وضعیت لرزه خیزی شمال غرب ایران بر اساس اطلاعات شبکه لرزه نگاری محلی

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Pattern of Seismicity in Northwest Iran, Revealed from Local Seismic Network

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چکیده

گزارشات تاریخی و اطلاعات ثبت شده توسط دستگاههای لرزه نگاری و نیز شواهد زمین‌شناسی همگی نشان می دهند که شمال غرب ایران یکی از مناطق لرزه خیز خاور میانه بشمار می آید. زمین لرزهء مخرب سال ۱۹۹۰رودبار- طارم نیاز منطقه به شبکه لرزه نگاری دائمی را گوشزد نمود و موسسه ژئوفیزیک دانشگاه تهران در سال ۱۹۹۵ یک شبکه لرزه نگاری دائمی تله متری جهت ثبت زلزله های محلی در شمال غرب ایران نصب و راه اندازی نمود. براساس داده های بدست آمده از این شبکه لرزه نگاری، نواحی فعال و لرزه خیز متعددی قابل تشخیص می باشند. توزیع کانونی زمین لرزه های محلی با روند کلی شمال غـرب- جنـوب شرق گسلهای اصلی در منطقه تطابق دارد. نوزیع کانونی زمین لرزه ها در شرق و غرب منطقه با گسل های آستارا و رودبـار در شـرق و گسـل ارومیـه در غـرب همخوانی دارد. نوعی وضعیت نبود لرزه ای در قسمت مرکزی در اطراف شهر تبریز قابل مشاهده می باشد. حالت مشابهی در حوالی گسل آستارا دیده می شـود. اغلب زمین لرزه ها کم عمق هستند و نشان می دهند که فعالیت لرزه خیزی در پوستهء فوقانی رخ می دهد و لایه لرزه خیز پوسته زمین دارای ضخامتی حدود ۲۰ کیلومتر می باشد. با توجه به سابقه لرزه خیزی و نیز زمین لرزه های ثبت شده در منطقه ، وقوع زمین لرزه ء قوی در شمال غرب ایران دور از انتظار نمی باشد.

واژ های کلیدی: تکتونیک فعال، زمینلرزه های تاریخی، لرزه خیزی شمال باختری ایران ، کهلرزه ها، شبکه لرزه خیزی محلی، نبود لرزه ای

Abstract

Historical background and instrumentally located earthquakes as well as the geological evidences all suggest that northwest Iran is one of the seismically active regions in the Middle East. The destructive Rudbar-Tarom earthquake of 1990 indicated the need to install a permanent seismological network in the region. In 1995 the Institute of Geophysics of Tehran University deployed a telemetric seismic network in NW Iran to monitor local earthquakes. Relying on the records obtained during this period, several seismically active areas were identified. The epicenters of local earthquakes are in agreement with the NW-SE trending major faults. The distributions of earthquakes in east and west parts are consistent with the related major faults (Astara- Rudbar faults in east and Orumiyeh fault in west). A kind of seismic quiescence exists in central part around Tabriz. A similar situation could be observed along the Astara fault in the east. The majority of events are shallow indicating that the seismic activity is mainly taking place in upper crust and the seismogenic layer has a thickness of about 20 km. Taking into account the background seismicity and present pattern of seismicity, the occurrence of a major earthquake in northwest Iran is expectable.

Keywords: active tectonics, historical earthquakes, seismicity of northwest Iran, microearthquakes, local seismic network, seismic gap.

1. Introduction

The region referred in this study as northwest Iran is enclosed between 44 and 50 east longitudes and 36 and 40 north latitudes. This region is one of seismologically active regions in the Middle East and has experienced many destructive earthquakes in the past centuries, causing extensive property damage and heavy human loss. Detailed and comprehensive seismicity studies require reliable data on the hypocentral parameters of earthquakes. However, there were not enough data to evaluate seismic activity in northwest Iran, mainly due to the lack of a seismological network operating full time with an acceptable quality. The destructive Rudbar-Tarom earthquake of June 20th, 1990 with magnitude 7.3 and heavy human losses highlighted the need to install a permanent seismological network in Iran. Therefore, in 1995 the Institute of Geophysics of Tehran University deployed a telemetric seismic network in the central part of northwest Iran to monitor the seismic activity. The outcome of this network enabled us to look into the region and investigate the seismically active areas, which could not be recognized teleseismically. In this paper, first we present a detailed and reliable faults map of northwest Iran and review the historical destructive earthquakes that have occurred in the region. Then, seismicity features of Iran from instrumental observations, during 1925-2001, are investigated. Finally, the locally recorded earthquakes in the region are analyzed and their relations with the active faults finally discuss.

