3 TECTONICS AND SEISMICITY OF MARMARA REGION

3.1 Tectonics

Ketin (1973) initiated the first studies on the tectonic evolution of Turkey with his finding on the westward movement of the North Anatolian Fault following the great Erzincan earthquake in 1939. His studies were later followed up and expanded by the next generation of Turkish earth scientists (Barka and Kadinsky-Cade 1988; engör 1979; engör and Y lmaz 1983; Aydan 1997). The plate tectonic model shown in Figure 3.1 is the widely accepted plate tectonic model for Turkey and its vicinity. The tectonic evolution of Turkey was associated with the uplift of the Levantine ocean base between Euro-Asia and Africa as a result of the northward motion of the Africa continent and Arabian plate (Ketin 1973, Barka and Reilinger 1997, Aydan 1997). This phenomenon explains why the tectonic structure of the Anatolian plate consists of melange Anadolu (Anatolides) and overlaying limestone-based sedimentary formations of Toros Da lar (Taurides) and Kuzey Anadolu Da lar (Pontides).

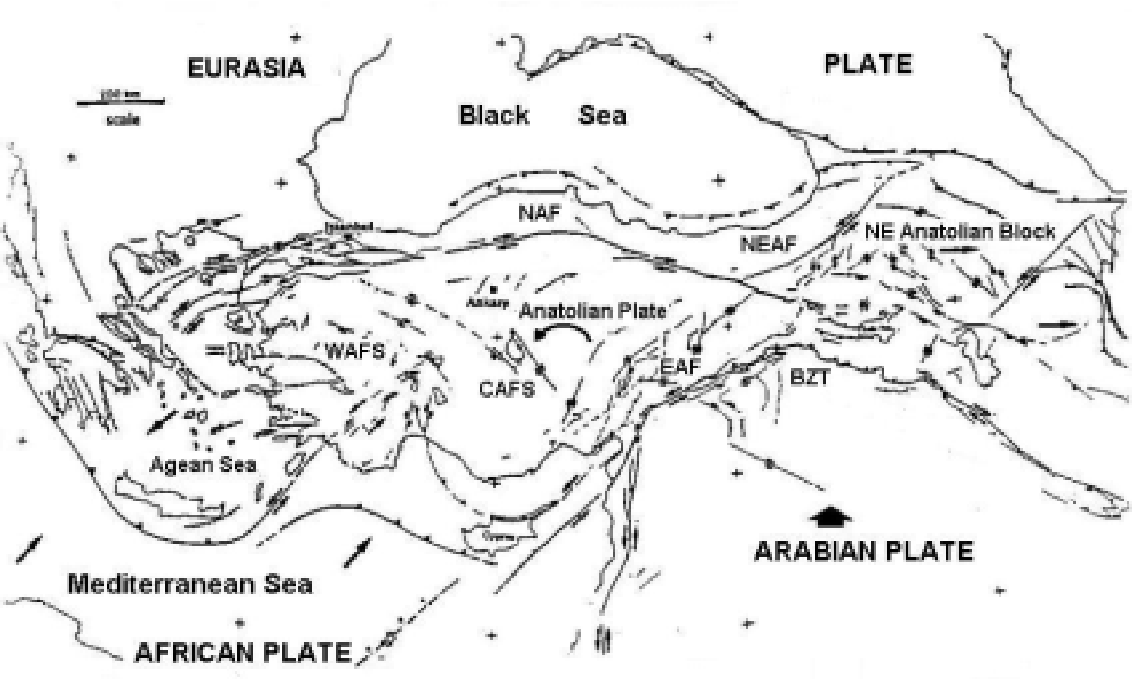

Figure 3.1 A plate tectonic model for Turkey modified from Barka and Reilinger 1997

The northward motion of the Arabian plate relative to Africa plate causes lateral movement and rotation of the Anatolian block to the west and the North-East Anatolian block to the east. The North Anatolian Fault (NAF) and East Anatolian Fault (EAF) constitute the northern and southern boundaries, respectively, of the westward moving Anatolian block (Barka and Reilinger 1997, Aydan 1997). The motion of the Northeast Anatolian block is more complicated by extensive internal deformation of the block along conjugate faults. The fault systems of Turkey is shown in Figure. 3.2.

