REPUBLIC OF AZERBAIJAN

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ABSTRACT

of the dissertation submitted for the
degree of Doctor of Philosophy

STRUCTURAL ANALYSIS OF CONTEMPORARY HORIZONTAL VELOCITIES AND STRAINS OF THE EARTH'S CRUST OF THE TERRITORY OF AZERBAIJAN

Specialty: 2507.01 - Geophysics, methods of geophysical exploration of minerals

Field of science: Earth sciences

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GENERAL CHARACTERISTICS OF THE WORK

Relevance and processing degree of the topic:

The contemporary geodynamic state of the territory of Azerbaijan is determined by the interaction of Arabian and Eurasian plates within the framework of plate tectonics. Space geodesy GPS (Global Positioning System) method is a modern method used in the world to study the interaction of plates and the strains resulting from this and to track horizontal movements in the lithosphere (J.T.Freymueller, T.A.Herring, Ch.Reigber, R.E.Reilinger, Floyd M., Vernant Ph., S.McClusky, F.Kadirov, R.King, A.Barka and others). Over the past 25 years, the application of space geodesy GPS method has created opportunities to measure the contemporary movement velocities of lithosphere plates and the strains at the contact boundaries of plates with high accuracy, at the same time to verify a large number of hypotheses about plate interactions[1, 2, 3, 4, 5, 6, 7]. Contemporary GPS velocity data not only allows the verification of many theoretical tectonic considerations, but also contributes to the investigation of the main point of the strains that occur during the contemporary development of the Earth's crust.

The study of the regularities of dislocations and strains happened in the Earth's crust within the plates is of great importance in clarifying

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[1] Herring T.A.Geodetic Applications of GPS.Proceedings of the IEEE, Vol. 87, No. 1, January 1999

[2] Kadirov F.A., Floyd M., Reilinger R., Alizadeh A. et al. Active geodynamics of the Caucasus region: implications for earthquake hazards in Azerbaijan // Proceedings of Azerbaijan National Academy of Sciences, The Sciences of Earth, - 2015. - vol. 3, - p.3-17.

[3] McKenzie, D.P. Davies D., Molnar P. Plate Tectonics of the Red Sea and East Africa // Published Nature, - 1970. April18. - vol. 226, - p. 243-248.

[4] McQuarrie N., Stock J., Verdel C. and Wernicke B.P. Cenozoic evolution of Neotethys and implications for the causes of plate motions // Geophys. Res. Lett., - 2003. - p.1-4.

[5] Freymueller, J.T., M.H. Murray, P. Segall, and D. Castillo, 1999, Kinematics of thePacific-North America plate boundary zone, northern California, J. Geophys. Res., 104, 7419-7441.

[6] Reilinger R., McClusky S., Vernant P. et al. GPS constraints on continental deformation in the Africa-Arabia-Eurasia continental collision zone and implications for the dynamics of plate interactions // Journal of Geophysical Research: Solid Earth (1978-2012), - 2006. - vol.111, - p. 1-26.

[7] Vernant Ph., Nilforoushan F., Hatzfeld D.et al. Present-day crustal deformation and plate kinematics in the Middle East constrained by GPS measurements in Iran and northern Oman // Geophysical Journal International, - 2004. April. - vol.157, Issue1. - p. 381-398.

the nature of geological processes (earthquakes, eruption of mud volcanoes, landslides, etc.) and is one of the topical issues of geophysics. One of the topical issues that need to be clarified from this point of view is the identification of different geodynamic areas in the structure of spatial distribution of GPS horizontal velocities of the lithosphere in the territory of Azerbaijan, which forms the eastern part of the Caucasus block, modeling the interaction of blocks and identifying small plate interior areas ("domains"). Besides GPS measurements, other field data is also used to solve the problem.

Research aims and objectives:

The aim of the dissertation is to conduct a structural analysis of the spatial distribution of contemporary horizontal velocities of the Earth's surface obtained from new measurement data in the Azerbaijan GPS network, to identify the small plate interior domains, which are distinguished by their individual kinematic features and to research the correlation of the area by its tectonic elements, gravitational anomalies and seismicity.

The following issues have been solved to achieve the aims:

- Conducting periodic measurements, collection and processing of database at the Azerbaijan GPS polygon;

- Calculation of the velocity field of GPS contemporary horizontal movements of Azerbaijan and neighboring areas (2000-2017), preparation of distribution maps of GPS velocity vectors, its Northern (VN) and Eastern (VE) components;

- Identification of areas with different geodynamic regimes and theoretical calculation of horizontal velocities for GPS points, which are located here, based on the model of block interaction;

- Creating digital 3D geological model of the Earth's surface, basalt and Mokhorovichich borders in the Caucasus region (Azerbaijan) with GOCAD and Abaqus software;

- Compilation of a map of stress distribution in Azerbaijan and neighboring areas according to the mechanisms of earthquake focuses with magnitude Mw ≥5 during 1990-2017 using the CASMO method (World Stress Map);

- Structural analysis of GPS velocity distribution in the territory of Azerbaijan, identification of domains with different GPS velocity and geophysical field characteristics and their comparative analysis with tectonic structures;

- Construction of distance dependence graphs of VN and VE components of GPS velocity vectors on selected profiles and study of kinematics of defined domains;

- Correlation of domains, which are distinguished by different characteristics, in the GPS velocity field with local gravitational anomalies and their geological interpretation.

Research methods:

The following research methods were used in the dissertation:

- The method of Space geodesy (GPS) was used to study contemporary movements in the Earth's crust;

- The data obtained by GPS method was processed by GAMIT/GLOBK software package developed by Massachusetts Institute of Technology;

- TDEFNODE – Fortran program for modeling the rotation of elastic lithosphere blocks;

- Stress and strain state of the Caucasus region (Azerbaijan) was investigated by using Abaqus^{TM} and "World Stress Map" programs;

- The distribution map of the earthquake counts was compiled by the sliding window technique;

- Generic Mapping Tools (GMT) and SURFER programs were used to compile the maps.

The key points of the defense:

1.Movement of the Lower Kura, Gobustan and Absheron structural areas in the direction of NE in accordance with the kinematics of the South Caspian block under the influence of the Iranian plate

2. Plate interior "domains", which are separated by a complex approach, in a new field of discrete GPS velocity and their correlation with the area of local gravitational anomalies in the territory of Azerbaijan based on the data of 2000-2017.

Scientific innovation of the research:

The following scientific innovations were obtained by a comprehensive comparative study of stress and gravitational anomalies using GPS measurement and seismic monitoring data in Azerbaijan and neighboring areas, topographies of the Earth's surface, Mokhorovich and Basalt geological surfaces and mechanisms of earthquake focuses:

1. Taking into account the new GPS measuring points of Azerbaijan, which is the eastern part of the Caucasus block, the parameters of contemporary horizontal movements were determined on the basis of the monitoring results of 2000-2017.

2. It was determined that Lower Kura, Gobustan and Absheron structural zones in the east of the Western Caspian fault are moving clockwise together with the South Caspian block under the influence of the Iranian plate.

3. A map of the distribution of the earthquakes counts for Azerbaijan and neighboring areas was compiled and it was determined that the maximum value of GPS velocity vectors belongs to the areas where both the direction and the value change.

4. It was noted that the direction of the horizontal stress vector (σ_{max}) calculated by the CASMO (World Stress Map) method in the territory of Azerbaijan is mainly in the direction of contemporary movement of the Earth's crust and there is a difference in some places and it is assumed that besides collision tectonics, local sources of stress also played a certain role in the formation of stress.

5. "Domains" that behave as plate interior block and are important in clarifying the nature of tectonic processes (earthquakes, eruption of mud volcanoes, landslides, etc.) have been identified in the field of GPS velocity and contemporary strain in the territory of Azerbaijan.

