DOI 10.4430/bgo00396

A critical overview of the January-February 1703 seismic sequence in central Italy

A. Tertulliani and L. Graziani

Istituto Nazionale di Geofisica e Vulcanologia, Roma, Italy

(Received: 16 February 2022; accepted: 13 May 2022; published online: 27 July 2022)

ABSTRACT Historical seismic sequences with multiple mainshocks or strong foreshocks and aftershocks make it difficult to attribute the damage distribution to one earthquake rather than another. As a matter of fact, historical reports often describe the cumulative picture of effects, preventing a correct reconstruction of what happened during the different earthquakes. This paper proposes a review of the catastrophic seismic sequence that hit central Italy starting from January 1703. The sequence is currently quoted in some seismic catalogues with three mainshocks that occurred on 14 and 16 January and 2 February, with magnitudes ranging between 6.0 and 6.9. The aim of this paper is to reconsider the sequence on a chronological basis, trying to reconstruct the impact of each single event, taking into account the damage progression when assigning macroseismic intensity. Through this approach, the earthquakes already quoted in the catalogue are reassessed as faithfully as possible, with a richer framework of knowledge than in the past.

Key words: central Italy, 1703 seismic sequence, cumulative effects, macroseismic intensity EMS-98.

1. Introduction

The 1703 seismic sequence was one of the most devastating events of Italian seismic history. It occurred in the central Apennines range, which was also the site of the 2009 L'Aquila earthquake and the recent 2016-2017 seismic sequence (Fig. 1). The knowledge on the earthquakes of January and February 1703 is based on a ponderous body of documentation made up of official reports by the governmental administrations and many journalistic reports written in the aftermath of the events. At the base of the considerable amount of documentation, there is certainly the great media resonance due to the dramatic impact on the territory, and probably also to the fact that the earthquakes caused damage and considerable fear in the far city of Rome (Tertulliani *et al.*, 2020). The reference study of the Italian Macroseismic Database [DBMI15: Locati *et al.* (2021)] and the Parametric Catalogue of Italian Earthquakes [CPTI15: Rovida *et al.* (2021)] of this seismic sequence is Guidoboni *et al.* (2018).

The sequence is quoted in the catalogues with two mainshocks, respectively on 14 January and 2 February 1703 [M_w 6.9 and 6.7, respectively: CPTI15 (Rovida *et al.* (2021)], separated by another event on 16 January [M_w 6.0: Guidoboni *et al.* (2018)]. Both mainshocks were felt from Naples to Venice, and provoked damage even in Rome (Molin and Guidoboni, 1989; Molin and Rossi, 2007; Galli and Molin, 2014; Tertulliani *et al.*, 2020). Valnerina, upper Reatino and northern Abruzzo were the most severely affected areas with the destruction of dozens of towns and villages, such as Norcia, Cascia, Amatrice, and the very serious damage to L'Aquila. The cost of the catastrophe, both in terms of victims, almost 10,000 (the number varies according to the sources), and of economic-social fallout, was enormous and left a deep mark in the memory of the cities and towns of central Italy that were involved. It is worth pointing out that the 1703 seismic sequence was preceded by some event in the Norcia - Cascia area during the autumn of 1702 (Molin *et al.*, 2008). Those earthquakes, so far poorly investigated, caused some damage in Norcia and Cascia and were also felt in Rome.

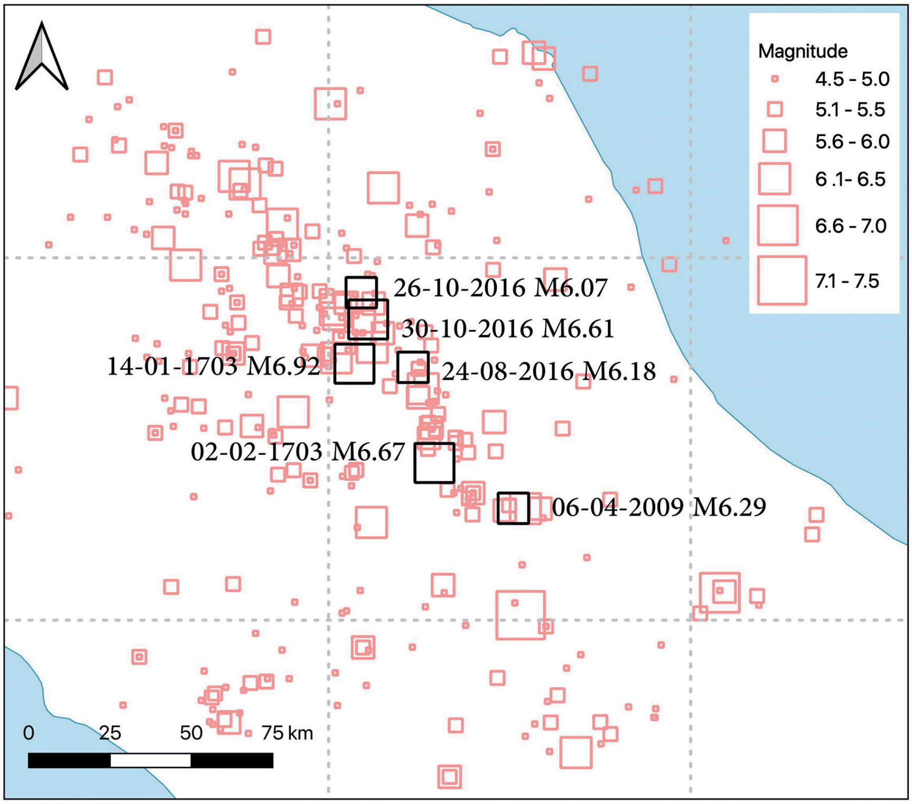

Fig. 1 - Map of the seismicity of central Apennines from CPTI15 (Rovida *et al.*, 2021). Black squares indicate the 1703, 2009, and 2016 major earthquakes.

Starting from Baratta (1901), many studies contributed to address and review the sequence, yielding, from time to time, significant improvements or new interpretations. The first modern studies provided a unique scenario for the whole sequence (Stucchi, 1985; Monachesi, 1987; Monachesi and Castelli, 1992), because of the objective difficulty in separating the three earthquakes of the sequence. Recent palaeoseismological investigations (Galli *et al.*, 2011, 2022b) revealed which faults may be responsible for the 14 January and 2 February 1703 earthquakes. Boschi *et al.* (1995) and all the following studies, instead, sought to separate the effects of each event. Recently, Tertulliani *et al.* (2022) reappraised the great amount of information collected in the last decades, adding new findings and assessing new intensities using the EMS-98 scale. On the basis of this last work, we summarise the updating of the knowledge of the 1703 seismic sequence, discussing the novelties based mainly on the underlying concept that during a seismic sequence the cumulative effect must necessarily be taken into account.

This assumption implies the need to identify the cause-effect relationship between earthquake and resulting damage within a seismic sequence, namely to establish which event of the sequence is responsible for the damage-induced picture provoked in each location.

