PART I DEFINING HISTORICAL SEISMOLOGY

1

What is historical seismology?

1.1 The interest in historical earthquakes and tsunamis

Mankind's interest in historical earthquakes and tsunamis arises from an innate human curiosity about history, both human history as well as that of the natural world. In highly concrete terms, these two strands of historical investigation and discovery are closely interrelated. The evolution of human history cannot be properly understood by society without appreciating the occurrences of the natural events of the past. At the same time, scientists seeking to achieve a better understanding of the natural world often rely heavily upon data from the historical records of past natural events when they put forward theories and models intended to predict the natural world's future evolution. Fundamentally, understanding human history means understanding natural science, whilst understanding natural science requires information contained in the documents recording human and natural history.

The interplay between developments in the civil societies of the past and some of the forces and effects of the natural world is well known and has been extensively studied. This is especially true for climate and weather phenomena as well as the secondary effects caused by weather events (such as flooding, landslides, forest fires and plagues). The effects of droughts, storms and floods are well chronicled throughout recorded history, as they are phenomena that have affected the daily lives and even the existence of human populations throughout the world. The floods of the Nile, Tigris and Euphrates rivers have enabled great early civilizations to develop in the otherwise arid climates of North Africa and the Middle East. Throughout history the outcomes of many major wars were decided, apart from by the level of technology available to either side, by changes in the weather that favoured one army over the other. Epidemics and plagues,

also well documented and widely studied, are natural biological menaces that have swept through human societies countless times in the past, causing much suffering and death. Invariably, these biological phenomena are also natural environmental responses to changes in the Earth's climactic, meteorological and hydrological systems.

One set of natural phenomena that on occasion have strongly affected human societies in the past but have been much less extensively studied by historians is that of earthquakes and tsunamis. Unlike weather events, which occur on a daily basis, earthquakes and tsunamis are much rarer occurrences, particularly major earthquakes and tsunamis that cause serious and widespread damage affecting human populations. Furthermore, earthquakes and tsunamis occur suddenly and without warning. In most parts of the world, many generations of people can live their lives without ever having experienced a major, damaging earthquake or tsunami, and many years may elapse between even mild events. Among people across the globe, there is much less understanding about the causes and effects of earthquakes and tsunamis than about much more frequent natural phenomena like storms and droughts.

Although thankfully rare, the impacts of some earthquakes and tsunamis on human societies have been great. In modern times, major earthquakes have had devastating consequences upon some major cities, such as Tokyo in 1923 and San Francisco in 1906, and some tsunamis have caused widespread damage and loss of life as did the 2004 tsunami in the Indian Ocean. Of course, the destruction of human structures and the disruption caused to human lives by recent major earthquakes and tsunamis have been documented in meticulous detail by modern scientific investigators. Also documented, although with less scientific precision and detail, have been the damage and destruction inflicted upon cities affected by strong earthquakes in earlier historic times, such as the 1755 earthquake and tsunami at Lisbon, Portugal, the 1356 earthquake at Basel, Switzerland and the 1117 earthquake at Verona in northern Italy. The same is true of large tsunamis that have caused large-scale destruction and many deaths along sea-coast areas. Thousands have been reported dead in some tsunamis, such as those in Japan in 1605 and in the Straits of Messina in 1783.

In general, the earlier in human history that a strong earthquake or tsunami took place, the less that is known about the event. This problem partly arises as a result of the inevitable deterioration and loss of historical records with time. However, it is also due to fact the ancient earthquake witnesses observed and interpreted the natural phenomena with the knowledge of their times. For seismic events in earlier historical times, descriptions of casualties, damage to structures, effects on water supplies, post-earthquake fires and so on, are very disparate in terms of quality and quantity. The chroniclers often did not know

which effects to ascribe to the earthquake or tsunami. For example, the collapse of a building could easily be attributed to the sudden, violent shaking of the earth, but a writer may not have realized that the earthquake could also have caused groundwater springs to stop flowing. Compounding this problem throughout most of history was the difficulty in obtaining information (especially accurate and reliable information) from distant places that were also affected by the same event. In addition, elements that we might call a colouring of the descriptions of earthquakes and tsunamis arose from the mindsets of many authors who believed that these phenomena were supernatural events imparted for a special reason upon human society by some god or other supernatural cause. In these cases, the descriptions are not literal records of the natural event and its consequences but rather are evidence to support a religious argument. In such cases it is highly likely that the evidence cited to support the hypothesis has been carefully selected and perhaps even altered to make the case put forward by the author even stronger. As we describe in more detail later on in this book, all historical earthquake descriptions must be evaluated along with the context in which they are presented.

