REPUBLIC OF AZERBAIJAN

On the right of the manuscript

ABSTRACT

of the dissertation for the degree of Doctor of Philosophy

APPARENT DETERMINISTIC SEISMIC HAZARD ANALYSIS OF THE TALYSH ZONE AND ADJACENT WATER AREA

Speciality:	2507.01 – Geophysics, geophysical methods of searches of minerals
Field of science:	Earth Sciences
Applicant:	**Yashar Namig Aliyev**

BAKU – 2024

The dissertation work was performed at the Institute of Geology and Geophysics Ministry of Science and Education of the Azerbaijan Republic

Scientific supervisors: Doctor of Earth Sciences, Associate professor
Gulam Rustam Babayev

Official opponents: Doctor of Geological and Mineralogical Sciences, professor
Tofig Rashid Ahmadov

Doctor of Physical and Mathematical Sciences, academician, professor
Tamaz Lukich Chelidze

Doctor of Philosophy in Geology and Mineralogy, Associate Prof.
Ilyas Eldar Kazimov

Dissertation council ED 1.01 Supreme Attestation Commission under the President of the Republic of Azerbaijan operation at the Instute of Geology and Geophysics Ministry of Science and Education Republic of Azerbaijan

Chairman of the Dissertation council:
Doctor of Geological and Mineralogical Sciences, academician, professor
Akpar Akpar Feyzullayev

Scientific secretary of Dissertation council:
Candidate of Technical Sciences, Associate professor
Dilgusha Ramzey Mirzayeva

Chairman of the scientific seminar:
Doctor of Geological and Mineralogical Sciences, academician, professor
Fakhraddin Abulfat Kadirov

GENERAL CHARACTERISATION OF THE WORK

Relevance and state of knowledge of the topic. Modern seismological methods are characterized by a wide range of tasks to be solved, from standard microzoning to seismic risk assessment. Recently, specialists in the seismological field have contributed to the improvement of existing methods for assessing the seismic hazard of various regions. Taking into account the parameters of seismic hazard, when creating buildings and structures in densely populated areas, made it possible to identify the degree of vulnerability of possible future buildings and structures.

In the process of seismic hazard assessment, the geological environment is of great importance, which experiences various loads under the influence of natural and artificial factors. It is necessary to take into account the fact that the territory of Azerbaijan is a seismically active region, which is also a region of mud volcanism and an oil-producing country. The Talysh folded zone is confined to the seismically active zones of Azerbaijan, which is the object of study of geological and geophysical processes from the historical period to the present day.

In recent years, there has been an increase in seismic activity in the region, as a result of which the magnitude of tremors can reach up to 5.0. The lack of modern microzoning maps of seismic hazard in the Talysh megazone demonstrates the need to assess the seismic hazard of the region in order to possibly reduce the degree of destruction from future earthquakes. Taking this fact into account, there is a need and relevance for a detailed assessment of seismic hazard and another review of existing maps based on new and modernized approaches.

The object and subject of the research. In this study, the seismic hazard of the Talysh territory is assessed for a certain period of time of occurrence of seismic events. The object of the presented dissertation is the seismic hazard of the Talysh zone and the adjacent part of the Caspian Sea. Seismic impacts, which are determined during seismic hazard assessment, can be expressed through earthquake intensity and the peak ground acceleration parameter. Thus, the subject of the study is macroseismic intensity, which is expressed in points and the dynamic ground acceleration parameter, namely its peak values.

Purpose and tasks of the research. The purpose of the dissertation is to develop maps of seismic hazard of the study area, based on the implementation of existing approaches and elements of deterministic assessment of seismic impact in the form of analysis of lithological-geological, tectonic, seismological data, physical and mechanical parameters of the soil layer of the Talysh zone and the adjacent water area of the Caspian Sea.

The following **tasks** will be solved during the study:

1. Analyze and systematize the seismic regime of the Talysh zone based on the study of the manifestation of strong and perceptible earthquakes according to existing catalogs of various sources;
2. Identify zones of occurrence of earthquake focus, determine the characteristics for each seismogenic source (fault) indicating the maximum magnitude of possible earthquakes;
3. Develop a mathematical method for estimating the maximum possible magnitude of earthquakes using elements of the law of attenuation of intensity and the equation of the macroseismic field based on the analysis of the seismic activity of tectonic elements;
4. Create a set of maps of differentiated areas of possible focuses of strong earthquakes in the Talysh zone and the adjacent waters of the Caspian Sea using mathematical modeling;
5. Develop typical models of ground conditions of bedrock and surface rocks based on lithological features, physical and mechanical properties of the composition of layers using the integrated use of geological and lithological maps and geological profiles;
6. Calculate the amplification factors of the seismic wave amplitude of the underlying and overlying layers using modern software, in order to assess the impact of ground conditions on the maximum values of seismic shaking accelerations on the surface;
7. Integrate the methodology for calculating the seismic effect in units of macroseismic intensity and maximum accelerations of shaking of surface grounds (in Gal) based on the macroseismic parameters of scenario earthquakes selected by the parameters of range and strength;

8. Make a quantitative assessment of the degree of seismic hazard of the Talysh zone and the adjacent waters of the Caspian Sea using a deterministic method.

Research methods. The research methodology used in the dissertation is based on the analysis of geological materials, topographic and engineering-geological features of the territory, geomorphological and lithological data. Seismological data, which form the basis of the research method, are used to assess the intensity of earthquakes and peak ground acceleration for selected scenario earthquakes. When assessing the risk of earthquakes using a deterministic approach, it is advisable to divide the study area into cells of the same size in order to identify and analyze the seismic effect for each cell. The research methodology also consists of collecting and analyzing borehole data and geological profiles. Integration is a process that forms the basis of the research method in this work, which results in the introduction of tectonic criteria, lithological and geological data into the seismic hazard assessment methodology.

Seismic hazard analysis is usually carried out to assess the intensity of ground shaking at a given location. There are two methodologies for conducting seismic hazard analysis at a given location: probabilistic seismic hazard analysis (PSHA) and deterministic seismic hazard analysis (DSHA). DSHA considers a critical scenario, assuming the occurrence of the most probable earthquake at the closest possible distance to the location. Therefore, this methodology often provides an upper bound for the seismic hazard at the study location. Deterministic seismic hazard analysis is used to obtain ground motion parameters for engineering design and other applications, especially in areas with high seismicity.

The dynamic parameters of the seismic wave, such as velocity and amplification factor, are the key factors in the use of the seismic hazard assessment method in this study. Thus, the research methods include: collection, analysis and generalization of literary sources; cartographic analysis; application of geographic information systems (GIS technology); analytical studies; mathematical and computer modeling using software.

The main provisions submitted to the defense.

1. Map of apparent-possible differentiated areas of earthquake focal zones, based on fault parameters, maximum possible magnitude and macroseismic intensity;

2. Developed modified approach for seismic hazard assessment based on the algorithm of dynamic soil properties, seismic and tectonic parameters of the study area.

