A «new generation» earthquake catalogue

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In 1995, we published the first release of the *Catalogo dei Forti Terremoti in Italia, 461 a.C. - 1980,* in Italian (Boschi *et al.*, 1995). Two years later this was followed by a second release, again in Italian, that included more earthquakes, more accurate research and a longer time span (461 B.C. to 1990) (Boschi *et al.*, 1997). Aware that the record of Italian historical seismicity is probably the most extensive of the whole world, and hence that our catalogue could be of interest for a wider international readership, Italian was clearly not the appropriate language to share this experience with colleagues from foreign countries. Three years after publication of the second release therefore, and after much additional research and fine tuning of methodologies and algorithms, I am proud to introduce this third release in English. All the tools and accessories have been translated along with the texts describing the development of the underlying research strategies and current contents. The English title is *Catalogue of Strong Italian Earthquakes, 461 B.C. to 1997.*

This Preface briefly describes the scientific context within which the *Catalogue of Strong Italian Earthquakes* was conceived and progressively developed. The catalogue is perhaps the most important outcome of a well-established joint project between the Istituto Nazionale di Geofisica, the leading Italian institute for basic and applied research in seismology and solid earth geophysics, and SGA (Storia Geofisica Ambiente), a private firm specialising in the historical investigation and systematisation of natural phenomena. In her contribution «*Method of investigation, typology and taxonomy of the basic data: navigating between seismic effects and historical contexts*», Emanuela Guidoboni outlines the general framework of modern historical seismology, its complex relation with instrumental seismology on the one hand and historical research on the other. This presentation also highlights the many other contributions making up the Introduction to this third edition of the catalogue. The authors hope that it will make for informative and useful reading.

Catalogues of Italian seismicity: from punched cards to Internet

The Italian National Nuclear Energy Committee (CNEN, subsequently renamed ENEA, the Italian Board for New Technologies, Energy and the Environment) first published its catalogue of Italian earthquakes in computerised form almost thirty years ago (Carrozzo *et al.*, 1973). This was the first work of its kind to make use of information technology as well as the printed page. Modern computers were becoming widely available in major research centres and proving especially suitable for the large database-type information synonymous with long-term earthquake census. Computerised database systems also revolutionised the approach to historical information on earthquakes, however, requiring that even the less objective accounts and descriptions be translated into parameters and codes suitable for electronic processing. Overcoming this conceptual hurdle led to new, more modern analytical techniques thanks to the retrieval speed of pertinent historical seismic data and the new processing capabilities providing both qualitative and statistical analyses.

The first catalogue edited by Edoardo Iaccarino and co-workers at CNEN (Carozzo *et al.*, 1973) was followed by several others, each improving on and refining the information processing method used in previous catalogues (*e.g.*, ENEL, 1979; Istituto Nazionale di Geofisica, 1981). Although seminal works, they were, however, only made available to experts working in the sector and not to the general public. In 1985, Daniele Postpischl edited the «*Catalogo dei terremoti italiani dall'anno 1000 al 1980*», a collation of studies carried out from the end of the seventies to the beginning of the eighties by the very many researchers involved in the *ad hoc* Geodynamics Project of Italy's National Research Council (CNR). In part as a result of the growing demand for information on Italy's seismic history, triggered by the catastrophic earthquake in Irpinia on November 23, 1980, this catalogue was published and circulated to a wider readership of institutions and practitioners, in both hard-copy and computerised versions, the latter consisting of more than 40000 strings of alphanumerical characters, each string summarising the essential parameters of a single earthquake.

Italy, the cradle of historical seismology

The catalogues prepared and perfected in those years were an exclusively Italian phenomenon, however, receiving scant acknowledgement from the rest of the world. In her paper «*Method of investigation...*», Emanuela Guidoboni outlines how the study of earthquakes of the past is an Italian tradition, culminating in 1901 with Mario Baratta's seminal work «*I terremoti d'Italia. Saggio di storia geografia e bibliografia sismica italiana*», a collection and appraisal of all available accounts of past earthquakes and a point of departure for every computerised catalogue in the past thirty years.

The Italian focus on earthquakes is readily explained by the fact that Italy can boast a substantial percentage of the world's artistic heritage, being the backdrop for more than two millennia of major civilisations and social systems whose cultural influence was felt throughout the Mediterranean and Europe. One such civilisation, the Roman Empire, extended to some of the most seismic regions of the world; subsequently, came the Roman Catholic Church. Although completely different, these two 'institutions' were similar in their solid, far-reaching administrative structure which ensured a continuous flow of information on natural and social events from the periphery to the centres of power. This has provided us with a priceless array of documentation. Ecclesiastical records and public authority reports abound especially during the Renaissance when cultural interest flourished. However, a surprising amount of information is also available on earthquakes during the less well documented Middle Ages. Emanuela Giudoboni is very enlightening on this subject in her review. The wealth of information available on Italian seismic activity contrasts markedly with neighbouring geographical areas. Although the cradle of an ancient civilisation, Greece, for example, provides surprisingly little in the way of an historical record from the fifth through to the nineteenth century.

