Earthquake effects on the environment: from historical descriptions to thematic cartography

Gianluca Valensise (1) **and Emanuela Guidoboni** (2)
(1) *Istituto Nazionale di Geofisica, Roma, Italy*
(2) *SGA, Storia Geofisica Ambiente, Bologna, Italy*

Abstract
In the *Catalogue of Strong Italian Earthquakes*, all testimonies relating to effects on the environment have been systematically analysed, geo-referenced and filed. This complex work of research and organisation has been conducted according to two main perspectives: the historical and the geological point of view. As regards the historical point of view, on the one hand the elements of complexity have been highlighted relative to data which, particularly before the seventeenth century, had been produced within cognitive and cultural contexts which are now extremely remote and beyond naturalistic logic. On the other hand, from the seventeenth century, the growing attention of the cultural élite of the era towards environmental phenomena (now being seen within a naturalistic perspective), favoured the gradual enhancement of the *corpus* of information, also as regards the quality of the data. 2053 effects of earthquakes on the environment are listed in the CFTI3, classified into five categories which are in turn divided into other descriptive typologies. Many examples are also provided with the purpose of outlining the specific problems concerning the available data. As regards the geological point of view, the effects described in historical sources may be divided into two categories: the effects related to shaking, and the effects which may be due directly to the seismogenic source, generally with less territorial impact but of considerable scientific interest. Reference is also made to the various attempts to codify the environmental effects of earthquakes within the traditional macroseismic scales, although it is acknowledged that this operation is fraught with ambiguities. Prospective users of the CFTI3 are encouraged to take advantage of the availability of the original testimonies to develop their own interpretations of the phenomena described.

Key words *earthquake effects – surface faulting – historical cartography*

1. Introduction

This is the first time that an earthquake catalogue has systematically made available the effects on the environment as mentioned in historical sources. Today, we can make reference to this important aspect of the description of the seismic scene, until now the subject of sporadic attention and limited to a few specific events, in a comprehensive way with the aid of systematic records and immediate access to the historical descriptions of such effects. The process of archiving required a typological scheme to be drawn up in which each environmental effect described by the sources used for the *Catalogue of Strong Italian Earthquakes* was organised. The classification remains intentionally detailed, even knowing that some of the categories identified represent phenomena that are almost certainly linked if not actually coinciding. This choice reflects the desire to respect in full the

Mailing address: Dr. Gianluca Valensise, Istituto Nazionale di Geofisica, Via di Vigna Murata 605, 00143 Roma, Italy; e-mail: valensise@ingv.it

Table I. Classification of the effects on the environment.

A	**Changes in the landscape**
1	Ground breakage, fractures, fissures, splitting
2	Subsidence, landslip
3	Uplifting
4	Collapse of cavities or effects on concretions in caves
5	Landslide, earth flow, mud flow
6	Avalanche, landslide, snowslide
B	**Watercourses**
1	Increase in the flow of watercourses
2	Decrease in the flow of watercourses
3	Overflow, land turns into marshland
4	Sudden deposition of alluvium
5	Changes in riverbeds, deviations, interruptions
6	Burst river banks, flooding
7	Clouding
C	**Lakes-basins**
1	Appearance or disappearance of lakes-basins
2	Clouding of lakes-basins
3	Variation in water level of lakes-basins
4	Flooding of lakes-basins
D	**Subterranean streams**
1	Changes in spring discharge
2	Appearance or disappearance of springs
3	Clouding of springs
4	Changes in level of water wells
5	Outflow of water or mud from the ground or soil liquefaction
6	Changes in water temperature
7	Changes in water chemistry
E	**Marine or coastal environment**
1	Generic changes of coastline
2	Erosion or retreat of coastline
3	Tsunami
F	**Others**
1	Mortality of fish and other organisms
2	Exhalation or emission of gases, eruptions of salse or mud cones
3	Sulphurous exhalations
4	Electrical or magnetic phenomena
5	Light phenomena

language and content of the historical descriptions, elaborated in different ages and cognitive frameworks, leaving to the reader the difficult task of bringing apparently different observations into the same framework of phenomena associated with earthquakes.

Each of the effects described has been coded according to the scheme in table I and located with the utmost precision allowed by the accuracy of the description itself.

There are 2053 descriptions of the effects of earthquakes on the environment available in the CFTI3. Altogether, such data represent an informative package of statistical significance which, considering the chronological span of investigation of almost 2500 years, obviously poses problems and requires explanations. Indeed, this repertory gathers data from different cultures, generated within different cognitive frameworks whose language is clearly far removed from that of the present day. These elements will certainly raise queries as to the general reliability of the data gathered, the problems caused by such data during their initial interpretation, and their practical use to increase knowledge about the earthquakes to which they refer. To facilitate the correct use of the effects on the environment collected in the CFTI3, we propose here clarifications of certain aspects we consider to be important, concerning both the historical and the geological points of view.

2. The historical point of view

Figure 1 shows the chronological distribution of data regarding the effects on the environment in relation to the earthquakes analysed throughout the whole chronological time span of the CFTI3 (461 B.C.-1997). If we exclude the 4th century A.D., there are very few descriptions of seismic effects on the environment until the sixteenth century, with these becoming more frequent in the last three centuries. To explain how difficult it is to reconstruct a coherent picture of the environmental effects of earthquakes in ancient and medieval times, we will now examine some problems that emerged during the research concerning these periods.

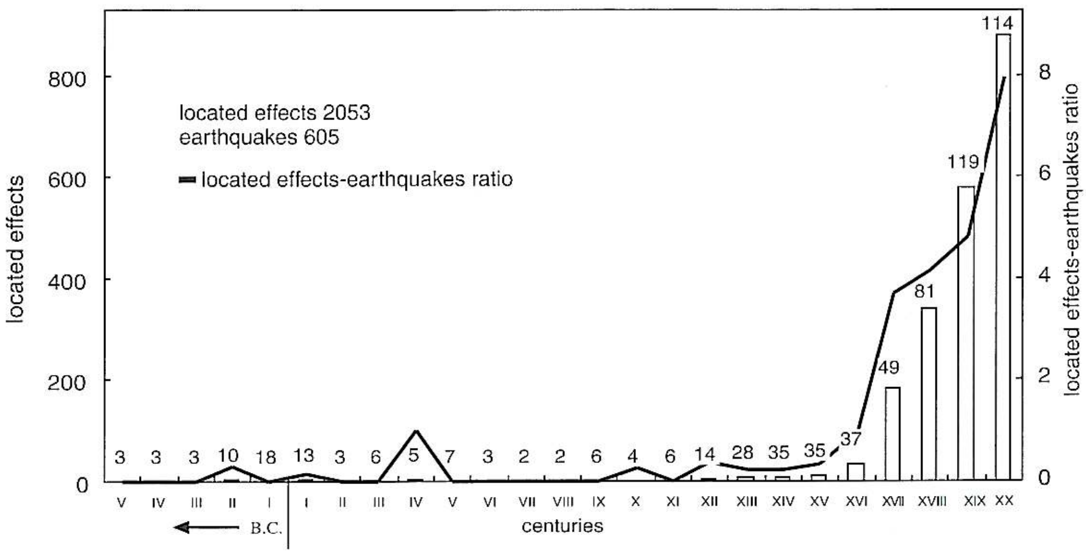

Fig. 1. Reported earthquake effects on the environment, 5th century B.C. - 20th century A.D. The numbers in the graph refer to earthquakes analysed for each century.

