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Seismicity and velocity structures along the south-Alpine thrust front of the Venetian Alps (NE-Italy)

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ABSTRACT

In this paper we show the seismicity and velocity structure of a segment of the Alpine retro-belt front along the continental collision margin of the Venetian Alps (NE Italy). Our goal is to gain insight on the buried structures and deep fault geometry in a "silent" area, i.e., an area with poor instrumental seismicity but high potential for future earthquakes, as indicated by historical earthquakes (1695 Me = 6.7 Asolo and 1936 Ms = 5.8 Bosco del Cansiglio). Local earthquakes recorded by a dense temporary seismic network are used to compute 3-D Vp and Vp/Vs tomographic images, yielding well resolved images of the upper crust underneath the south-Alpine front. We show the presence of two main distinct high Vp S-verging thrust units, the innermost coincides with the piedmont hill and the outermost is buried under a thick pile of sediments in the Po plain.

Background seismicity and Vp/Vs anomalies, interpreted as cracked fluid-filled volumes, suggest that the NE portion of the outermost blind thrust and its oblique/lateral ramps may be a zone of high fluid pressure prone to future earthquakes.

Three-dimensional focal mechanisms show compressive and transpressive solutions, in agreement with the tectonic setting, stress field maps and geodetic observations. The bulk of the microseismicity is clustered in two different areas, both in correspondence of inherited lateral ramps of the thrust system. Tomographic images highlight the influence of the paleogeographic setting in the tectonic style and seismic activity of the region.

1. Introduction

The study area is located along the Southern Alps front, i.e. the Alpine retro-belt, characterized by active compression with velocity on the order of a few mm/yr (Battaglia et al., 2004; D'Agostino et al., 2005). The collision between the Adria and European plates creates a N–S trending compression, which is accommodated in the piedmont zone on either S–SE (thrusts) or N–NW verging (back-thrusts) structures displacing intra-mountains basins (Poli et al., 2008 and reference therein). This compression is explained by the counter-clockwise rotation of the Adria plate (D'Agostino et al., 2005). The minor convergence resulting in this area, with respect to the contiguous Friuli region place of the 1976 Ms 6.5 and Ms 5.9 destructive earthquakes (Poli et al., 2002; Pondrelli et al., 2001; Slejko et al., 1999), is mirrored by a sharp decrease of background seismicity (Chiarabba et al., 2005). Like other regions of Italy, the absence of seismicity on faults quoted to generate large earthquakes may indicate that the faults are locked during this interseismic period (Bagh et al., 2007).

The most evident structure at the surface is the Bassano Line (Fig. 1) that forms a triangle zone and a tilt of the Flysch and Molasse deposits toward the Po Plain. To the east, the thrust front appears segmented into two branches: the Longhere–Fadalto–Cadola and the Cansiglio–Polcenigo-Maniago alignments (see Fig. 1). In the more external region, south of the Venetian Alps, the Montello hill appears to be a growing ramp anticline on top of an active north-dipping blind thrust named Montello Line thrust (Benedetti et al., 2000; Galadini et al., 2005).

Which of these faults is accommodating the compression is still not clear. The area is experiencing few and sparse seismicity, not clearly revealing the active faults. The low deformation rate, along with the absence of moderate to large magnitude events in recent years, is impeding the definition of active structures. The main goal of our study is to unravel the geometry of the structure and faults at depth by using micro-earthquakes recorded during the one-year long passive survey. We present Vp and Vp/Vs models obtained by the inversion of local earthquakes arrival times. Velocity anomalies in the upper crust reflect lithological heterogeneities and can shed light on the gross structure of the compressional front. Thrust faults responsible for stacking of the different tectonic units can be recognized by a joint analysis of micro-earthquake distribution and velocity contrasts between bodies with different lithology.

