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Visualization of Parameters of Hydrogeochemical Monitoring in Time and Space

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Abstract

Earth Crust of central Armenia were compiled. A seismological section according to the profile along which mineral water deposits are located was developed. The circle of the diagram of the chemical composition The visualization of graphical methods of hydrogeochemical information is shown. Maps of seismicity and stress-strain state of the of mineral water according to Tolstikhin is given. The vertical sections of the concentration of the chemical components of water were compiled.

Keywords: deformation, seismicity, visualization, profile, section, diagram, stress

Introduction

As is known, the deep and surface water of Earth are constantly interacting with each other, as well as with the atmosphere and lithosphere. The movements and deformations of Earth crust affect the changes of the normal regime of groundwater (level, temperature, chemical composition), providing information about deep tectonic processes. A brief description of the natural conditions of the locations of mineral springs are described in current work [1]. Geodynamic processes that took place in the central part of the region are reflected on the dynamics of changes of the components of the chemical composition of water.

In case of macrocomponent composition, a decrease or increase in the average values of their concentrations is considered to be an abnormal indicator, the maximum or minimum of which is recorded days and months before tectonic movements of the Earth Crust (earthquakes). The manifestation of anomalies for carbon dioxide, unlike macrocomponent composition, is a sharp change in their concentration [2]. Variations of geochemical components preceding seismic events are considered. In order to distinguish hydrogeochemical anomalies that are associated with the geodynamic processes of Earth crust, it was necessary to exclude variations in the indicators of the chemical composition of water not associated with seismic activity. For this purpose, the background variations in the mineral and gas components of groundwater were determined. Anomalies outside the intervals of background concentrations were compared with seismic activity. Statistical processing of time series of geochemical elements in time was carried out. Statistical processing of the data included the determination of the average value φ of the concentrations of chemical components, the standard deviation from the background value, dispersion, and correlation analysis. The results of correlation analysis have shown that

The results of the correlation analysis have demonstrated a statistically significant coonection between the parameters of the chemical composition of water and the characteristics of seismic events [3]. The objective of current work is to use the methods of graphical presentation of observational data of hydrogeochemical monitoring in order to link with seismicity and geodynamic processes of the Earth crust of the region and to interpret it. Seismic events are considered to be the indicators of geodynamic movements of Earth crust.

Materials and Method

The hydrogeochemical monitoring network includes observations of the chemical composition of the water of the mineral springs of Surenavan, Vedi, Arzni, Bjni which are located in the central part of the region.

Map with geographic coordinates of mineral water deposits and epicenters of the earthquakes that occurred between 2018-2021. is shown in Fig. 1.