2. Minor and Active Faults

Iran is located in a very complex tectonic environment, where two main seismic belts (Alborz and Zagros) are converging and many destructive earthquakes have occurred in the past centuries. Deformation and seismicity in this region is mainly due to the continental shortening between the Eurasian and Arabian plates. Geological evidences and fault plane solutions of earthquakes in this region indicate the existence of both thrust and conjugate strike-slip faulting (Jackson, 1992). Using the geological information and air-photos, an attempt has been made to provide a detailed faults map, including the observed local faults in this region. Figure 1 shows the detailed faults map of northwest Iran. As it is indicated in this figure, several NW-SE trending major faults such as Mishu fault in northwest, north Tabriz and Bostanabad faults in central part and Rudbar fault system in eastern extension are examples of well known major faults in northwest Iran. Salmas and Orumiyeh faults in west and Astara fault in east are other examples of major faults in the region. In addition to these major faults, northwest Iran includes a remarkable number of minor faults. All the observed minor faults are mapped and drawn with other active faults in figure 1. The distribution of minor faults in central and east central parts is significant. A group of N-S trending minor faults is observable around Tabriz and extended to the north. Another minor fault system with NE-SW trend, almost perpendicular to north Tabriz major fault, is observable from the northeast part of Ardabil, passing through Meshginshahr and Azarshahr and crossing Orumiyeh lake as well as Orumiyeh major fault in west extreme. More groups of faults with different trends could be observed in figure 1 indicating a complicated pattern of deformation in northwest Iran.

3. Historical Earthquakes

Historical earthquakes of Iranian plateau, including northwest, have been studied by several investigators (Ambraseys, 1974; Ambraseys & Melville, 1982; Berberian, 1976). Though the historical earthquakes are imperfectly known, these studied suggest that northwest Iran has experienced many destructive earthquakes in historical time. The following is a brief explanation of significant historical earthquakes:

In 858, an earthquake almost totally destroyed the growing town of Tabriz. On Thursday the 4th November 1042, a catastrophic earthquake occurred in Tabriz late in the evening, part of the city was totally destroyed and about 40,000 people are said to have been killed. On 7th November 1304, a strong earthquake caused much damage in Tabriz; its aftershocks continued for a few months. In 1550, a damaging earthquake in Tabriz caused many casualties and extensive landslides in the mountains. Aftershocks continued for six days, possibly affecting the region of northwest Sahand. In the summer of 1593, Sarab was totally destroyed by a destructive earthquake and its district was leveled with the ground. Damage extended to the district of Miyaneh, where landslides overwhelmed two villages. On 12th March 1717, a little after midnight an earthquake in Tabriz destroyed 4000 houses, killing more than 700 people. On 26th April 1721, early in the Sunday morning, a major earthquake took place in Tabriz region, killing at least 40,000 people. On 8th January 1780, preceded by a strong foreshock, a catastrophic earthquake in the region of Tabriz almost totally destroyed the city and devastated about 400 villages, including Marand, Tasuj and Iranaq. On 18th April 1843, a destructive shock in the district of Khoy killed 1000 people. On 30th December 1863, a destructive earthquake occurred in Ardabil and 500 people were killed. The epicentral distribution of historical earthquakes is shown on the faults map of northwest Iran in figure 2. More details about these earthquakes are given by Ambraseys and Melville (1982).

