Field investigation of the 2010 August 27 earthquake, Iran

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Summary
The Kooh-Zar earthquake of magnitude 5.9 (Mw), occurred in northeastern Iran on 27 August 2010, not far away from the region where the 1953 earthquake caused considerable damage and devastation. The shock was felt within a radius of 280 kilometers and it killed 4 people, injured 40, and caused destruction over 12 villages. The shock damaged more than 300 houses. The highest intensity of shaking VII (MMI) was observed in the Kooh-Zar village. The earthquake was not associated with any significant surface faulting but with coseismic folding.
The source of this shock was reported to have had a left-lateral strike-slip mechanism initiated in a fault in the northeastern-southwestern direction. A regional strong motion network (BHRC) consisting of 7 strong motion stations (SSA-2 Accelerograph), located within 4–130 km from the epicenter, recorded the earthquake. The pulse-shape arrivals of strong signals recorded at the Kooh-Zar station strongly suggest that the rupture propagated toward the Kooh-Zar. The directivity effects are clearly revealed by the considerably larger amplitude in strike-parallel direction. Results of the field investigation together with the strong motion evidence are presented here in order to give a seismologic view of the event.

Keywords: Field investigation, Macroseismic intensity, Strong motion, Iran

1. Introduction

The Kuh-Zar earthquake of 2010 August 27 with magnitude of Mw 5.7 (GCMT), Ms 5.9 (IIEES), and mb 5.8 (IRSC) occurred in the Kuh-Zar, in a sparsely populated desert region of Damghan county, north central Iran, close to the border of Alborz region(see Figure 1). Despite the low population density and moderate magnitude, the earthquake killed 4 people (two children and two women), injured 40, destroyed 50 houses, left a further 800 homeless and damaged 300 more in Kuh-Zar, Salmabad, Tuchahi, Kelu, Shemi, Bidestan, Hoseynian, Moalleman, Satveh, Reshm, Mehdiabad, and Torud villages of the Semnan province in Northeastern Iran.

2. TECTONICS

The Iranian Plateau has been frequently affected by disastrous earthquakes resulting in the massive loss of life (Berberian 2005). It can be characterized by active faulting and folding, varying crustal depth, and mountainous topography.

This area is surrounded in the north by branches of the active Damghan and Shahvar fault system. The motion of this fault system is left-lateral (Wellman 1966). The fault system is made up of a series of branches extending from north of Tehran to northeast of the city of Shahrud (Figure 1). The southern of this area is a segment of the Dorune fault which is about 600 Km long and contains several indications of cumulative left-lateral slip over various scales (Fattahi *et al.* 2007). During the past several decades, within this area, a number of earthquakes (Table 1) with magnitude over 6.2 have occurred (Ambraseys and Moinfar 1977). Both fault located around the epicenter are capable faults, and several other branches of the Torud fault system and other faults are within this area.

The Torud fault was represented as causative fault for 1953 Torud earthquake (Abdalian 1954, Gassner 1969, Berberian 1977). The only geologic evidence of the neotectonic activity of the Torud region is its seismicity which assumed to be related to the Torud seismogenic fault (Khademi 2008).

3. SEISMICITY

The long term seismicity of the Iranian plateau has been studied by Ambraseys and Melville (1982); Berberian (1981, 1995a, 1995b, 1996, 2005), and Berberian and Yeats (1999, 2001). The map of the 20th century instrumentally recorded and historical earthquakes are shown in Figure 1. The major earthquake recorded since 1900 are listed in Table 1.