This is very complex in the case of a historical sequence, since reports often describe the cumulative picture of effects, without providing the date of the different earthquake responsible for the damage description. However, while it is possible to reliably reconstruct the impact of the first shock from a description made shortly after the event, this is not feasible for subsequent earthquakes, due to the presence of prior damage that forces a cumulative assessment of damage. Not considering the progression of damage caused by repeated earthquakes introduces a distorting effect in intensity estimation, which affects the interpretation of earthquakes (Azzaro and Stucchi, 2000; Tertulliani *et al.*, 2018b; Azzaro *et al.*, 2019; Tertulliani, 2019). Due to this implication, the effects of cumulative damage on buildings undertaken by multiple shocks were also investigated in the frame of seismic engineering and hazard evaluation (Mouyiannou *et al.*, 2014; Penna *et al.*, 2014; Grimaz and Malisan, 2017; Iervolino *et al.*, 2018).

As occurred in previous events of the Italian seismic history [e.g. the catastrophic 1349 earthquake: Galli *et al.* (2022a)], even in the case of the 1703 seismic sequence the interpretation of the damage distribution is complicated by the presence of the political boundary between the Papal State and the Kingdom of Naples, which cuts the mesoseismic area in half. According to Hough and Martin (2021), geopolitical factors can introduce bias in the characterisation of earthquakes and their effects, adding uncertainties in the intensity assessment (among others, De Rubeis *et al.*, 1994; Tertulliani *et al.*, 1999, 2018a; Camassi *et al.*, 2011).

2. The 1703 seismic sequence: the source context

The 1703 seismic sequence struck a territory almost equally divided between the jurisdictions of the Papal State and the Kingdom of Naples.

The Holy See was quick to intervene, directly involved at a central level in the emergency measures in the damaged areas. The government of the Kingdom of Naples moved with a certain delay, because of the greater distance from the epicentral area, coupled with the slowness of the administrative organisation.

Given the short time interval - around two weeks - between the main earthquakes, many reference sources deal with the earthquakes of the sequence as a unique event, describing the effects in cumulative terms (Anonymous, 1703a), while there are only very few sources written between 14 January and 2 February.

Fig. 2 shows the chronological release of the sources according to their geographical origin: from the *corpus* of documents used by Tertulliani *et al.* (2022), we selected the sources released in the 30 years following the sequence. It is clear that the sources written at the end of the sequence are predominant, as are those coming from the Papal State both before and after the 2 February earthquake.

The event of 14 January is the object of the official report compiled by Pietro De Carolis, Apostolic Commissioner of the Holy See for the places struck by the earthquake. De Carolis, who left Spoleto on 21 January for a survey in the most damaged area, recorded on his own or through local correspondents (Galli *et al.*, 2020) reliable information about damage and mortality due to the earthquake of 14 January, likely summed with the shaking of 16 January, without ever mentioning this latter (De Carolis, 1703). In any case, the survey of De Carolis was confined to within the borders of the Papal State (Fig. 3). In turn, the administration of the Kingdom of Naples started its surveys only after the earthquake of 2 February (Fig. 3), as revealed

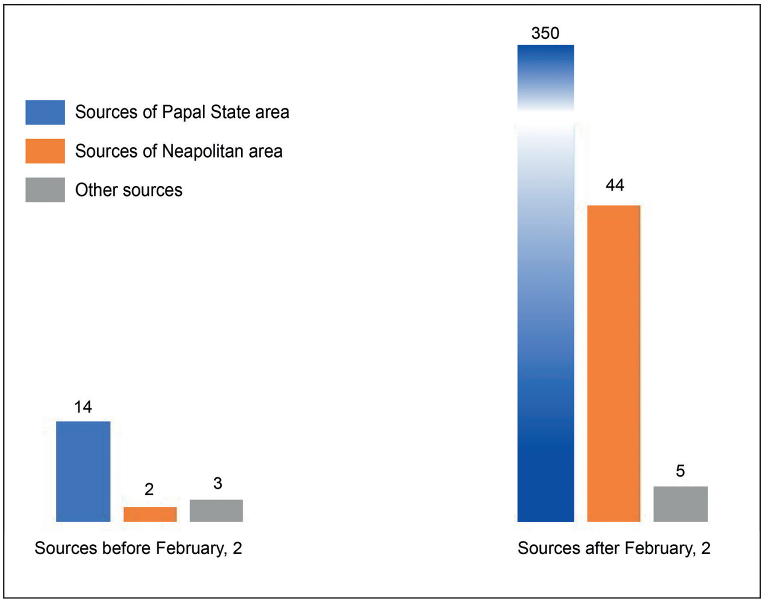

Fig. 2 - Chronological distribution of the number of sources regarding the 1703 seismic sequence written in the time span 1703-1730.

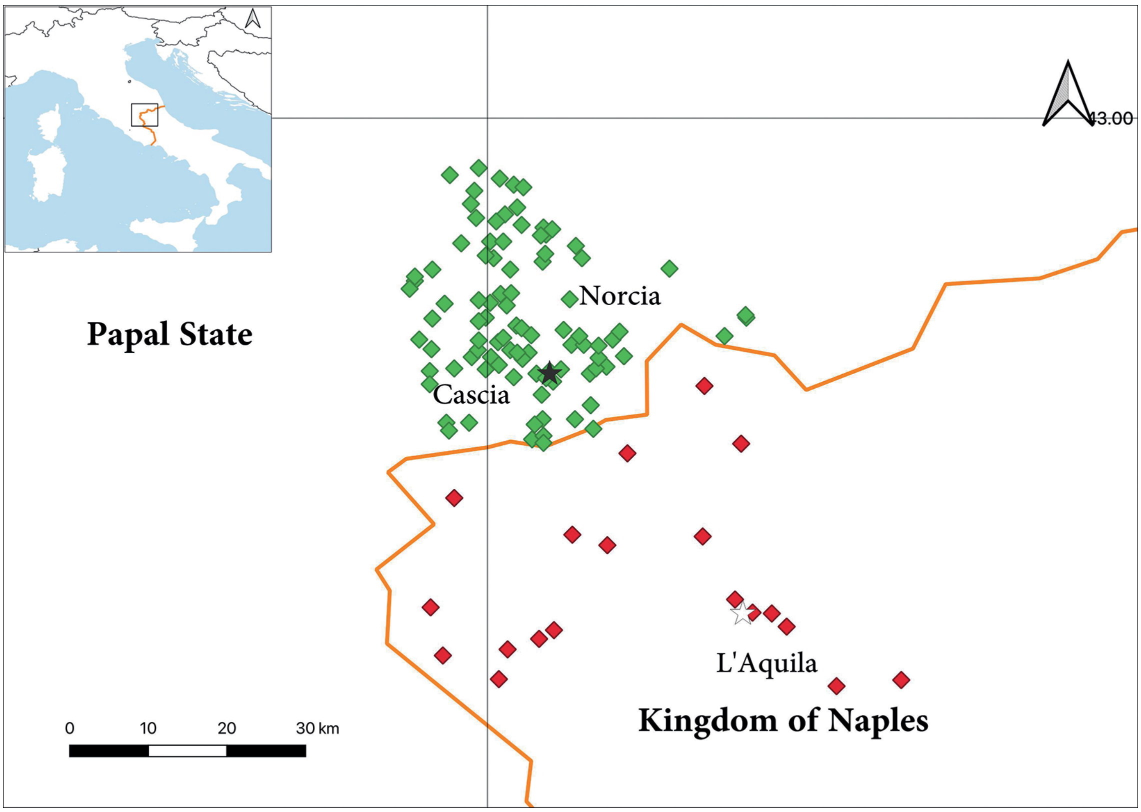

Fig. 3 - Distribution of the localities listed in the official reports. Green diamonds are localities of the Papal State surveyed by De Carolis (1703) before 2 February, with red diamonds the localities quoted in the reports by Uria De Llanos (1703) and Mancini (Cappa, 1871), visited after 2 February, located in the Naples Kingdom. The orange line represents the border between the Papal State and the Naples Kingdom. The stars represent the epicentres of the 14 January (black) and the 2 February (white) events, respectively (Rovida *et al.*, 2021).

