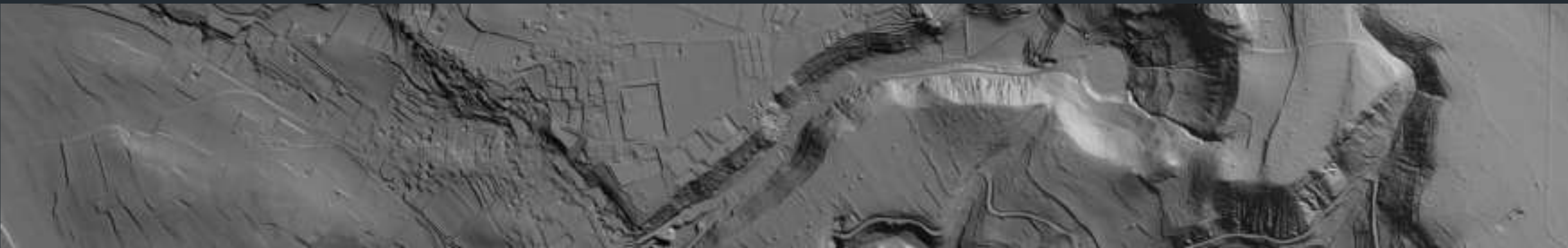


A little about me…and my institution…

I am a geologist, currently working as a Post-Doc at Istituto Nazionale di Geofisica e Vulcanologia (INGV), within the Active Tectonics and Paleoseismology group (Leaded by Daniela Pantosti).

Fields of interest:

- active tectonics
- identification and characterization of seismogenic faults
- geology of earthquake
- tectonic geomorphology
- paleoseismology
- post-earthquake geological surveys
- …and LiDAR!!!

INGV – Istituto Nazionale di Geofisica e Vulcanologia

The National Institute for Geophysics and Volcanology is a scientific institution of the Italian Government, dealing with research in Geophysics and Volcanology and with responsibilities within the Italian Civil Protection system.

INGV employs around 1000 people in Rome and in regional offices in Milano, Bologna, Pisa, Napoli, Catania and Palermo.

Besides research, the mission of INGV is 24-hour countrywide seismic and volcanic monitoring as well as the development of geophysical observations in solid and fluid Earth.

Other activities:

- Post-earthquake geological surveys
- Early warning and forecast
- Education and Outreach

Founding:

- Italian Ministry of Education, University and Research
- Italian Civil Protection
- Europe Union research projects

Post-earthquake geological surveys

EMERGEO

INGV geological survey team,
usually after M> 5.5 earthquakes

2009 L'Aquila earthquake

2012 Emilia seismic sequence

2012 Emilia seismic sequence

Post-earthquake geological surveys

Did You see earthquake geological effects?

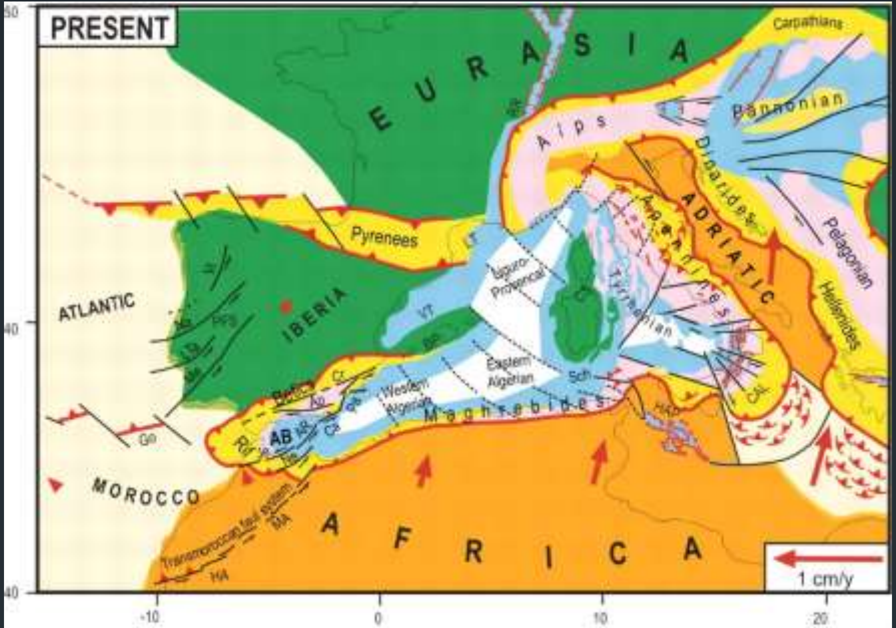
EMERGEO

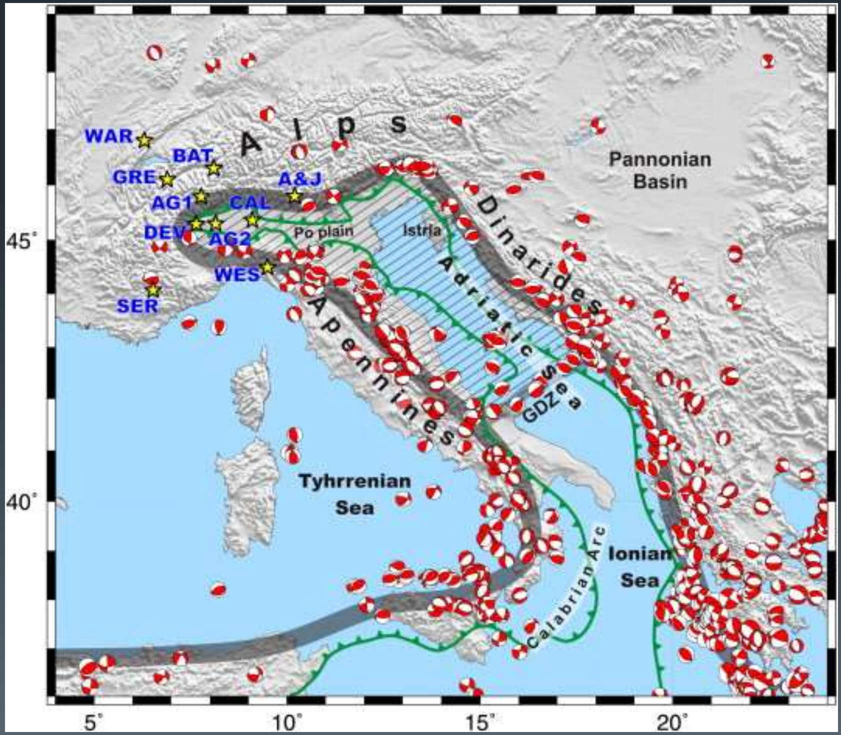
WebGIS

Ongoing projects

- **A)** High-resolution investigations for the estimate of seismic hazard and risk in the area struck by the April 6, 2009 L'Aquila earthquake (Central Italy)
- **B)** Detailed geomorphological analysis of the 2012 Emilia earthquakes epicentral area and liquefactions