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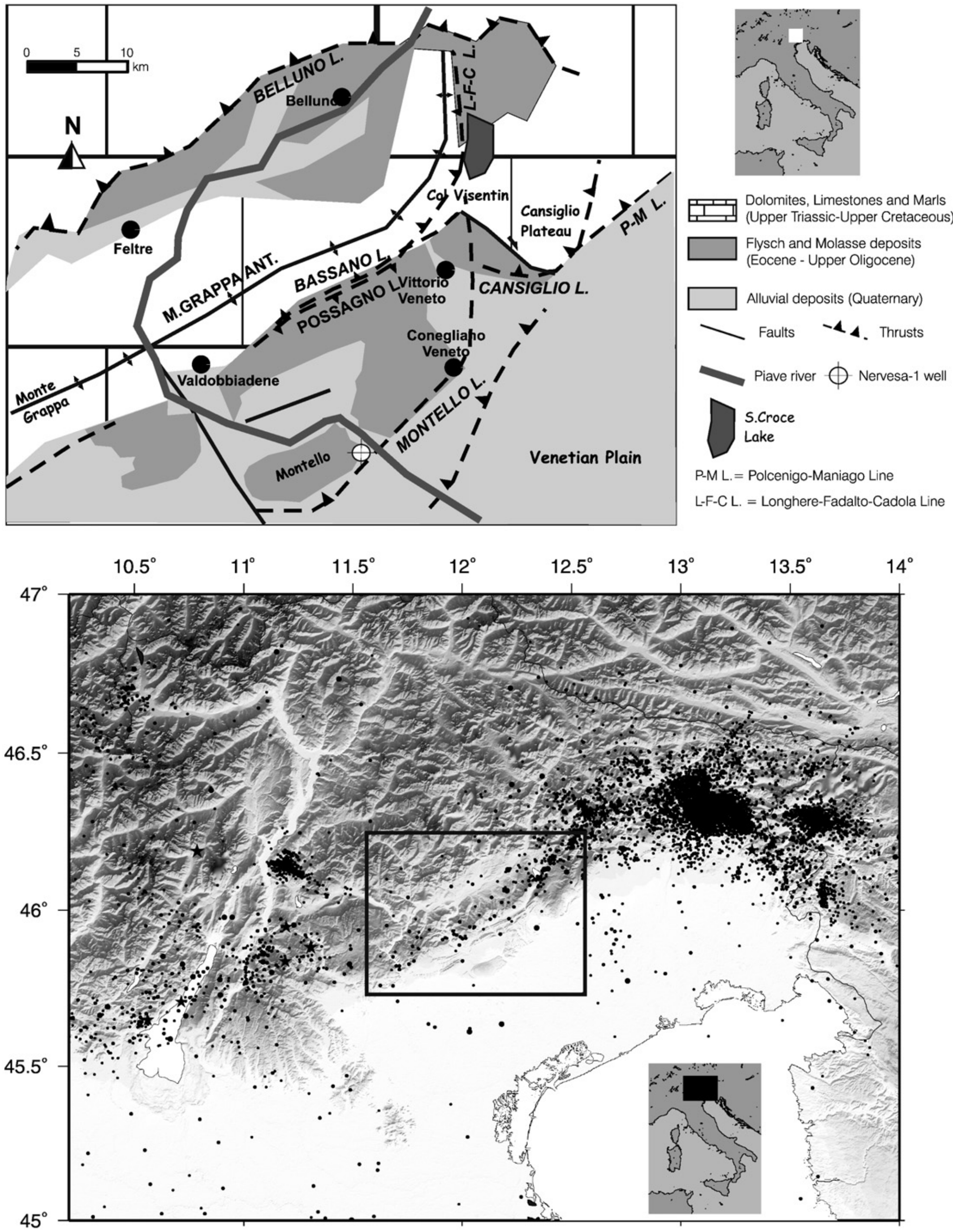

Fig. 1. Up) Sketch of the main tectonic and geological lineaments of the studied area. Down) Instrumental seismicity from C.S.I.1.1 catalog (Castello et al., 2006).

2. Data and inversion procedure

The passive seismic experiment was carried out from June 2004 to May 2005, with the deployment of 20 three-components stations, equipped with 3-component sensors, fashioned in a pseudo-rectangular grid that covers an area of about 3600 km^2, as described in Chiaraluce et al. (2009) and in Fig. 2. Data from permanent stations operating in the area are added to the analysis.

During the experiment, the local seismic network recorded about 310 local earthquakes. P- and S-wave arrival times were accurately picked on the digital three components waveforms. Following Eberhart-Phillips and Chadwick (2002), we assign weights 0, 1, 2, 3 or 4 for reading errors less than 0.1, 0.2, 0.3, 0.4 s. respectively. As commonly adopted for the quality of the phase picks, 0 is the best observation while 4 is associated to the worst one and it is skipped for Vp and Vp/Vs tomography.

A total amount of 1560 P wave and 960 S–P travel times from about 180 selected earthquakes preliminary located with a 1D velocity model (Chiaraluce et al., 2009) has been inverted for both a minimum 1D and 3D velocity models, by using the Velest code (Kradolfer, 1989) and the Simulps13q inversion technique (Eberhart-Phillips and Michael, 1998; Thurber, 1983). Selected earthquakes have initial hypocentral errors less than 1 km on average, azimuthal gap less than 180°, and a minimum of 12 seismic phases (Fig. 3).

Focal mechanism (F.M.) solutions are obtained using the P-wave first arrival polarities and the FPFIT code (Reasenberg and Oppenheimer,