Besides these general considerations, the specificity of historical seismic records in Italy is twofold: first, a series of historical events that laid the basis for study of the effects of earthquakes, and secondly, the great frequency and widespread distribution of earthquakes in Italy, and their enormous influence on the history of building and architecture, population distribution, land-use and even the formation of cultural and linguistic communities. Even if we consider only quakes that cause casualties and damage, the Italian peninsula is the scene every one hundred years of about 100 earthquakes in the 5.0 to 6.0 magnitude range, and five to ten earthquakes of a magnitude exceeding 6.0. The twentieth century suffered at least 6 earthquakes of or exceeding 6.5: September 8, 1905 in Calabria; December 28, 1908 in the Straits of Messina; January 13, 1915 at Avezzano; July 23, 1930 in Northern Irpinia; May 6, 1976 in Friuli and November 23, 1980 in Irpinia. As well as causing more than 150000 casualties, the earthquakes wrecked tens of thousands of buildings. This led to reconstruction, restoration, the abandoning of whole areas and the shift of whole communities, with the accompanying upheaval in town-planning and toponomastic systems as populations shifted out of and even into afflicted areas. In some cases, the physical environment itself underwent permanent change. Simply extending the figures for the last century back in time and to the other areas of the peninsula provides a stark idea of the extent to which earthquakes have impacted Italian history.

Geologically speaking, Italy is a young region, much of the peninsula having emerged no more than a million years ago following a series of vertical thrusts of differing intensity in various zones and the progressive filling of the Po River valley and other extensive coastal plains. These latter geological processes took place in regions that had already been subject to the forces that had created the Alps and the Apennines, generating the sharply contrasting topography and widely diversified landscapes that characterise the peninsula. The subsequent build-up of the coastal tracts, the creation of numerous water catchment areas, all of approximately the same size, and the marked climatic differences these created, all allowed for widespread human settlement in areas which, for many centuries, developed in relative isolation, protected by fairly high mountain ranges. These singular geodynamic phenomena not only characterise the geology of the peninsula but were key to its singular cultural history. Italy was unique in being a geologically young land mass still undergoing rapid change, and therefore subject to earthquakes and changing landscapes, a feature which led to human settlement in widely differing areas. This ubiquitous population distribution also meant that earth tremors were witnessed and minutely recorded down the ages for subsequent generations living in that area. This 'theory' is countered, however, by the above-mentioned tradition of information 'flows' to the main cultural centres. At the same time, the opposite was also true, with certain areas probably being cut off from the rest of the land mass not only by mountain ranges but also on account of wars, religious differences and other historical phenomena. The extent to which this isolation may have altered the 'collective memory' of Italian earthquakes is dealt with in the article «*Towards new research strategies: silent seismogenic areas or silent sources?*» by Gianluca Valensise and Emanuela Guidoboni.

From Baratta's «radianti di scuotimento» (quake radiants) to characteristic earthquakes

One of the most significant features of this close weave of seismic records down through history is their highly specific spatial reference. In the second part of «*I terremoti d'Italia*» dealing with the 'topographic distribution of Italian earthquakes', Mario Baratta describes the fact that «research into past tremors, together with the monographic study of each single quake occurring in a given region up to modern times, allow us to identify various quake 'focuses' or 'radiants'». Baratta proceeds to list more than 250 'seismic centres' in Italy, practically one every 1200 km^2, in other words, one every 35 km along any cross-sectional line drawn across the peninsula. This seismic density is further increased by the fact that about one third of Italy is virtually earthquake-free. Furthermore, many 'seismic centres' are subdivided by the author into a series of minor centres. Identification accuracy varies widely, however, with the particular historical period and the geographical area in consideration. For example, during ancient times, the city of Rome 'attracted' earthquakes occurring along the Apennine ridge running at least some 200 km between Umbria and Molise (see Molin *et al.*, 1995). Today we know that there are at least a dozen major independent seismogenic sources in this area which more superficial accounts indicate vaguely as one single source near Rome. A very different example is Sicily, where Baratta identified some 42 sources from accounts covering the 17th to 18th century. Indeed the accuracy with which the epicentres of quakes were determined by historical and more recent data was unrivalled until the first half of the seventies when instrumental earthquake detection took a quantum leap with new technological development.

