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Republican Seismic Survey Center of
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SEISMOPROGNOSIS OBSERVATIONS IN THE TERRITORY OF AZERBAIJAN

THE FIRST RESULTS OF PALEOSEISMOLOGICAL STUDIES BETWEEN OXFORD UNIVERSITY AND REPUBLICAN SEISMIC SURVEY CENTER OF ANAS

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Introduction

Science is the key to understanding the dangers of earthquakes and reducing the damage and loss of life caused by these events. It was not until the 1960s that seismic waves from earthquakes were proven to be caused by shifts on faults. Today, the knowledge of modern seismology makes it possible to solve a variety of applied and theoretical problems related primarily to the assessment of seismic hazard, based on information about the structure of all active geological structures. This knowledge will allow the creation of maps of risk zones to assess the likelihood of an earthquake, and then take steps to mitigate the associated risk. The methods and tools used in the Republican Seismic Survey Center have already gone far from traditional seismology and now Azerbaijan is investing in these new technologies that simply did not exist 20 years ago.

Paleoseismology is a young field of geosciences based on the contributions of seismology, tectonics, earthquake geology, sedimentology and Quaternary geology. The fundamental importance of the results of paleoseismology for the reliable determination of seismic hazard at a site or in an area has been recognized over the past two decades [4, 5, 7].

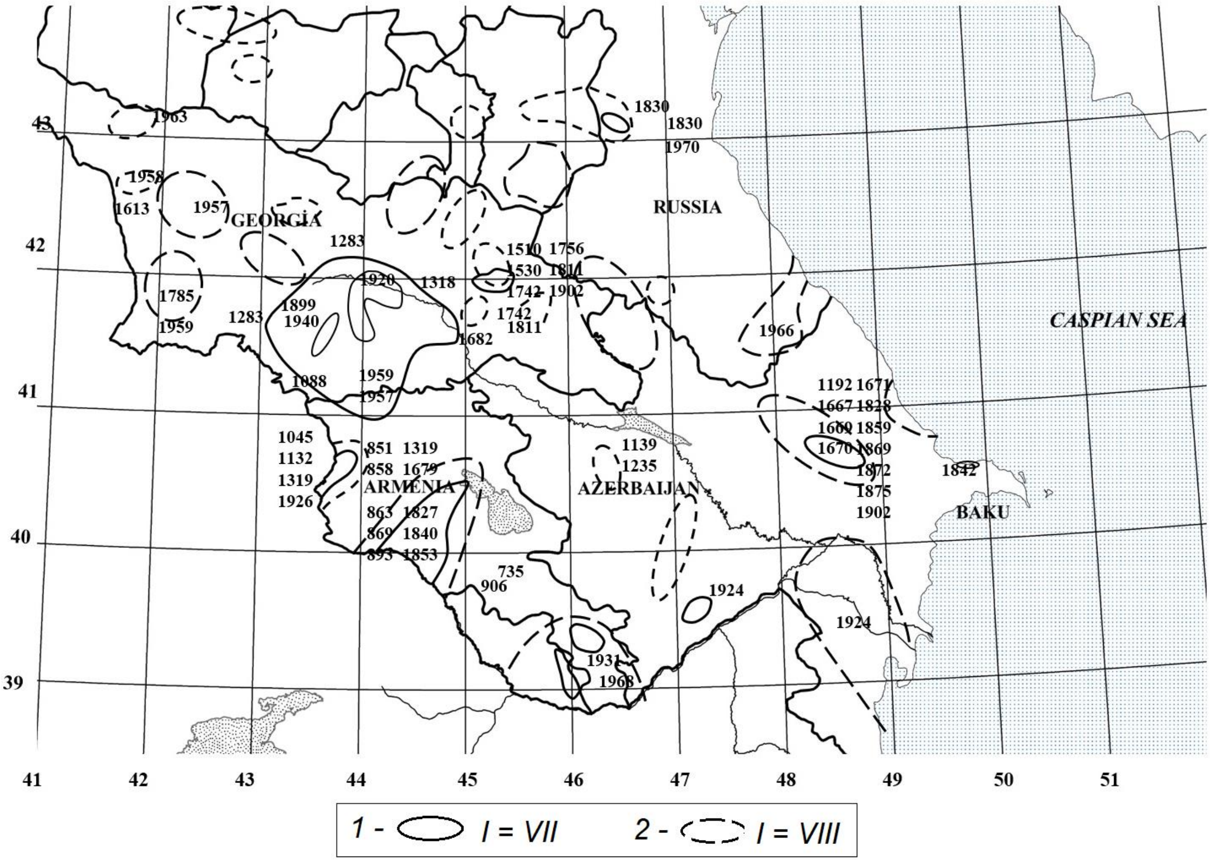

Figure1. Map of the strongest earthquakes in the Caucasus [8]

Older seismic dislocations, if they can be identified, cannot be used to determine the level of modern seismicity. In many seismically active zones, the seismic regime changed dramatically during the transition from the Lower to the Upper Holocene (about 5 thousand years ago). Paleoseismology makes it possible to determine the upper level of seismicity for the entire region as a whole and especially for specific seismogenic zones, to estimate the frequency of maximum earthquakes, and to trace the evolution of seismicity in separate

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stages of the Quaternary history. Geological evidence of earthquakes that occurred long ago is the only source of information for establishing the future seismicity of the region for very long periods. This is required by building codes for conventional buildings, as well as regulations for special buildings with a seismic hazard. For example, the new version of the German regulations for the construction and operation of nuclear reactors (called "KTA 2201.1") explicitly requires knowledge of paleoseismic data. Paleoseismology has advanced particularly seriously in California, Italy, Japan, and northern India and makes a significant contribution to our knowledge of the earthquake hazard in these regions [9].

As is known, the junction zone of mountain structures of the Greater and Lesser Caucasus is characterized by high tectonic activity, which is manifested by a variety of discontinuous-folded deformations of young deposits and landforms. Catastrophic destructive earthquakes have repeatedly occurred on the territory of Azerbaijan, such as Gandja in 1139 or Shamakhi in 1667 and 1902. Map 1 shows a macroseismic map of strong earthquakes compiled according to historical data in [8] the Greater Caucasus. Such events are accompanied by mud volcanism (fig. 1, 2), changes in the river network, and local areas of anomalously high activity of denudation processes.

Strong earthquakes of the globe occur in heterogeneous zones that differ sharply in the history of geological development, modern morphostructure, tectonic stress fields, and physical properties of the substrate in the foci. These circumstances have a direct impact on the morphology, morphometry, and genetic types of emerging seismic dislocations and should be taken into account when creating regional seismogeological scales for determining the intensity of earthquakes from residual deformations of the earth's crust [10].

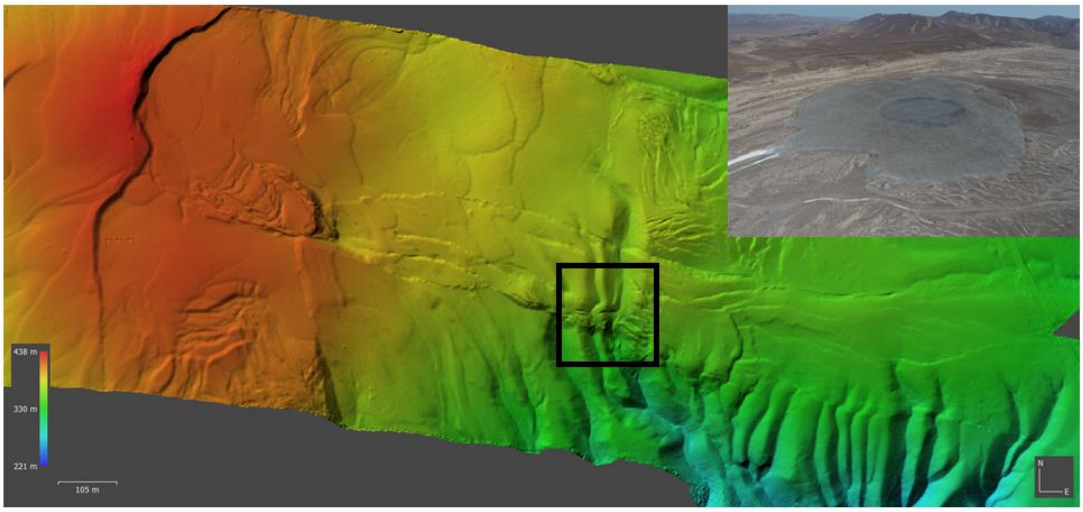

Figure 2. Gobustan: strike slip fault and mud volcano Akhtarma Pashali

However, the surface of the region over the past decades has been almost completely changed by human agricultural and construction activities. Capital new buildings - beautiful residential buildings, administrative complexes, and bridges are truly monuments of the revived traditions of national architecture. In such conditions, the integration of geological and geophysical methods is of particular importance. A unique network of seismological, geophysical, geodetic and geochemical studies was created at the RSSC, which makes it possible to study the dynamics of geodynamic processes directly when they occur and quickly respond to changes in the seismic situation in a particular area, which significantly expanded the possibilities of round-the-clock monitoring of the geodynamic situation of the republic.

The main goals of the project

In April 2021, negotiations began on the creation of a mega-project to study active tectonics and earthquakes in a vast territory stretching from China, through the Tien Shan Mountains to Kyrgyzstan, Turkmenistan, Iran and Turkey. Azerbaijan's participation in this serious project creates an excellent opportunity for cooperation between young Azerbaijani scientists of the RSSC with scientists from Oxford, Cambridge, California, Arizona and other universities, as well as with leading specialists from BP and SOCAR oil companies.

An important role in Azerbaijan's accession to this megaproject was played by Professor, Correspondent Member of ANAS Rashid Javanshir, Academician Ibrahim Guliyev, general director of the RSSC, Correspondent Member of ANAS, Professor Gurban Yetirmishli, Professor of Oxford University Richard Walker. We note that prof. Richard Walker is the author of numerous papers [1-3, 6] on paleoseismology.

The project will include the study of the history of tectonic development, active tectonics, earthquakes and natural risks and hazards that are possible in the Greater Caucasus and the South Caspian basin. The program includes a full range of studies - from the interpretation of seismic data at sea to tectonic geomorphology and paleoseismology on land.

First of all, it must be taken into account that paleoseismological observations are an integral part of complex seismological, seismogeological and geophysical studies. According to the analysis and interpretation of seismological, geophysical, geodetic data of the Republican Seismic Survey Center, results will be obtained on the history of tectonic development, active tectonism, prognosing of possible earthquakes and potential risks and dangers associated with them both for settlements and for a critical infrastructure network in the region, including pipelines.

During April and May 2022, a team of five scientists from the Department of Geosciences at Oxford, supervised by Professor Richard Walker, in collaboration with the young scientists of the RSSC, conducted the first field geological studies on paleoseismology, earthquake geology and active tectonics of Azerbaijan. Mr. Gurban Yetirmishli, General Director of the RSSC, provides great assistance in this study. The purpose of this study is to understand the possible locations and frequency of highly destructive earthquakes (M7+) that occurred prior to the development of modern seismic networks in the mid-20th century.

Field work at Aghsu and Salyan sites

We have focused on active faulting within the Kura basin and along the fold and thrust belt south of the Caucasus range front. We are aided in mapping and site selection through a satellite derived ~1 m digital elevation model obtained through the CEOS program (fig.3). Active faults have been mapped and a number of sites visited in the field, with drone surveys acquired over key sites. Two paleoseismic trenches have been excavated, with several more sites selected for future field visits. Long-term geological slip-rates have been measured from displaced river terraces. This study used advanced technologies including satellite imaging, drone simulation, GPS and InSar technologies, seismic deployment and paleoseismic excavation to study earthquake tectonic faults in Aghsu, Goychay, Ismayilli, Shirvan, Gobustan and Salyan districts. Two main sites were chosen for the initial detailed paleoseismic excavations. The first region was in Aghsu, and the second in the Salyan district.

In Aghsu, a trench was dug across the ledge of the fault, formed by the surface trace of the fault of the Main Caucasian Thrust. This trench found traces of two paleoseismic earthquakes and a total of 6 m of thrust displacement. These earthquakes probably had a magnitude of 7.0 and both occurred within the last 1000 years. It should be noted that this zone is composed mainly of clayey Paleogene and Miocene deposits of great thickness, folded into linear and brachiform folds. Folding in this region was most significant in the Late Miocene. A team of researchers from the University of Oxford will conduct a laboratory analysis of sedimentary rock samples to determine the exact timing of earthquakes. In the Ismayilli district, a temporary network of 30 (at a distance of 2.5 m) portable seismic stations was deployed to record microseismic earthquakes and study the structure of the surface crust.

In the Kura basin, adjacent to Salyan (fig.4), our satellite-based fault mapping revealed a series of very active strike-slip faults in a region with little modern seismicity. It should be noted that the transverse tectonic zone of the territory of the Caucasus, due to the existence of deep faults of the anti-Caucasian strike, is emphasized by the high values of horizontal gradients of isostatic anomalies in the zones of these faults. We have excavated successful trenches across the Kura faults (that reveal multiple surface-rupturing earthquakes. Age dating of these events is in progress (fig.5).

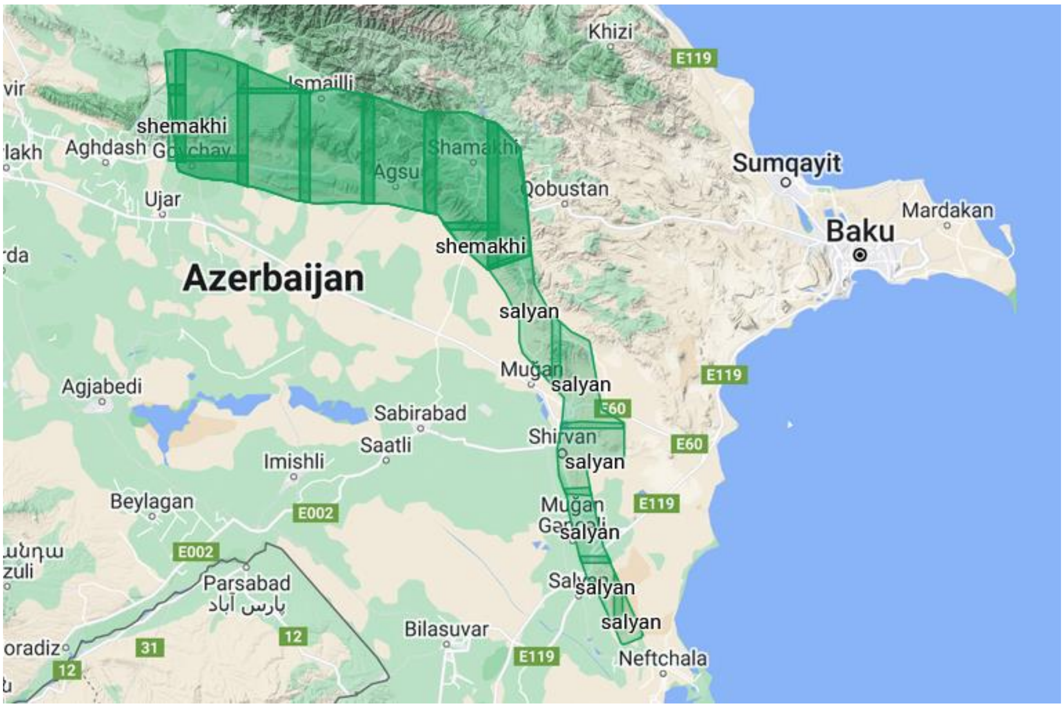

Figure 3. Coverage of satellite image derived digital topography (area in green) used to map active faulting and select field sites for detailed investigation

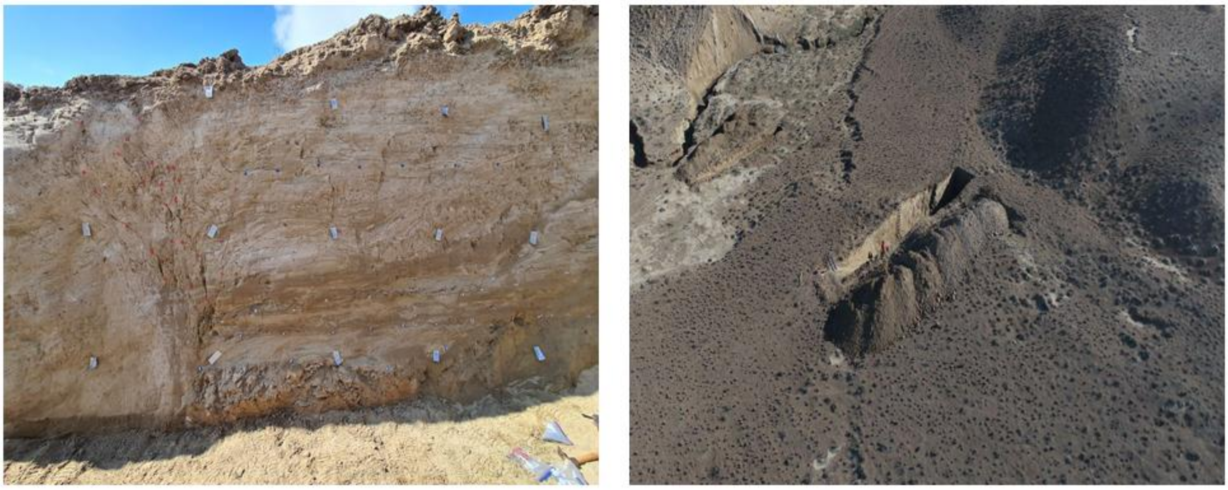

Figure 4. A trench dug in the Salyan district. There are at least six earthquakes within this fault zone.

In Salyan, a team of researchers discovered a shear fault that extends from Shirvan to Neftchala and flows into the Caspian Sea. A paleoseismic trench dug across this fault revealed very clear signs of an active fault. These strike-slip faults are potentially important features within the regional tectonics, accommodating relative motion between the South Caspian Basin and the Talesh. The faults constitute a large seismic hazard both to population centres and to infrastructure, including pipeline crossings and terminals.

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A detailed stratigraphic analysis of the Salyan trench has provided evidence of six prehistoric earthquakes that have occurred in the last 10,000 years. Each of these earthquakes had a magnitude from M= 6.5 to 7.5. More research is needed to determine possible magnitudes.

