MOTAE

The Marmara Sea earthquake of 1509

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INTRODUCTION

One of the largest earthquakes of the last five centuries in the Eastern Mediterranean region occurred in the Sea of Marmara on 10 September 1509. The earthquake was felt over a very large area (Fig. 1); it caused damage along the western part of the North Anatolian Fault Zone on either side of the Sea of Marmara (Fig. 2), and was particularly heavy in the larger urban centres such as Istanbul (Fig. 3). This earthquake is significant not only because of its seismotectonic implications, but also for its implications for earthquake hazard assessment in this densely-populated and rapidly-developing area.

This earthquake is listed in earthquake catalogues and its effects are very briefly described by modern writers, mainly from the overviews of nineteenth-century authors. These sources are neither reliable nor complete, making it necessary to re-examine this important event. Our intentions in this paper are twofold: first, to establish more accurately when and where this earthquake occurred and to consider its effects through more detailed use of the historical evidence that is available, and secondly, taking the 1509 earthquake as a case-study, to indicate how historical sources can be of use to the seismologist. Mechanical means of recording earthquakes have only been available for a century: in order to gain an understanding of tectonic processes over the longer term, it is imperative that all available historical sources be utilized, for data acquired during the last century alone are unlikely to be representative of the true seismicity of an area. **(20,46,57,59,40)**

SOURCES OF INFORMATION

Information on the effects of the 1509 earthquake is available from both Turkish and occidental authors. **(3,5, 6,8,9,10,11,12,13,14,15,16,18,19,22, 24,25,27,28,29,30,31,35,39,42,44,45, 47,51,52,54,56,61,63,64,67,68,70)** Of the former, the account of the chronicler Ruhi is contemporary and possibly eyewitness while, of the latter, the Diaries of the Venetian Marino Sanuto are a contemporary source: accordingly, we try to

Fig. 1. *Location map of the earthquake of 10 September 1509. Shading shows extent of epicentral area with associated intensities of c.VII (MSK).*

reconstruct the event taking these two accounts as our basis although neither, it must be said, is without textual problems. A third source from which the passage concerning the earthquake is considered to be authoritative is that known as the Codex Hanivaldus: this does not, however, add anything of substance to what we find in Ruhi and Sanuto. Ruhi's and Sanuto's accounts complement each other to a large extent, and concentrate mainly on the effects of the earthquake in Istanbul with little information about other localities. In spite of the large number of authors who refer to this event there are relatively few accounts that are contemporary or near-contemporary, and much of what has been written by sixteenth century and later writers is derivative and devoid of additional information. (**41,53,37**)

THE EARTHQUAKE

The earthquake occurred without a foreshock on the night of 10 September 1509, and caused widespread damage in the area along the North Anatolian Fault and its extension into the Sea of Marmara. Some 30 years before the earthquake, Istanbul and Galata had an estimated population of 160,000, in 35,000 households, although this is reckoned to have increased apace subsequently. The earthquake destroyed over 1000 houses, killing 4000–5000 people, among whom were the households of three members of the Imperial Council: in that of the vezir Mustafa Pasha alone, 360 cavalry perished with their horses. Indeed, not a single house in Istanbul and Pera remained undamaged. The number of those injured in the earthquake was put at 10,000. (**41,53**)