6. It was determined that there is a correlation between the area of local gravitational anomalies and the spatial distribution of domains in the territory of Azerbaijan, which indicates that these domains are related to the structural forms of the Earth's crust and the composition of rocks.

7. The sharp change of the direction of the velocity vector at the Yevlakh (YEVL) GPS point relative to the surrounding points is due to the nature of the Yevlakh-Agjabadi large negative local gravitational anomaly, especially volcanic occurrences in the geological structure of the depression in the Middle Kura "domain".

Theoretical and practical significance of the research:

The obtained research results and GPS measurement data can be used to determine the kinematics of lithosphere plates, as a rule, to discover and clarify the boundaries of the plate, where strong earthquake focuses are located; to identify major fault systems and relatively more seismic hazard zones; to monitor changes of stress and strain state of the environmental and the accumulation of elastic strain in this type of fracture zones.

The developed GPS velocities, the database of their processing and analysis results can be attached to the regional archive and used for applied research in the territory of the Republic of Azerbaijan, including for solving engineering seismological issues.

The obtained results can be useful in a research such as the assessment of endogenous processes and a study of the strain mechanisms of the Earth's crust. Especially, since the horizontal movements of the Earth's crust influence the processes in the mantle, the study of this interaction is a database for studying the contemporary evolution of the Earth's crust. The obtained results are important for evaluating interpretation in solution of the various raised issues.

So, the obtained structural and kinematic schemes can be useful in the creating seismotectonic models, as well as in the specifying contemporary seismic hazard maps.

Approbation and use:

The key points and results of the dissertation were presented at the Republican Scientific Conference on "Actual Problems of Geology" dedicated to the 91st anniversary of the National Leader of the Azerbaijani people Heydar Aliyev (Baku, 2014), the Republican Scientific Conference on "Actual Problems of Geology" dedicated to the 92nd anniversary of Heydar Aliyev (Baku, 2015), the 20th Republican Scientific Conference of Doctoral Students and Young Researchers held by Ministry of Education of the Republic of Azerbaijan (Baku, 2016), the Republican Scientific Conference on "Actual Problems of Geology" dedicated to the 93rd anniversary of the National Leader of the Azerbaijani people Heydar Aliyev (Baku, 2016), the General Assembly of the European Union of Geoscience (EGU) in Vienna, Austria (EGU-2017, 2018, 2019), the Republican Scientific Conference on "Actual Problems of Geology" dedicated to the 94th anniversary of the National Leader of the Azerbaijani people Heydar Aliyev (Baku, 2017), the 7th International Scientific Conference of Young Scientists and Students on "Information Technology in Solving Problems of Geology and Geophysics" dedicated to the 80th anniversary of the

ANAS Institute of Geology and Geophysics (Baku, 2018), the Republican Scientific Conference on "Actual Problems of Geology" dedicated to the 95th anniversary of the National Leader of the Azerbaijani people Heydar Aliyev (Baku, 2018), the Republican Scientific Conference on "Actual Problems of Geology" dedicated to the 96th anniversary of the National Leader of the Azerbaijani people Heydar Aliyev (Baku, 2019) . 7 articles, 12 theses and 2 programs on the topic of the dissertation were published.

Factual materials, devices and personal contribution of the author: The dissertation work was prepared on the basis of the results of measurements carried out by the staff of the ANAS Institute of Geology and Geophysics with the participation of the author during 2000-2017 in the Azerbaijan GPS network. The catalog of earthquakes in the territory of Azerbaijan during this period was received from the Republican Seismic Survey Center of ANAS. GPS data was obtained through Trimble 5700, Trimble R7 and Trimble NetRS type GPS receivers. The processing of GPS data was carried out by GAMIT/GLOBK program. Stress and strain data were calculated by CASMO software. Maps based on the results of the dissertation were prepared using the GMT (Global Mapping Tool) program. Maps based on the results of the dissertation were prepared by using the GMT (Global Mapping Tool) program.

The reliability of the dissertation is determined by the presence of high-precision monitoring results of the following factual materials:

1. Measurement data carried out periodically jointly with the Massachusetts Institute of Technology (USA) at cGPS and GPS stations operating stationary in the territory of Azerbaijan;
2. Use of SOPAC database of International Geodynamic System (IGS), which is situated in the USA, in the application of GAMIT/ GLOBK program;
3. GPS velocity data during 2000-2017 obtained with the participation of the author;
4. Data of the contemporary seismic network of the Republican Seismic Survey Center of the Azerbaijan National Academy of Sciences.

The personal contribution of the author in the implementation of the dissertation consists of the following:

1. Review of previous researches about the topic of the dissertation;

2. Selection of GPS space geodesy and seismic data;

3. Participation in the conduct and processing of GPS space geodetic measurements;

4. Calculation of lithosphere stress using CASMO software;

5. Graphical description and interpretation of final results.

Analysis of the obtained data and interpretation of the main results was carried out together with my scientific supervisor, academician F.Gadirov. Some results of the dissertation were obtained together with Doctor of Earth Sciences G.Babayev and PhD in Earth Sciences, Associate Professor R.Safarov.

Name of the organization where the dissertation work is carried out:

The dissertation work was carried out at the Department of "Seismology and Physics of the Earth" of Baku State University. This dissertation was partially completed with the assistance of training and master's program organized by the Science Development Foundation under the President of Azerbaijan (Grant # EIF-KETPL-2015-1 (25) -56/27/2) jointly with the USA National Science Foundation.

Volume and structure of the dissertation:

The dissertation consists of an introduction, five chapters, a conclusion and a list of 169 references. It covers 141 pages, including 50 figures and 8 tables. The introduction of the dissertation is 8 pages, consists of 15022 characters, the first chapter is 14 pages, 19889 characters, the second chapter is 27 pages, 50680 characters, the third chapter is 32 pages, 31760 characters, the fourth chapter is 30 pages, 38664 characters, the fifth chapter is 20 pages, 26918 characters, the conclusion is 2 pages, 2580 characters and the list of used 169 references is 16 pages, 29594 characters. The volume of the dissertation consists of 141 pages of computer writing, the total volume is 220593 characters (190999 characters excluding the list of used references).

Thanks:

First of all, I express my deep gratitude to my scientific supervisor, full member of ANAS, Professor F.A. Gadirov for his attention, scientific and practical assistance at all stages.

I express my deep gratitude to the General director of the ANAS Institute of Geology and Geophysics for using the opportunities of the basic department in the ANAS Institute of Geology and Geophysics

of the Department of "Seismology and Physics of the Earth" of Baku State University in the implementation of the dissertation. I would like to express my deep gratitude to the General Director of the Republican Seismic Survey Center (RSSC) under ANAS, corresponding member of ANAS, Professor G. Yetirmishli for the recommendations and notes for the use of seismic data during the dissertation work. I would like to thank a leading researcher of the Department of "Modern Geodynamics and Space Geodesy" of the ANAS Institute of Geology and Geophysics, PhD in Earth Sciences R.Safarov for his assistance in conducting measurements in the Azerbaijan GPS network and processing data obtained from GPS stations and joint analysis of the results and Head of the Department of "Seismology and Seismic Hazards", Doctor of Earth Sciences G. Babayev for his assistance in the use and interpretation of the CASMO (World Stress Map) methodology.

I would also like to thank the staff of the Department of Seismology and Physics of the Earth of Baku State University, especially the head of the department, Associate Professor A.G.Novruzov for the constructive discussion of the results.