In the ancient and late Roman world, the effects of earthquakes on the environment made a great impression in the minds of the observers. This was due to that feeling of the sacred and magical within which natural phenomena were perceived, in a context of «nature» seen as unchangeable and mysterious. Indeed, these effects are often recorded in the sources with such emphasis that the direct cause fades into the background, so that today's reader may sometimes doubt whether the phenomenon described was caused by an earthquake. Moreover, seldom in the Roman world were the effects of earthquakes even mentioned, especially if they belonged to smaller settlements. See the earthquakes of 133 B.C. at Luni, of 117/113 B.C. in Lucania and of 117/113 B.C. in Priverno, for example. In the first two cases, the source, a book of prodigious events written in 4th-5th century A.D. by Ossequente, does not clearly explain whether the environmental effect – extensive subsidence in Luni, large fissures in the ground in Lucania – was caused by an earthquake. In the third case, the sources, Cicero and the above-mentioned Ossequente, record the news of a landslide and subsidence without clearly indicating an earthquake as the cause of the two phenomena. It is true that in the third case, Priverno, the local geological setting led us to believe that the phenomenon was independent of a seismic event. In other cases the correlation is unquestionable: see for example the case of the earthquake in Rieti in 76 B.C. in which the effects of the earthquake on the course of the River Velino were described.

Evidence concerning the early Middle Ages (sixth to tenth centuries) was mainly produced in monastic circles and therefore in very important – though not urban – cultural contexts. One may think that this permitted more direct observations of effects on the environment to be made. However, the culture that permeated the production of such observations did not favour explicit and direct analyses of these phenomena. The earthquake was instead taken as a «symbol» with a plurality of meanings: its material and earthly traces did not thus belong solely to the naturalistic world (Guidoboni, 1989). Let us consider the description of the effects on the waters of the Po caused by the earthquake of 3 January 1117, in the heart of the Po valley. It was written and narrated that the waters came to a standstill and rose up «like a bridge», interpreted as a divine sign between God and Man. These particular cognitive and cultural contexts, as has often been noted, create a very strong filter between the actual observations and our current way of reinterpreting the phenomena described. Once these difficulties of a hermeneutic kind have been taken into consideration, the traces formed by these ancient descriptions of the effects of earthquakes on the physical environment are still important, and for this reason they have been included in the data bank. It is obviously up to the user to interpret this evidence according to the aims of his or her research. Another complexity is due to the fact that certain environmental effects concerning the Middle Ages, by chance preserved by the seismological tradition through a tradition of historiography often inaccurate and far from the primary sources, were found to be inexact or mistakenly correlated with earthquakes. A case in point could be the subsidence of a part of the island of Malamocco (in the Venice lagoon), which was considered the effect of an earthquake in the twelfth century (see the «earthquake» of Venice in 1106, which was eliminated).

Sometimes, however, medieval chroniclers of urban extraction have concentrated on the environmental effects and described them with surprising accuracy, as in the case of Sicily in the twelfth century. The main effects on the environment of the 1169 earthquake concerned changes in water-level in the ports of Catania and Messina. From these remote testimonies, a coherent point of view emerges: in Messina and Catania the sea-waters first withdrew and then suddenly flowed in again, exceeding their usual level. It is important to stress that the nature of the described movement of the sea plus the general rationality of the phenomena reported by the sources, suggest a desire to give a faithful description of the events, rather than a predominance of the logic of the «portent». Incidentally, the reported observations agree with current models of tsunami generation, thus allowing researchers in this disciplinary field to constrain aspects of the source-mechanism of this and other ancient earthquakes that would be hard to achieve on the basis of the distribution of the effects alone.

Language often envelops such phenomena in an aura of legend: mountains that split in two, smoking and howling. The recodification of this type of strongly figurative language within our present cognitive models is not immediate. In general, instead, a better understanding of the meaning of often fantastical descriptions only becomes possible when certain effects are repeated in the same areas and in later periods. Thus, if the *splitting* of a mountain can be explained with reference to the formation of fractures in uneven lands and the *smoke* to the dust raised by the rolling of boulders, the *howling* can be recognised as the acoustic perception of low frequencies, possibly amplified by particular characteristics of the subsoil.

In the sixteenth century, observations of environmental effects began to represent an important element leading to a better understanding of earthquakes. The descriptions of environmental effects became the subject of discussion regarding the actual origin of seismic phenomena: natural philosophers, doctors and naturalists began to observe the splitting of the earth, liquefactions of the ground (leading to general or differential subsidence of the foundations), the emission of flaming gases, poisonous exhalations and even phenomena of ionisation of the air («red sky»). The earthquakes that took place between 1570 and 1574 in Ferrara are a case in point. From the vast body of memorial sources analysed (correspondence, personal and family diaries, and chronicles), a detailed picture of environmental effects emerged which included splitting and liquefaction of the ground in the urban area and in an area around the city walls, fractures of the soil with the emission of hot water and steam, and gaseous emanations.

A separate section is made up of the iconography of seismic environmental effects, which despite being of notable interest, is not always immediately useable and may even be the cause of misinterpretations. This is due to the fact that, as in the case of messages expressed verbally, the communication transmitted through iconographic language relates to a cognitive and cultural context that refers to numerous suppositions that were «culturally situated»: these were therefore immediate for the contemporary reader, but not necessarily so for the modern reader, who is thus obliged to undertake the long task of interpretation. Nevertheless, there are cases in which the figurative elements to be decodified are simpler: see fig. 2, for example, showing some of the phenomena observed in 1690, perhaps triggered off or aggravated by the earthquake in Romagna in 1688. This iconographic portrayal was made in 1693 by doctor Marc'Antonio Melli, who identified the slopes of Mount Budrialto as the area that recorded the largest environmental effects of this event: the engraving shows the landslide and the subsequent formation of lakes due to the blocking and diversion of the River Lamone.