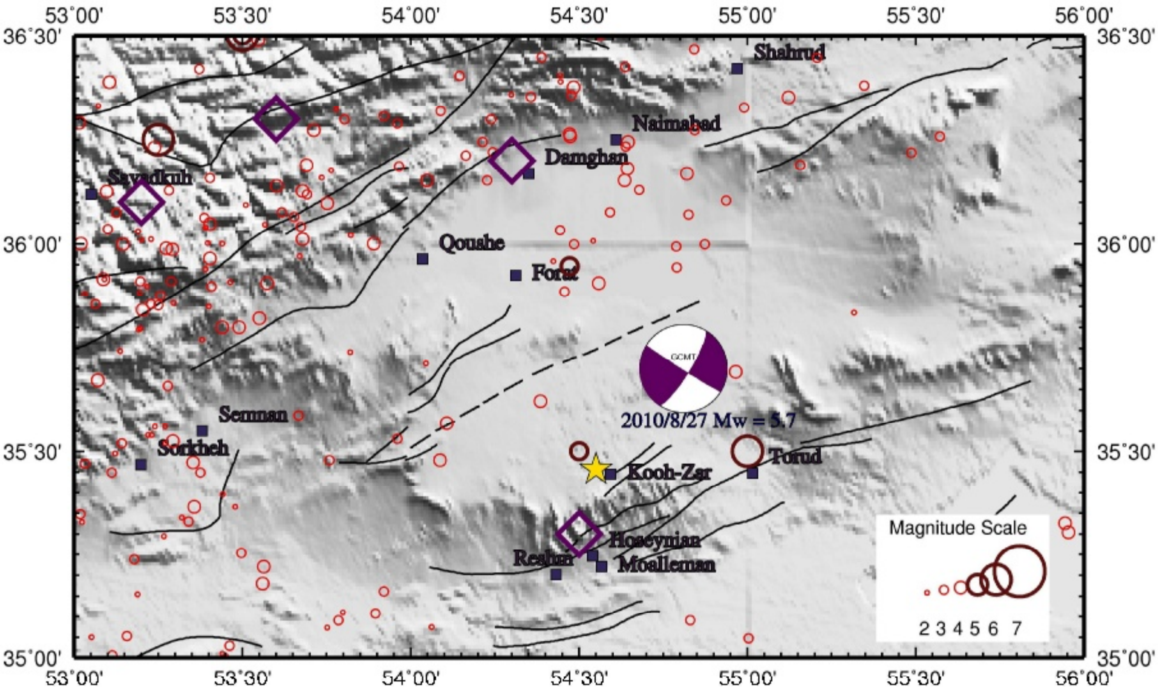

Figure 1. Instrumentally recorded earthquakes in the north central Iran region in the period 1939–2010

Table 1. Seismicity of area

Date [MM/DD/YYYY]	Lat [°]	Lon [°]	Magnitude[Mw]	Reference
6/26/1808	35.3	54.5	6.6	Ambraseys et al. 1982
7/22/1927	34.9	52.9	6.3	Ambraseys et al. 1978
4/6/1939	35.5	54.5	5.6	GUTE
2/12/1953	35.6	54.7	6.5	Ambraseys et al. 1977
2/13/1953	35.6	54.7	4.5	Ambraseys et al. 1977
4/1/1953	35.5	55.2	4	Ambraseys et al. 1977
7/11/1953	35.9	55.1	4.3	Ambraseys et al. 1977
7/24/1953	35.8	55.4	4.5	Ambraseys et al. 1977
8/24/1953	35.4	54.8	4.7	Ambraseys et al. 1977
2/16/1990	35.946	54.471	5	ISC
2/16/1990	35.905	54.559	4.6	EHB
7/3/2000	35.943	54.79	3.8	ISC
9/2/2004	35.622	54.385	4.1	ISC
10/23/2005	35.885	54.457	3.2	ISC
27/8/2010	35.457	54.5497	5.7	GCMT

The lack of more historical records is due to the fact that the region is sparsely populated and is located in a distant desert surroundings north of Dasht-e-Kavir Desert in North central Iran.

4. THE 2010 AUGUST 27 KUH-ZAR EARTHQUAKE

On 2010 August 27 at 19:23 UTC (11:53 local time), an Mw 5.7 earthquake struck the Kuh-Zar and Torud region in the north central Iran. These indicate almost pure strike slip on NE–SW striking fault plane, which dip is about 78° (Table 2, Figure 1).This earthquake was followed by aftershock at 00:29 UTC (mb 5). Focal mechanism for this earthquake is available from the Global CMT catalogue (Table 2).

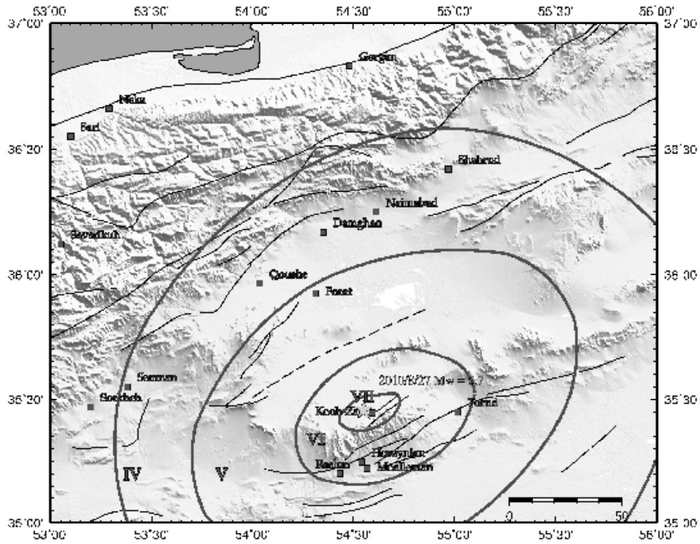

Figure 2. Isoseismal map of the earthquake area showing the main tectonic and damage features.

