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Local seismicity in Rome (Italy): recent results from macroseismic evidences

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Abstract
This paper presents the results obtained from the study of the macroseismic effects of the June 12, 1995 Rome earthquake. The event, $M_D = 3.8$, provoked VI degree MCS effects in neighbourhoods of Southern Rome. This earthquake is important within the framework of seismicity in the Rome area, as it is the first noteworthy one ever to be recorded in the instrumental age, and provides a good comparison with historical earthquakes which have occurred in the same area. The filtering procedure performed on the macroseismic field reveals out the anomalies of the attenuation pattern and the site effect. The results reconfirm what has only recently emerged from the analysis of historical earthquakes, *i.e.* Rome is affected by local seismicity, that can cause damage in the southern neighbourhoods and the downtown area, especially where the site contributes to the amplification of the effects.

Key words *macroseismic – Rome – site effects*

1. Introduction

The seismic vulnerability of Rome has recently been analysed by many authors (Rovelli *et al.*, 1994; Molin *et al.*, 1995; Rovelli *et al.*, 1995; Tertulliani and Riguzzi, 1995) in an attempt to explain the role of seismogenic areas responsible for effects in the city. Historically, Rome has been affected by earthquakes located in three clearly defined zones: the seismogenic area of the Central Apennines, the volcanic area of the Colli Albani and the district of Rome. The earthquakes are generally larger in the Central Apennines, up to a magnitude of approximately 7. In fig. 1 all the earthquakes affecting Rome are plotted, being distributed for felt intensity and distance Rome-epicentre. Among the different clusters of events, we can observe the group relative to local seismicity, within a range of 15-20 km, with maximum intensity not over VII MCS.

Recent studies have detailed the damage incurred in Rome from these different kinds of events, comparing them with Peak Ground Acceleration (PGA) modelling and geology (Rovelli *et al.*, 1994; Marra and Rosa, 1995). In synthesis we can affirm that Rome, during its history, suffered maximum effects, VII-VIII MCS, from Apennine earthquakes (about 100 km far) and lesser effects from local and Colli Albani earthquakes. The maximum intensity produced by local events is VII MCS which occurred in the southern neighbourhood of Rome after the 1895 earthquake (Riguzzi and Tertulliani, 1993). Further macroseismic studies have highlighted that local seismicity in Rome emanates from three different zones (fig. 2), within the urban area.

It has been stressed that heavy damage usually occurs to buildings built on the Tiber River alluvium, indicating how the local factor exerts more influence than the source effect with respect to the macroseismic evidences. In

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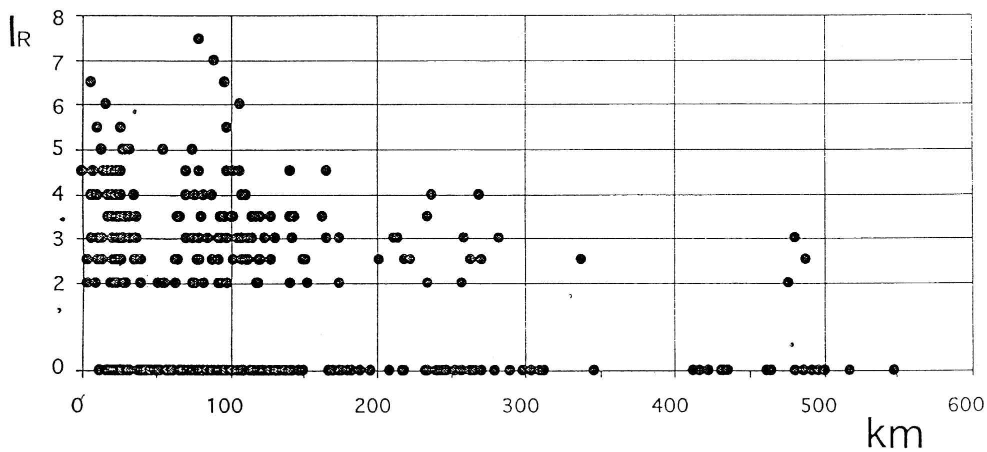

Fig. 1. Intensity distribution of past events observed in Rome, *versus* their epicentral distance. Three main clusters are distinguishable: 0-180 km, events from local, neighbouring and Apennine areas; 200-340 km events with intensities always lower than IV MCS; over 350 km distant earthquakes (from Molin *et al.*, 1995).

