

## THE SEISMICITY AND EARTHQUAKE HAZARD OF ANKARA

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### ABSTRACT

In 1996, The Ministry of Public Works and Settlement published Seismic Zoning Map of Turkey based on maximum acceleration. The whole country is divided into the 5 zones. Ankara City is at IV degree earthquake zone in accordance with this map. 8 percent of the surface area of Ankara province is in the first degree hazard zone, 21 percent in the second degree hazard zone, 32 percent in the third degree hazard zone and 38 percent in the fourth degree hazard zone.

The aim of this study is to investigate the seismicity and the earthquake hazard of Ankara. The seismicity of Ankara has been investigated by using the earthquakes equal or greater than  $M \geq 4$  that occurred in a region with a 140-km radius for the time interval 1900-1997. Epicenters of earthquakes were relocated to investigate the relation with the active faults and to see the seismic activity in the region. The earthquakes are particularly concentrated on the active tectonic lines. But sometimes they are concentrated at different places especially in Çankırı region.

Future earthquake activity may be predicted by using probabilistic models. In this study, The Poisson model that is based on the assumption that earthquake occurrence is spatially and temporally homogeneous if after-shocks are excluded from the process would be used. The earthquake hazard of Ankara has been determined using the classical linear magnitude-frequency relation of Gutenberg-Richter. It is calculated that the probability of occurrence of an earthquake magnitude equal or greater than 6.5 within 75 years in the region within a 140-km radius is 95 percent.

### INTRODUCTION

Ankara is located between the North Anatolian Fault Zone (NAFZ) to the north, the Salt Lake Fault to the southeastern, the Ezinepazarı Fault to the west and the Kaymaz Fault to the southwestern and is the second largest city in Turkey. Surface area is 25 706 square kilometers, Total Population of All Ankara province is 3 693 390 in according to the 1997 census of population and Density is 144 persons at every square kilometers.

The aim of this study is to investigate the seismicity and earthquake hazard of Ankara. The earthquake hazard of Ankara has been determined using classical linear magnitude-frequency relation of Gutenberg-Richter.

In 1996, The Ministry of Public Works and Settlement published Seismic Zoning Map of Turkey based on maximum acceleration. The whole country divided into the 5 zones. Ankara City is in the fourth degree earthquake zone on this map (Gencoğlu, vd., 1996). It means that is expected 0.1-0.2 g maximum acceleration at this city. 8 percent of the surface area of Ankara province (Figure 1) is in the first degree hazard zone, 21

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percent in the second degree hazard zone, 32 percent in the third degree hazard zone and 38 percent in the fourth degree hazard zone (Özmen vd, 1997).

## THE SEISMICITY OF ANKARA

The seismicity of Ankara has been investigated by using the earthquakes equal or greater than  $M \geq 4$  that occurred in a region with a 140-km radius for the time interval 1900-1997. Figure 2 shows both distributions of this earthquakes that are obtained from catalog prepared by Yatman et al. (1993) and active fault lines from published General Directorate of Mineral Research and Explorations by prepared Şaroğlu et al. (1992).

This earthquakes does not have a standart M value at this catalog because compiled from different source. All magnitudes have been converted to  $M_s$  using the following relationships.

$$M_s = 1.55 M_b - 2.49 \text{ ( Alsan et al. 1975 )}$$

$$M_s = 0.938 M_L + 0.181 \text{ ( Sipahioğlu, 1984 )}$$

Earthquake epicentres are particularly concentrated on the well-known North Anatolian Fault Zone and in the nearby vicinity. Another concentration is on the Tuzgölü and Akpınar fault and in the nearby vicinity to southeastern of Ankara. But sometimes they concentrated at the different places especially in Çankırı province region. This region should investigate more detail. We can say that is aseismicity to west of Ankara.

Epicentres of earthquakes with magnitudes smaller than 4 between 1990-1995 in and around Ankara that is obtained from Baran, (1996) were relocated to Neotectonic map of the Ankara region (Koçyiğit, 1991) in Figure 3. Microearthquakes are concentrated on the left strike-slip fault to west of Ankara and on the Bedesten thrust to southeastern of Ankara. There is seismic activity in the vicinity of Ankara in according to distribution of macro and micro earthquakes.

The seven damaging earthquakes occurred in this region. Some information about these earthquakes is as follows (see Figure 2):

### **9 March 1902 Çankırı Earthquake**

An earthquake of magnitude  $M_s = 5.6$  on the Richter Scale, maximum intensity (MSK)  $I_0 = IX$  and epicenter 40.65N, 33.60E occurred at 10:46 (07:46 GMT) on local time in the Central Anatolia. This earthquake preceded and followed by strong shocks, caused great destruction to the town of Çankırı and to nearby settlement. The 3000 houses of the town were almost totally destroyed. Four people died and over 100 were injured. The shock was widely felt in the Central Anatolia (Ambraseys and Finkel, 1987).

