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METAL-BEARENCE OF SIBERIAN COALS

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Results of long-term observations for Siberian coals are generalized. Geochemical peculiarities of coal-fields are determined. It was stated, that Siberian coals are perspective for search of Au, Sc, Ge and lithophilous rare metal (Zr, Hf, Y, Nb, Ta, U and lanthanide) commercial deposit. Prospects of evaluation of rare metal resources commercial developing in coals and their waste is fulfilled.

Introduction

In Siberian region, the most significant part of coals resources is amassed. Unique resource potential and high perspectives of increase in coal mining require science-based methods for further development.

Fossil coals are able to accommodate significant number of elements – impurities; quite often they reach commercially meaningful concentrations. In Russian coals, Ge, U, Au, Sc, Pt, Nb lanthanide and others elements [1–14] industrial concentrations are known. Exposure of coal basin, fields and separate stratum with industrially meaningful and ecologically dangerous elements – impurities content – is one of the most important tasks of coal geochemistry and mineraganicy, it is a search task.

In contemporary predictive – metallogenic and geochemical prospecting work, the geochemical specialization notion is used for evaluation of potential ore-bearence of geochemical blocks, structures and rock. It is accepted to emphasize the geochemical specialization of the first and the second type [15]. Specialization of the first type is evaluated according to an element concentration factor in the examined geological block (rock) regarding to Clarke in the earth's crust. Its task is to search for geological formations with heightened level of valuable elements accumulation. To evaluate specialization of the second type, one use parameters, characterizing geochemical heterogeneity, i.e. peculiarities, proving the metal ability to be drawn into the further redistribution and concentration

Attempts to evaluate the geochemical specialization of Siberian coals fields were made repeatedly, but generally the results do not satisfy contemporary claims due to insufficient data quantity, or analytical researches of low quality [16–19].

Already in the earlier researches geochemical specialization of Minusinsk basin coals was on Ge and Sc [20–22], Kuznetsk basin – on Au, Ge, Zr, Ni [17, 18, 23, 24], Kansko-Achinsk on U [25], Irkutsk – on Ga, Sn, B [17, 26], Tunguss – on Be and chalcophilios elements.

Research results

Application of the method of average as average weighted estimation [27] allows us to receive the reliable estimation of average elements – impurities content in Siberian coals. Basing on the contemporary analytical procedures, new received data on elements – impurities content in coals allows us not only supplement and specify the idea of geochemical specialization of separate coal fields and add new data on basin, which were not examined before, but change the conception of geochemical specialization of regional coals.

In comparison with global coal Clarke [3] and other world regions data, Siberian coals are enriched with lithophilous elements, character for alkaline rock (Zr, Hf, Nb, Y, lanthanide, Ba, Sr and Be), and separate elements – siderophiles (Sc, Fe, Cr, Ni, Co) (pic. 1). They differ in elements – chalcophiles decrease (Cu, Pb, Zn, Cd, Ga, Se, Te, Hg) and separate lithophyles (Li, Rb, B, V, Th). Such type of elements geochemical associations in coals coordinates with general geochemical specialization of intrusive – volcanogenic and sediment formations in the region.

Estimations, received by us, of average rare elements content as for separate basins, and for the region in general, differ from estimations received earlier by other authors [17, 18]. These differences exist not only in the numerous spectrum of examined elements, but in their higher content (table 1). The last circumstance is reasoned by the usage of contemporary quantitative methods of direct element determination in samples without prior ashing.

