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The contribution of historical records of earthquakes to the evaluation of seismic hazard

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Abstract
Historical earthquake records have often been badly used or even rejected in seismology because their qualitative nature has consigned them to the category of data that are «non-objective» and «unreliable». Nevertheless, these data are necessary in order to expand the temporal window of the knowledge of the earthquakes: therefore it is necessary to understand how these data are produced and how they can be used. This paper analyses first some problems connected with the common use of historical data in seismology, such as the compilation, or merging, of parametric catalogues. Next, this paper discusses the potential of historical records, suggesting some strategies for the investigation and exploring also the possible contribution of archaeological evidence and anthropological sources.

1. Historical records and seismological users

1.1. *Historical records: why*

It is an opinion commonly held by many scientists of countries endowed with good and numerous instrumental earthquake records – and hence of countries that are not only well-organized but also have a high level of seismicity – that it is possible to base the greater part of the assessment of seismicity and seismic hazard on instrumental data alone. On the contrary, it has become clear that the temporal window represented in theory by this century, and in practice only by a few decades, in many cases is not sufficient to give a picture of either the geometry or the seismic potential of the seismic sources.

Many zones with moderate seismicity show this problem, including some European areas. For instance, the area of Villach (fig. 1a), on the frontier between Austria, Italy and Slovenia, could in principle belong to an active zone stretching NE from the Friuli seismic area, the activity of which is better defined at the edges than in the middle. In fact, only two destructive (Io $\geq$ IX) earthquakes are reported in the Villach area by Van Gils and Leydecker (1991), both of which (1348 and 1690) happened before 1700 (fig. 1b and c): thus to take account only of the seismicity of this century would be to underestimate the potential of the source and, consequently, of the seismic hazard.

If the time-window of our knowledge of the earthquakes is to be expanded, it is obviously necessary to accept the use of «alternative» seismographs: buildings and even human beings themselves, indicators that are imprecise, variable, susceptible to a variety of influences, but which are irreplaceable. The use of the records produced by these «alternative» seismographs necessarily implies an understanding of their rules of function determined by the multiplicity of written and unwritten traces.

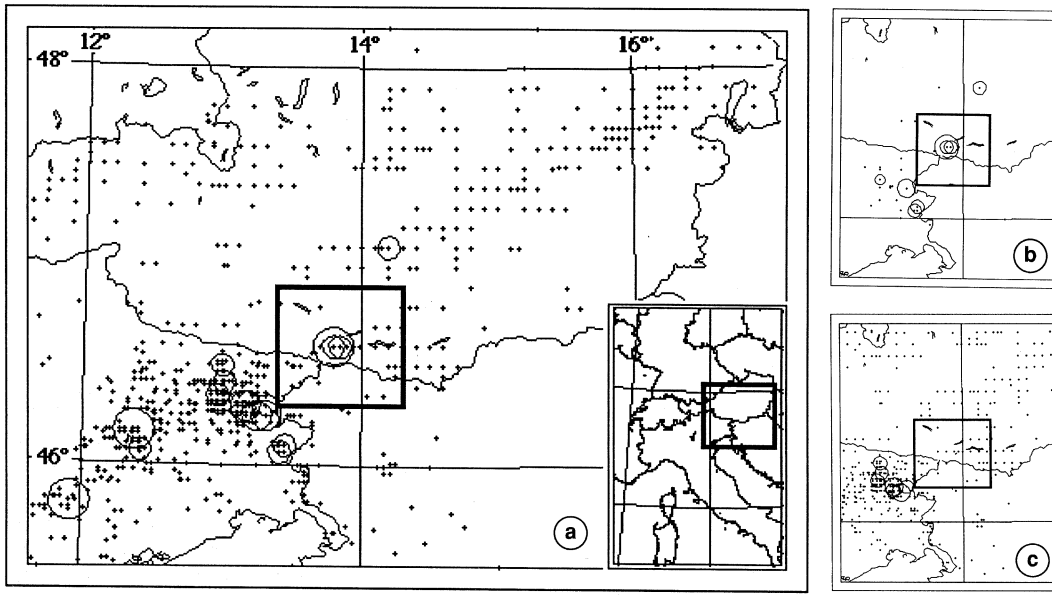

Fig. 1. Seismicity of North-Eastern Italy and Southern Austria (Van Gils and Leydecker, 1991): a) 1000 - 1980; b) 1000 - 1700; c) 1701 - 1980. Data of the Slovenian catalogue are not included. The Villach area is indicated.

1.2. *Historical records: what they are*

Historical records include written (whether narrative or not) sources, archaeological evidence and, in certain contexts, oral sources. Within the framework of seismology «historical records», as a first step, can be defined as any kind of evidence coming from the past. As a second step the nature of such evidence can be distinguished according to various criteria, none of which is absolute but rather refers to the goal and the strategy of the investigation.

A different level of authority can be assigned to the records: this is a typical task of historical investigation. Usually, the criteria concern the scope of the records, with respect to the institution which has produced the source. In reality, earthquake records differ depending whether they are official documents issued by institutions or accounts written by individuals with documental purposes.

Whatever classification will be adopted for tackling the great variety of historical records, they all have a common point: each one, qualitative or quantitative, is a product of the material conditions of life that determined it, the culture that produced it and the cognitive framework in which it is expressed.

It is just for these aspects, which are to be considered both intrinsic and valuable, that historical records have often been badly used or even rejected in seismology. Their character, generally qualitative and relative, has consigned them to the category of data that are «non-objective» (because not numerical) and «unreliable» (because not well understood).

These records, in order to be used properly, require a specific approach. The historical method has established itself as the optimal working method in historical seismology and, consequently, its application is obviously recommended together with the awareness, as far as it is possible, of the problems that this method might introduce into the results obtained. In historical analyses of earthquakes in the past, an inheritance of professionalism surrounding the historical discipline can usefully

be called upon, provided always that the requirement, demanded from the seismological side, for rigorous and unambiguous data is observed (Ambraseys and Melville, 1982; Helly and Pollino, 1984; Guidoboni, 1985).