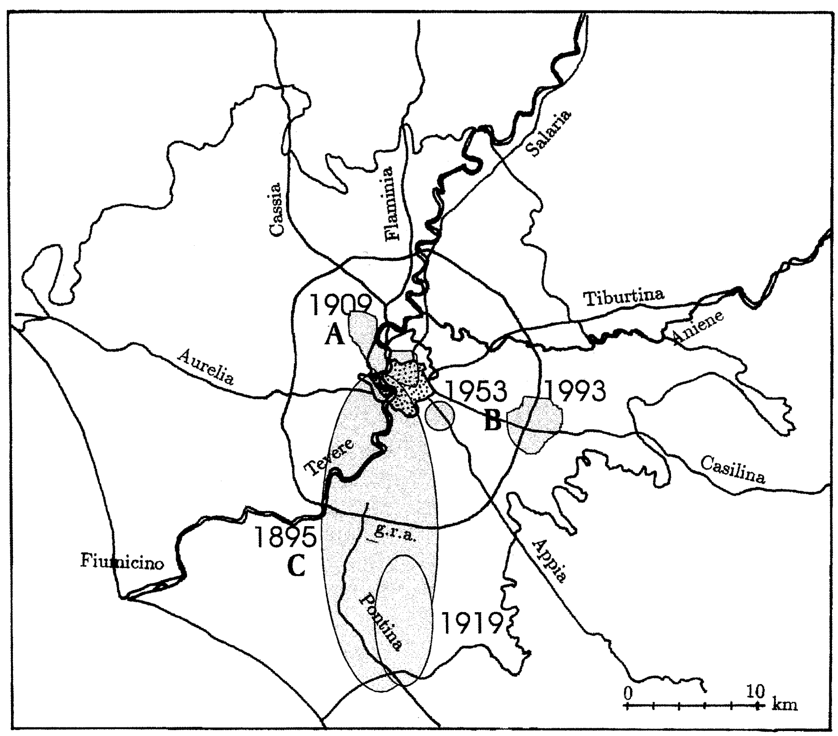

Fig. 2. Maximum intensity areas of local earthquakes, after Tertulliani and Riguzzi (1995). A: 31-8-1909, V-VI MCS; B: 3-4-1953, IV MCS and 11-1-1993, IV MCS, $M_L = 2.7$; C: 1-11-1895, VII MCS and 12-2-1919, V-VI MCS.

fact, this investigation has confirmed the results of the theoretical modelling of local response, which emphasise the increased ground acceleration corresponding to Holocene sediments and the topographic asperities of the bedrock (Rovelli *et al.*, 1995; Tertulliani and Riguzzi, 1995).

The whole state of the art concerning Roman seismicity is based on information from historical events only, as throughout the instrumental age a major earthquake has never been recorded in the Rome area. The occurrence of an earthquake in this area gave us the opportunity to carry out a detailed macroseismic campaign and to treat the collected data by means of statistical analysis, with the aim of enhancing the attenuation pattern of the regional macroseismic field and the eventual site effect.

2. June 12, 1995 Earthquake

On June 12, 1995 (h 18.13 GMT) Rome was shaken by an earthquake $M_D = 3.8$ ($M_L = 3.6$) located in the southern neighbourhood of Rome, $\Phi = 41.81°$N, $\lambda = 12.51°$E, h = 12-14 km (Basili *et al.*, 1995). An immediate macroseismic survey was carried out, collecting data by means of direct investigation and questionnaires. As the event involved a large city, it was not satisfactory to assess a single intensity value so that the urban area, within the ring-road (g.r.a.), was divided into cells with a side length of about two kilometers within which an intensity value was attributed. Subsequently, the macroseismic data were filtered and interpolated to construct a continuous macroseismic field (fig. 3). This procedure is

