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Historical seismology and seismic hazard

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Abstract
This paper analyzes the potential offered today by the macroseismic data to the evaluation of the seismic hazard. The first part of the paper surveys the development of historical seismology, with special reference to Italy in the last 15 years: the main innovations coming from the wedding between history and seismology are analyzed. The second part points out the main problems to be solved in order to improve the use of macroscismic data for the evaluation of sismic hazard, with respect to the main steps of analysis: historical investigation, intensity assessment, isoseismal maps and attenuation relations, focal-parameters assessment, catalogue completeness.

1. Introduction

The last years have seen a big development of methods and computer routines for the evaluation of seismic hazard (a complete set of references would be out of the scope of this paper, but some of them can be found in Mayer-Rosa and Schenk, 1989; Mayer-Rosa *et al.*, 1993). For most of these methods the catalogue represents the main, if not the only, seismological dataset and it is assumed as the «maximum possible» information, upon which the evaluation of seismic-hazard and risk relies to a large extent (fig. 1). Most users are satisfied with catalogues and, therefore, most energies are devoted to the best use of them: completeness analysis, definition of attenuation relations, seismic-hazard evaluation.

In the same period the interest for macroseismic data has grown again among seismologists, leading many countries to reactivate the macroseismic surveys by means of questionnaires and to undertake massive historical investigation. Actually, macroseismic data can be divided into two types, according to whether they are compiled in terms of questionnaires, or derived from written accounts. Data from questionnaires have some advantages: for instance, they are compiled to be processed directly in terms of intensity scales. This fact, nevertheless, represents also a weak-point, as in many cases a report would help understanding the general picture. This paper will not go deeper through this subject: however, it is important to recall the most recent activity in Italy (Postpischl *et al.*, 1985; Chignola *et al.*, 1989; De Rubeis *et al.*, 1989) and Europe, for which a good overview is given by the Proceedings of the Workshops organized by the Seismological Survey of Ljubljana (Cecic, 1989; 1992).

From the other side, the historical investigation of earthquakes has known an outstanding development, mostly due to a stimulating — though not easy — «wedding» of goals, methods and points of view belonging both to history and seismology. The result of this «wedding» can be seen today as the creation of a scientific discipline, which can be called «historical seismology» (Vogt, 1989), that is a branch of seismology which makes also use of historical methods: something very different from the sort of amateurish game that sometimes appeared — and to a certain extent was — a few years ago.

This paper will first survey the main outcome of historical investigation in the last years, with special reference to Italy, and then propose a

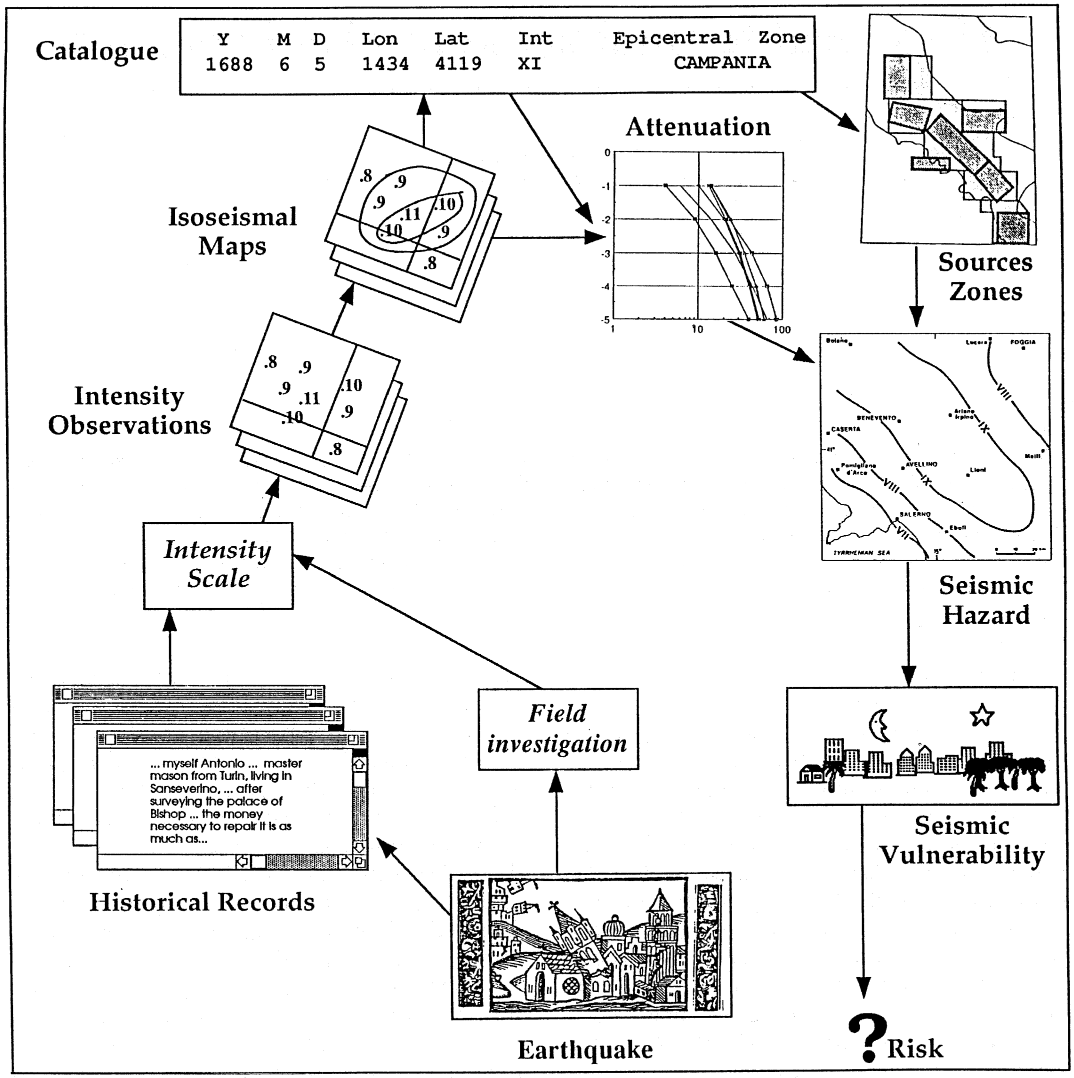

Fig. 1. General scheme of processing and using macroseismic data for the assessment of seismic hazard and risk.

rapid overview of the main problems open in the use of macroseismic data.

PART I. HISTORICAL SEISMOLOGY

2. Europe and the world

A careful survey of historical seismology in Europe and in the world is out of the scope of this paper. It is worth to remember that historical seismology started with some pioneer works by Ambraseys (1971), Ambraseys and Melville (1982) and Vogt (1979a; 1981), having a first moment of international discussion in 1978 at the XVI ESC Assembly in Strasbourg (Martinez Solares *et al.*, 1979; Mayer-Rosa and Cadiot, 1979; Ribaric, 1979; Udias and Muñoz, 1979). A further discussion took place in 1983 at the Antibes meeting (Helly and Pollino, 1984).

