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Estimation of Seismicity Parameters and Hazard Assessment of Maragheh City, Iran

Shahrzad Nikoobakht[1], Mohammad Azarafza[2], Homayon Safaei[2]

[1]*Department of Geology, University of Yazd, Yazd, Iran,*
[2]*Department of Geology, University of Isfahan, Isfahan, Iran,*
e-mail:shahrzad.nikoobakht@gmail.com,m.azarafza.geotech@gmail.com,Safaei@sci.ui.ac.ir

Abstract: This paper endeavours to assess seismicity and seismical engineering parameters and zonation of Maragheh city by using the NGA modelling. A definitive objective of this system is giving seismicity parameters which evaluated by in NGA modelling, directly used to hazard assessment and building design where utilized forMaragheh city . In order to hazard risk assessment for the city, the Gutenberg-Richter and kijko - sellevoll methods after NGA is applied. As indicated by the figured outcomes, seismic coefficients of Gutenberg-Richter connection are (Log N_c=3.692-0.501M_w) a=3.692, b=0.501 by R^2=0.98 and kijko - sellevoll propelled strategy are Beta =1.15±0.08 (b=0.50±0.03) and Lambda=2.70±0.041 then M_{max}=9.70±0.52 for the city. Finally, in light of NGA models, the seismicity parameters for Maragheh city are PGV=27.3 (cm/sec), PGD=2.2 (cm) and PGA=0.19 (g). According to the assessment results of seismicity the Tabriz and Urmia- Zarinehrud faults are main rule on seismical activity and the city is located in most hazardous zone in Iran.

Keywords: Seismicity, Hazard Assessment, Maragheh City, PGA, NGA.

1. Introduction

Natural phenomena such as earthquakes, hurricanes, cyclones and droughts are typically inescapable and it is conceivable to decrease the harming impacts through various strategies. Quake is a standout amongst the most noteworthy and expansive scale land perils that could bring about genuine harm to urban communities [1]. Urban areas seismic hazard appraisal is a vital issue in urban planning. Having engineering known of the seismic state in locales would be extremely useful in arranging and gauging eventual fate of the city and crisis management. Recognition and itemized consideration of parameters related to earthquake events are those

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vital strides in seismicity examination in urban areas [2]. Maragheh city is the second biggest city in the East Azerbaijan region, northwest of Iran [3]. The aim of this study is to estimate the seismicity parameters, ground strong motion (GSM) and seismic zonation of this city. Location of Maragheh city is shown in Figure 1.

East Azerbaijan province is a critical dynamic seismical region of Iran where diverse recent and historical quakes have occurred. Altogether, Iran is a standout amongst the most defenceless nations to cataclysmic events, particularly seismic tremors that are commonly observed all through the country [2]. A huge number of recorded quake occasions are the clear signs of this claim [4].

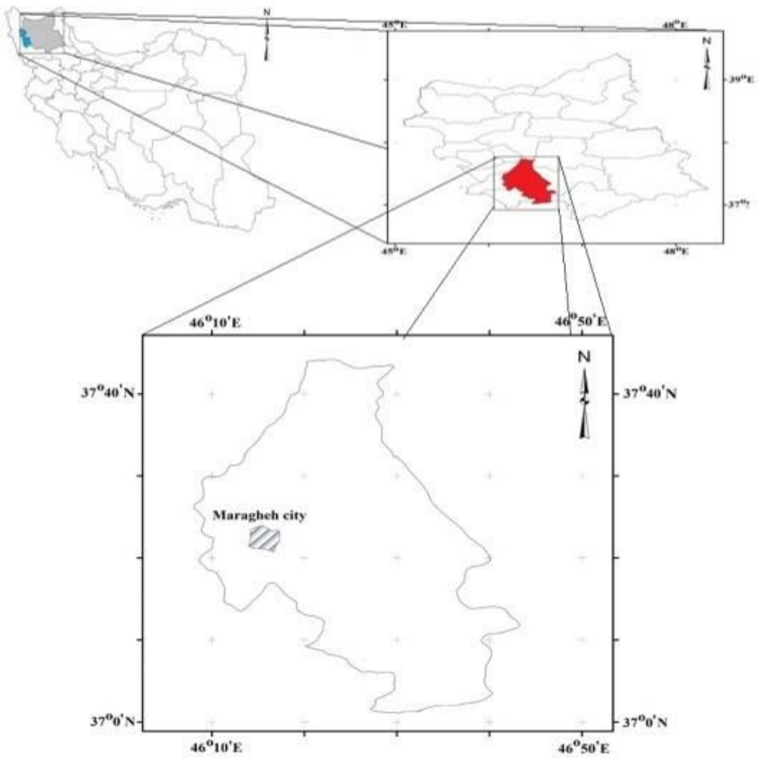

FIGURE 1. Maragheh city location in Iran.

2. Geological Setting

Maragheh is in an area amounted up to 2647 hectares stretches along Sofi-chay River and located in the foothills of Sahand Mountain and has semi-cold to cold climate in terms of climatological conditions [5]. As topographical condition, the Maragheh city is located in the valley of Sofi-chay River (a small valley that unearthed waterway of Sahand Mountain foothill) which is a basin for Sofi-chay River [6]. Given the geomorphological status of this city, it is mountain in the northern parts (the foothills of Sahand Mountain) and is flatted in the southwest named Maragheh-Bonab plain (Average altitude is 1485 m above sea level) [3]. For the geological state, Maragheh city has been made in alluvial aficionado of Sofi-chay river. The Sahand stratovolcan mountain (A stratovolcan known as a composite volcano is a conical volcano built up by many layers (strata) of hardened lava, tephra, pumice, and volcanic ash. Unlike shield volcanoes, stratovolcanoes are characterized by a steep profile and periodic explosive eruptions and effusive eruptions, although some have collapsed craters called calderas [7]) which is located in the northern city is made of pyroclastic, ignimbrites, dacite, felsic rocks and lavas. Therefore, the north and east parts of the city are on volcanic ashes and west of the city is covered by alluvium. Geographical formations around the city (from old to new ones) are SOLTANIEH DOLOMITE (massive dolomite, silty shale), BARUT formation (shale, red-purple, micaceous and dolomite), ZAIGUN formation (purple, silty shale and dolomite), LALUN SANDSTONE with TOP QZ (red sandstone, white top quartzite), MILA formation (sandstone, shale, dolomitic limestone), DORUD formation (sandstone, shale, quartzite), RUTEH formation (limestone wellbedded, fossiliferous), ELIKA formation (massive dolomite with thin bedded limestone), SHEMSHAK formation (shale, sandstone, coal lenses, laterite at the base), DALICHAI formation (marl, marl limestone, ammonites bearing), LAR formation (massive cherty limestone and dolomitic limestone), KARAJ formation (Green tuff, volcanic mainly andesite), MARAGEH BONE BEDs (Lava brecia, Tuff, poorly indurated claystone with bone beds) and Alluvial Formations include Q^{tr} (Teravertine), Q^{t2} (Old terraces and alluvial fan), Q^{t1} (Young terraces and alluvial fan), Q^{s} (Salt swanp) and Q^{al} (Recent alluvium) [8]. Figure 2 shows the geological map prepared for Maragheh city.Iran is structurally exceptionally dynamic because of its situation in Alps - Himalaya's belt and additionally is under compressive strengths by Arabian plate to Eurasia plate in SW-NE [9]. In the northwest of Iran (Azerbaijan) structural setting is more intricate than the entire country. This area is the piece of three Arabian, Eurasia and Aral tectonic plates and forehead compression stress with NNE-SSW strike [10]. The distribution of substantial tremors mechanism occurred in Iran is exhibited in Figure 3.