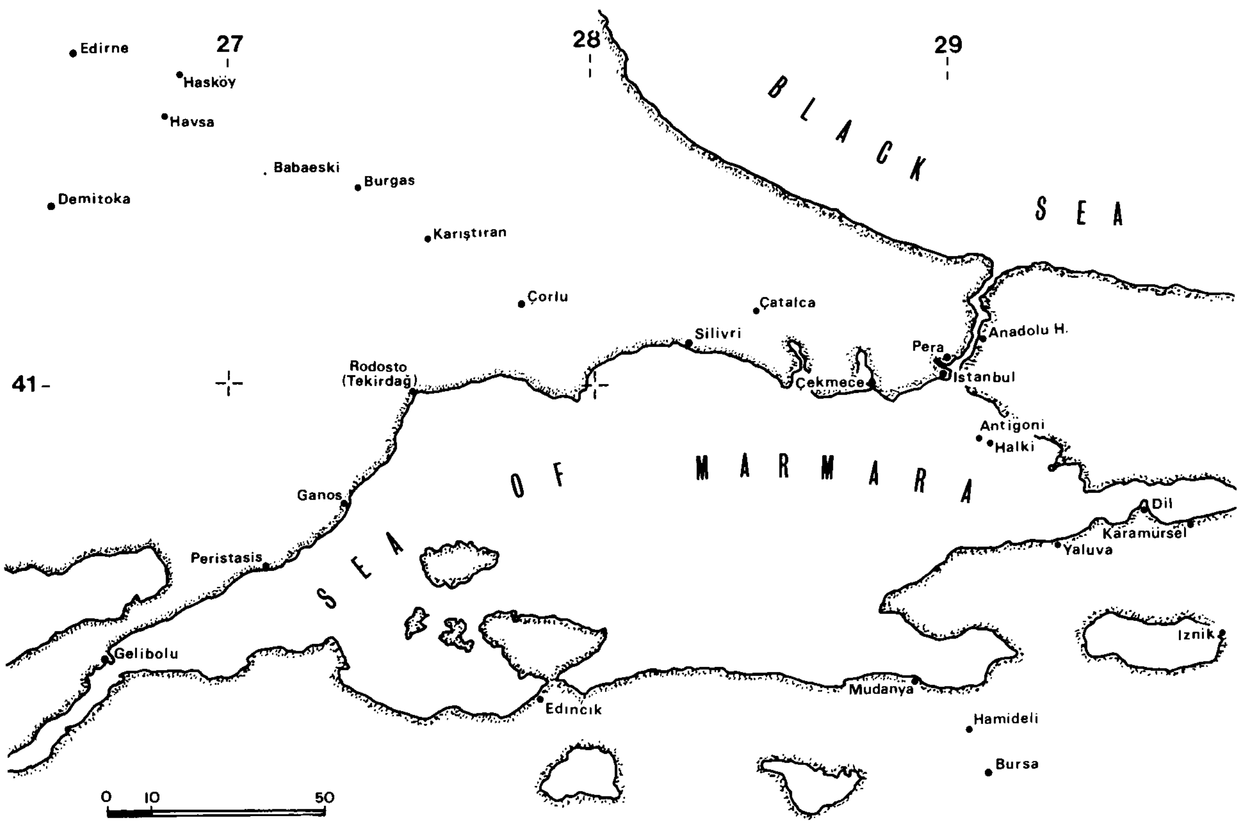
The fortifications of Istanbul were severely affected by the earthquake. The land-walls were demolished from Eğri Kapu as far as Yedikule (Fig. 3). The gate structures of Edirne Kapusu, Silivri Kapusu and Yedikule were ruined, and towers of the latter fortress were damaged. On the sea side, the walls were ruined as far round as Ishak Pasha Kapusu, and the sea-walls around the Topkapî Saray were breached between Hastalar Kapusu and Kayîklar Kapusu. Houses built adjacent to the sea-walls sunk into the sea. The earthquake destroyed the only substantial remnant of the Constantinian walls and the gate of Isakapusu, houses in the nearby Sukelnna (Avretpazarî) also being damaged. A total of 49 towers of the enceinte were shattered or destroyed and many km-length of the fortifications of the city were ruined. The walls of Galata also fell; the massive Galata Tower was shattered. (**41,53,36,4**)

The earthquake caused no damage to the former church of Agia Sophia except the collapse of the solitary minaret added after the Conquest and the fall of plaster applied at that time to conceal the mosaics which had adorned the walls and the vault of the dome. Damage to the Mosque of Sultan Mehmed the Conqueror, completed thirty-eight years earlier, was more serious. The capitals of four great columns cracked and the main dome was badly cleft, its plaster shattered; iron joists on both right and left sides of the Mosque buckled. The minarets were thrown down (**53**). Some of the buildings of the Mosque suffered badly: domes over the gates of the *imaret* and the hospital were demolished, as well as three domes and the schoolroom of the Zamiri Medresesi, one of eight such institutions attached to the Mosque; another of these *medreses* had two domes collapse. Shops in the Karaman Pazarî, in the vicinity of the Mosque of the Conqueror, collapsed. The earthquake also caused substantial damage to the newly-built Mosque of Sultan Bayazit: the *imaret* and the main dome fell to pieces, other domes and arches of the complex split, and the kitchen, storeroom and a minaret collapsed. The top of the minaret of the Davud Pasha *mescidi* fell, and two arches and a dome were destroyed. The church of St. John Theologos near the Hippodrome was destroyed. (**41,53,55**)

