Seismic Hazard Assessment of Tabriz, a City in the Northwest of Iran

Maral Hoseinpour[1] and Dr Mehdi Zare[2]

Abstract

Tabriz city, the center of Azerbaijan, a part of Central Iran province, in the northwest of Iran, is a seismotectonically active region, surrounded the study area. This region for which and probabilistic hazard analysis are performed, is sited between 44°, 32´- 48°, 00´E and 37°, 20´-39°, 00´N. The active fault map of the region is prepared as the first step. For this purpose, all active faults are recognized and their seismic and rapture parameters are determined. Correlation of fault orientation and earthquake epicenter distribution showed that there is a close relationship between them. Preparing the epicentral distribution map and calculating the seismogenic layer depths in the region are performed, the second step, using historical and instrumental earthquake catalog. Afterwards, for seismic hazard analysis, the seismic parameters of study region are determined and seismic zones classification is done using Arc GIS software. Maximum earthquake, seismic parameters, and occurrence rate are determined for each seismic zone. The probabilistic hazard analyses are performed using 3 different attenuation relationship, resulted in seismic hazard curves for Tabriz city, and seismic hazard maps with return periods of 50, 75 and 475 years for study area.

Keywords: Seismotectonics, Active Fault, Probabilistic seismic hazard assessment, GIS, Seismic Zonation, Return period, Seismic hazard Curves, Tabriz

Introduction

Seismic hazard analysis is to predict the influence of a future earthquake of certain magnitude on a site of interest. The risk originates from two aspects: the surrounding seismic zone of the potential seismic sources and the site itself. Hazard analysis assessment has normally three main steps:

- Locating the potential seismic sources or sources surrounding the site and estimating their activities
- Ascertain the path of seismic waves propagation and their attenuation characteristics
- Adopting an appropriate model for seismic analysis (Wang & Law, 1994)

There are two approaches for determining seismic hazards. Deterministic approach selects individual earthquake scenario and specified ground motion probability level and leads to a single ground motion for each considered scenario (Abrahamson, 2000). Deterministic analysis provides a natural basis for "disaster scenarios" that can be used to tie prepared planning to a constrictive standard for the most severe PGA that is likely to affect each site (Leonard & Steinberg, 2002).

The probabilistic approach is to identify the seismic hazard of a site in terms of the magnitude or intensity having the probability of exceedance within a certain time period (Wang & Law, 1994). This

[1] Graduate student, University of Tabriz
m.hoseinpour@gmail.com
[2] Associate Professor of International Institute of Earthquake Engineering and Seismology

approach considers different uncertainties in magnitude, location, time of occurrence, changes the characteristics of ground motion according to these parameters and presents logic prospective of seismic risk by combining these factors (Zare, 2005). Engineering study of probabilistic seismic hazard is due to Cornell (1986) who used Poisson distribution for earthquake occurrence and a deterministic attenuation of peak ground acceleration. The method used has been referred later as "compositional method" (Todorovska & Gupta, 1996).

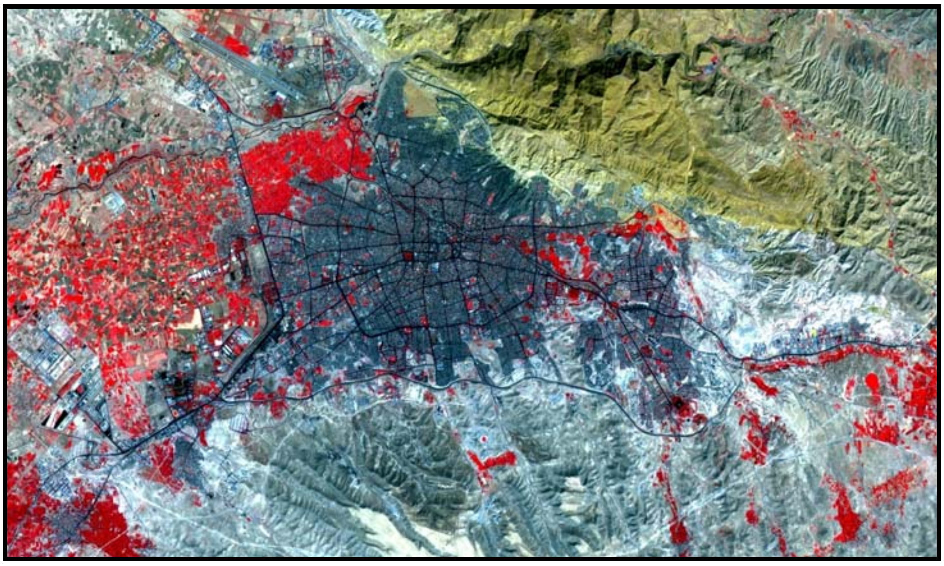

Fig. 1: Satellite view of Tabriz city, the sharp trace of North Tabriz Fault is obvious in northern boundary of the city that oriented in NW-SE trend

In this research probabilistic approach has been used to estimate seismic hazard of study region. Azerbaijan microplate that surrounded study area is located between two neotectonically active regions, Caucasus in the north and Zagros range in the south, hence it is under pressure and shows large seismicity. The study area has different and complex structural trends. The most evident and seismotectonically active faults are North Tabriz, Tasuj and Bozghush, among which North Tabriz Fault (NTF) with NW-SE trend passing through the vicinity of Tabriz city, is more dominant because of its obvious morphologic features and historical seismicity (Fig.1). Tabriz city, the second most populated city in Iran, was devastated completely during three destructive historical earthquakes pertinent to North Tabriz Fault. The region shows intense historical and moderate instrumental seismic activities and a significant 20th seismic gap existed in 50km around the city. Determining active faults and calculating their seismic and rapture parameters lead to specifying seismic zones by using of Arc GIS software. Seismic parameters of each zone were calculated and the processes of probabilistic seismic hazard analysis were performed in the region. The analysis results were presented as seismic hazard curves for Tabriz city and the seismic hazard maps with different return periods for the region were plotted, using two different attenuation relationships.

The high PGA, extracted from these maps for Tabriz city, the gap of major earthquakes in 20th century and lack of sensible creep along NTF, adjacent the city, confirm the importance of performing seismic hazard assessments in the region.

Tectonic Setting

Iran is a segment of one of the biggest compressional deformation regions of the world. This country is located in the collisional zone of Eurasia- Arabia plates and resultant of these plates convergence lead to the rotation of Iranian plate about Iran- Eurasia rotational pole (Jackson et al. 1995). This special tectonic situation causes many earthquakes in the country (Fig. 2).

