

Study of Tectonic Activity in Young Eastern Alborz, Central Iran on the Basis of Alluvial Fans in the Shahrud-Bastam Area

Ali Pourramezani*, Soheila Bouzari

Department of Geology, North Tehran Branch, Islamic Azad University, Tehran, Iran

Email: *alipourramezani@yahoo.com

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Abstract

Alluvial fans are grouped in buildings which can provide important evidence of tectonic and climatic changes [1], Shahrud-Bastam area as structure point is located between Eastern Alborz structural zones in the north and central Iran structural zone in the south. In this study, we have measured 16 indicators morphotectonic on 79 alluvial fans and 46 catchments, according to the results of the measurements of morphometric parameters of alluvial basins and watershed, we find out that Qods-Armiyan's fault zone has the most of tectonic activity between Tazareh and Shahrud fault regions. According to the index A_s , the development of alluvial fans often has a direct relationship with Level rise, which has a particular importance in the study field.

Keywords

Tectonic, Alluvial Fan, Morphometric Parameters, Shahrud-Bastam Region

1. Introduction

In this study, we have examined the morphology of alluvial fans, and this examination has taken place in Meyamey fault zone located on the southern slopes of the eastern Alborz and Central Iran. The reason of this study is learned about the young tectonic activity on that area.

Semnan is located in northern Iran, and Shahrud-Bastam is located in the north to the North East. The geographical location of the study area is $54^{\circ}30'00''$ to $55^{\circ}30'00''$ east longitude and $36^{\circ}00'00''$ to $36^{\circ}30'00''$ north latitude (**Figure 1**).

According to the topographic map (**Figure 2**) the North West and East have the highest height, and the highest point is Chaluy Mountain with an altitude of 3750 meters above sea level. The lowest section is located in the southwestern region and with height of 1080 meters.

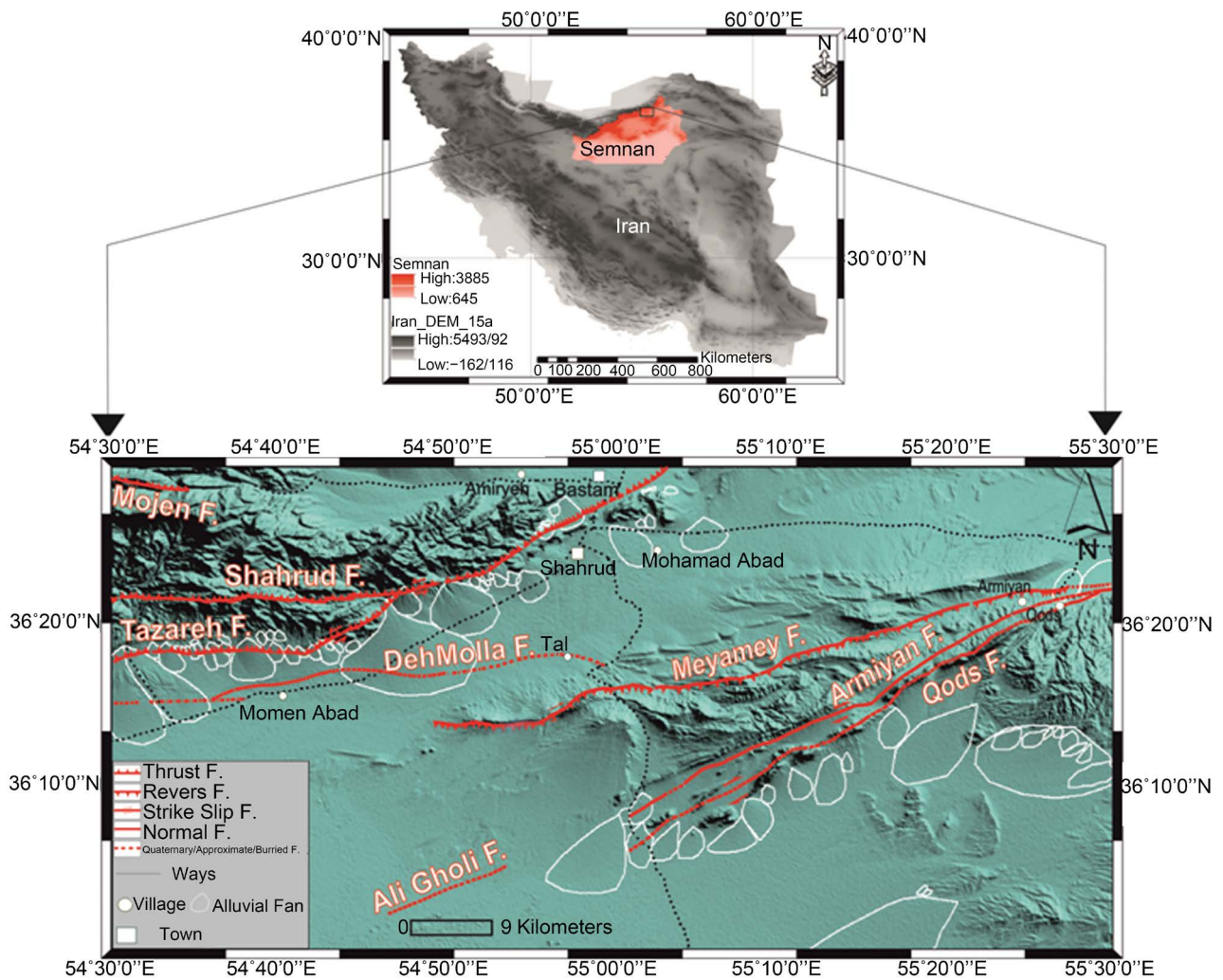


Figure 1. Location map of the study area, based on Srtm image and the location of alluvial fans.