by the dispatch of officials to gather information about the events by Viceregal Vicar Garofalo Marchese della Rocca (Uria De Llanos, 1703; Cappa, 1871; Zannetti, 1894). However, the few available sources prior to 2 February [Gazzetta di Mantova, 1703; Gazzetta di Napoli, 30 January (in Camassi and Castelli, 2007)] indicate that villages of the Kingdom of Naples, near the border, were seriously damaged by the 14 January earthquake. This information is confirmed by a letter to the Collateral Council (an organ of the Naples government) of 22 January 1703, recently found in the Naples archive (ASNa, 1703a), which generically reports that many villages of the Kingdom of Naples were heavily damaged by the 14 January earthquake. Despite its generic nature, this account would confirm that part of the area that would be devastated by the earthquake of 2 February was already damaged by the earthquake of 14 January, with the consequence that the intervention of the Neapolitan administration was able to record the overlap of the effects of all previous shocks.

The geopolitical setting, especially in the border area, caused overlapping of administrative procedures and different ways of collecting and circulating information, as is evident from the differences in the report style and accuracy between the Papal State and Kingdom of Naples. Proof of this discrepancy is in the majority of damage reports for the L'Aquila province, that were written in the form of lists of affected localities with relative number of victims and a brief description of the damage, often limited to only one adjective (e.g. destroyed, uninhabitable, ruined). An exception to this style is L'Aquila, the damage of which was described with thoroughness in several reports after the earthquake of 14 January.

3. The three 1703 earthquakes

3.1. January 14, 1703

The earthquake of 14 January 1703 is the best documented among the earthquakes of the sequence (Tertulliani *et al.*, 2022), and is characterised by a large number of Intensity Data Points (IDPs). It is also the only earthquake in the sequence for which it was possible to better identify a direct relationship between the event and the observed effects. A fruitful account of what happened in the Papal State is mainly due to the prompt intervention of its officers (De Carolis, 1703) that portrayed the situation before the February earthquake. De Carolis left Spoleto on 21 January and arrived in Norcia in a few days describing the extent of the disaster as follows: *"Arrived ... to see it (Norcia) from afar, I was astonished at such a deplorable sight, approaching I observed the city walls, which enclosed it, as if they had been beaten by cannon fire, all broken and fallen to the ground"*.

Later (but before 2 February), De Carolis reached the town of Cascia: *".... Not dissimilar is the tearful history of Cascia, and its County: as I got to visit it, ... I found that the city had been forced to acknowledge its total desolation, and the massacre of its inhabitants, where, although outside, buildings, churches and monasteries are still standing, inside, however, the sight is accompanied by the horror, due to great cracks that are in the walls, and the ruined dwellings, one can see in great numbers others falling down, some impracticable, and the rest no longer safe to live in"* (De Carolis, 1703).

Also the scholar Giorgio Baglivi, who wrote a general account of the earthquakes, drawn from other reports and sources, confirms the great destruction in Norcia: *"Norcia therefore by the earthquake of January 14, 1703 at 2 in the night was completely ruined and levelled to the ground, and a horrid pile of stone hints at the site of the ancient city"* (Baglivi, 1842).

Tertulliani *et al.* (2022) increases the number of IDPs from 197 of Guidoboni *et al.* (2018) to 279, including many new observations identified in unpublished sources never used before. A quick comparison (Fig. 4) with the data in Guidoboni *et al.* (2018) suggests that now the area under the jurisdiction of the Kingdom of Naples, close to the political border, is better documented, as well as the far field.

Many data points related to the Marche region, NE of the epicentral area, come from the studies of Monachesi (1987) and Monachesi and Castelli (1992), but they were overlooked by Guidoboni *et al.* (2018). Maximum intensity is assessed as 11 EMS-98 at a certain number of localities in the Papal State between Cascia and Norcia, and at two villages in the Kingdom of Naples, near the border.

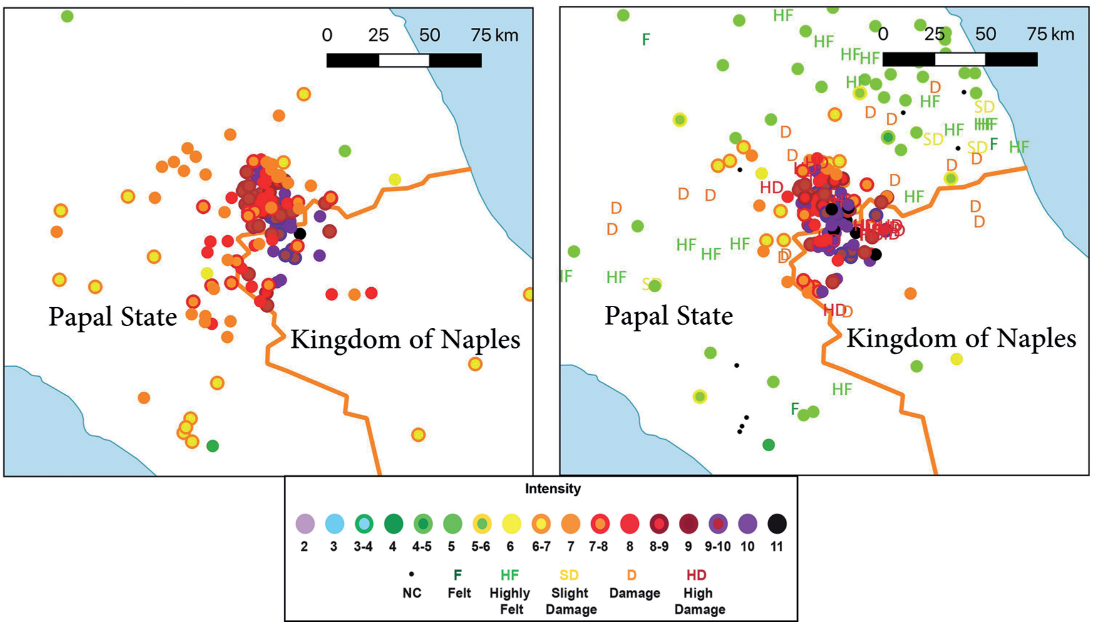

Fig. 4 - Comparison between the intensity distribution of 14 January 1703 in Guidoboni *et al.* (2018) (left) in MCS scale and in Tertulliani *et al.* (2022) (right) in EMS-98. The orange line represents the state border between the Papal State and the Naples Kingdom.

