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A soft linkage between major seismogenic fault systems in the central-southern Apennines (Italy): Evidence from low-magnitude seismicity

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ABSTRACT

We investigate the transfer zone and linkage between divergent extensional seismogenic fault systems on the border amid the central and southern Apennines (central Italy). These regional NW–SE striking sets include large seismogenic sources that caused major historical earthquakes ($M_w \leq 7$). The faults in the northern part of the study area dip to the southwest; those in the southern part dip to the northeast. The SW-dipping system (Abruzzi Apennines) terminates with the Aremogna–Cinque Miglia source; the NE-dipping system (southern Apennines) terminates with the Boiano Basin source.

To test whether the transfer zone model applies to the central-southern Apennines border, we analyzed and relocated seismicity that occurred from 2007 to 2011 between the Aremogna–Cinque Miglia and Boiano Basin sources, where we expect the transfer zone. Seismicity is made of independent events (MD < 3.5) and low-magnitude swarms. West of the Apennines, hypocenters are located within the uppermost 12–13 km. Events and swarms that occurred east of the axis affect the 13–25 km below. West of the chain, focal mechanisms show T-axes striking ~NNW–SSE. East of the chain, T-axes strike ~NE–SW. This trend is consistent with GPS data. The hypocentral distribution of swarms located between the Aremogna–Cinque Miglia and Boiano Basin sources shows a ~NNE–SSW trend, coincident with part of the Ortona–Roccamonfina Line, a regional transverse lineament.

The spatial distribution of seismicity, the geometry and kinematics of active faulting in the region, and the results from previous geophysical studies allow us to contend the existence of a transfer zone between these seismogenic normal fault systems. Our data also allow us to recognize the activity of such transfer along the central part of the Ortona–Roccamonfina Line. We infer that reverse in dip polarity between the two normal fault systems could also result from the passage between the diverse tectonic units composing the border between central and southern Apennines.

1. Introduction

Straddling the entire Italian peninsula and beyond, the Apennines ridge hosts the majority of Italy's seismic moment release (see Boschi et al., 2000; Guidoboni et al., 2007; Rovida et al., 2011). Active normal faults along the crest of the Apennines are sub-parallel to the NW–SE striking mountain range and are controlled by the current large-scale, NE–SW trending extensional regime (for a summary: Basili et al., 2008; Devoti et al., 2008, 2011; DISS Working Group, 2010; Petricca et al., 2013; Pierdominici and Heidbach, 2012). The area among the southern Abruzzi, northern Campania, southeastern Lazio and southwestern Molise regions is the border between the central and southern Apennines and encompasses a large section of the Ortona–Roccamonfina Line, a regional structure striking NNE–SSW discussed by numerous authors (Fig. 1; Centamore and Rossi, 2009; Di Bucci and Tozzi, 1991; Ghisetti and Vezzani, 1997; Locardi, 1982, 1988; Milano and Di Giovambattista, 2011; Milano et al., 2008; Patacca et al., 1991; Peccerillo, 2005; Pizzi and Galadini, 2009; Rosenbaum et al., 2008; Sani et al., 2004; Satolli and Calamita, 2008; Vannoli et al., 2012; Vezzani and Ghisetti, 1998).

This border marks the termination of three sub-parallel seismogenic fault sets (i.e., fault systems including faults either associated with or deemed capable of generating $M_w > 5.5$ earthquakes — modeled as seismogenic sources; see Basili et al., 2008) in the Abruzzi (to the north) and one in Molise (to the south), trending NW–SE. It also occurs near the western termination of the ca. E–W striking deep-seated Molise–Gondola shear zone (see *MGsz* in Fig. 1; Basili et al., 2008; Di Bucci et al., 2006b; DISS Working Group, 2010; Fracassi and Valensise, 2007; Valensise et al., 2004; Vallée and Di Luccio, 2005). The termination