CHAPTER I. TECTONIC STRUCTURE AND GEODYNAMIC STATE OF THE TERRITORY OF AZERBAIJAN

This chapter considers the tectonic zoning of the territory of Azerbaijan, contemporary geodynamic state, the distribution characteristics of contemporary vertical movements of the Earth's crust and gives a general explanation on the interaction of African-Arabian-Eurasian plates. Many researchers have engaged in tectonic zoning of the territory of Azerbaijan. The tectonic schemes compiled by V.P.Rengarten, V.E.Hann, K.N.Paffenhols, M.V.Muratov, E.E.Milanovsky, V.V.Belousov, I.V.Kirillova and A.A.Sorsky and others are relatively well known. The territory of Azerbaijan covers the eastern part of the Caucasus segment of the Alpine-Himalayan folding zone and joins the Scythian plate in the north by the Gusar-Shabran marginal trough and the Iranian platform in the south by the Nakhchivan folding system. The Talysh zone is connected with the northwestern part of the Elbrus folding system in the south. The primary structures in the tectonic zoning system of Azerbaijan (from north to south) are following: Gusar-Shabran marginal trough, Greater Caucasus folding system, Intermountain Kura depression, Lesser Caucasus folding system, Nakhchivan fold system and Talysh zone of Elbrus folding system. The Alpine-Himalayan belt is located in the southern part of the Eurasian plate, which separates it from the African plate in the west and the Arabian plate in the center. The interaction of Eurasian, African and Arabian plates is observed in this region[8, 9, 10]. As a result of tectonic researches, the territory of Azerbaijan is divided into structures such as Gusar-Shabran marginal trough, large Caucasus fold system, Intermountain Kura depression, Lesser Caucasus folding system, Nakhchivan folding system and Talysh zone of Elbrus folding system. The northward movement of the Arabian plate and its interaction with the Eurasian plate are the main factors determining the contemporary geodynamic and seismo-tectonic state of the territory of the Caucasus.

CHAPTER II. METHOD OF GPS SPACE GEODESY IN THE STUDY OF HORIZONTAL MOVEMENTS AND STRAIN OF PLATES

This chapter explains the basics of the application of GPS technology in the study of geodynamic processes. The development of space geodetic methods, especially the global positioning system – GPS has greatly increased the studying opportunities of contemporary movements of the Earth's crust and stress and strain state[11, 12, 13, 14, 15].

The Global Satellite Navigation System (GSNS) has entered our lives very quickly in the last 25 years and has been successfully applied to the solution of complex geological problems. Satellites that can

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[8] McKenzie, D.P. Active tectonics of the Mediterranean region, Geophys // J.R.Asron. Soc., 30, - 1972. - p.239-243.

[9] See: Reference 3

[10] Zonenshain, L.P. Savostin, L.A. Introduction to geodynamics. - Moscow: Nedra, - 1979 . - p 311.

[11] Bossier J.D., Goad C.D., Bender, P.L. Using the Global Positioning System (GPS) for geodetic positioning // Bulletin Geodesique, - 1980. - vol. 54, N 4, - pp.553-563.

[12] Hager B.H. King, R.W. and Murray, M.H. Measurement of crustal deformation using Global Positioning System // Annu. Rev. Earth Planet. Sci, - 1991. - vol. 19, N 2, - pp. 351-382.

[13] Calais E., Minster J.B. GPS, earthquakes, the ionosphere, and the Space Shuttle // Physics of the Earth and Planetary interiors, - 1998. - vol. 105, N 3. - pp. 167-181.

[14] Segall P., Davis J. GPS applications for geodynamics and earthquake studies // Annual Review of Earth and Planetary Sciences, - 1997. - v.25, No 1, -pp. 301-336.

[15] Makarov V.I., Trapeznikov A.Sh. Study of contemporary strain of the Earth's crust by methods of space geodesy // Geoecologiia, - 1996. # 3, - pp. 70-85.

be seen from anywhere of the world and sent high-frequency signals continuously provide the global work of the GSNS system. A coordinate-time information system is created around our planet by this method and this system allows a user to get information about its position and time with the help of a special receiver.

The GPS system is widely used to determine the size and shape of the Earth, to study the strains of the Earth's surface, the tectonic movements of continents and to explore earthquake hazards[16, 17].

GPS satellites move in an average orbit at a distance of 20200 km from the Earth. The orbital period of these satellites is half the stellar period of the Earth's rotation (23 hours 56 minutes). In other words, each satellite moves around the Earth twice during a day and a stationary observer on the Earth sees the same satellite moving in a fixed trajectory, azimuth and ascent angle in a dome of the sky every 11 hours and 58 minutes. GPS satellites with four satellites each are located in six equal orbits around the Earth at 60° intervals. This type of location of 24 satellites, each with an inclination of 55° to the equator, guarantees the observation of at least four satellites from any point on the Earth.

The GPS system consists of three segments: the space segment, the control segment and the user segment[18].

Two main applied issues are solved in GSNS using the method of the explained geodetic determination[19]. These issues are following:

1. Determining the coordinates of the coordinates of the Artificial Satellite on the Earth's surface by measuring the distances of a known station to the satellite (straight geodetic determination);

2. Determining the coordinate of the coordinates of an arbitrary point on the Earth's surface by measuring the distance from several known Artificial Satellites to it (inverse geodetic determination).

Inverse geodetic method is used in solving geodynamic problems in the application of GPS technology and the coordinates of this

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[16] Oduan, K., Gino B. Measurement of time. Basics of GPS. TECHNOSPHERE. Moscva: [n.y.], - 2002. - p 400.

[17] Dong, D., Herring, T.A., Geodesy R.W.K. et al. Estimating regional deformation from a combination of space and terrestrial geodetic data // Journ. Geodesy, - 1998. - p. 200-214.

[18] Hofmann-Wellenhof B. Lichtenberger H. and Collins J. Global Positioning System Theory and Practice // Springer Wien New York, - 2001. - p. 382.

[19] *See: reference 16.*

point are monitored by placing the receiver at an arbitrary point selected on the Earth or by repeated or continuously measurements based on relief and geological-tectonic state.

The study of contemporary horizontal movements and strains happened on the Earth's surface is carried out by repeated or continuous GPS measurements at plug or observation stations equipped with special GPS receivers.

CHAPTER III. RESULTS OF THE EXPLORATION OF CONTEMPORARY HORIZONTAL MOVEMENTS AT THE AZERBAIJAN GPS POLYGON (2000-2017)

The information about the Azerbaijan GPS network, the methods of GPS data analysis and the results on the contemporary geodynamic state of the area are explained in this chapter. The information received from the receivers in the Azerbaijan GPS network was processed by the GAMIT/GLOBK software package.

The Global Positioning System (GPS) of space geodesy has been intensively applied to study the horizontal movements of the Earth's crust in recent years[20]. GPS repeat measurements began to be used to study movements of plates and strains in plates beginning from the 80s of the last century.

Azerbaijan GPS network was established in 1998 by the ANAS Institute of Geology and Geophysics with the participation of the Massachusetts Institute of Technology of the USA. Today, the Azerbaijani GPS network includes 26 measuring points and continuously operating Baku, Pirshagi, Sheki, Ganja, Neftchala, Sabirabad GPS stations. 10-16 measurements were carried out at the observation points of the Azerbaijan GPS network during 1998-2017. Monitoring carried out in the Azerbaijan GPS network showed that the maximum value of horizontal movement velocities is 13 mm/year[21, 22, 23, 24]. Information for the territories bordering with Azerbaijan is taken from the articles of the

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[20] King, R.W. and Y. Bock, Documentation of the MIT GPS analysis software: GAMIT, Mass. Inst. of Technol., Cambridge: - 2002.

[21] Kadirov F. Mammadov S., Reilinger R., McClusky S. Some new data on modern tectonic deformation and active faulting in Azerbaijan (according to Global Positioning System measurements) // Proc. Sci. Earth Azerbaijan Nat. Acad. Sci. - 2008. - 1, - p. 82-88.

