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Imaging the three-dimensional architecture of the Middle Aterno basin (2009 L'Aquila earthquake, Central Italy) using ground TDEM and seismic noise surveys: preliminary results

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Abstract: We present preliminary results from a multidisciplinary geophysical approach applied to the imaging of the three-dimensional architecture of the Middle Aterno basin, close to the epicentral area of the 2009 L'Aquila earthquake (central Italy). We collected several time domain electromagnetic soundings (TDEM) coupled with seismic noise measurements focusing on the characterization of the bedrock/infill interface. Our preliminary results agree with existing geophysical data collected in the area, and show that the southeastern portion of the basin is characterized by a deepening of the Mesozoic-Tertiary bedrock down to a depth of more than 450 m. We found that a joint use of electromagnetic and seismic methods significantly contributes in obtaining new insights on the 3D geometry of the Middle Aterno basin. Moreover, we believe that our combined approach based on TDEM and noise measurements can be adopted to investigate similar geological settings elsewhere.

INTRODUCTION

The Middle Aterno Valley is a 18 km-long, 3 to 6 km-wide Quaternary intramontane basin located south-east of the town of L'Aquila. The basin is characterized by the presence of an extensive cover of lacustrine and fluvial/alluvial Quaternary deposits accumulated upon a Meso-Cenozoic mainly carbonatic bedrock and generally separated by unconformities, and/or displaced by the Paganica - San Demetrio fault system (PSDFS - Pucci et al., JoM 2014). The PSDFS bounds to theeast the Middle Aterno Valley and was interpreted as the causative fault for the Mw6.1 April 6, 2009 earthquake (Civico et al., TECTO 2015).

