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MULTIDISCIPLINARY PROJECTS TO LOOK BACK ON THE ROOTS OF SEISMOLOGY

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Summary: *The material traces of seismology –instruments, seismic recordings, letters between scientists– represent a scientific and cultural heritage of high relevance, but unfortunately they are often abandoned, scattered or even destroyed. It is thus necessary to start concrete, scientifically developed initiatives to stop such a heavy, progressive loss. Instruments, seismic recordings and scientific letters must be recovered and brought out on behalf of seismologists, using the tools of science history. Important results were already yielded by three initiatives: the former has been carried out in Italy; a second one on a European scale and the third one on a worldwide scale. In Italy, a census has been done of the historical potential of meteorological and seismic observatories, and of seismic instruments and recordings, besides providing information about the availability of scientific correspondence archives. In Europe, the census done by the Working Group of History of Seismometry allowed the discovery of information regarding the operative condition and the data availability of over 400 instruments since 1892. With the creation in 1998 of a specific Sub-Committee IASPEI, the initiative of the research, that is, the cataloguing and recuperation of the material heritage of seismology, has been extended to the entire world.*
As far as scientific letters are concerned, a similar experience was recently carried out in Italy: the rich seismological correspondence which spread in Europe in the 18th century and later, was gathered, microfilmed, sorted by subject and set by date of production. A further step was the computerized classification of these letters by the set–up of a complete database of the scientific letters concerning seismology. As a result one can now have fast access to the sources for scientific research.
Experiences made up to now have established clear goals, users, procedures and protagonists of the recovery. These initiatives must be taken in a coordinate and multidisciplinary reference framework, where each experience can be spread and shared by scholars and institutions.

Keywords: *history of seismology, old seismograms, scientific correspondence, scientific instruments*

Cultural heritage vs. scientific value

In the last few years more and more sensitivity and attention have been paid to the possible contribution of historical seismic information to the study of seismology. Seismology is one of the few scientific disciplines for which historical records are often of the greatest importance to corroborate statistical and deterministic patterns of the seismic dynamics of an area. Only think of the self–evident importance of historical seismology studies for the assessment of seismogenetic potential and of seismic hazard of an area.

As far as instrumental seismology is concerned, the study of the historical seismograms of the strongest earthquakes that occurred in the 20th century is of fundamental importance for the knowledge of seismogenetic patterns and potential of the examined areas. This does not necessarily mean that historical instrumental records are directly comparable with the present ones, nor that they have the same informative potential of modern recordings: modern instruments have superior technological characteristics, and, in addition, modern instruments and historical ones were planned within different scientific paradigms and, thus, for different purposes. Nevertheless, this concept is not taken for granted by that part of the scientific world that considers the history of a discipline (in our case, the history of seismology) in a finalist way.

Owing to historical and cultural reasons, it is hard to recover and bring out the seismological tradition. On the one hand, the extraordinary heritage of recordings, documents, and scientific letters is often scattered because of the vicissitudes of the observatories (Fig. 1). On the other hand, large part of the seismological world is convinced that scientific progress is strictly associated to technology. From this point of view, every experimental effort aimed at recovering records of the past is considered a useless waste of human resources and money. The scientific and financial problems that burden seismologists lead them to consider those aspects more as cultural or museological rather than as really useful for the growth of seismology.

Since 1990 were started up three projects for the recuperation of the scientific tradition of Seismology: one Italian, one European and one world–wide. The first project, promoted by the Istituto Nazionale di Geofisica and named TROMOS was the reference point on which afterwards were based the ESC for a European WG and IASPEI for a world–wide Sub-Committee. The aim of the three projects is to stress the problem of the recovery, the census and the scientific and cultural potential of the heritage of seismology. In addition, the intention was to tackle this demanding task from a multidisciplinary point of view, by overcoming the cultural bounds that often divide different disciplines like seismology, history or history of science. The recovery of the historical memory of seismology is not only important, both scientifically and culturally, but also possible.

Instruments or seismograms

The interest of historians of science in the material heritage of instruments and of seismological documents is not surprising, but why should the seismological community (and more in general, a scientific community) be interested in the recovery and protection of this heritage? To answer this question it is not enough to remember the undoubted scientific and cultural value of that heritage. The use of recordings of earthquakes or of phenomena that can be connected with them (tide gauge recordings, electromagnetic disturbances, piezometric variations, etc.) on the part of seismologists is well established. However, instrumental recordings have only in the last twenty years reached a satisfactory level of standardization at a worldwide level. But anyway, perhaps the only way to obtain useful indications about the characteristics of the origins of big earthquakes such as that of San Francisco (California) in 1906 or of Messina (Southern Italy) in 1908 is to look again at the historical recordings. These were the only major events, in the respective areas, that occurred during the period of instrumental seismology and that were recorded all over the world with instruments that are seldom used today.

Historical seismograms are of great importance not only for the study of single events, but also to expand the instrumental data catalogue. However, it is not so easy to find them. For example, few people know the difficulties of a seismologist who wants to improve the study of an earthquake by using original seismograms recorded in different parts of the world, which is even difficult with the seismograms recorded in his own country. Basically, this is due to the following reasons:

- the latest availability of these seismograms may or may not be known;
- the seismograms may or may not be available;
- if the seismograms are still available, they may or may not be ordered and complete.

In addition, many observatories are no longer in possession of their most important seismic recordings because they were sent to some scholars and never came back. It should be borne in mind that superficial investigations do not allow to see the difference between the actual absence of important seismograms and the absence of reliable information about them.

The first time a seismic instrument was mentioned in a scientific document was in 1703, when the astronomer Jean De Haute-Feuille described his mercury seismoscope. The construction of this instrument has never been described, as has happened to the other ones. Similar mercury outflow seismoscopes were the subject of experiments by the Italian abbot Atanasio Cavalli who even made a seismoscope with time recording (Fig. 2). In 1818 Nicolò Cacciatore, director of the Astronomic Observatory of Palermo made a seismoscope that was similar to the one described by Haute-Feuille. In the early 1870s, Timoteo Bertelli planned his study of the slight and natural movements of pendulums on the disturbances to astronomic observations (Ferrari, 1994, 182). The publication of the results of his experiments started a lively debate that directly involved Michele Stefano de Rossi. The thorough experimental activity led by both scientists, testified by the great number of letters, led to the planning and to the improvement of the tromometer, a simple pendular instrument 150 cm long, the first standard instrument for a seismic network on a national scale (Ferrari, 1994).