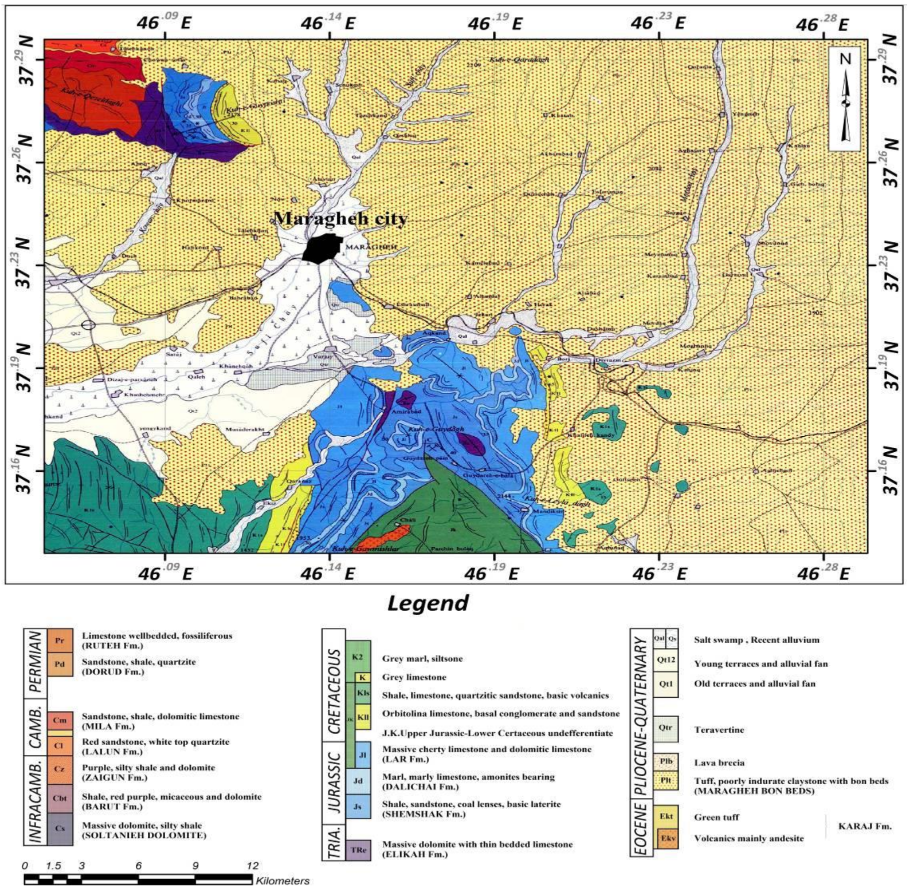

FIGURE 2. The geological map of Maragheh (Adapted from [6]).

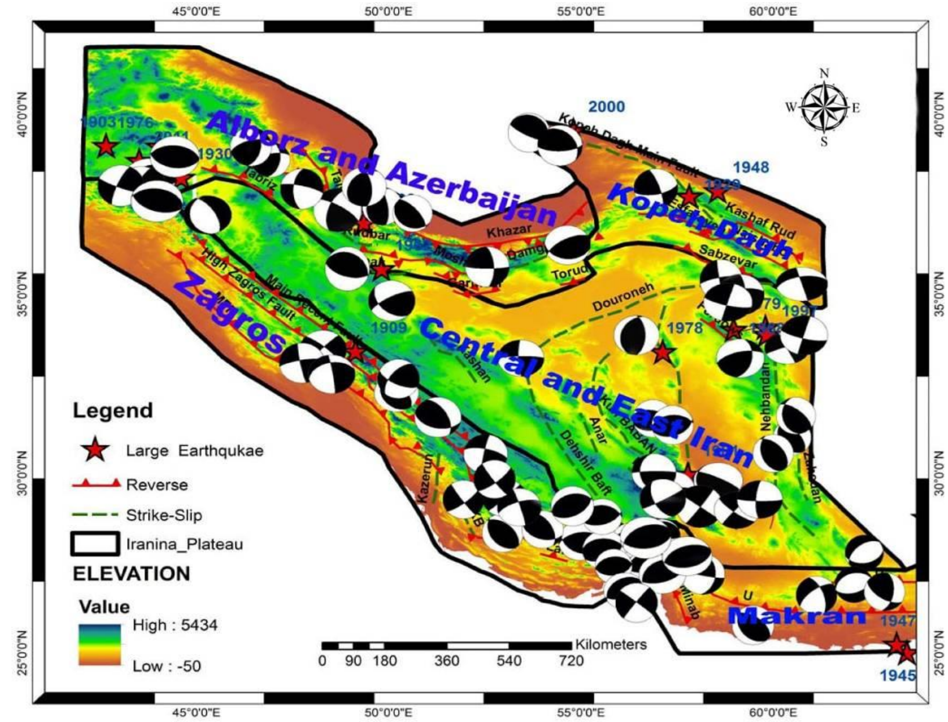

FIGURE 3. Distribution of substantial tremors mechanism occurred in Iran.

The studied area, referring to the seismotectonical classification by Nogol-Sadat and Almasian [11], is located in Tabriz - Esfahan zone (Figure 4).This zone is presented as one of the most dynamic seismic zones in the country. Substantial quantities of the quake events are demonstrative of the continuous movement of this zone [4]. High seismic activity of Maragheh city is followed in light of Arabian-Eurasia plates tectonical pressure in this area fault systems frameworks. General faults framework in the studied area can be viewed as follows:

Basement faults

Basement faults can be the main and older faults in the region which are not generally indicated in satellite images airborne photos due to the depth and coverage by Quaternary sediments. To distinguish these faults, geomagnetic magnetic intensity data were utilized, which were acquired in light of Aeromagnetic survey [12]. An aeromagnetic survey is a typical sort of geophysical investigations utilizing a magnetometer on board an airplane. The rule is similar, the magnetic survey carried out with a hand-held magnetometer, but it allows much larger areas of the Earth's surface to be covered quickly for regional reconnaissance [13]. In geomagnetic maps, faults headings are recognized by linear magnetic anomalies. In the seismotectonical considerations, distinguishing these shortcomings is imperative and assumed as a premise of the work. The geomagnetical map of studied area was provided and shown in Figure 5 According to this Fig., basement faults in the region, mostly in direction of NW-SE (in line with the Zagros) and some of the N-S were specified. A few numbers of faults in the basement of the NE-SW can be seen in the area. Most faults of this type are located in the southeast of Maragheh city.

The faults trend like Zagros fault general trend

The fault trends like Zagros fault trend, with their dominant reverse mechanism reception slip further into the NE. Slip surface geometry of a spoon and spread formations is limited deep in the second and third period [14]. These faults are generally small to moderate magnitudes earthquakes.

Strike-slip faults

Strike-slip faults extended to the north and south through the formation of the left lateral movement of the Arabian plate to Eurasia [15]. In addition, some researchers like Paul et al. [16] think that these faults prevent lateral displacement of the closing of the Zagros.

Normal faults

Although the study area is located in a compressional tectonic system, the formation of a normal fault in this situation is not expected, but these faults in the anticlines formed a limited basis.

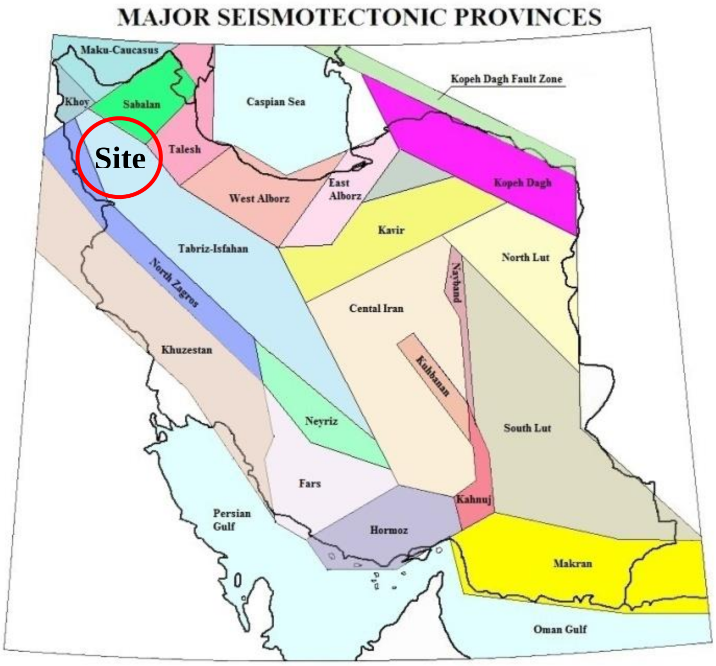

FIGURE 4. Seismotectonic provinces of Iran [11].