It may be argued that accurately defining the quake 'focus' is of marginal importance since earthquakes seem to disperse randomly over the territory. However, modern seismology suggests that this random dispersion is at least only apparent and largely the result of inaccurate determination of the various factors defining a quake epicentre. In fact, earthquakes tend to concentrate repeatedly on specific geological structures which are, however, not always readily identifiable at the surface. The examples of Rome and Sicily, together with trends in modern seismology indicate the importance of identifying the individual seismic sources rather than generic areas of seismic activity since this allows identification of 'gap' zones. This finding has considerably improved our ability to estimate seismic hazard, as is explained in the article «*From earthquake intensities to earthquake sources: extending the contribution of historical seismology to seismotectonic studies*» by Paolo Gasperini and Gianluca Valensise. This applies particularly to the sources of major tremors, where knowing whether one is 10 or 30 km from a fault can mean the difference between a destroyed or a slightly damaged building. Even here, however, there can be surprises, with source seismic levels being overestimated in the past on account of proximity to an observation point, a monastery or simply a built-up area. This often led in the past to overemphasis of a quake's effects. A case in point is the Alban Hills near Rome where a concomitant series of local tremors and the creation of the Rocca di Papa Observatory in 1889 led to overestimation of the real seismogenic potential of the area. A comparative analysis of historical records and geological and seismological information of the area should, however, allow the elimination of such 'distortions' and establish a correct hierarchy among the various earthquake centres.

The role of site effects: new understanding of old observations

One, as yet not fully appreciated, benefit from historic quake documentation is a greater understanding of so-called 'site effects', or the heterogeneous nature of widespread, small-scale property damage caused within a built-up area. The major earthquake that hit Mexico City in 1985 was perhaps the first occasion on which this heterogeneous local response was clearly evidenced, not only by mapping wrecked and damaged buildings but also thanks to a network of instrumental stations. Similar detection networks have since been set in place elsewhere. With the major tremors in California of 1989 and 1994, the catastrophe quake of Kobe in 1995 and the Izmit disaster in the summer of 1999, the aim of anticipating local response characteristics has become one of the key aims of modern risk-mitigation seismic practice. This is not a recent discovery, however. The uneven distribution of property damage even over small areas had already been observed with numerous earthquakes of the past. Italian scholars considered this a special feature of many Italian earthquakes. From the beginning of the twentieth century and in particular after the major quakes of the Straits of Messina in 1908 and Avezzano in 1915, these observations were tentatively explained in terms of the particular features of the subsoil layers and hence an intrinsic feature of the affected site. For example, the harbour area of Messina suffered the same sort of upheaval and damage both in 1783 and 1908 during earthquakes which, although of similar intensity, were located at least 30 km apart. Historical data would suggest that the same amplification patterns, leading to markedly heterogeneous damage, is true for a large number of sites, especially in Central and Southern Italy. Numerous studies (*e.g.*, Funiciello, 1995, and articles contained in this volume) show that the city of Rome itself presents the same pattern of systematically differentiated local damage following quakes of vastly differing magnitude and epicentre. While the theory underlying these phenomena is well understood today, only the historical record can verify the existence of these repeated localised damage patterns, which would not be revealed by mere surface geologic investigation or evidenced by a survey of the recent data.

The historical record of local seismic response to major quakes is as enlightening as it is untapped. However, the so-called 'site effects' must be considered only after discounting a series of local conditions, such as the state of disrepair and structural weakness of local property and the different construction techniques. In other words, an accurate assessment of the historical record entails much more than merely assigning a macroseismic intensity score to the event in question. In recent years the seismic response of several important urban centres like Bologna, Catania, Palermo, Ferrara and Florence has been studied specifically mainly by the SGA as part of the framework research programme of Italy's Istituto Nazionale di Geofisica. Emanuela Guidoboni and Graziano Ferrari summarise the results of this research effort in their contribution «*The effects of earthquakes in historical cities: the peculiarity of the Italian case*». In most cases, these studies entail detailed investigation of the huge body of information contained in the *Catalogue of Strong Italian Earthquakes*. The results of these studies are now becoming an integral part of the background knowledge available to town planners, architects and restorers and therefore an indispensable means of reducing the vulnerability of Italy's historic architectural heritage.

Yet another catalogue?