It would seem hardly necessary to spell out here the criteria that qualify such a method in relation to the identification, treatment and analysis of the sources, the correct contextualization of the information obtained and the attention paid to geographical and linguistic elements. Lists such as these of requirements that had their raison d'être in the past (Ambraseys, 1971; Vogt, 1981, 1983), would today inevitably be over-restrictive both for historians and seismologists. In this area there is now a considerable bibliography, some of it relating in particular to specific case studies; for a general overview see for instance Gouin (1979), Gutdeutsch *et al.* (1987), Perez *et al.* (1987), Wechsler (1987), Guidoboni (1989), Stucchi *et al.* (1991).

1.3. *Historical, parametric catalogues: problems and limits*

Parametric catalogues are the most commonly used tool for assessing seismicity and seismic hazard.

Users normally consider the records of parametric catalogues as the data. In the same way as for instrumental data (Postpischl *et al.*, 1991), the historical part of a catalogue is the terminal point of a number of investigations, elaborations and decisions which are performed on the primary data, that are the historical records described before. It should be clear that the compilation of parametric catalogues from historical records has been performed according to procedures which have not taken into account the real nature of historical records. Moreover, these procedures are far from having being carried out according to well accepted standards.

These problems are well known and will not be discussed in detail here: some references can be found in Stucchi and Albini (1991). However, it is important to stress certain points:

– parametric catalogues were created with the purpose of providing basic earthquake data in the most compact format compatible with the computer facilities of the end of the '60s;

– this operation made it necessary to squeeze and eliminate a large amount of data which, by contrast, could be easily stored today by the available computer facilities;

– for most catalogues today in use, no primary data, nor elaboration procedures are available;

– parametric catalogues are compiled more and more on a national basis. In many cases this means that only earthquakes with epicentral location inside a country are considered in the compilation of the country's catalogue.

Attempts to find alternative ways of using historical records and macroseismic data for the evaluation of seismic hazard are developing (Monachesi *et al.*, 1993; Mucciarelli *et al.*, 1990). Nevertheless catalogues remain very useful: it is therefore recommended that the investigations for updating catalogues are performed in such a way as to preserve all primary data which have contributed to the compilation of the catalogue.

1.4. *Merging historical, parametric catalogues*

A further problem is represented by the fact that any attempt to build up a comprehensive, regional catalogue by merging national ones may lead to many mistakes, if primary data are not properly taken into account.

The most important problem consists in duplications produced by the fact that the same earthquake could have been parametrized in two or more catalogues according to different criteria and/or different primary data. Seismologists normally tackle this problem by making use of automatic procedures, intended to detect earthquake duplications included in a certain space-time-window. Nevertheless, in the case of historical catalogues, the reasons why the same earthquake can be classified in different ways depend very much on the interpretation of historical records, which cannot

be a thing mastered by means of automatic procedures, as the following example shows.

The catalogue by Van Gils and Leydecker (1991) lists for the year 1670 the following events, which come from the Austrian and the Italian catalogues:

ITA	**1670 07 16**	**45:43**	**10:97**	**VI**	**Verona**
A	**1670 07 17**	**47:30**	**11:50**	**VIII**	**Tirol**

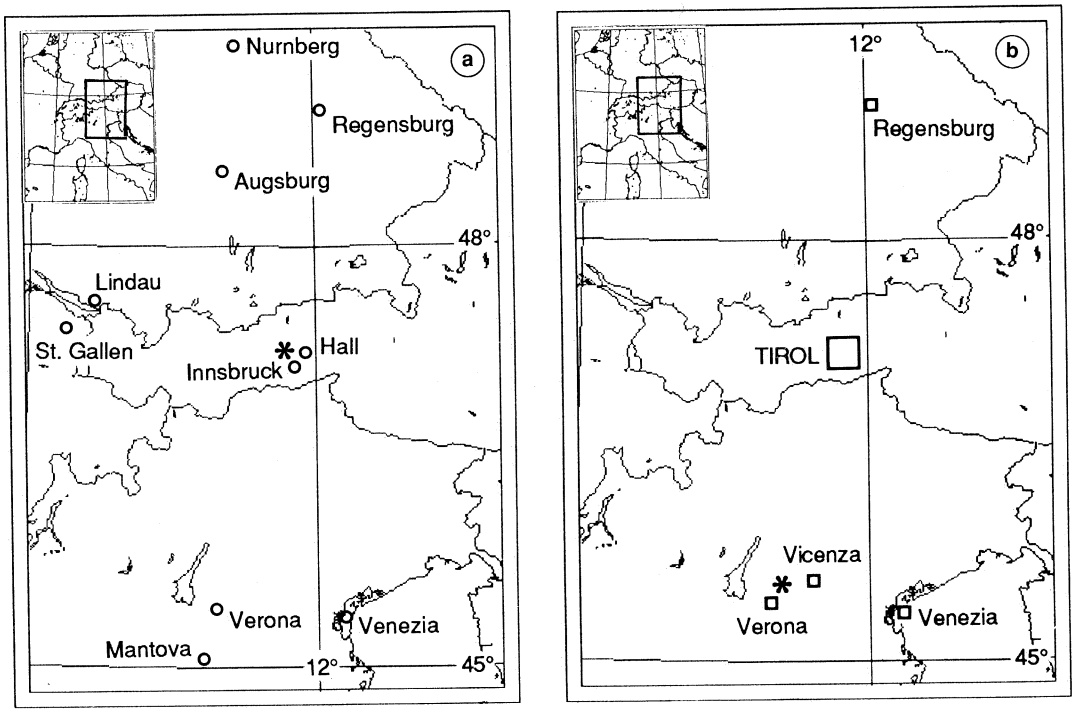

Fig. 2. 1670 earthquake: a) localities considered by Schorn (1902) and «Austrian» epicentre; b) localities considered by Baratta (1901) and «Italian» epicentre.

The two events are close in time, but the two epicentres are rather distant (fig. 2), therefore escaping any reasonable automatic window. Only by going back to the primary data is it possible to discover that the «two» earthquakes correspond to one set of primary data only, which have been handled according to different criteria by the seismological compilations that served as a basis for the national (Austrian and Italian) catalogues.