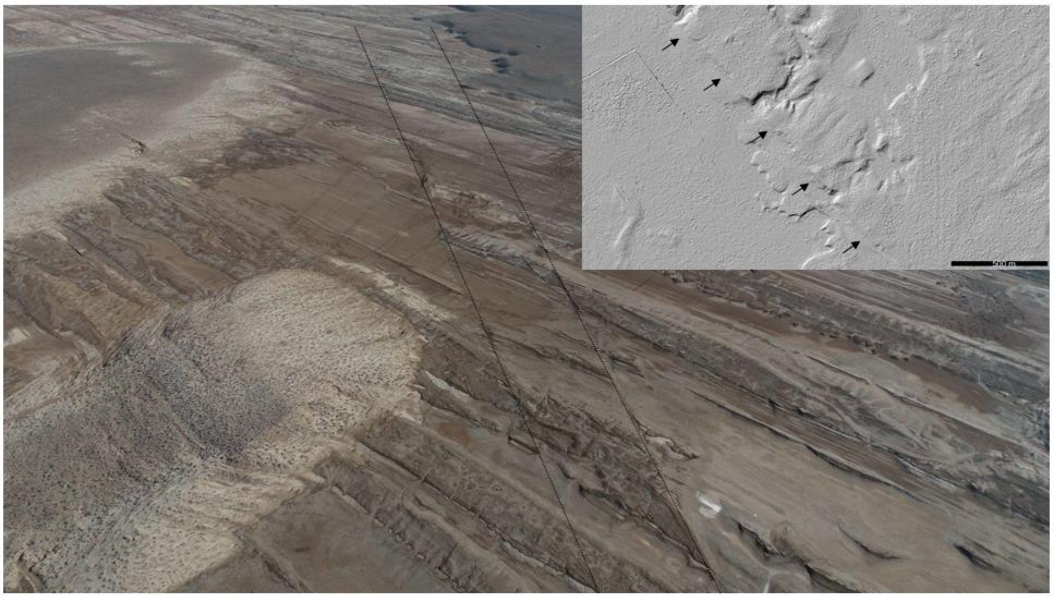

Figure 5. Optical satellite derived DEM of the Lower Kura fault trace, cutting across an anticline. Data obtained through the Committee for Earth Observing Satellites (CEOS) Seismic Hazard Demonstrator

The initial stage of interpretation of the 2D seismic reflection data on the shelf allowed us to identify the southward marine extension of strike-slip faults in the Kura basin (yellow, in the Figure 6). As is known, the structures in the offshore region of the Kura differ from the structures located further from the coast, due to their wavelength and asymmetry. It was found that the westernmost anticlines within the area of the study area grew in a short period of time from 1.8 Ma and are now cut by arrays of cracks, interpreted as shear deformation, which can be traced on land to the West Kura shear fault. More easterly anticlines have a longer history of deformation, move eastward, and shift the stratigraphy vertically.

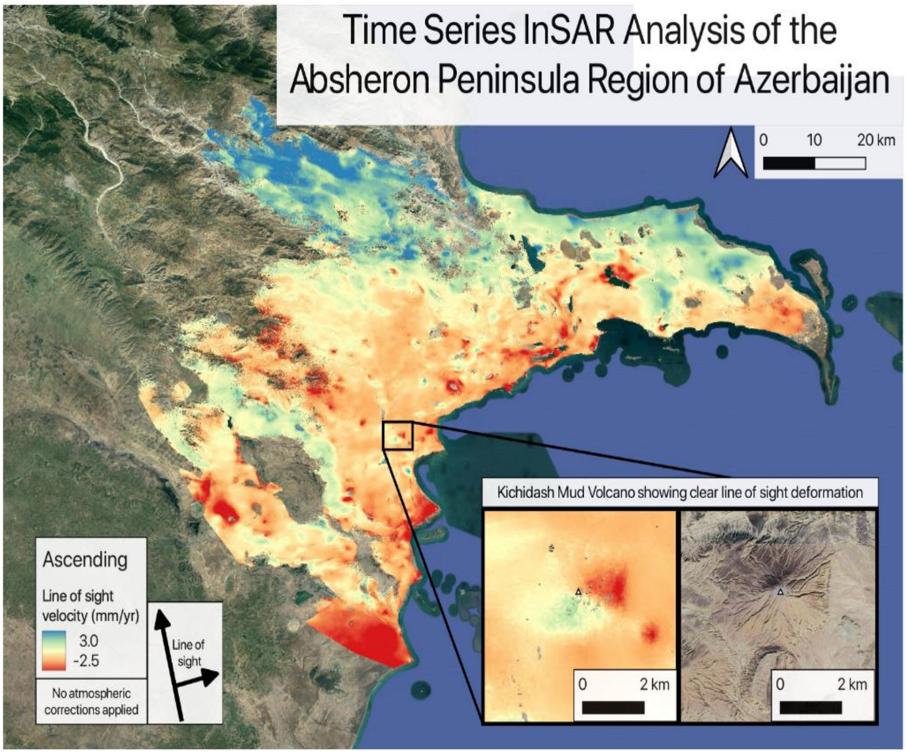

Figure 6. Line-of-sight velocity map within the Kura basin derived from satellite RADAR. Mud volcano inflation is clearly visible (see inset). It is hoped that corrections for atmospheric noise will allow better imaging of strain accumulation across the active faults.

Results

In Aghsu have excavated a trench across a small fault scarp, revealing rupture in at least two separate earthquake events on a low angle fault that has displaced sedimentary layers approximately 7 m. Initial sample dating suggests rupture occurred during the 1902 and possibly 1667 Shamakhi earthquakes. If confirmed this represents a major result in identifying the causative fault of the destructive earthquakes in Shamakhi.

In the Kura basin, adjacent to Salyan, our satellite-based fault mapping revealed a series of very active strike-slip faults in a region with little modern seismicity. We have excavated successful trenches across the Kura fault that reveals multiple surface-rupturing earthquakes. Age dating of these events is in progress.

We have correlated the Kura faults southwards onto structures visible within seismic reflection data, and also collected samples from displaced river terraces to determine geological rates of slip. The anticipation is to determine a full understanding of the geological development and the role of these strike-slip faults.

The results of the studies are preliminary, and more detailed analysis of the collected data and geological samples is required in order to obtain final results. The results will be published in scientific journals and distributed among the relevant state bodies of Azerbaijan. This first expedition shows that the Oxford method of paleoseismology works very well to determine the seismic and geological parameters of pre-instrumental earthquakes in Azerbaijan. This article describes the initial results of the first paleoseismological research in Azerbaijan, and this research collaboration between the RSSC ANAS and Oxford will last for many years and bring many fruitful results. Future research will include greater exchange of scientific knowledge and training between young staff of the RSSC and the University of Oxford. Improving scientific personnel, developing the knowledge and skills of young scientists to study earthquakes and promoting cooperation with countries with significant potential is a constant priority of the RSSC.

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ON HYDRO-GEOLOGICAL AND GEOMORPHOLOGICAL FACTORS AFFECTING THE LEVEL OF SEISMIC HAZARD IN SEISMICALLY ACTIVE AREAS

L.T.Fattakhova[1], L.A.Ibraghimova[1], A.B.Guliyeva[1], F.Z. Mehtizade[1], A.G. Babazadeh[1].

Introduction.

The effect of earthquake manifestation on the earth's surface depends on many factors - their magnitude (M), epicentral distance (Δ) and depth (H) [5]. In addition to these factors, the effect of seismic hazard is also influenced by local engineering-geological, hydro-geological, geomorphological conditions.

The general (background) level of seismic hazard of the regions is estimated on the basis of the general seismic zoning (GSZ) map. The level of seismic hazard in local territories (construction sites) is also strongly influenced by the parameters of the formations that make up the part of the geological section close to the earth's surface - structure, lithological composition, physical-mechanical and hydrogeological properties, thickness of the layers, relief of the earth's surface, etc.

In this regard, it is necessary to take into account the influence of engineering-geological and hydro-geological factors on the level of seismic impact during construction work in seismically active areas, especially at strategically important facilities, high-rise buildings.

Over the past 20-25 years, major construction work has been carried out in Azerbaijan, especially in Baku. Engineering-geological, hydro-geological and engineering-seismological studies carried out at these construction sites have made it possible to create a large database of the parameters of structures.

Based on the analysis of this database in the Sabail, Khatai, Nasimi, Nizami districts of the Absheron Peninsula, a number of construction sites have been identified that differ in variable lithological composition, structure, physical properties of soils, and hydro-geological conditions.

In these areas, construction site soils (bulk soil, silt, sand) have very poor bearing properties, and the water level regime directly depends on sea level.

Also on the sea terrace a few meters above sea level, located in the Primorsky park zone, areas located on flat terrain, the lithological composition consists of bulk soil, oil-saturated, dusty, water-saturated, free-flowing sand, soft plastic clay, plastic clay soils predominate. Although the slope at the construction sites in these areas is low (0.5-1°), the water flow is from the bottom up and the pressurized water mixes with the water in the upper layer. The supply of groundwater with pressure water, depending on their depth, increases soil moisture, which leads to a decrease in wave velocities in the soil.

Taking into account the fact that the construction sites are close to the Caspian Sea in the "White City" area of Sabail, Nasimi, Khatai districts of Baku city, the soils, which are intersections in these areas, are porous, which can be seen during visual inspection. At most construction sites located in the Khatai region, water is at 2 levels:

The water level in horizon I is 0.5-9.0 m;

The water level in horizon II varies between 10.0-22.0 m.

Water in the I horizon is formed due to the passage of water through the nearby territory, water in thermal, sewer networks, atmospheric sediments and condensation. These waters are classified as domestic waters and are usually removed from the territory by drainage.

The waters of the II horizon are classified as underground groundwater.

At some construction sites in the White City area of this region, the soil is contaminated with oil products. This is due to the fact that the study area is an old oil industrial zone and many local oil pipelines pass through it. The continuous seepage from these pipes was absorbed directly by the sandy soils.

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Table 1.

Calculation of points due to pressure and groundwater (examples).

№	Groundwater	Areas with pressurized water. Water level (m)	Soils (in which water is fixed)	$\Delta I_{q.s.s.}$ m	I_i (points)
1.	5,20-6,50 м	12,0-30,0м; 38,0-50,0м; 52,0-59,0м	Limestone, plastic sandstone	+1,0	9 points
2.	5,0-6,0 м	55,0-60,0м	Limestone	0,0	8 points
3.	5,50-7,0 м	29,0-54,0м; 56,0-63,0м; 79,0-92,0м	Limestone, fine sand	+1,0	9 points
4.	1,80-3,80 м	15,0-25,0м	Watery sand	+(0,9÷1,0)	9 points
5.	4,0 м	-	Limestone	+(0,53÷1,0)	9 points
6.	15,0-25,0 м	-	Sandy soil, watery	+0,60	9 points
7.	I horizon -3,30-4,0 м; II horizon -10,0-15,0 м	-	Sandy soil, watery	+(0,59÷1,0)	9 points
8.	I horizon -3,50-7,0 м; II horizon -12,0-13,30 м	-	Clay soil, semi-solid consistency	+(0,07÷0,10)	8 points
9.	I horizon -3,30-4,0 м; II horizon -11,30 - 16,40 м	-	Semi-solid loam, Limestone	+(0,50)	9 points
10.	I horizon 2,8-7,0 м II horizon 9,0-18,0 м	-	Limestone, watery sand	+(0,30)	9 points
11.	1,50-2,50 м	Pressure water (artesian)	Bulk soil	+(0,78÷0,94)	10 points
12.	1,50-2,50 м	-	Bulk soil	+(0,78÷0,91)	9,0 points
13.	3,0-4,0 м	-	Bulk soil Watery sand	+(0,29÷0,44)	9 points
14.	1,30-1,40 м	-	Bulk soil	+(0,48÷0,81)	9 points
15.	5,90-7,60 м	-	Hard plastic loaml, limestone	+(0,21÷0,49)	8 points
16.	1,0- 4,20 м	-	Dusty sand, bulk soil	+0,50	9 points
17.	2,50 - 4,70 м	-	Semi-hard clay	+(0,05÷0,22)	8 points
18.	1,0 - 4,0 м		Bulk soil	+0,50	9 points

Based on visual observations, it was noted that in some areas the contamination had reached saturation levels. Hard plastic clays and watery sands predominate in these areas. Underground waters, which are close to the surface of the earth, made these soils moist, watery and plastic, fluid.

If during the operation of buildings and structures a rise in the level of groundwater or flooding of the soil is predicted, then the class of the soil changes depending on its characteristics in the watered state.

To determine the effect of hydro-geological conditions on the soil, when considering well sections in some construction sites designed in the Nasimi and Nizami districts, the water pressure in these areas is mainly 12.0-30.0 m; 38.0-50.0; occurs in the depth interval of 52.0-59.0 m and there is a rise of these waters to the surface of the earth.

On geological and lithological sections of construction sites with difficult hydro-geological conditions and in the presence of pressurized water, sections of several wells are shown as examples (Fig. 1÷4), as well as the proximity of such construction sites to the sea and the presence of pressurized water in the area are factors that seriously affect to the level of seismicity (Table 1).

The study of well sections, determination of the depth of groundwater, assessment of the conditions of immersion of rocks reflect the main features of the geological environment.

The soils of these construction sites, which represent an area near the sea, belong to the III category of seismicity, and the presence of pressure water in the area causes an increase in the level of seismicity [1].

If pressure water is located at a shallow depth in the study area, then it does not affect the soils located in the upper layer (Fig. 4).

The presence of artesian water at construction sites can lead to building collapse, affecting the seismic properties of soils found in the area. Groundwater changes the engineering-geological quality of the rock in most cases, either due to its composition or due to the characteristics of the chemical composition.

Several examples of geological and lithological sections of construction sites in the Nasimi and Nizami regions.

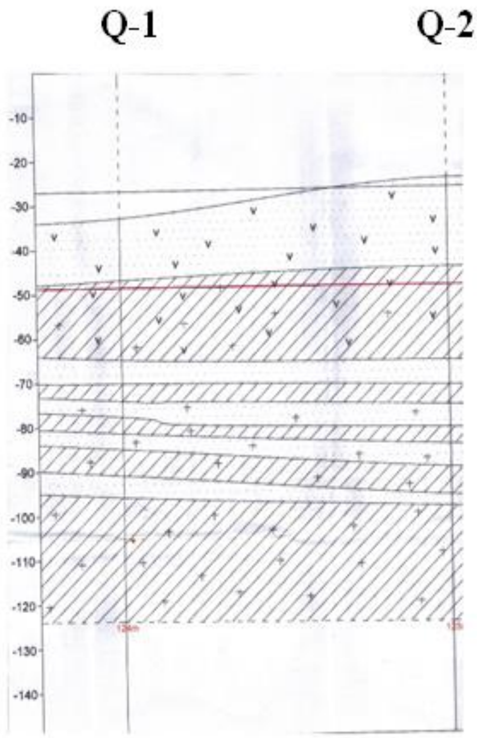


Figure 1. Nasimi district

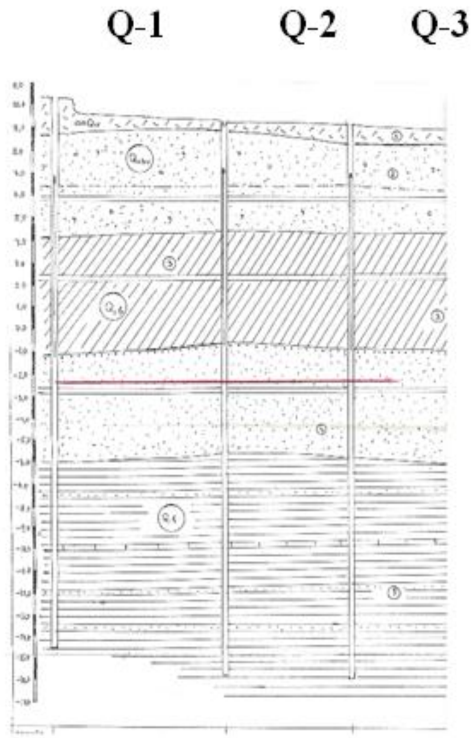


Figure 2. Nasimi district

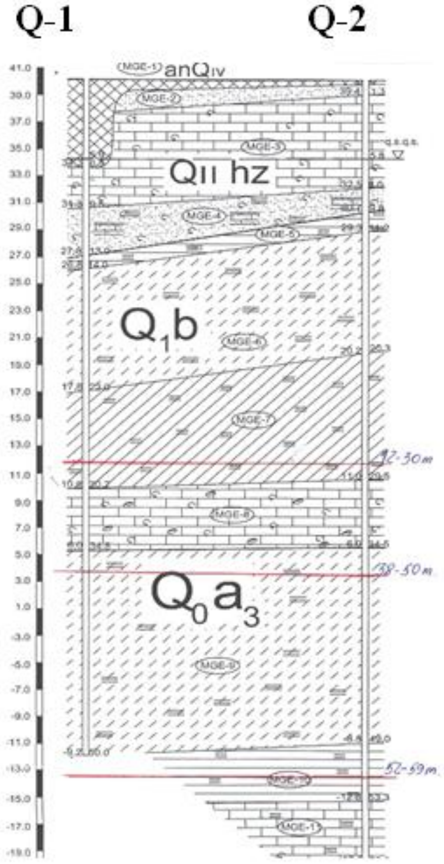


Figure 3. Nizami district

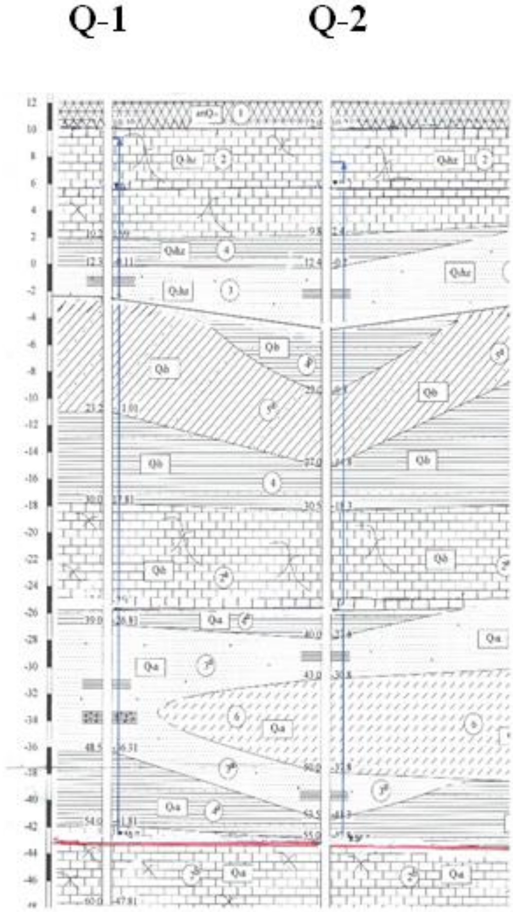
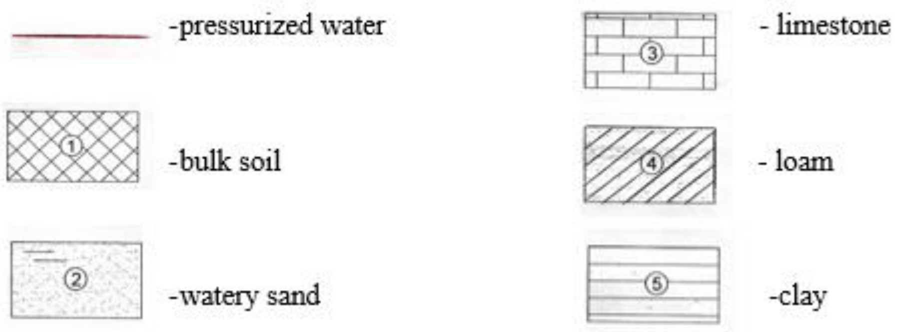


Figure 4. Nizami district

Symbols:
Pressurized water areas:



During its movement, water carries away with it small fractions present in the pores of the rocks, forming cavities of different sizes in the rocks, which leads to a decrease in water resistance. Under the influence of gravity, groundwater destroys rocks and causes a change in their physical and mechanical properties in a negative direction.