Scientific novelty of the study. The scientific novelty of the work is presented in the following main provisions:

1. A differentiated approach to a detailed assessment of macroseismic intensity was developed based on the ratio of the maximum magnitude of earthquakes, the length of faults, the magnitude of seismogenic movements and the epicentral distance;

2. Unified maps of the estimated values of focal intensity and maximum magnitude (M_{max}) of earthquakes in the Talysh zone were plotted using the empirical relationship between the focal depth and the length of faults;

3. Typical models of soil conditions were constructed based on the analysis of bedrock strata located at a depth of 5000 meters and higher, to the surface, taking into consideration lithological, physical parameters (elastic wave velocity, density, attenuation constant of the intensity of shaking) and geometric characteristics of the environment (thickness and layering);

4. The values of the seismic ground shakings amplitude amplification were calculated based on lithological data using the methods of mathematical statistics and software capabilities;

5. An integrated deterministic assessment of the seismic hazard of the Talysh zone and the adjacent water of the Caspian Sea was carried out taking into consideration ground conditions, on the basis of which a series of maps of the expected seismic effect in the values of shaking intensity and peak ground acceleration were created based on macroseismic data selected from earthquake catalogs (Lerik, 1998; Caspian, 2000; Iranian, 1980; Oguz, 2015) and adopted in this study as scenario seismic events.

Theoretical and practical significance of the study. The maps of peak ground accelerations for bedrock and surface obtained in the dissertation, as well as the map of expected ground shaking in intensity units (macroseismic) can be used for further detailed seismic zoning of the study area (DSZ), assessment of possible socio-economic damage from earthquakes, when designing buildings, structures, constructing strategically important objects and sites with tourist purposes. According to world practice, the design of earthquake-resistant buildings begins directly with the microzoning of the study area.

Approbation and application. The research methodology was reported at the International Conference "CTBT: Science and Technology" (Austria, Vienna; 2019), at the 25th International Conference "Students and Young Researchers" (Baku; 2021), at the VIII International Scientific Conference of Young Scientists and Students "Innovations in Geology and Geophysics" (Baku; 2021), at the VIII International Conference "Hazardous Natural and Man-Made Processes in Mountainous Regions: Models, Systems, Technologies" (Russia, Vladikavkaz; 2022), at the International Conference dedicated to the 100th anniversary of leader Heydar Aliyev "Heydar Aliyev and the Oil Strategy of Azerbaijan" (Baku; 2023), and the research results were proposed and confirmed as "The Most Important Results" at the Institute of Geology and Geophysics, Ministry of Science and Education of the Azerbaijan Republic in 2023.

On the topic of the dissertation, 18 scientific papers were published in local and international journals, as an author and co-author.

The name of the organization where the dissertation work was fulfilled. The dissertation work was completed in the department of "Seismology and seismic hazard assessment" of the Institute of Geology and Geophysics, Ministry of Science and Education of the Azerbaijan Republic.

The structure and volume of the dissertation. The dissertation consists of an introduction (14297 characters), 5 chapters (Chapter I - 73956 characters, Chapter II - 36779 characters, Chapter III - 30036 characters, Chapter IV - 18992 characters, Chapter V - 24675 characters), conclusion (2859 characters), list of references (15528 characters), list of abbreviations and symbols (1144 characters), and is presented in a total volume of 202738 characters, 46 figures and 108 titles of literature.

CHAPTER I. GEOLOGICAL AND GEOPHYSICAL STUDY OF THE TALYSH ZONE

1.1. Geological and tectonic features of the study area

The Talysh megazone, which is located in the northern part of the Lesser Caucasus-Elburz folded system, is separated from various structures of the Lesser Caucasus by the Lower Araz transverse depression. Within Azerbaijan, the territory of Talysh is the northeastern wing, while the southwestern part is the territory of Northern Iran [20]. The Garadagh zone of Iran, characterized by volcanogenic-sedimentary deposits of the Paleogene, is overlapped by Miocene and Pliocene complexes of magmatic origin of the Savalan volcano. In the structure of the Talysh zone, structural stages are distinguished that correspond to the pre-collisional (Cretaceous-Eocene) and collisional (Oligocene and Miocene) periods of development of the megazone[1].

On the territory of Talysh, the most possible area development and number of sections is only the Eocene stage, in the structure of which complexes of volcanogenic-sedimentary origin participate, with an approximate thickness of about 5000 m, united into the following formations of magmatic origin with the composition of their thicknesses[2]:

I. Trachybasalt-andesite and trachytic phase of the full Eocene with the following sequences (Cosmalyan depression):

- lavas, picrites, pyroclasts, and leucite basanites of the lower and middle Eocene;

- volcanic breccias of andesite-basalt and basalt origin of the lower and middle Eocene;

[1] Abadov, B.A., Məmmədova, E.A. Dağlıq Talış ərazisində ekzogen geoloji proseslərin intensivliyinin qiymətləndirilməsi // - Bakı: Bakı Universitetinin Xəbərləri, BDU, Təbiət elmləri seriyası, - 2010. №2, - s. 119-123.

[2] Хаин, В.Е. Геология Азербайджана. Том IV, Тектоника / Ак.А.Ализаде, Баку: Нафта-Пресс, –2005.–506 с.

- tuffaceous-sedimentary sequences of the middle Eocene;

- autoclastic lavas and breccias of trachyandesite-basalts and trachyandesites of volcanic origin, middle Eocene;

- flyschoid sedimentary-tuffaceous, upper Eocene;

- lavas and pyroclasts of trachyandesites and analcime trachyandesites of plagioporphyry origin, upper Eocene;

- tuffaceous-sedimentary sequence of the upper Eocene.

II. Trachybasaltic and phonolite phase of the Upper Eocene with the following strata (Dyman depressio):

- lavas and pyroclasts of basalts and trachydolites of subalkaline origin of the Upper Eocene;

- lavas of phonolites of leucite origin of the Upper Eocene.

According to the map of deep faults of the pre-Alpine basement of the territory of Azerbaijan, faults of various origins are distinguished for the Talysh zone: local, longitudinal, regional, etc. (Fig. 1).

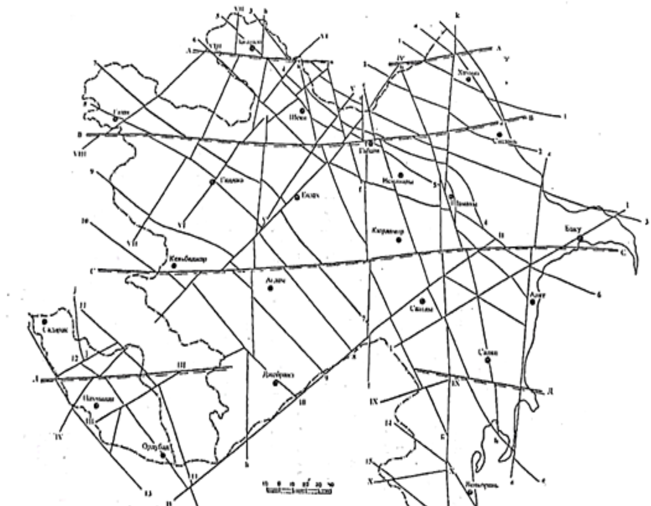

Figure 1. Map of the pre-Alpine basement deep faults of the Azerbaijan territory[3].