In reality, all contemporary sources mention that the earthquake happened in the night between 16 and 17; most of them clearly state that it caused heavy damage in Tirol (Innsbruck and Hall) and was felt over a large area (Regensburg, St. Gallen, Venezia, Mantova). The compilation by Schorn (1902), from which the Tirolian part of the Austrian catalogue probably is derived, summarized the records correctly. On the contrary, the Italian compilation by Baratta (1901), making an error of chronology, assumes that the earthquake happened on July 16, at 16.00, and, moreover, considers only some Italian localities. The compiler of the parametric catalogue has taken this to be a further event and, therefore, has located the earthquake near Verona, the Italian locality where it was most heavily felt. It appears that Baratta himself had some doubts about his interpretation: these doubts, that

might have lead to a correct interpretation, have been completely ignored by the compiler of the parametric catalogue.

The only way to compile catalogues, avoiding such problems, is to go back to the observations. Though it would be better to start from the primary observations – the historical records – in many cases this would be nearly impossible, as primary observations are seldom available in the form of a data bank. However, as historical records are normally processed in terms of macroseismic intensity, to compile catalogues starting from the intensity data points would represent a significant step forward with respect to the situation of many current catalogues. It is therefore recommended that intensity data point files be compiled for every earthquake and that the earthquake parameters be re-assessed proceeding from them.

2. Historical investigation

2.1. *Strategies*

Historical seismological investigations have produced a large amount of data, the quality of which is rather heterogeneous. Most users do not know how to evaluate their quality, not least because the compilers usually do not take care to provide such elements. Therefore, users normally choose one out of two extreme possibilities:

– to keep what is available as the best possible;
– to ask for new, *ex-novo* investigations.

The scheme which is proposed in the following (fig. 3) starts by the suggestion of re-analysing and fully exploiting all the data which are already available from the seismological compilations. After such analysis (which corresponds more or less to any bibliographical survey, usually performed by any investigator before starting a new research), new, *ad-hoc* historical investigations can be proposed in order to fill gaps or to improve the quality of the available data.

The investigation of written sources represents the most important part of historical seismology in many areas as, for example, in Europe. However, this does not mean that expanding the time-window on earthquakes is only possible when documentary data are available over a long period. On the contrary, the lack of written records has already stimulated new, original approaches for investigating the past in other fields: for instance, archaeological evidence and ethnographic sources can provide useful data for earthquake investigation.

2.2. *The seismological compilations*

As a first phase it is suggested that the historical sources and records which have already contributed, in some way, to the compilation of the current, parametric catalogues, the roots

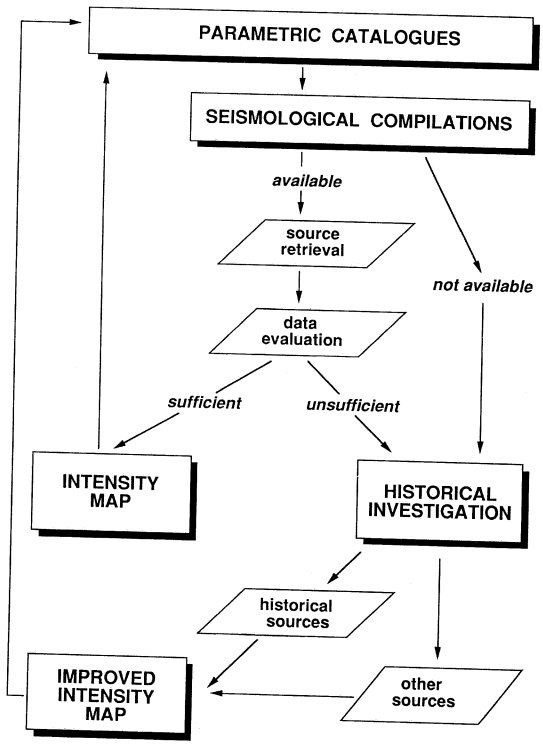

Fig. 3. Scheme of procedures for updating the macroseismic data set.

of which are found, to a large extent, in the main seismological compilations, be retrieved, analysed and carefully reused.

These compilations are far from being so transparent as to be used directly without problems, as they have been in many cases. On the contrary, they represent complex, layered compilations, a kind of container to which many men of letters, scholars, physicists and naturalists have contributed through many centuries.

The following considerations are unfortunately limited to Europe and, principally, to the «Latin» culture because of the limited experience of the authors on similar compilations for Eastern and Middle Eastern areas, with which Europe had and has cultural exchanges and debts.

The Mediterranean world of antiquity and late antiquity supplied a first set of observations. Later, through the concept of prodigium – in the meaning of an event out of everyday life – many data on past earthquakes have been collected along with the spreading of the interest in nature and then, science (Traina, 1989). The scholars of previous centuries dealt with earthquakes showing an amplitude of geographical horizons and little attention to frontiers and linguistic differences, no matter whether they were compiling in national languages or Latin. The basic idea that earthquakes were likely to happen in the same areas and that some areas were more exposed than other ones has existed since the antiquity, though the assessment of a seismic geography was beyond the scope of modern compilations.

The records used by the compilations are very different: together with data coming from ancient works, medieval chronicles or studies contemporary with the authors, there are also valuable, direct reports. It is to be stressed that not all the seismological compilations have been used by the compilers of parametric catalogues, such as the works by Pirro Ligorio (1574-77), still unpublished, by Giannozzo Manetti (1456), translated in Italian by D. Molin and C. Scopelliti, and by Matteo dell'Aquila (XV cent.), recently published by B. Figliuolo.

As an example of this complicated layering, fig. 4 shows the analysis of the sources which have contributed to the compilation by Marcello Bonito (1691), one of the most famous and frequently used Mediterranean compilations.

Later, in the second half of the XIX century, some European scientists, dealing with earthquakes and volcanoes, felt the need to improve their data sets, turning themselves, with varying degree of success, into investigators of historical records. Among them the following can be recalled: Hoff (1840), Perrey (1845, 1846), Volger (1857), Schmidt (1881), Mercalli (1883), O'Reilly (1886), Baratta (1901), Montessus de Ballore (1906), Milne (1911).

