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Data Descriptor

The 1688 Sannio–Matese Earthquake: A Dataset of Environmental Effects Based on the ESI-07 Scale

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Abstract: The 1688 Sannio–Matese earthquake, with a macroseismically derived magnitude of M_w = 7 and an epicentral intensity of I_{MCS} = XI, had a deep impact on Southern Italy, causing thousands of casualties, extensive damage and significant environmental effects (EEEs) in the epicentral area. Despite a comprehensive knowledge of its economic and social impacts, information regarding the earthquake's environmental effects remains poorly studied and far from complete, hindering accurate intensity calculations by the Environmental Seismic Intensity Scale (ESI-07). This study aims to address this knowledge gap by compiling a thorough dataset of the EEEs induced by the earthquake. By consulting over one hundred historical, geological and scientific reports, we have collected and classified, using the ESI-07 scale, its primary and secondary EEEs, most of which were previously undocumented in the literature. We verified the historical sources regarding some of these effects through reconnaissance field mapping. Analysis of the obtained dataset reveals some primary effects (surface faulting) and extensive secondary effects, such as slope movements, ground cracks, hydrological anomalies, liquefaction and gas exhalation, which affected numerous towns. These findings enabled us to reassess the Sannio earthquake intensity, considering its environmental impact and comparing traditional macroseismic scales with the ESI-07. Our analysis allowed us to provide an epicentral intensity ESI of I = X, one degree lower than the published I_{MCS} = XI. This study highlights the importance of combining traditional scales with the ESI-07 for more accurate hazard assessments. The macroseismic revision provides valuable insights for seismic hazard evaluation and land-use planning in the Sannio–Matese region, especially considering the distribution of the secondary effects.

Keywords: 1688 Benevento earthquake; historical seismicity; earthquake environmental effects; macroseismic intensity; Southern Apennines (Italy); ESI-2007 scale

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1. Introduction

The Sannio–Matese area (Southern Italy) (Figure 1) is one of the most seismically active zones in the Southern Apennines, characterized by historical seismicity of high energy focused along NW-SE-trending faults, e.g., [1–7] and by low-to-medium energy seismic swarms across structures transverse to the chain in more recent times, e.g., [8–11]. In a tectonically complex area such as the Southern Apennines, studying historical earthquakes is crucial to better understand the seismotectonic framework and seismic hazard of the area.

Among the various earthquakes that have historically struck the area, the one on 5 June 1688 stands out as noteworthy, with an intensity of XI on the Mercalli–Cancani–Sieberg (MCS) scale and a magnitude of $M_w = 7$ [12,13].

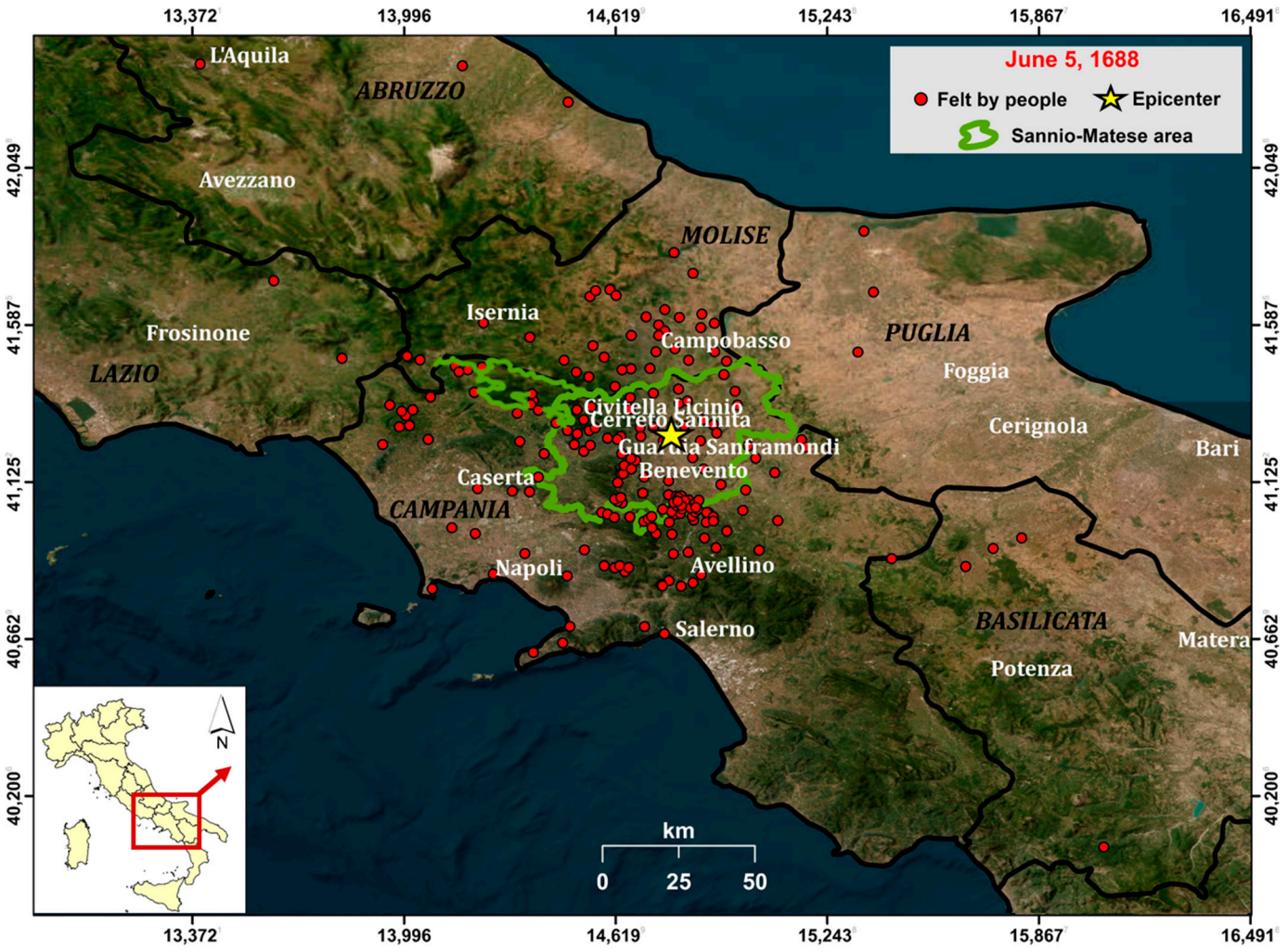

Figure 1. The area affected by the earthquake of 5 June 1688, including 6 current regions. The red points represent the 1688 reports of being felt and the yellow star is the epicenter of the 1688 earthquake from the CFTIMed catalog [14].

This earthquake is especially significant due to its catastrophic impact and extensive damage. The main shock was felt around 20:30 (CET, Central European Time) over an area of approximately 83,000 km^2, causing thousands of deaths and the total or partial destruction of numerous villages located in six different current regions (Campania, Basilicata, Puglia, Molise, Lazio and Abruzzo) (Figure 1). The most destructive effects were recorded in the Sannio area (Campania), where the most affected towns were Cerreto Sannita, Civitella Licinio and Guardia Sanframondi, experiencing nearly total destruction and a high number of fatalities despite their modest demographic size. Cerreto Sannita, identified as the epicenter of the earthquake (Figure 1) because of its total destruction, required rebuilding in a different location, e.g., [1,14].

The seismic event was characterized by various earthquake environmental effects (EEEs), both primary (such as surface faulting) and secondary (such as slope movements, hydrological anomalies, liquefaction, ground cracks and gas emissions). While there is a comprehensive and detailed overview of the damage to civil, public and ecclesiastical

buildings [1,12,14], the knowledge of the environmental effects induced by this earthquake is quite scarce.

EEEs are essential for determining the macroseismic intensity of an earthquake, especially when dealing with historical seismic events [15,16]. This is because damage assessments from historical events often mainly reflect the historical cultural and economic development of the affected area (e.g., building materials, construction practices) rather than the actual energy of the earthquake. Consequently, relying solely on structural damage data can lead to incomplete and inaccurate insights into the area's seismic–tectonic framework and long-term seismic hazard potential.

For these reasons, in 2007, the Environmental Seismic Intensity (ESI-07) scale was introduced by the International Union for Quaternary Research (INQUA) [15].

This 12-degree scale is based primarily on the study of EEEs, but does not aim to replace traditional macroseismic scales, which generally exclude EEEs in intensity assessments; instead, it aims to integrate them to provide a framework as complete as possible.

This scale collects and catalogs all the EEEs, both primary and secondary, to assess both epicentral (*I*) and local earthquakes intensities [17–19]. Specifically, the surface fault parameters and secondary effect distribution areas serve as independent criteria for evaluating *I*, as demonstrated by a standardized epicentral intensity evaluation table proposed by the INQUA Group (Figure 2a) [15]. This table was developed based on surface fault parameters and intensity data from over 400 global shallow crustal earthquakes [15]. On the other hand, the local intensity of an earthquake is typically assessed by evaluating the sum of all the secondary effects that affected a single locality, each one occurring within a diagnostic range of intensity degree (Figure 2b), although primary effects, such as fault displacement, can also contribute (Figure 2c). For a more detailed description of the expected effects for each single degree of intensity, refer to Michetti et al. [15] and Silva et al., [17]. Over the years, several studies have shown that this scale provides a useful and effective approach for reassessing the macroseismic intensities of historical earthquakes and for delimiting and constraining the seismogenic source of seismic events, e.g., [20–27]. These studies highlighted that ESI-07 values are more complete because they are constrained by local geology, geotechnical conditions and site morphology.

In this context, the goal of our paper is to collect and catalog the EEEs related to the 1688 historical earthquake. This work has been previously and partially performed by several authors, including Serva [1], Boschi et al. [28] and Serva et al. [21], who, although not focusing exclusively on the collection of environmental effects, documented approximately twenty environmental effects near the epicentral area. These effects are also reported in the Catalogue of strong earthquakes in Italy (461 BC-1997) and in the Mediterranean area (760 BC-1500) (CFTI5Med) [14]. Starting with these catalogs, we consulted various historical sources, geological reports and scientific articles at various libraries, state archives and local offices. This work has allowed us to identify and collect new environmental effects, both primary and secondary, significantly improving the knowledge of the 1688 earthquake.

This study enabled us to create a dataset containing about 20 previously unreported EEEs, which was used to reassess the intensity of the seismic event using the ESI scale guidelines. All these data are useful for redefining the seismic hazard of the area and potentially predicting which zones are most susceptible to experiencing effects during an earthquake similar to the one that occurred in 1688.

(a)

I_0 Intensity	PRIMARY EFFECTS		SECONDARY EFFECTS
	Surface Rupture Length	Max Surface Displacement / Deformation	Total Area
IV	-	-	-
V	-	-	-
VI		-	-
VII	(*)	(*)	10 km²
VIII	Several hundreds meters	Centimetric	100 km²
IX	1- 10 km	5 - 40 cm	1000 km²
X	10 - 60 km	40 - 300 cm	5000 km²
XI	60 – 150 km	300 –700 cm	10000 km²
XII	> 150 km	> 700 cm	> 50000 km²

(b)

	Environmental effects	Diagnostic range of intensity degrees	
	SURFACE FAULTING AND DEFORMATION	VIII (*)	XII
A	HYDROLOGICAL ANOMALIES	IV	X
B	ANOMALOUS WAVES/TSUNAMIS	IV	XII
C	GROUND CRACKS	IV	X
D	SLOPE MOVEMENTS	IV	X
E	TREE SHAKING	IV	XI
F	LIQUEFACTIONS	V	X
G	DUST CLOUDS	VIII	VIII
H	JUMPING STONES	IX	XII

(c)

