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G.J. Yetirmishli, H.O. Veliyev, I.E. Kazimov, S.E. Kazimova

CORRELATION BETWEEN GPS OBSERVATION OUTCOMES AND DEPTH STRUCTURE IN STUDYING HORIZONTAL MOVEMENTS

Republican Seismological Survey Center of National Academy of Sciences of Azerbaijan, Baku, Azerbaijan

In the article presents an analysis of the velocity of horizontal movements of GPS data for 2016-2017, which showed maximum velocity (12-13 mm / year) at the junction of the Lesser Caucasus and the Kura Basin. The connection of horizontal movements observed on the earth's surface with the characteristic features of the layer deformation in geological cross sections in depth, with interruptions of tectonic cracks and the appearance of stretching zones has been studied.

Key words: geodynamic processes, geophysical areas, seismic recording, seismic wave speed, seismic horizon, depth cross-section, complex tectonic fracture zone, horizontal movement, rock density, mass, anticlinal, synclinal.

Г.Дж. Етирмишли, Г.О. Велиев, И.Э.Казымова, С.Э.Казымовой

КОРРЕЛЯЦИЯ МЕЖДУ РЕЗУЛЬТАТАМИ НАБЛЮДЕНИЙ GPS И ГЛУБИННОЙ СТРУКТУРОЙ В ИЗУЧЕНИИ ГОРИЗОНТАЛЬНЫХ ДВИЖЕНИЙ

Республиканский Центр Сейсмологической Службыпри Национальной Академии Наук, Баку, Азербайджана

В статье представлен анализ скоростей горизонтальных движений GPS данных за 2016-2017 гг., который показал максимальные значения скоростей (12-13 мм/год) на стыке Малого Кавказа и Куринской впадины. Изучена связь наблюдаемых на земной поверхности горизонтальных движений с характерными чертами деформации слоя в геологических поперечных сечениях по глубине, с прермещениями тектонических трещин и появлением зон растяжения.

Ключевые слова: геодинамические процессы, геофизические процессы, сейсмическая регистрация, скорость сейсмических волн, сейсмический горизонт, поперечное сечение глубины, сложная зона тектонического разлома, горизонтальные перемещения, плотность горных пород, масса, антиклиналь, синклиналь.

Introduction

Scientists in many regions of the world more often refer to “Plates tectonic” model to bring clarification upon horizontal movements, spatial statuses, geodynamic-tension conditions and observed seismic activeness of the plates, tectonic blocks, and large structures [1-12]. It might be interesting to know which relocations corresponding to the intervals along the depth cross-section of the lithospheric plate are expressed by positions and measured values of the control

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stations chosen to trace observed horizontal movements.

The study of the dynamics of the movement and interaction of the plates (ie, the primary forces acting on the plates), as well as the rheology of the continental lithosphere, is one of the important fundamental problems of active geotectonics. For the Greater and Lesser Caucasus, this view implies, as a source of their deformation, an approximation in the submeridional direction of the Arabian lithospheric plate to the adjacent margin of the Eastern European part of the Eurasian plate. The convergence of these plates is established as a result of GPS measurements. It is assumed that as a result of these horizontal displacements, the Caucasian segment of the Alpine-Himalayan mobile belt shrinks, the layers of sedimentary and volcanic rocks collapse, the base blocks experience multidirectional displacements, and the upper crust horizons are broken by uplifts and thrusts.

GPS satellite and Azerbaijani GPS network

The GPS satellite (Global Positioning System) survey works have been regularly conducted and horizontal movements have beenstudied in the geodynamically active regions of the world beginning from 80th of the last century [2, 3, 7]. The Geology and geophysics Institute has been conducting observations through GPS stations in the Caucasus region beginning from 1991 and in the territory of Azerbaijan at 26 stations and 6 non-stop operating stations from 1998, while the Republic Seismological Service Center under ANAS has been conducting the same observations at 24 stations beginning from 2012. The obtained GPS data are analyzed through GAMIT / GLOBK program developed by Massachusetts Technology Institute [11], because of which, the vector direction of horizontal movement is established, relocation value is estimated, and maps are drawn at the measured station.

