCAPE MODIFICATION

SEVERAL EARTHQUAKES

ONE EARTHQUAKE



FROM THE SEISMIC LANDSCAPE

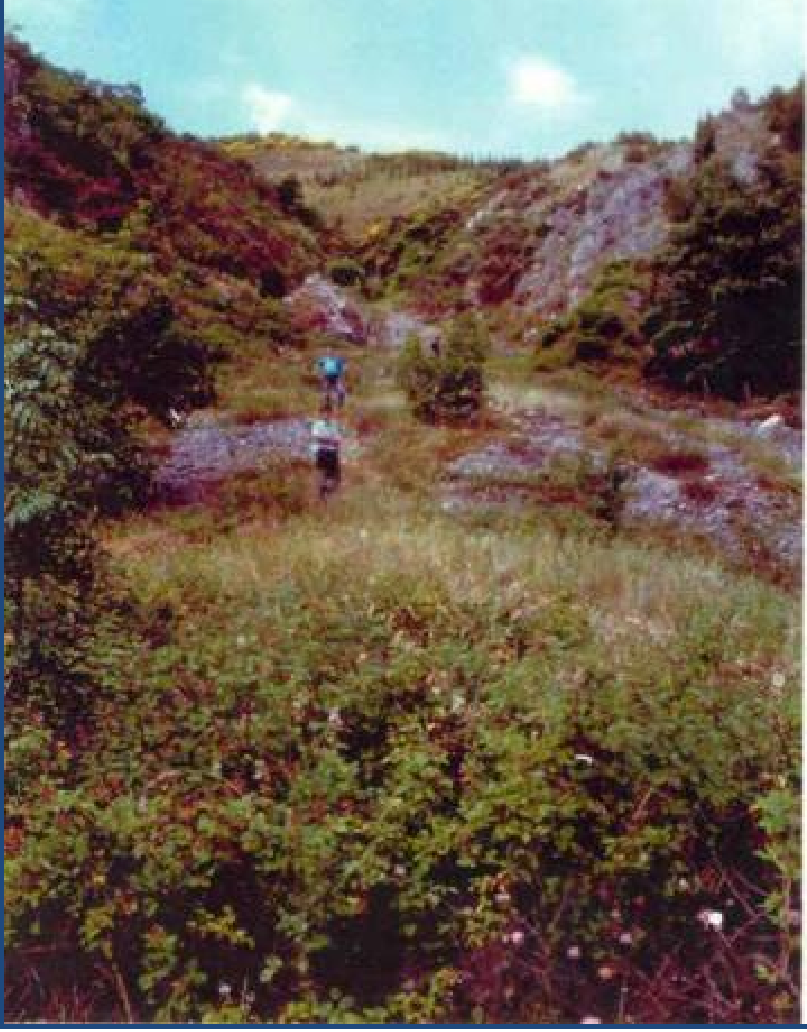
TO THE EARTHQUAKES

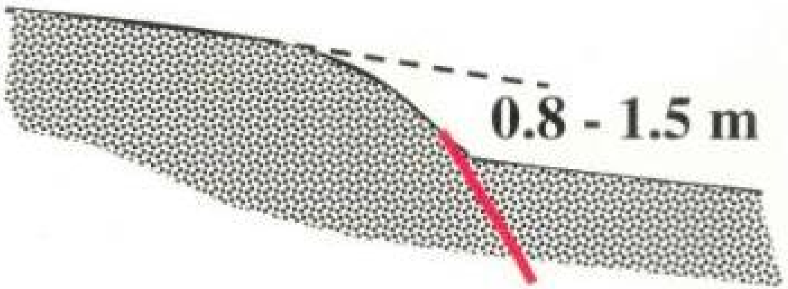
after Mayer, 1986, modified

Historical slip – rates in the Bojano basin

Historical surface faulting (1 or 2 events)

