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SEISMIC HISTORY OF AREAS OF MODERATE SEISMICITY: THE CASE OF THE EMILIAN PLAIN AND THE TREVISO AREA

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Abstract

This study is part of a research programme designed to enhance our understanding of seismic hazard through the analysis of historical earthquakes of moderate energy.
The main objective was to collect new information and conduct a review of existing data on seismic events that have occurred in two key areas: the Po Valley between Modena and Ferrara, and that of the Veneto pre-Alps between the cities of Asolo and Treviso, in order to update seismic hazard estimates and improve risk planning.
Particular attention was paid to the discovery of traces of earthquakes that were previously undocumented or overlooked, and to a critical analysis of historical sources, including archive documents, chronicles, and journalistic sources.
The methodology entailed a systematic collection and selection of seismological and documentary sources, which were then interpreted in terms of macroseismic intensity. The BOXER code was employed for the parameterisation of seismological data, resulting in a notable enhancement in the precision of magnitude estimates and the localisation of effects. A total of 55 earthquakes were re-examined, including 13 in the Modena-Ferrara plain, 23 in the Asolo area, and 19 in the Treviso region. Additionally, the research led to the discovery of new seismic events that had not been previously recorded, thus expanding the body of knowledge regarding regional seismicity.
The findings of this research are of paramount importance for the updating of seismic hazard maps and the development of seismic risk mitigation strategies in these two areas, which represent significant industrial and handicraft districts with a high seismic vulnerability due to their high population and infrastructure density, as well as their considerable economic impact.
The data collected enables the refinement of seismic hazard estimates and the recognition of the importance of moderate-energy earthquakes, which, while not destructive, are more frequently repeated over time and may cause significant damage. This study makes a valuable contribution to the existing body of knowledge on historical seismicity, providing data that can inform local and regional prevention planning.
The findings will serve as a new reference point for future research on these seismic events, contributing to the enhancement of both the Catalogo Parametrico dei Terremoti Italiani (CPTI15) [Rovida et al., 2022] and the Database Macrosismico Italiano (DBMI15) [Locati et al., 2022]. The latter enables the analysis of seismic activity across various Italian localities.

Introduction

The study of earthquakes has a long and venerable tradition, spanning many centuries. From the initial interpretative theories of antiquity to the formulation of the theory of continental drift and subsequently plate tectonics, the evolution of our understanding has been gradual and incremental. However, in recent decades, there has been a notable acceleration in the observation and study of earthquakes, largely due to the advent of increasingly sophisticated instrumental networks. These include seismic networks, GPS networks, InSAR, and others.

Nevertheless, to date, seismic hazard assessments, which underpin risk assessments and determine planning choices to reduce the impact of earthquakes, are largely based on knowledge of past earthquakes (Fig. 1).

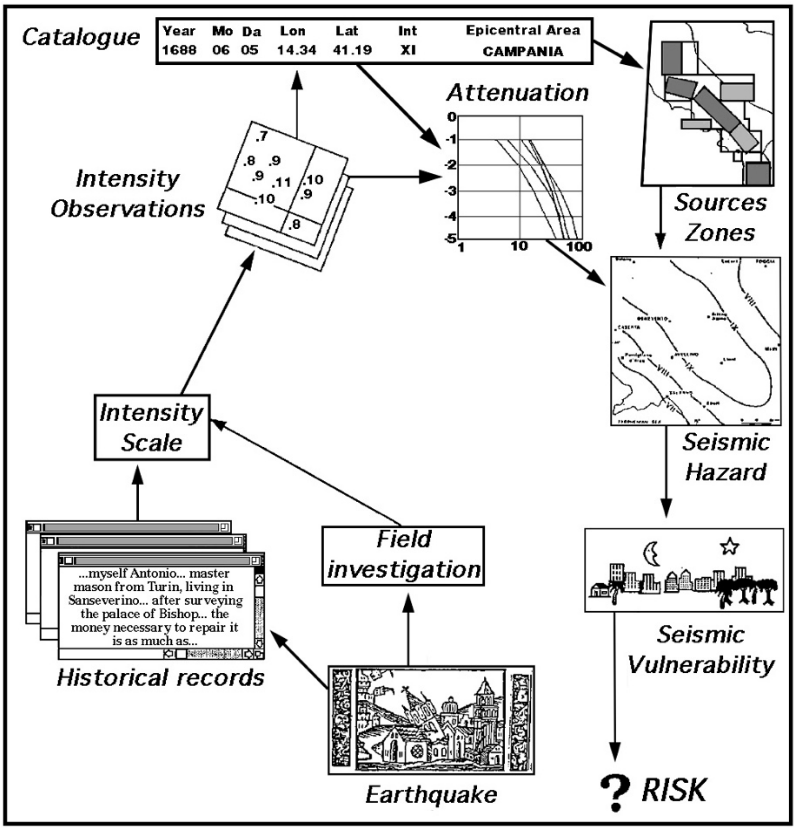


Figure 1. *General scheme of processing and using macroseismic data for the assessment of seismic hazard and risk [Stucchi, 1993].*

The collection of information on past earthquakes has a long tradition in Italy, as well as in several other European countries. It reached its apogee in the second half of the nineteenth century, when numerous individuals, such as Alexis Perrey and Robert Mallet, undertook the task of compiling data. In particular, Mallet is credited with creating a modern map of world seismicity (Fig. 2).

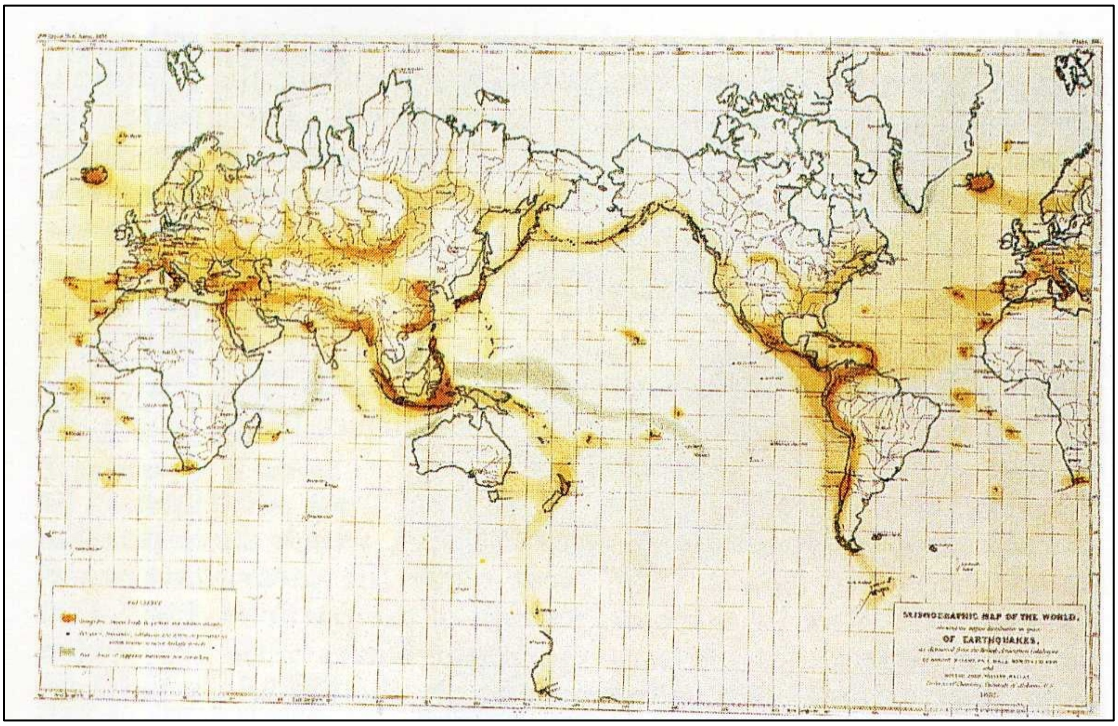


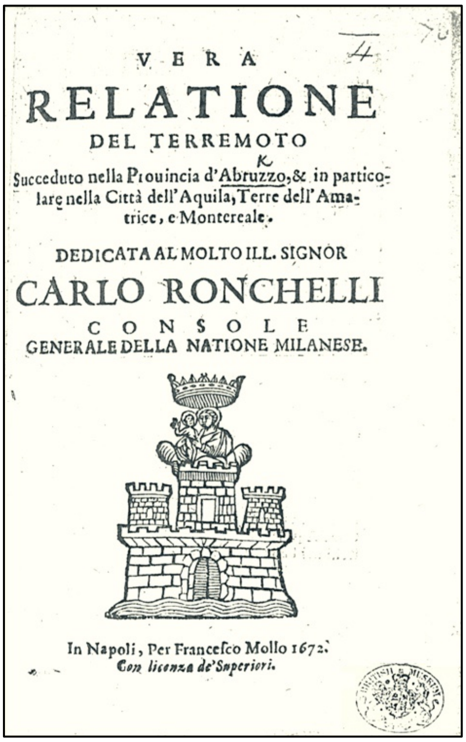
Figure 2. *The map of the world seismicity created by Mallet [1857].*

In Italy, the geographer Mario Baratta, in his comprehensive work 'Earthquakes of Italy' [Baratta, 1901], synthesizes the contributions of numerous compilers, including prominent figures such as the Neapolitan Marcello Bonito, whose repertoire of global seismic events is particularly noteworthy [Bonito, 1691]. After a long period of declining interest in this research/cataloguing activity, in the 1970s and 1980s, interest in the study of past earthquakes flourished again in Europe. It was during this period that historical seismology was born, emerging as a distinct discipline with its own set of rules, procedures, instruments and objectives.

Historical seismology is a field of study that employs the methods of quantitative historical research to investigate the effects of earthquakes in the past, including the recent past. Its objective is to document these effects as comprehensively as possible across a wide range of locations.

The research path is therefore constituted by the search for sources, their critical analysis, and their interpretation in seismological terms through a classification system and ranking of effect scenarios (macroseismic scale). Deriving from the collected data set, which is duly georeferenced, are the seismological parameters of each individual earthquake: time of origin, epicentral location, epicentral intensity, and magnitude.

The initial crucial phase of seismological-historical research is the identification and collation of sources. Evidence of seismic occurrences is indeed to be found in a plethora of documents, which may have been preserved in locations distant from the area of interest. One might, for example, consider the case of family correspondence that may have crossed oceans and been stored thousands of kilometres away, as for the printed report on the Abruzzo earthquake of 1672 [Vera relazione,…, 1672], the only known copy of which is in the British Library. (Fig. 3).


VERA

RELATIONE

DEL TERREMOTO

Succeduto nella Prouincia d'Abruzzo, & in particolare nella Città dell'Aquila, Terre dell'Amatrice, e Montereale.

DEDICATA AL MOLTO ILL. SIGNOR

CARLO RONCHELLI

CONSOLE

GENERALE DELLA NATIONE MILANESE.

In Napoli, Per Francesco Mollo 1672.

Con licenza de' Superiori.

Figure 3. *Front page of a printed report, the only known copy of which is in the British Library [Vera relazione…, 1672].*

The types of documentation pertinent to the study of earthquakes encompass narrative sources (chronicles, diaries, memoirs), journalistic sources (handwritten notices, gazettes and newspapers), administrative sources (minutes, registers, technical reports, etc.) and 'scientific' sources (meteorological and seismological registers, bulletins, seismic postcards), in addition to iconographic sources.

The second critical step is the seismological interpretation of the information collected and selected on the basis of a critical analysis. This transforms the information into a grade on a macroseismic scale, associating the effects scenario reconstructed on each individual locality (Macroseismic data point, Mdp) with the theoretical scenario described by the scale. This procedure should be applied to as many localities as possible, with each locality representing a sample of buildings or people. In this way, macroseismic intensity serves as an 'estimator of shaking' and cannot be used to assess effects specific to individual buildings or people.

Finally, based on the new geographical distribution of macroseismic intensities, the new epicentral parameters (epicentral location and magnitude) for each earthquake considered have been calculated using the BOXER code [Gasperini et al., 1999, 2010]. The aforementioned code was employed to estimate the main parameters of historical earthquakes (epicentre, magnitude and depth). The methodology involves the analysis of intensity maps, derived from observations of seismic effects on structures, individuals and the environment. The aim of this analysis is to identify the centre of gravity within the area of maximum intensity, thereby estimating the epicentre. The magnitude is then calculated utilising an empirical relationship between the area affected by the seismic effects and the maximum intensity. This approach has been shown to result in a significant enhancement in the precision of intensity estimates and the localization of effects.The data collected and formulated with regard to intensity serve two principal purposes: the definition of epicentral earthquake parameters and the compilation of seismic site histories. Hazard and risk assessments are based on this data set, which has considerable value, including economic value, for our societies.

The net result of these years of work is undoubtedly positive. Our country has the richest seismic catalogue in the world, and it has a wealth of historical knowledge on seismicity, which is organised in highly advanced databases and catalogues. Such resources include the Catalogo dei Forti Terremoti in Italia (CFTI) [Guidoboni et al., 2019], the Archivio Storico Macrosismico Italiano (ASMI) [Rovida et al., 2017], the Catalogo Parametrico dei Terremoti Italiani (CPTI) [Rovida et al., 2022] and the Database Macrosismico Italiano (DBMI) [Locati et al., 2022]. However, a significant number of the studies that form the foundation of the parametric reference catalogue are either severely outdated or are still in the preliminary stages of research. It is for this reason that the Italian historical seismological community has long since initiated a process of revising and updating data, as well as undertaking specific research on possible earthquakes that are unknown to seismological tradition.

The present research project is situated within this broader framework. Following an initial apprenticeship phase, during which the methodological approach and principal working tools were familiarised with, the decision was taken to undertake a targeted investigation on two areas that appeared to share similar characteristics. The objective of this research was twofold: firstly, to enhance the existing body of knowledge on earthquakes of moderate energy, which are of significant importance for seismic hazard assessments; and secondly, to investigate traces of previously unknown or relatively little-known earthquakes.

The first area of focus is the region between Ferrara and Modena, with a specific emphasis on identifying evidence of previously undocumented seismic activity. This approach is motivated by the observation that the May 2012 earthquake sequence (Fig. 8) occurred in an area where the perceived risk of seismic events was minimal, despite the presence of high exposure values (representing 2% of the national GDP) and elevated levels of seismic vulnerability.

The second area in which work was conducted is the Asolano and Trevigiano territories. Despite the limited impact of the 2012 seismic events, these areas exhibit similar hazard and risk characteristics to those observed in Ferrara and Modena, largely due to the presence of a significant industrial district.

It is important to keep in mind that, given the relative modesty of these events, and in some cases also the particular historical period in which they occurred, the evidence documented in journalistic communication and archival documentation are sometimes rather limited.

The thesis is structured into distinct chapters, each addressing a specific aspect of the investigation.

The initial section presents a geological and historical context, with an examination of the seismic activity (both historical and recent) in the two regions. The methodology applied, the research path, and the challenges inherent to the critical evaluation of historical sources are examined. The main seismological sources, such as documentary sources, seismological compilations, seismic postcards, seismic bulletins and journalistic sources, are examined, and the primary reasons for the loss of information on this type of earthquake are also explained.

The seismological framework of this study focuses exclusively on the two areas under analysis and is based on the knowledge consolidated in the CPTI15 catalogue, which summarises the results of seismological-historical research over the last 30 years. The historical framework focuses on the 16th-19th centuries, due to the temporal restriction of the research. It is crucial to acknowledge the intricate nature of the political framework of the Italian States in the modern age, characterised by the fragmentation of the territory into multiple independent political entities, which often acted as subjects to external influences. This fragmentation gave rise to complex historical dynamics, the implications of which may have influenced the documentation and perception of seismic events.

The initial phase of the research involved the verification of the references utilised by the parametric catalogue for documented earthquakes within the designated area. This was followed by the verification of the background, which encompassed the seismological compilations and their respective sources. The following stage of the research involved the identification of additional sources, including but not limited to journalistic, narrative, and administrative documents. It was from the verification of serial sources (e.g. gazettes, diaries) that traces of some unknown earthquakes emerged. Subsequently, a comprehensive examination of the earthquakes under investigation is provided. This entails a detailed account of the preliminary research conducted, the sources analysed, and the effects recorded at the various localities. A comprehensive list of all archives and libraries consulted is provided, along with a detailed account of the sources analysed. Additionally, the research outcomes, intensity tables, and distribution maps of the effects for each earthquake are presented.

1. GEOLOGICAL FRAMEWORK

The work focuses on two distinct sectors located at opposite ends of the Po Valley: the Modena area, situated along the northern front of the Apennine chain, and the Treviso area in the Southern Eastern Alps in the Veneto region (Fig. 4).

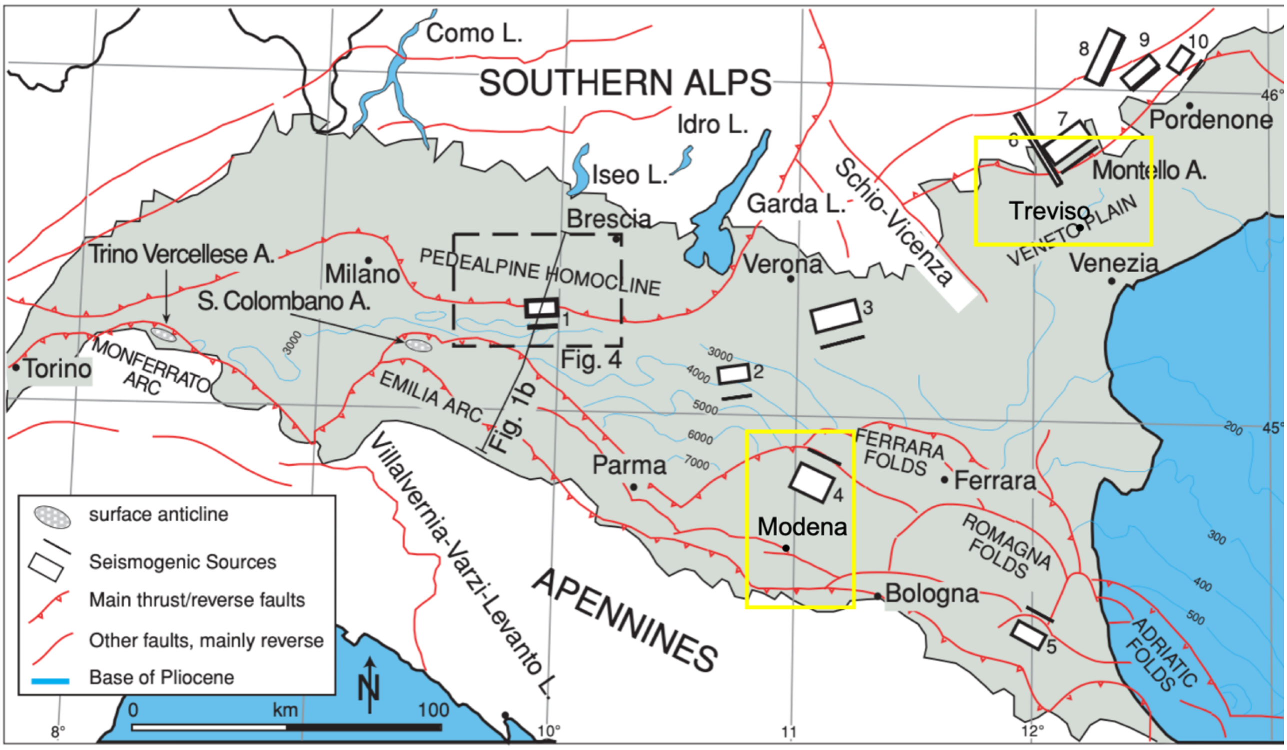


__Figure 4.__ Simplified structural map of the Po Plain and neighbouring Veneto Plain, showing the main tectonic elements, and contours of the base of the Plio-Quaternary sedimentary sequence. The plain is shaded in light grey, while higher topography regions are shown in white. The outer thrust fronts of the Southern Alps and of the Apennines are buried beneath the thick syn-orogenic clastic deposits [Burrato et al., 2003, and authors within]. The yellow rectangles indicate the areas of interest for this study.

The Po Valley is a plain that stretches over 400 km in an east-west direction, from the western Alps (Liguria and Piedmont regions) to the Adriatic Sea, following the alluvial plain of the Po River, Italy's major waterway.

Its geological evolution is linked to the ongoing convergence of two systems of folds and thrusts, those of the Southern Alps to the north and the Northern Apennines to the south, the result of the convergence of the African and European plates that began in the upper Cretaceous (c. 90-100 million years ago). Thus, the Po Plain hosts the foredeep of both mountain ranges, and for this reason, it has suffered subsidence and sedimentation over the past 5 million years [Vannoli et al., 2015].

Although it may appear as a large flat expanse, the Po Valley has different sectors, located at different altitudes and with specific geomorphological characteristics. The Po Valley is thus divided into 'high' and 'low' plains.

The high plain is the area close to the Alpine and Apennine reliefs, characterised by a still rather steep slope. In particular, alpine torrents, due to the greater slope of the upstream section, and the consequent greater speed of the water, have a great erosive capacity and for this reason, carry large quantities of debris. When they reach the less steep areas of the plain, and therefore the speed of the current decreases, they lose their transport capacity and begin to deposit the load.

The accumulation of these sediments gives rise to large fan-shaped structures, called alluvial fans, which are highly inhomogeneous and characterised by a continuous alternation of fine (silt and clay) and coarse (gravel and sand) levels.

The lower plain, however, is where the rivers connect with the Po; the slopes are decidedly lower thus increasingly finer materials are deposited (first the sands, then the silts and clays). Finally, above the Plio-Quaternary sediments are the most recent Holocene alluvial deposits. Unlike the rivers that flow from the Alps, the Po River and its Apennine tributaries flow on an active alluvial plain [Burrato et al., 2003]. It is precisely this transition between the gently sloping strata of the Po basin and the uplifted bedrock of the Apennines that marks the front of the Apennines that lies approximately 60 km southwest of the deformation front. These two are the external and internal thrust belts, known respectively as the Apennine Deformation Front (ADF) and the Apennine Range Front (ARF) [Bennet et al., 2012].

In the Tertiary and Quaternary periods, the Po-Venetian Plain was characterised by a marked subsidence phenomenon of tectonic and geodynamic origin. In recent decades, however, anthropic subsidence, linked to the extraction of fluids from the subsoil (groundwater and, to a lesser and limited extent, gas), has begun to overlap with the 'natural' one [Arpa Ingegneria Ambientale, 2007; 2011], thus, reaching higher ground lowering velocities.

Due to the fast subsidence rates induced by the tectonic loading of the two mountain chains in some areas, the outermost fronts of the two thrust belts are buried beneath the Po plain. Therefore, crucial information on the region's subsurface architecture and evolution was provided by hydrocarbon exploration activities [Tarabusi, 2015; Burrato et al., 2003], aiding in hazard assessment and risk mitigation for the safety of urban areas and human activities [Livani et al., 2023].

According to the seismic reflection data used for oil exploration, south of the Po River, at the base of the Pliocene-Quaternary succession, there are three arcs of blind, north-verging thrusts and folds. These represent the compressional front of the Apennine chain and are, from west to east: a) the Monferrato Arc; b) the Emilia Arc, and c) the Ferrara-Romagna Arc. The latter is further subdivided into three relatively minor structures: the Ferrara folds, the Romagna folds, and the Adriatic folds. The Ferrara folds («Dorsale Ferrarese») are the most external structures of this arc [Burrato et al., 2003]. The majority of seismic activity is concentrated to the south of the Po River, along the Apennine foothills (ARF), and some on the Apennine outer deformation fronts (ADF) [Burrato et al., 2003].

The active Northern Apennines thrust fronts exhibit a rather complex architecture, comprising potential seismogenic sources corresponding to thrust ramps lying at different structural levels. Conversely, the buried outer thrust fronts of the Southern Alps, which represent the non-metamorphic retro-belt of the double-verging Alpine chain [Livani et al., 2023], have simpler geometries with a single wide arc running from Milano to the Garda Lake [Vannoli et al., 2015].

The Po Plain exhibits a low rate of seismic activity, with infrequent occurrences of strong events (i.e. Mw 6.0), it however presents a significant seismic risk. First of all, because of the elevated degree of exposure, just think of the high-density civil and strategic infrastructures, the numerous plants, high-speed railways, oil pipelines, and waste dumps, in addition to the unfavourable geological conditions [Massa et al., 2017].

Recent studies of the local seismic response of deep sedimentary basins carried out around the world have shown that thick and soft sediments, typical of the Po Valley, can significantly amplify ground motion, primarily due to trapped surface waves, which can produce long-period amplifications of prolonged duration [Massa et al., 2017, and authors therein]. Even strategic structures located at large distances from the hypocentral region (i.e. 100 km) could be damaged as a result of the process. This phenomenon was also observed in the central part of the Po Plain during the recent 2012 Emilia mainshocks (Mw 6.1 and Mw 6.0) [Bordoni et al., 2012].

The E-W continuity of the Apennines thrust front is interrupted by the Schio-Vicenza Line, an important strike-slip fault system that separates the Po Plain thrust fronts to the west, from those of the Veneto Plain to the east [Burrato et al., 2003].

This is where the eastern Southern Alps (ESA) are located, a south-verging retro-belt of the eastern Alpine orogen verging towards the south. The ESA can be divided into two primary zones delimited by the regional-scale Valsugana Thrust: the Dolomites s.s. to the north and the Venetian pre-Alps to the south. The latter constitutes an E-W-trending fold-and-thrust belt characterised by significant tectonic movement directed mainly southward [Zuccari et al., 2021]. The transition between the ESA and the Venetian plain is marked by the Venetian pre-Alps, a band of hilly reliefs of varying widths. The area in question can be divided into four main geological units, from west to east: the Thiene-Bassano and Bassano-Cornuda thrusts, and the Montello-Conegliano thrust. The latter is interpreted to be seismically active and is thought to delineate the isolated Montello hill (Galadini et al., 2005).

This is understood to be an actively growing ramp anticline on an active north-dipping thrust that has migrated into the foreland to the south of the mountain. [Benedetti et al., 2000; Camassi et al., 2023]. Although there is geological and geomorphological evidence of Quaternary and actual deformation, the identification of active faults responsible for large earthquakes in the Montello area is inconclusive. Uncertainties remain regarding the location, geometry, and seismic potential of active faults in the Venetian Southern Alps. This is due to the complex structural framework of the region, the slow deformation rates along mainly blind faults, and sparse instrumental seismicity.

As a result, some areas where strong historical earthquakes occurred, may appear almost aseismic [Camassi et al., 2023].

2 HISTORICAL FRAMEWORK

Historically, the two areas (Fig. 5) are politically different.

The history of Modena since the 16th century is closely linked to the duchy of the House of Este that ruled it, except for a few brief interruptions, from 1452 until the arrival of Napoleon in 1796. But it was not until the death of Alfonso II d'Este in 1598 that Modena truly became an Este city and even the capital of the state. Despite having three wives Alfonso II died without legitimate heirs, so he designated his cousin Cesare as his successor in his will. Cesare d'Este was recognised as Duke of Modena and Reggio by Emperor Rudolph II of Habsburg, while Pope Clemente VIII denied him the fiefdom of Ferrara, thus succeeding in regaining control of the city.

Cesare therefore had to leave Ferrara and move to Modena, which became the capital of the duchy, taking with him the entire court, its traditions, and, above all, its entire archival heritage. A heritage that continued to grow even during the Austro-Estense period, and that made Modena a very important centre for preserving the documentary heritage of the Este family and their principality.

In the case of Treviso, however, the situation was somewhat different. Its province, which stretched northwards from the Venetian lagoon to the foothills of the Alps, was part of the Domini (or State) of Terraferma of the Venetian Republic. The formation of this state began in the mid-1200s, when Venice (previously an east-facing maritime community devoted exclusively to trade) began to require a land base. This was necessary both to secure the food supplies needed to feed its rapidly growing population and to provide a secure link to European markets, which were a natural outlet for goods imported by Venetian ships from the east.

While the initial nucleus was the area of Treviso closest to the lagoon, which had numerous rivers that could be used for the transport of bulky goods and one of the fastest routes to Germany, in the first half of the 15th century the state of Terraferma extended to most of north-eastern Italy, including important cities such as Padua and Verona.

The Republic administered its mainland possessions through Venetian officials stationed in the main urban settlements, who interacted with local assemblies or representative councils that acted as intermediaries between the local communities and the Republic. While the main towns had two officials, the 'podestà' (chief magistrate, responsible for civil matters) and the 'capitano' (responsible for military and fiscal matters), in the smaller towns a Venetian podestà combined civil and military functions. Finally, in smaller towns or castles (walled settlements), the representative of the state was a castellan or castle guard. The management of the affairs of the mainland was in the hands of the Venetian Senate, a body within which there was a special commission in charge of collecting all the necessary data to be able to discuss any issue.

From the 1600s onwards, the Republic of Venice was beset by a series of challenges, including frequent wars, widespread famine and plague epidemics, and the catastrophic earthquakes of 1695. These events precipitated a significant economic downturn on the mainland.
After the brief French occupation (1797) and the subsequent Austrian occupation, Treviso was annexed to the young Kingdom of Italy in 1805 [Woolf, 1973].

Figure 5. *Map of northern Italy in the atlas by Zatta et al., [1782]. David Rumsey Historical Map Collection [https://www.davidrumsey.com].*

3 SEISMICITY

3.1 HISTORICAL SEISMICITY

Despite the Po alluvial basin being characterised by a medium-low seismic hazard [Stucchi et al., 2012], it nevertheless presents a significant seismic risk (ESRM20) [Crowley et al. 2021] due to the high exposed value and therefore high vulnerability.

The Italian Macroseismic Database, DBMI15 [Locati et al., 2022], which was used to compile the most recent Parametric Catalogue of Italian Earthquakes, CPTI15 [Rovida et al., 2022], enables the reconstruction of seismic activity at various localitities from the year 1000 to 2020.

By interactively consulting these databases from the National Institute of Geophysics and Volcanology (INGV), it was possible to reconstruct the seismic history, i.e. the list of earthquakes that have produced macroseismic effects at a given locality, of the various sites within the study areas.

It seems that the seismicity of the Po Plain is concentrated along the foothills and the buried thrust fronts of the Northern Apennines and the Southern Alps [Vannoli et al., 2015], clear situation also by observing the distribution of earthquakes in the two areas from the CPTI15 (Fig. 4). In addition, seismicity is not evenly distributed but increases from west to east, i.e. from Monferrato to the Ferrara-Romagna arc [Vannoli et al., 2015].

The northern Apennines are distinguished by their low seismicity, predominantly attributed to normal faulting. The occurrence of diffuse small earthquakes is prevalent in this region, however, significant seismic events rarely exceed a magnitude of Mw 5.5. In fact, no earthquakes with a magnitude greater than Mw 6.5 have been documented either through instrumental measurements or via the analysis of historical data [Bennet, 2012].

Data on historical seismicity in the northern Apennines show that the strongest historical earthquakes epicentred in the province of Modena all had magnitudes between Mw 5.5 and Mw 6.5: the 1501 Apennino Modenese, 1639 Finale Emilia, and 1671 Modenese-Reggiano. Indeed, looking at the seismic history of the city of Modena (Fig. 6) certain details are clear.

First of all, the study area has historically been affected by earthquakes, in several cases even distant ones, with limited damage effects. In addition, we have a substantial number of events (159) whose effects have been recorded, the first of which dates back to 1222; the maximum intensity reached is 7-8 degrees MCS, recorded following the events of September 1249 and June 1501. In general, there are 16 earthquakes with $I_{max} \geq 6$ in the chronological span from 1000 to 1980, a number that is halved if we consider one more degree (only six events with $I_{max} \geq 7$).

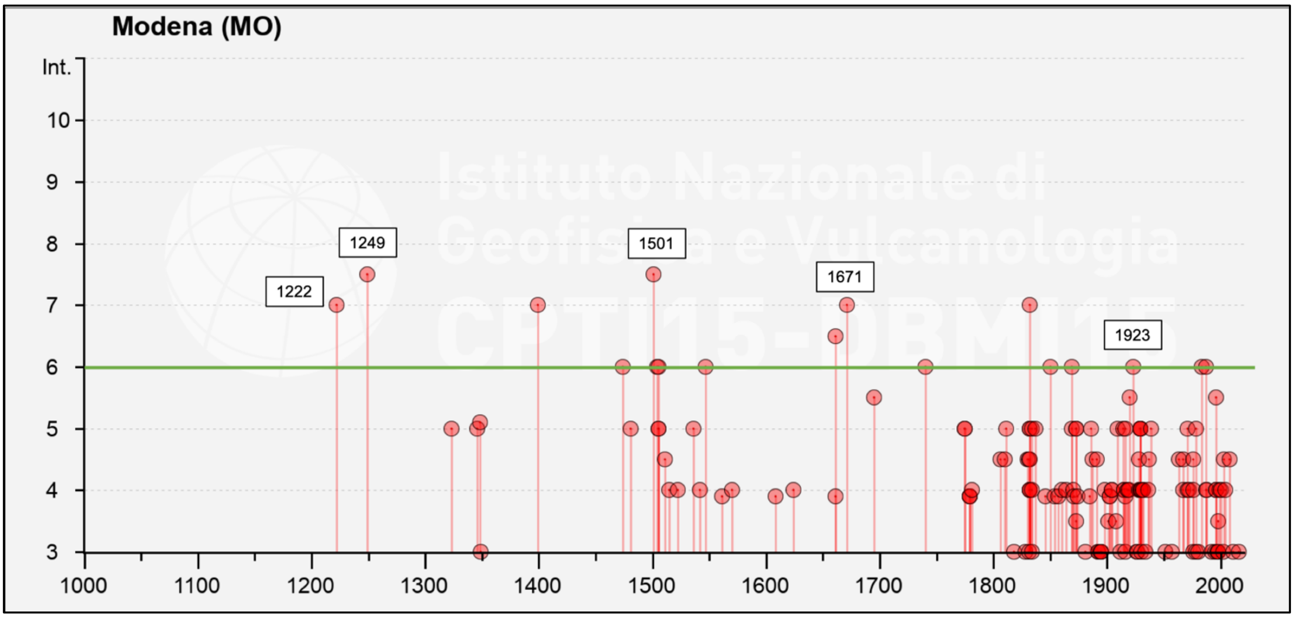


Figure 6. *Seismic history of Modena [Locati et al., 2022]. The green line represents the damage threshold (6 MCS).*

As far as the easternmost part of the Po Valley is concerned, i.e. the southern Eastern Alps, the strongest historical earthquakes (including, from east to west, 1695, 1117, and 1222) are located within a narrow strip on the border between the pre-Alps and the Friuli, Veneto, and Lombardy plains, with maximum magnitudes tending to decrease from E to W [Faccioli, 2013]. The area between the provinces of Vicenza and Treviso, on the edge of the Veneto pre-Alps, identifiable as 'Pedemontana Sud' in terms of seismic characterisation [Sugan and Peruzza, 2011], is influenced both by the occurrence of events in the Asolo area and by the effects of earthquakes in neighbouring areas, such as those in Friuli (1511 Mw 6.3, 1976 Mw 6.4) and Alpago Cansiglio (1873 Mw 6.3, 1936 Mw 6.1). The two strongest events in the Asolo area were in 1836 (Mw 5.5), and in 1695 (Mw 6.4) which is the most relevant historical earthquake that occurred near the Montello Hill [Danesi et al., 2015].

Unlike the seismic history of Modena, that of Treviso certainly shows a lower number of events (around 64), and the first recorded event dates back to 1348, a barely felt event located in the Julian Alps. Overall, the maximum intensity reached is 6-7 MCS degrees, with a total of five events recorded in the city with Imax ≥ 6 (Fig. 7)

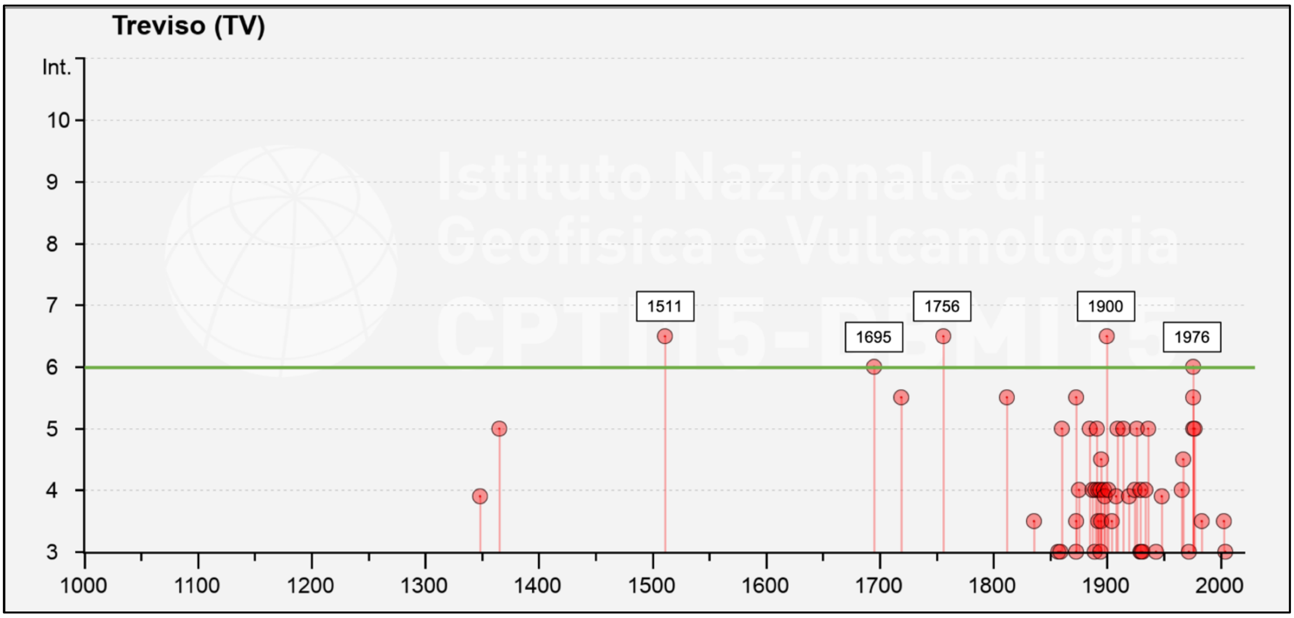


Figure 7. *Seismic histories of Treviso [Locati et al., 2022]. The green line represents the damage threshold (6 MCS).*

3.2 RECENT SEISMICITY

The country's 'recent' seismicity, and thus the instrumental one, has been known since 1985, when data from the recordings of the INGV National Seismic Network (RSN), a complex system for monitoring seismic activity throughout the country, became available. Currently, the Network has approximately 500 stations distributed throughout Italy. All of the aforementioned stations transmit data in real time to the Seismic Room of the INGV National Earthquake Observatory. This data comprises the epicentral parameters of all earthquakes occurring in Italy and neighbouring areas, including location, magnitude, and depth. This information is available on the Rete sismica Nazionale website. These data are then regularly published and distributed as the Italian Seismic Bulletin (BSI). Looking at the period from 2000 to the present, the records on the INGV Earthquakes online page (https://terremoti.ingv.it/) show that within a radius of 50 km from the city of Modena, there have been 3966 earthquakes, all within a depth of 100 km and magnitudes ranging from 2 to 6.

A review of the distribution map for these seismic events reveals a clear concentration of activity in three main areas, including the occurrence of the most significant earthquakes on record. The first is located south of Modena, along the Apennine deformation front (ADF), the second is located further west, in the Reggio Emilia area, and finally, the northernmost part of the province of Modena, along the border with Lombardy, which in 2012 was affected by the famous Emilia seismic sequence.

As the magnitude is increased to 4, the aforementioned situation is corroborated. There are a total of 40 earthquakes with $M \geq 4$ and they are all distributed in the three areas just described, leaving the city of Modena and the central part of the province (up to a distance of 20 km from the provincial capital) relatively unaffected. If the minimum threshold is raised even further by setting $M \geq 5$, the number of events is drastically reduced: only 8 earthquakes, all located in the northern belt and belonging to the 2012 sequence. The 20 and 29 May 2012 Emilia earthquakes (Mw 5.8 and 5.6, respectively), represent the largest earthquakes ever recorded instrumentally in this region [Vannoli et al., 2015] (Fig. 8).

