Mass contents of natural radioactive elements in the main types of rocks of the Mesozoic sediments of the West-Siberian Plate and their comparative assessment with the contents in the deposits of some sedimentary basins of the former USSR

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Abstract. The average and boundary contents of natural radioactive elements in sandy, aleuritic, argillaceous, mixed and carbonaceous types of sedimentary rocks of the main groups of productive strata of the Jurassic-Cretaceous age of Western Siberia are estimated; a comparison of the obtained values of the contents of radioelements with their contents in sedimentary deposits of some regions of the former USSR is performed.

1 Introduction

The history of a systematic study of the content of natural radioactive elements (NRE) in the earth's crust begins in the 50s of the last century (Adams, Weaver, 1958; Turekian, Wedepohl, 1961; Taylor, 1964; Lambert, Heier, 1968; Ruffel, Worden, 2000; Ruffel at al., 2003). In the 70-90s, the Novosibirsk and Tyumen researchers I.I.Pluman, V.M. Gavshin, V.A. Bobrov, L.P. Zuev, V.S. Kudryavtsev, V.G. Mamyashev, V.V. Khabarov, E.N. Volkov, N.I. Nefedova, V.M. Ivanov [1-5], and in the 2000s - M.Yu. Zubkov, Yu.A. Kuzmin et al [6-9] studied the regularities of the distribution of NRE in sedimentary terrigenous rocks of Western Siberia. The opportunity to conduct research appeared after the creation of nuclear-geochemical (physical) laboratories on the basis of low-background gamma-ray spectrometric facilities in various research organizations of Novosibirsk and Tyumen. The work resulted in the determination of the average and boundary values of the level of NRE accumulation in the main lithological types of sedimentary rocks, the patterns of distribution of radioelements according to the petrographic composition of sediments, and partially to a stratigraphic scale. In some cases, correlations were established between the content of radioactive elements and the mineral composition, mass clay content and the adsorption properties of terrigenous reservoir rocks.

However, only V. M. Gavshin and co-authors applied a rather strict approach to the statistical processing of the obtained data. As a rule, in the works of other specialists there are no such important parameters of statistical analysis as the sizes of the studied rock samples, the estimation of the error in determining the average NRE contents, the standard deviation, the coefficient of variation, the form of the NRE distribution law in the studied

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objects. Another drawback of previous studies can be considered a small amount of rock material (especially in Novosibirsk) and the limited range of studied objects - productive formations of the geological section - mainly in the Middle Ob region, where the main explored oil and gas deposits were concentrated.

In recent years, based on the NRE analyzes performed in Tyumen organizations, representative electronic data catalogs have been created that include the results of more than 10,000 measurements of the contents of radioactive elements in various oil and gas regions, rock types, stratigraphic units, facies and climatic conditions, in some cases with determination of the mineral properties, particle size distribution and permeability and porosity properties of the samples. All this made it possible to reach a new, higher qualitative and quantitative level of studying the radio geochemical characteristics of the sedimentary cover and pre-Jurassic formations of the West-Siberian Plate, clarify the existing ideas about the contents and patterns of distribution of radioactive elements in rocks with the aim of constructing mathematically sound radio geochemical models of deposits and carrying out radio geological mapping and lithological-facies analysis [10,11,12].

2 Materials and methods

Determination of NRE contents was carried out on a chip-scale gamma-ray spectrometric setup with a NaJ(Tl) detector measuring 150x100 mm, with a well 65x60 mm, including an FEU-94 type photomultiplier, recording equipment, and a protective lead block. Samples that did not require special preparation were immediately weighed on an analytical balance and in the form of rock fragments with a mass of ≈ 100 g were placed in an airtight glass and then in a crystal well. The measurement time for one sample was approximately 1 hour. The sensitivity threshold for determining potassium is 1500, uranium - 0.78, thorium - 2.55 (g/t). The relative error in determining potassium is 2.4, uranium - 6.5, thorium - 17.5 (%). In addition, when studying the rocks of the pre-Jurassic complex, a laboratory gamma-spectrometric method was used in the profile variety, implemented on a full-size core sample using the Elemental Gamma Logger (EGL) - 255 setup.

Approximately 8800 samples were analyzed: 1) sedimentary rocks of the Jurassic and Lower Cretaceous age, comprising more than 90 hydrocarbon deposits in Western Siberia; 2) igneous and metamorphic rocks of the pre-Jurassic crystalline basement of the West Siberian Plate. These samples represent 13 oil and gas regions of the West-Siberian megabasin (Shaimsky, Khanty-Mansiysky, Krasnoleninsky, Salymsky, Surgutsky, Nizhnevartovsky, Alexandrovsky, Vengapurovsky, Uvatsky, Urnensky, Purpeysky, Urengoysky, Yuzhno-Yamalsky).