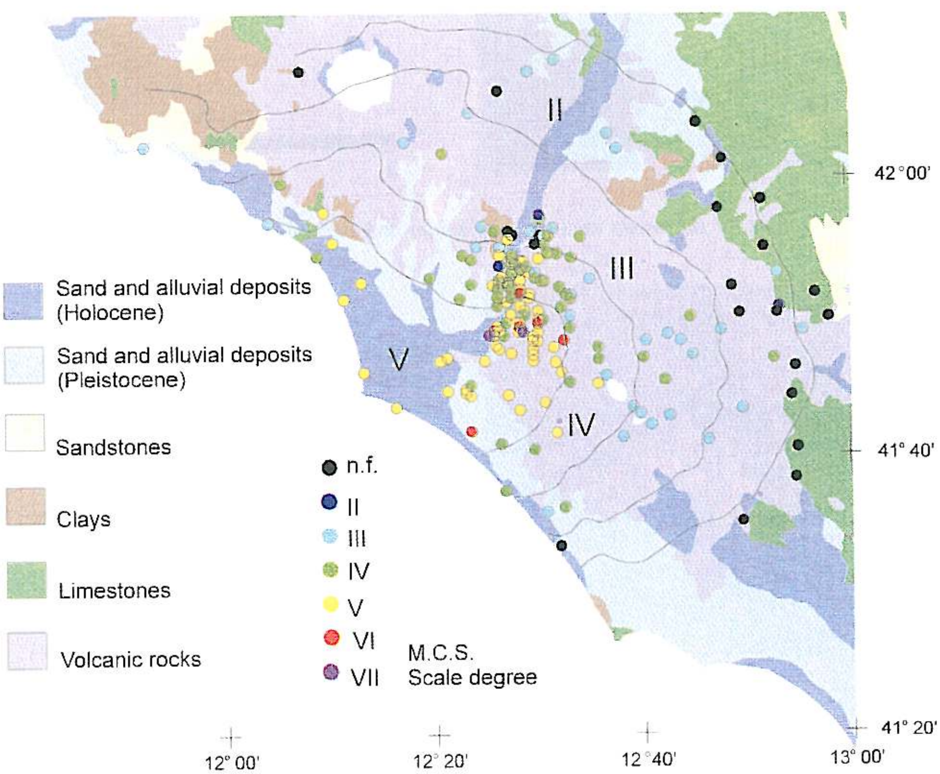

Fig. 3. Macroseismic field and geological map of the June 12, 1995 event area. The agreement between the shape of the V degree isoseismal and the alluvial deposits is noteworthy.

particularly necessary because the data distribution is not homogeneous, showing a high density of points inside the city, compared to the other zones. The filter is based on trend analysis conducted within sub-areas and is controlled through the fractal dimension of the intensity values. In fact the fractal dimension, essentially a measure of the roughness, tends to be very high in the presence of random noise in the data; it drops suddenly when the noise is filtered out. By the use of this parameter, calculated on filtered data, it is possible to gauge the filtering process and adjust the sub-area size, in order to define the regional component of the field, as separate from the noise and the purely local effects (Tosi *et al.*, 1995).