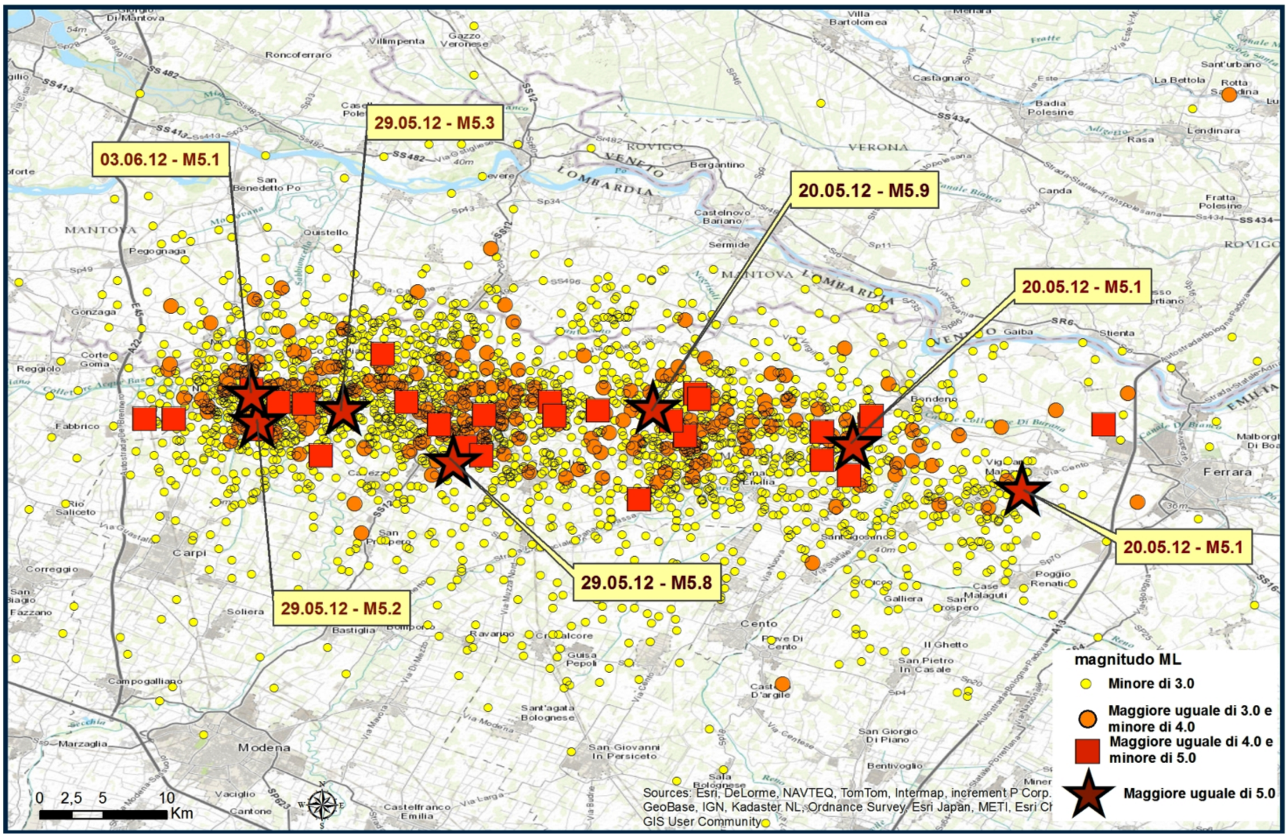


Figure 8. *Earthquakes in the Po Valley of Emilia from 19 May 2012 to 19 May 2013 ["Un anno dopo il terremoto in Emilia", https://ingvterremoti.com]*

Current seismic activity in the Veneto sector of the south-eastern Alps is relatively weak and is represented by earthquakes with Ml ≤ 4.0, mostly located east of the Montello area, along a band a few tens of kilometres wide on the border between the Po Valley and the mountain range, towards the Cansiglio area [Danesi et al., 2015]. Looking at the distribution map of these earthquakes, the description given by Danesi et al. [2015] is very clear. Performing the same operation for the Modena area (M ≥ 2; radius of 50 km from Treviso), 118 earthquakes with P ≤ 32 km and M ≤ 3.6 were recorded, confirming the occurrence of mostly small earthquakes, mainly along the pre-alpine belt.

It should be mentioned that these types of studies are also of great value in the estimation of seismic hazard and risk.

Seismic hazard, i.e. the probability that a ground shaking level will be reached in a given geographical area, and within a defined time interval; an assessment made on a geological, historical, and seismological basis, is the subject of careful scientific studies, involving the entire scientific community. These studies take the form of seismic hazard models and curves, which represent a synthesis of current knowledge about seismic hazard in the long, medium and short term. These are the result of in-depth analyses and provide essential information for understanding and assessing seismic hazard in a given geographical area. With input from the scientific community, hazard maps provide a solid basis for urban planning, resilient infrastructure design and preparedness for possible seismic emergencies.

In 2004, the INGV (MPS Working Group [2004]; Stucchi et al. [2011]) published the MPS04 seismic hazard map (http://zonesismiche.mi.ingv.it), expressed in terms of horizontal ground accelerations with a probability of greater than 10% in 50 years, referring to rigid soils.

The MPS04 is an update and improvement of the previous seismic hazard maps.

When assessing the hazard of an area, it is also very important to take into account ‘site effects’, which can cause significant variations in the amplitude, frequency content and duration of seismic shaking. In fact, the latter is strongly influenced not only by the source and propagation path of the earthquake, but also by the specific local geological, geomorphological and geotechnical conditions encountered by the seismic waves as they pass through the last layers of soil before reaching the surface. An example of this phenomenon could be the amplification of seismic waves in certain frequency ranges caused by the presence of loosely compacted deposits (alluvial, sedimentary, etc.) on more rigid formations - a very common situation in the Po Valley.

When we talk about seismic risk instead, we are essentially talking about the outcome of an earthquake in relation to the main characteristics of the exposed community, such as population, buildings, and infrastructure. Seismic risk is defined as the product of three different factors that can be expressed in numerical terms, namely hazard, exposure (or exposed value), and vulnerability. Depending on the methods and procedures used to measure these factors, seismic risk can be expressed in terms of loss of life, damage to buildings, economic losses, etc.

As mentioned before, hazard expresses the probability that a given level of ground shaking will be reached in a given area within a given time interval.

By exposed value, we mean everything that exists in a given geographical area that could potentially be destroyed or damaged by an earthquake, i.e. the population, buildings, architectural and artistic heritage, infrastructures, services, productive and economic activities, etc. Basically, in places such as the desert, the risk is practically zero for any earthquake, whereas in a city, it will be very high even for a small earthquake.

The final element that determines seismic risk is vulnerability, i.e. the propensity of a given building to suffer damage in the event of an earthquake of a given shaking. This value is strongly influenced by the quality of the construction of the buildings, so it obviously takes into account the quality of the materials and construction techniques used: a building constructed in masonry will certainly have a greater vulnerability than one built in reinforced concrete. Unfortunately, many buildings in Italy are old and made of masonry. They were not built according to modern seismic criteria and are therefore particularly vulnerable.

Unlike hazard, which depends on ‘natural’ factors such as the type of earthquake and the effects of the site (local geomorphological and stratigraphic factors that can modify seismic waves and surface shaking) and therefore cannot be changed by humans, exposure and vulnerability are the factors on which it is possible to intervene to reduce seismic risk.

With all that we have discussed so far, it is really important to think about what a strong or intermediate-energy earthquake might mean for these territories.

Another very important factor affecting the assessment of seismic risk is the influence of certain decisions, more political-administrative than scientific, taken during the 20th century and concerning certain areas of the national territory such as the Treviso area or the Romagna coast.

As already seen in the previous paragraph (3.1), the Veneto region was affected by a series of earthquakes with intensities close to or above the damage threshold (6 MCS), the most recent of which, the Alpago Cansiglio earthquake, occurred on 18 October 1936 (Mw 6.6). The latter, which was felt very strongly throughout north-eastern Italy, in the south in Emilia and Marche, and further north as far as Slovenia, Austria and Switzerland, caused widespread fatalities and damage in the Veneto region, including the town of Conegliano. The Alpago Cansiglio earthquake of 1936 was one of four major earthquakes (Mw > 5.5) that struck Italy in the 1930s, severely testing the Fascist regime’s ability to respond, and fuelling tensions [Camassi & Pessina, 2022].

In the 1920s and 1930s, some important steps were taken in the history of seismic legislation in Italy; the subsequent discussion will provide a concise overview of these developments.

Royal Decree no. 2089 (1924): Establishes technical and sanitary standards for construction in seismic zones.

Royal Decree no. 431 (1927): Introduced a second seismic category, updated the standards and listed the municipalities, excluding those of Veneto.

Royal Decree no. 640 (1935): Further updated standards with special provisions for seismic areas, including some municipalities in the province of Udine.

Ministerial Decree of 23 March 1937: Lists the municipalities affected by the earthquake of 18 October 1936, including those in the provinces of Belluno, Treviso and Udine. Conegliano was added at the end of 1937.

Obviously, this was an important decision that would guarantee a safe reconstruction and, in the following decades, would accompany the progressive urban development of the areas that were to experience a strong expansion. Suffice it to say that the population of Conegliano, for example, more than doubled between 1936 and 1981 and, in general, the area between Conegliano and Vittorio Veneto became a major industrial area [Camassi & Pessina, 2022].

Less than a year later, the Ministerial Decree of July 1, 1938, was published, deleting certain municipalities in the Provinces of Udine and Treviso from the list of municipalities that must comply with the special technical building regulations for earthquake-prone areas.

As a result, the municipalities of Conegliano, Folline, Gajarine, Revine Lago, Pieve di Soligo and Aviano (UD) were removed from the list of municipalities subject to seismic regulations. They remained so until the early 1980s, allowing the construction, urban and industrial development of certain municipalities to take place essentially in the absence of regulations.

Unfortunately, the situation described is not limited to these areas. In fact, before Conegliano and the others, there is Rimini, which, with the ministerial decree of 27/07/1938, is removed from the list of municipalities for which special technical building regulations are mandatory.

The reasons for the requests for declassification and the related measures are clearly expressed in a ministerial decree of 7 August 1941 concerning the removal of certain municipalities in the province of Pesaro-Urbino from the lists: "*The request of the entities [...] is based on the assessment that the area can be considered as having a low seismicity [...] and that, on the other hand, the application of the provisions of the aforementioned decree represents a significant obstacle to the development of the area...*"[Camassi & Pessina, 2022]. And so, Rimini was declassified and remained so until the 1980s; thus, the strong development of the coast, which increased after the Second World War, took place essentially in the absence of seismic legislation.

The main problem in the two areas studied, the Modenese pede-Apennines and the Venetian pre-Alps, is the alarming increase in exposure, both in terms of housing density and in terms of craft and industrial heritage. In fact, the vast expanse of buildings and warehouses is common to both the ceramic and mechanical engineering districts of Modena and the optical and electromedical districts of Veneto, economic sectors that represent an important part of the GDP and that would be in crisis if faced with a nearby magnitude 6 earthquake today.

4. METHODOLOGY

4.1 RESEARCH PATH

The research was conducted using the reference studies from the CPTI15 catalogue [Rovida et al., 2022], which are currently the most up-to-date works.

In order to compile the descriptive records, texts known to the seismological tradition were retrieved and critically analysed. Bibliographic and archival research was then conducted to supplement the available information.

As a first step, the main seismological compilations, both of national interest and specific to the studied areas, were then collected and thoroughly checked, and the main printed gazettes and daily newspapers made available on the web by some of Italy's main libraries were consulted. Additionally, seismic postcards and seismological bulletins were reviewed. Finally, for pre-nineteenth-century earthquakes, in addition to local historiography, documentary sources kept in the main archives and libraries were consulted, e.g. the State Archive of Modena, the Municipal Historical Archive of Carpi, the Historical Archive of Cento, and the University Library of Bologna, to name but a few (for all the types of sources analised see chapter 5).

The situation is different for the earthquakes that occurred in the Treviso area, specifically those from the 19th century onwards. Since these are earthquakes of moderate energy, there is no record of them in local historiography, which is based on the exploration of archival sources. Thus, archival research, in these specific cases, consists essentially of recovering the information beyond the bulletins, and therefore the seismic postcards (see paragraph 5.3). In the presence of damage, traces of any surveys carried out by the Genio Civile or archival documentation relating to verification interventions might be sought; however, in the cases studied, such evidence did not emerge, as the earthquakes analysed were of too low an intensity to have generated effects of this type.

4.2 INTENSITY ESTIMATES

The collected testimonies expanded knowledge about the events and detailed the affected localities and observed effects. This information was used to assign macroseismic intensity values, i.e. a qualitative metric employed for the evaluation of seismic effects, derived from observations of its impact on human populations, infrastructure, and the natural environment. In contrast to instrumental metrics, such as magnitude, which quantifies the energy released at the source of the earthquake, intensity focuses on the consequences of the seismic event at specific locality.

The process of interpreting the data in order to assign a level of intensity was conducted in accordance with the scheme proposed by Molin et al. [2008]. This approach considers the mean percentage of individuals who perceived the shock (for grades < 6) and the damage levels, which were derived from the MCS scale [Sieberg, 1930]. In the case of grades above 5, the average percentage of damaged buildings is also typically employed in the estimation process.

In addressing the question of utilising the Mercalli-Cancani-Sieberg macroseismic scale (MCS) [Sieberg, 1930] as opposed to the European macroseismic scale (EMS98) [Grünthal, 1998], a number of arguments can be made. Firstly, the greater personal familiarity with using the MCS scale, which is also widely represented in the database on which the parametric catalogue of Italian earthquakes (CPTI15) is based [Rovida et al., 2022]. Secondly, it is commonly accepted that for felt-only effects, without damage, the two scales are nearly equivalent [Musson et al., 2010], as is evidenced in this case by the consideration of only non-destructive earthquakes, with the exception of 1501, which, despite the depth of research and its level of detail, ultimately provides such 'weak' information that the distinction between the two scales is rendered inconsequential. Finally, the building heritage in both the Treviso and Emilia regions is characterised by extreme heterogeneity, which is predominantly attributable to the uppermost vulnerability class (A). This observation is particularly salient in the Treviso area, as evidenced by the historical period under consideration (17th-20th centuries). Moreover, one of the reasons that make the use of the EMS-98 scale critical in the case of moderate damage - as evidenced by the earthquakes under investigation in this study. In the absence of direct observation, as is typical of macroseismic surveys, the indications provided by journalistic or seismological sources are generally approximate and not fully adequate to be represented by an EMS98 estimate. This is due to the absence of information that would allow for the rigorous differentiation of levels of damage and their percentage distribution over the built heritage. The available data are at times limited to 'adjectives' or generic statements, such as "*Sassuolo et Castelvetri had notable ruins*", which do take into account possible conditions of high vulnerability. It is important to note that the MCS scale does not provide precise quantitative indications, except for grade 6, which requires that the tremor would be felt by everyone, i.e. 100% of the inhabitants [Molin et al., 2008]. To assign an intensity grade for localities where the recorded effects reach the level of damage, a further distinction is made based on the distribution of the damage. Light but fairly widespread damage is assigned 6 MCS, while light but sporadic damage and widespread damage throughout the building stock are assigned MCS grades 5 and 7, respectively. This classification system ensures greater objectivity in assessing the intensity of the damage. An example of this distinction can be seen for the earthquake of 1900 (4 March), specifically for the towns of Asolo and Treviso (6), and Santa Giustina (5-6). In fact, according to Cavasino [1935], "*In Asolo, the tremor caused a great deal of panic among the population, the ringing of bells, the falling of two chimneys, a ceiling, rubble and cracks in some houses that were not very solid. In Treviso, too, there were almost the same effects [...]*". In the case of Santa Giustina, on the other hand, "*it was felt by many,* *especially by those in a state of tranquillity; at first it was very light and [...] strong, so much so that the walls creaked and some chimneys fell [...]. There was no news of any misfortune, but general panic. In the churches the candelabra were overturned*". Here the uncertainty between the two degrees is justified by the fact that the tremor was generally felt with panic, and therefore it is certainly at least a grade 5, and slight damage was recorded, but it is not widespread, so a grade 6 is not fully reached.

The estimation of intensity is a very delicate operation, made even more difficult by the fact that the available information is sometimes insufficient to define a precise scenario of the effects so that the uncertainties are quite strong. This occurs especially when minor earthquakes, such as those studied here, occur at the same time as other events that could 'obscure' them: a heavy snowfall that limits the spread of the news, as in the case of the 1900 event that was followed, according to the sources, by "*a great snowfall that plunged us back into the cruellest winter*" (Il Gazzettino, prov. Di Vicenza, 7.3.1900 - from seismic postcard 1900_da01_10a03_04_029); or the occurrence of stronger earthquakes close in space and especially in time, such as the earthquake of 14 April 1887, which occurred about two months after the catastrophic Ligurian earthquake of 23 February, which had been the focus of attention for some time.

During the period of activity of the Italian Seismological Society (1895-1941) and the operation of the seismic monitoring network through seismic postcards, it often happened that the compilers, both of the postcards and of the summary bulletins, directly assigned a numerical intensity value, without adding further descriptive elements. This was the case, for example, with the 1900 earthquake where the author of the bulletin ('Notizie sui terremoti osservati in Italia...') - in this case Cancani [1901] - often limited himself to assigning only a degree of intensity, without adding further elements. In the presence of descriptive elements, however, the intensity estimation was made on this basis, and it can be observed that such estimates generally downgrade Cancani's assessments.

The intensity value represents a theoretical scenario. In the majority of cases, or at the very least in a significant number of cases, the sources do not provide all the necessary elements to reconstruct the scenario. Consequently, the information is insufficient and generalised to the extent that it is not possible to assign a number. Therefore, we provide an indication that encompasses all the inherent uncertainties. In light of the aforementioned considerations, we occasionally employ the following terms: SF, F, HF, SD, D, and HD, which correspond to Slightly Felt, Felt, Highly Felt, Slight Damage, Damage, and Heavy Damage, respectively.

Differences in macroseismic scales can also contribute to this variation in scaling. In the specific case of the 1900 earthquake, for example, the discordance between the two evaluations derives from the different number of degrees in which it is possible to classify the shaking: 10 degrees for the De

Rossi-Forel scale [Bullettino del Vulcanismo Italiano, 1883] used by Cancani, and 12 for the MCS, used instead in this review. This means that in some cases, with the same effects observed, especially for values above grade 5, the two intensity values may be slightly discordant. Discordance is also observed when descriptive elements of the effects are provided in addition to the assignment of a grade. In these circumstances, the estimation of intensity is based on the interpretation of the descriptions rather than solely on the value attributed by the source.

For each earthquake, an intensity table was compiled in which the name of the affected locality, accompanied by its precise coordinates, and the intensity assigned to it (Is) were listed. Each table also incorporated a comprehensive record of the event, including the date, the epicentral area (Ax), the reference study (St), the number of localities where effects were recorded (Mdps), and the maximum intensity reached (Ix). The tables do not include localities for which the seismic postcards only provide instrumental information.

4.3 FORMAL REPORTS

The information gathered during this work was organised according to a common reference scheme. For each earthquake, a descriptive sheet has been prepared (Fig. 9), which outlines the search path taken, starting with the review of preliminary studies and ending with the search of all available sources. The information provided includes the original CPTI15 record and the parameters assigned in various parametric catalogues. Additionally, it encompasses details on any issues identified in the data, details on the sequence, possible victims, injured parties or environmental effects, and a list of affected localities. The georeferenced list includes the estimated intensity for each parameterisable earthquake. Finally, to complete the sheet, all identified sources are transcribed.

In addition to the full transcript of the collected texts, the formal reports also contain a detailed account of the negative results. This encompasses all the documents that were examined but did not yield any useful insights into the effects caused. This process is of paramount importance as it enhances the transparency of these works.

Since these studies will contribute to the Italian Macroseismic Database (DBMI15) [Locati et al., 2022], they will become a heritage that can be used by future users, and in this operation, the negative feedback is just as important, because it will prevent a researcher, who decides to get his hands on these earthquakes one day, from going down a blind alley.

Summary of available knowledge

Catalogues
Clear, carefully verified reference to the source catalogues.

N	Year	Mo	Da	Ho	Mi	Lat	Lon	Int	Ref1	Ref2	Epic. Zone

Tab. 1 - Earthquake of ** ** **** in the catalogue *******.

Studies
Any previous studies available (arranged from oldest to most recent) that are being reviewed, any other studies, seismological compilations.

Research path
Description of the research carried out, level of detail, type of sources found, etc.

Description of effects
The outcomes of the research, the major effects, the felt area, possible inconsistencies, problems of reconstruction of effects, interpretation, and the possible criteria adopted for assigning intensity, are all to be considered.

Information on the sequence
Yes, No, possibly provide brief summary.

Information on victims (or injured people)
Yes, No, possibly report the numbers.

Environmental effects
Yes, No, possibly provide brief summary.

Room for improvement in knowledge and conclusions
Indication of any aspects to be further investigated and scope for improvement.

Intensity table

Year	Mo	Da	Ho	Mi	Ax	St	Np	Ix
****	**	**	**	**	*******	*********	***	***

Place	Sc	Pro	Lat	Lon	Is

References

Anthology of the texts
Transcripts of all texts found.

Figure 9. *Example of a formal report that is compiled for each earthquake.*

4.4 RESEARCH-RELATED UNCERTAINTIES

The process of compiling the sheets is not without a certain degree of uncertainty.

This is mainly due to the georeferencing of effects, whereby the difficulty lies in identifying and locating the toponyms mentioned in the sources, since some municipalities have undergone name changes over time, and in the interpretation of macroseismic data. In the latter case, the problem is that of transforming data from qualitative to quantitative and thus going from descriptive information to macroseismic intensity grades.

It is also important to note that from a macroseismic perspective, the location is defined as a built-up area. Nevertheless, the precision of the location of an observation can be significantly hindered by the variability of the available information. Consequently, certain studies have elected to document information pertaining to entities that cannot be unequivocally delineated as localities, including valleys, generic historical regions, expansive areas, and individual isolated structures such as towers, castles, or shrines. To enhance the identification of observations pertaining to specific spatial entities, a coding system has been incorporated in DBMI15 according to the type (Tab. 1), codes that are incorporated into the intensity tables (column marked 'Sc', i.e. special case) (Fig. 9).

Sc (Special Case)	**Meaning**	**Description**
TE	Territory	Indicates a geographical area (e.g. an entire region, a valley), for which the available information does not allow association with a precise locality.
IB	Isolated Building	Indicates a single isolated building (e.g. tower, lighthouse), i.e. a non-representative sample for the attribution of macroseismic intensity.
SS	Small Settlement	Indicates a small agglomeration (e.g. castle, parish, farm, monastery, small hamlet).
MS	Multiple Settlement	This code generally identifies Italian 'scattered municipalities', i.e. those municipalities within which no well-defined centre can be identified, and which usually have a name other than that of the hamlet in which the municipality is located.
DL	Deserted Locality	It indicates a settlement that has been definitively abandoned since a certain date and may be in the condition of 'ruins', 'vestiges or a simple toponym. In some cases, it may have been rebuilt elsewhere under a similar or different name.
AL	Absorbed Locality	It indicates a settlement that was progressively incorporated into an adjacent one.
CQ	City Quarter	Indicates a news item explicitly referring to a part of a locality, for which there is already an intensity item referring to the whole locality.
UL	Unidentified Locality	It indicates that there is insufficient information available to identify to which location the observations refer.

Table 1. *The following is a list of the codes employed in DBMI15 for the identification of special cases [Locati et al., 2022].*

Another aspect that, from a seismological point of view, is far from trivial and involves a great deal of uncertainty concerns the dating and time systems used, which are essential for assigning the correct descriptions to each tremor and for avoiding possible duplications.

The issue of dating arises particularly in the context of large earthquakes that can affect multiple countries. Identifying the precise time of an earthquake's occurrence is also crucial, as it allows the information obtained from the study in terms of epicentral parameters to be entered into international catalogues, making it available to all.
The problem of time allocation is not a small one and, above all, it occurs very often. This is especially the case of the 18th-century earthquakes when, in Italy, both the French and the Italian timetables were used at the same time. The difference between the two systems is considerable and can lead to misunderstandings. While the French system - which is the classic one and is still used today - considers the day from 00:00 to 23:59, 'Italian time' divides the day according to the sun, and therefore according to sunrise and sunset. As a result, the start and end times of a day are never the same, and the time, with its uncertainty, must be calculated each time.

5. SEISMOLOGICAL SOURCES

Every historical period is characterised by political, economic, social, and cultural circumstances that have influenced the type, completeness, and availability of documentary sources. Consequently, both the documentation produced and its analysis and interpretation have been conditioned by obvious limitations.

A comprehensive investigation into historical seismology must consider the existing body of knowledge, including the findings of previous studies and the material already available for review. In this regard, prior to embarking on a new research project, the extensive body of knowledge accumulated within the field of seismology was subjected to rigorous verification and comprehensive utilisation. Subsequently, targeted bibliographic and archival research was conducted to identify new sources, encompassing both local and national materials, and in some cases, also materials from abroad [Baranello, 2023].

The logic of the research path is to check everything backwards, starting with the analysis of the most recent sources and ending with sources contemporary with the event and possibly with completely unpublished testimonies.

The sources used for this work are highly heterogeneous, as they were produced over a period of four centuries and in two different geographical contexts.

The main types of sources analysed are described below.

5.1 DOCUMENTARY SOURCES

Documentary sources - or usually mistakenly called ‘archival’ sources - are undoubtedly one of the most useful and widely used sources of information in this type of study. They consist of documents of various kinds, both public, i.e. everything relating to the administrative machinery, such as the granting of titles and privileges, censuses and income declarations, parliamentary acts, etc., and private, such as notarial deeds, wills, contracts, private letters and correspondence, and so on. Luckily for us, Italy’s documentary heritage is among the oldest and most substantial in the world.

The significance of these sources lies in their lack of spontaneity and even randomness. Every public or private entity, institution, or person, has had to produce and collect all those papers that recorded its activities and, once their purpose was fulfilled, it was stored in the archives. Therefore, unless the documents have been lost or destroyed (e.g. by earthquakes, fires, rats, etc.), one is sure that something can be found in the archives.

For any institutional body, the number of documents produced depends on the complexity of the administration and the level of bureaucracy. In states with less complicated organisations or during periods of streamlined bureaucracy, fewer documents are produced. This was the case, for example, during the Middle Ages, when structures were less elaborate, less centralised, and less state-like. As time passes, administrations tend to become more complex, resulting in an increase in these types of documents.

Among sources of this kind, those of a narrative, chronicle or diaristic type, which preserve the memory of important events, are fundamental and even more useful.

Given the historical context of the two areas, it is not surprising that the search for this type of source differed according to the period in which the earthquake occurred as well as the territory considered. For the Emilian earthquakes, all of which occurred between 1500 and the end of 1700, research was carried out in various cultural institutes in the provinces of Modena, Bologna, and Ferrara.

First of all, the Archivio di Stato (the State Archives) of Modena was consulted. As already mentioned, in 1598 Cesare d'Este had to leave Ferrara and move the capital of the duchy to Modena, due to the various vicissitudes between the duchy of Ferrara and the Papal States. He also took with him his entire court and the rich documentary heritage, which was to be further enriched over the following centuries. The Archivio di Stato di Modena is therefore one of the most important repositories of the history of the Este family and their Duchy. More details on the archival research carried out for the events in Emilia will be given in chapter 6 where the earthquakes studied are described and the results are presented.

With regard to the Veneto earthquakes, local archival sources were researched at the State Archive of Treviso, the Civic Library of Bassano del Grappa, the Library of the Correr Museum in Venice (Fig. 10), the manuscripts fund of the Bertoliana Civic Library in Vicenza, just to name a few.

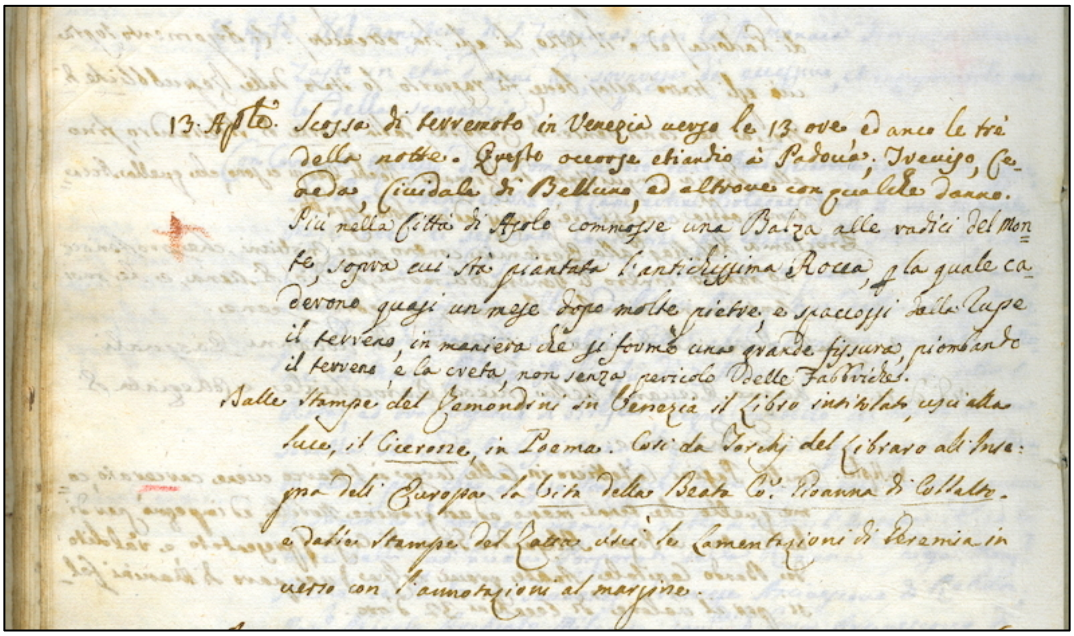

13. Agosto. Scossa di terremoto in Venezia verso le 13 ore ed anco le tre
della notte. Questo occorse etiandio a Padova, Treviso, Ce-
neda, Cividale di Belluno, ed altrove con qualche danno.
Più nella Città di Asolo commosse una Balza alle radici del mon-
te, sopra cui stà piantata l'antichissima Rocca, la quale ca-
derono quasi un mese dopo molte pietre, e spaccossi dalla Rupe
il terreno, in maniera che si formò una grande fissura, piombando
il terreno e la creta non senza pericolo delle Fabbriche.
Dalle Stampe del Remondini in Venezia il Libro intitolato uscì alla
luce, il Cicerone, in Poema. Coi de Torchj del Libraro all'Inse:
gna dell'Europa la Vita della Beata Co. [illegible] di Collalto.
e dalle Stampe del [illegible] le Lamentazioni di Geremia in
verso con l'annotazioni al margine.

Figure 10. *Example of a manuscript text describing the effects of the 1756 earthquake in Venice [Gradenigo, XVIII], held at the Library of the Correr Museum in Venice.*

The situation instead, is slightly different for the earthquakes that occurred between 1861 and 1921. Indeed, the fact that these were relatively 'minor' seismic events and that they took place in a particular period of Italian history (i.e. Unification of Italy, World War I) means that local historiography, which is based on the study of archival sources, has no record of them. For this reason, in this particular case, archival research essentially consists of recovering what lies behind the seismological bulletins and, therefore, the seismic postcards: questionnaires filled in with information on the effects observed in a given locality (for the seismic postcards, and the seismological bulletins see paragraphs 5.3 and 5.4, respectively).

5.2 SEISMOLOGICAL COMPILATIONS

Fundamental to the research is the contribution made by seismological compilations (Fig. 11, 12), a type of work typical of the last 30-40 years of the 19th century, which took up information provided by various historical sources: direct and indirect testimonies, journalistic and memoiristic sources, local historiography, to name but a few.

Particularly noteworthy among the compilations is the work of Baratta [1901], considered the progenitor of that season of research and the reference work for pre-twentieth-century events [Baranello, 2023]. To reconstruct the various events, Baratta [1901] uses mainly indirect sources, such as compilations (works based on other texts, not always explicit or recoverable, and often much later than the events described) and to a much lesser extent direct sources, i.e. those texts that represent the first transcription of an experience lived by the author or handed down to him by others.

From the 16th century onwards, the average quality of data improved considerably. On the one hand, more and more use is made of authentic archival documents, while on the other hand, the contribution of occasional seismological literature and contemporary journalistic accounts describing recent earthquakes becomes progressively more significant [Molin et al., 2008].

Between the 18th and 19th centuries, the contribution of seismological and historical compilations continued to be very consistent, with a better average level of reliability due to the relative temporal proximity to the events described.

Finally, certainly important are the seismological compilations based on the systematic perusal of coeval periodicals such as De Rossi [1889] who perused the Gazzetta di Bologna, or Baratta [1897] or, more sporadically, Hoff [1840], and Perrey [1848] [Molin et al., 2008].

These compilations represent the primary source of qualitatively significant information regarding the effects of earthquakes in specific localities. In this regard, the annual compilations of Perrey are of particular significance. Through a comprehensive network of correspondents, Perrey amassed a substantial body of material on Italian earthquakes, which is currently housed in the Library of the Neapolitan Society of Local History in Naples (Perrey Fund).

In addition to the compilations of national interest, such as the already mentioned Baratta [1897, 1899, 1901] or Mercalli [1883], De Rossi [1889], Agamennone [1897], Cancani [1901], and Cavasino [1935], the few compilations available of a regional nature and specific to north-eastern Italy were also checked, many of which were negative as they were not very thorough, such as Goiran [1886, 1892], Piovene [1888], Scarpa [1888], and Zanon [1937]. Among these, however, a relatively in-depth work, which therefore deserves special mention, is that of Spagnolo [1907] who reports on the events of 1887, 1897, and 1900.

About the earthquakes in the Emilia region, the results of our search of national and regional compilations were negative. With the exception of the earthquakes of 1501 and 1608, which are mentioned by Baratta [1899; 1901] none of the compilations in our possession contain any information on the effects caused.

MARIO BARATTA

I TERREMOTI D'ITALIA

SAGGIO DI STORIA
GEOGRAFIA E BIBLIOGRAFIA SISMICA ITALIANA

CON 136 SISMOCARTOGRAMMI

TORINO
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1901

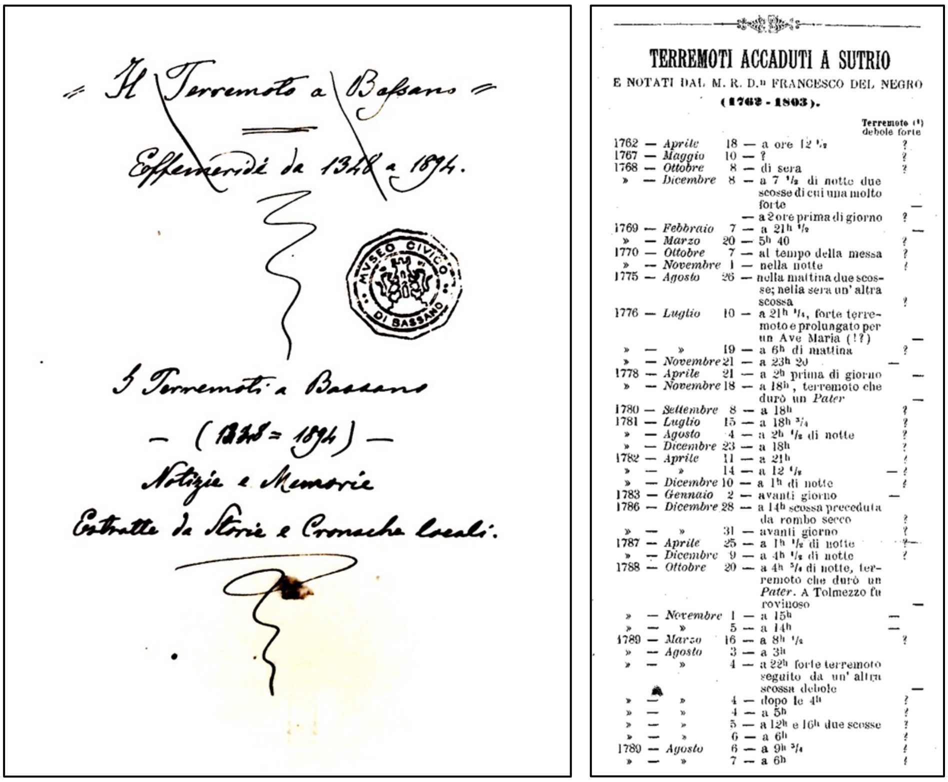
R. UFFICIO CENTRALE DI METEOROLOGIA E GEODINAMICA
AL COLLEGIO ROMANO - ROMA

NOTIZIE
SUI
TERREMOTI OSSERVATI IN ITALIA
durante l'anno 1900
COMPILATE DAL
Prof. ADOLFO CANCANI

La presente pubblicazione tiene luogo del *Supplemento* che, con le notizie sismiche a tutto il 1894, fu unito al *Bollettino Meteorico quotidiano del R. Ufficio Centrale di Meteorologia e Geodinamica*. — A queste notizie si dà una impaginazione a parte, affinchè possano essere raccolte tutte assieme e rilegate, come appendice, in fine del volume.
Le ore sono espresse **in tempo medio dell'Europa Centrale** (t. m. E. C.) e vengono contate da una mezzanotte all'altra, dalle 0^h alle 24^h.

IL DIRETTORE
P. TACCHINI.

Figure11. *Front page of the national seismological compilations "I terremoti d'Italia" by Baratta [1901] - on the left - and "Notizie sui terremoti osservati in Italia durante l'anno 1900" by Cancani [1901] - on the right.*



TERREMOTI ACCADUTI A SUTRIO

E NOTATI DAL M. R. D.n FRANCESCO DEL NEGRO

(1762 - 1803).

				Terremoto (1) debole	forte
1762 —	*Aprile*	18 —	a ore 12 1/2	?	
1767 —	*Maggio*	10 —	?	?	
1768 —	*Ottobre*	8 —	di sera	?	
» —	*Dicembre*	8 —	a 7 1/2 di notte due scosse di cui una molto forte		—
		—	a 2 ore prima di giorno	?	
1769 —	*Febbraio*	7 —	a 21^h 1/2		—
» —	*Marzo*	20 —	5^h 40	?	
1770 —	*Ottobre*	7 —	al tempo della messa	?	
» —	*Novembre*	1 —	nella notte	?	
1775 —	*Agosto*	26 —	nella mattina due scosse; nella sera un' altra scossa	?	
1776 —	*Luglio*	10 —	a 21^h 1/4, forte terremoto e prolungato per un Ave Maria (!?)		—
» —	»	19 —	a 6^h di mattina	?	
» —	*Novembre*	21 —	a 23^h 20	—	
1778 —	*Aprile*	21 —	a 2^h prima di giorno		—
» —	*Novembre*	18 —	a 18^h, terremoto che durò un *Pater*		—
1780 —	*Settembre*	8 —	a 18^h	?	
1781 —	*Luglio*	15 —	a 18^h 3/4	?	
» —	*Agosto*	4 —	a 2^h 1/2 di notte	?	
» —	*Dicembre*	23 —	a 18^h	?	
1782 —	*Aprile*	11 —	a 21^h	?	
» —	»	14 —	a 12 1/2	— ?	
» —	*Dicembre*	10 —	a 1^h di notte	?	
1783 —	*Gennaio*	2 —	avanti giorno	—	
1786 —	*Dicembre*	28 —	a 14^h scossa preceduta da rombo secco	?	
» —	»	31 —	avanti giorno	?	
1787 —	*Aprile*	25 —	a 1^h 1/2 di notte	?	—
» —	*Dicembre*	9 —	a 4^h 1/2 di notte	?	
1788 —	*Ottobre*	20 —	a 4^h 3/4 di notte, terremoto che durò un *Pater*. A Tolmezzo fu rovinoso		—
» —	*Novembre*	1 —	a 15^h	—	
» —	»	5 —	a 14^h	—	
1789 —	*Marzo*	16 —	a 8^h 1/2	?	
» —	*Agosto*	3 —	a 3^h		
» —	»	4 —	a 22^h forte terremoto seguito da un' altra scossa debole		—
» —	»	4 —	dopo le 4^h	?	
» —	»	4 —	a 5^h	?	
» —	»	5 —	a 12^h e 16^h due scosse	?	
» —	»	6 —	a 6^h	?	
1789 —	*Agosto*	6 —	a 9^h 3/4	?	
» —	»	7 —	a 6^h	?	

Figure 12. *Front page of the regional seismological compilations 'Il terremoto aBassano' by Crivellari [XIX] - on the left - and 'Terremoti accaduti a Sutro' by Del Negro [XVIII-XIX] - on the right.*

5.3 SEISMIC POSTCARDS

These types of sources diffused after the establishment of the Italian Seismological Society network in 1870, represent a turning point in the monitoring and study of earthquake effects. Whereas up to that time the type of sources available, i.e. documentary sources, were mostly 'involuntary', seismic postcards were made specifically for seismologists, although they too were sometimes not exempt from interpretation.

In the context of this study, the original postcards, preserved in the 'Fund of seismic postcards' of the Central Office of Agricultural Ecology (UCEA) in Rome, were recovered for some of the earthquakes of 29 March and 14 April 1887 (Marostica), 11 June 1897 (Asolano), 4 March 1900 (Trevigiano), and 10 June 1895 (Prealpi Trevigiane).

These are questionnaires that were sent to the various municipalities, post offices, observatories, thermo-udometric stations, etc., to collect information on the macroseismic effects observed in that particular locality; a service that would be operational until the mid-1970s (Fig. 13).

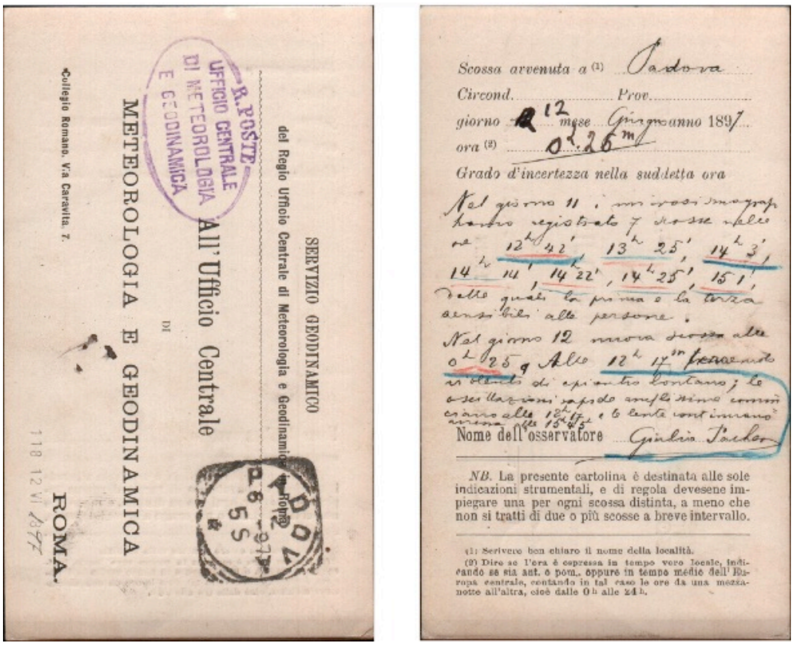


Figure 13. *Example of a "seismic postcard" of the Treviso earthquake of 11th June 1897.*

The first initiative of this kind was undertaken by the Italian scientist and presbyter Alessandro Serpieri (1823-1885) in the aftermath of the Adriatic earthquake of 1873. In the following years, the geophysicist Michele Stefano De Rossi (1834-1898) laid the foundation for the establishment of the Italian Seismological Society through the publication of the Bullettino del Vulcanismo Italiano.