Investigation followed up in several countries, leading to many remarkable studies: it is impossible to recall them all here, but interesting cases can be found in Vogt (1984; 1985; 1991), Alexandre (1984), Musson *et al.* (1984), Rodriguez de la Torre (1984), Gutdeutsch *et al.* (1987), Wechsler (1987), Ambraseys (1988; 1991), Themudo Barata *et al.* (1988; 1989), López Marinas and Salord (1990).

Since 1986 some international projects have been performing, starting from the need for international research standard and collaboration, in order to overcome the traditional frontier discontinuities. Among these projects the IAEA «Seismic Data for Nuclear Power Plant Siting» (IAEA, 1987; Margottini and Serva, 1988; IGN *et al.*, 1988; Gürpinar, 1989; GPSN *et al.*, 1990; IAEA-TAEA, 1991) and the EC «Review of Historical Seismicity in Europe» (Stucchi, 1988a) can be recalled.

The reflexes of these activities are also evidenced by the increasing number of sessions at international conferences (Payo, 1989; Roca and Mayer-Rosa, 1990; Kozak, 1991; Stucchi *et al.*, 1991a) and by the creation of international working groups (Gutdeutsch *et al.*, 1992).

It is worth to observe that historical seismology is flourishing also outside Europe and the Mediterranean area. Remarkable examples concern Ethiopia, performed by a French-Canadian investigator (Gouin, 1979), the Caribbean (Grases, 1986), Mexico (Perez *et al.*, 1987).

3. Italy, 1980-1990

The Irpinia and Basilicata earthquake of 1980 occurred in a period in which the historical earthquake investigation has recovered new energy in Italy. After a recognition of existing catalogues (Carrozzo *et al.*, 1973; 1975), compiled by deriving in some way focal parameters from the main seismological compilations (mostly Mercalli, 1883 and Baratta, 1901), on one hand the nuclear agencies stimulated ENEA (former CNEN) to carry on many detailed investigations in selected areas, such as Friuli and North-eastern Italy (Iaccarino and Molin, 1978a, b), Tosco-Emiliano Apennine (Margottini and Molin, 1983), Latium (Dell'Olio and Molin, 1980; Molin, 1981) and other areas (Margottini, 1981; Serva, 1981a, b).

On the another hand, the «Catalogue» Working Group of the Progetto Finalizzato Geodinamica, chaired by D. Postpischl, started revising the earthquake file made available by ENEL (1978), investigating in detail the major earthquakes . In this frame, considerable work led to the publication of isoseismal sets (Barbano *et al.*, 1980) and later of the «Atlas» (Postpischl, 1985a). The main innovation consisted in the compilation and publication of intensity datapoints and isoseismal maps as part of the dataset, therefore useful not only for the compilation of a catalogue, but also for other purposes, such as attenuation relations and so on.

As for the historical sources, this period shows the transition from the simple use of the main seismological compilations to detailed historical investigation of sources. Seismologists had the common feeling that careful historical investigation could help a lot. This feeling was translated into different approaches: for someone it was enough to retrieve some of the sources used by the compilations; someone added broad library investigations; someone, finally, started collaborating with professional historians and investigating the archives. Nevertheless, no standards were fixed, so that the output, represented by the «Atlas» (Postpischl, 1985a), shows a broad range of care with regard to this aspect.

The final goal of the «Catalogue» Working Group, the so-called «PFG Catalogue» (Postpischl, 1985b), was actually achieved by 1982, though the compilation took over up to 1985. The PFG catalogue had the basic value of being published, making most of the data available to the users. Nevertheless, like most catalogues of this generation, it appears like a puzzle of many inhomogeneous components.

The main point with this catalogue is that the increase in the number of the records has been paid in terms of increased inhomogeneity, and that the procedures for assessing earthquake parameters are far from being transparent, like in most current catalogues.

After the compilation of the data for the PFG catalogue and Atlas, historical investigations were carried on by small groups including increasing contributions by historians (Gentile *et al.*, 1984; Branno *et al.*, 1985; Monachesi *et al.*, 1985), while a major effort was undertaken in the frame of the ENEL nuclear-power plants siting project (ENEL, 1984a, b, c, d; Postpischl *et al.*, 1984; Berardi and Muzzi, 1988), under the leadership of the former coordinating unit of the PFG «Catalogue» Working Group, established as SGA.

This project succeeded in a dramatic improvement of the quality of the investigation, with respect to the type of investigated sources and of the efficiency of the investigation itself.

First of all, the investigation was planned carefully, by cross-checking the areas potentially shaken by the earthquakes to be investigated with the elements concerning the historical features of those areas and the distribution of the sources related to them. Some consequences followed with respect to the organisation. The investigation was not performed «per single earthquakes» but «per sources or depositories», involving tenths of researchers, covering large portions of archives and libraries, performing integral surveys of funds and sources. This approach allowed detailed knowledge of the sources, what is essential for a better interpretation of historical records. Next, the investigation was coordinated by a unique team and performed according to a definite standard; finally, the historical records were compiled in such a way to be ready for a databank.

This project led to the study of more than a 1700 earthquakes (Guidoboni and Ferrari, 1989), mostly distributed in Northern Italy; it included many important earthquakes, critical with respect to the seismicity of some regions, such as the 1117 and 1222 earthquakes (Guidoboni, 1984; 1986; Magri and Molin, 1986). Unfortunately, this huge amount of data is not yet public.

After the ENEL project, SGA carried out further pioneer investigations, such as the one on the 1786, Rimini earthquake (Guidoboni and Ferrari, 1986), and the investigation of the major earthquakes of Calabria and Sicilia, including the 1693 earthquake, performed for ING. Outstanding is the volume on the Mediterranean earthquakes before the year 1000 (Guidoboni, 1989), which has a double interest, as it provides a catalogue (in the sense of seismological compilation, not of parametric catalogue, which would spoil much of its content), and it can be seen as a laboratory, where authors of different expertise and scientific view have explored problems, methodologies and sources, also tackling the new-born seismic archeology.

In the most recent years, some contributions from ENEA (among other papers, Meloni and Molin, 1987; Molin and Mucci, 1990) show the continuous effort of this Agency in this field. Osservatorio Vesuviano performed some detailed investigation on Southern Italy earthquakes (Esposito *et al.*, 1987) and published a remarkable study of the 1456 earthquake (Figliuolo, 1988), one of the most important events of the Italian region; the main characteristics of this earthquake, as reconstructed by Meletti *et al.* (1988), stimulated seismologists to deal with possible, multiple, sub-contemporary earthquakes, requiring special care for the assessment of focal parameters.