Notwithstanding part of the territory of the Kingdom of Naples (today's northern Rieti province) has been enriched with new points, a huge lack of information in the L'Aquila area and in the whole Kingdom still remains. This is certainly caused by the superposition of the effects due to the earthquake of 2 February, with the probable obliteration of the traces of the previous event. In fact, we know that the *corpus* of documents for that region is mostly dated after 2 February: this situation has certainly caused the masking of any reports of damage due to the earthquakes of 14 and 16 January, assimilating them into a single set of information that can no longer be separated.

3.2. January 16, 1703

The earthquake of 16 January is reported in Guidoboni *et al.* (2018) with M_w 6.0 and epicentral intensity equal to 8 MCS. In CPTI15 (Rovida *et al.*, 2021) the same earthquake has not been parameterised because the intensity data were not considered sufficiently reliable. The present work demonstrates that the 16 January event, as it was depicted by Guidoboni *et al.* (2018), is misleading and overrated, with its 22 macroseismic observations. Our analysis, aimed at the chronological reordering of the news content, has highlighted the great difficulty in documenting this event and, therefore, the impossibility to distinguish not only between its effects, but also to generically present its impact in the area already affected by the 14 January mainshock. It is important to note that the majority of the accounts mention only the earthquakes of 14 January and 2 February, while only a very few sources note the earthquake of 16 January, always associated with the one two days earlier. Among these, Baglivi (1842) tells of a shock that in L'Aquila was more damaging than the previous one, and that in Rome was felt with less intensity. After the detailed screening of all the available sources, the effects attributable to this earthquake result clearly documented and identified in only 12 localities, all of them with intensity equal to, or lower than, 5 EMS-98 (Fig. 5), except for Norcia, Spoleto, Foligno, and L'Aquila. These towns appear in the 14 January chronicles with great abundance of details such as to allow an accurate estimate of intensity for this earthquake. For instance for the town of Norcia we read: *"On the aforesaid evening (January 14) ... the strongest earthquake caused the majority of the edifices, houses, noble buildings and churches to collapse, leaving an infinity of persons buried alive under the ruins ... On Tuesday the 16th (January) the people continued to feel the earthquake tremors, but toward the twenty-first hour of the aforesaid day much greater collapses were heard pulling down other edifices ..."* (Lorenzani, 1703). We underline that all the sources agree in affirming that the greater part of the buildings of Norcia collapsed during the 14 January earthquake, and also the buildings that remained standing were completely collapsed inside. The intensity assessed is 10 EMS-98. The 16 January earthquake finished knocking down what was left standing. Although the descriptions disclose further damage due to the 16 January earthquake, this is not enough to justify any increase in the intensity value after 14 January and, therefore, the cumulative intensity assigned to Norcia is 10 EMS-98 and is marked with a square in Fig. 5. This does not mean that on 16 January Norcia suffered an intensity 10 EMS-98 shaking, but only that the 16 January earthquake produced further documented effects and that an observer, who arrived in Norcia after that day, would not have been able to distinguish between the effects of the different earthquakes. As occurred for Norcia, also for Spoleto and Foligno, the cumulative intensity values are equal to those assigned for the 14 January earthquake, because the macroseismic scenario remained substantially unchanged.

Ten other localities that were present in the intensity map of Guidoboni *et al.* (2018) have been discarded because no evidence of the effects produced by the 16 January event was found in the sources.

Among them, we mention the cases of Coppito and Roio Piano villages, near L'Aquila, respectively intensity 7 and 8 MCS, for the following reasons. The reference source used by Guidoboni *et al.* (2018) reads "*On Tuesday (16) about twenty one hours later, there was another (shock) not so great, but with more damage, while two other bell towers fell, namely that of San Pietro di Coppito, and that of Santa Maria di Rojo"* (Anonymous, 1703b). In truth, these toponyms are, instead, two important churches in the L'Aquila downtown (i.e. San Pietro a Coppito and Santa Maria di Roio), so that such information is certainly referable to L'Aquila (see also Antinori, 1971-1973).

Information about other localities, to which Guidoboni *et al.* (2018) assigned intensity 8 MCS, turned out to be inconsistent, as any description of effects due to 16 January does not exist in the sources. In addition, many of such localities had already been damaged by the 14 January earthquake, with intensity between 9-10 and 11 MCS degree, so the 8 MCS degree assessment would be impossible to assess, the diagnostics being saturated (i.e. damaged buildings) to give any information on the shaking. The above described framework, scarce and incomplete (the IDPs decrease from 22 to 12), provides very few elements to delineate even a vague picture of the earthquake of 16 January 1703. The data allow us only to affirm that it was an earthquake, certainly with much lower energy than those of 14 January and 2 February, capable of producing aggravation in places already damaged on 14 January, such as L'Aquila, Spoleto, Norcia, and Foligno, and a clear warning in cities such as Rome, Fano, and Avezzano several tens of kilometres away. This picture leaves some hypotheses on the nature of this event open: an aftershock of the 14 January earthquake, an event caused by the activation of a third seismogenic structure localisable between Valnerina and L'Aquila, or a foreshock of the earthquake of 2 February. This latter hypothesis seems the weakest in view of the fact that the only available government document, the minutes of the meeting of the Collateral Council of 22 January 1703 (ASNa, 1703a), mentions damage and victims in the province of L'Aquila due to the earthquake of 14 January, without mentioning that of 16 January. We believe that if the earthquake of 16 January was located near L'Aquila, it would probably have been directly reported in the above-mentioned document.

