Open Journal of Geology, 2015, 5, 281-290
Published Online May 2015 in SciRes. http://www.scirp.org/journal/ojg
http://dx.doi.org/10.4236/ojg.2015.55025

Fault Movement Potentials in the Tehran-Semnan Region (North Iran)

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Received 13 April 2015; accepted 10 May 2015; published 13 May 2015

Abstract

The major Quaternary faults in the Tehran-Semnan region can be classified based on their strikes into three sets: northeast-southwest, northwest-southeast and east-west. In this paper, we use a model to evaluate fault movement potential (FMP). Their theoretical model is based on the relationship between fault geometrical characteristics and regional tectonic stress field. The results show that The Mosha, Emam Zadeh Davood and Pourlcan-Vardij fault zones have high FMP (0.9 or 90%) and the Parchin fault zone has very low FMP (0.0 - 0.1) in the area.

Keywords

Quaternary Faults, Semnan, Tehran, FMP, Iran

1. Introduction

Seismicity is closely related to active Quaternary faults. This attracts many researchers to investigate the quantitative relationships between them. As a new parameter, FMP is defined to quantify earthquake risk along active faults by [1]. Therefore, we use it for evaluation of earthquake risk along Tehran-Semnan region in north of Iran. The landforms in this area are mainly controlled by three sets of Quaternary faults, striking northeast, northwest and east-west, respectively (**Figure 1**). The activity levels of the main Quaternary faults have been investigated in Tehran-Semnan region, based on [2]-[4].

Previous work regarding these topics was mainly based on seismotectonics and risk analyses [5] [6] without ordering of main Quaternary faults. In this paper, we use a new method [1] to evaluate fault activity by considering the mechanical relationships between fault geometry and regional tectonic stress field. This method has

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How to cite this paper: Noroozpour, H., Arian, M. and Sorbi, A. (2015) Fault Movement Potentials in the Tehran-Semnan Region (North Iran). *Open Journal of Geology*, **5**, 281-290. http://dx.doi.org/10.4236/ojg.2015.55025

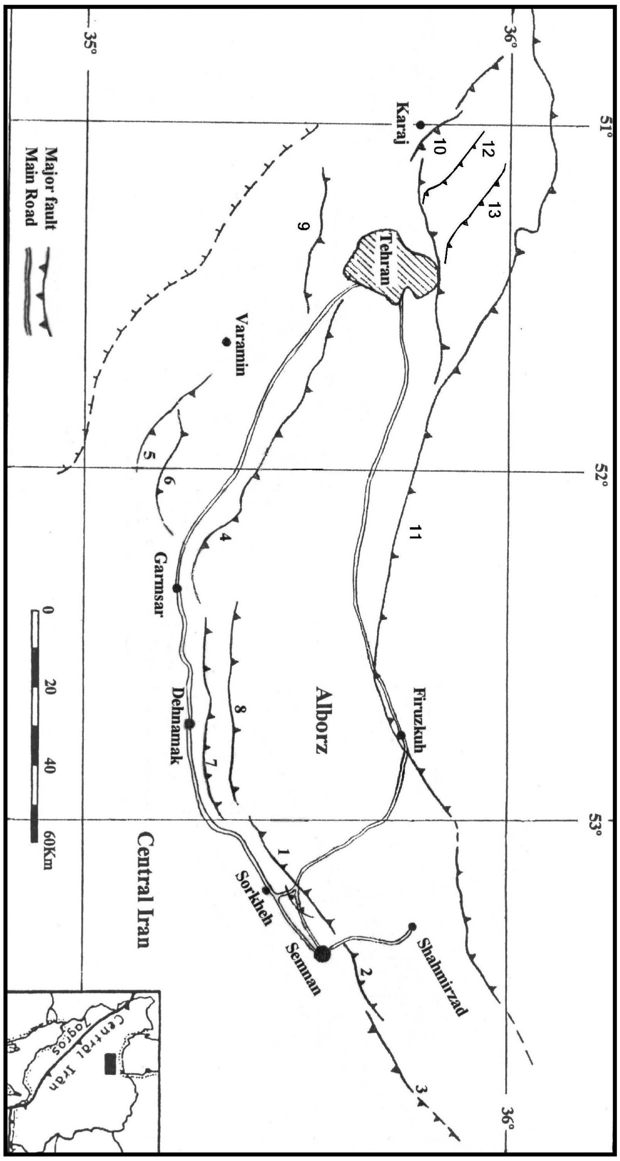

Figure 1. The major faults in Alborz-Central Iran border zone. Numbers in figure are: 1. North Sorkheh fault zone, 2. North Semnan fault zone, 3. Attary fault zone, 4. Parchin fault zone, 5. Pishva fault zone, 6. Kuh-e-Sorkh fault zone, 7. Garmsar fault zone, 8. Sorkheh Kalut fault zone, 9. Kahrizak fault zone, 10. North of Tehran fault zone, 11. Mosha fault zone, 12. Pourkan-Vardij fault zone, 13. EmamZadeh Davood fault zone.

been used to evaluate the fault movement potentials of all the major Quaternary faults in the Tehran-Semnan region in north of Iran.