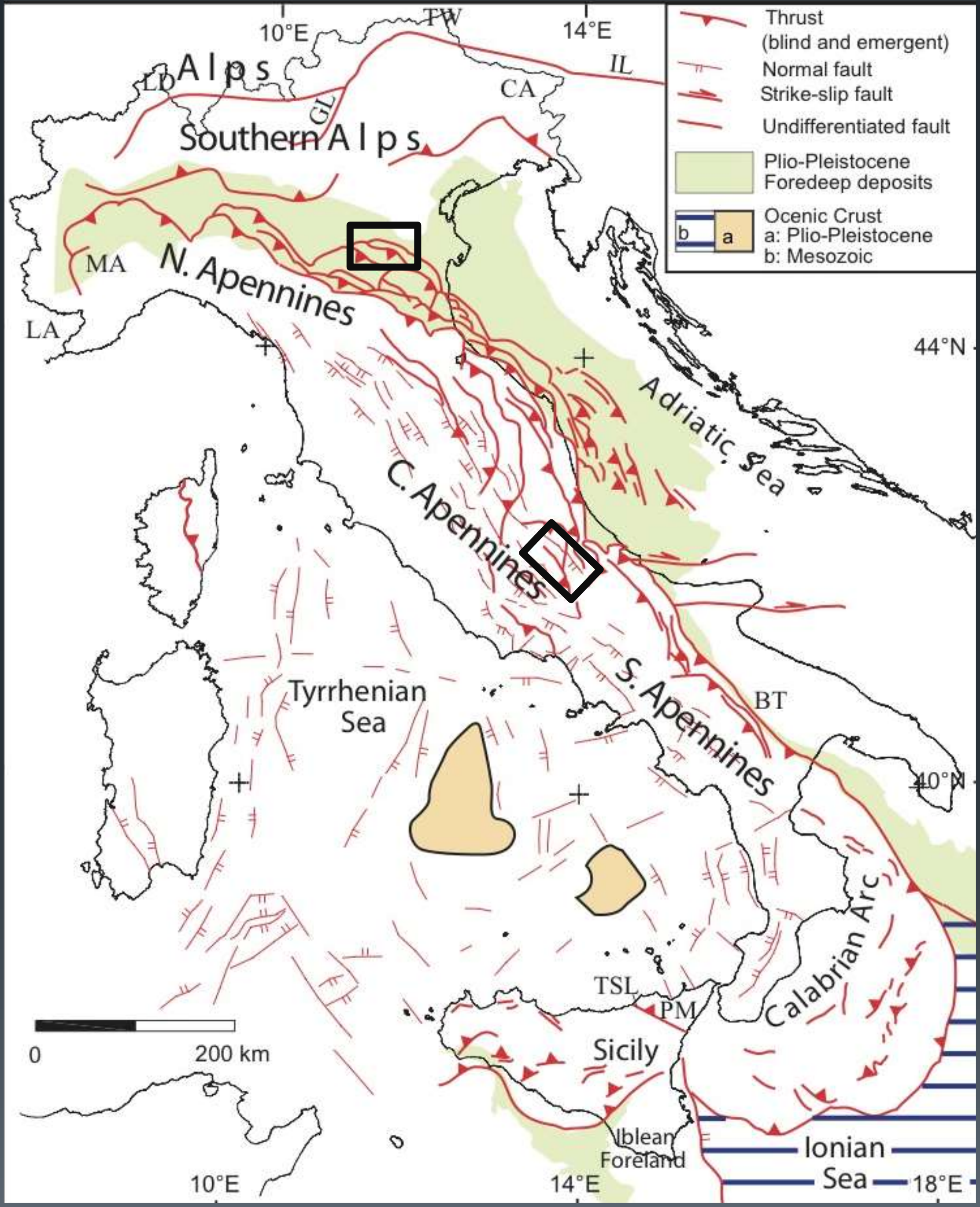
Simplified seismotectonic framework





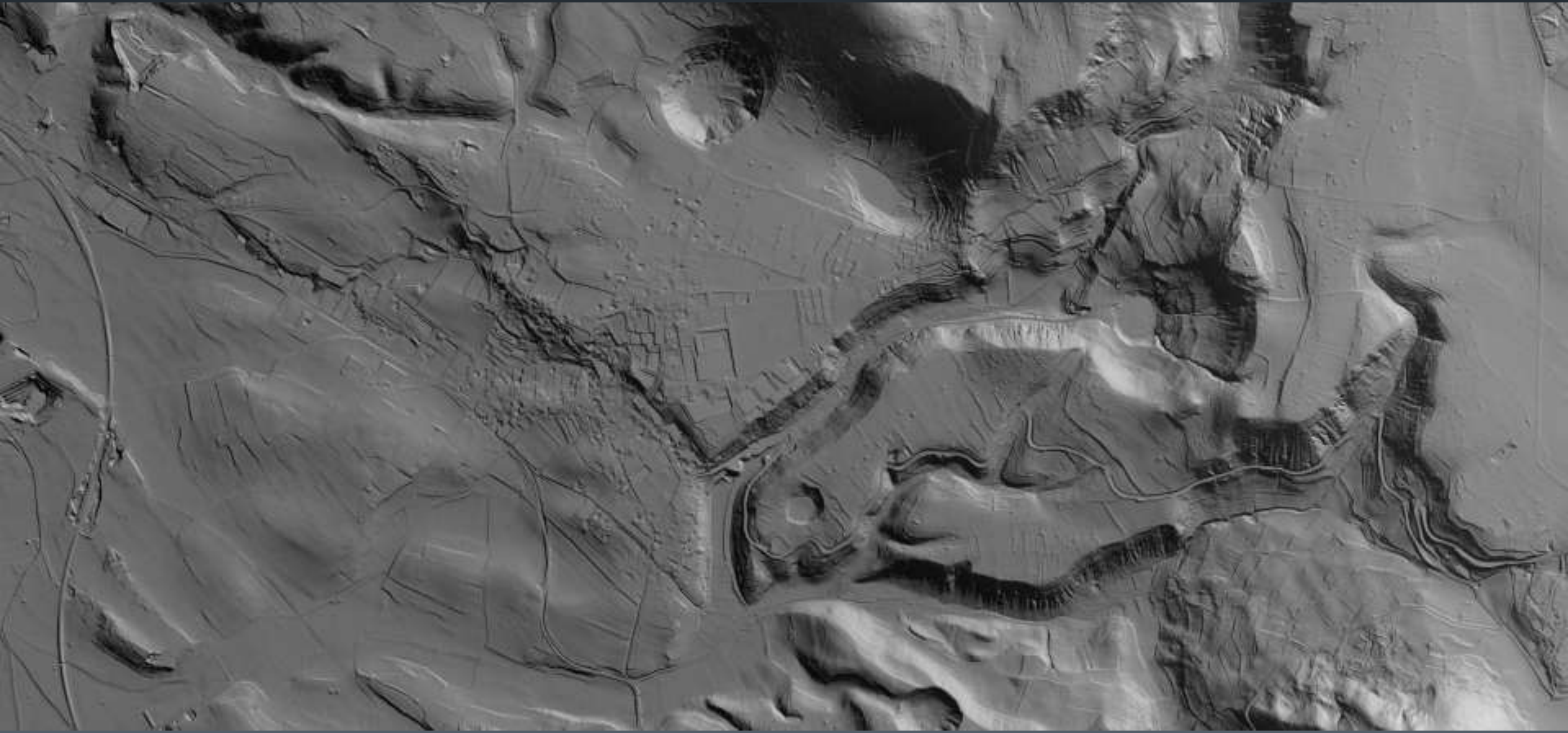
Weber et al., 2010

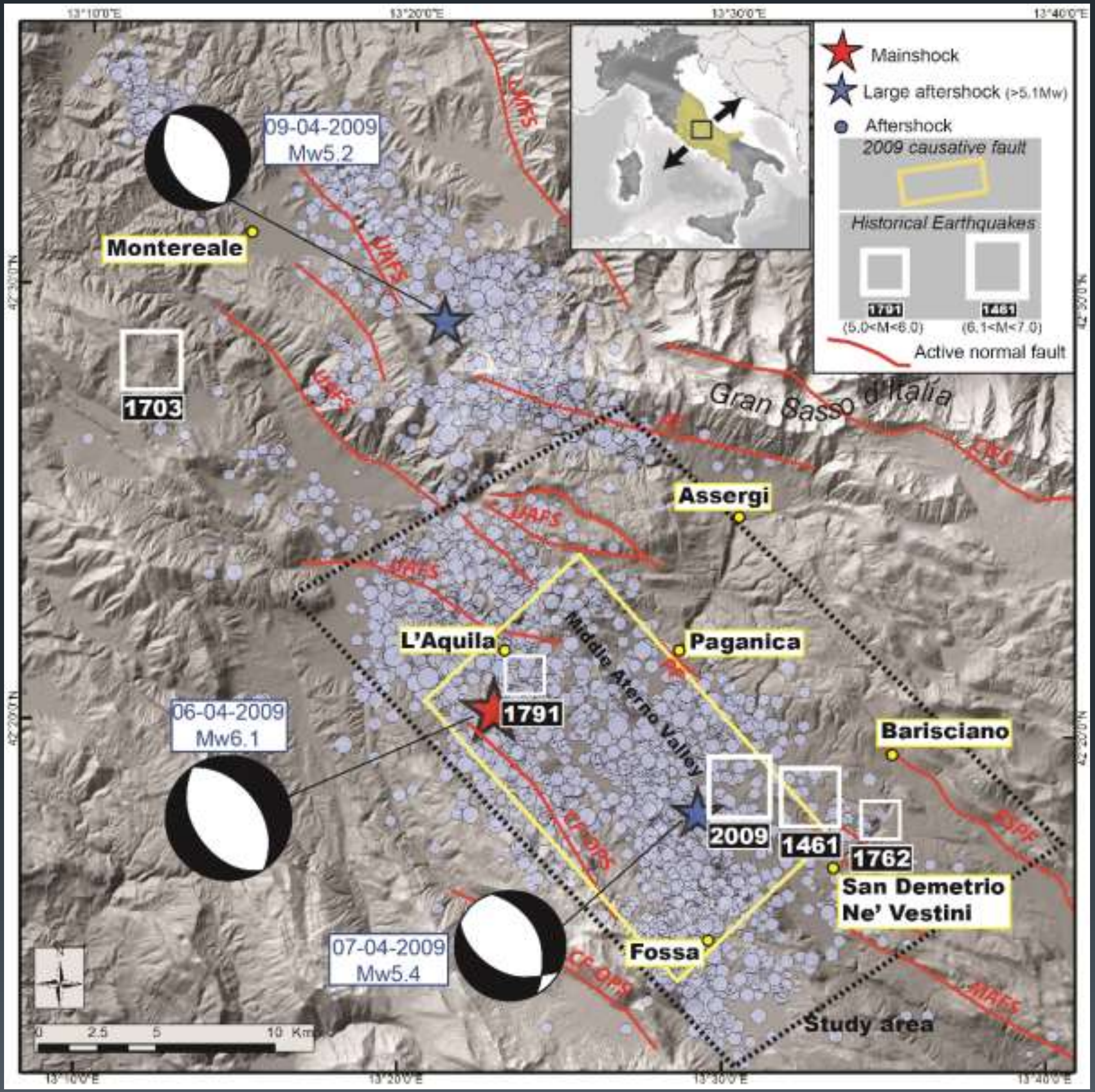
Simplified seismotectonic framework



Morphotectonic analysis of the long-term surface expression of the Paganica – San Demetrio Fault System (2009 L'Aquila earthquake, Central Italy)

RICCARDO CIVICO (*), STEFANO PUCCI (*), DANIELA PANTOSTI (*) & PAOLO MARCO DE MARTINI (*)
* Istituto Nazionale di Geofisica e Vulcanologia

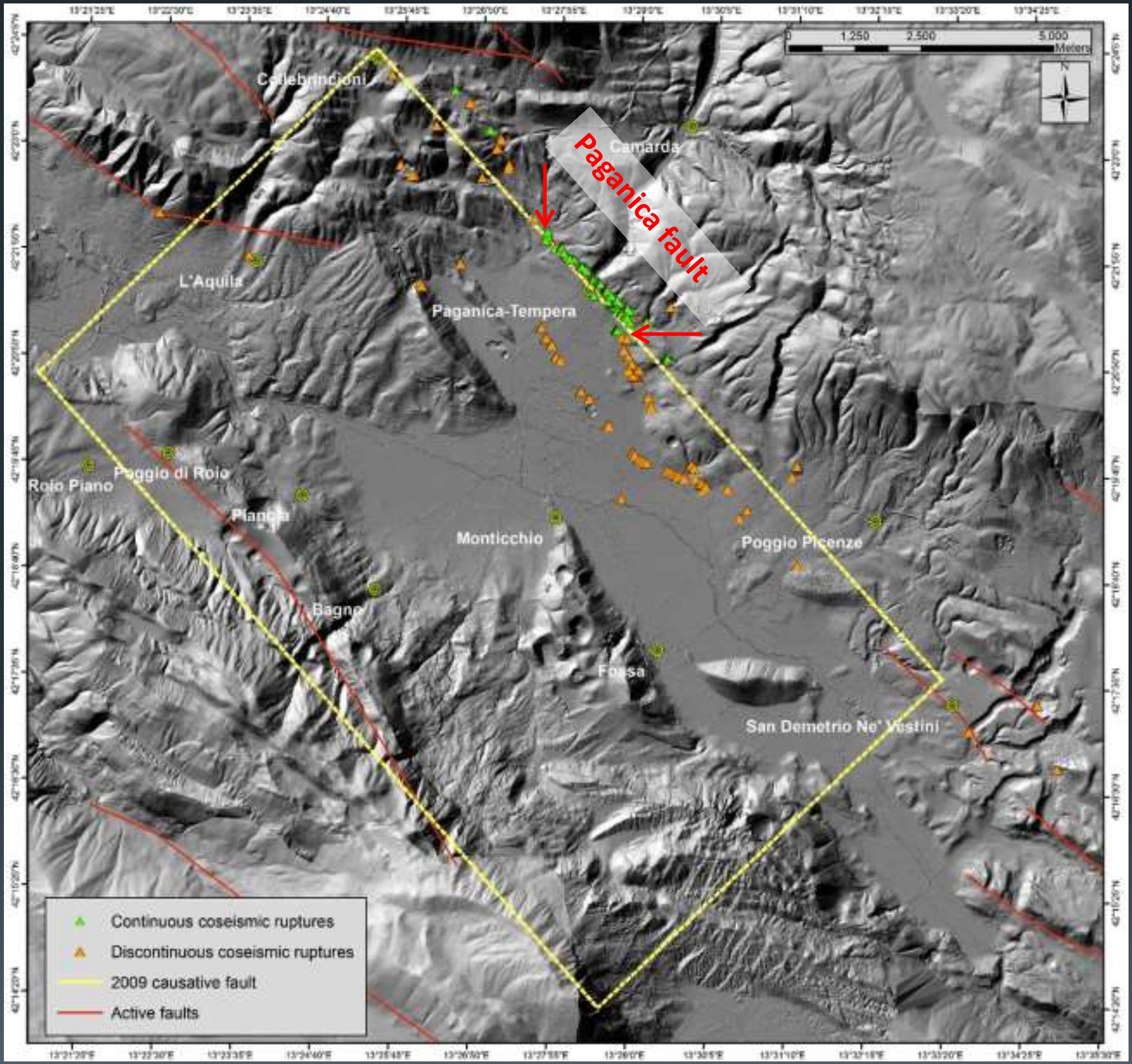




The 2009 L'Aquila seismic sequence, historical seismicity and active faults

- On April 6, 2009 (01:32 UTC – 03:32 Italian time), a Mw 6.1 earthquake struck a densely populated area in the Abruzzi Apennines and was felt in a wide area of central Italy
- Seismological and geodetic data depict a 12 to 18 km-long, NW-SE oriented, SW-dipping causative fault at depth, located to the east of the Middle Aterno valley

Coseismic ruptures



Distribution of the 2009 coseismic surface ruptures along the eastern side of the Middle Aterno valley

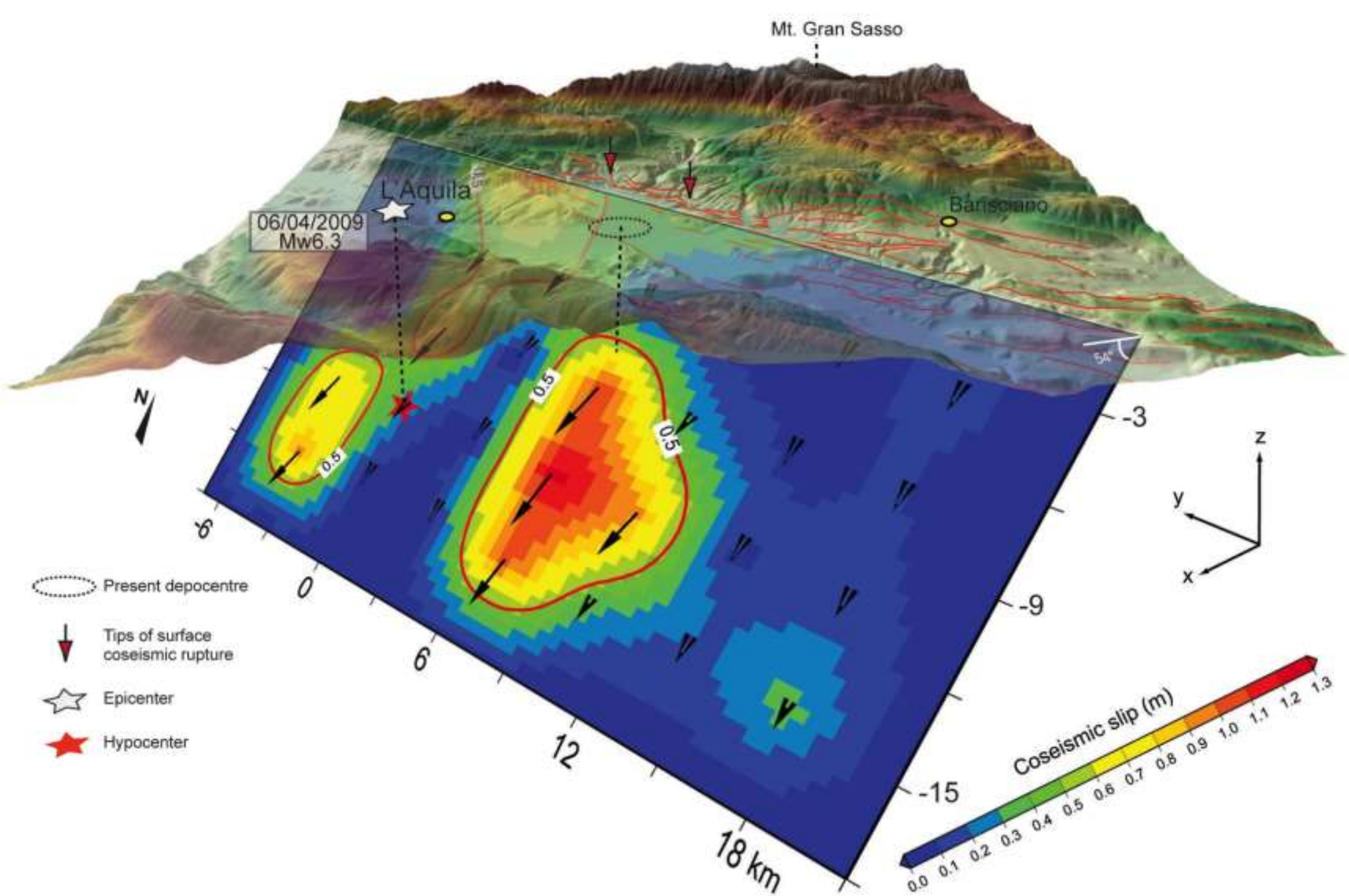
- Coseismic surface ruptures occurred along prominent pre-existing fault scarps and along secondary fault splays located in the eastern sector of the Middle Aterno Valley
- Continuous surface faulting (~3 km-long with maximum throw of 0.15m) was observed along the NW-SE trending, SW-dipping Paganica fault

Main characteristics of the surface ruptures

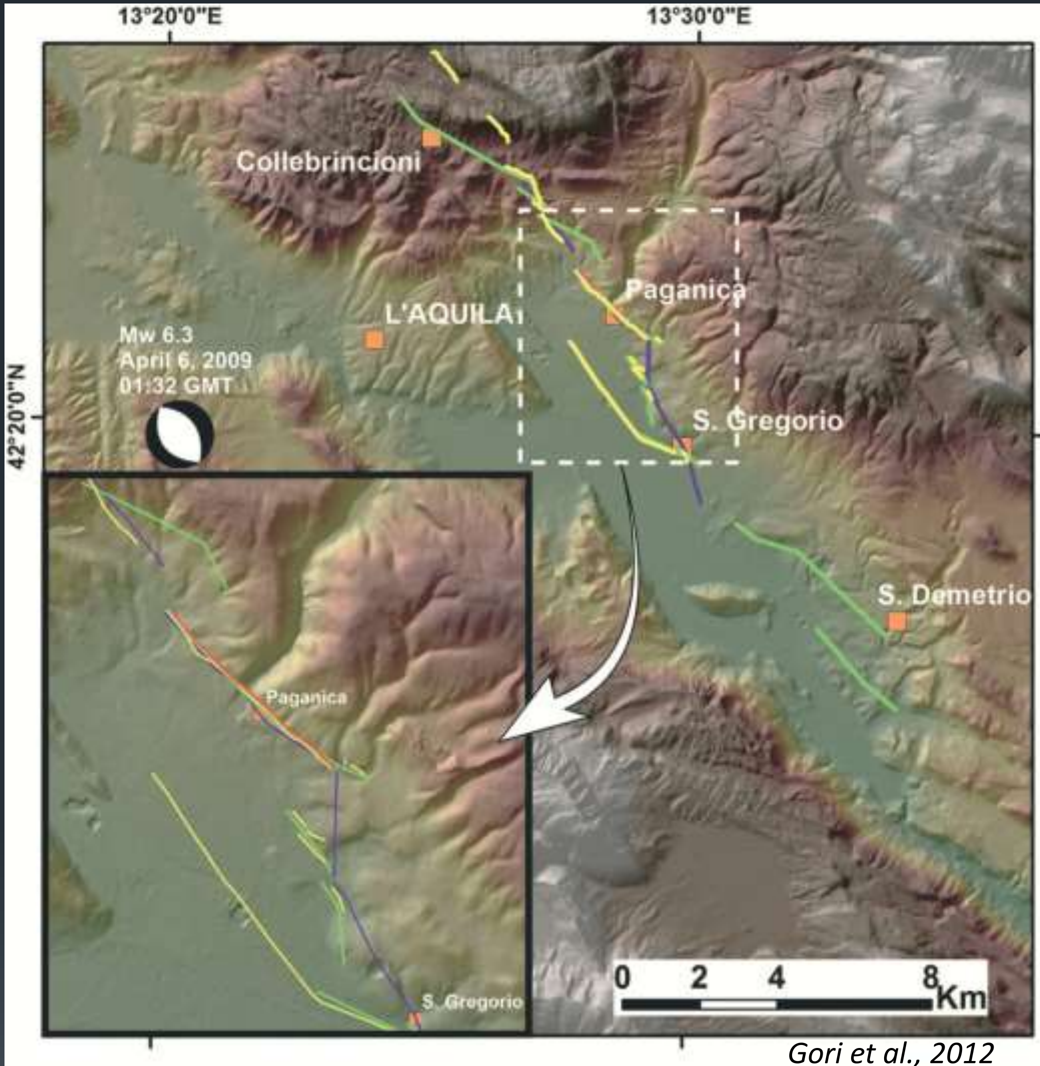
- mostly open cracks (av. 10 cm)
- slight vertical dislocations or warps (max 15 cm) SW-side down
- persistent orientation of N130°-N140°
- commonly organized in en-echelon arrangement
- occur regardless of slope angle, the type of deposits crossed, or the type of manmade feature

