COMBINED GRAVITY AND MAGNETIC ANOMALIES MODELING OF CENTRAL ITALY

P. Mancinelli[1], M. Porreca[1], C. Pauselli[1], G. Minelli[1], M.R. Barchi[1], F. Speranza[2]
[1] Dipartimento di Fisica e Geologia, Università degli Studi di Perugia, Italy - Member of CRUST (Centro inteRUniversitario per l'analisi SismoTettonica tridimensionale con applicazioni territoriali)
[2] Istituto Nazionale di Geofisica e Vulcanologia, Rome, Italy

Introduction. In complex geodynamic areas characterized by active tectonics, the combined gravity and magnetic modeling can contribute to validate subsurface geological models, defining the geometries and the thickness of the geological formations involved into the seismicity. Moreover, when the modeling is constrained to well documented geological observations both at the surface and at depth (borehole and seismic reflection profiles), its interpretation is certainly more straightforward. In these cases, relationships between the mechanical properties of the crust and the distribution of the seismicity can be also addressed.

The Umbria-Marche Apennines (e.g. Barchi *et al*., 2001) represent a typical fold and thrust belt (Fig. 1) mainly formed during the Late Miocene and successively dissected by extensional tectonics, still active, as demonstrated by the 2016-2017 seismic sequence (e.g. Tinti *et al*., 2016; Chiaraluce *et al*., 2017).

Methods. The subsurface geology of the investigated sector of the Apennines has been widely studied in the last three decades (e.g. Bally *et al*., 1986; Lavecchia *et al*., 1994; Barchi and Mirabella, 2009; Barchi, 2010; Bigi *et al*., 2011 and references therein). These authors propose contrasting structural styles, characterized by either thin-skinned or thick-skinned tectonics involving the sedimentary cover – consisting of Miocene-to-Quaternary turbidites, Meso-Cenozoic pelagic calcareous sequence and Triassic evaporites – and the deeper basement respectively.

In this work, we report the results obtained by the combined gravity and magnetic modeling of the region affected by the 2016-2017 seismic sequence, at the border between the Northern and the Central Apennines (Fig. 1).

The magnetic data used in this work (Fig. 2a) are derived from the aeromagnetic map obtained by integrating previous datasets (Caratori Tontini *et al*., 2004 and references therein). Across the study area, the magnitude of the anomaly is comprised between -15 and 50 nT, with a general eastward increasing trend.

The Bouguer anomaly map (Fig. 2b) was calculated from ~50,000 original data points provided by the Italian oil company (eni) across Central Italy, using a reduction density of 2670 kg m^{-3}. The Bouguer gravity anomaly shows an eastward-decreasing trend from maximum values of ~10 mGal (10^{-5} m sec^{-2}) to minimum values of -70 mGal toward the eastern sector of the study area.

Moreover, the modelling was constrained to the recent geologic model from Porreca *et al*. (2018) and to all the petrophysical properties (density and magnetic susceptibility) of the bodies involved in the modelling available from the literature.

Results and conclusions. In the grav-mag modeling of the section 2 (Fig. 3), where the geometries of the top of the basement and of the overlying Meso-Cenozoic units were constrained to the reference geological model, a coherent fit both at long and short wavelengths, is obtained between the two models.

The resulting best-fitting geometries for sections 1 and 3 are in agreement with the structural model of section 2. In fact, both magnetic and gravity calculated anomalies produced along these sections, fit the observed anomalies producing errors with magnitude similar to those obtained on the geologically-constrained section 2. In our opinion, these results further validate the initial geological model proposed by Porreca *et al*. (2018), which is consistently supported across the entire study area.

