1

Macroseismic information

1.1 A brief description and evaluation of documentary and archaeological source material

The sources on which we relied for the early period were of three types, archaeological, epigraphic and literary, whereas for later periods the chief sources were literary.

Archaeological data

With archaeological information one has to be very cautious when using it to locate and in particular to date earthquakes. I found that dating was frequently based on, or influenced by, literary sources, which often provided examples of how their assumed accuracy, coupled with inaccurate commentaries, has influenced archaeologists' interpretation and dating. This has developed into a circular process in which archaeological theories were transformed into facts and used by scientists to confirm the dates of their events.

Archaeological evidence for an earthquake is not always unambiguous. Displaced, leaning, damaged or collapsed walls in an excavation or in extant historical monuments are features that are often assigned by archaeologists to an earthquake as a *deus ex machina*. However, they can be due to other, non-seismic, causes such as differential settling, particularly arising from leaching or weathering of the foundation materials over the ages, a deterioration process that may be assisted by occasional earthquakes, particularly when these structures have been rendered more vulnerable by deliberate damage and acts of warfare. This is why the observed fractures in walls and pavements may wrongly be attributed to earthquakes. Damage can also be the result, perhaps cumulative, of more than one earthquake, even a long while after the abandonment of the site.

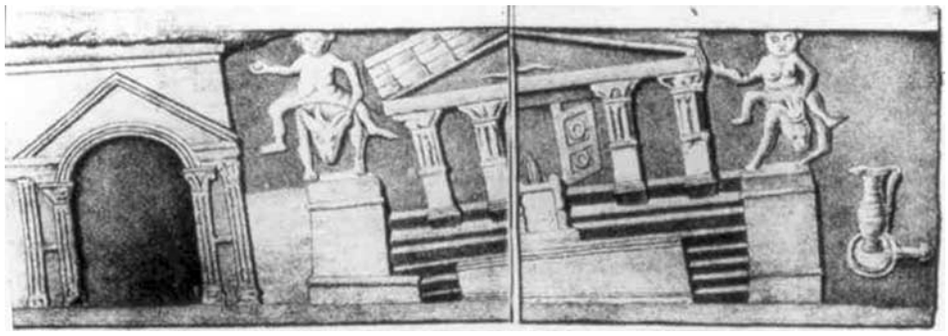

Figure 1.1 Pompeii relief.

Epigraphs and inscriptions

One of the earliest inscriptions is a letter from Nineveh describing an Assyrian earthquake in the eleventh century BC, see Figure 3.1. It says . . . *on 21 Elul an earthquake took place; all the back part of the town is down; all the wall at the back of the town remains except 30.5 cubits therefrom being strewn and fallen on the near-side of the town; all the temple is down . . . let the chief architect come to inspect* . . . (BM 123358: TH.1932-12-10,301).

Perhaps the most representative relief of an earthquake is that shown in Figure 1.1, which depicts the temple of Jupiter in Pompeii in the act of falling during the earthquake of 5 February 62 AD.

For some of the early events, information comes from inscriptions that explicitly mention earthquake destruction or extensive repairs after an earthquake. Epigraphic material may also refer to remission of tribute or taxes following an earthquake. The practice of inscribing such public proclamations on the walls of mosques in Iran, for example, is attested in the late seventeenth century and doubtless continued beyond that time, though no examples involving earthquakes are known. Since they are almost always contemporary, inscriptions provide valuable and indisputable evidence for the location and, quite often, the effects of earthquakes, which, either because of the remoteness of the site or for other reasons, are not recorded in literary sources. Following the same principle for epigraphy as for literary sources, excursions into linguistic or literary questions are, for present purposes, useful only when they contribute to our understanding of the earthquake in question.

Literary sources

In contrast with historical earthquakes after the Middle Ages, for which there is much unpublished information awaiting retrieval from archives and repositories, for the Classical and Roman periods in the BC era all the sources are well known, of a limited number and published. This makes it feasible to examine the original sources rather than relying on the interpretations of modern cataloguers, in order to guarantee a homogeneous and complete body of data, free of duplication and exaggerations, and thus suitable for assessing seismicity with an accuracy adequate for scientific and applied purposes.

Later periods

For later and more recent periods, and for most areas, information becomes fuller and the sources of historical data more numerous as we approach modern times. Partly, this is a function of the greater survival rate of relevant documents. In the Middle East, the accumulation of material in European and Middle Eastern sources greatly extends the opportunities for retrieval of 'new' information from old records. Partly, also, it reflects the increased production of written material and, in the European context, the growth in literacy and secular learning associated particularly with the Renaissance. Commensurate with this is a broadening of the range of sources that may preserve accounts and details of earthquake activity.