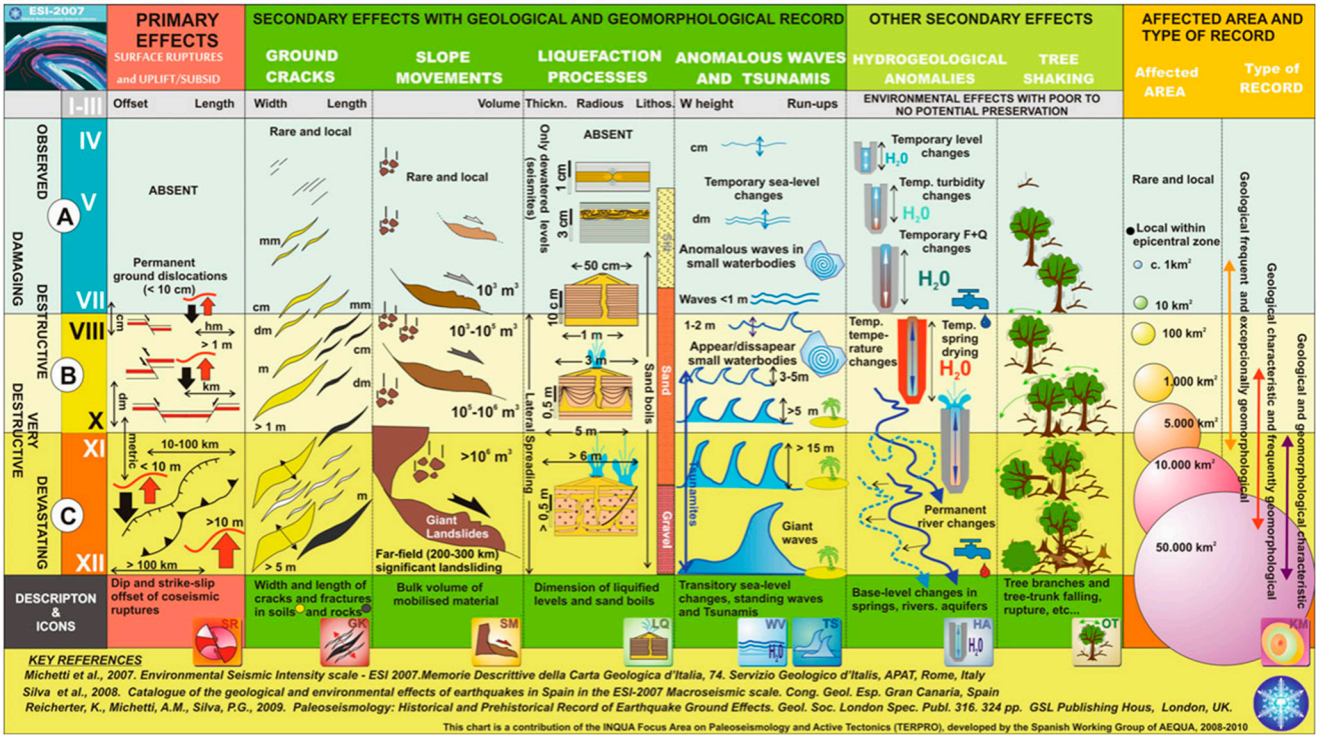

Figure 2. Guideline tables from Michetti et al. [15] for evaluation of (**a**) epicentral intensity: ranges of surface faulting parameters (primary effects) and typical extents of total area of secondary effects for each intensity degree; (**b**) local intensity: diagnostic criteria for assigning intensity degrees based on environmental effect classes. (**c**) Chart illustrating main features and size parameters of macroseismic ESI scale for different intensity degrees, from Silva et al., [17].

2. Data Description

The dataset is a collection of 43 EEEs (Figure 3) triggered by the Sannio–Matese earthquake, derived from our investigation of historical and recent reports and papers. We assessed EEE local intensities ranging between V and IX for 23 municipalities based on the primary and secondary effects that occurred (5% surface faulting, 12% surface faulting/ground cracks, 30% slope movements, 19% ground cracks, 23% hydrological anomalies, 7% gas exhalation, 2% jumping stones, 2% liquefaction).

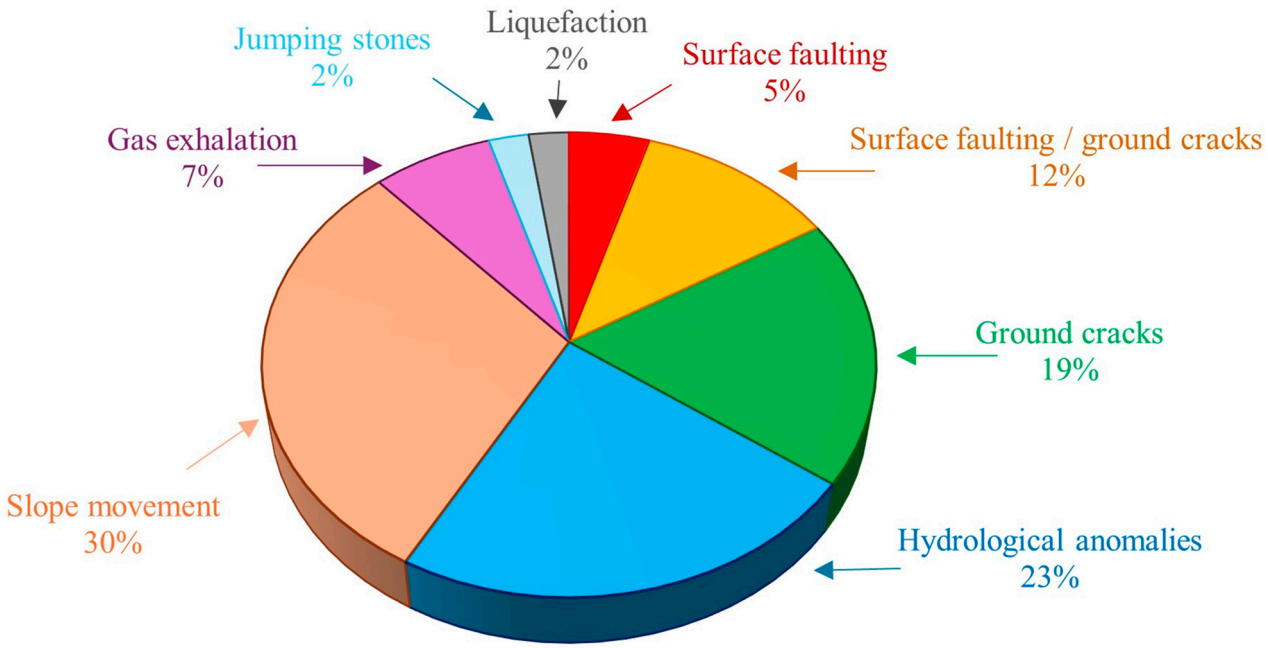

Figure 3. The distribution of the EEEs of the 1688 Sannio–Matese earthquake. The pie chart illustrates the frequency of various EEE occurrences, highlighting their respective proportions.

We present this dataset in table format (Table S1 in Supplementary Materials), and for each locality where an EEE has been documented, we provide the following information:

- *ID* is an identification number;
- *Locality* is the geographic location where the EEE occurred;
- *Latitude* and *longitude* are the geographic coordinates of the EEEs;
- *Epicentral distance (km)* is the distance from the epicenter of the earthquake to the locality of the EEE;
- I_{MCS} is the local macroseismic intensity assessed using the MCS (Mercalli–Cancaci–Sieberg) scale from the CFTIMed catalog [14];
- *EEE type* is the description of the environmental effect (ground cracks = GC; gas exhalation = GE; hydrological anomalies = HA; liquefaction = L; surface faulting = SF; slope movements = SM; JS = jumping stones);
- *Type of Environmental Effect* describes if the effect is primary (P) and/or secondary (S);
- *Main source of information coeval* with the earthquake describes the observed effect provided by the information coeval with the earthquake;
- *All contemporary and post-earthquake sources* contains the consulted original literature;
- I_{ESI} is the local macroseismic intensity assessed using the ESI-07 scale [15].

The dataset containing all the collected data can be consulted in the Supplementary Materials of this paper.

3. Methods

Our approach, schematized in Figure 4, started with a thorough and critical examination of the existing literature and catalogs that had previously documented, albeit partially, the environmental impact of the earthquake [1,14,21,28].

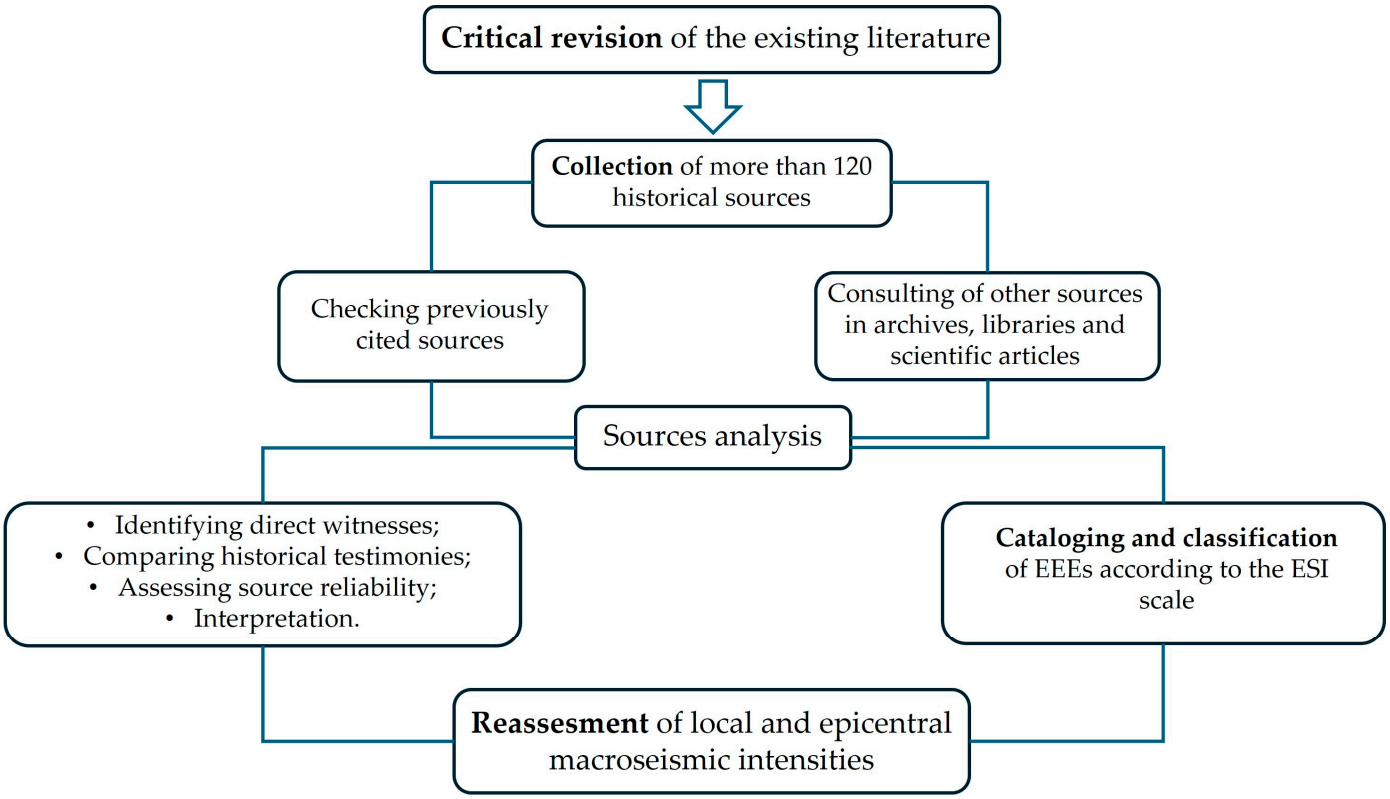

Figure 4. Flowchart illustrating the steps of this study.

Building upon the meticulous study of sources cited by these earlier authors, we undertook comprehensive and extensive archival research in Italy to reconstruct the history and effects on the territory of this devastating seismic event. We consulted documents concerning the Kingdom of Naples from the State Archives of Naples and the General Archive of Simancas (Spain). Additional valuable information was found in diplomatic documents at the State Archives of Benevento, as well as the State Archives of Rome and the Vatican Secret Archives, concerning the territory belonging to the Papal States, such as Benevento (at that time). Beyond archival sources, contemporary gazettes (e.g., Bologna, 29 June 1688 [29]) and printed reports from local inhabitants or eyewitnesses provided crucial descriptions of the earthquake's impact. Gazettes and reports were consulted at several Campanian libraries, such as those in Benevento, Avellino and Naples.

Each source was evaluated based on its historical context, authorship and consistency with other sources. The integration of these diverse documents (for a total of more than 120 sources) allowed a comprehensive understanding of the EEEs.

Key figures such as Vincenzo Magnati, Antonio Bulifon, Pompeo Sarnelli, Domenico Confuorto and Giovan Lorenzo Dalio offered firsthand witness, providing unique insights into the economic, social and environmental impacts of the earthquake.

Vincenzo Magnati, an Abbot from Cerreto Sannita and a scholar of seismic phenomena, in his work "*Notizie istoriche dei terremoti succeduti ne'secoli trascorsi, e nel presente*," [30] (Figure 5a), written just a few months after the catastrophic earthquake, provides important and detailed information about many of the affected villages. He gives a thorough description mainly of the social and economic aspects, but also of the environmental ones. The contemporaneity of his book, his connection to Cerreto Sannita and his knowledge of seismic phenomena make him one of the most reliable sources for this earthquake. Another important coeval source is the publisher Antonio Bulifon, of French origin, who was an important and famous cultural character in Naples and the kingdom at the time. Bulifon's

collection "*Lettere memorabili, istoriche, politiche, ed erudite, scritte, e raccolte da Antonio Bulifon*" [31,32] (Figure 5b) yields more information about the consequences of this seismic event and compares the news with that reported by Magnati, given the proximity of the sources in time and space.