3. From naturalists to seismologists: between observation and theory

A great observational leap towards more accurate and more immediately beneficial descriptions within current scientific frameworks took place in the eighteenth century, clearly as the result of the huge progress in the sciences and naturalistic thinking. The descriptions of the effects of major earthquakes had already in the previous century proved to be aware of the marks left on the environment. An example may be seen in the descriptions of the effects on the environment caused by the earthquakes in Calabria in 1638, which were also responsible for creating a large area of marshland south of Sant'Eufemia (about 180 km^2) and a «60-mile long», «3-palm high» fracture with displacement on the eastern slope of the Sila. Consider also the Sannio earthquake of 1688; despite the use of fairly general terms like «splitting» and «fissures» in the descriptions, the authors perhaps referred to much more articulate phenomena potentially providing important information about the seismic source. As regards the large earthquake that hit Eastern Sicily in 1693, the descriptions are highly detailed (see in particular the description of the tsunami at several sites along the coast and fig. 8).

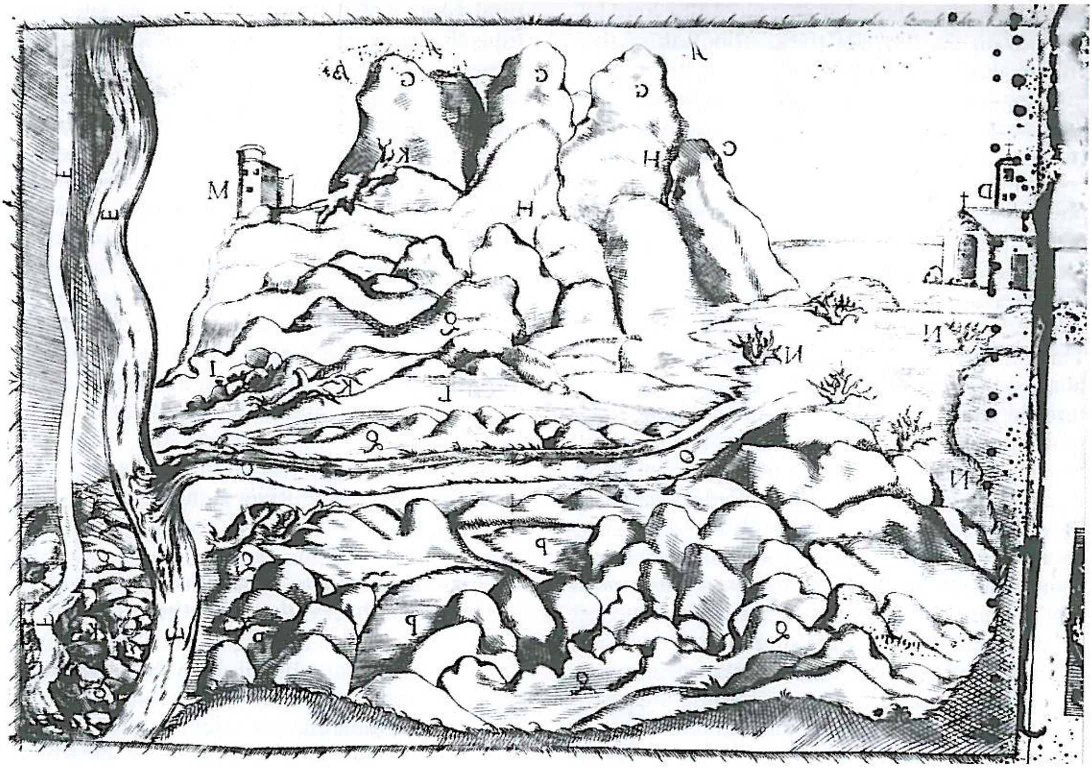

Fig. 2. Monte Budrialto (upper Romagna): this non specular engraving was made by Marc'Antonio Melli in 1690 and published in 1693; the author represented natural changes in the Lamone River caused by the landslide triggered or worsened by the April 1688 earthquake.

However, it was only after the major earthquakes in Calabria in 1783, with the mission of the Neapolitan academics in the areas worst hit (Schiantarelli and Stile), that the repertory of seismic environmental effects acquired a new importance: landslides, splitting, lakes, landslips and chasms were described and often drawn with great accuracy (see some of these illustrations in figs. 3 and 4 and on the cover of this volume). There are 267 geo-referenced and described observations of the effects on the environment relative to the 74 earthquakes of the eighteenth century listed in the CFTI3.

With the development of positivist sciences, increasing attention was paid to the earthquake effects on the environment. During the nineteenth century a true naturalistic and geological approach towards earthquakes was perfected which allowed as many as 514 observations on environmental effects to be archived for the 101 analysed events: more than a quarter of the total number of descriptions gathered. Many of these contain a remarkable wealth of detail and add important information about the earthquake itself. There are numerous cases: a typical example of this new attention is given by the scientific reports on the earthquake in Calabria in 1894, for which a ministerial board of experts (Gemmellaro, Riccò, Di Stefano) was set up in order to study the conditions leading to greater damage in certain areas and to prescribe new laws for rebuilding. The attention with which not

Fig. 3. Surroundings of Cinquefrondi (Southern Calabria): the observer, the Neapolitan academic Pompeo Schiantarelli, directly sketched the cracks and sinkings caused by the earthquakes of 5 February 1783. Table 29 of the atlas by Pompeo Schiantarelli and Ignazio Stile, in the *Istoria de' fenomeni del tremoto...* (History of earthquake phenomena...) published in Naples in 1784.