Geochemical specialization of the first type allows drawing the circle of elements, accumulating in coals ba-

Table 1. *Average content of rare elements in coals of Siberia, g/t*

Coal basin, deposit	Ad, %	Element content																									
		Li	Rb	Cs	Sr	Be	Sc	Y	Ga	Ge	Zr	Hf	Th	La	Ce	Sm	Eu	Tb	Yb	Lu	V	Nb	Ta	U	Ag	Au*	Sb
Devonian epoch of coal accumulation																											
Barzasskoe	32,5	19,1	36,0	2,8	61	2,3	6,4	35,5	7,1	2,7	144	2,9	3,9	35	68	5,4	1,7	0,7	1,5	0,31	47,5	21,3	0,7	3,2	0,018	9,5	0,3
Ubrusskoe	49,2	12,9	22,0	1,6	395	2,5	8,7	33,4	2,7	<1,0	604	8,2	3,1	38	79	17,8	6,9	3,1	5,7	1,31	43,5	3,9	0,51	27,2	0,05	21	4,4
Average	35,3	18,1	33,7	2,6	117	2,3	6,8	35,2	6,4	2,3	220	3,7	3,8	361	70	7,5	2,5	1,1	2,2	0,48	46,8	18,4	0,7	7,2	0,023	11,4	0,95
Carbon-Permian epoch of coal accumulation																											
Kuznetskiy	7,0	н.д.	6,3	0,39	195	н.д..	2,9	н.д.	н.д.	н.д.	н.д.	1,1	1,9	8,2	21,0	1,8	0,39	0,19	0,77	0,18	н.д.	н.д.	0,08	1,0	н.д.	7,9	0,11
Gorlovskiy	13,5	14,8	15,0	1,6	248	4,6	3,9	15,4	7,0	0,9	138	2,1	3,3	12,3	24,7	2,6	0,64	0,43	1,30	0,34	14,7	11,0	0,47	2,4	0,05	7,5	0,26
Minusinskiy	17,6	10,1	3,8	0,67	288	2,5	8,2	13,6	2,9	5,7	63	2,6	3,1	14,4	37,0	2,2	0,76	0,70	1,1	0,45	25,1	7,4	0,32	3,0	0,011	2,8	1,2
Tungusskiy	12,0	6,7	7,4	0,8	239	2,0	3,9	4,8	4,2	0,2	43	2,3	3,7	8,5	19,7	1,9	0,5	0,4	0,8	0,24	12,2	2,8	0,5	3,3	н.д.	4,1	0,8
Kurayskoe	25,2	20,0	16,7	1,0	686	2,0	6,9	18,5	4,7	0,2	79	2,7	4,2	38,2	44,1	4,8	1,5	0,75	2,0	0,51	7,5	4,9	0,49	1,1	0,011	2,6	0,01
Average	12,4	8,7	9,3	1,0	241	2,7	4,0	7,6	4,9	0,5	67	2,2	3,7	9,5	21,2	2,1	0,5	0,4	1,0	0,27	13,0	4,9	0,5	3,0	0,05	3,1	0,68
Mesozoic epoch of coal accumulation																											
Pyzhinskoe	6,5	4,5	15,3	1,3	36	0,8	2,9	4,9	1,0	н.д.	47	0,7	0,9	4,9	5,8	1,0	0,5	0,23	0,54	0,17	н.д.	6,0	0,08	0,95	н.д.	2,4	0,5
Kansko-Achinskiy	9,8	2,8	1,4	0,10	375	1,2	2,9	5,9	2,3	0,3	29,3	0,59	0,97	3,4	8,1	0,82	0,32	0,22	0,45	0,11	8,3	2,7	0,03	3,2	0,02	6,1	0,31
