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The scientific journal News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences has been indexed in the international abstract and citation database Scopus since 2016 and demonstrates stable bibliometric performance.

The journal is also included in the Emerging Sources Citation Index (ESCI) of the Web of Science platform (Clarivate Analytics, since 2018).

Indexing in ESCI confirms the journal's compliance with international standards of scientific peer review and editorial ethics and is considered by Clarivate Analytics as part of the evaluation process for potential inclusion in the Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI), and Arts & Humanities Citation Index (AHCI).

Indexing in Scopus and Web of Science ensures high international visibility of publications, promotes citation growth, and reflects the editorial board's commitment to publishing relevant, original, and scientifically significant research in the fields of geology and technical sciences.

«Қазақстан Республикасы Ұлттық ғылым академиясының Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналы 2016 жылдан бастап халықаралық реферативтік және ғылымиметриялық Scopus дерекқорында индекстеледі және тұрақты библиометриялық көрсеткіштерді көрсетіп келеді.

Сонымен қатар журнал Web of Science платформасының (Clarivate Analytics, 2018) халықаралық реферативтік және наукометриялық дерекқоры Emerging Sources Citation Index (ESCI) тізіміне енгізілген.

ESCI дерекқорында индекстелуі журналдың халықаралық ғылыми рецензиялау талаптары мен редакциялық этика стандарттарына сәйкестігін растайды, сондай-ақ Clarivate Analytics компаниясы тарапынан басылмды Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) және Arts & Humanities Citation Index (AHCI) дерекқорларына енгізу қарастырылуда.

Scopus және Web of Science дерекқорларында индекстелуі жарияланымдардың халықаралық деңгейде жоғары сұранысқа ие болуын қамтамасыз етеді, олардың дәйексөз алу көрсеткіштерінің артуына ықпал етеді және редакциялық алқаның геология мен техникалық ғылымдар саласындағы өзекті, бірегей және ғылыми тұрғыдан маңызды зерттеулерді жариялауға ұмтылысын айқындайды.

Научный журнал «News of the National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences» с 2016 года индексируется в международной реферативной и наукометрической базе данных Scopus и демонстрирует стабильные библиометрические показатели.

Журнал также включён в международную реферативную и наукометрическую базу данных Emerging Sources Citation Index (ESCI) платформы Web of Science (Clarivate Analytics, 2018).

Индексирование в ESCI подтверждает соответствие журнала международным стандартам научного рецензирования и редакционной этики, а также рассматривается компанией Clarivate Analytics в рамках дальнейшего включения издания в Science Citation Index Expanded (SCIE), Social Sciences Citation Index (SSCI) и Arts & Humanities Citation Index (AHCI).

Индексирование в Scopus и Web of Science обеспечивает высокую международную востребованность публикаций, способствует росту цитируемости и подтверждает стремление редакционной коллегии публиковать актуальные, оригинальные и научно значимые исследования в области геологии и технических наук.

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ANALYSIS OF THE RESULTS OF CHANGES IN THE GAS AND ISOTOPIC COMPOSITION OF GROUNDWATER DURING THE PERIOD OF EARTHQUAKE PREPARATION

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Abstract. The article is devoted to the study of the nature and mechanism of anomalous changes in the concentration of dissolved gases and isotopic composition in groundwater of the Cenomanian stage of the Upper Cretaceous period on the territory of the Tashkent geodynamic test site during the preparation of seismic activation. *Objective.* The study considers the results of monitoring observations of the nature of anomalies in the isotopic and gas composition of groundwater during the preparation periods of the Nazarbek (11.12.1980, $M = 5.5$, $R = 15$ km), Tuyabuguz (25.05.2013, $M = 5.5$, $R = 50$ km) and Marzhanbulak (26.05.2013, $M = 6.2$, $R = 200$ km) rivers. earthquakes. *Methods.* Traditional methods employed in hydrogeoseismological studies were used to determine dissolved gas anomalies and the isotopic composition of groundwater in the study area. Sampling from self-flowing water points was performed using vacuum degassing with a 2RS-1-SV forevacuum pump, including field and laboratory determinations of groundwater

hydrogeochemical parameters. An INGEM-1 instrument was used to determine the absolute dissolved helium content in groundwater, and chromatographic analysis using an LHM-8MD and Kristallux-4000M instrument was used to determine hydrogeochemical parameters. *Results and Conclusions.* A comparative analysis of the obtained gas-chemical and isotopic anomalies responsible for the earthquake preparation periods was conducted. Anomalies arising in both the isotopic (δD and $\delta^{18}O$) and gaseous (He, H₂, CO₂) composition of groundwater are caused by interactions in the gas-water-rock system for water-bearing rocks around the observation points. Furthermore, as a result of the transmitted elastic stresses during the earthquake preparation stage, rock fracturing and gas migration from deeper layers along existing faults occur. This, in turn, is an important direction for the development of hydrogeoseismological research. **Keywords:** groundwater, geodynamic landfill, helium, carbon dioxide, precursors, gas chemical and isotopic anomalies, variation, carbonates, bubbler, chromatograph.

