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Imaging the polarity switch between large seismogenic normal faults in the southern Apennines (Italy)

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Abstract: The transition between the central and southern Apennines (Italy) is marked, among other regional features, by a dramatic shift (from SW-dipping to NE-dipping) of the vergence of the large (more than 25 km long) seismogenic normal faults, responsible for M>6 pre-historical and historical earthquakes. Also, in the exact area where such accommodation occurs, in 2005 a low magnitude (M<3) seismic sequence took place along a short stretch of a long-lived transverse structure running across this transition zone. We believe this sequence sheds light on the geometry and the role of the interaction between these seismogenic domains.

Keywords: seismogenic source, transfer zone, seismic sequence, southern Italy.

The backbone of Italy's Apennines hosts the majority of the seismic moment release in the Italian peninsula (Boschi *et al.*, 2000; Gruppo di Lavoro CPTI, 2004; Guidoboni *et al.*, 2007). In particular, the area among the southern Abruzzo, southeastern Lazio and Molise regions in central-southern Italy includes the polarity switch, from north to south, between the large SW-verging seismogenic normal faults (the southernmost one being the Aremogna-Cinque Miglia, responsible for a Mw 6.4 event dated 800 BC-1030 AD) (D'Addezio *et al.*, 2001; DISS Working Group, 2007; Basili *et al.*, 2008) and those NE-verging ones (the northernmost one being the Boiano Basin, responsible for the July, 26th 1805, Mw 6.6 Molise earthquake) (Cucci *et al.*, 1996; DISS Working Group, 2007; Basili *et al.*, 2008), including the Carpino-Le Piane fault system (Di Bucci *et al.*, 2005) (Figs. 1 and 2). Moreover, the area between these two faults is the locus of extension parallel to the chain axis, as shown by a low-magnitude (M<3.3) seismic sequence occurred in 2001 (Milano *et al.*, 2005). As GPS data illustrate, NE-SW striking extension predominates in the western and the inner sectors of the Apennines (Serpelloni *et al.*, 2005).

All active normal faults along the crest of the Apennines are essentially parallel to the mountain range (NW-SE) and are governed by the current extensional regime (for a summary see DISS Working Group, 2007; Basili *et al.*, 2008) that has been in place since the Middle-Upper Pleistocene (Hippolyte *et al.*, 1994). However, the occurrence of such polarity switch between antithetic, conjugate seismogenic normal faults in Italy is very uncommon - probably it can be found only in another case at the tip of the southern Apennines. In addition, the area of research marks the abrupt end of the two (three?) sub-parallel seismogenic belts in Abruzzo (to the north) and the inception of the single, aligned one in Molise (to the south), including the western termination of E-W-striking, large oblique-slip faulting in the foreland