METHODS AND DATA ACQUISITION

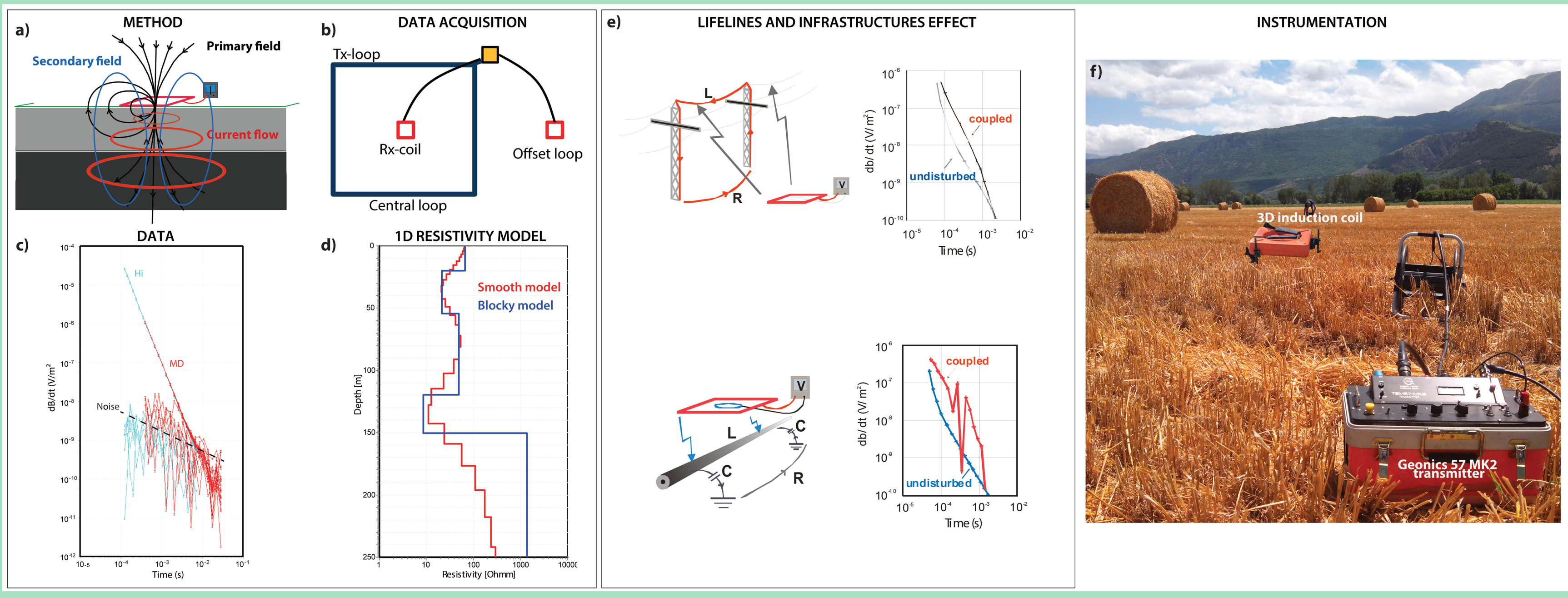

Fig. 1: a, b) Simplified scheme of TDEM method and acquisition configurations; c, d) Raw voltage data and recovered 1D resistivity model; e) Example of a coupled TDEM response compared to an indisturbed neighboring sounding; f) TDEM instrumentation.

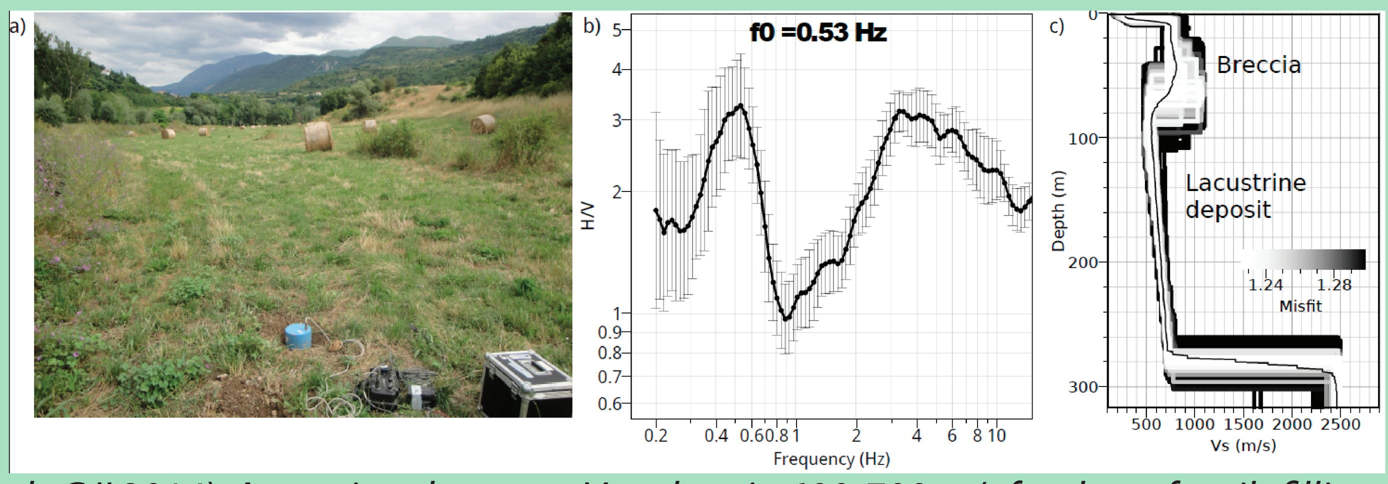

Fig. 2: a) Example of noise measurement; b) H/V spectral ratio. f0 shows the value of resonance frequency; c) Typical Vs profile in L'Aquila area estimated from joint inversion of surface-wave data and f0 (redrawn from Di Giulio et al., GJI 2014). Assuming the mean Vs values in 600-700 m/s for the soft soils filling the basin, we can approximate the bedrock depth (H) as H = Vs/(4.f0)

We calibrated TDEM and ambient seismic noise data against available wells and geophysical information (MS-AQ Working Group, 2010; Improta et al., IJG 2012; Porreca et al., AGU 2013 and deep ERT from Delcher et al., in prep.). As illustrated in figure 3 the recovered TEM 1D resistivity models show a good agreement with the seismic section both in the near surface and in the deeper part of the two models. In particular, we observe at ~230 m depth in the 1-D models a high resistivity contrast, with values larger than 500 Ωm, that we interpreted as the interface between the Quaternary infill and the Mesozoic-Tertiary bedrock. The f0 trend resulting from H/V curves is also fairly in agreement with the bedrock depth shown by the seismic section.