Keywords: groundwater, geodynamic landfill, helium, carbon dioxide, precursors, gas chemical and isotopic anomalies, variation, carbonates, bubbler, chromatograph

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ЖЕР СІЛКІСУГЕ ДАЙЫНДАУ КЕЗЕҢІНДЕГІ ЖЕР СУСЫНЫҢ ГАЗДЫҚ ЖӘНЕ ИЗОТОПТЫҚ ҚҰРАМЫНЫҢ ӨЗГЕРІСІНІҢ НӘТИЖЕЛЕРІН ТАЛДАУ

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Аннотация. Мақала сейсмикалық белсендіруді дайындау кезінде Ташкент геодинамикалық сынақ полигонының аумағында жоғарғы бор кезеңінің сеномандық кезеңінің жер асты суларында еріген газдар концентрациясының және изотоптық құрамның аномалдық өзгерістерінің сипаты мен механизмін зерттеуге арналған. *Мақсаты.* Зерттеуде Назарбек (11.12.1980 ж., $M = 5,5$, $P = 15$ км), Тұябұғыз (25.05.2013 ж., $M = 5,5$, $P = 50$ км) және $M = 5$, $M = 20$ км ($M = 20$, $M = 20$, $M = 5,5$ км) дайындық кезеңдеріндегі жер асты суларының изотоптық және газдық құрамының аномалияларының сипатына мониторингтік бақылаулардың нәтижелері қарастырылған. 6.2, $R = 200$ км) өзендер. жер сілкіністері. *Әдістері.* Зерттелетін аумақта еріген газ аномалиялары мен жер асты суларының изотоптық құрамын анықтау үшін гидрогесейсмологиялық зерттеулерде қолданылатын дәстүрлі әдістер қолданылды. Өздігінен ағатын су нүктелерінен сынама алу жер асты суларының гидрогеохимиялық параметрлерін далалық және зертханалық анықтауды қоса алғанда, 2RS-1-SV форевакуумдық сорғымен вакуумды газсыздандыруды қолдану арқылы орындалды. Жер асты суларында абсолютті еріген гелий құрамын анықтау үшін INGEM-1 құралы қолданылды, ал гидрогеохимиялық параметрлерді анықтау үшін LHM-8MD және Kristallux-4000M құралдары арқылы хроматографиялық талдау жүргізілді. *Нәтижелер мен қорытындылар.* Жер сілкінісіне дайындық кезеңдеріне жауап беретін алынған газ-химиялық және изотоптық аномалияларға салыстырмалы талдау жүргізілді. Жер асты суларының изотоптық (δD және $\delta^{18}O$) және газтәрізді (He , H_2 , CO_2) құрамында пайда болатын ауытқулар бақылау нүктелерінің айналасындағы суы бар тау жыныстары үшін газ-су-тау жыныстары жүйесіндегі өзара әрекеттесу нәтижесінде пайда болады. Сонымен қатар, жер сілкінісіне дайындық кезеңінде берілетін серпімді кернеулердің нәтижесінде тау жыныстарының жарылуы және бар жарықтар бойымен терең қабаттардан газдың миграциясы орын алады. Бұл өз кезегінде гидрогесейсмологиялық зерттеулерді дамытудың маңызды бағыты болып табылады.

Түйін сөздер: жер асты сулары, геодинамикалық полигон, гелий, көмірқышқыл газы, хабаршылар, газ-химиялық және изотоптық ауытқулар, вариация, карбонаттар, көпіршік, хроматограф

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АНАЛИЗ РЕЗУЛЬТАТОВ ИЗМЕНЕНИЙ ГАЗОВОГО И ИЗОТОПНОГО СОСТАВА ПОДЗЕМНЫХ ВОД В ПЕРИОД ПОДГОТОВКИ ЗЕМЛЕТРЯСЕНИЙ

