Assessment of relative changes in tectonic activity in the northern part of the fault Ardekul (Eastern Iran)

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Abstract

Ardekoul fault zone which is along NNW-SSE is located in eastern Iran and northern part of the Sistan subzone. Dextral strike-slip fault zone of Ardekuol is made of six main segments including Korizan (28 Km), Bohn Abad (8.8 Km), Abiz (32 Km), Gazkoon (20 Km), Moein Abad (30.4 Km), Ghal Maran (12 Km), and two minor segments including Olang Morgh (12.8 Km) and Seh Pestan (9.6 Km). The studied region in its northern part (From North to the South) is included of: Korizan, Bohn Abad and Abiz .The Parameters and their variation range are :SMF (Krizan:1.18, Bohn Abad:1.21 and Abiz:1.29), Facet% (0.725,0.771 and 0.941), S(1.04,1.13 and 1.16), V(0.97,0.83 and 0.63), SL(191.7,306.13 and 394.43), topography transverse symmetry index changes (T)(0.42,0.32 and 0.36), drainage basin asymmetry index changes(AF) (0.51,0.32 and 0.36), Reviewing uplift alluvial fan through satellite images and longitudinal profile, waterway fractal values ranging (1.982, 1.946 and 1.902), Fractal fracture ranges (1.482, 1.362 and 1.221). Neotectonic indices showed that the relative activity of each segment is different. The rate of activity has been reduced from middle part of each segment to their terminal. Generally, Ardakul fault activity rate from north to south is on the rise. We then conclude that the energy dissipation on the Ardekoul fault is linear. Although it has different amount, but it generally has a linear distribution from the North to the South. According to the neotectonic indicators the section which is studied is placed in the A class (Tectonic activities are very high).

Keywords: Gold and silver, Artificial neural network, Invasive weed optimization algorithm, Multiple linear regression.

1- Introduction

Gold is the main mineral resource in most countries because of its role in economic, industries and public culture. So, most exploration project in gold thread defined. The most important test that defines the presence or absence of mineralization is drilling. High cost of drilling and analysis of samples provide a model that has good agreement with reality. Sometimes it needs to decrease the cost and time exploration project implementation. Mineral prospectively mapping (MPM) and prediction of ore grade is main contributor to this work. Statistical methods such as kriging interpolation, weight of evidence and logistic regression has been applied in this field. Soft computing is also used as modern modeling in gold exploration projects. Skabar applied MPM to mapping gold mineralization potential in the Castlemaine region of Victoria, Australia, and results are compared with a method based on estimating probability density functions and using a range of geological, geophysical and geochemical input variables. Harris and Pan used probabilistic neural network (PNN) to classify mineralized and nonmineralized cells using eight geological, geochemical, and geophysical variables. This investigation demonstrates that a probabilistic neural network can be a useful tool for mineral favorability mapping. A PNN trained and calibrated well on training data, indicating that it could distinguish mineralized cells from those that are barren by a set of eight geological, geochemical, and geophysical variables (Harris and Pan, 1999; Harris *et al.*, 2003). Singer and Kouda used the ability of a probabilistic neural network to classify deposits into types based on a simple representation of mineralogy and six broad rock types. They concluded the comparison of the spatial distribution of the neural network's estimated deposit classes and permissive tracts determined by experts shows that the probabilistic neural network is able is perform well at generalization (Singer and Kouda, 1996).

Ardekoul fault zone is located in a place which is 70 km out of eastern part of Ghayen in southern Khorasan (east of Iran). The fault prevailing protraction (NSE) and its dynamic mechanism is dextral strike-slip (Khatib *et al*., 2006). Deformation caused by May 10, 1997 earthquake is the largest surface faulting that recorded in Iranian plateau. This deformation is resulted from four seismic events within 59 seconds on the four northern main segments (from six main segments) that mechanism of these four segments is deferent to each other (Berberian, 1999). Ardekoul fault seismic moment rate, geology and Geodetic evaluations; shows that seismic moment rate is reduced form the north to the south which means the fault activity is increasing (Heydari, 2015).so how is the Ardekoul fault seismic moment rate? Are its sections acts separately? How is the rate of the activity in each section?

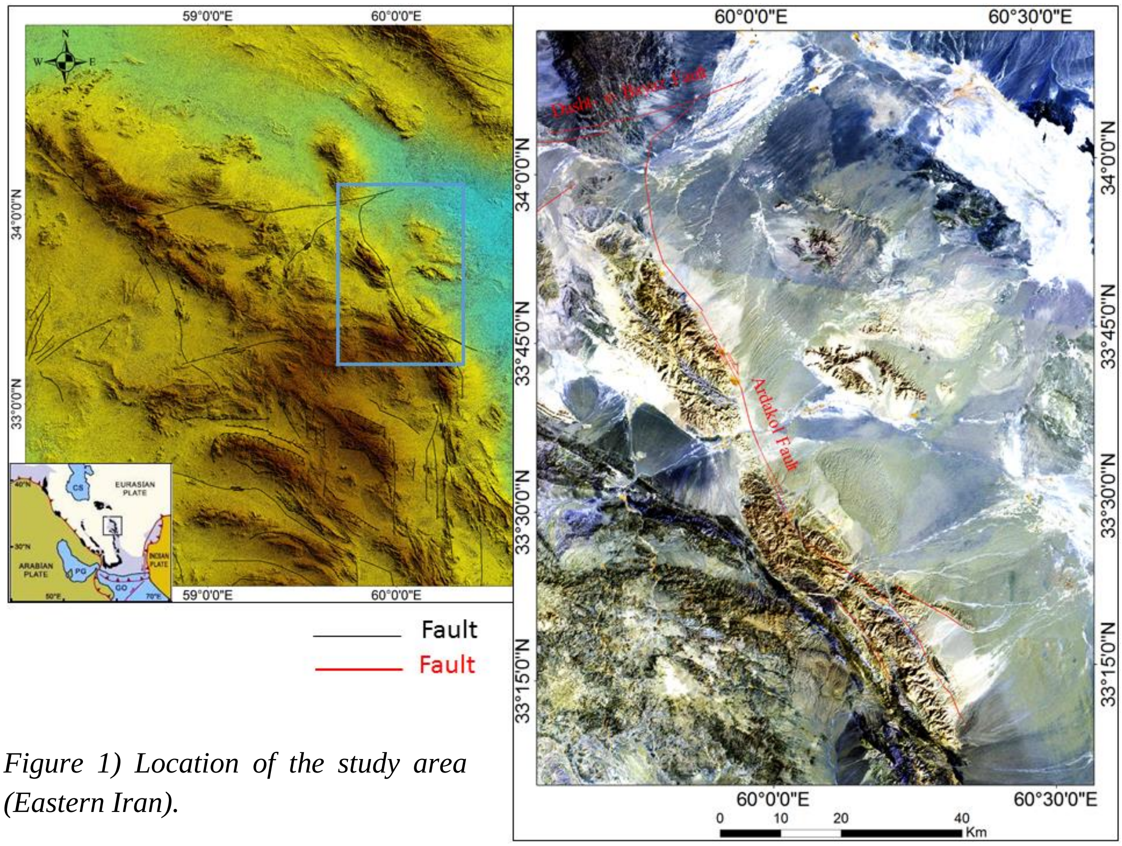


Figure 1) Location of the study area (Eastern Iran).

Ardekoul fault is moving through the mountains (Moein Abad and Gaalmaral sections) in the south, in the middle part of the border between the mountain and the valley (Bohn Abad, Abiz, Gazkoon sections) and finally in the north section (Korizan section) it moves through the valley and ended up in the Dasht- e- Bayaz, East-West fault (Fig. 1). Ardekoul fault consider as an important seismic source in this area because of its background seismicity in the past (1997 earthquake with a magnitude of 7.2). In this area Quaternary sediments and alluvial fans have been suffering interruption and displacement due to action of Ardekoul dextral fault. Therefor study of neotectonic indices as one of the most important tools for evaluation of fault's rate of activity and motion rate of this fault during the past.