Starting from 2012-2017. A network of permanent GPS / GLONASS observation stations was established on the territory of Azerbaijan RSSC. Regular observations have been conducted since 2013. The stations are equipped with Choke Ring (10), Zephyr geodetic2 (14) antennas and TrimbleNetR9 (24) L1 / L2 GPS / GLONASS / Galileo receivers. The current work of the stations is serviced by employees of the Geodynamics of the RSSC, in whose territory they are installed. Data from GPS receivers come through the Internet to the HP Proliant DL308P Gen8 server storage and processing complex with a total volume of 7 TB. Employees of the Department of Geodynamics of the RSSC, with the help of

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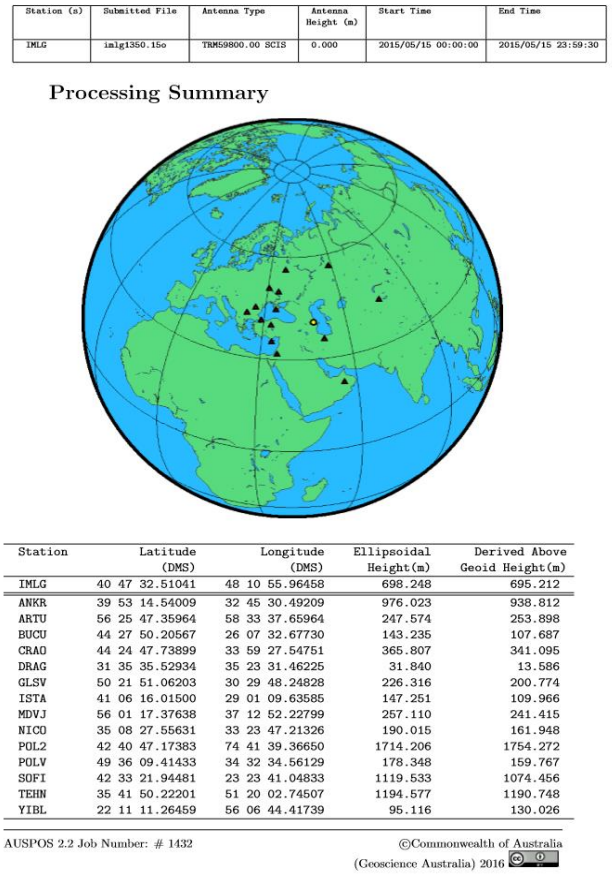
software, process GPS data based on modern techniques.

A set of 24 GPS stations cover the vast territory of Azerbaijan and form the geodetic network GPS_РЦСС. Thus, the formed geodetic network makes it possible to solve regional problems of studying the basic laws of modern earth crust movements in the territory of Azerbaijan.

Refinements of geodetic coordinates of 24 GPS stations were processed and refined on the server AUSPOS, Australia (fig. 1).



Station (a)	Submitted File	Antenna Type	Antenna Height (m)	Start Time	End Time
IMLG	imlg1350.15o	TRM59800.00 SCIS	0.000	2015/05/15 00:00:00	2015/05/15 23:59:30

Processing Summary

Station	Latitude (DMS)	Longitude (DMS)	Ellipsoidal Height(m)	Derived Above Geoid Height(m)
IMLG	40 47 32.51041	48 10 55.96458	698.248	695.212
ANKR	39 53 14.54009	32 45 30.49209	976.023	938.812
ARTU	56 25 47.35964	58 33 37.65964	247.574	253.898
BUCU	44 27 50.20567	26 07 32.67730	143.235	107.687
CRAO	44 24 47.73899	33 59 27.54751	365.807	341.095
DRAG	31 35 35.52934	35 23 31.46225	31.840	13.586
GLSV	50 21 51.06203	30 29 48.24828	226.316	200.774
ISTA	41 06 16.01500	29 01 09.63585	147.251	109.966
MDVJ	56 01 17.37638	37 12 52.22799	257.110	241.415
NICO	35 08 27.55631	33 23 47.21326	190.015	161.948
POL2	42 40 47.17383	74 41 39.36650	1714.206	1754.272
POLV	49 36 09.41433	34 32 34.56129	178.348	159.767
SOFI	42 33 21.94481	23 23 41.04833	1119.533	1074.456
TEHN	35 41 50.22201	51 20 02.74507	1194.577	1190.748
YIBL	22 11 11.26459	56 06 44.41739	95.116	130.026

AUSPOS 2.2 Job Number: # 1432

Fig. 1. AUSPOS, Australia (Internet GPS processing service).

