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Investigation of T Factor Variations along Atrak River to the Caspian Sea

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Abstract

The study area has located on Atrak river basin in the Iran-Turkmenistan border zone that is the greatest river on the southeastern margin of Caspian Sea. The study area was divided into 56 sub-basins and then T factors were calculated for all streams of the Atrak river. T factor is a geomorphic index for tilting identification by active tectonics. Our results show that, there are low, moderate and high relative tectonic activities levels. Low relative tectonic activities level has been found in sub-basins No. 1, 2, 3, 4, 10, 23, 25, 41 and 51, moderate relative tectonic activities level has been found in sub-basins No. 5, 6, 7, 8, 13, 14, 17, 18, 19, 20, 21, 24, 28, 29, 30, 31, 32, 34, 35, 39, 40, 42, 43, 46, 47,48, 49, 50, 52, 53, 55 and 56 and high relative tectonic activities level has been found in sub-basins No. 9, 11, 12, 15, 16, 22, 26, 27, 33, 36, 37, 38, 44, 45 and 54. Also, most part of the study area has got moderate tectonic activity that it is compatible with its tectonic setting on the Kopetdagh belt in Iran. It is shows that some sub-basins on the western parts of study area that river has got west-east trending, are more active. But, some sub-basins on the eastern parts of study area that river has got northwest-southeast trending, are less active. It means that migration direction of the most streams are toward north and south and the major faults and folds in the western parts of study area caused river tilting be perpendicular to structural trend. This variation along the most important river on the northeastern part of Iran was analyzed for the first time in this research.

Keywords

T Factor, River, Atrak, Tectonic, Caspian Sea

1. Introduction

Atrak is a bed rock river which begins in the mountains of north-eastern Iran, and flows 669 kilometers westward draining into the Caspian Sea in Turkmenistan. The Atrak River is located in the north east Iran (**Figure 1**). The Atrak river is located in the

Physiographic-tectonic zoning map of Iran's sedimentary basins
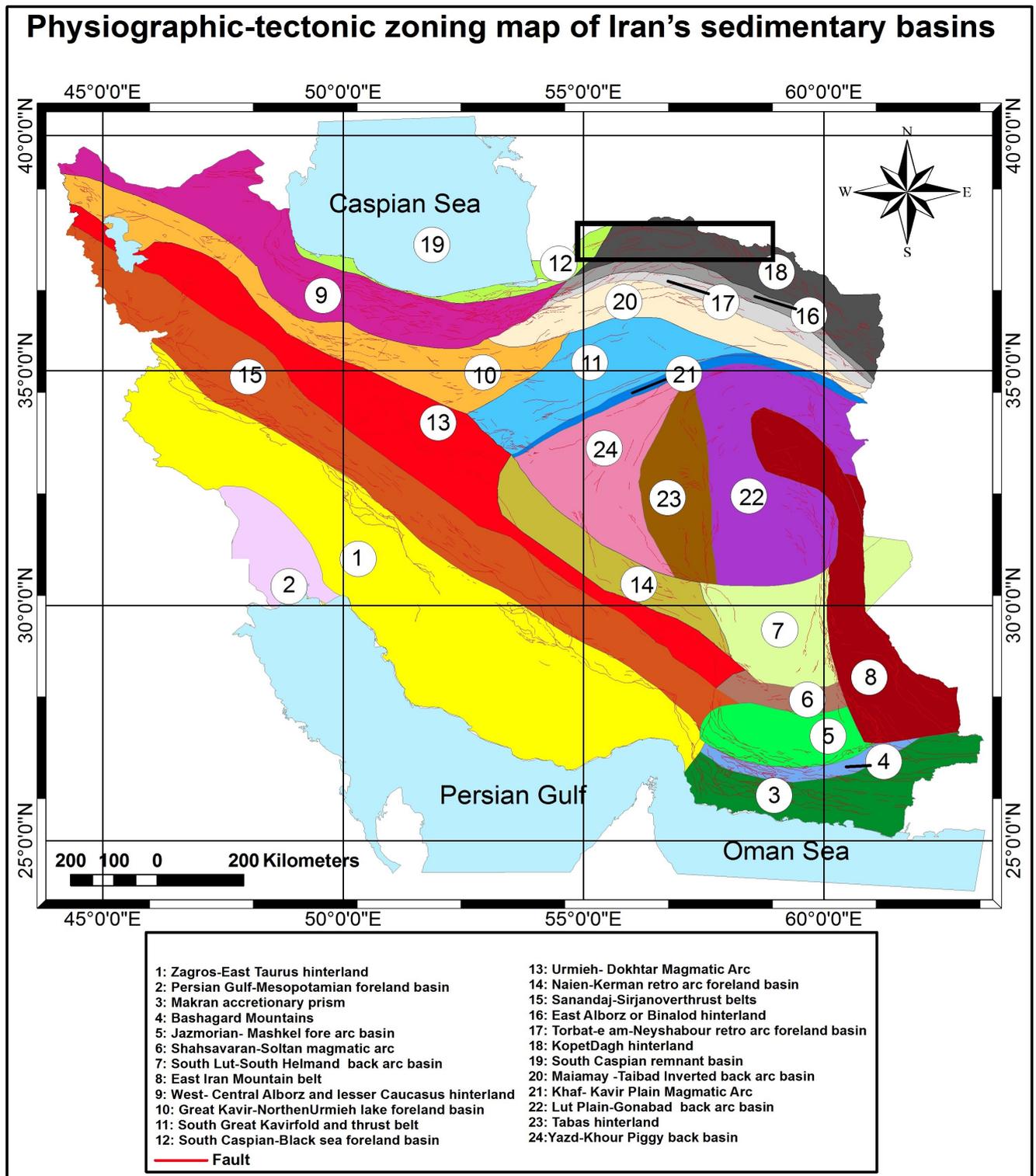
Figure 1. Physiographic-tectonic zoning map of Iran's sedimentary basins, modified from [1]. The study area is shown in the black rectangle.

