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Seismicity of the Southern Marmara Region (Türkiye) before and after the August 17, 1999 İzmit earthquake

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Abstract:

In the present study seismicity of the Southern Marmara Region before and after the 1999 İzmit earthquake are analyzed and compared. A homogeneous seismicity catalogue that have completeness above the M_C=2.9 and covers the time period between 1978 and 2020 is used. Comparison of the spatial mapping of the frequency-magnitude distribution before and after the 1999 İzmit earthquake revealed that *b*-values demonstrate a general increase after the earthquake indicating a general stress decrease in the region. The shortest computed T_L value of about 450 years in the east of city of Bursa vanished after the 1999 earthquake. The computed time variations of *b*-value have shown an increase from 0.8 to 1.6 between 1978 and 1997 and an anomalous increase from 1.1 to 2.1 between 2000 and 2006. After 2006, *b*-values have decreased from 2.1 to 0.8, implying that decreased stress after the 1999 İzmit earthquake begun to increase after that year.

Key words: The Northern Anatolian Fault Zone, The Southern Marmara Region, 1999 İzmit earthquake, seismicity parameters

1. Introduction

Main active tectonic property of the Marmara Region is the North Anatolian Fault Zone (NAFZ) [1] (Fig. 1a). The NAFZ enters the Marmara region at its east section and bifurcates into three fault strands, the Northern, Middle and Southern strands [2]. The northern strand passes under the Sea of Marmara while the other strands extend all over the Southern Marmara Region (Fig. 1b) [3]. The middle and southern strands produced a number of destructive large earthquakes over the past twenty centuries as revealed from the historical sources (Fig. 1b) [4, 5] indicating high seismic activity in the region.

In the present study seismicity of Southern Marmara region both in historical and instrumental periods is investigated. Large earthquakes in the last two millennia are used to define fault segments that not produced large earthquake for a long-time. The instrumental seismicity is analyzed to calculate *b*-values of the frequency-magnitude distribution (FMD) [6]. The results will then be utilized to interpret earthquake hazard in the study area.

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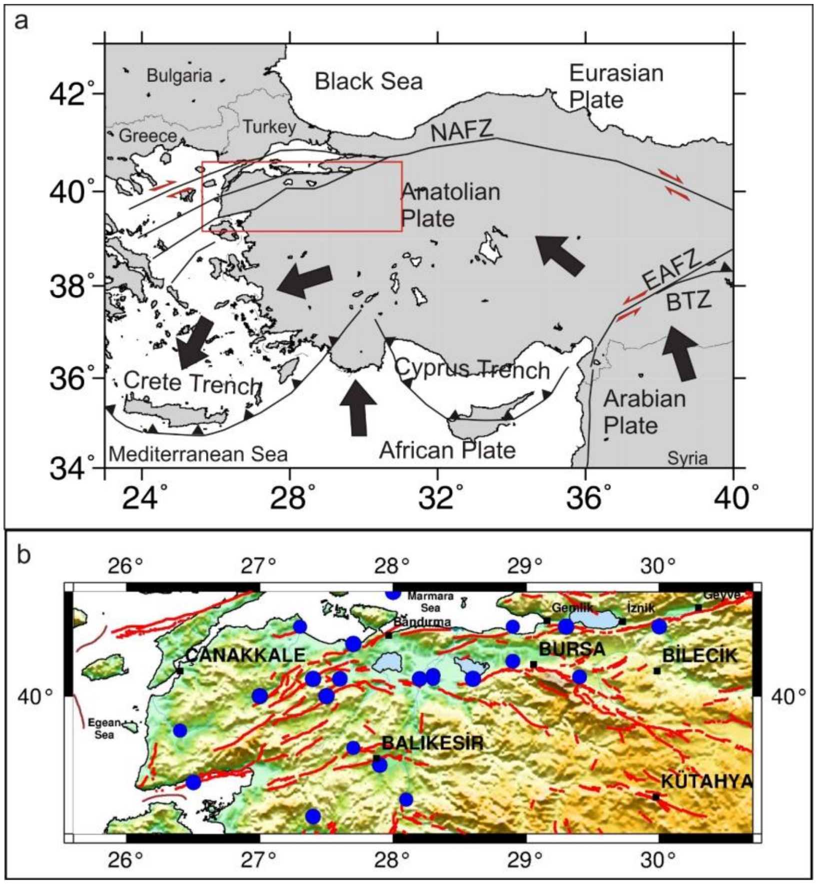

