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 verging of the large (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 accommodation zone between these seismogenic domains.

Keywords: seismogenic sources, transfer zone, relay ramp, seismic sequence, southern Italy

Introduction
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 B.C-1030 A.D.; 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 26 July 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). Also, 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: 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 one other 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 (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 (Md < 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; Locardi, 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, 1987) 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 (i.e., 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 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: 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 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 (1805 A.D. - 800 B.C÷1030 A.D., i.e. 1805 - 115±915). 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 (10³- yrs) is at least one order of magnitude smaller than that involved by the models of fault linkage (10⁴+) – 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


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Figure captions

**Fig. 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 (mod., from Butler et al., 2004). 1: Plio-Quat. 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.

**Fig. 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.
Fig. 1
Fig. 2