In order to determine the directions of horizontal movements of separate tectonic blocks of the Earth's crust, a calculated calculation of horizontal displacements for each stadium was performed.

Geodynamic-tension zones have been identified and the areas where activeness is assumed to have intensified in tectonic fracture zones, the instant processes likely to take place, and the areas where strong earthquakes are expected, have been established on maps drawn up according to the surveys conducted in different regions (fig. 2). Following the results achieved so far, the movement in

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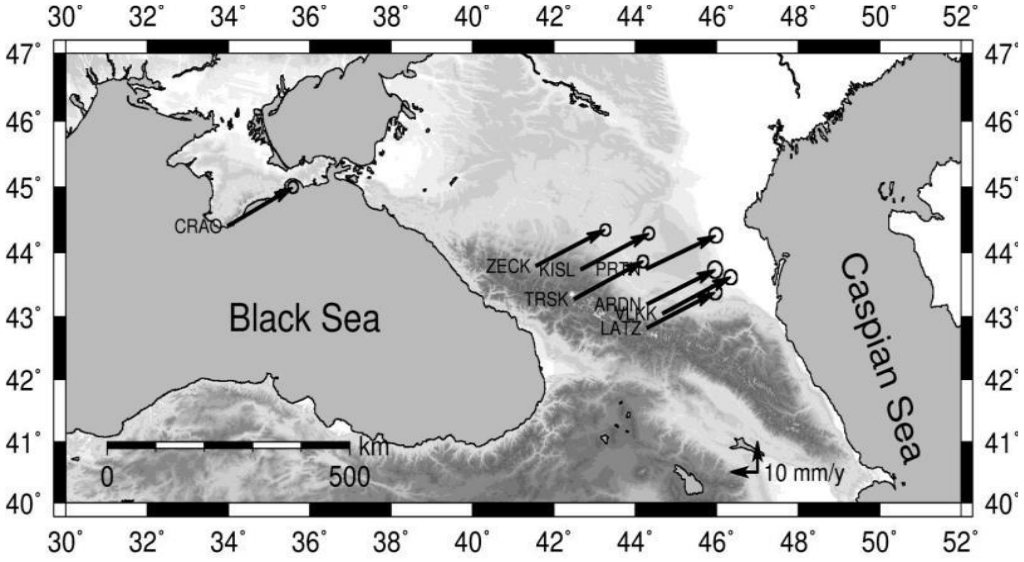
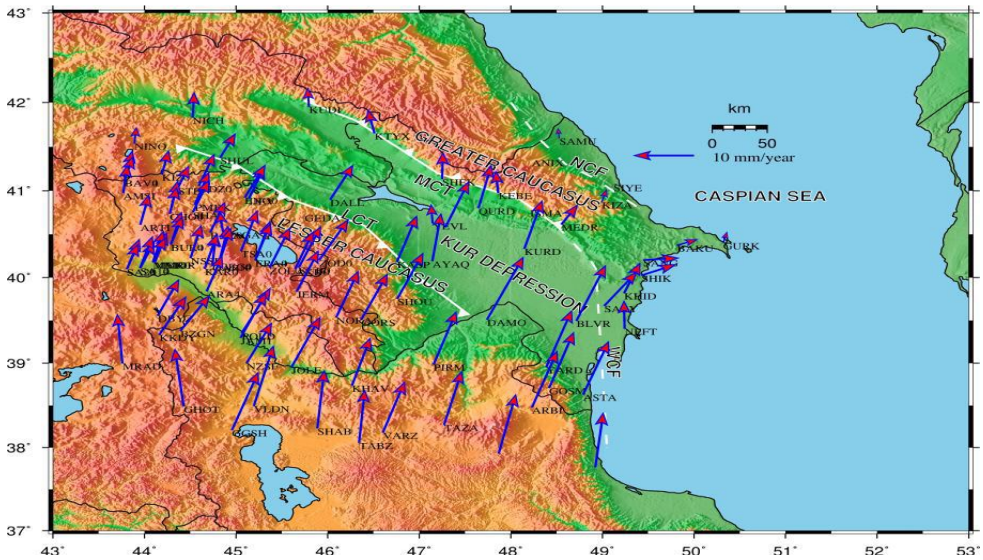
south-east zone of the Lesser Caucasus is more active and observed with value 9-12 mm/y and in north-north of the Greater Caucasus - 12 mm/y [4-7].



a)



b)

Fig. 2. Horizontal movements observed in the regions: a) North Caucasus and Crimea zone [1]; b) territory of Azerbaijan [5].