3 Results and discussion

3.1 Jurassic and Cretaceous sediments

When studying the Jurassic-Cretaceous sedimentary cover of the West-Siberian Plate, the results of gamma-ray spectrometric analyzes of ≈ 7000 rock samples were used. The ranges of changes in NRE contents, their average values in the Jurassic-Cretaceous sediments of Western Siberia, and distribution patterns in various petrophysical rock types were considered before in [12].

Comparisons of NRE contents in the main types of sedimentary rocks of the West-Siberian Plate with similar contents of radioelements in sedimentary deposits of other regions of the former USSR were performed (Table). For a number of formations, in particular, regions of Central Siberia, Cretaceous sediments of the Crimean peninsula, partially Upper Cretaceous deposits of the Scythian-Turanian Platform, Paleogene rocks of the Carpathian oil and gas province, close values of the NRE content are observed relative to the Jurassic-Cretaceous rocks of Western Siberia. At the same time, the NRE content in the sediments of the West-Siberian Plate is lower compared with the sedimentary rocks of the Permian Carboniferous Kuzbass (uranium and thorium), carbonate-terrigenous sediments of the Yenisei Ridge (potassium and thorium), Paleozoic sediments of Tatarstan (uranium and thorium), clays of the East European Platform (formerly known as the Russian Platform) (uranium and thorium), polymictic deposits of the Mangyshlak Peninsula (all three elements), partially with the Barremian sedimentary rocks of the Amudarya Basin (potassium and thorium). The indicated discrepancies are explained by different NRE contents in bedrocks and varying degrees of weathering of the latter, unequal migration and accumulation of NRE in ancient sedimentation basins, and the specificity of the tectonic and climatic factors of the considered regions.

Table. Comparison of the NRE content in the rocks of the Jurassic-Cretaceous deposits of the West-Siberian Plate with their content in the rocks of sedimentary deposits of other regions of the former USSR

Lithological type	Number of samples	K, %	U, g/t	Th, g/t	Th/U	Q, pg-eqRa/g
1	2	3	4	5	6	7
The content of NRE in the Jurassic-Cretaceous deposits of the West-Siberian Plate (according to the author)						
Sandstones	4273	0.01-8.29 1.73 ±0.02	0.01-25.5 1.4 ±0.05	0.3-28.1 5.5 ±0.09	0.1-48.2 4.0	0.02-10.5 2.12
Siltstones	1177	0.05-5.42 1.79 ±0.04	0.02-8.8 1.9 ±0.09	1.0-24.9 7.5 ±0.18	0.1-45.1 4.0	0.26-6.21 2.61
Mudstones	1207	0.06-8.81 1.97 ±0.04	0.2-22.4 2.3 ±0.09	0.6-24.7 8.6 ±0.17	0.2-32.8 3.7	0.24-10.50 3.00
Intercalation of sandstones, siltstones and mudstones	209	0.54-4.08 2.10 ±0.08	0.5-7.5 2.3 ±0.21	1.3-20.6 7.2 ±0.40	0.4-20.0 3.1	1.08-5.25 2.87
Average NRE contents in sedimentary rocks of Central Siberia (according to V.M. Gavshin, 1983)						
Upper Devonian deposits of the Minusinsk intermountain trough (Turanian series)						
Sandstones	244	0.87±0.03	1.6±0.1	4.7±0.2	3.0	-
Aleurite-pelites	346	1.76±0.06	1.8±0.1	6.4±0.2	3.5	-
Mudstones	130	2.72±0.10	2.3±0.1	8.0±0.2	3.4	-
Lower Carboniferous deposits of the Minusinsky and Tuvinian intermountain troughs						
Sandstones	16	1.33±0.25	1.2±0.2	6.3±1.1	5.2	-
Aleurite-pelites	64	2.30±0.27	3.3±0.7	7.6±0.7	2.3	-
Permoian Carboniferous deposits of Kuzbass						
Sandstones	26	1.94±0.29	2.5±0.2	7.3±0.2	2.9	-
Aleurite-pelites	37	2.45±0.14	3.5±0.2	10.6±0.6	3.0	-
Jurassic deposits of the Rybinsk Depression						
Sandstones	21	0.98±0.11	1.5±0.2	2.7±0.3	1.8	-
Aleurite-pelites	18	1.37±0.21	2.8±0.5	4.8±0.7	1.7	-
Average NRE contents in carbonate-terrigenous sediments of the Chingasan series of the Yenisei Ridge (according to V.A. Gavrilenko, 1975)						
Sandstones	160	1.17	1.2	5.0	4.0	-
Siltstones	71	2.21	2.2	9.5	4.3	-
Mudstones	31	3.05	2.4	11.8	4.8	-

