فعالیت لرزه خیزی البرز در شمال ایران براساس داده‌های شبکهٔ لرزه نگاری محلی

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Seismic Activity in Alborz, Northern Iran,Revealed by Local Seismic Network

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چکیده

اطلاعات تاریخی و زمین لرره‌های ثبت شده توسط دستگاههای لرزه نگاری و نیز شواهد زمین‌شناسی همگی نشان می‌دهند که منطقه البرز در شمال ایران، یکی از مناطق فعال و لرزه‌خیز در خاورمیانه به‌شمار می‌آید. در سال ۱۹۹۶ و به‌عنوان بخشی از شبکه لرزه نگاری کشوری، مؤسسه ژئوفیزیک دانشگاه تهران یک شبکه تلومتری لرزه نگاری برای ثبت زمین لرزه‌های محلی در منطقه البرز و اطراف تهران نصب و راه اندازی نمود. براساس داده های ثبت شده در فاصله زمانی ۱۹۹۶ الی ۲۰۰۵، در البرز چند ناحیه فعال و لرزه‌خیز مشاهده گردید. کانون سطحی زمین لرزه های محلی با موقعیت گسلهای اصلی و زمین ساخت منطقه همخوانی خوبی دارند. توزیع زمین لرزه ها در خاور و باختر با گسلهای مربوطه همبستگی خوبی نشان می‌دهند. یک نوع حالت نبود لرزه ای در البرز مرکزی در اطراف شهر تهران وجود دارد. وضعیت مشابهی در انتهای جنوب خاوری سامانه گسلی رودبار قابل مشاهده می‌باشد. بیشتر زمین لرزه‌های ثبت شده دارای عمق کم می‌باشند و نشان می‌دهند که فعالیت لرزه‌ای عمدتا در پوسته بالایی صورت می گیرد و لایه زلزله را ضخامتی حدود ۲۰ کیلومتر دارد. با توجه به پیشینه تاریخی و وضعیت فعلی، وقوع زمین لرزهٔ بزرگ در منطقه البرز در حوالی شهر تهران دور از انتظار نمی باشد.

کلید واژه‌ها: لرزه زمین‌ساخت، زمین‌ساخت فعال، گسلهای فعال، زمین لرزه‌های تاریخی، لرزه‌خیزی البرز، خرد زمین لرزه‌ها، شبکه لرزه‌نگاری محلی، آرامش لرزه‌ای و نبود لرزه‌ای.

Abstract

Historical background and instrumentally located earthquakes as well as the geological evidences all suggest that Alborz region in northern Iran is one of the seismically active regions in the Middle East. In 1996, as a part of national seismic network, the Geophysics Institute of Tehran University deployed a telemetric seismic network in Alborz region mainly to monitor local earthquakes. Relying on the records obtained during 1996-2005, several seismically active areas with the following aspects could be recognized. The epicenters of local earthquakes are in good agreement with the location of major faults as well as the regional tectonic settings. The distribution of earthquakes in eastern and western parts of the region are consistent with the related major faults. A kind of seismic quiescence exists in the central part of the Alborz around the Tehran city. A similar situation could be observed along the south eastern extension of Rudbar fault system. Most of the recorded earthquakes have shallow depths 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 historical background and the present situation, the occurrence of a major earthquake in Alborz in the vicinity of Tehran is not far from expectation.

Keywords: Alborz, northern Iran, faults, earthquake, seismic network, seismic activity

1. Introduction

Since 1996, the Geophysics Institute of Tehran University has deployed a telemetric seismic network in Alborz. The main purpose of the network is the acquisition of seismic data originated in a set of twelve remote seismological stations, and investigation of the origin of processes that cause earthquakes in this region. The data is transmitted from each remote station through telemetric link to a central station located at Tehran where all the information are processed. The new seismological network has been aimed at forecasting and warning capabilities concerning earthquakes, to study the spatial and temporal seismic distribution to identify seismogenic sources, their

mechanism and geometry; and to create public awareness about the causes, effects and mitigation of natural hazards. Thus, the operation of the new seismological network, brought new stages in gathering of and studies of seismic processes related to active tectonics in Alborz.