Topkapî Palace was damaged in places. The shock destroyed parts of the aqueduct of Valens, not only in the city but also along its course from the intake of the system. Free-standing columns such as the Dikili Taş, Diplokionion (Beşiktaş) and the obelisk of Theodosius in the Atmeidan were damaged or overturned: indeed, a total of 6 columns fell in the Atmeidan. The gate of the Ali Pasha Mosque, near to the Dikili Taş, also had minor damage. There is some evidence that many other buildings—caravanserais, baths and courtyards—were heavily damaged, while the number of mosques (*mescid*) ruined was put at 109. (**17,4,41**)

In some places, both in Istanbul and Pera, the ground opened up and sand was ejected, particularly along the coast where the sea flooded the shores to a great distance inland, waves crashing against the walls in the narrows between Galata and Istanbul. (**53**)

Details of repairs undertaken after the earthquake indicate that there was damage to Anadolu Hisarî and Yoros Kalesi on the Asian side of the Bosphorus, as well as to Rumeli Hisarî on the European side. In the Bosphorus, the Maiden's Tower (Kîz Kulesi) suffered badly. The walls of the district of Fener on the Golden Horn (former Castrum Petrii) also required repairs. On the islands of Antigone (mod. Burgaz) and Halki (Heybeliada) (Fig. 2) the earthquake damaged the domes of the churches of the Saviour and of Agios Prodromos, respectively. The bridges at Çekmece appear also to have been affected, as well as the walls and castle of Silivri. In Gelibolu, not a house was left intact and the fortifications were badly cracked. The town of Dimetoka was also ruined: it took 1000 builders to make good the damage. There was some material damage in Edirne, where parts of mosques and tops of minarets fell; the hospital complex of Sultan Bayezid I suffered only slight cracks, however. In Athos the dome of the monastery of M.Lavra was damaged at about this time. Although we have no information regarding damage in Çorlu, the population was apparently so afraid that they remained out-of-doors for almost two months. We know of damage in Bursa that needed repair but, again, specific details are



