A study on Seismicity of Eastern Alborz from October, 2009 to Jaunary, 2010 based on local network

H. Hamzehloo, M. Farokhi, G. Javan, A. Hushmand
International Institute of Earthquake Engineering and Seismology, Tehran, I.R.Iran

SUMMARY:
A local network has been installed in Eastern Tehran to analysis the seismicity of the region after the October 17, 2009 earthquake with magnitude 4.0. The network includes 38 stations. The October 17, 2009 earthquake occurred in southeast of Tehran closed to the city. The second earthquake occurred on August 28, 2010, with magnitude of 5.7 in Semnan province, which is located in east of Tehran. In this paper, the preliminary results of the seismicity analysis have been presented. We have also studied source parameters of October 17, 2009 earthquake and the causative fault parameters. A 1-D velocity model has been also presented based on preliminary analysis of 194 local earthquakes. This is very important from hazard point view for Tehran city, since the large destructive historical earthquakes occurred in this region.

Keywords: Local network, Seimicity, Tehran, Eastern Alborz

1. INTRODUCTION

Tehran, the capital of Iran, is located in a very high seismic zone at the foot of the Alborz Mountains. The Alborz is seismically active with E-W trending mountain belt of 100 km wide and 600 km long, which was formed in the late Triassic (Sengor et al.,1988). The recent Cenozoic evolution has been explained as the result of strain partitioning between left-lateral strike slip and thrust faults parallel to the belt (Jackson, et al., 2000). North- south shortening of 8±2 mm/yr has been reported across Alborz range between the central Iran and the Southern Caspian shore (Vernant, et al., 2004). Its total shortening since the early Pliocene is estimated to be 30 km at the longitude of Tehran (Allen et al., 2003). Several active faults affect the Tehran (Fig. 1). To the north, the Khazar and North Alborz reverse faults dip southward with a slight component of left lateral strike slip motion. Bounding the highest topography to the south, the main active faults are the North Tehran and Mosha faults and their westward continuation, the Taleghan fault]. The Mosha fault has accommodated a total left lateral displacement of 30-35 km and the present day average rate is of 3 mm/yr. To the south of Tehran, the Ipak, Eyvanaki, Garmsar and Pishva. The distribution of historical earthquakes (Fig.1) around Tehran shows that the region has been experiencing eight large destructive earthquakes with magnitude greater than 7 from 4th B.C to 1830 (Ambraseys and Melville, 1982). These large historical earthquakes caused severe damage to Shahre Ray City, which is a part of Tehran city at present. The last large historical event was the 1830 earthquake with magnitude 7.1, which occurred approximately 100 km from the city. The closest historical event regarding to the city was the 855 earthquake with magnitude 7.1 (Hamzehloo et al., 2007). The most important instrumental earthquakes, which occurred in this region, are the 1962 Buin Zahra earthquake with magnitude M_W 7.2, the 2002 Changureh (Avaj) earthquake with magnitude M_W 6.5, and the 2004 Firozabad Kojor earthquake with magnitude M_W 6.3 [12]. The strong ground motion network in Tehran recorded four large to strong earthquakes from 1990 to 2007. These records are related to the 1990 Manjil-Rudbar earthquake with magnitude M_W=7.3, the 2002 Changureh (Avaj) earthquake with magnitude M_W=6.5, the 2004

Firozabad Kojor earthquake with magnitude M_W=6.3 and the 2007 Kahak- Qom earthquake with magnitude M_W=5.9.

Recently, the M_W 4.0 earthquake occurred at 14: 23: 57 local time on October 17, 2009 in south of Tehran (Fig.1). This earthquake was felt at Tehran. Since Tehran is located in a very high seismic zone, it is therefore important to study this earthquake in more detail to identify the causative fault parameters. After this earthquake a local network include 51 station have been installed from east of Tehran to Semnan (Fig. 1). In this paper, the preliminary results of analysis of seismicity from local earthquakes and the causative fault parameters for October 17, 2009 earthquake by using SH-waves analysis of recorded acceleration data have been presented.