The study area is located in West-Central Alborz and lesser Caucasus province [7]. Dominant structural trend in West-Central Alborz and lesser Caucasus province is NW-SE. From tectonics view, it contains deformed zone (fold and thrust belt) of Cimmerian miniplate that formed in northern active margin until late Triassic. Then it has rifted by tension in a back arc basin of Neotethyian subduction zone in the south margin of Cimmerian miniplate. Development of that rift stopped in the late Cretaceous and then, renewed in the Eocene by spreading in submarine arc basin of Neotethyian subduction zone. In the other word, this hinterland is result of a magmatic arc system spreading in the evolutional back arc basin. After that, West-Central Alborz and lesser Caucasus hinterland has formed by deformation and regional uplift from SW part of Caspian Sea to Black sea [8] [9]. Also, based on previous work on the salt diapirism [10]-[19] and neotectonics regime in Iran [20], Zagros in south Iran is the most active zone [21]-[35]. Then, Alborz in north Iran [36]-[67] and Central Iran [68]-[78] have been situated in the next orders.

2. Materials and Methods

Quaternary faults are well developed in the Tehran-Semnan region. They were classified into three sets based on their strikes: northeast, northwest and east west.

2.1. The Northeast Striking Fault Set

The northeast striking fault set is the major paleogeographic fault set [79] in studied area. The faults in this set are multistaged active fault inferred to have significant effects on the development of the southern foreland fold and thrust belt of Alborz Mountain. Striking 053˚ - 072˚ with high dip angles, this fault set can be subdivided into three major faults the North Sorkheh fault zone, the North Semnan fault zone and Attary fault zone.

2.2. The Northwest Striking Fault Set

This fault set comprises three fault zones striking 306˚ - 324˚ with high dip angles. Among them, the Mosha (**Figure 2**), Parchin and Pishva fault zone are the major Quaternary fault zones. The Emam Zadeh Davood (**Figure 3**), Pourkan-Vardij (**Figure 4**) and Kuh-e-Sorkh are a minor Quaternary fault zones.

Figure 2. A view of the Mosha fault zone in northwest of Tehran (view to the east).

Figure 3. A view of the Emam Zadeh Davood fault zone in northwest of Tehran (view to the northeast).

Figure 4. A view of the Pourkan-Vardij fault zone in northeast of Karaj (view to the northwest).

2.3. The East-West Striking Fault Set

The faults of this set are well exposed and can be traced intermittently for a long distance (more than 55 km) in nearly east-west direction. In this set, there are two major Quaternary fault zones, the North Tehran, Kahrizak, Garmsar and the Sorkheh Kalut fault zone in the north of the Garmsar fault zone.

In summary, all of these fault zones are active in current tectonic regime (CTR) and characterized by micro-seismic events and geomorphic indices, because they formed mountain front faults system in the southern flank of the Alborz belt.

In the following sections, we will evaluate the earthquake risk along these faults, and discuss which fault is most favored to move under the influence of present-day tectonic stress field. We make this evaluation based on the relationships between tectonic stress orientation and fault geometric properties proposed by [1].

2.4. Theoretical Model for Analysis of Fault Movement Potential

The fault movement potential (FMP) is closely related to tectonic stress (σ), fault plane geometry (G) and the physical property of the medium within and on both sides of the fault (P). FMP is the function of these factors [1]:

$$FMP = f\ (s, G, P) \tag{1}$$

Although a geological medium is generally heterogeneous and very complicated, however it can be taken as homogeneous and isotropic in statistical view of our case. This region is the border zone of Alborz—Central Iran structural zones and thus, geological concepts and tectonic settings are similar along it. Based on this consideration, and for the purpose of simplification in the theoretical derivation, [1] also take the geological medium containing the faults as a homogeneous, isotropic and elastic material. Therefore fault movement potential can be simplified as:

$$FMP\ = f\ (s, G) \tag{2}$$

Finally, according to [80] and [81] researches, [1] define FMP to quantify the relationship between fault movement potential as a normalized factor by the following equations:

$$FMP = \begin{cases} 0 & \theta \in (0^\circ, 30^\circ) \\ \dfrac{\theta - 60^\circ}{30^\circ} & \theta \in (30^\circ, 60^\circ) \\ 1 - \dfrac{\theta - 60^\circ}{30^\circ} & \theta \in (60^\circ, 90^\circ) \end{cases} \tag{3}$$

θ is the angle between the regional maximum principal compressive stress orientation (σ_1) and the normal line of fault plane.

