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Fault Movement Potential of Marzanabad Area, North Alborz, Iran

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Abstract

The major Quaternary faults of Marzanabad in the north Alborz can be classified based on their strikes into two sets: northwest and eastwest. In this paper, we use a model to evaluate their movement potential. Their theoretical model is based on the relationship between fault geometrical characteristics and regional tectonic stress field. The results show that Taleqan, Kandovan Chitan-Dozbon and Makaroud-Dalir fault zones are of the highest movement potential in the area. Also, the region where the fault zones have been intersected (northeastern part of study area) is prone to high seismicity; however, these fault zones don't have high movement potentials.

Keywords

Marzanabad, Faults, Alborz, Movement, Potential, 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 Marzanabad in the north Alborz, Iran. The landforms in this area are mainly controlled by two sets of Quaternary faults, striking northwest and eastwest, respectively (**Figure 1**).

The questions to be addressed in this paper are: 1) what are the activity levels of these faults? And 2) will these faults cause destructive earthquakes? Previous work regarding these topics was mainly based on field works [2]. In this paper, we use a new method to evaluate fault activity by considering the mechanical relationships between fault geometry and regional tectonic stress field. This method has been used to evaluate the fault

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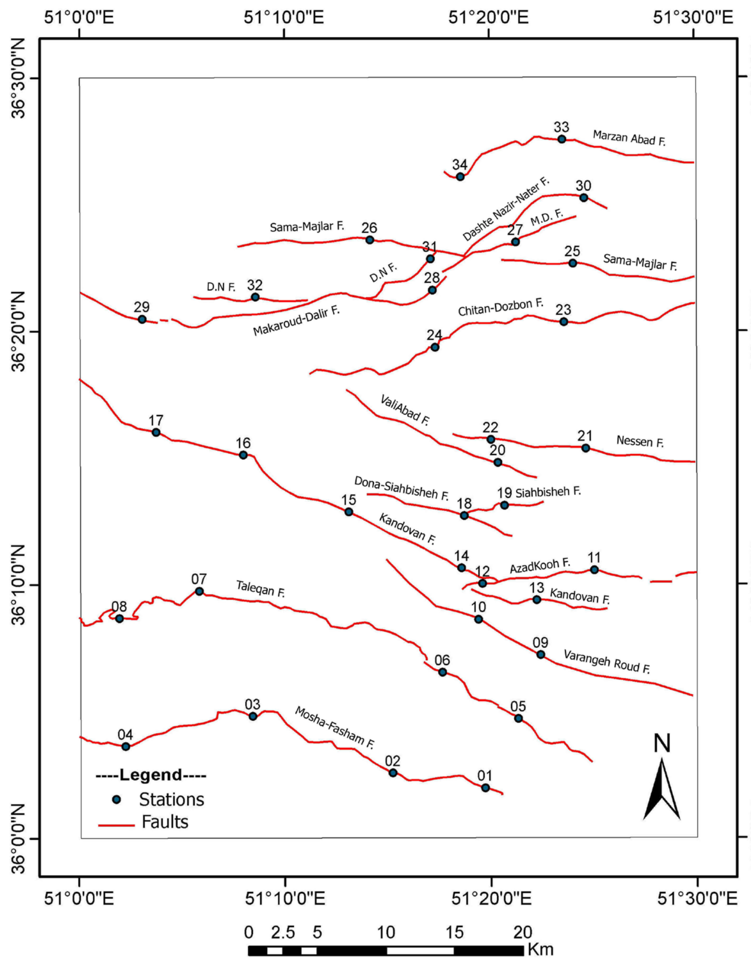

Figure 1. Stations of fault attitude measurements on Marzanabad area.

movement potentials of all the major Quaternary faults Marzanabad in the north Alborz.

2. Materials and Methods

2.1. Fault Sets

Quaternary faults are well developed in Marzanabad area. They were classified into two sets based on their strikes: northwest and east -west. The northwest striking fault set comprises Mosha-Fasham, Taleqan, Varangeh Roud, Kandovan, Dona-Siahbisheh and Valiabad fault zones in the southern part of study area (**Figure 1**).

