ANALYSIS OF MODERN MOVEMENTS OF EARTH CRUST BLOCKS IN AZERBAIJAN ACCORDING TO THE DATA OF GPS STATIONS IN 2020-2021

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Introduction

The tectonic activity of the Mediterranean was completely determined by the processes of closure of the relict basins of the Tethys Ocean with residual oceanic-type crust, taking place against the general background of the convergence of the African and Eurasian plates. The type of seismotectonic deformation of the earth's crust of the Caucasus corresponds to the setting of a thrust formation with a subhorizontal orientation of the main axis of compression (in the north-northeast direction, in the cross direction of the Caucasian structures) and a subvertical orientation of the main axis of extension, established on the basis of reconstruction according to a representated set of earthquake source mechanisms. On the whole, it is quite consistent with the ideas developed in the plate tectonic concept about a strong transverse narrowing of the Caucasian segment of the Alpine-Indonesian mobile belt as a result of the convergence of the Arabian and Eurasian lithospheric plates [5]. The tightness of the territory of the Caucasian Isthmus in the zone of collision of these lithospheric plates determines its modern geodynamic and, accordingly, seismic activity. At the same time, the southern slope of the Greater Caucasus remains one of the most seismically active regions of the Caucasian Isthmus, where large seismic events periodically occur, accompanied by the spontaneous release of large amounts of energy from the earth's interior.

A huge meridional depression of the Caspian Sea adjoins Azerbaijan from the east. The northern part of Azerbaijan covers the eastern segment of the intricately constructed southern wing of the Greater Caucasus meganticlinorium, while the Lesser Caucasus system and the Talysh Mountains are located in the southern part of Azerbaijan. Each zone separately is characterized by its seismicity and geodynamic conditions. The Global Positioning System (GPS) has provided a new opportunity for direct observation of modern movements and deformations of the earth's crust, as well as seismic and ionospheric disturbances. Previous GPS studies have helped quantify regional deformation in the plate interaction zone. Regional studies of plate movement use fault orientation, local observations, and constraints on relative plate movement. In order to determine the velocities and directions of horizontal movements of individual tectonic blocks on the territory of Azerbaijan, according to the data of 24 GPS stations, the values of the error of signal modulation and deviations in the ionosphere were calculated depending on the terrain of the stations during the day. Thus, taking into account previous studies, this article presented the results of the study for 2020-2021.

Seismicity of Azerbaijan for 2020-2021

The analysis of the seismicity of the territory of Azerbaijan in 2020-2021 was carried out on the basis of 40 digital data in the "Earthquake Research Bureau". To process the earthquakes recorded by the RSSC telemetry network, we used the dbloc2 program from the Antelope Real-Time System, v. 5.6 using the averaged velocity model of the deep geological structure of Azerbaijan [1, 2]. In 2020, parameters of 4030 earthquakes with M_{Lmax}=4.9 and released energy $\sum E=13.1\cdot10^{11}$J were determined within Azerbaijan. In 2021, the parameters of 4173 earthquakes with maximum magnitude M_{Lmax}=5.1 and released energy $\sum E=14.3\cdot10^{11}$J were determined.

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An analysis of the number of earthquakes and released seismic energy by months in Azerbaijan and adjacent areas shows that in 2020, seismic energy was highest in February, April and June. This is due to an earthquake with a magnitude of 5.9 that occurred on the Turkish-Iranian border. 20 perceptible earthquakes (M_L=2.5-5.9) were recorded on the territory of the republic. The maximum seismic activity was observed in the Shamakha-Ismayilli seismogenic zone, in the Talysh mountain zone, on the Iranian-Turkish border. Compared to 2019, activity in the Caspian Sea has increased.

In 2021, unlike other years, an increase in seismic activity was recorded in the Shakhbuz region of Shamakha, Agstafa district and the Nakhchivan Autonomous Republic. In the Zakatalo-Balakan zone on the southeastern slope of the Greater Caucasus, seismicity has noticeably decreased. At the same time, as in 2020, activity is observed in the central and northern parts of the Caspian Sea.

