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THE SEISMICITY OF GAZİANTEP, TURKEY

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ABSTRACT

Although some differences exist between the regional kinematic models in the literature, many studies have proposed that the boundaries between African, Arabian and Anatolian Plates meet at a triple junction in southern-central Turkey. Following the overview made of the previous works on the tectonic models, historical seismicity and the known slip rates along the faults in the region, the study has aimed to point out the northern part of the Dead Sea Fault Zone (DSFZ) in Turkey and Syria, and the western part of the East Anatolian Fault in south-eastern Turkey. It has been seen that the left-lateral slip on the DSFZ is associated with earthquakes of magnitude ~7.5 occurring at intervals of several hundred years on each fault segment. Also, it is interpreted that a possible earthquake could have significant economic and social effects on cities located in the region. The city of Gaziantep, with a population of over 1.000.000, is one of the cities in this region and located at approximately 37.08 N- 37.38 E. The study investigates the seismicity and the earthquake hazard of Gaziantep. The seismicity of Gaziantep has been investigated by using the earthquakes $M \geq 3$ that occurred in the region for the time interval 1973-2003. A fairly simple study has also been investigated using time-independent probabilistic model to predict the future earthquakes activities. Evidently, the paper is intended to serve as an additional reference for more advanced approaches and to stimulate discussions and suggestions on region, particularly on the city of Gaziantep.

Keywords: Gaziantep, seismicity.

INTRODUCTION

Turkey lies among the Mediterranean part of the Alpine-Himalayan orogenic system. The Alpine orogeny is result of the compressional motion between Africa and Europe; however the Himalayan orogeny is produced as a result of the India-Asia collision. The seismicity distribution among the Alpine-Himalayan system is not homogenous, which concentrates mostly along the plate margins. The African, Arabian and Eurasian plates are involved in the tectonics of the Mediterranean region (McKenzie, 1970); however the eastern Mediterranean is more complicated. The reason of the local increase in seismic activity in the region may be because of the rapidly moving smaller plates (Erdik et al., 1985). The reader is referred to the plate tectonics models for this region for details (i.e., McKenzie, 1972, Alptekin, 1973, Dewey and Şengör, 1979, Westaway, 2003).

The Gaziantep Basin is situated in southern Turkey, to the south of the suture zone that formed during the collisions of the Arabian and Anatolian plates in late Cretaceous (Maastrichtian) and Miocene times (Coşkun and Coşkun, 2000) (Figure 1). The City of Gaziantep is located between the lands of the Mediterranean and Mesopotamia and had been often chosen to be the settlement and transition place of mankind. Today, its population (over 1.000.000), industrial importance and tourism potential make the city metropolitan. Gaziantep City is the most developed city of the GAP (South Eastern Anatolian Project) region in industry and commerce as an export gate by its tens of hundreds different products exported to more than 100 countries. The project called Southeastern Anatolian Project

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(GAP: Turkish acronym) is a multi-sectoral and regional development project including the construction of 19 hydraulic power plants, 22 dams, 26.5 km long irrigation tunnels 25 ft in diameter on an area extending 74,000 km^2, one tenth of the country (Çetin et al. 2000).

