DOI: https://doi.org/10.59849/2219-6641.2023.2.33

SEISMOGEODYNAMICS OF THE GREATER CAUCASUS FROM GNSS DATA

G.J. Yetirmishli[1], I.E. Kazimov[1], A.F. Kazimova[1]

ABSTRACT

The article provides an analysis of modern seismogeodynamics of the Azerbaijan part of the Greater Caucasus. The purpose of the research was to reveal how complex geodynamic processes are reflected in the spatial and temporal distribution of strong earthquakes in the territory of the Azerbaijan part of the Greater Caucasus. For this purpose, GPS and seismological data for the period 2012-2022 were considered. The main tasks were to analyze the strong earthquakes that occurred in the territory under consideration, analyze the data on the velocities of horizontal movements obtained from the data of the GPS network of RSSC stations, and also make a correlation between these data. The velocity field clearly illustrates the movement of the earth's surface in a north-northeast direction. This phenomenon reflects the process of successive accumulation of elastic deformations in the zone of subduction interaction of the structures of the northern side of the South Caucasian microplate (Vandam-Gobustan megazone) with the accretionary prism of the Greater Caucasus. Comparing the seismic data with the data of GPS stations, it can be seen that with the gradual immersion of the seismogenic layer, the velocities increase. At SATG and ALIG stations, the data increase to 10-11 mm/g. It can be noted that the change in the values of horizontal movements on the territory of the Zakatalo-Balakan, Oguz-Gabala seismogenic zones is associated with the movement of layers (blocks) of the earth's crust at a depth of 5-20-40 km. In the Sheki seismogenic zone 2-30 km, in the Shamakhi-Ismayilli zone 5-45 km, and in the Hajigabul seismogenic zone 5-55 km.

Key words: GPS stations, seismogenic layer, seismic geodynamics of the Azerbaijan part of the Greater Caucasus.

QLOBAL NAVİQASİYA PEYK SİSTEMİNİN MƏLUMATLARINA GÖRƏ BÖYÜK QAFQAZIN SEYSMOGEODİNAMİKASI

Yetirmişli Q.C., Kazımov İ.E. Kazımova A.F.

ANNOTASİYA

Məqalədə Böyük Qafqazın Azərbaycan hissəsinin müasir seysmogeodinamikası təhlil edilir. Tədqiqatın məqsədi Böyük Qafqaz ərazisində güclü zəlzələlərin fəza-zaman paylanmasında mürəkkəb geodinamik proseslərin necə əks olunduğunu aşkar etmək idi. Bu məqsədlə 2012-2022-ci illər üçün GPS və seysmoloji məlumatlar nəzərdən keçirilmişdir. Əsas məsələlər nəzərdən keçirilən ərazidə baş vermiş güclü zəlzələlərin təhlili, RSXM-nin stansiyalarının GPS şəbəkəsinin məlumatlarından alınan üfüqi hərəkətlərin sürətləri haqqında məlumatların təhlili, həmçinin bu məlumatlar arasında korrelyasiyanın yaradılması olmuşdur. Sürət sahəsi yer səthinin şimal-şimal-şərq istiqamətində hərəkətini aydın şəkildə göstərir. Bu hadisə Cənubi Qafqaz mikroplitəsinin şimal tərəfi strukturlarının (Vandam-Qobustan meqazonu) Böyük Qafqazın akkresiya prizması ilə üstəgəlmə qarşılıqlı əlaqəsi zonasında elastik deformasiyaların ardıcıl toplanması prosesini əks etdirir. Seysmik məlumatları GPS stansiyalarının məlumatları ilə müqayisə etdikdə görmək olar ki, seysmogen təbəqənin tədricən batırılması ilə sürətlər artır. SATG və ALIG stansiyalarında məlumat 10-11 mm/il qədər artır. Qeyd etmək olar ki, Zaqatala-Balakən, Oğuz-Qəbələ seysmogen zonaları ərazisində üfüqi hərəkətlərin qiymətlərinin dəyişməsi Yer qabığının 5-20 dərinlikdə təbəqələrinin (bloklarının) yerdəyişməsi ilə əlaqədardır, Şəki seysmogen zonasında 2-30 km, Şamaxı-İsmayıllı zonasında 5-45 km, Hacıqabul seysmogen zonasında 5-55 km.

Açar sözlər: GPS stansiyaları, seysmogen təbəqə, Böyük Qafqazın Azərbaycan hissəsinin seysmik geodinamikası.

[1] *Republican Seismic Survey Center of Azerbaijan National Academy of Sciences*

СЕЙСМОГЕОДИНАМИКА БОЛЬШОГО КАВКАЗА ПО ДАННЫМ ГЛОБАЛЬНОЙ НАВИГАЦИОННОЙ СПУТНИКОВОЙ СИСТЕМЫ

Етирмишли Г.Дж., Казымов И.Э., Казымова А.Ф.