So, depending on the degree of hydration, the soils of construction sites, the mechanical parameters of which fluctuate over a wide range, are mainly represented by soft plastic clays, soft plastic loams and wet sands. With intense seismic vibrations, these soils are subjected to compaction, which, in turn, adversely affects the seismic resistance of buildings and structures erected on them.

Soils are unsuitable for construction, the strength of which has weakened, softened when interacting with water, the solidity of which is broken due to excessive cracking and corrosion processes.

It is known that the moisture of soft rocks and the slope of the terrain are the main conditions for the occurrence of landslides. Landslides are formed due to intense moisture of rocks. Groundwater wets the rocks of atmospheric sediments to fluidity, and the mass moves relatively quickly. The depth of coverage of the sliding mass does not exceed 10-15 m, and the length of the sliding is several times greater than its width.

The increase in slope creates favorable conditions for the collapse of fractured rocks and buildings due to the weight of water in areas with water, and the definition of landslides, groundwater, pressure water, slope and stability of the building base is an important factor that determines the geological conditions of the area.

When carrying out measures against the landslide process in areas prone to landslides, during construction work, one should take into account the study of the geological and hydrogeological conditions of the area and the prevention of water runoff in these areas, protecting the landslide massif from natural destruction, increasing the stability of the inclined surface, terracing slopes.

The study of geological and hydrogeological conditions in the construction sites of territories prone to landslides, prevention of groundwater, increasing the stability of an inclined surface by mechanical means is one of the important issues.

Features that can enhance the seismic impact on the earth's surface are soil compaction, landslides, subsidence, formation of cracks in the soil, etc. Since compacted soil is fluid, it subsides under buildings and structures and causes destruction [3] (Fig. 5).

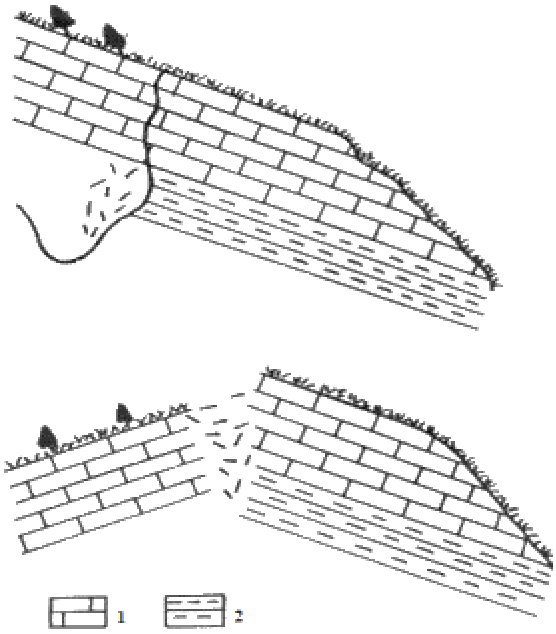
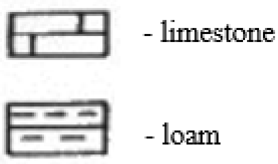


Figure 5. Influence of hydro-geological conditions on rocks

Symbols:



The riskiness and danger of geological processes should be assessed according to the patterns of their development, the nature and mechanism of the process, depending on the stage of research, the degree of knowledge and features of the area where the process develops [4].

Thus, another factor that changes the basic physical and mechanical properties of rocks during construction is hydrogeological and geomorphological conditions. The problem of assessing threats and risks arising from the development of geological processes is very relevant. Any engineering activity affects the geological environment, creates appropriate changes in this environment, ensures the durability of the ongoing construction with the geological environment and changes depending on the engineering-geological activity as the main issue of engineering geology.

Results

1. The presence of underground and pressure (artesian) waters in construction sites changes the physical and mechanical properties of soils in a given area, strength indicators in a negative direction, violates the solidity of rocks and causes an increase in the level of seismic hazard.

2. Geomorphological conditions are the main indicator during construction. In areas with water, an increase in slope, due to the gravity of the building, creates favorable conditions for the collapse of construction sites, and wetting of soft rocks leads to landslides.

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DETERMINATION OF THE DEPTHS OF THE ACTIVE BLOCKS ACCORDING TO THE DATA OF THE GPS STATIONS

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

Introduction

The advent of satellite geodetic observations was marked by their widespread use to determine the velocities and direction of horizontal movements of lithospheric plates. The accuracy of measuring the horizontal component of displacements of the earth's surface in GNSS measurements turned out to be significantly higher than the vertical one at a large spatial scale of observations. The objective features of the technology of geodetic observations make it possible to measure the vertical component of the earth's surface displacements much more accurately by terrestrial methods, and the horizontal component by satellite methods. This leads to the conclusion that it is fundamentally impossible to jointly analyze the results of measuring identical motion components obtained by ground-based and satellite methods.

With the development of the era of navigation satellite systems GPS, GLONASS, GALILEO, and the expansion of the network of receivers receiving their signals, it became possible to use these systems to study the ionosphere, as well as for a more detailed examination of ionospheric structures that occur on the eve of destructive earthquakes. J.Y. Liu, I.I. Shagimuratov, V.E. Kunitsyn, S.A. Pulinets, I.E. Zakharenkov [11].

As is known, the deformations of the earth's surface that accompany the strongest earthquakes reflect the action of physical processes of various natures, differing both in intensity and in spatio-temporal characteristics. According to the time of action, these deformations are subdivided into co-seismic, occurring immediately at the moment of an earthquake, and post-seismic, which can last a month, a year, or decades after a seismic event. Co-seismic deformations can be observed by both seismological and geodetic methods, while post-seismic deformations can be observed only by geodetic methods. In many countries of the world where high seismic activity is observed, geodynamic polygons are deployed and GPS stations operate on a permanent basis, and receivers continuously record high-precision deformations of the earth's crust. Practice shows that such monitoring makes it possible to track the processes of tectonic deformations of the earth's crust, calculate co-seismic/post-seismic deformations and contribute to the study of changes in the stress-strain state, which ultimately contributes to solving problems of earthquake prediction [17]. This article attempts to study the seismic deformations of the earth's surface, which are the result of the strongest earthquakes. Co-seismic deformations are considered for most of the strongest earthquakes that have occurred over the past ten years of active GPS monitoring in various seismically active regions of the republic. The purpose of this work was to analyze the time series of GPS measurements to determine the directions and correlation of the obtained results with the hypocenters of strong earthquakes.

The principle of determining coordinates by satellite navigation method.

The determination of the coordinates of the GPS station by the satellite navigation method is carried out by calculating the coordinates of the satellites and the distances to them. Figure 1 shows the principle of determining the position on the plane: the found distance to the satellite *r* allows you to determine the coordinates on the set of solutions presented on a ring-shaped figure (in projection).

The appearance of a new satellite reduces the solution area. Thus, there are a required minimum number of satellites so that the area for three-dimensional coordinates is sufficient to determine the position with certain accuracy. The orbits of the satellites are mathematically described by ephemeris (almanac), which are the Keplerian elements of the orbit. Ephemerides are transmitted in the navigation message from satellites with a period of 12.5 minutes [12]. From them, you can determine the satellite coordinates at any time during which these ephemeris are valid. Mathematically speaking, if the ephemeris is represented as a vector of parameters E, which are obtained for the *i-ro* satellite, then the process of calculating the coordinates of this satellite is reduced to the formula:

$$r_i\,(t) = f(t,E_i\,),\ (1)$$

where $f(t,E_i)$ is a well-formalized function, which is specified strictly mathematically, and $r_i\,(t) = (X_i, ,Y_i ,Z_i)^m$ - the desired satellite coordinates at the desired time in the corresponding coordinate system. The first chapter provides a detailed algorithm for calculating the coordinates of satellites for the GPS system [12].

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

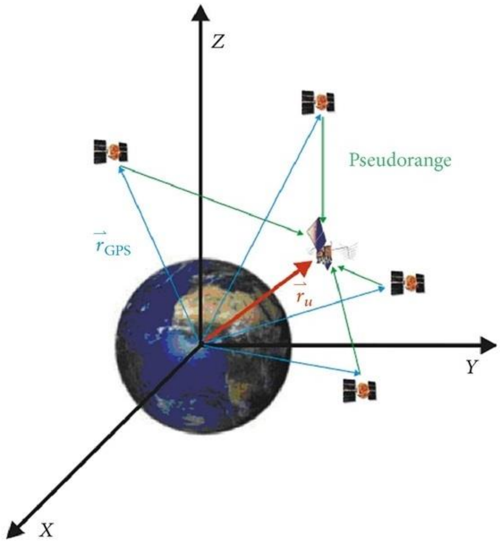


Figure1. Orbit determination using GPS [2]

The next step in solving the navigation problem is to determine the distances to each of the satellites. Traditionally, the distance to a satellite is determined by the propagation time of the phase-modulated signal multiplied by the speed of light. The propagation time of the navigation signal multiplied by the speed of light can be represented as a formula:

$$r_i = P_{Si} + d_{sat\,(i)} + D_{res} + r_{ion(i)} + r_{trop(i)} + r_{mp(i)} + e_{(i)}, \quad (2)$$

where r_i is the true (sought) range from the antenna to the satellite, P_{Si} is the measured range or pseudo-range (calculated by the receiver), $d_{sat\,(i)}$ is the satellite clock skew (the parameter is transmitted from the satellite), D_{res} is the receiver clock skew, $r_{ion(i)}$ and $r_{trop(i)}$ is the range error due to distortion in the ionosphere and troposphere, respectively, $r_{mp(i)}$ is the range distortion due to multipath signal propagation, $e_{(i)}$ is a random error including receiver internal noise. The main task of the navigation receiver is to simulate the propagation process in order to calculate all the parameters of the right side of equation (2) with a minimum error. The pseudo-range is corrected taking into account the calculated corrections and a navigation solution is made using the absolute method. It should be noted that the D_{res} correction applies only to the receiver and is calculated not at the stage of pseudo-range correction, but a little later, already during the solution itself [12]. The tropospheric effect on ranging can be calculated using special algorithms for modeling dry and wet atmospheres.

The ionospheric effect on ranging is calculated using the Klobuchar algorithm for ionospheric modeling (the algorithm is given in the first chapter). The algorithm allows eliminating up to 50% of the $r_{ion(i)}$ error. Next, the antenna coordinates are calculated by the absolute method. At the output of the algorithm, the coordinates and time of the receiver clock de-synchronization relative to the satellite system [12].

Satellite navigation

GPS (Global Positioning System) is a global positioning system that measures distance, time, and determines location in a coordinate system. Resolution is determined by the accuracy of measuring time and knowing the coordinates of the satellites. GPS consists of three main segments: space, control and user.

The idea of creating satellite navigation was born in the 50s. At that moment, when the USSR launched the first artificial satellite of the Earth, American scientists led by Richard Kershner observed the signal coming from the Soviet satellite and found that due to the Doppler Effect, the frequency of the received signal increases as the satellite approaches and decreases as it moves away. The essence of the discovery was that if you know exactly your coordinates on Earth, then it becomes possible to measure the position and speed of the satellite, and vice versa, knowing the exact position of the satellite, you can determine your own speed and coordinates. The GPS project started in 1973 under the direction of the US Department of Defense. The project started in 1994. Since 2000, the GPS system has become available to civilians. Countries with satellite navigation systems: GLONASS - Russia, GPS - USA, Galileo - Europe, Compass - China. Today, fully working, i.e. having the minimum required number of satellites in orbit, are two systems: the Global Navigation Satellite System (GLONASS), created in Russia and Navigation System with Timing and Ranging - NAVSTAR, created in the USA [10].

The total number of GPS satellites is 24, which covers almost the entire surface of the Earth except for the Polar Regions. The satellites revolve around the Earth (moving speed ~3.874km/s) in six different planes, 4 satellites in each. Satellites fly at an altitude of 20,200 km and have an orbital period of 11 hours 58 minutes; the satellite makes two orbits around the Earth in one day. An orbital inclination of 55° is also common to all satellites in the system. To date, to ensure greater reliability in orbits, the number of GPS satellites (NAVSTAR) is 30 and 24 GLONASS satellites [14].

Taking into account geomorphology, geotectonic, 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 (Fig. 2). A set of 24 GPS stations cover the vast territory of Azerbaijan and form the GPS_RSSC geodetic network. 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), registering the signal of the corresponding GPS and GLONASS satellites. 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 district, a GPS station was installed on the Saatli super-deep well (8324 meters).

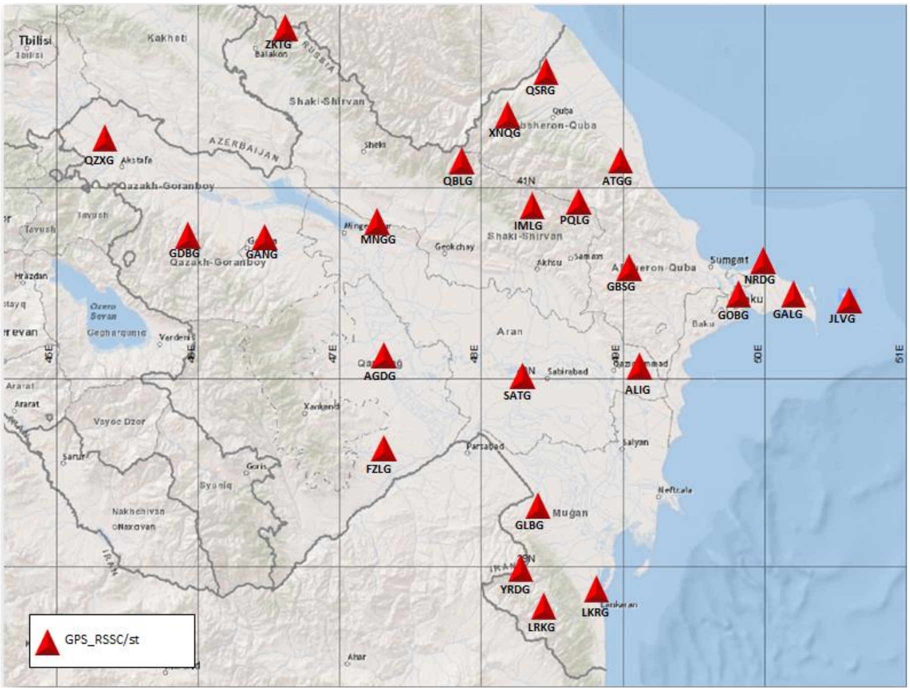


Figure 2. Network of RSSC GPS stations

Geodetic research

As is known, the stress state of the earth's crust is characterized not only by the surface layers themselves, which can be observed directly, but also by the deeper parts of the earth's crust, and the stress value is several hundred megapascals (MPa). The fact that rocks are under great stress has long been well known. It has been established that the stresses have not only a vertical, but also a horizontal component. The study of the stress state of the earth's crust to its entire depth as a whole and of rock masses is of not only scientific but also practical importance. Since all tectonic processes are associated with the current stress field in the earth's crust, knowledge of this field at the present time and the geological past is necessary for understanding geological phenomena [15].

The data obtained as a result of experimental work on the current stress-strain state of a rock mass and the patterns of its change over time, on the one hand, provide new fundamental knowledge about the nature of natural deformation processes occurring in the upper part of the earth's crust, and the impact on the formation of the stress state of a rock mass technogenic activity in the development of mineral deposits [15]. On the other hand, the data obtained serve to predict the development of the displacement process and make a whole range of technical solutions for safe and efficient field development.

Until now, geophysicists used GPS data to determine the speed and direction of horizontal movements of individual blocks or plates. In this article, we tried to connect the movement of blocks with the depths of strong earthquakes that occurred on the territory of Azerbaijan during the period 2012-2022 (Fig. 3). GPS data were processed and errors estimated using MIT's GAMIT software [6, 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 [1, 3]. The height cut off angle was taken as 10°.

Figure shows the velocity map of GPS points for Azerbaijan, which is used to calculate the two-dimensional deformations. The arrows in the figure show the direction of the velocity vectors, and the velocity values are characterized by the length of the arrows according to the scale, which is shown in the lower right corner of the map.