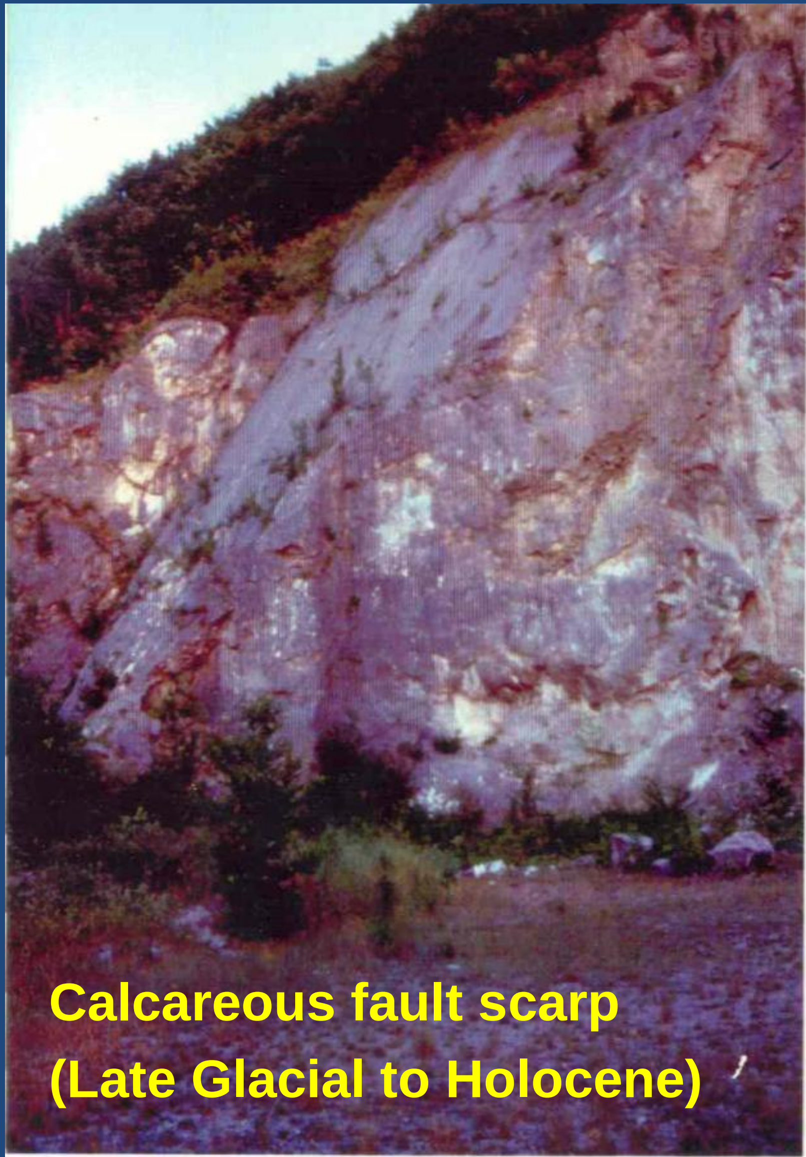
10^2 years

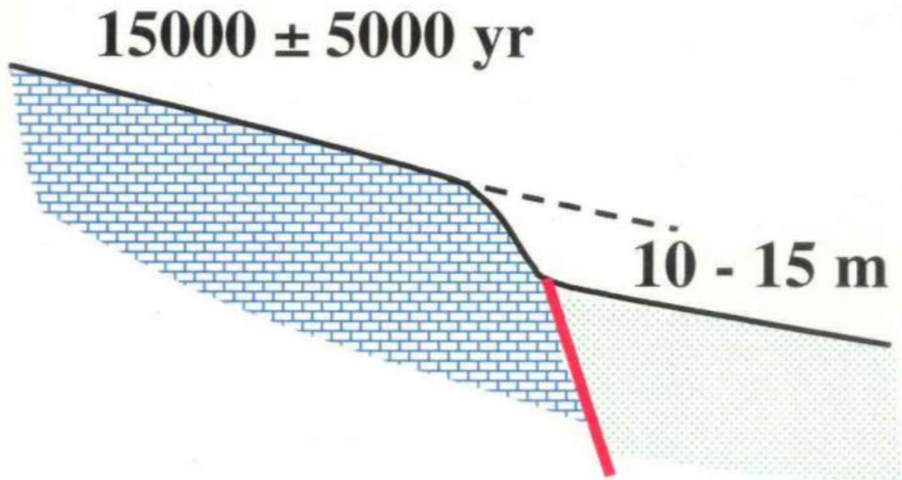




Uno o due terremoti storici
(Guerrieri, 1999)

