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Preliminary imaging of active faults in the Montello-Collalto area (Southeastern Alps, Italy) by a high-sensitivity seismometric network

Romano, M.A. (1), Peruzza, L. (1), Priolo, E. (1), Garbin, M. (1), Picotti, V. (2), Guido, F.L. (3) and Ponza, A. (3)

(1) OGS (Istituto Nazionale di Oceanografia e di Geofisica Sperimentale), CRS (Centro Ricerche Sismologiche), Borgo Grotta Gigante, 42/C – 34010 Sgonico (TS) and Via Treviso, 55 - 33100 Cussignacco (UD), Italy. Email: aromano@inogs.it
(2) ETH Zürich, Earth Science Department, Sonneggstrasse 5, 8092 Zürich, Switzerland
(3) GEOPHI S.r.L., Via Cristoni, 80 - 40033 Casalecchio di Reno (BO), Italy

Abstract: *The Montello-Collalto (MC) area, located at the front of Southeastern Alps, is very interesting for the high convergence rates documented by geodetic measurements; geological and geophysical surveys provide evidence of active compressive structures. Historically this area has been struck by at least one event with M>6; during the last decades the seismicity has been moderate, with one* M_D*=4.0 earthquake, and only few events with* M_D*>3.*

At the end of 2011, a high-quality seismometric network has been deployed in the MC area for monitoring the seismicity potentially induced by gas storage activities in an underground natural reservoir, depleted in the 90'ies. The network allows to record background microseismicity with a completeness magnitude that reaches M_L*=0.0 locally. None of the 518 events of our catalogue (January, 1st, 2012 till October, 31st, 2014) is located in proximity of the reservoir; instead the imaging at depth of the main tectonic structures can be clearly depicted.*

Key words: *Montello (Italy), Collalto seismometric network, microseismicity, fault geometry imaging.*

INTRODUCTION

We do not know all the tectonic structures dissecting the Earth's crust. Active faults, especially if not outcropping, are often revealed only by the imaging of earthquakes that occur on them, sometimes clustered in space and time. During the last years, however, the analysis of the background seismicity has demonstrated to be effective in recognizing and characterizing geometry and kinematics of active faults (e.g. De Matteis et al., 2012; Romano et al., 2013). With this aim, the deployment of local high-sensitivity seismometric networks is of crucial interest, as the networks operating for seismic alarm purposes at national or continental scale are not usually adequate for detecting and locating microseismicity (M<2) with sufficient accuracy.

The high-sensitivity Collalto Seismic Network

Since the beginning of 2012, a local seismometric network named Rete Sismica di Collalto (RSC) is operating in the Montello area (Veneto region, Northeastern Italy; Fig. 1). It has been realized and is being managed by OGS on the behalf of Edison Stoccaggio S.p.A. with the aim of monitoring the natural and induced seismicity of the natural gas storage concession known as 'Collalto Stoccaggio' (Priolo et al., 2015).

The RSC consists of ten seismometric stations and one Global Navigation Satellite System permanent geodetic station with the following features:

- 1 very broad-band and high-dynamics station (ED06);
- 3 extended short-period and high-dynamics stations (ED05, ED07 and ED08);
- 5 extended short-period stations (ED02, ED03, ED04, ED09 and ED10);
- 1 extended short-period station located in a deep well (ED01).

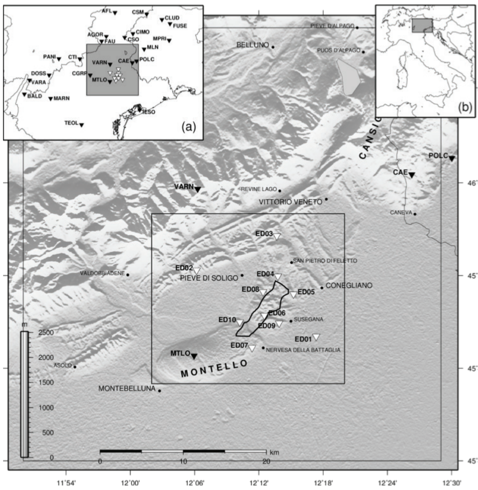

Figure 1: Location map of the study area, also at (a) regional and (b) national scales. Black and white triangles represent the stations belonging to the Northeastern Italy (NEI) Integrated Seismic Network, and those belonging to RSC, respectively. Both networks are managed by OGS. In the main panel, the solid irregular line indicates the gas storage reservoir; the thin rectangle shows the area where RSC has its maximum detection capability (hereinafter Area A). Modified by Priolo et al., 2015.

The double feature of high dynamics and high sensitivity of the instrumentation ensures high quality registrations of medium-strong earthquakes as well as micro-seismic events. Moreover, the deployment of the seismic stations with a spacing of 2-4 km above the reservoir guarantees an adequate resolution power at the reservoir depth (about 1.5 km). In order to improve the signal-to-noise ratio, all the seismological sensors are installed in boreholes with variable depth, depending on the local soil and instrument type.

