CHAPTER 5: EARTHQUAKES IN ANATOLIA

5.1. Case study regions in Anatolia

In Ottoman Empire, the masonry wall structures, domes, vaults and arches were the major structural elements and also the major geometrical forms. The historical structures have very complex load carrying behavior due to the massive and continues interaction of domes, vaults, arches, pillars and walls. Typically, these structures are more massive than contemporary structures and that usually carry their actions primarily in compression. The structural resistance depends on the geometry of the structure, shape of the structural components, the characteristic strength and stiffness of the materials and the special construction details. The characteristic thickness of the masonry structural components should be able to resist compression, tension and shear stresses results from the structure's own weights and those imposed by earthquake.

Edirne in Thrace and İznik, ancient Nicaea in Anatolia were the important locations in Ottoman Empire. Both of the locations were the capitals in historical period of the Ottoman. In addition these Edirne and İznik were the hosted Romans, Byzantines in the historical times. Therefore these locations were very rich in architectural heritage.

Bilecik city is another important location for the Ottoman which was the located on the main trade road of the İstanbul-Bagdad. In the history of Ottoman, Bilecik city was the on the edge line of the middle Anatolia with İstanbul and its surroundings. Bilecik city was developed better in the Ottoman era than past periods.

All the locations were affected by seismic forces. However İznik was under the big risk of seismic activity rather than Bilecik and Edirne. The data's form the past earthquakes in these three locations or closest locations could be seen in table in this chapter. İstanbul is one of the closest locations to Edirne. In the past big earthquakes in İstanbul were affected Edirne district. Similar thought could be applied to İznik, Bursa and Bilecik district. Also Eskişehir and Bilecik district are in the same manner of seismic activity. Closest locations seismic activities affect each other and cause damages in both areas.

The North Anatolian Fault Zone (NAFZ) bifurcates into three branches in the Marmara Region. NAFZ and the N-S directed extensional regime of Western Anatolia was a transitional zone between the strike-slip tectonics. Southern Marmara region is characterized by approximately E-W trending rhomb-like horst and graben complexes bounded by strike slip-faults with normal component. These components are striking mainly in E-W direction *(Gürer, Ö., F., Kaymakçı, N., Çakır, Ş., Özburan, M., 2003).*

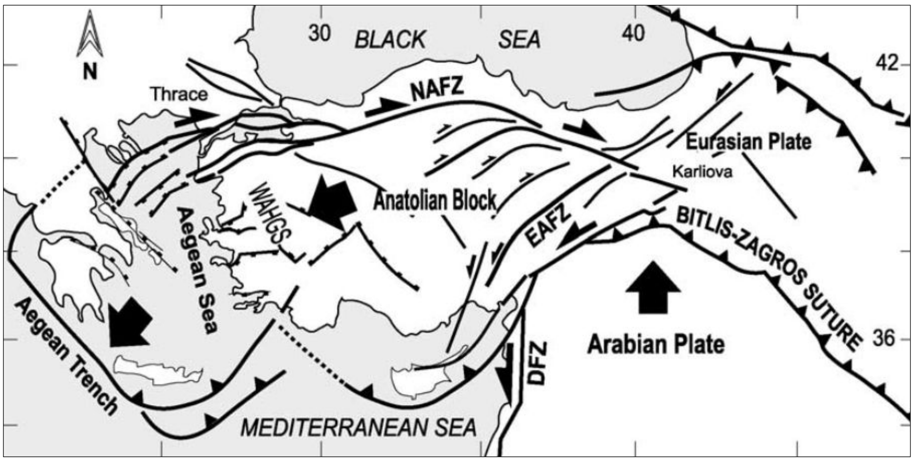

Fig 5.1: Tectonic outline of Turkey and eastern Mediterranean area. DFZ: Dead sea Fault Zone, EAFZ: East Anatolian Fault Zone, NAFZ: North Anatolian Fault Zone *(Modified from: Dewey and Şengör, 1979); (Citation: Gürer, Ö., F., Kaymakçı, N., Çakır, Ş., Özburan, M., 2003)*

Morphologically the NAFZ forms a relatively deep and narrow fault zone. They are extending from Karlıova in the east to the Marmara Sea in the west. As well in the area of Dokurcun in the west, the NAFZ are divided into two branches. Also in Marmara sea region, those two branches are divided into sub-branches which forming a zone of distributed deformation more than 120km wide *(Modified from: Şengör et al., 1985; Barka and Kandinsky-Cade, 1988; Koçyiğit, 1988); (Citation: Gürer, Ö., F., Kaymakçı, N., Çakır, Ş., Özburan, M., 2003).*

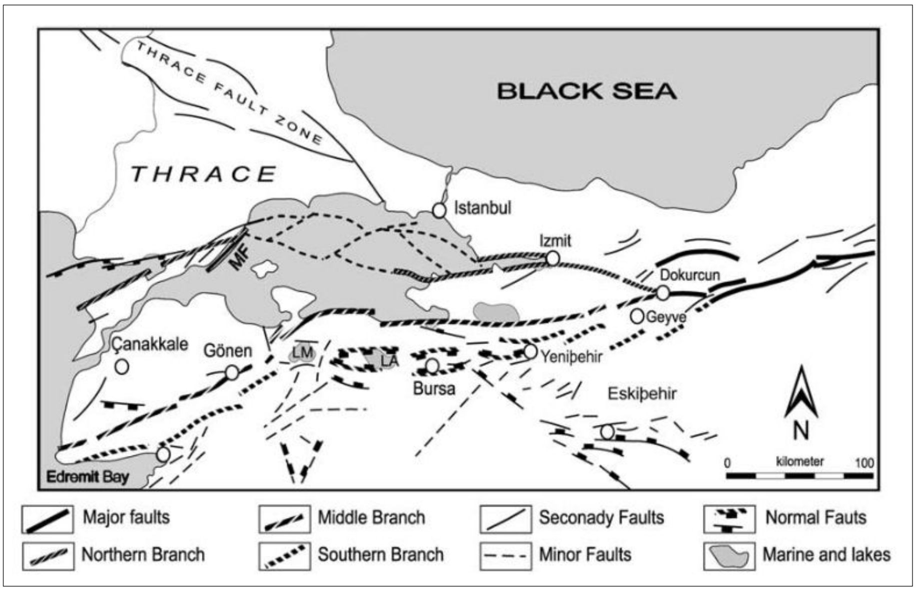

Fig 5.2: Major neotectonic structures in the Marmara region. MF: Mürefte Fault, GB: Geyve Basin, LM: Lake Manyas, LA: Lake Apolyont *(Gürer, Ö., F., Kaymakçı, N., Çakır, Ş., Özburan, M., 2003)*

According to the, “T.C. Başbakanlık Afet ve Acil Durum Yönetimi, Deprem Dairesi Başkanlığı”, seismic regions of the Turkey is shown on the below maps. The case studies are marked on the seismic map of Turkey.

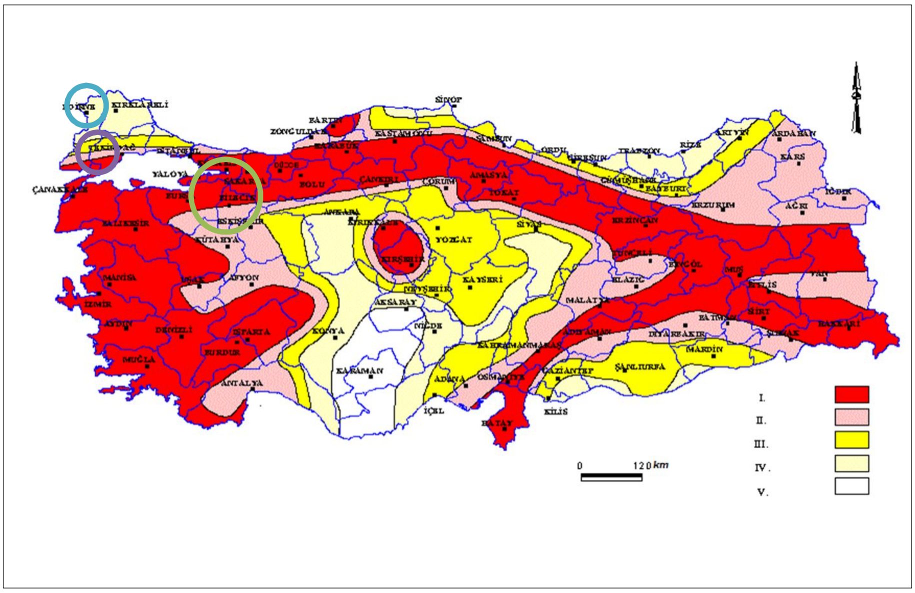

Fig 5.3: Seismic Regions of the Turkey (red; most risky / white; less risky) and the location of the case studies; Edirne, Keşan, İznik, Bilecik *(Turkey'.T.C. Basbakanlik Afet ve Acil Durum Yönetimi, Deprem Dairesi Baskanlığı)*

The detailed seismic maps for the locations of the cities which case studies were chosen shown in the fig 5.4.