In 1986 the «National Group for Protection against Earthquakes» (GNDT) of Italy started a five-year macroseismic project, the main goals of which are: a) the detailed investigation of some earthquakes critical for the hazard assessment; b) the compilation, according to standard criteria, of intensity maps for all earthquakes with $I_0 \geq$ VII-VIII MCS; c) the compilation of a database of intensity data and of a working catalogue. A description of criteria and procedures adopted can be found in Stucchi (1991), while some results are found in some compilations (Monachesi, 1987; Stucchi, 1988b; Postpischl, 1991) and in a volume (Albini and Barbano, 1991). The project has seen a significant participation of historians, as full-time investigators or university research units with *ad hoc* grants.

In the frame of this project a careful analysis of the macroseismic procedures has been performed, pointing out the weakest points and exploring solutions (Stucchi and Albini, 1991). The working file is in progress and will contain some innovating elements (GNDT Macroseismic Working Group, 1992), including the results of the continuous updating of the catalogue of the Eastern Alps (OGS, 1987), performed with the progressive merging of neighbouring countries catalogues, such as Austria, Slovenia and Croatia.

PART II. MACROSEISMIC DATA AND SEISMIC HAZARD

4. Macroseismic procedures

The results of the most recent historical-seismological investigations have provided such a large amount of data, of such an improved quality level, to lead many investigators to reconsider entirely the traditional macroseismic procedures with respect to historical data. It has made clear that the «classical» processing of the historical records:

sources → records → intensities → isoseismal map → catalogue

does not use but a very limited amount of information, the rest of which being lost to any use. Actually, if the only goal is the determination of the centre of mass of the earthquake (epicentre or focus), all data which contribute to it can be disregarded. But this was a minor simplification when the macroseismic information concerning an earthquake did not exceed a few datapoints. Today the situation is rather different: the number of datapoints per earthquake increases, the quality in the content of the historical records also increases and the classical synthesis, such as intensity assessment, epicentre determination and so on, appears more and more as a narrow-band filter. Moreover, simply «cutting out» the earthquake records from the source does not allow good interpretation in terms of intensity, what requires also a deep knowledge of the context (types and total number of buildings). The ignorance of such elements can lead to differences of one, two and even three intensity degrees, which is obviously of great impact for the assessment of seismic hazard, especially in the case of those earthquakes which have only few datapoints.

5. Historical records

The progress of the historical investigation has been recalled in Part I. It is important to stress that the procedures according to which historical records are processed are, in principle, quite similar to those by which instrumental data are processed (Postpischl *et al.*, 1991). Therefore, it can be required that such procedures accomplish a minimum standard of rigour and transparency, as in the case of instrumental data. Figure 2 shows how the processing of historical records can be divided in some steps (Stucchi and Albini, 1991).

a) Historical investigation

The historical investigation can range from a simple tour of a seismologist to a library next door, grasping a few records after consulting the library inventory at the voice «earthquake», to accurate library and archive investigations performed after careful analysis of the history of countries and archives. The output ranges from third-hand (or more) records, the reliability of which can be very low, to precise, unique information reported by careful eye-witnesses with no pretence to scientific interpretation.

The quality of the final result, obviously, depends strongly on the quality of the historical investigation. Unfortunately it is not frequent to find information about this point in papers on «historical earthquakes»: seismologists want to get the results without being bothered by history. But in such a way it is sometimes hard to classify the data, and any future investigator will find easier to start again the research, often repeating the same roads. Further, this kind of information is also important for assessing the completeness of the catalogues, discussed later.

b) Earthquake assemblement

Earthquake records can in some way be seen as pieces of puzzles which are to be properly assembled (Stucchi *et al.*, 1991b). This step is very critical, because the investigator needs to locate all the records with respect to a time-space reference system. Problems and pitfalls related to this problem are well known to most authors and analyzed for instance by Vogt (1979b), Ferrari and Marmo (1985). Nevertheless, catalogues are still full with duplications or misinterpretations which follow from uncareful handling of this problem.

c) Intensity assessment

The main procedure for processing historical records towards practical uses is the intensity

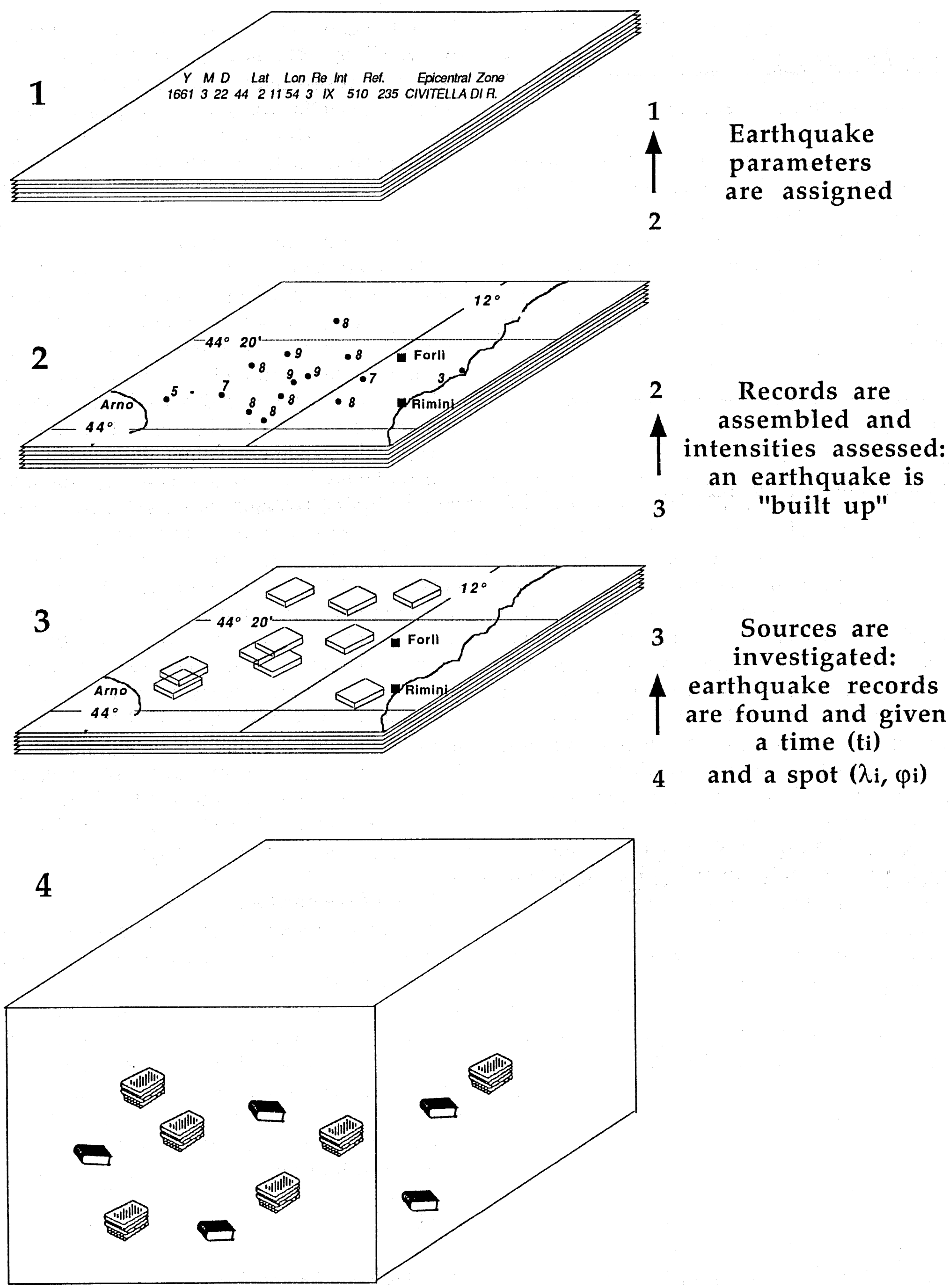

Fig. 2. Main steps of the processing of historical records.