The east-west striking fault set are well exposed and can be traced intermittently for a long distance in nearly east-west direction. In this set, there are Nessen, Chitan-Dozbon, Sama-Majlar, Makaroud-Dalir, Dashte Nazir-Nater, Marzanabad, Azadkooh, Siahbishehfault zone in the northern part of study area (**Figure 1**).

In summary, all of these fault zones are active in current tectonic regime (CTR) and characterized by seismic events (**Table 1**). These events have shown that, seismic layer is in 20 - 30 km depth. This area has low to moderate earthquakes with intermediate frequency and repeat time.

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.

2.2. 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

Table 1. Seismic events of study area (1957-2015).

No.	Date (yyyy/mm/dd)	Time (UTC)	Latitude	Longitude	Depth	Magnitude	Reference
1	1957/05/06	15:06:51.0	36.40	51.50		Ms:4.8	MEA
2	1959/05/01	08:24:02.0	36.38	51.16	33	M:5.3	NOW
3	1970/10/03	06:57:03.0	36.01	51.31	78	mb:4.1	ISC
4	1981/08/04	18:53:59.0	36.45	51.27		mb:4.7	ISC
5	1998/12/03	21:07:18.0	36.30	51.11	100	mb:3.9	ISC
6	2004/05/28	14:47:51.0	36.49	51.37	10	ML:2.8	IIEES
7	2004/05/28	16:45:21.0	36.26	51.46	28	ML:2.8	IIEES
8	2004/05/28	17:34:51.0	36.48	51.36	22	ML:3.3	IIEES
9	2004/05/28	17:51:21.0	36.27	51.38	15	ML:3.2	IIEES
10	2004/05/28	19:47:05.0	36.43	51.40	25	mb:4.5	EHB
11	2004/05/28	20:07:26.0	36.40	51.38	28	ML:3.2	IIEES
12	2004/05/28	20:09:18.0	36.41	51.37	28	ML:3.1	IIEES
13	2004/05/28	20:25:31.0	36.17	51.47	28	ML:3.4	IIEES
14	2004/05/28	20:31:20.0	36.41	51.40	28	ML:3.2	IIEES
15	2004/05/28	20:32:57.0	36.46	51.42	28	ML:3.3	IIEES
16	2004/05/28	20:49:25.0	36.45	51.37	28	ML:2.8	IIEES
17	2004/05/28	21:03:35.0	36.32	51.43	28	ML:3.5	IIEES
18	2004/05/28	21:22:48.0	36.37	51.42	28	ML:2.5	IIEES
19	2004/05/28	22:32:34.0	36.36	51.38	28	ML:2.6	IIEES
20	2004/05/28	23:07:27.0	36.39	51.40	28	ML:2.6	IIEES
21	2004/05/29	00:25:48.0	36.36	51.43	28	ML:3.4	IIEES
22	2004/05/29	01:57:58.0	36.36	51.37	28	ML:2.9	IIEES
23	2004/05/29	03:54:27.0	36.47	51.40	28	ML:3.3	IIEES
24	2004/05/29	04:53:04.0	36.37	51.42	28	ML:3.7	IIEES
25	2004/05/29	05:34:50.0	36.44	51.43	28	ML:2.8	IIEES
26	2004/05/29	06:14:20.0	36.47	51.41	28	ML:3.4	IIEES
27	2004/05/29	06:34:14.0	36.43	51.43	28	ML:3.2	IIEES
28	2004/05/29	09:23:49.0	36.49	51.40	14	mb:4.7	EHB
29	2004/05/29	10:20:40.0	36.37	51.41	28	ML:3.6	IIEES
30	2004/05/29	11:01:32.0	36.42	51.38	28	ML:4.2	IIEES
31	2004/05/29	12:56:43.0	36.50	51.42	28	ML:3.6	IIEES
32	2004/05/29	13:34:24.0	36.39	51.39	28	ML:3.3	IIEES
33	2004/05/29	14:56:46.0	36.45	51.44	28	ML:3.7	IIEES
34	2004/05/29	15:03:49.0	36.50	51.41	28	ML:3.2	IIEES
35	2004/05/29	15:23:49.0	36.50	51.35	28	ML:3.3	IIEES
36	2004/05/29	15:41:03.0	36.46	51.42	28	ML:3.9	IIEES
37	2004/05/29	17:30:26.0	36.49	51.44	28	ML:3.9	IIEES
38	2004/05/29	18:38:07.0	36.45	51.37	28	ML:4.6	IIEES
39	2004/05/29	18:42:45.0	36.43	51.41	28	ML:3.8	IIEES
40	2004/05/29	19:58:19.0	36.46	51.45	28	ML:3.5	IIEES
41	2004/05/29	22:55:19.0	36.43	51.36	28	ML:3.9	IIEES
42	2004/05/29	23:05:46.0	36.48	51.36	28	ML:2.6	IIEES

