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The Earthquake of 1509 in the Sea of Marmara, Turkey, Revisited

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Abstract This article is interdisciplinary in nature, relevant to the fields of both earth sciences and historiography, which come together in the investigation of long-term earthquake hazard. Taking here as an example the earthquake of 10 September 1509, which was associated with an inferred 70- ± 30-km-long offshore fault break in the Sea of Marmara (M_W 7.2 ± 0.3) and with widespread damage in Istanbul and the adjacent region, this article emphasizes the need for systematic and consistent analysis of historical earthquake data and sets an example for such a task.

The re-examination of this earthquake, in the context of the long-term seismicity of the region over the last 2000 yr and in comparison with larger historic and modern events in the region, shows no macroseismic, and to some extent, no tectonic evidence that the 1509 earthquake was a catastrophic event. It is one of the damaging shocks in the 17-century-long history of Istanbul, of a magnitude that was smaller than the large events that can occur further east in the Anatolian Fault Zone.

This is consistent with the evidence from seismic reflection surveys in the Sea of Marmara, which shows that faults are generally less continuous offshore than onshore, as well as from the long-term seismicity of the region, which is an implication of the opening up of the Sea of Marmara earthquakes and its association with relatively short faults compared with ruptures of great lengths in the Anatolian Fault Zone further east, which is dominated by strike slip.

Introduction

The Marmara Sea region is a densely populated and fast-developing part of Turkey (Figs. 1 and 2), which includes greater Istanbul, a megacity of about 10 million inhabitants. This region was seismically active during the twentieth century, with two large earthquakes in 1912 and 1999, which raises the question of short- and long-term seismicity that must be addressed in any realistic assessment of the earthquake hazard in this populous area. In this article we re-examine in some detail the earthquake of 1509, which caused extensive damage in Istanbul and has a bearing on the earthquake hazard in the region.

The importance of the long-term record of historical earthquakes has been generally recognized. However, opinions have differed over how much use can be made of historical evidence for seismic hazard studies. Some are content to associate earthquakes with known faults and assign them magnitudes or intensities, regardless of whether the evidence supports these interpretations.

Others consider that such evidence, generally imprecise and always to some degree subjective, cannot be quantified, and however useful as a general indication of past activity, it cannot be used for numerical or statistical analyses. To counter such a view, we may use the method of comparing historical earthquakes with modern earthquakes whose location, faulting style, and seismological parameters are known. This comparison has to be made not only in terms of damage and size of the affected area reported in early documents, but also from the perspective of the actual social, economic, and political situation at the time of the earthquake and of its aftermath, identifying spurious information, bias, and natural exaggeration in contemporary sources and by removing pseudo-objectivity from modern works (Vogt, 1996). In short, to be useful, this method requires considerable interpretation and evaluation of the source material, and we may use this method here, as we have done elsewhere (Ambraseys and Jackson, 2000), to assess the location and size of the 1509 earthquake. This approach requires trespassing into humanities, with the result that discussion becomes rather verbose for the scientist and somewhat pedestrian for the historian.

What prompted the writing of this article was that following the Kocaeli earthquake of 1999 and with the 1509 earthquake coming into prominence, earth scientists, without recourse to source material, proposed various interpretations of the seismological significance of the 1509 earthquake and of its tectonic implications. These varied widely, from an earthquake of a sensible size, associated with a relatively short fault rupture offshore Istanbul (Parsons *et al.,* 2000), to a catastrophic earthquake of magnitude M_S 7.6–8.0, rupturing the projection of the North Anatolian Fault all along

Figure 1. General location map, showing Marmara Region (inset A), and Marmara Sea area (B).

the Sea of Marmara, from the Gulf of Izmit to the Galipoli Peninsula (Le Pichon *et al.,* 2000).

In what follows, we present an example of the procedure of processing and reappraising background historical information as it becomes available with time, against which the assessment of a historical earthquake must be considered. The earthquake of 1509 was investigated in the same detail as other early events in Turkey and in the Middle East, and their reassessment today supercedes appraisals made 12 yr ago.

Sources of Information

Information about the effects of the 1509 earthquake is available from both Turkish and occidental sources. We have seen few original manuscripts, and the data used in this article have been taken chiefly from printed documents.

The period is a little too early for ample Ottoman archival evidence and too late for Byzantine. The most valuable account we have about this earthquake is that of the Ottoman chronicler Ruhi, who was a contemporary and pos-

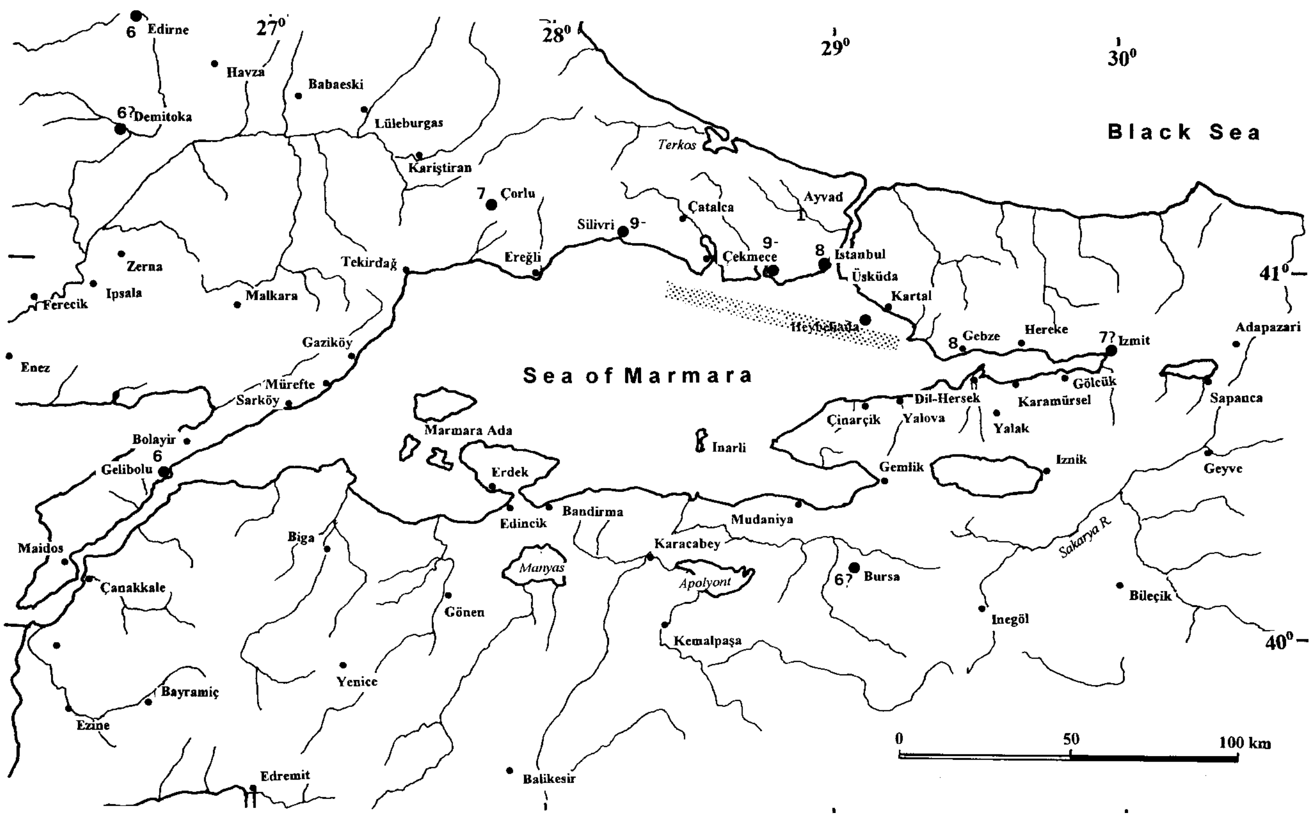

Figure 2. Location map of the Marmara Sea area, showing with large circles places mentioned in the text. Numbers refer to assessed intensities in MSK. Shaded zone off Istanbul indicates adopted fault break associated with the earthquake.

sibly an eyewitness, the contemporary Kemalpasazade (Tansel, 1966; Ugur, 1985), and various anonymous histories (Tevarih-i al-i osman, 1099; Giese, 1922; Kreutel, 1978). Further Ottoman accounts are based on those of Ali, whose observations are based on those of Ruhi, and of Solakzade, who takes his information from Ali, information we also find in Tarih-i Ebul'faruk (see Mehmed Murad 1907–1914). These accounts, however, apart from the significant details given by Ali, do not add much substance to what we find in Ruhi.

Contemporary information also comes from the Diaries of Marino Sanuto, which contain a letter from Istanbul written on 15 September 1509 by the Venetian Nicolo Zustignan. In the same diaries, news of the earthquake, not all that reliable, is also given in another letter dated 9 October 1509 sent by Mihnea, Voyvode of Wallachia, to the Doge of Venice, wherein he mentioned the news of the event he had received from his son who was in Istanbul at the time of the earthquake. Other letters, in the Diaries from Istanbul and Edirne dated October and November 1509, and February, April, May, and September 1510, give additional information about the aftermath of the earthquake.

Diplomatic correspondence from Constantinople in the Archivi di Stato in Venice (dispacci, deliberazioni) during the period 1509–1540 is very sparse. It contains no dispatches from Constantinople between 1509 and 1511, a period during which the relations of Venice with the Ottoman Empire were interrupted. We have, however, correspondence from the Genoese colony in Pera, which provides some information about the effects of the earthquake in Galata (Belgrano, 1888).

There are also two contemporary anonymous flysheets (Anonymous, 1509, 1510) based partly on the letter of Mihnea but with some additional information, probably from other correspondence, which we have not as yet identified, and which should be given some credence.

Brief accounts from two Europeans who happened to be in Turkey at the time, Spandouyn Cantacusin Th. (1896) and Menavino (1548), are also useful, as well as the accounts of Wilhelm von Bernkastel (see Hoffman and Dohms, 1988) and Zurita (1610). Although they were not contemporaries, their accounts contain some details not found elsewhere, probably derived from earlier sources.

Also useful is a Greek marginal note, probably contemporary or derived from a contemporary source , which gives details regarding the damage that occurred in Istanbul and on the Princes' Islands (Constantinos, 1824/1844; Eustratiades, 1924), which is not mentioned by other writers, and an anonymous chronicle by Sathas (1894). Seven other Armenian, Greek, and Slavic marginal notes (Lampros, 1932;

Stojanovic, 1927; Hakobyan, 1951) are telegraphic and give no useful details.