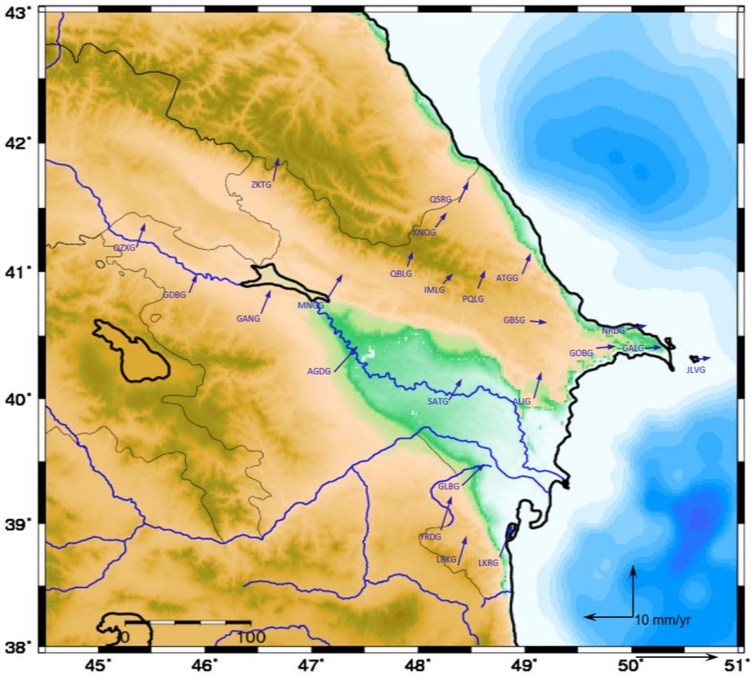


Figure 3. GPS velocity map of the territory of Azerbaijan

The velocity field of GPS observations on the territory of Azerbaijan clearly illustrates the predominance of the movement of the earth's crust in the N-NE direction relative to Eurasia. The most clearly manifested feature of the velocity field is a decrease in velocity at observation points located on the territory of the Greater Caucasus (Fig. 4). GPS observation points located along the main Caucasian thrust show a decrease in speed in an easterly direction, which is probably associated with the zone of influence of the West-Caspian Fault. N-NE movement of the earth's surface is interpreted as one of the reasons for the accumulation of stresses on this thrust. In addition, there is a tendency for horizontal movement within the Kura depression and the Lesser Caucasus, where the speed increases from west to east along the strike of the mountain range. In addition, the analysis of the azimuth angles showed an increase at the stations located on the Absheron Peninsula.

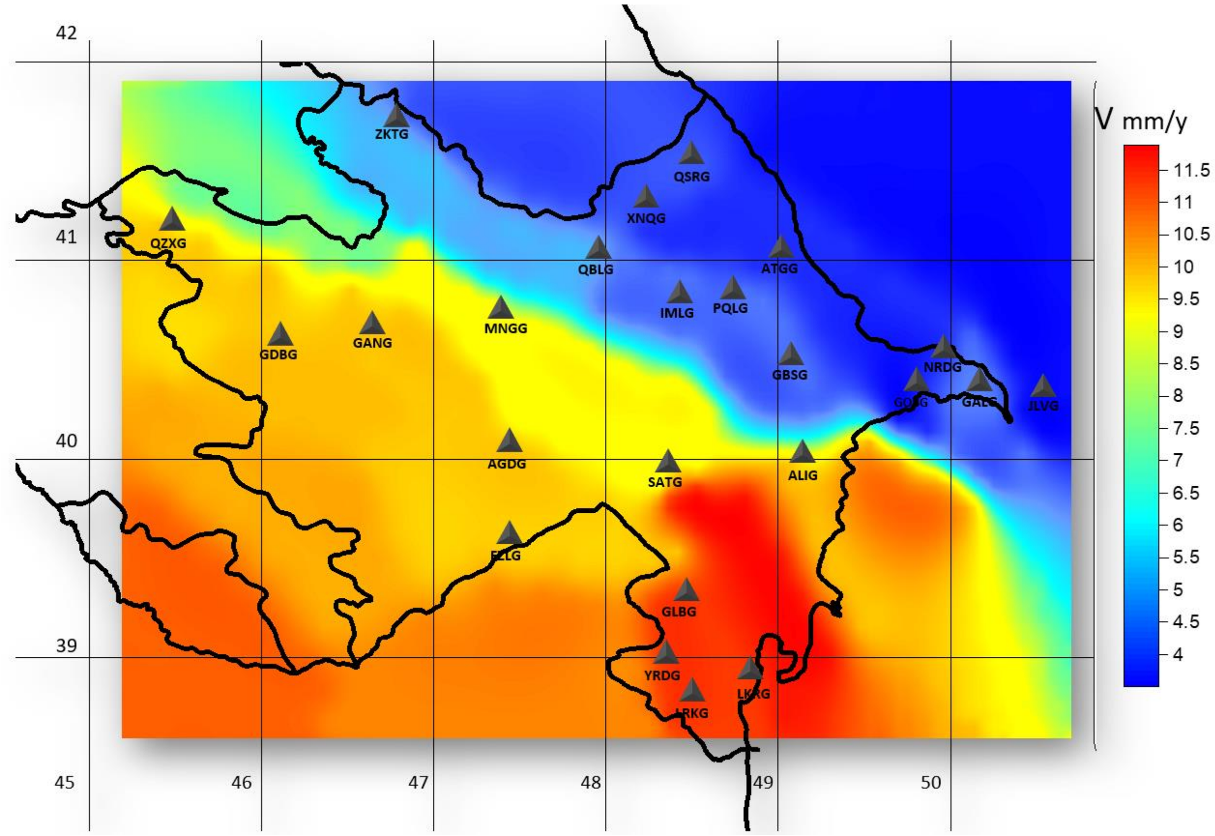


Figure 4. GPS velocity map of the territory of Azerbaijan

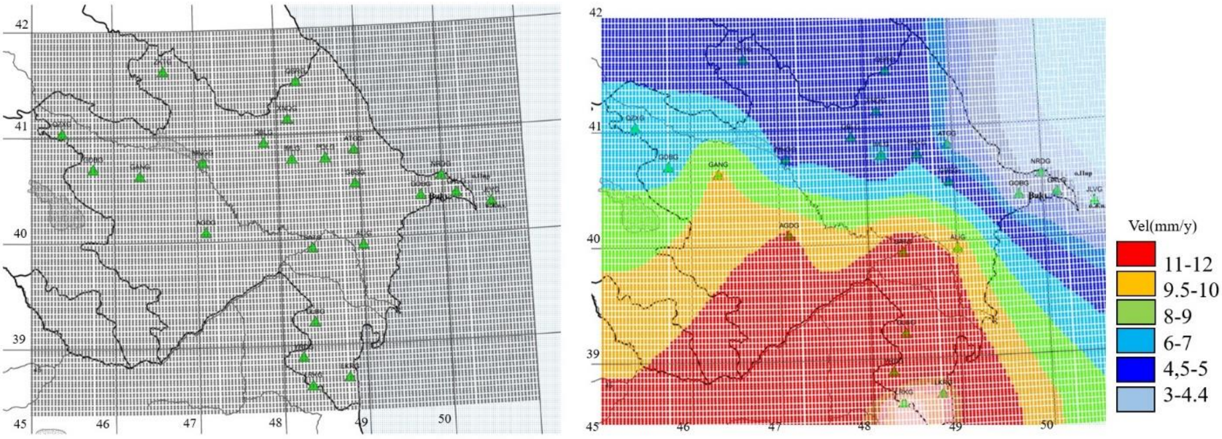
It has been established that along the Kura depression in the direction from the Middle Kura depression to the Low Kura depression (i.e. from NW to SE) there is a gradual increase in the rates of horizontal movements from 7.3 to 11.3 mm/year, which is characterized by the compression condition.

It should be noted that in the last 3 years, the zone of the Kura depression is characterized by the manifestation of high seismic activity, expressed in several earthquakes with a magnitude of more than 5, characterized by a reverse-type movement. 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/y, and further north, i.e. directly within the accretionary prism, and completely decreases to 3.5-5 mm/year. In general, the tangential shortening of the earth's crust in the region is estimated at 6.1-11 mm/year.

This is confirmed by the observed directions and speeds of movement of the earth's surface in the territory of Azerbaijan and adjacent regions according to the results of measurements at GPS points. It should be noted that the regional patterns of neotectonic and modern geodynamic development and landforms of the Caucasus region can be considered as a result of mechanical impacts on it of adjacent geodynamically active areas [13].

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 [16].

Based on the result obtained, we approximated the values of the horizontal motion velocities within the latitude coordinates 38.4-42.00 and longitude 45.00-51.00 150×150 points (Fig.5).



a) b)

Figure 5. Distribution map of approximated points (a) and points with values of horizontal motion velocities (b) according to GPS data of stations

Next, we plotted the epicenters of strong earthquakes (ml>3.0) for the period 2012-2022 years on the resulting grid of horizontal motion velocities. This transformation allowed us to match the depths of the hypocenters to the velocities. The k-nearest neighbor algorithm (k-NN) was used to select blocks. It is a metric algorithm for automatic object classification or regression. In the case of using the method for classification, the object is assigned to the class that is the most common among the neighbors of this element, whose classes are already known. In the case of using the method for regression, the object is assigned the average value of the objects closest to it, the values of which are already known. Having identified 4 depth intervals, we built spatial maps of the distribution of velocities with the selection of blocks (Fig.6).

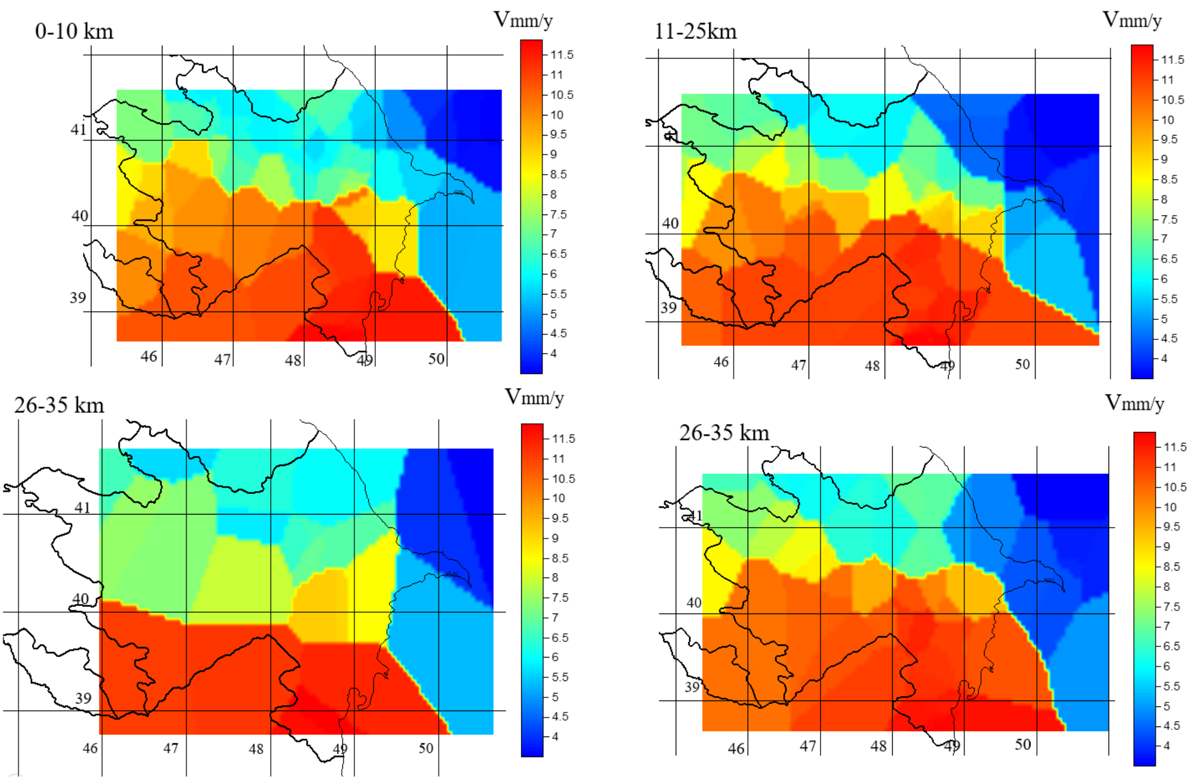


Figure 6. Map of tectonic blocks selected according to the data of GPS stations at different depth intervals

It was found that in the Guba-Gusar region in the direction NW-SE at a depth of 5 to 40 km, a block with velocities of 5.8 mm/y with a length of 55 km is distinguished. On the depth profile of Zakatala-Gobustan (NW-SE) in the southeast direction at an epicentral distance of 20 to 250 km, a gradual subsidence of the tectonic block is observed with velocities of 6.25 mm/y from a depth of 20 to 55 km. 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/y. On the eastern side of this block, a block is distinguished at depths of 10–25 km with values of 9 mm/y.

In the direction from the Middle Kura depression to the Low Kura at an epicentral distance of 150 km in the depth interval of 10-30 km, a block with velocities of 7.85 mm/y was noted, then in the depth interval of 15-38 km - a block with velocities of 9,2-9,6 mm/y, and within the Lower Kura at a depth of 15-40-50 km, a block with velocities of 11-11.9 mm/y was identified. In the Lesser Caucasus, a block with high seismic activity is observed in the depth interval of 20-40 km with velocities of 10,7-11,4 mm/y. In the Talysh region, in the direction from the NNW to the SSE, the activation noted over the entire depth from 5-60 km gradually subsides to 40 km. In the south of this region, a block with maximum velocities of 11,5-12 mm/y and a length of 50 km, the depth of which varies from 20 to 40 km, is divided by a block with velocities of 11-11,3 mm/y.

Results

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

The velocity field clearly illustrates the movement of the earth's surface in the N-NE direction. This phenomenon reflects the process of successive accumulation of elastic deformations in the zone of subduction interaction 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/yr.

Based on the correlation of GPS data and hypocenters of strong earthquakes, the boundaries were identified and the depths of occurrence of active tectonic blocks in the areas of the southeastern subsidence of the Greater Caucasus, the Kura depression and the Talysh zone of Azerbaijan were determined. In the Guba-Gusar region in the direction NW-SE at a depth of 5 to 40 km, a block with velocities of 5.8 mm/g and a length of 55 km is distinguished. On the depth profile of Zakatala-Gobustan (NW-SE) in the southeast direction at an epicentral distance of 20 to 250 km, a gradual subsidence of the tectonic block is observed with velocities of 6.25 mm/y from a depth of 20 to 55 km. 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/y. On the eastern side of this block, a block is distinguished at depths of 10–25 km with values of 9 mm/y.

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MODERN GEODYNAMICS AND SEISMICITY OF THE LOWER KURA OIL AND GAS BEARING REGION

Yetirmishli G.J.[1], Guseyn-zade G.E.[1], Kazimova S.E.[1]

Introduction

The Lower Kura depression oil and gas bearing region, as an integral part of the South Caspian depression, is a recognized oil and gas generating basin, characterized by positive stratigraphic, lithofacies and structural-tectonic criteria for oil and gas potential. The southwestern part of the area - the Mugan-Salyan syncline and the Mugan monocline, where the deposits of the productive stratum (PT) are completely wedged out, is also highly promising in terms of the genesis of hydrocarbons and the formation of oil and gas deposits [3]. As is known, the Kura depression is an intermountain synclinal trough, bounded in the north by the Greater Caucasus, in the southwest by the ridges of the Lesser Caucasus, in the west by the Suram ridge and is composed mainly of a thick layer of Cenozoic and Mesozoic deposits. In addition, it should be noted that Azerbaijan is a classic mud volcanic province. In terms of the number of mud volcanoes, their diversity and intensive activity, this region has no equal in the world. There are over 350 mud volcanoes here. Almost all manifestations of mud volcanism in Azerbaijan are associated with oil and gas bearing structures. Six oil and gas bearing regions are distinguished here, within which mud volcanoes are located: the Caspian-Guba, Shamakhi-Gobustan, Absheron, Lower Kura depression, Baku archipelago, the deep-water part of the South Caspian [12]. The seismicity of the Lower Kura depression is considered to be moderate. However, seismic analysis of recent years has shown an increase in activity in this region. The Lower Kura depression belongs to the zone of 8-point. However, it is important to study the seismicity of the southern part of the basin, where the population density is the highest, and settlements are located near active faults. Spatial migrations of the seismic process, as reflections of changes in the stress-strain state of the earth's crust, are interpreted in different ways [6].

At the same time, the trigger effects of strong earthquakes (stress transfer) are widely known, when events comparable in energy follow each other with a small (years, first decades) interval. At the same time, it is assumed that stress transfer can occur quickly as a result of the elastic reaction of the upper crust [1], and slowly as a result of the viscous-elastic reaction of the lower crust and upper mantle over long distances [2], which can affect the change in oil production in wells and activation of mud volcanic activity.

The Lower Kura depression oil and gas region occupies the northeastern part of the depression of the same name [4, 5, 13]. On the territory of this region, several large oil and gas fields have been discovered and are being developed, mainly associated with the productive strata (Kyurovdag, Garabagly, Neftchala, Kursanga, Mishovdag, Galmaz, Kalamaddyn (Fig. 1).

In tectonic terms, from the north-northeast, the region borders on the Shamakhi-Gobustan highlands through the Lengebiz-Alyat anticline belt. The southern limb of the belt serves as the northern edge of the Lower Kura depression. The western boundary of the depression is considered to be the West Caspian and Lower Araz faults, to the west of which the Goychay-Saatly uplifted zone and the Yevlakh-Agdjabady trough are located [7]. The southern side of the depression is known in the geological literature as the Mugan monocline (according to the Pliocene layers) and stands out as an independent promising and gas-bearing region - the Milsko-Mugan. The most submerged part of the modern depression, the Mugan-Salyan synclinal trough, serves as the boundary of these oil and gas bearing regions [11, 9].

To the east, the Lower Kura depression spreads to the junction with the Baku archipelago, tectonically separated from it by the Alyat-Gyzylagach transverse fault. The depression on the surface of the Mesozoic in the regional plan is the centroclinal part of a vast trough, the main part of which is located within the South Caspian.

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

The Lower Kura depression oil and gas bearing region is tectonically a complex geological body subjected to wave and fold movements of a regional and local nature. In the Neogene and Anthropogene, it experienced the greatest subsidence, which was compensated by sedimentation. The thickness of sedimentary formations here exceeds 15–16 km. The zone covers the southern side of the Lengebiz-Alyat anticlinorium, the Gargaly synclinorium, and the Harami-Salyan anticlinorium and is called the Shirvan tectonic zone [11].