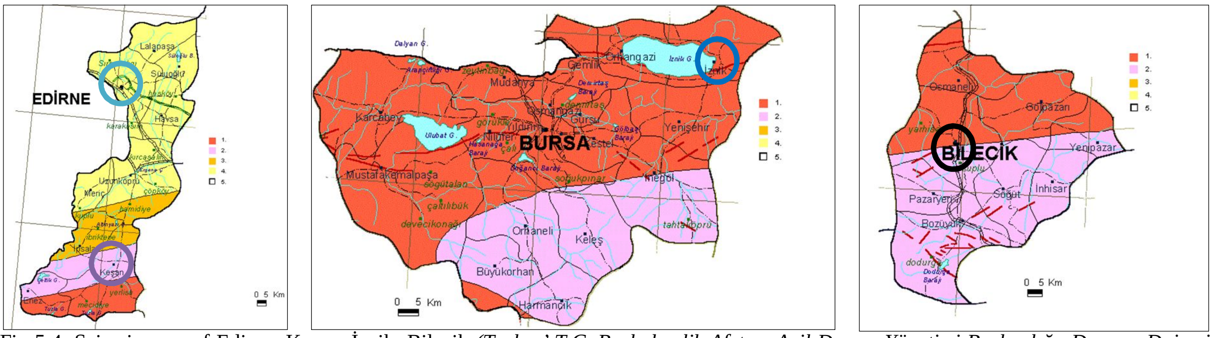

Fig 5.4: Seismic map of Edirne, Keşan, İznik, Bilecik *(Turkey'.T.C. Basbakanlik Afet ve Acil Durum Yönetimi Baskanlığı, Deprem Dairesi Baskanlığı)*

5.1.1. İznik region

Marmara region was cut by many active faults forming some distinct tectonic features such as İznik Lake. İznik region; the basin of İznik was active depression created by a serious of faults. These faults were developed with the integration of Middle Strand of the north Anatolian Fault (NAFMS). Sölüz fault was the most important one which runs parallel to the NAFMS. This fault plays an important role for evaluation of the 75m deep ellipsoid shaped depression in the southern part of the lake. İznik Lake is situated on an active interface between Eurasian Plate to the north and the Aegean-Anatolian microplate to the south *(Öztürk, Yaltırak, Alpar, 2008).*

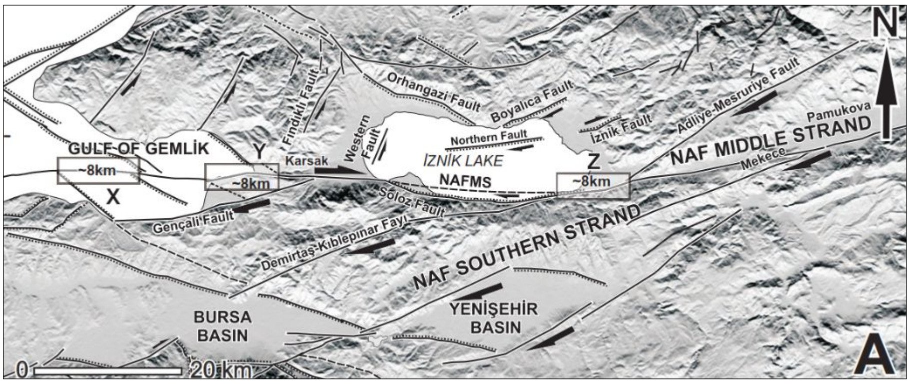

Fig 5.5: Tectonic map of the İznik basin *(Öztürk, Yaltırak, Alpar, 2008)*

Geology of the region surrounding İznik Lake was; Late Paleozoic, Mesozoic and Paleogene successions, forming the pre-Miocene basement. The Miocene sequence unconformable overlies the basement rocks and is covered by Pliocene-Quaternary units. The metamorphic rocks of the basement have undergone multiple deformations *(Öztürk, Yaltırak, Alpar, 2008).*

- Historical earthquakes in İznik

According to the data's of the natural disasters that were occurred in İznik Lake region showed many destructive facts during last 2000 years. Some important and well documented data are as follows: *(Modified from: Ambraseys & Finkel 1995); (Citation: Öztürk, Yaltırak, Alpar, 2008).*

- 362 AD December 02: It was a major earthquake and it felt in İstanbul city. This earthquake was destroyed all the ancient city of İzmit (Nicomedia) at the eastern end of the Gulf of İzmit and most of İznik (Nicaea). The intensity of the earthquake was 6 scale.

- 368 AD October 11: There was strong lethal shock with epicenter near İznik Lake and occurs a very big damage in İznik city and its surrounding settlements in Bithynia. The intensity of the earthquake was 6.4 scale.
- 1065 AD September: It was a local earthquake around the İznik Lake which was affected İznik city center and its surroundings. The intensity of the earthquake was 9 scale.
- 1854 AD December 29: Very strong earthquake hit the south coast of the İznik Lake and made some damages to the villages of Mehmetçik and Pamukçuk. The intensity of the earthquake was 4.5 scale.
- 1863 AD November 06: This earthquake caused damaged between İznik Lake and at Gemlik. The intensity of the earthquake was 9 scale. Many of the houses in the Umurbey, near Gemlik were ruined *(Modified from: Ambraseys & Finkel 1995); (Citation: Öztürk, Yaltırak, Alpar, 2008).*

Table 5.1: Earthquakes during historical periods (2100BC – 1900 AD) in and around İznik *(Adatepe, Erel 2006)*

Earthquake	Date	Center			Intensity
		Latitude	Longitude	Location	
1	24.01.29	40.40	29.70	İznik, İzmit	IX
2	33	40.40	29.70	İznik, İzmit, around Bursa	VIII
3	02.01.69	40.40	29.70	İznik, İzmit	VII
4	120	40.40	29.70	İznik, İzmit	VIII
5	129	40.40	29.40	İznik, Zeytinbağ (Mudanya)	VIII
6	03.10.350	40.80	30.00	İzmit, İznik	VII
7	24.08.358	40.75	29.90	İzmit, İznik, İstanbul	IX
8	02.12.362	40.75	29.60	İzmit, İznik, İstanbul	VIII
9	11.10.368	40.40	29.70	İznik	VII
10	378	40.40	29.70	İznik	VI
11	444	?	?	İznik	?
12	08.12.447	40.80	29.60	İzmit bay, İstanbul, İznik	IX
13	715	40.40	29.70	İznik, İstanbul	IX
14	26.10.740	40.80	29.00	İstanbul, İzmit, İznik	VIII
15	23.09.985	40.40	28.90	Bandırma, Erdek, İznik	VIII
16	23.09.1064	40.40	28.90	Bandırma, İznik, Mürefte, İstanbul	IX
17	20.01.1895	40.40	29.70	İznik	V

İznik city was located one of the major fault lines. Part of the city could be destroyed related to earthquakes. The historical records of the earthquakes were listed according to dates: 120 A.D., 363 A.D., 368 A.D. (this earthquake was killed large number people in the city), 557 A.D.,740 A.D. (the magnitude of this earthquake was very big, only one church was left standing), 1065 A.D. (this earthquake destroyed entire of the city). As well the earthquake in 1509 caused unspecific damaged in to the city. According to Ambraseys and Finkel; "one of the largest and most destructive earthquakes of the last five centuries in the Eastern Mediterrenean". This earthquake was the cause of die for four to five thousand people in İstanbul. Also this earthquake might be the cause of destruction of part of İznik and its inhabitants *(Lowry, 2003).*

There were many earthquakes happened in İznik city in the years from 1063 to 1065. These earthquakes cause many damages on the city walls but as well on the churches. For instance Hagia Sophia's roof structure, its colonnades and clerestory above the nave and the western wall collapsed. The building had maintenance in its major parts after 1065. After this earthquake the building was supported with new structural system which was constituted with pillars with two triple arcades inserted between columns. As well the floor level was raised 1m. New apse was erected. After these earthquakes, the building techniques were markedly differentiated from early Byzantine. In masonry construction technique, layer of rubble stone which were laid in the plenty of mortar accompanied with recessed brickwork. In addition to that tie beams were inserted inside of the masonry walls. The arches were built of bricks or ashlar *(Peschlow, 2003).*

