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The October–November 2010 earthquake swarm near Sampeyre (Piedmont region, Italy): A complex multicluster sequence

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ABSTRACT

During one month, in October and November 2010, the region of Sampeyre (Western Alps, Italy) was struck by a seismic activity of several hundred events. The location of 287 events recorded at least by three stations showed a diffuse swarm ranging between 8 and 13 km depth. The number of earthquakes in the database was increased thanks to a detailed analysis of the continued recordings of the nearest station (DOI) which allowed identifying 2612 earthquakes. The temporal distribution of the seismicity is characterized by the alternation of active and quiescent periods. Moment magnitude was computed for 730 events by a P wave spectral analysis of the DOI station data. The estimated magnitudes range between 0.7 and 3.15. The b-value of the cumulated frequency–magnitude distribution is around 1.4. Spatio-temporal analysis of the located earthquakes highlighted an overall northward migration of the seismicity. From spatio-temporal criteria, the seismicity was divided in three clusters. Each cluster is characterized by its own focal mechanism family. The stress tensor determined from the focal mechanisms indicates probable stress heterogeneities at small spatial scale. The observed migration of the seismicity could be compatible with earthquake triggering by fluid diffusion processes.

1. Introduction

The far south-east France and the northwestern Italy experience moderate seismicity: 76 events in the M_w range 4.0–6.0 or epicentral intensity V and more (MCS scale) occurred from 1920 to 2000 (Larroque et al., 2001) and more than 5000 microseismic events were listed by the BCSF (French central seismological office) since 1980. The origin and the distribution of this seismicity along the complex structures of the southwestern Alpine belt still raise some questions. The seismic activity defines two N–S elongated zones (Fig. 1) parallel with the structural direction of the belt (Béthoux et al., 1998; Eva et al., 1997; Rothé, 1941; Sue et al., 1999): (1) the Briançonnais seismic arc follows the peninic thrust front (thrusting of internal zones onto external zones mainly during Oligocene times) and (2) the Piemontais seismic arc that is located on the western edge of a mantelic structure indenting the deep alpine crust (the Ivrea Body). The seismicity is mainly shallow and can reach focal depth more than 20 km (Eva et al., 1998). Nevertheless, except some main fault systems as the Vuache fault (Thouvenot et al., 1998), the Middle-Durance fault (Cushing et al., 2007), the Trévaresse fault (Chardon and Bellier, 2003), the High-Durance and Serennes faults (Sue and Tricart, 2003) and the Belledonne fault (Thouvenot et al., 2003), the seismicity is rarely related to known faults (e.g. Courboulex et al., 2003; Jenatton et al., 2007).

Occasionally, seismic activities characterized by earthquake swarms occur in the Western Alps. Up to now, such swarms were mainly observed and documented in the southwestern French Alps as in 1983 near Saorge (Hoang-Trong et al., 1987), in 1989 in the Chambeyron massif (Guyoton et al., 1990), in 2000 near Blausasc (Courboulex et al., 2003) or in 2003–2004 (Daniel et al., 2011; Jenatton et al., 2007) in the Ubaye Valley (Fig. 1). In Northern Italy, seismic swarms were also observed in the southwestern Alps (Massa et al., 2006) and in the Ligurian Alps (e.g. Cattaneo et al., 1997). Earthquake swarms are characterized by a series of events without mainshock and are usually observed in volcanic context where they are induced by magmatic intrusions (e.g. Roman and Cashman, 2006). In other contexts, circulations of overpressured upgoing mantelic fluids as in Vogtland/Bohemia (Horálek and Fischer, 2008) or downgoing meteoric water as in Ubaye valley (Leclère et al., 2012) is invoked as generating earthquake swarms.

In October–November 2010, the eastern side of the southwestern Alps was again struck by a seismic swarm in the Varaita valley (Piedmont Italy), near the city of Sampeyre (Fig. 1). The study of this earthquake swarm gave the opportunity to explore the links between earthquake-swarm-type activity and the regional tectonic context. Detailed analysis of such earthquake sequences might allow to better understand the origin of the seismicity and the coupling between seismic and aseismic processes in the Alpine belt and more generally

