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Nature of radioactivity of quarry drainage waters in the Novosibirsk region

A.S. Derkachev[1,2], **A.A. Maksimova**[1,2], **D.A. Novikov**[1,2], **F.F. Dultsev**, **A.F. Sukhorukova**[1], **A.V. Chernykh**[1,2], **A.A. Khvaschevskaya**[3]

[1] *Trofimuk Institute of Petroleum Geology and Geophysics, Siberian Branch of the Russian Academy of Sciences, Novosibirsk, Russian Federation*

[2] *Novosibirsk State University, Novosibirsk, Russian Federation*

[3] *National Research Tomsk Polytechnic University, Tomsk, Russian Federation*

rock.nastaya64@gmail.com

Abstract

This study is relevant for obtaining the first geochemical data (including information on radionuclides) on the drainage waters of developed and flooded quarries in the eastern areas of the Novosibirsk Region. The objective of the study was to identify the features of the chemical composition of drainage waters (a wide range of chemical elements from Li to U). The study was carried out by titrimetry, ion chromatography and mass spectrometry with inductively coupled plasma in a laboratory setting at the Hydrogeochemical Problem Research Laboratory (PNIL GGH) of the Engineering School of Natural Resources of Tomsk Polytechnic University (IShPR TPU). Measurements of ^{222}Rn in waters were carried out at the Alfarad Plus facility of the Laboratory of Siberian Sedimentary Basins Hydrogeology of the A.A. Trofimuk Institute of Petroleum Geology and Geophysics, Siberian Branch of the Russian Academy of Sciences (INGG SB RAS). The data were divided into homogeneous geochemical populations using the coefficients Ca/Na, Ca/Mg, Ca/Si, Mg/Si, Na/Si. The chemical composition of the studied objects was found to be highly diverse. The dominant waters have the chemical formula SO_4–HCO_3/Na–Mg–Ca with a TDS (total dissolved solids) of 400 to 700 mg/dm^3. Three geochemical groups of waters were identified. The first is represented by drainage waters of the developed rubble stone quarries, the second includes facilities of the Gorlovka coal basin, and the third refers to abandoned flooded quarries. The first group is characterized by oxidizing conditions with Eh varying over a wide range from +84.6 to +261.0 mV, pH from 6.9 to 8.6, and $O_{2dissolved}$ from 3.43 to 14.39 mg/dm^3. The radionuclide concentrations are (mg/dm^3): ^{238}U $9.30 \cdot 10^{-3}$ – 1,40; ^{232}Th $1,00 \cdot 10^{-6}$ – $2,16 \cdot 10^{-3}$; ^{222}Rn activity varies from 1 to 572.5 Bq/dm^3. The $^{232}Th/^{238}U$ ratio ranges from $4.20 \cdot 10^{-5}$ to $2.69 \cdot 10^{-3}$ with an average of $8.40 \cdot 10^{-4}$. The second group has a smaller Eh variation range of +133.2 to +199.6 mV, pH from 7.5 to 8.5, and $O_{2dissolved}$ from 6.81 to 10.43 mg/dm^3. The radionuclide concentrations vary in the following ranges (mg/dm^3): ^{238}U $2.26 \cdot 10^{-3}$ – $2.90 \cdot 10^{-2}$; ^{232}Th $7.5 \cdot 10^{-6}$ – $5.57 \cdot 10^{-4}$. The $^{232}Th/^{238}U$ ratio ranges from $8.37 \cdot 10^{-4}$ to $4.80 \cdot 10^{-2}$ at an average of $9.54 \cdot 10^{-3}$. The third group is also characterized by an oxidizingizing geochemical environment with Eh +131.3 – +250.0 mV, pH from 6.9 to 8.8 and $O_{2dissolved}$ from 4.00 to 16.59 mg/dm^3. The radionuclide concentrations are (mg/dm^3): ^{238}U $3.00 \cdot 10^{-4}$ – $2.74 \cdot 10^{-2}$; ^{232}Th $1.65 \cdot 10^{-6}$ – $1.15 \cdot 10^{-5}$; ^{222}Rn activity varies from 2 to 31 Bq/dm^3. The $^{232}Th/^{238}U$ ratio ranges from $2.36 \cdot 10^{-4}$ to $1.02 \cdot 10^{-3}$ at an average of $6.25 \cdot 10^{-4}$. Overall, the $^{232}Th/^{238}U$ ratio of the studied waters indicates their uranium nature of radioactivity. The data obtained indicate a slight impact of the drainage water discharge from the abandoned quarries on the environment.

Keywords

drainage waters, geochemistry, radionuclides, quarries, Novosibirsk Region, Western Siberia

Acknowledgments

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ТЕХНОЛОГИЧЕСКАЯ БЕЗОПАСНОСТЬ В МИНЕРАЛЬНО-СЫРЬЕВОМ КОМПЛЕКСЕ И ОХРАНА ОКРУЖАЮЩЕЙ СРЕДЫ

Научная статья

Природа радиоактивности дренажных вод карьеров Новосибирской области

А.С. Деркачев[1, 2], **А.А. Максимова**[1, 2] ✉, **Д.А. Новиков**[1, 2], **Ф.Ф. Дульцев**[1, 2], **А.Ф. Сухорукова**[1], **А.В. Черных**[1, 2], **А.А. Хващевская**[3]

[1] *Институт нефтегазовой геологии и геофизики им. А.А. Трофимука СО РАН, г. Новосибирск, Российская Федерация*

[2] *Новосибирский государственный университет, г. Новосибирск, Российская Федерация*

[3] *Национальный исследовательский Томский политехнический университет, г. Томск, Российская Федерация*

✉ *rock.nastaya64@gmail.com*

Аннотация

Актуальность исследования заключается в получении первых геохимических данных (включая информацию о радионуклидах) о дренажных водах разрабатываемых и затопленных карьеров в пределах восточных районов Новосибирской области. Целью исследования является выявление особенностей химического состава дренажных вод (широкого спектра химических элементов от Li до U). Лабораторное изучение химического состава методами титриметрии, ионной хроматографии, масс-спектрометрии с индуктивно связанной плазмой проводилось в Проблемной научно-исследовательской лаборатории гидрогеохимии (ПНИЛ ГГХ) Инженерной школы природных ресурсов Томского политехнического университета (ИШПР ТПУ). Измерение содержаний ^{222}Rn в водах проводилось на комплексе «Альфарад плюс» в лаборатории гидрогеологии осадочных бассейнов Сибири Института нефтегазовой геологии и геофизики им. А.А. Трофимука Сибирского отделения Российской академии наук (ИНГГ СО РАН). Разделение данных на однородные геохимические совокупности выполнено с помощью коэффициентов Ca/Na, Ca/Mg, Ca/Si, Mg/Si, Na/Si. Установлено, что химический состав изученных объектов весьма разнообразен. Доминируют воды SO_4–HCO_3 Na–Mg–Ca состава с величиной общей минерализации от 400 до 700 мг/дм^3. Выявлены три геохимические группы вод. Первая представлена дренажными водами разрабатываемых карьеров бутового камня, вторая включает в себя объекты Горловского угольного бассейна и третья – отработанные затопленные карьеры. Первая группа характеризуется окислительными параметрами геохимической среды с Eh, изменяющимся в широком диапазоне от +84,6 до +261,0 мВ, pH от 6,9 до 8,6 и $O_{2\ раств.}$ от 3,43 до 14,39 мг/дм^3. Содержания радионуклидов составляют (мг/дм^3): ^{238}U $9{,}30 \cdot 10^{-3}$ – 1,40; ^{232}Th $1{,}00 \cdot 10^{-6}$ – $2{,}16 \cdot 10^{-3}$; активность ^{222}Rn изменяется от 1 до 572,5 Бк/дм^3. Отношение ^{232}Th/^{238}U находится в диапазоне от $4{,}20 \cdot 10^{-5}$ до $2{,}69 \cdot 10^{-3}$ при среднем $8{,}40 \cdot 10^{-4}$. Вторая группа отличается меньшей вариацией Eh от +133,2 до +199,6 мВ, pH от 7,5 до 8,5 и $O_{2раств.}$ от 6,81 до 10,43 мг/дм^3. Концентрации радионуклидов изменяются (мг/дм^3): ^{238}U $2{,}26 \cdot 10^{-3}$ – $2{,}90 \cdot 10^{-2}$; ^{232}Th $7{,}15 \cdot 10^{-6}$ – $5{,}57 \cdot 10^{-4}$. Отношение ^{232}Th/^{238}U находится в диапазоне от $8{,}37 \cdot 10^{-4}$ до $4{,}80 \cdot 10^{-2}$ при среднем $9{,}54 \cdot 10^{-3}$. Третья группа также характеризуется окислительной геохимической обстановкой с Eh +131,3– +250,0 мВ, pH от 6,9 до 8,8 и $O_{2раств.}$ от 4,00 до 16,59 мг/дм^3. Содержания радионуклидов составляют (мг/дм^3): ^{238}U $3{,}00 \cdot 10^{-4}$ – $2{,}74 \cdot 10^{-2}$; ^{232}Th $1{,}65 \cdot 10^{-6}$ – $1{,}15 \cdot 10^{-5}$; активность ^{222}Rn изменяется от 2 до 31 Бк/дм^3. Отношение ^{232}Th/^{238}U находится в диапазоне от $2{,}36 \cdot 10^{-4}$ до $1{,}02 \cdot 10^{-3}$ при среднем $6{,}25 \cdot 10^{-4}$. В целом ^{232}Th/^{238}U отношение изученных вод свидетельствует об их урановой природе радиоактивности. Полученные данные говорят о незначительном влиянии сброса дренажных вод разрабатываемых месторождений полезных ископаемых на окружающую среду.