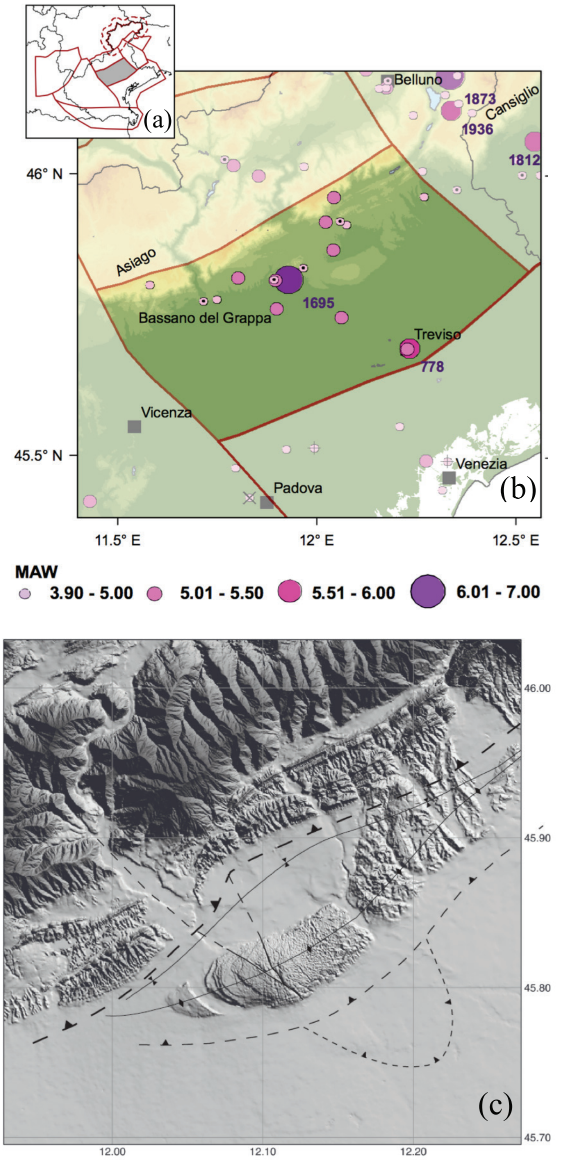

Figure 2: historical earthquakes and preliminary structural sketch of the investigated area: (a, b) the compilation of historical seismicity data is as reported in Sugan and Peruzza (2011); they refer to the PS (Pedemontana Sud) district. The biggest symbol at the centre represents the macroseismic location of the 1695 Asolo earthquake (MW 6.5, Rovida et al., 2011). (c) main thrusts and folds identified by seismic profiles.

The study area

The MC area and surrounding regions of the Venetian piedmont are located at the outer margin of Southeastern Alps, in the so-called PS district (Sugan and Peruzza, 2011). This is characterized by a fold-and-thrust system trending ENE-WSW, verging mainly S-SE (Poli et al., 2008) and buried under alluvial deposits. The compressive deformation, started in Messinian-Pliocene age, continues today with a deformation rate of 2-3 mm/yr (e.g. Castellarin et al., 1992; Benedetti et al., 2000; Serpelloni et al., 2005). The seismogenic potential in such a district is linked to the existence of faults capable of generating earthquakes with $M > 6$ (Galadini et al., 2005). According to the historical seismicity catalogue (CPTI11; Rovida et al., 2011) at least one event with $M>6$ occurred in this area (i.e. the 1695 Asolo earthquake; Fig. 2).

The instrumental seismicity recorded by the OGS in the PS district since 1977 (http://rts.crs.inogs.it) is moderate. The biggest event has M_D=4.0, while only few events exceed magnitude 3. Some other microseismic studies based on dense temporary networks (Lovisa et al., 2008; Anselmi et al., 2011; OMBRA Project Group, 2011) have been carried on in the Montello area, but they have not yet sketched out convincing images of the hypothetical “silent” sources.

In this paper, we describe the most recent and detailed picture of the natural microseismicity obtained by analysing the data acquired by RSC from 1 January 2012 to 31 October 2014.

DATA, ANALYSIS AND DISCUSSIONS

Data collection

RSC stations acquire and transmit raw data in continuous. Signals are sampled at 200 Hz, coherently with the aim of recording microseismicity with the adopted network geometry. At the OGS acquisition centers, the data are at first converted in MiniSEED format, and then saved in two independent storage systems, i.e. OASIS (http://oasis.crs.inogs.it, which is the OGS archiving infrastructure of instrumental seismological data), and a network archive unit for further processing.

Data are processed both in real-time and off-line modes. The first one is used for displaying the signals on dedicated monitors as they are acquired, performing some basic analysis on the fly, and for sending alert messages to the seismological team; the second one performs all the final standard processing (e.g.: detection, location, and magnitude estimation) with the maximum possible sensitivity and accuracy (see Priolo et al., 2015, for details).

Off-line processing works on the integrated dataset of both RSC and NEI data. It is tuned to detect and locate very weak events, thus it is not fully automatic, and it needs the control of a seismologist. Indeed, false events are unavoidable when high sensitivity is required and their removal by visual inspection is necessary. Once true earthquakes are identified, they are manually picked and re-located in a standard way.