Аннотация

В статье приводится анализ современной сейсмогеодинамики Азербайджанской части Большого Кавказа. Целью исследований являлось выявить, как отражаются сложные геодинамические процессы в пространственно-временном распределении сильных землетрясений на территории Азербайджанской части Большого Кавказа. Для этой цели рассматривался GPS и сейсмологические данные за период 2012-2022. Основными задачами было провести анализ сильных землетрясений, произошедших на рассматриваемой территории, проанализировать данные скоростей горизонтальных движений, полученных по данным сети GPS станций РЦСС, а также провести корреляцию между этими данными. Поле скоростей чётко иллюстрирует движение земной поверхности в север-северо-восточном направлении. Данное явление отражает процесс последовательного накопления упругих деформаций в зоне надвигового взаимодействия структур северного борта Южно-Кавказской микроплиты (Вандам-Гобустанская мегазона) с аккреционной призмой Большого Кавказа. Сопоставляя сейсмические данные с данными GPS станций видно, что с постепенным погружением сейсмогенерирующего слоя значения скоростей увеличиваются. На станциях SATG и ALIG данные увеличиваются до 10-11 мм/г. Можно отметить, что изменение значений горизонтальных движений на территории Закатало-Балаканской, Огуз-Габалинской сейсмогенных зон связано с подвижкой слоев (блоков) земной коры на глубине 5-20-40 км. В Шекинской сейсмогенной зоне 2-30 км, в Шамахы-Исмаиллинской - 5-45 км, и в Гаджигабульской сейсмогенной зоне 5-55 км.

Ключевые слова: GPS станции, сейсмогенерирующий слой, сейсмогеодинамика Азербайджанской части Большого Кавказа.

Introduction

To address the issues of the contribution of internal processes in the lithosphere to the latest and modern geodynamics of the region, there is also a lack of modern data on the deep structure of the earth's crust and upper mantle. As is known, the Azerbaijan part of the Greater Caucasus is the most geodynamical active region. Previous studies of Alpine folding and orogeny, in particular, quantitative estimates of the horizontal shortening of the surface, were based mainly on abstract ideas about folding and mountain building as a result of the collision of the Eurasian and Arabian lithospheric plates [16].

The question of the deep structure of the zones of large faults in the earth's crust is also relevant. The issue of flattening of tectonic faults with depth, the separation of the sedimentary cover from the surface of the crystalline basement, and, as a result of these processes in the zone of plate collision, the folding and orogeny [11] are often discussed in the literature.

Modern methods of space geodesy: satellite laser distance measurements (SLR), long-baseline interferometry (VLBI), and, above all, satellite-based global positioning system (GPS) have become widely used in geodynamic studies on a global and regional scale. These measurements make it possible to determine the velocities of the horizontal movement of lithospheric plates in general and the displacement velocities of numerous geodesic points in tectonically active zones with errors much smaller than the measured velocities themselves [18].

The active modern convergence of the Eurasian and African-Arabian lithospheric plates is well known. But direct geodetic measurements show that centrifugal displacements of overthrusts and shifts continue to this day. The evidence for this is the strong Turkish earthquake that occurred on February 6, 2023. The areas of modern extension correspond to the areas of Neogene-Quaternary normal faults and grabens in superimposed troughs, while the areas of modern compression correspond to the zones of Jurassic Cretaceous, Neogene Quaternary thrusts and covers. This means that the distribution of types of modern horizontal movements corresponds to the distribution of those in the indicated geological time intervals.

Thus, our conclusion about the modern expansion of the segments of the mobile belt is also valid for previous intervals of geological history. In this work, we set the goal of revealing how complex geodynamic processes are reflected in the spatial and temporal distribution of strong earthquakes in the territory of the Azerbaijan part of the Greater Caucasus. For this purpose, GPS and seismological data for the period 2012-2022 were considered.

Seismological data.

Seismic activity is associated with the ongoing intensive restructuring of the structural plan with significant amplitudes of recent and modern movements: earthquake sources, as a rule, are confined to the boundaries of large geotectonic elements of the earth's crust and the intersection nodes of faults of various directions.

The geology of the territory of Azerbaijan has been studied since the end of the 19th century, and over the past period a huge amount of actual geological and geophysical material has been accumulated, on the basis of which various geological and tectonic models of the environment, based mainly on the fixist ideology, have been developed in different years. In this context, the changes in views on the structure of the earth's crust of the Caucasus and the Caspian water area that took place in the last quarter of the 20th and early 21st centuries from the atonalistic positions with the adoption of the concept of the underthrust-thrust mechanism of the formation of their alpine structure are of particular importance. In particular, on the territory of Azerbaijan, a significant amount of productive information has been accumulated on ground geological survey, deep geological mapping of land and sea territories by methods of zoning geophysical fields, as well as deep drilling and remote sensing.