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Аннотация. *Актуальность.* Статья посвящена изучению природы и механизма аномальных изменений концентрации растворённых газов и изотопного состава подземных вод сеноманского яруса верхнемелового периода на территории Ташкентский геодинамический полигон в условиях подготовки сейсмической активности. *Цель исследования* - анализ результатов мониторинговых наблюдений аномалий газового и изотопного состава подземных вод в периоды подготовки Назарбекского (11.12.1980, $M=5,5$, $R=15$ км), Туябугузского (25.05.2013, $M=5,5$, $R=50$ км) и Маржанбулакского (26.05.2013, $M=6,2$, $R=200$ км) землетрясений. *Методы.* Для выявления аномалий растворённых газов и изотопного состава подземных вод использованы традиционные методы гидрогеосейсмологических исследований. Отбор проб из самоизливающих водопунктов проводился методом вакуумной дегазации с использованием форвакуумного насоса 2RS-1-SV с последующим выполнением полевых и лабораторных определений гидрогеохимических параметров. Абсолютное содержание растворённого гелия определялось с применением прибора ИНГЭМ-1, а анализ газового состава выполнялся хроматографическим методом на приборах ЛХМ-8МД и Кристаллюкс-4000М. *Результаты и выводы.* Проведён сравнительный анализ геохимических и изотопных аномалий, приуроченных к этапам подготовки

землетрясений. Установлено, что изменения как изотопного состава (δD , $\delta^{18}O$), так и газового состава (He , H_2 , CO_2) подземных вод обусловлены процессами взаимодействия в системе «газ–вода–порода» в водовмещающих породах вблизи пунктов наблюдения. Показано, что на стадии подготовки землетрясений под действием упругих напряжений активизируются процессы трещинообразования, что способствует миграции глубинных газов по разрывным нарушениям в зону наблюдения. Полученные результаты подтверждают информативность гидрогеохимических и изотопных индикаторов для выявления предвестников сейсмической активности и представляют важное направление развития гидрогеосейсмологических исследований.

Ключевые слова: подземные воды, геодинамический полигон, гелий, углекислый газ, предвестники, газохимические и изотопные аномалии, вариация, карбонаты, барботёр, хроматограф

Introduction. The study of variations in the content of gaseous components in groundwater occupies a special place in the complex of hydrogeoseismological methods for predicting earthquakes. According to literature sources, groundwater is an indicator of many processes occurring at depth (Ballentine et al., 2002; Kotarba et al., 1998). In particular, it reacts to changes in rock stresses associated with the preparation of earthquakes (Yusupov, 2004 b: 2, Yusupov, 2020 V: 9). It is no coincidence that there has been an increased interest in studying the nature and mechanism of anomalous changes in the concentration of helium in groundwater during periods of seismic activity. In this regard, it is worth noting the history of the emergence of a new branch of seismology in Uzbekistan: hydrogeoseismology. This field has provided an impetus for the development of systematic hydrogeoseismological research since the discovery of scientific fact No. 129 dated February 21, 1966. "The phenomenon of changes in the gas-chemical and isotopic compositions of groundwater during the period preceding and accompanying an earthquake" (Semenov et al., 2011); No. 68 dated December 30, 1968, "The pattern of helium distribution in the Earth's crust, where anomalously high concentrations of helium have been linked to deep faults, their movements, and related geodynamic processes" (Semenov et al., 2011).

In this regard, research on the mechanisms and patterns of changes in hydrogeochemical parameters in groundwater responsible for the formation of anomalies remains an urgent task of hydrogeoseismology at the present stage.

The relevance of the study lies in determining the component, gas and isotopic compositions of groundwater in the Tashkent Geodynamic polygon, which can help predict possible seismic activity in the territory. During earthquake preparation, rocks undergo significant elastic deformations. Spreading into the environment, these elastic deformations, in turn, affect the course of physico-chemical and hydrogeodynamic processes, expressed in changes in the level, flow rate,

chemical, gas and isotopic composition of groundwater (Sultankhodzhaev.1983, 1984; Zakirov, 2025 v: 7). At the same time, long-term monitoring studies and literature analysis indicate that no influence of seasonal meteorological conditions or anthropogenic impacts (water abstraction or industrial activity) on groundwater in the Cenomanian aquifer of the Cretaceous period was observed in the Tashkent Geodynamic Test Site. Furthermore, no changes in the flow rate of self-flowing wells were observed at the studied water points. (Sultankhodzhaev.1983, 1984).