Figure 3. Field photographs (a) Typical adobe-brick house at Kelu (b) Collapse started in the corner where it was easier to initiate instability. (c) Collapse of masonry arches due to the movement of the roof (d) Partly damage of the reinforced concrete elementary school building

Table 2. Fault parameter from the Global CMT.

Fault plan	**Strike** [°]	**Dip** [°]	**Slip**[°]	**Focal depth** [Km]	**Magnitude [Mw]**
1	212	78	-2	7	5.7
2	302	88	-168		

5. MACROSEISMIC EFFECTS

The 2010 earthquake destroyed the Kuh-Zar, Salmabad, Tuchahi, Kelu, Shemi, Bidestan, Hoseynian, Moalleman, Satveh, Reshm, Mehdiabad, and Toroud villages. The 2010 Kuh-Zar earthquake killed 4, injured 40, left 800 homeless, and damaged seven villages [Salmabad (MMI intensity VII), Tuchahi (VII), Kelu (VII), Shimi (VII), Kuh-Zar (VII), Bidestan (VI), Hoseynian (VI) , Moalleman (VI) , Satveh (VI) , Reshm (VI) , Mehdiabad (VI), and Torud(VI) (Figure 2)]. The closest strong-motion instrument that recorded the main shock was the KUZ station (6 km EW of epicenter, see Figure 4), and recorded 0.550g acceleration on the horizontal component (Figure 4) (discussed later). Moreover, the shock was felt strongly in Forat (V on MMI, 55 km north of Kuh-Zar), Damghan (IV+, 80 km N), Shahrud (IV, 110 km NE), and powerlessly in Seman (III+, 105 km NW) and Tehran (II, 270 km NW).