Irkutskiy	8,5	н.д.	н.д.	0,06	н.д.	2,0	5,7	7,3	0,6	н.д.	40	0,98	2,8	12,3	14,9	2,9	0,66	0,45	1,4	0,28	0,9	н.д.	0,22	1,9	н.д.	3,5	0,7
Ulugkhemskiy	9,5	1,6	1,8	0,55	250	1,7	2,3	5,1	1,4	0,3	21	0,68	1,2	4,3	8,2	1,0	0,34	0,19	0,40	0,11	7,7	0,1	0,07	1,2	<0,01	2,5	0,27
West-Siberian	10,5	4,2	3,5	1,1	213	5,4	16,0	17,0	2,1	2,7	126	3,3	2,3	8,2	16,6	2,5	0,83	0,67	2,1	0,47	15,6	5,5	0,05	1,2	0,006	30,0	7,1
Tungusskiy	12,6	6,7	6,8	0,06	117	0,7	3,9	5,5	0,3	0,2	30	0,66	0,8	5,1	6,7	0,9	0,49	0,25	0,40	0,10	1,6	0,4	0,02	2,1	0,006	1,5	0,01
Kuznetskiy	17,3	н.д.	10	0,6	450	0,6	6,4	3,0	3,0	н.д.	30	0,41	2,2	7,0	13,3	2,2	0,64	0,73	0,88	0,28	6,0	7,0	<0,05	2,1	<0,01	2,4	0,49
Average for ASFA	10,1	2,6	1,7	0,14	357	1,2	3,2	5,8	2,2	0,25	30	0,61	1,1	4,0	8,7	1,0	0,35	0,26	0,52	0,13	7,8	2,6	0,04	3,0	0,020	5,5	0,34
Average	10,5	4,2	3,4	1,0	217	5,2	15,6	16,7	2,1	2,6	123	3,3	2,3	8,1	16,4	2,5	0,81	0,66	2,0	0,46	15,4	5,5	0,05	1,2	0,006	29,0	6,9
Cainozoic epoch of coal accumulation																											
West-Siberian	30,7	16,1	2,6	0,99	159	1,9	13,3	11,4	2,6	0,6	42	2,0	3,5	18,5	24,2	4,3	1,51	0,54	2,1	0,76	21,0	5,3	0,13	4,6	0,021	10,6	0,43
Taldu-Dyurgunskoe	19,8	3,4	14,5	1,6	411	0,5	9,1	5,0	0,4	0,5	38	0,80	1,1	7,3	6,6	2,0	0,71	0,36	1,3	0,73	8,4	1,5	0,03	1,7	0,11	6,8	1,1
Average	30,7	16,1	2,6	0,99	159	1,9	13,3	11,4	2,6	0,6	42	2,0	3,5	18,5	24,2	4,3	1,5	0,54	2,1	0,76	21,0	5,3	0,13	4,6	0,021	10,6	0,43
Cainozoic epoch of peat accumulation																											
Peat buried	46,1	н.д.	44	4,4	138	н.д.	9,3	н.д.	н.д.	н.д.	н.д.	1,9	5,1	15,4	28,9	2,8	0,78	0,56	1,6	0,27	н.д.	н.д.	0,53	3,7	н.д.	н.д.	0,87
Peat modern	8,7	н.д.	4,1	0,33	88	н.д.	1,0	н.д.	н.д.	н.д.	н.д.	0,29	0,8	4,1	7,3	0,74	0,14	0,13	0,20	0,04	н.д.	н.д.	0,07	2,0	н.д.	6,0	0,15
Average for the region	**11,5**	**5,1**	**3,9**	**1,0**	**214**	**4,8**	**14,2**	**15,5**	**2,3**	**2,3**	**113**	**3,1**	**2,4**	**8,6**	**17,0**	**2,5**	**0,81**	**0,62**	**1,9**	**0,45**	**15,3**	**5,3**	**0,09**	**1,5**	**0,011**	**25,4**	**5,9**