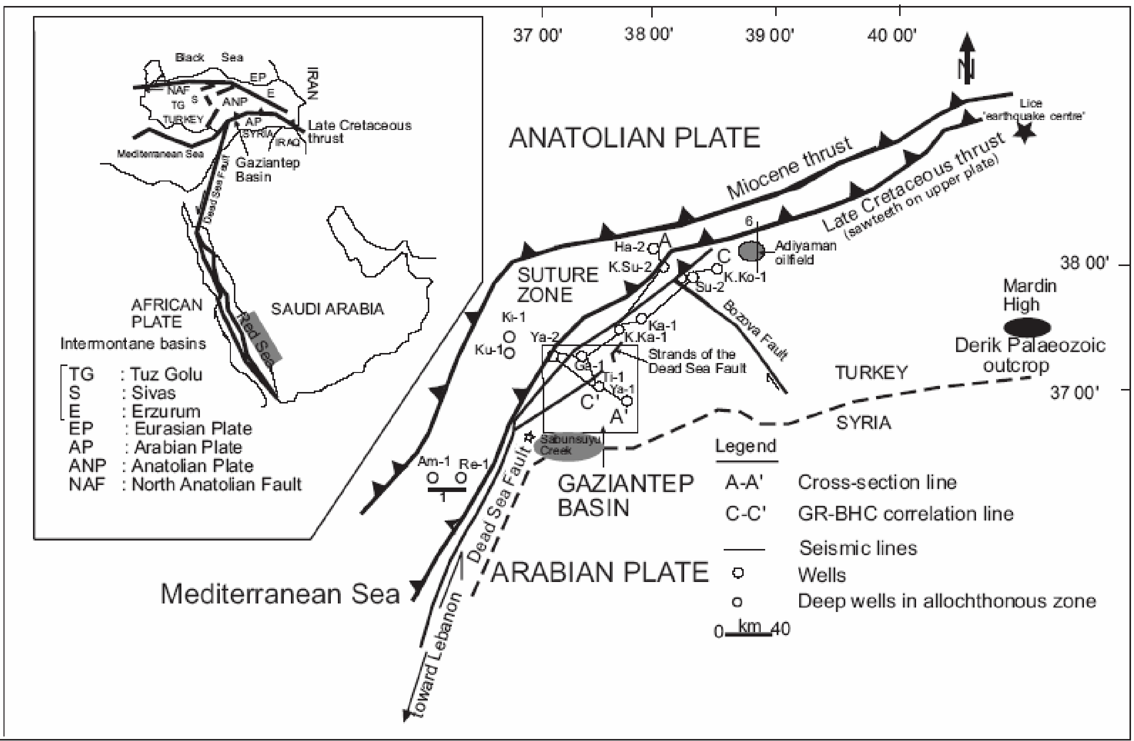

Figure 1 Location map showing the different plates that influenced the structural evolution of southeast Turkey (Coşkun and Coşkun, 2000).

SEISMICITY OF THE SOUTHERN-CENTRAL TURKEY AND WESTERN SYRIA

The northern DSF and western EAF regions are located between the Mediterranean and Mesopotamia and had been often chosen to be the settlement and transition place of mankind. Although earlier DSFZ seismicity less well documented, with some discrepancies between different studies, historical evidence for earthquake is fairly abundant. Ambraseys and Barazangi (1989), for example, reported destructive earthquakes in 1202 and 1759 in Bekaa Valley (33 ^{o}N- 34.5 ^{o}N), in 1157, 1170, 1404, 1407, 1796, and 1872 in Gharb Fault (34.5 ^{o}N- 37 ^{o}N), in 1822 in Karasu Fault Zone (36.5 ^{o}N- 37 ^{o}N). Also, documented seismicity since 1500 between Karliova and Kahramanmaras has had approximately M_o=200x10^{18} Nm, giving a spatially averaged left-lateral slip rate of approximately 2.2 mm yr^{-1} (Westaway, 1994). Ambraseys (1989) and Taymaz et al., (1991) reported major historical earthquakes in 1544, 1789, 1874, 1875, 1879. The earthquakes of 1905 and 1972 were the strongest EAFZ events of the 20th century. In addition, and earthquake having 6.6 magnitude in 1975 near the northern part of the EAFZ and 6.4 magnitude in 2003 in Bingol Province.

Seismicity in western part of the EAFZ and the northern DSFZ were described by many authors emphasized that seismic activations in both zones may be interrelated (e.g., Poirier et al., 1980, Ben-Menahem, 1979, 1981, 1991). Before 20th century, destructive earthquakes repeatedly occurred in the EAF and DSF zones. The last activation in both zones took place in the 19th century, with earthquake having 7 or more magnitudes in the EAFZ in 1874 and 1983, in the DSFZ in 1822 and 1872. The association of the largest historical earthquakes (i.e., Mw≥7 and 6<Mw<7) in the western EAFZ and north part of the DSFZ is given in Figure 2, which is based on the investigation of various studies by Balakani and Moskvina (2004). The reader is referred to the original study by Balakani and Moskvina

(2004) for further details on the earthquakes records. Map of significant fault segments of the region is also presented in Figure 3 to have a greater understanding on some of the locations.