In the first half of the 19th century, James David Forbes and Robert Mallet tried to establish a scientific approach to earthquake observation (Mallet, 1853-1855; Melville; Muir-Wood, 1987; Dean, 1991; Musson, 1993). Yet they had not enough earthquakes to observe, as they were not strong and not frequent. So in the last decades of the 19th century, John Milne, James Ewing and Thomas Gray were obliged to «emigrate» to Japan. There, in one of the most dangerous seismic region as for the frequency and magnitude of earthquakes, they laid the foundations of one of the most active seismological communities in the world (Ferrari, 1997a). Emil Wiechert in Göttingen and Prince Boris B. Galitzin in Pulkovo (early in the 20th century) can be considered two emblematic cases, both for their position and their scientific experience (Ferrari 1992b, 136-148). They both carried out their experiments in seismic laboratories located in former important astronomic observatories. Wiechert made a two-horizontal components astatic seismograph based on a reverse pendulum with a heavy mass and an air-damping system. Galitzin chose polarized horizontal pendulums on a single horizontal component with a type of astatization that had already been used by Zöllner (1869) or by von Rebeur-Paschwitz (1889) for their inclinometers. Galitzin, too, applied a damping system, but it was of the electromagnetic type. The recording methods used (Wiechert chose the mechanic one on smoked paper, while Galitzin chose a galvanometric optical lever on photographic paper) fostered the debate concerning qualities and defects of both approaches amongst experimental seismologists all over the world. Basically, mechanical recordings had these qualities: a slighter recording track, for a more precise reading of seismic signals; re-usability, upon re-smoking, of papers that were used before, but without seismic recordings. Their limits, on the other hand, were: the necessity of a heavy mass to overcome the friction of nibs upon smoked paper and to improve the instrument's sensitivity. Wiechert himself had a 17,000 kg (V = 2200, To = 1.2 sec) astatic horizontal seismograph made and installed in Göttingen (Wiechert, 1906), whereas in Switzerland de Quervain-Piccard seismographs (22,000 kg) were installed (Pavoni, 1990). Good characteristics of Galitzin seismographs were the lack of friction in the phase of recording on photographic paper and the possibility to vary the amplification of the instrument augmenting the distance of the recorder from the transductor galvanometer. The main defects were the lesser clearness of photographic recordings compared with mechanical ones, the fact that photographic paper was more expensive than smoked paper, and that already exposed photographic paper without trace of seismic recording could not be re-used. The instruments made by Galitzin and Wiechert were the highest achievement up to that time (Zöllner, Rebeur-Paschwitz, Ewing, Milne, Forbes, Cecchi and Vicentini). They were the turning-point for European and worldwide seismometry. The static amplification (V) reached values (1000-2000) that were unknown until then; new opportunities for the detection of regional earthquakes and teleseisms appeared. From the 1880s to the 1930s European seismology had a fundamental influence on the development of seismology in other continents. In the last decades of the nineteenth century, one of the most fertile and complex periods in the history of seismology, two different scales of approach, although as yet far from inspiring paradigms, can be seen in the planning and in the strategy for the diffusion of new seismic instruments. Both historical and geodynamic factors influenced the theoretical and above all experimental paths taken by the first European seismologists. The first approach was that the instruments and observation points developed by Italian scientists were designed to interpret seismic events on a local or a national scale. This is explained by Italy's high level of seismicity and by the scientists' feelings of a new national identity (Ferrari, 1992b; Boschi; Ferrari, 1994, 126). By contrast, scientists in countries with a long established national identity but a lower level of seismic activity –such as Great Britain or Germany– conducted their studies on a more global level: i.e. Milne, Wiechert, Gutenberg. This view of the earth as a single scientific laboratory was the inheritance of the European tradition that Beno Gutenberg brought to Caltech in Pasadena in the late 1920s. He was to bring about a radical change in the «local» perspective of American seismologists of that time (Goodstein, 1984; Goodstein; Roberts, 1988). These few cases are aimed at displaying how various and complex were the different historical and scientific paths that could be covered in the history of seismology; however, they neither render a chronological development, nor represent a range of historical or scientific values. Some further thematic investigations can be found in few bibliographic references (Davison, 1927; Dewey; Byerly, 1969; Ferrari, 1998a, b, c).

The documents, often unpublished, regarding the scientific debate about theories, patterns, scientific experiments, etc. is another aspect, actually not much examined, that contributes to the scientific value of the material heritage of seismology. Leaving aside, for the moment, the opposite points of view concerning method and scientific paradigms of major historians and philosophers of science like Kuhn (1970), Feyerabend, Lakatos (1970, 1971, 1978), Howson (1976), or Lakatos and Feyerabend (1995), it is important to revise some scientific processes that were inexplicably left out. Why did some research lines have followers and others not, and why were interesting processes abandoned?

The lack of a steady historiographical practice in seismology can also be recognized in seismological texts, where the historical paths of seismology are often reconstructed as a linear interpolation of some selected scientific events, therefore implying a sort of coherent plan of development for this discipline. Thus the discussions, the scientific, theoretical and experimental debates that produced a theory, a pattern or an instrument, are filtered. The recovery of the scientific contents of historical instrumental data is an important stage also in the perspective of its cultural use.