Literary review. The global experience of observing dissolved gases and the isotopic composition of groundwater has shown that with a rational selection of observation points on the eve of an earthquake, noticeable changes in their content can be recorded. The staff (A.N. Sultankhodjaev, A.A. Sultankhodjaev, I.G. Chernov, T.I. Isamukhamedova, Sh.S. Yusupov, and others) of the Institute of Seismology of the Academy of Sciences of the Republic of Uzbekistan investigated targeted studies of changes in the isotopic and gas composition of groundwater in Uzbekistan as a harbinger of an upcoming strong earthquake (Zakirov, 2025 v: 7; Sultankhodzhaev et al.,1983; Sultankhodzhaev et al., 1984; Yusupov, 2004 b: 2). Research by R.M.Semenov et al., 2011. Monitoring of the helium content in the deep water of the lake was carried out from the Institute of the Earth's Crust of the Siberian Branch of the Russian Academy of Sciences in order to possibly identify short-term precursors of earthquakes. Baikal in connection with the change of the seismic regime.

In connection with the above, the purpose of this article was to study the nature of variations in isotopic and gas compositions in groundwater during the earthquake preparation period and after its occurrence. The object of research is the groundwater of the Pritashkent Artesian basin, which is associated with one of the seismically active regions of Central Asia, where the possibility of earthquakes is quite high.

Materials and methods. An INGEM-1 device was used to obtain absolute dissolved helium content in groundwater, and samples were processed using a chromatographic method on an LHM-8MD and Kristallux-4000M device. Samples from self-discharging water points were collected using vacuum degassing with a 2RS-1-SV forevacuum pump, creating a vacuum in the sampler.

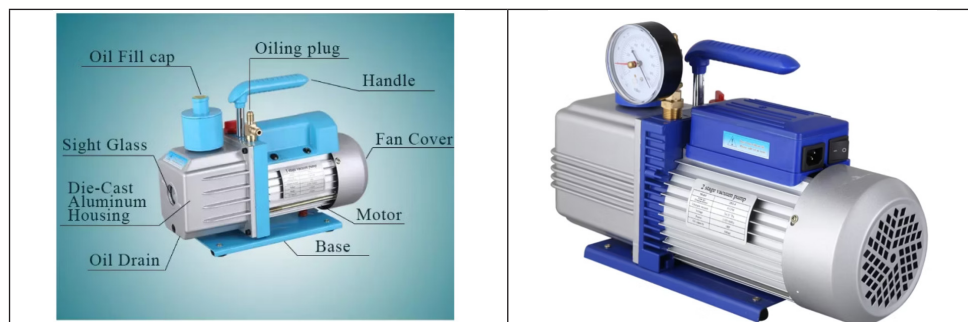


Figure 1. Elements of the 2RS-1-SV forevacuum pump.

Designed for scientific research, it can operate in both low and high ambient temperatures and is easy to transport. In the absence of electrical power, a G.F. Kamovsky pump is used, consisting of a 5-liter cylindrical metal cylinder and glass bubblers (0.2L) with vacuum hoses that are clamped with Kocher forceps.

Sampling from self-draining water points was carried out by vacuum degassing using a G.F.Kamovsky pre-vacuum pump, a 5-10-liter cylindrical metal cylinder and glass bubblers (0.2 liters) with vacuum hoses, which are clamped with Kocher (medical forceps). The creation of a reliable vacuum in the bubbler is controlled by a pressure gauge and air pumping time. When gas is sampled from a well into a cylinder, water is sucked into the cylinder under the action of a vacuum, and spontaneous gas accumulates in the upper part of it, which is then transferred to a bubbler. Then, the gas released from the groundwater under study by displacement with a saturated solution of table salt is transferred to a separation funnel and introduced into the chromatograph. The described method of sampling dissolved gas, unlike the Savchenko method, is simpler and reduces the likelihood of air entering the gas sample to a minimum.

This method of extraction of dissolved gas has advantages over the so-called thermal and thermal vacuum methods of extracting gases from groundwater, in which almost complete extraction of dissolved gas is achieved, however, a number of processes occur that change the composition of the extracted gases. Their selection and analysis in the laboratory for the gas content in the water should be carried out daily.

Hydrogeochemical studies of thermomineral waters in the Pritashkent region began long before the Tashkent earthquake of 1966. Systematic monitoring hydrogeochemical observations have been conducted since 1972 to the present (Zakirov et.al., 2019 a: 5; Zakirov, 2025 v: 7). The monitoring research area and earthquake occurrence points are mapped on the map of seismogenic zones of Uzbekistan (Fig. 2).