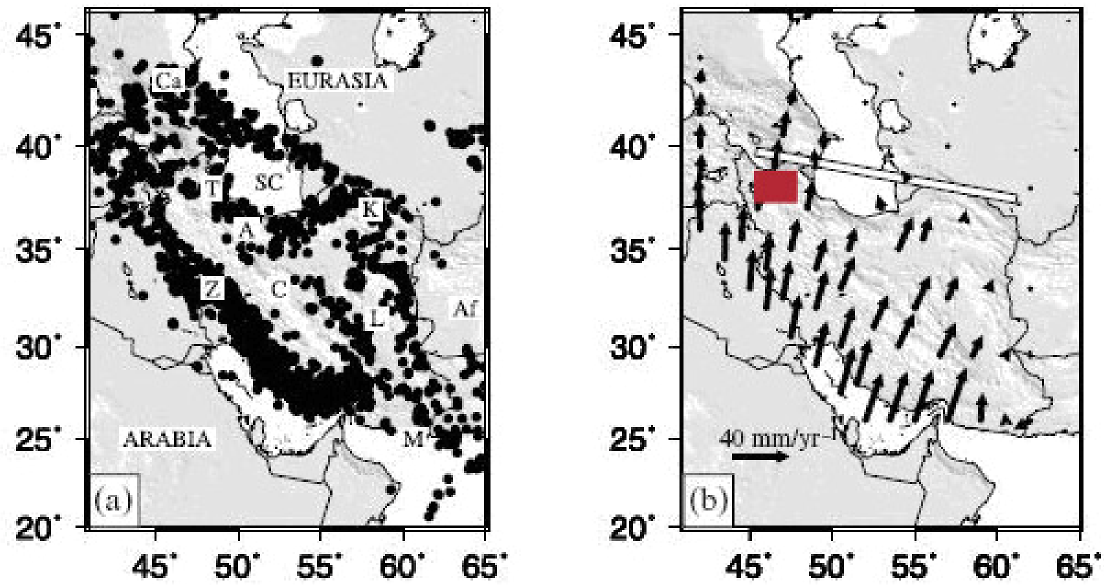

Fig. 1. (a): Seismicity of Iran plateau between (1964-1998) (b): Stress vector orientation and movement speed of continental plates due to movement of Arabic plate towards Iran (Marco et al, 2003)

Berberian (1986) divided Iran into four major seismotectonic provinces, of which Azerbaijan is a part of Central Iran province. Azerbaijan is located in the northwest of Iran and extended to eastern Turkey and Caucasia. This platform contains two major tectonic elements. First is the structural trend of Arak-Zarrinehrood that lies at western coast of Urmieh Lake, and the second is Tabriz-Zanjan structural trend, a part of which is North Tabriz Fault (NTF). This structural trend lengthens more than 250km and extends in the NW-SE direction (Zare, 2005). These two elements were collided in the north of Urmieh Lake and extend toward Turkey with almost the same trend as North Anatolian Fault (NAF) (Jackson & McKnenzie, 1984). Historical earthquakes in Azerbaijan and the existence of these active structural trends, illustrate the high seismicity of the region and high probability of disastrous earthquakes occurrences. The existence of several minor strike slips and reverse faults in the region along with right lateral and reverse motion of NTF make the fault plane solutions to show a significant degree of thrusting as well as right lateral strike slip (Jackson & McKnenzie, 1984).

Study area that is defined as a rectangular zone with 53000 km^2, centered by Tabriz city, and contains different structural elements. The NW-SE and E-W faults trends are the major trends of region and show reverse and trust mechanisms whereas N-S and NE-SW trend faults act as strike slip and normal faults in the region (Moayed, 2002). NTF, the major structural feature in the region, acts as right lateral strike slip fault with reverse component. Length of fault in the study area is 180km and its average displacement is 3mm/year (Hesami et al. 2003). The fault makes very obvious surface trace and morphotectonical features along its trend. Different seismic parameters and mechanism of fault in the north and south of Tabriz lead to segmentation of the fault to NW and SE sections. The fault has a rich catalog of intense historical and moderate instrumental earthquakes.

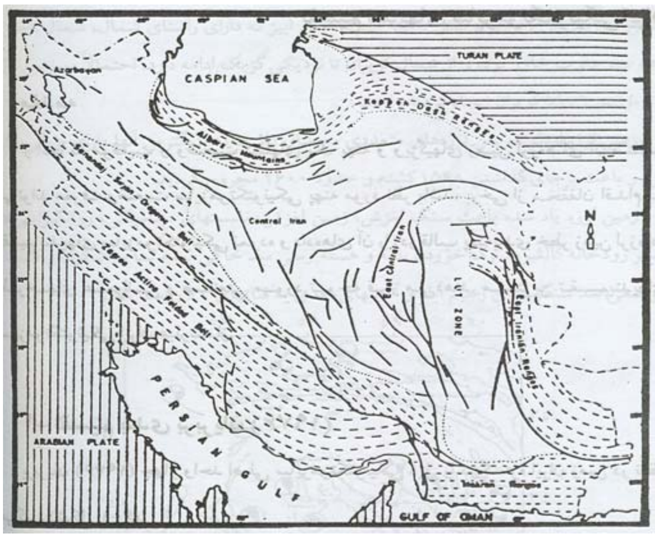

Fig. 2. Dominant seismic provinces of Iran (Berberian, 1976)

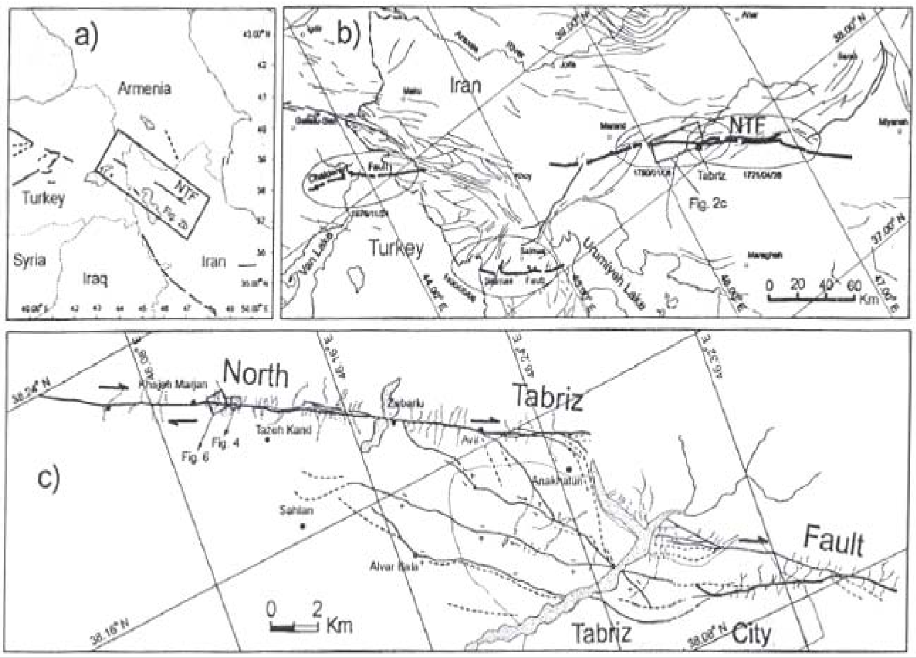

Fig. 3. a: active fault map of northwest of Iran- east of Turkey (Jackson & McKnenzie, 1984) b: simplified map of North Tabriz Faul (NTF) and its historical earthquakes (Berberian, 1997) c: canal displacement along northwestern segment of NTF (Hesami et al. 2003)