Mapping of horizontal movements based on research conducted by ANAS RSSC over the last two years (fig. 3). The horizontal velocities of the speeds are also shown and the directions for each station are calculated.

It has been established that in the Greater and Lesser Caucasus territory between 2016 and 2017, 1.0-2.0 mm north-northwest direction is recorded and 1.5-2.5 mm north-east movements are observed in the Middle and Lower Kura basin is taken. The GPS station, which is settled in Deep Saatli borhole, is up to 3.5 mm.

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The displacement of the station on Gilov Island in the Caspian Sea varies between 2-3mm.

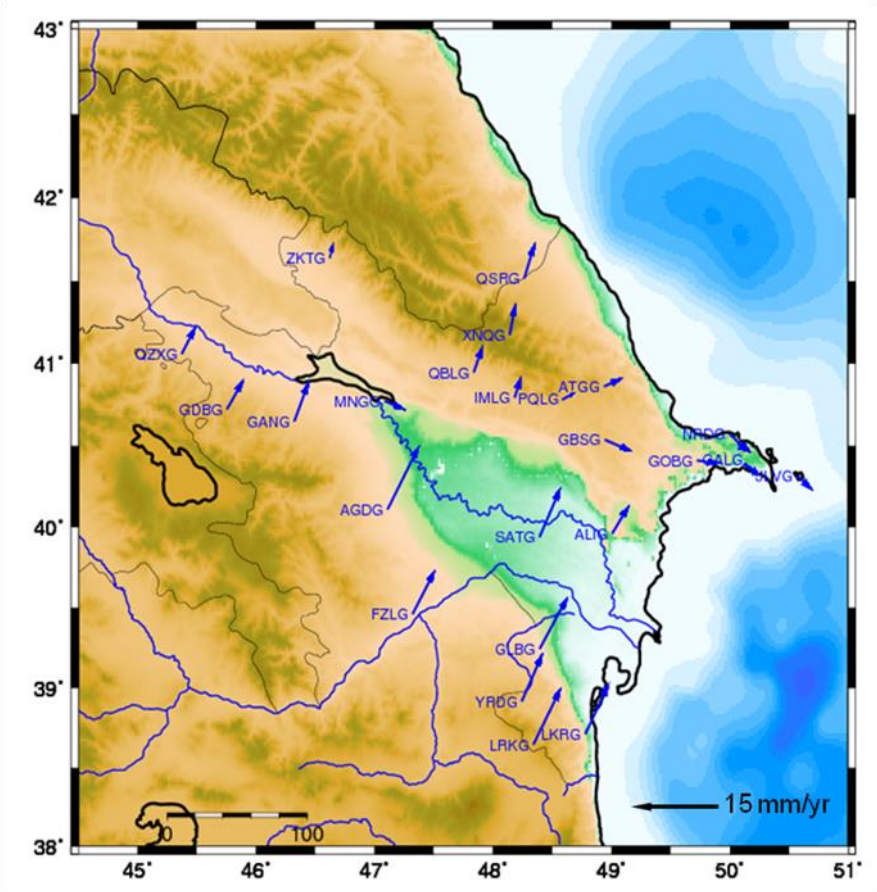

Fig. 3. Map of horizontal movements according to GPS data for 2016-2017, obtained under the GAMİT program, for the region of Azerbaijan.

