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Investigation of seismic hazard in Cankiri, Turkey, using Gumbel's first asymptotic distribution of extreme values

Funda Bilim*

*University of Ankara, Engineering Faculty, Department of the Geophysical Engineering, Besevler 06100 Ankara, Turkey.

Abstract: *Cankiri, Turkey, is located between 40.30^0 and 41.00^{0}N latitudes and between 32.50^0 and 34.50^{0}E longitudes. It is tectonically active because of the North Anatolian Fault to the North of it. In this paper, Gumbel I distribution model and the earthquakes with magnitude (Mb) greater than 4 that occurred between 1964 and 2002 were used to calculate the earthquake hazard that may happen in the study area. The probability of occurrence of Mb≥6.0 earthquake within 100 years and the return period were calculated to be 95% and 32 years, respectively.*

Key words: *The North Anatolian Fault, Gumbel I distribution, Earthquake hazard*.

SEISMIC ACTIVITY AND EARTHQUAKE DATA

Figure 1 shows the location of study area and regional tectonic setting simplified from Ketin (1966) and Kadioglu et al., (1998). The research area, indicated by the black box, is located at the Intra Pontide Suture. Cankiri, situated at the Cankiri-Corum basin, is one of the largest depocenters of Central Anatolia in Tertiary (Karadenizli et al., 1998). In this region the oldest units are mainly of marine origin (Fig. 2a). The surface geology shows that the region is dominantly covered by younger units.

In this paper, the earthquakes of the magnitude Mb$\geq$4.0 were used for Cankiri and its surrounding region located at the 40.30^0 - 41.00^{0}N latitude and 32.50^0 - 34.50^{0}E longitude between 1964 and 2002 for evaluating the seismicity in Cankiri. Earthquake data were taken from the catalogues of International Seismological Centre (http://www.isc.ac.uk) and the U.S. Geological Survey (http://www.usgs.gov).

The seismicity of the region is given in Figure 2b. The earthquakes are well correlated with the tectonic lines. The earthquakes cluster mainly in the north because of the North Anatolian Fault Zone. This fault zone, right-lateral strike-slip fault, was formed with the motion of the Arabia Plate with respect to the African continent towards the north resulting in the collision between Arabian and Eurasian plates. As a result, Cankiri and its surroundings are seismically active.

Magnitude - frequency relationship

The magnitude - frequency relation developed by Gutenberg and Richter (1954) is well known empirical relationship and defined by

$$Log\ N(M) = a - bM \qquad (1)$$

where N(M) is number of earthquakes of magnitude greater than magnitude M, the parameters a and b characterize the study area calculated from the slope and the intercept of the relationship.

Gumbel's first asymptotic distribution

The purpose of the seismicity of a region is to estimate the future hazard. The theory of extremes value is widely used in statistical model for determining the seismic characteristics of a region and has been applied by some researchers (Epstein and Lomnitz, 1966; Yegulalp and Kuo, 1974; Burton, 1979; Makropoulos and Burton, 1985; Bagci, 1995, 2000; Manakou and Tsapanos, 2000). This method does not require the complete record of earthquake occurrence and uses the maximum magnitude values in earthquake data set in a given period. The basic equation of first asymptotic distribution of the possibility of the occurrence of the maximum value of annual extreme magnitude M earthquake is given by:

$$G(M) = \exp\left(-\alpha e^{-\beta M}\right) \qquad (2)$$

where M= Magnitude; G(M) is the type 1 distribution of extreme values; α and β are regression coefficient depend on the seismicity of a region (Gumbel, 1958). From equations (1) and (2), a and b can be written as:

$$a = \text{Log}\ \alpha$$

b = β / ln 10 (Epstein and Lomnitz, 1966).

G(M) can be written in terms of a and b as:

$$\text{Log}\ (-\ln G(M)) = a - bM. \qquad (3)$$

Any probability for the occurrence of the earthquake of magnitude M within any D years period and the return period (T) are given by:

$$R(M) = 1 - e^{-DN(M)} \qquad (4)$$

$$T = 1/N(M) \qquad (5)$$

Seismic hazard of the study region

Some studies have been made to map probabilistic seismic hazard of Turkey (Tuksal, 1976; Bath, 1979; Erdik et al., 1985). Altinok and Kolcak (1999) applied of the semi-Markov model for earthquake occurrences in North Anatolia Fault zone. More recently, Bagci (2000) examined the seismic hazard of the Izmir and its surrounding region, Western Turkey, using Gumbel's first and third asymptotic distribution of extreme values.