2- Geological setting

The main deformations in east of Iran are the causes of dextral North-South faults (Walker and Jackson, 2004), therefore, correlation of the mentioned faults could cause different deformations in Sistan suture zone.

Sistan Zone structure which is easternmost zone in Iran, according to sedimentary- structural zoning that was offered by Tirrul *et al*. (1983); this region was introduced as Sistan suture zone. Sistan suture zone has N- S direction that shows indication of suture zone that arising from collision of Lut and Afghan blocks. Nehbandan fault structure among this state structure and loot border caused stone section deformations along Sistan margins and in its state structures. The top part of Nehbandan has a turn to the North of West that causes a Loot block counter clockwise rotation, so there is a huge deformation in the region accordingly (Tirrul *et el*., 1983).

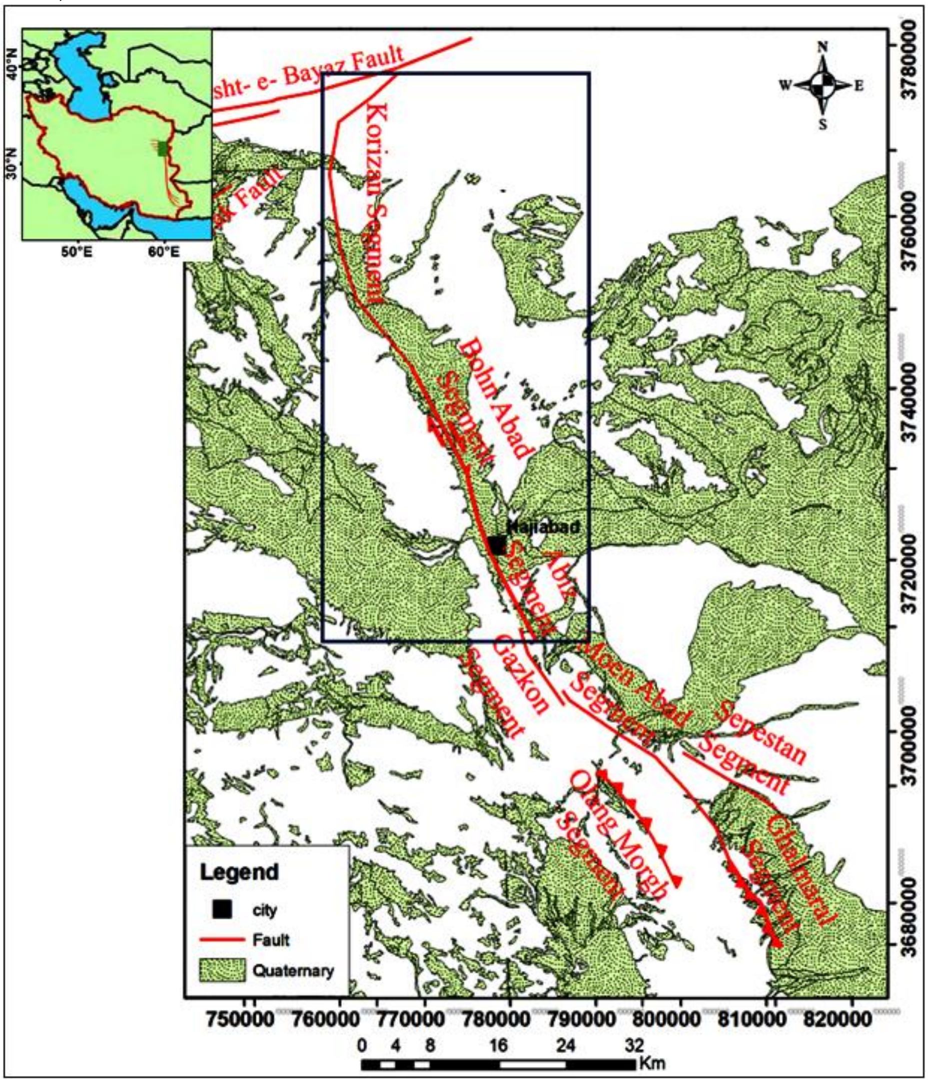


Figure 2) Ardekul fault segments (blue box case study).

Ardekoul fault is placed in the Iran orient and the northern zone part of Sistan. Its geological position is between 59°45' to 60°00' east and 33°30' to 34°00' north Lithology of study area consists of quaternary units (in plains) and limestones of upper Cretaceous and upper Jurassic (the western heights of Ardekoul fault zone). Ardekoul fault based on Nogol Sadat classification (1994) is in the northern part of Sistan crevice and in the northern part of Nehbandan main fault; plus, it has had an important role in making all these deformations so far. All the crucial earthquakes in the past have shown how high this fault activity is (1994 earthquakes which were 7.2 and the ones in 2012 which were 5.2 Richter).we should hereby mention that the fault is made of 6 main sections (Korizan 28, Bohn Abad 88, Abiz 32, Gazkon 20, Moein Abad 30.4, Ghal Maral 12 km) and two subsidiary ones (Oalang Morq 12.8 and Sepestan 9.6) (Fig. 2). General studies carried out on the Ardekoul fault indicate that rate of activity on its segments is changing and rate of activity is increasing from north toward south of area (Khatib *et al*., 1999). Due to action of Ardekoul fault western part of the fault has been rising than the eastern part (Zirkouh mountain) (Khatib *et al*., 1999). In this study, active tectonic of three segments including Korizan and Bohn Abad in the northern part of Ardekoul fault, based on neotectonic and seismic factors.

3- Geomorphic Features

Geomorphic indices record new tectonic activities of area and considered as one of the best tools for study activity rate of dynamic faults and tectonic of the area (Nathan *et al*., 2005). Geomorphic indices are high importance in tectonically studies because they are using for quickly evaluation areas and data gathered from aerial photos and topography maps easily (Hancock, 1994). In order to determine the neotectonic activity of Ardekoul fault in term of activity, geomorphic indices has been calculated including mountain front sinuosity, mountain front faceting (% Facet), V ratio, Vf ratio, river gradient index (SL), sinuosity channel index (S), transvers topography symmetry factor, drainage asymmetry factor, waterways fractal and fracture fractal. Moreover, we have also mentioned the alluvial fans of the region, drainage density maps, fracture and Seismic data density map in this paper. All these indexes are explained in the following part.

3.1- Transverse topographic symmetry index

«T» is a vector with specific orientation that its value changes 0 to 1. Whatever this index approaches to 1, indicates further morphodynamic activity and erosion (Fig. 3).

$$T = Da/Dd \qquad (1)$$

where, T=Transvers topographic symmetry index,

Dd= the midfield area Drainage to direct water line,

Da= the midfield area Drainage to the main river path.

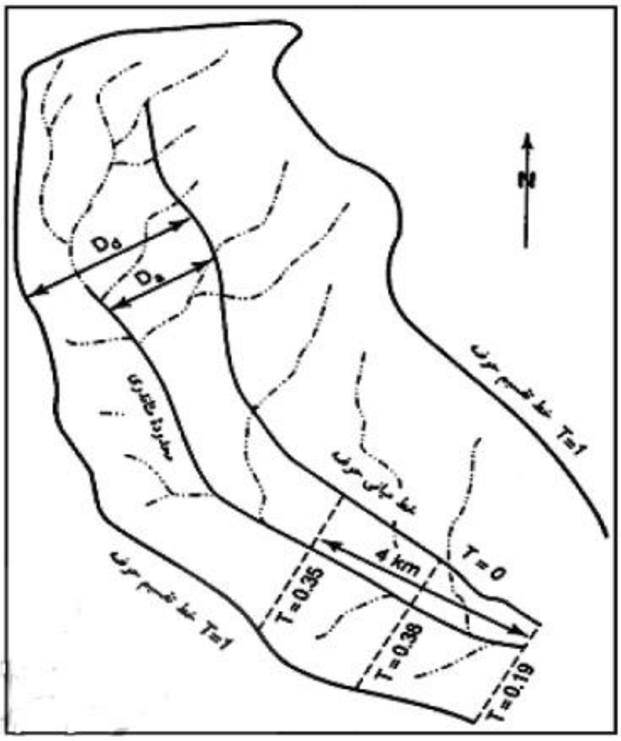


Figure 3) Map basin parameters required for the calculation of T.