4. Seismicity (1925-2001)

Compared with historical background, the seismicity of northwest Iran is better understood, in the present century both from the instrumental and macroseismic point of view. From 1900 till 1924, no recorded earthquake was reported for the region. However, during 1925-2001, source parameters of about 365 instrumentally recorded teleseismic earthquakes in northwest Iran were reported by international seismological agencies. The reliability of these source parameters depends on the quality and the quantity of seismic stations that have recorded these earthquakes. In the early years of nineteenth century, source parameters of earthquakes were poorly determined due to the lack of seismic stations and not enough coverage in the surrounding regions. While the epicenters were often mislocated by a few tens of kilometers, the depth of earthquakes determined by international seismological centers was even less accurate as shown by several micro earthquake studies, using master event technique and waveform modeling (Ambraseys, 1978; Jackson & Fitch 1979; Asudeh, 1983; Gheitanchi et al., 1998). Recently, because of remarkable developments in instrumentations and new techniques, the epicenteral determination of earthquakes is much more reliable. The time-frequency diagram of the instrumentally recorded earthquakes, in northwest Iran, during 1925-2001 is given in Figure 3. The magnitude-frequency diagram of these earthquakes during the same period is given in Figure 4. These figures indicate that the earthquakes that have occurred in this region so far are mostly moderate and only the magnitude of 1930 Salmas earthquake exceeded 7. The epicenters of these earthquakes are plotted on the faults map and indicated in Figure 5. The epicentral distribution of earthquakes in this figure indicates that seismic activity in the eastern and western parts of northwest Iran was remarkable during 1925-2001. Only limited earthquakes occurred in the east central part of the region. No major earthquake was reported in the central part including the major city of Tabriz. The reported depth for all earthquakes in this region are shallow, though due to lack of seismic stations the depth determination could not be reliable for this region.

5. Local Seismicity During 1995-1999

In 1995, as a part of national seismic network, the Institute of Geophysics of Tehran University deployed a telemetric seismic network in the central part of northwest Iran to monitor the seismic activity. The network included eight remote stations and was designed to cover the major part of northwest Iran where the city of Tabriz with dense population is located. Stations were selected to be in remote areas, away form various noises and in good condition from geological viewpoint and possibly to cover major faults in the area. Each seismic station included three component short period seismometers. The data processing center was located in Tabriz. The data was received in real time and the information transferred to a computer system. The accuracy of time in each station was checked and if necessary adjusted by GPS automatically. To process and locate the earthquakes, software called DAN (Data Analysis system provided by Nanometrics) was used. It worked under OS/2 in 32 bits or SUN workstations (DAN User's Guide, 1995). For locating the earthquakes, the modified version of HYPO71 program of Lee and Valdes (1985) was used. Regarding the geological and other seismological evidences, several crustal models were examined. Among them, the crustal model which was given by Gheitanchi (1996) had minimum residual errors and was selected for the computations. Thus, the operation of the new seismological network brought new stages in gathering knowledge and studies of seismic processes related to the northwest of Iran.

During 1995-1999, the local seismic network recorded about 2810 local earthquakes. The magnitude-frequency diagram of those earthquakes during the same period is given in Figure 6. This diagram shows that the network could detect the earthquakes with magnitudes greater than 1.5 and the majority of located local events had magnitudes within 2.5 and 3.5. The epicentral distribution of the locally located earthquakes is indicated on the faults map in Figure 7. As it is shown in this map, the seismic activity is not uniformly distributed in northwest Iran. In some parts of the region seismic activity is significant. The major seismically active area in northwest Iran, during 1995-1999, is located in south-west of Ardabil in the vicinity of the epicenter of the 1997 destructive earthquake with magnitude Mw=6.1 in the area. The epicenters of local earthquakes are in agreement with the NW-SE trending major faults. The distributions of earthquakes in east and west parts are consistent with the related major faults (Astara, Rudbar faults in east and Orumiyeh fault in west).

6. Discussion and Conclusion

Historical studies have shown that northwest Iran, including the major city of Tabriz, has been devastated by earthquakes several times in the past historical time. However, on the basis of those historical studies, it would appear that Tabriz and surrounding region has not experienced any major destructive earthquakes at least since the past two centuries. The seismic quiescence has continued to the present day during the period in which instrumentally recorded data, including the records of local seismic network has been reported. Comparison of the epicentral distributions given in figures 4 and 6 indicates that there is a good correlation between the seismic pattern of locally recorded earthquakes and the teleseismically

recorded earthquakes. The seismically active areas could be distinguished in both figures. A kind of seismic quiescence exists in central part around Tabriz. There is also a seismic gap noticeable along the Astara fault in the east. Several fault plane solutions for strong earthquakes in this region (Jackson & McKenzie, 1984; Jackson et al., 2002; Gheitanchi et al., 1998) indicate that the mechanism of these earthquakes has a remarkable strike-slip component. Therefore, the horizontal component of motion produced by the earthquakes in this region could be significant. The majority of local earthquakes are shallow, having a depth not greater than 20 km. It is concluded that seismic activity in northwest Iran is mainly taking place in upper crust and the seismogenic layer has a thickness of about 20 km. Regarding the destructive historical earthquakes in the past centuries and the lack of such kind of large earthquakes in the last two centuries, the occurrence of a major earthquake in northwest Iran is not out of imagination.