Late Glacial to Holocene slip – rates in the Bojano basin



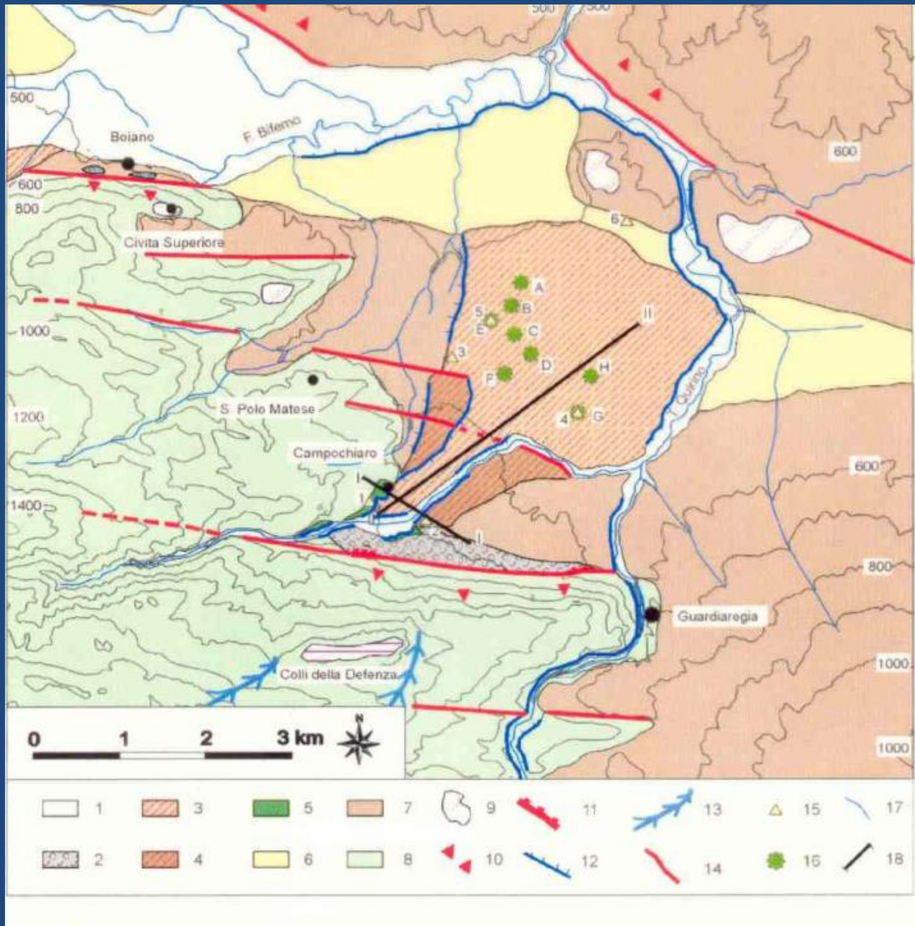


0.5 - 1.5 mm/anno

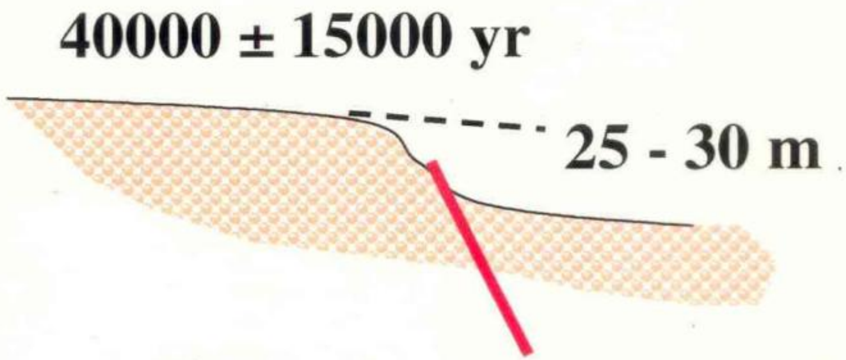
(Guerrieri, 1999)

10^4 yrs

Upper Pleistocene - Holocene slip – rates in the Bojano basin



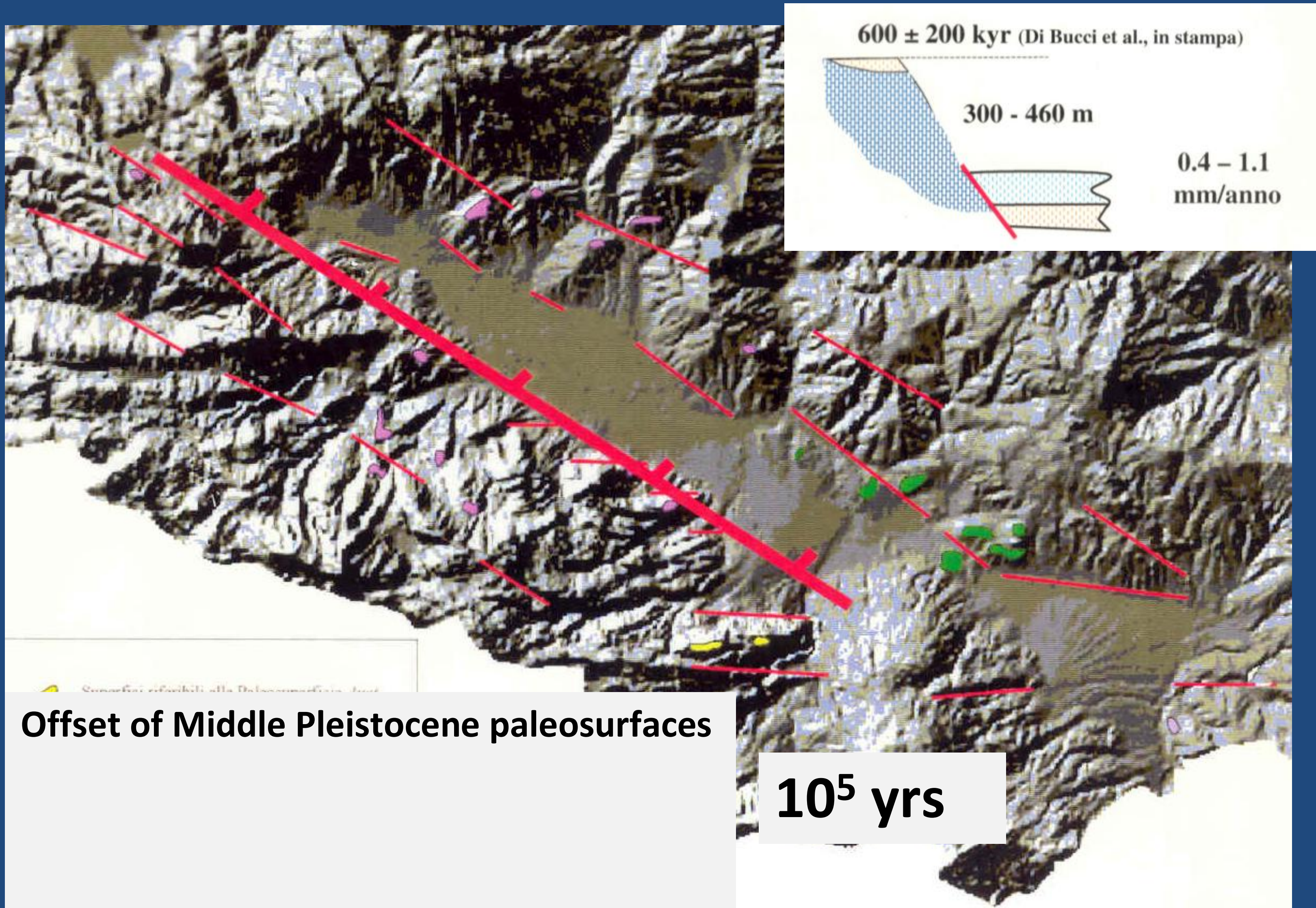
Offset along the Campochiaro alluvial fan (Upper Pleistocene)