Ключевые слова

дренажные воды, геохимия, радионуклиды, карьеры, Новосибирская область, Западная Сибирь

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Introduction

Novosibirsk is the only major city in Russia in the vicinity of which the Prigorodnoye uranium deposit has been discovered, therefore making the presence of radionuclides in its local waters a rather natural phenomenon. The elevated radionuclide concentrations are due to the presence of scattered radioactive minerals in the granitoids of the large Novosibirsk massif. In the 1980s and 1990s, more than ten deposits of radon water were discovered in the Novosibirsk Region that were used for medicinal purposes (the most famous were the Zaeltsovsky Bor sanatorium, Gorvodolechenitsa, and the Khimkoncentraty plant dispensary). The deposits were practically not described in scientific literature until the 2010s [1–3].

The majority of studies in world scientific literatureis devoted to research on geological [4–6], hydrogeological [7, 8], and geochemical [9–11] factors affecting the distribution of natural radionuclides in waters of various isotopic-hydrogeochemical compositions. In Russia, research work to study various aspects of the radiochemistry of natural waters and simulation of geological processes in aquatic environments has been going on for a long time. Some of the latest works in this area are notably the studies on the geochemistry of bottom sediments [12, 13], the techniques for extracting radionuclides from natural waters [14, 15], the geochemical features of different types of natural waters [16–18] and their isotopic composition [19–22], and issues related to mineral deposit development [23, 24].

The situation with studies conducted on the na-tural waters of the Novosibirsk Region has begun to change for the better in recent years. This is largely associated with the work of the Laboratory of Hydrogeology of Siberian Sedimentary Basins of the INGG SB RAS on studying the hydrogeological conditions of radon water deposits [25], their isotopic and geochemical features [26], their composition formation mechanisms [27], and radionuclide monitoring [28]. Exhausted and flooded quarries (for excavating building crushed stone, coal, marble, sand) are of special importance in these studies. There has been significant attention paid to studying a wide range of chemical elements (from Li to U) in connection with the development of hydrogeochemical prospecting. An important factor here is assessing the environmental impact of drainage water discharge, primarily its radioactive hazard, which was performed in this study.

Research Method and Subject

pH, Eh, temperature, and the dissolved O_2, HCO_{3-} concentrations were determined using special apparatus (Hanna HI9125, AKPM-1-02L oxygen meter) directly at the facilities and at a field hydrogeochemical laboratory. Measurements of the ^{222}Rn concentration in the waters were carried out at the Alfarad Plus facility of the Laboratory of Siberian Sedimentary Basins Hydrogeology of INGG SB RAS. The subsequent study of the chemical composition of 31 water samples by titrimetry, ion chromatography and inductively coupled plasma (ICP) mass spectrometry was carried out at the PNIL Instituteof Hydrogeochemistry of IShPR TPU (analysts O.V. Chebotarev, N.V. Bublii, A.S. Pogutsa, V.V. Kurovskaya, K.B. Krivtsova, L.A. Rakul).

The designation of the chemical type is given according to S.A. Shchukarev's classification (macrocomponents of concentrations >10%-eq are added to the formula) according to the hue principle from smallest to largest.

The division of data into homogeneous geochemical sets according to the composition formation processes with an assessment of their manifestation intensity was carried out based on the ratio of chemical elements in the waters. The coefficients Ca/Na, Ca/Mg, Ca/Si, Mg/Si, Na/Si were used to assess the characteristics of water enrichment due to the hydrolysis of aluminosilicates and the congruent dissolution of carbonates; $SO_4/Cl >> 1$ and $rNa/rCl >> 1$ – hydrolysis of aluminosilicates and oxidation of sulfide minerals; proportional increase in $SO_4/Cl = 1$, $rNa/rCl \geqslant 1$, $Ca/Na > 0$ – evaporative concentration.

Hydrogeological Structure

The studied quarries are distributed over a large territory, with the distance between the most remote facilities exceeding 200 km. The studied facilities include both active and mined out, currently flooded. The list of the studied ones is dominated by granite quarries. Coal, sand and one marble quarry were also considered. The most numerous granite quarry group is represented by the currently-operating Borok, Novobibeyevsky, Skalinsky; and the flooded Tulinsky, Kamensky and Gorsky. The group of operating quarries of the Gorlovka coal basin (Urgunsky, Gorlovka, and Kolyvansky) is located in the Iskitimsky district of the Novosibirsk Region. Sand quarries are represented by the flooded Kirov and Podgorny. The marble quarry group includes one facility – the Abrashinsky quarry in the Ordynsky district of the Novosibirsk Region. Overall, the studied quarries have similar hydrogeological conditions. There are two distinct hydrogeological complexes: the upper one is a Cenozoic-age sedimentary cover and the lower one consists of consolidated rocks of a Paleozoic foundation broken through by late Paleozoic granitoid intrusions. Cenozoic sediments are typically represented by alluvial sediments of the Ob River and its tributaries of various orders, as well as rocks of the Kochkovskaya (Q_{EI} $k\check{c}_1$) and Krasnodubrovskaya (*sa* Q_{I-II} *kd*) suites.

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We starts our analysis with the most representative granite quarry group. It is important to note that they are located within various granitoid massifs. Thus, the Borok, Tulinsky, Kamensky and Gorsky quarries extract granites of the Novosibirsk granitoid massif and Novobibeyevsky of the Ob massif. Both these massifs belong to the Priobsky monzodiorite-granosyenite-granitic mesoabyssal complex (P_3–T_1p). The Skalinsky quarry extracts granites from the Kolyvansky granitoid massif that belongs to the Barlak granite-leucogranite mesoabyssal complex (T_{1-2}b) [29].

The Ob massif is petrotypic. The first intrusion phase has a very limited distribution and is not considered in this work. The second and main phase is composed of biotite and hornblende-biotite monzogranite, less often granosienite, granite and granodio-

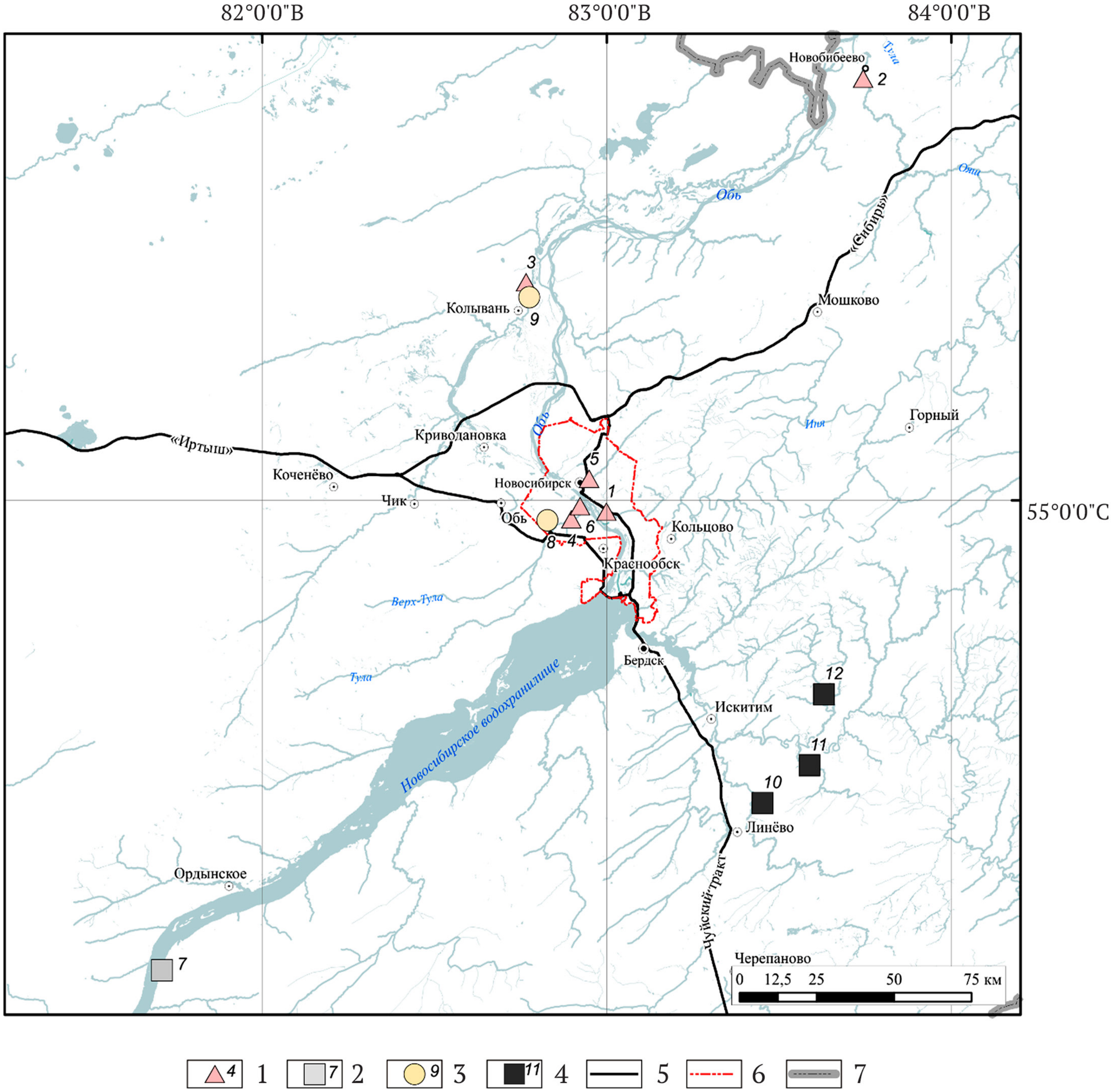

Fig. 1. Location of the studied quarries
1–4 – quarries: *1* – granite; *2* – marble; *3* – sandy; *4* – coal; *5* – federal highways; *6* – Novosibirsk Region border; *7* – Novosibirsk Region border; *1–3*, *10–12* – operating: *1* – Borok; *2* – Novobibeyevsky; *3* – Skalinsky; *4–9* – flooded: *4* – Tulinsky; *5* – Kamensky; *6* – Gorsky; *7* – Abrashinsky; *8* – Kirovsky; *9* – Podgorny; *10* – Urgunsky; *11* – Gorlovka; *12* – Kolyvansky

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rite. Moderately felsic granitoids gravitate to the endocontact zones of the massif. The third phase includes rare dykes of fine-grained monzogranite, monzoleucogranite, monzogranite porphyry, monzoleucogranite porphyry, and veins of aplite and pegmatite. In the Novobibeyevsky quarry and the bedrock outcrops along the bank of the Ob River, large and small xenoliths of quartz monzodiorite and quartz diorite in granite were identified. The Novosibirsk massif also includes the second and third phases. The second one is represented by hornblende-biotite monzogranite, granosyenite, normally alkaline granite and granodiorite. The rocks contain green hornblende and brown biotite. The biotite ferruginosity is 40–55 [30].