While the Italian earthquake record is an outstanding source of information, it nonetheless harbours the inherent danger of generating a distorted picture of the seismogenic potential of an area if analysis is summary. The result in most instances is an underestimation of the seismic potential, but also often an overestimation, which will have dire consequences on areas of potential economic development. Until today, the results of historical research have been summed up in traditional catalogues. This form of presentation tended to impoverish the information content, however, making it unsuitable for in-depth study and differentiation. An example is the estimated energy released by an earthquake: it is commonly known and theoretically proven that two crustal earthquakes of a magnitude of 6.5 and 8.0 can cause the same peak acceleration values, for example in the range of 0.3-0.5 *g*, and the same maximum macroseismic effects, of say, the X degree. In other words, peak acceleration and intensity in both cases have a 'saturation' level. The difference between the two, however, lies in the size of the area affected, which will be restricted to a few kilometres for the 6.5 magnitude quake but be of several hundred kilometres in the case of the 8.0 magnitude tremor. In the absence of instrumental data, the relative importance of the two earthquakes can be understood only by compiling a complete picture of their dynamic effects, something that traditional earthquake catalogues failed to supply, focusing only on epicentre intensity. Erroneous intensity assessment in either of the two examples cited above would provide a completely distorted picture of the residual seismogenic potential of the region: the less intense earthquake is probably associated with a 10 or 20 km fault rupture while the major quake could involve an area ten times that size.

Over the last fifteen years, research in Historical Seismology has focused on overcoming the shortcomings of traditional catalogues. Several research groups have set themselves the task of doing more than merely providing a chronological list of quakes denoted only by epicentre and energy parameters, providing the end user with an overall picture of each event, including property damage and the particular historical and geographical context. Using modern time- and cost-saving information technology, several interesting studies have been presented, such as Bergamaschi *et al.* (1981); Bellani *et al.* (1989); Stucchi (1991); Postpischl *et al.* (1991) and Bramerini *et al.* (1995). All these studies have developed complex IT data systems, in some cases even at local level, allowing rapid retrieval and consultation of the wealth of information available on specific locations, degree of after-effects, the original texts of the sources, diagrams and original sketches, photographs, if available, and any other piece of information used to assess the significant parameters of past quakes. About ten years ago the Istituto Nazionale di Geofisica and SGA together developed PERSEUS, a GIS (Geographic Informative System) database to enable systematic organisation and interactive analysis of national historical earthquake data (Boschi *et al.*, 1992). The first version of the *Catalogue of Strong Italian Earthquakes* was published as part of this project in 1995. Two years later came the *Database of Macroseismic Observations*, or DOM, by Monachesi and Stucchi (1997), a summary of the latest investigations of the National Group for Safeguard against Earthquakes (Gruppo Nazionale per la

Table I. Summary of national catalogues of Italian seismicity published by public and research institutions during a full century following Baratta (1901). Regional or local catalogues are not included. For each catalogue the diagram shows the date of publication, the reference time interval, the number of listed earthquakes, the minimum intensity threshold, the *parametric* and/or *descriptive* nature of the data supplied, and the medium used for the original release. Notice that for Baratta's work the table supplies the number of seismic sequences described as separate entities, not the total number of individually mentioned shocks (that is much larger). Also notice that the extension to the 16th century B.C. of the catalogue by ING (1982) was the object of subsequent research that reduced to the 5th century B.C. the interval of reliability for ancient earthquakes (see CFTI1 and CFTI2). Concerning the number of earthquakes listed by NT4.1.1, notice that this catalogue draws from several diverse sources and that the 68% of the events were derived from previous catalogues (essentially from PFG, 1985, but also from other European compilations and from CFTI1). CPTI was requested by the Italian Civil Defence as a reference parametric catalogue that blends information from CFTI2 and NT4.1.1. Finally, notice that the large number of shocks listed by the CNEN, ENEL and PFG catalogues is due (1) to the lower intensity threshold and (2) to the inclusion of large aftershock sequences (particularly for large earthquakes of the 20th century).

Year of publ.	Compilation	Reference time interval	Earthquakes n.	Intensity from	Paper	File	CDROM	Internet	Parametric	Descriptive
1901	Baratta	1 A.D.–1898	1,364	Felt	•					•
1935	Cavasino	1899 –1933	242	VI	•					•
1973	CNEN	1 A.D.–1973	10,604	Felt	•	•			•	
1979	ENEL	1000–1975	20,660	Felt		•			•	
1982	ING	1450 B.C.–1982	3,440	Felt		•			•	
1985	PFG	1000–1980	41,800	Felt	•	•				
1995	CFTI1	461 B.C.–1980	346	VIII-IX	•		•		•	•
1997	CFTI2	461 B.C.–1990	559	VIII-IX	•		•		•	•
1997	NT4.1.1+DOM4.1	1000–1980	2,421	V-VI	•	•		•	•	
1998	NT4.1.1+DOM4.1 (92)	1000–1992	2,488	V-VI				•		
1999	CFTI2.1	461 B.C.–1990	560	VIII-IX				•	•	•
1999	CPTI	217 B.C.–1992	2,480	V-VI	•			•	•	
2000	CFTI3	461 B.C.–1997	605	VIII-IX	•		•	•	•	•

1500 B.C. // 500 B.C. 1 A.D. 500 1000 1500 2000

CNEN (now ENEA) = Carrozzo *et al.* (1973); ING = Istituto Nazionale di Geofisica (1982); PFG = Postpischl (1985); CFTI1 = Boschi *et al.* (1995); CFTI2 = Boschi *et al.* (1997); NT4.1.1 = Camassi and Stucchi (1997); DOM4.1 = Monachesi and Stucchi (1997); CFTI2.1 = Boschi *et al.* (1999); CPTI = Gruppo di Lavoro CPTI (1999); CFTI3 = Boschi *et al.* (2000, this volume).