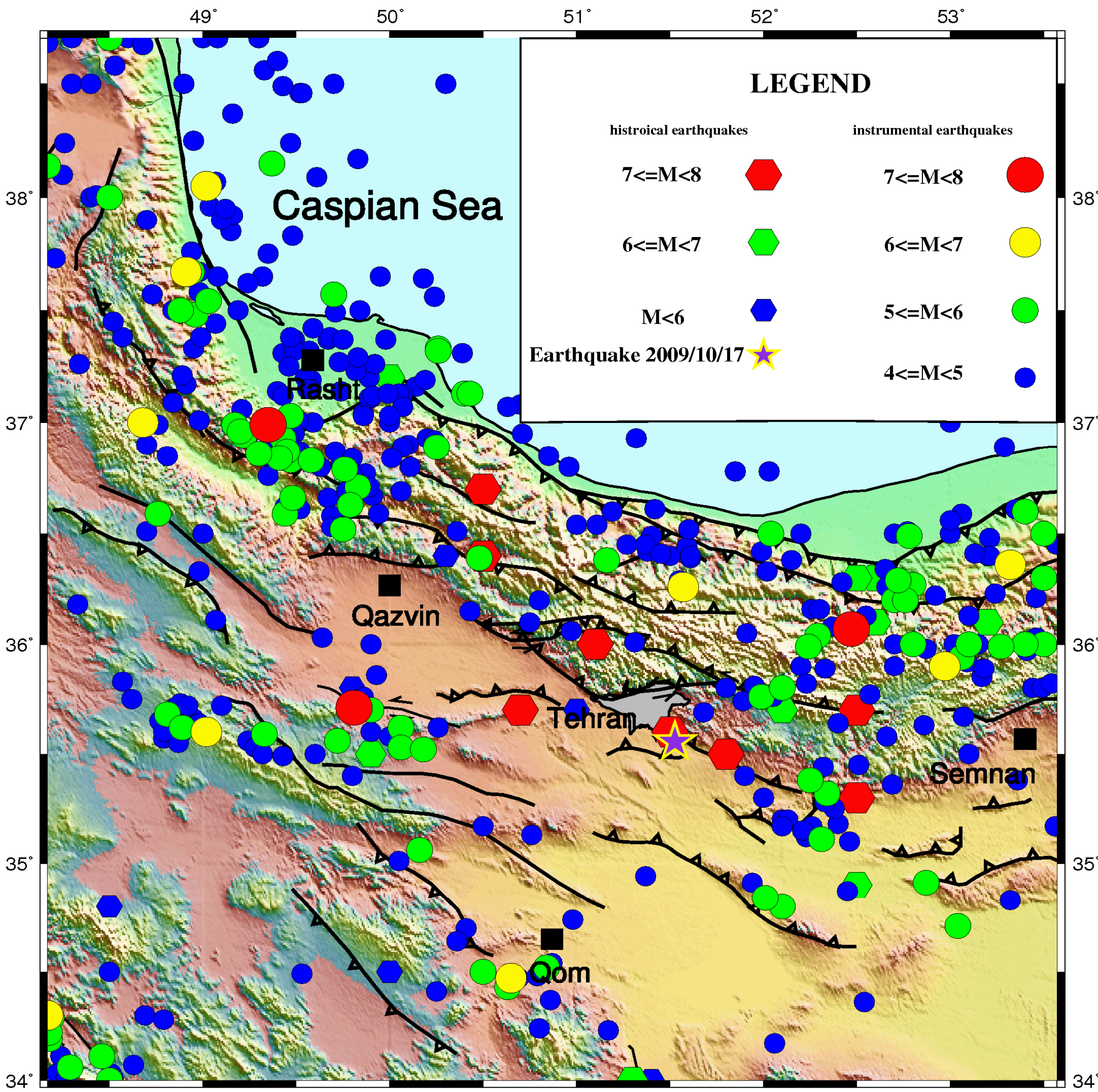

Figure.1. Active faults and seismicity around Tehran.