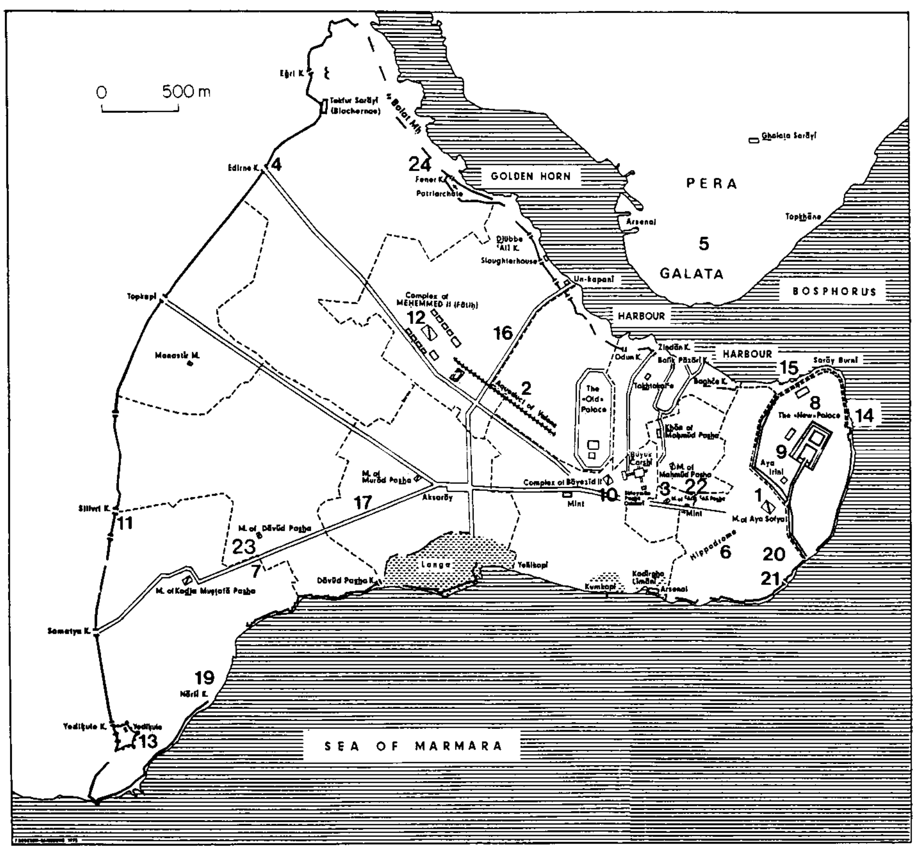


Fig. 2. *Epicentral area of the earthquake of 10 September 1509.*

Fig. 3. *Some of the most important structures, buildings and monuments destroyed or damaged by the earthquake of 1509 in Istanbul. 1: Agia Sophia; 2: Valens Aqueduct; 3: Dikiltas; 4: Edirne Kapusu; 5: Galata Tower; 6: Atmeidan; 7: Isakapusi; 8: Topkapi Serai (= 9); 9: Yeni saray; 10: Sultan Bayazit II Mosque; 11: Silivrikapu; 12: Sultan Mehmet II Mosque and complex; 13: Yedikule; 14: Odunkapisi; 15: Kayiklar Kapisi; 16: Karaman Pazari; 17: Suk Elnna; 18: Gri Kapi; 19: Narli Kapi; 20: Ishak Pasa; 21: Ahir Kapi; 22: Ali Pasa; 23: Davud Pasa; 24: Fener.*

lacking. Contemporary repairs in Iznik suggest that this town was also damaged. (**41,65,53,60,43**)

Further to the east the walls and towers of Bolu collapsed; the information available is only very brief and although it implies heavy damage there is no mention of loss of life. (**53**)

The shock was very widely felt. It was reported from Greece, from the Danube area and further north from Transylvania (Siebenburg and Birsa). In the south, it was perceptible in Cairo and the Nile Delta. Later writers suggest that the shock was also felt in Krain and Steiermark as far as Vienna, but it can be shown that these places were in fact affected by a different earthquake centring in the Alps. (**34,33,32,23**)

Aftershocks continued to be felt intermittently for almost a month in Istanbul and for eighteen days in Bolu. The aftershocks of 23 October and 16 November were apparently very strong, the former particularly in Thrace where it caused some damage in Edirne, and the latter throughout the Marmara region. During the following year shocks were reported from Edirne and Istanbul in April and again on 25 July, but these caused no damage. Finally, on 26 May 1511 there was another very strong shock that was felt in Edirne and caused some damage in Athos. (**53,41,21**)

The damage caused by the earthquake to Istanbul and other places was considerable. The Sultan mobilized 66,000 labourers from various parts of the Empire for reconstruction, as well as 3000 master craftsmen together with 11,000 assistants, and levied extra taxes to defray costs. Repair work started late in March 1510 and was completed in June of the same year. A woodcut drawn from the area of modern Tepebaşî Caddesi in Pera some 20 years after the earthquake, shows a view of Istanbul with the Mosque of Sultan Mehmed deprived of its minarets (Fig. 4): it is unlikely, however, that these would have remained unrepaired for so long (see Fig. 5 and long caption). Contemporary historians call this earthquake the 'Küçük Kîyamet', which may be translated as 'an intimation of the Day of Judgement', and rank it among the major calamities that befell Islam. (**41,69**)

DISCUSSION

The earliest information about this earthquake comes from a letter written by Nicolo Zustignan, a Venetian in Istanbul, five days after the event on 15 September. His letter reports that the earthquake happened on 10 September during the 4th hour of the night. This was a Monday in the Christian calendar and a Tuesday in the Moslem. The letter says explicitly that the shock felt in Istanbul was also experienced at the same time and with the same damaging effects in Bursa, Gelibolu and Edirne, towns from which news of the effects of the earthquake could easily have travelled to the capital by land or sea in less than five days. (**53**)

The contemporary Greek notices give exactly the same date, day of the week and time of the earthquake, and add to the list of damaged sites the Princes' Islands, and to the list of places where the shock was felt, Mt. Athos. (**38,65,21**)

