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Focal mechanism inversion in the Giudicarie–Lessini seismotectonic region (Southern Alps, Italy): Insights on tectonic stress and strain

Alfio Viganò [a,*], Gianni Bressan [b,1], Giorgio Ranalli [c,2], Silvana Martin [a]

[a] Department of Chemical and Environmental Sciences, Insubria University, Via Valleggio 11, 22100, Como, Italy
[b] Istituto Nazionale di Oceanografia e di Geofisica Sperimentale, Dipartimento Centro Ricerche Sismologiche, Via Treviso 55, 33100, Cussignacco (Udine), Italy
[c] Department of Earth Sciences and Ottawa-Carleton Geoscience Centre, Carleton University, Ottawa, Canada K1S 5B6

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ABSTRACT

A set of 41 focal mechanisms (1989–2006) from P-wave first polarities is computed from relocated seismic events in the Giudicarie–Lessini region (Southern Alps). Estimated hypocentral depths vary from 3.1 to 20.8 km, for duration magnitudes (M_D) in the range 2.7–5.1. Stress and strain inversions are performed for two seismotectonic zones, namely G (Giudicarie) and L (Lessini). This subdivision is supported by geological evidence, seismicity distribution, and focal mechanism types. The available number of data (16 in G, 22 in L) does not make possible any further subdivisions. Seismotectonic zones G and L are undergoing different kinematic regimes: thrust with strike-slip component in G, and strike-slip in L. Principal stress and strain axes in each sub-region show similar orientations. The direction of maximum horizontal compressive stress is roughly perpendicular to the thrust fronts along the Giudicarie Belt in zone G, and compatible with right-lateral strike-slip reactivation of the faults belonging to the Schio-Vicenza system in zone L. On the whole, kinematic regimes and horizontal stress orientations show a good fit with other stress data from focal mechanisms and breakouts and with geodetic strain rate axes.

1. Introduction

The Giudicarie–Lessini (GL) region is a crucial zone in the geodynamic context of the Alps (Fig. 1). It represents a primary discontinuity within the Southern Alps, with an orientation transversal to the strike of the Alpine chain. Moreover, the presence of a structural boundary along the Giudicarie fault system is evident both at crustal (e.g., Scarascia and Cassinis, 1997) and lithospheric scales (e.g., Lippitsch et al., 2003).

The low-to-moderate magnitude shallow seismicity of the GL region is mainly located along this fault system, which represents the western boundary of the Eastern Alps, one of the most important seismic provinces in Northern Italy (Slejko et al., 1989).

In this work we analyze a set of seismic events within the GL region covering the time span 1989–2006, and compute a set of focal mechanisms after accurate event relocations. The tensors of stress and strain (actually, the incremental strain over the period of observation, which is merely a snapshot of the contemporary deformation rate) are estimated from focal mechanism inversions and discussed in relation with regional tectonic patterns. The computed maximum horizontal compressive stress directions are compared with different stress data from focal mechanisms and breakouts, and with strain data from geodesy.

2. Geological background

The Giudicarie–Lessini region (Fig. 1) is located south of the Periadriatic Lineament (PL) and represents a tectonic boundary between the central-western and the eastern Southern Alps (e.g., Laubscher, 1996), which include the Mesozoic continental margin of the Adriatic plate. This region is considered to have played an important role in linking the Alpine orogenic wedge to the north to the Southalpine belt through a mega-scale fault system active from Miocene to present (Massironi et al., 2006).

After the Variscan orogeny, Mesozoic rifting produced N–S oriented extensional structures and differential subsidence between the Lombardian basin to the west and the Venetian platform to the east (Bertotti et al., 1993). The thickness of the sedimentary cover (mainly of Middle Triassic–Late Cretaceous age) generally decreases from NW to SE, with significant variations (~3–6 km), especially along the Ballino-Garda normal fault which bounds the Venetian platform to the west (BG in Fig. 1) (Picotti et al., 1995). Since the Late Cretaceous, the multi-phase Alpine orogeny inverted the previous extensional faults and built up the Southalpine chain (Doglioni and Bosellini, 1987; Castellarin et al., 2006). The main compressive phase which produced the Alpine belt developed during the Miocene (e.g., Castellarin et al., 2006). At present some of these faults are seismogenic (Slejko et al., 1989).