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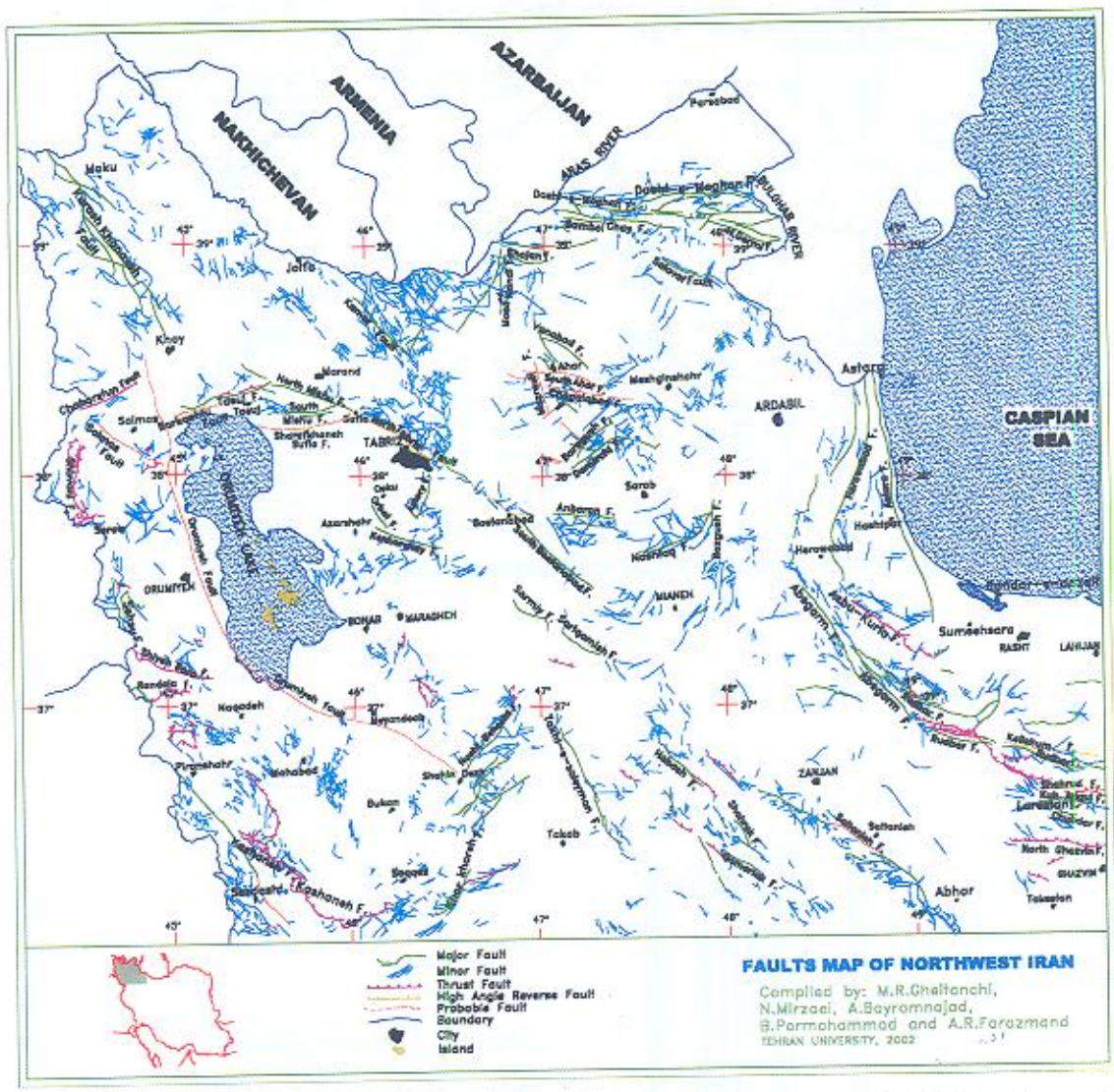

Figure 1. Detailed faults map of northwest Iran. As it is indicated in this figure, several major faults and many minor faults could be observed in the region.

