Tectonophysics 621 (2014) 101–122

Contents lists available at ScienceDirect

Tectonophysics

journal homepage: www.elsevier.com/locate/tecto

Rates of geodetic deformation across active faults in southern Italy

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ARTICLE INFO

Article history:
Received 8 November 2013
Received in revised form 10 February 2014
Accepted 11 February 2014
Available online 20 February 2014

Keywords:
GNSS velocity
Active fault
Geodetic slip rate
Southern Italy

ABSTRACT

Active deformation in southern Italy is accommodated by a distributed number of faults with low–moderate slip rates. Outcropping extensional faults and mostly blind transcurrent faults are mapped within a western (or axial) and an eastern domain, respectively. We use a combination of continuous (2001.00–2011.84) and episodic (1995.68–2010.79) GNSS observations to firstly estimate the geodetic deformation rate on 32 faults. Geodetic results were successively compared with geological displacement estimates. In agreement with seismological and geological information, a net spatial segregation emerges between the extensional axial belt, and the eastern domain where strike–slip faults are geodetically active. Although uncertainties are at times large, average displacement rates show broadly consistent patterns within both domains. A longitudinal gradient in extension rate is observed for the axial fault array, with two sectors of higher magnitude (~0.8–1.7 mm/yr for individual faults). This result is consistent with geological observations and supports the notion that extension occurs in discrete patches. Faults of the eastern domain have lower (few 0.1 to ~1.2 mm/yr) strike–slip rates and an eastward-decreasing extensional component, but significant geodetic displacement is detected in areas lacking clear evidence of activity. Few faults with 1–2 mm/yr extension rate are locally found in the eastern domain, but, based on their limited length and on inconsistency with seismology and geology, they are considered as due to deep-seated gravitational spreading. For crustal faults, although geodetic slip and moment rates are larger than geological rates, the broad trend of long- to short-term rates is similar, indicating the feasibility of geodetic analysis to contribute estimating fault slip rate and testing tectonic models in the region. Whereas the western domain extension is thought to be controlled by potential energy related to the Tyrrhenian Moho uplift beneath the Apennines, strike–slip in the east is related to shear on inherited faults within the Adriatic crust.

1. Introduction

Southern Italy is characterized as one of the highest seismic hazard in the Mediterranean region, as documented by historical and instrumental catalogs where several large ($6.5 \leq M \leq 7.5$) and destructive events have occurred (Fig. 1; Rovida et al., 2011). Despite that the largest earthquakes have been associated to a causative fault, large uncertainties still exist regarding definition of source geometric, kinematic and energetic parameters (e.g. slip rates); this represents a severe drawback for the growing practice of seismic hazard estimation based on tectonic information for individual seismogenic sources (e.g. Peruzza et al., 2010).

In southern Italy, active faults and focal mechanism solutions of crustal earthquakes define two laterally juxtaposed belts of contemporary deformation, with strike–slip faulting beneath the Apulia plains and plateau to the east, and extension along the axis of the Southern Apennines chain in the west (Figs. 2, 3). The current deformation regime in the Apennines started to form between Late Pliocene–Early Pleistocene, when it replaced contractional tectonics responsible for Neogene accretion of the Southern Apennines fold-and-thrust belt (Fig. 2, inset; Hyppolite et al., 1994; Patacca and Scandone, 2007).

Because of this relatively recent change in tectonic regime, the current deformation pattern in the Apennines is diffuse and is characterized by low geodetic (~3–5 mm/yr) and geologic (1–2 mm/yr) rates (Faure Walker et al., 2012; Ferranti et al., 2008; Giuliani et al., 2009; Palano et al., 2011; Papanikolaou and Roberts, 2007; Serpelloni et al., 2005), and the landscape still bears the dominant signature of contractional tectonics. Consequently, detection and characterization of active and seismogenic faults present significant challenges in the region,

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http://dx.doi.org/10.1016/j.tecto.2014.02.007
0040-1951/

