Journal of Asian Earth Sciences 147 (2017) 17–27

Contents lists available at ScienceDirect

Journal of Asian Earth Sciences

journal homepage: www.elsevier.com/locate/jseaes

Full length article

Aftershocks properties of the 2013 Shonbe M_w 6.3 earthquake, central Zagros, Iran

Shoja Ansari

Gilan Geosciences Center, Rasht, Iran

ARTICLE INFO

Keywords:
Zagros
Stress heterogeneity
Aftershock decay rate
Fractal dimension
Bath' law
Energy partitioning

ABSTRACT

The spatial and temporal seismicity parameters, stress state as well as the partitioning of the seismic energy of the Shonbe earthquake sequence have been investigated. The geodetic data and the stress tensor inversions of the focal mechanisms before and after the Shonbe main shock indicate the same NE–SW trend of the greatest principal stress. This stress orientation demonstrates a non-heterogeneous stress state in that region of the central Zagros which can be confirmed by the fractal dimension and the estimated *p-value*. The aftershock focal mechanisms show a diversity which may be associated with the approximately uniaxial stress field acting nearly perpendicular to the main-shock fault plane in which the co-seismic stress release is nearly complete. The spatial distributions of the *b* and *p*-values have been investigated and compared. The high *p-value* regions (e.g. far to the southeast, south and southwest of the main shock) are approximately consistent with the high *b-value* regions and the low *p-value* regions (e.g. the limited areas at the north- northeast of the main shock) are nearly consistent with the low *b-value* regions. The limited areas surrounding the main shock and also at the east-southeast of the main shock the *p-values* are not in agreement with the *b-values* which may be attributed to the local tectonic features in those regions. The seismic moment ratio and the Bath's law have been used to constrain the energy partitioning between the main shock and the aftershocks. It is found that a high fraction of the energy is released by the Shonbe main shock and nearly one third of the energy released by the aftershocks. This may be associated with the high stress imparted by the blind thrust main shock to the overlying crust in which promotes failure in the surrounding area and is often relieved by secondary faults and typically produce a high number of aftershocks.

1. Introduction

The Zagros Mountains are a seismically active fold-and thrust belt resulting from the collision of the Arabian plate with the continental crust of Central Iran (Fig. 1, inset map) that began in the Miocene and has continued to the present (Sepehr and Cosgrove, 2007). Mainly the Zagros Fold and Thrust Belt (ZFTB), on the basis of morphology, is divided into two adjacent belts: the High Zagros Belt (which is located between the Main Zagros Thrust and the High Zagros Fault) and the Zagros Simply Folded Belt (which is limited to the northeast by the High Zagros Fault and to the southwest by the Mountain Front Fault) (Fig. 1) (Berberian, 1995; Sherkati et al., 2006). The Zagros Simply Folded Belt (ZSFB), on the basis of lateral facies variations, is divided into different domains from SE to NW: The eastern Zagros, the central Zagros and finally the western Zagros (Sherkati et al., 2006). The greater part of the Zagros lies within the Simply Folded Belt (Allen et al., 2013) which can be distinguished from the rest of the orogen by the NW-SE–trending parallel folds and thrust-cored anticlines with SW verging (Hessami et al., 2001). The Simply Folded Belt formed in a thick pile of sedimentary rocks up to 12 km (Mouthereau et al., 2012) and developed above a basal decollement located in the Lower Cambrian incompetent Hormuz evaporates that directly overlie the crystalline basement (Oveisi et al., 2009).