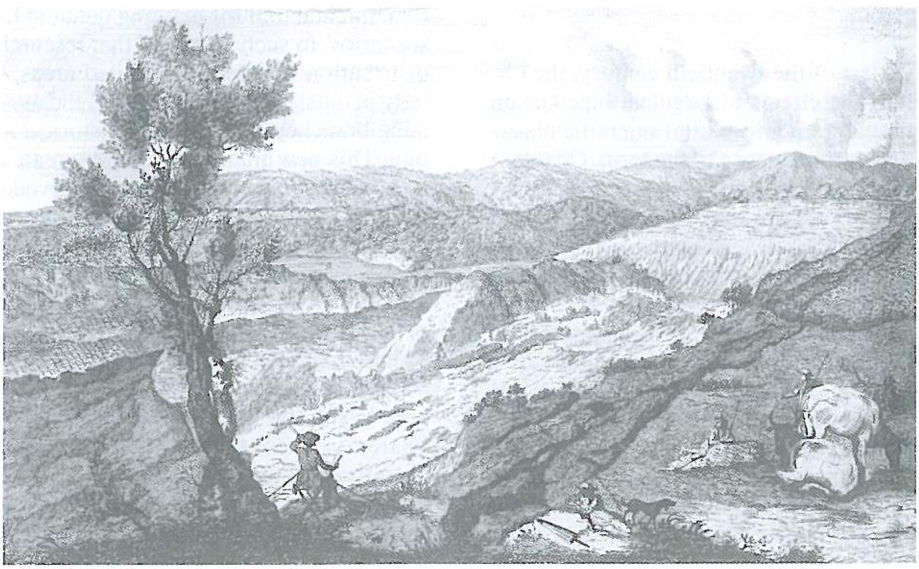

Fig. 4. Surroundings of Oppido (now Oppido Mamertina, Southern Calabria): ground cracks and landslips close to the course of the River Cumi, caused by the earthquakes of 5 February 1783. Table 45 of the atlas by Pompeo Schiantarelli and Ignazio Stile, in the *Istoria de' fenomeni del tremoto...* (History of earthquake phenomena...) published in Naples in 1784.

only the damage to buildings but also the effects on the environment were observed demonstrates a new awareness in which the balance between established facts and caution reveal an attentive and competent scientific environment. New elements were introduced that today, in a changed cognitive framework, allow us to hypothesise a source-mechanism for this earthquake of 1894. For example, Riccò describes as follows the instrumental measurement of altimetric variations observed at Punta Faro:

> «The next morning, at 8.30, the needle indicated a level slightly lower than that of the previous day at the same time; and afterwards, on starting the instrument's clock and paper, it traced a similar line to that of the day before, but somewhat lower, corresponding to a sea-level 5 or 6 centimetres lower; a longer study is needed (which cannot be done here) to see whether this small variation really depends on the relative lowering of the sea-level, or instead on a steady rising of the mareograph or of the ground on which it is installed caused by the earthquake, or if it is a question of the mechanism being moved as a result of the quake, or if it is simply a question of the change in the influence of the sun and the moon and of the marine and air currents on the tide, which is more probable» (Riccò, 1907, complete text stored in the CD-ROM).

At the start of the twentieth century, the observation of the effects of large earthquakes on the environment became part of scientific observation as the current sense of the term. Observations of the changes in the coastline caused by the earthquake at Messina in 1908 (Loperfido, 1909) and detailed descriptions of the ground failures caused by the Avezzano earthquake in 1915 (Oddone, 1915) were ahead of their time, placing Italy in an eminent position in the field of experimental seismology.

4. The geological point of view

Figure 5 shows the distribution of the environmental effects more frequently reported by the sources. The effects most often noted belong to category A (changes in the landscape). Within this scheme, the effects described as «ground breakage, fractures, fissures, splitting» (A/1, 517 descriptions of which fig. 6 shows the geographical distribution) and «landslide, earth flow, mud flow» (A/5, 468 descriptions shown in fig. 7) are clearly predominant. Where the descriptions do not contain elements allowing a more accurate classification, the general code of the most appropriate class has been attributed.

Besides the classification used, which provides particular detail for the reasons given above, from a strictly geological point of view the effects reported by the historical sources may be sub-divided into two large categories. The first of these categories includes all the descriptions that concern the natural environment's response to the shaking caused by the earthquake. The importance of such descriptions lies in the ability to illustrate the distribution of possible unstable areas and to quantify the levels of shaking that could trigger off destructive phenomena, although a correct reading of the descriptions and identification of the processes activated is generally difficult and potentially ambiguous.

Over the past few years, it has been seen that the availability of independent observations of the seismic response from buildings and the physical environment in a specific area is a fundamental tool for defining detailed high-risk scenarios, to such an extent that research on the distribution of effects in limited areas, particularly in cities, is becoming one of the most promising branches of traditional historical seismology. This new trend attempts to create a direct link between the phenomena observed and the parameters of the quake capable of generating them, in some way replacing the old inadequate macroseismic procedure which involved attributing a level of intensity to the different extent of modifications of the physical environment. The Mercalli Scale, for example, assigns degree VII to the incipient collapse of riverbanks, degree VIII to the formation of cracks and liquefaction of unconsolidated deposits, and degree X to the fall of «whole boulders», to reach the «grandiose devastation» described in the definition of level XII, in a crescendo that is more reminiscent of the collective imagination of catastrophes than of rigorous scientific classification. This also applies to similar observations in the MSK, MM and JMA (Japan Meteorological Agency) scales.

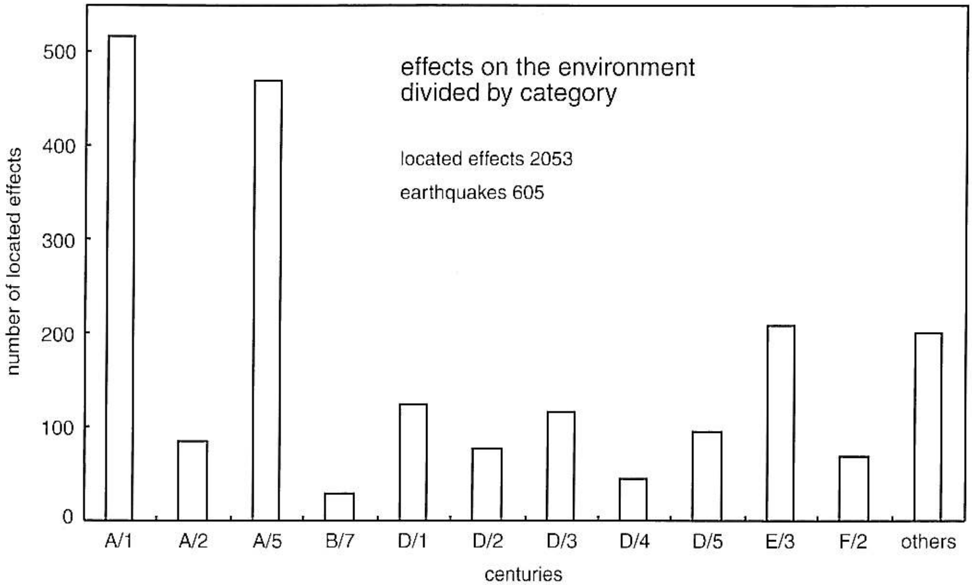

Fig. 5. A/1 = ground breakage, fractures, fissures, splitting (517); A/2 = Subsidence, landslip (84); A/5 = landslide, earth flow, mud flow (468); B/7 = clouding (30); D/1 = changes in spring discharge (123); D/2 = appearance or disappearance of springs (77); D/3 = clouding of springs (116); D/4 = changes in level of water wells (45); D/5 = outflow of water or mud from the ground or soil liquefaction (96); E/3 = tsunami (209); F/2 = exhalation or emission of gases, eruptions of salse or mud cones (69); others (219). Notice that the diagram includes only categories with more than 20 reported occurrences.

