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EARTHQUAKE HAZARD ASSESSMENT FOR DIFFERENT REGIONS IN AND AROUND TURKEY BASED ON GUTENBERG-RICHTER PARAMETERS BY THE LEAST SQUARE METHOD

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ABSTRACT

In this study, we made an assessment of earthquake hazard parameters for different 24 source regions in and around Turkey. We used the seismic source zones and the database defined by Bayrak et al. [12] and Bayrak et al. [17], respectively. For the goodness of fit to the Gutenberg-Richter (G-R) frequency-magnitude law, the parameters *a* and *b* were calculated from least square (LS) approach for each region. Also, it is estimated the mean return periods, the most probable maximum magnitude in the time period of *t*-years and the probability for an earthquake occurrence for an earthquake magnitude$\geq M$ during a time span of *t*-years. We then produced *b*-value map using G-R with the least square method and the spatial distribution of probabilities and the expected maximum earthquake magnitude in the next 100 years are plotted. The results show that region 21 (central part of NAFZ) is probably the next region for the occurrence of a large earthquake. This conclusion is strongly supported from the probability map in which shows that the largest value (98%) for an earthquake with magnitude greater than or equal to 7.0. The mean return period for such magnitude is the lowest in this region (27-years). It is also determined the most probable earthquake magnitude in the next 100 years. This parameter also supports our conclusion that in the middle of North Anatolian Fault zone the most probable earthquake magnitude in the next 100 years will exceed 7.5. Since it is necessary to have a plenty data in LS, the computed *b*-values from LS will contain extreme errors for the regions having too few data. So, the computed lower *b*-value and higher M_{100} value are completely related to small number of data. As a result, the G-R parameters computed from LS for a region having quite little number of data do not reflect tectonics very well.

Keywords: *Earthquake hazard, mean return period, the most probable maximum magnitude*

1. INTRODUCTION

It is a remarkable fact that the evaluation of earthquake hazard parameters is important in seismically active region. Qualitative techniques (epicenter maps, etc) as well as quantitative ones have been applied in order to present the spatial variability of earthquake hazard in different regions of the Earth and Turkey [1,2,3,4]. The maximum observed magnitude M_{max} [5,6], the annual number $N(M)$ or the mean return period T_m of earthquakes [7,8] with magnitudes greater or equal to a given value M are the commonest quantities considered as measures of seismicity. The knowledge of the return period is of great importance in studying and analyzing earthquake hazard and/or seismicity. It contributes with a great importance to the determination of the national seismic code and it conditions the priority of interventions on existing buildings [2]. However, assessment of earthquakes hazard involves the computation of long-term probabilities for the occurrence of earthquakes of a specified size in a given area during a certain time period.

Turkey is located in a very active seismic region, so the earthquake hazard studies in Turkey has been widely made by using a number of different techniques and seismic quantities [9,10,11,12,13]. For this purpose, the seismicity of Turkey is studied through the application of various methods using different parameters. The aim of the present study is to evaluate the earthquake hazard in Turkey in terms of different hazard parameters such as the mean return period for an earthquake occurrence, the most probable maximum magnitude of earthquakes in a certain time interval and the probabilities for the large earthquakes occurrences in the certain times.

2. TECTONIC PROPERTIES and DATA

Turkey is in the Mediterranean part of Alpine-Himalayan orogenic system and this system runs through a mean west-east direction from the Mediterranean to Asia. The tectonic characteristic of Turkey and in the vicinity is controlled by three major plates: African, Eurasian and Arabian, and two generally acknowledged minor plates: Aegean and Anatolian as shown in the neo-tectonic models of McKenzie [14] and Dewey et al. [15]. The most important tectonic characteristics of Turkey are the Aegean Arc, the West Anatolian Graben Complexes (WAGC), the North Anatolian Fault Zone (NAFZ), the East Anatolian Fault Zone (EAFZ), the North East Anatolian Fault Zone (NEAFZ) the Bitlis Thrust Zone (BTZ) and the Caucasus. The African plate is moving to the north, towards Eurasian Plate, pushing the Turkish Plate in a westward motion. NAFZ and EAFZ constitute the northern and southern boundaries, respectively, of this plate, while the southern boundary is not well defined by seismicity. The motion between Africa and Eurasia is not taken up one plate boundary, but is carried by the motion of the Aegean and Turkish plates. The boundary between the Aegean and Turkish plates forms a north-south trending belt of seismicity across western Turkey and the eastern Aegean. The Aegean plate is moving towards the southwest relative to the European plate, producing extension and strike-slip motion along the boundary between the two plates. The southern boundary of the Aegean plate is moving southwest relative to the African plate, and is over thrusting the Mediterranean Sea floor. At the eastern end of the Turkish plate, the motion is taken up by thrust faults associated with the Caucasus. The result of this geometry is a thickening of the continent throughout the active region, which continues to elevate the Caucasus. Thrusting in eastern Turkey and the Caucasus transforms to strike-slip motion between the Turkish and Eurasian plates at the eastern outset of the NAF [10]. McKenzie [14] conjectured that the relative motion between the Black Sea and the Eurasian plate must be in a north-south direction with the Black Sea moving towards Eurasia, though rather slowly, since the seismicity of this boundary has been low for most of this century [10]. The Arabian plate is moving in the north-northwest direction relatively to the Eurasian plate. This motion has resulted in continental collision along the Bitlis fold and the thrust belt which causes high topography in Eastern Turkey and the Caucasus. As a result of compression in the East Anatolia, the Anatolian plate moves to the west and the North Anatolian plate to the east. The major tectonic structures of Turkey adopted from Şaroğlu et al. [16] are shown in Figure 1.

For an ideal delineation of seismic source zones it is necessary a complete comprehension of the historical and instrumental seismicity, tectonics, geology, paleoseismology, and other neotectonic properties of the considering region. But, it is not always possible to compile detailed information in all these fields for the majority of the world. Thus, frequently, seismic source zones are determined with two fundamental tools; a seismicity profile and the tectonic structure of the region under consideration [10]. The seismic source zones used in this study are defined according as Bayrak et al. [12] as shown in Figure 2. Also, epicentral distributions of the earthquakes in Turkey and vicinity are shown in the same figure. The seismic source regions numbered from 1 to 24, all earthquakes with the maximum observed magnitude M_{max}^{obs}, locations and dates are given in Table 1.

