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Study of Guyum Fault Zone in Geodetic Approach, Zagros Mountains

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Abstract — Tectonics activities play an invaluable role in anticipating earthquakes in seismic zones including Iran. Using microgeodetical methods in extension of determining slip rate and its displacement, could lead to discover the rate of tectonic activity of the region. The aim of the present research is studying the behaviors and activities of Guyum fault zone in order to comprehend the locking points of this zone. Moreover, geological and microgeodetical studies have been done on this fault zone, proper places for creating network and station were chosen, and terrestrial and geodetic survey in the 9 month period was done. Result of this study shows that partial movement velocity of this fault decreases from NW to SE.

Keyword — Deformation, Earthquake, Guyum fault zone, Iran, Microgeodesy, Tectonics.

1. Introduction

Earth science, like other sciences is ascending and its progress needs other sciences' accompaniment. So, Microgeodesy is a science interpolated to earth science and has special usage in geophysics or allegedly tectonics. Use of terrestrial and satellite geodetic approaches is the most common way to register the continuous movements in local and global scale. Due to its acute velocity, it has lots of capabilities. Our country, Iran, considering geodynamic changes, is located in the Alpine-Himalayan seismic region with the frequent movement of earth's crust, and this attracts most of the earth science researchers towards study and research on the seismic studies. Some studies that could help researchers are as follows:

-Study of the structure of the earth's crust
- Modeling and monitoring of deformation and plate movements
- Determining the parameters of the earthquake center
- Study of historical-geological and deep distribution earthquakes
- Earthquake prediction

Although these studies succor the researchers in the future to gain the understanding of earthquakes' mechanism , the spatial prediction of earthquakes and their magnitude, but fail to distinguish the time of their happenings. Therefore, achieving more information in long time-scale with the help of different methods such as microgeodetical networks could be a great help to dissolve the problem. In general, geodetic and microgeodetic studies, alongside the geological, seismological and geophysical study, are capable of opening new horizon in determining the activities of active faults before the researchers.

In this study, with the help of optimized network design which go hand in hand with the appropriate sensitivity on some fault branches of Guyum fault zone in Fars province, NW of Shiraz in city threshold from Yasouj (the Shiraz-Sepidan route) (Fig. 1), the behavior of this fault zone has gone under study and the rate of its branch movements is determined.

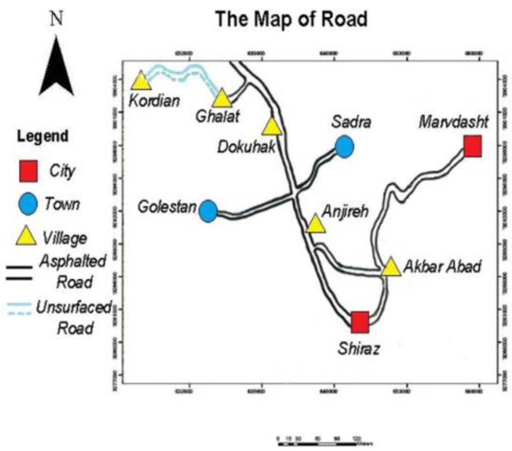

Fig.1. the available roads to Anjireh, Dokuhak and Ghalat

2. Geology and Structural Geology Studies

Iran is located in Alpine-Himalayan seismic belt where has been shaken by largely destroying historical and instrumental earthquakes (Engdahl et al., 1998; Ambraseys and Melville, 1982).Zagros is one of the most active seismotectonics provinces in Iran that has the most assembly of earthquakes focal in this state, (Fig.2).Fars province due to its locality in this state is of tectonically active spots. Fault zones like Sarvestan, Kareh-Bas, Sabz-Pushan and Guyum fault zones are of this area's strike-slip active faults, (Fig.3).