Recently, the matter has been the subject of different analyses and points of view, including that of Grünthal (1993) and Serva (1994), the former being expressed within the framework of the «European Macroseismic Scale 1992». These analyses share the basic awareness that the effects of earthquakes on the environment feature great variability for the same intensity level. Nevertheless, whilst Serva concludes by suggesting that such observations may still be used to evaluate the seriousness of the effects of past earthquakes as long as they are measured beforehand against the effects found in buildings, skepticism and worry seem to predominate among the compilers of the «European Macroseismic Scale 1992» that the inclusion of these effects in the evaluation of the earthquake may create more doubt than it dispels.

The large number of effects on the environment reported in the CFTI3 and the variety of events to which they refer should allow us to face this important aspect of research again, making use of truly significant statistical evidence (see, for example, in figs. 8 and 9 two maps of geo-referenced effects on the environment and their estimated impact, taken from the GIS which handles the data of the information system in the CD-ROM).

A method of solving certain problems of interpretation posed by the languages of historical sources in particular cultural settings is to analyse the cases from the standpoint of different disciplines. An example of this type of study is the Umbria-Marche earthquake of 30th April 1279. The opportunity to study this event in depth was offered by the now «famous» seismic sequence of September-October 1997 during which the basilica of St. Francis of Assisi was damaged. Indeed, the area of the medieval event of 1279 was very close to that of the recent earthquakes in the same area.

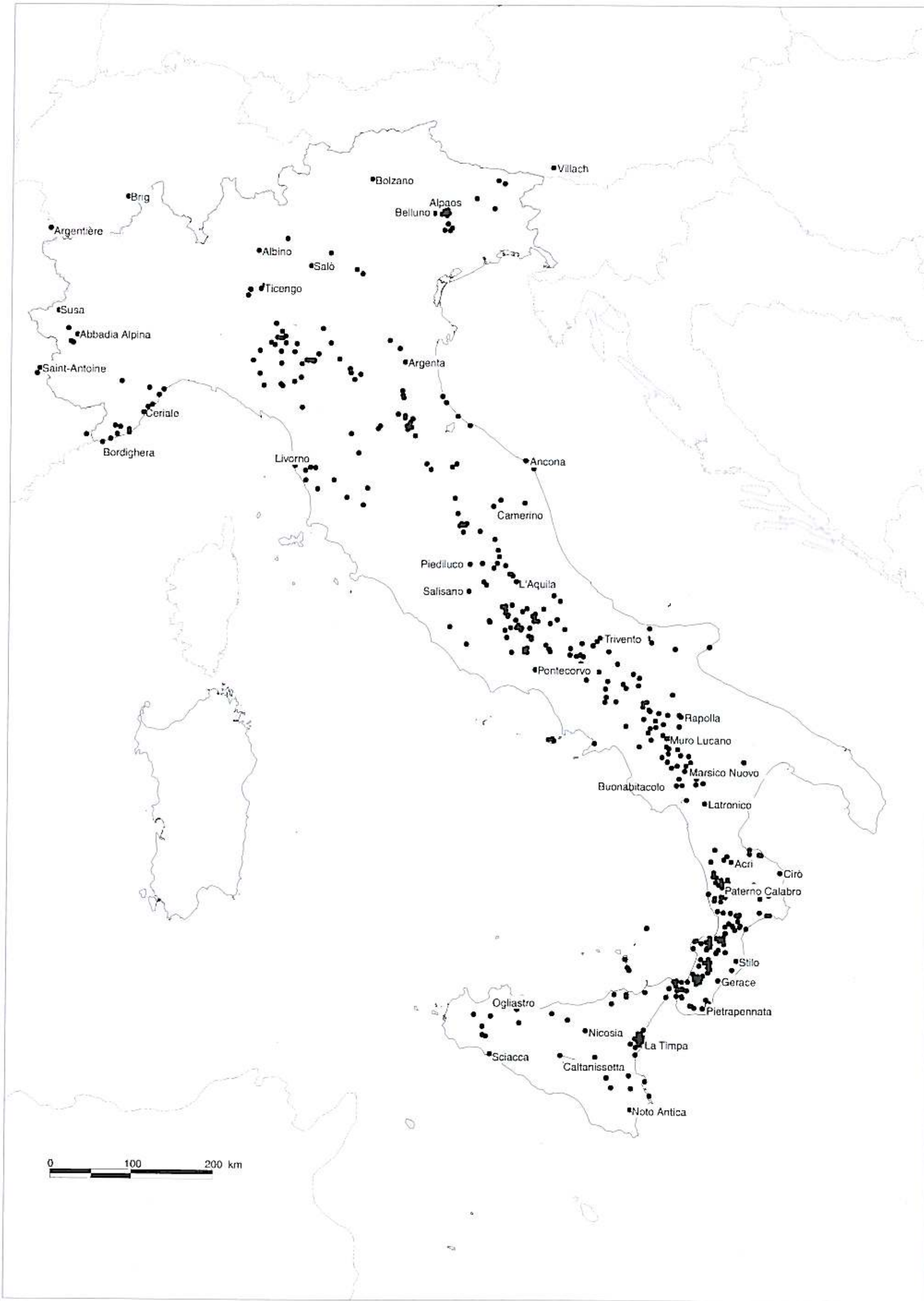

Fig. 6. 517 effects on the environment: category A/1 (ground breakage, fractures, fissures, splitting), from 461 B.C. to 1997 A.D. (605 earthquakes).

Fig. 7. 468 effects on the environment: category A/5 (landslide, earth flow, mud flow), from 461 B.C. to 1997 A.D. (605 earthquakes).

