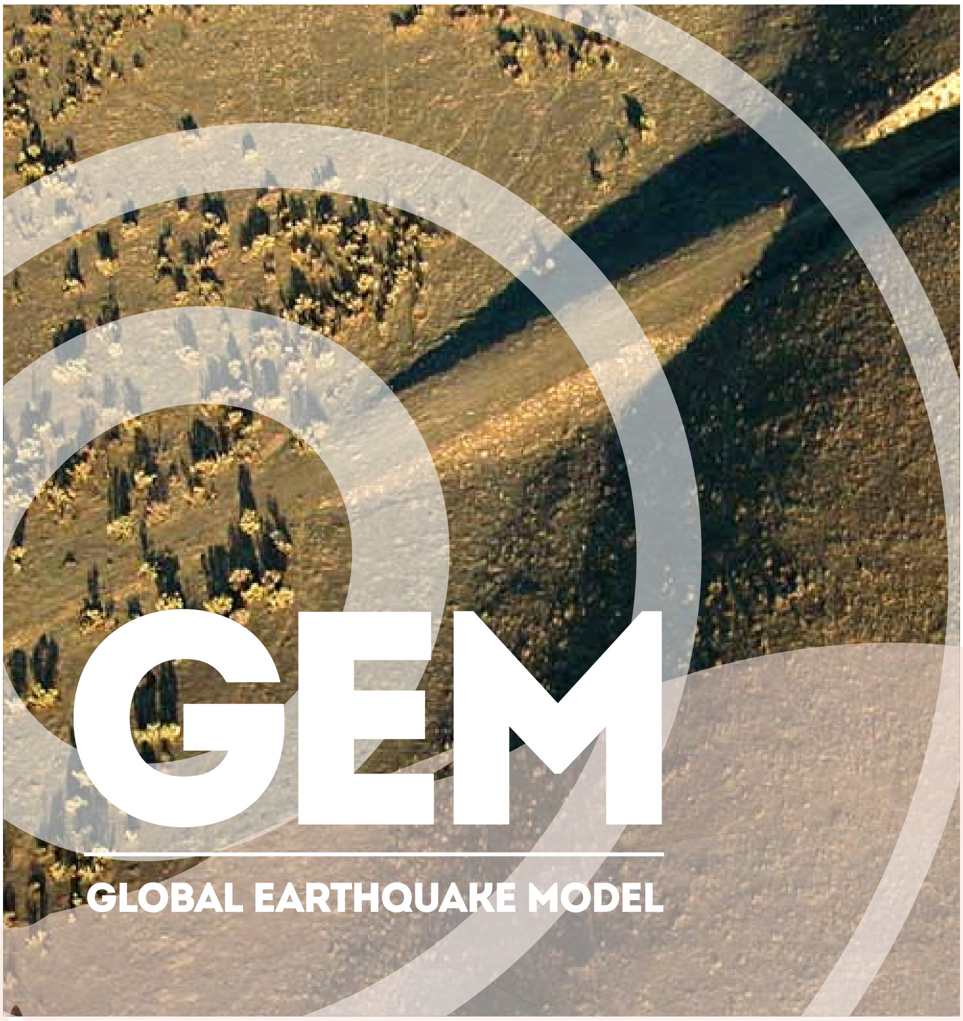
GEM TECHNICAL REPORT
2013-01 V1.0.0

Global Historical Earthquake Archive and Catalogue (1000-1903)

Albini, P., R.M.W. Musson, A.A. Gomez Capera,
M. Locati, A. Rovida, M. Stucchi, and D. Viganò

GEOLOGICAL, EARTHQUAKE AND GEOPHYSICAL DATA



Global Historical Earthquake Archive and Catalogue (1000-1903)

GEM Technical Report 2013-01

Version: 1.0.0

Date: October 2013

Authors*: P. Albini, R.M.W. Musson, A.A. Gomez Capera, M. Locati, A. Rovida, M. Stucchi, D. Viganò

(*) Authors' affiliations:

Paola Albini, Istituto Nazionale di Geofisica e Vulcanologia-INGV, Milano

Roger M.W. Musson, British Geological Survey-BGS, Edinburgh

Augusto Antonio Gomez Capera, Istituto Nazionale di Geofisica e Vulcanologia-INGV, Milano

Mario Locati, Istituto Nazionale di Geofisica e Vulcanologia-INGV, Milano

Andrea Rovida, Istituto Nazionale di Geofisica e Vulcanologia-INGV, Milano

Massimiliano Stucchi, Istituto Nazionale di Geofisica e Vulcanologia-INGV, Milano

Daniele Viganò, Istituto Nazionale di Geofisica e Vulcanologia-INGV, Milano

Citation advice

Albini, P., R.M.W. Musson, A.A. Gomez Capera, M. Locati, A. Rovida, M. Stucchi, and D. Viganò (2013), Global Historical Earthquake Archive and Catalogue (1000-1903), GEM Technical Report 2013-01 V1.0.0, 202pp., GEM Foundation, Pavia, Italy, doi: 10.13117/GEM.GEGD.TR2013.01.

Photo credits

Large cover image: © Scott Haefner/ USGS. Close-up shot of the southeast area along the surface trace of the San Andreas fault in the Carrizo Plain, north of Wallace Creek, where Elkhorn Rd. meets the fault.

Small cover image: Detail taken from an anonymous contemporary scroll showing Tokyo (then Edo) soon after the great 11 November 1855 Ansei-Edo earthquake (Japan). From "Documenting Disaster: Natural Disasters in Japanese History 1703-2003. Catalogue of the Exhibition, National Museum of Japanese History, Chiba, 2003", p. 40.

www.globalquakemodel.org

ACKNOWLEDGEMENTS

We would like to thank and acknowledge the contribution of:

Rogelio Altez (Caracas), Selda Altun Poyraz (Istanbul), Reina Aranguren (Merida), Mario Araujo (San Juan), Monica Arcila (Bogota), William Bakun (Menlo Park), Maria Belen Benito (Madrid), Mario Bufaliza (San Juan), Eduardo Camacho (Panama), Tomas Chuy (Santiago de Cuba), Hernan Cifuentes Avendaño (Bogota), Jim Cousins (Lower Hutt NZ), Mine B. Demircioglu (Istanbul), Domenico Di Giacomo (Thatcham, UK), Maria Cristina Dimaté Castellanos (Bogota), Armando Espinosa Baquero (Armenia), Julio Garcia Pelaez (Trieste), Grupo de trabajo del Proyecto RESIS II, Ron Harris (Provo, Utah), Andrew King (Lower Hutt NZ), Walter Montero (Costarica), Christl Palme de Osechas (Merida), Adriana Perez (Merida), Paola Ramirez Carvallo, Wilfredo Rojas (Costarica), Elkin de Jesus Salcedo Hurtado (Cali), Ana Milena Sarabia Gomez (Bogota),Karin Sesetyan (Istanbul), Dmitry Storchak (Thatcham, UK), Gerardo Suarez (Mexico DF), Ruben Tatevossian (Moscow), Tania Tatevossian (Moscow), Hernando Tavera (Lima), Marco-Antonio Torres-Vera (Mexico DF), Wang Jian (Beijing), Özge Zülfikar (Istanbul).

ABSTRACT

In one sense, all seismology is the study of historical earthquakes. Earthquakes are short-lived phenomena; over within a couple of minutes at most, well before the seismologist can arrive on the scene. Every earthquake is history, albeit recent history, by the time it can be studied.

This inability to observe an earthquake in real time has coloured the development of seismology as a science. In lieu of direct observation, scientists have been obliged to rely on secondary phenomena, or to put it another way, on traces left by the earthquake. These can be grouped into three: permanent marks left on the landscape, written descriptions of the effects of an earthquake, and the recordings made by instruments specifically designed to register the movement of the ground during an earthquake. These three different types of data are the three pillars on which seismological knowledge rests.

The relative importance of these three data types in reconstructing the patterns of global seismicity varies over time. For the 20th century, instrumental data is the richest source of information on which a catalogue of earthquakes can be built. Before the 20th century, written descriptions take over as the primary data source, back as far as written history goes, after which geological data is the source of information for earthquakes in prehistoric time.

It should be no surprise then, to someone introduced to the work of the Global Earthquake Model (GEM), to find three major subprojects on geological data (Faulted Earth), on historical information (Global Earthquake History), and instrumental data (Instrumental Earthquake Catalogue). This report is the output of two years of activity in the second of these, the Global Earthquake History (GEH).

The study of earthquakes from historical sources, or historical seismology, was for many decades of the 20th century a neglected subject. It seemed to many seismologists of the period that all necessary information could be obtained from seismometers. The impulse to treat historical seismology more seriously came from the development of seismic hazard studies, beginning in the 1970s, when it was realised that understanding of earthquake recurrence required a longer time history than instrumental data could provide. The difficulty has been (and this is true of the period before 1970 as well) that the impulse to study historical earthquakes has come from seismologists, who naturally are trained in the physical sciences, whereas the study of historical records requires expertise from the social sciences. Many blunders have been committed in the past by physics-trained seismologists misinterpreting documents through a lack of the skills of the historian.

The solution has been to recruit some seismologists with a social sciences background, and to interact directly with the community of professional historians. This has been facilitated in Europe by a series of international projects funded by the EU, which, by bringing together the specialists from different European countries, have strengthened links, and allowed the development of a mutually-supporting community of experts across the continent. In these projects, INGV has played a leading role, unsurprisingly given that Italy is the most seismically active country with the richest history in Europe. GEH exploits in a large degree the expertise gained in European projects over the last 25 years.

Elsewhere in the world, the situation varies greatly, both in terms of the amount and types of material available for study, and the effort, past and present, put into retrieving and exploiting it. A global synthesis of the pre-20th century earthquake history of the world is therefore a huge challenge. In compiling an instrumental

earthquake catalogue, one can take advantage of the fact that the basic materials, seismograms and bulletins, are international in nature, easily accessed and interpreted. A historical catalogue faces the problem that basic source materials are scattered and obscure, and in a plethora of different languages and scripts, while existing secondary studies vary hugely in quality and organisation. In some parts of the world it is easy to identify local experts with whom one can collaborate, in other places these do not even exist.

With these constraints, a circumspect approach to GEH was necessary. The project has therefore been conceived in such a way as to provide both a snapshot of the status quo of historical seismology as it exists today across the globe, and also a framework for future initiatives, that will support further work to improve understanding of historical seismicity (much needed in some regions).

The project is thus structured around three complementary deliverables: archive, catalogue and infrastructure.

The Global Historical Earthquake Archive (GHEA) is the most important of the three, in providing a complete (so far as is possible) account of the global situation in historical seismology, with all existing studies of historical earthquakes collected together in a syncretised way, retrievable either by earthquake or region. It is truly a global survey of historical seismology as it exists at present.

The Global Historical Earthquake Catalogue (GHEC) is a world catalogue of earthquakes for the period 1000-1903, with magnitude 7 Mw and over (less in some regions), derived from GHEA by a process of comparing the sets of parameters available for each earthquake and selecting the best-attested. This delivers to GEM the most comprehensive global historical catalogue of large earthquakes presently available, with the most reliable parameters selected, duplications and fakes removed, and in some cases, new earthquakes discovered.

Finally, the infrastructure consists of web software that allows the archive and catalogue to be stored, maintained, displayed and interrogated in an intuitive way, by means of easy-to-use web GIS tools.

Keywords

earthquake history; archive; catalogue; tools

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

1 Global Historical Earthquake Archive (1000-1903)

The most important output of the Global Earthquake History (GEH) project is the archive, entitled the Global Historical Earthquake Archive, or GHEA. This archive brings together the current state-of-the-art in historical seismology, and allows the user to see what material is available for any earthquake or any region. It underpins the earthquake catalogue that is the second product of GEH, and provides a starting point for future studies of historical earthquakes.

1.1 Structure and contents of the Archive

The overall goal in the compilation of the archive was to identify, collect and critically organise the best and most recent information available for earthquakes falling within the time-window 1000-1903 and with magnitude equal to or higher than 7 (preferably Mw, but in practice in any magnitude scale). A lower magnitude limit was allowed for intraplate areas, typically 6.5 Mw. In pursuing this goal, the project drew on practical experience and proven methods from the compilation of the "European Archive of Historical Earthquake Data" (AHEAD), which can be accessed at http://www.emidius.eu/AHEAD [1].

In a project with the scope of GEH, it is obviously impractical to study and revaluate hundreds of earthquakes from primary source materials. This was clearly envisaged from the very outset of the project. Instead, the archive relies on the collection of published material, which can be divided into three types:

- papers, reports, and volumes, describing the results of investigations of one or more earthquakes;
- sets of Macroseismic Data Points (MDPs); such datasets can be accompanied (or not) by papers and reports explaining from where, and how, the MDPs have been assessed;
- parametric catalogues, with or without the references to their sources of information.

These items differ from each other considerably, in structure as well as in content. To establish sound relationships between them and to present them clearly to the archive users, material has been arranged according to a transparent structure. Any given study, be it a paper or report, is envisaged as a series of records, where a record is defined as an account of one earthquake given by one study. Thus one study may contribute several records, each on a different earthquake, and an earthquake may be the subject of several records from different studies. This is analogous to a conventional database structure where a basic unit of information may be accessed from different database tables. In total, the archive contains 3,175 records for 994 earthquakes. The total number of studies included in the archive is 239 (Table 1.1). This is the total at the time of writing, but it needs to be stressed that GHEA is intended as a living archive, to be maintained, with new studies being added as they are made available.

Each earthquake is represented in the archive by the multiplicity of the studies of which it is the subject. In this way, the information supporting each earthquake is easily traced back and the state-of-the-art of the research on a specific earthquake is fully represented. According to how often an earthquake has been studied, it may be the subject of only one record, or of many records.

A recurring situation is that different studies of the same event provide conflicting information. In the database structure underlying the archive, records compiled from different data sources but referring to the same earthquake are grouped by means of the same identification number (a hidden parameter not displayed to users). Records with the same identification number constitute a group that have been confirmed as referring to one and the same earthquake.

The grouping of records is performed, case by case, by expert judgment, examining and comparing the content of each study, with special reference to earthquake date, location and size. Automatic clustering, performed on the basis of time and location, may lead to big mistakes, especially (but not only) when dealing with the earliest earthquakes. Assigning records to a group is not always easy, particularly if the same earthquake is reported in different studies with differing times or locations. A typical case is the use of the Julian calendar in some studies or catalogues and the Gregorian calendar in others; an obvious problem in Europe where the Gregorian calendar was introduced in different countries at different dates; but surprisingly, this is also a difficulty in the case of some Japanese earthquakes (see Section 2.10).

Figure 1.1 shows how many records are stored in GHEA per earthquake. This provides a new way of displaying the variety of situations worldwide with respect to historical seismology.

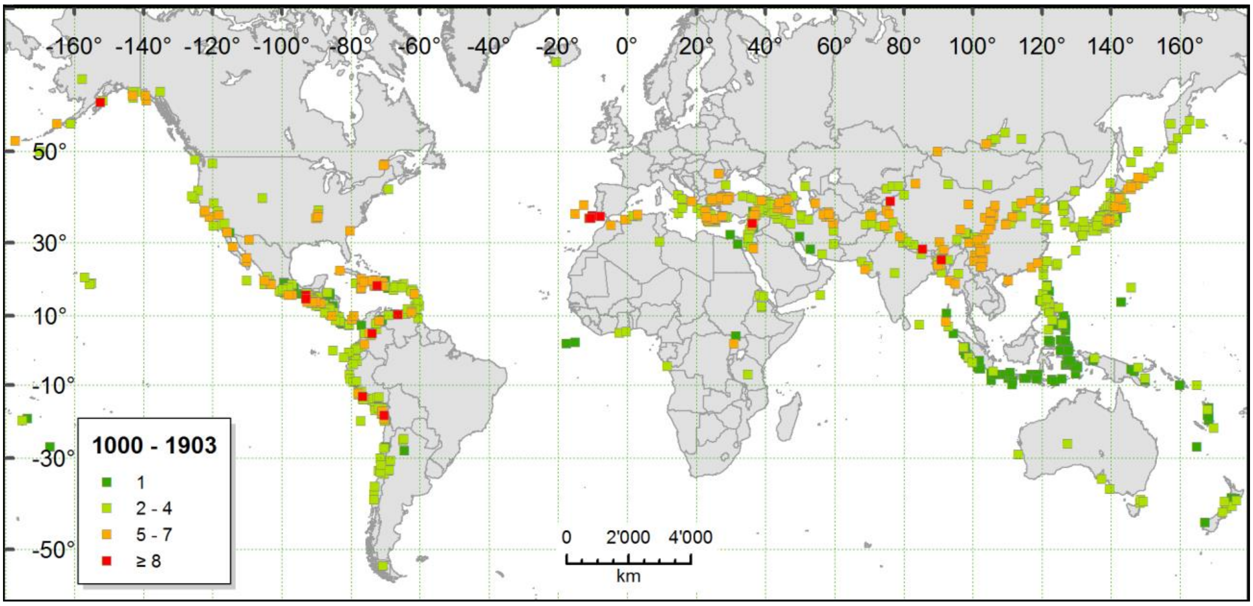


Figure 1.1 Earthquakes in GHEA showing number of records per earthquake

Among the world-famous and "over-studied" earthquakes at the top of this ranking, the leading earthquake is the 1 November 1755 Lisbon earthquake. There are historical as well as seismological reasons for this, but, unfortunately, this is not a sufficient condition to make it the best "studied" and "understood" earthquake of the archive. In fact, almost the reverse is true, since seismologists are completely unable to agree even on how many earthquakes took place, and suggested epicentres range from the Gorringe Bank to the Tagus Valley to the Straits of Gibraltar. Such controversy leads to an ever-increasing number of papers.

Another reason for multiple studies can be earthquakes in border areas, as witness the 26 August 1833 Nepal earthquake; a key regional event that has generated interest on both sides of the Himalayas; from Indian sources and from Chinese. In contrast, in a small isolated country like New Zealand, circumstances favour a single study that is then accepted as definitive.

The mass of dark green in Figure 1.1 covering much of Indonesia reflects a lack of any indigenous historical earthquake studies, and in many cases the only record in the archive for Indonesian earthquakes (particularly away from Sumatra and Java) had to be prepared by GEH itself.

In such a situation, the “living archive” concept behind GHEA is particularly useful in keeping track of the changing balance of opinion as new evidence emerges, and will undoubtedly continue to emerge.

A detailed report of what has been identified, considered and inventoried is supplied in descriptive form in this report (Chapter 2), divided into twelve geographical regions, chosen for historical and geographical considerations, without tectonic or political significance.

1.2 Macroseismic Data Points

Since about thirty years ago, the formal representation of historical earthquake information in terms of macroseismic intensity points is steadily increasing. In the early and mid-20th Century, up to about the 1980s, it was common to rely on contours called isoseismals, which in principle grouped localities with the same intensity; this representation was supposed to give an idea of the so-called macroseismic field. Drawing isoseismals implied a large amount of subjectivity, mixing up data with interpretation: rarely would two investigators give exactly the same result from the same data. Even the same investigator might contour the same data differently on separate occasions (Musson and Cecić, 2002).

More recent procedures for determining earthquake parameters are based on defined, formal models and, therefore, are repeatable: the model may be right or wrong, but the result is always the same for the same input dataset. This tendency has led to a decline in traditional isoseismal maps. They may still be drawn, particularly for non-scientific media consumption, but the days when it was thought that an isoseismal map was a sufficient end in itself, and that the raw data points were not important, are now thankfully over.

The phrase IDP, for intensity data point, is often encountered. It can be taken to represent one location at which earthquake effects were observed, defined as a latitude, longitude, and intensity value as minimum requirement - a place name, identity code, quality factor, etc can be included as well. Given the common difficulty in assigning reliable intensity values from obscure historical data, it is now often the practice to augment intensity scales with descriptive codes such as F for felt, D for damage, HD for heavy damage, and so on. This leads to the more general concept of the macroseismic data point, or MDP.

The individual MDP represents the “elementary cell” of macroseismic information for an earthquake, easily managed by databases and geographical information systems, and distributable in digital form.

The quality of any macroseismic data set strongly depends on a few factors which are difficult to monitor: a) the quality of the historical investigation, b) the quality of the historical data, c) the quality of the procedures for assessing intensity, and d) the quality of the geo-referencing procedures. In many cases these qualities are unknown and, in such cases, the reliability of earthquake parameters assessed from the data cannot be guaranteed.

Furthermore, data are expressed in different macroseismic scales; as a general rule, solution of this problem cannot be simply obtained by means of theoretical comparison tables (Musson et al., 2010), but (in lieu of complete reassessment) requires experimental procedures, huge quantities of data, and a correspondingly huge amount of manpower. In practice, different seismologists assessing the same data even using the same scale can come to quite different results because of different interpretations of how the scale should be applied.

A demo version of a macroseismic database has been implemented in this project as a component of GHEA.

The procedures followed to build the database strictly follow the standards first developed in the NA4 module “Distributed Archive of Historical Earthquake Data” of the EU project NERIES (2006-2010) and later adopted also in developing AHEAD. The AHEAD standard format takes into account the great variety of notations, flaws and special cases that were encountered while retrieving MDPs for more than 2,400 European earthquakes, and includes a standard intensity colour system.

Of the 239 studies collected together in GHEA, 77 include some sort of MDPs (Table 1.2), and the number of earthquakes represented is 432 out of the total of 994 (Figure 1.2). Some of these studies either do not contain a full description of their MDPs (place name, place coordinates and intensity), or some information has to be reconstructed from a map or, even worse, from a unintelligible low-quality isoseismal map. This reduces the number of studies with quality MDPs; the last column ("Demo") in Table 1.2 indicates the 29 studies, covering 292 earthquakes (Figure 1.3) accessible through GHEA.

There are also cases of several studies on the same earthquake, each with its own MDP dataset. This is the situation for 69 out of the 292 earthquakes mentioned above.

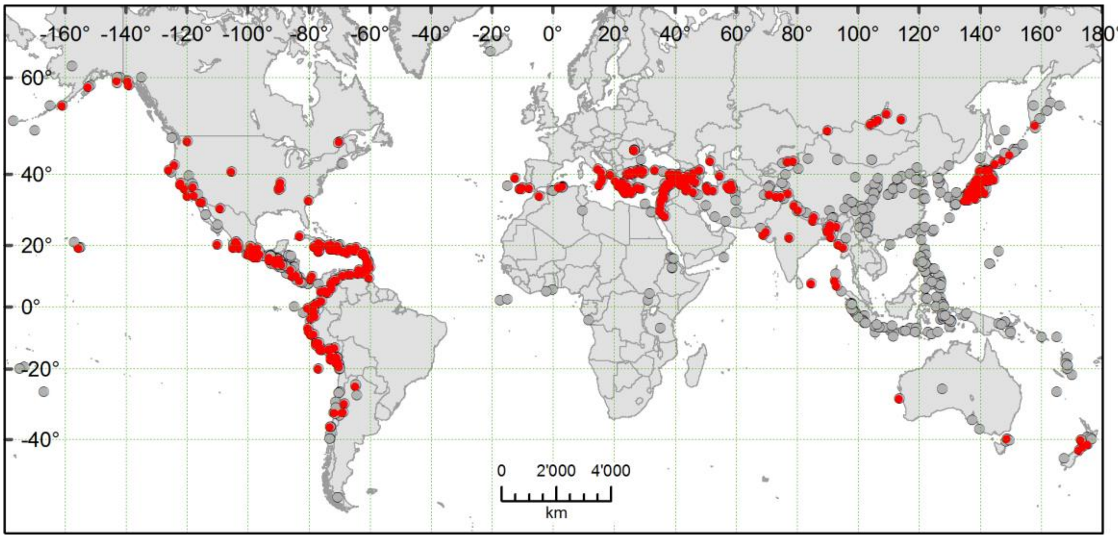


Figure 1.2 The 432 earthquakes GHEA for which some form of MDPs are included (red). Grey dots indicate events with no MDPs in GHEA

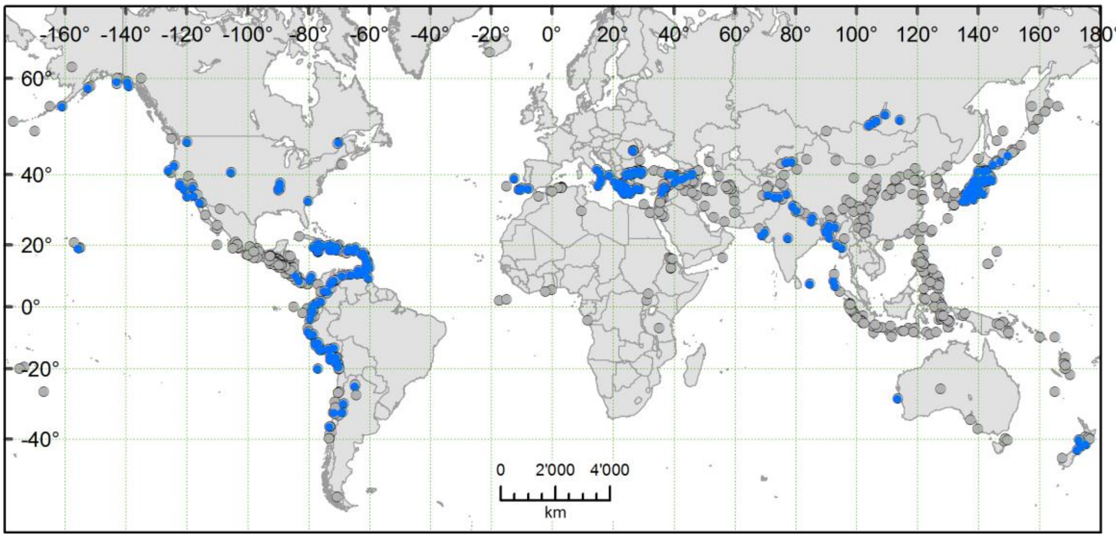


Figure 1.3 The 292 earthquakes GHEA for which usable MDPs are included (blue)

1.3 Fakes

In addition to true earthquakes, GHEA contains a special section on earthquakes present in previous catalogues and that have been identified as fake while compiling the archive, either by acknowledging the results of previous studies or as an output of research carried out in the present project.

There are two main categories that can be identified when speaking about fakes.

1) The most common situation is the duplication or multiplication of one, true event. An individual earthquake might be listed twice or more according to different interpretations of the original records of the earthquake as given by previous studies or catalogues, or because the catalogue compilation is done by automatically merging entries from different and overlapping regional catalogues and datasets that contain different parameters.

There can be duplications in time, space, or both. A common cause is that studies in which the background datasets of their sources of information were not checked may fail to note that dates are expressed according to different calendars (very common in historical times) or simply differ by one day (e.g. “midnight”), or a few hours (different styles of time computation)

Also, studies compiled by considering local and national sources only, are prone to suggest different locations for the same earthquake. For instance, this happens every time only effects within each country’s boundaries are considered. In addition, the geographical coverage of catalogues often overlaps, so that slightly different interpretations of the same earthquake as proposed by different studies are maintained, causing duplications and multiplications to appear.

2) The really fake events. Descriptions supplied by historical records are not always straightforward, especially as they were written in a completely different cultural and social context, that has to be carefully interpreted (Albini, 2011). A quick and careless reading might result in a mistaken interpretation of rather obscure records on other natural phenomena, such as eruptions, storms or landslides. To discover and properly document a really fake event there is no other way than to go back to the original records, and re-interpret the information. As an example, the word "earthquake" in English, or "terrae motus" in Latin, did not always have the same unique meaning that it has today. It is not uncommon to find landslides described in all seriousness as earthquakes in historical texts.

Another problem, thankfully uncommon, but by no means unknown, is the completely fictitious event invented by a foreign source to make up space on a slow news day, or for some other reason. Hence the need to be wary of earthquakes not supported by local evidence.

Duplications and multiplications (type 1 above) have been recognised as such and dealt with while processing the material and inventorying it: multiple and duplicated records have been linked so to belong to a unique group related to one and the same earthquake by having a unique identification number. There are 79 such cases (not visible in the online version of the archive).

The list of fakes identified in GEH now contains seventeen entries, all pertaining to the “really fake” category (type 2 above), which dedicated studies have declared to be fakes (e.g. 1737 Calcutta), or have been found to be fake in the course of GEH (e.g. 1618 Bombay).

In GEH, as was done in AHEAD, fake earthquakes are confined to a separate list (Figure 1.4). This is done to avoid any possibility of them contaminating future extractions from GHEA, and to prevent them re-appearing in future catalogues.

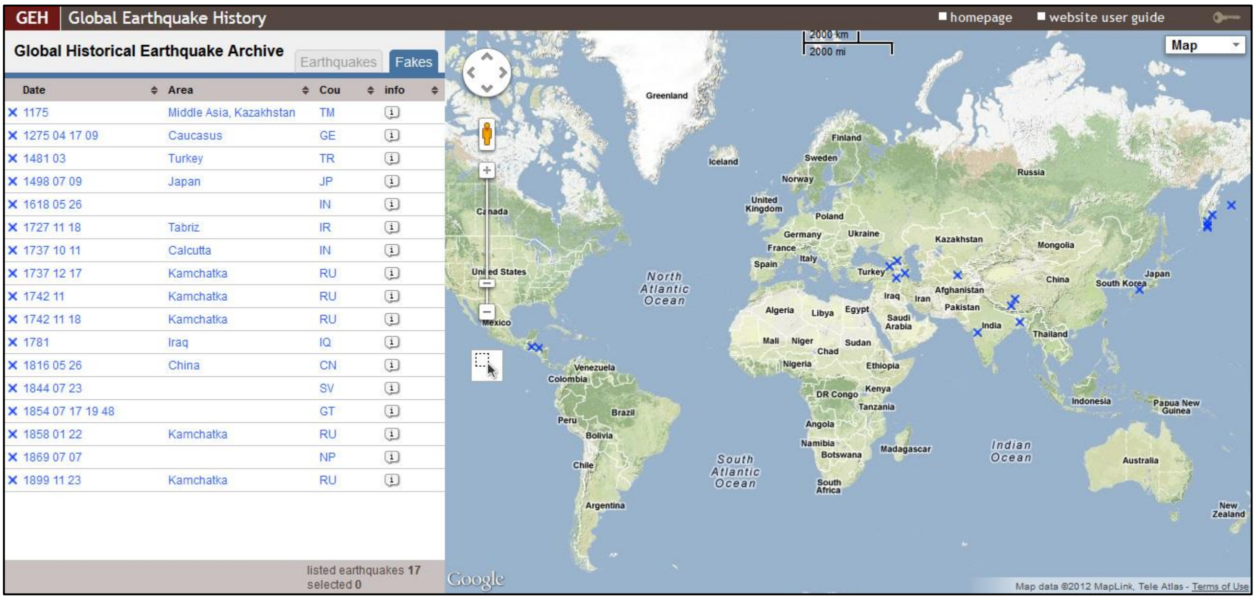


Figure 1.4 Fake earthquakes listed in GHEA

Table 1.1 The 239 studies inventoried in the Global Historical Earthquake Archive

Short reference	Reference	Records
Abe and Noguchi, 1983	Abe K. and Noguchi S., 1983. Revision of magnitudes of large shallow earthquakes, 1897-1912. Physics of the Earth and Planetary Interiors, 33, 1, 1-11.	28
Abe and Noguchi, 1983a	Abe K. and Noguchi S., 1983a. Determination of magnitude for large shallow earthquakes 1898-1917. Physics of the Earth and Planetary Interiors, 32, 1, 45-49.	20
Abe, 1979	Abe K., 1979. Size of Great Earthquakes of 1837-1974 Inferred From Tsunami Data. Journal Of Geophysical Research, 84, B4, 1561-1568, doi:10.1029/JB084iB04p01561	3
Agnew and Sieh, 1978	Agnew D.C. and Sieh K.E., 1978. A Documentary Study of the Felt Effects of the Great California Earthquake of 1857. Bulletin of the Seismological Society of America, 68, 6, 1717-1729.	1
Albini et al., 2012	Albini P., Demircioglu M.B., Locati M., Rovida A., Sesetyan K., Stucchi M., Viganò D., 2012. In Search of the Predecessors of the 2011 Van (Turkey) Earthquake. Seismological Research Letters, 83, 5, 855-862, doi:10.1785/0220110146	4
Alvarez et al., 1999	Alvarez L., Chuy T., Garcia J., Moreno B., Alvarez H., Blanco M., Exposito O., Gonzalez O., Fernandez A.I., 1999. An earthquake catalogue of Cuba and neighboring areas. ICTP Internal Report IC/IR/99/1, Miramare, Trieste, 60 pp.	36
Ambraseys and Adams, 1986a	Ambraseys N.N. and Adams R.D., 1986a. Seismicity of the Sudan. Bulletin of the Seismological Society of America, 76, 2, 483-493.	2
Ambraseys and Adams, 1986b	Ambraseys N.N. and Adams R.D., 1986b. Seismicity of West Africa. Annales Geophysicae, 4, B, 6, 679-702.	6
Ambraseys and Adams, 1991	Ambraseys N.N. and Adams R.D., 1991. Reappraisal of major African earthquakes, south of 20°N, 1900-1930. Natural Hazards, 4, 4, 389-419, doi:10.1007/BF00126646	2
Ambraseys and Adams, 2001	Ambraseys N.N. and Adams R.D., 2001. Seismicity of Central America: A Descriptive Catalog 1898-1995. World Scientific Publishing Company, London, 309 pp.	10
Ambraseys and Barazangi, 1989	Ambraseys N.N and Barazangi M., 1989. The 1759 Earthquake in the Bekaa Valley: Implications for Earthquake Hazard Assessment in the Eastern Mediterranean Region. Journal of Geophysical Research, 94, B4, 4007-4013.	2
Ambraseys and Bilham, 2003	Ambraseys N. and Bilham R., 2003. Earthquakes in Afghanistan. Seismological Research Letters, 74, 2, 107-123 + electronic supplement.	12
Ambraseys and Bilham, 2003a	Ambraseys N. and Bilham R., 2003a. Reevaluated Intensities for the Great Assam Earthquake of 12 June 1897, Shillong, India. Bulletin of the Seismological Society of America, 93, 2, 655-673.	1
Ambraseys and Douglas, 2004	Ambraseys N.N. and Douglas J., 2004. Magnitude calibration of north Indian earthquakes. Geophysical Journal International, 159, 165-206, doi:10.1111/j.1365-246X.2004.02323.x	20
Ambraseys and Finkel, 1988	Ambraseys N.N. and Finkel C., 1988. The Anatolian Earthquake of 17 August 1668. In: W.H.K. Lee, H. Meyers, K. Shimazaki (eds), Historical Seismograms and Earthquakes of the World, Academic Press, London, 173-180.	1
Ambraseys and Finkel, 1991	Ambraseys N.N. and Finkel C., 1991. Long-term seismicity of Istanbul and of the Marmara Sea region. Terra Nova, 3, 5, 527-539.	1

Short reference	Reference	Records
Ambraseys and Finkel, 1992	Ambraseys N.N. and Finkel C., 1992. The seismicity of the Eastern Mediterranean Region during the turn of the Eighteenth Century. Istanbuler Mitteilungen, 42, 323-343.	1
Ambraseys and Finkel, 1995	Ambraseys N.N. and Finkel C., 1995. The Seismicity of Turkey and adjacent areas. A Historical Review, 1500-1800. Eren, Istanbul, 240 pp.	10
Ambraseys and Finkel, 1999	Ambraseys N.N. and Finkel C., 1999. Unpublished Ottoman archival information on the seismicity of the Balkans during the period 1500-1800. In: E. Zachariadou (ed), Natural Disasters in the Ottoman Empire, Institute for Mediterranean Studies, Halcyon Days in Crete III, A Symposium Held in Rethymnon (Greece), 10-12 January 1997, 89-107.	3
Ambraseys and Jackson, 1990	Ambraseys N.N. and Jackson J., 1990. Seismicity and associated strain of central Greece between 1890 and 1988. Geophysical Journal International, 101, 3, 663-708.	1
Ambraseys and Jackson, 1998	Ambraseys N.N. and Jackson J.A., 1998. Faulting associated with historical and recent earthquakes in the Eastern Mediterranean region. Geophysical Journal International, 133, 2, 390-406, doi:10.1046/j.1365-246X.1998.00508.x	30
Ambraseys and Jackson, 2003	Ambraseys N. and Jackson D., 2003. A note on early earthquakes in northern India and southern Tibet. Current Science, 84, 4, 570-582.	6
Ambraseys and Karcz, 1992	Ambraseys N.N and Karcz I., 1992. The earthquake of 1546 in the Holy Land. Terra Nova, 4, 2, 253-262.	1
Ambraseys and Melville, 1982	Ambraseys N.N. and Melville C., 1982. A history of Persian earthquakes. Cambridge University Press, Cambridge, 219 pp.	29
Ambraseys and Melville, 1988	Ambraseys N.N. and Melville C.P., 1988. An analysis of the Eastern Mediterranean Earthquake of 20 May 1202. In: W.H.K. Lee, H. Meyers, K. Shimazaki (eds), Historical Seismograms and Earthquakes of the World, Academic Press, London, 181-200.	1
Ambraseys and Melville, 1989	Ambraseys N.N. and Melville C.P., 1989. Evidence for intraplate earthquakes in northwest Arabia. Bulletin of the Seismological Society of America, 79, 4, 1279-1281.	2
Ambraseys and Melville, 1995	Ambraseys N.N. and Melville C.P., 1995. Historical evidence of faulting in Eastern Anatolia and Northern Syria. Annali di Geofisica, 38, 3-4, 337-343.	2
Ambraseys and Vogt, 1988	Ambraseys N. and Vogt J., 1988. Materials for the investigation of the seismicity of the region of Algiers. European Earthquake Engineering, 3, 16-29.	5
Ambraseys et al., 1994	Ambraseys N.N., Melville C.P., Adams R.D., 1994. The Seismicity of Egypt, Arabia and the Red Sea. Cambridge University Press, Cambridge, 182 pp.	21
Ambraseys, 1989	Ambraseys N.N., 1989. Temporary seismic quiescence: SE Turkey. Geophysical Journal International , 96, 2, 311-331.	10
Ambraseys, 1997a	Ambraseys N.N., 1997a. The Krasnovodsk (Turkmenistan) earthquake of 8 July 1895. Journal of Earthquake Engineering, 1, 2, 293-317.	3
Ambraseys, 1997b	Ambraseys N.N., 1997b. The little-known earthquakes of 1866 and 1916 in Anatolia (Turkey). Journal of Seismology, 1, 3, 289-299, doi:10.1023/A:1009788609074	2
Ambraseys, 1997c	Ambraseys N.N., 1997c. The earthquake of 1 January 1837 in Southern Lebanon and Northern Israel. Annali di Geofisica, 40, 4, 923-935.	1
Ambraseys, 2000a	Ambraseys N., 2000a. Reappraisal of north-Indian earthquakes at the turn of the 20th century. Current Science, Special Section: Seismology 2000, 79, 9, 1237-1250.	1

Short reference	Reference	Records
Ambraseys, 2001	Ambraseys N.N., 2001. The earthquake of 1509 in the Sea of Marmara, Turkey, revisited. Bulletin of the Seismological Society of America, 91, 6, 1397-1416.	1
Ambraseys, 2001b	Ambraseys N.N., 2001b. Reassessment of earthquakes, 1900-1999, in the East Mediterranean and the Middle East. Geophysical Journal International, 145, 471-485.	1
Ambraseys, 2002	Ambraseys N.N., 2002. The seismic activity of the Marmara Sea Region over the last 2000 years. Bulletin of the Seismological Society of America, 92, 1, 1-18.	10
Ambraseys, 2004	Ambraseys N.N., 2004. The 12th century seismic paroxysm in the Middle East: a historical perspective. Annals of Geophysics, 47, 2-3, 733-758.	5
Ambraseys, 2004a	Ambraseys N.N., 2004a. Three little known earthquakes in India. Current Science, 86, 4, 506-508.	2
Ambraseys, 2006	Ambraseys N.N., 2006. Comparison of frequency of occurrence of earthquakes with slip rates from long-term seismicity data: the cases of Gulf of Corinth, Sea of Marmara and Dead Sea Fault Zone. Geophysical Journal International, 165, 516–526.	10
Ambraseys, 2009	Ambraseys N., 2009. Earthquakes in the Mediterranean and Middle East: A Multidisciplinary Study of Seismicity up to 1900. Cambridge University Press, 968 pp.	27
Audemard, 1999	Audemard F.M., 1999. Nueva percepcion de la sismicidad historica del segmento en tierra de la Falla El Pilar, Venezuela Nororiental, a partir de primeros resultados paleosismicos. Mem. VI congreso Venez. Sismologia e Ingenieria Sismica (CD-ROM), Merida, Venezuela.	1
Babayan, 2006	Babayan T., 2006. Atlas of strong earthquakes of the Republic of Armenia, Artsakh and adjacent territories from ancient times through 2003. Tigran Mets, Yerevan, 140 pp.	2
Bakun and Hopper, 2004	Bakun W.H. and Hopper M.G., 2004. Magnitudes and Locations of the 1811-1812 New Madrid, Missouri, and the 1886 Charleston, South Carolina, Earthquakes. Bulletin of the Seismological Society of America, 94, 1, 64-75.	4
Bakun et al., 2002	Bakun W.H., Haugerud R.A., Hopper M. G., Ludwin R.S., 2002. The December 1872 Washington state earthquake. Bulletin of the Seismological Society of America, 92, 8, 3239-3258.	1
Bakun et al., 2012	Bakun W.H., Flores C.H., ten Brink U.S., 2012. Significant Earthquakes on the Enriquillo Fault System, Hispaniola, 1500-2010: Implications for Seismic Hazard. Bulletin of the Seismological Society of America, 102, 1, 18-30, doi:10.1785/0120110077	5
Bakun, 1999	Bakun W.H., 1999. Seismic Activity of the San Francisco Bay Region. Bulletin of the Seismological Society of America, 89, 3, 764-784.	3
Bakun, 2000	Bakun W.H., 2000. Seismicity of California's North Coast. Bulletin of the Seismological Society America, 90, 4, 797-812.	2
Bakun, 2005	Bakun W.H., 2005. Magnitude and location of historical earthquakes in Japan and implications for the 1855 Ansei Edo earthquake. Journal of Geophysical Research, 110, B02304, 22 pp., doi:10.1029/2004JB003329	1
Bakun, 2006a	Bakun W.H., 2006a. Estimating Locations and Magnitudes of Earthquakes in Southern California from Modified Mercalli Intensities. Bulletin of the Seismological Society of America, 96, 4A, 1278-1295, doi:10.1785/0120050205	1

Short reference	Reference	Records
Bakun, 2006b	Bakun W.H., 2006b. MMI Attenuation and Historical Earthquakes in the Basin and Range Province of Western North America. Bulletin of the Seismological Society of America, 96, 6, 2206-2220, doi:10.1785/0120060045	2
Baptista et al., 2007	Baptista M.A., Miranda J.M., Lopes Fernando C., Luis Joaquim F., 2007. The source of the 1722 Algarve earthquake: evidence from MCS and tsunami data. Journal of Seismology, 11, 4, 371-380.	1
Bautista and Oike, 2000	Bautista M.L.P. and Oike K., 2000. Estimation of the magnitudes and epicenters of Philippine historical earthquakes. Tectonophysics, 317, 1-2, 137-169.	28
Beauval et al., 2010	Beauval C., Yepes H., Bakun W.H., Egred J., Alvarado A., Singaucho J.C., 2010. Locations and magnitudes of historical earthquakes in the Sierra of Ecuador (1587-1996). Geophysical Journal International, 181, 1613-1633, doi:10.1111/j.1365-246X.2010.04569.x	5
Beauval et al., 2013	Beauval C., Yepes H., Palacios P., Segovia M., Alvarado A., Font Y., Aguilar J., Troncoso L., Vaca S., 2013. An Earthquake Catalog for Seismic Hazard Assessment in Ecuador. Bulletin of the Seismological Society of America, 103, 2A, 773-786, doi:10.1785/0120120270	5
Benito and Torres, 2009	Benito Oterino M.B. and Torres Fernández Y. (eds), 2009. Amenaza sísmica en América Central. Entimema, Madrid, 371 pp.	21
Benito et al., 2012	Benito M.B., Lindholm C., Camacho E., Climent Á., Marroquín G., Molina E., Rojas W., Escobar J.J., Talavera E., Alvarado G.E., Torres Y., 2012. A New Evaluation of Seismic Hazard for the Central America Region. Bulletin of the Seismological Society of America, 102, 2, 504-523, doi:10.1785/0120110015	64
Bernard and Lambert, 1988	Bernard P. and Lambert J., 1988. Subduction and seismic hazard in the northern Lesser Antilles: revision of the historical seismicity. Bulletin of the Seismological Society of America, 78, 6, 1965-1983.	1
Bhatia et al., 1999	Bhatia S.C., Kumar R.M., Gupta H.K., 1999. A probabilistic seismic hazard map of India and adjoining regions. Annals of Geophysics, 42, 6, 1153-1164. http://www.seismo.ethz.ch/static/gshap/ict/indcat.txt	63
Bilham et al., 2005	Bilham R., Engdahl E.R., Feldl N., Satyabala S.P., 2005. Partial and complete rupture of the Indo-Andaman Plate Boundary 1847-2004. Seismological Research Letters, 76, 3, 299-311.	3
Bilham, 1994	Bilham R., 1994. The 1737 Calcutta Earthquake and Cyclone Evaluated. Bulletin of the Seismological Society of America, 84, 5, 1650-1657.	1
Bilham, 1995	Bilham R., 1995. Location and magnitude of the 1833 Nepal earthquake and its relation to the rupture zones of contiguous great Himalayan earthquakes. Current Science, 69, 2, 101-128.	1
Boschi and Guidoboni, 2001	Boschi E. and Guidoboni E., 2001. Catania terremoti e lave dal mondo antico alla fine del Novecento. INGV-SGA, Bologna, 414 pp.	2
Boschi et al., 2000	Boschi E., Guidoboni E., Ferrari G., Mariotti D., Valensise G., Gasperini P. (eds), 2000. Catalogue of Strong Italian Earthquakes from 461 B.C. to 1980. Annali di Geofisica, 43, 4, 609-868.	2
Bozkurt et al., 2007	Bozkurt S.B., Stein R S., Toda S., 2007. Forecasting Probabilistic Seismic Shaking for Greater Tokyo from 400 Years of Intensity Observations. Earthquake Spectra, 23, 3, 525-546, doi:10.1193/1.2753504	51
Brink et al., 2011	ten Brink U.S., Bakun W.H., Flores C.H., 2011. Historical perspective on seismic hazard to Hispaniola and the northeast Caribbean region. J. Geophys. Res. 116, B12318, doi:10.1029/2011JB008497	8

Short reference	Reference	Records
Camacho and Víquez, 1993	Camacho E. and Víquez V., 1993. Historical seismicity of the North Panama Deformed Belt. Revista Geológica de América Central, 15, 49-64.	2
CERESIS, 1985	CERESIS (Centro Regional de Sismología para América del Sur), 1985. Destructive earthquakes of South America 1530-1894. Earthquake Mitigation Program in the Andean Region, Project SISRA, Lima, 14 vols.	82
CERESIS, 1995	CERESIS (Centro Regional de Sismología para América del Sur), 1995. Catalogue for South America and the Caribbean prepared in the framework of GSHAP. File available and downloadable from http://www.seismo.ethz.ch/static/gshap/ceresis	119
CEUS, 2012	CEUS, 2012. SSC Uniform Moment Magnitude Earthquake Catalog. http://www.ceus-ssc.com	11
Chen et al., 2010	Chen L.C., Wang H., Ran Y.K., Sun X.Z., Su G.W., Wang J., Tan X.B., Li Z.M., Zhang X.Q., 2010. The MS7.1 Yushu earthquake surface rupture and large historical earthquakes on the Garzê-Yushu Fault. Chinese Science Bulletin, Geophysics, 55, 31, 3504-3509, doi:10.1007/s11434-010-4079-2	1
China State Seismological Bureau and Fudan University, 1986	China State Seismological Bureau and Fudan University, 1986. Atlas of the Historical Earthquakes in China - The Ming Dynasty Period (1368-1644). Compiled by Institute of Geophysics, State Seismological Bureau and Institute of Chinese Historical Geography, Fudan University, China Cartographic Publishing House, 232 pp. (in Chinese)	17
China State Seismological Bureau and Fudan University, 1990b	China State Seismological Bureau and Fudan University, 1990b. Atlas of the Historical Earthquakes in China - The Qing Dynasty Period (1644-1911). Compiled by Institute of Geophysics, State Seismological Bureau and Institute of Chinese Historical Geography, Fudan University, China Cartographic Publishing House, 244 pp. (in Chinese)	41
China State Seismological Bureau and Fudan University, 1990a	China State Seismological Bureau and Fudan University, 1990a. Atlas of the Historical Earthquakes in China - The Period from Remote Antiquity to the Yuan Dynasty (23 cent. B.C.-1368). Compiled by Institute of Geophysics, State Seismological Bureau and Institute of Chinese Historical Geography, Fudan University, China Cartographic Publishing House, 193 pp. (in Chinese)	7
Chiu and Kim, 2004	Chiu J.-M. and Kim S.G., 2004. Estimation of Regional Seismic Hazard in the Korean Peninsula using Historical Earthquake Data between A.D. 2 and 1995. Bulletin of the Seismological Society of America, 94, 1, 269-284.	5
Choy et al., 2010	Choy J.E., Palme C., Guada C., Morandi M., Klarica S., 2010. Macroseismic Interpretation of the 1812 Earthquake in Venezuela Using Intensity Uncertainties and A Priori Fault-Strike Information. Bulletin of the Seismological Society of America, 100, 1, 241-255.	2
Chuy and Alvarez, 1988	Chuy Rodríguez T. and Alvarez Gómez L., 1988. Sismicidad Histórica de La Española. Comunicaciones Científicas sobre Geofísica y Astronomia, Instituto de Geofísica y Astronomia, Academia de Ciencias de Cuba, La Habana, 14 pp.	19
Chuy, 1999	Chuy T., 1999. Macrosísmica de Cuba y su aplicación en los estimados de Peligrosidad y Microzonificación Sísmica. Tesis en opción al Grado de Doctor en Ciencias Geofísicas. Fondos del Centro Nacional de Investigaciones Sismológicas (CENAIS), CITMA, 273 pp.	10
Cisternas, 2012	Cisternas M., 2012. El terremoto de Chile central de 1647 como un evento intra-placa. XIII Congreso Geológico Chileno. Antofagasta, Chile. Libro de resúmenes, 1037-1039.	1

Short reference	Reference	Records
Costantinescu and Marza, 1980	Costantinescu L. and Marza V.I., 1980. A computer-compiled and computer-oriented catalog of Romania's earthquakes during a millennium (984-1979). Revue Roumanie de Geologie Geophysique et Geographie. Ser. Geophysique, 24, 171-191.	6
Cotilla and Córdoba, 2010a	Cotilla M.O. and Córdoba D., 2010a. Notes on three earthquakes in Santiago de Cuba (14.10.1800, 18.09.1826, 07.07.1842). Russian Geology and Geophysics, 51, 228-236.	1
Cotilla and Córdoba, 2010b	Cotilla Rodríguez M.O. and Córdoba Barba D., 2010b. The August 20, 1852 earthquake in Santiago de Cuba. Russian Geology and Geophysics, 51, 1227-1246.	1
Cotilla and Córdoba, 2011	Cotilla Rodríguez M.O. and Córdoba Barba D., 2011. Study of the Earthquake of the January 23, 1880, in San Cristobal, Cuba and the Guane Fault. Physics of the Solid Earth, 47, 6, 496-518.	1
Cotilla Rodríguez, 2003	Cotilla Rodríguez M.O, 2003. The Santiago de Cuba earthquake of 11 June 1766: Some new insights. Geofísica Internacional, 42, 4, 589-602.	1
CPTI Working Group, 2004	CPTI Working Group, 2004. Catalogo Parametrico dei Terremoti Italiani, versione 2004 (CPTI04). INGV, Bologna, doi:10.6092/INGV.IT-CPTI04. http://emidius.mi.ingv.it/CPTI	1
Cummins, 2007	Cummins P.R., 2007. The potential for giant tsunamigenic earthquakes in the northern Bay of Bengal. Nature, 449, 6 Sept 2007, 75-78.	1
de Polo et al., 1997	de Polo C.M., Anderson J.G., de Polo D.M., Price J.G., 1997. Earthquake Occurrence in the Reno-Carson City Urban Corridor. Seismological Research Letters, 68, 3, 401-412.	1
Deng and Liao, 1996	Deng Q. and Liao Y., 1996. Paleoseismology along the range-front fault of Helan Mountains, north central China. Journal of Geophysical Research, 101, B3, 5873-5893.	1
Dimate et al., 2005	Dimate C., Rivera L., Cisternas A., 2005. Re-visiting large historical earthquakes in the Colombian Eastern Cordillera. Journal of Seismology, 9, 1-22.	6
Dorbath et al., 1990	Dorbath L., Cisternas A., Dorbath C., 1990. Assessment of the size of large and great historical earthquakes in Peru. Bulletin of the Seismological Society of America, 80, 3, 551-576.	14
Dorel, 1981	Dorel J., 1981. Seismicity and seismic gap in the Lesser Antilles arc and earthquake hazard in Guadeloupe. Geophysical Journal of the Royal Astronomical Society, 67, 679-695.	7
Doser, 2006	Doser D.I., 2006. Relocations of Earthquakes (1899-1917) in South-Central Alaska. Pure and Applied Geophysics, 163, 8, 1461-1476, doi:10.1007/s00024-006-0085-3	6
DuBois and Smith, 1980	DuBois S.M. and Smith A.W., 1980. Earthquakes Causing Damage in Arizona. Bureau of Geology and Mineral Technology, 3 pp.	1
Ebel et al., 2013	Ebel J.E., Dupuy M., Bakun W.H., 2013. Assessing the Location and Magnitude of the 20 October 1870 Charlevoix, Quebec, Earthquake. Bulletin of the Seismological Society of America, 103, 1, 588–594, doi:10.1785/0120110063	1
Ebel, 2011	Ebel J.E., 2011. A New Analysis of the Magnitude of the February 1663 Earthquake at Charlevoix, Quebec. Bulletin of the Seismological Society of America, 101, 3, 1024-1038, doi:10.1785/0120100190	2
Egred, 2004	Egred J., 2004. El terremoto de Riobamba del 4 de febrero de 1797. In: "Investigaciones en Geociencias, vol. 1", IRD-Instituto Geofisico, Corporacion Editora Nacional, Quito, 133-161.	1

Short reference	Reference	Records
El Mrabet, 2005	El Mrabet T., 2005. The great earthquakes in the Maghreb region and their consequences on man and environment. CNRST-LAG, Rabat, 478 pp.	7
Engdahl and Villaseñor, 2002	Engdahl E.R. and Villaseñor A., 2002. Global seismicity: 1900-1999. In: W.H.K. Lee, H. Kanamori, P.C. Jennings, C. Kisslinger (eds), International Handbook of Earthquake and Engineering Seismology, Part A. Academic Press, San Diego, 665-690.	54
Espinosa Baquero, 2003	Espinosa Baquero A., 2003. Historia Sísmica de Colombia. Academia Colombiana de Ciencias Exactas, Físicas y Naturales - Universidad del Quindío, Bogotá. CD-ROM.	7
Felzer and Cao, 2008	Felzer K.R. and Cao T., 2008. WGCEP Historical California earthquake catalog, Appendix H in The Uniform California Earthquake Rupture Forecast, version 2 (UCERF 2): U.S. Geological Survey Open-File Report 2007-1437H and California Geological Survey Special Report 203H, 127 p. http://pubs.usgs.gov/of/2007/1437/h	14
Flores et al., 2012	Flores C.F., ten Brink U.S., Bakun W.H., 2012. Accounts of damage from historical earthquakes in the Northeastern Caribbean to aid in the determination of their location and intensity magnitudes. U.S. Geological Survey, Open-File Report 2011-1133, 237 pp.	18
Gao Mengtan et al., 2004	Gao Mengtan, Jin Xueshen, An Weiping, Lu Xiaojian, 2004. The GIS and analysis of earthquake damage distribution of the 1303 Hongtong M=8 earthquake. Acta Sismologica Sinica, 17, 4, 398-404.	1
Garcia et al., 1985	Garcia L.C., Valenzuela R.G., Arnold E.P., Macalingcag T.G., Ambubuyog G.F., Lance N.T., Cordeta J.D., Doniego A.G., Cordeta J.D.G.M., Dabi A.C., Balce G.R., Su S.S., 1985. South East Asia Association of Seismology and Earthquake Engineering, Series on Seismology, vol. IV, Philippines, 852 pp.	18
GeoNet, 2011	GeoNet, 2011. Historic Earthquakes. National Earthquake Information Database, GNS-EQC, New Zealand.	5
Godzikovskaya, 2007	Godzikovskaya A.A., 2007. A catalogue of macroseismic descriptions of Kamchatka earthquakes for pre-instrumental period of observation (18th-19th centuries). KF GS RAN Report, Moscow-Petropavlovsk, 167 pp. (in Russian).	13
Gouin, 1979	Gouin P., 1979. Earthquake history of Ethiopia and the Horn of Africa. IDRC-118e, IDRC, Ottawa, 259 pp.	5
Gouin, 1994	Gouin P., 1994. About the First Earthquake Reported in Canadian History. Bulletin of the Seismological Society of America, 84, 2, 478-483.	1
Gouin, 2001	Gouin P., 2001. Trémblements de terre "historiques" au Québec (de 1534 à mars 1925) identifiés et interprétés à partir des textes originaux contemporains. "Historical" earthquakes felt in Québec (from 1534 to March 1925) as revealed by the local contemporary literature. Gué, Montreal, 1491 pp.	2
Grigorova et al., 1978	Grigorova E., Christoskov L., Sokerova D., Rizhikova S., Roglinov A., 1978. Catalogue of earthquakes in Bulgaria and the nearby territories during the period 1st cent. BC - 1977. Geophysical Institute, Bulgarian Academy of Sciences, Sofia (unpublished).	1
Grunewald and Stein, 2006	Grunewald E.D. and Stein R.S., 2006. A new 1649-1884 catalog of destructive earthquakes near Tokyo and implications for the long-term seismic process. Journal of Geophysical Research, 111, B12306, 15 pp., doi:10.1029/2005JB004059	7

Short reference	Reference	Records
Gu Gongxu et al., 1989	Gu Gongxu et al., 1989. Catalogue of Chinese Earthquakes (1831 B.C.-1969 A.D.), translation into English of the 1983 edition in Chinese, Science Press, Beijing, China, 872 pp.	55
Guidoboni and Comastri, 1997	Guidoboni E. and Comastri A., 1997. The large earthquake of 8 August 1303 in Crete: seismic scenario and tsunami in the Mediterranean area. Journal of Seismology, 1, 55-72.	1
Guidoboni and Comastri, 2005	Guidoboni E. and Comastri A., 2005. Catalogue of earthquakes and tsunamis in the Mediterranean area from the 11th to the 15th century. INGV-SGA, Bologna, 1037 pp.	30
Guidoboni et al., 2004	Guidoboni E., Bernardini F., Comastri A., Boschi E., 2004. The large earthquake on 29 June 1170 (Syria, Lebanon, and central southern Turkey). Journal of Geophysical Research, 109, B07304, 1-21.	1
Guidoboni et al., 2004a	Guidoboni E., Bernardini F., Comastri A., 2004a. The 1138-1139 and 1156-1159 destructive seismic crises in Syria, south-eastern Turkey and northern Lebanon. Journal of Seismology, 8, 105-127.	2
Guidoboni et al., 2007	Guidoboni E., Ferrari G., Mariotti D., Comastri A., Tarabusi G., Valensise G., 2007. CFTI4Med, Catalogue of Strong Earthquakes in Italy (461 B.C.-1997) and Mediterranean Area (760 B.C.-1500). INGV-SGA. http://storing.ingv.it/cfti4med	5
Gupta and Gahalaut, 2009	Gupta H. and Gahalaut V., 2009. Is the Northern Bay of Bengal Tsunamigenic? Bulletin of the Seismological Society of America, 99, 6, 3496-3501.	1
Hamdache et al., 2010	Hamdache M., Peláez J.A., Talbi A., López Casado C., 2010. A Unified Catalog of Main Earthquakes for Northern Algeria from A.D. 856 to 2008. Seismological Research Letters, 81, 5, 732-739.	9
Harbi et al., 2007	Harbi A., Maouche S., Vaccari F., Aoudia A., Oussadou F., Panza G.F., Benouar D., 2007. Seismicity, seismic input and site effects in the Sahel-Algiers region (North Algeria). Soil Dynamics and Earthquake Engineering, 27, 427-447.	2
Harbi et al., 2010	Harbi A., Peresan A., Panza G.F., 2010. Seismicity of Eastern Algeria: a revised and extended earthquake catalogue. Natural Hazards, 54, 3, 725-747, doi:10.1007/s11069-009-9497-6	1
Hough and Elliot, 2004	Hough S.E. and Elliot A., 2004. Revisiting the 23 February 1892 Laguna Salada Earthquake. Bulletin of the Seismological Society of America, 94, 4, 1571-1578.	1
Hough and Hutton, 2008	Hough S.E. and Hutton K., 2008. Revisiting the 1872 Owens Valley, California, Earthquake. Bulletin of the Seismological Society of America, 98, 2, 931-949, doi:10.1785/0120070186	1
Hough et al., 2000	Hough S.E., Armbruster J.G., Seeber L., Hough J.F., 2000. On the Modified Mercalli intensities and magnitudes of the 1811-1812 New Madrid earthquakes. Journal of Geophysical Research, 105, b10, 23,839-23, 864.	3
Hough, 2013	Hough S., 2013. Missing Great Earthquakes. Journal of Geophysical Research (accepted), doi:10.1002/jgrb.50083	1
Icelandic Meteorological Office, 2007	Icelandic Meteorological Office, 2007. Earthquakes in Iceland larger than magnitude 4 in the years 1706-1990.	1
INPRES, 2012	INPRES (Instituto Nacional de Prevencion Sismica), 2012. Terremotos historicos de la Republica Argentina. http://www.inpres.gov.ar/seismology/historicos.php	6
Instituto Geografíco Nacional, 2010	Instituto Geografíco Nacional, 2010. Bases de datos macrosísmica. Macroseismic Data Points available at http://www.ign.es/ign/layoutIn/bdmacrosismica.do	5

Short reference	Reference	Records
ISC-GEM, 2012	ISC-GEM, 2012. ISC-GEM Global Instrumental Earthquake Catalogue (1900-2009), Final Scientific Report, 99 pp., http://www.isc.ac.uk/iscgem/index.php	5
Ishibashi, 2004	Ishibashi K., 2004. Status of historical seismology in Japan. Annals of Geophysics, 47, 2-3, 339-368.	2
Ishibashi, 2004a	Ishibashi K., 2004a. Seismotectonic modeling of the repeating M7-class disastrous Odawara earthquake in the Izu collision zone, central Japan. Earth Planets Space, 56, 843-858.	3
Jia Wali et al., 2004	Jiang Wali, Deng Qidong, Xu Xiwei, Xie Xinsheng, 2004. Surface rupture zone of the 1303 Hongtong M=8 earthquake, Shanxi Province. Acta Sismologica Sinica, 17, 4, 389-397.	1
Khilko et al., 1985	Khilko S.D., Kurushin R.A., Kochetkov V.M., Misharina L.A., Gilyova N.A., Lastochkin S.V., Balzhinnyam I., Monhoo D., 1985. Strong earthquakes, paleoseismogeological and macroseismic data. In: Earthquakes and the bases for Seismic Zoning of Mongolia, The joint Soviet-Mongolian scientific-research geological expedition, Transactions 41, Nauka, Moscow, 19-83 (in Russian).	1
Kingland et al., 2008	Kingland J., Torres R., Inglessis P., 2008. Ecuación de atenuación de intensidad macrosísmica y mapa de isosistas para el gran terremoto de los andes de 1894. IMME, 46, 1, 1-22.	1
Kondorskaya and Shebalin, 1982	Kondorskaya N.V. and Shebalin N.V. (eds), 1982. New Catalogue of strong earthquakes in the USSR from Ancient Times through 1975. 2nd edition, Boulder, Colorado, 608 pp. (1st edition, 1977, Moscow, 536 pp., in Russian).	18
Kondorskaya and Ulomov, 1999	Kondorskaya N.V. and Ulomov V.I., 1999. Special earthquake catalogue of Northern Eurasia from ancient times through 1995 (SECNE). Joint Institute of Physics of the Earth (JIPE), Russian Academy of Sciences, Moscow, Russia. http://www.seismo.ethz.ch/static/gshap/neurasia/nordasiacat.txt	77
Lamontagne et al., 2007	Lamontagne M., Halchuk S., Cassidy J.F., Rogers G.C., 2007. Significant Canadian Earthquakes 1600-2006. Geological Survey of Canada, Open File 5539, 32 pp. + 6 maps.	4
Lamontagne et al., 2008	Lamontagne M., Halchuk S., Cassidy J.F., Rogers G.C., 2008. Significant Canadian Earthquakes of the Period 1600-2006. Seismological Research Letters, 79, 2, 211-223, doi:10.1785/gssrl.79.2.211	5
Lee and Yang, 2006	Lee K. and Yang W.S., 2006. Historical Seismicity of Korea. Bulletin of the Seismological Society of America, 96, 3, 846-855 + electronic supplement, doi:10.1785/0120050050	8
Levret and Vogt, 1992	Levret A. and Vogt J., 1992. Towards the solution of some problems of the historical seismicity of Morocco. Proceedings of the regional workshop on archaeoseismicity in the Mediterranean region, November 4-7, 1992, Damascus, Syrian Arab Republic Atomic Energy Commission (AECS), Damascus, 106-115.	1
Levret, 1991	Levret A., 1991. The effects of the November 1, 1755 "Lisbon" earthquake in Morocco. Tectonophysics, 193, 1-3, 83-94.	1
Li, 1957	Li Zejiang, 1957. Earthquakes of Peking. Acta Geophysica Sinica, VI, 2, 181-219 (in Chinese).	2
LNEC, 1986	LNEC, 1986. A Sismicidade Histórica e a Revisão do Catálogo Sísmico. Laboratorio Nacional de Engenharia Civil, Lisboa, 189 pp.	5
Lomnitz, 2004	Lomnitz C., 2004. Major Earthquakes of Chile: A Historical Survey, 1535-1960. Seismological Research Letters, 75, 3, 368-378.	32

Short reference	Reference	Records
Lopez Marinas and Salord, 1990	Lopez Marinas J.M. and Salord R., 1990. El periodo sismico oranes de 1790 a la luz de la documentacion de los archivos españoles. MOPU-IGN, Monografias 6, Madrid, 64 pp.	1
Makropoulos et al., 2012	Makropoulos K., Kaviris G., Kouskouna V., 2012. An updated and extended earthquake catalogue for Greece and adjacent areas since 1900. Natural Hazards and Earth System Sciences, 12, 1425-1430. With supplement.	1
Maouche et al., 2008	Maouche S., Harbi A., Meghraoui M., 2008. Attenuation of Intensity for the Zemmouri Earthquake of 21 May 2003 (Mw 6.8): Insights for the Seismic Hazard and Historical Earthquake Sources in Northern Algeria. In: J. Fréchet, M. Meghraoui, M. Stucchi (eds), Historical Seismology, Interdisciplinary Studies of Past and Recent Earthquakes, Springer, 327-350.	1
Martin and Szeliga, 2010	Martin S. and Szeliga W., 2010. A Catalog of Felt Intensity Data for 570 Earthquakes in India from 1636 to 2009. Bulletin of the Seismological Society of America, 100, 2, 562-569, electronic Supplement, doi:10.1785/0120080328	24
Martinez Solares and Mezcua Rodriguez, 2002	Martinez Solares J.M. and J. Mezcua Rodriguez (eds), 2002. Catalogo sismico de la Peninsula Iberica (880 a.C.-1990). IGN, Madrid, Monografía Núm. 18, 254 pp.	7
Martins and Mendes Victor, 2001	Martins I. and Mendes Victor L.A., 2001. Contribuiçao para o estudo da sismicidade da regiao oeste da peninsula iberica, Universidade de Lisboa, Instituto Geofisico do Infante D. Luis, Publ. N. 25, 67 pp.	7
McCue, 1999	McCue K., 1999. Australian Seismological Report - 1999. Australian Seismological Centre, Canberra, 30 pp.	7
McCue, 2008	McCue K. (ed), Cuthbertson R., Gibson G., Love D., Payne C., Peck W., 2008. Australian Seismological Report 2008 - addendum. Geoscience Australia, 22 pp.	7
Meletti et al., 1988	Meletti C., Patacca E., Scandone P., Figliuolo B., 1988. Il terremoto del 1456 e la sua interpretazione nel quadro sismotettonico dell'Appennino meridionale. In: Figliuolo B. (ed), Il terremoto del 1456, Napoli, I, 1, 71-108. Macroseismic Data Points available at http://emidius.mi.ingv.it/DOM	1
Mezcua et al., 2004	Mezcua J., Rueda J., García Blanco R.M., 2004. Reevaluation of Historic Earthquakes in Spain. Seismological Research Letters, 75, 1, 75-81.	1
Min Ziqun, 1995	Min Ziqun (ed), 1995. Chinese Historical Catalog from 2300 B.C. to 1911 A.D. Seismological Press, Beijing, 514 pp. (in Chinese).	70
Mocquet, 2007	Mocquet A., 2007. Analysis and Interpretation of the October 21 1766 earthquake in the Southeastern Caribbean. Journal of Seismology, 11, 4, 381-403.	1
Musson, 2009a	Musson R.M.W., 2009. Subduction in the Western Makran: the historian's contribution. Journal of the Geological Society, 166, 3, 387-391, doi:10.1144/0016-76492008-119	1
Musson, 2012	Musson R.M.W., 2012. Seismicity of Ghana. British Geological Survey Open Report, OR/12/042, 16 pp.	2
Musson, 2012a	Musson R.M.W., 2012a. A provisional catalogue of historical earthquakes in Indonesia. British Geological Survey Open Report OR/12/073, Edinburgh, 21 pp.	76
Musson, 2012b	Musson R.M.W., 2012b. Large historical earthquakes in Australia. British Geological Survey Open Report OR/12/074, Edinburgh, 27 pp.	6
Musson, 2012c	Musson R.M.W., 2012c. Large historical earthquakes in New Zealand and South Pacific. British Geological Survey, Edinburgh.	20

Short reference	Reference	Records
Newcomb and McCann, 1987	Newcomb K.R. and McCann W. R., 1987. Seismic history and seismotectonics of the Sunda Arc. Journal of Geophysical Research, 92, 421-439.	3
NGDC-NOAA, 1985	NGDC-NOAA, 1985. U.S. Earthquake Intensity Database, 1638-1984. http://www.ngdc.noaa.gov/hazard/int_srch.shtml	24
Nishenko and Singh, 1987	Nishenko S.P. and Singh S.K., 1987. Relocation of the Great Mexican Earthquake of 14 January 1903. Bulletin of the Seismological Society of America, 77, 1, 256-259.	1
Oncescu et al., 1999	Oncescu M.C., Marza V.I., Rizescu M., Popa M., 1999. The Romanian earthquake catalogue between 984-1997. In: F. Wenzel and D. Lungu (eds), Contributions from the First International Workshop on Vrancea Earthquakes, Bucharest, Romania, November 1-4, 1997, Kluwer Academic Publishers, 43-48.	22
Ortiz and Bilham, 2003	Ortiz M. and Bilham R., 2003. Source area and rupture parameters of the 31 December 1881 Mw = 7.9 Car Nicobar earthquake estimated from tsunamis recorded in the Bay of Bengal. Journal of Geophysical Research, 108, B4, 2215, doi:10.1029/2002JB001941	1
Palme et al., 2005	Palme de Osechas C., Morandi M., Choy J.E., 2005. Re-evaluación de las intensidades de los grandes sismos históricos de la región de la cordillera de Mérida utilizando el método de Bakun & Wentworth. Revista Geografica Venezolana, Numero especial, 233-253.	6
Palme et al., 2009	Palme C., Choy J., Guada C., 2009. Wilhalm Sievers y el Terremoto del 29-oct-1900 reflexiones preliminares. V Jornadas Venezolanas de Sismología Histórica y VI Simposio Venezolano de Historia de las Geociencias, 25-28 de Junio, Mérida, 145-150.	1
Papazachos and Papazachou, 2003	Papazachos B.C. and Papazachou C., 2003. The earthquakes of Greece. Ziti Publ. Co., Thessaloniki, Greece, 286 pp. (in Greek).	37
Papazachos et al., 2009	Papazachos B.C., Comninakis P.E., Scordilis E.M., Karakaisis G.F., Papazachos C.B., 2009. A catalogue of earthquakes in the Mediterranean and surrounding area for the period 1901-2008. Publ. Geophys. Laboratory, University of Thessaloniki.	1
Pelaez et al., 2007	Peláez J.A., Chourak M., Tadili B.A., Aït Brahim L., Hamdache M., López Casado C., Martínez Solares C.M., 2007. A Catalog of Main Moroccan Earthquakes from 1045 to 2005. Seismological Research Letters, 78, 6, 614-621.	7
Peraldo and Montero, 1999	Peraldo H.G. and Montero P.W., 1999. Sismología Histórica de América Central. IPGH, México, Geofisica, 513, 347 pp.	35
Pinilla and Toral, 1987	Pinilla V. and Toral J., 1987. Sismicidad histórica sentida en el Istmo de Panamá. Revista Geofisica, 27, 135-165.	1
Poirier and Taher, 1980	Poirier J.P. and Taher M.A., 1980. Historical seismicity in the near and Middle East, North Africa, and Spain from Arabic documents (VIIth-XVIIIth century). Bulletin of the Seismological Society of America, 70, 6, 2185-2201.	8
Prachuab, 1988	Prachuab S., 1988. Historical Earthquakes of Thailand, Burma, and Indochina. In: W.H.K. Lee, H. Meyers, K. Shimazaki (eds), Historical Seismograms and Earthquakes of the World, Academic Press Inc., San Diego, 253-266.	4
Ramdani et al., 1989	Ramdani M., Tadili B., El Mrabet T., 1989. The present state of knowledge on historical seismicity of Morocco. Proceedings of the symposium on Calibration of historical earthquakes in Europe and recent developments in intensity interpretation, European Seismological Commission, Sofia 23-28 August 1988, Cursos y Seminarios 3, Instituto Geografico Nacional, Madrid, 258-279.	2

Short reference	Reference	Records
Reid and Taber, 1919	Reid H.F. and Taber S., 1919. The Porto Rico earthquake of 1918. House of Representatives, 66th Congress, 1st Session, Document No. 269, November 19, 1919.	1
Reid and Taber, 1920	Reid H.F. and Taber S., 1920. The Virgin Islands earthquakes of 1867-1868. Bulletin of the Seismological Society of America, 10, 1, 9-30.	1
Rengifo and Lafaille, 2000	Rengifo M. and Lafaille J., 2000. Reevaluacion del sismo del 28 de abril de 1894. Acta Científica Venezolana, 51, 160-175.	1
Richter, 1958	Richter C.F., 1958. Elementary Seismology. W.H. Freeman and Company, San Francisco, 768 pp.	2
Robson, 1964	Robson G.R., 1964. An earthquake catalogue for the Eastern Caribbean. Bulletin of the Seismological Society of America, 54, 2, 785-832.	7
Sakellariou et al., 2010	Sakellariou N., Kouskouna V., Makropoulos K.C., 2010. Macroseismic Intensities in Central-Southern Peloponnese during the 19th century. N&K University of Athens, Greece, Internal Report. Macroseismic Data Points available in the Hellenic Macroseismic Database of the University of Athens. http://macroseismology.geol.uoa.gr	1
Salcedo and Castaño, 2011	Salcedo Hurado E. de J. and A.N. Castaño, 2011. Reevaluacion macrosismica del terremoto del 12 de julio de 1785 en Colombia. Boletin de Geologia de la Univerisdad Industrial de Santander, Bucaramanga (in press).	1
Sarabia et al., 2010	Sarabia Gomez A.M., Cifuentes Avendaño H.G., Robertson K., 2010. Analisis historico de los sismos ocurridos en 1785 y 1917 en el centro de Colombia. Cuadernos de Geografia, Revista Colombiana de Geografia, Bogota, 19, 153-162.	1
Satake et al., 2003	Satake K., Wang K., Atwater B.F., 2003. Fault slip and seismic moment of the 1700 Cascadia earthquake inferred from Japanese tsunami descriptions. Journal of Geophysical Research, 108, B11, 2535, 17 pp., doi:10.1029/2003JB002521	1
Sbar and DuBois, 1984	Sbar M.L. and DuBois S.M., 1984. Attenuation of intensity for the 1887 Northern Sonora, Mexico earthquake. Bulletin of the Seismological Society of America, 74, 6, 2613-2628.	1
Sbeinati et al., 2005	Sbeinati M.R., Darawcheh R., Mouty M., 2005. The historical earthquakes of Syria: an analysis of large and moderate earthquakes from 1365 B.C. to 1900 A.D. Annals of Geophysics, 48, 3, 347-435.	19
Schulte and Mooney, 2005	Schulte S.M. and Mooney W.D., 2005. An updated global earthquake catalogue for stable continental regions: reassessing the correlation with ancient rifts. Geophysical Journal International, 161, 707–721, doi:10.1111/j.1365-246X.2005.02554.x	29
Nutalaya et al., 1985	Nutalaya P., Sodsri S., Arnold E.P., 1985. South East Asia Association of Seismology and Earthquake Engineering, Series on Seismology, vol. II, Thailand, 409 pp.	2
Shebalin (ed.), 1974	Shebalin N.V. (ed), 1974. Atlas of isoseismal maps. III, UNDP-UNESCO Survey of the seismicity of the Balkan region. Skopje, 275 pp.	2
Shebalin (ed.), 1977	Shebalin N.V. (ed), 1977. Atlas of isoseismal maps for the "New Catalogue of Strong Earthquakes on the USSR territory from Ancient Times through 1975". Archive of the Institute of Physics of the Earth (IPE), Moscow (unpublished).	7
Shebalin and Leydecker, 1997	Shebalin N.V. and Leydecker G., 1997. Earthquake Catalogue for the Former Soviet Union and Borders up to 1988. European Commission, Report No. EUR 17245 EN, Nuclear Science and Technology Series, Office for Official Publications of the European Communities, Luxembourg, 135 pp., 13 figs.	69

Short reference	Reference	Records
Shebalin and Leydecker, 1998	Shebalin N.V., Leydecker G., Mokrushina N.G., Tatevossian R.E., Erteleva O.O., Vassiliev V.Yu., 1998. Earthquake Catalogue for Central and Southeastern Europe 342 BC-1990 AD - Final Report to Contract ETNU - CT 93 - 0087.	1
Shebalin and Tatevossian, 1997	Shebalin N.V. and Tatevossian R.E., 1997. Catalogue of large historical earthquakes of the Caucasus. In: Giardini D. and Balassanian S. (eds), Historical and Prehistorical Earthquakes in the Caucasus, NATO ASI Series 2: Environment - vol. 28, Kluwer Academic Publishers, 201-232.	50
Shebalin et al., 1974	Shebalin N.V., Karnik V., Hadzievski D. (eds), 1974. Catalogue of earthquakes of the Balkan region. I, UNDP-UNESCO Survey of the seismicity of the Balkan region. Skopje, 600 pp.	41
SICAT, 2011	SICAT, 2011. Sistema de información para el inventario, catalogación, valoración y administración de la información técnico-científica: Sismicidad histórica en Colombia. Estudios macrosísmicos (1644-2008). INGEOMINAS, Instituto Colombiano de Geologia y Mineria, Bogotà.	10
Singh et al., 1996	Singh S.K., Ordaz M., Perez-Rocha L.E., 1996. The Great Mexican Earthquake of 19 June 1858: Expected Ground Motions and Damage in Mexico City from a Similar Future Event. Bulletin of the Seismological Society of America, 86, 6, 1655-1666.	1
SisFrance, 2010	BRGM-EDF-IRSN/SisFrance, 2010. Histoire et caractéristiques des séismes ressentis en France. http://www.sisfrance.net	47
Sismología Histórica de Venezuela, 2011	Sismología Histórica de Venezuela, 2011. At the Universidad de Los Andes. http://sismicidad.ciens.ula.ve	3
Slemmons et al., 1965	Slemmons D.B., Jones A.E., Gimlett J.I., 1965. Catalog of Nevada Earthquakes, 1852-1960. Bulletin of the Seismological Society of America, 55, 2, 537-583.	1
Sousa Moreira et al., 1993	Sousa Moreira V., Sousa Marques J., Fonseca Cruz J., Costa Nunes J., 1993. Review of the historical seismicity in the Gulf of Cadiz area before the 1 November 1755 earthquake. An intermediate report. In: M. Stucchi (ed), Materials of the CEC project "Review of Historical Seismicity in Europe", CNR, Milano, vol. 1, 225-235.	1
Sousa Moreira, 1984	Sousa Moreira V.J., 1984. Sismicidade historica de Portugal continental. Revista Nacional de Meteorologia e Geofisica, Lisboa, 79 pp.	1
Stover and Coffman, 1993	Stover C.W. and Coffman J.L., 1993. Seismicity of the United States, 1568-1989 (Revised). U.S. Geological Survey Professional, Paper 1527, 418 pp. http://pubs.er.usgs.gov/publication/pp1527	18
Stucchi et al., 2012	Stucchi M., Rovida A., Gomez Capera A.A., Alexandre P., Camelbeeck T., Demircioglu M.B., Gasperini P., Kouskouna V., Musson R.M.W., Radulian M., Sesetyan K., Vilanova S., Baumont D., Bungum H., Fäh D., Lenhardt W., Makropoulos K., Martinez Solares J.M., Scotti O., Živcic M., Albini P., Batllo J., Papaioannou C., Tatevossian R., Locati M., Meletti C., Viganò D., Giardini D., 2012. The SHARE European Earthquake Catalogue (SHEEC) 1000-1899. Journal of Seismology, doi:10.1007/s10950-012-9335-2	70
Suarez and Albini, 2009	Suarez G. and Albini P., 2009. Evidence for Great Tsunamigenic Earthquakes (M8.6) along the Mexican Subduction Zone. Bulletin of the Seismological Society of America, 99, 2A, 892-896.	1
Suarez et al., 1994	Suarez G., Garcia-Acosta V., Gaulon R., 1994. Active crustal deformation in the Jalisco block, Mexico: evidence for a great historical earthquake in the 16th century. Tectonophysics, 234, 1-2, 117-127.	1

Short reference	Reference	Records
Suarez, 2006	Suarez G., 2006. A macroseismic study of Mexican earthquakes. Internal report, INGV, Milano, 150 pp. ca.	45
Sutch Osiecki, 1981	Sutch Osiecki P., 1981. Estimated intensities and probable tectonic sources of historic (pre-1898) Honduran earthquakes. Bulletin of the Seismological Society of America, 71, 3, 865-881.	1
Suter, 2006	Suter M., 2006. Contemporary Studies of the 3 May 1887 Mw 7.5 Sonora, Mexico (Basin and Range Province) Earthquake. Seismological Research Letters, 77, 2, 134-147.	1
Szeliga et al., 2010	Szeliga W., Hough S., Martin S., Bilham R., 2010. Intensity, Magnitude, Location, and Attenuation in India for Felt Earthquakes since 1762. Bulletin of the Seismological Society of America, 100, 2, 570-584 + electronic supplement, doi:10.1785/0120080329	22
Tanner and Shepherd, 1997	Tanner J.G. and Shepherd J.B., 1997. Seismic hazard in Latin America and the Caribbean, Seismic Hazard in Latin America and the Caribbean, vol. 1. Final Report to the International Development Research Centre, Ottawa, Canada, Instituto Panamericano de Geografia y Historia, Mexico, D.F., 142 pp.	161
Tatevossian and Albini, 2010	Tatevossian R. and Albini P., 2010. Information background of 11th-15th century earthquakes located by the current catalogues in Vrancea (Romania). Natural Hazards, 53, 575-604, doi:10.1007/s11069-009-9448-2	7
Tatevossian and Mokrushina, 1998	Tatevossian R. and Mokrushina N., 1998. The 1802, October 26, Vrancea deep earthquake. Internal report for the BEECD project, Institute of Physics of the Earth (IPE), Moscow, 15 pp.	1
Tatevossian et al., 2012	Tatevossian R.E., Mokrushina N.G., Aptekman J.J., Tatevossian T.N., 2012. On relevancy of combination of macroseismic and palaeoseismic data. Problems of Engineering Seismology, 40, 1, 39-66 (in Russian; extended summary in English).	4
Tavera et al., 2001	Tavera H., Agüero C., Fernández E., Rodríguez S., 2001. Catálogo Sísmico del Perú 1471-1982, Versión Revisada y Actualizada. Instituto Geofísico del Perú Centro Nacional de Datos Geofísicos. http://www.igp.gob.pe/sismologia/bds/catalogo/presentacion.htm	53
Taxeidis, 2003	Taxeidis K., 2003. Study of Historical Seismicity of the Eastern Aegean Islands. PhD thesis, N&K University of Athens, Greece, 301 pp. Macroseismic Data Points available in the Hellenic Macroseismic Database of the University of Athens, http://macroseismology.geol.uoa.gr	3
Tello and Perez, 2005	Tello G. and Perez I., 2005. El Terremoto de 1894: Investigación Histórica. INSUGEO, Serie Correlación Geológica, 19, 23-40.	1
Thein et al., 2009	Thein M., Myint T., Thura Tun S., Lwin Swe T., 2009. Earthquake and tsunami hazard in Myanmar. Journal of Earthquake and Tsunami, 3, 2, 43-57, doi:10.1142/S1793431109000482	2
Tomblin and Robson, 1977	Tomblin J.M., Robson G.R., 1977. A catalogue of felt earthquakes for Jamaica, with references to other islands in the Greater Antilles, 1564 - 1971. Mines & Geology Division, Special Publication no.2, Kingston, Jamaica.	7
Toppozada and Borchardt, 1998	Toppozada T.R. and Borchardt G., 1998. Re-evaluation of the 1836 "Hayward Fault" and the 1838 San Andreas Fault Earthquakes. Bulletin of the Seismological Society of America, 88, 1, 140-159.	1
Toppozada et al., 2002	Toppozada T.R., Branum D.M., Reichle M.S., Hallstrom C.L., 2002. San Andreas Fault Zone, California: M >= 5.5 Earthquake History. Bulletin of the Seismological Society of America, 92, 7, 2555-2601.	7