*Note: * – in mg/t; н.д. – no data*

sins in the Siberia in general, and in qualities, determining geochemical elements background. It is evident, that it would be not all elements, determining geochemical specialization of structures framing basins, but only those, which are able to accumulate coals excessely, i.e. typomorphic or coalphilles according to Ya.E. Yudovich's terminology [1, 3]. This conclusion can be illustrated by comparison of coals of various world regions (Fig. 1). As it is evident from the diagram, they have a close geochemical specialization according to elements line.

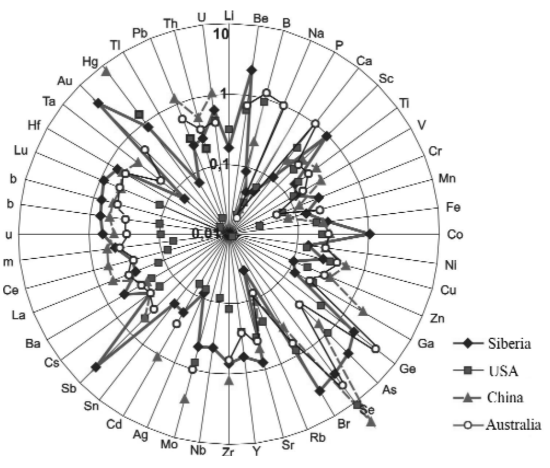

Fig. 1. *Graph of element distribution in Siberian coals normed to average of the Earth's crust*

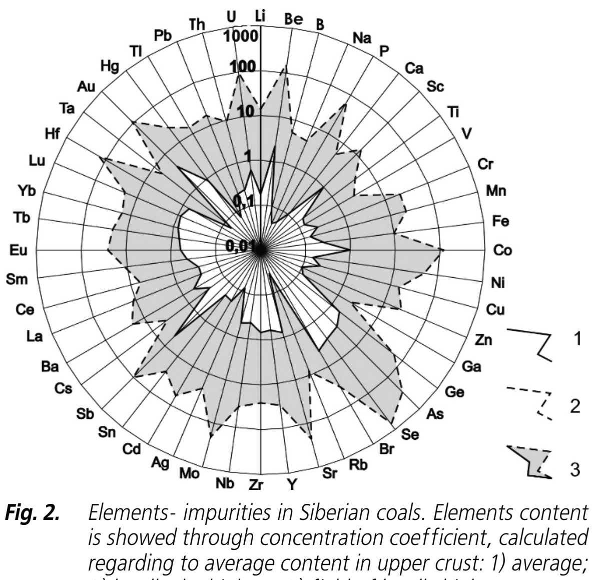

Fig. 2. *Elements- impurities in Siberian coals. Elements content is showed through concentration coefficient, calculated regarding to average content in upper crust: 1) average; 2) locally the highest; 3) field of locally high content*

Specialization of the second type, pointing out the presence of presupposition for commercial elements concentration formation, can be estimated according to A.A. Smyslov method [19]. It is established through comparing of maximum anomalous elements content in coals with its Clarkes in the Earth crust. The results are shown in the form of a pie chart; geochemical specialization of the first type is imposed on a pie chart (Fig. 2) and in the form of geochemical specialization formula (Fig. 3). Coefficients before elements in formula characterize anomaly contrast.

This type of geochemical specialization is closely connected with specialization of the first type, at the same time differs from it, as it depends not only on general geochemical background of structure – framing, as on source presence, able to form contrast geochemical anomalies. These can be destructing deposits or specified rock complexes in framing structures, volcanogenic material (ashes, etc.), hydrothermal activity or subterranean waters or groundwater supply in the stratum, enriched with ore elements. Generally, it is formed on the geochemical specialization of the first type background.

The researches show that Se, As, Sr, Mo, Be, Co, Au, Sb, U, Ge, Nb, Y, Zr, HREE, Br, Hg и Cd form the most contrast anomalies in Siberian coals (Fig. 2). Variety of coal-bearence conditions determined the diversity of geochemical and mineragenic characteristics of coal fields and basins. At the same time, along with separate basins specific peculiarities, general patterns of