Figure 1. (a) The map demonstrating main tectonic elements of Türkiye. Red rectangle encloses the study area (b) The epicentral distribution of the $M_S \geq 6.8$ earthquakes occurred in the Southern Marmara Region, NW Türkiye, after 1 AD and $M_S \geq 6.0$ earthquakes after 1800 (compiled from [4, 5, 7])

2. Method

The relationship between the size of an earthquake and its frequency of occurrence named as FMD [6] and defined as:

$$\log_{10} N = a - bM \tag{1}$$

where N cumulative number of earthquakes with a magnitude exceeding a given magnitude, *M*, and *a* and *b* are constants. The constant *a* is positively related to level of seismic activity. The *b*-value has been shown to be inversely related to the shear stress in the crust [8]. After determining the FMD relation from the seismicity catalogue probabilistic recurrence time (T_r) of an earthquake of targeted magnitude (M_{targ}) can be estimated by

$$T_r = \frac{\Delta T}{10^{(a - bM_{targ})}} \tag{2}$$

where ΔT is the recording period covered by the seismicity catalogue. To calculate b-value, we have used the maximum likelihood method [9].

$$b = \frac{\log_{10} e}{(M_{mean} - M_{\min})} \tag{3}$$

where M_{mean} is the average value of magnitude and $M_{\min}$ is the minimum magnitude of completeness in the seismicity catalogue to be analysed. A software package called *ZMAP* is used for mapping b-value of FMD and T_L value, which is a finer scale estimation of T_r, as a function of space [8].

3. Seismicity

The Southern Marmara region is a seismically active area with a number of destructive large earthquakes over the past two millennia as compiled from the historical seismicity (Fig. 1b), [4, 5, 7]. The seismicity data used in the study is taken from homogenized catalogue published by Tan (2021), which is based on the earthquake parameters obtained from ISC seismicity bulletins. The catalogue of Tan (2021) covers the time period from 1900 to October 2018 and is based on moment magnitude. The catalogue is extended till July 2020 using Kandilli Observatory and Earthquake Research Institute (KOERI) catalogue. After initial checking of the catalogue the seismicity after 1978 is decided to be used in the seismicity analysis (Fig. 2).

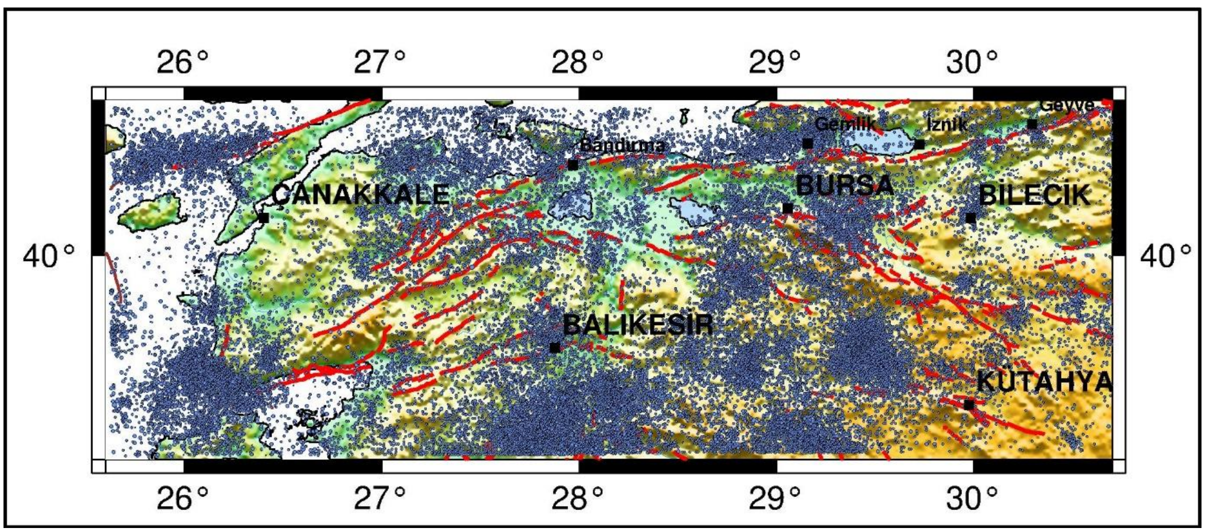

Figure 2. Map showing seismicity of the study area after 1978.