Short reference	Reference	Records
Torres-Vera, 2010	Torres-Vera M.A., 2010. Historical seismicity in Mexico during 1568-1837: intensity evaluation and data reliability. Natural Hazards, 54, 863-878, doi:10.1007/s11069-010-9510-0	11
Udías et al., 2012	Udías A., Madariaga R., Buforn E., Muñoz D., Ros M., 2012. The Large Chilean Historical Earthquakes of 1647, 1657, 1730, and 1751 from Contemporary Documents. Bulletin of the Seismological Society of America, 102, 4, 1639-1653 + electronic supplement, doi:10.1785/0120110289	4
University of Thessaloniki, 2003	University of Thessaloniki, 2003. Macroseismic Data used for the compilation of Papazachos and Papazachou (2003) catalogue. In: Online Macroseimic Data of Southern Balkan area, http://www.itsak.gr/en/db/data/macroseimic_data	34
Usami, 1979	Usami T., 1979. Study of Historical Earthquakes in Japan. Bulletin of Earthquake Research Institute, 54, 399-439.	93
Usami, 2002	Usami T., 2002. Historical earthquakes in Japan. In: W.H.K. Lee, H. Kanamori, P.C. Jennings, C. Kisslinger (eds), International Handbook of Earthquake and Engineering Seismology, Part A. Academic Press, San Diego, 799-802.	101
USGS online	US Geological Survey, 2011. Historic United States Earthquakes (1568-2011). http://earthquake.usgs.gov/earthquakes/states/historical.php + Earthquake Intensity Database 1638-1985. http://www.ngdc.noaa.gov/hazard/int_srch.shtml	29
UTSU online	Utsu T., 2011. Catalog of Damaging Earthquakes in the World (through 2009). http://iisee.kenken.go.jp/utsu/index_eng.html	102
Vilanova and Fonseca, 2007	Vilanova S.P. and Fonseca J.F.B.D, 2007. Probabilistic Seismic-Hazard Assessment for Portugal. Bulletin of the Seismological Society of America, 97, 5, 1702-1717.	4
Viquez and Camacho, 1993	Víquez V. and Camacho E., 1993. El terremoto de Panamá La Vieja del 2 de mayo de 1621. Revista Universidad, 48, 186-195.	1
Vogt and Ambraseys, 1992	Vogt J. and Ambraseys N., 1992. The seismicity of Algeria during the first half of the 18th century. Proceedings of the regional workshop on archaeoseismicity in the Mediterranean region, November 4-7, 1992, Damascus, Syrian Arab Republic Atomic Energy Commission (AECS), Damascus, 90-95.	2
White et al., 2004	White R.A., Ligorria J.P., Cifuentes I.L., 2004. Seismic history of the Middle America subduction zone along El Salvador, Guatemala, and Chiapas, Mexico: 1526-2000. In: W.I. Rose, J.J. Bommer, D.L. Lopez, M.J. Carr, J.J. Major (eds), Natural hazards in El Salvador. Geological Society of America, Boulder, Colorado, Special Paper 375, 379-396.	87
White, 1984	White R.A., 1984. Catalog of historic seismicity in the vicinity of the Chixoy-Polochic and Motagua faults, Guatemala. Open-File Report 84-88, USGS, Menlo Park, 26 pp.	7
White, 1985	White R.A., 1985. The Guatemala earthquake of 1816 on the Chixoy-Polochic fault. Bulletin of the Seismological Society of America, 75, 2, 455-473.	1
Wyss and Koyanagi, 1992	Wyss M. and Koyanagi R., 1992. Isoseismal Maps, Macroseismic Epicenters, and Estimated Magnitudes of Historical Earthquakes in the Hawaiian Islands. U.S. Geological Survey Bulletin, 2006, 104 pp. http://pubs.usgs.gov/bul/2006	4
Zhai et al., 2004	Zhai W., Wu G., Han S., 2004. Research in historical earthquakes in the Korean peninsula and its circumferential regions. Acta Seismologica Sinica, 1.17, 3, 366-372 (in Chinese).	5

Short reference	Reference	Records
Zhang et al., 1986	Zhang B., Liao Y., Guo S., Wallace R.E., Bucknam R.C., Hanks T.C., 1986. Fault Scarps Related to the 1739 Earthquake and Seismicity of the Yinchuan Graben, Ningxia Huizu Zizhiqu, China. Bulletin of the Seismological Society of America, 76, 5, 1253-1287.	1
Zhang et al., 1999	Zhang P., Yang Z.X., Gupta H.K., Bhatia S. C., Shedlock K.M., 1999. Global Seismic Hazard Assessment Program (GSHAP) in continental Asia. Ann. Geophys., 42, 6, 1167-1190. http://www.seismo.ethz.ch/static/gshap/eastasia/final-cata.txt	120
Zsìros et al., 1988	Zsìros T., Mónus P., Tóth L., 1988. Hungarian Earthquake Catalog (456-1986). Geodetic & Geophysical Research Institute, Budapest, 182 pp.	1
Zúñiga et al., 1997	Zúñiga R., Suárez G., Ordaz M., García-Acosta V., 1997. Seismic Hazard in Latin America and the Caribbean, Capitulo 2: Mexico. Reporte final, Pan American Institute of Geography and History (PAIGH), 82 pp.	50

Table 1.2 The 77 archived studies with MDPs

Study						GEH Archive			
Dataset	Int.	Scale	Place names	Place coordinates	Iso-seismals	Area	EQs	MDPs	Demo
Agnew and Sieh, 1978	YES	MM	YES	map only	--	Canada and USA	1	25	--
Ambraseys and Adams, 2001	YES	MSK	--	map only	--	Central America and Chiapas	3	77	--
Ambraseys and Bilham, 2003a	YES	MSK	YES	YES	YES	South Asia and the Himalayas	1	285	1
Ambraseys and Douglas, 2004	YES	MSK	YES	YES	YES	South Asia and the Himalayas	9	561	9
						Southeast Asia and the Philippines	1	25	1
Ambraseys and Melville, 1988	YES	MSK	YES	map only	--	Turkey, the Middle East and Iran	1	45	--
Ambraseys and Vogt, 1988	--	MSK	YES	map only	YES	North Africa	1	9	--
Audemard, 1999	--	MM	YES	--	--	South America	1	4	--
Babayan, 2006	--	MSK	--	map only	YES	Russia and Central Asia	1	10	1
						Turkey, the Middle East and Iran	1	38	1
Baptista et al., 2007	YES	MSK	YES	YES	YES	Europe	2	18	2
Beauval et al., 2010	--	MSK	--	map only	--	South America	5	253	--
Bilham, 1995	YES	MM	YES	YES	YES	South Asia and the Himalayas	1	101	--
Boschi et al., 2000	YES	MCS	YES	YES	YES	Europe	3	372	2
Boschi and Guidoboni, 2001	YES	MCS	YES	YES	YES	Europe	2	201	1
CERESIS, 1985	YES	MM	YES	YES	--	Central America and Chiapas	1	7	1
						South America	80	1062	71
Choy et al., 2010	YES	MM	YES	YES	--	South America	2	56	--
Chuy and Alvarez, 1988	YES	MSK	YES	YES	--	Antilles	19	173	--
Chuy, 1999	YES	MSK	YES	--	--	Antilles	10	164	--
Cotilla and Córdoba, 2010b	YES	MSK	YES	--	--	Antilles	1	25	--
Cotilla and Córdoba, 2011	YES	MSK	YES	--	--	Antilles	1	17	--
Cotilla R., 2003	YES	MSK	YES	YES	--	Antilles	1	22	--
Dimate et al., 2005	YES	MSK	--	map only	--	South America	1	27	--
Egred, 2004	YES	MSK	YES	YES	--	South America	1	120	--
Espinosa Baquero, 2003	YES	MSK	YES	YES	--	South America	7	107	--
Flores et al., 2012	YES	MM	YES	YES	--	Antilles	18	250	--
GeoNet, 2011	YES	MM	YES	YES	--	Australia, New Zealand and the South Pacific	4	191	4
Guidoboni et al., 2004	YES	MM	YES	YES	--	Turkey, the Middle East and Iran	1	29	--
Guidoboni et al., 2004a	YES	MM	YES	map only	--	Turkey, the Middle East and Iran	2	31	--
Guidoboni et al., 2007	YES	MCS	YES	YES	--	Europe	9	2274	9
Guidoboni and Com., 2005	YES	MCS	YES	YES	--	Europe	8	101	8
						Russia and Central Asia	1	1	1

Study						GEH Archive			
Dataset	Int.	Scale	Place names	Place coordinates	Iso-seismals	Area	EQs	MDPs	Demo
						Turkey, the Middle East and Iran	10	46	8
Guidoboni and Comastri, 1997	YES	MCS	YES	YES	--	Europe	1	41	1
Hough et al., 2000	YES	MM	YES	map only	--	Canada and USA	3	213	--
Hough and Elliot, 2004	YES	MM	YES	YES	--	Canada and USA	1	77	--
Instituto Geografíco Nacional, 2010	YES	EMS	YES	YES	--	Europe	7	1393	7
Khilko et al., 1985	YES	MSK	YES	--	YES	Mongolia	1	19	--
Kingland et al., 2008	YES	MM	YES	YES	--	South America	1	100	--
Levret, 1991	YES	MSK	YES	YES	--	Europe	1	13	1
Martin and Szeliga, 2010	YES	EMS	YES	YES	--	South Asia and the Himalayas	22	677	22
						Southeast Asia and the Philippines	2	60	2
Meletti et al., 1988	YES	MCS	YES	YES	--	Europe	2	398	2
Mocquet, 2007	YES	EMS	YES	YES	--	South America	1	62	1
Musson, 2012b	YES	EMS	YES	YES	--	Australia, New Zealand and the South Pacific	2	12	1
NGDC-NOAA, 1985	YES	MM	YES	YES	--	Canada and USA	24	1334	24
Nishenko and Singh, 1987	--	MM	--	--	YES	Central America and Chiapas	1	13	--
Palme et al., 2005	YES	MSK	YES	YES	YES	South America	1	11	--
Palme et al., 2009	YES	MM	YES	YES	YES	South America	1	26	--
Peraldo and Montero, 1999	YES	MM	YES	map only	YES	Central America and Chiapas	1	21	--
Poirier and Taher, 1980	YES	MM	YES	YES	--	North Africa	1	1	--
						Turkey, the Middle East and Iran	7	30	--
Reid and Taber, 1919	YES	MM	YES	--	--	Antilles	1	1	--
Rengifo and Lafaille, 2000	--	MSK	--	map only	YES	South America	1	43	--
Robson, 1964	YES	MM	YES	--	--	Antilles	13	65	--
						South America	1	6	--
Sakellariou et al., 2010	YES	EMS	YES	YES	--	Europe	2	384	2
Salcedo and Castaño, 2011	YES	EMS	YES	YES	YES	South America	1	28	--
Sarabia et al., 2010	YES	EMS	YES	map only	YES	South America	1	17	--
Sbar and DuBois, 1984	YES	MM	YES	YES	--	Mexico	1	171	--
Sbeinati et al., 2005	YES	EMS	YES	map only	--	Turkey, the Middle East and Iran	18	183	4
Shebalin (ed.), 1977	YES	MSK	partial	--	YES	China	1	19	--
						Europe	15	301	15
						Russia and Central Asia	6	150	3
Shebalin and Tatevossian, 1997	--	MSK	--	--	--	Russia and Central Asia	6	73	--
						Turkey, the Middle East and Iran	42	408	--

Study						GEH Archive			
Dataset	Int.	Scale	Place names	Place coordinates	Iso-seismals	Area	EQs	MDPs	Demo
Sism. Hist. Ven., 2011	YES	MCS	YES	YES	--	South America	1	1	--
SICAT, 2011	YES	MM & EMS	YES	YES	--	Central America and Chiapas	1	18	--
						South America	8	171	--
Singh et al., 1996	YES	MM	--	map only	--	Mexico	1	20	--
SisFrance, 2010	YES	MSK	YES	YES	--	Antilles	38	446	38
						Central America and Chiapas	2	6	2
						Europe	2	72	2
						South America	4	48	4
Sousa Moreira, 1984	YES	MM	YES	YES	YES	Europe	2	256	2
Suarez and Albini, 2009	YES	MM	YES	YES	--	Mexico	1	11	--
Suarez, 2006	YES	MM	YES	YES	--	Central America and Chiapas	2	35	--
						Mexico	36	942	--
Tatevossian and Albini, 2010	YES	EMS	YES	--	--	Europe	7	12	7
Tatevossian et al., 2012	YES	MSK	YES	YES	--	Russia and Central Asia	4	21	4
Tatevossian and Mokrushina, 1998	YES	MSK	YES	YES	--	Europe	2	162	2
Tavera et al., 2001	YES	MM	YES	YES	--	South America	43	292	--
Taxeidis, 2003	YES	EMS	YES	YES	--	Europe	6	52	6
Tello and Perez, 2005	YES	MM	YES	--	YES	South America	1	35	--
Tomblin and Robson, 1977	YES	MM	YES	--	--	Antilles	7	21	--
Toppozada et al., 2002	YES	MM	YES	--	--	Canada and USA	3	27	--
Toppozada and Borchardt, 1998	YES	MM	YES	--	--	Canada and USA	1	9	--
Torres-Vera, 2010	YES	MM	--	YES	--	Mexico	11	94	--
University of Thessaloniki, 2003	YES	MM	YES	YES	--	Europe	56	334	56
						Turkey, the Middle East and Iran	4	29	4
Bozkurt et al., 2007	YES	JMA	--	YES	--	Japan and Korean peninsula	51	1477	43
Viquez and Camacho, 1993	--	MM	--	--	YES	Central America and Chiapas	1	11	--
White, 1985	YES	MM	YES	--	--	Central America and Chiapas	1	37	--

2 Analysis of the Archive Contents by Geographical Area

Thorough and comprehensive investigation of materials available for each region have filled in a number of gaps in the record that existed at the beginning of the project. Inevitably, though, the end product is still uneven: in different parts of the world the situation varies widely.

In the following pages, a detailed report of what has been identified, considered and inventoried is supplied in descriptive form. The chapter is divided into twelve geographical regions, chosen for historical and geographical considerations, without tectonic or political significance.

2.1 A global perspective

The idea of studying the earthquake history of the world is not a completely new one. It can be dated back at least as far as Marcello Bonito, who in his 1691 "Terra Tremante" gathered and discussed records from both the Old and the New Worlds, and from the Far East including earthquakes from China and Japan. Previous European authors had confined themselves to European earthquakes, working largely from Classical authors.

Much more familiar to many researchers in this field are the 19th century compilations by Karl Ernst Adolf von Hoff, Robert Mallet and Alexis Perrey. As will be seen these authors, Perrey and Mallet particularly, are still at the very root of the contents of many earthquake catalogues in the world.

While there is no space in this report for a complete retrospective of modern global earthquake catalogues, it should be mentioned at the outset of this chapter that the Global Historical Earthquake Archive, fully owes much to late 20th century-early 21st century initiatives adopting the same global perspective in describing the earthquake history of the world. Two important milestones are the *International Handbook of Earthquake and Engineering Seismology* (Lee et al., 2002), and the Proceedings of the 21st Course of the International School of Geophysics, Erice-Sicily (Italy), 1-7 July 2002, published as a volume called *Investigating the Records of Past Earthquakes* (Albini et. al., 2004).

The two volumes of the IASPEI Centenary Handbook (Lee et al. 2002) include a survey of the state-of-the-art of seismology around the world, with special attention to historical and macroseismic studies. Contributions were sought at a national level, with seismologists of different countries invited to compile a précis of their local seismicity. These two imposing volumes are complemented by three CD-ROMs, supplying extended versions of some contributions and more data. Amongst the materials included, there are the two lists of "Deadly Earthquakes in the World" (1400-2000) compiled by T. Utsu. Though these were the effort of a single person, they are still among the most reliable contributions on the world seismicity from a global perspective.

The *21st Course ot the International School of Geophysics* was held on 1-7 July 2002 at the "Ettore Majorana Foundation and Centre for Scientific Culture", Erice-Sicily (Italy), and was devoted to the Workshop "*Investigating the Records of Past Earthquakes*". Researchers from more than thirty different countries throughout the world and different areas of expertise discussed ongoing initiatives in the field of historical earthquake studies. The list of invitees was specifically compiled with the aim of attracting the lead experts from every region, so that the discussion could be truly representative at a global level. In the introduction to the published proceedings, the editors write:

"*The situation facing those who would reconstruct the earthquake record of past centuries varies from country to country, not only as regards the material available for study, but also reflecting the differing traditions and opportunities relating to earthquake studies in the past: in some countries the modern earthquake historian has a pre-existing fabric of catalogues on which to build; in others it is necessary to start almost from scratch … Even the organisation of such a Workshop proved to be a considerable task. Without pre-existing lines of communication between the historians and seismologists working in this field, it was often a matter requiring some research and enquiry to determine who were the leading experts who could be invited for each country*" (Albini et al., 2004).

The preparation of the proceedings took two years, and included peer reviewed papers, not just by those who actually attended the workshop. This allowed the editors to include in the volume a map (Figure 1) showing the countries represented in the papers, even if such countries are not included in the list of the participants in the workshop.

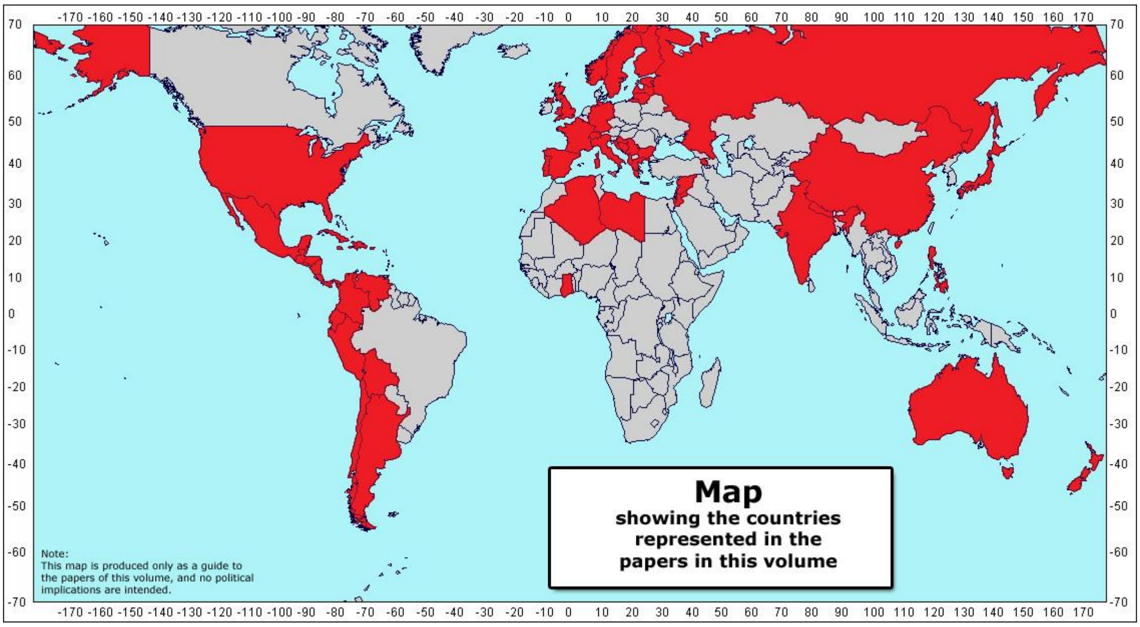


Figure 2.1 Map showing the countries represented in the volume edited by Albini et al. (2004)

The proceedings of this workshop are still the most updated overview of the historical seismological studies around the world. Furthermore the workshop succeeded in giving an impulse to a series of national and international initiatives, and finally to the proposal to GEM for the compilation of a Global Earthquake History.

In introducing this chapter, one last observation is worthwhile. Surveying previous compilations of earthquake studies with a global perspective indicates that there has been hitherto an imbalance between those earthquakes and countries that have been heavily studied, and those that have been relatively and neglected.

The Archive compiled in the framework of the Global Earthquake History project aims as far as possible to overcome such an imbalance, not only by presenting a global archive, but especially establishing a common methodology and language, to face a very important challenge in better understanding seismic hazard in the future.

2.2 The Americas

The seismicity of the Americas provides a contrast between areas of high seismicity, mostly along the plate boundaries of the Pacific margin in the west, and lower seismicity in the stable continental regions of the eastern parts of both North and South America. The plate boundary fault system includes both subduction zones (Alaska, Mexico and Central America, the Lesser Antilles, the west coast of South America) and strike-slip zones (California, parts of the Caribbean). Moderate to strong crustal seismicity is also encountered in the inter-Andean valleys and the volcanic chain faults systems in Central America. The stable continental parts of Eastern North America have been subject to occasional strong earthquakes, even exceeding 7 Mw, whereas the equivalent regions of South America show no such events, possibly indicating that intraplate seismicity in North America has a connection with glacial isostatic rebound.

2.2.1 Canada and United States of America

The earthquake history of North America is shorter than that of other American regions.

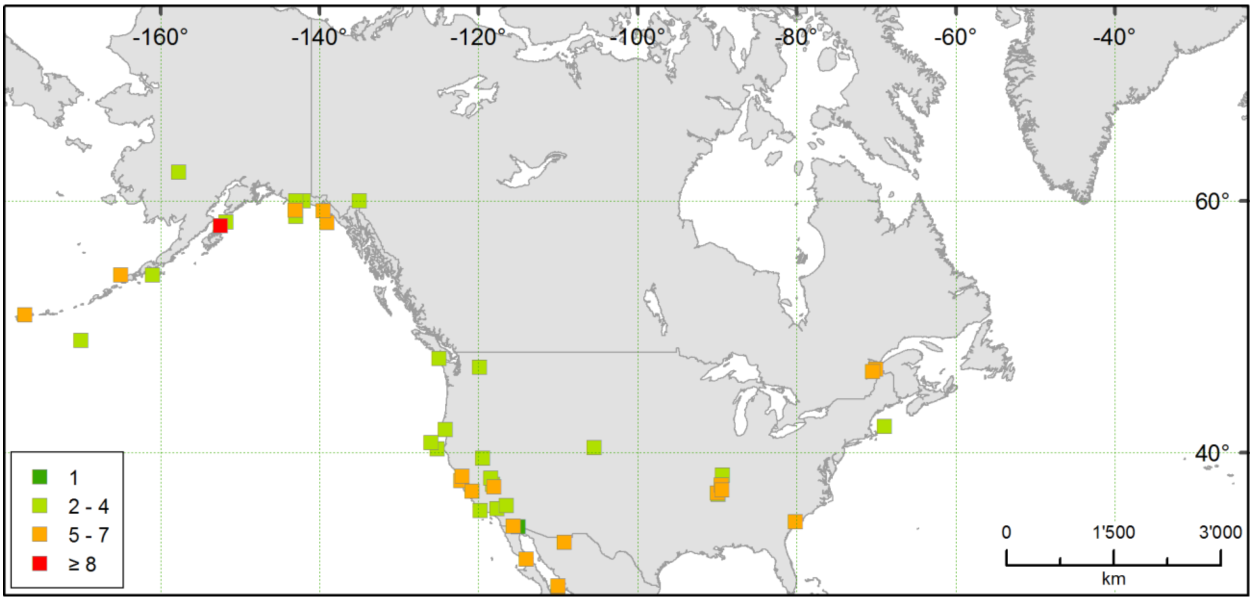


Figure 2.2 Earthquakes in GHEA (1000-1903) in Canada and USA, and number of records per earthquake

Nevertheless the first entry of the Global Earthquake History archive dates as back as 1663 (Quebec, Saguenay), this earthquake being so important to be reported even by the Italian compiler Bonito (1691), among others. Much has been written on this earthquake, and the most authoritative paper is the one by Gouin (1994), who recognises that little can be said about the parameters of this earthquake.

Initial material on the earthquake history of Canada is found in Smith (1962); for the Cascadia area in Ludwin and Qamar (1995); and for Quebec the best and most complete source is the extensive work by Gouin (2001), recently supplemented by two papers, one on the 1663 earthquake (Ebel, 2011) and another on the 1870 earthquake (Ebel et al., 2013). The state-of-the-art of the most significant earthquakes is found in Lamontagne et al. (2007; 2008). The gigantic earthquake (Mw 9.0) of 1700, is the object of several dedicated studies (see for instance Satake et al., 2003). This earthquake was unearthed initially from the analysis of the historical tsunamis which affected Japan, and then confirmed from oral history and palaeoseismic investigation.

The principal modern compilation for the US is that by Stover and Coffmann (1993). Earlier studies include the Earthquake Intensity Database (NGDC-NOAA, 1985) that collects damage and felt reports for over 23,000 earthquakes in the U.S., nearby territories, and areas of Mexico and Canada in the time-window from 1638 to 1984. The total number of MDPs is 157,015, of which 2,550 MDPs before the year 1900. To be mentioned is also a remarkable paper by Agnew and Sieh (1978) on the 1857 Fort Tejon, California earthquake. The history of the investigation of the earthquake history of California is given by Toppozada and Branum (2004), which also describes the work behind the compilation on the earthquake history of California with Mw≥5.5, published by Toppozada et al. (2002). Among other interesting results, they write that:

> "*The destructive 1989 Loma Prieta earthquake provided the impetus for Toppozada et al. (1996) to study the San Francisco bay area earthquake history in detail. This led to a better understanding of the major 1838 San Andreas fault event and to a radical re-evaluation of the 1836 «Hayward Fault earthquake» by Toppozada and Borchardt (1998) …*"

Bakun (1999; 2000; 2006a; 2006b), Bakun et al. (2002) and Bakun and Hopper (2004) investigated many individual North American earthquakes, assessing Macroseismic Data Points (MDPs) and determining their parameters using the method by Bakun and Wentworth (1997). Most of these results are reported in the compilation by Felzer and Cao (2008), who present alternative estimates for a number of events. Similar analyses were performed by Hough et al. (2000), Hough and Elliot (2004) and Hough and Hutton (2008). The catalogues by Wang et al. (2009) and Kagan et al. (2006) simply recompile data available from other sources.

As for other regions, initial material on Nevada earthquakes can be found in de Polo et al. (1997). Doser (2006) revised the seismicity of Alaska, which appears in most compilations starting with the great Yakutat earthquake of 1899.

The USGS website has a section entitled "Historic Earthquakes in the United States and Its Territories", which also contains data and parameters on some tens of historical earthquakes (US Geological Survey, 2011).

The recent CEUS (2012) catalogue provides homogeneous parameters assessment for the earthquakes of Central-Eastern US, including Eastern Canada. The development of this catalogue, compiled for the CEUS SSC (Seismic Source Characterisation) Project, included: catalogue compilation, assessment of a uniform size measure to apply to each earthquake, identification of dependent earthquakes (catalogue declustering), and an assessment of the completeness of the catalogue as a function of location, time, and earthquake size.

Finally, for the Hawaiian islands, the main reference is the work by Wyss and Koyanagi (1992); also worthy of mention is the report by Klein and Wright (2000).

2.2.2 Mexico (excluding Chiapas)

The sequence of initiatives for the compilation of the earthquake history of Mexico is described by Garcìa-Acosta (2004). Orozco y Berra (1887-1888) made the first systematic compilation of Mexican historical earthquakes. The first modern isoseismal compilations and catalogues were made available by Figueroa (1963; 1970), Lomnitz (1974) and Nuñez Cornú and Ponce (1989). Singh et al. (1981) determined the parameters of some 19th century earthquakes from isoseismal maps. After the destructive earthquake of 1985, the lack of a modern national catalogue, based on reliable historical information, became apparent. It became, therefore, "a joint interest among historians, anthropologists, ethnohistorians and seismologists to construct a reliable and multidisciplinary catalogue" (Garcìa-Acosta, 2004). A short time later, in 1987, the joint effort yielded its first product with the publication of a book by Rojas Rabiela et al. (1987). The title of this book, "Y volvió a temblar" (And it trembled again), is reminiscent of the first sentence of many colonial documents that reported earthquake occurrence. One year later, in 1988, the second product appeared as García-Acosta et al. (1988).

Research continued for several years, the most recent publication being “Los sismos en la historia de México” (Earthquakes in Mexican History) covering the period of over 450 years of Mexican earthquake history, from 1455 to 1913 (García-Acosta and Suárez, 1996).

Building on this, Zúñiga et al. (1997) compiled the Mexican section of the catalogue by Tanner and Shepherd (1997) for the “Seismic Hazard in Latin-America and the Caribbean Project”, promoted by the Pan American Institute of Geography and History. This catalogue was released to the GSHAP Programme (Giardini and Basham, 1993).

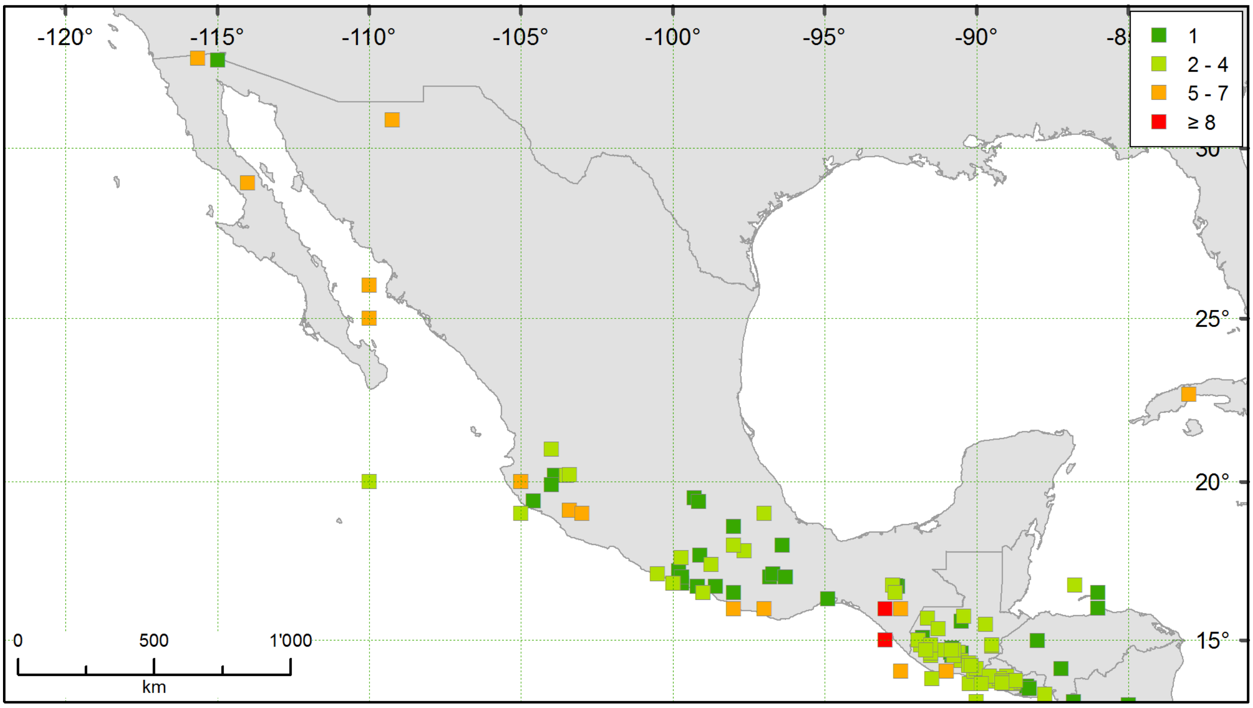


Figure 2.3 Earthquakes in GHEA (1000-1903) in Mexico (excl. Chiapas), and number of records per earthquake

Studies on individual historical earthquakes are also available (see for instance Suárez et al., 1994; Singh et al., 1996; Molina del Villar, 2004; Suarez and Albini, 2009), with a concentration of investigation on the 1887 Sonora earthquake (Sbar and Dubois, 1984; Suter, 2006; Bakun, 2006b). Torres-Vera (2010) compiled intensity data points and maps for eleven large events from 1575 to 1837, determining earthquake parameters from those data. A project for the systematic compilation of a “Mexican historical catalogue (until 1912)” was started in 2006 (Suarez, 2006) and is currently in progress at UNAM (Suárez, 2012, pers. comm. to GEH). The aim is to compile intensity data and, where possible, the magnitude and epicentres of historical earthquakes, from the wealth of information in the mentioned book “Los sismos en la historia de México” (García-Acosta and Suárez, 1996) and other published sources.

2.2.3 Central America and Chiapas

Turning to Central America, which for the purposes of this project can be considered to include the state of Chiapas, the history and the state-of-the-art of the historical earthquake investigation, as it stood at 2004, is described in detail by Montero and Peraldo (2004):

> *“Research and compilations of the Central American destructive earthquakes which occurred since the Spanish Conquest in the 16th century up to 1900 are found in different works. At the*

Central American level, the principal compilations came from Montessus de Ballore (1888), Sapper (1925), Díaz (1933) and Grases (1974). At national level we mention González (1910) for Costa Rica; Lardé (1960) and Martinez and Maximiliano (1978) for El Salvador and Kirkpatrik (1920) for Panamá. All the previous works were descriptive catalogues compiling historical earthquake information, but they do not include intensities or isoseismal estimates or define focal parameters obtained from macroseismic information".

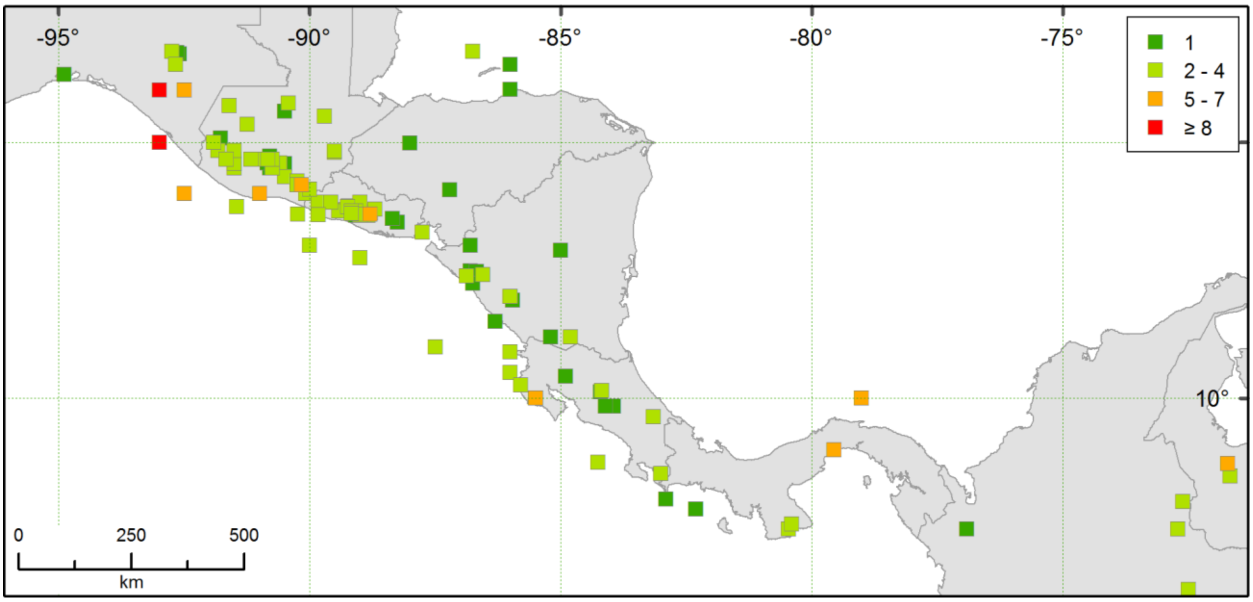


Figure 2.4 Earthquakes in GHEA (1000-1903) in Central America and Chiapas, and number of records per earthquake

Parametric catalogues started first in Nicaragua (Leeds, 1974), as a follow-up of the 1972 Managua earthquake. Then they were compiled for Honduras (Sutch Osiecki, 1981), Costa Rica (Miyamura, 1980; Montero, 1989) and Panama (Víquez and Toral, 1987). Rojas (1993) and Rojas et al. (1993) produced the main seismological parametric catalogue currently existing at a regional level. The compilation by Tanner and Shepherd (1997) also covers this area, though this is not mentioned by Montero and Peraldo (2004).

Feldman (1985; 1986; 1993) gathered a large number of new primary documents about destructive earthquakes occurred in Guatemala and in Central America between 1500 and 1899, with input from R.A. White, who was involved in the study of Guatemala – El Salvador earthquakes. Feldman compiled descriptive catalogues, not including intensity data or isoseismal maps, upon which White at al. (2004) based their work on subduction earthquakes in the region.

Studies on individual Panama earthquakes were published by Pinilla and Toral (1987) and Camacho and Viquez (1993). Peraldo and Montero (1999) published an earthquake catalogue including information obtained from archives and other different sources. They studied Central America destructive earthquakes occurred from 1469 to 1899 and obtained new seismological interpretations, such as intensity data points, isoseismal maps and macroseismic focal parameters that were collected into a digital database. Unfortunately, the data points no longer exist. Much other important and useful information is reported by Montero and Peraldo (2004).

Regarding earthquakes at the turn of the century, beside the work of Abe and Noguchi (1983; 1983a), Ambraseys and Adams (2001) provides descriptions and intensity data for the earthquakes between 1898 and

1995. For the period 1900-1903, as in the other regions, the input catalogues have been integrated with entries from the "Centennial Catalog" by Enghdal and Villaseñor (2002).

Recently, a new round of investigation started in the frame of the RESIS I and II projects, under the auspices of the Norway Cooperation Agency (NORAD) and the "Centro de Coordinación para la Reducción de Desastres en America Central" (CEPREDENAC). Seismologists from all Central America countries, with the exception of Belize, have been involved in these studies. The aim was to obtain a new evaluation of seismic hazard for the region, and a new regional seismic catalogue was compiled as part of the input data needed. The catalogue of the largest earthquakes reported in the region, with Mw≥7 and/or macroseismic intensity I(MM) ≥ 8 was published in Benito et al. (2012). Short summaries and the parameters of some earthquakes are also found in Benito and Torres (2009), although not always coinciding with Benito et al. (2012), for example, for Guatemala.

2.2.4 Antilles

Vogt (2004) describes the historical earthquake investigation of the so-called "West Indies", from the classical seismological compilations of Perrey (1846), Poey (1857), and Salterain y Legarra (1884), to the pioneer compilation of Scherer (1912) and Taber (1920; 1922) for Haiti and Jamaica, and the studies by Reid and Taber (1919) on the 1919 earthquake of Puerto Rico, and Reid and Taber (1920) for the Virgin Islands (1867-1868) ones.

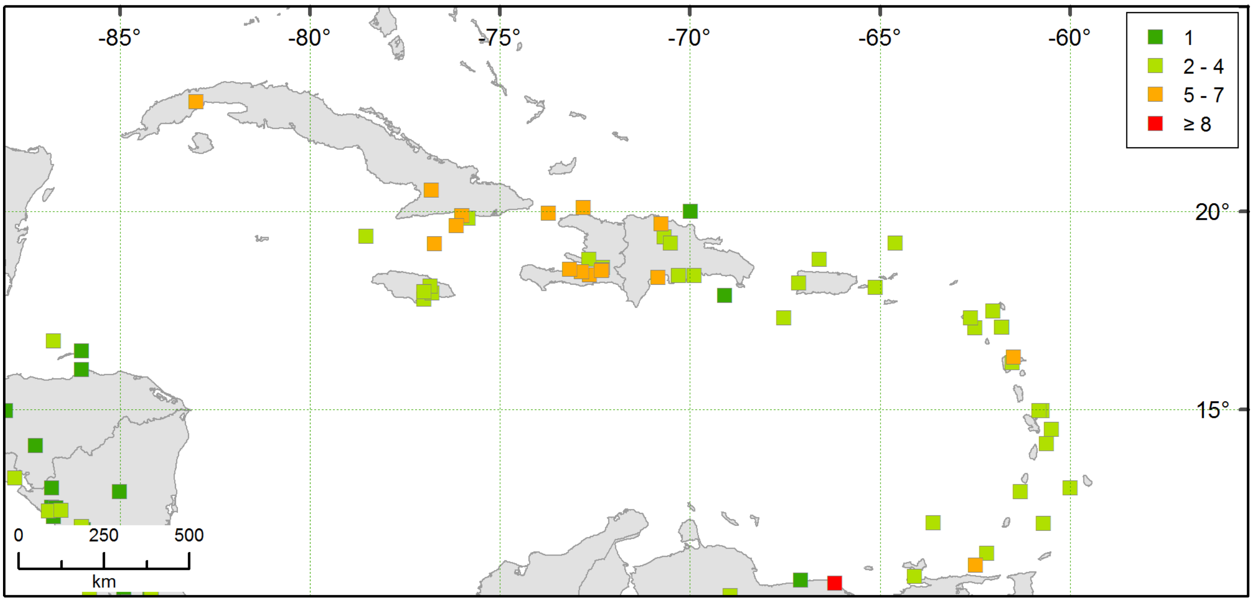


Figure 2.5 Earthquakes in GHEA (1000-1903) in Antilles, and number of records per earthquake

Modern regional catalogues started with the works by Robson (1964) for the eastern Caribbean; Tomblin and Robson (1977) for Jamaica and the Greater Antilles; Chuy and Rodríguez (1980) and Chuy and Álvarez (1988) for Cuba and Hispaniola; Feuillard (1988) for the French islands and Grases (1990) for the entire region.

Vogt (2004) does not mention the compilation by Iñiguez et al. (1975) for Hispaniola, nor that of Tanner and Shepherd (1997), known as IPGH/PAIGH catalogue, which was the product of a big probabilistic seismic hazard project for the Latin America and the Caribbean region, developed in collaboration with the GSHAP initiatives (Giardini and Basham, 1993). Though it can be mentioned that the Tanner and Shepherd (1997) catalogue is an elusive document, and subsequent studies often refer only to a conference paper describing the catalogue.

The catalogue was never published (despite it being referenced as a report), which would explain the reluctance of Montero and Peraldo (2004) and Vogt (2004) to mention it.

Since it covers a wide region, Tanner and Shepherd (1997) is still the reference catalogue, although it contains a large number of duplications, due to the fact that it recompiled national catalogues. In addition, the magnitudes values (Mw), where available, were assigned by a variety of methods based on felt area and/or maximum intensity, which are not certain to be compatible.

More recently, macroseismic data and catalogues have been made available for Cuba and the Lesser Antilles. The publication of the catalogue by Alvarez et al. (1999), first, and the free access to the macroseismic Cuban dataset (Chuy, 1999) granted to GEH, allowed this project to use information not available until now. In addition, recent studies by Cotilla (2003) and Cotilla and Cordoba (2010a; 2010b; 2011) bring in new information about Cuban historical earthquakes.

The SisFrance online database (i.e. the French data bank for the West Indies and the Caribbean Sea, SisFrance, 2010) provides macroseismic information (epicentral location, intensity, macroseismic data points, but no magnitude value) for the so-called “overseas regions and territories” of France, including the Lesser Antilles and part of the Greater Antilles and northern South America.

The Haiti disaster in 2010 triggered some investigations on historical earthquakes in Hispaniola and Puerto Rico (Bakun et al., 2012; ten Brink et al., 2011; Flores et al., 2012). Flores et al. (2012) is the most recent and complete compilation of historical earthquakes in the north-eastern Caribbean region. This compilation provides descriptions of damage for each event, with assigned intensities and coordinates of places where the earthquake caused damage or was felt. These data were used by Bakun et al. (2012) and ten Brink et al. (2011) to determine epicentral/hypocentral coordinates of historical events in this area. A recent paper (Hough, 2013) is focused on the 1843 Lesser Antilles event.

For most earthquakes of this region (35 out of 37), Macroseismic Data Points are available.

Although the situation has improved since 2004, it is worthwhile remembering that Jean Vogt was not happy about the available knowledge and forecasted, well before the 2010 Haiti earthquake, that:

> ”*Besides the weight of shortcomings, not all of the numerous valuable arguments and suggestions given by historical seismology are properly implemented for the needs of seismology as a whole, for instance the analysis of earthquake sequences. Consequences could be disastrous in the case of the West Indies, with their major events, often at large intervals, easily forgotten, and seismic gaps. Despite the work done so far, over-research is not yet a problem for the historical seismology of the West Indies*” (Vogt 2004).

2.2.5 South America

In South America most of the large earthquakes are either: (a) crustal events of the inter-Andean valleys; or (b) shallow and deep earthquakes that occur along the South America margin, at the interface between the subducting oceanic Nazca plate and the overriding South American continental plate (Bilek, 2010; Taboada et al., 2000).

South America has a long tradition of earthquakes description, which reached some peaks in correspondence with the largest and deadliest events, such as the 1530 Cumaná (Venezuela), 1610 Bailadores (Venezuela), 1730 Valparaiso (Chile), 1746 Lima, 1766 Cumaná and Trinidad and Tobago, 1785 Bogotá, 1797 Riobamba (Ecuador), 1812 Caracas, 1868 Arica (Chile), 1875 Cúcuta (Colombia), 1894 San Juan Province (Argentina), among others. The works by Perrey (1858) and the monumental compilations by Boussingault and Roulin (1849) and Montessus de Ballore (1911; 1912; 1916) supplied the first comprehensive view of the seismic history of the region. The first earthquake in the CERESIS (1985) catalogue is dated 1471, before the Spanish Conquest; the city of Arequipa, in its original site, was destroyed and all the inhabitants perished (Silgado, 1978).

An overview of the investigation performed in the last century is found in Giesecke et al. (2004), who recognises the contribution of the Jesuits to early seismology:

> *"Jesuit seismologists gave an outstanding contribution to the development of modern seismology in South America. Fathers Pierre Descotes, Luis Fernández and Ramon Cabré in Bolivia, German Saa in Chile and Peru, Rafael Goberna in Cuba and Colombia, Jesus Emilio Ramirez in Colombia, were part of a generation of Jesuits who played an important role in studying earthquakes in different parts of the world."*

In the 1960s to 1980s, some pioneer seismologists started investigating historical sources in detail (Grases, 1979; 1980; 1986; Ramirez, 1969; 1975; Egred, 1968; Silgado, 1968; 1985; Greve, 1964; Lomnitz, 1970; Kausel, 1979a; 1979b; Volponi, 1962).

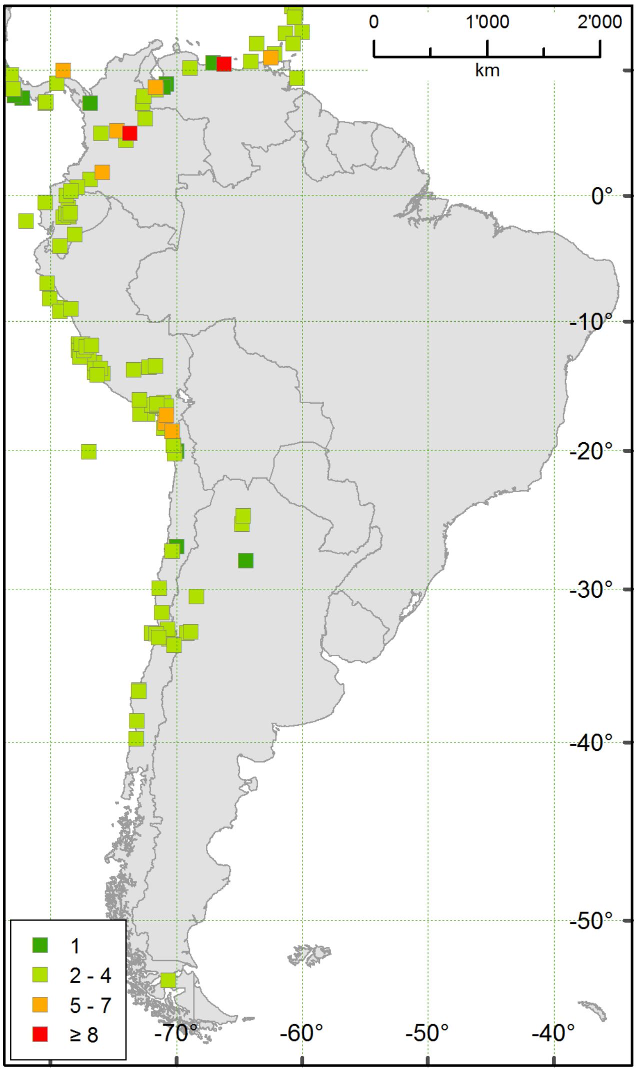


Figure 2.6 Earthquakes in GHEA (1000-1903) in South America, and number of records per earthquake

A big step forward was made in the frame of the SISRA (Programa para la Mitigación de los Efectos de los Terremotos en la Región Andina, Earthquake Mitigation Program in the Andean Region) project, which published 14 volumes mainly focussed on the determination of hypocentral parameters of earthquakes, and on the compilation of a catalogue and a macroseismic intensity database for the whole South American region. Historical compilations of destructive earthquakes of South America from 1530 to 1894 are published in volume 10, which contains information collected by Silgado (1978; 1985) in the archives of South America and Europe (Seville, Madrid, London, Paris, and Strasbourg). Finally, Silgado (1985; 1992) derived intensities of historical earthquakes in South America from an interpretation of the historical descriptive texts.

The CERESIS (1985) database includes the earthquake catalogue and the relevant macroseismic intensity database, which contains 16,318 intensity data points, in terms of MMI or MSK intensity scales, for 3,183 events. Appearing in 1996, it was the first online intensity database released on the Internet in the world (Rubbia, 2004). Although rather homogeneous, the database shows some problems across national boundaries, where some earthquakes appear twice with two distinct epicentres (see for instance the great 1868 Arica earthquake, well known not only in the scientific literature). Intensity data points are not immediately usable, as the list of them for a single earthquake may contain two or even three entries for the same locality, resulting from different compilers' assessments or uncertain intensity assessment, such as 7-8, split into two entries.

An updated version of the catalogue (CERESIS, 1995) was released to the PILOTO program (Dimaté et al., 1999), launched in the frame of GSHAP (Giardini and Basham, 1993).

After 1985, historical investigations have been extensively performed for some earthquakes or regions of Venezuela. Examples include Palme et al. (2005) for the Merida Andes, Moquet (2007) for the 1766 Cumaná and Trinidad earthquake, Rengifo and Lafaille (2000), and Kingland et al. (2008) for the 1894 Andean earthquake, and Choy et al. (2010) and Altez (2005a; 2005b; 2005c; 2010) for the large and complex 1812 Venezuela earthquake. An overview of the investigations performed on historical earthquakes in Venezuela is found in Altez and Grases (2004). Data are available at Sismologia Historica de Venezuela (2011) and SICAT (2011).

In Colombia, an overview of the investigations performed up to 2003 can be found in Espinosa Baquero et al. (2004). Espinosa Baquero (2003) compiled a macroseismic database for historical earthquakes from 1550 to 1830. Together with intensity data points, descriptions of earthquake effects at single places, and information about the historical sources are provided. In addition, this work provides information about the earthquake history of Popayán and Bogotá, describing historical earthquakes effects in the "Antiguo Caldas y El Norte del Valle" (Coffee region in Central Colombia), and for some earthquakes such as the 16 March 1644 Tunjuelo. Studies of historical earthquakes in the Colombian Eastern Cordillera has been released by Dimaté et al. (2005); the largest earthquake that hit Santafe de Bogotá in Spanish colonial times in 1785 has been studied by Sarabia Gomez et al. (2010), Salcedo and Castaño (2011), and Gómez Capera et al. (2012a).

For Ecuador the only available study concerns the 1797 Riobamba earthquake (Egred, 2004). More studies devoted to the historical crustal earthquakes of "Sierra of Ecuador" (Andean Cordillera) have been summarised and used by Beauval et al. (2010), although the relevant Macroseismic Data Points are not published. The recently published catalogue by Beauval et al. (2013) has also been included in the archive.

Most of the mentioned studies have been used to re-assess earthquake parameters, in some cases with modern techniques (Giesecke et al., 2004; Palme et al., 2005; Dimaté et al., 2005; Palme et al., 2009; Beauval et al., 2010).

For Peru, Chile and Argentina not much recent historical investigation is available. Tavera et al. (2001) updated the CERESIS (1985) catalogue for Peru by integrating the available information from other national catalogues. Dorbath et al. (1990) assessed the size of fourteen "large and great historical earthquakes" in Peru from the rupture length, determined in turn from the size of the intensity 8 isoseismal areas. For Chile the most comprehensive overview is provided by Lomnitz (2004) who updated his 1970 work without new investigation, and supplying short summaries, epicentral areas and magnitudes for 41 events. Recently, Udías et al. (2012) published the results of a detailed historical investigation on the four largest historical earthquakes of central Chile in the seventeenth and eighteenth centuries: 1647, 1657, 1730, and 1751.

For Argentina an interesting paper by Tello and Perez (2005) on the 1894 earthquake provides macroseismic data points, which, although less than those in the CERESIS database (1985), are better documented. Among the few remaining earthquakes of the area, information from INPRES (2012) is available on the event on 4 July 1817 in Santiago del Estero.

No earthquakes within the GEH magnitude range have been found in the remaining countries of South America.

2.3 Europe

Europe has a very long tradition in the investigation of historical earthquakes, although it is not one of the most seismic continents of the world. The evolution of historical earthquake investigation in Europe is long, and difficult to be summarised as a whole. The political and cultural fragmentation of Europe, both in the past and present has led to differences in the way historical earthquakes have been recorded across the continent. This has affected research on historical earthquakes and, consequently, the state of knowledge. Even in recent years, although a number of earthquake catalogues were compiled, updated and improved at national scales, the basic data and the methodologies used in their compilation were very different.

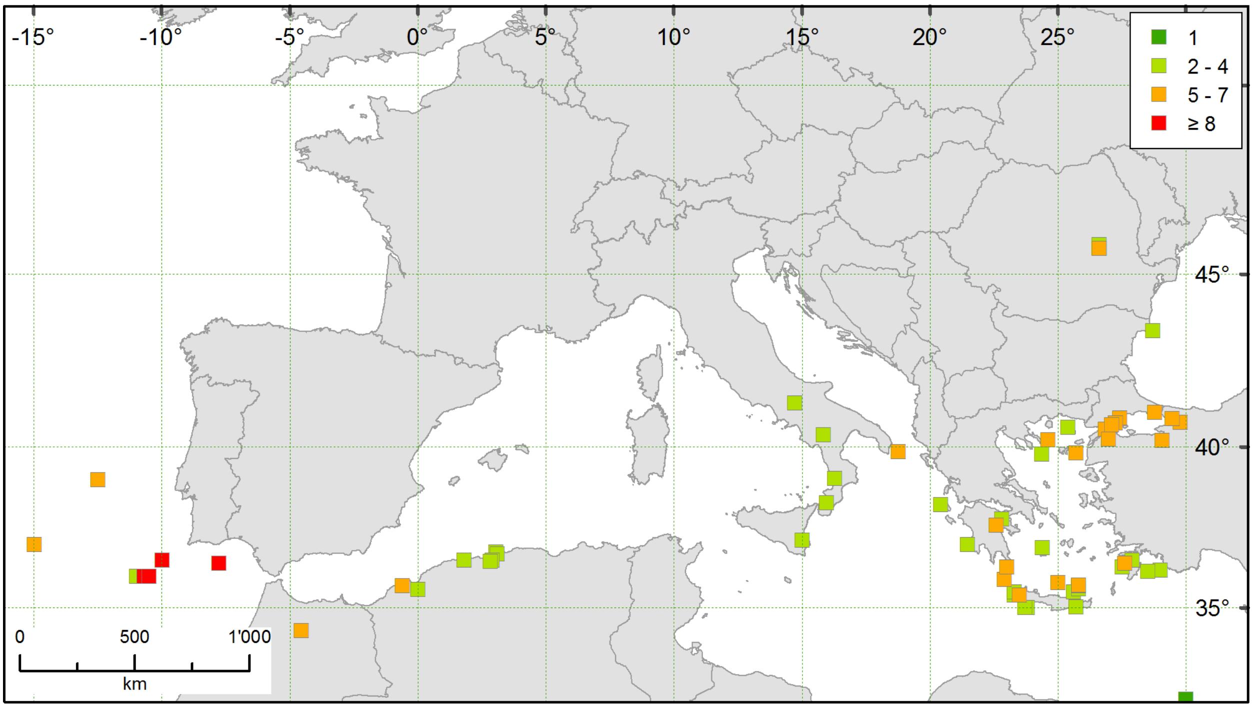


Figure 2.7 Earthquakes in GHEA (1000-1903) in Europe, and number of records per earthquake

Although the need for a homogeneous European earthquake catalogue has been recognised long ago, no modern, homogeneous, continent-wide catalogue, covering a sufficiently long time span was available until recently.

One of the first efforts in this direction was made by V. Kárník, but his prominent work was limited to the time-window 1800-1958 (Kárník, 1969; 1971), and the posthumous edition of the catalogue (Kárník, 1996) was only extended to 1990.

A "Catalogue of earthquakes of the Balkan region" (Shebalin et al., 1974) and an atlas of isoseismal maps (Shebalin, 1974) were among the results of the major "Balkan Project" promoted by the UNESCO.

As an initiative of the European Community, Van Gils (1988) started the harmonised compilation of both historical and recent seismic data provided by national catalogues, with the specific goal of producing "seismicity maps" for seismic hazard evaluation at nuclear power plants. The resulting catalogue, published as Van Gils and Leydecker (1991), spanned from the ancient times to 1981 and covered the twelve member countries of the European Community as of 1986. An "Earthquake Catalogue for Central and South-eastern Europe (342 B.C. - 1990 A.D)" was compiled by Shebalin and Leydecker (1998), as a complement to the "New catalogue of USSR" (Kondorskaya and Shebalin, 1982), and included two sections: i) an extended one, containing all the available determinations from the data sources investigated, and ii) a summary one, containing a unified estimate of parameters with uncertainty assessments. Grünthal and Wahlström (2003) published a catalogue for Central, Northern and Northwestern Europe (CENEC), covering the time-window 1300-1993, compiled assembling national catalogues with a geographical priority scheme, supplemented with data from specific studies. The geographical scope was Europe north of 44°N. Uniform Mw was assessed for all the earthquakes, through the conversion of the magnitude or intensity of the source catalogue, with published or specifically derived regressions. CENEC was later expanded to the years 1000 and 2004 (Grünthal et al., 2009) and the input catalogues were integrated with updated ones. A further development of CENEC consists of EMEC, the European Mediterranean Earthquake Catalogue (Grünthal and Wahlström, 2012), which also covers southern Europe and the Mediterranean area and spans from 1000 to 2006.

The common feature shared by all the above-mentioned catalogues is that they relied on previous catalogues, putting together parameters that actually derive from very different elaborations of very different background data.

Van Gils (1988) was aware of such limitations and he clearly stated that future efforts should: i) systematically collect macroseismic data, and; ii) homogeneously gather and treat historical data, with particular reference to earthquakes with effects across national borders. To turn these ideas into practice, the EC project RHISE, "Review of Historical Seismicity in Europe", 1989-1993 (Stucchi, 1993; Albini and Moroni, 1994) provided some guidelines and recommendations (Stucchi, 1994; Camassi et al., 1994).

In 1995-1998 the EC project "A Basic European Earthquake Catalogue and a Database (BEECD)" was funded with the aim of establishing and testing the methodologies for compiling a parametric earthquake catalogue of Europe starting from the creation of a database of primary data (Stucchi and Camassi, 1997; Albini and Stucchi, 1997; Stucchi, 1998).

In the same years, institutions in Italy, France, and Switzerland started building up national archives of background information and/or macroseismic datapoints (MDPs) and compiling from these their own national catalogues with formalised, transparent procedures for determining earthquake parameters (Monachesi and Stucchi, 1997; Camassi and Stucchi, 1997; SisFrance, 2001; Swiss Seismological Service, 2002). These databanks, available on the web since their establishment, have been subsequently maintained and updated on a regular basis, but they remained alone on the European scene for a more than a decade.

In 2006, in the framework of the European Commission project NERIES ("Network of Research Infrastructures for European Seismology"; http://emidius.mi.ingv.it/neries_NA4), a module was dedicated to establishing a distributed archive of historical earthquake data (AHEAD) 1000-1899 and providing the methodologies for homogeneously assessing earthquake parameters from historical macroseismic data.

The resulting Archive of Historical Earthquake Data (AHEAD; http://www.emidius.eu/AHEAD/) inventories and makes available the results of the historical investigations compiled in a format suitable for being used by seismologists: a report or a paper providing an overview of the investigation and the distribution of the effects; a map and/or a list of MDPs, and so on.

AHEAD is based on:

- the most recent versions of the European online archives providing MDPs, such as the Swiss ECOS-02 (Swiss Seismological Service, 2002) and ECOS-09 (Fäh et al., 2011), the latest version of SisFrance (BRGM-EDF-IRSN/SisFrance, 2010), and the Italian DBMI04 (Stucchi et al., 2007) and DBMI11 (Locati et al., 2011);
- the macroseismic intesity databases made available for the first time in the framework of the NERIES Project, such as those of the United Kingdom (British Geological Survey, 2010), Greece (University of Thessaloniki, 2003; University of Athens, 2010), Iberian region (Instituto Geografíco Nacional, 2010), and Catalunya (Institut Geològic de Catalunya, 2010),
- a number of recent historical studies on individual earthquakes;
- the main current catalogues and the relevant background studies, when existing and available.

The compilation of AHEAD recognised the fact that different studies or catalogue may refer to the same earthquake, providing coinciding or conflicting information. Studies referring to the same earthquake have been grouped case by case, examining and comparing their content. In such a way, the following problems have been critically solved:

- duplications: earthquakes with different origin time and/or location, due to conflicting interpretations of the historical record(s) in different studies, but basically the same event;
- fake events: usually created by the incorrect interpretation of historical records referring to other natural phenomena, such as landslides or storms;
- earthquakes missing in one or more catalogues.

AHEAD contains data retrieved from more than 300 different sources dealing with 4722 earthquakes with approximately Io > 5 and/or Mw > 3.5, and covers the territories belonging to EU member states and neighbouring areas up to 32°E.

For about 51% of events, the archived studies provide MDPs (42358 macroseismic data points), derived from databases or literature. For 40% of the earthquakes it was possible to at least retrieve a study without MDPs, while for the remaining 9% no study could be found. For these latter events only the entries from national or regional catalogues are available, without any possibility of tracking the supporting background information.

In 2010 the European Commission project SHARE ("Seismic Hazard Harmonisation in Europe"; http:// http://www.share-eu.org/) required the compilation of a homogeneous earthquake catalogue based on the most updated knowledge, compiled with transparent and repeatable procedures, and with uncertainty estimates of the main parameters, to be built on the experiences of NERIES and CENEC. The result was named SHEEC ("SHARE European Earthquake Catalogue").

The 1000-1899 portion of SHEEC relies entirely upon the best available background data stored in AHEAD, and the most updated methodology for deriving earthquake parameters from the MDPs gathered by the NERIES project. The catalogue has been recently published as Stucchi et al. (2012). The time-window 1900 onwards was compiled according to the methodology used for CENEC, time-window which was later developed into EMEC, the European Mediterranean Earthquake Catalogue (Grünthal and Wahlström, 2012).

To accomplish the requirements of SHARE, for the 1000-1899 portion, SHEEC earthquake parameters are derived from the MDPs provided by AHEAD, and processed with updated, repeatable procedures, regionally calibrated against a set of recent instrumental parameters. From the same recent data, a set of epicentral intensity-to-magnitude relations has been derived, with the aim of providing another set of homogeneous Mw estimates for the historical earthquakes. To maximise the homogeneity of the final epicentral location and Mw, they are obtained from blending the two determinations.

The philosophy adopted in the Global Earthquake History project for the compilation of GHEA and GHEC follows that of AHEAD. For the European area the Global Archive entirely coincides, for the period 1000-1899, with AHEAD, which contains 69 earthquakes with Mw ≥ 7 according to SHEEC. For these earthquakes, AHEAD contains 43 studies, the majority of which have MDPs.

The earthquakes included are, of course, located in Europe's most seismic areas: the northwestern Atlantic Ocean, Southern Italy, the Hellenic Arc, the Marmara Sea, and the Vrancea Region, and represent the largest ever observed in the continent. However, it is interesting to notice that, despite the quality and the long tradition of historical earthquake research in Europe, ten of these earthquakes are, even today, still not supported by MDPs and, in particular, most of those in Portugal and Vrancea are known only from parametric catalogues. Moreover, the location and size of the two strongest historical earthquakes, the 8 August 1303 "Crete" and the 1 November 1755 "Lisbon" events, are still today debatable, despite many careful studies.

The Global Archive also includes two events with M ≥ 7 in Europe in the time window 1900-1903, which were out of the AHEAD time-window. For these two earthquakes, 31 March 1901 (Bulgaria/Black Sea) and 11 August 1903 (Greece), only entries from parametric catalogues have been retrieved.

2.4 North Africa

The African continent is often, with good reason, divided into a northern part, facing the Mediterranean, and a southern, Sub-Saharan part. All of North Africa has been inhabited by literate people since Roman times, and some parts even before, whereas Sub-Saharan Africa has no pre-European written history. Even in colonial times, penetration of the African interior by explorers was limited. From the standpoint of historical seismology, Africa lives up to its reputation as the "Dark Continent".

In this report, Africa is represented by two sections, the first on North Africa, followed by a second on Sub-Saharan Africa. In both cases, the sections are subdivided into regional components.

2.4.1 The Maghreb

The seismicity of the entire Maghreb region has been included in some catalogues dealing with the Iberian Peninsula, such as Galbis Rodriguez (1932; 1940) and Mezcua and Martinez Solares (1983), which mainly relied on earlier historical compilations published in Europe (e.g. Perrey, 1847). The seismicity of North Africa is also described in Montessus de Ballore (1906).

The "chronological list" of earthquake effects at different places all over the southern Mediterranean area by Poirier and Taher (1980) also covers the Maghreb region and Southern Spain. The study contains information on the seismicity between the 7th and 18th century from Arabic sources (mainly unpublished manuscripts), but it recognizes an incomplete sampling of the documents in those areas and only ten events are included.

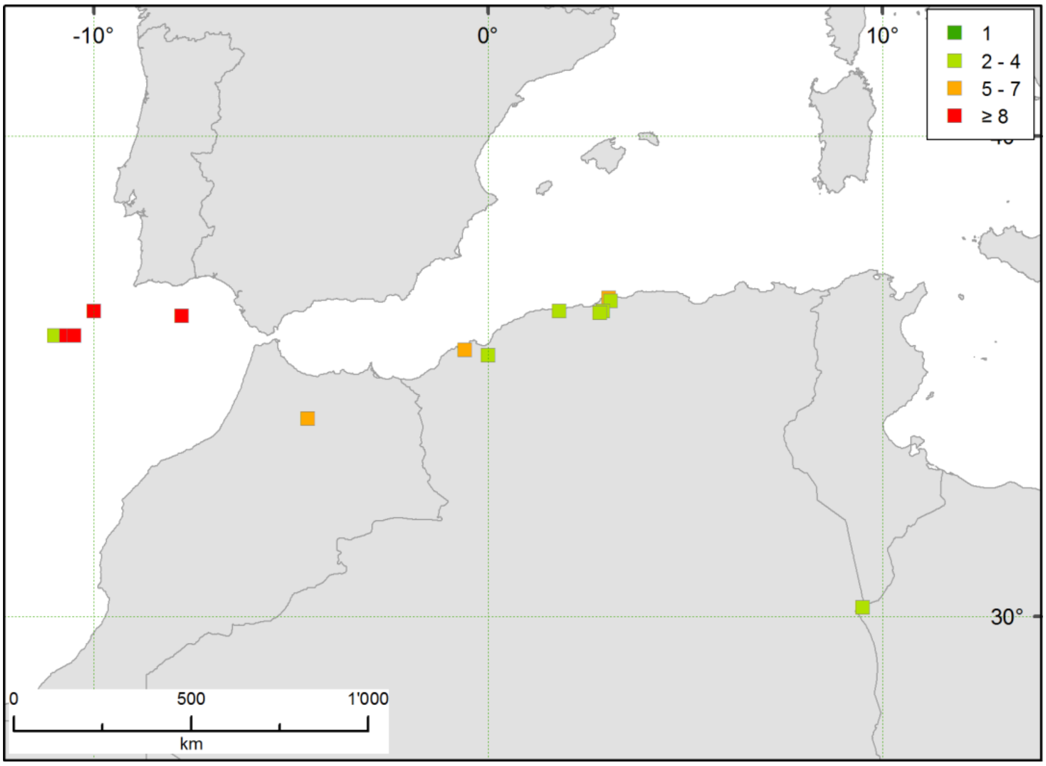


Figure 2.8 Earthquakes in GHEA (1000-1903) in Maghreb, and number of records per earthquake

El Mrabet (2005) published a comprehensive study - in Arabic (with English abstract) - on the earthquakes of the entire region, making use of local sources and focussing on the destructive events. The catalogue included in the book contains short notes on each earthquake, its location and sometimes an estimate of the epicentral intensity but no magnitude. The Maghreb region is included in the European-Mediterranean Earthquake Catalogue (EMEC; Grünthal and Wahlström, 2012), which consist of a re-compilation of existing regional, national and local catalogues.

Other investigations on the historical seismicity of the region were carried on only at national, or even local, scales.

For Morocco, Ramdani et al. (1989) published a catalogue of earthquakes up to 1899 integrating with information from Arabic manuscripts what was already known from Galbis Rodriguez (1932; 1940), Roux (1934) and Mezcua and Martinez Solares (1983). In particular, the compilation on earthquakes in Morocco by Roux (1934) relies on Galbis Rodriguez (1932) and/or Perrey (1847) for almost all the historical events. Ramdani et al. (1989) provide short notes on each earthquake, an estimate of the location and, for some events, the intensity at affected places but no magnitude. Their work has then been revised and developed into El Mrabet (2005).

Levret and Vogt (1992), gathering and interpreting new European historical sources, reappraised some of the earthquakes in Morocco and, mainly, the effects of the 1755 Lisbon earthquake in that country.

A small area of Northern Morocco (around Melilla) is included in the catalogue of the Iberian Peninsula by Martinez Solares and Mezcua Rodriguez (2002).

For seismic hazard assessment purposes, Peláez et al. (2007) recently assembled a catalogue for Morocco, southern Spain and western Algeria using available catalogues and provided a uniform Mw assessment. For the time period before 1900 the input catalogues consist of El Mrabet (2005), Mezcua and Martinez Solares

(1983) for Morocco, and, for Algeria, Mokrane et al. (1994). The Mw values are obtained through the conversion of maximum or epicentral intensities with published relationship for southern Spain (López Casado et al., 2000).

The development of studies on the historical seismicity of Algeria is summarized in both Ambraseys and Vogt (1988) and Benouar (2004). Before the contribution by Ambraseys and Vogt (1988), the documentary information about historical earthquakes in Algeria was limited and basically derived from the compilations by Perrey (1848), Chesneau (1892) and Hée (1950), upon which also some regional catalogues relied (Rothé, 1950; Roussel, 1973). Ambraseys and Vogt (1988) reappraise the seismicity of the Algiers region and define a better knowledge of it, although they recognise that not all the possible sources were explored, in particular Arabic and Turkish ones. They provide brief descriptions of the major events of the area accompanied by some maps of the effects, but they also note that the gathered information was not detailed enough to draw isoseismals and that their results are highly preliminary. Some improvements of the research on the seismicity of the 18th century, in a wider area of northern Algeria, were preliminarily published as Vogt and Ambraseys (1992); unfortunately, the announced publication of the full results never happened.

Ambraseys and Vogt (1988) and, at a lesser extent, Vogt and Ambraseys (1992) remain the principal base upon which subsequent studies and catalogues are built. This is the case of the studies by Harbi et al. (2003; 2010; 2007), respectively for northeastern Algeria, and the region of Algiers. The studies consist of the systematic check of the sources quoted by previous catalogues and the integration with information from historical documents. In the three papers by Harbi et al. some case histories are presented, for which Harbi et al. (2003) provide also some maps of the macroseismic intensity distributions and an estimate of the magnitude (Ms). Harbi et al. (2007) supply a catalogue of the region of Algiers for the period 1359-1895 which contains references, details on the quality of the data and additional remarks, but only a few intensities, partly assessed by the authors and partly derived from other catalogues. The same applies to the catalogue 419-2008 of northeastern Algeria by Harbi et al. (2010).

Among the main references of Harbi et al. (2003; 2007; 2010) there is an official catalogue of Algeria (Mokrane et al., 1994), also quoted by a number of other studies on the area. Several attempts to have the report officially delivered to the EU-SHARE Project were not successful, and its content remains unknown also to the Global Earthquake History Project.

The catalogue of northern Algeria by Hamdache et al. (2010) is compiled from all the catalogues, except Harbi et al. (2007; 2010), and studies mentioned above, and it claims to be “the most complete and homogeneous catalog” for the area. Hamdache et al. (2010) covers the period 856-2008 and provide for all the entries Mw values derived, for the historical events, from maximum or epicentral intensities with the conversion relation by López Casado et al. (2000). The authorship, the approach and the used sources of Hamdache et al. (2010) are similar to those of Pelaez et al. (2007), but a comparison of the two catalogues in their overlapping area showed a number of different solutions, in particular for locations, for the same events. For example, the Mw 6.7 earthquake of 11 May 1624 that, according to all the previously mentioned authors (Poirier and Taher, 1980; Levret and Vogt, 1992; El Mrabet, 2005) caused severe damage at Fès (Morocco) and its surroundings, is located by Hamdache et al. (2010) to the west of Algiers, apparently due to a mistake of positive/negative longitudes.

A few other studies exist on single earthquakes, namely on the 1356 Algiers earthquake (Guidoboni and Comastri, 2005), the 1790 Ouran sequence (Lopez Marinas and Salord, 1990), and on the 1856 Djidjelli earthquakes (Ambraseys, 1982; Maouche et al., 2008; Harbi et al., 2011).

From the studies and catalogues analysed, eight earthquakes are included in the Global Archive, considering magnitudes greater than or equal to 6.7 instead of 7, with the warning that, given the lack of a robust magnitude assessment in the most recent studies (e.g. Harbi et al., 2007; 2010) and the low reliability of the solutions by Hamdache et al. (2010), this is a preliminary list and although it is the best available today, it is likely to change in the future.

2.4.2 Tunisia, Libya and western Egypt

The seismicity of the eastern part of North Africa is considerably lower than in the Maghreb. For the territory of Tunisia, partly considered in the catalogue by Harbi et al. (2010), no specific study on historical seismicity has been identified. Libya was affected by a M 7 earthquake in 1935 (Ambraseys, 1984), but a comprehensive historical catalogue is still lacking. Suleiman and Doser (1995) list six significant earthquakes in Libya between 262 and 1811, with very high maximum intensities for the earliest ones. Suleiman et al. (2004) supplies information on earthquake effects in Libya up to 1900 and identify some fakes. Libya and Egypt are included in Ambraseys et al. (1994), but only the earthquake of August 1883 reaches magnitude 6 and has been included in the Global Archive, although Schulte and Mooney (2005) lower its magnitude to 4.9. Ambraseys et al. (1994) do not report any earthquake with magnitude in the range considered by GEH in western and central Egypt; the few events reported to the east of the Nile River and in the Sinai will be considered in the Section on the Middle-East.

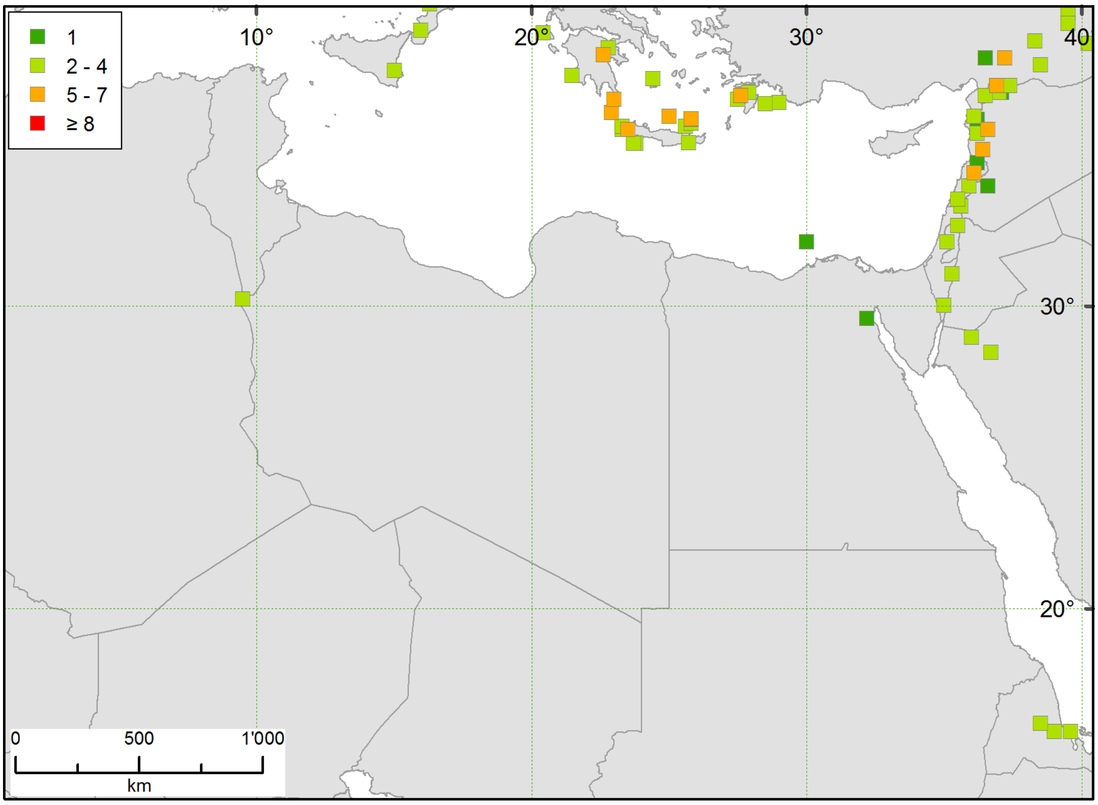


Figure 2.9 Earthquakes in GHEA (1000-1903) in Tunisia, Libya and W Egypt, and number of records per earthquake

2.5 Sub-Saharan Africa

Sub-Saharan Africa comprises two tectonically different regions, the West Africa Craton and the active East African rift, where the highest seismicity of the continent is concentrated. Sub-Saharan African earthquakes were not initially included in GHEC, since the selected regional catalogue (Midzi et al., 1999; used for the GSHAP East African Rift test area) does not report events with M≥7 in the time-window 1000-1903. However, recent seismicity demonstrates that the East Africa rift is prone to large earthquakes, since some of the strongest events of the 20th century exceeded M 7, such as the 13 December 1910 Rukwa, Tanzania (Ms 7.4: Ambraseys, 1991a), 20 and 24 May 1990 Sudan (Ms 7.0-7.4: Giardini and Beranzoli, 1992; Ms 7.0: Ambraseys et al., 1994), and 22 February 2006 Mozambique (Mw 7.0: Fenton and Bommer, 2006). The recent seismicity of the West Africa Craton is low and sparse, with only a few earthquakes of M ≥ 6, with a maximum of M 6.4 for the earthquake of 22 June 1939 (Ambraseys and Adams, 1986b; Engdahl and Villaseñor, 2002).

To take into account the described situation, the Global Archive for Sub-Saharan Africa considers earthquakes with a lower threshold of M 6; the high seismicity of the central part of the Mid-Atlantic ridge (between latitudes 2°S and 4°N) is considered in this part of the report.

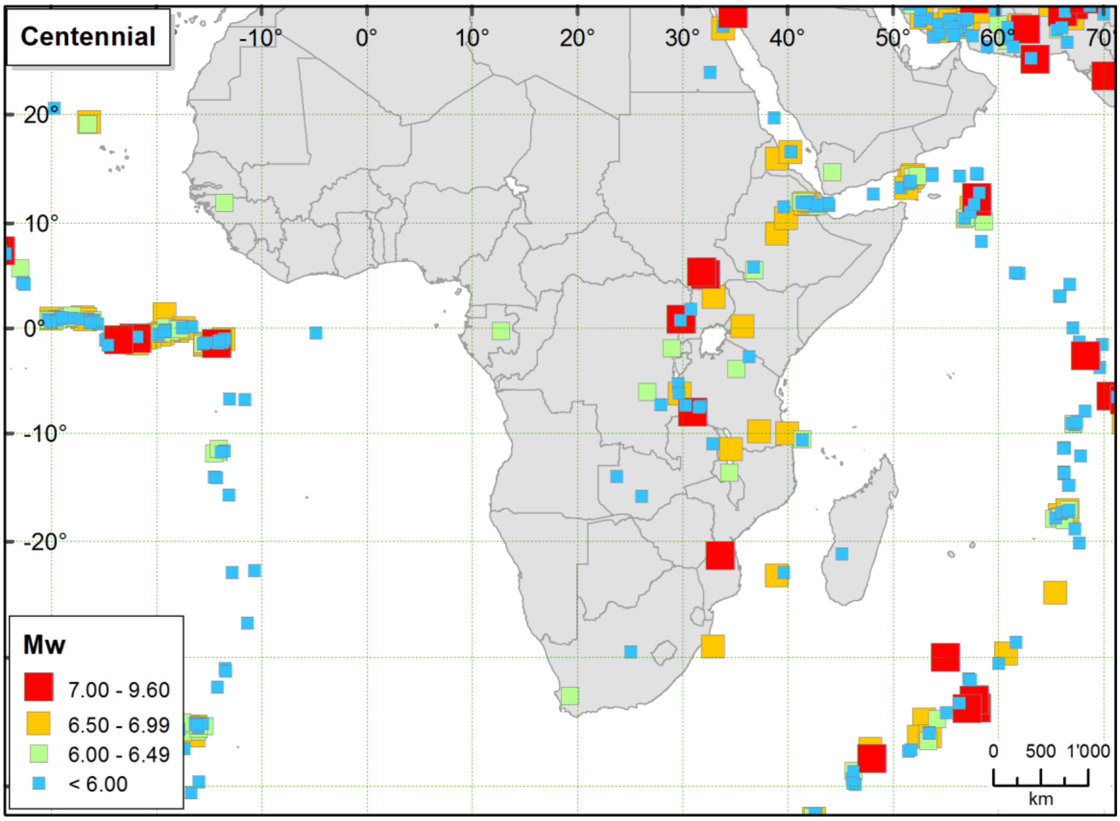


Figure 2.10 20th century seismicity according to Engdahl and Villaseñor (2002)

2.5.1 East Africa Rift

Historical records on the seismicity of the East Africa Rift are extremely sparse, due to its geographical and historical peculiarities.

The seismicity of the northern part of the region, the Horn of Africa, is the subject of the prominent work by Gouin (1979). For historical earthquakes, Gouin's investigation is based on the re-evaluation of the primary sources quoted in the survey by Palazzo (1915), integrated with sources collected in various libraries around the world, including local chronicles and manuscripts. The first event reported by Gouin (1979) dates back to 1400, although it is a volcanic explosion related to the Dubbi volcanic complex and observed by sailors on the Red Sea. The first proper earthquake is reported in 1431-32, based on two manuscripts, one in Tigrinya and the other in Ge'ez languages. For each earthquake, Gouin provides descriptions that include the sources used and a comment; the information collected is summarised in a catalogue of earthquakes and volcanic eruptions from 1400 to 1977, which provides also a magnitude estimate derived, for historical earthquakes, from the account of effects.

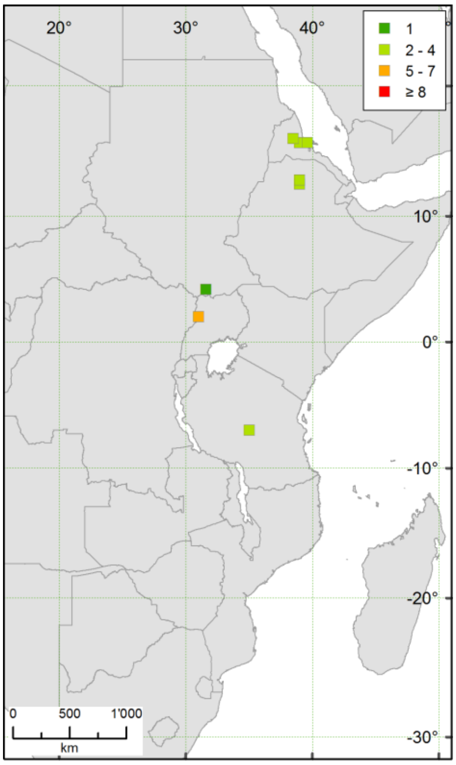


Figure 2.11 Earthquakes in GHEA (1000-1903) in East Africa Rift, and number of records per earthquake

Ambraseys and Adams (1986a) investigate the seismicity of Sudan and adjacent areas (roughly from the Equator to latitude 24°N). The information on historical earthquakes is mainly derived from the files of local meteorological and geological agencies and from reports by explorers and missionaries, supported by local traditions. The first reported earthquake is dated January 1850 and, according to local traditions, it caused widespread damage in the north of the Tanganyika-Nile Valley. Ambraseys and Adams (1986a) provide the description and the parameters of some 65 earthquakes from 1850 to 1981; only eleven are before 1903, and out of these only three have a magnitude estimate. The northernmost earthquakes in Ambraseys and Adams (1986a) are quoted from Gouin (1979); Ambraseys et al. (1994) also largely rely on Gouin (1979) for the earthquakes in the Red Sea and Gulf of Aden areas.

Around and south of the Equator, historical seismicity is even less known than to the north, and totally unknown before 1896, although according to the local tradition the Gregory Rift Valley (Kenya) was shaken by a very severe earthquake about 1873 (Ambraseys, 1991). Ambraseys and Adams (1991) reappraise the macroseismic and instrumental information on major earthquakes south of 20°N in the period 1900-1930. In the time and magnitude ranges of interest for the Global Archive, Ambraseys and Adams (1991) provide data on the 16 March 1901 (Ms 6.9) and 4 June 1903 (Ms 6.4) earthquakes only.