There is also a notice in a contemporary Arabic history (Ibn Iyas Muhammad b. Ahmed, 1955) that is important because it provides some evidence about the furthermost point at which the earthquake was perceived. Very few later Arab authors mention the event, even by way of a passing reference (Hajji Khalifeh, 1058/1648).

There are many other occidental chronicles that merely mention the 1509 earthquake without details (Giovio, 1555; Anonymous, 1574; Garcaeus, 1568), some of which are given in Bonito (1691). All these accounts are brief and grossly exaggerated. In spite of the large number, there are only few accounts that are near contemporary, and much of what has been written by the writers of the sixteenth century and later is a derivative with little additional information (Sohrweide, 1965). For instance, Lycosthenes (1553), Frytschius (1563), and Surius (1568) copy Munster (1550), whose work appeared in 1544, whereas Goulard (1610) repeats Leunclavius (1558).

Although almost all these sources of information that we retrieved over the years from various libraries were hitherto unknown to the seismologist, they are, however, with a few exceptions, well known to historians and are easily accessible.

There is considerable confusion in these works. Some writers syncretize the 1509 earthquake in Istanbul with separate events in Carinthia and Styria (Nauclerus, 1579), or they amalgamate the event with the earthquake in Crete the previous year and with a seismic sea wave there that allegedly drowned 12,000 people (Lancellotti, 1673). Other chronicles are essentially similar in form and content, indicating translation and revision with a tinge of exaggeration from a few common sources. There are, however, few of these accounts that seem to have been based on sources that we have not as yet identified, and these, although they may seem superfluous, for the sake of completeness, have been retained. With few exceptions there is no point in laboriously quoting repetitive sources.

We have no documentation of European travellers who passed through Thrace and the Marmara Sea region shortly after the earthquake. Minio Marco (1845) visited Galipoli and Istanbul in 1521 but his account is short and says nothing about the earthquake. Also, Lamberg (1910), who passed through Edirne and stayed in Istanbul during the period October–December 1531, noticed the large caravanserai at Çekmece and other monuments in Istanbul, but he did not report remnants of any damage. The earthquake is not mentioned by some of the contemporary Ottoman chroniclers such as Idris-i Bitlisi and Kemalpasazade, which suggests that the shock did not have any long-lasting social, economic, or political effects worth recording.

We also have sources from a number of modern writers (Arinci, 1945; Öztüire, 1969) who add information not found elsewhere; they quote no references, and their bibliography does not indicate that they have used contemporary sources or sicils. This casts doubt about the information they provide, and, therefore, we did not use it.

Also Ambraseys and Finkel (1990, 1991, 1995) and Öztin and Bayülke (1991) have published extensive reviews of this earthquake.

Exaggerated and False Information

It might be useful to draw attention to the natural exaggeration in early and later chronicles. To describe the effects of earthquakes on man-made structures, early writers often used indiscriminately terms such as "ruined," "collapsed," "destroyed," "collapsed completely," "swallowed up in the ground," or, in describing the severity of an earthquake they used terms such as "violent," "great," "destructive," "not seen before," or "catastrophic." Taken literally, these telegraphic descriptions often lead to absurd and contradictory conclusions, as they do in modern intensity ratings. For example, we hear that Istanbul was so-called destroyed more than 20 times since its establishment, or that in a so-called catastrophic earthquake people in Istanbul took refuge in mosques and churches. These are obvious contradictions that show how loosely these terms are used and how misleading they can be when used, without scrutiny, to assess intensities. In fact, Istanbul has never been destroyed by an earthquake, and churches and mosques are unlikely to have been spared in a catastrophic event for people to take refuge in them.

Also, the appellation of the 1509 earthquake, the Little Apocalypse, the Day of Judgment (Menavino, 1548), or in Turkish, küçük kiyamet (Ali Gelibolulu Mustafa; Solakzade Mehmed Hemdemi, 1880), a term adopted to describe the event even by some modern sources (Çorum Il Yiligi, 1973), and more recently, after the earthquake of 1999 by the Turkish press and scientists (Le Pichon *et al.,* 2000), is not justifiable.

Information about the 1509 earthquake from the sixteenth century flysheets, pamphlets, and occidental chronicles ranges from useful to absurd and needs scrutiny. As an example of confused information that could have turned the 1509 earthquake into a major event, we found a flysheet of 1542 that reports that the said event destroyed Scarparia in Turkey and that at about the same time an unnamed place, a day's march from Thessaloniki, which is 500 km west of Istanbul, was overwhelmed by a landslide(?), killing all of its inhabitants (Anonymous, 1542c). However, this information was taken from earlier notices that mention an earthquake in Tuscia (Toscana) in Italy on 13 June 1542, with Tuscia written as "Turcia" (Anonymous, 1542d,e; Fincelius, 1556).

Another example of a spurious event that had it not been detected could have added to the chronicles a destructive earthquake at Istanbul of an estimated moment magnitude of the order of M_W 7.5 is the alleged earthquake of 12 June 1542 that, in fact, never occurred. This event, widely publicized in Europe, is nothing more than a rehashing of the 1509 earthquake. We read in an Italian dispatch from Constantinople dated 15 July 1542 that " . . . amongst myriad calamities . . . on 12 June, about midnight, there was a terrible earthquake that cast to the ground many noble and worthy buildings, among which half of the palace of the Signor, and there were here 2,000 people killed. It ruined almost all of the New Palace killing 24 favourites of the Sultan . . . all the janissaries who were on guard were either killed or injured; the ruin was great, but more important was the loss of human and animal life. There are 120,000 dead and innumerable animals lost in the cities of Constantinople, Adrianople, Callipoli and in their respective districts . . . " (Anonymous, 1542a).

Another flysheet in German repeats this information saying that " . . . in June 1542 there was an awful earthquake in Constantinople, Adrianople, Cassiopol [*sic*] and within 20 [German] miles [= 150 km] circuit from them . . . " (Anonymous, 1542b). Also, in a letter from Ausburg, dated 21 November 1542, we read that as a result of an earthquake in Constantinople, on 20 August 1542, 1700 houses in the city collapsed killing 4500 people (Schiess, 1910), details of which are reproduced in later sources (Schmidt, 1879).

All these reports echo the effects of the 1509 earthquake. The anonymous flysheets in which this earthquake is reported are essentially similar in form and content, indicating translation and revision from a common source. A modern study of these pamphlets shows that the contemporary European press of the time was wont to publish news concerning the Turks at times when relations were unstable or on the occasion of a Turkish military victory, in order to build confidence that the Turks would be overcome by the West (Bataillon, 1966). The probability that this event was spurious is increased by the fact that there is no corroborating evidence in Ottoman sources. A detailed, new history of the Topkapi Palace, based on contemporary sources, makes no reference to such an event (Necipoglu, 1992). Several of these pamphlets also mention a conflagration and thunderstorms that occurred at that time, which match the information we have for the 1509 earthquake; if not fabricated, the exaggerated damage ascribed to an earthquake could possibly have been due to these calamities (Hammer-Purgstall J. Von, 1828).

In what follows, the currently available material about the effects of the earthquake is presented as reported in the sources, and this material is examined in some detail for a critical evaluation of the event.

The Earthquake of 10 September 1509

We may proceed with the presentation of the various accounts of the effects of the earthquake, as reported in the sources, without comments or critique, in the way historical data are usually presented in modern works.

Date

The earliest information about the earthquake comes from a letter, dated 15 September 1509, written five days after the event, by Nicolo Zustignan, a Venetian in Istanbul. His letter reports that the earthquake occurred on 10 September during the fourth hour of the night (Sanuto, 1879–1903). This was a Monday in the Christian calender and a Tuesday in the Muslim calender. The letter says explicitly that the shock felt in Istanbul was also experienced at the same time in other adjacent towns, presumably the towns he refers to in his letter: Bursa, Gelibolu, and Edirne, from where news of the effects of the earthquake in Istanbul could have traveled to the capital by land or sea in less than five days. Exactly the same date, day of the week, and time of the earthquake are given in contemporary Greek marginal notes (Eustratiades, 1924; Lampros, 1932). The contemporary Arab historian Ibn Iyas also mentions the same year, month, and time of day, but gives no date.

Another letter conveying the news of the earthquake was sent from Wallachia by the then Voyvode to the Doge of Venice and is dated 9 October. The son of the Voyvode, who was in Istanbul, had sent this news to his father through a messenger (Sanuto, 1879–1903). This letter dates the event to the day of the Exaltation of the Cross, which is 14 September 1509, a date adopted by almost all occidental sources.

Turkish sources, which otherwise follow one another fairly closely, contain variations in the date of the earthquake, but they do not split its effects into accounts of separate events in different years. The variations in the dates are as much as four weeks, but the day of the week over which most of them agree is a Thursday in the Muslim calendar.

Effect on People

Ground shaking in Istanbul was violent and protracted. A European resident, who experienced the earthquakes of 18 October 1493 in Rhodes and 29 May 1508 in Candia, asserted that the 1509 earthquake was the most major (Sanuto, 1879–1903).

People could not stay indoors and took refuge in open spaces and squares (Ali Gelibolulu Mustafa; Lancellotti, 1673). The Sultan went out into the Palace garden, where in 10 days, a temporary shelter was erected for him, wherein he stayed before leaving for Edirne. It is said that shocks lasted with intermissions for more than half an hour (Menavino, 1548).

Damage to Dwellings

Estimates of the damage in Istanbul vary. Late occidental chroniclers estimated that 10,000 houses were destroyed in the city (Zurita, 1610). More realistic contemporary reports do not give a number but simply say that many houses collapsed (Eustratiades, 1924), or that in Istanbul and Pera chimneys toppled and walls cracked, and in the district of Sukelna, houses, presumably made of wood, leaned over so that not a single one was left upright (Muhyieddin, see Giese; Tevarih-i al-i osman).

Damage to Public Buildings

Little is known about the specific damages to many of the large and well-known buildings in the city (Fig. 3). The earthquake did considerable damage to the newly built mosque of Sultan Bayazid: the imaret (soup kitchen for the poor) and the main dome fell to pieces, other domes and arches of the complex split, and its storeroom and minaret collapsed (Ruhi, see Ménage, 1976; Solakzade Mehmed Hemdemi, 1880).

The shock also cracked the capitals of four great columns of the mosque of Sultan Mehmed-II the Fatih (Conqueror), causing the iron joists on both the right and left sides of the mosque to buckle and the main dome to split, badly shattering the plaster (Ruhi, see Ménage, 1976) and necessitating temporary repairs (Solakzade Mehmed Hemdemi, 1880). Some of the ancillary buildings of the mosque also suffered: domes over the gates of the imaret (Sanuto, 1879–1903) and the hospital, as well as three domes and the schoolroom of the Zamiri, were demolished, and two domes of one of the Semaniyye *medreses* (theological schools) collapsed (Ruhi, see Ménage, 1976). Sanuto says that the Fatih mosque collapsed.