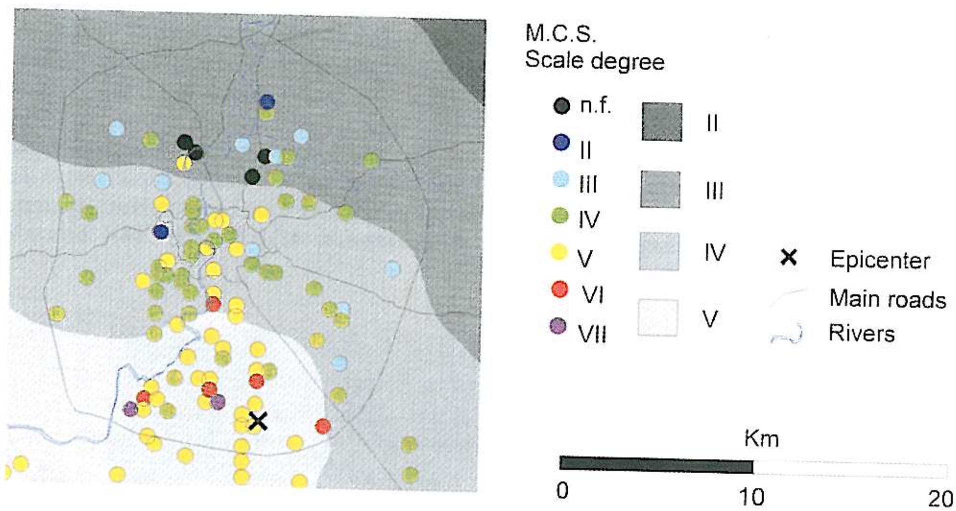

Fig. 4. Macroseismic field of the urban area (in grey scale) and intensity points.

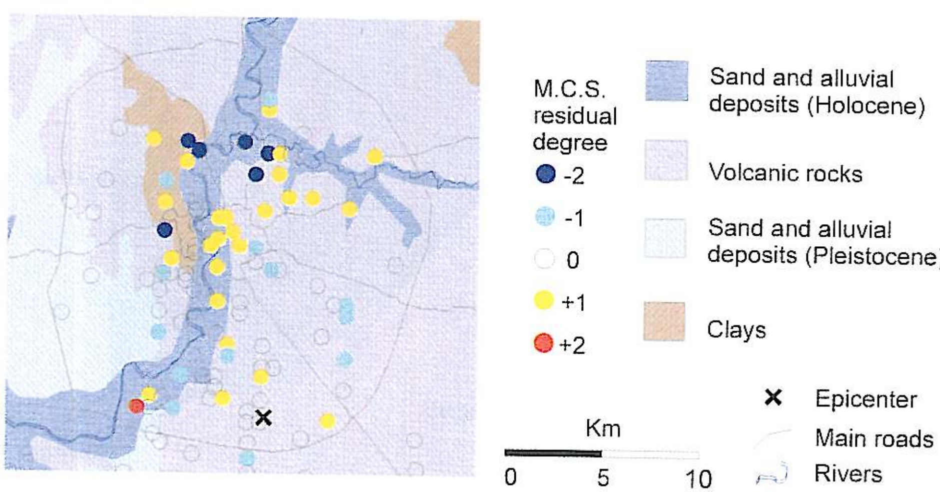

Fig. 5. Intensity residual values plotted on the geological map of Rome. Positive anomalies are indicated by yellow spots (+1) and red spots (+2), negative anomalies are indicated by cyan (−1) and blue (−2) spots.

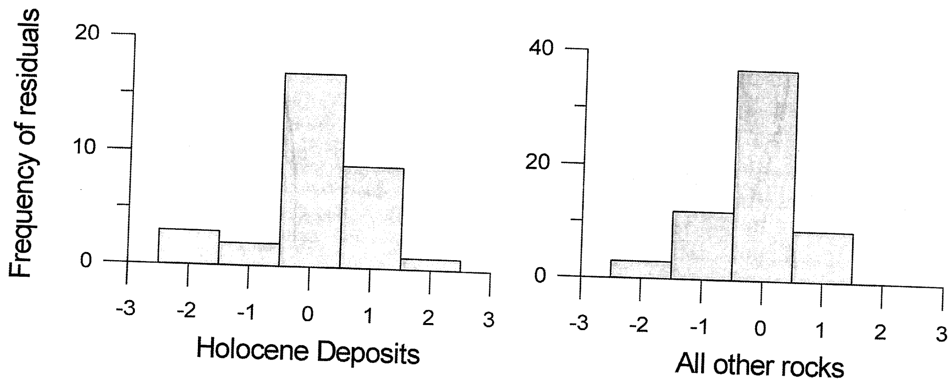

Fig. 6. Distributions of the intensity residual values inside the urban district pertaining respectively to the Holocene alluvial and fluviolacustrine deposits and to the other rocks.