The basement longitudinal (blind) thrust and transverse right-lateral active faulting (with surface rupture) (Berberian, 1995) defined the present geometry of the Zagros Fold-Thrust Belt. The majority of the belt-oblique fault zones are lateral ramps or transfer faults that link various segments of the major belt-parallel fault zones, such as the Mountain Front Fault (MFF) and Zagros Foredeep Fault (ZFF). The overlying folds associated with thrust faults terminate against the transfer faults (e.g. Kazerun Fault) (Sepehr and Cosgrove, 2007). The Kazerun Fault Zone (KFZ) comprises several roughly north–south-trending right-lateral strike-slip faults which segmented the mountain front strongly (Hatzfeld et al., 2010) and are marked by an alignment of the Salt diapirs (Berberian, 1995; Sherkati et al., 2006; Jahani et al., 2009). The Borazjan Fault is constructed the southern segment of the

E-mail address: shojaansari@yahoo.com.

http://dx.doi.org/10.1016/j.jseaes.2017.07.042
Received 1 December 2016; Received in revised form 19 July 2017; Accepted 19 July 2017
Available online 21 July 2017
1367-9120/

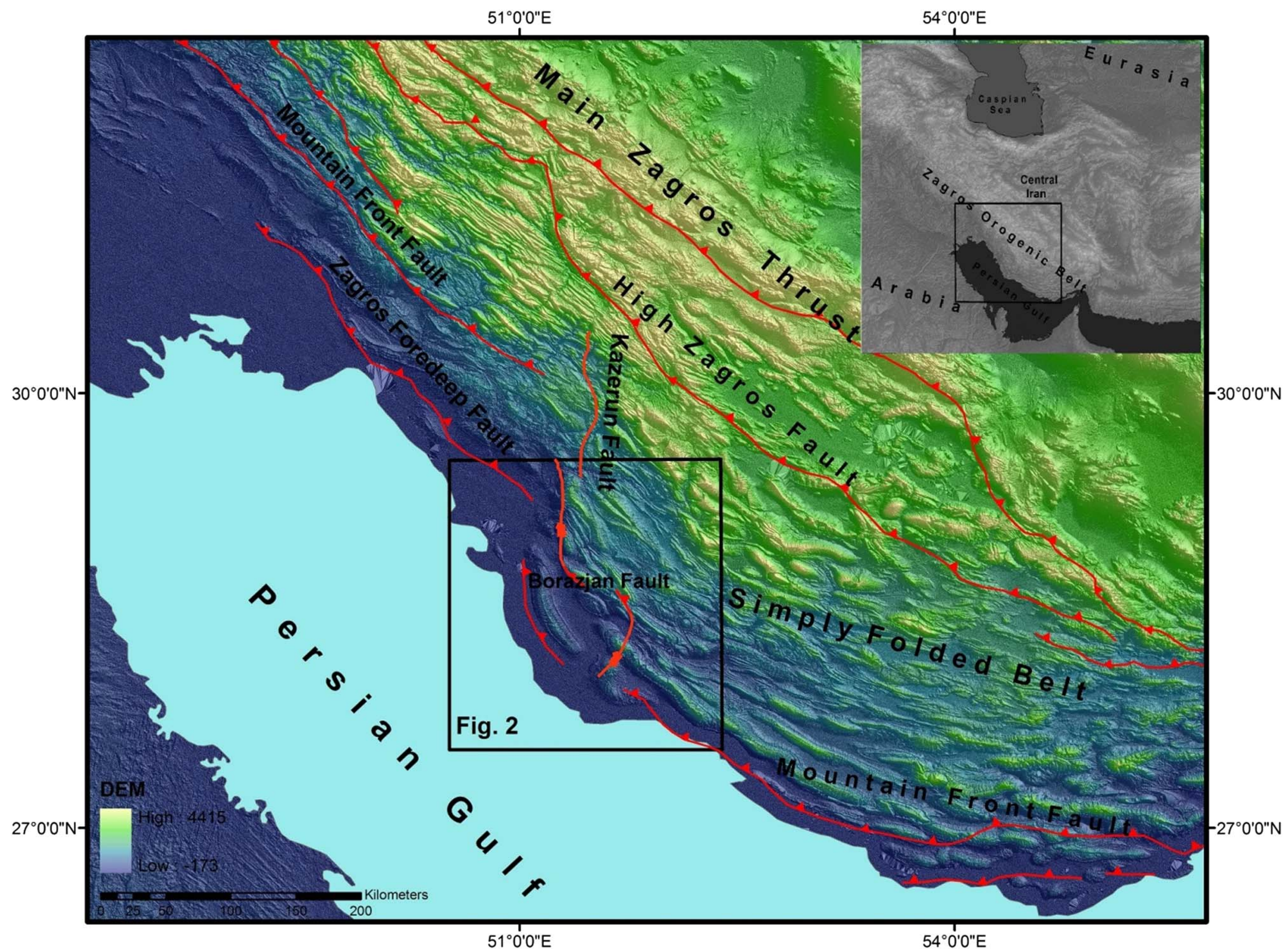

Fig. 1. Map showing the Zagros Fold and Thrust Belt in the southern Iran. The square marks the position of the Fig. 2. The inset map indicates the location of the Zagros orogenic belt relative the Arabian plate and Central Iran.

Kazerun Fault Zone with a right-lateral motion which dragged and folded the NW-SE-striking anticlinal axes to a N-S trend (Berberian, 1995). The Kazerun Fault Zone is seismically active and can be considered as a major transfer zone where transpressional earthquakes occur. The majority of moderate-sized earthquakes (M_w 5–6) along this fault zone occur close to the junction with the Mountain Front Fault (Sepehr and Cosgrove, 2007; Carminati et al., 2014). A notable characteristic of the ZSFB is the predominance of moderate-sized earthquakes and the complete absence of any larger than Mw ~ 7 in the instrumental catalogs. Although the strike-slip faulting plays an important role in the central SFB, most earthquakes in the range involve blind reverse faults (Nissen et al., 2014).