An analysis of the spatial distribution of epicenters showed that the events of this period are confined to transverse (northwestern, northeastern, and submeridional strike) disjunctive dislocations, but the epicentral zones as a whole have a "all Caucasian" elongation, being located along and north of Ganikh-Ayrichay-Alyat deep over thrust within the Kakheti-Vandam-Gobustan longitudinal structural block. In addition, high seismic activity in 2020-2021 was associated with the activation of the Tayraldjachay-Salyan, Dashgil-Mudrese, Ismayilli-Sighirli, Arpa-Samur, West Caspian, Sangachal-Ogurchu, Garabogaz-Safidrud and Palmir-Absheron faults.

GPS surveys on the territory of Azerbaijan for 2020-2021

In order to determine the velocities and directions of horizontal movements of individual tectonic blocks of the earth's crust on the territory of Azerbaijan, an analysis of the data obtained in 2020-2021 was carried out. The error in determining the velocity varies mainly within the limit of less than 0.6 mm/year, which makes it possible to fairly accurately estimate the convergence of plates across the Caucasus mountain system (i.e., the error is 5% of the total convergence rate) [7]. As one of the main sources of GPS positioning errors, ionospheric delays play a very important role in data processing. Because it is difficult to accurately model ionospheric attenuation, virtually all GPS data processing programs always use a no-ionosphere (LC) linear combination to avoid ionospheric delay effects, including GAMIT, Bernese, GIPSY, and PANDA [3].

It has been established that in 2020 in the Greater Caucasus the average velocity was 6.8 mm/year, in the Lesser Caucasus - 8.7 mm/year, in the territory of the Middle and Lower Kura 7.6 mm/year, in the territory of the Talysh region 9.8 mm/year, on the Absheron Peninsula 3.7 mm/year. The maximum values of horizontal velocities were noted at the stations of Aghdam, Lerik, Lankaran, Djalilabad, Fizuli and Saatly. The average value of velocities throughout the republic was 7.3 mm/year.

In 2021, on the territory of the Greater Caucasus, the average velocity value was 5.4 mm/year, in the Lesser Caucasus - 8.9 mm/year, on the territory of the Middle and Lower Kura 8.8 mm/year, on the territory of the Talysh region 11.6 mm/year, on the Absheron Peninsula 4.2 mm/year. The average value of velocities throughout the territory of the republic was 7.6 mm/year. The maximum velocities were noted at Yardimly (12.2 mm/year), Lankaran (13.1 mm/year), and Saatly (12.3 mm/year) stations. Compared to 2020, the velocity values in 2021 have decreased. On a comparison graph between 2019-2020 and 2020-2021 we put strong earthquakes that occurred in this period (Fig. 1).

The trend of horizontal movements on the territory of Azerbaijan predetermines the activation of seismic processes in the zones of accumulation of elastic stresses and in adjacent areas [6]. As a result of horizontal movements of the lithosphere, plastic deformation of the crust occurs. At the same time, the Kura depression descends and the Greater and Lesser Caucasus rise. The boundaries between the depression and the surrounding mountain blocks are marked by clear breaks. As can be seen in the Figure in 2019-2020 activation was observed mainly in the Ismayilli and Zagatala seismogenic zones. In 2021, strong earthquakes with M_L>4.0 were observed in the Caspian, Ismayilli and Nakhichevan regions.

Consideration of data on the distribution of velocity vectors of horizontal displacements of data from GPS stations on the territory of Azerbaijan leads to the conclusion that there is a significant displacement velocity in the north-north-east direction of the southwestern side and the central strip of the South Caucasian microplate, including the territory of the southeastern segment of the Lesser Caucasus, Kura depression and Talysh (Fig. 2, 3).