Cumulative number of earthquakes and FMD for the declustered seismicity data are shown in Fig. 3. Fig. 3 indicate that magnitude of completeness (M_C) is 2.5. Nevertheless, cumulative number of earthquake curves indicate relatively nonhomogeneous seismicity data (Fig. 3a). Cumulative number of earthquakes and FMD of the declustered seismicity data for M>=2.9 are shown in Fig. 4 which indicates relatively homogeneous seismicity. Therefore M>=2.9 seismicity is used in the analysis.

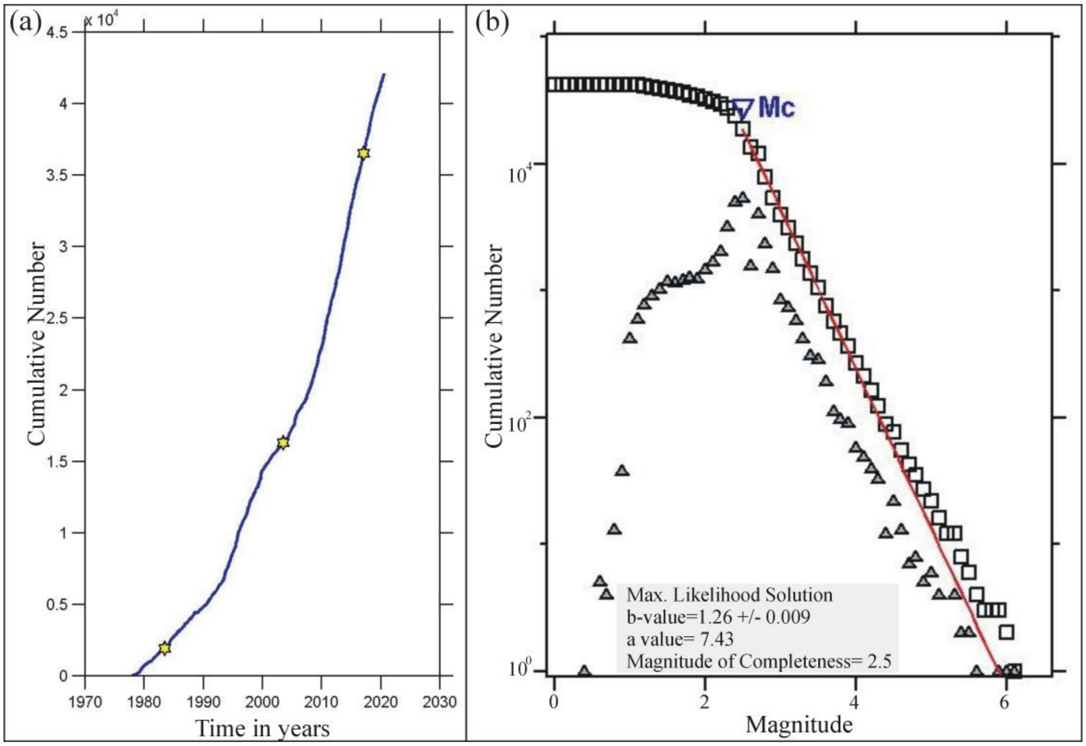

Figure 3. (a) Cumulative number and (b) frequency magnitude distribution of earthquakes for the declustered seismicity of the Southern Marmara Region between 1978 and 2020.