Scientific and historical documents

Undoubtedly instruments played a major role in the development of the science of earthquakes. Many historians of instruments have confirmed this, even stating that modern science would not exist without instruments (Turner, 1983). This statement can be shared, at least partially, though it would not be possible to reconstruct the history of seismology through the instruments alone, nor even a history of the instruments themselves. It is necessary to reconstruct the history of a scientific community that should be considered not as a whole, but as the single individual contribution of scholars from different national scientific traditions. To reconstruct this sort of mosaic it is necessary not only to describe instruments and provide biographical sketches of scientists or theoreticians, but also to stress their limits with regard to contemporary interpretative models. It is necessary that such reconstruction take place in a diachronic perspective, i.e., composing biographical sketches, instruments, theories, etc., side by side, placing them back to their own scientific, historical and cultural contexts. Therefore, it is necessary to find out, recover and study scientific and historical documents connected to the activity of scholars, to the observation and research places, to the instruments, etc. Without the use of historical documentation, it would be impossible, for example, to document and analyze, both historically and scientifically, the long period of experimentation with various types of instruments, often very distinct in form and function. Unlike those in other fields, seismological instruments up to the end of the last century –and in Italy even later– had no tradition of instrument manufacturers and their construction was often entrusted to local artisans or university workshops. In addition, even instruments with a given standard level were modified in different places and times in order to relate them to new interpretative contexts. For this reason it is particularly important to study the techniques of construction and experimentation of these instruments, relating them to their historical and scientific context. The materials we examine are mostly seismograms, instruments, documents related to the scientific and institutional activity of research agencies and of scholars. Last but not least, we have letters written by scientists and libraries of seismological institutions. These libraries are interesting not only because of the texts that can be found there, but also for the places in themselves, that are often like a «mirror» of the scientific history of the institutes which they belong to. As outlined above, documents preserved in old seismic observatories testify about the scientific debate; letters, above all, are the «connective tissue» of early seismology from the last 25 years of the 19th century.

Scientific historical letters in seismology

The scientific letter collections of seismology are generally rich (some scholars can get up to 10,000 letters, see Fig.3), and extraordinary tools to understand the evolution of theories, of scientific institutions or, in general, of experimental paths. Among the historical materials produced by scientists in general and by earth scientists in particular, letters play a special role both in the reconstruction of the development of seismic instruments and in the analysis of the different phases of development of seismology (Ferrari; Bianchi, 1997).

The first scientific observations of earthquakes, deeply connected to the study of meteorology, began around the 18th century; initially with the simple observation of seismic phenomena, then, in the second half of the 19th century, with the birth of a real science. The first scholars not only observed but also designed, planned and often personally built the instruments for earthquake detection and recording. The study of their letters has made it possible in some cases to reconstruct the phases of planning, building, improvement and functioning of the different seismic instruments. This persisted until the end of the 19th century, that is to say, as long as the letters between scholars still made up the most customary system of scientific comparison of ideas, theories and experiments.

The close mutual relationship between the meteorological, astronomical and seismic observation methods can also be noticed in the content of the letters: one can find meteorological, astronomic, seismic and geomagnetic observations, advice about the design and building of the observation devices, theories and proofs complete with drawings, tables and diagrams, instrumental recordings and methods for the calculation of earthquake parameters. Scholars often discovered connections between the observations of the various phenomena: earthquakes with meteorological displays or with astronomic phenomena, etc. In Italy a large number of documents concerning the birth of the seismic observation network has been traced (Table 1).

Table 1. Some correspondence of seismological and meteorological interest still existing in Italy

correspondence				
Francesco Denza (Moncalieri, Vatican)	1856 –	1894	>9,000	1,400
Timoteo Bertelli (Florence)	1870 –	1905	~ 500	200
Guido Alfani (Florence)	1901 –	1940	>10,000	1,300
Pietro Tacchini (Rome, Modena)	1861 –	1900	4,300	800
Alessandro Serpieri (Florence)	1843 –	1885	1,100	200
«Valerio» Observatory (Pesaro)	1876 –	?	~ 500	?
«Nigri» Observatory (Foggia)	1876 –	?	>1,000	?
Observatory of the Seminary (Chiavari)	1883 –	?	~ 200	?

Scientific correspondence in observational seismology has been taking on a particular role. Earthquakes are extreme natural events that can affect areas that are often very wide, whether destructive or not.

Before the achievements of instrumental seismology, macroseismic questionnaires were extensively used for the study of the interaction between earthquakes and inhabited territories. Now they are still being used as tools of investigation and are considered not alternative, but complementary to instrumental ones.

In Italy, Alessandro Serpieri was the first to gather information through the circulation of a questionnaire in the area affected by the earthquake of 12 March 1873 in Central Italy. Since then, macroseismic questionnaires have been structured with regard to the evolution of seismic scales (de Rossi-Forel, Taramelli-Mercalli, Mercalli, Mercalli-Cancani-Sieberg, etc.) and are still widely used. According to an approximate estimate (Ferrari; Bianchi, 1997), over 35,000 seismic questionnaires were produced in Italy in the last 20 years of the 19th century. This particular method for gathering scientifically usable data has survived almost unchanged for over 100 years. This method starts from and intermingles with scientific correspondence in a broad sense.

Filing and coding letters

The experimental stages in the development of seismology, the debates among the scholars of that time, and the creation of a seismic network all over Italy, are documented by the material gathered in the course of the TROMOS ING-SGA project (Ferrari, 1992b).

In the last few years some research projects carried out census and filing of scientific correspondence relating to Earth science in Italy, with different approaches, both regarding the selection of letters from the whole correspondence and concerning the elaboration.

Materials of all sorts have been traced in the course of this project in all kinds of conditions. Some letters have been preserved in excellent conditions; others have been spoiled by time's wear, by mutilation due to the removal of the stamps, etc. In the development of that stage of the project, SGA set up a specific approach for the recovery, census and cataloguing of the letters that were found. First, letters and manuscripts have been microfilmed on 16 mm. films; they have been sorted by subject, set in chronological order with distinction between incoming and outgoing correspondence. Afterwards, the pre-inventory of the documents has been carried out with concise lists of the groups of materials to be analyzed. As soon as the importance by subject and historical period was established, SGA inventoried and indexed the documents by giving a numeric code to each letter, then it summarized (and fully transcribed when necessary) the most important documents. In this phase the codes given to each document provide data about the content of the letter, independent of the language of the summary (Tables 2 and 3). This coding allows easy use of these groups of letters, limiting the number of the documents to refer to and to translate if necessary, in order to get the information required. This allows a considerable saving of time, greater reference efficiency and a very low cost/benefit ratio. This codification method allows a scholar to identify the letters he is looking for without being obliged to read the whole content or the summary of hundreds of letters in a language he does not know.

Table 2. List of codes associated to the letters' state and content
Codes associated to the different states and contents of the letters, divided into main classes.