Photos by EMERGEO WG, 2009

Slip distribution



Slip distribution after Cirella et al., 2009



Falcucci et al., 2009

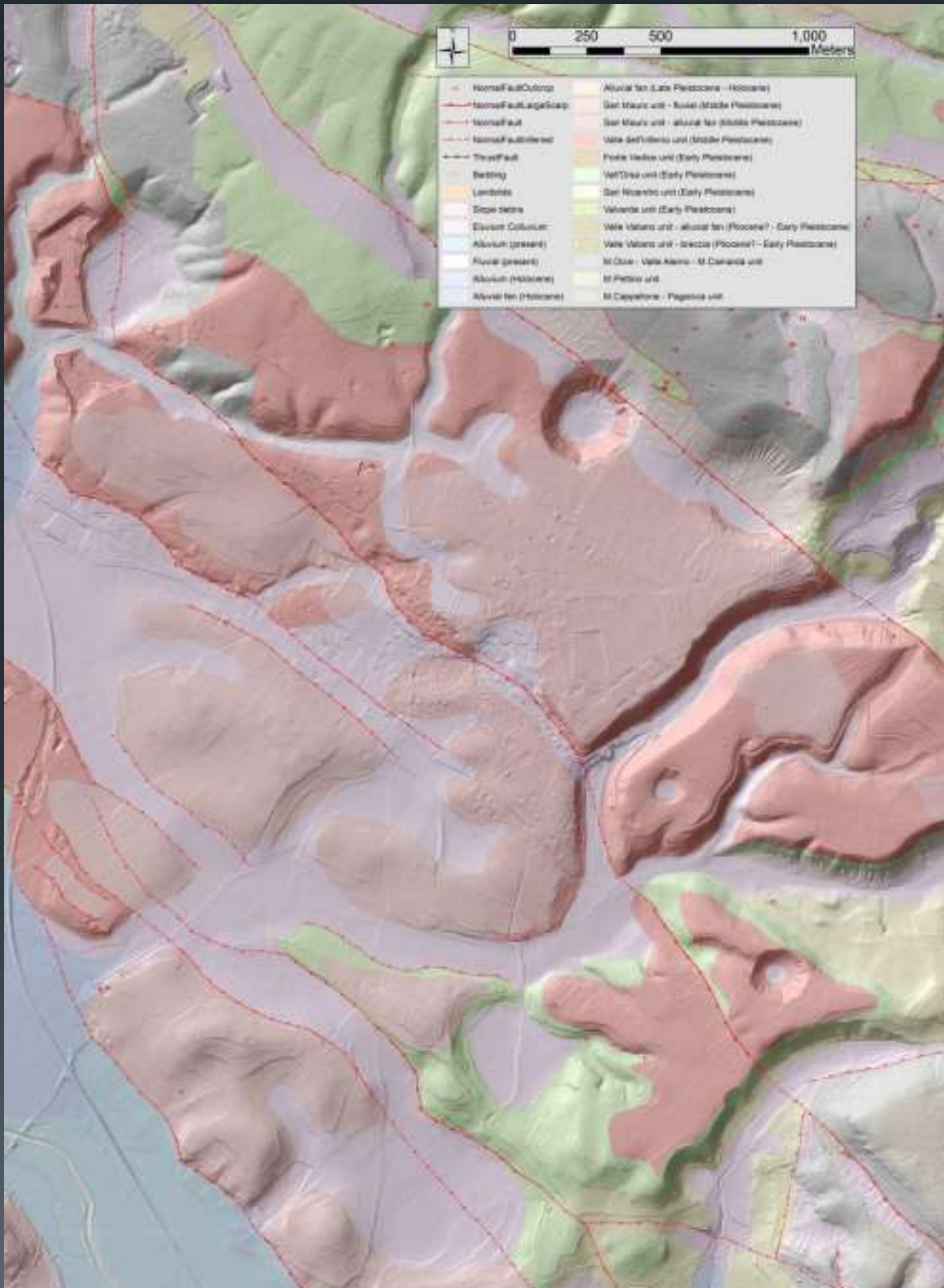
Boncio et al., 2010

Emergeo WG, 2010
Vittori et al., 2011

Galli et al., 2012

Different interpretation of the coseismic discountinuous ruptures

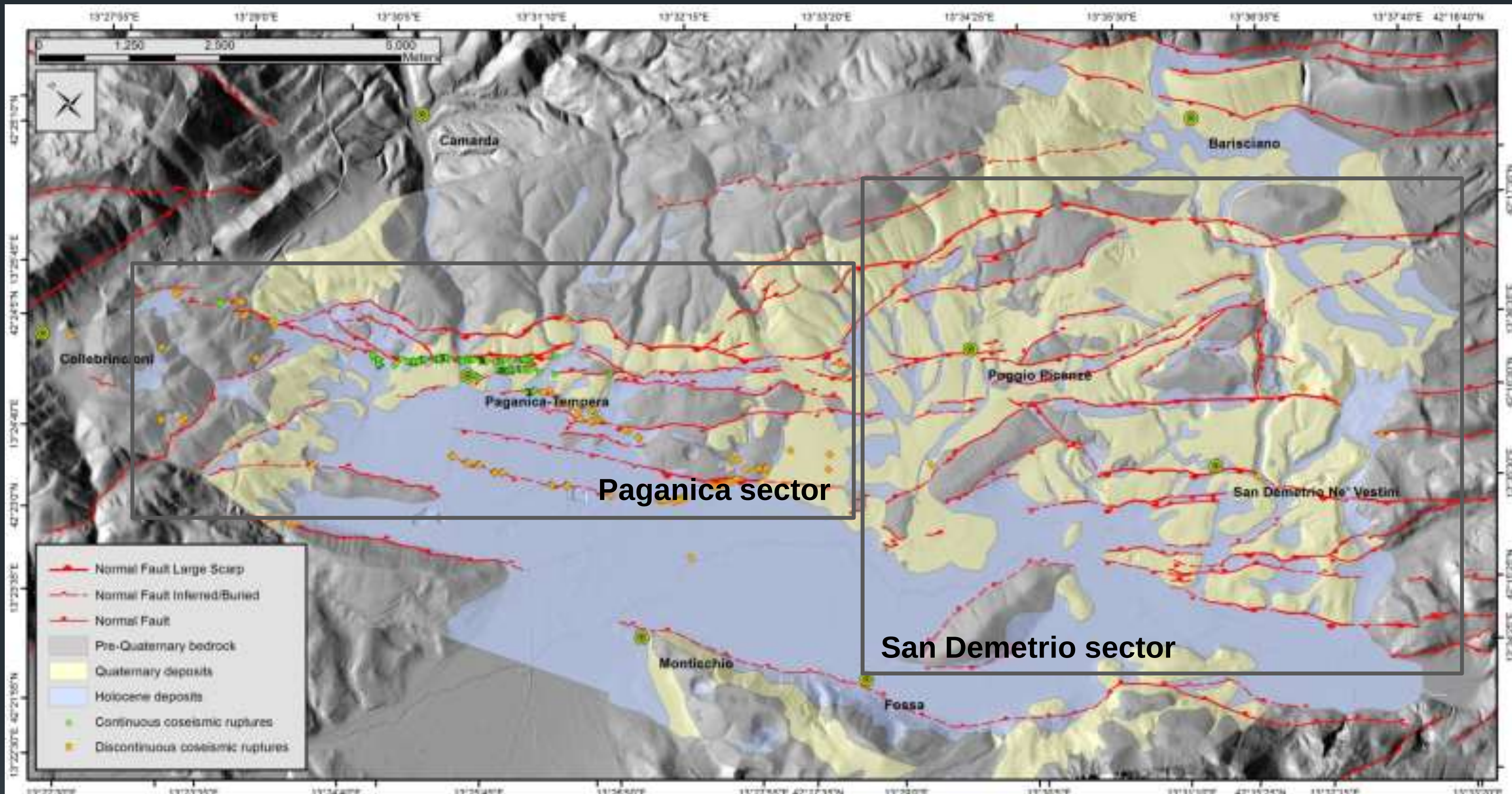
- Estimated surface faulting total length between 3 and 19 km
- The extent of the long-term morphological expression of the earthquake causative fault and of the modeled seismologic/geodetic coseismic fault contrasts with the observed primary coseismic surface ruptures, both in terms of size and location
- This discrepancy has open a debate about the maximum length of rupture within this fault system
- Is the 2009 earthquake a typical event for this fault system?



Mapping the fault system bounding the eastern flank of the Middle Aterno Valley

- Based on the availability of an airborne LiDAR survey performed in the area after the 2009 earthquake – first application in Italy with tectonic purposes
- Refinement of the fault system and Quaternary geology mapping
- Focus on the imaging of the long-term morphological expression of the fault system to highlight its geometrical arrangement at the surface (length, number of fault splays and boundaries) and to define a first-order hierarchy among the numerous fault splays

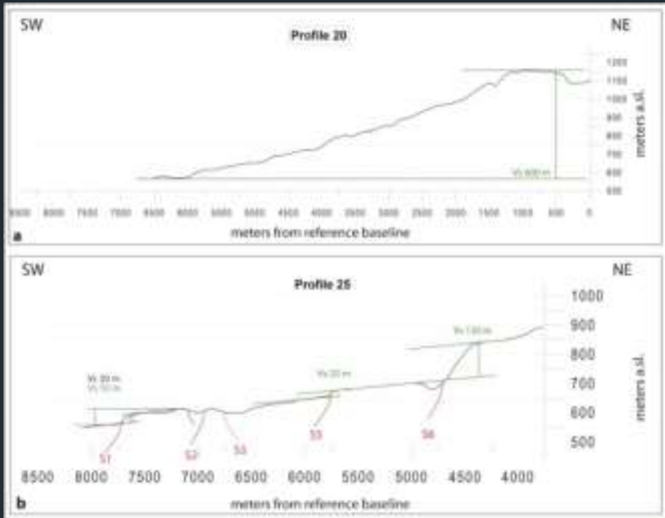
Geometrical arrangement of the Paganica - San Demetrio fault system at the surface



At the LiDAR resolution, it is noticeable a complex surface structural setting, with several normal parallel fault splays both synthetic and antithetic.
We can distinguish two main sectors of the fault system:

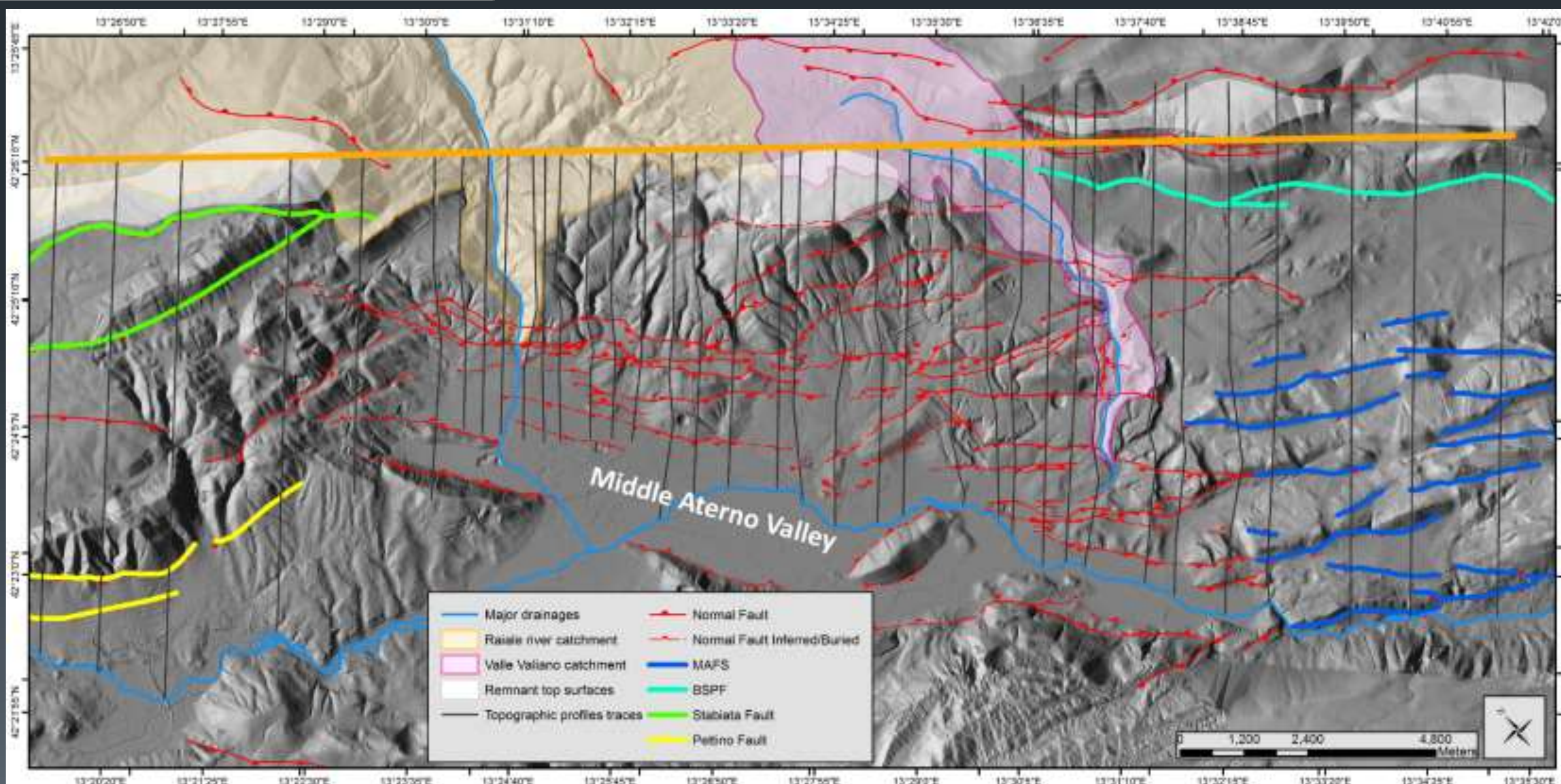
Paganica sector:
- narrow deformation zone (≤2 km wide)
- small Quaternary basin