The spatial distribution of the basement is coherent across the entire area, with the top of the

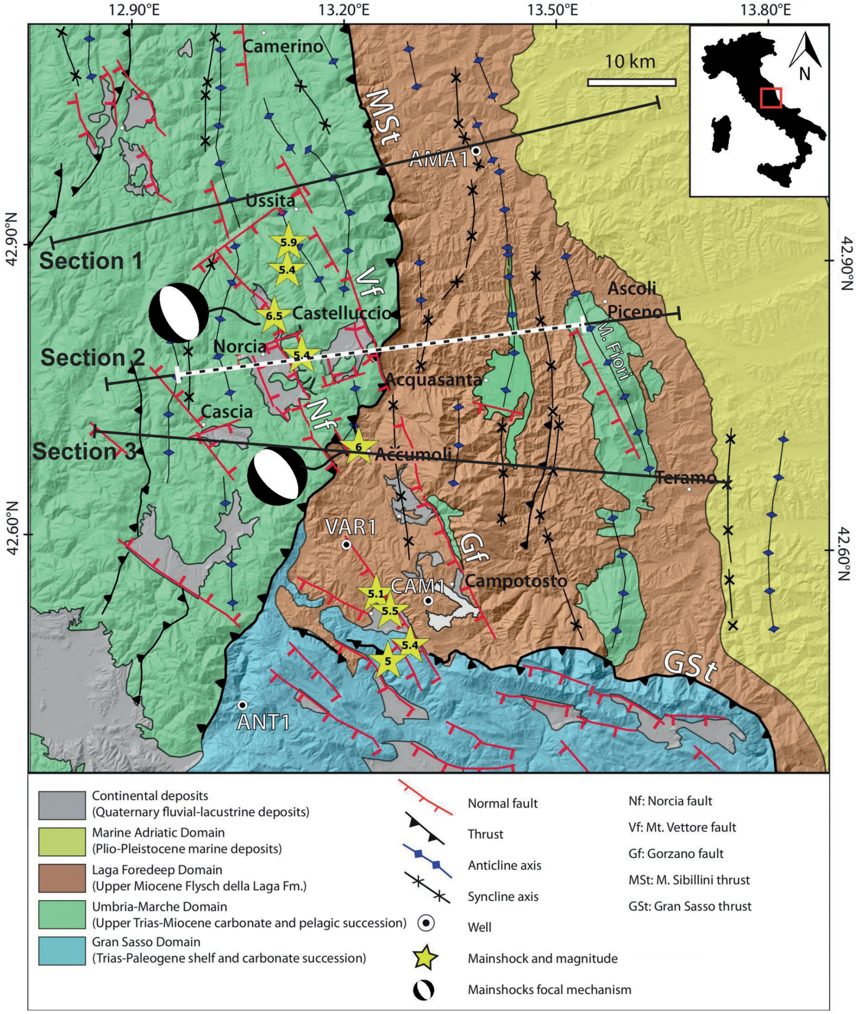

Fig. 1: Geological map of the investigated area with the location of the three sections used in this study. White dashed line across section 2 corresponds to the geological cross-section described by Porreca *et al*. (2018). Basemap topography is from Tarquini *et al*. (2007; 2012).

basement ranging between 8 and 12 km, being interested by major thrusts across all the three sections and slightly deepening toward ESE. In-depth layering of the basement is coherently represented across all the three sections with two basement layers contributing to the gravity and magnetic anomaly together with the deep crust.

In particular, the basement and the upper portion of the deep crust contributes with low susceptibilities (0.001 SI units) while the major contribution to the magnetic anomaly has a deep origin at the base of the crust with an anomalous body with high susceptibility (0.05 SI units). This anomalous body is found to reach a thickness up to ~10 km (i.e. ranging in depths from 25 to 35 km) in the eastern part of the sections and its thickness decreases northward (i.e. from section 3 to section 1) and westward across all models.

