Strengthening the Dynamic Processes of the Earth's Crust in Central Armenia - the Activation of Garni and Ararat-Sevan Faults.

[1]Pashayan R.A.*, [2]Karapetyan.J.K., [3]Arutunyan L.V.

[1]PhD, Leading Researcher of the Institute of Geophysics and Engineering Seismology after A. Nazarov of the National Academy of Sciences of Republic of Armenia Yerevan,

[2]PhD, Director of the IGES NAS RA, Republic of Armenia, Gyumri.

[3]PhD, Head of Laboratory of the Institute of General and Inorganic Chemistry after M.G. Manvelyan of the National Academy of Sciences of Republic of Armenia Yerevan,

[1]romellapashayan@sci.am, [2]jon_iges@mail.ru, [3]levonharutyunyan35@mail.ru

Abstract

Over the past ten years (2011-2022), a large number of seismic events have been registered in the region of central Armenia. A map of the seismicity of the territory of Armenia for the indicated years has been compiled. The purpose of this study is to confirm the activation of the geodynamics of central Armenia according to seismic geodynamics, based on the data of studying the movement of the earth's crust and establishing a connection between variations in the stress-strain state of the earth's crust and the kinematics of deep faults. The stress-strain state of the earth's crust in the central region is calculated based on the data of water level variations in hydrogeodynamic wells and anomalous changes in the chemical composition of mineral waters. The stress-strain state of the earth's crust in central Armenia contributed to the formation of a compression structure along the middle segment of the Garni fault and along the Ararat-Sevan fault. Anomalous changes in the composition and level of groundwater revealed hydrogeochemical and hydrogeodynamic effects that preceded tectonic movements of the earth's crust. The gas composition is the first to react to the stressed state of rocks: carbon dioxide (CO2), the second is the macrocomponent composition of mineral waters. The epicenters of the occurred earthquakes are mainly confined to the zones of deep faults: Garni, Ararat-Sevan and partly along the Yerevan deep faults. Based on the research results, the dependence of earthquake epicenters on the longitude and latitude of coordinates is shown. A graph of the dependence of occurred earthquakes on depth has been compiled

Keywords: *seismicity, deformation, stress, faults, earth's crust, earthquake, well, mineral water.*

Introduction

According to the works of several authors [1]., the confinement of earthquake epicenters to zones of active deep faults were established in Armenia.

*Corresponding Author

However not all the faults are characterized by the same seismicity.The most seismically active faults are the general Caucasian faults and two faults of northeast: Akhuryan and Ararat-Sevan. According to seismo-statistical data, Pambak-Sevan, Pambak-Sevan-Syunik, Garni, Akhuryan are especially highly active. The differentiation of faults according to seismic activity along their borders is observed.During the earthquakes of medium and large strength, it is necessary to consider active blocks and fractured knots. Seismically active fractured knots are Spitak and Sevan. To determine the activation of seismicity in the study area, based on the catalogs of earthquakes for 2011-2022 and the general seismic regime, a map of background seismicity was developed. The hydrogeodynamic effects preceding the geodynamic processes of the Earth's crust in the central region were revealed based on the changes in the dynamics of the groundwater level and the chemical composition of mineral water. The task of the research is to confirm the activation of the geodynamics of Central Armenia according to seismic geodynamics, based on the data of the study of the movement of the Earth's crust and establishing a connection between variations in the stress-strain state of the Earth's crust and the kinematics of deep faults.

Material and processing methods.

The studies of the activation of geodynamic processes of the Earth's crust of central Armenia were carried out according to the seismic regime, changes in the dynamics of groundwater in hydrogeodynamic wells, and variations in the chemical composition of mineral waters. The seismically active region of Armenia is characterized by complex tectonics with multiple deep faults of the pan-Caucasian and anti-Caucasian lineaments. Tectonics of the research area includes seismotectonic megablocks of Yerevan and Gegam-Vedi. The intensive development of the tectonic movements of the Gegam-Vedi megablock were accompanied by subhorizontal tectonic movements directed to the SW. Currently, the movement of the Yerevan megablock is developing towards the SW-SE direction. All these movements are accompanied by the development of centers of numerous relatively weak earthquakes on the front-facing SW and SE parts of the formations of the folded and covered complexes. At the same time, the faults of the folded complex are transformed into structures of the first-order, and the structural plan for the development of modern tectonic movements are outlined by the locations of epicenters of relatively strong earthquakes at the intersection knots of transverse (NE)–longitudinal (NW), i.e., fundamental-crustal faults [2].. The Yerevan seismotectonic knot under consideration is distinguished by the development of a regional NE-SW prostration of the fault along the river. Khndzorut - v. Chambarak - v. Shorzha- Lake Sevan - v. Yeranos - Geghama Highlands between the rivers Jrvezh - Azat, further moving to the East, according to the earthquakes that occurred on October 23, 2011, follows the line of Aigezard - Mount Ararat - the city of Van. At the same time, according to geophysical data, the Ararat-Sevan fault is distinguished here [3].. The regional fault is distinguished by geological interpretation of aerial and space photographs [2]., a set of geophysical data, and field studies. Yerevan seismotectonic knot is mainly the result of tectonic movements of the fault-interfault zone. Moreover, the mentioned movements were accompanied by multistep left-shifts of blocks both inside the Azat fault zone and in the contact aureole of parts of the Gegham-Vedi megablock and are the consequences of the subhorizontal displacement of the Gegham-Vedi megablock in the SW direction approximately within 28-36 km. As a result, Garni seismically active fault was identified in this place [4].. Moreover, the mentioned movements were accompanied by multistep left-shifts of blocks both inside the Azat fault zone and in the contact aureole parts of the

Gegham-Vedi megablock and are the consequences of the subhorizontal movement of the Gegham-Vedi megablock in the SW direction approximately within 28-36 km. As a result, the Garni seismically active fault was identified in this place [4].. At present, the mentioned relatively active tectonic movements have largely been stabilized. Accordingly, the movement of the near-fault parts of the Yerevan megablock continues relatively weaker and more interestingly and is accompanied by Yerevan fault and formations of the folded complex. This is confirmed by the development of modern, as on the example of 2006-2007, earthquake epicenters, relatively weak and medium, slightly stronger than the earthquake in the frontal SW and SE parts of the Yerevan megablock. The earthquake centers of relatively weak earthquakes are developed on the right bank of the Araks River [5]. . Thus, with the help of paleotectonic analysis, it is possible to identify seismically active and passive tectonic blocks and faults, as well as to determine the nature and direction of modern tectonic movements.