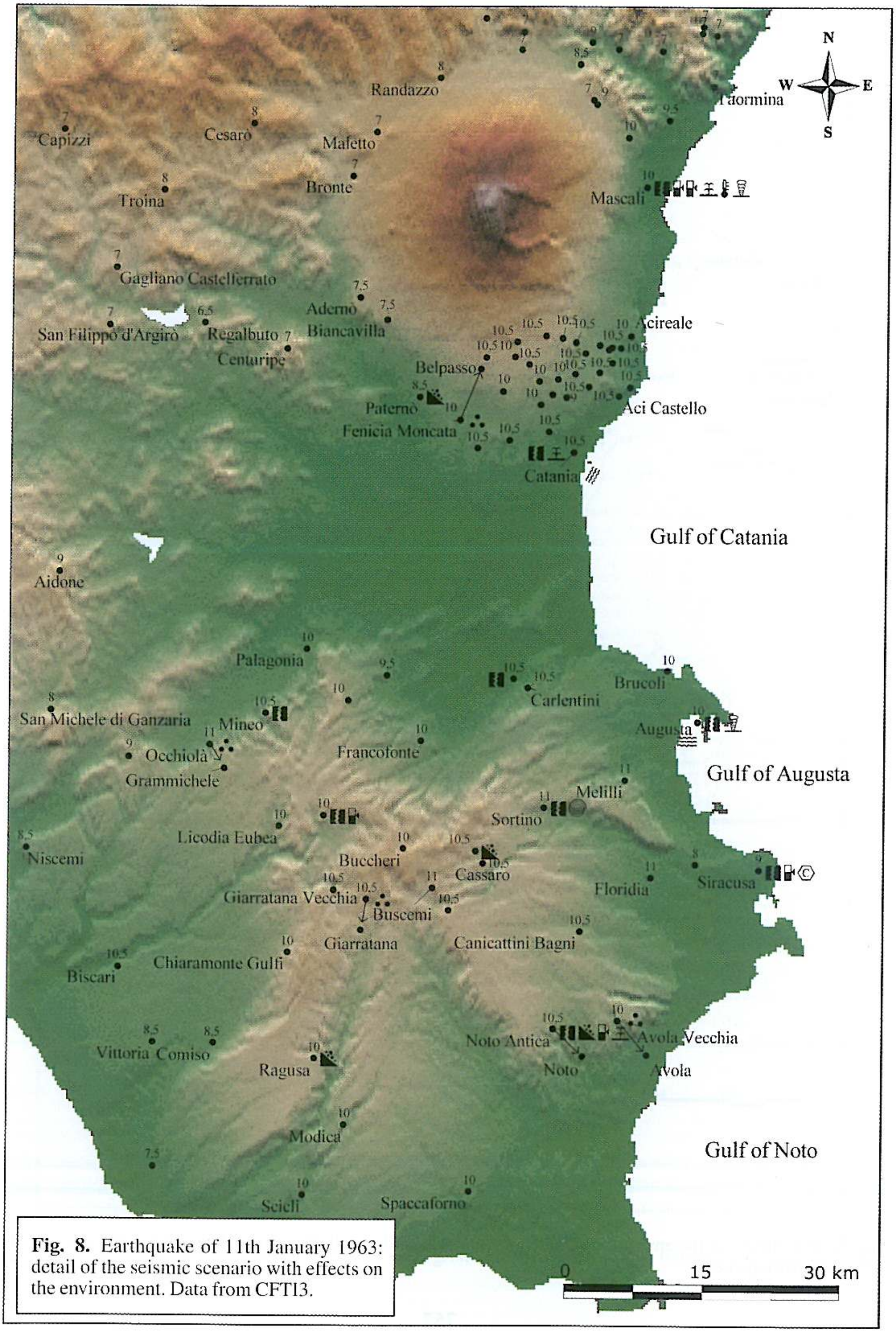

Fig. 8. Earthquake of 11th January 1963: detail of the seismic scenario with effects on the environment. Data from CFTI3.

The interpretation of the 1279 earthquake was in part hampered because the information from monastic sources of the time could not be fully understood. According to these sources, the heavy damage to the fortified hamlet of Castello di Serravalle was added to the effects of a landslide which had caused a temporary change in the local water supply, creating marshy areas and diverting the river flow. The question that usually arises in these cases is: how accurate are the sources? How much is due to direct information and how much to literary reports or information transmitted orally and hence with inaccurate or unusable geographical references? One answer to these questions was found when we started a field recognition in the area, *i.e.* when we were able to move from criticism of the texts to direct geological observations. In this case it was possible to identify the remains of a landslide near Serravalle di Chienti and identify those caused by a historical seismic event which did not contradict the date of the earthquake – a valuable finding for the preventive assessment of seismic effects in inhabited areas. In addition, we found consistency between the geomorphological features in the area including Castello di Serravalle and Serravalle di Chienti (fig. 10) with the effects of the 1279 earthquake described by the sources. This analysis *in loco* also solved the problem of place names regarding the Serravalle site, the same name being very common in the Apennines and also in the area most damaged by that earthquake.

The second large category of effects of earthquakes on the environment includes all the phenomena of permanent displacement of the surface directly leading back to the seismogenic source. Descriptions of ground breakage, of fractures with lowering of one side with respect to the other, of subsidence and formation of marshland, particularly if spread over some or many kilometres, may all represent the surface evidence of the permanent deformations induced by the earthquake. Although such evidence may also have great practical importance, for instance in planning industrial plants or large-scale public facilities which would be seriously damaged by the permanent ground displacement, throughout the world observations of this category have fascinated generations of historians, naturalists and geologists above all for their relative rarity and for their matchless quality of direct testimony of the endogenic activity.

There are numerous testimonies in the CFTI3 that describe phenomena which resemble what today we refer to as «fault scarps», although at least in some cases these could be purely gravitational and extremely localised phenomena. Testimonies of potential «fault scarps» had already been reported a century earlier by Baratta (1901) for almost all the major earthquakes in the Southern Apennines (1456, 1688, 1805, 1857), and many more were revealed by twentieth-century research. However, each testimony has not always offered easily deciphered points of view, to the extent that it was not until the 1980 earthquake in Irpinia that the geodynamic significance of this category of effects was fully recognised by the seismological community (Pantosti and Valensise, 1990). The CFTI3 contains many of these testimonies which are still being worked on. This is why at this stage we have preferred to avoid forcing geological interpretations which could mislead the reader or result in the loss of descriptive elements that could be reinterpreted if necessary in the light of new knowledge.