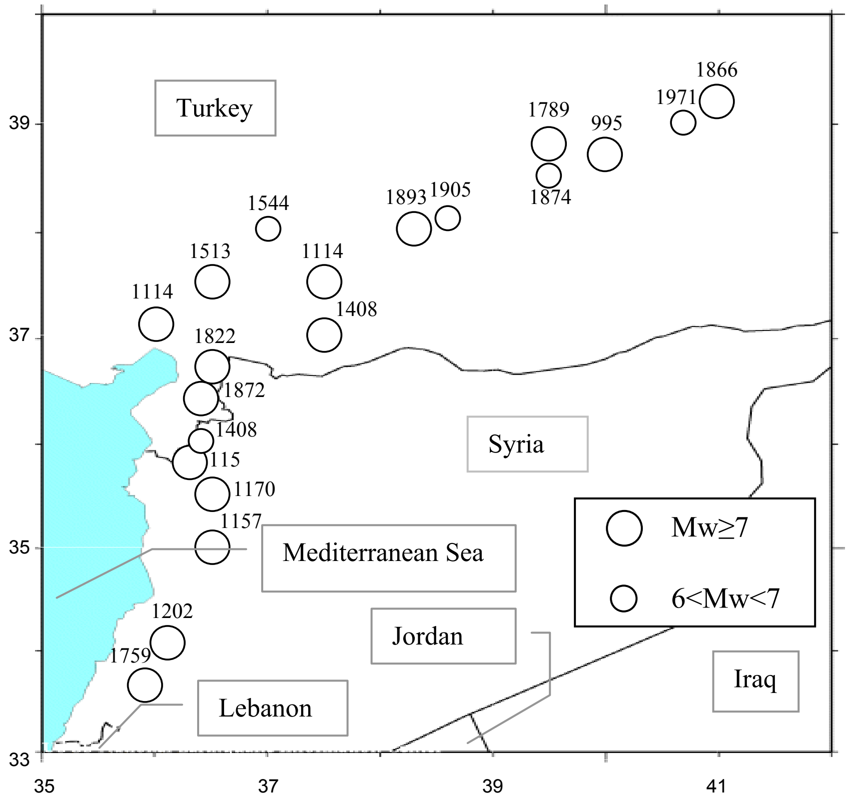

Figure 2 The long-term seismicity of the region (modified from Balakani and Moskvina, 2004).

METHOD AND ANALYSIS

Probabilistic Seismic Hazard Analysis (PSHA) provides a framework in which size, location, and rate of recurrence of earthquakes can be identified, quantified, and combined in a rational way to have a more understanding of the seismic hazard. The steps taken to perform PSHA are (i) to use geological data and the historical earthquake record to define the locations of earthquake sources and likely magnitudes and frequencies of earthquakes that may be produced by each source, (ii) to estimate the ground motions that cover the entire region.

Estimation of future seismic activity is based on the rates of past earthquakes as determined from earthquake catalogs. Even small earthquakes that are not felt although detected by seismographs may help to make a more realistic judgment on these rates form the frequency-magnitude distributions of past seismicity. The investigation presented here is based on the readily available reference that is cited. The catalog compiled from the USGS covers and area from 36.5^{o}E to 38.5^{o}E longitude and 36.5^{o}N to 38.5^{o}N latitude, and is complete for earthquakes of magnitude 3 and greater from 1973 to 2003. Using data of a larger time period will be used in further research regarding this subject. A basic assumption of the author's seismic hazard methodology is that earthquake sources are independent. Therefore, a catalog that is used to estimate future seismic activity must be free of dependent events such as aftershocks and foreshocks.