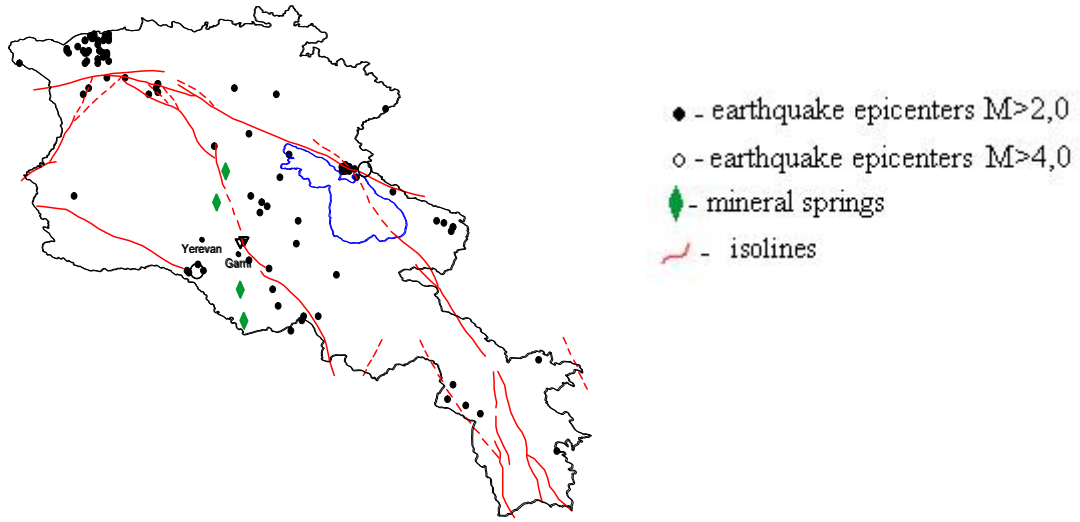
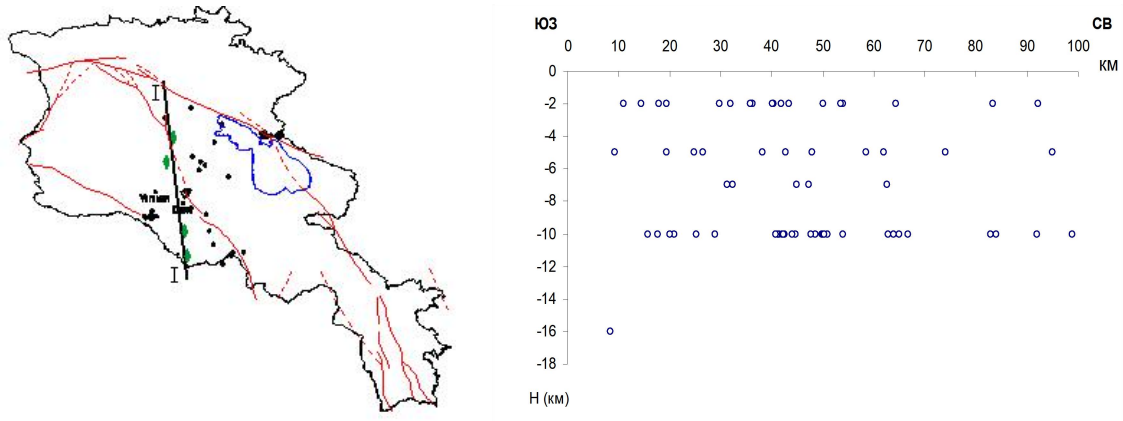


Fig. 1 Seismicity map of the territory of Armenia.

The map reflects the seismicity of the entire territory of Armenia. Earthquake data are presented in the form of a catalog of current seismicity. During the study period, seismic events occurred on the territory of Armenia - 102> 2 as well as two earthquakes: 13.02.21, M = 4.9; 5.02.21, M = 5.1, which occurred in the central and eastern part of the region, near the lake Sevan.

Thus, the seismicity map Fig. 1 reflects the distribution of earthquake epicenters along Garni deep fault, the accumulation of epicenters is observed to the north of Shirak highland and along the Bazum - Sevan fault and as well as a small amount in the southwest. In order to reveal the deep distribution of earthquake focus that occurred in central Armenia, a seismological section was built along the hydrogeochemical profile I-I, in the direction from the SW to the NE, Fig. 2a



a) **b)**

Fig. 2a Hydrogeochemical profile I-I, b) Seismic section along profile I-I.

The earthquakes shown in Fig. 2b took place in the central part of the region and are given in Table 1.

Table 1

Data (dd/mm/yyyy)	*Earthquake Coordinates*		*Coordinates of Mineral Sources*		*Epicentral state Δ, km*	*Magnitude ML*	*Depth H*
	φ	*λ*	*φ*	*λ*			
13.06.2019	40.68	44.78	40.30	44.60	46.7	2.6	10
12.10.2018	40.38	44.79	40,30	44,60	22.9	2.1	10
21.07.2018	40.35	44.85	40,30	44,60	28.3	2	10
18.12.2018	40,3	44,84	40,30	44,60	26.6	2	5
25.04.2019	40,62	44,59	40,45	44,65	19,5	2,1	5
13.06.2019	40,68	44,78	40,45	44,65	29,0	2,6	10
12.10.2018	40,38	44,79	40,45	44,65	17,7	2,1	10
09.07.2018	40,33	44,88	40,45	44,65	29,1	2,6	7
14.03.2019	40,26	45,05	40,45	44,65	49,5	2,6	10
24.01.2018	40,07	44,78	39,93	44,73	16,5	2,2	7
23.10.2018	40,03	44,89	39,93	44,73	20,9	2,2	10
06.11.2018	39,93	44,91	39,93	44,73	20,0	2,3	10
15.12.2018	39,85	44,94	39,93	44,73	24,9	2,3	5
29.01.2019	39,73	45,01	39,93	44,73	38,2	2	5