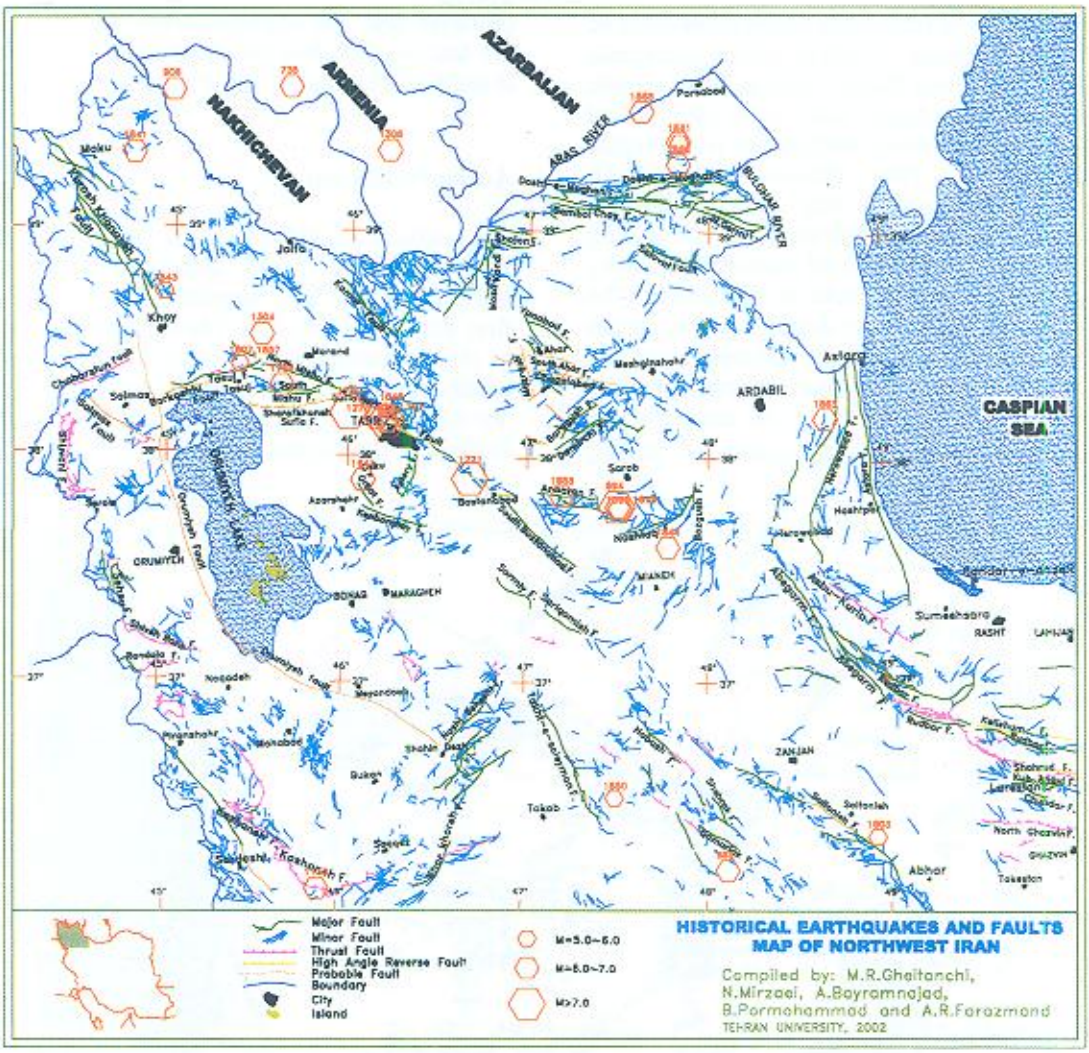

Figure 2. The epicentral distribution of historical earthquakes is shown on the faults map of northwest Iran.

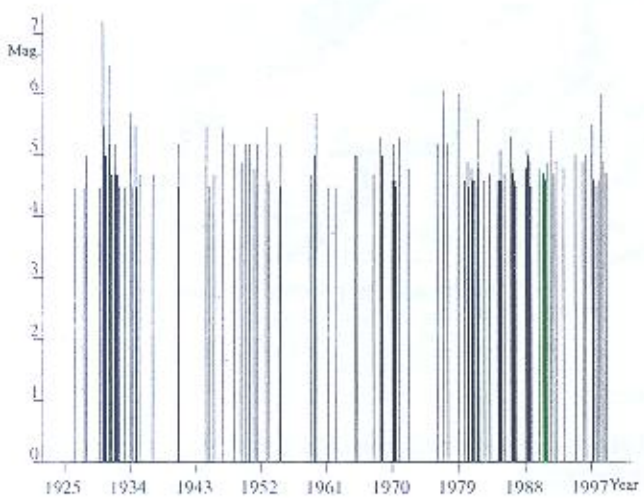

Figure 3. The time-frequency diagram of the instrumentally recorded earthquakes during 1925-2001 in northwest Iran. The horizontal axis indicates the time scale in terms of years. The vertical axis shows the magnitude of earthquakes in the Richter scale.