The I_{max} area, V MCS (fig. 4), includes the southern part of the modern city of Rome, where slight damage, like fissures in plaster and partition walls in a few reinforced concrete buildings, and some damage to masonry houses was recorded. Most of the damage affected a very recently constructed settlement. In some parts of the city intensity locally reached VI and VII degrees MCS, probably due to a site effect. The general macroseismic field of this event (fig. 3) displays some interesting aspects: firstly, a minor attenuation of intensity in NW direction, due to a large amount of alluvial river sediments from the Tiber; secondly, a large attenuation in direction ESE, towards the Apennine chain; and finally the remarkable variability felt within the urban area of Rome, ranging from the *not felt* to the characteristic damage of the VII MCS degree (fig. 4). The complicated intensity distribution in this area can be attributed to the geological and urbanistic complex. However, this kind of feature is also quite clearly recognizable in other local earthquakes, re-analysed in a historical manner (Riguzzi and Tertulliani, 1993; Molin *et al.*, 1995).

To evidence the site effect in the urban district, the intensity regional field (fig. 4) was subtracted from each data point to obtain a residual map (fig. 5). The localization of the residuals shows that, in the urban district of Rome, there is not a random pattern, rather, there are zones of intensity amplification and of depression. Moreover, a correlation appears between the amplification points and the alluvial deposits. In particular, a noticeably large area of positive anomaly crosses the central part of the city. This positive anomaly runs along the Tiber valley and those of its tributaries extending to that part of the city founded at the beginning of the century, where the thickness of the embankment is higher than 5 m (Corazza and Marra, 1995). Contrarily, negative anomalies appear where piroclastic formations are widely present, and where the thickness of the alluvial sediments tends to decrease (fig. 5). To confirm this behaviour, the frequency distribution of the residuals, connected with alluvial Holocene deposits in respect to those belonging to the other rocks, is shown in fig. 6: it can be seen that the distribution for Holocene deposits is shifted towards the positive values, compared to the more symmetric distribution for the other rocks.

3. Comments

Literature has already highlighted the main features of the seismicity of the Rome area. The occurrence of this earthquake, although moderate, provided the elements with which it was possible to give a definitive aspect to the local seismicity of Rome. One result obtained is the confirmation of a local seismogenic area, located in the southern part of the modern city of Rome, as proposed by Riguzzi and Tertulliani (1992). Some other events of doubtful location (1811, 1812, 1919) can now also be attributed to this area (De Rossi, 1897; Agamennone, 1922, 1923; Molin and Guidoboni, 1989; Riguzzi and Tertulliani, 1993; Molin and Rossi, 1993; Molin *et al.*, 1995). These local earthquakes are distinct from nearby Colli Albani events. Although their locations are quite near, and in the past they have often been confused, the events located closer to Rome show a higher depth (Amato and Chiarabba, 1995; Basili *et al.*, 1995), confirmed also by the lower attenuation of the macroseismic field. Moreover, this kind of local earthquake produces a characteristic pattern of effects in Rome, shaking more western districts than eastern ones (Molin *et al.*, 1995).

The shape and orientation of the maximum intensity area of the event under study, has also proved to be different from that of historical events (fig. 1). This discrepancy arises both from the larger number of quoted points collected and the urban growth, especially southwards, over the past 100 years. Areas most shaken by the June 12, 1995 earthquake are of recent construction, being uninhabited at the beginning of the century, with the exception of some rural settlements ribboned along the main roads (De Rubeis *et al.*, 1995). The increase in suburban areas in Rome has changed the vulnerability distribution of the city, widening the risk from a few areas downtown to the modern districts of southern Rome. Nevertheless, a common aspect among the local earthquakes is noticeable: an elongation, more or less pronounced, N-S orientated, parallel to the Tiber valley within Rome. This shape of the trend effect is in agreement with both the Holocene alluvial plane, and the presence of the buried N-S oriented faults, which could influence the seismic propagation in the shallowest layers. Finally, the method used to extract the intensity residuals, supported by a statistical analysis, has confirmed the important role of the local amplification of earthquakes in a city like Rome.