2. THE OCTOBER 17, 2009 EARTHQUAKE

On October 17, 2009, at 14: 23: 57 (local time), an earthquake, with estimated magnitude $M_w = 4.0$, occurred in the southeastern of Tehran. The earthquake was felt not very strongly in Tehran. Various agencies e.g. International Institute of Earthquake Engineering and Seismology (IIEES), Institute of Geophysics, Tehran University (IGTU), and Tehran Disaster Mitigation and Management Organization (TDMMO) estimated the hypocentral locations of this event. The earthquake epicenter is located close to the Eyvanaki fault southeastern of Tehran (Fig. 2) with the local geological structures trending NW-SE.

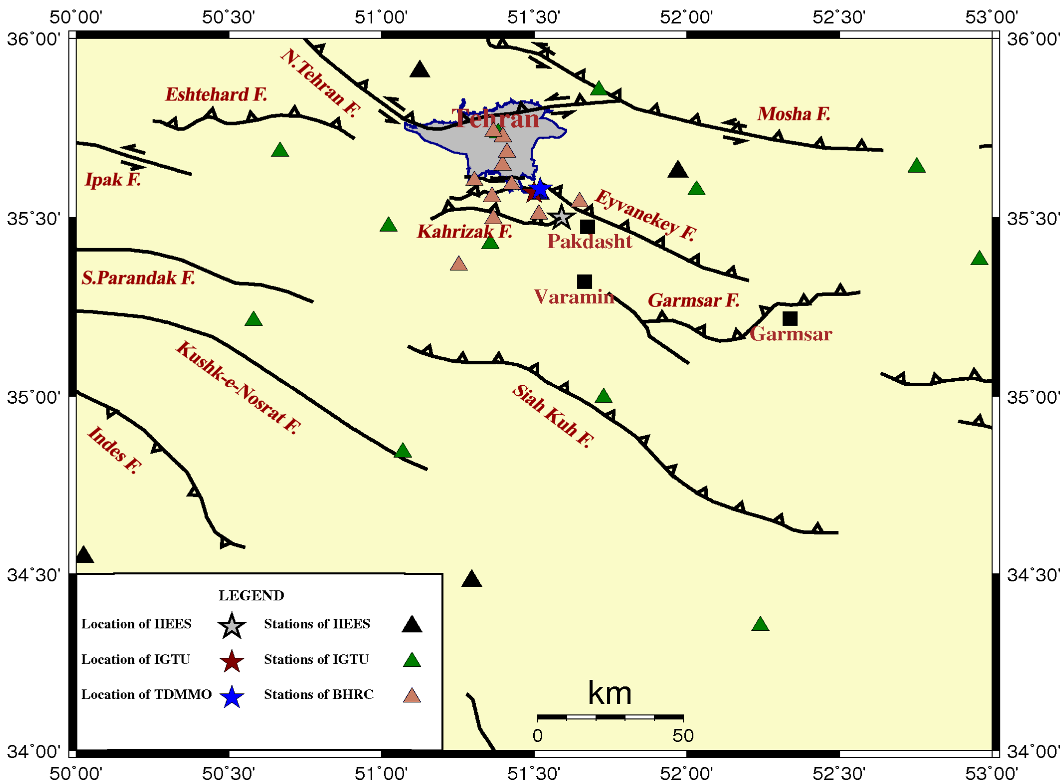

Figure 2. The locations of epicenter reported by IIEES, IGTU and TDMMO.

The 2009 earthquake was recorded by 12 SSA-2 type accelerographs of the strong motion array operated by BHRC (Fig. 2). In this study we report a detailed analysis of this strong ground motion data recorded at Chehel Ghez (CHE), Qani Abad (QAN), Ghaleno (GHA), Tehran 1 (TE1), Tehran 18 (T18), Hassan Abad (HAS), Tehran 2 (TE2), Tehran 29 (T29), Kahrizak (KAH), Tehran 13 (T13), Tehran 58 (T58) and Chahardangeh (CHE) stations (Fig.2). We first investigate the SH-wave acceleration time histories, derived from these induced ground motion time histories and then, we perform a non-linear least square analysis of the spectral components of this derived SH-wave data to estimate causative fault parameters. We derived accelerograms transverse to the azimuth directions from the recorded acceleration data in the following way. We considered the estimated earthquake epicenters reported by different agencies, calculated the back azimuths to the epicenters from BHRC stations and then suitably rotated the horizontal component accelerograms. These transverse accelerograms can be reliably assumed to be good representations of the corresponding SH-wave accelerograms of this event. For estimation of causative fault plane parameters, we have considered only five out of 12 stations. These stations are Tehran-1, Tehran-13, Qani Abad, Hasanabad and Chardangeh.