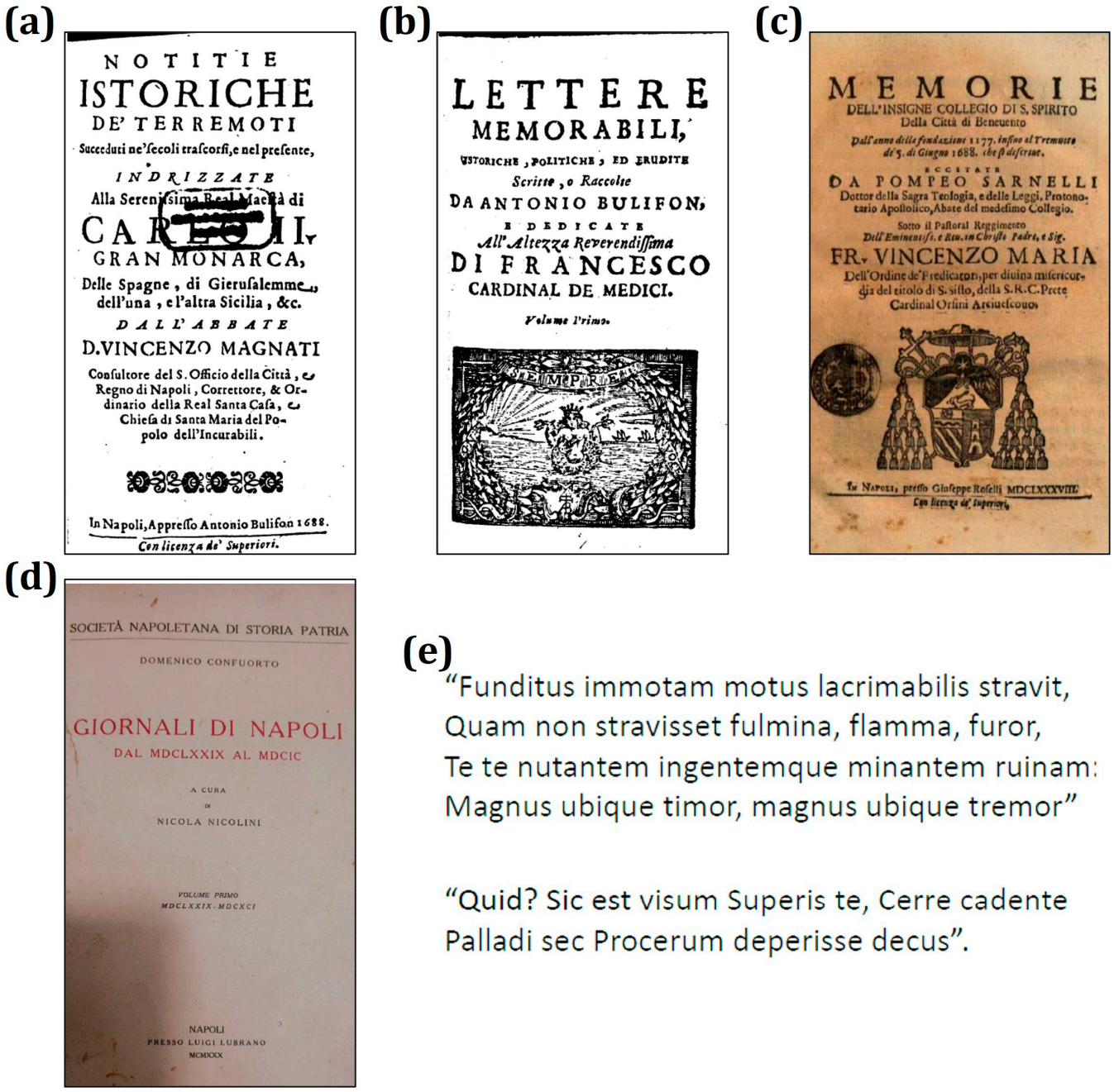

Figure 5. Examples of the contemporary sources consulted include the following: (**a**) Magnati, 1688 [30]; (**b**) Bulifon, 1688 [31,32]; (**c**) Sarnelli, 1688 [33]; (**d**) Confuorto, 1688 [34]; and (**e**) a short extract from Dalio's elegy, 1715 [35].

Pompeo Sarnelli, the Abbot of the prestigious College of S. Spirito in Benevento at the time, on 5 June 1688, was rescued alive from the earthquake rubble and thus was an eyewitness to the event. He reports the terrible moments of the shock he experienced in three different volumes, published between 1688 [33] and 1691, focusing more on the environmental impact than the social and economic one (Figure 5c). Domenico Confuorto, a renowned Neapolitan notary and historian, provides an accurate description of the

catastrophe in his collection 'I giornali di Napoli' [34] (Figure 5d), written a few days after the catastrophe but published posthumously. Among other contemporary sources, we included the poet and humanist from Cerreto Sannita, Giovan Lorenzo Dalio, who in his elegy titled "De Cerreti excidio et terrae motu" [35] (Figure 5e) mourns his Cerreto, providing a unique testimony of that tragic event from the 5th of June that destroyed his beloved county.

These contemporary sources reported by direct witnesses of the earthquake report comparable information, confirming their reliability. Beyond these historical sources, recent articles have provided additional information. Obviously, recent sources or sources reported by individual authors have a lower level of reliability compared to contemporary sources, but they still deserve to be cited and considered.

The reassessment of the ESI scale, based on the guidelines provided by Michetti et al. [15], was performed, accounting the cited documents that allowed us to reconstruct the devastating environmental impact of the earthquake. The local intensities were assessed based on the variety of effects observed at each locality and are detailed in the dataset presented in Supplementary Materials. Critically analyzing the historical sources together with geology from the cartography of the literature, we considered as superficial coseismic faulting the fractures that some authors had described as ground cracks.

Historical Sources

Below, we present a detailed list of sources contemporary to the 1688 earthquake and of sources after the 1688 earthquake that we tracked down, analyzed and interpreted for each locality. We report the source's most meaningful sentences, in the original language and translated in English. Finally, for each site, we point out the EEEs that occurred based on our understanding/translation/interpretation of the sources.

ALIFE (Caserta)

Contemporary earthquake source

– Vicino la terra di Cerrito in una montagna s'è aperta una voragine, dalla quale esce in gran quantità acqua solfurea, com'anco se n'è aperta un'altra consimile in Alife./*Near the land of Cerrito in a mountain a chasm has opened up, from which sulphurous water flows in great quantities, as has another similar one in Alife (Confuorto, 1688)* [34].

Post-earthquake sources

– Vicino la terra di Cerrito in una montagna s'è aperta una voragine, dalla quale esce in gran quantità acqua sulfurea, com'anco s'è aperta un'altra consimile in Alife./*Near the land of Cerrito in a mountain a chasm has opened up, from which sulphurous water flows in great quantities, as has another similar one in Alife* (*De Blasiis, 1896*) [36].

– In una montagna s'è aperta una voragine, dalla quale esce in gran quantità acqua solfurea, com'anco se n'è aperta un'altra consimile in Alife [ed a] due miglia e mezza di distanza dalla terra di S. Giorgio [La Molara] è voce che sia aperta la terra in campagna, facendo diverse fissure, una delle quali lunga quasi due miglia e larga più di tre palmi e che essendosi calata una funicella con il piombo per vedere quando era profonda, non si sia trovato il fondo./*In a mountain a chasm has opened up, from which sulphurous water flows out in large quantities, as has another similar one in Alife [and] two and a half miles away from the land of S. Giorgio [La Molara] it is said that the land in the countryside has opened up, making various cracks, one of which is almost two miles long and more than three palms wide and that when a leaden cord was lowered to see how deep it was, the bottom was not found* (*Germino, 1999*) [37].

Inferred EEEs: Ground cracks.

Notes: De Blasiis [36] and Germino [37] report Confuorto [34].

ALVIGNANO (Caserta)

Contemporary earthquake sources

– In Alvignano, e nella Vallata di Piedimonte sua Diocesi, precipitate pure infinite case si veggono, e morte molte persone, essendosi similmente osservato per qualche tempo il fiume alquanto torbido, e non correre, secondo il solito costume./*In Alvignano, and in the Vallata di Piedimonte its Diocese, an infinite number of houses have also been seen collapsed, and many people have died. Similarly, for some time, the river was observed to be somewhat turbid and not flowing according to its usual custom* (*Magnati, 1688*) [30].

Post-earthquake sources

– Alvignano, cadute molte case con molti morti. Ivi il fiume Volturno si vede torbido e non correre come al solito./*Alvignano, many houses collapsed with many dead. There, the Volturno river is seen to be turbid and not flowing as usual* (*Vari, 1927*) [38].
– Possiamo, con molta prudenza, ritenere come probabili la formazione di diverse voragini apertesi nel territorio di S. Giorgio la Molara; le fenditure che comparvero nei territori di S. Marco dei Cavoti; la caduta di massi che si distaccarono dal monte Erbano e distrussero S. Lorenzello, come già detto, l'intorbidimento delle acque del Volturno, presso Alvignano, le emanazioni più o meno intense di vapori solforosi e bituminosi che spesso accompagnano tali fenomeni, nonché le diverse faglie o specchi di faglia che sovente fanno capolino nelle nostre montagne. Sono quest'ultime che denotano maggiormente le modificazioni geologiche a cui furono sottoposti gli strati rocciosi./*We can, with great caution, consider as probable the formation of various chasms that opened in the territory of S. Giorgio la Molara; the cracks that appeared in the territories of S. Marco dei Cavoti; the fall of rocks that broke away from mount Erbano and destroyed S. Lorenzello, as already mentioned, the turbidity of the waters of the Volturno, near Alvignano, the more or less intense emanations of sulphurous and bituminous vapors that often accompany such phenomena, as well as the various faults or fault mirrors (slickenside) that often appear in our mountains. It is these latter that most denote the geological modifications to which the rock layers were subjected* (*Franco, 1966*) [39].
– *Serva, 1981* [1] reports Magnati [30].
– Hydrological anomalies (HA) (*Serva* et al. *2007*) [21].
– Intorbidamento di un corso d'acqua/*Turbidity of a watercourse* (*Guidoboni* et al. *2019*) [14].

Inferred EEEs: Hydrological anomalies—turbidity of the river.

Notes: Vari [38] and Franco [39] report Magnati [30]. Guidoboni et al. [14] report Anonimo, Vera fedele, e distintissima [40] and Magnati [30].

APICE (Benevento)

Contemporary earthquake sources

– Nella Terra di Apici, della quale scrive Padre Alberti, che vien situata vicino al fiume Calore nella parte sinistra, di là dal fiume Sabbato fece Valente Imperadore, non già Valentiniano un Ponte, congiongendolo con la via Appia, e perciò nomarsi Ponte Valentiniano, e presentemente si vede consumato, e rovinato, dove similmente vi appariva, un altro Ponte per servigio di quei, che passavano per la suddetta Via Appia, in questo accidente è sorto un fiume di acqua bituminosa, non però fra pochi giorni si consumò, altrimenti havrebbe brugiato tutto quel paese d'intorno, e ha fatto perdita di cento, e sei de suoi cittadini, essendo essa rimasta, e da fondamenta abbattuta, e molto addolorata per la perdita de suoi suddetti cittadini./*In the land of Apici, of which Father Alberti writes, which is situated near the river Calore on the left side, beyond the river Sabbato, Emperor Valens, not Valentinian, built a bridge, connecting it to the Appian Way, and therefore called the Valentinian Bridge, and currently it looks consumed and ruined, where similarly*

there appeared, another bridge for the service of those who passed through the aforementioned Appian Way, in this accident a river of bituminous water arose, however in a few days it was consumed, otherwise it would have burned all that surrounding country, and it has suffered the loss of one hundred and six of its citizens, it having remained, and demolished from its foundations, and very saddened by the loss of its aforementioned citizens (*Magnati, 1688*) [30].

- Vicino Apice ne sorse un fiume, che medesimamente in pochi dì seccossi./*Near Apice a river arose, which dried up within a few days* (*Bulifon, 1688*) [31].
- Vicino Apice uscì un fiume di acqua bituminosa, che fra pochi dì si seccò./*Near Apice a river of bituminous water flowed out, which dried up within a few days* (*Sarnelli, 1688*) [33].

Post-earthquake sources

- Vicino ad Apice sgorgò un fiume lattiginoso (??) che si essiccò pochi giorni dopo./*Near Apice a milky river flowed (??) which dried up a few days later* (*Baratta, 1901*) [40].
- Presso Apice uscì una sorgente di acqua bituminosa, che si seccò dopo pochi giorni./*Near Apice a spring of bituminous water came out, which dried up after a few days* (*Vari, 1927*) [38].
- *Serva, 1981* [1] reports the sources of Bulifon [31] and Magnati [30].
- Ad Apice, invece, sgorgò un fiume di acqua bituminosa che fra pochi dì si seccò./*At Apice, instead, a river of bituminous water flowed which dried up within a few days* (*Germino, 1999*) [37].
- Hydrological anomalies (HA) *(Serva et al. 2007)* [21].
- Fuoriuscita di acqua, sabbia o fanghi dal terreno (liquefazione)./*Outflow of water, sand, or mud from the ground (liquefaction)* (*Guidoboni et al. 2019*) [14].

Inferred EEEs: Liquefaction.

Notes: Baratta [40], Vari [38] and Germino [37] report Sarnelli [33]. Vari [38] and Guidoboni et al. [14] report Magnati [30].