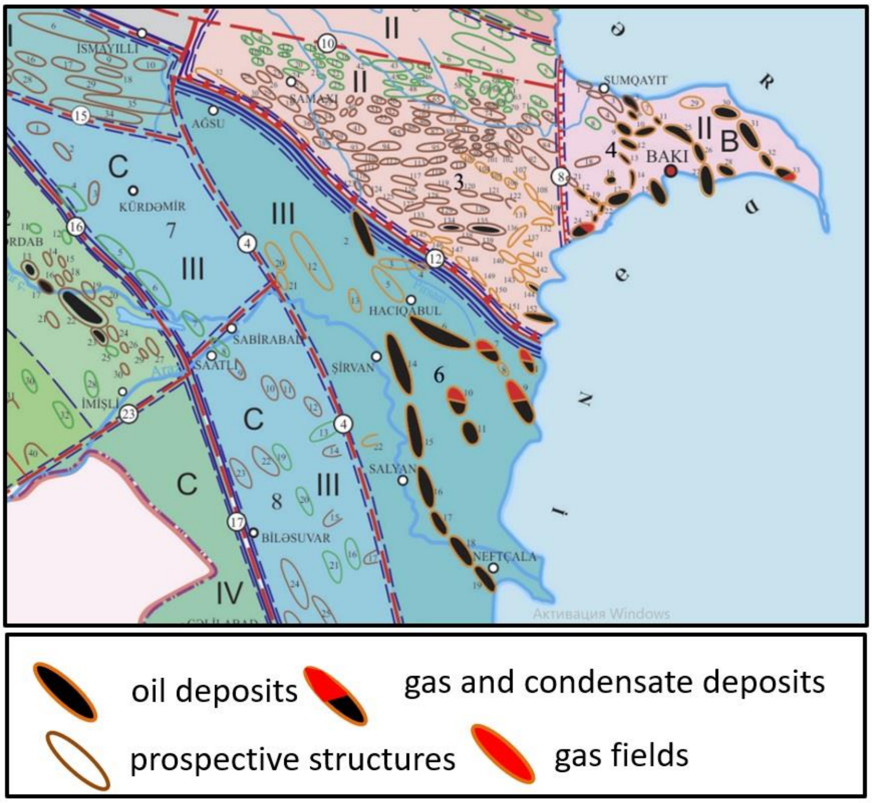

Figure 1. Map of the oil and gas bearing zone of the Lower Kura depression [14].

With the exception of the Kursangi and Padar folds identified by seismic exploration, the rest of the uplifts of the Lower Kura depression were identified by geological surveys and studied by structural mapping and exploration drilling. In the geological section of the folds, mainly Anthropogenic-Pliocene deposits take part. Within some uplifts, deep boreholes also uncovered Oligocene-Miocene deposits (Kalamaddyn, Harami, Kyurovdag). In most cases, on the vaults of anticlines, an eroded productive stratum protrudes to the day surface from above, successively bordered by the Akchagyl and Apsheron layers. Anticlinal belts are complicated by regional longitudinal faults along the crests of folds, sometimes doubled. Transverse discontinuous disturbances are frequent, giving the folds a blocky character. In the northwestern part of the region (Kala-Maddyn-Kharami zone), through (regional) transverse faults are also observed [11]. On the vaults of many folds, mud volcanoes are active, associated with faults. Among the ejecta of mud volcanoes there are pieces of rocks up to the Cretaceous age. There are also buried mud volcanoes (Padar) and layered hilly breccias (Kalamaddyn, Harami, etc.)

The main object for prospecting and exploration of industrial deposits of oil and gas are the productive strata, the Akchagyl and Apsheron stages, as well as in the near future Paleogene-Miocene deposits and, probably, Mesozoic deposits on the sides of the depression.

Seismicity of the Lower Kura depression

The Lower Kura depression is one of the regions of Azerbaijan where the probability of strong earthquakes is not high. As mentioned above, the Lower Kura depression belongs to the zone of 8-point. In addition, in recent years, active construction of oil and gas production and processing facilities and related infrastructure has been carried out on the territory of the region under study. New lines of gas and oil pipelines are stretching, which pass through seismically dangerous territories. It should be noted that similar studies were carried out earlier and were presented in [8].

The seismicity of the Lower Kura depression is considered to be moderate. Throughout the history of seismic observations, earthquakes have been recorded here. As an example, we can note the earthquakes that occurred in the Imishly region on February 5, 1985 with an intensity of I=5-6 points, on April 24, 1989 with an intensity of I=5 points, on January 1, 1991 with an intensity of I=6 points and the Saatly-Sabirabad earthquake that occurred on April 19, 1989 with intensity I=5 points.

In depression zones, earthquakes with magnitude M=4-5, intensity I=V-VI points can be generated. The Kurovdag-Neftchala seismogenic zone is caused by an active fault, which is practically a seismogenic in plastic media. Within the Lower Kura depression, the maximum magnitude of expected events associated with local seismogenic structures in the West Caspian zone is 5.4 and 5.7, and in the Kurovdag-Neftechala zone - 5.5.

In recent years, in connection with the modernization of the seismic network and the increase in seismic stations, new data on the seismicity of the territory of the Lower Kura depression have appeared, which require systematization and analysis. Figure 2 shows a map of the epicenters of earthquakes that occurred within the study region for the period 2003-2022 with ml≥3.0 and ml≥4.0. The catalog of earthquakes was taken from the Scientific Reports of the RSSC ANAS [15]. As can be seen in the Figure, earthquakes are not evenly distributed. It is possible to single out an accumulation in the zone of Saatly-Imishli and Gobustan-Shirvan regions. This accumulation indicates the presence of seismogenic zones in this region. As can be seen on the seismic profiles in the NW-SE direction, two zones of distribution of hypocenters 0-10 km and 10-25 km are distinguished with a slight tendency to dip. On the seismic profile in the SW-NE direction, at a depth of 35-60 km, the Saatly-Imishli seismogenic zone is distinguished, at the epicentral distance of 60-85 km, the Hadjigabul, at the epicentral distance of 85-110 km, the Shamakhi seismogenic zone (Fig. 3).

Over the past 20 years, there has been a gradual increase in seismic activity in the study region.

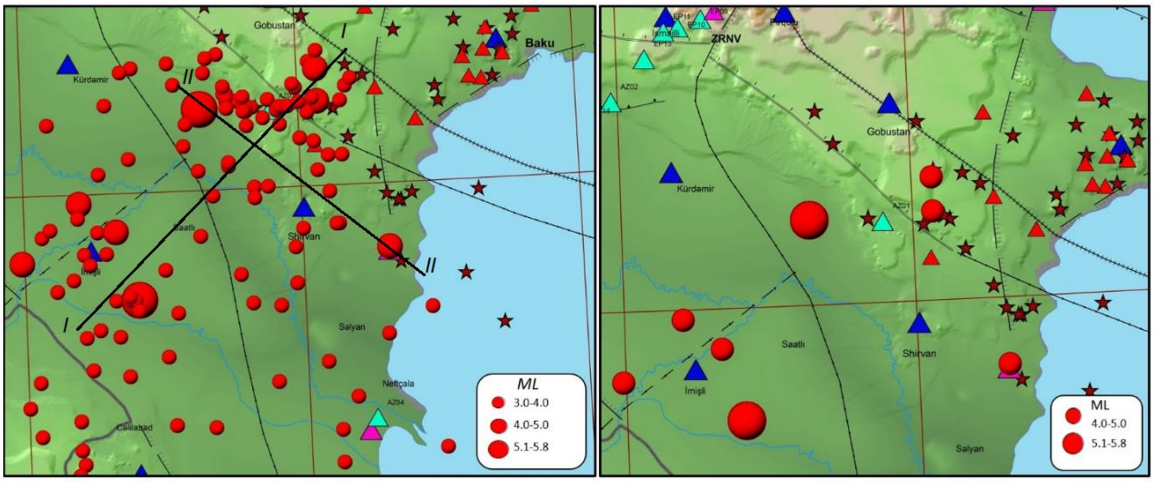

Figure 2. Maps of earthquake epicenters that occurred on the territory of the Lower Kura depression in 2003-2022.

A burst of released seismic energy observed in 2014 and 2017 was recorded in August ($E=38.6\times10^{11}$ Joule), when an earthquake occurred on August 1 at 04^h46^m with K=12.3, ML=5.6 in the Kura depression. In 2014, on the territory of the Lower Kura depression on February 10 at 12:06 pm, the strongest seismic event occurred on the territory of the republic with Ml=5.7. This earthquake occurred at a significant depth h=46 km and was felt at the epicenter with an estimated intensity of 6 points. The source of the earthquake is confined to the surface of Moho. Eight aftershocks with Ml≤2.0 were registered. A small number of aftershocks after strong earthquakes is characteristic of relatively deep seismic events in the Kura Depression. Their source area is located in the zone of action of the orthogonal Astara-Derbent and transverse Palmyr-Absheron faults [10].

In 2017, a burst of released seismic energy was registered in May ($E=30.4\times10^{11}J$) and in July ($E=59.1\times10^{11}$ Joule), when strong earthquakes with Ml>5 occurred: May 11 at 03^h24^m with Ml=5.4 and November 15th at 19^h48^m with Ml=5.7. These earthquakes also occurred in the Kura depression and near it, in the territory of the Lesser Caucasus.

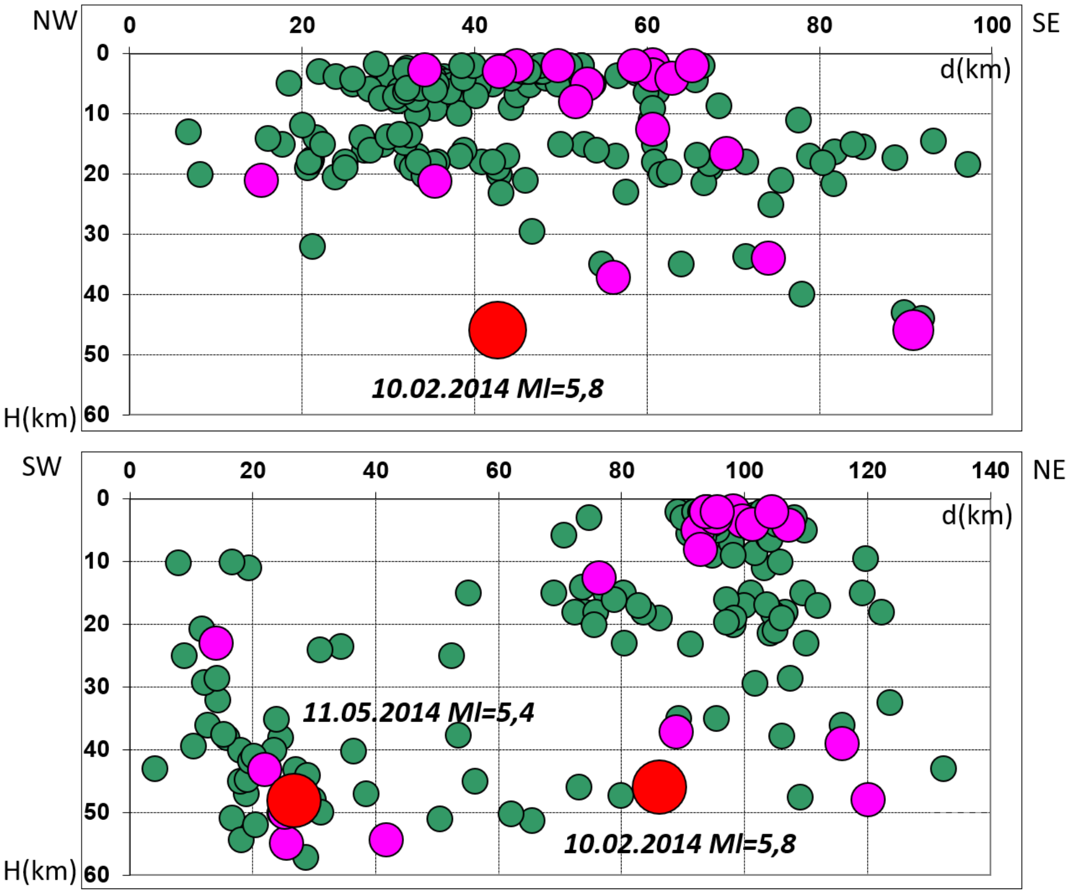

Figure 3. Seismological profiles along and across the strike of the Lower Kura depression.

It should be noted that in 2016 the strongest earthquake on the territory of the republic was the earthquake on August 1 with Ml=5.6, which occurred on the territory of the Kura depression, adjacent to the northeastern part of the Lesser Caucasus. 14 aftershocks with Ml=1.0–4.1 were registered. The earthquake was felt at the epicenter with an intensity of 5 points. The strongest aftershock with Ml=4.1 occurred on the same day at 07^h51^m and was felt with an intensity of up to 3 points. The focal area is located in the zone of action of the Kura longitudinal and Chakhirly-Gabala orthogonal faults. In addition, on May 11 at 03^h24^m with Ml=5.4 another earthquake occurred in the territory of the Lower Kura Depression. The earthquake caused tremors in settlements with an intensity of up to 3-4 points. Eight aftershocks were registered. The increase in the number of earthquakes in 2019-2020-2021 is also associated with activity on the border of the Gobustan and Shirvan regions.

As can be seen on the maps of the distribution of seismic activity, activity with values A=1.6-2.0 was noted at the junction of the Shamakhi and Shirvan seismogenic zones, and the Saatly-Imishli seismogenic zone is also distinguished (Fig. 4).

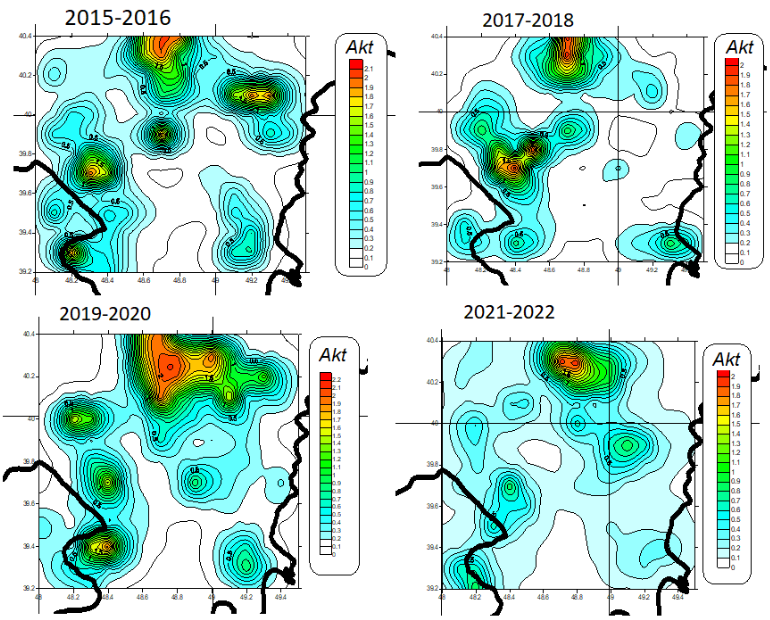

Figure 4. Map of the distribution of seismic activity in the Lower Kura depression for 2015-2022.

Source parameters of earthquakes in the Lower Kura depression

The study considered seismological data recorded by a network of telemetry stations for the period 2003-2022. The earthquake source mechanisms were calculated from the signs of the first arrivals of P-waves at digital stations, which are located in the range of epicentral distances of 15-350 km with a fairly uniform distribution in azimuths. For a perceptible earthquake that occurred on February 10 in the Hadjigabul region, the compressive stresses are oriented near-latitudinal (AZM=87°) and near-vertical (PLP=61°), and the tensile stresses are near-meridional (AZM=192°) and near-horizontal (PLP=8°) (Fig. 5). Type of movement along both planes (DP1=59°, DP2=44°) – fault with shear elements. Plane NP1 has a southeast trend (STK1=125°), and NP2 has a west-southwest trend (STK2=253°). The source region is located in the zone of action of the orthogonal Astara-Derbent and transverse Palmyro-Absheron.

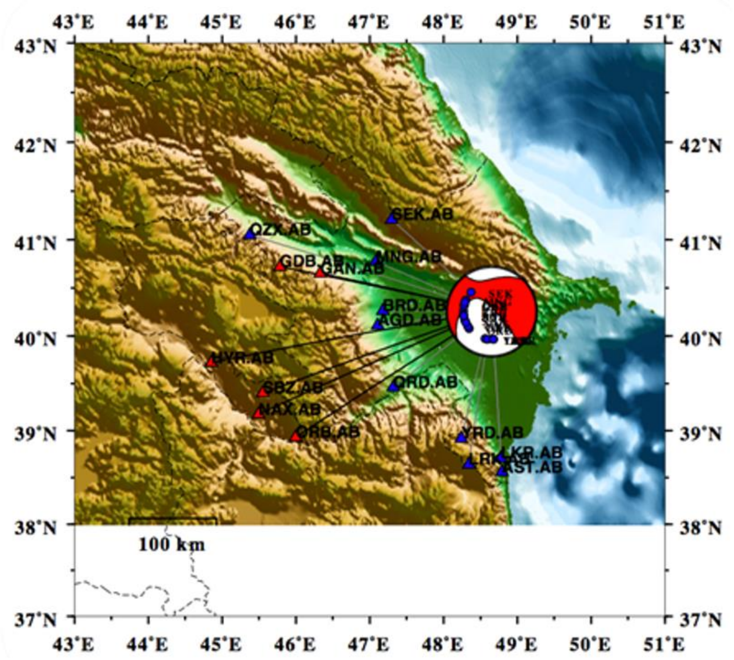

Figure 5. Source mechanism of the Hadjigabul earthquake that occurred on February 10, 2014.