0.4 -1.2 mm/anno
(Guerrieri, 1999)

10^4 yrs

Middle Pleistocene - Holocene slip – rates in the Bojano basin



Offset of Middle Pleistocene paleosurfaces

10^5 yrs

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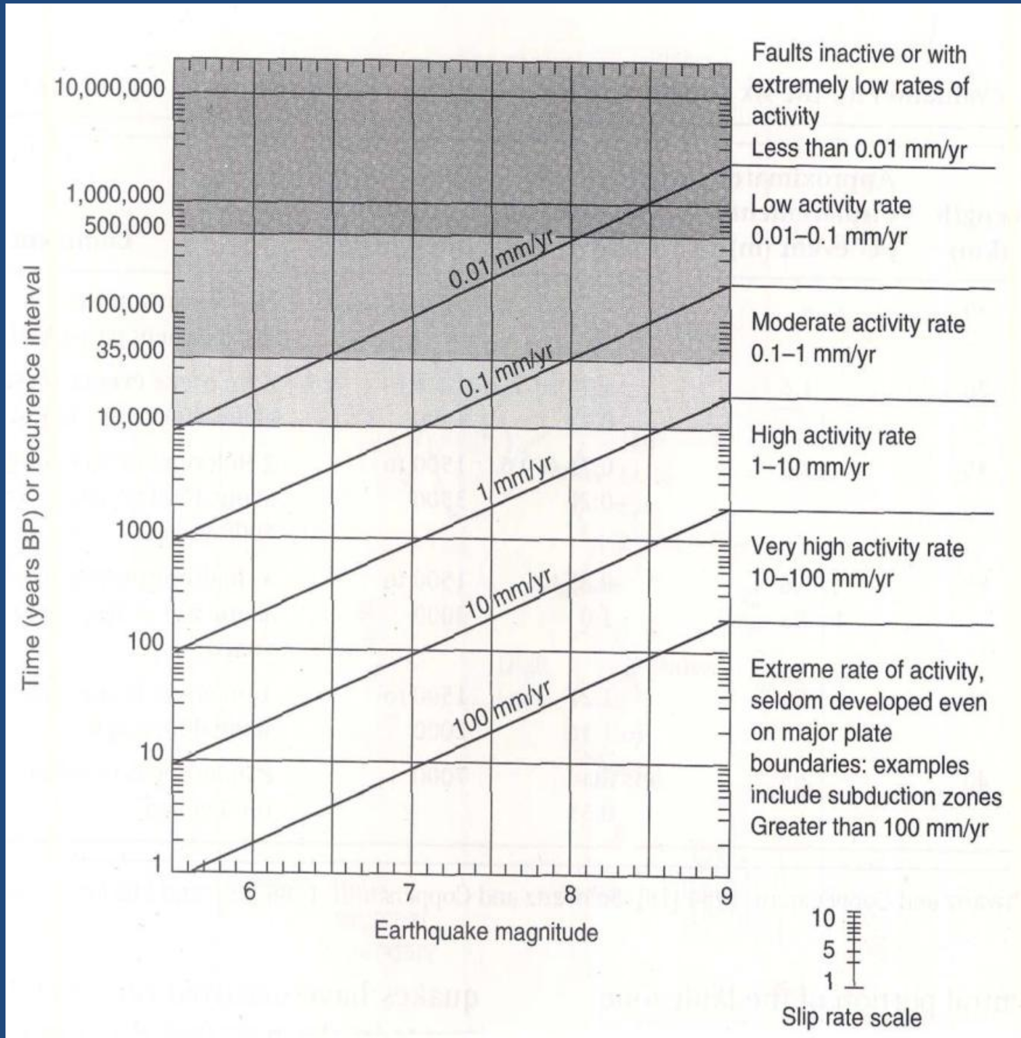
Slip rates, recurrence interval and magnitude