The list of accessory minerals includes sphene, zircon, apatite, magnetite, ilmenite and fluorite [29]. The third phase is represented by small bodies of inclined stocks of the north-eastern extension and dykes up to 15 m thick. The composition of the stocks is represented by monzogranite-porphyry and the dykes by monzogranite-porphyry, fine-grained monzoleucogranite, quartz monzodiorite-porphyry and spessartite. The monzogranite-porphyry has a similar composition to the fine-grained monzoleucogranite, and the porphyric inclusions are composed of feldspar. The content of quartz and K-Na feldspar is higher in the monzoleucogranite than in the monzogranite, while the Ca-Na-plagioclase content is respectively lower. The Borok quarry is located in the contact zone of the Novosibirsk massif. Here, the contact is sharp, dipping towards the host rocks, and is often represented by veins and leucogranite and aplite dykes.

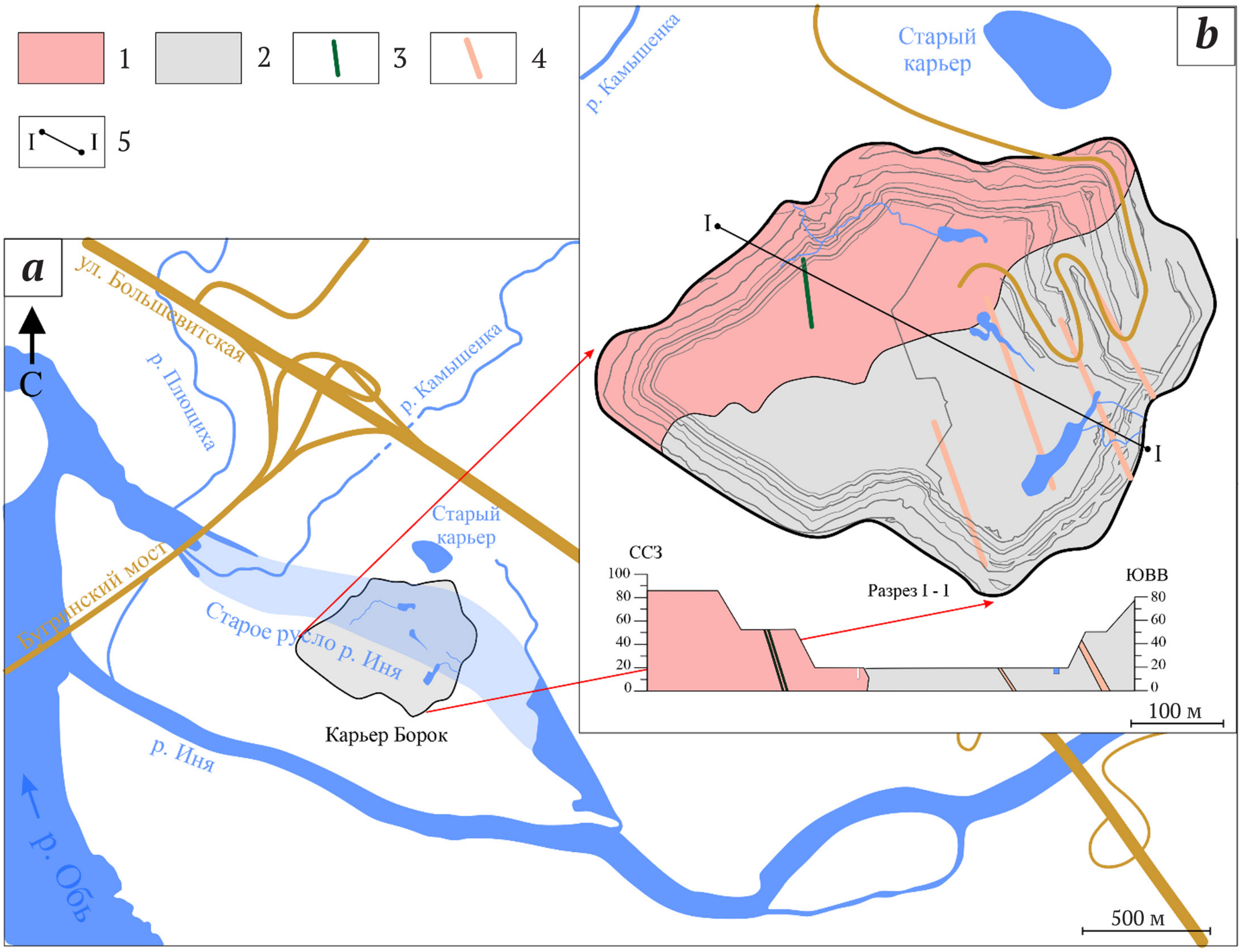

Fig. 2. Borok quarry location (*a*) and geological structure schematics (*b*):
1 – granitoids; *2* – hornfels; *3* – lamprophyre; *4* – granodiorite; *5* – cross-section line

The host rocks are represented by sandy-clayey shales of the Upper Devonian Pacha Formation that were transformed into hornfels by contact metamorphism. The Kolyvansky massif is composed of medium-grained granitoids that are predominated by monzoleucogranite. Second-phase rocks are represented by fine-grained monzoleucogranite dykes up to 3 m thick of a sublatitudinal/NE-SW strike. Pegmatite veins, lenses and nodes are observed

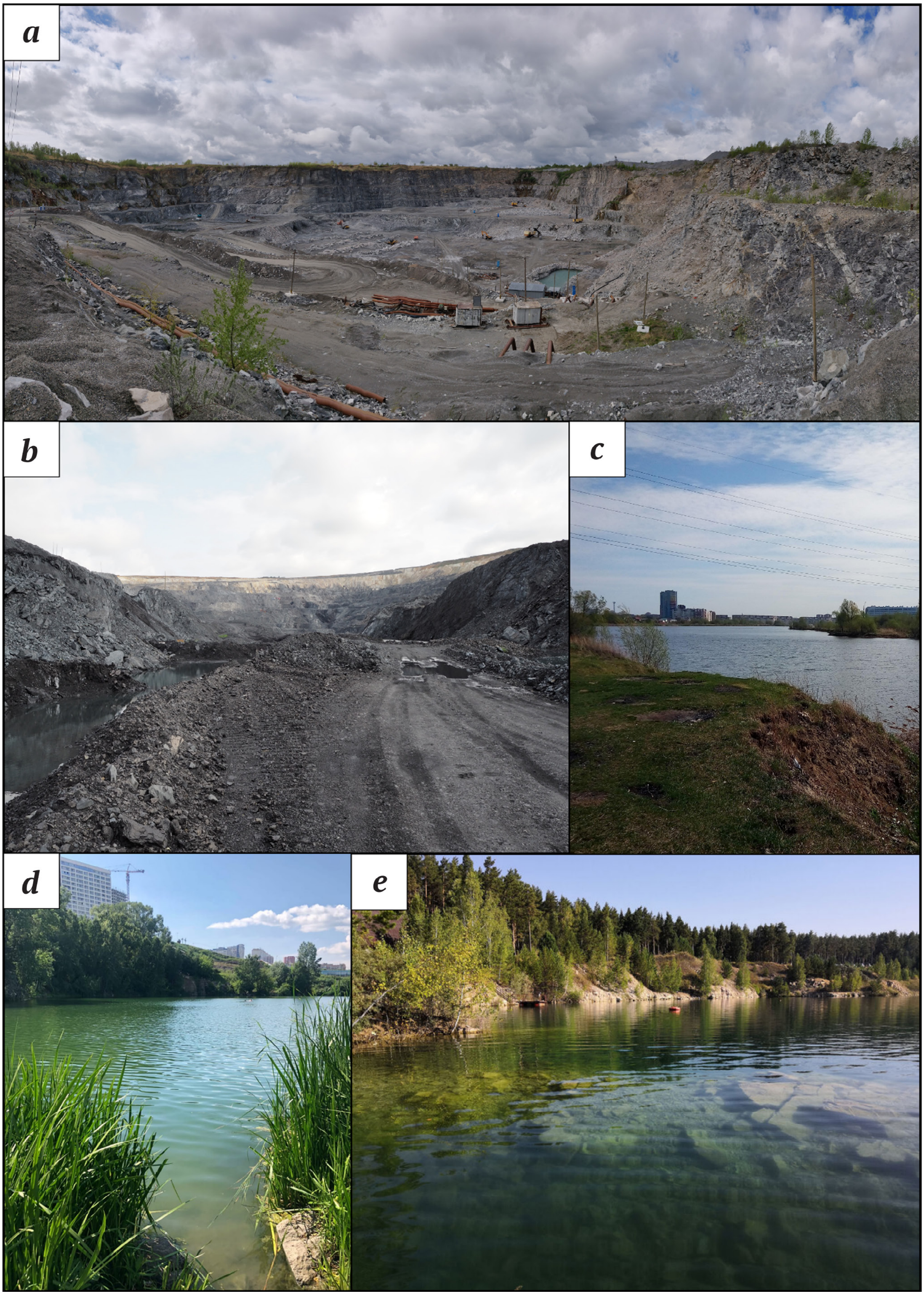

Fig. 3. Studied facilities. Quarries: Borok (*a*); Kolyvansky (*b*); Kirovsky (*c*); Gorsky (*d*); Abrashinskiy (*e*)

The studied coal quarries correspond to the similar-named deposits located within the Gorlovka coal basin. The latter has a highly complex geological structure, and is a narrow (4–8 km) graben-syncline that is elongated from northwest to southeast and sandwiched between the Kolyvan-Tomsk folded zone in the northwest and the Salair Ridge in the east. This basin is characterized by a single waterlogged fractured zone in sedimentary-terrigenous Upper Paleozoic rocks: medium- and fine-grained coal-bearing sandstone, siltstone, mudstone, carbonaceous mudstone and coal seams.