The second example for the churches that exposed to earthquake was the Koimesis church. The dome and three tympana were damaged. The vaults of the aisle with narthex were affected from the earthquake. Only apse and bema withstood the quake. The reconstruction of the Koimesis church was carried out brickwork with wide bed joints. This type of brickwork gave an impression of recessed brick technique. The new floor for the naos built up with "opus sectile" technique with white marbles slabs and colored frame endings which was technique in middle Byzantine furnishing *(Peschlow, 2003).*

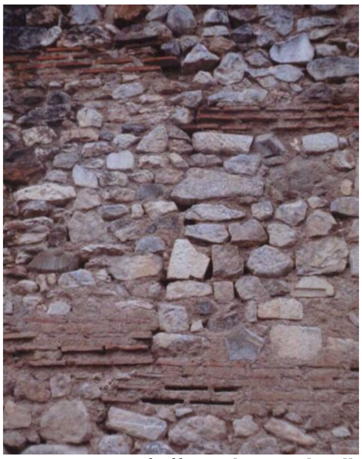

Fig 5.6: Traces of offset in historical walls surrounding İznik (south wall) *(Adatepe, Erel 2006)*

5.1.2. Bilecik region

Bursa – Bilecik relief: It was formed the landscapes between east of Bursa and Sakarya valley. The main elements of this landscape are İnegöl and Bursa depressions, plateaus and mass-like blocks in the region. These areas has been separated from each other by the Sakarya River and its drainage. İnegöl and Yenişehir depressions lie in NW-SE and NE-SW directions, they are skew to each other. The bases of these depressions filled with Quaternary alluviums. Around the quaternary alluviums, upper Miocene-Piocene aged sediments are located. Their bases are corresponded the Mudanya formation. On the upper levels of these depressions, lacustrine sediments appear at the surface. These sediments are also seen in the SE slopes of Uludağ and on the Bilecik plateau. A water-shed line separates the NAF zone and Yenişehir depression at present. Upper part of the Miocene-Pliocene aged sediments on the Bilecik plateau are observed in paleo-karst depressions as relicts of denudation *(Emre, Erkal, Tchepalyga, Kazancı, Keçer, Ünay, 1998).*

The plateaus that were surrounded the depression valley forms which relicts from an old drainage are observed. Samandağ formation which was located in the bases of these valleys are appear at the surface. In Armulu peninsula in the North of NAF, same valley forms are also seen. NAF divided Bursa-Bilecik relief. Sakarya River are buried in this valley system. This valley system, along with in NAF zone between Gemlik and Geyve is cut down and deformed *(Emre, Erkal, Tchepalyga, Kazancı, Keçer, Ünay, 1998).*

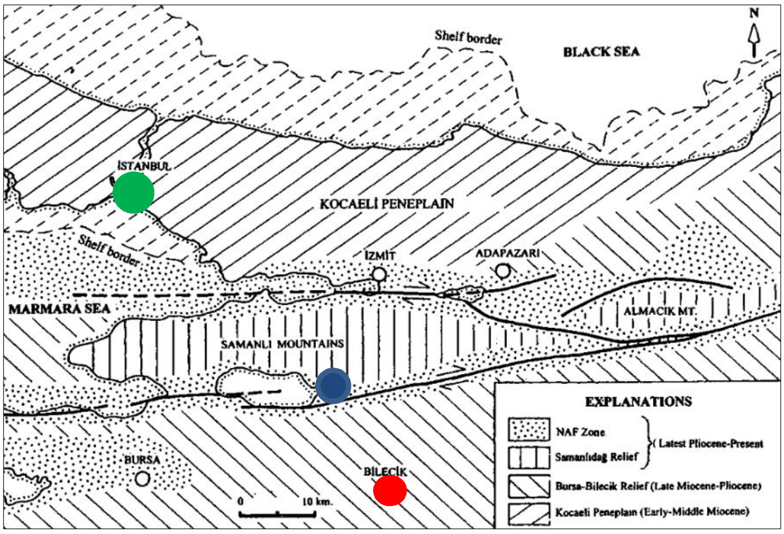

Fig 5.7: Morphotectonic units of the Marmara region, [red; Bilecik city, blue; İznik city, green; İstanbul city *(Emre, Erkal, Tchepalyga, Kazancı, Keçer, Ünay, 1998)*

5.1.3. Edirne region

Edirne region was safer place for the seismic activities related to other regions particularly İznik and Bilecik. Therefore in the research area of seismicity in Anatolia, Edirne region considered related with earthquakes in İstanbul. Therefore in this chapter Edirne region was not examined particularly but the found documentation related to this place was shown in figures, on tables and found citations were written on the texts.

5.2. Past Earthquakes

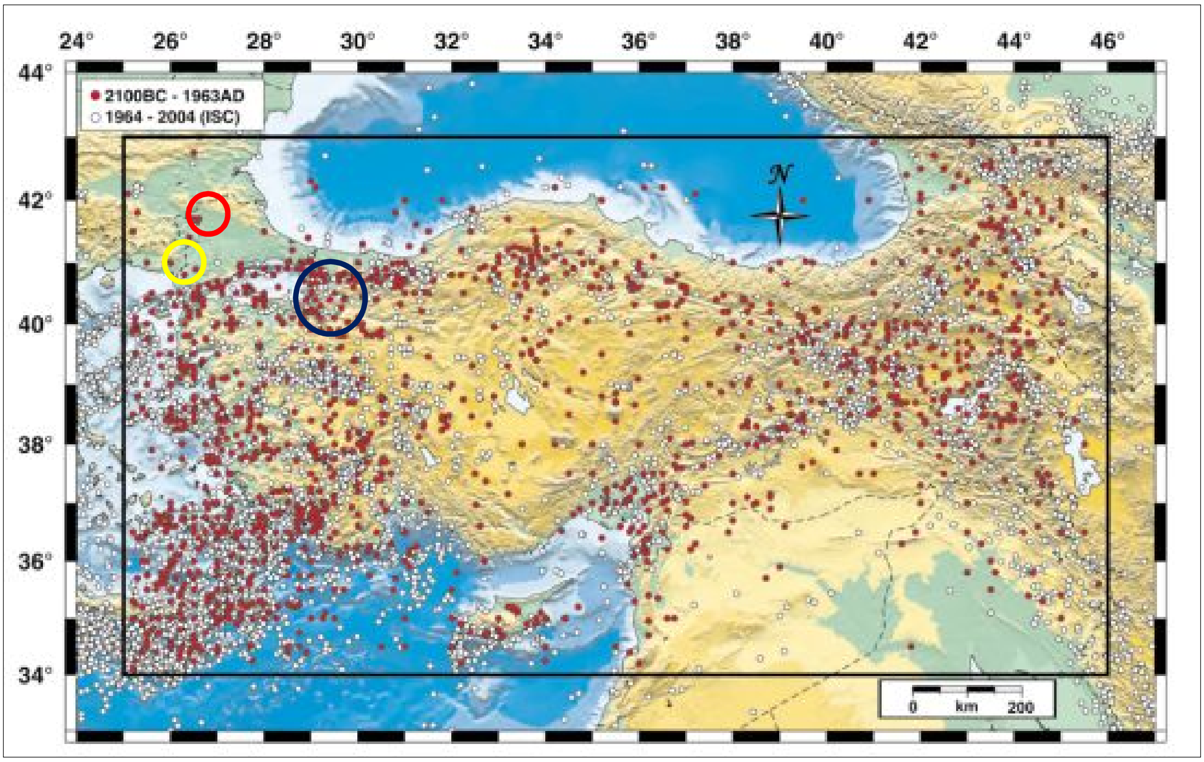

Fig 5.8: Historical earthquakes (red points) and recent earthquakes of Turkey (white points) and the location of the case studies *(Tan, Tapırdamaz, Yörük, 1998)*

According to the map of seismic zones in Turkey and table of earthquake magnitudes in Edirne, Keşan, İznik and Bilecik; the high risk of seismicity could be seen in İznik rather than Edirne, Keşan and Bilecik. However some of the historical buildings in İznik were survived from the big earthquakes. And also Edirne was affected from earthquakes in İstanbul. Bilecik is in the middle edge line of first and second degree of seismicity. Bilecik affected the seismic activity in Eskişehir and Bursa. Keşan is in the border line of Edirne district but seismicity of the city is higher than Edirne. Although Edirne is safer for seismicity compared to İznik and Bilecik.