Difesa dai Terremoti, GNDT), which from 1987 had taken over where the Geodynamics Project had left off. DOM in turn was created as a 'container' for the database of the NT4.1 parametric catalogue (Camassi and Stucchi, 1997), and is a follow-on from the Geodynamics Project catalogue (Postpischl, 1985). Finally, between 1997 and 1999, all these catalogues were made available on the Internet (Monachesi and Stucchi, 1997; Boschi *et al.*, 1999) with consequent widespread availability of all historical records on past earthquakes (see table I).

The publication of the *Catalogue of Strong Italian Earthquakes* in 1995 marked a turning point in earthquake investigation, starting a period of intense interest and study of the history of earthquakes and marking the end of a period during which this discipline suffered from scant interest. Despite the solid tradition of Historical Seismology in Italy, for a whole decade work had practically ceased following the conclusion of the Geodynamics Project and the publication of its catalogue in 1985. New proposals for the use of IT data processing had largely been ignored or were being carried on by isolated groups of determined researchers. The upshot of this was a decade of virtually no publications. One of the main causes of this lack of activity was undoubtedly the nuclear disaster of Chernobyl in 1986 and the subsequent referendum in 1987 when the Italian population confirmed a moratorium on the development of nuclear power plants in Italy – a moratorium which should have lasted only 5 years but which in fact has become a permanent measure. Between 1983 and 1987, ENEL, Italy's state-owned Electricity Board, commissioned SGA to conduct a series of in-depth researches into Italy's seismic history record as part of the National Energy Plan which included investigation into the possible location of sites for both nuclear and conventional power-generating plants (Guidoboni and Ferrari, 1989). As in all industrialised countries, Historical Seismology research in Italy was largely sustained by the requirement to mitigate risks inherent in power plant location. Although ENEL had sponsored four years of intense research, after the referendum of 1987, it understandably reduced its investment budget significantly.

In 1987, the Istituto Nazionale di Geofisica took up the role previously played by ENEL promoting new research to build on the wealth of classified data already available in order to preserve this knowledge and skills base. Although vast, the information collected under ENEL's sponsorship had had an understandably geographic bias since it catered for the requirements of nuclear power development. In fact, most investigations focused on moderately seismic areas such as the Po valley and the Salento, or on the propagation characteristics of severe Apennines quakes. As the national authority on seismology with more than fifty years experience, the *Istituto* proceeded to redress the balance and commissioned new research that would provide a better understanding of seismic activity and its effects throughout the peninsula. The *Istituto* and SGA have since worked together constantly, adding new pieces to the mosaic of information, conducting critical reviews and generally filling in the context of the many hundreds of severe earthquakes that make up Italy's quake record. In some cases this has resulted in a very different overall picture than before. The articles «*Historical variables of seismic effects: economic levels, demographic scales and building techniques*» and «*Seismic scenarios and assessment of intensity: some criteria for the use of the MCS scale*» by Graziano Ferrari and Emanuela Guidoboni, and «*Earthquake effects on the environment: from historical descriptions to thematic cartography*» by Gianluca Valensise and Emanuela Guidoboni provide an essential insight into the methods used and the results of this new series of investigations. As well as the first two versions of the *Catalogue of Strong Italian Earthquakes*, monographs such as the *Catalogue of ancient earthquakes in the Mediterranean area up to the 10th century* (Guidoboni *et al.*, 1994) and *I terremoti dell'Appennino umbro-marchigiano, area sud-orientale dal 99 a.C. al 1984* (Boschi *et al.*, 1998) are also part of the most recent production.

As well as providing a user-friendly, new generation catalogue, the *Catalogue of Strong Italian Earthquakes* aims to make available to the scientific community the vast body of work developed by ENEL and SGA and subsequently by the Istituto Nazionale di Geofisica and SGA over more than fifteen years. In fact, the 230 Mbyte database is designed to provide easy access with indexes, links and cross references to the equivalent of more than 25 000 printed pages of facts, original texts and commentaries. This new catalogue is designed to allow improved, innovative data utilisation and is a quantum quality leap, comparable to the change from the analogue seismometry of the early seventies to state-of-the-art digital detection techniques.