06.06.2019	39,78	45,07	39,93	44,73	41,2	2,6	10
25.02.2018	39,80	45,08	39,93	44,73	41,4	3,2	10
25.02.2018	39,80	45,16	39,93	44,73	49,9	3,2	10
24.01.2018	40,07	44,78	39,78	44,75	32,4	2,2	7
23.10.2018	40,03	44,89	39,78	44,75	31,8	2,2	10
06.11.2018	39,93	44,91	39,78	44,75	24,3	2,3	10
15.12.2018	39,85	44,94	39,78	44,75	22,5	2,3	5
29.01.2019	39,73	45,01	39,78	44,75	29,4	2	5
06.06.2019	39,78	45,07	39,78	44,75	35,5	2,6	10
25.02.2018	39,80	45,08	39,78	44,75	36,7	3,2	10
25.02.2018	39,80	45,16	39,78	44,75	45,6	3,2	10
13.02.2021	39,80	45,16	39,93	44,73	50	4.9	2
15.02.2021	40,02	44,53	39,78	44,75	36,1	2,5	2
17.02.2021	40,01	44,45	39,78	44,75	42,0	2,3	2
18.02.2021	40,05	44,5	39,78	44,75	40,8	2	10
13.02.2021	40,02	44,53	40,30	44,60	32,0	2,5	2
15.02.2021	40,01	44,45	40,30	44,60	36,2	2,3	2
18.02.2021	40,05	44,5	40,30	44,60	29,9	2	10
18.02..2021	40,05	44,5	40,45	44,65	47.8	2	10

The depth of distribution of earthquake focuses varies from 2 km to 10 km, which indicates that the occurred earthquakes are crustal. The concentration of earthquake hypocenters is observed in the center of the profile, where the Garni fault is suposedly located. This indicates the possible activation of the fault. At a depth of 10 km, the hypocenters of earthquakes are located in a dense layer in lateralis, which indicates the stressed state of the upper part of the Earth crust in the study area and in deposits of mineral water .

According to chemical composition, the water of the above-mentioned mineral springs are classified as hydrocarbonate, hydrocarbonate-chloride, sodium and chloride-sodium. The groundwater of the study area belongs to the intermontane Ararat valley, which includes large reserves of mineral water, characterized by water of hydrocarbonate-calcium composition, confined to the terrigenous-carbonate rocks of the Paleozoic [1].

Data of the results of long-term hydrogeodynamic monitoring observations of the mineral water of central Armenia have been collected. To visualize the chemical composition of water for each of the mineral water deposits of Surenavan; Vedi; Arzni and Bjni, a circle diagram of N.I. Tolstikhin has been developed which is shown on Fig. 3. [4],

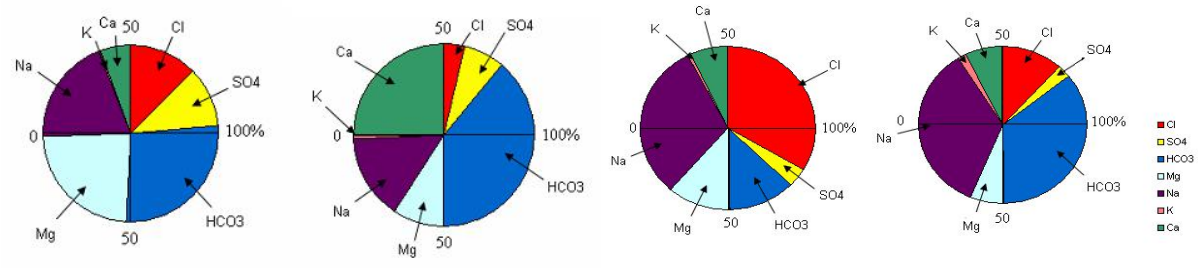


Fig.3 Circle diagram of the composition of mineral water of deposits.
I - Surenavan, II - Vedi, III - Arzni, IV - Bjni.