REFERENCES

AGAMENNONE, G. (1922): Il terremoto di Castel Romano (Roma) del 12 febbraio 1919, *R. Oss. Geod. di Rocca di Papa*, Rome, 1-8.

AGAMENNONE, G. (1923): Contributo allo studio del terremoto Romano del 1 novembre 1895, *Boll. Soc. Sism. It.*, **24**, 89-91.

AMATO, A. and C. CHIARABBA (1995): Earthquake occurrence and crustal structure, in *The Volcano of the Alban Hills*, edited by R.TRIGILA, Roma.

BASILI, A., L. CANTORE, M. COCCO, A. FREPOLI, L. MARGHERITI, C. NOSTRO and G. SELVAGGI (1995): Impatto di microterremoti nella città di Roma: il terremoto del 12 giugno 1995, in *14° GNGTS*, Rome (in press).

CORAZZA, A. and F. MARRA (1995): Carta dello spessore dei terreni di riporto, in *La Geologia di Roma*, edited by R. FUNICIELLO, Mem. desc. della Carta Geol. d'Italia, **L**.

DE ROSSI, M.S. (1897): I terremoti nella città di Roma, *Bull. Vulc. It.*, **18-20**, 9-21.

DE RUBEIS, V., C. GASPARINI, A. MASSUCCI, A. TERTULLIANI, P. TOSI and M. VECCHI (1995): Il terremoto del 12 giugno 1995, conferma di una sismicità romana, in *14° GNGTS*, Rome (in press).

MARRA, F. and C. ROSA (1995): Stratigrafia e assetto geologico dell'area romana, in *La Geologia di Roma*, edited by R. FUNICIELLO, Mem. desc. della Carta Geol. d'Italia, **L**, 49-118.

MOLIN, G. and E. GUIDOBONI (1989): Effetto fonti effetto monumenti a Roma. I terremoti dall'antichità ad oggi, in *I Terremoti Prima del Mille in Italia e nell'Area Mediterranea*, edited by E. GUIDOBONI, Bologna, 194-223.

MOLIN, D. and A. ROSSI (1993): Terremoto di Roma del 22 marzo 1812 – studio macrosismico, in *Atti 12° GNGTS*, Rome, 279-286.

MOLIN, D., S. CASTENETTO, E. DI LORETO, E. GUIDOBONI, L. LIPERI, B. NARCISI, A. PACIELLO, F. RIGUZZI, A. ROSSI, A. TERTULLIANI and G. TRAINA (1995): Sismicità di Roma, in *La Geologia di Roma*, edited by R. FUNICIELLO, Mem. desc. della Carta Geol. d'Italia, **L**, 331-410.

RIGUZZI, F. and A. TERTULLIANI (1992): I terremoti romani del 1895 e del 1909, *Geol. Tec. Amb.*, **1**, 39-44.

RIGUZZI, F. and A. TERTULLIANI (1993): Re-evaluation of minor events: the examples of the 1895 and 1909 Rome earthquakes, *Natural Hazards*, **7**, 219-235.

ROVELLI, A., A. CASERTA, L. MALAGNINI and F. MARRA (1994): Assessment of potential strong ground motions in the city of Rome, *Annali di Geofisica*, **37**, 1745-1769.

ROVELLI, A., L. MALAGNINI, A. CASERTA and F. MARRA (1995): Using 1-D and 2-D modelling of ground motion for seismic zonation criteria: results for the city of Rome, *Annali di Geofisica*, **38**, 591-606.

TERTULLIANI, A. and F. RIGUZZI (1995): Earthquakes in Rome during the past one hundred years, *Annali di Geofisica*, **38**, 581-590.

TOSI, P., V. DE RUBEIS and C. GASPARINI (1995): An analytic method for separating local from regional effects on macroseismic intensity, *Annali di Geofisica*, **38**, 55-65.

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