The database used in this study is taken from Bayrak et al. [17]. It is compiled from different sources and the seismicity data from different catalogues were provided in different magnitude scales. Turkey earthquake catalogue from 1900 to 1974 come from the International Seismological Centre (ISC) and instrumental catalogue of KOERI. The earthquakes, starting from 1974 until 2005, are taken from the Boğaziçi University, Kandilli

Observatory and Earthquake Research Institute (KOERI). The catalogue contains the origin time, different magnitudes scales (m_b-body wave magnitude, M_S-surface wave magnitude, M_L-local magnitude, M_D-duration magnitude, and M_W-moment magnitude), epicenters and depths information of earthquakes. The earthquake data from different catalogues are given in different scales. An earthquake data set used in the assessment of earthquake hazard must be homogenous in other words it is necessary to use the same magnitude scale. In order to prepare a homogeneous earthquake catalogue, Bayrak et al. [17] are developed some new relationships between the different magnitudes scales (m_b, M_S, M_L, and M_D) for 24 different regions of Turkey shown in Figure 2. Consequently, using the relations given it has been constructed a uniform catalogue of M_S. Thus, the final data catalogue consists of 70876 earthquakes with magnitude 1.0 or greater.

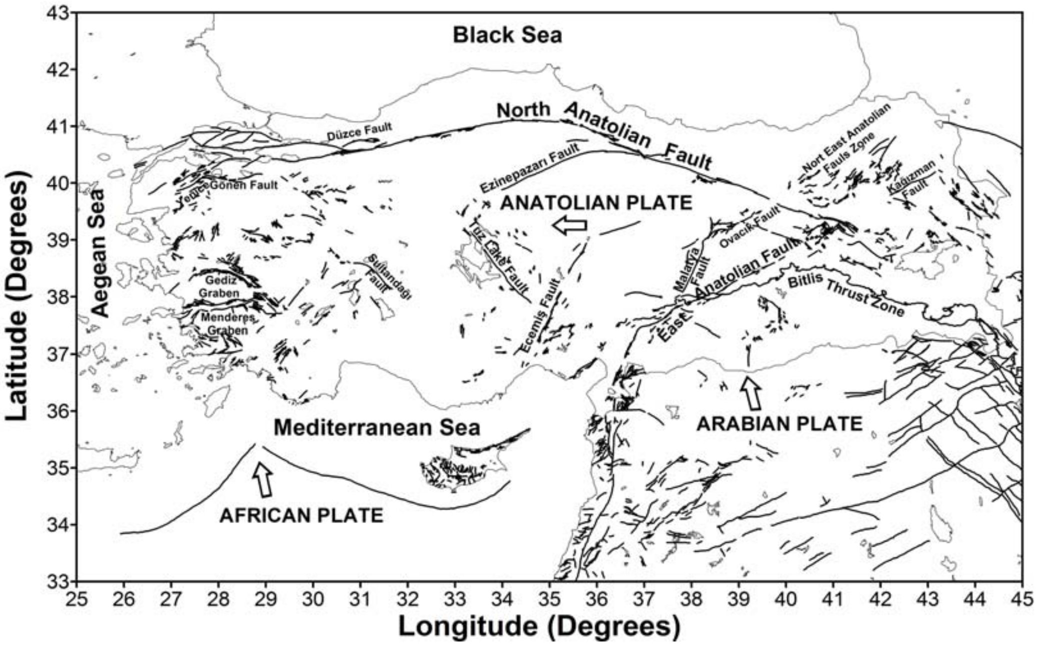

Figure 1. Active tectonics of Turkey. The major tectonic structures are modified from Şaroğlu et al. [16].

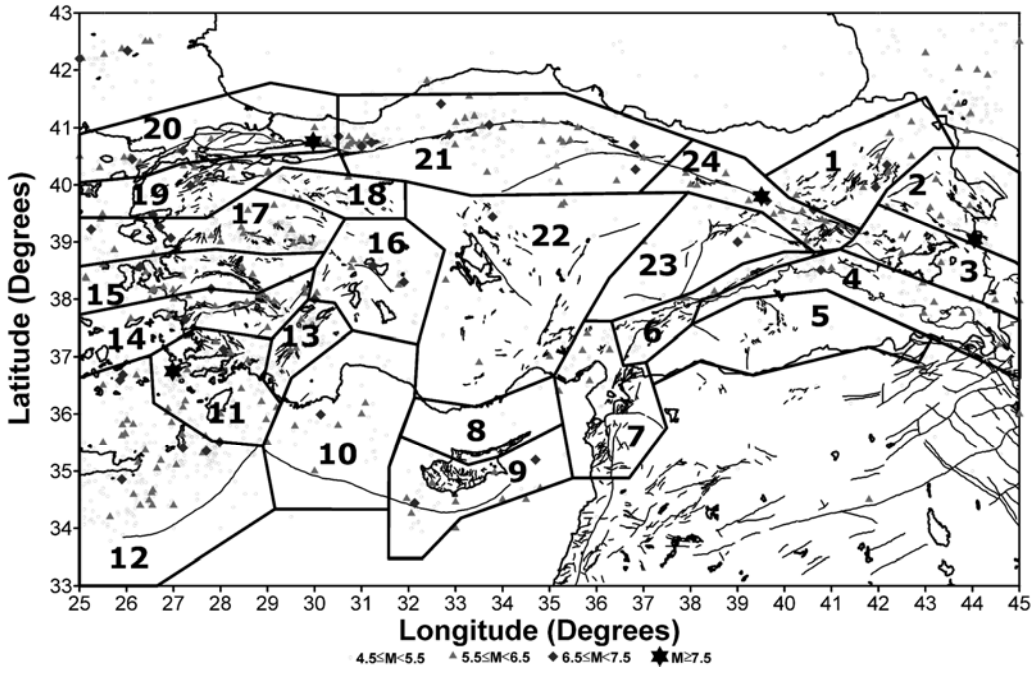

Figure 2. Different seismic zones (Bayrak et. al. [12]) and epicenter distribution of earthquakes in Turkey from 1900 to 2005 with major tectonics. Magnitude sizes of earthquakes are shown by different symbol.

Table 1. Different 24 seismic source regions in and around Turkey, maximum observed magnitudes (M_S) in each region, their date and locations.