Chronicles and annals remain the preponderant source of such data, in some areas in the East even well into the twentieth century for Arabic works, supplemented only occasionally by biographical, geographical or topographical works. In contrast, European writings provide an ever-growing volume and range of data. Compilation of chronicles gives way to antiquarian study, travel literature, private diaries, personal letters and official archives, including diplomatic correspondence.

By the eighteenth century in Europe and the nineteenth century in the Eastern Mediterranean and the Middle East, newspapers (the modern equivalent of the annals of old, in their indiscriminate reportage of ephemera, trivia and the sensational alongside matters of serious material or moral concern), provide an accurately dated and reasonably full record of newsworthy events (as differently perceived in various places and at different

times). It is symptomatic of cultural changes since the First World War that, as instrumental, electronic or other mechanical reporting of events has grown, and news is increasingly disseminated by radio and television, a parallel decline is visible in both the volume and the quality of documentary and descriptive accounts of earthquakes in the twentieth century. While such information allows considerable gains to be made, much material is still unpublished, often difficult of access and hard to read.

There is no doubt that much remains to be discovered in Middle Eastern archive collections, particularly in Turkey and Egypt. Such work is time-consuming and presents serious hurdles. Nevertheless, pursuit of such data in recent decades has spawned a new generation of earthquake catalogues and studies of regional seismicity.

Insofar as **European (Occidental)** sources are concerned, in contrast with the period after around 1400, for Classical, Roman and Byzantine times almost all the sources are well known, and they are relatively limited in number and mostly published. This makes it feasible to re-examine the original sources, rather than rely exclusively on modern cataloguers, who may have been working from a variety of different standpoints. The result should be a body of data that is homogeneous and as complete as possible, free of duplications and exaggerations, and therefore suitable for assessing seismicity with accuracy adequate for scientific and applied purposes.

The main **Arabic** historical sources too, while relatively numerous in the 'classical' age of the Islamic period, that is from approximately the eighth to the thirteenth century, have generally been identified and published. These are for the most part narrative histories, usually arranged in annals, which report events in a precise chronological framework.

However, little or no archival material survives from this early period. Many works known to have been composed have not been discovered, but such information as they may have contained about earthquakes has very probably survived in the work of later annalists.

The most significant events are frequently recorded, with characteristic details, by several authors. Critical comparisons of the various accounts are normally sufficient to identify and resolve small inconsistencies in dating, which have often found their way into modern earthquake catalogues (see, for one example, Ambraseys & Melville (1988)).

The **Ottoman** archival material utilised for the present study consists for the most part of the documents from the Maliyeden Müdevvar (MMD) series in the Ottoman central archives, the Başbakanlik Osmanli Arşivi (BBA) in Istanbul. This is an important source of information since the Ottoman empire covered the whole of the study area for most of the time of interest.

These documents are in registers into which they were copied for the records of the central bureaucracy and are extremely disparate in topic, but have in common that they all concern financial matters, as do most of the other Ottoman documents utilised here. The aim of the writers of the documents which refer to earthquake damage was chiefly to assess the exact cost for the repair or reconstruction of structures affected by the shock, to dictate the administrative route to be followed in effecting the repairs and to ensure that the money assigned was spent as decreed.

Another series of Ottoman documents, which might have been useful and have given further information from different sites, is the records of the kadi courts, but these cannot easily be located.

Among the most detailed documents are those relating to the repair of public buildings, in which are found a record of the dimensions of the damaged part of a structure and a complete accounting for the costs involved. The material relating to each event located is copious, but in isolation is of little value since it almost always relates to damage to individual buildings and in particular to military structures. It is only rarely that there is any reference to damage elsewhere or to casualties and material losses. So, for the region and later period under investigation here, such vital features of an earthquake must be retrieved from these types of non-Ottoman or Venetian sources.

Most Ottoman documents relating to earthquakes provide no date for the events they describe and only a *terminus ante quem* can be established from the date of their issue. This makes it almost impossible to establish simultaneity, so the association of such information with earthquakes known from other sources can only be tentative. Some of the cases may relate to the same event but at present there is not sufficient information to justify their amalgamation, or their association with known events.

Another difficulty in assessing the severity or grade intensity of an earthquake at a particular locality is that in many cases earthquake damage in Ottoman documents is reported together with damage arising from other causes, such as ageing, weathering, neglect and military operations, or as the result of more than one earthquake.