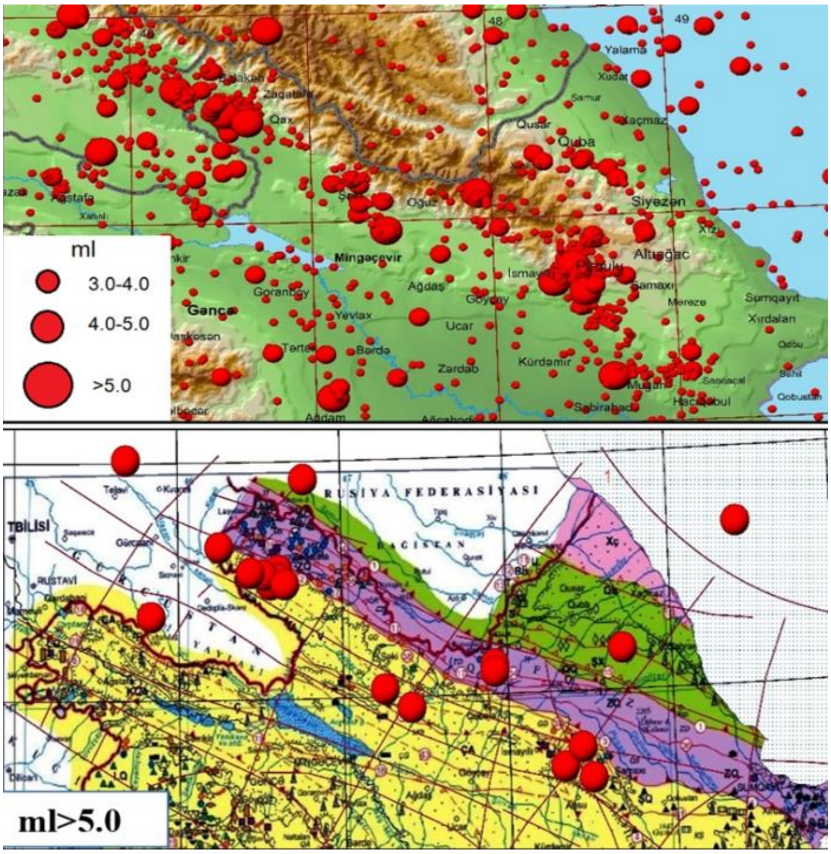

Fig.1. Maps of earthquake epicenters for the period 2003-2022 with ml< 3.0 and ml>5.0 geological map comp. [12]

In the last decade, significant progress has been made in research related to the interaction of faults and how the occurrence of an earthquake perturbs the stress field in its vicinity, which can cause aftershocks and subsequent earthquakes. These studies are of great importance for assessing the seismic hazard of the region, since voltage changes can either delay or accelerate the occurrence of future earthquakes. In addition, since the seismic hazard assessment depends on the destruction parameters of past earthquakes, it is important to reliably estimate such parameters, rupture location, geometry and extent of past earthquakes [13].

It should be noted that since 2012, a number of strong earthquakes with Ml≥5.0 have been occurring on the territory of the republic. In 2012 and, after some lull, in 2014-2018 a series of strong earthquakes occurred here: Zagatala on May 7, 2012 with Ml=5.6, 5.7, Balakan on October 14, 2012 with Ml=5.8, which were felt in the epicenter with J0=7 b.; Ismailli 07.10.2012 with Ml=5.3; Caspian 10.01.2014 with Ml=5.0, Ajigabul 10.02.2014 with Ml=5.8, Zagatala 29.06.2014 with Ml=5.3, Gabala series 29.09 and 04.10.2014 with Mlmax=5.5; as well as Okhuz on September 4, 2015 with Ml=5.9, Imishli on August 1, 2016 with Ml=5.6, Lerik on August 28, 2018 with Ml=5, etc (fig.1). The intensity of shaking in some of them at the epicenter reached 7 points. An analysis of the spatial distribution of epicenters shows that most of the sources of perceptible earthquakes are located in the zone of the junction of the Kura depression and the southeastern subsidence of the Greater Caucasus or the activation of the southern side of the Kura depression in the zone of transition to the fold system of the Lesser Caucasus [1].

From a tectonic point of view, the modern structure of the Caucasus was formed at the Alpine stage of tectogenesis within the spatial limits covering the southern edge of the Eurasian continent and the northern edge of the South Azerbaijan segment of the Central Iranian microcontinent (microplates, quasi-platforms). In the structure of the eastern, Azerbaijani part of the Caucasus, the decisive role belongs to the following megastructures (from north to south): the North Caucasian microplate, the southern slope trough, the South Caucasian microplate, the South Azerbaijan segment-fragment of the Central Iranian microcontinent, and the Caspian megadepression [4]. As seen in figure strong earthquakes with a magnitude above 5 occurred mainly at the junction of the accretionary prism of the Greater Caucasus with the South Caucasian microplate.