As the seismicity distribution on the map shows, earthquake epicenters are not located on faults, but it is possible to identify segments of regional faults, to which areas of seismicity concentration (seismogenerating zones) gravitate. Active and passive fault segments (as regards the presence of modern movements) are determined based on the data of GPS velocities: 2.7+-0.9mm/g in Metsamor, 1.7+-1mm/g in Yerevan and 2.0+-0.9mm/g in Sevan tectonic blocks .

Seismicity analysis

:It is typical for the seismicity of central Armenia that the vast majority of earthquake sources have a depth of 10-15 km, the stress field is sharply inhomogeneous. Earthquake epicenters are stretched out along regional deep faults and boundaries of tectonic faults. The territory of central Armenia includes the following sources of seismic events: Yerevan, Dvin, Ararat, Parakar and Garni earthquakes [6].. The earthquakes belong to the types of neotectonic movements and their development zones correspond to areas of high velocity gradients of the modern (Neogene-Anthropogenic) vertical tectonic movements. In the study area the seismogenic knot Ararat is distinguished as the area of the intersection of the Ararat zone of deep faults with Ararat-Sevan. Ararat strong earthquakes dating back to 739 and 1840 (M=6.7) are also confined to the knot zone of earthquakes, which includes Garni earthquake (1679, M=7.0), the epicenter of this event was located in the area of the Garni village. The process of seismic activity of the earth's crust manifests itself in the form of discrete events - earthquakes.

The catalog of earthquakes in central Armenia includes about 150 events. The depths of the earthquakes that occurred are in the range between 2.0÷16 km. In the work, a sample of earthquakes with $K \geq 8.5$ for 2011-2022 was done as well as a diagram of the distribution of seismicity in central Armenia was developed (Fig. 1). The spatial distribution of earthquakes with $K = 7 \div 8$ compose the background seismicity of the study area (Figure. 2)

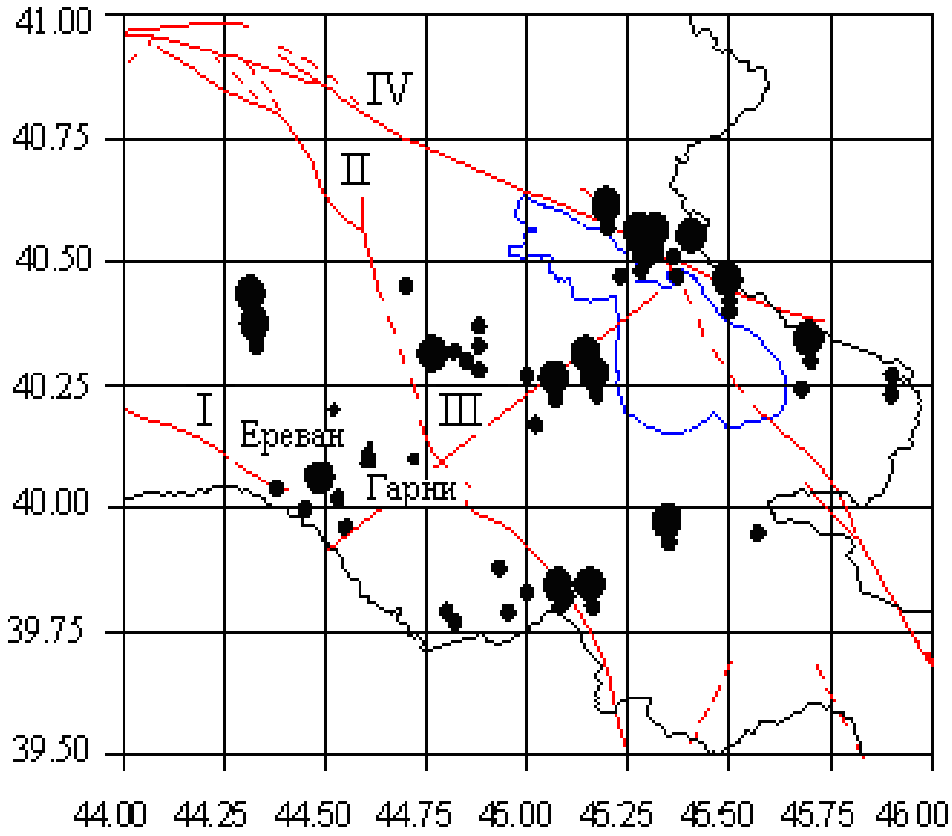


Figura.1. Scheme of location of earthquake epicenters in central Armenia
● - M>2,5 - 10≤ K≤8.5; ●- M>4 - K≥12.; - deep faults : I-Yerevan fault, II- Garni fault, III- Ararat Sevan fault, IV- Pambak Sevan,

The diagram indicates the confinement of strong earthquakes to deep faults: in the west to the Yerevan fault, in the east to the Pambak-Sevan fault, and in the center to the Garni fault. The map of the seismic background of the region (Figure. 2) reflects an increased background of seismicity, which, possibly, contributes to the activation of the dynamic processes of the Earth's crust in the central part of the region and the development of movements along the Bazum-Sevan, Garni and Ararat-Sevan deep faults.

The map of the seismic background reflects the density of earthquake epicenters inside and at the borders of tectonic blocks: Metsamor, Yerevan, Aparan-Sevan and Sevan research areas, as well as at the fault zones of Yerevan, Ararat-Sevan, Garni and Pambak-Sevan deep faults.