The only published regional catalogue covering the area is the one compiled in the frame of the GSHAP East African Rift test area (Midzi et al., 1999), but for the time-period before 1903 it entirely relies on the quoted papers.

In conclusion, the Global Historical Earthquake Archive includes eight earthquakes in East Africa with M ≥ 6 (none exceeding M 6.9), based on seven studies.

2.5.2 West African Craton

The whole of West Africa is a highly stable area of very low seismicity, with one important exception. The coastal region of Ghana has been a persistent hotspot of activity since earliest recorded colonial history; the larger earthquakes have caused significant damage, and have generally been associated with long aftershock sequences. It is generally believed that the reason for this isolated patch of earthquake activity is connected with the coastal termination of the Romanche Fracture Zone (Sykes, 1978).

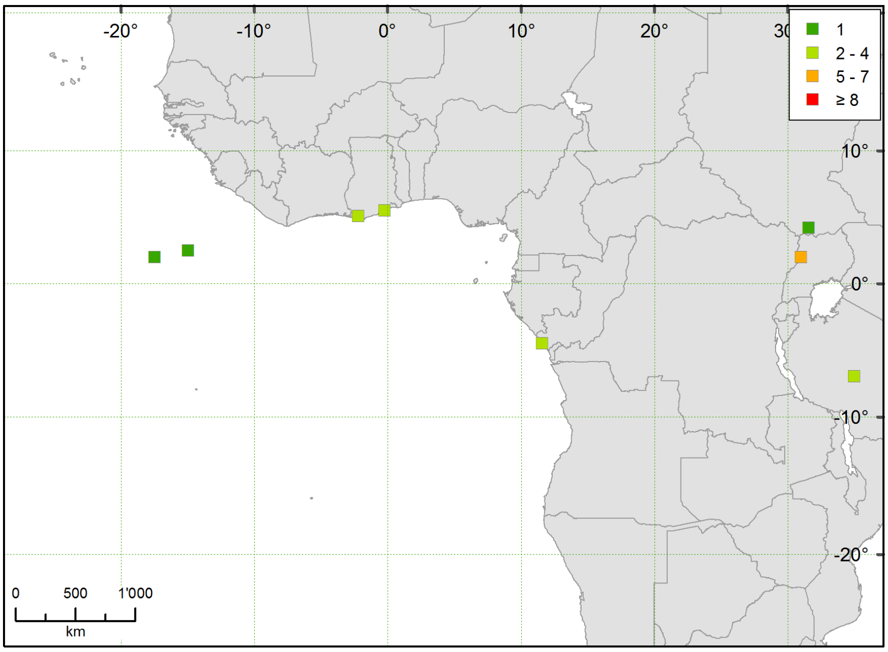


Figure 2.12 Earthquakes in GHEA (1000-1903) in West African Craton, and number of records per earthquake

Current knowledge of historical earthquakes in West Africa essentially derives from the study by Ambraseys and Adams (1986b) on the seismicity between latitudes 5°S and 25°N and longitudes 20°W and 27°E. For the early events, Ambraseys and Adams (1986b) rely on information derived from local tradition of the original inhabitants, while from the beginning of 19th century they consider primary European sources, such as official archives, diplomatic correspondence, newspaper reports and existing studies. They also use the instrumental data available from 1900, re-evaluating early determinations and making use of reports on the effects. The result is an earthquake catalogue of 123 records, spanning in time from as early as 1615 to 1984, for which magnitude has been assessed from felt areas or instrumental data. The effects of most of the earthquakes are described and mapped in the paper.

After Ambraseys and Adams (1986b), no new study on the 1000-1903 seismicity of West Africa has been published. The major study of intraplate seismicity by Johnston et al. (1994) includes data sheets for the important earthquakes of the area, but largely following Ambraseys and Adams (1986b). The updated catalogue for stable continental regions (Schulte and Mooney, 2005) does not introduce changes with respect to Johnston et al. (1994) in this area. The only recent study, by Amponsah (2004), deals with the seismicity of Ghana, but again largely reprises Ambraseys and Adams (1986b) regarding historical seismicity.

In the frame of the Global Earthquake History project, Musson (2012) provides a short summary of the seismicity of southern Ghana, including a revaluation of the 10 July 1862 and 22 June 1939 Accra earthquakes.

In conclusion, the Global Inventory contains five earthquakes in West Africa in the period 1000-1903, with magnitudes between 5.7 and 6.8 (10 July 1868, Accra; Musson, 2012).

2.5.3 Earthquakes in south and south-western Africa and the Atlantic

The seismicity of the Cameroons, the Congolese region and Angola is obscure even for the 20th century. Any surviving records of earthquakes must lie in various (principally Portuguese) archives. It is unclear how much effort has been made by previous investigators to trace such records; there is no known study that this project has been able to draw upon for this region.

The situation for modern South Africa and Namibia is that documentary mention of earthquakes begins in the late 17th century, first exclusively for the area around the Cape of Good Hope, and then progressively extending east and north, mostly in the 19th century. There is no record of any historical earthquake in this area that might have reached a magnitude of 6 Mw.

It might seem self-evident that there is no possibility of observing historical earthquakes in the Atlantic Ocean. This is not entirely true, since there are documentary records of earthquakes felt on the island of St Helena, between the west coast of Angola and the southern Mid-Atlantic ridge. The historical seismicity of the island has been traced by Musson and Holt (2001) as far back as 1756. As is usual with island seismicity, there is no way to discriminate between a small close earthquake and a larger distant one.

2.5.4 The wandering earthquake of 4 June 1903

According to Schulte and Mooney (2005), the earthquake of 4 June 1903 (Mw 6.3) is the easternmost in the stable continental region of Africa in the time-window up to 1903, being located at latitude 0°N and longitude 26°E, in the eastern part of the Democratic Republic of Congo.

The earthquake first appeared in both the studies by Ambraseys and Adams on the seismicity of Sudan and adjacent regions (Ambraseys and Adams, 1986a) and West Africa (Ambraseys and Adams, 1986b). Ambraseys and Adams (1986a; Table 1.3) instrumentally assess the epicentre at latitude 2.0°N and longitude 35.0°E (at the Uganda-Kenya today border) with an error of ±4°, based on 11 reporting stations, the assessed Ms is 5.8. In the text they state that supporting macroseismic information is missing and that this event was originally located near the Red Sea (23°N, 37°E) by Milne (1911) but no shock was felt at that time either in the Middle East or in Africa.

Ambraseys and Adams (1986b; Table 1.3) determine for the earthquake an epicentre at latitude 0.0°N and longitude 26.0°E (Democratic Republic of Congo), with an error of ±7°. This event is not commented in the text but references to “Press Reports”, Sieberg (1932), and Tams (1908) are supplied in the table. The table lists a maximum reported intensity of 5 (MSK) and a mean radius of isoseismal 3 of 800 km; magnitudes assessed from both felt information (M 6.5) and instrumental recordings (Ms 6.3) are given.

Later on, Ambraseys and Adams (1991) dedicate a section of the appendix to the 4 June 1903 “Lake Albert (Uganda)” earthquake, where the authors state that since the publication of Ambraseys and Adams (1986a) they found new macroseismic information on the event, making reference to “Press”, Ambraseys and Adams (1986a; 1986b), Cornet (1909), and Tams (1908). The map provided of the effects is reproduced in Figure 2.13. The conclusion by Ambraseys and Adams (1991) is that “the best instrumental determination agrees with the macroseismic position within its errors”. Table 1 in Ambraseys and Adams (1991) gives both macroseismic (2.0°N, 31.0°E; Lake Albert region) and instrumental (0.0°N, 30.0°E; Uganda) epicentres and the latter is marked as “re-examined by us either for this study or in previous publications”. A general note to the table says that macroseismic epicentres are to be preferred in most of the cases, although their accuracy is generally worse than 0.5°. According to this study, the origin time is 14:56 instead of 14:58 as in all the previous ones.

In the catalogue of earthquakes 1899-1992 published in Ambraseys et al. (1994), the 4 June 1903 earthquake is again located, as in Ambraseys and Adams (1986a), at the Uganda-Kenya border (2.0°N, 35°E) and the epicentre is marked as relocated in the same study or in “other special studies”. The magnitude is given as Ms 5.8 (with no other specifications, so it has to be assumed as assessed from instrumental data) and the column Io (“maximum recorded intensity”) in the table is left blank. The earthquake is not mentioned in the text, but it is reported in Section 3.4 “Spurious and mislocated events” as relocated to Sudan (sic.) with respect to the reports of the British Association for the Advancement of Science.

The parameters determined by Ambraseys and Adams (1986b) have been then adopted in the study on the seismicity of the stable continental regions by Johnston et al. (1994). They however note the high uncertainty (±7°) of the epicentre provided by Ambraseys and Adams (1986b) and conclude that this might have been an East African rift event.

In the GSHAP catalogue for the Eastern and Southern Africa (Midzi et al., 1999) the earthquake appears twice: i) at 14:56 with latitude 2.0°N , longitude 31°E and reference to “AM1”, and ii) at 14:58 with latitude 2.0°N, longitude 35°E and reference to “AMB”. The codes “AM1” and “AMB” used in the catalogue are not explained anywhere, but Ambraseys and Adams (1986a; 1991) and Ambraseys et al. (1994) are all quoted in the paper among the sources used in the catalogue compilation. Comparing the parameters, it appears that one of the identical solutions by Ambraseys and Adams (1986a) or Ambraseys et al. (1994) has been interpreted as a different event with respect to the macroseismic solution in Ambraseys and Adams (1991), although both entries have strangely magnitude 5.8, i.e. the value from Ambraseys and Adams (1986a) or Ambraseys et al. (1994), only.

Finally, Schulte and Mooney (2005) uncritically adopt the solution of Johnston et al. (1994), i.e. the one of Ambraseys and Adams (1986b) but deprived of its high uncertainty in the epicentral coordinates.

Table 1.3 Parameters of the 4 June 1903 earthquake. Different solutions for the epicentre are highlighted

Study	Lat	Lon	Epic.unc.	Epicentre determination/source.	Imax	Mag	Mag Type
Schulte and Mooney, 2005	0.0	26.0		Johnston et al., 1994		6.3	w
Midzi et al., 1999	2.0	31.0		“AM1”		5.8	s
Midzi et al., 1999	2.0	35.0		“AMB”		5.8	s
Johnston et al., 1994	0.0	26.0		Ambraseys and Adams, 1986b		6.3	w
Ambraseys et al., 1994	2.0	35.0		Instrumental		5.8	s
Ambraseys and Adams, 1991	0.0	30.0		Instrumental	6	6.4	s
	2.0	31.0	> ±0.5°	Macroseismic	6	6.4	s
Ambraseys and Adams, 1986b	0.0	26.0	±7°	Instrumental	5	6.5	M
Ambraseys and Adams, 1986a	2.0	35.0	±4°	Instrumental		5.8	s
Milne, 1911	23.0	37.0		Instrumental			

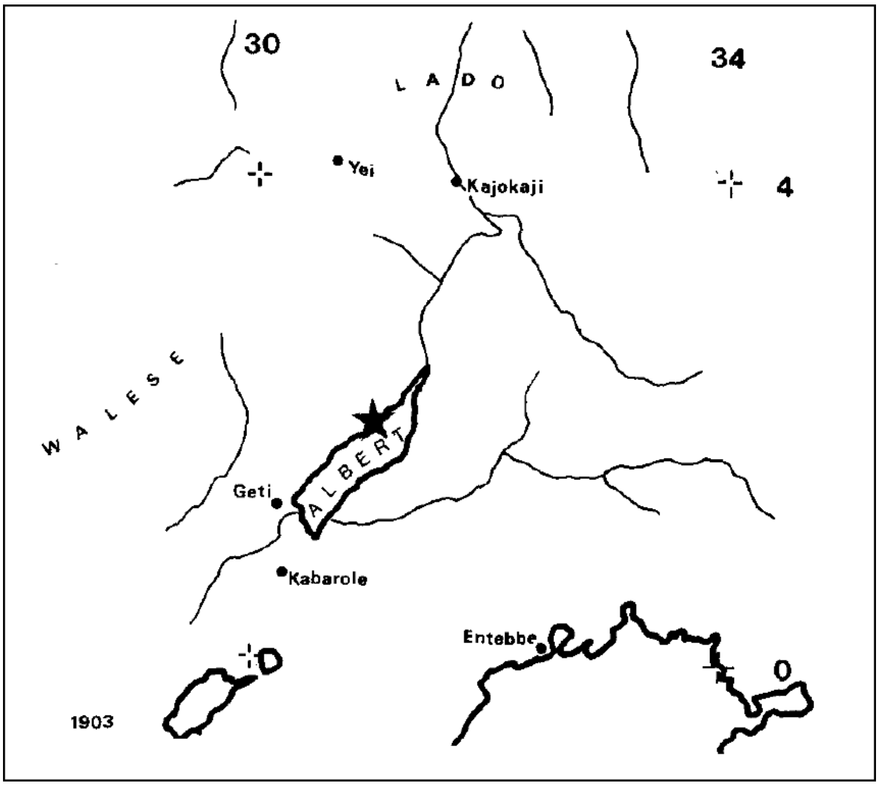


Figure 2.13 Places and areas where the 4 June 1903 earthquake was felt (Ambraseys and Adams, 1991)

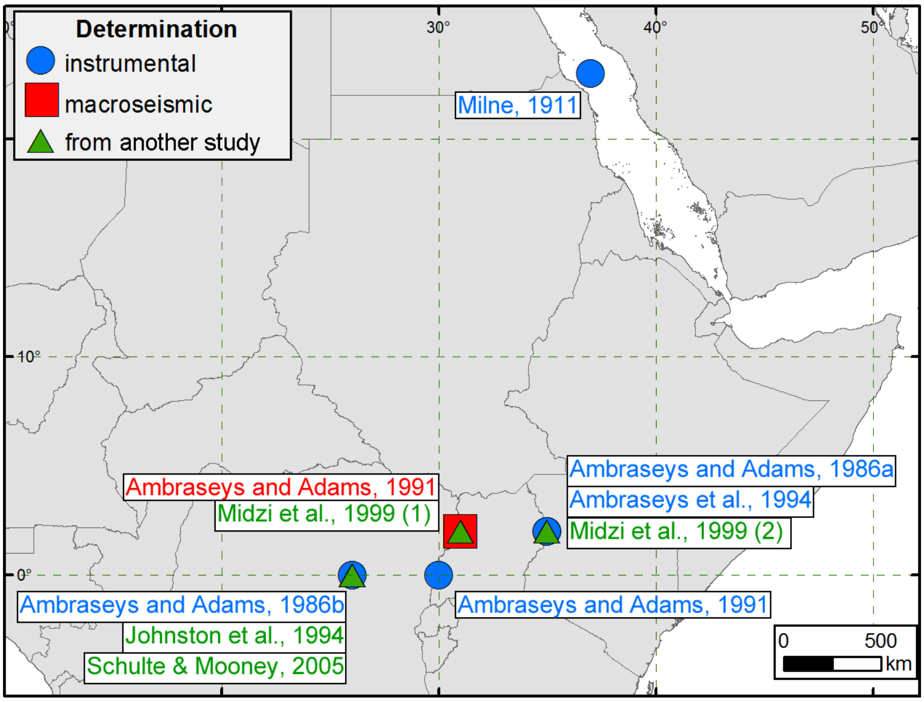


Figure 2.14 Maps of epicentral locations of the 4 June 1903 earthquake according to the mentioned studies

2.6 Turkey, the Middle East and Iran

Knowledge concerning the historical seismicity of the Middle East benefits from the region's very long written history and its position at the intersection of ancient land and sea trading routes.

2.6.1 Central and Eastern Turkey

Central and Eastern Turkey are characterised by rather complex tectonics resulting from the collision of the Arabian and Eurasian continental plates. Two major tectonic structures, the North and East Anatolian faults, cross the region, accompanied by a complex system of conjugate structures.

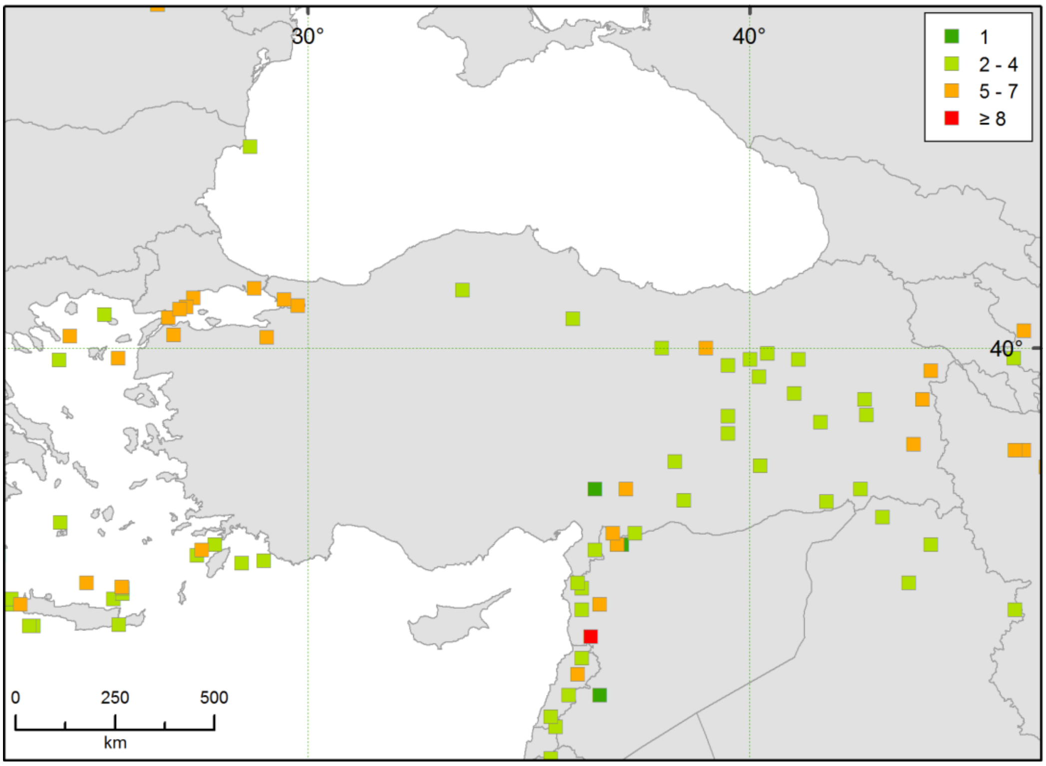


Figure 2.15 Earthquakes in GHEA (1000-1903) in Turkey, and number of records per earthquake

The high level of activity of these two fault systems results in an important zone of seismic activity, represented by several destructive earthquakes that have struck the region in both historical and recent times. In spite of the long historical record of the region and the number of multidisciplinary studies on the North and East Anatolian faults (NAF and EAF), a catalogue of historical earthquakes in Turkey, compiled with modern methodology, is not yet available.

A critical review of the descriptive and/or parametric catalogues of earthquakes in Turkey and surrounding areas is provided in Ambraseys and Finkel (1995). Although this study addresses specifically the period 1500 - 1800, the authors provide a comprehensive list and review of both historical and instrumental catalogues of seismicity for the region that were available up to its publication. Among the cited references, the authors give particular importance to the works by Bonito (1691), Hoff (1840), Mallet (1853), Schmidt (1879), Mushketov and Orlov (1893), Sieberg (1932; 1932b), Stepanian (1942; 1964), and Shebalin et al. (1974) in terms of their methodology and data sources used for the historical period.

Ambraseys and Finkel (1995) itself is a reference book related to the seismicity of Turkey and surrounding areas. The core of the book is a descriptive catalogue of all earthquakes for which there is any record, between 1500 and 1799; full bibliographical references, detailed comments and English translations of primary source material utilised are included. The book contains location sketch maps for selected earthquakes, and a table of events with date, time and location.

Although criticized by Ambraseys and Finkel (1995) for the compilation methods used, the main data source for many historical seismicity related studies in Turkey is the work carried out by Soysal et al. (1981). It consists of a parametric earthquake catalogue, from 2100 BC to 1900 AD providing the preferred epicentral location (mostly macroseismic epicentre), preferred epicentral intensity and in some cases a brief list of affected localities. It also provides the different date, epicentre and intensity information given in different sources. The catalogue does not rely on primary sources but on previous parametric or descriptive catalogues such as Calvi (1941), Pınar and Lahn (1952), Ergin et al. (1967), Ocal (1968), Karnik (1971), Shebalin et al. (1974) and some other earthquake- or region-specific studies. The concept of “quality code” is introduced to define the number of data sources and quality of information for each event. Although it was a comprehensive study for its time of compilation, the information provided in the catalogue has been mostly updated by more recent studies.

Following the comprehensive work of Ambraseys and Finkel (1995), several other catalogues have been published. Among these, the studies described below have been used in addition to Ambraseys and Finkel (1995) as main sources for the compilation of the Global Historical Earthquake Archive.

Earthquakes from 1500-1988 in the Turkey, Syria and Iraq border area were investigated by Ambraseys (1989) who published a catalogue of earthquakes with epicentral coordinates and Ms estimates.

Guidoboni and Comastri (2005) provide a catalogue of historical seismicity in the Mediterranean region from the 11th to the 15th century. This comprehensive volume includes both a descriptive catalogue, relying on the interpretation of primary sources, which are provided in both their original languages and their English translations. Macroseismic data points (MDPs) are given for all events. The epicentral coordinates and magnitudes are estimated based on the MDPs whenever possible. For the Global Historical Earthquake Archive, the MDP datasets provided by Guidoboni and Comastri (2005) have been compiled and added to the GEH macroseismic database.

Ambraseys (2009) includes historical evidence from the last 2000 years for earthquakes in the eastern Mediterranean and Middle East, summarising the results of either published or unpublished research conducted by the author and co-workers. The “descriptive catalogue” has more than 4000 earthquakes that have been identified from historical sources. Most events are supported by textual evidence extracted from primary sources and translated into English. The major drawback of Ambraseys (2009) is that it does not provide any assessment of parameters. But the recently re-evaluated comprehensive information provided, and the large area and time span it addresses, make it an indispensable source for the evaluation and validation of almost all the earthquakes in the area.

Ambraseys and Jackson (1998) is also a useful source as it includes a parametric catalogue of events associated with surface faulting. The authors have compiled data for surface faulting in historical and recent earthquakes in the Eastern Mediterranean region and in the Middle East, based on a variety of published and unpublished sources and field investigations. A total of 78 events associated with faulting for pre-1900, and 72 events for the post-1900 period, are listed with date, epicentral coordinates, estimate of magnitude (Ms), azimuth, fault mechanism, length of faulting, and relative displacement. For early events of the pre-instrumental period, magnitudes are derived from macroseismic information calibrated against instrumental Ms values.

Ambraseys (1997b) assessed the size and effects of the earthquake of 12 May 1866, re-evaluating it on the basis of primary sources.

Following the recent and destructive 7.2 Mw Van earthquake of 23 October 2011 in eastern Anatolia, Albini et al. (2012) re-evaluated the historical events around Lake Van using several studies.

Earthquakes in Eastern Turkey are also dealt with in catalogues covering the Caucasus (Kondorskaya and Shebalin, 1982; Shebalin and Leydecker, 1997; Shebalin and Tatevossian, 1997), described in Section 2.7 on Russia, Caucasus and Central Asia, and partly by the studies on the Middle-East mentioned below.

2.6.2 The 17 August 1668 North Anatolia earthquake

An example of a major but poorly documented event in the seismic history of Turkey is the 17 August 1668 central North Anatolian region earthquake, for which the first comprehensive analysis was provided by Ambraseys and Finkel (1988). The 1668 earthquake was in fact suggested by several paleoseismic studies as the major event that ruptured the central portion of NAF in the cycle preceding the 20th century, but the scarce and diffuse character of the related macroseismic information has most probably lead to the underestimation of the intensity and the rupture extent of the event by seismologists. Ambraseys and Finkel (1988) state that several earthquake catalogues such as Hoff (1840), Perrey (1850), Mallet (1850), Sieberg (1932), Calvi (1941), Pinar and Lahn (1952) and Soysal et al. (1981) either ignore the earthquake, or refer unclearly to a series of earthquakes that occurred in different parts of Asia Minor during the period 3 July to 13 September 1668.

The study by Ambraseys and Finkel (1988) is a macroseismic analysis of the 17 August 1668 event, defined as one of the largest earthquakes associated with North Anatolian fault zone, with an extent similar to (or even larger than) the great 1939 Erzincan earthquake. It caused heavy damage within a narrow band about 100 km wide and 600 km long, running along the fault zone from Bolu in the west to near Erzincan in the east (Figure 2.16).

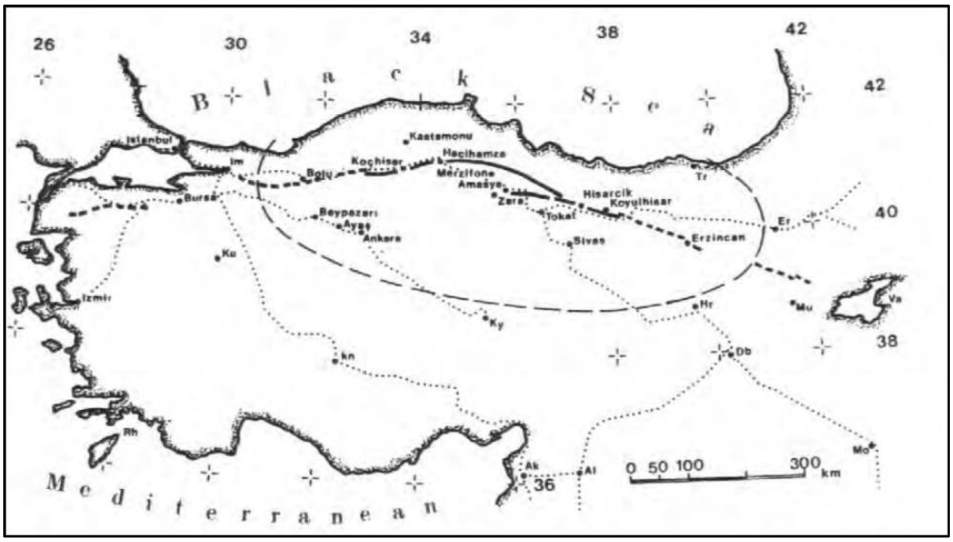


Figure 2.16 Location map of the 17 August 1668 earthquake (Ambraseys and Finkel, 1988)

The main source of information for the event is an item in the “Dressdnische Gelehrte Anzeigen” (1756), which in turn is an extract from the contemporary “Theatrum Europaeum”, which appears to have had access to reliable local information, most probably deriving from correspondence with European merchants living in different parts of western Anatolia. Ambraseys and Finkel (1988) also use other primary sources such as chronicles, travellers' accounts, and letters of merchants, delimiting the extent of damage at both its western and eastern ends. According to Ambraseys and Finkel (1988), one-third of the entire known length of NAF broke during this one shock. The length of the rupture zone and the associated fault breaks provide a demonstration of the very large magnitude. The event was preceded by widely felt, damaging foreshocks at its western end, and was followed by aftershocks that continued for six months. The major argument of Ambraseys and Finkel (1988) is that there was only one major event during the period 3 July to 13 September 1668, preceded and followed by damaging shocks, the main shock occurring on August 17, as opposed to other catalogues which give a number of events of similar (but lower) magnitude distributed over the affected zone.

Ambraseys and Finkel (1988) estimate a magnitude of 8.0 Ms from the rupture length associated with the earthquake, and 7.8 Ms from the average radius of the isoseismal 6 (Fig. 2.16).

2.6.3 The Dead Sea system, the Red Sea, Egypt, and Arabia

This area includes the active boundary of the African and Arabian plates, whose major expressions are the Dead Sea Fault System and the rift system of the Red Sea and Gulf of Aden. In spite of the high tectonic deformation and movement rate of the interacting plates, the seismicity of the 20th century along the Dead Sea Fault is moderate and the few earthquakes that exceeded magnitude 6 are mainly located in the gulfs of Suez and Aqaba, where the 7.3 Mw earthquake of 22 November 1995 occurred (Klinger et al., 1999). A few other M > 6 events have been observed in the southern Red Sea and in the Gulf of Aden. The remaining parts of the region, intraplate areas, show either much lower levels of seismicity, as in the case of Egypt, or have no earthquakes at all, such as most of the Arabian Peninsula.

Descriptions of the historical earthquakes of the most seismic areas date back to the early compilations by Hoff (1840), Mallet (1853), Perrey (1850), Tholozan (1879), and Montessus De Ballore (1906). Earthquakes in Palestine and Syria between 1606 B.C. and 1928 A.D. were listed by Willis (1928) as an introduction to a report on the 11 July 1927 Jericho earthquake. Earthquake effects in the region were also collected by Sieberg (1932) and Amiran (1950). Ambraseys (1962) pointed out that in the list by Willis (1928), the dates of the earthquakes derived from a 15-16th century Egyptian source were not translated from Anno Hegira to AD, and this error propagated to other compilations, such as Sieberg (1932).

Later, Ben-Menahem (1979) compiled a comprehensive catalogue for places within 1600 km from Jerusalem (i.e. a wide area from the Hellenic arc to Teheran and from the Black Sea to the Red Sea), considering a number of earthquake lists, including most of those mentioned above, and presenting reports on major historical earthquakes, complemented with archaeological evidence. The catalogue by Ben-Menahem (1979) provides epicentral coordinates and a local magnitude (ML) estimate for 270 earthquakes. The same catalogue is published also in Ben-Menahem (1991).

Poirier and Taher (1980) supply a "chronological list" of earthquake effects at different places in a wide area that covers the entire Middle East region. The study contains information on the seismicity between the 7th and 18th century from contemporary Arabic sources, mainly consisting of unpublished manuscripts.

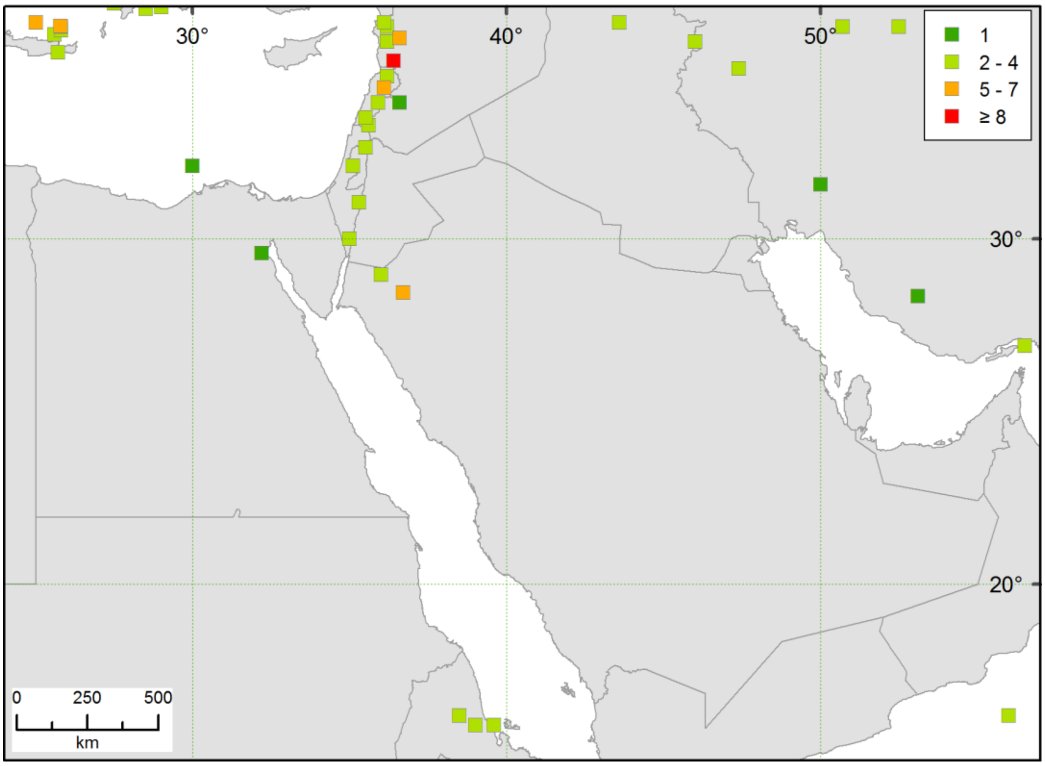


Figure 2.17 Earthquakes in GHEA (1000-1903) in Dead Sea system, Red Sea, Egypt and Arabia, and number of records per earthquake

Ambraseys et al. (1994) also deals with a large area that includes Egypt, Arabia and the Red Sea. This comprehensive study summarises several years of research on the historical earthquakes of Saudi Arabia and adjacent areas, mainly based on medieval Arabic chronicles and later European travel reports, complemented by local sources in the different languages of the region, diplomatic correspondence and newspaper reports. Ambraseys et al. (1994) provide "macroseismic information", consisting of short descriptions of the events and the sources reporting them, sometimes complemented by maps of earthquake effects for a number of earthquakes, and two catalogues. The first catalogue, from 184 BC to 1899 AD, is based on the described macroseismic information and provides magnitudes derived from felt areas, the second, from 1899 to 1992, derives from instrumental data. Of particular interest is the section dedicated to "False and mislocated events", which helps sorting out confusions of dates and locations among different catalogues.

Ambraseys et al. (1994) include the results previously published by the same author(s) in individual papers on single earthquakes or sequences, periods, and small areas, and sometimes updates them. Among these, the papers considered for the compilation of the Global Historical Earthquake Archive are:

- Ambraseys and Melville (1988), on the earthquake of 1202 in Lebanon;
- Ambraseys and Barazangi (1989) on the 1759 Earthquake in Lebanon and Syria;
- Ambraseys and Karcz (1992) on the earthquake of 1546 in Palestine;
- Ambraseys and Melville (1983) on the seismicity of Yemen;
- Ambraseys and Melville (1989) on the seismicity of northwestern Arabia.

Further studies, dealing with particular events or aspects, were published later by Ambraseys (and co-authors) either relying on the historical research already described in Ambraseys et al. (1994) or updating it with new findings and new conclusions, particularly on earthquake parameters. Ambraseys and Melville (1995) analyse the earthquakes of 1254 and 1280 in Eastern Anatolia and Northern Syria, not included in Ambraseys et al. (1994), and their relationship with surface faulting. The same applies to the earthquake of 1837 in Southern Lebanon and Northern Syria, dealt with in Ambraseys (1997c). Earthquakes associated with surface faulting in the region are described also in Ambraseys and Jackson (1998). The sequences of 1114, 1138, 1157, and 1170 in Southern Turkey, Lebanon and Syria are the subject of the studies by Ambraseys (2004) and Guidoboni et al. (2004a; 2004b). The parameters of large earthquakes in the Dead Sea Fault Zone are revised by Ambraseys (2006). Earthquakes in the region, up to the 15th century, are also dealt with by Guidoboni and Comastri (2005).

Finally, Sbeinati et al. (2005) provide a catalogue of large and moderate earthquakes in the broader Syrian region from 1365 BC to 1900 AD. For the compilation of the catalogue, the authors have relied on a large number of original documents in Arabic, Latin, Byzantine and Assyrian languages and also identified some events not mentioned in previous works. The MDPs are provided for many events in the catalogue and are included in GHEA.

Existing catalogues and specific studies on the Dead Sea area (up to longitude 35°E) are recompiled in the European-Mediterranean Earthquake Catalogue (EMEC; Grünthal and Wahlström, 2012).

2.6.4 Iran and Iraq

Proceeding eastwards, in the area that today is made up of Iran and north-eastern Iraq, the convergence of the Arabian and Eurasian plates results in the highly deformed Alborz and Zagros mountain belts, respectively in the north and southwest of Iran. The high tectonic deformation rate of the region is also testified by the number of destructive earthquakes that happened in Iran in recent times, such as the 28 July 1981, 20 June 1900, and 10 May 1997 events, just to mention only the most recent with M > 7.

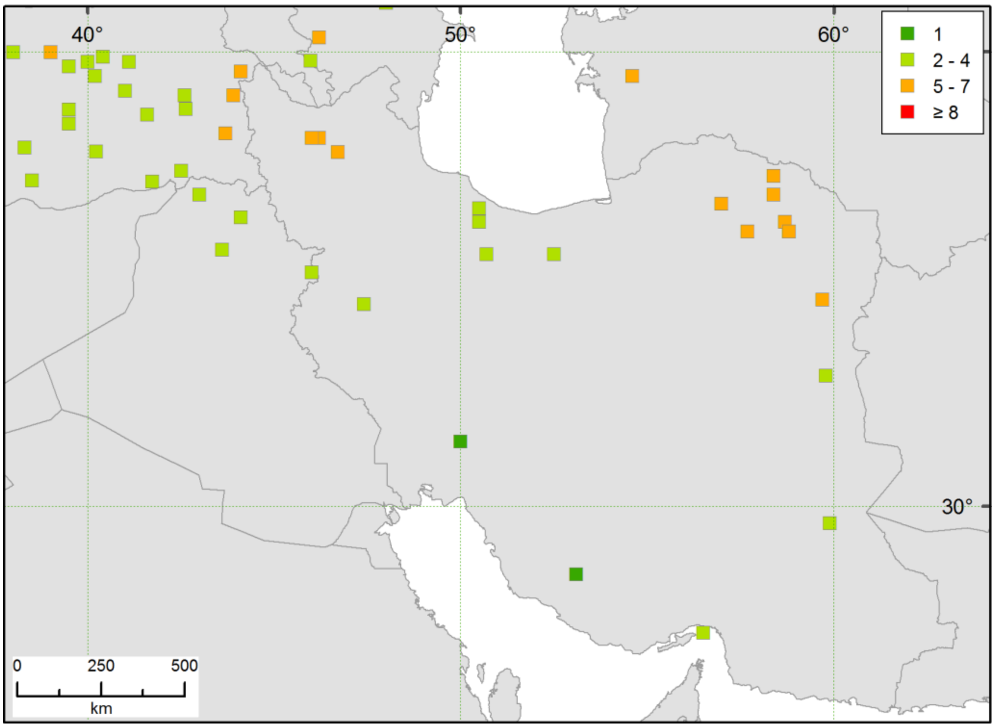


Figure 2.18 Earthquakes in GHEA (1000-1903) in Iran and Iraq, and number of records per earthquake

Information on the historical earthquakes of the region can be found in several compilations of the second half of the 19th century and the first part of the 20th, such as Perrey (1850), Abich (1857), Montessus de Ballore (1906), Wilson (1930) and Sieberg (1932).

Ambraseys (1968) published a study on the early (850 to 1150) earthquakes of North-Central Iran (in an area between 33°N to 38°N and 47°E to 55°E), deriving information from a search of Arabic and Persian writings of the last ten centuries and finding a number of previously unknown earthquakes. Data on earthquakes up to 1898 are also included in the study, derived from the compilations mentioned above and from press reports.

A list of 79 earthquakes in Iraq between 1260 BC and 1900 AD was compiled by Al-Sinawi and Ghalib (1975) from various sources that include, besides those quoted above, an Arabic manuscript that brought to light fourteen previously unknown events.

The 1970s saw significant local research on historical seismicity in Iran, of which the chief products are Berberian (1976, 1977) and Nabavi (1978). Berberian's work is intended as a contribution to the study of seismotectonics in Iran, presented in the form of two reports to the Geological Survey of Iran. These excellent studies, not easy of access, form the basis for much of the later work on the earthquakes of the area. Nabavi (1978) presents a descriptive catalogue of earthquakes in Iran from 300 BC to 1900 AD. Nabavi (1978) was used as a source for the NOAA database (Dunbar et al., 2002), unfortunately with some confusion where Nabavi (1978) gives Anno Hegira dates which are then treated as AD dates, giving rise to duplicate events ~600 years before the true date.

Ambraseys and Melville (1982) investigated the seismicity of historical Persia, roughly extending from 24°N to 40°N in latitude and from 44°E to 66°E in longitude, analysing a number of Arabic, Persian and European sources. Ambraseys and Melville (1982) describe several case histories, with the help of maps of earthquake effects, and the work also contains two catalogues, one for the period from the 3rd millennium BC up to 1899 AD, with epicentres, classes of epicentral intensities, radii of the meizoseismal area and of perceptibility and a Ms estimate, and one for the period 1900-1979, compiled also with instrumental data.

A catalogue of earthquakes in Iran is included in the study on natural hazards in Iran by Berberian (1994). The catalogue is compiled collecting information from scattered primary and secondary sources, including Iranian, Arabic, Armenian, Russian and European ones. Berberian’s catalogue covers a period from pre-historical times to 1897 and provides epicentral location, epicentral intensity and both Ms and Mw estimates together with side information (such as the causative fault and/or the number of casualties). The parameters are in most cases the same as those in Ambraseys and Melville (1982), although epicentres were revised and some magnitudes lowered, but the reason for this is not clearly stated. Berberian (1994) provides also a kind of “inventory”, i.e. a table presenting, for each earthquake, the different solutions according to previous catalogues and studies; another table is dedicated to “dubious earthquakes”.

The northern borders of Iran and Iraq are also considered in the catalogues by Kondorskaya and Shebalin (1982), Shebalin and Leydecker (1997), Shebalin and Tatevossian (1997), and Kondorskaya and Ulomov (1999), which are described in Section 2.7 - “Russia and Central Asia”.

Some of the earthquakes in the area are also dealt with in Ambraseys and Jackson (1998) and most of the earthquakes contained in the paper entitled “Earthquakes in Afghanistan” by Ambraseys and Bilham (2003), described in Section 2.8, are actually located in eastern Iraq.

Musson et al. (2005) provide a catalogue of earthquakes in southern Iran (south of 30°N), which also extends over the United Arab Emirates and surrounding areas. Historical events were reappraised, mostly from British colonial records, and some events significantly revised, and new ones discovered. Most of the earthquakes considered were below the GEH magnitude threshold; the one significant revision involves the earthquake of

18 February 1483 in the Gulf of Oman. This is given a magnitude of 7.7 Ms by Ambraseys and Melville (1982), making it an event of paramount regional importance for hazard. Musson et al. (2005) conclude that in fact it was a much more modest event (~ 6 Mw) near Qeshm island (see also Musson, 2009).

The catalogue compiled in the frame of the EMME (Earthquake Model of the Middle East region) Project, a Regional Component of the GEM initiative, puts together the content of the above-mentioned catalogues; since it is not yet published and it adds nothing new, it has not been considered.

In conclusion, for the Middle-East the GEH Archive contains 304 entries from 32 different sources, related to 80 earthquakes.

2.7 Russia, Caucasus and Central Asia

The vast territory comprised by Russia, Caucasus and Central Asia is uneven with respect to seismicity and historical sources. Seismicity is scarce in the Russian Plain, and increases substantially at the borders of the region, such as in the former Soviet republics of Central Asia, and in Kamchatka and the Caucasus. The same applies to historical sources on earthquakes, which are quite non-existent for Siberia as well as the southern lands of present-day Russia.

2.7.1 Russia

The first comprehensive compilation of historical earthquakes in the Russian Empire was published in 1893 by Mushketov and Orlov; it included events up to 1887. Except for earthquakes in border regions, on which some studies had already been published, the authors collected and published primary information, from chronicles and archive materials, as well as newspapers. To these high-quality sources of information, they added all the information they could retrieve from earlier earthquake compilations, such as Perrey (1843) and Abich (1882).

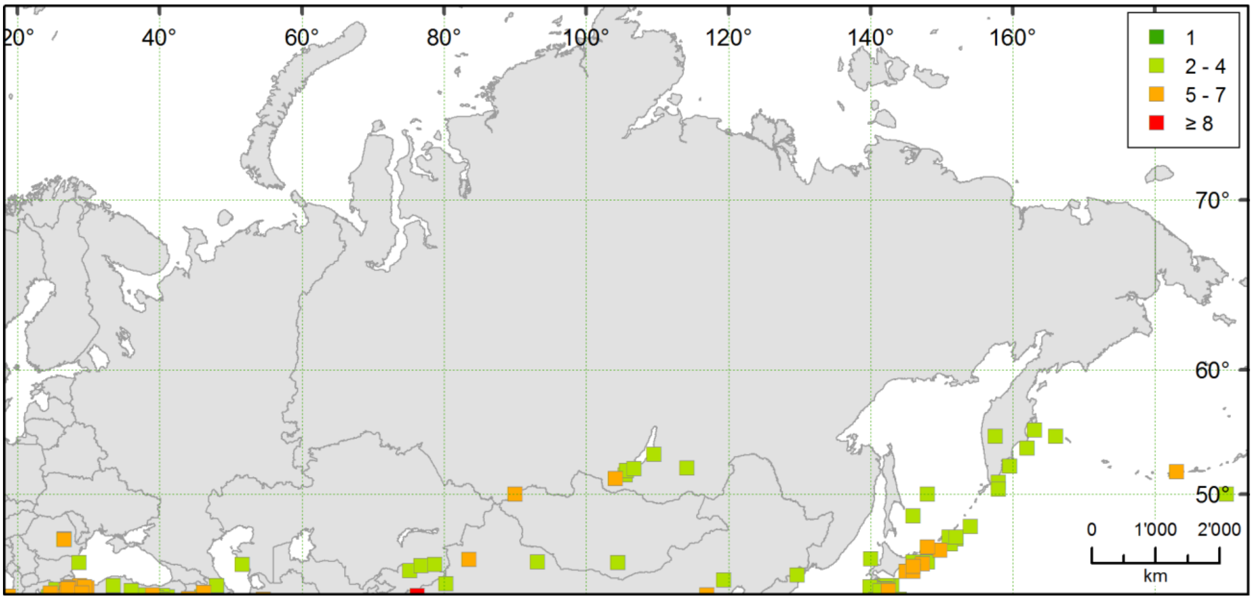


Figure 2.19 Earthquakes in GHEA (1000-1903) in Russia, and number of records per earthquake

Mushketov and Orlov had a clear view of the importance of their work, as they stated in the introduction:

> *"Destructive earthquakes recurring from time to time within the Russian boundaries or neighbouring countries often arouse the interest of the Russian society and government; when such an event happens, expeditions are sent to study the destructive consequences of the earthquake, with the idea of establishing permanent seismic observatories, money has even been found to alleviate the consequences of such a natural calamity. But, alas, regardless of such temporary excitement, earthquake studies in Russia do not go forward, and the interest in them gradually subsides, as soon as the subterranean shocks die down."* (translation into English from Tatevossian, 2004).

The compilation by Mushketov and Orlov (1893) became the basis for the first parametric catalogue of historical earthquakes for the former Soviet Union, compiled by Kondorskaya and Shebalin (1977 in Russian, 1982 in English). Most of the studies of historical earthquakes following its publication were aimed at verifying the sources contained in Mushketov and Orlov (1893), attempting to replace, when possible, the summarised descriptions they included in their compilation with the original items they referenced.

However, the starting point for any historical earthquake parameteric catalogue remains to this day the catalogue by Kondorskaya and Shebalin (1982). This applies especially to most of the contributions included in the Global Historical Earthquake Archive, even though they have been produced from the 1990s onwards.

A second, fundamental step in the study of the historical seismicity of former USSR was the preparation of the catalogue by Shebalin and Leydecker (1997), the so called “FSU – Former Soviet Union – catalogue”, which was actually completed in May 1994.

The area, magnitude and intensity thresholds of Shebalin and Leydecker catalogue (1997) are the same as in Kondorskaya and Shebalin (1982), but their catalogue differs from the previous one as it includes some corrections collected since its publication. The corrections are based on: a) comments sent by contributors from regional institutions; b) studies (papers, reports, etc.) devoted to individual earthquakes; c) errors found by Shebalin himself.

In addition, the structure adopted by Shebalin and Leydecker (1997) differs substantially from the one adopted by Kondorskaya and Shebalin (1982) in that:

- the earthquakes are listed chronologically for the whole area considered in the catalogue, while in Kondorskaya and Shebalin (1982) the information is given by seismic zones;
- there are no references in the FSU catalogue, and though many corrections have been included, the reasons for such corrections are not given;
- there is no descriptive information (neither in the form of short comments nor in any appendix).

In compiling the GEH Archive, the choice was for the revised and corrected version of the catalogue as supplied by Shebalin and Leydecker (1997). In any unclear situation, the catalogue by Kondorskaya and Shebalin (1982) was thoroughly checked, especially in search for textual descriptions (comments and appendices).

Another, more recent, catalogue covering the territory of former USSR was compiled by Kondorskaya and Ulomov. Its compilation started in relation with the General Seismic Zoning project for the USSR, intended to replace the previous one, which had been adopted in 1976. This catalogue has never been published, and the version included in GEH Archive is the one delivered to GSHAP in 1999 (Kondorskaya and Ulomov, 1999). Today, it is available directly from Ulomov or from the Institute of Physics of the Earth, Russian Academy of Sciences. The basis of this catalogue is, once more, the one by Kondorskaya and Shebalin (1982). Because it (Kondorskaya and Ulomov, 1999) was never published and it is continuously updated, there are no clear explanations available on which data and criteria its content was updated. For examples, earthquake parameters derived from palaeoseismological studies are included, but without any explanation, as well as some earthquakes in mainland China, far away from the borders of the former USSR. It has been used here only after a careful cross-check with other available material, especially regional studies.

In parallel with the compilation of the catalogue by Kondorskaya and Shebalin (1982), Shebalin (1977) prepared an "Atlas of isoseismal maps for the New Catalogue of Strong Earthquakes on the USSR territory from Ancient Times through 1975". The Atlas remained unpublished, both because, at the time of its preparation, the great value of intensity data points was still not widely recognised, and secondly because financial problems caused the publication to be postponed several times.

The many maps of which the Atlas is composed are now stored in the Archive of the Institute of Physics of the Earth, Moscow.

A comparison between the earthquake parameters given in the legend of each isoseismal map and those in the catalogue by Kondorskaya and Shebalin (1982) proves that the Atlas is the ghost root of the catalogue. An attempt to use such data has been made for two large Kazakhstan earthquakes (see details below, section 2.7.3 on Central Asia).

After the break-up of the USSR, some of the contributors to the Kondorskaya and Shebalin (1977) catalogue started the preparation of regional catalogues. A discussion follows of what has been included in the GEH archive for Kamchatka and the Lake Baikal region, while the material related to Caucasus is presented in a separate section (see below, section 2.7.2).

The work by Godzikovskaya (2007) considers earthquakes both with epicenters located in Kamchatka and felt there. The author clearly states that the starting point is the list of earthquakes from Kondorskaya and Shebalin (1982), who in their turn used the catalogue for Kamchatka by Fedotov et al. (1968).

This study presents the material supporting the assessment of the parameters of historical earthquakes in Kamchatka as supplied by the previous catalogues. A history of the exploration of Kamchatka is given, together with a critical review of the historical sources containing descriptions of earthquake effects. The main aim of the study is that of establishing knowledge of the supporting materials for earthquakes in this region.

Extensive quotations and reproduction of the original sources are included, to preserve them for posterity. No specific efforts were made to collect new sources, and it is clearly stated that there are almost no chances to discover new, unknown macroseismic data for the region.

Since the material available is scarce and generally of poor quality, the parameters derived for historical earthquakes in Kamchatka do not carry a high accuracy.

In the framework of a recent project devoted to the Baikal area, the study by Tatevossian et al. (2012) has reappraised the supporting datasets and parameters of four historical earthquakes included in the catalogue by Kondorskaya and Shebalin (1982).

These are the largest magnitude seismic events in the Baikal regional historical earthquake catalogue; the largest earthquake of the four occurred in 1725, with a magnitude cited of 8.2. Kondorskaya and Shebalin (1982) declared that these four earthquakes had been parameterised using a combination of macroseismic and palaeoseismic information. The study by Tatevossian et al. (2012) does not discuss the palaeoseismic data, concentrating instead entirely on the macroseismic data. For all the earthquakes, the later compilations and the summary translations by Mushketov and Orlov (1893) have been replaced with the original sources of information in their own languages. This allowed the authors to reinterpret the primary sources in terms of macroseismic intensity, and provide this project with four sets of newly determined macroseismic data points. Tatevossian et al. (2012) draw the conclusion that the previously assessed magnitudes were all overestimated, and a new set of parameters is provided. For the 1725 earthquake in particular, the paucity of information do not allow a unique parametric solution, and the study discusses some possible alternatives.

2.7.2 Caucasus

The Caucasus was nominated as a test area in the GSHAP project, which required the compilation of an ad hoc catalogue for the region, completed in 1995 and published in 1997 (Shebalin and Tatevossian, 1997). The main work was done by N.V. Shebalin, though it was finished after his death.

Only earthquakes with magnitude ≥6 Mw, and strictly within the spatial limits of the Caucasus test area as defined in the GSHAP project, are included in the catalogue. Actually, the catalogue is the product of a consensus reached among the eighteen co-authors from Russia, Georgia, Armenia and Ukraine.

The Kondorskaya and Shebalin (1982) catalogue included regional contributions from a number of collaborators; one of these was Tamara Babayan, who supplied material on Armenia. More recently, Babayan (2006) published an "Atlas of strong earthquakes of the Republic of Armenia, Artsakh and adjacent territories from ancient times through 2003". She used the material collected in the early 1970s, when most of the historical investigation for the USSR was done, and added newly-found information together with reassessment of the parameters for some earthquakes.

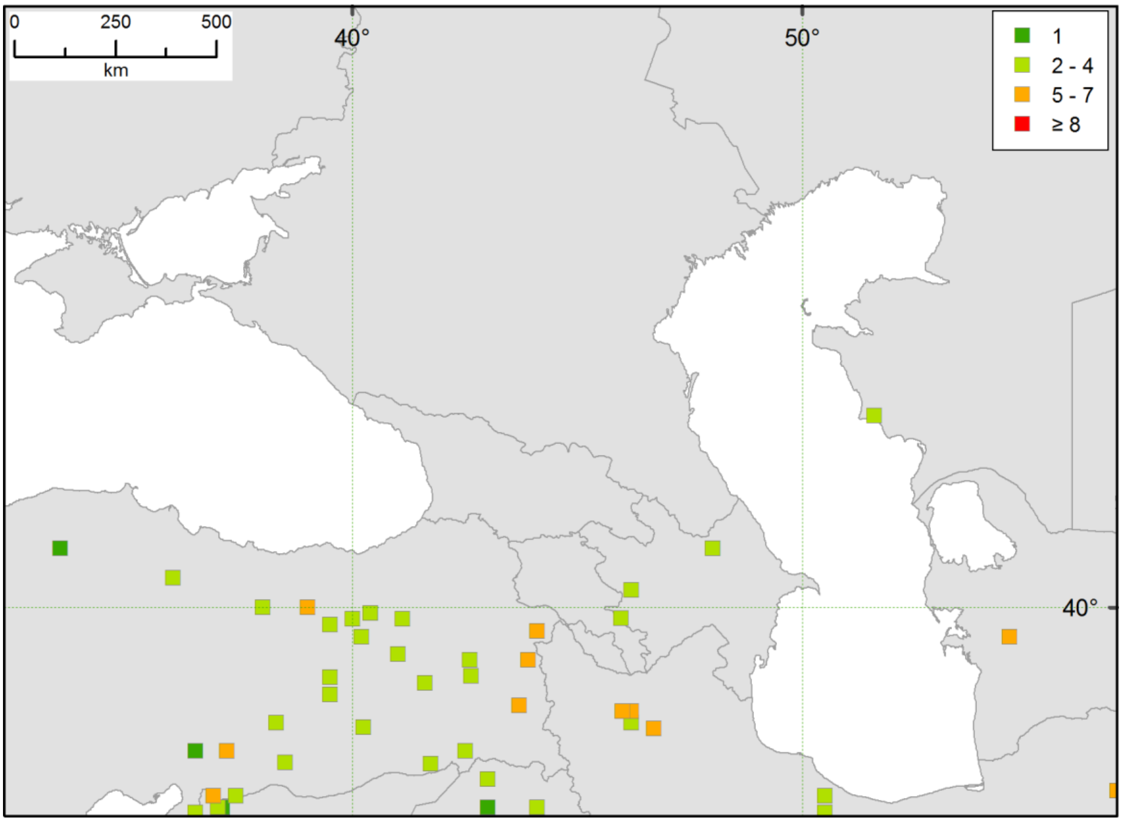


Figure 2.20 Earthquakes in GHEA (1000-1903) in Caucasus, and number of records per earthquake

This atlas deals with earthquakes with epicentres located within Armenia and Artsakh or felt over these territories, and contains isoseimal maps (including a list of places - without co-ordinates- and related intensity values), earthquake descriptions, parameters, and references. The introduction contains some notes on historical aspects of the region, supported by historical maps of the territory. Parameters were assessed using mean isoseimal radii and the attenuation equation for Armenia already used in Kondorskaya and Shebalin (1982).

2.7.3 *Central Asia*

Data on historical earthquakes of the former Soviet Republics of Central Asia (Kazakhstan, Kyrgystan, Tajikistan, Turkmenistan, Uzbekistan) come from studies of varied origin:

- isoseismal maps included in the unpublished "Atlas" by Shebalin (1977)
- former USSR regional studies, which, unlike those for from Caucasus and Kamchatka have not yet been fully published, with the only exception being some material for Kyrgystan (Kalmetieva et al., 2009)
- studies which are devoted to bordering regions, such as the one by Ambraseys and Bilham (2003) ranging from northern Iran to northern Pakistan
- a monographic study of the 8 July 1895, Krasnovodsk (Turkmenistan) earthquake (Ambraseys, 1997a).

Some attempts in GEH project have been done to try and retrieve intensity data points from the unpublished maps of the atlas by Shebalin (1977) that support the earthquake parameters. To this end the maps of the 8 June 1887, Verny (Kazakhstan) and the 11 July 1889, Chilik (Kazakhstan) earthquakes were selected.

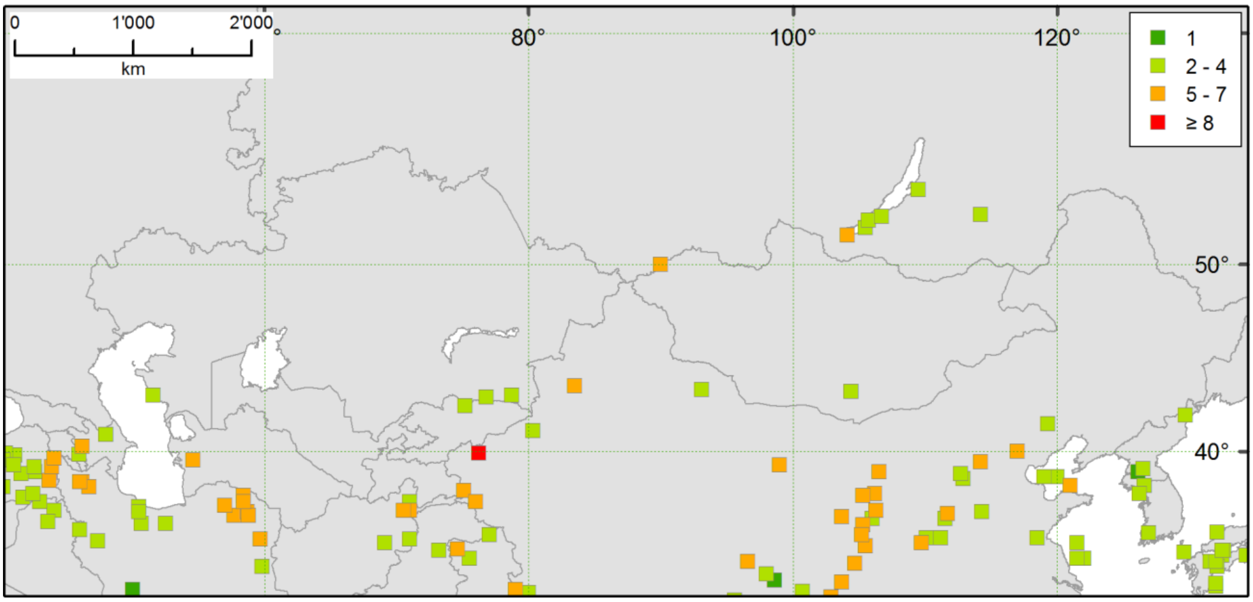


Figure 2.21 Earthquakes in GHEA (1000-1903) in Central Asia, and number of records per earthquake

Some of the problems that were encountered are general ones, such as that the names on maps are given for a few places, and for most of them only the symbol of the intensity degree is plotted. Other problems are specific to Shebalin's maps, such as: (i) gross errors in the geographical elements, (ii) even if the locality name is given on the map, place names have changed several times since the 1970s, when the isoseismal maps were compiled; or the place itself has disappeared (for instance, is now underwater due to the construction of a dam). Due to these obstacles, the efforts were restricted to intensity degree 4 (MSK), but even with this limitation it has not been possible to attribute co-ordinates and place name to all the data included in the maps.

2.8 South Asia and the Himalayas

The modern seismological literature on the Indian subcontinent and the Himalayan region still largely relies on the catalogue compiled by the seismologist R.D. Oldham, who was chief officer of the Geological Survey of India, "A catalogue of Indian earthquakes from the earliest time to the end of A.D. 1869, by the late Thomas Oldham [his father]" (Oldham, 1883). In his introduction, Oldham clearly states the authorities accessible to him, among which he first mentions the earthquake compilations by Mallet (1853-1855) for the period up to 1842 and those by Perrey, especially for periods after 1842. This situation is very similar to that ascertained for other areas of the world, such as the Philippines and North Africa. The other contributions that Oldham mentions go from local press to travellers' reports.

Recent papers (e.g. Rajiendran and Rajendran, 2011, in their Fig. 1) still reference Oldham's catalogue as a main source, particularly for the earliest period. In the last twenty years, the number of studies on historical seismicity in this area has increased significantly, thanks to the work initiated by Nick Ambraseys, Roger Bilham and others, but all of whom use Oldham's (1883) work. Care is needed, therefore, to prevent that vulnerabilities in Oldham (1883), inherited from Mallet or Perrey, do not propagate further into modern studies.

In building the Global Earthquake History Archive, a painstaking effort was required to compose a coherent picture from the several partial contributions available. These are considered here as they relate to the subregions within the general area of South Asia, and are described starting from the west (Afghanistan and Pakistan), proceeding eastwards (India and Bangladesh; for Burma see section 2.11.2 below), to conclude with the northern part of India and the Himalayan region.

2.8.1 Afghanistan and Pakistan

The main reference for Afghanistan is a paper by Ambraseys and Bilham (2003). Though in the introduction it is stated that the paper is focused on Afghanistan and its seismic history "*from the time of the earliest known Afghan earthquakes in the 8th century, to the present time*", in fact the study area of Ambraseys and Bilham (2003) extends so as to include "*the whole of Afghanistan; the eastern part of Iran; southern-most Turkmenistan, Uzbekistan, and Tajikistan; western Baluchistan; and northwestern Pakistan*". The authors state that "The GSHAP catalogue, in particular, is uncritical and occasionally misleading", and go back to the historical sources, complementing the available compilations (such as Oldham, 1883), for the early period, with Persian documents, "*while for the later period British and French consular reports are available that occasionally refer to earthquakes outside the Kabul region*".

In this area, Ambraseys and Bilham (2003) deal with three earthquakes included in Global Historical Earthquake Archive, all of them located in eastern Afghanistan: 6 July 1505, 22 January 1832 and 19 February 1842.

The case of the 6 July 1505 Kabul earthquake is of particular interest, because of its proximity in time to the devastating earthquake of 7 June 1505 (6 June in some sources) in Tibet and Nepal. Some writers, including Oldham (1883), conflate the two events, partly due to the fact that until recently, Tibetan accounts of the June earthquake were inaccessible, and the earthquake was only known from reports of the distant effects in the North Indian plain (Musson, 2012d). Ambraseys and Bilham (2003) assess a magnitude of 7.2 Mw for the July earthquake, making it the largest in the vicinity of Kabul.

The same three eastern Afghanistan earthquakes are considered also by Ambraseys and Douglas (2004), whose study supplies an important set of 29 macroseismic data points for the 19 February 1842 earthquake.

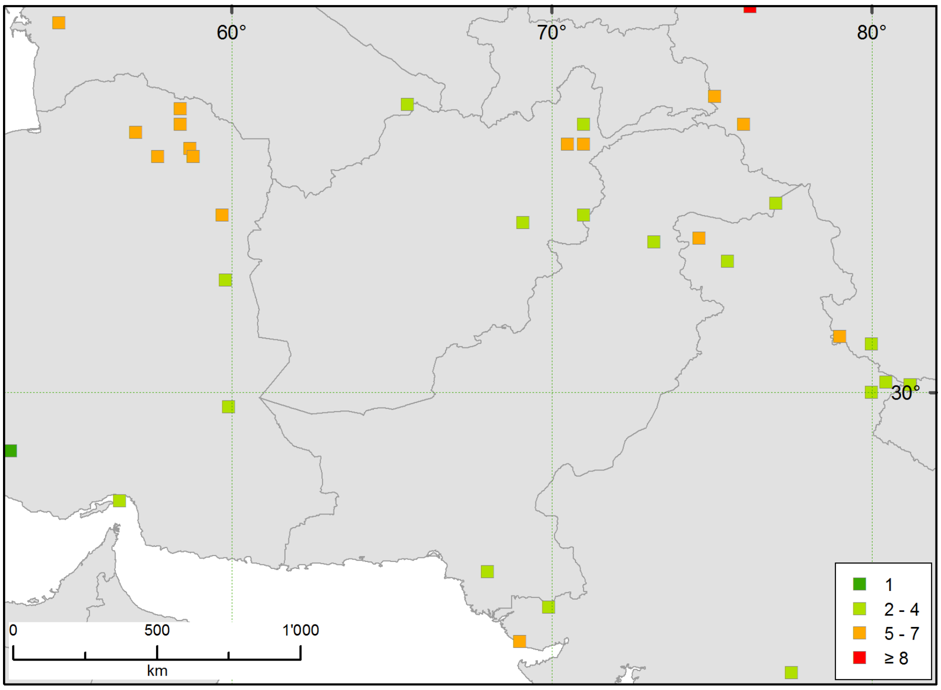


Figure 2.22 Earthquakes in GHEA (1000-1903) in Afghanistan and Pakistan, and number of records per earthquake

For this earthquake the study by Ambraseys and Douglas (2004) has been preferred to the one by Ambraseys and Bilham (2003), which does not contain any intensity assessment. It has been preferred to Martin and Szeliga (2010), who supply less intensity data.

2.8.2 Peninsular India and Bangladesh (excluding Himalayas)

The South Asian peninsula is recognized to be a low seismicity area, with the exceptions of the southern Pakistan/Gujarat area, to the west, and to the east the northern part of Bangladesh at the border with Burma. This was confirmed by the activity performed in the framework of GEH.

Jaiswal and Sinha (2007) produced a catalogue for Peninsular India from 1842 on (available at www.earthquakeinfo.org, see Jaiswal and Sinha, 2005); it does not contain any earthquake within the GEH magnitude threshold (just one earthquake with M 6.1 is listed between 1842 and 1903). An earthquake in Bombay on 26 May 1618, to be found in some global catalogues currently in use (e.g. NOAA; Dunbar, 2002), and given a magnitude of 6.9 by Bhatia et al. (1999), was investigated in the course of the GEH project and found to be spurious (a misreported storm, included by Oldham, 1833, in his earthquake list).

For southern Pakistan/Gujarat and Bangladesh areas, the reference contributions for pre-1903 earthquakes are two: i) Ambraseys and Douglas (2004), who supply reliable and updated intensity data points, as well as re-evaluated parameters for the 1819 Rann of Kutch earthquake in the west and for four earthquakes in the region of Bangladesh; ii) Martin and Szeliga (2010), who partly supplement the previous study, with the inclusion of four more earthquakes in Bangladesh and North East India.

Though used by Ambraseys and Douglas (2004), another short contribution on Indian earthquakes by Ambraseys (2004a) is worth being mentioned, as it seems to have been forgotten/overlooked by the most recent studies (including Martin and Szeliga, 2010). This paper deals with a 893 event (in a period not considered by this project) and two 17th century earthquakes, a 1664 event in Bangla and a May 1668 in the Indus Delta. Ambraseys concludes that the 1664 earthquake "*probably was associated with the Shillong*

Plateau" (see parameters in Ambraseys and Douglas, 2004) while the May 1668 earthquake "*in the Indus Delta was a relatively small event*". This latter earthquake of 1668 is a discussed event, as by recent studies it is located at Tatta (Bhuji), and interpreted as an earlier earthquake to be associated to the same area of the 1819 and especially the 2001 Bhuji earthquake (Bhatia et al., 1999; Gupta et al., 2001).

Though Ambraseys (2004a) does not assess the parameters, we share his conclusion on the relatively small size of the 1668 earthquake, and we do not include it in the catalogue notwithstanding the M 7.5 assessed by Bhatia et al. (1999).

The largest earthquake affecting what today is Bangladesh is the great earthquake of 2 April 1762. Technically, this is a Burmese earthquake, taking place on the plate boundary along the Arakan coast. However, because until recently it has been known more or less exclusively from Oldham (1883), who only had reports from colonial outposts at places like Chittagong and Calcutta, it has been wrongly represented as a Chittagong earthquake with a modest magnitude: Szeliga and Martin (2010) give 6.3 Mw. The magnitude is more realistically 8.8 Mw (Cummins, 2007; Musson, 2012d).

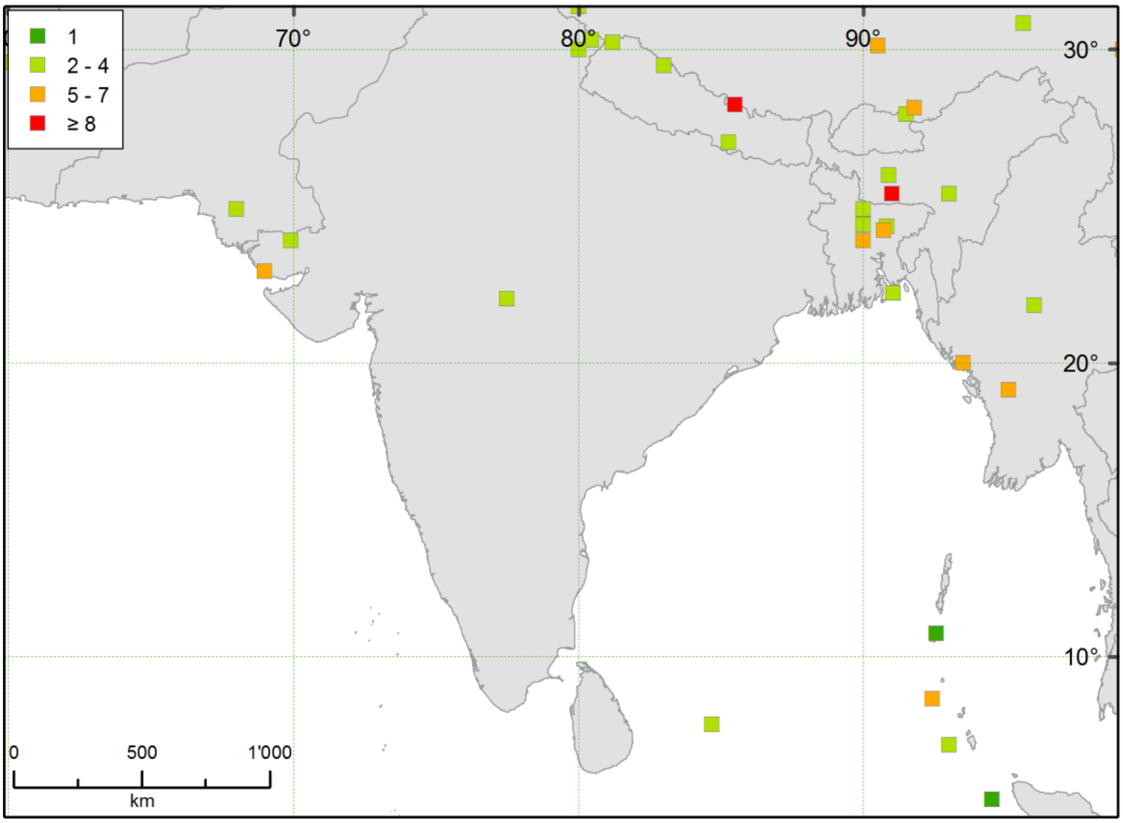


Figure 2.23 Earthquakes in GHEA (1000-1903) in India and Bangladesh, and number of records per earthquake

Disagreements on key events continue in the literature. The great earthquake of 7 June 1505, already mentioned above, was obscure until revaluated by Ambraseys and Jackson (2003) with an estimated magnitude of about 8.2 Mw. Rajendran and Rajendran (2011) consider this to be a considerable exaggeration, while work by Bilham presented at AGU in 2011, and so far unpublished, argues that the magnitude was probably close to 9 Mw. In such a situation, the "living archive" concept behind GHEA is particularly useful in keeping track of the changing balance of opinion as new evidence emerges, and will undoubtedly continue to emerge.

2.8.3 Northern India and the Himalaya

On the area of northern India and southern Tibet, four important contributions should be mentioned:

- a comprehensive study of the 26 August 1833 earthquake by Roger Bilham (1995) (see more below)
- a study by Ambraseys and Jackson (2003) dealing with seven, pre- to early 19th century large earthquakes in the Himalaya
- the study by Ambraseys and Douglas (2004), which in fact extends from Afghanistan to Bangladesh, including northern India
- the study by Martin and Szeliga (2010), already mentioned for other areas, and covering the same geographical area as Ambraseys and Douglas (2004).

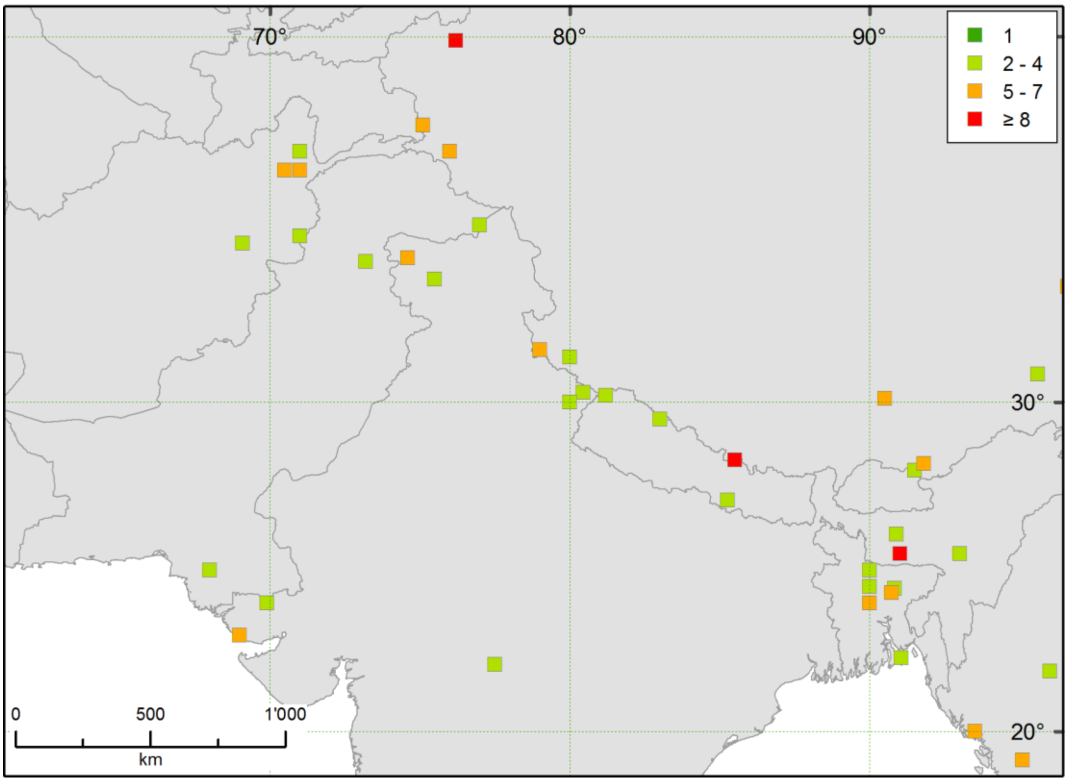


Figure 2.24 Earthquakes in GHEA (1000-1903) in N India and the Himalaya, and number of records per earthquake

For this area, as well as for previously discussed areas of this region, the study by Ambraseys and Douglas (2004) should be reckoned to be by far the most complete and reliable study published so far. It is the preferred source of information for fourteen earthquakes in this region in the GEH Archive.

Finally, concerning catalogues for South Asia, the only two published and publicly available parametric catalogues were those produced in the framework of GSHAP (Bhatia et al., 1999; Zhang et al., 1999). They overlap completely from the geographic point of view but disagree on parameters in most cases. The most recent overall contribution is Szeliga et al. (2010) and its supporting paper by Martin and Szeliga (2010). Despite the title of the latter ("A Catalog of Felt Intensity Data for 570 Earthquakes in India from 1636 to 2009"), the paper does not supply a complete catalogue, that could be relied upon by GEH; there are cases such the 1664 Bangladesh earthquake, which is mentioned in the introduction to Szeliga et al. (2010) but for which no parameters are supplied.

Individual studies have also been published on some key earthquakes of this area. One such is the famous 12 June 1897 Shillong earthquake, important in seismological history for providing the first reliable reports of vertical accelerations in excess of 1 g. The first comprehensive modern evaluation of this earthquake is given in the paper by Ambraseys (2000a), who used the survey data contained in the report by Oldham (1899).

A few years later, a complete re-assessment of the distribution of intensity data was done by Ambraseys and Bilham (2003a), who enlarged the coverage of Oldham's report by collecting new data from sources previously not considered. This paper does not supply epicentral location or magnitude, leaving this task to a following paper (Ambraseys and Douglas, 2004). The latter paper includes a full table of intensity datapoints fully coincident with those supplied by Ambraseys and Bilham (2003), and with the same magnitude and location estimated by Ambraseys (2000a).

There is still no shortage of questions to be answered concerning historical earthquakes in the Indian subcontinent. A number of problematic cases presented themselves in the course of the GEH research. Some of these relate to irregular results coming from different assessments of epicentres and magnitudes, as in the case of the 1505 and 1762 earthquakes mentioned above.

Others might depend on issues relating to the influence of population distribution on the pattern of reporting in bordering countries. A paradigmatic case is the 26 August 1833, Nyalam (Tibet) earthquake, for which in GEH Archive are inventoried eight different studies (a limit case in a positive sense, since there are just twelve out of the 994 earthquakes in the Archive with eight or more items inventoried).

These eight items are quite equally divided into two branches, one branch made of a) studies on Indian/Himalayan earthquakes, the other of b) studies on Chinese earthquakes, in chronological order in the following:

a) the 1833 earthquake in studies on India and the Himalayas

- a monographic study by Bilham (1995), who gathered Nepalese and English officers' reports and assigned an intensity value in MM scale at 101 different places; the author assessed a magnitude (Mw 7.70 ± 0.2) but not an epicentral location (in terms of co-ordinates);
- the parametric catalogue by Bhatia et al. (1999).
- the study by Ambraseys and Douglas (2004), supplying 61 macroseismic data points in MSK scale that are the background data they used to derive the earthquake parameters
- the study by Martin and Szeliga (2010), supplying 85 macroseismic data points in EMS scale
- the study by Szeliga et al. (2010), who derived the parameters of the earthquake starting from the intensity data assessed by Martin and Szeliga (2010).

b) the 1833 earthquake in studies on Chinese earthquakes

- the "Atlas of the Historical Earthquakes in China-Qing Dynasty" (China State Seismological Bureau and Fudan University, 1990b), supplying a colour isoseismal map, a descriptive text and a full set of parameters
- the official Chinese catalogue in use, edited by Min Ziqun (1995), in Chinese, that further than a full set of parameters includes a descriptive text, and a black and white location map, with a few intensity data points
- the parametric catalogue by Zhang et al. (1999).

The magnitude values range from Mw 7.60 (Ambraseys and Douglas, 2004) to M 8.0 (e.g. Min Ziqun, 1995), but what varies considerably is the epicentral location. The adopted solution is the full set of parameters of the Chinese catalogue edited by Min Ziqun (1995). These parameters are in their turn based on the effects distribution supplied by the "Atlas" (China State Seismological Bureau and Fudan University, 1990b), which according to the critical analysis, performed in the framework of GEH on the full set of available studies, best represent the location of the 26 August 1833 earthquake.

As it has been remarked elsewhere in describing the content of this archive, it is especially in bordering areas that the comprehensive vision offered by the GEH Archive can suggest new insights into the understanding of large earthquakes of the past centuries.

2.9 China

China is a particular example of a case where the amount of effort required to produce a catalogue is as nothing compared to the effort required to build the archive. For the first time, the previously scattered material in two languages (English and Chinese) has been inventoried and put together in a way that will certainly provide new insights into China's long earthquake history, and form the basis for future studies. What follows in this chapter is simply an introduction to a rather complicated situation, indicating lines along which further investigation is needed, in the field of historical seismology and in collaboration with other disciplines.

Collecting records on historical earthquakes goes back a long time in China. The history and state-of-the-art of research on past earthquakes in China is described in detail in the paper by Wang (2004). Its content is summarised and further commented on here, firstly to give an idea of the activities carried out locally, and at the same time to introduce the studies included in GHEA.

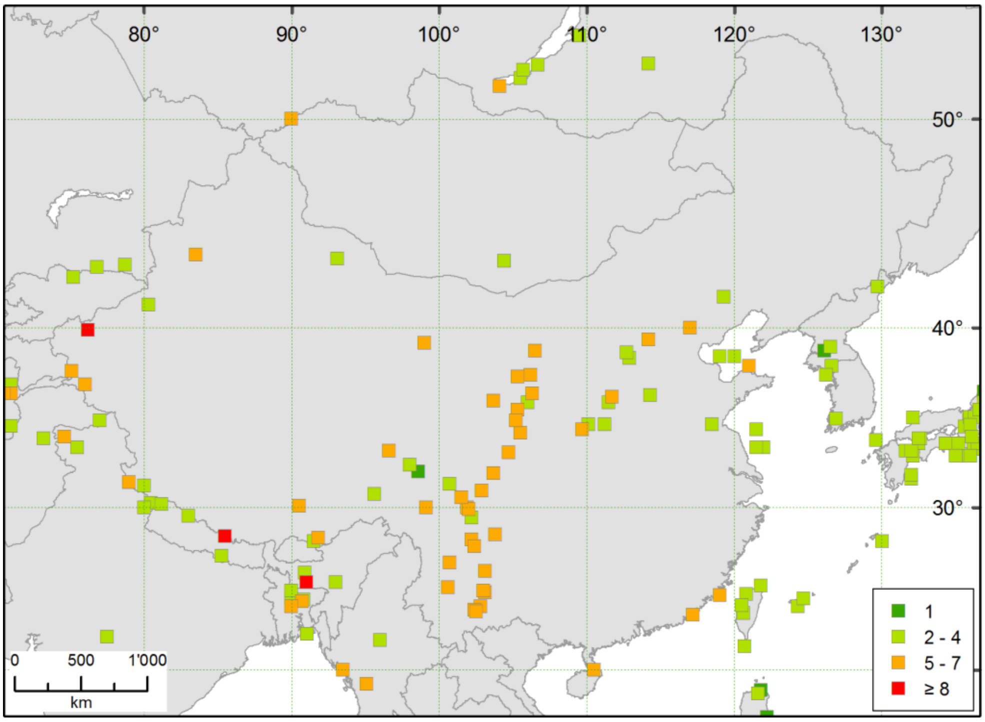


Figure 2.25 Earthquakes in GHEA (1000-1903) in China, and number of records per earthquake

Since the Ying dynasty (16th-11th century B.C.) officially-appointed officers took care of recording political events; their records also include mention of natural phenomena, among which large damaging earthquakes were obviously included. As changes occurred in the central adminsitration of the Empire, partly due to territorial expansion, these central officials were replaced by local, mainly provincial, ones who were entrusted with this important task. The first collection of Chinese earthquake records is a chapter of the "Imperial

Readings of the Taiping Era” (Taiping Yulan), a sort of encyclopedia commissioned by Emperor Taiping Xingguo of the Song dynasty and compiled between 977 and 983; its 1,000 volumes include quotations from thousands of documents, and in the related section are found descriptions of 45 earthquakes between 11th century B.C. and 618 A.D.

Turning to the 20th century, after the establishment of the People’s Republic of China (1949), two large-scale efforts to collect records of historical earthquakes were promoted by government scientific institutions, and their results were presented in two publications:

- “Chronological Data of Historical Earthquakes in China” (1956), in two volumes, is due to the joint efforts of historians and seismologists of the Academia Sinica who investigated historical sources in search of descriptions of earthquake effects in 26 Chinese provinces (Historical Earthquake WG of Seismological Committee of Academia Sinica, 1956)
- “Compilation of Historical Materials of Chinese Earthquakes” (Xie and Cai, 1983-1987), in five volumes, is the result of the work done by historians and seismologists from 1977, as organized by the then State Seismological Bureau (SSB) (nowadays Chinese Earthquake Administration, CEA), the China Academy of Social Sciences and the Academia Sinica.

Individual researchers also collected information, but their efforts were mostly at a local level, and their results were not integrated into the national projects. These two collections are at the roots of modern, parametric catalogues of historical earthquakes.

Between 1960 and 1995, supported by the data collected in the two publications mentioned above, four successive editions of the national earthquake catalogue were published, “sponsored by governments and recognised in the whole country” (Wang, 2004).

The latest publication on historical earthquakes, which resulted from the combined efforts of historians, seismologists and geographers, is a three-volume “Atlas of the Historical Earthquakes in China” (1986, 1990a and 1990b). The three volumes of the “Atlas” are a publication of paramount importance, supplying 678 coloured maps complete with isoseismals and parameters (epicentral intensity and coordinates, magnitude). For some large events, a text describing the map and pictures (of a damaged building or original sources, e.g. a stele) is included.

In the preparation of GHEA, the following were used:

- the third edition of the catalogue (Gu Gongxu et al., 1983) in the English version (Gu Gongxu et al., 1989);
- the fourth edition of the catalogue, that is the first volume covering the period up to 1911 (Min Ziqun, 1995), in Chinese;
- the three volumes of the “Atlas” of the Historical Earthquakes in China” (respectively 1990a, 1986, and 1990b), covering namely:
  - The Period from Remote Antiquity to the Yuan Dynasty (23 cent. B.C.-1368)
  - The Ming Dynasty Period (1368-1644)
  - The Qing Dynasty Period (1644-1911).