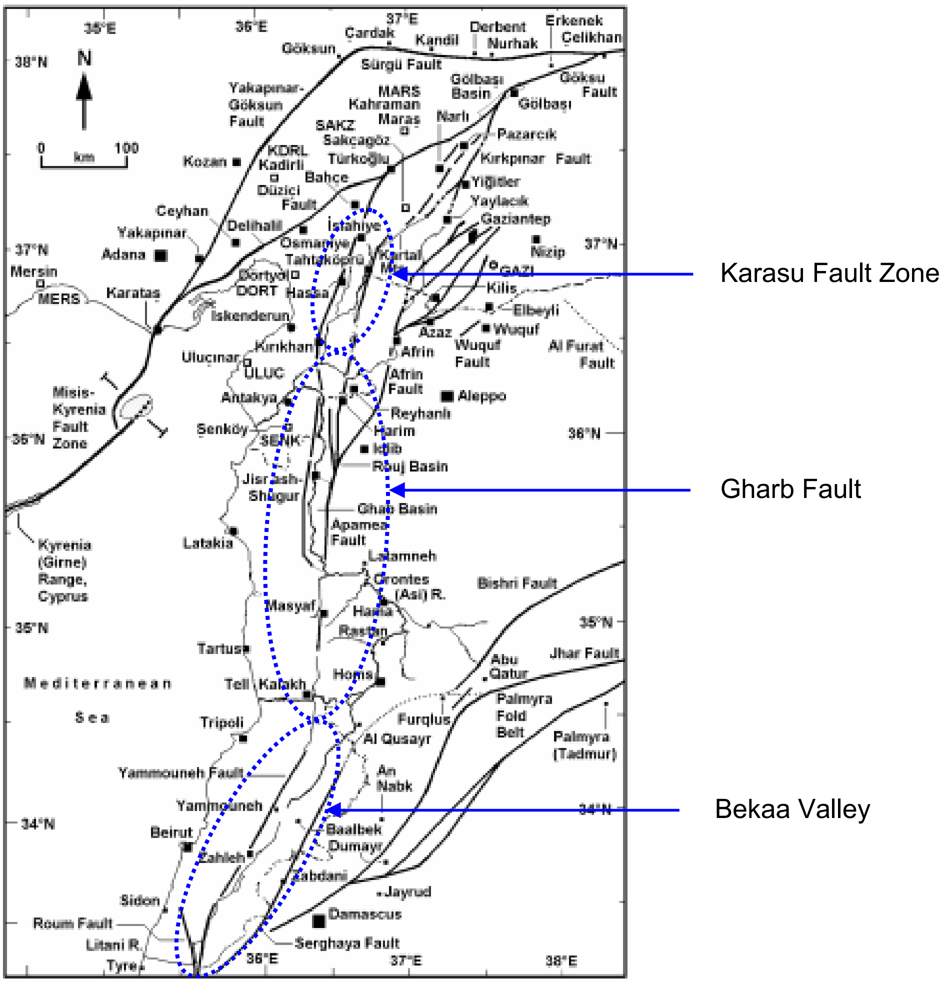

Figure 3 Map of significant fault segments of the region (modified from Westaway, 2003).

Magnitude-Frequency Relations

Gutenberg and Richter (1956) developed an empirical formula relating the magnitude M with corresponding frequency N. The number of exceedances of each magnitude is divided by the length of the time period to define a mean annual rate of exceedances of an earthquake. The annual rate of exceedances for a particular magnitude is referred as the return period of earthquakes exceeding that magnitude. A plot of the logarithm of the annual exceedances rate against earthquake magnitude gives a linear relationship. The Gutenberg and Richter formula is as follow;

$$\log N = a - bM \qquad (1)$$

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 on the investigated area. The parameters of the magnitude-frequency relation are calculated using the least square method. Normal and cumulative frequency values for the investigated region have been determined with the 0.25 magnitude increment (Table 1).

Table1 Normal and cumulative frequency values and logN with 0.25 increment in magnitude.

ΔM	Normal frequency	logN	Cumulative frequency	logN
3.0 - 3.25	1	0	67	1.83
3.25 - 3.5	5	0.70	66	1.82
3.5 - 3.75	6	0.78	61	1.79
3.75 - 4.0	8	0.90	55	1.74
4.0 - 4.25	13	1.11	47	1.67
4.25 - 4.5	15	1.18	34	1.53
4.5 - 4.75	13	1.11	19	1.28
4.75 - 5.0	1	0	6	0.78
5.0 - 5.25	3	0.48	5	0.70
5.25 - 5.5	0	0	2	0.30
5.5 - 5.75	0	0	2	0.30
5.75 - 6.0	2	0.30	2	0.30

The author has used logN values of cumulative frequency in Table 1 for calculating a and b constants. The results given in Table 1 covers the results plotted in the Figure 4, also gives some other data out of the USGS catalogue (i.e., normal frequency). Therefore, it seems to be useful to present the Table 1 here in this study so that could make the processing of basic data wider to the reader.

As can be seen from the Figure 4, the magnitude-frequency relation for the investigated area is as follow;

$$\log N = 4.32 - 0.7M \quad (2)$$

The line seen on Figure 4 has been plotted based on an average value in an every interval shown in Table 1, which is 0.25 in magnitude. Therefore, note that the first value at the x-axis is 3.125 instead of 3.0, which is the corresponding value between 3.0 and 3.25.

Earthquake Hazard

It is necessary to know the probability of occurrence of earthquake in a given time interval. This probability is called as earthquake hazard. The recurrence of earthquakes is most widely described by a Poisson model. The Poisson model consists of independent events that occur randomly in time, where the probability of an event occurring in an interval dt is vdt and v is the average number of events that occur per second. The probability of exactly k events occurring during a given time interval of length T is

$$P(k) = \frac{(vT)^k}{k!} e^{-vT} \quad (3)$$

The average number of events occurring during the time interval T is vT while the standard deviation is $\sqrt{vT}$.

Poisson model possess the following properties (Kramer, 1996);

(i) The number of occurrences in a time interval are independent of the number that occur in any other time interval.

(ii) The probability of occurrence during a short time interval is proportional to the length of the time interval.

(iii) The probability of more than one occurrence during a short time interval is negligible.