San Demetrio sector:
- several tectonic structures, wider fault system (ca. 5 km)
- exhumation and dissection of a larger Quaternary basin

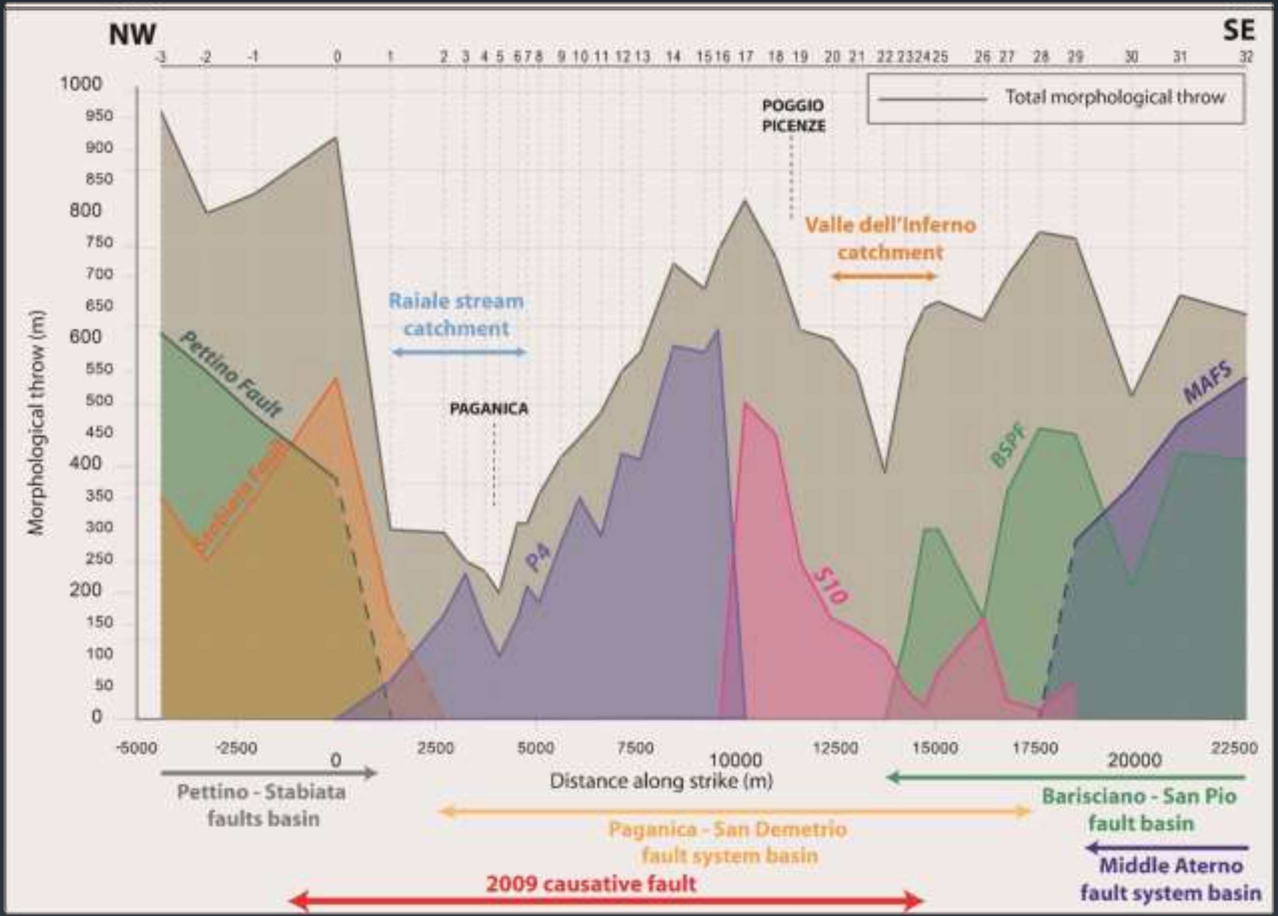


Along strike morphological throw

Cumulated fault throws have been measured by vertical offsets of topographic surfaces across individual fault splays as well as across the entire fault system

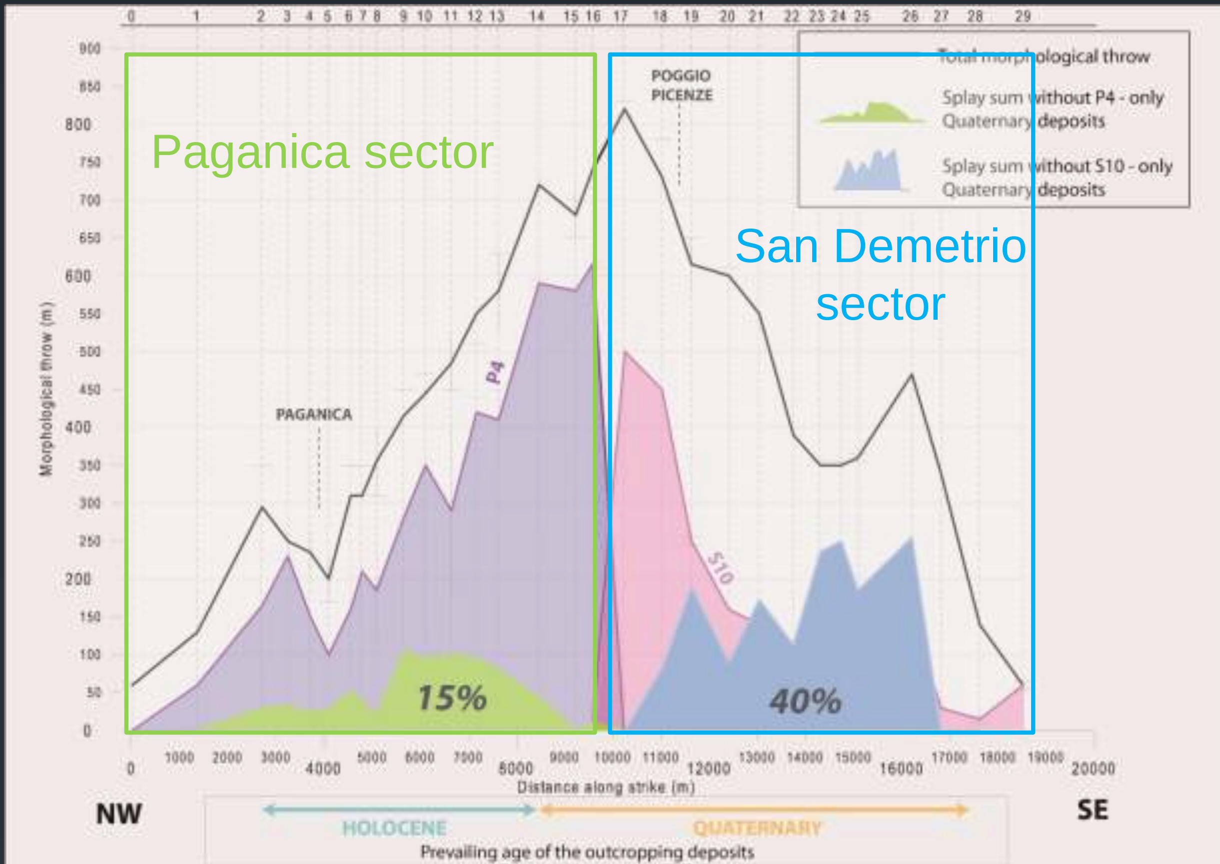


Along strike cumulative morphological throw distribution



- Morphological throw distribution along the main faults of the area showing a decrease of throw values in coincidence with the interaction zone between different fault segments and with major drainage incisions

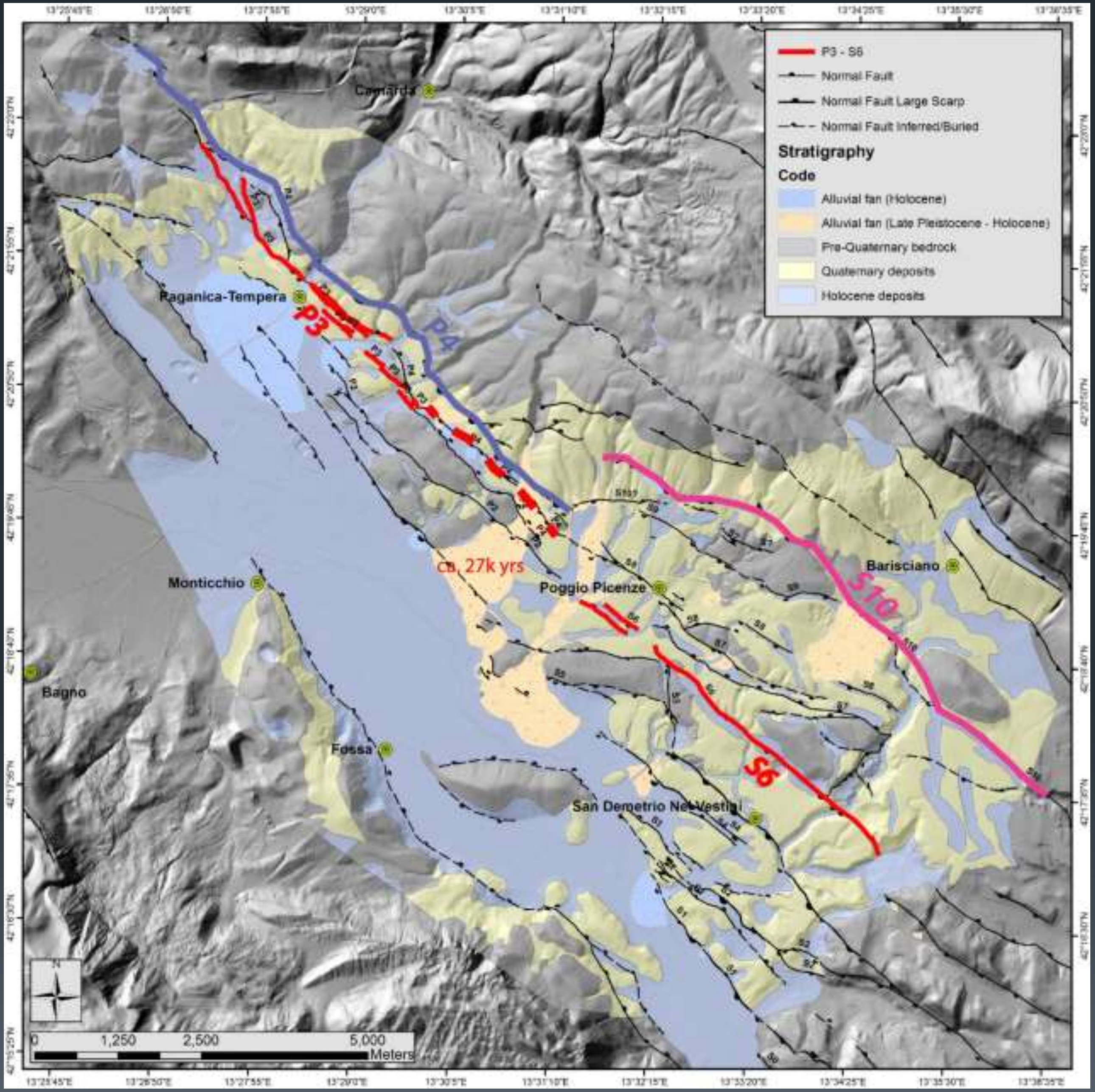
Along-strike plot of the morphological throws



Different amount of deformation related to the fault spalys displacing Quaternary deposits:

- Persistence of the deformation across a narrow fault zone (Paganica), allowing the development of a small Quaternary basin
- Distributed deformation (San Demetrio), resulting in the development of a wider Quaternary basin

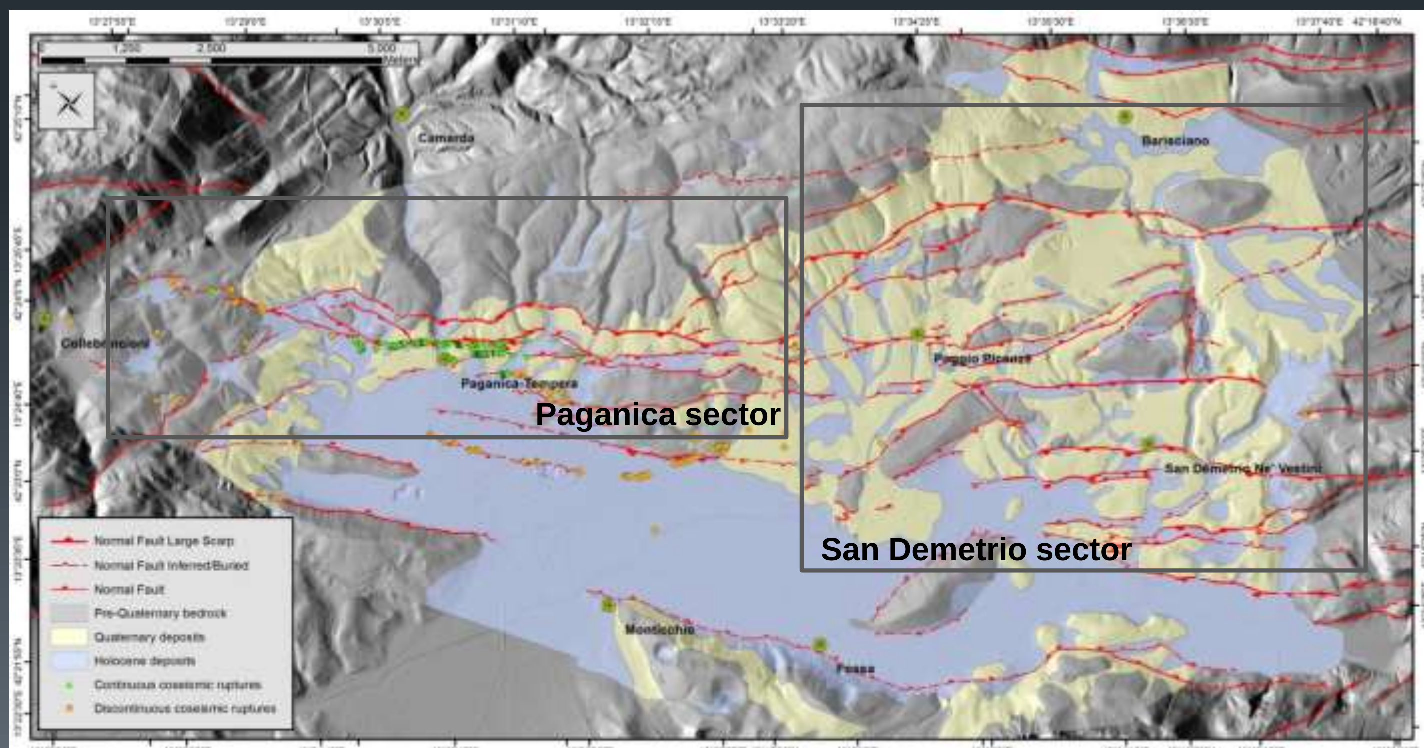
Fault splays hierarchy



- Among the fault splays affecting mainly the Quaternary deposits, the main contributors are fault splays P3 and S6
- Aligned in map view
- The subtle fault-related geomorphic expression in the central portion can be explained by the presence of a Late Pleistocene (ca. 27k yrs) alluvial fan
- The linkage of P3 and S6 seems to represents the most active surface trace of the PSDFS during the Quaternary