Kopetdagh and it is divided into 56 sub-basins (**Figure 2**). This area belongs to Kopetdagh geologic province [1] [2]. Dominant structural trend in Kopetdagh province (**Figure 3**) is NW-SE. From tectonics view, it contains the Kopetdagh hinterland or
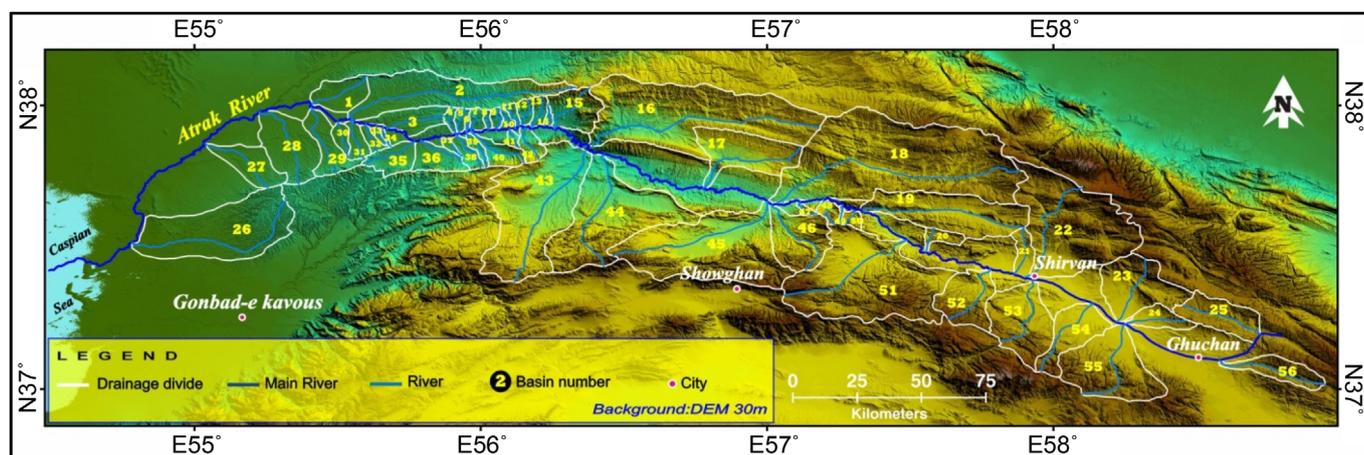
Figure 2. The fifty six sub-basins of the Atrak River basin, modified from [72].

Figure 3. Two views from the Atrak streams (toward west) that show transverse topographic asymmetry in sub-basins No. 22 (left) and No. 17 (right).