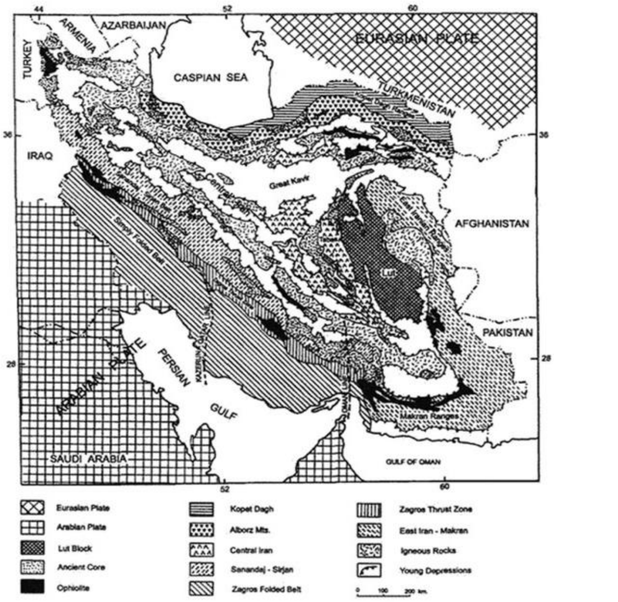

Fig.2. Iran general tectonics map (Stöcklin, 1968; Stöcklin and Nabavi, 1973)

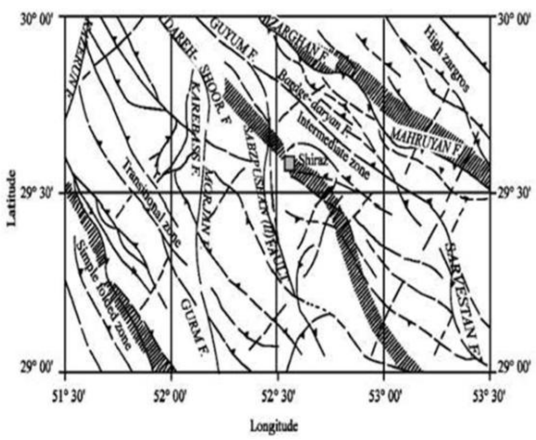

Fig.3. Shiraz active faults based on the Geological map 1:100,000 series 6549

Shiraz is located in folded Zagros tectonically (Berberian, 1995) and is surrounded by lots of faults which put this city in the peril zone in the view of seismic hazard zonation, (Azadmanesh, 2007).

The area under study is located in the Kelestan map with 1:100,000 scale that on the structural and sedimentary features, this extension is put in the range of tow transitional and intermediate zones, (Andalibi *et al.*, 1998).Happening of some historical earthquakes in NW of Shiraz are believed to have connection with Guyum fault zone, (Ambraseys and Melville, 1982).

Guyum deformed transcurrent zone with the NW-SE trend which has dextral strike-slip mechanism is located in the NW of Shiraz. This fault zone is surrounded from south by Sabz-Pushan fault zone and north, *Mahrouyan* fault zone.

The impact of this zones leads to certain of Guyum's deep. Rapture surface of this fault zone in relation to other surrounded structures is in the shape of lengthy fault zone, (Andalibi *et al.*, 1998).In this region, Eocene Jahrom formation, Oligocene-Miocene Asmari and finally low Miocene Razak could be seen. In Ghalat also Fars group formations are on the display including: Gachsaran, Aghajari, Bakhtiari formations. The prominent lithologies of these regions' formations are limestone and marn, (Fig.4).