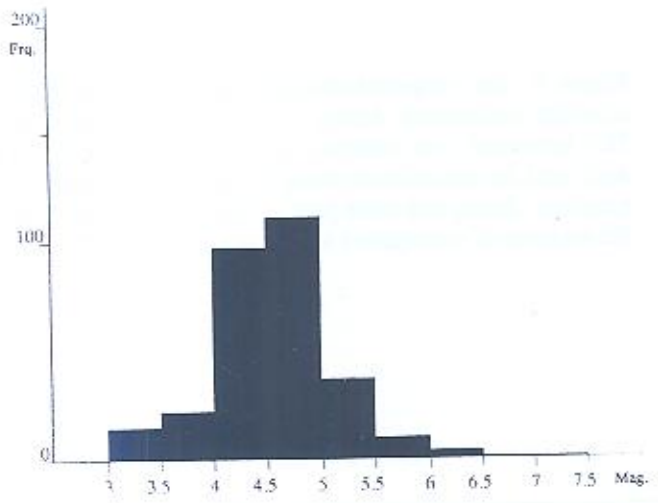

Figure 4. The magnitude-frequency diagram of the instrumentally recorded earthquakes during 1925-2001 in northwest Iran. The horizontal axis indicates magnitude in Richter and the vertical axis shows of earthquakes occurred during that period. This figure indicates that the earthquakes that have occurred in this region so far are mostly moderate.