Quite paradoxically, in the new cultural context of the beginning of the twentieth century even the lack of testimonies of surface breaks may have a strong scientific significance. In his «*La catastrofe sismica calabro-messinese*», Baratta (1910) brings extremely detailed descriptions of the earthquake effects both on the

- Landslide, earth flow, mud flow
- Changes in water temperature
- Clouding of springs
- Ground breakage, fractures, fissures, splitting
- Changes in the flow of springs, appearance or disappearance of springs
- Exhalation or emission of gases
- Tsunami
- Outflow of water or mud from the ground or liquefaction
- Changes in water chemistry
- Abandoned site
- New site

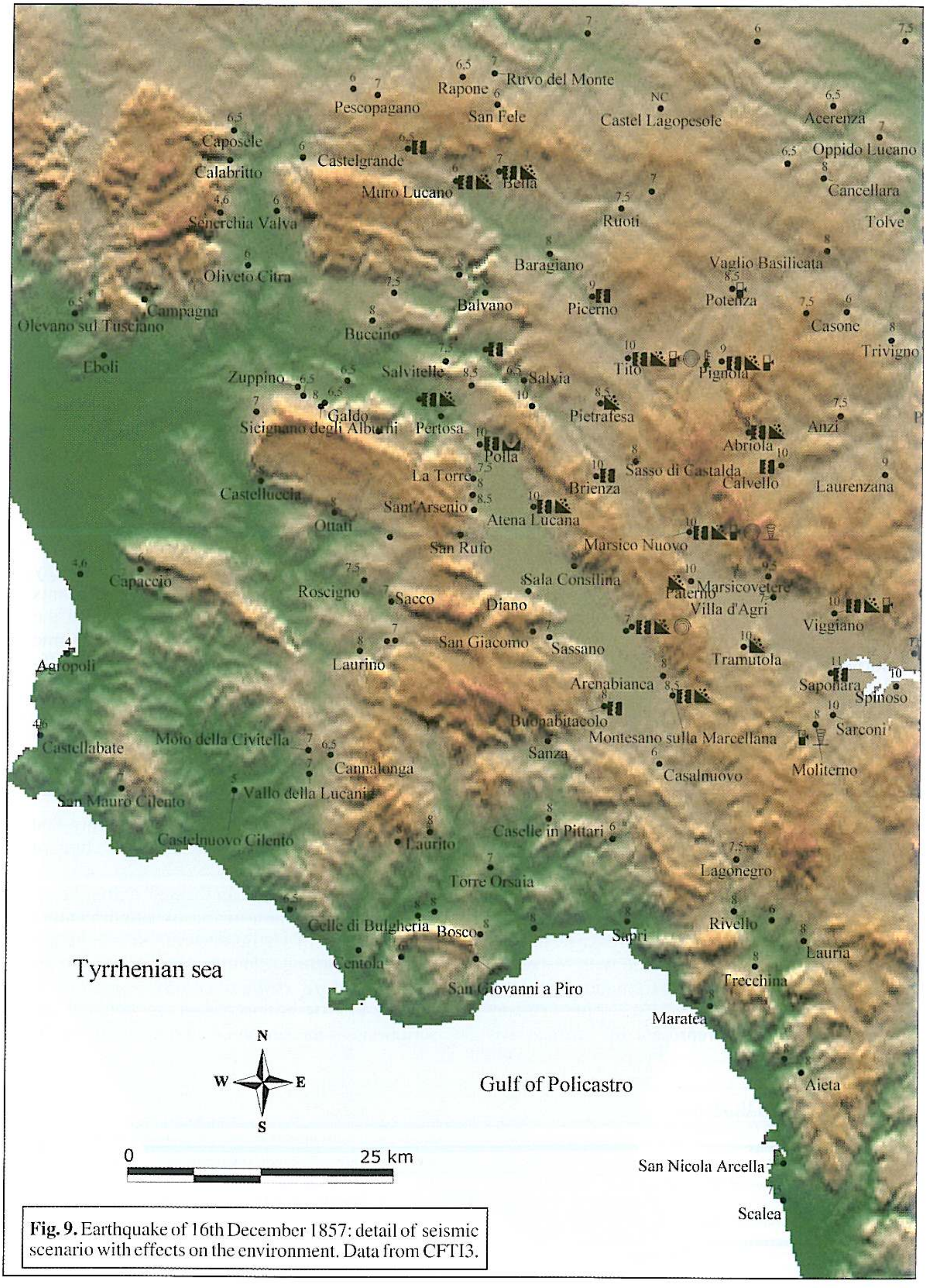

Fig. 9. Earthquake of 16th December 1857: detail of seismic scenario with effects on the environment. Data from CFTI3.

- Landslide, earth flow, mud flow
- Changes in water temperature
- Clouding of springs
- Ground breakage, fractures, fissures, splitting
- Outflow of water or mud from the ground or liquefaction
- Changes in the flow of springs, appearance or disappearance of springs
- Subsidence, landslip
- Exhalation or emission of gases