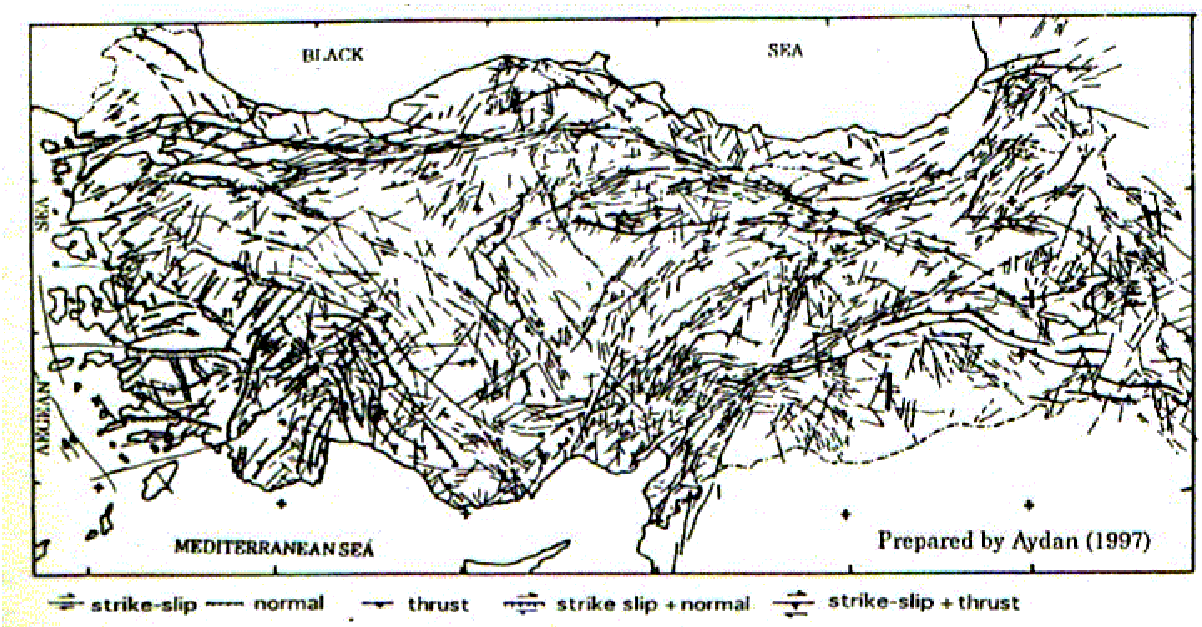

Figure 3.2 Fault systems of Turkey (after Aydan et al. 1998)

The tectonics of the Marmara region were studied by many earth scientists (Ketin 1973, Üçer et al. 1997; Barka 1997) Although many aspects were clarified, there are still some topics to be clarified due to the very complex structure of the region. These works were summarised in a recent extensive work by Barka (1997). According to Barka, many tectonic events are associated with the North Anatolian Fault (Figure 3.3). This fault splays into three strands in the vicinity of Mudurnu valley. These strands are named as the northern, central and southern strands. The northern strand passes through the Izmit bay, Marmara thorough and Saros gulf and extends towards Greece. The central strand follows the path through Geyve, Iznik, Mudanya, Band rma and Biga. The southern strand follows the path through Bursa, Manyas Lake, Bal kesir and Edremit Gulf. The basins in Marmara Sea and Lakes of Sapanca, Iznik and Manyas are considered to be as a result of pull-apart mechanism associated with the strike-slip motion of the strands of the NAF. Although the Marmara thorough is divided into several basins, this is likely to be due to the negative flower structure of a trans-tensional faulting regime near the ground surface.