The studied construction sand quarries are characterized by a different position relative to granitoid massifs: the Podgorny quarry is located in the inner part of the Kolyvansky granitoid massif, while the Kirovsky sand quarry is located in the exocontact zone of the Novosibirsk granitoid massif. The latter was focused on the extraction of fine-grained sands from alluvial deposits of the second terrace above the Ob River floodplain. In the Podgorny quarry, sands were excavated from the sediments of the first terrace above the Ob River floodplain.

The Abrashinsky marble quarry is located within Bugotagsky suite (D_2*bg*). In addition to effusive, volcanogenic-sedimentary, and sedimentary rocks, as well as subvolcanic formations, this stratigraphic unit includes layers of marbled limestone. This geological situation therefore suggests that the formation of the Abrashinsky deposit marble occurred due to the impact of a magmatic body on the limestone of the Bugotagsky suite. Such a plutonic body could be a gabbro-dolerite stock, located no further than 3 km west of the quarry. The quarry is also located within a tectonic block, so metamorphosed rocks and a heat source could be spaced along the tectonic boundary.

Geochemical Features

Analysis of available data on drainage water composition allowed identifying three geochemical populations based on coefficients (Ca/Na, Ca/Mg, Ca/Si, Mg/Si, Na/Si, Si/Na, rNa/rCl и SO_4/Cl). The first one includes drainage waters of the developed granite quarries (Novobibeyevsky, Skalinsky, Borok). They have the following coefficient values: Ca/Si 17.61; Mg/Si 4.17; Na/Si 6.73; Mg/Na 4.17; Si/Na 0.25; Ca/Na 2.84; Ca/Mg 4.23; rNa/rCl 5.24; SO_4/Cl 9.14. The second population is represented by the waters of coal quarries (Urgunsky, Gorsky, Kolyvansky). They differ from the first in the increased ratios of Ca/Si 21.49; Mg/Si 9.78; Na/Si 14.89; Mg/Na 9.78; rNa/rCl 7.38; SO_4/Cl 24.91 and decreased Si/Na 0.10; Ca/Na 2.36; Ca/Mg 2.26. The third population includes the flooded quarry waters (granite: Gorsky, Tulinsky; sandy: Kirovsky, Podgorny; marble: Abrashinsky), which differ from the Gorlovka coal basin facilities in terms of their geochemical coefficients by increased Ca/Si 95.84; Mg/Si 51.02; Na/Si 58.82; Mg/Na 50.58; Ca/Mg 3.88 and decreased Si/Na 0.05; Ca/Na 1.75; rNa/rCl 1.77; SO_4/Cl 1.79. The waters of the flooded quarries compared to the first population are characterized by increased ratios of Ca/Si 95.84; Mg/Si 51.02; Na/Si 58.82; Mg/Na 50.58 and decreased Ca/Mg 3.88; Si/Na 0.05; Ca/Na 1.75; rNa/rCl 1.77; SO_4/Cl 1.79.

In this study, drainage waters of the Borok, Kamensky, Tulinsky and Gorsky quarries located within the Novosibirsk Region (similar-named massif) were analyzed. The *Borok* quarry waters are characterized by SO_4–HCO_3 Na–Mg–Ca, Cl–SO_4–HCO_3 Mg–Na–Ca and Cl–SO_4–HCO_3 Na–Mg–Ca compositions (Fig. 4, Table 1) with a total salinity of 583–697 mg/dm^3 and a silicon concentration of 0,89–10,53 mg/dm^3. The geochemical parameters of the geological environment correspond to the oxidizing conditions with Eh +150,2 – +261,0 mV, pH 7,6–8,5 and $O_{2dissolved}$ 3.43–11.43 mg/dm^3. The average values of the geochemical coefficients (ratios) are as follows: Ca/Si 23.54; Mg/Si 5.32; Na/Si 9.64; Mg/Na 0.53; Si/Na 1.15; Ca/Na 2.34; Ca/Mg 4.49; rNa/rCl 2.67; SO_4/Cl 3.63 (Figure 5).

Kamensky quarry waters are characterised by SO_4–Cl–HCO_3/Ca–Na composition with a total salinity of 166–349 mg/dm^3 and a silicon concentration of 1.87–4.21 mg/dm^3. The waters are characterized by a slightly alkaline pH of 7.6–8.5 and an $O_{2dissolved}$ concentration of 4.00 mg/dm^3. The average geochemical coefficients are increased in Ca/Mg (8.68) and decreased in Mg/Na (0.24); Ca/Na (1.52); rNa/rCl (1.19); SO_4/Cl (0.76). *Tulinsky* quarry waters are haracterised by Cl–SO_4–HCO_3/Na–Ca–Mg and SO_4–Cl–HCO_3/Ca–Mg–Na composition with a total salinity of 454–541 mg/dm^3 and a silicon concentration of 0.32–0.78 mg/dm^3. The geological environment geochemical parameters correspond to oxidizingizing conditions with Eh +131.3 – +250.0 mV, pH 8.7–8.8 and $O_{2dissolved}$ 8.58–11.30 mg/dm^3. The average geochemical coefficients are as follows: Ca/Si, 88.39; Mg/Si, 60.92; Na/Si, 103.45; Mg/Na, 0.66; Si/Na, 0.01; Ca/Na, 0.92; Ca/Mg, 1.43; rNa/rCl, 2.06; SO_4/Cl, 1.51. *Gorsky* quarry waters are characterized by a Cl–SO_4–HCO_3/Na–Mg–Ca and SO_4–Cl–HCO_3/Na–Mg–Ca composition with a total salinity of 403 mg/dm^3 and a silicon concentration of 0.25–0.40 mg/dm^3. The geological environment geochemical parameters correspond to oxidizing conditions with Eh +139.3 – +250.0 mV, pH 8.5–8.7 and $O_{2dissolved}$ 8.20–16.59 mg/dm^3. The average geochemical coefficients are increased for Ca/Si, 154.83; Mg/Si, 81.38; Mg/Na, 1.13; Ca/Na, 2.17; Ca/Mg, 1.91, and decreased for Na/Si, 74.32; rNa/rCl, 1.05; SO_4/Cl, 1.33, while comparable values are characteristic for Si/Na (0.02). Overall, the values of the geochemical coefficients for all quarries are characteristic of sulfide oxidation, which is pronounced in the values of the ratios SO_4/Cl (0.67–11.51) and rNa/rCl (0.53–9.19).

Novobibeyevsky quarry waters drain the Ob massif granitoids and are characterized by a SO_4–HCO_3/Na–Mg–Ca composition with a total a salinity of 385–461 mg/dm^3 and a silicon concentration of 5.02–9.60 mg/dm^3. The geological environment geochemical parameters correspond to oxidizing conditions with Eh +107.8 – +145.6 mV, pH 7.8–8.6 and $O_{2dissolved}$ 6.50–14.38 mg/dm^3. The averaged geochemical coefficients are as follows: Ca/Si, 9.55; Mg/Si, 3.07; Na/Si, 2.97; Mg/Na, 1.08; Si/Na, 0.39; Ca/Na, 3.51; Ca/Mg, 3.33; rNa/rCl, 9.46; SO_4/Cl, 11.49. *Skalinsky* quarry waters correlate with the Barlak granite-leucogranite mesoabyssal complex. They belong to the chemical types HCO_3–SO_4/Na–Mg–Ca and SO_4–HCO_3/Na–Mg–Ca with a total salinity of 279–787 mg/dm^3 and a silicon concentration of 8.22–10.21 mg/dm^3. The geological environment geochemical parameters correspond to oxidizing conditions with Eh +84.6 – +167.0 mV, pH 6.9–7.0 and