Region	**Maximum observed magnitude (M_S)**	**Date (m.d.y)**	**Location**	**Tectonics**
1	6.8 / 6.8	09.13.1924 / 10.30.1983	Pasinler / Horasan	North East Anatolian Fault Zone (NEAFZ)
2	7.5	11.24.1976	Çaldıran-Muradiye	Kağızman, Iğdır, Tutak and Çaldıran faults (KITÇF)
3	6.3	04.28.1903	Patnos	Malazgirt, Erçiş and Süphan faults and Muş Thrust Zone (MESF)
4	6.6	09.06.1975	Lice-Diyarbakır	Bitlis Thrust Zone (BTZ)
5	5.4	05.19.1915	Şanlıurfa	Karadağ Extension Zone (KEZ)
6	5.9	08.11.2004	Elazığ	East Anatolian Fault Zone (EAFZ)
7	6.0 / 6.0	02.17.1908 / 03.20.1945	Adana-Ceyhan / Adana-Ceyhan	A part of Dead Sea Fault
8	5.2	02.14.1995	Cyprus Region	North part of Cyprus
9	6.7	10.09.1996	Cyprus Region	South part of Cyprus, including east part of Cyprus Arc
10	6.8	03.18.1926	Finike	Western part of Cyprus Arc
11	7.7	06.26.1926	Rhodes	Muğla and Rhodes
12	7.4	07.09.1956	Aegean Sea	Aegean Arc
13	6.4	03.01.1926	Burdur	Burdur Fault Zone (BFZ)
14	6.8	07.16.1955	Aydın-Söke	Büyük and Küçük Menderes Grabens
15	6.6	07.23.1949	İzmir-Karaburun	Gediz Graben
16	7.0	04.09.1931	Akşehir	Sultandağı, Beyşehir and Tatar faults (SBTF)
17	7.2	12.19.1981	Aegean Sea	Kütahya, Simav and Zeytindağ-Bergama faults (KSZBF)
18	6.4	02.20.1956	Eskişehir	Eskisehir, İnönü-Dodurga and Kaymaz faults (EİDKF)
19	7.2	03.18.1953	Çanakkale-Yenice	Yenice-Gönen, Manyas, Ulubat and Etili faults (YGMUEF)
20	7.8	08.17.1999	İzmit	Marmara part of North Anatolian Fault Zone (MNAFZ)
21	7.4	11.12.1999	Düzce	Anatolian part of North Anatolian Fault Zone (ANAFZ)
22	6.6	04.19.1938	Kırsehir	Mid Anatolian Fault System (MAFS)
23	6.8	12.04.1905	Çemişgezek	Ovacık fault and Malatya fault (OMF)
24	7.9	12.26.1939	Erzincan	Eastern part of North Anatolian Fault Zone (ENAFZ)

3. METHOD

The commonest description of earthquake occurrence is provided by the Gutenberg-Richter (G-R) law. The parameters currently used for quantitative evaluation of seismicity are the well-known ones, a_t and b, of the magnitude frequency relationship introduced by Gutenberg and Richter [18]:

$$LogN = a_t - bM \tag{1}$$

The parameter b depends on factors like the mechanical heterogeneity and the density cracks in the medium and on the state of stress in a region [19,20]. The parameter a_t depends on the seismicity of the area, on the time interval for which we have reported events and also on the surface area S outlined by the epicenters. For seismicity study purposes usually a_t is expressed in 1 year by the equation:

$$a_1 = a_t - Logt \tag{2}$$

where t is the whole time period covered by the data set. Because of Equation (2), relationship (1) transforms to:

$$LogN = a_1 - bM \tag{3}$$

The expected time interval for the occurrence of an earthquake with magnitude greater than or equal to M is defined as the mean return periods T_m and is given by:

$$T_m = 10^{\mathrm{bM}} / 10^{\mathrm{a}_1} \tag{4}$$

This quantity is adopted as a measurement of seismicity. The most probable maximum magnitude of earthquakes in a time period of t years:

$$M_t = (\mathrm{a}_1 + \log t)/\mathrm{b} \tag{5}$$

The probability P_t for an earthquake occurrence with magnitude $\geq M$ during the time span of t years:

$$P_t = 1 - \exp(-10^{\mathrm{a}_1 - \mathrm{bM}}\, t) \tag{6}$$

In this paper, we aimed to make a quantitative appraisal of earthquake hazard parameters in and around Turkey. Particularly the analysis of the expected time interval for the occurrence of an earthquake, the most probable maximum magnitude of earthquakes in a given time period and the probability for an earthquake occurrence supply information on the earthquake hazard. In order to evaluate the quantitative seismicity for different 24 regions, in which Turkey and the adjacent areas are divided we applied Equations 4, 5 and 6. We used M_S magnitude scale in these equations since our catalogue is uniform of M_S.

4. RESULT and DISCUSSION

An effort is made in this study for evaluation of earthquake hazard parameters of Turkey. The parameters a and b of magnitude-frequency (M-F) relationship is estimated by the least square (LS) method for 24 seismic regions (Figure 2). Then the most probable maximum magnitudes, the mean return periods (in years) and the probabilities for different time periods for a given magnitudes were computed in order to evaluate the seismicity of the 24 seismic regions.

The M-F graphs are shown in Figure 3 and the G-R parameters as well as cut of magnitudes (Mc) for 24 seismic regions of Turkey are given in Table 2. The computed b-values are between 0.52 and 1.27. Minimum b-value is related to North part of Cyprus whereas maximum value is observed in KEZ (abbreviations are given in Table 1). We divided b-values into four groups changing between 0.40 and 0.59, 0.60 and 0.79, 0.80 and 1.00 and larger than 1.00. These four groups drawn with different grey scale are shown in Figure 4. The highest b-values computed in regions 5, 7, 9 and 13, which are related to, KEZ, a part of the Dead Sea fault, South part of Cyprus, including east part of Cyprus Arc and BFZ. The second level b-values changing between 0.80 and 0.99 are obtained in regions of 3, 4, 6, 11, 12, 14, 15, and 17. MESF, BTZ, EAFZ, Aegean Arc, Büyük and Küçük

Menderes Grabens, Gediz Graben and KSZBF are in the borders of these regions. The *b*-values varying between 0.60 and 0.79 are observed in the regions 1, 2, 10, 16, 18, 19, 20, 21 and 22. These regions are related to NEAFZ, KITÇF, Muğla and Rhodes, SBTF, EİDKF, YGMUEF, Marmara and Anatolian parts of NAF. The values lower than 0.60 are related to regions 8, 23 and 24 covering the North part of Cyprus, Ovacık and Malatya faults and eastern part of North Anatolian Fault zone. Since region 8 includes too few data (Figure 3), we observed very low *b* values in this region. Fitting a straight line such as that implied by the G-R law through recurrence data in which the mean rate of exceedance of small earthquakes is underestimated will tend to flatten the line. As a result, the actual mean rate of small earthquakes will be underpredicted and the mean rate of large earthquakes will be overpredicted [21]. Since it is necessary to have a plenty data in LS, the computed *b* values from LS will contain extreme errors for the regions having too few data.