assessment; this means to compare the earthquake records with a set of effect descriptions, ordered in a progressive way, and to select the one to which the record corresponds better. Only very seldom the records are written in such a way to be exactly comparable with intensity scales: therefore, intensity assessment has always been performed according to personal standards, often leading to differences of one or even two intensity degrees for estimates performed on the same data.

Some uncertainties which come from the interpretation can be lowered by improving the wording of the scales (this is one of the tasks recently committed to the Working Group «Macroseismic Scales» of the European Seismological Commission — chaired by G. Grünthal — for updating the MSK scale), in order to lower the need for personal interpretation; or by implementing computer routines or expert systems, in order to guarantee at least that different investigators (or the same one in different times) obtain — more or less — the same estimates from the same data. Some other uncertainties are incorporated in the records, and cannot be lowered without further investigation. In many cases, additional sources may improve the general picture of the effects, though it is not infrequent that they may introduce contradictions (Stucchi *et al.*, 1991c).

Furthermore, records are to be interpreted in the light of the context where they are located and have been produced. Investigators often literally cut off from the text few words describing earthquake effects, what can lead to partial or even biased interpretations. Finally, type and total number of buildings are often scarcely investigated, though they play a major role in intensity assessment. An overview of the problems connected with intensity assessment from historical records can be found in Stucchi (1992).

6. Intensity distributions, isoseismal maps and attenuation relations

An intensity map, that is the distribution of observed intensity datapoints of an earthquake, is the best compromise between the qualitative nature of historical records and the quantitative needs of the users. An intensity map tells at a glance how good is the knowledge of the earthquake itself; the total number of intensity datapoints, their density and azimuthal coverage can be used for assessing quality factors, in the same way as number and distribution of the recording stations in the case of instrumental data. The importance of datapoints has started to be recognized in the 70's (Shebalin, 1974; Karnik and Prochàzchovà, 1978).

Isoseismals lines have been considered at the beginning as isolines of effects, but have become in the common practice isolines of a «macroseismic field», that is the earthquake propagation pattern observed by means of its effects. There are still a lot of problems to be solved with respect to a proper use of isoseismal lines. First of all, isoseismals are deeply influenced not only by the criteria according to which they are drawn, but also by the representativeness of the datapoint sample, which in many cases is very poor (Berardi *et al.*, 1990). Actually, datapoints are found in correspondence to localities; these are not found everywhere along the Earth surface, are not distributed regularly, but are denser for instance along valleys and coastlines, scarce along mountain chains, and not found in the sea. Other problems come from the fact that intensity may not reflect directly the shaking, being deeply influenced also by soil conditions and buildings vulnerability. As a reliable transfer function has not yet been found, the use of isoseismal maps as pictures of the propagation pattern for comparison with theoretical radiation/propagation pattern is to be dealt with a lot of care.

Attenuation relations are used to predict shaking at the sites. As an output of the processing of isoseismal maps, they suffer from the same problems of the last ones; nevertheless, some recent attempts have tried to take into account in a proper way the real nature of intensity in attenuation problems (Grandori *et al.*, 1991).

7. Focal parameters and catalogues

The macroseismic epicentral location used to be defined as the centre of mass of the inner closed isoseismal area. However, it is well known that the cases in which this procedure can be applied are very few; nevertheless, catalogues are full with macroseismic epicentres derived from very poor intensity datapoint distributions, according to some procedures. The same holds, more or less, for epicentral intensities, the assessment of which can be heavily influenced by an investigator having in mind that they will be used to evaluate the size of the events rather as starting points for applying attenuation relations.

As for the depth, it is well known how unstable this parameter is with respect to the current calculation procedures. As they stand, today, depth figures are in most cases of little use for seismotectonic purposes, while for hazard assessment some attenuation relations do not need to take depth into consideration (Grandori *et al.*, 1991).

Magnitude is still a major problem, as the traditional relations $M = M(I_0)$ or $M = M(I_0, h)$ have shown unsatisfactory. Some attempts to find out relationships between M and the size of some isoseismals have shown encouraging results, though only on a regional basis (Margottini *et al.*, 1993).

Focal parameters generally fill in the catalogue records, which sometimes include also some propagation parameters. It is to be stressed that, generally, most macroseismic parameters are given without reliability estimates: when they are given, in many cases they appear difficult to understand and uneasy to use. Reliability estimates can be easily added to the parameters of the catalogues, provided that the primary data are available.

It is obvious that for many purposes it would be very useful to have all primary data available, together with the trace of the processing through which they did undergo. Some ideas with respect to this problem can be found in Postpischl *et al.*, 1991; some attempts of building up databanks of this kind are in progress (Godefroy *et al.*, 1990; Margottini, 1991; Boschi *et al.*, 1992).

8. Catalogue completeness

The completeness of the catalogues is a problem which intrigues many seismologists, as it represents a condition for the use of many approaches to the evaluation of seismic hazard. The completeness of a catalogue in a given time-window should follow in principle from the rate of the available sample, per class of size, *versus* the earthquakes, per class of size, which actually took place (fig. 3). As the second element is not known, the only way to assess the completeness is to evaluate the representativeness of the available sample.

The most common procedures for assessing the completeness of a catalogue, such as the one proposed by Stepp (1971), investigate the content of the available sample itself. Some of them rely on assumptions which require, more or less explicitly, that seismicity is stationary over a certain period of time, what is hard to accept in most cases.

A better way to deal with the problems of completeness would be to consider the factors which may influence the feeding of a catalogue, with respect to both the possibility of incorporation of an earthquake and the reliability of its parameters (date, location and size). It is well known, for instance, that presumed seismic gaps can be explained by historical sources gaps or, simply, by non-exhaustive investigations, and that the pretended linear increase with time of the completeness of a catalogue with reference to a presumed, linear increase with time of recorders and historical sources may represent a misleading oversimplification.

The most critical steps which may influence the representativeness of the historical content of a catalogue, with special reference to the written records, are summarized in table I. Similar concepts could be applied, in principle, for the instrumental content.