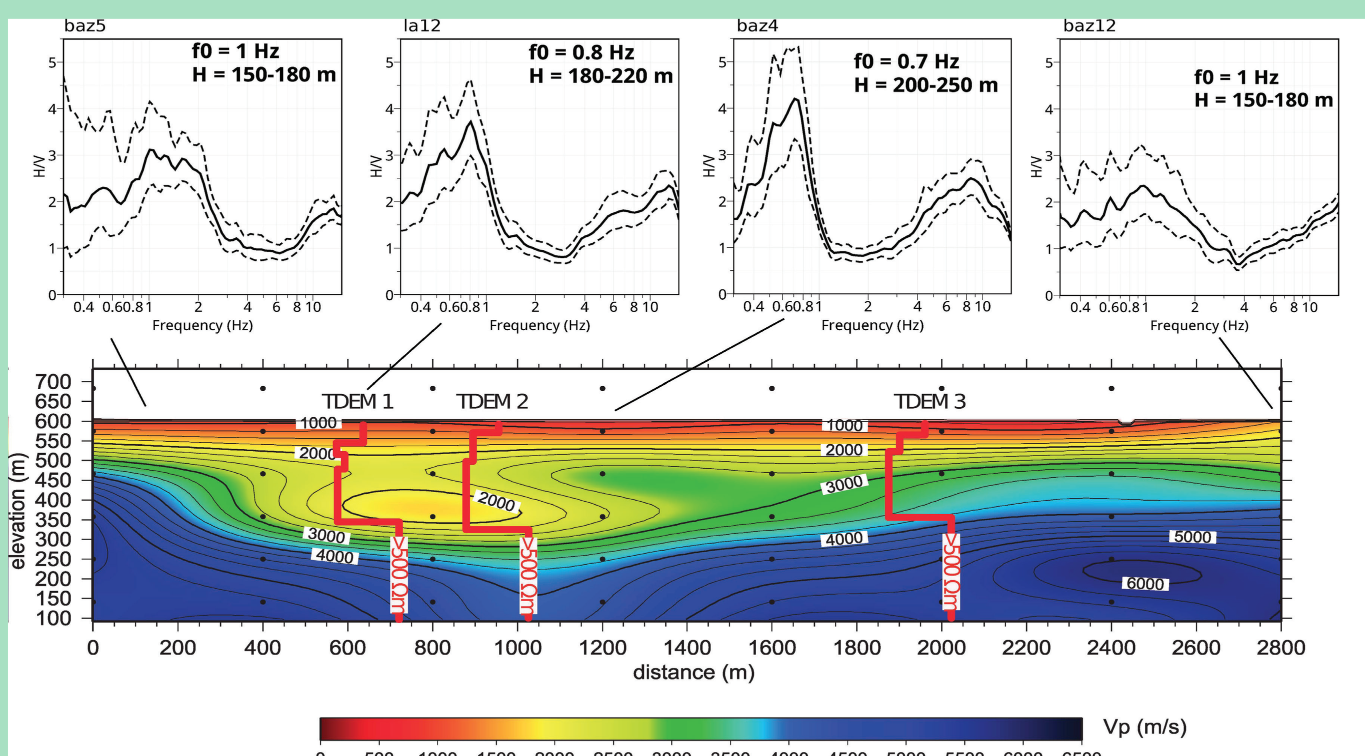

Fig. 3: Vp tomogram of two merged high-resolution seismic lines across the Bazzano basin (modified after: Improta et al., IJG 2012). Three 1-D resistivity models derived from the inversion of TDEM data (solid red lines), and four H/V curves computed from noise measurements (upper panel), projected along the Vp model.

We then expanded our survey performing TDEM and microtremor measurements at regularly spaced intervals (taking into account logistical difficulties related to lifelines/infrastructures) collecting a total of 55 TDEM and 86 seismic noise measurements respectively (Figure 4).