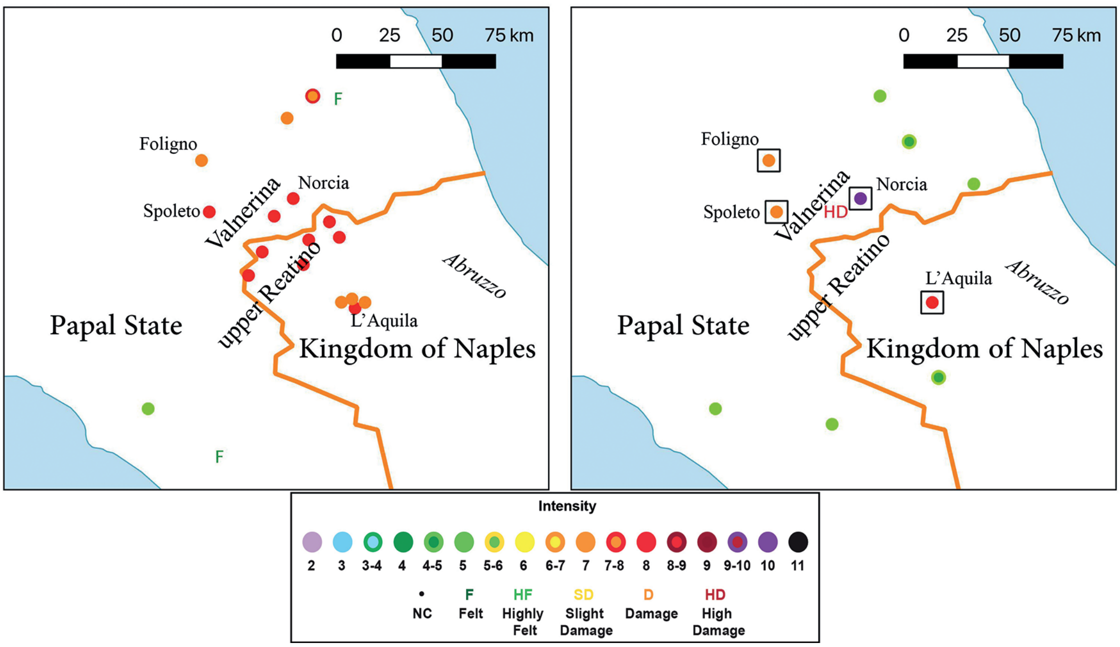

Fig. 5 - Map of the intensity distribution of 16 January 1703 from Guidoboni *et al.* (2018) (left) in MCS scale and from Tertulliani *et al.* (2022) (right) in EMS-98. The intensities marked with the square are cumulative. The orange line represents the state border between the Papal State and the Kingdom of Naples.

3.3. February 2, 1703

The 2 February earthquake is quoted in Guidoboni *et al.* (2018) with M_w 6.7 and maximum intensity 10 MCS.

The reappraisal by Tertulliani *et al.* (2022) doubled the number of IDPs from 69 of Guidoboni *et al.* (2018) to 137 (Fig. 6). Notwithstanding the important increase of data, this improvement of knowledge is insufficient to conclusively define the impact of this earthquake. This depends on the nature of the available data event, and it is mainly due to: a) cumulative effect, being the third event of the sequence, and b) inaccuracy of information in the coeval accounts.

As far as point a) is concerned, the sources indicate that several localities in the upper Rieti and L'Aquila area were severely damaged by the 14 January earthquake (see Fig. 4 and black squares in Fig. 5 right). As in the case of the 16 January earthquake, some localities suffered further damage due to the 2 February earthquake. However, as they were already severely damaged, they do not show important variations with respect to the intensity assessment of 14 January. In addition, there are other localities that were mentioned for the first time in the sources as being damaged by the 2 February earthquake that probably suffered the effects of the previous earthquakes as well. This is also suggested by the aforementioned document of the Collateral Council of 22 January (ASNa, 1703a), that mentions damage and victims in the province of L'Aquila due to the event of 14 January. We can hypothetically identify this area with the territory between the state border and the town of L'Aquila, being contiguous to the maximum intensity areas of 14 January.

In addition, the scarcity of IDPs in the northern area, already hit by the 14 and 16 January events, suggests that the interventions aimed at damage assessment by the Papal authorities had been exhausted with the report of De Carolis (1703) and that any effects of the 2 February earthquake were comprised in the very heavy effects of the 14 January earthquake.

As far as point b) is concerned, the careful analysis of the accounts related to the 2 February earthquake in the localities around L'Aquila highlighted a lack of details. Many places are vaguely described or grouped together in one description with no detail. For instance, the description from Anonymous (1703b) provides information on the effects suffered by many villages near L'Aquila: *"The places around the City (L'Aquila), such as Pizzoli, Scoppita, Arrischia, and Barete*

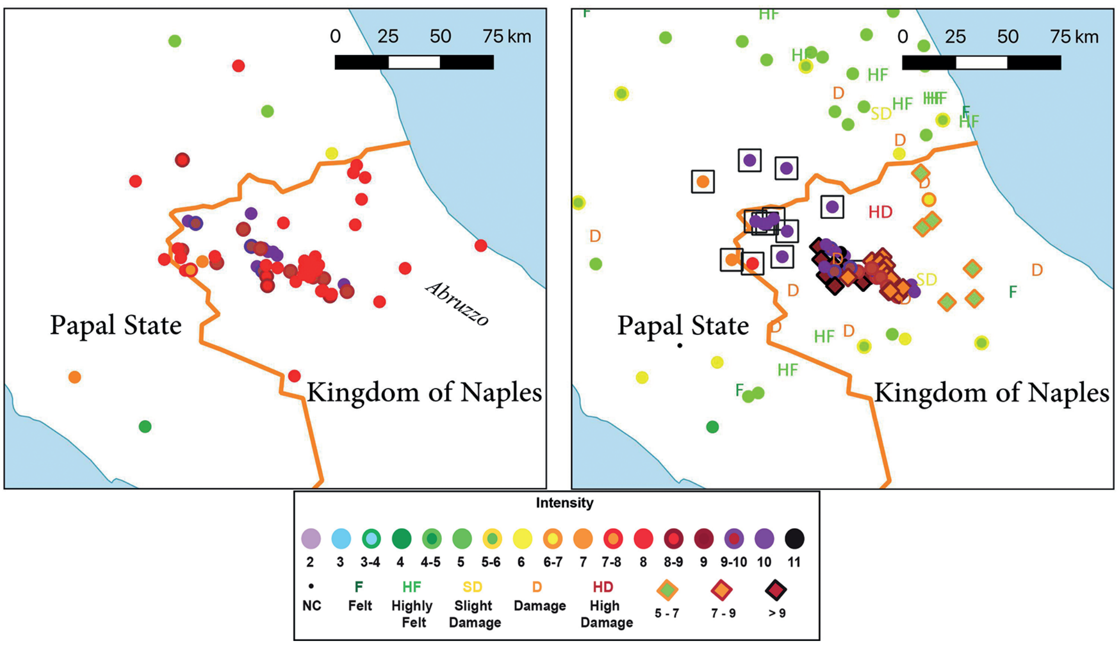

Fig. 6 - Map of the intensity distribution of 2 February 1703 from Guidoboni *et al.* (2018) (left) in MCS scale and from Tertulliani *et al.* (2022) (right) in EMS-98. The intensities marked with the square are cumulative. The orange line represents the state border between the Papal State and the Kingdom of Naples.

are levelled, and Paganica, Campana, Tempera, S. Gregorio, S. Eufanio, and Onda have suffered the same disaster".

Many of those accounts do not allow us to understand if the effects were due to the 2 February shock, or to cumulative damage.

In the diversity of the sources, the case of about 30 settlements in the Kingdom of Naples is notable, for which the estimate of intensity is critical, since the only information on the earthquake effects is the number of years of granted tax exemption. In fact, to help communities recover after calamitous events, it was common practice to grant tax exemptions for a certain number of years. The benefit was granted after a series of investigations aimed at ascertaining whether what the affected communities requested was true and well-founded, and after a negotiation between the central government and the local community (Cecere, 2017; Senatore, 2018). This procedure was certainly mediated by local mayors, based on existing political relationships and also on other factors, such as the strategic and economic importance of the places (presence of garrisons or fortifications important for the Kingdom, production of essential goods, presence of bishop's seat, and the risk of losing the tax revenue derived from the decrease in hearts (fiscal families).

Unfortunately, part of that documentation relating to the 1703 earthquakes, useful to shed light on the real conditions of many of the places involved in the calamity, has been dispersed, while only the scant information of the number of years of tax exemption (ASNa, 1703b) has come down to us.