Thus, on the basis of the received data, an average of up to 10 mm north-north-east movements are observed for the territory of Azerbaijan. For each station, separate speeds are calculated. It was stated that the velocity of the horizontal movements in the QSRG, PQLG and ALIG stations from 24 GPS stations increased by 1-2 mm/y. In the remaining 21 stations, the speed of the speeds fell. At the stations located on the Absheron peninsula, the speeds of the speeds are reduced to 4-5 mm/y. An epicentre map of powerful (ml> 5.0) earthquakes that took place during 2012-2017 was established to determine the relationship of horizontal movements with geodynamic conditions of clothing (fig. 4). The GPS network stations and the directions of the breakthroughs created by Shikhalibeyli have been added above that map. As you can see from the picture, the most seismic area is characterized by Greater Caucasus and Saatli.

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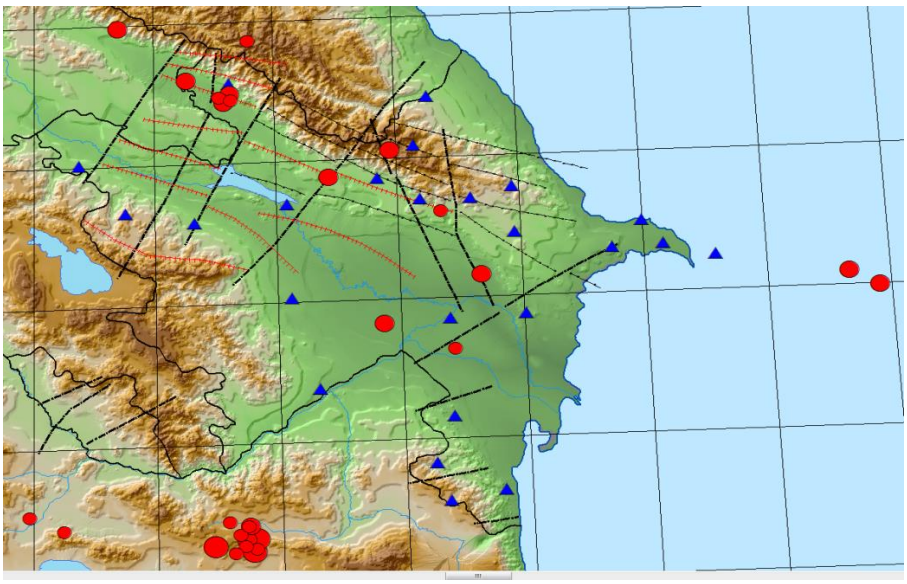

Fig. 4. The network of GPS stations and the epicenter of earthquakes (ml>5.0), which occurred during 2012-2017.

It has been established that in 2017 the highest speeds are GSRG, SATG, ALIG, LRGG and LRGG stations, and the most active regions are characterized by the middle part of the Greater Caucasus, Saatli, Talish and Caspian Sea. The depth of each strong earthquake can indicate the depth of movement of any tectonic block. Thus, the mechanism of earthquake disasters in Zagatala, Sheki and Gabala regions in 2016-2017 shows the advantage of movement movements in the left-hand side. The depth of these earthquakes varies from 10 to 20 km. ZKTG, QZXG, GDBG and QBLG GPS stations in this area show their wear in the direction of 8.9 mm/y, 7.8 mm/y, 6.7 mm/y and 8.1 mm/y. An earthquake measuring 24 km south of Saatli was registered on 07-24-19 local time. The Episentr was felt almost 5 puppies. The magnitude of the earthquake was 5.4 and the depth was 48 km. It can be assumed that the quake is associated with the movement of the block of 48 km. It should be noted that in 2017 the speeds of the SATG GPS station reached 14.7 mm/y.

Identification of horizontal movements on seismic profiles

It might be interesting to know whether the horizontal movements observed on the earth surface are marked by characteristic features in layer deformation in the geological cross-sectionsalong the depth, directional relocation of tectonic fractures, and emergence of tension zones.

The activeness of deformations and relocations is very high as observed at two-dimensional (2D) profiles, at depth cross-sectionson upper layers at two depth intervals from 50-100 m to 3500-4000 m. The tectonic fractures themselves take

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on a gradually inclined form due to the influence of tension – deformation energy. Tectonic fractures and decompositions decrease at a greater depth intervals 3500-9000 m maintaining their previous vertical direction more characteristically, layer deformation indicators decrease, and more anticlinal – synclinal structures develop (fig. 5).