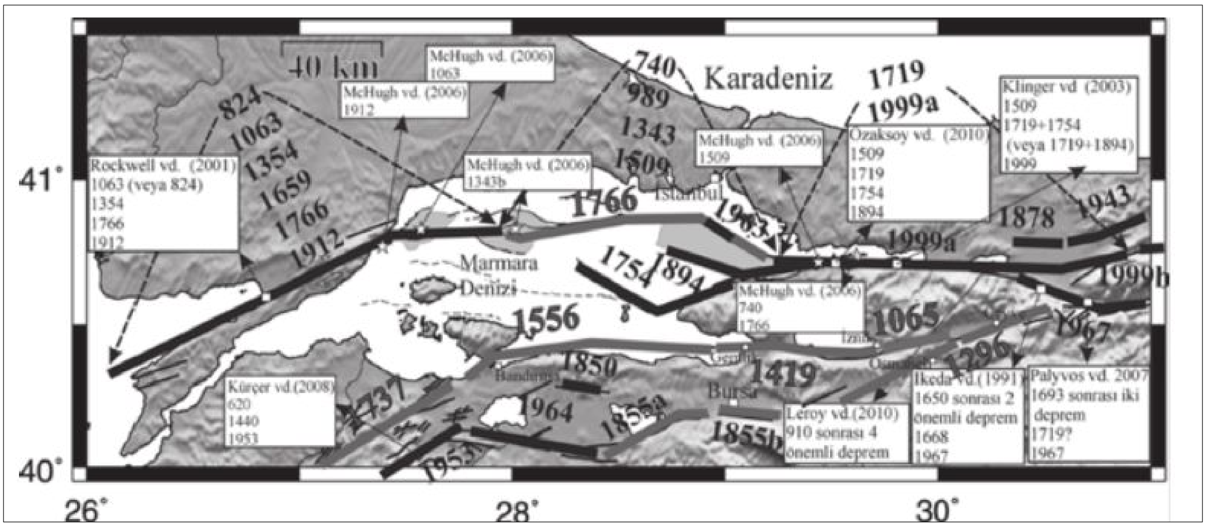

Fig 5.9; Earthquake occurrences in the Marmara region which derived from the data's of paleoseismological studies *(Utkucu, M., Budakoğlu, E., Durmuş, H., 2011)*

The map in Fig 5.9; the earthquake occurrences in the Marmara region which derived from the data's of paleoseismological studies. The thick and black lines indicated the raptured faults in last 300 years. Inside of the white boxes the big earthquakes are shown. The grey thick lines indicated the unbroken faults for 200 years (north segment) and 400 years (other segments). The grey numbers shows the last rupture of these faults *(Utkucu, M., Budakoğlu, E., Durmuş, H., 2011).*

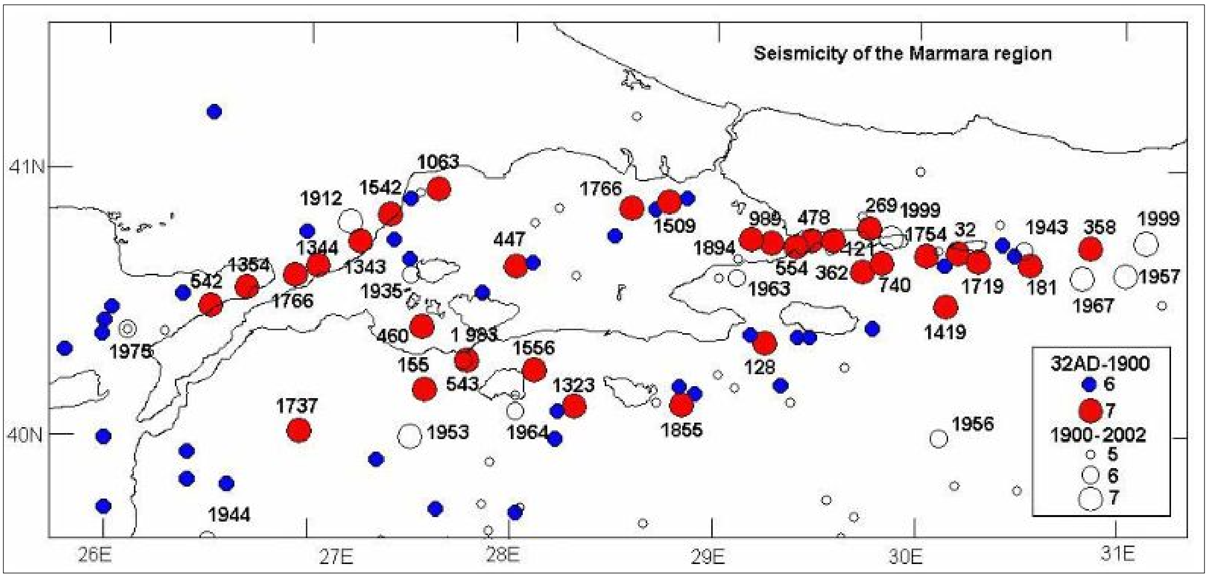

Fig 5.10: Long-term seismicity of the Marmara region, seismicity between 32 AD-1983 taken from Ambraseys *(Erdik, M., Demircioğlu, M., Sesetyan, K., Durukal, E., Siyahi, B., 2004)*

5.2.1. Historical earthquakes in Marmara region

- 23 September 1063

This earthquake had a high intensity along the north cost of the Sea of Marmara. It was damaged many districts along with Constantinople (İstanbul) and Dardanelles. The masonry walls of the towns, aqueducts, churches and public buildings were collapsed throughout all southern Thrace particularly at Myriophyto (Mürefte), Panioon (Barbaros) and Redestos (Tekirdağ). Many of the houses were collapsed in Constantinople (İstanbul) and the public buildings were damaged or destroyed. The shocks of this earthquake which originated from the Marmara Sea was continued for two years *(Modified from: Ambraseys & Finkel 1995); (Citation: Erdik, M., Eren, U., 1983).*

- 1st June 1296

This earthquake happened in Constantinople (İstanbul) which is caused considerable damage such as old houses, some public buildings and free standing structures and to the city walls. After this earthquake the emperor was obliged to return to Constantinople *(Modified from: Ambraseys & Finkel 1995); (Citation: Erdik, M., Eren, U., 1983).*

- 1323

This earthquake caused damaged on the buildings in Constantinople (İstanbul) such as churches and monumental columns. Militopolis (Karacabey), Apollonia (Apolyontköy) were destroyed by the effect of this earthquake *(Modified from: Ambraseys & Finkel 1995); (Citation: Erdik, M., Eren, U., 1983).*

- 18 October 1343

This earthquake and its followed shocks were given severe damages in the western part of the Marmara Sea particularly Trace and along the coast to Chersonesus (Gelibolu Peninsula). As well other settlements such as Myriophyto (Mürefte), Hora (Hoşköy) were almost destroyed. Lysimachia (Bolayır) was ruined. In Constantinople (İstanbul), the walls of the city damaged and some part of the fortifications walls were destroyed. Houses, public buildings and churches were damaged in different levels. After shocks were damaged throughout the region. The earthquake was followed with sea-wave which flooded inland 2.2km. It caused several damages into the settlements *(Modified from: Ambraseys & Finkel 1995); (Citation: Erdik, M., Eren, U., 1983).*

- 6th November 1344

This seismic activity was an aftershock of the earthquake in 1343 in Thrace. It was destroyed almost the region of Ganohora (Gaziköy), Hora (Hoşköy), Marmara Island and the long walls of the Chersoneus or Tihos at Hexamili (Ortaköy). The shock of the earthquake were felt from Constantinople (İstanbul) and it caused some damages to the city walls *(Modified from: Ambraseys & Finkel 1995); (Citation: Erdik, M., Eren, U., 1983).*

- 19th May 1346

This earthquake caused damages on the free standing structures in İstanbul, for instance the church of Sta Sophia. The eastern part of this church was collapsed *(Modified from: Ambraseys & Finkel 1995); (Citation: Erdik, M., Eren, U., 1983).*

- 1st March 1354

This earthquake was ruined the region of the Marmara sea from Redestos (Tekirdağ) to Madytos (Hacıabad) as well Callipolis (Gelibolu) and the other places in Thrace. The damage of the earthquake was very big such as houses and the walls of Constantinople (İstanbul), and settlements in the districts of Thrace and Macedonia. Tenedos (Bozcaada) was affected this earthquake. The seismic shock felt over the large area *(Modified from: Ambraseys & Finkel 1995); (Citation: Erdik, M., Eren, U., 1983).*