Seismological and paleoseismotectonic studies, seismic and seismotectonic zoning, carried out in various seismic regions of the Caucasus (including the territory of Azerbaijan), confirm the version of the controllability of earthquake source areas by a network of faults of general Caucasian and anti-Caucasian strike with various types of displacement [4]. However, in general, the cause of modern seismic activity is the horizontal movements of different-scale tectonic blocks of the earth's crust, sandwiched in the band of collisional interaction between the Afro-Arabian and Eurasian continental plates.

Analysis of satellite navigation system (GPS) data

Reliable information on the achieved accuracy in determining the annual displacement rates of permanent stations can be obtained from the materials contained in the ITRF data system "International Earth Reference System" for the Earth as a whole and for its European part, that the average error of the ITRF network for the horizontal displacement components is 0.7 and 1.5 mm/year for vertical components [18]. According to the analysis of the European network of permanent stations, which includes 30 sites, the error of the horizontal component for the most stable stations was 0.2 mm/year.

The ITRF system is a catalog that uses as input data time series of station positions and Earth orientation parameters (EOP) provided by the technical centers of four space geodetic methods (VLBI, SLR, GNSS and DORIS) [19]. Comparison of data for ITRF97 and ITRF2014 showed the coordinates of geodetic observation stations, selected in accordance with the accuracy of determining their coordinates and the stability of the position. For these stations, annual values of coordinate changes are given. Station movement velocities are represented in most cases by latitudinal, longitude and vertical velocity components on the reference ellipsoid, best fitted to the geoid figure and used in the processing of geodetic measurements. The velocity vectors defined in the ITRF system are “absolute” vectors in the sense that their direction is set relative to the geodetic coordinate grid fixed on the Earth’s body by ITRF stations [18]. The origin of the coordinate system coincides with the center of mass, the position of which is determined using the satellites Lageos1 and Lageos2, which rotate in orbits at an altitude of about 6000 kilometers. According to Kepler's laws, the satellite revolves around the planet in an elliptical orbit, and the center of mass of the planet is located at one of the foci of the orbit. As established using SLR, the position of the center of mass changed during 1993–2003 by ±0.6 mm for the equatorial and ±1.8 mm for the polar component [2].

GPS instruments have been successfully used for a number of years to monitor changes in the earth's surface due to geodynamic processes, as described above. High-precision GPS measurements of almost any line are carried out on the basis of the differential method using the so-called GPS base stations (this method is also called the relative kinematics method). In this case, during measurements, one base station of the satellite receiver is constantly located at a point with known coordinates, and the other moves, fixing the position of the points being taken. The analysis of GPS station data was carried out using the GAMIT/GLOBK program version 10.71. [7]

GPS data were processed and errors estimated using MIT's GAMIT software [7] following the procedure described in [8, 9]. To estimate the speeds of the determined stations, it is necessary to have at least one reference point in the network, and preferably several. GNSS for geodynamics, **YIBL**_OMAN, **SOFI**_BULGARIA, **ANKR**_TURCIYA, **ARTU**_RUSSIAN, **NICO**_CYPRUS, **NOT1**_ITALY, **POL2**_KYRGYZTAN, **POLV**_UKRAINE, **TEHN**_IRAN, **MDVJ**_RUSSIAN, **DRAG**_ISRAEL,**RAMO**_ISRAEL, **SOFI**_BULGARIA, **BUCU**_ROMANIA, **ISTA**_TURKEY, **GLSV**_UKRAINE [3]. The height cutoff angle was taken as 10°.

Taking into account geomorphology, geotectonics, relief and taking into account the influence of external factors, in 2012 the Republican Center installed a network of 24 stationary GPS stations in Azerbaijan. A set of 24 GPS stations cover the vast territory of Azerbaijan and form the GPS_RCSS geodetic network (fig.2). Note that the stations are equipped with Choke Ring model antennas, the number of installed stations of this model is 10, Zephyr Geodetic2-14 and TrimbleNetR9-24 receivers (USA), which record the signal of the corresponding GPS and GLONASS satellites [9]. The formed geodetic network allows solving regional problems of studying the main patterns of modern movements of the earth's crust in the territory of Azerbaijan. It should be noted that for the first time in the world on the territory of the Republic of Azerbaijan in the Saatli region, a GPS station was installed on the Saatli super-deep well (8324 meters) SG-1.