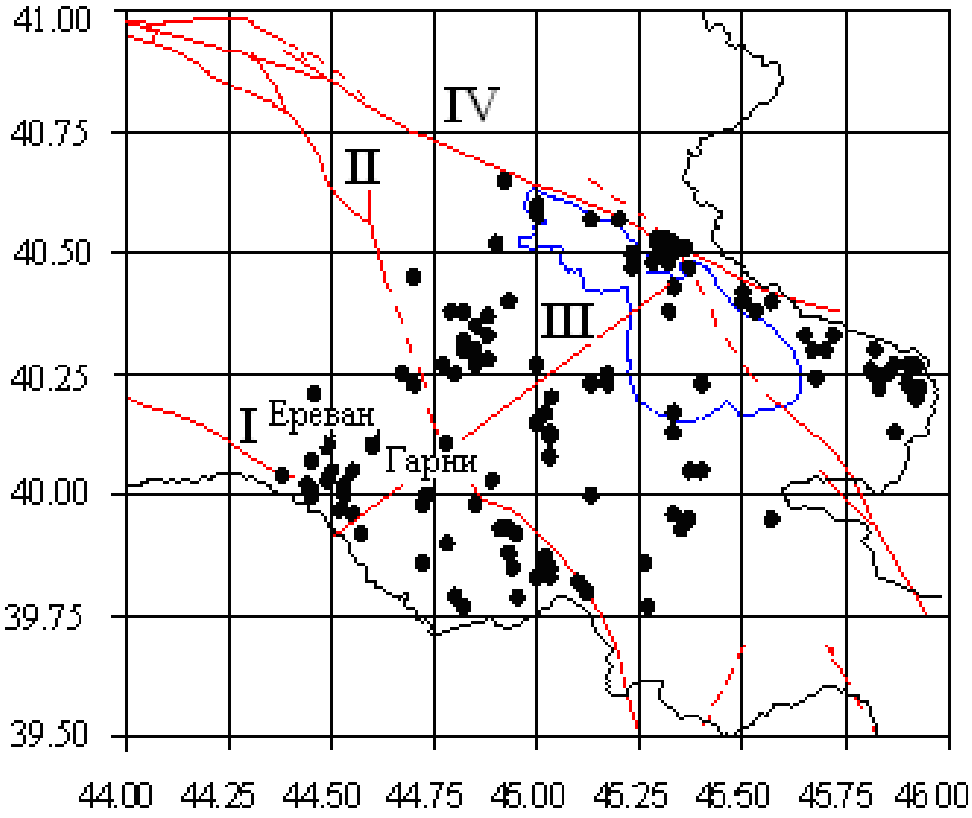


Figure 2. The map of seismic background of Central Armenia for 2011÷ 2022. ●- 9≤K≤8.

A graph of earthquake recurrence based on the Gutenberg-Richter law (Gutenberg, Richter, 1954) in the integral form Lg N=a +bM has been developed(Figure. 3).

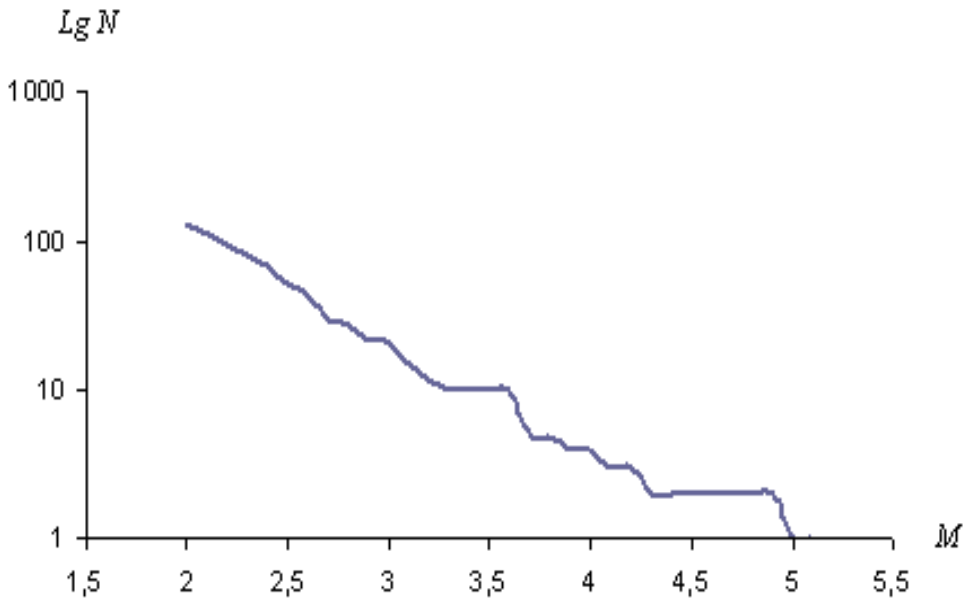


Figure. 3. Cumulative graph of earthquake recurrence

The main parameters of the seismic regime are determined: a=3.5 - seismic activity and b=0.7 - graph inclination. The value of parameter b is overestimated in relation to the average value b=0.5. on the territory of Armenia. Figure. 3 shows that the rectilinear section of the graph is typical only for the interval of magnitudes 2.0< M<3.0. The M>3.0 graph indicates the recurrence of stronger earthquakes. The reason for the nonlinearity of the recurrence graph in the layered-block structure of the Earth's crust [7]. is that large sources of big earthquakes do not fit in the same layer as small ones, but have deeper horizons.

The paper studies a graph of the dependence of earthquake epicenters on the longitude and latitude of coordinates (Figure. 4). As a result, it was revealed that the earthquakes that occurred in central Armenia in 2018 have a near-meridional direction (compression), earthquakes for 2019 have a latitudinal direction (compression). Epicenters of earthquakes that occurred in 2021 on the eastern coast of Lake Sevan, also have a meridional direction (compression). From which it follows that in central Armenia the Earth's crust is subject to deformation processes (compression) both in the meridional and latitudinal directions, and on the eastern coast of Lake Sevan in the latitudinal direction (compression).