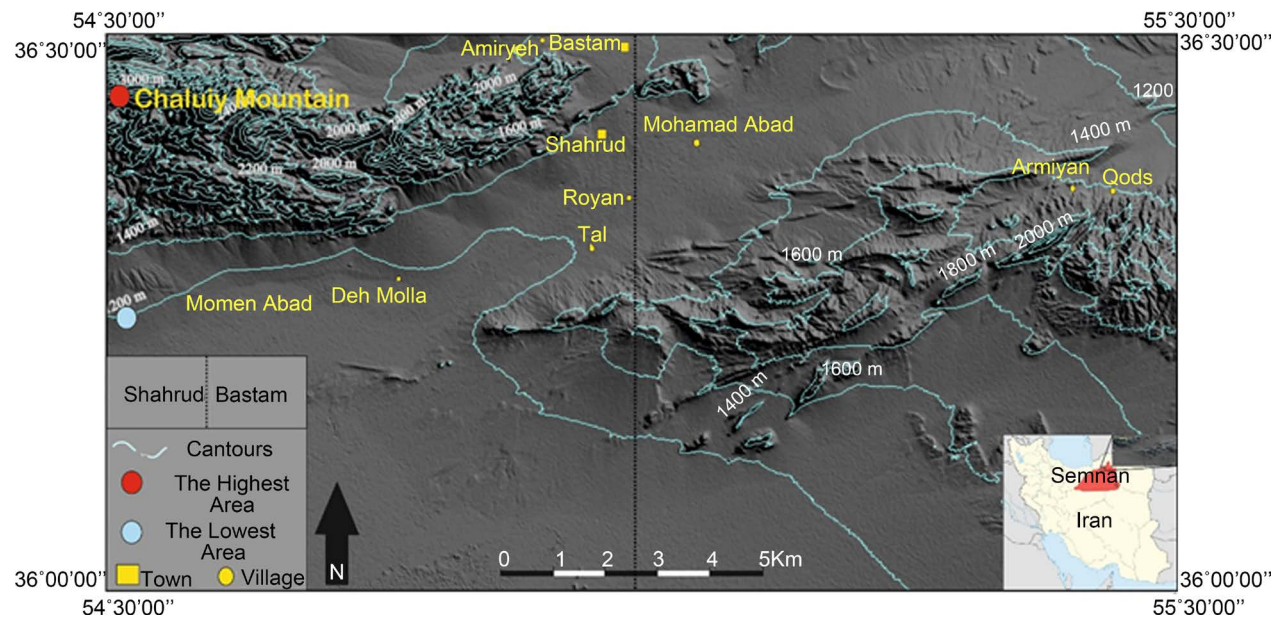


Figure 2. Topographic map of the area based on Srtm images [2] [3].

The most important research taking place in the region is research [4], with the study of earthquakes in the twentieth century, he managed to divided Alborz into several seismic states and concluded that seismic activity in Alborz can be shown short time activities. [5] concluded that Meyamey fault had, until the last stages of folding in the Pliocene Alpine has a right state. [6] concluded that the highest movement is potential in the area, mainly fault zones in north of Semnan and Sorkhe. [7] concluded that the fault is along the East-Northeast Meyamey steep slope to the south, and has a reverse mechanism with right turn slip component. [8] concluded that the maximum possible magnitude of earthquakes on Mullah, Tazareh and Damghan, faults tens are respectively, 6/9, 7/3 and 7/4. [9] examined the Quaternary activity of the region, and they managed to prove quaternary activity of boundary fault zone with sinisterly component. [10] concluded that, through independent factors, the variables area, En-Closed Area, during the basin, total length of waterways, the main stream watersheds and drainage density catchment have the greatest impact on the development of alluvial fans. This study will follow measuring 16 indicators morphotectonic on 79 alluvial fans and 46 catchments by using 16 indexes of morphotectonic methods (Table 1).

2. Geological Framework

The geological characteristics of this study belongs to two states in eastern Alborz and central Iran, Thus, the northern region belongs to structure of Alborz

Table 1. Morphotectonic indicators used in the area.

No.	Indicators	Source	No.	Indicators	Source
1	The process of alluvial Fans fractionated.	[11]	9	The relationship between the En-closed area in alluvial fans and En-closed area in the watershed.	[15] and [16]
2	As	[12]	10	FCI	[17] and [18] and [12]
3	Smf	[13]	11	Fmf	[13]
4	Vf	[14]	12	Fd	[19]
5	Measuring the slope of the alluvial fans.		13	Af	[20]
6	The relationship between the Slope and En-closed areas in alluvial fans.		14	T	[21]
7	The relationship between the slope of the alluvial fan and En-closed areas in the watershed.	[15] and [16]	15	SL	[20]
8	The relationship between the radius and slope alluvial fans.		16	Bs	[22]

and central and southern regions belongs to structure of central Iran state. Trending of mountains in this area are ‘east-west mountain ranges’ that are relatively Wriggler mainly located in the north of Iran and south of Lake Caspian and their performances show orogenic events. These mountains they self are some part of Alpine-Himalaya orogeny in the north side in west Asia, this area we are talking about is limited to Caspian blocks from north and Central Iranian Plateau from sought. These mountains in their sought sides, not only have the geological structure similar to central Iran, but they have the same stratigraphy with the whole sought. Whereas the north side of Alborz have very different looks, in stratigraphy and geological structure with sought side of it [23] and [24].