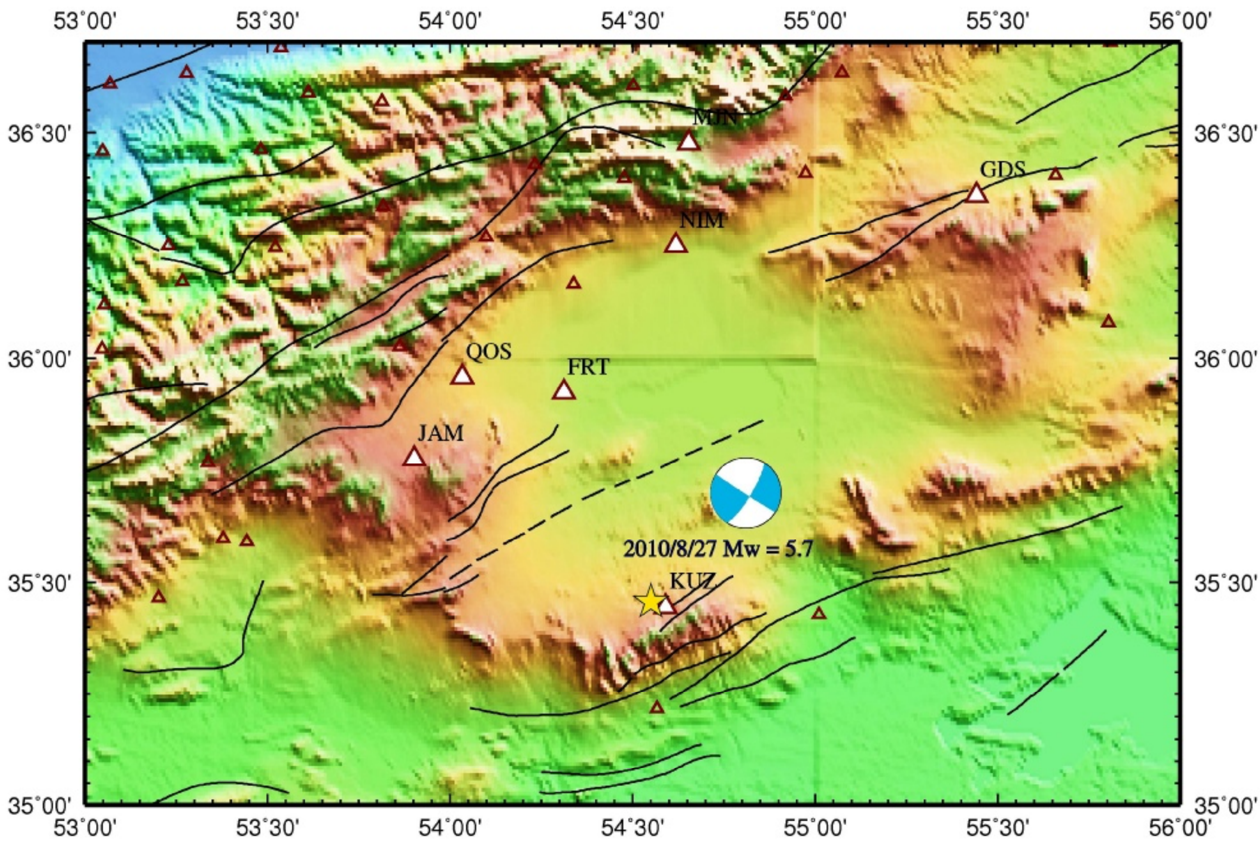

Figure 4. Strong motion stations surrounding the epicentral region

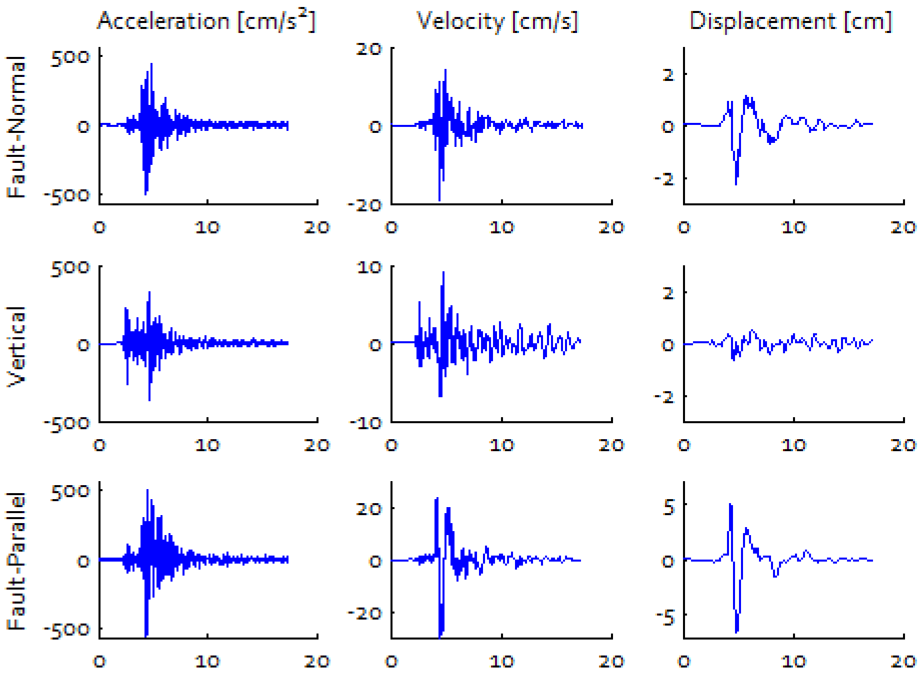

Figure 5. Corrected acceleration, velocity, and displacement time histories of the strike-parallel, strike-normal, and up-down components of strong motion records