In this paper, the geological background of Alborz is overviewd and a detailed map of active faults in the region are presented. The historical earthquakes in Alborz are summarized and instrumentally recorded earthquakes during 1964-2005 are presented. Finally, the locally recorded earthquakes during 1996-2005 are analyzed and discussed with the other results.

2. Geological background

The region referred in this study as Alborz is situated between 47º and 58º east longitudes and 34º and 39º north latitudes. The region consists of a broad arch of parallel anticlines and synclines which forms the southern border of the vast depression of the Caspian Sea. They face the Caspian block on the north and to the south grade into the plateau of Central Iran. In its western part, the range shows NW-SE, trending structures, roughly parallel to the northern part of the Zagros seismic zone and to the structural alignements of Caucasus. On the other, hand, the eastern part of Alborz is characterized by structural features trending approximately NE-SW, parallel to the Great Kavir (Doruneh) fault. These two different structural trends meet in the Central Alborz, assuming a critical position in the framework of the range. In the zone of convergence between these two different alignements, the great Quaternary volcano of Damavand is located.

Using the geological information and air-photos, an attempt has been made to provide a detailed fault map, including the observed local faults in this region. Figure 1 shows the detailed fault map of Alborz. As indicated in this figure, several major faults with almost east-west trends in north and northeast Tehran, the Rudbar fault system in northwest, and the Ipak in west are examples of well known major faults in Alborz region that have experienced destructive earthquakes in the past. In addition to these major faults, central Alborz includes a remarkable number of minor faults. All the observed minor faults are mapped and drawn with other active faults in Figure 1. Distribution of minor faults in central and east central parts is significant. Several groups of faults with different trends could be observed in Figure 1 indicating a complicated pattern of deformation in Alborz. Geological evidence and fault plane solutions of earthquakes in Alborz region indicate the existence of both thrust and conjugate strike-slip faulting (Jackson, 1992). The epicenters and focal mechanisms of selected strong earthquakes during 1977-2005 that were obtained by centroid moment tensor and reported by Harvard university are overlapped on the faults map of Alborz region in Figure 2.

3. Historical earthquakes

Historical earthquakes of Iranian plateau, including Alborz region, has been studied by several investigators (Ambraseys, 1974; Ambraseys & Melville, 1982; Berberian, 1976). Though the historical earthquakes are imperfectly known, these studies suggest that Alborz region has experienced many destructive earthquakes in historical time. A brief explanation of significant historical earthquakes is presented below.

Late in spring of 743, there was a destructive earthquake east of Ray, the former capital of Iran. In 855, a major earthquake in Ray destroyed many houses and caused a large number of casualties and was followed by aftershocks for more than a month. The shock was strongly felt in Qum and Kashan. In 856, on Tuesday December 22, there was a catastrophic earthquake in eastern Alborz and more than 200000 people were killed. In the mountain ous regions, there were extensive ground deformation. In January 864, Ray was affected by an earthquake which destroyed many houses and killed a large number of people. Late in 874, a locally destructive earthquake killed 2000 of the troops that had taken refuge in Gorgan. Violent shocks continued for three days. In 956, Asadabad and Hamadan were seriously damaged by an earthquake, killing a large number of people. On 23 February 958, there was a catastrophic earthquake in north central Iran. It destroyed all villages in the districts of Ray and Taliqan and much of the city of Ray was totally ruined, heavy casualties were reported. Damaging aftershocks continued for forty days. In November 1087, Hamadan and nearby regions were shaken by an earthquake and a number of people were killed. Strong aftershocks lasted a week. On 10 December 1119, a sever earthquake in Qazvin killed many people and caused extensive damage. In May 1177, an earthquake destroyed many towns along the southern slopes of Alborz up to the region beyond Ray and many people were killed. The Ray area, eastern Buyin Zahra and the Karaj settlements were the worst affected regions. In 1191, a strong shock was felt in Hamadan without any damage. In 1384, a destructive earthquake occurred in Ray. In 1470, there was an earthquake in Gorgan and Gonbad-e Kavus was affected by this earthquake. On Sunday 15 August 1485 and just before sunset, there was a catastrophic earthquake in Gilan affecting a large area between Gilan and Mazandaran. Aftershocks continued for six weeks keeping the survivors camping out in the open. In 1498, a destructive earthquake caused the collapse of most of the houses in Gorgan, killing 1000 of its inhabitants. On the 20 April 1608, there was a major earthquake in southern Gilan, causing great damage over a large area. It caused large waves in the Caspian Sea and resulted in geart alarm. In 1639, a destructive earthquake is said to have killed 12000 people in Qazvin. In 1665, there was a destructive earthquake in Damavand. It destroyed many houses and buildings in the region. On 3 February 1678, an earthquake in Lahijan, followed by many aftershocks, ruined many houses, mosques and bridges. In 1687, a serious earthquake in Mazandaran destroyed many villages and triggered landslides. On 7 June 1755 a destructive earthquake in Kashan destroyed 3000 houses and more than 12000 people were killed. On Tuesday 15 December 1778 just before dawn, an earthquake strongly felt in the regions of Ray, Qom and Isfahan but destruction was centered in the districts of Kashan, where more than 8000 people were killed and almost all houses were