In this paper, the occurrence of maximum magnitude earthquakes for Cankiri located at the 40.30^0 - 41.00^0N latitude and 32.50^0 - 34.50^0E longitude occurred between 1964 and 2002 has been modeled by Gumbel's first asymptotic distribution. The largest event per year was taken. Estimations of annual maximum distribution for Cankiri are given in Table 1. The magnitude-frequency relationship (Fig. 3) from magnitude - Log N graph given in the results in Table 1 were estimated by the least- square method as

$$LogN = 1.89(\pm 0.15) - 0.56(\pm 0.03)M$$

The terms in parenthesis shows the standard error. The estimated parameters of Gumbel's I Model are given in Table 2.

The estimated return periods for various magnitudes are given in Table 3. Table 4 shows the results of seismic hazard of the study region. Relationship between magnitude and the possibility of earthquake occurrence is given in Figure 4. Figure 5 shows the magnitude- return period relationship.

CONCLUSION

For the study area, the b- value of the magnitude - frequency relationship estimated to be 0.56. This value is the same as that of Tuksal's estimated value (1976) for the Central North Anatolian fault zone including Cankiri and surrounding region using the method of maximum likelihood approximation. For the area located at the 39^0 - 41^0 N latitude and 33^0 - 35^0E longitude, Bath (1979) determined the b-value to be 0.7 using the Ms catalogue for the period 1913-1970.

The probabilities and the return period of earthquake occurrences were also determined. The occurrence probability of Mb≥ 7.0 earthquake in 50, 100 and 150 years were found to be 32%, 55% and

69% respectively. The return period of Mb$\geq$7.0 earthquake was estimated as 116 years.

Acknowledgement

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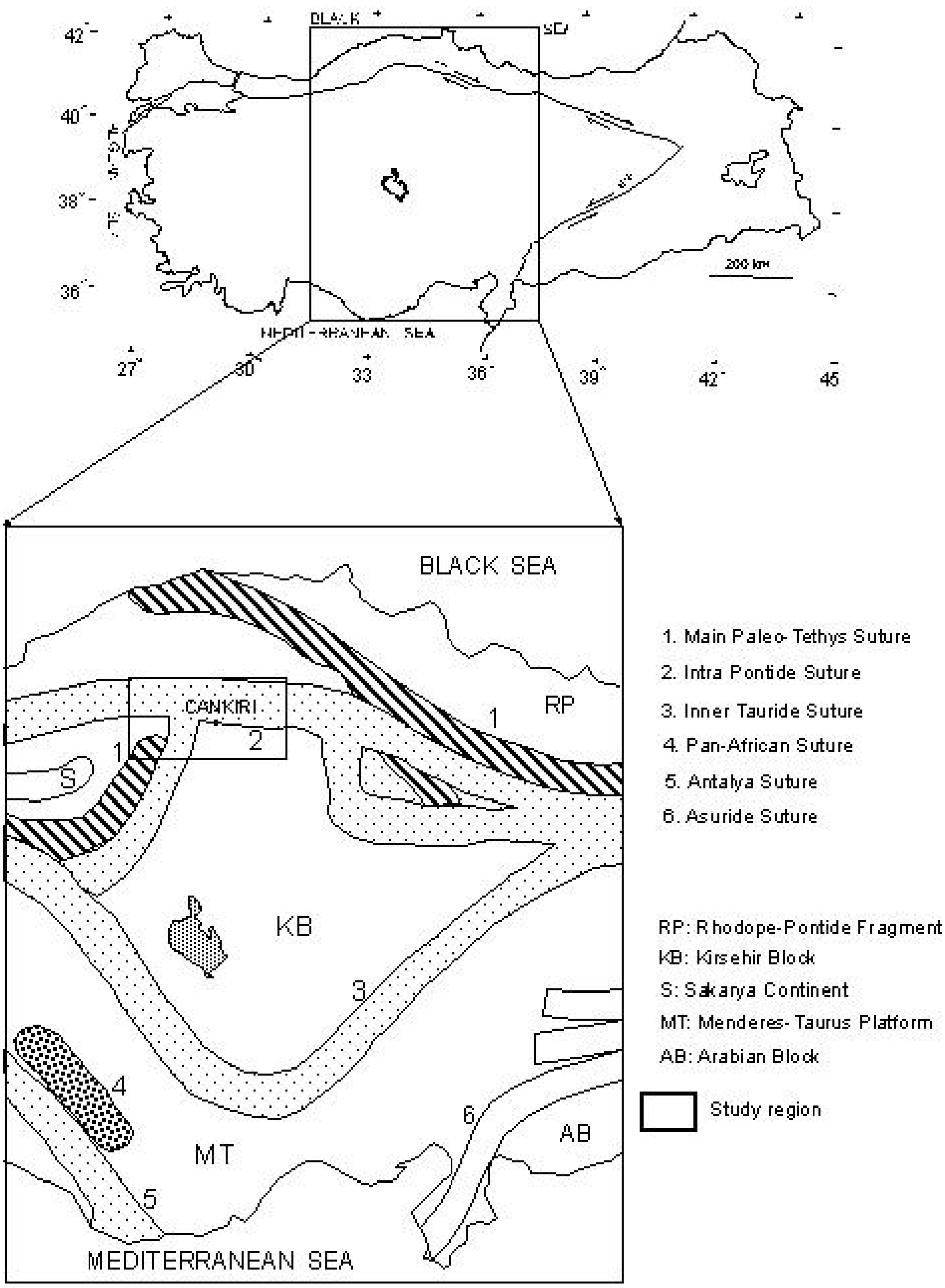