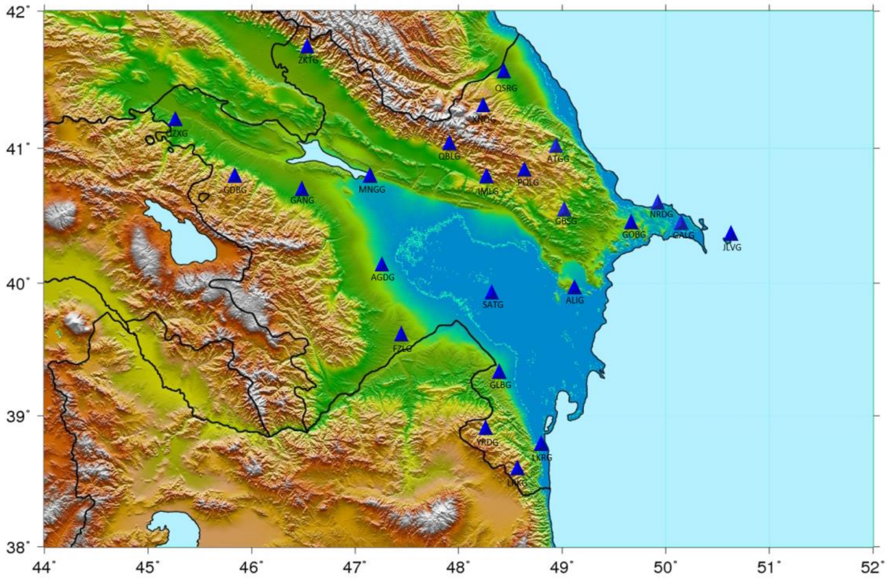

Fig. 2. Network of GPS stations of RSSC

Correlation of seismological activity with satellite navigation data.

As a result of research carried out by the Department of Geodynamics of the RSSC at ANAS, the field of velocities of modern motions throughout the entire territory of the republic was obtained. The velocities of modern movements were estimated based on the results of measurements at 24 stationary GPS stations of the RSSC. The accuracy of determining the coordinates is within 1–3 mm per day. The coordinates of the reference stations of the IGS network used in the analysis are characterized by the same accuracy.

An analysis of the distribution of horizontal displacement rates showed that there is a stable orientation of the velocity vectors (2–15 mm/year) both in the NE direction, typical for the territory of the Arabian Plate, and in the N-E direction, typical for the southeastern part of the Lesser Caucasus.

These data confirm the existing ideas about the northern drift of the Arabian lithospheric plate. The shift to the NE is probably due to the thrust structure located in the Jurassic rocks and dipping to the north (fig.3). The ENE direction of the velocity vectors of horizontal displacements within the Gobustan and Absheron regions (points GBSG, GOBG, GALG, NDRG) most likely indicates that the influence of the northern drift of the Arabian Plate is little felt here.

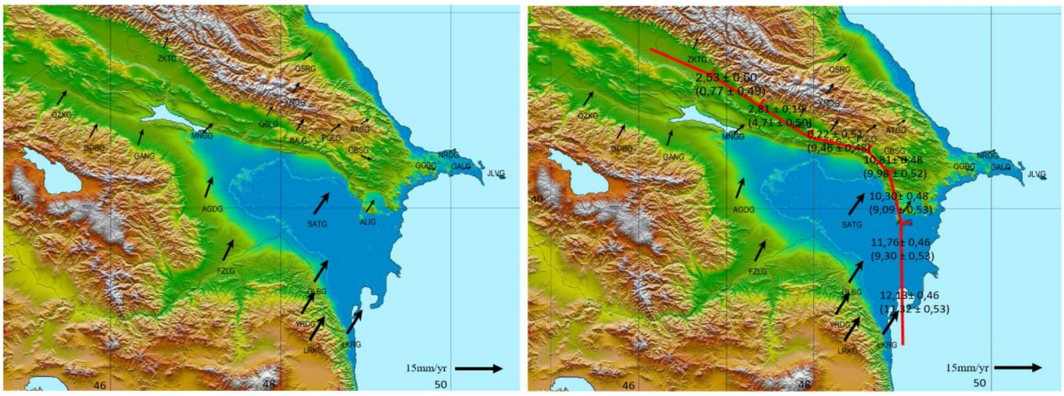

Fig. 3. Horizontal velocity vector map for 2014-2022 and fault velocities (mm/yr) obtained from the block model.

The process of formation of the fold-cover tectonic structure of the territory of the Republic of Azerbaijan is explained within the framework of geodynamic models developed for the Mediterranean fold-charge belt and based on the primacy of tangential forces and underthrust mechanism during the formation of modern orogens [10-11]. This is indicated by the scaly-thrust structure of both the Precambrian-Paleozoic basement and the Alpine cover of all the main tectonic zones, which indicates the existence of vast sea basins in the Caucasus region, which were transformed as a result of the Hercynian, Cimmerian and Alpine cycles of tectogenesis into narrow zones of general collapse of rocks or into ophiolite suture belts [12, 15].