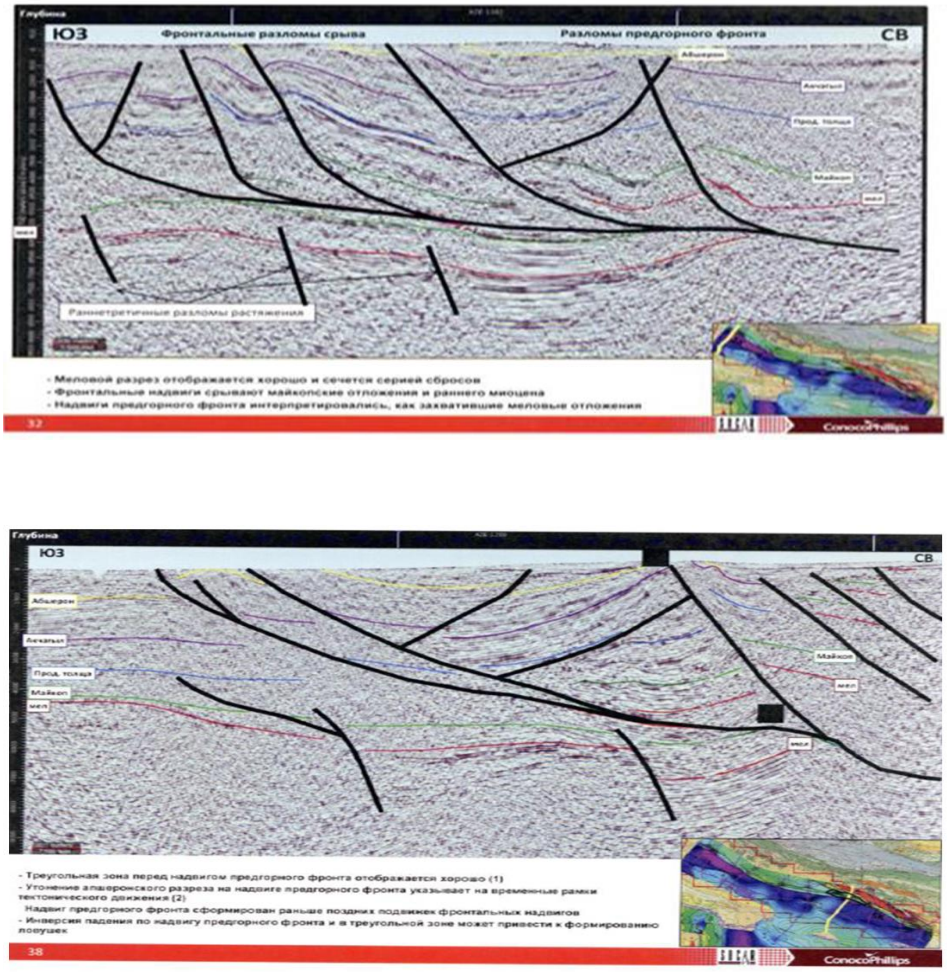

Fig. 5. Regional seismic profiles of the southern slope Greater Caucasus in Azerbaijan.

In the Kur valley, visually different picture is more clearly observed both in deformation indicators and directions of tectonic fractures at three depth intervals from 50-100 m to 1500-200 m, 4000-4500 m, and 8000-10000 m in the regional profiles (fig. 6). Deformation indicators decrease in Granite and Basalt layers and density of tectonic fractures both decrease and virtually change their original forms.

It is worth noting one characteristic feature here. Horizontal relocations are more clearly observed in the arc of most of the structures on maps drawn up along the different stratigraphic cross-sectionsof observed anticlinal and synclinal

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structures discovered during exploration and development of oil and gas fields in the depression layer and multiple tectonic disorders are observed in the arc of the structure. The relocations observed in the arc of the anticlinal structures occasionally change their directions and this may be possibly due to the influences of geodynamic tension developing in the environment.