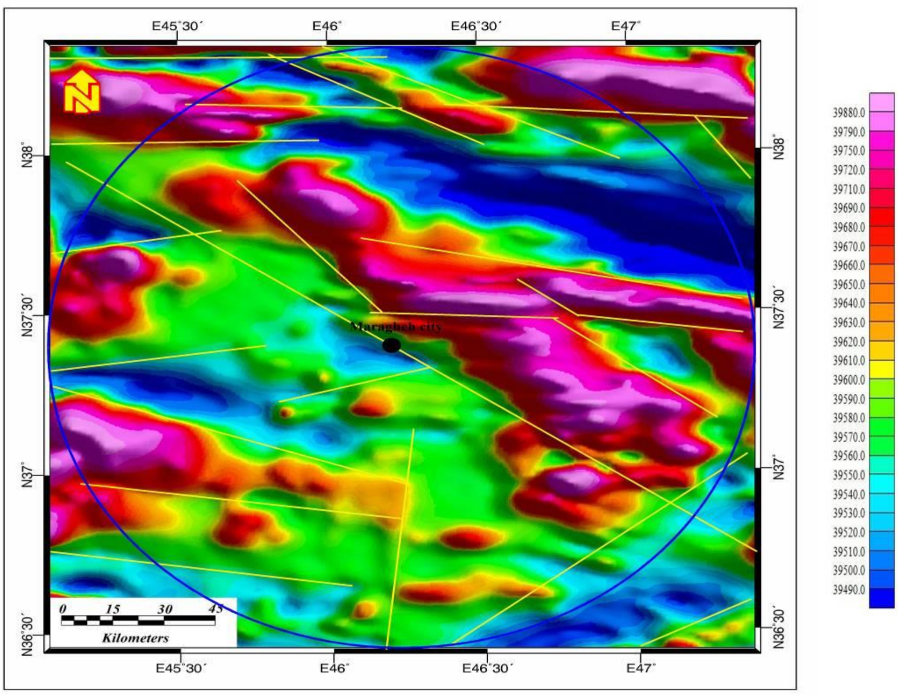

FIGURE 5. Geomagnetic map prepared of Maragheh in 100 km radius.

In general, the first step in seismic studies of urban areas is the specification of the seismical source or faults. This is usually performed in two ways, radial investigate or seismotectonic states. In radial investigations, an appropriate radius is used to identify tectonical lineaments and allocated occurred earthquakes in the specified radius of studied area. In order to achieve such a map, the satellite imagery is used as the basic images of tectonical lineaments mapping. The tectonical lineaments exploitation is mainly divided into two manual and automatic extraction methods. In the automatic way parameters such as filtering diameter, threshold line length, threshold line fitting, etc. are measured [17], but in this method the geological and geo-structural factors are ignored. In manual way, after filtering, colour composites (RGB process), spectral ratios, etc. the principal component analysis is controlled manually [18]. In present study, we used the manual lineament exploitation method. In addition, to enhance the accuracy of the analysis and tectonical lineaments identification, the geomagnetic images were used. In this study, for Maragheh region, the radial investigate method (100 km radius) by ETM+ [19] geomagnetic satellite images and geological maps were used to cover 100 km radius in order to complete the data of this radius seismical source. In this investigation, all active sources were considered. The reason of this consideration was high seismic activity of this area. The results of remote sensing surveys presented in Figures 6 to 8.

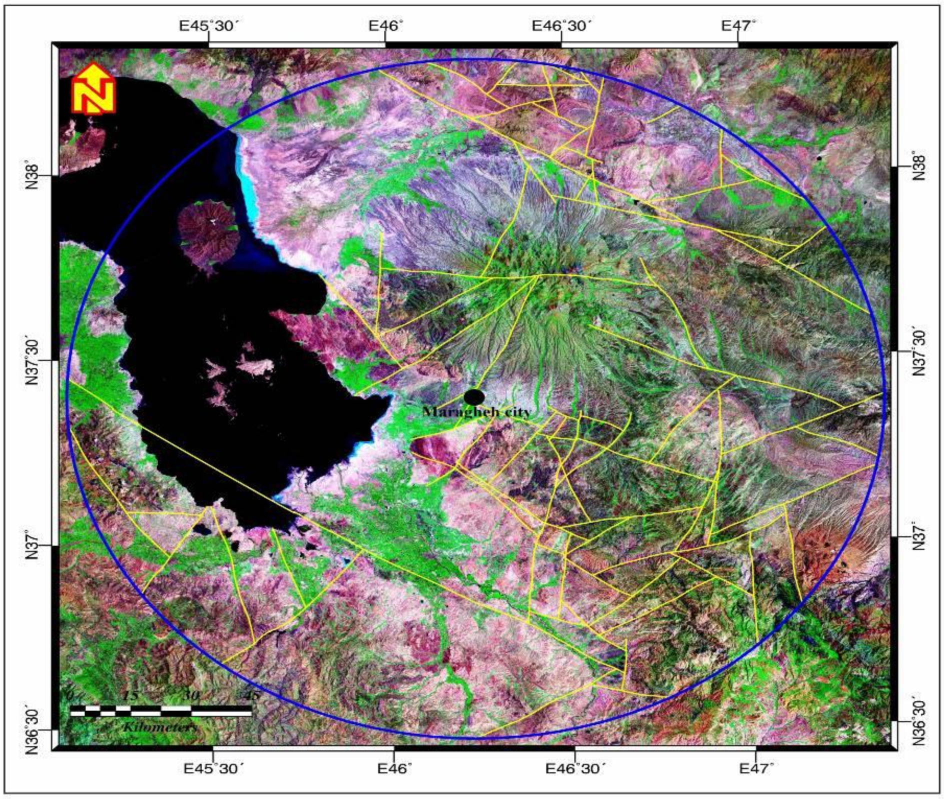

FIGURE 6. Faults and lineaments identified from ETM$^+$ images of city in100 km radius.