The circle diagram reflects the content in the quantitative ratio of cations and anions in the composition of mineral water in % equiv. Cation-Mg2 + was mainly considered from the cationic composition, and Cl-, SO2-4, HCO-3 from the ionic composition as chemical elements that more often respond to the dynamic processes of the Earth crust, in the form of anomalies against the background of concentration of values of hydrogeodynamic observations.

To detect hydrogeochemical anomalies, the statistical methods of processing time series of chemical elements of the composition of water were applied as well as methods of graphical visualization of the received data in space in the form of graphs, maps and cross sections. The revealed hydrogeochemical anomalies, mainly present in the changes of the above-mentioned chemical components and the gas composition of water (CO2), precede seismic events and geodynamic movements of the Earth crust of central Armenia [5].

The relationship between the parameters of the chemical composition was determined based on those seismic events, the epicentral distance and deformation of which were determined on the basis of a well-known method [6],

$$\varepsilon = \left(\frac{d}{10^{0.413\mathrm{M}-2.66}} - \right)^{-3}$$

where ε is deformation, d is the epicentral distance, M is the magnitude of the earthquake.

Most of the anticipated hydrogeochemical precursors are registered in a zone that coincides in size with the zone of distribution of deformation. The radius of the manifestation zone was determined by the $R = 10^{-0.43M}$ (km) formula. Thus the identified seismic events are shown in Table 1.

Results

Based on the gas composition of mineral water, observations were carried out for variations of the concentration of carbon dioxide (CO2) dissolved in water of Arzni mineral water, the monitoring in time (2019-2021) is shown in Fig. 4a (actual data). The research results were obtained according to the changes in the dispersion of carbon dioxide concentration (Fig. 4b) which is connected with the manifestation of seismicity.

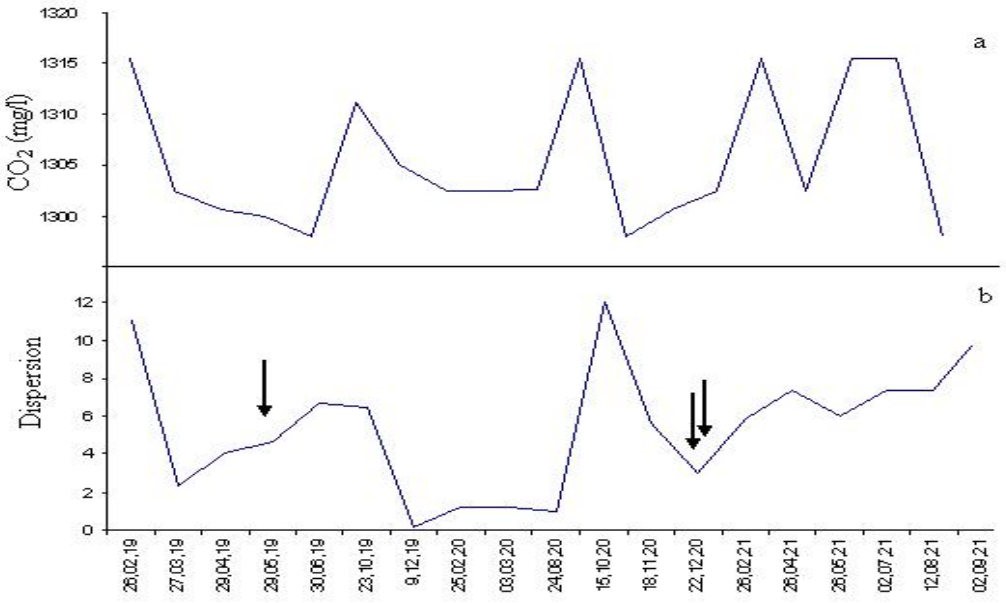


Fig 4. Dispersion of variations of the concentration of carbon dioxide in the water of Arzni deposit.