The former church of Aghia Sophia was not damaged, and only the minaret that was added after the Conquest, allegedly to support the structure, collapsed, the fall of which did no damage to the monument (Sanuto, 1879–1903; Anonymous, 1510; Wilhelm von Bernkastel, see Hoffman and Dohms, 1988). Inside the mosque the plaster applied to conceal the mosaics that had adorned the walls and the vault of the dome fell off, exposing scenes from the Passion and images of Christ and of all the saints, a miraculous effect that is featured with variations in most European flysheets and theological tracts (Sanuto, 1879–1903; Fincelius, 1556; Nauclerus, 1579, Anonymous, 1660).

Among the damaged structures, occidental sources include the marble tomb of the old Emperor, presumably of Mehmed-II, which probably was the marble structure behind the Suleymaniyye (Anonymous, 1510, Wilhelm von Bernkastel; see Hoffman and Dohms, 1988).

It is said that almost all minarets in Istanbul were destroyed and that the top of the minaret of the Davud Rasa *mescids* (small mosque) fell, and two arches and a dome of the building were destroyed (Ruhi, see Ménage, 1976).

Also, the gate of the Hadim Ali Pasa mosque, near Çemberlitas, had some minor damage (Ruhi, see Ménage, 1976). In addition to these structures and a mosque that is said to have collapsed, but that is not mentioned by name (Ruhi, see Ménage, 1976), the number of *mescids* ruined is estimated to be 109 (Ruhi, see Ménage, 1976).

Sanuto says that many Greek churches collapsed,

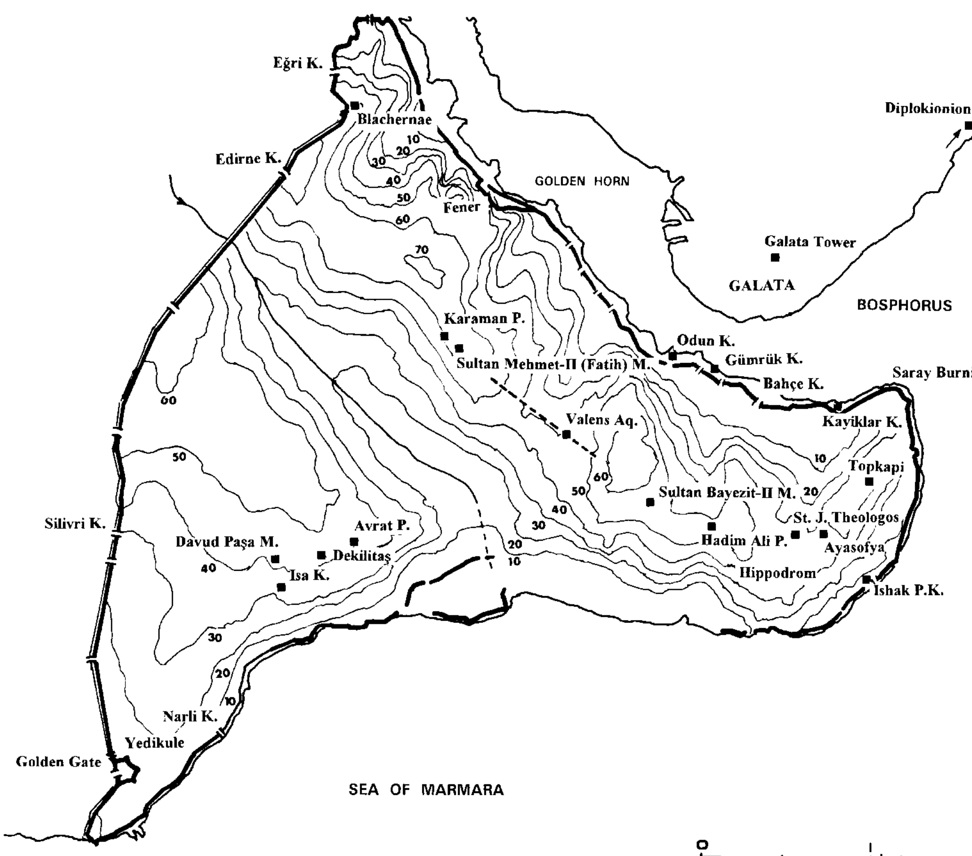

Figure 3. Location, topographic map of Istanbul; altitude in meters.

whereas Christian churches were unharmed (Sanuto, 1879–1903) among which is the church of St. John Theologo's near the Hippodrome (Eustratiades, 1924).

The effect of the earthquake on the aqueduct of Valens (Bozdogan) is not clear. Contemporary and later occidental writers maintain that the earthquake destroyed (Sanuto, 1879–1903; Munster, 1550; Leunclavius, 1558; Batman, 1581; Anonymous, 1660) or damaged (Anonymous, 1510) the aqueduct and water pipes (Biddulf, 1747) of Valens, which ran to Istanbul, passing through mountains and valleys, traversing a distance of 200 miles from its intake on the Danube (Wilhelm von Bernkastel, see Hoffman and Dohms, 1988).

The earthquake destroyed the only remnant of the Constantinian walls, the Isa Kapisi (gate), which was in a parlous state (Ruhi, see Ménage, 1976; Eustratiades, 1924).

Damage to Topkapi Palace was slight (Ugur, 1985; Necipoglu, 1992) and only some of its walls were cracked and had to be repaired (Sanuto, 1879–1903).

Other buildings, caravanserais, baths, and courtyards, which are not named, were also damaged, and shops in the Karaman Pazari (market), in the vicinity of the Mosque of the Conqueror, collapsed (Solakzade Mehmed Hemdemi, 1880; Ruhi, see Ménage, 1976).

The free-standing column of Dikilitas (Column of Arcadius) was also damaged, and allegedly six columns in the Hippodrome were overturned with it.

The custom's house, a large structure built outside the walls, presumably near Gümrük kapani (Custom's area), apparently slid as a whole into the sea with its foundations and was destroyed (Anonymous, 1510; Munster, 1550; Batman, 1581; Sanuto, 1879–1903).

Also, the depots in Istanbul and Galata, which were a part of the Hudavendigar, were also damaged and had to be repaired (Ruhi, see Ménage, 1976).

Occidental chroniclers say that "a notable house wherein the lions are enclosed" was also destroyed (Munster, 1550, pp. 1449, 1460; Leunclavius, 1558; Batman, 1581; Anonymous, 1510). This must have been the Arslanhane, the former church of Jesus of Chalki, which was located southeast of Ayasofia, where the Sultans' menagerie was housed, the ruins of which were burned down in the middle of the nineteenth century (Eyice, 1964).

Damage to the City Walls

The earthquake took a heavy toll on the walls of Istanbul. According to Ruhi, along a length of 140,000 arsin (1 arsin = 68 cm), the walls, towers, and turrets were demolished and ruined, that is, the double land walls from Egrikapi as far as Yedikule and from there along the single sea walls as far as Ishak Pasa Kapusi and in and around the Topkapi Palace from Dilsuz Kapusi to Kayiklar Kapusi.

Solakzade says that the double walls were demolished along their entire length and that on the seaside from Narli Kapi to Ishak Pasa Kapusi and further on, from Hastalar Kapusu to Kayiklar Kapusu the single sea walls were destroyed only at some places. He reckons that 40,300 arsin of walls were ruined and fell to the ground.

Other sources maintain that the whole length of the land walls, from near Yedikule to the palace of Palaelogus, and many parts of the sea walls fell down (Eustratiades, 1924). They add that the major part of both land walls and sea walls were destroyed above their foundation, together with 49 towers, including the towers of Yedikule (Sanuto, 1879–1903), the rubble from which filled the moat in front of them (Batman, 1581).

The sea walls, which were in a better state of preservation, suffered far less damage.

Occidental sources mention the heavy damage to the castle that they say housed the public treasury, referring apparently to Hazine or Yedikule, five towers of which, they add, collapsed as a result of the earthquake (Anonymous, 1510; Munster, 1550; Leunclavius, 1558; Batman, 1581; Anonymous, 1660; Wilhelm von Bernkastel, see Hoffman and Dohms, 1988).

Damage in Galata

The suburb of Galata probably suffered less than Istanbul did. It is not known how many houses were destroyed, but among the Europeans, no Venetians were killed and only one Florentine house collapsed. Almost all the houses suffered some damage (Sanuto, 1879–1903) and some churches had to be repaired (Menavino, 1548), the works of which were completed in June 1510 (Ruhi, see Ménage, 1976).

Sections of the walls of Galata, which were built much later than the walls of Istanbul, were also damaged, and houses adjacent to the walls suffered the most (Eustratiades, 1924). The section of the walls where they join the Galata Tower were also damaged. Otherwise damage in Pera was in general repairable (Menavino, 1548), and little or no reference is made to this damage in Ottoman sources.

It is said that the Galata Tower, the lead tower of the Europeans, was destroyed (Anonymous, 1510; Munster, 1550; Batman, 1581; Sanuto, 1879–1903; Solakzade Mehmed Hemdemi, 1880).

Damage Elsewhere

Damage in the immediate vicinity of Istanbul seems to have been considerable. According to a contemporary source, Salici (Chelis = Bebek), Calcopolis (Chalkidon = Kadiköy), and other sites on either side of the Golden Horn between Galata and Constantinople, which are not mentioned, were also damaged, including Theloneum (Tarabya?) (Wilhelm von Bernkastel, see Hoffman and Dohms, 1988).

The free-standing columns at Diplokionion (in Basiktas) were damaged or overturned (Eustratiades, 1924; Schreiner, 1975–1979).

Details of repairs undertaken after the earthquake indicate that the forts of Istanbul were also damaged: these were the Anadolu Hisari and Yoros Kalesi (Anadolu Kavagi) on the Asian side of the Bosphorus, as well as the Rumeli Hisari on the European side. Also in the Bosphorus, the Maiden's

Tower lighthouse (Kizkulesi), which suffered badly, as well as the walls of the district of Fener (formerly, Castrum Petrii) on the Golden Horn, all required repairs (Ruhi, see Ménage, 1976).

The two wooden bridges at Çekmece, about 30 km west of the capital, were also damaged and had to be repaired (Ruhi, see Ménage, 1976) (Fig. 2).