The need to better understand the occurrences and effects of earthquakes and tsunamis throughout historical times is one that affects both the scientists who investigate the causes and effects of earthquakes and the historians and social scientists who study the historical events of past societies. Scientists have learned that continued earthquake activity is a natural part of the Earth's plate-tectonic processes and that strong and damaging earthquakes and tsunamis are an unavoidable occurrence. The ever-growing human population on the Earth and its increasing concentration in urban centres make many societies more and more vulnerable to future earthquake-induced and tsunami-driven catastrophes. That is why research into earthquake causes, earthquake hazard and earthquake prediction involves many different crucially important disciplines in countries throughout the world. The search for earthquake causes, the identification of active earthquake faults and research into ways of predicting future earthquakes all rely on a database of earthquake information that is both spatially and temporally extensive. On any single fault, strong earthquakes have average repeat times of centuries to millennia or even longer. Seismically active countries may only experience a major earthquake catastrophe on average once every few decades. Thus, an ideal research database of earthquake information for a region would extend throughout historical time and as long ago into prehistoric times as can be reliably determined.

For the historian, a better knowledge of past earthquake and tsunami history in seismically active parts of the world is vital for understanding all of the forces that have shaped human civilization and determined its evolution. The historian

might be rather surprised to see how certain societies and cultures have been deeply marked over time by their cohabitation with earthquakes. In historical research, there are numerous references to earthquakes and tsunamis, but the impacts of these events on the local human populations are often not adequately analyzed. Moreover, historians may not fully understand or appreciate the long-term impact that major earthquakes or tsunamis have had on some societies.

This book is addressed to two disparate and yet inevitably interlinked audiences: the scientist who needs to know about historical earthquakes and tsunamis and their effects, and the historian who wants to understand how earthquakes and tsunamis may have affected the societies that they study. For the scientist, this book is intended as a reference that describes the many complexities one faces when interpreting historical earthquake and tsunami reports as observations of past natural phenomena. It is crucial that the scientist is able to assess the accuracy and uncertainty of historical observations, since scientific analyses of the observations are used to relate the past events to the present and possible future earthquakes and tsunamis. It is important that a scientist has the most precise perception possible of the problems concerning the historical data used for the hazard estimations.

For the historian, this book provides a summary description of earthquake and tsunami phenomena, and it is a guide summarizing how these natural events have been described in the historical literature. It is primarily the historian's task to take hold of the historical reports and separate the facts from the interpretation and amplification, the wheat from the chaff. This demands an understanding of the natural phenomena as well as the historical and cultural context in which those phenomena are depicted. This book should be a useful reference for historians working closely with scientists as well as for those historians engaged in individual research in which earthquake or tsunami issues arise.

1.2 The historical approach to seismology

Modern seismology research is not confined simply to instrumental monitoring and physical–mathematical elaboration. Another vital part of the world of seismology research consists of the accumulation and interpretation of qualitative data, that is, descriptions of the effects of the earthquakes that occurred in recent times as well as in the distant past. *Historical seismology* is the branch of seismology that uses historical data in order to assess long-term seismic activity. It strives toward this end by seeking knowledge of earthquake effects that took place in the past, based on historical data. As a discipline, historical seismology stands at the recent intersection of historical research with

the questions and issues specific to modern earthquake seismology. This means that the working methods and hermeneutic rules of historical seismology are derived from historical disciplines, while its aims and the questions it asks usually come from the science of seismology.