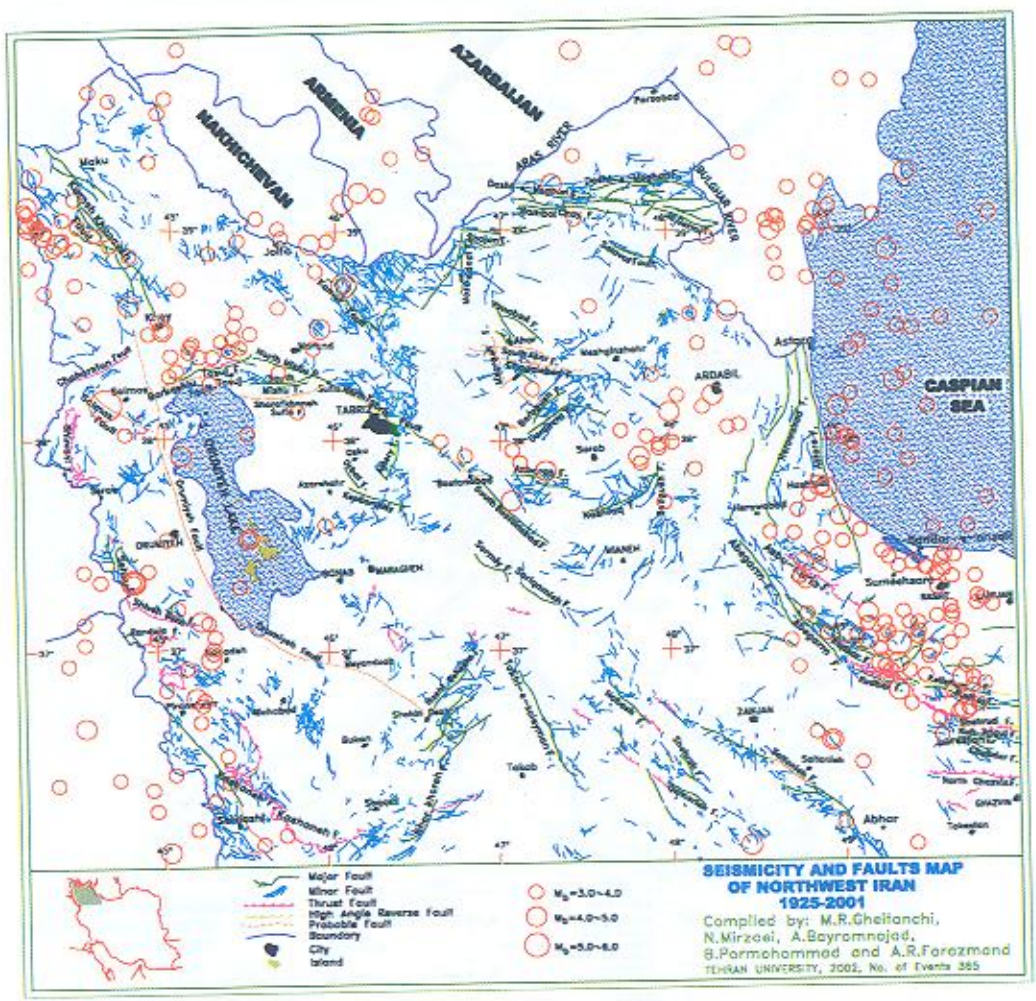

Figure 5. The epicentral distribution of instrumentally located earthquakes as well as the local faults map in northwest Iran. As it is indicated in this figure, seismic activity in both eastern and western parts of northwest Iran were remarkable during 1925-2001.

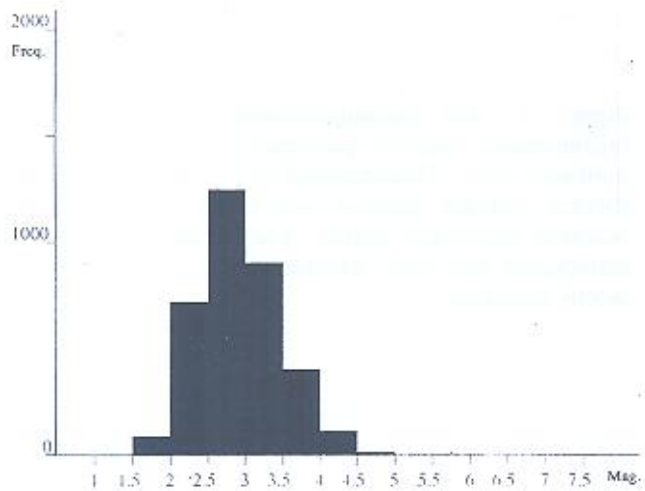

Figure 6. The magnitude-frequency diagram of the locally recorded earthquakes during 1995-1999 in northwest Iran. The horizontal axis indicates local magnitude in Richter scale and the vertical axis shows the number of earthquakes occurred during that same period. This figure indicates that the majority of earthquakes had magnitudes within 2.5-3.5.