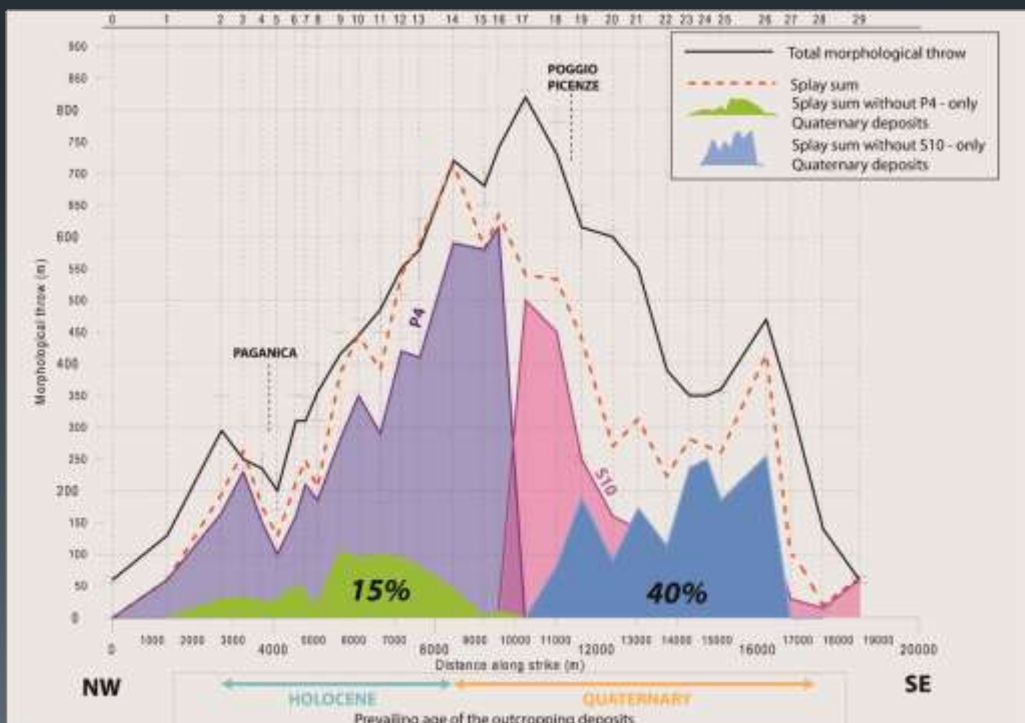
Conclusions 1

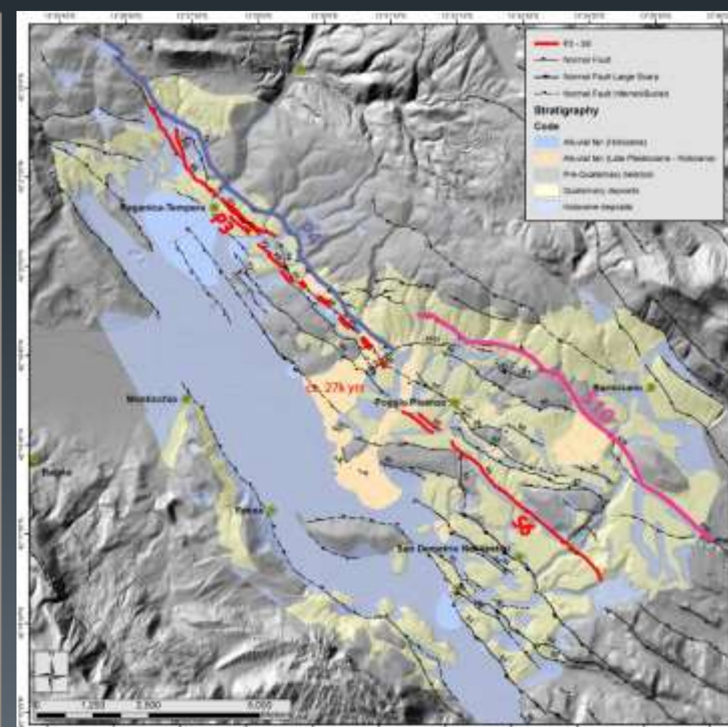
- We imaged the long-term morphological expression of the Paganica-San Demetrio fault system:
  - ✓ complex geometrical arrangement at the surface, with several normal parallel fault splays both synthetic and antithetic;
  - ✓ two main sectors: **a)** Paganica sector with a narrow deformation zone and a small Quaternary basin and **b)** San Demetrio sector, characterized by a wider fault system and by the exhumation and dissection of the Quaternary basin;



Conclusions 2

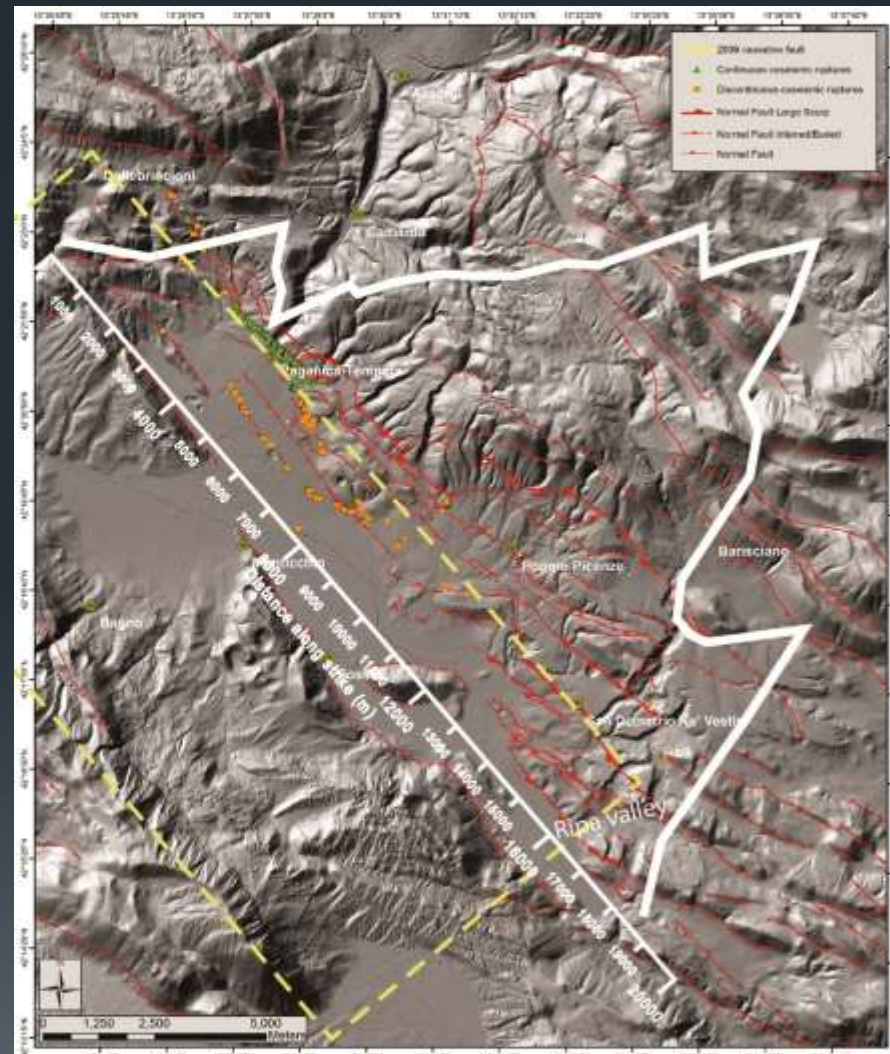
- We identified the relative contribution of individual fault splays to the overall deformation across the system:
  - ✓ most of the deformation of the PSDFS is accommodated by the two easternmost basin-bounding fault-splays (P4 and S10), affecting mainly the bedrock;
  - ✓ the linkage of fault splays P3 and S6 seems to represents the most active surface trace of the PSDFS during the Quaternary.





Conclusions 3

- We defined the length of the PSDFS:
  - ✓ The morphological throw graph approximates a symmetric bell-shaped curve, suggesting the existence of an isolated extensional fault;
  - ✓ The tips of the curve represent the fault boundaries, resulting in a 19 km-long structure, in good agreement with the up to 18 km-long 2009 seismogenic fault;
  - ✓ The extent of the long-term morphological expression of the PSDFS, when compared with the 3 km-long 2009 continuous coseismic ruptures, suggests that larger magnitude earthquakes with respect to the 2009 event are needed to built-up the present morphology;
  - ✓ By using the PSDFS length, we estimated (W&C) a maximum expected magnitude ≥ 6.3



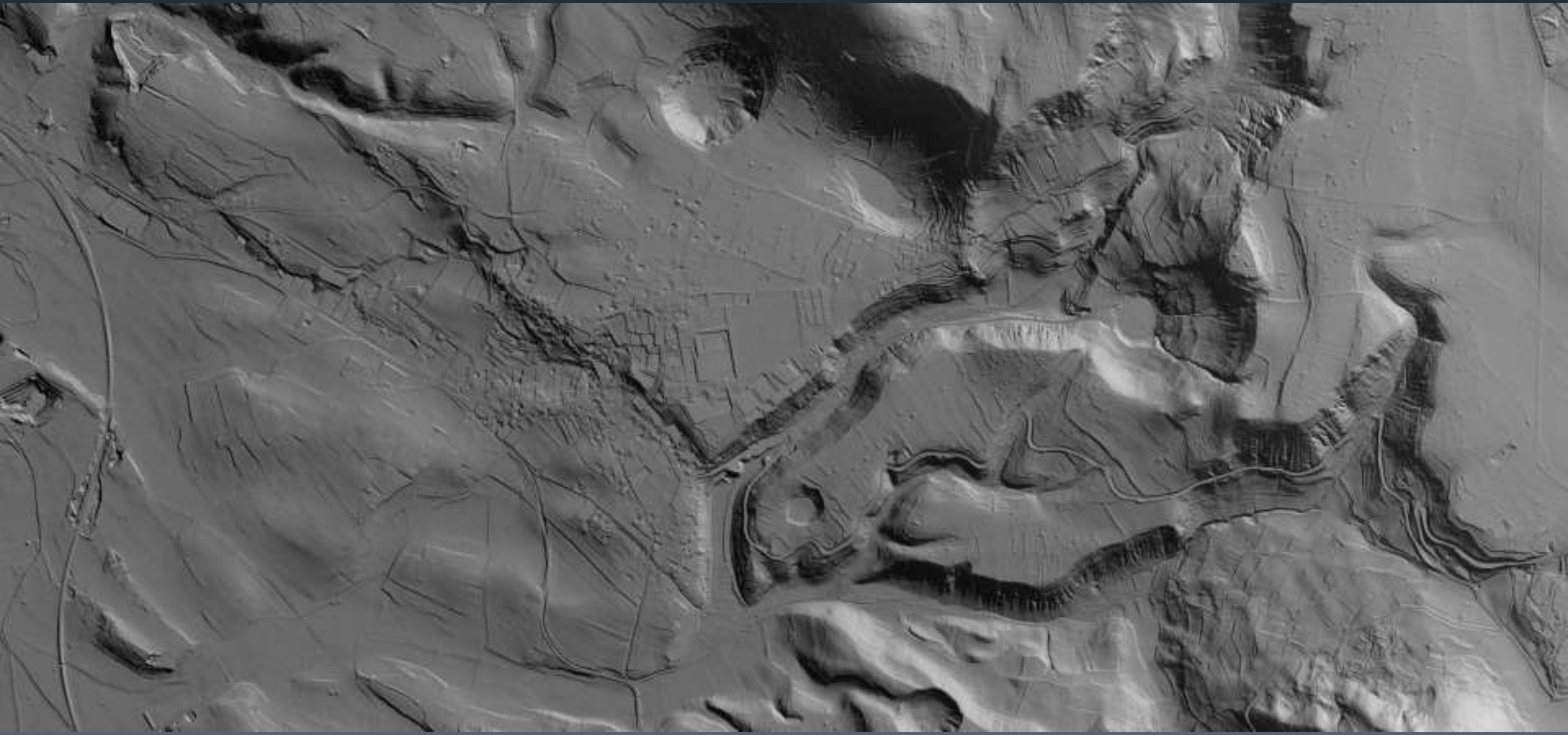
What's next...

- Geology
  - ✓ compare geological and morphological throws;
  - ✓ obtain slip-rate estimates;

- Subsurface geophysics
  - ✓ include subsurface data in the estimation of cumulative throws;

Contribution to the assessment of surface faulting hazard

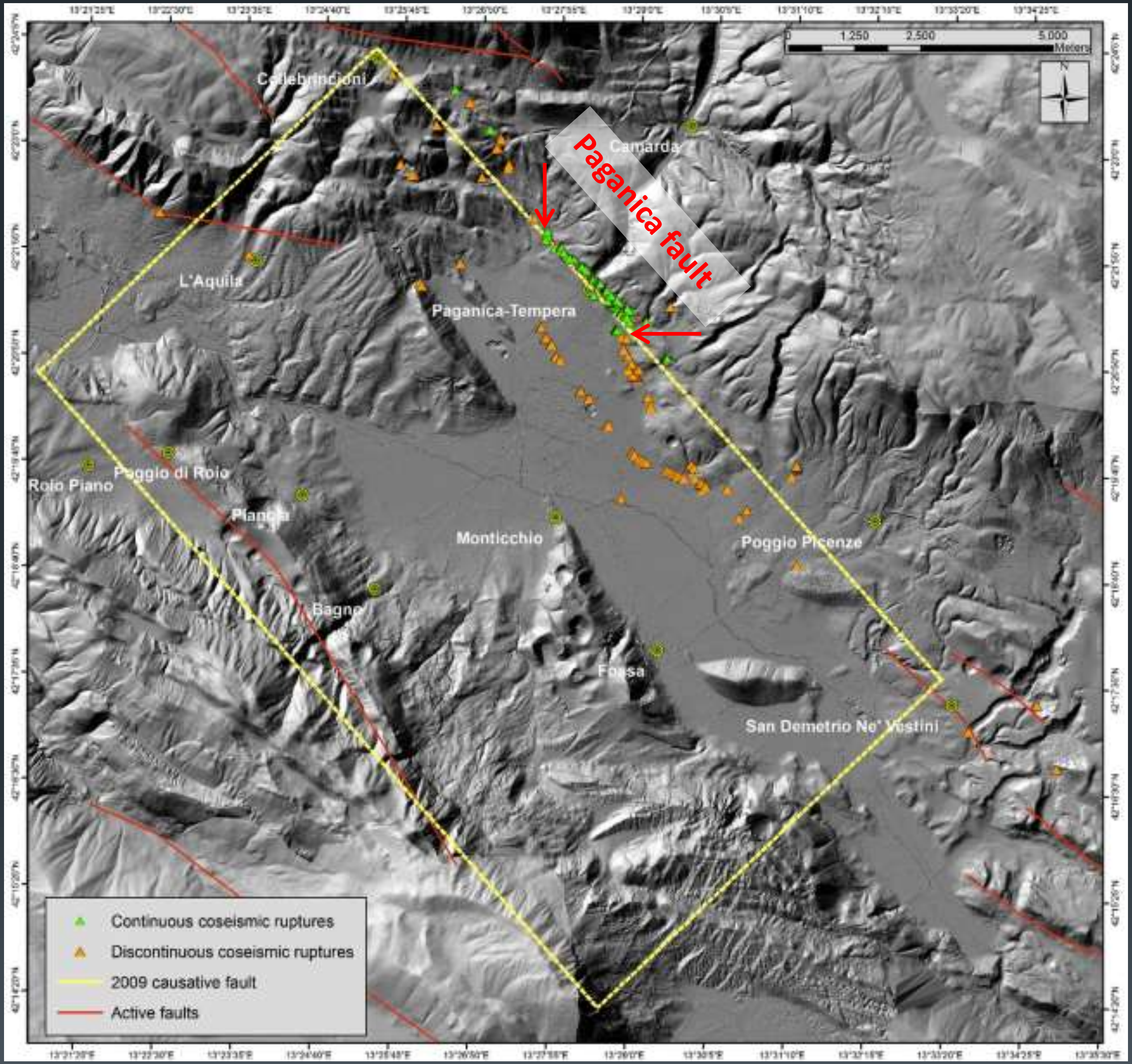
RICCARDO CIVICO (*), DANIELA PANTOSTI (*), STEFANO PUCCI (*) & PAOLO MARCO DE MARTINI (*)
* Istituto Nazionale di Geofisica e Vulcanologia



In Italy the assessment of surface faulting hazard is often a difficult task because of: a) lack of detailed map of active faults at a national level; b) the frequent complex geometrical pattern of active tectonic structures related to inherited structural and deformational style.