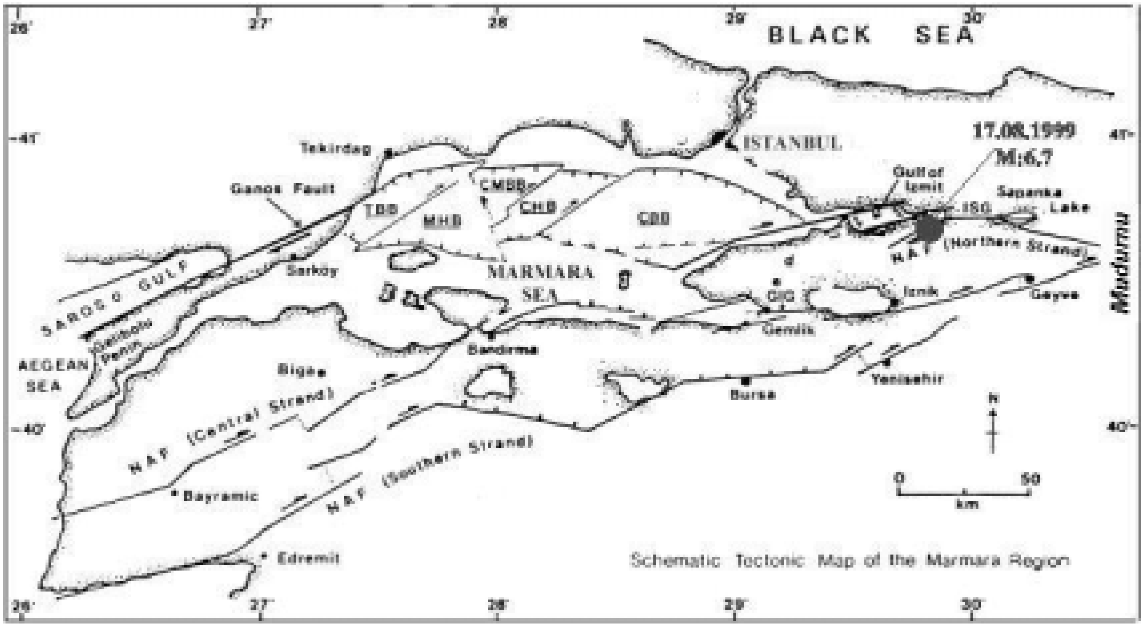

Figure 3.3 Tectonic map of the Marmara Region (After Barka 1997)

In addition to the strands of the NAF, the tectonics of the Marmara region are also influenced by Istranca fault, Terzili fault in Trakya (Thrace) which may be the continuations of some faults originating in the Anatolian Plate and extending into Trakya.

As seen in Figure 3.3, the North Anatolian Fault consitute a zone through Marmara sea and converges into a single line between Ganos and Saros Gulf. There is no doubt that any fault is not a single plane and it is a band with a given thickness. Furthermore, every strike-slip fault cause a positive or negative flower structures near the ground surface depending upon whether it is trans-pression or trans-tension fault. Therefore, The North Anatolian Fault should be a curved narrow band passing beneath Sapanca Lake, zmit Gulf and Marmara sea. This fact is, in fact, validated in the geophysical investigation in Marmara Sea and zmit Gulf (i.e. Bargu and Yüksel, 1993; Barka 1997; Akay et al. 1999). Figure 3.4 shows the results of a geophysical investigation and its interpretation in zmit Gulf .