Still included in GHEA is the catalogue for continental Asia compiled by Zhang et al. (1999) in the framework of GSHAP (1992-1999), which was the only input for initial versions of GHEC. As explicitly mentioned by Zhang et al. (1999), for mainland China up to 1900 they relied upon the same two catalogues used by this project (Gu Gongxu et al., 1989; Min Ziqun, 1995).

The two catalogues considered in this project differ substantially from many other parametric-only catalogues, because they include a qualitative description of the earthquakes.

Gu Gongxu et al. (1989) and Min Ziqun (1995) (in English and Chinese respectively; as mentioned above, the later of these updates the earlier one) have the same structure:

- date and parameters, including the definition of the epicentral area
- a textual description of the earthquake effects, starting from the most damaged area, and supplying details of damage and other effects in each place
- a location map (in black and white), usually of the most damaged area; for some large earthquakes there are two maps, and sometimes isoseismals and/or intensity data are also drawn.

They do not supply a one-by-one list of references nor a list of historical sources, their reference being the “Compilation of Historical Materials of Chinese Earthquakes” (Xie and Cai, 1983-1987).

The "China Seismic Intensity Scale (CSIS)" used in the preparation of the "Atlas" was first established in the late 1950s (Wang, 2004), by Xie (1957) who published a twelve-degree scale, modelled on the Modified Mercalli 1931 (Wood and Neumann, 1931), and taking into account the Scale of the Institute of Physics of the Earth, USSR, 1952 (Wang, 2004; Xie, 1957). This was the scale formalised and finally adopted around 1980 by CEA, and it is referred in the explanatory remarks at the beginning of Min Ziqun's catalogue (1995) as "A new scale of seismic intensity adapted to the conditions in Chinese territories" (this is the exact title of the paper by Xie, 1957).

As for magnitudes (Min Ziqun, 1995), they were calculated according to "magnitude-intensity empirical equations", for three different areas:

$Ms=0.579Io+1.403$ for the eastern part of China mainland

$Ms=0.605Io+1.376$ for the western part of China mainland

$Ms=0.507Io+2.108$ for the Taiwan region.

It may be mentioned in passing that this causes some clear problems in the case of some large earthquakes, where large magnitudes result from high epicentral intensity values: for instance, the 25 September 1303 earthquake, with an epicentral intenstiy of 11, gets a magnitude of 8.0 from the second of the equations above. But as much of the damage was – most probably - caused by liquefaction, not directly by shaking, the intensity assignment is not dependable, and thus the magnitude is potentially exaggerated.

A survey of two majior Chinese academic journals (“Acta Seismologica Sinica” and “Acta Geophyisica Sinica”) has shown that, with a few exceptions such as Wang (2007), large historical earthquakes in China have not been recently investigated in monographic studies, according to the historical seismological approach. Many large earthquakes are conversely included in a number of recently published papers, which are quite entirely devoted to palaeoseismology or surface faulting studies. These papers increased in number especially after the 12 May 2008 Wenchuan, Sichuan (7.9 Mw) earthquake and that of 14 April 2010 Yushu, Tibet (6.9 Mw).

In preparing the Global Archive many of these papers were consulted, but were taken into account with regard to magnitude assessments; if these varied from those in the catalogues, they were generally not derived from macroseismic data, but from slip estimates. Likewise, some papers appear to include earthquakes not known from previous studies, but presented in an unusable way. One can find maps of fault systems with lists of years written against each branch – supposedly the years in which the segment ruptured. In some cases these years do not correspond to any known earthquake; but unless these can be confirmed by studies supported by historical documentation, they may simply be errors and cannot be used.

To show how the archive might be complemented by retrieving and inventorying further material on large historical earthquakes in China, a few exceptions were made to include studies dealing with specific earthquakes:

- Li (1957, in Chinese), because it supplies descriptions of effects in Beijing of some large earthquakes, including two important events in the 17th century (1626 and 1679);
- Zhang et al. (1986) and Deng and Liao (1996), because they give interesting information on the 3 January 1739 earthquake (8 Mw);
- Xu et al. (2010), because though their paper deals mainly with surface ruptures in Gansu, they also supply a detailed description of effects of the 11 July 1609 earthquake.

With respect to possible future studies, it might be worthwhile to investigate the local (and quite unknown outside of China) scientific production of the several provincial offices of China Earthquake Administration and their connected publishing houses.

Given the limited movement of Europeans in China in historical times, European sources on historical earthquakes in China, possibly not accessed by Chinese researchers, are relatively unimportant, though Musson (1995) demonstrated that they can include information not represented in Chinese sources, at least in South China in the 19th and early 20th centuries. Musson (1991) compiled an earthquake catalogue for South China for use in hazard assessments for Hong Kong using both European sources, and mostly Xie and Cai (1983-1987). He reports that in some cases, different interpretations are possible of some events, from what appears in Chinese catalogue; for instance, cases where reports probably relating to the same event have been split by compilers into different earthquakes. However, such problems chiefly affect minor earthquakes and are therefore not important for Global Historical Earthquake Archive.

Earthquakes in Mongolia in GEH Archive are one in 1761 and one in 1903. The 1903 earthquake is listed in the catalogues by Zhang et al. (1999) and Kondorskaya and Ulomov (1999) with the same location, but different magnitudes (Mw 7.50 and 7.60 respectively), and with different location and magnitude in Engdahl and Villaseñor (2002). The 9 December 1761 earthquake is listed in catalogues of former Soviet Union (Shebalin, 1977; Shebalin and Leydecker, 1997; Kondorskaya and Ulomov, 1999) as well as in a joint Soviet-Mongolian study on major earthquakes (Khilko et al., 1985; see also Baljinnyam et al., 1993).

No studies on historical earthquakes in Mongolia have been retrieved. Consequently, with the exception of the 1761 earthquake at the borders between Soviet Union and Mongolia (Khilko et al., 1985), it was not possible to check the “completeness” of the Global Earthquake History Archive for what Mongolia is concerned.

2.10 Japan and Korean peninsula

2.10.1 Japan

Japan combines a high seismicity with a long history of earthquake recording. What has been done in the field of investigation of historical documents on earthquakes is clearly detailed in the paper by Usami (2002), as well as in Ishibashi (2004).

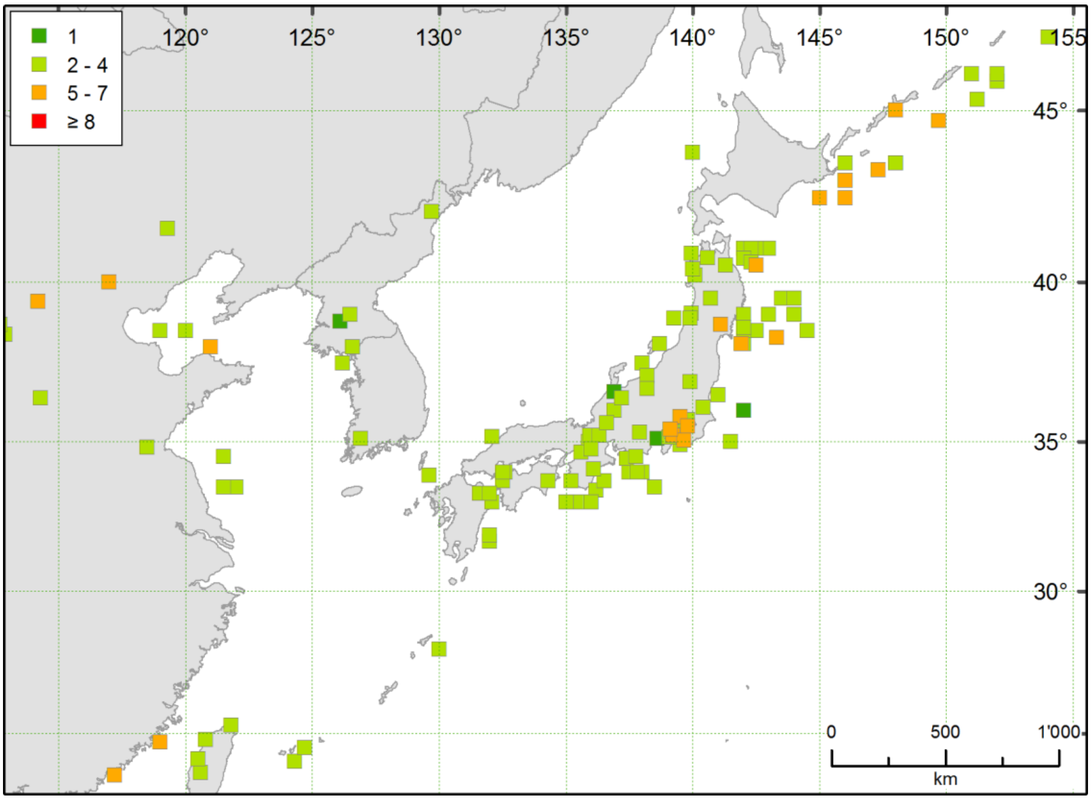


Figure 2.26 Earthquakes in GHEA (1000-1903) in Japan, and number of records per earthquake

The oldest earthquake catalogue surviving for Japan is contained in a section devoted to earthquakes in "Ruiju Kokushi" (Classified National History), compiled by Sugawara no Michizane (845- 903), an eminent court scholar, and completed c. 900 (Ishibashi, 2004).

As in many other countries, it was in the late 19th century when the first seismological compilations of historical earthquakes started to be produced, in Japan's case in the wake of the large 1891 Nobi earthquake of magnitude 8.0 Mj (JMA magnitude, approximately equal to Mw). In early 1892 the Imperial Earthquake Investigation Committee was established, and since then, studies of historical earthquakes have continued to be carried out, with the combined efforts of seismologists, historians, geographers and researchers in other disciplines.

Among the great collections of documents on Japanese earthquakes, the two which have been largely used since their publication, and which are at the roots of catalogue compilations, are the following:

- "Collection of Historical Documents on Earthquakes in Great Japan, Enlarged and Revised Edition", in three volumes, published in 1941 and 1943 with the support of the Japan Society for the Promotion of Science (Musha, 1941, 1943a, 1934b); the fourth volume, with a slightly different title, was published later (Musha, 1951)
- "Historical Documents on Earthquakes in Japan, New Collection", for a total of 21 volumes (ERI - Earthquake Research Institute of the University of Tokyo, 1981-1994), published as the result of an investigation started in the 1970s at ERI by Usami, then endorsed and funded by the Ministry of Education, and which saw the cooperation between ERI and the History Institute of the University of Tokyo.

Publications on individual earthquakes or dealing with specific aspects related to historical earthquakes (such as the calendar to be adopted, and the re-evaluation of damage caused by large historical earthquakes in today's densely inhabited metropolitan areas) have increased since early 1980s, most of them in Japanese scientific journals.

In building the GEH Archive, the project was not able to establish an effective collaboration with Japanese colleagues involved in this field, and this has meant a slightly narrowed perspective so far as Japan is concerned. In particular, operational constraints meant that the inventorying activity was restricted to papers and websites available in English, though with the awareness that there are results of recent investigations that have not yet been included in publicly available catalogues, and thus are outside the reach of the project.

There are at least two branches of parametric catalogues produced since the early 1980s and published in English, which stem from the investigation of the historical seismicity of Japan:

- One branch derives from the works by Tatsuo Usami (e.g. Usami 1987, 1996, 1998, 1999, 2002a, all in Japanese). Data included in the GEH archive are taken from his "Study of Historical Earthquakes in Japan" (Usami, 1979) and “Historical Earthquakes in Japan”(Usami, 2002).
- The other branch has its root in the works by Tokyji Utsu (1988, 2002) and has been compiled by him, and more recently updated in an online database (Utsu, 2011).

The first catalogue by Usami (1979) is contained in a paper introducing in a five-page description the "study of historical earthquakes before 1970" in Japan; apart from using the collections already mentioned above, Usami included material from other previous data collections, among which he mentions the "Tables of historical large earthquakes between 416 and 1918" by Omori (1919).

Most of Usami’s paper (1979) is occupied by Table 1, "List of earthquakes with damage in Japan before 1975". This table is in fact a catalogue, and it includes date and time, epicentre, depth (from 1926 onwards), magnitude, "grade of damage" according to JMA scale, "number of dead and of totally destroyed houses", and he states that the Gregorian calendar has been used.

As for the magnitude values, Usami (1979) states that

> "*Magnitude and epicentre location of earthquakes before 1884 were taken from Kawasumi's work. He derived magnitude using the relation*
>
> $$M = 0.5Mk + 4.85$$
>
> *where Mk is the Japanese intensity scale at a point 100 km distance from the epicentre* [...] *For those between 1885 and 1925, values given by Utsu (1979) were adopted. However, for special earthquakes, values revised by the present author were adopted*.”

Usami (2002) could be considered as a revised version of the previous catalogue, with a somewhat expanded table, with more information in the column “Area/outline of the damage”. The catalogue has the same format as Usami (1979), and supplies magnitude values in general slightly different from the previous ones, and it is explained that in some cases this is due to new information collected and a new intensity data distribution. No further details on how magnitude and epicentral location were assessed is supplied.

An important contribution to the GEH Archive also comes from the works by Utsu, who focused on two aspects: i) a catalogue for Japan in the time-span 1885-1925 (Utsu 1979; 1982; 1988); ii) a global list of “deadly earthquakes in the world” (Utsu, 2002).

The portion of Utsu’s catalogue for Japan (Utsu, 1979) was referenced and used by Usami (1979); and its revised version (1982; 1988) was included in the revised version of the world catalogue by Utsu himself (2002).

To make the best possible use of Utsu’s contribution, in compiling the GEH Archive the portion on Japan from the latest available version of the “Catalog of Damaging Earthquakes in the World (through 2009)” was used, and named “Utsu online” (2011) to distinguish it from other versions. This is in accordance with the guiding philosophy of the GEH project, to give preference to publicly available data in all possible respects.

In the description accompanying the printed version of the world catalogue (Utsu, 2002) the author specifies what sources he used for Japan, and that “no new estimation of epicentres and magnitudes has been made”. In addition, Utsu (2002) states that “all magnitudes of the earthquakes in Japan [pre-1900] are the JMA magnitudes or equivalents”.

An important point concerns the dates of earthquakes in the different studies. A full account of the standard adopted in Japanese studies is supplied by Utsu (2011) in the notes to the columns of the table:

> “*The Julian calendar is assumed for earthquakes before 1582 and the Gregorian calendar for earthquakes thereafter. This rule, however, is not perfectly observed, and some references mix up these two calendars. For example, Milne (1911) tabulates Japanese earthquakes before 1582 using the Julian calendar, but I found some earthquakes recorded using the Gregorian calendar … It is common for Japanese earthquakes before 1582 to be recorded using the Gregorian calendar, but I rewrote the dates of occurrence using the Julian calendar for the table of this file.*”

In GHEA, care has been taken to avoid duplicating earthquakes because of events appearing with two different dates in the two selected catalogues for Japan (Usami always uses the Gregorian calendar, even for earthquakes before 1582, while Utsu uses both the Julian and the Gregorian calendars). This is not the case with some previous lists of earthquakes, as is pointed out by Utsu online (2011): “*Other references tabulate two earthquakes occurring in the same place with an interval of a few days with the first one using the Julian calendar, and the other corresponding to the same date in the Gregorian calendar*.”

The area of northern Japan is also covered in GHEA by the catalogue from Shebalin and Leydecker (1997), a description of which is given in the chapter on Russia (see section 2.7 of this report).

The work conducted by "Team Tokyo" (http://usgsprojects.org/tokyo/about.html and for publications http://usgsprojects.org/tokyo/publications.html) between 2005 and 2008 was thoroughly analysed and included in the GEH Archive. Though the focus of the project was obviously Tokyo, the intensity data points they made available, retrieved from Usami (1994), constitute a very important contribution to the understanding of historical seismicity of Japan. Such intensity data points are made available as supplementary data to the paper by Bozkurt et al. (2007). They have been retrieved and georeferenced in a homogeneous way and the original intensity scale, that is the one used by JMA (Japan Meteorological Agency), was maintained. They have been included in the GEH Macroseismic Database (demo version) without any modification, in the original intensity scale. Their importance lie in being the supporting data of the parameters as re-assessed in the papers by Bakun (2005) as well as Grunewald and Stein (2006). For an easily readable version of the JMA scale, a slightly edited English version is found in the appendix to Musson et al. (2010).

The paper by Bakun (2005) is focused on the calibration of the method developed by Bakun and Wentworth (1997) to Japanese seismicity. In particular, the author discusses the implications of the re-assessed parameters for the 1885 Ansei Edo and the 1923 Great Kanto earthquakes.

Grunewald and Stein (2006) used the method developed by Bakun and Wentworth (1997), calibrated as described in Bakun (2005), “to create location and magnitude models from intensity data for fifteen destructive earthquakes that occurred near Tokyo between 1649 and 1884”. They went further in analysing all the available intensity data on historical earthquakes, so as to supply a fully updated catalogue for the time-span 1649-1884.

The GEH Archive contains 100 earthquakes with M≥7 for Japan.

In general, GHEC adopted the parameters supplied by “Utsu online”, with a few exceptions. There are two earthquakes for which Usami (1979) was selected, and six other earthquakes for which the parameters derived by Grunewald and Stein (2006) have been adopted. The latter study was preferred when their parameters differed significantly in magnitude ("the mean increase is 0.3 MJMA units") and/or in location ("inferred epicentres from this study are less tightly clustered around Tokyo and suggest a more dispersed region of seismicity, consistent with the instrumental catalog") from those in Utsu online.

2.10.2 Korean peninsula

Studies on historical seismicity originated in the Korean peninsula are available in languages other than Korean from 2004 onwards, only. Before that year, most of the data had been made available either in Japanese (Wada, 1912; Musha, 1951) or in Chinese language and mostly from Chinese authors, such as in the works by Li (1986) and later by Wu et al. (1994; 2001). These latter contributions are mentioned by Zhai et al. (2004), who in their paper include a table with a “Catalogue of M≥6 earthquakes in the Korean peninsula” (Table 5, p. 370).

Chiu and Kim (2004) make reference to the data supplied by Li (1986), and explain how they have used his data in their hazard estimate:

> *“Li (1986) reported historical earthquakes in the Korean Peninsula between A.D. 2 and 1983 with magnitude information directly converted from a few typical empirical formulas used in China. Kim and Gao (1995) adapted a few empirical formulas for the Korean Peninsula to convert intensity information to magnitudes for larger historical earthquakes […] In another independent effort, Lee (1999) compiled historical earthquake data in the Korean Peninsula from historical documents and Japanese reports and reported historical earthquake locations and intensity information. A comparison with magnitudes reported by the Japan Meteorological Administration between 1905 and 1945 reveals that the magnitudes reported in Kim and Gao (1995) are probably overestimated. For example, there were 28 historical earthquakes with magnitudes larger than 7.0 reported in Kim and Gao (1995), which would place Korea among the most active intraplate regions in the world. […] Since no magnitude information is available in Lee (1999) historical earthquake location and magnitude information documented in Kim and Gao (1995) is used in this study”.*

The earthquake data supplied by Chiu and Kim (2004) have been included in GHEA, but because of what they write on the fact that magnitudes by Kim and Gao (1995) are overestimated their set of parameters have been selected as the preferred ones to be inserted in GHEC in one case only (see conclusions at the end of this section).

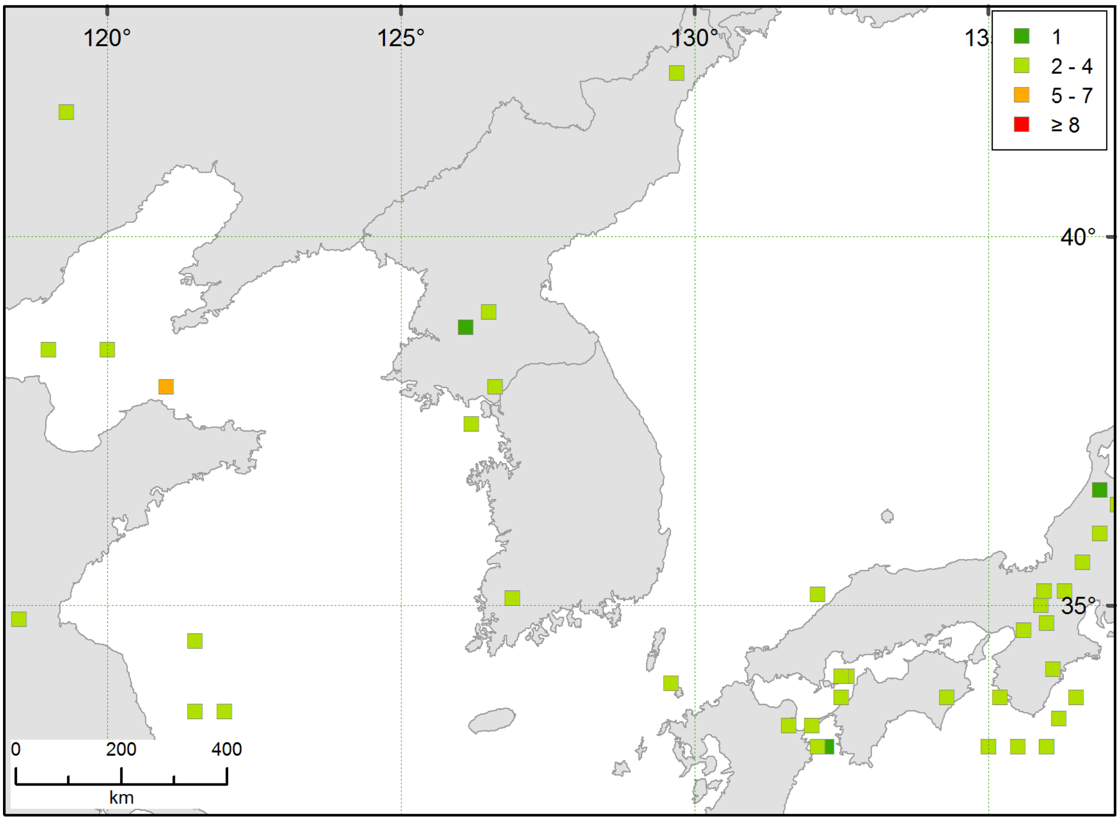


Figure 2.27 Earthquakes in GHEA (1000-1903) in Korean peninsula, and number of records per earthquake

Considering the most recently published literature, there are more hints that in the past ten years some attention and research efforts has been devoted to this topic by Korean institutions and individual researchers.

This is shown by the above mentioned papers, as well as by an M.S. Thesis submitted by Rho (2000), but especially by the work done by Lee and Yang (2006).

They recall the first compilation of historical data on Korean seismicity, done in the early 20th century by Wada (1912), who documented effects due to 1644 earthquakes, together with accounts of damage and "list of felt localities but did not determine their epicenters and intensities". The work by Wada relied on sources not available in today Korea (they are stored in Japan), and on Japanese sources only relies a later work by the Japanese Musha (1951) as well.

Lee and Yang (2006) describe also what kind of historical earthquake data are available for the Korean peninsula, classifying them according to the three main historic periods of the area, and concluding with important remarks on the types of historical sources available: "*There are primary and secondary sources of historical earthquakes in each of the three periods*. […] *All of these sources are official documents except for some private documents from the Choseon period (1392-1911).* […] *All Korean historical seismic records are written in Chinese characters*".

Lee and Yang compared Wada's and Musha's lists of earthquakes, selected the duplicated and the dubious events (see their Appendix II, in the Electronic Supplement). Finally, they fully reassigned intensities and explained how they determined epicenters and magnitudes from their newly obtained data.

In all, GEH Archive contains seven earthquakes between 1260 and 1810 with a magnitude between 5.8 and 7.0, which have survived to the comparison among the three main papers considered (Chiu and Kim, 2004;

Zhai et al., 2004; Lee and Yang, 2006) and which do not duplicate any records concerning earthquakes located in China and Japan.

The 28 May 1563, Pyongyang Region earthquake is the only one with M 7.0 listed by Chiu and Kim (2004) and not included in the list from Lee and Yang (2006). The reliability of the magnitude has been discussed above, but for the sake of completeness (and because there is no possibility to further check this event now) this earthquake is the only one with M 7.0 located in the Korean Peninsula that is included in GHEC.

2.11 South-East Asia and the Philippines

In this chapter, we deal with South-East Asia, excluding Indonesia, and the Philippines. For the purposes of this report, South-East Asia is taken to mean Burma, Thailand, Cambodia, Laos, Vietnam, Malaya and Singapore.

2.11.1 South-East Asia excluding Burma

The historical seismicity of South-East Asia is not fully described in any previous study. The area is politically and economically diverse, and includes both countries that have fallen under European colonisation and those that have not. It also shows a marked variation in seismicity. While major earthquakes have affected Burmese territory from time to time, much of the region is highly stable. There is some seismicity in the north of Vietnam arising from tectonics associated with the Red River Fault (Allen et al., 1984), but this has not given rise to major earthquakes, at least in the 20th century.

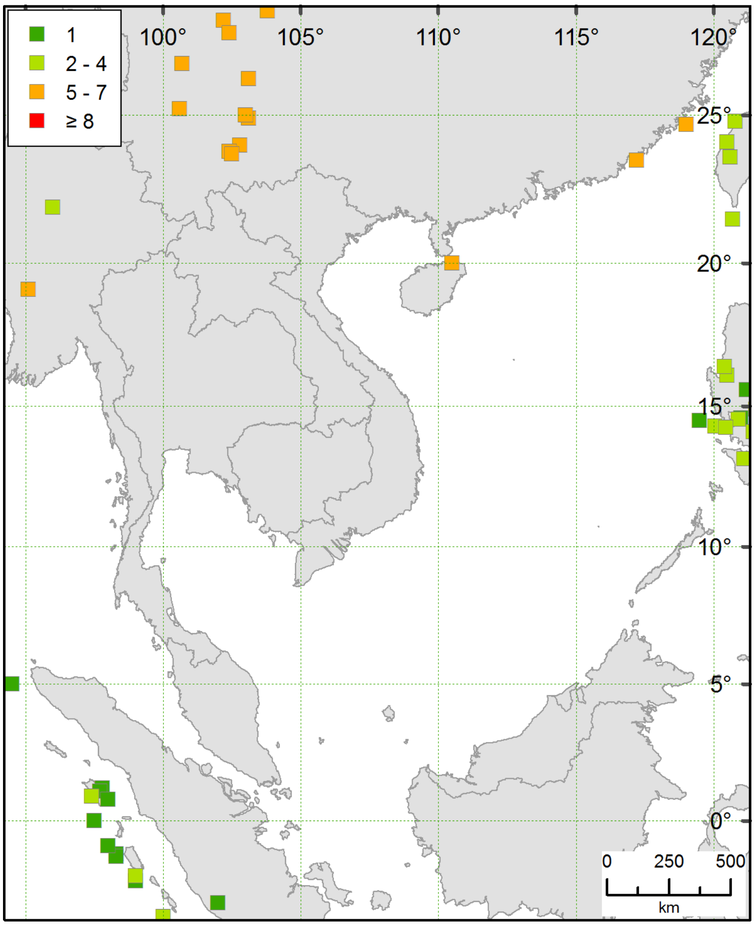


Figure 2.28 Earthquakes in GHEA (1000-1903) in South East Asia, and number of records per earthquake

A general problem with historical studies in the area is a lack of local interest, and hence of indigenous specialists. The catalogue of Nath et al. (2010), for instance, although it extends into Burma, contains no historical earthquakes in Burma. A recent hazard study for the region (Petersen et al., 2007) ignores historical seismicity entirely, and a paper by Ornthammarath et al. (2010) on Thailand remarks sourly that “The first historical earthquake recorded in a written document in Thailand was dated back to 624 B.C. … nevertheless, neither pre-instrumental tremor locations nor their sizes are well constrained. This information is therefore deemed qualitative and not suitable for direct use in quantitative hazard analysis”.

The only paper considering the whole area is from Prachuab (1988), which was published in the collection edited by Lee et al. (1988), “Historical Seismograms and earthquakes of the world”. In this paper, earthquakes are listed according to “12 seismic zones”, including the Andaman Arc and the Arakan coastal area to the west and the southern part of Yunnan to the north-east (Table 1, p.256). Only the large events are considered and very briefly described, while no earthquake parameters, such as magnitude or epicentral intensity, are assigned.

In addition, an abstract by Nguyen (1994a) describes an earthquake catalogue for all of Indochina, which apparently included historical events. The catalogue itself has not been traced. Nguyen (1994a) states that within the region, large earthquakes are only found in north-west Vietnam and north Laos, and that in the rest of Vietnam, southern Laos, and Cambodia, no large earthquakes are known.

Prachuab (1988) stated in the introduction of his paper that he relied on the, so far, only available collection of sources on historical earthquakes done by Nutalaya et al. (1985) for Thailand and Burma, published in the SEASEE Series on Seismology vol. II, available online (http://pdf.usaid.gov/pdf_docs/PNABF348.pdf for vol. II).

Nutalaya et al. (1985) is structured in three parts, reflecting successive phases of the investigation. Part A is “Seismicity data of Thailand and adjacent areas”, while Part B is “Additional seismicity data of Thailand and adjacent areas”. (Part C deals with seismic source zones). Each part has its own series of appendices; thus the authors present their data on historical earthquakes in two different appendices, both labelled “A”:

- (Part A) Appendix A, “Historical earthquakes in Thailand and Burma”, from 624 BC to 1887 (pp.14-19) was compiled by investigating published collections of historical sources related to Thailand and Burma, such as for instance the “Collection of Annals” and “Collections of Stone Inscriptions”, all in the Thai language;
- (Part B) Appendix A, “Earthquakes in Thailand and Burma prior to 1900”, from 442 BC to 1897 (pp.151-173) includes in the investigation a thorough analysis of the Geological Survey of India “Memoirs” and “Records”, which are described as “the most comprehensive records and descriptions of historical earthquakes which occurred in northeastern India, Bangladesh, Burma and the Andaman Islands”.

While the first Appendix A gives quite regularly an evaluation of intensity (presumed to be the maximum intensity, though this is not explicitly stated), in the second Appendix A the related field (“D”) is mostly empty.

There is no final list of earthquakes combining data contained in the two appendices nor any evaluation of magnitude for events pre-1900.

The situation for Vietnam is similar. A historical catalogue by Nguyen (1994b) lists 37 earthquakes ranging in date from 114 to 1882. The catalogue is in Vietnamese, and for each event, gives only date, place, intensity (scale not stated), and a note of the principal observed effects. There are no magnitudes or epicentres, and while a map is presented of the ten strongest shocks, it is illegible in the printed copy. The paper itself, which is mostly in French, mentions that four earthquakes reached intensity 8, as follows:

1278 – “secousses à trois reprises au cours d’une journée; furent morts le gros bétail et le menu bétail”

1285 – “furent brisées les stèles de la pagode Bao Thien; apparurent les affaissements au mont Cao Son”

1635 – “apparurent les affaissements sérieux dans les régions montagneuses”

1821 – “les maisons rurales furent sévèrement inclinées”

Such material is impossible to interpret in the scope of the present project.

No study of historical earthquakes in Laos could be traced. A recent study of seismic hazard in the Khorat Plateau was also unable to trace any archival study of seismicity in Laos (Harnpattanapanich and Luddakul, 2011). For Cambodia it seems safe to say that no earthquakes have occurred that would merit inclusion in the present study.

As with Thailand, the SEASEE Series on Seismology contains a report (published in vol. III, available online at http://pdf.usaid.gov/pdf_docs/PNABF349.pdf) on Malaya (Leyu et al., 1985). This study made an investigation of local sources, mostly newspapers and government gazettes.

The report supplies a full list of repositories and of time coverage for different areas, which is summarized here.

<u>Repositories</u>

- University Library, University of Malaya, Kuala Lumpur
- National Archives, Kuala Lumpur
- Sabah State Library
- Sabah State Archives
- Sarawak Museum
- Singapore National Library

<u>Time Coverage</u>

- Peninsular Malaysia, 1805 to May 1984 (“Prince of Wales Island Gazette”, from 1806 to 1827, “Straits Times”, established 1831, “Singapore Chronicle”, 1827-1835)
- Sarawak, 1870 to May 1984 (“Sarawak Gazette”)
- Sabah, 1884 to May 1984 (“British North Borneo Herald”, 1884 to 1960)

In all, the report lists fourteen different earthquakes felt in Peninsular Malaysia between 1815 and 1892. Two are considered doubtful, and most of them originated in Indonesia (e.g. the 1861 sequence and 1892 May 17). The maximum assigned intensity is 4 MM scale (Singapore, 1861 February 16). The results of Leyu et al. (1985) are confirmed by Pan and Sun (1996), who improved the data for the post 1900 period only.

In all, the investigation carried out in the framework of GEH confirms that “Singapore is in a low seismicity area. The closest earthquake source consists of the Great Sumatra fault and the Sumatra subduction zone” (Pan and Sun, 1996).

2.11.2 Burma

Burma, on the other hand, is a highly seismic country, crossed by the plate boundary between the Indian Plate and the Persia-Tibet-Burma orogen (Bird, 2003), and also the major Sagaing Fault.

The only study that published a list of “Major Historical Earthquakes in and near Burma” independently of (and shortly before) the publication of Nutalaya et al. (1985) is Le Dain et al. (1984). Their Table 1 is reproduced verbatim in Gupta (1993). Oldham (1883) also includes Burmese earthquakes in his study of historical earthquakes in India. In fact, from a geological point of view, western Burma fits better into regional consideration as part of South Asia, and is generally included in studies that consider the broad Himalayan area, studies which are fully described in Section 2.8 above.

With a lack of any catalogue supplying parameters of pre-1904 earthquakes in Burma, those included in the GEH inventory of events with M≥7 were selected after a careful cross-check of the following studies:

- Le Dain et al. (1984) – and Gupta (1993)
- Nutalaya et al. (1985) – and Prachuab (1988)

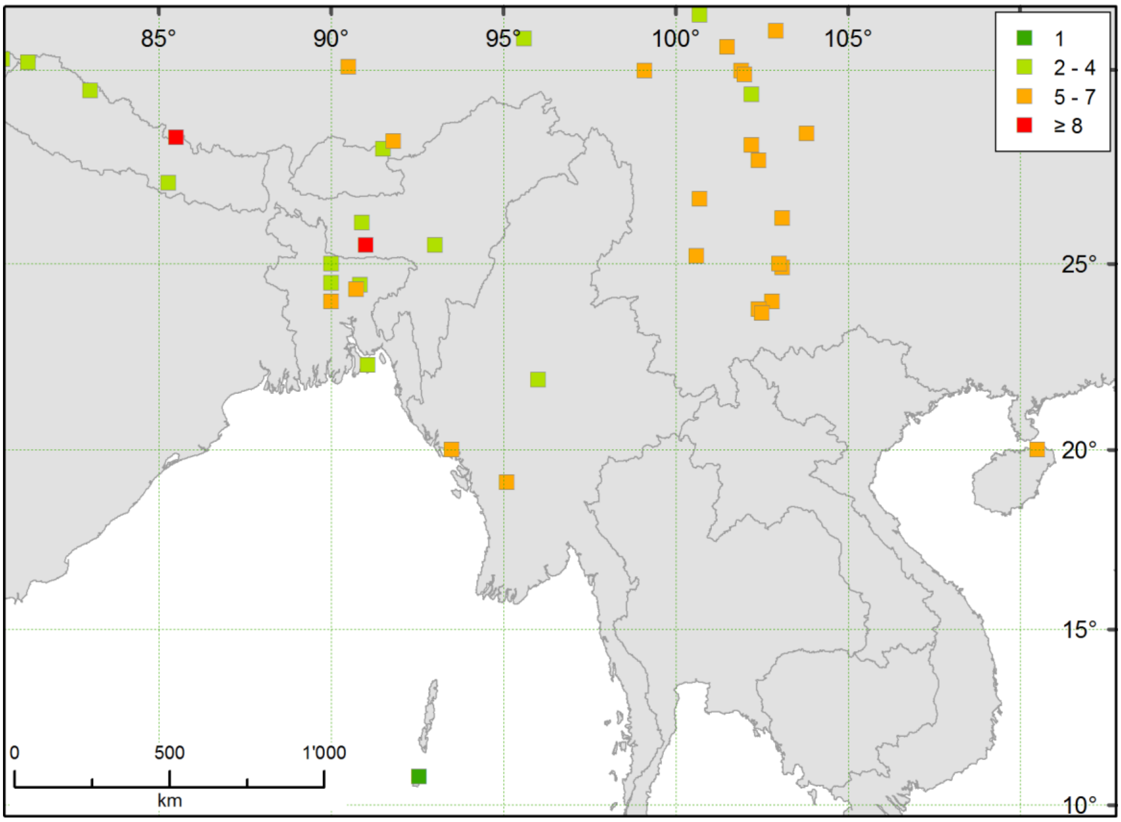


Figure 2.29 Earthquakes in GHEA (1000-1903) in Burma, and number of records per earthquake

A preliminary research for further data was done in UNESCO reports and literature that appeared as a consequence of the damaging earthquake (6.5 Mw) that hit Pagan on 8 July 1975. Pagan the city was capital of Pagan the kingdom, which flourished on the Irrawaddy River between 849 and 1297 (when it was overthrown by the Mongols). In the wake of the heavy destruction caused by the earthquake to the numerous temples in the area (more than 2,200) "the architect Pierre Pichard was tasked by UNESCO with creating an inventory in which every known structure was mapped, measured, photographed and characterized" (Hudson, 2008). The role of earthquakes, as well as of floods, in causing damage to Pagan is also described by Hudson (2008), who in retracing the history of the place says that "at least sixteen earthquakes between 1174 and 1975" are listed in the historical sources. Hudson states that his main sources are the outstanding works by the late Burmese historian Than Tun, who published ten volumes of "The Royal orders of Burma", between 1983 and 1990. This means that the previously mentioned studies, such as Nutalaya et al. (1985), could not have taken advantage of this collection of edited primary sources of information for historical earthquakes in Myanmar when preparing their lists of earthquakes.

As is the case for Indonesia, a dedicated investigation might bring to light new and high quality data on historical events. This would really result in an improvement of historical earthquake data and of seismic hazard assessment, considering that the most recent contributions, such as Thein et al. (2009) still repeat the information included in Nutalaya et al. (1985). Swe (2006) and Zaw (2006) are both studies cited by Wang et al. (2011) as giving lists of historical earthquakes from 1564 onwards; but both are only abstracts, and it has not been possible to access the actual catalogues. One suspects that some chronological research is greatly necessary – are the earthquakes of 1564 and 1570 (see Table 2 in Wang et al. 2011) actually different events from the 1568 earthquake included in Nutalaya et al. (1985)? Without reference to primary sources it is difficult to judge. There is also archaeoseismological evidence available – for instance, according to Wang et al. (2011) the earthquake of 9 October 1888 produced 2.5 m of slip as deduced from displacement of a fort wall at Payagyi, suggesting a major earthquake. However, no parametric entry has been traced for this event, nor is there sufficient historical material currently to hand to estimate even preliminary values. The earthquake appears as an entry in Milne's (1911) catalogue, referenced to "official documents", suggesting that material on this earthquake may exist in the India Office archives. If an earthquake in Burma producing 2.5 m of slip can go unrepresented in earthquake catalogues as late as 1888, it suggests that catalogue completeness for Burma is rather poor.

Similarly, the great earthquake of 1762 on the Arakan coast, with a magnitude certainly above 8.7 Mw, was more or less unknown, being represented only by its effects in the Chittagong area, which give a wholly inadequate idea of the size of the rupture. It was properly "rediscovered" independently and more or less simultaneously by Musson and Sargeant (2006) and Cummins (2007), and is also discussed by Gupta and Galahaut (2009). The report prepared for GEH by Musson (2012d) summarises the regional impact of this great earthquake.

2.11.3 Philippines

The situation for the Philippines is much more satisfactory, both as regards early compilations and recent studies of historical earthquakes.

Studies on the historical earthquakes in the Philippines started in the mid 19th century with the first attempt at a comprehensive compilation; this was the "Documents sur les tremblements de terre et les phénomènes volcaniques dans l'Archipel des Philippines" by Alexis Perrey (1861). Earthquakes are described in the second part (from p. 130 to p. 189) for the time-window 1600-1855, with the addition of some information on an earthquake in February 1858, added after the general conclusions (p. 194). The sources used by Perrey are mostly previous collections, such as the "Collection Academique" (Montbéliard, 1761) and the works by von Hoff (1840), to which, depending on the period, Perrey added reports from travellers, academic journals and newspapers that were available to him.

This first European-based survey was followed some thirty years after by a local one, thanks to the efforts of the Jesuit Father Saderra-Maso (1895), while he was in charge of the seismological station at the Manila Observatory (1890-1928). Unfortunately, no reliable and complete copy of Saderra-Maso's book could be retrieved in the framework of GEH.

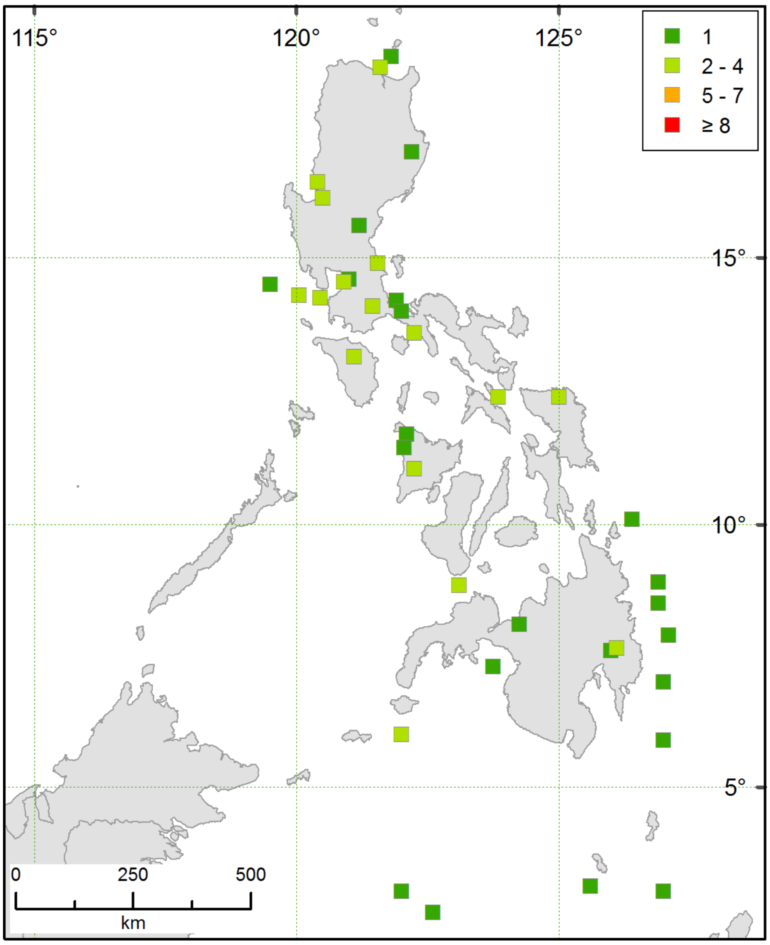


Figure 2.30 Earthquakes in GHEA (1000-1903) in Philippines, and number of records per earthquake

The most complete contribution in the first half of 20th century on the subject of historical earthquakes in the Philippines is by another Jesuit Father, William C. Repetti, who filled the post of the "office of seismologist of the Manila Observatory" after Saderra-Maso retired (1928-1942). Repetti wrote in 1944-1945 while at Georgetown University (Washington D.C.) and after his work in the Philippines had ended. It is a descriptive catalogue, supplying no intensity data nor parameters, but with a very complete list of the sources used, which range from the previous two compilations of Perrey (1861) and Saderra-Maso (1895), to documents and books of other Jesuits on the history of Philippines, to documents in the "Roman Archives of the Society of Jesus", travellers' reports and newspapers. The time-window covered is 1589 to 1899, the year that "ended the Spanish regime in the Philippines". Among other reasons, Repetti wrote that he refrained from extending the catalogue further because "the outbreak of war in 1941 put an end to the work of the Jesuits in the Manila Observatory", which had started in 1865.

There are indeed no better words than those of the author's to describe how the catalogue gained its way to publication, and why it is a historical document in itself:

> *"The war has added a new value to this catalogue, because no small amount of the source material was lost in the battle of Manila in February, 1945 … It would not have been at all surprising if the catalogue itself had been destroyed. We are indebted for its preservation through all the vicissitudes and hardships of three years of enemy occupation and tyranny, and of danger to life and limb in the crossfire between opposing armies, to the Rev. Pablo Guzmán-Rivas, of the*

> *Society of Jesus. Forced to change his abode from time to time on very short notice, filled with anxiety for the safety of his relatives, charged with responsibility for his companions, he nevertheless always gave thought to the safety of this catalogue. Having brought it intact through three years of danger on land, he brought it safely across the Pacific through typhoon, gale, danger from mines, and narrow escape from grounding*." (Repetti, 1946).

The most recent collection of earthquake data retrieved in the framework of the GEH project is the work by Garcia et al. (1985), published in the SEASEE Series on Seismology, vol. IV, and available online (pdf.usaid.gov/pdf_docs/PNABF350.pdf).

This rich contribution (852 pages) is a report (for details see the introduction to Part A, p. 1), and it takes advantage of the three "catalogues" mentioned above, and for the period considered by GEH (up to 1903), it is stated that "most of the information contained in this catalogue was culled from Repetti's work which consists mainly of seismic activity during the Spanish regime" (to 1899) and then from the "official reports of the Weather Bureau of the Philippines, which started in 1901".

Unlike Perrey (1861) and Repetti (1946), Garcia et al. (1985) do not explicitly mention the sources they used with reference to each earthquake, deciding instead to present a summary of the information and a general list of references at the end of the report. For the period of interest of the GEH project, they do not supply any of the assigned intensity points but just four isoseismal maps (1852 to 1892, on pp. 750-753). Also, they do not supply any parameters apart from the date of the earthquake.

A summary of the recent work done on the historical seismicity of the Philippines and on parametric catalogues is contained in Bautista and Bautista (2004). Besana and Ando (2005) still refer to Garcia et al. (1985) as the main source of data on earthquakes before the 20th century.

There is currently no online database supplying the macroseismic data from which the parameters were derived; one would expect such a thing, if it existed, to be maintained by the Philippine Institute of Volcanology and Seismology (PHIVOLCS - www.phivolcs.dost.gov.ph). The PHIVOLCS website has no trace of any information about earthquakes before the year 1968.

From the point of view of GEH, the archive for the Philippines is well provided with descriptions of earthquake effects, but in terms of earthquake parameters as an input to GHEC we could only rely on the so far unique published catalogue, which is the one by Bautista and Oike (2000). They obtained a magnitude (Ms) from calibrated magnitude-felt area relations for 485 earthquakes, in the time-window 1600-1895.

Two earthquakes were subsequently added from Table 1 (p. 555) of Garcia et al. (1985) in September and October 1897, with a M 8.7 and 8.1 respectively, as assessed by Richter (1958). Given Richter's (1958) track record with very early instrumental data, these values are likely to be overestimates, but not by more than one magnitude unit.

In conclusion, the historical earthquake record in the Philippines is probably as good as it is likely to get, especially given the destruction of local material in Manila during WW II; though it is possible that untapped material may exist in Spanish archives. In contrast, the record for Burma is definitely in need of further work and improvement. The rest of the area covered in this chapter is a low seismicity area, and not likely to yield major earthquakes in the historical period.

2.12 Indonesia

In the scope of the Global Earthquake History project, Indonesia presents one of the most challenging areas. It is a highly seismic region, but there is an acute lack of previous studies or parametric catalogues, and particularly, there appear to be no indigenous seismologists working on this subject. A further difficulty is presented by the history of the region itself; records are likely to be scattered amongst archives in the Netherlands, Portugal, France and the UK, rather than being concentrated in local archives. This makes it a difficult subject for local institutes to devote themselves to.

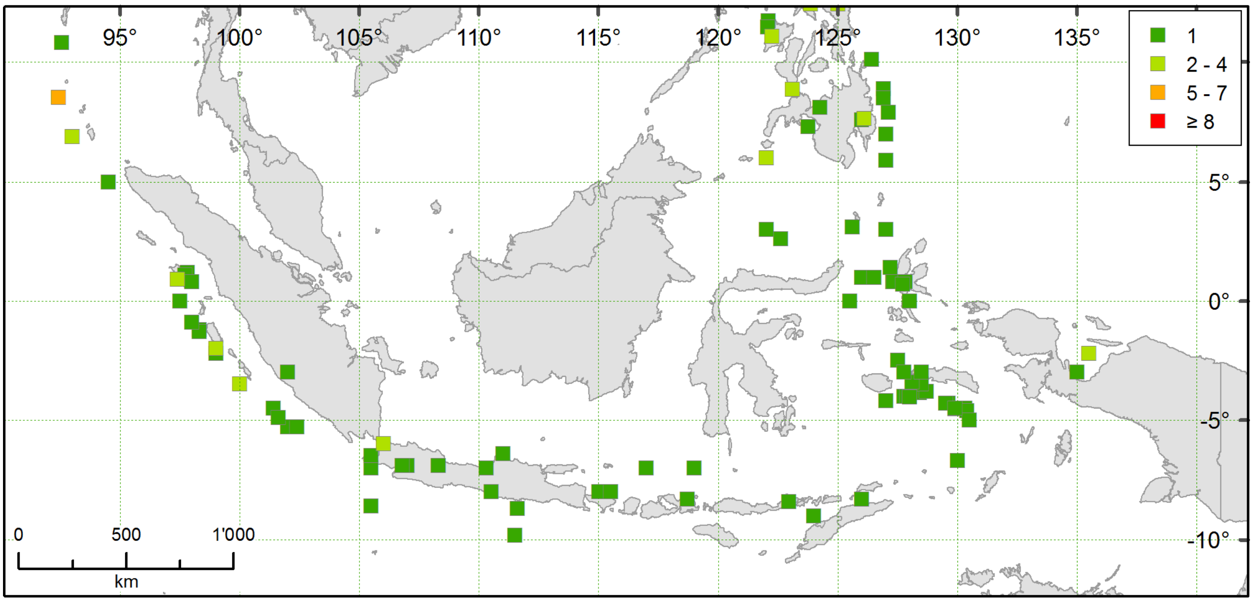


Figure 2.31 Earthquakes in GHEA (1000-1903) in Indonesia, and number of records per earthquake

The major ongoing initiative is a study of historical earthquakes in Indonesia that has continued for some years at Brigham Young University, Provo, Utah, under the leadership of Ron Harris (Harris and Major, 2012). Since this study is not expected to produce a parametric catalogue within the timeframe of GEH, a separate report was compiled, intended to provide a stop-gap, so that reasonable parametric values can be included in a catalogue of global historical earthquakes for GEM (Musson, 2012a).

For the purposes of GHEC, "Indonesia" is considered a geographical term devoid of political import, and is defined as the area between 7° N and 11° S, 93° E and 154° E, excluding earthquakes between 120° E and 130° E north of 5° N, which are associated with the Philippines.

2.12.1 Data Sources

Five inputs were selected in Musson (2012a), as follows:

1. The Significant Worldwide Earthquakes database of the USGS National Earthquake Information Center (NEIC) (http://earthquake.usgs.gov/earthquakes/eqarchives/epic/)
2. The Significant Earthquake Database of the NOAA National Geophysical Data Center (http://www.ngdc.noaa.gov/nndc/struts/form?t=101650&s=1&d=1)
3. Utsu (2002) updated at http://iisee.kenken.go.jp/utsu/index_eng.html
4. Newcomb and McCann (1987)
5. Wichmann (1918; 1922).

The first two of these are nominally the same; the USGS page links to the NOAA page as its source, and both appear to derive from Dunbar et al. (2002). However, in fact they are quite different, and it is not a matter of the USGS database being a selection of events from the NOAA database, since the USGS database contains events not in the NOAA one.

Newcomb and McCann (1987) is the only significant modern study of historical earthquakes in the region, bar some papers on individual events, assessed from palaeoseismic data (e.g. Sieh et al., 2004). It deals only with Sumatra and Java, and while some estimated magnitudes are labelled on figures, there is no parametric list of events.

The two volumes of Wichmann (1918; 1922) are limited in time to the period prior to 1878. They present comprehensive descriptive accounts of individual earthquakes in a mixture of languages, including Old Dutch, which makes for problems of reading. The work of Ron Harris's team includes a translation of the work into English, to be published soon (Harris and Major, 2012). An advance copy was kindly supplied to the GEH project, and has been used in the preparation of Musson (2012a). As might be expected from the publication date of Wichmann's work, no parameters are included. Wichmann's sources are many, but include some known to be unreliable, such as Montbéliard (1761). A critical revisiting of original source material is long overdue.

For earlier earthquakes, the NOAA database relies largely on Soloviev and Go (1974), who in turn rely largely on Wichmann (1918; 1922). However, since Soloviev and Go (1974) are concerned only with tsunamigenic earthquakes, they omit other large earthquakes, which are therefore missing from the NOAA list, especially for earlier events where Wichmann is the main secondary source, primary sources not having been consulted.

In Musson (2012a), all events in sources 1-3 were considered to be potentially equal or greater than 7 Mw. They were compared to each other initially, and then checked against sources 4 and 5 if needed. Where possible, references given by source 2 for individual events were also checked. Additional events are added using Harris and Major (2012) as a guide.

2.12.2 Parameters

The following procedures were followed by Musson (2012a) to determine parameters.

Epicentre

For very large earthquakes in subduction zones, epicentre is an almost meaningless concept, particularly for purposes of hazard assessment. What is more meaningful is the midpoint of the rupture. Firstly, this is more likely to approximate to the position of maximum energy radiation, and secondly, from these co-ordinates, together with the rupture length, one can reconstruct the position of the actual rupture, which is the true representation of the localisation of the earthquake, rather than an unrealistic point source.

Indonesia presents a particular problem, in that so much of the seismicity is offshore. Given a coastal observation, one cannot easily tell if the earthquake was far offshore or close in. It is thus easy to underestimate the size of an event that occurred some distance offshore. Historical data tend to reflect places that were important for trade; thus there are a disproportionate number of reports from Ambon and Ternate, as these were significant trading ports, and relatively few from New Guinea. Thus completeness varies at quite short spatial scales.

Assigned epicentres are therefore rather subjective and arbitrary, and should be considered very approximate. An earthquake felt in Ternate, for instance, may have occurred on the Ternate Trough, or on the northern edge of the Halmahera Plate. From a tectonic perspective, large earthquakes affecting Ambon would seem to be more likely to originate on the northern side of Seram, but the historical descriptions, where sufficiently detailed, do tend to suggest a source in the Banda Sea.

In the case of Sumatra, the maps from Newcomb and McCann (1987) are a convenient guide to the approximate rupture position. But a comparison with modern seismicity shows that earthquakes may originate on the up-dip edge of the subduction front, or quite close to shore. Some of the aftershocks of the great 16 February 1861 Sumatra earthquake were felt only moderately over about 200 km of coast. If such a pattern arises from a near-shore event, the magnitude is most likely less than 7 Mw; if these events were further out to sea, they could have exceeded 7 Mw.

Magnitude

Without the use of MDPs, the best guide to magnitude is rupture length, although this cannot be directly observed. It is necessary to assume that the area most strongly shaken indicates the extent of the rupture, as in Newcomb and McCann (1987), which has been used as a guide where possible. In the case of, for instance, the 12 September 2007 Sumatra earthquake, the damaged area was roughly twice the rupture length.

Stirling and Goded (2012), as part of another GEM project (Faulted Earth), reviewed available magnitude/rupture length relationships for different tectonic environments. The recommended equations for use with subduction earthquakes are those of Strasser et al. (2010):

$$Mw = 4.441 + 0.846 \log A \quad (1)$$

and Blaser et al. (2010):

$$\log L = -2.81 + 0.62 \, Mw \quad (2)$$

where A is rupture area in km2 and L is subsurface length in km. Area is harder to estimate than length, so since equation (2) is derived from orthogonal regression it can be inverted to obtain:

$$Mw = 1.61 \log L + 4.53 \quad (3)$$

This can be given a quick test against the earthquake of 26 December 2004 – a rupture length of around 850 km yields 9.2 Mw from equation (3). Given that the magnitudes in this report are provisional values and the rupture lengths are estimates, this is quite acceptable accuracy. It is not practical to estimate rupture lengths from historical data to a resolution of less than 100 km, so this approach really only discriminates great earthquakes.

For some earthquakes, particularly away from the Sunda Arc, there is insufficient information to make any estimate of rupture length. Here the practice has been to assign a minimum likely magnitude of 7.0 Mw to those events that appear to have been heavily damaging. Since the major use of this catalogue will be for hazard calculation, information on major earthquakes will be most important for constraining Gutenberg-Richter curves which will already be to some extent determined by profuse 20th century data. Thus, knowing the number of earthquakes larger than 7 Mw is useful, even if they cannot be graded to finer accuracy.

As indicated in the previous section, there is a trade-off between the decision made with regard to epicentre and the magnitude. Some earthquakes may be grossly underestimated because they are known only from distant observations. It is to be stressed that the parameters in Musson (2012a) are to be regarded as highly provisional, pending the results of a much larger, systematic analysis of all the data available, and building on the work of Harris and Major (2012). Such a dedicated project is outside the scope of the present report.

Time

Times for all events up to 1877 were taken from the two Wichmann reports, correcting to UTC, which in some cases meant altering the date. For events after 1877, times are to be found in Utsu (2002). For early events some conventions were adopted. “Just after the hour” would be taken to be five minutes after the hour. “Between the hour and half past” would be taken as fifteen minutes past the hour. “During the night” would be taken as no time information.

2.12.3 Notes on New Earthquakes

Musson (2012a) identified a number of earthquakes not found in any of the databases hitherto available. Identification of these is made from Wichmann (1918; 1922) via the agency of Harris and Major (2012). Parameters are assigned to these earthquakes in a very approximate way; then, the parameters given by NOAA and Utsu (2002) are also rather approximate. A systematic assessment of historical earthquake parameters for Indonesia awaits another project. These new earthquakes are the following.

12 May 1644 Ambon

Harris and Major (2012) give a maximum intensity of 8-9 MMI for this earthquake. It was damaging at Ambon and caused local ground deformation; was described as the strongest ever experienced in the area (Wichmann, 1918). A strong aftershock on 17 May was widely felt. Aftershocks continued for two weeks (Harris and Major, 2012).

2 February 1648 Flores

This earthquake badly damaged Fort Henricus on the north coast of Solor, and was also felt strongly around Larantuka on Flores (Wichmann, 1918). Aftershocks continued for over three months (Harris and Major, 2012), which suggests a high magnitude.

17 October 1671 Saparua

Destruction and heavy damage reported on the island of Saparua; shaking was felt at Ambon, Haruku, and along the south coast of Seram (Wichmann, 1918). Aftershocks continued for two months (Harris and Major, 2012). There was substantial subsidence associated with this earthquake (Wichmann, 1918), which suggests a magnitude as high as 7.5 Mw.

17 February 1675 Ambon

This earthquakes occurs in the NOAA database with the wrong year (1674) and a magnitude of 6.8. However, in addition to the earthquake being very destructive at Ambon (said to be the strongest ever felt), the effects were widespread across from Buru to western Seram. The shock was weakly perceptible in the Banda Islands (Wichmann, 1918). The magnitude must have approached 8 Mw. Aftershocks continued for three months (Harris and Major, 2012).

16 October 1683 Banda

A very destructive earthquake on the Banda Islands (Wichmann, 1918) with an aftershock sequence that lasted a year (Harris and Major, 2012). With no other localities mentioned, it is hard to gauge the magnitude, but the long aftershock sequence suggests it was large.

4 January 1699 Batavia

A powerful earthquake in west Java and the southeast parts of Sumatra, which caused damage in the Jakarta (Batavia) area and Lampung province, Sumatra, and was accompanied by triggered landslides and mudflows (Wichmann, 1918). On the southwest coast of Sumatra the shaking was weak. Aftershocks continued for over a year (Harris and Major, 2012). A tentative magnitude of 7.5 Mw has been assigned, but it could have been larger.

October 1705 Ambon

This was a damaging shock at Ambon, Hitu and Huwamuhal, apparently with liquefaction; shocks continued throughout the month (Wichmann, 1918).

26 July 1770 Ternate

This was considered as a candidate earthquake, given an intensity of 9 MMI by Harris and Major (2012) and an aftershock length of five years. The sequence actually began in April 1770, but the earthquakes are clearly volcanic in nature, and so have not been included in the catalogue.

30 March 1777 Ambon

Two very strong shocks occurred with a space of four minutes between them; the first was said to have lasted two minutes. There was a very intense aftershock sequence lasting some months. Buildings were damaged and a few collapsed. In the western part of the island there was a major landslip as a result of the earthquake (Wichmann, 1918). The reported length of shaking suggests a high magnitude, but there are no accounts from elsewhere.

22 January 1780 Java

This is clearly one of the largest earthquakes ever to strike Java in historical times, so it is surprising that it is not better known. It was felt over the whole island, more strongly in the west, and also in eastern Sumatra. Houses collapsed in Bogor, Banten and Jakarta (Wichmann, 1918). The magnitude must have been at least 8.5 and possibly larger. Harris and Major (2012) list the aftershock sequence as lasting a year.

14 October 1816 Banda

This sequence started on either 8 October or 11 October, with the strongest shock (said to have lasted two and a half minutes) on 14 October, and aftershocks for the next three months. Banda Neira was devastated, with parts of the island reportedly uninhabitable due to the amount of damage to buildings (Wichmann, 1918).

28 March 1830 Ambon

A damaging shock across the whole island (Wichmann, 1918), but no other places are mentioned. Harris and Major (2012) list the aftershock sequence as lasting four months.

31 October 1847 Nicobar

According to Bilham et al. (2005)

> *"The first of the three large historical earthquakes in the Andaman/Nicobar region for which we have information occurred in 1847. Following discussions with Nicobar islanders, Hochstetter (1866) reported a 'very remarkable earthquake, which is said to have lasted from 31 October to the 5th of December, 1847, on the Nicobar Islands, at which time earthquakes occurred in Java. ...the description of the earthquake seems trustworthy, as I had myself occasion to observe on Kondul the mountain slips referred to in the account.' … No original account of the 1847 earthquake survives, and all secondary accounts appear to derive from Hochstetter's."*

However, Wichmann (1918) was able to draw on accounts from contemporary newspapers (Javasche Courant, 23 Feb 1848) for a more detailed account. Houses collapsed, boulders were dislodged, and coastal areas were flooded. Bilham et al. (2005) suggest a minimum magnitude of 7.5, which is adopted here.

25 April 1855 Ternate

This earthquake was damaging on Ternate and also at Dodinga on Halmahera (Wichmann, 1918). It was followed by a year of aftershocks (Harris and Major, 2012). The magnitude has been set at 7 Mw as a minimum, but could have been larger.

18 August 1871 Bengkulu

The absence of this event from Newcomb and McCann (1987) and other sources is surprising. It caused houses to collapse in Bengkulu city, and was felt as far east as Java (Wichmann, 1922). Reports from Palembang, Lingga and Bogor at 14h 30m and 14h 50m (compared to 14h 16m at Bengkulu) are assumed to refer to the same shock.

2.12.4 Discussion

The resulting catalogue in Musson (2012a) has been entered into GHEA as well as GHEC, as the best available pending further study. Musson (2012a) attempted to assess completeness in an approximate way; the usual statistical approaches are not really applicable for a dataset that only includes events larger than 7 Mw. Comparing the number of historical earthquakes with modern seismicity suggests that the completeness of the catalogue leaves much to be desired. For the purposes of analysis, the area can be divided into three: the Sunda Arc (Sumatra to Timor), the Moluccas (including the Banda Sea and Sulawesi) and New Guinea (including New Britain). The number of events in the catalogue (i.e. 7.0 Mw or greater) was counted for successive 50-year periods beginning with 1601-1650. The results are shown in Figure 2.32 (for neatness, 1601-1650 is labelled 1600, etc). Analysis for larger magnitudes (7.5 or 8 Mw) has not been attempted owing to the episodic nature of such events.

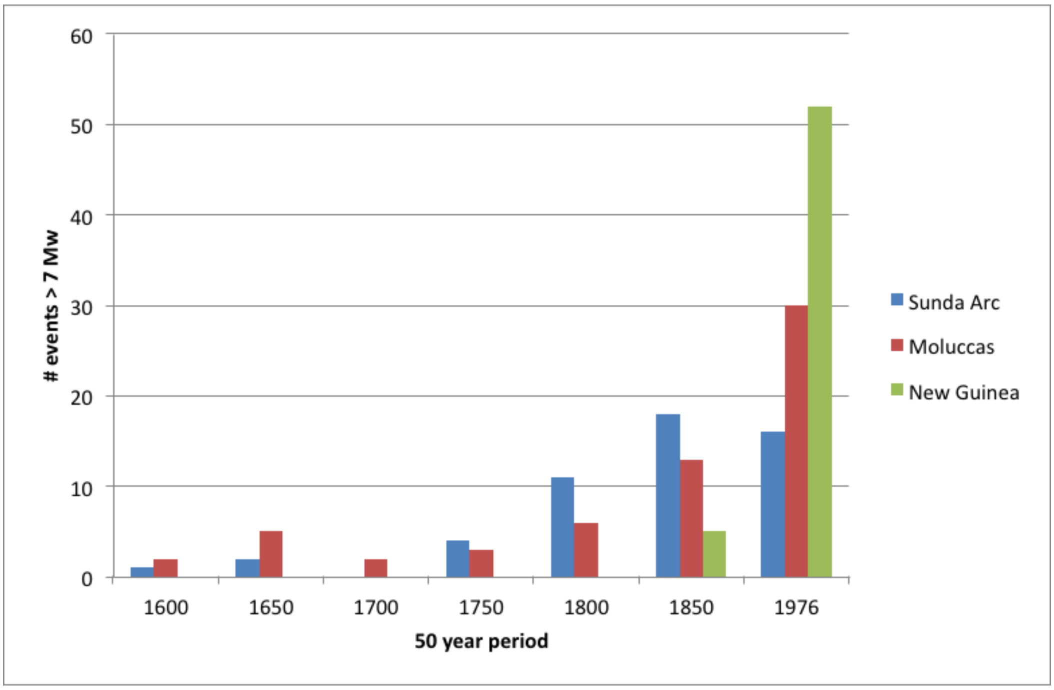


Figure 2.32 Comparative numbers for 50 year periods

The numbers are compared with modern data by taking PDE data from 1976-2000 (thus predating the intensive Sumatra seismicity after 2004), counting the events and doubling the number.

For the Sunda Arc, the catalogue has comparable numbers to the 1976-2000 data for the period 1851-1900, and quite possibly the catalogue has acceptable completeness back to 1800. For the other regions the catalogue is very incomplete.

There are three principle reasons for this. One is the difficulty of dealing with intermediate and deep focus events from historical data. When the modern data was restricted to crustal events, the total for the Moluccas dropped from 30 to 22, and for New Guinea from 52 to 26.

The second is the concentration of reports from important trading centres, and the relative lack of information from areas such as Sulawesi and New Guinea.

The third is the difficulty, mentioned previously, of recognising large offshore events from very limited historical data. The two volumes of Wichmann contain reports of earthquakes in New Britain, many of which are probably larger than 7 Mw, and which would go some way towards making up the shortfall shown in Figure 2.32. The problem is that most of these reports do not give details that allow one to identify the earthquakes as major events with any degree of assurance. A thorough, systematic processing of Wichmann's work, combined with examination of colonial archives in Europe, may in time improve the situation, but such a labour is something for future projects.

2.13 Australia, New Zealand and the South Pacific

The region of Australia, New Zealand, and the South Pacific, which for convenience can be referred to as Australasia, share one prominent characteristic when it comes to the study of historical earthquakes: that the historical record is short due to the relatively late date of arrival of significant numbers of European settlers. The first documentation of earthquakes, in both Australia and New Zealand, begins with the establishment of colonies. The first fleet of colonists to settle in New South Wales arrived in 1788; the first recorded earthquake was noted the same year, at Port Jackson (Doyle et al., 1968). In New Zealand, the first written record of an earthquake is even earlier, in 1773, but from a passing ship, the Adventurer, wintering at Motuara (Cook, 1777). The earthquake record for New Zealand becomes much better after significant settlement began in the 1840s.

Otherwise, the three regions are very different in character. Australia is a huge land mass, most of which is either very sparsely populated or desert. As a stable continental region, the overall seismicity is low, though moderately large events are not unknown. The bulk of the population is concentrated in the south-east, whereas, from 20th century data, it appears that the larger earthquakes tend to occur in the interior. Therefore it is quite likely that even large (~ 7 Mw) events in the pre-instrumental era could go unremarked. On the other hand, in the south-east of the country, earthquakes above 4 Mw are likely to be well documented from the mid 19th century on.

New Zealand, in contrast, is an active plate boundary subject to great earthquakes (Mw > 8). The shape of the country is elongated along the line of the plate boundary; as a result, any major earthquake is likely to be felt by a substantial proportion of the country's population, and should be reasonably locatable from macroseismic data.

The South Pacific, on the other hand, is a vast oceanic region dotted with small, dispersed islands with small populations. Parts of the region are among the most seismically active areas of the planet, but the chances of being able to locate or parameterise any earthquake from pre-instrumental data are very slim.

The three regions, and their contribution to GHEA, will now be discussed in turn.

2.13.1 Australia

Australia, as a stable continental region, has generally a fairly low rate of seismicity. There have occurred some moderately large earthquakes in the 20th century, of which the largest have just failed to exceed 7 Mw. The only Australian earthquake with an unqualified magnitude of 7 Mw or more was in 1906, with an epicentre offshore from Western Australia, on the continental slope of the Exmouth Plateau. The magnitude is given as 7.2 Mw by Johnston et al (1994). For the purposes of the Global Earthquake History project, the magnitude limit of interest has been lowered to 6.5 Mw, but even so, the number of earthquakes prior to 1903 that are even candidates is very small.

In fact, only seven events in this period appeared to be possibly larger than 6 Mw at the commencement of this project. Some confusion exists because of magnitude scales cited in the literature, with values of local magnitude (ML) being cited that exceed the normal saturation threshold for the scale. Most likely the higher magnitudes shade into some form of surface-wave magnitude (Ms). Accordingly, a detailed study was made to assess whether any of these earthquakes could actually be as large as 6.5 Mw, and also to determine which were larger than 6 Mw (Musson, 2012b). Much of the material in this study came from the papers and reports such as Doyle et al. (1968), Everingham and Tilbury (1972), Everingham et al. (1982), Michael-Leiba (1989), McCue (1999) and Johnston et al. (1994). In addition, use was made of the online database of Geoscience Australia (www.ga.gov.au/earthquakes/, last accessed August 2012). Some primary sources were also consulted.

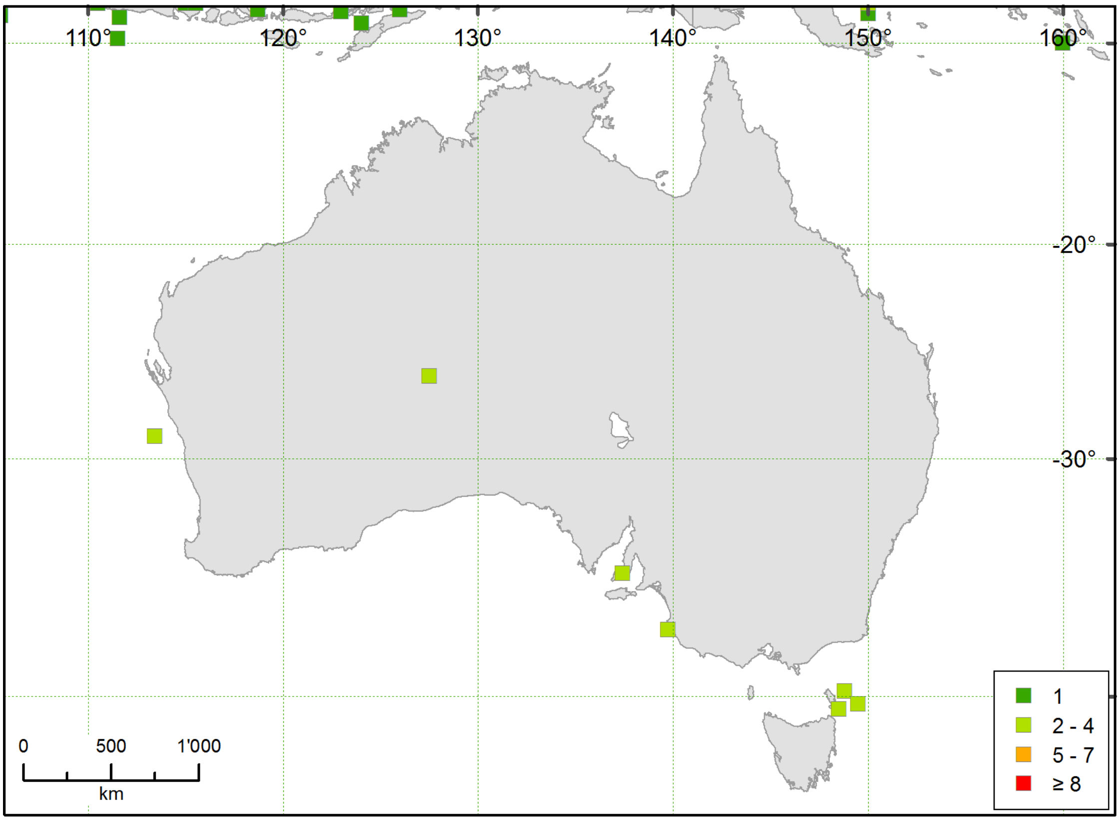


Figure 2.33 Earthquakes in GHEA (1000-1903) in Australia, and number of records per earthquake

Australian sources mostly cite local magnitude (ML) or less frequently, surface wave magnitude (Ms) or body wave (mb). For historical events, magnitudes are not calculated from seismograms, and thus estimates of magnitude from macroseismic data have to be referred to some equivalent instrumental value, and it is not always clear what the relationship between scales is. For instance, Everingham et al. (1982) assign 6.5 ML to the 1897 Beachport earthquake, which is shown as 6.5 Ms in McCue (1999). In contrast, Michael-Leiba's (1989) magnitude of 6.9 ML for the 1892 Tasman Sea quake is translated to 6.6 Ms in McCue (1999). In any case, most seismologists would regard a value of 6.9 ML as above the saturation point of the scale. From instrumental data, Allen et al. (2011) recently published conversions from ML to Mw for both eastern and western Australia. The approach followed by Musson (2012b) was to assess the effective radius for different intensities from published isoseismal maps, checked at least partially against primary data. These were used to compute magnitude following Gaull et al. (1990), and values were then converted to Mw using Allen et al. (2011).

The fact that the earliest event to be considered is as late as 1873 says something about the sparseness of settlement in the more seismically active parts of Australia in historical times. This is the highly obscure Barrow Range earthquake of 15 December 1873, and is known from a single report by the explorer Ernest Giles (1835-1897). A magnitude of around 6 is estimated by Everingham and Tilbury (1972) on account of the fact that the quake shook down rocks from hillsides. With only one observation, the magnitude of the event could have been almost anything, and a tentative 6 Mw has been left faute de mieux, in line with Johnston et al. (1994).

At the outset of the project, the event in the period that appeared to be the largest, at least according to Johnston et al. (1994), was the Mt Narryer earthquake of 5 January 1885, with a magnitude of 6.5 Mw. This earthquake was substantially revised by Musson (2012b) in the light of primary data and new palaeoseismic evidence, and has been relocated to an offshore epicentre and reduced in magnitude to less than 6 Mw.

The results of Musson (2012b) are that, of the seven large earthquakes up to 1903 identified at the outset of the study, none appear to be as large as 6.5 Mw. In fact, only two exceed even 6.0 Mw, not counting the 1873 earthquake, the magnitude of which is, as stated above, uncertain in the extreme. Table 1.4 provides final parameters for all the earthquakes considered in Musson (2012b).

Table 1.4 Large historical earthquakes in Australia, to 1903

Date	Time	Latitude	Longitude	Mw	Location
15 Dec 1873		-26.25	127.50	6.0?	Barrow Range
13 Jul 1884	03h55m	-40.50	148.50	5.7	Cape Barren Island
5 Jan 1885	14h45m	-29.00	113.40	5.8	Geraldton
12 May 1885	23h37m	-39.80	148.80	5.9	Tasman Sea
26 Jan 1892	16h48m	-40.30	149.50	6.1	Tasman Sea
10 May 1897	05h26m	-37.33	139.75	6.1	Beachport
19 Sep 1902	10h35m	-35.00	137.40	5.2	Warooka

2.13.2 New Zealand

The situation in New Zealand is somewhat different, in that major and even great earthquakes are not uncommon, and are reasonably well documented after about 1840. Furthermore, they have been studied extensively, and so there are modern assessments of most major earthquakes, including intensity data points and isoseismals – though the IDPs have only been traced in map form, e.g. Downes (1995). Primary historical material is reasonably accessible, particularly in the case of the two important earthquakes of 1848 and 1855, where descriptions have been extracted and collected in Grapes et al. (2003) and Downes and Grapes (1999) respectively.

The earthquakes greater than 7 Mw in GHEA and GHEC are listed in Table 1.5, but some comments on each event are presented first.

Early earthquakes in New Zealand are taken principally from Eiby (1968a). Eiby uses a classification system for A to D, which substitute for magnitude. The classes are to be interpreted as follows:

A – Earthquakes causing much damage, or geological changes, or very widely felt – these are considered to be larger than 7½. Class A events are assigned a magnitude of 8 Mw in Musson (2012c) in the absence of other determinations.

B – Earthquakes with insufficient information to class as A, but which reached damaging intensities, and were probably between 6 and 7½; these are assigned a magnitude of 7 Mw in Musson (2012c) in the absence of other determinations.

C – Earthquakes with intensity around 6 MMI; probably 4½ to 6 in magnitude; excluded from GHEA.

D – Minor earthquakes with intensity less than 6 MMI; excluded from GHEA.

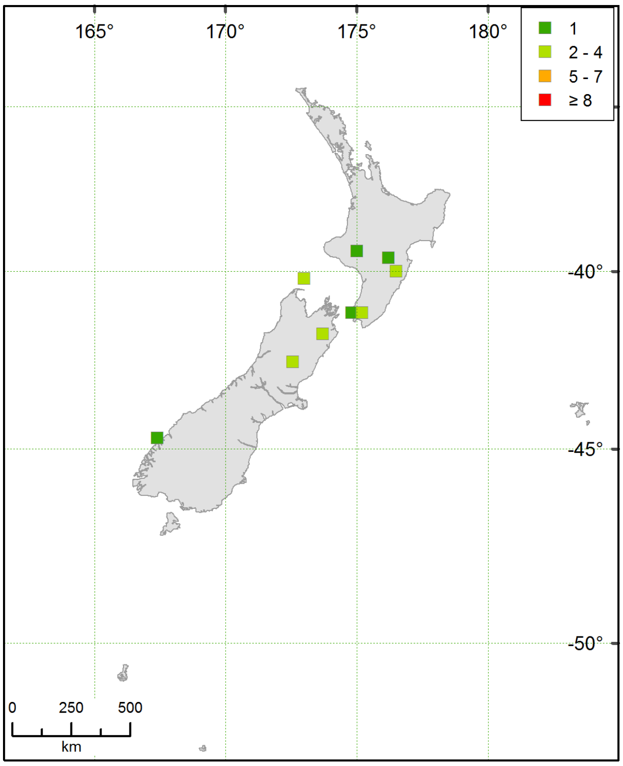


Figure 2.34 Earthquakes in GHEA (1000-1903) in New Zealand, and number of records per earthquake

The rounding up of magnitudes is justified by Eiby's remark that his assessments are to be considered minimum values – "additional information can easily raise a shock to a higher class, but it is unlikely to demote it" (Eiby, 1968a).

For earthquakes after 1840, the parameters in Table 1.5 mostly follow the GNS (Institute of Geological and Nuclear Sciences) database, retrieved from geonet.org.nz. It is assumed that GNS magnitudes equate to Mw, though this is not stated (see particularly the discussion of the 1848 Marlborough earthquake below).

This gives the following earthquakes:

About 1460 – While this is not strictly historical, Maori oral tradition records the great "Haowhenua" event (land swallower, or destroyer). However, the tradition makes it clear that uplift and not subsidence took place. The channel between Motu Kairangi and the mainland became shallow enough to wade and eventually silted up to convert that island into the present Miramar peninsula. This is supported by geological evidence (Eiby, 1968a). Best (1918) dates it to about eighteen generations before 1900, or roughly 1460.

A second event listed by Eiby (1968a) on the basis of Maori tradition, in around 1600, appears to be non-seismic in origin.

An anonymous internet page (http://en.wikipedia.org/ wiki/Earthquakes_in_New_Zealand, retrieved 29 October 2012) also includes earthquakes in 1100, ~1615 and 1717, all on the Alpine Fault. The last two are all reckoned from tree-ring dating, and so are not historical at all (Cullen et al., 2003). The 1100 event comes from a palaeoseismological study of silt-peat couplets (Berryman et al., 2012).

Curiously, Cullen et al. (2003) also identify an earthquake c. 1460 from dendrochronology, which seems to be quite clearly unconnected with the Haowhenua event. The dendrochronological evidence for a 1460 earthquake is all from the southern part of Westland, suggesting most likely an earthquake on the southern part of the Alpine Fault. The Haowhenua event is unambiguously connected with uplift in the Wellington area.

The occurrence of two great earthquakes in New Zealand within at most a few years of each other is rather notable, and commented on by Cullen et al. (2003). Goff and Chague-Goff (2001) consider that around 1450 there was near-synchronous rupture of both Alpine and Wellington Faults, with a significant tsunami that resulted in abandonment of coastal settlement sites. They also report that a similar near-synchronous rupturing event took place around 1220, again with a tsunami.

Two other early events from the period of early European contact, between 1810 and 1820, rest on very slender documentary evidence, are considered doubtful by Eiby (1968a), and not included here. They are treated as genuine in the GNS database, assigned dates of 1815 and 1817, but no magnitudes. Similarly, an earthquake dated 1835 in the GNS database is treated as dubious by Eiby (1968a). Correspondence with Gaye Downes (2013, pers. comm.) indicates that no new historical material has come to light since Eiby (1968a) wrote; the precise years 1815 and 1817 assigned by GNS are not based on any data.

1826 – An earthquake at Milford Sound and Dusky Sound, with a long aftershock sequence, and uplift of 2-3 m that turned a former anchorage to dry land. Landslides were common all along the coast, and in places trees were seen under water (Taylor, 1855; Eiby, 1968a).

1838 – This earthquake caused massive landslides in the upper valley of the Wanganui River (Eiby, 1968a).

8 July 1843 – Eiby (1968a) describes this as a “major seismic event, shallow, and with a magnitude not less than 7½. The epicentre appears to have been close to Wanganui, or within 50 kilometres to the north-east of it.” None of the buildings at Wanganui were very substantial, but brick or stone chimneys were common, all of which were thrown down (Taylor, 1844). There were landslides and superficial slumping, but possibly also tectonic uplift. The magnitude given at geonet.org.nz is 7.6 Mw, adopted here, which agrees well with Eiby’s (1968a) assessment, made by comparison of the effects with more recent events. The shock was felt practically over the whole of North Island. Table 1.5 adopts the epicentre from GNS, but the time from Eiby (1968a) - the GNS database gives a time 45 minutes later. According to Hawke’s Bay Civil Defence and Emergency Management Group (http://www.cdemhawkesbay.govt.nz/hawkes-bay-civil-defence-emergency-management-group/earthquakes_idl=2_idt=496_id=1814_.html, retrieved 31 October 2012) there is evidence for coastal landslides south of Cape Kidnappers and ground cracking near Napier, suggesting the earthquake may have been centred closer to Hawke’s Bay than previously thought, possibly along its western boundary, but no reference is cited. The epicentre may therefore have been significantly east of that given here.

15 October 1848 – This earthquake was damaging (intensities around 8 MMI) in the north-east corner of South Island and in the Wellington area, and peaked at 9 MMI (Downes, 1995; Grapes et al., 2003). There is some confusion about the magnitude, partly deriving from uncertainty about scales, and application of ML beyond its saturation point. The GNS database gives 7.4, magnitude unspecified; Downes (1995) has 7.1 “ML” but quotes Dowrick (1991) as giving 7.9, magnitude unspecified. Grapes et al. (2003) has 7.5, magnitude unspecified. A compromise value of 7.5 Mw is adopted here. Grapes et al. (2003) presents a complete collection of primary source material for this earthquake. The epicentre adopted in Table 2 is from Grapes et al. (2003).

23 January 1855 – The great Wairarapa earthquake of 1855 is of seminal importance in the history of seismology, as it was the first ever case witnessed by Europeans of coseismic ground rupture, establishing conclusively the link between earthquakes and faulting (Grapes and Downes, 2010). Damage in the epicentral area was reduced due to the fact that many vulnerable brick buildings had already been thrown down by the 1848 earthquake, and rebuilt in wood. Contemporary reports of the earthquake have been collected and published as Downes and Grapes (1999); and analysis will be found in Grapes and Downes (1997). There is little disagreement in published sources about the parameters of the earthquake; the GNS values have been adopted here.

22 February 1863 – The 1863 Hawke's Bay earthquake is something of a Cinderella event. It is entirely missing from Downes (1995), and it has not been possible to trace any study of it. Eiby (1968b) assigns it as class "B" and states that it was felt over most of the country. At Napier:

> *The want of a "new sensation," which has become a prevalent complaint in our dull town, was amply supplied on the morning of Monday last. At a few minutes past one, the inhabitants were suddenly startled from slumber by a violent oscillation, attended with hideous din, produced by shelves being emptied of crockery and their other contents, furniture being upset, and chimneys falling to the ground. The time of its duration is variously estimated at from twenty seconds to two minutes; but we think it must have lasted very nearly a minute. Its effects were very alarming for the time — the sensation being as if the houses were about to fall over, and many having turned giddy from the peculiarity of the motion. The damage in the hotels and stores has been extensive — the contents of whole shelves having been swept to the ground and destroyed. In this respect, Messrs. Robottom, Sutton, Bridge, and Gill probably, experienced the greatest loss. Innumerable chimneys have been broken off at the roof, and, in one or two instances, the bricks came through, but without leading to any accident. The barrack chimneys have all gone, also one side of the mud wall which surrounded the reserve. It was, however, a feeble structure at best of times. The road to the Spit exhibits several cracks, but it having been all new ground at a comparatively recent period renders this an unimportant fact. These effects would seem to denote that the shock was rather a serious one; and of course those to whom such visitations are strange felt rather queer during its continuance; but the old Wellingtonians among us say that it was quite a minor affair.* (Hawke's Bay Herald, 25 Feb 1863, p2)

Epicentre and magnitude have been taken from the GNS database.