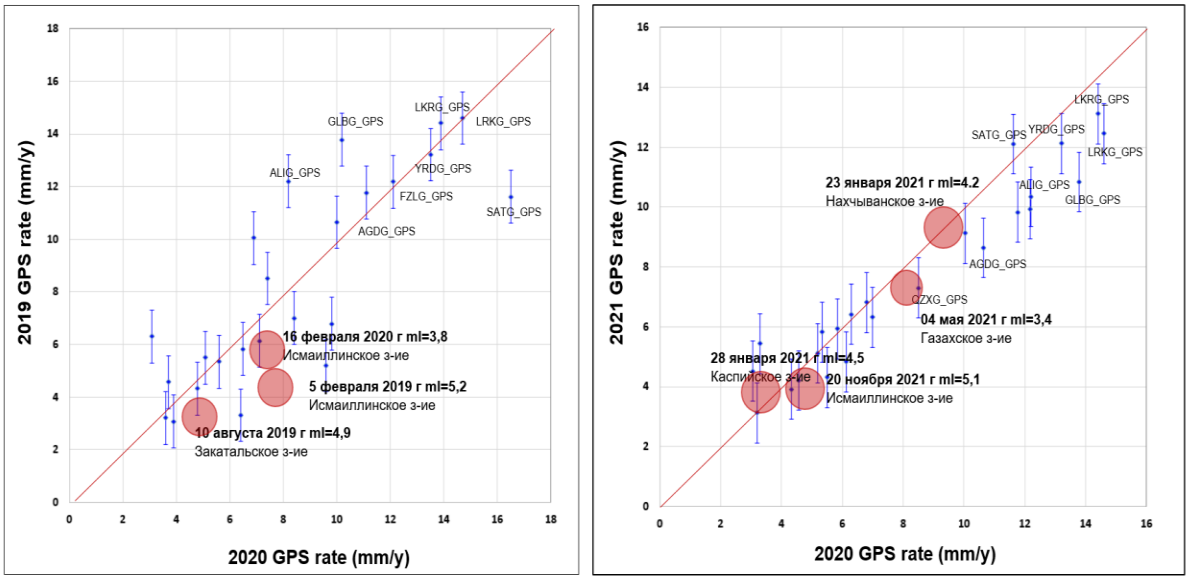


Figure 1. Graph of changes in velocity values according to GPS stations for 2020-2021

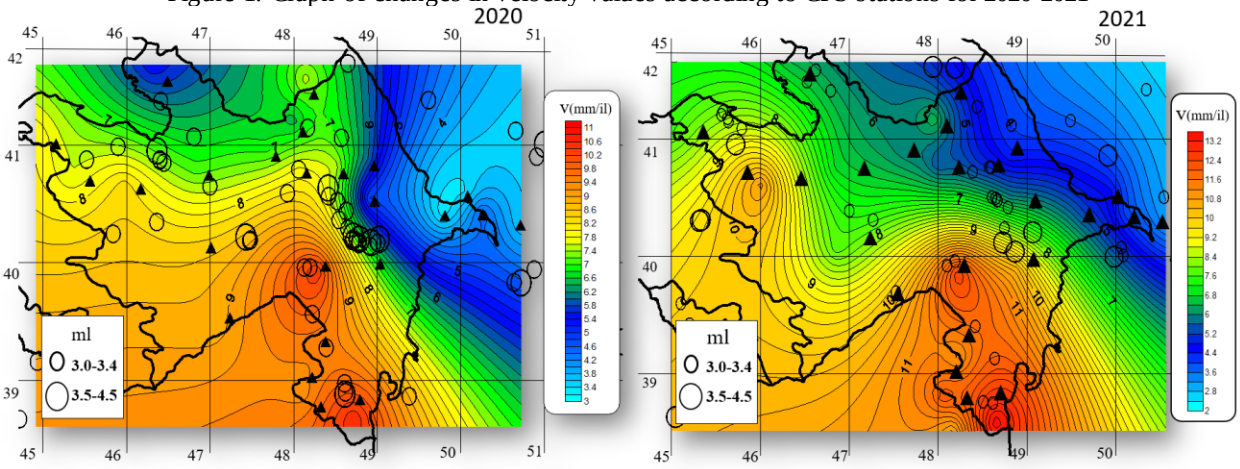


Figure 2. Scheme of the spatial distribution of velocities according to GPS station data for 2020-2021

It has been established that along the Kura depression in the direction from the Middle Kura depression to the Lower Kura depression (i.e. from NW to SE) there is a gradual increase in the rates of horizontal movements from 7.3 to 11.3 mm/year, which is characterized by the condition of compression. It should be noted that in the last 3 years, the zone of the Lower Kura depression is characterized by the manifestation of high seismic activity, expressed in several earthquakes with a magnitude of more than 5, characterized by a uplift type of movement [8].