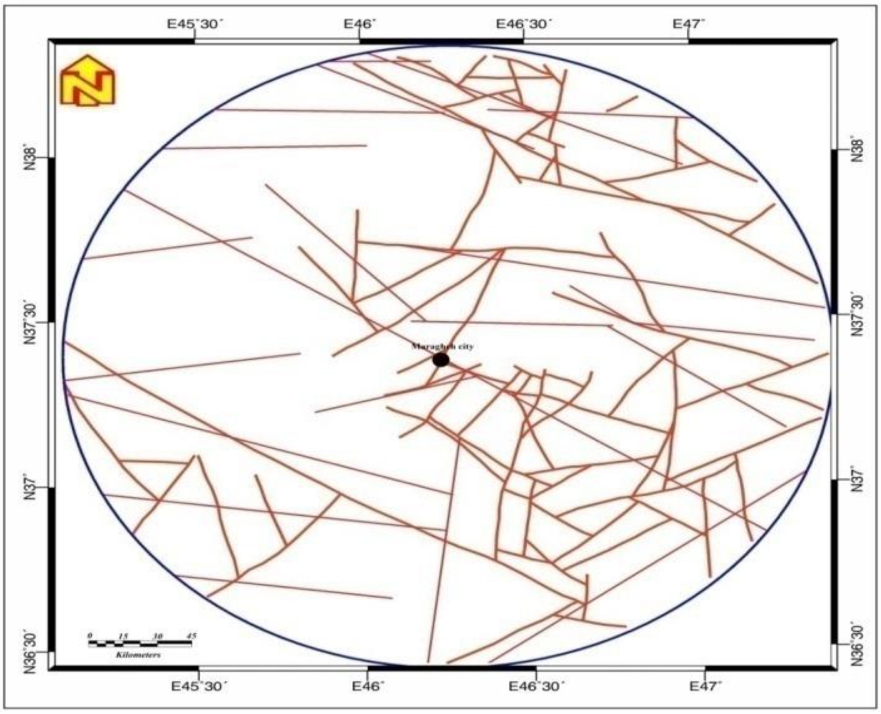

FIGURE 7. Main fault map prepared of Maragheh in 100 km radius

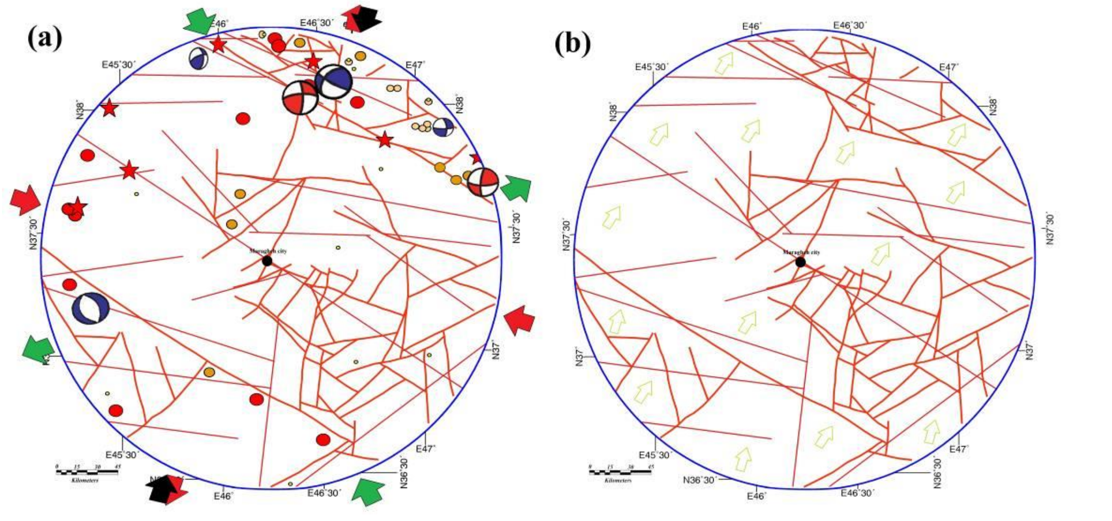

FIGURE 8. Geo-structural status of Maragheh region (a) results from the tectonically stress arrangement, (b) results separation of tectonically direction

3. Results and Discussion

3.1. Seismic hazard analyses

To assess the risk of an earthquake in a site (urban area or structural engineering) –seismic hazard analyses–it was needed to know the existing tectonic seismotectonical status of the site

[20]. In addition, identification and classification of occurred earthquakes data (an indicator of seismic activity) were very important. In General, in order to assess and analyse seismic hazard after tectonic studies of the site, the first step was preparing a suitable database of local earthquakes events. With this database, seismic features of studied site were assessed and interpreted. In the second step in the seismic analysis seismic parameters were calculated by various deterministic methods. The final step was seismical zonation of site by earthquake activity.

3.2. Seismic database

Earthquake occurrences indicate seismic activity in each region and detailed study of these events (past to present) can be helpful in Seismic assessment of the areas. In earthquake engineering, identification and gathering earthquake data is the first phase of the seismic study. This phase can be done by using appropriate statistical methods to estimate and assess events. A list of earthquakes in the study area was prepared in three main categories. Aim of preparing the list was to provide a suitable seismic database of the situation and characteristics of earthquakes in the studied area. These categories comprise a list of historical and instrumental earthquakes. The instrumental list is divided into two parts, the twentieth century earthquakes data and the present earthquakes data [2].

Given the relatively short time interval of the recorded instrument earthquakes (about a hundred years), as compared to the return period of major seismic events, the use of historical earthquakes in the calculations is very necessary [20]. In historical data mapping, the earthquake events prior to 1900 has been written, recorded and mapped. The main references used in this article include “A history of Persian earthquakes” [21] and “Natural hazards and the first earthquake catalogue of Iran” [22]. By the beginning of the twentieth century, earthquakes events recording by devices led to the establishment of Global Seismographic Network (GSN) after several decades. The GSN is a +150 station, globally distributed, state-of-the-art digital seismic network that provides free, real time, open access data through the IRIS DMC [23]. In general, twentieth century earthquake data refers to earthquakes that occurred in the period from 1900 to 1963 [21]. After the establishment of GSN (After 1963), all occurred earthquakes have been accurately recorded (named present earthquakes data). Recent data have minimal errors as compared to other two categories. Due to the differences in the type of magnitude scale in recorded events like surface-wave magnitude (Ms), body-wave magnitude (m_b), local magnitude (ML) and recently moment magnitude (M_w), it was necessary to prepare a seismic database of magnitude scale unification in order to reduce the error rate in data [24]. In this study, the moment magnitude (M_w) was used due to the strong basic mathematics and lack of saturation in high magnitude value in the database.

3.3. Seismicity parameters estimation

In earthquake hazard assessment, estimation of long-term probabilities of earthquake occurrences parameters is the most important issue. Various methods have been used to estimate earthquake hazard parameters (like Lambda, M_{max}, Beta, etc.), such as Gutenberg-Richter relationship and kijko-sellevoll method [25]. The G-R relationship was used as a standard way to normalize uncertainty in estimating earthquake magnitudes [26]. Kijko-sellevoll method, similar to G-R method, was used for estimation of earthquake hazard parameters. Earthquake return period (1, 50, 100, 475 and 2475 years), annual event distribution of earthquakes and probability of occurrence were calculated with this method [25]. According to seismic database obtained from the study area (100 km radius of city), seismicity parameters of site were estimated by using the G-R method [26] and kijko-sellevoll advanced method [27]. The results of the parametric estimation are presented below.

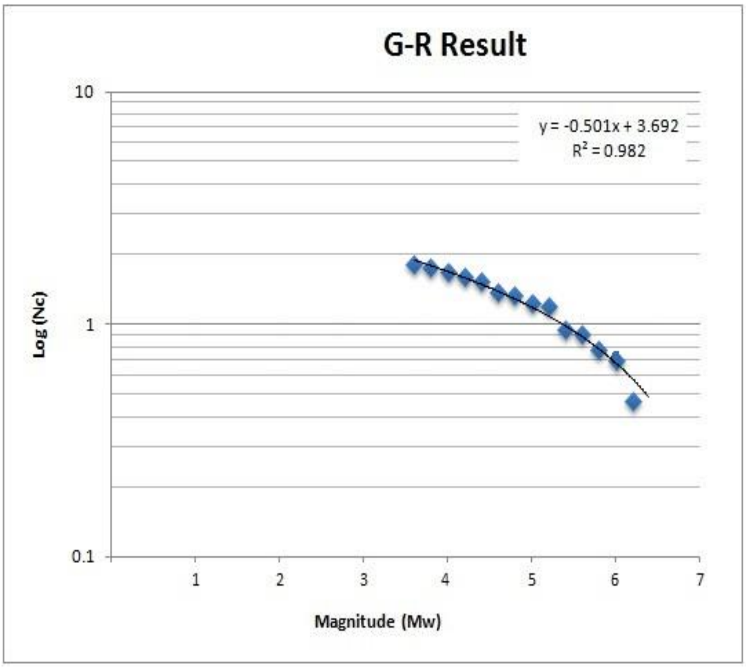

FIGURE 9. The relationship between cumulative frequency (N_c) and moment magnitude (M_w) based on G-R method.

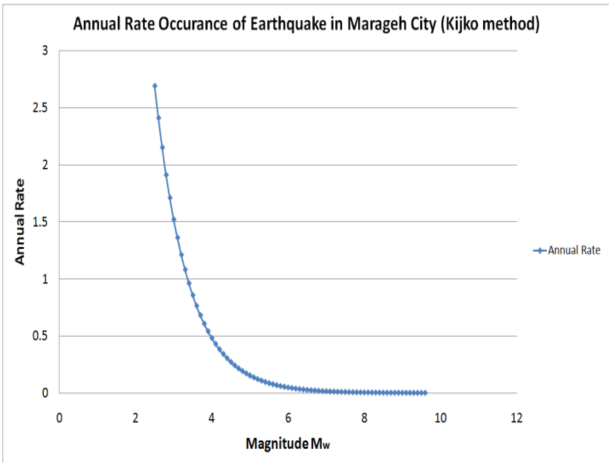

FIGURE 10. Annual event distribution of earthquakes in 100 km radius of city (Kijko method).