18 October 1868 – Downes (1995) reproduces an isoseismal map for this earthquake from Anderson et al. (1994), described as "preliminary". She notes that earlier studies located this earthquake either in the South Taranaki Bight or Cook Straits, but that further data indicated a probable epicentre just off Cape Farewell.

31 August 1888 – Downes's (1995) intensity map for this earthquake is taken from Cowan (1991). The earthquake caused widespread damage, and is attributed by Downes (1995) to a segment of the Hope Fault. GNS gives a magnitude of 7.0.

Table 1.5 Large historical earthquakes in New Zealand, to 1903

Date	Time	Lat	Long	Mw	Place
1460		-41.20	174.80	8.0	Wellington
1826		-44.70	167.40	8.0	Milford Sound
1838		-39.40	175.00	7.0	Utapu
8 Jul 1843	4h45m	-39.60	176.20	7.6	Wanganui
15 Oct 1848	14h10m	-41.80	173.70	7.5	Marlborough
23 Jan 1855	9h32m	-41.20	175.20	8.2	Wairarapa
22 Feb 1863	13h5m	-40.00	176.50	7.5	Hawke's Bay
18 Oct 1868	12h35m	-40.20	173.00	7.2	Cape Farewell
31 Aug 1888	16h45m	-42.60	172.55	7.0	North Canterbury

There are no further earthquakes in New Zealand with magnitudes above 7.0 Mw until the 8 August 1904 Cape Turnagain earthquake, which is assigned 7.0 by GNS but 6.7 Ms by Dowrick and Smith (1990). The 11 February 1893 Nelson earthquake falls just short at "6.6-6.9" given by Downes (1995) from a personal communication from Dowrick.

Of particular interest from the point of view of earthquake risk in New Zealand is the conclusion that the Alpine and Wellington Faults have ruptured synchronously on not just one, but two occasions within the past thousand years, with a major tsunami on both occasions. The 1220 event is not listed in Table 1.5 because, although it falls within the time span of GHEA, the policy of the project is not to include events that rely exclusively on palaeoseismic evidence. It is clear, though, that what has happened twice can happen again, and the consequences of such an event in the near future would completely dwarf that of the Christchurch earthquake of 2011.

2.13.3 South Pacific

This region, comprising Micronesia, Melanesia excluding New Guinea, and Polynesia excluding New Zealand, is one of the most intractable for historical earthquake studies. Parts of it (Tonga and the Kermadec Islands) are among the most seismically active places on the planet, but the vast expanses of ocean with few small islands, and the dearth of written history, makes it difficult to reconstruct any earthquake even if one can find a reference to it at all. It is notable that a recent hazard study for Vanuatu (Suckale and Grünthal, 2009) confines itself entirely to analysis of seismicity since 1970. On the other hand, the high rate of seismicity means that for places like Vanuatu, post-1970 seismicity is copious enough to be sufficient for seismic hazard purposes. Historical seismicity is therefore less critical an issue.

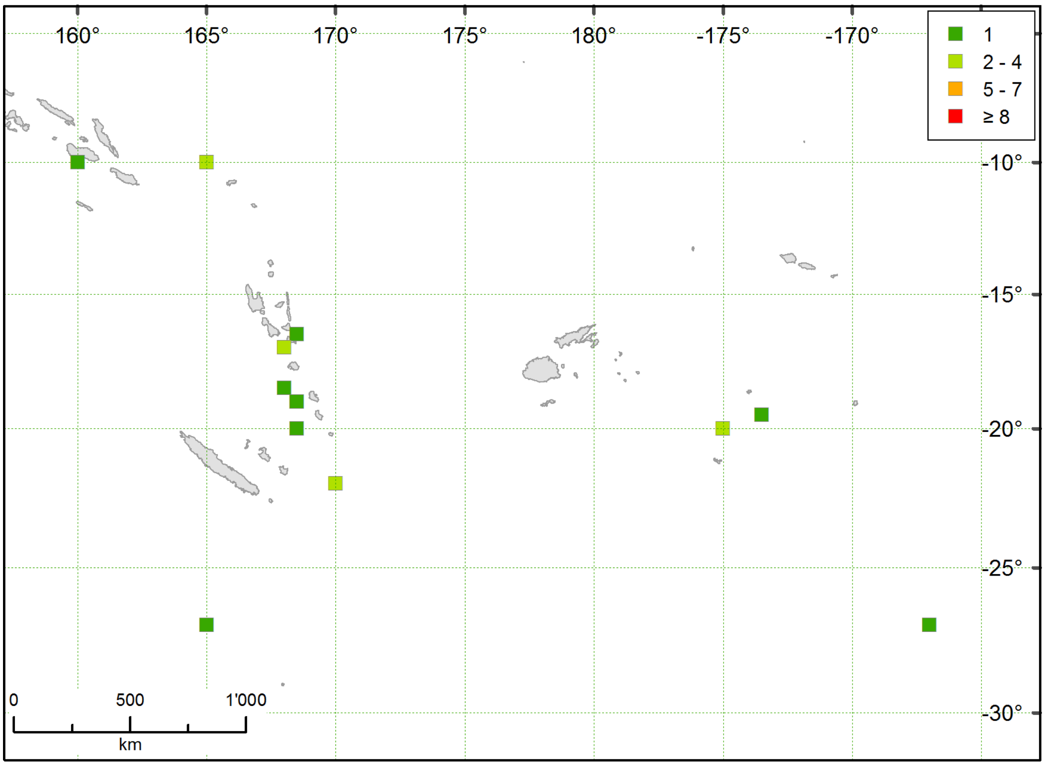


Figure 2.35 Earthquakes in GHEA (1000-1903) in South Pacific, and number of records per earthquake

For the purposes of this study, the region is defined by two rectangles. The southern one runs from 154° E, across the date line to 160° W, and from the Equator to 35° S. The northern one, taking in Guam, the Carolines and Marshall Islands, runs from 135° E to 160° W, and 30° N to the Equator. This region abuts those used in this project for Indonesia, New Zealand and the Philippines. For the remainder of the Pacific, Hawaii is grouped with North America, and the rest of the ocean is either devoid of land or devoid of seismicity, or both.

There are no earthquake reports at all that have been found for this region before the 19th century, the earliest being a report of a strong earthquake with a tsunami in the Bonin Islands in January 1826 (Soloviev and Go, 1974).

Three databases have been consulted for earthquakes in this region. The SisFrance database (2010) contains a special section on French possessions in the area: New Caledonia, Wallis and Futuna. Altogether, 45 events are listed between 1839 and the end of 1903, but of these, only three are given intensity values, and none are given either epicentres or magnitudes. The second is the NOAA database previously referred to. This relies heavily on Soloviev and Go (1974) for its information for earthquakes before 1900 and is therefore mostly confined to tsunamigenic events. After 1900, the ultimate source is Richter (1958). The third is Utsu (2002), who has few events before 1900, but, while citing magnitudes values from Richter (1958) as does NOAA, comments that they are overestimated.

Table 1.6 lists all the earthquakes in the region above magnitude 7.0 Mw, with parameters largely from NOAA. Obviously, these have been assigned in a very approximate way, but given the difficulties, it does not appear that any improvement can be made in the scope of the present project. In one case in Table 1.6 it has been possible to add time information from SisFrance, missing in NOAA. For events after 1900, magnitudes have been taken from Engdahl and Villaseñor (2002). This means dropping the Tonga earthquake of 9 February 1902, which is 7.8 in Richter (1958), and hence NOAA, but 6.9 in Engdahl and Villaseñor (2002).

Utsu (2002) gives a slightly different epicentre for the 28 March 1875 earthquake, 190 km to the south-west of the NOAA location. The NOAA location is in the New Hebrides Trench, Utsu's is on Lifou Island, which is where the earthquake was felt. The former is preferred here. This damaging and tsunamigenic earthquake was followed by many aftershocks, and was clearly a great earthquake. There is also disagreement about the time of the Guam earthquake of 16 May 1892. Soloviev and Go (1974) give 21h10m, which Utsu (2002) treats as UTC and NOAA treat as local time, which is probably correct.

A paper by Everingham et al. (1974) claims to cover earthquakes in the area of the Solomon Islands from 1873 onwards, but in fact covers only the period after 1900. Everingham (1983) lists earthquakes felt in Fiji from 1850, but none of these are considered to exceed 6.5 in magnitude.

The fact that of all the earthquakes in Table 1.6, more than a third occur in the final four years 1900-1903, i.e. the early instrumental period, is a measure of the complete inadequacy of historical material for giving any idea of the seismicity of this region.

Table 1.6 Large historical earthquakes in the Pacific, to 1903

Date	Time	Lat	Lon	Mw	Place
25 Jan 1849	5h10m	14.00	143.00	7.5	Guam
17 Aug 1863		-19.00	168.50	7.5	Vanuatu
18 Nov 1865		-19.50	-173.50	8.0	Tonga
28 Mar 1875	12h	-20.00	168.50	8.0	Loyalty Islands
10 May 1875		-18.50	168.00	7.0	Vanuatu
10 Jan 1878		-19.00	168.50	7.5	Vanuatu
11 Feb 1878		-19.00	168.50	8.0	Vanuatu
16 May 1892	11h10m	14.00	143.00	7.5	Guam
29 Jul 1900	6h59m	-10.00	165.00	7.6	Santa Cruz
9 Aug 1901	13h01m	-22.00	170.00	7.9	Loyalty Islands
22 Sep 1902	1h46m	18.00	146.00	7.5	Guam
4 Jan 1903	5h07m	-20.00	-175.00	7.8	Tonga
13 May 1903	6h34m	-17.00	168.00	7.0	Vanuatu

2.13.4 The earthquake of 19 September 1902

While the scope of Musson (2012b) is earthquakes before 1900, the Global Historical Earthquake Catalogue (GHEC) extends to the end of 1903. This brings one further earthquake into consideration – the Warooka earthquake of 19 September 1902 (Table 1.4). This earthquake had an epicentre on the Yorke Peninsula, west of Adelaide. Damage was significant at Warooka, with fall of chimneys and partial collapse of walls (Everingham et al., 1982). McCue (1999) gives the magnitude as 6.0 Ms.

Johnston et al. (1994), however, obtain a magnitude of only 5.4 Mw. Given that the radius of perceptibility was at most 350 km, even this may be generous. Calculations from isoseismals 3 and 4 according to the method applied elsewhere in this report yield a magnitude of 5.2 Mw.

3 Global Historical Earthquake Catalogue (M≥7.0, 1000-1903)

One of the goals of GEH is to supply GEM with a Global Parametric Catalogue for earthquakes above magnitude 7 for the period 1000-1903. This was to match the Global Instrumental Catalogue for GEM, which begins in 1904 with Mw ≥ 7. This goal was accomplished by critically merging and carefully selecting the most reliable input datasets stored in the Global Archive.

3.1 Strategy in Catalogue compilation

Traditionally, the parametric catalogue is considered the most handy and popular description of the seismic history of a region. Its synthetic structure represents both an advantage (essential parameters of a large number of events can be stored in a very small space and easily processed) and a drawback, as it does not contain, except in a very reduced form, the often huge amount of information from which the essential parameters have been determined.

The compilation of a (global) earthquake catalogue can be approached in two ways: 1) merging national or regional compilations, trying to sort out duplications in the overlapping areas and homogenising the parameters, as far as possible, and 2) go back to the studies and their sources, and repeat the whole process from the raw data to assessment of parameters.

The first procedure is the one followed by previous attempts at compiling global catalogues, performed since the mid-1970s. Of these, the only readily available is the "Significant Earthquake Database" maintained by the National Oceanic and Atmospheric Administration (NOAA; Dunbar, 2002), which provides a listing of historical earthquakes throughout the world that range in date from 2150 BC to the present, derived from scientific and scholarly sources, regional and worldwide catalogues, and individual event reports. This had its origin in a project to provide a world map of significant earthquakes up to 1979, as described in Ganse and Nelson (1982). The most recently published (though started many years ago) is Utsu's (2002) catalogue and its online version, which compiles a list of deadly historical earthquakes from 1400 through 2006, again compiled from various accounts, earthquake catalogues, research articles, and reports on global and regional earthquakes. Databases of a similar nature, but private, were established by the Institute of Geological Sciences (now British Geological Survey) and SwissRe at about the same time, and possibly by others. The compilation of the former is described in detail by Henni et al. (1998); about the latter, less information is available.

A general problem with catalogues derived from merging existing compilations is that, firstly, they preserve errors present in the input catalogues, and secondly, they introduce new errors as a product of the merging process. This can arise in two main ways. Firstly, the merging process is usually automatic. Weeding out of duplicate events is left to an unsupervised algorithm which may not be equal to the task (or in some cases, there is no checking for duplicates at all). This is particularly problematic in cases where there is some issue with the input catalogues regarding notation of time or date. One catalogue may give local times, where another has corrected to UTC, and the result can be duplicate events some hours apart. Similarly, different calendars may be in use. Many of these errors are extremely obvious to a trained seismologist on inspection; but since the catalogues were never reviewed event by event, the errors did not come to light. What happens, then, is that a catalogue is taken on trust by users, again with no review, and the errors will propagate into hazard studies or other applications.

To avoid these problems, the second of the two strategies, i.e. going back to the studies and their sources, and repeating the whole process from the raw data to parameters assessment, would be preferable. However, this procedure implies a huge amount of work and manpower, mostly devoted to the retrieval, archiving, and analysis of the background information. This is probably why, throughout the world, catalogues compiled this way are few in number.

In Europe, a major effort to compile a homogeneous continent-wide catalogue has taken place over the last several decades, aided by a succession of European-funded projects: RHISE, BEECD, NERIES, AHEAD, and lastly, in the framework of the SHARE project (2009-2012) a new earthquake catalogue for Europe, SHEEC, has finally been produced (Stucchi et al., 2012). It relies on the background data collected and critically organized within the AHEAD archive (see Section 2.1), the structure of which permitted sorting out problems related to:

a) duplications, derived from conflicting interpretations, by different studies, of the historical records as regards origin time and/or location of the same event;

b) earthquakes missing in one or more catalogues.

c) fake events, derived from the incorrect interpretation of historical records referring to other natural phenomena.

SHEEC parameters were then assessed, as much as possible, from the MDPs provided by the studies archived in AHEAD, and processed with updated, repeatable procedures, regionally calibrated against a set of recent instrumental parameters.

The only other comparable continent-wide effort was performed for South America in the frame of the SISRA project in 1985 (Programa para la Mitigación de los Efectos de los Terremotos en la Región Andina; Earthquake Mitigation Program in the Andean Region), which focussed on compilation of both a catalogue and a macroseismic intensity database for the whole continent, and resulted in the CERESIS (1985) catalogue and database. Unfortunately, since its creation only the earthquake catalogue has been updated.

The Global Historical Earthquake Catalogue - GHEC - is compiled according to the best possible compromise between the two strategies described above, given the very different situations throughout the world as concerns the availability and quality of data. The Global Historical Earthquake Archive supplies, for each earthquake candidate to enter the catalogue, the material upon which to build the catalogue. The catalogue results from a selection of the most reliable supporting dataset, among those inventoried, performed mainly according to the following criteria:

- *public availability of the material*. Input datasets are selected - as much as possible - from publically-available material. It frequently happens that local and regional catalogues and datasets exist, circulate as files and are widely used, although they are not public. Moreover, such datasets are updated frequently without explanation; so it happens that varied versions of the same dataset are circulating with the same title. In some cases the compilers of such material are ready to deliver it for being used in projects, under the condition that they do not allow it to be made public. This project aims at delivering a public catalogue and a public archive: therefore, it makes use of published material, with only a very few exceptions.
- *clarity and reliability*. The preferred input datasets are those providing descriptions of the research done, references to the sources, and the procedures for the assessment of parameters. Thus in-depth studies on single or a few earthquakes or small areas have often been preferred to national catalogues and, sometimes, old studies and catalogues have been preferred to more recent ones.

At the outset of the project, the intention was to compile a world catalogue for earthquakes above 7 Mw for the period 1000-1903. However, taking into account the uncertainty associated with magnitude estimates for the historical earthquakes, it was found practical and useful to lower the magnitude threshold to 6.7 or 6.5 Mw, or in the extreme cases of Sub-Saharan Africa and Australia, to 6.0 Mw.

3.2 The Catalogue

In compiling the catalogue, the Archive content was thoroughly analysed on a region-by-region, and in most cases, an earthquake-by-earthquake, basis. The selection of each GHEC reference study or catalogue took into account the availability of parameters and their quality, which, whenever possible, was carefully checked against the studies and the data they supply on the earthquake. This implied, though only for a limited number of cases (65), the selection of different studies, one for the epicentre and another one for the magnitude. Another consequence of the adopted selection criteria was that 169 earthquakes, contained in the Global Archive on the basis of a magnitude ≥ 7 provided by a given study, are not included in the catalogue because the selected study assessed a magnitude lower than 7, which has been considered consistent with the available information.

In a few problem cases, new reports were compiled, and new parameters assessed, although mostly in a fairly simple way. This particularly concerned Indonesia, a problem area from the outset of the project, where existing databases and studies are clearly very unsatisfactory.

3.2.1 Earthquake parameters

GHEC contains 825 earthquakes (Figure 3.1), the parameters of which are derived from a total of 87 sources, out of which eight were considered only for magnitudes and four only for epicentres, as shown in Table 1.9 at the end of this chapter.

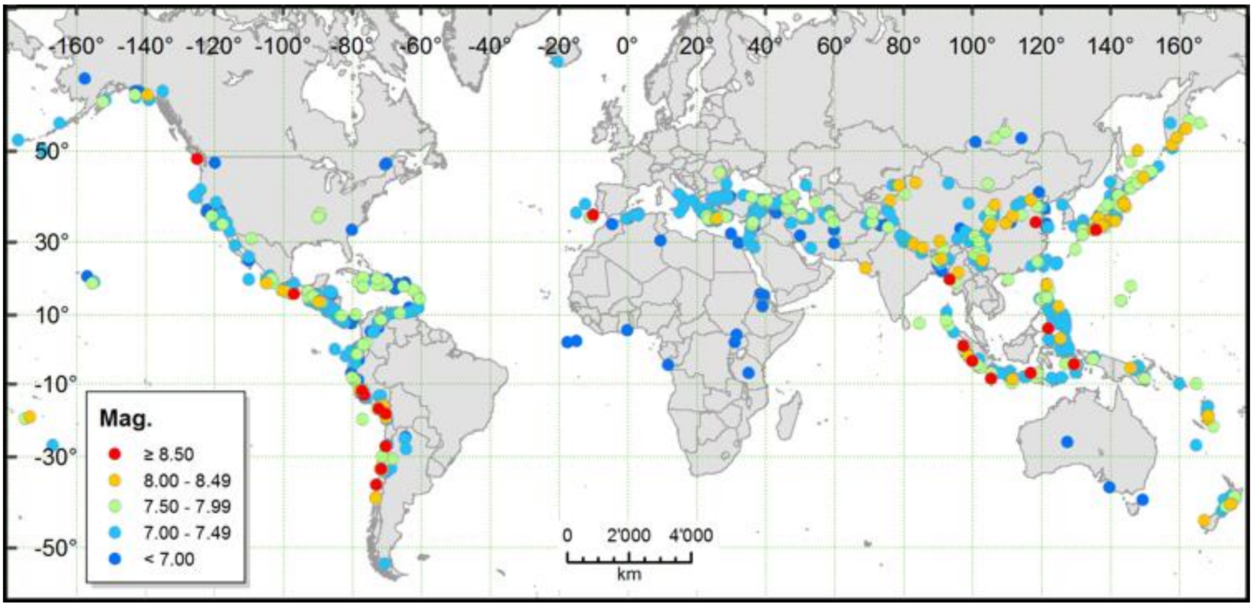


Figure 3.1 Map of GHEC

The main earthquake parameters in GHEC are described in the following paragraphs. The full format of the catalogue is presented in the next section.

Epicentral location

Epicentres are adopted from the selected source. The epicentre of historical events is usually estimated from the area of the strongest documented effects, aside from those calculated from MDPs using documented algorithms (e.g. Bakun and Wentworth, 1997; Gasperini et al., 1999, 2010). In some particular areas, epicentres of large earthquakes are placed by catalogue compilers on known active faults, or located with reference to the distribution of modern seismicity. In GEH, the practice has been to select the epicentres that are most consistent with the available historical information on each earthquake. When explicitly mentioned, the method used by the input dataset for assessing the epicentre is reported in GHEC; 39 epicentres are as determined using the method by Bakun and Wentworth (1997), and 19 using the one by Gasperini et al. (1999; 2010). Other studies, such as Ambraseys and Douglas (2004) and Doser (2006), derive epicentres from MDP distributions according to their own procedures.

It has also to be recalled that the epicentres of some earthquakes after 1897, especially those in the circum-Pacific region, are of instrumental origin.

Uncertainty of location

The variety of criteria and procedures used in earthquake catalogues for estimating the uncertainty of location is high. The values supplied by the catalogues derive from unclear criteria or unrepeatable procedures, and often represents the "quality" of the assessed epicentre rather than a generic uncertainty estimate. The location uncertainty assessed by both the methods by Bakun and Wentworth (1997) and Gasperini et al. (2010) depends on the number of MDPs used in the calculation, and is not influenced by other factors such as the magnitude of the earthquake. Nor does it take into account factors such as population distribution, which actually provides much of the true uncertainty. Bakun and Wentworth (1997) model uncertainty using contour lines of varied confidence level of the residuals of the calculated magnitudes, and this information cannot be included in the columns of a parametric catalogue. When supplied by studies, uncertainty of location has been preserved in both the archive and the catalogue. Out of the 825 entries of GHEC, only for 188 (i.e. for 23% of them) is this information available. The input datasets supplying it are listed in Table 1.7. Values in degrees have been converted into km, and the maximum values of the ranges in km have been taken as the uncertainty value. On the other hand, for large earthquakes, the earthquake source is probably hundreds of kilometres long and tens of kilometres wide, and the uncertainty of the point epicentre should be at least equal to the source dimensions, assuming that epicentre is even a meaningful concept in such circumstances.

Table 1.7 GHEC input datasets supplying uncertainty in location

Dataset	Uncertainty of location	Nr. of entries in GHEC
Ambraseys, 1989	ranges in km	6
Bilham et al., 2005	values in degrees (asymmetrical)	1
Min Ziqun, 1995	ranges in km	66
Nishenko and Singh, 1987	values in degrees	1
Shebalin and Leydecker, 1997	values in degrees	28
Shebalin and Tatevossian, 1997	values in degrees	8
SisFrance, 2010	ranges in km	9
Stucchi et al., 2012	values in km (asymmetrical)	69
Total		**188**

Depth

The depth of historical earthquakes is even more difficult to be parameterised than the epicentre. Many catalogues recognise earthquakes as deep or intermediate just on the basis of the distribution of recent instrumental seismicity, mostly in subduction zones. In GHEC the depth values are adopted from the selected source, whenever they are available, but 75% of the earthquakes have no depth information (Figure 3.2).

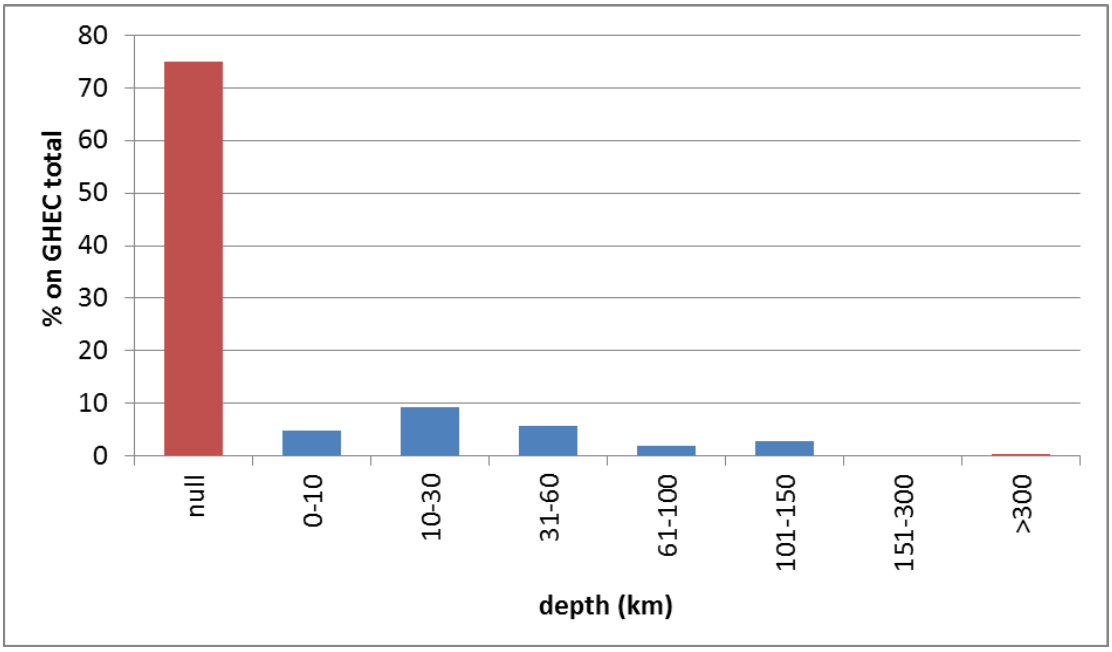


Figure 3.2 Depth distribution in GHEC

Epicentral intensity

Epicentral intensity has been adopted from the selected source, when available. For some catalogues the epicentral intensity has to be assumed to be the same as the maximum observed.

Magnitude

For historical events, magnitudes are estimates from macroseismic data referred to some equivalent instrumental value. In some cases the instrumental scale is not mentioned, and the original catalogue generically defines the magnitude as “macroseismic”. In the compilation of GHEC, priority was given to magnitude values expressed as moment magnitude. When the original catalogue expresses it in more than one scale the following hierarchy was adopted: 1) Mw, 2) Ms, 3) other types. Aside from issues of saturation, scales tend to converge for magnitudes between 6.5 and 8. Given the high magnitude threshold of the catalogue, magnitudes expressed as Ms can be considered equivalent to Mw. The same applies, for shallow earthquakes, to MJMA (Katsumata, 1996). Conversion to Mw from other magnitude types provided by input studies was not considered worthwhile. Any differences in values due to conversion would lie within the uncertainty associated with the determination itself. However, information on the original scale has been preserved in GHEC, together with the method used by the input dataset for determining it. Table 1.8 and Figure 3.3 show the proportion and geographical distribution of different magnitude types in the catalogue, Figure 3.4 show the distribution of the magnitude values in the catalogue.

Table 1.8 Proportion of different magnitude types in GHEC

Type	Nr.	%
Mw	395	47.9
Ms	321	38.9
MJMA	104	12.6
unspec.	5	0.6
Total	**825**	**100.0**

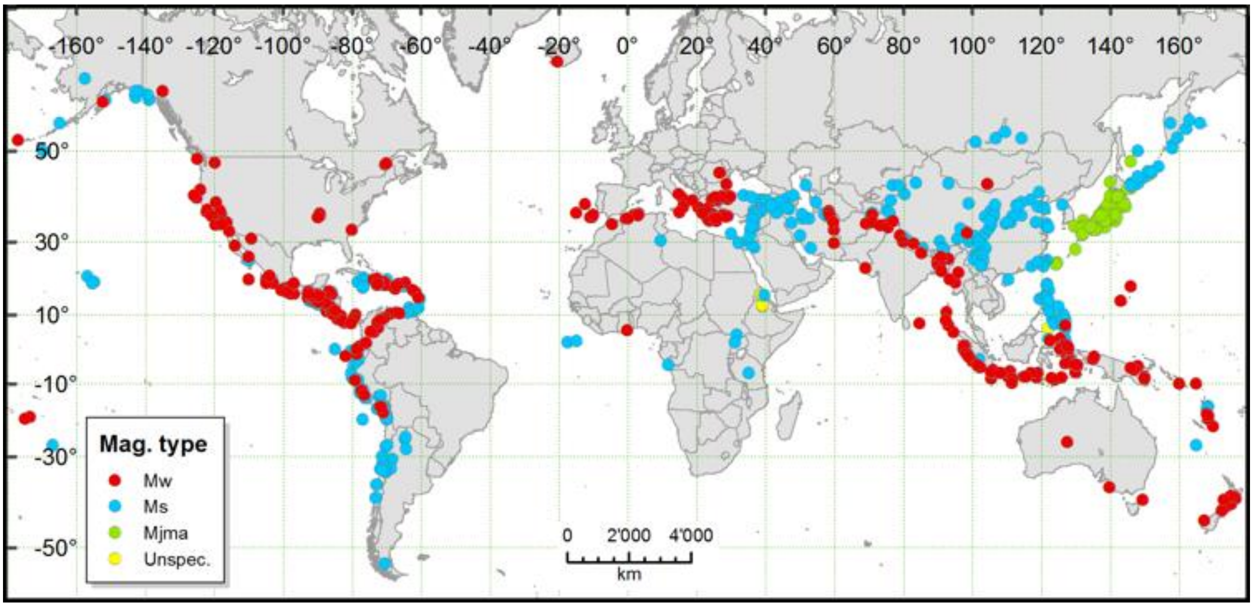


Figure 3.3 Geographical distribution of the different magnitude types in GHEC

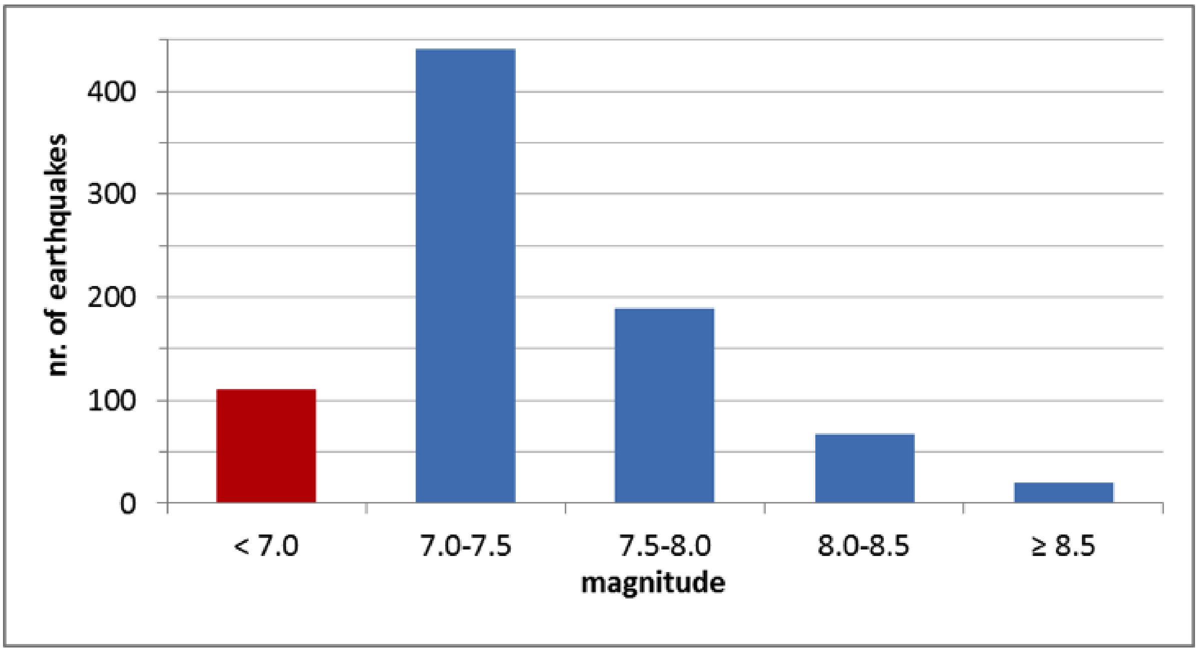


Figure 3.4 Magnitude distribution in GHEC

Magnitude uncertainty

Magnitude uncertainty is assessed and reported in the catalogues in varied ways. For historical earthquakes it is often inferred from the quality and number of the sources or the number and spatial distribution of places reporting the earthquake. Also the uncertainty calculated by the methods by Bakun and Wentworth (1997) and Gasperini et al. (1999, 2010) is a function of the MDPs used. When magnitude is converted from the epicentral or maximum observed intensity, the associated uncertainty is usually expressed as the standard deviation of the regression used. In GHEC 182 magnitude values are associated with an uncertainty estimate, ranging from 0.1 to 1.0, the frequency of which is represented in Figure 3.5.

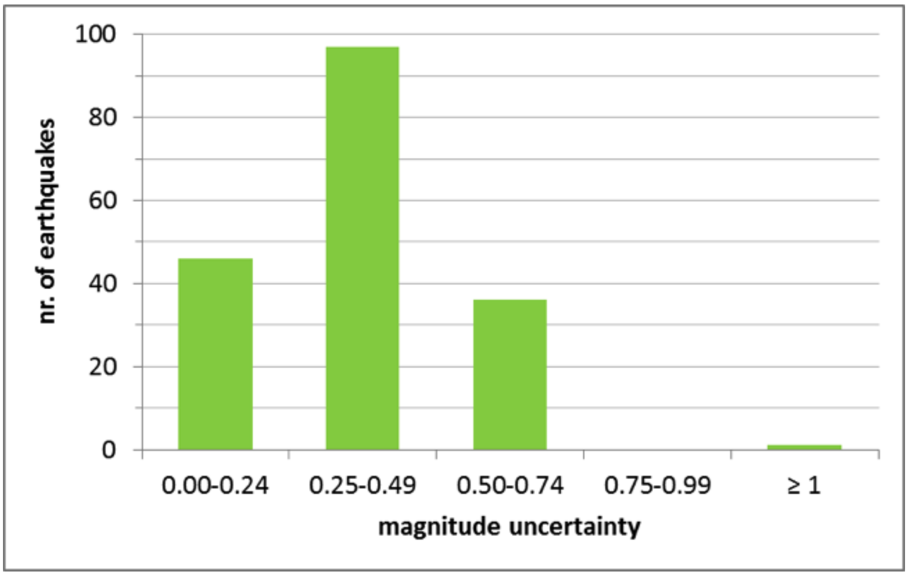


Figure 3.5 Magnitude uncertainty distribution in GHEC

3.2.2 Format

The GHEC format is shown in Table 1.10 at the end of this chapter. This format represents an exhaustive synthesis of the essential parameters of each considered earthquake. Given the close relationship between GHEC and the GEH Global Archive, once the preferred dataset(s) are selected, the archive structure easily allows different subsets of data to be transferred into a catalogue. In other words, this means that alternative catalogue formats can be generated from the archive.

Further magnitude determinations could be added to the catalogue, in order of preference, for each earthquake, e.g. as in Engdahl and Villaseñor (2002), and CEUS (2012), to show the multiplicity of possible solutions and to emphasise the epistemic uncertainty of historical earthquake parameters. This can also be applied to the epicentral location, when robust alternative solutions are provided by different sources. This was observed for example in Guatemala and Salvador, where White et al. (2004) locate the epicentres of subduction events onshore, on the basis of the distribution of effects, while other catalogues, such as Benito et al. (2012), locate them offshore, probably on the basis of recent instrumental seismicity. There is no good reason to prefer one approach over the other, and this problem applies equally to subduction areas where there is only one catalogue to choose from – the true distance of the epicentre from the shore is always unknowable. On the other hand, for such earthquakes, the epicentre determined from historical data is merely a point of convenience, since the actual earthquake source is probably hundreds of kilometres long and tens of kilometres wide. Representing this by a point is a convenient fiction, and this has to be remembered when examining such data.

When the source reports the features of the macroseismic dataset used for deriving the parameters (source and number of macroseismic datapoints, maximum intensity, macroseismic scale), this information is included in GHEC. Information on the macroseismic data is available for 175 earthquakes.

3.3 Results

GHEC lists 825 earthquakes and (probably) contains the largest possible number of known events ≥ 7 Mw. The parameters, carefully selected among those provided by the most updated and reliable catalogues and studies, are the best available at present in many areas, while in some they can be improved.

The maps in Figure 3.6 show the catalogue content in six different selected time-windows.

Figure 3.6.a shows that in the first 250 years of the catalogue, from 1000 to 1250, the only known earthquakes are those in the Western Mediterranean, the Middle-East, China and Japan.

From 1251 to 1490 (Figure 3.6.b), earthquakes start to be reported from Europe. The first earthquake in New Zealand appears as well (from oral history), as does the only earthquake known in America in pre-Columbian times.

Between 1491 and 1650 (Figure 3.6.c) earthquakes in South and Central America (but not in North America) appear, as well as in the Himalayan region and south-eastern Asia. The contrast between North and South America reflects the differences in colonial history. Whereas the Spanish conquests rapidly took them into seismic areas in South and Central America, in North America English and French colonists remained largely settled on the low-seismicity eastern coast. The difference in the number of events in the Dead Sea Fault Zone with respect to the previous time-windows is remarkable.

After 1650 (Figure 3.6.d), the first earthquakes in North America appear and also the first in Eastern Russia (Baikal Region and Kamchatka peninsula), together with the first event reported from East Africa.

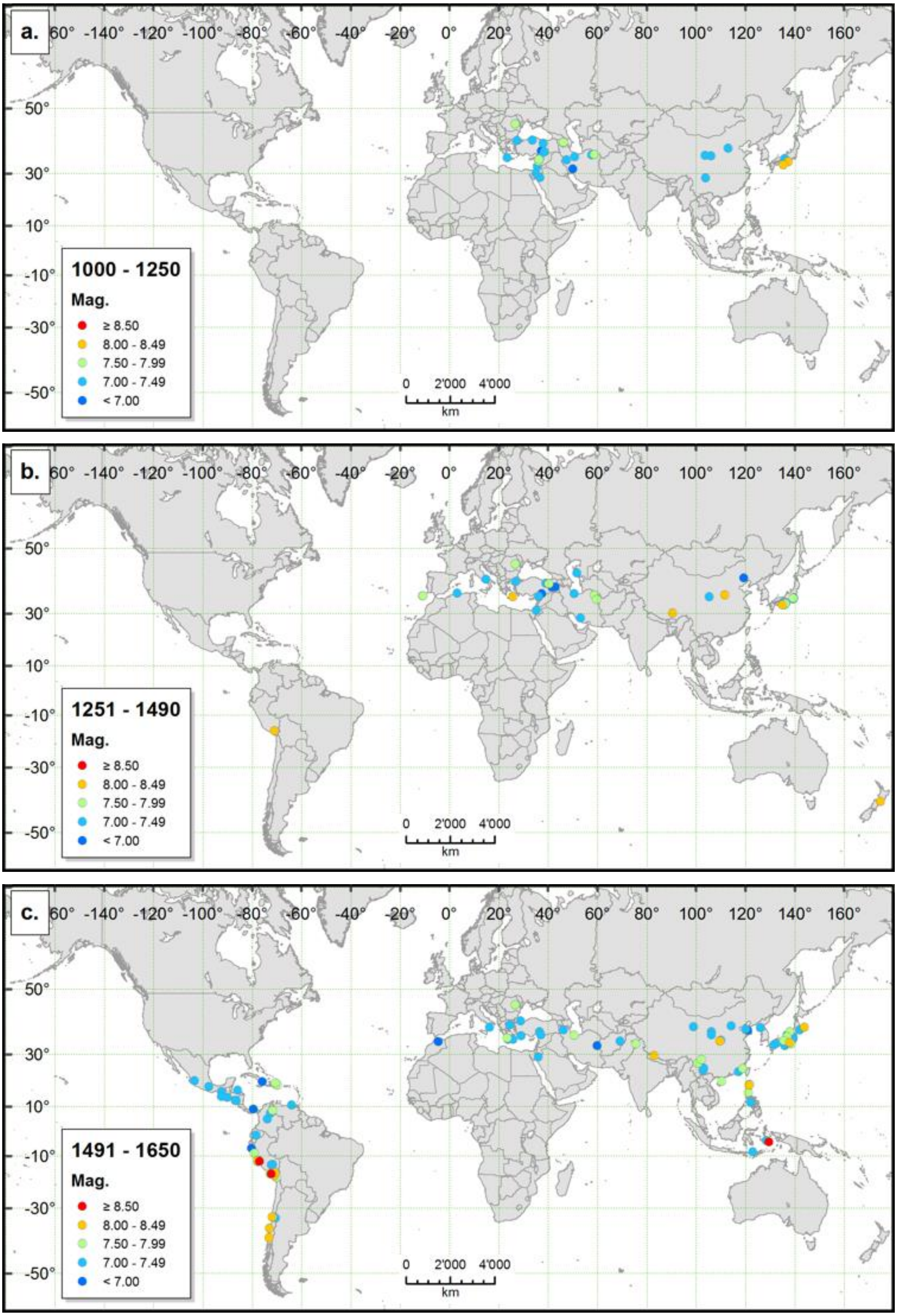


Figure 3.6 GHEC earthquakes in different time-windows

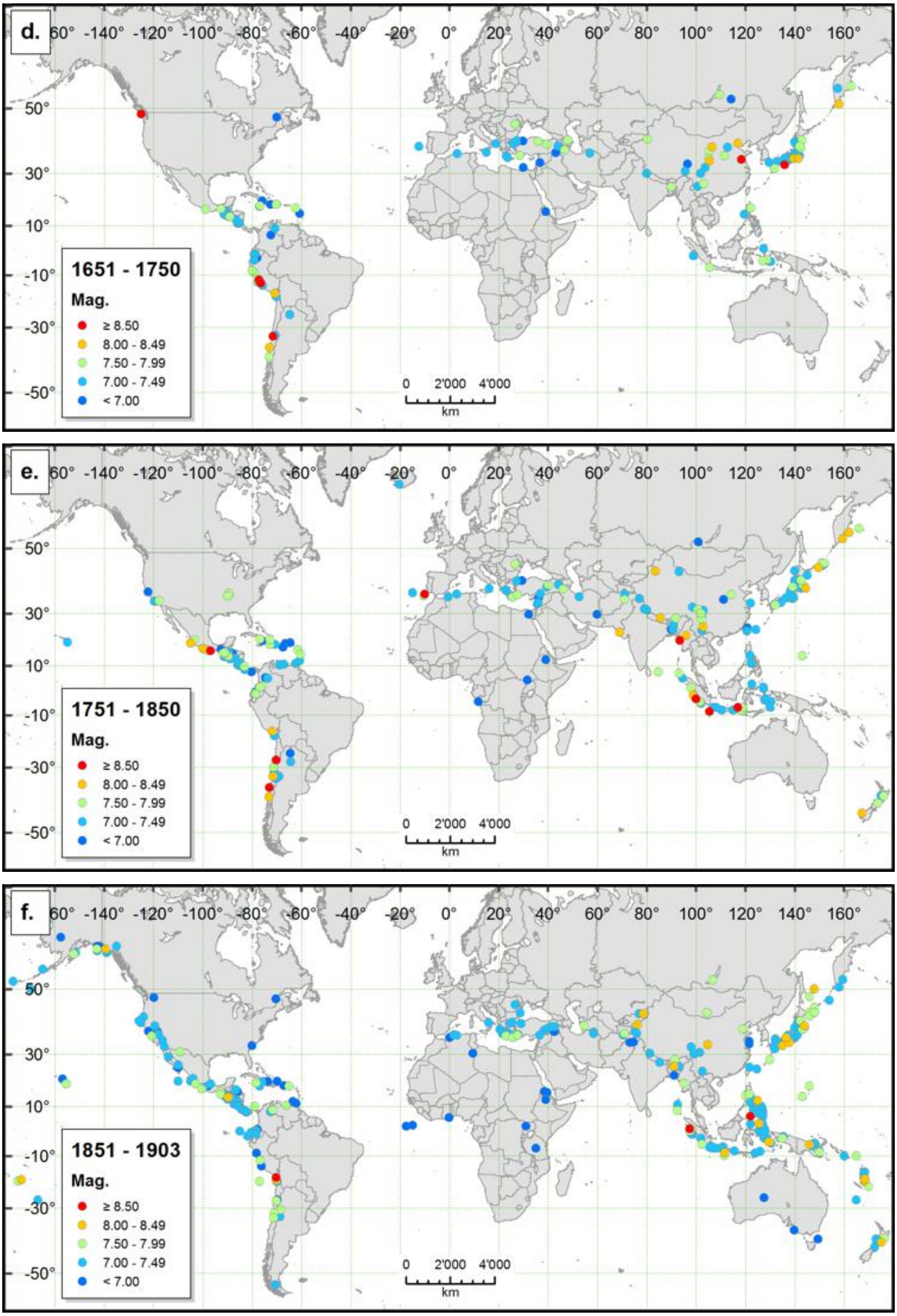


Figure 3.7 GHEC earthquakes in different time-windows (continued)

In the time-window 1751-1850 (Figure 3.6.e) the number of earthquakes reported from North, Central and South America increases. The seismicity of Indonesia starts to be comparable with that of today. A few earthquakes are reported also from Sub-Saharan Africa.

In the last time-window, from 1850 to 1903 (Figure 3.6.f) the most significant changes with respect to the previous century are in the circum-Pacific, and the picture of global seismicity starts to be similar to that of the 20th century.

3.4 Improvements on previous catalogues

The significant advance made in this project is shown by the comparison of Figure 3.7 and 3.8, presenting, respectively, the contents of the NOAA database (Figure 3.7) and GHEC (Figure 3.8) with the same time and magnitude criteria (1000-1903, ≥ 7 Mw). Even at first sight, remarkable differences in both the number of earthquakes and their magnitude values are evident.

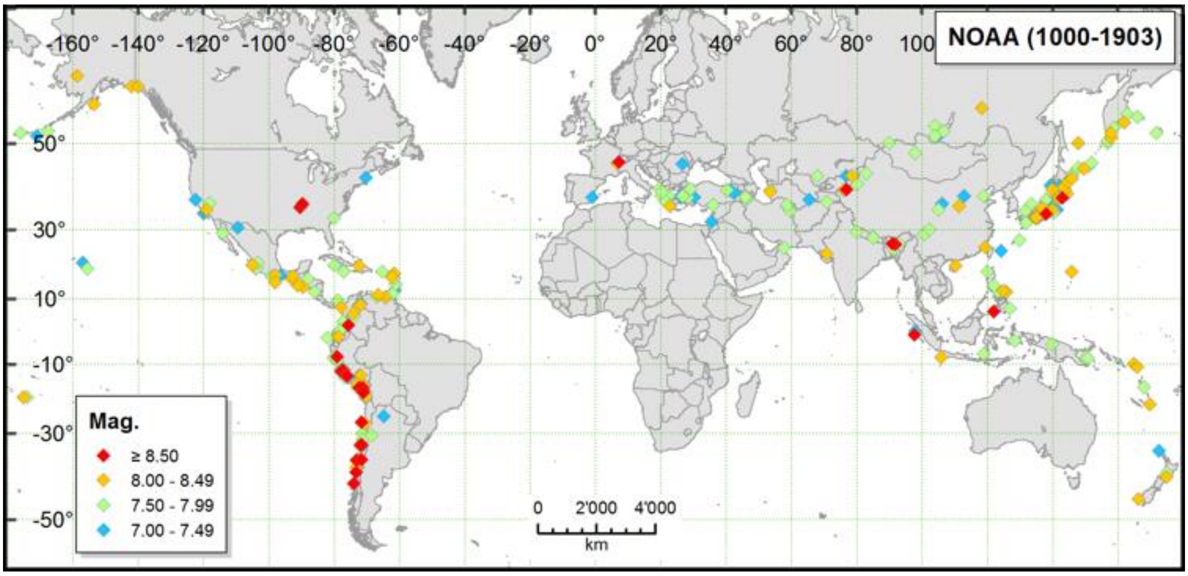


Figure 3.8 NOAA database in the time-window 1000-1903 and M≥7

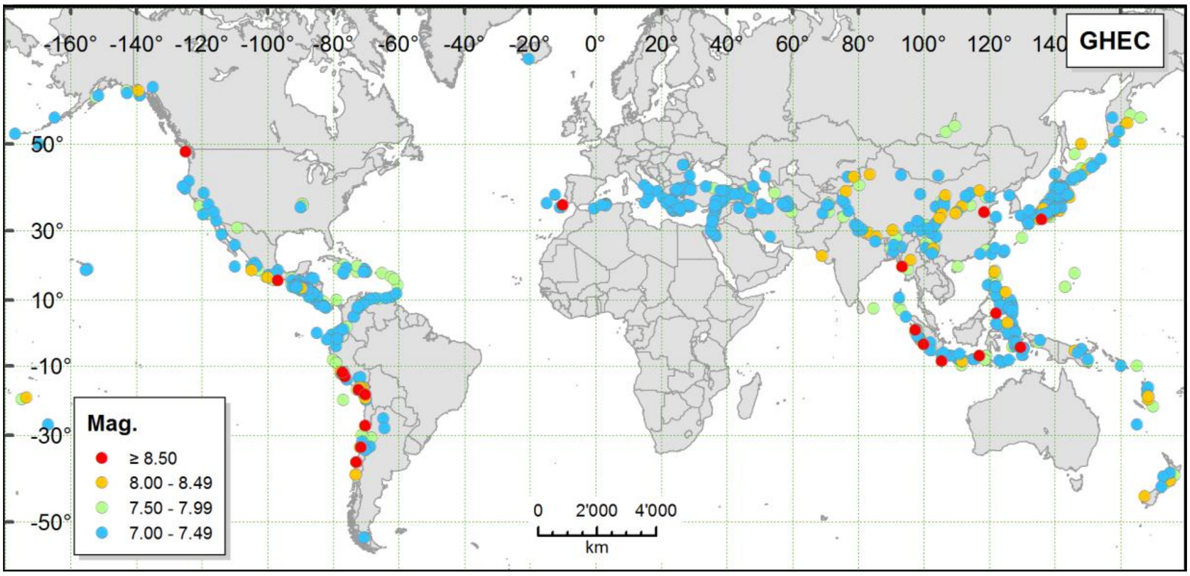


Figure 3.9 GHEC global seismicity 1000-1903, ≥ 7 Mw

Although the NOAA database reports 2224 earthquake in the time-period 1000-1903, only the 40% of them have a magnitude value. Out of these, M ≥ 7 earthquakes are 422, to be compared with the 715 earthquakes of the same size in GHEC. In addition, NOAA reports Mw only for 8 of the M ≥ 7 earthquakes, most of the remaining being Ms (68%) or not specified (27%), (see Table 1.8 for the magnitude types in GHEC). Hough (2013) recently pointed out the scarce reliability of high magnitude values in NOAA, among which the most striking is probably the magnitude 8.5 attributed to the 25 July 1855 Valais (Switzerland), resulting from a confusion with epicentral intensity.

An exhaustive comparison of NOAA and GHEC would require a one-to-one check of the earthquakes, which is out of the scope of this report. In the following, two examples of such a comparison are shown for the Himalayas and Indonesia.

GHEC lists 20 earthquakes in the Himalayas, mostly derived from Ambraseys and Douglas (2004), Szeliga et al. (2010) and Min Ziqun (1995). In the same area NOAA reports a total of 12 earthquakes (Figure 3.9), out of which only six with magnitude. Even the largest event in the area, the 2 April 1762, Mw 8.8 according to Cummins (2007), has no magnitude in NOAA. All the earthquakes in NOAA are also in GHEC, but the differences in both the epicentral location (Figure 3.10) and magnitude (Figure 3.11) are remarkable. In addition, the 26 August 1833 Nyalam earthquake is duplicated in NOAA, once with the correct date and magnitude (Ms 8), and once dated 30 May with M 7.5 and a significantly different location (more than 500 km to the West).

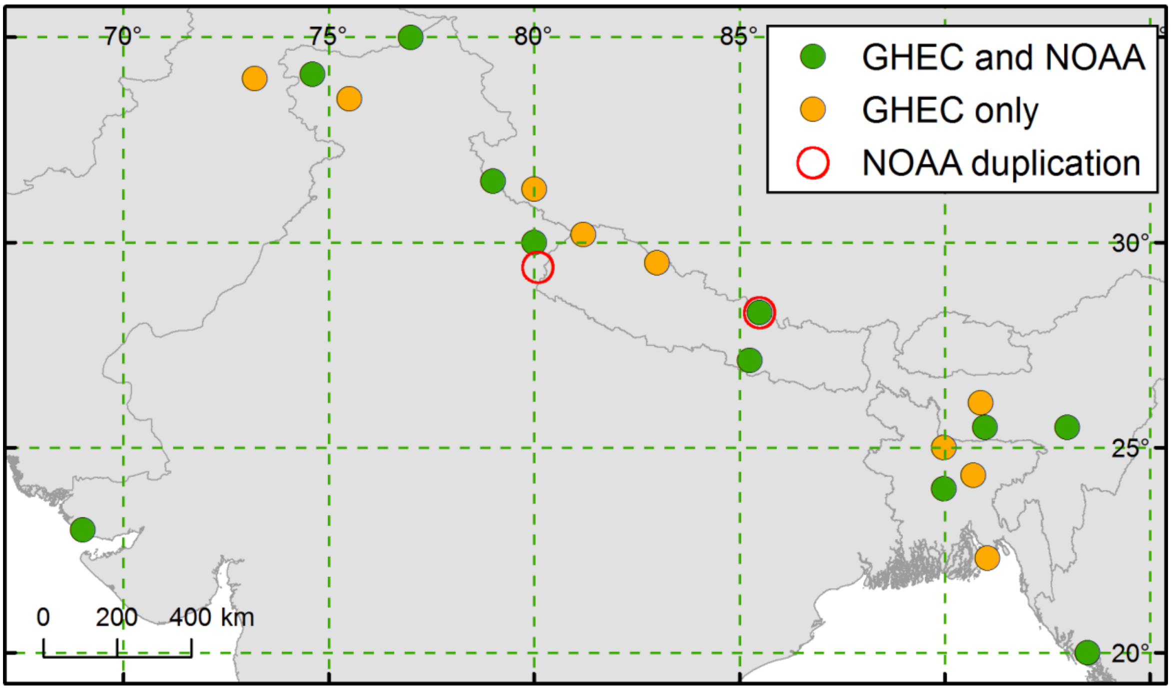


Figure 3.10 GHEC and NOAA content in the Himalayas

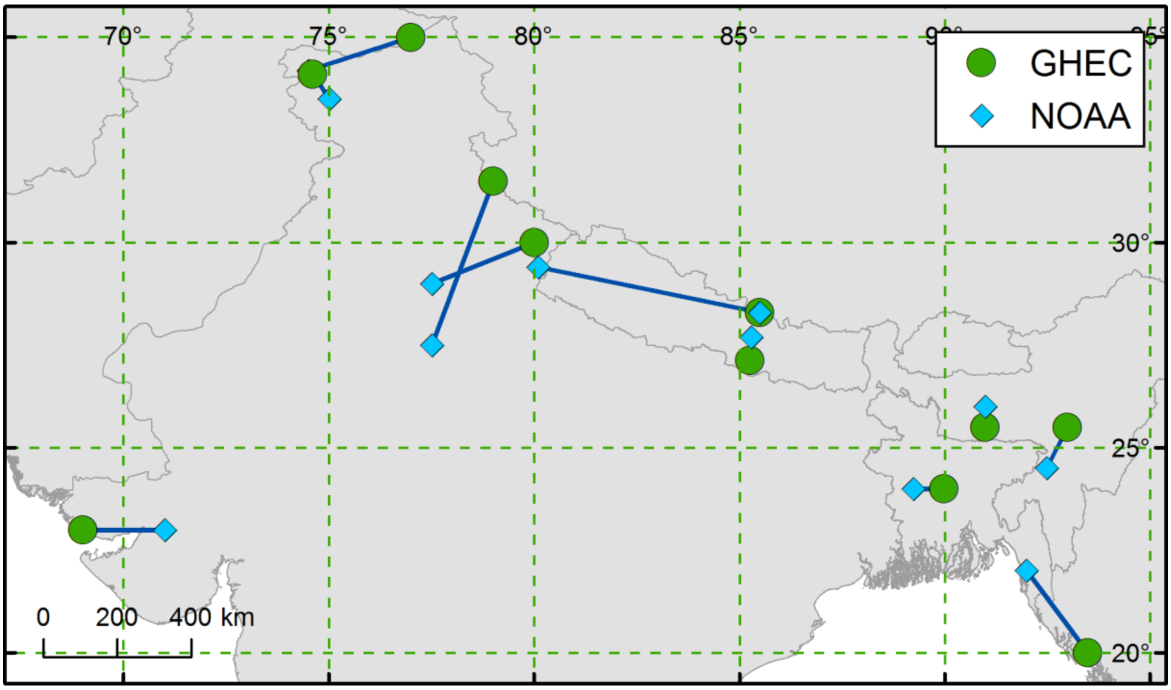


Figure 3.11 Differences in the location of Himalayan earthquakes in both GHEC and NOAA

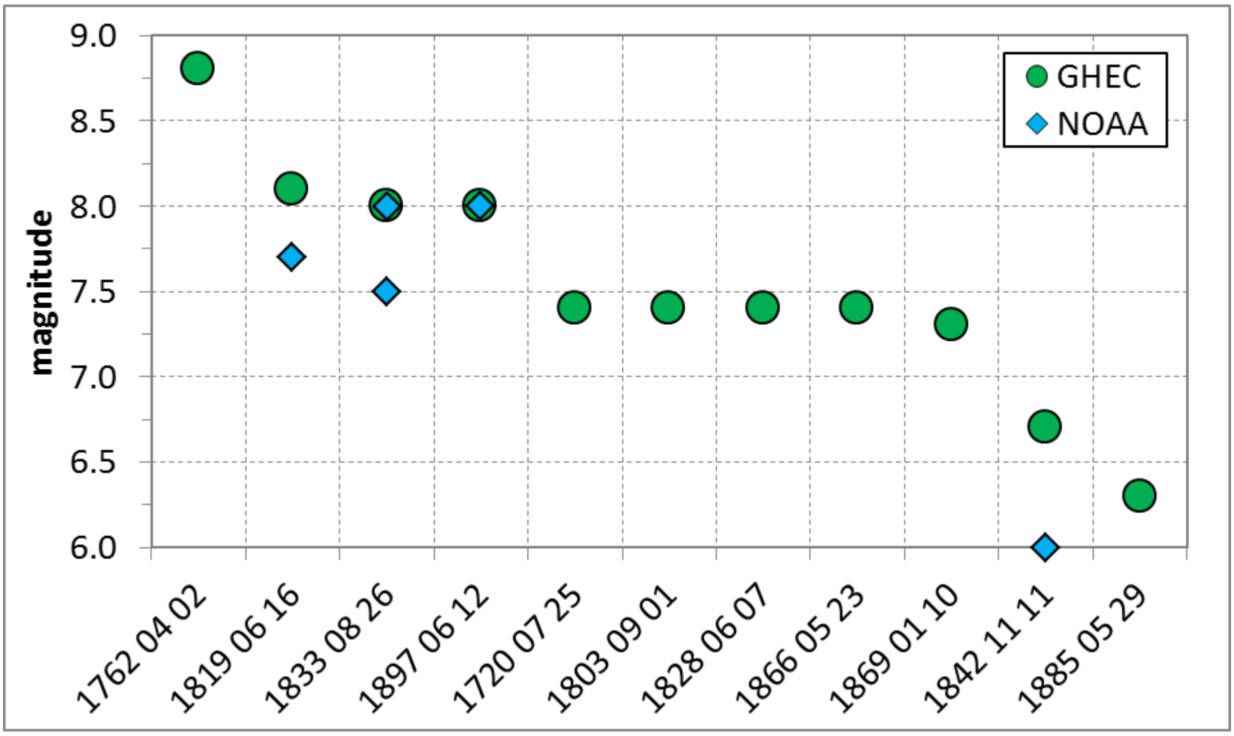


Figure 3.12 Differences in the magnitude of Himalayan earthquakes in both GHEC and NOAA

As detailed in Section 2.12, Indonesia represents one of the areas where GEH achieved the most significant improvements with respect to the previous knowledge. In Indonesia, a highly seismic area, the NOAA database lists only six earthquakes with M ≥ 7 (Figure 3.12). Conversely, GHEC contains 75 earthquakes (Figure 3.13), 70 of which were newly studied in the framework of GEH, although with preliminary parameters (Musson, 2012a).

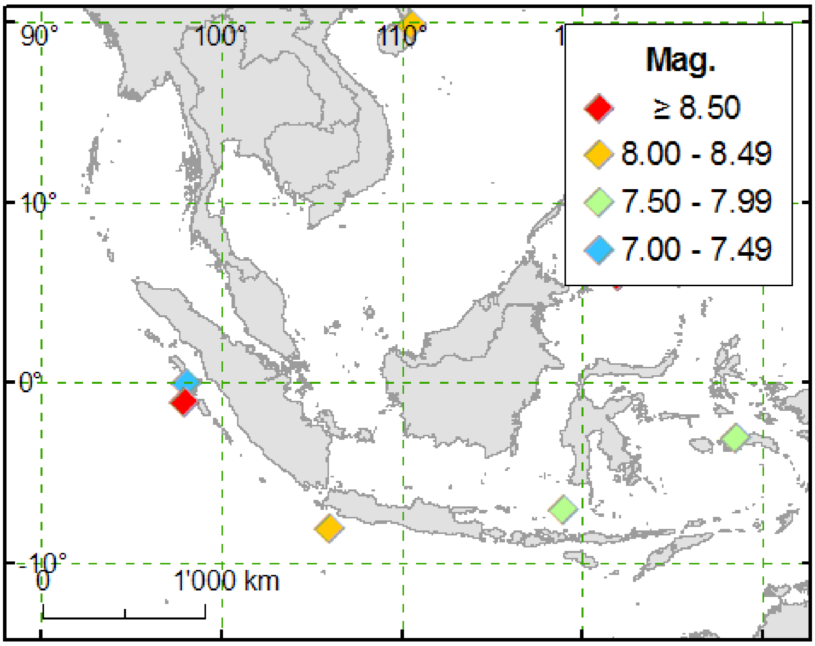


Figure 3.13 Seismicity of Indonesia according to the NOAA database

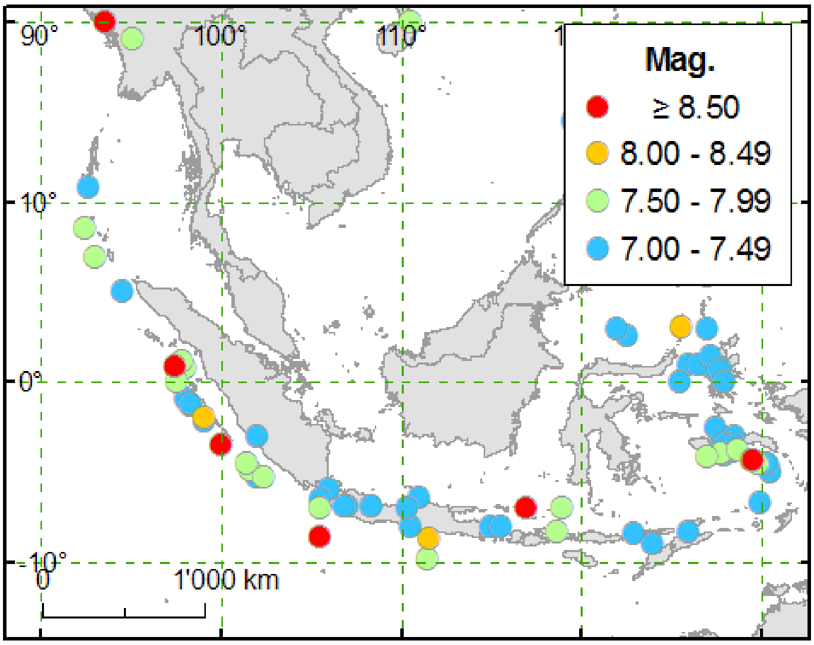


Figure 3.14 Seismicity of Indonesia according to GHEC

Table 1.9 List of GHEC data sources, the parameters used, and their geographical area

Reference	Epicentre	Mw	Ms	Mjma	M	Areas
Felzer and Cao, 2008	7	7				Canada and United States
CEUS, 2012	6	6				Canada and United States
Doser, 2006	6		5			Canada and United States
Bakun, 1999	3	3				Canada and United States
Lamontagne et al., 2008	3	2				Canada and United States
Bakun, 2000	2	2				Canada and United States
Bakun, 2006a	1	1				Canada and United States
Wyss and Koyanagi, 1992			4			Canada and United States
Stover and Coffman, 1993	8		3			Canada and United States; Mexico
Bakun, 2006b	1	2				Canada and United States; Mexico
White et al., 2004	43	42	1			Mexico; Central America and Chiapas
Zúñiga et al., 1997	18	17				Mexico; Central America and Chiapas
Tanner and Shepherd, 1997	4	8	1			Mexico; Central America and Chiapas; Antilles; South America
Torres-Vera, 2010	3		3			Mexico
Suarez and Albini, 2009		1				Mexico
CERESIS, 1995	46		14			Central America and Chiapas; South America
Benito et al., 2012	33	33				Central America and Chiapas
SisFrance, 2010	15					Central America and Chiapas; Antilles; South America
Alvarez et al., 1999	9		12			Central America and Chiapas; Antilles
Peraldo and Montero, 1999	6		5			Central America and Chiapas
Nishenko and Singh, 1987	1					Central America and Chiapas
ISC-GEM, 2012		4				Central America and Chiapas; South America
White, 1984		1				Central America and Chiapas
Flores et al., 2012	9	15				Antilles
Chuy and Alvarez, 1988	1					Antilles
Dorel, 1981			2			Antilles; South America
Tavera et al., 2001	36	5	31			South America
Beauval et al., 2010	5	5				South America

Reference	Epicentre	Mw	Ms	Mjma	M	Areas
Dimate et al., 2005	4	4				South America
Palme et al., 2005	4	4				South America
Beauval et al., 2013	2	2				South America
Choy et al., 2010	2	2				South America
INPRES, 2012	1		1			South America
Mocquet, 2007	1		1			South America
Palme et al., 2009	1	1				South America
Sismología Histórica de Venezuela, 2011	1		1			South America
Dorbath et al., 1990		2				South America
Lomnitz, 2004			30			South America
Stucchi et al., 2012	69	69				Europe
Makropoulos et al., 2012	1	1				Europe
Oncescu et al., 1999	1	1				Europe
Hamdache et al., 2010	6	6				North Africa
Pelaez et al., 2007	2	2				North Africa
Gouin, 1979	4				4	Sub-Saharan Africa
Ambraseys and Adams, 1986b	3		3			Sub-Saharan Africa
Ambraseys and Adams, 1991	2		2			Sub-Saharan Africa
Ambraseys and Adams, 1986a	1		1			Sub-Saharan Africa
Musson, 2012	1	1				Sub-Saharan Africa
Sbeinati et al., 2005	13		13			Turkey, the Middle East and Iran
Ambraseys and Melville, 1982	12		12			Turkey, the Middle East and Iran; Russia, Caucasus and Central Asia
Ambraseys, 1989	6		7			Turkey, the Middle East and Iran
Ambraseys et al., 1994	5		5			Turkey, the Middle East and Iran, North Africa, Sub-Saharan Africa
Ambraseys, 2006	4		4			Turkey, the Middle East and Iran
Ambraseys, 1997b	2		2			Turkey, the Middle East and Iran
Ambraseys, 1997a	1		1			Turkey, the Middle East and Iran; Russia, Caucasus and Central Asia
Ambraseys, 2001b	1		1			Turkey, the Middle East and Iran
Ambraseys, 2009	1		1			Turkey, the Middle East and Iran
Guidoboni and Comastri, 2005	1					Turkey, the Middle East and Iran, North Africa

Reference	Epicentre	Mw	Ms	Mjma	M	Areas
Shebalin and Leydecker, 1997	28		28			Russia, Caucasus and Central Asia; Turkey, the Middle East and Iran; South Asia and the Himalayas
Shebalin and Tatevossian, 1997	8		9			Russia, Caucasus and Central Asia; Turkey, the Middle East and Iran
Tatevossian et al., 2012	3		3			Russia, Caucasus and Central Asia
Ambraseys and Douglas, 2004	14	14				South Asia and the Himalayas
Ambraseys and Bilham, 2003	11	11				South Asia and the Himalayas
Ambraseys and Jackson, 1998	6		5			South Asia and the Himalayas
Szeliga et al., 2010	5	5				South Asia and the Himalayas
Ambraseys and Jackson, 2003	1		1			South Asia and the Himalayas
Bilham et al., 2005	1	1				South Asia and the Himalayas
Ortiz and Bilham, 2003	1	1				South Asia and the Himalayas
Min Ziqun, 1995	66		66			China
Zhang et al., 1999	4	4				China; South Asia and the Himalayas; South-East Asia and the Philippines
China SSB and Fudan University, 1990a	1		1			China
UTSU online	92			92		Japan and Korean Peninsula
Grunewald and Stein, 2006	6			6		Japan and Korean Peninsula
Usami, 1979	3			3		Japan and Korean Peninsula
Bozkurt et al., 2007	1			1		Japan and Korean Peninsula
Chiu and Kim, 2004	1		1			Japan and Korean Peninsula
Bautista and Oike, 2000	20		20			South-East Asia and the Philippines
Cummins, 2007	1	1				South-East Asia and the Philippines
Garcia et al., 1985	1		1			South-East Asia and the Philippines
Richter, 1958	1				1	South-East Asia and the Philippines

Reference	Epicentre	Mw	Ms	Mjma	M	Areas
Musson, 2012a	74	74				Indonesia
Musson, 2012c	17	17				Australia, New Zealand and the South Pacific
Musson, 2012b	3	3				Australia, New Zealand and the South Pacific
GeoNet, 2011	1	1				Australia, New Zealand and the South Pacific
Engdahl and Villaseñor, 2002	32	13	15	2		Global
Abe and Noguchi, 1983	5		5			Global
Schulte and Mooney, 2005		1				Global
Total	825	395	321	104	5	

Table 1.10 GHEC format

Code	Description	Notes
En	Event number	unique ID of the catalogue, in chronological order
Source	Main source	selected dataset for time, epicentral coordinates, depth, Io
Year	Origin time: year	from the selected dataset
Mo	Origin time: month	from the selected dataset
Da	Origin time: day	from the selected dataset
Ho	Origin time: hour	from the selected dataset
Mi	Origin time: minutes	from the selected dataset
Se	Origin time: minutes	from the selected dataset
Area	Epicentral area	from the selected dataset, or (in square brackets) the country (as of today) where the epicentre is located
Lat	Epicentral latitude	from the selected dataset
Lon	Epicentral longitude	from the selected dataset
LatUnc	Uncertainty of epicentral latitude	in km, from the selected dataset, when available
LonUnc	Uncertainty of epicentral longitude	in km, from the selected dataset, when available
EpDet	Type of epicentre determination	bx: determined according to the method by Gasperini et al. (1999; 2010)
		bw: determined according to the method by Bakun and Wenthworth (1997)
		cat: derived from another catalogue
		instr: instrumental
Dep	depth	in km
Io	epicentral intensity	from the selected dataset
Msource	source for the magnitude	the same as "Source", with 65 exceptions
M	magnitude	from Msource
MUnc	magnitude uncertainty	from Msource, when available
MType	type of magnitude	w: Mw
		s: Ms
		jma: Mjma
		<blank>: not specified by the source
MDet	Type of magnitude determination	bx: determined according to the method by Gasperini et al. (1999; 2010)
		bw: determined according to the method by Bakun and Wenthworth (1997)
		int: converted from epicentral or maximum intensity
		cat: derived from another catalogue
		instr: instrumental
MDPsource	Source of the Macroseismic Data Points	
MDPn	Number of Macroseismic Data Points	
MDPIx	Maximum intensity	
MDPsc	Macroseimic scale of the MPDs	MM: modified Mercalli
		MSK: Medvedev-Sponheuer-Karnik
		EMS: European Macroseimic Scale
		MCS: Mercalli-Cancani-Sieberg
		JMA: Japan Meteorological Agency
Remarks	Additional information from the source	

4 Completeness of GHEC

4.1 Approach

There are two basic approaches to estimating the completeness of any earthquake catalogue for the purpose of hazard assessment: statistical and historical. In this chapter, a simple regional evaluation is made statistically. The issues surrounding a historical appraisal are outside the scope of this project.

There are a number of statistical methods that have been used in the past, though all are essentially variants of the principle first formulated by Stepp (1972). This is that for long time periods, the rate of earthquakes above a threshold magnitude should be constant. For early time periods where the rate of occurrence is less than the long-term average, the catalogue is incomplete. Thus by plotting rate of occurrence as a function of time, the onset of incompleteness is indicated by a break in slope. Examples of ways to calculate this are given in Musson (1996) and Albarello et al. (2001).

The problems of applying this sort of approach to a global historical catalogue are immense. The statistical method really depends on a sufficient number of events to achieve a stable rate. This is fine for 20th century catalogues of predominantly instrumental earthquakes over a wide magnitude range, or in areas such as Europe where the historical material is so rich that there is a generally good record of events down to around magnitude 4 Mw in many places. But GHEC is mostly confined to magnitudes above 7, which means one needs to know the long term rate of occurrence above this magnitude. Since such large earthquakes are uncommon (the global rate is around ten per year) it is difficult to establish a stable rate for any region. A small number of events means that short-term fluctuations in the rate are much more difficult to smooth out. It is therefore both hard to estimate an accurate long-term rate, and difficult to say whether the rate in any historical time window is influenced by short-term variability.

Even in Europe, in the case of the SHARE project, it was found very difficult to estimate completeness for the largest magnitudes (Stucchi et al., 2012). For those parts of the world where the GHEC magnitude threshold is lower, the situation is no better, since the number of regional earthquakes is still too small to calculate any sort of stable rate estimates.

A further problem is the case of deep and intermediate focus earthquakes. These are very difficult to recognise or parameterise from historical data, and therefore it may be taken almost as a given that those areas prone to deep-focus events from subduction zones will be incomplete for the whole historical period. Any comparison between historical and modern instrumental catalogues will be meaningless, unless one accepts that deep-focus events are a separate category, not to be expected to be found in historical catalogues except in some special cases. To compare like with like, it is necessary to use only modern shallow seismicity.

4.2 Analysis

This analysis that follows is somewhat rudimentary, as will be apparent, and it is provided really for indicative purposes rather than formal use. For local applications, a more detailed examination would be required. The regional division here is not the same as that used in the structure of the present report. While one can discuss, say, the earthquakes of North America as a report chapter, from the point of view of completeness this region is very diverse, and cannot be treated as a unity. To avoid any misleading appearance of precision, the regions for which completeness is discussed will not be formally defined or mapped; it must be stressed that the following analysis is only intended to give a rough indication of the nature of the problem. Also, the regions discussed do not cover the entire globe. Some places are omitted due to a lack of magnitude 7 events (e.g. Australia, Africa), a total lack of completeness (e.g. South Pacific), or some complex cases (e.g. Eastern North America).

For purposes of numerical comparison, a test data set was prepared from the Centennial Catalogue of Engdahl and Villasenor (2002), consisting of all the events with magnitude 7 Mw or higher, and depth no greater than 40 km, in the period 1960-1999.

The catalogue was then divided into a series of time windows, each 40 years long, advancing five years at a time. The procedure was then, for a given region, to count the number of events ≥ 7 Mw in the years 1000-1039, 1005-1044, 1010-1049 and so on. This moving window is then compared to the number of events of 7 Mw or larger in the years 1960-1999. To check the stability of this yardstick, the expected number of events ≥ 7 M in 40 years was calculated for the zones using Gutenberg-Richter plots based on the entire Engdahl and Villasenor (2002) catalogue for 1960-1999 and depths no larger than 40 km. It was found that the expected number of events and actual numbers agreed very well, such that there was no obvious disadvantage in using the observed counts as a yardstick.

In the figures that follow, the plotting point is the start of a 40-year window. So (as in Figure 4.1) in the case of a single event in 1700, this will register as "1" for all 40-year windows starting between 1665 and 1700. The last point on the right-hand side of each figure is the total for the period 1860-1899.

4.2.1 Alaska and the Pacific Northwest

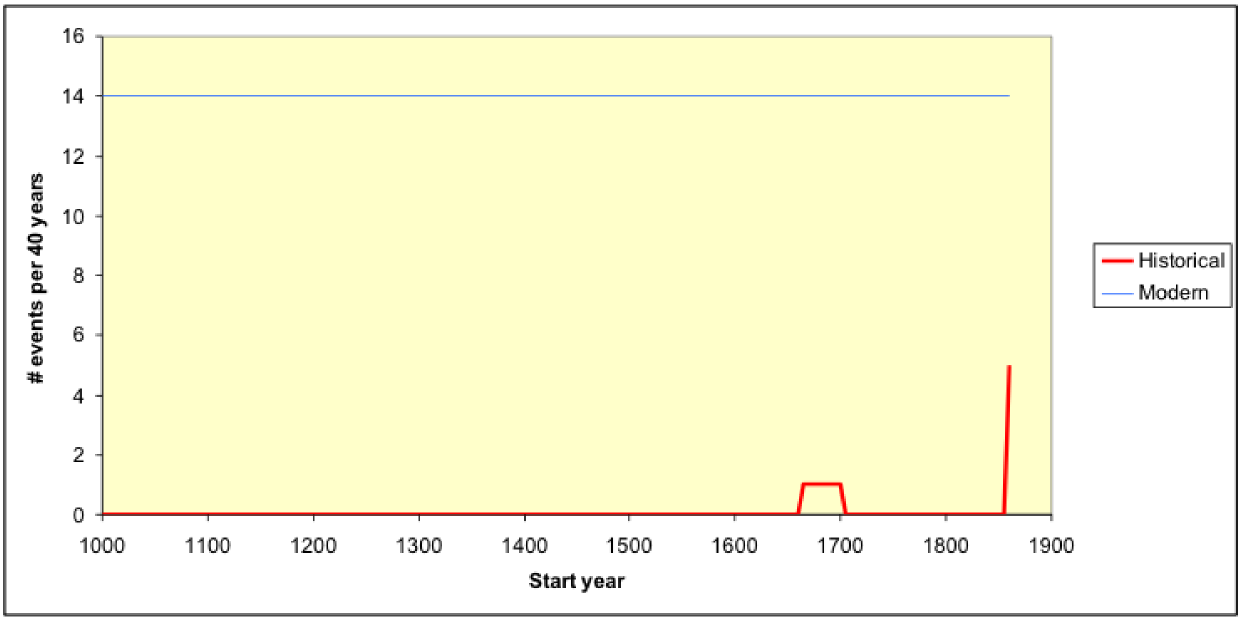


Figure 4.1 Completeness for Alaska

Given the high seismicity of this region and its very low population, one can hardly expect the historical count to come close to the instrumental one. Nor does it. A similar pattern can be seen for the Kamchatka region (not shown here).

4.2.2 California

This region is taken as all of modern California, plus north-western Mexico. It should not be forgotten that Europeans arrived in California first of all from the south, not the east, around the beginning of the 19th century, and this is reflected in Figure 4.2. By the middle of the century the count is approaching modern levels.

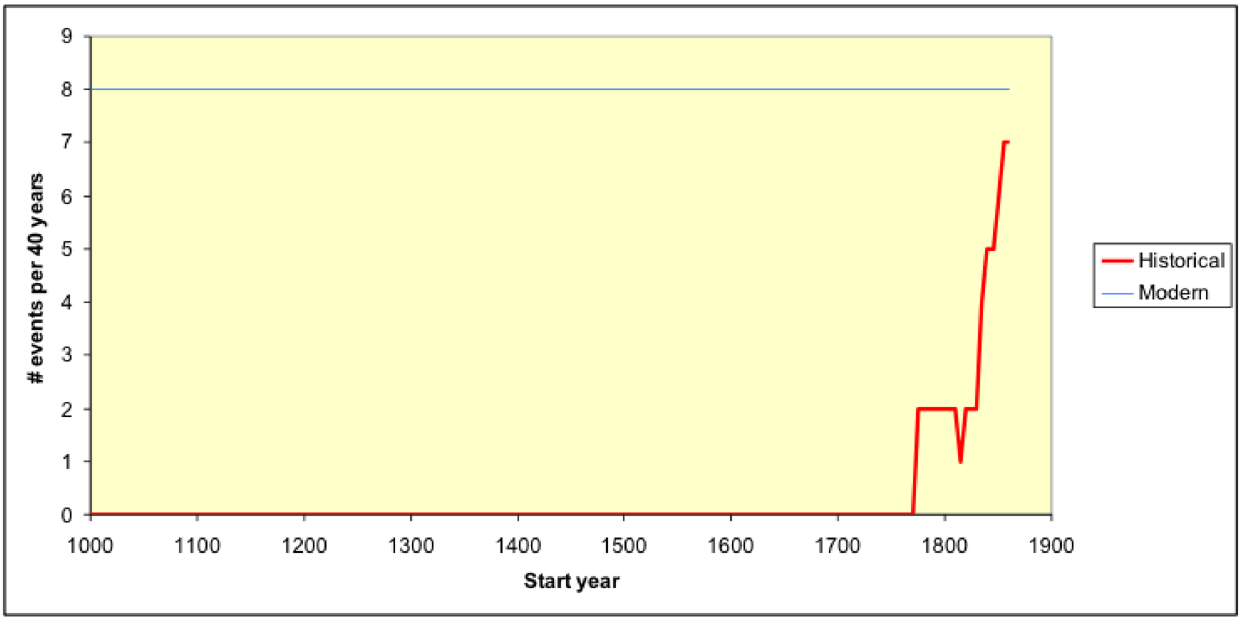


Figure 4.2 Completeness for California

4.2.3 Mexico

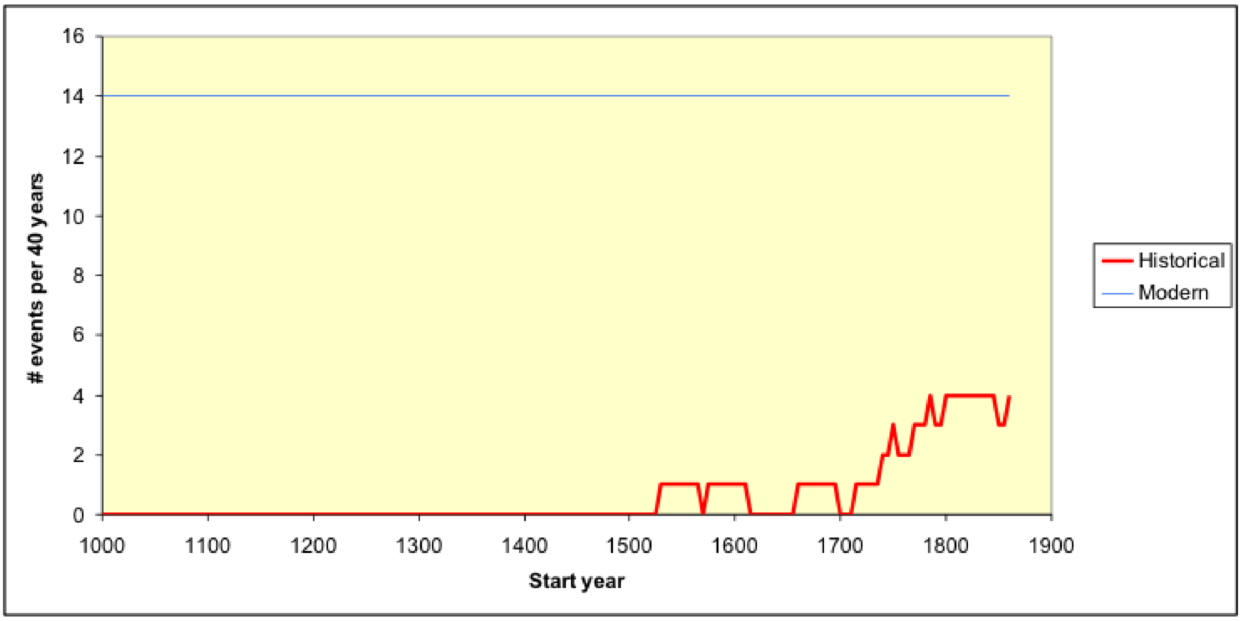


Figure 4.3 Completeness for Mexico

Mexico here refers only to the central part of the Mexican subduction zone, since the north-west of the country is taken with California, and Chiapas with Central America. The results are disappointing (Figure 4.3), and nowhere near the instrumental record.

4.2.4 Central America

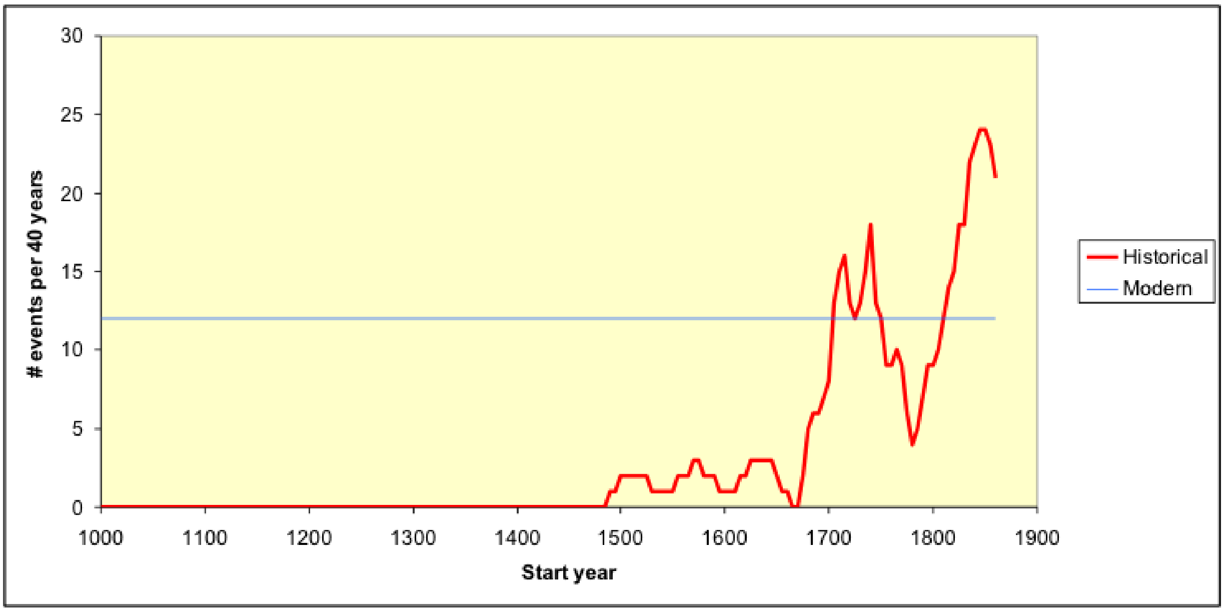


Figure 4.4 Completeness for Central America

As with Mexico, the record begins with the start of European colonisation after 1500. But the record appears rather better than that for Mexico, and looks complete from roughly the first quarter of the 18th century (Figure 4.4).