3. LOCAL NETWORK

We have installed 38 stations after the October 17, 2009 earthquake from east of Tehran to Semnan (Fig.3). The instruments were Guralp CMG-6TD and CMG-5TD. The network was operated from October 19, 2009 to November, 2010. Based on the analysis of the continuous recording, 3061 event have been extracted. The preliminary results of location for 194 events are shown in figure 2. The magnitude range of these events is from 0.6 to 4.0 for 196 located earthquakes. Figure 4 shows magnitude histogram for 194 located events.

The program VELEST has been used to solve the coupled hypocenter velocity model problem for local earthquakes. It performs a simultaneous inversion for hypocenters and velocity model. Figure 5 shows the preliminary velocity model for east of Tehran. Table 1 gives the estimated values for P-wave and S-wave with their standard deviations and thickness of each layer.

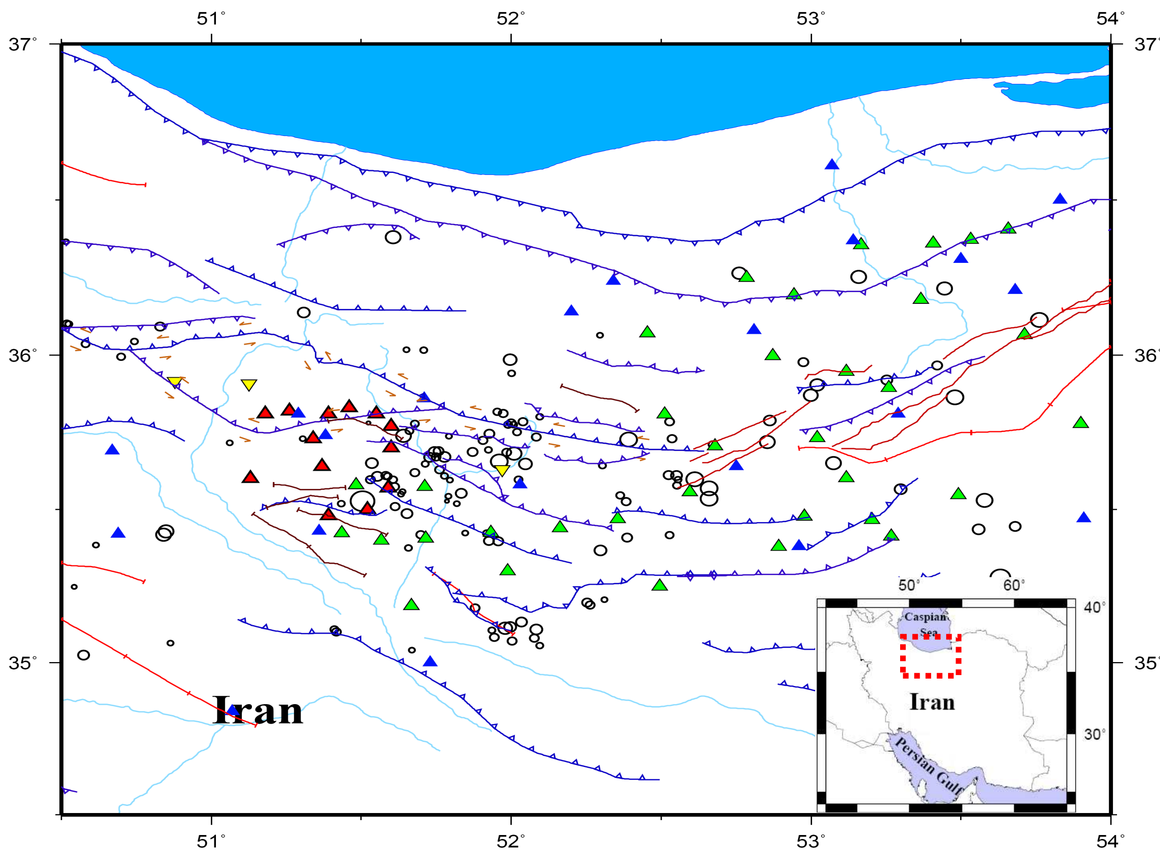

Figure 3. Local network (green triangle) which installed east of Tehran.