[3] Ахмедбейли, Ф.С. Тектонические типы сейсмических очагов Азербайджана / Ф.С. Ахмедбейли, А.Г. Гасанов, - Баку: Элм, - 2004. - 130 с.

Basically, 7 main deep faults have been identified, each of which is characterized by its own significance and length. For example, the Astara, Yardimli and Bilasuvar faults belong to the group of transverse faults. The Talysh and Pre-Talysh tectonic faults belong to the group of faults of the Pan-Caucasian direction. The Astara-Samur fault, which is transverse in origin, is characterized by the greatest length. Part of the Akhvay fault, which also falls on the Talysh zone, is orthogonal.

1.2. Geophysical research of the Talysh zone

In petrophysical terms, the Talysh zone is known as the territory of development of the main volcanogenic (Eocene) and ultramafic intrusive (late Eocene-Oligocene) complexes[4].

The radioactivity gradient in the southwestern part of the Talysh territory, extending in a northwestern direction, called Pre-Talysh, coincides in space with the transition zone between the Bilasuvar-Karadonlim maximum (+20) and the Nameless minimum (-8)." The productive thickness of this zone, determined by seismic exploration data, is characterized by a wedging process, which explains the presence of geofield anomalies associated with a geological nature. The boundary for geophysical fields of any type is the Pre-Talysh fault.

Based on the data on the change in the velocities of longitudinal seismic waves in both the vertical and horizontal directions, it can be assumed that the crust of the Talysh zone is characterized by a layered-block structure. A general study of the data on the distribution of velocity parameters indicates that in the upper part of the crust of the Talysh region, blocks of the earth with V_p = 6.0-6.50 km/s predominate, and in the lower part - V_p = 6.60-7.60 km/s. Further, there is an earth's crust with a thickness of approximately 10 km., with Vp = 7.70-7.90 km/s. The thickness of the Earth's crust, with a thickness of 10 km, lies directly above the Moho boundary and is a transitional region between the earth's crust and the upper mantle.

[4] Ализаде, Ак.А. Геология Азербайджана. Том V, Физика Земли / Ак.А.Ализаде. – Баку: Нафта-Пресс, - 2005. – 352.

1.3. Lithological features of the study area

The oldest deposits of the Talysh region directly relate to the Eocene epoch. In the studies conducted by F.A. Mustafayev, H.R. Aliyev and others in 1979-1982 (mapping at a scale of 1:50000) it is said that *"Lithologically, the territory of Talysh is composed of volcanogenic and volcanogenic-sedimentary rocks, and the geological structure of the research area includes Paleogene and Neogene deposits of the Tertiary period, as well as deposits of the Quaternary period"*. The average thickness of deposits of the III period of the Talysh zone reaches 8-9 km. Of these, volcanic deposits are 3500-4000 m thick. The thickness of deposits of the IV period varies within several hundred meters.

According to lithological and paleontological features, the Eocene deposits of the Talysh zone are divided into 3 floors: lower, middle and upper. The alkaline basaltoid formation is the most common type of deposits of this age. A detailed study of the lithological features revealed the presence of trachybasaltic formations.

CHAPTER II. HISTORY OF SEISMOLOGICAL RESEARCH IN THE TERRITORY OF AZERBAIJAN

2.1. History of the seismicity study in the territory of Azerbaijan

The plot of maps and schemes of seismic hazard of our Republic originates from the work of Mikhalevsky (1926). At that time, the maps of seismic field zoning of the USSR represented a complete systematic complex of geological hazard, which since 1937 have been reconstructed almost every 10 years[5].

The seismic zoning scheme, which was built in 1978, contains new parameters and data, such as historical sources of perceptible earthquakes; indicators of the frequency of oscillations of a certain intensity; zones of standard intensity, i.e. that required for construction. Some differences of this map/scheme from the previous one is that the Nakhichevan seven-point zone and the Talysh eight-point

[5] Бабаев, Г.Р. Оценка сейсмического риска территории города Баку: / дисс. доктора философии по наукам о земле / - Баку, 2004. - 149 с.

zone are not indicated here. The forms of the eight-point zones have also undergone some changes.

The territory of the Azerbaijani part of the Greater Caucasus, the Lesser Caucasus region, the Kur Depression, the Talysh megazone and the adjacent water area of our republic (the Caspian Sea), by the nature of seismic activity and the properties of the location of the hypocenters of seismic events, are characterized as the most seismically dangerous zones. The uneven distribution of focuses of imperceptible earthquakes in these zones is their feature. Focuses of strong seismic events are mainly attributed to the fault systems of the Caucasus, of various strikes. At the same time, there is an accumulation of a large number of weak earthquakes at the intersections of the above faults. The sea depth at which the accumulation of focuses of weak events occurs reaches 50 km, while on land up to 35 km.

2.2. Research in the field of seismic hazard assessment of the Talysh zone

It should be noted that, despite the availability of information on the magnitude of the energy class of earthquakes, the location of epicenters and the attenuation factor, there is a need to use modernized methods of seismic microzoning of the Talysh folding. It is also necessary to take into account an important parameter - the coefficient of amplification of the amplitude of the elastic wave. This coefficient factor depends on the speed of wave propagation in the strata, as well as on the lithology and thickness (power) of the strata. In addition, it is necessary to study the properties of grounds from a dynamic point of view and take into account the above-mentioned amplitude factor. This process will allow creating a seismic model of the Talysh territory. Today, with the help of special software, it is possible to determine not only the coefficients of wave amplitudes, but also to determine the type of deposits lying at certain depths.

In order to modernize the network of observations and instrumental research in the field of seismology, in 2009-2010, additional stations of the “Kinemetrics” brand were installed to the existing ones (e.g., “Astara”, “Lerik”), in the amount of eleven. 2011 was characterized by the introduction of an additional 6 telemetry stations into the network by the RSSC (named “Gobustan”, “Gabala”, “Gusar”, “Ordubad”, “Shahbuz”, “Heydarabad”). Since 2011, the number of stations in Azerbaijan for seismological research has reached 31[6].

The seismicity level parameter of the entire territory of Azerbaijan was used in the process of placing seismic stations in our country. According to the RCSS data, seismic stations are located as follows: “On the southern slope of the Greater Caucasus - three stations (Pirgulu, Ismayilli and Sheki); on the northern slope and in the eastern part of the Greater Caucasus - two stations (Guba and Siyazan, respectively); in the southeast of the republic - three stations (Alibayramli, Jalilabad and Lenkoran, later renamed Lankaran); in the west of the republic - two stations (Ganja and Barda)”.

CHAPTER III. SEISMICITY OF THE TALYSH ZONE AND THE ADJACENT WATER AREA OF THE CASPIAN SEA

3.1. Research of macroseismic fields of the Talysh zone

The study of the macroseismic fields of the Talysh megazone began with the Iranian earthquake of May 1860, which was felt in the cities of Shamakhi and Shusha, while the epicenter of the event, located at a depth of 35 km, was characterized by a magnitude of 5.2. The intensity in the adjacent areas of Iran, on the Iran-Azerbaijan border (near the Talysh region) was estimated in the range of 5-6 points.