De Rossi's work culminated in 1895, when the collection of "Notizie sui terremoti osservati in Italia durante l'anno..." [Notices of earthquakes observed in Italy during the year...] [Baratta, 1895] was published for the first time as an appendix to the Bulletin of the Italian Seismological Society [Camassi, 1991].

Observers were asked to indicate basic information about the shock, such as place, date, time, and duration, followed by more specific information such as the direction of the movement, its quality (whether undulatory or sussultatory), or whether environmental effects had occurred. Finally, the effects observed had to be reported, indicating, as required, *"whether the shock was felt by a few or many people in a state of stillness or motion; whether it produced shaking of small or large objects, glazing, doors; ringing of bells; serious or light cracks in a few or many well or poorly constructed houses; the partial or general ruin of buildings; numerous victims or not*".

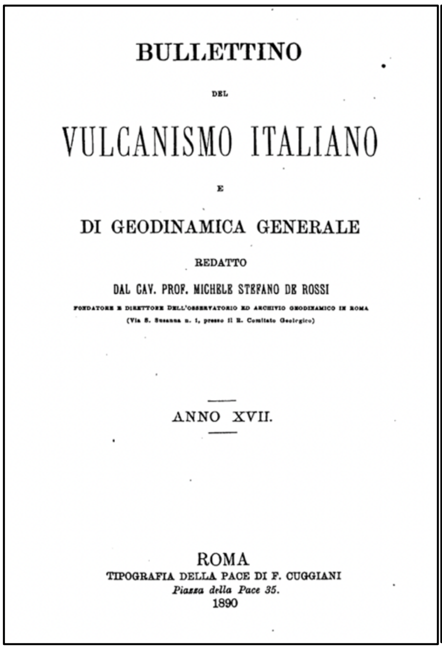
The majority of these documents are represented by seismic postcards in the strict sense, while a small part consists of correspondence or telegrams, and in some cases, they are also enriched by brief descriptive reports or newspaper clippings.

It is important to emphasise that sometimes this documentation can be of little use for the assignment of an intensity value. While in most of the postcards the main fields have been exhaustively filled in, in others, the observer or rapporteur has merely assigned an intensity value without providing further

descriptive elements to supplement them with other sources, making the interpretation process even more difficult [Baranello, 2023].
The seismic postcards have been transcribed using as the identification code the number corresponding to the digital file kept in the archive of the Central Office for Agricultural Ecology. As far as the text of the postcards is concerned, only those points for which there is a comment by the speaker are reported, leaving out the 'negative' ones.

5.4 BULLETINS

Not marginal sources are the seismological bulletins, which appeared following the formation of the Italian National State in 1870 when the meteorological and geodynamic services began to be organised [Molin et al., 2008].
Around that time, a network for monitoring the effects of earthquakes by the Italian Seismological Society, i.e. that network spread throughout the country that collects all the information on the country's seismicity (and flows into Baratta and Cavasino), was being organised. In the following years, the network was implemented until 1887, when the collection of information on the effects of earthquakes became systematic. This provided a product that revolutionised the process of producing historical data on earthquakes by becoming a privileged source for reconstructing their effects and still representing an important reference in the history of Italian seismology [Molin et al., 2008].
The bulletins are mainly based on news collected through seismic postcards, or on material gathered from observatories, newspapers, and local correspondence. At the beginning of the 20th century, this service faded until it was discontinued in 1913. It would later be replaced by other headings although they would no longer provide descriptive information on the effects, but merely assign an intensity value expressed in the Mercalli scale.
The most important bulletin is undoubtedly the Bollettino Mensuale (Monthly Bulletin), published by the Central Observatory of the Real Collegio Carlo Alberto in Moncalieri, which reports information for the events of 1887, 1897 and 1900; in addition to this, for 1887 only, there is also the Bollettino Meteorico Giornaliero (Daily Meteorological Bulletin), published by the Ufficio Centrale di Meteorologia in Rome, and the Bullettino del Vulcanismo Italiano (Fig. 14). Instead, for the two most recent earthquakes (1919 and 1921), only the Bollettino Sismico Settimanale and the Bollettino Sismico, published by the Regio Ufficio Centrale di Meteorologia e Geofisica in Rome and compiled by Ingrao [1927a; 1927b], are available. In the case of 1861, on the other hand, no news of the event was found in any bulletin.


BULLETTINO

DEL

VULCANISMO ITALIANO

E

DI GEODINAMICA GENERALE

REDATTO

DAL CAV. PROF. MICHELE STEFANO DE ROSSI

FONDATORE E DIRETTORE DELL'OSSERVATORIO ED ARCHIVIO GEODINAMICO IN ROMA

(Via S. Susanna n. 1, presso il R. Comitato Geologico)

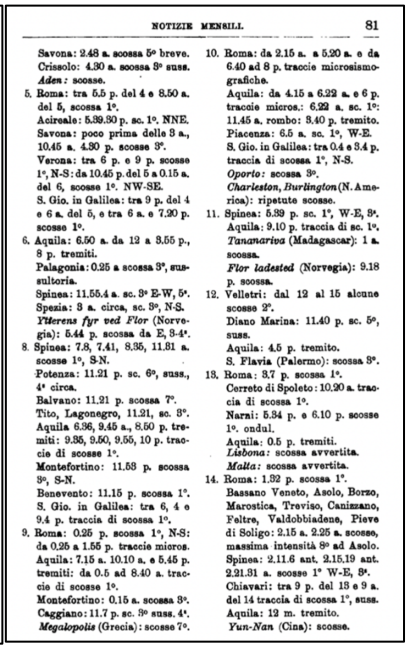
ANNO XVII.

ROMA

TIPOGRAFIA DELLA PACE DI F. CUGGIANI

Piazza della Pace 35.

1890


NOTIZIE MENSILI. 81

Savona: 2.48 a. scossa 5° breve.
Crissolo: 4.30 a. scossa 3° suss.
Aden: scosse.
5. Roma: tra 5.5 p. del 4 e 8.50 a. del 5, scossa 1°.
Acireale: 5.39.30 p. sc. 1°. NNE.
Savona: poco prima delle 3 a., 10.45 a. 4.30 p. scosse 3°.
Verona: tra 6 p. e 9 p. scosse 1°, N-S: da 10.45 p. del 5 a 0.15 a. del 6, scosse 1°. NW-SE.
S. Gio. in Galilea: tra 9 p. del 4 e 6 a. del 5, e tra 6 a. e 7.20 p. scosse 1°.
6. Aquila: 6.50 a. da 12 a 3.55 p., 8 p. tremiti.
Palagonia: 0.25 a scossa 3°, sussultoria.
Spinea: 11.55.4 a. sc. 3° E-W, 5ª.
Spezia: 3 a. circa, sc. 3°, N-S.
Ytterens fyr ved Flor (Norvegia): 5.44 p. scossa da E, 3-4ª.
8. Spinea: 7.8, 7.41, 8.35, 11.31 a. scosse 1°, S-N.
Potenza: 11.21 p. sc. 6°, suss., 4ª circa.
Balvano: 11.21 p. scossa 7°.
Tito, Lagonegro, 11.21, sc. 3°.
Aquila 6.36, 9.45 a., 8.50 p. tremiti: 9.35, 9.50, 9.55, 10 p. traccie di scosse 1°.
Montefortino: 11.53 p. scossa 3°, S-N.
Benevento: 11.15 p. scossa 1°.
S. Gio. in Galilea: tra 6, 4 e 9.4 p. traccia di scossa 1°.
9. Roma: 0.25 p. scossa 1°, N-S: da 0.25 a 1.55 p. traccie micros.
Aquila: 7.15 a. 10.10 a. e 5.45 p. tremiti: da 0.5 ad 8.40 a. traccie di scosse 1°.
Montefortino: 0.15 a. scossa 3°.
Caggiano: 11.7 p. sc. 3° suss. 4ª.
Megalopolis (Grecia): scosse 7°.
10. Roma: da 2.15 a. a 5.20 a. e da 6.40 ad 8 p. traccie microsismografiche.
Aquila: da 4.15 a 6.22 a. e 6 p. traccie micros.: 6.22 a. sc. 1°: 11.45 a. rombo: 3.40 p. tremito.
Piacenza: 6.5 a. sc. 1°, W-E.
S. Gio. in Galilea: tra 0.4 e 3.4 p. traccia di scossa 1°, N-S.
Oporto: scossa 3°.
Charleston, Burlington (N. America): ripetute scosse.
11. Spinea: 5.39 p. sc. 1°, W-E, 3ª.
Aquila: 9.10 p. traccia di sc. 1°.
Tananariva (Madagascar): 1 a. scossa.
Flor ladested (Norvegia): 9.18 p. scossa.
12. Velletri: dal 12 al 15 alcune scosse 2°.
Diano Marina: 11.40 p. sc. 5°, suss.
Aquila: 4.5 p. tremito.
S. Flavia (Palermo): scossa 3°.
13. Roma: 3.7 p. scossa 1°.
Cerreto di Spoleto: 10.20 a. traccia di scossa 1°.
Narni: 5.34 p. e 6.10 p. scosse 1°. ondul.
Aquila: 0.5 p. tremiti.
Lisbona: scossa avvertita.
Malta: scossa avvertita.
14. Roma: 1.32 p. scossa 1°.
Bassano Veneto, Asolo, Borzo, Marostica, Treviso, Canizzano, Feltre, Valdobbiadene, Pieve di Soligo: 2.15 a. 2.25 a. scosse, massima intensità 8° ad Asolo.
Spinea: 2.11.6 ant. 2.15.19 ant. 2.21.31 a. scosse 1° W-E, 3ª.
Chiavari: tra 9 p. del 13 e 9 a. del 14 traccia di scossa 1°, suss.
Aquila: 12 m. tremito.
Yun-Nan (Cina): scosse.

Figure 14. *Front page and text page from the Bullettino del Vulcanismo Italiano with the text concerning the 14th April 1887 earthquake.*

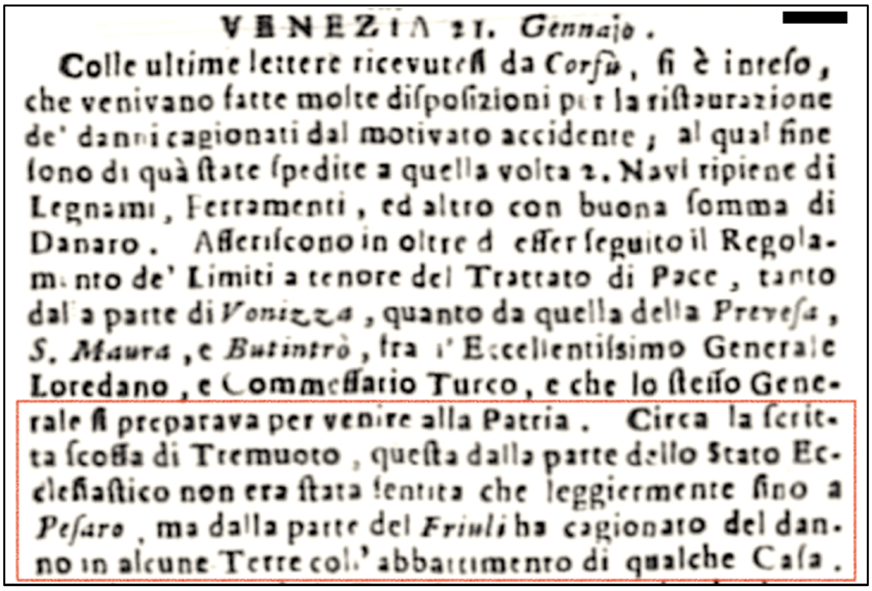
5.5 JOURNALISTIC SOURCES

Of particular interest in the study of earthquakes are journalistic sources which in some cases become of fundamental importance for improving the information framework.

Modern journalism was born in the 16th century with handwritten 'notices' (a modern newsletter) distributed weekly to a limited audience [Infelise, 2002]. These consist of a single folded sheet of paper containing a collection of unconnected, stringy news items put together one after the other without much logical thread other than their provenance. The handwritten notices market remained alive for almost three centuries, even after the rise of printed gazettes (first half of the 17th century), which were the immediate forerunners of the modern newspaper and that experienced a period of significant growth in the 1700s.

The gazettes are of great use in historical seismology investigations because they were printed periodically and for a wide audience, they covered long periods and had a multiplicity of news and 'correspondents' in various European capitals [Camassi et al., 2011]. Around 1800, with the French Revolution and the Napoleonic wars, news content was almost totally monopolised by the political situation and military operations. During this period, the gazettes became an official political organ, also publishing laws and government decrees and devoting some sections to cultural or scientific events and commercial announcements. In addition, mid-nineteenth-century gazettes tended to publish little local news (e.g., the Gazzetta di Bologna rarely mentioned Bologna) and tended to take up news already published in the gazettes of other cities, declaring the name of the newspaper from which the news came [Camassi et al., 2011]. For this reason, this type of source has a different value depending on the period considered.

Newspapers, as we understand them, were born in the 19th century and developed strongly in the second half of the century, thanks also to technological innovations in printing systems, as well as communication systems, which led to the birth of modern news agencies, already envisaged by the European network of 18th-century gazettes (Fig. 15).


VENEZIA 21. *Gennajo*.

Colle ultime lettere ricevutesi da *Corfù*, si è inteso, che venivano fatte molte disposizioni per la ristaurazione de' danni cagionati dal motivato accidente; al qual fine sono di quà state spedite a quella volta 2. Navi ripiene di Legnami, Ferramenti, ed altro con buona somma di Danaro. Asseriscono in oltre d'esser seguito il Regolamento de' Limiti a tenore del Trattato di Pace, tanto dalla parte di *Vonizza*, quanto da quella della *Prevesa*, *S. Maura*, e *Butintrò*, fra l'Eccellentissimo Generale Loredano, e Commessario Turco, e che lo stesso Generale si preparava per venire alla Patria. Circa la scritta scossa di Tremuoto, questa dalla parte dello Stato Ecclesiastico non era stata sentita che leggiermente fino a *Pesaro*, ma dalla parte del *Friuli* ha cagionato del danno in alcune Terre coll'abbattimento di qualche Casa.

Figure 15. *The news of the earthquake of 7 January 1719 in the Mantova gazette [Baranello et al., 2024].*

An important role in this research is certainly played by the most recent national newspapers, made available online by some of the main Italian libraries, such as Il Corriere della Sera, La Nazione, L'Unità, and La Stampa, to name but a few, and above all local newspapers (when available and accessible). To this end, digital newspaper collections of potential interest for this study were systematically explored.

Concerning the study of earthquakes in the Veneto region, the Braidense Digital Emeroteca for the Lombardy area, the collection of Local Historical Periodicals of the Biblioteca Teresiana in Mantua, the Emeroteca of the Biblioteca Civica Hortis in Trieste, the collection of digital periodicals of the Sistema Bibliotecario del Friuli, the Emeroteca Digitale del Veneto, and the Emeroteca Digitale of Bolzano, to name the most important ones, were consulted.

The usability of these sources through the network of digital archives greatly facilitated the work, which was more complex when it came to the direct consultation of local newspapers, as was the case for Il Gazzettino, a newspaper from the Veneto region kept at the Biblioteca Comunale di Treviso, whose collection was severely incomplete and partly non-consultable due to deterioration problems.

In several cases, useful information has also been found in foreign newspapers, mainly from the

French and German regions, such as the Gazette de France, the Courrier d'Avignon the Gazette de Leyde, or the Bozner Zeitung and the Innsbrucker Nachrichten, just to name a few.

As previously mentioned, documentary availability reflects the socio-political, economic, and cultural peculiarities of the historical phase in which they are produced, a phenomenon that is even more marked in the case of newspapers.

Despite this, however, the contribution of the recovered press reports proved to be of fundamental importance, in most of the earthquakes examined, to reconstruct the picture of macroseismic effects [Baranello, 2023].

5.6 LOSS OF INFORMATION

Historical research on earthquakes often comes up against the harsh reality of the existence of special conditions that can lead to the possible loss of information. This happens especially with minor events, those that are non-destructive but close to the damage threshold (6 MCS), which are nevertheless of interest for seismic hazard assessment and risk estimates.

There are several reasons why important information on earthquakes may be lost. Among these, there is certainly the concurrence of other phenomena that tend to attract more attention from potential witnesses, such as wars, epidemics, or a particular historical period, like the French one which greatly influenced the circulation of information in Italy during the late 18th and early 19th centuries, as the war period leads to a transformation in the priorities of the journalist network.

Even the occurrence of a strong earthquake can lead to this issue. Indeed, in the aftermath of a strong earthquake, the journalists of the 17th and 18th centuries tended to react in two ways. Either their interest in seismic news would increase, making it possible that more earthquakes than usual would be given coverage; or they would focus exclusively on the 'big event' to the disadvantage of minor contemporary earthquakes that were overlooked and shadowed by the larger one [Castelli & Camassi, 2005].

The geographical characteristics of certain areas can also strongly influence the production and dissemination of news. For example, earthquakes occurring in mountainous regions, which are far from the main communication routes, in border areas with other states, or more generally in the south of Italy , where the density of the settlement network is relatively low until at least the 16th century and there is a distinct social and cultural isolation, would have less resonance.

Another important factor is certainly the decline in the efficiency of the journalistic network, which occurred roughly between the last two decades of the 18th century and the first half of the 19th century. At that time, Italy's journalistic network was highly developed although it was not yet homogeneous. Indeed, the majority of the gazettes were concentrated in the central and northern parts of the country, with the South remaining largely underserved. Until the end of the 18th century, for example, the South had a journalistic production that was essentially limited to Naples, as the point of production and gathering of news, leaving provincial and rural areas practically uncovered.

This uneven distribution of networks capable of intercepting earthquake news underlines very obvious ‘shadow zones’, as defined by Castelli & Camassi [2005], which led to the loss of traces of many minor earthquakes, and often even some of the significant ones.

The compilation of the parametric catalogues in the late 1970s could also be a cause of the possible loss of information. The PFG catalogue [Postpischl, 1985], which is still a reference catalogue for Italy, as it is not declustered, is the result of a very delicate operation of assembling other parametric catalogues, both national and regional. It is therefore possible that this process may have resulted in both the creation of duplicate data and the loss of some records.

Sometimes, however, there can be problems also in the preservation of the records. Historical documentation may be severely lacking, inaccessible or completely lost, so there are sometimes great difficulties in finding useful information.

It is important to consider that, for ancient earthquakes, the sources often do not provide an overall picture of the effects, but generally the information available tends to cluster around the main centres of the time. A comparison between the seismic histories of Ferrara and Modena and those of smaller towns indicates that the former has more extensive and detailed records. This indicates the impact of the phenomenon known as ‘urban fixation’, which refers to the inclination to prioritize events occurring in urban centers over those taking place in rural areas or villages. This proclivity was particularly pronounced during eras when the literacy rate was higher among urban residents than among those living in rural areas [Castelli et al., 2012].

It can be reasonably deduced that, in historical terms, the further back in time we examine, the more probable it is to find documented instances of seismic activity and its subsequent effects in the more prominent provincial capitals, with a paucity of such information for less significant localities. It is therefore not uncommon to find that a provincial capital is the epicentre of a macroseismic event, with the possibility that the recorded maximum intensity may in fact correspond to an earthquake of greater magnitude for which insufficient data is available to enable an accurate evaluation and location.

The Italian catalogue [Rovida et al., 2022] is certainly one of the richest in the world. Despite this, however, analyses of completeness, both statistical and historical [Albarello et al., 2001], point to very diversified situations throughout the country, varying across time, space, and intensity levels. Despite the fact that seismicity is not a stationary phenomenon over time, analysis of the seismic histories of some localities reveals significant gaps in the available knowledge. A notable example is

Bassano del Grappa (Fig. 16), where there is a discernible absence of data for the period prior to 1695, a lacuna that extends to the entire Treviso and Asolo area. A particularly pronounced absence of data is evident in the seismic history of Mirandola (Fig.17), where the dearth of information extends to the period prior to 1796. These evident lacunae in the documentation may be indicative of either the absence of significant seismic occurrences or a paucity of research endeavours focused on this particular aspect. This phenomenon is intricately linked to the research strategies that have been adopted in Italy over recent decades. These strategies have placed greater emphasis on the study of regions deemed to be more critical from a seismic perspective, particularly those affected by nuclear power plant projects during the 1980s. Consequently, regions that have received less attention, such as those mentioned, have experienced significant knowledge gaps in their seismic history.

The seismic history of some areas of the country is considered uniformly complete since the mid-18th century. For higher intensity events (Io ≥ 8 and Mw ≥ 5.5), there is significant spatial heterogeneity in completeness, that is even more obvious in several areas of the Apennines, and especially in southern Italy. Northern Italy shows completeness back to 1400-1600, central Italy and Sicily to 1600-1700, and southern Italy to 1700-1800 for Io ≥ 8 events [Stucchi et al., 2004; Albarello et al., 2001]. This depends on many factors and makes us think that there are still important margins for identifying earthquakes not known to the catalogues.

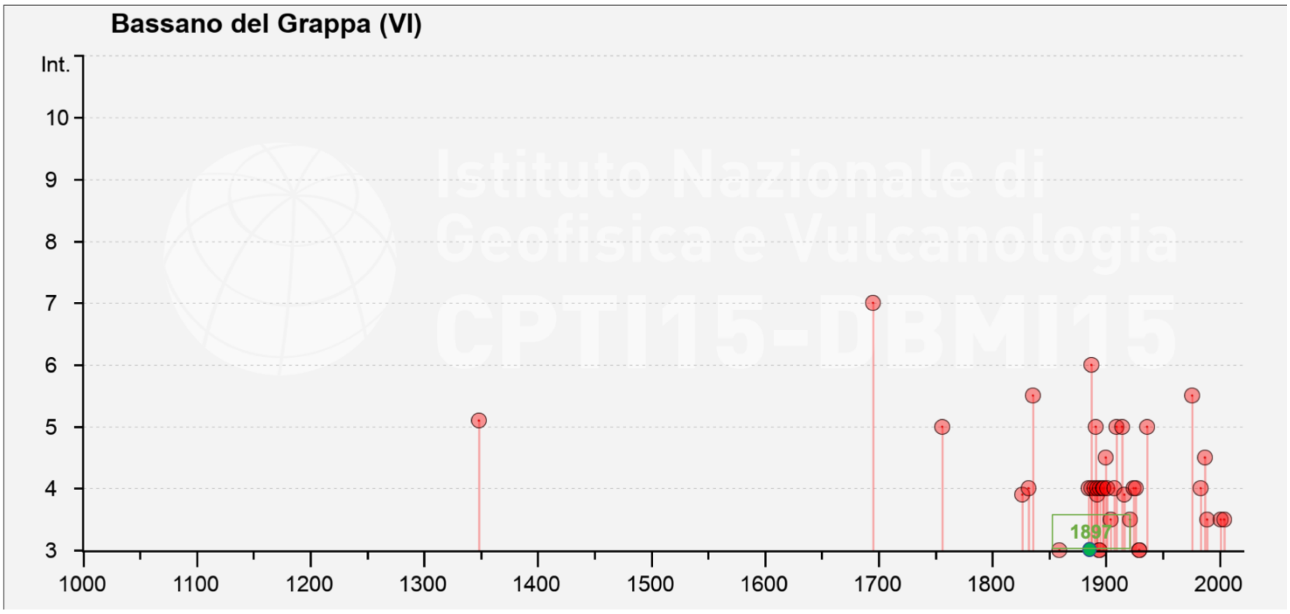


Figure 16. *Seismic history of Bassano del Grappa (TV) [Locati et al., 2022]. In green the new earthquake detected during this study.*

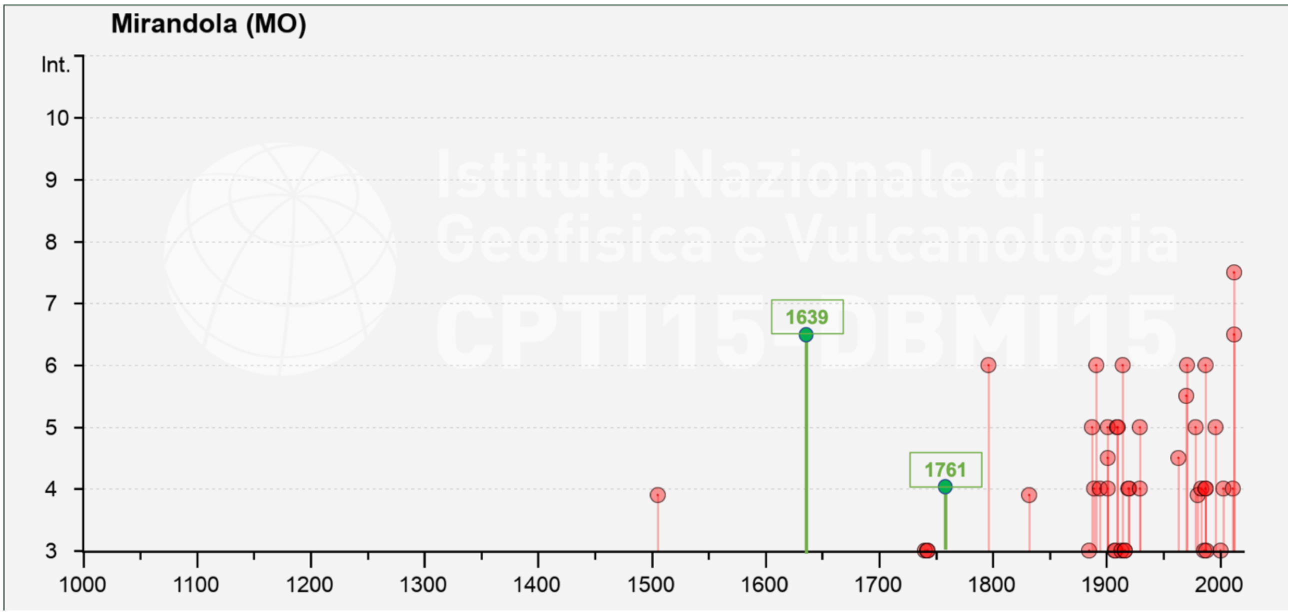


Figure 17. *Seismic history of Mirandola (MO) [Locati et al., 2022]. In green the new earthquakes detected during this study.*

6. STUDIED EARTHQUAKES

The following paragraphs (6.1–6.2) will present a detailed account of all the earthquakes that were analysed as part of this PhD research project.

This discussion will initially focus on earthquakes that took place in Emilia, with a particular attention on the Modena area (paragraphs 6.1-6.1.5), and then on those occurred in Veneto (paragraphs 6.2-6.2.2). In the latter case, to facilitate the discussion, I will distinguish the earthquakes that occurred close to Asolo - studied and reported in Baranello [2023] (https://editoria.ingv.it/quaderni/2023/quaderno186/) - from those in the Treviso area, which have epicentres scattered throughout the province and which are reported in Baranello et al. [2024] (in press).

6.1 EMILIAN PLAIN EARTHQUAKES

In order to enhance understanding of the relatively minor seismic activity observed in the vicinity of Modena (Fig. 18), the seismic events that occurred on 6 January 1608, 6 April 1639, 15 December 1761, and 11 May 1778 were studied. Additionally, the data set was expanded to include the event of 5 June 1501, which is currently one of the most significant earthquakes in the region. Consequently, despite its earlier temporal occurrence, it was deemed essential to review and incorporate it into the present study. The majority of these events (1501, 1607, 1608, 1639) are included in the current parametric catalogue on the basis of relatively dated work (CFTI4med [2007] for 1501, 1607, and 1608; Camassi et al. [2011] for 1639) (Tab. 2). In contrast, the two later cases (1761 and 1778) are not yet included in the catalogues, and can therefore be considered as ‘new’ earthquake entries. Consequently, this study will serve as the reference point for them.

Year	Mo	Da	Ho	Mi	Epicentral area	Ref	Lat	Lon	Io	Mw
1501	06	05	05	10	Modenese	CFTI4med	44.519	10.844	9	6.05
1607	12	31	--	--	Reggio Emilia	CFTI4med	44.698	10.631	5	4.16
1608	01	06	22	20	Reggio Emilia	CFTI4med	44.698	10.631	5-6	4.40
1639	04	06	--	--	Finale Emilia	CAMAL011	44.833	11.294	7-8	5.33
1761	12	15	--	--	--	--	--	--	--	--
1778	05	11	--	--	--	--	--	--	--	--

Table 2. *Earthquakesof the Modena area covered by this study in the CPTI15 catalogue [Rovida et al., 2022]. In the reference column: CAMAL011 [Camassi et al., 2011], CFTI4med [Guidoboni et al., 2007].*

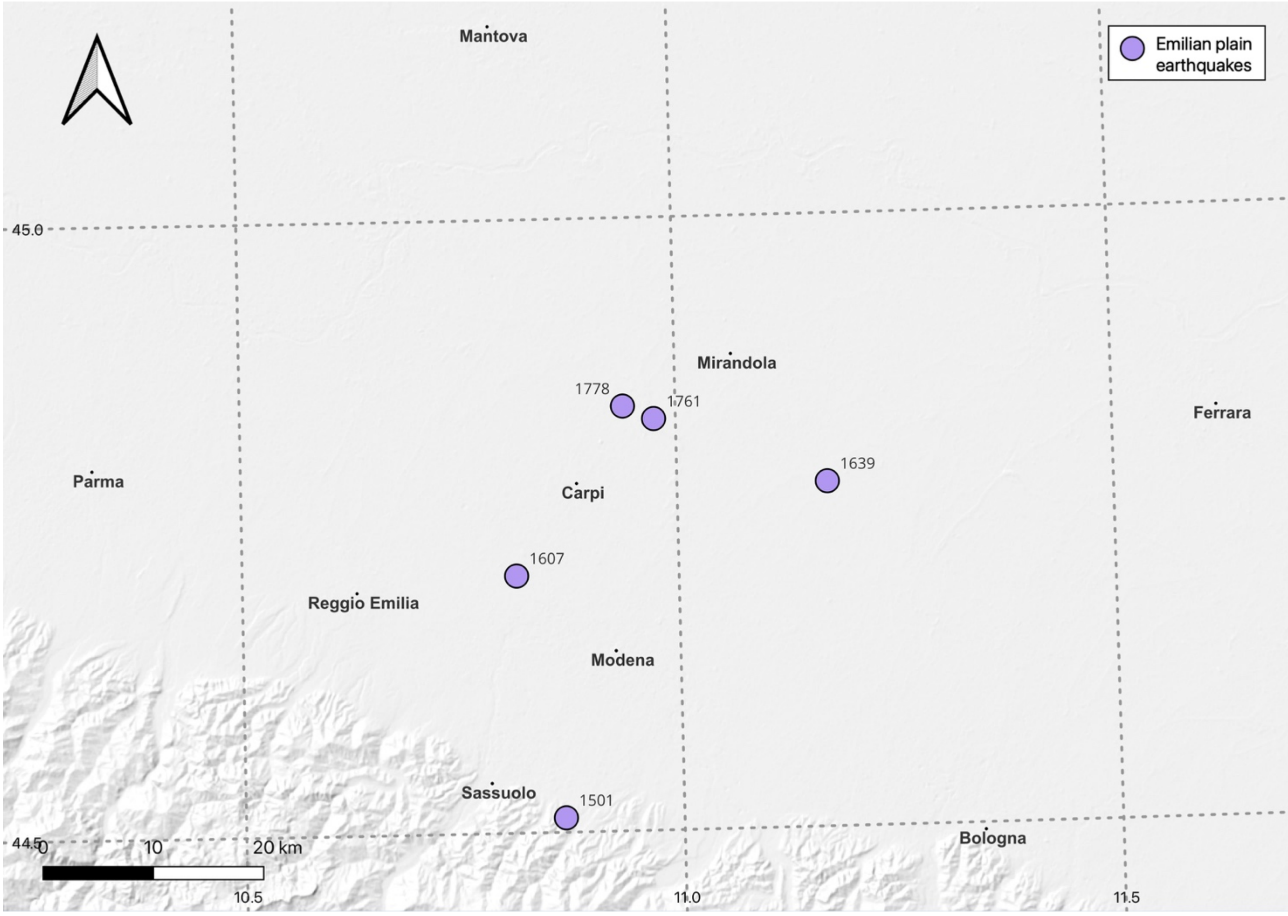


Figure 18. *Spatial distribution of the Emilian plain earthquakes covered by this study.*

All the main seismological compilations of general interest were consulted, in addition to those of a strictly Emilian area, and the main national, regional, and European printed gazettes available. Manuscript notices held at the State Archives in Modena were also checked. In particular, envelopes no. 3, 18, 30, 81, and 87 (for the earthquakes of 1501, 1608, 1639, 1761, and 1778 respectively) kept in the 'Avvisi e notizie dall'estero' fund was checked, unfortunately with negative results, and the Biblioteca Estense e Universitaria in Modena was also consulted. The Archivio Storico Comunale and the Archivio del Seminario in Carpi, the Biblioteca Abbaziale in Nonantola and the Centro Studi Nonantolani were also consulted.

In the Bologna area, the Biblioteca Universitaria of Bologna, the Biblioteca Comunale of Crevalcore, and the Biblioteca Comunale of San Giovanni in Persiceto were checked. Finally, the Cento Municipal Historical Archive, in the province of Ferrara.

Along with the Italian cultural institutions, the Bibliothèque Nationale de France (BnF) and the Diplomatic Archives in Paris were also consulted, again without results. Indeed, at the beginning of the final year of my PhD, I travelled to Paris to complete the 3-month period abroad required by my course, from 1 September to 1 December 2023, to obtain further information on the Emilian earthquakes studied in this thesis.

The research carried out in Paris focused mainly on documents held in the French 'Centre des Archives diplomatiques du ministère des Affaires étrangères' in La Courneuve (Paris).
The decision to visit this facility was motivated by the historical connection between France and Italy, which suggests the possibility of locating materials comparable to those consulted at the State Archives in Modena, where French news is notably predominant.
A La Courneuve I consulted the political correspondence, preserved on microfilm and in some cases on the original paper, between the King of France and his ambassadors resident in some Italian cities. Specifically, I selected and analysed the correspondence between the French court and the cities of Mantua, Milan, Modena, Parma, Rome, Tuscany, and Venice. For each of these localities, I checked which dates were available and examined all those available for the years 1608, 1639, 1761, and 1778, for a total of 31 series.
Unfortunately, in the majority of cases, I found very incomplete collections, with time gaps in the order of days, months, or, in other cases, even years. Very few had reports on the year of interest, but nothing about the earthquakes. Considering, however, that these were 'minor' earthquakes, and therefore unlikely to have been considered important news to report to the king, and that they occurred in peripheral areas of the court, it is not surprising that they were not mentioned in official documents. This is not the case for 1501, as the archive was not established until 1600, so there is not much material from before the 17th century. In all five cases, therefore, the search yielded negative results, although, in the overall picture, this is still an improvement as it rules out the possibility of finding anything in this particular collection.
Given the modest nature of these events, which did not cause significant damage or impact, further investigation is possible, but the scope for improvement seems very limited.

6.1.1 THE 5 JUNE 1501 EARTHQUAKE, APPENNINO MODENESE

On 5 June 1501, between 1 p.m. and 3 p.m. 'Italian time' (10:00 GMT), the province of Modena was struck by what many sources describe as a very powerful earthquake (Fig. 19).
This earthquake is well known to the main Italian parametric catalogues and the main national and regional seismological compilations. This event is also present in the most recent Italian parametric catalogue (CPTI15) [Rovida et al., 2022] based on the study conducted by the CFTI4med working group (Catalogue of Strong Earthquakes in Italy) [Guidoboni et al., 2007].
Among the various sources, the one that provides the most complete and detailed description is the contemporary chronicle of Jacopino de' Bianchi, known as de' Lancellotti - who lived in Modena from around 1440 to 1502 -, later taken up by other chroniclers such as his son Tommasino de' Bianchi and by Pirro Ligorio [ed. Guidoboni, 2005]. The chronicler Alessandro Tassoni (16th

century), who was a direct witness of the event, also speaks of a "*great earthquake in Modena, so much so that there was not a house that did not suffer some damage*", adding that even "*the castles of the diocese of Modena, especially those located in the mountains, collapsed almost from their foundations, such as Castel Vetro, Maranello and Montegibbio and others*".

According to the testimonies collected, the area most affected was the city of Modena where many merlons fell from the buildings, causing the death of eight people and indirect damage to the buildings below, and several churches, public and private buildings were partially damaged. As well as the numerous damages to the anthropic environment, the effects on the natural environment were also recorded. According to the Modenese Chronicle of Jacopino de' Bianchi, later echoed by Baratta [1901] and Pirro Ligorio [ed. Guidoboni, 2005], in Modena the earthquake caused the water in the springs to become turbid, the water in the fountains to overflow and the flow rate of the canals to increase.

In addition to the city of Modena, the towns of Castelvetro, Maranello, Sassuolo and Montegibbio suffered serious and widespread damage, affecting a large part of their architectural heritage, with collapses and damage that rendered most of the houses uninhabitable [Guidoboni et al., 2018].

Less serious damage was reported in Reggio Emilia, where "*a terrible earthquake was felt with the ruin of several houses*" [Baldi, XVII] and "*with great fright of the citizens*" [Tedeschi, XVIII].Bologna, Ferrara and Forlì were also affected, but no damage was reported.

Upon examination of the sources, several exceptional cases were identified, the analysis of which presented a certain degree of complexity. This is exemplified by the cases of Fiorano Modenese, Montecreto, Parma, and Verona, where doubts have been raised as to the veracity of the information presented by some of the collected sources. As a result, it was decided that these sources should not be taken into consideration and that these localities should be excluded from the list of those in which damage effects were documented.

With regard to Parma, the only information available is that of a "*very violent tremor*", a statement reported only by Baratta [1901] without corroboration from any other source, especially the contemporary ones. Consequently, the statement lacks sufficient robustness to be taken into consideration. Baratta also asserts that the earthquake was felt in Verona; however, there are no direct sources attesting to this, only a treatise on the history of the city dating back to the end of the 18th century.

As for Fiorano Modenese and Montecreto, there are no contemporary sources. In both instances, there are only exceedingly late sources that also appear to lack substantial supporting evidence.

The case of Dismano is of particular interest. The only information that has been collated in this regard has been derived from the texts of Giacobazzi [XIX] and Banorri [2000]. The texts are both very late and appear to report the same generic information - which is indicative of a mere replication -, and are therefore devoid of valid information. Moreover, further research revealed that the toponym Dismano has survived to the present day only due to the continued use of the name associated with a dairy. Indeed, it is documented that the castle was destroyed by a landslide that is thought to have occurred in the 15th century.

In the case of Marano sul Panaro, I have elected to retain the information despite the absence of explicit disclosure by the authors [Poggi e Poggi, 1962] regarding the sources they consulted. In this case, there are no direct sources available. However, in contrast to the other localities for which there are only recent and very weak studies, the local historiographical work of Poggi e Poggi [1962] is, despite being relatively recent, of an acceptable quality.

For the localities of Montegibbio and Denzano, the alphanumeric values HD and D, which stand for 'heavy damage' and 'damage' respectively, have been assigned as intensities.