According to (Figure 3), the oldest unit of the Pre-Cambrian and Paleozoic units is in the vicinity of the fault Tazareh and, in the western part of the region. Paleozoic units, in the western part of the region, mainly in the North East-South West apartments available for modest expansion in southern and south—can be seen at eastern region. Mesozoic units in the north and northwest and the eastern parts are visible. Paleogene units in the North West and fault between Meyamey, Armiyan and Qods are located in the eastern part of the region. Neogene units, parts of the Northwest and East region have been widely, meanwhile, units of the Quaternary have formed a large part of the area.

3. Regional Structure

3.1. Faults

As shown in Figure 4, the region is composed of eight faults. However, because of the relationship between alluvial fans and some of the faults formed, we are going to mention the most important regional fault.

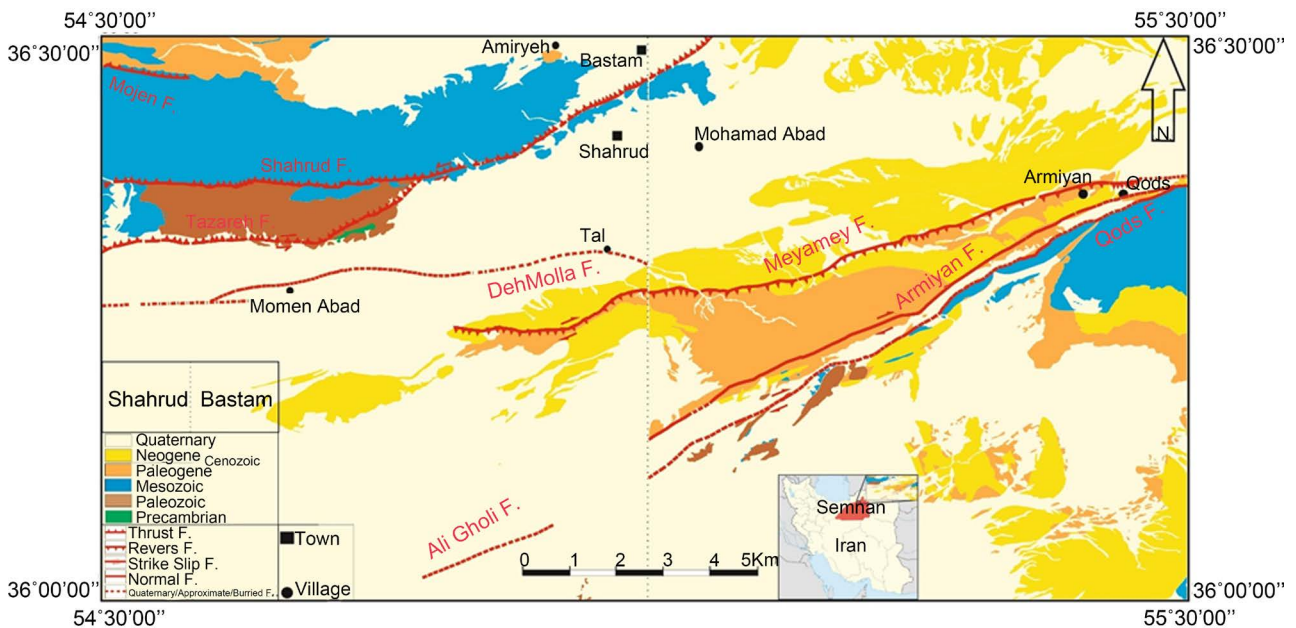


Figure 3. Simplified geological map of the study area, based on the geological map at a scale of 1: 100,000-Shahrud and Bastam.

- **Shahrud Thrust Fault:** Shahrud Thrust fault in its north side has an approximate length of 55 km and it is a left on fault. The above fault has a northwest-southeast trend and it is dip to the north-north east. During the Shahrud fault zone we have measured 24 alluvial fans and 15 Catchment (Figure 4).
- **Tazareh Thrust Fault:** Tazareh Thrust fault is located in the west side, has an approximate length of 30 km, it has a northwest-southeast trend and it is dip to the north east. Kinematic measurements show thrust left on fault implies. During the Tazareh fault zone we have measured 27 alluvial fans and 9 Catchment (Figure 4).
- **Armiyan fault and Qods fault:** Armiyan faults, with an approximate length of 52 km and Qods fault with 53 km length, located in the eastern part of the region, the approximate trends northeast-southwest and has strike-slip components, However, the mechanism of these faults has not been exactly determined. These faults in the surface, measured tilt 65 degrees to 75 degrees to north and northeast. In general, Armiyan and Qods fault zone have 28 alluvial fans and 25 Catchment (Figure 4).

3.2. Folds

Anticline and syncline buildings, forming a major part of regional folding, some of the most important folds of the region are noted as follows:

- **Deh Molla syncline:** It is an asymmetric steeped in the western part of the region, this syncline has a NE-SW direction parallel thrusts Shahrud and Tazareh, and it is aligned with the western part of the watershed. North limb of this syncline has been cut by large drift of Shahrud fault (Figure 4).
- **Syncline among the Shoqal Mountain and Bineh Mountain:** syncline among the Shoqal Mountain and Bine Mountain is located almost in the