[22] See: Reference 1

[23] See: Reference 2

[24] See: Reference 6

following authors[25, 26, 27].

Figure 1 also shows the distribution of GPS velocities in Azerbaijan and neighboring areas and profiles Aa, Bb and Cc. GPS measurement results show that the geodynamic regime is different. So, the vector of horizontal movement of the Earth's surface is directed to the NNE in the south within the borders of the Lesser Caucasus. GPS velocities are high and show little change and the velocity of stress accumulation is low here.

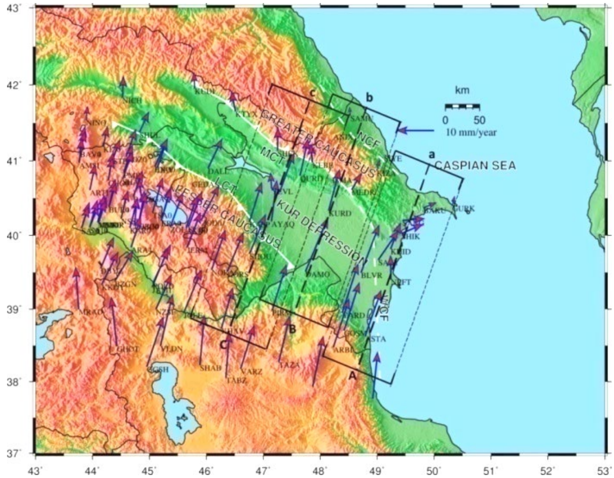

Figure 1. Simplified tectonic scheme and GPS velocities of the territory of Azerbaijan, NCF-North Caspian fault, MCT-Greater Caucasus thrust, WCF-Western Caspian fault, LCT-Lesser Caucasus thrust (Safarov R., Ahmadova E., 2017)

The GPS velocity of the Earth's surface in the Kura depression decreases as approaching the Greater Caucasus Mountains. This collision zone of the Arabian and Eurasian plates is distinguished by tectonic activity and high seismicity.

Figure 2 shows the distance dependence graphs of the northern components (VN) of GPS velocities along profiles A-a, B-b, and C-c. The northern component (VN) of the velocity from south to north decreases as

25 See: Reference 7
26 See: Reference 6
27 See: Reference 5

approaching the Greater Caucasus in the velocity area on profiles. Horizontal movement velocities increase from west to east within the borders of the Kura depression and the Lesser Caucasus. The velocity is 10.49 mm/year at SHOU (Shusha) GPS station in the western part of Azerbaijan and 13-14 mm/year in the Talysh zone in the east.

On the other hand, there is a decrease of velocities in the western direction at GPS points along the MCT (Greater Caucasus thrust). The north-northeast movement of the Earth's surface is interpreted as one of the reasons for the accumulation of stress in this thrust. Shortening of the Earth's crust at a speed of ~6 mm/year was observed in the area from the GPS observation point located about 50 km south-west of Baku (SHIK) to the point at the eastern end of the Absheron Peninsula (GURK) (Fig. 2, profile A).

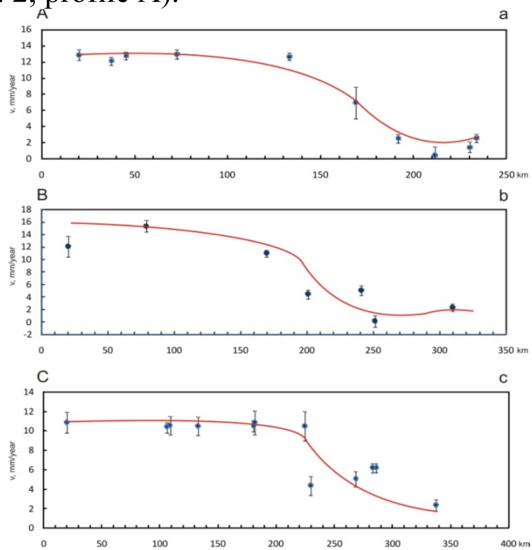

Figure 2. Distance dependences of northern components (VN) of GPS velocities along selected A-A, B-B and C-C profiles

The northern components (VN) of GPS velocities are sharply decreased as approaching the Greater Caucasus Mountains in all three profiles.

Figure 3 shows the distance dependence graphs of the eastern components (VE) of the GPS velocities in the selected directions A-a, B-b and C-c. The VE velocity component increases from 4.05 mm/year to 4.8 mm/year from the GOSM (Gosmalyan) GPS point to the BLVR (Bilasuvar) GPS point in the selected profile A-a in the direction of Astara-Salyan-Baku-Gurgan. The VE velocity component decreases sharply to 2.66 mm/year at Khidirli (KHID) station. The value of the VE velocity component increased again to 5.95 mm/year at Shikhlar and Sangachal stations. It should be noted that the VE velocity component is twice as high as the VN velocity component at Shikhlar (SHIK), Sangachal (SANG) and Baku (BAKU) GPS stations. The VE velocity is significantly weaker than the VN velocity in Gurgan (GURK) station located in the east of the Absheron Peninsula and the role of this velocity component can be neglected. It can be concluded that the VN velocity prevails in the western border of the Absheron-Pribalkhan uplift zone.

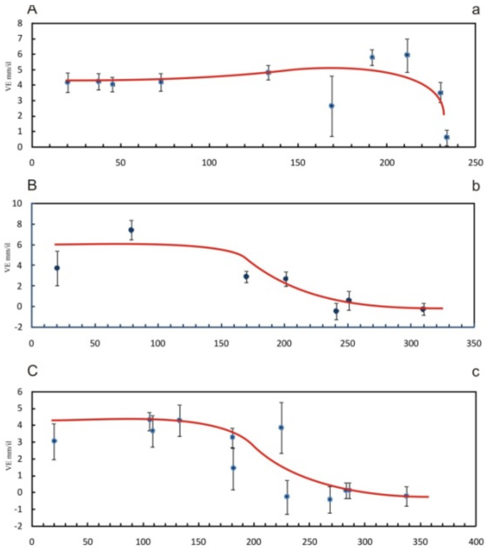

Figure 3. Distance dependences of eastern components (VE) of GPS velocities along selected A-A, B-B and C-C profiles

It is observed that the VE velocity vector in the direction Bb extending from the PIRS GPS point in Iran to the Kurdamir (KURD), Madrasa (MEDR), Gabala (KEBE), Siyazan (SIYE) and Samur (SAMU) stations decreases as approaching the southern slope of the Greater Caucasus and the velocity VE=2.94 mm/year at the KURD GPS station is VE≈0 mm/year at Gabala (KEBE) station.

It is observed that the VE velocity vector decreases as approaching the southern slope of the Greater Caucasus and is VE≈0 mm/year in the C-c profile extending from the KHAV GPS point in the territory of Iran to the Sheki (SHEK) point. The difference of the VN components of GPS velocities between YEVL (Yevlax) station in the zone of Kura Depression and SHEK (Sheki) station on the southern slope of the Greater Caucasus is ~ 1.83 mm/year. Considering that the distance between these stations is 62 km and the strain velocity is ~ 1.83 mm/year, it is determined that the stress around Sheki is ~ 29 nanostrain/year. The difference of VE components of GPS velocities between the BLVR (Bilasuvar) in the west of the Western Caspian fault (WCF) and the SALY (Salyan) in the east is ~ 2.05 mm/year. As VE = 6.87mm/year in Salyan station is greater, the eastward movement causes stress here.

The VE velocity component receives a value of 3.49 mm/year at the BAKU station (Baku). VE reaches a value of ~ 0 mm/year at the GURK (Gurgan) station. We see in these graphs that the VE velocity components at the YEVL and KHID (Khidirli) GPS stations go beyond the general regularity.

Analysis of velocity distributions along the Aa profile shows that the Kura depression zone and the Lower Kura – Gobustan-Absheron structural zones have different kinematic characteristics.