Other sesmotectonically important faults in the study region are Tasuj, Shabestar, Dehkharghan, Salmas and Bozghush, having different trends and mechanisms, along which historical and instrumental activities are recorded. In this study all active faults in the region of length more than 20km were recognized and depicted in active faults map.

Rapture parameters of active faults

It has been known that earthquake magnitude is correlated to the rapture parameters such as length of displacement (Wells & Coppersmith, 1994) so the maximum earthquake, caused by a fault, may be estimated by empirical relationships between magnitude and fault length. Surface rapture length is the most important factor in these functions and has been assumed as 37% or in very conservative situations 50% of the fault length. In this paper three functions are used and the average value is taken out of them as:

(1) $M_s = 5.4 + Log(L_R)$

(2) $M_W = 0.91Ln(L_R) + 3.66$

(3) $M_W = 5.8 + 1.16Log(L_R)$

Where, (1) is proposed by Mohajer ashjaii- Noruzi (1984), (2) refers to Zare (1994) and (3) is taken from Wells & Coppersmith (1994). L_R is surface rapture length in km. Since M_W is available only for some earthquakes and agrees well with M_S for the earthquakes below saturation level (Kanamori, 1977), in this paper M_S magnitude is chosen to be used. As there is a relationship between M_{max} and rapture parameters of faults, it can be concluded that in case of knowing M_{max} of each fault, other rapture parameters can be calculated.

Here downdip rapture width is calculated using Wells & Coppersmith (1994) empirical relationships. Downdip rapture width is estimated from depth distribution of the best defined zone of aftershocks or from the depth of the seismogenic zone or from the depth of the hypocenter and the assume dip of the fault plane. This parameter played an important role in seismic zonation, accomplished in Arc GIS environment. The empirical relationship for its estimation is:

(4) $M_W = 4.06 + 2.25Log(WID)$

Table (1) represents some raptures and seismic parameters of the active faults in the study area.

Table1: Seismic parameters of more dominant faults in the studied region (M-N: Mohajer ashjaii-Noruzi, Z:Zare, W-C:Wells & Coopersmith)

Source	F.L(km)	Rapture Length (km)			Maximum Magnitude			R.W(km)	R.W(km)
		W-C	M-N	Z	M-N	Z	Ave		
NTF (NW)	80	35	40	29	7.0	6.7	6.9	18	718
NTF (SE)	112	55	56	41	7.1	7.0	7.1	22	1228
Dehkharghan	60	24	30	22	6.9	6.5	6.7	15	454
Tasuj	58	23	29	22	6.9	6.5	6.7	14	440
S of Bozghush	72	30	36	26	7.0	6.6	6.8	16	607

Seismicity of the region

Earthquake catalog is the most important input data for seismotectonic investigation and seismic hazard analysis. In this study, earthquakes are studied in three periods: historical period (up to 1900), early instrumental period (1900-1963) and instrumental period (1963-2005). As in the historical and early instrumental periods are many earthquakes are ignored or have not been recorded due to the lack of appropriate devices, a percentage of incompleteness is seen in every catalog.

Historical period

Historical sources record large surface raptures, small raptures not being spectacular enough to attract attention (Ambraseis & Jackson, 1998). These earthquakes were recorded by Iranian and europium explorers. The most reliable sources for historical earthquakes in Iran and Azerbaijan are gathered by (Ambraseys and Melville, 1982) and (Berberian, 1977). 17 reliable historical earthquakes that had clear evidences and explicit epicentral coordinates were selected. Most intense historical earthquakes records registered along NTF were vanished as Tabriz city was devastated completely during three destructive historical earthquakes related to this fault. Perusing the data, it can be concluded that the earthquake of magnitude 7.7, are the ones characterized by North Tabriz Fault. Other faults like Tasuj, Dehkharghan and Bozghush faults show historical seimicity as well. Historical earthquakes were used in designating maximum magnitude and seismic parameters for seismic zones. Table 2 represents some reliable historical earthquakes in the region.

Table2: historical seismicity in the region (Ambraseys and Melville, 1982)

Year (A.C)	Intensity (I_o)	Magnitude (M_s)	Human Lost	Other Characteristics
858	VIII	6.0	-	-
1042	VIII-X	7.6	40000	-
1273	VII-IX	6.5	250	-
1304	VII	6.7	-	-
1550	-	5.9	-	landslide
1641	VII	6.8	1200	change in water table
1721	VIII-X	7.7	-	-
1780	IX	7.7	-	liquification, landslide
1819	-	<5	-	-
1883	-	<5	-	
1894	-	<5	-	

Instrumental period

During this period the information about seismological parameters of earthquakes are improved. However, during the first half of this century this approach went very slowly (Ambraseis & Jackson, 1998). In Iran, the earthquakes, recorded up to 1963 have high error levels in magnitude and hypocentral depth. These errors were corrected by development of recording devices after 1963. Instrumental catalog of the study was gathered form ISS (1900-1964), ISC (1964-2005), USGA, NEIC and seismic data of Tabriz Local seismic network (2000-2005). This network has more that 8 active stations in the region and is able to record earthquakes with minimum magnitudes of 1. Totally, 232 earthquakes were included in the study that contain the recordings with magnitude higher that 3.0.