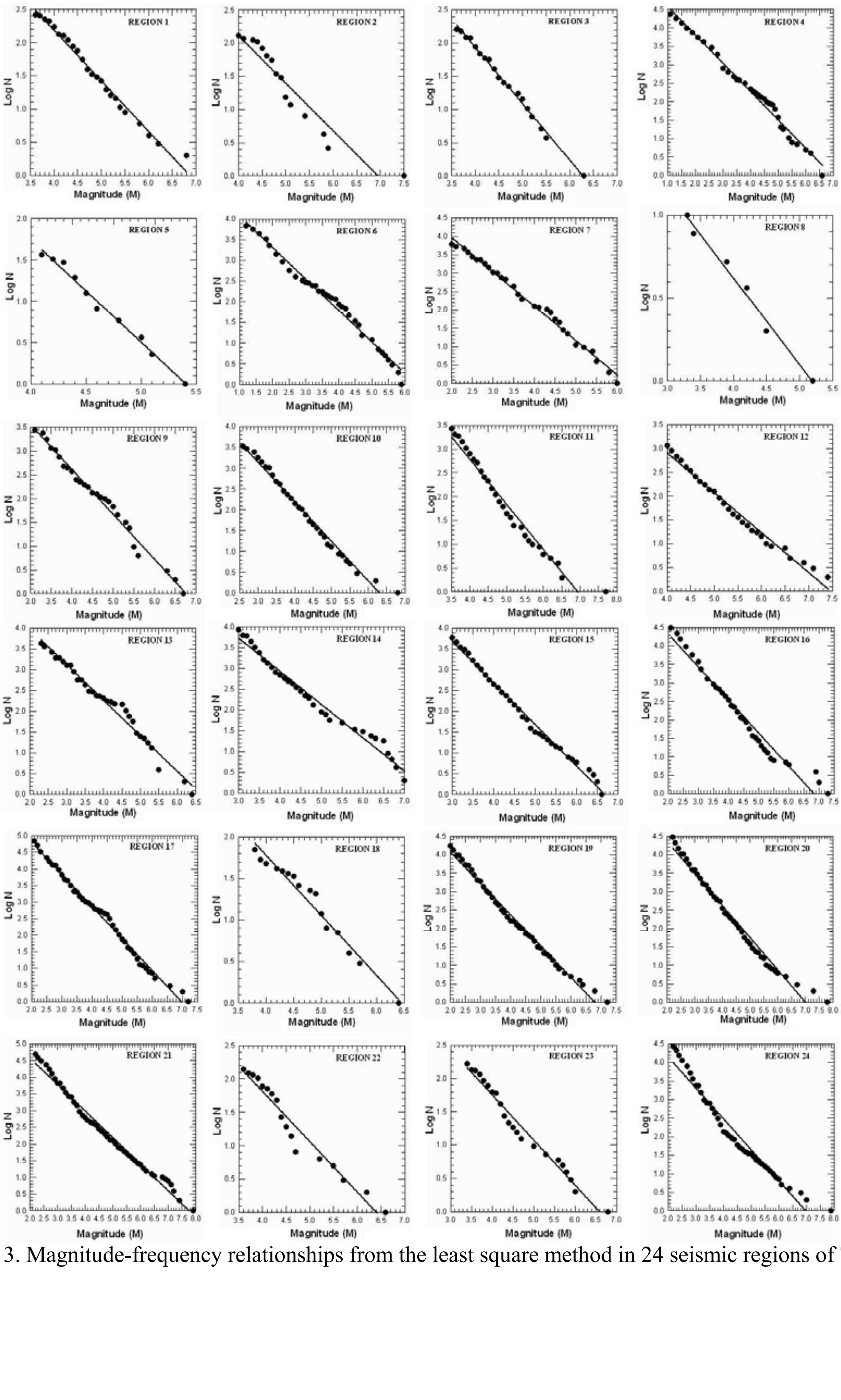

Figure 3. Magnitude-frequency relationships from the least square method in 24 seismic regions of Turkey

Table 2. Gutenberg-Richter parameters, mean return periods for magnitude range between 5.0 and 7.5 and the most probable maximum magnitudes for certain times between 1 and 100 years in the studied regions

		LogN=a-bM			**M_S=5.0**	**M_S=5.5**	**M_S=6.0**	**M_S=6.5**	**M_S=7.0**	**M_S=7.5**	**most probable maximum magnitudes**				
Region	M_c	a	a_1	b	T_m	T_m	T_m	T_m	T_m	T_m	M_1	M_{10}	M_{25}	M_{50}	M_{100}
1	3.6	5.07	3.07	0.73	3.8	8.8	20.4	47.3			4.2	5.6	6.1	6.5	7.0
2	4.0	4.47	2.66	0.65	3.9	8.2	17.4	36.7	77.6	164.1	4.1	5.6	6.2	6.7	7.2
3	3.5	5.39	3.38	0.86	8.3	22.4	60.3				3.9	5.1	5.6	5.9	6.3
4	1.0	6.42	4.43	0.97	2.6	8.0	24.5	75.0			4.6	5.6	6.0	6.4	6.6
5	4.1	6.87	4.92	1.27	26.9						3.9	4.7	5.0	5.2	5.5
6	1.1	5.78	4.03	0.95	5.2	15.7					4.2	5.3	5.7	6.0	6.4
7	2.0	6.63	4.65	1.09	6.3	22.1	77.6				4.3	5.2	5.6	5.8	6.1
8	3.3	2.68	2.07	0.52	3.4						4.0	5.9	6.7	7.3	7.8
9	3.0	6.86	4.92	1.02	1.5	4.9	15.8	51.3			4.8	5.8	6.2	6.5	6.8
10	2.5	4.96	3.07	0.76	5.4	12.9	30.9	74.1			4.0	5.4	5.9	6.3	6.7
11	3.5	6.09	4.15	0.86	1.4	3.8	10.2	27.5	74.1	199.5	4.8	6.0	6.5	6.8	7.2
12	4.0	6.23	4.25	0.85	1.0	2.7	7.1	18.8	50.1		5.0	6.2	6.7	7.0	7.4
13	2.3	6.69	4.79	1.06	3.2	11.0	37.2				4.5	5.5	5.8	6.1	6.4
14	3.0	5.78	3.78	0.86	3.3	8.9	24.0	64.6			4.4	5.6	6.0	6.4	6.7
15	3.0	5.92	3.91	0.86	2.5	6.6	17.8	47.9			4.6	5.7	6.2	6.5	6.9
16	2.0	4.56	2.60	0.64	4.0	8.3	17.4	36.3	75.9		4.0	5.6	6.3	6.7	7.2
17	3.0	6.56	4.55	0.94	1.4	4.2	12.3	36.3	117.2		4.8	5.9	6.3	6.7	7.0
18	3.8	4.89	2.99	0.77	7.2	17.6	42.7				3.9	5.2	5.7	6.1	6.5
19	2.0	5.09	3.09	0.72	3.2	7.4	17.0	38.9	89.1		4.3	5.7	6.2	6.7	7.1
20	2.1	5.07	3.08	0.69	2.3	5.2	11.5	25.4	56.2	124.5	4.5	5.9	6.5	6.9	7.4
21	2.1	4.92	2.91	0.62	1.5	3.2	6.5	13.2	26.9		4.7	6.3	7.0	7.4	7.9
22	3.6	4.52	2.59	0.70	8.1	18.2	40.7	91.2			3.3	5.0	5.7	6.2	6.7
23	3.3	3.90	1.90	0.58	10.0	19.5	38.0	74.1			3.7	5.1	5.7	6.1	6.6
24	2.1	4.26	2.38	0.56	2.6	5.0	9.5	18.2	34.7	66.1	4.3	6.0	6.8	7.3	7.8