DISS Working Group, 2010

ITHACA - (ITaly HAzard from CApable faults)

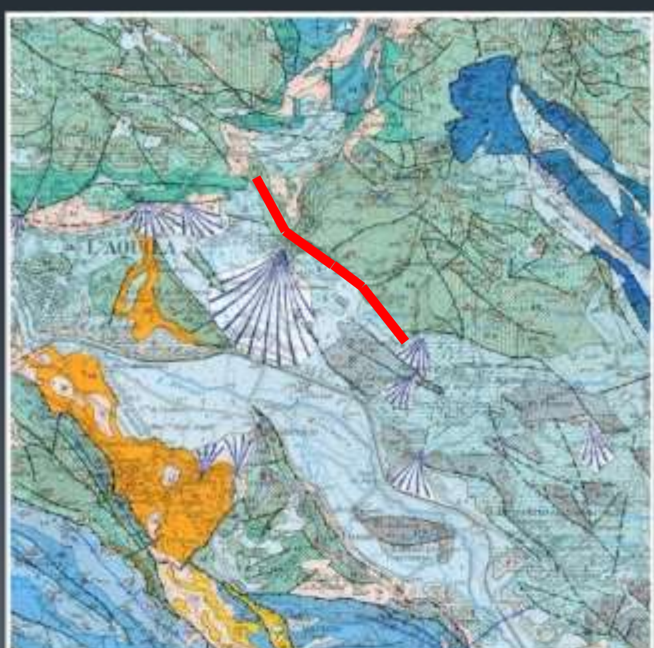


Surface faulting: 2009 L'Aquila earthquake

During the Mw 6.1 April 6, 2009 L'Aquila earthquake, coseismic surface ruptures occurred along several fault splays.

The occurrence of the 2009 L' Aquila earthquake strongly highlighted how critical is a deep knowledge of the location and characterization of the active faults and also of their secondary splays to prevent damage directly related to surface faulting.

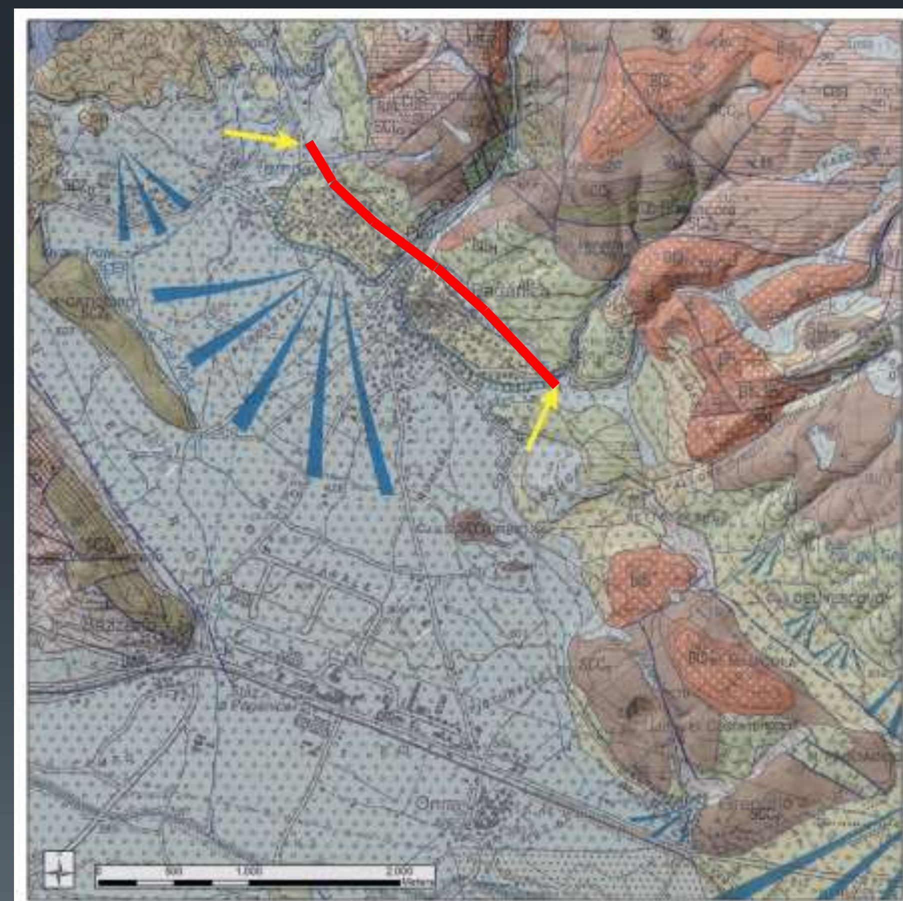
Bagnaia et al., 1992



Vezzani, L. and Ghisetti, F. (1998)

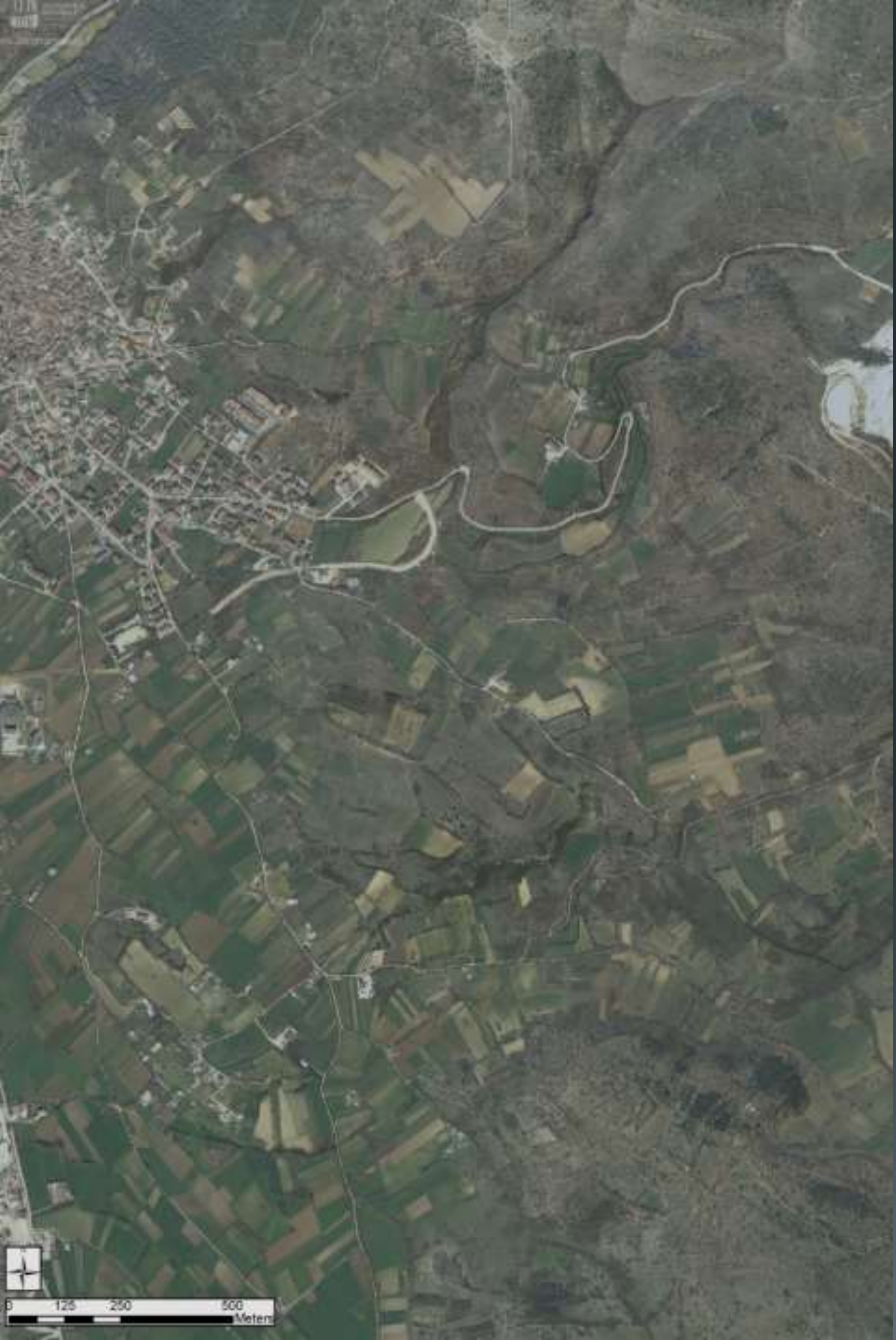
The Paganica fault

Prior to the 2009 earthquake, the Paganica fault was reported in the official geological maps as a single, simple fault trace affecting Middle to Late Pleistocene continental deposits.