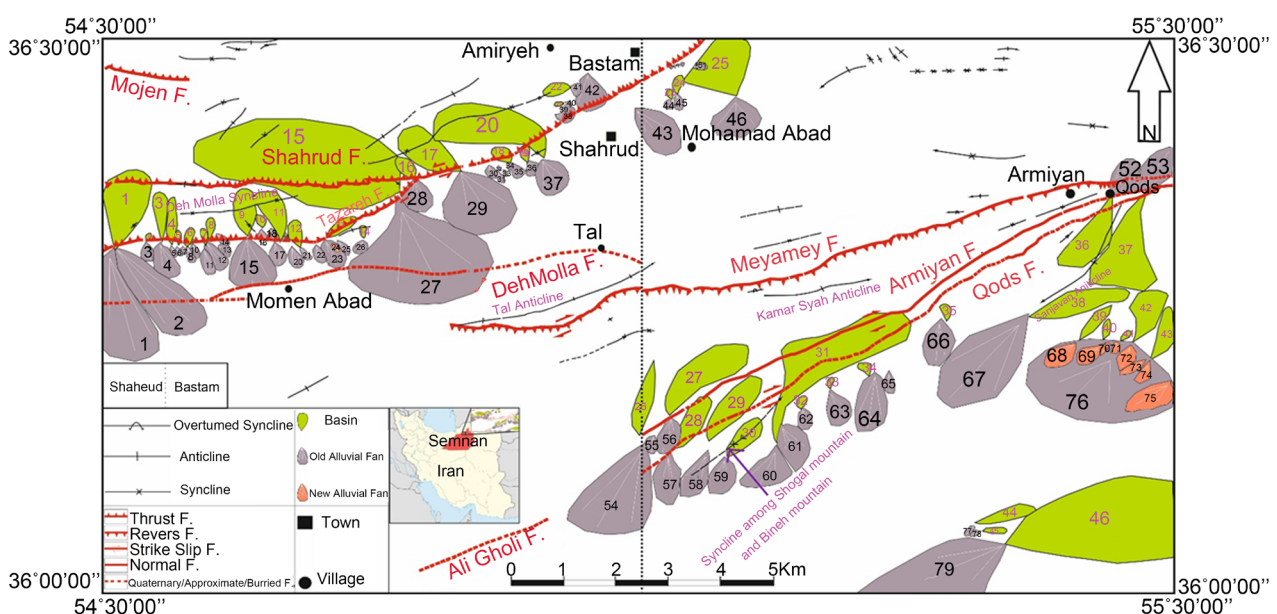


Figure 4. Distribution map of the region based on the geological maps with a scale of 1:100,000 Shahrud-Bastam.

center of the study area towards the East. The hiding central effect of this syncline is toward the north East-southwest, and aligned with the direction of alluvial fans and watershed in the east side (**Figure 4**).

- **Tal anticline:** this asymmetric anticline is taken place in the western part of the study area, with parallel drift along the NE-SW West and Drift of Meyamey fault. The southern edge of the Tal anticline has been cut by Meyamey faults. Zigzag folding is also well visible in the subsequence (**Figure 4**).
- **Sanjavan anticline:** This anticline is located in the easternmost part of the study area and they made a anticlinal structure in the southern side of Qods village. And effect of its axial is to north, north-east-south and south West. In addition, this anticline is aligned Fans and watershed that have arisen in the eastern part of the study area (**Figure 4**).
- **Kamar Syah anticline:** Kamar Syah anticline located almost in the middle of the study area and effect of its axial is to east-west (**Figure 4**).

4. Discuss

4.1. Morphotectonics

Reviews carried out of the 16 indicators morphotectonic on 79 alluvial fans and 46 watersheds in the study area and the information obtained from the calculations of reviews, can be followed in **Table 2** and **Figure 4**.

Using the values calculated from the slope of the alluvial fans, alluvial fans radius, En-Closed area of alluvial fans and watershed area measured in the study area, graphs were plotted in three general methods.

1) There is an inverse relationship between the slope of the alluvial fan and the Watershed En-Closed area of the region (**Chart 1**).

2) Whatever the length radius of alluvial fans in the area increased, its slope reduced (**Chart 2**).

3) There is a direct relationship between, En-Closed area of alluvial fan and, En-Closed area of the Watershed (**Chart 3**).

According to the position of alluvial fans and watershed plotted in the range of faults (**Figure 4**), the area is divided into three major zones: Tazareh fault zone in the western part of the region, and Shahrud fault zone in the western part of the region, and Armiyan and Qods fault zone in the eastern part of region (**Figure 5**). To this end, maximum, minimum and average 11 indicators related to regional tectonic morphotectonic like(process Fans of fractionated, As, Smf, Vf, FCI, Fmf, Fd, Af, T, SL, Bs) , are placed in **Table 3**. In addition, the red color represents high tectonic activity, yellow represents moderate tectonic activity and green represents weak tectonic activity.

Thus, according to measurements taken of each index, summarizing the index is (**Table 3**):

1) Four indicators (process fractionated alluvial fans, Fmf, T, Bs) show that Armiyan-Qods fault zone with high construction activities, Tazareh fault zone with moderate tectonic activities and Shahrud fault zone with low tectonic activities in the region.

Table 2. Morphotectonic data from indices used in the area.