Plotting the coordinate of earthquake epicenters on fault map indicates a major seismic gap in 50km around Tabriz city from 1963 till now. The maximum concentration of earthquake epicenters is in NW, SE and west limits of the area. The SW segment of NTF shows small earthquakes from 2000 to 2005, but the same seismic gap for intense activities still continues around the city. (Fig.4)

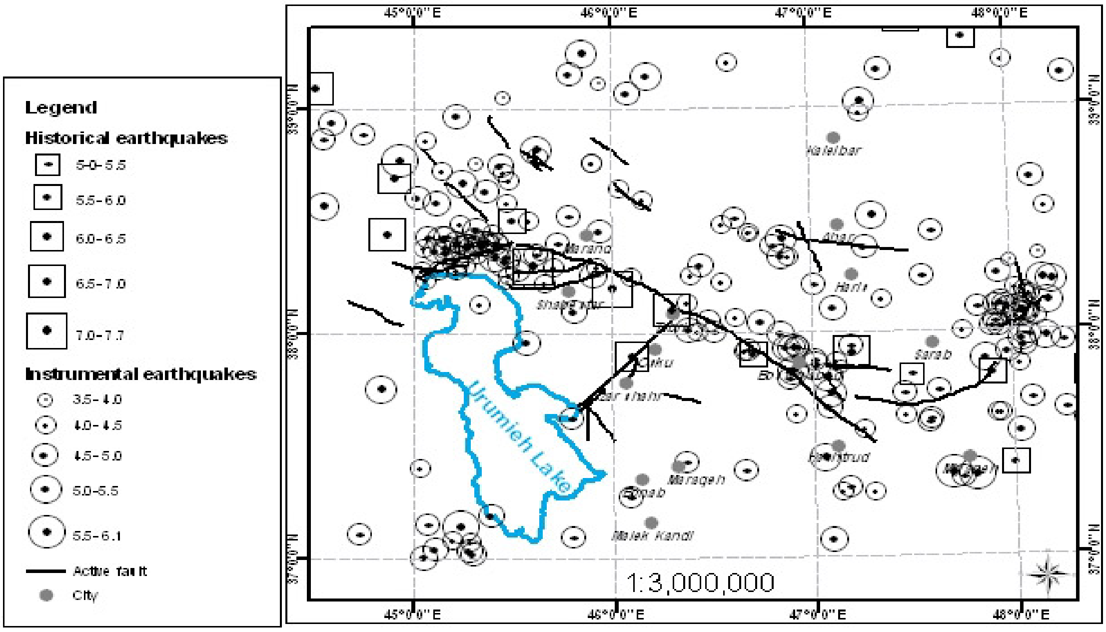

Fig. 4. Tectonic elements and seismicity map of study region

Depth of seismogenic zone in the study area

Estimation of seismogenic layer depth is a necessary element for comprehending the nature and origin of the earthquakes happen in the region. Sibson (1984) assume three layers for his model: brittle layer, gradual changes layer and plastic layer which are detectable by distribution of thermal gradient. He believes that most earthquakes are of the brittle layer which can be extended to the gradual changes layer in the earthquakes with great deformations.

Using his model, it is possible to determine maximum depth of seismicity. For estimating the depth of seismic zone in the study area magnitude versus hypocentral depth diagram was plotted (Fig. 5). Earthquakes recorded, from 2000 to 2005, by Tabriz local seismic network were used for estimating process due to the completeness of the catalogs. The results show that seismic depth in the region varies between 4 and 34 km. As it is seen in the diagram, most of the earthquakes happened in a depth of 10 to 25 km and the average depth of seismicity in the region is 20 km (Fig.5). According to the proposed mode, considering the thickness of gradual changes 5 km, the maximum seismic depth in the region will reach to 25 km. This depth is representative of shallow earthquakes hypocenter for the study region.

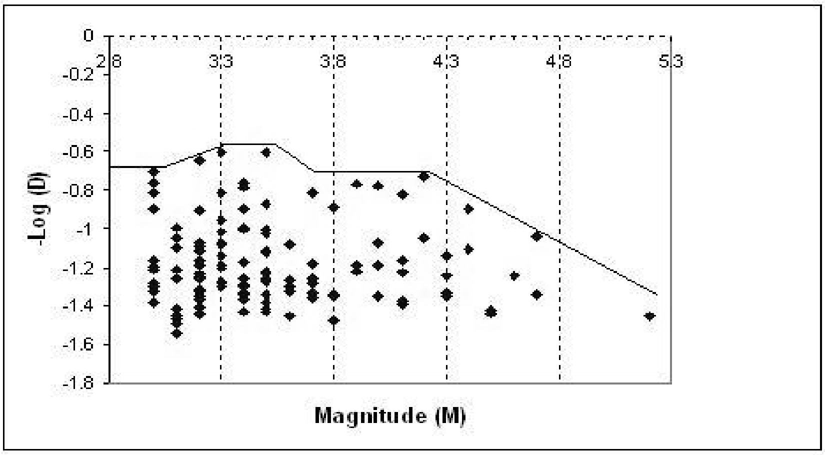

Fig. 5. Relationship between magnitude and depth of seismogenic layer for data in time range of (2000-2005)

Seismic zonation

Earthquakes occur at irregular intervals in space, size and time and in order to quantify seismic hazard at any given site, it is necessary to identify the pattern in the spatial, size and temporal distribution of seismic activity in the surrounding region. Understanding the tectonic reasons of earthquakes and identifying the seismogenic geological features in a region develope the formulation of distribution patterns of potential sources (chapter4 of book copied). Seismic sources can be classified as linear and area sources. As the faults are the major sources of seismicity in the region so Learning about rapture parameters, fault segmentation according with its structural conditions and the maximum earthquake that a fault could produce are required in seismic zoning.

Arc GIS software played an important role in seismic sources recognition in this study. Two layers of tectonic and seismological features were the basic inputs of the software. Active faults map of the region together with maximum earthquake that each fault may cause and rapture width of each fault were inputted in the program as layers and tables. Afterwards, the faults were weighted on the basis of M_{max} and rapture width. Later element were supposed as maximum distance and the constant factor was assumed to be varied between one on the fault and zero at the farthest distance. After preliminary estimation the maximum earthquake that each fault may produce were applied in the output results (Fig.6).

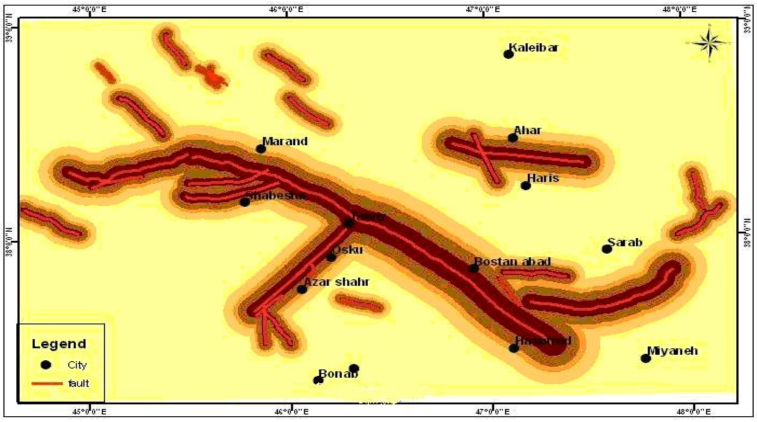

Fig. 6: Weighting of Faults on the basis of maximum magnitude and rupture width

A seismological feature layer is consists of epicenter coordinates of historical and instrumental earthquakes, analyzed by density method. In This method density of earthquake epicenters were estimated on the basis of their spatial distributions. Resulting map represent an acceptable coordination between spatial location of earthquakes and trends of seismic faults of the region (Fig.7).