A significant achievement that was made possible by the characteristics of the catalogue is the creation of a database of Italy's main seismogenic sources (Valensise and Pantosti, 2000). The database incorporates and blends geological, instrumental and historical evidence for past earthquakes to generate a set of about 300 potential sources for destructive events. Historical evidence strongly complements the limited geological evidence available for Italy's active faults (see the article

«From earthquake intensities to earthquakes source: extending the contribution of historical seismology to seismotectonic studies» by Paolo Gasperini and Gianluca Valensise for details on how this task is accomplished) and is largely used to highlight the fundamental characteristics of seismic release throughout the country.

Main features of the catalogue

As already mentioned, this is a new generation catalogue. Along with summarised information typical of traditional catalogues, it also contains original accounts, a structured series of commentaries on particular aspects of the quake (*i.e.* immediate and long-term effects, specific historical context etc.) and a compendium of information on the specific features, demographic data and construction features of the area in question. Because of its sheer size, only part of this database has been published in printed form. The two volumes (one for the first, the second for the subsequent version) contain only selected data and commentary. The entire catalogue is available as a CD-ROM together with dedicated software. The decision to use the CD-ROM format was dictated by the flexibility this affords and the possibility of memorising on the same disk different versions of the database to run on different systems (MS-DOS and Macintosh), all at minimum cost and universally accessible. Since this third version comprises even more data, and given the ubiquitous availability of computer access, the printed version has been reduced to a user-guide, indicating the consultation possibilities and providing practical examples and a series of introductory texts. Furthermore, the 'hypertext' format of the database means that information access is no longer sequential as in a printed version but can be varied according to user-requirements thanks to embedded links.

The new catalogue is truly dynamic. It can be constantly updated as historical records become available as well as accept new contributions from practitioners. Research goals are fixed each year by the Istituto Nazionale di Geofisica whose overall aim is to provide an increasingly better understanding of the specific features of seismogenesis in Italy. Following significant contributions that have been made in recent years in the areas of Recent Tectonics, Paleoseismology and strong-motion seismology, Historical Seismology research priorities have been more readily identified, the key focus being nation-wide mitigation of risk.

Finally this new work is intended to be an exhaustive account of 'severe earthquakes', their geodynamic impact and the social and economic upheaval caused. The decision to confine the survey to the largest earthquakes was dictated by the need to establish a priority among the vast number of events reported in traditional catalogues. The recent *Catalogo Parametrico dei Terremoti Italiani* (Gruppo di Lavoro CPTI, 1999) reports around 2480 quakes exceeding the V-VI intensity degree. Our choice was also dictated by earthquake source physics, since it is known that only major earthquakes are truly representative of the seismic process in the region where they occur. As a result, resources and effort have been directed exclusively to the most severe earthquakes and not diluted in an attempt to cover minor events that pose limited seismic hazard.

As may be expected, not always does the picture of major earthquakes drawn by this latest revised edition coincide with the representation given in previous catalogues. On several occasions earthquakes formerly considered severe have been down-scaled following reassessment of epicentre intensity or reappraisal of the area really affected. On other occasions, the opposite has occurred: major earthquakes with epicentres out at sea or in sparsely inhabited areas, previously considered moderate on account of their limited intensity in the neighbouring settled areas, are now listed for what they are: major seismic events. This new edition also corrects mistaken epicentre identification – which has led to certain areas being erroneously dubbed as seismically active and other insidious seismic sources being ignored - and erroneous energy-release calculations – which have significant repercussions on the attribution of seismogenic potential to a given location. The criteria adopted focus on the area's historical record and the context within which the seismic effects are felt; as a result, several potentially seismic areas have been identified (see «*Towards new research strategies: silent seismogenic areas or silent sources?*» by Gianluca Valensise and Emanuela Guidoboni).

The reappraisal of severe earthquakes is just one aspect of the new catalogue. Many other innovative features include the availability and selection of basic information and survey methods used. Emanuela Guidoboni's paper: «*Method of investigation, typology and taxonomy of the basic data: navigating between seismic effects and historical contexts*» gives an overview of this new approach. There are, however, two different innovations which clearly illustrate the philosophy behind the work.

First, unlike its 'predecessors', this new catalogue provides access in many cases to the historiographic interpretations employed to attribute a given intensity to a past quake. This immediately removes any dogmatic overtones, since the degree attributed can be checked by end-users against the historical, demographic and town-planning data available on the afflicted area or individual location.

Secondly, objective, reproducible techniques have been used to estimate the 'synthetic' parameters (epicentre location, intensity and magnitude). «*Reducing the subjectivity of intensity estimates: the Fuzzy Sets approach*» by Gianfranco Vannucci, Paolo Gasperini and Graziano Ferrari, and «*Deriving numerical estimates from descriptive information: the computation of earthquake parameters*», by Paolo Gasperini and Graziano Ferrari, describe the long and meticulous development of what is now a widely accepted and consolidated objective system of analysis.