It is clear from what we have said that there is a very weak change in GPS velocity in the Lesser Caucasus, a significant change in the Kura depression zone and a complete decrease in velocity in the Greater Caucasus. The direction of the velocity vector changes at SALY (Salyan), SHIK (Shiklar), SANG (Sangachal) and BAKU (Baku) GPS stations located in the east of the Western Caspian fracture. In other words, the Lesser Caucasus, Kura Depression, Greater Caucasus, Talysh, Lower Kura – Gobustan-Absheron zones differ in their kinematic characteristics. As a result of the values of the VE velocity components being greater than the VN velocities in the Lower Kura - Gobustan-Absheron structural zones, it is observed that the velocity vector gradually rotates in the direction of the NE and moves clockwise on the Earth's surface on the west coast of the South Caspian Basin in this part. This indicates a change in the kinematics of the region.

For the first time, Yahya Djamour and others clarified the movement of the South Caspian Basin in 2010 by analyzing GPS, gravimetric and seismic data and showed that the SCB is subject to a clockwise rotation relative to Eurasia [80]. Based on the velocity of GPS stations in Iran and surrounding areas, the authors assume that the south Caspian Sea rotates clockwise around the Euler Pole (59.1±0.8°E, 40.4±0.3°N), which is situated about 500 km east, relative to Eurasia.

Mousavi and others [119] used new GPS data in 2013 and showed once again that the South Caspian Basin rotates around the Euler pole at a maximum speed of ~ 7 mm/year on an azimuth of 317° N relative to Eurasia.

Let's theoretically calculate the horizontal velocities for the GPS points within the model to study the relationship of GPS velocity distribution in the territory of Azerbaijan with clockwise rotation of the South Caspian Basin around the Euler pole relative to Eurasia and the direction alteration of the velocity vector to the east at the points in the Lower Kura – Gobustan-Absheron structures. It is assumed that the Lower Kura – Gobustan-Absheron structures are bounded on the west by the Western Caspian fault and on the north by the Central Caspian Seismic Zone in the model. The South Caspian Basin and the Iranian Plate were selected as regional tectonic elements in the formation of this strain in our model. Theoretical velocities were defined within the model for the area bounded with these two fractures by assuming that the clockwise rotation of the South Caspian Basin relative to Eurasia at a speed of ~ 7 mm/year deforms the Lower Kura – Gobustan-Absheron structural elements. The dimensions of the selected area are indicated by square brackets at the beginning and end of the Mm profile selected for model calculations. The profile covers ARBI, ASTA, GOSM, YARD, BILE, SALY, KHID, SHIK, BAKU, GURK, KIZA and SIYE GPS stations. Calculations were carried out for the remaining GPS points within this area. The model velocities at the remaining GPS points within the area, which is covered by the Mm profile, were realized by using the Okada formula [123] by TDEFNODE software [110]. Figure 4 shows the measured GPS velocity vectors obtained from the model calculations[28]

The distance dependence of the GPS velocity values that was obtained and measured from the model in a direction parallel to the Mm profile is shown in Figure 5. As can be seen, the velocities, which were measured by the velocities and obtained from the model calculations, correspond to each other.

[28] Ahmadova E.V. Modeling of modern Earth surface movements along the east coast of the Caspian sea by GPS data. ANAS transactions, Earth Sciences 2/2021, p. 63-68

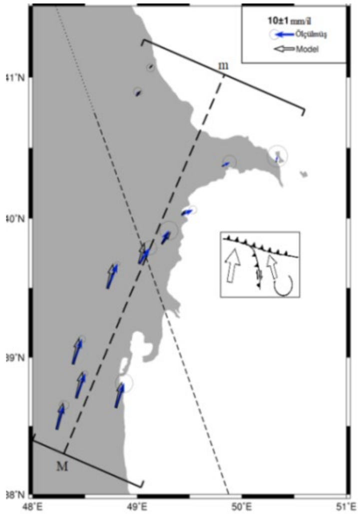

Figure 4. Distribution of measured GPS and model velocities on Mm profile. Measured velocities are shown with a blue arrow and the model velocities are shown with black arrows.

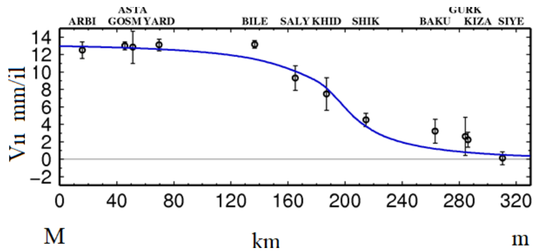

Figure 5. Distance-dependent distribution of GPS velocity values obtained and measured from the model in a direction parallel to the Mm profile. The measured GPS velocity distribution is shown with a blue curve, model velocities with black circles.

Based on our modeling data and the results of research conducted by Yahya Djamour, Mousavi and colleagues, it can be concluded that the structural areas of Ashagi Kura, Gobustan and Absheron in the east of the South Caspian fault move clockwise under the influence by the Iranian plate[29]

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[29] Malekzade Zaman. Block rotation induced by the change from the collision to subduction: Implications for active deformations within the areas surrounding South Caspian Basin // Marine Geology. 1 October 2018, - vol. 404, - p. 111-129.

CHAPTER IV. ANALYSIS OF THE STRESS-STRAIN STATE OF THE LITHOSPHERE AND UPPER MANTLE IN THE CAUCASUS (AZERBAIJAN) WITH THE APPLICATION OF THE "WORLD STRESS MAP" PROJECT PROGRAM

One of the most obvious occurrences of stress release in the Earth's crust is tectonic earthquakes. The focus mechanisms of many strong earthquakes collected from regional seismic surveys and the earthquake focus mechanisms identified by the Global Centroid-Moment-Tensor (CMT) and NEIC/USGS make up the **"World Stress Map"** (WSM) database. The focus mechanism data provide information on the relative intensity of the main stresses, which allows directly the determination of the tectonic regime. Stress and strain distributions at different depths of the lithosphere were studied according to the database of earthquake focus mechanisms using CASMO program within the framework of the "World Stress Map" project and taking into account topographic anomalies. According to seismological data[30, 31, 32, 33, 34, 35], earthquake focuses with magnitude Mw≥5 during 1990-2015 were used to compare the results of the modeling with the observed stresses using the methodology of CASMO focal mechanisms mapping ("World Stress Map")[36]. According to the "World Stress

[30] Agayeva S.T. Stress state of the Earth's crust in Azerbaijan. Recent geodynamics, georisk and sustainable development in the Black Sea to Caspian Sea region // Conference proceedings of American Institute of Physics. New-York, USA, Melville, - 2006, - p. 97-102.

[31] Agayeva S.T., Babayev G.R. Analysis of earthquake focal mechanisms for Greater and Lesser Caucasus applying the method of World Stress Map. Azerbaijan// National Academy of Sciences. Proceedings of Geology Institute, -Baku: - 2009. № 2, - pp. 40-44.

[32] Babayev G.R. Analysis of earthquake focal mechanisms for Greater and Lesser Caucasus applying the method of World Stress Map //Azerbaijan National Academy of Science. Catalogue of Azerbaijan Republican Seismological Center, - 2009.- p. 67-74.

[33] Kadirov F.A., Safarov R.T. Strain of the Earth's crust in Azerbaijan and adjacent territories according to GPS measurements data // Izvestiya NAS Azerbaijan, Earth Sciences, - 2013. # 1, - pp. 47-55.

[34] See: reference 2

[35] Yetirmishli G.J., Kazimova S.E.Types of tectonic movements of seismogenic regions of Azerbaijan by mechanisms of earthquake foci // Geological-geophysical studies of the deep structure of the Caucasus: geology and geophysics of Caucasus, Vladikavkaz, -2017. - p. 20-25.