9. Conclusions

Historical seismology is on the way to establish as a «full right» branch of seismology, providing a huge amount of good-quality, macroseismic data. The most recent experiences for assessing seismic hazard have shown that the input data play an important role on the final results. The full exploitation of the available data for improving the seismic-hazard assessment seems to have a weak point in the procedures by which macroseismic data are processed in order to supply focal and attenuation parameters. By

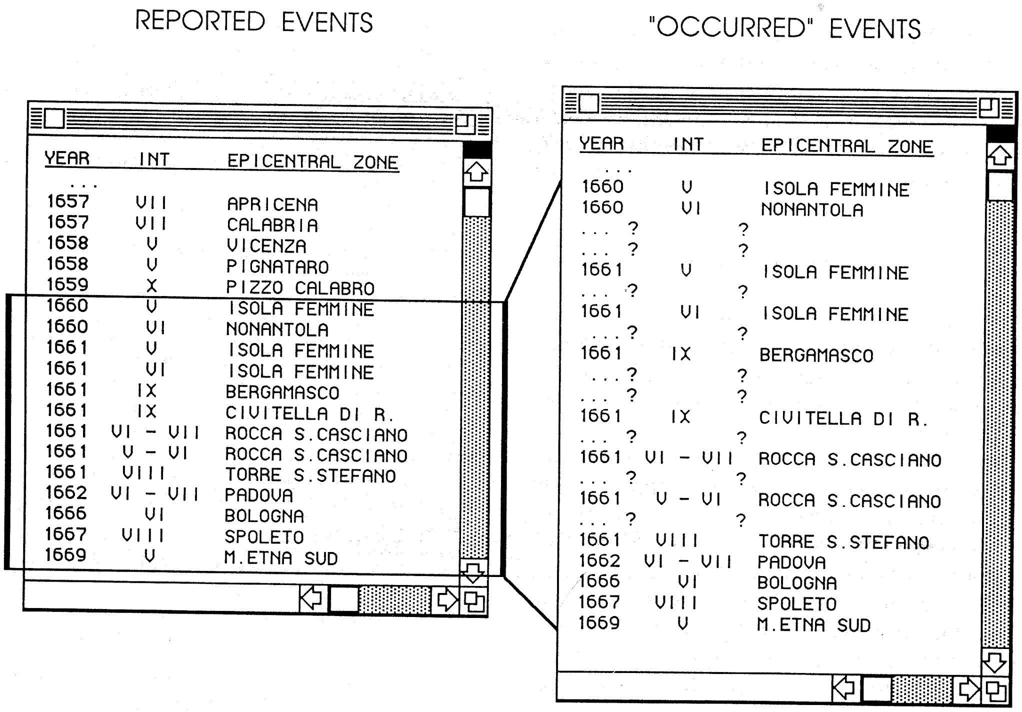

Fig. 3. Uncomplete (reported events) *versus* complete (occurred events) catalogue: a sketch.

Table I. Steps which contribute to the «completeness» (representativeness) of the historical part of a catalogue.

Earthquake	(It is not necessary that an earthquake occurs in order to be listed in a catalogue...)
Sources	
Recorders: type, distribution, ...	*Recorders* are those people who, regardless their motivation, have produced historical sources, that are collections of historical records. Earthquake records are produced voluntarily on involuntarily, and can be found in a large variety of historical sources.
Sources: scattering preservation	*Sources* are not necessarily preserved at the sites where they are produced, but they are scattered through a number of depositories; they, in their turn, undergo complicated histories which affect deeply the preservation of the records. All these factors need to be taken into account in order to assess the *source potential.*
Investigation: expertise, skill, budget, ...	Of course, the *investigation* of the sources can be exhaustive or preliminary, depending on the investigator's skill and budget. It has to be stressed that the quality of the seismic compilations upon which most parametric catalogues rely is deeply influenced by these factors.
Records	
Interpretation	The correctness of the *historical interpretation* also influences the content of the catalogue, for instance with respect to the problem of duplications.
Seismological processing	It is also clear that the «completeness» of a catalogue above a certain size can depend strongly also on the *procedures* by which *earthquake parameters* have been assessed, with reference mostly to epicentral intensity and location.

another side, the availability of so many data has stimulated alternatives in order to use the intensity datapoints (seismic histories at the sites), without drawing isoseismals (Mucciarelli *et al.*, 1990; Peruzza *et al.*, 1991) for evaluating the seismic hazard.

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REFERENCES

ALBINI, P. and M.S. BARBANO (Editors) (1991): *GNDT, Atti del Convegno, Gruppo di Lavoro Macrosismica, Pisa, 25-27 giugno 1990*, 2.

ALEXANDRE, P. (1984): Problèmes de méthode relatifs à l'étude des séismes médiévaux, in *Tremblements de terre, histoire et archéologie, Actes du colloque, Antibes, 2-4 Novembre 1983*, edited by B. HELLY and A. POLLINO, pp. 221-226.

AMBRASEYS, N.N. (1971): Value of historical records of earthquakes, *Nature*, **232**, 374-379.

AMBRASEYS, N.N. (1988): Temporary seismic quiescence: S.E. Turkey, *Geophys. J. Int.*, **96**, 311-331.

AMBRASEYS, N.N. and C.P. MELVILLE (1982): *A History of Persian Earthquakes* (Cambridge).

AMBRASEYS, N.N. and C. FINKEL (1991): Long-term seismicity of Istanbul and of the Marmara Sea region, *Terra Nova*, **3**, 527-539.

BARATTA, M. (1901): *I terremoti d'Italia* (Torino).

BARBANO, M.S., M. COSENTINO, G. LOMBARDO and G. PATANÉ (1980): Isoseismal maps of Calabria and Sicily earthquakes (Southern Italy), CNR-PFG, pubbl. 341, Catania.

BERARDI, R. and F. MUZZI (1988): Research on historical seismicity performed by ENEL within the activities for Nuclear Power Plant siting in Italy, in *Proceedings IAEA Workshop on «Historical Seismicity of Central-Eastern Mediterranean Region», Roma, 27-29 October 1987*, edited by C. MARGOTTINI and L. SERVA, pp. 195-212.

BERARDI, R., L. MAGRI and M. MUCCIARELLI (1990): Do different experts and computer programs agree on the interpretation of the same intensity map? in *Proc. XXII ESC General Assembly and Activity Report 1988-1990, Barcelona, 17-22 September 1990*, edited by A. ROCA and D. MAYER-ROSA, Vol. I, pp. 371-376.

BOSCHI, E., G. FERRARI and E. GUIDOBONI (1992): Perseus, the first GIS for historical seismology. Organization and first results, *Proc. XXIII ESC General Assembly, Prague, 7-12 September 1992* (in press).

BRANNO, A., E. ESPOSITO, G. LUONGO, A. MARTURANO, S. PORFIDO and V. RINALDIS (1985): Il terremoto del Vulture del 14 agosto 1851, *GNGTS, Atti 4° Convegno, Roma, 29-31 ottobre 1985*, Vol. I, pp. 329-336.