For the earthquake on August 1, 2016 at 04^h46^m with Ml=5.6 that occurred in the Imishli region of the Kura depression, the focal mechanism stereogram is shown in Fig.6. According to this solution, the movement in the source occurred under compression conditions: the compressive stress axis is near-horizontal (PLP=18°) and oriented in the NE direction (AZM=47°), while the tensile stress axis is near-vertical (PLT=70°) and oriented to the SW direction (AZM=254°). The movement in the source along the NP1 plane is a reverse fault (DP1=63°), along the NP2 plane it is a thrust (DP2=28°). Plane NP1 has a northwest strike (STK1=324°), NP2 - southeast (STK2=123°). The focal area is located in the zone of action of the Kura longitudinal and Chakhirly-Gabala orthogonal faults.

01.08.2016 ML=5.6 11.05.2017 ML=5.4

Figure 6. Source mechanisms of earthquakes on August 1, 2016 with ML=5.6 and May 11, 2017 with Ml=5.4.

For the Saatly earthquake on May 11, 2017 at 03^h24^m with Ml=5.4 that occurred on the territory of the Lower Kura depression, the main tectonic stresses that acted in the source correspond to near-horizontal (PLP=19°) extension of the northeast orientation and intermediate (PLT=41°) extension south-southeast orientation. The slope of the first nodal plane is DP1=77°, the second one is DP2=46°. The movement along the first plane NP1 of northwestern orientation is a reverse fault, along the second plane NP2 of southwestern orientation it is a right-sided strike-slip with small elements of reverse fault. The focal area is located in the zone of action of the Savalan-Absheron transverse fault.

After analyzing 105 earthquake source mechanisms, it was revealed that in 2003-2014 fault-shear movements prevailed on the territory of the Lower Kura depression, in 2015-2022 surges are observed. An analysis of the orientations of the axes of compression and extension of the region under study showed that the axis of compression in the Shamakhi-Gobustan region is oriented in the NE-SW direction, however, in the Saatli and Imishli regions, the orientation changes and fluctuates within the azimuth angles of 300-340 and 110-150 (Fig. 7). An analysis of the stress state coefficient of the Lower Kura depression showed the predominance of tensile stresses.

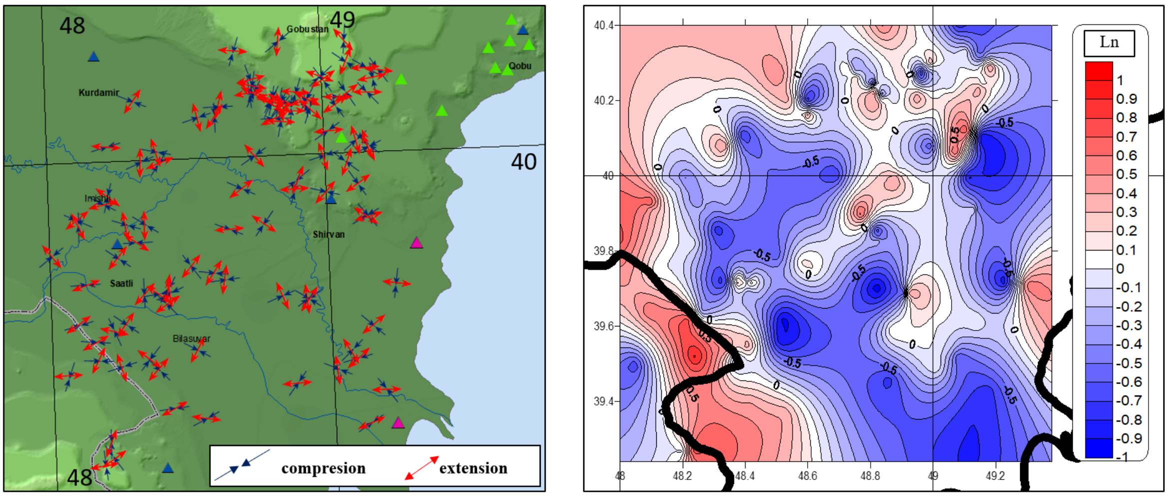

Figure 7. Map of the distribution of compression and tension axes, as well as the stress state coefficient of the Lower Kura depression

Results

The distribution of earthquake epicenters by area occurred within the study region for the period 2003-2022 showed an uneven distribution of earthquake sources. The accumulation of earthquakes is highlighted in the zone of Saatly-Imishli and Gobustan-Shirvan regions. This accumulation indicates the presence of seismogenic zones in this region. The change in the magnitudes of earthquakes over time showed a periodicity in the release of energy: after a burst of energy, its decline is observed. Analysis of seismic profiles in the NW-SE direction made it possible to identify two zones of distribution of hypocenters 0-10 km and 10-25 km with a slight tendency to subside. On the seismic profile in the SW-NE direction, at a depth of 35-60 km, the Saatly-Imishli seismogenic zone is distinguished, at the epicentral distance of 60-85 km, the Hadjigabul, at the epicentral distance of 85-110 km, the Shamakhi seismogenic zone.

An analysis of 105 earthquake focal mechanisms made it possible to identify in the territory of the Lower Kura depression in 2003-2014, fault-slip movements mainly prevailed, in 2015-2022 surges are observed. An analysis of the orientations of the axes of compression and extension of the region under study showed that the axis of compression in the Shamakhi-Gobustan region is oriented in the NE-SW direction, however, in the Saatli and Imishli regions, the orientation changes and fluctuates within the azimuth angles of 300-340 and 110-150. An analysis of the stress state coefficient of the Lower Kura depression showed the predominance of tensile stresses.

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THE NATURE OF THE SEISMOMAGNETIC EFFECT BEFORE THE STRONG HADJIGABUL EARTHQUAKE IN 2014

A.G.Rzayev[1], M.K.Mammadova[1], A.N.Sultanova[1]

Researchers are well aware of the fact of an anomalous change in the intensity of the geomagnetic field under the influence of an earthquake, which is observed in seismically active zones. The predictive parameters of earthquakes in a magnetic field have been obtained at many international geodynamic testing sites. In Azerbaijan, these studies have also been carried out for many years on the basis of modern magnetic variation stations and confirm the seismic predictive properties of local changes in the geomagnetic field.

The accumulation of stress strains at different depths of the earth's crust is associated with both intracrustal processes and processes occurring in the ionosphere (cosmogenic factor).

Accumulation of excessive stress strains in source zones in the rocks of the lower and middle parts of the Kura depression, on the southern slope of the Greater Caucasus, Talysh and the Caspian Sea are characterized by different dynamics of the source zone and various physical, chemical and mechanical changes in the geological environment of seismogenic zones. These processes are reflected in local changes in geophysical fields (gravitational, magnetic, electrical, geochemical) and are seismic precursor factors that are studied at many world seismic prognostic sites [1].

High seismicity is observed in the southeastern subsidence of the Greater Caucasus. Earthquake epicenters migrate along faults of the general Caucasian direction. Starting from the Pirgulu region, the line of migration of sources is traced in a south-southeast direction, showing high seismicity in the Hadjigabul region.

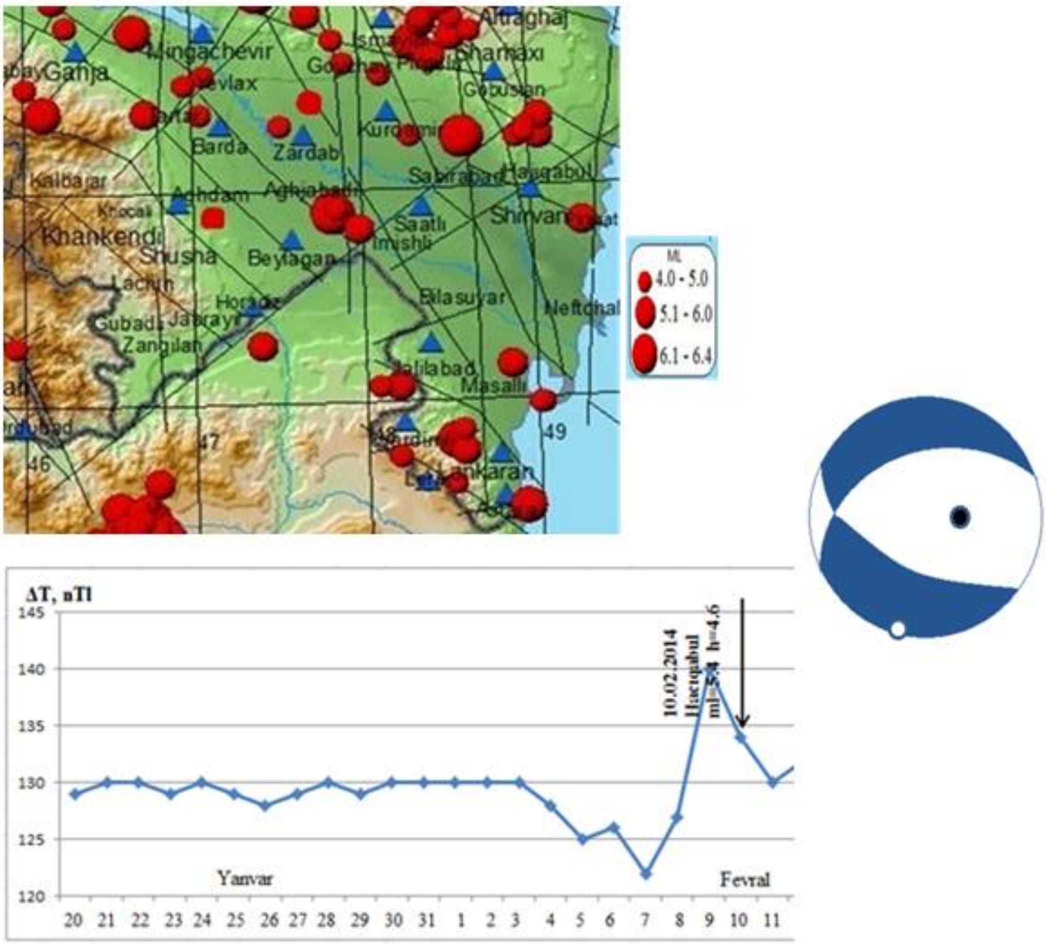

Figure 1. Seismomagnetic effect and source mechanism of the Hadjigabul earthquake (10.02.2014, ml=5.7)

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

Here, in the first quarter of 2014, 2005 earthquakes were observed. The released seismic energy was E=67.1*10^{11}C. The maximum magnitude was ml=5.7. This earthquake occurred on 02/10/2014, time 12:06:47, at a distance of 41 km southwest of the city of Hajigabul. Coordinates φ°, N=40.25 , λ°, E=48.63, h=46 km, ml=5.7, J_0=6 points [2].

The axis of compression in the source (P) has a vertical direction (PL=61), the axis of extension (T) is close to horizontal (PL=8). The type of the first nodal plane (DP=59) is falling, the second nodal plane (DP=44) is falling. The assessment of movement in the source (SLIP=-57-(-132)) is defined as a break-fall and shows the predominance of this type of movement in the source (Fig. 1) [2].

2014.10.02 Lat=40.05 Lon=48.63 h=46 ml=5.7

The seismomagnetic effect of the Hadjigabul earthquake was registered by the magnetometric station of the region based on modern technology. The dynamics of the earthquake source is characterized by alternating processes of concentration of tensile and compressive stresses. This is clearly seen in the graph ΔT~f(t), where the concentration of tensile stresses is reflected in a decrease in the increment of the geomagnetic field strength by 10 nT in the period from 02/03/2014 to 02/07/2014. Then, three days before the main seismic shock, there is a sharp increase in compressive stresses in the source, an increase in the local field strength ΔT by 15 nT, and the formation of a seismomagnetic effect. This nature of the formation of the seismomagnetic effect corresponds to the dynamics of the mechanism of the earthquake focus "stretch-rupture-fault".

In 2014, a magnetic survey was carried out in the area of the Near Kura-Talysh geodynamic test site in order to assess the stress-strain state of the geological environment. The survey results are presented on the maps of the increment of the strength gradient ΔT~f(t) of the geomagnetic field in 2D and 3D formats (Fig. 2).

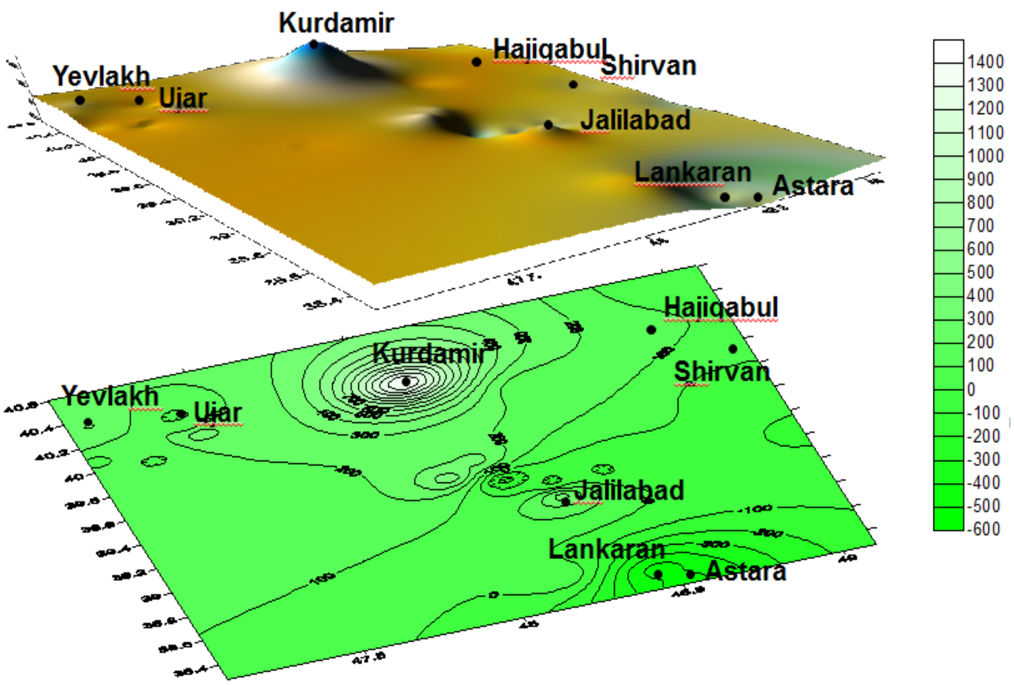

Figure 2. Stress-strain state of the geological environment at the Near Kura-Talysh geodynamic test site according to magnetic data in 2D and 3D format

Analysis of the maps indicates the presence of stressed zones in the area of the polygon, reflected in local positive and negative anomalies of the geomagnetic field strength along the Djalilabad-Imishli-Hadjigabul-Kurdamir line (Fig. 2).

The Hadjigabul earthquake is a consequence of the geodynamic regime in the Kura-Talysh zone, which is reflected in the maps of the stress-strain state of the environment according to magnetic data.

The dynamics of the Lower Kura depression is expressed in the subduction of its blocks under the structures of the Greater Caucasus, which are moving southward [3,4].

As a result of these two counter motions, excess elastic stresses accumulate at the junction boundary between the Kura and Caucasian structures. An additional example of this can be the Hadjigabul earthquake, which is reflected in the formation of the seismomagnetic effect of tension-compression and the dynamics of the source of which is fully consistent with the data of magnetic observations.

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METHOD OF DYNAMIC MODELING AND DYNAMIC ANALYSIS OF BUILDINGS AND STRUCTURES

S.M.Shakhbandayev

The design of buildings and structures with resistance to seismic effects is complicated in the absence of detailed information about the earthquake. When entering correct information about the nature of an earthquake, its magnitude and frequency into modern computer calculation programs, design engineers should not forget to include earthquake intensity in these programs. The idea of an earthquake, its epicenter, hypocenter, magnitude and strength is easy to understand from the figures and formulas below.

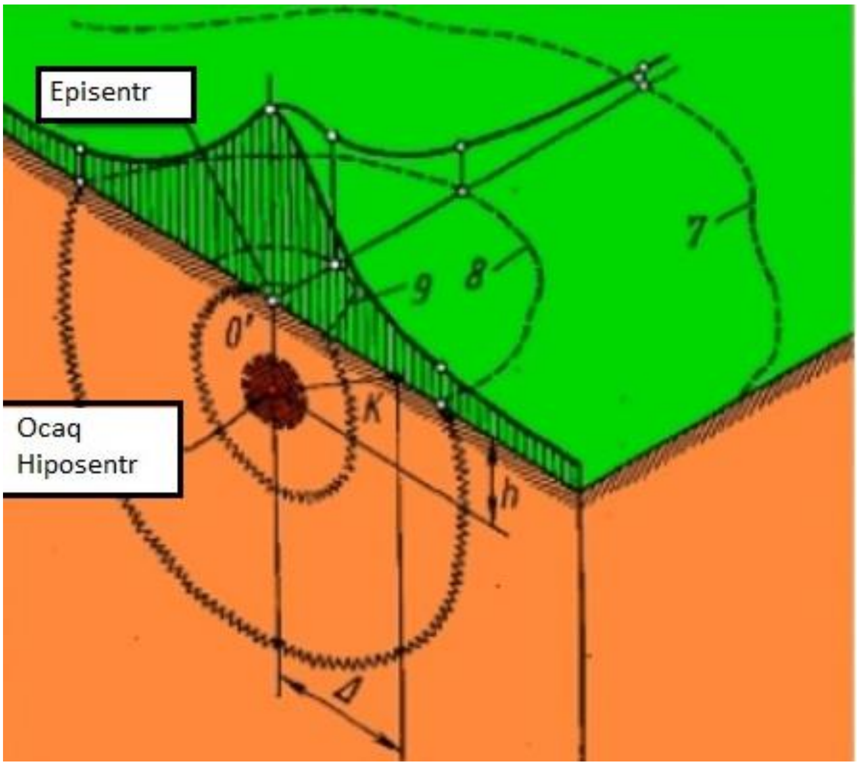

Figure 1. Seismic impact

The relationship between magnitude and intensity of an earthquake can be roughly expressed as follows.

$$I=1.5M-3.5Lg(h2+l2)1/2+3$$

Here, *M* is the magnitude of the earthquake at the earthquake source on the Richter scale.