We believe that these innovations are a real step towards achieving effective separation between the basic data and their possible interpretations, ensuring that the former always outlive the latter.

Another major issue is that of the 'unknown earthquakes', *i.e.* quakes thus far not part of the seismic record. Basic research carried out to compile the catalogue brought to light evidence of formerly unknown quakes, either due to shortage of accounts or because overshadowed by other, more serious quakes. In some cases, the discovery of a 'new' earthquake was the result of painstaking work piecing together seemingly irrelevant social and community accounts. These findings are perhaps the most convincing and stimulating outcomes of the new working method used by the *Catalogue of Strong Italian Earthquakes*. Although the new quakes listed are generally not serious enough to alter the degree of hazard of the source area, it is nonetheless obvious that they throw new light on the potential as well as the limits of research conducted in many parts of Italy. In a fascinating paper entitled «*Unknown earthquakes: a growing contribution to the Catalogue of Strong Italian Earthquake*», Dante Mariotti, Alberto Comastri and Emanuela Guidoboni provide an insight into the work conducted.

Seismological content

The first version of the catalogue provided data on 346 quakes occurring between 461 B.C. and 1980. The second version extended this to the year 1990, accounting for 559 tremors and providing considerably more in-depth accounts of some of the most significant quakes mentioned in the first version. With the third version presented here, some 605 earthquakes are analysed, of which 35 studied in better detail than in past versions. For every event information is provided on the amount of in-depth studies available (see the indications of Guidoboni, in the contribution «*Method of investigation, typology and taxonomy of the basic data: navigating between seismic effects and historical contexts*»). Figure 1 provides a graphic summary of the amount of data contained in the versions 1, 2 and 3 of the CFTI.

As in the previous versions, each quake is reported in summary form providing macroseismic epicentre parameters and equivalent estimated magnitude, the number of locations where the quake effects have been assessed and finally any reappraisals of the original data. All other information and analysis must be taken from the CD-ROM. Data retrieval can be chronological, spatial or energy-based, with the consequent possibility of creating sub-groups of earthquakes. A further level of

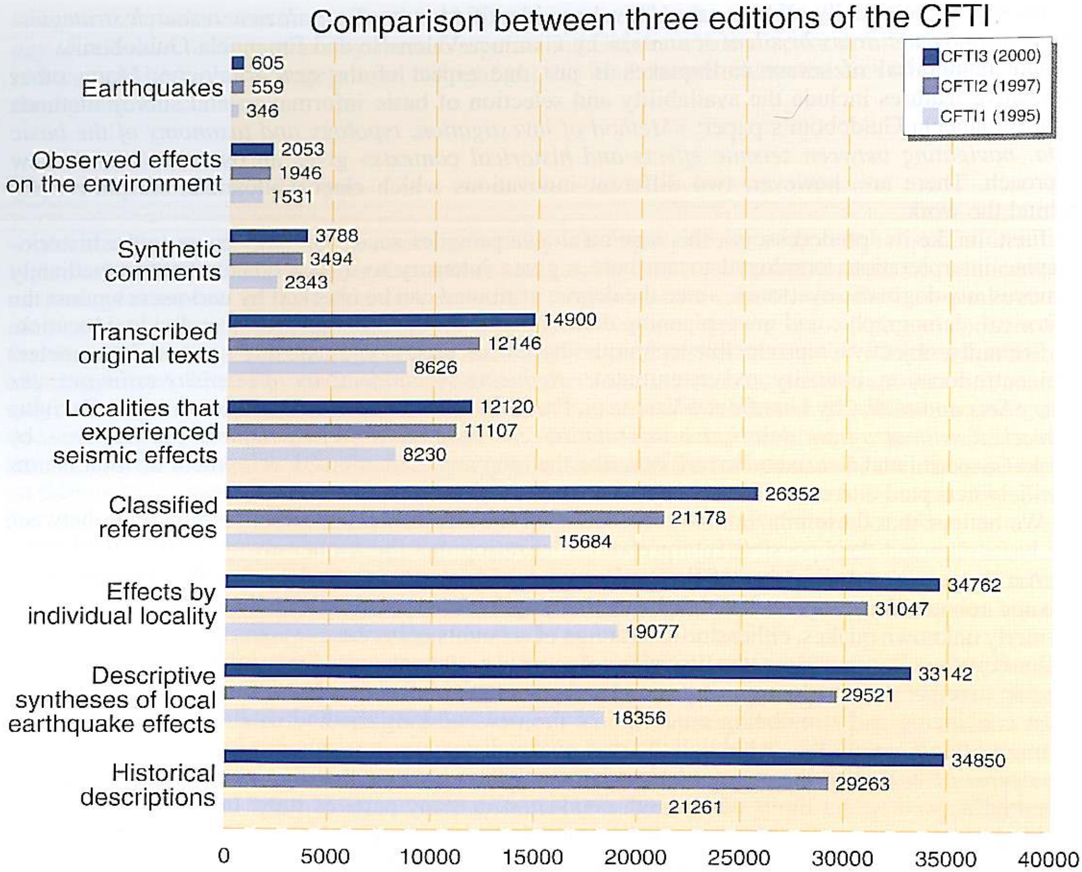

Fig. 1. Summary of the data increase throughout different published versions of the CFTI.