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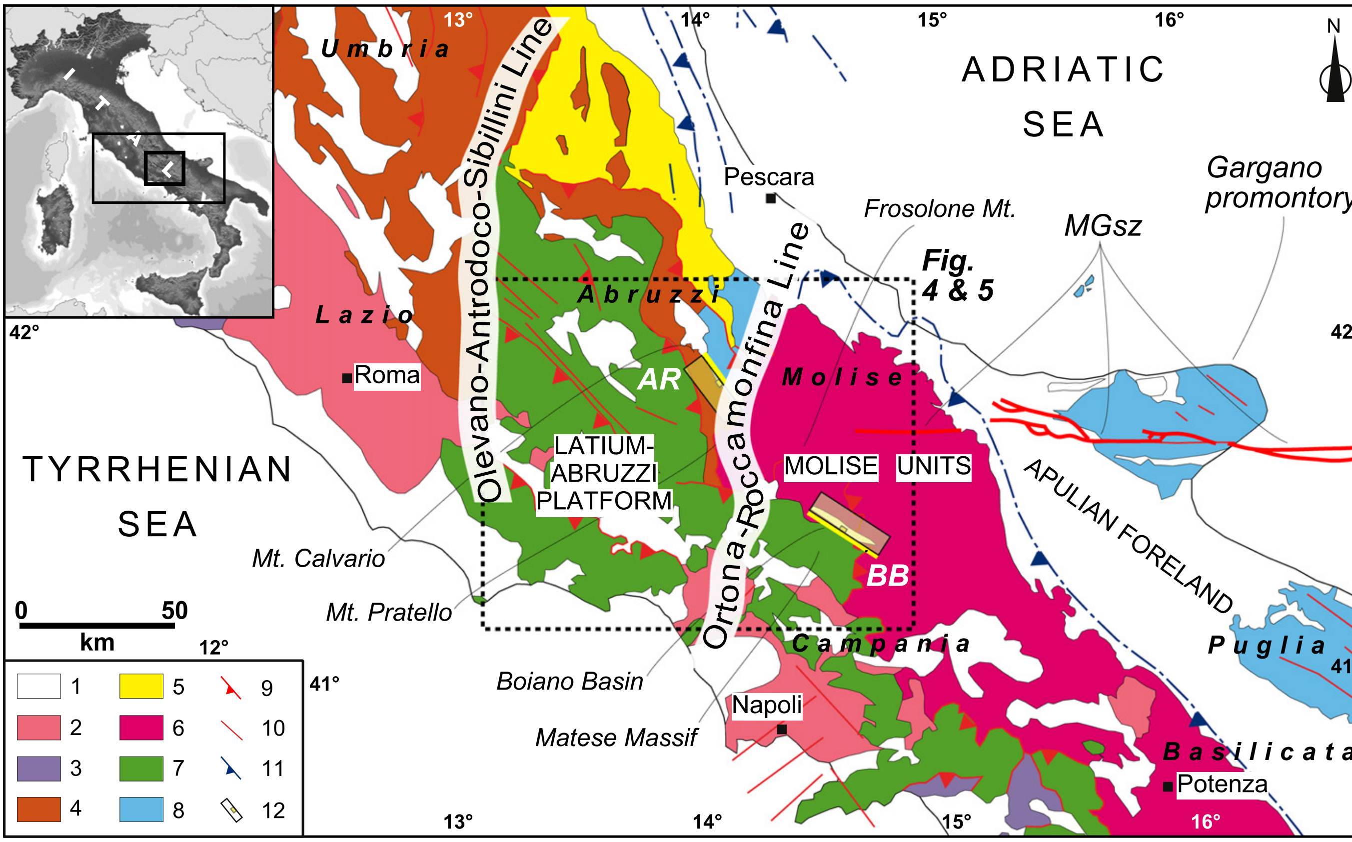

Fig. 1. Geological sketch of the central Italian peninsula, showing the main tectonic units. Study area, shown by box, includes Molise basin units and deposits of the Latium–Abruzzi carbonate platform (mod., after Butler et al., 2004). 1: Plio-Quaternary terrigenous deposits; 2: magmatic units; 3: Liguride 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: major thrust fronts; 10: major normal and strike-slip faults; 11: major buried thrust fronts; 12: seismogenic sources (AR and BB in figure indicate Aremogna–Cinque Miglia and Boiano Basin faults, respectively). MGsz: Molise–Gondola shear zone (mod., after Di Bucci et al., 2006b). The swaths of the Olevano–Antrodoco–Sibillini Line (to the northwest) and of the Ortona–Roccamonfina Line (to the southeast) are redrawn after Centamore and Rossi (2009).