The resumption of seismic activity in the Talysh region occurred after another Iranian earthquake, which was characterized as destructive. The seismic event of 1879 was felt in the areas of the settlements of Lankaran, Bilasuvar and Ordubad. The main parameters of the earthquake of March 22, 1879 are represented by the values of the depth of the source of 25 km. and the magnitude of 6.5. Despite the fact that the intensity of ground shaking classified the event as destructive (intensity - 7 points), no serious damage was detected[7].

[6] AMEA nəzdində Respublika Seysmoloji Xidmət Mərkəzinin rəsmi veb-saytı [Elektron resurs]. - Bakı, 2024; https://seismology.az/ru/stranica/seismologiya.

[7] İsmayılova, S.S. Talış struktur zonasının seysmogeodinamikası: / yer elmləri üzrə fəlsəfə doktoru dis. / - Bakı, 2018- 179 s.

3.2. Seismic regime and distribution of earthquake epicenters in the study area

General seismic situation in the Talysh territory for the period 891-2023 can be obtained on the basis of the map (Fig. 2) of the distribution of earthquake epicenters constructed in this work, according to the homogenized catalog. In the dissertation work, to represent the modern seismic situation and general seismicity of the Talysh territory, a single, homogenized catalog of earthquake epicenters was compiled. Events for the catalog were used from various local and foreign sources.

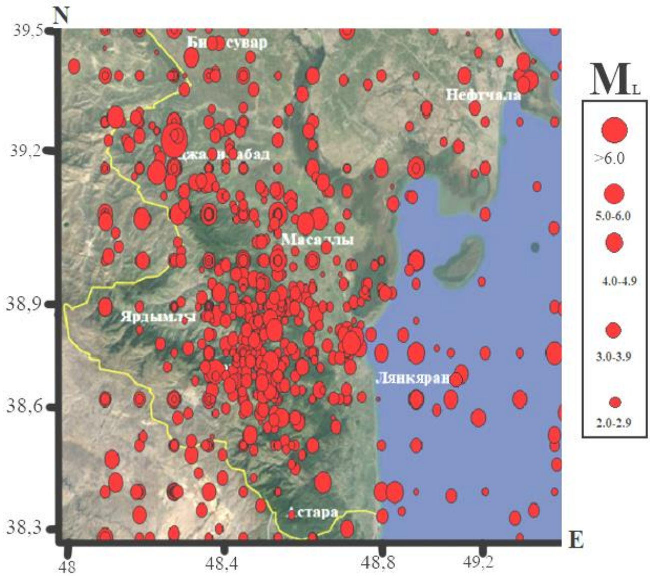

Figure 2. Map of the distribution of epicenters of Talysh zone, constructed for the period 891-2023 (compiled by Aliyev Ya.N.).

Based on the plotted map, it is possible to reason that the concentration of earthquake epicenters, for the specified period, is observed directly in the central part of the Talysh megazone, near the Lankaran, Lerik and Yardimly regions. Of the seven main regions of Talysh, the lowest seismicity is observed in the Astara region, which, in comparison with other regions, is characterized by smaller seismic events. The adjacent water area of the Caspian Sea is also characterized by the presence of seismic events of varying magnitude over time. Earthquakes have been occurring along the entire Azerbaijan-Iran border for a long time.

3.3. Dynamics and mechanisms of earthquake focuses of the Talysh zone and adjacent water area

The map of focal mechanisms of strong earthquakes in this work was constructed using ArcGIS software, version 10.8. For seven strong events, a selection was made from the general catalog of the focal mechanism, the work of Ismailova S.S. Compression of most of the territory of Talysh is observed, and shear processes are identified in the zones of the Lerik and Yardimly districts.

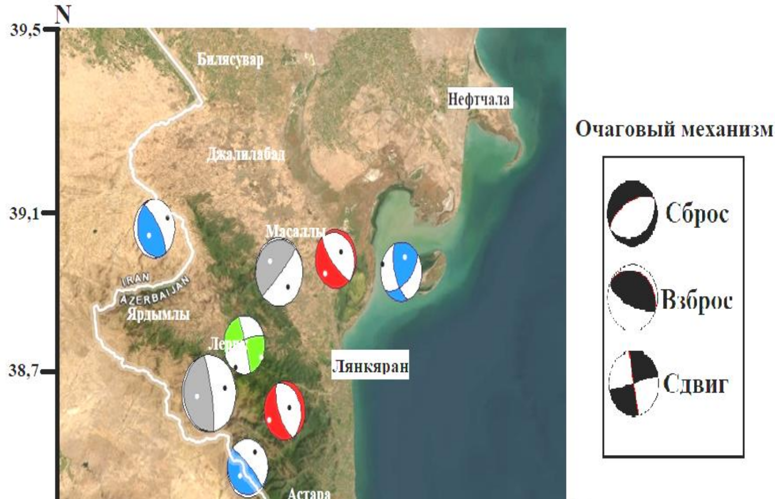

Figure 3. Map of focal mechanisms of strong earthquakes on the territory of Talysh for 1990-2023 (compiled by: Aliyev Ya.N.).
Сброс – Normal fault; Взброс – Reverse fault; Сдвиг – Strike slip

It is known that during tectonic deformations, stress accumulates in an elastic medium, and the deformation itself can be either elastic or plastic. In the process of stress release, a tectonic earthquake source is formed. In the process of transforming one type of deformation into another, a process of underground vibrations is formed - that is, earthquakes[8].

The earthquake focal mechanism is one of the most important parameters that describes an earthquake. In modern seismology, the mechanism is attributed to the random movement of rocks, resulting in the dispersion of elastic waves. It is possible to judge the stress state of the Earth's depths using data on earthquake focal mechanisms, which also carry information about rupture planes and stress axes orientations.

As a result of the study, comparison and evaluation of instrumental data and macroseismic materials, it was revealed that within the Talysh region, noticeable and strong earthquakes occurred in: 891 (M=6.3); 1990 (M=6.0); 1996 (M=5.4); 1998 (M=6.0); 2007 (M=5.2); 2012 (M=4.0); 2014 (M=4.5); 2016 (M=4.6); 2023 (M=4.9 and M=5.1).

More than half of all earthquakes, in the process of deformation, are characterized by the value of PL≤30°, the remaining part of seismic events is observed PL≤20°. According to these values, upthrust and strike-slip are the main processes in the territory of Talysh. SLIP angles, which characterize the immersion indicator, change for positive directions by 60%, and for negative up to 40%. Based on these data and materials on fault tectonics, heterogeneity of the lithosphere in the study area was revealed[9].

By integrating the available data on the seismicity of Talysh zone and the adjacent Caspian Sea area with the values obtained in this work, it can be argued that earthquake sources in the coastal part of the Caspian Sea are capable of being generated from the Talysh and Astara-Derbent faults and sources located within the South Caspian

---

[8] Воронина, Е.В. Механика очага землетрясения. Учебное пособие / Е.В.Воронина. – Москва: Физический факультет МГУ, - 2004. - 92 с.

[9] Казымова С., Казымов И. Геодинамика Талышского региона по данным механизмов очагов землетрясений и GPS-станций // - Геология и геофизика Юга России, - 2020. №3, - с. 40-55.