Foglio CARG 1:50.000 N. 359, L'Aquila, 2009

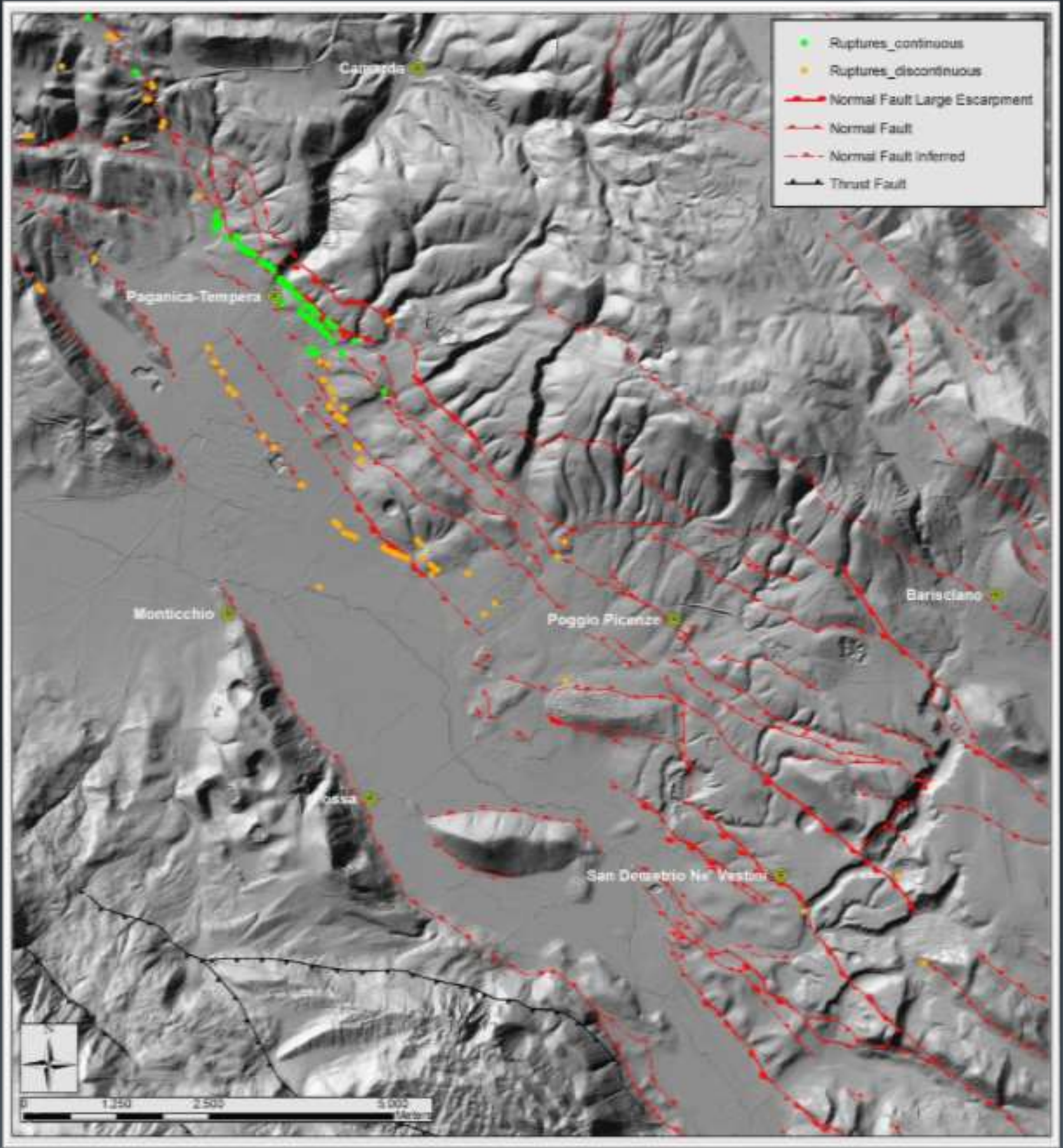
Damaged water pipeline - Paganica



Refinement of the Paganica fault mapping

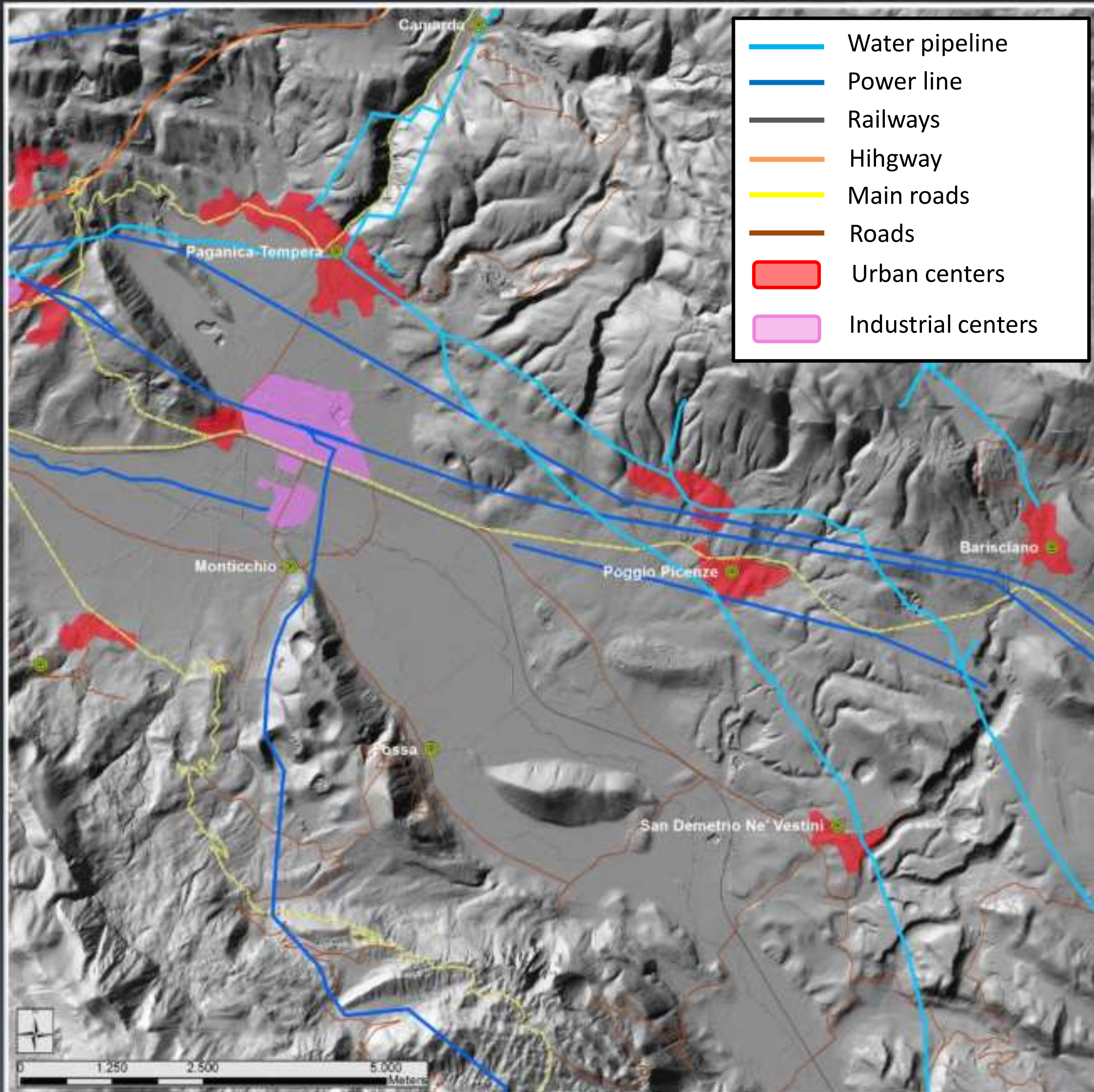
- The complexity of the 2009 coseismic surface breaks highlighted the need for a substantial refinement of the Paganica fault mapping, including minor and hidden active fault traces.

Surface structural setting of the Paganica – San Demetrio fault



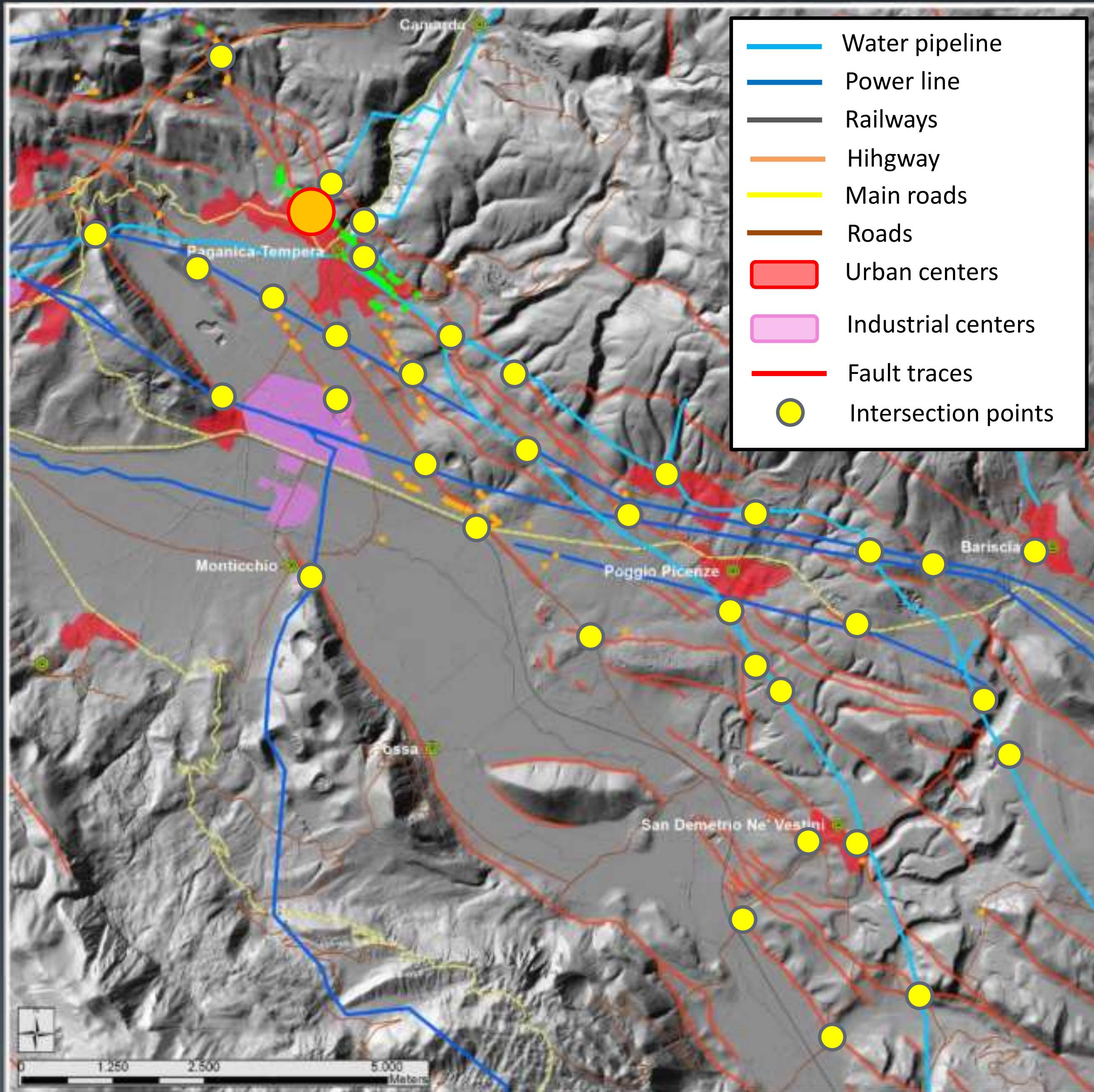
LiDAR-derived shaded relief showing the surface structural setting of the Paganica- San Demetrio fault

- At the LiDAR resolution, the surface structural setting of the Paganica – San DEmetrio fault appears to be much more complex than expected from the official geological map but also from previous works.
- Presence of several normal parallel fault splays both synthetic and antithetic.



Infrastructures

Urban areas as well as important infrastructures, facilities and lifelines are developed in the area hit by the April 6 2009 earthquake



Infrastructures

- LiDAR data analysis contributed to a better imaging of the location of the active fault splays
- More than 80 points of intersection of fault lines with urban centers and main infrastructures (roads, railways, pipelines, etc.)

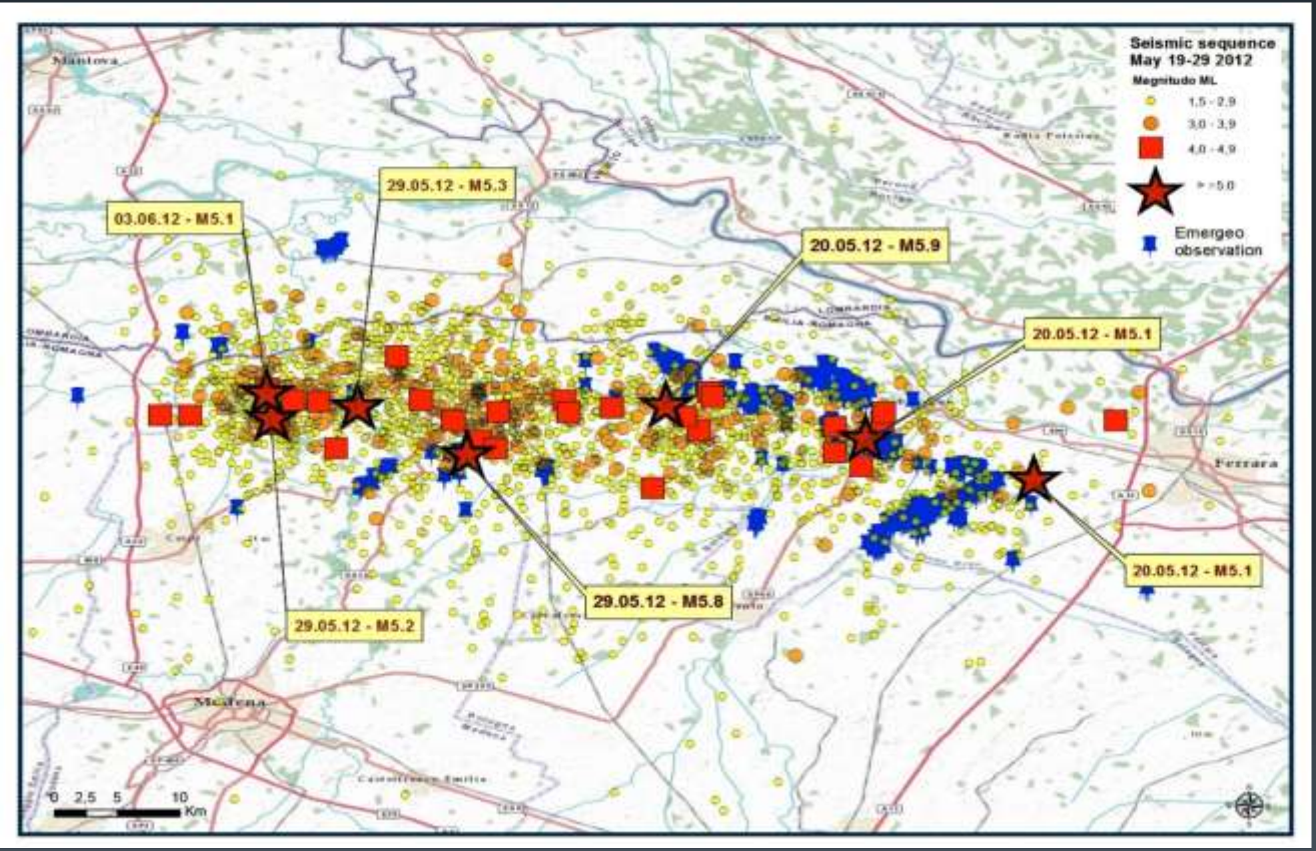
Infrastructures

Following the detailed identification and mapping of the active fault traces crossing a portion of the Gran Sasso aqueduct, the engineers of the GSA s.p.a. arranged the installation of a new water pipeline cut-off valve, in order to prevent future spills in case of surface faulting-related damages.

Detailed geomorphological analysis of the 2012 Emilia earthquakes epicentral area and liquefactions

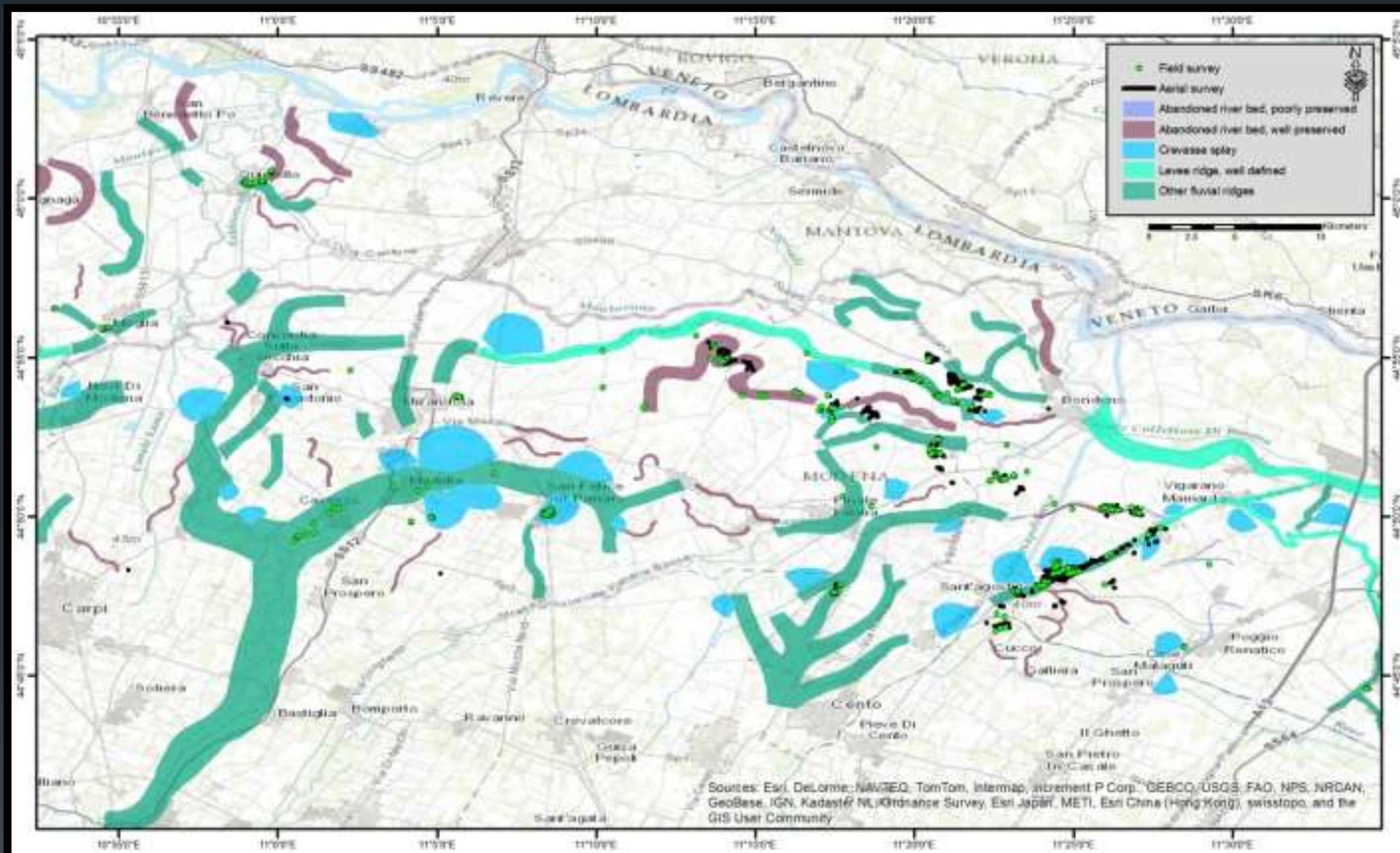
RICCARDO CIVICO (*), CARLO ALBERTO BRUNORI (*) & PAOLO MARCO DE MARTINI (*)
* Istituto Nazionale di Geofisica e Vulcanologia

The 2012 Emilia seismic sequence caused extensive liquefaction phenomena over an area of 1200 km^2 in the Po Plain, following the 20 May, M_L5.9 and 29 May, M_L 5.8 mainshocks, both occurred on about E– W trending, S dipping blind thrust faults.