ATELLA (Potenza)

Contemporary earthquake sources

- Ad Atella rovinarono molte case, ma il più notabile si fù, che quasi tutti gli habitanti, ch'erano per le strade caddero colla faccia per terra, di dove si sentiva un vapor caldo, e puzzolente, che li lasciò per molti giorni storditi, e ad uno di essi se gli aprì sotto la faccia la terra, che lo lasciò stordito più de gli altri quell'esalazione, e aprendo una tal bocca il suolo, colla lingua di quel vapor maligno, par che del Divino castigo esprimesse la possanza./*In Atella many houses were ruined, but the most notable was that almost all the inhabitants who were in the streets fell face-first to the ground, from where a hot, smelly vapor could be smelled, which left them stunned for many days, and for one of them the earth opened up under his face, which left him stunned more than the others by that exhalation, and by opening such a mouth the ground, with the tongue of that malignant vapor, seems like the Divine punishment expressed power* (*Anonimo, Vera fedele, e distintissima, 1688*) [41].
- La Terra di Atella, alla quale mi si presenta dinanzi agli occhi, fu rovinata ne' pubblici, e particolari edificij con l'abbatimento de' medesimi, ma il caso più notabile da osservarsi, per comprobare quanto si è scritto da Naturali, e antichi, e moderni Filosofi, si fù, che quali la maggior parte degli habitanti di essa ritrovatasi per le strade, e nelle Campagne cadde tutta bocconi per terra, donde usciva un vapor caldo, e puzzolente, lasciando quei poveri disgratiati storditi, e fuori de' sensi, anzi fede qualche apertura in più luoghi, e ritrovatosi uno di essi così bocconi, fù talmente sorpreso da quella esalazione, e fetore, che vi ebbe a perdere la vita./*The land of Atella, which presents itself before my eyes, was ruined in public and private buildings with the demolition of the same, but the most notable case to be observed, to confirm what has been written by naturalists, and ancient, and modern philosophers, was, that the majority of its inhabitants found themselves in the streets,*

and in the countryside, fell all face down on the ground, from which came out a hot, smelly vapor, leaving those poor wretches stunned, and out of senses, indeed it made some openings in several places, and one of them found himself thus face down, was so surprised by that exhalation, and stench, that he lost his life (*Magnati, 1688*) [30].

Post-earthquake sources

- Gli abitanti di Atella che si trovavano la maggior parte nelle strade e nelle campagne, caddero tutti bocconi per terra, donde emanavano caldi e puzzolenti vapori, lasciando quei miseri istupiditi e svenuti. Ivi in più luoghi la terra si aprì e un cittadino, caduto bocconi, morì asfissiato per le esalazioni./*The inhabitants of Atella, who were mostly in the streets and in the countryside, all fell face down on the ground, from which hot and smelly vapors emanated, leaving those wretched people stupefied and unconscious. There in several places the earth opened up and a citizen, having fallen face down, died asphyxiated by the fumes* (*Vari, 1927*) [38].
- *Serva, 1981* [1] reports the source of Anonimo, Vera Fedele, e distintissima [41] and Magnati [30].
- Ground cracks (GC) (*Serva et al. 2007*) [21].
- Esalazione di gas associata a eruzioni di salse o maccalube. Rottura del terreno, fratturazione, fessure, spaccature./*Gas exhalation associated with eruptions of salse or maccalube. Ground rupture, fracturing, fissures, cracks* (*Guidoboni et al. 2019*) [14].

Inferred EEEs: Ground cracks; gas exhalation.
Notes: Vari [38] and Guidoboni et al. [14] report Magnati [30].
BENEVENTO (Benevento)

Contemporary earthquake sources

- Nel ristretto della Parrocchia di S. Modesto, e S. Giacomo si per essere le case affatto ruvinate, come di sopra si è notato, e si anco per esser detti quartieri situati in luogo il più basso della Città, e d'aria cattiva per l'acque vicine, che con tutto siino correnti, in ogni modo ivi per il lento corso, causano nebbie quasi continue. . . /*In the area of the Parish of S. Modesto and S. Giacomo, both because the houses are completely ruined, as noted above, and also because these quarters are situated in the lowest part of the city, and have bad air due to the nearby waters, which, even if they are currents, in any case due to their slow flow, cause almost continuous fog*. . . (**Archivio Segreto Vaticano, 1688*) [42].
- La città di Benevento, han patito maggior danno, perché con maggior'empito tra quell'angustie furono necessarie disvaporare; anzi essendosi sperimentate dagli effetti, dal sibilo, e fragore la diversità de' luoghi sotterranei, e caverne dove per la dilatazione, e meati ampij han potuto l'esalazioni svaporare ad un tratto, incontanente, e con momentanee straordinarie scosse ne primi scoppi son cessate le concussioni;. . . /*The city of Benevento, suffered greater damage, because with greater force it was necessary to evaporate in those narrow spaces; indeed, having experienced from the effects, from the hiss, and roar, the diversity of underground places, and caverns where due to the dilation, and wide passages, the exhalations were able to evaporate suddenly, immediately, and with momentary extraordinary shocks in the first explosions the concussions ceased;*. . . (*Magnati, 1688*) [30].
- Dalla parte del Sabato resta la città spianata, e ne pianse il fiume Sabato, veduto uscir, come per gran dolore, dal suo letto: dalla parte di Calore vi sono delle case, ma conquassate, che han bisogno o di gran riparazione, o di essere sgravate dagli appartamenti superiori. . . Ruina di repente cagionata dal moto, che fu per successione, come di una ruina sotterranea; ed infatti bisogna, che siano state accese esalazioni di materie nitrose, e sulfuree, come la puzza delle medesime uscita fuori dimostrava./*On the side of Sabato the city remains leveled, and the river Sabato wept over it, seeing it rise, as if in great pain, from its bed: on the side of Calore there are some houses, but in ruins, which*

either need great repair, or to be relieved from the upper apartments... Ruin suddenly caused by the movement, which was by succession, like an underground ruin; and in fact it must have been ignited by fumes of nitrous and sulphurous materials, as the stench of the same which came out demonstrated (*Sarnelli, 1688*) [33].

- Venite, e su le sponde del mio Sebbeto intanto, dove col mesto pianto dono il tributo all'onde, Miriam sedendo il resto tutto dirotto, e pesto, per cui non mostra di zaffiri ondosi l'acque il mio mar, ma solchi e vorticosi./*Come, and on the banks of my Sebbeto meanwhile, where with mournful tears I pay tribute to the waves, let us sit and gaze at the wreckage all broken and trampled, for it does not show like sapphire waves my sea, but furrows and whirlpools* (*Sigillo, 1688*) [43].
- La Città di Benevento espone humilmente all'Eminenze Vostre essere sboccato dal suo letto il fiume Sabbato pigliando altra strada la quale continuando portarebbe gran danno al Ponte di S.Maria degl'Angeli et essendosi i Consoli conferiti con gli esperti sù la faccia del luogo hanno questi giudicato esser necessario far una palificata per ridurre detto fiume al suo corso con la spesa di ducati cinquanta./*The City of Benevento humbly presents to Your Eminences that the river Sabbato has overflowed from its bed, taking a different course which, if continued, would cause great damage to the Bridge of St. Maria degli Angeli, and, the Consuls, having conferred with experts on the site, have deemed it necessary to construct a dam to redirect said river to its original course at an expense of fifty ducats* (**Archivio di Stato di Roma, 1691*) [44].
- Sopra il ricorso fatto a Vostra Eminenza ad instanza di questa Città per la licenza di potere applicare docati cinquanta per riparare il fiume Sabato nel suo corso devo riverentemente rappresentare all'Eminenza Vostra ch'essendomi portato sù la faccia del luogo col'intervento de' periti e considerato il danno che può portare il detto fiume al ponte di S.Maria degl'Angeli per essere uscito dal suo letto ho ritrovato essere necessaria la detta riparatione./*Regarding the appeal made to Your Eminence at the request of this City for the license to apply fifty ducats to repair the river Sabato in its course, I must respectfully present to Your Eminence that having gone to the site with the intervention of experts and considering the damage that said river may cause to the bridge of S. Maria degli Angeli due to having overflowed its banks, I have found it necessary to carry out the aforementioned repairs* (**Archivio di Stato di Roma, 1691*) [45].
- . . . Pestilente quell'aria in acquedotti fece alla terra un veleno dono, e scoppiò tanto, istabile, e repente che ridusse sostanza in accidente . . . O del Sebeto, Sabato fugace, Torbido miro il cristallino umore, cerchi letto cambiar, ma non di pace, mentre il vento ti sforza a più rumore ti trasportano i moti, e poi fallace senza brillar non mi zampilli al core, torbido è il chiaro, ed in formar la piena vedo in corbo cambiar la tua Sirena./*. . . Pestilential that air in aqueducts made a poisonous gift to the earth, and it burst forth so unstable and sudden that it reduced substance into accident... O of the Sebeto, fleeting Saturday, murky I see the crystalline water, seeking to change its bed, but not for peace, while the wind forces you to more noise; the motions carry you away, and then deceitful, without shining, do not spring forth to my heart; murky is the clear, and in forming the flood I see in a whirl your Siren changing* (*Piperni, 1699*) [46].

Post-earthquake sources

- Si racconta che un medico avesse predetto il terremoto, avendo osservato in Benevento le acque di un pozzo intorbidarsi e dare odore di zolfo . . . L'acque in alcuni luoghi perduta la loro natural chiarezza si ritirarono da loro fonti et in altri luoghi crescere sopra abbondantemente et esalare qualche fetore, e puzzolenza poco grata al palato. . . . Dalla parte del Sabato resta la città spianata, e ne pianse il fiume Sabato, veduto uscir, come per gran dolore, dal suo letto. . ./*It is said that a doctor had predicted the earthquake after observing the waters of a well in Benevento become murky and emit a sulfurous smell...*

The waters in some places, having lost their natural clarity, withdrew from their sources, while in other places they abundantly rose and emitted an unpleasant odor, which was not pleasing to the palate... On the side of the Sabato river, the city remains flattened, and the Sabato river wept, seen emerging, as if in great sorrow, from its bed... (*Vari, 1927*) [38].

- *Serva, 1981* [1] reports Anonimo, Vera e Fedele [41] and Sarnelli [33].
- Il corso dei fiumi fu alterato da improvvise mancanze d'acqua seguite da straripamenti; furono segnalate, in particolare, deviazioni e intorbidimenti dei fiumi Sabato e Volturno./*The course of the rivers was altered by sudden water shortages followed by flooding; in particular, deviations and turbidity of the Sabato and Volturno rivers were reported* (*Boschi et al. 1995*) [28].
- Molti edifici subirono danni soprattutto nelle vicinanze del fiume Sabato, ormai fiancheggiato da macerie, oltretutto inondate dalle acque fuoriuscite dall'alveo./*Many buildings suffered damage, especially near the Sabato River, which is now flanked by rubble, furthermore flooded by waters that overflowed from its bed* (*Germino, 1999*) [37].
- Hydrological anomalies (HA), slope movements (SM) (*Serva* et al., *2007*) [21].
- Variazione d'alveo, deviazione, interruzione (corsi d'acqua)./*Change of riverbed, diversion, interruption (watercourses)* (*Guidoboni et al., 2019*) [14].

Inferred EEEs: Surface faulting; ground cracks; hydrological anomalies—variation in water flow, turbidity of springs or wells, appearance and disappearance of springs, change in water chemistry.

Notes: Vari [38], Boschi et al. [28] and Germino [37] report Magnati [30] and Sarnelli [33]. Guidoboni et al. [14] report Archivio di Stato di Roma [45,46].

CERRETO SANNITA (Benevento)

Contemporary earthquake sources

- Accresce il terrore e lo spavento in quei contorni l'essersi aperta una montagna nelle vicinanze di Cerreto, non arrischiandosi alcuno d'avvicinarsi, e misurare la larghezza dell'apertura, per non incontrare maggior pericolo del passato./*The terror and fear in those surroundings increase with the opening of a mountain near Cerreto, as no one dares to approach, and measure the width of the opening, for fear of encountering greater danger than before* (*Anonimo, Vera e distinta relatione, 1688*) [47].
- Vicino la terra di Cerrito in una montagna s'è aperta una voragine, dalla quale esce in gran quantità acqua solfurea, com'anco se n'è aperta un'altra consimile in Alife./*Near the land of Cerrito in a mountain a chasm has opened up, from which sulphurous water flows in great quantities, as has another similar one in Alife* (*Confuorto, 1688*) [34].
- Caretto… terror and grief in those parts are the more increased by the opening of a Mountain in its Neighbourhood, no one daring to approach it, so as to measure the largeness of its Mouth, fearing therefrom a greater than the past danger (*Randal, 1688*) [48].
- Nel riferito luogo (terra di Cerreto) per tre giorni le acque chiare restarono intorbidite di rosso con puzza sulfurea./*In the reported place (land of Cerreto), for three days the clear waters remained clouded with red and a sulfurous smell* (*Bulifon, 1693*) [32].
- (Cerro)… la terra ch'era ferma si muove e grandi sassi e gran boato fanno l'altre caverne aperte. E dalle rupi eccelse precipitan le pietre, precipita gran mole della montagna rotta. E tutt'intorno i campi emettono boati, si toccan con le cime i monti e spaventate, volgon le spalle e fuggono le fiere a quel fragore. Con rauco suono i rivi vanno qua e là fluendo, pei sassi giù piombati, torbida scorre l'acqua. L'onde dai pozzi uscenti scorrono ribollenti e i pozzi un fiume d'acqua versano dalle bocche./*(Cerro)… the earth that was still moves, and great stones and loud booms cause the other caves to open. And from the high cliffs, stones fall; the massive bulk of the broken mountain plunges down. All around, the fields emit roars; the mountains touch with their peaks and frightened, turn*

their backs and flee from that noise. With a hoarse sound, the streams flow here and there; through the fallen stones, murky water flows. The waves emerging from the wells run boiling and the wells pour forth a river of water from their mouths (*Dalio, 1715*) [35].