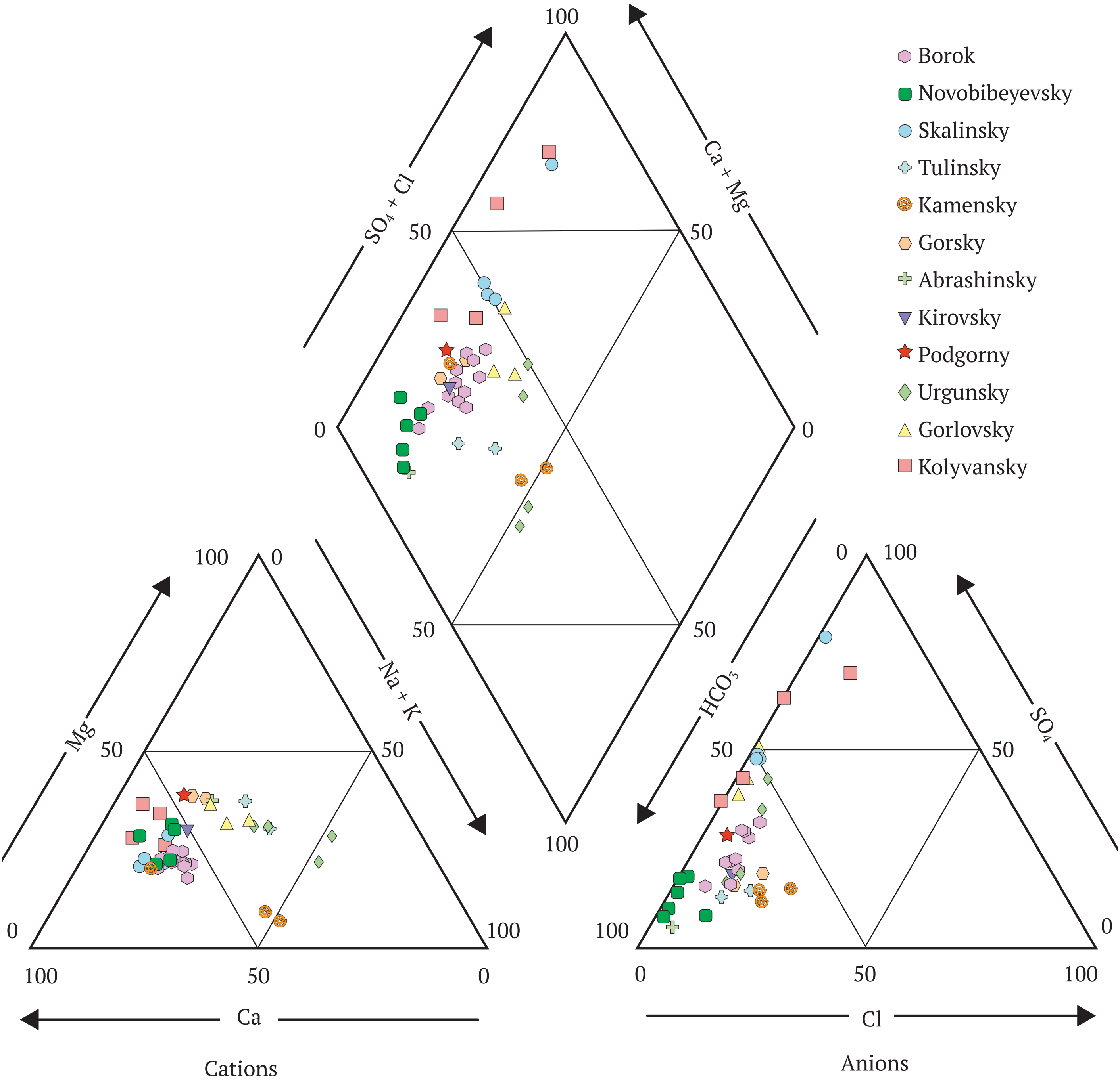

Fig. 4. Drainage water chemistry Piper diagram

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Table 1

Chemical composition of drainage waters of the Novosibirsk Region quarries

No. in Fig. 1	pH	Eh, mV	O_2, mg/dm³	^{222}Rn, Bq/dm³	HCO_3^-	SO_4^{2-}	Cl^-	Ca^{2+}	Mg^{2+}	Na^+	K^+	M	Si	Th	U	Th/U	Chemical type
					mg/dm³												
1	8.3	261.0	9.30	17	378	96	38	101	22	50	4.2	697	6.98	$5.10\cdot10^{-5}$	$9.26\cdot10^{-2}$	$5.51\cdot10^{-4}$	Cl–SO_4–HCO_3 Mg–Na–Ca
1	8.1	225.0	10.58	19	371	107	32	109	25	41	4.0	696	0.89	$1.24\cdot10^{-5}$	$1.08\cdot10^{-2}$	$1.15\cdot10^{-3}$	SO_4–HCO_3 Na–Mg–Ca
1	8.3	256.3	10.90	4	378	90	34	102	19	54	3.9	687	7.07	$9.90\cdot10^{-6}$	$8.00\cdot10^{-2}$	$1.24\cdot10^{-4}$	Cl–SO_4–HCO_3 Mg–Na–Ca
1	8.3	246.5	11.21	1	348	82	28	90	21	45	3.6	619	6.70	$5.40\cdot10^{-6}$	$2.96\cdot10^{-2}$	$1.82\cdot10^{-4}$	SO_4–HCO_3 Mg–Na–Ca
1	8.3	244.7	11.43	8	388	58	25	99	22	35	2.7	630	5.96	$6.50\cdot10^{-6}$	$9.30\cdot10^{-3}$	$6.99\cdot10^{-4}$	SO_4–HCO_3 Na–Mg–Ca
1	8.5	215.8	11.10	16	386	61	5	95	18	32	5.0	603	5.03	$1.00\cdot10^{-6}$	$1.03\cdot10^{-2}$	$9.71\cdot10^{-5}$	SO_4–HCO_3 Na–Mg–Ca
1	7.6	194.3	3.61	45	319	111	36	97	26	44	4.7	660	7.74	$1.39\cdot10^{-5}$	1.16E-01	$1.20\cdot10^{-4}$	Cl–SO_4–HCO_3 Na–Mg–Ca
1	8.2	195.1	8.55	38	308	113	29	94	24	37	3.9	619	6.70	–	$1.19\cdot10^{-2}$	–	SO_4–HCO_3 Na–Mg–Ca
1	7.6	184.7	3.43	88	320	118	28	95	22	50	6.2	663	10.53	$5.48\cdot10^{-5}$	$2.13\cdot10^{-1}$	$2.57\cdot10^{-4}$	SO_4–HCO_3 Mg–Na–Ca
1	8.2	209.7	8.98	89	331	56	37	89	21	36	4.7	583	4.85	$1.54\cdot10^{-5}$	$1.03\cdot10^{-2}$	$1.49\cdot10^{-3}$	Cl–SO_4–HCO_3 Na–Mg–Ca
1	7.9	201.7	7.52	51	352	77	41	101	22	41	4.5	652	6.56	$9.62\cdot10^{-5}$	$9.15\cdot10^{-2}$	$1.05\cdot10^{-3}$	Cl–SO_4–HCO_3 Na–Mg–Ca
1	8.0	150.2	7.11	57	272	116	34	91	21	43	3.9	605	7.11	$4.62\cdot10^{-5}$	$7.95\cdot10^{-2}$	$5.81\cdot10^{-4}$	Cl–SO_4–HCO_3 Mg–Na–Ca
2	7.8	107.8	6.49	25	224	20	3	55	15	20	3.3	385	7.00	$2.60\cdot10^{-6}$	$1.07\cdot10^{-2}$	$2.43\cdot10^{-4}$	SO_4–HCO_3 Na–Mg–Ca
2	8.0	111.0	7.91	15	248	28	3	65	16	20	3.0	434	6.49	–	$1.02\cdot10^{-2}$	–	SO_4–HCO_3 Na–Mg–Ca
2	8.6	121.7	14.39	6	232	48	3	58	22	20	2.3	433	5.02	$1.76\cdot10^{-5}$	$1.02\cdot10^{-2}$	$1.72\cdot10^{-3}$	SO_4–HCO_3 Na–Mg–Ca
2	7.9	139.7	7.88	39	256	40	3	62	25	20	2.9	461	5.72	$2.90\cdot10^{-5}$	$1.08\cdot10^{-2}$	$2.69\cdot10^{-3}$	SO_4–HCO_3 Na–Mg–Ca
2	8.1	145.6	7.44	2	268	43	3	72	20	13	4.5	423	9.60	$3.10\cdot10^{-5}$	$1.16\cdot10^{-2}$	$2.67\cdot10^{-3}$	SO_4–HCO_3 Mg–Ca
3	6.9	84.6	4.58	573	67.1	215	6	120	22	29	5.1	787	8.34	$2.96\cdot10^{-4}$	1.40	$2.12\cdot10^{-4}$	HCO_3–SO_4 Na–Mg–Ca
3	6.9	153.6	4.60	495	140	106	7	105	22	27	4.1	773	8.22	$3.93\cdot10^{-5}$	$9.38\cdot10^{-1}$	$4.20\cdot10^{-5}$	SO_4–HCO_3 Na–Mg–Ca
3	7.0	167.0	4.49	154	98	73	4	63	19	20	4.5	282	10.21	$3.90\cdot10^{-4}$	1.16	$3.35\cdot10^{-4}$	HCO_3–SO_4 Na–Mg–Ca
3	7.0	164.5	3.75	259	98	77	4	62	13	21	4.5	279	9.96	$2.16\cdot10^{-3}$	1.21	$1.78\cdot10^{-3}$	SO_4–HCO_3 Na–Mg–Ca
4	8.8	250.0	11.30	2	325	53	31	46	35	43	7.8	541	0.78	$3.20\cdot10^{-6}$	$1.21\cdot10^{-2}$	$2.64\cdot10^{-4}$	Cl–SO_4–HCO_3 Na–Ca–Mg
4	8.7	131.3	8.58	–	244	49	38	37	24	48	8.6	454	0.32	$7.08\cdot10^{-6}$	$1.23\cdot10^{-2}$	$5.77\cdot10^{-4}$	SO_4–Cl–HCO_3 Ca–Mg–Na
5	7.5	–	–	–	109	18	20	–	–	–	–	166	3.27	–	–	–	–
5	6.9	–	4.00	–	183	24	36	59	11	19		349	4.21	–	–	–	SO_4–Cl–HCO_3 Na–Mg–Ca
5		–	–	–	146	28	39	35	3	51		316	1.87	–	–	–	SO_4–Cl–HCO_3 Ca–Na
5	7.5	–	–	–	109	18	20	27	3	35		231	3.27	–	–	–	SO_4–Cl–HCO_3 Ca–Na
5		–	–	–	146	28	39					228	1.87	–	–	–	–
6	8.7	250.0	16.59	–	239	40	29	48	24	20	3.7	403	0.40	$1.00\cdot10^{-5}$	$9.80\cdot10^{-3}$	$1.02\cdot10^{-3}$	Cl–SO_4–HCO_3 Na–Mg–Ca
6	8.5	139.3	8.21	–	207	47	37	48	26	25	4.5	403	0.25	$1.15\cdot10^{-5}$	$1.24\cdot10^{-2}$	$9.30\cdot10^{-4}$	SO_4–Cl–HCO_3 Na–Mg–Ca
7	8.6	144.0	5.42	31	239	16	8	36	22	22	1.4	353	0.29	$1.65\cdot10^{-6}$	$2.28\cdot10^{-3}$	$7.24\cdot10^{-4}$	HCO_3 Na–Ca–Mg
8	8.7	205.0	15.50	2	449	107	45	100	41	45	2.0	789	1.29	–	$3.00\cdot10^{-4}$	–	Cl–SO_4–HCO_3 Na–Mg–Ca
9	8.4	186.5	9.34	–	177	59	11	42	21	15	3.2	330	0.18	$6.47\cdot10^{-6}$	$2.74\cdot10^{-2}$	$2.36\cdot10^{-4}$	SO_4–HCO_3 Na–Mg–Ca
10	8.3	145.6	7.70	–	561	96	57	65	33	158	2.5	973	6.55	$1.92\cdot10^{-5}$	$5.97\cdot10^{-3}$	$3.22\cdot10^{-3}$	Cl–SO_4–HCO_3 Mg–Ca–Na
10	8.2	160.4	8.16	–	378	186	44	72	42	97	3.9	823	3.68	$1.40\cdot10^{-5}$	$1.67\cdot10^{-2}$	$8.37\cdot10^{-4}$	Cl–SO_4–HCO_3 Mg–Ca–Na
10	7.5	148.8	6.81	–	360	240	36	83	43	94	4.4	860	5.24	$3.78\cdot10^{-5}$	$1.30\cdot10^{-2}$	$2.91\cdot10^{-3}$	SO_4–HCO_3 Mg–Na–Ca
10	8.5	133.2	8.26	–	344	71	43	32	28	102	2.5	625	6.59	$2.68\cdot10^{-5}$	$7.86\cdot10^{-3}$	$3.41\cdot10^{-3}$	Cl–SO_4–HCO_3 Ca–Mg–Na
11	8.1	174.7	8.58	–	315	289	4	90	53	54	2.9	808	4.15	$7.15\cdot10^{-6}$	$3.41\cdot10^{-3}$	$2.10\cdot10^{-3}$	HCO_3–SO_4 Na–Mg–Ca
11	7.7	185.2	7.44	–	421	243	12	96	51	77	3.2	907	4.19	$1.59\cdot10^{-5}$	$2.26\cdot10^{-3}$	$7.02\cdot10^{-3}$	SO_4–HCO_3 Na–Mg–Ca
11	7.8	190.4	7.61	–	414	285	11	88	54	94	4.4	950	4.15	$4.68\cdot10^{-5}$	$4.02\cdot10^{-3}$	$1.17\cdot10^{-2}$	SO_4–HCO_3 Na–Ca–Mg
12	7.8	190.7	7.65	–	302	182	9	104	28	36	3.0	673	5.25	–	$9.16\cdot10^{-3}$	–	SO_4–HCO_3 Na–Mg–Ca
12	7.5	198.8	8.40	–	153	456	65	150	56	40	1.7	922	4.62	$5.57\cdot10^{-4}$	$1.16\cdot10^{-2}$	$4.80\cdot10^{-2}$	Cl–HCO_3–SO_4 Na–Mg–Ca
12	8.0	194.8	10.43	–	257	118	2	84	22	13	3.3	500	3.80	$9.32\cdot10^{-6}$	$1.11\cdot10^{-2}$	$8.39\cdot10^{-4}$	SO_4–HCO_3 Mg–Ca
12	8.0	199.6	9.18	–	366	502	9	190	72	28	4.1	1171	4.13	$4.47\cdot10^{-4}$	$2.90\cdot10^{-2}$	$1.54\cdot10^{-2}$	HCO_3–SO_4 Mg–Ca