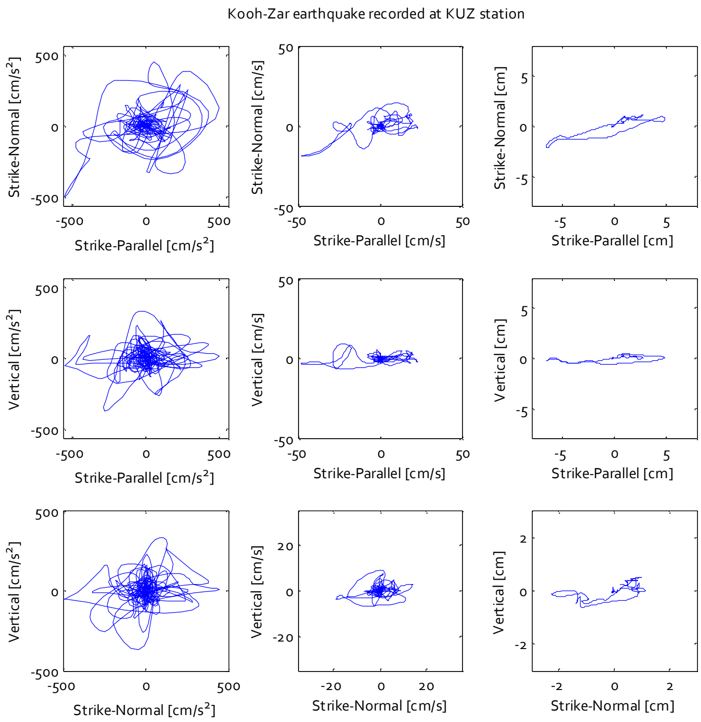

Figure 6. Acceleration, velocity, and displacement particle motions

6. DAMAGE TO BUILDINGS

In Kuh-Zar region, amage was most intense to the traditional, constructed from very poor clay materials, single-storey houses of weak masonry and non-reinforced adobe (Figure 3a), heavily built, with flat wooden-beamed and steel-beamed roofs (Figure 3b), numerous of which damaged in the earthquake. Moreover, several non-reinforced free-standing brick or Clay walls around houses and gardens in Tuchahi and Kelu villages also fell down. The majority of these houses in the epicentral region experienced partial collapse and in numerous cases it was likely to examine the progressive failure typically starting at the wall corners and move forwarding into the walls make happening the roof to collapse same as most previous devastated earthquakes (Figure 3c. The only engineering structure close to the epicentral region is a new constructed school. This school had been inaugurated a few months before the earthquake. It had been partly damaged during the earthquake (Figure 3d).

7. STRONG MOTIONS RECORDED

The Building and Housing Research Center (BHRC) of the Ministry of Housing and Urban Development, operates the Iranian strong Motions Network (ISMN), the only strong motion network in Iran. The strong motions of this event were recorded at 7 stations of the ISMN (According to BHRC 2010 report). All of the strong motion data obtained during the Kuh-Zar earthquake were recorded by digital Kinemetrics SSA-2 accelerographs. As shown in Figure 4, the strong motion stations are not uniformly distributed in the area. They are mostly located at the north side of the earthquake epicenter due to the great desert located south of epicenter.

Three stations (KUZ, TRD, and MLM) are in relatively close proximity to the Kuh-Zar mainshock source, but only the KUZ station recorded the event. Of all 7 triggered stations, only one station was located close to the event (Figure 4). The record obtained at KUZ station (Figure 5) after band-pass filtering shows a vertical ground acceleration (PGA) of nearly 369 cm/s/s and horizontal acceleration of 550 cm/s/s and 501 cm/s/s for the strike-parallel and strike-normal components, respectively. The strong-motion records were accessible in uncorrected format; therefore they must be corrected for baseline shifts, high-frequency noise and also infectivity by long-period. Strong motion data of all the stations were processed following the method used by Boore *et al.* (2002) and Boore and Bommer (2005). The velocity and displacement time histories of the Kuh-Zar records were obtained based on single and double integration of the accelerogram is shown in Figure 5.

In addition, Figure 6 demonstrates particle motions of acceleration, velocity, and displacement of the KUZ station records on three planes. The time series are using only five seconds of the beginning part of the record to consist of the time duration until the rupture pass near the station. The directivity effects are clearly revealed by the considerably larger amplitude in strike-parallel direction compared with those in the other direction.

8. Conclusion

This study has investigated the 2010 Kuh-Zar earthquake using seismological aspects, the geomorphology and structural damage from field observations, and study and process of strong motion instrumental recorded of station near the earthquake source. Results of the field investigation together with the strong motion evidence are presented here in order to give a seismologic view of the event.

The highest intensity of shaking VII (MMI) was observed in the Kuh-Zar village. The earthquake was not associated with any significant surface faulting but with coseismic folding. The source of this shock was reported to have had a left-lateral strike-slip mechanism initiated in a fault in the northeastern-southwestern direction. A regional strong motion network consisting of 7 strong motion stations (SSA-2 Accelerograph) located within 1-126 km from the epicenter, recorded the earthquake.

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