Seismicity resulting from anthropic activity recorded in the INGV Italian Seismic Bulletin

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Quarry mining activity is intense in Italy. It produces low magnitude events recorded by the Italian National Seismic Network operated by INGV. Therefore, the Italian Seismic Bulletin (BSI) includes both tectonic earthquakes and quarry explosion recordings. Accurate seismic monitoring and analysis allow us to distinguish between anthropic and tectonic seismicity. We have analyzed data from the BSI in the period 2005-2011 using the ZMAP software (by S. Wiemer) that spatially maps out areas with an anomalous ratio of daytime to nighttime events. We pinpointed 16 areas characterized by intense extractive activities. However the number of quarries in Italy is so large that our list cannot be considered by any means complete. Extraction areas frequently coincide with regions affected by high seismicity rate. Recordings of explosion quakes can have distinctive characteristics (i.e. compressive first onset and low frequency secondary phase). Nonetheless these markers are not typical of all artificial events and are not enough to exclude all explosion recordings from the bulletin. At present, along with true tectonic earthquakes, the BSI includes a significant number of low magnitude quarry blasts, ranging between 3% and 9% per year.

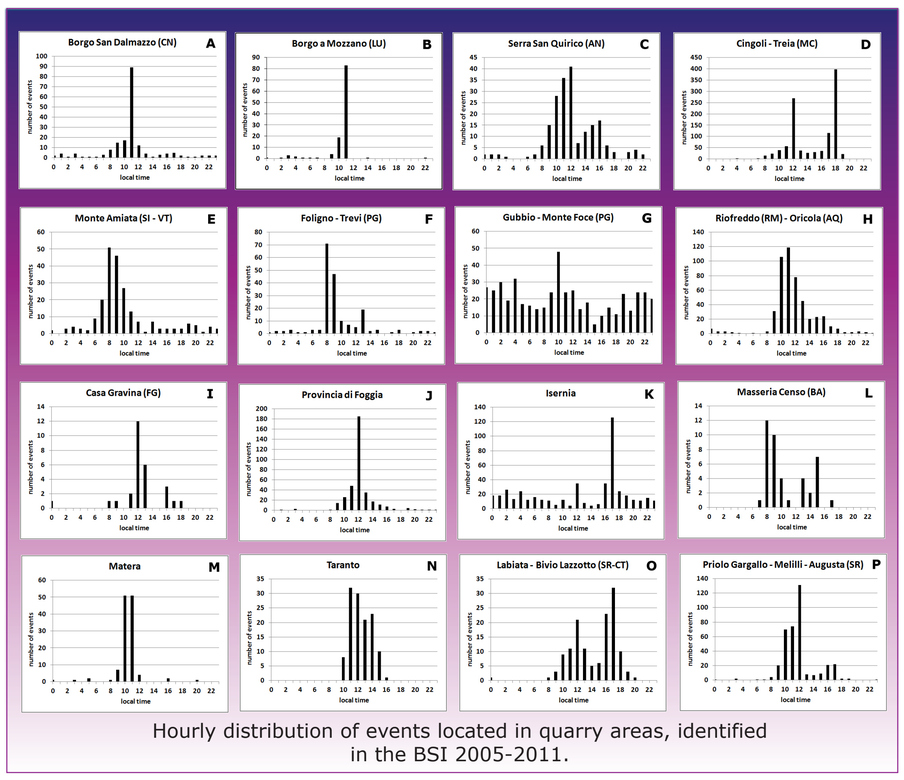
Quarry blasts can affect seismic catalogues (Gulia, 2010). An easy way to point out areas where anthropic explosions appear is to compare daytime seismicity with nighttime seismicity. Wiemer and Baer (2000) defined the normalized ratio of daytime to nighttime events as:

$$R = (Nd / Ld) / (Nn / Ln)$$

where *Nd* and *Nn* are the total number of events in daytime and nighttime respectively, and *Ld*, *Ln* are the length of day and night in hours *(Ld + Ln = 24h)*. Averaging over a long period of time, the expected value of *R* is 1 for natural seismicity. Anthropic explosions are supposed to occur only during daytime, causing larger values of R locally.