1	2	3	4	5	6	7
The content of NRE in the Paleozoic sedimentary rocks of Tatarstan (according to R.Sh. Kharitonova, 1964)						
Sandstones	6	0.2-1.4 1.3	1.1-6.9 3.2	1.4-18.0 9.6	3.0	-
Siltstones	20	0.2-5.7 1.3	1.3-14.0 5.9	3.3-32.0 18.6	3.2	-
Mudstones	22	0.1-5.4 2.2	2.4-20.4 6.1	1.9-63.5 22.6	3.7	-
Average contents of uranium and thorium in the Crimean rocks (according to Yu.G. Gerasimov, 1983)						
Albian Stage						
Sandstones gritstones	10	-	1.9	<2.0	<1.0	-
Clays, mudstones	25	-	1.9	9.0	4.7	-
Valanginian Stage						
Limestones, sandstones, gritstones	15	-	1.9	<2.0	<2.0	-
Carbonate clays	10	-	1.8	7.0	3.9	-
The content of NRE in the rocks of the Turonian-Cenonian age of the Scythian-Turanian Platform (according to G.M.Shor et al., 1975)						
Sands, sandstones, siltstones	-	-	1.1-12.5 2.4	2.6-9.5 5.8	0.8-4.2 2.8	-
Clays	-	-	1.6-3.2 1.7	5.7-10.6 7.1	2.7-4.6 4.3	-
Average NRE content in clays of the Russian Platform (according to V.I. Baranov et al., 1956)						
Clays	4795	-	4.1	11.0	2.7	-
The content of N RE in sedimentary rocks of the Barremian age of the Amudarya Basin (according to R.P. Gottikh, 1980)						
Sandstones	-	0.4-3.8	0.5-9.0	3.5-9.5	-	-
Siltstones	-	1.2-4.2	0.5-5.0	5.5-12.0	-	-
Clays	-	2.0-4.6	0.5-5.0	9.0-12.0	-	-
Averaged contents of NRE in the Jurassic sandy-clay deposits of the Mangyshlak Peninsula. Zhetybai field (according to V.V. Larionov, N.I. Nefedova. 1969)						
Sandstones	-	1.88	4.7	7.9	-	-
Siltstones	-	2.45	6.5	16.3	-	-
Clays	-	2.62	-	13.0	-	-
Average NRE contents in sedimentary rocks of the Paleogene of the Carpathian oil and gas province (according to V.A. Bulmasov. 1981)						
Sandstones	-	- 1.2	-	… - 14.7 4.3	-	-
Siltstones	-	- 1.7	-	- 6.3	-	-
Mudstones	-	- 2.2	-	… -24.0 7.3	-	-

Note: in the numerator - the limits of the parameter change; in the denominator - the average value; Q is the total specific activity. Confidence ranges of average values are given with a 95% probability.

As you know, the main sources of ablation in the Jurassic-Cretaceous time for the West Siberian lowland were, among others, the eastern (East Sayan, Kuznetsk Alatau, Kolyvan-Tomsk Arc, Yenisei Ridge) and north-eastern (Taimyr, north of the Siberian Platform, foundation ledges of the Kara-Barents Platform) areas that supplied mainly the destruction products of ancient metamorphic shales and traps of the Siberian Platform with low radioactivity. Most of the Jurassic and Lower Cretaceous paleogeographic environments (with the exception of the Late Valanginian and Late Aptian) were marked by intensive chemical weathering in weakly dissected catchment areas, a humid climate, and passive tectonic conditions. These factors contributed to the accumulation of generally small amounts of radioactive elements in the sedimentary deposits of Western Siberia, compared with some other sedimentary basins of the territory of the former USSR.

3.2 Pre-Jurassic deposits

Approximately 1.790 samples of core and cuttings from the wells of the Tyumensky, Nizhnevartovsky, Severo-Surgutsky and Krasnoleninsky regions and several individual deposits were studied. The content of natural radioactive elements in them is considered in [12.13].

4 Conclusions

The conducted studies allow us to proceed to the following generalizations.

1. In some cases, a comparison of the NRE contents in the main types of sedimentary rocks of the West-Siberian Lowland with the contents of radioactive elements in sedimentary deposits of other regions of the former USSR demonstrates their relative proximity (areas of Central Siberia, Cretaceous deposits of the Crimean peninsula, Upper Cretaceous sediments of the Scythian-Turanian Platform, Paleogene rocks of the Carpathian oil and gas province). In other cases (Permian Carboniferous deposits of Kuzbass, deposits of the Yenisei Ridge, Paleozoic rocks of Tatarstan, clays of the Russian Platform, polymictic deposits of the Mangyshlak Peninsula), the content of radioelements (mainly uranium and thorium) in sedimentary rocks of Western Siberia is lower, which may be due to reduced radioactivity of destroyed source rocks, their prevailing chemical weathering, humid climate and calm tectonic conditions.

2. The characterization of the radioactive properties of rocks of pre-Jurassic age is consistent with theoretical ideas about an increase in the content of radioactive accessory minerals in igneous rocks and an increase in the radioactivity of the latter as the degree of oxidation increases. The average values of the nuclear physical properties of the rocks of the pre-Jurassic complex are close to the average values given in literary sources.

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