These compilations have the great merit of supplying a large set of data, though many conclusions they provide come from a careless synthesis of layered data on time and effect distribution, often carried out without mastering the historical sources in the proper way.

What went really wrong was rather the fact that the forced parametrization, imposed in order to render historical data compatible with instrumental data, was not accomplished with the instruments and expertise necessary for taking into account the contents and the nuances of these qualitative data.

In many cases, therefore, it is sufficient to return from the compilations back to the original sources, and to reconsider them carefully, to find out and eliminate errors or misinterpretations which have been later incorporated into the parametric catalogues, as is shown in the following examples.

2.2.1. The case of the «1563, Catania earthquake»

The Italian catalogue (Postpischl, 1985) lists an earthquake in Catania in the year 1563 (fig. 5). Strangely enough, the date is exactly the same as that of a famous, major earthquake which devastated the Montenegro coast (former Yugoslavia) and which is listed in the catalogue of the UNESCO Balkan Project (Shebalin *et al.*, 1974).

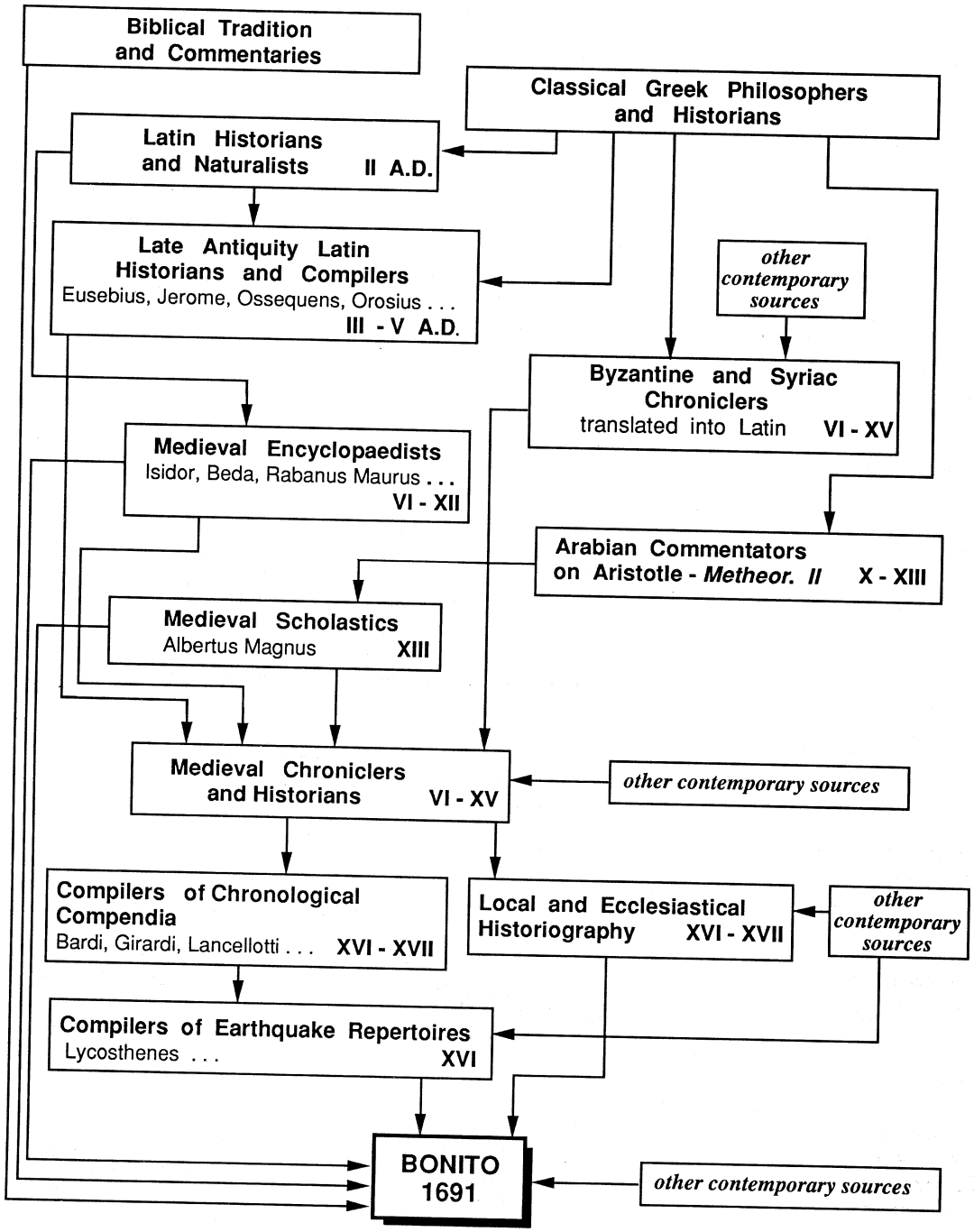

Fig. 4. Scheme of the contributions to the compilation by Bonito (1691).