Fan	Basin	Zone	Boll (1962)	As	FCI	Af	T	SL	Bs	Slop fan (m)	En-closed area fan(km ²)	En-closed area basin (km ²)	Radius fan(m)	Vf	Smf	Fmf	Fd	
1	1		B	58	0/62	63/75	0/39	60/72	2/14	1/83	43/71	20/83	11623	2/39				
2	-		B	63	0/16	-	-	-	-	1/94	32/20	-	10871	-				
3	2		A	100	0/65	63/63	0/61	15/30	2/26	2/80	1/57	0/22	1954	5				
4	3	Tazareh F.	C	75	0/58	56/10	0/65	103/97	4/21	2/91	5/36	3/85	3652	9/75				
5	4		A	50	0/45	72/29	1	165/35	5/17	2/86	0/39	3/14	1229	6/41				
6	5		A	60	0/80	54/76	0/27	0	3/84	3/37	0/33	0/42	1005	6/41				
7	-		A	40	0/40	-	-	-	-	-	4	0/25	-	870	5/83			
8	6		A	86	0/24	61/94	0/64	71/42	2/75	3/54	0/85	1/13	1736	-				
9	-		B	44	0/87	-	-	-	-	-	4	0/28	-	694	-			
10	-		C	107	0/48	-	-	-	-	-	4/17	0/70	-	1506	-			
11	7		A	88	0/16	29/23	0/58	65/90	3/33	3/37	2/15	0/65	2661	3/95				
12	8		A	106	0/13	56/63	0/43	115/84	3/06	3/77	2/95	1/13	3117	2/57				
13	-		B	113	0/35	-	-	-	-	-	4/80	1/01	-	1548	-			
14	-	A	70	0/48	-	-	-	-	-	5/08	0/83	-	1595	-				
15	9	B	106	0/51	61/74	0/57	261/06	2/46	3/77	14/12	6/77	4992	15/48					
16	10	C	93	0/29	62/33	0/22	0	1/72	6/27	0/96	0/77	1647	8/06					
17	11	C	76	0/44	75/29	0/33	257/77	2/55	3/94	2/38	7/53	2484	-					
18	-	Tazareh F.	A	77	0/42	-	-	-	-	6/84	0/68	-	1266	-				
19	-		A	81	0/73	-	-	-	-	-	4/91	0/92	-	1370	7/14			
20	-		A	66	0/57	-	-	-	-	-	3/60	1/90	-	2285	16			
21	12		A	112	0/27	61/80	0/41	153/15	2/38	3/49	0/70	2/33	1451	19/51				
22	-		C	88	0/64	-	-	-	-	-	4/11	1/35	-	1931	1/80			
23	13	B	113	0/20	35/65	0/14	0	2/90	3/83	3/99	2/58	3015	5/47					
24	-	C	60	0/31	-	-	-	-	-	4/46	0/42	-	1067	-				
25	-	B	80	0/30	-	-	-	-	-	3/54	0/84	-	1777	6/84				
26	14	B	131	0/56	50	0/33	0	2/19	4	1/25	0/56	1439	1/56					
27	15	C	42	0/53	52/13	0/17	269/78	2/11	1/89	80/72	112/28	11512	3/19					
28	16	C	96	0/50	17/46	0/41	376/01	1/98	5/37	6/27	6/47	3472	1/91					
29	17	A	114	0/34	52/03	0/59	253/31	1/99	3/09	28/85	14/28	6814	0/75					
30	-	Shahrud F..	C	105	0/47	-	-	-	-	5/54	0/90	-	1449	0/48				
31	-		C	57	0/66	-	-	-	-	-	4/57	0/58	-	1419	-			
32	-		A	71	62/0	-	-	-	-	-	6/27	0/12	-	572	-			
33	-		A	80	0/39	-	-	-	-	-	5/08	0/23	-	759	-			

Continued

34	-	A	35	0/56	-	-	-	-	5/48	0/21	-	963	-	
35	18	A	67	0/65	38/91	0/59	0	1/46	5/08	1/24	2/03	1680	8/75	
36	19	A	72	0/51	50/53	0/53	41/01	2/33	3/49	1/48	0/93	1642	25/45	
37	20	A	122	0/74	76/82	0/18	191/70	2/42	2/51	7/81	25/11	3589	3/69	
38	-	C	70	0/62	-	-	-	-	3/43	1/75	-	1716	7/47	
39	-	D	110	0/48	-	-	-	-	6/84	0/15	-	512	-	
40	21	B	100	0/67	56/52	0/01	0	2/05	5/71	0/32	0/23	905	1/55	
41	22	D	108	0/63	77/27	0/32	0	1/92	2/29	0/91	2/20	1068	1/90	
42	-	Shahrud F.	D	95	0/53	-	-	-	0/97	6/65	-	3857	-	
43	-		C	88	0/39	-	-	-	-	0/97	12/86	-	5636	-
44	23		C	130	0/85	62/50	0/49	0	1/86	3/14	0/58	0/40	938	4/65
45	24		C	82	0/69	43/58	0/42	49/38	2/13	2/63	1/04	1/17	1672	3/81
46	25		B	106	0/71	93/32	0/19	30/62	0/92	0/34	11/37	18/27	4038	25/58
47	-		C	70	0/86	-	-	-	-	5/31	0/07	-	369	-
48	-		C	100	0/77	-	-	-	-	6/27	0/06	-	316	-
49	-		D	70	0/82	-	-	-	-	7/96	0/04	-	329	-
50	-		A	101	0/81	-	-	-	-	4/06	0/13	-	451	-
51	-		D	80	0/67	-	-	-	-	4/11	0/75	-	1184	-
52	36	A	90	0/73	14/64	0/15	0	3/20	2/17	6/69	19/19	4065	5/04	
53	37	C	131	0/39	31/67	0/43	223/24	1/82	2/11	10/57	27/53	5184	4/34	
54	26	C	70	0/50	47/45	0/35	112/83	5/31	0/80	41/68	7/27	9805	-	
55	-	A	108	0/34	-	-	-	-	1/31	1/38	-	1828	-	
56	27	A	107	0/43	63/41	0/66	173/37	3/01	1/31	5/11	22/44	3726	4/85	
57	28	C	60	0/72	36/50	0/49	0	3/29	0/97	8/76	7/89	5376	-	
58	29	C	57	0/48	52/12	0/46	87/28	3/28	1/26	7/02	13/08	5178	-	
59	30	C	62	0/60	65/61	0/47	33/94	2/57	1/31	6/37	5/73	3764	-	
60	31	C	70	0/43	32/06	0/25	92/90	4/66	1/37	10/10	47/62	4583	-	
61	-	Qods and Armiyan F.	B	85	0/79	-	-	-	1/60	9/01	-	4441	-	
62	32		D	101	0/70	51/94	0/27	0	1/58	3/49	2/11	0/77	2149	1/69
63	33		B	61	0/56	70	0/69	0	2/03	2/40	5/42	0/40	3794	13/05
64	34		C	105	0/79	44/55	0/68	55/77	1/65	1/60	12/30	1/01	5872	4/66
65	-		C	58	0/32	-	-	-	-	1/94	1/56	-	2324	-
66	35		A	90	0/37	42/10	0/62	51/52	2/07	1/31	8/83	0/95	4687	5/85
67	38		C	62	0/61	41/06	0/44	106/64	3/65	1/26	43/85	13/71	11430	21/15
68	39		C	75	0/57	63/78	0/79	153/56	4/30	2	4/57	3/12	3407	38/40