Code	
Library Science Information	
1	Document: signed (Lf,cf) or not (Lsf,csf)
2	Identified date
3	Existence of heading
4	Number of pages of the document
5	Document integrity
6	Existence of enclosures
7	Drawings within the document
8	Tables within the document
9	Graphics within the document
20	The summary was drawn by the addressee
Scientific content	
10	Information about earthquakes or any other natural phenomena
11	General notes of scientific character and private notes
13	Description of scientific instruments or parts of them
14	Description of scientific experiments or measurements
History of science	
12	Explication of scientific theories
13	Description of scientific instruments or parts of them
14	Description of scientific experiments
15	References to associations (Academies, Scientific Societies etc.)
16	References to manuscripts or editions related to the two correspondents
Cultural content	
17	Private letter
18	Contents of the letter (references of scientific/historical character)
19	References to manuscripts or editions not pertinent to the sender or to the addressee

Scheme of the summarization

The computerized classification of the letters contains 19 different codes, each of which corresponds to a field in a database. These codes are listed in Table 2. The field holds the abstract of the content of the letter. Therefore, each document is identified by the summary and by 19 identification fields that are equal for all of the documents. The codification of the contents allows the creation of document subsets with the progressive narrowing of the quantity of the material to be examined. This process should produce a brief but effective summary (in general no more than 5-6 lines) showing the name and surname of the sender, of the addressee, abbreviated with his initials (Table 3).

The correspondence cataloguing carried out with this classification allows one to use the materials sorting by specific subjects. Above all, it allows fast access to the sources for scientific research. Therefore, the user can take advantage of the contents in short time.

Elaboration of scientific correspondence data

There are basically three levels for the pre-processing of information available in scientific letters: total transcription, summarization and coding. In principle, one level does not exclude the other; still, reasons generally connected to financial, strategic or research goals suggest one or at most two of them. If two levels are chosen, the coding can be connected with total transcription or summarization.

Total transcription allows one to use the contents of the letter completely and contextually. Summarization allows one to compare a great number of letters quickly and synthetically, confronting them on a chronological and thematic base. Details are lost, but the historical plot of a period, or of an aspect, or of a biographical sketch is emphasized. Finally, coding allows one to gain a more statistical and global view on a broader scale –national and continental– where the analysis of cultural trends on a statistical basis is pointed out rather than the contents of each single letter.

On the one hand, scientific texts and publications generally are the framework of scientific knowledge. On the other hand correspondence amongst scientists emphasizes the more complex and human plot of the growth of scientific thought.

In order to bring out this considerable historical and scientific heritage, an articulated approach has been set up and tested for the recovery, census, cataloguing, indexing and coding of letters of Italian seismologists and meteorologists. The different elaboration levels mentioned of such correspondence, and the potentiality of circulation of data on electronic file, above all on the Internet, may help to create a basis of shared, diffused knowledge for a real comprehension of the historical paths of seismology.

Table 3. Example of summarization and coding of a letter sent to Francesco Denza

Summary

374125 (bibl. code). Lettera di BT da Firenze a DF in Moncalieri, 7/XII/1873.
Dà le notizie sulle osservazioni declinometriche durante l'eclisse di maggio, dà poi le perturbazioni del suo tromometro per i primi giorni di dicembre. Si compiace che dRMS approvi il il progetto di DF per le osservazioni sismiche nella stazione Alpina, e aggiunge: «Per me ho un'intima convinzione che gli studi microscopici sismici debbono aprire un vasto campo alla scienza meteorologica e alla fisica terrestre.»
• Codifica del contenuto:1 Ls; 2 «2»; 10 Ecl; 11 Gsn; 14 Deob/Trob; 15 AMN.

Translation
374125. Letter of BT (Florence) to DF in Moncalieri (near Turin), 7 Dec. 1873.
He gives news about the declinometric observation during the eclipse of May. Then he gives information about the disturbance of his tromometer early in December. He is happy because de Rossi approves of DF's project to collect seismic observation in the Alpine station and

says: «I'm sure that the microscopic seismic studies must open a wide field to the meteorological and earth physics sciences».
• Coding of the contents: 1 signed letter; 2 «2 pages»; 10 Eclipse; 11 General scientific notes; 14 Declinometric observations / Tromometric observations; 15 Alpine Meteorological Network.

Short biographies
BT Bertelli Timoteo (Bologna 1826–Florence 1905)
Indefatigable observer of seismic pendulums, bolognese Barnabite, he taught physics at the boarding school «alla Querce» in Florence, where he installed and improved seismic instruments setting the basis for a measuring method in seismology from 1870 to 1905 (the year of his death).

DF Denza Francesco (Naples 1834–Moncalieri 1894)
Barnabite, he worked in Moncalieri from 1856 to 1894; he was one of the founders of modern Italian meteorology; he established the first private meteorological network in Italy, starting the publication of the first bulletin in 1865. Corresponding with Bertelli and de Rossi, Denza helped to carry out the national meteorological network that proved itself of the utmost importance for the creation of the first seismological network.

dRMS de Rossi Michele Stefano (Rome 1834–Rome 1898)
de Rossi was the inspirer of the first Italian seismic survey and the founder of the first nucleus of the Italian seismological community. Distinguished Roman scientist, great experimenter but above all ardent supporter of a constant observation of geodynamic phenomena from the most numerous observers. He was the first director of the first Italian geodynamic Observatory, the Rocca di Papa one.

Example of the summary of a letter from Timoteo Bertelli to Francesco Denza selected from the database of TROMOS. The summaries can be selected by the general code of the sender –BT in this case– or of the address (DF), by date or by content code. The codes linked to the summary allow its selection every time their value meets the user's requests. In this case, if the user requires letters referring to eclipses, or to scientific experiments, this summary will be extracted from the database. Simple or multiple selections are possible. The value each code may take can be simplified in order to allow a reduction of time and of errors during codification. For example, in code no. 1 «signed letter» is indicated as «Ls»; «letter not signed» is indicated as «Lns». In code no. 10, the phrase «general scientific notes» has been simplified into «Gsn».

In the final output of the selection, the code values have been indicated in full detail. In case the coding takes more time than expected, it is possible to activate a code with a value Y without further specifications.

In this example, the code values are synthesized in the Italian version of the summary and are given in full in the English translation.

Seismologists or historians?