In the next step these maps were classified and merged with each other with different weights. Eventually the maps of more coordination with tectonic and seismological features of the region were selected as final ones and amended to be used as the seismic zonation maps for the analyses. 8 area sources were recognized in the region.

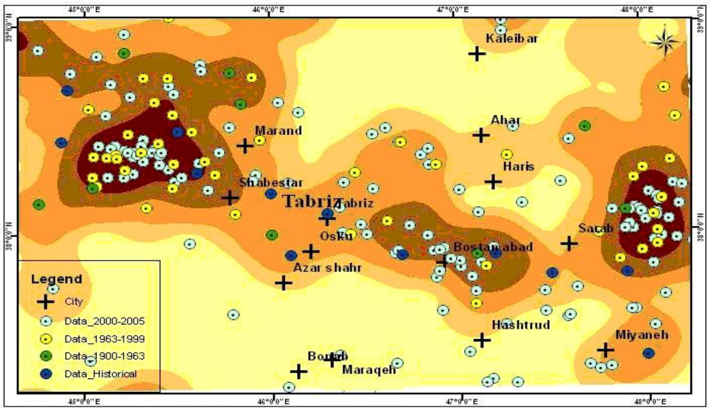

Fig. 7: Density of spatial distribution of earthquake epicenters

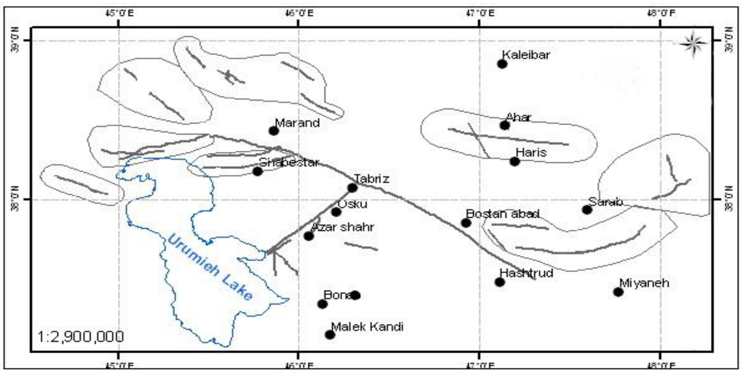

Fig. 8: Final zonation of seismic sources

Because of the satisfactory correlation between earthquakes and faults, in Dehkhargha fault and NTF, these faults considered as linear sources. North Tabriz

Fault divided into two segments, representing different structural and seismic characteristics in each segment (Fig.8).

Seismic parameters of study area and seismic zones

The term of seismicity represents the earthquake distribution in time and space, defined for a seismic province or zone. During any given interval time, the general underlying patterns or distribution of size of events are the firs described by Gutenberg & Richter (1954) derivimg an empirical relationship between magnitude and frequency in the form of:

$$Log\lambda_m = a - bm \qquad (5)$$

where, λ_m is mean annual rate of earthquake occurrence with the magnitude of m, and a & b refers to regression constants or seismic parameters of a seismic zone. These parameters were estimated for study area using seismic events from 1900 to 2005. As the historical earthquake catalog of area was incomplete, these data were not included in the regression. The regression resulted in this equation:

$$LogN_c = 5.1668 - 0.79M \qquad (6)$$

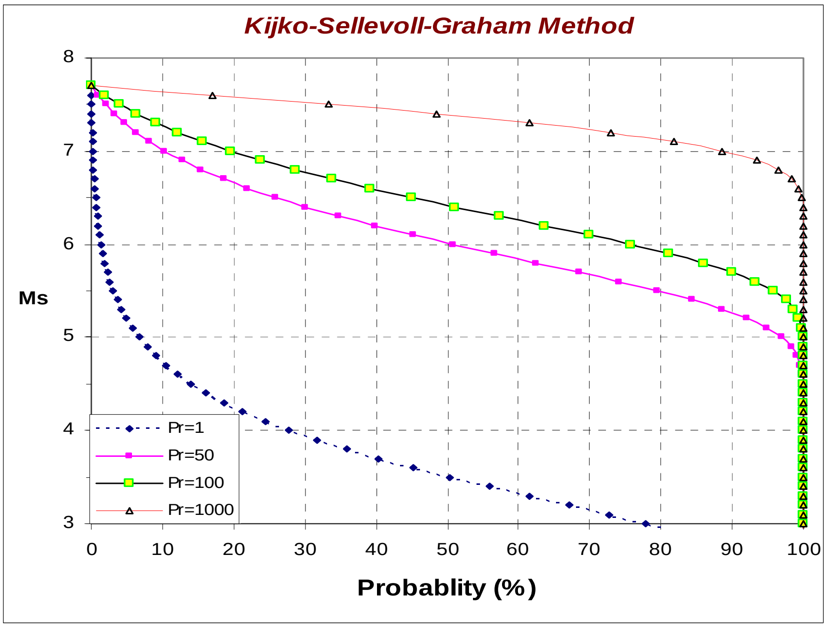

Fig. 9: magnitude probability of exceedance for different time intervals in study area

A new method of Kijko-Sellevoll-Graham (1992) allows us to estimate seismic parameters of area from incomplete data catalog; hence, including the historical events for getting more reliable results, is possible in this method. Furthermore, using this method-program it is possible to compute and depict return period, annual rate and probability of earthquake recurrence in different time intervals (Fig.9). Depiction of these parameters in different diagrams revealed that this part of Azerbaijan is susceptible for intense earthquake with short to moderate return periods. The annual rate of moderate events in the area is low representing the stress aggregation along seismic faults and increasing the probability.

After recognizing seismic zones, seismic parameters of each domain were defined by Kijko-Sellevoll-Graham (1992) method- program. The historical data were included in computations. Wherever the earthquake data were not sufficient for analysis, seismic parameters were estimated by tectonic analogy of these regions with neighbour zones (Table 3).