The 9 April 2013 Shonbe earthquake (28.446°N - 51.629°E, M_w 6.3, I_o VIII, M_o 3.5×10^{18} N m at 11: 52 UTC) took place on a southwest-dipping blind thrust fault at the depth of 12 km (Table 1) in the central Zagros (~20 km from Shonbe, ~28 km from Khurmoj and ~89 km from Bushehr), southern Iran (Fig. 2). The main shock blind thrust fault located in the Simply Folded Belt between the Kaki and Kangan anticlines near the Borazjan fault junction with the Mountain Front Fault. Berberian (1995) proposed that the gaps between the blind faults corresponding to the surface gaps in the fold trains will probably be the candidate sites for nucleation of the future events (i.e. as observed in the case of the 2013 Shonbe earthquake). The length (~17 km) and width (~12 km) of the 2013 Shonbe main shock fault have been calculated using the empirical relations of Leonard (2010). The blind thrust faults that cause M ≤ 6.8 earthquakes, following Stein and Lin (2006), tend to be square in aspect ratio; in other words, their length is similar to their width. Such short faults are highly efficient at increasing the stress beyond the fault ends along strike.

The unrecognized buried thrusts generating large-magnitude hidden earthquakes pose serious threat to millions of people in many parts of the world. These hidden events can cause unusually widespread damage (Berberian, 1995). The 2013 Shonbe earthquake caused 37 deaths and 850 injuries. Over 1000 houses in 92 villages were damaged and left a further 1000 homeless and damaged 500 more houses in nearby villages (Ardalan et al., 2013; Zare and Shahvar, 2013). The aftershocks pose a significant seismic hazard, which sometimes can even enhance the main shock hazard. The Shonbe earthquake was followed by nine

Table 1
The 2013 Shonbe main shock parameters were taken from the ISC catalog.

Date	Time (UTC)	Lat (°N)	Lon (°E)	Depth (km)	Mw	Mo (10^{18}°N°m)	Mechanism			Length (km)[a]	Width (km)[a]
							Strike(°)	Dip(°)	Rake(°)		
2013–04-09	11:52	28.446	51.629	12	6.3	3.5	157	41	117	17	12

[a] Length and Width were taken from the empirical relationships of Leonard (2010).