As outlined above, the multidisciplinary approach of seismologists and historians is part of a rather steady practice in some applicative aspects of seismology. A concrete example is provided by the studies of historical seismic scenarios related to historical seismology (Guidoboni, 1998). In the field of historical seismometry or of the history of seismology, a convergence of competence and of different disciplinary approaches on the part of historians and of seismologists has not yet been noticed. Both seismologists and historians have been working separately up to now, sometimes ignoring, sometimes shunning one another. Paradoxical situations often happen: seismologists do not know where instruments and historical materials can be found, while historians often preserve but do not thoroughly understand those instruments or those documents which scientists are looking for. As outlined above, one should not lower the history of seismometry to the chronological order of appearance of seismic instruments; these events should, instead, be connected to the scientific, cultural, economic reasons which produced them, that is, to connect the study directly to the history of scientific thought within the framework of Earth science in the world. The increasing specialization of seismology in the last 100 years, together with the fortuitousness of some seismological discoveries in other fields of science, suggest that it is necessary to view the history of seismology beyond the disciplinary frame of seismology. In seismology, too, as in other scientific disciplines, some important observations and discoveries come from casual events that happen during other experimental observations. For example, the first recording of a distant earthquake (Japan, 17 April 1889) was made by chance with a Rebeur-Paschwitz apparatus, a modified horizontal Zöllner pendulum (von Rebeur-Paschwitz, 1889). Two specimens of such instruments were installed in Potsdam and in Wilhelmshaven in order to observe the slight motions of the ground. Von Rebeur-Paschwitz noticed some disturbances in the recordings, the most remarkable of which was on 17 April. Only after reading on Nature (13 June 1889, p. 162) about the Japanese earthquake, could he explain the seismic origin of such disturbances. We have previously mentioned that the designs of several seismographs (i.e. Galitzin horizontal seismograph) were inspired by the functioning principle of the Zöllner instrument. It should be stressed that Zöllner, too, had first noticed that his horizontal pendulum, which he had designed to study tides, could also record earthquakes. Another notable instance of chance in earthquake detection and recording by instruments designed for completely different purposes occurred in occasion of the Chilean earthquake of 1960. Ness et al. (1961) recorded long-period earth motions on a LaCoste-Romberg tidal gravity meter following the main Chilean earthquake of 22 May 1960, with periods ranging from 3 to 55 minutes. The recovery of the seismology heritage, both in a speculative and cultural way, needs seismologists and historians of science to work together, because seismologists know what they are searching for, but historians have the disciplinary tools to do it. In addition, dialogue and close relationships between seismologists and historians are of fundamental importance for the growth of a multidisciplinary historical-seismological community.

How to preserve? Potential and perspectives of coordinated research

Once the reference frame has been defined where the scientific and cultural recovery of the heritage of seismology can be set up, it is necessary to outline what has been done up to now and what can be done for the future. To do that it is important, first of all, to understand the reasons for loss or neglect of historical material. As mentioned above, in the area of seismic research this neglect and loss was in the past a very common occurrence. The reasons for this are many and to some extent different from those in other areas of science. If we disregard the most common causes of loss, such as neglect or physical destruction resulting from war or natural disasters, we can say that two things have determined whether the instruments and documentation of the seismological tradition have survived or not. The first is the great number of changes that have occurred in the network of observation, reducing the role and importance of individual observatories. The second consists in the particular nature of the development of the instruments. In Europe and, as far as my own experience is concerned, in Italy, since the early days to the first decades of this century, the production and use of seismic instruments took place within a network of observation significantly different from that of today. The evolution of this network is complex, both because of the different types of centres –public and private– that have contributed to it, particularly in the last hundred years, and because of the significant changes that have occurred in the methods of earthquake recording as a result of theories of interpretation and advance in technology. The present need to detect even smaller earthquakes and the increased man-made noise makes it necessary to place the sensors in areas where there is the least human or natural (wind, sea etc.) noise. Furthermore, in recent years, the increasing importance of seismic monitoring in the role of the organizations for civil defense has hastened the process of centralization –by radio, telephone cable or satellite– of the seismic signals picked up by sensors all over the country. Thus the relationship between the observatories and the coordinating bodies has changed even if, fortunately, this has not always resulted in the disappearance of the observatories or their research tradition. In some cases, observatories were established by private initiative. Often, in such cases, that led to the risk of loss and of scattering: the death of the founder or of the last director of the observatory could lead to the termination of its activity and to the loss of its production.

The second element that has significantly conditioned the loss or scattering of historical, and particularly instrumental, material is the way in which seismic instruments developed. In the second half of the nineteenth and the first decades of the twentieth centuries, the construction of instruments or the improvement of the extant ones sometimes involved the reuse of pieces or materials salvaged from obsolete instruments. Many mechanical instruments were, until recently, «improved» or modified in order to conform with the performance of electronic instruments (Boschi; Ferrari, 1994, 127-128). The results of these alterations are highly questionable, both from the historical and the scientific point of view. The historical changes are very evident, since they often destroyed original technical solutions, significantly altering the characteristics of the instrument. Scientific changes should demand a necessary quality for all procedures involving measurement: the comparability of the measurements carried out with those made on other instruments. As a result of these alterations, this quality is often missing, and leads to highly questionable data.

In these last few years, undertakings for the recovery of the historical heritage of worldwide seismology have seldom been made. Also, a seismological emphasis has often been imposed, i.e., the scientific aspect was the only one to be stressed within the whole «historical-scientific» operation. Moreover, it should be pointed out that the reasons for the incomplete achievement in this sector (compared with its potentiality) are due both to organization problems and to this discipline's sector, which often delegitimates the work done by those who believe in the scientific and also in the cultural value of such recovery operations. Important initiatives of recovery, microfilming and electronic scanning of historical seismograms have been recently carried out in the world (i.e. Glover; Meyers, 1988; Qu, 1988; Umeda; Ito, 1988). However, often a lot of historical seismograms were not successfully interpreted because of the lack of information about the instruments or about their dynamic characteristics (Ferrari, 1992b). In fact, accurate knowledge of the dynamic characteristics of the detecting and recording instrument is vital in the interpretation of instrumental seismic recording. As pointed out by Kanamori (1988) the most common problems in analyzing historical seismograms are: unknown instrument constants, missing or uncalibrated time marks, large solid friction between stylus and recording paper, no damping device, cross-coupling between the N-S and E-W component and unknown polarity. Therefore, calibration of the dynamic characteristics of the original historical instrument is necessary when carrying out historical recording (see e.g. Herak et al., 1997). Then, the necessary reconstruction of a sort of «anamnesis» of the variations made to the constructions and dimensions of the instrument which might influence its dynamic behaviour, is an important part of the bringing out of the seismological heritage. According to this direction, the TROMOS project has been started in Italy, with the microfilming of 5,000 historical seismograms, as described below.