of the NW–SE striking fault system is characterized by the change in polarity of faulting from SW-dipping seismogenic normal faults in the north to NE-dipping ones in the south. The southernmost end of the northern group is the Aremogna–Cinque Miglia source, responsible for a M_w 6.4 event dated 800 B.C.–1030 A.D. (Fig. 1; D'Addezio et al., 2001; Giraudi, 1989, 1995); the northernmost termination of the southern set is the Boiano Basin source, responsible for the 26 July 1805, M_w 6.6 Molise earthquake (Fig. 1; Cucci et al., 1996; Di Bucci et al., 2005). The area between these two major faults is the locus of local, small-scale NE–SW striking extension, orthogonal to the one prevailing along the chain axis (Milano et al., 2005, 2008). In contrast, NE–SW striking extension predominates in the western and the inner sectors of the central and southern Apennines, as shown by GPS data and crustal models (Angelica et al., 2013; Anzidei et al., 2005; Babbucci et al., 2004; Barba et al., 2010; Carafa and Barba, 2013; Devoti et al., 2008, 2011; Hunstad et al., 2003; Petricca et al., 2013; Pierdominici and Heidbach, 2012; Serpelloni et al., 2005, 2007). Finally, numerous puzzling historical earthquakes ($5.2 < M_w < 6.2$) characterize this narrow region, and still lack an explanation both convincing and compatible with known seismogenic normal faulting. Due to its complexity, this area seems to be a seismotectonic "hot spot" in Italy, with the occurrence of regional transverse features that appear to play a role, to-date unclear.

The mechanism by which seismogenic normal faults in Italy exhibit opposite polarity along strike has thus far been ignored. Besides few case studies that focused on specific faults (for instance, Di Bucci et al., 2006a; Galli et al., 2011), research on the occurrence of transfer zones in peninsular Italy is quite uncommon. This is all the more true if one concentrates on normal faults longer than 20–25 km with opposite polarity along strike, such as the Aremogna–Cinque Miglia and the Boiano sources. In the words of Morley et al. (1990), transfer zones consist of "conservation of fault displacement in three dimensions" occurring between the terminations of adjacent faults that can dip in either the same direction or not (Fig. 2). Although first studied in thrust belts (Dahlstrom, 1970), transfer zones belong to virtually every tectonic regime. For instance, they occur between normal fault segments that either 1) laterally overlay/overstep enough to interfere kinematically with each other, or 2) whose respective geometry creates a restricted region, where stress/deformation is being transferred from one fault to the other (McClay, 1995). Several field cases worldwide show that to accommodate strain between the two faults requires either a hard (transfer fault) or soft (relay ramp) linkage (Bose and Mitra, 2010; Davison, 1994; Gawthorpe and Hurst, 1993; Matmon et al., 2010; McClay and White, 1995; Morley, 1988; Morley et al., 1990; Schlische and Withjack, 2009).

Despite numerous geophysical and geological studies probed the border between the central and southern Apennines, some key issues seem to never have been addressed. Among them: 1) What controlled the development and the boundary of the two adjacent, divergent seismogenic normal fault sets (sensu Morley, 1988)? 2) Does such boundary result from a mere transition between tectonic units, or is it rather the expression of a regional discontinuity crossing the Apennines that could be the source of damaging earthquakes? 3) The transfer zone model was extensively studied in passive margins, characterized by competent units and clear long-term landscape signatures; does such model apply to the boundary between the central and southern Apennines, with its tectonic complexity and superposed landscapes? 4) Does a transfer zone between two adjacent, divergent seismogenic normal faults require seismological evidence of activity — or could it be quiescent, maybe accompanied by low-magnitude seismicity?