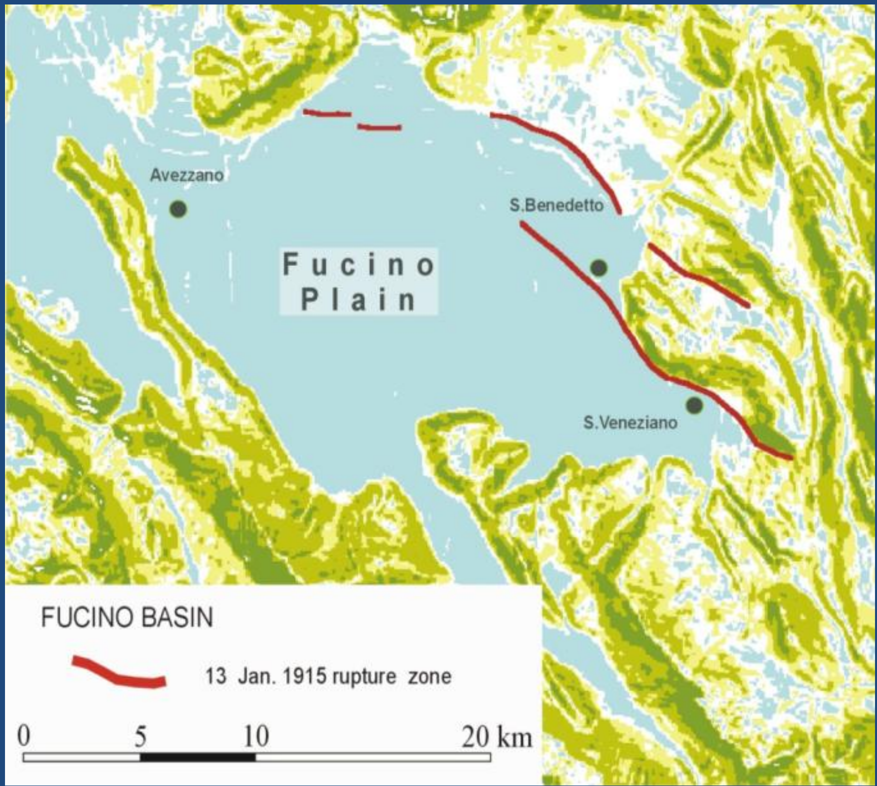


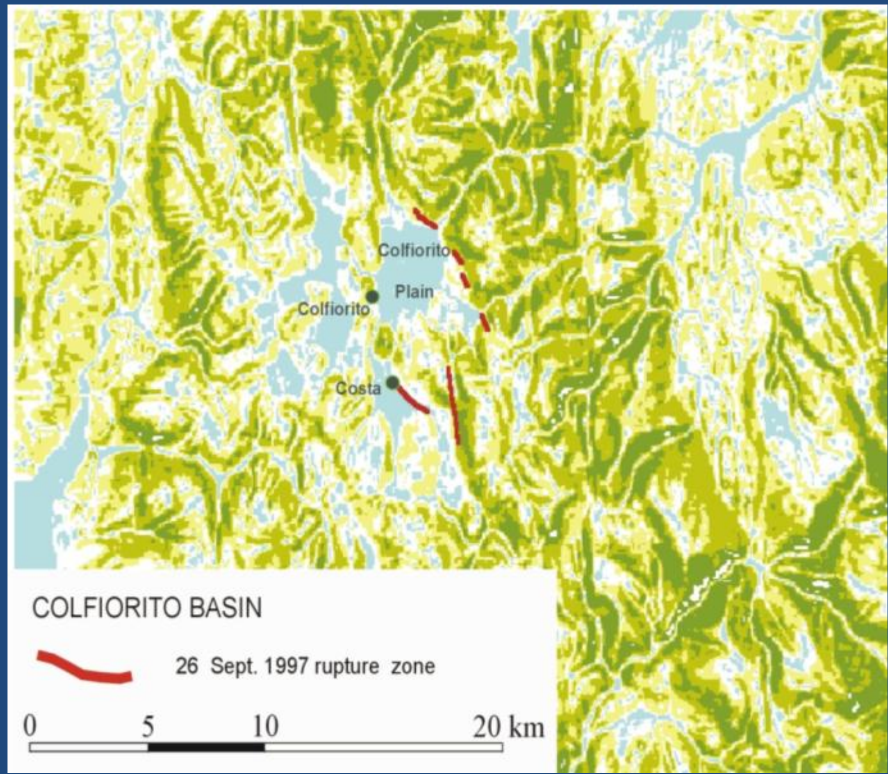
Slemmons & de Polo (1986)