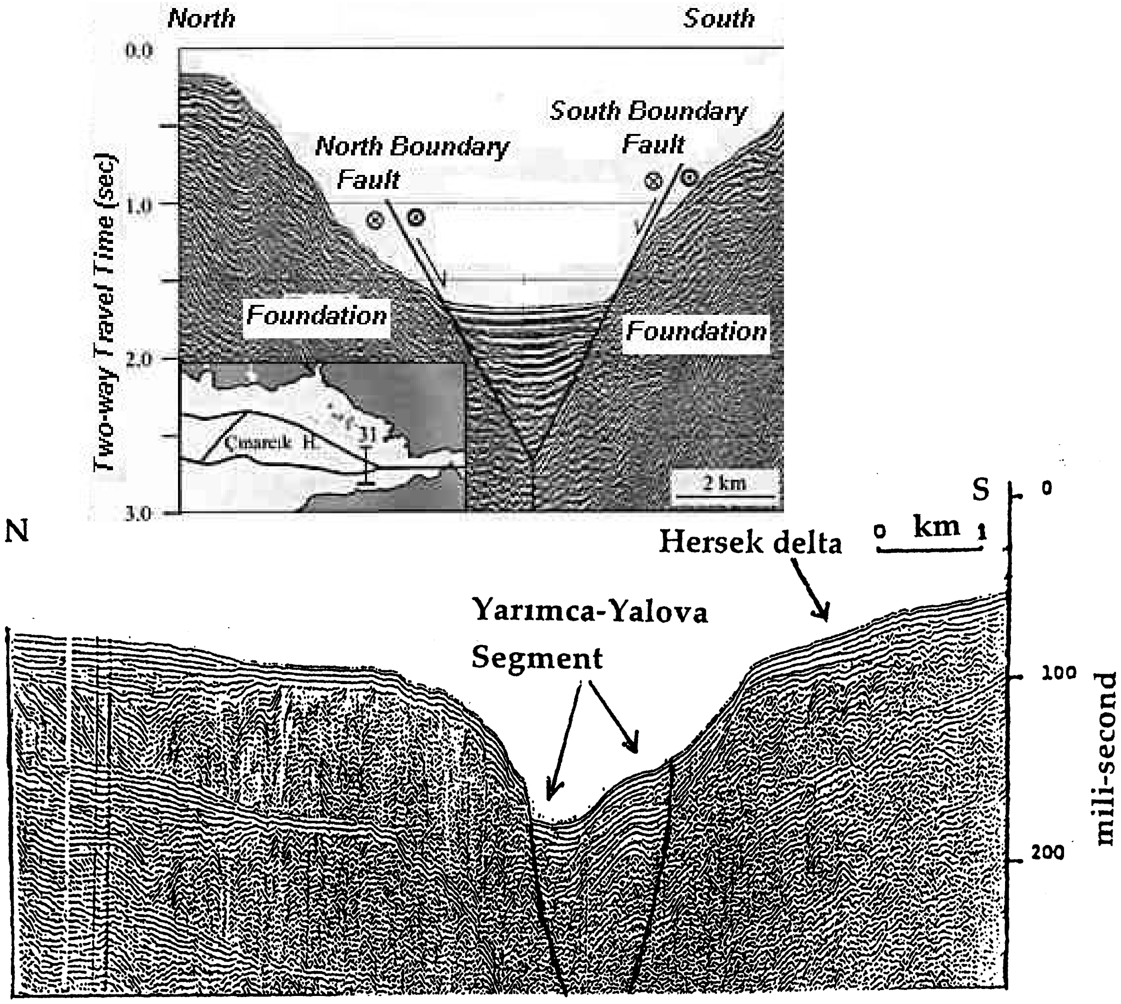

Figure 3.4 Geophysical profiles of zmit Gulf in N-S direction

3.2 Seismicity

Turkey is one of the most seismically active countries in the world and it is situated on the Alpine belt. The seismicity of Turkey is well documented for a period of 2000 years (Ergin et al. 1967; Ey do an et al. 1988, Aydan et al. 1996. 1997). Figure. 3.5 shows the distributions of the epicenters of earthquakes greater than magnitude 4 for the period between 1900 and 1998. It is noted that epicenters are concentrated on the North Anatolian Fault (NAF), East Anatolian Fault (EAF) and West Anatolian Fault System (WAFS) and North-East Anatolian Fault (NEAF). The depth of hypocenters along the NAF and the WAFS are generally between 10 to 20 km.