This kind of information has often been used as a parameter proportional to the macroseismic intensity. However, for the reasons mentioned above, the number of years granted for tax exemption is not correlated to the severity of damage, and, therefore, cannot be directly converted to macroseismic intensity. This is also supported by a test we made selecting all the localities for which the number of years of tax exemption is accompanied by a description of damage. The result shows that there is no proportionality between these two quantities (Fig. 7), i.e. for one year of tax exemption granted the intensity ranges from 7 EMS-98, which means 'damaging', to 10 EMS-98, which stands for 'very destructive'. Similarly, for localities with effects

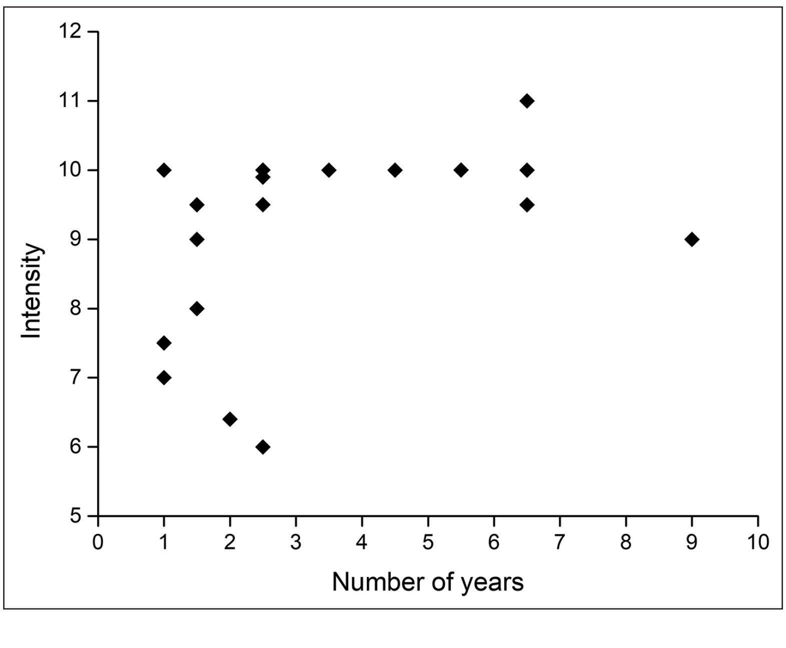

Fig. 7 - Distribution of the tax exemption years vs. intensity, for the localities accompanied by description of effects.

corresponding to intensity 10 EMS-98, exemption periods ranging from one to seven years, have been granted.

For the localities accompanied by the number of years of tax exemption granted as unique information, a wide range of intensity values has been assigned, as suggested by the EMS-98 guidelines (Grünthal, 1998). The intensity ranges have been chosen in reasonable continuity with the estimates from nearby sites accompanied by accounts: in less damaged areas, the range is 5-7 EMS-98, for areas with medium-severe damage 7-9 EMS-98, and for locations in areas of very severe damage the intensity >9 EMS-98. This type of assessment enables evaluating inaccurate information without making arbitrary interpretative choices. Assigning a range of intensity expresses the uncertainty that each value of the range is equally probable. Those intensities are represented in Fig. 6 with diamonds.

In the end, by comparing Tertulliani *et al.* (2022) and the Guidoboni *et al.* (2018) data sets, the 2 February earthquake results documented by 68 new IDPs. Notwithstanding this major step forwards, cumulative effects, sources vagueness, and a general documentary gap, make the knowledge of the 2 February earthquake still incomplete.

4. Conclusions

The present work was aimed at the macroseismic review of the scenarios of the earthquakes occurring from 14 January to 2 February 1703. We investigated the temporal scanning of these events and the progression of the effects in the various localities based on the recent study of Tertulliani *et al.* (2022). The occurrence of earthquakes in a narrow time span, with the presence of a territorial border, renders an extremely complex picture and prevents a clear reconstruction of the effects caused by the single earthquakes. The seismic sequence caused a large overlapping area of the major effects at the border of the two states, within which there was a reciprocal cancellation of information: the earthquake of 14 January, even if extremely detailed in the Norcia epicentral area and in the far field, remains indeterminate in the Kingdom of Naples areas, due to the late intervention of the Bourbon administration. The earthquake of 2 February, although enriched with numerous new observations, remains unsatisfactorily documented in the area straddling the border between the two states; this is due to both a scarcity of observations and because the available ones are likely inclusive of the effects of the 14 January earthquake. Moreover, the picture is made even more indefinite by the poorness of sources, which, in many cases, renders only the number of years of tax exemption granted by the administration of the Kingdom of Naples.

The earthquake of 16 January, mostly ignored by the sources, is documented by very few macroseismic observations, partly cumulative, leaving the interpretation on its real epicentral parameters uncertain. Indeed, the effects of this aftershock are not clearly recognisable, and, therefore, cannot be distinguished from those of the mainshock of 14 January. The re-reading of this sequence highlighted what had already been experienced in the field with the 2016-2017 sequence (Galli *et al.*, 2017; Rossi *et al.*, 2019), when cumulative effects play a key role in the study of seismic sequences, adding indeterminacy to the interpretation of subsequent damaging shocks. This indeterminacy reflects in the reconstruction of following earthquakes that are inevitably less constrained, in terms of both information and intensity, than the first one. The influence of the cumulative effects is more marked in the historical seismic sequences, where the comparison with the instrumental data is lacking and the presence of areas of superposition of the effects make it difficult to identify the epicentral areas. In order to mitigate the weight of cumulative intensities in the parametrisation, we suggest discarding these intensity values from the computation (Tertulliani *et al.*, 2021). Nevertheless, we think that cumulative intensities should in any case appear in the intensity maps, in a distinguishable way, in order to provide all elements that contribute to the composition of the scenario.

The issue of the 1703 seismic sequence represents an example among the many cases present in the Italian seismic catalogues, where incorrect intensity assessments, as in the cases of the 1627 Gargano (southern Italy) and 1783 southern Calabria seismic sequences, produced misleading or questionable parametrisations.

In the end, we wish to highlight how delicate the role of historical seismology is, especially in the case of seismic sequences, where the knowledge of the chronology of the shocks is fundamental to reconstruct the damage scenario due to each shock, not neglecting the cumulative damage contribution.

Acknowledgments. This work was presented at the 39th Meeting of the National Group of Solid Earth Geophysics (GNGTS), held in on-line mode 22-24 June, 2021. We thank two anonymous referees that helped improve and make the paper clearer.

REFERENCES

Anonymous; 1703a: *Relazione distinta de' danni cagionati da' passati Tremuoti nel Regno di Napoli e nello Stato di Santa Chiesa in quest'Anno 1703.* Napoli.

Anonymous; 1703b: *Veridica, e distinta Relazione overo diario de' danni fatti dal Terremoto dalli 14 Gennaro, fino alli 2 di Febraro 1703.* Roma.

Antinori A.L.; 1971-1973: *Annali degli Abruzzi dalle origini all'anno 1777.* Arnaldo Forni Editore, Bologna, Italy, 24 vols.