The convergence of these two disciplines, which are traditionally so far apart in terms of research instruments and aims, came about from the need to enlarge the temporal frame for which seismic activity is observed. For while it is true that instrumental data have been available for more than a century, only in the last 30 or 40 years have the instrumental data become sufficiently homogeneous and suitable for truly self-consistent analyses, and that is not a sufficient span of time for establishing the characteristics of seismic hazard and source areas that can only be delineated on the basis of long-term data. Especially in the case of earthquakes, a great many working groups and individual researchers recently have produced a strikingly large and valuable mass of historical earthquake data (not always easily accessible, however), which is helping to improve hazard and risk estimates in many parts of the world. A useful survey of these studies and of the different research levels and methods adopted is to be found in Albini *et al.* (2004).

The historical approach to seismology is a research field that has established its specific role in the last 30 years, even though it has its roots in work carried out by masterful scientific pioneers before the twentieth century who made many discoveries and encountered many obstacles in their efforts to accumulate information on historical earthquakes. During the past few decades research into historical seismology by scholars such as Nicholas Ambraseys, Pierre Gouin, S. J. (1917–2005) and Jean Vogt (1929–2005) has helped to greatly advance this neo-discipline, and their work is now enriching both historical and seismological studies. Historical seismology has proven to be most successful when one is dealing with an ancient written culture and a substantial number of available documents, but also it is of great importance even for regions where few documents have been preserved or have been available for the last two or three centuries. Even in the cases of earthquakes for which instrumental data are available, oral and written reports of non-scientific observations, the essence of historical seismology, usually are necessary to document otherwise unmeasured effects in inhabited areas. Indeed, instrumental surveillance invariably is of insufficient spatial density to document the complete scope and variations of the surface effects of earthquake shaking or tsunami inundation, and human observation is always required to accumulate some types of macroseismic data. Historical seismology is based on the qualitative data from human observers.

The current state of research into historical tsunamis remains at a very immature stage relative to that of historical earthquakes, partly because the tradition

of tsunami studies is not directly linked to that of historical research and partly because the characteristics of the phenomenon concerned involve a number of special problems. Relatively few catalogues of historical tsunamis have been compiled, and those that exist suffer from many uncertainties that arise from the variable nature of tsunamis as well as from the ambiguities of historical records of tsunamis.

From an epistemological point of view, historical seismology might be defined as earthquake semiology in that it reconstructs the details of the effects of seismic events on the basis of signs or traces they have left behind. A number of other scientific disciplines, from medicine to psychology along with some sectors of geology, also adopt this evidential method of enquiry. The qualitative nature of many kinds of earthquake effects does not mean that the results obtained from their analysis are considered less scientific than direct instrumental observations. Indeed, the scientific validity of data does not depend so much their nature but rather on the methods used to analyse the data and on the interpretation of the results of the analysis. Repeatability of the decision-making processes and general coherence of the results with the levels of knowledge shared by a scientific community – in the case of historical seismology, on that of historians and seismologists – determines the value of historical seismological research.

1.3 Some key ideas in historical seismology

Historical seismology is a *multidisciplinary research* field in which the decision processes are *repeatable* and the analyses of earthquake and tsunami reports take due account of *regional history*, which means the human and historical context which colours the description of the seismic event. We summarize here some of the important details of each of these key ideas in historical seismology.

1.3.1 Multidisciplinary research

What historical seismology does in practice is to translate seismological questions into historiographical questions, find answers, and then translate the results back into seismological terms. However, this is no straightforward matter. Different cognitive models, such as those used in science or in the humanities, obviously have their own different cognitive paradigms. Seismologists have started to accept the fact that the human beings who have left written traces of earthquakes can be viewed as special 'seismographs'. They may be imperfect, subject to outside influence and sometimes very unreliable, but nevertheless they are irreplaceable. Furthermore, it must be accepted that the decoding rules for these particular traces, as well as their contextualization, fall within the specific

research discipline of historians. On the other hand, historians need to begin querying historical sources from new perspectives and with new aims in mind. In other words, they should adopt a different attitude from that of traditional historiographical research by learning also to work out the answers to questions that come from scientific interests and needs.

Collecting and using historical data for seismological purposes calls for great care and a systematic approach, as well as transparent methods and a determination to check everything that is endemic to scientific research. Today it can be stated with confidence that historical seismology is no longer an ancillary discipline, a sort of 'sub-seismology' in which specific responsibilities and specializations were never made clear. The present profile of historical seismology is partly due to the importance it has attributed not only to a meticulous hermeneutics of the sources and the philological analysis of the texts, but also to the economic and social *contexts* of earthquakes. The set of these elements outlines the methodological heart of the historical seismology and makes possible a correct assessment of seismic effects in an inhabited environment.