Continued

43	2004/05/30	02:41:27.0	36.46	51.45	28	ML:3.6	IIEES
44	2004/05/30	07:48:53.0	36.46	51.38	28	ML:3.5	IIEES
45	2004/05/30	08:57:06.0	36.18	51.49	28	ML:2.9	IIEES
46	2004/05/30	11:49:02.0	36.36	51.36	28	ML:2.8	IIEES
47	2004/05/30	13:09:55.0	36.41	51.45	28	ML:4	IIEES
48	2004/05/30	15:48:46.0	36.44	51.46	28	ML:3.5	IIEES
49	2004/05/30	16:18:24.0	36.26	51.44	28	ML:3.2	IIEES
50	2004/05/30	18:03:19.0	36.44	51.45	28	ML:2.7	IIEES
51	2004/05/31	08:12:16.0	36.46	51.26	14	ML:3.7	IIEES
52	2004/06/01	00:35:32.0	36.45	51.49	28	ML:3.2	IIEES
53	2004/06/01	02:41:28.0	36.37	51.46	28	ML:3.3	IIEES
54	2004/06/01	06:22:01.0	36.39	51.45	28	ML:2.6	IIEES
55	2004/06/01	10:57:46.0	36.45	51.41	28	ML:2.7	IIEES
56	2004/06/02	11:12:25.0	36.50	51.41	28	ML:3	IIEES
57	2004/06/05	00:10:45.0	36.40	51.40	28	ML:2.8	IIEES
58	2004/06/05	20:58:14.0	36.42	51.43	28	ML:3.2	IIEES
59	2004/06/06	06:08:21.0	36.44	51.41	28	ML:2.8	IIEES
60	2004/06/08	04:34:36.0	36.47	51.38	28	ML:2.5	IIEES
61	2004/06/24	02:36:28.0	36.47	51.42	28	ML:2.8	IIEES
62	2004/06/27	04:51:35.0	36.49	51.40	12	ML:3.3	IIEES
63	2004/07/11	13:16:46.7	36.35	51.31	14	ML:3.3	IIEES
64	2004/07/18	13:44:18.9	36.43	51.42	31	ML:2.5	IIEES
65	2006/03/07	19:58:42.7	36.30	51.41	33	ML:2.9	IIEES
66	2006/03/08	00:04:20.8	36.44	51.38	14	ML:2.5	IIEES
67	2006/12/25	20:06:54.5	36.12	51.31	14	ML:2.7	IIEES
68	2006/12/25	20:15:48.2	36.12	51.32	14	ML:3.1	IIEES
69	2006/12/26	15:53:29.9	36.37	51.39	20	ML:2.5	IIEES
70	2007/06/04	08:04:16.6	36.37	51.32	34	ML:3.8	IIEES
71	2007/07/04	09:25:54.9	36.38	51.33	15	ML:2.5	IIEES
72	2007/07/04	09:41:22.8	36.31	51.34	14	ML:2.5	IIEES
73	2007/12/01	21:51:37.1	36.14	51.09	14	ML:2.9	IIEES
74	2007/12/01	22:12:45.8	36.08	51.14	13	ML:2.8	IIEES
75	2008/10/17	21:01:21.9	36.46	51.01	18	ML:2.9	IIEES
76	2008/10/19	22:28:49.3	36.42	51.01	15	ML:2.8	IIEES
77	2008/10/21	22:23:05.7	36.15	51.23	12	ML:3	IIEES
78	2009/02/02	10:14:10.5	36.41	51.40	14	ML:2.8	IIEES
79	2011/08/11	12:28:35.6	36.39	51.33	14	ML:2.6	IIEES
80	2013/04/12	07:50:48.0	36.40	51.31	14	ML:2.9	IIEES
81	2013/09/12	03:52:30.4	36.44	51.09	14	ML:2.9	IIEES
82	2013/09/12	14:56:11.5	36.44	51.12	14	ML:3.2	IIEES
83	2013/09/20	06:33:26.2	36.44	51.24	14	ML:2.5	IIEES
84	2013/09/20	12:42:35.0	36.45	51.17	14	ML:2.9	IIEES
85	2013/12/12	06:18:05.9	36.23	51.43	14	ML:2.5	IIEES
86	2014/08/29	22:57:04.1	36.26	51.50	14	ML:2.6	IIEES