It has been established that along the Kura depression in the direction from the Middle Kura depression to the Low 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 compression condition. It should be noted that in the last 3 years the zone of the Low Kura depression is characterized by the manifestation of high seismic activity, expressed in several earthquakes with a magnitude greater than M> 5ml, characterized by a reverse-type movement [5]. 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/yr, and further north, i.e. directly within the accretionary prism, and completely decreases to 3.5-5 mm / yr. In general, the tangential shortening of the earth's crust in the region is estimated at 6.1-11 mm/yr (fig.4).

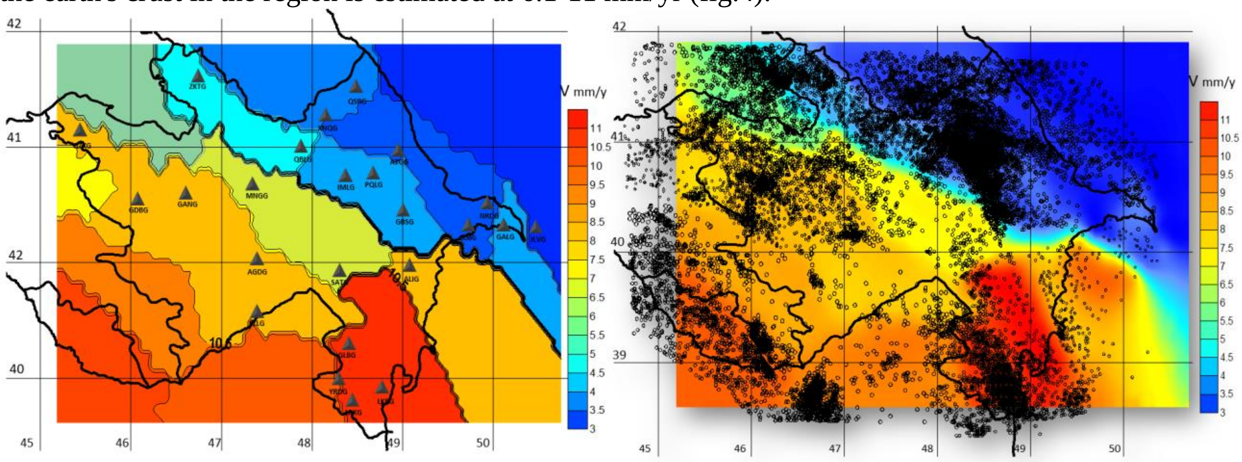

Fig.4. Velocity map of horizontal movements according to GPS stations for 2014-2022 and epicenters of earthquakes for 2003-2022

It should be noted that the regional patterns of neotectonics and modern geodynamic development and landforms of the Caucasus region can be considered as a result of mechanical impacts on it of adjacent geodynamical active areas. It is interesting to note that the rate of modern vertical movements of the QBLG, ZKTG, QSRG, and XNQG GPS points 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). Consequently, wave-like deformations are not linear, and this determined all the main features of the neotectonics of the region.

The revealed heterogeneous nature of the velocity field of the region allows us to state the block model of the structure of the region, which is closest to the real one. A similar conclusion about the block structure was also obtained for other regions [14]. It was found that in the Guba-Gusar region in the direction NW-SE, a block with velocities of 5.8 mm/g with a length of 55 km is distinguished.

At the GPS stations Nardaran "NRDG", Gobu "QOBG", Gala "GALG" and Zhiloiy Island "JLVG", which are part of the Apsheron zone, almost similar values of horizontal displacement velocities (3.8, 4.9, 4.1 and 3.2 mm/ year respectively). In the direction from the Talysh region to the Apsheron Peninsula (southwest–northeast 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/yr, LRKG_GPS=12.5 mm/year, GLBG_GPS=12.3 mm/yr, YRDG_GPS=12.7 mm/yr). It should be noted a noticeable increase in the azimuthal angles of the Apsheron stations, indicating a clockwise movement in the east–southeast direction up to 88°.

Earthquakes with a magnitude greater than ml>2 were analyzed based on the earthquake catalog data of the RCSS Bureau of Earthquake Research. A deep section of the distribution of magnitudes along the Greater Caucasus was built in order to identify the seismogenic layer of the earth's crust. As seen in fig. This layer in the territory of Georgia and the Belokan region is distributed at a depth of up to 40 km, further in the direction of the Zagatala region, the depth decreases to 20 km, and starting from the Sheki region, a gradual subsidence towards the Caspian Sea is observed. Against the general background of earthquakes, zones of maximum magnitudes are distinguished, corresponding to the Zagatala-Balakan, Oguz-Gabala, Shamakhi-Ismayilli and Hajigabul seismogenic zones (fig.5).

