Tectonophysics 653 (2015) 95–108

Contents lists available at ScienceDirect

Tectonophysics

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

Active deformation and seismicity in the Southern Alps (Italy): The Montello hill as a case study

Stefania Danesi [a,*], Silvia Pondrelli [a], Simone Salimbeni [a], Adriano Cavaliere [a], Enrico Serpelloni [b], Peter Danecek [b], Sara Lovati [c], Marco Massa [c]

[a] Istituto Nazionale di Geofisica e Vulcanologia (INGV), Sezione di Bologna, Via Donato Creti 12, 40128 Bologna (BO), Italy
[b] Istituto Nazionale di Geofisica e Vulcanologia (INGV), Centro Nazionale Terremoti (CNT), Via di Vigna Murata 605, 00143 Roma (RM), Italy
[c] Istituto Nazionale di Geofisica e Vulcanologia (INGV), Sezione di Milano–Pavia, Via Bassini 15, 20133 Milano (MI), Italy

ARTICLE INFO

Article history:
Received 15 July 2014
Received in revised form 26 February 2015
Accepted 2 March 2015
Available online 20 April 2015

Keywords:
Northern Italy
Eastern Southern Alps
Tectonic deformation
Satellite geodesy
Earthquake source observation
Continental neotectonics

ABSTRACT

The Montello anticline is a morphotectonic feature of the east pede-mountain of the South Alpine Chain in northern Italy, which lies ca. 40 km northwest of Venice, Italy. The purpose of this study is to characterize the present-day crustal deformation and seismotectonics of the Montello area through multi-parametric geophysical observations. We used new data obtained from the installation of a temporary network of 12 seismic stations and 6 GPS sites. The GPS observations indicate that there is ~1 mm/yr shortening across the Montello thrust. Sites located north of the Montello thrust front deviate from the ~NNW-ward Adria–Eurasia convergence direction, as they are constrained by a relative rotation pole in northwestern Italy that has a NNE-ward motion trend. Over 18 months, seismographic recordings allowed us to locate 142 local seismic events with Ml 0.5–3.5 with good reliability (rms < 0.5). After cross-correlation analysis, we classified 42 of these events into six clusters, with cross-correlation thresholds >0.80. The source focal solutions indicate that: (i) there is thrusting seismic activity on the basal, sub-horizontal, portion of the Montello structure; and (ii) strike-slip source kinematics prevail on the western edge of the Montello hill. Our observations on the source mechanisms and the measured crustal deformation confirm that the Montello thrust is tectonically active.

1. Introduction

The north-east of Italy, and in particular the Veneto and Friuli pede-mountain areas, has been repeatedly hit by strong earthquakes (CPTI11, Rovida et al., 2011). These have generally been associated with the south-verging thrust faults that characterize the east South Alpine Chain (Fig. 1). This area is characterized by a notable seismic risk, due to the high seismic hazard of northeastern Italy (http://zonesismiche.mi.ingv.it/), the elevated density of the population, and the diffuse industrial activities.

From a geodynamic point of view, the north-east of Italy is involved in the general process of convergence between the Adria micro-plate and Eurasia (e.g., Battaglia et al., 2004; D'Agostino et al., 2005, 2008; Serpelloni et al., 2005). GPS data have suggested that the Adriatic region is composed of at least two smaller tectonic blocks (i.e., Adria to the north, Apulia to the south; see also D'Agostino et al., 2008), where the northern tectonic block rotates counterclockwise with respect to the Eurasian plate, around a rotation pole in north-west Italy. This means that in this region, the rates of convergence between the northern Adriatic domain and the Alps increase from west to east, by up to 1.5 mm/yr to 2.0 mm/yr (D'Agostino et al., 2005).