The collapse of or damage to a dilapidated building therefore is not always an indication of severe earthquake shaking but rather a measure of the vulnerability of the structure. Large, distant earthquakes can destroy buildings of this class at distances of hundreds of kilometres from where the earthquake happened,

particularly those built on soft and saturated ground, and their collapse can give the false impression of severe shaking. The lack of interest of the Ottoman administration in the maintenance of public buildings then contributes to false or exaggerated estimates of intensity.

Events known only from Ottoman sources and their retrieval provide a clue to direct further research. We have found it to be the case that while many large known earthquakes go unmentioned in the Ottoman sources, equally, even what are clearly large earthquakes may remain undocumented except in Ottoman sources. Nevertheless the contribution of Ottoman and Venetian source material is of significance in cases where more macroseismic information is added to that for poorly known events. This not only improves the understanding of the location and size of the earthquake in question but also increases the reliability of the estimates.

When we consider the diversity of sources, the numerous languages involved and the paucity of libraries of the relevant types of material, it is clear that such research is extremely time-consuming. This is especially true with respect to the retrieval of earthquake-related material from Ottoman sources.

Venetian archival sources cover a long period of observations, chiefly from coastal regions of the northeast part of the Mediterranean. They provide interesting, although not always useful, information, since these registers and correspondence refer, like some of the Ottoman material, only to the rebuilding and repair of those structures, chiefly defensive, which were of interest to the Republic of Venice.

Venetian correspondence relating to earthquakes shares some of the same characteristics: both Ottoman and Venetian sources suffer from a lack of information regarding non-pecuniary matters, the very information which is of most interest to the scientist. Both Ottoman and Venetian documents rarely name affected sites other than those that had petitioned for or required financial assistance for repairs or reconstruction, seldom mention casualty figures and hardly ever list sites at which an earthquake was felt without damage.

In general each type of source reflects the concerns of its author. In contrast with the narrow administrative concerns of the Ottoman and Venetian bureaucracy, the contemporary accounts of merchants and travellers, for instance, provide an impressionistic and personal picture of the effects of an earthquake, often grossly exaggerated, while the authors of church records are often careful in giving the date of an event, which the Ottoman records usually do not. Consular reports and newspapers give a wider view of the event but are few until well into the seventeenth century.

1.2 Descriptive and parametric catalogues

There is a large number of descriptive and parametric, global, regional and country-specific catalogues of historical earthquakes. Obviously the value of parametric catalogues will be only as good as that of the descriptive catalogues. The following descriptive earthquake catalogues are published and readily available.

Manetti's work is the earliest-known compendium of earthquakes and contains an annotated list of earthquakes in the Eastern Mediterranean and elsewhere up to 1456. Manetti does not always cite his sources and quite often the year of an earthquake is recorded only by reference to other events.

Al-Suyuti's earthquake catalogue was compiled in the early part of the sixteenth century and extended by his continuators to the year 1588. It is a reliable source of information for the Muslim world, covering the region from Morocco to Transoxania (Sprenger 1843, Ambraseys 1961, Sa'adani 1971).

Bonito's large world earthquake catalogue is an invaluable compendium of information about earthquakes that ends with 1690. Its 822 pages contain a wealth of information culled from a variety of sources, which Bonito quotes and occasionaly annotates. His work provides an excellent starting point for the identification of earthquakes in Europe and in the New World (Bonito 1691).

Coronelli's work, although prepared as a global catalogue of earthquakes up to 1693, deals mainly with events in the central and eastern Mediterranean. Annotations are kept very brief, making no reference to sources of information and occasionally neglecting to give the full date of an event (Coronelli 1693).

An anonymous compilation of earthquakes throughout the world was published in a series of issues of the *Dresdenische Gelehrte Anzeigen* in 1756, and is a useful source of information for earthquakes worldwide during the sixteenth and seventeenth centuries up to 1691 (PDGA 1756).

Von Hoff's general catalogue of earthquakes is a valuable work, covering events worldwide for the period up to the end of the seventeenth century. It is an accurate and methodical study, drawing on a variety of published sources, which are cited (Hoff 1826–35).

The compilation of Seyfart's work on earthquakes was prompted, like many similar works of the mid eighteenth century, by the large Lisbon earthquake of 1755. It contains interesting entries, mostly extracted from published material in Europe, such as flysheets and

newsletters, as well as from the European press (Seyfart 1756).

Berryat's long chronological list is an annotated collection of information about earthquakes up to 1760. The author does not cite his sources but they seem to include, among others, earlier catalogues and information from the European press (Berryat 1761).

Von Hoff compiled twelve annual earthquake catalogues for the years 1821–32. He extracted much of the information from press reports, travel diaries and correspondence. His work is of interest for areas outside Europe (Hoff 1840–41).