The closer to 1 the region is more active tectonically (Keller and Pinter, 1996). The concluded data says that this index arises from the north to the south (Table 1).

3.2- Drainage basin asymmetry index (AF)

Length of the waterway and drainages on both sides of the main channel also can be used for evaluation rate of active uplift. Usually in regions with active uplift, due to topographic demonstration from uplift on one side of the region, consequently appearance subsidence on the other side, length of drainages and as a result area containing these drainages on the raised side will be more than the front side (Table 2).

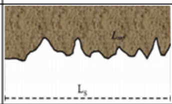
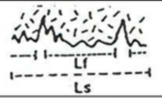
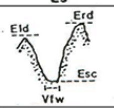
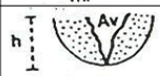
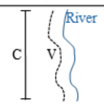
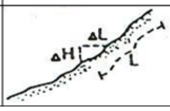
Table 1) The calculated T amounts for the three sections of Korizan, Bohnabad and Abiz fault.

Basin	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	Av
Korizan	52	49.4	74.5	53	77.3	74.3	28.9	39.5	26.5	40.4	50.9	45.1	31.5	-	49.5
Bohn Abad	51.7	52.9	64.1	53.1	36.4	45.2	-	-	-	-	-	-	-	-	50.3
Abiz	42.6	44.7	44.4	63.9	42.6	74.9	37.9	39.7	69.5	53.3	58.5	64.6	24.2	27.6	49.2

Table 2) AF index calculated amounts for the studied region.

Basin	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	Av
Korizan	0.29	0.34	0.8	0.37	0.69	0.41	0.54	0.12	0.54	0.45	0.58	0.51	0.43	-	0.42
Bohn Abad	0.35	0.15	0.22	0.38	0.47	0.37	-	-	-	-	-	-	-	-	0.32
Abiz	0.2	0.21	0.25	0.43	0.3	0.61	0.56	0.38	0.26	0.25	0.34	0.28	0.28	0.73	0.36

Table 3) The used Neo-tectonic indexes.

References	Relationship with tectonic	Method of measurement	Formula	Name	Index
Bull & Mkfadn (1977) Bull (1978)	As this amount is closer to 1 indicates a higher activity of tectonic region		$S_{mf}= (L_{mf}/ L_s)$	Maze Mountain	Smf
Velmz et al. (1988)	High levels of this indicator is activated, Mountain Front		$\%F= L_f/ L_s$	Faceting forehead Mountain	% Facet
Bull & Mkfadn (1977) Bull (1978)	forehead active mountain V-shaped and low values of Vf		$V_f= 2V_{fm}/ [(E_{Id}- E_{sc}) + (E_{Id}- E_{sc})]$	The width of the valley floor to the valley	Vf
Mayer (1986) Burbank (2001)	Low values of V is V-shaped valley, the Active Tectonics		$V= Av/ Ac$	Valley school	V
Adams et al (1999)	High activity of tectonic uplift area caused rivers to be more direct.		$S=C/V$	Maze river channel	S
Hake (1973)	likely to high levels SL of active mountain face		$SL= (\Delta H/ \Delta L) \times L$	River slope index	SL

Regions that are tectonically inactive have rates about of 50, whatever activity's rate of the area has increase, the amount of this factor is moved away from 50 (larger amounts and less than 50, respectively represents tilt on the right side and left side of main channel) that shows basin drainage is tilted (Keller and Pinter, 1996). The resulted data and also the diagrams set, we may conclude that the amount in Abiz region is farther from the mean which is 50, and it shows that indicate activity of this segment is more than Bohn Abad and Korizan segments. In order to understand this index amount easier, the difference of the results which is called the mean (50) is calculated (the more index amount, the more relative activity, Table 1).

The studied parameters and their variation range (Table 3) in order for the Korizan, Bohn Abad and Abiz are: Smf: 1.29, 1.21 and 1.18, %Facet: 0.727, 0.771 and 0.949, Vf: 0.27, 0.132 and 0.121, S: 1.14, 1.13 and 1.06, V: 0.97, 0.83 and 0.63, SL: 191.7, 306.13 and 394.43. Although there is a difference in the amounts counted, but there is still a specific order in the mean of the variation range for all the three regions which generally shows the linear operation difference from the north to the south.

3.3- Alluvial Fan

Alluvial fans are triangle feature that are formed in boundary between mountains and plains (Rachocki, 1981). The fans are considered dynamic features and for this reason, any changes in them indicate these changes are new. Disconnection, displacement and rising of these features which are done by the fault, indicate area tectonically is being active (Amerson *et al*., 2007). Tectonic variables affect their construction and position (Bull, 1977; Harvey, 1987). Alluvials surface tilt is also under the influence of tectonic control. Morphological traits of the alluvial surface may be used as a sign of tectonical activities (Bull, 1972 and 2009,). At first, to study for fans, 20 fans were chosen that located near of the fault zone (Fig. 4). All the quantitative data’s such as the area, tilt, height, oriented cone factor and Longitudinal and transverse profiles were calculated by the software and satellite pictures (Table 5). Pictures highlighted the alluvial right-handed rotation along the Abiz fault. By all these quantitative data we could conclude that the uplifting amount of all these alluvials increase forming of the north to the south, moreover they seem to be more in the middle of each section comparing with the its margin.

Fan comicality index describes the difference between the shape of fans in study area and shape of ideal one (Mokhtari *et al*., 2003). The mentioned ration has been calculated for the Korizan, Bohn Abad and Abiz faults which clearly show that the activity decreases from the middle to the margin of the uplifting area and generally it is increasing from the north to the south (Fig. 5). The mean of rising for three segments Korizan, Bohn Abad and Abiz is respectively 1193, 1205 and 1214 (Table 5).

Table 4) Neo-tectonic indexes calculated in each region.

Index	Abiz	Bohn Abad	Korizan
S_{mf}	1.29	1.21	1.18
%Facet	0.725	0.771	0.9491
V_f	0.27	0.137	0.1219
V	0.63	0.83	0.97
S	1.26	1.13	1.06
Sl	394.43	306.13	191.7

In the tectonically active areas Alluvial fans are also affected and go under the uplifting process accuse to the uplifting’s cause by the tectonical movements. Variation of rising rate in fans can indicate variation of rate of tectonic activity (of the fault) in the area. The histograms of the alluvial fans of the each section clearly show that the uplifting in the middle of each section is much more than its margins. The height mean line in the columns shows that the uplifting amount from the Korizan region (Northern Part) to the Abiz (Southern part) is increasing (Fig. 4).