### **19 April 1938 Kırşehir-Keskin Earthquake**

An earthquake of magnitude  $M_s = 6.6$  on the Richter Scale, maximum intensity (MSK)  $I_0 = IX$  and epicentre 39.44N latitude, 33.79E longitude occurred at 13:59 (10:59 GMT) on local time in the Central Anatolia. This earthquake caused the loss of 149 people, the injured of 211 people and collapsed 3860 houses. Its maximum intensity area was Akpınar district of Kırşehir province and Köşker villages around. It was also been felt in Ankara and caused some building crack and collapsed chimney. Damage was more than other places around Yenişehir (Ergünay, 1978). Fault plane solution was shown right lateral strike-slip fault (Kocaefe, 1981).

### **26 November 1943 Ladik (Samsun) Earthquake**

An earthquake of magnitude  $M_s = 7.2$  on the Richter Scale, maximum intensity (MSK)  $I_0 = VIII-IX$  and epicentre 41.05N latitude, 33.72E longitude occurred at 01:20

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(22:20 GMT) on local time in the north Anatolian. This earthquake caused the loss of 4000 people, the injured of 5000 people and collapsed 40000 houses (Pinar and Lahn, 1952).

#### **1 February 1944 Bolu-Gerede Earthquake**

An earthquake of magnitude  $M_s = 7.2$  on the Richter Scale, maximum intensity (MSK)  $I_o = X$  and epicentre 40.80N latitude, 32.20E longitude occurred at 06:22 (03:22 GMT) on local time in the northeastern Anatolian. This earthquake caused the loss of 3958 lives, the injured of 3513 lives, collapsed 20 865 houses and some damage of 21 000 houses. It caused the loss of 125 people, the injured of 158 people, 1450 destroyed and 2716 damaged building at the Ankara province. It caused also some damage especially around Yenisehir and Ankara castle in the town of Ankara (Ergünay, 1978).

#### **13 August 1951 Kurşunlu (Çankırı) Earthquake**

An earthquake of magnitude  $M_s = 6.9$  on the Richter Scale, maximum intensity (MSK)  $I_o = IX$  and epicentre 40.88N latitude, 32.87E longitude occurred at 21:33 (18:33 GMT) on local time in the Central Anatolia. This earthquake caused the loss of 50 people, the damage of 8000 houses. Fault plane solution was shown right lateral strike-slip fault (Kocaefe, 1981).

#### **7 September 1953 Çerkeş (Çankırı) Earthquake**

An earthquake of magnitude  $M_s = 6.0$  on the Richter Scale, maximum intensity (MSK)  $I_o = VII$  and epicentre 41.09N latitude, 33.01E longitude occurred at 06:59 (03:59 GMT) on local time in the Central Anatolian (Eyidoğan et al. 1991). Fault plane solution was shown left lateral strike-slip fault (Kocaefe, 1981).

#### **21 April 1983 Köşker Earthquake**

An earthquake of magnitude  $M_s = 4.1$ ,  $M_b = 4.8$  on the Richter Scale, maximum intensity (MSK)  $I_o = VII$  and epicentre 39.31N latitude, 33.06E longitude occurred in the Central Anatolian. This earthquake caused 3 villages.

#### **Historical Earthquakes**

The three destructive earthquakes occurred in this region on the historical time Soysal et al. (1991). Some information about these earthquakes is as follows (see Figure 2).

- An earthquake of maximum intensity (MSK)  $I_o = VIII$  and epicentre 40.70N latitude, 31.60E longitude occurred. It caused damage around Bolu and Kastamonu provinces.
- An earthquake of magnitude  $M = 6.1$ , maximum intensity (MSK)  $I = VIII$  and epicentre 40.60N latitude, 33.60E longitude occurred. It affected Çankırı around and caused the loss of 12 people.
- An earthquake of maximum intensity (MSK)  $I_o = VI$  and epicentre 41.00N latitude, 33.70E longitude. It caused damage around Kastamonu and Çankırı province.

Destructive earthquakes did not occur near to Ankara. However, The city was affected at the important degree from Bolu-Gerede earthquake (1944), 100-km epicentre distance to the Ankara city and  $M_s = 7.2$ , that occurred North Anatolian Fault Zone (NAFZ) and Kırşehir earthquake (1938), 108-km epicentre distance to the Ankara city and  $M_s = 6.6$ , that occurred on the Akpınar Fault (Parejas and Pamir, 1939) and caused some damage at Ankara city.

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### Magnitude – Frequency Relations

