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Multiparametric data analysis for identifying active fault geometries in the Abruzzo and Molise regions (Central-Southern Apennines, Italy)

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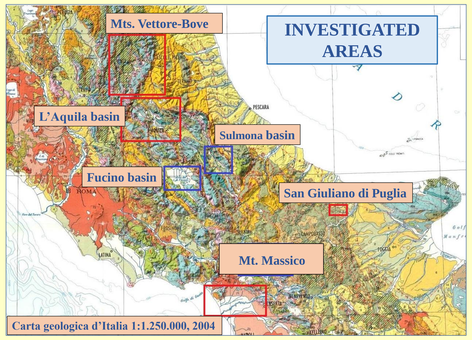
The aim: *to identify and constrain the geometry (strike, dip direction and dip angle) of seismogenic structures in areas of Central-Southern Apennines characterized by outcropping/ buried and/or active/silent faults.*

The method: *an integrated analysis of geo-structural, seismological and gravimetric data by **MDA** and **DEXP** methods in GIS environment. The identification and geometrical description of faults is possible if a density contrast, at the surface and/or at depth exists.*

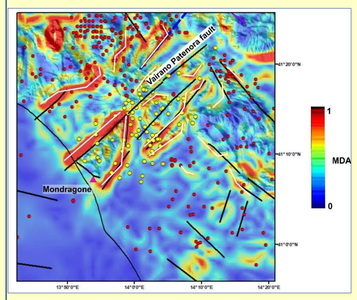
The ***MDA* method** is based on the computation of the *EHD* (*Enhanced Horizontal Derivative*, Fedi et al., 2005), formed by taking the horizontal gradient of a sum of vertical gradients of the gravity field of increasing order. The location of *EHD* maxima is used to outline the source boundaries.

*The **DEXP** method* computes the modulus of the horizontal gradient of the *n*-order vertical derivative of upward continued gravity data scaled with a power-law of the altitude and yields images of the distribution of the density *versus* depth (e.g., Fedi, 2007).

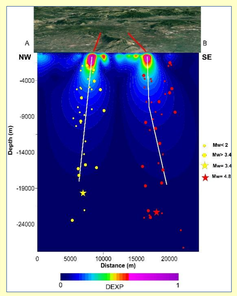


Case-history areas: *We studied different areas by our multi-method approach: the Mt. Vettore-Mt. Bove, L'Aquila basin, Mt. Massico and San Giuliano di Puglia areas (Central and Southern Apennines), which are affected by different Quaternary tectonic environments.*

Mt Massico fault system (Campania), Tyrrhenian margin of Apennines



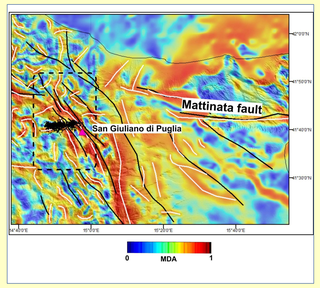
Merge of faults (black lines), earthquakes (yellow dots) and gravimetric lineaments from MDA maxima (white lines)



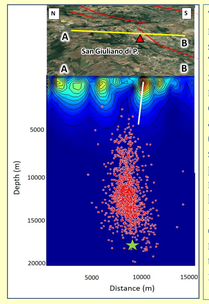
2D section of the DEXP image and relocalized instrumental earthquakes

Mt. Massico is a NE trending carbonatic horst in the northern Campanian region (Southern Italy) bordered by two anti-Appenninic normal faults. It is located in the inner portion of the Appennines chain and characterized by poor and low-medium magnitude (M_{max} = 4.8) seismicity. Our analysis identified several **buried active faults** in the plain and characterized the geometry and depth of the **outcropping Mt. Massico active fault system** (Gaudiosi et al., 2012; Luiso et al., 2018).

San Giuliano di Puglia fault system (Molise), Adriatic foredeep-foreland



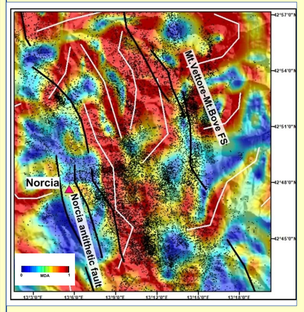
Merge of faults (black lines), earthquakes (black dots) and gravimetric lineaments (white lines)



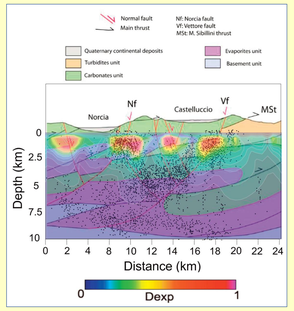
2D section of the DEXP image and 2002-2003 San Giuliano hypocentral distribution

The **San Giuliano di Puglia** area (Molise region) was hit by the 2002-2003 seismic sequences (M_{wmax}= 5.8 on October 31, 2002). The area falls between the Apennines axial zone and the Apulia-Gargano foreland, a region where no comparable earthquakes occurred in the last 1000 years (Valensise et al., 2004). The aftershocks alignment (Chiarabba et al., 2005; Chiarabba et al., 2014) suggests that the rupture occurred on an EW plane of focal solution, with a dextral fault motion. Our analysis (Luiso et al., 2016) highlighted a good correlation between the EW re-localized San Giuliano di Puglia earthquake seismic sequence and a MDA maximum with EW direction. Nevertheless, there is no evidence of EW surface mapped faults. This suggests that this is **a buried fault**.

Mt. Vettore-Mt. Bove fault system, backbone of the Central Apennines chain



Merge of faults (black lines), earthquakes (black dots) and gravimetric lineaments from MDA maxima (white *lines*).