Post-earthquake sources

- . . . Cerreto, nelle cui vicinanze si aprì una montagna, che oggi da chiunque si osserva, restò distrutto con otto vicine Terre./*Cerreto, where a mountain opened nearby, which today can be seen by anyone, was destroyed along with eight neighboring towns* (*Vivenzio, 1788*) [49].
- Vicino la terra di Cerrito in una montagna s'è aperta una voragine, dalla quale esce in gran quantità acqua sulfurea, com'anco s'è aperta un'altra consimile in Alife./*Near the land of Cerrito in a mountain a chasm has opened up, from which sulphurous water flows in great quantities, as has another similar one in Alife* (*De Blasiis, 1896*) [36].
- Per tre giorni le acque chiare restarono intorbidite di rosso, con puzza sulfurea./*For three days, the clear waters remained clouded with red, with a sulfurous smell* (*Mazzacane, 1908*) [50].
- Nel riferito luogo per tre giorni le acque chiare restarono intorbidate di rosso, con puzza solforea./*In the mentioned place, for three days the clear waters remained clouded with red, with a sulfurous smell* (*Vari, 1927*) [38].
- I boati dovuti al rotolio delle rocce interne, il cambiamento dei corsi d'acqua delle sorgenti, l'intorbidimento di esse, il ribollire di queste dai pozzi, senz'altro si saranno verificati a Cerreto, nel terremoto del 1688./*The disturbances caused by the rolling of internal rocks, the changing courses of spring waters, their turbidity, and the bubbling from wells certainly occurred in Cerreto during the earthquake of 1688* (*Franco, 1967*) [51].
- *Serva, 1981* [1] reports Anonimo, Vera e distinta relatione [47], Bulifon [32], Confuorto [34] and De Bellis (1688).
- Vicino Cerreto, ad esempio, in una montagna s'è aperta una voragine, dalla quale esce in gran quantità acqua solfurea, com'anco se n'è aperta un'altra consimile in Alife [ed a] due miglia e mezza di distanza dalla terra di S. Giorgio [La Molara] è voce che sia aperta la terra in campagna, facendo diverse fissure, una delle quali lunga quasi due miglia e larga più di tre palmi e che essendosi calata una funicella con il piombo per vedere quando era profonda, non si sia trovato il fondo./*In a mountain a chasm has opened up, from which sulphurous water flows out in large quantities, as has another similar one in Alife [and] two and a half miles away from the land of S. Giorgio [La Molara] it is said that the land in the countryside has opened up, making various cracks, one of which is almost two miles long and more than three palms wide and that when a leaden cord was lowered to see how deep it was, the bottom was not found* (*Germino, 1999*) [37].
- Hydrological anomalies (HA), slope movements (SM), ground cracks (GC) (*Serva et al., 2007*) [21].
- Giovan Lorenzo Dalio, sacerdote e poeta cerretese, spettatore della tragedia, da ragguagli che riguardano Cerreto, ma si adattano, sia pure genericamente, anche a Pietraroia. . . le pietre staccatesi dalle rocce rotolavano dall'alto; pezzi di montagna precipitavano a valle. I torrenti, intorbidati, scorrevano tra le pietre, con rumore roco. L'acqua dei pozzi ribolliva, si gonfiava, fuoriusciva./*Giovan Lorenzo Dalio, a priest and poet from Cerreto, witnessed the tragedy and described events related to Cerreto that also generally apply to Pietraroia. He noted that stones detached from the rocks rolled down from above; pieces of the mountain fell to the valley. The torrents, muddied, flowed among the stones with a hoarse noise. The water from the wells bubbled, swelled, and overflowed* (*Di Lello, 2009*) [52].

Inferred EEEs: Surface faulting/ground cracks; slope movement; hydrological—change in water chemistry and physics.

Notes: De Blasiis [36], Mazzacane [50] and Vari [38] report Bulifon [32]. Germino [37] reports Confuorto [34]. Di Lello [52] reports Dalio [35].

CIVITELLA LICINIO (Benevento)

Post-earthquake sources

- Al contrario, S. Lorenzello, Civitella, S. Lupo, Solopaca furono danneggiate massimamente per la caduta di materiale ruinato dai monti sovrastanti./*On the contrary, S. Lorenzello, Civitella, S. Lupo, and Solopaca were severely damaged due to the fall of materials from the surrounding mountains* (*Franco, 1966*) [39].
- La scissione di una gran parte del monte che poi si staccò e precipitò, molto probabilmente, avvenne a S. Lupo e a Civitella, in quest'ultima più precisamente nei pressi di Ponte Lavella ove fino a poco tempo fa era visibile un picco solitario staccato./*The splitting of a large part of the mountain that then detached and fell, very likely, occurred at S. Lupo and Civitella, more precisely in the latter near Ponte Lavella, where until recently a solitary peak that had broken off was visible* (*Franco, 1967*) [51].
- Insomma, non è inverosimile che, nel pomeriggio del 5 giugno, lo scuotimento più energetico abbia portato al distacco di masse e a frane. Alcuni, di grosse dimensioni, sono ancora visibili sul posto e sotto lo strapiombo di Civita, in località Pezzapiana, dove, si dice, venne rinvenuta pure una campana della chiesa./*In short, it is not implausible that, in the afternoon of June 5, the most energetic shaking led to the detachment of masses and landslides. Some, of large dimensions, are still visible on site and beneath the overhang of Civita, in the Pezzapiana area, where it is said, a church bell was also found* (*Di Lello, 2009*) [52].

Inferred EEEs: Slope movement.

MONTORO (Avellino)

Contemporary earthquake sources

- Montuoro del Signor Prencipe della Riccia ha patito infinito danno, essendo cascate più di 50 case & il Palazzo Baronale, né vi è morto alcuno per haver havuto il tempo di salvarsi, e nell'istesso tempo del terramoto caderno dalla montagna contigua una grandissima quantità di pietre, a segno tale che spiantorno un gran numero di alberi./*Montuoro, the estate of the Lord Prince della Riccia, has suffered immense damage, with over 50 houses and the Baronial Palace collapsing, no one died as there was time to escape, and at the same time as the earthquake, a vast quantity of stones fell from the adjacent mountain, uprooting a significant number of trees* (*Anonimo, Vera e distinta relatione, 1688*) [47].
- È venuta nuova che in Montuoro, terra del signor Principe della Riccia, abbia per alquanto spazio d'ora piovuto pietre, e in Castelluccia, terra vicino Sora, abbia piovuto sangue: del che dal vescovo di quella diocesi se n'è presa informazione./*News has come that in Montuoro, land of the lord Prince of Riccia, stones have rained for some time, and in Castelluccia, a town near Sora, blood has fallen: of which the bishop of that diocese has taken information* (*Confuorto, 1688*) [34].
- Montoro. . . at the same time of the earthquake there fell from the adjacent Mountain, a very great quantity of Stones, of such a degree, that they rooted up a great number of Trees *(Randal, 1688*) [48].

Post-earthquake sources

- È venuta nuova che in Montuoro terra del principe di Riccia, habbia per alquanto spatio d'hora piovuto pietre, et in Castelluccia, terra vicino Sora, habbia piovuto sangue, del che dal vescovo di quella diocesi se n'è presa informatione./*News has come that in Montuoro, land of the prince of Riccia, stones have rained down for some time, and in Castelluccia, a town near Sora, blood has rained down, of which the bishop of that diocese has taken information* (*De Blasiis, 1896*) [36].

- Serva 1981 report Anonimo, Vera e Distinta Relazione e Anonimo—Aneddoti di Storia napoletana [53]. Il Terremoto del 1688. Arch Storico per le prov. Nap.; 1895 Vol. XX.fasc.IV.
- Conforto riporta la notizia arrivata da Montoro di una violenta e continua pioggia di pietre. . . /*Conforto reports the news coming from Montoro of a violent and continuous rain of stones. . .* (*Scaramella, 1992*) [54].
- Vi fu una frana a Montoro e si aprirono fenditure nel terreno a Pomarico./*There was a landslide in Montoro, and fissures opened in the ground in Pomarico* (*Boschi et al. 1995*) [28].
- Slope movements (SM) (*Serva et al. 2007*) [21].
- Frana, colata di fango, scoscendimento, scivolamento, crollo, distacco./*Landslide, mud-flow, sliding, collapse, detachment* (*Guidoboni et al. 2019*) [14].

Inferred EEEs: Slope movement.

Notes: Guidoboni et al. [14] report Anonimo, Vera e distinta relatione [47]. De Blasiis [36] and Scaramella [54] report Confuorto [34].

MATESE MT (Benevento)

Contemporary earthquake sources

- Nel tempo che durò il terremoto mancò il corso al fiume che scaturisce nella sudetta terra di Piedemonte alla falda della montagna del Matese, e doppo passato ritornò l'acqua in maggior copia, ma torbida, puzzolente e caldissima, havendo nel Matese medesimo spezzati monti, e nel piano fatte diverse aperture con sorgenti d'acqua./*During the time the earthquake lasted, the river that flows from the aforementioned land of Piedemonte at the foot of the Matese mountain ceased its course, and after a while, the water returned in greater quantity, but muddy, foul-smelling, and extremely hot. This was due to the breaking of mountains in the Matese itself and the formation of various openings in the plain with water springs (Anonimo, Vera e distinta relatione, 1688)* [47].

Inferred EEEs: Surface faulting/ground cracks.

NAPOLI (Napoli)

Contemporary earthquake sources

- L'acque in alcun luoghi perduta la loro natural chiarezza si ritirarono da loro fonti; e in altri luoghi crescere sopra abbondantemente, e esalare qualche fetore, e puzzolenza poco grata al palato. . . /*The waters in some places having lost their natural clarity withdrew from their sources; and in other places they grew abundantly, and exhaled some stench and stench not very pleasant to the palate;... (Magnati, 1688)* [30].
- In Napoli nelle parti della Salute s'aprì una collina, d'onde usciva vento, e di più nelle nostre Padule all'Acqua, detta della Bufala, scaturì un fonte d'acqua bituminosa, che poi seccò./*In Naples, in the areas of Salute, a hill opened up from which wind emerged, and furthermore in our Padule all'Acqua, called of the Bufala, a spring of bituminous water gushed forth, which later dried up* (*Bulifon, 1688*) [31].

Post-earthquake sources

- E in Napoli, al luogo detto "la Salute" dalla fenditura d'una collina soffiò vento, e alle paludi, ove dicevasi "acqua della bufera" scaturì una fonte d'acqua bituminosa che poi si disseccò./*In Naples, at a place called "la Salute," a wind blew from the crack of a hill, and at the marshes, where it was said "water of the storm," a spring of bituminous water burst forth that later dried up* (*De Blasiis, 1896*) [36].
- Hydrological anomalies (HA) (*Serva et al. 2007*) [21].
- Intorbidimento di sorgenti o pozzi. Variazione del chimismo dell'acqua./*Turbidity of sources or wells. Change in the water chemistry* (*Guidoboni et al. 2019*) [14].

Inferred EEEs: Ground cracks; hydrological anomalies—change in water chemistry, turbidity of springs or wells, appearance and disappearance of springs.

Notes: De Blasiis [36] reports Bulifon [31]. Guidoboni et al. [14] report Magnati [30].

PIEDIMONTE MATESE (Caserta)

Contemporary earthquake sources

- Nel tempo che durò il terremoto mancò il corso al fiume che scaturisce nella sudetta terra di Piedemonte alla falda della montagna del Matese, e doppo passato ritornò l'acqua in maggior copia, ma torbida, puzzolente e caldissima, havendo nel Matese medesimo spezzati monti, e nel piano fatte diverse aperture con sorgenti d'acqua./*During the time the earthquake lasted, the river that flows from the aforementioned land of Piedemonte at the foot of the Matese mountain ceased its course, and after a while, the water returned in greater quantity, but muddy, foul-smelling, and extremely hot. This was due to the breaking of mountains in the Matese itself and the formation of various openings in the plain with water springs* (*Anonimo, Vera e distinta relatione, 1688*) [47].
- In Alvignano, e nella Vallata di Piedimonte sua Diocesi, precipitate pure infinite case si veggono, e morte molte persone, essendosi similmente osservato per qualche tempo il fiume alquanto torbido, e non correre, secondo il solito costume./*In Alvignano, and in the Vallata di Piedimonte its Diocese, an infinite number of houses have also been seen collapsed, and many people have died, as it has also been observed for some time that the river is somewhat turbid and does not flow, contrary to its usual course* (*Magnati, 1688*) [30].
- In Piedimonte, Terra del Signor Duca di Lorenzano, si fermò per buona pezza il corso di due grosse sorgenti, che hanno lor'origine dalle Montagne di quel luogo, e formando unite un fiume servono a quei artigiani nella fabbrica dei panni, e carta./*In Piedimonte, land of the Lord Duke of Lorenzano, the course of two large springs was stopped for quite a while, which originate from the mountains of that place, and by joining together form a river that serves those artisans in the production of cloth and paper* (*Bulifon, 1688*) [31].
- In the time of the Earthquake the course of the River failed, which runs through the said Lands of Piedimont, at the bottom of the Mountain of Matese, and after the Earthquake was over, the Water returned in greater abundance, but thick, stinking, and very hot, having in the same Mountain Matese broken several small Mountains in sunder, and in the Valley caused divers openings of the Ground, with springs of water (*Randal, 1688*) [48].