Basin. As a result, seismic processes are frequently activated throughout the region.

CHAPTER IV. DIFFERENTIATION AND ANALYSIS OF EARTHQUAKE PROBABILITY FOCUS AREAS

4.1. Calculation of the earthquakes' maximum possible magnitude parameter of the study area

For landslide areas, it is important to determine the parameter of possible ground shaking, in the intensity scale. The expected maximum shaking of the territory of Talysh and the adjacent water area of the Caspian Sea were determined based on the equation of attenuation of macroseismic intensity.

The intensity of ground shaking, in macroseismic units, is one of the main parameters that is determined when solving engineering and geophysical problems, in addition to seismic hazard parameters (PGA, PGV, displacement, shaking amplitude). M_{max} - the maximum magnitude of the seismogenic structure earthquake was determined based on the data on the length of faults and lineaments of Talysh, based on the correlation relationship of Shebalin H. Considering the fact that the territory of Talysh is located in a mountainous region, it is advisable to calculate the maximum magnitude based on the right limit of the correlation relationship, which has the form:

$$M = 2 \text{ Lg } L + 2.0$$

Where: L – length of seismogenic structure (km).

Based on the use of a tectonic map, the length L of each of the seven main faults of the Talysh zone was determined. Using the Shebalin relation, the value of the maximum possible magnitude that can generate faults was determined and a corresponding map of the distribution of the parameter in the study area was plotted (fig. 4).

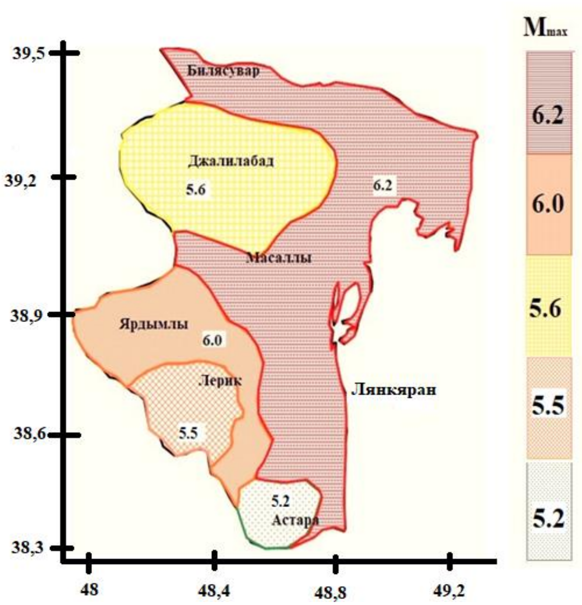

Figure 4. Map of distribution of earthquakes possible maximum magnitudes (M_{max}) in the study area (compiled by: Aliyev Ya.N.).

Ground shaking in intensity is used to determine the seismicity of seismically active areas in historical proportions, as well as when compiling seismic zoning maps of various scales.

4.2. Estimation of expected maximum shakings in the Talysh zone and adjacent water area

Obtained data on the extent of structures and the maximum possible magnitude of faults (fig. 1) and lineaments, the intensity of ground shaking was determined on the basis of the ratio (Kuliyev F.T.) of the macroseismic equation for the territory of Talysh (fig. 5).

Based on the compiled map, it is evident that shakings with an intensity of VIII are concentrated mainly in the southern continuation of the Yardimly region, extending in the south-east direction, towards the Lerik region. More than 85% of the studied territory is characterized by probable earthquake focuses, with an intensity of VII. The adjacent water area of the South Caspian basin, washing the shores of the Talysh region, is also confined to the zone of shakings of VII according to fault tectonics.

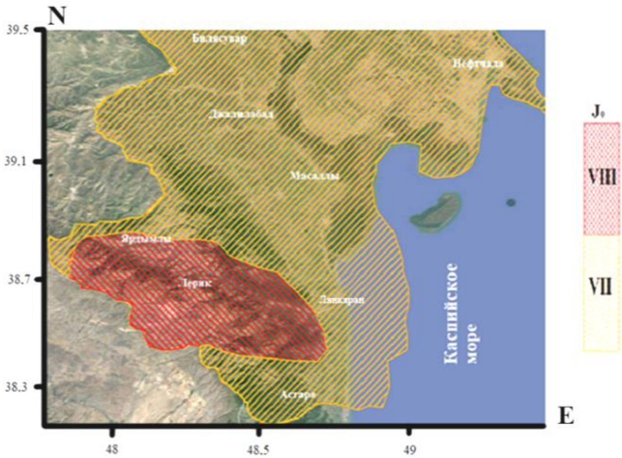

Figure 5. Map of differentiated areas of probable sources of strong earthquakes (in intensity units) (compiled by: Aliyev Ya.N).

Based on maps 4 and 5, it can be stated that the Talysh fault is capable of generating earthquakes with a maximum magnitude of M_{max}=6.0 and intensity of J_0=VIII; the Pre-Talysh fault is capable of generating earthquakes with a maximum magnitude of M_{max}=6.0 and intensity of J_0=VII; the Astara fault with a maximum magnitude of M_{max}=5.2 and intensity of J_0=VII; the Yardymly fault - M_{max}=5.5, intensity J_0=VIII; the Bilasuvar fault - M_{max}=5.6, intensity J_0=VII; the Akhvay fault - M_{max}=5.6, intensity J_0=VII and the Astara-Samur (Derbent) fault generates earthquakes with a maximum magnitude of M_{max}=6.2 and intensity J_0=VII.

Therefore, based on the conducted assessment of the maximum possible tremors of the Talysh territory, it can be concluded that the study area is a zone of actual manifested risk. The development of risk in the territory occurred as a result of earthquakes that generated the Talysh, Pre-Talysh, Yardymlin and Astara-Samur (Derbent) faults, which also contributed to the formation of landslides.

CHAPTER V. SEISMIC HAZARD ASSESSMENT OF THE TALYSH ZONE AND THE ADJACENT WATER AREA OF THE CASPIAN SEA

5.1. Application of scenario earthquake in seismic hazard assessment

In this paper we use an analytical approach to microseismic zoning based on a sample of local, near and distant earthquakes. Understanding new methods of seismic hazard assessment that have emerged in recent years is the subject of close attention by seismologists, and there is an increasing interest in this area. Today, there are two main directions in the world that are based on probabilistic and deterministic approaches. The methods are modified by new additions, and are also enriched and expanded during seismic monitoring.

The main parameters here are instrumental earthquake data (magnitude, epicentral distance, earthquake focal depth), physical and dynamic ground properties. Using them and calculating the peak amplitude of ground acceleration of foundation layers, the maximum amplitudes of earth surface shakings are calculated, the correlation comparison of which with seismic intensity is carried out on the generally accepted international scale (Trifunac, Brady, 1975)[10].

It is advisable, when conducting a deterministic assessment of seismic hazard, to divide the study areas into equal cells (squares) and perform a calculation for each cell of the area (Fig. 6). When obtaining the values of the elastic wave amplitude amplification, the PGA parameter of surface rocks is calculated for each cell, as a result of which a model is plotted. Consequently, in this work, the seismic hazard models of the Talysh territory and the adjacent Caspian Sea water area are expressed in peak ground shakings accelerations. As a result of comparing all models, it is possible to identify zones that are characterized by high hazard.