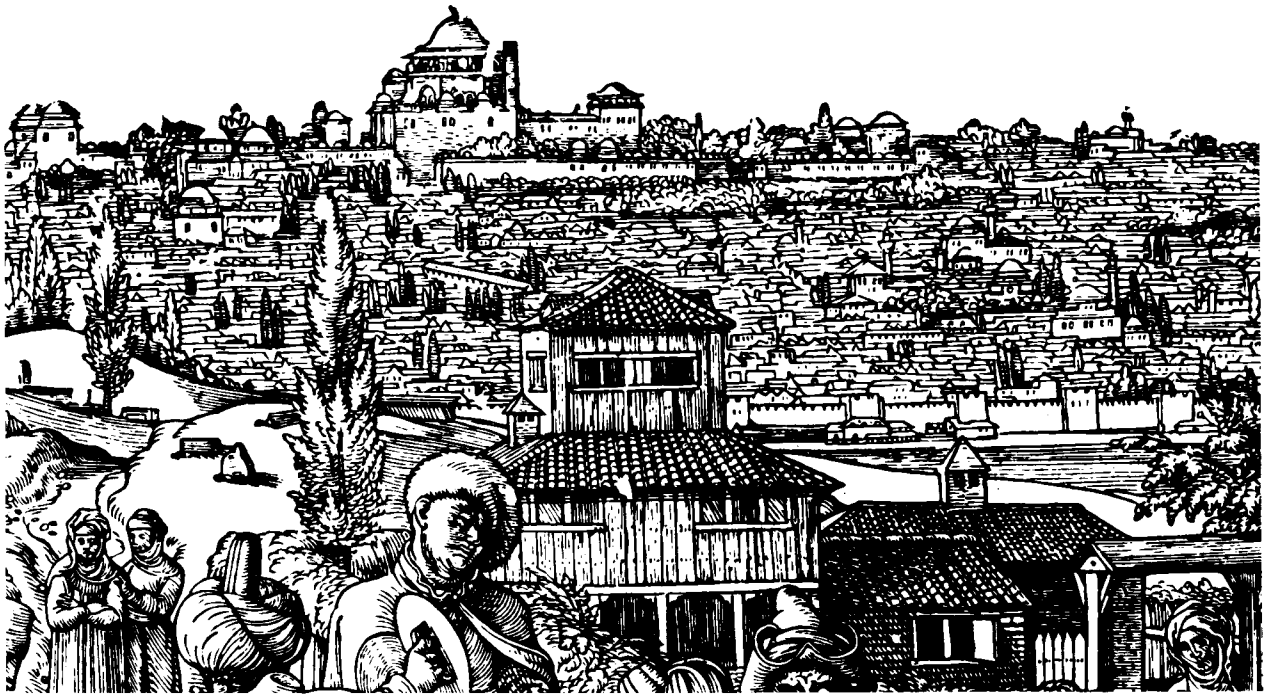


Fig. 4. *Woodcut by Peter Coecke (c.1529) of mosque of Sultan Mehmet II (no. 12 in Fig. 3, without minarets. That these would have remained unrepaired for so long, seems rather strange. (Original: The British Library, London, Coecke P. Woodcut: Coecke van Aelst, BM.146.1.10)*

Another letter giving news of the earthquake was sent from Transylvania 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 by messenger. This letter adds Bolu to the towns damaged, saying that the shock was felt from Chienam* to the Danube. However, this letter dates the event to the day of the Exaltation of the Cross, which is 14 September. This letter seems to be the basic source of information used in contemporary European fly-sheets to circulate the news of the disaster, and also by near-contemporary historians, all of whom date the event, accordingly, to 14 September. It is obvious that this date is in error as Zustignan, who was writing on 15 September, could not so quickly have received reports from towns at 300 km distance from Istanbul. The contemporary Arab historian who records that the shock was perceptible in the Nile Delta, gives the correct year, month and time of day, but no date. 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 dating are as much as four weeks, but the day of the week on which most of them agree is a Tuesday. Thus, there can be no doubt that the correct Christian date is 10 September 1509. (**53,2,26,66,62,50, 49,1,58**)

As a first approximation we may define the epicentral area of this event as lying between Gelibolu, Dimetoka, Bolu and Bursa (Fig. 1), an area within which there was damage and evidence of repair work after the earthquake. This would place the source of the earthquake offshore in the Sea of Marmara and imply a large magnitude event associated with source dimensions of at least 200 km. This is consistent with the large distance at which the shock was felt, 750 km to the north in Transylvania and even further to the south, in Cairo (**48,33**).