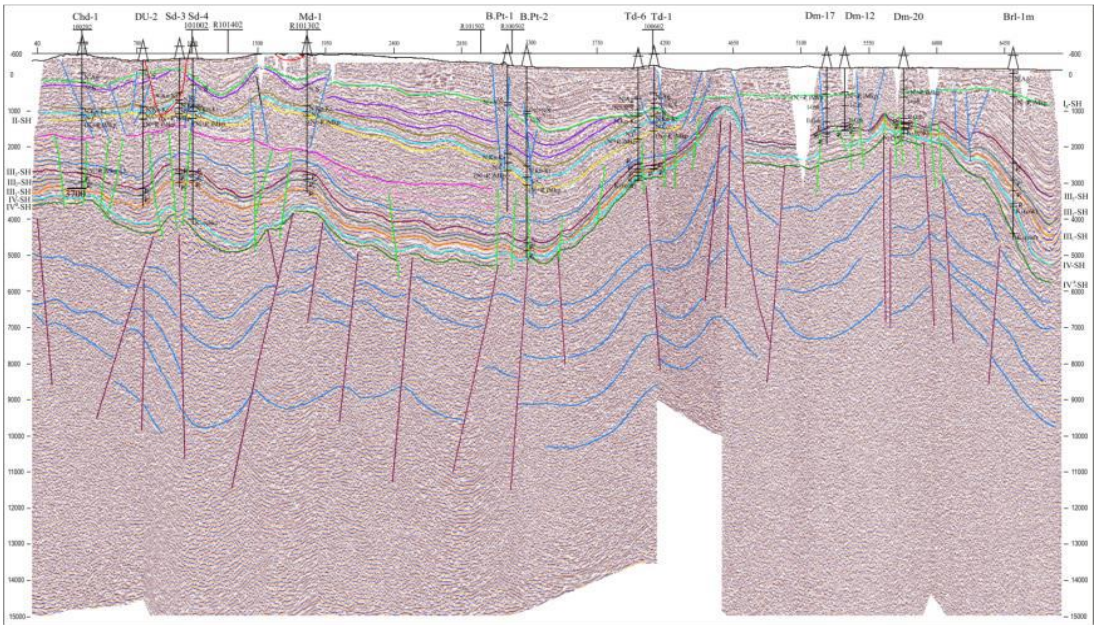

Fig. 6. Poylu-Dalimammadly regional profile in Azerbaijan.

While the number of earthquakes with corresponding changes of seismic activeness at the above noted intervals taking place at upper 3-5 km interval of the cross-sectionsin the epicenters maps and their locations along the hypocenter depth in the territory of Azerbaijan is large, their magnitude does not exceed M≥4 threshold. Deformation is intensive in cross-sectionsat this interval and the tectonic disorders taking place and multiple fractures minimize tension energy despite the high speed of horizontal movements. Relatively strong earthquakes M ≥ 6-8 take place at interval 7-20 km. Here, tension – deformation energy may accumulate in larger amounts with potential earthquakes covering larger areas, bringing about bigger scale devastations and human casualties.

As seen from the cross-sections built following seismic data, deformation indications at interval 7-20 km are long-term with geodynamic – tension energy accumulated at this interval escaping at larger volumes during instant events – earthquakes and speed of horizontal movements associated with them must be low in terms of time and space. Earthquake epicenters are observed in contacts block zones andintrablock fracture zones. The accumulated tension energy develops to

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some value in the epicenter up to a certain time resulting from horizontal movements and ends up with instant tectonic movement – earthquake. The movement in the epicenter mechanism, being of instant break and fall or rise nature, does not reflect movement of the tectonic block. Earthquake epicenters are observed in the contact zones of the crusts and blocks and intrablock tectonic fracture zones. The geodynamic-tension energy accumulated as a result of the horizontal, vertical and different movements is stabilized due to mechanical relocation taking place after the earthquake.

Summary

1. The surveys conducted show that horizontal movements corresponding to GPS observation stations primarily reflect the relocations along intrablock depth.

2. More intensive relocation is observed at the upper cross-section layers. Structural forms developing at the upper layers are complicated for their deformation features and tectonic fractures.

3. Forms and configurations of tectonic fractures are both linear and circular. The seismic activeness observed does not necessarily build the image of full tectonic model.

4. Location of the GPS observation station, thickness of the earth crust where it is situated and depth geological structure shall be borne in mind when clarifying mechanism of horizontal movements of the plates and tectonic blocks as well as analyzing the data obtained through state of art cosmic geodesy measures.