Kopetdagh fold and thrust belt that formed in passive margin of Eurasian plate until late Triassic and then marine sedimentation on Kopetdagh proforeland basin has continued to Eocene. Kopetdagh hinterland has uplifted related to Karakorum foreland basin in northeast along Eshghabad fault.

The western part of studied area has located in South Caspian foreland basin. Dominant structural trend in South Caspian foreland basin province (**Figure 3**) is NW-SE. From tectonics view, it contains the northern foreland basin of West-Central Alborz and lesser Caucasus hinterland in the south margin of Eurasian plate since late Eocene. Although, median part of South Caspian and Black sea basin has uplifted by collision between Eurasian and Cimmerian plates [3].

Based on previous work on the salt and mud diapirism [4]-[15] and neotectonic regime in Iran [16]-[21], Zagros in south Iran is the most active zone [22]-[43]. Then, Alborz [44]-[83] and Central Iran [84]-[99] have been situated in the next orders.

2. Materials and Methods

The calculation of transverse topographic symmetry factor (T) is suitable for rapid assessment of active tectonics. Therefore, transverse topographic symmetry factors have

calculated for the streams in the Atrak River. Based on digital elevation model of Atrak River, there are 56 sub-basins. The study area is located between longitudes 55˚E - 59˚E and latitudes 37˚N - 38˚N in the Northern Khorasan province, in the north east part of Iran.

The study area is mainly composed of limestone (Tiregan Formation), marl (Sarcheshmeh Formation), shale and marl (Sanganeh Formation), sandstone and shale (Aitamir Formation) and Quaternary alluvial deposits The East Alborz or Binalod Mountains are parallel to the Kopetdagh hinterland on the north east Iran. The Atrak valley, which separates the East Alborz and Kopetdagh, forms a major structural boundary between Central Iran and Eurasia, known as the Paleo-Tethyian suture zone, which formed before the Alpine-Himalayan orogenies since late Triassic.

Transverse Topographic Symmetry Factor (T)

The transverse topographic symmetry factor (T) was calculated as follows:

$$T = Da/Dd$$

which Da is the space from the midline of the drainage basin to the midline of the active belt and Dd is the space from the midline to the basin limit [100]. In a completely symmetric basin T = 0 and as asymmetry increases T approaches to value of 1.0 [101]. Two views from the Atrak streams that used for calculation of T index in study area have presented in **Figure 3**.

Finally, we can consider class 1 for T > 0.4, class 2 for T between 0.2 and 0.4 and class 3 for T < 0.2 and so, sub-basins No. 9, 11, 12, 15, 16, 22, 26, 27, 33, 36, 37, 38, 44, 45 and 54 shows higher activity (**Table 1** and **Figure 4**).

3. Results and Discussion

There are three level of active tectonics. Low relative tectonic activities in sub-basins No. 1, 2, 3, 4, 10, 23, 25, 41 and 51, moderate relative tectonic activities in sub-basins No. 5, 6, 7, 8, 13, 14, 17, 18, 19, 20, 21, 24, 28, 29, 30, 31, 32, 34, 35, 39, 40, 42, 43, 46, 47, 48, 49, 50, 52, 53, 55 and 56 and finally high relative tectonic activities in sub-basin No. 9, 11, 12, 15, 16, 22, 26, 27, 33, 36, 37, 38, 44, 45 and 54 (**Figure 4**). On the other hand,
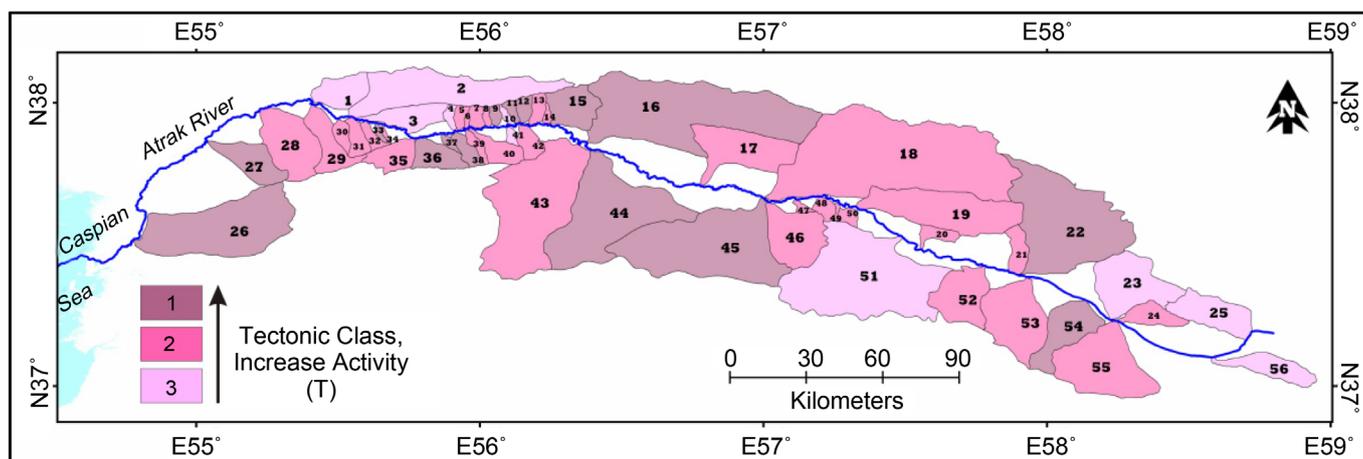
Figure 4. The classification map for T index.