About 70 km west of Istanbul the castle of Silivri, which together with the Istanbul forts was a part of the defense of the capital, was damaged to such an extent that it was included in the list of other forts repaired near the city (Ruhi, see Ménage, 1976).

There is no evidence of serious damage in Çorlu, about 100 km west of Istanbul; the palace of Bayezit-I located here was not damaged, but some cracks appeared in the inner baths, which were repaired (Ruhi, see Ménage, 1976). There is no reference to repairs to public buildings, but the population was apparently so afraid that they remained outdoors for a long time.

At greater distances from Istanbul damage was sporadic and not serious. Zustignan, in his letter of 15 September, mentions, without details, that the earthquake affected the whole region, which includes Gelibolu, Edirne, and Bursa (Sanuto, 1879–1903).

Damage to the castle of Gelibolu is mentioned in the letter of the Voyvoda of Wallachia, dated 9 October, which says that the strong castle at Gelibolu was badly cracked and not a house in it was left intact (. . . in cvitate Calipoli, castrum fortissimum penitus ruptum est, nulla domo integra permanente . . .) (Sanuto, 1879–1903, p. 565). Later sources, probably different recensions of Sanuto, refer to the effects of the earthquake in more dramatic words (Anonymous, 1510; Munster, 1550; Leunclavius, 1558; Batman, 1581).

In Edirne, a city with a population of 80,000 230 km northwest of Istanbul, which is included by Zustignan (Sanuto, 1879–1903) among the towns affected by the earthquake, the porches of the mosques of Kazancilar and Saraçlar came down, the top of four minarets fell, the hospital complex of Sultan Bayazid-I suffered only slight cracks, and in the district of Uzumçiler two shops collapsed (Ruhi, see Ménage, 1976).

Bursa, 90 km south of Istanbul, a city of about 35,000, was also mentioned by Zustignan (Sanuto, 1879–1903) as having been affected by the earthquake, but information about damage in Ottoman sources is strangely lacking. A contemporary register refers only to repairs to the baths of the city in December 1510, which Meriç thinks were the repairs needed because of the earthquake but he does not quote his source (Meriç, 1957).

All we know about the effects of the earthquake at Demitoka (Dimetoka), about 200 km northwest of Istanbul, is that at about the same time the Sultan gave his assent for the repair of his palace (Sa'adeddin Hoca, 1862; Meriç, 1957). A European who was in Edirne shortly after the earthquake mentioned the repairs made to the walls of Istanbul (Spandouyn Cantacusin Th., 1896) and added that the Sultan had constructed a palace in Dimetoka.

To the east of Istanbul, on the small and sparcely inhabited islands of Antigoni (Burgaz) and Halki (Heybeliada), the earthquake caused the collapse of the domes of the Church of the Savior and of Aghiou Prodromou (Schreiner, 1975–1979). It is also probable that on the island of Pringipos the earthquake destroyed the monastery of St. Nicholas (Batmis Monastir). There is some evidence that at about this time the island was abandoned temporarily for reasons that are not clear (Constantinos, 1824/1844).

We could find no evidence that Iznik was damaged except for a notice dated February 1511 that mentions repair work on the imaret, which, however, was not attributed to an earthquake (Meriç, 1957).

We have no evidence that Bolu was affected by the earthquake; however, see the following section.

Ground Effects

The only information we have about the effect of the earthquake on the ground comes from Tevarik-i al-i osman (p. 1099) which states "we have heard that as a result of the earthquake in some places in Istanbul and Pera, the ground opened up and it was fissured," presumably along the coast of the Golden Horn (Muhyieddin, see Giese, 1922).

Sea Waves

We are told that as a result of the earthquake the sea retreated from the shore and returned, flooding the coast over a very large area at places that are not named, and that when the sea came back to its previous place, the ground near the coast opened up and was left fissured (Anonymous, 1510; Eustratiades, 1924). This phenomenon was observed on both the sides of the Golden Horn on the coasts of Istanbul and Pera (Sanuto, 1879–1903).

Far-Field Effects

The earthquake was felt at Chiena (Sanuto, 1879–1903) and also in Greece (Anonymous, 1510; Polyacarpus, 1560?), but no specific place is mentioned.

In Transylvania, 680 km northwest of Istanbul, the earthquake was slight at Siebenbürgen (Hain, 1853) and it was reported from Misr (Cairo?), 1300 km south of Istanbul, where the shock was slight and noticed by very few persons (Ibn Iyas Muhammad b. Ahmed, 1955). This was recorded by Ibn Iyas some months before the news of the earthquake in Istanbul reached Cairo. Also it is said that the shock was perceptible in Ukraine (Bevzo, 1971).

Loss of Life

The loss of life in Istanbul and its suburbs is difficult to assess. One estimate of 13,000 people having been killed is reported in the letter sent by the Voyvode of Transylvania to the Doge of Venice (Sanuto, 1879–1903), a figure to which most of the occidental chroniclers adhere (Munster, 1550; Leunclavius, 1558; Sansovino, 1580; Batman, 1581; Gottfried, 1592; Sanderson, Calvisius Sethus, 1650; Bautista de S. Antonio, 1734; Wilhelm von Bernkastel, see Hoffman and Dohms, 1988). Lancellotti (1673) and Goutoulas (1653) have reported the deaths of 12,000 and 10,000 people, respectively. A much smaller number, of a few hundred, is reported by Bugati Gaspare (1587). Less exaggerated figures are given by contemporary sources, that is, 1000 by Sofianos (1986), 1500 by Menavinio (1548), 4000 by Sanuto, and 5000 by Ruhi. The number of those injured is estimated to be 10,000 (Sanuto, 1879–1903).

Among the dead were members of the households of two members of the Imperial Council. From the household of Mustafa Pasa, the Sultan's chief minister, 360 people were buried together with their horses when the stables collapsed, and Bay Pasa, the Sultan's second minister, lost many members of his family and his cattle (Sanuto, 1879–1903). However, it is not known whether this happened in Istanbul or at their estates in the country.

Aftershocks

Aftershocks in Istanbul and Silivri continued for 18 days without damage. A strong aftershock on 23 October 1509 caused the collapse of some nonstructural parts of mosques in Edirne (Ruhi, see Ménage, 1976). Another aftershock on 16 November 1509 was reported also from Edirne (Ruhi, see Ménage, 1976; Ali Gelibolulu Mustafa). During March 1510 more shocks were reported from Edirne (Sanuto, 1879–1903). Then on 10 July 1510 a strong shock was reported; there was no damage, but some panic ensued in Istanbul and delayed reconstruction (Bardi, 1581).

Finally, the shock of 26 May 1511 in Edirne was probably an altogether different event. It followed a flood that caused the banks of the Maritsa river to burst and added to the confusion (Sanuto, 1879–1903). It is likely that it was this shock that caused the long vault that covered the refectory of the monastery of Megistis Lavras on Mt. Athos to crack (Eustratiades, 1924), but its epicenter is not possible to locate.

Aftermath

The length of the walls ruined by the earthquake that needed repair or reconstruction is estimated to be between 40,300 (Solakzade Mehmed Hemdemi, 1880) and 140,000 arsin (Ruhi, see Ménage, 1976).

On 23 October 1509 the Sultan went to Edirne where he stayed until the repair work in Istanbul had been completed and returned the following summer (Ruhi, see Ménage, 1976). From there, he ordered the mobilization of 66,000 laborers from various parts of the Empire, as well as 3000 master craftsmen, together with 11,000 assistants, for the repair of the fortification and reconstruction of the public buildings of Istanbul and levied extra taxes to defray costs. He recruited one workman from every 20 houses and levied 22 *akçe* (small silver coin) per household. Twenty-nine thousand men came from Rumeli and 37,000 came from Anatolia. There were 3000 builders and carpenters from each *kaza* (township) and from Istanbul. The workmen who came from Rumeli were not from lands in the vicinity of the Christian powers or from the Morea, and they came from central lands (Ruhi, see Ménage, 1976). They were all paid and returned home after the completion of the work (Menavino, 1548). This rapid repair of the fortifications of Istanbul after the earthquake is the most important detail of the event noted by most later writers (Ypsilantis, 1870).

Repair work on the walls of Istanbul started on 29 March 1510 and finished on 1 June 1510 (Ruhi, see Ménage, 1976), taking 63 days to complete. Repairs of the walls of Galata began on 4 April 1510 and were completed 64 days later on 7 June 1510 (Ruhi, see Ménage, 1976), or according to the diary of Haidar Çelebi (Elezovic, 1940), on 20 July 1510.

Prediction

As with many other earthquakes in early and modern times, the 1509 earthquake is alleged to have been predicted. It is said (Anonymous, 1510) that a Greek monk from the monastery of St. Catherine on the Sinai (Wilhelm von Bernkastel, see Hoffman and Dohms, 1988; Polyacarpus, 1560?), who was in the Sultan's court, foretold the event (Sanuto, 1879–1903). European chroniclers, however, considered the earthquake to be a God-sent castigation of the Turks for taking up arms against the Christian kingdom of Hungary (Zwinger, 1604), while Sultan Bayezid himself ascribed the cause of the earthquake, rather than its effects, to the misdeeds of his *vizlers* (ministers) (Sa'adeddin Hoca, 1862).

Evaluation of Results

The preceding descriptions of the effects of the 1509 earthquake give, at first sight, the impression that the earthquake was of exceptional destructiveness, and this raises the question to what extent this impression is correct. Here, the sources assume great importance, and this in turn is mainly responsible for their interpretation by those who want to quantify the event. Although earth scientists and engineers are aware of the value of historical data and are alert to their inherent limitations, the effects of these limitations are seldom examined (Guidoboni, 2001).

Background Information

The main difficulty in the assessment of historical information is to find a common ground between the humanities and the sciences, particularly in the area of the verification of factual information, which in turn can be used to compare historical earthquakes with modern earthquakes. Essentially, the issue is that the historical details must be assessed in the perspective of the actual social, economic, and political situations at the time of the event (Finkel, 2000).

Regional Tectonics and Seismicity

The active tectonics of the Marmara Sea area in northwest Turkey is dominated by the right-lateral North Anatolian Fault Zone that has produced many large ($M_S > 7$) earthquakes with coseismic surface faulting (Barka, 1996; Stein *et al.,* 1997). Right-lateral faulting continues west of Izmit but becomes more distributed over several subparallel strands in the Sea of Marmara. Seismic reflection surveys in the Sea of Marmara itself reveal many faults with large normal components (Parke *et al.,* 2002), and earthquakes with normal-faulting mechanisms are seen around its margins. The Sea of Marmara was presumably formed by this component of crustal extension, and Global Positioning System surveys demonstrate that the E-W shear across the region is about 23 $\pm$ 3 mm/yr (Straub *et al.,* 1997).