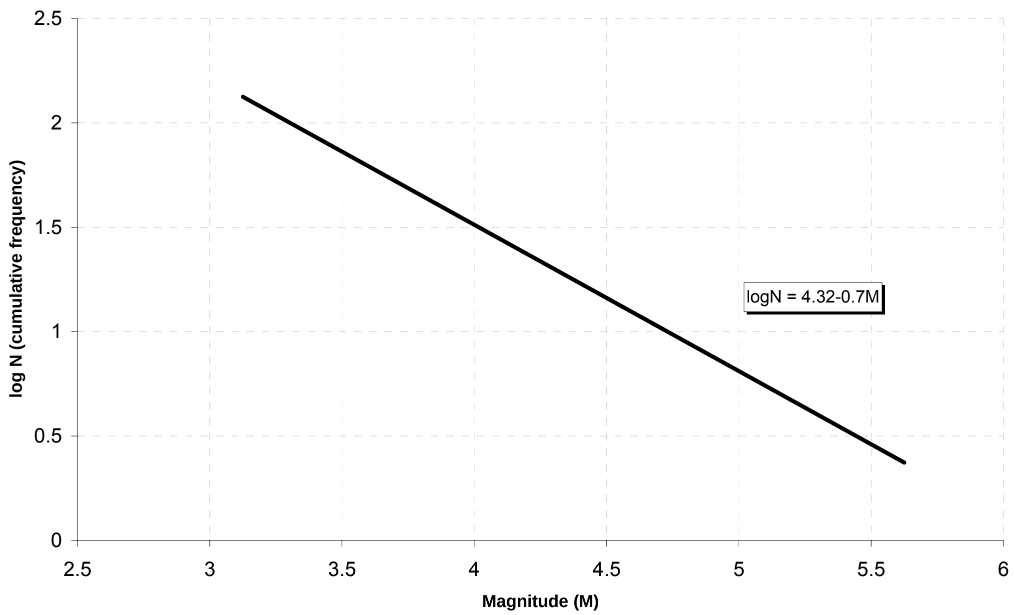

Figure 4 Application of Gutenberg-Richter law to the seismicity data on the studied region.

The probabilities of earthquake occurrence for the investigated area are calculated for periods of T= 5, 10, 15, 20, 25, 30, and 40 years, and magnitudes of M= 3.0, 3.25, 3.5, 3.75, 4.0, 4.25, 4.5, 4.75, 5.0, 5.25, 5.5, 5.75, and 6.0 are presented in Table 2. The mean return periods of earthquakes have been also calculated. From the table, such as; the probability of an earthquake occurrence of equal or greater than magnitude 5.5 in 10 years can be found as 45 percent and, 16 years return period.

It is observed that there is an agreement between the results given by the author in Table 2 and the results obtained by following the method described in Alptekin (1978) that could make the details of the procedure pursued wider to the reader.

Table 2 The computed earthquake risk for the investigated area.

M (magnitude)	5 (year)	10 (year)	15 (year)	20 (year)	25 (year)	30 (year)	40 (year)	Return period (year)
3	1	1	1	1	1	1	1	0.29
3.25	0.99	1	1	1	1	1	1	0.44
3.5	0.99	1	1	1	1	1	1	0.65
3.75	0.99	0.99	1	1	1	1	1	0.97
4	0.96	0.99	0.99	0.99	1	1	1	1.46
4.25	0.89	0.98	0.99	0.99	0.99	0.99	1	2
4.5	0.78	0.95	0.98	0.99	0.99	0.99	0.99	3
4.75	0.64	0.87	0.95	0.98	0.99	0.99	0.99	4
5	0.49	0.74	0.87	0.93	0.96	0.98	0.99	7
5.25	0.36	0.59	0.74	0.83	0.89	0.93	0.97	10
5.5	0.26	0.45	0.59	0.70	0.78	0.83	0.91	16
5.75	0.18	0.33	0.45	0.55	0.63	0.70	0.80	24
6	0.12	0.23	0.33	0.42	0.49	0.55	0.66	36

CONCLUSIONS

Following the disastrous İzmit and Düzce earthquakes on the North Anatolian Fault (NAF) in 1999, the earthquake hazard in Turkey, particularly İstanbul in northwest of Turkey, has become a great concern. However, this study has aimed to present an investigation on seismicity on the northern part of the Dead Sea Fault Zone in southern Turkey. Investigating on the region has been concluded that a seismic hazard analysis in detail is needed for possible earthquakes on Northern Dead Sea Fault Zone. Although there are some differences between the kinematic models as compared by Yurtmen et al. (2002), Coşkun and Coşkun (2000) had concluded that the faulting influencing the structural evolution of Gaziantep Basin is the Dead Sea Fault Zone. As a preliminary study, the parameters of magnitude-frequency relation and an earthquake risk were determined for the city of Gaziantep located in the Gaziantep Basin.

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