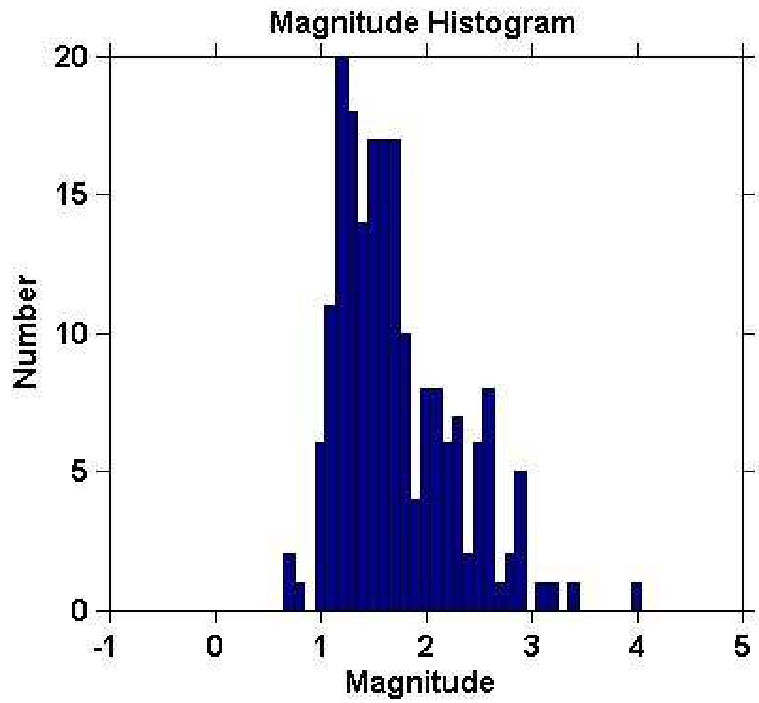

Figure 4. Magnitude histogram for 194 local events.

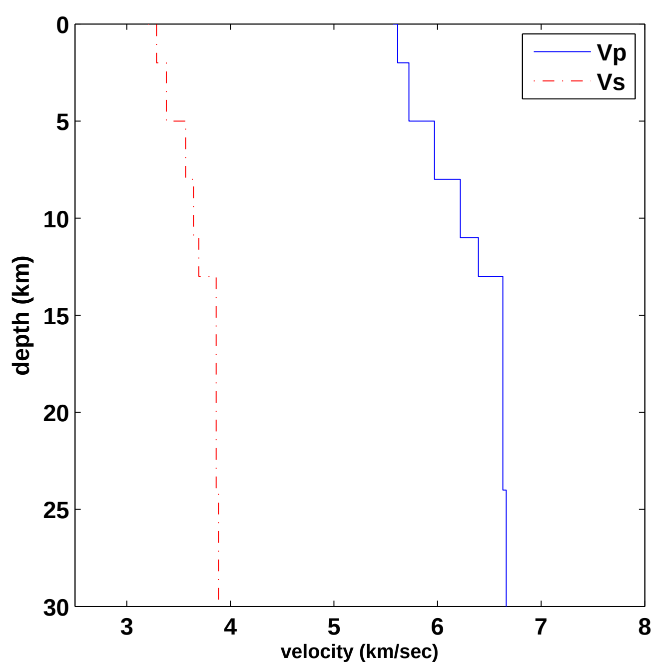

Figure 5. Preliminary 1-D velocity model for east of Tehran.

Table 1. Preliminary velocity model for east of Tehran.