Standard analysis

The standard level of the RSC processing is designed in order to preserve an adequate level of coherency with that one performed by the NEI network. Therefore, the location is performed by using the same code and regional velocity model (see details in Priolo et al., 2015).

The local magnitude (M_L) of all events is estimated from the signal amplitude by using the attenuation relationship proposed by Bragato and Tento (2005), as for the NEI. In our case, however, the systematic station residuals are iteratively minimized.

The completeness magnitude (M_c) is about 0.6 if the whole dataset (from 1 January 2012 to 31 October 2014) is taken into account, and it reduces to 0.0 (Fig. 3) considering only the earthquakes belonging to the area A (Fig. 1), where the capability detection of the local network is at best. Estimates of the seismicity rate (a-value) and of the b-value for the area A, obtained with ZMAP (Wiemer, 2001), are also given in Figure 3.

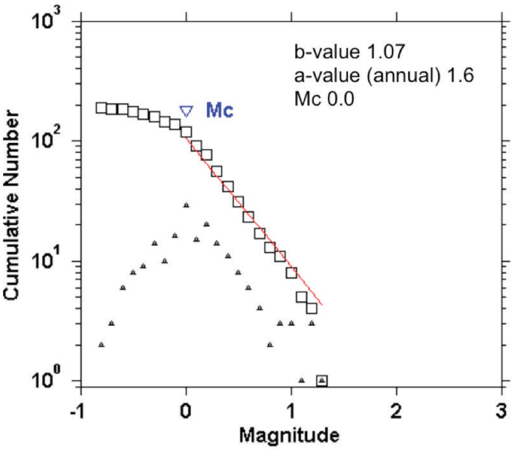

Figure 3: Magnitude–frequency distribution and completeness magnitude (Mc) for earthquakes located in area A in the period 1 January 2012-31 October 2014.

The M_c obtained from our catalogue conveys the noticeable performances of our local network, especially close to the gas storage reservoir.

DISCUSSION

From 1 January 2012 to 31 October 2014, 518 events have been located in the MC area and surrounding regions, with M_L ranging from -0.8 and 2.9; a main earthquake of M 4.6 occurred during this period falls outside the study area represented in Fig. 4. The full list of events and their location parameters are monthly released on the RSC web site (http://rete-collalto.crs.inogs.it).

In most of cases, the hypocentral depths are between 7 and 15 km, although shallower and deeper events have been located. The statistical horizontal and vertical errors exceed 3 km only in few cases, being of about 1 km outside the area A and of hundreds of meters inside it.

From the map and section represented in Fig. 4, it can be observed that seismicity is not homogeneously distributed in the space, but the seismic events located by RSC tend to align themselves along a surface, which deepens from south-east to north-west. This spatial distribution depicts a trend in accordance to the main structural features reconstructed by integrating surface geology and seismic profiles. This observation, together with the absence of seismicity within 3 km from reservoir edges, might suggest a fully tectonic origin of recorded microearthquakes; it reasonably excludes a connection between actual seismicity and the gas storage activities (Priolo et al., 2014).

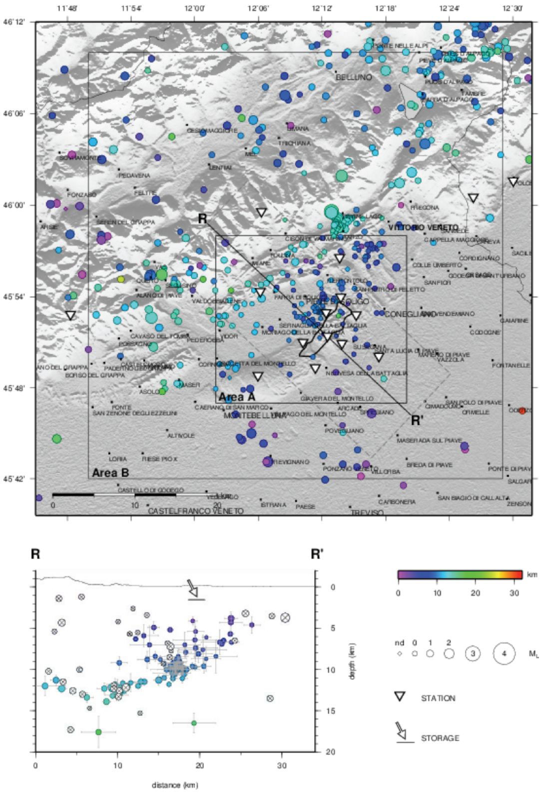

Figure 4: Map and section view of earthquakes located by RSC in the period 1 January 2012 - 31 October 2014. The thin dashed line encloses earthquakes plotted on section RR'. The horizontal and vertical bars represent the location errors. White circles with an internal cross represent events for which the horizontal or the vertical errors are larger than 3 and 5 km, respectively. (Modified by Priolo et al., 2015).

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