I - earthquake intensity on the earth's surface (points)

h - the depth of the earthquake source, km

d - distance to the epicenter, km

It is on the basis of these parameters that the issues of the dynamics of various structures modeled using the finite element method should be solved in accordance with the requirements of the current building codes and regulations and the following provisions of the science of structural mechanics.

$$Mx(t)+Cx(t)+Kx(t)=F(t)$$

The problem is solved in two ways by solving the equation below. The first and most applicable is the method that is more convenient to perform during the initial design, based on the linear spectral method and performed in the interval where the frequencies of the corresponding vibrations are calculated. At the same time, nodal loads and moments are applied to the nodal points in the design scheme in accordance with the regulatory documents (AzDTN 2.3-1. SP 20.13330.2016). Based on these loads and moments, a finite element model of buildings and structures with applied quasi-static loads is modeled.

$$Si=mi*ai*Ksn$$

where, *mi* denotes the mass at node *i*, *ai* denotes the seismic wave of node *i*, and *Kn* denotes the appropriate coefficients intended to be applied in the building code.

In the second method, dynamic reports are performed during an appropriate time interval while checking the effectiveness and quality of the implemented design solutions.

When solving these dynamic tasks, you must perform the following tasks in the following order.

1. First of all, it is necessary to determine the intensity of the seismic impact A. In this case, it is necessary to accurately determine and apply the velocity of the seismic wave along the selected soil base according to the relevant maps of seismic microzoning, the results of engineering geological and geophysical research. This information must be included in the reports.

2. Dynamic factor β(t) should be selected from the appropriate response spectrum curves for the selected ground conditions.

3. You should correctly select the appropriate coefficients from building codes and regulations.

4. The spatial work of buildings and structures (torsion, asynchronous movements of the soil base and orthogonal movements along special vibration modes) should be taken into account.

5. Modes of seismic loads summation according to CQC or SRSS should be precisely defined.

6. Design and dangerous directions of seismic actions should be determined and selected.

7. Calculation results should be combined in different directions (seismic components).

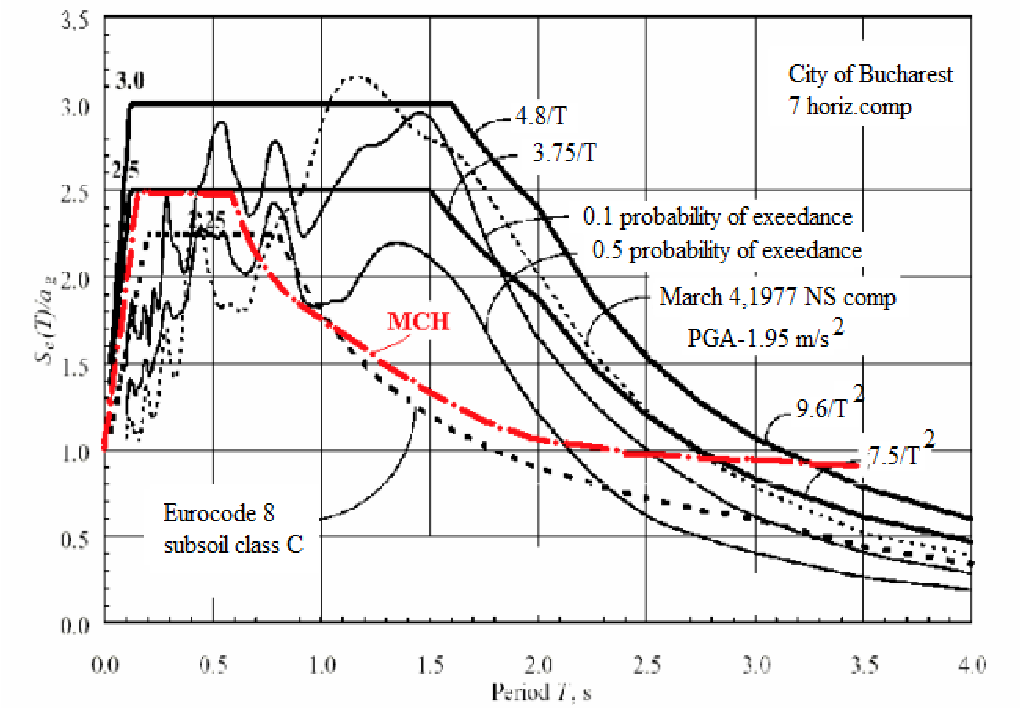

Figure 2. Response spectra for dynamic analysis

The determination of the maximum seismic loads by the linear spectral method (calculation in the frequency interval) is carried out according to the following formula.

$$Sik=QkA\ \beta i\eta ik*Ksn$$

Here, *Qk* is the mass of the structure, *A* is the intensity of the seismic action. *βi* is the coefficient of dynamism. *ηik* and *Ksn* are the corresponding coefficients intended for use in building codes.

The following shows the execution and sequence of applying the calculations performed by the dynamic analysis method when searching for the right options for a constructive solution.

1. To determine the modes of natural vibrations, a preliminary dynamic analysis should be carried out by limiting six degrees of freedom on the basis of the soil using the coefficient of dynamic stiffness of the base.

2. Analysis of the dynamic model should be carried out in the frequency range found by finding the maximum inertia forces (quasi-static loads) by the linear spectral method.

3. Internal forces should be determined by calculation using static and quasi-static combinations of loads at the nodal points of structural elements.

4. Design calculations (including determination of rebars, determination of cross sections, determination of material characteristics, unfavorable load combinations, combinations of static and quasi-static loads) must be performed.

5. Calculations should be checked, if necessary, the effectiveness of the adopted design solutions should be studied, a temporary nonlinear dynamic analysis should be performed, corresponding acceleration graphs should be entered into the program, and seismic displacements of the soil base should be assessed.

While performing, these calculations should be performed periodically (cyclically) until the specified accuracy is obtained by iteration.

When calculating by the spectral method (clause 2.2 "a") according to

*CSM→CDM→CSIM→CIM**

Calculations must be performed in a loop. Here, CSM is the calculated static model, CDM is the calculated dynamic model, CSIM is the calculated static impact model, and CIM- is the calculated impact model.

When performing a dynamic calculation in the time domain (according to clause 2.2 "b")

→ CSM→CDM→CSIM→CIM* →checks→↓
↑ ←←←←←←←←←←←←←←←←←

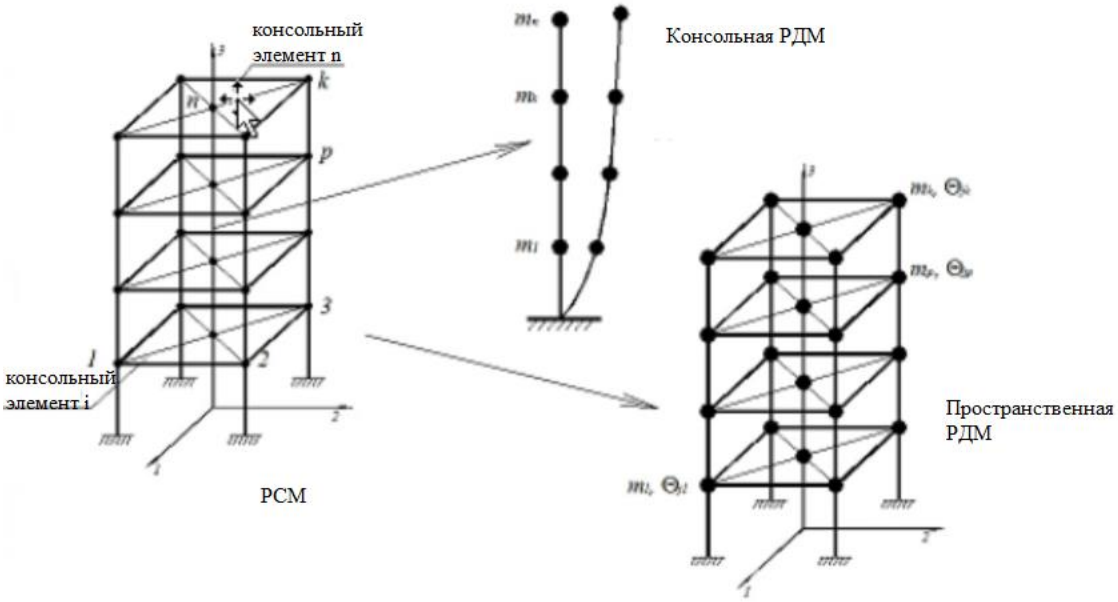

Figure 3. Console and spatial dynamic models of buildings

According to paragraph (2.2 "a"), the loop is executed 1 time.

According to paragraph (2.2 "b"), the cycle is performed each time during the control until plastic deformation occurs in the structure and until the final assessment of this plastic deformation.

CSIM is a mathematical description of the seismic effect. The CSIM must be installed in the same spatial area as the CDM.

In dynamic analysis (analysis of the equivalent seismic load or the so-called cantilever model), it is assumed that the linear displacement and acceleration of the CDM soil base acts at the support nodes, and the linear displacement and acceleration of the elements at the nodes of mass application in the CSIM model.

In the spatial CDM, the CDM is considered as the field of seismic displacements of the subgrade layer surrounding the foundation, while the subgrade modeling using spatial finite elements provides more accurate results.

The CSIM is modeled in two ways. Integral CSIM and differential CSIM. In the integral model, it is assumed that the soil foundation moves in space in the form of a whole soil massif. In this case, it is assumed that the seismic impulse action vector is directed along the horizontal (X, Y) axes or along the vertical axis (Z) in the direction of torsion.

The differential CSIM takes into account the seismic action vectors (displacement and velocity vectors) of each point of the soil base, the ratio of which is normalized by comparing the parameters of the seismic wave and the parameters of the seismic movements of the soil. In both methods, the seismic action vectors change direction in space and time variably.

All six components of the seismic motion of the subgrade are easily determined by the program by applying the finite element method based on the following formula.

$$\chi j(t)=\varphi j\rightarrow TM(AQx\rightarrow(t) + BQa\rightarrow(t))$$

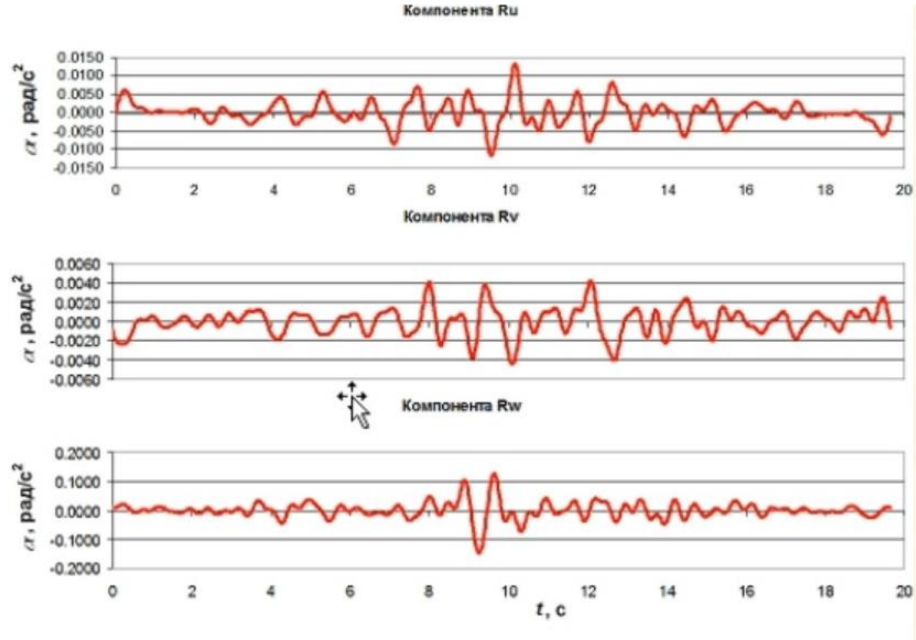

Figure 4. Rotational seismic components of dynamic analysis

Figure 5. Strength factors of dynamic analysis

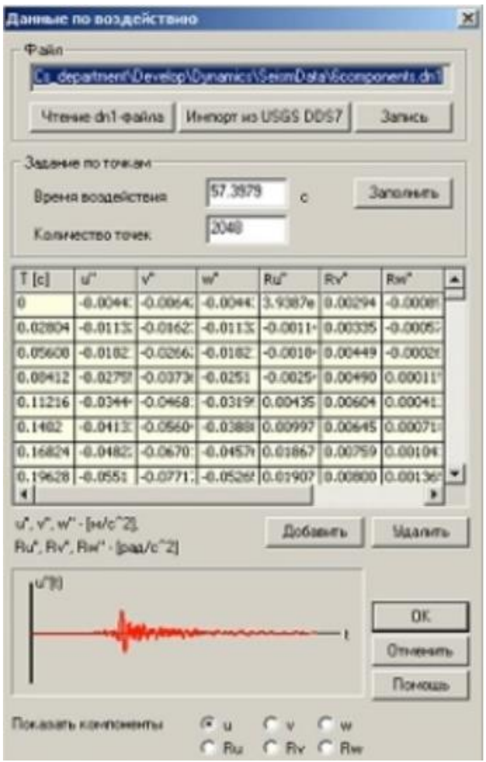

Figure 6. Nodal calculated seismic displacements of dynamic analysis

There are advantages and disadvantages of the spectral method.

Advantages:

1. Simplicity
2. Availability at the design stage.

Disadvantages:

1. The impossibility of a full-fledged application in solving problems of linear elasticity.
2. Determination of vibration modes by approximation.
3. The impossibility of taking into account the change in the direction of the seismic action vector during an earthquake.

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ANNOTATIONS

1. THE FIRST RESULTS OF PALEOSEISMOLOGICAL STUDIES BETWEEN OXFORD UNIVERSITY AND REPUBLICAN SEISMIC SURVEY CENTER OF ANAS

Walker R., Yetirmishli G.J., Pierse I., Kazimova S.E., Kazimov I.E.

The article presents the first results of paleoseismological studies between the University of Oxford and the RSSC of ANAS. In April 2021, negotiations began on the creation of a mega-project to study active tectonics and earthquakes in Azerbaijan. The first field geological studies under the supervision of Professor Richard Walker were conducted in April 2022after numerous meetings and negotiations. According to advanced technologies, including satellite imaging, drone modeling, GPS and InSar technologies, seismic deployment and paleoseismic excavations in the Aghsu and Salyan districts, the fault traces of the Main Caucasian thrust and the West Caspian strike-slip faults were studied. The results of the studies are preliminary, and more detailed analysis of the collected data and geological samples is required in order to obtain the final results.

Key words: *paleoseismology, historical earthquakes, macroseismic data, Main Caucasian thrust.*

2. ON HYDRO-GEOLOGICAL AND GEOMORPHOLOGİCAL FACTORS AFFECTİNG THE LEVEL OF SEİSMİC HAZARD İN SEİSMİCLY ACTİVE AREAS

L.T.Fattakhova, L.A.Ibraghimova, A.B.Guliyeva, F.Z. Mehtizade , A.G. Babazadeh

During the construction of high-rise buildings on the territory of the Absheron Peninsula, engineering-geological and hydro-geological studies made it possible to create a large database of soil parameters. Based on these basic data, the influence of local engineering-geological, hydro-geological, geomorphological and other impacts on the effect of seismic hazard has been studied.

Key words: *construction sites, seismicity, engineering-geological, soils, groundwater, artesian waters, inclination, landslides.*

3. DETERMINATION OF THE DEPTHS OF THE ACTIVE BLOCKS ACCORDING TO THE DATA OF THE GPS STATIONS

Yetirmishli G.J., Kazimov I.E., Kazimova A.F.

Based on the correlation of GPS data and hypocenters of strong earthquakes, the boundaries were identified and the depths of occurrence of active tectonic blocks in the areas of the southeastern subsidence of the Greater Caucasus, the Kura depression and the Talysh zone of Azerbaijan were determined. It has been established that the velocity field of GPS observations on the territory of Azerbaijan clearly illustrates the predominance of the movement of the earth's crust in the N-NE direction relative to Eurasia. The most clearly manifested feature of the velocity field is a decrease in velocity at observation points located on the territory of the Greater Caucasus. GPS observation points located along the MCT show a decrease in speed in an easterly direction. N-NE movement of the earth's surface is interpreted as one of the reasons for the accumulation of stresses on this thrust. In addition, there is a tendency for horizontal movement within the Kura depression and the Lesser Caucasus, where the speed increases from west to east along the strike of the mountain range. In addition, the analysis of the azimuth angles showed an increase at the stations located on the Absheron Peninsula. Based on the correlation of GPS data and hypocenters of strong earthquakes, in the Guba-Gusar region in the direction NW-SE at a depth of 5 to 40 km, a block with velocities of 5.8 mm/g and a length of 55 km is distinguished. On the depth profile of Zakatala-Gobustan (NW-SE) in the southeast direction at an epicentral distance of 20 to 250 km, a gradual subsidence of the tectonic block is observed with velocities of 6.25 mm/g from a depth of 20 to 55 km. 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/y. On the eastern side of this block, a block is distinguished at depths of 10–25 km with values of 9 mm/y.

Key words: *Earthqukes, fokal machanizms, compression and extention axes, oil and gas deposits.*

4. MODERN GEODYNAMICS AND SEISMICITY OF THE LOWER KURA OIL AND GAS BEARING REGION

Yetirmishli G.D., Huseyn-zade G.E., Kazimova S.E.

The article analyzes the modern geodynamics and seismicity of the Lower Kura depression oil and gas region. Maps of epicenters, seismic profiles, mechanisms of earthquake sources, a map of the orientations of the compression and tension axes, as well as maps of the spatial distribution of the stress state coefficient were constructed and analyzed. Thus, the distribution of earthquake epicenters by area occurred within the study region for the period 2003-2022 showed uneven distribution of earthquake sources. The accumulation of earthquakes is highlighted in the zone of Saatly-Imishli and Gobustan-Shirvan regions. This accumulation indicates the presence of seismogenic zones in this region. The change in the magnitudes of earthquakes over time showed a periodicity in the release of energy: after a burst of energy, its decline is observed. Analysis of seismic profiles in the NW-SE direction made it possible to identify two zones of distribution of hypocenters 0-10 km and 10-25 km with a slight tendency to subside. On the seismic profile in the SW-NE direction, at a depth of 35-60 km, the Saatly-Imishli seismogenic zone is distinguished, at the epicentral distance of 60-85 km, the Hadjigabul, at the epicentral distance of 85-110 km, the Shamakhi seismogenic zone.