The suggested epicentral area encompasses a zone about 500 km long and about 200 km wide of an equivalent radius of about 160 km. In this region many public buildings, fortifications and bridges were damaged or destroyed and the people were obliged to stay in the open for up to two months. Long-period effects on tall structures, such as minarets, seem to have been widespread and there is evidence of a seismic sea-wave of considerable magnitude in the Golden Horn, i.e. the inlet between Istanbul and Pera (Fig. 3). Specific information about damage to houses comes only from a few and widely-scattered places such as Gelibolu, Demitoka and Istanbul, but the indications are that damage was widespread on both sides of the Sea of Marmara. Casualties are reported only from Istanbul, for which we have detailed reports, but there is no reason to suppose that there were

Fig. 5. *Fatih mosque complex from a mid-sixteenth-century engraving by M. Lorichs; compare with Fig. 4.*

Attention to the missing minarets of the Fatih mosque in Coecke's woodcut (Fig. 4) was drawn by Wultzinger (**69**)*, who attributed this to the 1509 earthquake. Inspection of a print of this woodcut kept at the British Library (BM.146.1.10.b) shows some damage in that area, and may have lost a bit off the minarets and dome. The flaw is on the right side of the mosque and to the left of the stub of the minarets which, incidentally, form part of the structure of the mosque. Wulzinger did not use the British Library copy and his print still shows the decapitated minarets but not the flaw between them and the mosque. Later prints at the British Library show small hoods on short minarets and no flaw, maybe better pressings from the same block. In contrast, Lorichs engraving made in the 1550s* (above) *shows tallish minarets, built outside the main body of the mosque structure, which could mean repairs between 1530 and 1550. But how do we know that there ever was much by way of minarets? We could find no pre-earthquake prints of the complex, and the only indication we have for their existence is Sanuto's statement that in this earthquake ". . . li marati (= minarets) del Signor vechio va in rovina et la mazor parte de le moschee . . ."* (**53**)*. (Added in press, Ed.)*

*Professor E. Zachariadou suggests that this may be Tamen on the Straits of Kerch, which would indicate that the shock was felt from the Danube through to the Crimea.

no casualties elsewhere. Our sources, although they give no details for the effects of the earthquake on the many villages and small towns on the Marmara region, do say that its damaging effects extended to both the European and Asian parts of the Empire.

It is clear that the attention given to this earthquake in historical works reflects the importance and size of the event. This is partly due to the fact that it affected one of the largest urban centres of the contemporary world and also because of the wide area over which it was felt and the damage it caused. Although it is not possible at this stage to assess the magnitude of the earthquake, its macroseismic characteristics suggest a magnitude greater than the $M_s = 7.4$ associated with the Saros-Marmara earthquake of 9 August 1912. (**71**)

Although many of the details of this earthquake are quite clear, two later Turkish sources, the second of which is based on the first, introduce a serious complication regarding the size of the event. These chroniclers, Gelibolulu Mustafa Ali (writing some eighty years after the event) and Solakzade respectively, add that in the town of Çorum (Fig. 1) the earthquake caused the destruction of two quarters, *mescids* and minarets being razed to the ground. Ali and Solakzade otherwise follow Ruhi's account closely, but do not mention, as he does, Çorlu among the towns affected, and at first sight one may suspect that a copyist wrote Çorum in place of Çorlu. However, this does not seem to be the case, since Çorum is explicitly described as being 'in the *vilayet* of Rum in Anatolia'. A modern writer repeats this information, that Istanbul and Çorum were damaged by the same earthquake in 1509, but cites as his authority only the early twentieth century *Tarih-i Ebü'l Faruk*. He further adds that there was another earthquake in AH 920/AD1514 which affected both Istanbul and Çorum: this time one third of the latter town collapsed and, in particular, the Great Mosque fell as did the domes of the Çakîrlî Mosque; in addition, part of the population was obliged to migrate to Egypt and other places although he gives no source for this information. We have been unable to identify the Çakîrlî Mosque in either Çorum or Çorlu. The extension of the damaging effects of an earthquake, be it that of 1509 or 1514, to Çorum, about 700 km east of Gelibolu, would imply a very large magnitude event, which is theoretically possible, unprecedented in this region, but must be rejected until further conclusive evidence becomes available. (**1,58,7**)