The implication of the opening up of the Sea of Marmara is that earthquakes are associated with relatively short faults, compared with ruptures of great lengths in the Anatolian Fault Zone further east that is dominated by strike slip. This is consistent with the evidence from seismic reflection surveys in the Sea of Marmara, showing that faults are generally less continuous offshore than onshore (Parke *et al.,* 2002), as well as from the long-term seismicity of the region.

A recent re-evaluation of the long-term seismicity of the greater Marmara Sea region over the last 2000 years (Ambraseys and Finkel, 1988) has identified 15 earthquakes of estimated magnitudes ranging from 6.8 to 7.4, at source distances less than about 70 km, which have caused considerable damage in the city. These events include the 1509 earthquake for which no macroseismic, and to some extent, no tectonic evidence can be found. It was a very large event, but one of the damaging shocks in the seventeen-century-long history of Istanbul, of an estimated magnitude that is smaller than that of the large events in the upper range of 7.0, which can occur further east in the Anatolian Fault Zone, such as, for instance, the earthquake of 17 August 1668 (Ambraseys and Finkel, 1988) and of 1939 in Erzincan.

Thus the megacity of Istanbul is located few tens of kilometers north of these short offshore faults, and this implies that relatively more frequent earthquakes occur in this area than elsewhere along the Anatolian Fault Zone, but they are of smaller magnitude, and this observation is consistent with the long-term seismicity of the region (Ambraseys and Jackson, 2000).

Istanbul in the Early Sixteenth Century

The city of Istanbul occupies a peninsula roughly triangular in shape, of about 17 km^2 in area. The intra muros population of Istanbul at the time of the 1509 earthquake is not known, but it can be estimated at about 250,000. We know that some 30 yr before there were 160,000 people living in 35,000 households. We also know that just before Süleyman's reign (1520–1566) the population of greater Istanbul, which included Beyoglu, Basiktas, Sisli, Kadiköy, and Eyüp, excluding the floating population of troops and visitors, had risen to about 650,000 (Ayverdi, 1958). This compares well with the population of the city after the Balkan Wars in 1927 when the intra muros population was 245,000 and that of greater Istanbul about 700,000 as compared to today's figures of 500,000 and 11,000,000 for intra muros and greater Istanbul, respectively.

Given that in the very early part of the sixteenth century houses in the city consisted of a single story, and there were such wide areas of garden and open spaces (building upward, with several stories, began slowly, after the Crimean War in the 1860s), it is unlikely that at the time of the earthquake the *intra muros* population of Istanbul was higher than 250,000. This figure, covering 17.2 km^2, gives a density of 14,500 persons per km^2 (Inalcik) living in 54,000 households, which is comparable to the density of other medieval cities. The population density outside Istanbul was very low.

Streets

The streets of Istanbul were typically those of a medieval Eastern city; twisting and full of blind alleys. Difficulties of communication in the narrow streets meant that goods were usually transported by sea from the various gates and landing places on the Golden Horn (Mayer, 1942) making evacuation difficult in the case of fire or rescue in the event of an earthquake.

Building Stock

Before the fall of Constantinople in 1453 and as far back as the fifth century A.D., the maximum height permitted for the construction of houses in the city had been about 33 m (Mayer, 1942; Turpçoğlu-Stefanidu, 1999). However, after the Conquest the height of houses was restricted to two stories, a regulation that came into power in the early 1520s but that was not usually observed and often led to the construction of all sorts of extensions upward (çardak, balakhane, etc.) (Refik, 1935; Inalcik; Inalcik, 1993) (see Lorichs in [Göllner, 1961] for a view of Istanbul).

Because wood is inexpensive, most of the houses of Istanbul and of towns around the Sea of Marmara were built of wood, and the ordinary *mahalle* (district) house was usually a primitive one- or two-story dwelling of wood or mud-bricks, with a courtyard shut off from the street by a high mud-brick wall. NonMuslims were subject to severe regulations: their houses were not to be made more than 9 *dira* (4.5 m) high and the ground floor was not to be built of free stone, although these regulations were rarely followed. After great fires it was ordered that houses, especially those adjacent to public buildings, should be constructed of stone or brick, but after earthquakes, construction in wood was decreed.

Public Buildings

After the Conquest there were about 480 relatively new *tekyes* (dervish lodges), *mescids*, and *camis* (Friday mosques) of all sizes in Istanbul, some of them erected on the foundations of earlier Byzantine buildings or incorporating churches. There were also about 200 Greek Orthodox churches and 160 monasteries, many old and some in a ruinous state, as well as 11 churches in the Galata district where only the Catholic churches could be found (Seyid Ali, 1864; Paspatis, 1877).

Fires

Much of the building stock in Istanbul had suffered from fires. Although the reports are frequently exaggerated, they do indicate that there was very substantial damage. Many fires were deliberately started by dissident factions, and they were difficult to control.

The number of fires in the city was abnormally high. For instance, in the seventeenth century alone, 20,000 houses were destroyed in the fire of 1633 with a third of the city burned down; two thirds of the city was destroyed in 1660 with 4000 deaths and, in 1693, 18 *camis,* 19 *mescids,* 2547 houses, and 1146 shops were burned down (Schneider, 1941; Cezar, 1963). Fires caused various political, social, and economic crises in the life of Istanbul, which invariably were more serious than those caused by earthquakes. As a matter of fact, losses of life and property in Istanbul from fires rank well above those from earthquakes.

The aftershock of the 1509 earthquake of 10 July 1510 in Istanbul was followed by a conflagration that burned down 1500 houses (Sanuto, 1879–1903), destroying as many houses as the mainshock did, and was followed by looting.

City Walls

The circumference of Istanbul is about 20 km. The land walls stretched from the Blachernae quarter on the Golden Horn, where they were single with a moat cut in silt, to the Studion quarter on the Sea of Marmara. They were some 6 km in length and had been damaged and repaired a number of times.

Around Blachernae the walls joined the massive Theopdosian walls, which were double, and ran from the terminus of the Blachernae in an unbroken line to the Sea of Marmara. On the outside was a deep ditch, a foss, some 18 m in width, sections of which could be flooded. On the inside of the ditch there was a low breastwork with crenelles within which was a passage some 15 m in breadth, running the whole length of the walls. Then there rose the outer wall, about 6 m in height, with square towers placed along it at intervals varying from 45 to 90 m. Within it was another space which was 15–20 m in width. Then rose the inner wall, about 12 m in height, with towers, standing about 18 m above the ground (Meyer-Plath and Schneider, 1938). Thus, including the rubble masonary infill between the walls, the average cross section of the defenses was about 60 m thick and 30 m high.

The sea walls along the Golden Horn were about 5 km long; they ran from Blachernae, where they were provided with a moat, to the Acropolis Point, now usually known as Seraglio Point, which faces northward up the Bosphorus. The walls were single with 16 gates. Along the shore, a foreshore of made ground had emerged during the course of centuries, which was covered with warehouses and the customs house where earthquake damage was always high.

The distance from the Acropolis point to Studion was about 9 km; the walls went round the apex of the peninsula, facing the entrance to the Bosphorus, then curved along the Marmara shore. The walls along the Marmara were single, in fairly good condition, and rose fairly straight out of the sea with 11 gates (Millingen A. van, 1899).

Damage from Past Earthquakes, Storms, and Warfare

In 1509, with very few exceptions, most of the more significant public buildings in Istanbul were old structures from the Byzantine period that had suffered from ageing, fires, earthquakes, and neglect. They had survived earthquakes through a process of natural selection, most of them sustaining different degrees of damage, they have been repaired many times, and occasionally strengthened.

The massive church of Sta. Sophia had been damaged a number of times before 1509; its dome, weakened by the earthquake of 14 December 557, collapsed 6 months later and it was rebuilt. Further damage was caused by the earthquakes of 9 January 869, 25 October 989, and by the shocks of 18 October 1343 that caused progressive damage to the apse that led to the collapse of its upper part (Antoniadis, 1907; Müller-Wiener, 1977).

The sea walls facing the Marmara Sea had been breached a number of times by storms, particularly by the storm of 12 February 1332, and sections of the walls at Saray Point were shattered by ice flows from the Black Sea in the winter of 762–763 (Theophanes, 1883).

Also the outer land walls and towers of the city had suffered from sieges, digging of mines, and in 1453 from bombardment, which lasted for more than 6 weeks, as well as from earthquakes. They had been repaired repeatedly, in many cases in a hurry, at times when the city was threatened, falling in neglect after the fall of Constantinople.

The most vulnerable sections of the land walls were: from Blachernae where the single walls joined the Theodocian walls and where they had been damaged in the siege of 1422 but largely repaired in the following years. They were damaged again and breached at a number of places in the siege of 1453. Also, the central section of the walls, between Blachernae and the Charisian Gate, particularly where they crossed the valley of the little river Lycus, had been weakened by mining (Runciman, 1965). Inscriptions testify to the repairs (renewal) carried out at different times chiefly to the gates and towers (Paspatis, 1877; Ziya Mehmed, 1918; Meyer-Plath and Schneider, 1938).

Earthquake Damage in 1509

We may now proceed with the assessment of the effects of the 1509 earthquake.

Date

There can be no doubt that the correct date of the earthquake is 10 September 1509, at about 10 p.m. in the New

Style (NS) (Gregorian calendar). From what has already been said, the date 14 September, assigned to the event by most writers, is erroneous. Considering that in those days the normal rate at which news could travel overland was about 40 km/day, Zustignan, who was writing from Istanbul on the 15 of September, could not have received reports from towns 250 km away from the capital in 1 day. Therefore the date, 10 September, that other chroniclers have given is the correct date.

For the assessment of the size and location of an event this small difference in the date, at first sight, may seem unimportant, but as will be seen later, adopting the wrong data would synchronize the earthquake in Istanbul with other quite separate shocks in central Europe, which occurred on 14 September, the amalgamation of which would create an event of an enormous region.

Loss of Life

As to the casualty and loss figures reported at the time, they are ludicrously high. Few official records exist and all of them deal with relatively modest numbers. The little that we know of the population and logistics all point to the smaller figures and one should often divide the chronicler's figures by 10 or more. The estimate of 13,000 people killed could have been exaggerated and probably was a rough estimate as the letter from Istanbul that quotes this number was written too soon after the earthquake for the actual toll to be known. For the estimates of 12,000 people killed we could find no original sources. The most likely estimate would be between 1500 and 5000 people, which, provided it refers only to Istanbul, would be between 0.4 and 2% of the intra muros population. Reliable statistics simply do not exist.