Seismic events of the 2016-2017 sequence have been plotted in the resulting models of sections 1-3 and mainshocks of Mw > 5.5 fall within the deep evaporite unit, overlying the basement, where the seismicity cutoff was previously observed (Porreca *et al*., 2018). Considering the maximum depth of the seismicity across the area – i.e. 10-12 km (Chiaraluce *et*

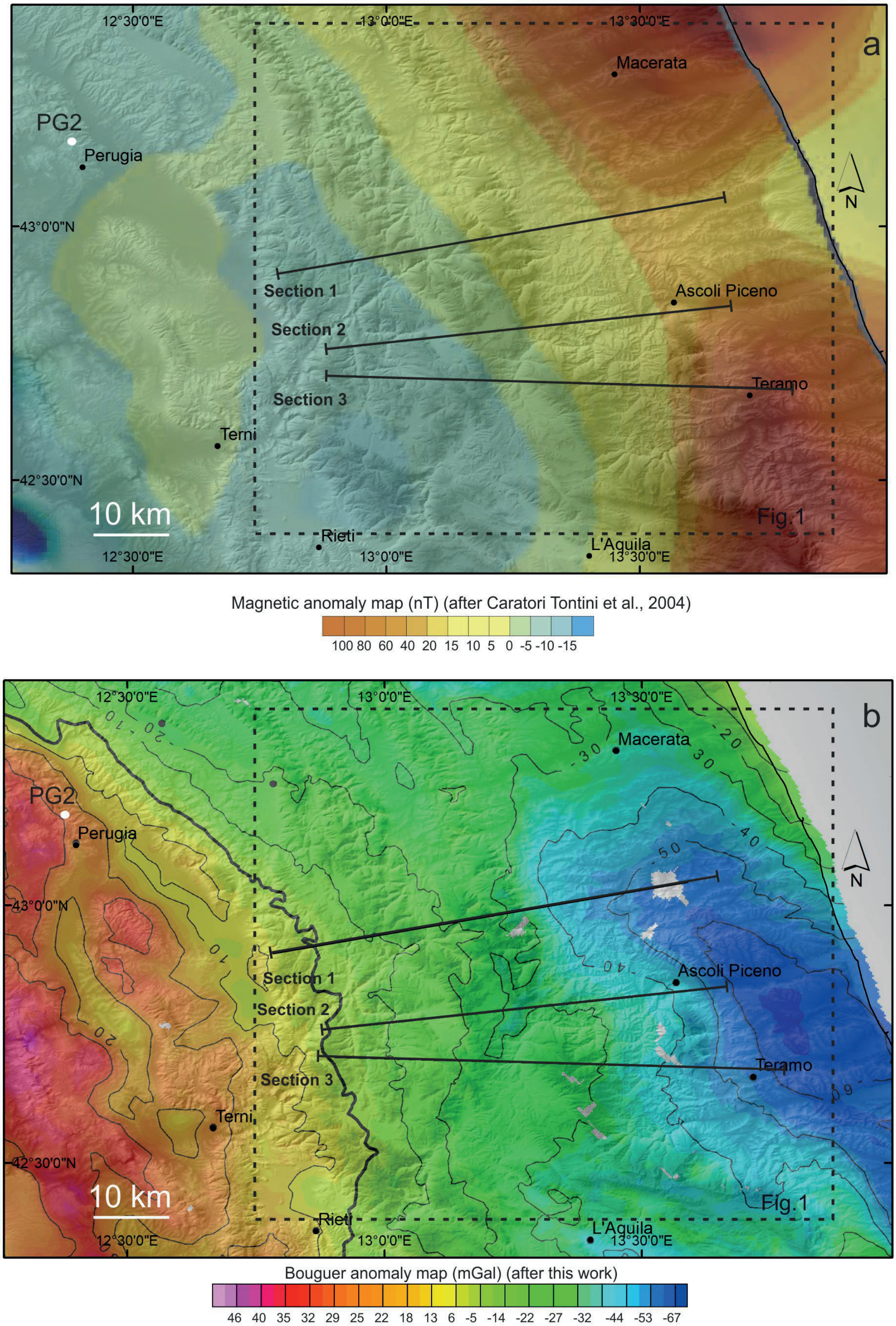

Fig. 2 - (a) Magnetic anomaly map after Caratori Tontini *et al*. (2004) covering the study area. (b) Bouguer anomaly map as obtained after interpolation of ~50,000 data points. Black bold isoline in (b) represents the zero-gravity anomaly. White dots locate the Perugia 2 borehole. Basemap topography is from Tarquini *et al*. (2007; 2012).