Figure 1. Location map and the geotectonic structures around the study area simplified from Ketin (1966) and Kadýoðlu et al. (1998).

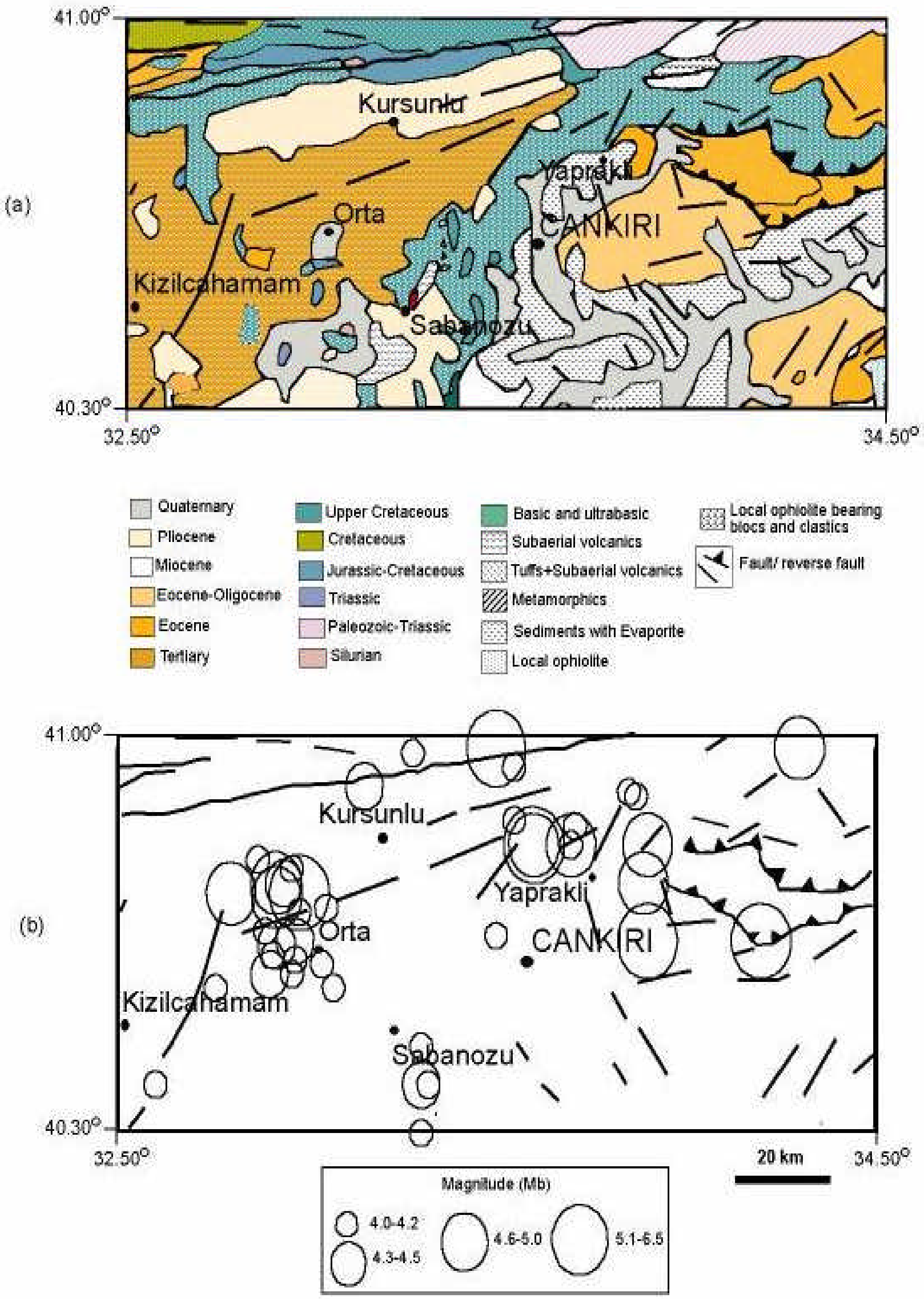

Figure 2. a) Geological map of the study area (Bingol, 1989)
b) Seismicity

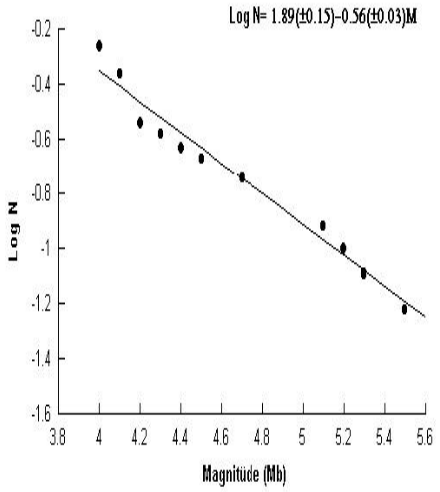

Figure 3. Magnitude- frequency relationship.

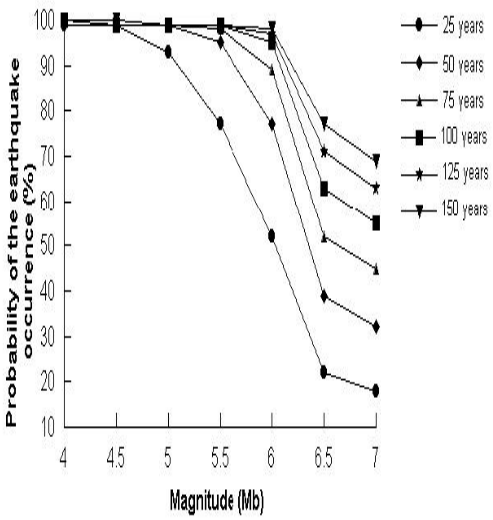

Figure 4. Relationship between magnitude and the possibility of earthquake occurrence.

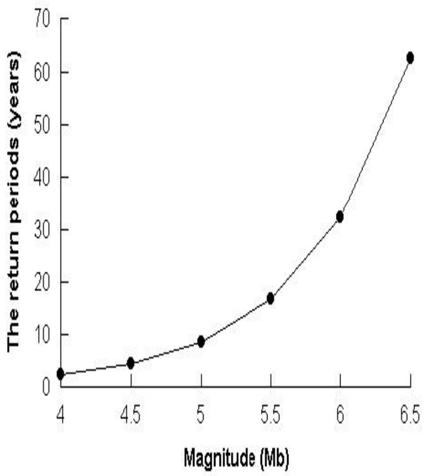

Figure 5. Magnitude- return period relationship.

Table 1. Estimation of annual maximum distribution of Cankýrý.

Magnitude (Mb)	i	P=i/(n+1)	G(M)	N=-LnG(M)	Log N
4	23	0.58	0.58	0.54	-0.26
4.1	3	0.07	0.65	0.43	-0.36
4.2	4	0.1	0.75	0.28	-0.54
4.3	1	0.02	0.77	0.26	-0.58
4.4	1	0.02	0.79	0.23	-0.63
4.5	1	0.02	0.81	0.21	-0.67
4.7	1	0.02	0.83	0.18	-0.74
5.1	2	0.05	0.88	0.12	-0.92
5.2	1	0.02	0.9	0.1	-1
5.3	1	0.02	0.92	0.08	-1.09
5.5	1	0.02	0.94	0.06	-1.22

Table 2. Estimated parameters using Least-square method.

Gumbel's Model	Type-I Distribution
Least-Square Method	a= 1.89; a =77.62 b= 0.56; b =1.30

Table 3. Estimated return periods for various magnitudes of the study area.

Magnitude (Mb)	Return periods in years
4.0	2.38
4.5	4.48
5.0	8.62
5.5	16.66
6.0	32.25
6.5	62.50
7.0	116.27

Table 4. Probability of earthquake occurrence using Gumbel I model.

Gumbel's Type I Distribution						
Magnitude (Mb)	Probability of earthquake occurrence (%)					
	25 years	50 years	75 years	100 years	125 years	150 years
4.0	99	99	100	100	100	100
4.5	99	99	99	99	100	100
5.0	93	99	99	99	99	99
5.5	77	95	98	99	99	99
6.0	52	77	89	95	97	98
6.5	22	39	52	63	71	77
7.0	18	32	45	55	63	69

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