Mallet's catalogue occupies nearly 600 pages and contains almost 7000 events worldwide. Although it is based on several earlier catalogues, especially those of Hoff and Perrey, his catalogue for the period after the seventeenth century contains a considerable amount of information from relatively early press reports, some of which are useful for investigating the seismicity of the Americas and the Far East (Mallet 1850–58).

Perrey's annual lists of earthquakes for the 28 years 1844–71 are invaluable. They occupy 28 papers and the total number of pages in these Mémoires is just over 2500. Perrey collected much of the material by correspondence and also gleaned information from the international press. His annual lists are a vast storehouse of facts; for the most part he was content to leave discussion of the results to others. There is seldom any attempt to determine the position of the epicentre, and none to discover the relation between main shock and aftershocks or the relation between shocks felt at the same time at different places (Perrey 1848–75).

Schmidt's catalogue for the Southern Balkans and Asia Minor is one of the most important sets of data for the region. It depends very little on previous lists or catalogues and, from about 1800 onwards, is the result of his own labours. From after about 1858 to the end of 1878, his catalogue contains just under 4000 entries, derived chiefly from correspondence with observers, travellers and consuls throughout the Eastern Mediterranean and from the press in Athens, Istanbul, Izmir and other places in the area (Schmidt 1867a, b, 1879).

A long memoir containing lists of earthquakes for the 20 years 1865–84 was published by Fuchs. These lists include nearly 10 000 entries altogether, containing a substantial amount of information for earthquakes worldwide. In common with some other catalogues, this work must be used with caution, for nowhere does Fuchs cite his sources and it is accordingly difficult now to appreciate the value of the information which he retrieved (Fuchs 1886).

Mushketoff and Orloff's earthquake catalogue for the Russian empire ends in 1888. It is based on previous catalogues but also on contemporary national and local Russian press reports and, to a lesser extent, on unpublished documents. Events are fully annotated and sources are given in full. This is a very useful source of information (Mushketoff and Orloff 1891).

Milne's world catalogue of destructive earthquakes up to 1899 is based entirely on previous lists. It is devoid of information from original sources, except for the first decades of the period for which information comes from unpublished documents (Milne 1911).

Montessus de Ballore's world catalogue consists of 171 434 entries covering the period up to 1906. Only a small fraction of this enormous volume of information, which covers mainly the second half of the last century, has been published, and it remains little known. However, the published information is not of very great value; the unpublished files, kept in the Département des Cartes et Plans, Depot de la Société de Géographie of the Bibliothèque Nationale in Paris, where they occupy 30 metres of bookshelf, did not prove, on examination, to be as useful as had been expected. Much of the information in these files was extracted from previous catalogues and press reports, with little original material derived from correspondence with observers (Ballore 1900, 1905, 1924, 1925).

Sieberg's annotated world catalogue of earthquakes contains a considerable amount of information, including isoseismal maps for the larger historical earthquakes worldwide up to 1930. His work, he admits, is subjective, influenced by his experience as a professional architectural engineer who in the first quarter of the twentieth century visited many sites of earthquakes. He was one of the first in Europe to test models of buildings on shake-tables.

However, his catalogue contains many errors and duplications in entries and gives little indication of his sources of information, despite which this highly inaccurate work has for many years been regarded as a standard reference on the subject (Sieberg 1932a, b).

Stepanian's annotated catalogues of earthquakes in Greater Armenia are a useful set of documents. They are based on a considerable number of primary published Armenian sources. These Armenian catalogues of Stepanian are little known; they are accurate and methodical, and contain about 800 events (Stepanian 1942, 1964).

Byus' book of earthquakes in the Caucasus and adjacent regions is a systematic compilation of information from previous catalogues, in some cases critically selected, as well as from local Georgian, Armenian and Russian sources, including local newspapers and reports. This 600-page-long work contains a wealth of information about events in the Middle East (Byus 1948).

Rethly's book of earthquakes in the Carpathian region and central Europe is a serious piece of work. It includes extracts from original sources and is fully referenced. This work is invaluable for the identification of events that affected southeast Europe (Rethly 1952).

Ambraseys' three-volume Corpus of Documents of early earthquakes in the Near and Middle East is a collection of little-known Greek, Arabic and Syriac sources of information, compiled for UNESCO during the period 1961 to 1970 in Ambraseys (1970b), *Early Earthquakes in the Near and Middle East 17–1699 AD*:

Part I: *Documentation of Historical Earthquakes in the Middle East*, UNESCO Report SC/1473/1969, 410 pp.;
Part II: *Historical Earthquakes after 17 AD*, UNESCO Report SC/2129/1970, 45 pp.;
Part III: *North Africa and South-east Europe*, UNESCO Report SC/2129/1970, 40 pp.