destroyed. On 16 December 1808, a destructive shock in western Mazandaran and Taliqan destroyed many villages. In Tehran the shock caused panic and the inhabitants left their houses and camped in the open. Continuing aftershocks felt in Tehran added to the panic. In 1809, a destructive earthquake occurred in Amol and caused widespread liquefaction in the river valleys and rockfalls in the mountains. In June 1815, a strong earthquake was felt in Damavand and caused a spring of cold water to dry up. In 1825, a destructive earthquake in the Haraz Valley ruined many villages, causing the death of a large number of people. In the morning of the 27th March 1830, a major earthquake in southern Mazandaran destroyed more than 70 villages. More details about these earthquakes are given by Ambraseys and Melville (1982).

4. Instrumentally recorded earthquakes during 1964-2005

Detailed and comprehensive seismicity studies require reliable data on the hypocentral parameters of earthquakes (Ambraseys, 1978). However, there were not enough data to evaluate seismic activity in Alborz, mainly due to the lack of a seismological network operating full-time with an acceptable quality (Asudeh, 1983). Compared to the historical background, the seismicity of Alborz is better understood in the present century. From 1900 till 1962, no recorded major earthquake was reported for the region. In 1962, the Buyin-Zahra earthquake and its major aftershocks occurred in Qazvin Province. During 1964-2005, source parameters of about 597 instrumentally recorded teleseismic earthquakes in Alborz were reported by international seismological agencies. The reliability of 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. Recently, by remarkable developments in instrumentation and new techniques, the epicenteral determination of earthquakes are much more reliable. The time-magnitude diagram of the instrumentally recorded earthquakes, in Alborz, during 1964-2005 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. The epicenters of these earthquakes are plotted on the faults map represented in Figure 5. The epicentral distribution of earthquakes in this figure indicates that seismic activity in both eastern and western parts of Alborz were remarkable during 1964 - 2005. Only limited earthquakes occurred in the east central part of the region. No major earthquake was reported in the central part including the capital city Tehran. The reported depth for all earthquakes in this region are shallow, though due to the lack of seismic stations the depth determination could not be reliable in this region.

5. Locally recorded earthquakes during 1996-2005

The destructive Rudbar-Tarom earthquake of 1990 in Alborz indicated the need to install a permanent seismological network in the region. Therefore, in 1996, as a part of national seismic network, the Institute of Geophysics of Tehran University deployed a telemetric seismic network in Alborz to monitor the seismic activity. The network includes twelve remote stations and is designed to cover the major part of Alborz where the city of Tehran with dense population is located. The location of stations are selected so that to be in remote areas, away from various noises and in good condition from the geological point of view and possibly to cover major faults in the area. Each seismic station includes three component short period seismometers. The data processing center is located in Tehran. The data is received in real time and the information is transferred to a computer system. The accuracy of time in each station is checked and if necessary adjusted by GPS automatically. To process and locate the earthquakes, the software called DAN (Data Analysis System provided by Nanometrics) is used. It works 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) is used. Regarding the geological and other seismological evidences, several crustal models are examined. Among them, the crustal model presented by Gheitanchi (1996) has minimum residual errors and is selected for computations. During 1996-2005, about 5907 local earthquakes are recorded by the local seismic network. The time-magnitude diagram of local earthquakes with magnitude larger than 3.5 during 1996-2005 is shown in Figure 6. The magnitude-frequency diagram of those earthquakes during the same period is given in Figure 7. This diagram shows that the network could detect the earthquakes with magnitudes smaller than 1.0 inside the network and the majority of located local events had magnitudes within 2 and 3. The epicentral distribution of the locally located earthquakes is indicated on the fault map in Figure 8. As it is shown the seismic activity is not uniformly distributed in Alborz. In some parts of the region, seismic activity is significant. The major seismically active area in Alborz, during 1996-2005, is located in west and northwest in the vicinity of the epicenters of the 1962 Buyin Zahra and the 1990 Rudbar destructive earthquakes. East central part of the region is seismically active, indicating a cluster pattern. The epicenters of local earthquakes are in agreement with the trends of major faults.