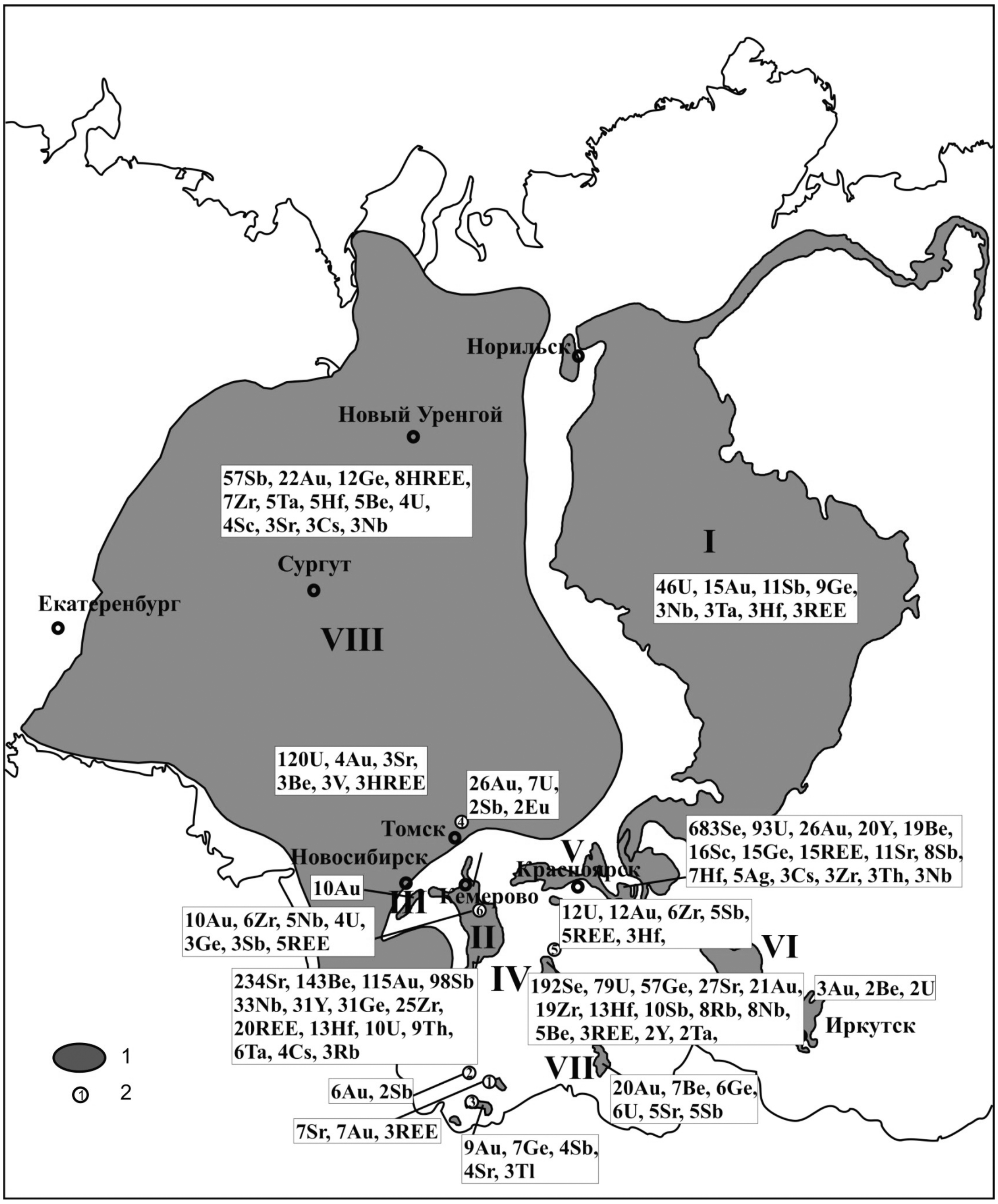

Fig. 3. *Map of rare-metal specialization of Siberian coal. 1 – Coal basins: I) Tunguskiy; II) Kuznetskiy; III) Gorlovskiy; IV) Minusinskiy; V) Kansko-Achinskiy; VI) Irkutskiy; VII) Ulugkhemskiy; VIII) West-Siberian; 2 – coal fields.*

Explanation to Fig. 3: Норильск – Norilsk; Новый Уренгой – Noviy Urengoy; Сургут – Surgut; Екатеринбург – Ekatirenburg; Томск – Tomsk; Новосибирск – Novosibirsk; Красноярск – Krasnoyarsk; Кемерово – Kemerovo geochemical specialization of regional coals are distinguished, especially evident are peculiarities for rare metals. Lithophilous- chalcophanites- siderophiles mixed type of geochemical specialization with various geochemical associations ratio is peculiar for all coal basins. This fact corresponds to geochemical zoning of Altai-Sayan folded structure data.