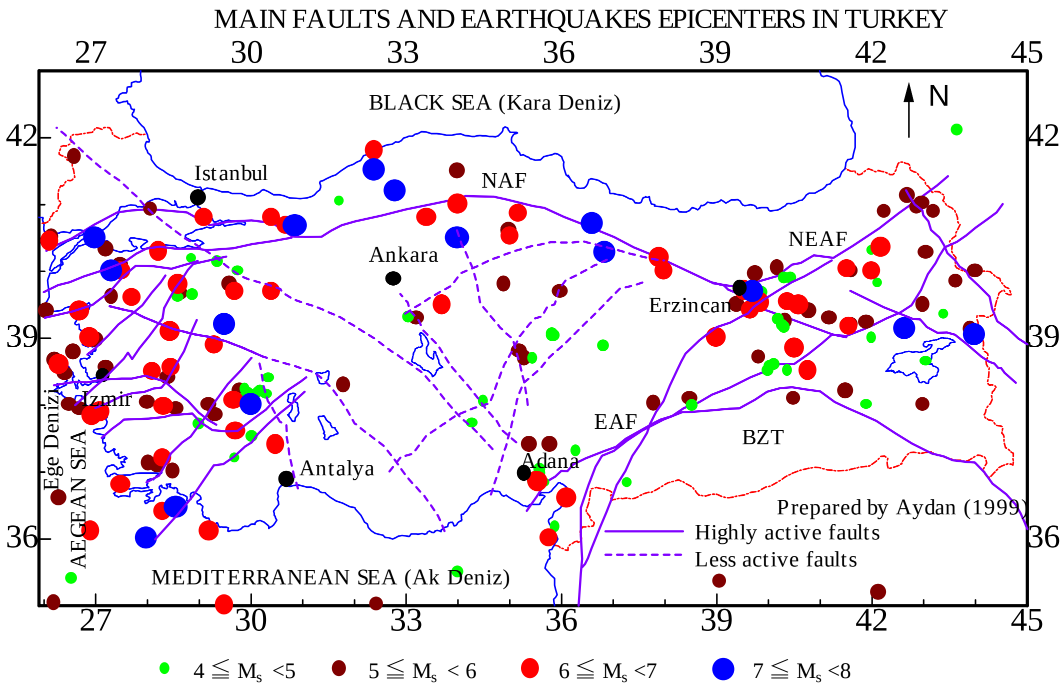

Figure 3.5 Epicenter distributions in Turkey and its close vicinity between 1900-1998

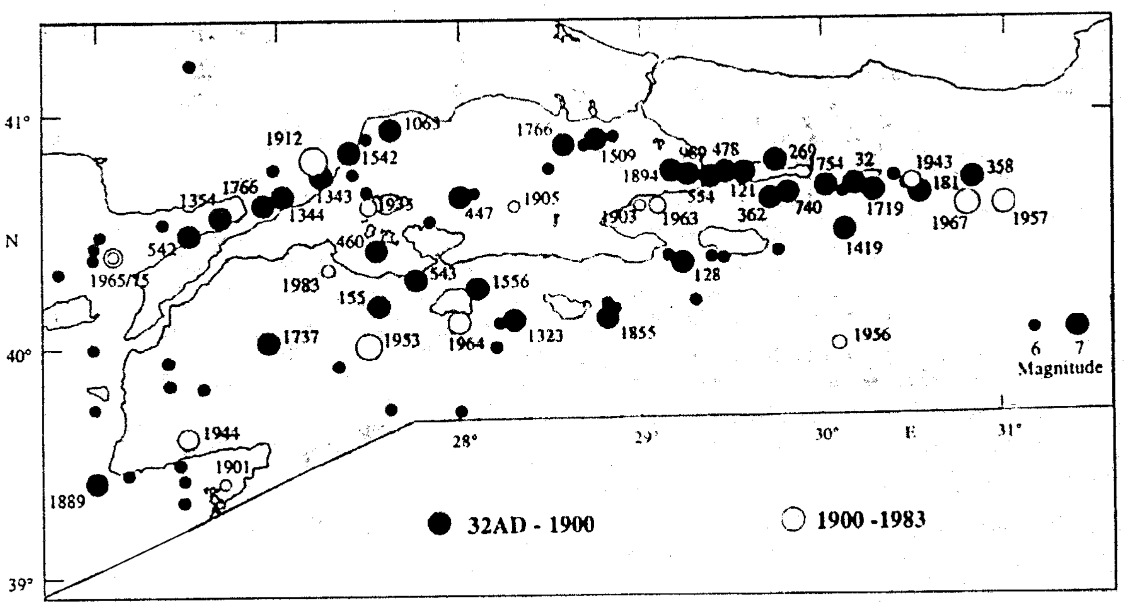

Figure 3.6 Historical seismicity of the Marmara region

The seismicity of the Marmara region was recently reviewed by Üçer et al. (1997) and Barka (1997). Most of devastating earthquakes for more than 2000 years took place along the so-called northern strand of the NAF (Figure 3.6). The northern strand seems to be more active than the central or southern strand of the NAF. Figure 3.7 shows the focal plane solutions of earthquakes in the region. The solutions indicates that the large events take place by right lateral strike-slip faulting while small events do by normal faulting with right-lateral strike slip component.