Comparison between Fucino and Colfiorito basins

MAXIMUM DISPLACEMENT

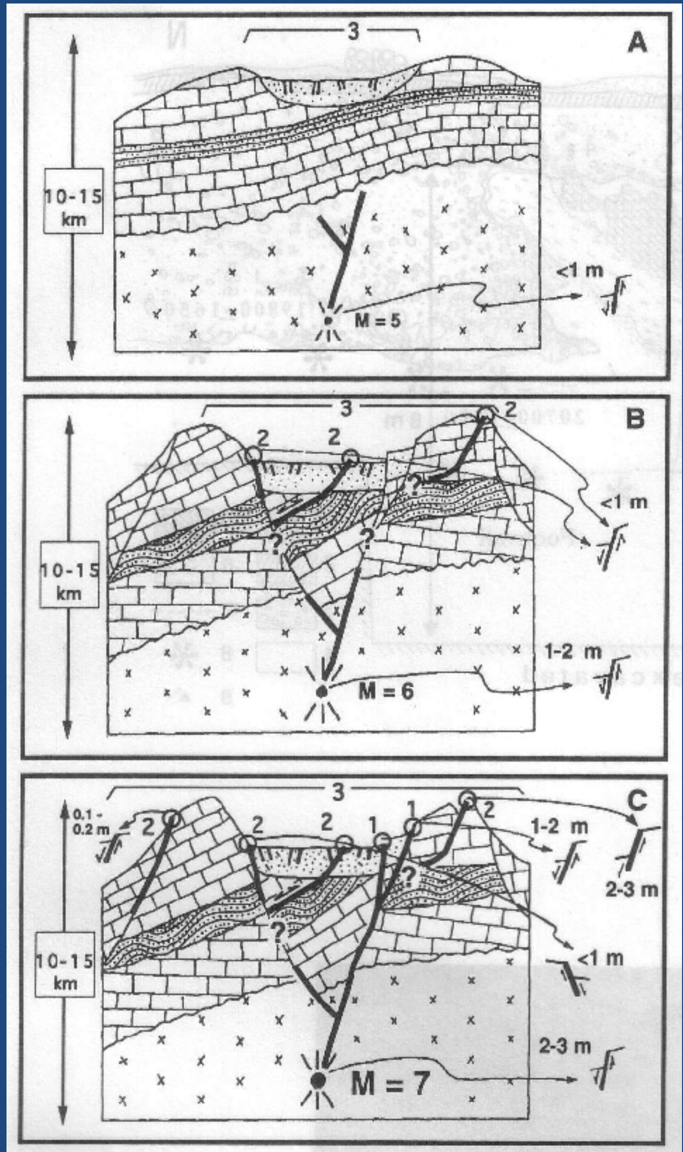
Comparison between Fucino and Colfiorito basins