Researches showed, that Siberian coals are specialized on Be, Ge, Se, Au, Sc, U, Co, As, Sb, Mo, Nb, Y, Zr and REE. High anomaly contrast of rare elements allows forecasting high probability of deposit search and coal stratums with commercially meaningful content. This coincides with presence in the area of commercial coals concentration of Ge (Minusinskiy, Kuzbas, West-Siberian basins), Au contrast anomaly (Kuzbas, West-Siberian basins), Sc (Minusinskiy, West-Siberian basins), Uranium and thorium (Kansko-Achinskiy, Irkutsk, West-Siberian basins), Be (Tungyskiy basin), Nb, Zr, Y and REE (Kuzbas), Mo (Ubrusskoe deposit).

The change in geochemical specialization of regional coals during coal-bearence evolution was determined. The change in geotectonic conditions of deposit formation along whole Siberian territory was synchronous and regional. That is why quite reliable correlation of coal-bearing formations of palaeozoic, secondary, neozoic levels of coal-bearing is probable. It allows examining rare-metal coals content evolution as in separate basins and in Siberia in general.

Volcanic activity significantly influence coal-bearing process in Siberia, this is a peculiarity of palaeozoic coal-bearing age. This revealed in general coals enriching with D, C-P aged lithophilous, including weakly coalphilles elements, such as как Zr, Hf, Y, REE, Nb, Ta, Th and U. In the territories with powerful pyroclast streak, accumulation levels of these elements – impurities in coals can reach commercially significant values [6, 11].

Coal-bearing of Mesazoic Age in the region is relatively auriferous, scandium-bearing and germanium-bearing. If germanium-bearence is limited by cretaceous lignite of West-Siberian and Tunguss basins, scandium-bearing and auriferous is general phenomenon. Scandium-bearing and auriferous are especially strikingly revealed in West-Siberia basin [12, 13].

Cainozoe coal-bearing inherits geochemical specialization of Mesazoic Age, but it has proper peculiarities. The rarest elements – impurities content in Cainozoe coals is less than in secondary coals (table 1). It is even less in contemporary peats.

High uranium-bearence is the most peculiar feature of Cainozoe in the region. Siberian coals of this age are enriched with uranium practically in the whole territory. Cainozoe uranium-bearing influenced coals of Mesazoic Age. Uranium and thorium contrast anomalies are distinguished in jurassic coals of Itatskiy, Berezovskiy and Kozuliskiy deposits, in paleogene coals in Yayskiy and Ysmanskiy deposits. Commercial hydrogen Malinovskiy uranium deposit is known here [28]. Special intrusive – volcanogenic complex, distributed in framing structures of coal-bearing cavity is a uranium source. Due to several characteristics, general mass of definite radioactive anomalies in Jurassic Siberian coals are of the young age. But exactly at this points uranium anomalies in coals of Kansko-Achinskiy basin along with quaternary oxidation of coal stratums [25] and numerous uranium-bearing peatbog presence in the region.

Thus, for Siberia, evolution of rare-metal coals content from palaeozoic to Cainozoe is character for Siberia. Palaeozoic coals are specialized on lithophilous rare metals, such as Zr, Hf, Y, REE, Nb, Ta, Th, Ge and Sc, secondary – on Au, Sc and Ge, and Cainozoe – on Au, Ge and U.