CARROZZO, M.T., G. DE VISINTINI, F. GIORGETTI and E. IACCARINO (1973): General Catalogue of Italian earthquakes, CNEN, RT/PROT (73) 12, Roma.

CARROZZO, M.T., M. COSENTINO, A. FERLITO, F. GIORGETTI, G. PATANÉ and M. RIUSCETTI (1975): Earthquakes catalogue of Calabria and Sicily (1783-1973), *Quad. Ric. Scient.*, **93**.

CECIC, I. (Editor) (1989): *Proceedings of the First AB Workshop on Macroseismic Methods, Poljce, Slovenia, 9-11 May 1989*.

CECIC, I. (Editor) (1992): *Proceedings of the Second AB Workshop on Macroseismic Methods, Poljce, Slovenia, 15-18 October 1990*.

CHIGNOLA, E., G. MONACHESI, S. RACCICHINI, A. RIGGIO and N. VASAPOLLO (1989): Indagine macrosismica di terremoti recenti: alcuni risultati, *GNGTS, Atti 8° Convegno, Roma, 7-9 novembre 1989*, pp. 213- 224.

DE RUBEIS, V., C. GASPARINI and A. TERTULLIANI (1989): Procedure per la valutazione dell'intensità macrosismica da questionari in uso presso I.N.G, *GNGTS, Atti 8° Convegno, Roma, 7-9 novembre 1989*, pp. 237- 244.

DELL'OLIO, A. and D. MOLIN (1980): *Catalogo e atlante macrosismico del Lazio dall'anno 1000 al 1975* (ENEA, Roma).

ENEL (1978): File of Italian earthquakes, Computer output (restricted).

ENEL (1984a): Rapporto per la localizzazione di una centrale elettronucleare nella Regione Piemonte, Area Po 1, Rapporto N. 8401, Roma (restricted).

ENEL (1984b): Rapporto per la localizzazione di una centrale elettronucleare nella Regione Piemonte, Area Po 2, Rapporto N. 8402, Roma (restricted).

ENEL (1984c): Rapporto per la localizzazione di una centrale elettronucleare nella Regione Lombardia, Area Viadana, Rapporto N. 8403, Roma (restricted).

ENEL (1984d): Rapporto per la localizzazione di una centrale elettronucleare nella Regione Lombardia, Area San Benedetto Po, Rapporto N. 8404, Roma (restricted).

ESPOSITO, E., G. LUONGO, A. MARTURANO and S. PORFIDO (1987): Il terremoto di S. Anna del 26 luglio 1805, *Mem. Soc. Geol. It.*, **37**, I.

FERRARI, G. and C. MARMO (1985): Il «quando» del terremoto, *Quaderni Storici*, **60**, 691-715.

FIGLIUOLO, B. (1988): *Il terremoto del 1456, Storia e Scienze della Terra* (Edizioni Studi Storici Meridionali, Nocera Inferiore), Vol. I.

GENTILE, G.F., G. RENNER, A.M. RIGGIO, D. SLEJKO and M. ZACCHIGNA (1984): Problematiche riguardanti lo studio dei terremoti storici: tre esempi significativi, in: *Regione Autonoma Friuli-Venezia Giulia- OGS, Finalità ed esperienze della Rete Sismometrica del Friuli-Venezia Giulia, Trieste, 7 dicembre 1984*, pp. 211-229.

GNDT Macroseismic Working Group (1992): The «Working Catalogue» of the National Group for Protection against the Earthquakes (GNDT) of Italy. Problems and results of a preliminary investigation of major earthquakes before 1690, *Proc. XXIII ESC General Assembly, Prague, 7-12 September 1992* (in press).

GODEFROY, P., J. LAMBERT, A. LEVRET and P. VASKOU (1990): The French Macroseismic data base «SIRENE», in *Proc. XXII ESC General Assembly and activity report 1988-1990, Barcelona, 17-22 September 1990*, edited by A. ROCA and D. MAYER ROSA, Vol. I, pp. 377-382.

GOUIN, P. (1979): *Earthquake History of Ethiopia and the Horn of Africa* (Ottawa).

GPSN, INMG, LNEC, CSN (1990): *Proceedings of the Workshop «Historical Earthquakes in the Ibero-Maghrebian Region. Methodological approach and case studies», Lisbon, 15-17 November 1989.*

GRANDORI, G., A. DREI, F. PEROTTI and A. TAGLIANI (1991): Macroseismic intensity versus epicentral distance: the case of Central Italy, *Tectonophysics*, **193**, 165-171.

GRASES, J. (1986): Hacia la reconstrucción de la história de los terremotos del Caribe, *Rivista Geofisica*, **24**, 53-69.

GUIDOBONI, E. (1984): 3 Janvier 1117: le tremblement de terre du moyen age roman, aspects des sources, in *Tremblements de terre, histoire et archéologie, Actes du colloque, Antibes, 2-4 Novembre 1983*, edited by B. HELLY and A. POLLINO, pp. 119-139.

GUIDOBONI, E. (1986): The earthquake of December 25, 1222: analysis of a myth, in *Proc. International Symposium on «Engineering Geology Problems in Seismic Areas», Bari, 13-19 April 1986*, edited by V. COTECCHIA, Vol. 3, pp. 413- 424.

GUIDOBONI, E. (Editor) (1989): *I terremoti prima del Mille. Storia archeologia sismologia* (Bologna).

GUIDOBONI, E. and G. FERRARI (1986): *Il terremoto di Rimini e della costa romagnola: 25 dicembre 1786. Analisi e interpretazioni* (Bologna).

GUIDOBONI, E. and G. FERRARI (1989): The inexact catalogue: the study of more than 1700 earthquakes from the XI to the XX century in Italy, *Terra Nova*, **1**, 2, 151-162.

GÜRPINAR, A. (1989): Importance of Historical Earthquakes Research in the Siting of Nuclear Facilities, in: *GPSN, INMG, LNEC, CSN, Proc. Workshop «Historical Earthquakes in the Ibero-Maghrebian Region. Methodological approach and case studies», Lisbon, 15-17 November 1989*, pp. 3-7.

GUTDEUTSCH, R., C. HAMMERL, I. MAYER and K. VOCELKA (1987): *Erdbeben als historisches Ereignis. Die Reconstruktion des Bebens von 1590 in Niederösterreich* (Berlin-Heidelberg).

GUTDEUTSCH, R., G. GRÜNTHAL and R. MUSSON (Editors) (1992): Historical earthquakes in Europe, *Abhandlungen der Geologischen Bundesanstalt*, **48**.

HELLY, B. and A. POLLINO (Editors) (1984): *Tremblements de terre, histoire et archéologie, Actes du colloque, Antibes, 2-4 Novembre 1983.*

IACCARINO, E. and D. MOLIN (1978a): Raccolta di notizie macrosismiche dell'Italia Nord-Orientale dall'anno 0 all'aprile 1976, CNEN, RT/DISP (78) 7, Roma.

IACCARINO, E. and D. MOLIN (1978b): Atlante macrosismico dell'Italia Nord-Orientale dall'anno 0 all'aprile 1976, CNEN, RT/DISP (78) 8, Roma.