The *b*-value for a region not only reflects the relative proportion of the number of large and small earthquakes in the region, but is also related to the stress condition over the region. Many factors can cause perturbation of the normal *b*-value. On average, *b*-value is near unity for most seismically active regions on Earth [22]. However, a detailed mapping of *b*-value often reveals significant deviations. The spatial variation of *b*-values is related to the distribution of stress and strain [19,20]. On the other hand, high *b*-values are reported from areas of increased geological complexity [23] indicating the importance of multifracture area. Thus, the low *b*-value is related with low degree of heterogeneity, large stress and strain, large velocity of deformation and large faults [24]. We observed the low *b* values (< 0.70) in regions 20, 21 and 24 which are related the NAFZ. The NAFZ is a large fault zone, has low degree heterogeneity and is a very active structure according to geodesy accommodates 24-30mm/yr of dextral motion [25]. This observation interprets our results, obtained by G-R method (low *b*-values), and lead us to the conclusion that even after the occurrence of the two recent large earthquake, the NAFZ remains a tectonic structure of high risk. The western Anatolian including regions 11, 13,14, 15 and 17 is a multifracture area where the seismicity related to graben systems and other faults is high and displays swarm-type activity with remarkable clustering of low-magnitude earthquakes in time and space [26,27]. The high *b* values (>0.8) in these regions are consistent with the tectonics.

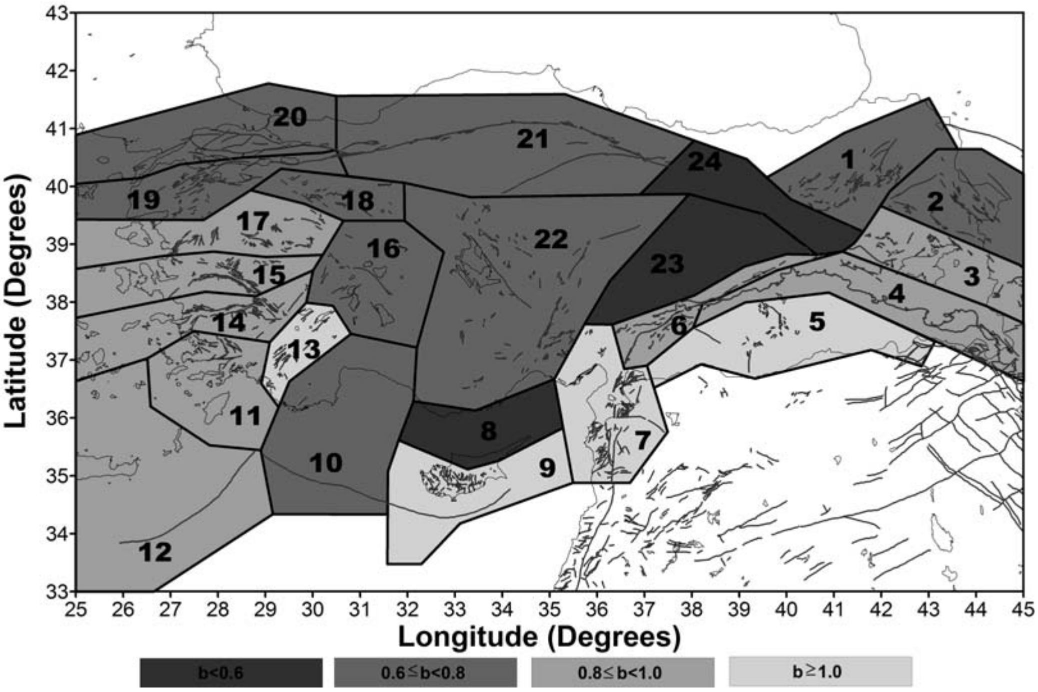

Figure 4. *b* values of G-R relationships from the least square method in 24 seismic region of Turkey

Earthquake recurrence times (return periods) can be evaluated from paleoseismic observations, patterns of seismicity and strain rates measured from GPS networks. The mean return periods (T_m) computed from G-R parameters during a given time span are listed in table 2. Also, earthquake hazard curves expressed in terms of the mean return period of earthquakes that are expected for the maximum observed magnitudes are shown in Figure 5.