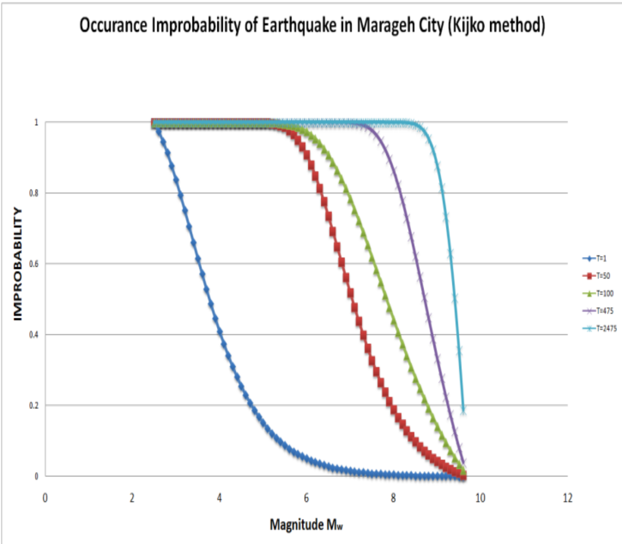

FIGURE 11. Probability of occurrence of earthquakes in 100 km radius of city (Kijko method).

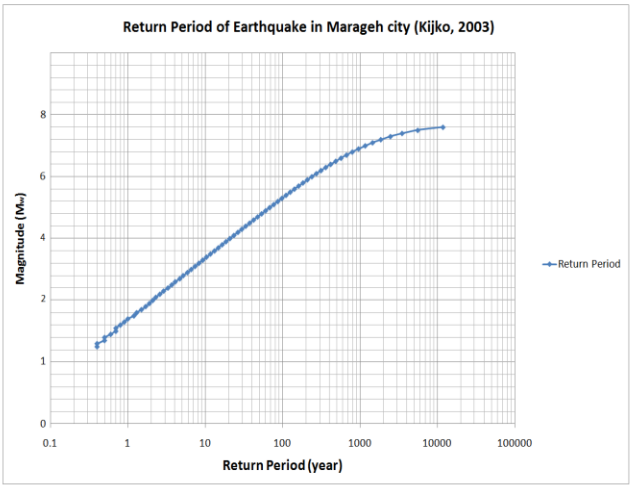

FIGURE 12. Recurrence of earthquakes in 100 km radius of city (Kijko method).

TABLE 1. The values of the parameters and coefficients by G-R relation.

G-R Method in R=100 Km around of the City				
M_w		Data Results		
From (≤)	To (<)	No.	No. Cum.	Log (N_c)
3.5	3.7	9	66	1.82
3.7	3.9	9	57	1.75
3.9	4.1	8	48	1.68
4.1	4.3	7	40	1.60
4.3	4.5	9	33	1.52
4.5	4.7	2	24	1.38
4.7	4.9	5	22	1.34
4.9	5.1	1	17	1.23
5.1	5.3	7	16	1.20
5.3	5.5	1	9	0.95
5.5	5.7	2	8	0.90
5.7	5.9	1	6	0.78
5.9	6.1	2	5	0.70
6.1	6.3	2	3	0.47
6.3	6.5	1	1	0.00
Regression Output		G-R Relation		
a	3.692	Log (N_c)=a-bM_w		
b	0.501	Log (N_c)=3.692- 0.501 M_w		
SD	0.25			
R^2	0.982			

TABLE 2. The values of the parameters and coefficients by Kijko - Sellevoll method.

Number of earthquakes	72
Beta	1.15±0.08(b=0.50±0.03)
Lambda	2.70±0.041
M_{max}	8.7±0.52

3.4. Seismicity zonation

Seismicity zonation or specification of the seismic equipotential places is the final step in mapping of hazard potential in each region. The purpose of zonation is mapping the situation under risk (hazardous effect) of a particular phenomenon such as earthquake. According to the distribution of earthquakes epicenters, intensity and magnitude of the events and seismic sources, the seismicity zonation of Maragheh city was produced and shown in Figure 13.

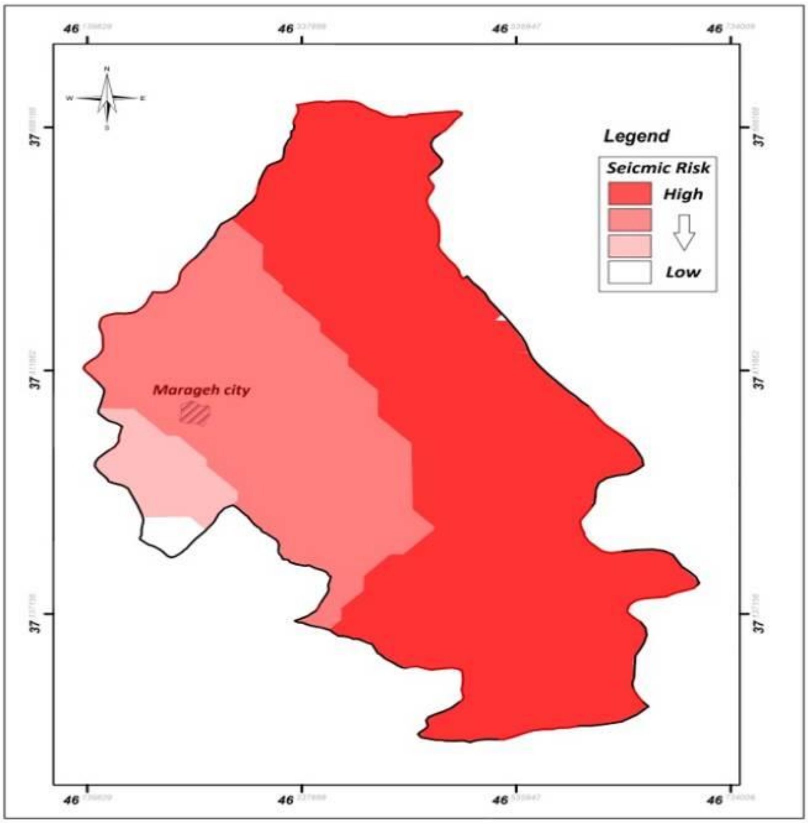

FIGURE 13. Seismicity zonation map of Maragheh.

4. NGA Modeling

To predict strong ground motion (GSM), various relations mentioned that each relation has certain advantages [28, 29]. The equations relate ground shaking to earthquake magnitude, distance from source, style of faulting, rupture characteristics (depth to top of rupture, hanging-wall and foot-wall shaking differences, and so forth), and ground-motion modifications along the path between the source and the site [30]. In this study, the ground motions were calculated for each fault resources in the study area, which used the Campbell and Bozorgnia relation [29]. Parameters considered in this method are presented in Table 3 and Figure 14. When the fault is entirely on outcrop of surface, the value of Z_{TOR} is ZERO (0) and the city is in the footwall $R_{RUP} = R_{JB}$. In addition, Maragheh city is considered V_{s30} equal to 600 (m/sec). Based on the above statements, the NGA model results of city estimation are shown in Table 4 and Figure 15.

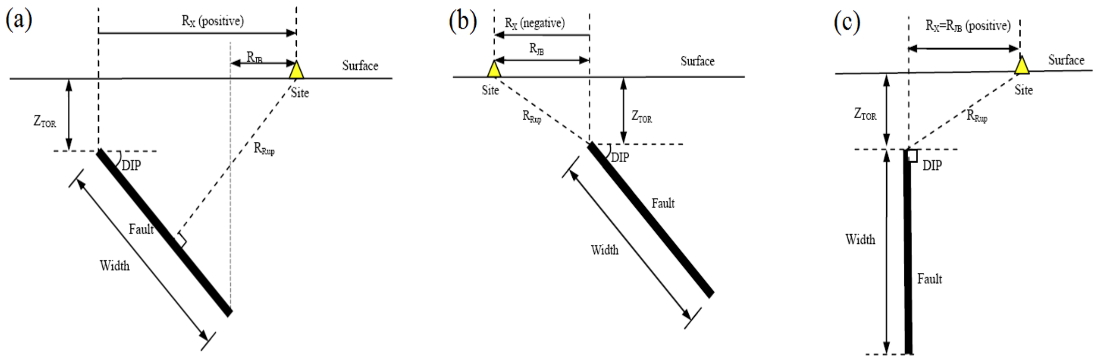

FIGURE 14. Consideration of the parameters: (a) Reverse or normal faulting, hanging-wall site, (b) Reverse or normal faulting, foot-wall site, (c) strike-slip faulting