ASNa; 1703a: *Consiglio Collaterale.* Notamenti, 107, cc. 97v-98r (manuscript).

ASNa; 1703b: *Nota relativa alla stesura dell'elenco delle università del ripartimento di Penne alle quali vanno concesse esenzioni fiscali in seguito ai danni causati dal terremoto del 1703, Napoli 1 ottobre 1703.* Regia Camera della Sommaria, Notamentorum, fascio 144, c. 1033 (manuscript).

Azzaro R. and Stucchi M.; 2000: *The evaluation of the effects of earthquake sequence in the light of the EM-98 intensity scale.* In: Castelli V. (ed), Papers and memoranda from the first workshop of the ESC working group "historical seismology", Macerata, Italy, pp. 48-53.

Azzaro R., Barbano M.S., Tertulliani A. and Pirrotta C.; 2019: *A reappraisal of the 1968 Valle del Belìce seismic sequence (western Sicily): a case study of intensity assessment with cumulated damage effects*. Ann. Geophys., 63, SE105, doi: 10.4401/ag-8308.

Baglivi G.; 1842: *Serie delle città, dei villaggi e dei castelli del Dominio Ecclesiastico nell'Umbria e nei Sabini che da questi terremuoti o furono rovinati o quasi devastati nell'anno 1703*. In: Baglivi G., Opere complete medico-pratiche ed anatomiche, Tipografia Sansone Coen, Firenze, Italy, pp. 628-635.

Baratta M.; 1901: *I terremoti d'Italia. Saggio di storia, geografia e bibliografia sismica Italiana.* (Forni, ristampa anastatica, Sala Bolognese, 1979), Torino, Italy, 950 pp.

Boschi E., Ferrari G., Gasperini P., Guidoboni E., Smriglio G. and Valensise G.; 1995: *Catalogo dei Forti Terremoti in ltalia dal 461 a.*C. *al 1980.* ING-SGA, Bologna, Italy, 973 pp.

Camassi R. and Castelli V.; 2007: *La percezione dei terremoti del 1703 nelle fonti giornalistiche coeve.* In: Colapietra R., Marinangeli G. and Muzi P., a cura di, Atti del Convegno di Studi nel III Centenario della nascita di Antonio Ludovico Antinori (1704-2004), Settecento abruzzese. Eventi sismici, mutamenti economico-sociali e ricerca storiografica, L'Aquila, 2004, Italy, pp. 43-68.

Camassi R., Caracciolo C.H., Castelli V. and Slejko D.; 2011: *The 1511 eastern Alps earthquakes: a critical update and comparison of existing macroseismic datasets*. J. Seismol., 15, 191-213, doi: 10.1007/s10950-010-9220-9.

Cappa F.; 1871: *Sul terremoto che a' 2 di febbraio 1703 rovinò L'Aquila e molti paesi di Abruzzo.* Tipografia Aternina, Aquila, Italy, 19 pp.

Cecere D.; 2017: *Scritture del disastro e istanze di riforma nel Regno di Napoli (1783)*. *Alle origini delle politiche dell'emergenza.* Studi storici, 1, 187-214.

De Carolis P.; 1703: *Relazione generale delle ruine, e mortalità cagionate dalle scosse del Terremoto de' 14 Gennaro, e 2 Febbraro 1703 in Norcia, e Cascia, e loro contadi, compresi li Castelli delle Rocchette, e Ponte, Giurisdizione di Spoleto.* Roma, Italy, 25 pp.

De Rubeis V., Maramai A. and Tertulliani A.; 1994: *National borders earthquakes: an attempt at intensity maps unification*. Ann. Geophys., 37, 77-91.

Galli P. and Molin D.; 2014: *Beyond the damage threshold: the historic earthquakes of Rome*. Bull. Earthquake Eng., 12, 1277-1306, doi: 10.1007/s10518-012-9409-0.

Galli P., Giaccio B., Messina P., Peronace E. and Zuppi G.M.; 2011: *Palaeoseismology of the L'Aquila faults (central Italy, 2009, Mw 6.3 earthquake): implications for active fault linkage.* Geophys. J. Int., 187, 1119-1134, doi: 10.1111/j.1365-246X.2011.05233.x.

Galli P., Castenetto S. and Peronace E.; 2017: *The macroseismic intensity distribution of the 30 October 2016 earthquake in central Italy (Mw 6.6): seismotectonic implications.* Tectonics, 36, 1-13, doi: 10.1002/2017TC00458.

Galli P., Galderisi A., Marinelli R., Peronace E., Messina P. and Polpetta F.; 2020: *A reappraisal of the 1599 earthquake in Cascia (Italian central Apennines): hypothesis on the seismogenic source*. Tectonophys., 774, 228287, doi: 10.1016/j.tecto.2019.228287.

Galli P., Galderisi A., Messina P. and Peronace E.; 2022a: *The Gran Sasso fault system: paleoseismological constraints on the catastrophic 1349 earthquake in central Italy.* Tectonophys., 822, 229156, doi: 10.1016/j.tecto.2021.229156.

Galli P., Peronace E. and Messina P.; 2022b: *Archaeoseismic evidence of surface faulting in 1703 Norcia earthquake (central Italian Apennines, Mw 6.9).* Geosci., 12, 14, doi: 10.3390/geosciences12010014.

Gazzetta di Mantova; 1703: Gazzetta di Mantova, 7.2.1703, n. 6, Mantova, Italy.

Grimaz S. and Malisan P.; 2017: *How could cumulative damage affect the macroseismic assessment?* Bull. Earthquake Eng., 15, 2465-2481, doi: 10.1007/s10518-016-0016-3.

Grünthal G. (ed); 1998: *European Macroseismic Scale 1998 (EMS-98)*. Cahiers du Centre Européen de Géodynamique et de Séismologie, 15, 100 pp., doi: 10.2312/EMS-98.full.en.

Guidoboni E., Ferrari G., Mariotti D., Comastri A., Tarabusi G., Sgattoni G. and Valensise G.; 2018: *CFTI5Med, Catalogo dei Forti Terremoti in Italia (461 a.C.-1997) e nell'area Mediterranea (760 a.C.-1500)*. Istituto Nazionale di Geofisica e Vulcanologia (INGV), Roma, Italy, doi: 10.6092/ingv.it-cfti5.

Hough S.E. and Martin S.S.; 2021: *Which earthquake accounts matter?* Seismol. Res. Lett., 92, 1069-1084, doi: 10.1785/0220200366.

Iervolino I., Chioccarelli E. and Giorgio M.; 2018: *Aftershocks' effect on structural design actions in Italy*. Bull. Seismol. Soc. Am., 108, 2209-2220, doi: 10.1785/0120170339.

Locati M., Camassi R., Rovida A., Ercolani E., Bernardini F., Castelli V., Caracciolo C.H., Tertulliani A., Rossi A., Azzaro R., D'Amico S. and Antonucci A.; 2021: *Database Macrosismico Italiano (DBMI15), versione 3.0.* Istituto Nazionale di Geofisica e Vulcanologia (INGV), Roma, Italy, doi: 10.13127/dbmi/dbmi15.3.