Mt Vettore - Mt Bove is the normal Quaternary active fault system that ruptured the surface during the August 24 (M_w=6.0) and October 30 (M_w =6.5), 2016 earthquakes (Chiaraluce et al., 2017). Our multi-parametric investigation (Luiso et al., 2018) depicted the NW–SE Mt. Vettore-Mt.Bove fault system dipping westward, the splays of this primary fault system and its blind antithetic NW–SE structure, dipping northeastward. In the Norcia basin, we highlight two main faults bordering the basin with a dip of about 45°. The one edging the basin-eastern side dips westward, whereas the fault edging the basin-western side dips eastward and is likely silent. Thus, thanks to our analysis we could identify and characterize the geometry of the **Norcia** and **Vettore outcropping master faults**, as well as **other blind/buried** and/or **silent faults** that are related to the 2016 seismogenic structure.

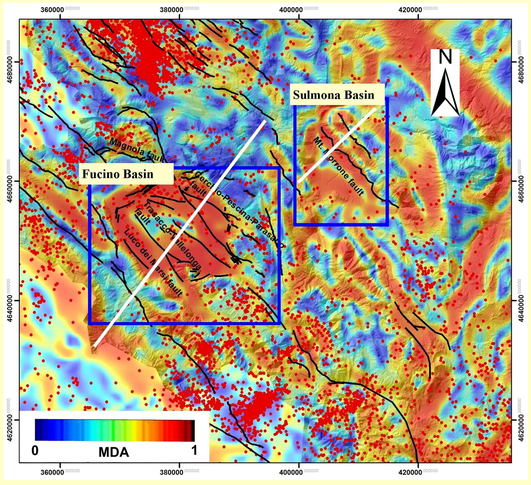
Combined analysis of the DEXP image and seismological data of 2016-2017 seismic sequence across the Norcia and Castelluccio basins and Mt. Vettore-Mt. Bove faulty system. Our analysis is overlaid to the seismic and geological section from Porreca et al. (2018)

Work in progress: a multiparametric study of two areas of the Abruzzo region

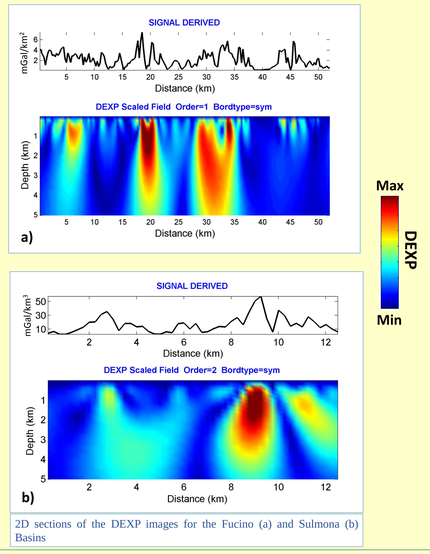
The **Fucino basin** was struck by a M_w=7.0 earthquake on January 13 1915, causing 30,000 causalities within a large area surrounding the basin. At present, the area is characterized by scarce instrumental seismicity with low magnitude. Our analysis highlighs a good correlation between the NW-SE and NE-SW well-known faults (Galli et al., 2016 and references therein) and clear gravimetric. MDA maxima bordering the plain. This area can be currently considered **silent** but, from historical seismological studies, it is one the highest seismic risk area of Central Apennines.

The area of the **Sulmona basin** is the southwards extension of the eastern system of central Apennines developing from Mt. Vettore, Mt. Gorzano and Mt. Gran Sasso. In historical times, the faults of the most external extensional alignment, defined as **silent** and considered as probable **seismic gaps** (Galadini and Galli, 2000), activated during the 2016 Amatrice–Visso–Norcia seismic sequence. Further to the southeast, two relatively large earthquakes occurred on the eastern flank of the Mt. Maiella on 3 November 1706 (M_w=6.6) and on 26 September 1933 (M_w=5.7). The Sulmona area is presently characterized by poor and low magnitude instrumental seismicity. Our multi-parametric analysis highlighted a strong correlation between MDA maxima and the Mt. Morrone normal fault (Gori et al., 2014; Galli et al., 2015) bordering the western side of Mt. Maiella and the eastern side of the Sulmona basin.

For the **Fucino** and **Sulmona Basins**, we considered the DEXP image of the modulus of the horizontal gradient of the first and second vertical derivative of gravity data, respectively. The DEXP maxima are at about the depth-to-the-top of the fault plane, and the area covered by the DEXP highs is oriented similarly to the faults' dip.



Map of the MDA gravimetric data in the Fucino and Sulmona basins with the capable faults (ITHACA, Michetti et al., 2000, black lines) and the earthquakes (ISIDe 2016, red dots). The white lines show DEXP profiles at the Fucino and Sulmona basins.



2D sections of the DEXP images for the Fucino (a) and Sulmona (b) Basins

CONCLUSIONS

The results of our multi-method approach allowed to characterize the geometry of outcropping/ buried and/or active/silent faults for contributing to the knowledge of the Apennine seismic hazard.

The correlation between faults, earthquakes and MDA maxima allowed us to highlight three possible scenarios:

1) the existence of active outcropping faults, shown by a strong correlation among epicentral location of seismic clusters, faults and MDA lineaments (the areas of Mt.Massico, Mt. Vettore-Mt. Bove);

2) the existence of buried active faults, highlighted by a correlation of MDA maxima with the spatial distribution of epicenters, but without correspondence with faults known from geological data (the San Giuliano di Puglia fault);

3) the existence of inactive or silent faults, detected by the presence of faults reported in the geological datasets and literature, which are correlated with MDA maxima, but show a scarce seismicity (the Fucino and Sulmona basins). In these areas, the DEXP profile yielded the depth-to-the-top of the faults' plain and their dip in agreement with the known capable fault, reported in the literature, bordering the two basins.

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