At the same time, within the northeastern side of the microplate corresponding to the Vandam-Gobustan megazone of the Greater Caucasus, the velocity vectors experience a decrease to 10-12 mm/year, and further to the north, i.e. directly within the accretionary prism, and completely decreases to 3.5-5 mm/year. In general, the tangential shortening of the earth's crust in the region is estimated at 6.1-11 mm/year. This is confirmed by the observed directions and velocities of movement of the earth's surface in the territory of Azerbaijan and adjacent regions according to the results of measurements at GPS points in 2017-2021, as well as strong earthquakes that occurred during this period. Comparative analysis of GPS station data for the last 5 years is shown in Fig.4. At the same time, the presented graph clearly shows the peculiarity of the velocity field - a contrasting decrease in velocity at the observation points located in the southern flank of the Zanga thrust, compared with the velocities recorded within the Kura and Lesser Caucasus. This phenomenon reflects the process of successive accumulation of elastic deformations in the zone of subduction interaction between the structures of the northern side of the South Caucasian microplate [7]. In turn, it should be noted that the regional patterns of neotectonic and modern geodynamic development and landforms of the Caucasus region can be considered as a result of mechanical impacts on it of adjacent geodynamic active areas. The Scythian part of the Scythian-Turanian Plate, which occupies the plain territories of the Crimea and Ciscaucasia and is limited from the north by the East European Platform, experiences compressive forces from the folded structures of the Greater Caucasus and the Mountainous Crimea, the latest and modern geodynamic movements of which are due to pressure from the Alpine fold belt, which thrust of the Arabian plate. The southern part of Turan is also subject to the same effects of submeridional compression [11].