IAEA (1987): Methodology and procedures for compilation of historical earthquake data, IAEA-TECDOC-434, Vienna.

IAEA-Turkish Atomic Energy Authority (1991): *Proceedings of the Workshop on «Historical Seismicity and Seismotectonics of the Mediterranean Region», Istanbul, 10-12 October 1990.*

IGN, CSN, GPSN (1988): *Proceedings of the «Jornadas de Estudio sobre Metodología para la Investigación Histórica de Terremotos», Madrid, April 1-3 1987*, Comunicaciones y Ponencias, 6.

KARNIK, V. and D. PROCHÀZCHOVÀ (Editors) (1978): *Atlas of isoseismal maps. Central and Eastern Europe* (Prague).

KOZAK, J. (Editor) (1991): *Proceedings of the 3rd ESC Workshop on «Historical Earthquakes in Europe», Liblice by Prague, 4-6 April 1990.*

LÓPEZ MARINAS, J.M. and R. SALORD (1990): *El período sísmico Oranes de 1790 á la luz de la documentación de los archivos españoles* (MOPU, Instituto Geografico Nacional, Monografías, 6, Madrid).

MAGRI, G. and D. MOLIN (1986): I terremoti del 3 gennaio 1117 e del 25 dicembre 1222. RTI PAS-ISP-GEOL LO(86)2.

MARGOTTINI, C. (1981): Il terremoto del 1743 nella penisola salentina, in Contributo alla caratterizzazione della sismicità del territorio italiano, *Memorie del Convegno annuale del Progetto Finalizzato Geodinamica sul tema «Sismicità dell'Italia: stato delle conoscenze scientifiche e qualità della normativa sismica», Commissione ENEA-ENEL, Udine, 12-14 maggio 1981.*

MARGOTTINI, C. (1991): An example of a data bank for historical documents on natural hazard, in *Proc. 3rd ESC Workshop on «Historical Earthquakes in Europe», Liblice by Prague, 4-6 April 1990*, edited by I. KOZAK, pp. 25-29.

MARGOTTINI, C. and D. MOLIN (1983): Risultati preliminari delle ricerche di sismica storica condotte nell'Appennino tosco-emiliano, ENEA, PAS-ISP BR (83) 2, Roma (restricted).

MARGOTTINI, C. and L. SERVA (Editors) (1988): *Historical Seismicity of Central-Eastern Mediterranean Region, Roma, 27-29 October, 1987.*

MARGOTTINI, C., G. MARTINI and D. SLEJKO (1993): Instrumental seismological data since 1900 for north-eastern Italy, *Earthq. Eng. Struct. Dyn.* (in press).

MARTINEZ SOLARES, J.M., A. LÓPEZ ARROYO and J. MEZCUA (1979): Isoseismal map of the 1755 Lisbon earthquake obtained from Spanish data, *Tectonophysics*, **53**, 301-314.

MAYER-ROSA, D. and B. CADIOT (1979): A review of the 1356 Basel earthquake: basic data, *Tectonophysics*, **53**, 325-333.

MAYER-ROSA, D. and V. SCHENK (Editors) (1989) Special issue on TERESA, TEst Regions for Evaluations of Algorithms for Seismic Hazard Assessment in Europe, *Natural Hazards*, **2**, 3-4.

MAYER-ROSA, D., D. SLEJKO and G. ZONNO (1993): *Assess-*

ment of seismic hazard for the Sannio-Matese area, Southern Italy (project «TERESA»), this volume.

MELETTI, C., E. PATACCA, P. SCANDONE and B. FUGLIUOLO (1988): Il terremoto del 1456 e la sua interpretazione nel quadro sismotettonico dell'Appennino meridionale, in *Il terremoto del 1456. Storia e Scienze della Terra*, edited by B. FIGLIUOLO (Edizioni Studi Storici Meridionali, Nocera Inferiore), Vol. I, pp. 71-108.

MELONI, F. and D. MOLIN (1987): Il terremoto padano del 13 gennaio 1909, *GNGTS, Atti 6° Convegno, Roma, 14-16 dicembre 1987*, Vol. I, pp. 269-294.

MERCALLI, G. (1883): *Vulcani e fenomeni vulcanici in Italia* (Milano).

MOLIN, D. (1981): Sulla sismicità storica dei Colli Albani, CNEN/RT/AMB (81) 11, Roma.

MOLIN, D. and L. MUCCI (1990): Il terremoto di Senigallia del 30 ottobre 1930, *GNGTS, Atti 9° Convegno, Roma, 13-15 novembre 1990*, Vol. I, pp. 31-46.

MONACHESI, G. (Editor) (1987): Revisione della sismicità di riferimento per i comuni di Cerreto D'Esi (AN), Esanatoglia (MC), Serra San Quirico (AN), Rapporto interno (Osservatorio Geofisico Sperimentale di Macerata, Macerata).

MONACHESI, G., F. PERGALANI and M. STUCCHI (1985): I terremoti del 1741 - 1747 - 1751 nell'Appennino umbro-marchigiano, *GNGTS, Atti 4° Convegno, Roma, 29-31 ottobre 1985*, Vol. I, pp. 505-516.

MUCCIARELLI, M., D. ALBERELLO and L. MAGRI (1990): Un metodo alternativo all'uso delle leggi di attenuazione nella stima di rischio sismico, *GNGTS, Atti 9° Convegno, Roma, 13-15 novembre 1990*, Vol. I, pp. 47-56.

MUSSON, R.M.W., G. NEILSON and P.W. BURTON (1984): *Macroseismic reports on historical British earthquakes*, British Geological Survey, Edinburgh.

OGS (1987): Earthquake catalogue of the Eastern Alps, Computer file.

PAYO, G. (Editor) (1989): *Proceedings of the Symposium «Calibration of Historical Earthquakes in Europe and Recent Developments in Intensity Interpretation», XXI ESC General Assembly, Sofia, 23-28 August 1988*, Cursos y Seminarios, 3.

PEREZ, Z.J.M., A.V. GARCIA and R.T. RPJAS (1987): Cronologia de los Sismos en Mexico (de 1 Padernal a 1821), *Quadernos de la casa chata*, **135**, Mexico.

PERUZZA, L., G. MONACHESI, D. SLEJKO and M. STUCCHI (1991): Valori di intensità osservati e calcolati per la stima della pericolosità sismica, *GNGTS, Atti 10° Convegno, Roma, 6-8 novembre 1991* (in press).

POSTPISCHL, D. (Editor) (1985a): Atlas of isoseismal maps of italian earthquakes, *Quad. Ric. Scient.*, **114**, 2A, Bologna.

POSTPISCHL, D. (Editor) (1985b): Catalogo dei terremoti italiani dall'anno 1000 al 1980, *Quad. Ric. Scient.*, **114**, 2B, Bologna.

POSTPISCHL, D. (Editor) (1991): *San Marino e il terremoto* (Bologna).