The TROMOS Project

At the beginning of 1990 the Istituto Nazionale di Geofisica began working on the TROMOS project devoted to researching, recovering, restoring and re-establishing of the historical heritage of scientific earthquake observation in Italy. The name of the project refers to one of the most fruitful periods in early seismology. In 1872, Timoteo Bertelli, one of the pioneers in this field, drew on the Greek word trómos to name the instrument he had made to observe and measure the tremors of the earth –the tromometer. The project is not confined to strictly seismological disciplines, embracing as it does the history of science, scientific instruments and technology. The chief aims of the project are:

- the listing of the centres of meteorological and seismic observation operating in Italy from the eighteenth century to the present day, with details of the present whereabouts of the relevant materials and historical instruments;
- the restoration of some of the most important historical seismic instruments in Italian meteorological and seismic observatories;
- the reproduction of the historical seismograms of major Italian earthquakes recorded in this century in the European centres;
- the publication of the historical and scientific results of the research carried out.

The listing of the observation centres

A specific index system has been created for the storing of information gathered from the systematic collection and analysis of published and unpublished contributions uncovered in the course of the research. A specific database has been designed for the electronic storage of the indexed information. The Banca di dati dell'osservazione scientifica dei terremoti in Italia (secc. XVIII-XX) (Databank of the scientific observation of earthquakes in Italy –18th to 20th centuries) includes bibliographic, descriptive and illustrative information relating to instruments, observations, scientists and instrument-makers. We can summarize the numbers of the research: 5,500 bibliographic and documentary sources together with information related to over 1,000 meteorological and seismic observation centres (Fig. 4), over 600 instruments (Fig. 5) and 250 scientists and instrument-makers. Over 10,000 historical and scientific sources (eighteenth – twentieth centuries) have been identified and analyzed including: scientific publications, recordings in manuscript, seismic bulletins and letters between scientists. Over 5,000 letters have so far been individually and partially microfilmed, analyzed and classified by the above described original method (see also Ferrari; Bianchi, 1997). Besides this storage system, the databank includes other menus capable of producing a synthesis. Thus it is possible to enter all the indexed information discovered during research in any order and then retrieve it according to individual requirements. In the second phase of the project both the general and the more detailed information have been analyzed in greater depth in various ways: – the identification of observatories still in operation or centres that still keep historical scientific instruments and documentation; – visits to particular historical centres and the rapid listing of the relevant documents and instruments. Over 50 historical observatories or centres with a tradition of recordings have been visited (Fig. 4). Out of more than 600 instruments listed in the databank, about 150 have been identified and photographed in the Italian centres visited. Many individual parts of the instruments have been photographed, catalogued and classified in the databank according to various keywords such as: type, function (supposed or certain), materials, manufacture, probable provenance etc. Out of the total number of meteorological or seismological centres, the history of more than 60 has been recorded extensively with the principal historical references. More detailed information about the results of the TROMOS Project are available in Ferrari (1992b, 1994). In addition, the historical development of 126 instruments and the scientific biographies of 120 scientists and instrument makers are described in detail. These historical details, besides giving us a historical and scientific picture of the centres, instruments and protagonists of seismology, represented an indispensable element for a complete historical and cultural framework for the planning and making of specific directions of research. Since 1997 in an internet web (http://storing.ingrm.it/tromos) site presents the most important information about instruments, observatories and scholars in Italy from 1731 up to 1950.

Restoration of important historical seismic instruments in Italy

In the period 1990-94 the TROMOS project has so far carried out the restoration of 90 instruments (Figs. 5-6). The entire collection of seismic instruments of the Collegio «alla Querce» in Florence belonging to Timoteo Bertelli and his successor as head of the observatory, Camillo Melzi d'Eril, has been restored. The archives have been recatalogued, the most important scientific documents (including the seismograms) have been reproduced on microfilm and the scientific correspondence of the observatory has been re-examined in depth. This, together with the restoration of the entirety of the school's seismic instruments, has made it possible for the valuable scientific and cultural inheritance of one of the most important historical centres in the history of seismology to be exploited to its fullest extent. The restoration work is generally aimed at reinstating the correct functioning of the instrument in order to carry out the above-mentioned calibrations thus allowing a re-reading of the historical recordings for current scientific purposes. It should be emphasized that this work of restoration, reduced to the essential minimum, is the result of wide and careful study of historical documents describing other similar instruments available in Italy and abroad. It is more a practical necessity than a restoration procedure. Moreover, all the restoration work is documented for future reference. Not only large instruments like the Wiechert 1,000 kg horizontal astatic seismograph (Fig. 6), but also smaller instruments such as a portable tremitoscope have been restored. In some cases, historical copies of particularly rare instruments have been made (e.g. the above mentioned de Rossi portable tremitoscope) (Ferrari, 1992b, 106). The duplication of the prototype of the Palmieri seismograph (1856) is in process; the instrument is kept in the Museum of Palaeontology of the University of Naples (Palmieri, 1859; Ferrari, 1991, 29; 1992b, 54-57). The duplication includes the integration –drawn from rare photographs– of the recording device lacking in two clocks: the former was supposed to indicate the time of the recorded earthquake and the latter supplying the recording drum. In some cases the available elements make it possible to reconstruct missing instruments from individual pieces traced in different institutions. The most intriguing case is that of the dual speed Agamennone microseismograph. Complementary parts of three different specimens of the instrument available in the Fabra Observatory, Barcelona (recording system), in the «Pio Bettoni» Observatory, Salò (mass) and in the Central Office of Agricultural Ecology, Rome (small parts of the mass-recording system transmission) allowed the reconstruction of one original piece out of three instruments (Ferrari, 1994, 133).