Post-earthquake sources

- Nel tempo del Tremuoto mancò il corso al fiume, che scaturisce dalle falde della montagna del Matese, terminato il quale ritornò in maggior copia l'acqua, ma torbida, puzzolente, e caldissima. Nel Matese medesimo si spezzarono de' monti, e nel piano si fecero diverse aperture con sorgenti d'acqua./*During the time of the earthquake, the river that springs from the slopes of Mount Matese ceased to flow. After this, the water returned in greater quantity, but it was muddy, foul-smelling, and extremely hot. In the Matese area itself, mountains collapsed, and several openings with water springs formed in the plains* (*Vivenzio, 1788*) [49].
- Nel tempo del terremoto venne a mancare il corso del fiume che scaturisce nella terra di Piedimonte, alle falde dei monti del Matese, e che cessati gli scuotimenti, l'acqua ritornò in maggior copia, ma calda e puzzolente./*During the time of the earthquake, the river that springs from the land of Piedimonte, at the foot of the Matese mountains, ceased to flow. After the tremors stopped, the water returned in greater quantity, but it was warm and foul-smelling* (*Baratta, 1901*) [40].
- *Serva, 1981* [1] reports Anonimo, Vera e distinta relatione [47], Bulifon [31] and Magnati [30].

- Mentre a Piedimonte, si fermò il corso di due sorgenti./*While in Piedimonte, the course of two springs was stopped* (*Germino, 1999*) [37].
- Hydrological anomalies (HAs), ground cracks (GC) (*Serva et al. 2007*) [21].
- Comparsa o scomparsa di sorgenti. Variazione di temperatura dell'acqua. Intorbidamento di sorgenti o pozzi. Variazione del chimismo dell'acqua. Variazione della portata di un corso d'acqua. Rottura del terreno, fratturazione, fessure, spaccature./*Appearance or disappearance of sources. Change in water temperature. Turbidity of sources or wells. Change in the chemistry of the water. Change in the flow rate of a watercourse. Ground rupture, fracturing, cracks, fissures* (*Guidoboni et al. 2019)* [14].

EEE: Surface faulting/ground cracks; hydrological anomalies—appearance and disappearance of springs, variation in water flow, change in temperature and water chemistry, turbidity of springs or wells.

Notes: Piedimonte Matese until 1970, it was called Piedimonte d'Alife.

Vivenzio [49], Baratta [40] and Guidoboni et al. [14] report Anonimo, Vera e distinta relatione [47]. Germino [37] reports Bulifon [31].

PIETRAROJA (Benevento)

Contemporary earthquake sources

- Spostamento della statua di San Nicola, sul proprio asse, verso l'altare Maggiore./*Movement of the statue of Saint Nicholas on its axis toward the Main altar… (Mons. Manzella, App. Mem, 100-101, 1688 in Di Lello, 2009)* [52].

Post-earthquake sources

- E se Pietraroia, benchè saldamente costruita sulla roccia viva, fu totalmente distrutta, ciò probabilmente dipese dalle numerose fratture, tuttora visibili, del monte su cui poggiava./*Even though Pietraroia, although solidly built on solid rock, was completely destroyed, this was likely due to the numerous fractures, still visible, of the mountain on which it rested* (*Franco, 1966*) [39].
- Giovan Lorenzo Dalio, sacerdote e poeta cerretese, spettatore della tragedia, da ragguagli che riguardano Cerreto, ma si adattano, sia pure genericamente, anche a Pietraroia… le pietre staccatesi dalle rocce rotolavano dall'alto; pezzi di montagna precipitavano a valle. I torrenti, intorbidati, scorrevano tra le pietre, con rumore roco. L'acqua dei pozzi ribolliva, si gonfiava, fuoriusciva…/*Giovan Lorenzo Dalio, a priest and poet from Cerreto, witnessed the tragedy that befell the area, gives a report concerning Cerreto, which can generally apply to Pietraroia … as well, stones detached from the rocks rolled down from above; pieces of the mountain crashed to the valley. The torrents, muddied, flowed among the stones with a hoarse noise. The water from the wells bubbled, swelled, and overflowed*… (*Di Lello, 2009*) [52].

Inferred EEEs: Slope movement; ground crack; hydrological anomalies—variation in water flow, turbidity of springs or wells.

Notes: The current Pietraroia is in the valley, while at the time of the earthquake it was built on the rock at the crest of the slope (Civita). Moreover, Mons. Manzella writes that Pietraroja, before being built on the crest (at least 5 centuries earlier), was located further down the valley (likely the current position of the town). Franco 1966 reports a poetic composition by a priest from Cerreto, Giovan Lorenzo Dalio, an eyewitness of the earthquake.

POMARICO (Matera)

Contemporary earthquake sources

- Nel Territorio di Pomarico vicino Matera s'aprì una gran voragine.../*In the territory of Pomarico near Matera, a large chasm opened up… (Bulifon, 1688)* [31].

Post-earthquake sources

- Anche nel territorio di Pomarico, presso Matera s'era aperta una grande voragine./*Also in the territory of Pomarico, near Matera, a large chasm had opened (De Blasiis, 1896)* [36].
- *Serva, 1981* [1] reports Bulifon [31].
- Vi fu una frana a Montoro e si aprirono fenditure nel terreno a Pomarico./*There was a landslide in Montoro and fissures opened in the ground in Pomarico (Boschi et al. 1995)* [28].
- Una grande voragine si aprì a Pomarico, vicino Matera./*A large chasm had opened in Pomarico, near Matera (Germino, 1999)* [37].
- Slope movements (SM), ground cracks (GC) (*Serva et al. 2007*) [21].
- Sprofondamento, avvallamento, voragine./*Sinking, depression, chasm (Guidoboni et al. 2019)* [14].

Inferred EEEs: Slope movement; ground cracks.
Notes: De Blasiis [36], Germino [37] and Guidoboni et al. [14] report Bulifon [31].
POZZUOLI (Napoli)

Contemporary earthquake sources

- Nella vostra Città di Napoli con gagliardissime concussioni, e fremito per l'ampiezza delle due caverne, e per la vicinanza del Vesuvio, e delle Solfatare di Pozzuoli, le quali svaporando han reso sempre più ampi gli meati, dilatandosi con l'espulsione continua delle materie./*In your city of Naples, with powerful concussions and tremors due to the vastness of the two caverns, and the proximity of Vesuvius and the Solfataras of Pozzuoli, which, by emitting vapors, have continuously expanded the channels, dilating with the continuous expulsion of materials* (*Magnati, 1688*) [30].
- Pozzuol, che puzza immensa preparaste a miei fidi dentro i miei cari nidi, nella mia lenta mensa, qual mal mai ti commisi, che tu di cari uccisi mi contracambi e d'edificij rotti, fando li giorni miei vedove notti?... co Sali, zolfi, e co bitumi misti faceste i gionri miei vedovi e tristi./*Pozzuoli, which immense stench you prepared for my faithful within my dear nests, at my slow table, what wrong did I ever commit against you, that you repay me with dear ones killed and ruined buildings, making my days widowed nights?... with salts, sulfurs, and mixed bitumens you made my days widowed and sad* (*Sigillo, 1688*) [43].

Inferred EEEs: Gas exhalation.
SAN GIORGIO LA MOLARA (Benevento)

Contemporary earthquake sources

- S.Giorgio, terra del Marchese di Torrecusa, s'è aperta una voragine di 3 palmi, larga due miglia in circa di lunghezza, che havendovi voluto misurare il fondo non si trova./*S.Giorgio, land of the Marquis of Torrecusa, has opened a chasm of 3 palms, approximately two miles wide in length, which upon attempting to measure the bottom cannot be found* (*Anonimo, Vera e distinta relatione, 1688*) [47].
- Due miglia e mezza di distanza dalla terra di San Giorgio è voce che sia aperta la terra in campagna, facendo diverse fissure, una delle quali sia lunga quasi due miglia e larga più di tre palmi, e che, essendovisi calata una funicella con il piombo, per vedere quanto era profonda, non si sia ritrovato il fondo./*Two and a half miles away from the land of San Giorgio, there is a rumor that the ground has opened in the countryside, creating several fissures, one of which is nearly two miles long and more than three palms wide, and that when a string with a weight was lowered to check how deep it was, the bottom could not be found* (*Confuorto, 1688*) [34].
- In San Giorgio della Molinara, situata, al parer del Padre Leandro Alberti, del Ferraro, e di altri, presso de fiume Calore, e Sabbato, che dall'itinerario di Antonino, e dal Mazzella vien detto Tamarus, e no corre più pieno di acque del Calore, e nel mezzo

di amendue questi fiumi vi è ugualmente distante l'uno dall'altro Paduli sudetta, e di sopra a man sinistra questa Terra, dove si sono stati scuotimenti horribilissimi, con morte di quattro persone, e dove riguarda la parte di Mezzo giorno in circuito di sei miglia si sono aperte voraggini amplissime, e innumerabili, e alcune così grandi, che si hanno assorbiti molini, e altri edifici, de quali non si riconoscono li segni, e tutta la Diocesi di questa Metropoli ha patito danno molto notabile in questo ottavo terremoto.../*In San Giorgio della Molinara, located, according to Father Leandro Alberti, of Ferraro, and others, near the Calore and Sabbato rivers, which from Antonino's itinerary and Mazzella is called Tamarus, it no longer flows fuller with waters from the Calore, and in the middle of both these rivers is equally distant from each other Paduli mentioned above, and above on the left side of this land, where there have been horrifying tremors resulting in the death of four people, and where in the area facing south, within a circuit of six miles, vast chasms have opened up, some so large that they have swallowed mills and other buildings, of which no signs are recognizable, and the entire Diocese of this Metropolis has suffered very notable damage in this eighth earthquake* (*Magnati, 1688*) [30].

- Nelle Campagne di San Giorgio della Molinara, in circuito di sei miglia è profondata in moltissimi luoghi la terra, e alcune parti tanto, che sono stati ingoiati molini intieri./*In the countryside of San Giorgio della Molinara, in a circuit of six miles, the earth has sunk in many places, and in some areas so much that entire mills have been swallowed up* (*Bulifon, 1688*) [31].
- Nel territorio di S. Giorgio della Molara verso al mezzo di in circuito di sei miglia si sono aperte innumerevoli voragini, alcune delle quali sono state si grandi, che hanno ingoiato interi molini./*In the territory of San Giorgio della Molara, towards the midpoint of a six-mile circuit, numerous sinkholes have opened up, some of which have been so large that they swallowed entire mills* (*Sarnelli, 1688*) [33].
- In St. George, a Village belonging to the Marques of Torrecusa, there is a Mouth opened about three palms wide, about two miles in length; and some trying to measure its bottom, could find none (*Randal, 1688*) [48].

Post-earthquake sources

- In S. Giorgio, Terra del Marchese di Torrecuso di quel tempo, s'aprì una voragine larga tre palmi, e lunga da due miglia, che volendosene misurare la profondità, non fu possibile determinarla./*In S. Giorgio, in the territory of the Marquis of Torrecuso at that time, a chasm opened that was three palms wide and two miles long, that attempting to measure its depth, it was not possible to determine it* (*Vivenzio, 1788*) [49].
- Due miglia e mezzo di distanza dalla terra di S. Giorgio è voce che siasi aperta la terra in campagna facendo diverse fissure, una delle quali sia lunga quasi due miglia e larga più di tre palmi, et essendovisi calata una funicella col piombo per vedere quanto era profonda, non vi si è ritrovato il fondo./*Two and a half miles away from the land of San Giorgio, there are reports that the earth has opened in the countryside, creating several fissures, one of which is almost two miles long and more than three palms wide. A string with a plumb line was lowered to see how deep it was, but no bottom was found* (*De Blasiis, 1896*) [36].
- S. Giorgio la Molara, verso sud, si aprirono delle grandi voragini, alcuna delle quali al dire del Sarnelli, era si ampia da inghiottire interi mulini;/*In San Giorgio la Molara, towards the south, large chasms opened up, some of which, according to Sarnelli, were so wide as to swallow entire mills* (*Baratta, 1901*) [40].
- Nel territorio di S. Giorgio la Molara, dal lato di mezzodi e in un circuito di 6 miglia si aprirono innumerevoli voragini, alcune delle quali così grandi che ingoiarono interi molini ed altri edifici./*In the territory of S. Giorgio la Molara, on the south side and within a circuit of 6 miles, numerous chasms opened up, some of which were so large that they swallowed entire mills and other buildings* (*Vari, 1927*) [38].