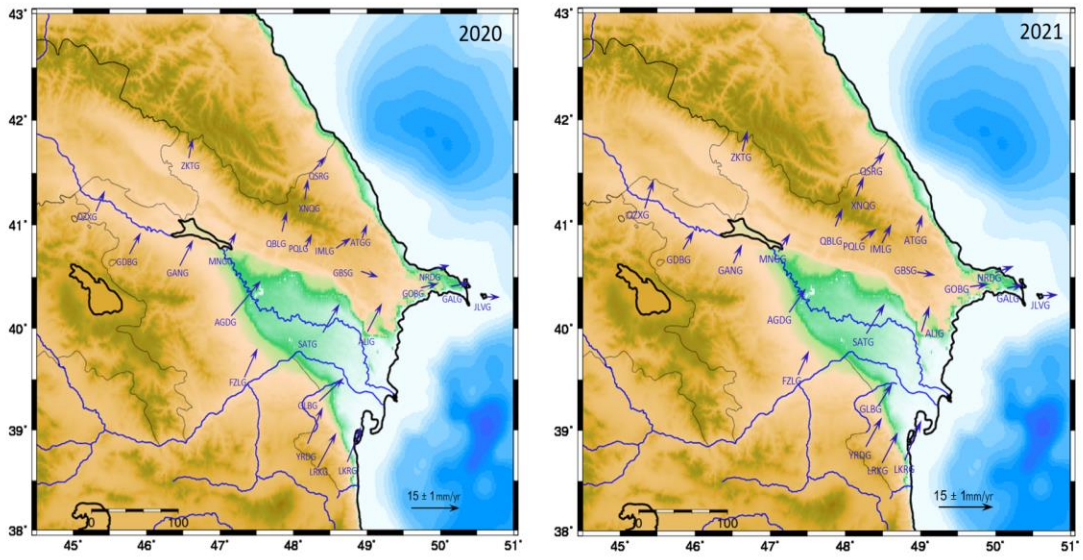


Figure 3. GPS horizontal velocity vectors for 2020-2021

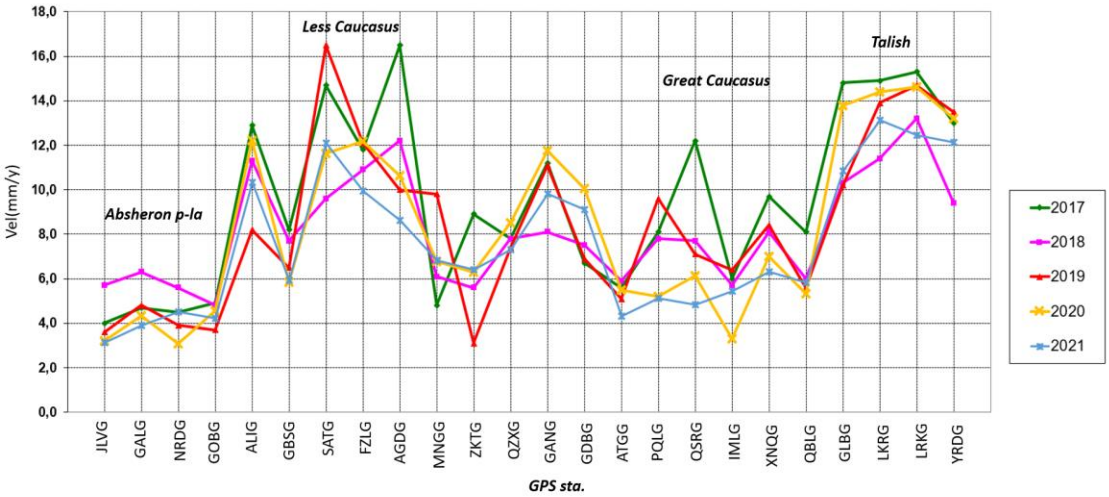
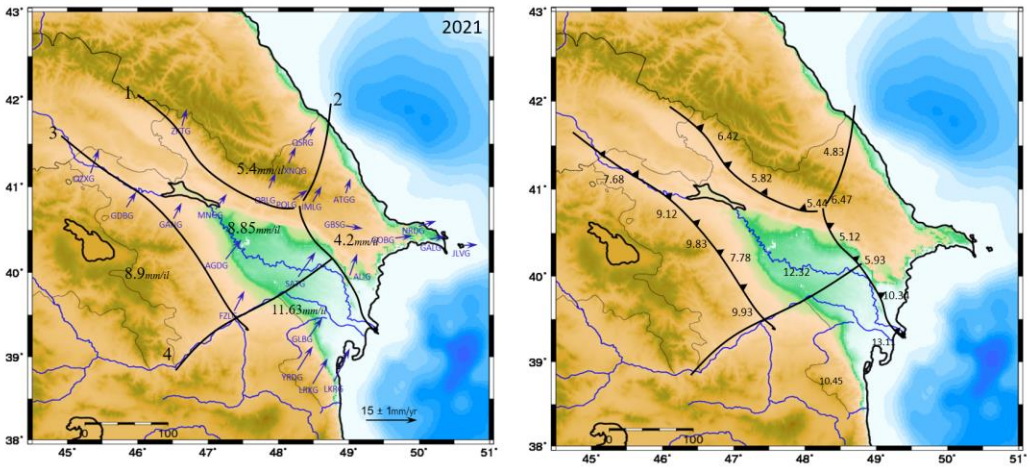


Figure 4. Comparative graph of GPS station data for the last 5 years

At GPS stations Nardaran, Gobu, Gala and Zhiloy Island, which are part of the Absheron zone, almost similar values of horizontal displacement rates are traced (3.8 mm/year; 4.9 mm/year; 4.1 mm/year; 3.2 mm/year, respectively). In the direction from the Talysh region to the Absheron Peninsula (SW-NE direction), there is a noticeable decrease in the northern component of displacement velocities compared to high values of points located in the southwestern part of the selected profile (LKRG_GPS=13.8 mm/year; LRK_GPS=12.5 mm/year; GLBG_GPS = 12.3 mm/year; YRDG_GPS = 12.7 mm/year). It should be noted a noticeable increase in the azimuthal angles of the Absheron stations, indicating a clockwise movement in the east-southeast direction up to 88º.

The discussion of the results

Thus, taking into account the above, we identified several tectonic blocks along large tectonic faults, which differ in the value of the horizontal movement velocities: Artvin Karabakh megazone of the Lesser Caucasus, the Middle Kura megazone, the megazone of the southern slope of the Greater Caucasus, the Talysh megazone (Fig. 5).