4.2.5 Caribbean

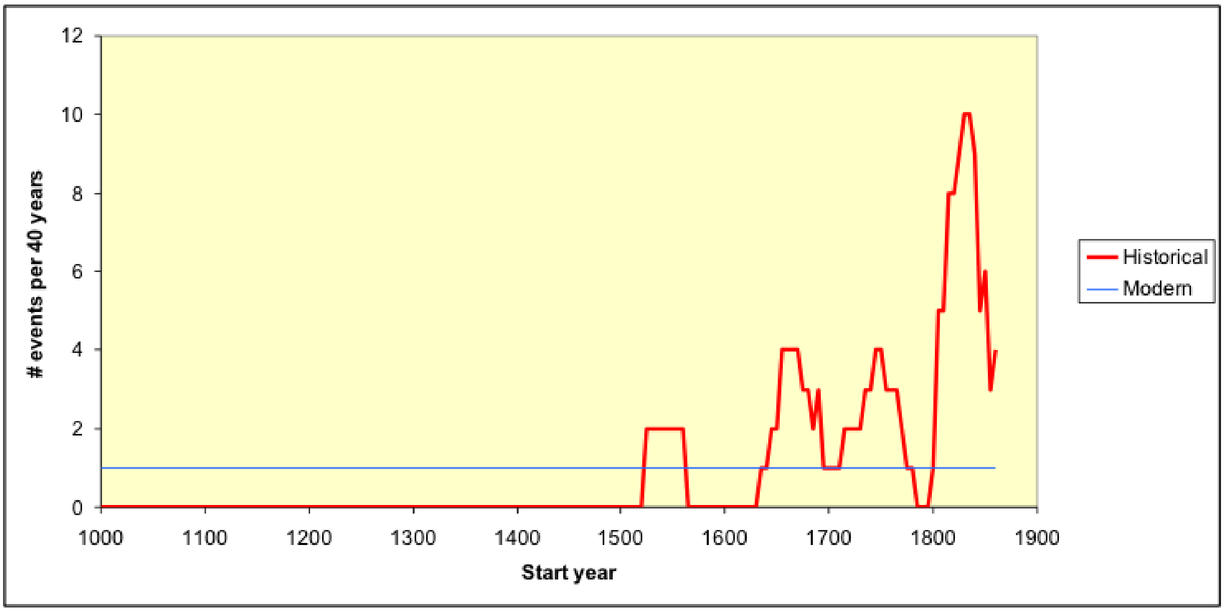


Figure 4.5 Completeness for the Caribbean

Here the issue is the lack of large earthquakes in the 1960-1999 time window, far fewer than the peak frequency reached in the 19th century. The historical total fluctuates considerably, but looks to be substantially complete from the late 17th century on, reflecting the colonial history of the region (Figure 4.5).

4.2.6 South America

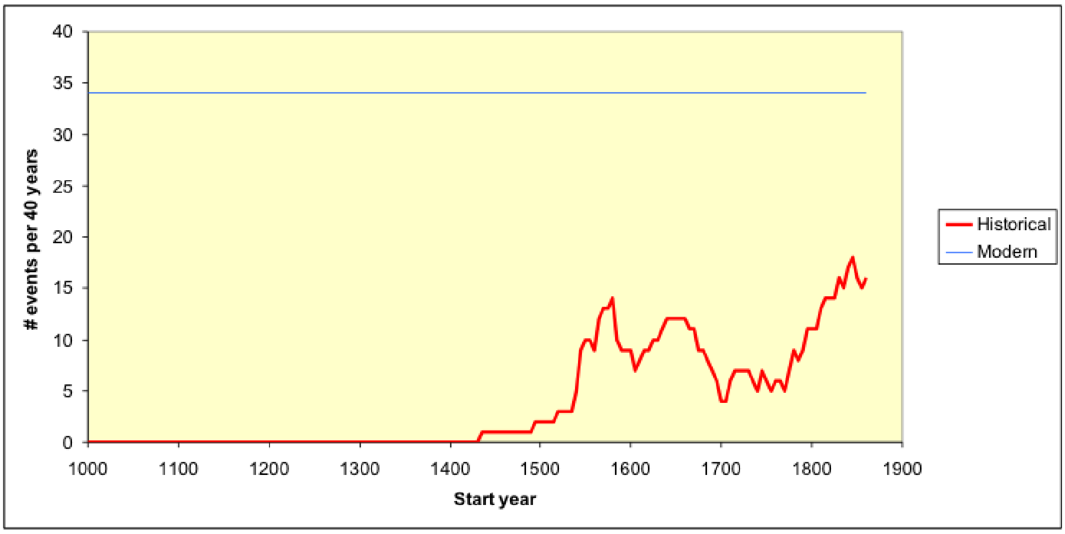


Figure 4.6 Completeness for South America

This region merges together all of South America from Venezuela to Chile (Figure 4.6). A stable number of events per 40 years is reached as early as the late 16th century, but it is nowhere near the modern rate of activity in a highly seismic part of the world. Of course, this is a large region, and a more detailed analysis is needed to reveal local variations.

4.2.7 Europe

For Figure 4.7, all of Europe has been grouped together, though in practice, this means Portugal, Italy and Greece. While historical conditions are not the same for these three countries for smaller events, it is possible that completeness may be similar for earthquakes larger than 7 Mw. Further subdivision would not be statistically practical, and there are difficulties interpreting Figure 4.7 as it is; while it is not until the 18th century that the count reaches the post 1960 level, is the difference between two events and four in the late 13th century significant or not? Probably it isn't, and there are historical reasons for supposing that for large events, the European record should be complete back into the medieval period.

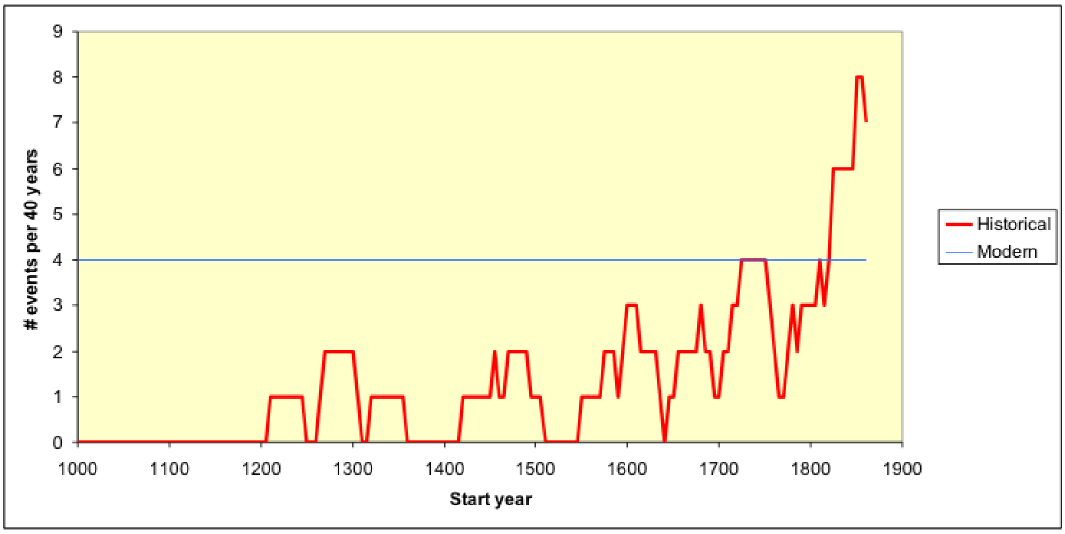


Figure 4.7 Completeness for Europe

4.2.8 Middle East

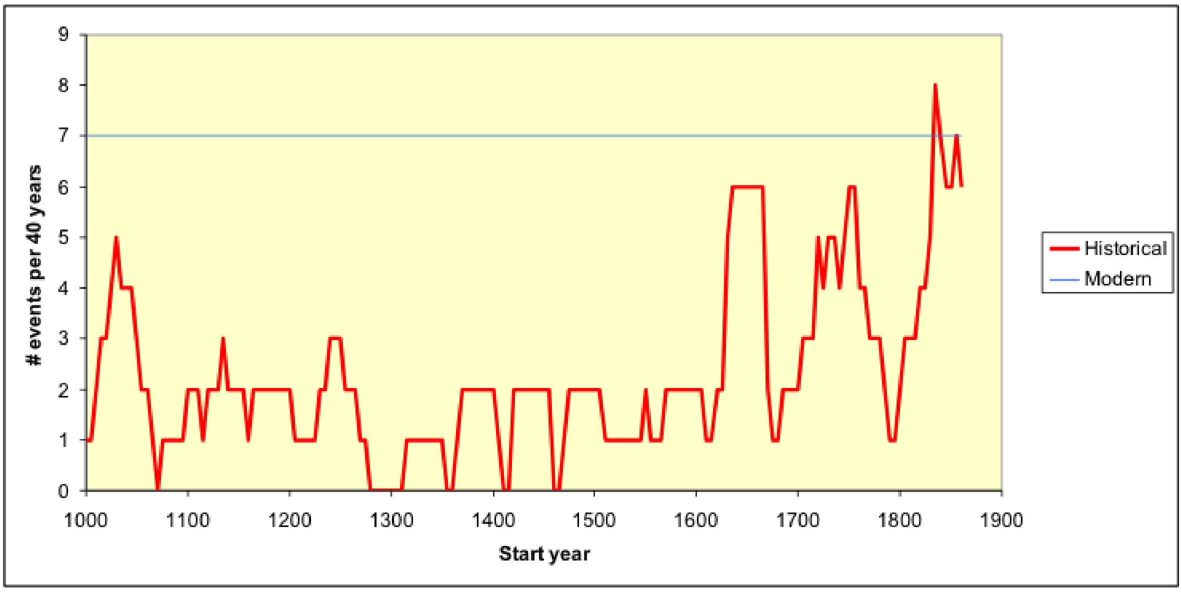


Figure 4.8 Completeness for the Middle East

This region is defined here as all of Turkey, the Caucasus and the Levant. Initially these three divisions were treated separately, but the number of events was too small. Over the whole catalogue, the variation between two events and six per 40 years is not great (Figure 4.8), and the fact that the modern count is only reached in the 19th century does not preclude the catalogue being substantially complete for the whole time period.

4.2.9 Iran

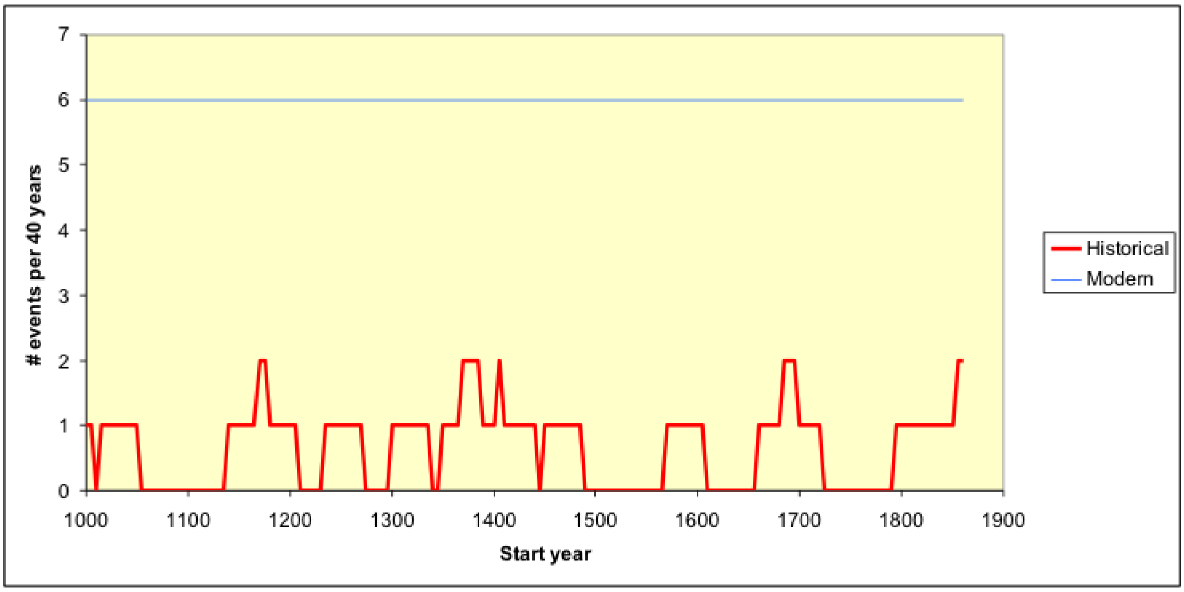


Figure 4.9 Completeness for Iran

The plot for Iran in Figure 4.9 shows surprisingly poor results, but could also be explained by a larger than usual number of events after 1960; the discrepancy is only four. The rate of events throughout the whole catalogue is consistent.

4.2.10 Central Asia

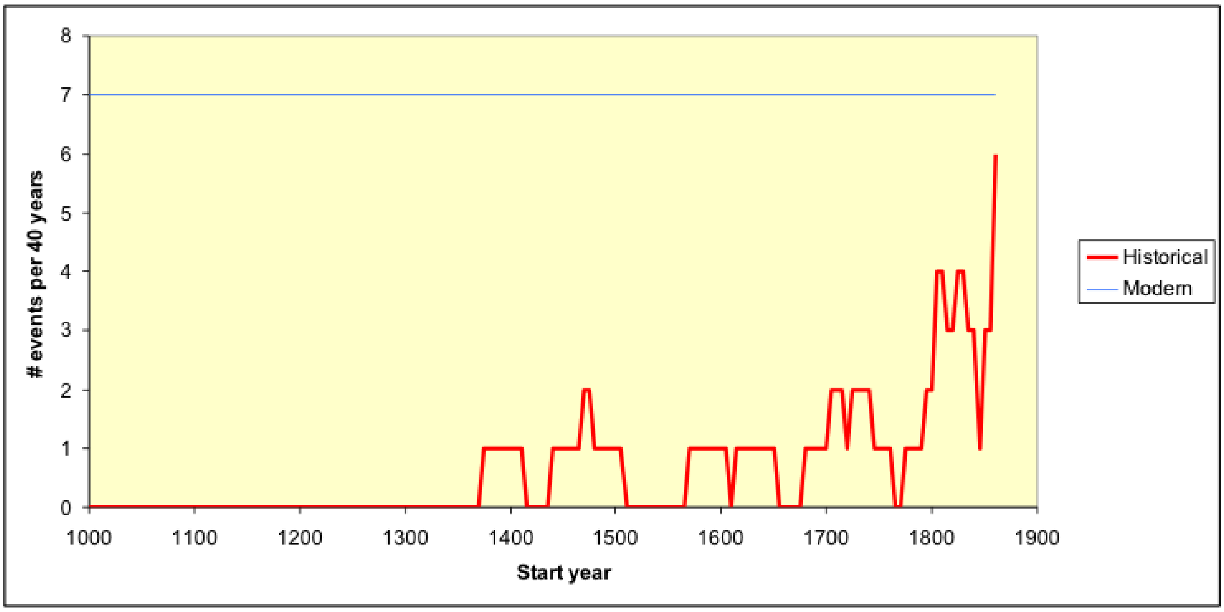


Figure 4.10 Completeness for Central Asia

This area is made up of Afghanistan, the former Soviet Republics of Central Asia, and western China. The picture shown in Figure 4.10 contrasts with that in Figure 4.9. The record only begins in the 15th century, and the number events increases markedly after 1800.

4.2.11 India

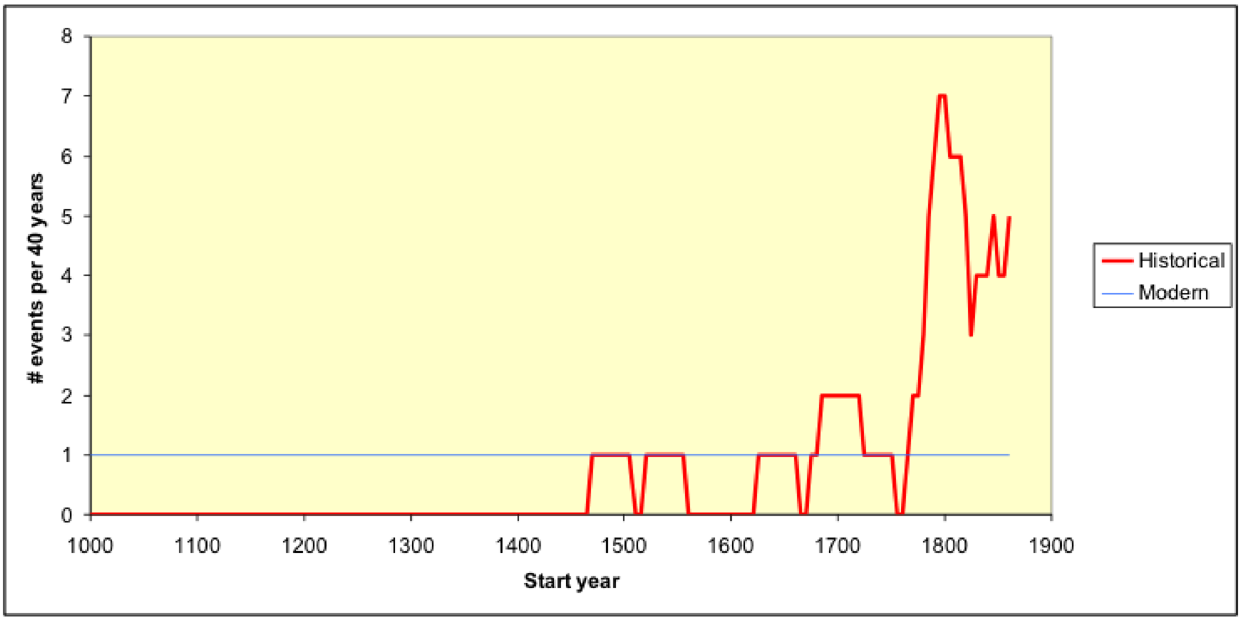


Figure 4.11 Completeness for India

For the Indian subcontinent (Figure 4.11), there happened to be only one large earthquake in the 40 years after 1960, so the historical count actually considerably exceeds the modern count after 1800. Historical circumstances suggest the catalogue should certainly be complete for the 19th century and possibly for much of the 18th.

4.2.12 China

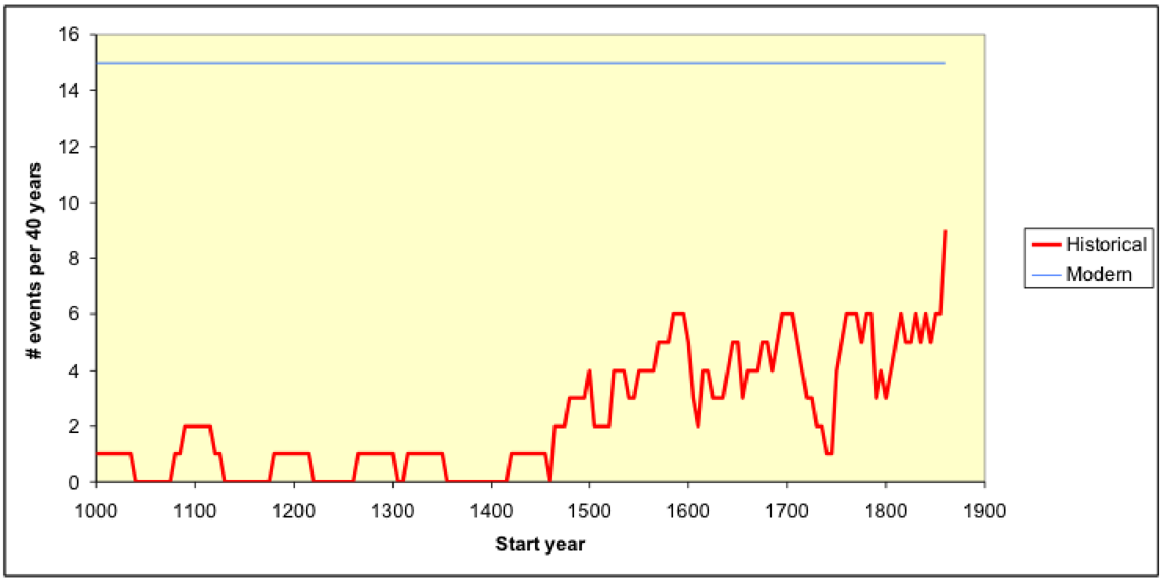


Figure 4.12 Completeness for China

Given China's fame for the length and richness of its history, it is quite surprising to see the performance shown in Figure 4.12. China as defined here comprises all of eastern China up to and including the north-south Dali fault system; also Korea. The conclusion to be drawn is that completeness varies within this region, and is undoubtedly better in the historical Chinese heartlands than in the southern provinces. The moving count is fairly stable from the late 16th century onwards, suggesting that, at least for the heartlands, the catalogue is probably complete for this period.

4.2.13 Japan

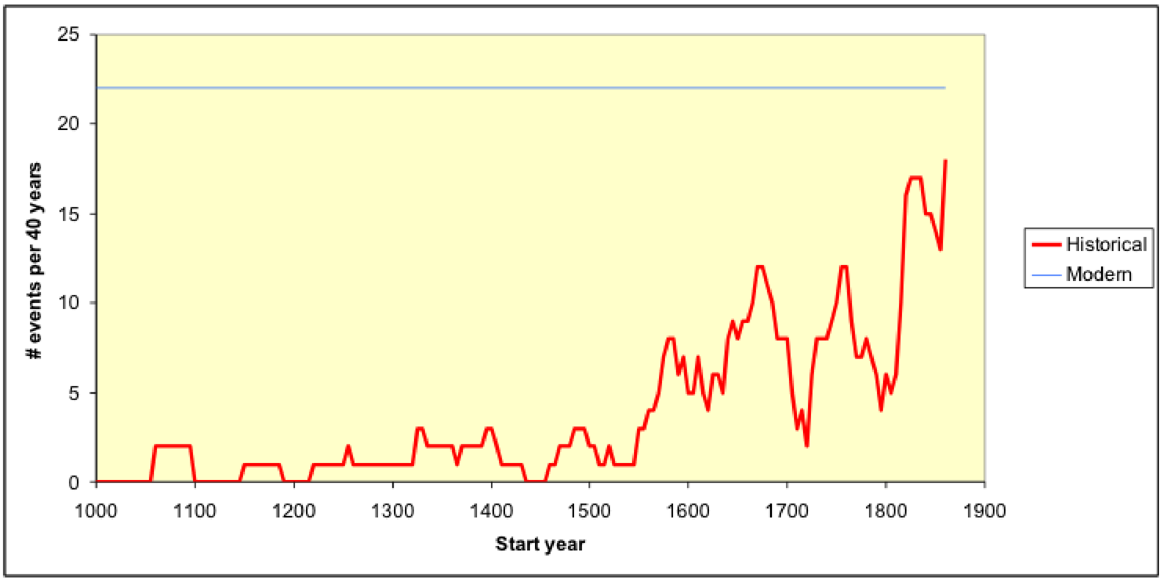


Figure 4.13 Completeness for Japan

The situation for Japan is similar to that for China; the catalogue starts very early on, in the 11th century, and improves markedly in the late 16th century, but never reaches the modern level (Figure 4.13). In the case of Japan, the situation is complicated by offshore seismicity that is unlikely to be captured by historical records as well as it is by instrumental monitoring. Once again, one is likely to see local variations on finer examination.

4.2.14 Philippines

In the Philippines, the issue of colonial history becomes relevant once more, and the record only starts at the beginning of the 17th century. The steep increase in the late 19th century indicates the catalogue is not complete before this period, and even at the end of the 19th century the count is short of the modern value, though not by much (Figure 4.14).

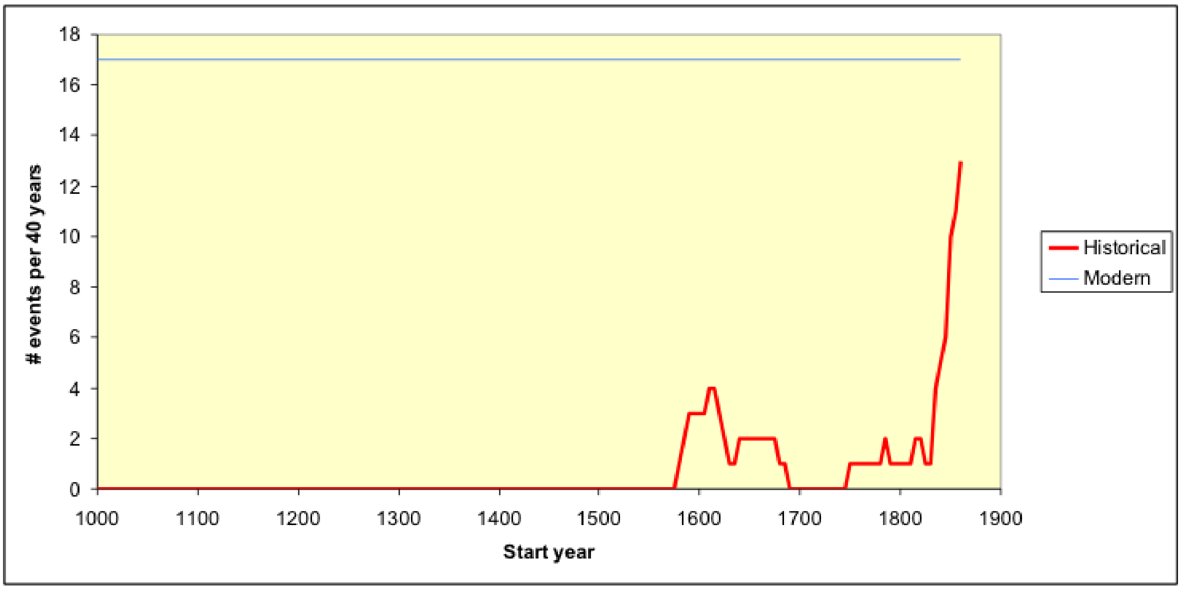


Figure 4.14 Completeness for the Philippines

4.2.15 The Sunda Arc

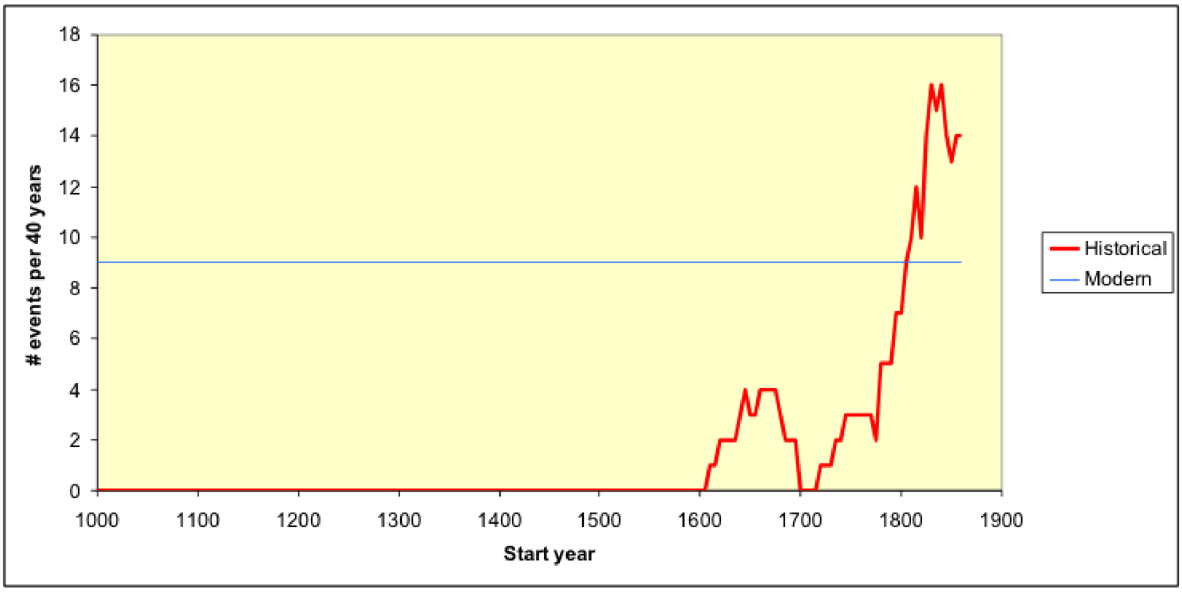


Figure 4.15 Completeness for the Sunda Arc

Following Musson (2012), Indonesia is not treated as a whole, completeness being markedly better for the Sunda Arc (Sumatra to Timor) than for the rest of the area. This is born out by Figure 4.15; the historical record is good for most of the 19th century.

4.2.16 The Moluccas

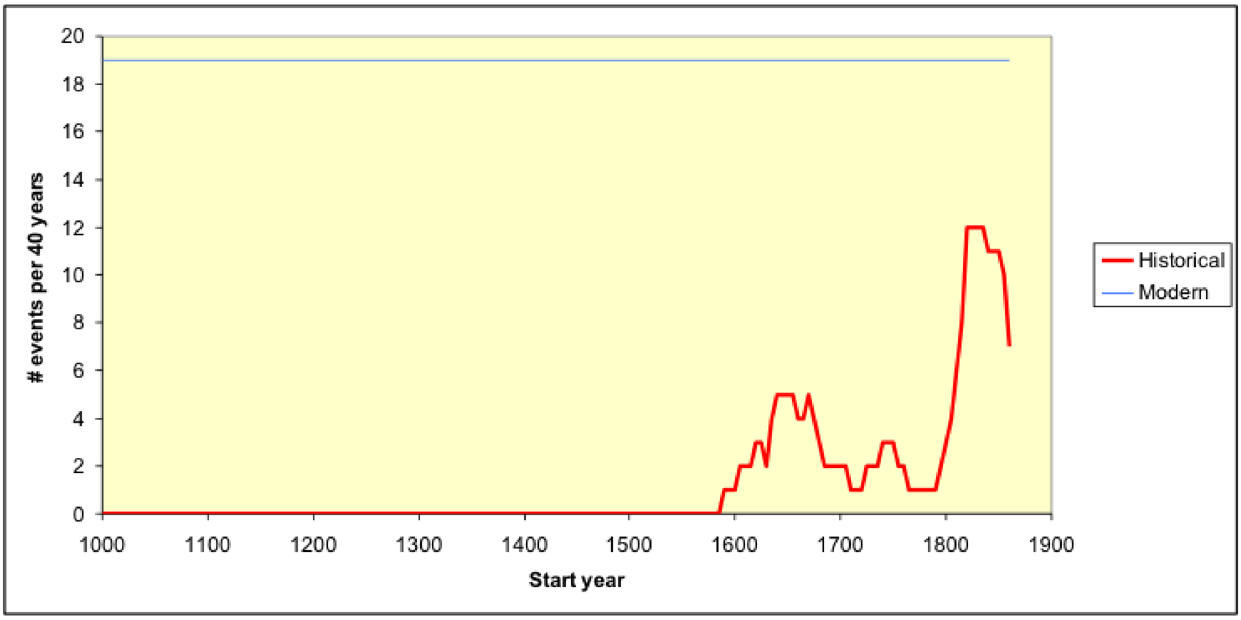


Figure 4.16 Completeness for the Moluccas

Figure 4.16 is based on the seismicity of the rest of Indonesia, north of the Sunda Arc, south of the Philippines, and west of (and not including) Irian Jaya. The pattern is similar to that in Figure 4.15, with a start after 1600, and a sharp rise after 1800 - but the count never comes close to the modern value, owing to geographical and demographical constraints.

5 IT Infrastructure

5.1 Accessing the Archive

The archive is accessed by means of a website where a two depth level approach has been implemented: 1) a general view with the list of all earthquakes and 2) a more detailed view showing all the archived items about a selected earthquake.

The layout adopted is strongly inspired by the website designed and implemented for the European archive AHEAD, so they both shares most of the interface elements.

5.1.1 General view

The general view is used as an index to access the archive content and features both an interactive map with a plot of the epicentres, and the corresponding list of earthquakes. It is subdivided into two sections: “Earthquakes” and “Fakes” (see Section 1.3).

In the “Earthquake” section (Figure 5.1) two colours are used, red and orange, to identify respectively the earthquakes included in GHEC, and the earthquakes not included in GHEC that were previously interpreted as having M > 7 by some catalogues and retained in the archive for inspection.

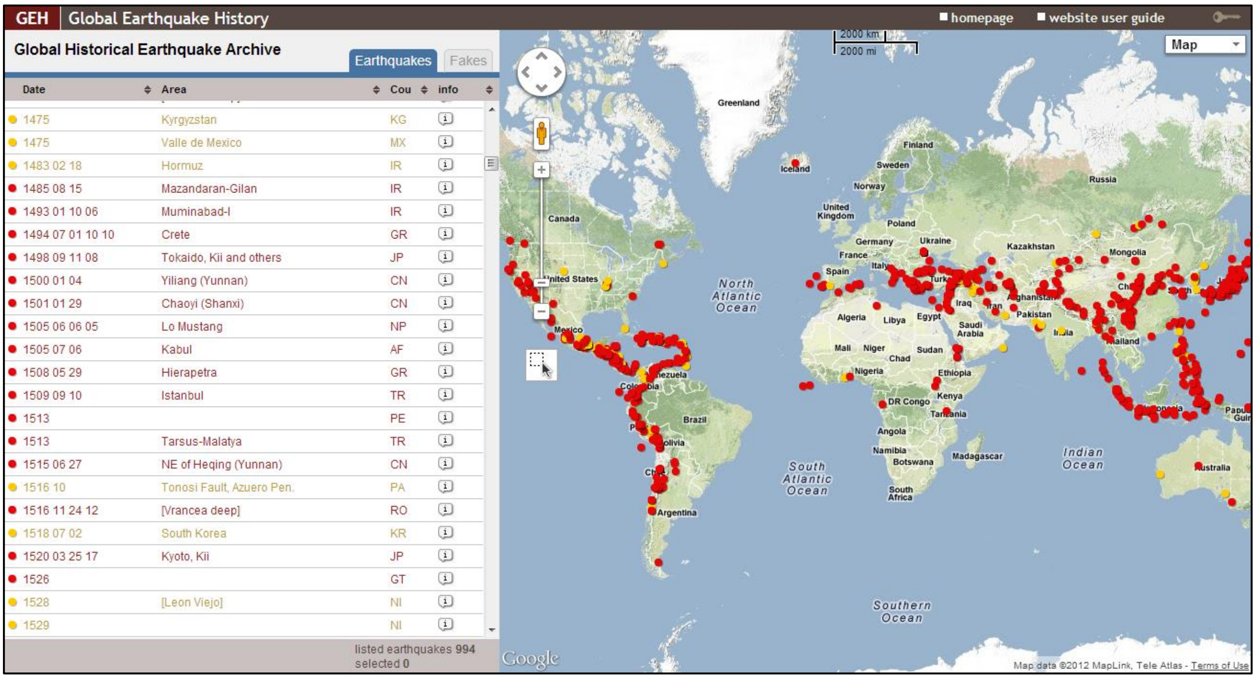


Figure 5.1 Global Historical Earthquake Archive: general view

By moving the mouse pointer over an epicentre, a label will appear with the earthquake date (Figure 5.2); by clicking on the epicentre a popup window will appear with all the archived items about the selected earthquake.

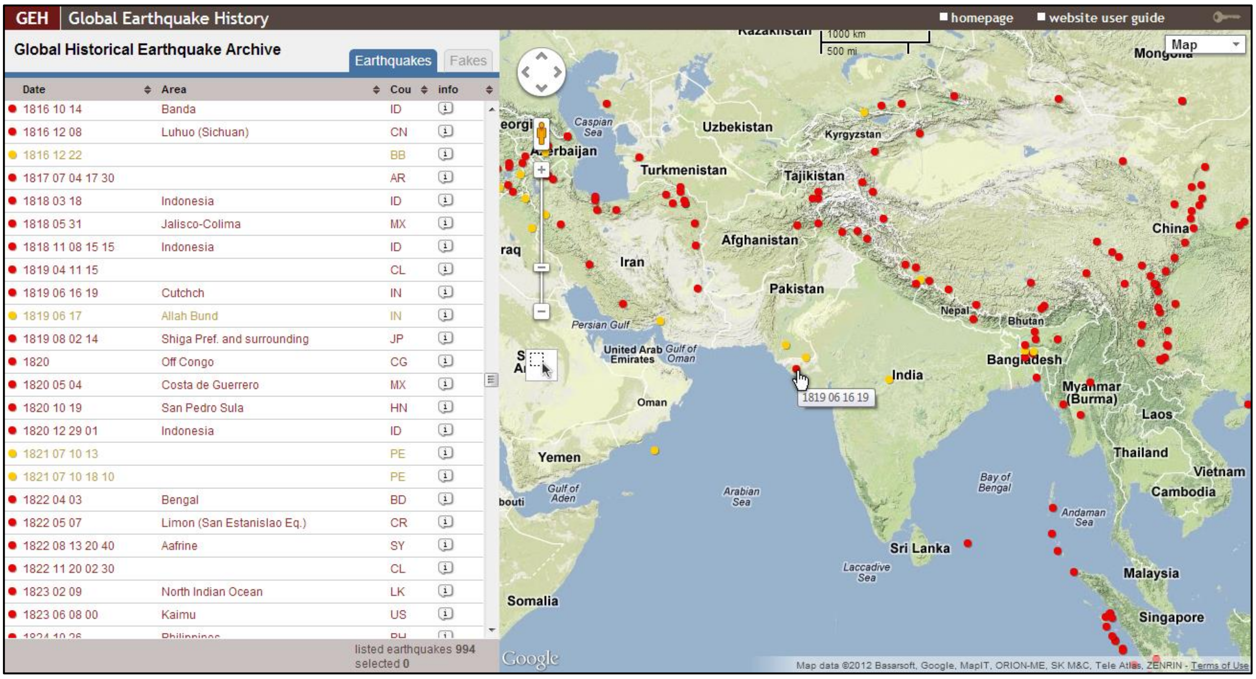


Figure 5.2 Selection of an earthquake using the overview map

The user can select more than one earthquake at once by using the “multi-selector tool” () and drawing a rectangle over the map (Figure 5.3). All the epicentres falling into the area will be automatically selected.

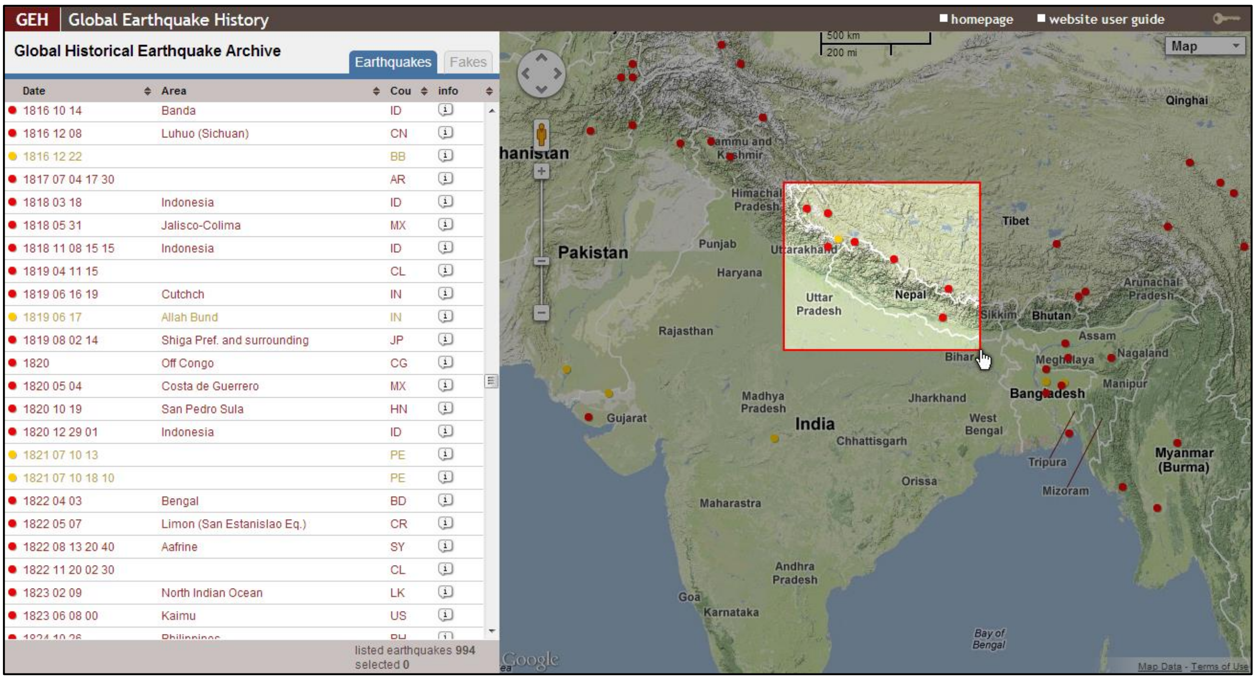


Figure 5.3 Using the multi-selector tool: all earthquakes falling into the rectangle will be selected

One can inspect an earthquake also through the list: by moving the mouse pointer over a row, the corresponding earthquake will be highlighted on the map; by clicking on a row the earthquake will be selected, the line will be highlighted in yellow and the corresponding epicentre on the map will be circled in black. To open the popup window to access the archive items about the earthquake, the user can click on the “info icon” ().

By default the table is sorted by date, but it can be sorted differently clicking on other two table headers, “Area” of maximum effects and “Cou”, the country where the earthquake epicentre falls. (This refers to modern territories; at the time of the earthquake the country may have been different).

To facilitate the analysis of a set of previously selected earthquakes, the user can isolate them in the list (Figure 5.4) by clicking the “isolator tool” () icon. The tool works as an ON/OFF switch: to go back to the complete list of earthquakes, it has to be clicked again.

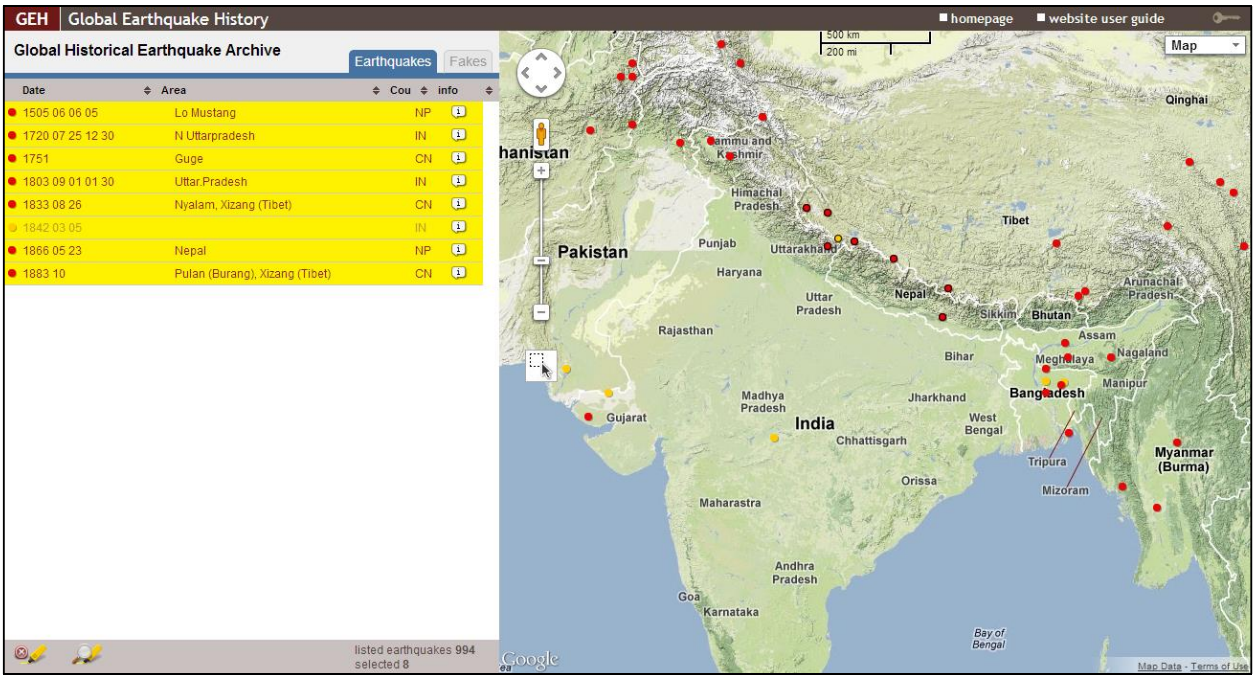


Figure 5.4 Using the isolator-tool: only selected earthquakes are shown in the table

To clear the selected earthquakes, one can click the “clear tool” ().

In the “Fakes” section fake earthquakes are represented with a blue cross on the map (see Section 1.3).

5.1.2 Detailed view

The detailed view will open the archive content for the selected earthquake. It is subdivided into two sections: a) “archive”, with the complete list of items archived and b) “catalogue”, with the parameters selected to be included in GHEC.

The webpage shows on the right the studies related to the selected earthquake, while on the left an interactive map centred on the area of maximum effects appears.

In the first tab, labelled “Archive” (Figure 5.5), all the archived studies are represented in a reverse chronological order of publication and identified by the short citation, which only contains the author and the year of publication.

The selected study for GHEC is highlighted in yellow.

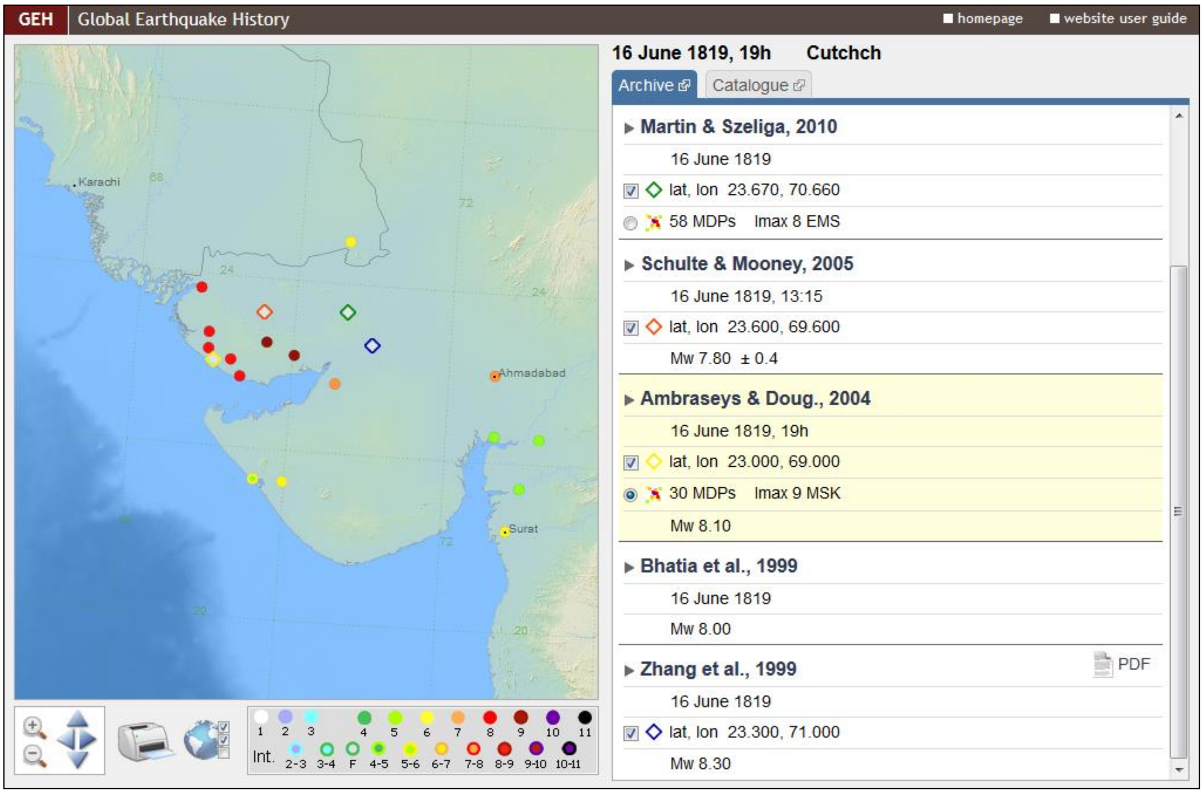


Figure 5.5 Detailed view of the Archive contents related to the 16 June 1819 earthquake, Cutchch (India)

The complete bibliographical citation of the study can be accessed clicking on the short citation; by clicking again on the short citation the full reference will be hidden.

All the relevant parameters retrieved from the study are reported: the date, the epicentral coordinates, the available MDPs (Macroseismic Data Points) and their corresponding scale, the epicentral intensity, the depth and the magnitude. Whenever available, magnitude uncertainty is reported also.

The user can interactively show on the map epicentres and MDPs from a study by clicking on the activation button () on the left of the corresponding parameter. For copyright reasons, MDPs are displayed on the map only, and no public download is available.

If the copyright covering a study allows a free reproduction over the Internet, the complete text can be downloaded as a PDF file (Figure 5.6); otherwise a link to a website containing the study is presented, if available (Figure 5.7).

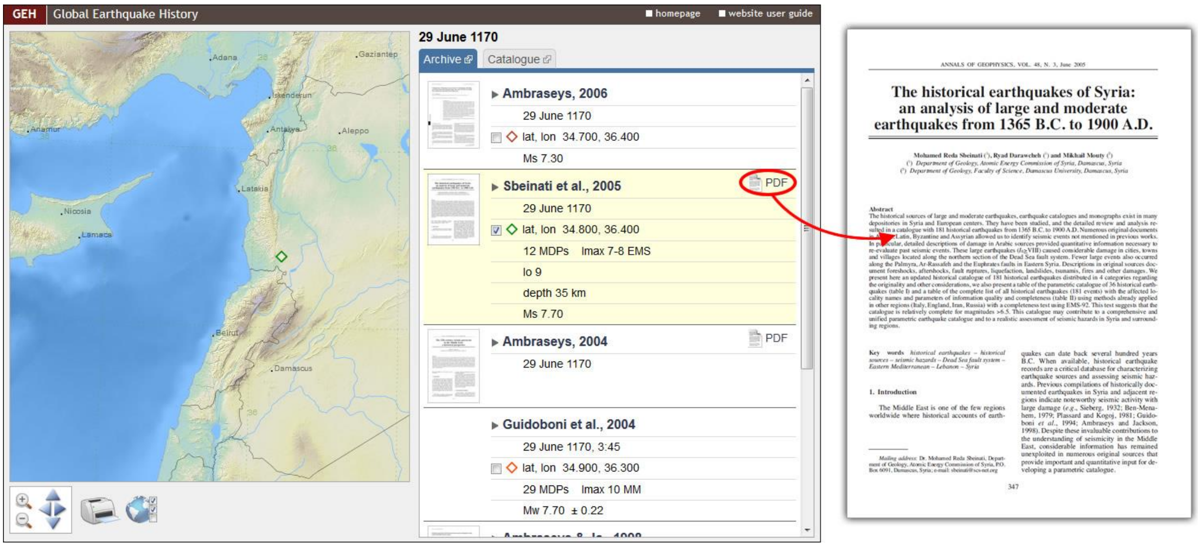


Figure 5.6 A downloadable PDF of an archived study: Sbeinati et al. (2005)

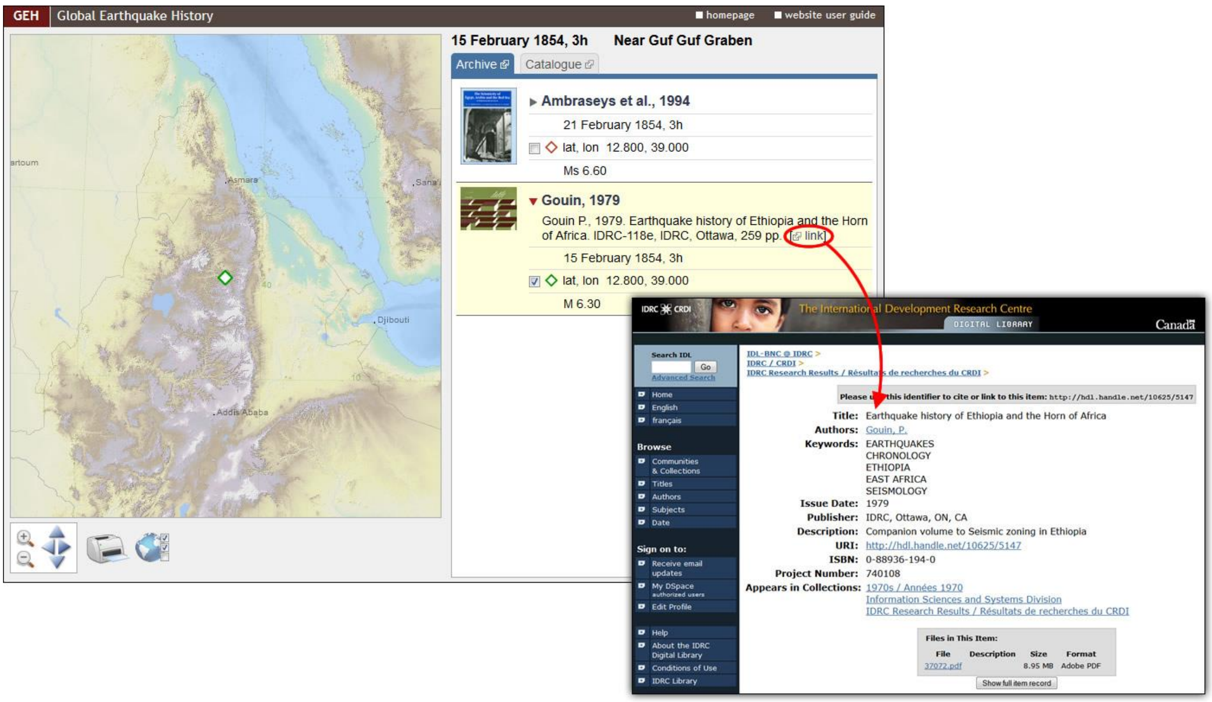


Figure 5.7 Link to an external digital library giving public access to the whole volume by Gouin (1979)

The map can be panned and zoomed and can be further customised by clicking the map customisation icon (). Users can change the rendering type of the DEM (Digital Elevation Model) (none, black and white flat shading, hill-shading, and colourful hill-shaded) and can plot temporarily a symbol on the map by entering the geographical coordinates.

The second tab is labelled “Catalogue” and reports the earthquake parameters included in GHEC (Figure 5.8).

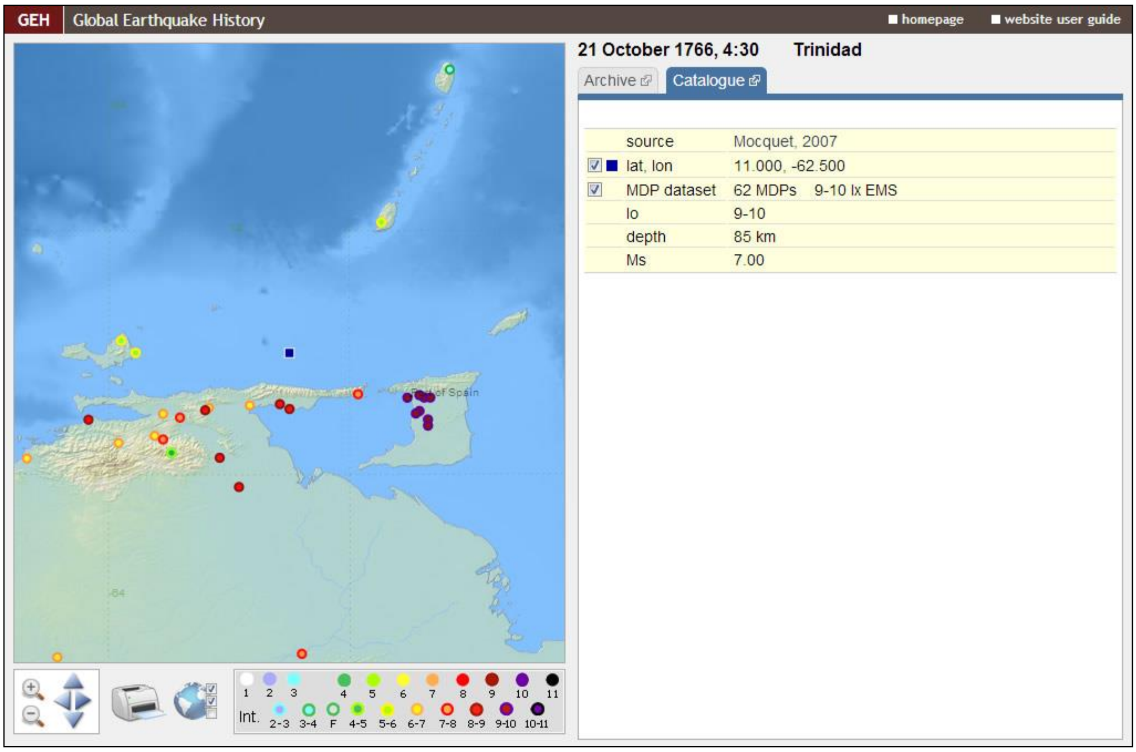


Figure 5.8 Detailed view of the Catalogue contents related to the 21 October 1766 earthquake, Trinidad

Finally, it is possible to open the tabs of the two sections ("Archive" and "Catalogue") at the same time by clicking the icon ( ) inside each label.

5.2 Technical solutions and standards

From the IT point-of-view, implementing an archive of historical earthquake data involves an approach completely different from that used with instrumental data. The key points are:

1. Historical earthquake data do not come in a digital format, but from printed texts or maps, which are not directly suitable for automatic processing. In order to build a digital archive a series of pre-processing steps are required. Documents have to be carefully analysed in order to i) get rid of misleading information, ii) extract the relevant data, iii) put them in a format compatible with a database structure;
2. Earthquake parameters with their related uncertainties such as date, epicentral coordinates and magnitude may vary considerably, particularly for the earliest events. Earthquakes can even be deleted, as they can be proved to be duplications of other events or simply not earthquakes at all (see Chapter 1);
3. Macroseismic data are generally less in volume than instrumental data. This makes a big difference in the technologies involved while storing, manipulating and searching through data, and thus can use a simpler IT infrastructure. Exchanging macroseismic data does not need the creation of complex data interfaces between data centres. When data exchange is required, it should be preferable to adopt a human readable format such as a QuakeML with an extension to support macroseismic data.

Consequently, the overall IT infrastructure design should be focused on human interaction, and the design of GUIs (Graphical User Interfaces).

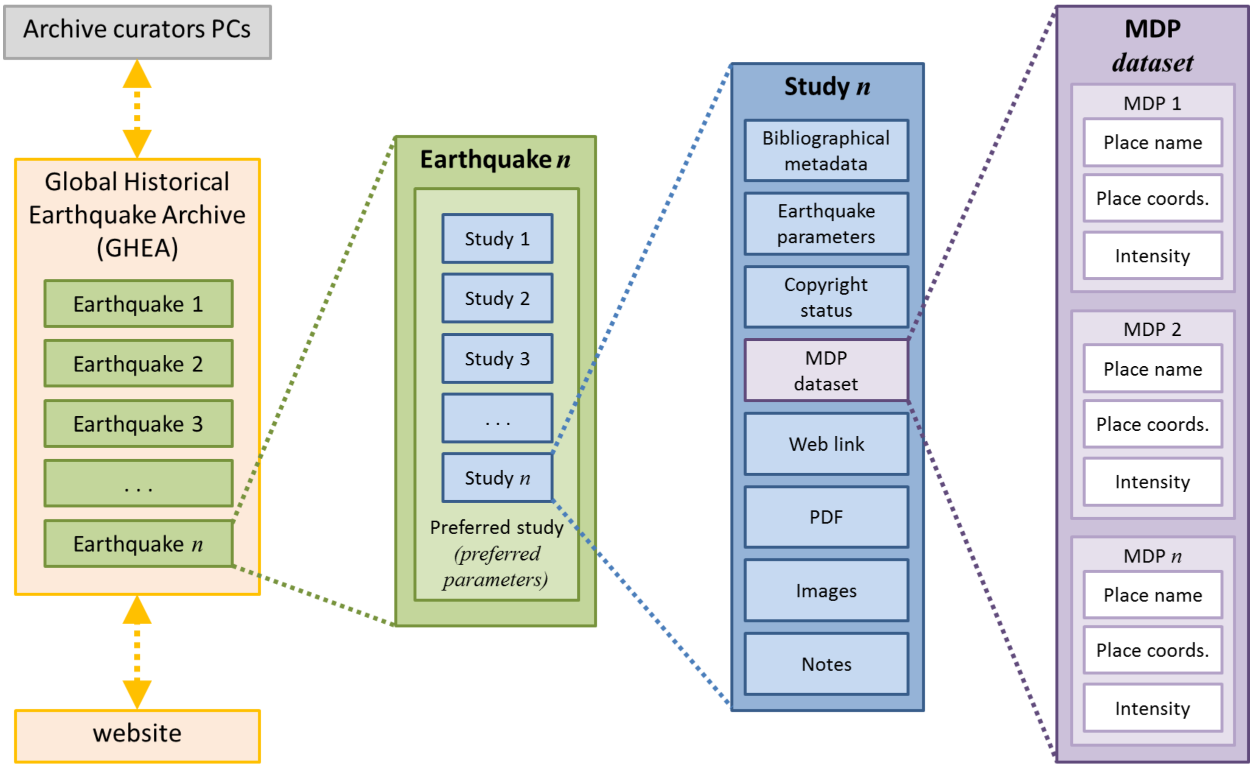


Figure 5.9 Relations among GHEA core components, website and archive curators

An extremely flexible archiving architecture has been adopted in order to enhance the Archive structure based on the multiple relations among the data (Figure 5.9) as described in Chapter 1.

This architecture was first conceived and developed in the framework of the “European Archive of Historical EArthquake Data” (AHEAD), and it is now adopted by the Global Earthquake History project because of its flexibility and modularity. The database structure, the source code running the website and some internal tools for managing metadata and MDP datasets are similar to the one currently running the core of AHEAD.

5.2.1 Managing the Global Historical Earthquake Archive content

The Archive is structured as a relational database where every stored item can be retrieved by means of unique identifiers. The database is implemented on a MySQL data server and uses these identifiers to create links between tables, avoiding data redundancy among different tables. The resulting structure is dynamic and efficient, and allows data curators to be more focused on a specific data type, leaving other data tables safe and untouched.

The Archive is designed around the activities of the data curators (data entry, data analysis and data processing), usually carried out in parallel and each with its particular needs (see Chapter 1). In order to satisfy these requirements, more than one solution can be used to interact with the database.

A direct connection to the remote MySQL server is transparently implemented using a user-friendly front-end such as Microsoft Access. The connection between server and front-end tool is established creating an ODBC (Open Database Connectivity) connection, which transparently enables ODBC-aware software (such as MS Access) to connect with a remote data server.

As data curators should not need to be skilled IT professionals, only a basic knowledge of what is a relational database is, and its fundamental rules are required (e.g. relations between tables, reference to external keys, no duplicated keys and the knowledge of the available query possibilities). A user-friendly tool, very much similar to a widely-used spreadsheet generates a more efficient and less error-prone workflow, as there is no interposed step between whoever creates the data and whoever enters such data into the database. In addition, by adopting tools that hides some of the IT technicalities, a solution more focused on the curators' tasks can be offered, resulting in a dramatic improvement of the overall usefulness of the Archive; activities such as spotting mistakes, understanding relations between different sources of information or identifying potential trends in the data, becomes a much easier task for the data curators.

Managing historical earthquake studies involves inserting and updating bibliographical metadata information and the related original document as PDFs or image files. These activities can be tricky when using a table-only approach as multiple fields in multiple tables are usually involved and files should be managed on the remote server file system. In order to simplify, and at the same time making the updating procedure error-proof, an internal tool implemented as a web application was developed in the framework of AHEAD. The tool lets curators updating the bibliographical metadata using a series of simplified and interactive forms that updates multiple tables and related files at once.

Isoseismal maps can be also stored when no other material is available. While isoseismal maps are an order of magnitude less useful than MDP sets, they are better than nothing. Digitally scanned isoseismal maps can be included as standard images.

To digitally store macroseismic intensity data, the Global Historical Earthquake Archive adopts the format and procedures proposed by AHEAD. The task of putting together heterogeneous MDP datasets may lead to a potential loss of the original information, thus requiring particular care. This is particularly true for the earliest historical earthquakes where the uncertainties related to the assessment intensities are not stored in a standard way. Stucchi and Locati (2008) present an overview of the solutions adopted to solve problems that might arise.

The standard format adopted to store MDP datasets is based on an extended version of the QuakeML standard (Schorlemmer et al., 2004), an XML dialect (eXtensible Markup Language) that was created for exchanging earthquake parameters generated by modern instruments.

The implemented IT solution does not store the MDP datasets into the earthquake study table; there is only a reference to an external resource. Once the user requests visualisation of a MDP dataset, the Global Historical Earthquake Archive website takes care of looking (locally or remotely) for the real data stored as QuakeML, and then displays the MDPs on a map using the Ajax functions from the jQuery library. This transformation is made simpler because maps are not bitmap, but SVG (Scalable Vector Graphic) elements, with SVG being another W3C XML standard format created for generating graphical elements on standard web browsers.

Finally, all activities carried out by the data curators that involves a change in the database content or structure, should be monitored by the database administrator (usually indicated as "DBA"), in order to avoid faulty tables and keep the data consistent. Technically speaking, these kinds of activities are carried out sending direct SQL commands to the MySQL server using a remote text console and setting up some automatic integrity check. The role of the database administrator should not, however, not be limited to the mere technical aspects. It should also involve an active support of the curators' activities, optimising their procedures and facilitating information flow between all data curators (e.g. alerting about a change in the structure of a table or about new features implemented for one specific task that can be useful for other tasks, too).

As mentioned above, much of the original material is stored in the Archive as PDF or image files. It should be stressed that directly including others’ work material must be carefully evaluated and severe limits must be adopted because of the copyright limitations that might apply. The need for including original material should be judged on a case-by-case basis, and should keep into mind the availability of the retrieved item: the more rare an item is, the more important it is to preserve it. One can that a fair dealing can be adopted, but a simple formula expressing the allowed percentage of an item that may be legally included does not exist, as it varies very much depending on the source, and on what is going to be included.

For these reasons the copyright status of each item is retained, stored as metadata, and used in controlling whether such material is displayed or not. The solution for displaying images is to use a watermark on each item stating the authorship and the provenance of the originals.

5.2.2 Further notes on the macroseismic intensity data format

The macroseismic extension for archiving intensity data developed by AHEAD, and adopted by the Global Historical Earthquake Archive is not yet part of the QuakeML standard; however, it has been submitted and is currently under discussion.

QuakeML being an XML dialect, it is both a human-readable and a computer-readable format, a format in which it is possible to abstract the data itself from how the data content will be presented to the user. These key factors grant an extreme flexibility in data manipulation, making the automatic generation of completely different data-driven outputs easy (e.g. tables, with maps or diagrams).

In addition to the advantages for archiving and manipulation, the adoption of such a standard avoids the common misbehaviour of stripping intensity data information from the study metadata associated to it. As already mentioned in Section 1.2, it should be stressed that MDPs are not free-standing elements detachable from their own historical studies; merging MDPs assessed by different studies written by different authors should be avoided, if possible. Keeping a tight link between all the original data will support a better calibration of the automatic procedures for calculating earthquake parameters in a repeatable way.

The proposed extension includes two groups of tags to describe:

1. the concept of MDP, with tags describing its core components, i.e. place name, place coordinates, macroseismic intensity (and related quality factors) and macroseismic scale;
2. the concept of an MDP dataset, a tag for grouping MDPs related to one and the same earthquake.

The advantages of a standardised format should, ideally, facilitate its adoption. A standard supports the establishment of a network acting as a self-coordinated archive. This solution can be implemented using both resources distributed among many subjects and a partly centralised one, according to the model that best suits each MDP contributor.

Out of the good qualities of a standard itself, what makes a standard successful are a few key aspects that must be taken into account:

- the need for such a standard;
- no alternative standards are available, as in the case of MDP datasets;
- clear documentation and examples;
- easy to use conversion tools, supporting both transmission from a foreign format into the new standard, and vice-versa, minimising the loss of information;
- tools for allowing manipulation and native use of the data in the new format, exploiting all its advantages.

In these respects, GEH took advantage of a ready-made tool for storing intensity data following the macroseismic extended QuakeML standard implemented in the framework of AHEAD. The tool is called MIDOP and stands for “Macroseismic Intensity Data Publisher” (Locati and Cassera, 2010) and it is freely available from http://www.emidius.eu/MIDOP (Figure 5.10). The tool is based on the AMP (Apache, MySQL, PHP) solution, and comes with complete documentation. As it is developed using the PHP macro language, all of its sources are available and easily customisable. The tool uses two tables, 1) the list of earthquakes and 2) the corresponding list of MDPs, and with a few clicks, generates a standalone website with interactive maps and downloadable tables; no source coding ability at all is required. MIDOP is a tool that by design tries to produce a very long-lasting output, in the sense that it only uses W3C standards and does not rely on any external resources; the generated interactive maps are server-agnostic (any standard web server can publish them) and no database management system nor server side scripting is required.

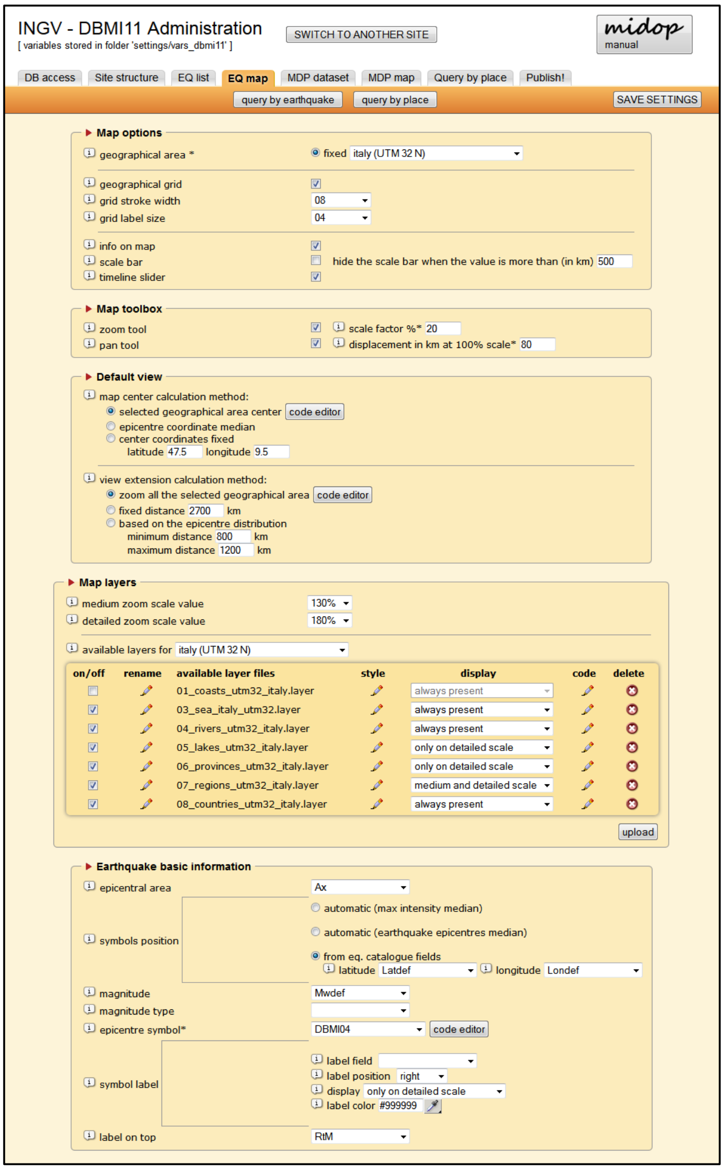


Figure 5.10 Screenshot of the MIDOP control panel settings

The MIDOP tool is currently used to generate most of the online European macroseismic databases such as the "Italian Macroseismic Intensity Database", the "Macroseismic Data of Spain", the "Base de Dades Macrosísmica" (Catalonia), the "Hellenic Macroseismic Database" and the "UK Historical Earthquake Database" (see website references).

5.2.3 The GEH website

The website is developed using server-side PHP scripts and client-side JavaScript scripts that work together creating a "Web Application". It allows the user to browse and interact with the Archive content using the two core elements, the "General view" and the "Detailed view", as described in Section 5.1.

The "General view" (Figure 5.1) is the initial page through which users can navigate all the archived earthquakes globally.

The solution adopted for visualising the world map is based on the Google Maps APIs (Application Programming Interface), a set of functions for making the web mapping tasks easier. The framework is based on maps generated remotely by Google servers; the webpage requests these remote maps and interacts with them only by sending JavaScript calls to add clickable symbols on the map. Google maps adopt a close variant of the Mercator projection, and allow the user to switch between a satellite view and a traditional view, whose visualised elements may vary depending on the current zoom level.

Once accessed, the "General view" page retrieves the earthquakes from the MySQL server, and uses JavaScript both to generate the table with the list of earthquakes and interact with the Google APIs to plot the epicentres.

The solutions adopted for implementing the "Detailed view" (Figure 5.5) rely on a custom mapping technique whose source code is in common with that used for the AHEAD website.

The "Detailed view" is generated using a server-side PHP script that queries MySQL tables and retrieves additional resources such as PDFs, images or MDP datasets. The copyright status included with the metadata is also retrieved to prevent the publication of a copyright protected PDF.

Once all this information is collected from the server, it is then transferred to the client browser using an on-the-fly generated JavaScript code that carries a limited amount of user interactivity without the need to further query the source web server. This solution results in a much more responsive user interface working directly in the browser. As a side effect, interactive functions, as the map zoom and pan, rely heavily on the client browser and the computational power of the computer.

Most of the user actions are focused on the interaction with the map for visualising the available earthquake parameters. The map itself it is not a simple bitmap file, but a pre-generated SVG (Scalable Vector Graphic) file where each visual element is part of the DOM (Document Object Model) of the HTML page. SVG elements can therefore be easily manipulated by JavaScript calls; it is possible to show or hide existing elements, and to generate new visual elements in real-time directly within the browser. MDP datasets are for instance visualised using this SVG feature: intensity points are "SVG-circle" elements created by JavaScript after parsing the downloaded QuakeML MDP dataset.

An additional advantage of adopting such a custom mapping solution is the extreme freedom to customise every aspect of the map layout. In the future, this custom mapping technique will make it possible to implement additional Digital Elevation Models, custom place names shown as a geographical reference, or adding historical administrative boundaries.

6 Future Prospects for GEH

It should be very apparent from reading this report that GEH is not a project that can ever come to an abrupt termination, with a conclusion to be placed on the shelf and left there. This is evident from the very fact that the main output is a website, not a document. Websites are by their nature mutable, and require upkeep. Further, the full title of the project is "Tools for compiling a Global Earthquake History" - the history itself is not yet fully written, and, as should be clear, much writing remains to be done.

In this chapter, the future course of the Global Earthquake History will be considered, under three main topics: maintenance, expansion in time, and expansion in scope.

Maintenance

Maintaining the GEH website is not just a matter of ensuring that it remains on an active server, and that the URL does not expire. The archive is an inventory of studies, as complete as possible up to the present day (*March 2013*). In the next years, new studies will be published, that should be added to the inventory. In many cases these will provide new and improved roots, which will replace the existing preferred studies in GHEC. There is need, therefore, for a continuing process of periodic updating of GHEC to reflect changes in the state of knowledge, and this needs to be performed in a transparent and controlled manner.

This is what could be considered "passive" maintenance, since in most cases (it is hoped) users will supply their studies to GHEA for inclusion, and it will form a focal point for an informal community of earthquake historians, as was discussed (without tangible result) at the workshop on historical earthquakes in Erice in 2004.

There is also, however, an "active" maintenance needed, which is envisaged as actively seeking contributors in parts of the world where they are lacking, to an extent that was not possible within the duration of the project so far. As was said previously, it is not possible for a project like GEH to dictate the speed of work of other initiatives being performed outside the project. Instead, it is necessary to maintain contact and offer encouragement and assistance as needed. Also, in cases where it was not possible in the two years of GEH to establish contacts in some countries, the identification of suitable partners is not necessarily ruled out for the future. One can particularly point to Southeast Asia as a region where there is a possibility to improve the situation compared to what was achievable in the past two years.

Expansion in time

The temporal scope of GEH, as agreed at the outset of the project, was 1000-1903. The termination date was chosen to coincide with the start year of the GEM instrumental seismicity module. The question naturally arises as to whether it is worthwhile undertaking further work to expand the scope of the archive either further back in time, or further forward.

As to the first option, the answer is almost certainly in the affirmative. Obviously, for many parts of the world, the historical record begins with the date of first European contact, which will be after 1500, or in some cases as late as 1800. The only possibility of finding first millennium earthquakes is in countries with their own indigenous written histories, which means Europe through to Iran, China and Japan.

While it is not likely to be possible to achieve any sort of completeness for this earlier period, what matters is that some key events occur in this period that are very important for understanding worst-case scenarios. Two obvious instances come to mind – the 869 earthquake and tsunami off the northeast coast of Japan was a clear indication, to those able to see it, that magnitude 9 earthquakes were possible in this region, in advance of the 2011 Tohoku earthquake. The second obvious case is the 365 Crete earthquake, which dominates any discussion of tsunami hazard in the eastern Mediterranean.

There are two problem issues to be considered here. The first is that, as one goes back further and further in time, the more one has to deal with legendary earthquakes that have no real historical basis – this is particularly the case in China. On the other hand, discriminating these and marking them as unreliable (if not fakes) is a historian's task, and worth undertaking.

The second problem is more intractable, which is what to do about earthquakes known only from palaeoseismic or archaeoseismic evidence. These become increasingly significant as one goes back in time, and even within the scope of GEH there are cases of earthquakes that have both historical and palaeoseismic evidence, the great 1700 Cascadia earthquake being a prominent case in point. In New Zealand (see chapter 2.13.2) one has the strange case of an earthquake in the 15th century known from both historical (albeit oral) and palaeoseismic data, but later events known only from palaeoseismic evidence. Leaving out events with no historical data, one misses the earthquake of c. 1220 in New Zealand, which is both within the timeframe of GEH, and important for understanding the hazard in New Zealand.

However, palaeoseismic data are not historical data, and their evaluation requires different skills. Opening up GEH to palaeoseismic and archaeoseismic earthquakes is a step that would require careful consideration.

Expansion forward in time, to overlap with the instrumental catalogue module, is a different proposition. It is true that there are many 20th century cases, especially for moderate-sized earthquakes, where macroseismic locations are likely to be more accurate than instrumental ones. But these cases vary from region to region, and it is not possible to pursue a systematic global approach. Even in the present project, especially for the 1900-1903 period, but actually starting in 1899, problems arise because of earthquakes where the main information, or even the only information, is from instrumental data, which need a different type of evaluation.

One problem case was the earthquake of 17 August 1899. This event appeared in the original preliminary working file for GEH, with an epicentre near Oman. The epicentre and magnitude alike were previous calculations from bulletin entries in the Shide Circulars for 1899; there are no historical supporting data for such an earthquake occurring in Oman (and there is evidence that it did not occur there); nor are there any known reports of a large earthquake occurring anywhere on that date. To resolve this, GEH approached Dmitry Storchak of ISC, who examined the data and concluded that the parameters were completely untrustworthy, but no better location could be obtained. This earthquake was duly deleted from GHEC.

After 1900, instrumental data dominate the record for large earthquakes around the Pacific, especially for the South Pacific, Kamchatka and Alaska regions. A systematic global approach based on historical data is a pointless endeavour. Where 20th century historical data is most useful is in examining moderate seismicity in less active regions, such as Northern Europe or Africa. This work needs to be addressed, therefore, by regional projects. The tools established in GEH can be useful in such work, but GHEC cannot be extended as a global catalogue beyond 1903, and really, it should be cut at 1899.

Expansion in scope

The original scope for GHEC was magnitude 7 Mw and greater worldwide, with extension down to 6.5 for intraplate areas. In practice, this limit was treated flexibly, with lower magnitudes used in some regions, down to a minimum of 6 Mw for Australia. As already mentioned elsewhere in this report, in a number of cases borderline events were examined, and ultimately assessed as below the magnitude threshold, and excluded from GHEC, while retained in the archive.

There exists the possibility for future work to extend GHEC to a lower magnitude limit overall. This is perfectly feasible, but some things need to be taken into consideration. Firstly, one should consider the impact of the frequency magnitude distribution. For every 1,000 earthquakes > 7 Mw, there are potentially 10,000 events > 6 Mw. In practice, there are not so many, as many smaller earthquakes go undocumented where the larger ones are still recorded. But undoubtedly, for some regions the labour required to inventory all known earthquakes even down to 6 Mw would be considerable.

Secondly, the usefulness of such an extension would vary regionally. As already shown, the completeness of GHEC for magnitude 7 events is surprisingly low, in most cases because of local variations. In China, for instance, one cannot expect the same historical completeness for Yunnan province as for Hebei, yet the former is more seismically active. So extending the catalogue to magnitude 6 might yield useful results for Hebei province, but not for Yunnan. This suggests that work on lower magnitude events is more useful in a regional context. As with 20th century earthquakes, the tools for earthquake history are applicable, but expanding GHEC downwards in magnitude is probably not appropriate as a global initiative.

So in conclusion, extending the scope of the GEH project forward into the 20th century or downwards to lower magnitudes is something best suited to regional projects, and not appropriate at a global level. On the other hand, extending the scope of GHEC back in time is rather more useful, but a policy has to be decided on regarding prehistoric data and whether they are to be assessed, and if so, how and by whom. Improvements in GHEA and GHEC within the existing timeframe and scope should be actively sought, by monitoring and encouraging historical earthquake research initiatives in different parts of the world.

REFERENCES

Abe K. and Noguchi S., 1983. Revision of magnitudes of large shallow earthquakes, 1897-1912. Physics of the Earth and Planetary Interiors, 33, 1, 1-11.

Abe K. and Noguchi S., 1983a. Determination of magnitude for large shallow earthquakes 1898-1917. Physics of the Earth and Planetary Interiors, 32, 1, 45-49.

Abe K., 1979. Size of Great Earthquakes of 1837-1974 Inferred From Tsunami Data. Journal Of Geophysical Research, 84, B4, 1561-1568, doi:10.1029/JB084iB04p01561

Abich H., 1856. Sur les derniers tremblement de terre dans la Perse septentrionale et dans le Caucase, ainsi que sur des eaux et des gaz s'y trouvant en rapport avec ces phénomènes. Bulletin de la classe physico-mathématique de l'Acdeémie Impériale des Sciences de Saint-Pétersbourg, St.-Petersbourg & Leipzig, nn. 516-517, tome XIV, 4-5, 50-71.

Abich H., 1882. Geologie des armenischen Hochlandes: Westhälfte, vol. 1. In: Geologische Forschungen in den kaukasischen Ländern, Part 2, in commission bei A. Hölder, K. K. Hof- und Universitäts-Buchhändler, Wien, 478 pp.

Agnew D.C. and Sieh K.E., 1978. A Documentary Study of the Felt Effects of the Great California Earthquake of 1857. Bulletin of the Seismological Society of America, 68, 6, 1717-1729.

AHEAD Working Group, 2013. AHEAD, the European, distributed Archive of Historical Earthquake Data, doi:10.6092/INGV.IT-AHEAD

Albarello D., Camassi R., Rebez A., 2001. Detection of Space and Time Heterogeneity in the Completeness of a Seismic Catalog by a Statistical Approach: An Application to the Italian Area. Bulletin of the Seismological Society of America, 91, 6, 1694-1703.

Albini P. and Locati M. (eds), 2008. Electronic archive of historical earthquake studies (demo version). NERIES Project, Networking Activity 4, Deliverable D2, 34 pp.

Albini P. and Moroni A. (eds), 1994. Materials of the CEC project "Review of Historical Seismicity in Europe", vol. 2, CNR, Milano, 254 pp.

Albini P. and Stucchi M., 1997. A Basic European Earthquake Catalogue and a Database for the evaluation of long-term seismicity and seismic hazard (BEECD). In: Ghazi A., Yeroyanni M. (eds), Seismic risk in the European Union, vol. I, Brussels-Luxembourg, 53-77.

Albini P., 2011. The True Case of the 1276 Fake Earthquake. Seismological Research Letters, 82, 1, 111-114, doi:10.1785/gssrl.82.1.111

Albini P., Demircioglu M.B., Locati M., Rovida A., Sesetyan K., Stucchi M., Viganò D., 2012. In Search of the Predecessors of the 2011 Van (Turkey) Earthquake. Seismological Research Letters, 83, 5, 855-862, doi:10.1785/0220110146

Albini P., Garcia Acosta V., Musson R.M.W., Stucchi M. (eds), 2004. Investigating the Records of Past Earthquakes. Proceedings of the 21st Course ot the International School of Geophysics, Erice-Sicily (Italy), 1-7 July 2002. Annals of Geophysics, 47, 2-3, 335-911.

Allen C.R., Gillespie A.R., Yuan H., Sieh K., Buchun Z., Chengnan Z., 1984. Study of the Quaternary activities of the Red River fault (I) - General survey of its contemporary activities and evidence of the active faulting, Journal of Seismological Research, 7, 39-51.