physical property of the medium within and on both sides of the fault (P). FMP is the function of these factors [1]:

$$\mathrm{FMP} = \mathrm{f}\left(\sigma, \mathrm{G}, \mathrm{P}\right) \tag{1}$$

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. Based on this consideration, and for the purpose of simplification in the theoretical derivation, they also take the geological medium containing the faults as a homogeneous, isotropic and elastic material. Therefore fault movement potential can be simplified as:

$$\mathrm{FMP} = \mathrm{f}\left(\sigma, \mathrm{G}\right) \tag{2}$$

Finally, according to [3] and [4] researches, [1] defines FMP to quantify the relationship between fault movement potential as a normalized factor by the following equations:

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

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

2.3. 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 [5]-[7] 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 15˚, 040˚.

This area belongs to West-Central Alborz and lesser Caucasus hinterland [8] [9] that formed on the inverted back arc intra-continental rift since Oligocene. Dominant structural trend in West-Central Alborz and lesser Caucasus province is NW-SE (**Figure 1**). 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, this region has converted to back arc regime again and West-Central Alborz and lesser Caucasus hinterland has formed by its deformation and regional uplift from SW part of Caspian Sea to Black sea. Recently, Damavand and Sebalan cones have formed by late volcanism that related to final subduction of oceanic slab (Neotethys) toward north and northeast [10]. This area has an active tectonics regime [11]-[25] in compared to the Central Iran [26]-[35] and Zagros in the southern Iran [36]-[43]. Also, some concepts of its metal mineralization, have been investigated by [44]-[48].

3. Results and Discussion

The fault movement potential of the major Quaternary faults of Marzanabad have calculated using the equations (3) and the regional stress orientation as well as the fault plane attitudes. The results are shown in **Table 2** and **Figure 2**. Also, seismic events have 25 Km depth as average of focal depth. The earthquakes are related to two sets of Quaternary faults with northwest-southeast and east-west strikes.

Taleqan, Kandovan, Chitan-Dozbon and Makaroud-Dalir fault zones 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. This situation has been shown by contoured map, too (**Figure 3**).

Table 2. The calculation of fault movement potential in Marzanabad in the north Alborz.