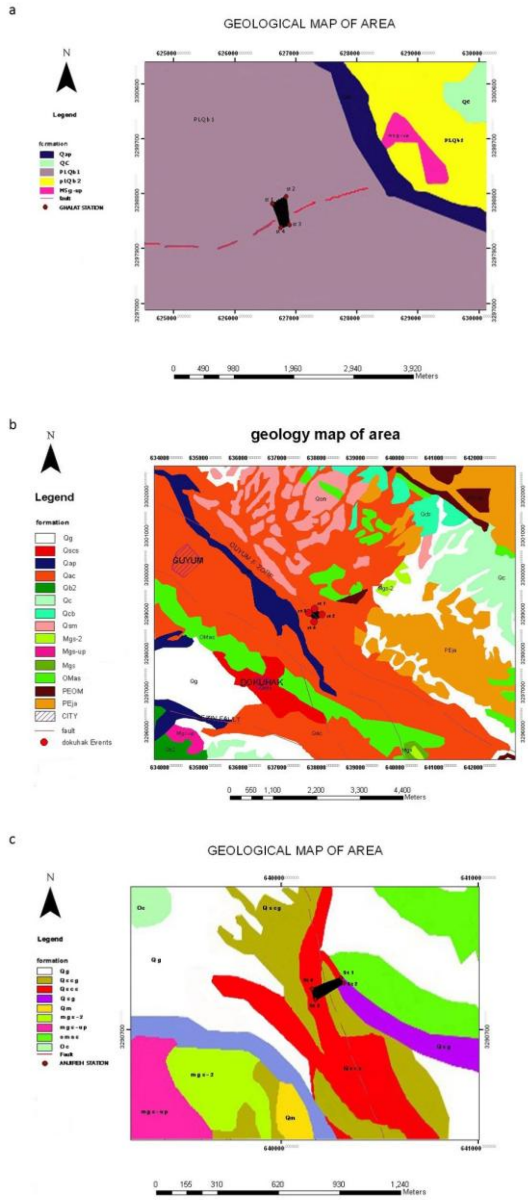

Fig.4. Geological map of the region under study, a. Ghalat (Zareiefard Jahromi, 2010) b. Dokuhak (Nikoonejad, 2010) and c. Anjireh (Khashayar, 2010)

Three branches of Ghalat, Dokuhak and Anjireh of this fault zone with the information in table-1 are division for establishing geodetic observation network which has been distinguished according to geological, microgeodetic properties (Quanbari *et al.*,2010) and geophysics (Asadi *et al.*,2010b) investigations for the sake of clarification of local crust movements.

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Table (1) attribute of the studied branches of fault zone

coordinate	fault zone	branch fault
52°18'2"E 29°49'3"N	The north of fault zone	Ghalat
52°7'-52°30'E 29°47'-29°52'N	The center of fault zone	Dokuhak
52°26'40"-52°30'E 29°44'-29°52'N	The south of fault zone	Anjireh

3. MICROGEODETICAL STUDIES

The usage of microgeodetical network in determining displacement and deformation the natural phenomenon of the earth's crust in regions which are active geodynamically have a lot of functionalities, and can be of use in clarification of the fault movement, (Asadi et al., 2010a; Asadi et al.,2013). Microgeodetical research of Guyum fault zone for the all three branches in 3 stages: network design, execution and calculations were done.

3.1. Network design stage

In this stage, the zero design for determining the coordinate system ,the first design order for detecting network shape ,the second design order for detecting the weight and precision of observations and third design order for Optimizing the networks (Kuang,1996),were executed. Finally, three networks with four points composed of four triangles in Ghalat, Dokuhak and Anjireh for clarification of movement considering microgeodetical network design basis (Quanbari, 2010) and the geology of area positioned on this fault zone, (Fig. 5).

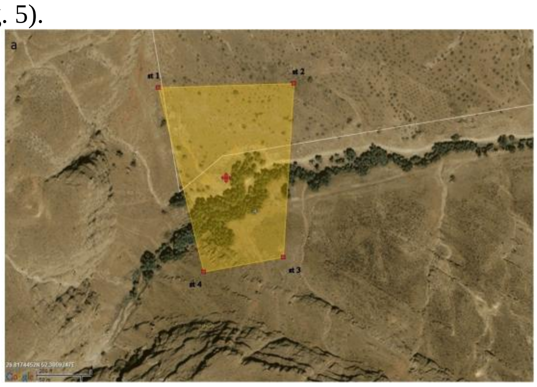


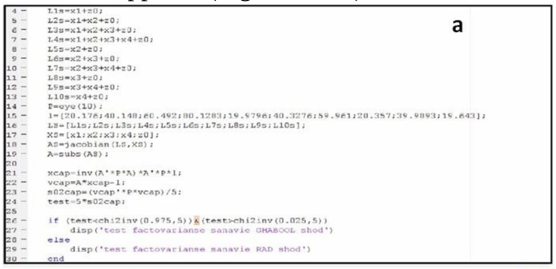
Fig.5. Situation and the shape of the networks under study in Guyum fault zone a. Ghalat. Dokuhak and c. Anjireh