The survey of the seismicity of the Balkan region carried out by UNESCO in the mid 1970s contributed a summary of the material available at that time for the assessment of regional seismicity. Isoseismal maps for a few events before 1900 and a parametric catalogue were published, but they must now be used with caution (Shebalin, Karnik and Hadzijevski 1974).

The catalogues of earthquakes in the Middle East and along the Dead Sea Rift by Ben-Menahem (1979, 1991) contain information extracted from earlier catalogues of varying quality and from secondary works. These lists, which include a parametric catalogue going back to 2050 BC, must be used with very great caution.

The earthquake catalogue of the former USSR covers a large geographical area for the period before 1977 (Kondorskaya and Shebalin 1982). It is based chiefly on secondary macroseismic sources but includes a detailed procedure for the systematic quantification of historical events.

The catalogue of Poirier and Taher (1980) covers the seismicity of the Middle East, listing nearly 200 events up to 1800. It summarises information taken from a thorough survey of Arabic source material, presented in Taher's doctoral thesis at the Sorbonne (Taher 1979). References are properly identified and cited. Though the catalogue contains various errors and duplications, this is a considerable improvement on earlier works. A more extended summary of the primary data, although regrettably without any reference to modern studies of the last two decades, is currently in progress (Taher 1996).

A useful catalogue by Russell (1985) for Palestine in the period up to the mid eighth century presents the texts of the accounts of earthquakes in the region from contemporary sources and attempts to resolve discrepancies in dating. The catalogue also provides archaeological evidence of damage that has been adduced to support the dating of some of these events, or to be dated by them.

The books by Ambraseys and Melville (1982) and Ambraseys *et al.* (1994) present a thorough re-evaluation of the long-term seismicity of Iran, Saudi Arabia and the Red Sea, based as far as possible on primary Persian, Arabic and occidental sources. These works present in some detail the methodology proposed to assess historical seismicity by combining instrumental data and macroseismic information.

The paper by Guidoboni (1989) is a descriptive catalogue of information on earthquakes in Italy and in the eastern Mediterranean as a whole and covers the period from the eighth century BC to the tenth century AD. Events are annotated and texts originating from sources in Greek and Latin are given in their original script with a translation into Italian. Generally no attempt is made to discuss and assess the seismological aspect of the information it presents.

The part of the Catalogue (and Map) of the Global Seismic Hazard Assessment Programme (GSHAP 1992, Giardini 1999) that refers to the eastern Mediterranean region is the result of a compilation of heterogeneous data taken from a kaleidoscope of national catalogues.

The book by Ambraseys and Finkel (1995) covers Turkey and parts of the Middle East for the period from 1500 to 1800. Its value is chiefly the presentation of unpublished Turkish and occidental sources of information for this period about earthquakes.

The catalogues of Papazachos and Papazachou (1989) cover the historical seismicity of Greece and adjacent regions. These are annotated compilations essentially based on previous catalogues without scrutiny, adding little or no new information.

The book by Guidoboni, Comastri and Traina (1994) deals with earthquakes in the Mediterranean area up to the tenth century AD. Events are annotated and texts originating from sources written in Hieroglyphic, Greek, Hebrew, Latin, Syriac, Coptic,

Armenian, Aethiopic and Arabic are given in their original scripts with a translation into English, obviously for the very many readers who are not familiar with these languages. The book is decorated with maps, figures and photographs.

The work by Spyropoulos (1997) is an exhaustive annotated corpus of extracts from original but chiefly secondary sources relating to historical earthquakes in Greece.

Sbeinati, Darawcheh and Mouty (2005), 'The historical earthquakes of Syria: an analysis of large and moderate earthquakes from 1365 BC to 1900 AD', *Annals of Geophysics*, **48**, 347–435.

The book by Guidoboni and Comastri (2005) consists of a compilation of information about earthquakes in the Eastern Mediterranean region and in the Middle East over the period 1000 to 1499. This impressive catalogue is 1037 pages long. It is written in the same style as the earlier book by Guidoboni, Comastri and Traina and lists 383 events, of which 154 belong to Italy and 229 to the rest of the region.

The existence of all these readily available descriptive catalogues does not, of course, mean that no further research remains to be done and no new sources remain to be discovered. A catalogue at best can sum up the state of knowledge at the time it was written, and provides a basis for new work with a view to promoting knowledge of studies on local seismic activity and to evaluating their contribution to the previous state of knowledge.