Table 1. Values of T index for sub-basins.

Basin	Number	Da (m)	Dd (m)	T (m)	T_{ave} (m)	Tectonic class
	1	260.9	1937	0.13		
1	2	1197	5180	0.23	0.18	3 (Low Activity)
	3	353.7	5310	0.07		
	4	485.1	1593	0.30		
	1	56.2	1531	0.04		
2	2	478.8	5820	0.08	0.16	3
	3	1840	7490	0.25		
	4	1110	4204	0.26		
3	1	398.6	5750	0.07	0.11	3
	2	391.5	2771	0.14		
	1	183.6	1993	0.09		
4	2	228.5	1151	0.20	0.13	3
	3	86.8	933.9	0.09		
	1	442.2	2316	0.19		
5	2	456.6	1776	0.26	0.25	2 (Moderate Activity)
	3	707.1	1532	0.46		
	4	113.4	1475	0.08		
6	1	56	509.9	0.11	0.21	2
	2	241.1	766.3	0.31		
7	1	503.6	2114	0.24	0.24	2
8	1	250.1	1015	0.25	0.25	2
	2	313	1217	0.26		
9	1	813	1574	0.52	0.57	1 (High Activity)
	2	1256	2007	0.63		
10	1	367	1445	0.25	0.19	3
	2	184.6	1454	0.13		
	1	577	2281	0.25		
11	2	1214	1497	0.81	0.54	1
	3	568	997.3	0.57		
12	1	1528	2322	0.66	0.70	1
	2	883	1196	0.74		
	1	746	2475	0.30		
13	2	478.2	2389	0.20	0.26	2
	3	351	1296	0.27		
	1	176	583.5	0.30		
14	2	383	1129	0.34	0.35	2
	3	640	1589	0.40		

Continued

	1	397	851	0.47		
15	2	474.1	10,630	0.04	0.44	1
	3	2137	2595	0.82		
	1	3935	7550	0.52		
16	2	9420	15,040	0.63	0.51	1
	3	862	2288	0.38		
	1	2281	5020	0.45		
	2	4277	7020	0.61		
17	3	513.4	2656	0.19	0.37	2
	4	277	1244	0.22		
	1	2438	7250	0.34		
	2	7800	12,850	0.61		
	3	4171	17,860	0.23		
18	4	1970	21,080	0.09	0.29	2
	5	499	9080	0.05		
	6	1120	2610	0.43		
	1	2132	6010	0.35		
	2	740	8050	0.09		
19	3	877	7790	0.11	0.27	2
	4	3399	7380	0.46		
	5	2685	8100	0.33		
20	1	317	9870	0.03	0.24	2
	2	395	884.7	0.45		
	1	997	2671	0.37		
21	2	157.2	2509	0.06	0.27	2
	3	577	2884	0.20		
	4	1486	3390	0.44		
	1	3874	18,590	0.21		
22	2	6260	12,800	0.49	0.43	1
	3	5290	7670	0.69		
	4	54.1	158.3	0.34		
	1	1456	11,690	0.12		
23	2	998	8440	0.12	0.16	3
	3	501.1	2031	0.25		
	1	352.8	2631	0.13		
	2	782.2	6030	0.13		
24	3	786.2	5090	0.15	0.22	2
	4	313.2	2786	0.11		
	5	150.7	272.3	0.55		