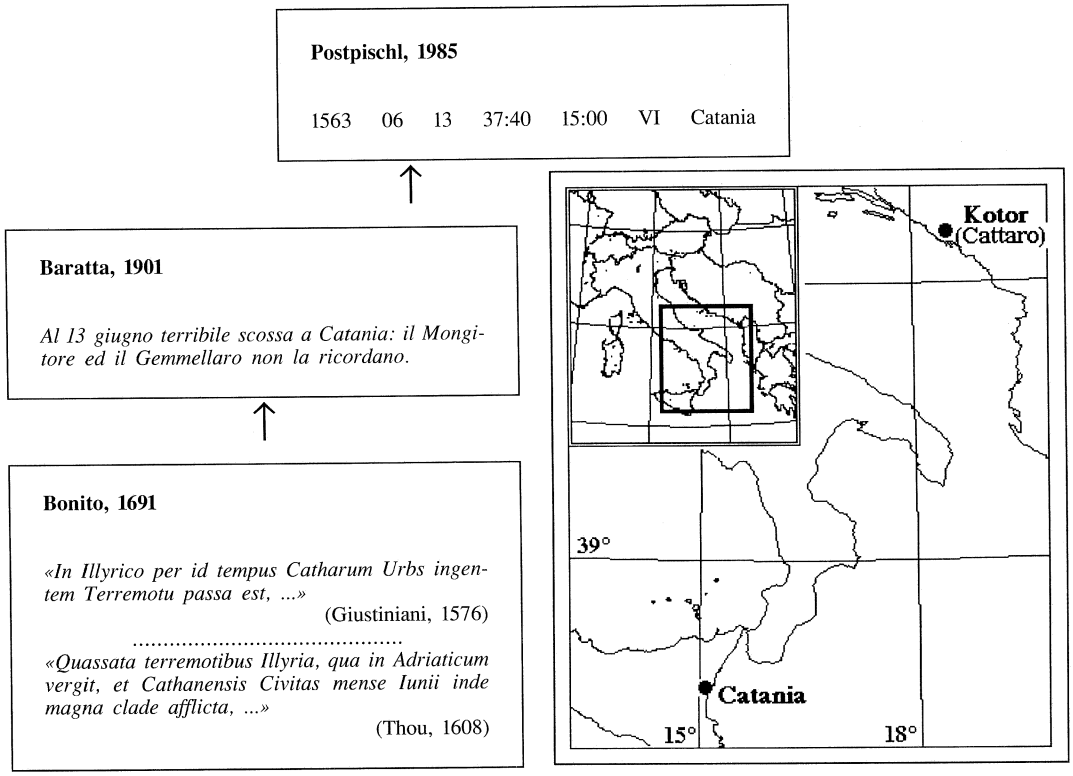

Fig. 5. Scheme of «formation» of the «1563, Catania earthquake».

Going back, it can be seen that the oldest sources, including the compilation by Bonito (1691), mention only the Montenegro earthquake. On the contrary, a late compiler, Amati, has interpreted «cathanensis» (a probable misprint of Bonito reporting his source Thou), as related to the city of Catania. Now, the wording related to this city never contained an «h», while there is one in the word «Catharensis», which means «of Cattaro», today Kotor, one of the most damaged localities. Baratta (1901) assumed that an earthquake happened in Catania, rising the warning that some Sicilian compilers did not mention this earthquake. Eventually, the catalogue incorporated the earthquake as happened in Catania with Io = VI.

It is therefore enough to go back to the original sources – and to pay some attention to a broader area – to recover the true data.

2.2.2. The case of the «1017 and 1020» earthquakes

The calculation of time before modern age was not absolute, but relative to other events, a problem which caused mistakes not only in the seismological compilations, but also in the historical tradition. For instance, the investigation of two events listed by the Italian catalogue in the years 1017 and 1020, in Rome, has shown that these years are nothing but the edges of a period, 1017-1020, indicated by a coeval source (Ademarus Cabannensis, a benedictine monk of Angouleme, France) as the time-span during which an earthquake took place. Figure 6 shows the steps which the record went through, from the source to the compilations; it also shows that some historical studies have not sorted out the exact chronol-

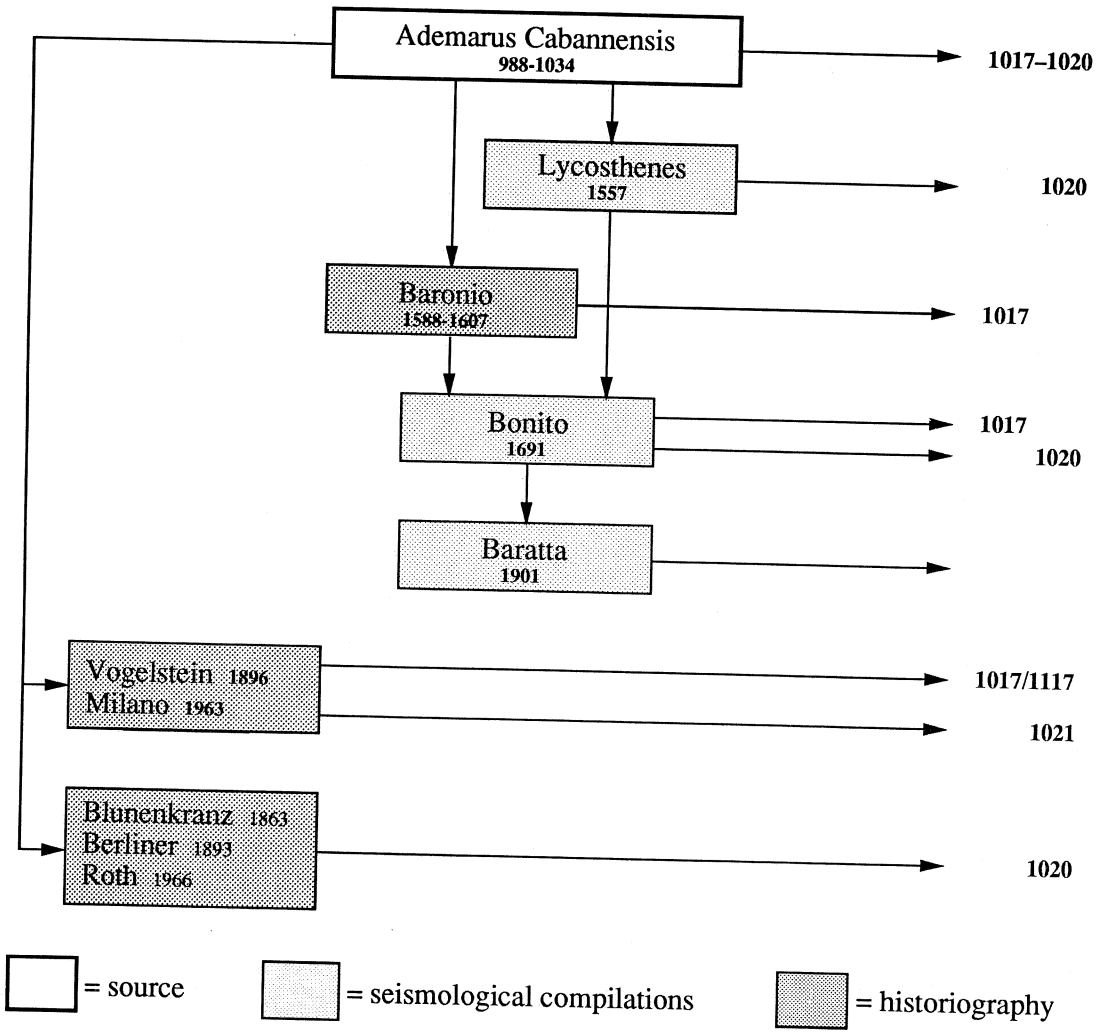

Fig. 6. Summary of the chronological interpretations of the «1017 and 1020» earthquakes.