enquiry allows the user to retrieve and visualise all available summary commentaries, information on the ground shaking in the various locations and bibliographic references. Some of this information may even be stored on a separate file for subsequent use in further in-depth analysis. This latter function has been made possible thanks to the embedded links mentioned above which allow a rapid overview of the seismic record of any site and are an example of the usefulness of the hypertext format.

Earthquakes were selected on the basis of their 'significance' as described above. The first version of the catalogue contained all the quakes of intensity greater than the VIII degree on the MCS intensity scale reported by the catalogue produced by the Geodynamics Project, therefore including all events of unproved intensity between the VIII and IX degree. This covered magnitudes ranging from 5.5 to 7.2 (5.5 corresponding approximately to an intensity of VIII-IX, while 7.2 is normally assigned on an instrumental basis to the earthquake of the Straits of Messina of 1908, considered the worst quake in the recent Italian history). The first version of the catalogue also contained minor tremors, studied in detail for specific reasons *e.g.* their proximity to sites earmarked for major infrastructure works. In fact this first version was a summary of the revision and research carried out over 15 years mainly on a wide range of diverse studies. Research over the five subsequent years brought down the minimum intensity threshold of earthquakes contained in the catalogue and at the same time allowed for greater homogeneity of research and their consequent seismological interpretations. As well as listing significant quakes with an epicentre intensity of VIII, numerous bibliographic sources have been reviewed, problematic texts re-examined, new data and a large number of locations added to the classification of intensity values with their relevant bibliographical notes. The research programmes that have made this improvement possible were conducted according to a preordained methodology which was maintained throughout, a fact which encouraged a unified approach by all team members in their reading, interpreting and attributing of intensity values. The outcome has been a well managed, successfully completed project.

Similarly to any large earthquake compilation of historical seismicity, our catalogue is the result of a complex and ongoing research project. Therefore the Istituto Nazionale di Geofisica does not take any responsibility as to the completeness of the catalogue and correctness of any numerical estimates supplied therein. For similar reasons, and to preserve the rights of all the scientists that contributed to this important effort, the Istituto Nazionale di Geofisica can not publish in full the large computer archive of original historical sources on which the catalogue is based. Nevertheless, specific subsets of this archive can be obtained upon motivated request to be addressed to the management of the Istituto Nazionale di Geofisica in Rome.

Conclusions: in search of «unknown earthquakes»

The papers that form this Introduction describe our catalogue in detail and highlight its main characteristics. Perhaps the most important of them is that this catalogue was conceived as an «open composition» that can be often and readily improved and updated. In addition to this effort, which we hope will soon become a standard in seismological research, we are pursuing a new line or research concerned exclusively with «unknown earthquakes», that is, real events that are not known to any current compilation. This new line of research, to which the ING has dedicated significant resources in the past six years, involves two different but complementary approaches. The first approach deals with written sources (see the contribution «*Unknown earthquakes: a growing contribution to the Catalogue of Strong Italian Earthquakes*» by Dante Mariotti, Alberto Comastri and Emanuela Guidoboni). The second approach utilizes the specific methodologies and tools of modern archaeology to reveal the traces of strong earthquakes that occurred in areas and historical periods for which no written sources are available (see the chapter on archaeological sources and on work already completed within the ING research programmes in the contribution «*Method of investigation, typology and taxonomy of the basic data: navigating between seismic effects and historical contexts*», by Emanuela Guidoboni). Both these research paths, historical seismology and archaeoseismology, have already produced exciting results that will certainly benefit the completeness of our catalogue and improve the resolving power of the database of Italy's potential earthquake sources (Valensise and Pantosti, 2000). The next issue of the catalogue, that is already under way, will be specifically and entirely dedicated to such «unknown earthquakes».

These new and promising research strategies stem from a model of knowledge that responds to specific questions posed by the seismologists and takes advantage from the unique characteristics of Italian history, the country's rich written culture, the continuity and state and preservation of its cities. The *Catalogue of Strong Italian Earthquakes* is hence the vault that preserves all the accomplishments of old and new research strategies in a uniform and formalized fashion. For all these reasons we hope that the users will find our catalogue not only useful but also interesting and stimulating.

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