Within this framework, the Montello hill, which is located immediately south of the pede-mountain Alpine front, ca. 40 km north-west of Venice, is the most external tectonic feature of the South Alpine fold-and-thrust belt. The Montello hill is considered to be an example of an actively growing ramp anticline (Benedetti et al., 2000), which is a geomorphic body that was created by the deformation that has accumulated on a south-verging thrust known as the Montello thrust (Fig. 1, inset). The tectonic activity of this whaleback-shaped, WSW–ENE-elongated hill has been studied from the geological and geomorphological points of view, whereby several studies have dealt with its geometry and evolution (Benedetti et al., 2000; Burrato et al., 2009; Fantoni et al., 2001). The core of the Montello hill is made of Mio-Pliocene conglomerates that are overlain to the west by terraces of Quaternary fluvial deposits which can be attributed to a former course of the Piave River. Benedetti et al. (2000) suggested that the Piave river changed its course because of the growth of the Montello hill, at a rate of 0.5 mm/yr to 1.0 mm/yr estimated from the ages of the river terraces. If all of the hill growth is translated into the slip rate that has occurred on the Montello blind thrust, this gives a value of 1.8 mm/yr to 2.00 mm/yr (Benedetti et al., 2000).

* Corresponding author. Tel.: +39 051 4151472.
E-mail address: stefania.danesi@ingv.it (S. Danesi).