- January 1400

This earthquake was felt in strongly in Constantinople (İstanbul) and Bursa *(Modified from: Ambraseys & Finkel 1995); (Citation: Erdik, M., Eren, U., 1983).*

- 15th March 1419

This earthquake occurred in the eastern part of the North Anatolian fault. It affected Constantinople (İstanbul) and around *(Modified from: Ambraseys & Finkel 1995); (Citation: Erdik, M., Eren, U., 1983).*

- 16th January 1489

This earthquake occurred in İstanbul and number of minarets were collapsed. The epicenter of the earthquake was some distance away from Istanbul. However there were no information about the damage of the city and its surroundings *(Modified from: Ambraseys & Finkel 1995); (Citation: Erdik, M., Eren, U., 1983).*

- 10th September 1509

This earthquake was the one of the catastrophe in eastern Mediterranean region. It was gave a big damage and extremely destructive in İstanbul. It caused a tsunami in eastern Marmara Sea *(Modified from: Ambraseys & Finkel 1995); (Citation: Parsons, T., 2004).*

Gelibolu to Bolu and from Edirne and Demitoka to Bursa, the consequences of the earthquake was catastrophic and ruined many buildings. In İstanbul, many mosques and other buildings, part of the city walls and about 1000 houses were destroyed. Many houses and public buildings had faced various degrees of damage in Demitoka, Gelibolu, İznik and Bolu. The radius of the shock waves were 750km and sea wave followed earthquake in the eastern part of the Marmara Sea. After shocks were continued for two years of time *(Modified from: Ambraseys & Finkel 1995); (Citation: Erdik, M., Eren, U., 1983).*

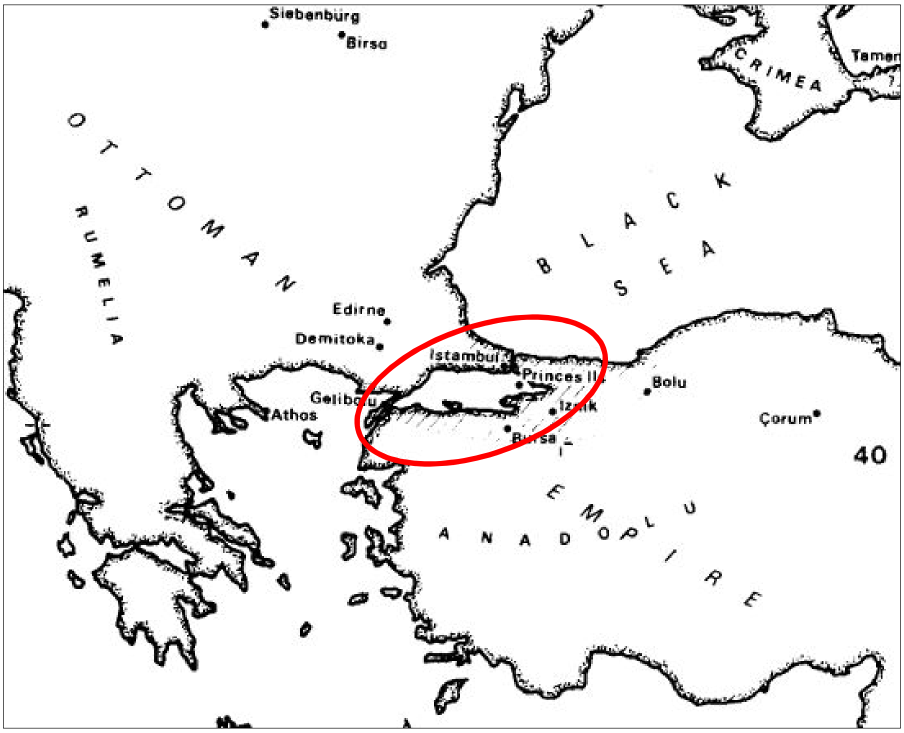

Fig 5.11: Location map of the earthquake of 10th September 1509. Circle was shown the epicentral area with associated intensities of VII *(Ambraseys, Finkel)*

Some of the most important structures, buildings and monuments destroyed or damaged by the earthquake of 10th September 1509 in İstanbul. The damaged building were listed as: Saint Sophia (1), Velens Aqueduct (2), Dikilitaş (3), Edirne Kapısı (4), Galata Tower (5), Almedian (6), Isa kapısı (7), Topkapı Place (8), Yeni Place (9), Sultan Beyazıt II Mosque (10), Silivri kapısı (12), Sultan Mehmet II Mosque and complex (13), Yedikule (13), Odun kapısı (14), Kayıklar kapısı (15), Karaman Pazarı (16), Suk Elnna (17), Gri Kapı (18), Narlı Kapı (19), Isak Pasa (20), Ahir kapı (21), Ali Pasa (23), Davud Paşa (23), Fener (24). They were shown on the city map of the İstanbul. *(Ambraseys, Finkel).*

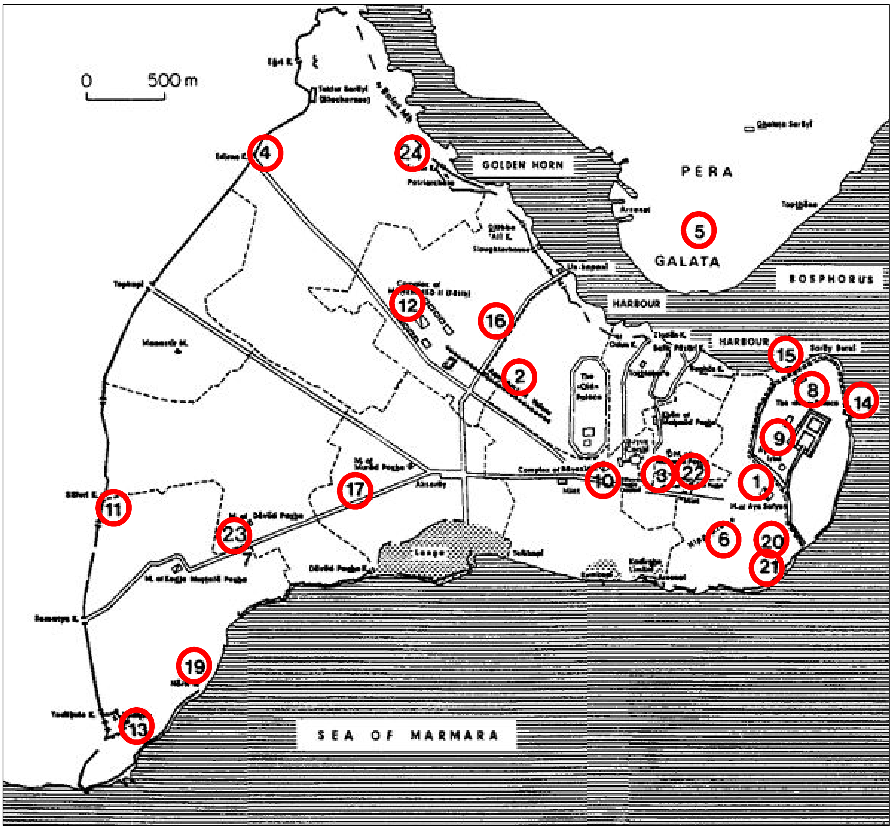

Fig 5.12: The map of İstanbul in 16th century and the location of the damaged buildings after the earthquake 10th September 1509 *(Ambraseys, Finkel)*

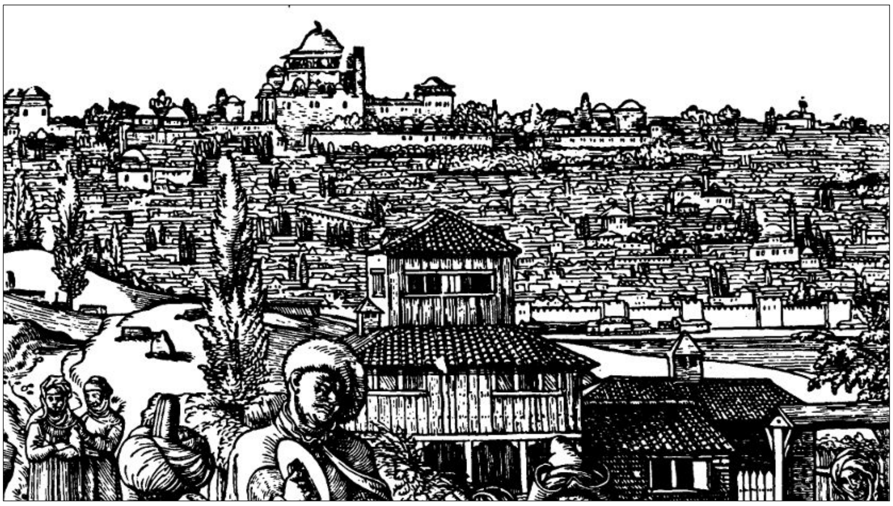

Fig 5.13: Woodcut by Peter Coecke (1529) of mosque of Sultan Mehmet II, without minarets and damaged on its dome structure *(Ambraseys, Finkel)*