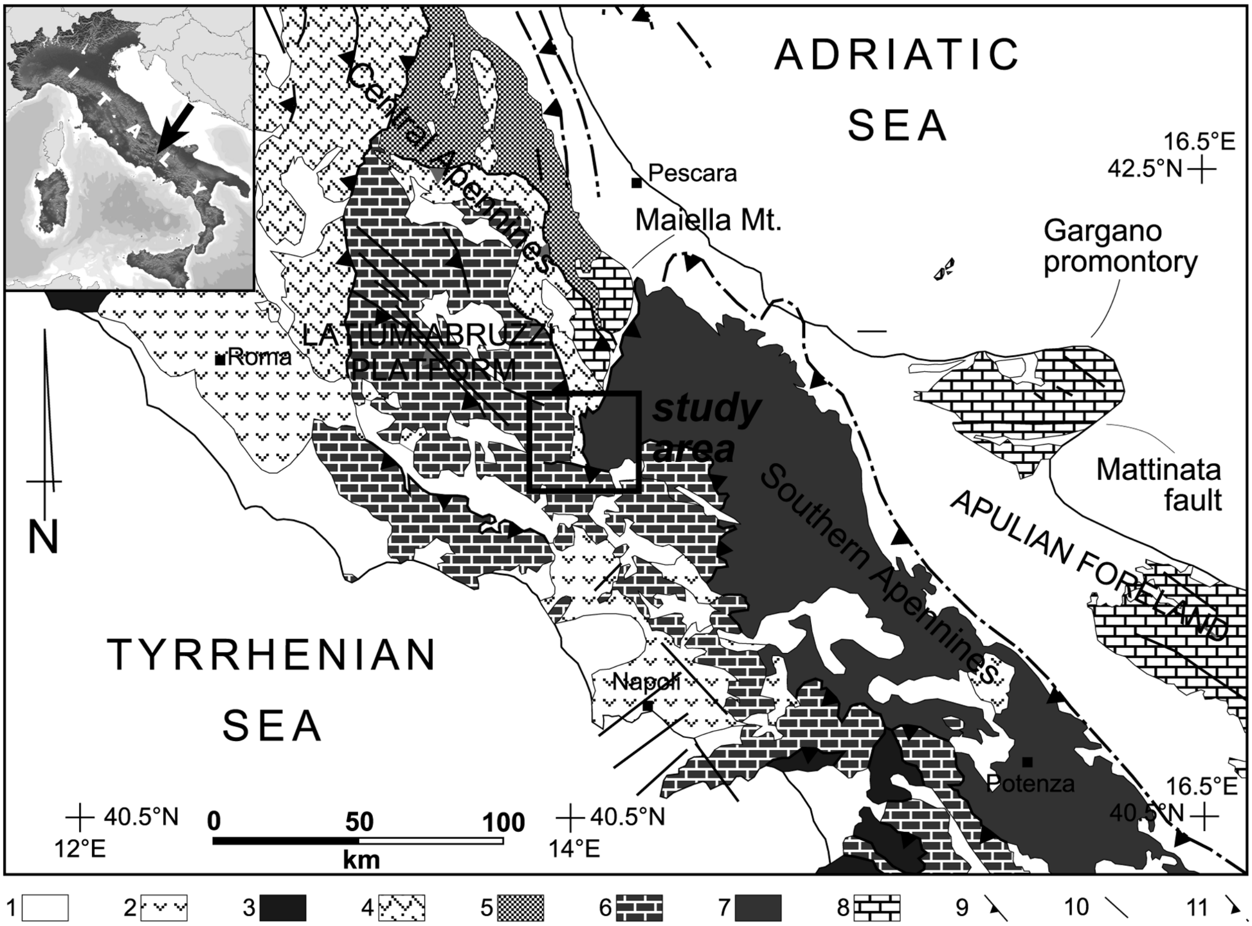

Figure 1. Geological sketch of the Italian peninsula showing the main tectonic units. The research area lies among the Molise units and the deposits of the Latium-Abruzzi carbonate platform (modified from Butler *et al.*, 2004). 1: Plio-Quaternary terrigenous deposits; 2: magmatic units; 3: Liguride units; 4: Umbria-Marche pelagic basin; 5: Laga Fm; 6: Molise-Sannio-Lagonegro pelagic basin; 7: Apennine carbonate platform and foredeep; 8: Apulian carbonate platform; 9: main thrust fronts; 10: main faults (normal and strike-slip); 11: main buried thrust fronts.

(data from DISS Working Group, 2007; Fracassi and Valensise, 2007; Basili *et al.*, 2008; and references therein). In other words, this is a critical area concerning seismogenesis in central Italy and, therefore, the tectonic mechanism that either causes or influences such polarity switch could represent a key ingredient in the above scenario.

Data

Between January and May 2005, the RSN (Italy's National Seismometric Network) recorded a rise in the background seismicity, that has been recently relocated by Milano *et al.* (2008) (Fig. 2), This sequence is essentially a low magnitude (M<3), swarm activity that clustered within the Ortona-Roccamonfina line, a regional structure striking NNE-SSW and separating the central from the southern Apennines, hypothesized and discussed by numerous authors (Locardi, 1982, 1988; Patacca and Scandone, 1989; Di Bucci and Tozzi, 1991).

Analysis and discussion

According to Locardi (1982), the Ortona-Roccamonfina is a crustal right-lateral, strike-slip lineament active during the Pliocene. The presence of such major fault has been based on evidence from subsurface, gravimetric, aeromagnetic and remote sensing data, and has been inferred from geodynamic and paleo-geographic history of the Italian peninsula. Although Locardi (1982, 1988) claims that the Ortona-Roccamonfina line straddles the full width of central-southern, its field evidence is still debated, as much as its present-day activity (Di Bucci and Tozzi, 1991). Our data show that, at least in the area where the 2005 sequence has occurred, the spatial trend of seismic activity essentially coincides with a sector of the Ortona-Roccamonfina line.

Concerning fault polarity switches, there are numerous case-studies in the literature where such examples have been recognized and associated with accommodation zones (see McClay and White, 1995, and references therein). Various authors have shown that either a hard (transfer fault) or soft linkage (relay ramp) is kinematically needed to accommodate strain between the two faults (e.g. Ramsay and Huber, 1987; Rosendahl, 1987; Hancock, 1994). This would be particularly true in the case we present, i.e. with two large (~20-25 km long) convergent, approaching faults, at a distance (20-25 km) comparable in size to the length of the faults in question (Morley, 1988; Morley *et al.*, 1990, McClay, 1995). According to these literature models for transfer zones, such transfer would occur at ~45° to the strike of the concerned faults, that is ~N-S in the studied area.