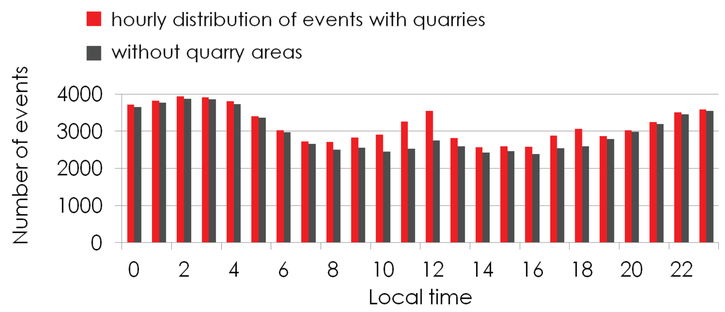
Applying the ZMAP software (Wiemer, 2001) to 7-years data registered in the Italian Seismic Bulletin (2005-2011), we were able to point out 16 areas with anomalous values of R (listed in the table; Mele et al., 2010).

	Geographic area	Latitude range	Longitude range
A	Borgo San Dalmazzo (CN)	44.20N : 44.35N	7.33E : 7.58E
B	Borgo a Mozzano (LU)	43.90N : 44.00N	10.42E : 10:63E
C	Serra San Quirico (AN)	43.38N : 43.46N	12.97E : 13.02E
D	Cingoli-Treia (MC)	43.28N : 43.36N	13.17E : 13.34E
E	Monte Amiata (SI-VT)	42.70N : 43.00N	11.70E : 12.10E
F	Foligno-Trevi (PG)	42.87N : 42.94N	12.72E : 12.80E
G	Monte Foce-Gubbio (PG)	43.30N : 43.40N	12.54E : 12.70E
H	Riofreddo-Oricola (RM-AQ)	41.97N : 42.11N	12.85E : 13.10E
I	Casa Gravina (FG)	41.67N : 41.75N	15.46E : 15.58E
J	Foggia (FG)	41.56N : 41.69N	15.57E : 15.73E
K	Isernia (IS)	41.54N : 41.62N	14.11E : 14.47E
L	Masseria Censo (BA)	40.87N : 40.96N	16.55E : 16.69E
M	Matera (MT)	40.64N : 40.72N	16.58E : 16.79E
N	Taranto (TA)	40.48N : 40.64N	17.13E : 17.47E
O	Catania (CT)	37.30N : 37.50N	14.87E : 15.08E
P	Melilli (SR)	37.10N : 37.30N	14.90E : 15.20E

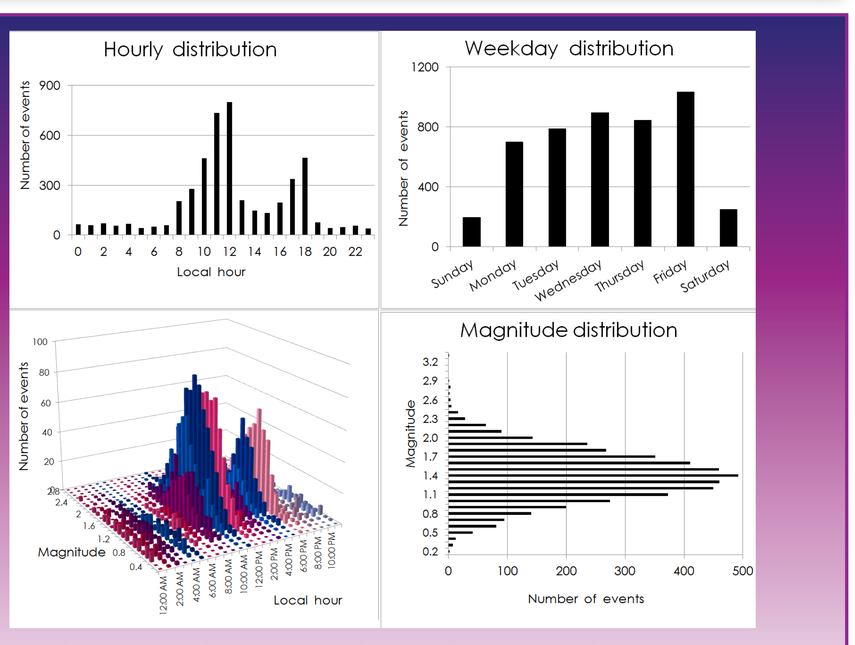


Hourly distribution of events located in quarry areas, identified in the BSI 2005-2011.