Assessing the maximum magnitude for each zone

Maximum magnitude for each zone is defined as the maximum credible earthquake or maximum earthquake. The seismicity is considered as energy release in individual event (Todorovska & Gupta, 1996). Two methods were applied:

1. Historical Earthquakes: the best sample are historical earthquakes of NTF (1042, 1721, 1780 A.C) which can be considered as characteristic earthquake of this fault. It should be considered that return period for many of intense earthquakes are exceeded to the time interval of historical data. Therefore, this method is not always reliable.
2. Magnitude- rapture length empirical relationships: as mentioned before, this method is one of the most dependent ones in calculating M_{mac} for a seismic source. This method is applied directly for linear sources. In the case of area sources, M_{max} is estimated for each fault segment in the zone and the highest magnitude was taken as maximum magnitude for that area source.

If the earthquake catalog were completed, magnitude- frequency relationships could be applied for computing $M_{max.}$ Utilizing empirical relationships between other rapture parameters of a fault and magnitude and tectonic similarities among different zones are other methods for determining maximum earthquake.

For engineering purposes a threshold magnitude are defined and lower magnitudes are eliminated because of not being damaged. In this study, threshold magnitude is considered as 4.

Table 3. Seismic parameters of seismic zones

Source	M_{min}	M_{max}	α	β	L(km	A(km^2)
NTF (NW)	4	7.7	0.87	1.37	80	-
NTF (SE)	4	7.1	1.61	1.45	112	-
Dehkharghan	4	6.7	1.8	1.45	60	-
Tasuj	4	6.7	1.54	1.74	-	1190
Bozghush	4	6.8	2.06	1.88	-	2616

In the next step mean annual rate of earthquakes in each zone were computed:

(7) $$\lambda_t = [\upsilon(M_0) - \upsilon(M_{\max})] \cdot (L, A) f$$

where, $\upsilon(M_0)$ and $\upsilon(M_{\max})$ are average number of earthquakes per year for $M>M_0$ and $M>M_{max,}$ and (L,A)f refers to length of linear and area of zonal sources. Magnitudes between M_{max} and M_0 were divided to N_M equal intervals and magnitude probability of exceedance for each interval was estimated using magnitude density distribution function.

(8) $$F_{M(m)} = \frac{\beta \exp[-\beta(m - m_0)]}{1 - \exp[-\beta(m_{Max} - m_0)]}$$

This function originates from Gutenberg and Richter (1954) and Richter (1958) bounded magnitude- frequency relationship. Finally, the probability of rapture occurrence was assessed for each fault. Because of the lack of seismic data, it is supposed that earthquakes have the equal probability of occurrence in each point of seismic source. Distances between sources to site were classified to N_R equal segments and the occurrence probability was calculated for each interval.

Attenuation relationships

Whereas various regions have different Tectonic and seismotectonic characteristics so, using local attenuation relationships were strongly recommended. Seismic hazard analysis in this study is based on Zare (1999) and Sinaian (2006) relationships.

(9) LogPGA=0.322M-0.0004r-Log -0.688+0.26

(10) LogPGA=0.3764M-0.0005099r-Logr1.062+0.26

where, PGA is peak ground acceleration, M refers to magnitude and r to hypocentral distance. 0.26 is standard deviation of the relationship. The constants are measured for central Iran- Alborz seismic provinces. Joyner, Boore & Fumal (1993) attenuation relationship was included in the analysis for comparing global and local relationships.

(11)

$$LogPGA = -0.038 + 0.216 \cdot (M-6) - 0.777 \cdot Log\left|(\sqrt{R^2}) - 30.03\right|$$

PGA probability of exceedance from acc is evaluated for all compositions of magnitude and distance using these attenuation relationships, Φ function and tables of normal probability standards.

Probabilistic seismic hazard analysis

Modern probabilistic seismic hazard analysis follows the basic approach developed by Cornell (1968). The mail changes from the original work is that the variability in ground motion (for a given magnitude and distance) is included. In addition, it has been generalize to fault sources. The hazard analysis computes the annual number of events that produce a ground motion parameter (e.g.PGA) that exceeds to a specified level (e.g .acc). This number of events per year (υ) is also called "the annual frequency of exceedance". The inverse of (υ) is called "the return period". For converting the annual rate of events into probability, we consider the probability that PGA is exceeded acc level at least once during a specified time interval. It was defined by Poisson model without any memory of the past earthquakes. If the occurrence of earthquake is a Poisson process, then the occurrence of PGA is a Poisson process either. For a Poisson process the probability of at least one occurrence of PGA in t years is given by:

(12)

$$P(PGA > acc) = 1 - \exp(-\lambda_t \cdot t \cdot p(a))$$

$$p(a) = P(PGA > acc|EQ)$$

These computations were performed for all 11 seismic zones around the Tabriz city with two attenuation relationships of Zare (1999) and Sinaian (2006) and eventually all the probabilities of exceedance for linear and area sources were merged to exhibit total probability of exceedance of PGA from acc for Tabriz city.

(13)

$$P(PGA > acc) = 1 - \{1 - P(PGA > acc)_1 \times 1 - P(PGA > acc)_2$$

The results were presented as seismic hazard curves for the city of Tabriz. Fig.10 and Fig.11 show the curves of total probability of exceedance of PGA.