On Fig. 4a, changes in the amplitude and frequency of variations of carbon dioxide in time are indicated. A sharp decrease and increase in CO_2 concentration is observed in March 2019 and August 2020. This is probably conditioned by the earthquakes that took place in the central part of Armenia: 13.06.2019, M=2.6; 13.02.2021, M=4.9; 15.02.2021, M=2.3. Periods of increase and decrease in the dispersion of the carbon dioxide concentration accompanied by earthquakes are shown in Fig. 4b.

The dispersion value increase is followed by a sharp decrease which is often corresponds to seismic event. The observations have shown that the changes in the value of the dispersion

variation of CO_2 does not depend on the parameters of earthquakes, magnitude and epicentral distance, which emphasizes its predictive value.

The nature of the distribution of hydrogeodeformation processes in time and space has been studied. Based on the results received, the stress-strain state of Earth crust of Armenia was assessed. The mechanism of the formation and analysis of anomalies in the variations of the parameters of the chemical composition of mineral water preceding the geodynamic processes of Earth crust of the region is explained by a change in the stress-strain state of the environment. Map 5 was developed for a graphical display of the change in the stress-strain state of Earth crust in the central part of the region.

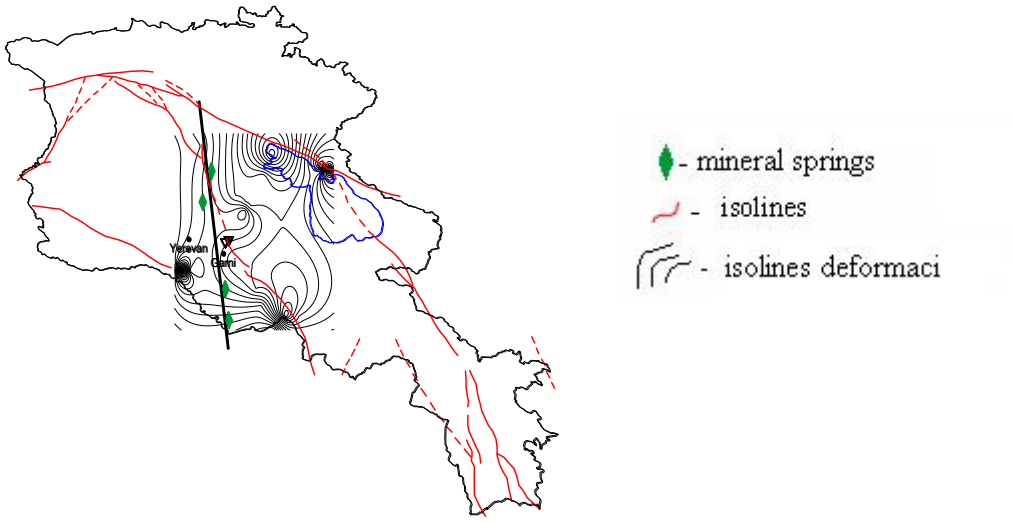


Fig.5 Map of the stress-strain state of Earth crust of Central Armenia

The map reflects changes in stress in the profile along which mineral water deposits are located (Surenavan, Vedi, Arzni and Bjni). The calculated deformation values [7] are shown on the map in the form of isolines, the angels of thickening of the isolines indicate more stressed areas. Stressed areas are observed in the west and east, where the deep Garni and Bazum-Sevan faults intersect.

A hydrogeochemical profile (Fig. 6) was developed for tracing the nature of the variation of chemical composition of groundwater according to a certain direction, as well as to quantify the change in the ionic and cationic composition of water [8].