Year	**Mo**	**Da**	**Ho**	**Mi**	**Ax**	**St**	**Mdps**	**Ix**
1501	**06**	**04**	**10**	**00**	**Appennino modenese**	**This study**	**14**	**9**

Place	**Sc**	**Pro**	**Lat**	**Lon**	**Is**
Castelvetro		MO	44.503	10.943	9
Maranello		MO	44.525	10.866	9
Montegibbio	SS	MO	44.507	10.785	HD
Colombaro		MO	44.552	10.893	8-9
Sassuolo		MO	44.541	10.781	8
Gorzano		MO	44.514	10.879	7-8
Marano sul Panaro		MO	44.456	10.971	7-8
Modena		MO	44.647	10.926	7-8
Spezzano		MO	44.532	10.845	7-8
Reggio Emilia		RE	44.698	10.631	7
Denzano	SS	MO	44.456	10.921	D
Bologna		BO	44.494	11.343	4-5
Ferrara		FE	44.835	11.620	4-5
Forlì		FC	44.222	12.040	4-5

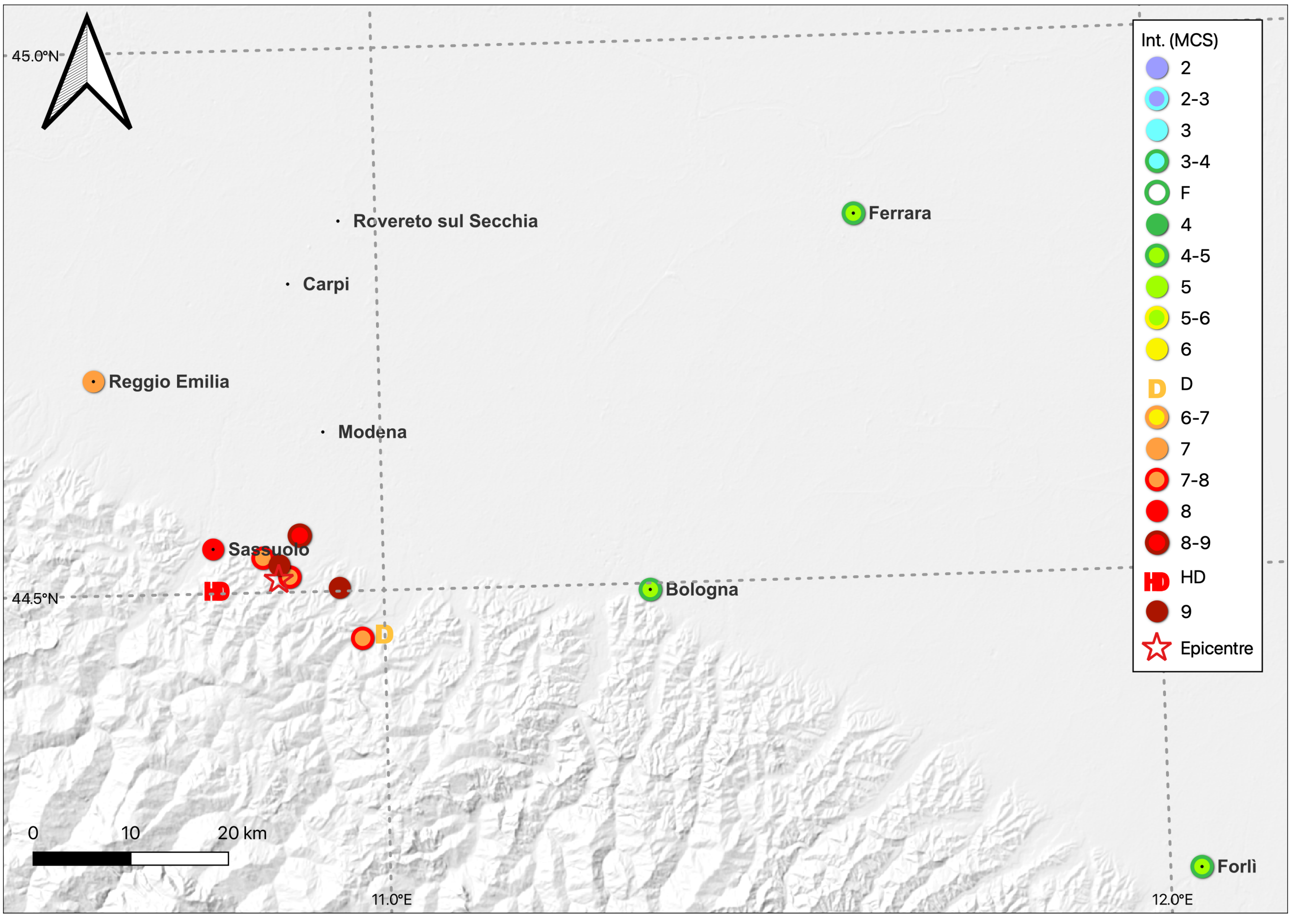


Figure 19. *Macroseismic intensity distribution map of the 10:00 GMT earthquake of 5 June 1501; the red star shows the macroseismic epicentre from this study.*

6.1.2 THE 31 DECEMBER 1607 - 6 JANUARY 1608 EARTHQUAKES, MODENESE

On the night of 31 December 1607 at 7.45 a.m. 'Italian time' (23:45 in GMT), which corresponds to 00.45 a.m. local time on 1 January 1608, the city of Reggio Emilia was struck by a strong earthquake that caused all the buildings to shake and the bells of the towers to ring [Rubini, XVII; Pellicelli, XVIII; Bracchi, 1776; Reginus, 1880]. This event is also reported in a contemporary chronicle of Modena [Spaccini, XVII], according to which on 1 January a strong earthquake was felt in Modena that "*must have thrown three chimneys to the ground, consquasate walls, an iron chain broke under the vault of the heirs of the splendid Prospero Abbati […]. In the houses he did much damage, such as breaking the kitchen, opening doors and windows*". Spaccini also reports that it was felt in Carpi, where "*it did much damage*".

A few days later, on 6 January, at about 22:20 GMT - around 6 a.m. 'Italian time' - another "*huge earthquake*" was felt in Reggio, where it caused many chimneys to collapse [Visdomi, XVII]. Since the earthquake occurred at the same time as a heavy snowfall that "*destroyed* [...] *many houses*" [Visdomi, XVII], as also recalled by Rubini [XVII] and by the Chronicle of Modena from the origins of the city until 1658 [XVII], there is an overlap between the damage caused by the two events, which makes it difficult to distinguish those caused by the earthquake. Moreover, as Aleotti [1916] reported in those years, the inhabitants of Reggio "*were not free from public misfortunes, being damaged by a serious earthquake (1608), afflicted by a fierce plague that took more than 1,000 of them (1610), and saw the municipalities of Brescello and Gualtieri threatened by the Po*".

The 1608 earthquakes are both known from Baratta's compilation [1901], which uses two of his earlier compilations [Baratta, 1899] in addition to Visdomi's local historical compilation [XVII].

The events are present in the Postpischl catalogue [1985] and are included in the CPTI15 catalogue [Rovida et al., 2022] based on a study carried out by the CFTI5med group [Guidoboni et al., 2018].

Thanks to the research carried out by Guidoboni et al. [2018] at the Reggio Emilia State Archives, in particular in the documentary section 'Provisions', some documents have been found, such as measures taken by the Municipal Council for the damage to buildings, or petitions sent by private citizens asking to be allowed to repair their houses that were about to collapse, which confirm that most of the damage was in fact caused by the exceptional snowfall. Il Giornale del Massaro [1608] also reports on all the city's expenses and the measures taken by the city council to deal with the snow damage. These documents are not presented here because they are not considered relevant to the earthquake, but can be consulted on the CFTI website (https://storing.ingv.it/cfti/cfti5/).

Searches in the historical archives of the municipalities of Cento, Nonantola, Novellara, Correggio, Mirandola and Brescello, and in the municipal libraries of Crevalcore and San Giovanni in Persiceto were negative. Also negative is the analysis of Cronaca di Modena dal 1466 al 1665 [XVII], Cronache e notizie modenesi, [XVII-XVIII], Ristretto dell'historia di Modena e del Frignano [XVI-XVII], Ancini C., [XVII], Gatti [XVIII], Monteforti [XVIII], Setti [XVIII], Forni [XX], Tornini [XVIII], and Memorie [2012], and the volume 12/2012 of the journal of the Centro Studi Storici Nonantolani.

The work carried out has certainly improved our knowledge of these two earthquakes. Firstly, with regard to the New Year's Eve event of 1607, there is an increase in the number of places affected - Reggio Emilia, where the MCS grade 5 is confirmed, is in fact joined by Carpi and Modena - and an increase in the maximum intensity reached, which goes from degree 5 in Reggio Emilia, to 6 for Modena. Carpi, given the very general description, can only be treated with a category that keeps it on the generic side, which is why it is assigned an intensity 'D', which stands for generic damage (Fig. 20).

As for the earthquake of 6 January 1608, it seems that only Reggio Emilia was affected, but in this case there was a decrease in the intensity from 6-7 to 6 MCS.

Year	**Mo**	**Da**	**Ho**	**Mi**	**Ax**	**St**	**Mdps**	**Ix**
1607	**12**	**31**	**23**	**45**	**Modenese**	**This study**	**3**	**6**

Place	Sc	Pro	Lat	Lon	Is
Modena		MO	44.647	10.926	6
Carpi		MO	44.784	10.885	D
Reggio Emilia		RE	44.698	10.631	5

Year Mo Da	Ho	Mi	Ax	St	Mdps	Ix
1608 01 06	**22**	**20**	**Modenese**	**This study**	**1**	**6**

Place	Sc	Pro	Lat	Lon	Is
Reggio Emilia		RE	44.698	10.631	6

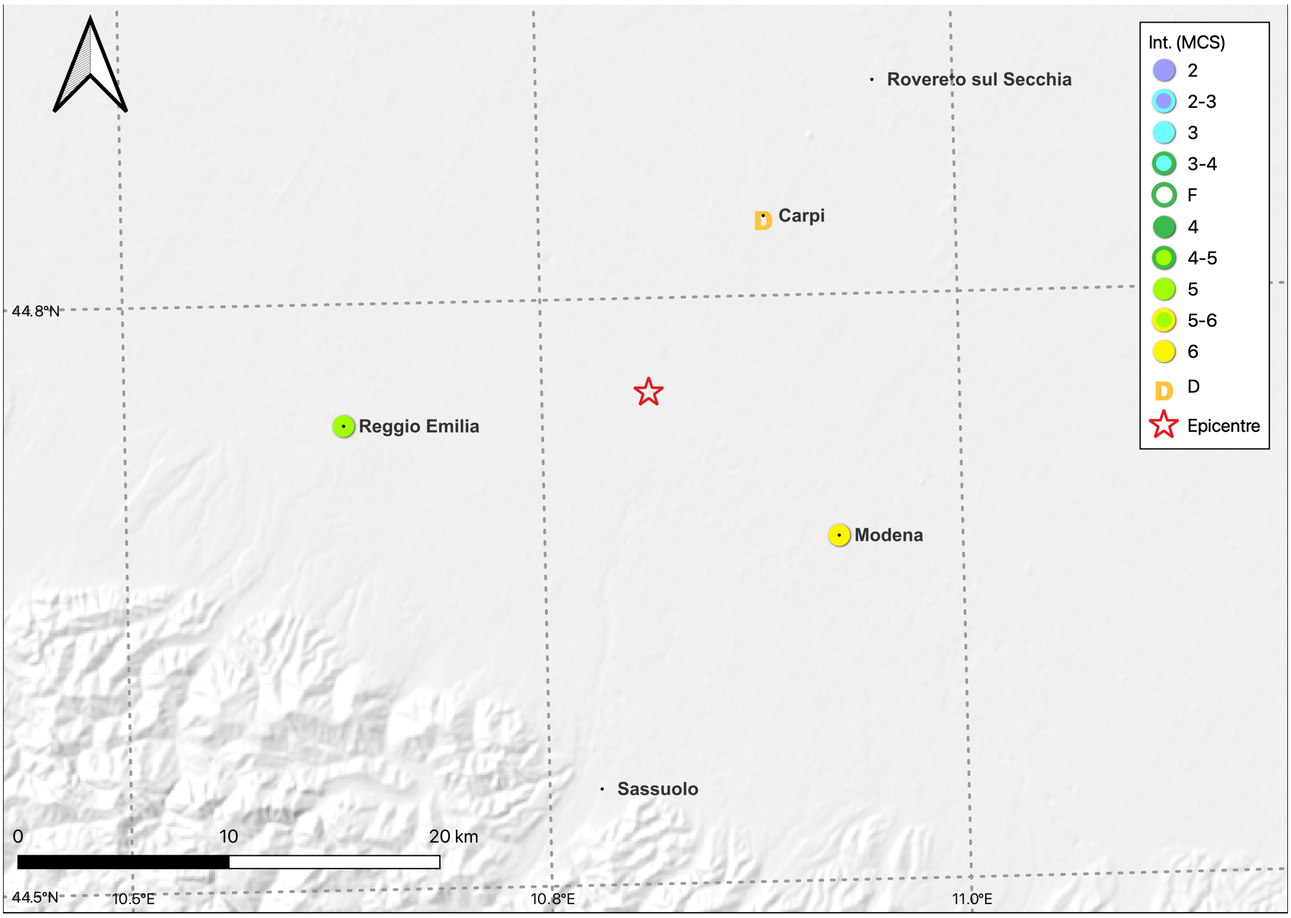


Figure 20. *Macroseismic intensity distribution map of the 23:45 GMT earthquake of 31 Decembre 1607; the red star shows the macroseismic epicentre from this study.*

6.1.3 THE 6 APRIL 1639 EARTHQUAKE, FINALE EMILIA

The earthquake that struck Finale Emilia (MO) and its surroundings on 6 April 1639 (Fig. 21) is reported in a recent historiographical text on the history of the Jewish community of Finale Emilia in the 16th century [Balboni, 2005], which refers to two different editions of an authoritative 18th-century local history [Frassoni, 1752; 1778]. The event is also confirmed by an explicit reference to

the earthquake in the pastoral visit of the Bishop of Modena in October of the same year [AAMoNo, 1639] stating that "*due to the earthquake, the wall is in danger of collapsing*" in Nonantola.
A document in the municipal archives of Carpi, transcribed from research on the local seismic history [D'Orazi, 2012], contains a reference to an earthquake dated 1638, which may in fact refer to the event of 1639: a circumstance that must be carefully verified.
According to Gatti [XVIII], several earthquakes were felt in Cento "*from St. George's Day to Easter, but without causing any damage, only terror and fright*". Gatti reports this news by dating it to 1640 and not 1639, which suggests that he is referring to a different event, but he also gives a very precise time reference. In fact, according to the author, the earthquakes occurred from St George's Day, which falls on 23 April, until Easter. In 1639, Easter was celebrated on the 24th of April, while in 1640 it was the 8th of April, which makes us realise that this was just a dating error on Gatti's part.
In Finale Emilia the earthquake caused widespread damage and some partial collapse, resulting in at least one fatality: Mrs. Silvia Grillenzoni who, as stated by Frassoni [1778] "*perished under some ruins*" caused by the collapse of some houses and chimneys [Frassoni, 1752; 1778].
The effects of the 1639 earthquake in Mirandola are described by Maria Pico in three letters to her sister Fulvia, wife of the future Duke Alberico II Cybo Malaspina, and reported by Ghidoni [2013] in his 'Terremoti mirandolesi'.
In the first letter, dated 9 April, Maria explains that she and the whole family had moved to the garden "*to escape the danger of the earthquake*", which had caused "*many chimneys to fall and the vault of the door […] in the castle to open*". Even more dramatic is the news reported in the letter of 22 April, in which she repeats, in the plural, that "*we are again troubled by the earthquake*" and that "*on Wednesday night [20 April, ed.] it was repeated twice more, so frightening that it caused the bell here in the tower […] to ring twice, and all the people came out of their houses, having thrown some chimneys to the ground and caused other disturbances*" [Ghidoni, 2013].
This event, unknown to the main Italian parametric catalogues and the main national and regional seismological compilations, is not included in the PFG catalogue [Postpischl, 1985], but it was quickly studied by Camassi et al. [2011], which is the reason for the inclusion of this event in the latest Italian parametric catalogue (CPTI15) [Rovida et al., 2022].
The review of seismological compilations was negative, as was the review of the Cronaca di Modena dalle origini di essa città al 1658 [XVII], Cronaca di Modena dal 1466 al 1665 [XVII], Cronache e notizie modenesi, [XVII-XVIII], Ristretto dell'historia di Modena e del Frignano [XVI-XVII], Monteforti G.F. [XVIII], Setti [XVIII], Tornini [XVIII], and Memorie [2012], the volume 12/2012 of the journal of the Centro Studi Storici Nonantolani.

Again, there is a clear improvement in information compared to the baseline study, and the picture that emerges from this review is one of a certainly significant earthquake, not only in terms of the increase in the number of sites affected, but also in terms of intensities. The highest intensity was reached in Finale Emilia, confirming the 7-8 MCS grade assigned by the reference study by Camassi et al. [2011]. What is new compared to the previous work [Camassi et al., 2011] is the addition of three new localities where effects above the damage threshold were recorded, i.e. Cento and Mirandola with an intensity of 6-7 MCS, and Nonantola (D). Research has also shown that another earthquake, in addition to the main one, struck the area on the 20th of the same month, affecting the town of Mirandola (MO).

Year	Mo	Da	Ho	Mi	Ax	St	Mdps	Ix
1639	**04**	**06**	**21**	**00**	**Finale Emilia**	**This study**	**4**	**7-8**

Place	Sc	Pro	Lat	Lon	Is
Finale Emilia		MO	44.833	11.294	7-8
Cento		FE	44.727	11.289	6-7
Mirandola		MO	44.887	11.065	6-7
Nonantola		MO	44.678	11.041	D

Year	Mo	Da	Ho	Mi	Ax	St	Mdps	Ix
1639	**04**	**20**	**16**	**15**	**Finale Emilia**	**This study**	**1**	**6-7**

Place	Sc	Pro	Lat	Lon	Is
Mirandola		MO	44.887	11.065	6-7

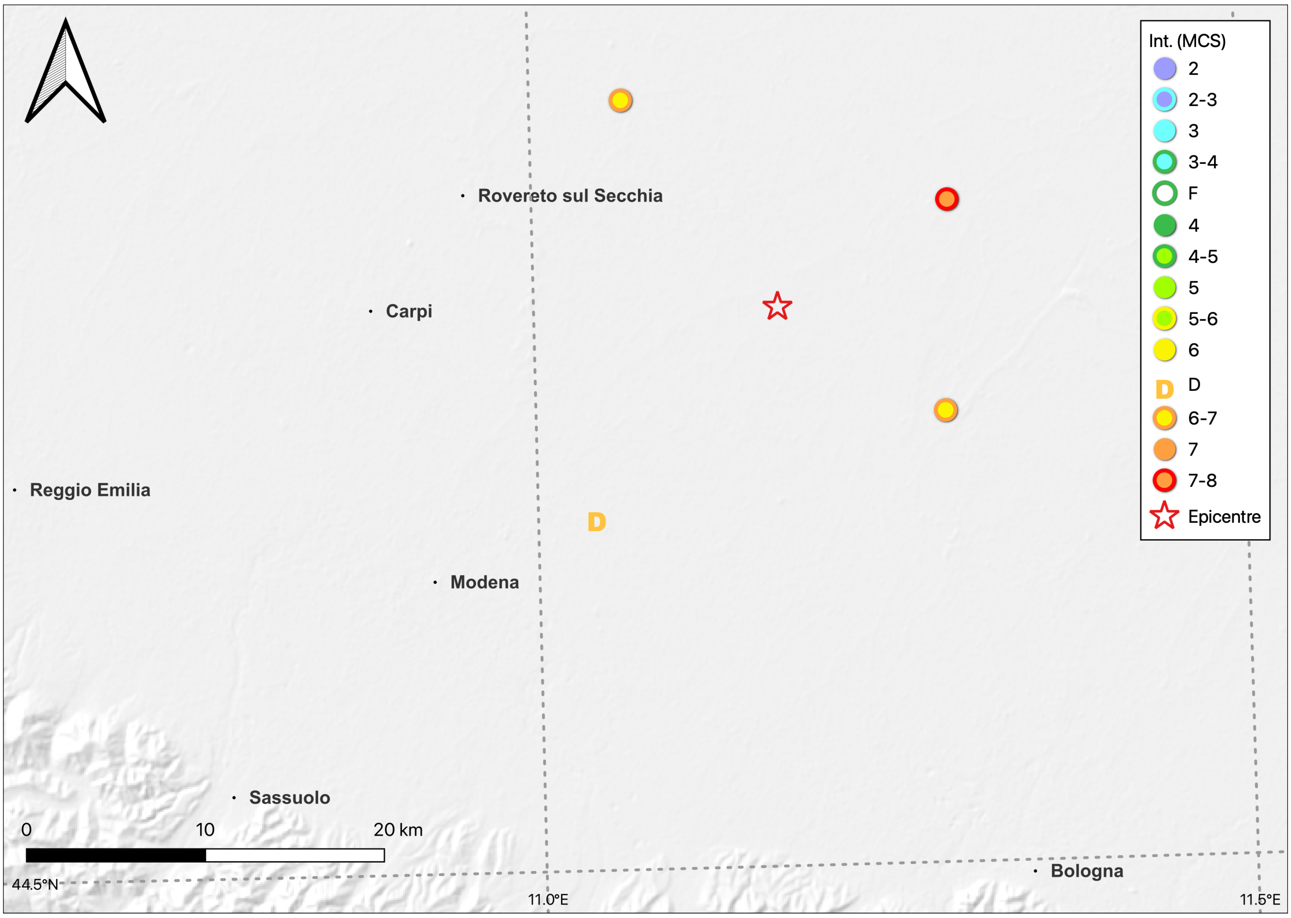


Figure 21. *Macroseismic intensity distribution map of the 21:00 GMT earthquake of 06 April 1639; the red star shows the macroseismic epicentre from this study.*

6.1.4 THE 15 DECEMBER 1761 EARTHQUAKE, ROVERETO SULLA SECCHIA

On 15 December 1761, 21:45 GMT (Fig. 22), "*a great earthquake was felt in Carpi, which frightened the entire population of Carpi*" [Memorie storiche…, (XVIII); Estratto…, (XVIII); D'Orazi, 2012], and more weakly in Modena [[Gazzetta di] Mantova, 1761; Gazette de Leyde, 1762], but caused no damage, environmental effects, or casualties and injuries. The earthquake was also slight in Modena and barely felt in Mirandola where the commotion caused by the earthquake is testified by the great altarpiece that an important local family donated to the church of San Francesco as an ex-voto in gratitude for having been saved from it [Ceretti, 1890]. The painting - now in the Museo Civico di Mirandola and visible in the online catalogue Emilia Romagna Heritage [IBC, 2010] - depicts the Virgin and Child with two saints - one of whom is Francesco Solano, venerated as a special protector against earthquakes [Castelli and Camassi, 2006] - and the buildings of Mirandola in the background. The event is unknown to the main Italian parametric catalogues and the main national and regional seismological compilations, therefore is not included in the PFG catalogue [Postpischl, 1985] or the CPTI15 catalogue [Rovida et al., 2022]. There is very little information available about the earthquake and its aftermath; the only pieces of information available are from a compilation of earthquakes that occurred in Carpi [D'Orazi 2012], based on some Caprigian chronicles, and some contemporary journalistic correspondence.

The review of most of the seismological compilations was negative, as was the review of Gatti [XVIII], Monteforti [XVIII], Bagni [XVIII], Setti [XVIII], Forni [XX], Ruspaggiari [XVIII - XIX], Tornini [XVIII], Cronache e notizie modenesi [XVII-XVIII], and the volume 12/2012 of the journal of the Centro Studi Storici Nonantolani.

Year	Mo	Da	Ho	Mi	Ax	St	Mdps	Ix
1761	**12**	**15**	**21**	**45**	**Rovereto sulla Secchia**	**This study**	**3**	**5**

Place	Sc	Pro	Lat	Lon	Is
Carpi		MO	44.784	10.885	5
Mirandola		MO	44.887	11.065	4
Modena		MO	44.647	10.926	3

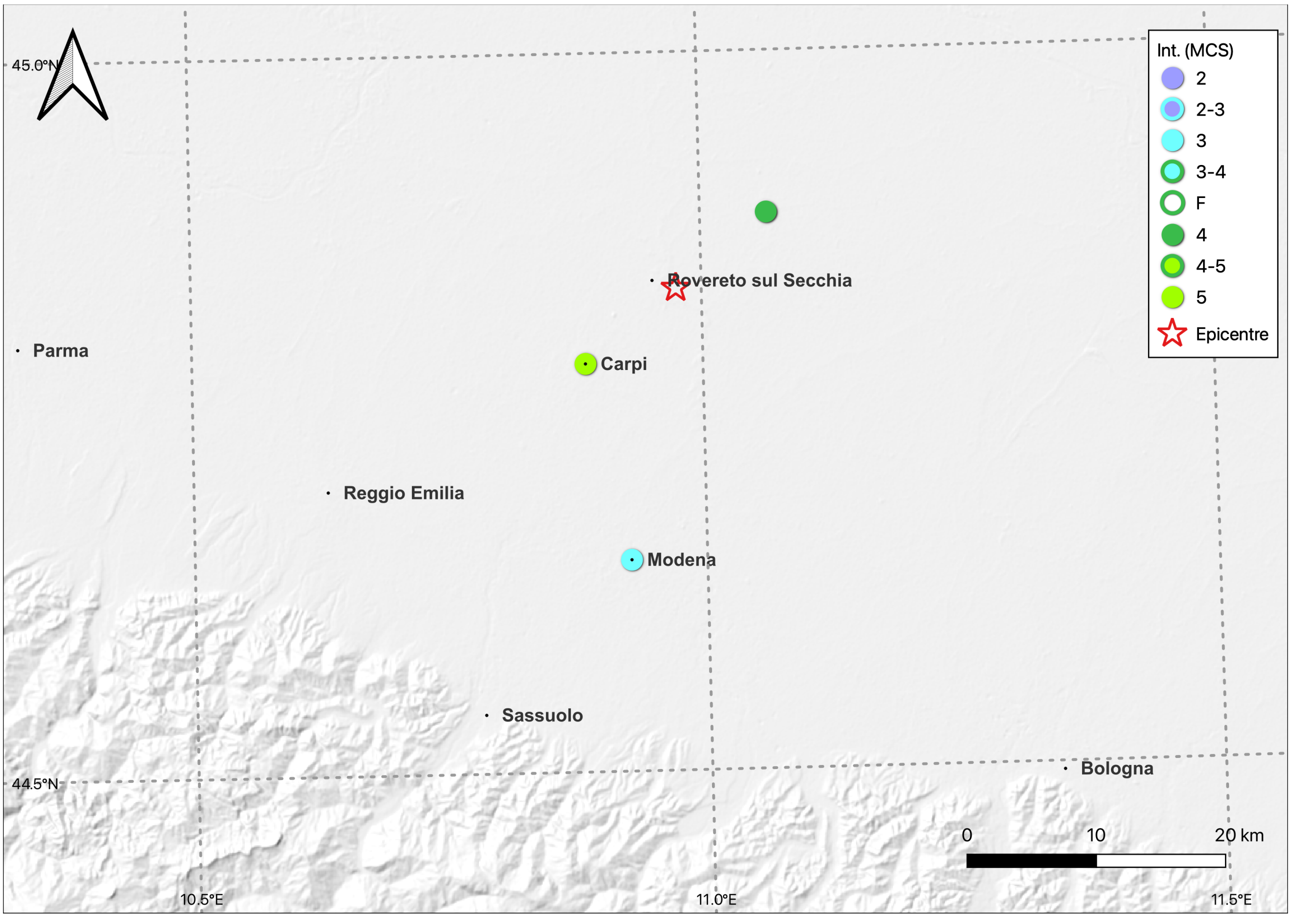


Figure 22. *Macroseismic intensity distribution map of the 21:45 GMT earthquake of 15 Decembre 1761; the red star shows the macroseismic epicentre from this study.*

6.1.5 THE 11 MAY 1778 EARTHQUAKE, CARPIGIANO

In 1778, a series of earthquakes that began at the end of April with a 'frightening' earthquake felt in Carpi, and lasted until the end of August of that year [D'Orazi, 2012], affecting the Modena area and some localities of the provinces of Ferrara, Reggio Emilia, and Vicenza (Veneto). According to Tornini [XVIII], the tremors began to be felt in Carpi at the end of April and continued "*sometimes more, sometimes less violently, for several years, to the great apprehension of many*".

In general, the effects of the earthquakes were limited to the severe fright of the population, who "*slept in the open air, not daring to stay in their houses*" [D'Orazi, 2012]. Again, D'Orazi [2012] reports that the only damage recorded was in the hamlet of Rovereto sulla Secchia, near Carpi (MO), where the "*old and strong*" tower of Sacchella, was irreparably damaged, and had to be completely demolished, after the main quake on 11 May (Fig. 23). Fearing further collapses, the inhabitants of Rovereto [sulla Secchia] and those of nearby Concordia sulla Secchia left their homes and camped in the fields until the tremors stopped.

From the information gathered, it appears that the area affected by these events is quite wide, including not only the Modena area, but also a few localities in the provinces of Ferrara, Reggio Emilia, and Vicenza (Veneto).

Although this event is reported by D'Orazi [2012] in his compilation of earthquakes that occurred in Carpi, based on some Caprigian chronicles and some contemporary journalistic correspondence, it is unknown to the main Italian parametric catalogues and the main national and regional seismological compilations. Consequently, is not included in the PFG catalogue [Postpischl, 1985] or the latest Italian parametric catalogue (CPTI15) [Rovida et al., 2022].

The review of seismological compilations was negative, as was the review of Gatti [XVIII], Monteforti [XVIII], Setti [XVIII], Forni [XX], Ruspaggiari [XVIII - XIX], Diario familiare dei Conti Pegolotti-Nuzzi dal 1763 al 1812 [Diario familiare… (XIX)], Tornini [XVIII], Cronache e notizie modenesi [XVII-XVIII], and the volume 12/2012 of the journal of the Centro Studi Storici Nonantolani.

Of the many earthquakes that have occurred during this period, there are seven for which the date and time have been recorded, and for which intensity values have been assigned.

Year	Mo	Da	Ho	Mi	Ax	St	Mdps	Ix
1778	**04**	**30**	**19**	**30**	**Carpigiano**	**This study**	**1**	**F**

Place	Sc	Pro	Lat	Lon	Is
Carpi		MO	44.784	10.885	F

Year Mo Da Ho Mi Ax St Mdps Ix
1778 05 01 02 50 Carpigiano This study 2 HF

Place	Sc	Pro	Lat	Lon	Is
Carpi		MO	44.784	10.885	HF
Rovereto sulla Secchia		MO	44.841	10.952	HF

Year Mo Da Ho Mi Ax St Mdps Ix
1778 05 02 02 45 Carpigiano This study 1 HF

Place	Sc	Pro	Lat	Lon	Is
Carpi		MO	44.784	10.885	HF

Year Mo Da Ho Mi Ax St Mdps Ix
1778 05 02 05 45 Carpigiano This study 1 HF

Place	Sc	Pro	Lat	Lon	Is
Carpi		MO	44.784	10.885	HF

Year Mo Da Ho Mi Ax St Mdps Ix
1778 05 11 03 00 Carpigiano This study 4 D

Place	Sc	Pro	Lat	Lon	Is
Concordia sulla Secchia		MO	44.914	10.982	D
Carpi		MO	44.784	10.885	5
Rovereto sulla Secchia		MO	44.841	10.952	5
Guastalla		MO	44.921	10.654	F

Year Mo Da Ho Mi Ax St Mdps Ix
1778 06 02 -- -- Carpigiano This study 1 3

Place	Sc	Pro	Lat	Lon	Is
Argenta		FE	44.615	11.837	3

Year Mo Da Ho Mi Ax St Mdps Ix
1778 06 11 03 00 Carpigiano This study 1 F

Place	**Sc**	**Pro**	**Lat**	**Lon**	**Is**
Vicenza		VI	45.548	11.546	F

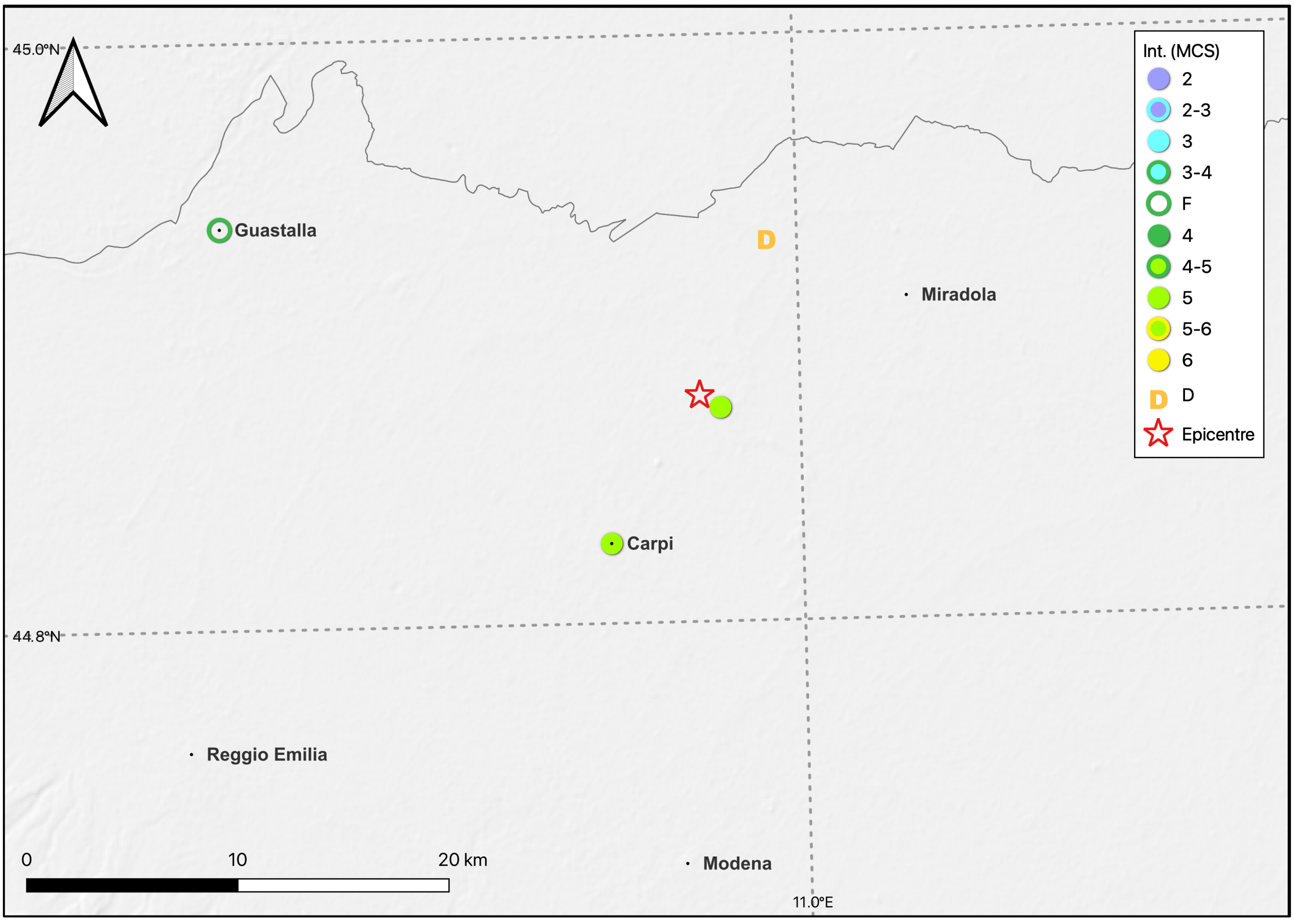


Figure 23. *Macroseismic intensity distribution map of the 03:00 GMT earthquake of 11 May 1778; the red star shows the macroseismic epicentre from this study.*

6.1.6 RESULTS

The aim of the research, which was conducted in the Modenese plain sector affected by the May 2012 seismic sequence, was to verify possible traces of seismic activity within a time frame spanning from the early 16th to the late 18th century. Furthermore, the objective was to identify traces that were previously unknown or not subjected to investigation within the context of the seismological tradition, which is represented by a network of compilations from the nineteenth century. These were summarised by Baratta's monumental work [1901] and subsequently incorporated, or not, into the PFG catalogue (Postpischl, 1985).

Table 3 presents a numerical comparison between the data obtained from the CPTI catalogue and those derived from this study, which are considered as new, additional intensities and Mdps.

		CPTI15			THIS STUDY	
Date	**Area**	**Study**	**Mdps**	**Ix**	**Mdps**	**Ix**
1501.06.05	Appennino modenese	CFTI4med	20	9	14	9
1607.12.31	Modenese	CFTI4med	1	5	3	D
1608.01.06	Modenese	CFTI4med	2	6-7	1	6
1639.04.06	Finale Emilia	CAMAL011	1	7-8	4	7-8
1639.04.20	Finale Emilia	-	-	-	1	5-6
1761.12.15	Rovereto sulla Secchia	-	-	-	3	5
1778.11.05	Carpigiano	-	-	-	4	D

Table 3. *Numerical comparison between the data used by the CPTI15 catalogue and those derived from this study.*

Furthermore, an investigation was conducted into the 1501 earthquake that occurred in the Modena area on 5 June, in order to verify possible margins for improving knowledge. It would appear that the reconstruction of the impact and effects of this earthquake is of a notably poor quality. The number of macroseismic observations is decidedly reduced, and even the simple felt effects are very few.

The result of this research, which entailed considerable effort in the retrieval and digitisation of the documented material, as well as bibliographic and archival research to identify new information, was both paradoxical and exemplary of the manner in which historical seismological research is conducted.

Firstly, the recovery and critical analysis of documentation already known from previous studies, dating as far back as 1985 [Ferrari et al., 1985], confirmed the excellent work of the initial studies. During the course of this research, new material was acquired, primarily local historiography from recent decades, though no new coeval evidence was obtained. The work of processing and evaluating macroseismic intensities on a documentary basis has also substantially confirmed the initial interpretations, including the most recent one contained in the CFTI5Med catalogue [Guidoboni et al., 2019].

The paradoxical effect is evident in the differing assessments of the consistency and relevance of certain testimonies, which have been excluded from this work on the grounds that they lack corroboration from contemporaneous sources or sufficient historical evidence.

For these reasons, the intensity estimates proposed by CFTI5 with regard to Montecreto and Dismano have been set at zero. This is because the historiography attesting to them appears to be of very low quality, and therefore the estimates are not supported by data.
Moreover, the intensity table includes at least two localities that can be classified as ‘special cases’ namely, two ‘small settlements’. These localities are so small that they do not provide an adequate sample size for macroseismic intensity assessment. To be precise, the localitiesin question are Denzano in the municipality of Marano sul Panaro and Montegibbio in the municipality of Sassuolo. In both cases, the intensity value expressed has been changed to an alphanumeric value, which suggests that caution should be exercised when deriving earthquake parameters from these values.
Consequently, the result of this research is that the number of usable macroseismic observations is significantly reduced.
With regard to the search for and investigation of traces of little-known or unknown earthquakes, the outcome of the research in the local area was positive.
The research conducted on the two earthquakes in the Reggio Emilia area (31 December 1607 and 6 January 1608) has prompted a reassessment of the information previously available. This has resulted in a change in the cities affected and the maximum intensity reached, as well as a shift in the geolocation of the epicentre. It is now understood that the epicentre is not in Reggio Emilia, as previously thought, but is situated further east, closer to Modena. The data set pertaining to the two seismic events has been refined, thereby substantiating their classification as relatively minor occurrences (Mw 4.63 in both cases).
A significant focus was placed on a comprehensive examination of the Finale Emilia earthquake that occurred on April 6, 1639. This event had previously been identified by another study, however, that study utilized a single macroseismic intensity measurement. The research enabled the identification of information on three other localities, with relatively moderate damage effects, which significantly enhanced the reliability of the parameters associated with this earthquake. The estimated energy reached a value approaching Mw 5, and the location was precisely determined to be in the vicinity of the 20 May 2012 earthquake. Additionally, a recurrence of this earthquake was documented on 20 April.
The case of two earthquakes from the second half of the 18th century, which are currently absent from the relevant catalogues, is distinct.
The first of these events, occurring on December 15, 1761, was recorded in the Carpi area and was also felt in Mirandola and Modena. It resulted in no discernible damage but was nevertheless a cause for concern.

This event, despite the faint traces it left in the area's historiography, had a significant impact on the populations of the area, to the point of facilitating the spread of the cult of a patron saint against earthquakes. It is noteworthy that a painting of St. Francis Solano, an alternative patron saint to St. Emidio, is preserved in Mirandola. This serves as evidence of the strong sensitivity present in that cultural context in response to an experience that was highly unusual at the time, namely an earthquake. The seismic activity in the region was relatively low over the following two centuries, which led to a decline in awareness of the potential for seismic events.

The second unconfirmed seismic event, the earthquake of 11 May 1778, was in fact a minor sequence that commenced on 30 April 1778 and continued at least until mid-June. The main tremor occurred on 11 May and caused damage in Concordia sulla Secchia, as well as being perceptible in Carpi and Rovereto sulla Secchia.

The results of the research carried out on the aforementioned earthquakes are presentedin Table 4. This also includes the epicentral parameters that were calculated from macroseismic data using the BOXER Code [Gasperini et al., 2010].

Year	**Mo**	**Da**	**Ho**	**Mi**	**Epicentral area**	**Lat**	**Lon**	**Io**	**Mw**
1501	06	05	10	00	Appennino Modenese	44.5117	10.8647	9	6.1
1607	12	31	23	45	Modenese	44.7097	10.814	6	4.63
1608	01	06	22	20	Modenese	44.698	10.631	6	4.63
1639	04	06	21	00	Finale Emilia	44.7812	11.1723	7-8	4.86
1639	04	20	16	15	Finale Emilia	44.887	11.065	6-7	4.40
1761	12	15	21	45	Rovereto sulla Secchia	44.8355	10.975	5	3.7
1778	05	11	03	00	Carpigiano	44.8463	10.9397	D	4.35

Table 4. *Parameters of the earthquakes considered in the present study determined from macroseismic data, using BOXER [Gasperini et al., 2010].*

6.2 VENETO EARTHQUAKES

With regard to the Veneto area, a comprehensive review of all available information was carried out for 14 earthquakes, the majority of which with little in-depth reference studies. These earthquakes, that spacially interest distinct yet contiguous territories, are divided into two series for the sake of simplicity. On the one hand we have the Asolano earthquakes, studied in detail in Baranello [2023], and on the other hand the Treviso earthquakes, studied in Baranello et al. [2024] (Fig. 24).

These sets of moderate-energy earthquakes have never been studied in depth, as it is an area that was not involved, for example, in the research carried out between 1980 and 1985 to qualify sites for nuclear settlement, which in fact led to the birth of modern historical seismology.

The aim of this work is therefore to complete the study of minor seismicity in the Veneto region. This will entail a review of the earthquakes that were rapidly studied three decades ago, as well as an examination of some traces of previously overlooked events, starting from the reports proposed by some regional compilations.