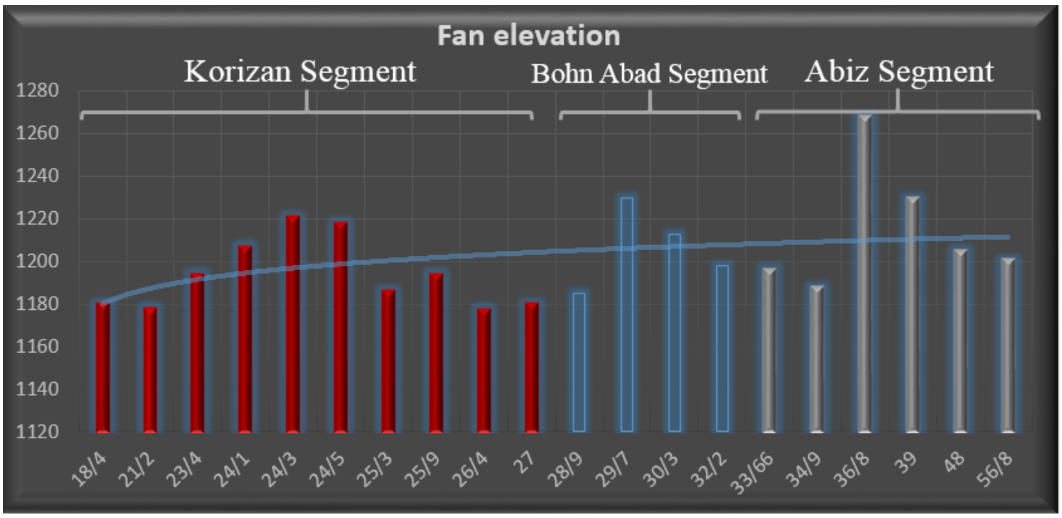


Figure 4) Elevation changes in three Korizan changes (Blue column), Bohn Abad (red column), and Abiz (gray column).

Table 5) the calculated index for the studied Alluvial fans.

Height	Radius (Km)	Cone shrinkage ratio	Average slope	Environment	Area (Km^2)	No	Fault
1180	1.2	%78	%5.55	12.23	8.65	1	Korizan
1178	1.48	%84	%5.85	9.6	5.68	2	
1194	0.24	%81	%6.85	1.42	0.09	3	
1207	0.42	%81	%8.4	2.48	0.24	4	
1221	0.48	%78	%10.8	3.35	0.48	5	
1218	0.66	%83	%5.95	4.48	1.02	6	
1186	0.35	%82	%14.3	2.08	0.15	7	
1194	0.76	%88	%12.3	4.4	0.98	8	
1177	0.54	%92	%13.3	3.1	0.39	9	
1180	0.74	%89	%9.45	3.72	0.75	10	
1185	2.7	%96	%8.4	17.8	20.5	11	Bohn Abad
1227	0.52	%91	%10.7	16.7	18.6	12	
1213	0.82	%83	%12.4	14.3	15.2	13	
1198	1.8	%97	%14.4	15.7	13	14	
1196	1.52	%86	%7	12.6	6.2	15	
1188	1.53	%87	%9.7	12.01	6.9	16	Abiz
1268	1.9	%84	%7.4	1.0.82	6.5	17	
1230	3.4	%82	%7.04	17.1	18.9	18	
1205	1.89	%90	%4.6	11.6	7.9	19	
1201	2.1	%91	%6.4	17.1	19.1	20	

The β and also the Cone oriented index (Fig. 5) diagram shows that the β changes are more from the Korizan to the Abiz part , while the mean line of this index changes shows the decrease from the Korizan to the Abiz region. The Cone oriented index changes diagram indicates less change than the β diagram.

4. Fractal analysis of Ardekoul fault

Based on Euclidean geometry, Geometric elements are point, line, page and volume which are represented by the geometric dimensions (that represent infinite ones) in order 0, 2, 1 and 3, however, all these parameters are definitely finite in the materialist nature. Therefore, the dimensions of Euclidean geometry can well reflect the characteristics of the phenomena and compare them with each other. While the fractal dimension can be decimals, so there would be no limitation on the measuring of any natural phenomena.

General relation of the fractal dimension is:

$$N_n=c/r_n^D \qquad (2)$$

In this formula N_n is the number of known variables for a phenomena, r_n the specific line, C constant and D the fractal. Torket square method (1998) is used as the most efficient method to measure Fractal distribution fault and also the fractal (D). In this method, at first the desired structure for the fractal, like waterway fault, seismic data measured. Then, the studied region is reticulated in the squares with the different scales; after that the squares with any kind of scale (N_s) will be counted and finally set as a table. In order to calculate the fractal, we have to count the (N_s) amount in at least five networks with the different length. Finally, the fractal will be counted by the formula of the Logarithm-Logarithm diagram:

$$\text{Log (Ns) =aldol (I/S)} \qquad (3)$$

that means, D line ration is the fractal (Mandelbort, 1983).

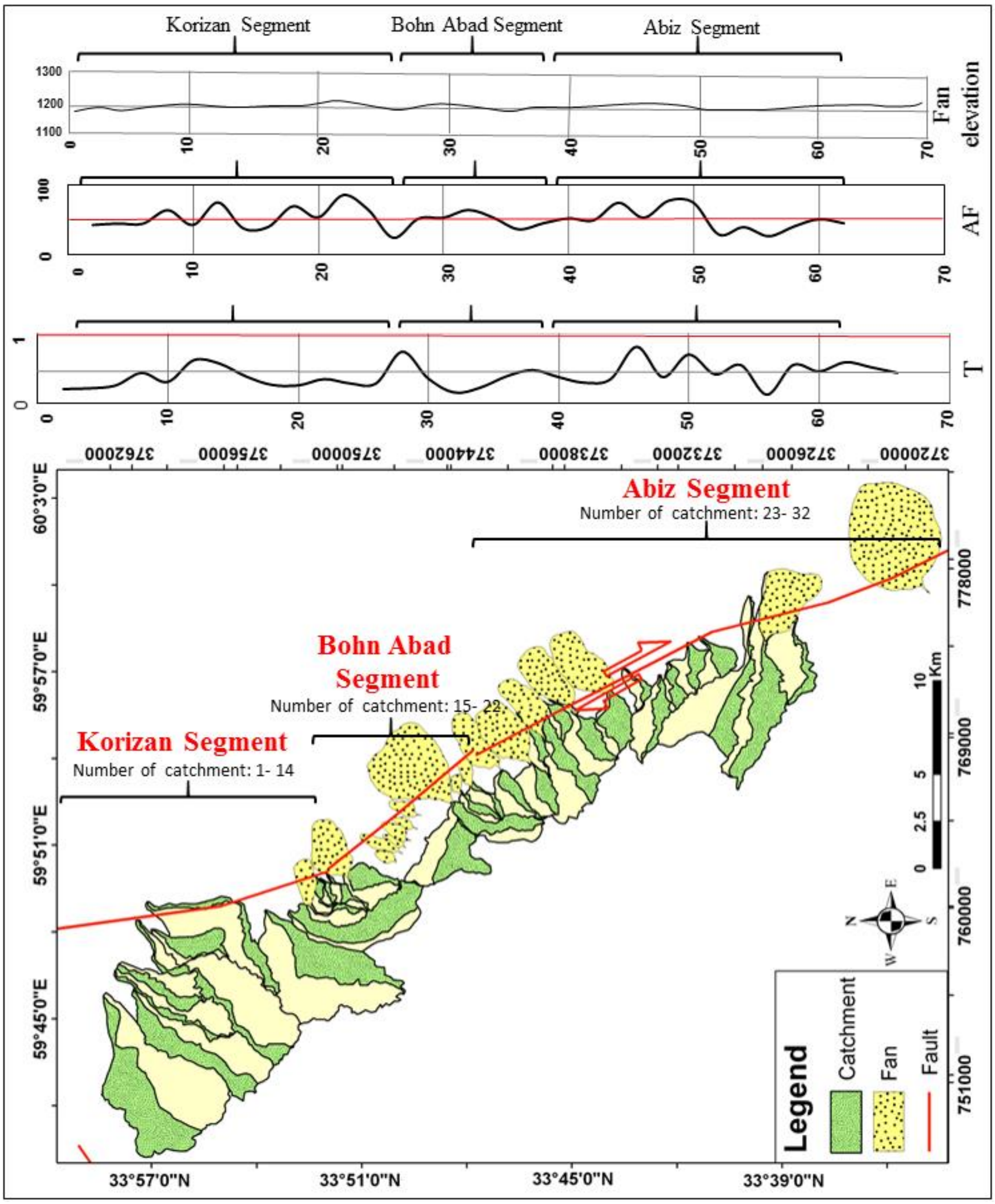


Figure 5) activity rate changes based on T, AF and the cone oriented indices.