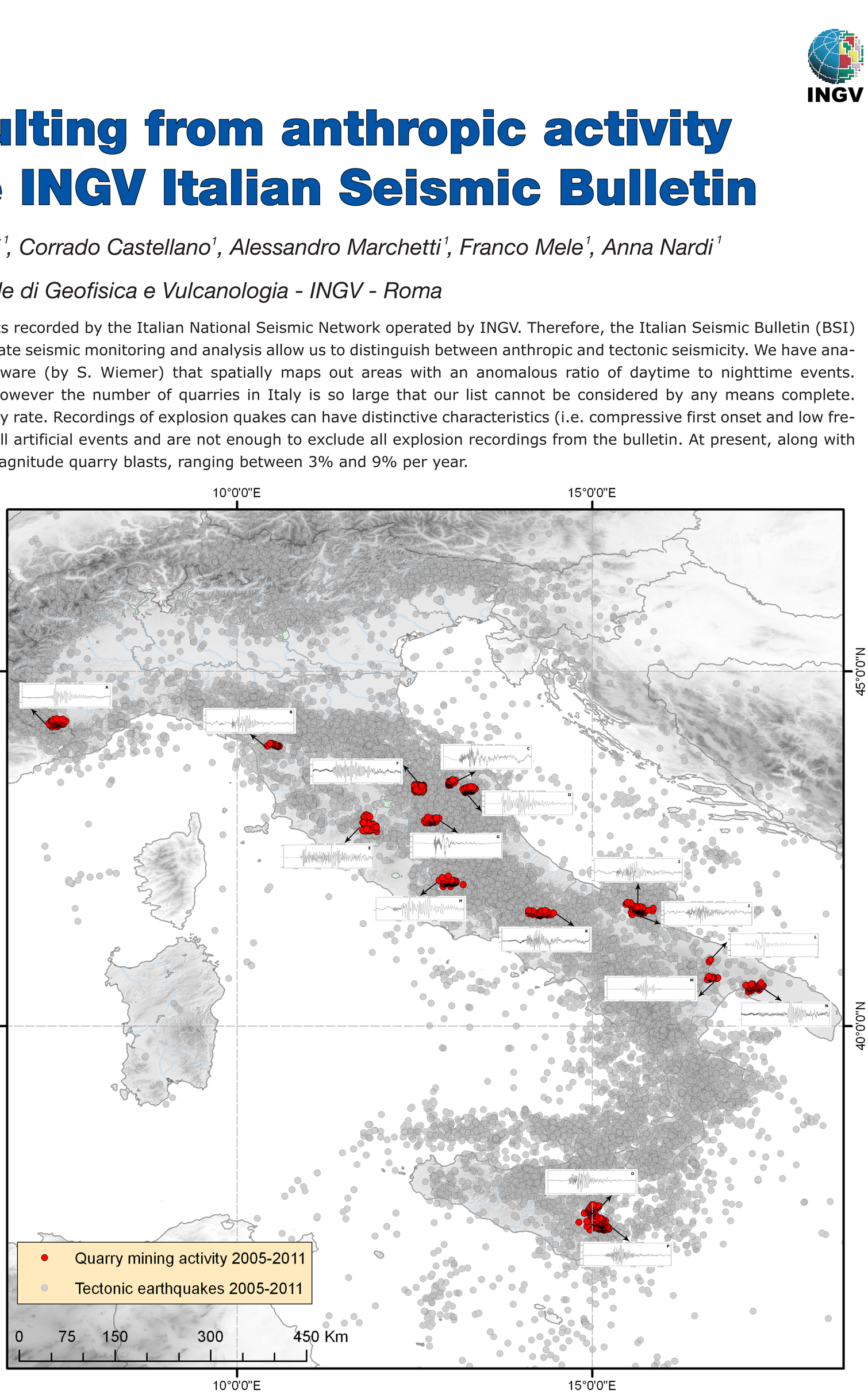
An extremely reduced activity was found in all areas during evening and night hours when compared to diurnal activity. In the histograms we plot the number of events versus local time. In some areas there is a total lack of nighttime events (natural earthquake) as in Masseria Censo (**L**), province of Bari, situated in the stable Apulian foreland. In other areas the prevalent diurnal activity is mixed up with natural seismicity and this aspect is confirmed by the presence of nighttime events, as in the Isernia area (**K**) located close to large seismogenic, NW-SE striking, normal fault systems in the southern Apennines.