Loss of Houses

Sensible contemporary loss estimates for Istanbul are 1070 houses (housing units) destroyed (Ali Gelibolulu Mustafa), with many houses shedding tiles off their roofs (Ruhi, see Ménage, 1976). Sanuto has recorded the destruction of 1500 houses in both Istanbul and Pera. These figures correspond to about 0.5% loss of the vulnerable building stock in the city, the earthquake affecting ageing buildings in a densely populated mediaeval urban center. This phenomenon in many respects is quite different from that of today.

Churches

Damage to churches is difficult to assess. Sanuto says that many Greek churches collapsed, whereas Christian churches were unharmed (Sanuto, 1879–1903), the implication being that Greek Orthodox churches were not Christian. Presumably, Sanuto here refers to the Roman Catholic churches that were only in Galata, and that as we know, suffered less than Istanbul.

It is significant that the church of Sta. Sophia, by then converted into a mosque, though damaged and portions of it had collapsed in four previous earthquakes, was not damaged by the 1509 earthquake.

The only church we know that collapsed is the church of St. John. We found no evidence that any other Orthodox church intra muros was destroyed or damaged to the extent that it needed substantial repairs (Ducange, 1680; Paspatis, 1877).

Mosques

The number of *mescids* ruined is put at 109. However, we found no evidence that such a large number of small mosques were destroyed or seriously damaged (Ducange, 1680; Seyid Ali, 1864; Paspatis, 1877) either because their damage was not recorded or because it was relatively minor.

There is no doubt that the complex of the newly built mosque of Sultan Bayazid was damaged. However, the information that the main dome of the structure caved in is in need of authentication, as no reference to the repairs to the mosque has been found (Meriç, 1957).

Fatih Mosque

The Fatih Mosque, which was completed 38 yr earlier suffered some structural damage. Formerly, the church of the St. Apostles, built in the fourth century, had been damaged repeatedly by earthquakes before its conversion into a mosque (Müller-Wiener, 1977). The information that the structure collapsed (Sanuto, 1879–1903) is unfounded.

A woodcut by Coecke, made at about 1529, shows the Fatih mosque with truncated minarets (Maxwell, 1873). Attention to the missing minarets in Coecke's woodcut (Fig. 4) was drawn by Wulzinger (1932) who attributed this to the 1509 earthquake. That the minarets would have remained unrepaired for 20 yr seems rather strange and an inspection of a print of this woodcut, kept at the British Library, shows some damage in that area and a portion of the minaret and dome may have been lost. The flaw is on the right side of the mosque and to the left of the stub of the minarets that, incidentally, forms a part of the structure of the mosque. Wulzinger did not use the British Library copy and his print shows the decapitated minarets but not the flaw between them and the mosque. Later prints at the British library show small hoods on the short minarets and no flaw. This may be a better pressing from the same block.

In contrast, Lorich's engraving made in the 1550s shows tallish minarets built outside the main body of the mosque structure (Oberhummer, 1902). We could find no pre-earthquake prints of the complex and the only indication of their collapse is the misinterpretation of Sanuto's statement that" . . . li *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, and not minarets. Early writers have written the word in various ways (see more specifically Sathas, 1894).

Minarets

With the exception of the minaret of the Davud Rasa *mescid*, the upper part of which was shaken off (Ruhi, see Ménage, 1976), we have no evidence that other minarets fell,

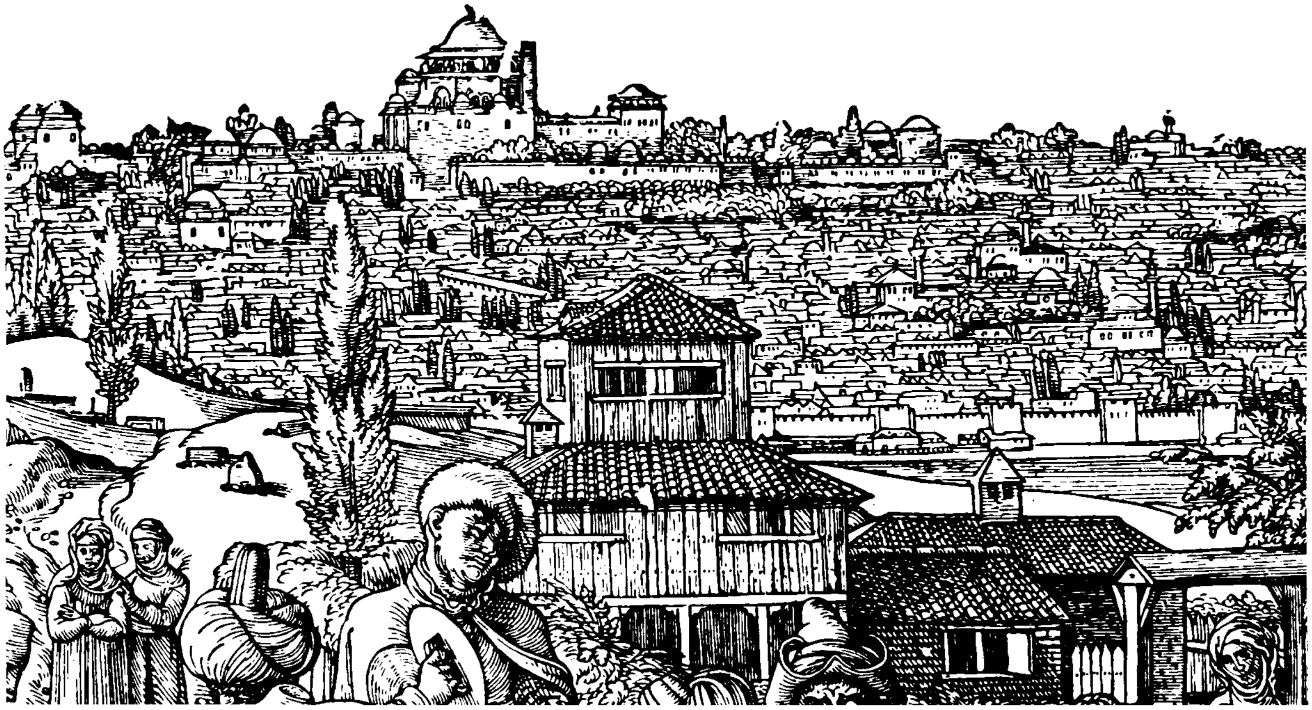

Figure 4. A woodcut by Coecke, made in about 1529, showing the Fatih mosque with its truncated minarets.

although all of them were left leaning after the earthquake (Ali Gelibolulu Mustafa).

Column

It is said that the column of Dikilitas (Column of Arcadius) was damaged and six columns in the Hippodrome fell to the ground. However, drawings of the Hippodrome (At meydani) made in 1536 show these columns as being erect (Müller-Wiener, 1977). Their state of preservation is so precarious that it is unlikely that they had collapsed and had been restored to their former position after the earthquake. The column of Arcadius, in spite of storms, earthquakes, and fires survived until 1715, when, threatening to fall, it was taken down as far as its pedestal, considering the safety of neighboring buildings (Millingen A. van, 1906).

Aqueduct

The information that the aqueduct of Valens ran to Istanbul, allegedly passing through mountains and valleys traversing a distance of 200 miles from its intake in the Danube (Wilhelm von Bernkastel, see Hoffman and Dohms, 1988), and also that the structure was destroyed, is inaccurate.

The intake of the aqueduct was not the Danube River but the small stream of Belgrad (Topuz), which is only 15 km north of Istanbul (Çeçen, 1992). The only section of the aqueduct that was damaged and repaired, and that is mentioned in Ottoman sources, seems to be at a place in Istanbul, which was known as the büyük batak (great swamp), southwest of the Sehzade medrese (Dalman, 1933; Müller-Wiener, 1977).

Walls

The earthquake caused considerable damage chiefly to vulnerable segments of the outer land walls and towers, the collapse of which, in places, filled in remnants of the foss, and to battlements that were shaken off the top of walls (Leunclavius, 1558). A number of gates, such as Edirne and Silivri, which were already in a parlous state, were badly damaged. Inscriptions attest to the repairs after the 1509 earthquake but not to any reconstruction of gate structures (Ziya Mehmed, 1918; Meyer-Plath and Schneider, 1938; Kömürcüyan Eremya Çelebi, 1952; Meriç, 1957). No coeval inscriptions referring to reconstruction have been found on the enceinte (Paspatis, 1877; Erdogan, 1938).

The length of the walls ruined by the earthquake that needed repair or reconstruction is estimated to be between 40,300 arsin by Solakzade and 140,000 arsin by Ruhi. These figures are grossly exaggerated. If we take one arsin to be equal to 0.68 m, the length of the walls that allegedly required rebuilding would be between 27 and 95 km as compared with the 20-km circumference of Istanbul, which consisted of 6 km of land walls, 5 km of the Golden Horn sea walls, and 9 km of the Marmara sea walls. The Galata walls would have added another 3 km.

Excluding breastworks and towers, the outer walls had an average masonry cross section of 30 m^2 and the inner walls 100 m^2 (Meyer-Plath and Schneider, 1938). Therefore, the total volume of masonry of the outer walls would be about 0.6 million cubic meters and about the same for the inner land walls. Providing allowance for the collection from the ruins and assuming that such pieces of masonry could have been used again, this would still have required an enormous amount of building material and fire-wood to make lime and bricks. As even approximate figures for the volume of masonry needed are lacking, it is very probable that only segments of the enceinte needed reconstruction and that much of the work was for repairs.

The speed with which the walls were repaired and the large number of laborers employed for the works is often interpreted as an indication of the enormous damage caused by the earthquake. This is not so. One of the earliest examples of rapid repair of the walls of Constantinople, that was completed in 2 months, is after the earthquakes of 6 November 446 and 26 January 447 that damaged long segments of the land and sea walls and 57 of their towers (Marcellinus Comes, 1846). The duration of these repairs is mentioned in inscriptions on the Gate of Rhegium (Yeni Mavlevi Kapusi) (Millingen A. van, 1906).

A later example, not associated with an earthquake, is the rapid construction of the Rumeli Hisari (Yeni Hisar or Bogazkesen) by Mehmed-II who, using about 3000 masons and unskilled workmen, completed the work in 138 days between 15 April and 31 August 1452. The walls were 0.7 km long, about 9 m high, and 4 m thick, defended by three towers that, incidentally, were damaged by the 1509 earthquake (Müller-Wiener, 1977). The volume of masonry needed for the construction of Rumeli Hisari was 25 times smaller than that allegedly needed for the walls of Istanbul (30,000 m^3/138 days).