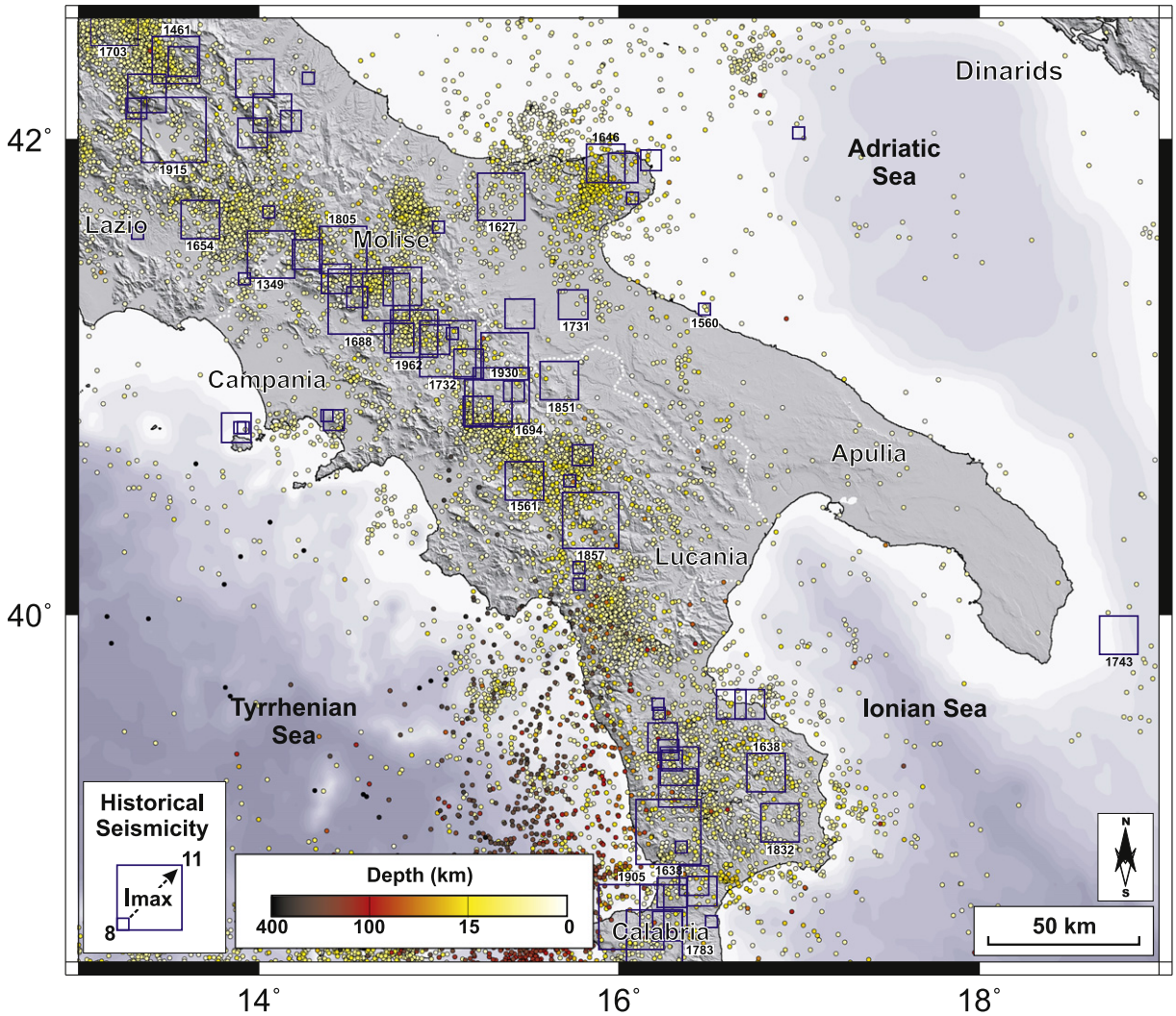

Fig. 1. Instrumental seismicity (M ≥ 2.2) in southern Italy 1983–2012 (http://iside.rm.ingv.it). Blue squares are historical earthquakes from CPTI catalog (Rovida et al., 2011); I_{max}, maximum macroseismic intensity.

and to this end the GNSS (Global Navigation Satellite System; formerly known as GPS) observations can offer a vital contribution.

In the last decade, GNSS data analysis has contributed to the understanding of the pattern of active deformation in southern Italy (D'Agostino et al., 2008; Devoti et al., 2011; Ferranti et al., 2008; Hunstad et al., 2003; Oldow et al., 2002; Palano et al., 2011; Serpelloni et al., 2005). Although published geodetic studies have singled out the regional scale pattern of crustal deformation, the relation between surface displacement and inter-seismic strain accumulation at the scale of individual faults or fault arrays has been established only locally and with a significant uncertainty (Ferranti et al., 2008; Giuliani et al., 2009). In addition, a comparison between geodetic and geologic rates of fault slip has not been attempted yet. The geodetic displacement resolved onto the fault may embed components of seismic and aseismic slip, and of strain accumulation because of block coupling on the fault slip surface; whether this displacement pattern is however representative of the long-term behavior of crustal faults requires comparison of different datasets.

In this paper, we use a dense combination of: *i*) continuous GNSS data collected between 2001.00 and 2011.84 on geodetic networks installed in southern Italy, and *ii*) episodic GNSS measurements collected between 1995.68 and 2010.79, in order to provide the first estimation of geodetic horizontal slip rate on a significant number of active faults. Later, we compare the geodetic results with information obtained from geological studies of active faults with the aim of reconciling contemporary and geologic displacements and provide insights into the pattern of moment accumulation and release over different time spans.

Although our estimation of geodetic displacement is on occasion biased by a considerable uncertainty, results of this study help to refine and implement the poorly constrained magnitude of slip rate on active faults, which is a timely contribution for fault-based seismic hazard assessment in this highly-populated region (e.g. Peruzza et al., 2010, 2011; Roberts et al., 2004). Combination of site velocities with local seismicity and structural studies as discussed in this paper indicates that, although broadly driven by convergence between Europe and Nubia (e.g. the African plate west of the East African Rift), the pattern of crustal displacement in southern Italy is strongly influenced by a combination of processes not immediately related to plate boundary forces, such as crustal delamination and mantle upwelling, and exploitation of intra-plate anisotropy.

2. Regional setting

Southern Italy is floored by the Southern Apennines fold-and-thrust belt in the western and central part, and by the Apulia foreland in the eastern part (Fig. 2, inset). The Southern Apennines accreted from