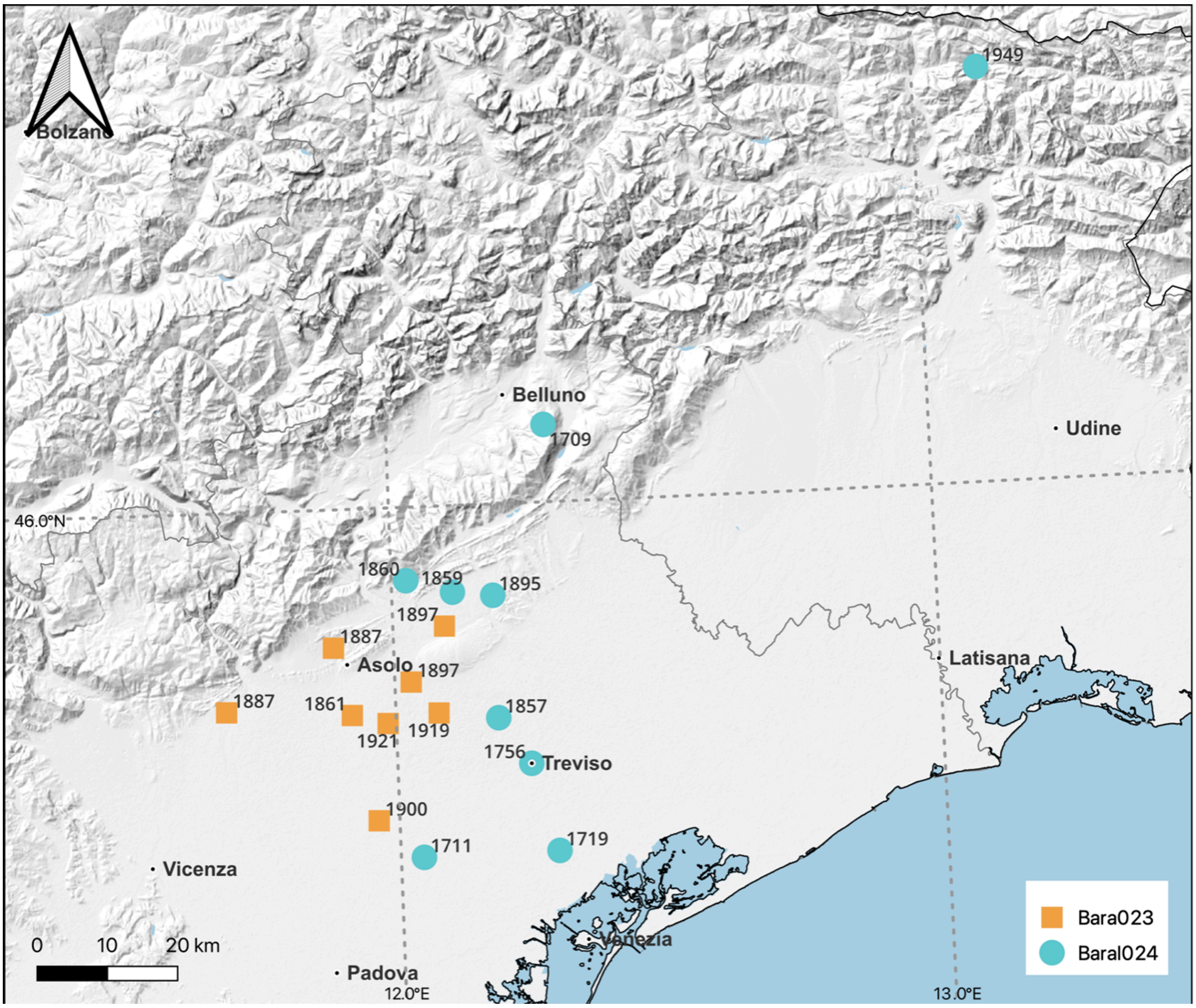


Figure 24. *Spatial distribution of the Asolo earthquakes studied by Baranello [2023] and those covered by Baranello et al. [2024].*

6.2.1 EARTHQUAKES IN THE ASOLO AREA

For the earthquakes of 19 May 1861, 29 March 1887, 14 April 1887, 11 June 1897, 4 March 1900, 12 July 1919, and 12 September 1921, a comprehensive review of all available information was carried out (Tab. 5). These are 7 earthquakes sharing little in-depth reference studies. They are also earthquakes of relatively moderate energy that occurred in the area between Treviso, Asolo, and Bassano del Grappa (Veneto), within a relatively short time. These characteristics - moderate energy, a very specific area, and a defined historical period - have certainly posed difficulties for historical research; indeed, there are few or very few records available, such as for the 1861 earthquake, news of which cannot be found in journalistic sources, let alone in bulletins or seismic postcards, making the work of verifying and interpreting the data very complex and subject to considerable uncertainties [Baranello, 2023].

For each event, if available, both the main seismological compilations of general interest [Agamennone, 1897; Baratta, 1897, 1899a, 1901; Cancani, 1901; Cavasino, 1935; De Rossi, 1889; Mercalli, 1883; Perrey, 1864a, 1864b] and regional ones specific to the Veneto region [Goiran, 1886, 1892; Piovene, 1888; Scarpa, 1888; Spagnolo, 1907; Zanon, 1937] were reviewed. A survey was then made of the main printed gazettes available. The macroseismic postcards preserved in the 'Fund of macroseismic postcards relating to the period 1871-1900' of the Ufficio Centrale di Ecologia Agraria (UCEA) in Rome were then examined.

The intensity table for the main earthquakes will be provided for each event.

Year	Mo	Da	Ho	Mi	Epicentral Area	Ref	Mdp	Lat	Lon	Io	Mw
1861	05	19	-	-	Asolano	ALBI001	2	45.736	11.920	6	4.63
1887	03	29	08	58	Valle del Brenta	CAMAL012	2	45.734	11.668	5	4.16
1887	04	14	02	15	Asolano	ALBI001	9	45.822	11.860	6	4.82
1897	06	11	12	45	Asolano	ALBAL003	47	45.859	12.002	5-6	4.44
1900	03	04	16	55	Asolano	AMGNDT995	98	45.849	12.067	6-7	5.05
1919	07	12	12	06	Asolano	MOLAL008	7	45.801	11.914	4-5	5.03
1921	09	12	00	25	Asolano	AMGNDT995	3	47.771	11.768	3-4	4.81

Table 5. *Earthquakes covered in Baranello [2023] in the CPTI15 catalogue [Rovida et al., 2022]. In the reference column: ALBI001 [Albini, 2001], ALBAL003 [Albini et al., 2003], AMGNDT995 [Archivio Macrosismico GNDT, 1995], CAMAL012 [Camassi et al., 2012], MOLAL008 [Molin et al., 2008].*

19 May 1861. In May a series of tremors were felt at Asolo, Castelfranco Veneto, and other nearby localities, the strongest of which occurred at 19:45 GMT on the 19th (Fig. 25) and reportedly caused the ringing of bells at unspecified localities [Perrey, 1864a, 1864b]. This event was analysed in the study 'Preliminary study of some medium-low energy earthquakes in the Vittorio Veneto area (19th century)' [Albini, 2001], conducted as part of the GNDT Project 'Damage scenarios in the Veneto-Friuli area'.

The paucity of information regarding this seismic event is evidenced by the works of Perrey [1864a, 1864b], subsequently elaborated upon by Bittner [1874] and Mercalli [1883]. Perrey's account, as cited in the aforementioned studies, details the occurrence of tremors of varying intensity in Castelfranco, Asolo and other nearby localities on 19 and 20 May. However, the nature and consequences of these tremors remain unelucidated. Furthermore, Perrey notes the occurrence of several tremors in Asolo and its province on the night of the 26th and 27th of May, though the specific times and localities remain undetermined. The available information does not allow for determination of the precise location, although the absence of references to damage in both Asolo and Castelfranco Veneto suggests that the epicentral intensity of 6-7 may be overestimated [Albini, 2001].

Year	Mo	Da	Ho	Mi	Ax	St	Mdps	Ix
1861	**05**	**19**	**19**	**45**	**Asolano**	**Baranello, 2023**	**2**	**5**

Place	Sc	Pro	Lat	Lon	Is
Asolo		TV	45.801	11.914	5
Castelfranco Veneto		TV	45.671	11.926	5

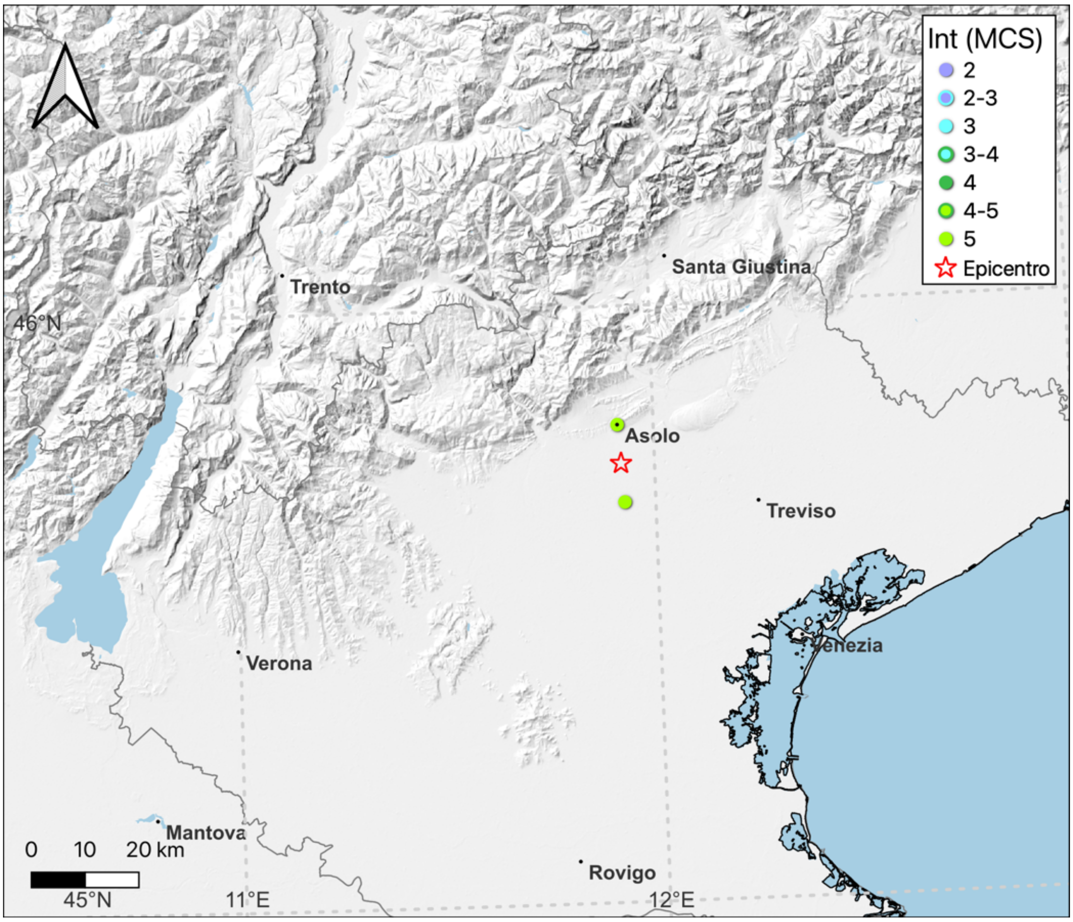


Figure 25. *Macroseismic intensity distribution map of the 19:45 GMT earthquake of 19 May 1861; the red star shows the macroseismic epicentre from Baranello [2023].*

29 March and 14 April 1887. On 29 March 1887, an earthquake that occurred at 08:58 GMT (Fig. 26) (although some uncertainties remain in the identification of time and date) started a small seismic sequence that lasted for two weeks. The sequence, which mainly affected the towns of Marostica, Asolo, and Bassano, ended with two tremors felt during the night of 13 to 14 April.
As for the 1861 earthquake, a review of this event was carried out in the 'Preliminary study of some medium-low energy earthquakes in the Vittorio Veneto area (19th century)' [Albini, 2001], as part of the GNDT Project 'Damage scenarios in the Veneto-Friuli area', based on information found in two seismological bulletins, Bollettino Mensuale [1887] and Bullettino del Vulcanismo Italiano [1890], and in the compilation of Spagnolo [1907].
Three observers documented the occurrence of two tremors in Veneto during the night of 13th-14th April 1887, as published in the Bollettino Mensuale [1887]. Chilesotti from Bassano defines the first as "*very light*" and the second as "*rather sensitive*"; he also adds that "*to the east of Bassano, and especially in the mountains, the earthquake was felt more strongly*". In contrast, Ciorro from Treviso documented two "*light*" tremors. Finally, an editorial note states that "*the tremors were felt strongly in several other places in Veneto, such as in Bassano, Marostica, Canizzano, Feltre, Valdobbiadene, Pieve di Soligo, Asolo, etc.*".
The information published in the Bullettino del Vulcanismo Italiano [1890] is scarce, limited to the timetable, which coincides with that of the Bollettino Mensuale, and to a list of localities of resentment, which adds to the previous one only the locality of 'Borzo' (Borso del Grappa) [Albini, 2001].
The news of the earthquake of 14 April was also reported in some newspapers of the time; the Corriere della Sera of 15-16 April spoke of two tremors that occurred on the night of the 14th that "*were felt throughout the stretch of country between the Brenta and Piave rivers, at the foot of Mount Grappa, and even beyond these two rivers*". According to the aforementioned newspaper, the second tremor was much stronger than the first and, following an underground rumble, was more noticeably felt in Borso, Crespano and Asolo, where the population abruptly awakened, rushed into the streets, and many chose not to return to their beds. The article goes on to state that in Bassano and Marostica (mistakenly called Tarostica) the tremors were not very noticeable.
Based on some seismic postcards, the main event was that of 29 March, which reached its maximum intensity (5-6 MCS) in Marostica, where the epicentre is thought to be (Fig. 26). According to Spagnolo [1907], this earthquake caused some cracks in various buildings, the collapse of some ceilings, and great panic among the population, who fled their homes.

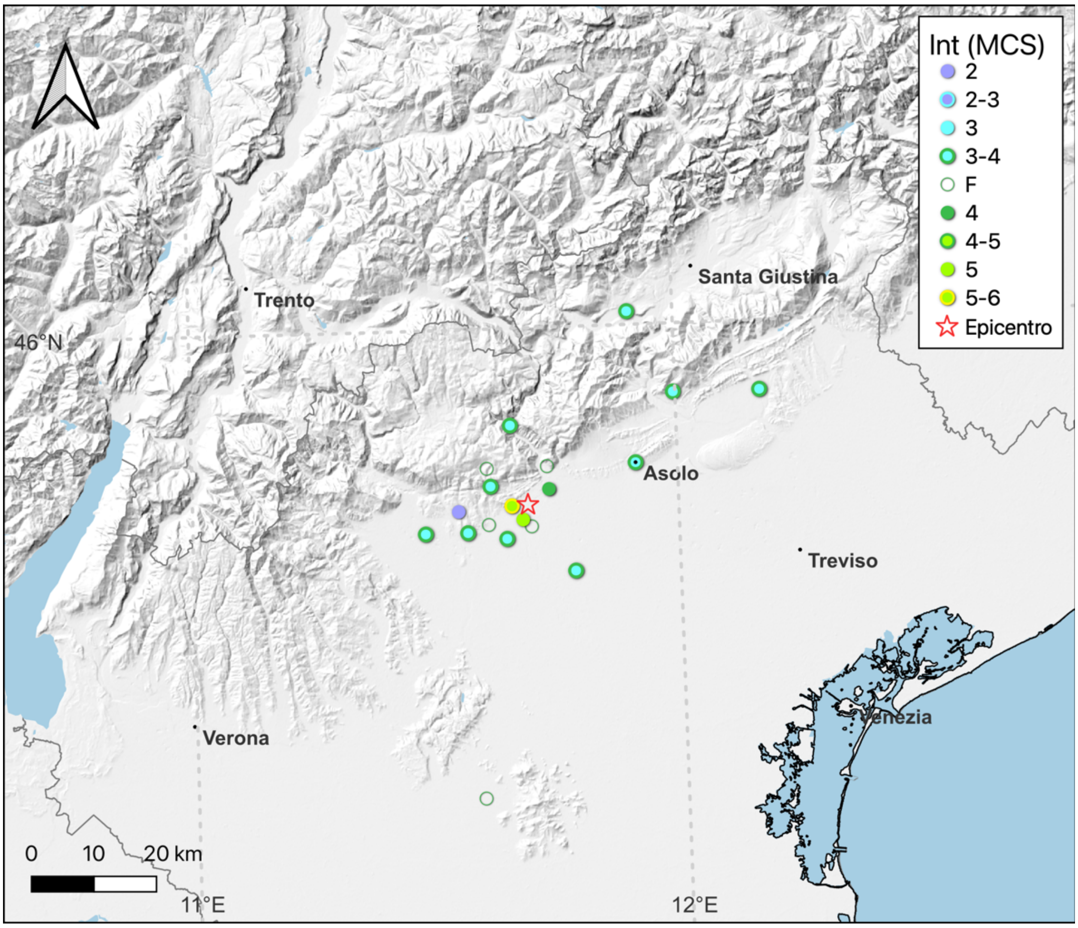
Year	**Mo**	**Da**	**Ho**	**Mi**	**Ax**	**St**	**Mdps**	**Ix**
1887	**03**	**29**	**08**	**58**	**Marostica**	**Baranello, 2023**	**20**	**5-6**

Place	Sc	Pro	Lat	Lon	Is
Marostica		VI	45.744	11.657	5-6
Nove		VI	45.724	11.679	5
Bassano del Grappa		VI	45.767	11.734	4
Agugliaro		VI	45.324	11.585	F
Cartigliano		VI	45.714	11.696	F
Conco		VI	45.799	11.607	F
Mason Vicentino		VI	45.718	11.608	F
Nove		VI	45.724	11.679	F
Pove del Grappa		VI	45.800	11.731	F
Asolo		TV	45.801	11.914	3-4
Breganze		VI	45.707	11.565	3-4
Cittadella		PD	45.648	11.784	3-4
Crosara		VI	45.773	11.614	3-4
Feltre		BL	46.019	11.906	3-4
Pieve di Soligo		TV	45.900	12.174	3-4
Schiavon		VI	45.697	11.645	3-4
Thiene		VI	45.707	11.478	3-4
Valdobbiadene		TV	45.901	11.996	3-4
Valstagna		VI	45.860	11.658	3-4
Fara Vicentino		VI	45.738	11.547	2

Year	Mo	Da	Ho	Mi	Ax	St	Mdps	Ix
1887	**04**	**14**	**01**	**15**	**Bassano del Grappa**	**Baranello, 2023**	**10**	**HF**

Place	Sc	Pro	Lat	Lon	Is
Bassano del Grappa		VI	45.767	11.734	5
Marostica		VI	45.744	11.657	5
Asolo		TV	45.801	11.914	HF
Borso del Grappa		TV	45.820	11.796	HF
Canizzano		TV	45.642	12.190	HF
Crespano del Grappa		TV	45.827	11.838	HF
Feltre		BL	46.019	11.906	HF
Pieve di Soligo		TV	45.900	12.174	HF
Valdobbiadene		TV	45.901	11.996	HF

Treviso		TV	45.666	12.245	2



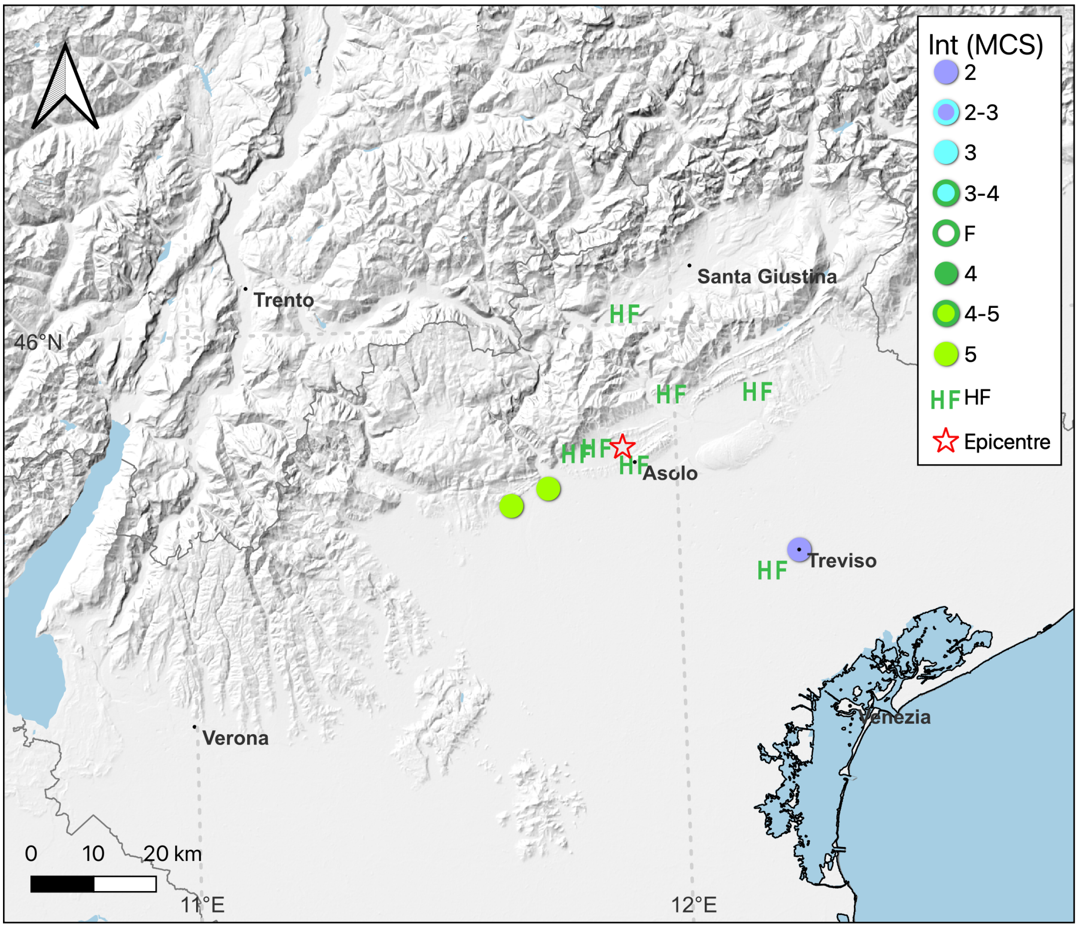


Figure 26. *Macroseismic intensity distribution maps of the 08:58 GMT earthquake of 29 March 1887 - on the top - and the 01:15 GMT earthquake of 14 April 1887 - on the bottom; the red stars shows the macroseismic epicentres from Baranello [2023].*

11 June 1897. On 11 June 1897, at 11.45 GMT (Fig. 27), the Asolo area was struck by a strong earthquake, followed by another of similar intensity at 13.00 on the same day (Fig. 27).

A review of this event was carried out in the 'Study of some earthquakes of moderate epicentral intensity in northern Italy' [Albini et al., 2003] and in the 'Review of the minor seismicity of the national territory' [Molin et al., 2008], which are based on information found mainly in Agamennone [1897] and Baratta [1901].

The main source of information on this event is the compilation by Agamennone [1897], which mentions numerous aftershocks that occurred throughout the day of the 11th and into the early hours of the following day, most of which, however, were small and felt only by people standing still, while others were recorded only by instruments. Following a preliminary overview, the text goes on to provide a detailed description of the effects of the earthquake in the various localities. According to Agamennone [1897] the greatest effects were felt at Cornuda and Maser, with 'falling rubble and chimney pots', and at Volpago, where a rumble was heard. It was generally felt by the population, most of whom were gathered in their homes for meals, where shaking of large objects was felt. It was also felt outdoors, causing panic, and the fall of a chimney cap.

In the other places mentioned we go from the tremor felt by almost everyone with the ringing of bells, the shaking of large and small objects and glass, to the simple instrumental recording in S. Luca (BO). In regard to the news concerning the locality of Treviso, Agamennone explicitly cites the newspaper from Rome 'La Tribuna' of 12 June as his source. However, this newspaper has not been found. It is noteworthy that the indication of the locality of Rossano is only found in Baratta [1901], while it does not appear in Agamennone [1897]. In contrast, Agamennone's work does include information regarding Bassano Veneto (Bassano del Grappa), Cavaso, Nervesa and Quintarello. Finally, the information provided for Quinto Vicentino does not agree: Baratta [1901] reports a light tremor, while for Agamennone [1897] the mayor of the village replied negatively about the tremor [Albini et al., 2003].

Year Mo Da Ho Mi	**Ax**	**St**	**Mdps**	**Ix**
1897 06 11 11 45	**Asolano**	**Baranello, 2023**	**53**	**6**

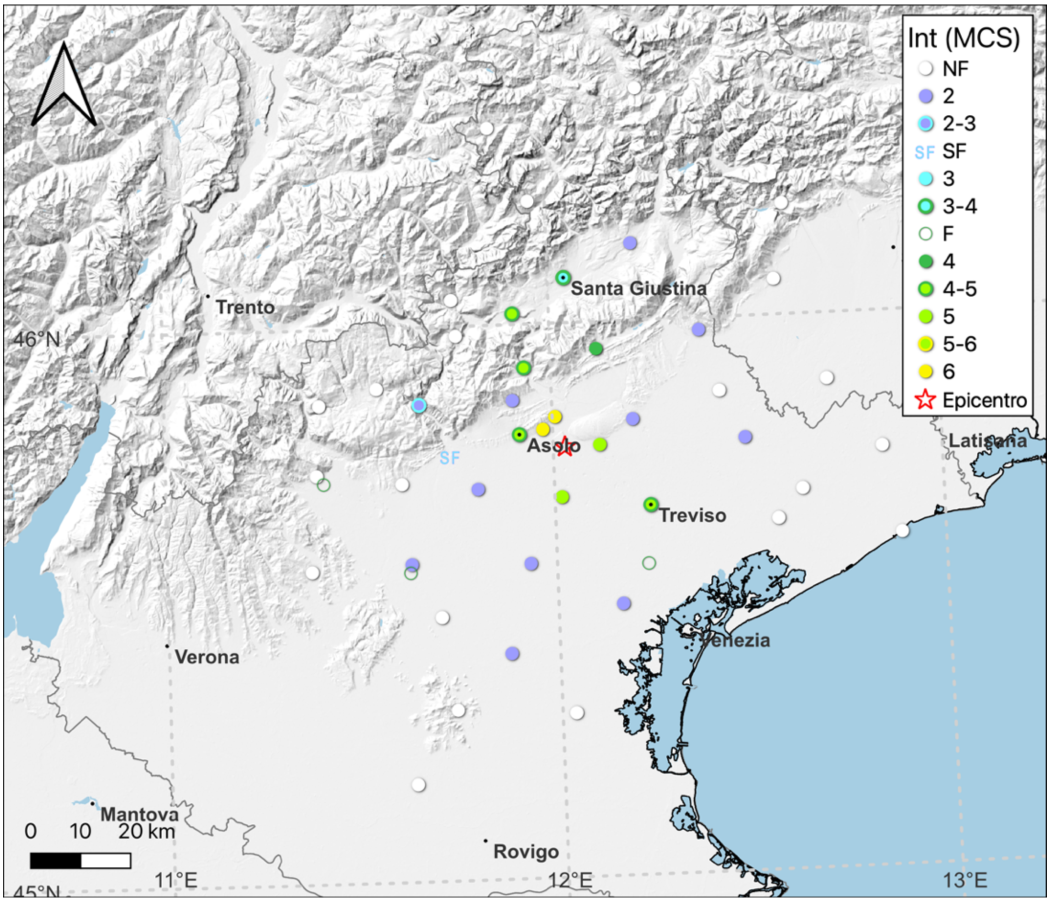
Place	**Sc**	**Pro**	**Lat**	**Lon**	**Is**
Cornuda		TV	45.831	12.007	6
Maser		TV	45.809	11.975	6
Vedelago		TV	45.686	12.018	5
Volpago		TV	45.778	12.120	5
Asolo		TV	45.801	11.914	4-5
Feltre		BL	46.019	11.906	4-5
Quero Vas	MS	BL	45.921	11.931	4-5
Treviso		TV	45.666	12.245	4-5
Follina		TV	45.951	12.119	4
Campo Romano		VI	45.722	11.406	F
Mogliano Veneto		TV	45.561	12.234	F
Quintarello		VI	45.558	11.623	F
Santa Giustina		BL	46.081	12.042	3-4
Valstagna		VI	45.860	11.658	2-3
Bassano del Grappa		VI	45.767	11.734	SF
Belluno		BL	46.139	12.218	2
Camposampiero		PD	45.568	11.932	2
Cavaso del Tomba	MS	TV	45.863	11.899	2
Nervesa della Battaglia		TV	45.822	12.207	2
Oderzo		TV	45.781	12.494	2
Padova		PD	45.407	11.875	2
Quinto Vicentino		VI	45.573	11.627	2
Rossano Veneto		VI	45.705	11.803	2
Sarmede		TV	45.978	12.386	2
Spinea (Orgnano)	MS	VE	45.490	12.165	2

Andreis		PN	46.200	12.614	NF
Arsiè		BL	45.982	11.758	NF
Aviano		PN	46.064	12.585	NF
Azzano Decimo		PN	45.881	12.711	NF
Caorle		VE	45.599	12.887	NF
Ceggia		VE	45.685	12.637	NF
Codognè		TV	45.867	12.433	NF
Concordia Sagittaria		VE	45.756	12.846	NF
Falcade (Alto)	MS	BL	46.355	11.858	NF
Gallio		VI	45.891	11.549	NF
Galzignano Terme		PD	45.308	11.733	NF
Gosaldo	MS	BL	46.221	11.956	NF
Grisignano di Zocco		VI	45.476	11.700	NF
Lamon		BL	46.047	11.749	NF
Mason Vicentino		VI	45.718	11.608	NF
Piove di Sacco		PD	45.296	12.035	NF
Rotzo		VI	45.863	11.400	NF
San Donà di Piave		VE	45.633	12.572	NF
Santorso		VI	45.737	11.389	NF
Trissino		VI	45.564	11.371	NF
Vighizzolo d’Este		PD	45.176	11.625	NF
Vodo di Cadore		BL	46.418	12.246	NF
Burano		TV	45.600	12.442	NC
Caerano di San Marco		TV	45.785	12.001	NC
Cimolais		PN	46.287	12.437	NC
Cittadella		PD	45.648,	11.784	NC
Cologna Veneta		VR	45.309	11.385	NC
Malamocco		VE	45.374	12.342	NC

Year	Mo	Da	Ho	Mi	Ax	St	Mdps	Ix
1897	**06**	**11**	**13**	**00**	**Asolano**	**Baranello, 2023**	**25**	**5**

Place	Sc	Pro	Lat	Lon	Is
Follina		TV	45.951	12.119	5
Quero Vas	MS	BL	45.921	11.931	5
Feltre		BL	46.019	11.906	4-5
Mogliano Veneto		TV	45.561	12.234	4
Treviso		TV	45.666	12.245	4
Campo Romano		VI	45.722	11.406	F
Camposampiero		PD	45.568	11.932	F
Padova		PD	45.407	11.875	F
Quintarello		VI	45.558	11.623	F
Volpago		TV	45.778	12.120	F
Lamon		BL	46.047	11.749	3-4
Spinea (Orgnano)	MS	VE	45.490	12.165	3
Bassano del Grappa		VI	45.767	11.734	SF

Arsiè		BL	45.982	11.758	2
Asolo		TV	45.801	11.914	2
Belluno		BL	46.139	12.218	2
Cavaso del Tomba	MS	TV	45.863	11.899	2
Concordia Sagittaria		VE	45.756	12.846	2
Galzignano Terme		PD	45.308	11.733	2
Grisignano di Zocco		VI	45.476	11.700	2
Mason Vicentino		VI	45.718	11.608	2
Nervesa della Battaglia		TV	45.822	12.207	2
San Donà di Piave		VE	45.633	12.572	2
Santa Giustina		BL	46.081	12.042	2
Venezia		VE	45.438	12.336	NF



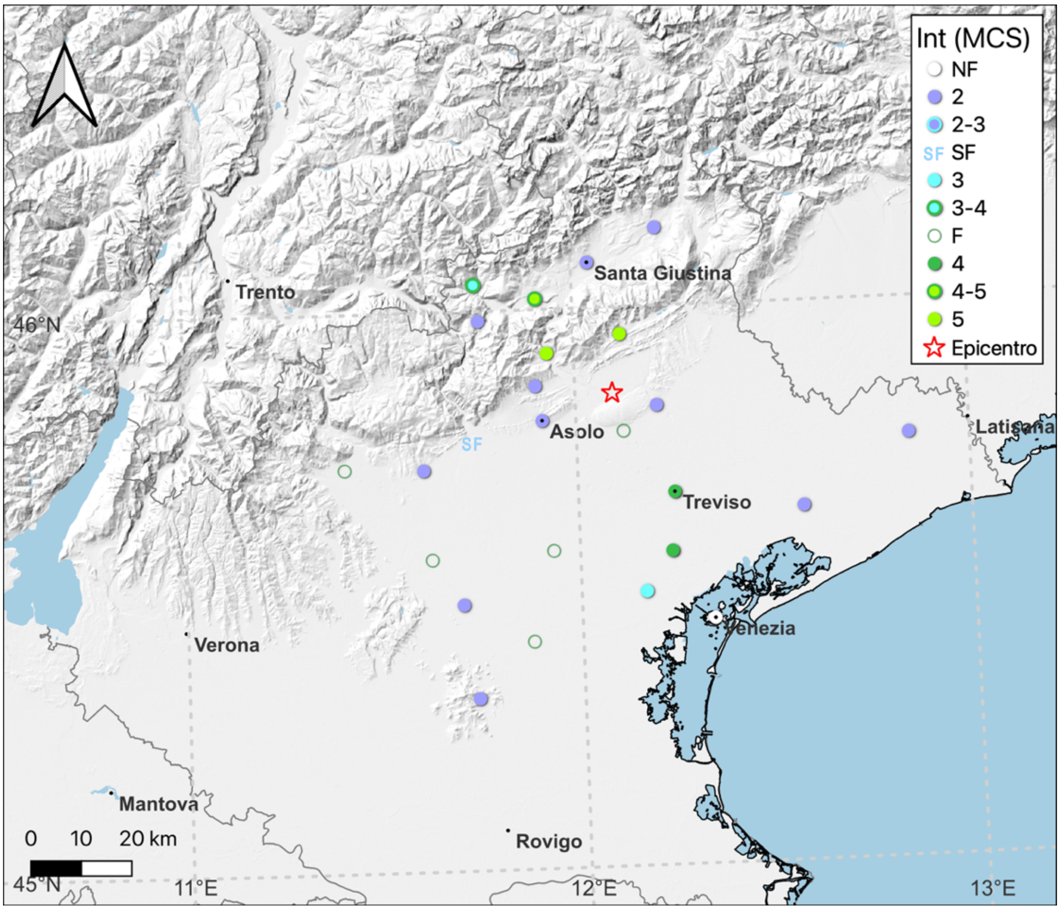


Figure 27. *Macroseismic intensity distribution maps of the 11:45 GMT earthquake of 11 June 1897 - on the top - and the 13:00 GMT earthquake of the same day - on the bottom; the red stars shows the macroseismic epicentres from Baranello [2023].*

4 March 1900. On 4 March 1900, at 17.00 GMT, an earthquake described as very strong struck the Treviso area (Fig. 28).

The review of this event was carried out from material collected by the GNDT's 'Analysis Through Repertories' project in the early 1990s [Archivio Macrosismico GNDT, 1995].

The main source of information about this event is the study 'Notizie sui terremoti osservati in Italia durante l'anno 1900' by Cancani [1901], which is based almost exclusively on the 103 seismic postcards and, to a lesser extent, on newspaper reports.

Cancani reported that "*just before 6pm on 4 March, the Treviso area was hit by an intensity VII (very strong) earthquake. [...] It could be deduced that the towns in the epicentral area were Treviso, Asolo, and Cornuda*", although he does not give any further information about Cornuda.

A few years later, Cavasino [1935] took up the information provided by Cancani, adding a further description of the effects in some localities and highlighting the uncertainties in determining the intensity of the effects of the earthquake.

According to the various sources, the localities where the effects of the earthquake exceeded the damage threshold (6 MCS) were Asolo and Treviso, while in Vedelago the uncertainty in the estimation of the intensity remained between degrees 5 and 6 on the MCS scale. In Vicenza, Trissino, and Follina, on the other hand, the earthquake was felt quite strongly (intensity 5).

Spagnolo [1907] and Zanon [1937], reporting news from Bassano del Grappa and Treviso respectively, also speak of the event of 4 March, adding that on the following day, at 19.30 GMT, there was a new earthquake, but it was very slight.

The news of the earthquake was also reported by several newspapers, such as La Stampa [1900.03.05-06], l'Avvenire [1900.03.05], Il Cittadino di Brescia [1900.03.06], Il Messaggero Veneto [1900.03.11], La Patria del Friuli [1900.03.05], Il Giornale di Udine [1900.03.05], and Il Messaggero [1900.03.05].

As with other earthquakes during the period of activity of the Italian Seismological Society and the operation of the seismic monitoring network through seismic postcards, in many cases both the postcards and the compilers of the summary bulletins ('Notizie sui terremoti osservati in Italia...') - in this case Cancani [1901] - directly assigned an intensity value. In instances where descriptive elements pertaining to the effects were absent in these or other sources, the intensity value in the table has been marked with an asterisk. However, in instances where such elements were present, the intensity estimate was derived on this basis, and it can be observed that these estimates generally scale down Cancani's assessments. Localities for which the seismic cards provide only instrumental information have not been included in the table.