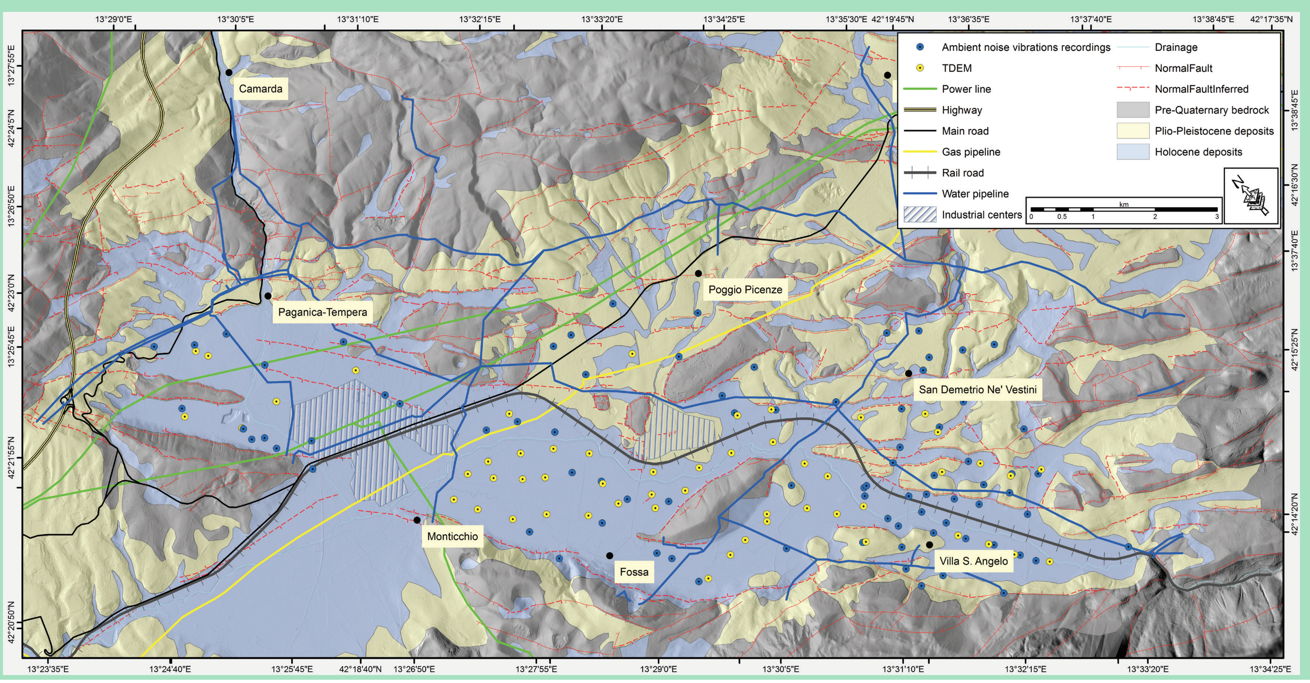

Fig. 4: Location map of TDEM and seismic noise surveyed sites, showing the main infrastructures and lifelines in the Middle Aterno basin. Simplified geology and main faults of the area redrawn after Pucci et al. (JoM 2014).

Acknowledgements: The measurements were collected in the Abruzzo project "High-resolution analyses for assessing the seismic hazard and risk of the areas affected by the 6 April 2009 earthquake" (http://progettoabruzzo.rm.ingv.it/en

SUBSURFACE GEOMETRY OF THE MIDDLE ATERNO BASIN

We obtained two raster surfaces by interpolating (Natural neighbor technique) two different input data: 1) the depth of the basin substratum with respect to the present-day surface (Figure 6), and 2) the estimated absolute elevation of the basin substratum (Figure 8).