1.3.2 Repeatability of decision processes

A second indispensable characteristic of historical seismology is the transparent nature of the various phases of analysis and thus of the results. The use of intensity scales (see Chapter 12) always involves a certain level of uncertainty and some subjective elements of interpretation. This is true for all historical reports, both those far removed in time and those closer to modern time. Although it is obviously easier to interpret the news from newspapers of a century ago than a text written on a medieval parchment, the conceptual problem remains the same: one needs to use an intermediary to know the effects on the inhabited world that cannot be seen directly. Thus, it is crucial that the assessment of seismic intensity, from which many other seismological parameters are calculated, should derive from a series of repeatable decisions, both in the descriptive elements of the intensity scale itself and in the reasons underlying choices of those descriptive elements. It is this repeatability of methodology that gives historical seismology its scientific value and makes it possible not only to carry out research and interpretation, but also to organize the various work-stages all the way to the final results.

In historical seismology, it is necessary to lower to a minimum the part of subjectivity inherent in the assignment of seismological parameters like seismic intensity. It is necessary to make available the basic historical data, the research and criteria used to accumulate those data and the analyses performed using the data. Also, extra-textual factors, typically historical as we shall see, can constrain the qualitative data and make them less vague and uncertain. In the last

few years computational linguistic approaches (that is, automatic selection and classification) have also been tried in order to elaborate texts using a 'fuzzy' approach (Vannucci *et al.*, 1999b). However, this is only possible for events that are very well documented from a single type of source, such as newspapers or macroseismic questionnaires.

1.3.3 Seismic effects in regional history

A third key idea in historical seismology is that of situating seismic effects within their human and historical contexts. This makes it possible not only to differentiate more realistic effects from those that were exaggerated or did not take place, but also to explain information *gaps* by distinguishing two different reasons why some areas may be informationally mute regarding earthquake activity in the historic past (i.e. the silence of quiescent faults and the silence due either to a lack of research or to a lack of historical sources). Differentiating between these two possibilities requires a thorough knowledge of the history of the areas under examination on top of the already available documentary evidence.

In the past it was very often the case that information about historical earthquake effects was gathered and interpreted quite independently of the history of the region to which it refers. This prevented an assessment of the informational value of the historical reports in relation both to the total available documentary evidence and to the particular environment involved. Attention to common elements characterizing the context to which the historical sources of information belong can make a new contribution to historical seismology and, as mentioned above, also help seismological researchers to assess whether an earthquake catalogue is more or less complete with respect to given classes of events.

2

The importance of historical earthquake and tsunami data

2.1 The scientific understanding of earthquakes and tsunamis

It is important for both scientists and non-scientists investigating historical earthquakes and tsunamis to have a common understanding of these natural phenomena. For this reason, included here is a brief summary of what earthquakes and tsunamis are, what causes them, how often they occur and what their primary effects are.

2.1.1 Earthquakes

The term *earthquake* actually refers to a combination of two phenomena. An earthquake is a sudden fracturing or cracking of rock in the earth, where the rock crack (called a *fault*) releases vibrational waves (called *seismic waves*) that radiate in all directions away from the rock crack (Figure 2.1). All the rock in the Earth is under pressure, due to the natural gravitational pull holding the planet together, the movement of the tectonic plates over the surface of the Earth, local tectonic processes such as volcanism, and other effects such as variations in rock density and topography close to and at the Earth's surface. If the pressure in the rock in every direction is near the same value, the rock resists that pressure intact without breaking. However, if the pressure in the rock at some place in the Earth becomes much greater in one direction than in any other, then the rock can crack and slip along that crack. The slip takes place suddenly, occurring over just a few or several seconds even in moderately strong earthquakes. Through the orientation of the crack and the direction of the rock slippage on the crack, the Earth seeks to equilibrate the stress differences in the rock.

Globally, it is observed that faults of all orientations have experienced earthquakes, and all directions of rock slip have also been observed on faults. The