[10] Trifunac, M.D., Brady, A.G. On the correlation of seismic intensity scales with the peaks of ground motion records // - Bulletin of the Seismological Society of America, - 1975. №65(1), - p. 139-162.

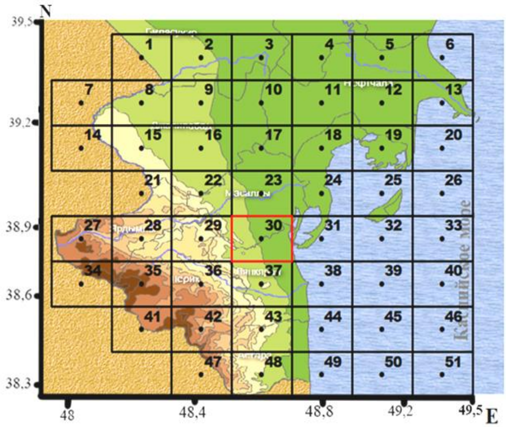

Figure 6. Basemap of the Talysh territory, with the grid of the study area into cells (17x15 km) (compiled by: Aliyev Ya.N.).
The central cell of the study area is highlighted in red.

5.2. Determination of the seismic wave's amplification factor of the ground (soil) layer in the study area

The main focus of the seismic hazard assessment in this paper is the application of a deterministic approach, the purpose of which is to define a "maximum earthquake" scenario. This scenario is intended to illustrate the strongest ground movements in the study area [11]. The definition of the earthquake scenario mechanism is the basis for seismic hazard assessment using a deterministic approach. The choice of a scenario earthquake allows an assessment of the magnitude of the earthquake and a possible seismic catastrophe in the future.

When assessing seismic hazard using a deterministic approach, an important parameter is the seismic wave amplification factor, namely its amplitude. Thus, a seismic wave passing through a thickness of layers is characterized by different values of the wave amplitude amplification factor, depending on the lithological and stratigraphic

[11] Babayev, G., Babayev, T., Luciano, T. Deterministic ground motion modeling with target earthquakes and site effects in eastern Azerbaijan //- Arabian Journal of Geosciences, - 2024. №61, - p.1-12, https://doi.org/10.1007/s12517-024-11866-y.

features. To calculate the amplification parameter of the Talysh zone and the adjacent Caspian Sea area, it is necessary to identify the lithological stratigraphic properties of each cell of the study zone. For all cells of the Talysh folded zone (51 cells), with a dimension of 17x15 km, wave amplification factors (amplitudes) were calculated and used, which are based on the wave propagation velocity V_s, sediment density and lithological composition. Naturally, rocks of a looser composition will be characterized by higher values of the Amp coefficient, which corresponds to cells 3, 4, 5, 6, etc. Denser rocks, of the hard type, which belong to the Oligocene-Miocene era, are characterized by lower Amp values, down to 0.53.

Calculation of hypocentral and epicentral distances to each cell of the study area is the next step in seismic hazard assessment using the deterministic approach, since these distances belong to the group of macroseismic parameters. Epicentral distance, i.e. from the epicenter to the observation point (in our case, to the central point of the cells) is defined as "A simple mathematical concept based on the linearity of identical values, represented by the Pythagorean theorem".

5.3. Calculation of the expected seismic effect of the Talysh zone and the adjacent water of the Caspian Sea

Based on the obtained values of the coefficient Amp, it is possible to calculate the parameter of peak acceleration of the ground (oscillation) directly on the surface of the Earth. Calculations of the parameter PGA for bedrock were made for the purpose of calculating the parameter PGA on the surface of the Earth.

In order to fully understand the picture of expected tremors in PGA units, in this work, maps of the distribution of average PGA values were constructed for both bedrock and the Earth's surface (Fig. 7 and 8).

Based on the obtained data on peak ground accelerations, it is evident that according to scenario earthquakes, the study area is characterized by high values of the PGA parameter, practically in all cells. Each cell, characterized by its own lithology, based on the application of the wave amplification parameter, is determined by a different range of accelerations, in Gal units.

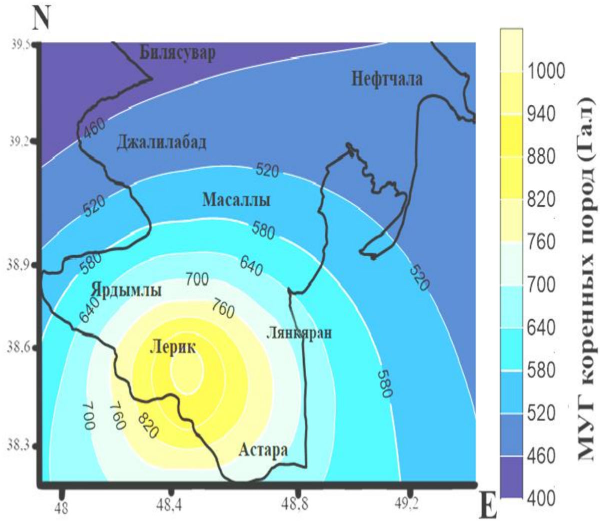

Figure 7. Map of the peak ground acceleration (PGA) parameter distribution for bedrock in the Talysh zone (compiled by: Aliyev Ya.N.).

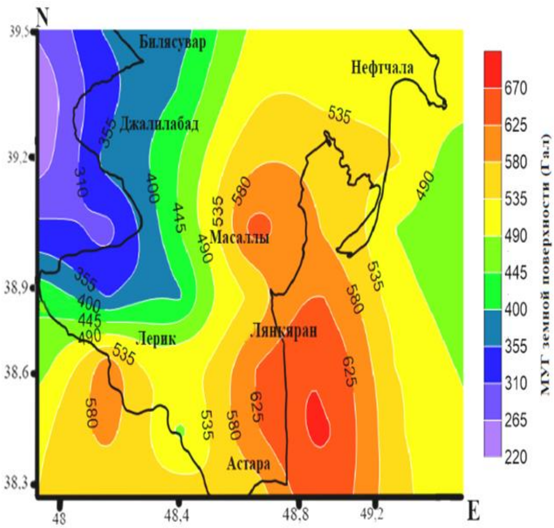

Figure 8. Map of the peak ground acceleration (PGA) parameter distribution for surface in the Talysh zone (compiled by: Aliyev Ya.N.).

According to Figure 7, the bedrock located in the northern part of the study area is characterized by lower values of peak ground acceleration relative to the entire area (400-500 gal). For the adjacent Caspian Sea, accelerations are characterized by values above the lowest, reaching a maximum of up to 700 gal. An increase in acceleration values is observed when moving in the southwest direction of the Talysh zone, in the area of the Talysh Mountains and the Lerik region. Accelerations in this area reach their maximum of 900 gal. The Jalilabad-Masalli region is characterized by transitional values of PGA (500-700 gal). The Lankaran region is also characterized by values above average, while acceleration in this region reaches the range of 700-850 gal.