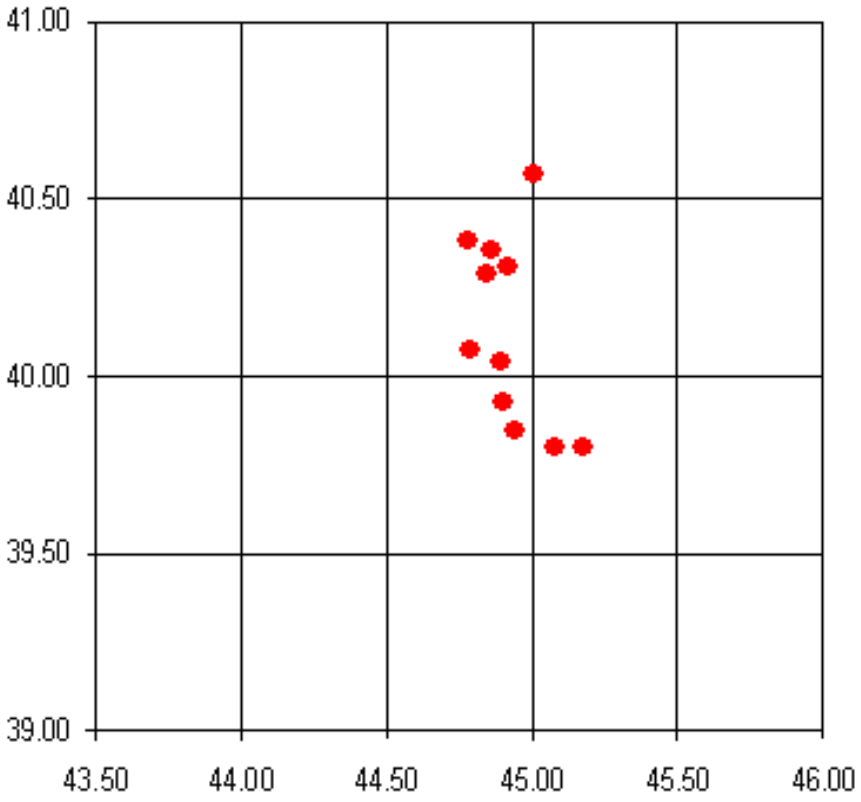


Fig. 4 Graph of dependency from the longitude and latitude of the epicenters of earthquakes in central Armenia ●- earthquake epicenters

Hydrogeodynamic and hydrogeochemical data. At present, great importance is given to the dynamics and geochemistry of groundwater and their role in the development of geotectonic processes. According to the method of hydrogeodynamic (HGD) precursors developed at the Institute of Physics of the Earth [8]., we have been conducting

research on the territory of Armenia since 1989. There are long time series on the water level of the observational network of hydrogeodynamic boreholes and the chemical composition of the waters of mineral springs in the central region of Armenia. In this area NN 2,3,8,18.27 hydrogeodynamic boreholes and I, II, III, IV mineral springs are located (Figure. 5).

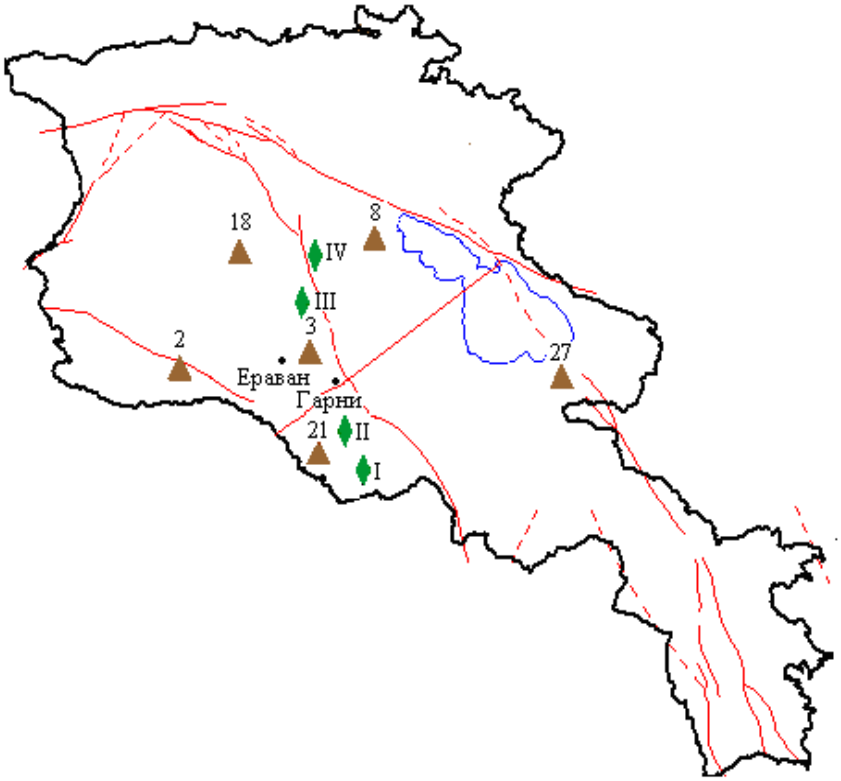


Figure.5. Map of the territory of Armenia with hydrogeodynamic and hydrogeochemical observation points in the central part.

♦ I- Surenavan, II- Vedi, III-Arzni, IV-Bjni- Mineral sources, ▲(2,3,8,18,21,27) – hydrogeodynamic boreholes, - deep faults.

The method for highlighting hydrogeodynamic effects from the data of hydrogeodynamic boreholes includes statistical processing methods and data interpretation. Periodic variations in the level of groundwater have been identified, which can be associated with the influence of tide-forming forces. Low-amplitude periodic groundwater variations are identified, caused by sawtooth variations, which are associated with a slow rise in the water level and its sharp decline and indicate the presence of weak deformations.