[36] Heidbach O., Tingay M., Barth A. et al. The World Stress Map database release // Tectonophysics, 2008. 482: p.3-15

Map" project, information is provided on the directions of the main stress axes P and T of strong earthquake focuses that can be used in the World Stress Map[37]. A geological 3D finite-element model of the surfaces was obtained by applying the HyperMesh™ program shown on the 5x5 km network of all three boundaries in the first stage. The geological model, which takes into account the three surfaces obtained in this way, is closed by side borders. The study of stress and strain state in the Caucasus (Azerbaijan) was carried out by using Abaqus™ software and the 3D approximated geological model of the lithosphere shown above. Figure 6 (a, b) shows the distribution of the maximum horizontal stress vector (σ_{max}) at 100 and 200 km depths corresponding to the lithosphere and upper mantle, which was obtained by numerical calculation of the σ_{max} maximum horizontal stress vectors on the model by the finite-element method as a result of the application of Abaqus™ program. The results obtained from the distribution of stress vectors characterizing the stress and strain state of the Caucasus region show (Fig. 6b) that the right-sided compression effects are practically submeridional in the southern part of the Caspian Sea. This is consistent when comparing the obtained stress and strain data with GPS data[38, 39, 40, 41, 42]. In all probability, such compression in this province is more affected by the movement of the Arabian plate than the Eurasian plate[43, 44, 45, 46, 47].

[37] Zoback, M. First and second order patterns of tectonic stress: The World Stress Map Project // Journal of Geophys. Res. 97, -1992.- pp. 11703-11728.
[38] See: reference 6
[39] See: reference 1
[40] See: reference 21
[41] See: reference 32
[42] Alizadeh A.A., Guliyev I.S., Kadirov F.A. et al. Geosciences of Azerbaijan Geology. - Springer International Publishing, - 2016. - p. 237.
[43] See: reference 6
[44] See: reference 21
[45] See: reference 1
[46] Koptev A., Ershov A. Numerical modeling of the thermal state of the lithosphere, distribution of intraplate stresses in the lithospheric folds of the Black Sea-Caucasian-Caspian region. Bull. Moscow Society of Nature Testers, Dept. Geol., - vol. 86, - issue. 5, - 2011 .-- p. 3-11.
[47] See: reference 32

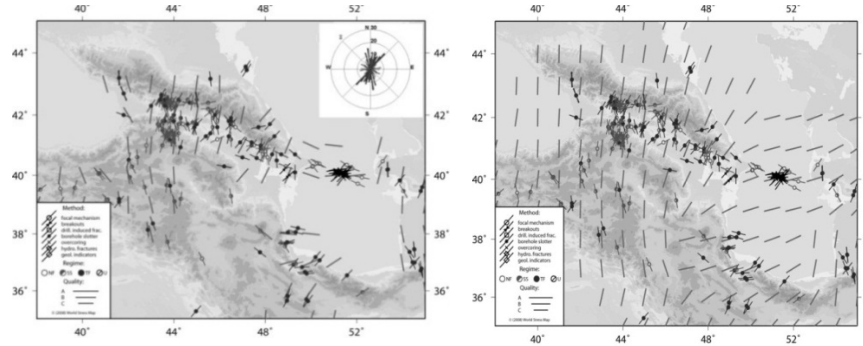

Figure 6. Distribution of σ_{max} maximum horizontal stress vectors comparable to the map of focus mechanisms built with the help of CASMO (World Stress Map) project at depths of 100 km (a) and 200 km (b) (Babayev and Ahmadova)

According to the data on the territory of Azerbaijan, the orientation of stress happens in the north-northeast direction. This corresponds to GPS-geodetic data. Upthrust and upthrust-dislocation fractures predominate throughout the area. Comparison of the regional stress state of the lithosphere of the Caucasus region under the influence of topographic anomalies with the results of static processing of "World Stress Map" data shows that the results have the same regional tendency as a whole, despite some local differences. In fact, the western and central parts of the Greater Caucasus are in a state of north-east – south-west stress. This stress is replaced by intensive compression in the eastern part. Compression is observed in the western part of Azerbaijan. Besides, the transition of the left-sided landslide to the right-sided dislocation is clearly observed from the Greater Caucasus Range to the south, which is consistent with geological and geodynamic data[48].

Stress and strain state is different in the Caucasus block: a north-eastern and south-western (NE-SW) stress happens in the western and central part of the Greater Caucasus, but an intensive compression happens in the eastern part. Although the direction of the horizontal stress vector (σ_{max}) is generally the same as the direction of contemporary movement of the Earth's crust throughout Azerbaijan, there are

[48] See: reference 32

changes in the direction of σ_{max} in some places. This fact has shown us that not only collision tectonics but also local sources of stress play a certain role in the formation of stress.

CHAPTER V. STRUCTURAL ANALYSIS OF GPS HORIZONTAL VELOCITIES OF THE EARTH'S CRUST IN THE TERRITORY OF AZERBAIJAN

The structural analysis of the horizontal velocities field was carried out by using the data of the Azerbaijan GPS network and "domains" were identified in the GPS horizontal velocity field in this chapter. The "domain" in GPS horizontal velocity field refers to areas on the Earth's surface that have different GPS velocity characteristics than the surrounding areas. The correlation of the identified "domains" with seismicity and Bouguer gravitational anomalies was studied.

A density distribution map of M≥2 earthquakes for Azerbaijan and neighboring areas, which happened during 2003-2017, was developed and used by the sliding window method according to the catalog of the Republican Seismic Survey Center of ANAS [34]. Almost high and approximately stable horizontal velocities and weak seismic activity are observed in the Lesser Caucasus structural zone. This region can be divided as a "domain" of the Lesser Caucasus in the field of GPS horizontal velocity. A slight change is observed in the directions and values of GPS velocity vectors in the structural zone of Kura depression. The number of seismic events in this area is more than the Lesser Caucasus domain and this area can be considered as the Middle Kura "domain" in the field of GPS horizontal velocity. A sharp change of velocity is observed at the Yevlakh (YEVL) GPS station in this region. The alteration of directions of GPS velocity vectors and decrease of velocity values are observed on the southern slope of the Greater Caucasus structure. The active seismic region on the southern slope of the Greater Caucasus structure is characterized by high shortening of the Earth's crust and velocity gradients. This region can be divided as the Greater Caucasus "domain" in the field of GPS horizontal velocity.

GPS horizontal velocity vectors have also high value in the Talysh region and a slight change is observed in its direction and value to the north. Although the number of seismic events is high here, earthquakes are not very strong. This region can be considered as the "domain" of Talysh in the field of GPS horizontal velocity.

A sharp change of direction is observed in the velocity vectors starting from Neftchala GPS station located in the east of the Western Caspian fault to Salyan, Khidirli, Shikhlar, Sangachal and Baku GPS stations in the field of GPS velocity of the territory of Azerbaijan. At the same time, the velocity value is also decreasing to the north in these areas. A moderate number of seismic events are observed in this area, which covers the Lower Kura depression and a part of the Gobustan region. This region can be considered as the "domain" of Lower Kura-Gobustan-Absheron in the field of GPS velocity of the territory of Azerbaijan.

This area can also be characterized as a special domain, as the GPS velocity field in the Gusar-Shabran marginal trough differs in its minimum value. The domains with different characteristics in the field of GPS velocity are shown in Figure 7.