However, one has to take into account that the Aremogna-Cinque Miglia fault lies within the Latium-Abruzzi carbonate platform, a broad, thick tectonic edifice, while the Boiano basin fault occurs within the Molise-Sannio-Lagonegro diverse basin units. The remarkable degree of tectonic complexity, the role of inherited geology, and the crucial difference among the paleogeographic and topographic domains in this region has been thoroughly addressed in the literature (for a summary see Butler *et al.*, 2004; Di Luzio *et al.*, 2008; Patacca *et al.*, 2008).

Last but not least, while the transfer zone model is a proven one and suits the geometry, kinematics and

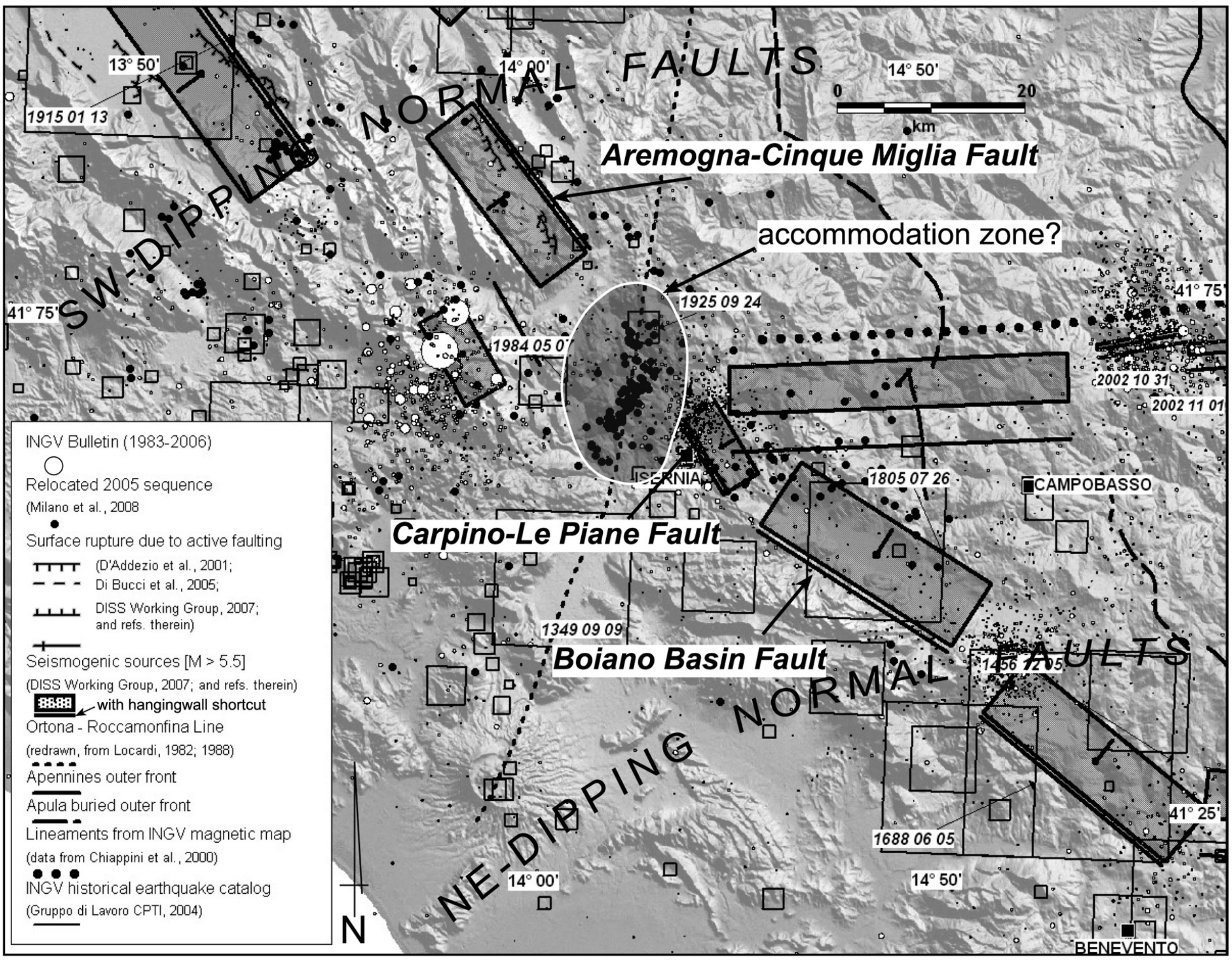

Figure 2. Map showing location of the 2005 sequence we discuss with respect to the pattern of M>5.5 seismogenic normal faults at the transition between the central and southern Apennines. Despite the very complex geology of this area that results from a poly-phased tectonic history, we show only fault segments that have been recognized in the literature to be active and, where known, seismogenic. Size of black squares (historical earthquakes, with dates) is proportional to magnitude.