ogy, the date of the event still remaining uncertain over four years.

2.3. *Historical investigation and multidisciplinary collaboration*

Historical investigation can be required from two starting points:

– to investigate more carefully and in detail a data set which is already available;

– to start *ex-novo* a project for retrieving data.

In both cases it is important to consider the necessity of appropriate expertise. Historical investigation carries *ad-hoc* investigation tools, rules and time-window expertise which can effect goals, procedures and, even, the data sought in the sources. For these reasons it is necessary to establish collaboration between historians and seismologists in order to opti-

mize results with respect to funds and human resources. Furhermore, multidisciplinary collaboration is a must for this kind of research which can span large areas and time-windows and which concerns a topic – *the earthquake* – which usually does not fit in the specific interests of even historiography of environments (Caracciolo, 1988).

Obviously, any research strategy requires some knowledge about availability, consistency and quality of historical sources. Sources can be concentrated in archives, scattered in many places and located outside the countries whose seismicity is to be investigated: therefore, professional historians should contribute to the general coherence of the project and the methodologies of investigation. In order to evaluate the effects of the earthquakes properly, it is also necessary to investigate the social context in which the earthquake took place, including population, building typologies and, even, economy and culture.

A general sketch of the steps of historical seismology is presented in fig. 7; further references can be found in Margottini and Serva (1988), Proceedings (1988, 1989, 1990), Kozak, (1991), Stucchi *et al.* (1991).

Organization is also a major problem: historical investigation on a large scale is no less important an initiative than a seismological instrumental network, and requires appropriate care. When the project is large, the expertise of individual professionals can be insufficient and a central coordinating unit may be necessary. Basic tasks of such a unit are to suggest which depositories are to be investigated, which sources are available, which strategies are to be followed, including the compilation of forms and the reproduction and computer storage of the records. Of particular use are the personal reports of individual investigators, which show not only the «positive» results but also the so-called «negative» output (the earthquake was not noticed) or the «silence» of sources. As the reliability of the data is strongly influenced by the type of investigation, the value of a research can be more easily assessed if the routes are shown.

An example of a successful initiative performed according to such criteria can be found, for instance, in the project for the Nuclear Power Plant Siting by ENEL (1983-1987), which has investigated more than 1700 earthquakes (fig. 8).

Further contributions may come from photographic materials and depictions. Photographic sources can provide useful data on building typologies and towns morphologies, to be cross-checked with documentary data or scientific reports about earthquakes (Ariès *et al.*, 1981; Guidoboni and Ferrari, 1987).

As for depictions, some seismologists have recently shown a lot of interest in drawings, wood-cuts, paintings, maps, miniatures, pretended as potential sources of earthquake records: but this potential is still to be proved. Depictions tend to be considered as direct, easy-access sources, not requiring historical interpretation: as this is obviously not true, it might happen that information will be extracted from their context and analysed without proper instruments, producing the same kind of mistakes which came from careless use of written sources.

2.4. *Seismic archaeology*

In recent years the interest in archaeological sources with respect to seismic effects has grown again. This interest is not new: in the last century De Rossi (1874) first formulated some hypothesis on the basis of observations in paleo-christian excavations in Rome, which were followed by similar observations by Lanciani (1918), again in Rome. In the Aegean region several contributions were formulated including, for instance, the hypothesis by Marinatos (1939) on the extinction of the Minoan civilization.

This kind of suggestions has been reconsidered by Karcz and Kafri (1978, 1981), who have proposed a new area of research to which, later, other investigators have contributed (Rapp, 1982, 1986; Soren, 1985; Stiros, 1988). The results obtained so far by the archaeologists with respect to the detection of seismic effects have been subjected to contradictory evaluations. The difficulty of achieving results scientifically acceptable for differ-