Gutenberg – Richter (1956) developed an empirical formula relating the magnitude M with corresponding frequency N, as follows:

$$\text{LogN} = a - bM$$

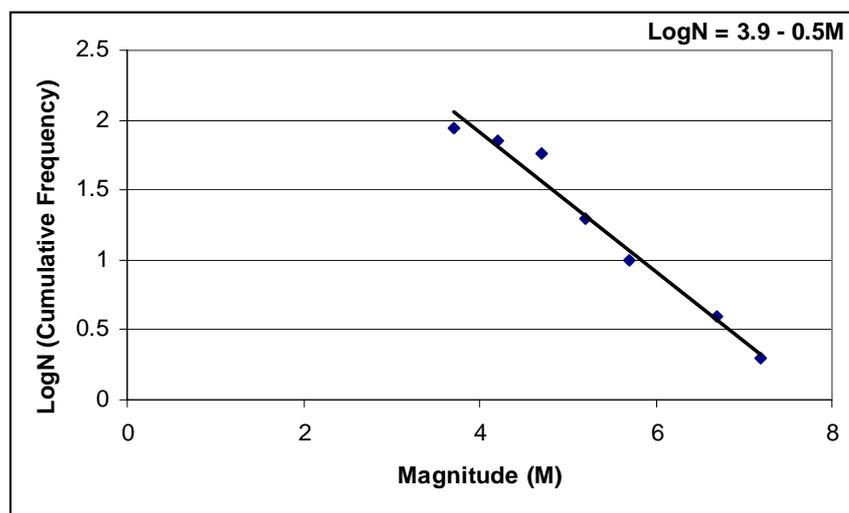
The constant a depends on the period of observation, on the size of the investigated area and on the level of seismic activity. The constant b depends on the tectonic properties of the investigated area.

The parameters of the magnitude-frequency relation are calculated using the least squares method in this study. Normal and cumulative frequency values have been found with the 0.5 magnitude increment (Table 1 ).

**Table 1 : Normal and cumulative frequency values and LogN with the 0.5 magnitude increment.**

$\Delta M = 0.5$	Normal Frequency	LogN	Cumulative Frequency	LogN
3.5 – 4.0	16	1.20412	87	1.939519
4.0 – 4.5	14	1.146128	71	1.851258
4.5 – 5.0	37	1.568202	57	1.755875
5.0 – 5.5	10	1	20	1.30103
5.5 – 6.0	6	0.778151	10	1
6.5 – 7.0	2	0.30103	4	0.60206
7.0 – 7.5	2	0.30103	2	0.30103

We used LogN values of cumulative frequency in Table 1 for calculating a and b parameters (Figure 4).



**Figure 4 : Magnitude-Frequency relations**

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We found magnitude-frequency relations for investigated area, as follows:

$$\text{Log}N = 3.9 - 0.5M$$

### EARTHQUAKE HAZARD OF ANKARA

It is necessary to know the probability of occurrence of destructive earthquake during the given time interval from the engineering point of view. This probability called as earthquake hazard. Probability of earthquake occurrence and return period were calculated from statistical aspects, by using Poisson model. The probability of occurrence earthquakes during a period T may be calculated as follows (Alptekin, 1978):

$$R(M) = 1 - e^{-n(M) T}$$

$n(M)$  is obtained from magnitude – frequency relations as follows:

$$a' = a - \text{Log} (b \text{Ln} 10)$$

$$a_1 = a - \text{Log} T$$

$$a_1' = a' - \text{Log} T$$

$$n(M) = 10^{a_1' - bM}$$

Table 2 shows parameters of the regional seismic activity.

**Table 2 : Parameters of the regional seismic activity**

<b>a</b>	<b>b</b>	<b>a'</b>	<b>a<sub>1</sub></b>	<b>a'<sub>1</sub></b>
3.9	0.50	3.839	1.913	1.852

The probabilities of earthquake occurrence for investigated area are calculated some periods of T = 10, 20, 30, 40, 50, 75, 100 years and magnitudes of M = 5.0, 5.5, 6.0, 6.5, 7.0, 7.5 are presented in Table 3. The mean return period of earthquakes was also calculated by taking:

$$Q = 1 / n(M)$$

**Table 3 : The computed earthquake risk for investigated area**

<b>M</b>	<b>n(M)</b>	<b>10</b>	<b>20</b>	<b>30</b>	<b>40</b>	<b>50</b>	<b>75</b>	<b>100</b>	<b>Return Period(Year)</b>
5.0	0.2249	0.89	0.99	1.00	1.00	1.00	1.00	1.00	4.4
5.5	0.1265	0.72	0.92	0.98	0.99	1.00	1.00	1.00	7.9
6.0	0.0711	0.51	0.76	0.88	0.94	0.97	1.00	1.00	14.1
6.5	0.0400	0.33	0.55	0.70	0.80	0.86	0.95	0.98	25.0
7.0	0.0225	0.20	0.36	0.49	0.59	0.68	0.81	0.89	44.5
7.5	0.0126	0.12	0.22	0.32	0.40	0.47	0.61	0.72	79.1

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The probability of an earthquake occurrence of equal or greater than magnitude seven in 75 years within 140-km radius of Ankara was calculated 81 percent and return period is 44 years

## CONCLUSIONS

The parameters of magnitude – frequency relation were computed for Ankara. Based on these values, the parameters of the regional seismic activity were determined. Afterwards, The earthquake risk values were calculated for Ankara.

Bolu – Gerede (1944) and Kırşehir (1938) earthquakes caused some damage in Ankara city. The city population of Ankara at 1945 year was 279 491. Now is 2 984 099 in according to census of 1997 population approximately 10 multiple more. It seems that Ankara will be affected much more from an earthquake with similar magnitude may be occur in the future.

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