In fig 5.13: woodcut by Peter Coecke in 1529, the mosque of Sultan Mehmet II were seen without minarets. They would not repaired for a long time after the earthquake. However the engraving of Fatih mosque complex in mid sixteenth century by M. Lorichs (fig 5.14); it was seen that there were tall minarets outside of the main body of the building. From those evidences it could be understand that the repairs of the minaret and the mosque done between 1530 and 1550 *(Ambraseys, Finkel).*

Fig 5.14: Fatih mosque complex from a mid-sixteenth century engraving by M. Lorichs *(Ambraseys, Finkel)*

- 12th June 1542

The earthquake in Trace was caused extensive damage. The region Gelibolu, Edirne and İstanbul was affected because of this earthquake. In İstanbul 1700 hundred houses were ruined *(Modified from: Ambraseys & Finkel 1995); (Citation: Erdik, M., Eren, U., 1983).*

- 10th May 1556

It was given a damage around the Sea of Marmara in Edincik, Bursa and İstanbul *(Modified from: Ambraseys & Finkel 1995); (Citation: Parsons, T., 2004).*

Many of the houses, mosques and large part of the city walls were collapsed. The walls of the Saint Sophia were cracked. The Fatih mosque was damaged. The epicenter of this earthquake was offshore of the Marmara Sea *(Modified from: Ambraseys & Finkel 1995); (Citation: Erdik, M., Eren, U., 1983).*

- 1st October 1567

This earthquake happened in the Sapanca settlement and its surroundings. The shock were felt in İzmit and İstanbul which caused some collapses of the houses *(Modified from: Ambraseys & Finkel 1995); (Citation: Erdik, M., Eren, U., 1983).*

In Marmara region seismic magnitudes in last century was shown on Fig 5.15.

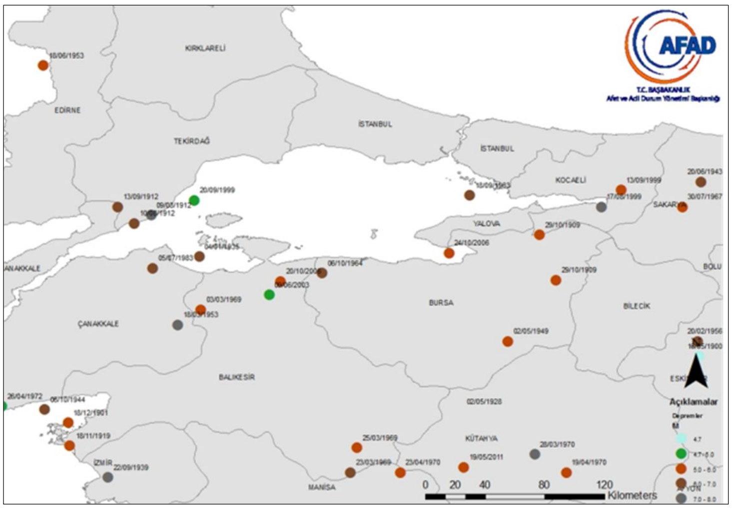

Fig 5.15: Marmara region seismic magnitudes in last century: Grey color: 7.0-8.0, Brown color: 6.0-7.0, Red: 5.0-6.0, Green: 4.7-5.0, Aqua: 4.7 *(Turkey'.T.C. Basbakanlik Afet ve Acil Durum Yönetimi Baskanlığı, Deprem Dairesi Baskanlığı).*

Table 5.2: Historical earthquakes *(Turkey'.T.C. Basbakanlik Afet ve Acil Durum Yönetimi Baskanlığı, Deprem Dairesi Baskanlığı)*

LOCATION	DATE	LATITUDE	LONGITUDE	Ms (surface-wave magnitude)	Mb (body-wave magnitude)	Ml	Mw	Md	MAGNITUDE	DEAD	COLLAPSED OR HIGHLY DAMAGED	AFFECTED LOCATIONS
Gelibolu	08.01.1010	40.6	27.0	7.4								
Barbaros	23.09.1053	40.8	40.8	7.4								
İstanbul	??.??.1231	41.0	28.0	6.9								
Geyve	01.05.1295	40.5	30.5	7.0								
Ganos	18.10.1343	40.7	27.1	6.9								
Ereğli	18.10.1343	40.9	28.0	7.0								
Gelibolu	01.03.1354	40.7	27.0	7.4								
Bursa	15.03.1419	40.4	29.3	7.2								
İstanbul	10.09.1509	40.9	28.7	7.2								
Erdek	10.05.1556	40.6	28.0	7.1								
Saros	18.05.1625	40.3	26.0	7.1								
Saros	17.02.1659	40.5	26.4	7.2								
İzmit	25.05.1719	40.7	29.8	7.4								
Biga	05.02.1737	40.0	27.0	7.0								
Edirne	29.07.1752	41.5	26.7	6.8								
İzmit	02.09.1754	40.8	29.2	6.8								
Marmara	22.05.1756	40.8	29.0	7.1								
Ganos	05.08.1756	40.6	27.0	7.4								
Gönen	07.02.1809	40.0	27.0	6.1								
Adalar	06.10.1841	40.8	29.0	6.1								
Manyas	18.04.1850	40.1	28.3	6.1								
Bursa	28.02.1855	40.1	28.5	7.1								
Bursa	11.04.1855	40.2	28.9	6.3								
Historical earthquakes around the İznik region												
İznik,İzmit	24.11.0029	40.4	29.7	10								
İznik,İzmit	02.01.0069	40.4	29.7	7								
Nicomedia	120-123	40.5	30.1	7.4								
İznik, Zeytinbağ, Mudanya	0128-0129	40.4	29.4	8								
İznik	03.05.0180	40.6	30.6	7.3								
İznik	00.00.0268	40.7	29.9	7.3								
İznik	02.12.0362	40.7	29.6	6								
İznik	11.10.0368	40.4	29.7	6.4								
İznik	00.00.0378	40.4	29.7	6								
İznik	00.00.0715	40.4	29.7	9								
İznik, Bandırma, Erdek	23.09.0985	40.4	28.9	8								
İznik, Bandırma, İstanbul	29.09.1064	40.4	28.9	9								
South coast of lake İznik	29.12.1854	40.4	29.5	4.5								
Gemlik, İznik, Bursa	17.09.1857	40.4	29.2	5.4								
Gemlik, Umurbey, İznik	06.11.1863	40.4	29.1	5.0								
İznik	21.01.1895	40.4	29.7	5								
Gemlik, Bursa	14.03.1897	40.4	29.1	5								

Table 5.3: Historical earthquakes *(Turkey'.T.C. Basbakanlik Afet ve Acil Durum Yönetimi Baskanlığı, Deprem Dairesi Baskanlığı)*