Average 2 Area: 1/41

Average 4 Area: 3/16

Average 2 Area: 1/20

Average 7 Area: 5/26

Average 6 Area: 0/51

Continued

69	40	A	40	0/63	53	0/33	0	3/03	2/29	2/89	1	3071	5/29
70	-	A	110	0/12	-	-	-	-	2/57	0/50	-	1485	-
71	41	A	128	0/49	38/77	0/24	0	2/33	2/57	0/70	0/49	1214	19
72	42	A	95	0/38	10/52	0/88	129/62	2/11	1/60	2/61	9/79	2738	-
73	-	A	48	0/53	-	-	-	-	1/31	1/51	-	2695	-
74	43	A	48	0/74	57/50	0/48	126/22	3/62	1/26	1/63	5/60	2479	4/85
75	-	A	70	0/29	-	-	-	-	1/14	7/86	-	4900	-
76	-	B	143	0/85	-	-	-	-	1/43	82/07	-	9385	9/86
77	44	A	96	0/74	67/56	0/77	39/18	4/10	1/14	0/55	4/81	1299	12
78	45	A	50	0/38	60/63	0/73	33/70	3/41	1/31	0/38	0/94	1037	7/14
79	46	C	70	0/82	81/04	0/61	179/94	1/91	0/80	149/32	98/45	22844	1/69

Qods and Armiyan F.

Average 2 Area: 1/20

Average 7 Area: 5/26

Average 6 Area: 0/51

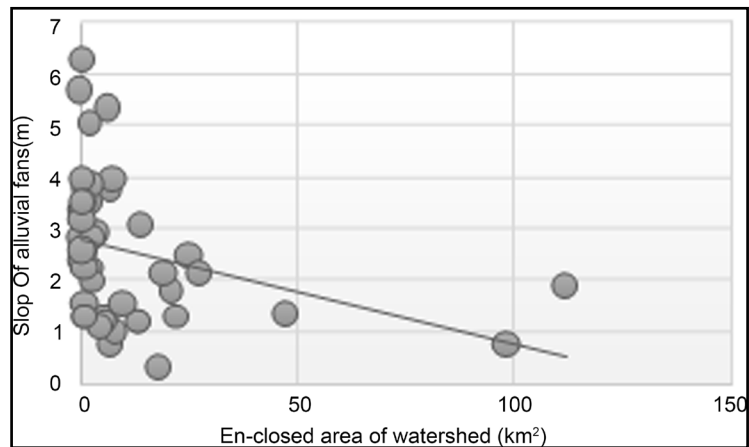


Chart 1. The relationship between the slope of the alluvial fan and, en-closed area watershed in the region.

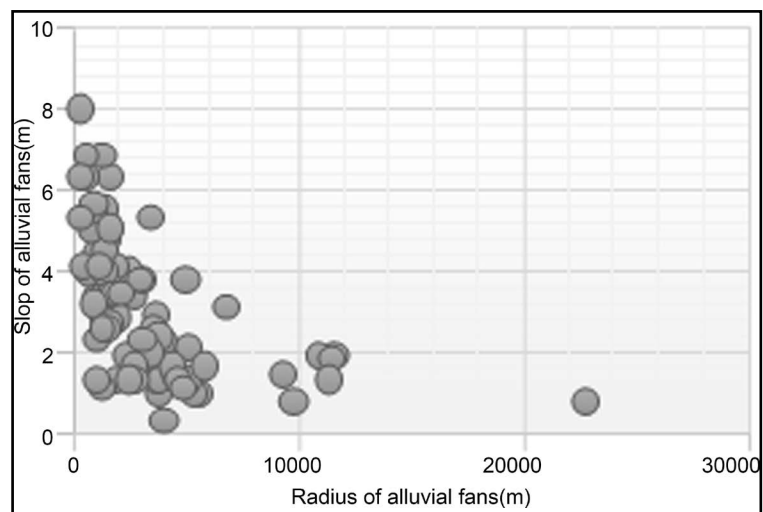


Chart 2. The relationship between the slope and radius alluvial fans in the region.