Therefore, the geology and Ardekoul waterway fault plans in the scale of 15000 were provided and the fractal analysis was done in a square manner. The fractal analysis for the Korizan, Bohn Abad and Abiz faults were in order 1.482, 1.362 and 1.221. One of the reasons for the fractal dimension decrease from the North to the South may be the earthquake ruptured compliance in1997 which was 7.2 Richter on the earthquake fault is Ardekul 1980. Here less energy and crusted formation due to a lack of perennial surface energy of motion and displacement caused by fault on its walls. Korizan segment fractal dimension of the piece reaches its maximum value, which reflects the reduction in the stress field (Khatib *et al*., 2006). Korizan segment to its terminus at Dasht- e-bayaz fault in this area is the increase model for how to end strike-slip faults in the area. Rate of change of fractal dimension to the fault terminals changes the geometry of fault elements such as direction, slope, aspect, direction of movement, as hear zone and the amount of displacement. However, the overall scale of the north to the south will rise, which represents an ideal environment for accumulation of energy (Fig. 6).

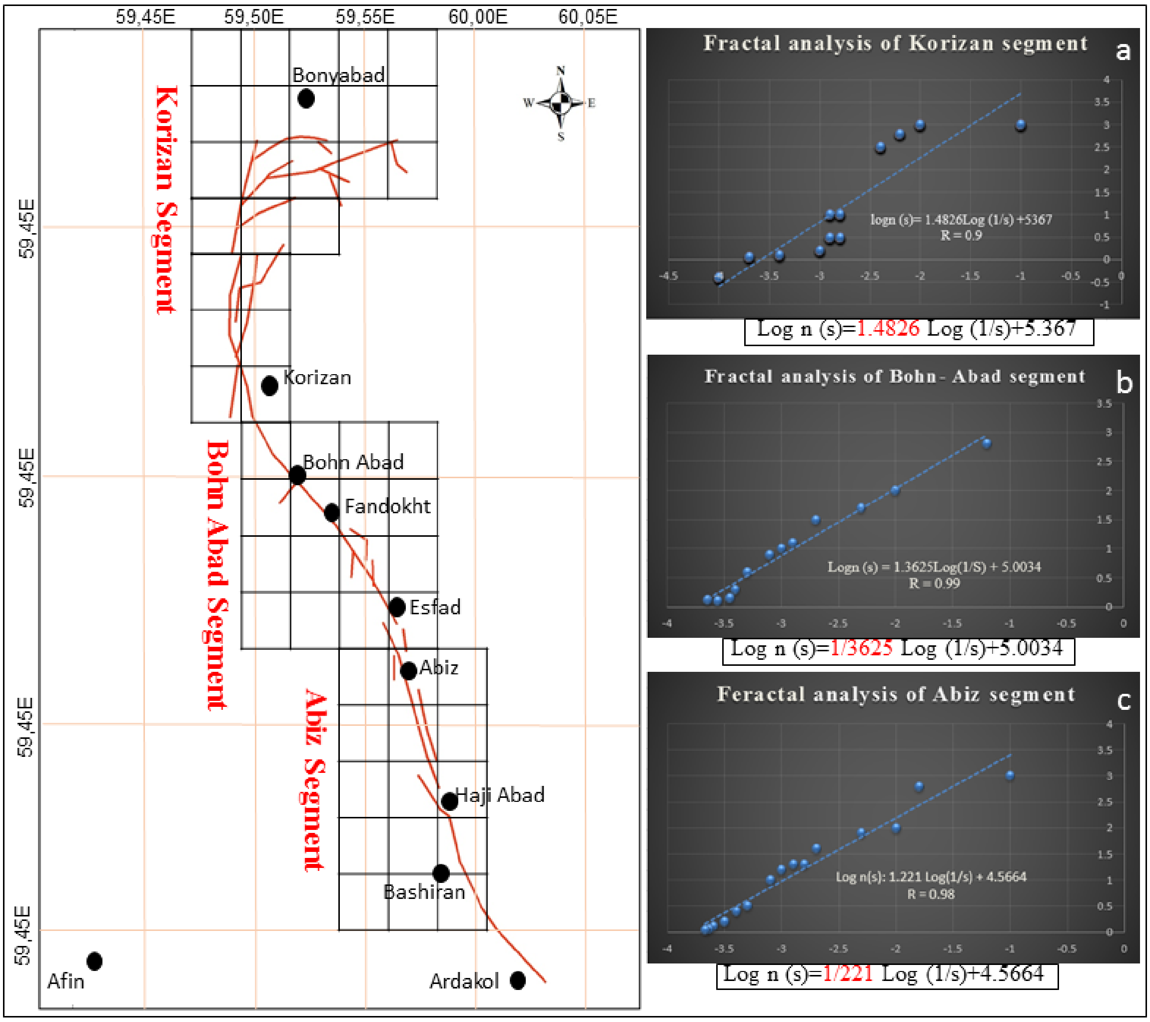


Figure 6a) Abiz fault fractal plan with the specific sections. (b) Korizan fault fractal diagram. (c) Bohn Abad fault fractal diagram. (d) Abiz fault fractal diagram.

In order to get the fractal changes better, its amounts were calculated on the region waterways by the waterways plans in a 150000 scale in a square manner. The results for the Korizan, Bohn Abad and Abiz fault in order are 1.982, 1.946 and 1.9021 that show the operation increases from the north to the south (Fig. 7).

To get the operation rate of the changes, waterway aggregation plans were taken (Fig. 8) in order to get into these plans, the data's were analyzed by the GIS 9.3 software after preparing the region's waterway plans; finally the aggregation plan was mapped by the Toolbox kernel (Jamshidi,1384). Analysis of these plans indicates that the waterway aggregations decrease from the north to the south. Aggregation decrease shows the growth of the uplifting accused by the tectonically operations while its decrease shows the tectonical peace in the region (Shahriari and Khatib, 1997). By the analysis of these plans we conclude that the uplifting rate is increasing to the southern part.

To map the seismic aggregation data plan, we were supposed to collect such data's from 1900 to 2015 from the earthquake data bank for each section. Afterwards, the synchronization process passed them to the ARCGIS 9.3 software. Finally, the earthquake aggregation data map for each section of the fault was initialized.

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These maps indicate that the seismic operations increase from the north to the south (Fig 9). Increasing the density of the seismic centers in the Korizan fault section is because of that the ending part of the northern eastern-southern western Korizan by the right turn movement meets the eastern-western Dasht- e- Bayaz flat fault with the left turn movement which are all ended into the region like this (Khatib, 1998) (Fig. 9, Blue border). Since these two faults having the very same characteristics causing the increase in releasing the energy so there would be many earthquakes in this region. However, generally seismic aggregation data increases from the north to the south which surely is a good reason to indicate this operation rate changes.