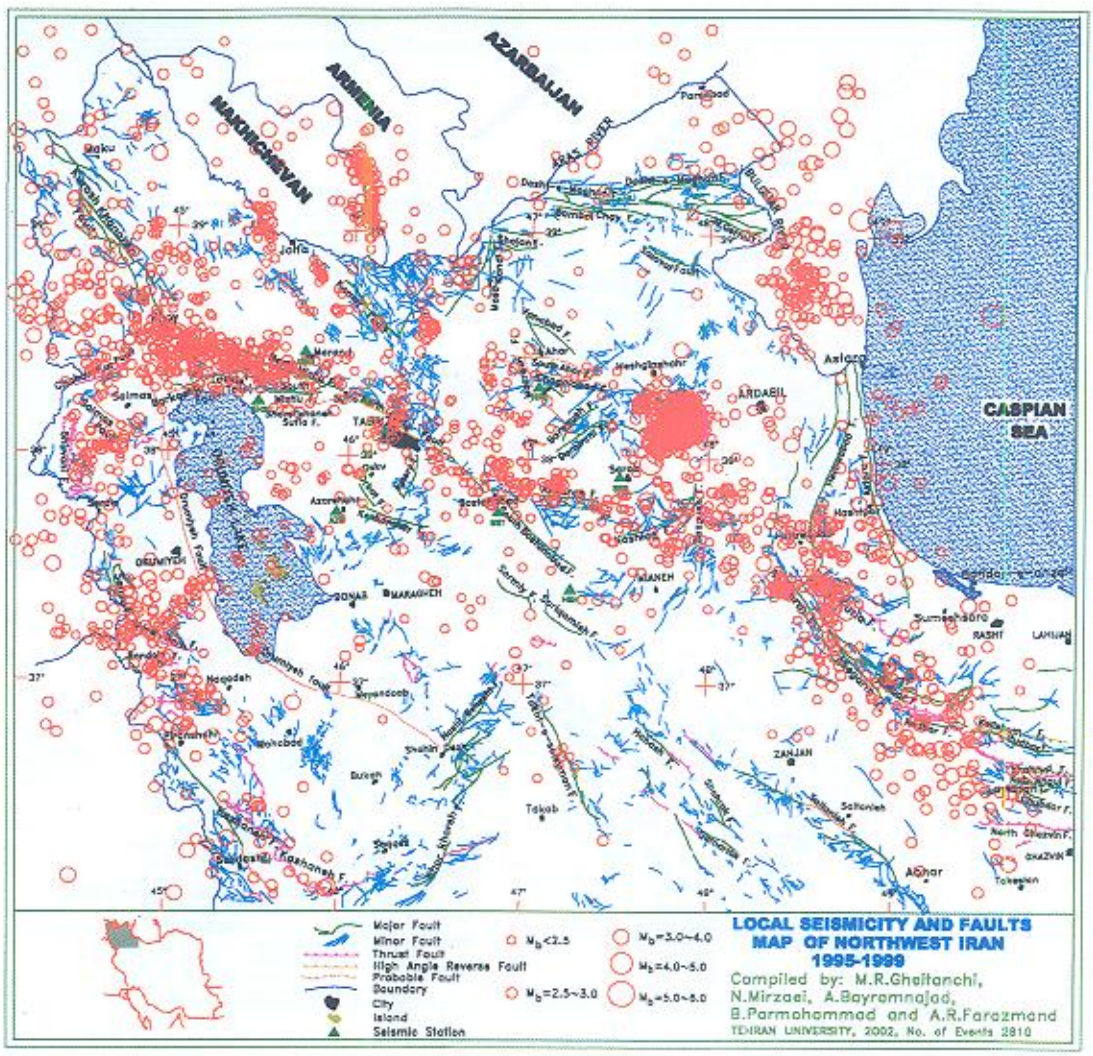

Figure 7. The epicentral distribution of located earthquakes by the local seismic network as well as the local faults map in northwest Iran.

References

Ambraseys, N.N., 1974- Historical seismicity of North-Central Iran, Geol. Surv. Iran, Rep. No. 29, 47-95.
Ambraseys, N.N., 1978- The relocation of epicenters in Iran, Geophys. J. R. astr. Soc., 53, 117-121.
Ambraseys, N.N. and Melville, C.P., 1982- A History of Persian Earthquakes, Cambridge University Press, 219 P.
Asudeh, I., 1983- ISC mislocation of earthquakes in Iran and geometrical residuals, Tectonophysics, 95, 61-74.
Berberian, M., 1976- An explanatory note on the first seismotectonics map of Iran; A seismo-tectonic review of the country, Geol. Surv. Iran, Rep. No. 39, 7-141.
DAN User's Guide, 1995- Nanometrics, Inc., Canada.
Gheitanchi, M.R., 1996- Crustal structure in NW Iran, revealed from the 1990 Rudbar aftershock sequence, J. Earth & Space Physics, Vol. 23, Nos. 1&2, 7-14.
Gheitanchi, M.R., Shafiei, D. and Bayramnajad, E., 1998- The February 28, 1997, Ardabil, Northwest Iran, Earthquake and its Aftershocks, J. Earth & Space Physics, Vol. 24, Nos. 1&2, 1-9.
Jackson, J., 1992- Partitioning of strike-slip and convergent motion between Eurasia and Arabia in eastern Turkey and the Caucasus, J. Geophys. Res., 97, 12471-12479.
Jackson, J. and Fitch, T.J., 1979- Seismotectonics implications of relocated aftershock sequences in Iran and Turkey, Geophys. J. R. astr. Soc., 57, 209-229.
Jackson, J. and McKenzie, D., 1984- Active tectonics of the Alpine-Himalayan belt between western Turkey and Pakistan, Geophys. J. R. Astron. Soc., 77, 185-264.
Jackson, J., Priestley, K., Allen, M.B. and Berberian, M., 2002- Active tectonics of the South Caspian Basin, Geophys. J. Int., 8, in press.
Lee, W.H.K. and Valdes, C.M., 1985- HYPO71PC: A personal computer version of the HYPO71 earthquake location program. U.S. Geol. Surv. Open File Report 85-749, 43pp.

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