Key words: *GPS stations, geodynamics, horizontal displacements velocity fields, plate tectonics.*

5. THE NATURE OF THE SEİSMOMAGNETİC EFFECT BEFORE THE STRONG HADJİGABUL EARTHQUAKE İN 2014

A.G.Rzayev, M.K.Mammadova, A.N.Sultanova

An anomalous change in the geomagnetic field near the earthquake source is considered. Correspondence of the nature of the seismomagnetic effect with the dynamics of the source mechanism is shown. The reflection of the current geodynamic regime in the Lower Kura deposits in spatio-temporal increments of the geomagnetic field intensity gradient is noted.

Key words: *SME-seismomagnetic effect, nTl-nanotesla, earthquake source mechanism, geodynamic regime, geomagnetic field strength, ml-magnitude.*

6. METHOD OF DYNAMİC MODELİNG AND DYNAMİC ANALYSİS OF BUİLDİNGS AND STRUCTURES

S.M.Shakhbandayev

The article provides brief information about the earthquake, a comparison of the magnitude and intensity of the earthquake, the application of the requirements of modern building codes and rules in the dynamic calculation of buildings and structures, the comparative performance of various options for dynamic calculation using modern computer calculation programs and the use of the finite element method.

Key words: *Final elements, earthquake magnitude and intensity, dynamic factor, intensity of seismic activity, quasi-static loads, linear spectral method, calculation model of activity.*

ANNOTASIYALAR

1. OKSFORD UNİVERSİTETİ VƏ AMEA RESPUBLİKA SEYSMOLOJİ XİDMƏT MƏRKƏZİ ARASINDA PALEOSEYSMOLOJİ TƏDQİQATLARIN İLK NƏTİCƏLƏRİ

Volker R., Yetirmişli G.J., Pirs I., Kazimova S.E., Kazimov I.E.

Məqalədə Oksford Universiteti ilə AMEA nəzdində RSXM arasında aparılan paleseysmoloji tədqiqatların ilk nəticələri təqdim olunur. Qeyd edək ki, 2021-ci ilin aprelində Azərbaycanda aktiv tektonika və zəlzələlərin öyrənilməsi üzrə meqalayihənin yaradılması ilə bağlı danışmalar başlanılmışdır. 2022-ci ilin aprelində prof. Richard Walker rəhbərliyi altında Oksford və RSXM-nin əməkdaşları ilə birlikdə ilk paleoseysmology tədqiqatlar aparıldı. Muasir texnologiyalar, o cümlədən peyk təsviri, dron modelləşdirmə, GPS və InSar texnologiyaların əsasında Ağsu və Salyan rayonlarında seysmik yerləşdirmə və paleoseysmik qazıntılar əsasında Böyük Qafqazın əsas üstəgəlmə qırılmanln izləri və sağ tərəfli Qərbi Xəzər hərəkətləri tədqiq edilmişdir.

Açar sözlər: *paleseysmologiya, tarixi güclü zəlzələlər, makroseysmik məlumatlar, Böyük Qafqazın əsas üstəgəlmə qırılması*

2. SEYSMİK CƏHƏTDƏN AKTİV ƏRAZİLƏRDƏ SEYSMİK TƏHLÜKƏNİN SƏVİYYƏSİNƏ TƏSİR EDƏN HİDROGEOLOJİ VƏ GEOMORFOLOJİ AMİLLƏR HAQQINDA

L.T.Fəttahova, L.A.İbrahimova, A.B.Quliyeva, F.Z. Mehdizadə, A.G.Babazadə

Abşeron yarımadası ərazisindəki yüksəkmərtəbəli binaların tikintisi aparılarkən mühəndisi-geoloji və hidrogeoloji tədqiqatlar qruntların parametrləri haqqında böyük məlumat bazasını yaratmaq imkanı vermişdir. Bu baza məlumatları əsasında yerli mühəndisi-geoloji, hidrogeoloji, geomorfoloji və digər təsirlərin seysmik təhlükənin effektinə təsiri araşdırılmışdır.

Açar sözlər: *tikinti sahələri, seysmiklik, mühəndisi-geoloji, qruntlar, qrunt suları, təzyiqli sular, maillik, sürüşmələr.*

3. GPS STANSİYALARINA UYĞUN OLARAQ AKTİV BLOKLARIN DƏRİNLİKLƏRİNİN MÜƏYYƏN EDİLMƏSİ

Yetirmişli G.J., Kazimov I.E., Kazimova A.F.

GPS məlumatlarının və güclü zəlzələlərin hiposentrlərinin korrelyasiyası əsasında Böyük Qafqazın cənub-şərq yamacında, Kür çökəkliyi və Azərbaycanın Talış zonası ərazilərində aktiv tektonik bloklarının sərhədləri və dərinlikləri müəyyən edilmişdir.

Müəyyən edilmişdir ki, Azərbaycan ərazisində GPS müşahidələrinin sürət sahəsi Yer qabığının Avrasiyaya nisbətən şimal-şərq istiqamətində hərəkətinin üstünlük təşkil etdiyini aydın şəkildə göstərir. Sürət sahəsinin ən açıq şəkildə təzahür edən xüsusiyyəti Böyük Qafqazın ərazisində yerləşən müşahidə məntəqələrində sürətin azalmasıdır. Böyük Qafqazın cənub-şərq yamacı boyunca yerləşən GPS müşahidə məntəqələri şərq istiqamətində sürətin azalmasını göstərir. Ocaqlarda sağ tərəfli yer-dəyişmələrin hərəkətləri ərazidə gərginliklərin toplanmasının səbəblərindən biri kimi şərh olunur. Bundan əlavə, Kür çökəkliyi və Kiçik Qafqazın daxilində üfüqi hərəkət tendensiyası müşahidə olunur. Burada dağ silsiləsinin zərbəsi boyunca qərbdən şərqə doğru sürət artır. Bundan əlavə, azimut bucaqlarının təhlili Abşeron yarımadasında yerləşən stansiyalarda artım göstərib.

GPS məlumatlarının və güclü zəlzələlərin hiposentrlərinin korrelyasiyası əsasında Quba-Qusar bölgəsində ŞQ-CŞ istiqamətində 5-40 km dərinlikdə sürətləri 5,8 mm/y, uzunluğu 55 km olan blok fərqlənir. Zaqatala-Qobustan (ŞQ-CŞ) dərinlik profilində cənub-şərq istiqamətində 20-250 km episentral məsafədə 20-55 km dərinlikdən 6,25 mm/y sürətlə tektonik blokun tədricən çökməsi müşahidə olunur. Qərbi Xəzər qırılması zonasında 5 km-dən 35 km-ə qədər dərinlikdə 7,25 mm/y sürətlərlə blok sərhədi fərqlənir. Bu blokun şərq tərəfində 10-25 km dərinlikdə 9 mm/y dəyərində blok seçilir.

Açar sözlər: *GPS stansiyaları, geodinamika, üfüqi yerdəyişmələrin sürət sahələri, plitələrin tektonikası*

4. AŞAĞI KÜR NEFTLİ VƏ QAZLI RAYONUN MÜASİR GEODİNAMİKASI VƏ SEYSMİKLİYİ

Yetirmişli Q.C., Hüseyn-zadə H.E., Kazımova S.E.

Məqalədə Aşağı-Kür neft-qaz bölgəsinin müasir geodinamika və seysmikliyi təhlil edilir. Episentrlərin xəritələri, seysmik profillər, zəlzələ ocaqlarının mexanizmləri, sıxılma və gərilmə oxlarının oriyentasiya xəritəsi və gərginlik əmsalının paylanma xəritələri qurulmuş və təhlil edilmişdir. Belə ki, zəlzələ episentrlərinin ərazilər üzrə bölgüsü 2003-2022-ci illər ərzində tədqiq olunan rayon daxilində zəlzələ ocaqlarının qeyri-bərabər paylanmasını göstərdi. Saatlı-İmişli və Qobustan-Şirvan rayonları zonalarında zəlzələlərin akkumulyasiyası xüsusi qeyd olunur. Zəlzələlərin toplanması regionda seysmogen zonaların mövcudluğundan xəbər verir. ŞQ-CŞ istiqamətində seysmik profillərin təhlili cüzi çökməyə meylli 0-10 km və 10-25 km hiposentrlərin iki paylanma zonasını müəyyən etməyə imkan verdi. CQ-ŞŞ istiqaməti üzrə seysmik profilin analizi 35-60 km dərinlikdə Saatlı-İmişli seysmogen zonası, 60-85 km episentral məsafədə Hacıqabul, 85-110 km episentral məsafədə Şamaxı seysmogen zonası müəyyən olunub.

Açar sözlər: *Zəlzələlər, fokus mexanizmləri, sıxılma və genilmə oxları, neft və qaz yataqları.*

5. 2014-CÜ İLDƏ BAŞ VERMİŞ GÜCLÜ HACIQABUL ZƏLZƏLƏSİNDƏN ÖNCƏ SEYSMOMAQNİT EFFEKTİN DƏYİŞMƏ XÜSUSİYYƏTLƏRİ

A.Q.Rzayev, M.K.Məmmədova, A.N.Sultanova

Məqalədə zəlzələ ocaqlarının yaxınlığında geomaqnit sahə gərginliyinin anomal dəyişmələri haqqında məlumatlar öyrənilir. Seysmomaqnit effektin yaranma xarakteri ocaqdakı gedən geomaqnit rejimlə təyin olunur. Geomaqnit sahəsinin gərginlik qradientinin məkan-zamana görə paylanması Aşağı Kür çökəkliyində gedən geodinamik rejimini əks etdirir.

Açar sözlər: SME-seysmomaqnit effekt, nTL-nanotesla, zəlzələ ocağının mexanizmi, geodinamik rejim, geomaqnit sahə gərginliyi, ml-maqnituda.

6. BİNA VƏ QURGULARIN DINAMIK MODELLƏŞDIRILMƏSI VƏ DINAMIK ANALIZIN APARILMASI ÜSULU

S.M.Şahbəndəyev

Məqalədə zəlzələ haqında qısa məlumat, zəlzələnin maqnitudası və intensivliynin müqayisə edilməsi, müasir inşaat norma və qaydalarının tələblərinin bina və qurguların duinamik analizində tətbiqi, həmcinin müasir computer hesablama proqramlarının və sonlu elementlər üsulunun köməyi ilə müxtəlif dinamik analiz variantlarının müqayisəli şəkildə yerinə yetirilməsindən bəhs edilir.

Açar sözlər: *sonlu elementlər, böyüklük, intensivlik, seysmik təsir, dinamizm əmsalı, kvazistatik yüklər, xətti spektral üsul, hərəkətin hesablama modeli, hesablama dinamik modeli.*

АННОТАЦИИ

1. ПЕРВЫЕ РЕЗУЛЬТАТЫ ПАЛЕОСЕЙСМОЛОГИЧЕСКИХ ИССЛЕДОВАНИЙ МЕЖДУ ОКСФОРДСКИМ УНИВЕРСИТЕТОМ И РЕСПУБЛИКАНСКИМ ЦЕНТРОМ СЕЙСМОЛОГИЧЕСКОЙ СЛУЖБЫ НАНА

Уолкер Р., Етирмишли Г.Дж., Пирс Й., Казимова С.Е., Казимов И.Е.

В статье представлены первые результаты палеосейсмологических исследований между Оксфордским Университетом и РЦСС НАНА. В апреле 2021 года были начаты переговоры о создании мегапроекта по исследованию активной тектоники и землетрясений на территории Азербайджана. После многочисленных встреч и переговоров в апреле 2022 года под руководством проф. Ричарда Волкера были проведены первые полевые геологические исследования. По данным передовых технологий, включая спутниковую визуализацию, моделирование беспилотника (дрона), GPS и InSar технологии, сейсмическое развертывание и палеосейсмические раскопки в районе Агсу и Сальян были изучены следы разлома Главно-Кавказского надвига и Западно-Каспийского правостороннего сдвига.

Ключевые слова: *палеосейсмология, исторические землетрясения, макросейсмические данные, Главно-Кавказский надвиг.*

2. О ГИДРОГЕОЛОГИЧЕСКИХ И ГЕОМОРФОЛОГИЧЕСКИХ ФАКТОРАХ, ВЛИЯЮЩИХ НА УРОВЕНЬ СЕЙСМИЧЕСКОЙ ОПАСНОСТИ В СЕЙСМИЧЕСКИ АКТИВНЫХ РАЙОНАХ

Л.Т.Фаттахова, Л.А.Ибрагимова, А.Б.Гулиева, Ф.З. Мехтизаде, А.Г.Бабазаде.

При строительстве высотных зданий на территории Абшеронского полуострова инженерно-геологические и гидрогеологические исследования позволили создать большую базу данных параметров грунтов. На основе этих базовых данных исследовано влияние локальных инженерно-геологических, гидрогеологических, геоморфологических и других воздействий на действие сейсмической опасности.

Ключевые слова: *строительные участки, сейсмичность, инженерно-геологические, грунты, грунтовые воды, артезианские воды, наклонность, оползни.*

3. ОПРЕДЕЛЕНИЕ ГЛУБИН АКТИВНЫХ БЛОКОВ ПО ДАННЫМ GPS-СТАНЦИЙ

Етирмишли Г.Дж., Казимов И.Е., Казимова А.Ф.

На основе корреляции GPS данных и гипоцентров сильных землетрясений выделены границы и установлены глубины залегания активных тектонических блоков на площадях юго-восточного погружения Большого Кавказа, Куринской депрессии и Приталышской зоны Азербайджана. Установлено, что поле скорости GPS наблюдений на территории Азербайджана четко иллюстрирует преобладание движения поверхности земной коры в С-СВ направлении относительно Евразии. Явно проявленная особенность скоростного поля – уменьшение скорости в пунктах наблюдений, расположенных на территории Большого Кавказа. Пункты GPS наблюдений, расположенные вдоль ГКН, показывают уменьшение скорости в восточном направлении. С-СВ движение земной поверхности интерпретируется как одна из причин накопления напряжений на этом надвиге. Кроме того, здесь имеется тенденция горизонтального движения в пределах Куринской депрессии и Малого Кавказа, где увеличивается скорость с запада на восток вдоль простирания горной цепи. Кроме того, анализ

азимутального углов, показал увеличение на станциях, расположенных на Апшеронском полуострове.

На основе корреляции GPS данных и гипоцентров сильных землетрясений в Губа-Гусарском районе в направлении СЗ-ЮВ на глубине от 5 до 40 км выделяется блок со значениями скоростей 5,8 мм/г длиной 55 км. На глубинном профиле Закатала-Гобустан (СЗ-ЮВ) в юго-восточном направлении на эпицентральном расстоянии от 20 до 250 км наблюдается постепенное погружение тектонического блока со значениями скоростей 6,25 мм/г с глубины от 20 до 55 км. В зоне западно-каспийского разлома на глубинах от 5 до 35 км выделяется граница блока со значениями скоростей 7,25 мм/г. С восточной стороны данного блока выделяется блок на глубинах 10-25 км со значениями 9 мм/г.

Ключевые слова: *GPS станции, геодинамика, горизонтальные смещения скоростей поля, тектонические плиты.*

4. СОВРЕМЕННАЯ ГЕОДИНАМИКА И СЕЙСМИЧНОСТЬ НИЖНЕКУРИНСКОГО НЕФТЕГАЗОНОСНОГО РАЙОНА

Етирмишли Г.Дж., Гусейн-заде Г.Е., Казимова С.Е.

В статье проведен анализ современной геодинамики и сейсмичности Нижнекуринского нефтегазоносного района. Построены и проанализированы карты эпицентров, сейсмические профиля, механизмы очагов землетрясений, карта ориентаций осей сжатия и растяжения, а также карты пространственного распределения коэффициента напряженного состояния. Таким образом, распределение эпицентров землетрясений по площади, произошедших в пределах исследуемого региона за период 2003-2022 гг., показал неравномерное распределение очагов землетрясений. Скопление землетрясений выделены в зоне Саатлы-Имишлинского и Гобустан-Ширванского районов. Данное скопление указывает на наличие сейсмогенных зон в данном регионе. Изменение значений магнитуд землетрясений во времени показало периодичность в выделении энергии: после всплеска энергии наблюдается ее спад. Анализ сейсмических профилей в направлении СЗ-ЮВ позволили выделить две зоны распределения гипоцентров 0-10 км и 10-25 км с небольшой тенденцией погружения. На сейсмическом профиле в направлении ЮЗ-СВ на глубине 35-60 км выделяется Саатлы-Имишлинская сейсмогенная зона, на эпицентральном расстоянии 60-85 км Гаджигабульская, на эпицентральном расстоянии 85-110 км Шамахинская сейсмогенная зоны.

Ключевые слова: *Землетрясения, механизмы очагов, оси сжатия и растяжения, залежи нефти и газа.*

5. ХАРАКТЕР СЕЙСМОМАГНИТНОГО ЭФФЕКТА ПЕРЕД СИЛЬНЫМ ГАДЖИГАБУЛЬСКИМ ЗЕМЛЕТРЯСЕНИЕМ 2014 ГОДА

А.Г.Рзаев, М.К.Маммедова, А.Н.Султанова

Рассматривается аномальное изменение геомагнитного поля вблизи очага землетрясения. Показано соответствие характера сейсмомагнитного эффекта динамике механизма очага. Отмечается отражение текущего геодинамического режима в Нижнекуринских отложениях в пространственно-временных приращениях градиента напряженности геомагнитного поля.

Ключевые слова: *SME-сейсмомагнитный эффект, nTl-нанотесла, механизм очага землетрясения, геодинамический режим, напряженность геомагнитного поля, ml-магнитуда.*

6. МЕТОД ДИНАМИЧЕСКОГО МОДЕЛИРОВАНИЯ И ДИНАМИЧЕСКОГО АНАЛИЗА ЗДАНИЙ И СООРУЖЕНИЙ

С.М.Шахбандаев

В статье приведены краткие сведения о землетрясении, сравнение магнитуды и интенсивности землетрясения, применение требований современных строительных норм и правил при динамическом расчете зданий и сооружений, сравнительная производительность различных вариантов динамического расчета с помощью современных компьютерных расчетных программ и применения метода конечных элементов.

Ключевые слова: *конечные элементы, магнитуда, интенсивность, сейсмическое воздействие, коэффициент динамичности, квазистатические нагрузки, линейный спектральный метод, расчетная модель воздействия, расчетная динамическая модель*

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