The regions 20, 21 and 24 are covered by NAFZ which is best-known strike slip fault in the world which generates devastating, threatening to human life, earthquakes from time to time. Between 1939 (Erzincan earthquake, M_S=7.9) and 1999 (İzmit earthquake, M_S=7.8) NAFZ ruptured in a westward migration series of nine moderate-large earthquakes (M_S>6.7). The mean return periods estimated indicate that the region 21 (a part of NAFZ) is the most dangerous seismic region, with mean return period ranging between 27 and 48 (the lowest values) years for magnitudes 7.0 and 7.4, respectively. The largest earthquake in region 21 is Düzce earthquake of 1999 with M_S=7.4 which is occurred in the western part of this seismic region. This region is a very seismically active one and experienced of a series of large earthquakes (with magnitudes 7.0-7.3) during the years 1942, 1943, 1944 and 1957. In the regions 20 and 24 which are the other parts of NAFZ (Figs.1 and 2) the mean return periods for magnitude M_S≥7.5 are 124 and 66 years, respectively. The mean return periods for magnitude M_S≥7.0 are shorter than 100 years as in the regions 11, 12, 16 and 19. The regions 11 and 12 are covered by the subduction zone of the south Aegean area. In this specific area earthquake are known since historic epoch with the very large event of magnitude M_S=8.0 occurred in 1303 [28]. Sultandağı fault (normal fault), Beyşehir and Tatar faults (strike-slip faults) are situated in the region 16 where observed maximum earthquake size is 7.0 (Table 1). The regions 14, 15 and 17 cover E-W trending grabens and their basin-bounding active normal faults generally generate earthquakes with magnitude lower than 7.0. The earthquake (M_S=7.2) observed in region 17 is not related to these graben systems and occurred in Aegean Sea. The mean return periods for magnitude M_S≥6.5 are 65 and 48 and 36 years for the regions 14, 15 and 17, respectively. In the regions 2 and 19 return periods for earthquake of magnitude M_S=7.0 are greater than 75 years. The region 2 is covered by Kağızman, Iğdır, Tutak and Çaldıran faults which are active strike-slip faults [29] and experienced of 1976 large Çaldıran earthquake (M_S=7.5). Strike-slip faulting mechanism dominates in region 19 where there are Yenice-Gönen, Manyas, Ulubat and Etili Faults and observed largest earthquake is 1953 Çanakkale-Yenice earthquake (M_S=7.5). Unlike NAFZ, EAFZ covered by region 6 has been relatively quiescent in the instrumental period when compared to historical epoch [30]. The data used in this study includes only instrumental period earthquakes occurred from 1900 to 2005. Since the very large earthquakes did not occurred in the instrumental period, we could not calculate the mean return periods of the earthquakes greater than 7.0 in this region.

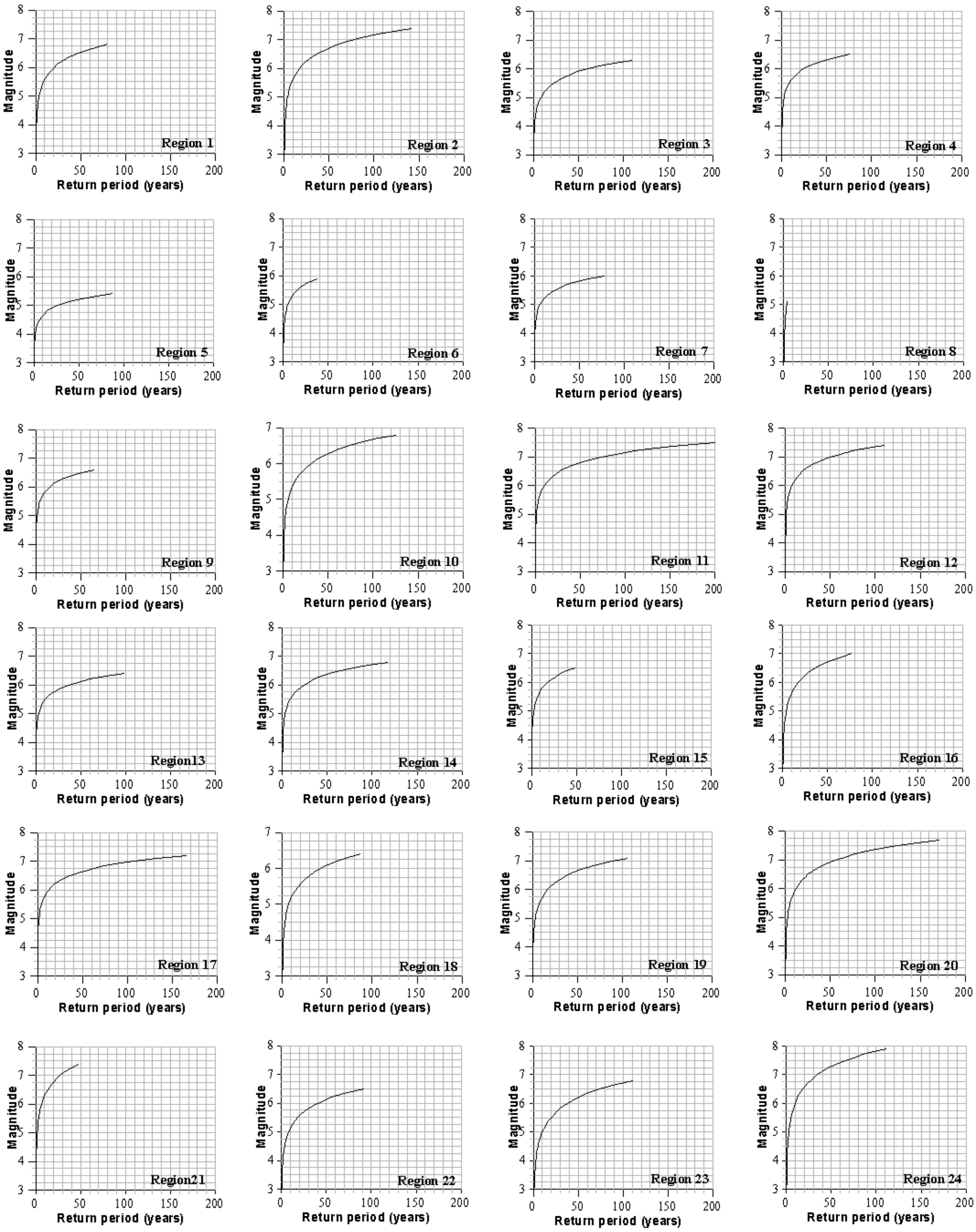

Figure 5. The mean return periods expected for given magnitudes in 24 seismic region of Turkey

Earthquake hazard curves expressed by the probability expected for earthquakes with the maximum observed magnitudes and plotted for magnitudes and during the time span of 25, 50 and 100 are shown in Figure 6. Spatial variability of the probabilities in the next 100 years, P_{100}, with a magnitude≥7.0 in each 24 seismic regions are shown in Figure 7. The P_{100} is divided in four groups of grey scale indicated in this way regions with different probabilities. The probability of occurrence for the earthquakes with M_S≥7.0 is greater than 75 percent in NAFZ and Aegean subduction zone. Especially, region 21 (central part of NAFZ) has a very high probability value calculated as 98%. The second level probability of occurrence values ranges between 65% and 75% are related to regions 11, 16 and 19. The first level probability of occurrence value smaller than 65% is related to KSZBF and YGMUEF (abbreviations are given in Table 1). In the other regions with white color, we cannot expect an earthquake for magnitude M_S≥7.0 in the next 100 years.