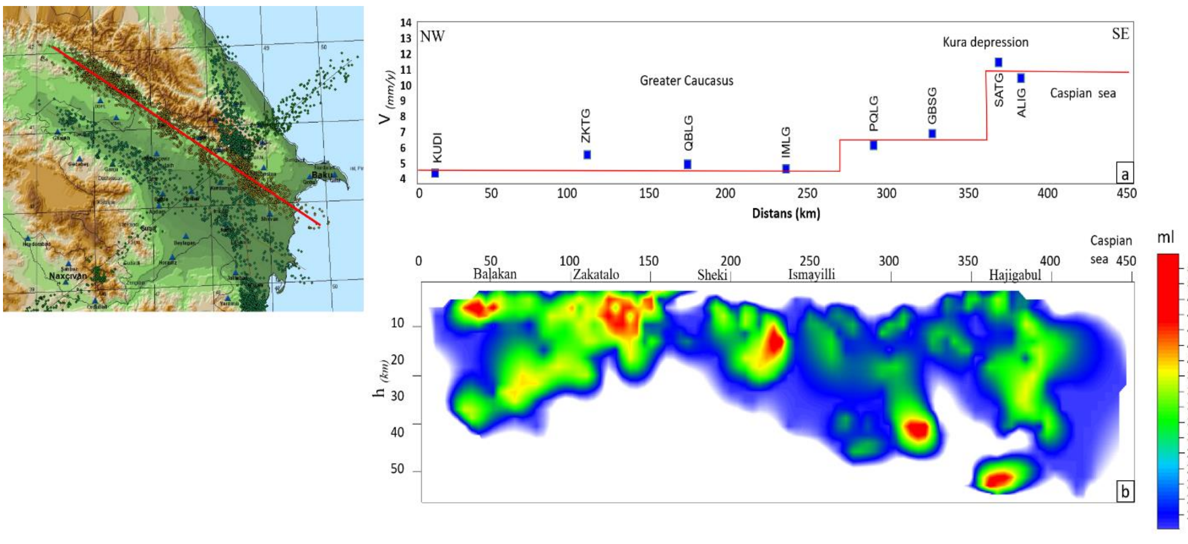

Fig.5. Velocity profile according to GPS data (a) and depth distribution of earthquake magnitudes along profile 1-1 (b)

Comparing the seismic data with the data of GPS stations, it can be seen that with the gradual immersion of the seismogenic layer, the velocities increase. At SATG and ALIG stations, the data increase to 10-11 mm/yr. It can be noted that the change in the values of horizontal movements on the territory of the Zakatalo-Balakan, Oguz-Gabala seismogenic zones is associated with the movement of layers (blocks) of the earth's crust at a depth of 5-20-40 km. In the Sheki seismogenic zone 2-30 km, in the Shamakhi-Ismayilli zone 5-45 km, and in the Hajigabul seismogenic zone 5-55 km [5-6].

In the zone of the West Caspian Fault, at depths from 5 to 35 km, a block boundary is distinguished with velocities of 7.25 mm/yr. On the eastern side of this block, a block is distinguished at depths of 10–25 km with values of 9 mm/yr.

Conclusions.

Thus, the global positioning system (GPS) has provided a new opportunity for direct observation of modern movements and deformations of the earth's crust.

Comparison of the obtained results 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 motion rates, which allows us to delineate this region with average horizontal motion rates of 11.6 mm/year.

The velocity field clearly illustrates the movement of the earth's surface in a north-northeast direction. This phenomenon reflects the process of successive accumulation of elastic deformations in the zone of subduction interaction of 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 speed 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.

Comparing the seismic data with the data of GPS stations, it can be seen that with the gradual immersion of the seismogenic layer, the velocities increase. At SATG and ALIG stations, the data increase to 10-11 mm/g. It can be noted that the change in the values of horizontal movements on the territory of the Zakatala-Balakan, Oghuz-Gabala seismogenic zones is associated with the movement of layers (blocks) of the earth's crust at a depth of 5-20-40 km. In the Sheki seismogenic zone 2-30 km, in the Shamakhi-Ismailli zone - 5-45 km, and in the Hajigabul seismogenic zone 5-55 km.

Preliminary data on the comparison of velocity vectors of GPS points with the structure of the Earth's crust of the Greater Caucasus shows that within the projections of these blocks, the directions of velocity vectors are quite consistent. This makes it possible to formulate as an urgent task the search for the relationship between deep sources of tectonic stresses and their possible connection with near-surface geodynamics and seismic regime, which could become the basis of geoecological zoning.

Data on the velocities of vertical and horizontal displacements of individual blocks within various seismogenic zones of the Greater Caucasus, in addition to scientific, are of practical importance, since with their help it will be possible to choose safe places within the BC for the construction of hotels, camp sites, small hydroelectric power stations, cable lifts, roads and railways [17]. In addition, the analysis of available GPS data showed that it is necessary to continue these measurements in the Caucasus, which will increase the accuracy of the results obtained, for which it is necessary to thicken the existing network of points and, as a result, obtain a more detailed picture of the distribution of modern movements.