The distribution pattern of acceleration values for the soil surface differs from accelerations for bedrock. Thus, according to Figure 8, the entire northwestern part of the Talysh territory is characterized by the lowest acceleration values, within 200-355 gal.

As a result of applying the seismic wave amplification parameter (its amplitude), the zone of high acceleration values was shifted to the east, to the coastal sea-land boundary. Thus, the maximum values of soil acceleration are characterized by a value of up to 670 gal, which represents this zone as a high-hazard area.

Intermediate acceleration values are observed in the central-western part of Talysh, in the Jalilabad-Yardymly area, reaching values of up to 500 gal. The Masalli-Lankaran zone, as a result of applying the Amp coefficient, is characterized as a zone close to high hazard, since accelerations in this area reach 600 gal.

Based on the obtained values, a map of the intensity distribution of possible focal areas of high seismic hazard in the Talysh folded zone was plotted (fig. 9).

According to the constructed map 9 for the Talysh zone, the greatest intensity is represented by the centers of possible earthquake zones of the Lankaran-Caspian Sea region. The intensity in this zone is characterized by its highest values, reaching intensity of up to IX (9.4). For the study area, the Bilasuvar-Jalilabad region is represented by the intensity of tremors in the value of VIII points. When comparing the entire study area, it is evident that the eastern part of the Talysh megazone is more dangerous, compared to the western part. The values of maximum ground acceleration and intensity obtained in this work are the main indicator for putting forward this statement.

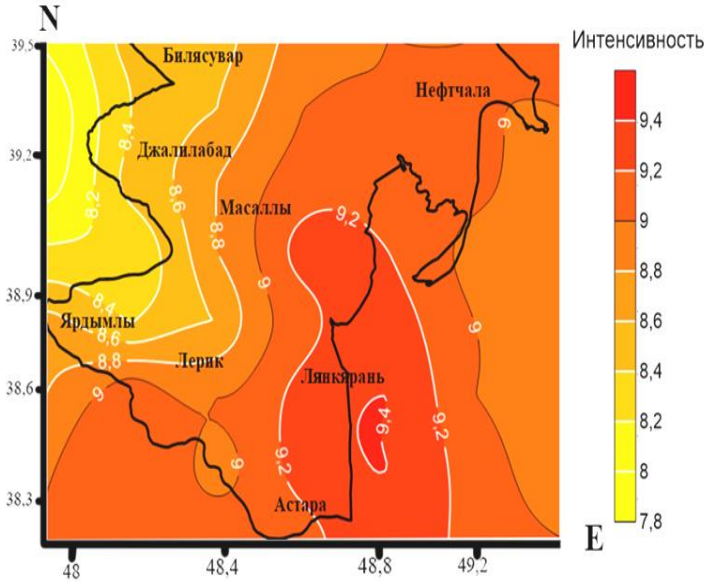

Figure 9. Map of distribution of macroseismic intensity (in points) for the Talysh zone and adjacent water of the Caspian Sea, from 4 scenario earthquakes (compiled by: Aliyev Ya.N.).

Thus, in Chapter V, the seismic hazard of the Talysh folded megazone was assessed using the constructed seismic microzoning maps of peak ground acceleration and earthquake intensity (macroseismic). An important parameter in this case is the elastic wave amplification factor, namely its amplitude. Thanks to the four selected scenario earthquakes (Lerik, Iranian, Caspian and Oguz), a wide range of approaches for deterministic seismic hazard assessment was covered, ranging from lithological features to dynamic ground (soil) parameters.

Conclusion

Based on the results of the research conducted in this dissertation, the following main conclusions were made:

1. Based on the existing methods, a unified differentiated approach to seismic hazard assessment was developed, which takes into account the ratios of the values of the maximum magnitude of earthquakes, the size and length of the fault, as well as the epicentral distance;
2. According to the analysis of the combined catalog of earthquakes compiled in the dissertation work with the value of a single representative magnitude calculated using correlation formulas, it was confirmed that the main seismogenerating structures in the Talysh zone and the adjacent waters of the Caspian Sea are the areas of intersection and junction of the Astara-Samur (Derbent), Pre-Talysh and Yardymly faults;
3. Based on the analysis of the plotted unified map of the distribution of macroseismic intensity of the Talysh zone, taking into account the estimated maximum magnitude M_{max}, the length of the faults and the equation of the macroseismic field, it was revealed that the Talysh fault is capable of generating earthquakes with an intensity of VIII and poses the greatest danger to the study area, while it is shown that most of the Talysh zone is subject to seismic hazard of VII;
4. The developed models of ground (soil) conditions from the deep strata of the Paleogene-Neogene age to the soil surface, developed in this study, taking into account the lithological, physical parameters and geometric characteristics of the environment, were used in calculating the amplification factors of the amplitude of seismic waves in layered packs and in constructing the corresponding map of the distribution of the coefficient using the methods of mathematical statistics and software;
5. An integrated seismic hazard assessment was carried out taking into account the ground (soil) conditions of the Talysh zone and the adjacent Caspian Sea, on the basis of which a series of deterministic maps were created in the values of the peak ground acceleration of the deep strata of siltstone-sandy composition of the Paleogene-Neogene age at a five-kilometer depth and for sandy-clayey rocks on the exposed

soil surface, and the intensity of shaking according to macroseismic data of scenario (Lerik, 1998; Caspian, 2000; Iranian, 1980; Oguz, 2015) earthquakes;

6. According to the results of the seismic hazard assessment based on scenario earthquakes, the settlements of Masalli, Lankaran and Astara of the Talysh zone, as well as the adjacent Caspian Sea, are characterized by a high intensity of IX. However, the western and northwestern parts of the study area, including the areas of the settlements of Bilasuvar and Jalilabad, are characterized by a lower intensity of VIII;
7. A comparative analysis of the series of maps of the expected seismic effect obtained in this work using the two integrated and unified methods developed by us made it possible to reveal that the Talysh zone and the adjacent southern part of the Caspian Sea are characterized by seismically dangerous zones with an estimated maximum magnitude of $M_{max} = 5.2 \div 6.2$, with a peak ground acceleration on the surface within 220-670 gal and a calculated shaking intensity in the range of VII-VIII-IX, which significantly increases the reliability of the characteristics of seismic effects.

List of the author's publications on the topic of the dissertation

1. Babayev, G., Agayeva, S., Telesca, L., Niemi, N., Ismail-zade, T., Muradi, I., Aliyev, Y. “Estimation of local seismic activity by deterministic hazard assessment. A case study in north-eastern of Azerbaijan”. CTBT: Science and Technology conference. T1.2-O3. Book of Abstracts, Vienna, Austria, p.19, 2019, (printed in Austria);
2. Бабаев, Г.Р., Агаева, С.Т., Исмаил-заде, Т.Т., Муради, И.Б., Алиев, Я.Н. “Оценка сейсмических воздействий на южном склоне Большого Кавказа (Азербайджан) по сценарным землетрясениям: параметры и модели ускорения перемещения грунта”. Геофизический журнал. 2019. Т. 41, С. 170-188. https://doi.org/10.24028/gzh.0203-3100.v41i3.2019.172471;
3. Babayev, G., Kadirov, F., Tibaldi, A., Bonali, F., Aliyev, Y. “Dynamic triggering of mud volcanos in Azerbaijan by Caspian earthquakes”. ANAS Transactions, Earth Sciences, N2, 2019, pp.