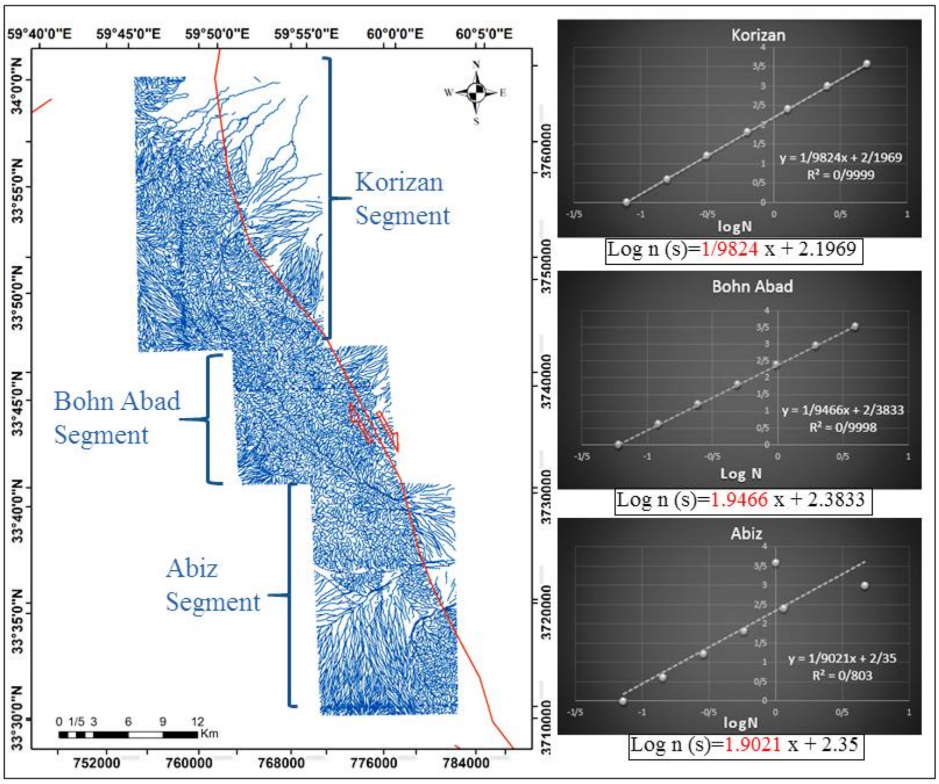

Figure 7) Fractal plans for the waterways within the Abiz fault area.

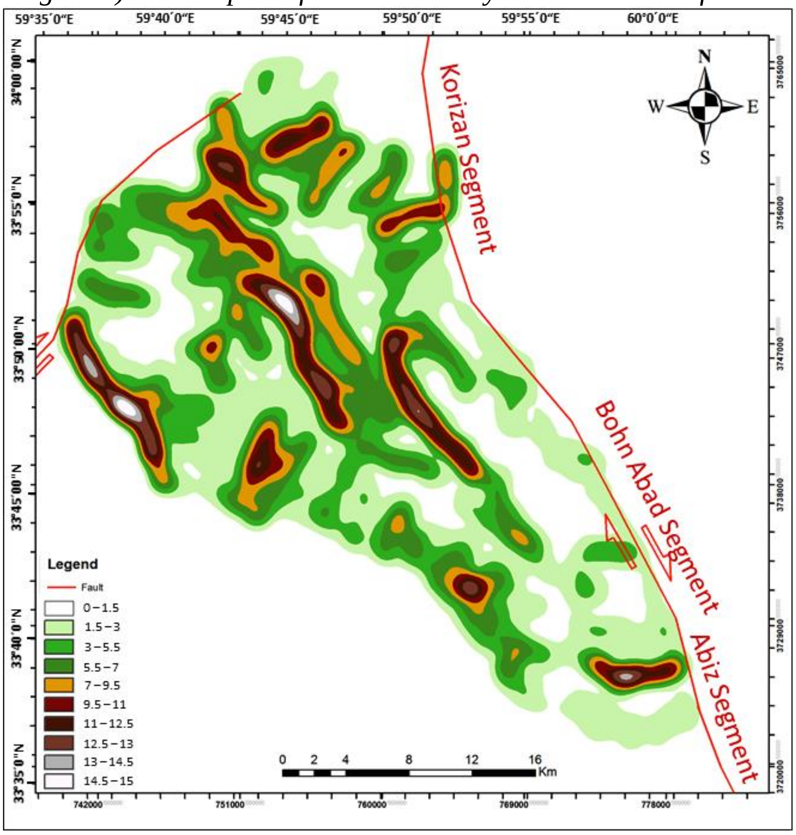

Figure 8) waterway aggregation plan within the Ardekul fault region.

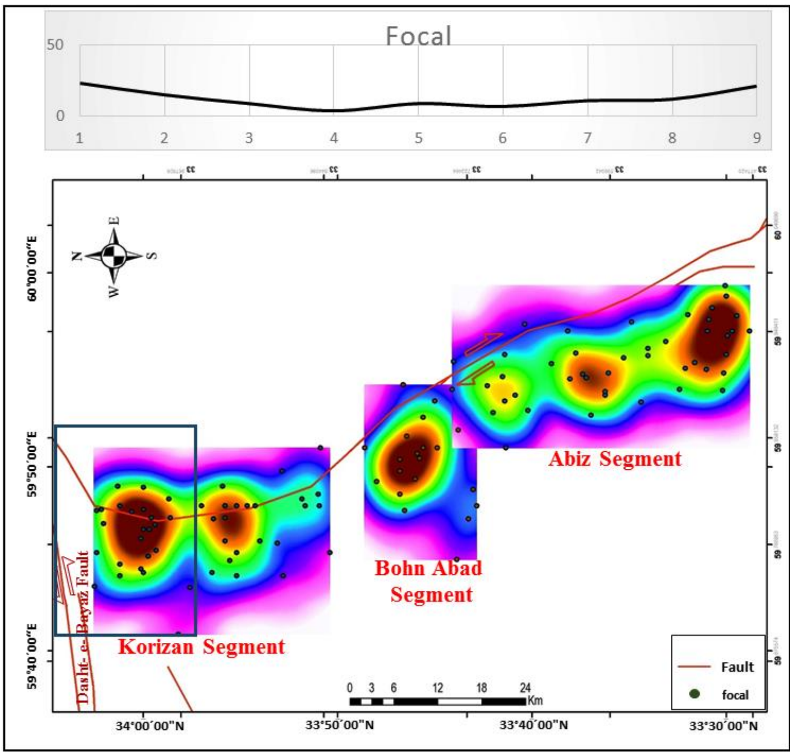

Figure 9) Breakdown of seismic data density map for fault segments Ardekul.

5. Field Evidence

5.1- Waterway dislocations

Ardekoul fault right turn operation caused that Aqueducts (21.5 meter), waterways (Fig d.10, 1.8 meter) and the rivers (Figs 9a and b in order 241 and 361 meter) that move across this fault go under the very same deviation by the fault movements (Fig. 11) this deviation in a long time may even cause the river to deviate from its main root and flow into a new way. This displacement that is parallel to direction of movement of the fault, its value is as much as 318 meter.

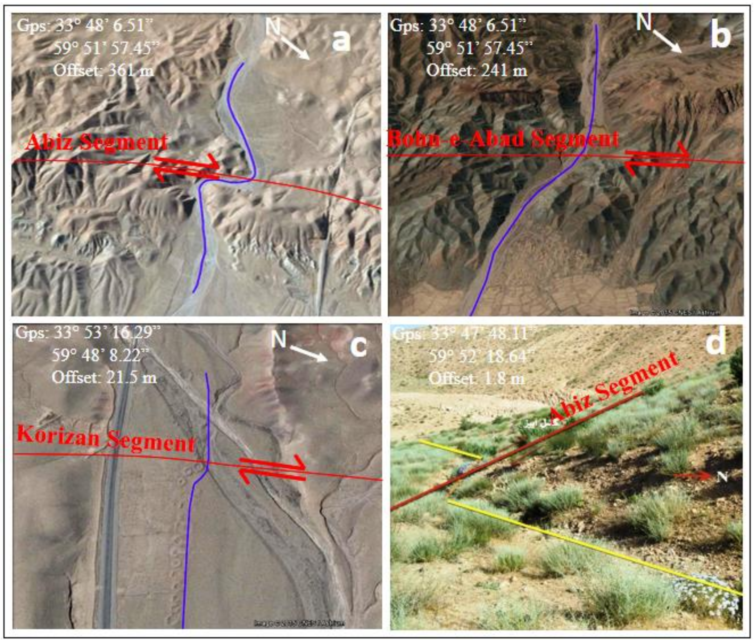

Figure 10) The waterway tilting in the satellite pictures,(a) river right turn movement in Abiz section,(b) river right turn movement in Bohn Abad section, (c) Aqueduct right turn deviation in the Korizan section moving region,(d)waterway right turn incision on the Bohn Abad section.