Unfortunately, some authors of twentieth-century descriptive catalogues then go on to do a disservice to the study of historical seismicity and go backwards rather than forwards. Their work, which is supposed to be a critical review of the data and a comparative study of seismicity, becomes in fact neither critical nor comprehensive in scope. They accept much of what previous catalogues say without further inquiry, and no attention is paid to other recent works devoted to the seismicity of the region except for their own published work. Despite the fact that some of these works epitomise the twentieth-century trend towards undiscriminating cataloguing, they have been standard references on the subject for historians, archaeologists and Earth scientists.

Early descriptive catalogues are few and necessarily summary, and cannot go into all the details that exist in manuscripts, tracts and pamphlets, which are numerous and difficult to locate.

There is relatively little I could find in unpublished manuscripts, much of which is in short, almost telegraphic, notices, see Figure 3.12, or in general references of the period from the fourteenth to the sixteenth century to events illustrated with imaginary wood-cuts or drawings (Figures 1.2 and 1.3).

Figure 1.2 A manuscript depicting the horrors of earthquakes (Exposition de l'Art Byzantin, no. 350, Athens 1964).

One of the few interesting manuscript notes of that period is that of Leonardo da Vinci, who describes the effects of the earthquake of 1481 at sea near Cyprus, Figure 3.13. The year he gives is clearly written as '89, probably a slip of the pen for '81. From the style of his account it seems that Leonardo was not an eyewitness of the earthquake, but it is known that in late 1480 or early 1481 he was in Cyprus. There is also an interesting news-sheet of 1545 that gives first-hand information for an earthquake in central Greece about which little is known from other sources, Figure 3.18. The same

Figure 1.3 A late sixteenth-century mural in the monastery of St Dionysious, Mt Athos, in northern Greece. The artist has sought to evoke the nightmare atmosphere of a violent earthquake by depicting, in addition to collapsing buildings, haloes around the Sun and Moon and falling stars.

Christelijke Aanmerkingen

Op de Sware

AARDBEEVINGE,

Geweeſt den 18. September 1692. des naarmiddags ten 2. uuren 19. minuten.

Neffens een kort verhaal en overweginge van de 8. ſchrikkelijke Aardbevingen, die 'er nu in 25. Jaren herwaarts op verſcheide Plaatſen, gevoelt en beſuurt zijn.

Tot noodige Opwekkinge van de Vroomen, en ernſtige Waarſchouwinge voor de Godloozen.

Vervat in een Brief uit het Gooy, aan een Heer tot Amſterdam geſchreven, den 27. des ſelven Maands September.

Σημεια τε μεγαλα ἐσται κατα τοπους. Lucæ 21. 11.

Gedrukt tot Utregt

By Willem Jansz. 1692.

Figure 1.4 One of the Dutch pamphlets of the period 1690–1710 that referred frequently to earthquakes worldwide (J. Vogt).

applies to a few other sixteenth-century news-sheets that report earthquakes in Thrace; one of them is shown in Figure 3.17.

There is a lot of information that can be found in tracts and pamphlets written at second or third hand of this and of later periods, but tracts would focus, understandably, on the local information available for a particular event rather more than would be appropriate in a more general work. Accounts at second hand were published for calamities, among which earthquakes, for Cyprus and Palestine, Figure 3.19, as well as in Dutch pamphlets, bringing to light events little known or unknown from other sources, Figure 1.4. Turkish court documents referring to repairs of public buildings after earthquakes show quite often that damage was far less serious than that presented by church writers and the occidental press reports, Figure 3.29.

The effects in Istanbul of the earthquake of 10 September 1509 in the Sea of Marmara have been grossly exaggerated in secondary sources, to the extent that the earthquake became known as *küçük kiyamet* (little apocalypse). Figure 3.16 shows a wood-cut made in 1529 by Coecke, illustrating the Fatih mosque with truncated minarets attributed to the 1509 earthquake. That the minarets would have remained unrepaired for 20 years seems rather strange and an inspection of another print of this wood-cut, kept at the British Library, shows some damage in that area such that a portion of the minaret and dome may have been lost. Later prints from a better pressing from the same block at the British Library show no flaw and the tallish minarets built outside the body of the mosque, so that the only indication of their collapse is the misinterpretation of Sanuto's statement that'...il *marati* del Segnor vechio va in rovina et la mazor parte de le mochee...' In fact *marati* should be *imarets*, the ancillary buildings of the mosque, not minarets.