Results and discussions. The main gas components under routine monitoring are hydrogen, helium and carbon dioxide. These components have a high migration ability coming from the earth's interior and reactivity with the environment, which makes it possible to use their abnormal changes as a harbinger of an earthquake.

This position is supported by the accumulated 40 years of factual material on the study of changes in the concentrations of groundwater parameters over time, as well as observations of variations in stable isotopes ($^3\text{He}/^4\text{He}$, $^{13}\text{C}/^{12}\text{C}$ in CO_2 , D/H and $\delta^{18}\text{O}$ of water, etc.). In the ongoing research, special attention is paid to the phenomena occurring in the gas–water–rock system, since the ratio between the earthquake preparation time and the rate of chemical components entering the rock into the pore solution is defined as a hydrogeochemical anomaly of the observed parameters. Our research provides data on variations in the carbon isotopic composition $\delta^{13}\text{C}$ and CO_2 content, concentration of helium, molecular hydrogen and isotopic composition of water (δD and $\delta^{18}\text{O}$) of the Ulugbek well

in the Tashkent geodynamic polygon during the preparation and completion of the Nazarbek earthquake (11.12.1980, $M = 5.3$) and during the preparation and completion of the Tuyabuguz earthquake (25.05.2013, $M = 5.5$) and Marzhanbulak (26.06.2013, $M = 6.2$, $L = 230-240$ km from Tashkent) earthquakes (Fig. 3, 4). As shown by the results of monitoring studies during the time before the earthquakes occurred in both the Nazarbek 1980, Tuyabuguz and Marzhanbulak earthquakes in 2013, hydrogeochemical components had a background value (Yusupov et.al., 2020 v: 9). During the preparation period of both earthquakes before the event, anomalies of components were observed - concentrations of hydrogen, helium, nitrogen, hydrocarbonate, carbon dioxide and isotopes in groundwater above background values, characteristic of the geological and tectonic conditions of the Ulugbek and Chatkal water points.

During the preparation period of both earthquakes before the event, anomalies of the components were observed – concentrations of hydrogen, helium, nitrogen, bicarbonate, carbon dioxide and isotopes in groundwater above the background values.

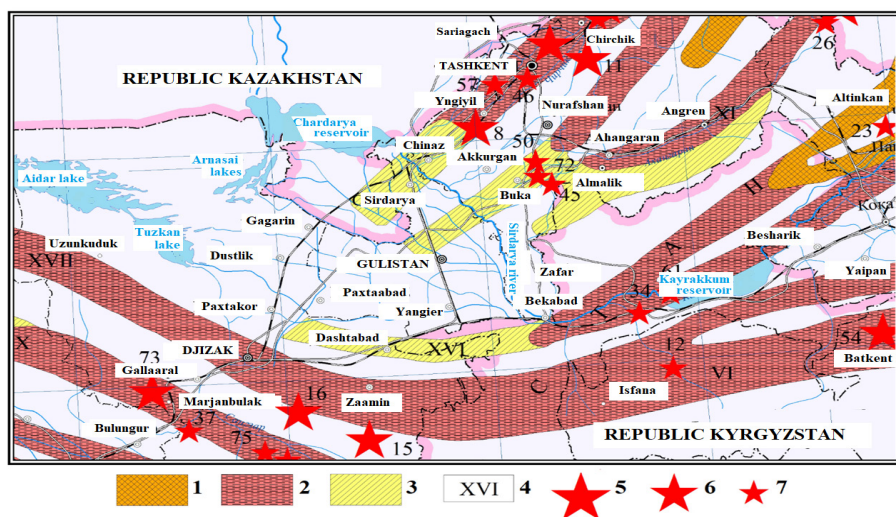


Figure 2. Excerpt from the map of seismogenic zones of Uzbekistan and adjacent territories (R.N.Ibragimov, Yu.M.Sadykov, U.A.Nurmatov, 2017). Symbols: Seismogenic zones in which earthquakes may occur: 1 - $M \leq 7.0$; 2 - $M \geq 6.0$; 3 - $M \geq 5.0$; 4 – number of the seismogenic zone. Magnitude of earthquakes: 5th is less than 7.0; 6th is ≥ 6.0 ; 7th is > 5 . The epicenters of past earthquakes are 46 – Tashkent (1966); 57 – Nazarbek (1980); 70 – Tashkent (2008); 72 – Tuyabuguz (2013); 73 – Marzhanbulak (2013).