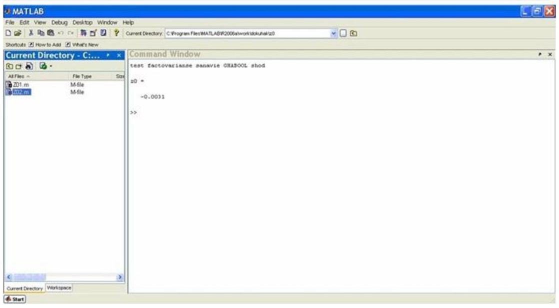
3.2. Execution

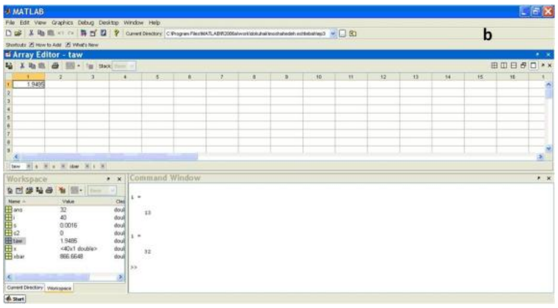
After the design stage and the positioning the stations, data survey with the help of terrestrial Geodetic approaches and on the basis of group sampling has begun since September 2009 and was done in 9 month period in 3 month intervals with the use of laser sets and reiteration approach.

3.3. Calculations

In this stage ,related data according to statistical inference approaches went through trial and after processing , pre adjustment analyze ,systematic error test, numerical machine precision test, to be random or normal observation test and wrong observation test, due to corrections for observation transfer to mathematical space have been applied, (Figs. 6 and 7).







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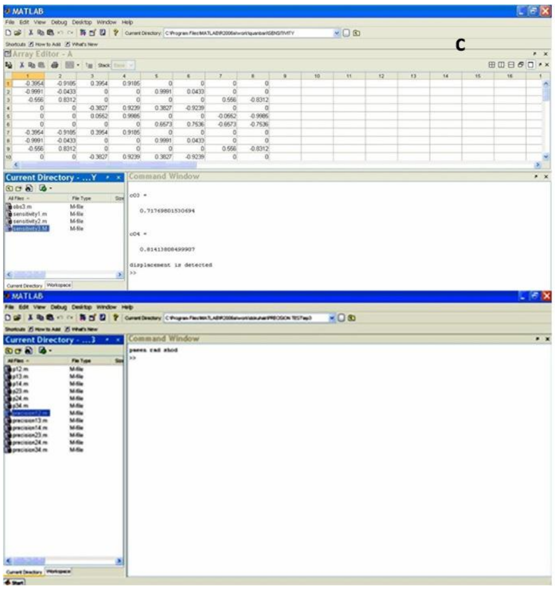

Fig.6. Pre adjustment analyzes a. Z0 Error Program and its output, b. Wrong Observation Test, c. Sensitivity Network and the Numerical machine Precision Test

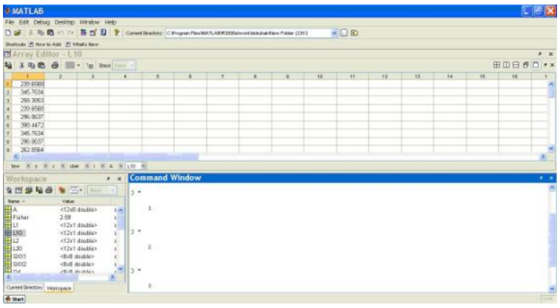

Fig.7. the output of adjustment network

At last, surveyed data has been adjusted by the least square method, (Farzaneh and Nesari, 2009).

$$\hat{X} = (A^T PA)^{-1} A^T PL$$
$$\|V\|^2 = V^T V \rightarrow Min \qquad \text{(Eq.1)}$$

L = observation space
A= efficient matrix
P = weight matrix
X = unknowns
V = residual
If
$u < r < n$

$$F_{r1}(\hat{x}_{u1}, Ln1) = 0 \Rightarrow A_{ru}\hat{\delta}X + B_{rn}\hat{V}_{n1} + W_{r1} = 0 \qquad \text{(Eq.2)}$$

Therefore, generally, inner -constraint for one two dimensional network is as follows, (Farzaneh and Nesari, 2009).