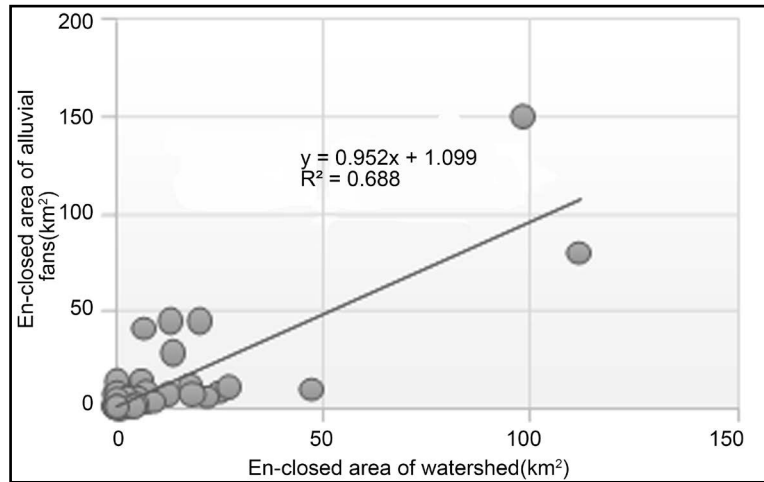


Chart 3. The relationship between en-closed area of alluvial fan and, en-closed area of the watershed of the region.

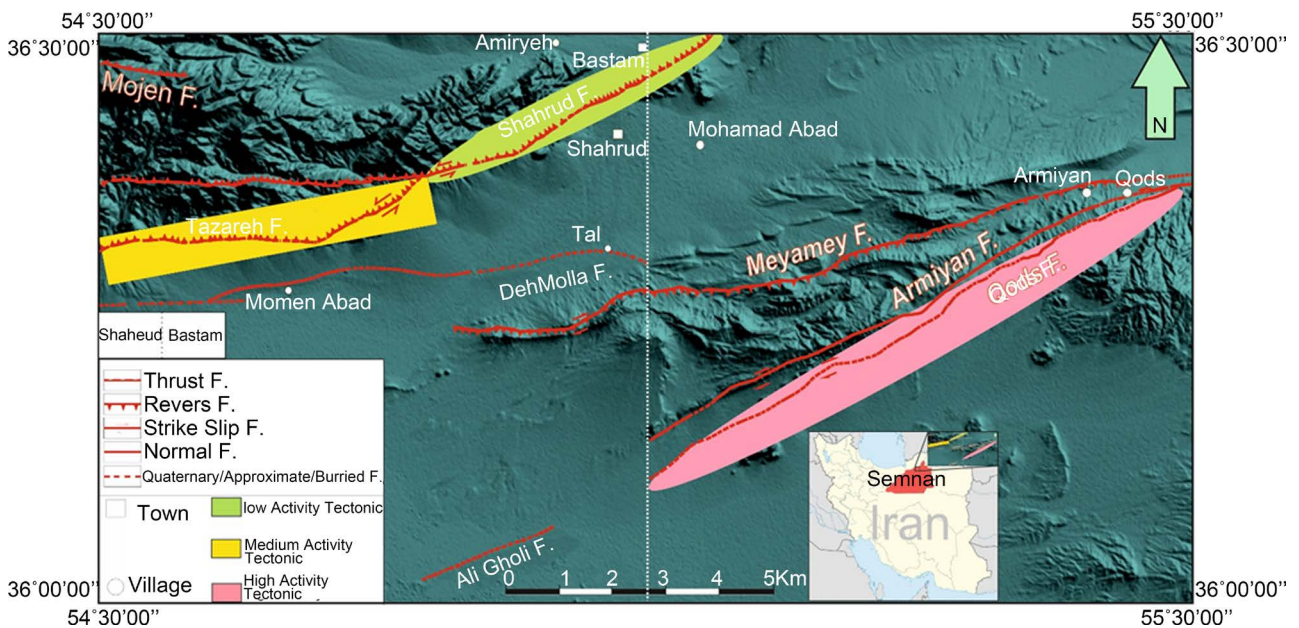


Figure 5. Map index measured based on the overall outcome of the fault zone in the region.

2) Two indicators (FCI, S_mf) show that Tazareh fault zone with high tectonic activities, Armiyan-Qods fault zones with moderate Construction activities and Shahrud fault zone with less tectonic activities in the region.

3) two indicators (A_f, S_L), show that Tazareh fault zone has high tectonic activities, Shahrud fault zone moderate earth construction of tectonic activities, and Armiyan-Qods fault zones have low activities in the region.

4) Indicator (A_s), it shows the Shahrud fault zone with the high construction activities, Armiyan-Qods fault zones with normal tectonic activities and Tazareh fault zone with low tectonic activities in the region.

5) Index (V_f), showst Armiyan-Qods fault zone with high tectonic activities, Shahrud fault zone with moderate Tectonic activities and Tazareh fault zone with low Tectonic activities, in region.

Table 3. Zoning and draw conclusions from data to calculate indicators used in the area morphotectonic.

Groups	Boll (1962)	As	FCI	Af	T	SL	Bs	Vf	Smf	Fmf	Fd
Tazareh F.											
Maximum	A	131	0/87	75/29	1	269/78	5/17	19/51	1/21	4/30	0/46
Minimum	C	40	0/13	29/23	0/14	0	1/72	1/56	1/15	1/83	0/10
Average	9 C	81	0/44	57/15	0/44	102/68	2/87	7/07	1/18	3/36	0/28
Shahrud F.											
Maximum	C	130	0/86	93/32	0/59	376/01	2/42	25/58	1/56	3/72	-
Minimum	D	35	0/34	17/46	0/01	0	0/92	0/48	1/26	2/78	-
Average	7 C	92	0/62	56/89	0/37	94/20	1/90	7/16	1/41	3/16	-
Qods and Armiyan F.											
Maximum	A	143	0/85	81/04	0/88	223/24	5/31	38/40	1/32	7/72	0/87
Minimum	D	40	0/12	10/52	0/15	0	1/58	1/69	1/08	3/17	0/08
Average	11 C	82	0/54	48/85	0/51	76/17	2/99	9/92	1/20	5/26	0/51

6) Index (Fd), shows Armiyan-Qods fault zone with high tectonic activity, Tazareh fault zone with low tectonic activity in region.