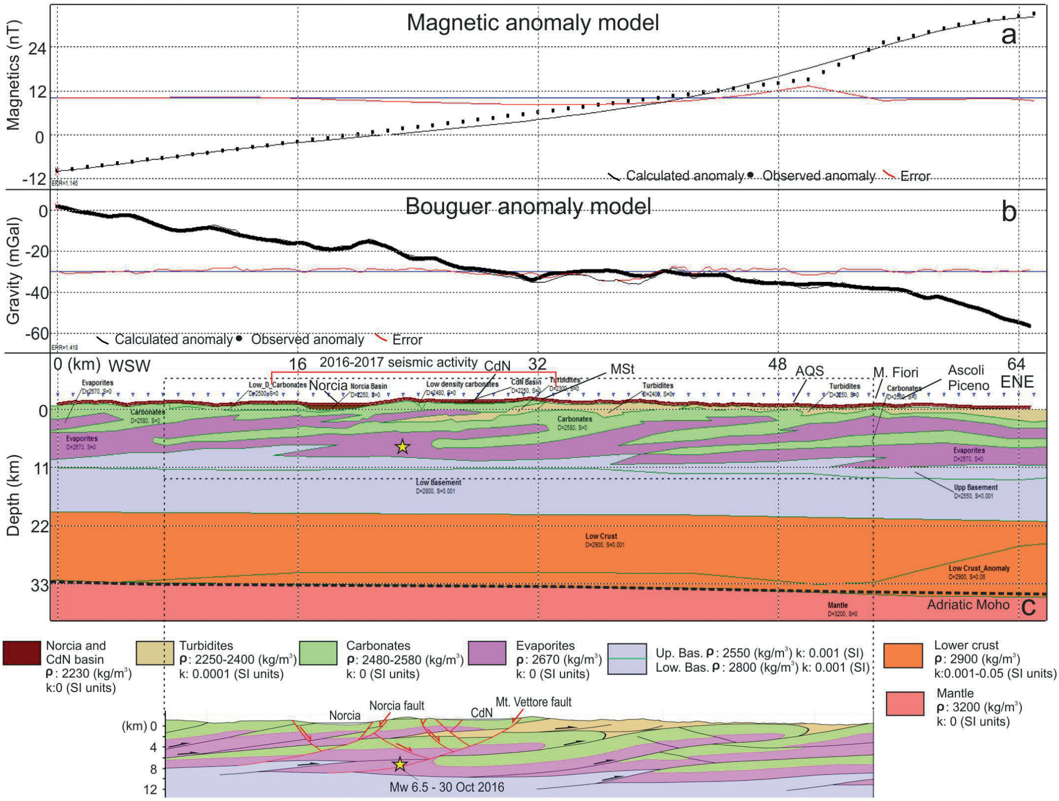

Fig. 3 - Combined gravity and magnetic anomaly on section 2. (a) Magnetic modeling. (b) Bouguer modeling. (c) Modelled blocks. The geological model after Porreca et al. (2018) is reported at the bottom of the figure. The star locates the projected Mw 6.5 30 October 2016 event. ϱ and k for the modeled units are given in the Figure. CdN: Castelluccio di Norcia basin, AQS: Acquasanta thrust, MSt: Mount Sibillini thrust. ϱ of the turbidites range from 2300 kg m^{-3} in the central part of the section, to 2400 kg m^{-3} east of the MSt to 2250 kg m^{-3} further east from 41 km to end of the section. Lower ϱ (2480 kg m^{-3}) for the carbonates are found between 8 and 20 km along section model and between the Norcia and CdN basins and from surface to ~0 km in depth. Black dashed line in (c) locates the Curie isotherm (600 °C).

al., 2017) - and the spatial distribution of the top of the basement as resulting from our models, we believe that these models, by constraining the top of the basement in the area, provide also constraints to the seismicity cutoff for the 2016-2017 sequence. These findings highlight the lithologic control exerted by the sedimentary cover on the extensional seismogenic layer which is mainly confined in the Meso-Cenozoic sequences across the entire area.