2.5. Regional Tectonic Stress Orientations

Tectonic stress means an additional stress to lithostatic stress state, in the other words, the part of stress deviated from lithostatic stress. Earthquake focal mechanism solution is one of the commonly used methods in the study of contemporary tectonic stress field.

Therefore, we use results of [82]-[84] and our field study to estimate the regional maximum principal compressive stress orientation (σ_1). The statistical result shows that the average attitude of σ_1 is 10˚, 207˚.

3. Results and Discussion

The fault movement potential of the major Quaternary faults in the Tehran-Semnan region are calculated using the Equations (3) and the regional stress orientation as well as the fault plane attitudes. The results are shown in **Table 1**.

1) The northeast striking fault set have large angle between the normal to the fault planes and the compressive principal stress along these fault zones. The fault movement potential of this fault set ranges from medium to high, suggesting that this fault set has the sufficient potential for generating destructive earthquakes, especially along the north Sorkheh) and north Semnan fault zone.

2) The northwest striking fault set have small to medium angle between the normal to the fault planes and the compressive principal stress along these fault zones. The fault movement potential of this fault set ranges from medium to high, suggesting that this fault set has the sufficient potential for generating destructive earthquakes.

3) The east-west striking fault set have medium angle between the normal to the fault planes and the compressive principal stress along these fault zones. The fault movement potential of this fault set is medium, suggesting that this fault set has not the sufficient potential for generating destructive earthquakes.

Although, many earthquakes occurred at the intersection of the Garmsar fault zone with the southeast continuation of Parchin fault zone and the intersection of the Mosha fault zone with the northeast continuation of North Tehran fault zone (**Figure 5**).

Figure 5. A view of the North Tehran fault zone in north (Hesarak) Tehran (view to the north).

Table 1. The calculation of fault movement potential in the Tehran-Semnan region.

No	Name of fault zone	Fault set	θ	FMP
1	North Sorkheh	North-east striking	65˚ - 66˚	0.8
2	North Semnan	North-east striking	64˚ - 65˚	0.8
3	Attary	North-east striking	70˚ - 78˚	0.4 - 0.6
4	Parchin	North-west striking	28˚ - 33˚	0.0 - 0.1
5	Pishva	North-west striking	36˚ - 40˚	0.2 - 0.3
6	Kuh-e-Sorkh	North-west striking	40˚ - 51˚	0.3 - 0.7
7	Garmsar	East-west striking	43˚ - 48˚	0.4 - 0.6
8	Sorkheh kalut	East-west striking	42˚ - 46˚	0.4 - 0.5
9	Kahrizak	East-west striking	68˚	0.7
10	North Tehran	East-west striking	70˚ - 82˚	0.3 - 0.7
11	Mosha	North-west striking	50˚ - 88˚	0.1 - 0.9
12	Pourkan-Vardij	North-west striking	55˚ - 57˚	0.8 - 0.9
13	Emam Zadeh Davood	North-west striking	50˚ - 52˚	0.7 - 0.9

Therefore, it seems that, the northwest striking fault set has got more potential for movement in the current tectonic regime related to other fault sets. The Emam Zadeh Davood, Pourkan-Vardij and Mosha have got the highest movement potential (to 90 percent).

Based on [85], the study area has situated in Central Alborz seismotectonic province. It has got b = 0.71 and M_{max} = 7.8. Dominant structural trend in Central Alborz province is NE-SW in eastern part and NW-SE in western part. Focal mechanisms of many earthquakes are sinistral strike slip faulting such as Manjil (Ms = 7.3, 1990) and reversed with sinistral strike slip component such as Boien Zahra (Ms = 7.2, 1962).

Central Alborz province has moderate to high earthquakes with low frequency, long repeat time and down to 20 Km focal depth. Intensity of earthquakes is in high levels. The most important seismic hazards in Central Alborz province that contains large cities such as Tehran, Ghazvin and Zanjan are landslide in high regions, settlement in some plains, surface faulting and volcanic hazards around Damavand cone.

4. Conclusions

According to this research, the contemporary movements potential along fault zones of various orientations are different under the action of present-day regional north-northeast compressive stress field in studied region. The Mosha, Emam Zadeh Davood and Pourkan-Vardij fault zones have high FMP (0.9% or 90%) and the Parchin fault zone has very low FMP (0.0 - 0.1).

The region where the SE continuation of the northwest striking Parchin fault zone intersects the east-west striking Garmsar fault zone and the NE continuation of the north Tehran fault intersects the Mosha fault zone prone to big earthquakes.

Acknowledgements

This work has funded by the Department of geology, Islamic Azad University, Science and Research branch, Tehran, Iran. Also, Special thanks to vice-president for research in Science and Research branch, Tehran.

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