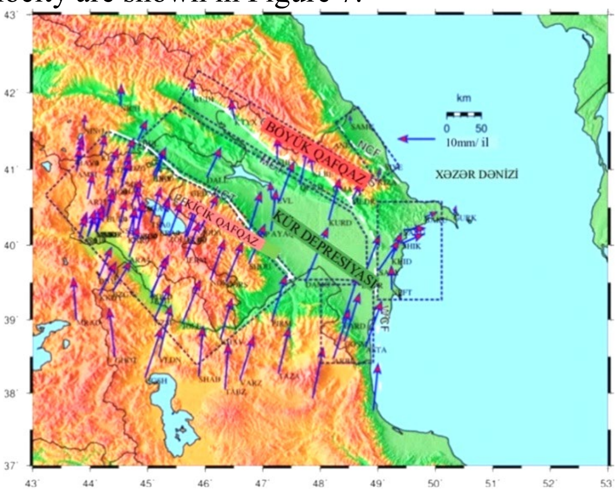

Figure 7. "Domain" regions with different characteristics in the field of GPS velocity [Akhmadova E.V and others]

A comparative analysis of local anomalies of the gravitational field of Azerbaijan and neighboring areas with a distribution map of "domains" with different characteristics in the field of GPS velocity shows that there is a correlation between these two distributions. Areas of large negative local gravitational anomalies (-9 – and -27 mGal) that are marked as Gilar-Khudat and the northern slope of the Greater

Caucasus correspond to the domain of the Gusar-Shabran marginal trough, which is separated in the area of contemporary horizontal movement velocities of Earth's crust, in the field of local gravitational anomalies. The northern and eastern components of the horizontal movement velocities have small values here.

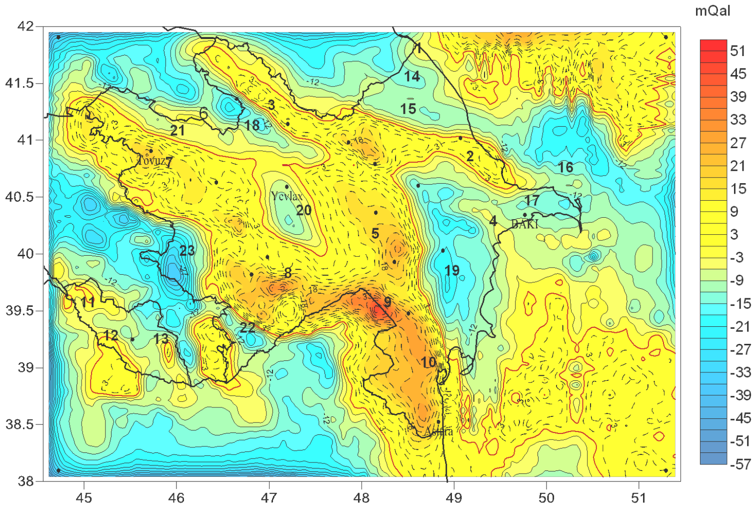

Figure 11. Map of local anomalies of Azerbaijan and neighboring areas [Gadirov F.A.]

Positive local anomalies: 1–Yalama, 2–Dubrar, 3–Ismayilli-Balakan, 4–Yavanidagh-Sangachal, 5–Saatli-Kurdamir, 6–Eldar, 7–Ganja-Gazakh, 8–Khojavend, 9–Chakhirli, 10–Talyshonu, 11–Sadarak-Badamli, 12–Nakhchivan-Julfa, 13–Ordubad. Negative local gravitational anomalies: 14–Gilar-Khudat, 15–Northern slope of the Greater Caucasus, 16–Northern Absheron, 17–Absheron-Central Gobustan, 18–Alazan-Ayrichay, 19–Lower Kura, 20–Yevlakh-Agjabedi, 21–Chatma, 22–Khanlig, 23–Kalbajar.

Two large positive local gravitational anomaly areas, such as Dubrar (2) and Ismayilli-Balakan (3) are separated in the zone distinguished as the domain of the Greater Caucasus folding system and the "domains" are characterized by a local maximum (~ +21) in the central part of the region. The northern components dominate in the field of horizontal movement velocities of the Earth's crust here. Although the direction of horizontal movement of the Earth's is in the north-east direction crust in the domain of the Lesser Caucasus folding system, an increase is observed in velocity values from the north-western part of the region to the south-eastern part. This domain corresponds to the large positive anomaly of Khojavend (8) on the map of the central local gravitational anomaly. Ganja-Gazakh (7) positive gravitational anomaly with relatively low value is observed in the north-western part of the domain.

The zone, which is marked as the area of Talyshonu (10) large positive anomalies, is separated as Talysh "domains" belonging to the Talysh folding system in the field of local gravitational anomalies. Although there is a coincidence in the directions and velocities of horizontal movement of the Earth's crust on the southern and northern borders of Kura depression "domain", the Yevlakh-Agjabadi (20) large negative local gravitational anomaly is separated in the area of local gravitational anomaly in the area where the YEVL GPS station differs in both direction and velocity in the central part of the region. The south-eastern part of this domain is characterized by the Saatli-Kurdamir (5) large positive local gravitational anomaly.

The sharp change of the direction of the velocity vector in the Yevlakh (YEVL) GPS station in the Middle Kura "domain" and its correspondence to the area of the Yevlakh-Agjabadi (20) large negative local gravitational anomaly show the correctness of the separation of a small different area here. Such accordance is determined by the geological structure of the Yevlakh-Agjabadi depression, particularly by the influence of volcanic derivatives [13].

Lower Kura-Gobustan-Absheron "domain" corresponds to the Absheron-Central Gobustan (17) and Lower Kura (19) negative local gravitational anomalies in the areas of local gravitational anomalies.

So, as a result of the analysis of the area of local gravitational anomalies obtained for the territory of Azerbaijan and the "domains" separated in the field of horizontal movement velocities of the Earth's crust, the existence of a correlation between these two areas was determined.

As a result of structural analysis of the distribution of GPS horizontal velocities and strain parameters of the Earth's crust, seismicity, tectonic structure and local gravity of the study area, the following "domains" of the Caucasus block in the territory of Azerbaijan were identified: Greater Caucasus folding system, Lesser Caucasus folding system, Kura, Talysh, Gusar-Shabran marginal trough and Gobustan-Absheron-Lower Kura zone.

The Lesser Caucasus structural zone is characterized by weak alteration of the value and direction of GPS velocity vectors, weak seismic activity, rising vertical movements of the Earth's surface, the area of positive local gravitational anomalies, small strain velocity in stress zones.

The Kura depression structural zone is characterized by significant alteration in the values and directions of GPS velocity vectors, moderate seismic activity, a decrease of the vertical movement of the Earth's surface and an average rate of strain velocity.

The Greater Caucasus structural zone is characterized by alteration of the direction of GPS velocity vectors, decreasing velocity values to zero, high seismic activity, rising vertical movements of the Earth's surface, the area of positive local gravitational anomalies, high strain velocity.

The Talysh structural zone is characterized by high value of GPS velocity vectors, weak alteration of their directions and value, moderate seismic activity, rising vertical movements of the Earth's surface, the presence of positive local gravitational anomalies and low strain velocity.

The Gusar-Shabran marginal trough zone is characterized by a minimum value of the GPS velocity field, different rising vertical movements of the Earth's surface, small strain velocity and negative local gravitational field.

The Lower Kura-Gobustan-Absheron structural zone is distinguished by a sharp alteration of the direction of GPS velocity vectors in the NNE direction, a decrease of the value of GPS velocity to the north, a descent in vertical movements of the Earth's surface, high strain velocity and negative local gravitational field.

CONCLUSION

- The velocity field, which has been obtained from GPS observations over the last 20 years, describes clearly the movement of the Earth's crust in the NNE direction in relation to Eurasia in the territory of Azerbaijan and in areas adjacent to the Lesser Caucasus.
- One of the clearly defined features of the GPS velocity field is a decrease of the value of GPS velocity components (northern component VN) perpendicular to the direction of extension of the Greater Caucasus Thrust from south to north.