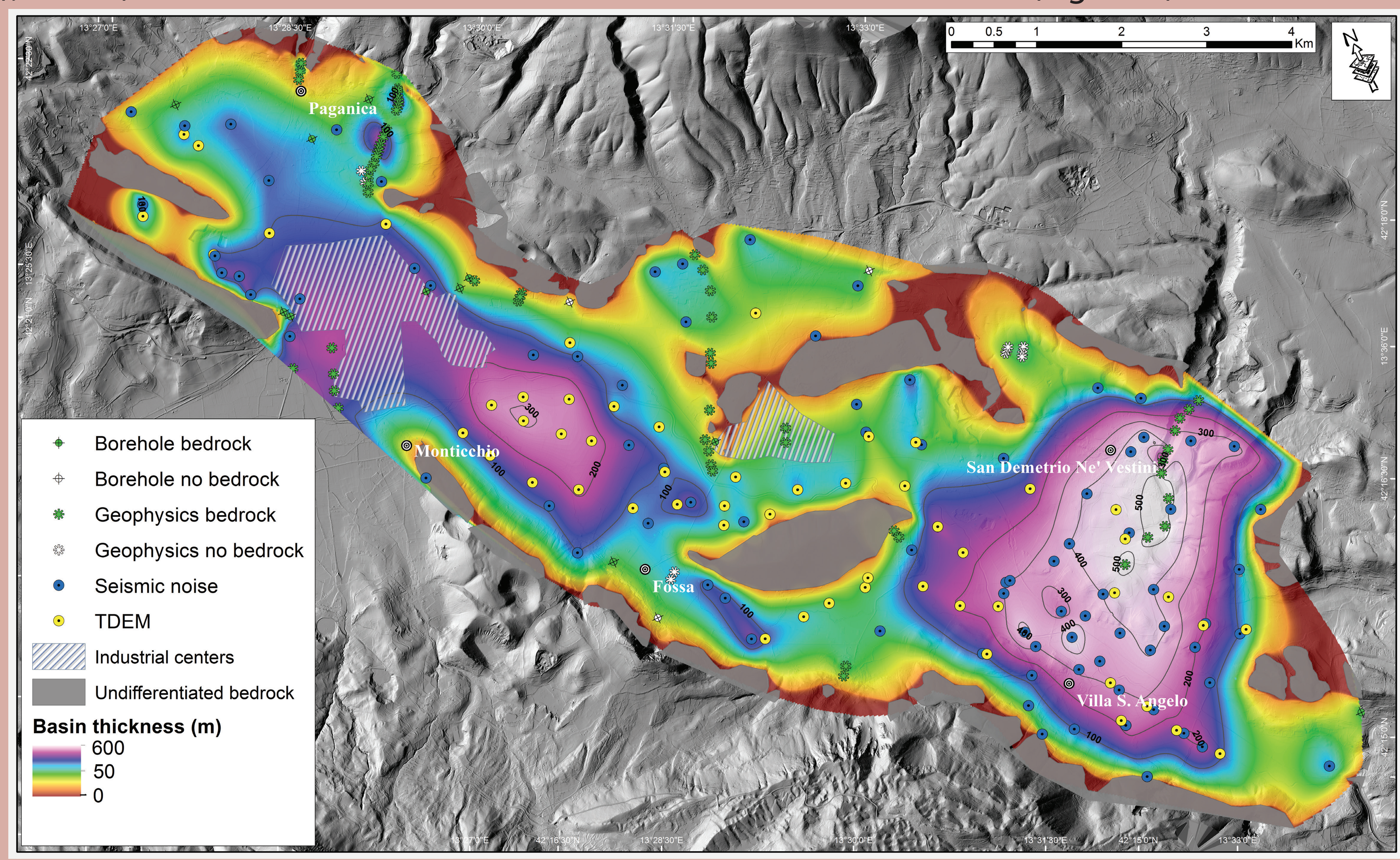

Fig. 6: isopach map of the basin infill (contour interval: 100 m). This surface is irrespective of the absolute elevation of measure points: it may provide useful information about the time relationships between sedimentation and activity of the PSDFS.