TABLE 3. The values of the parameters in NGA model

No.	Parameters	Definition
1	PSA	Pseudo-absolute acceleration response spectrum (g: 5% damping)
2	PGA	Peak ground acceleration (g)
3	PGV	Peak ground velocity (cm/s)
4	PGD	Peak ground displacement (cm)
5	M	Moment magnitude (M_w)
6	RRUP	Closest distance to coseismic rupture (km)
7	RJB	Closest distance to surface projection of coseismic rupture (km)
8	FRV	Reverse faulting factor (1 for reverse, thrust, oblique, 0 for other)
9	FNM	Normal faulting factor (1 for normal Fault and 0 for other)
10	ZTOR	Depth to top of coseismic rupture (km)
11	δ	Average dip of rupture plane (degree)
12	V_{S30}	Average shear-wave velocity in top 30m of site profile
13	A_{1100}	PGA on rock with V_{S30} = 1100 m/s (g)
14	$Z_{2.5}$	Depth of 2.5 km/s shear-wave velocity horizon (km)

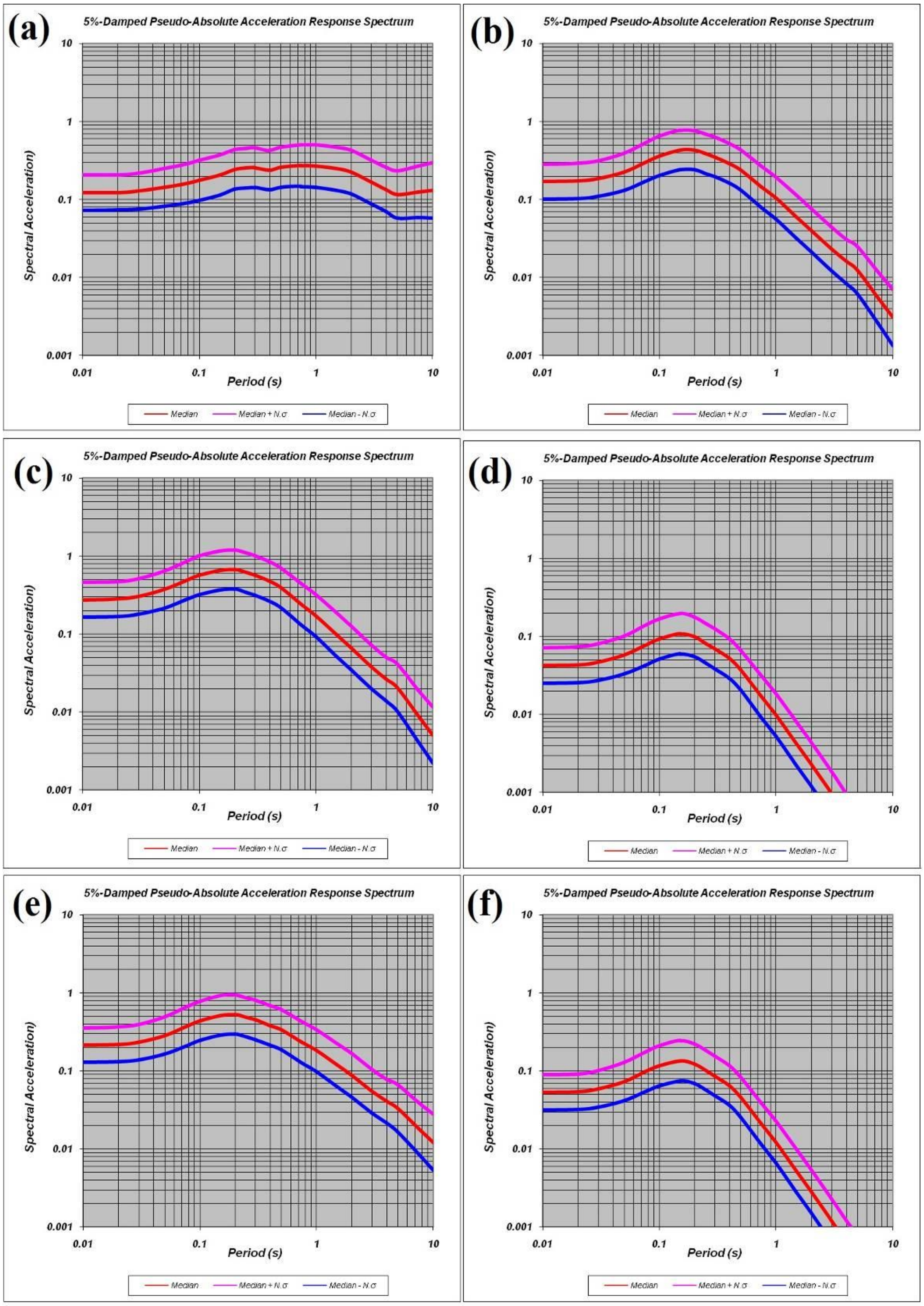

FIGURE 15. Estimated values by NGA for 100 km radius of Maragheh City, (a) Tabriz Fault, (b) MNF, (c) MSF, (d) KhNF, (e) SNF, (f) GF

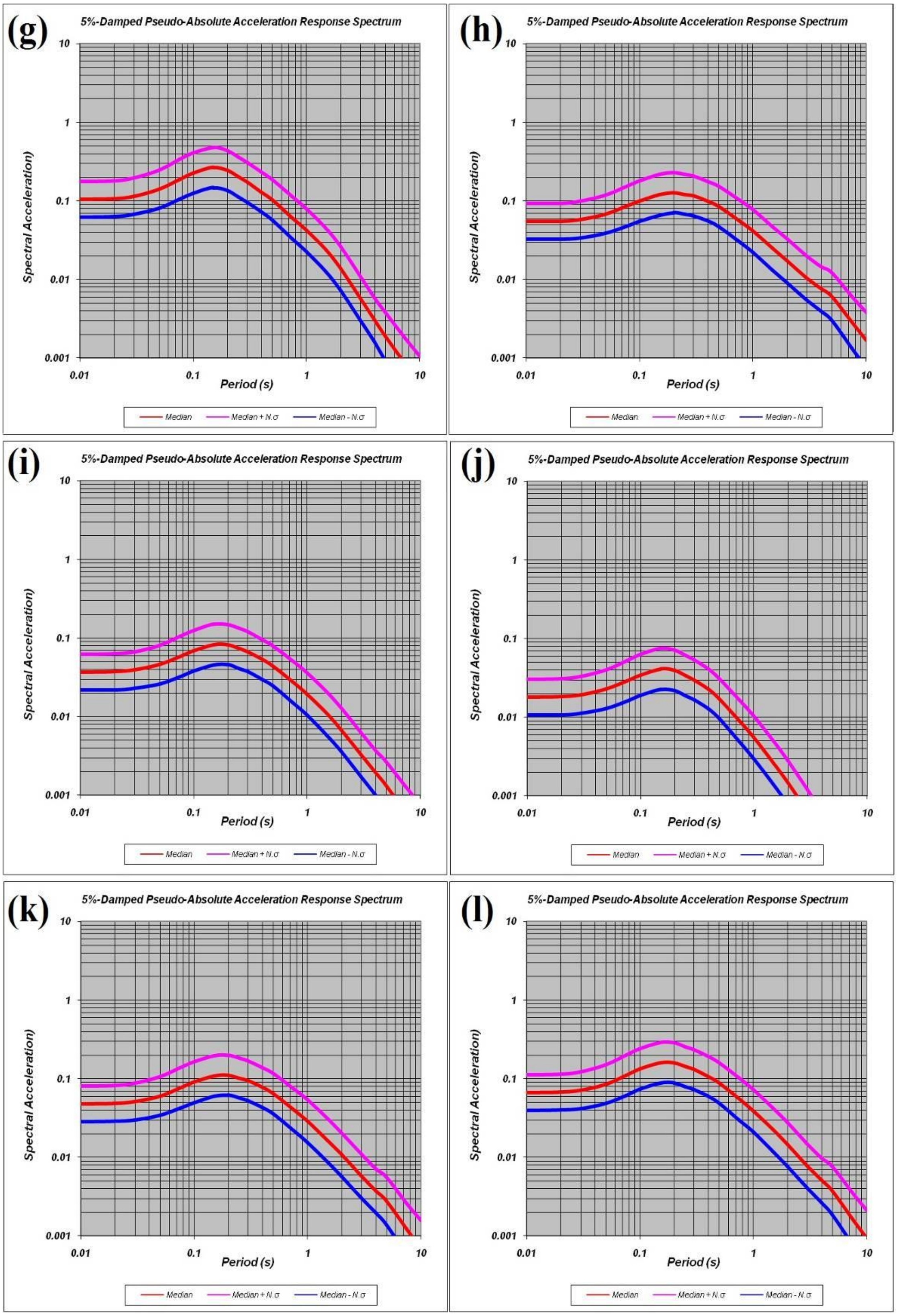

FIGURE 15. Contd., (g) B-L F, (h) GoF, (i) F-SG_1, (j) F-SG_2, (k) A-KhF, (l) Malekan SF