Note: "–" – data are not available; M is total salinity.

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$O_{2dissolved}$ 3.75–4.60 mg/dm³. Compared to the *Novobibeyevsky* quarry waters, the average values of the geochemical coefficients are almost similar, and are as follows: Ca/Si, 9.89; Mg/Si, 2.12; Na/Si, 2.71; Mg/Na, 0.78; Si/Na, 0.39; Ca/Na, 3.52; Ca/Mg, 4.59; rNa/rCl, 7.65; SO_4/Cl, 22.76.

The Gorlovka coal basin drainage waters have been studied in several quarries. Thus, *Gorlovka* quarry waters are characterized by a HCO_3–SO_4/Na–Mg–Ca and SO_4–HCO_3/Na–Mg–Ca composition with a total salinity of 808–950 mg/dm³ and a silicon concentration of 8.22–10.21 mg/dm³. The geological environment geochemical parameters correspond to oxidizing conditions with Eh +174.7 – +190.4 mV, pH 7.7–8.1 and $O_{2dissolved}$ 7.44–8.58 mg/dm³. The averaged values of geochemical coefficients are as follows: Ca/Si, 21.95; Mg/Si, 12.70; Na/Si, 18.01; Mg/Na, 0.74; Si/Na, 0.06; Ca/Na, 1.28; Ca/Mg, 1.73; rNa/rCl, 14.36; SO_4/Cl, 38.19. *Urgunsky* quarry waters are characterized by a Cl–SO_4–HCO_3/Mg–Ca–Na composition with a total salinity of 625–973 mg/dm³ and a silicon concentration of 3.68–6.59 mg/dm³. The geological environment geochemical parameters correspond to oxidizing conditions with Eh +133.2 – +160.4 mV, pH 7.5–8.5 and $O_{2dissolved}$ 6.81–8.26 mg/dm³. The average values of the geochemical coefficients compared to those de-

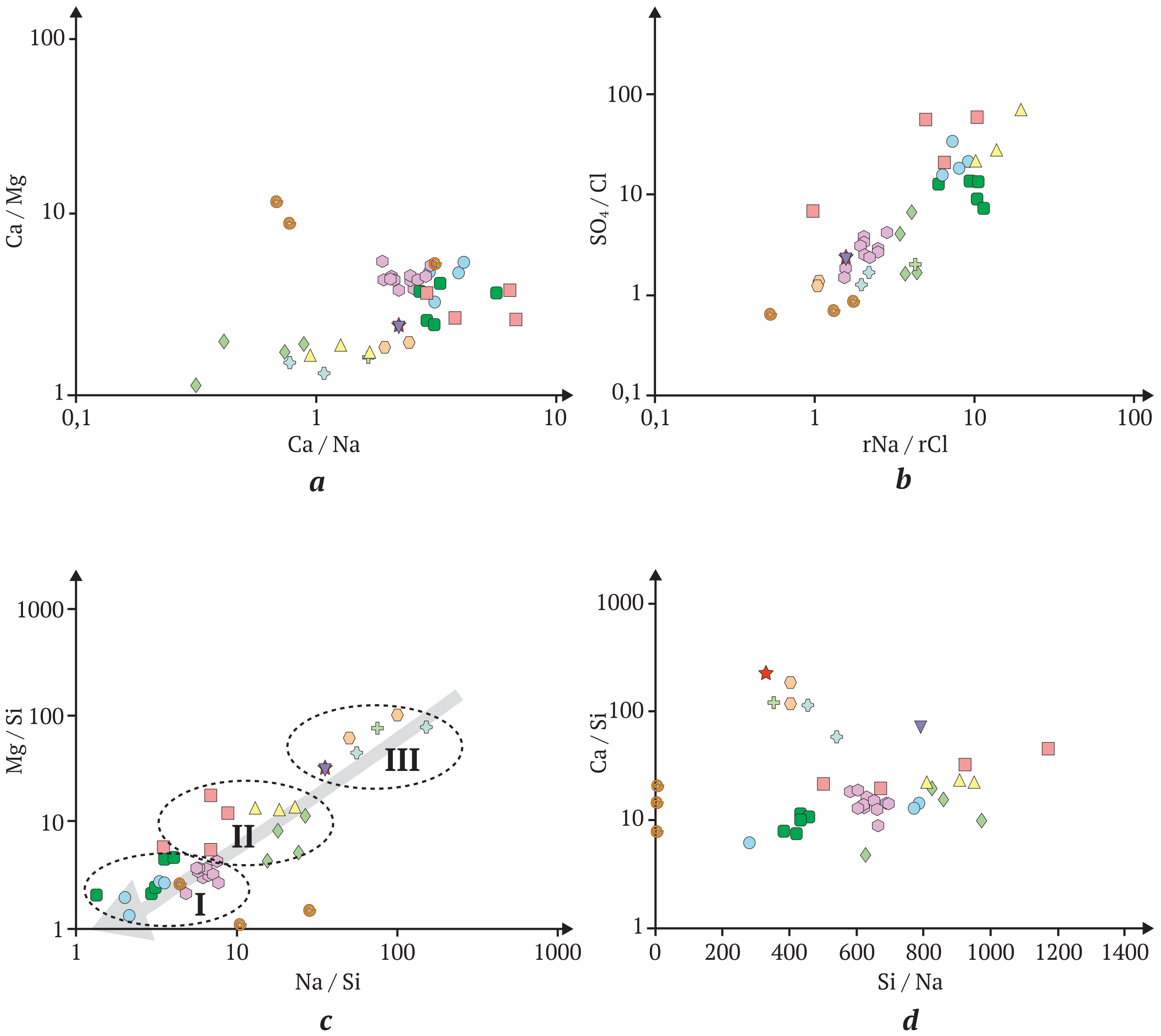

Fig. 5. Geochemical types of drainage water based on the relationship of the coefficients Ca/Mg – Ca/Na (*a*), SO_4/Cl – rNa/rCl (*b*), Mg/Si – Na/Si (*c*), Ca/Si – Si/Na (*d*). The arrow indicates an increase in the silicon concentration. See Legend in Fig. 4

scribed above are higher for Na/Si, 20.99 and lower for Ca/Si, 12.55; Mg/Si, 7.21; Mg/Na, 0.34; Si/Na, 0.05; Ca/Na, 0.59; Ca/Mg, 1.69; rNa/rCl, 3.84; SO_4/Cl, 3.56. *Kolyvansky* quarry waters are characterized by a Cl–HCO_3–SO_4/Na–Mg–Ca and SO_4–HCO_3/Mg–Ca composition with a total salinity of 500–1171 mg/dm^3 and a silicon concentration of 3.80–5.25 mg/dm^3. The geological environment geochemical parameters correspond to oxidizing conditions with Eh +190.7 – +199.6 mV, pH 7.5–8.0 and an $O_{2dissolved}$ concentration of 7.65–10.43 mg/dm^3. Compared to the Gorlovka quarrywaters, these waters are characterized by increased Ca/Si, 30.10; Si/Na, 0.17; Ca/Na, 4.93; Ca/Mg, 3.21 and decreased Mg/Si, 10.17; Na/Si, 6.46; Mg/Na, 1.60; rNa/rCl, 5.69; SO_4/Cl, 36.28. Drainage waters of the Gorlovka coal basin are characterized by high concentrations of sulfates (71–502 mg/dm^3) and sodium (13–158 mg/dm^3), as well as increased Na/Si, rNa/rCl, SO_4/Cl ratios, which indicate sulfide oxidation processes.