6. Discussion and Conclusion

Historical documents indicate that Shahr-e Ray, the former capital of Iran has been devastated by earthquakes several times. However, on the basis of those historical studies, it would appear that Tehran and surrounding areas have not experienced any major destructive earthquakes at least since the past centuries. The seismic quiescence has continued to 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 in Figures 5 and 8 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 Tehran. There is also an obvious seismic gap noticeable along the Rudbar fault system in the southeast extension. Several fault plane solutions for strong earthquakes in this region (Jackson & McKenzie, 1984; Jackson et al., 2002; Gheitanchi et al., 1998) indicate that the these earthquakes has a remarkable strike-slip component (Figure 2). 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 Alborz 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, occurrence of a major earthquake in Alborz is not out of imagination.

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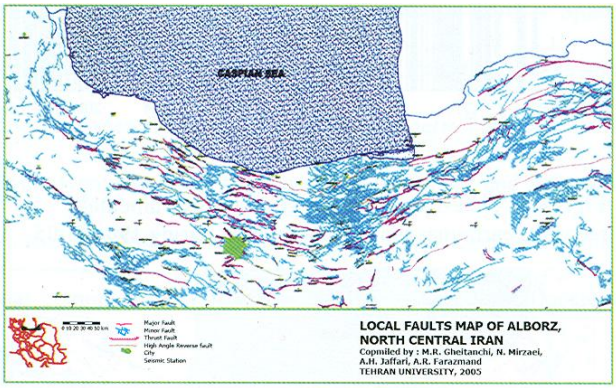

Figure 1. Local faults map of Alborz region. The informations of faults were obtained from the Geological maps publisted by Geological Survey of Iran.

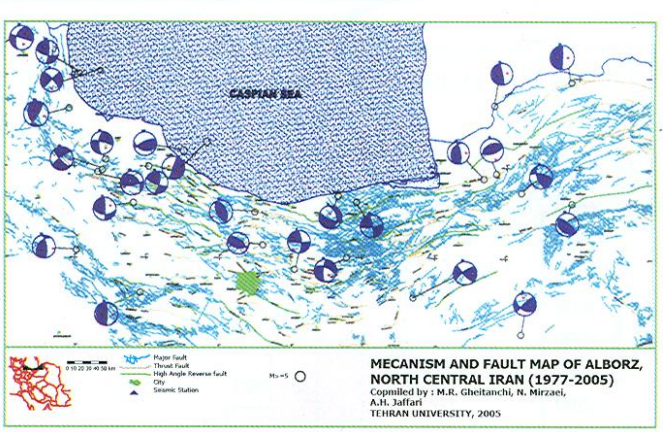

Figure 2. The epicenters and focal mechanisms of strong earthquakes during 1977-2005 that were obtained by centroid moment tensor and reported by Harvard university are overlapped on the faults map of Alborz region.

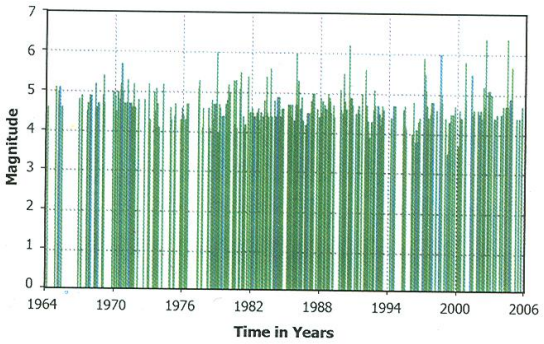

Figure 3. Time-magnitude diagram for instrumentally recorded earthquakes in Alborz region during 1964-2005.