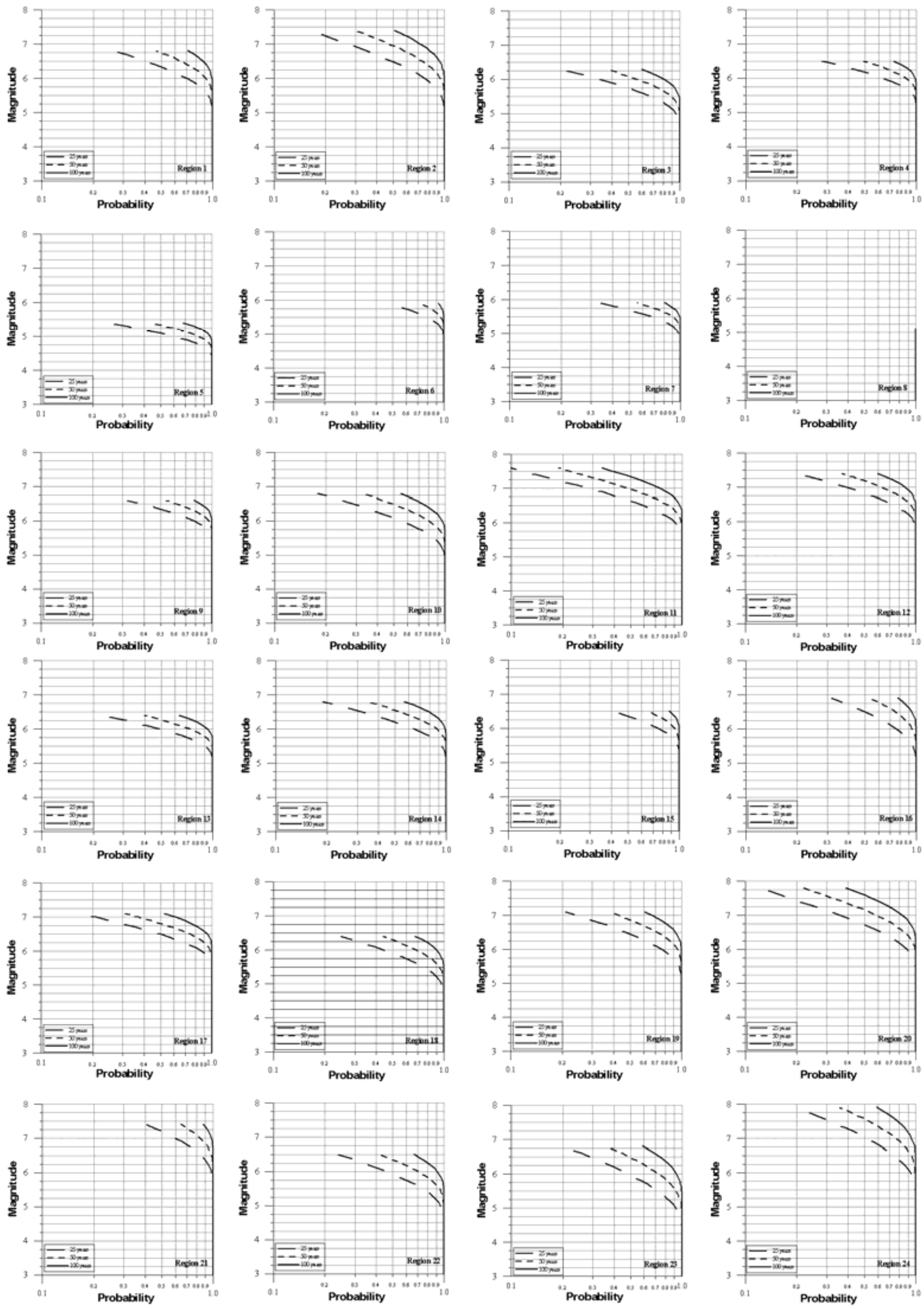

Figure 6. The probability that a given magnitude M will be exceeded in the time period T=25, 50 and 100 years, for 24 seismic regions of Turkey

Regional variability of most probable maximum magnitudes to be occurred in the next 100 years for each 24 region is shown in Figure 8. Also, a list of the most probable maximum magnitudes for the certain times is given detailed in Table 2. We divided M_{100} values into four groups as shown by legends with different grey scale in Figure 8.

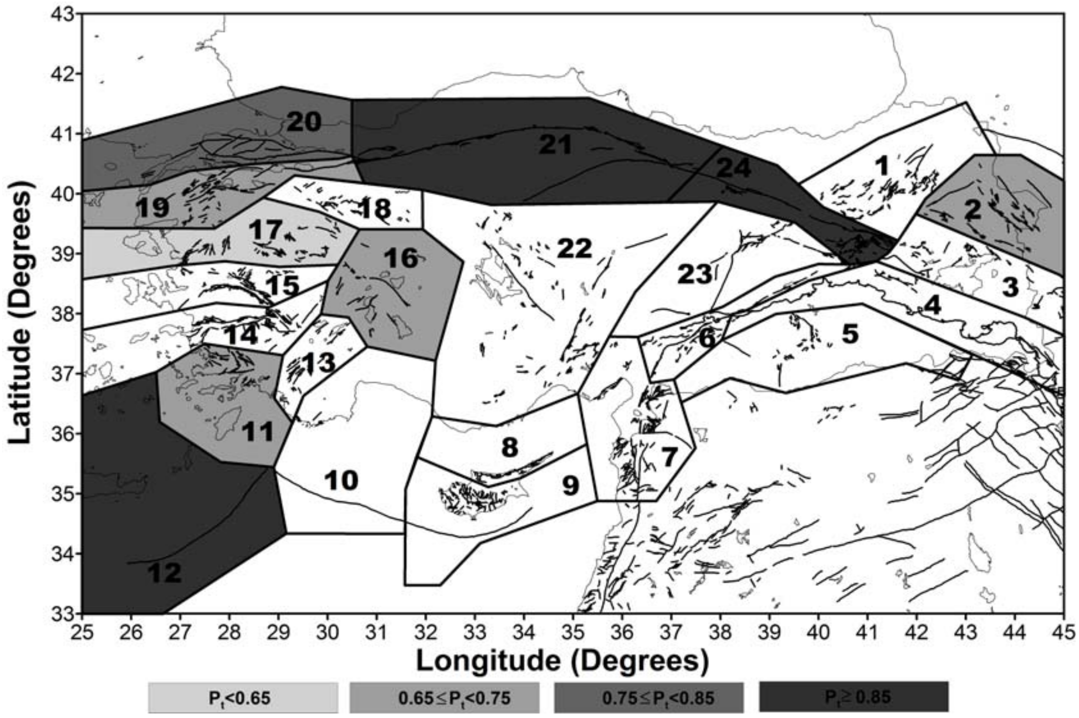

Figure 7. Probabilities in the next 100 years with a magnitude≥7.0 for different 24 seismic source regions in and around Turkey. In regions with white color, there is not an earthquake probability of occurrence for magnitude M_S≥7.0 in the next 100 years.