Continued

25	1	190	5450	0.03	0.07	3
	2	552	4903	0.11		
26	1	9170	13,230	0.69	0.49	1
	2	2943	9830	0.30		
	3	4690	9640	0.49		
27	1	2622	5330	0.49	0.45	1
	2	2044	5100	0.40		
28	1	1201	4647	0.26	0.29	2
	2	274	8370	0.03		
	3	3444	5850	0.59		
29	1	2325	8710	0.27	0.37	2
	2	2375	4229	0.56		
	3	812.1	3006	0.27		
30	1	444	1585	0.28	0.24	2
	2	732.4	2825	0.26		
	3	103	603.7	0.17		
31	1	617.3	3618	0.17	0.24	2
	2	696.1	2324	0.30		
	3	327.6	1277	0.26		
32	1	758.4	2901	0.26	0.25	2
	2	378.1	1803	0.21		
	3	407.4	1466	0.28		
33	1	475.8	1021	0.47	0.47	1
34	1	185.5	670	0.28	0.31	2
	2	237.2	708.6	0.33		
35	1	3008	5370	0.56	0.36	2
	2	2786	5820	0.48		
	3	451	3360	0.13		
	4	292	1077	0.27		
36	1	5850	7260	0.81	0.75	1
	2	3890	5580	0.70		
37	1	318.3	657.1	0.48	0.48	1
	2	815.6	1748	0.47		
38	1	1627	2993	0.54	0.51	1
	2	2182	3518	0.62		
	3	963.4	2598	0.37		
39	1	385	800.2	0.48	0.30	2
	2	170	1360	0.13		

Continued

	3	573	1685	0.34		
	4	292	1367	0.21		
	5	228	704.1	0.32		
	1	4355	6920	0.63		
40	2	345.7	3502	0.10	0.32	2
	3	321	1397	0.23		
	1	111.5	939.3	0.12		
41	2	421.2	1398	0.30	0.17	3
	3	268.5	1317	0.20		
	4	65.3	864.2	0.08		
	1	507.6	4171	0.12		
42	2	642	3397	0.19	0.36	2
	3	583.2	1974	0.30		
	4	1171	1395	0.84		
	1	2999	12,390	0.24		
43	2	3388	13,800	0.25	0.38	2
	3	4804	7200	0.67		
	1	6640	11,270	0.59		
44	2	3016	8700	0.35	0.49	1
	3	9110	16,650	0.55		
	1	17,960	25,640	0.70		
45	2	3224	12,030	0.27	0.43	1
	3	657	2023	0.32		
	1	686.1	8550	0.08		
46	2	1035	11,230	0.09	0.25	2
	3	1110	6770	0.16		
	4	1622	2518	0.64		
47	1	811	2386	0.34	0.34	2
	2	305	912.1	0.33		
	1	306.5	1585	0.19		
48	2	2280	3188	0.72	0.32	2
	3	144	3143	0.05		
	1	426	1134	0.38		
	2	123.1	977.8	0.13		
49	3	97	436.2	0.22	0.23	2
	4	235	937.6	0.25		
	5	158	825.8	0.19		
50	1	1417	3217	0.44	0.32	2
	2	520	2525	0.21		

Continued

51	1	1538	8190	0.19	0.19	3
	2	758	12,240	0.06		
	3	5930	23,290	0.25		
	4	782.7	3289	0.24		
52	1	1716	10,370	0.17	0.31	2
	2	3021	6060	0.50		
	3	1622	6230	0.26		
53	1	2529	10,570	0.24	0.27	2
	2	4294	10,160	0.42		
	3	675	4998	0.14		
54	1	2033	4416	0.46	0.48	1
	2	2650	5370	0.49		
	3	3440	6920	0.50		
55	1	4706	20,170	0.23	0.26	2
	2	1583	5620	0.28		
56	1	625	3015	0.21	0.27	2
	2	2029	3929	0.52		
	3	1166	4540	0.26		
	4	432	2025	0.21		
	5	130	806.2	0.16		

T classification: 1 (High Activity): >0.4, 2 (Moderate Activity): 0.2 - 0.4, 3 (Low Activity): <0.2.

although based on [102] northern side of sub-basin No. 46 or the Qharajeh area is inactive and its southern side is active, but T factor value is 0.25.