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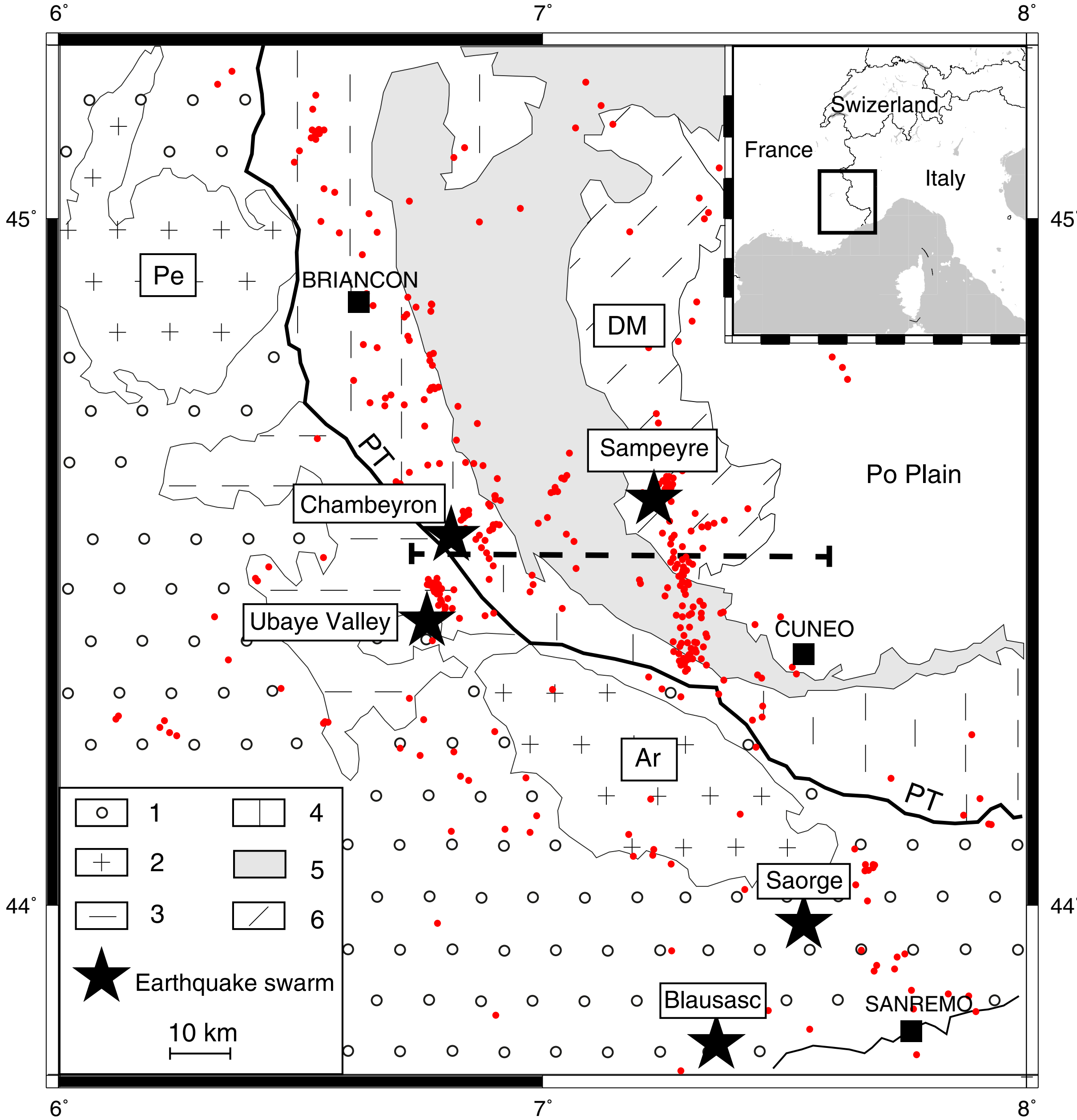

Fig. 1. Simplified structural map of the south-western Alps (modified from Paul et al., 2001), $M_L > 2$ seismicity between 1989 and 2011 (Sismalp catalog, Thouvenot and Fréchet, 2006) and location of the earthquake swarms of Saorge (Hoang-Trong et al., 1987), Chambeyron (Guyoton et al., 1990), Blausasc (Courboulex et al., 2003), Ubaye Valley (Jenatton et al., 2007) and Sampeyre (this study). 1: Meso-Cenozoic sedimentary cover of the external crystalline massifs; 2: External crystalline massifs; 3: Embrunais–Ubaye internal nappes thrust onto the external zone; 4: Briançonnais and Sub-Briançonnais zone; 5: Piedmont zone; 6: Internal crystalline massifs. Pe: Pelvoux; Ar: Argentera; DM: Dora Maira; PT: Penninic thrust. Dashed line indicates the E–W cross-section of Fig. 12.

in fault zones. In this paper we precisely describe the swarm in space and time and discuss the contribution of the long-term tectonic loading and the potential implication of fluid diffusion processes.

2. Geodynamic and tectonic setting

The Alpine belt was built at the ancient plate boundary between Eurasia and Africa (e.g. Dercourt et al., 1986; Stampfli et al., 2002). The complex structure of the Alpine belt (Roure et al., 1990; Schmid and Kissling, 2000), displaying strong changes of crustal nature and thickness with many inherited structures, is the result of the convergence between the Africa and the Eurasia plates which led to the subduction of the Tethyan Ocean and, then, to the collision between continental blocks initiated 60 million years ago.

Currently, the convergence between the Nubia (Africa) and Eurasia plates continues at a rate of 6.2 ± 0.5 mm/yr in a N343 $\pm$ 9° direction at the longitude of the western Alps, according to the Nuvel-1A plate motion model (DeMets et al., 1994). Recent geodetic studies (Nocquet and Calais, 2003; Vigny et al., 2002) suggest that the convergence is mainly accommodated along the Maghrebides boundary (North Africa) and Nocquet (2012) proposes that the upper bound on horizontal motion across the Western Alps is 0.5 mm/yr.

Despite this very low convergence rate, significant deformations occur in the western alpine/Mediterranean area (e.g. Chardon and Bellier, 2003; Larroque et al., 2012; Thouvenot et al., 1998). The origin of these active deformations is largely debated and the current strain pattern could be mainly controlled by (1) the counter-clockwise rotation of the Adriatic microplate, (2) the gravitational collapse of the