(Eq.3)

$$\begin{cases} \sum_{i=1}^{P} \delta x_i = 0 \\ \sum_{i=1}^{P} \delta y_i = 0 \\ \sum_{i=1}^{P} y_{0i}\delta x_i - x_{0i}\delta y_i = 0 \\ \sum_{i=1}^{P} x_{0i}\delta x_i + y_{0i}\delta y_i = 0 \end{cases} \qquad E\delta x = 0 \qquad \delta x = \begin{bmatrix} \delta x_1 \\ \delta y_1 \\ \delta x_2 \\ \delta y_2 \\ \vdots \\ \delta x_p \\ \delta y_p \end{bmatrix}$$

$$E = \begin{bmatrix} 1 & 0 & 1 & 0 & \cdots & 1 & 0 \\ 0 & 1 & 0 & 1 & \cdots & 0 & 1 \\ y_{01} & -x_{01} & y_{02} & -x_{02} & \cdots & y_{0P} & -x_{0P} \\ x_{01} & y_{01} & x_{02} & y_{02} & \cdots & x_{0P} & y_{0P} \end{bmatrix}$$

(Matrix Inner Constraint)

So the problem has been improved with reiteration approach and norm δX used for ending the work, (table2).

$$\|\delta x_2\| \longrightarrow \min \qquad \text{یا} \qquad \|\delta x_2\|_2^2 = \delta x^T \delta x \longrightarrow \min \qquad \text{(Eq.4)}$$

In the last stage, the rate of the displacement model (Quanbari ET AL., 2010) IS CALCULATED IN MATLAB software.

Table (2) Adjustment results a. Ghalat network (Zareiefard Jahromi, 2010), b. Dokuhak network (Nikoonejad, 2010), c. Anjireh network (Khashayar, 2010)

The number of table: 2a				
Length				
n.	EPOCH1	EPOCH2	EPOCH3	EPOCH4
L1-2	239.65677	239.65677	239.65677	239.65677
L1-3	345.76343	345.76296	345.76249	345.76249
L1-4	258.38528	258.38537	258.38545	258.38545
L2-3	296.06370	296.06371	296.06372	296.06372
L2-4	398.44719	398.44766	398.44813	398.44813
L3-4	262.05635	262.05635	262.05635	262.05635
Angels				
n.	EPOCH1	EPOCH2	EPOCH3	EPOCH4
213	66.39523	66.39609	66.39695	66.39781
314	24.40892	24.40917	24.40942	24.40967
214	90.80416	90.80526	90.80637	90.80748
324	23.92601	23.92574	23.92547	23.92520
421	67.41691	67.41605	67.41519	67.41433
321	91.34293	91.34180	91.34066	91.33953
431	69.01684	69.01770	69.01856	69.01942
231	42.26184	42.26211	42.26238	42.26265
234	111.27870	111.27980	111.28090	111.28210

142	41.77893	41.77868	41.77843	41.77819
243	64.79531	64.79445	64.79358	64.79272
143	106.57420	106.57310	106.57202	106.57090

The number of table: 2b				
Length				
N.	EPOCH1	EPOCH2	EPOCH3	EPOCH4
L1-2	239.65677	239.65677	239.65677	239.65677
L1-3	345.76343	345.76296	345.76249	345.76249
L1-4	258.38528	258.38537	258.38545	258.38545
L2-3	296.06370	296.06371	296.06372	296.06372
L2-4	398.44719	398.44766	398.44813	398.44813
L3-4	262.05635	262.05635	262.05635	262.05635
Angels				
N.	EPOCH1	EPOCH2	EPOCH3	EPOCH4
213	63.75771	63.75781	63.75790	63.75800
314	54.24736	54.24744	54.24751	54.24759
214	118.00507	118.00524	118.00541	118.00559
324	45.68677	45.68671	45.68664	45.68657
421	42.79428	42.79419	42.79411	42.79403
321	88.48105	88.48090	88.48075	88.48060
431	53.23695	53.23705	53.23715	53.23724
231	47.76124	47.76130	47.76135	47.76141
234	100.99820	100.99835	100.99850	100.99865
142	39.20065	39.20056	39.20048	39.20039
243	53.31503	53.31495	53.31487	53.31478
143	92.51568	92.51551	92.51534	92.51517