A characteristic feature of sawtooth variations is that they occur against the background of a trend of rising or falling water levels in a borehole, which can be used as an indicator for determining the activity of tectonic blocks [9].. Further, we consider the results received on changes in water levels in hydrogeodynamic boreholes located in various tectonic blocks of central Armenia (Figure. 5) in order to identify active blocks, in comparison with the seismic regime of the region for 2011÷2022.

Observation well No. 2 is located in the northern part of the Metsamor tectonic block, limited from the north by the Yerevan deep fault. Metsamor block GPS data is 2.7±0.9 mm/yr. The water level in the borehole has a weak seasonal value, the average statistical level is 16.2m. The amplitude of level fluctuations is 2-3 cm. The upward trend has been observed in the water level of well No. 2 since 2006. Hydrogeodynamic effects are observed before earthquakes with M≥4, the duration of the effect is 1.0÷1.5 months, the effect is stepped. From 2011 to 2013, an increase in the water level in the then a decrease in the water level of the borehole was registered. The water level in the borehole has been rising from 2017 to 2021.

Borehole: No. 3 was drilled in the Yerevan tectonic block and is located near the NE-SE fault, which runs diagonally along the marked tectonic block, with the SW - Yerevan deep fault. The data of the Yerevan tectonic block according to GPS measurements in the block is 1.7±1 mm/yr. Weak seasonal value. The amplitude of water level variations is 0.92m. It is characterized by low-amplitude variations in the water level in the borehole. A sharp increase in the amplitudes of water level variations was recorded from 2011 to 2015. Then, an abrupt change in the water level in the borehole is observed. Until 2021 a slow decrease then a slow increase was recorded in the water level in the borehole .

Borehole No. 18 is located in the SW of the Aparan-Ankavan block. The borehole is characterized by a multistage and continuously rising groundwater level. From 1990 till mid 1994, within the Aparan-Hankavan tectonic block, a continuous increase in stress was observed, associated with the movements of this block, mainly in the northeast direction. From 1999 till 2008 the water level in well No. 18 slowly increased. Starting from 2009 until 2018 the water level in the borehole almost remained unchanged, then a dramatic rise in the water level by 126 cm started and since 2021 there is a trend of water level increase. The level of this borehole is characterized by the presence of tidal variations, which is an indicator of the response of the borehole-formation system to a change in volumetric deformation.

Borehole No. 21 is located on the SE of the Yerevan tectonic block. Since 2008 there has been an increase in the water level in the borehole, which continued until 2015. Sawtooth changes amidst the rising of the water levels were observed in the borehole between 2011-2015, which is a reflection of the geodynamic processes (compression) occurring in the upper layers of the Earth's crust of the Yerevan tectonic block. During the next two years, a decrease in the level was observed, followed by an increase in the water level until 2021. Hydrogeodynamic effects according to the variations of the water level of boreholes No. 21 before earthquakes with M≥2.5, the duration of the effect is 1.0÷1.5 months, the form of effects in most cases is stepwise.

Hydrogeodynamic borehole No. 27 was drilled in the SE of Sevan tectonic block. The change in the water level in the borehole is characterized by a weak seasonal variation of the groundwater level. According to the GPS data the Sevan block is -1.2 ± 0.9 mm/yr. Since 1994, according to the variations of the water level of borehole No. 27, a three-stage continuous increase has been observed, which probably indicates the tectonic activity of the Sevan block. Periodic variations in the water level of borehole No. 27 for 2011÷2015 have been identified, which can be associated with the impact of tide-forming forces. Since 2019 there is an increase in the water level in the borehole.

When compared with the seismic regime of the region (for 2011÷2022) the data on the water level in hydrogeodynamic boreholes, according to the method for identifying hydrogeodynamic effects [8]., hydrogeochemical effects were revealed that preceded the geodynamic processes of the Earth's crust.

Hydrogeodynamic effects of earthquakes according to the changes in water levels in observation wells.
Table1

dd.mm.yyyy.	Earthquake parametres				Hydrogeodynamic effects (HGD)		
	φ	λ	M	D*	$\overline{K}*$	Dispersion δ	A*
Borehole №3							
28.03.2012	40,05	44,55	2,7	19	8,21	0.02	A= $\overline{K}+3\delta$
27.09.2012	40,12	45,03	2,4	45	8,28	0.03	A= $\overline{K}+4\delta$
Borehole №18							
10.02.2012	40,68	44,35	2,9	20	25,19	0.02	A= $\overline{K}+3\delta$
Borehole №21							
05.01.2012	39,95	44,42	2,3	20	23,68	0.01	A= $\overline{K}+3\delta$
01.05.2012	40,00	44,53	2	10	23,96	0.01	A= $\overline{K}+4\delta$
Borehole №27							
29.01.2012	40,33	45,65	2,4	20	22,91	0.04	A= $\overline{K}+3\delta$
28.09.2012	40,38	45,53	2,3	25	21,93	0.16	A= $\overline{K}+2\delta$
05.02.2021	40,51	45,41	5,1	43	23,88	0.02	A= $\overline{K}+2\delta$

*D**-epicentral distance, $\overline{K}$ *- average value of water level in boreholes, *A**-value of hydrogeodynamic effect

Thus, the geodynamics of the mentioned tectonic blocks limited by deep faults are described: Yerevan, Ararat-Sevan faults, the Garni deep transverse fault intersects the Yerevan tectonic block. The strengthening of the activity of the geodynamic processes of the earth's crust under study in the central region of Armenia confirms the seismic activity of the region in recent years, the spatial distribution of earthquake epicenters in the middle and on the borders of tectonic blocks, near-fracture zones of deep faults. The strengthening of the activity of the geodynamic processes of the earth's crust under study in the central region of Armenia confirms the seismic activity of the region in recent years, the spatial distribution of earthquake epicenters in the middle and on the borders of tectonic blocks, near-fracture zones of deep faults. Near meridional direction of the epicenters of the earthquakes, indicating the presence of deformation processes (compression), in the studied part of the region.