Allen T.I., Burbidge D.R., Clark D., McPherson A.A., Collins C.D.N., Leonard M., 2011. Development of the next generation Australian National Earthquake Hazard Map. Proceedings of the Ninth Pacific Conference of Earthquake Engineering, Auckland, New Zealand, Paper No 207.

Al-Sinawi S.A. and Ghalib H.A.A., 1975. Historical seismicity of Iraq. Bulletin of the Seismological Society of America, 65, 2, 541-547.

Altez R. and Grases J., 2004. A brief history of a restless vision: seismological research in Venezuela. Annals of Geophysics, 47, 2/3, 451-464.

Altez R., 2005a. Todo lo que se movió en 1812 en la placa del Caribe: sismos, volcanes y transmisión de energía. Revista Geográfica Venezolana, Número especial 2005, 143-170.

Altez R., 2005b. El terremoto de 1812 en la ciudad de Caracas: un intento de microzonificación histórica. Revista Geográfica Venezolana, Número especial 2005, 171-198.

Altez R., 2005c. Los sismos del 26 de marzo de 1812 en Venezuela: nuevos aportes y evidencias sobre estos eventos. Boletín Técnico IMME, 43, 2, 11-34.

Altez R., 2010. New interpretations of the social and material impacts of the 1812 earthquake in Caracas, Venezuela, in Sintubin M., Stewart I.S., Niemi T.M. and Altunel E. (eds), Ancient Earthquakes: Geological Society of America Special Paper 471, 47-58, doi:10.1130/2010.2471(05)

Alvarez L., Chuy T., Garcia J., Moreno B., Alvarez H., Blanco M., Exposito O., Gonzalez O., Fernandez A.I., 1999. An earthquake catalogue of Cuba and neighboring areas. ICTP Internal Report IC/IR/99/1, Miramare, Trieste, 60 pp.

Ambraseys N. and Bilham R., 2003. Earthquakes in Afghanistan. Seismological Research Letters, 74, 2, 107-123 + electronic supplement.

Ambraseys N. and Bilham R., 2003a. Reevaluated Intensities for the Great Assam Earthquake of 12 June 1897, Shillong, India. Bulletin of the Seismological Society of America, 93, 2, 655-673.

Ambraseys N. and Jackson D., 2003. A note on early earthquakes in northern India and southern Tibet. Current Science, 84, 4, 570-582.

Ambraseys N. and Vogt J., 1988. Materials for the investigation of the seismicity of the region of Algiers. European Earthquake Engineering, 3, 16-29.

Ambraseys N., 2000a. Reappraisal of north-Indian earthquakes at the turn of the 20th century. Current Science, Special Section: Seismology 2000, 79, 9, 1237-1250.

Ambraseys N., 2009. Earthquakes in the Mediterranean and Middle East: A Multidisciplinary Study of Seismicity up to 1900. Cambridge University Press, 968 pp.

Ambraseys N.N and Barazangi M., 1989. The 1759 Earthquake in the Bekaa Valley: Implications for Earthquake Hazard Assessment in the Eastern Mediterranean Region. Journal of Geophysical Research, 94, B4, 4007-4013.

Ambraseys N.N and Karcz I., 1992. The earthquake of 1546 in the Holy Land. Terra Nova, 4, 2, 253-262.

Ambraseys N.N. and Adams R.D., 1986a. Seismicity of the Sudan. Bulletin of the Seismological Society of America, 76, 2, 483-493.

Ambraseys N.N. and Adams R.D., 1986b. Seismicity of West Africa. Annales Geophysicae, 4, B, 6, 679-702.

Ambraseys N.N. and Adams R.D., 1991. Reappraisal of major African earthquakes, south of 20°N, 1900-1930. Natural Hazards, 4, 4, 389-419, doi:10.1007/BF00126646

Ambraseys N.N. and Adams R.D., 2001. Seismicity of Central America: A Descriptive Catalog 1898-1995. World Scientific Publishing Company, London, 309 pp.

Ambraseys N.N. and Douglas J., 2004. Magnitude calibration of north Indian earthquakes. Geophysical Journal International, 159, 165-206, doi:10.1111/j.1365-246X.2004.02323.x

Ambraseys N.N. and Finkel C., 1988. The Anatolian Earthquake of 17 August 1668. In: W.H.K. Lee, H. Meyers, K. Shimazaki (eds), Historical Seismograms and Earthquakes of the World, Academic Press, London, 173-180.

Ambraseys N.N. and Finkel C., 1991. Long-term seismicity of Istanbul and of the Marmara Sea region. Terra Nova, 3, 5, 527-539.

Ambraseys N.N. and Finkel C., 1992. The seismicity of the Eastern Mediterranean Region during the turn of the Eighteenth Century. Istanbuler Mitteilungen, 42, 323-343.

Ambraseys N.N. and Finkel C., 1995. The Seismicity of Turkey and adjacent areas. A Historical Review, 1500-1800. Eren, Istanbul, 240 pp.

Ambraseys N.N. and Finkel C., 1999. Unpublished Ottoman archival information on the seismicity of the Balkans during the period 1500-1800. In: E. Zachariadou (ed), Natural Disasters in the Ottoman Empire, Institute for Mediterranean Studies, Halcyon Days in Crete III, A Symposium Held in Rethymnon (Greece), 10-12 January 1997, 89-107.

Ambraseys N.N. and Jackson J., 1990. Seismicity and associated strain of central Greece between 1890 and 1988. Geophysical Journal International, 101, 3, 663-708.

Ambraseys N.N. and Jackson J.A., 1998. Faulting associated with historical and recent earthquakes in the Eastern Mediterranean region. Geophysical Journal International, 133, 2, 390-406, doi:10.1046/j.1365-246X.1998.00508.x

Ambraseys N.N. and Melville C., 1982. A history of Persian earthquakes. Cambridge University Press, Cambridge, 219 pp.

Ambraseys N.N. and Melville C.P., 1983. Seismicity of Yemen. Nature, 303, 321-323.

Ambraseys N.N. and Melville C.P., 1988. An analysis of the Eastern Mediterranean Earthquake of 20 May 1202. In: W.H.K. Lee, H. Meyers, K. Shimazaki (eds), Historical Seismograms and Earthquakes of the World, Academic Press, London, 181-200.

Ambraseys N.N. and Melville C.P., 1989. Evidence for intraplate earthquakes in northwest Arabia. Bulletin of the Seismological Society of America, 79, 4, 1279-1281.

Ambraseys N.N. and Melville C.P., 1995. Historical evidence of faulting in Eastern Anatolia and Northern Syria. Annali di Geofisica, 38, 3-4, 337-343.

Ambraseys N.N., 1962. A note on the chronology of Willis's list of earthquakes in Palestine and Syria. Bulletin of the Seismological Society of America, 52, 1, 77-80.

Ambraseys N.N., 1968. Early earthquakes in North-Central Iran. Bulletin of the Seismological Society of America, 58, 2, 485-496.

Ambraseys N.N., 1982. The seismicity of North Africa: the earthquake of 1856 at Jijeli, Algeria. Bollettino di Geofisica Teorica ed Applicata, 24, 93, 31-37.

Ambraseys N.N., 1984. Material for the investigation of the seismicity of Tripolitania. Bollettino di Geofisica Teorica ed Applicata, 26, 143-153.

Ambraseys N.N., 1989. Temporary seismic quiescence: SE Turkey. Geophysical Journal International , 96, 2, 311-331.

Ambraseys N.N., 1991. Earthquake hazard in the Kenya Rift: the Subukia earthquake 1928. Geophysical Journal International, 105, 1, 253-269.

Ambraseys N.N., 1991a. The Rukwa earthquake of 13 December 1910 in East Africa. Terra Nova, 3, 2, 202-211.

Ambraseys N.N., 1997a. The Krasnovodsk (Turkmenistan) earthquake of 8 July 1895. Journal of Earthquake Engineering, 1, 2, 293-317.

Ambraseys N.N., 1997b. The little-known earthquakes of 1866 and 1916 in Anatolia (Turkey). Journal of Seismology, 1, 3, 289-299, doi:10.1023/A:1009788609074

Ambraseys N.N., 1997c. The earthquake of 1 January 1837 in Southern Lebanon and Northern Israel. Annali di Geofisica, 40, 4, 923-935.

Ambraseys N.N., 2001. The earthquake of 1509 in the Sea of Marmara, Turkey, revisited. Bulletin of the Seismological Society of America, 91, 6, 1397-1416.

Ambraseys N.N., 2001b. Reassessment of earthquakes, 1900-1999, in the East Mediterranean and the Middle East. Geophysical Journal International, 145, 471-485.

Ambraseys N.N., 2002. The seismic activity of the Marmara Sea Region over the last 2000 years. Bulletin of the Seismological Society of America, 92, 1, 1-18.

Ambraseys N.N., 2004. The 12th century seismic paroxysm in the Middle East: a historical perspective. Annals of Geophysics, 47, 2-3, 733-758.

Ambraseys N.N., 2004a. Three little known earthquakes in India. Current Science, 86, 4, 506-508.

Ambraseys N.N., 2006. Comparison of frequency of occurrence of earthquakes with slip rates from long-term seismicity data: the cases of Gulf of Corinth, Sea of Marmara and Dead Sea Fault Zone. Geophysical Journal International, 165, 516–526.

Ambraseys N.N., Melville C.P., Adams R.D., 1994. The Seismicity of Egypt, Arabia and the Red Sea. Cambridge University Press, Cambridge, 182 pp.

Amponsah P.E., 2004. Seismic activity in Ghana: Past, present and future. Annals of Geophysics, 47, 2-3, 539-544.

Anderson H., Beanland S., Blick G., Darby D., Downes G. L., Haines J., Jackson J., Robinson R., Webb T., 1994. The 1968 May 23 Inangahua, New Zealand, earthquake: an integrated geological, geodetic and seismological source model. New Zealand Journal of Geology and Geophysics, 37, 59-86.

Audemard F.M., 1999. Nueva percepcion de la sismicidad historica del segmento en tierra de la Falla El Pilar, Venezuela Nororiental, a partir de primeros resultados paleosismicos. Mem. VI congreso Venez. Sismologia e Ingenieria Sismica (CD-ROM), Merida, Venezuela.

Babayan T., 2006. Atlas of strong earthquakes of the Republic of Armenia, Artsakh and adjacent territories from ancient times through 2003. Tigran Mets, Yerevan, 140 pp.

Bakun W.H. and Hopper M.G., 2004. Magnitudes and Locations of the 1811-1812 New Madrid, Missouri, and the 1886 Charleston, South Carolina, Earthquakes. Bulletin of the Seismological Society of America, 94, 1, 64-75.

Bakun W.H. and Wentworth C.M., 1997. Estimating earthquake location and magnitude from seismic intensity data. Bulletin of the Seismological Society of America, 87, 6, 1502-1521.

Bakun W.H., 1999. Seismic Activity of the San Francisco Bay Region. Bulletin of the Seismological Society of America, 89, 3, 764-784.

Bakun W.H., 2000. Seismicity of California's North Coast. Bulletin of the Seismological Society America, 90, 4, 797-812.

Bakun W.H., 2005. Magnitude and location of historical earthquakes in Japan and implications for the 1855 Ansei Edo earthquake. Journal of Geophysical Research, 110, B02304, 22 pp., doi:10.1029/2004JB003329

Bakun W.H., 2006a. Estimating Locations and Magnitudes of Earthquakes in Southern California from Modified Mercalli Intensities. Bulletin of the Seismological Society of America, 96, 4A, 1278-1295, doi:10.1785/0120050205

Bakun W.H., 2006b. MMI Attenuation and Historical Earthquakes in the Basin and Range Province of Western North America. Bulletin of the Seismological Society of America, 96, 6, 2206-2220, doi:10.1785/0120060045

Bakun W.H., Flores C.H., ten Brink U.S., 2012. Significant Earthquakes on the Enriquillo Fault System, Hispaniola, 1500-2010: Implications for Seismic Hazard. Bulletin of the Seismological Society of America, 102, 1, 18-30, doi:10.1785/0120110077

Bakun W.H., Haugerud R.A., Hopper M. G., Ludwin R.S., 2002. The December 1872 Washington state earthquake. Bulletin of the Seismological Society of America, 92, 8, 3239-3258.

Baljinnyam I., Bayasgalan A., Borisov B. A., Cisternas A., Dem'yanovich M. G., Ganbaatar L., Kochetkov M., Kurushin R. A., Molnar P., Philip H., Vashchilov Y. Y., 1993. Ruptures of major earthquakes and active deformation in Mongolia and its surroundings. Geological Society of America Memoir 181, 62 pp.

Baptista M.A., Miranda J.M., Lopes Fernando C., Luis Joaquim F., 2007. The source of the 1722 Algarve earthquake: evidence from MCS and tsunami data. Journal of Seismology, 11, 4, 371-380.

Bautista M.L.P. and Bautista B.C., 2004. The Philippine historical earthquake catalog: its development, current state and future directions. Annals of Geophysics, 47, 379-385.

Bautista M.L.P. and Oike K., 2000. Estimation of the magnitudes and epicenters of Philippine historical earthquakes. Tectonophysics, 317, 1-2, 137-169.

Beauval C., Yepes H., Bakun W.H., Egred J., Alvarado A., Singaucho J.C., 2010. Locations and magnitudes of historical earthquakes in the Sierra of Ecuador (1587-1996). Geophysical Journal International, 181, 1613-1633, doi:10.1111/j.1365-246X.2010.04569.x

Beauval C., Yepes H., Palacios P., Segovia M., Alvarado A., Font Y., Aguilar J., Troncoso L., Vaca S., 2013. An Earthquake Catalog for Seismic Hazard Assessment in Ecuador. Bulletin of the Seismological Society of America, 103, 2A, 773-786, doi:10.1785/0120120270

Benito M.B., Lindholm C., Camacho E., Climent Á., Marroquín G., Molina E., Rojas W., Escobar J.J., Talavera E., Alvarado G.E., Torres Y., 2012. A New Evaluation of Seismic Hazard for the Central America Region. Bulletin of the Seismological Society of America, 102, 2, 504-523, doi:10.1785/0120110015

Benito Oterino M.B. and Torres Fernández Y. (eds), 2009. Amenaza sísmica en América Central. Entimema, Madrid, 371 pp.

Ben-Menahem A., 1979. Earthquake catalogue for the Middle East (92 B.C. - 1980 A.D.). Bollettino di Geofisica Teorica e Applicata, 31, 84, 245-313.

Ben-Menahem A., 1991. Four thousand years of seismicity along the Dead Sea rift. Journal of Geophysical Research, 96, B12, 20195-20216.

Benouar D., 2004. Materials for the investigation of historical seismicity in Algeria from the records of past earthquakes. Annals of Geophysics, 47, 2-3, 555-560.

Berberian M. (ed), 1976. Contribution to the seismotectonics of Iran (Part II). Geological Survey of Iran Report. No. 39, Geological Survey of Iran, Tehran.

Berberian M. (ed), 1977. Contribution to the seismotectonics of Iran (Part III). Geological and Mining Survey of Iran Report., 40, Geological Survey of Iran, Tehran.

Berberian M., 1994. Natural hazards and the first earthquake catalogue of Iran. Volume 1: Historical hazards in Iran prior to 1900. UNESCO-IIEES-IDNDR, 603 pp.

Bernard P. and Lambert J., 1988. Subduction and seismic hazard in the northern Lesser Antilles: revision of the historical seismicity. Bulletin of the Seismological Society of America, 78, 6, 1965-1983.

Berryman K.R., Cochran U.A., Clark K.J., Biasi G.P., Langridge R.M., Villamor P., 2012. Major earthquakes occur regularly on an isolated plate boundary fault. Science, 336, 1690-1693.

Besana G.M. and Ando M., 2005. The central Philippine Fault Zone: Location of great earthquakes, slow events, and creep activity. Earth Planets Space, 57, 987-994.

Best E., 1918. The land of Tara and they who settled it. Journal of the Polynesian Society, 27, 49-71.

Bhatia S.C., Kumar R.M., Gupta H.K., 1999. A probabilistic seismic hazard map of India and adjoining regions. Annals of Geophysics, 42, 6, 1153-1164. http://www.seismo.ethz.ch/static/gshap/ict/indcat.txt

Bilek S.L., 2010. Seismicity along the South American subduction zone: Review of large earthquakes, tsunamis, and subduction zone complexity. Tectonophysics, 495, 2-14.

Bilham R., 1994. The 1737 Calcutta Earthquake and Cyclone Evaluated. Bulletin of the Seismological Society of America, 84, 5, 1650-1657.

Bilham R., 1995. Location and magnitude of the 1833 Nepal earthquake and its relation to the rupture zones of contiguous great Himalayan earthquakes. Current Science, 69, 2, 101-128.

Bilham R., Engdahl E.R., Feldl N., Satyabala S.P., 2005. Partial and complete rupture of the Indo-Andaman Plate Boundary 1847-2004. Seismological Research Letters, 76, 3, 299-311.

Bird P., 2003. An updated digital model of plate boundaries. Geochemistry Geophysics Geosystems, 4, 1-52.

Blaser L., Krüger F., Ohrnberger M., Scherbaum F., 2010. Scaling relations of earthquake source parameter estimates with special focus on subduction environment. Bulletin of the Seismological Society of America, 100, 6, 2914-2926.

Bonito M., 1691. Terra tremante, o vero continuatione de' terremoti dalla Creatione del Mondo fino al tempo presente. Napoli (reprint, A. Forni, Sala Bolognese, 1980), 822 pp.

Boschi E. and Guidoboni E., 2001. Catania terremoti e lave dal mondo antico alla fine del Novecento. INGV-SGA, Bologna, 414 pp.

Boschi E., Guidoboni E., Ferrari G., Mariotti D., Valensise G., Gasperini P. (eds), 2000. Catalogue of Strong Italian Earthquakes from 461 B.C. to 1980. Annali di Geofisica, 43, 4, 609-868.

Boussingault J.B. and Roulin F., 1849. Viajes cientificos a los andes Ecuatoriales. Coleccion de Memorias sobre Fisica, Quimica e Historia Natural de la Nueva Granada, Ecuador y Venezuela, traducidas por J. Acosta y precedidas de algunas nociones de geologia por el mismo. Lasserre, Paris, 322 pp.

Bozkurt S.B., Stein R S., Toda S., 2007. Forecasting Probabilistic Seismic Shaking for Greater Tokyo from 400 Years of Intensity Observations. Earthquake Spectra, 23, 3, 525-546, doi:10.1193/1.2753504

BRGM-EDF-IRSN/SisFrance, 2001. Fichier de Sismicité Historique de la France.

BRGM-EDF-IRSN/SisFrance, 2010. Histoire et caractéristiques des séismes ressentis en France. http://www.sisfrance.net

British Geological Survey, 2010. UK Historical Earthquake Database. http://quakes.bgs.ac.uk

Calvi V.S., 1941. Erdbebenkatalog der Turkei und Einiger Benaehbarter Gebiete. Report No.276, MTA Enstitüsü, Ankara (unpublished).

Camacho E. and Víquez V., 1993. Historical seismicity of the North Panama Deformed Belt. Revista Geológica de América Central, 15, 49-64.

Camassi R. and Stucchi M. (eds), 1997. NT4.1: un catalogo parametrico di terremoti di area italiana al di sopra della soglia di danno (versione 4.1.1). Milano, 93 pp. http://emidius.mi.ingv.it/NT/CONSNT.html

Camassi R., Mirenna S., Rebez A., Stucchi M., Zerga A., 1994. Problems and pitfalls in the compilation of comprehensive earthquake catalogues. In: P. Albini and A. Moroni (eds), Materials of the CEC project "Review of Historical Seismicity in Europe", vol. 2, CNR, Milano, 241-254.

CERESIS (Centro Regional de Sismología para América del Sur), 1985. Destructive earthquakes of South America 1530-1894. Earthquake Mitigation Program in the Andean Region, Project SISRA, Lima, 14 vols.

CERESIS (Centro Regional de Sismología para América del Sur), 1995. Catalogue for South America and the Caribbean prepared in the framework of GSHAP. File available and downloadable from http://www.seismo.ethz.ch/static/gshap/ceresis

CEUS, 2012. SSC Uniform Moment Magnitude Earthquake Catalog. http://www.ceus-ssc.com

Chen L.C., Wang H., Ran Y.K., Sun X.Z., Su G.W., Wang J., Tan X.B., Li Z.M., Zhang X.Q., 2010. The MS7.1 Yushu earthquake surface rupture and large historical earthquakes on the Garzê-Yushu Fault. Chinese Science Bulletin, Geophysics, 55, 31, 3504-3509, doi:10.1007/s11434-010-4079-2

Chesneau M., 1892. Note sur les tremblements de terre en Algérie. Annales de Mines, 9è Sér., 1, 5-46.

China State Seismological Bureau and Fudan University, 1986. Atlas of the Historical Earthquakes in China - The Ming Dynasty Period (1368-1644). Compiled by Institute of Geophysics, State Seismological Bureau and Institute of Chinese Historical Geography, Fudan University, China Cartographic Publishing House, 232 pp. (in Chinese)

China State Seismological Bureau and Fudan University, 1990a. Atlas of the Historical Earthquakes in China - The Period from Remote Antiquity to the Yuan Dynasty (23 cent. B.C.-1368). Compiled by Institute of Geophysics, State Seismological Bureau and Institute of Chinese Historical Geography, Fudan University, China Cartographic Publishing House, 193 pp. (in Chinese)

China State Seismological Bureau and Fudan University, 1990b. Atlas of the Historical Earthquakes in China - The Qing Dynasty Period (1644-1911). Compiled by Institute of Geophysics, State Seismological Bureau and Institute of Chinese Historical Geography, Fudan University, China Cartographic Publishing House, 244 pp. (in Chinese)

Chiu J.-M. and Kim S.G., 2004. Estimation of Regional Seismic Hazard in the Korean Peninsula using Historical Earthquake Data between A.D. 2 and 1995. Bulletin of the Seismological Society of America, 94, 1, 269-284.

Choy J.E., Palme C., Guada C., Morandi M., Klarica S., 2010. Macroseismic Interpretation of the 1812 Earthquake in Venezuela Using Intensity Uncertainties and A Priori Fault-Strike Information. Bulletin of the Seismological Society of America, 100, 1, 241-255.

Chuy Rodríguez T. and Alvarez Gómez L., 1988. Sismicidad Histórica de La Española. Comunicaciones Científicas sobre Geofísica y Astronomia, Instituto de Geofísica y Astronomia, Academia de Ciencias de Cuba, La Habana, 14 pp.

Chuy T., 1999. Macrosísmica de Cuba y su aplicación en los estimados de Peligrosidad y Microzonificación Sísmica. Tesis en opción al Grado de Doctor en Ciencias Geofísicas. Fondos del Centro Nacional de Investigaciones Sismológicas (CENAIS), CITMA, 273 pp.

Chuy T.J. and Rodríguez M., 1980. La actividad sísmica de Cuba por datos historicos. Investigaciones Sismologicas en Cuba, 1, 5-17.

Cisternas M., 2012. El terremoto de Chile central de 1647 como un evento intra-placa. XIII Congreso Geológico Chileno. Antofagasta, Chile. Libro de resúmenes, 1037-1039.

Cook J., 1777. A voyage towards the South Pole and round the World. Strachan and Cadell, London, 378 pp.

Cornet J., 1909. Sur la répartition des tremblements de terre dans le bassin du Congo. Annales de la Société géologique de Belgique, t. 36, B. 264-269.

Costantinescu L. and Marza V.I., 1980. A computer-compiled and computer-oriented catalog of Romania's earthquakes during a millennium (984-1979). Revue Roumanie de Geologie Geophysique et Geographie. Ser. Geophysique, 24, 171-191.

Cotilla M.O. and Córdoba D., 2010a. Notes on three earthquakes in Santiago de Cuba (14.10.1800, 18.09.1826, 07.07.1842). Russian Geology and Geophysics, 51, 228-236.

Cotilla Rodríguez M.O, 2003. The Santiago de Cuba earthquake of 11 June 1766: Some new insights. Geofísica Internacional, 42, 4, 589-602.

Cotilla Rodríguez M.O. and Córdoba Barba D., 2010b. The August 20, 1852 earthquake in Santiago de Cuba. Russian Geology and Geophysics, 51, 1227-1246.

Cotilla Rodríguez M.O. and Córdoba Barba D., 2011. Study of the Earthquake of the January 23, 1880, in San Cristobal, Cuba and the Guane Fault. Physics of the Solid Earth, 47, 6, 496-518.

Cowan H.A., 1991. The North Canterbury earthquake of September 1, 1888. Journal of the Royal Society of New Zealand, 21, 1-12.

CPTI Working Group, 2004. Catalogo Parametrico dei Terremoti Italiani, versione 2004 (CPTI04). INGV, Bologna, doi:10.6092/INGV.IT-CPTI04. http://emidius.mi.ingv.it/CPTI

Cullen L.E., Duncan R.P., Wells A., Stewart G.H., 2003. Floodplain and regional scale variation in earthquake effects on forests, Westland, New Zealand. Journal of the Royal Society of New Zealand, 33, 693-701.

Cummins P.R., 2007. The potential for giant tsunamigenic earthquakes in the northern Bay of Bengal. Nature, 449, 6 Sept 2007, 75-78.

de Polo C.M., Anderson J.G., de Polo D.M., Price J.G., 1997. Earthquake Occurrence in the Reno-Carson City Urban Corridor. Seismological Research Letters, 68, 3, 401-412.

Deng Q. and Liao Y., 1996. Paleoseismology along the range-front fault of Helan Mountains, north central China. Journal of Geophysical Research, 101, B3, 5873-5893.

Diaz V., 1933. Conmociones Terrestres de America Central. Editorial Jose Ibarra, Guatemala, 267 pp.

Dimaté C., Drake L., Yepez H., Ocola L., Rendon H., Grünthal G., Giardini D., 1999. Seismic hazard assessment in the Northern Andes (PILOTO Project). Annali di Geofisica, 42, 6, 1039-1055.

Dimate C., Rivera L., Cisternas A., 2005. Re-visiting large historical earthquakes in the Colombian Eastern Cordillera. Journal of Seismology, 9, 1-22.

Dorbath L., Cisternas A., Dorbath C., 1990. Assessment of the size of large and great historical earthquakes in Peru. Bulletin of the Seismological Society of America, 80, 3, 551-576.

Dorel J., 1981. Seismicity and seismic gap in the Lesser Antilles arc and earthquake hazard in Guadeloupe. Geophysical Journal of the Royal Astronomical Society, 67, 679-695.

Doser D.I., 2006. Relocations of Earthquakes (1899-1917) in South-Central Alaska. Pure and Applied Geophysics, 163, 8, 1461-1476, doi:10.1007/s00024-006-0085-3

Downes G.L. and Grapes R.H., 1999. The 1855 Wairarapa, New Zealand, earthquake-historical data. Institute of Geological & Nuclear Science Report, 99/16.

Downes G.L., 1995. Atlas of isoseismal maps of New Zealand earthquakes. Institute of Geological & Nuclear Sciences Monograph, 11, 295 pp.

Dowrick D.J. and Smith E.G.C., 1990. Surface-wave magnitudes of some New Zealand earthquakes, 1901-1988. Bulletin of the New Zealand Society for Earthquake Engineering, 23, 198-210.

Dowrick D.J., 1991. A revision of attenuation relationships for Modified mercalli intensity in New Zealand earthquakes. Bulletin of the New Zealand Society for Earthquake Engineering, 24, 210-224.

Doyle H.A., Everingham I.B., Sutton D.J., 1968. Seismicity of the Australian continent. Journal of the Geological Society of Australia, 15, 295-312.

DuBois S.M. and Smith A.W., 1980. Earthquakes Causing Damage in Arizona. Bureau of Geology and Mineral Technology, 3 pp.

Dunbar P., 2009. Global Significant Earthquake Database, National Oceanic and Atmospheric Administration (NOAA), Boulder, CO, USA. http://www.ngdc.noaa.gov/nndc/struts/form?t=101650&s=1&d=1

Dunbar P.K., Lockridge P.A., Whiteside L.S., 2002. Catalog of Significant Earthquakes (2150 B.C.-1991 A.D.). National Oceanic and Atmospheric Administration Report SE-49.

Earthquake Research Institute of the University of Tokyo (ed), 1981-1994. Historical Documents on Earthquakes in Japan. New Collection, vols. 1-5, 2 suppl., 21 volumes in total (in Japanese).

Ebel J.E., 2011. A New Analysis of the Magnitude of the February 1663 Earthquake at Charlevoix, Quebec. Bulletin of the Seismological Society of America, 101, 3, 1024-1038, doi:10.1785/0120100190

Ebel J.E., Dupuy M., Bakun W.H., 2013. Assessing the Location and Magnitude of the 20 October 1870 Charlevoix, Quebec, Earthquake. Bulletin of the Seismological Society of America, 103, 1, 588–594, doi:10.1785/0120110063

Egred J., 1968. Breve historia sísmica de la República del Ecuador (1534-1965). Boletín bibliográfico de geofísica y oceanografía americana, México, vol. 4, 147-190.

Egred J., 2004. El terremoto de Riobamba del 4 de febrero de 1797. In: "Investigaciones en Geociencias, vol. 1", IRD-Instituto Geofisico, Corporacion Editora Nacional, Quito, 133-161.

Eiby G.A., 1968a. A descriptive catalogue of New Zealand earthquakes: Part I - Shocks felt before the end of 1845. New Zealand Journal of Geology and Geophysics, 11, 16-40.

Eiby G.A., 1968b. An annotated list of New Zealand earthquakes, 1460-1965. New Zealand Journal of Geology and Geophysics, 11, 630-647.

El Mrabet T., 2005. The great earthquakes in the Maghreb region and their consequences on man and environment. CNRST-LAG, Rabat, 478 pp.

Engdahl E.R. and Villaseñor A., 2002. Global seismicity: 1900-1999. In: W.H.K. Lee, H. Kanamori, P.C. Jennings, C. Kisslinger (eds), International Handbook of Earthquake and Engineering Seismology, Part A. Academic Press, San Diego, 665-690.

Ergin K., Guclu U., Uz Z., 1967. A Catalog of Earthquakes for Turkey and Surrounding Area (11 A.D. to 1964 A.D.), Istanbul Technical University, Faculty of Mining Engineering, Istanbul, Turkey.

Espinosa Baquero A., 2003. Historia Sísmica de Colombia. Academia Colombiana de Ciencias Exactas, Físicas y Naturales - Universidad del Quindío, Bogotá. CD-ROM.

Espinosa Baquero A., Gómez Capera A.A., Salcedo Hurtado E. de J., 2004. State-of-the-art of the Historical Seismology in Colombia. Annals of Geophysics, 47, 2-3, 437-449.

Everingham I.B. and Tilbury L., 1972. Information on West Australian earthquakes which occurred during the periods 1849-1960 and 1923-1960. Bureau of Mineral Resources, Report No 1971/40.

Everingham I.B., 1974. Large earthquakes in the New Guinea-Solomon Islands area, 1873-1972. Tectonophysics, 23, 4, 323-338.

Everingham I.B., 1983. Reports of Earthquakes Felt in Fiji, 1850-1940. Fiji Ministry of Energy and Mineral Resources, Mineral Resources Department, Report 48.

Everingham I.B., McEwin A. J., Denham D., 1982. Atlas of isoseismal maps of Australian earthquakes. Bureau of Mineral Resources, Bulletin No 214.

Fäh D., Giardini D., Kästli P., Deichmann N., Gisler M., Schwarz-Zanetti G., Álvarez-Rubio S., Sellami S., Edwards B., Allmann B., Bethmann F., Wössner J., Gassner-Stamm G., Fritsche S., Eberhard D., 2011. ECOS-09 Earthquake Catalogue of Switzerland Release 2011 Report and Database. Public catalogue, 17. 4. 2011. Swiss Seismological Service ETH Zurich, Report SED/RISK/R/001/20110417, 42 pp + Appendixes.http://hitseddb.ethz.ch:8080/ecos09/index.html?&locale=en

Fedotov S.A. and Shumilina L. S., 1971. Seismic hazard of Kamchatka, Izv. Akad. Nauk S.S.S.R. Fiz. Zemli 9, 3-15 (in Russian).

Fedotov S.A., Kirillov F.A., Godzikovskaya A.A., 1968. Preliminary report on seismic zoning of the Kronotskiy HPP in Kamchatka. Institute of Physics of the Earth (IPE), USSR Academy of Sciences, Moscow (in Russian).

Feldman L.H., 1985. Disasters, Natural and Otherwise, and Their Effects upon Population Centers in the Reino de Guatemala. In: D. Kinkead (ed), Estudios del Reino de Guatemala, Publicaciones de la Escuela de Estudios Hispano-Americanos de Sevilla, 49-60.

Feldman L.H., 1986. A Master List of Historic (pre-1840) Earthquakes and Volcanic Eruptions in Central America. In: R.H. Claxton (ed), Investigating Natural Hazards in Latin America History, Studies in the Social Sciences, West Georgia College, vol. 25, 63-105.

Feldman L.H., 1993. Mountains of fire, lands that shake. Earthquakes and Volcanic Eruptions in the Historic Past of Central America. Labyrinthos, California, 295 pp.

Felzer K.R. and Cao T., 2008. WGCEP Historical California earthquake catalog, Appendix H in The Uniform California Earthquake Rupture Forecast, version 2 (UCERF 2): U.S. Geological Survey Open-File Report 2007-1437H and California Geological Survey Special Report 203H, 127 p. http://pubs.usgs.gov/of/2007/1437/h

Fenton C.H. and Bommer J.J., 2006. The M(w)7 Machaze, Mozambique, earthquake of 23 February 2006. Seismological Research Letters, 77, 4, 426-439.

Feuillard M., 1988. Macro-sismicite de la Guadeloupe et de la Martinique. Observatoire Volcanologique de la Soufriere, Guadeloupe.

Figueroa A.J., 1963. Historia sísmica y estadística de temblores de la costa occidental de México. Boletín Bibliográfico de Geofisica y Oceanografia Americanos, 3, 107-134.

Figueroa A.J., 1970. Catalogo de sismos ocurridos en la Republica Mexicana. Revista del Instituto de Ingenieria, 272, 1-88.

Flores C.F., ten Brink U.S., Bakun W.H., 2012. Accounts of damage from historical earthquakes in the Northeastern Caribbean to aid in the determination of their location and intensity magnitudes. U.S. Geological Survey, Open-File Report 2011-1133, 237 pp.

Galbis Rodríguez J., 1932. Catálogo Sísmico de la Zona comprendida entre los meridianos 5° E y 20° W de Greenwich y los paralelos 45° y 25° N. Madrid, tomo I, 807 pp.

Galbis Rodríguez J., 1940. Catálogo Sísmico de la Zona comprendida entre los meridianos 5° E y 20° W de Greenwich y los paralelos 45° y 25° N. Madrid, tomo II, 278 pp.

Ganse R.A. and Nelson J.B., 1982. Catalog of significant earthquakes 2000 b.c. to 1979, including quantitative casualties and damage. Bulletin of the Seismological Society of America, 72, 3, 873-877.

Gao Mengtan, Jin Xueshen, An Weiping, Lu Xiaojian, 2004. The GIS and analysis of earthquake damage distribution of the 1303 Hongtong M=8 earthquake. Acta Sismologica Sinica, 17, 4, 398-404.

Garcia L.C., Valenzuela R.G., Arnold E.P., Macalingcag T.G., Ambubuyog G.F., Lance N.T., Cordeta J.D., Doniego A.G., Cordeta J.D.G.M., Dabi A.C., Balce G.R., Su S.S., 1985. South East Asia Association of Seismology and Earthquake Engineering, Series on Seismology, vol. IV, Philippines, 852 pp.

García-Acosta V. and Suarez G.R., 1996. Los Sismos en la Historia de México, Tomo I. Universidad Nacional Autonoma de Mexico, Centro de Investigaciones y Estudios Superiores en Antropologia Social, Fondo de Cultura Economica.

García-Acosta V., 2004. Historical earthquakes in Mexico. Past efforts and new multidisciplinary achievements. Annals of Geophysics, 47, 2-3, 10 pp.

García-Acosta V., Hernández R., Márquez I., Molina A., Pérez J.M., Rojas T., Sacristán C., 1988. Cronología de los sismos en la cuenca del Valle de México. Estudios sobre sismicidad en el Valle de México, 409-498.

Gasperini P., Bernardini F., Valensise G., Boschi E., 1999. Defining Seismogenic Sources from Historical Earthquake Felt Reports. Bulletin of the Seismological Society of America, 89, 1, 94-110.

Gasperini P., Vannucci G., Tripone D., Boschi E., 2010. The Location and Sizing of Historical Earthquakes Using the Attenuation of Macroseismic Intensity with Distance. Bulletin of the Seismological Society of America, 100, 5A, 2035-2066.

Gaull B. A., Michael-Leiba M.O., Rynn J.M.W., 1990. Probabilistic earthquake risk maps of Australia. Australian Journal of Earth Sciences, 37, 169-187.

GeoNet, 2011. Historic Earthquakes. National Earthquake Information Database, GNS-EQC, New Zealand.

Giardini D. and Basham P., 1993. The Global Seismic Hazard Assessment Program (GSHAP), Annals Of Geophysics, 36, 3-4, 3-13.

Giardini D. and Beranzoli L., 1992. Waveform modeling of the May 20, 1990 Sudan earthquake. Tectonophysics, 209, 1-4, 105-114.

Giesecke A., Gómez Capera A.A., Leschiutta I., Migliorini E., Rodriguez Valverde L., 2004. The CERESIS earthquake catalogue and database of the andean Region: background, characteristics and examples of use. Annals of Geophysics, 47, 2-3, 421-435.

Godzikovskaya A.A., 2007. A catalogue of macroseismic descriptions of Kamchatka earthquakes for pre-instrumental period of observation (18th-19th centuries). KF GS RAN Report, Moscow-Petropavlovsk, 167 pp. (in Russian).

Goff J.R. and Chague-Goff C., 2001. Catastrophic events in New Zealand coastal environments. Department of Conservation, Conservation Advisory Science Notes No. 333.

Gómez Capera A.A., Garcia Pelaez J., Chuy Rodriguez T.J., Stucchi M., 2012. Calibracion y validacion de un modelo para calcular parametros de terremotos historicos a partir de datos macrosísmicos en Cuba. Proc. IV Conferencia internacional de peligrosidad, riesgo geologico e ingenieria sismica y de desastres. Santiago de Cuba, Maggio 8-11, 10 pp.

Gómez Capera A.A., Salcedo Hurtado E. de J., Garcia Pelaez J., 2012a. Determinacion del Epicentro y magnitud del terremoto del 1785 en Colombia a partir de intensidades macrosismicas. Proc. Latin American Symposium of Seismology 2012, Lima (Peru), September 22-26, 5 pp.

Gonzalez C., 1910. Temblores, Terremotos, Inundaciones y Erupciones Volcanicas en Costa Rica 1608- 1910. Alsina, San Jose, 200 pp.

Gouin P., 1979. Earthquake history of Ethiopia and the Horn of Africa. IDRC-118e, IDRC, Ottawa, 259 pp.

Gouin P., 1994. About the First Earthquake Reported in Canadian History. Bulletin of the Seismological Society of America, 84, 2, 478-483.

Gouin P., 2001. Trémblements de terre "historiques" au Québec (de 1534 à mars 1925) identifiés et interprétés à partir des textes originaux contemporains. "Historical" earthquakes felt in Québec (from 1534 to March 1925) as revealed by the local contemporary literature. Gué, Montreal, 1491 pp.

Grapes R.H. and Downes G.L., 1997. The 1855 Wairarapa, New Zealand, earthquake - analysis of historical data. Bulletin of the New Zealand Society for Earthquake Engineering, 30, 271-368.

Grapes R.H. and Downes G.L., 2010. Charles Lyell and the great 1855 earthquake in New Zealand: first recognition of active fault tectonics. Journal of the Geological Society, 167, 35-47.

Grapes R.H., Downes G.L., Goh A., 2003. Historical documents relating to the 1848 Marlborough earthquakes, New Zealand. Institute of Geological & Nuclear Science Report, 2003/34.

Grases J., 1974. Sismicidad de la Región Centroamericana Asociada a la Cadena Volcánica del Cuaternario. Instituto de Geociencias-Organización de Estados Americanos, Caracas, vol. II, 253 pp.

Grases J., 1979. Investigación Sobre los Sismos Destructores que han Afectado el Oriente de Venezuela, Delta del Orinoco y Regiones Adyacentes. INTEVEP, Caracas.

Grases J., 1980. Investigación Sobre los Sismos Destructores que han Afectado el Centro y Occidente de Venezuela. INTEVEP, Caracas.

Grases J., 1986. Hacia la reconstrucción de la historia de los terremotos del Caribe. Revista Geofísica, Instituto Panamericano de Geografía e Historia, 24, 53-69.

Grases J., 1990. Terremotos Destructores del Caribe, 1502- 1990. UNESCO-RELACIS, Montevideo, 132 pp.

Greve F., 1964. Historia de la sismología en Chile. Publicación Instituto de Geofísica y Sismología, Santiago de Chile, 94 pp.

Grigorova E., Christoskov L., Sokerova D., Rizhikova S., Roglinov A., 1978. Catalogue of earthquakes in Bulgaria and the nearby territories during the period 1st cent. BC - 1977. Geophysical Institute, Bulgarian Academy of Sciences, Sofia (unpublished).

Grunewald E.D. and Stein R.S., 2006. A new 1649-1884 catalog of destructive earthquakes near Tokyo and implications for the long-term seismic process. Journal of Geophysical Research, 111, B12306, 15 pp., doi:10.1029/2005JB004059

Grünthal G. and Wahlström R., 2003. An Mw based earthquake catalogue for central, northern and northwestern Europe using a hierarchy of magnitude conversions. Journal of Seismology, 7, 507-531.

Grünthal G. and Wahlström R., 2012. The European-Mediterranean Earthquake Catalogue (EMEC) for the last millennium. Journal of Seismology, 16, 3, 535-570, doi:10.1007/s10950-012-9302-y

Grünthal G., Wahlström R., Stromeyer D., 2009. The unified catalogue of earthquakes in central, northern, and northwestern Europe (CENEC) - updated and expanded to the last millennium. Journal of Seismology, 13, 517-541, doi:10.1007/s10950-008-9144-9

Gu Gongxu et al., 1989. Catalogue of Chinese Earthquakes (1831 B.C.-1969 A.D.), translation into English of the 1983 edition in Chinese, Science Press, Beijing, China, 872 pp.

Guidoboni E. and Comastri A., 1997. The large earthquake of 8 August 1303 in Crete: seismic scenario and tsunami in the Mediterranean area. Journal of Seismology, 1, 55-72.

Guidoboni E. and Comastri A., 2005. Catalogue of earthquakes and tsunamis in the Mediterranean area from the 11th to the 15th century. INGV-SGA, Bologna, 1037 pp.

Guidoboni E., Bernardini F., Comastri A., 2004a. The 1138-1139 and 1156-1159 destructive seismic crises in Syria, south-eastern Turkey and northern Lebanon. Journal of Seismology, 8, 105-127.

Guidoboni E., Bernardini F., Comastri A., Boschi E., 2004. The large earthquake on 29 June 1170 (Syria, Lebanon, and central southern Turkey). Journal of Geophysical Research, 109, B07304, 1-21.

Guidoboni E., Ferrari G., Mariotti D., Comastri A., Tarabusi G., Valensise G., 2007. CFTI4Med, Catalogue of Strong Earthquakes in Italy (461 B.C.-1997) and Mediterranean Area (760 B.C.-1500). INGV-SGA. http://storing.ingv.it/cfti4med

Gupta H. and Gahalaut V., 2009. Is the Northern Bay of Bengal Tsunamigenic? Bulletin of the Seismological Society of America, 99, 6, 3496-3501.

Gupta H. K., Rao N. P., Rastogi B. K. and Sarkar D., 2001. The deadliest intraplate earthquake. Science, 291, 5511, 2101-2102, doi:10.1126/science.1060197

Gupta H.K., 1993. Seismic hazard assessment in the Alpide belt from Iran to Burma. Annali di Geofisica, 36, 3-4, 61-82.

Hamdache M., Peláez J.A., Talbi A., López Casado C., 2010. A Unified Catalog of Main Earthquakes for Northern Algeria from A.D. 856 to 2008. Seismological Research Letters, 81, 5, 732-739.

Harbi A., Benouar D., Benhallou H., 2003. Re-appraisal of seismicity and seismotectonics in the north-eastern Algeria Part I: Review of historical seismicity. Journal of Seismology, 7, 115-136.

Harbi A., Maouche S., Vaccari F., Aoudia A., Oussadou F., Panza G.F., Benouar D., 2007. Seismicity, seismic input and site effects in the Sahel-Algiers region (North Algeria). Soil Dynamics and Earthquake Engineering, 27, 427-447.

Harbi A., Meghraoui M., Maouche S., 2011. The Djidjelli (Algeria) earthquakes of 21 and 22 August 1856 (Io VIII, IX) and related tsunami effects revisited. Journal of Seismology, 15, 105-129.

Harbi A., Peresan A., Panza G.F., 2010. Seismicity of Eastern Algeria: a revised and extended earthquake catalogue. Natural Hazards, 54, 3, 725-747, doi:10.1007/s11069-009-9497-6

Harnpattanapanich T. and Luddakul A., 2011. Seismic hazard of the Khorat Plateau: Preliminary review. In: Proceedings of International Conference on Geology, Geotechnology and Mineral Resources of Indochina (GEOINDO 2011), Khon Kaen, Thailand, pp 457-466.

Harris R. and Major J., 2012. Waves of destruction in the East Indies: English translation and analysis of the Wichmann catalog of earthquakes and tsunami in the Indonesian region from 1538 to 1877. in preparation.

Hée A., 1950. Catalogue des séismes algériens de 1850 à 1911. Annales de l'Institute de Physique du Globe, Strasbourg 6, 41-49.

Henni P.H.O., Fyfe C.J., Marrow P.C., 1998. The BGS World Seismicity Database. BGS Technical Report WL/98/13.

Hoff K.E.A. von, 1840. Chronik der Erdbeben und Vulkan Ausbrüche. Perthes, Gotha, IV, 470 pp.

Hough S., 2013. Missing Great Earthquakes. Journal of Geophysical Research (accepted), doi:10.1002/jgrb.50083

Hough S.E. and Elliot A., 2004. Revisiting the 23 February 1892 Laguna Salada Earthquake. Bulletin of the Seismological Society of America, 94, 4, 1571-1578.

Hough S.E. and Hutton K., 2008. Revisiting the 1872 Owens Valley, California, Earthquake. Bulletin of the Seismological Society of America, 98, 2, 931-949, doi:10.1785/0120070186

Hough S.E., Armbruster J.G., Seeber L., Hough J.F., 2000. On the Modified Mercalli intensities and magnitudes of the 1811-1812 New Madrid earthquakes. Journal of Geophysical Research, 105, b10, 23,839-23, 864.

Hudson B., 2008. Restoration and reconstruction of monuments at Bagan (Pagan), Myanmar (Burma), 1995-2008. World Archaeology, 40, 4, 553-571.

Icelandic Meteorological Office, 2007. Earthquakes in Iceland larger than magnitude 4 in the years 1706-1990.

Iñiguez H.M., Acosta R., Vizcaino J.A., 1975. Relación de sismos ocurridos en la Isla de Santo Domingo, (1551-1975). UASD, Santo Domingo, Dominican Republic, 45 pp.

INPRES (Instituto Nacional de Prevencion Sismica), 2012. Terremotos historicos de la Republica Argentina. http://www.inpres.gov.ar/seismology/historicos.php

Instituto Geografíco Nacional, 2010. Bases de datos macrosísmica. Macroseismic Data Points available at http://www.ign.es/ign/layoutIn/bdmacrosismica.do

ISC-GEM, 2012. ISC-GEM Global Instrumental Earthquake Catalogue (1900-2009), Final Scientific Report, 99 pp., http://www.isc.ac.uk/iscgem/index.php

Ishibashi K., 2004. Status of historical seismology in Japan. Annals of Geophysics, 47, 2-3, 339-368.

Ishibashi K., 2004a. Seismotectonic modeling of the repeating M7-class disastrous Odawara earthquake in the Izu collision zone, central Japan. Earth Planets Space, 56, 843-858.

Jaiswal K. and Sinha R., 2005. Table: Earthquake catalog data for Peninsular India (10-26 N, 68-90 E) after removal of dependent events using Rao and Rao (1984), Seeber et al. (1999) and NEIC PDE (2003). http://www.earthquakeinfo.org

Jaiswal K. and Sinha R., 2007. Probabilistic Seismic-Hazard Estimation for Peninsular India. Bullettin of the Seismological Society of America, 97, 1B, 318-330.

Jiang Wali, Deng Qidong, Xu Xiwei, Xie Xinsheng, 2004. Surface rupture zone of the 1303 Hongtong M=8 earthquake, Shanxi Province. Acta Sismologica Sinica, 17, 4, 389-397.

Johnston A.C., Coppersmith K.J., Kanter L.R., Cornell C.A., 1994. The earthquakes of stable continental regions: assessment of large earthquake potential. TR-102261, Electric Power Research Institute (EPRI), Palo Alto, 5 volumes.

Kagan Y.Y., Jackson D.D., Rong Y., 2006. A New Catalog of Southern California Earthquakes, 1800-2005. Seismological Research Letters, 77, 1, 30-38.

Kallner-Amiran D.H., 1950. A Revised Earthquake-Catalogue of Palestine. Israel Exploration Journal, 1, 4, 223-246.

Kalmetieva Z.A., Mikolaichuk A.V., Moldobekov B.D., Meleshko A.V., Jantaev M.M., Zubovich A.V., Havenith H.B., 2009. Atlas of earthquakes in Kyrgystan. CAIAG, Bishkek, 75 pp.

Kárník V., 1969. Seismicity of the European area, Part 1. Reidel Publishing Company, Dordrecht, Holland, 220 pp.

Karnik V., 1971. Seismicity of the European area, Part 2. Reidel Publishing Company, Dordrecht, Holland, 218 pp.

Kárník V., 1996. Seismicity of Europe and the Mediterranean, edited by Karel Klima. Geophysical Institute of the Academy of Sciences of the Czech Republic and StudiaGeo s.s.r.o., Praha.

Katsumata A., 1996. Comparison of Magnitudes Estimated by the Japan Meteorological Agency with Moment Magnitudes for Intermediate and Deep Earthquakes. Bulletin of the Seismological Society of America, 86, 3, 832-842.

Kausel E., 1979a. Comportamientos de diferentes suelos durante el terremoto del 16 de agosto de 1906. Informe para la Comisión Chilena de Energía Nuclear, 9 pp.

Kausel E., 1979b. Los terremotos de agosto 1868 y mayo 1977, que afectaron al sur del Perú y Norte de Chile. Inédito, Departamento de Geofísica, Santiago de Chile.

Khilko S.D., Kurushin R.A., Kochetkov V.M., Misharina L.A., Gilyova N.A., Lastochkin S.V., Balzhinnyam I., Monhoo D., 1985. Strong earthquakes, paleoseismogeological and macroseismic data. In: Earthquakes and the bases for Seismic Zoning of Mongolia, The joint Soviet-Mongolian scientific-research geological expedition, Transactions 41, Nauka, Moscow, 19-83 (in Russian).

Kim S.G. and Gao F.C., 1995. Korean Earthquake Catalogue. Seismological Institute, Hanyang University, Seoul, Korea, 120 pp.

Kingland J., Torres R., Inglessis P., 2008. Ecuación de atenuación de intensidad macrosísmica y mapa de isosistas para el gran terremoto de los andes de 1894. IMME, 46, 1, 1-22.

Kirkpatrik R., 1920. Earthquakes in Panamá up to January 1, 1920. Bulletin of the Seismological Society of America, 10, 120-128.

Klein F.W. and Wright T.L., 2000. Catalog of Hawaiian Earthquakes, 1823-1959. U.S. Geological Survey Professional Paper 1623. http://pubs.usgs.gov/pp/pp1623

Klinger Y., Rivera L., Haessler H., Maurin J-C., 1999. Active faulting in the Gulf of Aqaba: new knowledge from the Mw 7.3 earthquake of 22 November 1995. Bulletin of the Seismological Society of America, 89, 4, 1025-1036.

Kondorskaya N.V. and Shebalin N.V. (eds), 1982. New Catalogue of strong earthquakes in the USSR from Ancient Times through 1975. 2nd edition, Boulder, Colorado, 608 pp. (1st edition, 1977, Moscow, 536 pp., in Russian).

Kondorskaya N.V. and Ulomov V.I., 1999. Special earthquake catalogue of Northern Eurasia from ancient times through 1995 (SECNE). Joint Institute of Physics of the Earth (JIPE), Russian Academy of Sciences, Moscow, Russia. http://www.seismo.ethz.ch/static/gshap/neurasia/nordasiacat.txt

Lamontagne M., Halchuk S., Cassidy J.F., Rogers G.C., 2007. Significant Canadian Earthquakes 1600-2006. Geological Survey of Canada, Open File 5539, 32 pp. + 6 maps.

Lamontagne M., Halchuk S., Cassidy J.F., Rogers G.C., 2008. Significant Canadian Earthquakes of the Period 1600-2006. Seismological Research Letters, 79, 2, 211-223, doi:10.1785/gssrl.79.2.211

Larde J., 1960. Obras Completas. Publicaciones del Ministerio de Cultura, San Salvador, 597 pp.

Le Dain A.Y, Tapponnier P., Molnar P., 1984. Active Faulting and Tectonics of Burma and Surrounding Regions. Journal of Geophysical Research, 89, B1, 453-472.

Lee K. and Yang W.S., 2006. Historical Seismicity of Korea. Bulletin of the Seismological Society of America, 96, 3, 846-855 + electronic supplement, doi:10.1785/0120050050

Lee K., 1999. Historical earthquake data of Korea. Journal of the Korea Geophysical Society, 1, 3-22 (in Korean with abstract in English).

Lee W.H.K., Kanamori H., Jennings P.C., Kisslinger C. (eds), 2002. International Handbook of Earthquake and Engineering Seismology. Academic Press, San Diego, Part A, 1200 pp.; Part B, 1000 pp.

Lee W.H.K., Meyers H., Shimazaki K. (eds), 1988. Historical seismograms and earthquakes of the World. Academic Press, San Diego.

Leeds D., 1974. Catalogue of Nicaraguan earthquakes. Bulletin of the Seismological Society of America, 64, 4, 1135-1158.

Levret A. and Vogt J., 1992. Towards the solution of some problems of the historical seismicity of Morocco. Proceedings of the regional workshop on archaeoseismicity in the Mediterranean region, November 4-7, 1992, Damascus, Syrian Arab Republic Atomic Energy Commission (AECS), Damascus, 106-115.

Levret A., 1991. The effects of the November 1, 1755 "Lisbon" earthquake in Morocco. Tectonophysics, 193, 1-3, 83-94.

Leyu C.-H., Chang C.-F., Arnold E.P., Kho S.-L., Lim Y.-T., Subramaniam M., Ong T.-C., Tan C.-K., Yap K.-S., Shu Y. K., Goh H.-L., 1985. South East Asia Association of Seismology and Earthquake Engineering, Series on Seismology, vol. III, Malaysia, 104 pp.

Li Y.C., 1986. Korean earthquake catalogue (2 AD-1983). Seismological Press, Beijing, China, 69 pp.

Li Zejiang, 1957. Earthquakes of Peking. Acta Geophysica Sinica, VI, 2, 181-219 (in Chinese).

LNEC, 1986. A Sismicidade Histórica e a Revisão do Catálogo Sísmico. Laboratorio Nacional de Engenharia Civil, Lisboa, 189 pp.

Locati M. and Cassera A., 2010. MIDOP: Macroseismic Intensity Data Online Publisher. Rapporti Tecnici INGV, 123, 92 pp. http://istituto.ingv.it/l-ingv/produzione-scientifica/rapporti-tecnici-ingv/archivio/copy_of_numeri-pubblicati-2010/2010-01-29.1754295499

Locati M., Camassi R., Stucchi M. (eds), 2011. DBMI11, the 2011 version of the Italian Macroseismic Database. Milano, Bologna. http://emidius.mi.ingv.it/DBMI11

Lomnitz C., 1970. Major Earthquakes and Tsunamis in Chile During the Period 1575 to 1955. Geologische Rundschau, 59, 3, 938-960.

Lomnitz C., 1974. Developments in Geotectonics 5: Global Tectonics and Earthquake Risk. Elsevier Scientific Pub. Co., 320 pp.

Lomnitz C., 2004. Major Earthquakes of Chile: A Historical Survey, 1535-1960. Seismological Research Letters, 75, 3, 368-378.

López Casado C., Molina S., Delgado J., Peláez J.A., 2000. Attenuation of intensity with epicentral distance in the Iberian Peninsula. Bulletin of the Seismological Society of America, 90, 1, 34-47.

Lopez Marinas J.M. and Salord R., 1990. El periodo sismico oranes de 1790 a la luz de la documentacion de los archivos españoles. MOPU-IGN, Monografias 6, Madrid, 64 pp.

Ludwin R.S. and Qamar A.I., 1995. Historic seismicity catalog and macroseismic accounts for Cascadia, 1793-1929. University of Washington Geophysics Program, 72 pp.

Makropoulos K., Kaviris G., Kouskouna V., 2012. An updated and extended earthquake catalogue for Greece and adjacent areas since 1900. Natural Hazards and Earth System Sciences, 12, 1425-1430. With supplement.

Mallet R., 1853-1855. Third Report on the facts of Earthquakes Phenomena, Catalogue of recorded Earthquakes from 1606 B.C. to A.D. 1850. Report of the 22nd Meeting of the British Association for the Advancement of Science,1-176; Report of the 23rd Meeting of the British Association for the Advancement of Science, 117-212; Report of the 24th Meeting of the British Association for the Advancement of Science, 1-326.

Maouche S., Harbi A., Meghraoui M., 2008. Attenuation of Intensity for the Zemmouri Earthquake of 21 May 2003 (Mw 6.8): Insights for the Seismic Hazard and Historical Earthquake Sources in Northern Algeria. In: J. Fréchet, M. Meghraoui, M. Stucchi (eds), Historical Seismology, Interdisciplinary Studies of Past and Recent Earthquakes, Springer, 327-350.

Martin S. and Szeliga W., 2010. A Catalog of Felt Intensity Data for 570 Earthquakes in India from 1636 to 2009. Bulletin of the Seismological Society of America, 100, 2, 562-569, electronic Supplement, doi:10.1785/0120080328

Martinez H. and Maximiliano A., 1978. Cronologia Sismica y Eruptiva de la Republica de El Salvador a partir de 1520. Ministerio de Obras Publicas, Centro de Investigaciones Geotecnicas, 40 pp.

Martinez Solares J.M. and J. Mezcua Rodriguez (eds), 2002. Catalogo sismico de la Peninsula Iberica (880 a.C.-1990). IGN, Madrid, Monografía Núm. 18, 254 pp.

Martins I. and Mendes Victor L.A., 2001. Contribuiçao para o estudo da sismicidade da regiao oeste da peninsula iberica, Universidade de Lisboa, Instituto Geofisico do Infante D. Luis, Publ. N. 25, 67 pp.

McCue K. (ed), Cuthbertson R., Gibson G., Love D., Payne C., Peck W., 2008. Australian Seismological Report 2008 - addendum. Geoscience Australia, 22 pp.

McCue K., 1999. Australian Seismological Report - 1999. Australian Seismological Centre, Canberra, 30 pp.

McCue K.F., 1975. Seismicity and Seismic Risk in South Australia. University of Adelaide, Report ADP 137.

Meletti C., Patacca E., Scandone P., Figliuolo B., 1988. Il terremoto del 1456 e la sua interpretazione nel quadro sismotettonico dell'Appennino meridionale. In: Figliuolo B. (ed), Il terremoto del 1456, Napoli, I, 1, 71-108. Macroseismic Data Points available at http://emidius.mi.ingv.it/DOM

Mezcua J. and Martinez Solares J.M., 1983. Sismicidad del Area Ibero-Mogrebi. Instituto Geografico Nacional, Publ. 303, Madrid, 189 pp.

Mezcua J., Rueda J., García Blanco R.M., 2004. Reevaluation of Historic Earthquakes in Spain. Seismological Research Letters, 75, 1, 75-81.

Michael-Leiba M.O., 1989. Macroseismic effects, locations and magnitudes of some early Tasmanian earthquakes. Journal of Australian Geology and Geophysics, 11, 89-99.

Midzi V., Hlatywayo D.J., Chapola L.S., Kebede F., Atakan K., Lombe D.K., Turyomurugyendo G., Tugume F.A., 1999. Seismic hazard assessment in Eastern and Southern Africa. Annali di Geofisica, 42, 6, 1067-1083.

Milne J., 1911. A catalogue of destructive earthquakes, A.D. 7 to A.D. 1899. British Association for the Advancement of Science, Seismological Committee, London, 92 pp.

Min Ziqun (ed), 1995. Chinese Historical Catalog from 2300 B.C. to 1911 A.D. Seismological Press, Beijing, 514 pp. (in Chinese).

Miyamura S., 1980. Sismicidad de Costa Rica. Editorial Universidad de Costa Rica, San Jose, pp. 190.

Mocquet A., 2007. Analysis and Interpretation of the October 21 1766 earthquake in the Southeastern Caribbean. Journal of Seismology, 11, 4, 381-403.

Mokrane A., Aït Messaoud A., Sebaï A., Menia N., Ayadi A., Bezzeghoud M., 1994. Earthquakes in Algeria from 1365 to 1992. CRAAG Report, Algiers, Algeria (in French).

Molina del Villar A., 2004. 19th century earthquakes in Mexico: three cases, three comparative studies. Annals Of Geophysics, 47, 2-3, 497-508.

Monachesi G. and Stucchi M., 1997. DOM4.1, un database di osservazioni macrosismiche di terremoti di area italiana al di sopra della soglia del danno. GNDT, Milano. http://emidius.mi.ingv.it/DOM

Montbéliard G.D., 1761. Liste chronologique des éruptions de volcans, de tremblements de terre… jusqu'en 1760. Collection Académique, Partie Etrangère, t. VI, 488-681.

Montero W. and Peraldo G., 2004. Current knowledge on the Central America historical seismicity: an analisys of recent catalogues. Annals of Geophysics, 47, 2-3, 477-485.

Montero W., 1989. Sismicidad histórica de Costa Rica, periodo 1610-1910. Revista Geofisica International, 28, 531-559.

Montessus de Ballore F. de, 1888. Tremblements de terre eruptions volcaniques dans le Centre Amerique, depuis la conquête espagnole jusqu'à nos jours. Societe des Sciences Naturelles de Saone-et-Loire, Dijon, 293 pp.

Montessus de Ballore F. de, 1906. Les tremblements de terre: Geographie seismologique. Librairie Armand Colin, Paris, 475 pp. + 3 cartes.

Montessus de Ballore F. de, 1911. Historia sísmica de los andes Meridionales. Imprenta Universitaria, Santiago de Chile, 345 pp.

Montessus de Ballore F. de, 1912. Bibliografía general de temblores y terremotos. Sociedad Chilena de Historia y Geografía, Santiago de Chile.

Montessus de Ballore F. de, 1916. Historia sísmica de los andes Meridionales. Editorial Cervantes, Santiago de Chile.

Musha K. (ed), 1941, 1943a, b. Historical Documents on Earthquakes in Great Japan, vols. 1-3 (Earthquake Prevention Council, Ministry of Education), enlarged and revised edition, 945 pp., 754 pp., 945 pp. (in Japanese).

Musha K. (ed), 1951. Historical Documents on Earthquakes in Japan. The Mainichi Newspapers Co., Tokyo, 757 pp. (in Japanese).

Mushketov I.V and Orlov A.P., 1893. Catalogue of earthquakes of Russian Empire (Katalog zemletryaseniy Rossiyskoi Imperii). Notes of Russian Geographic Soc., St. Peterburg, 26, 582 pp. (in Russian).

Musson R.M.W. and Cecic I., 2002. Macroseismology. In: W.H.K. Lee, H. Kanamori, P.C. Jennings, C. Kisslinger (eds), International Handbook of Earthquake and Engineering Seismology, Part A. Academic Press, San Diego, 807-822.

Musson R.M.W. and Holt D.N., 2001. Napoleon's earthquake: The seismicity of St Helena. Seismological Research Letters, 72, 712-724.

Musson R.M.W. and Sargeant S.L., 2006. Potential tsunami sources in the Bay of Bengal. British Geological Survey Technical Report, CR/06/061.

Musson R.M.W., 1991. A provisional earthquake catalogue for the Hong Kong Region. BGS Global Seismology Report No WL/91/39.

Musson R.M.W., 1995. Historical seismicity of South China from European sources: example of the Hong Kong newspaper press. Acta Seismologica Sinica, 8, 487-490 (in Chinese).

Musson R.M.W., 1996. An earthquake catalogue for the Circum-Pannonian Basin. In: D. Papanikolaou and J. Papoulia J. (eds), Seismicity of the Carpatho-Balcan Region, Proc. XV Congress of the Carpatho-Balcan Geol. Ass., Athens, 17-20 Sep 1995, 233-238.

Musson R.M.W., 2009. Subduction in the Western Makran: the historian's contribution. Journal of the Geological Society, 166, 3, 387-391, doi:10.1144/0016-76492008-119

Musson R.M.W., 2012. Seismicity of Ghana. British Geological Survey Open Report, OR/12/042, 16 pp.

Musson R.M.W., 2012a. A provisional catalogue of historical earthquakes in Indonesia. British Geological Survey Open Report OR/12/073, Edinburgh, 21 pp.

Musson R.M.W., 2012b. Large historical earthquakes in Australia. British Geological Survey Open Report OR/12/074, Edinburgh, 27 pp.

Musson R.M.W., 2012c. Large historical earthquakes in New Zealand and South Pacific. British Geological Survey, Edinburgh.

Musson R.M.W., 2012d. Two neglected great earthquakes in South Asia. British Geological Survey Open Report, OR/12/061, Edinburgh.

Musson R.M.W., Grünthal G., Stucchi M., 2010. The comparison of macroseismic intensity scales. Journal of Seismology, 14, 413-428, doi: 10.1007/s10950-009-9172-0

Musson R.M.W., Sargeant S.L., Phillips E.R., Long D., McCue K., Ambraseys N.N., 2005. Seismic hazard of the United Arab Emirates, British Geological Survey Technical Report, CR/05/229.

Nabavi M.S., 1978. Historical Earthquakes in Iran c. 300 B.C. - 1900 A.D,. Journal of the Earth and Space Physics, 7, 70-117.

Nath S.K., Thingbaijam K. K. S., Ghosh S. K., 2010, Earthquake catalogue of South Asia - a generic MW scale framework. http://earthqhaz.net/sacat

Newcomb K.R. and McCann W. R., 1987. Seismic history and seismotectonics of the Sunda Arc. Journal of Geophysical Research, 92, 421-439.

NGDC-NOAA, 1985. U.S. Earthquake Intensity Database, 1638-1984. http://www.ngdc.noaa.gov/hazard/int_srch.shtml

Nguyen K.M., 1994b. Les séismes au Vietnam d'après les documents historiques. Proceedings of International Workshop on Seismotectonics and Seismic Hazard in South East Asia, Hanoi, 150-156.

Nguyen N.T., 1994a. Seismicity of Indochina. Proceedings of International Workshop on Seismotectonics and Seismic Hazard in South East Asia, Hanoi, 158.

Nishenko S.P. and Singh S.K., 1987. Relocation of the Great Mexican Earthquake of 14 January 1903. Bulletin of the Seismological Society of America, 77, 1, 256-259.

Nuñez-Cornu F. and Ponce L., 1989. Seismic zoning of Oaxaca, Mexico: maximum earthquakes and times of recurrence for the period 1542-1988. Geofísica Internacional, 28, 587-641.

Nutalaya P., Sodsri S., Arnold E.P., 1985. South East Asia Association of Seismology and Earthquake Engineering, Series on Seismology, vol. II, Thailand, 409 pp.

Öcal N., 1968. Türkiyenin Sismisitesi ve Zelzele Corafyas1 , 18501960. Y1llar1 0çin Zelzele Katolou, Kandilli Rasathanesi Yay1nlar1, 8, 0stanbul (in Turkish).

Oldham R.D., 1883. A catalogue of Indian earthquakes from the earliest time to the end of A.D. 1869. Memoirs of the Geological Survey of India, Calcutta, 19, 3, 163-215.

Oldham R.D., 1899. Report on the great earthquake of 12th June 1897 (incl. the reports by P. Bose, G. Grimes, H. Hayden, T. LaTouche, E. Vredenburg), Memoirs of the Geological Survey of India, Calcutta, 29, 1379 pp.

Olivera C., Redondo E., Lambert J., Riera Melis A., Roca A., 2006. Els terratrèmols dels segles XIV I XV a Catalunya. Institut Cartogràfic de Catalunya, Barcelona. http://www.igc.cat/web/ca/sismologia_bdmacrosis.html

Omori F., 1919. Descriptive table of Japanese great earthquakes. Report of the Imperial Earthquake Investigation Committee, 88, B, 1-71 (in Japanese).

Oncescu M.C., Marza V.I., Rizescu M., Popa M., 1999. The Romanian earthquake catalogue between 984-1997. In: F. Wenzel and D. Lungu (eds), Contributions from the First International Workshop on Vrancea Earthquakes, Bucharest, Romania, November 1-4, 1997, Kluwer Academic Publishers, 43-48.

Ornthammarath T., Warnitchai P., Warnitchai K., Warnitchai S., Sigbjörnsson R., Lai C.G., 2010. Probabilistic seismic hazard assessment for Thailand. Bulletin of Earthquake Engineering, 9, 367-394.

Orozco y Berra J., 1887-1888. Efemérides seísmicas mexicanas. Memorias de la Sociedad Cientifica "Antonio Alzate", 303-541.

Ortiz M. and Bilham R., 2003. Source area and rupture parameters of the 31 December 1881 Mw = 7.9 Car Nicobar earthquake estimated from tsunamis recorded in the Bay of Bengal. Journal of Geophysical Research, 108, B4, 2215, doi:10.1029/2002JB001941

Palazzo L., 1915. Cronistoria dei terremoti etiopici anteriori all'anno 1913. Bollettino della Società Sismologica Italiana, 19, 293-345.

Palme C., Choy J., Guada C., 2009. Wilhalm Sievers y el Terremoto del 29-oct-1900 reflexiones preliminares. V Jornadas Venezolanas de Sismología Histórica y VI Simposio Venezolano de Historia de las Geociencias, 25-28 de Junio, Mérida, 145-150.

Palme de Osechas C., Morandi M., Choy J.E., 2005. Re-evaluación de las intensidades de los grandes sismos históricos de la región de la cordillera de Mérida utilizando el método de Bakun & Wentworth. Revista Geografica Venezolana, Numero especial, 233-253.

Pan T.-C. and Sun J., 1996. Historical Earthquakes Felt in Singapore. Bulletin of the Seismological Society of America, 86, 4, 1173-1178.

Papazachos B.C. and Papazachou C., 2003. The earthquakes of Greece. Ziti Publ. Co., Thessaloniki, Greece, 286 pp. (in Greek).

Papazachos B.C., Comninakis P.E., Scordilis E.M., Karakaisis G.F., Papazachos C.B., 2009. A catalogue of earthquakes in the Mediterranean and surrounding area for the period 1901-2008. Publ. Geophys. Laboratory, University of Thessaloniki.

Peláez J.A., Chourak M., Tadili B.A., Aït Brahim L., Hamdache M., López Casado C., Martínez Solares C.M., 2007. A Catalog of Main Moroccan Earthquakes from 1045 to 2005. Seismological Research Letters, 78, 6, 614-621.

Peraldo H.G. and Montero P.W., 1999. Sismología Histórica de América Central. IPGH, México, Geofisica, 513, 347 pp.

Perrey A., 1843. Nouvelles recherches sur les tremblements de terre ressentis en Europe, et dans les parties de l'Afrique et de l'Asie de 1801 à juin 1843. Comptes Rendus Hebdomadaires des séances de l'Académie des Sciences, Paris, 17, 608-625.

Perrey A., 1846. On Earthquakes in Northern Europe and Asia, translated by A. Kupfer, Summary of Magnetic and Meteorological Studies, St. Petersburg.

Perrey A., 1847. Note sur les tremblements de terre en Algerie et dans l'Afrique Septentrionale. Mémoires de l'Academie de Dijon, Partie des Sciences, 299-323.

Perrey A., 1850. Mémoires sur les tremblements de terre ressentis dans la peninsule Turco-héllenique et en Syrie. Mémoires couronnées et mémoires des savant etrangers. Academie Royale des Sciences, des Lettres et des Beaux Arts de Belgique, Bruxelles, 23, 73 pp.

Perrey A., 1858. Documents sur les tremblements de terre au Pérou, dans la Colombie et dans le bassin de l'Amazone. Académie Royale des Sciences, des Lettres et des Beaux-Arts de Belgique, 3e Mémoires couronnés et autres mémoires, t. 7, 134 pp.

Perrey A., 1861. Documents sur les tremblements de terre et les phénomènes volcaniques dans l'Archipel des Philippines. Mémoires de l'Académie impériale des sciences, arts et belles-lettres de Dijon, Section des Sciences, Année 1860, Dijon-Paris, 85-194+1 map of volcanoes.

Petersen M.D., Harmsen S.C., Mueller C., Haller K.M., Dewey J.F., Luco N., Crone A.J., Lidke D., Rukstales K.S., 2007. Documentation for the Southeast Asia seismic hazard maps. USGS, Administrative Report September 30, 2007.

Pinar N. and Lahn E., 1952. Catalogue of Turkish earthquakes. Ministry of Public Works and Settlement, Office of Public Works, Ankara, 6 (in Turkish).

Pinilla V. and Toral J., 1987. Sismicidad histórica sentida en el Istmo de Panamá. Revista Geofisica, 27, 135-165.

Poey A.M., 1857. Catalogue chronologique des tremblements de terre ressentis dans les Indes-Occidentales de 1530 a 1857, accompagne d'une Revue bibliographique contenant tous les travaux relatifs aux tremblements de terre des Antilles. Annuaire de la Societe Meteorologique de France, Bullettin des Seances, t.5, 2 partie, 75-127.

Poirier J.P. and Taher M.A., 1980. Historical seismicity in the near and Middle East, North Africa, and Spain from Arabic documents (VIIth-XVIIIth century). Bulletin of the Seismological Society of America, 70, 6, 2185-2201.

Prachuab S., 1988. Historical Earthquakes of Thailand, Burma, and Indochina. In: W.H.K. Lee, H. Meyers, K. Shimazaki (eds), Historical Seismograms and Earthquakes of the World, Academic Press Inc., San Diego, 253-266.

Rajendran K. and Rajendran C.P., 2011. Revisiting the earthquake sources in the Himalaya: Perspectives on past seismicity. Tectonophysics, 504, 75-88.

Ramdani M., Tadili B., El Mrabet T., 1989. The present state of knowledge on historical seismicity of Morocco. Proceedings of the symposium on Calibration of historical earthquakes in Europe and recent developments in intensity interpretation, European Seismological Commission, Sofia 23-28 August 1988, Cursos y Seminarios 3, Instituto Geografico Nacional, Madrid, 258-279.

Ramírez J.E., 1969. Historia de los terremotos en Colombia. Editorial Argra, Bogotá, 218 pp.

Ramírez J.E., 1975. Historia de los terremotos en Colombia, segunda edición. Instituto Geográfico Agustín Codazzi, Bogotá, 250 pp.

Reid H.F. and Taber S., 1919. The Porto Rico earthquake of 1918. House of Representatives, 66th Congress, 1st Session, Document No. 269, November 19, 1919.

Reid H.F. and Taber S., 1920. The Virgin Islands earthquakes of 1867-1868. Bulletin of the Seismological Society of America, 10, 1, 9-30.

Rengifo M. and Lafaille J., 2000. Reevaluacion del sismo del 28 de abril de 1894. Acta Científica Venezolana, 51, 160-175.

Repetti W.C., 1946. Catalogue of Philippine Earthquakes, 1589-1899. Bulletin of the Seismological Society of America, 36, 3, 133-322.

Rho S.G., 2000. Analysis of the supplemented historical earthquake data since the 17th century in the Korean peninsula. M.S. Thesis, Korea National University of Education (in Korean).

Richter C.F., 1958. Elementary Seismology. W.H. Freeman and Company, San Francisco, 768 pp.

Robson G.R., 1964. An earthquake catalogue for the Eastern Caribbean. Bulletin of the Seismological Society of America, 54, 2, 785-832.

Rojas Rabiela T., Pérez Zevallos J.M.,García-Acosta V. et al., 1987. "Y volvió a temblar" Cronología de los sismos en México (De 1 Pedernal a 1821). Centro de Investigaciones y Estudios Superiores en Antropología Social México.

Rojas W., 1993. Catalogo de sismicidad historica y reciente en America Central, desarrollo y analisis. Tesis de Licenciatura en Geologia, Universidad de Costa Rica, San Jose, 91 pp.

Rojas W., Bungum H., Lindholm C., 1993. Historical and recent earthquakes in Central America. Revista Geologica de America Central , 16, 5-22.

Rothé J.P., 1950. Les séismes de Kherrata et la séismicité de l'Algérie. Bulletin du Service de la carte géologique de l'Algérie, 4 ème série, Géophysique, 3, 40 pp.

Roussel J., 1973. Les zones actives et la fréquence des séismes en Algérie 1716-1970, Bulletin de la Société d'histoire naturelle d'Afrique du Nord, 64, 3, 11-227.

Roux G., 1934. Notes sur les tremblements de terre ressentis au Maroc avant 1933. Mémoires de la Société des sciences naturelles du Maroc, 39, 42-71.

Rubbia G., 2004. A review of intensity data bank online. Annals of Geophysics, 47, 2-3, 873-884.

Saderra-Maso M., 1895. La seismologia en Filipinas; datos para el estudio de terremotos del archipelago Filipino. Observatorio de Manila, Manila, 122 pp.+ 42 maps.

Sakellariou N., Kouskouna V., Makropoulos K.C., 2010. Macroseismic Intensities in Central-Southern Peloponnese during the 19th century. N&K University of Athens, Greece, Internal Report. Macroseismic Data Points available in the Hellenic Macroseismic Database of the University of Athens. http://macroseismology.geol.uoa.gr

Salcedo Hurado E. de J. and A.N. Castaño, 2011. Reevaluacion macrosismica del terremoto del 12 de julio de 1785 en Colombia. Boletin de Geologia de la Univerisdad Industrial de Santander, Bucaramanga (in press).

Salterain y Legarra P., 1884. Ligera resena de los temblores de tierra ocurridos en la Isla de Cuba. Anales Academia de Ciencias de Cuba, 21, 203-218.

Sapper K., 1925. Los Volcanes de la America Central. Max Niemeyer, Halle, 116 pp.

Sarabia Gomez A.M., Cifuentes Avendaño H.G., Robertson K., 2010. Analisis historico de los sismos ocurridos en 1785 y 1917 en el centro de Colombia. Cuadernos de Geografia, Revista Colombiana de Geografia, Bogota, 19, 153-162.

Satake K., Wang K., Atwater B.F., 2003. Fault slip and seismic moment of the 1700 Cascadia earthquake inferred from Japanese tsunami descriptions. Journal of Geophysical Research, 108, B11, 2535, 17 pp., doi:10.1029/2003JB002521

Sbar M.L. and DuBois S.M., 1984. Attenuation of intensity for the 1887 Northern Sonora, Mexico earthquake. Bulletin of the Seismological Society of America, 74, 6, 2613-2628.

Sbeinati M.R., Darawcheh R., Mouty M., 2005. The historical earthquakes of Syria: an analysis of large and moderate earthquakes from 1365 B.C. to 1900 A.D. Annals of Geophysics, 48, 3, 347-435.

Scherer J., 1912. Great earthquakes in the island of Haiti. Bulletin of the Seismological Society of America, 2, 3, 161-180.

Schmidt J.F., 1879. Studien über Erdbeben, Leipzig, 360 pp.

Schorlemmer D., Wyss A., Maraini S., Wiemer S., Baer M., 2004. QuakeML - An XML schema for seismology. ORFEUS Newsletter, 6, 2, October 2004. http://www.orfeus-eu.org/Organization/Newsletter/vol6no2/quakeml.shtml

Schulte S.M. and Mooney W.D., 2005. An updated global earthquake catalogue for stable continental regions: reassessing the correlation with ancient rifts. Geophysical Journal International, 161, 707–721, doi:10.1111/j.1365-246X.2005.02554.x

Shebalin N.V. (ed), 1974. Atlas of isoseismal maps. III, UNDP-UNESCO Survey of the seismicity of the Balkan region. Skopje, 275 pp.

Shebalin N.V. (ed), 1977. Atlas of isoseismal maps for the "New Catalogue of Strong Earthquakes on the USSR territory from Ancient Times through 1975". Archive of the Institute of Physics of the Earth (IPE), Moscow (unpublished).

Shebalin N.V. and Leydecker G., 1997. Earthquake Catalogue for the Former Soviet Union and Borders up to 1988. European Commission, Report No. EUR 17245 EN, Nuclear Science and Technology Series, Office for Official Publications of the European Communities, Luxembourg, 135 pp., 13 figs.

Shebalin N.V. and Tatevossian R.E., 1997. Catalogue of large historical earthquakes of the Caucasus. In: Giardini D. and Balassanian S. (eds), Historical and Prehistorical Earthquakes in the Caucasus, NATO ASI Series 2: Environment - vol. 28, Kluwer Academic Publishers, 201-232.

Shebalin N.V., Karnik V., Hadzievski D. (eds), 1974. Catalogue of earthquakes of the Balkan region. I, UNDP-UNESCO Survey of the seismicity of the Balkan region. Skopje, 600 pp.

Shebalin N.V., Leydecker G., Mokrushina N.G., Tatevossian R.E., Erteleva O.O., Vassiliev V.Yu., 1998. Earthquake Catalogue for Central and Southeastern Europe 342 BC-1990 AD - Final Report to Contract ETNU - CT 93 - 0087.

Shepherd J.B. and Lynch L.L., 1992. An earthquake catalogue for the Caribbean Part I, the pre-instrumental period 1502-1900. Report submitted to the Executive Committee of the Latin American and Caribbean Program of Seismic Vulnerability, 59 pp.

SICAT, 2011. Sistema de información para el inventario, catalogación, valoración y administración de la información técnico-científica: Sismicidad histórica en Colombia. Estudios macrosísmicos (1644-2008). INGEOMINAS, Instituto Colombiano de Geologia y Mineria, Bogotà.

Sieberg A., 1932. Erdbebengeographie. Handbuch der Geophysik, Berlin, Bd. 4, 687-1005.

Sieberg A., 1932b. Untersuchungen über Erdbeben und Bruchschollenbau im ostlichen Mittlemeergebiet. Denkschriften der Medizin-Naturwissenschaften Gesellschaft zu Jena, Jena, 2.

Sieh K., Natawidjaja D.H., Chlieh M., Galetzka J., Avouac J-P., 2004. The giant subduction earthquakes of 1797 and 1833, west Sumatra: characteristic couplets, uncharacteristic slip. Proceedings of the Transactions of the American Geophysical Union.

Silgado E., 1968. Historia de los sismos más notables ocurridos en Perú (1515-1960). Boletín Bibliográfico de Geografía y Oceanografía Americana 4, 191-241.

Silgado E., 1978. Historia de los sismos más notables ocurridos en el Perú (1513-1974). Instituto Geología y Minería, Boletín, Lima, 3, 130 pp.

Silgado E., 1985. Destructive earthquakes of South America 1530-1894. Earthquake Mitigation Program in the andean Region (Project SISRA), vol. 10, CERESIS, Lima, 328 pp.

Silgado E., 1992. Investigación de Sismicidad Histórica en la América del Sur en los Siglos XVI, XVII, XVIII y XIX. Concytec-CERESIS, Perú, 108 pp.

Singh S.K., Astiz L., Havskov J., 1981. Seismic gaps and recurrence periods of large earthquakes along the Mexican Subduction Zone: a reexamination. Bulletin of the Seismological Society of America, 71, 3, 827-843.

Singh S.K., Ordaz M., Perez-Rocha L.E., 1996. The Great Mexican Earthquake of 19 June 1858: Expected Ground Motions and Damage in Mexico City from a Similar Future Event. Bulletin of the Seismological Society of America, 86, 6, 1655-1666.

Sismología Histórica de Venezuela, 2011. At the Universidad de Los Andes. http://sismicidad.ciens.ula.ve

Slemmons D.B., Jones A.E., Gimlett J.I., 1965. Catalog of Nevada Earthquakes, 1852-1960. Bulletin of the Seismological Society of America, 55, 2, 537-583.

Smith W.E.T., 1962. Earthquakes of Eastern Canada and Adjacent Areas 1534-1927. Publications of the Dominion Observatory, Ottawa, 26, no. 5.

Soloviev S.L. and Go C.N., 1974. A catalogue of tsunamis on the western shore of the Pacific Ocean (173-1968). Nauka Publishing House, Moscow (in Russian).

Sousa Moreira V., Sousa Marques J., Fonseca Cruz J., Costa Nunes J., 1993. Review of the historical seismicity in the Gulf of Cadiz area before the 1 November 1755 earthquake. An intermediate report. In: M. Stucchi (ed), Materials of the CEC project "Review of Historical Seismicity in Europe", CNR, Milano, vol. 1, 225-235.

Sousa Moreira V.J., 1984. Sismicidade historica de Portugal continental. Revista Nacional de Meteorologia e Geofisica, Lisboa, 79 pp.

Soysal H., Sipahioglu S., Kolcak D., Altinok Y., 1981. Turkiye ve Cevresinin Tarihsel deprem Katalogu. TUBITAK, Proje no. TBAG 341, Istanbul, 86 pp.

Stepanian V.A., 1942. Istoricheskii obzor zemletriaseniiakh v Armenii i v prilegaiuscchikh rayonakh: kratkaia chronologiya. Proceedings of Zakaykazskaia Konferentsiaa po Antiseismitseskoi Struitel'stvu, Akad. Nauk Izdat. Armen. F.A.N., Erivan, 43-72.

Stepanian V.A., 1964. Zemlettriasenia v. Arminskom nagorie i okrestnostiakh, Izdat, Ayastan, Erivan.