Intensive repairs and reconstruction of the fortifications of the city, like the repairs carried out after the 1509 earthquake, are known to have been carried out also before or after periods of hostile inroads deploying very large numbers of workers. However, the extent of these repairs depended more on the vulnerability of the ageing walls of Istanbul rather than on the severity of a siege or an earthquake. It would be difficult, therefore, to deduce the degree of damage to the city from the information that the repair of its walls required the mobilization of 60,000 laborers.

Galata Tower

The Galata Tower was not destroyed and only cantilevering parts of the structure fell off (Belgrano, 1888). Repairs of the tower were completed in April 1510, which is recorded on an inscription near the Yag Kapan Gate (Ruhi, see Ménage, 1976).

Castles

Also, contrary to what occidental sources say, there is no evidence that the Yedikule was destroyed. A marginal note says explicitly that the land walls adjacent to the tower were damaged (Eustratiades, 1924). Yedikule does not appear among the castles repaired after the earthquake (Ruhi, see Ménage, 1976), perhaps because the damage was insignificant.

Apart from the castles near Istanbul, from Silivri to the Bosphorus, which were damaged, (Ruhi, see Ménage, 1976), we can find no evidence that any other forts were affected. Had there been serious damage to the defenses of Istanbul along the Marmara coast and further west in the Dardanelles, it should have been mentioned by Ruhi or other chroniclers.

Damage Outside Istanbul

Tekirdag, about 130 km west of Istanbul, is not mentioned among the towns damaged by the earthquake and there is no evidence of repairs after the earthquake in the documents. There is some evidence that Tekirdag contributed masons, kiln bricks, and tiles for the reconstruction of Istanbul. (This information comes probably from Rodosçuk Seriyye: nos. 1480–1512, Kadi sicilleri, which we have not seen and is in need of authentication).

Zustignan says that the earthquake affected Gelibolu, Edirne, and Bursa (Sanuto, 1879–1903). It is important, therefore, to clarify whether affected implies that these sites were destroyed, damaged, or simply shaken.

Gelibolu

We have no evidence that Gelibolu was ruined by the earthquake (Anonymous, 1522). It is probable that its castle and the houses in it suffered some damage, not serious enough to need repairs or to be recorded in Ottoman and Greek sources. Gelibolu, 150 km west of Istanbul, was an important town with a fortress and naval base controlling the Strait and, had it been seriously damaged, occidental sources would not have omitted to mention it. Damage in Gelibolu in 1509 was less serious than that sustained during the other, earlier and later large earthquakes of comparable epicentral distances (Ambraseys and Jackson, 2000).

Edirne

The effects of the earthquake in Edirne would have been insignificant. A European who was in the city shortly after the earthquake (Spandouyn Cantacusin Th., 1896) did not mention any damage in the city where the Sultan took refuge until the restoration of Istanbul had been completed, an additional indication that city was not much affected.

Dimetoka

For Dimetoka it is not clear from these texts whether the repair works at the palace, which started in September 1519, were to rectify the damage caused by the earthquake 10 yr earlier or, as Sanuto seems to imply, for the construction of a new building in the palace complex.

Bolu

For Bolu we have the letter of the Voevode of Wallachia that says, that " . . . in the town of *Bolomon* there was an earthquake for eighteen days; it threw down walls and strong towers . . . " (. . . In civitate Bolomonens i decam et octo diebus terremotus; cadentes muri et fortissimae turres . . .) (Sanuto, 1879–1903). However, a contemporary flysheet in old German gives verbatim the same information but Bolomon is substituted for Selewrüst (Anonymous, 1510).

Bolomon is not known from other source even if one allows for a corruption of the name. It is tempting to suggest that what is meant here is perhaps Bolu, a town about 250 km east of Istanbul (Ambraseys and Finkel, 1995). But Bolu, which has had no walls to speak of and no towers, is not mentioned in contemporary sources as having suffered from the earthquake and we can find no reference to reconstruction or repairs to its most important public buildings. We know that a mosque complex was built in 1499, and early in 1510 a new palace was erected at Bolu (Meriç, 1957), as well as a mosque at Ilica, south of the city. In the records of these and other structures in Bolu, prior to this time, there is no reference to damage to any of them in the 1509 earthquake. Bolu can hardly lie behind the Bolomon of Sanuto, even though occidentals tended to mutilate place names in various ways.

The similarity of the texts of Anonymous (1510) and Sanuto suggests that Sanuto's Bolomon is the Anonymous's Selewrüst, easily recognized to be Silivri, the castle and walls of which we know were damaged by the earthquake and subsequently repaired, and from where aftershocks lasting for 18 days were reported (Ruhi, see Ménage, 1976).

Far-Field Effects

The earthquake was not felt as far as Tanem in the Crimea, as suggested by Ambraseys and Finkel (1995), but much nearer Istanbul, at Cirmen, the Chiena of Sanuto, in Bulgaria.

It was most definitely barely perceptible in Cairo. However, the abnormal extension of the lower isoseismal into Egypt, is a typical feature of felt effects on the soft deposits of the Nile Delta from large earthquakes originating north of the Hellenic Arc (Ambraseys, 2001a). The earthquake was not felt in southern Ukraine. The Ostroh chronicle simply refers to the news of the earthquake reaching Ukraine (Bevzo, 1971).

The damage to one of the monasteries in Athos, attributed to this earthquake by Ambraseys and Finkel (1995), is now certain to have been caused by a separate earthquake in 1511.

Sea Waves

Modern writers claim that as a result of the earthquake the sea overtopped the sea walls of the city (Papadopoulos and Chalkis, 1984; Papazachos and Papazachou, 1997). This information comes from later authors who say that the sea in the Golden Horn (Haliç) was so strongly shaken that it was thrown over the walls of Istanbul and Galata (Munster, 1550; Leunclavius, 1558; Batman, 1581) killing 12,000 people (sic) (Lancellotti, 1673). We have no indication in primary sources that the flooding of the coast of the Golden Horn (Haliç) by the sea at the time of the earthquake caused any damage or that the Sea of Marmara flooded the south coast of the city.

Social Effects

Apart from the obvious adverse effect that taxation for reconstruction had in some parts of the Empire (Sanuto, 1879–1903), we could find no social or economic repercussions that can be attributed to the earthquake. There is no evidence of looting after the earthquake that, however, happened after the fire of 1510 in Istanbul in which janissaries sacked the houses of Jews (Sanuto, 1879–1903).

Confusion with Other Earthquakes

The size of an earthquake can be assessed from the size of the area over which it was felt or from its radius of perceptibility. It is important, therefore, to establish the date of occurrence of individual events as accurately as possible and minimize the risk of amalgamating two or more separate events into a large earthquake. This is understandable in view of the tendency of later and modern writers to amalgamate or duplicate seismic events.

In the case of the earthquake in Istanbul some writers amalgamate it with a separate earthquake in Crete, whereas others syncretize it with different shocks in Carniola and Irdrija in Austria and Slovenia.

The principal source of confusion of the earthquake in Istanbul and in Crete is a seventeenth century chronicler who says that in 1509 there was an earthquake in Candia and Constantinople, as a result of which the sea ran over its walls killing 12,000 people (Lancellotti, 1673). In fact, the earthquake in Candia occurred on 29 May 1508; probably it was an intermediate depth earthquake with an epicenter in the Helleic Arc and affected a wide area, chiefly Crete, where it caused widespread destruction (ASV; Lampros, 1914; Platakis, 1950). There is no evidence that this shock was even felt in Istanbul.

The reason for the amalgamation of the earthquake in Carniola with the earthquake in Istanbul is interesting. The earthquake in Carniola occurred at 8 p.m. on 14 September 1509, which happens to be the wrong date of the earthquake that most European chroniclers give for the earthquake in Istanbul. The Carniola earthquake was 1400 km northwest of Istanbul and is well recorded by local sources; it ruined the castle of Bled and damaged those of Slatna and Begunje in upper Carniola. It was strong in Styria, Carinthia, and Tyrol, and was felt in the Schwabisch Jura, but not further (Nauclerus, 1579; Valvasor, 1689; Thalnitscher v. Thalberg, 1691; Peinlich, 1877, 1880; Rethly, 1952).

The reason for the amalgamation of the earthquake in the Sea of Marmara with the shock of 26 March 1511 in Idrija, 1100 km northwest of Istanbul, is that the latter happened on the same day as the earthquake of 26 May 1511 in Edirne, which some writers stated as March, confusing Mazo (March) in Venetian, with Maggio (May) in Italian. The Idrija earthquake caused heavy damage in western Slovenia, at Ljubljana, and to 26 towns and castles. This was a locally damaging shock, which was not reported from very far (Frytschius, 1563; Tarcagnota, 1585; Valvasor, 1689; Peinlich, 1877; Hoernes, 1902).

A late seventeenth century chronicle from Ostroh in Ukraine mentions the earthquake in Istanbul, and adds Tuzla in Bosnia, Dalmatia, and Moldavia to the places where the 1509 earthquake caused destruction (Bevzo, 1971), apparently amalgamating information from more than one earthquake.

Unresolved Questions

Although many of the details of the 1509 earthquake are quite clear, an Ottoman source, compiled probably in the 1520s, introduces a complication. A near-contemporary Ottoman chronicle, the Vekayi-i Sultan Bayezit ve Selim Han, adds that in the town of Çorum the 1509 earthquake caused the destruction of two quarters, and *mescids* and minarets were razed to the ground (Tansel, 1966). The anonymous author of this chronicle otherwise follows Ruhi's account closely but does not mention Çorlu among the towns affected; this suggests either a copyist's error or the conflation of two separate events. By the end of the sixteenth century, Ali, in his account of the earthquake, describes Çorum as being in the district of Rum in Anatolia, (Ali Gelibolulu Mustafa), and subsequent authors follow him (Solakzade Mehmed Hemdemi, 1880; Arinci, 1945). The extension of the damaging effects of the 1509 earthquake to Çorum, which is about 500 km east of Istanbul, must be rejected until further conclusive evidence is available. One may suspect that Ali's Çorum is a misreading of Ruhi's Çorlu, but the addition of Anatolia quite clearly indicates that he meant Çorum.