The nature of changes in the level of water in hydrogeodynamic boreholes: raising and lowering, against the background of the trend, water levels in hydrogeodynamic boreholes, the presence of periodic sawtooth variations of the water level. Hydrogeodynamic and hydrogeochemical effects (tab. 1, 2) have been revealed preceding the earthquakes that occurred in the region. All of the above-mentioned reflects the increased activity of the Yerevan tectonic block and the concentration of stress along the Ararat-Sevan and Garni deep faults.

Hydrogeochemical data. The task of hydrogeochemical monitoring is to identify hydrogeochemical effects, generally in the changes of the macrocomponent and gas

composition of water accompanying geodynamic movements of the Earth's crust. The monitoring network includes observations of hydrogeochemistry of mineral water sources. Surenavan (I), Vedi (II), Arzni (III), Bzhni (IV) (fig.5). The quantitative composition of total mineralization and carbon dioxide dissolved in water mineral sources for the period of observation is presented on Fig. 6. Methodology for identifying hydrogeodynamic effects includes statistical methods of data processing and interpretation. The observations on mineral water sources. NN I, II started in 2006, and NN III, IV started in 2008. Hydrogeochemical anomalies have been revealed, mainly in changes in the macrocomponent and gas composition of water, preceding and accompanying geodynamic movements of the Earth's crust of central Armenia. Anomalies of the gas and macrocomponent composition of groundwater are a reflection of the stressed state of formations. Concentration changes under the influence of tectonic activity occur in a certain sequence. Gas composition is the first to react to the stressed state of formations: carbon dioxide (CO2), the second macrocomponent composition. In the current research, the obtained results of the geochemical composition of mineral waters for the last years are presented, comparing them with the seismicity of the region.

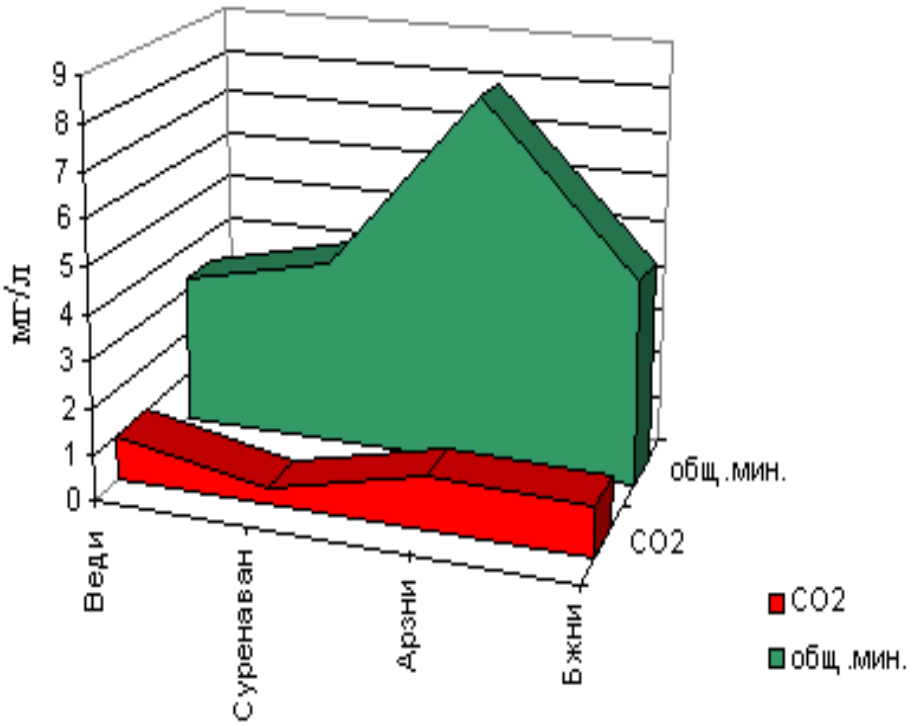


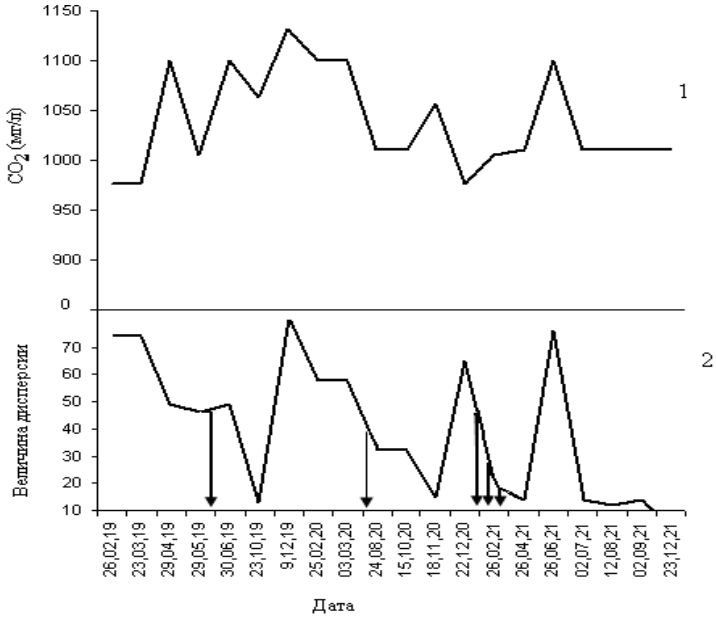
Fig.6. Figure.6. Diagram of the content of total mineralization and dissolved in water mineral sources of carbon dioxide (CO_2).

In the statistical processing of the data of geochemical time series, the method based on the estimation of variability of dispersion in time intervals was used. The considered forecasting method is based on statistical evaluation of the variability of carbon dioxide dispersion in adjacent time intervals. At the same time, the average value of the dispersion as well as the speed of its changes is used. The processing of time series of the change of concentration of carbon dioxide has been carried out based on the water of

hydrogeochemical observation stations: NN II,IV. The average value of carbon dioxide content in water is 1161mg/l and 1957mg/l. The graph of variations of the time series of carbon dioxide gas, according to the laboratory analysis of water samples of mineral springs and variations of the CO2 dispersion value was developed (Figure. 7). The obtained image reflects the periods of increase and correspondingly decrease of the dispersion values. The obtained results were compared with seismic events that took place at different distances from the observation point.