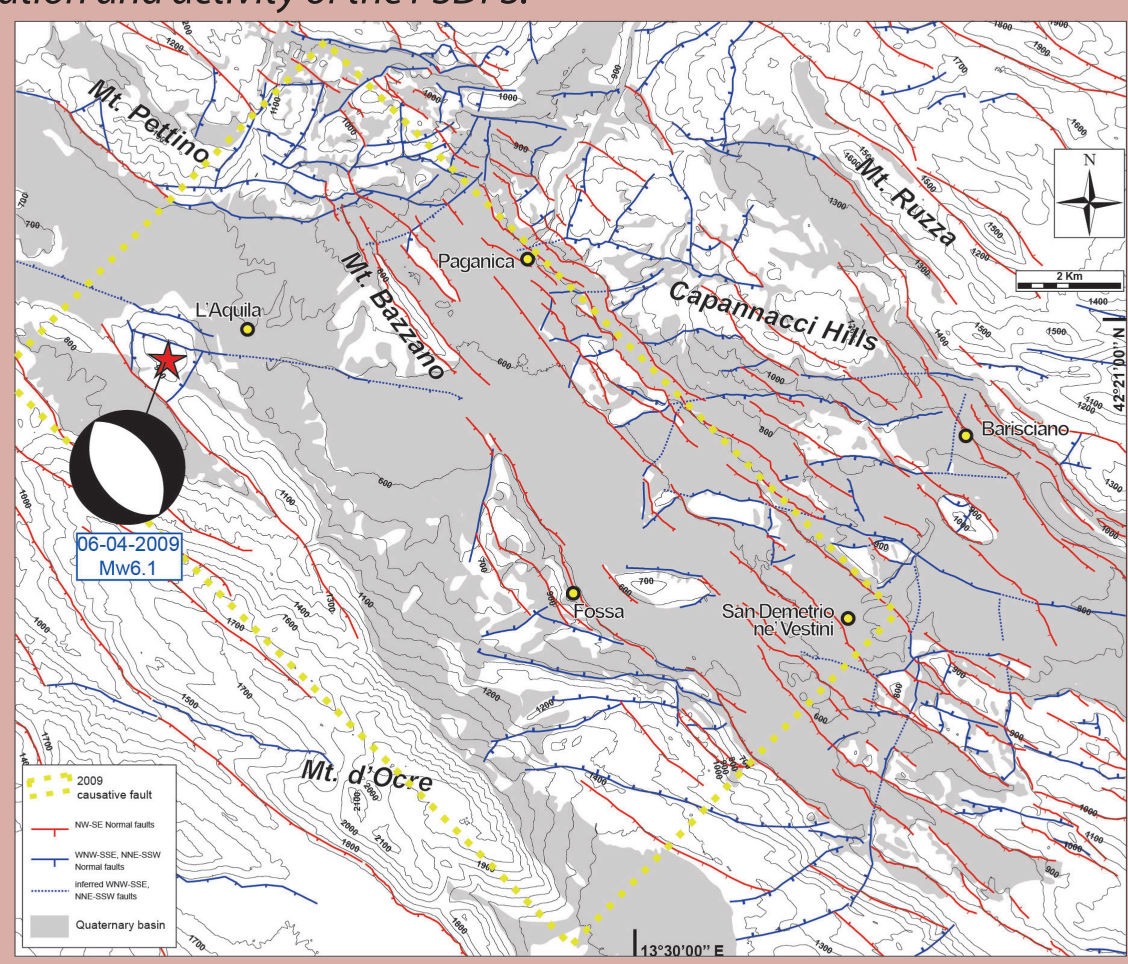

Fig. 7: The Middle Aterno basin is characterized by a complex surface structural setting, with normal faults offsetting both the Quaternary deposits and the bedrock. The structural analysis highlighted the presence of two fault systems: a NW-SE system with parallel normal fault splays, both synthetic and antithetic and a WNW-ESE and NNE-SSW conjugate sytem (Pucci et al, in prep.). The NW-SE system appear to cross-cut the WNW-ESE and NNE-SSW (at the mesoscale). The yellow box is the approximate projection to the surface of the ~16 km-long 2009 mainshock causative fault according to various investigators (see a review in Vannoli et al., IJG 2012 and Chiaraluce, JSG 2012).