As can be seen from Fig. 3, all the geochemical and isotopic parameters shown on it vary during the preparation period of the specified earthquake. It should be noted that along with the anomaly in the concentrations of He, H_2 and CO_2 during the earthquake period, there is also an anomaly in the isotopic composition of water. Moreover, if the anomaly is represented as two peaks for the CO_2 concentration,

then for the $\delta^{13}\text{C}$ value it is represented by only one, which coincides with the second peak of CO_2 in time of manifestation. The first peak of the total carbon dioxide content, according to the authors (Sadykov F.S et.al., 2015), may be due to the initial earthquake preparation processes. During this period, fluctuations in the values of $\delta^{13}\text{C}$ were not large.

The second peak of CO_2 , correlating with the maximum values of $\delta^{13}\text{C}$, may be associated with a more intensive development of elastic stresses and corresponding deformations of rocks, with the generation of elastic waves that facilitate the entry of carbon dioxide from carbonates heavier in isotope 13C ($\delta^{13}\text{C} = -4.9...+5.6\%$) (Sadykov F.S et.al., 2015; Yusupov et.al., 2020 v: 9). The latter statement was made based on the results of isotopic determinations of the values of $\delta^{13}\text{C}$ from both dissolved CO_2 , HCO_3 (H_2CO_3), and CO_2 isolated from core samples of water-bearing rocks (Sadykov F.S et.al., 2015; Yusupov, 2004 b:2). There is a clear manifestation of anomalies in the gas composition of the groundwater of the Chatkal sanatorium water point during the preparation of the Tuyabuguz and Marzhanbulak earthquakes (Fig.4). The red vertical line shows the time of the hydrogeochemical parameters of the earthquake that occurred directly in the study area. There is an increase in concentrations of isotopes of helium, hydrogen, oxygen, and carbon dioxide immediately before the earthquake itself, and at the time of seismic activity there is a sharp decrease in the isotope content. From the standpoint of isotopic geochemistry of helium, the main radiogenic source of gases in the sedimentary cover are its constituent rocks (Krupnova et.al., 2005; Kotarba et.al., 1998).

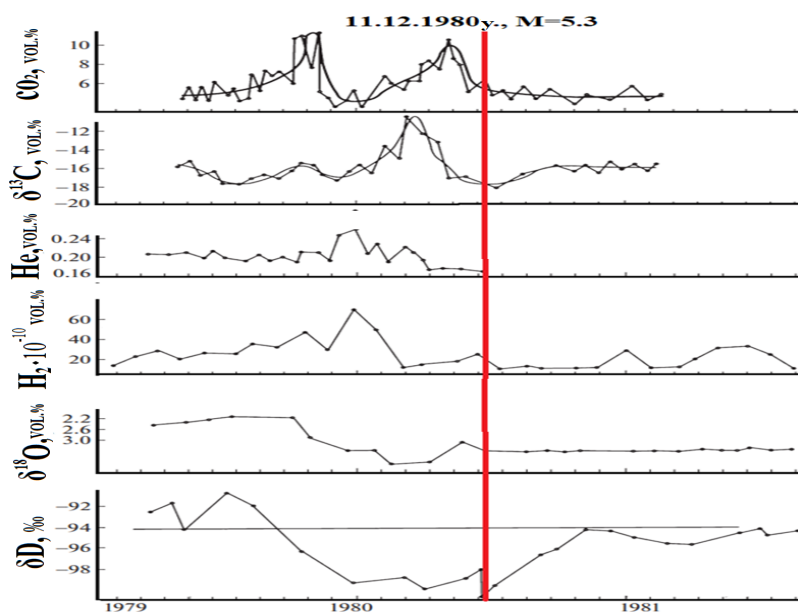


Figure 3. Changes in the isotopic composition: of carbon $\delta^{13}\text{C}$ and CO_2 content, concentration of helium, molecular hydrogen and isotopic composition δD and $\delta^{18}\text{O}$ of water in the groundwater of the Ulugbek water point during the preparation of the Nazarbek earthquake on 11.12.1980 M = 5.3.

For example, helium is mainly concentrated in areas of fractures, in rocks of high radioactivity and hydrocarbon accumulations. The main factors of the increase in helium concentration can be overestimated: from the proximity of alpha radiation sources (granites and their destruction products); shallow occurrence of the crystalline basement and the presence of rocks; the process of decomposition of hydrocarbons in ancient gas accumulations (Zakirov et.al.2019 a: 5; Matveev et.al.1978; Finkelstein, 1978; Yusupov et.al., 2020).The duration of contact of groundwater with helium-producing rocks can also be considered one of the most important factors for the accumulation and preservation of helium. Having been released from the destroyed minerals by chemical and mechanical means, the helium bubbles dissolved in the waters migrate through disturbances to the upper layers of the lithosphere.