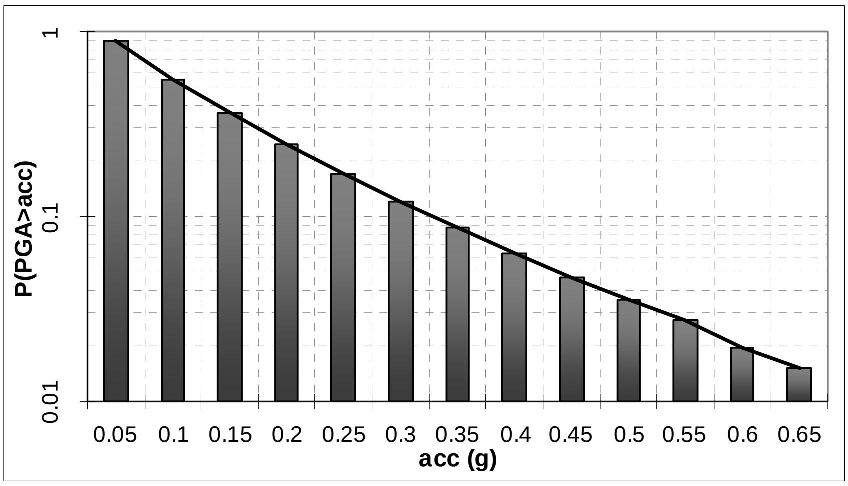

Fig. 10: Hazard curve for Tabriz site using Zare (1999) attenuation relationship

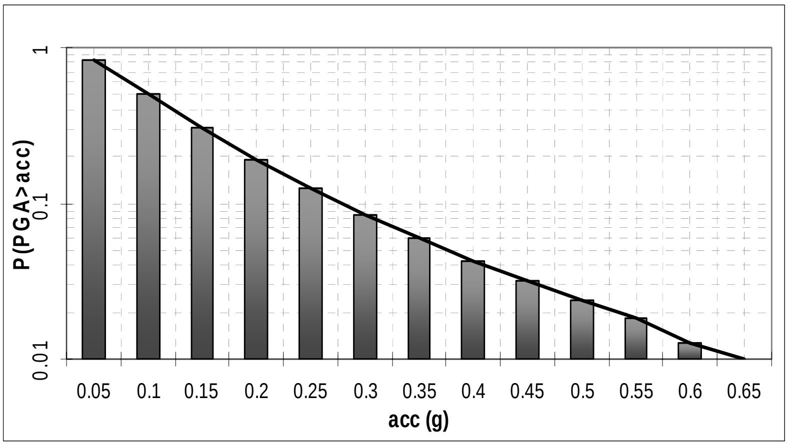

Fig. 11: Hazard curve for Tabriz city using attenuation relationship of Sinaian (2006)

Return period for the life of the structure

Results of hazard analysis were used in engineering projects so they should be expressed in applicable form for engineers. Typical probabilistic approach proposes that the structure be designed for the ground motion that will be exceeded at least once during the life of the structure with a given probability level. Depending of the importance of the structure a lower or higher probability level is chosen (Todorovska & Gupta, 1996). Return periods of different ground accelerations were evaluated using specified time intervals (t) and different probabilities of exceedance that were derived from hazard curves. In this study risk levels of 64%, 50% and 10% were selected to calculate return period of 50, 75 and 475 years for 50 years that considered as life of the structure.

Seismic hazard maps

As the last step in seismic hazard analysis, acceleration of ground motion was taken to depict seismic hazard maps for the study area. Return periods of 50, 75 and 475 years and Zare (1999) and Sinaian (2006) attenuation relationships were applied in map depiction. The result maps show a good correlation with trend of important seismic faults like NFT and Dehkharghan fault (Fig.12 and 13). Since the basic aim is to obtain PGA values for Tabriz city, so the main focus was made there. High PGA values for all return periods indicate the probability of intense earthquakes occurrence near this city (Table 4). According to seismic hazard map of Iran (IIEES, 1999) which shows the exceedance probability of 50%, Tabriz is located in the boundary between regions with high risk and very high risk, where PGA values differ between 0.3-0.35g. Our results for return period of 75 years which varies between 0.25- 0.33g, are in a good accordance with this map. In addition, our results are confirmed by the results of the study taken place on microtermometers in Tabriz. These studies presented the value of 0.32g for return period of 75 years. Joiner, Boore & Fumal(1993) attenuation relationship gave the most conservative results and Zare (1999) relationship was led to the mean values of PGA for the city. The highest values of PGA were observed in northwest corner of the city. It could be interpreted that these high amounts were resulted because of intersection of NTF and Dehkharghan faults in this area. Arise from this point, it can be concluded that Tabriz city is seated in the most hazardous location of these two seismic faults conjunction.