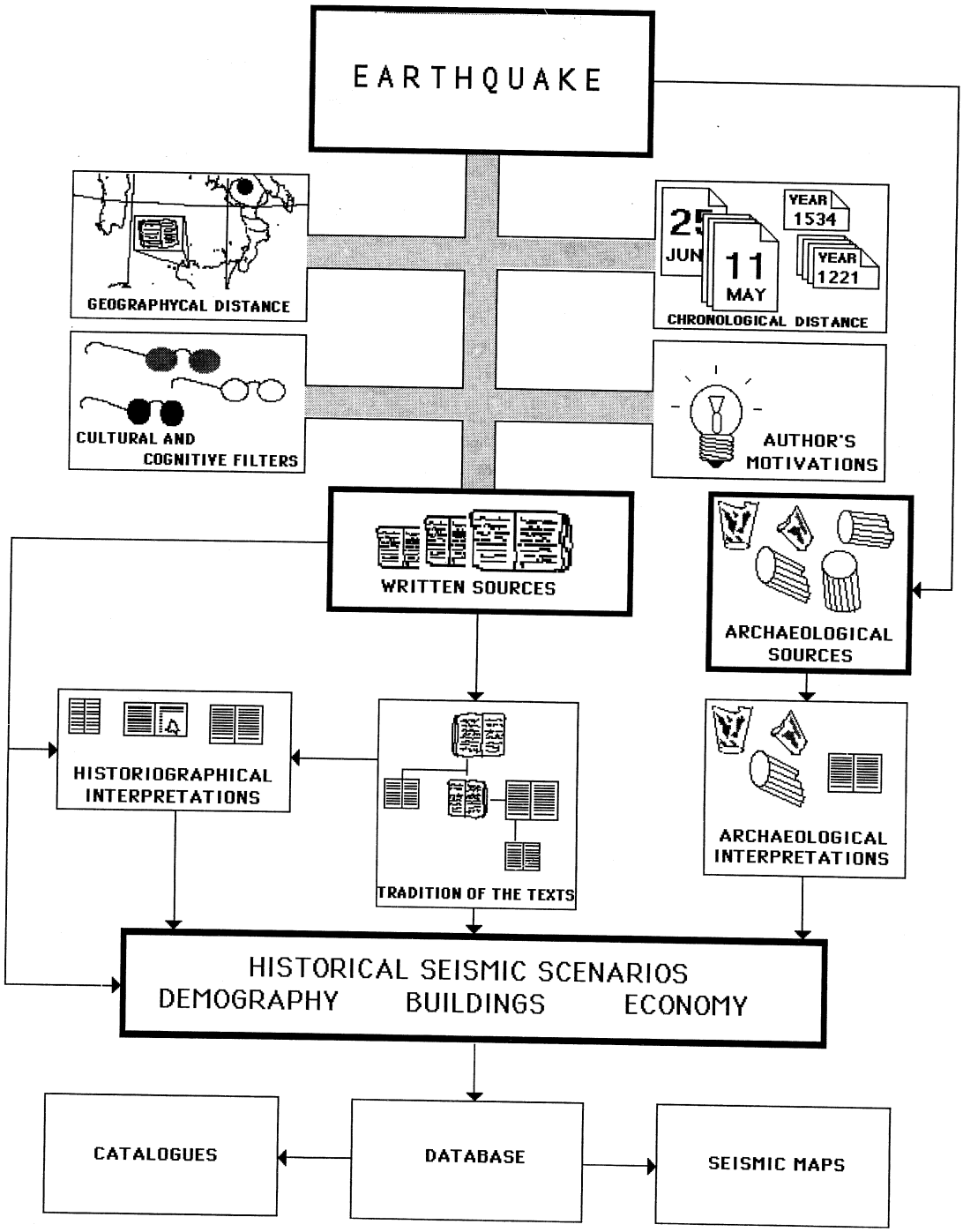

Fig. 7. General sketch of historical seismology.

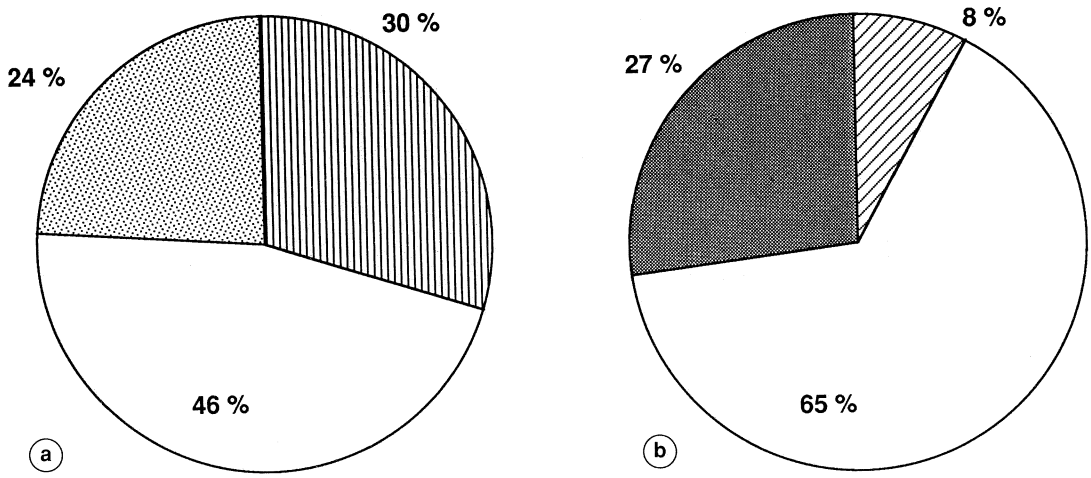

Fig. 8. Change of earthquake parameters for a sample of about 1000 events in Italy (from Guidoboni and Ferrari (1989), modified). a) Maximum intensity: □ confirmed; ▥ reduced; ▩ augmented; b) epicentral displacement: □ ≤ 10 km; ▩ 10 to 50 km; ▨ 50 to 200 km.

ent disciplines has created some areas of conflict. The interpretation of seismic evidence in archaeology has caused much debate, as for instance the discussion, about the 365 A.D. earthquake between De Vita, Jacques, Bousquet and Soren, shows (Guidoboni, 1989).

There are great hopes that archaeological earthquake evidence will be able to provide interesting results in the near future; nevertheless, today the methodology is still far from being consolidated and, therefore, the risk of uncritically assuming suggestions coming from archaeology is still very high.

The main problem, that is how a seismic collapse may be detected in archaeology, is still unsolved, because the evidence may often be distorted by the effects of natural or man-made events. Very few are the cases in which archaeological excavation has assessed earthquake effects beyond any reasonable doubt; in such cases, evidence came from many factors, such as the presence *in loco* of victims, the hystological exams of which clearly showed that the building collapse was the cause of death (Ward-Perkins, 1989).

To get reliable answers it is necessary to follow scientific criteria with respect to the manner in which the determinant clues are gathered and interpreted. What is needed is a wide spectrum of expertise, from paleoseismology to geotechnics, from engineering structural analysis to the history of architecture and building technology and, of course, historical seismology. Only by opening the discussion to all expertises and comparing methodologies and investigative tools, can seismic archaeology become a true, multidisciplinary research, able to supply scientific data (Guidoboni, 1991).

2.4.1 The case of the Kerch peninsula

A case history of recent years has shown that archaeological readings based only on the study of building reconstructions can be distorting if it is assumed, by prejudice, that any evidence of building reconstruction is to be related to destructions caused by some earthquake. The case concerns the investigation carried out in 1989-90 for the seismic siting of the nuclear power plant of Cape Zyuck, Kerch peninsula, Eastern Crimea.