Stepp J.C., 1972. Analysis of Completeness of the Earthquake Sample in the Puget Sound Area and Its Effect on Statistical Estimates of Earthquake Hazard. Proceedings of the International Conference on Microzonation, Seattle, U.S.A., 2, 897-910.

Stirling M.W. and Goded T., 2012. Magnitude scaling relationships. GEM Faulted Earth & Regionalisation Global Components, GNS, GNS Science Miscellaneous Series 42.

Stover C.W. and Coffman J.L., 1993. Seismicity of the United States, 1568-1989 (Revised). U.S. Geological Survey Professional, Paper 1527, 418 pp. http://pubs.er.usgs.gov/publication/pp1527

Strasser F.O., Arango M.C., Bommer J.J., 2010. Scaling of the source dimensions of interface and intraslab subduction-zone earthquakes with moment magnitude. Seismological Research Letters, 81, 6, 941-950.

Stucchi M. (ed), 1993. Materials of the CEC project "Review of Historical Seismicity in Europe", vol. 1, CNR, Milano.

Stucchi M. (ed), 1998. The EC project "A Basic European Earthquake Catalogue and a database for the evaluation of long-term seismicity and seismic hazard". Final Report, Milano.

Stucchi M. and Camassi R., 1997. Building up a parametric earthquake catalogue in Europe: the historical background. In: Giardini D., Balassanian S. (eds), Historical and prehistorical earthquakes in the Caucasus. Dordrecht, NATO ASI Series, 2 Environment, 28, 357-374.

Stucchi M. and Locati M. (eds), 2008. European Macroseismic Database (demo version) 1000-1600, M > 5.0. NERIES Project, Networking Activity 4, Deliverable D4, 41 pp. http://www.neries-eu.org/main.php/NA4_D4.pdf?fileitem=9502744

Stucchi M., 1994. Recommendations for the compilation of a European parametric earthquake catalogue, with special reference to historical records. In Albini P. and Moroni A. (eds), Materials of the CEC project "Review of Historical Seismicity in Europe", vol. 2, CNR, Milano, 181-190.

Stucchi M., Camassi R., Rovida A., Locati M., Ercolani E., Meletti C., Migliavacca P., Bernardini F., Azzaro R. (eds), 2007. DBMI04, il database delle osservazioni macrosismiche dei terremoti italiani utilizzate per la compilazione del catalogo parametrico CPTI04. Quaderni di Geofisica 49, INGV. http://emidius.mi.ingv.it/DBMI04

Stucchi M., Rovida A., Gomez Capera A.A., Alexandre P., Camelbeeck T., Demircioglu M.B., Gasperini P., Kouskouna V., Musson R.M.W., Radulian M., Sesetyan K., Vilanova S., Baumont D., Bungum H., Fäh D., Lenhardt W., Makropoulos K., Martinez Solares J.M., Scotti O., Živcic M., Albini P., Batllo J., Papaioannou C., Tatevossian R., Locati M., Meletti C., Viganò D., Giardini D., 2012. The SHARE European Earthquake Catalogue (SHEEC) 1000-1899. Journal of Seismology, doi:10.1007/s10950-012-9335-2

Suarez G. and Albini P., 2009. Evidence for Great Tsunamigenic Earthquakes (M8.6) along the Mexican Subduction Zone. Bulletin of the Seismological Society of America, 99, 2A, 892-896.

Suarez G., 2006. A macroseismic study of Mexican earthquakes. Internal report, INGV, Milano, 150 pp. ca.

Suarez G., Garcia-Acosta V., Gaulon R., 1994. Active crustal deformation in the Jalisco block, Mexico: evidence for a great historical earthquake in the 16th century. Tectonophysics, 234, 1-2, 117-127.

Suckale J. and Grünthal G., 2009. Probabilistic seismic hazard model for Vanuatu. Bulletin of the Seismological Society of America, 99, 4, 2108-2126.

Suleiman A.S. and Doser D.I., 1995. The seismicity, seismotectonics and earthquake hazards of Libya, with detailed analysis of the 1935 April 19, M = 7.1 earthquake sequence. Geophysical Journal International, 120, 312-322.

Suleiman A.S., Albini P., Migliavacca P., 2004. A short introduction to historical earthquakes in Libya. Annals of Geophysics, 47, 2-3, 545-554.

Sutch Osiecki P., 1981. Estimated intensities and probable tectonic sources of historic (pre-1898) Honduran earthquakes. Bulletin of the Seismological Society of America, 71, 3, 865-881.

Suter M., 2006. Contemporary Studies of the 3 May 1887 Mw 7.5 Sonora, Mexico (Basin and Range Province) Earthquake. Seismological Research Letters, 77, 2, 134-147.

Swe W., 2006. Earthquake hazard potentials in Myanmar: a science to public welfare outlook. In: Proceedings of Symposium on Tectonics, Seismotectonics, and Earthquake Hazard Mitigation and Management of Myanmar, Yangon (Abstract).

Swiss Seismological Service, 2002. ECOS - Earthquake Catalog of Switzerland. ECOS Report to PEGASOS, Version 31. 3. 2002, Appendix A: ECOS Database. SED, Zürich. http://histserver.ethz.ch

Sykes L. R., 1978. Intraplate seismicity, reactivation of preexisting zones of weakness, alkaline magmatism, and other tectonism postdating continental fragmentation. Reviews of Geophysics and Space Physics, 16, 621-688.

Szeliga W., Hough S., Martin S., Bilham R., 2010. Intensity, Magnitude, Location, and Attenuation in India for Felt Earthquakes since 1762. Bulletin of the Seismological Society of America, 100, 2, 570-584 + electronic supplement, doi:10.1785/0120080329

Taber S., 1920. Jamaica Earthquakes and the Bartlett Trough. Bulletin of the Seismological Society of America, 10, 2, 55-89.

Taber S., 1922. The seismic belt of the Greater Antilles. Bulletin of the Seismological Society of America, 12, 4, 199-219.

Taboada A., Rivera L.A., Fuenzalida A., Cisternas A., Philip H., Bijwaard H., Olaya J., Rivera C., 2000. Geodynamics of the northern andes: Subductions and intracontinental deformation (Colombia). Tectonics, 19, 5, 787-813.

Tams E., 1908. Die mikroseismischen Registrierungen einiger Beben des Jahres 1903. Gerlands Beiträge zur Geophysik, 9, 509-546.

Tanner J.G. and Shepherd J.B., 1997. Seismic hazard in Latin America and the Caribbean, Seismic Hazard in Latin America and the Caribbean, vol. 1. Final Report to the International Development Research Centre, Ottawa, Canada, Instituto Panamericano de Geografia y Historia, Mexico, D.F., 142 pp.

Tatevossian R. and Albini P., 2010. Information background of 11th-15th century earthquakes located by the current catalogues in Vrancea (Romania). Natural Hazards, 53, 575-604, doi:10.1007/s11069-009-9448-2

Tatevossian R. and Mokrushina N., 1998. The 1802, October 26, Vrancea deep earthquake. Internal report for the BEECD project, Institute of Physics of the Earth (IPE), Moscow, 15 pp.

Tatevossian R., 2004. History of earthquake studies in Russia. Annals of Geophysics, 47, 2-3, 811-830.

Tatevossian R.E., Mokrushina N.G., Aptekman J.J., Tatevossian T.N., 2012. On relevancy of combination of macroseismic and palaeoseismic data. Problems of Engineering Seismology, 40, 1, 39-66 (in Russian; extended summary in English).

Tavera H., Agüero C., Fernández E., Rodríguez S., 2001. Catálogo Sísmico del Perú 1471-1982, Versión Revisada y Actualizada. Instituto Geofísico del Perú Centro Nacional de Datos Geofísicos. http://www.igp.gob.pe/sismologia/bds/catalogo/presentacion.htm

Taxeidis K., 2003. Study of Historical Seismicity of the Eastern Aegean Islands. PhD thesis, N&K University of Athens, Greece, 301 pp. Macroseismic Data Points available in the Hellenic Macroseismic Database of the University of Athens, http://macroseismology.geol.uoa.gr

Taylor R., 1844. Report of the Rev. Taylor R. Church Missionary Record, 15, 14.

Taylor R., 1855. Te Ika a Maui. Wertheim and Macintosh, London.

Tello G. and Perez I., 2005. El Terremoto de 1894: Investigación Histórica. INSUGEO, Serie Correlación Geológica, 19, 23-40.

ten Brink U.S., Bakun W.H., Flores C.H., 2011. Historical perspective on seismic hazard to Hispaniola and the northeast Caribbean region. J. Geophys. Res. 116, B12318, doi:10.1029/2011JB008497

Thein M., Myint T., Thura Tun S., Lwin Swe T., 2009. Earthquake and tsunami hazard in Myanmar. Journal of Earthquake and Tsunami, 3, 2, 43-57, doi:10.1142/S1793431109000482

Tholozan J.D., 1879. Sur les tremblements de terre qui ont eu lieu en Orient du VII au XVII siècle. Compte Rendus de l'Académie des Sciences de France, 88, 1063-1066.

Tomblin J.M., Robson G.R., 1977. A catalogue of felt earthquakes for Jamaica, with references to other islands in the Greater Antilles, 1564 - 1971. Mines & Geology Division, Special Publication no.2, Kingston, Jamaica.

Toppozada T.R. and Borchardt G., 1998. Re-evaluation of the 1836 "Hayward Fault" and the 1838 San Andreas Fault Earthquakes. Bulletin of the Seismological Society of America, 88, 1, 140-159.

Toppozada T.R. and Branum D., 2004. California earthquake history. Annals of Geophysics, 47, 2-3, 509-522.

Toppozada T.R., Borchardt G., Hallstrom C.L., Ransom D., 1996. Using 1800's earthquake sequences to elucidate the increased San Francisco Bay area seismicity since 1979. Annual Technical Report to USGS/NEHRP, 32 pp.

Toppozada T.R., Branum D.M., Reichle M.S., Hallstrom C.L., 2002. San Andreas Fault Zone, California: M >= 5.5 Earthquake History. Bulletin of the Seismological Society of America, 92, 7, 2555-2601.

Torres-Vera M.A., 2010. Historical seismicity in Mexico during 1568-1837: intensity evaluation and data reliability. Natural Hazards, 54, 863-878, doi:10.1007/s11069-010-9510-0

Udías A., Madariaga R., Buforn E., Muñoz D., Ros M., 2012. The Large Chilean Historical Earthquakes of 1647, 1657, 1730, and 1751 from Contemporary Documents. Bulletin of the Seismological Society of America, 102, 4, 1639-1653 + electronic supplement, doi:10.1785/0120110289

University of Athens, 2010. Hellenic Macroseismic Database, compiled and made available to the public in the frame of the activities of the EU NERIES project, NA4 module "A Distributed Archive of Historical Earthquake Data". http://macroseismology.geol.uoa.gr

University of Thessaloniki, 2003. Macroseismic Data used for the compilation of Papazachos and Papazachou (2003) catalogue. In: Online Macroseimic Data of Southern Balkan area, http://www.itsak.gr/en/db/data/macroseimic_data

US Geological Survey, 2011. Historic United States Earthquakes (1568-2011). http://earthquake.usgs.gov/earthquakes/states/historical.php + Earthquake Intensity Database 1638-1985. http://www.ngdc.noaa.gov/hazard/int_srch.shtml

Usami T. (ed), 1998, 1999. Historical Documents on Earthquakes in Japan: Gleanings, Gleanings Supplement. Japan Electric Association, 512 pp., 1045 pp. (in Japanese).

Usami T. (ed), 2002a. Historical Documents on Earthquakes in Japan. Gleanings 2, 583 pp. (in Japanese).

Usami T., 1979. Study of Historical Earthquakes in Japan. Bulletin of Earthquake Research Institute, 54, 399-439.

Usami T., 1987. Materials for Comprehensive List of Destructive Earthquakes in Japan. University of Tokyo Press, new edition, 434 pp. (in Japanese).

Usami T., 1994. Seismic Intensity Maps and Isoseismal Maps of Historical Earthquakes of Japan. Japan Electric Association, Tokyo (in Japanese).

Usami T., 1996. Materials for Comprehensive List of Destructive Earthquakes in Japan 416-1995. University of Tokyo Press, revised and enlarged edition of the CD- ROM version published in 1997, 493 pp. (in Japanese).

Usami T., 2002. Historical earthquakes in Japan. In: W.H.K. Lee, H. Kanamori, P.C. Jennings, C. Kisslinger (eds), International Handbook of Earthquake and Engineering Seismology, Part A. Academic Press, San Diego, 799-802.

Utsu T., 1979. Seismicity of Japan from 1885 through 1925. Bulletin of Earthquake Research Institute, 54, 253-308 (in Japanese).

Utsu T., 1982. Seismicity of Japan from 1885 through 1925 (correction and supplement). Bulletin of Earthquake Research Institute, 57, 111-117 (in Japanese).

Utsu T., 1988. A Catalog of Large Earthquakes (Me6) and Damaging earthquakes in Japan for the Years 1885-1925. In: W.H.K. Lee, H. Meyers, K. Shimazaki (eds), Historical Seismograms and Earthquakes of the World, Academic Press, San Diego, U.S.A., 150-161.

Utsu T., 2002. A List of Deadly Earthquakes in the World: 1500-2000. In: W.H.K. Lee, H. Kanamori, P.C. Jennings, C. Kisslinger (eds), International Handbook of Earthquake and Engineering Seismology, Part A. Academic Press, San Diego, 691-717.

Utsu T., 2011. Catalog of Damaging Earthquakes in the World (through 2009). http://iisee.kenken.go.jp/utsu/index_eng.html

Van Gils J.M. and Leydecker G., 1991. Catalogue of European Earthquakes with intensities higher than 4. CEC, Nuclear Science and Technology, Report EUR 13406 EN, 353 pp.

Van Gils J.M., 1988. Catalogue of European earthquakes and an atlas of European seismic maps. CEC, Nuclear Science and Technology, Report EUR 11344 EN, 168 pp.

Vilanova S.P. and Fonseca J.F.B.D, 2007. Probabilistic Seismic-Hazard Assessment for Portugal. Bulletin of the Seismological Society of America, 97, 5, 1702-1717.

Víquez V. and Camacho E., 1993. El terremoto de Panamá La Vieja del 2 de mayo de 1621. Revista Universidad, 48, 186-195.

Viquez V. and Toral J., 1987. Sismicidad historica sentida en el istmo de Panama. Instituto Panamericano de Geografia e Historia, Revista Geofisica, 27, 135-166.

Vogt J. and Ambraseys N., 1992. The seismicity of Algeria during the first half of the 18th century. Proceedings of the regional workshop on archaeoseismicity in the Mediterranean region, November 4-7, 1992, Damascus, Syrian Arab Republic Atomic Energy Commission (AECS), Damascus, 90-95.

Vogt J., 2004. A glimpse at the historical seismology of the West Indies. Annals of Geophysics, 47, 2-3, 465-476.

Volponi F., 1962. Aspectos sismólogicos del Territorio Argentino, Actas Primeras Jornadas Argentinas de ingeniería Antisísmica, Buenos Aires.

Wada Y., 1912. A survey of Korean ancient and recent earthquakes. Report of the study of Korean ancient observations, Meteorological Observatory of the Government General of Korea, 79-105 (in Japanese).

Wang J., 2004. Historical earthquake investigation and research in China. Annals of Geophysics, 47, 2-3, 831-838.

Wang J., 2007. Historical earthquakes and a tsunami in Bohai Sea. Acta Seismologica Sinica, 20, 5, 584-592, doi:10.1007/s11589-007-0584-z

Wang Q., Jackson D., Kagan Y., 2009. California Earthquakes, 1800-2007: A Unified Catalog with Moment Magnitudes, Uncertainties, and Focal Mechanisms. Seismological Research Letters, 80, 3, 446-457, doi:10.1785/gssrl.80.3.446

Wang Y., Sieh K., Aung T., Min S., Khaing S.N., Tun S.T., 2011. Earthquakes and slip rate of the southern Sagaing fault: insights from an offset ancient fort wall, lower Burma (Myanmar). Geophysical Journal International, 185, 49-64.

White R.A., 1984. Catalog of historic seismicity in the vicinity of the Chixoy-Polochic and Motagua faults, Guatemala. Open-File Report 84-88, USGS, Menlo Park, 26 pp.

White R.A., 1985. The Guatemala earthquake of 1816 on the Chixoy-Polochic fault. Bulletin of the Seismological Society of America, 75, 2, 455-473.

White R.A., Ligorria J.P., Cifuentes I.L., 2004. Seismic history of the Middle America subduction zone along El Salvador, Guatemala, and Chiapas, Mexico: 1526-2000. In: W.I. Rose, J.J. Bommer, D.L. Lopez, M.J. Carr, J.J. Major (eds), Natural hazards in El Salvador. Geological Society of America, Boulder, Colorado, Special Paper 375, 379-396.

Wichmann C.E.A., 1918. Die Erdbeben des indischen Archipels bis zum Jahre 1857. J. Muller, Amsterdam, 193 pp.

Wichmann C.E.A., 1922. Die Erdbeben des Indischen Archipels von 1858 bis 1877. Koninklijke Akademie van Wetenschappen, Amsterdam, 209 pp.

Willis B., 1928. Earthquakes in the Holy Land. Bulletin of the Seismological Society of America, 18, 2, 73-103.

Wilson A.T., 1930. Earthquakes in Persia. Bull. SOAS, 6, 1, 103-131.

Wood H.O. and Neumann F., 1931. Modified Mercalli intensity scale of 1931. Bulletin of the Seismological Society of America, 21, no.4, 277-283.

Wu G., Liu C., Zhai W., 2001. Compilation and Research of Historical Earthquakes in the Yellow Sea and its Coast. Seismological Press, Beijing, China, 152 pp. (in Chinese)

Wu G., Ma M., Xu D., 1994. Research in Historical Earthquakes in Northeast Continent. Chengdu Cartographic Publishing House, Chengdu, China, 139 pp. (in Chinese)

Wyss M. and Koyanagi R., 1992. Isoseismal Maps, Macroseismic Epicenters, and Estimated Magnitudes of Historical Earthquakes in the Hawaiian Islands. U.S. Geological Survey Bulletin, 2006, 104 pp. http://pubs.usgs.gov/bul/2006

Xie Y.S and Cai M.B. (eds), 1983-1987. Compilation of Historical Materials of Chinese Earthquakes. 5 volumes, Science Publishing House, Beijing (in Chinese).

Xie, Yusuo, 1957. A new scale of seismic intensity adapted to the conditions in Chinese territories. Acta Geophysica Sinica, 6, 1, 35-47 (in Chinese).

Xu X., Yeats R.S., Yu G., 2010. Five Short Historical Earthquake Surface Ruptures near the Silk Road, Gansu Province, China. Bulletin of the Seismological Society of America, 100, 2, 541-561, doi:10.1785/0120080282

Zaw S.H., 2006. Hazard assessment in Multi-hazard Design. Proceedings of Symposium on Tectonics, Seismotectonics, and Earthquake Hazard Mitigation and Management of Myanmar, Yangon, (Abstract).

Zhai W., Wu G., Han S., 2004. Research in historical earthquakes in the Korean peninsula and its circumferential regions. Acta Seismologica Sinica, 1.17, 3, 366-372 (in Chinese).

Zhang B., Liao Y., Guo S., Wallace R.E., Bucknam R.C., Hanks T.C., 1986. Fault Scarps Related to the 1739 Earthquake and Seismicity of the Yinchuan Graben, Ningxia Huizu Zizhiqu, China. Bulletin of the Seismological Society of America, 76, 5, 1253-1287.

Zhang P., Yang Z.X., Gupta H.K., Bhatia S. C., Shedlock K.M., 1999. Global Seismic Hazard Assessment Program (GSHAP) in continental Asia. Ann. Geophys., 42, 6, 1167-1190. http://www.seismo.ethz.ch/static/gshap/eastasia/final-cata.txt

Zsìros T., Mónus P., Tóth L., 1988. Hungarian Earthquake Catalog (456-1986). Geodetic & Geophysical Research Institute, Budapest, 182 pp.

Zúñiga R., Suárez G., Ordaz M., García-Acosta V., 1997. Seismic Hazard in Latin America and the Caribbean, Capitulo 2: Mexico. Reporte final, Pan American Institute of Geography and History (PAIGH), 82 pp.

Website references

1. Google Maps API
Application Programming Interface for accessing the web mapping service application run by Goggle
[Available at https://developers.google.com/maps]

2. JavaScript
the web scripting language
[Available at http://www.w3.org/standards/webdesign/script.html]

3. jQuery
the JavaScript library
[Available at http://jquery.com]

4. MIDOP
the Macroseismic Intensity Data Online Publisher
[Available at http://www.emidius.eu/MIDOP]

5. MySQL
the open source DataBase Management System
[Available at http://www.mysql.com]

6. PHP
the server-side scripting language
[Available at http://www.php.net]

7. QuakeML
the extensible format definition for seismic data using XML
[Available at https://quake.ethz.ch/quakeml/QuakeML]

8. SVG
the Scalable Vector Graphic format
[Available at http://www.w3.org/Graphics/SVG]

APPENDIX A Online Resources on Historical Earthquake Data (last accessed in October 2012)

a) In the Americas

Earthquakes Canada - *http://earthquakescanada.nrcan.gc.ca/index-eng.php*

The "Earthquakes Canada" website of the Natural Resources Department of Canada includes general information about earthquakes, earthquake data, earthquake hazard and preparedness. In the "Historic Events" section of the website, the "Important Canadian Earthquakes" page provides an interactive map and a list of damaging earthquakes in Canada from 1663 to the present. The parameters of each earthquake are listed in the table, through which the user can access a webpage containing a description of the earthquake and a list of studies dealing with it. For some of the earthquakes a isoseismal map is provided, but Macroseismic Data Points (MDPs) are not available.

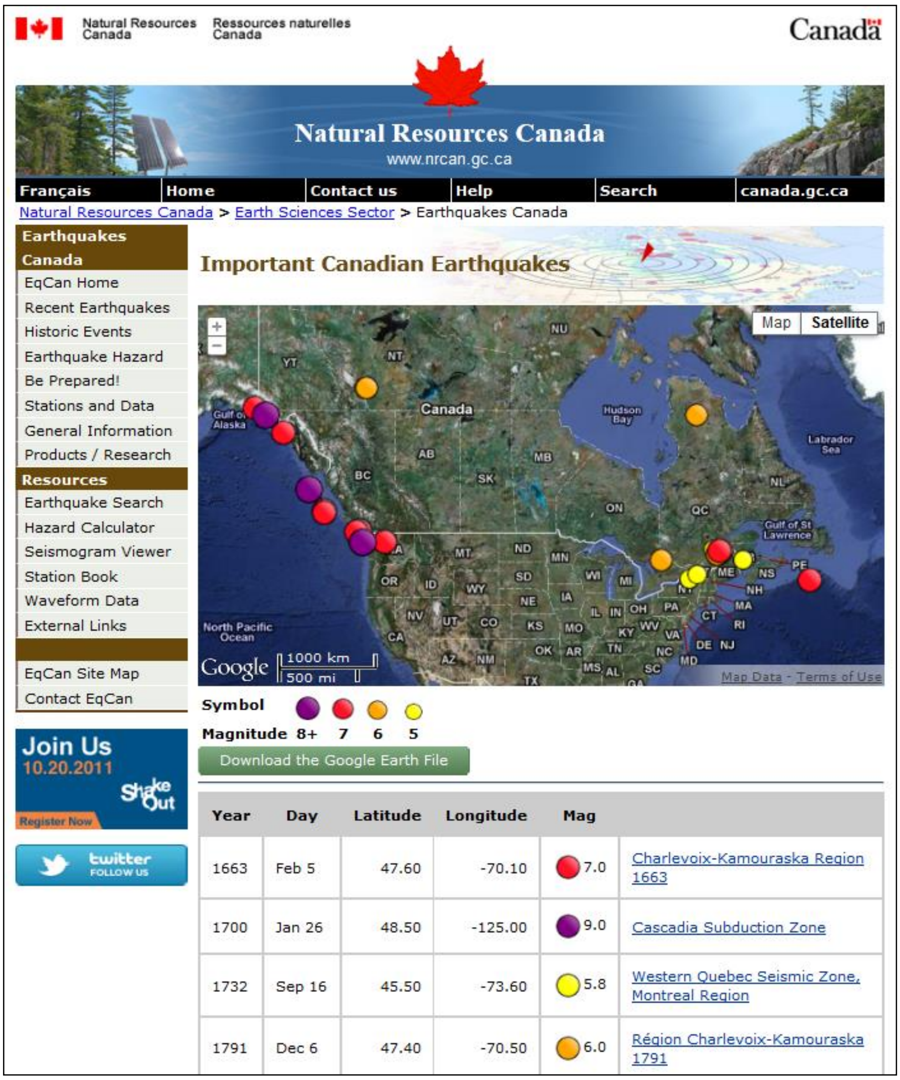


Figure A.1 The "Important Canadian Earthquakes" webpage of Natural Resources Canada

Earthquake Intensity Database (U.S.) - ***www.ngdc.noaa.gov/hazard/int_srch.shtml***

The webpage entitled “Earthquake Data and Information” of the U.S. National Geophysical Data Center - National Oceanic and Atmospheric Administration (NGDC-NOAA) contains a list of databases related to earthquake hazards. Among these, the Earthquake Intensity Database (NGDC-NOAA, 1985) collects damage and felt reports for over 23,000 earthquakes in the U.S., nearby territories, and areas of Mexico and Canada in the time-window from 1638 to 1984.

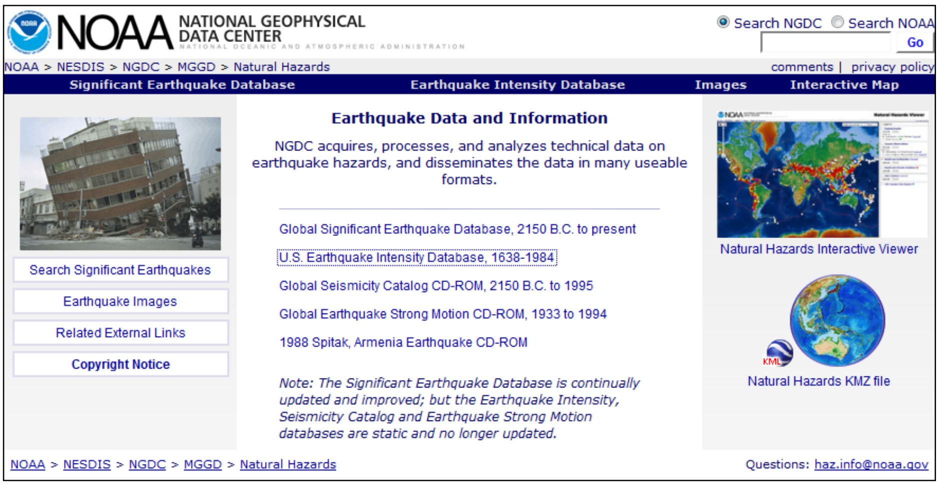
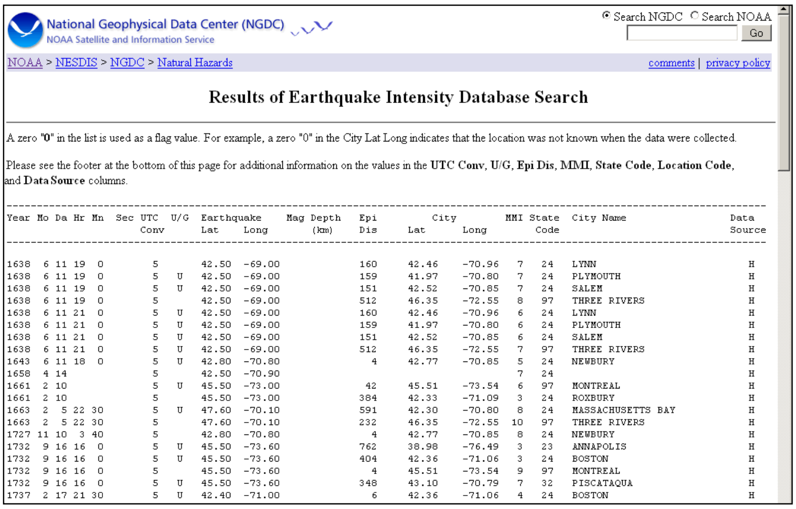


Figure A.2 The “Earthquake Data and Information” webpage of the U.S. NGDC-NOAA

The database contains information regarding epicentral coordinates, magnitudes, focal depths, and MDPs. The total number of MDPs is 157,015, of which 2,550 MDPs before the year 1900.

According to the “Introduction” to the database reported in the same website, about 25% of the earthquakes reported from 1638 to 1928 and 10% of the events from 1928 to 1980 do not have epicentres. Moreover, several of the reporting places listed in the file have not been assigned geographic coordinates. For each MDP, the database outputs the source code of one or more of the reported parameters (e.g., epicentre, city and intensity). The main sources are unpublished reports and annual/monthly bulletins by varied agencies collecting macroseismic information through time, the full reference of which is not clearly reported on the website.


National Geophysical Data Center (NGDC)
NOAA Satellite and Information Service
Search NGDC Search NOAA Go
NOAA > NESDIS > NGDC > Natural Hazards — comments | privacy policy

Results of Earthquake Intensity Database Search

A zero "0" in the list is used as a flag value. For example, a zero "0" in the City Lat Long indicates that the location was not known when the data were collected.

Please see the footer at the bottom of this page for additional information on the values in the **UTC Conv**, **U/G**, **Epi Dis**, **MMI**, **State Code**, **Location Code**, and **Data Source** columns.

Year	Mo	Da	Hr	Mn	Sec	UTC Conv	U/G	Earthquake Lat	Earthquake Long	Mag	Depth (km)	Epi Dis	City Lat	City Long	MMI	State Code	City Name	Data Source
1638	6	11	19	0		5		42.50	-69.00			160	42.46	-70.96	7	24	LYNN	H
1638	6	11	19	0		5	U	42.50	-69.00			159	41.97	-70.80	7	24	PLYMOUTH	H
1638	6	11	19	0		5	U	42.50	-69.00			151	42.52	-70.85	7	24	SALEM	H
1638	6	11	19	0		5		42.50	-69.00			512	46.35	-72.55	8	97	THREE RIVERS	H
1638	6	11	21	0		5	U	42.50	-69.00			160	42.46	-70.96	6	24	LYNN	H
1638	6	11	21	0		5	U	42.50	-69.00			159	41.97	-70.80	6	24	PLYMOUTH	H
1638	6	11	21	0		5	U	42.50	-69.00			151	42.52	-70.85	6	24	SALEM	H
1638	6	11	21	0		5	U	42.50	-69.00			512	46.35	-72.55	7	97	THREE RIVERS	H
1643	6	11	18	0		5	U	42.80	-70.80			4	42.77	-70.85	5	24	NEWBURY	H
1658	4	14				5		42.50	-70.90						7	24		H
1661	2	10				5	U	45.50	-73.00			42	45.51	-73.54	6	97	MONTREAL	H
1661	2	10				5		45.50	-73.00			384	42.33	-71.09	3	24	ROXBURY	H
1663	2	5	22	30		5	U	47.60	-70.10			591	42.30	-70.80	8	24	MASSACHUSETTS BAY	H
1663	2	5	22	30		5		47.60	-70.10			232	46.35	-72.55	10	97	THREE RIVERS	H
1727	11	10	3	40		5		42.80	-70.80			4	42.77	-70.85	8	24	NEWBURY	H
1732	9	16	16	0		5	U	45.50	-73.60			762	38.98	-76.49	3	23	ANNAPOLIS	H
1732	9	16	16	0		5	U	45.50	-73.60			404	42.36	-71.06	3	24	BOSTON	H
1732	9	16	16	0		5		45.50	-73.60			4	45.51	-73.54	9	97	MONTREAL	H
1732	9	16	16	0		5	U	45.50	-73.60			348	43.10	-70.79	7	32	PISCATAQUA	H
1737	2	17	21	30		5	U	42.40	-71.00			6	42.36	-71.06	4	24	BOSTON	H

Figure A.3 Output of the U.S. earthquake intensity database

CERESIS – *http://www.ceresis.org/*

The archive of CERESIS - Centro Regional de Sismología para América del Sur (Regional Centre of Seismology for South America) makes available the results of the activities carried out and on-going by the member states since 1971.

The section of the archive of interest for this project is contained in the section “Información Sismológica”:

- Catálogo de Hipocentros
- Catálogo de Intensidades
- Mapas SISRA

In the section “Actualizaciones” is “hidden” part the material produced in the framework of the SISRA (Earthquake Mitigation Program in the Andean Region Project) project (1985). One of the outputs of the SISRA project is a series of 14 printed volumes, which are no more available in hard copy. They are being made available to the public in pdf format, starting from vols. 1, 5, 13, 7-a and 10.

Figure A.4 CERESIS home page

The CERESIS intensity database (1985) is the outcome of the SISRA Project (see above). Since its creation only the earthquake catalogue has been separately updated as the South American countries lost interest contributing to the intensity collection. Nevertheless it still attracts attention, thanks to a good quantity of data (more than 3100 events for about 16,000 MDPs) spanning from year 1471 to year 1985 and covering the whole South America.

The intensity database is subdivided by country. For each earthquake the observations coming from different investigators are simply put together, and no final solution is provided in the case of different interpretations.

CATALOGO DE INTENSIDADES

IND	INFO	PAIS	NUM	AÑO	MES	DIA	HORA	LAT	LONG	DEP	MS	MB	INT
301		CO	3350	1875	5	18	16:15:00	7.9	-72.5	20	7.3	0	10M

LUGAR	DIS EPIC	DIS HYP	LAT	LONG	ELEV	AZI	INT
SANTIAGO	0	0	7.87	-72.7	411	0	10M
VILLA DE ROSAR.	0	0	7.83	-72.47	431	0	10M
SAN CAYETANO	0	0	7.88	-72.63	235	0	10M
MATANZAS	0	0	7.33	-73.02	1550	0	6M
PAMPLONA	0	0	7.38	-72.65	2287	0	8M
CUCUTA-SAN JOSE	0	0	7.9	-72.5	320	0	9M
VILLA DE ROSAR.	0	0	7.83	-72.47	431	0	9M
SALAZAR	0	0	7.78	-72.82	815	0	8M
SALAZAR	0	0	7.78	-72.82	815	0	9M
GRAMALOTE	0	0	7.88	-72.8	1044	0	9M
GRAMALOTE	0	0	7.88	-72.8	1044	0	8M
SAN ANTONIO	0	0	7.82	-72.45	350	0	9M
SAN ANTONIO	0	0	7.82	-72.45	350	0	8M
TARIBA	0	0	7.79	-72.21	887	0	9M
SAN FAUSTINO	0	0	8.12	-72.4	200	0	9M
SAN FAUSTINO	0	0	8.12	-72.4	200	0	8M
BOCHALEMA	0	0	7.62	-72.65	1051	0	9M
ARBOLEDAS	0	0	7.06	-72.8	946	0	8M
ARBOLEDAS	0	0	7.06	-72.8	946	0	9M
ARBOLEDAS	0	0	7.06	-72.8	946	0	7M
SAN CRISTOBAL	0	0	7.75	-72.24	826	0	9M
SAN CRISTOBAL	0	0	7.75	-72.24	826	0	8M
SAN CRISTOBAL	0	0	7.75	-72.24	826	0	7M
LA GRITA (VEN.)	0	0	8.15	-71.98	1440	0	6M
LA GRITA (VEN.)	0	0	8.15	-71.98	1440	0	9M
LA GRITA (VEN.)	0	0	8.15	-71.98	1441	0	8M
COLON (VENEZ.)	0	0	8.05	-72.27	500	0	9M
COLON (VENEZ.)	0	0	8.05	-72.27	500	0	8M
COLON (VENEZ.)	0	0	8.05	-72.27	500	0	7M
PAMPLONA	0	0	7.38	-72.65	2287	0	7M

Figure A.5 The CERESIS intensity database, example with more than one record describing effects in one place

Sismología Histórica de Venezuela - *http://sismicidad.ciens.ula.ve/*

The online database "Sismología Histórica de Venezuela" is developed by FONACIT (Fondo Nacional de Ciencia, Tecnología e Innovación), ULA (Universidad de los Andes), UCV (Universidad Central de Venezuela), and FUNVISIS (Fundación Venezolana de Investigaciones Sismológicas). It provides a collection of data for 183 destructive earthquakes that occurred in Venezuela since 1530 and in the neighbouring areas of Colombia and Trinidad and Tobago.

For each earthquake, the database gives access to a comprehensive archive of varied information and data, including: i) earthquake parameters; ii) the MDPs according to different studies; iii) the list of the studies related to the earthquake and the study itself (in digital format or as a link to the original); iv) a description of the historical context of the earthquake; v) the list of the historical sources of the earthquakes; available images related to the earthquake. The database provides also a short general description of the earthquake and of its effects on buildings, the environment and society. As for MDPs, the database entirely includes the CERESIS data.

The database can be queried through different parameters (date of the earthquake(s), area, etc.), and all the information is cross-referenced, so that the user can, for example, access the data related to earthquakes in the same region as the selected one and so on.

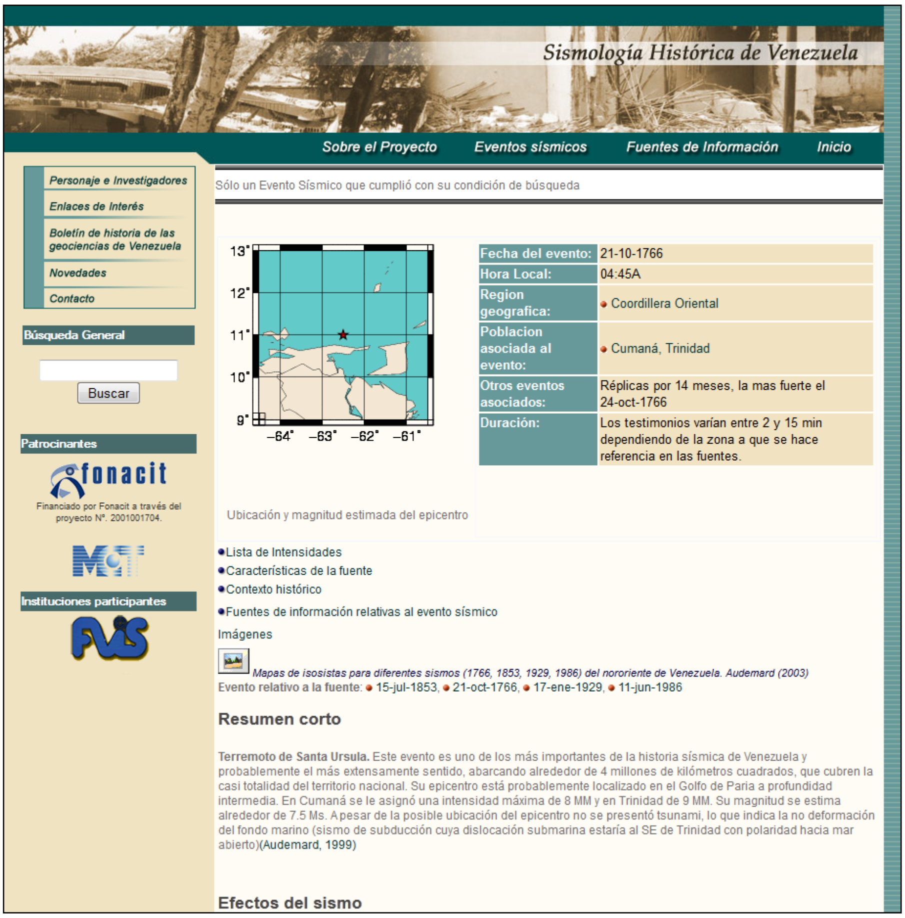


Figure A.6 Query for a single event from the Sismología Histórica de Venezuela database

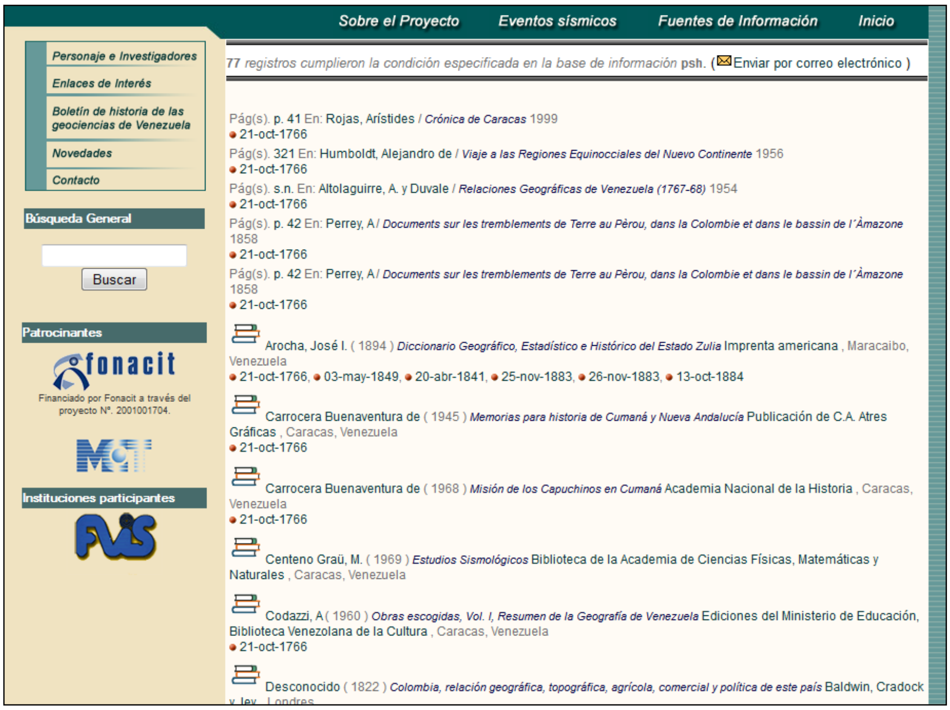


Figure A.7 Bibliography of a single earthquake from Sismología Histórica de Venezuela database

b) In Europe

AHEAD - ***http://www.emidius.eu/AHEAD/***

AHEAD is the Archive of Historical EArthquake Data of Europe developed in the framework of the NERIES NA4 and SHARE EU projects.

AHEAD puts together the historical earthquake data of European earthquakes in the time-window 1000-1900, data which:

a) were already available online in the national databases described below

b) have been made available in the frame of the projects by several partner institutions and published online, for the very first time, such as UK Historical Earthquake Database (BGS), Bases de datos de intensidad macrosísmica (IGN), Base de Dades Macrosísmica(IGC), Hellenic Macroseismic Database (UoA), Macroseismic Data of Southern Balkan area (ITSAK);

c) have been retrieved from published papers, reports and volumes, all listed in and made available online through the AHEAD digital library.

For details, see section 2.3 of this report.

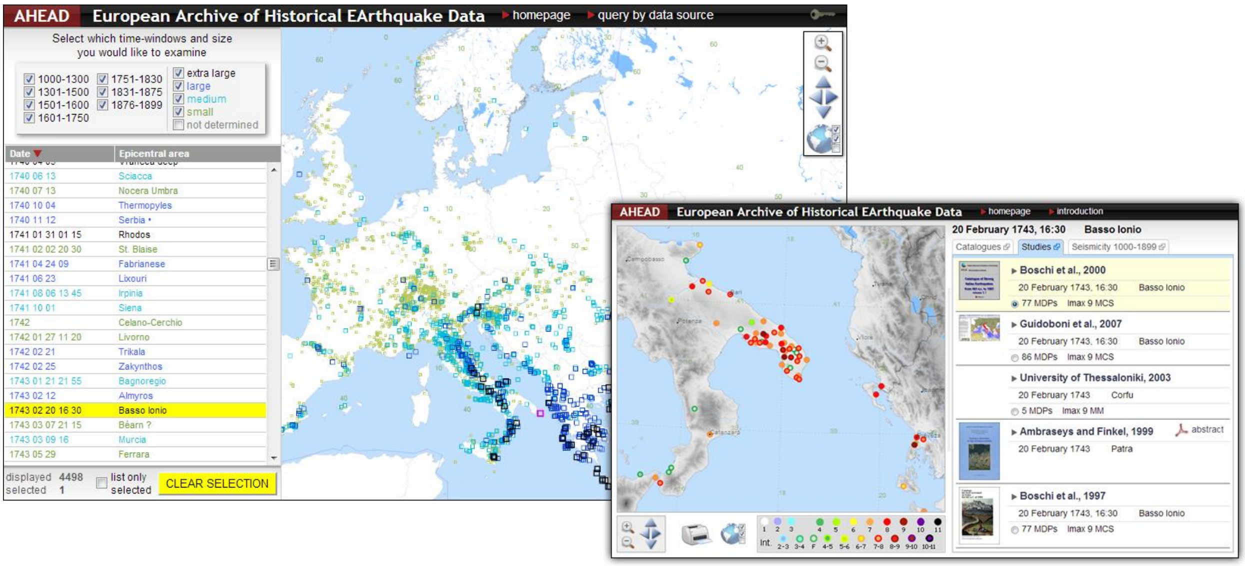


Figure A.8 Querying AHEAD by earthquake

SisFrance - ***http://www.sisfrance.net/***

The SisFrance online database is one of the oldest and best structured earthquake databases in Europe. It was established in the late 1980s by BRGM (Bureau de Recherches Géologiques et Minières), EDF (Electricité de France) and IRSN (Institut de Radioprotection et de Sûreté Nucléaire). SisFrance contains around 6,000 earthquakes in the French territory and nearby areas in the time-window from 463 to 2007 of which 2,811 are before the year 1900.

The database can be accessed by earthquake date, coordinates or French department or district and provides, for each earthquake, a list of MDPs, the related map, and a bibliographical section that lists both sources and studies (published and unpublished) on the earthquake. Sometimes, a scanned image of the exact piece of information on the earthquake is linked. There are more than 100,000 MDPs, 16,300 MDPs before year 1900, each with a quality index of the intensity estimation. Epicentral location and intensity, but no magnitude, are assessed for only the 1,800 best known earthquakes with epicental intensity greater or equal to 4, a small part of the total number of historical events. SisFrance covers also the so called “overseas regions and territories”, such as New Caledonia and French Guiana.

Sismicité de la France
Métropole

Liste des observations | Caractéristiques du séisme | Carte macrosismique | Bibliographie | Carte d'isoséistes | Page d'accueil

Identité : **1150004**

Date du séisme : **6 Avril 1580**
Heure du séisme : **16 h**
Région épicentrale : **MANCHE (DETROIT DE CALAIS-DOUVRES) – GRANDE-BRETAGNE**

1 2 3 4

Localité	Dept/Pays	Indice	Intensité	Effet	Longitude	Latitude
ABBEVILLE	80	B	4,5		1° 50' E	50° 06' N
AIRAINES	80	C			1° 57' E	49° 58' N
AMIENS	80	B	5		2° 18' E	49° 54' N
AMSTERDAM	HOL	B	5,5		4° 54' E	52° 21' N
ANTWERPEN	BEL	C	5,5		4° 25' E	51° 13' N
ARRAS	62	A	6		2° 46' E	50° 17' N
AXEL	HOL	B	6,5		3° 54' E	51° 16' N
BEAUVAIS	60	B	5		2° 05' E	49° 26' N
BETHUNE	62	B			2° 38' E	50° 32' N
BISHOP'S STORTFORD	GBR	C	6,5		0° 10' E	51° 52' N
BOULOGNE-SUR-MER	62	B	7		1° 37' E	50° 44' N
BOURBOURG	59	A			2° 12' E	50° 57' N
BRISTOL	GBR	B	4		2° 35' W	51° 27' N

Figure A.9 MDPs list from SisFrance

Auteur	Article	Référence	Tomaison, série	Lieu d'édition	Date de publication
OUTREMAN . P (D')		ABBREGE DE L'HISTOIRE DE VALENCIENNES		LILLE	1688
BLOMEFIELD. F		AN ESSAY TOWARDS A TOPOGRAPHICAL HISTORY OF THE COUNTY OF NORFOLK	VOL 3	LONDON	1806
BATCHELLER. W		A NEW HISTORY OF DOVER CASTLE		DOVER	
DESCAMPS. A (PUBL.)		ANNALES DE LA PROVINCE ET COMTE DU HAINAUT CONTENANT LES CHOSES LES PLUS REMARQUABLES ADVENUES DANS CESTE PROVINCE PAR FRANÇOIS VINCHANT	T 5	MONS	1853
CORLIEU. A	NOTE SUR LE TREMBLEMENT DE TERRE ARRIVE A CHATEAU-THIERRY LE 6 AVRIL 1580 (D'APRES MEMOIRES DE CL.HATON)	ANNALES DE LA SOCIETE HISTORIQUE ET ARCHEOLOGIQUE DE CHATEAU-THIERRY		CHATEAU-THIERRY	1873
STOW. J		ANNALES OR GENERAL CHRONICLE OF ENGLAND		LONDON	1631
CAMDEM. W		ANNALES RERUM ANGLICARUM ET HIBERNICARUM REGNANTE ELISABETHA AD ANNUM SALUTIS MDLXXXIX		FRANKFURT	1616
LEROY. A, DINAUX. A (EDIT.)	MEMOIRE CONTENANT DES FAITS ET ANECDOTES TIRES DES REGISTRES DE L'HOTEL DE VILLE D'ARRAS	ARCHIVES HISTORIQUES ET LITTERAIRES DU NORD DE LA FRANCE ET DU MIDI DE LA BELGIQUE	T 6, NS	VALENCIENNES	1847
MORAND. F	EPHEMERIDES DE L'HISTOIRE DE BOULOGNE ET DU BOULONNAIS	ARCHIVES HISTORIQUES ET LITTERAIRES DU NORD DE LA FRANCE ET DU MIDI DE LA BELGIQUE	T 2, SERIE 3	VALENCIENNES	1851
LEROY. A, DINAUX. A (EDIT.)	"PARTICULARITES ET ANTIQUITES DE LA VILLE DE LILLE"	ARCHIVES HISTORIQUES ET LITTERAIRES DU NORD DE LA FRANCE ET DU MIDI DE LA BELGIQUE	T 4	VALENCIENNES	1934
VAN LERBERGHE. L, RONSSE.J (PUBL.)	AERDBEVING 1580	AUDENAERDSCHE MENGELINGEN	T 1	AUDENARDE	1845
ORLER. J-J		BESCHRYVINGHE DER STAAT LEYDEN	T 2		1641

Figure A.10 Bibliography of a single earthquake from SisFrance

DBMI, DataBase Macrosismico Italiano - *http://emidius.mi.ingv.it/DBMI04/*

The DBMI, DataBase Macrosismico Italiano - Italian Macroseismic Database is available online in its 2004 version (Stucchi et al., 2007) and contains the macroseismic data used to compile the parametric catalogue CPTI04 (Gruppo di lavoro CPTI, 2004), also available online at http://emidius.mi.ingv.it/CPTI/.

The database collects and put together the MDPs provided by 68 studies by different authors dealing as a whole with 1041 events from the Ancient Time to 2002 mostly with epicentre in the Italian territory. The total number of MDPs in the database is 58146.

The database can be queried either by earthquake or by place and displays for each earthquake the MDPs list, an interactive map, the parameters from CPTI04 and the full reference of the study providing the MDPs. The full database is downloadable from the website.

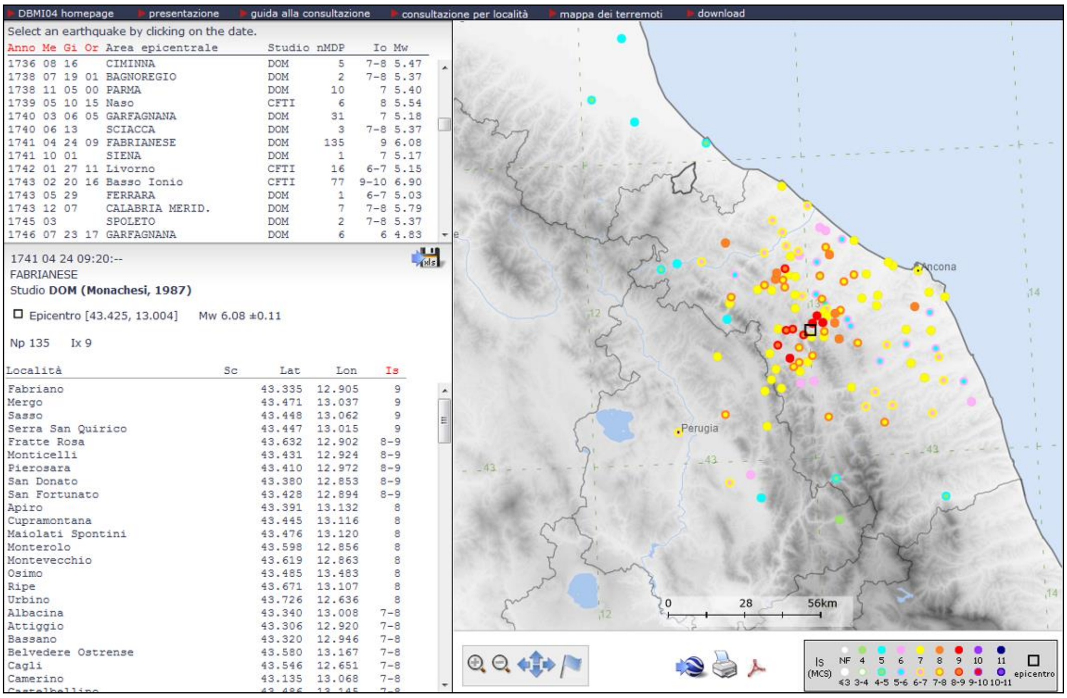


Figure A.11 Intensity distribution (list and map) from DBMI04

CFTI4med – Catalogue of strong earthquakes in Italy 461 b.C.-1997 and Mediterranean Area 760 b.C. – 1500. http://storing.ingv.it/cfti4med/

CFTI4med (Guidoboni et al., 2007) is the last release of the "Catalogo dei forti terremoti in Italia" - Catalogue of Strong Italian Earthquakes, the first edition of which appeared in 1995 as a volume with a CD-ROM.

CFTI4med lists 1257 Italian earthquakes with epicentral intensity greater than or equal to 8 and a selection of smaller earthquakes and a total of 42,607 MDPs. The database provides the results of ad-hoc investigations in terms of MDPs and earthquake parameters together with the list of the sources analysed. For most of the earthquakes a series of descriptions, such as the major earthquake effects, the previous investigations on the earthquake, and the socio-economic impact of the earthquake, are also available (only in Italian).

Since this last version, CFTI includes also the 482 earthquakes of the Mediterranean area up to the year 1500 studied by Guidoboni et al. (1994), and Guidoboni and Comastri (2005). These earthquakes are only listed without either MDPs or descriptions.

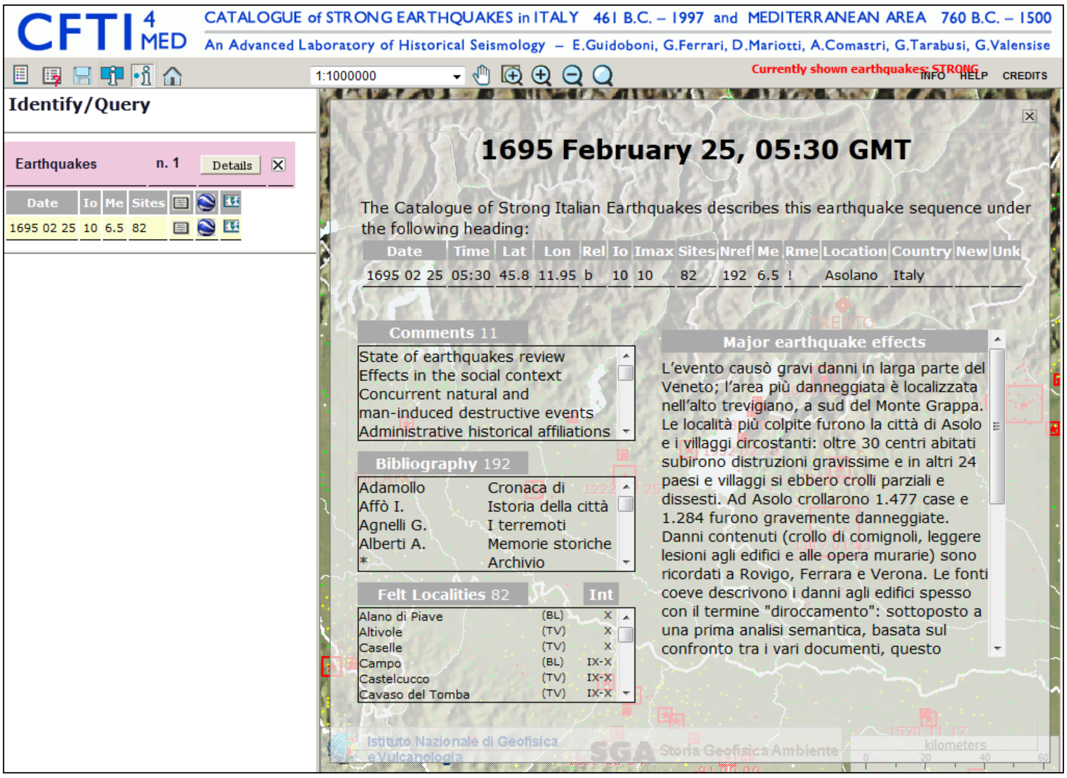


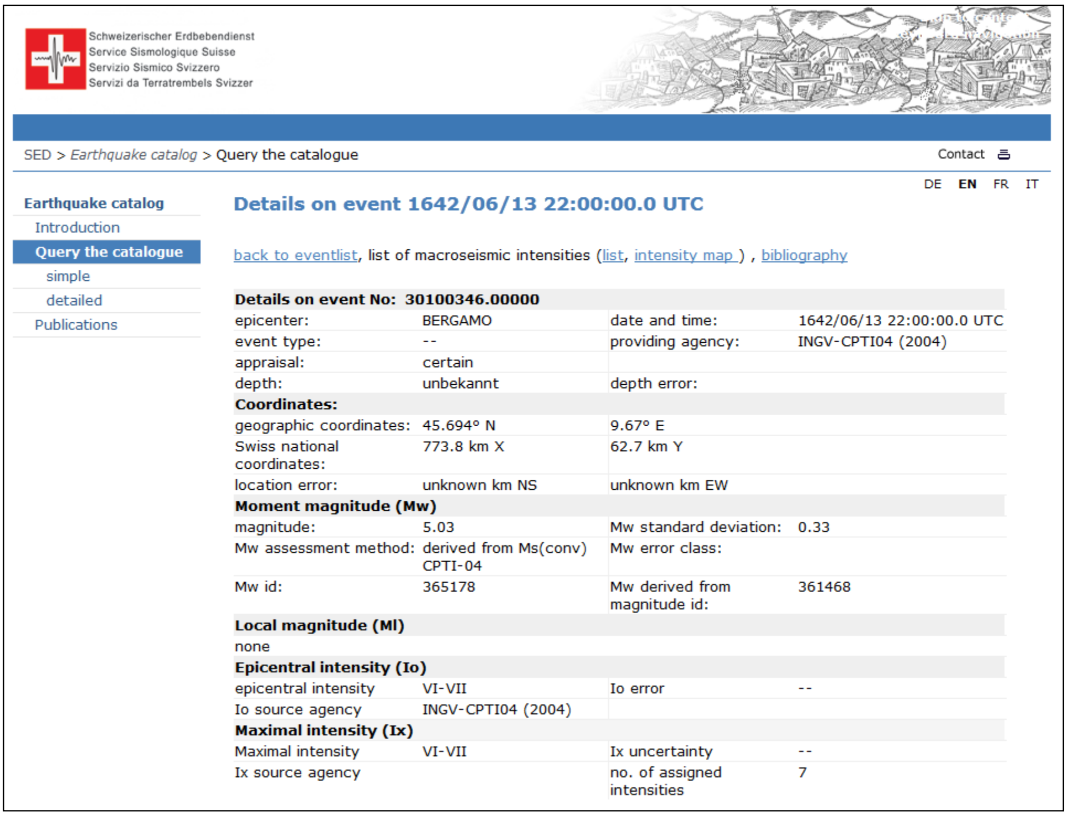
Figure A.12 Information on an earthquake from CFTI4med

ECOS, Earthquake Catalogue of Switzerland - *http://hitseddb.ethz.ch:8080/ecos09/*

The online Earthquake Catalogue of Switzerland was published in 2002 (ECOS, 2002) and has been updated in 2011 with the ECOS-09 version, covering the period from 250 to the end of 2008 and the area of Switzerland and bordering regions with 19,600 earthquakes.

The database integrates the revised Macroseismic Earthquake Catalogue of Switzerland, yearly reports of the Swiss earthquake commission since 1879, instrumental locations since 1975, and data from earthquake catalogues of neighbouring countries as long as international agencies.

For each earthquake the database provides the full parameters, including different magnitudes and the methods used to derive them, and, when available, the MDPs table and static map. The bibliography of both historical sources and studies is provided. The total number of available MDPs is about 14,000 MDPs.


Schweizerischer Erdbebendienst
Service Sismologique Suisse
Servizio Sismico Svizzero
Servizi da Terratrembels Svizzer

SED > *Earthquake catalog* > Query the catalogue   Contact

DE EN FR IT

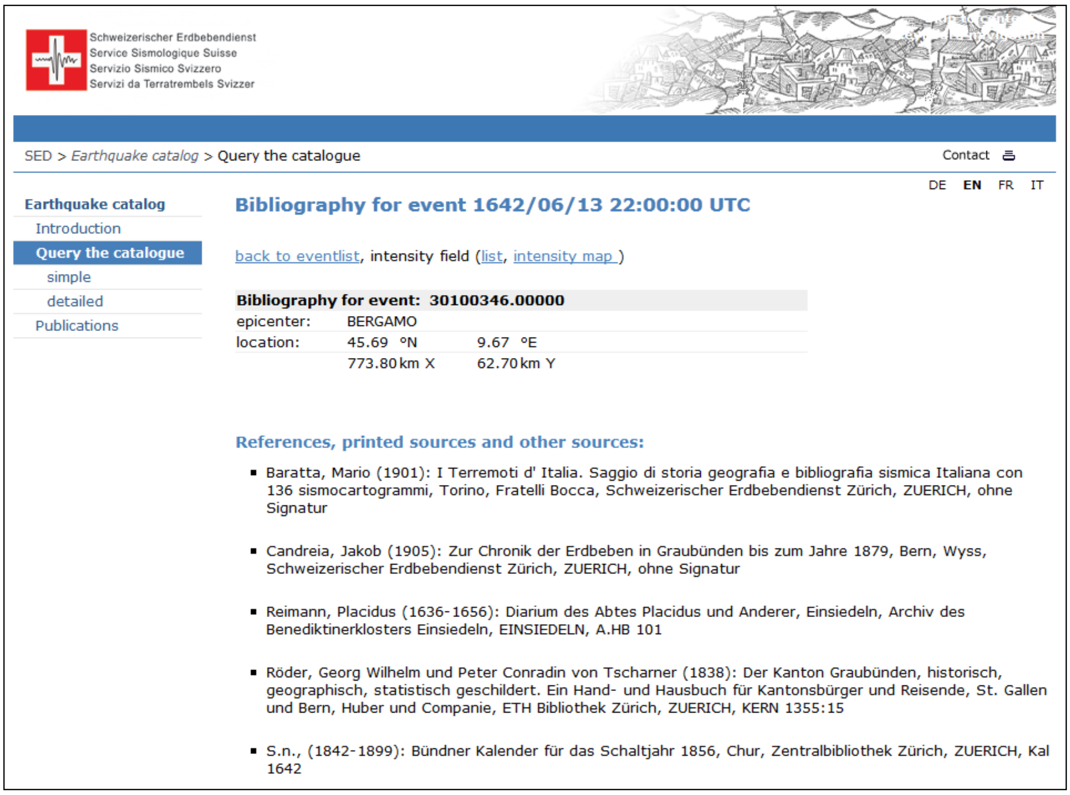
Earthquake catalog
Introduction
Query the catalogue
simple
detailed
Publications

Details on event 1642/06/13 22:00:00.0 UTC

back to eventlist, list of macroseismic intensities (list, intensity map) , bibliography

Details on event No: 30100346.00000			
epicenter:	BERGAMO	date and time:	1642/06/13 22:00:00.0 UTC
event type:	--	providing agency:	INGV-CPTI04 (2004)
appraisal:	certain		
depth:	unbekannt	depth error:	
Coordinates:			
geographic coordinates:	45.694° N	9.67° E	
Swiss national coordinates:	773.8 km X	62.7 km Y	
location error:	unknown km NS	unknown km EW	
Moment magnitude (Mw)			
magnitude:	5.03	Mw standard deviation:	0.33
Mw assessment method:	derived from Ms(conv) CPTI-04	Mw error class:	
Mw id:	365178	Mw derived from magnitude id:	361468
Local magnitude (Ml)			
none			
Epicentral intensity (Io)			
epicentral intensity	VI-VII	Io error	--
Io source agency	INGV-CPTI04 (2004)		
Maximal intensity (Ix)			
Maximal intensity	VI-VII	Ix uncertainty	--
Ix source agency		no. of assigned intensities	7

Figure A.13 Earthquake parameters from ECOS09



Schweizerischer Erdbebendienst
Service Sismologique Suisse
Servizio Sismico Svizzero
Servizi da Terratrembels Svizzer

SED > *Earthquake catalog* > Query the catalogue   Contact

DE **EN** FR IT

Earthquake catalog
- Introduction
- **Query the catalogue**
  - simple
  - detailed
- Publications

Bibliography for event 1642/06/13 22:00:00 UTC

back to eventlist, intensity field (list, intensity map)

Bibliography for event:	**30100346.00000**	
epicenter:	BERGAMO	
location:	45.69 °N	9.67 °E
	773.80 km X	62.70 km Y

References, printed sources and other sources:

- Baratta, Mario (1901): I Terremoti d' Italia. Saggio di storia geografia e bibliografia sismica Italiana con 136 sismocartogrammi, Torino, Fratelli Bocca, Schweizerischer Erdbebendienst Zürich, ZUERICH, ohne Signatur
- Candreia, Jakob (1905): Zur Chronik der Erdbeben in Graubünden bis zum Jahre 1879, Bern, Wyss, Schweizerischer Erdbebendienst Zürich, ZUERICH, ohne Signatur
- Reimann, Placidus (1636-1656): Diarium des Abtes Placidus und Anderer, Einsiedeln, Archiv des Benediktinerklosters Einsiedeln, EINSIEDELN, A.HB 101
- Röder, Georg Wilhelm und Peter Conradin von Tscharner (1838): Der Kanton Graubünden, historisch, geographisch, statistisch geschildert. Ein Hand- und Hausbuch für Kantonsbürger und Reisende, St. Gallen und Bern, Huber und Companie, ETH Bibliothek Zürich, ZUERICH, KERN 1355:15
- S.n., (1842-1899): Bündner Kalender für das Schaltjahr 1856, Chur, Zentralbibliothek Zürich, ZUERICH, Kal 1642

Figure A.14 Bibliography of a single earthquake from ECOS09

c) In Asia

National Geoscience Database of Iran - *http://www.ngdir.ir/Earthquake/Earthquake.asp*

The section entitled "Earthquake Database" of the National Geoscience Database of Iran contains, among general and educational information about earthquakes (in English), an "Earthquake Databank" that consists of a list of earthquakes since 1900, with parameters and a reference code. Earthquakes before 1900 are only displayed on the "Map of Iran's earthquakes". The epicentres in the map are clickable in order to retrieve, one-by-one, the parameters of the earthquake.

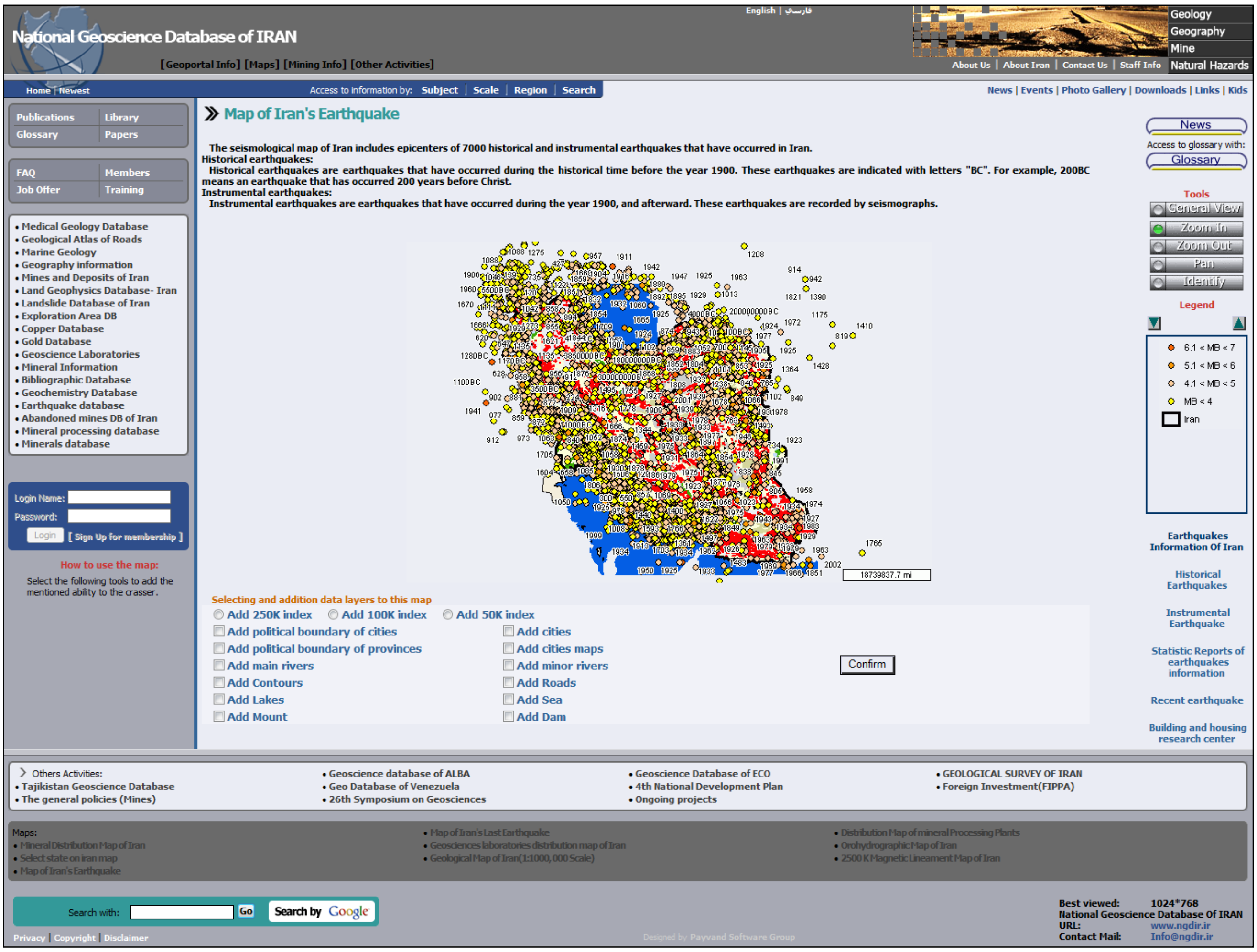


Figure A.15 Map of Iran's earthquakes from the National Geoscience Database of Iran

NGDTJ - National Geoscience Database of Tajikistan - *http://www.ngdtj.com/*

The National Geoscience Database of Tajikistan provides a "Tajikistan distribution Map of Earthquakes", which displays the epicentres of recent earthquakes. The epicentres can be clicked in order to retrieve the earthquake parameters.

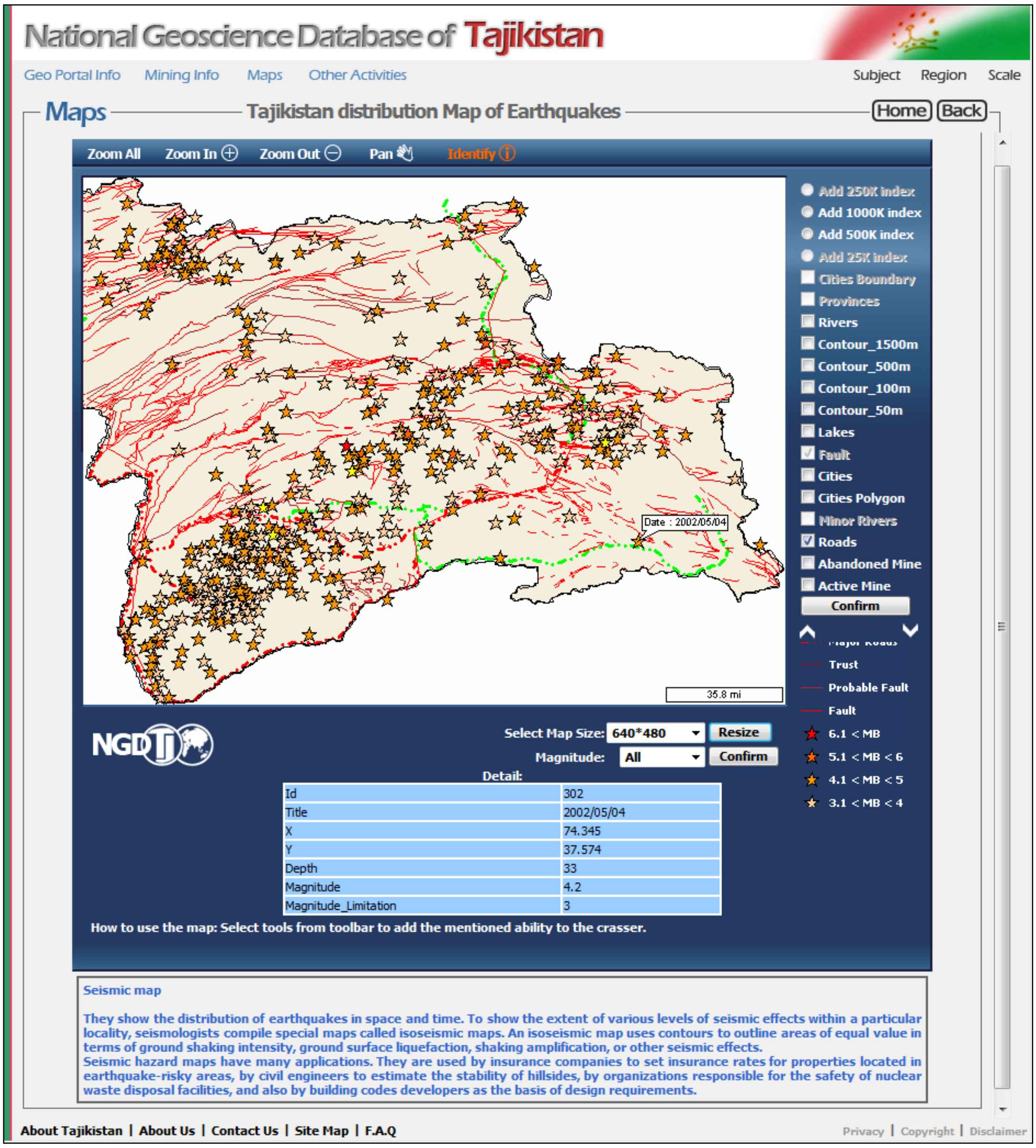


Figure A.16 Tajikistan distribution Map of Earthquakes National Geoscience Database of Tajikistan

Database of historical earthquakes in Japan's ancient medieval time *http://historical.seismology.jp/erice/*

This database (in Japanese) collects and makes available the documents on 3002 historical earthquakes and eruptions previously stored at different Japanese institutions.

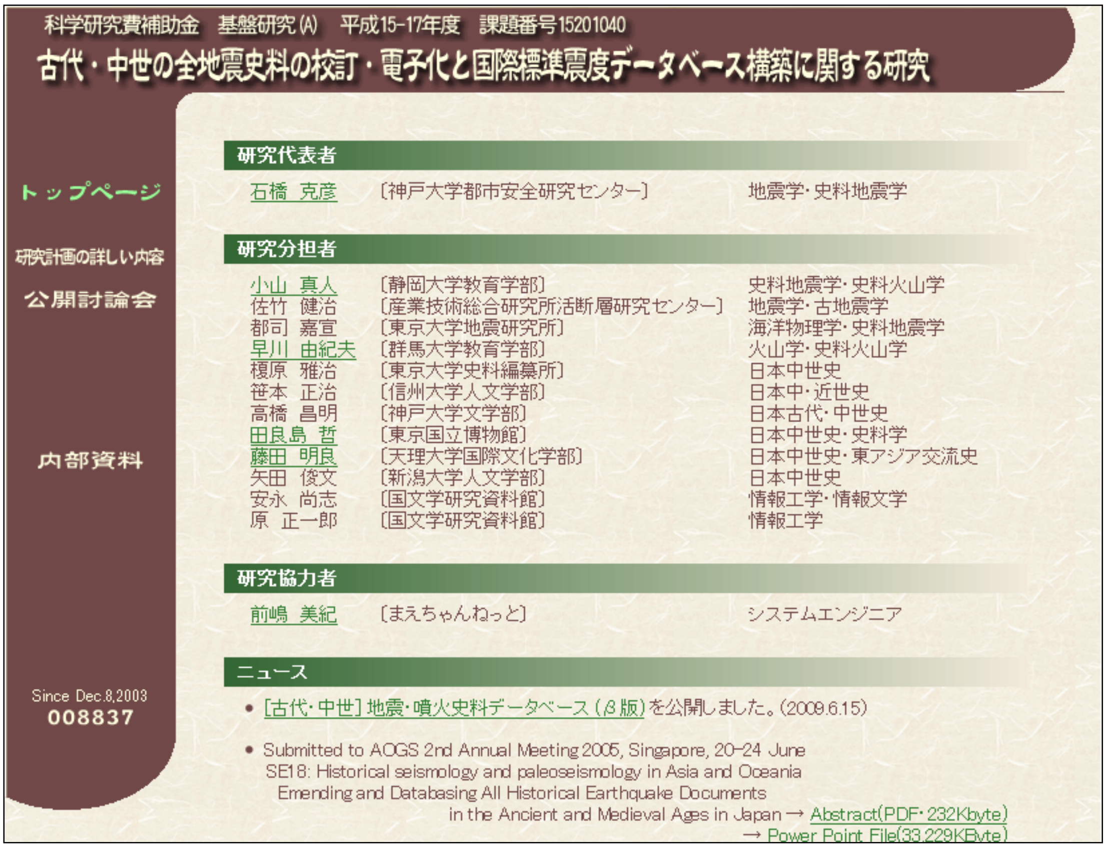


Figure A.17 Homepage of the Database of historical earthquakes in Japan

d) In Oceania

GeoNet - ***http://www.geonet.org.nz/***

GeoNet is geological hazard monitoring system, managed by GNS Science and the Earthquake Commission of New Zealand.

In the "Earthquake Section" of the website, containing general information and data about earthquakes, the "Historic Earthquake" page provides a list of significant earthquakes. The list gives access to earthquake parameters and a short summary of the earthquake effects. A link to the informative webpages on the same earthquake contained in the online Encyclopaedia of New Zealand ("Te Ara", http://www.teara.govt.nz/en) is also provided.

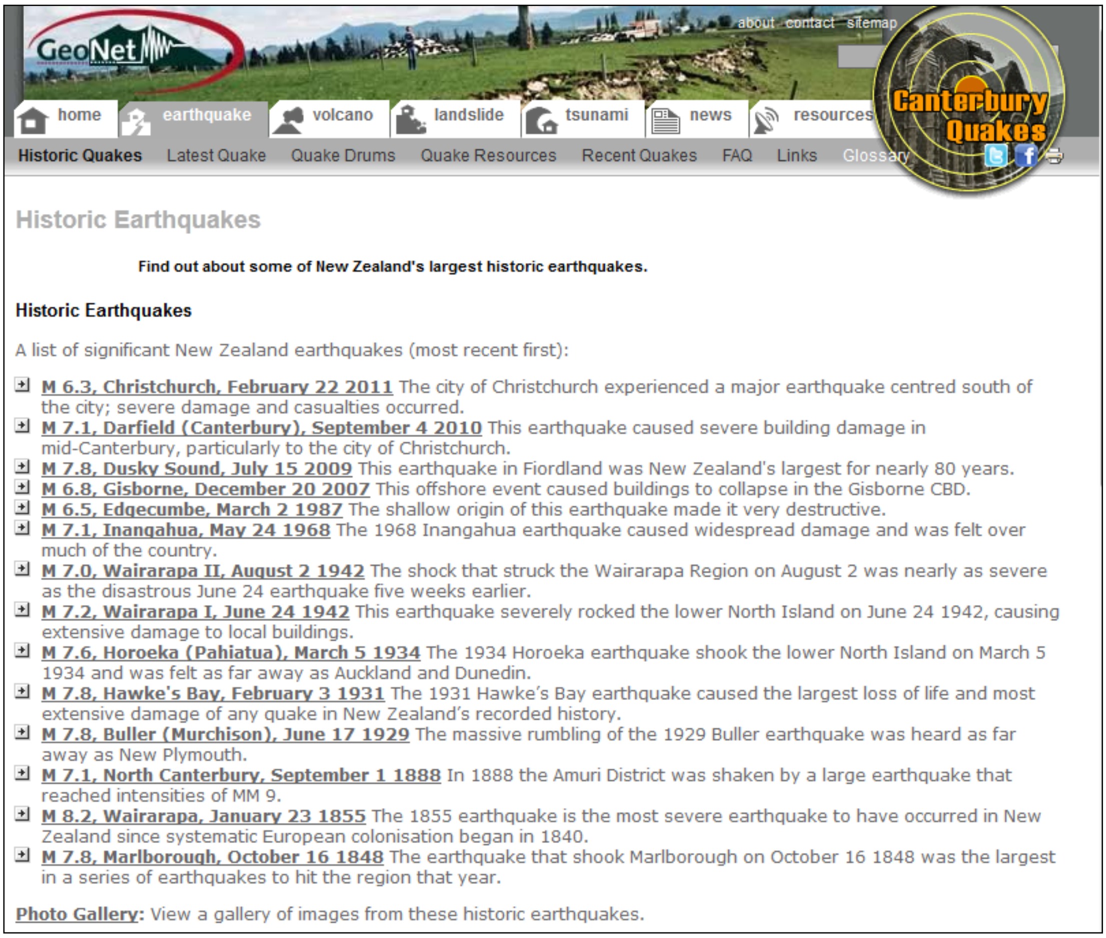


Figure A.18 Historic earthquake webpage from GeoNet

APPENDIX B Glossary

Historical sources (of earthquake information)

Generally they are written works (papers, volumes, archive files, reports, diaries, newspapers, etc.), compiled by an author who reports accounts of earthquake effects.

Historical earthquake studies

Results of historical investigation, generally providing a distribution of earthquake effects, in terms of either accounts or MDPs. They may provide a short description of the investigation in terms of historical sources carrying information (in some cases also of the ones not carrying information, equally useful), comments, etc. and names of affected localities with or without the relevant co-ordinates.

Macroseismic intensity

"Classification of the severity of the ground shaking on the basis of observed effects in a limited area" (EMS98 introduction).

It involves concepts of a statistical nature (effects on a proportion of a sample) over a limited area (not single buildings, not large cities)

Intensity Data Point (IDP)

Semi-quantitative expression of the earthquake effects, as derived from written accounts, questionnaires, etc, formalized in terms of macroseismic intensity at a given location.

Macroseismic Data Point (MDP)

Same as Intensity Data Point, but extended to non-numerical assignments such as, for instance: Damage, Slight damage, Heavy Damage, Destruction, Felt, Not Felt, not classified, sea waves, environmental effects, etc,which cannot be more precisely rendered by the macroseismic scale and therefore are "unconventional", although they may supply useful information.

Seismic History of a site

Chronological sequence of the macroseismic effects suffered by the given site, irrespective of the location and magnitude of the earthquakes which have generated them

Macroseismic epicentre

Epicentre determined from macroseismic information, by means of repeatable procedures (computer codes) or by expert judgment. In general it represents the centre of mass of the most damaged area. For this reason very often it does not coincide with the instrumental epicentre. Also called intensity centre, etc.

Maximum intensity (Ix)

Maximum intensity value experienced in a particular earthquake.

Epicentral intensity (Io)

Intensity experienced at the epicentre; as such, virtual in most cases, but can be the observed intensity at a location close to the epicentre. Many compilers put Io = Ix

Macroseismic magnitude

A magnitude value determined on the basis of macroseismic data, either from Io or by means of repeatable procedures (computer codes) or by expert judgment. Also called intensity magnitude.

Depending whether the procedure has been calibrated against instrumental data, such as Mw, it can be Mw equivalent, and so on.

Isoseismals (also Isoseismal lines)

Lines contouring IDPs or MDPs corresponding to the same intensity degree. Can be of some use if MDPs are shown.

Suffers from subjectivity, although attempts have been made (with very limited success) to use automatic procedures. Potentially, isoseismals can be drawn to overcome cases where the pattern of data distribution is constrained by geography (oceans, seas, lakes, rivers, etc,) and settlement distribution (mountains, deserts, etc.)

Isoseismal maps

Maps showing earthquake effects as a set of isoseismal lines

THE GLOBAL EARTHQUAKE MODEL

The mission of the Global Earthquake Model (GEM) collaborative effort is to increase earthquake resilience worldwide.

To deliver on its mission and increase public understanding and awareness of seismic risk, the GEM Foundation, a non-profit public-private partnership, drives the GEM effort by involving and engaging with a very diverse community to:

- Share data, models, and knowledge through the OpenQuake platform
- Apply GEM tools and software to inform decision-making for risk mitigation and management
- Expand the science and understanding of earthquakes

GEM Foundation

Via Ferrata 1
27100 Pavia, Italy
Phone: +39 0382 5169865
Fax: +39 0382 529131
info@globalquakemodel.org
www.globalquakemodel.org

OCTOBER 2013

The GEM Foundation wishes to acknowledge the following institutions/organizations, for their contributions to the development of this report:

- Istituto Nazionale di Geofisica e Vulcanologia-INGV, Milano
- British Geological Survey-BGS, Edinburgh

GLOBAL EARTHQUAKE MODEL
working together to assess risk