Year	**Mo**	**Da**	**Ho**	**Mi**	**Ax**	**St**	**Mdps**	**Ix**
1900	**03**	**04**	**17**	**00**	**Trevigiano**	**Baranello, 2023**	**111**	**6**

Place	**Sc**	**Pro**	**Lat**	**Lon**	**Is**
Asolo		TV	45.801	11.914	6
Treviso		TV	45.666	12.245	6
Santa Giustina		BL	46.081	12.042	5-6
Este		PD	45.228	11.656	5*
Follina		TV	45.951	12.119	5
Lonico		VR	45.569	11.031	5*
Mestre		VE	45.493	12.242	5
Padova		PD	45.407	11.875	5
Trento		TN	46.068	11.122	5*
Vedelago		TV	45.686	12.018	5
Venezia		VE	45.438	12.336	5
Vicenza		VI	45.548	11.546	5
Voltascirocco		RO	45.049	12.109	5
Abano Terme		PD	45.360	11.790	4-5
Barbarano Vicentino		VI	45.409	11.540	4-5

Bassano del Grappa		VI	45.767	11.734	4-5
Belluno		BL	46.139	12.218	4-5
Conco		VI	45.799	11.607	4-5
Crespano del Grappa		TV	45.827	11.838	4-5
Feltre		BL	46.019	11.906	4-5
Lamon		BL	46.047	11.749	4-5
Meledo		VI	45.433	11.415	4-5
Monte di Malo		VI	45.659	11.362	4-5
Oderzo		TV	45.781	12.494	4-5
Piovene Rocchette		VI	45.760	11.434	4-5
San Pietro Mussolino		VI	45.587	11.257	4-5
Trissino		VI	45.564	11.371	4-5
Valstagna		VI	45.860	11.658	4-5
Colzè		VI	45.466	11.629	4
Conegliano		TV	45.887	12.298	4
Conselve		PD	45.231	11.876	4*
Lastebasse		VI	45.915	11.272	4
Latisana		UD	45.777	12.998	4*
Legnago		VR	45.192	11.311	4
Lendinara		RO	45.084	11.598	4
Maniago		PN	46.167	12.708	4*
Quintarello		VI	45.558	11.623	4
Rovereto		TN	45.888	11.037	4
Rovigo		RO	45.071	11.791	4
San Vito		BL	45.958	11.716	4
Sant'Andrea Barbarana		TV	45.698	12.458	4
Sant'Ulderico		VI	45.749	11.347	4
Trieste		TS	45.650	13.772	4
Udine		UD	46.063	13.234	4
Valli del Pasubio		VI	45.739	11.261	4
Verona		VR	45.439	10.994	4
Camposanpiero		PD	45.568	11.932	F
Caorle		VE	45.599	12.887	F
Cologna Veneta		VR	45.309	11.385	F
Cornuda		TV	45.831	12.007	F
Gorizia		GO	45.946	13.625	F
Pieve di Soligo		TV	45.900	12.174	F
Poleo		VI	45.724	11.334	F
San Martino di Lupari		PD	45.650	11.855	F
Tirolo	TE				F
Valdobbiadene		TV	45.901	11.996	F
Arco		TN	45.917	10.882	3-4
Arsiè		BL	45.982	11.758	3-4
Arsiero		VI	45.803	11.354	3-4
Auronzo di Cadore		BL	46.552	12.439	3-4
Claut		PN	46.267	12.515	3-4
Cresole		VI	45.599	11.532	3-4
Eraclea [Grisolera]		VE	45.577	12.674	3-4
Forno di Zoldo		BL	46.348	12.181	3-4

Innsbruck			47.266	11.393	3-4
Lonigo		VI	45.387	11.388	3-4
Montagnana		PD	45.232	11.466	3-4*
Quinto Vicentino		VI	45.573	11.627	3-4
Recoaro Mille		VI	45.683	11.225	3-4
San Donà di Piave		VE	45.633	12.572	3-4
Sanguinetto		VR	45.183	11.152	3-4*
Spinea (Orgnano)	MS	VE	45.490	12.165	3-4
Valdagno		VI	45.651	11.304	3-4
Cittadella		PD	45.648	11.784	3*
Cividale del Friuli		UD	46.093	13.431	3
Dolo		VE	45.426	12.076	3
Enego		VI	45.941	11.709	3*
Falcade (Alto)	MS	BL	46.355	11.858	3
Gemona del Friuli		UD	46.279	13.135	3
Pieve di Cadore		BL	46.425	12.365	3*
Sacile		PN	45.953	12.499	3
San Bortolo		VI	45.512	11.338	3
San Pietro in Cariano		VR	45.520	10.887	3*
Spilimbergo		UD	46.110	12.899	3*
Aviano		PN	46.064	12.585	2-3
Livigno		SO	46.539	10.135	2-3
Ljubljana			46.048	14.505	2-3
Malcesine		VR	45.764	10.809	2-3*
Mantova		MN	45.158	10.794	2-3
Montebello Vicentino		VI	45.457	11.386	2-3
Pordenone		PN	45.959	12.658	2-3
Bardolino		VR	45.548	10.721	2
Resia (Prato)	MS	UD	46.373	13.305	2*
Trivignano Udinese		UD	45.946	13.340	2
Arzignano		VI	45.521	11.338	NF
Bondeno		FE	44.889	11.417	NF
Casaloldo		MN	45.254	10.477	NF
Chioggia		VE	45.219	12.279	NF
Forni Avoltri		UD	46.585	12.777	NF
Gargnano		BS	45.689	10.664	NF
Loreo		RO	45.062	12.190	NF
Massa Fiscaglia		FE	44.808	12.013	NF
Montichiari		BS	45.413	10.393	NF
Piadena		CR	45.130	10.368	NF
Pontebba		UD	46.506	13.306	NF
Portogruaro		VE	45.775	12.843	NF
Rezzato		BS	45.512	10.318	NF
Roma		RM	41.899	12.477	NF
San Felice sul Panaro		MO	44.840	11.141	NF
Trasaghis		UD	46.282	13.075	NF
Volta		MN	44.937	10.547	NF

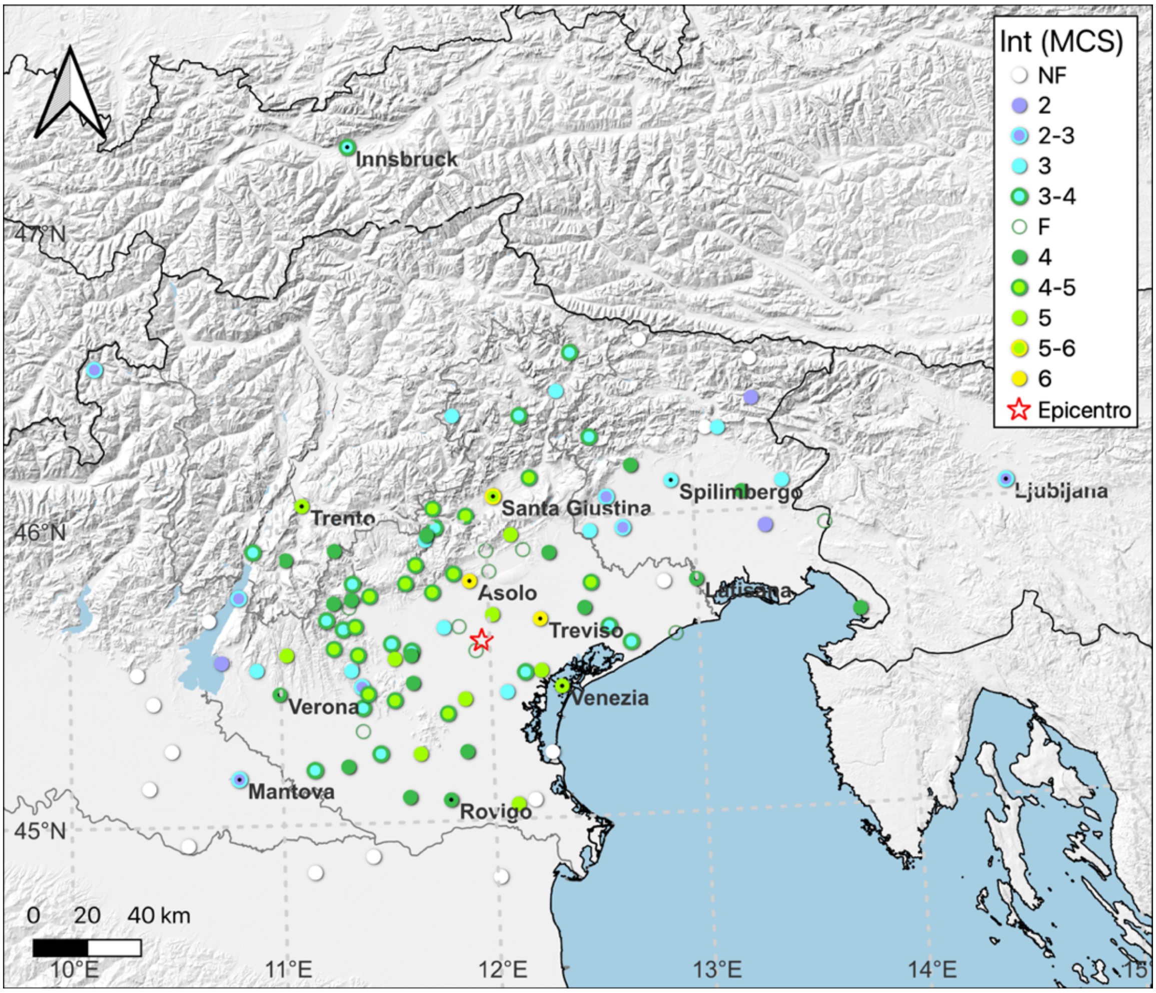


Figure 28. *Macroseismic intensity distribution map of the 17:00 GMT earthquake of 4 March 1900; the red star shows the macroseismic epicentre from Baranello [2023].*

12 July 1919. The information available is extremely scarce for an event that seems to have been of modest dimensions, affecting both Treviso and other nearby towns (Fig. 29). According to a local newspaper, in Treviso the main tremor was felt slightly [Il Gazzettino giornale del Veneto [Treviso], 1919.07.13], but by the majority of the population. The available sources do not report any other significant events.

The only other descriptive information available concerns Venice, where, according to two newspaper correspondences, "*three small tremors*" with intensity II of the Mercalli scale were felt, information confirmed by Zanon's compilation [1937], which does not provide any further elements to distinguish them.

The intensity estimates for Asolo, Este, Marostica, Bassano del Grappa and Ferrara are derived directly from the Seismic Bulletin [Ingrao, 1927], probably based on seismic postcards, which are currently unavailable.

The intensity estimate for Asolo - uncertain between grades V and VI on the Mercalli scale according to Ingrao [1927] - is in slight contrast with that reported by a seismological source [Bollettino Sismico

Settimanale, 1919.07.6-12], which reports the earthquake as being of grade 5. In the absence of comparisons in newspapers from the Treviso and Veneto areas, we believe we can downgrade that intensity estimate to grade V.

Year	Mo	Da	Ho	Mi	Ax	St	Mdps	Ix
1919	07	12	12	06	Asolano	Baranello, 2023	9	5

Place	Sc	Pro	Lat	Lon	Is
Asolo		TV	45.801	11.914	5
Treviso		TV	45.669	12.244	4
Padova		PD	45.407	11.875	F
Vicenza		VI	45.548	11.546	F
Este		PD	45.228	11.656	3*
Marostica		VI	45.745	11.657	2-3*
Venezia		VE	45.438	12.335	2
Bassano del Grappa		VI	45.767	11.734	2*
Ferrara		FE	44.836	11.618	SF*

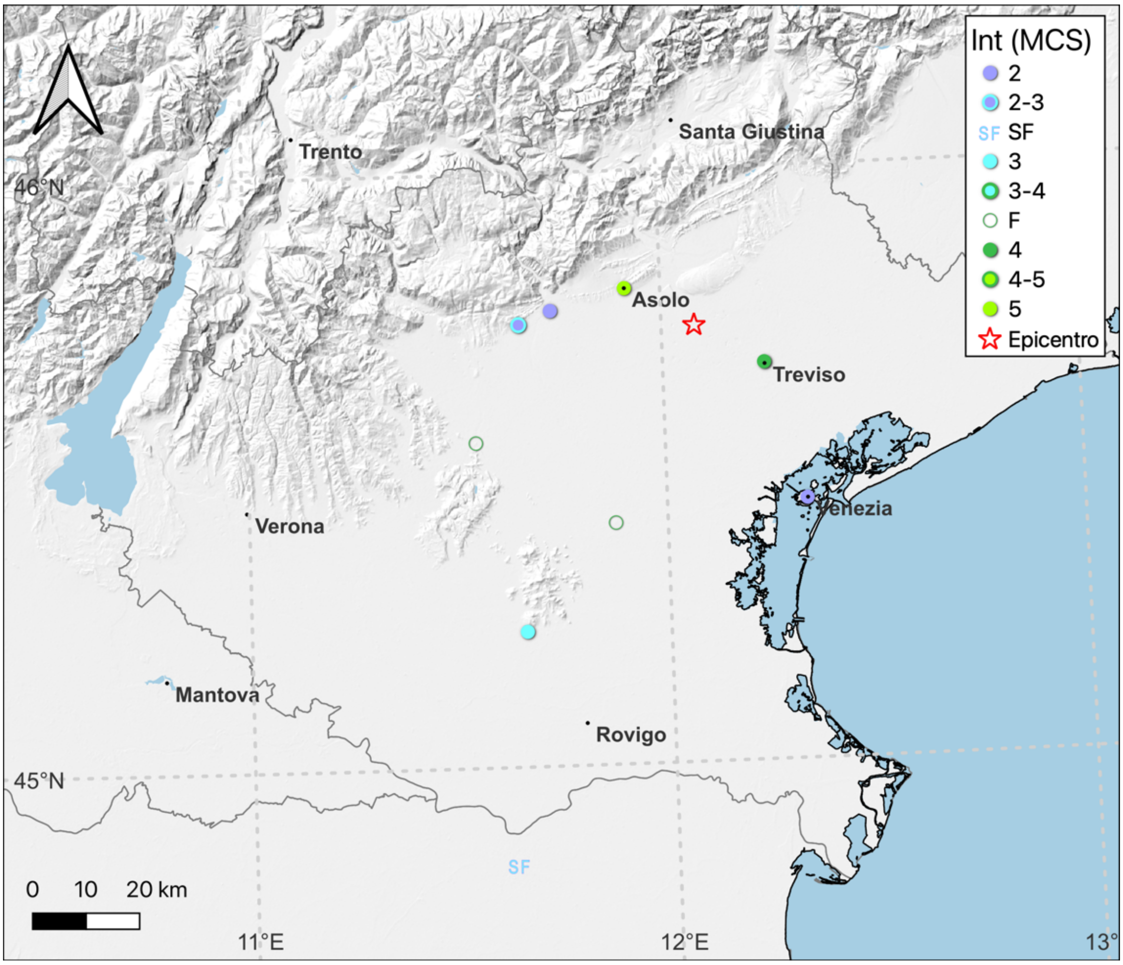


Figure 29. *Macroseismic intensity distribution map of the 13:06 GMT earthquake of 12 July 1900; the red star shows the macroseismic epicentre from Baranello [2023].*

12 September 1921. On 12 September 1921, shortly after midnight, an earthquake tremor was felt very strongly in Asolo and Treviso (Fig. 30).

According to Il Gazzettino giornale del Veneto [Treviso], of 1921.09.13, in Treviso the earthquake caused a great deal of panic among the people, who "*during the night [...] ran into the streets*". Even in Asolo, where it was felt as very sensitive, there was a similar situation of panic. According to the numerous national and regional newspapers consulted, the tremor was clearly felt in Feltre and Padua, and more moderately in Bassano del Grappa and Marostica.

Very little information is available about this earthquake, and it is limited to what is reported in the Seismic Bulletin [Ingrao, 1927b], which directly expresses intensity values, and in the Weekly Seismic Bulletin.

Year	Mo	Da	Ho	Mi	Ax	St	Mdps	Ix
1921	**09**	**12**	**00**	**25**	**Trevigiano**	**Baranello, 2023**	**6**	**5**

Place	Sc	Pro	Lat	Lon	Is
Treviso		TV	45.669	12.244	5
Asolo		TV	45.801	11.914	4-5
Feltre		BL	46.019	11.906	4
Padova		PD	45.407	11.875	4
Bassano del Grappa		VI	45.767	11.734	3-4
Marostica		VI	45.745	11.657	3-4*

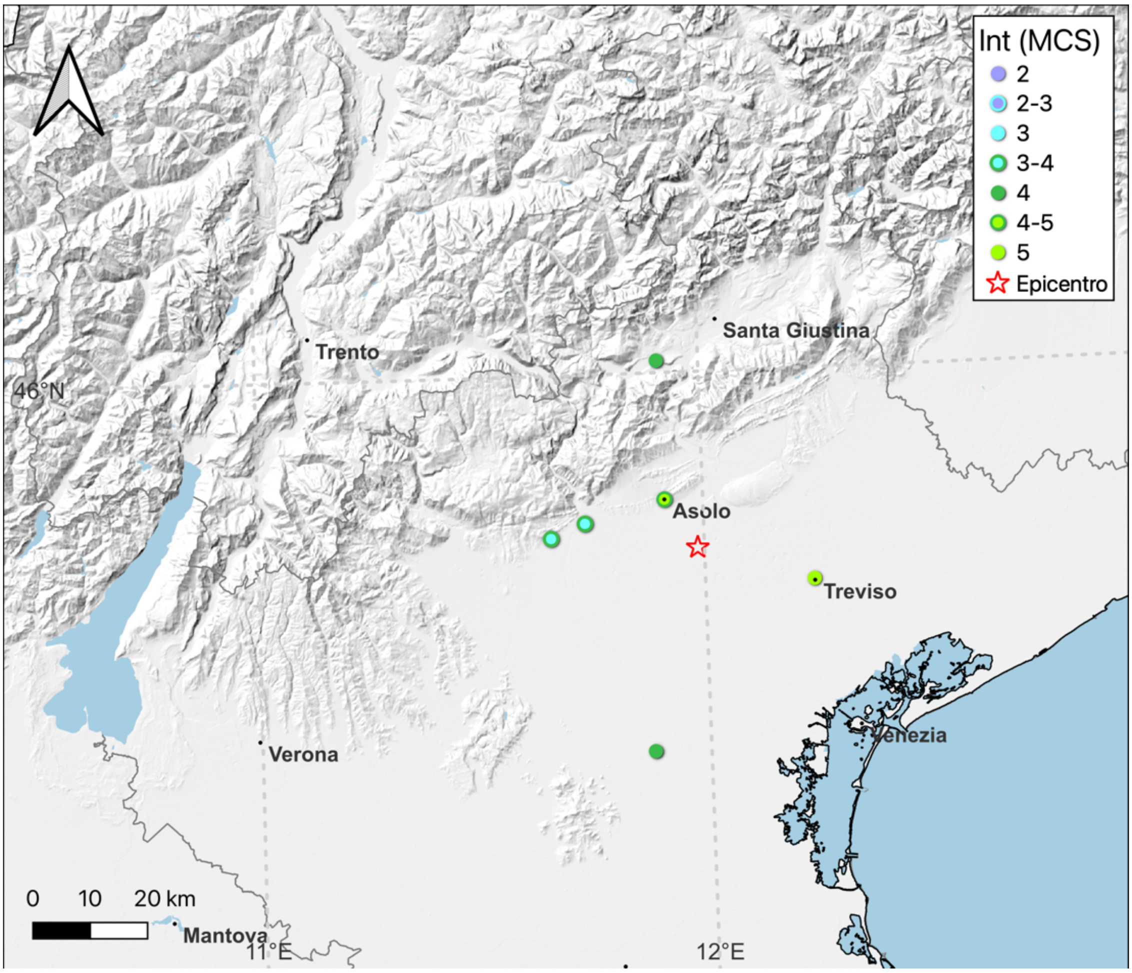


Figure 30. *Macroseismic intensity distribution map of the 00:25 GMT earthquake of 12 September 1921; the red star shows the macroseismic epicentre from Baranello [2023].*

6.2.1.1 RESULTS

On the basis of the reference studies for the Parametric Catalogue of Italian Earthquakes (CPTI15), a large amount of data was found that made it possible to increase the knowledge available for each of the earthquakes considered and to update the estimates of the intensity of the earthquake effects in the various localities.

Starting from the 7 events already included in the CPTI15, several earthquakes associated with the main shocks were identified during the course of the study, varying in number depending on the case, for a total of 23 shocks.

The most important results obtained thanks to the discovery of original sources and testimonies concern the re-evaluation of the maximum intensity estimates (Ix) and the general increase in the number of documented localities (Mdps), as can be seen in Table 6 regarding the main shocks.

			CPTI15			BARA023	
Data	Ora	Area		Mdp	Ix	Mdps	Ix
1861.05.19	19:45	Asolano	ALBI001	2	6	2	5
1887.03.29	08:58	Marostica	CAMAL012	2	5	19	5-6
1887.04.14	01:15	Bassano del Grappa	ALBI001	9	6	10	5
1897.06.11	11:45	Asolano	ALBAL003	47	5-6	53	6
1897.06.11	13:00	Asolano	-	-	-	25	5
1900.03.04	17:00	Trevigiano	AMGNDT995	98	6-7	111	6
1919.07.17	12:06	Asolano	MOLAL008	7	4-5	9	5
1921.09.12	00:25	Trevigiano	AMGNDT995	3	3-4	6	5

Table 6. *Numerical comparison between the data used by the CPTI15 catalogue and those derived from Baranello [2023].*

Comparing the ‘new’ data with those reported in CPTI15, there is a general increase in the number of Mdps, ranging from two for 1919, to 13 for 1900, to a maximum of 18 additional localities for the 29 March 1887 quake, rising from 2 to 19. The only exception is the 1861 earthquake, where the number of documented localities has remained unchanged since the work of Albini [2001], which is the current reference study for the CPTI15.

In the case of intensity estimates, on the other hand, for each event there is a revaluation of Ix by at least half a degree. The case of the earthquake of 12 September 1921 stands out. According to the Veneto newspaper Il Gazzettino on the day after the event, Treviso felt a tremor lasting 54 seconds, “*which was felt with varying degrees of intensity depending on the* locality*, but which undoubtedly left a considerable impression. In the city and just outside the gates, the tremor was felt to such an extent that it caused panic. During the night several people ran into the streets*”; this information was later confirmed by Ingrao [1927], who gave Asolo a degree 4 on the MCS scale and 3-4 to Bassano del Grappa and Marostica .

As can be seen, the descriptive sheet drawn up in this work proposes an increase in the value of Ix from degree 3-4 to 5 on the basis of the information provided by the sources and, in particular, the panic effects on the population. Looking at Table 5, we can also see that another earthquake close to the damage threshold has been identified and parameterised: the earthquake at 13:00 GMT on 11 June 1897, localised in the Asolo area, with effects documented in no less than 25 localities and a maximum intensity of 5 MCS .

Finally, the new epicentral parameters (epicentral location and magnitude) for each earthquake considered have been calculated using the BOXER code [Gasperini et al., 2010] (Table 7). The comparison between the magnitudes obtained in this work and those in CPTI15 shows a general reduction of a few decimals for each earthquake, except for the one at 11.45 GMT on 11 June 1897, for which there is a slight increase, from Mw 4.44 to 4.51.

Year	Mo	Da	Ho	Mi	Epicentral area	Study	Lat	Lon	Io	Mw
1861	5	19	19	45	Asolano	BARA023	45.736	11.920	5	4.16
1887	3	29	08	58	Marostica	BARA023	45.745	11.690	5-6	4.16
1887	4	14	1	15	Bassano del Grappa	BARA023	45.823	11.890	5	4.53
1897	6	11	11	45	Asolano	BARA023	45.776	12.030	6	4.51
1897	6	11	13	00	Asolano	BARA023	45.846	12.095	5	4.41
1900	3	4	17	00	Trevigiano	BARA023	45.600	11.962	6	4.82
1919	7	12	12	06	Asolano	BARA023	45.735	12.079	5	4.22
1921	9	12	0	25	Trevigiano	BARA023	45.724	11.985	5	4.14

Table 7. *Parameters of the 7 earthquakes considered in the present study, including the second earthquake of 1897 that was identified and parameterised in the course of this work, determined from macroseismic data, using BOXER [Gasperini et al., 2010].*

6.2.2 EARTHQUAKES IN THE TREVISO AREA

As for the Treviso area 8 earthquakes (Tab. 8) were reviewed (7 November 1709, 20 May 1711, 7 July 1719, 26 February 1756, 10 March 1857, 10 March 1859, 19 July 1860, and 10 June 1895), all studied three decades ago and distributed, for the most part, in the area between the provinces of Treviso and Belluno, in a more easterly area than that of the Asolano earthquakes described in the previous paragraphs.

Four of these studies deal with earthquakes in the first half of the 18th century (1709, 1711, 1719, 1756), when information circulated through the efficient network of Italian and European gazettes. Another four studies concern earthquakes in the second half of the 19th century (1857, 1859, 1860, 1895), when the newspaper network was much weaker.

The reasons for the interest in these events are manifold. Firstly, the evidence of two earthquakes, in 1709 and 1719, in mountainous areas, away from the main communication routes, makes it difficult to identify documentation of non-destructive effects to which local communities may have responded by simply repairing the damage themselves.

Another interesting case was the review of the earthquake of 13 April 1756, which was in danger of being forgotten because it occurred a few months after the great Lisbon earthquake of 1 November 1755. On the contrary, the great European resonance of this event also draws attention to relatively small earthquakes that are nevertheless of great importance in seismic risk assessment [Baranello et al., 2024 – in press].

Year	Mo	Da	Ho	Mi	Epcentral area	Ref	Mdps	Lat	Lon	Io	Mw
1709	11	07	--	--	--	--	--	--	--	--	--
1711	05	11	--	--	Vicentino	CAMAL012	2	45.548	11.546	4	3.70
1719	01	07	--	--	Italia nord-orientale	CAMAL011	11	46.123	11.991	5-6	4.94
1756	04	13	--	--	Treviso	AMGNDT095	1	45.666	12.245	6-7	4.86
1857	03	10	03	--	Prealpi Trevigiane	MOLAL008	4	45.726	12.188	4-5	4.04
1859	01	20	07	55	Prealpi Trevigiane	AMGNDT095	36	45.893	12.103	6	4.80
1860	07	19	--	--	Prealpi Trevigiane	ALBI001	10	45.889	12.146	6-7	4.92
1895	06	10	01	47	Prealpi Trevigiane	AMGNDT095	73	45.943	12.073	6	4.85

Table 8. *Earthquakes covered by this study in the CPTI15 catalogue [Rovida et al., 2022]. In the reference column: ALBI001 [Albini, 2001], AMGNDT095 [Archivio Macrosismico GNDT, 1995], CAMAL011 [Camassi et al., 2011], CAMAL012 [Camassi et al., 2012], MOLAL008 [Molin et al., 2008].*

The revision of knowledge was initiated through a meticulous examination of the primary seismological compilations of national [Hoff, 1840; Perrey, 1848; Mercalli, 1883; Piovene, 1888; Tommasi, 1888; De Rossi, 1889; Baratta, 1901] and regional interest [Goiran, 1886; Scarpa, 1888; Trener, 1903; Spagnolo, 1907; Zanon, 1937]. An accurate perusal of the main Italian and European printed gazettes was was subsequently conducted.

7 November 1709. The 1709 earthquake struck the Belluno area on the afternoon of 7 November (Fig. 31). The interest in this event is due to the presence of signs of damage: "*a slight earthquake* *was felt here with the fall of a few chimneys*", in Venice, in the edition of 20 November of Il Corriere Ordinario.

In the seismological compilation by Fulcis [1883] we find a reference to the news - rather vague - from the Belluno, according to which an earthquake was felt on 7 November, for which an annual procession to the Chiesa dei Cappucini was instituted.

Relevant information has also emerged from the examination of the Treviso Chronicle of Mestriner [XVII-XVIII], a contemporary narrative source that mentions an earthquake that caused "*walls and chimneys*" to fall. Traces of the earthquake can also be found on the Internet, where the effects on some churches in Belluno and a church in Valle di Cadore are mentioned, while some art-historical studies point to damage in Belluno and Curago (a hamlet of Pieve d'Alpago).

Fulcis [1883] also mentions a second earthquake, felt in Belluno on 28 December, for which it was decided to erect an altar in the Cathedral dedicated to Saints Paolo Apostolo and Gaetano. However, since it is not recorded in any contemporary newspaper, it was probably a moderate earthquake.

Keeping track of Fulcis 's[1883] report is the catalogue for north-eastern Italy by Iaccarino and Molin [1978] in which, however, the epicentral intensity is not given, which is why this event is not included in the most recent parametric catalogues.

Year	Mo	Da	Ho	Mi	Ax	St	Mdps	Ix
1709	**11**	**07**	**17**	**--**	**Bellunese**	**Baranello et al., 2024**	**5**	**6**

Place	Sc	Pro	Lat	Lon	Is
Belluno		BL	46.139	12.218	6
Treviso		TV	45.666	12.245	6
Curago		BL	46.175	12.366	D
Valle di Cadore		BL	46.417	12.334	D
Venezia		VE	45.438	12.336	5-6

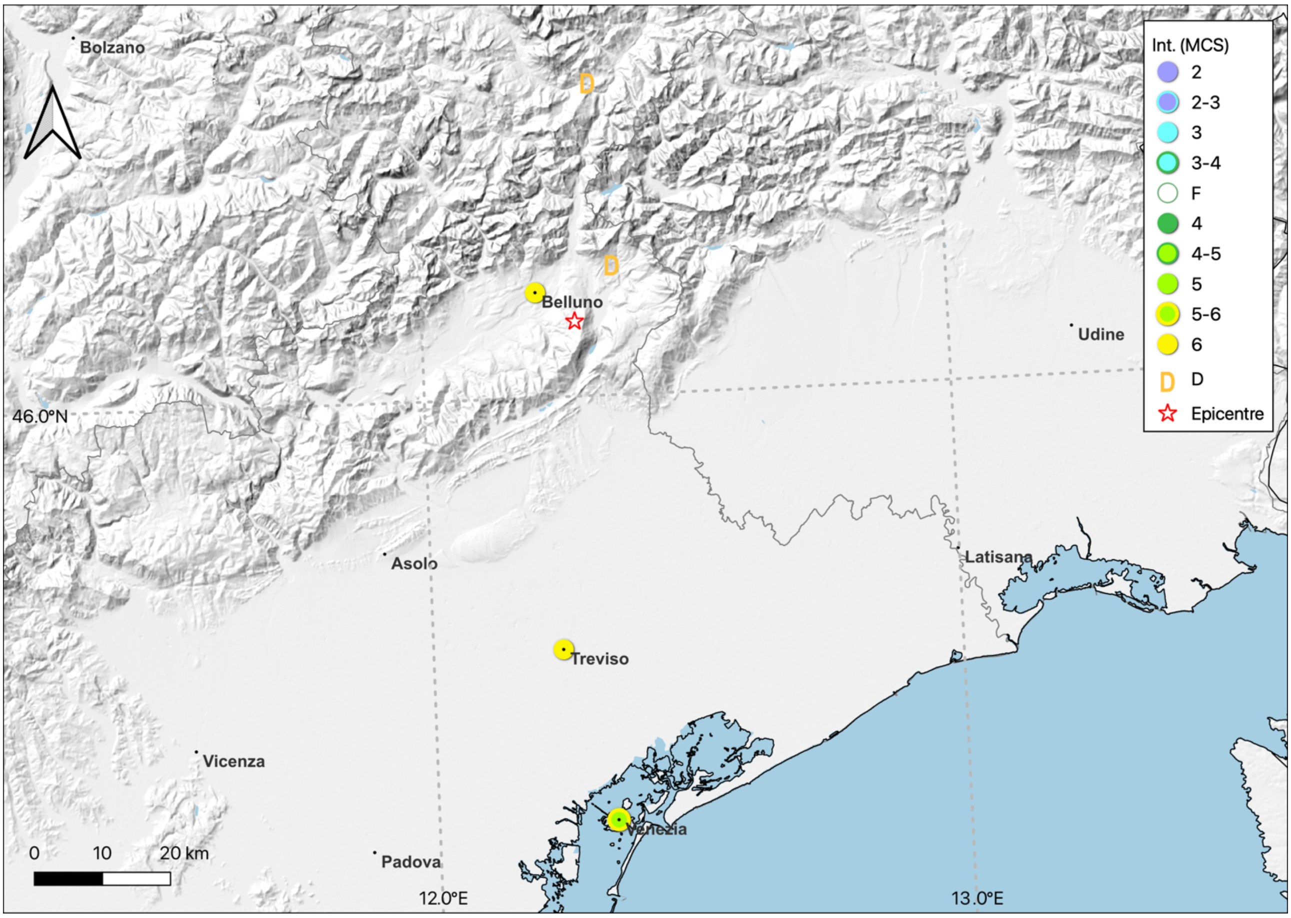


Figure 31. *Macroseismic intensity distribution map of the 7 January 1709 earthquake; the red star indicates the macroseismic epicentre in Baranello et al. [2024].*

21 May 1711. Based on the rapid study carried out within the INTERREG HAREIA project [Camassi et al., 2012], which is currently the reference study for this earthquake in the CPTI15 catalogue [Rovida et al., 2022], seismological compilations, journalistic sources, and some contemporary diaristic sources were verified.

The main source of information is Piovene's Seismological Compilation of Vicenza [1888], which is mostly based on contemporary local chronicles. In the case of the earthquake of 21 May 1711 (Fig. 32), Piovene reports no less than three testimonies from three different chroniclers from Vicenza: "*21 May - At h 4 the earthquake was felt with no small tremor (Lanzi). 1711. 21 May - At about 24 o'clock the great earthquake (Dian) 1711. 21 May - At 4 o'clock great earthquake trembling that caused several bells to ring. (Favetta)*" [Piovene, 1888].

On the other hand, news of a slight tremor in Venice comes from some contemporary newspapers such as the Gazzetta di Mantova, Il Corriere Ordinario, or the Gazette d'Amsterdam.

The local Trevisan chronicle of Mestriner [XVII-XVIII] is particularly important for finding evidence of discontent in Treviso, where there is evidence that a strong earthquake was felt, and that caused "*a great shock to those who heard it*". The time stamps place the earthquake "*on Wednesday at 4am,* *with effects felt on Thursday*", so we are talking about the night of 20-21 May. Since sunset on 20 May is around 20:35, the earthquake occurred at 23:35 GMT on the same day.

Year	Mo	Da	Ho	Mi	Ax	St	Mdps	Ix
1711	**05**	**20**	**23**	**35**	**Trevigiano**	**Baranello et al., 2024**	**3**	**5**

Place	Sc	Pro	Lat	Lon	Is
Treviso		TV	45.666	12.245	5
Vicenza		VI	45.548	11.546	4-5
Venezia		VE	45.438	12.336	4

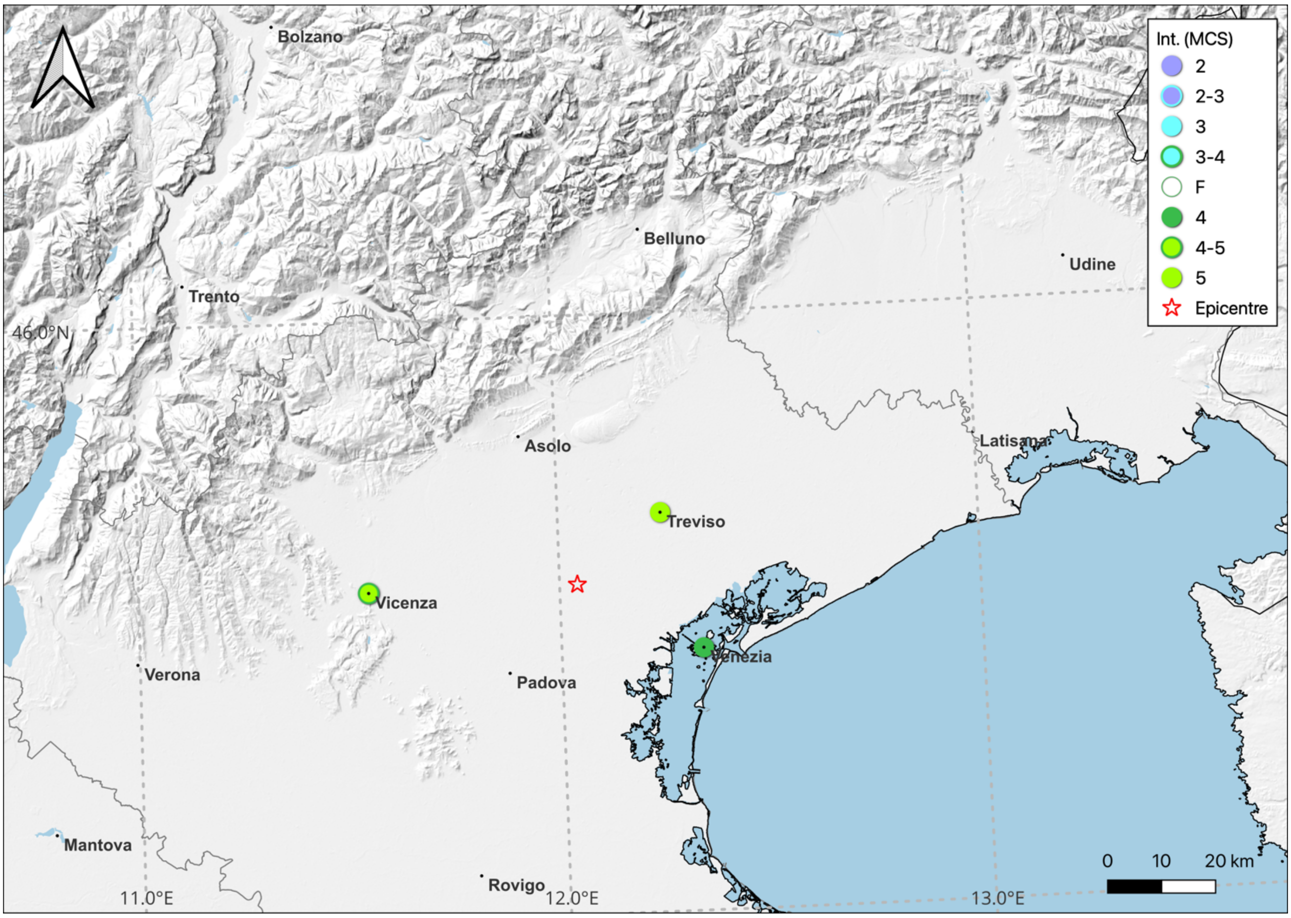


Figure 32. *Macroseismic intensity distribution map of the 20 May 1711 earthquake; the red star indicates the macroseismic epicentre in Baranello et al. [2024].*

7 January 1719. The earthquake in Friuli, which occurred on 7 January 1719 at 19:40 GMT (Fig. 33), is reported in numerous seismological compilations, both national and local [Perrey, 1848; De Rossi, 1889; Scarpa, 1886; Piovene, 1888; Baratta, 1901], which tend to use information from Italian and European journalistic sources.

The event is described in two contemporary newspaper reports: the first, dated 14 January, from Venice, published in the [Gazzetta di] Bologna [1719.01.17], states that "*a terrible tremor of an* *earthquake was felt throughout the city, which lasted for the space of a Credo [a catholic religious prayer]*", with much fright among the population. He also adds that it was felt "*slightly as far as Verona, and also in Ferrara*". Again, Mestriner [XVII-XVIII] reports light damage in Treviso, where many chimneys collapsed, and in Venice. Other damage occurred in other parts of Friuli.

According to Mestriner [XVII-XVIII] indeed, the "*earthquake was felt in several countries, particularly in the Friuli region, where a number of houses were destroyed, but the damage in the mountain areas was considerable*".

Although it has not been possible to identify precisely the places in Friuli where the alleged serious damage occurred, the picture that emerges from the research carried out is certainly that of a major earthquake that affected a wide area that goes from Pesaro and Bologna to Innsbruck.

This event is certainly an example of a 'neglected' earthquake, i.e. an earthquake known to the seismological tradition. It is recorded both in the regional catalogue of Iaccarino and Molin [1978], where it is listed with conventional epicentral coordinates but without epicentral intensity, to signal it as a possibly relevant earthquake and subject of future studies, and in Postpischl [1985]. Unfortunately, however, it was discarded by subsequent catalogues, which interpreted it as below the damage threshold precisely because of the lack of epicentral intensity.

Year	**Mo**	**Da**	**Ho**	**Mi**	**Ax**	**St**	**Mdps**	**Ix**
1719	**01**	**07**	**19**	**15**	**Friuli**	**Baranello et al., 2024**	**15**	**HD**

Place	**Sc**	**Pro**	**Lat**	**Lon**	**Is**
Friuli	TE		0.000	0.000	HD
Treviso		TV	45.666	12.245	6
Venezia		VE	45.438	12.336	6
Vicenza		VI	45.548	11.546	4-5
Bolzano		BZ	46.499	11.352	4
Trento		TN	46.068	11.122	4
Bassano del Grappa		VI	45.767	11.734	F
Innsbruck			47.266	11.404	F
Padova		PD	45.407	11.875	F
Bologna		BO	44.494	11.343	F
Cento		FE	44.727	11.289	F
Tirolo	TE		0.000	0.000	F
Ferrara		FE	44.835	11.620	3
Pesaro		PS	43.910	12.910	3
Verona		VR	45.439	10.994	3

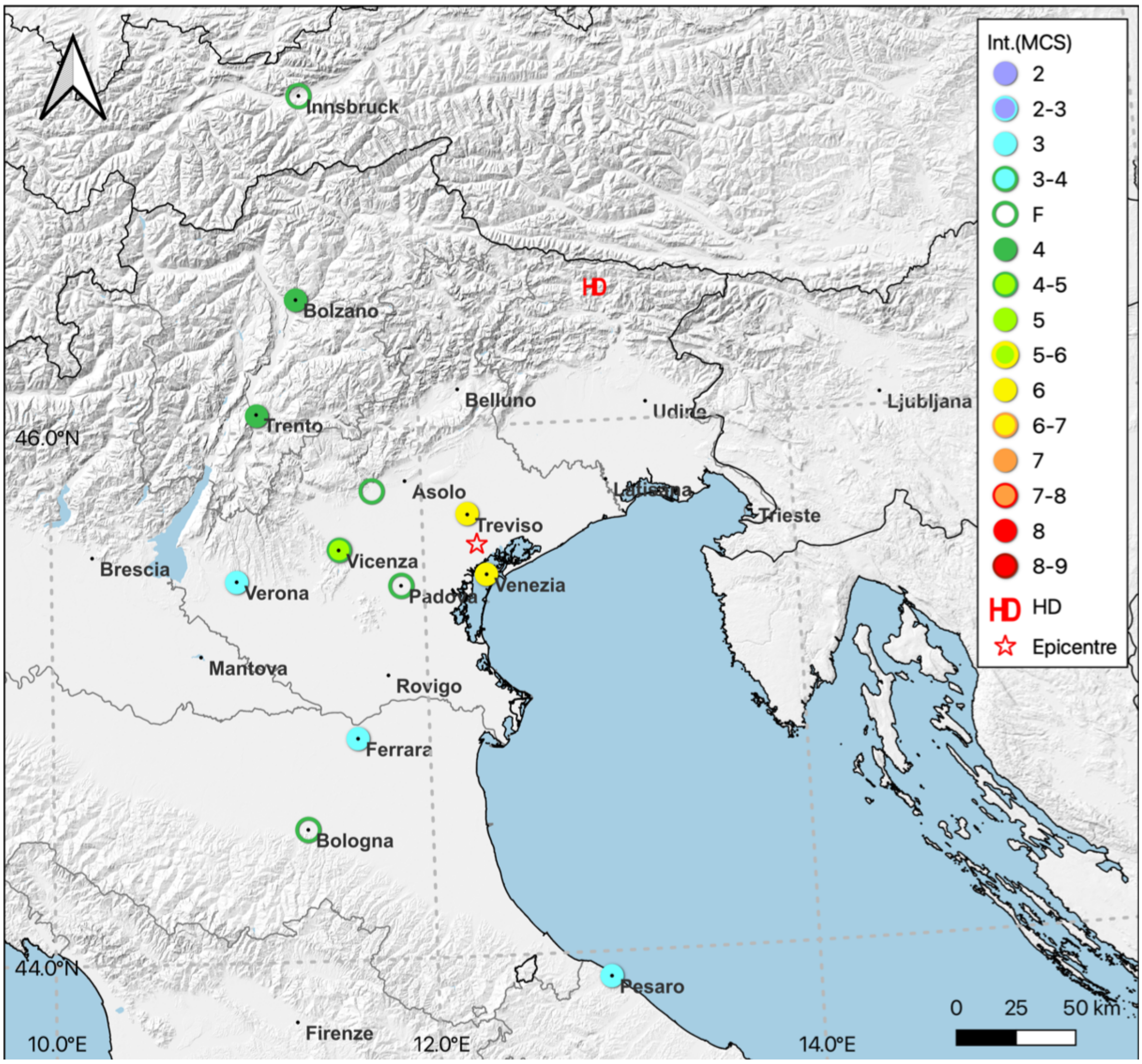


Figure 33. *Macroseismic intensity distribution map of the 7 January 1719 earthquake; the red star indicates the macroseismic epicentre in Baranello et al. [2024].*

13 April 1756. At the beginning of 1756, the Treviso area was affected by a seismic sequence, the two main events of which were originally dated 25 February and 13 April. Information on the sequences is very limited: the first tremor occurred at 15:10 GMT on 25 February, the second, perhaps stronger, at about 10 minutes after midnight (GMT).

As for 13 April, the sources do not specify the time of the first tremor, which occurred in the morning; the second occurred in the early afternoon, around 14:00 GMT, while a third tremor is reported in Venice and the Treviso area on the night of 18 to 19 April (at 00:10 GMT on 19 April).