Depth Range (KM) [± 1.0 Km]	P-wave velocity [Km/s]	Standard deviation [Km/s]	S-wave velocity [Km/s]	Standard deviation [Km/s]
0.0	5.57	0.15	3.21	0.11
2.0	5.62	0.17	3.29	0.13
5.0	5.72	0.19	3.38	0.16
8.0	5.97	0.16	3.57	0.10
11.0	6.22	0.15	3.64	0.06
13.0	6.39	0.08	3.70	0.05
24.0	6.63	0.12	3.86	0.11
30.0	6.66	0.13	3.89	0.11

4. RESULTS

The SH-wave accelerograms from the five stations Tehran-1, Tehran-13, Qani Abad, Hasanabad and Chardangeh provide some insight into the characteristics of propagation of the causative rupture of the main event (Fig.6). The accelerograms at Tehran-1, Tehran-13, Ghaniabad lying to the northwest of the TDMMO located hypocentre, exhibit front-loaded shear wave energy release suggesting that these stations are located in the direction of rupture propagation. We note further that the accelerogram at Hasanabad is more spread out than the accelerogram at Tehran-1, Tehran-13, Ghaniabad possibly implying that the rupture propagated toward northwest. To estimate the causative fault parameters, we have considered, IIEES, IGTU and TDMMO locations. Our near field estimates of the strike, dip and rake of causative fault are given in Table 3. Our fault plane solution suggests reverse faulting with left lateral strike slip motion (Fig. 7). The estimated strike, dip and rake for the causative fault are 292^o, 36^o and 59^o, respectively. The total standard error of estimate is 0.16 by considering TDMMO location. While these estimates for IIEES and IGTU locations are 0.26 and o.24, respectively. The direction of the estimated strike is consistent with the strike of Eyvanaki fault.

Table 2. Causative fault parameters for the 2009 earthquake.

Date	Standard error of estimate	Fault plane			Auxiliary plane			P axis		T axis	
		Strike	Dip	Rake	Strike	Dip	Rake	P-Az	P-Dip	T-Az	T-Dip
22/10/2009	0.16	292	36	59	149	60	111	224	13	101	68

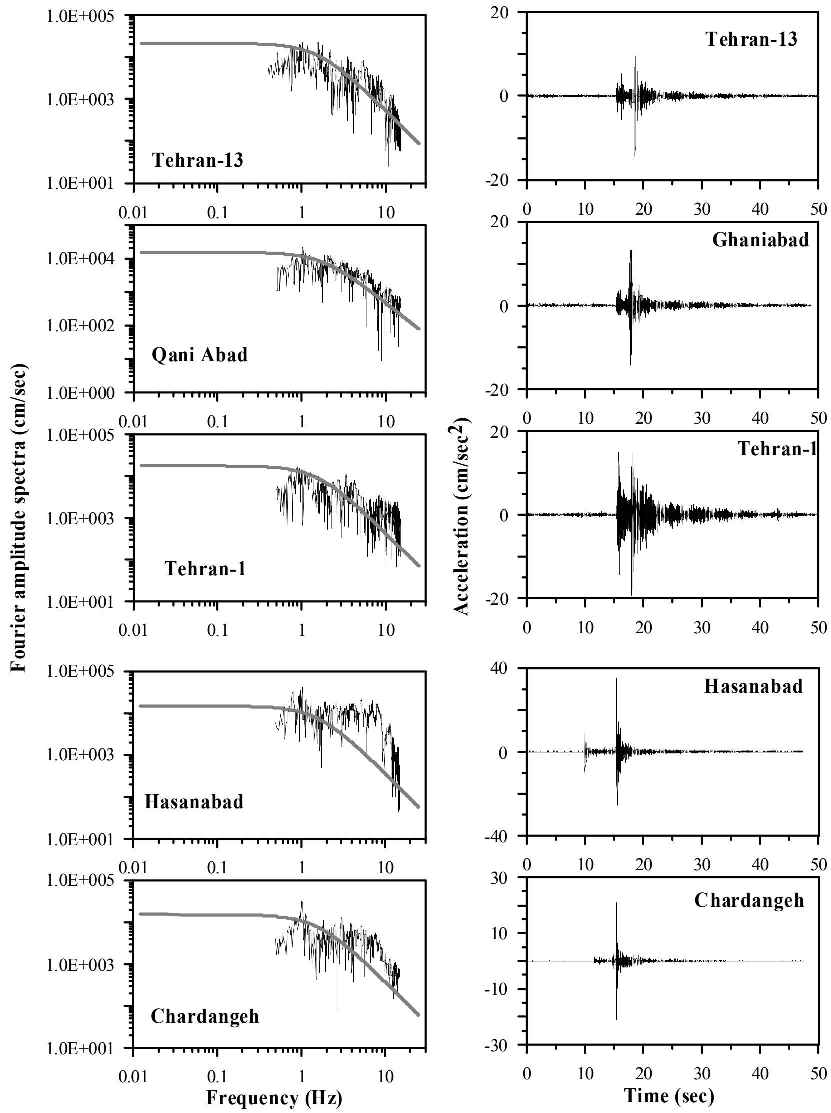

Figure.6 The SH waves (right) and observed and best fit displacement Brun spectrum (left).