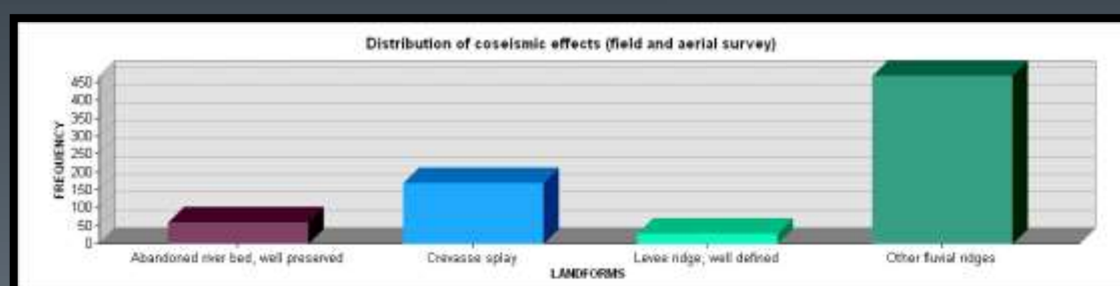
Seismic sequence in the Emilia Padania Plain since the 19th of May up to 19th of June 2012. In a month almost 2000 seismic events occurred, seven having Ml greater or equal 5.0 (red stars). Blue pinpoints locate the observation records made, through field and aerial survey, by the Emergeo working group.

We want to perform a quantitative analysis of the spatial distribution of the 2012 coseismic observations using GIS tools and to define areas where liquefaction is more likely to occur.

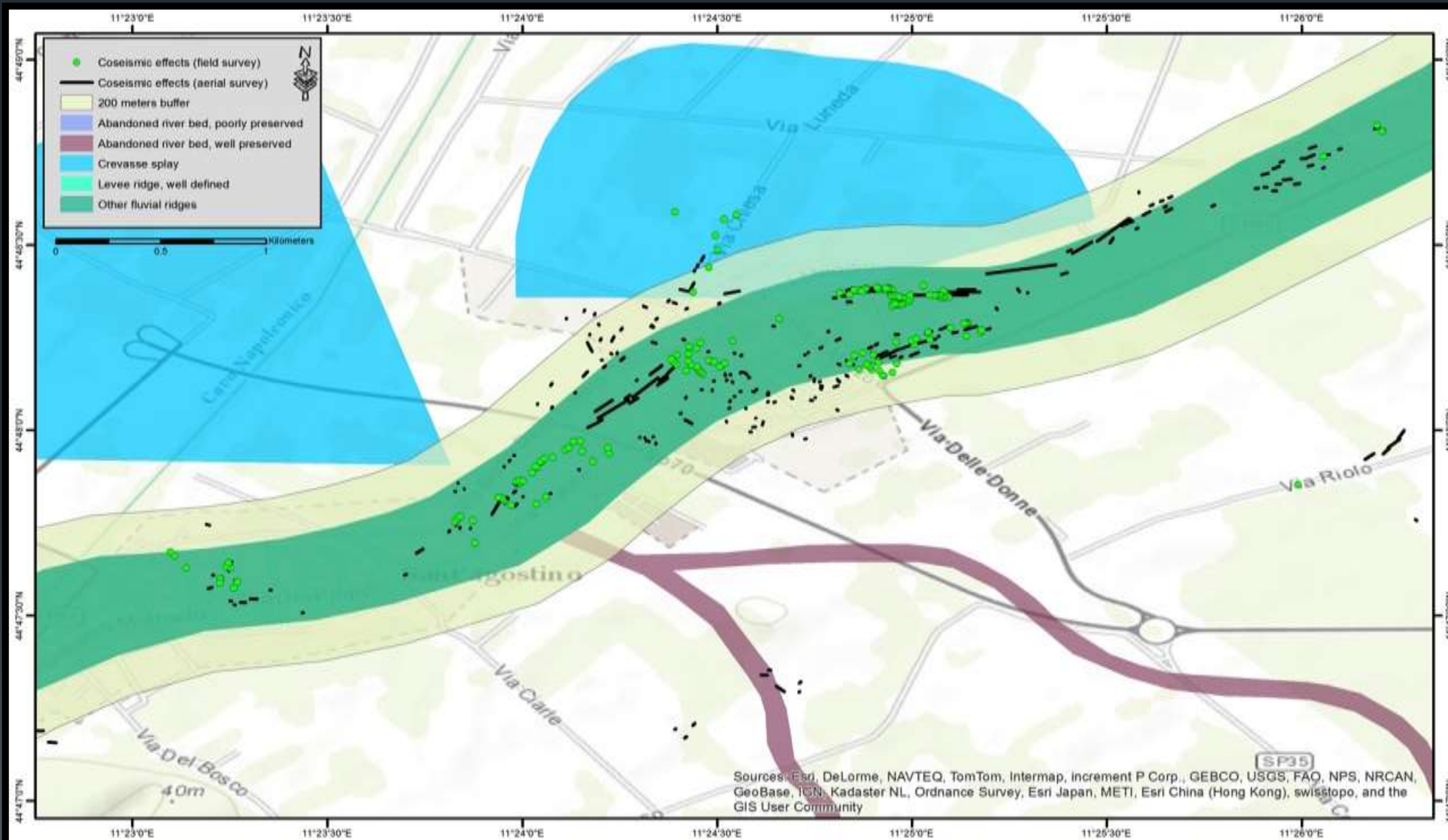


718 (~ 52%) out of a total of 1374 coseismic observations (both from field and aerial surveys) are located in coincidence with known fluvial landforms

Levee and other fluvial ridges were preferred location for liquefaction, hosting together ~69% of them while crevasse splays account for ~23%.



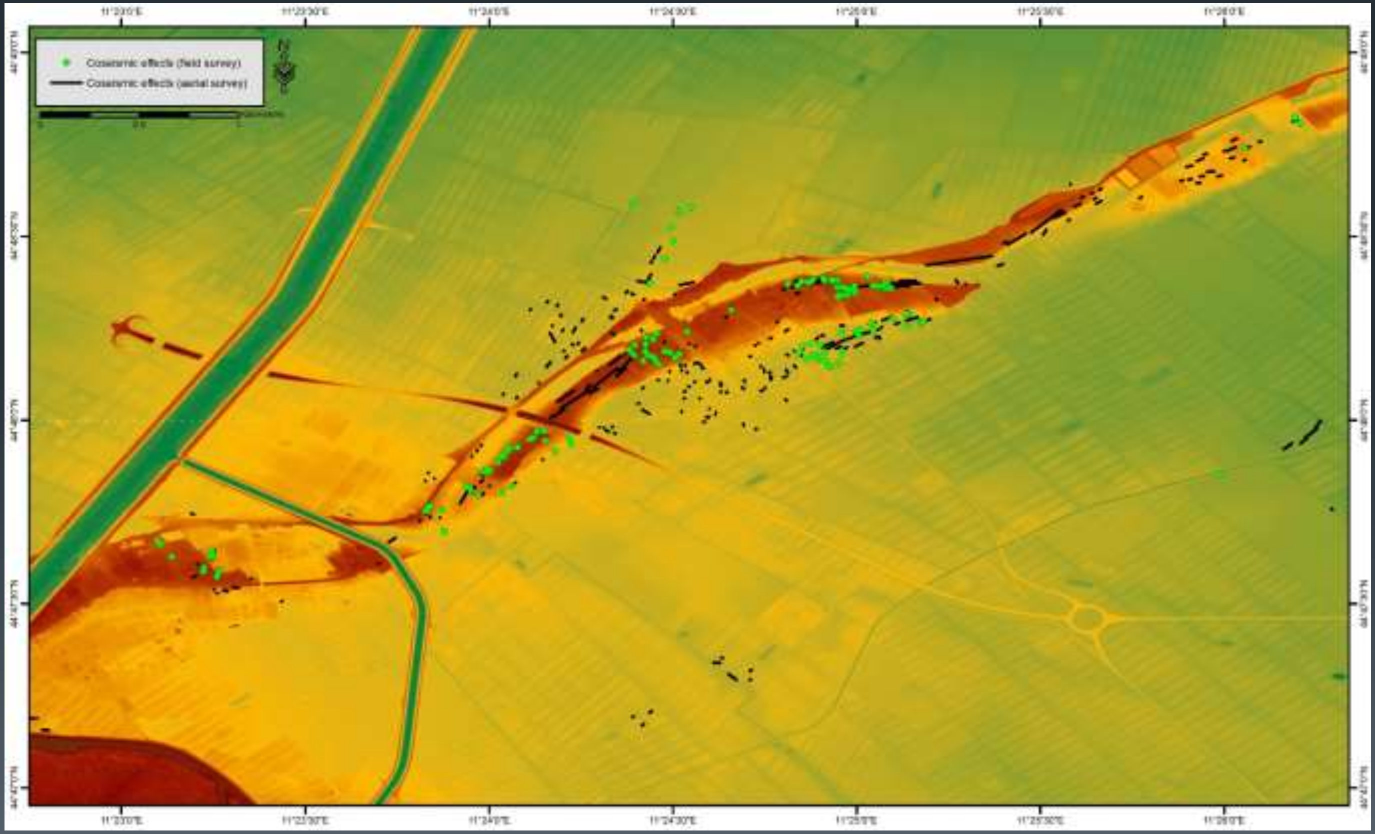
Most of the liquefaction phenomena were located in proximity (within 200m) of levee and other fluvial ridges (~67%).

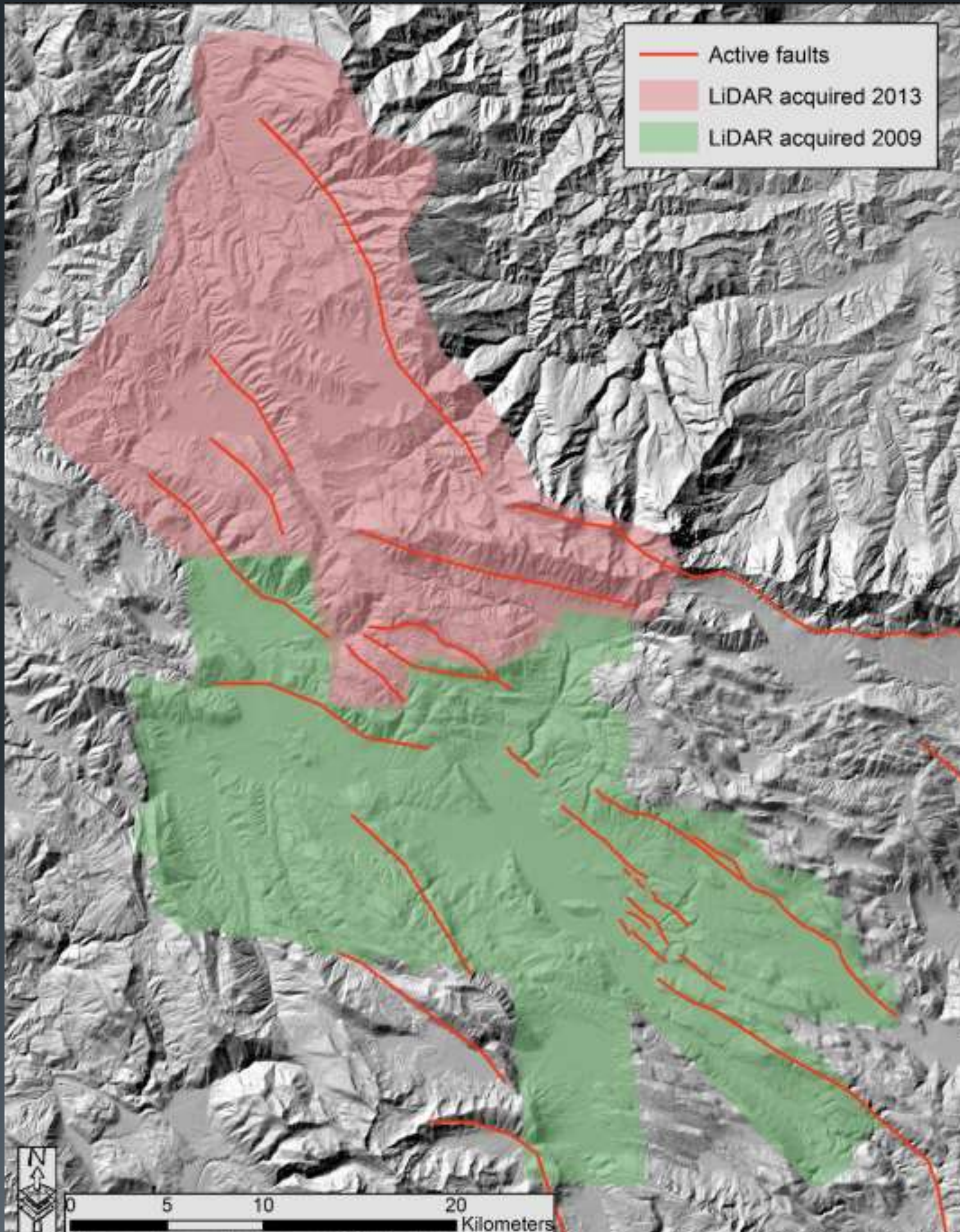


Detail of the spatial distribution of the 2012 coseismic effects (from field and aerial surveys) at S. Agostino Village.

Future detailed high-resolution topographic analysis are needed in order to:

- refine the geomorphological mapping of this sector of the Po Plain also by identifying new subtle fluvial landforms
- quantify the minimum distance from these fluvial features needed to reduce the liquefaction hazard to a low level.





What I would like to take home

- create DEM from point cloud data
- Identify and map landforms and quantify fault displacement
- extract landscape metrics for tectonic interpretation
- landscape morphometry and stream network delineation

Thank you!