Name of Fault Zone	No.	Dominant Attitude of Fault (Dip Dir.)	Normal Line of Fault Plane	θ	FMP
Mosha-Fasham	01	017,80	10,197	39	0.3
	02	022,77	13,202	33	0.1
	03	025,67	23,205	41	0.4
	04	009,62	28,189	52	0.7
Taleqan	05	210,58	32,030	19	0.0
	06	191,50	40,011	36	0.2
	07	162,39	51,342	58	0.9
	08	182,35	55,002	50	0.7
Varangeh Roud	09	028,70	20,208	37	0.2
	10	025,80	10,205	29	0.0
Azadkooh	11	181,77	13,001	38	0.2
	12	180,78	10,000	39	0.3
Kandovan	13	002,53	37,182	63	0.9
	14	027,63	27,207	44	0.5
	15	024,67	23,204	41	0.4
	16	004,47	43,184	67	0.8
	17	019,58	32,199	51	0.7
Dona-Siahbisheh	18	020,72	18,200	38	0.3
Siahbisheh	19	175,60	30,355	44	0.5
Valiabad	20	016,82	08,196	33	0.1
Nessen	21	009,78	12,189	41	0.4
	22	004,80	10,184	44	0.5
Chitan-Dozbon	23	183,55	35,003	39	0.3
	24	155,61	29,335	61	0.9
Sama-Majlar	25	358,55	35,178	64	0.8
	26	008,72	18,188	46	0.5
Makaroud-Dalir	27	154,58	32,334	62	0.9
	28	138,63	27,318	76	0.5
	29	192,62	28,012	29	0.0
Dashte Nazir-Nater	30	197,45	45,017	36	0.2
	31	131,60	30,311	82	0.3
	32	166,42	48,346	55	0.8
Marzanabad	33	182,58	32,002	38	0.3
	34	166,70	20,346	52	0.7

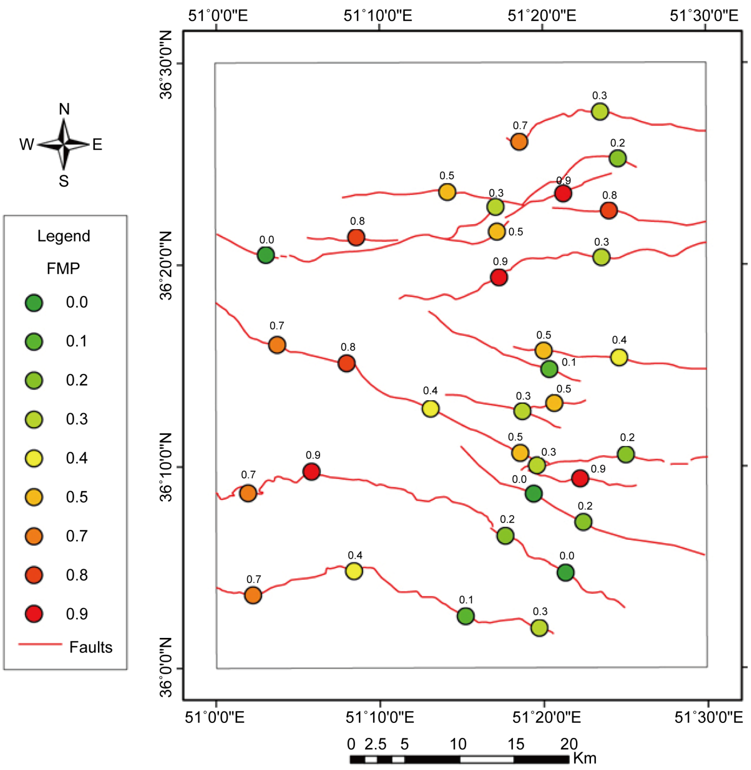

Figure 2. Stations of FMP measurements on Marzanabad area.