The worst affected locality, where effects of 7-8 MCS were recorded, was certainly Treviso, followed by Ceneda (5 MCS) and Bassano del Grappa, Belluno, Feltre and Serravalle [V.Veneto], where a 4-5 MCS was reached (Fig. 34). For Asolo, on the other hand, the alphanumeric value 'EE' was assigned, which is used in cases where only environmental effects have been recorded. Indeed, the only information available on this locality is that of Gradenigo [XVIII], who speaks of a landslide that occurred approximately one month after the earthquake, which affected the roots of the mountain on which the ancient castle stood.

A further quake, dated 17 April, is reported from Venice by an original letter from the London Gazette [1756.05.08-11] "*April 21. On Monday last a Shock of an Earthquake was felt in this City; and though it was more severe than that on the 13th, it did very little Damage*" and probably corresponds to what some compilations, starting with Hoff [1840], date to 16 April.

Year	Mo	Da	Ho	Mi	Ax	St	Mdps	Ix
1756	**04**	**13**	**11**	**56**	**Trevigiano**	**Baranello et al., 2024**	**11**	**7-8**

Place	Sc	Pro	Lat	Lon	Is
Treviso		TV	45.666	12.245	7-8
Ceneda	AL	TV	45.974	12.297	5
Bassano del Grappa		VI	45.767	11.734	4-5
Belluno		BL	46.139	12.218	4-5
Feltre		BL	46.019	11.906	4-5
Serravalle [V.Veneto]		TV	45.999	12.292	4-5
Venezia		VE	45.438	12.336	F
Padova		PD	45.407	11.875	F
Verona		VR	45.439	10.994	F
Pordenone		PN	45.959	12.658	F
Asolo		TV	45.801	11.914	EE

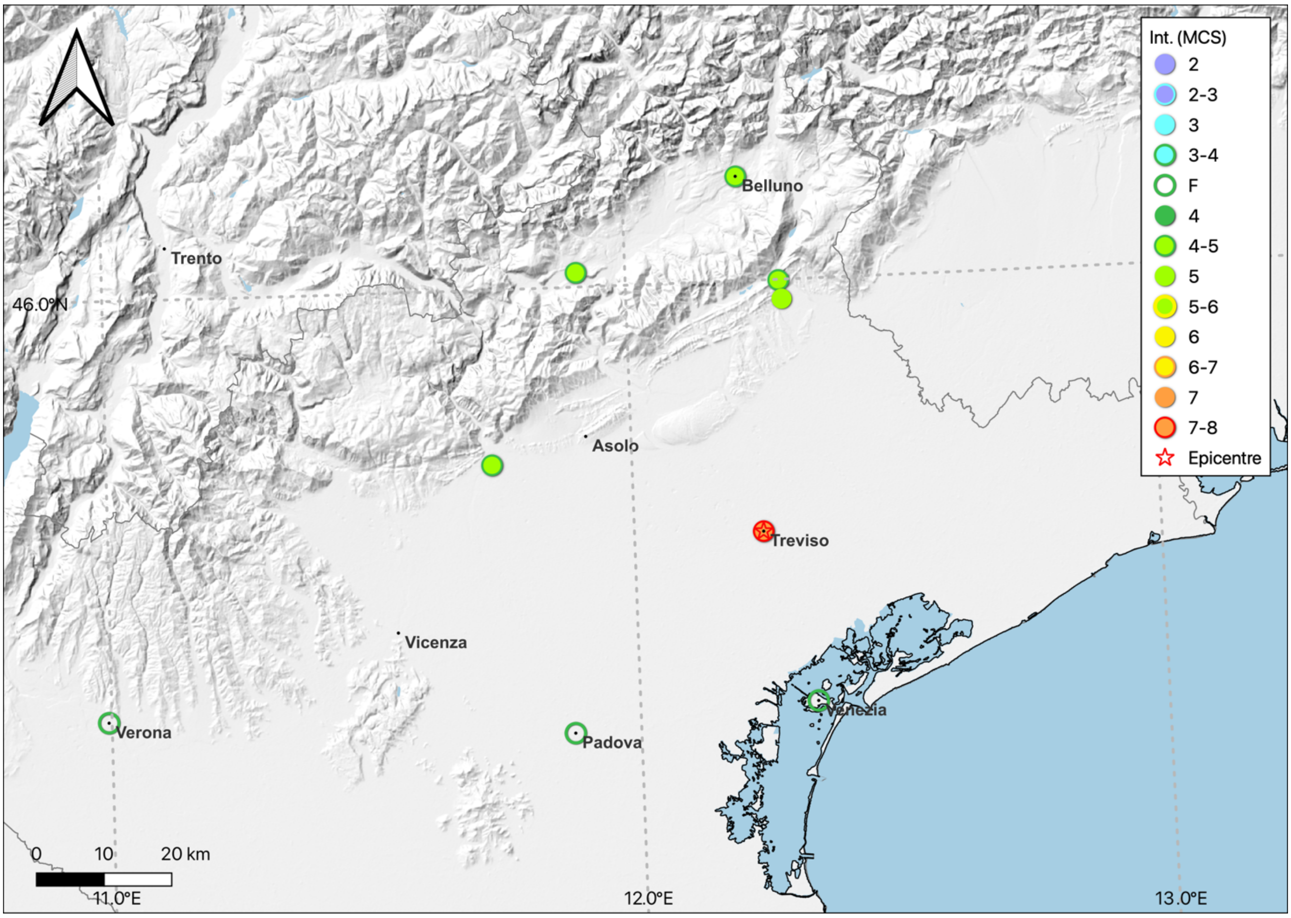
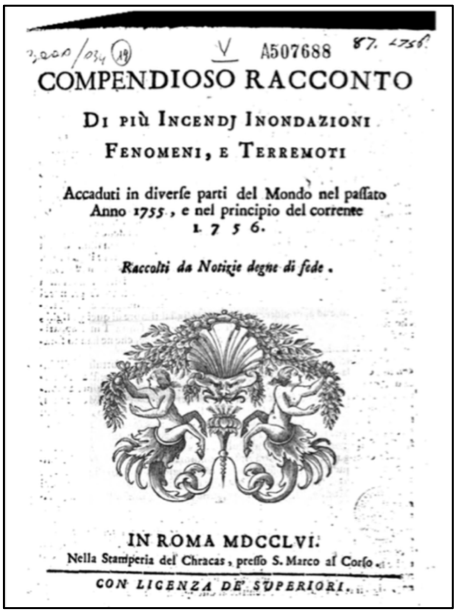


Figure 34. *Macroseismic intensity distribution map of the 13 April 1756 earthquake; the red star indicates the macroseismic epicentre in Baranello et al. [2024].*

In the months following November 1755, the European press was awash with news of the aftermath of the great Lisbon earthquake, and also published a series of reports on other earthquakes in Europe and the Mediterranean (Fig. 35). Some - the Valais earthquake of 9 December 1755, the Rhodes earthquake of 13 February 1756 and the Düren earthquake of 18 February - are important earthquakes, thoroughly studied and well defined. Others are probably, or in some cases certainly, entirely fictitious events.

The case of the earthquake of 13 April 1756 belongs to a slightly different category: the earthquake is remembered by seismological compilations and, from them, merged into parametric catalogues, starting with Iaccarino and Molin [1978], but the related information is extremely confused, entangled as it is in the chaotic flow of news about real or fictitious earthquakes.

Research based on a wide range of journalistic sources has led to a significant re-evaluation of this event, which appears to be the most powerful in the seismic history of Treviso. According to some accounts, several chimneys in Treviso collapsed, as did part of the vault of the Church of Santa Margherita and a corner of the College of the Vescovado. According to other correspondences, the damage was even greater and the earthquake was felt over a wide area, including Bassano, Feltre, Belluno, Serravalle and Ceneda.



COMPENDIOSO RACCONTO

DI PIÙ INCENDJ INONDAZIONI FENOMENI, E TERREMOTI

Accaduti in diverse parti del Mondo nel passato Anno 1755, e nel principio del corrente 1756.

Raccolti da Notizie degne di fede.

IN ROMA MDCCLVI.

Nella Stamperia del Chracas, presso S. Marco al Corso.

CON LICENZA DE' SUPERIORI.

LA VRAIE ET FIDELE RELATION DU TREMBLEMENT DE TERRE EN LISBONNE CAPITALE DE PORTUGAL, Le 1. de Novembre M. D. CC. LV.

Qui a causé en dix heures de tems, presque la totale Destruction de cette très-riche & très-florissante Ville:

AVEC LE DETAIL De plusieurs Tremblemens de Terre, Suites, Desastres, Phénomènes, & Secousses horribles & réiterées presque dans tout l'Univers: avec tout ce qui s'est passé de plus remarquable depuis, par rapport au Tremblement de Terre: & une Dissertation de sa Cause Physique & Naturelle: comme aussi une briéve Description de ladite Ville de Lisbonne.

A ANVERS, Dans l'Imprimerie d'*Hubert Bincken*, dans la rue dite Cathelyne-vest.

Figure 35. *Front pages of two journalistic compilations on the earthquakes of 1755-1756.*

10 March 1857. On 10 March 1857, at 4 a.m., a small earthquake was felt in the area of the Veneto pre-Alps (Fig. 36). The only real information on this event coincides with the few references made by Berti [1857], later taken up by other authors and compilations such as Perrey [1862], Bittner [1874], Mercalli [1883], Baratta [1901], and Zanon [1937].

The effects described by Berti [1857] were so limited that even their occurrence was doubted, and in any case, they did not merit a single word in the city's newspapers. In Venice, "*some people said they felt a small tremor*", which was also slightly felt in Treviso. In Valdobbiadene and Pieve di Soligo, on the other hand, the most Berti [1857] can say is that "*such a shock was felt*", adding that the affected area was limited to the provinces of Treviso and Venice.

The lack of information in most of the compilations, especially those of a national character based on the verification of journalistic sources [Baratta, 1897; De Rossi, 1889], and in those of interest to the north-eastern region or even to Vicenza and Treviso [Piovene, 1888; Scarpa, 1888; Spagnolo, 1907], is certainly significant.

A check was then made of some newspaper sources [[Gazzetta di] Mantova, 1857.03; Gazzetta Uffiziale di Venezia, 1857.03; Gazzetta Piemontese, 1857.03; Gazzetta del Popolo, 1857.03; Il Diavoletto [Trieste], 1857.03]], which however proved negative.

It is very difficult to estimate the macroseismic intensity based on these references. In Valdobbiadene and Pieve di Soligo, the earthquake was felt, while in Venice and Treviso, it was a very weak quake.

Year Mo Da Ho Mi	Ax	St	Mdps	Ix
1857 03 10 03 --	**Prealpi Friulane**	**Baranello et al., 2024**	**4**	**F**

Place	Sc	Pro	Lat	Lon	Is
Pieve di Soligo		TV	45.900	12.174	F
Valdobbiadene		TV	45.901	11.996	F
Treviso		TV	45.666	12.245	2-3
Venezia		VE	45.438	12.336	2-3

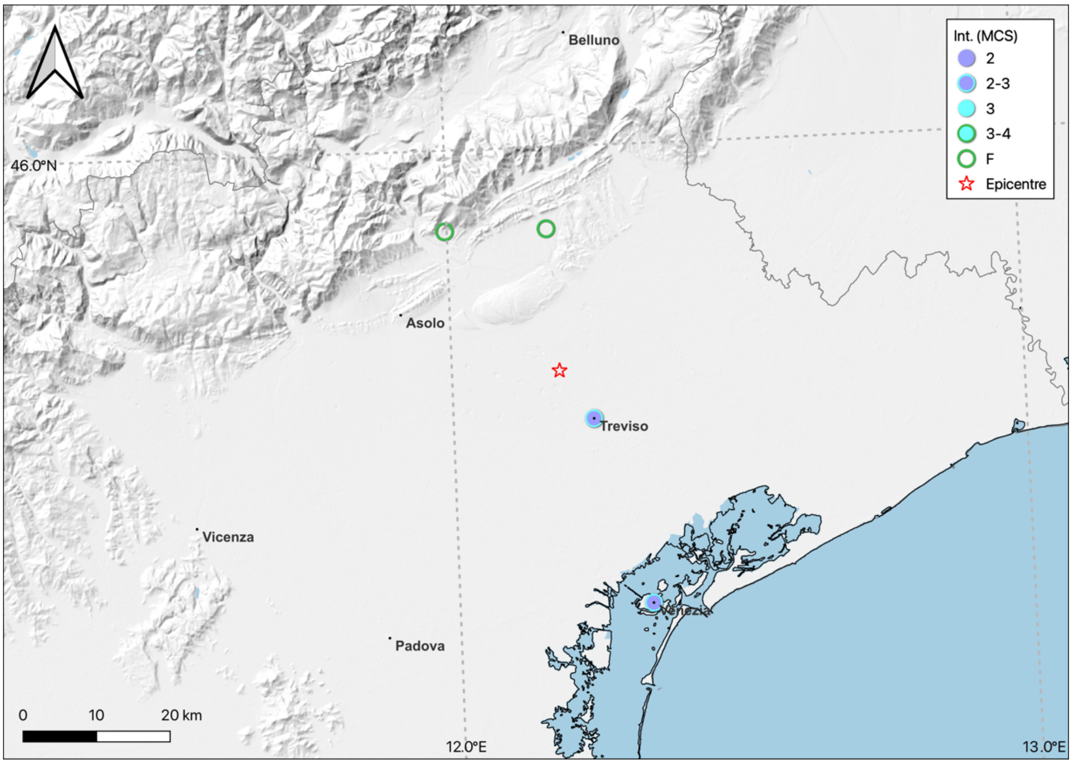


Figure 36. *Macroseismic intensity distribution map of the 10 March 1857 earthquake; the red star indicates the macroseismic epicentre in Baranello et al. [2024].*

20 January 1859. The event at 7.55 on the morning of 20 January 1859 began a long seismic sequence that lasted at least five months and mainly affected the area of the Veneto pre-Alps. (Fig. 37).

The verification of all the seismological compilations of national interest and those specific to north-eastern Italy was unsuccessful, as was that of Piovene [1888] for Vicenza, that of Spagnolo [1907] for Bassano del Grappa and that of Zanon [1937] for Venice.

Despite the recovery of the sources cited in the compilations and additional journalistic sources, the contemporary testimony of Berti [1859] and the contribution of Perrey [1862; 1864], with his formidable network of correspondents, remain central.

The earthquake of 20 January caused very serious damage in Collalto, where, according to Berti, the castle was damaged, and in particular the tower, which was "*cracked from top to bottom and some stones fell from its cell*". It was also noted that "*the greatest damage was done to the modern or rebuilt part of the castle, where the procurator of the Counts of Collalto lives, as well as to the spinning wheel, the parish house, the recently built church and almost all the other houses in the village*" [Berti, 1859].

In the Collalto area, several towns, such as Falzè di Piave, Pieve di Soligo, Sernaglia della Battaglia, Moriago della Battaglia, Col San Martino, Guia, Combai, Miane, Valdobbiadene and Vidor, suffered minor damage such as falling plaster, cracks in walls or chimneys falling, while in S. Pietro di Borbozza the bell tower was damaged. The damage was more serious and widespread in Ceneda, where "*some chimneys fell, the walls of several houses cracked, and large pieces of plaster fell from the walls*" [Berti, 1859], and in Treviso, where some chimneys fell. The tremor was very strong in the areas of Conegliano and Vittorio Veneto, but without causing any damage, while it was very noticeable in Venice, Padua, and Trento.

As Baratta [1901] wrote, "*in Collalto, after the 20th of January, there were daily tremors, which, although small and of short duration (about 5s), caused further damage to the houses*". An exhaustive list of the many tremors from 20 January to the end of May is given in the very detailed compilation by Perrey [1862], whose impressive network of direct correspondents included also the Count of Collalto.

Year	**Mo**	**Da**	**Ho**	**Mi**	**Ax**	**St**	**Mdps**	**Ix**
1859	**01**	**20**	**07**	**55**	**Prealpi Trevigiane**	**Baranello et al., 2024**	**43**	**7-8**

Place	Sc	Pro	Lat	Lon	Is
Collalto		TV	45.865	12.206	7-8
Ceneda	AL	TV	45.974	12.297	6-7
Col San Martino		TV	45.895	12.089	6
Combai		TV	45.929	12.071	6
Falzè di Piave		TV	45.860	12.174	6
Guia		TV	45.910	12.058	6
Miane		TV	45.942	12.091	6
Moriago della Battaglia		TV	45.867	12.106	6
Pieve di Soligo		TV	45.900	12.174	6
San Pietro di Barbozza		TV	45.900	12.019	6-7
Sernaglia della Battaglia		TV	45.875	12.134	6
Valdobbiadene		TV	45.901	11.996	6
Vidor		TV	45.863	12.039	6
Chiusa		BZ	46.641	11.569	5
Conegliano		TV	45.887	12.298	5
Serravalle		TV	45.999	12.292	5

Treviso		TV	45.666	12.245	5-6
Padova		PD	45.407	11.875	4-5
Sacile		PN	45.953	12.499	4-5
Trento		TN	46.068	11.122	4-5
Asolo		TV	45.801	11.914	4
Belluno		BL	46.139	12.218	4
La Valle (San Genesio)	MS	BZ	46.658	11.924	4
Venezia		VE	45.438	12.336	4
Brescia		BS	45.539	10.220	3-4
Segusino		TV	45.918	11.954	3-4
Udine		UD	46.063	13.234	3-4
Agordo		BL	46.282	12.037	3
Auronzo di Cadore		BL	46.552	12.439	3
Bassano del Grappa		VI	45.767	11.734	3
Bolzano		BZ	46.499	11.352	3
Bressanone		BZ	46.715	11.657	3
Canale		TN	46.043	11.228	3
Ljubljana			46.048	14.505	3
Parma		PR	44.801	10.330	3
Pieve di Cadore		BL	46.425	12.365	3
Trieste		TS	45.650	13.772	3
Lancisca	TE				HF
Mantova		MN	45.158	10.794	F
Rovigo		RO	45.071	11.791	F
Verona		VR	45.439	10.994	F
Vicenza		VI	45.548	11.546	F
Zevio		VR	45.373	11.134	F

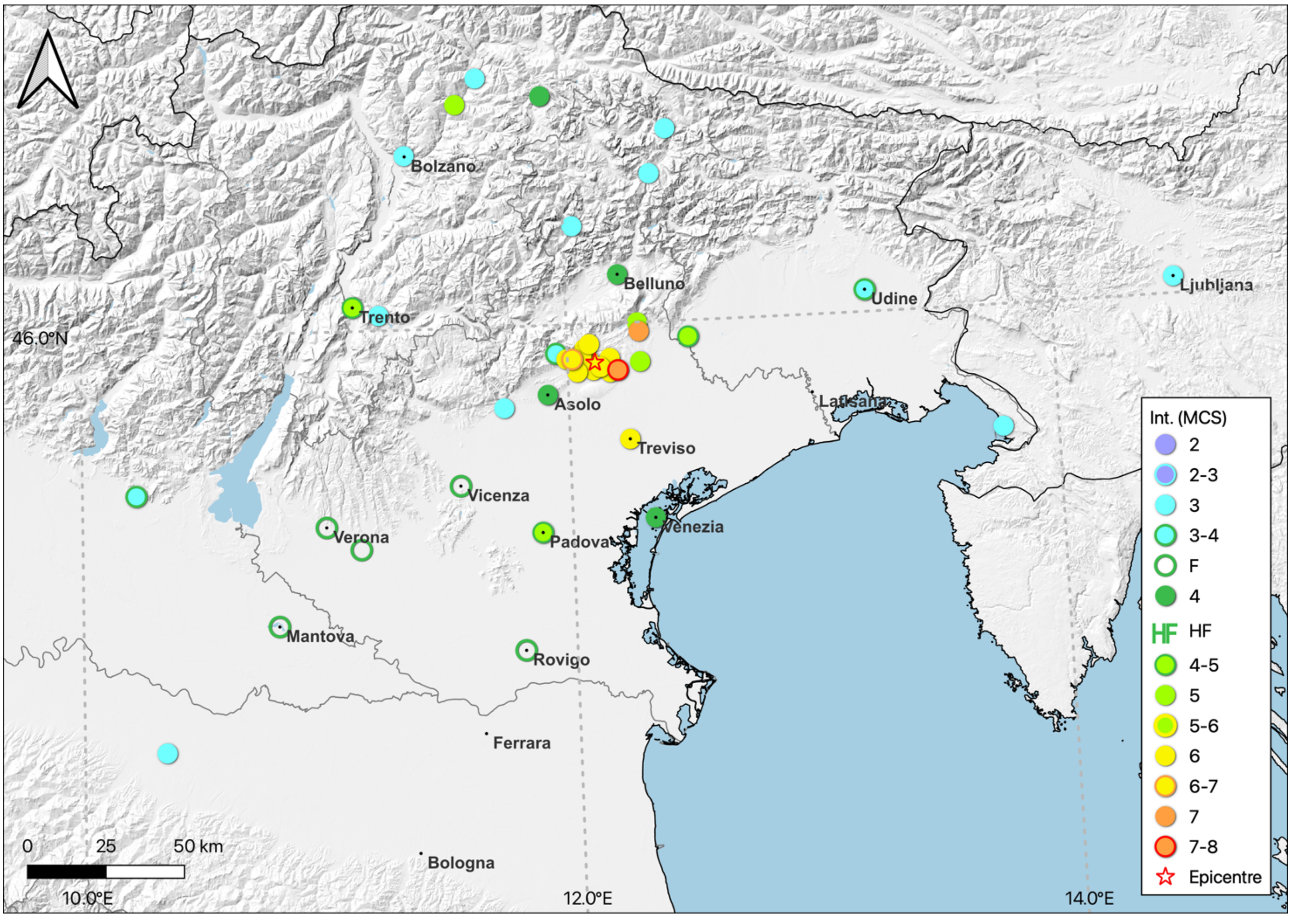


Figure 37. *Macroseismic intensity distribution map of the 20 January 1859 earthquake; the red star indicates the macroseismic epicentre in Baranello et al. [2024].*

19 July 1860. Here too, the main source of information - if not the only one - is Antonio Berti's report, based not only on personal observation but also on a network of local correspondents.

As far as journalistic sources are concerned, which are extremely scarce for this historical period, only one correspondence has been collected, published by the Gazzetta Uffiziale di Venezia [20.07.1860], which only reports that the earthquake was felt in Venice and Treviso (Fig. 38).

According to Berti [1860], the most severe effects were felt in Valdobbiadene, where "*some chimneys collapsed, some walls cracked and in some houses the cracks were so large that they had to be supported*". Similar effects were felt in the hamlet of Guia. The earthquake was felt in Padua, Treviso, and Venice, but without causing much concern.

Year Mo Da Ho Mi	Ax	St	Mdps	Ix
1860 07 19 15 38	**Prealpi Trevigiane**	**Baranello et al., 2024**	**12**	**6-7**

Place	Sc	Pro	Lat	Lon	Is
Guia		TV	45.910	12.058	6-7
Valdobbiadene		TV	45.901	11.996	6-7
Padova		PD	45.407	11.875	4

Treviso		TV	45.666	12.245	4
Venezia		VE	45.439	10.994	3-4
Belluno		BL	46.139	12.218	F
Collalto		TV	45.865	12.206	F
Pieve di Soligo		TV	45.900	12.174	F
Rovigo		RO	45.071	11.791	F
Trieste		TS	45.650	13.772	F
Verona		VR	45.439	10.994	F
Vicenza		VI	45.548	11.546	F

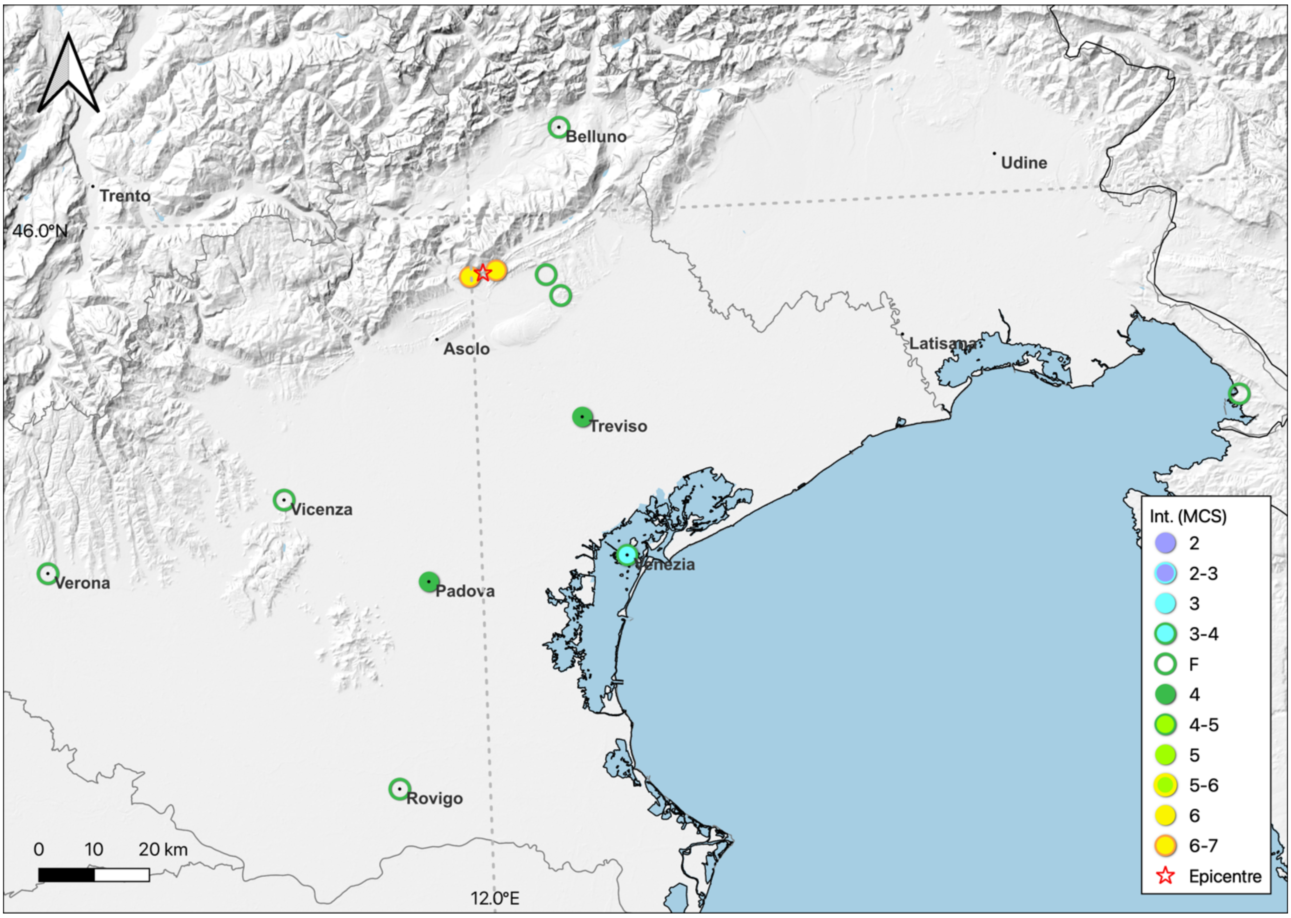


Figure 38. *Macroseismic intensity distribution map of the 19 July 1860 earthquake; the red star indicates the macroseismic epicentre in Baranello et al. [2024].*

10 June 1895. On 10 June 1895, the area of the Treviso pre-Alps was again affected by a small seismic sequence that ended in the evening of the following day (Fig. 39). Of the dozen or so tremors that followed one another over the two days, the only reports that seem to be well-founded are those on the seismic postcards sent from Follina. These postcards report a strong tremor at 21:34 on the 10th and two tremors on the 11th, one light at midnight and the other sensitive at 8:35 GMT.

According to the Corriere della Sera [11-12.06.1895], another tremor was felt in Venice on the 10th (at 15:00 local time); a tremor, however, of which there is no trace in other seismological sources such as bulletins and seismic postcards.

The main event of the sequence, which occurred at 1:47 GMT, had very limited effects (damage to buildings and falling chimneys) confined to two localities in the Treviso area, Follina and Valmareno. The earthquake was very sensitive in several localities in the Veneto region, especially in the Vicenza area, but also in Trentino, Friuli, and Brescia. In the Emilia-Romagna region, the effects were much less severe, and the earthquake was only felt.
The basic information on this event comes mainly from the collection of news edited by Baratta [1895], who summarised the descriptive information contained in the seismic postcards received at the Central Office of Meteorology and Geodynamics in Rome [Cartoline sismiche, 1895], which in several cases also reported news taken from the local press, especially that from the Vicenza area.
The communication of this earthquake was certainly affected by the occurrence of two other possible events. The first, which occurred almost at the same time in the Siena area, of which we have an instrumental recording accompanied by a report indicating that the population within the city of Siena felt it, and the second, which occurred at around 8:35 a.m. on the 10th, and that is probably a strong replica of the Ljubljana earthquake of 14 April of that year, which was also felt in Italy.

Year	Mo	Da	Ho	Mi	Ax	St	Mdps	Ix
1895	**06**	**10**	**01**	**48**	**Prealpi Trevigiane**	**Baranello et al., 2024**	**87**	**6**

Place	Sc	Pro	Lat	Lon	Is
Follina		TV	45.951	12.119	6
Valmareno		TV	45.969	12.126	6
Oderzo		TV	45.781	12.494	5-6
Cornuda		TV	45.831	12.007	5
Arsiè		BL	45.982	11.758	4-5
Asolo		TV	45.801	11.914	4-5
Cologna Veneta		VR	45.309	11.385	4-5
Conco		VI	45.799	11.607	4-5
Feltre		BL	46.019	11.906	4-5
Folgaria		TN	45.916	11.170	4-5
Lisiera		VI	45.579	11.611	4-5
Lonigo		VI	45.387	11.388	4-5
Marostica		VI	45.744	11.657	4-5
Moggio Udinese (di Sotto)	MS	UD	46.406	13.197	4-5
Noventa Vicentina		VI	45.290	11.542	4-5
Rovigo		RO	45.071	11.791	4-5
Salò		BS	45.606	10.522	4-5
Santa Giustina		BL	46.081	12.042	4-5
Spinea (Orgnano)	MS	VE	45.490	12.165	4-5
Treviso		TV	45.666	12.245	4-5
Valli del Pasubio		VI	45.739	11.261	4-5
Vivaro		PN	46.076	12.777	4-5
Ala		TN	45.757	11.001	4

Auronzo di Cadore		BL	46.552	12.439	4
Barbarano Vicentino		VI	45.409	11.540	4
Belluno		BL	46.139	12.218	4
Bondeno		FE	44.889	11.417	4
Brescia		BS	45.539	10.220	4
Colzè		VI	45.466	11.629	4
Desenzano del Garda		BS	45.471	10.537	4
Este		PD	45.228	11.656	4
Gradisca d'Isonzo		GO	45.890	13.498	4
Latisana		UD	45.777	12.998	4
Longarone		BL	46.269	12.301	4
Montebelluna		TV	45.776	12.045	4
Pergine Valsugana		TN	46.062	11.238	4
Podresca		UD	46.088	13.564	4
San Donà di Piave		VE	45.633	12.572	4
Sant'Ulderico		VI	45.749	11.347	4
Tolmezzo		UD	46.398	13.019	4
Valstagna		VI	45.860	11.658	4
Verona		VR	45.439	10.994	4
Bassano del Grappa		VI	45.767	11.734	3-4
Fontaniva		PD	45.636	11.756	3-4
Maniago		PN	46.167	12.708	3-4
Montebello Vicentino		VI	45.457	11.386	3-4
Padova		PD	45.407	11.875	3-4
Riva del Garda		TN	45.887	10.844	3-4
Ronchi		BS	45.627	10.511	3-4
Trento		TN	46.068	11.122	3-4
Argenta		FE	44.615	11.837	3
Aviano		PN	46.064	12.585	3
Bresega (Adria)		RO			3
Ferrara		FE	44.835	11.620	3
Gemona del Friuli		UD	46.279	13.135	3
Montereale Valcellina		PN	46.160	12.661	3
Nanto (Ponte)	MS	VI	45.423	11.594	3
Palmanova		UD	45.905	13.310	3
Quintarello		VI	45.558	11.623	3
Recoaro Terme		VI	45.703	11.221	3
Retinella		RO	45.047	12.178	3
Tirano		SO	46.216	10.169	3
Trieste		TS	45.650	13.772	3
Udine		UD	46.063	13.234	3
Vicenza		VI	45.548	11.546	3
Claut		PN	46.267	12.515	2-3
Bologna		BO	44.494	11.343	2
Firenze		FI	43.773	11.257	2
Marmirolo		MN	45.220	10.756	2
Abano Terme		PD	45.360	11.790	F
Appiano sulla Strada del Vino (San Michele)	MS	BZ	46.454	11.263	F

Arcella		PD	45.424	11.872	F
Bolzano		BZ	46.499	11.352	F
Borgo Valsugana		TN	46.052	11.458	F
Brez		TN	46.431	11.107	F
Caldaro sulla Strada del Vino		BZ	46.412	11.242	F
Camposampiero		PD	45.568	11.932	F
Cavalese		TN	46.291	11.460	F
Crespino		RO	44.982	11.885	F
Pieve Tesino		TN	46.069	11.608	F
Rovereto		TN	45.888	11.037	F
San Nazario		VI	45.839	11.691	F
San Pietro in Cariano		VR	45.520	10.887	F
Stienta		RO	44.940	11.544	F
Thiene		VI	45.707	11.478	F
Trissino		VI	45.564	11.371	F
Venezia		VE	45.438	12.336	F

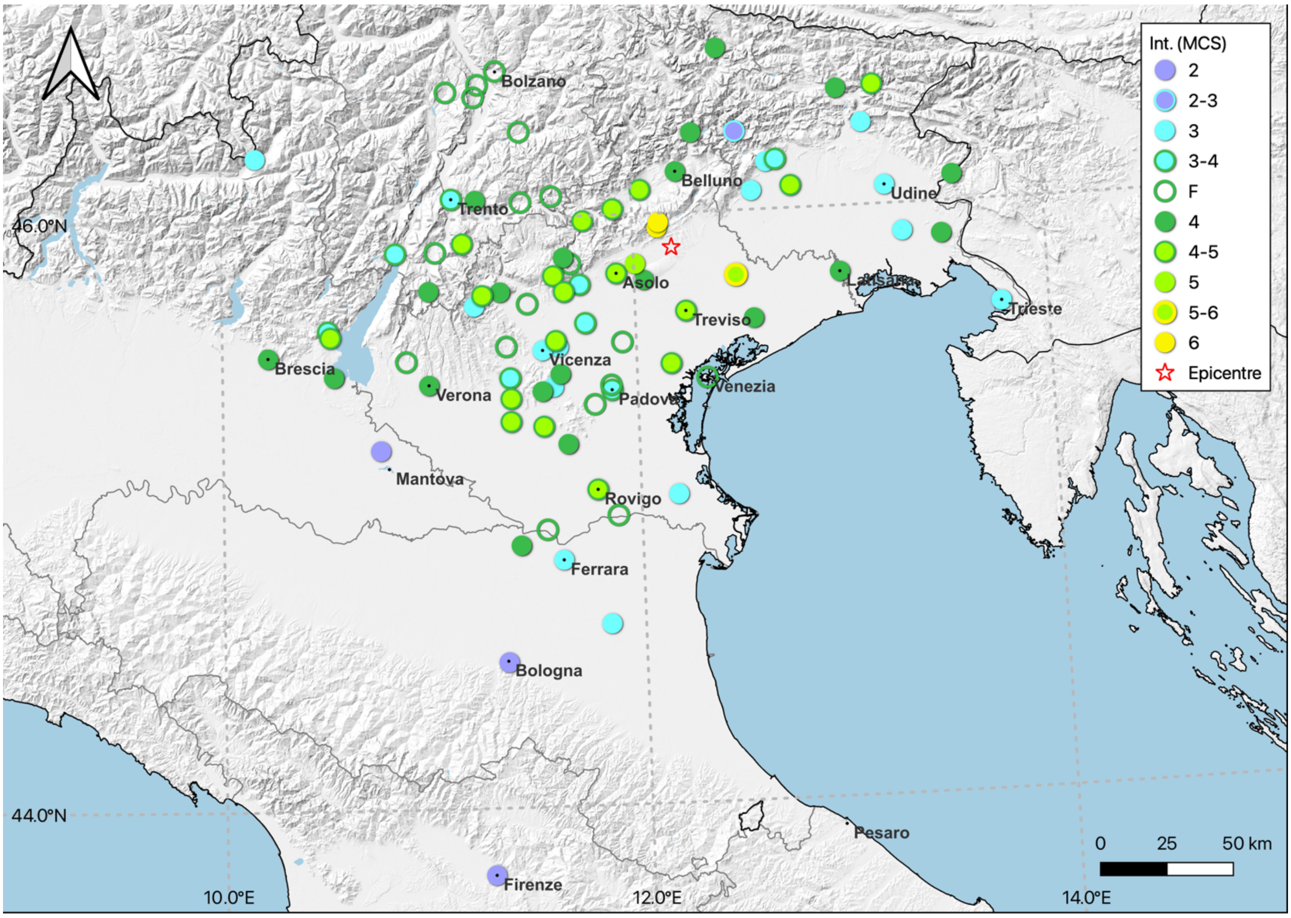


Figure 39. *Macroseismic intensity distribution map of the 6 June 1895 earthquake; the red star indicates the macroseismic epicentre in Baranello et al. [2024].*

6.2.2.1 RESULTS

The level of investigation of these earthquakes, which belong to the category of moderate energy earthquakes, is very high and, for most of them, substantially conclusive.

The most significant findings, which were achieved through the discovery of original sources and testimonies, involve the re-evaluation of maximum intensity estimates (Ix) and an overall increase in the number of documented localities (Mdps), as illustrated in Table 9 for the main shocks. Specifically, in four cases (1711, 1719, 1756, and 1859), there was an increase in the degree of intensity; in two cases (1860, 1895), the value remained unchanged; and in the case of 1857, there was a slight decrease from 4-5 to 'F'.

With regard to the Mdps, on the other hand, apart from the 1857 earthquake for which there is no difference, the number increased in all the cases considered, varying from a minimum of 1 to a maximum of 14.

			CPTI15			**BARAN024**	
Data	**Ora**	**Area**		**Mdps**	**Ix**	**Mdps**	**Ix**
1709.11.07	17:00	--	--	--	--	5	6
1711.05.20	22:30	Vicentino	CAMAL012	2	4	3	5
1719.01.07	19:40	Italia nord-orientale	CAMAL011	11	5-6	12	6
1756.04.13	11:56	Treviso	AMGNDT095	1	6-7	9	7-8
1857.03.10	3:00	Prealpi Trevigiane	MOLAL008	4	4-5	4	F
1859.01.20	7:55	Prealpi Trevigiane	AMGNDT095	36	6	42	7-8
1860.07.19	15:38	Prealpi Trevigiane	ALBI001	10	6-7	12	6-7
1895.06.10	01:48	Prealpi Trevigiane	AMGNDT095	73	6	87	6

Table 9. *Numerical comparison between the data used by the CPTI15 catalogue and those derived from Baranello [2024].*

The new epicentral parameters (epicentral location and magnitude) for each earthquake considered were then calculated using the BOXER code [Gasperini et al., 2010] (Tab. 10).

Year	Mo	Da	Ho	Mi	Epicentral area	Mdps	Lat	Lon	Io	Mw
1709	11	7	17	--	Cadore	5	46.099	12.291	6	5.13
1711	5	20	22	30	Trevigiano	3	45.551	12.042	5	3.93
1719	1	7	19	40	Friuli	12	45.553	12.29	6	5.01
1756	4	13	11	56	Treviso	9	45.666	12.245	7-8	4.99
1857	3	10	3	--	Prealpi Trevigiane	4	45.726	12.188	F	4.04
1859	1	20	7	55	Prealpi Trevigiane	42	45.889	12.112	7-8	5.11
1860	7	19	15	38	Prealpi Trevigiane	12	45.906	12.027	6-7	4.91
1895	6	10	1	48	Prealpi Trevigiane	87	45.883	12.186	6	4.9

Table 10. *Parameters of the earthquakes considered in this study, determined from macroseismic data using BOXER [Gasperini et al., 2010].*

A number of more detailed studies could be carried out with several objectives in mind: to verify various indications of possible damage in the areas of Belluno and Cadore for the earthquake of November 1709; to identify, through complex research in local archives, the areas in Friuli where damage was likely to have occurred in the earthquake of January 1719; to acquire evidence of administrative documentation of damage in Treviso in the earthquake of 1756.

At the same time, however, some traces of earthquakes between the end of the 14th century and the middle of the 16th century remain unexplored, events which, if confirmed, could significantly improve the seismic history of Treviso and the main localities in the area. These considerations are intended to underline how significant the margins of improvement in the knowledge of the seismic history of the different areas of our country still are.

7 CONCLUSIONS

The principal objective of the present doctoral research was to analyse historical earthquakes from a historical seismology perspective. This was done with the aim of reconstructing the seismic evolution of specific geographical areas and improving the understanding of seismic hazard over a long period. In particular, the historical seismicity of the Emilian Po Valley and the Veneto pre-Alps was examined, with a specific emphasis on moderate-to-intermediate-energy earthquakes within the 16th to 20th century time period. While these seismic events do not always result in significant destruction, they are of paramount importance for elucidating the tectonic dynamics of these regions, which are characterised by a complex and incomplete seismic history.

One of the principal outcomes of the research was the enhancement of historical seismic cataloguing, achieved through a critical re-examination of archival sources and the incorporation of previously unconsidered information.