REFERENCES

1. Babayev G., Yetirmishli G., Kazimova S., Kadirov F., Telesca L. Stress field pattern in the Northeastern part of Azerbaijan // Pure and Applied Geophysics, on-line, 201
2. Chavet X., Valette J., Feissel) Vernier M. Analysis of Geo" center Time Series derived from SLR, GPS, DORIS. Am. Geophys. Union. Fall Meeting, 8–12 Dec, San Fran" cisco. 2003. P. 1–4.

3. Herring T.A. GLOBK: Global Kalman filter VLBI and GPS analysis program version 4.1. Cambridge, MA: Massachu setts Institute of Technology. 2004
4. Kangarli T.N., Kadirov F.A., Yetirmishli G.J., Aliyev F.A., Kazimova S.E., Aliyev A.M., et al. Recent geodynamics, active faults and earthquake focal mechanisms of the zone of pseudosubduction interaction between the Northern and Southern Caucasus microplates in the southern slope of the Greater Caucasus (Azerbaijan) // Geodynamics & Tectonophysics. – 2018. – T. 9, № 4. – P. 1099–1126.
5. Kazimov I.E. Geodynamics of the territory of Azerbaijan on the basıs of GPS data in 2017–2019 yy // Геология и Геофизика Юга России. – 2021. – Т. 11, № 2. – С. 51–61. doi:10.46698/VNC.2021.47.92.004. EDN: WTROIW
6. Kazimov I.E., Kazimova A.F. Modern geodynamics of Azerbaijan on GPS station data for 2017-2018 years // Seismoprognosis observations in the territory of Azerbaijan. – 2019. – V. 16, N 1. – P. 35–42.
7. King R.W., Herring T.A., Floyd M.A., McClusky S.C. GAMIT/GLOBK Overview [Электронный ресурс]. – URL: http://geoweb.mit.edu/~floyd/courses/gg/201807, Bishkek, 2018.
8. Ulomov V.I., Danilova T.I., Medvedeva N.S., Polyakova T.P. (2006). Seismogeodynamics of lineament structures in the mountainous regions bordering the Scythian-Turan plate. Izvestiya, Physics of the Solid Earth, 42(7), 551-566. doi:10.1134/S1069351306070032. EDN: LJRSKJ
9. Yetirmishli G.J., Kazimov I.E., Kazimova A.F. Contemporary geodynamics of the Eastern Mediterranean // Seismoprognosis observations in the territory of Azerbaijan. – 2021. – V. 20, N 2. – P. 3–10.
10. ГУРБАНОВ А.Г., МИЛЮКОВ В.К. и др. Оценка векторов скорости современных горизонтальных и вертикальных смещений литосферных блоков на территории Большого Кавказа и их геодинамическая интерпретация (по данным ГНСС), Вестник Владикавказского научного центра, Т 23, №1, 2023, с. 49-61
11. Дотдуев С.И. О покровном строении Большого Кавказа // Геотектоника. 1986. № 5. С. 94–106.
12. Кенгерли Т.Н., Особенности геолого-тектонического строения юго-восточного Кавказа и вопросы нефтегазоносности, Elmi əsərlər, №9, Гос. Нефт. Компания Респ. Азербайджан, 2007 г., с. 3-12.
13. Коновалов А.В. Система алгоритмов для определения параметров слабых землетрясений по записям цифровых сейсмических станций на примере юга Сахалина, Док. Диссертация, 2006, 79 с.
14. Костюк А.Д., Сычева Н.А., Юнга С.Л., Богомолов Л.М., Яги Ю. Деформация земной коры Северного ТяньШаня по данным очагов землетрясений и космической геодезии // Физика Земли. 2010. No 3. С. 52–65
15. Рзаев А.Г., Етирмишли Г.Дж, Казымова С.Э., Отражение геодинамического режима в вариациях напряженности геомагнитного поля (на примере южного склона Большого Кавказа) Известия, Науки о Земле. Баку 2013, № 4., с. 3-15
16. Рогожин Е.А., Горбатиков А.В., Степанова М.Ю., Овсюченко А.Н. и др. Структура и современная геодинамика мегантиклинория Большого Кавказа в свете новых данных о глубинном строении, геотектоника, 2015, № 2, с. 36–49
17. Стогний В.В., Заалишвили В.Б., Пономарева Н.Л. Современная геодинамика и сейсмичность Северного Кавказа: проблемы мониторинга, Geology and Geophysics of Russian South 12 (2) 2022, с. 34-52
18. Шевченко В.И., Лукк А.А., Прилепин М.Т., Рейлинджер Р.Е. Современная геодинамика средиземноморской–малокавказской части альпийско-индонезийского подвижного пояса, 2014 г., Физика земли, 2014, № 1, с. 40–58
19. https://itrf.ign.fr/en/solutions/ITRF2020