The helium content in the groundwater of the Tashkent geodynamic polygon varies between 0.03–2.7 vol. %. Abnormal changes in all water points are 6-8 times higher than the background value. Based on our (Matveev, 1978; Yusupov et.al., 2020) and literature data (Zakirov, 2025 v: 7; Kropotkin et.al., 1976; Semenov et.al., 2011; Sultankhodjaev et.al., 1983), it can be stated that at the stage of earthquake preparation, as elastic stresses increase, numerous microcracks form in the water-bearing rocks.

This, in turn, leads to an increase in the release of buried gases from the pores of the water-bearing rocks. At the same time, the main source of the increase in the concentration of helium in groundwater is the migration of gases from deeper layers of the earth along discontinuous faults and tectonic faults. All the water points analyzed by us are located in the Karzhantau deep fault zone of the Pskov-Tashkent seismogenic zone (Zakirov, 2022 b: 6).

The isotopic composition of hydrogen and oxygen in the water itself also changes over time. The seismically calm period is characterized by stable deuterium and oxygen-18 levels close to the background levels. According to the results of monitoring studies, during the earthquake preparation period, changes in the groundwater of the Ulugbek water point began about a year before the event. Long-term observations of changes in gas composition have not revealed the influence of seasonal fluctuations in water levels, meteorological conditions, or anthropogenic impact (Kopylova, et al., 2020; Zakirov, 2026 g: 5). Increased concentrations of these isotopes (by ~4‰ for deuterium and ~0.6‰ for $\delta^{18}\text{O}$) were recorded relative to the average background values. There is a slow decrease in concentrations to the minimum values observed for δD over a period of five months, and for $\delta^{18}\text{O}$ over two months.

The reduction in the isotopic composition of hydrogen and oxygen relative to the background values was 4 and 0.2‰, respectively. The moment of the earthquake occurred at the ^{18}O content that had been stabilized by that time and the minimum deuterium content, which recovered over the next three months. Along with the anomalies in the values of δD and $\delta^{18}\text{O}$ for the period of the Nazarbek earthquake,

anomalies in the contents of hydrogen, helium, carbon dioxide and its isotopic carbon dissolved in groundwater were also observed (see Fig. 3).

In this regard, an assessment was made of the effect of the isotope exchange process between these gases and the underground waters of the basin, which showed that even an increase in the concentrations of H_2 and CO_2 to the maximum values ever observed in the groundwater of the Pritashkentky Artesian basin can change the content of deuterium (increase) and oxygen-18 (decrease) in these The water level is only $\sim 0.002\%$, which is more than a number of times less accurate than the measurements.

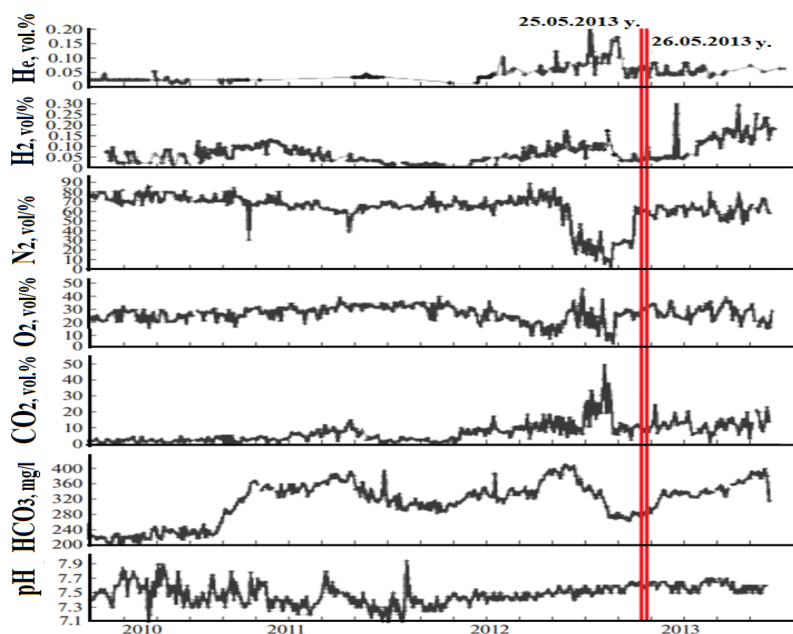


Figure 4. Changes in the hydrogeochemical parameters of groundwater over time at the following water points: Chatkal sanatorium during the preparation of the Tuyabuguz (25.05.2013, $M = 5.5$, $R = 50$ km) and Marzhanbulak (26.05.2013, $M = 6.2$, $R = 200$ km) earthquakes.