5. Since the horizontal movement speeds and its vector direction observed on the earth crust depends on tectonic structure, geodynamic setting, lithological and density features of the deep layers of the area, the results shall be presented taking into account complex geophysical and particularly, seismic data.

REFERENCES

1. Milyukov V.K., Mironov A.P., Stebleov G.M., Shevchenko V.I., Kusraev A.G., Drobyshev V.N., Khubaev Kh.M. Modern horizontal movements of the main elements of the tectonic structure ossetian part of the large caucasus on gps measurements physics of the earth. 2015. 4: 68-80.
2. Allen M., Jackson J., Walker R. Late Cenozoic reorganization of the Arabia-Eurasia collision and the comparison of short-term and long-term İS / PRF / 01/022 Rev.№00 Nəşrtarixi: 02.02.2012 deformation rates, Tectonics. 2004: 23 (doi: 10.1029 / 2003TC001530). ANSS (Advanced National Seismic System) earthquake catalog of USA (http://www.ncedc.org/anss/catalog-search.html).
3. Sokhadze G., Floyd M., Godoladze T., King R., Cowgill E.S., Javakhishvili Z., Hahubia G., Reilinger R.. Active convergence between the Lesser and Greater Caucasus in Georgia: Constraints on the tectonic evolution of the Lesser-Greater Caucasus continental collision. Earth and Planetary Science Letters. 2018. 481 (2018): 154-161.

DOI: 10.24411/2304-9081-2019-14013

4. Jackson J. Partitioning of strike-slip and convergent motion between Eurasia and Arabia in eastern Turkey. J. Geophys. Res. 1992. 97: 12471-12479.
5. Kadirov F.A., Safarov R.T. Deformation of the Earth's crust of Azerbaijan and adjacent territories according to GPS-measurements. Proceedings of ANAS, Earth Sciences. 2013. 1: 47-55.
6. Kadirov F., Floyd M., Alizadeh A., Guliev I., Reilinger R.E., Kuleli S., King R., Toksoz M.N., Kinematics of the eastern Caucasus near Baku. Azerbaijan, Natural Hazards, 2012. 63: 997-1006 (doi: 10.1007 / p11069-012-0199-0)/
7. Kadirov F.K., Floyd M., Rueinger R., Alizadeh Ak.A., Guliyev I., Mammadov S.G., Safarov R.T.. Active geodynamics of the Caucasus region: implications for earthquake hazards in Azerbaijan. Proceedings of Azerbaijan National Academy of Sciences. The Sciences of Earth, 2015. 3: 3-17.
8. Kadirov F., Mammadov S., Reilinger R., McClusky S. Some new data on modern tectonic deformation and active faulting in Azerbaijan. Proceedings Azerbaijan National Academy of Sciences. The Sciences of Earth. 2008. 1: 82-88.
9. Reilinger R., McClusky S., Vernant P. et al. GPS constraints on continental collision zone and implications for the interactions of the continental deformation. Journal of Geophysical Research: Solid Earth (1978-2012). 2006. 111: B05411.
10. Kadirov FA, Kadyrov AG, Aliyev F.A., Mamedov SK, Saffarov RT. Interconnections between the horizontal limits of GPS measurements in Azerbaijan and the seismicity of the Big Caucasus. Catalog of Seismoprographic observations in Azerbaijan in 2008, Baku, 2009: 121-126.
11. Herring T.A., King R.W., McClusky S.M. Introductionto GAMIT / GLOBK Release 10.4. Mass. Inst. Of Technology, 2010. 48p.
12. Gok R., Sandvol E., Turkelli N., Seber D., Barazangi M. Snattenuation in the Anatolian and Iranian plateau and surrounding regions.Geophys. Res. Lett. 2003. 30: 24 (doi: 10.1029 / 2003GL018020).

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(*Контактная информация:* **Етирмишли Гурбан Джалал оглы** – доктор геолого-минералогических наук, член-корреспондент НАНА, генеральный директор Республиканского Центра Сейсмологической Службы при Национальной Академии Наук Азербайджана; адрес: 1001, Азербайджан, г. Баку, ул. Нигяр Рафибейли, 25. Тел. (99412) 492-31-65; E-mail: azay_r@yahoo.com).

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