Highest value of T index (0.81) for streams of Atrak river is related to sub-basins No. 11 and 36 and lowest value (0.03) is related to sub-basin No. 20 it seems that folds and thrusts parallel to this sub-basins caused more tilting. Calculating this geomorphic index for the study area shows that, average values of T factor are between 0.11 for sub-basin No. 3 and 0.75 for sub-basin No. 36 which the latter case shows high seismicity (Figure 5).

It is shows that some sub-basins on the western parts of study area that river has got west-east trending, are more active. But, some sub-basins on the eastern parts of study area that river has got northwest-southeast trending, are less active. It means that migration direction of the most streams are toward north and south and the major faults and folds in the western parts of study area caused river tilting be perpendicular to structural trend.

Also, there are no logic relationship between the values of T index and seismic frequency. It has shown in Figure 5.

4. Conclusions

The T factor variations along the most important river on the southeastern margin of
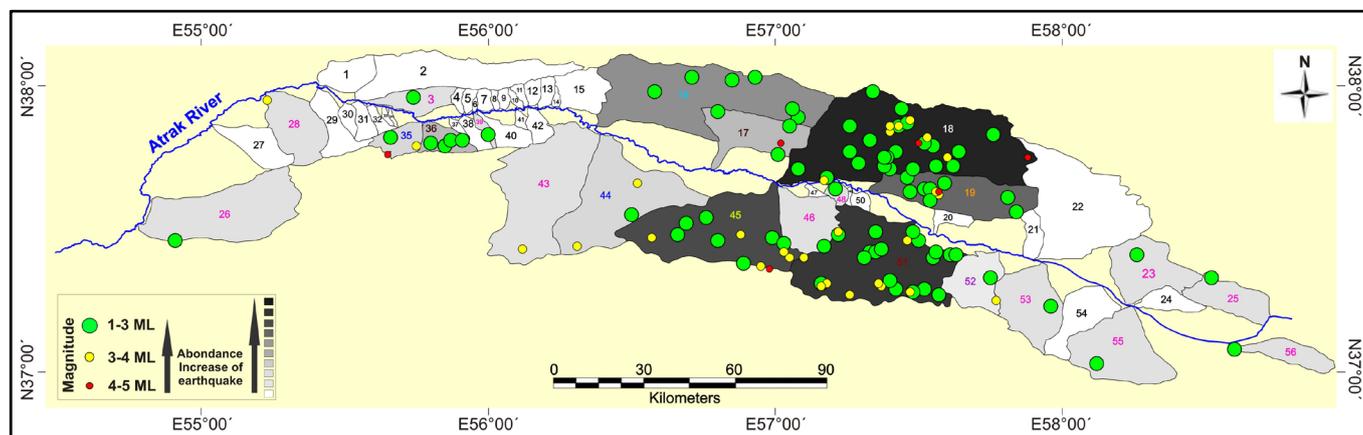
Figure 5. The seismic records of study area on sub-basin map (compare it with **Figure 4**).

Caspian Sea were analyzed for the first time in this research. The calculation of transverse topographic symmetry factor (T) is suitable for rapid assessment of active tectonics. The transverse topographic symmetry factor has calculated in the Atrak River.

The study area was divided into 56 sub-basins and then transverse topographic symmetry factors were calculated for each one. Based on values of this index, there are low, moderate and high relative tectonic activities levels.

Low relative tectonic activities level has been found in sub-basins No. 1, 2, 3, 4, 10, 23, 25, 41 and 51, moderate relative tectonic activities level has been found in sub-basins No. 5, 6, 7, 8, 13, 14, 17, 18, 19, 20, 21, 24, 28, 29, 30, 31, 32, 34, 35, 39, 40, 42, 43, 46, 47, 48, 49, 50, 52, 53, 55 and 56, and high relative tectonic activities level has been found in sub-basins No. 9, 11, 12, 15, 16, 22, 26, 27, 33, 36, 37, 38, 44, 45 and 54. It is shows that some sub-basins on the western parts of study area that river has got west-east trending, are more active. But, some sub-basins on the eastern parts of study area that river has got northwest-southeast trending, are less active.

Acknowledgements

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