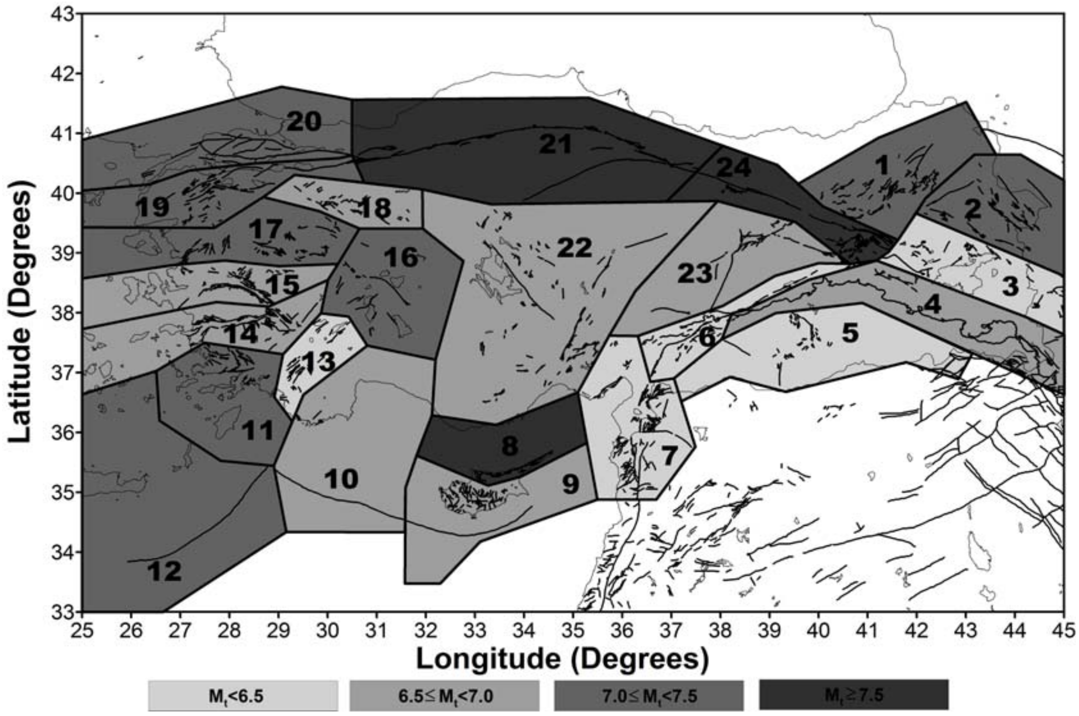

Figure 8. Maximum earthquake size to be occurred in the next 100 years for different 24 seismic source regions in and around Turkey

In the next 100 years, the earthquakes with magnitude $M_S \geq 7.5$ were only estimated in the central and eastern parts of NAFZ and the northern Cyprus (region 8). The most probable maximum magnitudes depend on G-R parameters (Equation 5). Since region 8 includes too few data, we observed very low *b* value and very high M_{100} value in this region. The central part of NAFZ (region 21) has the maximum earthquake hazard level in and around Turkey according to computed M_{100} value as 7.9. Bayrak et al. [12] calculated the earthquake hazard level for 24 seismic regions of Turkey used in this study from *K* index, defined as relative earthquake hazard scale. They found that the central part NAFZ between Bolu and Erzincan (particularly region 21) is of very high level because it is unbroken for very large earthquakes ($M_S \geq 7.8$, like those in Erzincan in region 24 and İzmit in region 20). In addition, Bayrak et al. [13] estimated the seismicity in terms of the modal values (a_m/b) for each one of the 24 seismic region and concluded that NAFZ (regions 20, 21 and 24) are ranked to the first position according to their seismicity. We computed M_{100} value of the region 21 in accordance to the results of the studies mentioned above.

5. CONCLUSIONS

In this study, an effort is made in order to assess the earthquake hazard for different regions in and around Turkey. The seismic source zones used in this study are defined according as Bayrak et al. [12]. The database used in this study is taken from Bayrak et al. [17]. Turkey earthquake catalogue from 1900 to 1974 come from the International Seismological Centre and instrumental catalogue of KOERI. The earthquakes, starting from 1974 until 2005, are taken from the Boğaziçi University, Kandilli Observatory and Earthquake Research Institute. The parameters *a* and *b* of magnitude-frequency relationship is estimated by the least square method for 24 seismic regions. Also, the hazard parameters such as the mean return periods, the most probable magnitude in a time period of *t*-years and the probability of earthquake occurrence for a given magnitude during a time span of *t*-years are estimated. The results lead us to a general conclusion that region 21 (central part of NAFZ) is probably the next region for the occurrence of a large earthquake. This region between Bolu and Erzincan is unbroken since 1943 with magnitude M_S=7.2. This conclusion is strongly supported from the probability map in which shows that the largest value (98%) for an earthquake with magnitude greater than or equal to 7.0. The mean return period for such magnitude is the lowest in the region (27-years). We also estimated the most probable earthquake magnitude in 100 years. This parameter also supports our conclusion that in the specific region the most probable earthquake magnitude in the next 100 years will exceed 7.5. This can be a kind of a proposition to the Turkish authorities to have an open eye to this particular region. The maps of (Figs.5 and 6) provide brief atlas which both depict variations of earthquake hazard throughout Turkey and the adjacent areas. As a result the G-R parameters by LS for a region having quite little number of data do not reflect tectonics because the computed lower *b* value and higher M_{100} value in the region 8 are almost related to too few data. In order to quantify answers to question how high is the seismicity of a region; numerate methods of earthquake hazard are essential and provide a clear statistical guide. Thus, an attempt is made to form a simple quantitative classification of the studied regions in terms of their earthquake hazard.

6. REFERENCES

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