spatial arrangement of the two conjugate faults we study, the timing of activity is not a straightforward issue. If the Aremogna-Cinque Miglia and the Boiano basin faults are linked (be it either by hard or soft transfer), there is an apparent "activity hiatus" of some 2000 years. Although one would expect a semi-contemporaneous activation of all segments involved in the linked system (the two major faults and the transfer zone), it is not clear whether such "apparent hiatus" is relevant to the case studied –or should not be regarded as a hiatus at all. The time resolution of seismogenic faults (10^3 a) is at least one order of magnitude smaller than that involved by the models of fault linkage (10^4 a) –not to mention instrumental seismicity–, so addressing active linkage using a known structural model could be beyond the geological resolution of the tectonic mechanism causing it. In other words, we believe that the difference in timing among the Aremogna-Cinque Miglia and the Boiano Basin faults and with the hypothesized transfer would not rule out the accommodation zone model.

Conclusions

The location of the clustered seismicity that occurred in 2005 between the Abruzzo and Molise regions shows a ~NNE-SSW alignment and falls within the area where a major polarity switch between large seismogenic faults occur. On the basis of: i) the spatial-temporal characteristics of this data, and ii) the geometry and kinematics of active faulting in the region, we hypothesize: a) the existence of a transfer zone between the Aremogna-Cinque Miglia and Boiano Basin faults, and b) the activity of such linkage along the Ortona-Roccamonfina line in this sector of the chain where a major transition, both structural and seismogenic, occurs.

Alternatively, this polarity switch could result mainly from the rheologic and tectonic control exerted by the abrupt passage between the two diverse paleogeographic domains that make up the boundary between the central and southern Apennines. The role of such possible control onto the nature and geometry of the transfer zone and their interaction with one another, including seismic activity, is part of a larger study currently underway.

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References

Basili R., Valensise, G., Vannoli, P., Burrato, P., Fracassi, U., Mariano, S. and Tiberti, M. M. (2008): The Database of Individual Seismogenic Sources (DISS), version 3: summarizing 20 years of research on Italy's earthquake geology. *Tectonophysics*, 453: 20-43. doi: 10.1016/j.tecto.2007.04.014.

Boschi, E., Guidoboni, E., Ferrari, G., Mariotti, D., Valensise, G. and Gasperini, P. (2000): Catalogue of strong italian earthquakes from 461 B.C. to 1997. *Ann. Geophys.*, 43, 259 pp.

Butler, R. W. H., Mazzoli, S., Corrado, S., De Donatis, M., Scrocca, D., Di Bucci, D., Gambini, R., Naso, G., Nicolai, C., Shiner, P. and Zucconi, V. (2004): Applying thick-skinned tectonic models to the Apennine thrust belt of Italy – Limitations and implications. In: K. R. McClay (ed): *Thrust tectonics and hydrocarbon systems*, *AAPG Mem.*, 82: 647-667.

Chiappini, M., Meloni, A., Boschi, E., Faggioni, O., Beverini, N., Carmisciano, C. and Marson, I. (2000): Shaded relief magnetic anomaly map of Italy and surrounding marine areas. *Ann. Geophys.*, 43: 983-989.

Cucci, L., D'Addezio, G., Valensise, G. and Burrato, P. (1996): Investigating seismogenic faults in Central and Southern Apennines (Italy): modeling of fault-related landscape features. *Ann. Geofis.*, 39: 603-618.

D'Addezio, G., Masana, E. and Pantosti, D. (2001): The Holocene paleoseismicity of the Aremogna – Cinque Miglia Fault (Central Italy). *J. Seismolog.*, 5: 181-205. doi: 10.1023/A:1011403408568.

Di Bucci, D. and Tozzi, M. (1991): La linea "Ortona-Roccamonfina": revisione dei dati esistenti e nuovi contributi per il settore settentrionale (media Valle del Sangro). *Stud. Geol. Cam.*, Vol. Spec. 1991/2, CROP 11: 397-406.

Di Bucci, D., Naso, G., Corrado, S. and Villa, I. M. (2005): Growth, interaction and seismogenic potential of coupled active normal faults (Isernia Basin, Central-Southern Italy). *Terra Nova*, 17: 44-55. doi: 10.1111/j.1365-3121.2004.00582.x.