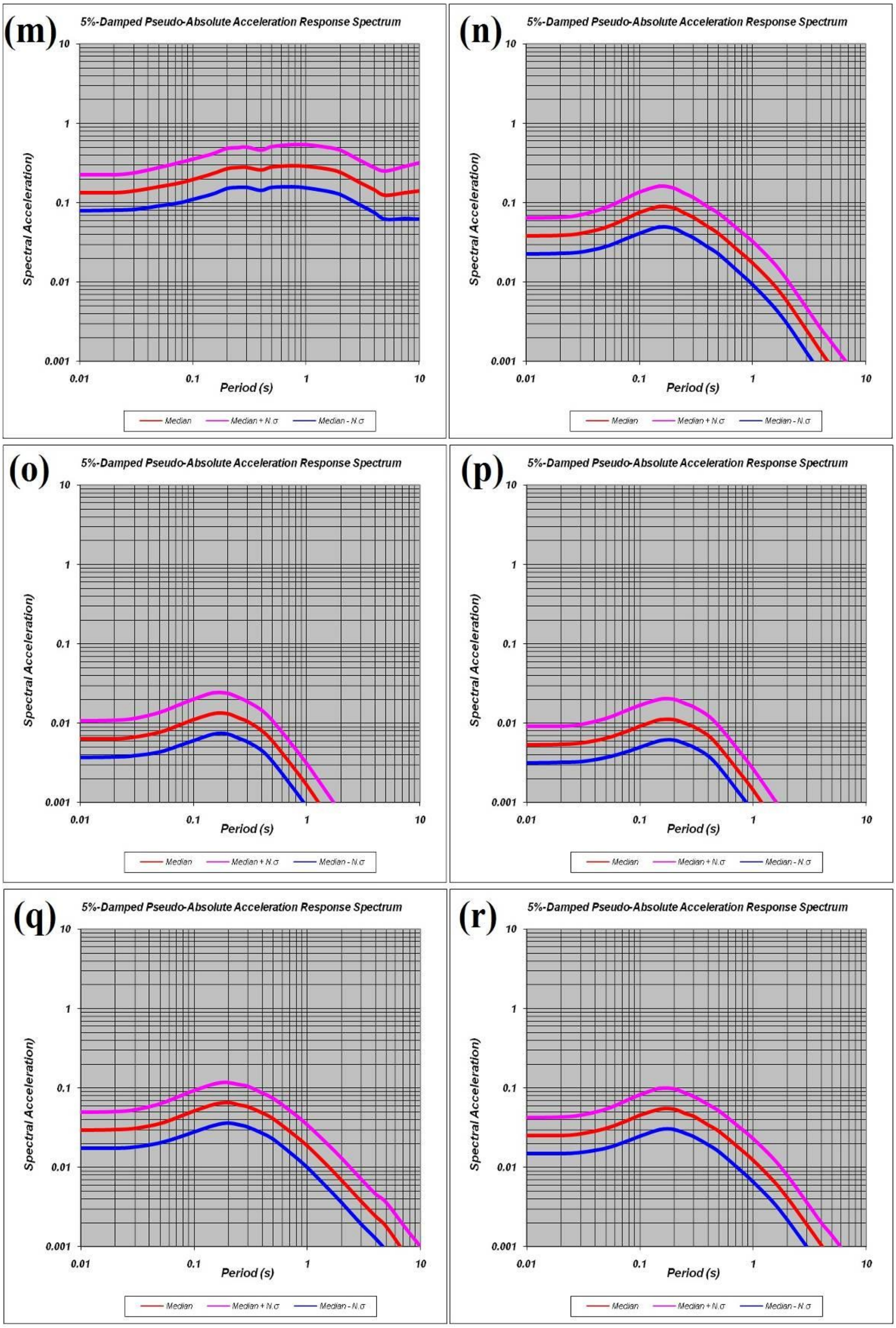

FIGURE 15. Contd., (m) U-ZF, (n) MEF, (o) SkSWF, (p) SkNF, (q) BNF, (r) BSF

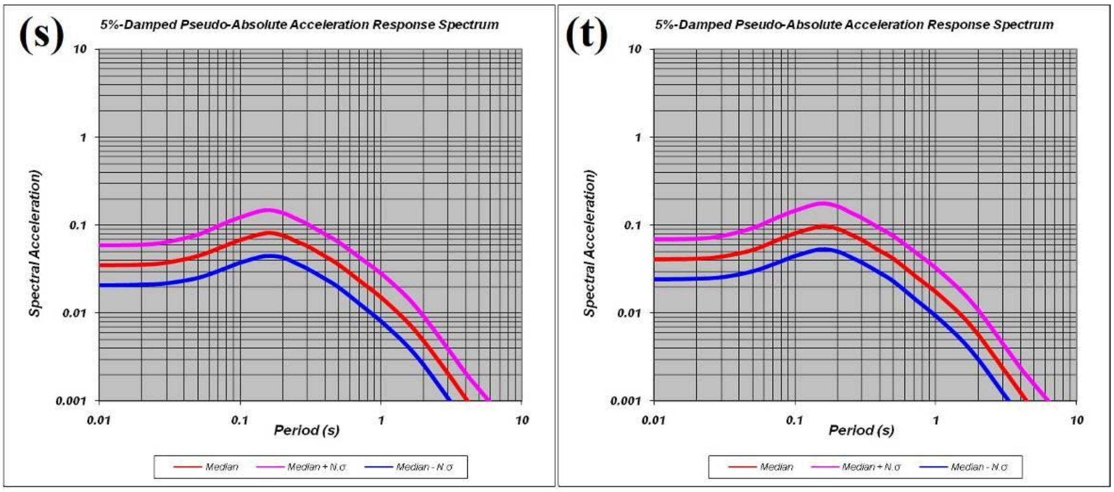

FIGURE 15. Contd., (s) AF, (t) KF

TABLE 4. The estimated values of the NGA modelling of city (*)

No.	Fault Name	PGV (cm/sec)	PGD (cm)	PGA (g)	A_{1100}
1	Tabriz F	51.32	1.017 E+03	0.129	0.1024
2	MNF	1.022	7.65	0.169	0.1443
3	MSF	1.698	1.257	0.274	0.2393
4	KhNF	1.480	0.192	0.042	3.50 E-02
5	SNF	2.134	4.030	0.213	1.83 E-02
6	GF	1.844	0.239	0.053	4.39 E-02
7	B-LF	4.306	1.153	0.104	8.77 E-02
8	GoF	4.196	4.531	0.054	4.48 E-02
9	F-SG_1	1.907	0.821	0.036	3.00 E-02
10	F-SG_2	0.705	0.122	0.17	1.46 E-02
11	A-KhF	2.806	1.701	0.044	3.93 E-02
12	Malekan SF	3.815	2.301	0.066	5.50 E-02
13	U-ZF	55.19	1.091 E+03	132	0.1120
14	MEF	1.727	0.526	0.038	3.14 E-02
15	SkSWF	0.244	0.032	6.2 E-03	5.11 E-03
16	SkNF	0.210	0.038	5.3 E-03	4.35 E-03
17	BNF	1.789	1.092	2.9 E-02	2.39 E-02
18	BSF	1.215	0.417	2.4 E-02	2.03 E-02
19	AF	1.509	0.410	3.4 E-02	2.86 E-02
20	KF	1.474	0.474	4.1 E-02	3.35 E-02

*) MNF = Marageh North Fault, MSF = Marageh South Fault, KhNF = Khodajo North Fault, F-SG_1

&F-SG_2 = name of Faults, SNF= Saraju North Fault, GF = Gavmish-daghi Fault, B-L F= Babak KLK-Leylidaghi Fault, GoF = Gorichay Fault, A-KhF= Ajabshir-khangah Fault, U-ZF = Urmia – Zarinehrud Fault, MEF = Miandoab East Fault, SkSWF= Sares kand South West Fault, SkNF= Sares kand North Fault, BNF= Bostanabad North Fault, BSF= Bostanabad South Fault, AF=Azarshahr Fault, KF= Kenberchay Fault

As seen in the Table 4 the Tabriz and Urmia- Zarinehrud faults are main rule on seismical activity in Maragheh region. The seismicity assessment results of the studied area is summarised in Table 5. According to the IRAN CODE-2800 (4th edition) forseismicity assessmentfrom the seismical design of structures, the Iran is classified in 4 classesincluded the very high risk (A), high risk (B), moderate risk (C) and low risk (D) groups of entire of Iran. As shown from theresults of the NGA models and the seismicity assessment, the Maragheh region is located on the moderate to high risk zone and the need considering the seismic engineering principles in constructions and improvements.