- Shortening of the Earth’s crust with a rate of <2 mm/year and process of weak strain have been identified in the Lesser Caucasus.
- The VE east velocity component predominates in Shikhlar, Sangachal and Baku GPS stations.
- The VN north velocity component predominates at the Gurgan (GURK) GPS station on the western border of the Absheron-Pribalkhan threshold.
- The South Caspian Basin, which rotates clockwise under the influence of the Iranian plate, determines the kinematics of the Lower Kura, Gobustan and Absheron structural areas.
- The dominant influence of the topography of the Earth’s surface and geological boundaries is observed in the formation of regional stress areas in the Earth’s lithosphere in the Caucasus region (Azerbaijan).
- The western and central parts of the Greater Caucasus are in a state of stress with the NE-SW direction, while this stress is replaced by intense compression in the eastern part.
- Although the σ_{max} direction of the horizontal stress vector in Azerbaijan is generally the same as the temporary movement direction of the Earth’s crust, the fact that differences are observed in some places shows that not only collision tectonics, but also local sources play a certain role in the formation of stress.
- The following “domain” areas with different velocity characteristics were identified in relation to the surrounding areas where GPS velocities were structurally analyzed on the Earth’s surface: the “domain” of Greater Caucasus folding system; “domain” of Lesser Caucasus folding system; “domain” of Kura depression; “domain” of Lower Kura depression-Gobustan-Absheron; “domain” of Talysh zone; “domain” of Gusar-Shabran marginal trough.
- There is a correlation between the area of local gravitational anomalies and the distribution of domains in the territory of Azerbaijan.
- The sharp change of the direction of the velocity vector at the Yevlakh (YEVL) GPS station in the “domain” of Middle Kura is related to the geological structure that determines the nature of the Yevlakh-Agjabadi large negative local gravitational anomaly, particularly the influence of volcanic derivatives here.

The main content of the dissertation is reflected in the

following scientific works:

1. Ahmadova E.V. Forecast Problems of Preparation Periods of Earthquakes. Materials of the Republican Scientific Conference on "Actual Problems of Geology" dedicated to the 91^{st} anniversary of the National Leader of the Azerbaijani people Heydar Aliyev. Baku, 2014, p. 334-335 (in Azerbaijani)
2. Ahmadova E.V. Structural Analysis of Contemporary Horizontal Velocities and Strains of the Earth's Crust in the Territory of Azerbaijan. Materials of the Republican Scientific Conference on "Actual Problems of Geology" dedicated to the 92^{nd} anniversary of the National Leader of the Azerbaijani people Heydar Aliyev. Baku, 2015, p. 345-347 (in Azerbaijani)
3. Ahmadova E.V. Relation of Contemporary Horizontal Movements of the Earth's Crust with Seismicity in the Territory of Azerbaijan. Materials of the Republican Scientific Conference on "Actual Problems of Geology" dedicated to the 93^{rd} anniversary of the National Leader of the Azerbaijani people Heydar Aliyev. Baku, 2016, p. 242-245 (in Azerbaijani)
4. Ahmadova E.V. Contemporary Geodynamics and Strain of the Earth's Crust in Azerbaijan (based on GPS Monitoring Data). Geophysical Innovations in Azerbaijan. Scientific and Technical journal. 2016, # 3-4, p. 13-20 (in Azerbaijani)
5. Akhmadova E.V., Babayev G., Babayev E.T. Geodynamics and Stress State of the Earth's Crust in the Greater and Lesser Caucasus (Azerbaijan) Collision Region. European Geosciences Union (EGU) General Assembly Science and Technology conference. Vienna, Austria, Book of Abstracts, 2017, T1.2-P6
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7. Ahmadova E.V., Babaev G. Analysis of stress-strain state of Caucasus region (Azerbaijan) on the basis of maximum horizontal stress vectors and "World Stress Map" application technique Geophysical Journal, Vol. 39, # 3 (2017), p. 26-39 (in Russian)

8. Ahmadova E.V. Interaction of Plates and Regional Geodynamics of the Territory of Azerbaijan. Materials of the Republican Scientific Conference on "Actual Problems of Geology" dedicated to the 94th anniversary of the National Leader of the Azerbaijani people Heydar Aliyev. Baku, 2017, p. 204-207 (in Azerbaijani)
9. Ahmadova E.V. Contemporary Geodynamic State of the Territory of Azerbaijan: Based on GPS and Seismic Data. Geophysical Innovations in Azerbaijan. Scientific and Technical Journal. 2018, # 2, p. 47-53 (in Azerbaijani)
10. Ahmadova E.V. Analysis of Stress and Strain State in the Caucasus Region (Azerbaijan) with WORLD STRESS MAP Software. Materials of the Republican Scientific Conference on "Actual Problems of Geology" dedicated to the 95th anniversary of the National Leader of the Azerbaijani people Heydar Aliyev. Baku, 2018, p. 306-308 (in Azerbaijani)
11. Ahmadova E.V. Results of GPS Monitoring of the Territory of Azerbaijan. Materials of the Republican Scientific Conference on "Actual Problems of Geology" dedicated to the 95th anniversary of the National Leader of the Azerbaijani people Heydar Aliyev. Baku, 2018, p. 304-306 (in Azerbaijani)
12. Akhmadova E.V. Analysis of the data of GPS satellite system in the study on the seismicity of the territory of Azerbaijan. VII International Conference of Young Scientists&Students Information Tecnologies In Solving Modern Problems Of Geology And GeophysicsDedicated tothe 80th anniversary of Institute Geology and Geophysics Azerbaijan National Academy of Sciences Book of Abstracts, Baku, 2018, p. 222-223
13. Ahmadova E.V. Analysis of Stress and Strain State in the Lithosphere of the Caucasus Territory (Azerbaijan). ANAS Transactions, Earth Sciences 2 / 2018, DOI: 10.33677/ggianas20180200020, p. 97-104 (in Azerbaijani)
14. Ahmadova E.V., Safarov R.T., Aslanov R.E. Structural Analysis of GPS Horizontal Velocity Field of the Earth's Surface in the Territory of Azerbaijan. News of Baku State University. Natural sciences series, Baku, 2019, # 1 (in Azerbaijani)
15. Ahmadova E.V. Analysis of Seismicity and Stress and Strain State

of the Territory of Azerbaijan. Materials of the Republican Scientific Conference on "Actual Problems of Geology" dedicated to the 96th anniversary of the National Leader of the Azerbaijani people Heydar Aliyev. Baku, 2019, p. 231-232 (in Azerbaijani)
16. Ahmadova E.V. Comparative Analysis of Seismicity with the Field of GPS Velocities in the Territory of Azerbaijan. Materials of the Republican Scientific Conference on "Actual Problems of Geology" dedicated to the 96th anniversary of the National Leader of the Azerbaijani people Heydar Aliyev. Baku, 2019, p. 238-240 (in Azerbaijani)
17. Ahmadova E.V. Comparative Analysis of the GPS Velocity Field of the Domain Region of Kura Depression with Other Fields. Materials of the Republican Scientific Conference on "Actual Problems of Geology" dedicated to the 96th anniversary of the National Leader of the territory of Azerbaijan Heydar Aliyev. Baku, 2019, p. 234-235 (in Azerbaijani)
18. Ahmadova E.V. Structural analysis of Azerbaijan territory horizontal velocity movement based on GPS-measurements. Geophysical Journal, # 1, Vol. 42, 2020. p. 65-75 DOI:https://doi.org/10.24028/gzh.0203-3100.v42i1.2020.195468 (in Russian)
19. Ahmadova E.V. Modeling of modern Earth surface movements along the east coast of the Caspian sea by GPS data. ANAS transactions, Earth Sciences 2/2021, p. 63-68 (in Azerbaijani)

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