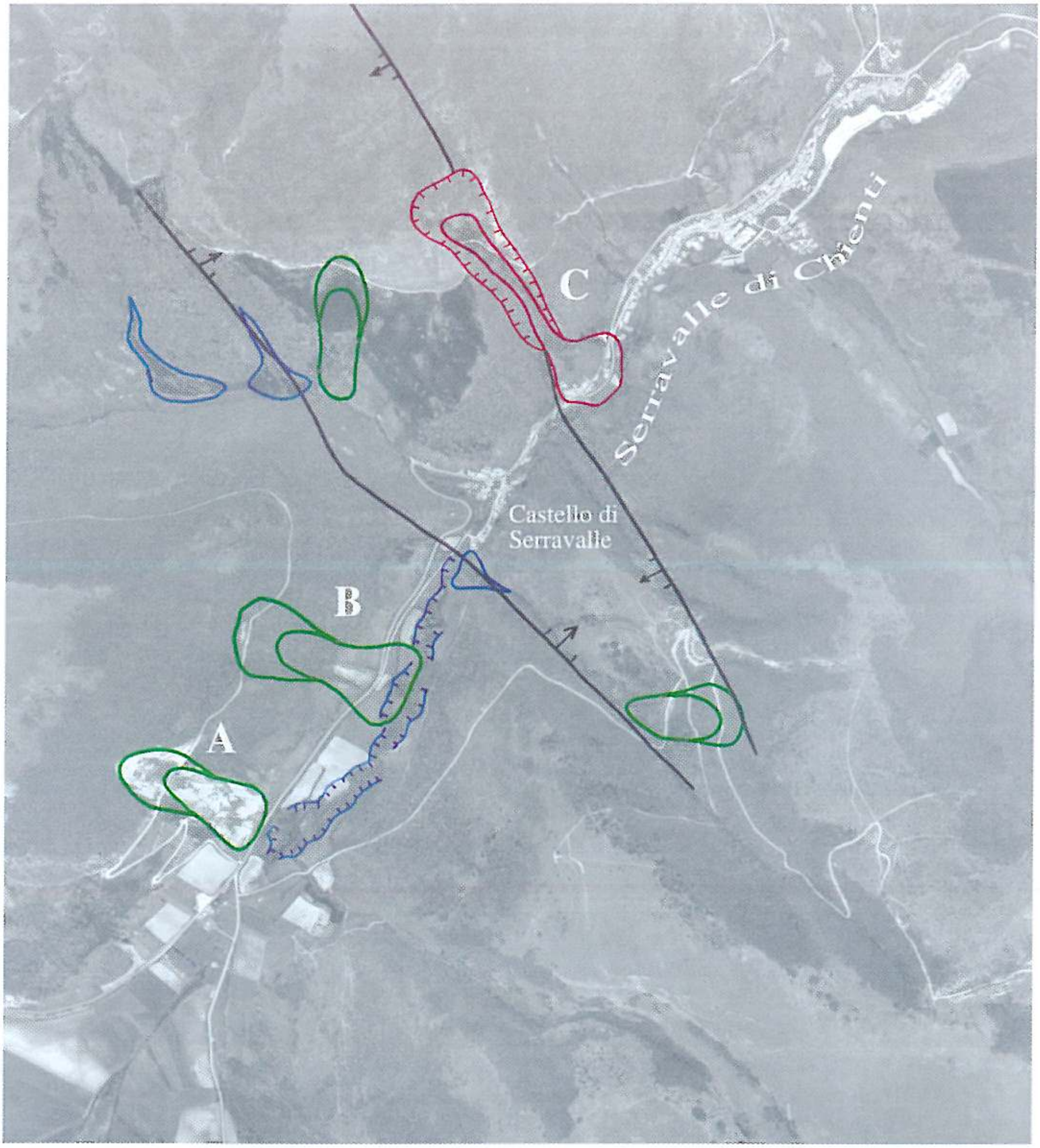

Fig. 10. Location of the main historical landslides of the upper Chienti valley near the town of Serravalle di Chienti. The flat triangular feature at the bottom left corner is the northeastern edge of the Colfiorito plain, that overlies the causative fault of the 26 September 1997 earthquake. Landslide A is recent (1988-1989) and partly due to the presence of a quarry. B indicates an undated debris flow that reached the valley floor temporarily blocking the river flow. Landslide C affects the northernmost part of the village of Castello di Serravalle. The slide (about 1 million cubic metres) originated between 950 and 560 m elevation, involved the local bedrock and blocked the flow of the river. The approximate age, morphological features, type of movement and shape of this landslide suggest that it could have been triggered by the 1279 earthquake (from Boschi *et al.*, 1998: data from an unpublished research by Fausto Guzzetti and Mauro Cardinali of the «Istituto di Ricerca per la Protezione Idrogeologica nell'Italia Centrale», Perugia, Italy).

human and natural environment, but never mentions any geological occurrence that could be taken as positive evidence for the generation of «fault scarps». Later on, an investigation by Boschi *et al.* (1989) based on the elevation changes measured by Loperfido (1909) reached the conclusion that the 1908 earthquake was generated by a «blind» fault (a fault that does not break through the shallowest portion of the crust), in agreement with Baratta's unexpected silence on this important matter.

5. Ancient measurements and micro-toponymy

Since the data on the environmental effects reported and analysed in the CFTI3 represent an interpretation of historical data, we considered it useful to retain a direct contact with the original sources both when reporting the ancient measurements and when including the exact words used to describe the phenomenon in the most uncertain cases.

All the quantitative elements of the historical descriptions have been «translated» as accurately as possible, using the appropriate conversion from the different old systems to those of today. Old measurements of length and surface area have therefore been given their corresponding values, with all the implicit approximations (Martini, 1883).

Evident exaggerations or apparent incongruencies sometimes appear in the descriptions. These may derive directly from the original sources in the absence of reliable elements to compare these indications and modify them. In these cases we have chosen to retain the original version of the description, leaving the reader with the task of re-evaluating the statements of the historical sources or dispelling any possible ambiguity in interpretation.

In other cases, considerable difficulty was encountered in correctly locating the effects described. This element clearly emerges from the comparison between the data summarised under the general heading «effects on the environment» and the relative analytical data in the section «located effects on the environment». Indeed, it has not always been possible to correctly interpret general indications of micro-toponymy, or references to names of mountains and reliefs no longer identifiable, or to stretches of road between two sites.

REFERENCES

BARATTA, M. (1901): *I terremoti d'Italia. Saggio di storia, geografia e bibliografia sismica italiana*, Torino.

BARATTA, M. (1910): La catastrofe sismica calabro-messinese (28 dicembre 1908), *Rel. Soc. Geogr. It.*, Roma, pp. 496 (2 volumes).

BOSCHI, E., D. PANTOSTI and G. VALENSISE (1989): Modello di sorgente per il terremoto di Messina del 1908 ed evoluzione recente dell'area dello stretto, in *Proceedings VIII Annual Meeting GNGTS, Rome 7-9 November 1989*, 245-258.

BOSCHI, E., E. GUIDOBONI, G. FERRARI and G. VALENSISE (Editors) (1998): *I terremoti dell'Appennino Umbro-Marchigiano: area sud orientale dal 99 a.C. al 1984*, ING-SGA, Bologna, pp. 268.

GRÜNTHAL, G. (Editor) (1993): European Macroseismic Scale 1992 (up-dated MSK-scale), Conseil de l'Europe, *Cahiers du Centre Européen de Géodynamique et de Séismologie*, vol. 7, Luxembourg.

GUIDOBONI, E. (Editor) (1989): *I terremoti prima del Mille in Italia e nell'area mediterranea. Storia archeologia sismologia*, ING-SGA, Bologna, pp. 765.

LOPERFIDO, A. (1909): Livellazione geometrica di precisione eseguita dall'IGM sulla costa orientale della Sicilia, da Messina a Catania, a Gesso ed a Faro Peloro e sulla costa occidentale della Calabria da Gioia Tauro a Melito di Porto Salvo, per incarico del Ministro dell'Agricoltura, Industria e Commercio, *Relazione alla Commissione della Reale Accademia Nazionale dei Lincei*, pp. 35.

MARTINI, A. (1883): *Manuale di metrologia ossia misure, pesi e monete in uso attualmente e anticamente presso tutti i popoli*, Torino (anastatic reprint, Roma, 1979).

ODDONE, E. (1915): Gli elementi fisici del grande terremoto marsicano-fucense, *Boll. Soc. Sism. It.*, **19**, 71-291.

PANTOSTI, D. and G. VALENSISE (1990): Faulting mechanism and complexity of the 23 November 1980, Campania-Lucania earthquake, inferred from surface observations, *J. Geophys. Res.*, **95**, 15319-15341.

RICCÒ, A. (1907): Il terremoto del 16 novembre 1894 in Calabria e Sicilia. Parte I: relazione sismologica, in *Annali dell'Ufficio Centrale Meteorologico e Geodinamico Italiano*, s. II, vol. 19 (1897), part I, 7-261.

SERVA, L. (1994): Ground effects in intensity scales, *Terra Nova*, **6**, 414-416.