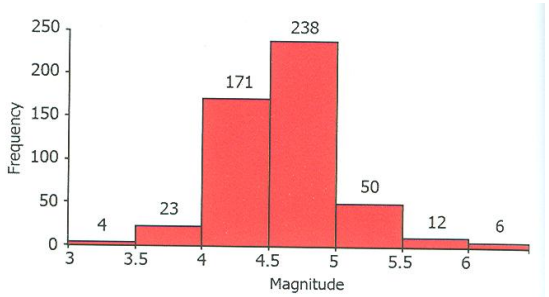

Figure 4. Magnitude-frequency diagram for instrumentally recorded earthquakes in Alborz region during 1964-2005. The horizontal axis indicates the magnitudes and the vertical axis indicates how frequentely the earthquakes occurred.

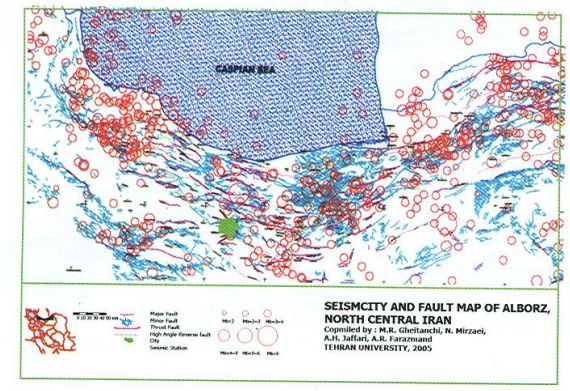

Figure 5. The epicenters of instrumentally recorded earthquakes are plotted on the faults map in Alborz region.

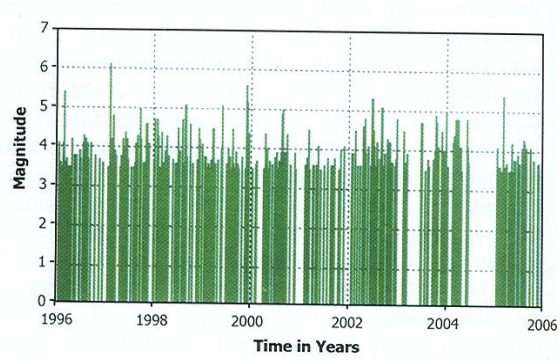

Figure 6. Time-magnitude diagram for local earthquakes recorded by the local seismic network in Alborz during 1996-2005.

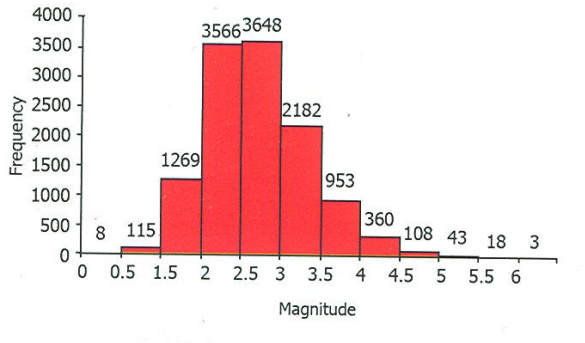

Figure 7. Magnitude-frequency diagram for local earthquakes recorded by the local seismic network in Alborz during 1996-2005. The horizontal axis indicates the magnitudes and the vertical axis indicates how frequentely the earthquakes occurred.

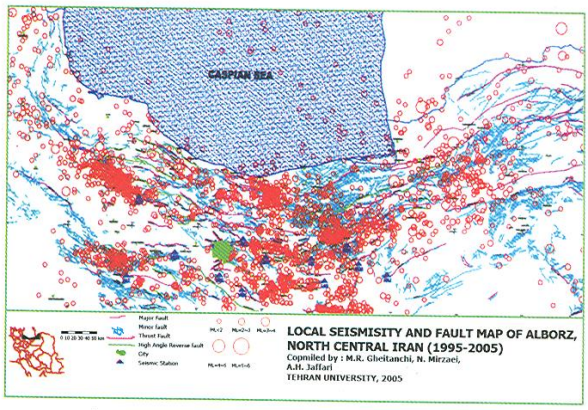

Figure 8. Epicentral distribution of locally located earthquakes in Alborz region during 1996-2005. As indicated, the seismic activity is not uniformly distributed in the region.

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