Di Luzio, E., Mele, G., Tiberti, M. M., Cavinato, G. P. and Parotto, M. (2008): Moho deepening and shallow upper crustal delamination beneath the central Apennines. *Earth Planet. Sc. Lett.* doi: 10.1016/j.epsl.2008.09.018.

DISS Working Group (2007): *Database of Individual Seismogenic Sources (DISS)*, Version 3.0.4: A compilation of potential sources for earthquakes larger than M 5.5 in Italy and surrounding areas. http://www.ingv.it/DISS/, © INGV 2007 – Istituto Nazionale di Geofisica e Vulcanologia - All rights reserved.

Fracassi U. and Valensise, G. (2007): Unveiling the sources of the catastrophic 1456 multiple earthquake: Hints to an unexplored tectonic mechanism in Southern Italy. *B. Seismol. Soc. Am.*, 97: 725-748. doi: 10.1785/0120050250.

Gruppo di Lavoro CPTI (2004): *Catalogo Parametrico dei Terremoti Italiani, versione 2004 (CPTI04)*. INGV, Bologna. http://emidius.mi.ingv.it/CPTI/

Guidoboni E., Ferrari, G., Mariotti, D., Comastri, A., Tarabusi, G. and Valensise, G. (2007*): CFTI4Med, Catalogue of Strong Earthquakes in Italy (461 B.C.-1997) and Mediterranean Area (760 B.C.-1500)*. INGV-SGA. Available from http://storing.ingv.it/cfti4med/.

Hancock, P.L. (1994): *Continental deformation*. Pergamon Press, Oxford, 421 pp.

Hippolyte, J. C., Angelier, J. and Roure, F. (1994): A major geodynamic change revealed by Quaternary stress patterns in the Southern Apennines (Italy). *Tectonophysics*, 230: 199-210.

Locardi, E. (1982): Individuazione di Strutture sismogenetiche dall'esame dell'evoluzione vulcanotettonica dell'Appennino e del Tirreno. *Mem. Soc. Geol. Ital.*, 24: 569-596.

Locardi, E. (1988): The origin of the Apenninic Arcs. *Tectonophysics*, 146: 105-123.

McClay, K. R. and White, M. (1995): Analogue modelling of orthogonal and oblique rifting. *Mar. Petrol. Geol.*, 12: 137-151.

Milano, G., Di Giovambattista, R. and Ventura, G. (2005): The 2001 seismic activity near Isernia (Italy): Implications for the seismotectonics of the Central-Southern Apennines. *Tectonophysics*, 401: 167-178. doi: 10.1016/j.tecto.2005.03.010.

Milano, G., Di Giovambattista, R. and Ventura, G. (2008): Seismic activity in the transition zone between Southern and Central Apennines (Italy): evidences of longitudinal extension inside the Ortona-Roccamonfina tectonic line. *Tectonophysics*, 457: 102-110. doi: 10.1016/j.tecto.2008.05.034.

Morley, C. K. (1988): Variable Extension in Lake Tanganyika. *Tectonics*, 7: 785-801.

Morley, C. K., Nelson, R. A., Patton, T. L. and Munn, S. G. (1990): Transfer zones in the East African rift system and their relevance to hydrocarbon exploration in rifts. *AAPG Bull.*, 74: 1234-1253.

Patacca, E. and Scandone, P. (1989): Post-Tortonian mountain building in the Apennines. The role of the passive sinking of a relic lithospheric slab. In: A. M. Boriani, M. Bonafede, G. B. Piccardo and G. B. Vai (eds): *The lithosphere in Italy*: 157-176.

Patacca, E., Scandone, P., Di Luzio, E., Cabinato, G. P. and Parotto, M. (2008): Structural architecture of the central Apennines: Interpretation of the CROP 11 seismic profile from the Adriatic coast to the orographic divide. *Tectonics*, 27: TC3006. doi: 10.1029/2005TC001917.

Ramsay, J. G. and Huber, M. I. (1987): *The techniques of modern structural geology, Volume 2: folds and fractures*. Academic Press, London, U.K., 700 pp.

Rosendahl, B. L. (1987): Architecture of continental rifts with special reference to east Africa. *Annu. Rev. Earth Pl. Sc.*, 15: 445-503.

Serpelloni, E., Anzidei. M., Baldi, P., Casula, G. and Galvani, A. (2005): Crustal velocity and strain rate fields in Italy and surrounding regions: new results from the analysis of permanent and non-permanent GPS networks. *Geophys. J. Int.*, 161: 861-880. doi: 10.1111/j.1365-246X.2005.02618.x.