* Corresponding author. Fax: +39 031 326230.
E-mail addresses: alfio.vigano@uninsubria.it (A. Viganò), gbressan@inogs.it (G. Bressan), granalli@earthsci.carleton.ca (G. Ranalli), silvana.martin@uninsubria.it (S. Martin).
[1] Fax: +39 0432 522474.
[2] Fax: +1 613 520 5613.

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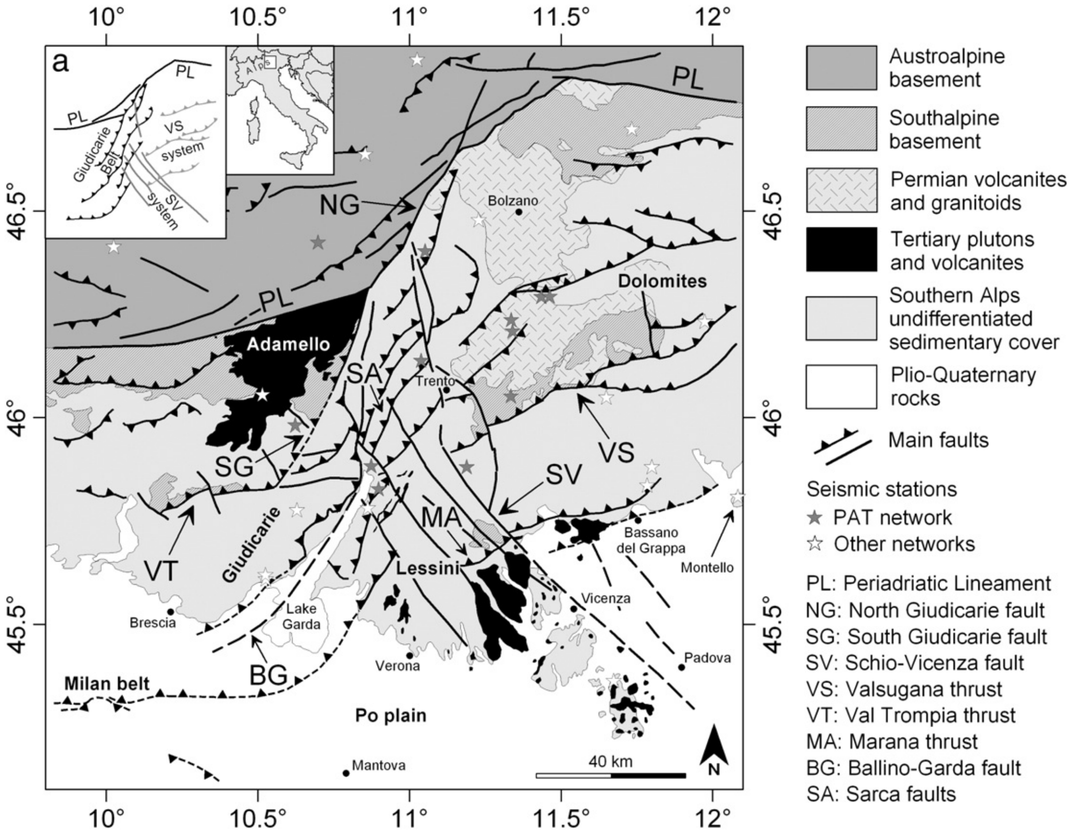

Fig. 1. Simplified geology and tectonic lineaments (see also sketch "a") of the Giudicarie–Lessini region (modified after Bigi et al., 1990 and Castellarin et al., 2006). The seismic stations in the region are also shown.