Alternatively, it may be that Vekayi-i Sultan Bayezit amalgamates the effects of two earthquakes; those in Ruhi for 1509 in the Marmara Sea area with the effects of a later earthquake in Çorum in Anatolia about which we have no other source. Arinci dated the earthquake to have occurred Çorum in 920 aH (Muslim calendar) (26 February 1514 to 29 March 1514) 5 yr after the earthquake in Istanbul. Arinci asserts that it had its center in Istanbul and that in Çorum, due to the earthquake, the Great Mosque was damaged, the Çakirli mosque collapsed, and one in three dwellings had become uninhabitable. He adds that as a result of the earthquake the people were obliged to migrate to Egypt and other places (Arinci, 1945). We cannot trace a Çakirli mosque in Çorum and have otherwise been unable to authenticate this statement, particularly the detail that the earthquake obliged people to migrate to Egypt, the details of which if true, suggest a source of information not as yet found and also an earthquake in Çorum of considerable magnitude. The only earthquake we know in Anatolia in 1514 occurred before July and affected the region of Malatya, about 400 km southeast of Çorum (Barbaro, 1842), an event that is not mentioned in Ottoman sources.

Another piece of information we have been unable to authenticate, also coming from a modern writer, is that that in the Gulf of Izmit the 1509 earthquake caused the complete collapse of the castles of Tuzla, Eskihisar, and Hereke and the dome of the mosque in Gebze (Öztüre, 1969). In Hereke, Öztüre adds, the Byzantine villas along the coast flew into the sea and new ones were not built until recently. In Izmit, he says, the sea wave created by the collapse into the sea of the quays of the dockyards on the coast, flooded the low-lying areas of the town. This is a very detailed account, unusual in style for a sixteenth century account. The mention of Tuzla in Turkey in this and of Tuzla in Bosnia in the Ostroh chronicle (Bevzo, 1971) needs authentication. Öztüre gives no references, and his bibliography does not indicate that he used contemporary or near-contemporary writers.⁂erefore, these details are uncertain and we disregard them. Had the earthquake caused such destruction only 25–50 km from Istanbul, our sources would not have omitted to mention or give some indication.

Intensity Assessment

In spite of the large number, there are only few accounts that can be used to assess intensities in any scale. In the present case, inasmuch as we are not in a position to be rigorous in our definitions of various ratings, we used a simplified version of the Medvedev-Sponheuer-Karnik (MSK, 1981) intensity scale by removing criteria relating to effects on the ground and on modern types of construction. The MSK scale was designed for the European environment and gives the assessors enough leeway to use their own judgment without being hemmed-in by a scale that is too specific. Note that intensities, by definition, can be assessed only in steps of one whole intensity unit.

In the case of Istanbul, with a population density of 14,500 per km^2 and with a building stock of aging timber houses, our intensity estimates for different parts of the city ranged between VII and X with a mode at IX or less. No modal intensity estimate can be made from loss figures (Ambraseys and Finkel, 1987), as there are no calibration formulas for such high population densities and types of construction.

Elsewhere, intensities assessed are at Çekmece (IX), Silivri (IX), Galata (VIII), Gebze (VIII?), Çorlu (VII), Izmit (VII?), Bursa (VI?), Gelibolu (VI). Demitoka (VI?), and Edirne (VI). These values have been estimated by the writer with the help of two independent assessors (G. Pantelopoulos and D. White [White, 2000]), the minus sign indicating possibly smaller modal intensity.

There is no direct or indirect evidence of high intensities west of Silivri or along the coast of the Gulf of Izmit. It is significant that many towns in these areas contributed masons and building materials for the reconstruction of Istanbul, suggesting that damage to these towns was not all that important. Also, heavier damage over an area larger than that defined previously would have implied serious economic and social repercussions for which we could find no evidence.

Assessment of Location and Size of the Event

All the evidence points to an earthquake on 10 September 1509 associated with a fault rupture from offshore, from halfway between Silivri and Çekmece to the Princes' Islands (Heybeli), running for about 70 km parallel to the zone of maximum damage on land, with a midpoint at 40.9° N and 28.7° E (Ambraseys and Jackson, 2000). Its inferred location offshore on a known fault, parallel to the maximum linear dimension of the damage area, is shown in Figure 2.

A rough estimate of the probable moment and surface-wave magnitude can be obtained from

$$M_0 = \mu \alpha W L^2, \tag{1}$$

where μ is the rigidity (ca. 3.0×10^{10} Nm^{-2} and α the ratio of incremental slip to fault length, which is typically ca. 5×10^{-5} for intraplate strike-slip earthquakes (Scholz *et al.,* 1986). For a rupture length of 70 km, assuming a fault width $W = 10$ km, we have $M_0 = 7.35 \times 10^{19}$ Nm, from which, using the global relation M_S (M_0) of Ekström and Dziewonski (1988), we find that M_S is 7.2. Since L depends on the square root of M_0 and W, small changes in the values of M_0 and W do not have a considerable effect on estimates of L. In order to allow for uncertainties in the inferred location and size of the fault rupture shown in Figure 2, we assumed $10 \leq W \leq 15$ km, and $40 \leq L \leq 100$ km, for which the mean value of M_S is 7.2 ± 0.25, with a mean moment uncertainty within acceptable limits (Helffrich, 1997).

Another way to estimate the surface magnitude of the event would be from the intensity and source distance from different sites. The choice to estimate M_S in terms of intensity has several disadvantages over and above the obvious problems of attempting to correlate a continuous variable, M_S, with a discrete variable, I_0, the range of which is too small. As a consequence, M_S values would be tightly packed, contrary to the distribution of a set of M_S.

It might be considered that high intensities would be the appropriate quantity with which to scale magnitude conveniently; however, this is not so, particularly in the case of the 1509 earthquake. Intensity assessment is influenced by local soil conditions and high structural vulnerability, particularly in a coastal area where the very concept of intensity is poorly defined, and the drawing of an open isoseismal is subjective and often made through the inward extrapolation of outer isoseismals, graphically or by a numerical model. Also, where the epicentral region includes a large urban area, such as Istanbul, problems arise that could give a misleading impression of the physical size of the event. Large uncertainties also result from bias of the assessor and from the coarse nature of intensity scales. Also, for the identification of the size and location of the epicentral area, which contains the fault rupture, a fairly even distribution of data is needed in the near field to ensure that the sharp transition zone leading to the medium field is properly modeled. If there is insufficient near-field data, it will not be possible to provide a valid description of this zone.

Using the calibration relation

$$M_S = -1.54 + 0.65(I) + 0.0029(r) + 2.14 \log(r) + 0.32p \tag{2}$$

which was derived for the the Balkans and western Turkey (Ambraseys, 1992) in which I is the intensity in the MSK scale at a site that is at a distance r (km) from the assumed surface projection of the fault rupture, with $p = 0$ for mean values and $p = 1$ for 84%, and $r = (R^2 + 9.7^2)^{0.5}$, provided $I \leq$ VIII MSK. This last condition excludes sites of high intensity for which the criteria are of limited value and irrelevant when applied to vulnerable structures, particularly in the historical period. It also reduces the error associated with the uncertainties in the inferred location of the fault rupture shown in Figure 2.

From the intensities assessed and from equation (2), the magnitude of the earthquake is M_S 7.2(± 0.3), which, by coincidence, is identical to the value estimated from fault length.

Our intensity estimates are close to those of Parsons *et al.* (2000), who estimate M_W 7.6 as compared with our 7.2, a difference that is chiefly caused by the calibration formula they used from earthquakes in Californian in terms of epicentral distances, regardless of magnitude.

Other estimates are M_S 7.7, with a maximum intensity X at Çorum [*sic*] (Papazachos and Papazachou, 1997) and $M_S = 7.6$–8.0 (Le Pichon *et al.,* 2000).

Conclusions

The assessment of historical seismicity is an evolving subject and much depends on the retrieval of new sources of information and on the reassessment of old ones. Clearly no study of historical earthquakes can claim to be exhaustive in retrieving all sources of information for a particular event.

The comparison of the 1509 earthquake by Ambraseys and Finkel (1990, 1995) and the present reassessment offer an example of such an evolution. The 1990 article, written 12 yr ago, was based on limited information, whereas the 1995 article relied on a few more but not fully researched sources. These works were as comprehensive as the sources allowed and provided a bibliography for those who wished to carry out an interpretation and re-evaluation of the event in terms of seismological parameters.

The present reassessment is the result of a systematic study of large earthquakes in the Eastern Mediterranean, carried out during the last decade, with new sources of information examined in their regional context with improved methods (Wilhelm von Bernkastel, see Hoffman and Dohms, 1988). For instance, the overestimation of the damage in Bolu, Bursa, Dimetoka, and Gelibolu in 1995 was caused by the lack of contemporary and near-contemporary source material, particularly of negative, direct or indirect evidence of serious damage at these places, which introduced a high degree of uncertainty in interpretation about which readers of these articles were cautioned. The mislocation of Chiena in the Crimea comes from expert advice that, on reappraisal, proved to be incorrect. All these points have been discussed previously from which it is evident that any work based on documentary research can only be as comprehensive as its sources allow.

The purpose of this article, therefore, is, taking as an example the earthquake of 1509, to present in some detail the intricacies and complexities inherent in the interpretation of earthquakes of the preinstrumental period. The article demonstrates the need for a systematic and consistent analysis of sources of information. It shows that it is not sufficient merely to receive some information and then, without understanding how this information has been obtained and what it really means, to proceed with intensity assessment. In addition, it is necessary to develop an intimate knowledge of all aspects of the real interdisciplinary problems and cooperate closely with the historian. Our interpretations should be established on a rational basis and not on the so-called intuitive approach.

The earthquake of 10 September 1509 in the Sea of Marmara occurred close enough to Istanbul to cause, 500 yr ago, considerable but not unprecedented damage to the city and to other towns along the coastal strip between Silivri and the Princes' Islands, including settlements along the southern part of the Bosphorus. In Istanbul the earthquake affected an aging and vulnerable building stock, destroying 0.5% of its 35,000 dwellings and causing a loss of life of less than 1% of the inhabitants. Very few of the better-known public buildings suffered irreparable damage. The earthquake caused heavy damage to the battlements, parapets, and towers of the city walls. Damage outside this coastal strip was widespread but relatively minor, confirming an estimated offshore fault rupture about 70 km long, associated with an estimated magnitude of $M_S \sim 7.2$.

We find that the 1509 earthquake was an event that must be classed as one that excites widespread interest due to the nature of the locality-Istanbul being the capital of the powerful Ottoman Empire-rather than because of the large magnitude of the shock.

There is no evidence that the earthquake was a Little Apocalypse (Küçük kiyamet), but its repetition, in what is today a densely inhabited region of vulnerable structures, could easily cause a disaster. However, it would be unsafe to extrapolate casualty and damage statistics from an early sixteenth century earthquake to assess losses for a twenty-first century event.

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I am responsible for the figures in this article, the quality of which betrays my total lack of familiarity with computer graphics and reluctance to depend on others to provide such services.

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