Lorenzani G.A.; 1703: *Terremoto accaduto in Norcia nel 1703 regnante Clemente XI Pontefice Optimo Maximo. Raguaglio delli terremoti accaduti in Norcia e ruvine della detta città e suo contado nel 1703*. Biblioteca Apostolica Vaticana, Manoscritti, Urbinati Latini 1699, cc. 175-186 (manuscript).

Molin D. and Guidoboni E.; 1989: *Effetto fonti, effetto monumenti a Roma: i terremoti dall'antichità ad oggi*. In: Guidoboni E. (ed), I terremoti prima del Mille in Italia e nell'Area Mediterranea, Istituto Nazionale di Geofisica (ING), Bologna, Italy, pp. 194-223.

Molin D. and Rossi A.; 2007: *Effetti prodotti in Roma dai terremoti del 1703*. In: Colapietra R., Marinangeli G. and Muzi P., (a cura di), Atti del Convegno di Studi nel III Centenario della nascita di Antonio Ludovico Antinori (1704-2004), Setttecento abruzzese. Eventi sismici, mutamenti economico-sociali e ricerca storiografica, L'Aquila, Italy, pp. 69-106.

Molin D., Bernardini F., Camassi R., Caracciolo C.H., Castelli V., Ercolani E. and Postpischl L.; 2008: *Materiali per un catalogo dei terremoti italiani: revisione della sismicità minore del territorio nazionale.* Quad. Geof., 57, 75 pp.

Monachesi G.; 1987: *Revisione della sismicità di riferimento per i comuni di Cerreto d'Esi (AN), Esanatoglia (MC), Serra San Quirico (AN).* Osservatorio Geofisico Sperimentale, Macerata, Italy, Internal report, 240 pp.

Monachesi G. and Castelli V.; 1992: *Sismicità dell'area aquilano-teramana dall'analisi "attraverso i cataloghi"*. Osservatorio Geofisico Sperimentale, Macerata, Italy, Rapporto tecnico, 245 pp.

Mouyiannou A., Penna A., Rota M., Graziotti F. and Magenes G.; 2014: *Implications of cumulative seismic damage on the seismic performance of unreinforced masonry buildings*. Bull. New Zealand Soc. Earthquake Eng., 47, 157-170, doi: 10.5459/bnzsee.47.2.157-170.

Penna A., Morandi P., Rota M., Manzini C.F., da Porto F. and Magenes G.; 2014: *Performance of masonry buildings during the Emilia 2012 earthquake*. Bull. Earthquake Eng., 12, 2255-2273.

Rossi A., Tertulliani A., Azzaro R., Graziani L., Rovida A., Maramai A., Pessina V., Hailemikael S., Buffarini G., Bernardini F., Camassi R., Del Mese S., Ercolani E., Fodarella A., Locati M., Martini G., Paciello A., Paolini S., Arcoraci L., Castellano C., Verrubbi V. and Stucchi M.; 2019: *The 2016-2017 earthquake sequence in central Italy: macroseismic survey and damage scenario through the EMS-98 intensity assessment.* Bull. Earthquake Eng., 17, 2407-2431, doi: 10.1007/s10518-019-00556-w.

Rovida A., Locati M., Camassi R., Lolli B., Gasperini P. and Antonucci A.; 2021: *Catalogo Parametrico dei Terremoti Italiani (CPTI15), versione 3.0*. Istituto Nazionale di Geofisica e Vulcanologia (INGV), Roma, Italy, doi: 10.13127/cpti/cpti15.3.

Senatore F.; 2018: *La corrispondenza interna nel regno di Napoli (XV secolo). Percorsi archivistici nella Regia Camera della Sommaria.* In: Giorgi A. and Occhi K., a cura di, Carteggi fra basso medioevo ed età moderna. Pratiche di redazione, trasmissione e conservazione, Il Mulino, Bologna, Italy, pp. 215-258.

Stucchi M.; 1985: *The earthquakes in central Italy, January-February 1703. Some questions, some preliminary answers.* In: Postpischl D. (ed), Atlas of isoseismal maps of Italian earthquakes. Quaderni della Ricerca Scientifica, 114, 56-57.

Tertulliani A.; 2019: *Historical earthquake sequences: handle with care*. In: Proc. AGU Fall Meeting 2019, San Francisco, CA, USA, Paper Number S21E-0554.

Tertulliani A., Cecic I. and Godec M.; 1999: *Unification of macroseismic data collection procedures: a pilot project for border earthquakes assessment*. Nat. Hazards, 19, 221-231, doi: 10.1023/A:1008083632762.

Tertulliani A., Cecić I., Meurers R., Sović I., Kaiser D., Grünthal G., Pazdirkova J., Sira C., Guterch B., Kysel R., Camelbeeck T., Lecocq T. and Szanyi G.; 2018a: *The 6 May 1976 Friuli earthquake: re-evaluation and unification of transnational macroseismic data*. Boll. Geof. Teor. Appl., 59, 417-444, doi: 10.4430/bgta0234.

Tertulliani A., Graziani L., Rovida A. and Antonucci A.; 2018b: *Effetti cumulativi nelle sequenze sismiche e stima dei parametri macrosismici: cosa abbiamo imparato dalla sequenza del centro Italia del 2016-2017*. In: Proc. 37th Convegno Nazionale del Gruppo Nazionale per la Geofisica della Terra Solida (GNGTS), Bologna, Italy, pp. 101-102.

Tertulliani A., Graziani L. and Esposito A.; 2020: *How historical seismology can benefit from bureaucracy: the case of the "Lettere Patenti" of the city of Rome in 1703*. Seismol. Res. Lett., 91, 2511-2519, doi: 10.1785/0220200046.

Tertulliani A., Graziani L. and Rovida A.; 2021: *Macroseismic source parameters of seismic sequences: study of the 2016-2017 and 1703 central Italy.* In: Poster Virtual 37th General Assembly of the European Seismological Commission ESC2021, Session 37, 427.

Tertulliani A., Graziani L. and Locati M.; 2022: *Nuovo studio della sequenza sismica del gennaio-febbraio 1703 in Italia centrale*. Quad. Geof., 178, 1-578, doi: 10.13127/qdg/178.

Uria De Llanos A.; 1703: *Relazione, overo itinerario fatto dall'auditore D. Alfonso Uria De Llanos per riconoscere li danni causati dalli passati Terremoti seguiti li 14 Gennaro, e 2 Febraro MDCCIII con il numero de' Morti, e Feriti nella provincia dell'Aquila, e tutti li luoghi circonvicini per darne di essi distinta notizia al Signor Vice Ré di Napoli.* Roma, Italy, 4 pp.

Zannetti V.; 1894: *Di due diverse relazioni sul tremoto del 2 febbraio 1703*. Bollettino della Società di storia patria Anton Ludovico Antinori negli Abruzzi, ser. 1, a. 6, 59-65.

Corresponding author: Andrea Tertulliani
Istituto Nazionale di Geofisica e Vulcanologia
Via di Vigna Murata 605, 00143 Roma, Italy
Phone: +39 06 51860219; e-mail: andrea.tertulliani@ingv.it