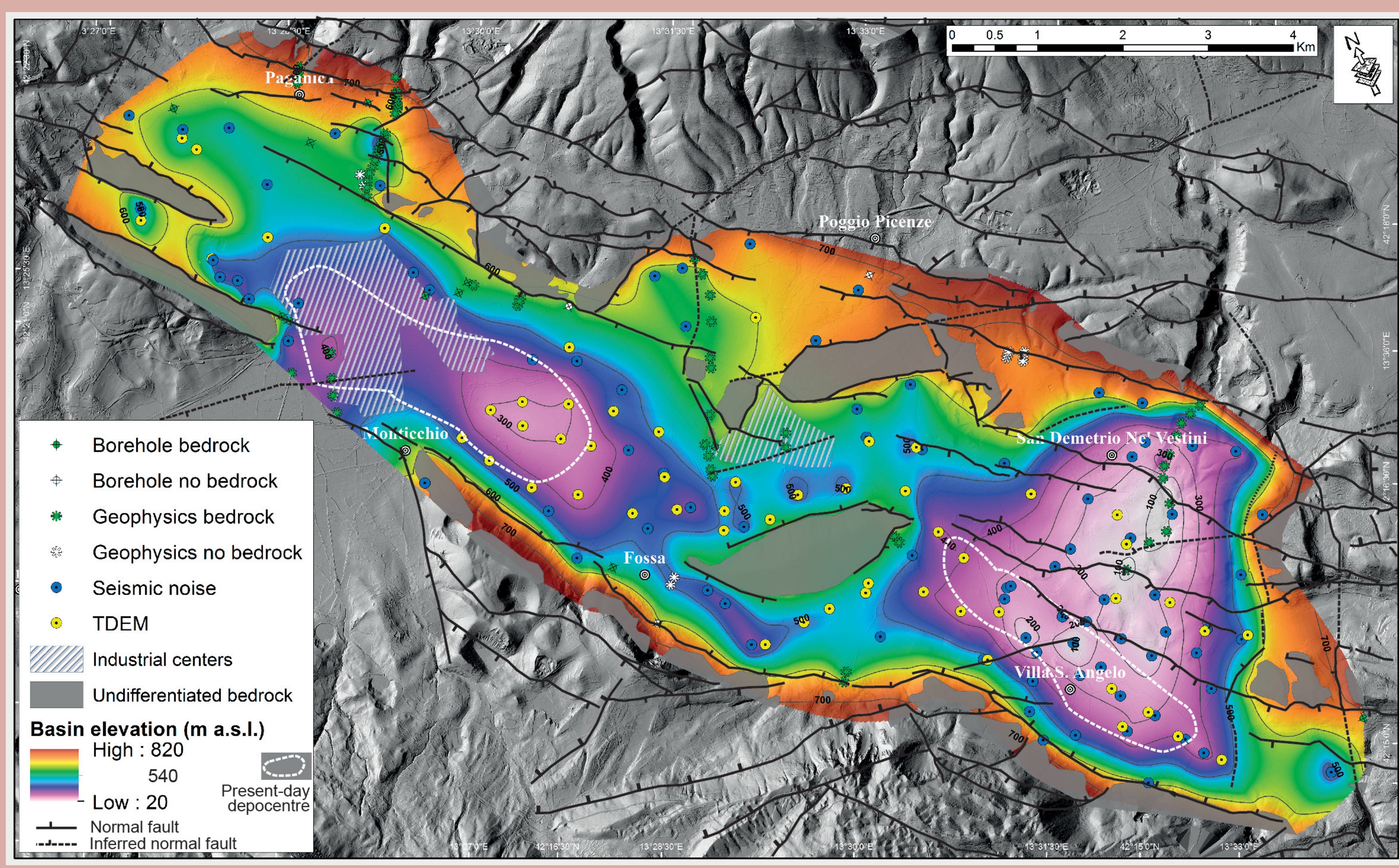

Fig. 8: Shape of the continental basin bottom (contour interval: 100 m). It results from the combined effects of erosion and faulting. The basin architecture is compared with the fault system at the surface and the present-day depocenter (Pucci et al., JoM 2014).

CONCLUSIONS

We obtained a preliminary reconstruction of the three-dimensional architecture of the Middle Aterno basin at depth. Our results highlight the presence of a complex basin structure, formed by thresholds separating two main depocenters with a maximum depth of about 300 m and >500m, respectively. The deeper depocenter, located at the southern end of the basin (between San Demetrio ne' Vestini and Villa Sant'Angelo villages) presents a triangular shape with its SE side characterized by a strong topographic gradient. Notably, this geometry suggests a tectonic control by the older NNE-SSW/E-W conjugate fault system. Conversely, the northern depocenter (between Paganica and Fossa villages) shows a southeastern deepening and a roughly elongated geometry parallel to the NW-SE fault system. The present-day depocenter appears to be shifted with respect to the former one, probably due to a later onset of the NW-SE fault system activity. The southeastern tip of the Quaternary basin is strongly controlled by a N-S trending fault, that could have played a role as a boundary for the 2009 fault rupture (see a review in Vannoli et al., IJG 2012). Our study emphasizes the effectiveness of combining two different geophysical methods in reconstructing the 3D geometry of a Quaternary basin at depth, despite logistical difficulties related to the presence of lifelines/infrastructures that hampered the survey.