The number of table: 2c				
Length				
N.	EPOCH1	EPOCH2	EPOCH3	EPOCH4
L1-2	43.26970	43.26970	43.26970	43.26970
L1-3	341.28452	341.28385	341.28318	341.28251
L1-4	305.61229	305.61241	305.61254	305.61267
L2-3	332.34239	332.34203	332.34167	332.34131
L2-4	310.78558	310.78605	310.78652	310.78699
L3-4	109.04473	109.04473	109.04473	109.04473
Angels				
N.	EPOCH1	EPOCH2	EPOCH3	EPOCH4
213	82.76757	82.77693	82.77737	82.77782
314	20.39912	20.38824	20.38831	20.38838
214	103.16569	103.16516	103.16568	103.16620
324	21.27229	21.26533	21.26536	21.26538
421	87.95670	87.96313	87.96263	87.96213
321	109.22899	109.22846	109.22799	109.22751
431	68.86778	68.85826	68.85871	68.85916
231	8.00444	8.01569	8.01571	8.01574
234	76.87223	76.87395	76.87442	76.87490
142	8.87761	8.88391	8.88390	8.88388
243	101.85548	101.84851	101.84801	101.84751
143	110.73310	110.73243	110.73191	110.73139

4. DATA ANALYSIS

In this stage with the help of collating the results from the 3 branches of fault zone, behavior was analyzed and the movement map of fault zone was drawn on the satellite image of area in ARCGIS software, (Fig. 8).

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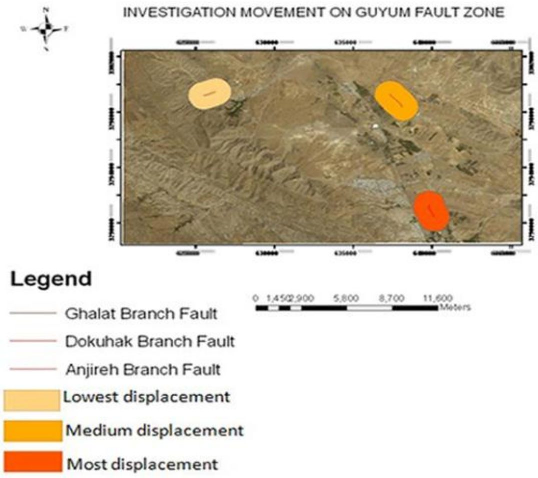

Fig.8. Movement investigation of Guyum fault zone

The rate of elongation strain for each network in every interval was individually calculated, (fig. 9) and movement vector of fault in each branch was drawn, (Fig. 10).

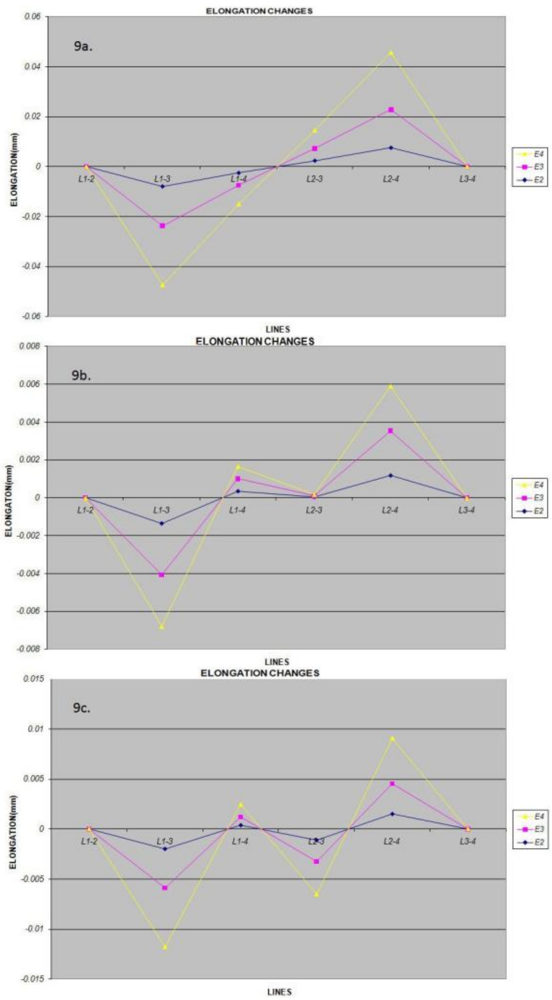

Fig.9. Elongation strain rate of every network in interval survey. A. Ghalat network, B. Dokuhak network, C. Anjireh network (E2: second 3months, third 3 months & fourth 3months)