The process of isotope exchange in the water–rock–gas system, which takes place in the changed thermal conditions of earthquake preparation zones, can also affect the isotopic composition of groundwater. The temperature coefficient of oxygen isotope fractionation during the interaction of waters with Lower Cretaceous sediments with the greatest oxygen shift is estimated at $\sim 0.2\%/1^\circ C$. However, since isotope exchange is a long–term process and not comparable in time to temperature variations, it can be argued that as a result of its implementation, a change in the O_2 content cannot be caused during a limited observation time.

For a hydrogen anomaly of $\sim 5\%$ to occur, it is necessary that about ten times more of these be released than strongly bound ones, which is observed. The presence of anomalies only in wells located in fault zones, i.e. in areas characterized by

increased rates of fracture formation. Based on this, it is assumed that the anomalies in the values of δD and $\delta^{18}O$ are caused by processes occurring in the water–rock–gas system not throughout the entire aquifer, but only in its local sections. The idea of their locality is confirmed by the assessment of the balance of radiogenic components of inert gases carried out for the water–rock–gas system in the conditions of the Pritashkentsky Artesian basin. If we have come to a conclusion about the nature of the formation of anomalies in the isotopic composition of water, the same cannot be said about the nature of the formation of anomalies in the gas composition, in particular molecular hydrogen. As noted above, with insignificant background concentrations of H_2 , individual bursts are observed when its concentration increased by 1-2 orders of magnitude during the preparation and after the occurrence of strong earthquakes. At the time of the earthquakes, as a rule, the concentrations of molecular hydrogen were minimal. During the preparation period for the Nazarbek earthquake (see Fig. 3), the background H_2 content was ten thousandths and thousandths of a percent, and an increase in hydrogen concentration to hundredths of a percent was considered an anomaly, but after 1983, the background H_2 content increased by 2-3 orders of magnitude. This suggests that the observed increased variations in helium and hydrogen gases in groundwater are a consequence of elastic stresses transmitted from the hypocenter, leading to the formation of microcracks in water-bearing rocks. Gas migration through these cracks from deeper layers contributes to an increase in the quantitative and volumetric content of dissolved gases during the pre-earthquake stage (Zakirov, 2022 b: 6, Zakirov, 2025 v: 7). Based on the results obtained, the following conclusions can be drawn below: –the isotopic composition of molecular hydrogen in the studied area is characterized by concentrations of δD , varying in the range from -200 to -130‰. A possible source of molecular hydrogen with the observed isotopic composition entering the aquifer may be a chemical reaction between the groundwater of the underlying aquifers and the fracturing of rocks formed during their cracking; –the observed variations of helium and hydrogen gases in groundwater are a consequence of transmitted elastic deformations at the stage of preparation for the main earthquake shock; – anomalies of CO_2 dissolved in groundwater and carbon isotope $\delta^{13}C$ carbon dioxide during the earthquake preparation period may be associated with a more intensive development of elastic stresses and corresponding deformations of rocks with the generation of elastic waves facilitating the entry of carbon dioxide heavier in isotope ^{13}C from carbonate rocks into the water (Yusupov et.al., 2020; Yusupov et.al., 2013).

Conclusion. During earthquake preparation, rocks in the Tashkent Geodynamic polygon undergo significant elastic deformations. Spreading into the environment, these deformations affect the course of changes in the hydrogeochemical and isotopic parameters of groundwater at certain water points. Anomalies that occur during earthquake preparation periods in both the isotopic and gaseous (He , H_2 , CO_2) composition of groundwater are caused by the processes of interaction in the

«gas-water-rock» system for water-bearing rocks around the observation points of the studied area;

The observed variations of helium and hydrogen gases in groundwater are a consequence of transmitted elastic stresses at the stage of earthquake preparation, leading to the processes of fracturing of water-bearing rocks and migration of gases from deeper layers, according to existing discontinuous disturbances, i.e. tectonic faults;

The anomaly in the isotopic composition of carbon $\delta^{13}\text{C}$, carbon dioxide dissolved in groundwater during the earthquake preparation period, is associated with a more intensive development of elastic stresses accompanied by fracturing and corresponding deformations of rocks with the generation of elastic waves providing gases and heavier isotope ^{13}C carbon dioxide from fractured carbonate rocks into the water.

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