POSTPISCHL, D., G. FERRARI and E. GUIDOBONI (1984): Recherches de sismicité historique en Italie: premiers résultats et nouveaux développements, in *Tremblements de terre, histoire et archéologie, Actes du colloque, Antibes, 2-4 Novembre 1983*, edited by B. HELLY and A. POLLINO, pp. 109-117.

POSTPISCHL, D., A. BRANNO, E. ESPOSITO, G. FERRARI, A. MARTURANO, S. PORFIDO, V. RINALDIS and M. STUCCHI (1985): The Irpinia earthquake of November 23, 1980, in *Atlas of isoseismal maps of Italian earthquakes, Quad. Ric. Scient.*, edited by D. POSTPISCHL, **114**, 2A, pp. 152-159, Bologna.

POSTPISCHL, D., M. STUCCHI and A. BELLANI (1991): Some ideas for a databank of macroseismic data, *Tectonophysics*, **193**, 215-223.

RIBARIC, V. (1979): The Idrija earthquake of March 26, 1511 - a reconstruction of some seismological parameters, *Tectonophysics*, **53**, 315-324.

ROCA, A. and D. MAYER-ROSA (Editors) (1990): *Proceedings of the XXII ESC General Assembly and activity report 1988-1990, Barcelona, 17-22 September 1990*, Vol. I-III.

RODRIGUEZ DE LA TORRE, F. (1984): *Los terremotos alicantinos de 1829* (Publicaciones del Instituto de Estudios Alicantinos, Alicante), Vol. I, p. 100.

SERVA, L. (1981a): Il terremoto del 1688 nel Sannio, in *Contributo alla caratterizzazione della sismicità del territorio italiano, Memorie del Convegno annuale del Progetto Finalizzato Geodinamica sul tema «Sismicità dell'Italia: stato delle conoscenze scientifiche e qualità della normativa sismica», Commissione ENEA-ENEL, Udine, 12-14 maggio 1981.*

SERVA, L. (1981b): Il terremoto del 1694 in Irpinia e Basilicata, in *Contributo alla caratterizzazione della sismicità del territorio italiano, Memorie del Convegno annuale del Progetto Finalizzato Geodinamica sul tema «Sismicità dell'Italia: stato delle conoscenze scientifiche e qualità della normativa sismica», Commissione ENEA-ENEL, Udine, 12-14 maggio 1981.*

SHEBALIN, N.V. (Editor) (1974): *Atlas of Isoseismal Maps Balkan Region* (Skopje).

STEPP, J.C. (1971): An investigation of earthquake risk in the Puget Sound area by use of the type I distribution of largest extremes, PhD thesis, Pennsylvania State University.

STUCCHI, M. (1988a): The CEC Project «Review of Historical Seismicity», in *Proc. IAEA Workshop on «Historical Seismicity of Central-Eastern Mediterranean Region», Roma, 27-29 October 1987*, edited by C. MARGOTTINI and L. SERVA, pp. 333-337.

STUCCHI, M. (Editor) (1988b): Revisione della sismicità storica dell'area anconetana. Rapporto interno, CNR, Milano.

STUCCHI, M. (1991): Verso una razionalizzazione della base di dati macrosismici, in *GNDT, Atti del Convegno, Gruppo di Lavoro Macrosismica, Pisa, 25-27 giugno 1990*, edited by P. ALBINI and M.S. BARBANO, **2**, pp. 1-23.

STUCCHI, M. (1992): Historical records, macrosesimic scales and seismic hazard, *Proc. Tenth World Conference on Earthquake Engineering, Madrid, 19-24 July 1991*, 11 (in press).

STUCCHI, M. and P. ALBINI (1991): New developments in macroseismic investigation, *Proc. Mexico-EC Workshop «Seismology and Earthquake Engineering», Mexico City, 22-26 April 1991*, pp. 47-70.

STUCCHI, M., D. POSTPISCHL and D. SLEJKO (Editors) (1991a): Investigation on historical earthquakes in Europe, *Tectonophysics*, **193**.

STUCCHI, M., A. BELLANI and E. CHIGNOLA (1991b): Behind the intensity map: assessing the quality of historical-seismological information, in *Proc. 3rd ESC Workshop on «Historical Earthquakes in Europe», Liblice by Prague, 4-6 April 1990*, edited by J. KOZAK, pp. 41-58.

STUCCHI, M., G. MONACHESI and F.M. MANDRELLI (1991c): Investigation on XVIII century seismicity in central Italy in the light of the 1741, Fabriano earthquake, in *Investigation on Historical Earthquakes in Europe*, edited by M. STUCCHI, D. POSTPISCHL and D. SLEJKO, *Tectonophysics*, **193**, pp. 65-82.

THEMUDO BARATA, M.R., L. BRAGA, M. NORONHA WAGNER, B. GUERRA, J. FÉLIX ALVES and J. NETO (1988): Sismicidade de Portugal, Estudo da documentação dos séculos XVII e XVIII. I - Heurística, crítica e interpretação, GPSN, Lisboa.

THEMUDO BARATA, M.R., L. BRAGA, M. NORONHA WAGNER, B. GUERRA, J. FÉLIX ALVES and J. NETO (1989): Sismicidade de Portugal, Estudo da documentação dos séculos XVII e XVIII. II - Apêndice documental, GPSN, Lisboa.

UDIAS, A. and D. MUÑOZ (1979): The Andalusian earthquake of 25 December 1884, *Tectonophysics*, **53**, 291-300.

VOGT, J. (Editor) (1979a): *Les tremblements de terre en France, Memoire n. 96, BRGM, Orleans.*

VOGT, J. (1979b): Problèmes de méthode, in *Les tremblements de terre en France, Memoire n. 96, BRGM, Orleans*, edited by J. VOGT, pp. 9-15.

VOGT, J. (1981): Problèmes de sismicité historique en France, *Geologues (U.F.G.)*, **57**, 53-56.

VOGT, J. (1984): Problèmes de sismicité historique: exemples de faux séismes, de séismes méconnus et de séismes réinterprétés dans l'ensemble Allemagne/Belgique/Nord-Ouest de la France/Sud de la Grande-Bretagne, in *Seismic Activity in Western Europe* [...], edited by P. MELCHIOR (Dordrecht-Boston-Lancaster).

VOGT, J. (1985): Riesame di sismi: ricerche in Francia, *Quaderni Storici*, **60**, 743-770.

VOGT, J. (1989): Historical seismology. Some notes on sources for seismologists, Report for the CEC project «Review of Historical Seismicity in Europe».

VOGT, J. (1991): L'imbroglio des catalogues de sismicité historique: à propos d'une crise sismique ressentie à la fin du XVIIIe siècle à Hagueneau et ailleurs, *Etudes Haguenoviennes*, **XVII**, 217-220.

WECHSLER, E. (1987): *Das Erdbeben von Basel 1356, Teil I: Historische und kunsthistorische Aspekte* (Zürich).