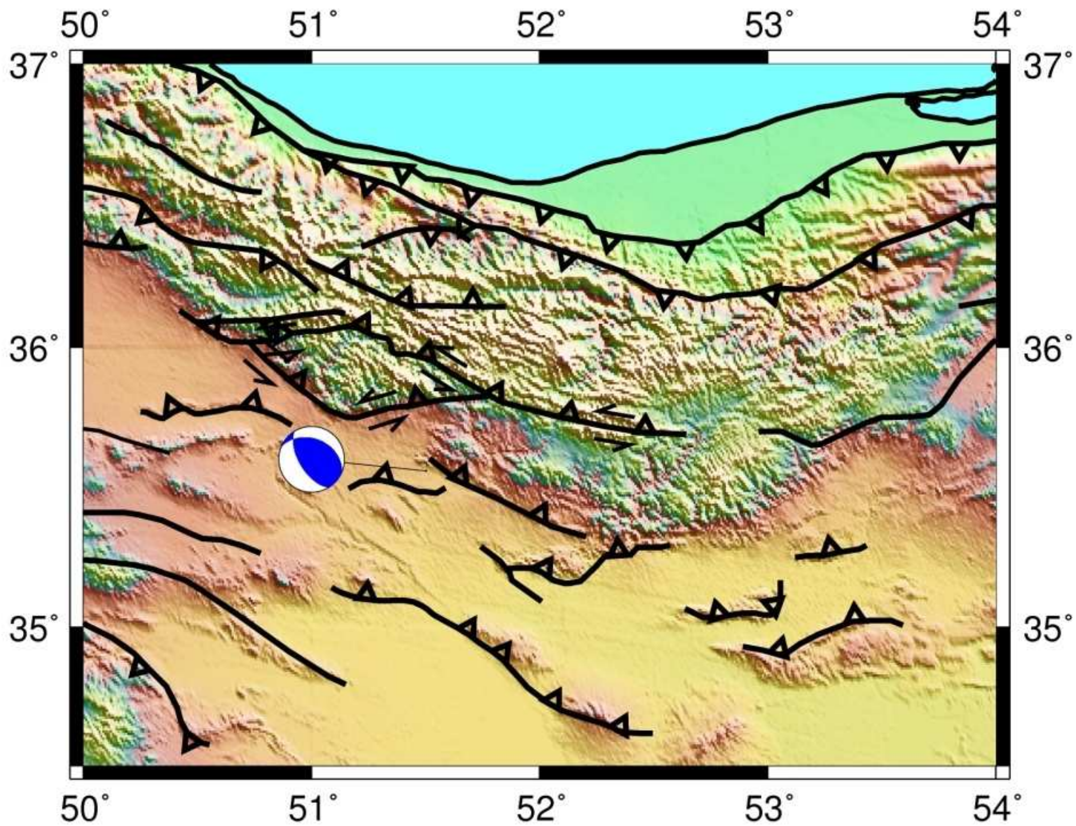

Figure.6 Focal mechanism of Ray- Tehran earthquake from analysis of SH-waves near field data

5. CONCLUSIONS

The analysis of the October 17, 2009 earthquake and the preliminary seismicity of eastern Tehran based on local network indicates that the strike, dip and rake of the causative faults of the 2009 Ray-Tehran earthquake are 292°, 36°, and 59°, respectively. Our estimated fault plane solutions suggest a reverse faulting mechanism with minor left lateral strike slip component. The estimated strike is consistent with the direction of Eyvanaki fault. The depths of local earthquakes are mostly concentrated at 10 km.

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