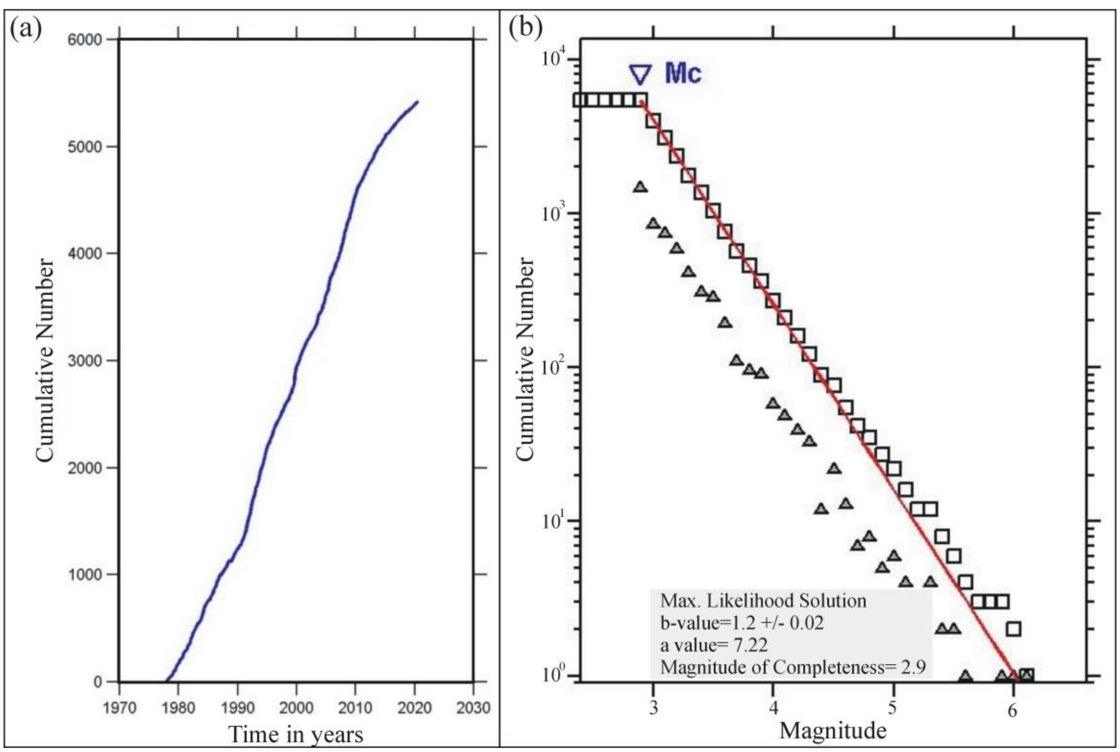

Figure 4. (a) Cumulative number and (b) frequency magnitude distribution of earthquakes for the declustered M>=2.9 seismicity of the Southern Marmara Region between 1978 and 2020.

4. Results

In order to compare seismicity of the Southern Marmara Region before and after the 1999 İzmit earthquake spatial mapping of the FMD distributions are carried out [8]. The cylindrical data volumes with radius of 15 km that are centered at grid nodes separated by 0.015 are utilized for the spatial mapping. The minimum number of events within the cylindrical data volumes are set to 50. The results of the calculations are demonstrated as the spatial distributions of b and T_L values. The spatial mapping is first implemented for the seismicity before the 1999 İzmit earthquake or for the rime period between 1978 and 1999. The results of the seismicity analysis before the 1999 İzmit earthquake are demonstrated in Fig. 5. Fig. 5 indicates that b *and* T_L values are changing in the range 0.78-2.3 and 130-660 years, respectively. As apparent from Fig. 5b one of the shortest T_L value of about 450 years is computed in the east of Bursa.

Results of the seismicity analysis for the seismicity after the 1999 İzmit earthquake are shown in Fig. 6. Anomalously low b-value is notable in Gemlik Bay and Karabiga areas and SW tip of Biga Peninsula (Fig. 6a). Fig. 6b indicates longer T_L values of as much as 1500 years. The shortest T_L value for the Southern Marmara Region is computed for offshore SW of Biga Peninsula.