Before seismic events, there is an increase in the dispersion value at the beginning, and then its decrease. Most often, seismic events correspond to minimal dispersion values, which can be taken as a prognostic sign [11]..

a)



b)

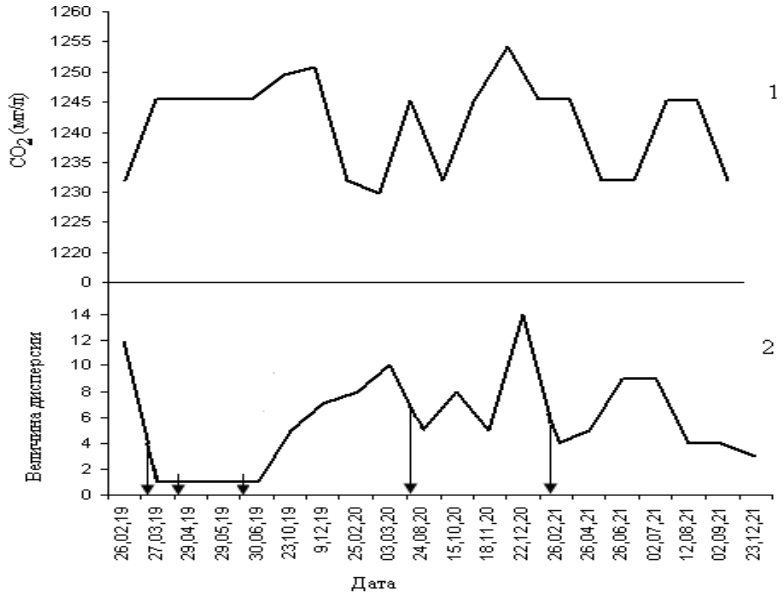


Figure.7a,b. Graph of variation of CO_2 concentration and its dispersion in the waters of mineral springs of Vedi (a) and Bjnim (b). 1-actual data, 2- dispersion. Arrows indicate earthquakes.

According to the changes in the value of the total mineralization of the water of the Arzni mineral spring, there has been an increase in recent years, which indicates the deformation processes in the areas where the mineral waters are released due to the geodynamic processes of the Earth's crust. It is possible to assume that the water-bearing rocks of the Arzni deposit are undergoing deformation-compression, which suggests the activation of tectonic movements of the Yerevan-Ordubat block, where the Arzni and Bjni mineral water deposits are located.

As a result of comparing the seismic regime of the region (for 2011÷2022) with the parameters of the chemical composition of mineral waters, hydrogeochemical effects preceding the geodynamic processes of the earth's crust, in particular earthquakes, were received [11]. (Table 2).

Hydrogeochemical effects according to the parameters of the chemical composition of mineral waters preceding earthquakes..

Table 2

ДД.ММ.ГГ	Параметры землетрясений				Гидрогеохимические эффекты (ГГХ)											
					Mg			Cl			Общ.мин.			HCO3		
	φ	λ	M	D*	$\overline{K}$*	δ*	A*	$\overline{K}$*	δ*	A*	$\overline{K}$*	δ*	A*	$\overline{K}$*	δ*	A*
Ахни																
14.10.2011	40,3	44,66	3,6	9	218	2	$A=\overline{K}+8\delta$	2503	8	$A=\overline{K}+13\delta$	8371	11	$A=\overline{K}+18\delta$			
13.02.2021	40,02	44,49	4,9	38										2055	6	$A=\overline{K}+13\delta$
Бжни																
14.10.2011	40,3	44,66	3,6	29	73	4	$A=\overline{K}+2\delta$	427	11	$A=\overline{K}+5\delta$	4388	9	$A=\overline{K}+4,5\delta$			
06.06.2018	40,92	44,28	3,1	40							4614	32	$A=\overline{K}+6\delta$	2266	10	$A=\overline{K}+3\delta$
Веди																
13,02,2021	40,02	44,49	4,9	28	111	9	$A=\overline{K}+3\delta$	136	6	$A=\overline{K}+3\delta$				2002	7	$A=\overline{K}+2,5\delta$
Сурenaван																
13,02,2021	40,02	44,49	4,9	39							4051	28	$A=\overline{K}+5\delta$			

$\overline{K}$*- average value of the parameter of the chemical composition of the mineral source, *A**-.magnitude of hydrogeochemical effect

Thus, changes in the gas and chemical macro component composition of mineral waters of central Armenia are an indicator of the stressed-deformed state of the Earth's crust in the region. The map of the stress-strain state of the Earth's crust in central Armenia was built based on the numerical values of calculated deformation values, located around each observation point of hydrogeodynamics and hydrogeochemistry, as a result of the earthquakes that occurred in recent years with M>3. Based on the obtained values of calculated deformations, maps of isolines of equal deformation values were developed with the use of weight coefficients [10].. According to the map (figure. 8), in the central part of the region of Armenia, a compression structure is formed. The structure

of the compression is most intense along the middle segment of the Garni fault and almost along the entire Ararat-Sevan fault. The resulting stress field is characterized by high values of deformations (E=10-6, 10-7), which took place on the near-fault zones of the Garni and Ararat-Sevan faults, as a result of the earthquakes.