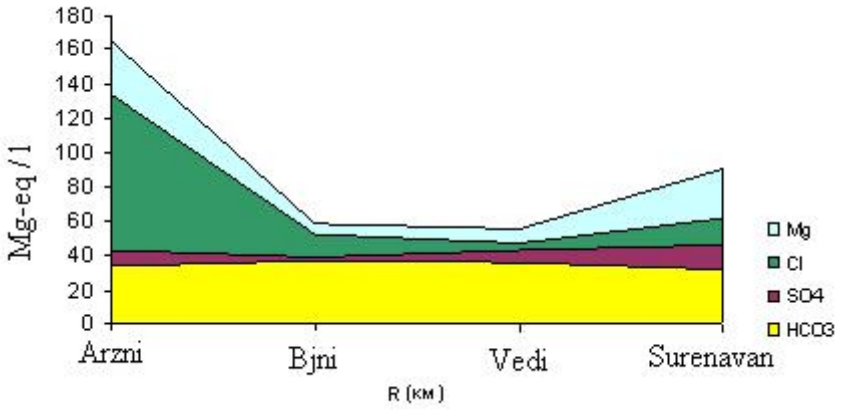


Fig.6 Hydrogeochemcial profile according to A. A. Brodsky

The diagram of the cationic and anionic composition of mineral water in space and in time was developed in total during observation period. It reflects the variations of the chemical composition of water in time in units of Mg-eq / l, Fig.

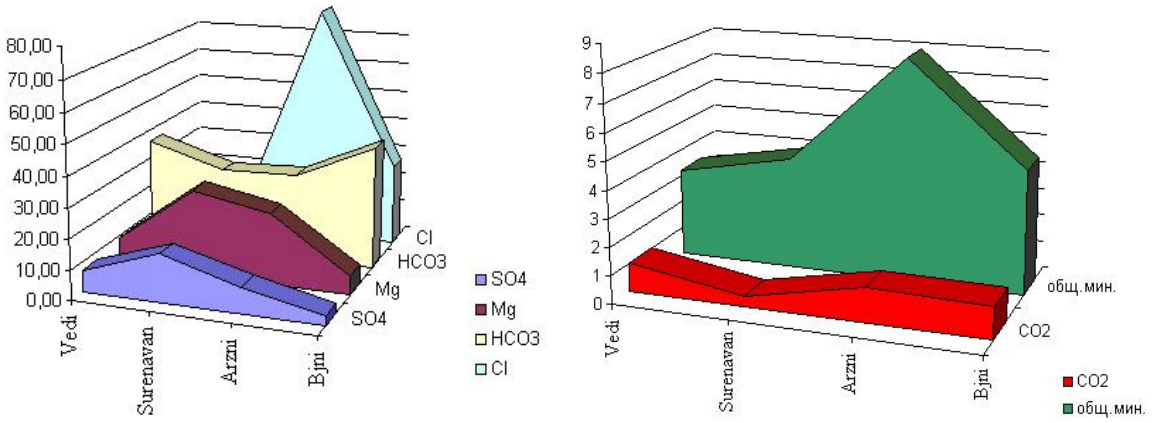


Fig. 7 Diagram of the components of the chemical composition of the value of mineral water in total.

Based on the application of a graphical method for systematizing hydrogeochemical information, the maps of the content of chemical components, in particular, of carbon dioxide dissolved in water and of total mineralization were developed. For this purpose, a program using spatially statistical methods of analysis based on spatial averaging were applied which makes it possible to obtain the spatial background of a given parameter.

Vertical sections reflect the distribution of the dynamics of concentration of CO_2 and of total mineralization during the month along the vertical section along the mineral spring locations [9] in time (Fig. 8), which can be used to visually observe the change in their concentrations over time.