- Possiamo, con molta prudenza, ritenere come probabili la formazione di diverse voragini apertesi nel territorio di S. Giorgio la Molara;/*We can, with great caution, consider as probable the formation of various chasms that opened in the territory of S. Giorgio la Molara;*. . . (*Franco, 1966*) [39].
- *Serva, 1981* [1] reports Anonimo, Vera e distinta relatione [47], Bulifon [31] and Magnati [30].
- Nei pressi di San Giorgio la Molara e di San Marco dei Cavoti furono osservate fenditure di alcuni chilometri./*Near San Giorgio la Molara and San Marco dei Cavoti, fissures several kilometers long were observed* (*Boschi et al. 1995*) [28].
- In una montagna s'è aperta una voragine, dalla quale esce in gran quantità acqua solfurea, com'anco se n'è aperta un'altra consimile in Alife [ed a] due miglia e mezza di distanza dalla terra di S. Giorgio [La Molara] è voce che sia aperta la terra in campagna, facendo diverse fissure, una delle quali lunga quasi due miglia e larga più di tre palmi e che essendosi calata una funicella con il piombo per vedere quando era profonda, non si sia trovato il fondo./*In a mountain a chasm has opened up, from which sulphurous water flows out in large quantities, as has another similar one in Alife [and] two and a half miles away from the land of S. Giorgio [La Molara] it is said that the land in the countryside has opened up, making various cracks, one of which is almost two miles long and more than three palms wide and that when a leaden cord was lowered to see how deep it was, the bottom was not found* (*Germino, 1999*) [37].
- Slope movements (SM), ground cracks (GC) (*Serva et al. 2007*) [21].
- Rottura del terreno, fratturazione, fessure, spaccature. Sprofondamento, avvallamento, voragine./*Ground rupture, fracturing, cracks, fissures. Sinking, depression, chasms* (*Guidoboni et al. 2019*) [14].

Inferred EEEs: Surface faulting/ground cracks; slope movement.

Notes: Vivenzio [49], Boschi et al. [28] and Guidoboni et al. [14] report Anonimo, Vera e distinta relatione [47]. De Blasiis [36] reports Bulifon [31]. Baratta [40] reports Sarnelli [33]. Vari [38] and Guidoboni et al. [14] report Magnati [30]. Germino [37] reports Confuorto [34].

SAN LORENZELLO (Benevento)

Contemporary earthquake sources

- È totalmente profondata, per averla abbattuta un monte chiamato M. Erbano, per esservi precipitata buona parte di esso co pietre e sassi infiniti sopra quella terra e di 1000 anime che ivi si numeravano, per quanto si ha di notizia vi sono rimaste da 400./*It is completely profound, for having brought down a mountain called M. Erbano, for a good part of it to have fallen with infinite stones and rocks upon that land and of 1000 souls that were counted there, as far as information goes, there are left about 400* (*Magnati, 1688*) [30].

Post-earthquake sources

- Dal Mont'Erbano venne lanciata una continua pioggia di sassi e pietre che precipitando in buona parte su San Lorenzello vi seppellirono 600 persone su 1000 che abitavano quella Terra./*A continuous rain of stones and rocks was launched from Mont'Erbano, which fell largely on San Lorenzello, burying 600 people out of the 1000 who lived in that land* (*Vari, 1927*) [38].
- . . . la caduta di massi che si distaccarono dal monte Erbano e distrussero S. Lorenzello, come già detto. . . S. Lorenzello, riporta il MAGNATI: "è totalmente profondata, per haverla abbattuta un monte, chiamato Mont'Erbano, per esservi precipitata buona parte di esso con pietre e sassi infiniti sopra quella terra. . . scagliando dall'apertura di quel monte continui sassi e pietre;/. . . *the fall of rocks that detached from Mount Erbano and destroyed S. Lorenzello, as already mentioned. . . S. Lorenzello, reports the MAGNATI: "is completely submerged, due to being struck by a mountain called Mont'Erbano, as a good part*

of it has fallen with infinite stones and rocks upon that land. . . continuously hurling stones and boulders from the opening of that mountain (*Franco, 1966*) [39].

- La caduta dei sassi però più che a Cerreto si verificò a S. Lorenzello: la cittadina soffrì danni notevoli per le pietre che precipitarono dal monte Erbano alle cui pendici era sita./*The fall of the rocks, however, occurred more in S. Lorenzello than in Cerreto: the town suffered significant damage from the stones that fell from Mount Erbano, at the foot of which it was located* (*Franco, 1967*) [51].
- *Serva, 1981* [1] reports Magnati [30].
- Dal Monte Erbano una massa di sassi e pietre si abbattè su San Lorenzello, dove perirono 600 persone./*From Monte Erbano, a mass of rocks and stones fell upon San Lorenzello, where 600 people perished* (*Boschi et al. 1995*) [28].
- Slope Movements (SM) (*Serva et al. 2007*) [21].
- Frana, colata di fango, scoscendimento, scivolamento, crollo, distacco./*Landslide, mudflow, rockfall, sliding, fall, detachment* (*Guidoboni et al. 2019*) [14].

Inferred EEEs: Slope movement.
Notes: All the recent references report Magnati [30].
SAN LORENZO MAGGIORE (Benevento)

Post-earthquake sources

- It destroyed almost completely Benevento, San Lorenzello, San Lorenzo Maggiore (covered by numerous rocks fallen from the Erbano mountain), San Lupo, (fully demolished) and Civitella, totally buried under the ruins of its buildings (*Marotta, 2017*) [55].

Inferred EEEs: Slope movement.
Notes: Marotta [55] does not report the original source.
SAN LUPO (Benevento)

Contemporary earthquake sources

- Per San Lupo fattesi pure le diligenze più esatte, di 800 anime, che in essa si numeravano, ne mancano solamente da 30 e tutte le sue habitazioni cascate da fondamenti, habitando quei poveri cittadini sotto delle capanne, e mal concie barracche, conforme tutta la Contea, dove per li tempi varij sorpresi da febbri acure continuamente, essendosi anche in quella aperta un'aspra Montagna.../*In San Lupo, the most precise efforts were made regarding the 800 souls that were counted there; only 30 are missing, and all its buildings have collapsed from their foundations, with the poor citizens living under huts and poorly constructed shacks, as is the case throughout the County. During various times, they were continually struck by severe fevers, especially since there is a harsh mountain opened up in that area* (*Magnati, 1688*) [30].

Post-earthquake sources

- Anche in quel di S. Lupo si aprì una montagna donde cascarono sassi e pietre infinite./*Even in that of S. Lupo, a mountain opened from which infinite stones and rocks fell* (*Vari, 1927*) [38].
- Al contrario, S. Lorenzello, Civitella, S. Lupo, Solopaca furono danneggiate massimamente per la caduta di materiale ruinato dai monti sovrastanti. . . Degli 800 abitanti di S. Lupo, 30 trovarono la morte sotto le rovine, . . . essendosi anche in essa aperta un'aspra montagna donde cascano sassi e pietre. . ./*On the contrary, S. Lorenzello, Civitella, S. Lupo, and Solopaca were severely damaged due to the fall of materials from the surrounding mountains. . . Of the 800 inhabitants of S. Lupo, 30 lost their lives under the ruins,... a harsh mountain opened up from which stones and rocks fall...* (*Franco, 1966*) [39].

- La scissione di una gran parte del monte che poi si staccò e precipitò, molto probabilmente, avvenne a S. Lupo e a Civitella, in quest'ultima più precisamente nei pressi di Ponte Lavella ove fino a poco tempo fa era visibile un picco solitario staccato./*The splitting of a large part of the mountain that then detached and fell, very likely, occurred at S. Lupo and Civitella, more precisely in the latter near Ponte Lavella, where until recently a solitary peak that had broken off was visible* (*Franco, 1967*) [51].
- *Serva, 1981* [1] reports Magnati [30].
- Slope Movements (SM) (*Serva et al. 2007*) [21].
- Rottura del terreno, fratturazione, fessure, spaccature. Frana, colata di fango, scoscendimento, scivolamento, crollo, distacco./*Ground rupture, fracturing, cracks, fissures. Landslide, mudflow, rockfall, sliding, fall, detachment* (*Guidoboni et al. 2019*) [14].

Inferred EEEs: Surface faulting; slope movement.
Notes: All the recent references report Magnati [30].
SAN MARCO DEI CAVOTI (Benevento)

Contemporary earthquake sources

- S. Marco delli Cavoti si vede tutto conquassato con morte di nove, o dieci persone, anzi si è in essa aperta la terra per tre miglia di circuito con infinite fenditure, benché non molto profonde./*San Marco dei Cavoti appears completely devastated with the death of nine or ten people; indeed, the earth has opened up for three miles in a circuit with countless fissures, although not very deep* (*Magnati, 1688*) [30].
- . . . e nel Territorio di San Marco per lo spazio di tre miglia si vedono per la terra grosse fenditure./*... and in the Territory of San Marco, for the span of three miles, there are large fissures visible on the land* (*Bulifon, 1688*) [31].
- Nel territorio di S. Marco si è aperta la terra per lo spazio di tre miglia, se bene le fenditure non sono così profonde, come quelle di S. Giorgio./*In the territory of St. Marco, the earth opened up for the distance of three miles, although the fissures are not as deep as those of St. Giorgio* (*Sarnelli, 1688*) [33].

Post-earthquake sources

- Nella campagna circostante a S. Marco si produsse un'altra fenditura di tre miglia di lunghezza ma non ampia come la precedente (S. Giorgio)./*In the surrounding countryside of S. Marco, another fissure occurred, three miles long but not as wide as the previous one (S. Giorgio)* (*Baratta, 1901*) [40].
- Nel territorio di S. Marco dei Cavoti si aprì la terra per lo spazio di 3 miglia con infinite fenditure, benchè non molto profonde./*In the territory of San Marco dei Cavoti, the earth opened for a distance of 3 miles with infinite fissures, although not very deep* (*Vari, 1927*) [38].
- Le fenditure che comparvero nei terreni di S. Marco dei Cavoti;/*The cracks that appeared in the territories of S. Marco dei Cavoti;* (*Franco, 1966*) [39].
- *Serva, 1981* [1] reports Bulifon [31] and Magnati [30].
- Nei pressi di San Giorgio la Molara e di San Marco dei Cavoti furono osservate fenditure di alcuni chilometri./*Near San Giorgio la Molara and San Marco dei Cavoti, fissures several kilometers long were observed* (*Boschi et al. 1995*) [28].
- Cose più modeste (e credibili) furono notate nel "territorio" di S. Marco dove la terra si è aperta di tre miglia./*More modest (and credible) things were noted in the "territory" of St. Marco where the earth opened up three miles* (*Germino, 1999*) [37].
- Slope movements (SM), ground cracks (GC) (*Serva et al. 2007*) [21].
- Rottura del terreno, fratturazione, fessure, spaccature./*Ground rupture, fracturing, cracks, fissures* (*Guidoboni et al. 2019*) [14].

Inferred EEE: Ground Crack; Slope movement.

Notes: Baratta [40] and Vari [38] report Sarnelli [33]. Vari [38] and Guidoboni et al. [14] report Magnati [30]. Franco [39] reports Magnati [30], Bulifon [31], Baratta [40] and Vari [38]. Germino [37] reports Bulifon [31] and Sarnelli [33].

SOLOPACA (Benevento)

Post-earthquake sources

– Al contrario, S. Lorenzello, Civitella, S. Lupo, Solopaca furono danneggiate massimamente per la caduta di materiale ruinato dai monti sovrastanti./*On the contrary, S. Lorenzello, Civitella, S. Lupo, and Solopaca were severely damaged due to the fall of materials from the surrounding mountains* (*Franco, 1966*) [39].

Inferred EEEs: Slope movement.
Notes: Franco [39] does not report the original source.
TABURNO (Benevento)

Contemporary earthquake sources

– Le montagne di Cervinara in diocesi furono vedute, come navi fluttuanti: ed il gran Taburno, da Virgilio commemorato, videsi aprire, e chiudere, e ne cadde un sasso immenso infin da su lacime. Si videro ne' giardini i vasi de fiori alzarsi in aria, ricadere, e fragnersi ne medesimi luoghi, donde erano stati innalzati./*The mountains of Cervinara in the diocese were seen as floating ships: and the great Taburno, commemorated by Virgil, appears to open and close, and an immense stone fell from the summit. In the gardens, the flower vases were seen rising into the air, falling back down, and shattering in the same places from which they had been lifted* (*Sarnelli, 1688*) [33].