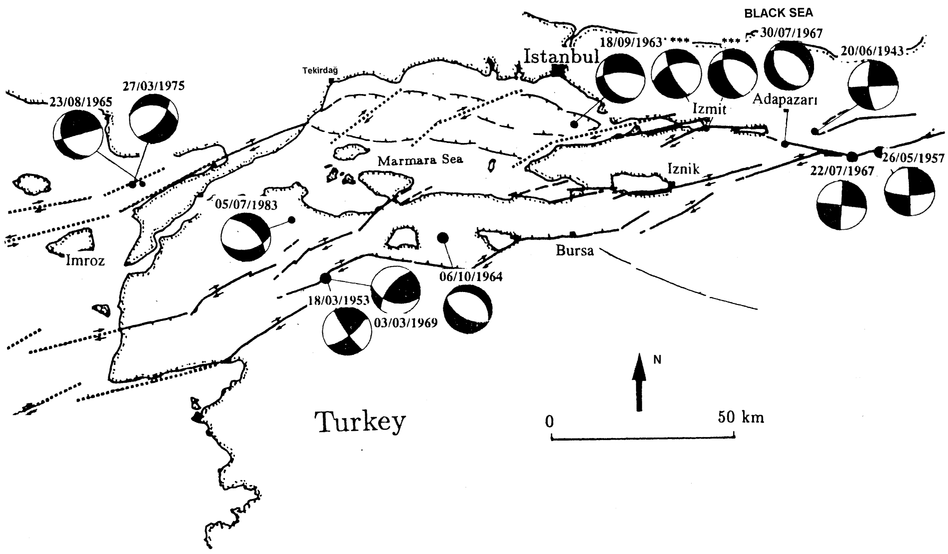

Figure 3.7 Focal plane solutions of earthquakes in the Marmara region

After the establishment of the MARNET seismic network in the region, the locations of seismic events having magnitude of 2.5 could be determined. Figure 3.8 shows the epicenter distribution of events between the period of 1976-1990 (Üçer et al. 1997). The numbers in the figure indicates the years of large earthquakes. They pointed out that there are 3 areas with low seismicity and they regarded these areas as seismic gaps which are encircled in the figure. One of these gaps is associated with the location of the present earthquake and was named Karamürsel gap. The other seismic gaps are situated in the northern central Marmara sea and between Saros Gulf and Ganos which is the location of 1912 Mürefte- arköy earthquake.

Yüksel (1995) recently investigated the seismic risk of zmit Gulf. In his investigation he considered the earthquakes within the period of 1900-1986. He computed the coefficients of a function for the regional earthquake recurrence

$$\log N = a - bM$$

He suggested that the value of *a* and *b* should have the values of 3.41-3.39 and 0.72-0.73, respectively. It seems that these functions could estimate the average recurrence period of earthquakes. Nevertheless, it should be noted the actual recurrence periods are not easily predictable from such a simple equation. The data implies that the earthquake activity is very small for a 150 years period and then it becomes very active for a period of 50 years.

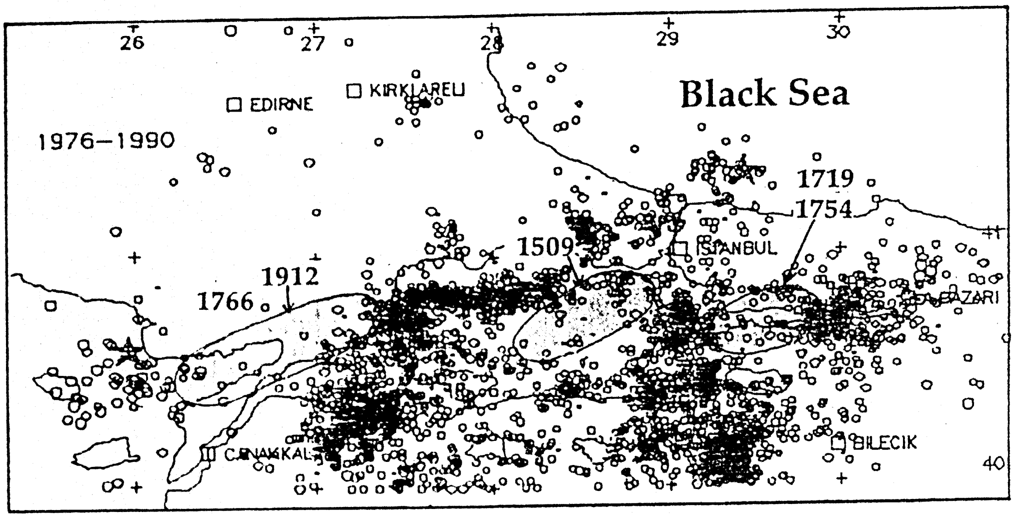

Figure 3.8 Epicenters of earthquakes between 1976 and 1995 in the Marmara region

Recently, Stein et al. (1997) analysed the rupturing process using a simple two dimensional elastic boundary element method by introducing a given relative displacement field between the two sides of the fault and the fault geometry. They identified several faults with a heightened probability of failure. The city of Izmit was found to be most vulnerable to an earthquake on the Sapanca fault. Stress increase of 1.3-2.5 bars were found for the Geyve and Sapanca faults, which pose the greatest threat to Istanbul, particularly if the faults ruptured from east to west.

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