The ESC Working Group History of Seismometry

In 1991 the European Seismological Commission (ESC) set up the Working Group History of Seismometry (WGHoS). The aim of the WG is to improve the co-operation between seismologists and historians of science and scientific instruments in the retrieval, study and evaluation of the historical heritage of scientific observation of earthquakes in Europe. The project was based in Europe but contributions, suggestions and future developments can involve the whole seismological community. Starting from the experience of the TROMOS project, in 1992 the WG HoS started a census of the historical centres (private and public) of the material preserved in existing centres and of historical seismic instruments. 250 questionnaires were sent to seismologists and historians of science and scientific instruments; 60 of them answered (about 25%) 30 with useful information: from Portugal to Siberia, from Ethiopia to Sweden. Also seismologists and historians of science from USA, Japan, Canada etc. have shown interest in the activity of the Working Group. In most cases (80%) in the old observatory or somewhere, something (such as parts of instruments, instruments, papers) still exist. In a few cases instruments are still in operation. In general, historical papers are not in special archives, or well ordered and preserved. The analysis of the questionnaire outlined the serious threat of loosing a considerable proportion of the historical heritage of European seismology. This could occur mainly where the necessary cultural sensitivity is absent, or in practice where monetary funds, to keep and make available instruments, seismograms and historical documents, are lacking. Special recommendations, to highlight high risk situations such as deterioration or loss of instruments, seismograms or historical documents, were given in the special session devoted to the history of seismology at the 23rd General Assembly of the European Seismological Commission in Prague (Ferrari, 1992a). In 1994 at Luxembourg, a workshop was held based on the themes of the recuperation and scientific use of the historical seismometric data. Thanks to this occasion it has been possible to update the results of the above–mentioned census (Ferrari, 1997). Figure 7 summarizes the data collected by the census. It are more than 400 seismic instruments which were being used in about hundred observatories from 1892 till the beginning of the seventies. At the moment, the census is not yet completely representative of the whole picture of the geographic and chronological distribution of seismic instruments and recordings in Europe. The preliminary impression yielded by the answers to the census carried out until now is of unquestionable usefulness to seismological research, a first important step that also meets the ESC recommendations made up in occasion of the twenty-fifth General Assembly (ESC, 1996).

The IASPEI Sub-Committee «Historical instruments and documents in Seismology»

The results of the TROMOS project and of the ESC WGHoS have increased the interest of the international seismological community in the research on the history of seismology. The cultural and scientific value of such results has stimulated the International Association of Seismology and Physics of the Earth Interior (IASPEI) to establish a Sub-Committee Historical instruments and documents in Seismology within the Committee Education. The S–C, which is operative since 1999 and coordinated by the author, has as aim to promote: 1) research, inventory, and restoration of historical instruments, recordings, station bulletins, papers, and scientific correspondence, 2) preservation and reproduction of seismograms and historical documents, especially scanning/digitizing into computer files; 3) experimentation of techniques for the scientific investigations of all historical seismic data.

The objectives of the Sub-Committee include: 1) to create a database of seismic observatories, including their histories, installed instruments and activity period, access the recordings and related documents; 2) to produce biographies of the deceased scientists who contributed significantly to seismology and earthquake engineering, including their life, work, and publications; 3) to collaborate with local historians of science and of scientific instruments.

The S-C has about ten members who coordinate the activities of research and elaboration in a certain number of geographical areas.

In the first phase, SGA Storia Geofisica Ambiente has realized a first census of the seismic stations which worked on a world–wide scale, from the end of the nineteenth century until the sixties. There has been realized and published in Internet (http://www.sga-storia-geo.it/sga/english/his_en.htm) a database with the information gathered until now. For Spain and Great Britain the data base has been use of the information made available by respectively, Battló (1999) and Lovell & Henni (1998). In recently started second phase the database will be updated, corrected and integrated with the information that will come especially from the members of the S-C, but also from anyone who is interested in the activity of the S-C.

Conclusions

The historical heritage of scientific earthquake observation in the world is of great importance for seismological research and for the identity of the seismological community. The scientific value of such memory (instruments, seismograms, scientific correspondence, etc.) is worth being recovered urgently, before degradation, natural events or human neglect irreparably scatter it. The three initiatives for the recovery of the historical memory of seismology, the TROMOS project in Italy, the census promoted by the WGHoS of ESC in the rest of Europe and the recent establishment of the IASPEI S-C Historical instruments and documents in Seismology provide – though at different levels of investigation– preliminary reference frameworks on the condition of observatories, instruments, seismograms, scientific correspondence etc. Despite their preliminary character, the results of these initiatives are of great importance for the history of seismology studies, since they highlight a hidden heritage of fundamental importance for research. This first result must give rise to considerations about the potential of such material heritage and what should be done –both individually and collectively– to protect and bring it out, both scientifically and culturally. It is important that such operations are made within a international coordinated reference framework, and that they are developed together with historians of science and scientific instrumentation. That would allow a better circulation of approach methods and of the results of each single initiative (instrument census, lists of available seismograms, scientific correspondence archives, etc.). In times when any type of communication such as telephone, fax, e–mail, foster the so-called «eclipse of memory», and when new, advanced technology and software might be mistaken for real knowledge, it is worthwhile for seismologists to recall the forgotten paths of their scientific tradition.

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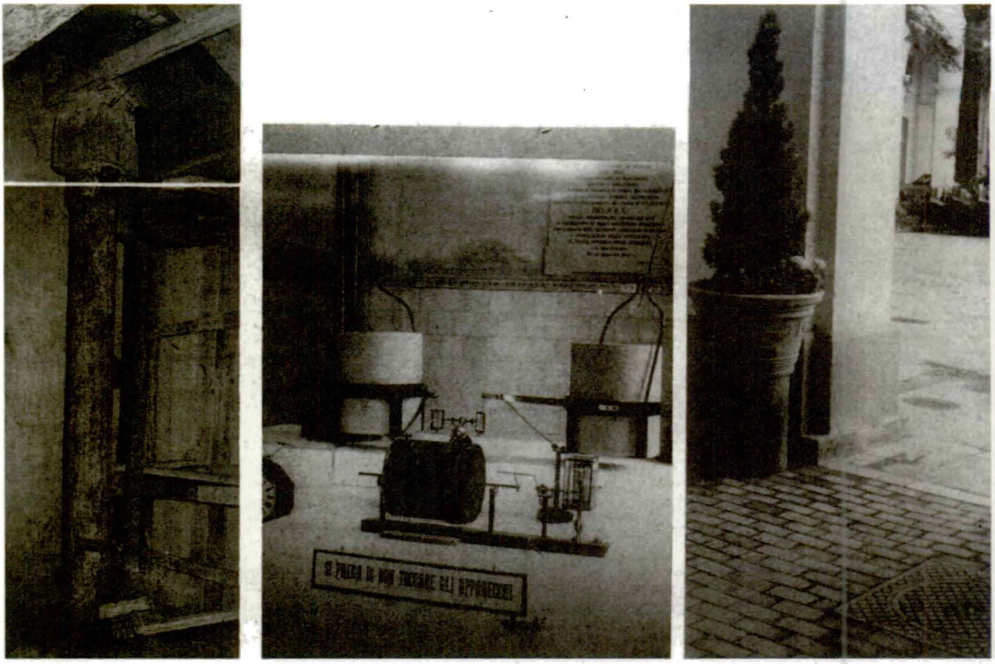