Post-earthquake sources

– La cima del Taburno si aprì e da essa si staccarono grossi ammassi di roccie./*The summit of Taburno opened, and from it large masses of rock detached* (*Baratta, 1901*) [40].
– Le Montagne di Cervinara furono vedute come navi agitate dai flutti e il monte Taburno si vide aprire e chiudere, mentre dalla cima cadde un enorme macigno./*The Mountains of Cervinara were seen as ships tossed by the waves, and Mount Taburno appeared to open and close, while a huge boulder fell from its summit* (*Vari, 1927*) [38].
– Dal monte Taburno, che fu visto aprirsi e richiudersi, si staccò un enorme masso; le montagne di Cervinara furono smosse violentemente./*An enormous boulder detached from Mount Taburno, which was seen opening and closing, while the mountains of Cervinara were violently shaken* (*Boschi et al. 1995*) [28].

Inferred EEEs: Ground cracks; slope movement; jumping stones.
Notes: All the recent references report Sarnelli [33].
VICO EQUENSE (Napoli)

Post-earthquake sources

– Slope movements (SM) (*Serva* et al. *2007*) [21].

Inferred EEEs: Slope movement.
Notes: Serva et al. [21] does not report the original source.
VITULANO (Benevento)

Contemporary earthquake sources

– Vitulano con tutta la Valle comprende[n]te 36 Casali, e le Terre di Tocco, e Cagiano del Sig. Prencipe di Montesarchio rovinata in buona parte, Casali nove con Tocco rovinati intieramente, e gli altri poco meno, essendo necessario abbattere la maggior parte delle case, e l'altre accomodarle, e solame[n]te il Casale di Cicignano, è restato in tutto disfatto, faceva anime 800, morte 150 e nel Casale chiamato terra di fuoco, nel quale non vi è altro, che una strada si fece un'apertura larga un palmo, e mezzo,

molto profonda, che tira da un capo all'altro della detta strada./*Vitulano, along with the entire valley comprising 36 Casali, and the lands of Tocco and Cagiano belonging to the Prince of Montesarchio, are largely ruined. The nine Casali with Tocco are completely destroyed, and the others are not much better, requiring most houses to be demolished and the rest renovated. Only the Casale of Cicignano remains entirely devastated, having had 800 inhabitants and 150 deaths. In the Casale called Terra di Fuoco, where there is nothing than a street where a large and deep opening was made, stretching from one end of the street to the other* (*Anonimo, Vera fedele, e distintissima, 1688*) [41].

- In Vitulano Terra del Sudetto Principe di Montesarchio, che vien composta di 36 Casali, o Castella, come voglion chiamarsi da Scrittori, vi perirono da 40 persone, ma tutte rovinate, e danneggiate, e dalla Valle di essa uscì una gran trave di fuoco, che con le sue fiamme, strisciandosi per quei vicini Monti, v'impressero le loro vestigia./*In Vitulano, Land of the South, Territory of the Prince of Montesarchio, which is composed of 36 Casali, or Castella, as writers choose to call them, about 40 people perished, but all were ruined and damaged. From the valley of this place, a large beam of fire emerged, which with its flames, spreading across those nearby mountains, left their marks* (*Magnati, 1688*) [30].
- Nella Valle di Vitulano si vide, come scrive l'accuratissimo Signor Abate Sarnelli, una gran trave di fuoco, che strisciandosi su l'erbe, le lasciò abbrustolite. Ed appresso il Tremuoto si sentì una puzza spiacevolissima, come di zolfo, e si sollevò un vento gagliardissimo/Derivar poi il Tremuoto d'accensione di bituminose, e solfuree particelle, ce lo dan chiaramente a divedere lo spiacevolissimo odore, che per lo più dopo i grandi scuotimenti sentiamo, come appunto in questo di Napoli abbiam sperimentato, il caldo eccessivo, ed eziandio il fuoco medesimo, che alle volte all'aperture della Terra vien cacciato fuori, sicome nella Valle di Vitulano anche in questo Tremuoto osservossi./*In the Valley of Vitulano, as the very meticulous Abbot Sarnelli wrote, a large beam of fire was seen, which, sliding over the grass, left it scorched. After the earthquake, a very unpleasant smell, like sulfur, was perceived, and a very strong wind arose. It is clear that the earthquake caused the ignition of bituminous and sulfurous particles, which explains the unpleasant odor we often experience after major tremors, as we have seen in Naples, where excessive heat and even fire are sometimes expelled from the earth, just as observed in this earthquake in the Valley of Vitulano* (*Bulifon, 1688*) [31].
- Segno di ciò evidente è la gran trave di fuoco, che uscì dalla Valle di Vitulano, e strisciandosi per que monti lasciò le vestigie su l'erbe incendiate./*Clear sign of this is the great beam of fire, which came out of the Valley of Vitulano, and crawling across those mountains left its marks on the burned grass* (*Sarnelli, 1688*) [33].

Post-earthquake sources

- Dalla valle di Vitulano uscì una gran trave di fuoco le cui fiamme, strisciandosi per quei vicini monti, v'impressero le loro vestigia./*From the valley of Vitulano, a great beam of fire emerged, whose flames, crawling over those nearby mountains, impressed their marks upon them* (*Vari, 1927*) [38].
- *Serva, 1981* [1] reports Anonimo, Vera fedele, e distintissima [41], Magnati [30] and Bulifon [31].
- Una gran trave di fuoco vista nella valle di Vitulano che strisciandosi per quei monti, lasciò le vestigie su l'erbe incendiate./*A large beam of fire seen in the valley of Vitulano, crawling through those mountains, left its marks on the burned grass* (*Germino, 1999*) [37].
- Rottura del terreno, fratturazione, fessure, spaccature./*Ground rupture, fracturing, cracks, fissures* (*Guidoboni et al. 2019*) [14].

Inferred EEEs: Surface faulting/ground cracks; gas exhalation.

Notes: Vari [38] and Germino [37] report Magnati [30] and Sarnelli [33]. Guidoboni et al. [14] report Magnati [30] and from the *Archivio General de Simancas [56]: 'The center

was composed of about thirty casali; in one of them, called Terra dei Turchi, the road was erased by the opening of a very deep and about 40 cm wide crack (a palm and a half)'.

4. Discussions and Conclusions

The dataset of EEEs from the 1688 earthquake presented in this paper is based on a critical analysis of several documents, including historical sources as well as data published by other authors [1,12–14,21]. Our dataset reports 43 environmental effects (primary and secondary) that occurred in 23 localities, including 8 novel sites: Alife, Civitella Licinio, Matese Mt., Pietraroja, Pozzuoli, San Lorenzo Maggiore, Solopaca and Taburno Mt. (see Table S1 in Supplementary Materials).

Our study of the distribution of the various coseismic effects shows that, excluding effects observed further than 100 km from the epicenter (such as in Atella and Pomarico, approximately 103 km and 188 km from the epicenter, respectively), most EEEs were focused over an area of approximately 5500 km^2. Moreover, except for liquefaction and jumping stones, which were noted in one case near Benevento, the other effects such as ground cracks, rockfalls and landslides appear clustered for multiple localities (Figure 6). Hydrological anomalies were the most frequently observed effects. Slope movements were the most widespread secondary EEE within a 10 km radius from the epicenter, mostly focused west of Cerreto Sannita (Figure 6).

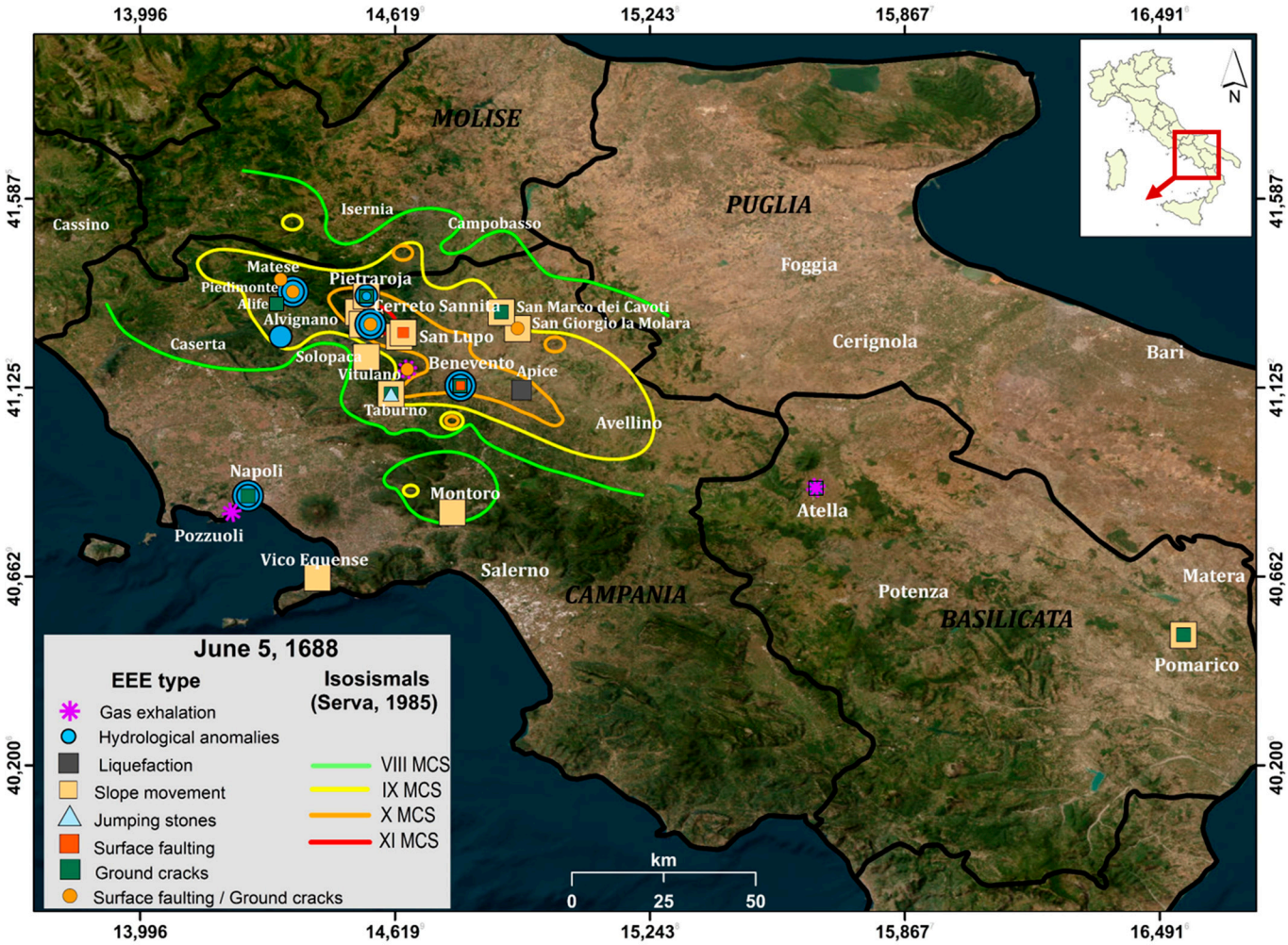

Figure 6. The spatial distribution of the 43 EEEs of the 1688 Sannio–Matese earthquake presented in our database [12].

Our sources enabled the identification of the potential localities for the primary effects, although confirmation will depend on subsequent field studies. As mentioned, we reassessed the intensity of the 1688 earthquake using the ESI-07 scale based on the analysis of the total area affected by secondary EEEs and on the variety of these effects (see Michetti et al. [15] for guidelines).

Considering these new data and the ESI-07 scale, we evaluated an end-to-end surface faulting length of about 40 km, thus assigning an epicentral intensity value of I_0 = X.

We compared the epicentral intensity value that we estimated for the 1688 Sannio–Matese earthquake using the ESI-07 scale with the MCS intensity values [14,21], which are based on damage to human-built structures.

The MCS intensity value is one degree higher than the ESI-07 values, likely due to the increased vulnerability of structures in 1688. This comparison validates the ESI-07 scale and highlights its utility in providing a more comprehensive and reliable assessment of intensity distribution for historical earthquakes. Our study suggests that combining MCS intensity values with ESI-07 intensity data, without prioritizing one scale over the other, can enhance seismic hazard estimation for the study area and surrounding regions. In fact, only by integrating the information obtained from different scales can we overcome the limitations of individual approaches, such as the dependence of the intensity degree on the historical period, the economy and the different areal distribution of cities and villages in traditional macroseismic scales (e.g., MCS, MSK) vs. the reliability and accuracy of the data obtained from historical sources, regarding the ESI scale.

The primary limitation of the approach presented here is the scarcity of information regarding the precise location of the observed and reported effects in the historical sources consulted. This results in a degree of imprecision when mapping these effects. However, this challenge can be addressed by conducting geological–geomorphological fieldwork in the affected localities. This will provide essential constraints to refine the positioning of these effects, thereby minimizing imprecision as much as possible.

We have already conducted several field campaigns in some localities, such as Apice, Benevento, San Giorgio la Molara and San Marco dei Cavoti. However, this is a phase of our work that is still in progress. These geological–geomorphological data will be implemented and compared with ESI data and other data types from the area, such as geophysical data, to minimize as much as possible the subjectivity and imprecision inherent in historical sources.

Concluding, ESI data, when used independently, provide large-scale insights into the affected areas of greatest interest. These insights can guide further investigations and studies, which in turn enable us to progressively refine the seismic hazard of the region.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/data10030039/s1, Table S1.

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