TABLE5. The results of the Maragheh regionseismicity assessment

No.	Fault Name	PGV (cm/sec)	PGD (cm)	PGA (g)
1	Tabriz F	51.32	1.017 E+03	0.2209
2	MNF	1.022	7.645	0.1952
3	MSF	1.698	1.257	0.1909
4	U-ZF	55.19	1.091 E+03	0.2104
5	Maragheh	27.3075	2.2260	0.1965

5. Conclusions

The seismicity study is the most powerful step in urban planning. This study has focused on Maragheh region seismic surveys and seismic parameter estimation by NGA model. In order to achieve these models, it was required to define faults location, mechanism, length, etc. As known, this study covered 100 km radius of city, location and length of faults using RS technique and ETM^+ and geomagnetic imagery using manual extraction methods (after filtering, colour composites). The results show that the region is tectonically active and various faults with the NW-SE direction (dominance in area) and N-S was created. This event represents the in-situ stress in line with Arabian plate to Eurasia plate compressive forces direction. Then, by creating a database of earthquakes magnitude (as historical, twentieth century and present data categories) and mounting on tectonical map, the earthquake occurrence distributions map was prepared. According to the distributions map the Tabriz and Urmia- Zarinehrud faults are main rule on seismical activity. Finally, based on seismic zonation map, Maragheh region is located in moderate to high risk zone.

References

[1] M. Azarafza, A. Ghazifard, *Urban geology of Tabriz city: environmental and geological constraints*, Advances in Environmental Research (AER), An International Journal, 5(2), (2016), 95-108.

[2] M. Azarafza, S. Nikoobakht, M.R. Moshrefy-far, *Study of seismicity for Shahrekord quadrangle emphasis on the of seismic activation cause on active fault in studied area*, Journal of Tectonic and Structures. 2(4), (2014), 49-67.

[3] Statistical Center of Iran, Report of Maragheh city census. Results of national 2007 census, Iran, (2012) [in Persian], Available: http://www.amar.org.ir.

[4] IIEES, Earthquake Data from Maragheh Station for 100 Km radial, International Institute of Earthquake Engineering and Seismology, (2017), [in Persian], Available: http://www.iiees.ac.ir.

[5] M. Azarafza, M.H. Mokhtari, *Evaluation drought effect on the Urmia lake salinity change by using remote sensing techniques*, Arid Biome Scientific and Research Journal, 3(2), (2013), 1-14.

[6] Geological Survey of Iran, GSI, Geological map of Maragheh city in scale: 1:100000 (map sheet), Geological Survey of Iran press, maps unit, Tehran, (2009).

[7] P. Francis, C. Oppenheimer, Volcanoes, (2nd Ed.), New York: Oxford University Press, (2003).

[8] A. Agha-Nabati, Geology of Iran, Tehran: Geological and Mining Survey of Iran press, (2007).

[9] M. Berberian, Contribution to the Seismotectonics of Iran (Part III), Tehran: Geological and Mining Survey of Iran press, (2006).

[10] G. Rostam, G.M Pakzad, N. Mirzaei, SR Sakhaei, *Analysis of the stress field and strain rate in Zagros-Makran transition zone*, Journal of Seismology,21(6), (2017), 1-15.

[11] A. A. Nogol-sadat, A. Almasian, Tectonic map of Iran, 1:1,000,000. Treatise on the geology of Iran, Tehran: Geological and Mining Survey of Iran press, (1993).

[12] K. Aki, P. G. Richards, Quantitative seismology, (2nd Ed.), Herndon: University science books, (2009).

[13] R. H. Burger, A.F. Sheehan, C.H. Jones, Introduction to Applied Geophysics, New York: Norton Publications, (2006).

[14] H. Mousavi-Bafrouei, N. Mirzaei, E. Shabani, M. Eskandari-Ghadi,*Seismic hazard zoning in Iran and estimating peak ground acceleration in provincial capitals*, Journal of the Earth and Space Physics 40(4) (2015), 15-38.

[15] J. Jackson, J. Haines, W. Holt, *The accommodation of Arabia-Eurasia plate convergence in Iran*, Journal of Geophysical Research, 100, (1995) 15205-15219.

[16] A. Paul, A. Kaviani, D. Hatzfeld, J. Vegne, M. Mokhtari, *Seismological evidence for crustal-scale thrusting in the Zagros mountain belt (Iran)*,Geophysical Journal International, 166(1), (2006), 227-237.

[17] S. Cambazoğlu, M.K. Koçkar, H. Akgün, *A generalized seismic source model for the Eastern Marmara Region along the segments of the North Anatolian Fault System*, Soil Dynamics and Earthquake Engineering, 88, (2016), 412-426.

[18] J. A. Richards, Remote Sensing Digital Image Analysis: An Introduction, (5th Ed.), New York: Springer-Verlag, (2012).

[19] USGS, Landsat Satellite imagery ETM^{+}, USGS Global Visualization Viewer, USGS, (2017), Available: http://glovis.usgs.gov/.

[20] International Commission on Large Dams, ICOLD, Selecting Seismic Parameters for large Dams Guidelines, International Commission on Large Dams, Bull no. 72, (1989).

[21] N. N. Ambraseys, C.P. Melville, A history of persian earthquakes, Cambridge: Cambridge University Press, (2005).

[22] M. Berberian, Natural hazards and the first earthquake catalogue of Iran vol. 1, Historical hazards in Iran prior to 1900, A UNESCO/ IIEES Publication during UN/IDNDR, Tehran: International Institute of Earthquake Engineering and Seismology press, (1995).

[23] IRIS, The Global Seismographic Network (GSN), Incorporated Research Institutions for Seismology, (2016), Available: https://www.iris.edu/

[24] P. M. Shearer, Introduction to Seismology, (2nd Ed.), Cambridge: Cambridge University Press, (2009).

[25] A. Kijko, M. Singh, *Statistical tools for maximum possible earthquake magnitude estimation*, Acta Geophysica, 59(4), (2011), 674-700.

[26] B. Gutenberg, C.F. Richter, *Magnitude and energy of earthquakes*, Annals of geophysics, 53(1), (2010), 7-12.

[27] A. AKijko, *Eastimation of the maximum earthquake magnitude, m max*, Pure and Applied Geophysics (Pageoph), 161(27), (2003), 1655-1681.

[28] K.W. Campbell, Y. Bozorgnia, *NGA Ground Motion Model for the Geometric Mean Horizontal Component of PGA, PGV, PGD and 5% Damped Linear Elastic Response Spectra for Periods Ranging from 0.01 to 10 s, Earthquake Engineering Research Institute*, Earthquake Spectra, 24(1), (2008), 139-171.

[29] K. W. Campbell, Y. Bozorgnia, 2012 Update of the Campbell-Bozorgnia NGA Ground Motion Prediction Equations: A Progress Report, *15th World Conference on Earthquake Engineering (WCEE)*, Lisbon, Portugal, (2012), 24-28 Sep, 2012.

[30] S. Akkar, M.A. Sandıkkaya, J.J. Bommer, *Empirical ground-motion models for point- and extended-source crustal earthquake scenarios in Europe and the Middle East*, Bulletin of Earthquake Engineering, 12(1), (2014), 359-387.

[31] Road, Housing and Development Research Center, Regulations for buildings designing under earthquakes conditions, Building regulations of Iran - IRAN CODE-2800 (4thEd.),253(Z), (2017), 238.