Abrashinsky marble quarry drainage waters are characterized by a HCO_3/Na–Ca–Mg composition with a total salinity of 500–1171 mg/dm^3 and a silicon concentration of 3.80–5.25 mg/dm^3. The geological environment geochemical parameters correspond to oxidizing conditions with Eh +190.7 – +199.6 mV, pH 7.5–8.0 and $O_{2dissolved}$ 7.65 – 10.43 mg/dm^3. The average values of the geochemical coefficients are: Ca/Si, 123.50; Mg/Si, 75.47; Na/Si, 74.95; Mg/Na, 1.01; Si/Na, 0.01; Ca/Na, 1.65; Ca/Mg, 1.64; rNa/rCl, 4.24; SO_4/Cl, 2.03. Abrashinsky quarry waters accumulate magnesium, sodium and calcium that is expressed in high Ca/Si, Mg/Si and Na/Si ratios.

Kirovsky sand quarry waters are characterized by a Cl–SO_4–HCO_3/Na–Mg–Ca composition with a total salinity of 789 mg/dm^3 and a silicon concentration of 1.29 mg/dm^3. The geological environment geochemical parameters correspond to oxidizing conditions with Eh +205.0 mV, pH 8.7 and an $O_{2dissolved}$ concentration of 15.50–3 mg/dm^3. The average values of the geochemical coefficients are as follows: Ca/Si, 77.52; Mg/Si, 31.71; Na/Si, 35.09; Mg/Na, 0.90; Si/Na, 0.03; Ca/Na, 2.21; Ca/Mg, 2.44; rNa/rCl, 1.55; SO_4/Cl, 2.38. *Podgorny* sand quarry waters are characterized by a SO_4–HCO_3/Na–Mg–Ca composition with a total salinity of 330 mg/dm^3 and a silicon concentration of 0.18 mg/dm^3. The geological environment geochemical parameters correspond to oxidizing conditions with Eh +186.5 mV, pH 8.4 and O2dissolved 9.34 mg/dm^3. The average values of the geochemical coefficients are increased for Ca/Si, 229.91; Mg/Si, 113.31; Na/Si, 80.12; Mg/Na, 1.41; Ca/Na, 2.87; rNa/rCl, 2.11; SO_4/Cl, 5.51 and decreased for Si/Na, 0.01; Ca/Mg, 2.03. The geochemical coefficients indicate that the Podgorny quarry waters are enriched with calcium, magnesium and sodium.

Types of Radionuclides

The development of solid mineral (ore and non-metallic) deposits carries a significant threat to the environment. This primarily applies to the elements of the first hazard class, which include beryllium, arsenic, mercury and thallium[1]. The influence of radionuclides on ecosystems is also extremely dangerous, despite the fact that uranium now belongs to the second hazard class (MPC of 15 μg/dm^3). The applicable regulatory documents of the Russian Federation indicate that there are no approved MPCs (maximum permissible concentrations) for thorium. The natural radioactivity of natural waters of various isotopic-geochemical compositions attracts genuine interest in the world. In this regard, in this work, for the first time, studies were carried out to assess the distribution of uranium and thorium in drainage waters, given that the studied region is characterized by an increased natural background radiation due to the presence of scattered radioactive minerals in granite and granodiorite. The features of the distribution of uranium, thorium and radon in the waters of the studied quarries are considered below.

The current concentrations of natural radionuclides in the *Borok* quarry waters are within the following limits (mg/dm^3): ^{238}U from 0.009 to 0.213 and ^{232}Th from $1.00 \cdot 10^{-6}$ to $9.62 \cdot 10^{-5}$. The ^{232}Th/^{238}U ratio in the waters ranges from $9.71 \cdot 10^{-5}$ to $1.49 \cdot 10^{-3}$ (Fig. 6). The ^{222}Rn activity ranges from 1 to 89 Bq/dm^3, which allows referring them to the class of very low- radon waters (according to the classification of N.I. Tolstikhin) [1]. The concentration of natural radionuclides in the Tulinsky quarry waters varies in the following ranges (mg/dm^3): ^{238}U from 0.0121 to 0.0123 and ^{232}Th from $3.20 \cdot 10^{-6}$ to $7.08 \cdot 10^{-6}$. The ^{232}Th/^{238}U ratio in the waters varies in the range from $2.4 \cdot 10^{-4}$ to $5.77 \cdot 10^{-4}$, and the ^{222}Rn activity does not exceed 2 Bq/dm^3. The concentration of natural radionuclides in the *Gorsky* quarry waters ranges as follows (mg/dm^3): ^{238}U from 0.010 to 0.012 and ^{232}Th from $1.00 \cdot 10^{-5}$ to $1.15 \cdot 10^{-5}$. ^{232}Th/^{238}U ratio in the waters ranges from $9.30 \cdot 10^{-4}$ to $1.02 \cdot 10^{-3}$.

Novobibeyevsky quarry waters contain natural radionuclides within the following limits (mg/dm^3): 238U from 0.010 to 0.012 and ^{232}Th from $2.60 \cdot 10^{-6}$ to $3.10 \cdot 10^{-5}$. ^{232}Th/^{238}U ratio in the waters ranges from $2.43 \cdot 10^{-4}$ to $2.69 \cdot 10^{-3}$. The ^{222}Rn activity varies from 2 to 39 Bq/dm^3, which allows classifying them as very low-radon. *Skalinsky* quarry waters contain natural radionuclides within the following limits (mg/dm^3): ^{238}U from 0.940 to 1.400 and ^{232}Th from $3.93 \cdot 10^{-5}$ to

[1] GOST R 58573-2019 “The nature conservancy. Hydrosphere. Water quality. Risk-based control”; GOST R 58556-2019 “Assessment of water quality of water bodies from ecological view points”.

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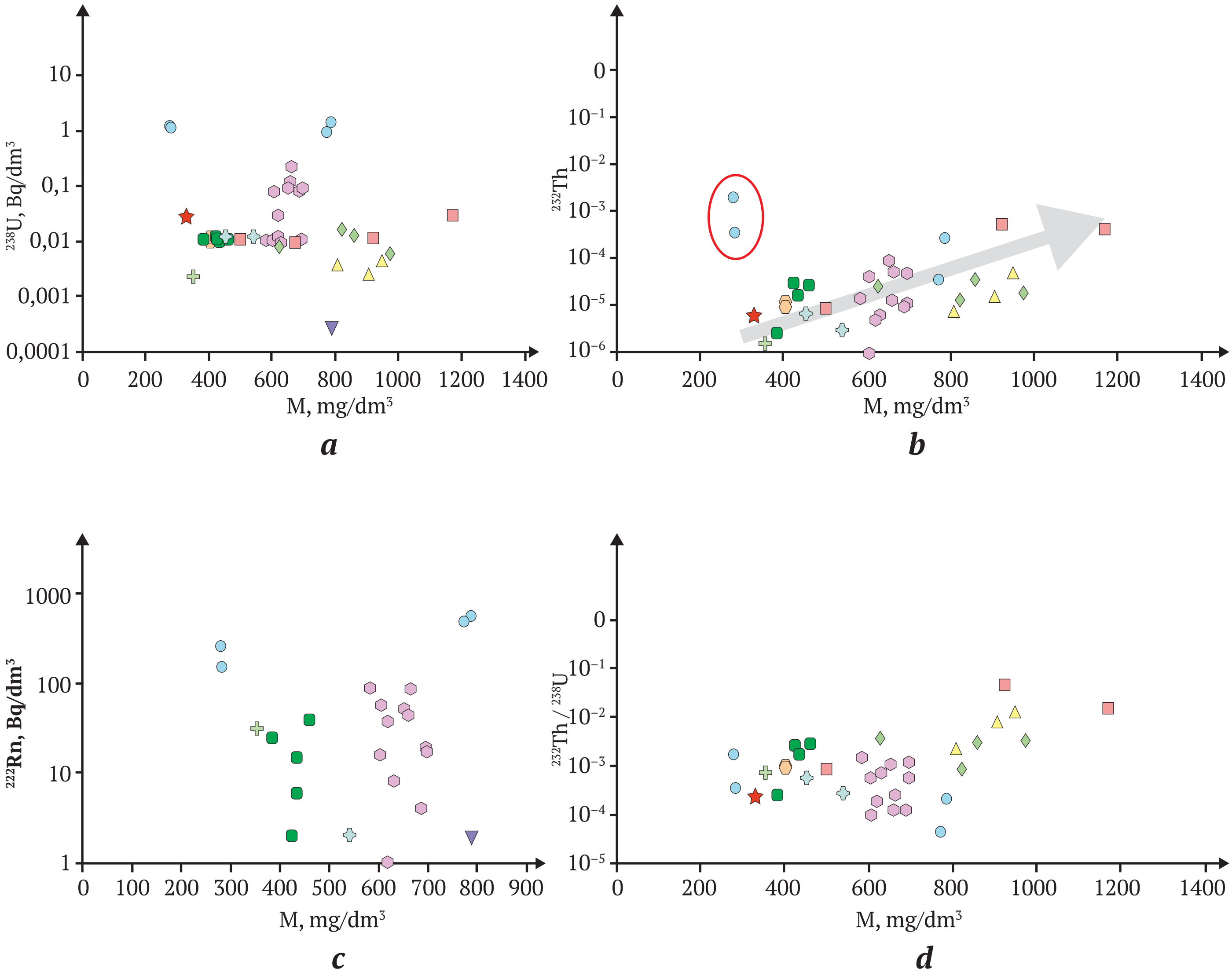