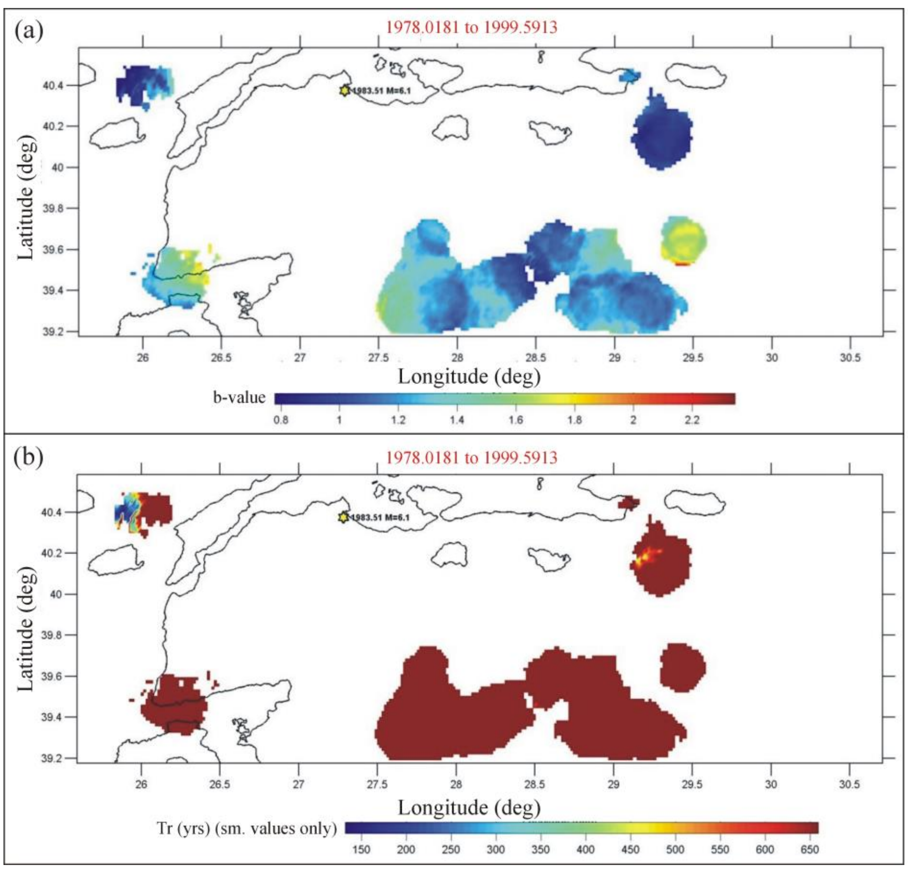

Figure 5. Spatial distributions of (a) b-value and (b) local earthquake recurrence times-T_L (targeted event has Mw=7.0) obtained for the declustered M≥2.9 seismicity of the Southern Marmara Region between 1978 and 1999.