The stratigraphic succession of the study area extends from pre-Permian metamorphic basement to Plio-Quaternary rocks (refer to Fig. 1). The Southalpine basement outcrops east of Trento at the hangingwall of the Valsugana thrust, and in the Adamello area at the hangingwall of the South Giudicarie and Val Trompia thrusts. To the south of the North Giudicarie fault (NG in Fig. 1), a triangle-shaped wedge of dominantly sedimentary sequences (mainly Middle Triassic–Early Miocene) is highly tectonised. It includes the Giudicarie Belt (G) (*sensu* Castellarin et al., 1986) and the Lessini mountains (L) (Zampieri, 2000). Three main fault systems affect the GL region: the NNE-trending transpressive Giudicarie, the NW-trending strike-slip Schio-Vicenza, and the ENE- to NE-trending compressive Valsugana (sketch "a" in Fig. 1). The region located between the southern sector of the Giudicarie line and the Schio-Vicenza fault zone ("Adige embayment" in Laubscher, 1996) is only slightly affected by Neogene Alpine south-vergent thrusts. From fault slip data Castellarin and Cantelli (2000) proposed a change of the maximum horizontal stress direction during Neogene from N340° (Serravalian–Tortonian), which was responsible for most of the shortening along the Giudicarie line, to N310° (Messinian–Pliocene). This late compressional phase produced the southernmost outcropping Bassano-Montello thrust front, together with out-of-sequence and strike-slip reactivations along the Giudicarie and the Schio-Vicenza systems (Zampieri and Massironi, 2007). Neotectonic activity in the GL region, inferred from morphologic and morphotectonic structures (Zanferrari et al., 1982; Fellin et al., 2002), has caused local reactivations along faults belonging to the Giudicarie, Schio-Vicenza and Valsugana systems (Galadini and Galli, 1999; Benedetti et al., 2000; Galadini et al., 2001; Sauro and Zampieri, 2001).

On the basis of geological observations about structural patterns and faulting type, the GL region can be subdivided in two contiguous sub-regions: G (Giudicarie) and L (Lessini). (The boundaries of these two zones, adopted in this paper for seismological purposes, are shown in Fig. 5.) Sub-region G includes the ticker Lombardian basin cover sequences and the internal NNE-trending thrust faults, which are characterized by lateral continuity along the whole Giudicarie Belt from the Periadriatic Lineament (PL) to the buried fronts under the Po plain (Ravaglia et al., 2006). Sub-region L includes the Venetian platform cover sequences where strike-slip faults of the Schio-Vicenza system are pervasive and dislocate the easternmost thrust faults of the Giudicarie Belt (Castellarin and Cantelli, 2000). West of G and east of L, the main tectonic structures become roughly parallel to the strike of the chain.

3. Data and results

3.1. Seismicity and seismological databases

The GL region is characterized by light seismicity ($M_W<5.0$), except for only one moderate earthquake ($M_W\cong5.0$; Pondrelli et al., 2007) in the period 1981–2002 (Chiarabba et al., 2005). The seismicity ($M\geq1$) is distributed along the Southalpine boundary (Castello et al., 2006) (Fig. 2a), as confirmed by historical seismicity until 1980 (Gruppo di lavoro CPTI, 2004) (Fig. 2b). In the internal chain, a seismic area is recognized north of the Periadriatic Lineament (PL) in the Swiss Alps. The seismicity in the GL region is clustered near the junction between the Giudicarie and the Schio-Vicenza fault systems, and decreases in frequency and magnitude away from this junction in both EW and NS directions (Fig. 2c). Most earthquakes are located in the upper crust ($z<20$ km; e.g., Scarascia and Cassinis, 1997).

The main local seismic network in the GL region is maintained by the *Provincia Autonoma di Trento* (PAT, http://www.protezionecivile.tn.it). At present, the PAT network consist of 7 short-period stations which are equipped with 3-D (6 stations) or 1-D (1 station) seismometers (Lennartz LE). In this work, data were collected from PAT stations and other close seismic networks (INGV — *Istituto Nazionale di Geofisica e Vulcanologia*, Italy; OGS — *Istituto Nazionale di Oceanografia e di Geofisica Sperimentale*, Italy; Switzerland, Austria, Germany,