RUPTURE ZONE – SIZE OF THE BASINS

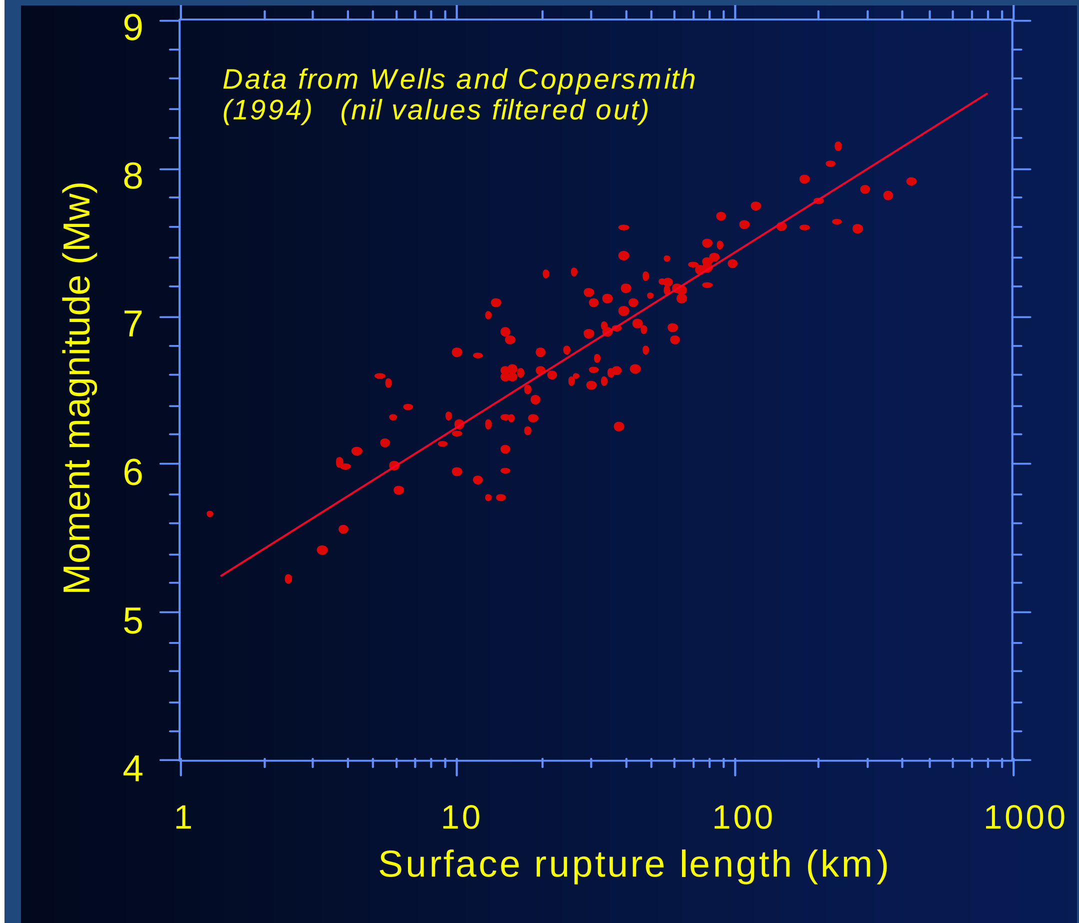
Seismic landscapes in the Apennines



Type B - Colfiorito

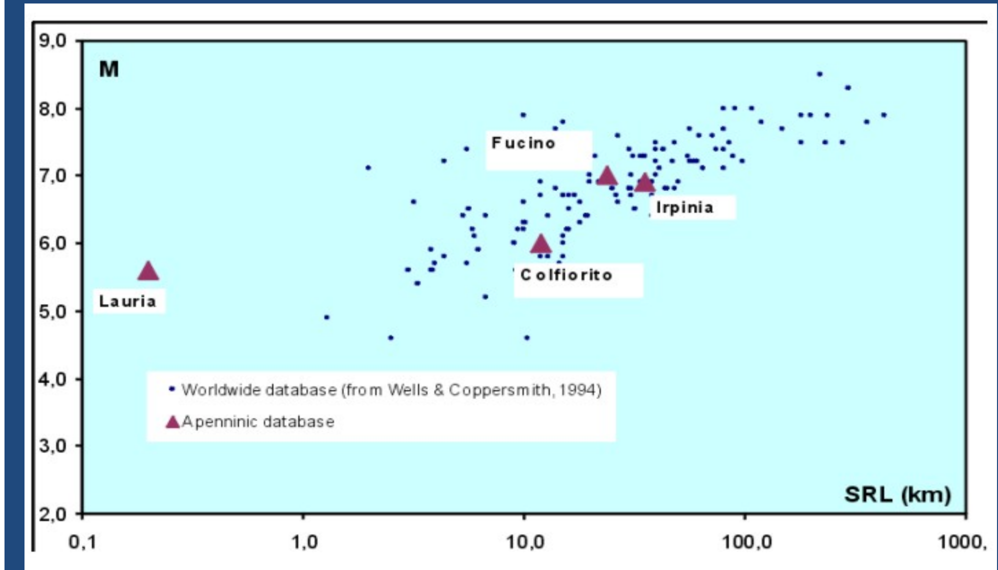
Type C - Fucino

Relationships between surface faulting and magnitude



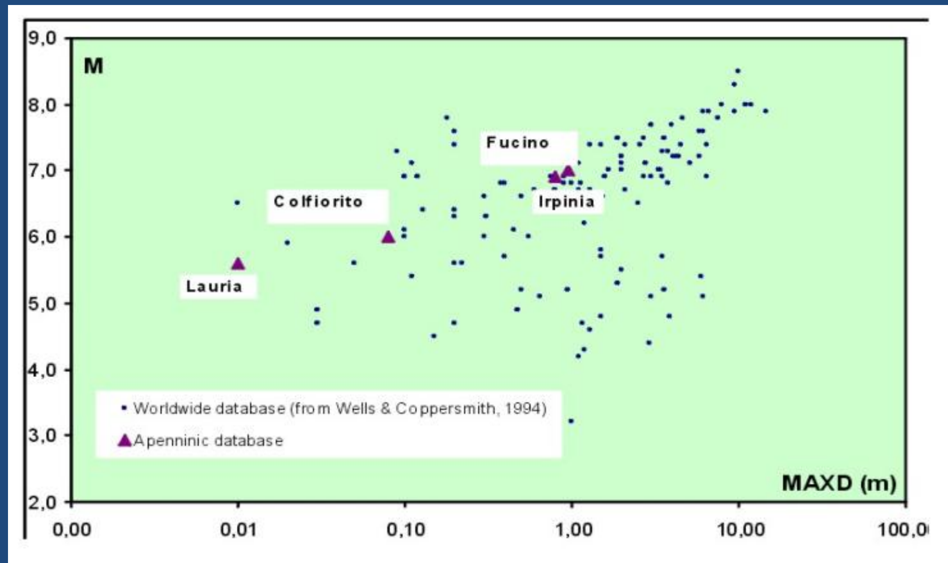
Magnitude	Surface rupture (km)	Average deformation (cm)
9.00	800	800
8.00	250	500
7.00	50	100
6.00	10	20
5.00	3	5
4.00	1	2