ESKİŞEHİR	16.05.1900	39.8000	30.5000	4.7					VI		1	
Ayvalık	18.12.1901	39.4000	26.7000	5.9					VIII		102	
Karamürsel	29.10.1909	40.5300	29.5400	5.5					VII			
Karamürsel	29.10.1909	40.2600	29.6400	5.8					VII		13	
Şarköy-Mürefte	09.08.1912	40.6500	27.2000	7.3					X	2836	39629	
Şarköy-Mürefte	10.08.1912	40.6000	27.1000	6.3					VIII			
Şarköy-Mürefte	13.09.1912	40.7000	27.0000	6.8					IX			
Soma	18.11.1919	39.2600	26.7100	5.8					IX			
Emet-KÜTAHYA	02.05.1928	39.5000	291000	>4,6					VIII		800	
Erdek-BALIKESİR	04.01.1935	40.4000	27.4900	6.7						5	600	
Dikili-İZMİR	22.09.1939	39.0700	26.9400	7.1						60	1235	
Hendek-SAKARYA	20.06.1943	40.8500	30.5100	6.6						336	2240	
Mudurnu-BOLU	04.05.1944	40.8400	31.1200	5.6						30	900	
BALIKESİR	06.10.1944	39.4800	26.5600	7.0						27	1158	
Harmancık	02.05.1949	39.8900	29.3500	5.2							150	
Yenice-Gönen	18.03.1953	39.9900	27.3600	7.4						265	9670	
EDİRNE	18.06.1953	41.5500	26.5500	5.1							323	
Eskişehir	20.02.1956	39.8900	30.4900	6.4						2	1219	AFFECTED BİLECİK
Abant-BOLU	26.05.1957	40.6700	31.0000	7.1						52	4201	
Çınarcık-YALOVA	18.09.1963	40.7700	29.1200	6.3						1	230	
Manyas	06.10.1964	40.3000	28.2300	7.0	6.0					23	5398	
ADAPAZARI	22.07.1967	40.6700	30.6900	7.2	6.0					89	5569	
Akyazı	30.07.1967	40.7000	30.4000	6.0	5.4					2		
Gönen	03.03.1969	40.0800	27.5000	5.7	5.6					1	20	
Demirci	23.03.1969	39.1000	28.4000	6.1	5.6						1100	
Demirci	25.03.1969	39.2500	28.4400	6.0	5.5						1826	
Gediz	28.03.1970	39.2100	29.5100	7.2	6.0					1086	9452	
Çavdarhisar-KÜTAHYA	19.04.1970	39.1000	29.7000	5.9	5.5						41	
Demirci	23.04.1970	39.1000	28.7000	5.2	5.2						150	
Ezine	26.04.1972	39.5000	26.3000	5.0	5.0						400	
Gelibolu	27.03.1975	40.4500	26.1200	6.4	5.5					7	980	
Biga	05.07.1983	40.3300	27.2100	6.1	5.7				VIII	3	85	
Gölcük-KOCAELİ	17.08.1999	40.7000	29.9100	7.4	6.1					17480	66441	
Gölcük-KOCAELİ	13.09.1999	40.8000	30.0300	5.7	5.6							
Marmara Adası	20.09.1999	40.7400	27.4600	5.0	4.7							
(Uruş -Güdül)-ANKARA	22.08.2000	40.2500	32.1300	4.8	4.4							
Hendek-Akyazı	23.09.2000	40.7900	30.7600	5.2				4.0				
Bandırma-BALIKESİR	09.06.2003	40.1700	27.9100					5.0				
Bandırma-BALIKESİR	20.10.2006	40.2519	27.9792					5.2				
Gemlik Körfezi	24.10.2006	40.4221	28.9937					5.2				
Simav-KÜTAHYA	19.05.2011	39.1328	29.0820			5.7				2	1903	

5.3. Geological specifications of the case study locations

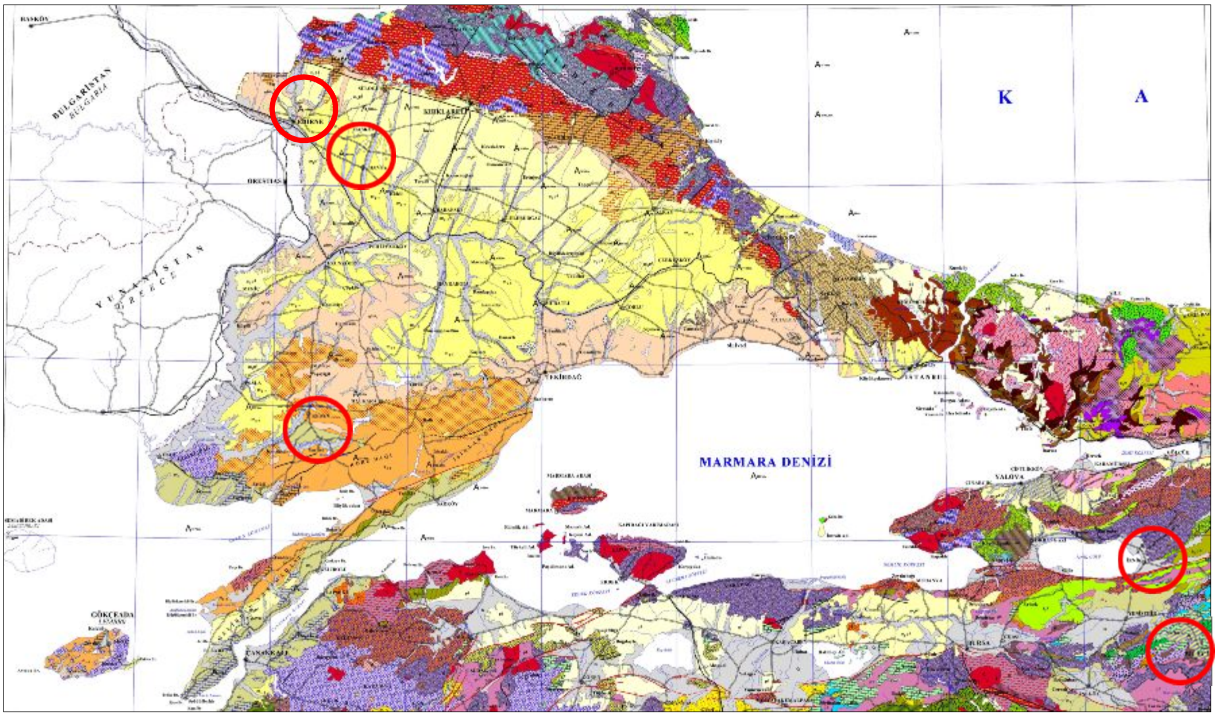

Fig 5.16: Geological Map of Marmara region-Turkey and the location of the case studies *(The Geological Map of Turkey, 2002)*

5.3.1. İznik settlement

Undifferentiated quaternary rocks are the geological specification of İznik.

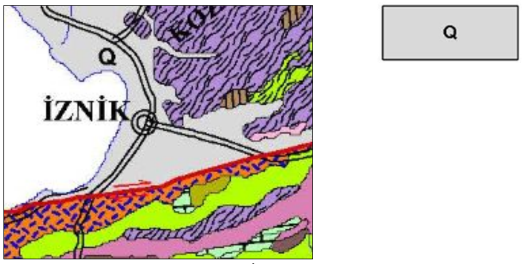

Fig 5.17: Geological Map of İznik settlement
(The Geological Map of Turkey, 2002)

5.3.2. Bilecik city

Carbonate and clastic rocks are the geological specification of Bilecik.

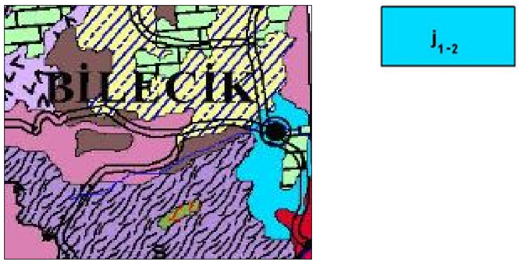

Fig 5.18: Geological Map of Bilecik city
(The Geological Map of Turkey, 2002)

5.3.3. Keşan settlement

Clastic and carbonate rocks are the geological specification of Keşan.

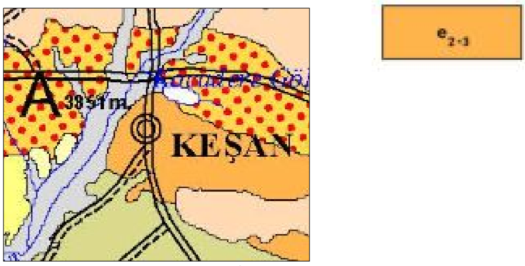

Fig 5.19: Geological Map of Keşan settlement
(The Geological Map of Turkey, 2002)

5.3.4. Edirne city

Clastic and continental rocks are the geological specification of Edirne.

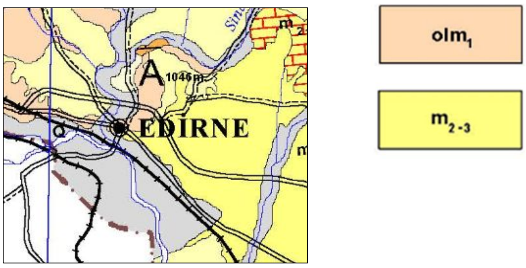

Fig 5.20: Geological Map of Edirne city
(The Geological Map of Turkey, 2002)

5.3.5. Havsa settlement

Continental rocks are the geological specification of Havsa.

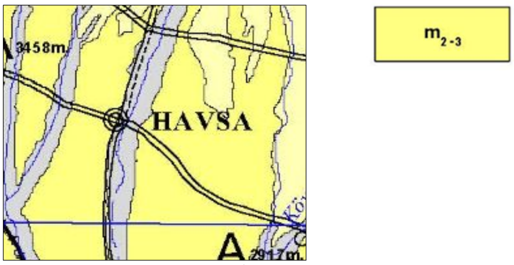

Fig 5.21: Geological Map of Havsa settlement
(The Geological Map of Turkey, 2002)

5.4. The earthquake shaking potencial for Marmara region

This part of research was essential for this study to persive the potensial risky areas for sesimic activity in Marmara for better evaluation of the histrorical bath structures in Turkey.