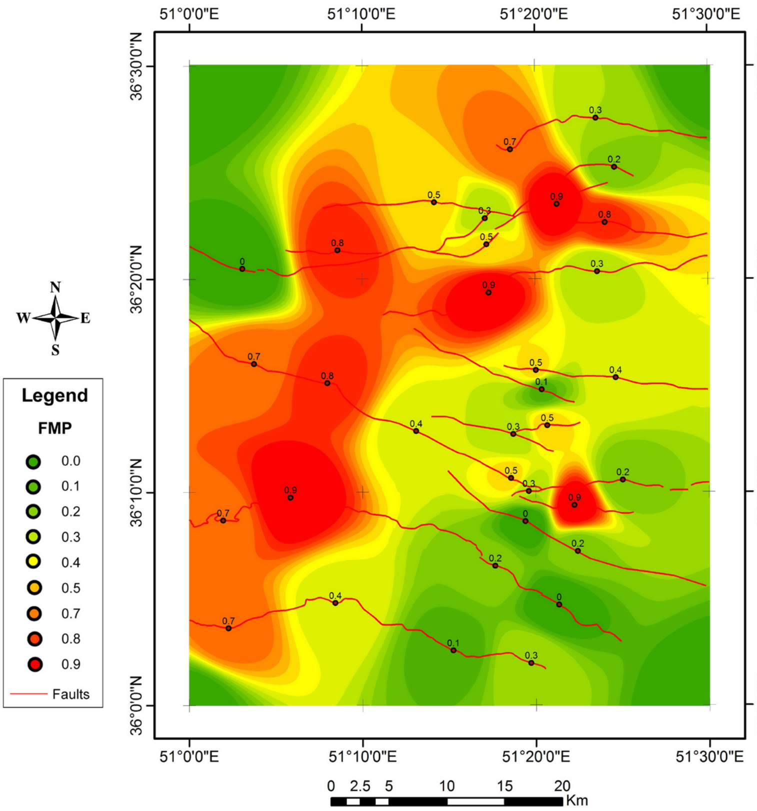

Figure 3. FMP contoured map of Marzanabad area.

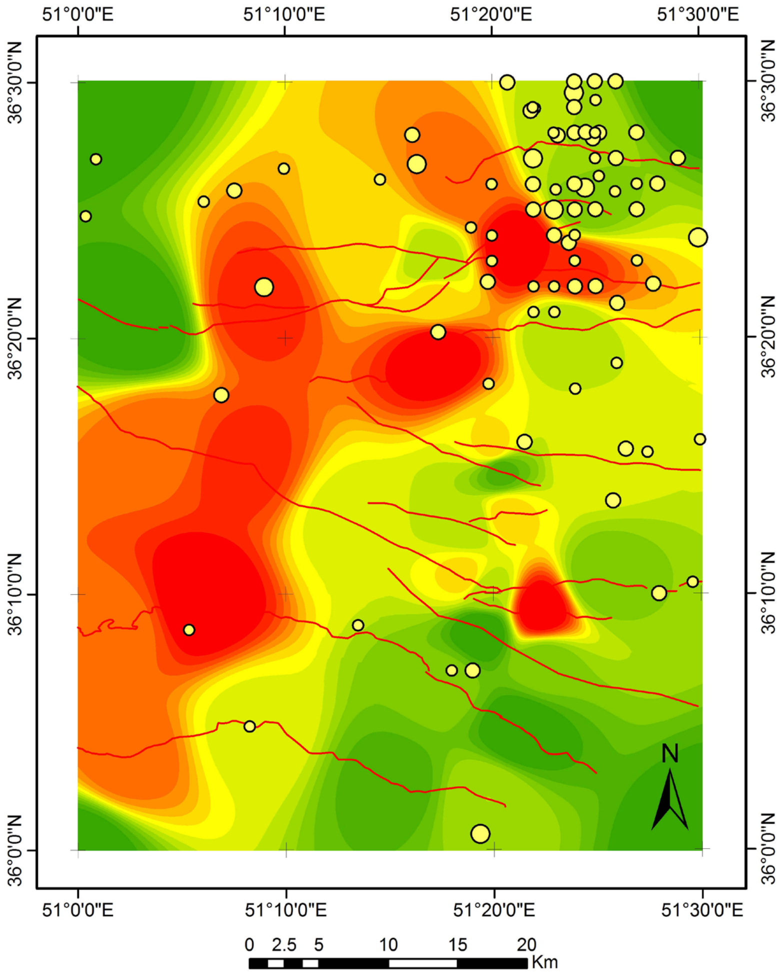

Figure 4. Epicenter of earthquakes on FMP contoured map of Marzanabad area.

In **Figure 4**, Epicenter of earthquakes (**Table 1**) on FMP contoured map of Marzanabad area have shown and it implied that high FMP values are not always coincident to previous seismic history.

4. Conclusion

Based on 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 study region. Taleqan, Kandovan, Chitan-Dozbon and Makaroud-Dalir fault zones have medium to high movement potentials. Also, the region where the fault zones have been intersected (northeastern part of study area) is prone to high seismicity; however these fault zones don't have high movement potentials.

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