Two committees produced opposite results. From one side seismic destructions were pointed out in most towns of the coast, on the

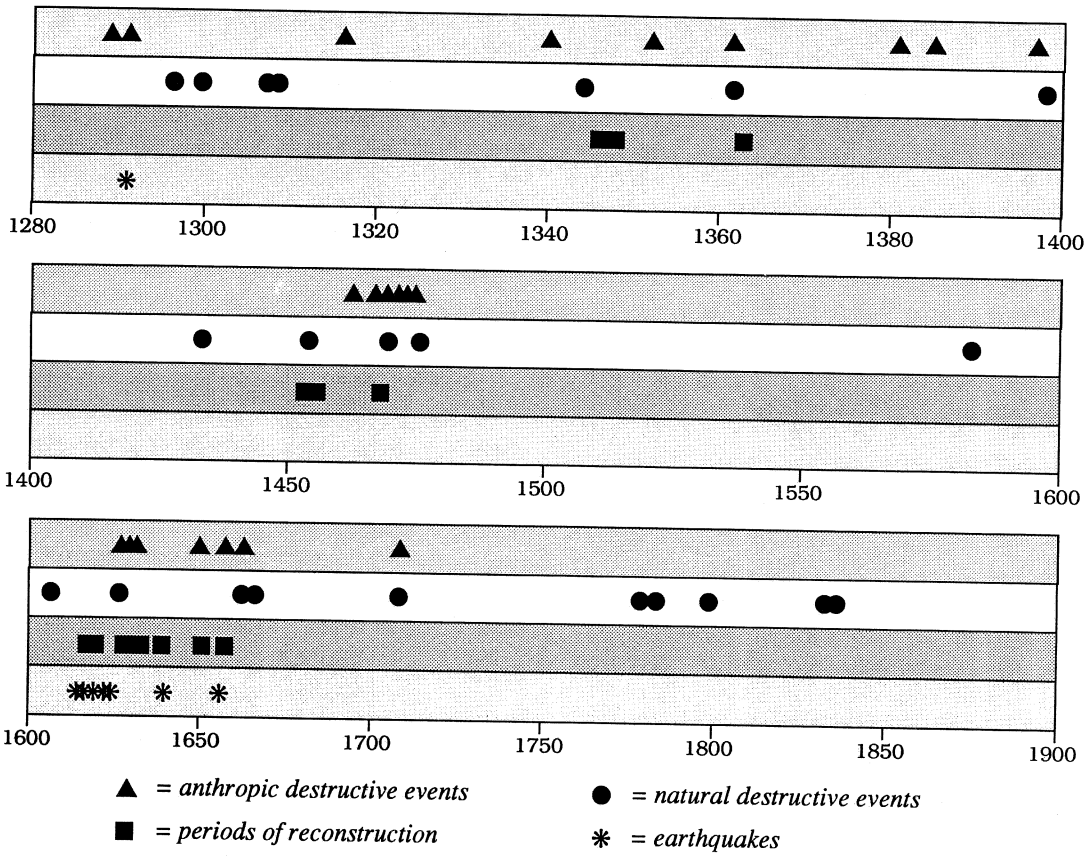

Fig. 9. Chronological correlation between anthropic or natural destruction and building reconstruction, as assessed by written sources in the area of Caffa (today Feodoija), Eastern Crimea.

basis of direct building investigations. From the other side a broad historical investigation of the whole region, spanning more than five centuries, was carried out on written sources (SGA, 1990), leading to a general improvement of the knowledge on earthquakes. This research has also pointed out a strong correlation between building reconstructions, as reported by the sources, and anthropic, destructive events of two kinds: wars and invasions from one side and demolitions accomplished by public powers in phases of overlapping religious cultures. A third kind of destructions was caused by natural events, mostly by floods, while earthquakes did not show strong correlation with reconstructions (fig. 9).

2.5. *Anthropological sources: oral witnesses and ethnographic sources*

Further areas of research of interest for historical seismology, though more anthropological than historical, are oral history and ethnographic research.

The first one concerns the possibility of using methodologies of sociological investigation in order to collect, in a systematic way, data from eye-witnesses of earthquakes for which poor written documentation is available. Of course, criteria based on significant samples are to be followed, producing reports and analysing them as sources.

The second, the ethnographic research,

makes it possible to retrieve evidence, though of a very general sort, of recollection of seismic activity layered into an oral tradition. This can be of some interest in those cases where written sources are lacking over a large time-window, provided that the proper expertise is taken into account: however, no studies of this kind on earthquakes are known.

3. Conclusions

Historical records are indispensable for expanding the temporal window on earthquakes beyond the limited period for which instrumental data are available.

Parametric catalogues have uncritically incorporated the output of some elaborations of historical records, often performed without care and proper expertise. Therefore, these data need to be carefully reviewed in order to be used for reliable hazard assessment.

The most suitable strategies for investigating historical earthquake records have been explored by several investigations (only a few of which have been mentioned in this paper), providing well established methodologies. The historical inheritance of each country can be used, provided that it is taken into account according to its peculiarity.

The research in this field should be programmed in order to optimize the resources. Available data can be upgraded, avoiding a return to a *tabula rasa* at each change of investigator; scattered initiatives are not to be recommended, while some coordination may help in respecting goals and schedules. In order to get good results within a convenient cost/benefit rate, the definition of priorities is desirable. Furthermore, the extensive and to some extent unknown scattering of historical sources suggests that historical investigation is organized on the basis of international programmes, allowing significant exchanges of data.

Finally, it is important to be aware that new research fields, such as seismic archaeology, are not yet well established from the methodological point of view and that it is difficult to obtain reliable data from them. It would seem to be premature to establish large projects in this area, though some well designed experiments should be encouraged. It is especially recommended that supposed archaeological evidence of seismic effects on standing structures be carefully evaluated, before assuming as data useful for the evaluation of seismic hazard.

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