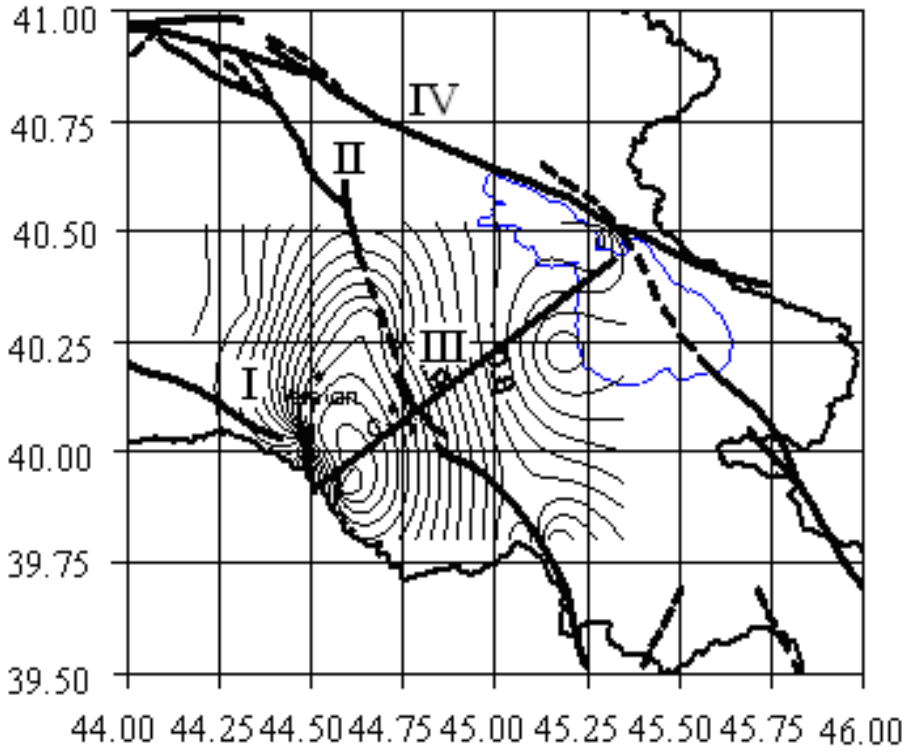


Figure.8. Map of stress strain state of Earth's crust of Central Armenia
-isolines of deformations, - deep faults: I-Yerevan fault, II- Garni fault, III- Ararat-Sevan fault, IV- Pambak-Sevan,

Thus, the stress strain state of the Earth's crust in time in the territory of central Armenia was assessed, as a result of the interpretation of the data obtained according to the water level of hydrogeodynamic boreholes, the geochemistry of mineral water and the seismic regime. According to the obtained results, it should be noted that the strengthening of geodynamic processes in central Armenia is a manifestation of the activation of the Garni and Ararat-Sevan deep faults.

Conclusions

Paleotectonic analysis of the researched material helps to identify seismically active and passive tectonic blocks and faults, as well as to determine the nature and direction of modern tectonic movements.

The seismogenic knot of Ararat - the area of intersection of the Ararat zone of deep faults with Ararat - Sevan should be mentioned on the territory of central Armenia.

The distribution scheme of seismicity in central Armenia (Figure. 7a) indicates that strong earthquakes are limited to deep periods. in the west to the Yerevan, in the east to Pambak-Sevan and in the center Garni fault. The seismic background of the studied area

(Figure. 7b) is high, which probably contributes to the activation of geodynamic processes of the Earth's crust in the central part of the region.

According to hydrogeodynamic and hydrogeochemical observations of the central region of Armenia, hydrogeological effects preceding earthquakes occurring during the period of research are revealed.

It was also revealed that the change in tidal deformations can be taken as a prognostic sign. Slow drops (rises) in the level of groundwater in the form of a trend reflect long-term changes in the stress-strain state of the environment.

A map of the stress-strain state of the Earth's crust in time and space, based on the changes in the dynamics of the water level in hydrogeodynamic boreholes, the geochemistry of mineral waters and the seismic regime is developed. According to the map, it can be mentioned that in the central part of the region of Armenia, deformation-compression is formed.

References

Journal Article

[2] Tumanyan G.A. “New data on Large Movements of the Lesser Caucasus”. Geotectonics, M., 1983, N4, p.99-111.

[3] Oganesyan S.M., Geodakyan E.G. “Anomalous Manifestations of Seismicity on the Territory of Armenia Preceding the Destructive Van (Turkey) Earthquake on October 23, 2011”. Journal of Ecological Bulletin of the Scientific Center. 2012. No. 1. S.115-123.

[4] Trifonov V.G., Karapetyan A.S., Kozhurin A.I. “Active faults and seismicity”. Journal of Nature, 1989, N12, pp. 32-39.

[9] Pashayan R.A “Hydrogeochemical Monitoring of Geodynamic Processes in Garni Polygon”. Journal of Izvestiya. NAS RA, Nauki o Zemle, 2004, N3, p.25-29.

[7] Ulomov V.I. “The dynamics of the earth's crust in Central Asia and the prognosis of earthquakes”. Journal of Tashkent: Fan, 1974, p. 215.

[10] Pashayan R.A., Sargsyan A.Z. "Hydrogeo-deformation characteristics of Earth's crust in the Region of Armenia (2002-2004)". Journal Izvestiya HAS RA, Earth Sciences, 2006, LIX, N2-P .30-36

Book

[1] Nazaretyan S.N., Durganyan R.R., Shahbenyan T.A. and others. “Regional Faults of the Territory of Armenia According to Geophysical Data and Their Seismicity”. Yerevan Pub. "Gitutyun" HAS RA, 2015.

[6] Karapetyan N.K. “Seismogeodynamics and the mechanism of occurrence of earthquakes in the Armenian highlands”. Yerevan: Arm. SSR, 1990,

[8] Kissin I.G. Fluids in the Earth's Crust. Moscow, Nauka, 2015,

[11] Barsukov V.L.. Belyaev A.A. “Geochemical Methods of Earthquakes Forecasting”. M. Nauka. 1992..

Conference Proceedings

[5] Pashayan P.A., Tumanyan Г.А.”Seismic Regime and Tectonics of the Ararat Seismo Prognostic Polygon”. Modern Methods of Processing and Interpretation of Seismological Data Materials of the 5th International Seismological School. Obninsk, 2010, pp. 149-154.