Fault map by Shikhalibeyli E.: 1-1 – Ganix-Ayrichay-Alat,2-2 – West-Caspian,3-3 – Pre-Lesser Caucasus Fault,4-4 – Palmir - Absheron

Figure 5. Schematic maps of identified tectonic blocks and average velocities according to data of GPS stations

It is interesting to note that the rate of modern vertical movements covering the GPS points of Gabala, Zagatala, Gusar and Khinalig on the southern slope of the Greater Caucasus lags behind the rate of the general uplift. Modern movements along the line stretching from the Lesser to the Greater Caucasus (from south to north) have a wave nature, which is the result of the interference of various tectonic waves, i.e. the result of a complex combination of horizontal and vertical movements of the earth's crust (possibly, the asymmetry of its movements is due to the simultaneous manifestation of waves with different lengths and amplitudes) [10]. Consequently, wave-like deformations are not linear, and this determined all the main features of the neotectonics of the region. The average value of the megazone of the Southern slope of the Greater Caucasus varies within 4.2-5.4 mm/year. The Middle Kura megazone is characterized by the values of 8.85 mm/year.

Comparison of the obtained measurement data of GPS stations shows that the stations located in the Lesser Caucasus and in the zone of the Talysh Mountains move in the northeast direction almost identically. These facts allow us to state that the Lesser Caucasus and Talysh participate in the horizontal movement as a single bloc. On the other hand, the stations located on the territory of the Talysh Mountains are characterized by high horizontal movement rates, which allow us to delineate this region with average horizontal movement rates of 11.6 mm/year.

Conclusion

On the basis of GPS space geodesy data and seismological data, the current geodynamic conditions of the territory of Azerbaijan for 2020-2021 are analyzed. One of the most pronounced features of the velocity field of horizontal movements is the decrease in velocity values perpendicular to the direction of the Greater Caucasus strike from south to north. The velocity field clearly illustrates the movement of the earth's surface in the N-NE direction. This phenomenon reflects the process of successive accumulation of elastic deformations in the zone of subduction interaction between the structures of the northern side of the South Caucasian microplate (Vandam-Gobustan megazone) with the accretionary prism of the Greater Caucasus.

In addition, within the Middle Kura depression and in the Lesser Caucasus, there is a trend towards horizontal displacement, which is reflected in an increase in the velocity of movement from west to east along the continuation of the ridge. It has been established that on the Absheron Peninsula the earth's crust is shortening at a rate of ~ 5 mm/year. The earthquakes that occurred during this period are located in the gradient zones of transition from maximum to minimum velocities. These are mainly Ismayilli, Shamakha, Aghdam and Shamkir districts (Fig.). In this zone, there is a change in the magnitude of the GPS velocity vectors, which can be explained as the main reason for the accumulation of stress.

It was found that in 2020 the maximum values of horizontal velocities were noted at the stations of Aghdam, Lerik, Lankaran, Djalilabad, Fizuli and Saatly, and the average value of velocities throughout the republic was 7.3 mm/year. In 2021, the average velocity across the entire territory of the republic was 7.6 mm/year. The maximum velocities were noted at Yardimly (12.2 mm/year), Lankaran (13.1 mm/year), and Saatly (12.3 mm/year) stations.

Along the Kura depression in the direction from the Middle Kura depression to the Lower Kura depression (i.e. from NW to SE), a gradual increase in the rates of horizontal movements from 7.3 to 11.3 mm/year is observed, which is characterized by the condition of compression. In the direction from the Talysh region to the Absheron Peninsula (SW-NE direction), there is a noticeable decrease in the northern component of displacement velocities compared to high values

of points located in the southwestern part of the selected profile (LKRG_GPS=13.8 mm/year; LRK_GPS=12.5 mm/year; GLBG_GPS = 12.3 mm/year; YRDG_GPS = 12.7 mm/year).

Considering the above, we have identified several tectonic blocks that differ in the value of horizontal movement velocities: the Artvin Karabakh megazone of the Lesser Caucasus, the Middle Kura megazone, the megazone of the Southern Slope of the Greater Caucasus, and the Talysh megazone. The average value of the mega zone of the Southern slope of the Greater Caucasus varies within 4.2-5.4 mm/year. The Middle Kura megazone is characterized by the values of 8.85 mm/year.

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