Many earthquakes are illustrated with contemporary wood-cuts and prints, almost all of them accompanied by a caption written with some poetic licence, Figure 3.32. The earthquake of 14 January 1546 in Palestine is considered by late sources to be one of the most important earthquakes to have occurred in Jerusalem and its district. It caused some slight damage in the region, but in contemporary sources and wood-cuts the reported damage was grossly exaggerated. Voldrich, a Czech pilgrim, who was in Jerusalem very early in the summer of 1546 noticed that only the top part of the church of the Holy Sepulchre collapsed because it was heavy, revetted with sheets of lead. A view of the Holy Sepulchre and its square was drawn by Voldrich's companion, Dominik de la Greche, and appended to his book, Figure 3.21. The detailed panoramic view of Jerusalem also drawn by de la Greche shows no other tall structures missing or the collapse of the dilapidated city walls, Figure 3.20.

Even in more recent times damage and loss of life reported in private correspondence, for instance after the destructive earthquake of 1894 from the region between Adapazari and Lake Iznik in Turkey, is not mentioned in the Turkish press, which concentrated chiefly on the effects of the earthquake in the capital. This supports the opinion expressed by foreign eyewitnesses at the time that news in the press about the disasters in Turkey was being systematically censored, Figure 1.5.

There is also a substantial number of 'original' descriptions of destructive earthquakes, reported not only in contemporary sixteenth- and seventeenth-century fly-sheets (*flugblätter*) but also in early documents, regarding which on examination the information proved to be spurious. This shows that the fact that the information is coeval or even eyewitnessed is not a guarantee that it is not spurious, biased or invented for political reasons, or a figment of the religious imagination.

For instance, Figure 3.25 shows the front page of a tract published in the last quarter of the sixteenth century regarding a destructive earthquake somewhere in Palestine or northern Arabia. The whole episode, for which neither the exact year of its occurrence nor its exact location can be fixed, might well be a pious fiction, with a tinge of Biblical Gomorrah when it refers to an earthquake and fire from Heaven destroying the region.

The *flugblatt* shown in Figure 3.26 describes a damaging earthquake in 1661 affecting much of Bulgaria and Panonia, not mentioned in any other contemporary document, which is in need of authentication.

Also Figure 3.24 is an illustration in a contemporary fly-sheet that shows imaginary damage in Istanbul in an earthquake in 1542. This is a typical theme of the contemporary European press, which was wont to publish such 'news' concerning the Ottomans at times when relations were unstable, or on the occasion of an Ottoman military victory, in order to encourage confidence that they would be overcome by the West (Anonymous 1542a, b, c).

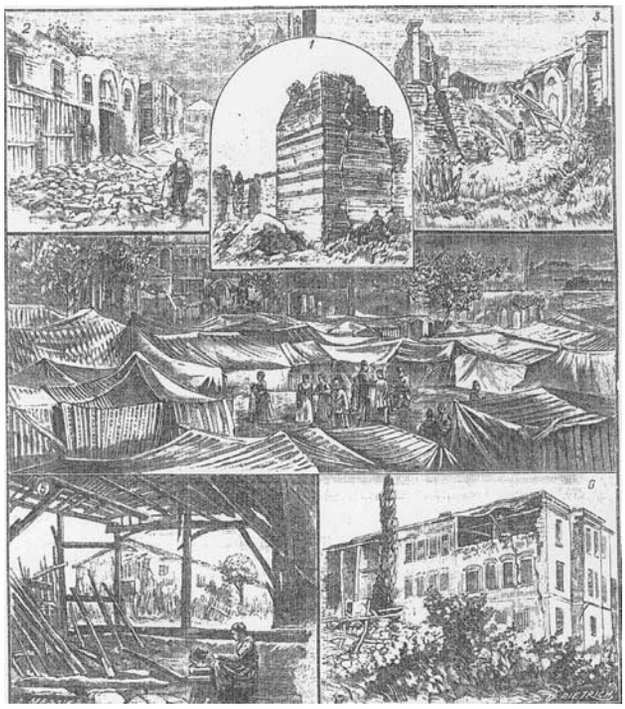

Figure 1.5 Scenes of the effects of the earthquake of 1894. (1) Damage to the Constantinian walls of Istanbul. (2) An aspect of a street in Istanbul after the earthquake. (3) The ruins of the library of the theological school on Princes Island. (4) A refugee camp in the Garden of Dervishes in Pera. (5) A ruined house in Adapazari. (6) Damage to the theological school at Chalki (*La Nature* 1894, no. 1114).

1.3 Archaeoseismology

An incidental benefit from the study of literary and archaeological field data is a warning of caution for those who find it easier to ascribe the demise of a city, the end of a civilisation or the ruins found in an excavation to earthquakes. If the solution to a problem is not immediately obvious, amateurs eagerly consider a catastrophe theory that the pioneers of this discipline developed to account for the collapse, for example, of the Aegean Bronze Age.