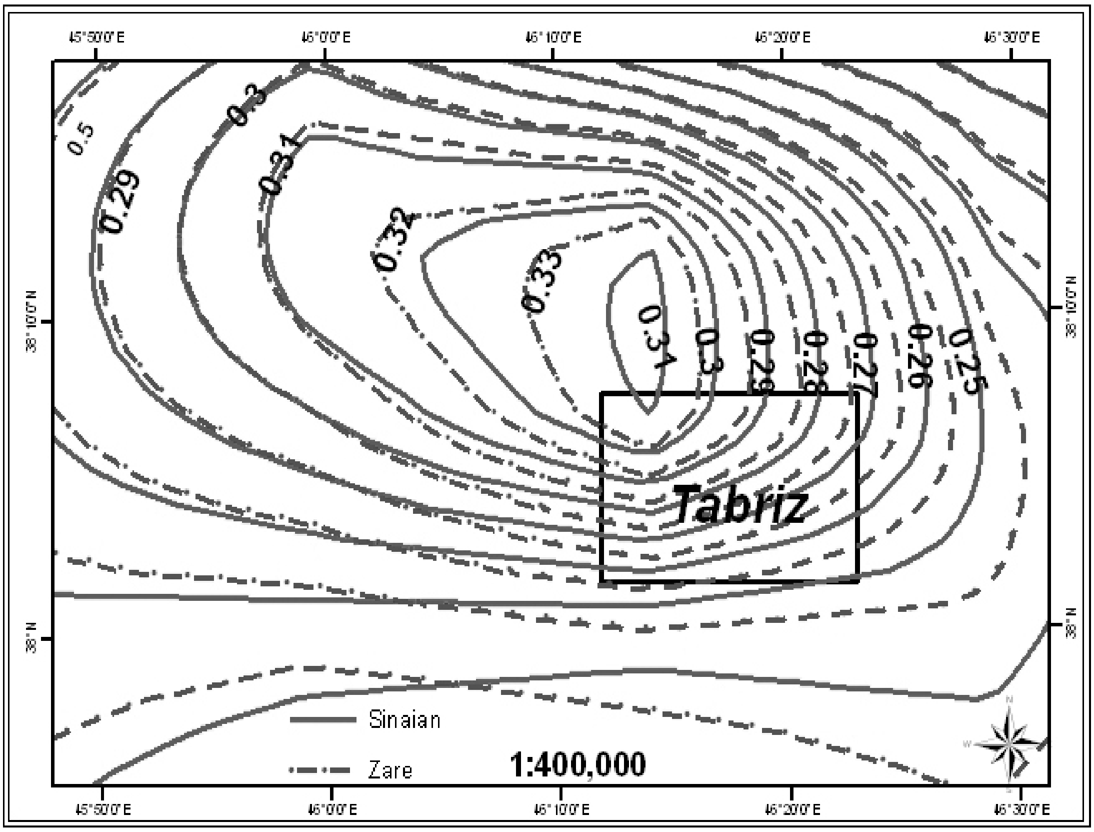

Fig. 12: Seismic hazard map for city of Tabriz for return period of 75 years

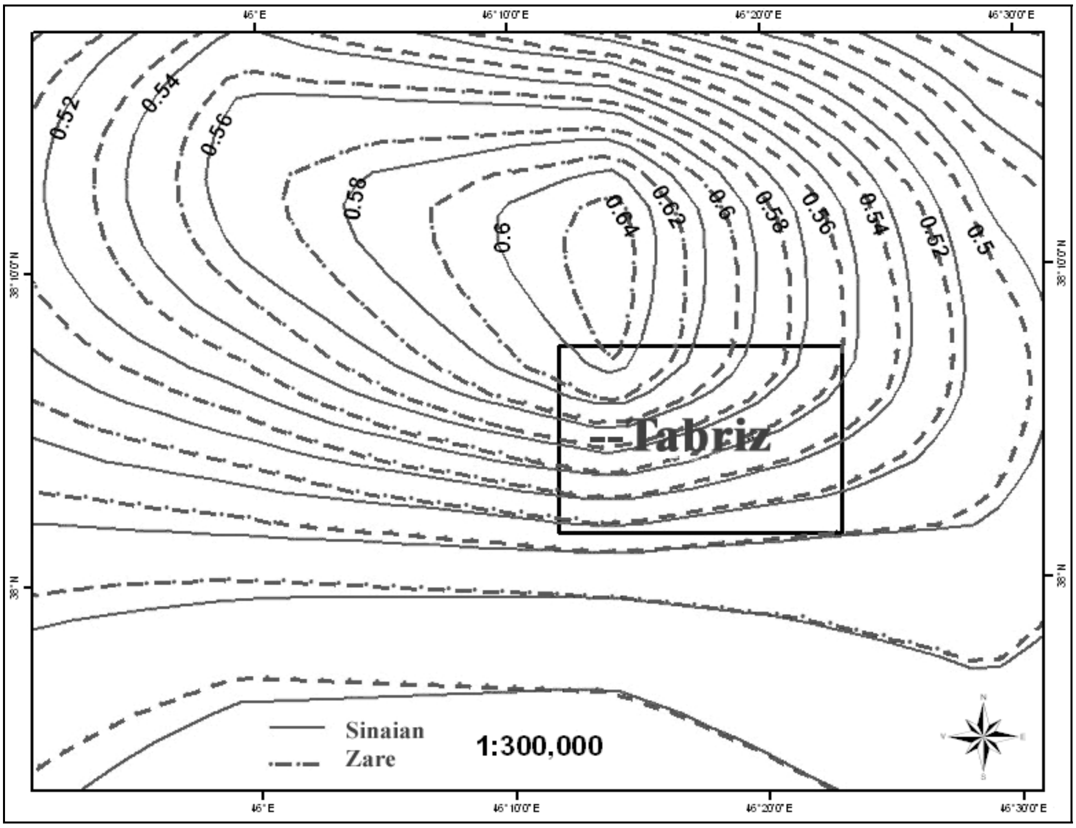

Fig. 13: Seismic hazard map for the city of Tabriz for return period of 475 years

Table 4: Values of PGA for Tabriz city considering different attenuation relationships and time intervals

Site	t	attenuation. R	q	HPGA(g)
			64%	(0.28-0.3) g
	50	Joiner-Boore-Fumal (1993)	50%	0.29-0.33) g
			10%	(0.53-0.6) g
			64%	(0.25-0.3) g
Tabriz	**5**	Zare (1999)	50%	(0.28-0.33) g
			10%	(0.5-0.64) g
			64%	(0.23-0.27) g
	5	Sinaian (2006)	50%	(0.25-0.31) g
			10%	(0.48-0.6) g

Conclusion

Tabriz is situated in an active tectonical region of Azerbaijan, a sub province of Central Iran seismic province and surrounded by several active and hazardous faults that most of them especially NTF has experienced several catastrophic historical earthquakes. Seismotectonical investigations show a major seismic gap around Tabriz city in the instrumental period. The average Focal depth of earthquakes in the region is 20km, representing shallow earthquake sources for the region. Hazard analyses were performed with probabilistic approach. Seismic zonation is performed in Arc GIS environment by merging tectonic and seismological features layers (Fig.14). Seismic parameters of study area and seismic zones were computed by Gutenberg and Richter (1958) frequency-magnitude relationships and Kijko-Sellevoll-Graham (1992) method. Maximum magnitudes for each zones are derived from magnitude- rapture length empirical relationships for hazardous faults and historical earthquakes of the region. Magnitude probability of expedience was originated from Gutenberg and Richter (1954) and Richter (1958) bounded magnitude- frequency relationships. Three attenuation relationships of Joiner, Boore & Fumal (1993), Zare (1999) and Sinaian (2006) were used in seismic hazard analysis and seismic hazard curves were derived from computations. Seismic hazard map for peak ground acceleration is depicted for return periods of 50, 75 and 475 years. High PGAs gained here show accordance with the previous studies.

As the city is located in the intersection of tow hazardous faults of NTF and Dehkharghan, performing more tectonic, seismotectonic and hazard studies on the region and Tabriz city.are indispensable.

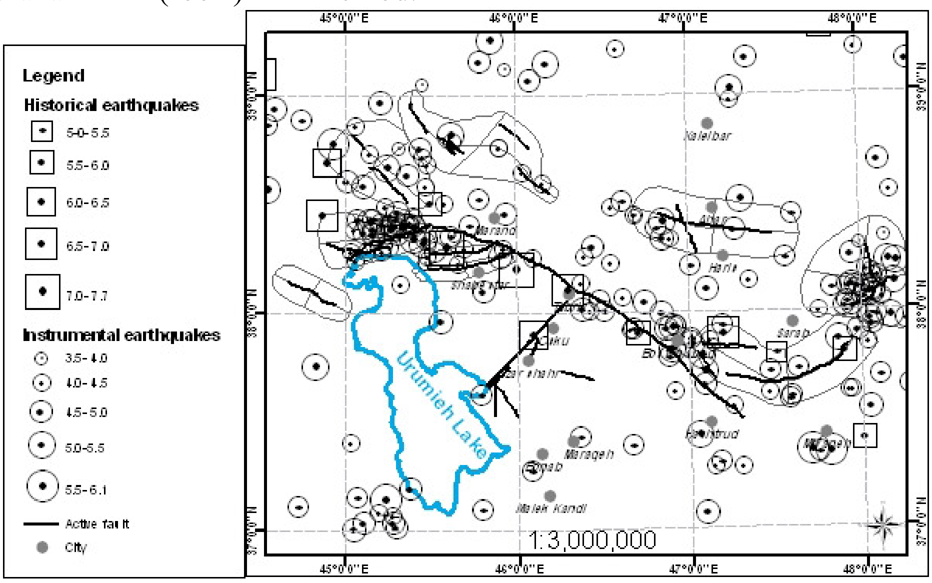

Fig. 14: Seismic zones together with epicenter and active map of study region

Acknowledgement

The authors are thankful to International Institute of Earthquake Engineering and Seismology (IIEES), Tabriz University, Tabriz local seismic network stuffs for providing instrumental earthquake data also H. Rejayi for his supports on GIS related parts. The help of Dr. M. Hajialilu and M. Faridi on fulfilling this study are aooreciated as well.

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