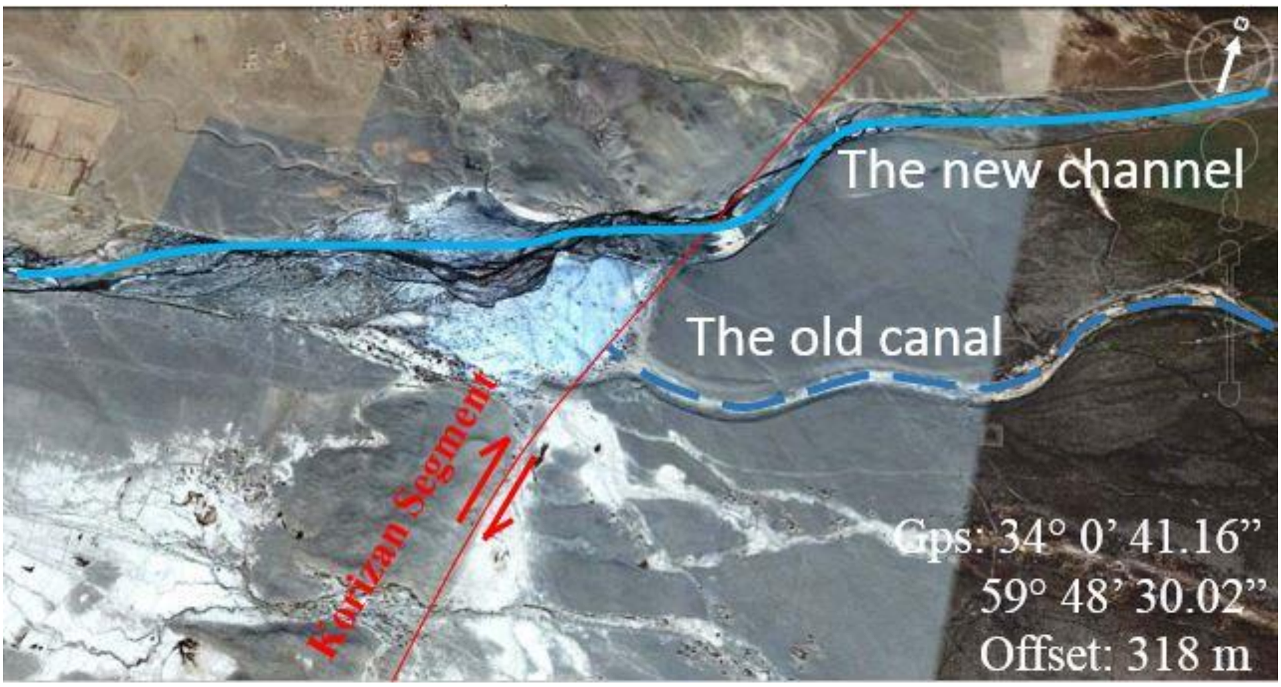

Figure 11) river redirection from the old root to the new one accuse to the Korizan fault right turn operation.

5.2- River Terrace

In tectonically active regions tectonically, due to rate of uplifting is much more than erosion and rising of mountain, waterways are eroding their riverbeds and make high terraces. Whatever the rate of tectonic activity has been more; these terraces are higher (Volms *et al*., 1989). The terrace measured in this area was 2-4 meter high (Fig. 12).

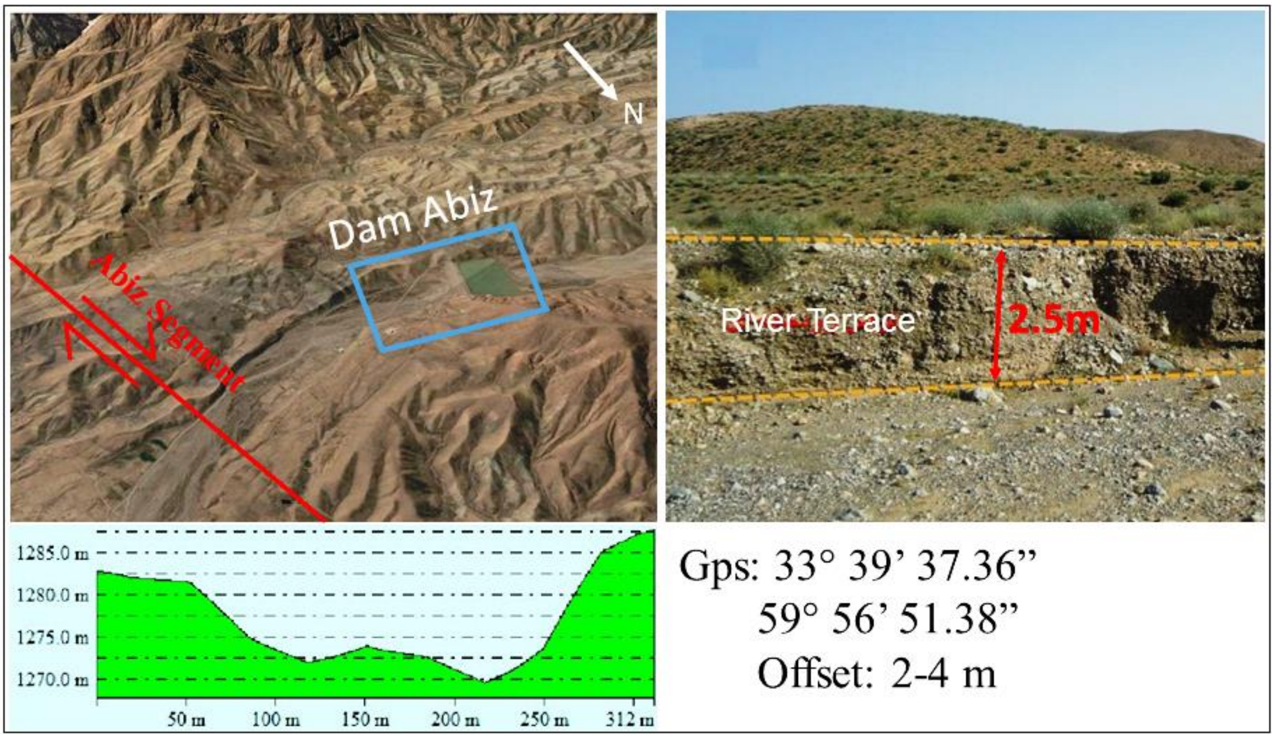

Figure 12) River terraces, on the Abiz River in the Abiz village dam.