Previous research has uncovered evidence of destructive earthquakes in areas of the eastern Mediterranean where only small events have been experienced recently, with the evidence drawn from realistic physical considerations and input data. For earthquakes before

our era, however, historical and archaeological data have attracted interpretations that are influenced by the dogma of catastrophism, attributing to earthquakes the obliteration of the eastern Mediterranean region in the Bronze Age, large movements of peoples and the demise of flourishing city-states.

In the early part of the nineteenth century geology was under the influence of the dogma of catastrophism, the hypothesis that changes in the Earth occurred as a result of isolated major catastrophes of relatively short duration, as opposed to the idea implicit in uniformitarianism, namely that small changes are taking place continuously. Catastrophism passed off the scene, now more or less completely discarded, and uniformitarianism took over.

However, the last few decades have seen a gradual re-emergence of neo-catastrophism, this time in the field of archaeoseismology, particularly for earthquakes before our era in the Eastern Mediterranean, bringing back into prominence the ideas of Velikovski (1950). To mention a few of the propounders of this dogma, Marinatos in the late 1930s postulated a catastrophic eruption of the volcano of Santorini and a seismic sea wave responsible for the demise of the Minoan civilization (Marinatos 1939). Then followed Schaeffer (1948), who attempted to account for gaps in the sequence of civilizations in the third or second millennia BC in the Middle East within a relatively short period by invoking a series of major seismic upheavals. He was followed by, among others, Galanopoulos, who suggested another catastrophe that became quite controversial and is still being debated today, namely that the island of Santorini was the lost continent of Atlantis. Galanopoulos claimed that it was the sinking of Santorini into the Aegean Sea c. 1500 BC that wiped out the Minoans in a single volcanic eruption that was as 'cataclysmic as nuclear war' (Galanopoulos and Bacon 1969). Then, Kilian contributed with another, more local, catastrophe at the end of the late Bronze Age, one that allegedly caused the collapse of Mycenae and all of Peloponnesus due to a massive earthquake (Kilian 1980, 1988, 1996). Others followed in more recent times, attributing to earthquakes the obliteration of the eastern Mediterranean region in the Bronze Age and the demise of flourishing city-states, including Troy. The reason for the revival of catastrophe hypotheses is perhaps that they are easy to explain. They are too simple, too obvious and too coincidental, particularly when they are based on inadequate or biased historical evidence and also because they have become fashionable in recent years. If the solution to a problem is not immediately obvious, a catastrophe theory, which attracts considerable publicity, can account for it (Lewis and Terris 2002).

It is not suggested that destructive earthquakes are unlikely to happen in the Eastern Mediterranean region but rather that there are good reasons why one should be careful not to accept such theories at face value. Conclusions about the significance of early earthquakes, particularly those that happened before the recent historical era, must be drawn from realistic physical considerations and data so that theories and uncertainties can actually be verified by testing the data.

It is too much to expect that this kind of information can be gleaned from archaeological evidence alone, which is always ambiguous and can seldom be used to provide the more precise answers that are needed by the engineer in order to assess earthquake hazard. Nevertheless, archaeological evidence can potentially provide confirmation of long-term seismicity rates and, with greater collaboration between disciplines, it is likely that many refinements of the existing results will be possible.

We may mention here three of the earliest earthquakes to which modern cataloguers invariably give a cosmic dimension, the primary sources for which hardly support such an interpretation.

Regarding the earthquake in Jericho, some Bible readers have supposed that an earthquake toppled the walls of the city. However, the account of Israelites conquering the city contains no reference to earthquakes. Moreover, we have no conclusive evidence to associate the fall of Jericho either with the earthquake damage preserved on the site of the old city or with the damming of the River Jordan at Al-Damieh, which may be the result of earthquakes over a long period of time (Kenyon 1978a, p. 36; see also the section on Case Histories). Archaeological reports give little or no technical justification to support the conclusion that the destruction was due to an earthquake and, if so, due to the very same earthquake as that mentioned by Amos, while the available stratigraphy cannot rule out the possibility that the observed damage resulted from later earthquakes.

Searching for archaeological evidence for the earthquake destruction of Jericho (which is not mentioned in the Bible narrative, our only source), occurring at the time of the Israelite invasion (the date of which is uncertain), reminds one of **Kaplan's parable** of the drunkard searching under a street lamp for his house key, which he had dropped some distance away, but he searches there because there is more light.

About the effects of Zechariah's earthquake, one is left with even more questions. For instance, on what evidence is the meagre historical information in the Bible translated according to Ben-Menahem (1979, p. 262) into a catastrophic earthquake of magnitude M_L 8.2 (*sic.*), shaking Jerusalem with intensities VIII to IX. Why has this earthquake been associated so precisely by Austin