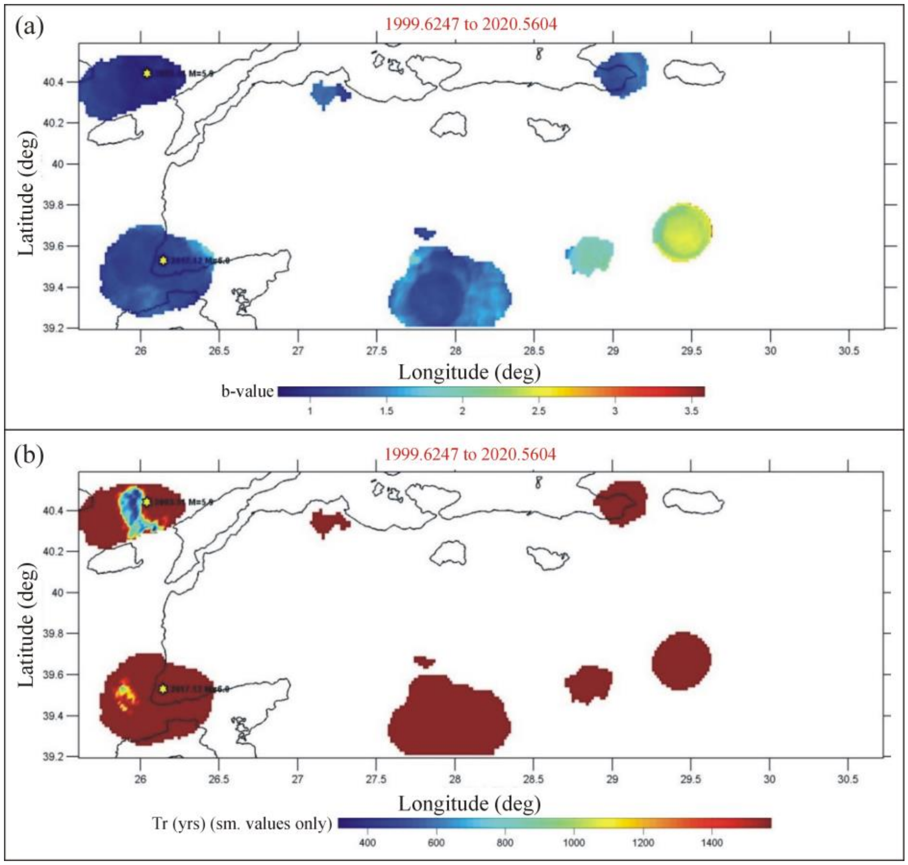

Figure 6. Spatial distributions of (a) *b*-value and (b) local earthquake recurrence times-T_L (targeted event has Mw=7.0) obtained for the declustered M≥2.9 seismicity of the Southern Marmara Region between 1999 and 2020.

5. Discussions

Comparison of Figs. 5 and 6 indicates significant changes of seismicity within the Southern Marmara Region. The computed *b*-values demonstrate a general increase. For example, anomalously low *b*-value area in the east of Bursa (Fig. 5a) vanishes after the 1999 İzmit earthquake (Fig 6a) while a new one appears in Karabiga Area. Gemlik, Balıkesir and SW of Biga Peninsula areas show decrease in *b*-values. T_L values show about two-fold increase after the 1999 İzmit earthquake in coincidence with general increase of *b*-value, indicating a general stress decrease in the Southern Marmara Region.

We also computed *b*-value time variations. The result is shown in Fig. 7. Fig. 7 indicates that *b*-value increased from 0.8 to 1.6 between 1978 and 1997 and exhibited short-time variations both decrease and increase before the 1999 İzmit earthquake. After occurrence of the 1999 İzmit earthquake *b*-values demonstrated an anomalous increase from 1.1 to 2.1 between 2000 and 2006. This implies that the 1999 İzmit earthquake decreased the stress in the crust. After 2006 *b*-values have decreased from 2.1 to 0.8 indicating that the stress begun to increase after 2006.

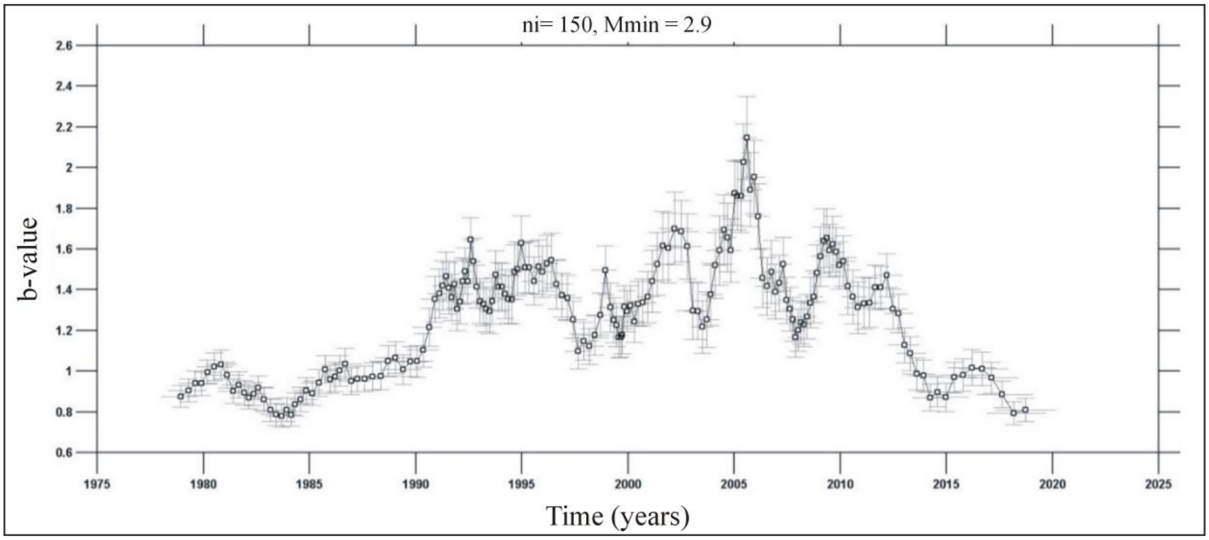

Figure 7. *b*-value variations with time for the declustered M>=2.9 seismicity of the Southern Marmara Region between 1999 and 2020.