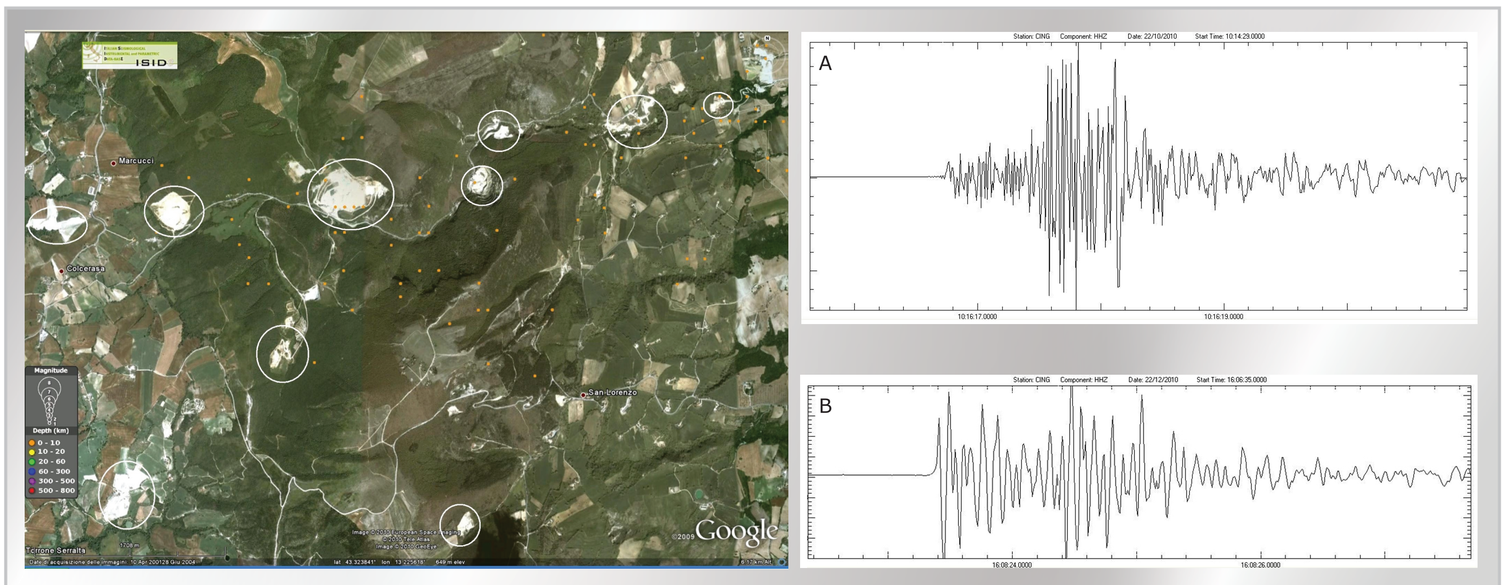
Hourly distribution of all BSI events in the period 2005-2011 including (red bars) and excluding (gray bars) the events from quarry areas. The histogram shows an apparent prevalence of nightly seismicity, probably due to a reduced anthropic noise and a consequent enhanced detection capability of the seismic network. A residual high value of seismic events (in gray) between 12 a.m. and 1 p.m. could provide evidence of other undetected quarry areas.



Distribution of events recorded in the BSI, from 2005 to 2011, in the 16 areas listed in the above table. The number of night events is considerably smaller than the number of daytime events; the number of events occurred during weekends is substantially smaller than the number of events recorded between Monday and Friday. Most events have a magnitude ranging from 0.5 and 2.4. The modal value is 1.4.



Map of Italy showing the identified 16 areas where quarry mining activities were recorded in the period 2005-2011 (in red). For each quarry area an example of digital waveform (vertical component) of the nearest station is represented. Seismicity data from the BSI in the period 2005-2011 are available at: ***http://iside.rm.ingv.it/***.



Google map showing a group of quarries between Marcucci (near Cingoli) and San Lorenzo (near Treia), in the province of Macerata, marked as white ellipses. Small orange circles show the position of events included in the Italian Seismic Bulletin (BSI); most of them are blasts from mining activity. The two digital seismograms represent the most striking differences between a tectonic earthquake (A) and a quarry blast (B). The main characteristics of an explosion are displayed in figure B: compressive onset of the P phase and nearly monochromatic appearance of the entire signal. Secondary phases (probably Rg) are frequently misinterpreted as Sg; false attributions can bias the computation of the depth of the explosion events. Therefore, the hypocentral depth is not a clear evidence that can discriminate between tectonic and anthropic quakes.

References

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