Fig. 6. Radionuclide composition as a function of the total salinity of drainage waters

$2.16\cdot10^{-5}$. ^{232}Th/^{238}U ratio in the waters ranges from $4.20\cdot10^{-5}$ to $1.78\cdot10^{-3}$. The ^{222}Rn activity ranges from 154 to 573 Bq/dm^3, which allows classifying the waters as low-radon and moderately-radon waters.

The concentration of natural radionuclides in the *Gorlovka* quarry waters are as follows (mg/dm^3): ^{238}U from 0.002 to 0.004 and ^{232}Th from $7.15\cdot10^{-6}$ to $4.68\cdot10^{-5}$. The ^{232}Th/^{238}U ratio in the waters ranges from $2.10\cdot10^{-3}$ to $1.17\cdot10^{-2}$. The radionuclide concentrations in the *Urgunsky* quarry waters are as follows (mg/dm^3): ^{238}U from 0.006 to 0.017 and ^{232}Th from $1.40\cdot10^{-5}$ to $3.78\cdot10^{-5}$. ^{232}Th/^{238}U ratio in the waters ranges from $8.37\cdot10^{-4}$ to $3.41\cdot10^{-3}$. The concentration of ^{238}U in the *Kolyvansky* quarry watersvaries from 0.009 to 0.029 and that of ^{232}Th from $9.32\cdot10^{-6}$ to $5.57\cdot10^{-4}$, while the ^{232}Th/^{238}U ratio ranges from $8.39\cdot10^{-4}$ to $4.80\cdot10^{-2}$.

The radionuclide concentrations in the *Abrashinsky* quarry waters do not exceed the following levels (mg/dm^3): ^{238}U, 0.002 and ^{232}Th, $1.65\cdot10^{-6}$. ^{232}Th/^{238}U ratio in the waters is $7.24\cdot10^{-4}$, the ^{222}Rn activity is 31 Bq/dm^3.

The thorium concentration in the *Kirovsky* quarry watersis $3.00\cdot10^{-4}$ mg/dm^3, and the ^{222}Rn activity does not exceed 2 Bq/dm^3. The concentration of natural radionuclides in the *Podgorny* quarry waters is as follows (mg/dm^3): ^{238}U, 0.027 and ^{232}Th, $6.47\cdot10^{-6}$, and the ^{232}Th/^{238}U ratio is $2.36\cdot10^{-4}$.

This paper assesses the environmental impact of the drainage water discharge from minedquarries (on non-metal deposits) in the eastern districts of the Novosibirsk Region. The volumes of radionuclides carried by drainage waters was assessed using the example of the Borok quarry. The automaticaccounting indicate an average drainage water volume of 2.3 million m^3 per year. The average concentrations of uranium and thorium are $6.58\cdot10^{-2}$ mg/dm^3 and $2.67\cdot10{-5}$ mg/dm^3, respectively, based on the data of the geochemical studies of the waters. Thus, the annual uranium and thorium discharge volumes are 151.4 and 61.4 kg, respectively. It is important to note that radioactive element contamination of the Inya River into which the waters are discharged is not observed. Due to the mixing of river waters with drainage waters, the concentrations (mg/dm^3) in the river water are as follows: the concentrations of ^{238}U range from $2.32 \cdot 10^{-3}$ to $2.40 \cdot 10^{-3}$ and those of ^{232}Th from $3.08 \cdot 10^{-6}$ to $1.39 \cdot 10^{-5}$. Similar assessments were carried out for the Oyash, Chaus, and Elbash rivers into which the drainage waters are discharged from the Novobibeyevsky and Skalinsky quarries and the Gorlovka coal basin quarries, respectively. Thus, the radionuclide concentrations in the Oyash river are as follows (mg/dm^3): 238U, $2.36 \cdot 10^{-3}$; ^{232}Th, $5.85 \cdot 10^{-6}$, in the Chaus river U, $3.55 \cdot 10^{-3}$; Th, $4.09 \cdot 10^{-6}$, and in the Elbash river $2.46 \cdot 10^{-3}$ and $4.54 \cdot 10^{-6}$, respectively. The identified radionuclide concentrations in the river waters are correlated with radiochemical background values for surface waters in the Novosibirsk Region.

Conclusion

The study findings can be summarized briefly as follows.

Geological and hydrogeological conditions directly influence the geochemical parameters of the surveyed waters. As such, granite and coal quarry waters are characterized by a neutral pH, while sand and marble quarries are mainly characterized by alkaline conditions (pH > 7). Coal quarries are also observed to generate greater quantities of mineralized waters with a total salinity of up to 1,171 mg/dm^3, which corresponds to the low-salinity water category, while the other studied quarry drainage waters are ultra-fresh/actually fresh waters. This fact is not surprising, since the Gorlovka coal basin is hosted by sedimentary strata containing more ancient and salty waters not occurring in granite massifs. The calculated geochemical coefficients (Ca / Na, Ca / Mg, Ca / Si, Mg / Si, Na / Si, Si / Na, rNa / rCl, and SO_4 / Cl) allow concluding that the waters of the sand and marble quarries accumulate sodium, calcium and magnesium to a greater extent, while the granite and coal quarry waters accumulate silicon. The growth of the sodium concentration in quarry waters is also due to anthropogenic pollution. The highest radionuclide concentrations were detected in the waters of granite massif quarries, where uranium and thorium concentrations reached 1.40 mg/dm^3 and $2.16 \cdot 10^{-3}$ mg/dm^3, respectively, since the rocks contain increased radionuclide concentrations. The studies indicate that the development of industrial mineral and coal deposits does not pose a danger to the environment in terms of water pollution. The discharge of drainage water into the river system of the eastern districts of the Novosibirsk Region does not affect the quality of surface water.

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Information about the authors

Anton S. Derkachev – Engineer, Laboratory of Hydrogeology of Sedimentary Basins of Siberia, Trofimuk Institute of Petroleum Geology and Geophysics of Siberian Branch of Russian Academy of Sciences, Novosibirsk, Russian Federation; Novosibirsk State University, Novosibirsk, Russian Federation; Scopus ID 57223290521; e-mail a.derkachev@g.nsu.ru

Anastasia A. Maksimova – Junior Researcher, Laboratory of Hydrogeology of Sedimentary Basins of Siberia, Trofimuk Institute of Petroleum Geology and Geophysics of Siberian Branch of Russian Academy of Sciences, Novosibirsk, Russian Federation; Novosibirsk State University, Novosibirsk, Russian Federation; ORCID 0000-0002-5068-555X, Scopus ID 57221031742; e-mail rock.nastaya64@gmail.com

Dmitry A. Novikov – Cand. Sci. (Geol. and Min.), Researcher, Laboratory of Hydrogeology of Sedimentary Basins of Siberia, Trofimuk Institute of Petroleum Geology and Geophysics of Siberian Branch of Russian Academy of Sciences, Novosibirsk, Russian Federation; Novosibirsk State University, Novosibirsk, Russian Federation; ORCID 0000-0001-9016-3281, Scopus ID 35318389700, ResearcherID N-9520-2015; e-mail NovikovDA@ipgg.sbras.ru

Fedor F. Dultsev – Researcher, Laboratory of Hydrogeology of Sedimentary Basins of Siberia, Trofimuk Institute of Petroleum Geology and Geophysics of Siberian Branch of Russian Academy of Sciences, Novosibirsk, Russian Federation; Novosibirsk State University, Novosibirsk, Russian Federation; ORCID 0000-0002-6848-5775, Scopus ID 57198442950, ResearcherID T-9088-2018; e-mail DultsevFF@ipgg.sbras.ru

Anna F. Sukhorukova – Cand. Sci. (Geol. and Min.), Researcher, Laboratory of Hydrogeology of Sedimentary Basins of Siberia, Trofimuk Institute of Petroleum Geology and Geophysics of Siberian Branch of Russian Academy of Sciences, Novosibirsk, Russian Federation; Scopus ID 56524401600; e-mail SukhorukovaAF@ipgg.sbras.ru

Anatoliy V. Chernykh – Researcher, Laboratory of Hydrogeology of Sedimentary Basins of Siberia, Trofimuk Institute of Petroleum Geology and Geophysics of Siberian Branch of Russian Academy of Sciences, Novosibirsk, Russian Federation; Novosibirsk State University, Novosibirsk, Russian Federation; ORCID 0000-0001-8680-420X, Scopus ID 7005156647; e-mail ChernykhAV@ipgg.sbras.ru

Albina A. Khvashchevskaya – Cand. Sci. (Geol. and Min.), Head of the Problematic Research Laboratory of Hydrogeochemistry, School of Natural Resources Engineering, Tomsk Polytechnic University, Tomsk, Russian Federation; Scopus ID 55799519300; e-mail Garibova@yandex.ru

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