http://dx.doi.org/10.1016/j.tecto.2015.03.028
0040-1951/

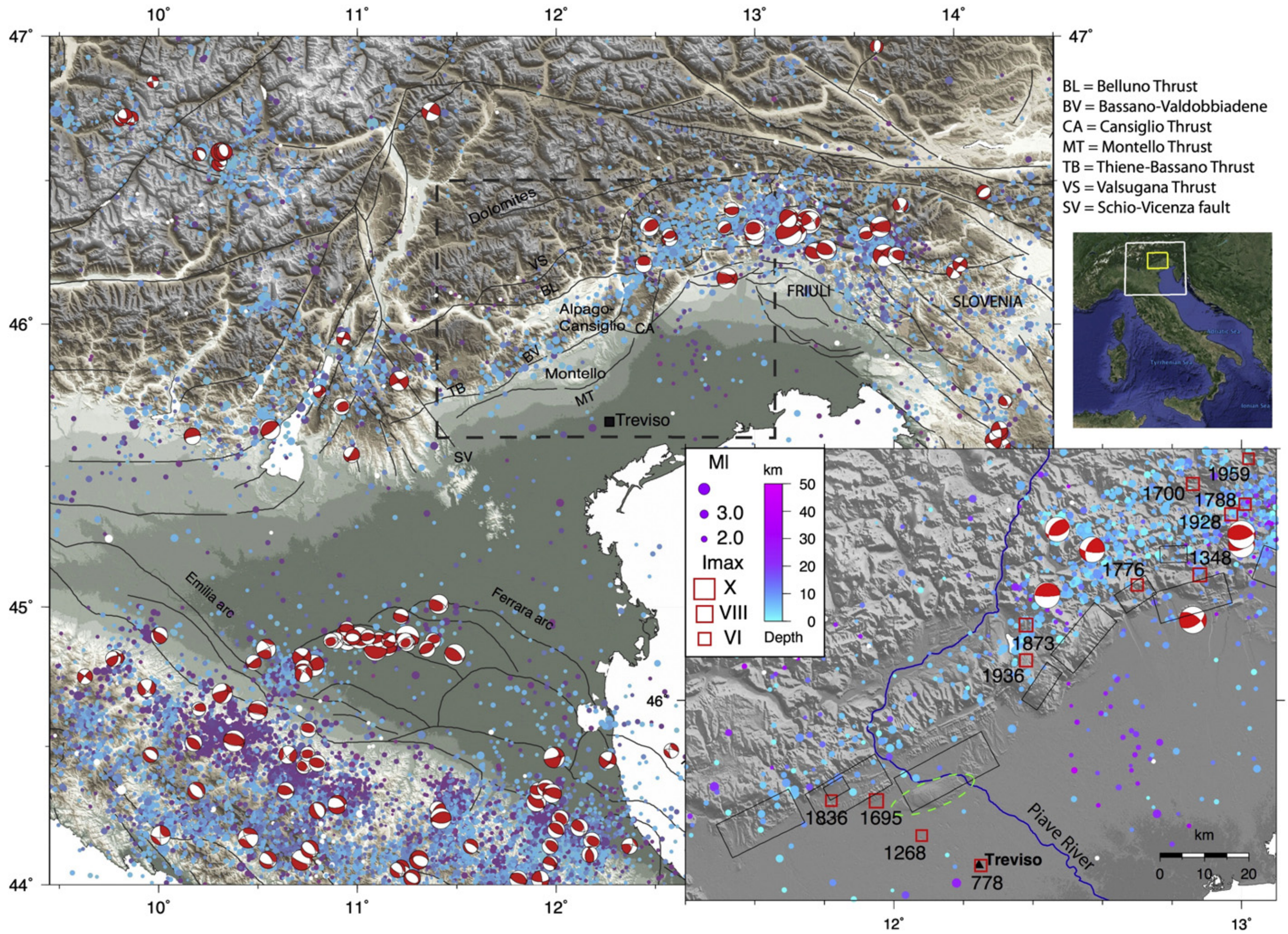

Fig. 1. Seismotectonic map of the North-Eastern Italy, with the major tectonic lineaments in black. The seismicity since 1960 was extracted from the International Seismological Centre Bulletin (http://www.isc.ac.uk/), and the colors represent the hypocentral depths. The focal mechanisms (red) were extracted from the European–Mediterranean RCMT Catalogue (Pondrelli et al., 2006; http://www.bo.ingv.it/RCMT). The yellow box highlights the study region mapped in the inset. Inset: The dashed green oval indicates Montello hill. The seismicity since 1960 is shown, as historical events (red squares; Rovida et al., 2011), seismic moment tensors (Euro-Mediterranean RCMT Catalogue; Pondrelli et al., 2006; Anselmi et al., 2011), and seismogenic sources (black boxes; from DISS 3; DISS Working Group, 2010).

Plio-Quaternary fault maps (Basili et al., 2008; Burrato et al., 2009; DISS Working Group, 2010; Valensise and Pantosti, 2001) include the Montello blind thrust as one of the south-verging seismogenic segments that characterize the tectonically active South Alpine thrust front (Galadini et al., 2005; Poli et al., 2008). This has been described as a buried thrust that is overridden by the Cansiglio thrust fault to the east. To the west, the Montello thrust has a right-stepping transition to the adjoining Bassano–Valdobbiadene line (Galadini et al., 2005); this structure has been imaged by tomographic studies (Anselmi et al., 2011). Moving to the north, other relevant thrust structures are the Bassano–Valdobbiadene line, the Belluno thrust and the Valsugana thrust (Fig. 1).

Despite the number of published studies, the shallow and deep geometry of the Montello thrust fault are still uncertain. Most of the interpretations rely on seismic reflection data but are somehow different. For example, the ramp-flat transition at depth is interpreted by Benedetti et al. (2000) to occur at ~5 km, while in the interpretation of the TRANSALP profile (e.g., Castellarin et al., 2006) it is placed at ~10 km depth, as in Galadini et al. (2005). Fantoni and Franciosi (2009), as well, provided a subsurface interpretation that is similar to the ones given in Galadini et al. (2009) and Castellarin et al. (2006). Another uncertain structure is a possible back-thrust of the Montello thrust fault, which is reported by Galadini et al. (2005) and is also interpreted from the TRANSALP profile (Castellarin et al., 2006) but it is not reported in the interpretation by Benedetti et al. (2000). Additionally, also the seismic potential of the Montello fault is still under debate (Barba et al., 2013; Burrato et al., 2009). In particular, the fault dimensions in the DISS are deduced on a reflection profile that was interpreted by Galadini et al. (2005), which does not, however, cross Montello hill perpendicularly, but in the ENE direction, leaving the great uncertainties around its geometry largely unresolved.

The most recent destructive event of this sector of the Alps occurred in Friuli during the seismic sequence that started on May 6, 1976, with a maximum magnitude MW 6.5 (Pondrelli et al., 1999, and references therein) that left ca. 1000 victims, with 100,000 people evacuated. The recent instrumental seismicity in north-eastern Italy has been weaker than in the Apennines, although it is not negligible, and it has been clustered along the mountain front, at the boundary with the Po Plain, with increasing seismicity rates toward the Eastern (Friuli) Alps (Fig. 1).

The present-day seismic activity of the Veneto sector of the south-east Alps is relatively weak, and has been represented by earthquakes with Ml < 4.0, that have mostly been located east of the Montello area, across a belt that is a few dozen kilometers wide, along the boundary between the Po Plain and the mountain range, toward the Cansiglio area (Castello et al., 2006) (Fig. 1).

In addition, during the last 2000 years, a few significant seismic events have shaken this region, all of which have been located either