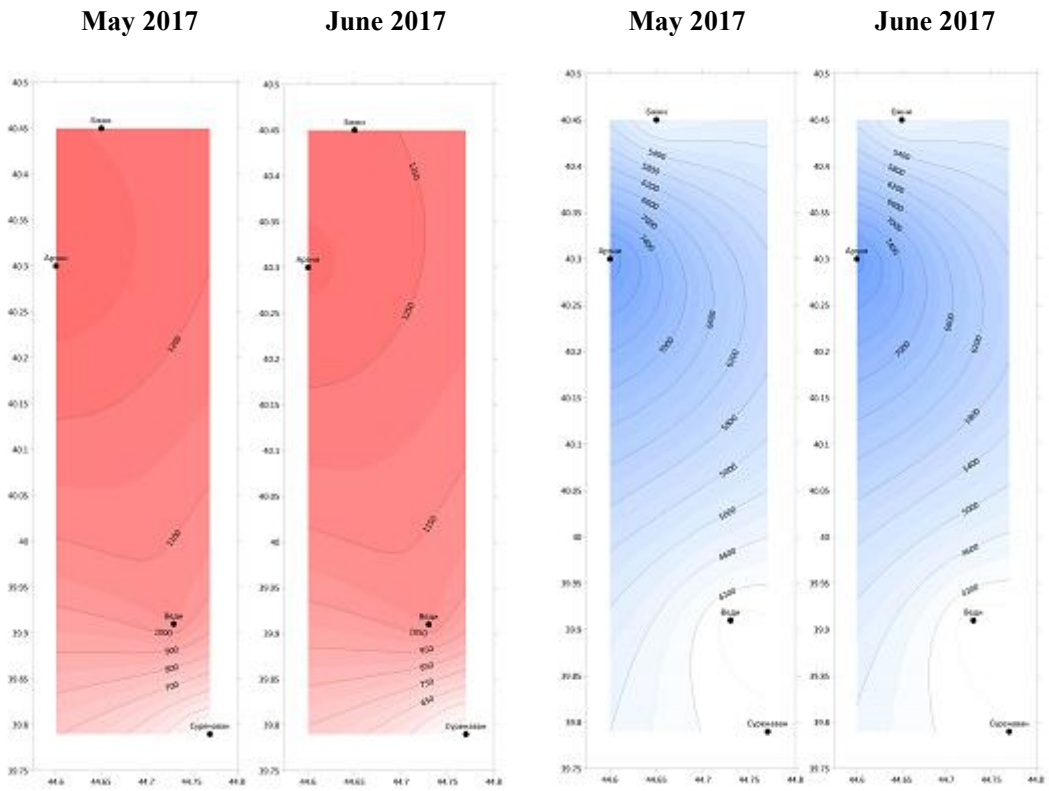


Fig.8 Vertical sections of the distribution of the dynamics of the concentration of carbon dioxide and the total mineralization of the water sources: Surenavan, Vedi, Arzni, Bjni.

● mineral springs, ~ isolines

As a result, the vertical sections (Fig. 8) visually demonstrate the changes in CO_2 concentration and total mineralization in months.

Discussions

The results of long-term monitoring observations of the chemical composition of mineral water, as well as their systematization, improve and accelerate the achieving of the defined task.

New methods of visualizing data and their application in future during processing and analysis of hydrogeochemical information, make it possible to expand the possibilities of interpreting geophysical information.

Conclusion

The developed map of seismicity of central Armenia reflects the distribution of epicenters of the occurred earthquakes for the study period, most of which are confined to Garni and Bazum-Sevan deep faults.

The circle diagram of the content in the quantitative ratio of cations and anions of the chemical composition of mineral water is graphically illustrated, which makes it possible to visually compare the chemical composition of mineral water.

Based on the results recieved, the stress-strain state of Earth crust of central Armenia was asessed. An increase in stress is observed in the southwestern Garni and northeastern Bazum-Sevan deep faults.

The mechanism of the formation of anomalies in variations of the parameters of the chemical composition of mineral water preceding the geodynamic processes of the Earth crust of the region is explained by a change in the stress-strain state of the environment.

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