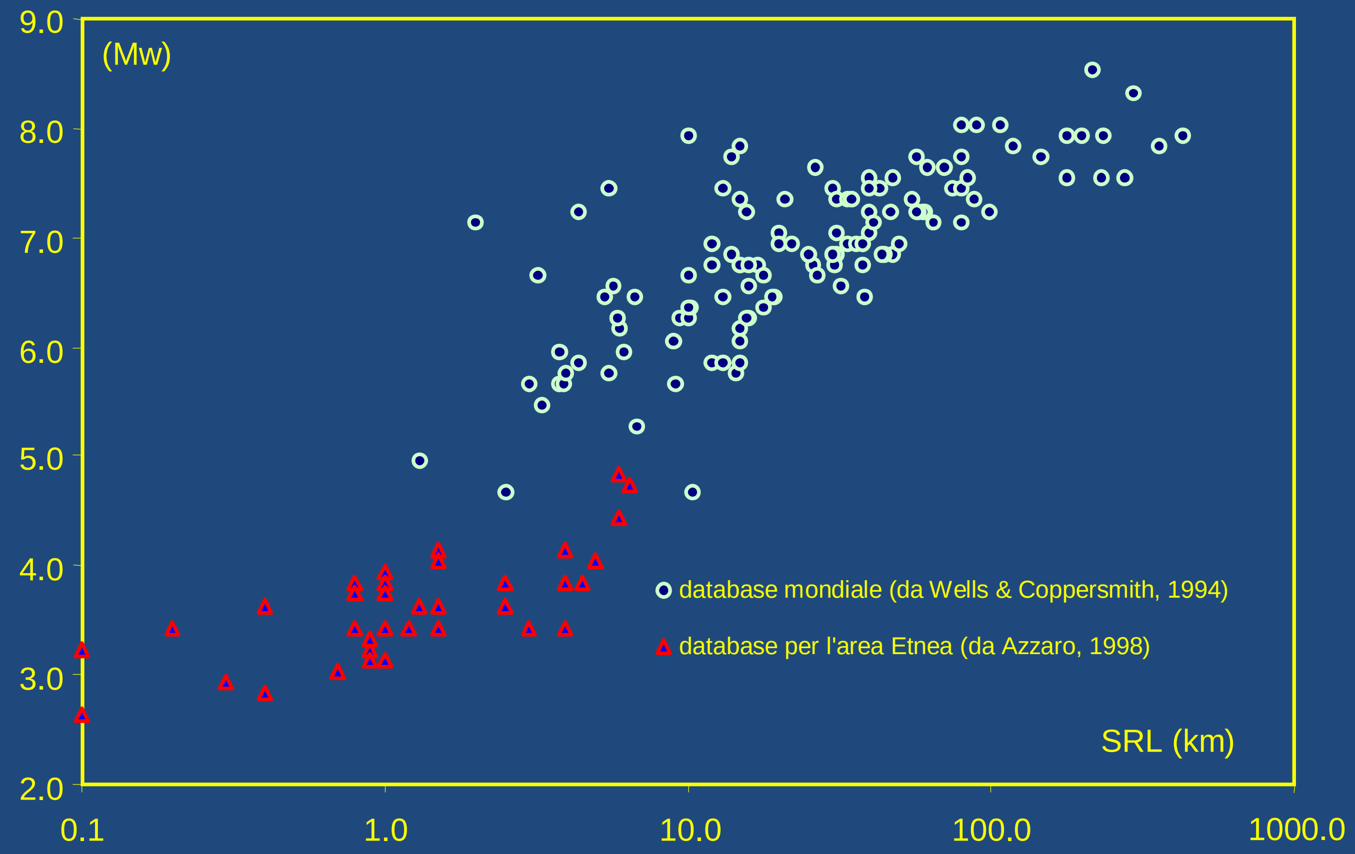
Relationships between surface faulting and magnitude



Surface Rupture Length - Magnitude

Maximum Displacement - Magnitude





Earthquakes in a volcano-tectonic environment (Eastern Sicily)

Relationships between surface faulting and magnitude

Magnitude	
magnitudo 1	Active faults without surface faulting
magnitudo 2	
magnitudo 3	
magnitudo 4	
magnitudo 5	Minimum threshold for the occurrence of surface faulting
magnitudo 6	Surface faulting parameters are proportional to the magnitude
magnitudo 7	
magnitudo 8	

- Rupture length
- Maximum displacement per event
- Average slip rates