Acknowledgments. We thank eni for providing the gravity anomaly data covering the area. The data integration was carried out using the MOVE 2017 © Midland Valley Exploration Ltd.

References

Bally, A. W., Burbi, L., Cooper, C., & Ghelardoni, R. (1986), Balanced cross-sections and seismic reflection profiles across the Central Apennines. Memorie della Società Geologica Italiana, 35, 257-310.

Barchi, M. R., Landuzzi, A., Minelli, G., & Pialli, G. (2001). Outer northern Apennines. In anatomy of an orogen: The Apennines and adjacent Mediterranean Basins (pp. 215–253). Netherlands: Springer.

Barchi, M. R. & Mirabella, F. (2009), The 1997-98 Umbria-Marche earthquake sequence: "Geological" vs. "seismological" faults. Tectonophysics, 476, 170-179. doi:10.1016/j.tecto.2008.09.013

Barchi, M. R. (2010), The Neogene-Quaternary evolution of the Northern Apennines: crustal structure, style of deformation and seismicity. Journal of the virtual explorer 36 (10), doi:10.3809/jvirtex.2010.00220

Bigi, S., Casero, P., & Ciotoli, G. (2011). Seismic interpretation of the Laga basin; constraints on the structural setting and kinematics of the central Apennines. Journal of the Geological Society, 168(1), 179–190. https://doi.org/10.1144/0016-76492010-084.

Caratori Tontini, F., Stefanelli, P., Giori, I., Faggioni, O. & Carmisciano C. (2004). The revised aeromagnetic anomaly map of Italy. Annals of Geophysics 47(5), 1547–1555.

Chiaraluce, L., et al. (2017), The 2016 Central Italy Seismic Sequence: A First Look at the Mainshocks, Aftershocks, and Source Models. Seismological Research Letters, 88(3), 757–771. https://doi.org/10.1785/0220160221

Lavecchia, G., Brozzetti, F., Barchi, M., Keller, J., & Menichetti, M. (1994). Seismotectonic zoning in east-central Italy deduced from the analysis of the Neogene to present deformations and related stress fields. Geological Society of America Bulletin, 106, 1107–1120.

Porreca, M., Minelli, G., Ercoli, M., Brobia, A., Mancinelli, P., Cruciani, F., Giorgetti, C., Carboni, F., Mirabella, F., Cavinato, G., Cannata, A., Pauselli, C., & Barchi, M.R. (2018), Seismic reflection profiles and subsurface geology of the area interested by the 2016-2017 earthquake sequence (Central Italy). Tectonics, doi: 10.1002/2017TC004915

Tarquini, S., Isola, I., Favalli, M. and Boschi, E. (2007). TINITALY/01: a new Triangular Irregular Network of Italy. Annals of Geophysics, 50-3.

Tarquini S., Vinci S., Favalli M., Doumaz F., Fornaciai A., Nannipieri L., (2012). Release of a 10-m-resolution DEM for the Italian territory: Comparison with global-coverage DEMs and anaglyph-mode exploration via the web. Computers and Geosciences 38, 168-170. doi:10.1016/j.cageo.2011.04.018.

Tinti, E., Scognamiglio, L., Michelini, A., & Cocco, M. (2016), Slip heterogeneity and directivity of the ML 6.0, 2016, Amatrice earthquake estimated with rapid finite-fault inversion. Geophysical Research Letters, 43(20), 10,745-10,752. https://doi.org/10.1002/2016GL071263