It is possible that Çorum was affected by a separate earthquake in the North Anatolian Fault Zone and that the damaging effects of the 1509 Marmara earthquake did not extend to the east beyond Bolu, but we can find no evidence of more than one principal event in contemporary sources, and these do not mention Corum. The only earthquake in AH 920 for which we have been able to find data are, first, a damaging shock in the Ionian Islands on 16 April 1514, a shock of the 1509 sequence in Istanbul, and secondly, a destructive event on the East Anatolian Fault near Malatya in 1513. (**55,72**)

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Note: (i) asterisks indicate what are clearly much later sources or which do not quote contemporary or near-contemporary material; (ii) we have tried, where possible, to indicate the date of compilation of passages relating to the earthquake contained in each source, where this differs from the date of publication; the estimated date of compilation appears in square brackets after each of the entries in the Bibliography.

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Terrae Motae

At the beginning of the International Decade of Natural Hazard Reduction this section of *TERRA Nova* will be devoted to studies of 'Earth disasters' – eruptions, earthquakes and landslides. We welcome field reports of recent disasters, as well as evaluations of past events. We have the potential for rapid publication and welcome approaches by those on field missions, both for the publication of 'first impression' articles as well as more considered reviews.

EARTHWORKS

ROCK AND ROUBLES

Robert Muir Wood

A heady cocktail of glasnost and hard currency has led to an increasing number of commercial arrangements between Western geoscience companies and their Soviet state-owned counterparts. These contacts have provided an opportunity to gain windows into Soviet Earth sciences. The view has often been surprising; in its isolation from the West the Soviet Union has developed a parallel culture of the Earth Sciences. How many other countries have their own Ministry of Geology?

Following the Armenian earthquake the British manufacturer of seismic monitoring instrumentation, Earth Data, won a contract valued at £400,000. Strangely this came not from the Armenian SSR, but from neighbouring Azerbaijan. Sixteen state-of-the-art, three-component digital outstations with radio telemetry facilities, radio relay stations, long-run digital tape recorders and a range of data aquisition software were bought by the Geological Institute of the Azerbaijan SSR Academy of Sciences to further a research programme into earthquake prediction, based on studies of dynamic noise at distant seismic stations. According to the Baku researchers sedimentary basins 'hum' in advance of distant earthquakes, as a result of energy radiated prior to fault rupture. The particular harmonics of the resonance are even considered sufficient to identify the source from which the earthquake will come. Records from Azerbaijan a few hours in advance of the Armenian earthquake were claimed to display such resonance, although no attempt at a prediction seems to have been made. However, the earthquake seems to have been sufficient to trigger some hard currency funding of the all-important digital equipment. Western seismologists who have seen a selection of the analogue records and heard the arguments remain to be convinced believing that the noise is 'cultural' or wind-related and that the scientific case has been based on a very partial data-set. Yet Earth Data's sale is an important demonstration of the priority that Soviet Earth scientists have given to research in earthquake prediction; an area that has now been almost abandoned in every European country apart from Greece.

Oil and gas exports sustained the Soviet economy through years when the grain harvest fell short of the five-year plan, and many of the recent Western contacts have concerned joint-ventures in hydrocarbon prospecting and production. Extraction of 635 million tons of oil and gas liquids is planned for the 1990s requiring the drilling of around 8 million metres of wells each year. Most of the new fields are smaller or more difficult to produce: low productive reserves have increased more than four times faster than total reserves and in 25 years the amount of oil recovered for every metre drilled has halved. The majority of this production continues to be in western Siberia.

Remote sensing techniques have been more highly valued in the Soviet Union as fundamental to hydrocarbon exploration; the focus on space technology has created the necessary platforms and cameras to achieve high-resolution images. Following a conference in Stavanger last December Norwegian Geoteam has offered to market considerable Soviet expertise in this area.

In contrast, land-based seismic reflection profiling is expensive and has not received the same technological priority. However, several million kilometres of seismic reflection data has been collected across the Soviet Union's hydrocarbon-rich sedimentary basins, most of it only available on paper-copy because magnetic tapes are so scarce that they are continually re-used. The small British independent seismic contractor JEBCO in April 1989 signed an exclusive agreement with the USSR Ministry of Geology to market and sell by licence this proprietary information along with associated geological data. In a project likely to last more than a decade al the seismic data will have to