Fig. 1. Different examples of abandonment or loss of historical seismic instruments. Left: what remained in 1992 of the tromometer by Francesco Bovieri (1880s) in Ceccano (Central Italy). Presumably it is no longer existent. Center and right: the masses of the Omori-Alfani tromoseismometer of the Valle di Pompei Observatory at the beginning of this century and in its present use.

Fig. 2. Cavalli mercury seismoscope (1784). Historical copy made by SGAfrom description and drawings (Cavalli, 1785). A clockwork version of the instrument was also designed by Cavalli (Ferrari, 1992b, 42-46).

Fig.3. Network of the Alfani's correspondents (1901-1940) from the letters preserved in the Archivium

Fig.4. Geographical distribution of the over 1000 meteorological and seismic observation sites (cross symbol) which operated in Italy in different periods between the 18th and the 20th centuries. It represents the map of potential seismic observation points (not only instrumental): instrumental seismic observation was carried out in only one hundred approximately. The solid circles refer to local sites which have been visited or thoroughly closely examined during the TROMOS project (from Ferrari, 1992b, 20).

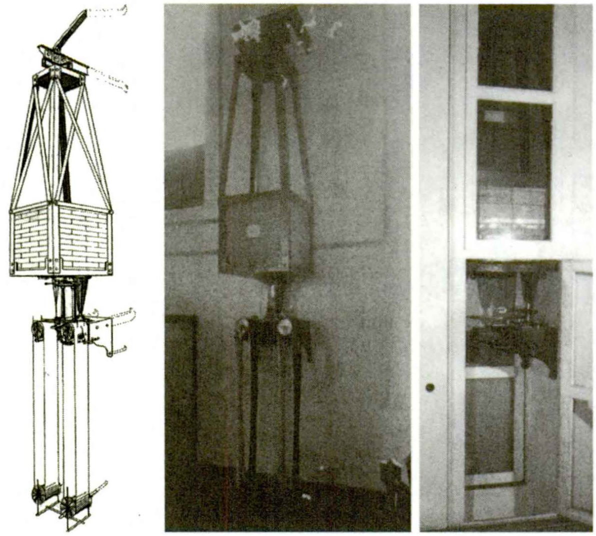

Fig.5. The heaviest instrument found during the TROMOS project: the Agamennone microseismograph of 2,000 kg (left) in a drawing from the catalogue of its instrument-maker Fascianelli; (centre) at the National exposition in Milan where it was presented first in 1906; (right) its present state in the «Andrea Bina» Observatory of Perugia. The instrument, a two horizontal component designed by Agamennone, and used by him in the Rocca di Papa Observatory (near Rome) from 1907 to the 1930s.

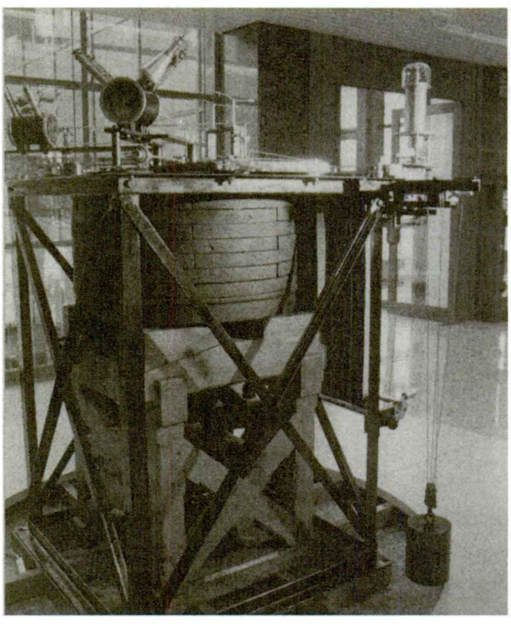

Fig. 6. 1,000 kg Wiechert astatic horizontal seismograph of the Istituto Nazionale di Geofisica: in pieces after restoration and arrangement in the new centre of the Istituto.

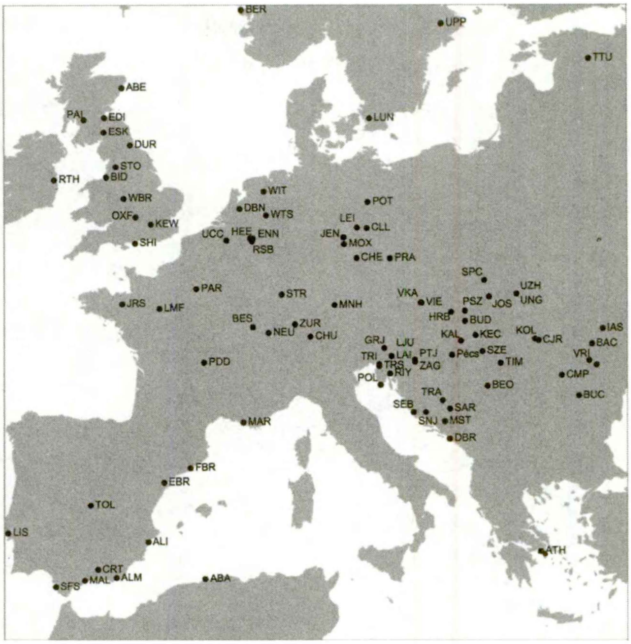

Fig. 7. Map of the observatories and seismic stations for which the census taken by the WG HoS yielded the information summed up in tables 1 and 2. For Italy see Fig.4 and Ferrari 1992b.