The frequency of the shaking potencial of the earthqueke was important to understand the risky areas for seismic activity. There was strong relation between the type of the soil and frequency of shaking potencial *(Kalkan, Gülkan, Yılmaz, Tüysüz, Sevilgen, 2010).*

Seismic waves may be amplified by near surface materials. Soft soils with low shear wave velocity, amplified the earthquake shaking. In hard rocks with high shear velocity earhquake shaking potencial is lower related to soft soils. From the surface geological map of Marmara, different shear velocities can be used to estimate seismic asssensments *(Kalkan, Gülkan, Yılmaz, Tüysüz, Sevilgen, 2010).*

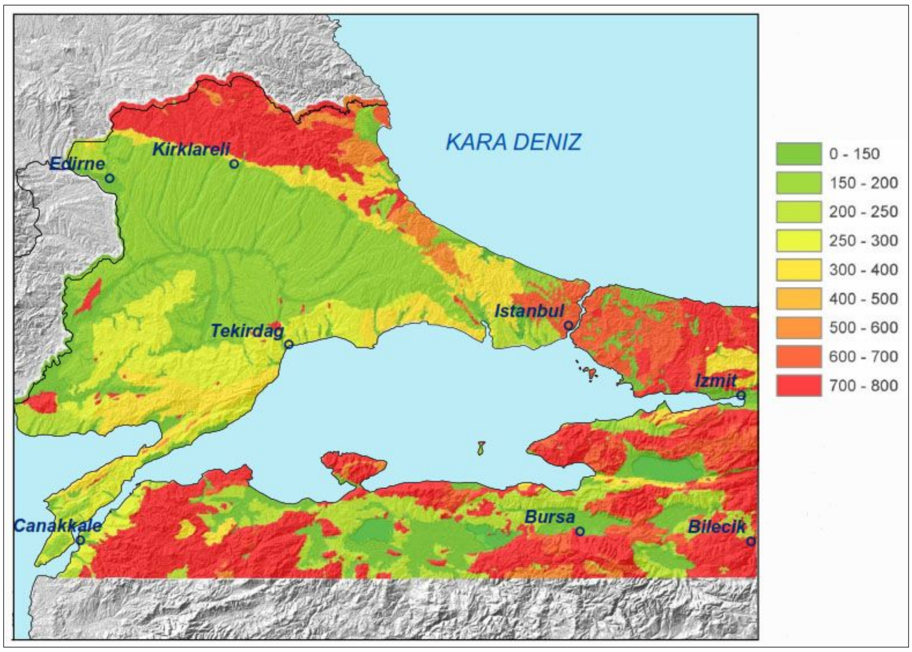

Fig 5.22: The map of surface geological materials in Marmara; the colors identifies the surface shear velocity (m/s) of upper 30 meters; green color identifies 0-150(m/s) and the red color identifies 700-800(m/s) *(Kalkan, Gülkan, Yılmaz, Tüysüz, Sevilgen, 2010)*

In low frequency shaking potencial; if earthquake shaking at 1.0 second period affects tall, relatively flexible buildings and corelates well with overall earthquake damage. Local soil conditions have greater effect on low frequency shaking, the map shows ratio of round motion estimate between soft soil (VS30=180m/s), rock (VS30=760m/s) *(Kalkan, Gülkan, Yılmaz, Tüysüz, Sevilgen, 2010).*

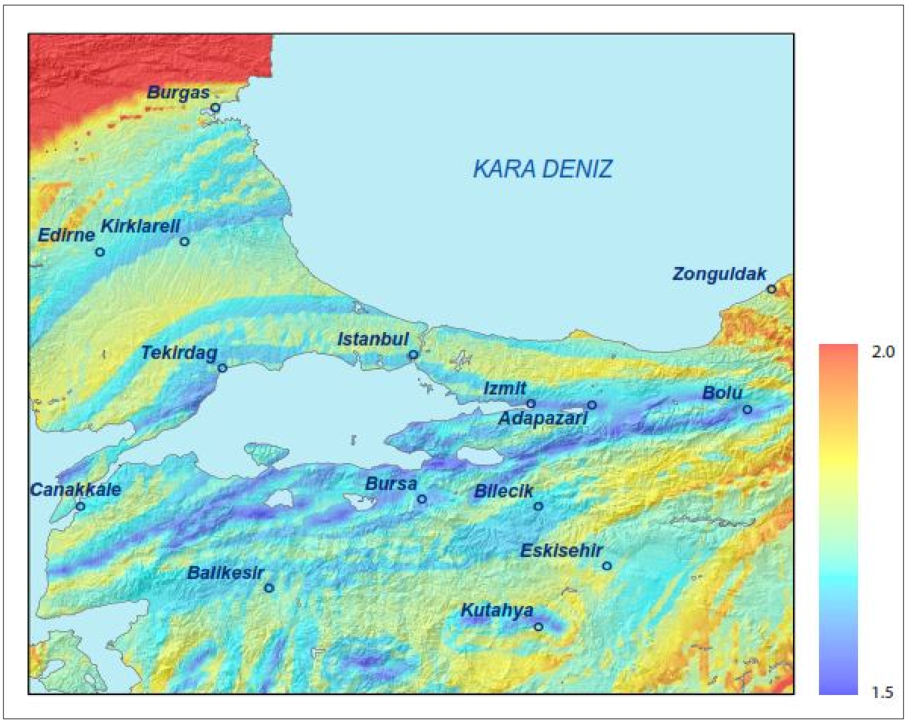

Fig 5.23: Map of low frequency shaking potencial in Marmara *(Kalkan, Gülkan, Yılmaz, Tüysüz, Sevilgen, 2010)*

In high frequency shaking potencial; İf earthquake haking at 0.2 second period affects short, stiff structures and also used in estimating furute earthquke damage. Local soil conditions have less effect on high frequency shaking *(Kalkan, Gülkan, Yılmaz, Tüysüz, Sevilgen, 2010).*

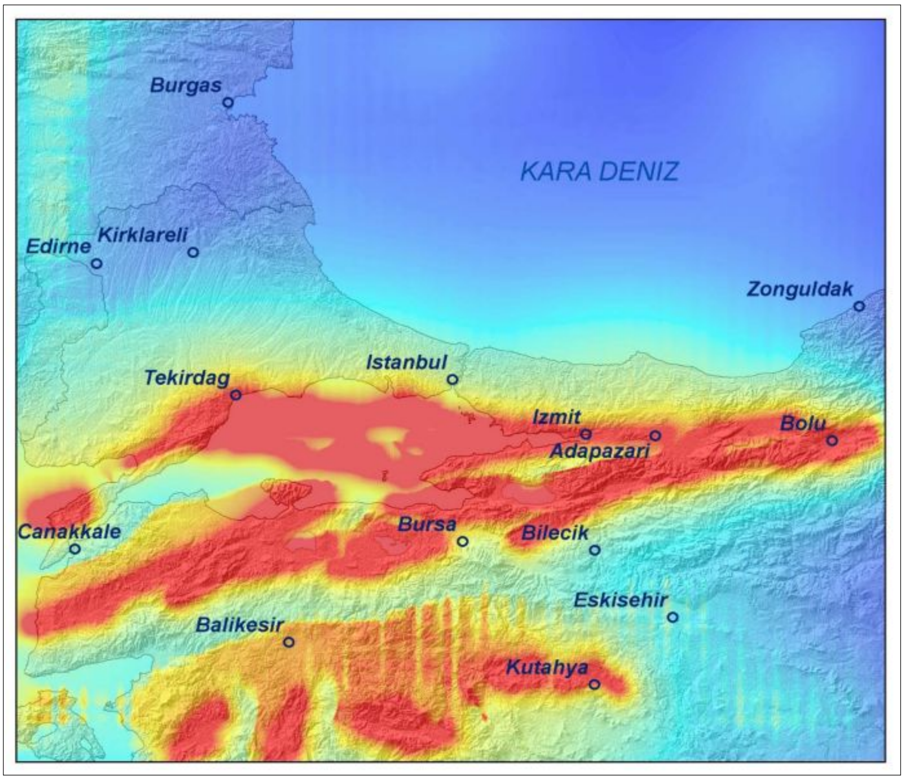

Fig 5.24: Map of high frequency shaking potencial *(Kalkan, Gülkan, Yılmaz, Tüysüz, Sevilgen, 2010)*