[10] pointed out that the fault segments of the Northern Strand have a mean recurrence interval of 250-300 years and the other strands have at least twice larger intervals (600-700 years) comparing with the Northern Strand for a target event of M_W=7.4 using the seismicity between 1981 and 1999. T_L value of 450 years calculated for the east of Bursa in the present study agrees on larger earthquake intervals for the middle and southern strands. Since historical earthquake activity indicates no large earthquakes in the last 400 years for the fault segments of the NAFZ extending along Geyve, İznik, Gemlik and Bandırma geographic line, suggesting relatively higher earthquake hazard.

Conclusions

Seismicity of Southern Marmara region both in historical and instrumental periods has been studied. A homogeneous seismicity catalogue that have completeness above the M_C=2.9 and covers the time period between 1978 and 2020 has been analyzed. The seismicity before and after 1999 İzmit earthquake is compared. Comparison of the spatial mapping of the frequency-magnitude distribution before and after the 1999 İzmit earthquake has shown that *b*-values increase after the earthquake indicating stress decrease in the region. The shortest computed T_L value of about 450 years in the east of Bursa vanished following the 1999 earthquake. The computed time variations of *b*-value have demonstrated an increase from 0.8 to 1.6 between 1978 and 1997 and an anomalous increase from 1.1 to 2.1 between 2000 and 2006. After 2006 *b*-values have decreased from 2.1 to 0.8, implying that decreased stress after the 1999 İzmit earthquake begun to increase after 2006.

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References

[1] Şengör A. M. C, Tüysüz O, Imren C, Sakınç M, Eyidoğan H, Görür N, et all. The North Anatolian Fault: A new look. Annu. Rev. Earth Planet. Sci. 2005; 33; 37–112.

[2] Barka A, Kadinsky-Cade K. Strike-slip fault geometry in Turkey and its influence on earthquake activity. Tectonics 1988; 7; 663-684.

[3] Yalçın H, Kürçer A, Utkucu M, Gülen L. Seismotectonics of the Southern Marmara Region, Nw Turkey. Proceedings of the 14th Thessaloniki, May 2016. Bulletin of the Geological Society of Greece 2016; 50(1); 173.

[4] Papazachos B C, Papazachou CB. The earthquakes of Greece. Ziti Publication, Thessaloniki 1997; 304.

[5] Ambraseys N. Earthquakes in the Mediterranean and Middle East: a multidisciplinary study of seismicity up to 1900. Cambridge University Press. 2009; ISBN: 978-0-521-87292-8.

[6] Gutenberg R, Richter C. F. Frequency of earthquakes in California. Bull. Seismol. Soc. Am 1944; 34; 185-188.

[7] Tan A. A homogeneous earthquake catalogue for Turkey. Nat. Hazards Earth Syst. Sci. 2021; 21; 2059–2073.

[8] Wiemer S, Wyss M. Mapping the frequency-magnitude distribution in asperities: an improved technique to calculate recurrence times. J. Geophys. Res. 1997; 102; 15115-15128.

[9] Aki K. Maximum likelihood estimate of b in the formula log N= a-bM and its confidence limits. Bull. Earthquake Res. Inst. Univ Tokyo 1965; 43; 237-239.

[10] Utkucu M, Budakoğlu E, Durmuş H. A Discussion on the Seismicity and Seismic Hazard of the Marmara Region (NW Turkey). Bulletin of the Earth Sciences Application and Research Centre of Hacettepe University 2011; 32 (3); 187-212.

Web References

http://www.isc.ac.uk

http://www.koeri.boun.edu.tr/new/