4.2. Seismicity

According to **Figure 6**, compression, and earthquakes, in the north-west (Tazareh and Shahrud faults) increases. But in Armiyan-Qods fault zone in eastern district, despite high morphometry activity (**Figure 5**), Low density and seismic activity in the region. But in this area, there are a number of minor structures. The greatest depth recorded Earthquake occurred was 32 km to the ground and in the eastern part of the region. There focal mechanisms registered in the eastern part of the region in relation to earthquakes of magnitude 4.5 (Arrow in **Figure 6**), reverse faults trending north-east Meyamey and South West in the region proves and movement in the compression zone.

5. Conclusions

5.1. Pluralization Geomorphologic Indicators

Given the importance of Tazareh fault zone, Armiyan-Qods fault zones, Shahrud faults zone in associated with alluvial fans and Catchment area, tectonic activity was measured using 11 indicators according to the conclusions of the index Mentioned fault zone in the region that are divided as follows (**Table 3** and **Figure 5**):

1—Armiyan-Qods fault zones, with 6 indicators (process fractionated alluvial fans, Fmf, Fd, Vf, T, Bs) and frequency of 54/54 Percent, high tectonic activity, with 3 index (As, Smf, FCI) and frequency of 27/27% with an average yield of tectonic and 2 Index (Af, SL) and the frequency of 18/18% with low-yield earth, represents the most active tectonic fault zone in the study area (**Table 3**).

2—Tazareh fault zone, with 4 index (Smf, FCI, Af, SL) with a frequency of 36/36%, the high tectonic activity, with 4 indicators (alluvial Fans of fractionated

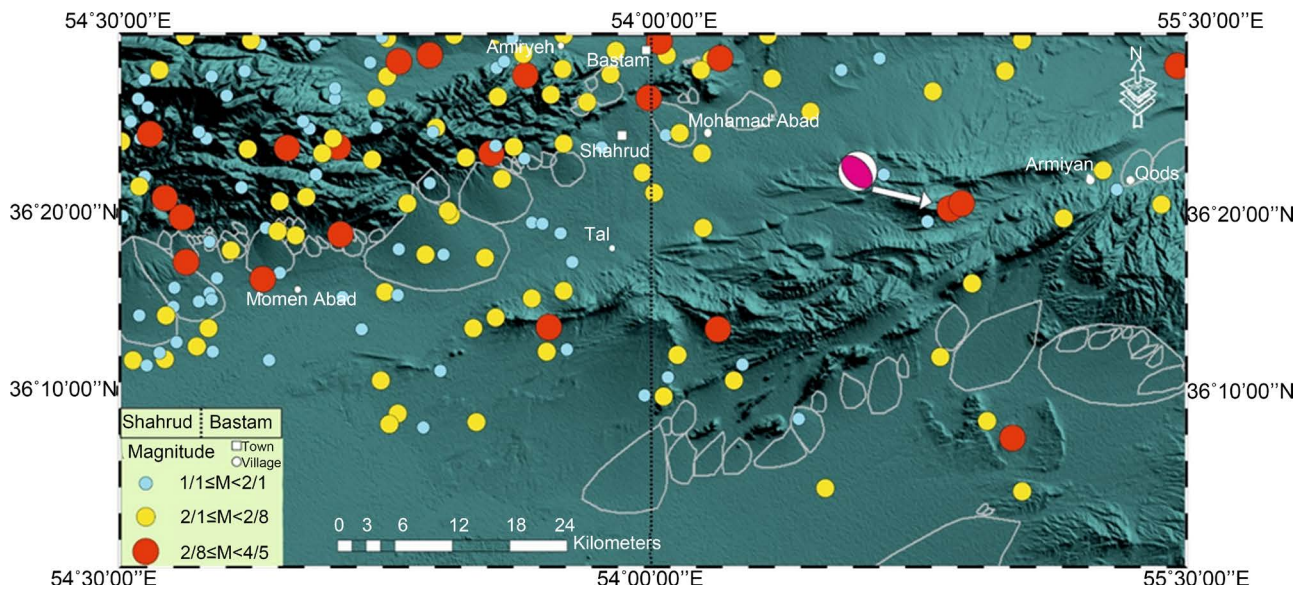


Figure 6. Seismotectonic map of the study area, adapted from Tehran University Geophysics Institute [25].

process, Bs, Fmf, T) with a frequency of 36/36%, with 3 tectonic activity indexes (Vf, As, Fd) with a frequency of 27/27% with low tectonic activity, shows this fault zone with moderate activity in the studied area (Table 3).

3—Shahrud Fault zone, with one indicator (As) with the frequency of 9/09%, and high tectonic activity, with 3 indexes (Vf, Af, SL) with The frequency of 27/27 percent, and with average tectonic activity and 6 indexes (process fractionated alluvial fans, Fmf, Smf, T, FCI, Bs) with a frequency of 54/54% and low tectonic activity. This table shows that this fault zone compared with Armiyan-Qods zone faults and Tazareh fault zone is significantly different and indicates low tectonic activity (Table 3).

5.2. Check Subsidence or Rising in the Region

Subsidence and rising in the region can be examined via index As. The data extracted from the index show that rising alluvial fans in the 83/54 percent, has specific effect on subsidence of the alluvial fan to 10/12% and high subsidence tectonic to 6/32 percent in the affected area. So, these high percents show high isostatic and tectonic impact in the region.

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