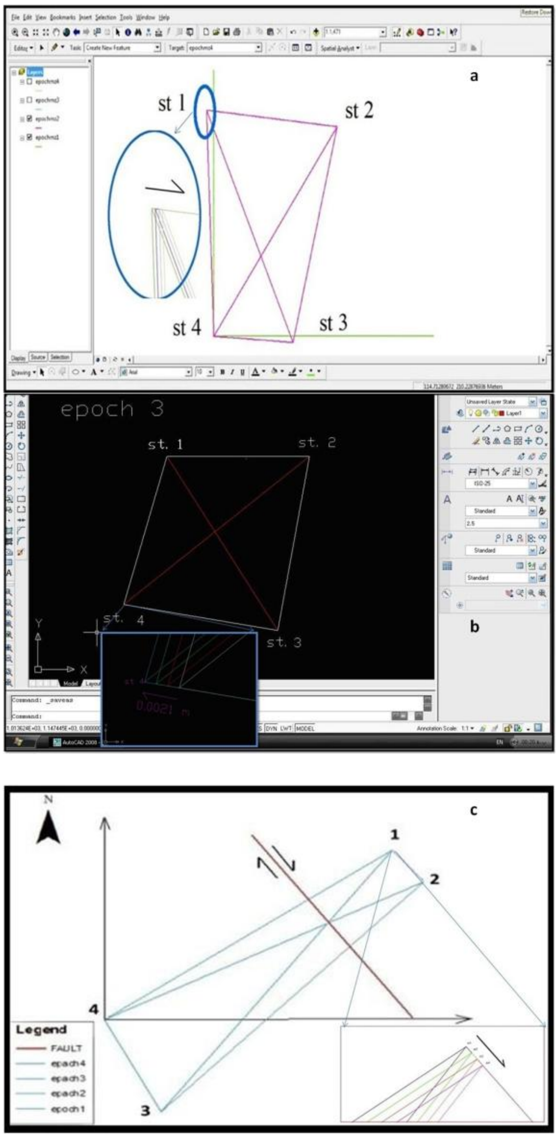

Fig.10. the drown networks after the adjusted coordinate of network points and the movement vector of fault branches. a. Ghalat network (Zareiefard Jahromi, 2010), b. Dokuhak network (Nikoonejad, 2010), c. Anjireh network (Khashayar, 2010)

And with the investigation of mathematical equations which exist among the old and new network points, it is clarified that this fault zone has simple shear movements. Results of terrestrial surveys in this study have shown a small deformation in designed terrestrial networks, (Table 3).

Table (3) Total displacement values in each of fault branches

The under geodetic investigation branches of Guyum fault zone	Obtained displacement values(mm/yr)
Ghalat	3.5
Dokuhak	2.8
Anjireh	1.7

5. Discussion and Conclusion

Iran's placement in one seismic-prone area of the world and the probability of destructive earthquakes in every parts of the country raise the importance of recognition of the nature of Iran's seismic from the seismicity view point. So, geodetic studies beside the earthquake studies expand our views of the country seismicity in order to execute geodynamic study with help of developed methods in Iran, like other parts of the world.

The results of terrestrial surveys indicate a small deformation in the designed networks which could influence negatively on structures and power transfer lines located in the path of this fault zone in the long time so it is essential that responsible of urban development take the matter into serious consideration.

It was evident from collation of the results of studies on the 3 terrestrial branches that partial velocity in this fault zone decrease from NW to SE. that itself indicates the more we go towards south, the more the possibility of the earthquakes; beside studies of each network portends a dextral movement with movement vector from NW to SE.

Creating microgeodetical networks around the most important faults of the country to see the deformations and local movements and integration of these studies with GPS and seismic studies could be of great help to disclosure of the changes from crust movements and temporal and estimation of seismic potentiality. Also, having information of fault's behaviors alongside these studies in urban and crowded areas which located on the faults could be a worthy of attention help to comprehend how to construct buildings and control the faults movements' impact on the buildings. Moreover, geodetic study after the earthquake on each of the faults could lead to estimation of damage based on deformation, rebuilding of destroyed buildings and etc.

In general, it can be said that parallel execution of studies, in the long run, could possibly predict later faults' behaviors.

6. Acknowledgements

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