47-53; DOI: 10.33677/ggianas20190200031;
4. Babayev, G., Telesca, L., Agayeva, S., Ismail-zade, T., Muradi, I., Aliyev, Y., Aliyev, M. “Seismic Hazard Analysis for Southern Slope of the Greater Caucasus (Azerbaijan)”. Pure and Applied Geophysics, Vol. 177 (8), 2020, pp. 3747–3760, https://doi.org/10.1007/s00024-020-02478-0;
5. Aliyev, Y.N. “Earthquake-triggered peak ground acceleration assessment (Case Study: Absheron oilfield deposit)”. 25th Annual International Conference of Students and Young Researchers. Book of Abstracts, Baku, Azerbaijan. 2021, p.4;
6. Abbasov, R.Y., Bayramov, Z.F., Malikov, R.I., Jodry, C.S., Babayev, G.R., Aliyev, Y.N., Muradi, I.B. “Determination of marine water intrusion via electrical resistivity tomography (ERT) method”. VIII International Scientific Conference of Young Scientists & Students. Innovations in Geology and Geophysics. Book of Abstracts, Baku, Azerbaijan. 2021, pp.36-37;
7. Aliyev, Y.N. “Characterization of seismic hazard assessment methods: state of the art and challenges”. VIII International Scientific Conference of Young Scientists & Students. Innovations in Geology and Geophysics. Book of Abstracts, Baku, Azerbaijan. 2021, p.8;
8. Муради, И.Б., Бабаев, Г.Р., Алиев, Я.Н. “Оценка сейсмической обстановки Апшеронского полуострова по результатам анализа контактных измерений и космического мониторинга Земли”. Журнал “Геофизика”, Пермский Государственный Национальный Исследовательский Университет, Пермь, Россия. №5. 2022, с.34-40. https://doi.org/10.34926/geo.2022.66.54.001;
9. Babayev, G.R., Aliyev, Y.N., Muradi, I.B., Aliyev, T.R., Gasimov, E.E., Aliyev, M.M. “Application of electrical exploration methods for geological hazard assessment”. Dangerous natural and technogenıc processes ın mountaın regıons: models, systems, technologies, Vladikavkaz, Russia, 2022, pp.120-124;
10. Aliyev, Y., Babayev, G. “Catalogue-based spatio-temporal analysis and evaluation of seismic scenarios in the Talysh zone (Azerbaijan)”. Geofizicheskiy Zhurnal, 45(5), 2023. pp.108-118. https://doi.org/10.24028/gj.v45i5.289114;

11. Babayev, G.R., Babayev, T.H., Aliyev, Y.N., Muradi, I.B. "Numerical earthquake ground motion modeling for southern slope of Greater Caucasus". Materials of VII International Conference "Seismology and Engineering Seismology", dedicated to the 100th anniversary of the birth of the Nationwide Leader H.Aliyev, 2023, pp. 264-268;
12. Бабаев, Г.Р., Алиев, Я.Н., Муради, И.Б., Бабаев, Т.Х. "Дифференцированная сценарная оценка опасности землетрясений областей месторождений нефти и газа Абшеронского полуострова". Международная научно-практическая конференция "Гейдар Алиев и Нефтяная Стратегия Азербайджана: Достижения Нефтегазовой Геологии и Геотехнологий." Сборник трудов. Баку, Азербайджан. Май 2023, с.659-663. https://conference.ogi.az/abstract.php;
13. Babayev, T.H., Aliyev, Y.N., Muradi, I.B., Aliyev, M.M. "Seismic analysis of the Shamkir reservoir area through insights into the dynamics of the earthquake characteristics". ANAS Transactions, Earth Sciences 2/2023, pp.51-63. DOI: 10.33677/ggianas20230200102;
14. Муради, И.Б., Бабаев, Г.Р., Алиев, Я.Н., Бабаев, Т.Х., Самедова, К.Ф. "Изучение взаимосвязи землетрясений и извержений грязевых вулканов Абшеронского полуострова". Журнал "Геофизика" (Россия) № 5, 2023. с.72-77. https://www.elibrary.ru/item.asp?id=54819705;
15. Babayev, G.R., Muradi, I.B., Aliyev, Y.N., Babayev, T.H. "Differentiated scenario-based assessment of earthquake hazard in the oil and gas deposit areas of the Absheron Peninsula". International Scientific-Practical Conference Heydar Aliyev and Azerbaijan Oil Strategy: Advances in Oil and Gas Geology and Geotechnologies. ANAS Transactions. Earth Sciences (Special Issue). Baku, Azerbaijan. October 2023, pp. 95-97. DOI:10.33677/ggianasconf20230300022;
16. Muradi, I., Babayev, T., Aliyev, Y., Aliyev, M. "On the possibility of using space sounding methods for a deterministic assessment of the seismic hazard of the Absheron peninsula". 9th International

scientific conference of young scientists & students. Geoinformatics, Georesources, Geoecology. Book of Abstracts. Azerbaijan. October 2023. pp.86-88. https://sites.google.com/view/ggi2023/book-of-abstracts?authuser=0;

17. Babayev, T., Muradi, I., Aliyev, Y., Aliyev, M. "Post-seismic activity review of 06.02.23 Kahramanmaraş Türkiye earthquake". 9th International scientific conference of young scientists & students. Geoinformatics, Georesources, Geoecology. Book of Abstracts. Azerbaijan. October 2023. pp.91-93. https://sites.google.com/view/ggi2023/book-of-abstracts authuser =0;
18. Муради, И.Б., Бабаев, Г.Р., Алиев, Я.Н., Бабаев, Т.Х., Алиев, М.М., Рустамов, Х.Ш. "О возможности применения РСА интерферометрии с использованием снимков со спутников Sentinel-1 при изучении оползневой активности в районе горного кластера Малого Кавказа". Теория и практика разведочной и промысловой геофизики. Сборник научных трудов. Пермь, Россия, № 6 (11), Ноябрь 2023. с.152-159.

The defense will be held on _25_ _November_ 2024 at __14^{30}__ at the meeting of the Dissertation council ED 1.01 of Supreme Attestation Commission under the President of the Republic of Azerbaijan operating at the Institute of Geology and Geophysics Ministry of Science and Education of Azerbaijan Republic.

Address: AZ1143, Azerbaijan, Baku city, H. Javid Ave. 119
Fax: (+99412) 537 22 85
E-mail: gia@azdata.net

It is possible to get acquainted with the dissertation in the library of the Institute of Geology and Geophysics Ministry of Science and Education of the Azerbaijan Republic.

Electronic version of the abstract are posted on the official internet website of the Institute of Geology and Geophysics Ministry of Science and Education of Azerbaijan Republic.

Abstract was sent to the required addresses on _23_ _October_ 2024.

Signed for print:14.10.2024

Paper format: $60x84^{1/16}$

Volume: 36586

Number of hard copies: 20