This has enabled the identification of previously unrecorded historical events and the enhancement of existing data on documented earthquakes. This has resulted in more precise information (date, location, magnitude) and a deeper comprehension of seismic occurrences that were previously underestimated or overlooked. As a result, it has become possible to reconstruct the seismic effects and their consequences on human settlements, infrastructure and the natural environment with greater accuracy.

Despite the numerous studies that have been conducted, there is still considerable scope for further research into the seismic activity of the national territory. This is particularly the case for certain historical periods, for which analysis of the completeness of the data reveals gaps in our knowledge (for example, before the mid-17th century and the first decades of the 19th century), or even loss of information. Indeed, historical research on earthquakes reveals significant challenges in preserving information about minor seismic events, particularly those near the damage threshold (6 MCS), which are crucial for seismic hazard assessments. Incomplete seismic catalogues can significantly impact hazard assessments in several ways. The Italian catalogue, despite being one of the world's richest, shows considerable spatial and temporal heterogeneity in its completeness. Historical records demonstrate significant regional disparities, with Northern Italy having completeness dating back to 1400-1600, while Southern Italy only reaches back to 1700-1800 for major events. Several factors contribute to these gaps: competing historical phenomena, such as wars and epidemics, and geographical isolation, particularly in mountainous or rural areas of southern Italy. The 'urban fixation', a tendency to prioritize the documentation of events in urban areas over those in rural regions, and the uneven distribution of journalistic networks, have compounded this issue, leading to the under-recording of minor seismic events.

An example is the emergence of unknown earthquake traces in Emilia following the investigations conducted after the 2012 seismic events. Despite not being destructive earthquakes, these traces provide invaluable data for enhancing hazard studies. Indeed, while seismic hazard and risk assessment are traditionally determined by the occurrence of strong earthquakes, the most recent hazard models increasingly incorporate information related to intermediate and moderate-energy earthquakes. Indeed, when such events occur repeatedly over time, they can cause considerable damage, particularly in regions with a rich architectural heritage. The vulnerability of buildings that have not been adequately designed to withstand seismic events, coupled with the frequency of such earthquakes, underscores the necessity of incorporating these events into seismic risk planning.
The necessity for enhanced hazard assessments based on more up-to-date basic data is also corroborated by the recognition of the significance of the seismic activity in these two regions, that is the foundation for the formulation of updated hazard maps, which can inform local and regional risk mitigation strategies. Indeed, these are two particularly significant industrial and handicraft districts, characterised by a high level of exposure, reflected in the density of the settlement and population network, and a substantial economic weight.
For the areas examined in this study, a 'qualitative' hazard assessment was carried out without simulating the acceleration values estimated from the macroseismic data. This assessment has been carried out for the cities of Modena and Treviso, which have been taken as the composing cities for the two areas of interest, on the basis of the seismic history of the two cities. In order to do this we always start from the DBMI15 database.
As far as Modena is concerned, 159 effects of earthquakes with intensities ranging from 2 to 7-8 MCS were recorded in the DBMI15. In particular, about one hundred effects with Is ≥ 4 were recorded, of which about sixty with Is > 4. If we consider instead effects with Is ≥ 5, the number is reduced to only 48, with about 20 effects with Is ≥ 5-6.
In this instance, the augmentation of data is not substantial. Indeed, while two events affecting the city of Modena (1607 and 1761) have been incorporated, the 1608 earthquake has been excluded. In the case of 1501, the report is already present in the catalogue, and the 1639 event is not considered to have affected the city, although it is plausible that it was at least felt.
In the case of Treviso, a total of 64 seismic events with a maximum intensity of 6-7 MCS were recorded. Of these, about thirty with Is ≥ 4 and only nine with Is ≥ 5-6.
Regarding this study, 18 of all the earthquakes analysed - taking into account all the events that affected the Veneto region, and considering both main events and foreshocks and aftershocks - had a resonance here, eight of which are 'new' effects for this city.

For the other ten earthquakes, all of which are already known, a general variation in intensity can be observed. In particular, in three cases (1857, 1860, 1900) this value decreased by at least half a degree, while in six others (1719, 1756, 1859, 1887, 1897, 1919) it increased, albeit only slightly. However, only in one case, that of 1895, did the assigned intensity coincide with that of the previous study [Archivio Macrosismico GNDT, 1995 (AMGNDT995)] used as a reference in CPTI15 and DBMI15. A particular case is 1919, for which we change from ‘F’, i.e. felt (= 3.9 MCS), to a numerical value (4 MCS), which somewhat improves the evaluation of the effects without actually changing the result. Looking at the tables 7 and 10 with the contributions of thestudies by Baranello [2023] and Baranello et al. [2024], respectively, discussed in this thesis, one can certainly observe a general revaluation of the intensity values, a consolidation of the seismic history of Treviso and an improvement in the historical completeness of the data, for example, for the 1700s, where the number of observations increased from 2 to 6.

This is no small achievement, because by extending the observation window or, as in this case, increasing the number of observations, one gets a much better defined picture of the city’s seismic history, and the knowledge base is much richer.

Information on the effects in Treviso before 1695 is still very scarce, although traces of earthquakes have been found in the 16th century, but these are not the subject of this study.

The effects recorded in the seismic history are in fact a representation of the hazard characteristics of that site.

If the characteristic seismicity is that of an earthquake that generally produces effects around MCS 6 (light damage), the fact that the seismic history has been further populated with such data strengthens and consolidates the general picture of the hazard of the area under consideration, which depends mainly on the frequency of occurrence of tremors with certain characteristics.

It was thus decided to undertake a systematic review of the ‘minor’ seismicity of the two regions, commencing with earthquakes that had been documented by expeditious studies and, as a consequence, not subjected to in-depth analysis or incorporated into the seismological tradition. The resulting detailed records represent a contribution to updating the catalogue.

In particular, a total of 55 earthquakes were subjected to review, encompassing the principal events, the aftershocks, and finally those identified in the course of this study. Of these, 13 occurred in the Modena-Ferrara area, 23 in the Asolo area, and 19 in the Treviso area.

The most significant findings of this study, resulting from the discovery of original sources and testimonies, pertain:

- **Parameterisation of new earthquakes**. Five new earthquakes close to the damage threshold were found and parameterised. Specifically: 20 April 1639 (Io 6-7), 15 December 17611 (Io 5), 5 November 1778 (Io D), 11 June 1897 (Io 5), and 7 November 1709 (Io 6).

- **Intensity (Ix) and localities affected (Mdps)**. In almost all cases there has been a reassessment of the original intensity estimates, and of the number of localities where effects were documented. Focusing on the 18 main earthquakes that have been parameterized—excluding the five newly identified events—there is a revision in intensity estimates: nine cases show an increase, five a decrease, and four remain unchanged. Regarding the number of documented locations (Mdps), 14 cases exhibit an increase, two a decrease, and in two instances, no change was observed. In both instances, there is a clear improvement in the estimates, which are now more accurate.

- **Epicentral parametres**. In light of the revised geographical distribution of macroseismic intensities, the epicentral parameters (epicentral location and magnitude) for each of the main earthquake have been calculated using the BOXER code [Gasperini et al., 2010]. Tables 11, 12 and 13, which relate respectively to the Emilia, Asolo and Treviso earthquakes, compare the epicentral values of the earthquakes analysed. These tables compare the data from the CPTI15 catalogue with those obtained in the present study. This comparison demonstrates a general variation in both epicentre location and magnitude estimates. While underscoring an enhancement in the available information, the outcomes substantiate that these seismic occurrences persist in maintaining a moderate intensity with respect to the energy they release.

						CPTI15			Present Study		
Year	**Mo**	**Da**	**Ho**	**Mi**	**Epic. area**	**Lat**	**Lon**	**Mw**	**Lat**	**Lon**	**Mw**
1501	06	05	10	00	Modenese	44.519	10.844	6.05	44.511	10.864	6.1
1607	12	31	23	45	Modenese	44.698	10.631	4.16	44.709	10.814	4.63
1608	01	06	22	20	Modenese	44.698	10.631	4.40	44.698	10.631	4.63
1639	04	06	21	00	Finale Emilia	44.833	11.294	5.33	44.781	11.172	4.86
1639	04	20	16	15	Finale Emilia	-	-	-	44.887	11.065	4.40
1761	12	15	21	45	Rovereto s. S.	-	-	-	44.835	10.975	3.7
1778	05	11	03	00	Carpigiano	-	-	-	44.846	10.939	4.35

Table 11. *Comparison of the epicentral parameters of the earthquakes considered between the CPTI15 catalogue and this study.*

						CPTI15			Present Study		
Year	**Mo**	**Da**	**Ho**	**Mi**	**Epic. area**	**Lat**	**Lon**	**Mw**	**Lat**	**Lon**	**Mw**
1861	05	19	-	-	Asolano	45.736	11.920	4.63	45.736	11.920	4.16
1887	3	29	08	58	Marostica	-	-	-	45.745	11.690	4.16
1887	04	14	02	15	Asolano	45.822	11.860	4.82	45.823	11.890	4.53
1897	06	11	12	45	Asolano	45.859	12.002	4.44	45.776	12.030	4.51
1897	6	11	13	0	Asolano	-	-	-	45.846	12.095	4.41
1900	03	04	16	55	Asolano	45.849	12.067	5.05	45.600	11.962	4.82
1919	07	12	12	06	Asolano	45.801	11.914	5.03	45.735	12.079	4.22
1921	09	12	00	25	Asolano	47.771	11.768	4.81	45.724	11.985	4.14

Table 12. *Comparison of the epicentral parameters of the earthquakes considered between the CPTI15 catalogue and this study.*

						CPTI15			Present Study		
Year	**Mo**	**Da**	**Ho**	**Mi**	**Epic. area**	**Lat**	**Lon**	**Mw**	**Lat**	**Lon**	**Mw**
1709	11	7	17	--	Cadore	-	-	-	46.099	12.291	5.13
1711	5	20	22	30	Trevigiano	45.548	11.546	3.70	45.551	12.042	3.93
1719	1	7	19	40	Friuli	46.123	11.991	4.94	45.553	12.29	5.01
1756	4	13	11	56	Treviso	45.666	12.245	4.86	45.666	12.245	4.99
1857	3	10	3	--	Prealpi Trev	45.726	12.188	4.04	45.726	12.188	4.04
1859	1	20	7	55	Prealpi Trev.	4.5.893	12.103	4.80	45.889	12.112	5.11
1860	7	19	15	38	Prealpi Trev.	45.889	12.146	4.92	45.906	12.027	4.91
1895	6	10	1	48	Prealpi Trev.	45.943	12.073	4.85	45.883	12.186	4.9

Table 13. *Comparison of the epicentral parameters of the earthquakes considered between the CPTI15 catalogue and this study.*

- **Total number of earthquakes**. Increase in the number of foreschocks and aftershocks , which in some cases had not been considered at all. In particular, the total number of earthquakes in the Modena area increased from six to 13, those in the Asolo area rose from seven to 23, and those in the Treviso area increased from eight to 19.

- **Expanding the research to new areas**. Ultimately, the implementation of the methods of historical seismological investigations in other regions of Italy, or globally, would enhance the comprehension of the impacts and dynamics of intermediate-magnitude seismic events.

References

Corriere della Sera [Milano], 1895.06.11-12.

[Gazette d'] Amsterdam, 1711.06.05.

[Gazzetta di] Bologna, 1719.01.17.

[Gazzetta di] Mantova, 1711.05.28.

[Gazzetta di] Mantova, 1761.12.25.

[Gazzetta di] Mantova, 1857.03.

Gazzetta Piemontese [Torino], 1857.03.

Gazzetta del Popolo [Torino], 1857.03.

Gazzetta Uffiziale di Venezia, 1857.03.

Gazzetta Uffiziale di Venezia, 1860.07.20.

Gazette de Leyde, 1762.01.15.

Il Cittadino di Brescia, 1900.03.06.

Il Corriere Ordinario, 1709.11.20.

Il Corriere Ordinario, 1711.06.03.

Il Diavoletto, giornale triestino, 1857.03.

Il Gazzettino, prov. Di Vicenza, 1900.03.07.

Il Gazzettino giornale del Veneto [Treviso], 1919.07.13.

Il Gazzettino giornale del Veneto [Treviso], 1921.09.13.

Il Giornale di Udine, 1900.03.05.

Il Messaggero [Roma], 1900.03.05.

Il Messaggero Veneto, 1900.03.11.

La Patria del Friuli, 1900.03.05.

La Stampa [Torino], 1900.03.05-06.

L'Avvenire [Bologna], 1900.03.05.

The London Gazette, 1756.05.08-11.

AAMoNo [Archivio Arcidiocesi di Modena-Nonantola], (1639). Visite Pastorali, 24, c. 33v.

Agamennone G., (1897). Notizie sui terremoti osservati in Italia durante l'anno 1897. Bollettino della Società Sismologica Italiana, III, Modena.

Albarello D., Camassi R., Rebez A., (2001). Detection of space and time heterogeneity in the completeness of a seismic Catalog by a statistical approach: An application to the Italian area, Bulletin of the Seismological Society of America, 91, 6, 1694-1703, doi: 10.1785/0120000058

Albini P., (2001). Studio preliminare di alcuni terremoti di energia medio-bassa nell'area di Vittorio Veneto (sec. XIX). Milano.

Albini P., Migliavacca P., Moroni A. (2003). Studio di alcuni terremoti di intensità epicentrale moderata in Italia settentrionale. Istituto Nazionale di Geofisica e Vulcanologia (INGV), Milano, 58 pp. + appendices.

Aleotti A., (1916). Storia della città e provincia di Reggio nell'Emilia. Reggio Emilia.

Ancini C., (XVII). Raccolta di varie cose della Città di Reggio, [Origini-1665], Biblioteca Panizzi di Reggio Emilia, Manoscritti Reggiani, C. 62.

Archivio Macrosismico GNDT, (1995). Studi preliminari di terremoti attraverso i repertori sismologici. Archivio macrosismico del GNDT (AMGNDT), Milano.

Arpa Ingegneria Ambientale, (2007). Rilievo della subsidenza nella pianura emiliano-romagnola. Analisi interferometrica, https://www.arpae.it/it/temi-ambientali/suolo/rapporti/rapporti-subsidenza/rilievo-subsidenza-nella-pianura-emiliano-romagnola-analisi-interferometrica/view

Arpa Ingegneria Ambientale, (2011). Rilievo della subsidenza nella pianura emiliano-romagnola, Prima Fase, http://www.arpa.emr.it/cms3/documenti/subsidenza/Relfin_2011.pdf.

Bagni B., (XVIII). Raccolta degli annali del padre Bagni Biagio dal 752 al 1759 per cura del padre Antonio Tosi, Archivio Storico Comunale di Cento.

Balboni M.P., (2005). Gli ebrei del Finale nel Cinquecento e nel Seicento, Firenze.

Banorri A., (2000). Montese e suo territorio. Formigine.

Baranello S., (2023). Materiali per un catalogo dei terremoti italiani. Terremoti "minori" dell'Asolano (1861-1921). Quad. Geofis., 186: 1-158, https://doi.org/10.13127/qdg/186

Baranello S., Camassi R., Castelli V., (2024). Materiali per un catalogo dei terremoti italiani. Terremoti del Trevigiano e Bellunese tra '700 e '900. Quad. Geofis., 1-113 (accepted in December 2024).

Baratta M., (1895). Notizie sui terremoti osservati in Italia durante l'anno 1895, compilate da M. Baratta, 1895. Appendice al Bollettino della Società Sismologica Italiana.

Baratta M., (1897). Materiali per un catalogo dei fenomeni sismici avvenuti in Italia (1800-1872). Memorie della Società Geografica Italiana, 7, Roma, pp. 81-164.

Baratta M., (1899). Saggio dei materiali per una storia dei fenomeni sismici avvenuti in Italia raccolti dal Prof. Michele Stefano De Rossi. Bollettino della Società Geologica Italiana, 18, pp. 432-460.

Baratta M., (1901). I terremoti d'Italia; saggio di storia geografia e bibliografia sismica italiana. Torino, p. 950.

Benedetti, L., P. Tapponnier, G. C. P. King, B. Meyer, Manighetti I., (2000). Growth folding and active thrusting in the Montello region, Veneto, northern Italy, J. Geophys. Res. 105, 739–766, doi: 10.1029/1999JB900222

Bennett R. A., Serpelloni E., Hreinsdóttir S., Brandon M. T., Buble G., Basic T., Casale G., Cavaliere A., Anzidei M., Marjonovic M., Minelli G., Molli G., Montanari A., (2012). Syn-convergent extension observed using the RETREAT GPS network, northern Apennines, Italy, J. Geophys. Res., 117, B04408, doi:10.1029/2011JB008744

Berti A., (1857). Sugli ultimi tremuoti di Venezia. Atti I.R. Istituto Veneto di Scienze Lettere e Arti. III, II, pp. 553-559.

Berti A., (1859). Nota sul terremoto di Venezia del 20 gennaio 1859, Atti del Regio Istituto Veneto, 1858-59, III, IV, 393-400.

Berti E., (1860). Sul terremoto di Venezia del 19 luglio 1860. Atti del Regio Istituto Veneto, serie III, vol. VI, pp. 65- 74.

Bittner A., (1874). Beiträge zur Kenntniss des Erdbebens von Belluno vom 29 Juni 1873. Sitzungsberichte der Wiener Akademie, m.-nw. Classe, LXIX, II, pp. 541-637.

Bollettino Mensuale, (1887). Bollettino Mensuale pubblicato per cura dell'Osservatorio Centrale del Real Collegio Carlo Alberto in Moncalieri. Torino, S. II, vol. VII.

Bollettino Meteorico Giornaliero, Ufficio Centrale di Meteorologia, Roma, [1887-1894].

Bullettino del Vulcanismo Italiano, (1890). Notizie ossia catalogi dei fenomeni endogeni, anno 1887. XVII, 81 pp.

Bullettino del Vulcanismo Italiano, Anno X (1883), pp. 67-68.

Bollettino Sismico Settimanale, n. 89, 1919.07.6-12.

Bollettino Sismico Settimanale, n. 204, 1921.09.18-23.

Bonito, M., (1691). Terra tremante. Napoli.

Bordoni, P., R. Azzara, F. Cara, R. Cogliano, G. Cultrera, G. Di Giulio, A. Fodarella, G. Milana, S. Pucillo, G. Riccio, A. Rovelli, P. Augliera, L. Luzi, S. Lovati, M. Massa, F. Pacor, R. Puglia, Ameri G., (2012). Preliminary results from EMERSITO, a rapid response network for site-effect studies, Annals of Geophysics, 55 (4); doi:10.4401/ag-6153

Bracchi F.A., (XVIII), Memorie della città di Reggio di Lombardia dall'origine al 1776, Biblioteca Panizzi" di Reggio Emilia, Manoscritti Reggiani, C.

Burrato, P., Ciucci, F., Valensise G., (2003). An inventory of river anomalies in the Po Plain, Northern Italy: evidence for active blind thrust faulting, Annals of Geophysics, 46(5). doi: 10.4401/ag-3459

Camassi R., (1991). Bollettini sismici e studio dei terremoti dei secoli XIX e XX, In: Albini P. e Barbano M. S. (eds.), GNDT, Atti del Convegno, Pisa, 25-27 giugno 1990, 2, Macrosismica, Bologna, 207-222.

Camassi R., Castelli V., Molin D., Bernardini F., Caracciolo C.H., Ercolani E., Postpischl L., (2011). Materiali per un catalogo dei terremoti italiani: eventi sconosciuti, rivalutati o riscoperti, Quaderni di Geofisica, 96, INGV, Roma, 51 + 391 pp.

Camassi, R., Castelli V., Serpelloni E., Pondrelli S., (2023). Reappraising the 25 February 1695 Asolano Earthquake, Seismol. Res. Lett. XX, 1–13, doi: 10.1785/0220230238

Camassi R., Caracciolo C.H., Castelli V., Ercolani E., Bernardini F., Albini P., Rovida A., (2012). Contributo INGV al WP2 del progetto HAREIA - Historical and Recent Earthquakes in Italy and Austria: Studio della sismicità storica del Friuli Venezia-Giulia, Veneto e Alto Adige. Rapporto finale, Istituto Nazionale di Geofisica e Vulcanologia (INGV), Bologna, 23 pp. + 5 Allegati

Camassi R., Pessina V., (2022). "Le autorità sono sul posto: la popolazione è calma". Il terremoto dell'Alpago Cansiglio del 18 ottobre 1936. Blog INGV Terremoti. https://ingvterremoti.com/2022/01/25/le-autorita-sono-sul-posto-la-popolazione-e-calma-il-terremoto-dellalpago-cansiglio-del-18-ottobre-1936/

Cancani A., (1901). Notizie sui terremoti osservati in Italia durante l'anno 1900. Appendice al Bollettino della Società Sismologica Italiana, VII, Roma. pp. 51-57.

Cavasino A., (1935). I terremoti d'Italia nel trentacinquennio 1899-1933. Memorie del Reale Ufficio Centrale di Meteorologia e Geofisica, Appendice, s. 3, vol. 4, 266 pp.

Cartoline sismiche, (1871-1900). Cartoline sismiche inviate all'Ufficio Centrale di Meteorologia e Geodinamica di Roma. Archivio dell'Ufficio Centrale di Ecologia Agraria (Roma), c.n.n.

Castelli V., Bernardini F., Camassi R., Caracciolo C., Ercolani E., Postpischl L., (2012). Looking for missing earthquake traces in the Ferrara-Modena plain: An update on historical seismicity. Annals of geophysics = Annali di geofisica. 55. 519-524. 10.4401/ag-6110

Castelli V., Camassi R., (2005). The shadow-zone of large Italian earthquakes. Early journalistic sources and their perception of 17th-18th centuries seismicity. Journal of Earthquake Engineering, 9, 3, 333-348.

Castelli V., Camassi R., (2006). A che santo votarsi. L'influsso dei grandi terremoti del 1703 sulla cultura popolare, in Settecento abruzzese. Eventi sismici, mutamenti economico-sociali e ricerca storiografica, R. Colapietra, G. Marinangeli and P. Muzi (Editors), Libreria Colacchi, L'Aquila, 107-130.

Ceretti F., (1890). Delle chiese, dei conventi e delle confraternite della Mirandola. In: Memorie storiche della città e dell'antico ducato della Mirandola, 8, Mirandola, 240 pp., p. 28, 29.

Crivellari G., (XIX). I terremoti a Bassano (1348-1894). Notizie e memorie estratte da storie e cronache locali, mss 30-C-2-13, Biblioteca Civica di Bassano del Grappa.

Cronaca di Modena, (XVII). Cronaca di Modena dalle origini di essa città al 1658. Biblioteca Estense e Universitaria di Modena, Manoscritti San Carlo, 18 (F.Y.2)].

Cronaca di Modena, (XVII). Cronaca di Modena dal 1466 al 1665 [Cronaca del sec. XVII, da attribuirsi forse a Lodovico Vedriani, contenente diverse notizie sugli avvenimenti modenesi] Biblioteca Estense e Universitaria di Modena, I.1735 =a H.10.33.

Cronache e notizie modenesi, (XVII-XVIII). Cronache e notizie modenesi, Manoscritto Sorbelli, ms Misc., Biblioteca Estense e Universitaria di Modena.

Crowley, H., Dabbeek, J., Despotaki, V., Rodrigues, D., Martins, L., Silva, V., Romão, X., Pereira, N., Weatherill, G., and Danciu, L.: European Seismic Risk Model (ESRM20), EFEHR Technical Report 002, V1.0.1, 84 pp., https://doi.org/10.7414/EUCEFEHR-TR002-ESRM20, 2021.

Danesi S., Pondrelli S., Salimbeni S., Cavaliere A., Serpelloni E., Danecek P., Lovati S., Massa M., (2015). Active deformation and seismicity in the Southern Alps (Italy): The Montello hill as a case study. Tectonophysics. 653. 10.1016/j.tecto.2015.03.028.

Del Negro F., (XVIII-XIX). Terremoti accaduti a Sutrio e notati dal M.R.D.n Francesco del Negro (1762-1803), in "Pagine Friulane", a. 3, n. 8 (21 settembre 1890), p. 136. Udine 1890.

De Rossi M.S., (1889). Documenti raccolti dal defunto conte Antonio Malvasia per la storia dei terremoti massimi d'Italia. Mem. Pont. Acc. Nuovi Lincei, 5: 169-289.

Diario familiare…, (XIX). Diario familiare dei Conti Pegolotti-Nuzzi dal 1763 al 1812. Di Gavioli F. – Marchesi G. Editore: Centro Studi Storici Nonantolani Data pubblicazione: Gennaio 1993 Biblioteca Estense e Universitaria di Modena

D'Orazi M., (2012). Terremoti avvenuti o percepiti a Carpi in base alle cronache storiche locali, dalle ricerche di Gianfranco Guaitoli e Luciana Nora (Barabba Elettrolibri), http://barabba-log.blogspot.it/2012/06/barabba-elettrolibri-terremoti-avvenuti.html

Estratto…, (XVIII). Estratto dal manoscritto intitolato "Libro che contiene varie memorie di me Francesco Caleffi" (15 settembre 1769 – 6 luglio 1791). Archivio Storico Comunale di Carpi, Archivio Guaitoli, n.224.

Faccioli E., (2013). Recent evolution and challenges in the Seismic Hazard Analysis of the Po Plain region, Northern Italy. The second Prof. Nicholas Ambraseys distinguished lecture. Bull Earthquake Eng (2013) 11:5–33 DOI 10.1007/s10518-012-9416-1

Ferrari G., Manenti E., Martinelli G., Postpischl D., (1985). The Modena earthquake of June 5, 1501, in Atlas of Isoseismal Maps of Italian Earthquakes, a cura di D. Postpischl, CNR-PFG, Quaderni de "La Ricerca Scientifica", vol. 114, 2A, Roma, pp.24-25.

Forni G., (XX). Appunti di memorie persicetane raccolte dal notaio Giovanni Forni, Biblioteca Comunale di San Giovanni in Persiceto, Manoscritti Forni, 1.

Frassoni C., (1752). Memorie Istoriche del Finale in Lombardia, Modena.

Frassoni C., (1778). Memorie del Finale di Lombardia, Modena.

Fulcis A., (1883). Note storiche sui terremoti nel Bellunese, raccolte dal reverendo Antonio Fulcis. Taramelli T., Note illustrative alla carta geologica della provincia di Belluno rilevata negli anni 1877-1881, 203-212.

Galadini F., Poli M. E., Zanferrari A., (2005). Seismogenic sources potentially responsible for earthquakes with M ≥ 6 in the eastern Southern Alps (Thiene-Udine sector, NE Italy), Geophysical Journal International, Volume 161, Issue 3, June 2005, Pages 739–762, https://doi.org/10.1111/j.1365-246X.2005.71

Gasperini, P., F. Bernardini, G. Valensise, and E. Boschi (1999). Defining seismogenic sources from historical earthquake felt reports, Bull. Seis-mol. Soc. Am. 89, 94–110.

Gasperini P., Vannucci G., Tripone D., Boschi E., (2010). The location and sizing of historical earthquakes using the attenuation of macroseismic Intensity with distance. Bull. Seism. Soc. Am., 100, pp. 2035–2066. https://doi.org/10.1785/0120090330

Gatti J., (XVIII). Storia di Cento dall'origine al 1795, Archivio Storico Comunale di Cento, Manoscritti, 1.3.27.

Ghidoni E., (2013). Terremoti mirandolesi. Quaderni della Bassa Modenese, Storia, tradizione, ambiente. 64, A. XXVII, 2, pp. 100-103.

Giacobazzi P., (XIX). Storia del territorio di Montese. Trascrizione dattiloscritta realizzata da Il Trebbo, Maserno, Montese (MO), p. 69.

Giornale del Massaro, (1608). Giornale del Massaro, 1608, I semestre. Archivio di Stato di Reggio Emilia, Comune di Reggio Emilia.

Goiran A., (1886). Appendici e note al Catalogo dei terremoti veronesi. Atti Accademia di Agricoltura Arti e Commercio di Verona, serie III, vol. 63, Verona, pp. 287-313.

Goiran A., (1892). Seconda Appendice al catalogo dei terremoti veronesi. Atti dell'Accademia di Agricoltura Commercio ed Arti di Verona, III, LXVII, pp. 14-15, Verona.

Gradenigo P., (XVIII). Notatori (1747-1774), Biblioteca del Museo Correr, ms Gradenigo Dolfin 67/III, c. 70v (13 aprile 1756).

Grünthal G., (ed.), (1998). European Macroseismic Scale 1998 (EMS-98). European Seismological Commission, sub commission on Engineering Seismology, Working Group Macroseismic Scales. Conseil de l'Europe, Cahiers du Centre Européen de Géodynamique et de Séismologie 15. Luxembourg.

Guidoboni E., Ferrari G., Mariotti D., Comastri A., Tarabusi G., Valensise G., (2007). CFTI4Med, Catalogue of Strong Earthquakes in Italy (461 B.C.-1997) and Mediterranean Area (760 B.C.-1500). INGV-SGA. https://storing.ingv.it/cfti/cfti4/

Guidoboni E., Ferrari G., Mariotti D., Comastri A., Tarabusi G., Sgattoni G., Valensise G., (2018). Historical earthquake data from the CFTI5Med catalogue - epicenter details [dataset]. PANGAEA, https://doi.org/10.1594/PANGAEA.896750.

Guidoboni E., Ferrari G., Tarabusi G., Sgattoni G., Comastri A., Mariotti D., Ciuccarelli C., Bianchi M.G., Valensise G., (2019), CFTI5Med, the new release of the catalogue of strong earthquakes in Italy and in the Mediterranean area, Scientific Data 6, Article number: 80 (2019). https://doi.org/10.1038/s41597-019-0091-9

Hoff K.E.A. von, (1840). Chronik der Erdbeben und Vulkan-ausbrüche. Geschichte der durch Uberlieferung nachgewiesenen natürlichen veränderungen der Erdoberfläche. Gotha, v. 4.

Iaccarino E., Molin D., (1978). Raccolta di notizie macrosismiche dell'Italia Nord-orientale dall'anno 0 all'anno 1976. CNEN - RT/DISP (78) 7.

IBC [Istituto per i Beni Artistici, Culturali e Naturali della Regione Emilia-Romagna], (2010). Madonna con Bambino in gloria con san Felice Cappuccino e san Francesco Solano, available online: http://bbcc.ibc.regione.emilia-romagna.it/samira/v2fe/loadcard.do?id_card=141922&force=1.

Infelise M., (2002). Prima dei giornali: alle origini della pubblica informazione, secoli 16 e 17, Roma-Bari, Laterza.

Ingrao G., (1927a). Macrosismi - Anno 1919. Bollettino Sismico, R. Uff. Centr. Meteor. E Geofisica, Roma.

Ingrao G., (1927b). Macrosismi - Anno 1921. Bollettino Sismico, R. Uff. Centr. Meteor. E Geofisica, Roma.

Ligorio P., (XVI). Libro di diversi terremoti, a cura di E.Guidoboni, Torino, 2005, volume 28, codice Ja.II.15

Livani M., Petracchini L., Benetatos C., Marzano F., Billi A., Carminati,E., Doglioni C., Petricca P., Maffucci R., Codegone,G., Rocca,V., Verga F., Antoncecchi I., (2023). Subsurface geological and geophysical data from the Po Plain and the northern Adriatic Sea (north Italy), Earth Syst. Sci. Data, 15, 4261–4293, https://doi.org/10.5194/essd-15-4261-2023, 2023.

Locati M., Camassi R., Rovida A., Ercolani E., Bernardini F., Castelli V., Caracciolo C.H., Tertulliani A., Rossi A., Azzaro R., D'Amico S., Antonucci A., (2022). Database Macrosismico Italiano (DBMI15), versione 4.0. Istituto Nazionale di Geofisica e Vulcanologia (INGV). https://doi.org/10.13127/DBMI/.4.

Mallet R., (1858). Fourth report upon the facts and theory of earthquake phenomena, Report of 28th Meet- ing of British Association for the Advancement of Science (John Murray, London), 1-136 (plate XI).

Massa M., Mascandola C., Ladina C., Lovati S., Barani S., (2017). Fieldwork on local-site seismic response in the Po Plain: examples from ambient vibration array and single station analyses. Bull Earthquake Eng 15, 2349–2366. https://doi.org/10.1007/s10518-016-0017-2

Memorie, (2012). Rivista del centro studi storici nonantolani, Volume 12/2012. Biblioteca Estense e Universitaria di Modena.

Memorie storiche…, (XVIII). Memorie storiche carpigiane dall'anno 1701 al 1796 notate nelle schede dell'avvocato Eustachio Cabassi indi raccolte ed ordinate da G.G. nel 1842. Archivio Storico Comunale di Carpi, Archivio Guaitoli, n.217.

Mercalli G., (1883). Vulcani e fenomeni vulcanici in Italia. Milano, 374 pp.

Mestriner G., (XVII-XVIII). Libro macaronico di Zuanne Mestriner. In: Moro M. (ed.), Libro macaronico di Zuanne Mestriner. Cronache di Treviso raccontate da un barbiere tra il 1682 e il 1731, Verona 2003.

Molin D., Bernardini F., Camassi R., Caracciolo C.H., Castelli V., Ercolani E., Postpischl L., (2008). Materiali per un catalogo dei terremoti italiani: revisione della sismicità minore del territorio nazionale. Quaderni di Geofisica, Vol. 57, 78 (+1444 pp. su CD-Rom).

Monteforti G.F., (XVIII). Storia della città di Cento [origini-1782], Archivio Storico Comunale di Cento, Manoscritti, 1.3.39-42.

Musson R.M.W., Grünthal G., Stucchi M., (2010). The comparison of macroseismic intensity scales. J. Seismol., 14. https://doi.org/10.1007/s10950-009-9172-0

Pellicelli G.D., (XVIII). Continuazione delle historie di Reggio (dal 1510 al 1700), Biblioteca Municipale A. Panizzi di Reggio Emilia, Manoscritti Reggiani, C.54.

Perrey A., (1848). Memoire sur les tremblements de terre de la peninsule Italique. Mem. Cour. et Mem. Sav. Ètran., Acad. R. des Sciences, Lettres et Beaux-Arts de Belgique, pp. 145. Bruxelles.

Perrey A., (1862). Note sur les tremblements de terre ressentis pour les annés 1859, Mémoires couronnés et autres mémoires publiés par l'Academie royale des sciences, des lettres et des beaux-arts de Belgique, VIII, XIII. Bruxelles.

Perrey A., (1864a). Note sur les tremblements de terre en 1861, avec suppléments pour les années antérieures [Séance du 10/1/1863]. Mémoires couronnés et autres mémoires, publiés par l'Académie royale des sciences, des lettres et des beaux-arts de Belgique, collection in-8°, t.16, juin 1864, p. 1-112.

Perrey A., (1864b). Note sur les tremblements de terre en 1862, avec suppléments pour les années antérieures [Séance du 9/1/1864]. Mémoires couronnés et autres mémoires, publiés par l’Académie royale des sciences, des lettres et des beaux-arts de Belgique, collection in-8°, t.16, juin 1864. (Supplément 1843-1861 p.9-106, année 1862, p.107- 179).

Piovene G., (1888). Cronaca dei terremoti a Vicenza, Ann. Uff. Centr. Meteo. e Geod., vol. VIII, ser. II, parte IV, 1886, Roma.

Poggi F., Poggi S., (1962). Marano sul Panaro dalle origini ad oggi. Modena.

Postpischl D., (1985). Catalogo dei terremoti italiani dall’anno 1000 al 1980. Quaderni della Ricerca Scientifica, 114, 2B, Bologna, 239 pp.

Reginus, (1880). Notizie di terremoti sentiti in Reggio dall’anno 1223 in avanti.Il Crostolo. Almanacco istoriografico reggiano per l’anno 1880, p.87, Reggio Emilia.

Rete sismica Nazionale website. https://www.mi.ingv.it/index.php/it/monitoraggio-sismologico/rete-sismica-nazionale#:~:text=La%20Rete%20Sismica%20Nazionale%20(RSN,e%20valutazione%20della%20magnitudo%20degli].

Ristretto…, (XVI-XVII). Ristretto dell’historia di Modena e del Frignano, ms. Sec. XVI-XVII Biblioteca Estense e Universitaria di Modena.

Rovida A., Locati M., Antonucci A., Camassi R. (a cura di), (2017). Archivio Storico Macrosismico Italiano (ASMI). Istituto Nazionale di Geofisica e Vulcanologia (INGV). https://doi.org/10.13127/asmi

Rovida A., Locati M., Camassi R., Lolli B., Gasperini P., Antonucci A., (2022). Catalogo Parametrico dei Terremoti Italiani (CPTI15), versione 4.0. Istituto Nazionale di Geofisica e Vulcanologia (INGV). https://doi.org/10.13127/CPTI/CPTI15.4

Rubini E., (XVII). Historia della città di Reggio de' suoi tempi (1584-1614). Biblioteca Municipale A. Panizzi di Reggio Emilia, Manoscritti Turri, C.123.

Ruspaggiari B., (XVIII-XIX). Cronaca di Reggio di Lombardia dal 1701 al 1741, continuata dall'anno 1742 al 1814 dal conte Gaetano Rocca, Mss. Turri C 15, Biblioteca Panizzi, Reggio Emilia]

Scarpa G., (1886). Terremoti avvenuti in Treviso. Annali dell'Ufficio Centrale di Meteorologia e Geodinamica, II, 8, 181.

Scarpa G., (1888). Terremoti avvenuti in Treviso. Allegato G di: Taramelli T., 1888. Relazione alla Reale Sottocommissione Geodinamica sulla distribuzione delle aree sismiche nell'Italia Superiore e Media, Ann. Uff. Meteorologico e Geodinamico It., s. 2a, 8, p. 4a, 1886, 181.

Setti S. M., (XVIII). Memorie di Crevalcore ed altre differenti raccolte e scritte da Stefano Maria Setti detto Genvina, Biblioteca Comunale di Crevalcore, ms. fol. 77.

Sieberg A., (1930). Geologie der Erdbeben. Handbuch der Geophysik, Gebrüder Bornträger, Berlin, vol. 2, pt 4, 550-555.

Spaccini G.B., (XVII). Cronaca di Modena (1603-1611), ed. E.P. Vicini, Modena 1919

Spagnolo G., (1907). I terremoti a Bassano (1348-1907). Boll. Museo Civ. di Bassano. A. IV, n. 2, 15 pp.

Stucchi M., (1993). Historical seismology and seismic hazard, Annals of Geophysics, 36(1). doi: 10.4401/ag-4314.

Stucchi, M., Albini, P., Mirto, C., Rebez, A., (2004). Assessing the completeness of Italian historical earthquake data. Annals of Geophysics 47, 28. https://doi.org/10.4401/ag-3330

Stucchi M., Meletti C., Bazzurro P., Camassi R., Crowley H., Pagani M., Pinho R., Calvi G., (2012). I terremoti del maggio 2012 e la pericolosità sismica dell'area: che cosa è stato sottostimato? (The earthquakes of May 2012 and the seismic hazard of the area: anything underestimated?). Progettazione Sismica.

Sugan M., Peruzza L., (2011). Distretti sismici del Veneto. Boll. Geof. Teor. Appl., 52, pp. 3–90. https://doi.org/10.4430/bgta0057

Tarabusi G., (2015). L'uso delle misure di microtremore per investigare le strutture tettoniche sepolte: il caso di studio dell'anticlinale di Mirandola. Tesi di dottorato. 1-136

Tommasi A., (1888). I terremoti nel Friuli dal 1116 al 1887. Annali dell'Ufficio Meteorologico e Geodinamico Italiano, s. 2a, 8, p. 184-205.

Tornini L., (XVIII). Delle origini, progressi, vicende e successivi dominij, nonché delle diverse serie de' varii soggetti in ogni arte e scienza più insigni della città di Carpi, 3 tomi. Archivio Storico Comunale di Carpi, Archivio Guaitoli, n. 246.

Trener G. B., (1903). I terremoti del Trentino, "Tridentum", Vi. Fasc. I. Marzo.

Un anno dopo il terremoto in Emilia", INGVterremoti, (2013). https://ingvterremoti.com/2013/05/20/un-anno-dopo-il-terremoto-in-emilia/

Vannoli P., Burrato P., Valensise G., (2015). The Seismotectonics of the Po Plain (Northern Italy): Tectonic Diversity in a Blind Faulting Domain. Pure and Applied Geophysics. 172. 1105-1142. 10.1007/s00024-014-0873-0.

Vera relatione del terremoto succeduto nella Provincia d'Abruzzo, & in particolare nella citta' dell'Aquila, terre dell'Amatrice, e Montereale. In Napoli, per Francesco Mollo, (1672). [British Library, London, 444.c.41.(4.)]

Visdomi A., (XVII). Alcune cose estratte dalli diarii di Messer Alfonso Visdomi, a cura di A. Malaguzzi Reggio Emilia 1881

Woolf S.J. (1973). Dal primo Settecento all'Unità. La storia politica e sociale. Storia d'Italia Einaudi, vol. III, Torino, 508 pp..

Zanon F.S., (1937). Storia sismica della provincia di Venezia, Annuario dell'Osservatorio Geofisico del

Seminario Patriarcale di Venezia, II, 10, 53-89.

Zatta A., Zuliani G., Pitteri G., (1782). L'Italia. Venezia, 1782. David Rumsey Historical Map Collection

Zuccari C., Vignaroli G., Viola G., (2021). Geological map of the San Donato – Costa Thrust Zone, Belluno Thrust System, eastern Southern Alps (northern Italy), Journal of Maps, 17:2, 337-347, DOI: 10.1080/17445647.2021.1946444.