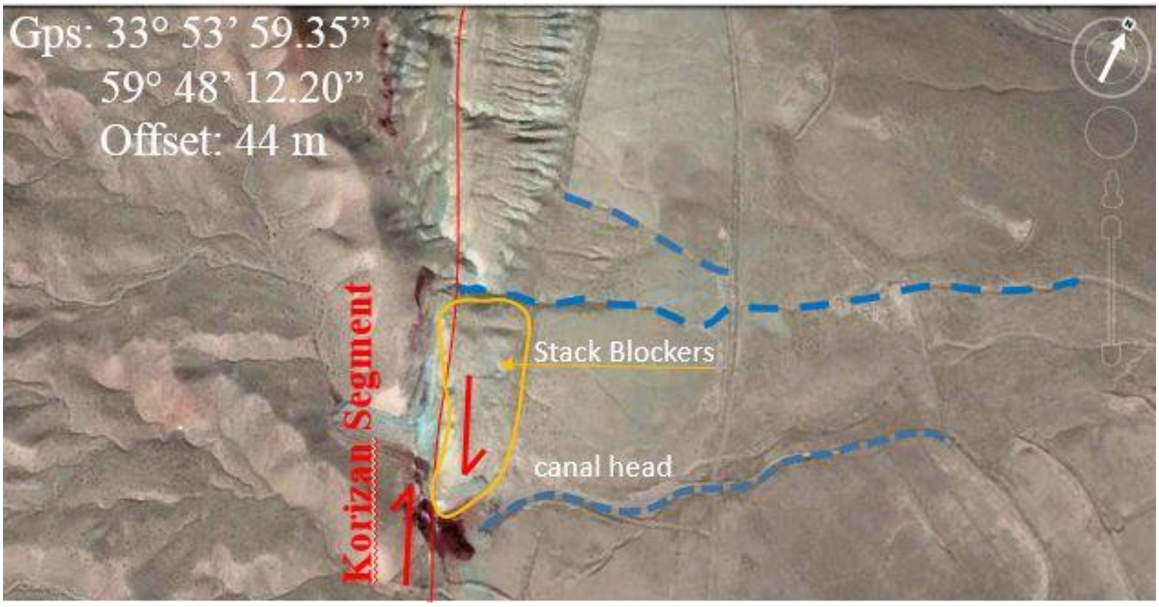

Figure 13) Move the stack to the south and block the path waterway

5.3- Stack Blockers

The horizontal movement of the fault causes the movement of the phenomenons of the fault itself. Sometimes these movements lead to a feature due to his Motion, dam path of a waterway. This phenomenon is called Stack Blockers in geology and the waterway which is blocked is called the beheaded waterway (Keller, 1996) (Fig. 13).

6- Conclusions

According to the information obtained from neo-tectonic indicators, quantitative studies related to alluvial fans, fractal fracture, waterways, drainage density maps and seismic data we can conclude that energy dissipation on the Abiz fault in performing in a linear way, although the depreciation has different values, it generally has a linear distribution from the south to the north. Seismic exploration carried out shows that most release energy focuses on segments of the fault are located in middle part of them. This study specifies that each piece operates separately, although in the terminal connection part of the Korizan fault to Dasht- e-Bayaz fault the seismic data accuse to the very same operation of the two faults increases. But in general, the density scales of the centers from the north to the south increases which accordingly increase the activity rate from the north to the south.

References:

Adams, K. D., Wesnousky, S. G., Bills, B. G. 1999. Isotactic rebound, active faulting, and potential geomorphic effects in the Lake Lahontan basin, Nevada and California.

Amerson, B. E., Montgomery, D. R., Meyer, G. 2007. Relative size of Fluvial and Glaciated Valleys in Central Idaho. Geomorphology: 50, 20–32.

Arab khazayi, M., 2011, Analysis of seismic tectonic fault south of Birjand to assistance geomorphic evidence, tectonic. MSc thesis, University of Birjand, p. 180.

Burbank, W. D., Anderson. R. S. 2001. Tectonic Geomorphology. Progress in Physical Geography: 1, 205–506.

Berberian, M., Jackson, J. A., Qorashi, M., Khatib, M. M., Priestley, K., Talebian, M., Ghafuri-Ashtiani, M. 1999. The 1997 May 10 Zirkuh (Qaenat) earthquake (Mw 7.2):

faulting along the Sistan suture zone of eastern Iran. Geophysical Journal International: 136, 671–694.

Bull, W. B., Fadden, L. D. 1997. Character, Genesis and Tectonic Sitting of Igneous Rocks in the Sistan suture zone, Eastern Iran, lithos: 3, 221–329 .

Bull, W. B. 1977. The Alluvial Fan Environment. Progress in Physical Geography: 1, 222–270.

Bull, W. B. 2009. Tectonically Active Landscape, John Wiley and Sons Publication, New York.

Bull, W. B. 1972. Recognition of Alluvial Fan Environment, Progress in Physical Geography, Vol. 1, pp. 222–270.

Chaychi, Z. 2006. 1:100000 geological map of Abiz. Geological Survey of Iran (GSI).

Hack, T., 1973. Stream profile analysis and stream gradient index, U. S. Geol. Surv. J. Res. 1, 421-429.

Hancock, D. L. 1994. The Bactrocera dorsalis complex of fruit flies in Asia. Bulletin of Entomological Research: Supplement Series. Supplement No. 2. CAB International, Wallingford, UK.

Harvey, A. M. 1987. Alluvial Fan Dissection: Relationship between Morphology and Sedimentation, In: Frostik, L., Reid, I. (Eds.), Desert Sediments: Ancient and Modern. Geological Society of London Special Publication: 35, 87–103.

Jamshidi, F., Falah Khani, Z., Keshavarz, M. 2006. Estimation Density and Statistics, Institute of Statistics, Statistical Center of Iran.

Keller, E. A., Pinter, N. 1996. Active tectonic (Earthquake, Uplift and landscape). Prentice-Hall, Upper Saddle River, NJ, pp. 338.

Khabazi, M. 2015. Fans quantitative relationships between volume and its relation to active tectonics. Quantitative Geomorphological Researches: 2, 103–126 (In Farsi).

Khatib, M. M. 1999. Terminal geometry Strick-slip faults, PhD thesis, Shahid Beheshti University, Tehran, Iran.

Khatib, M. M., Golami, A. 2000. Geometric analysis of seismic fault sin the earthquake 20.02.76 Qaen- Birjand, Research Project, Birjand of University, Vol 1, pp 76–77.

Khatib, M. M., Golami, A. 2007. Segmentation fault Ardekul, Research Project, Birjand of University, Vol 1, pp 19–26.

Khatib, M. M. 2012. Theory of oceanic basin East Iran. The first Conference of Tectonic of Iran, Geological Survey of Iran (GSI), Tehran, Iran.

Mokhtari Kashki, D., Khayam, M. 2004. Performance Evaluation of tectonic activity on the basis of the morphology of alluvial fans (e.g. the northern slopes of alluvial fans hot walk). Geographic Research: 35, 1–10.

Harkins, N. H., David, J., Anastasia, J. Frank., Pazzaglia. 2005. Tectonic geomorphology of the Red Rock fault, insights into segmentation and landscape evolution of a developing range front normal fault. Journal of Structural Geology: 27, 1925–1939.

Nogol Sadat, M. A. A. 1985. Les zones de croc Hemant et les variations of Iran. Report No. 55.

Mandelbort, B.B., 1983. The Fractal Geometry of Nature, W.H. Freeman New York.

Rachocki, A. 1981, Alluvial Fans, an Attempt at an Empirical Approach. John Wiley Publications, New York.

Radfar, Sh., Porkermani, M. 2006, Morphotectonic of Kuhbanan fault. Geosciences (GSI), 58: 166–183.

Shahriyari, S., Khatib, M. M. 1998. Nehbandan fault system fractal analysis. Geosciences (GSI): 23–24, 32–34.

Tirrule, R., Bell, L. R., Griffins, R. J., Camp, V. E. 1983. The Sistan Suture zone of eastern Iran. Geological Society of America Bulletin: 94, 134–150.

Walker, R. T., Jackson, J. 2004. Active tectonic and late Cenozoic strain distribution in central and eastern Iran. Tectonics: 23. DOI: 10.1029/2003TC001529

Walker, R. T., Khatib, M. M. 2006. Active faulting in the Birjand region of in eastern Iran. Tectonics: 25, 1–17.

Welles S. G., Bullard, T. F. 1988, Regional Variation in tectonic geomorphology along a segmented convergent. Plate boundary Pacific coast of crista Rica. Geomorphology: 1, 239–265.