From rare metal group, characterized by high accumulation level in coals and coal ashes, practically interesting are the following independent minerals Ge, Au, Sc, U, Nb, Ta, Y, Zr and REE.

Germanium. The estimation of germanium coals of Siberia with different degree of minuteness is fulfilled for most deposits and basins. Supply of metal of industrial categories is determined in energetic coals of Chernogorskiy deposit of Minysinskiy basin [21] and in two deposits of Kuzbas coking coal [4]. Germanium probable supply, calculated for cretaceous lignite only for Nizhniy-Kasskiy area of east part of West-Siberia basin, corresponds to 11 thousands years [29]. Highly germanium-bearing coals exist and in other area of West-Siberian and Tyngyskiy basin [21, 30].

Germanium-bearing coals of the region drawing in industrial recycle for metal extraction is limited by various reasons. Germanium receiving from coking coals of Kyznetskiy basin is held by absence of extraction technology, inbuilt in basic technological process of coking adaptation for concrete coals. Traditional technology, used for metal extraction from Donetsk coals requires completion with reference to Kuzbas coals [4].

Germanium received from energetic coals of Minusinsk basin is limited by low metal content. Ge supply is enough for creation of production of optimal capacity, but its low concentrations prevent creation of paying production, oriented only on Ge [11]. High scandium content in coals and ashes can be regarded as positive aspect. Joint extraction of these metals can provide necessary production profitability.

Highly germanium-bearing lignite from east part of East Siberian basin is limited by object playback remoteness, severe climatic conditions, and seasonal character of mining, concentration and transportation [29].

Scandium – is one of the most perspective elements for coal extraction. In the Siberian territory there are several coal deposits, suitable for organization of Sc industrial receive.

The most interesting are coals of well developed Chernogorskiy deposit of Minusinsk basin [11]. Calculations show that in Chernogorskiy deposit, Sc resource potential is sufficiently big. Available resources are sufficient for creation basing on a deposit a large-scale production of associated extraction of Sc and other elements-impurities. The only Dvukharshinniy stratum is able to provide contemporary world consumption of this metal during several decades (table 2)

Table 2. *Resources of valuable elements – impurities in coals of Chernogorskiy deposit, g/t*

Deposit, basin	Coal reserves (resources), thousand tons	Resources, t						
		Sc	Ge	V	Zr	Y	Au	РЗЭ
Chernogorskiy	1620263	13853	8895	62850	93327	16769	4,81	63725
Including Dvukharshinniy stratum	5000 (50000)	68,5 (685)	25,7 (257)	194 (1940)	288 (2880)	51,8 (518)	0,015 (0,15)	196 (1960)
Total in the basin	24862289	205860	93979	754073	1409692	304314	62,7	1266485

Anomalous Sc is peculiar for brown coal of separate deposits of Kansko-Achinskiy basin. Calculations showed that Sc resource potential of Borodinskiy and Sayan-Partizanskiy deposits is sufficient for creation basing on it large-scale production of associated extraction (table 3).

Anomalously high scandium-bearing is determined for brown coals of Jurassic age of West-Siberian basin. Sc content here in coal ashes sometimes exceeds 0,2 % [12, 31]. However, the prospects of industrial examination of these coals are not evident, as depth of coal stratum deposition is significant. One needs to examine the regions, where coals of this age are available for playing back.

Table 3. *Resources of valuable elements – impurities in coals of separate deposits of Kansko-Achinskiy basin. Category P_1*

Deposit, basin	Coal reserves, million tons	Resources, t					
		Sc	Nb	V	Zr	Y	Au
Borodinskoe	1164	3840	3026	12801	57139	4888	8,3
Including Rybinskiy and Profilniy stratum	140	1008	–	–	7420	–	1,1
Bolshesyrskoe	194	292	253	545	6347	117	1,2
Sayan-Partizanskoe, site Ivanovskiy 3–4	263,5	2160	–	–	12120	5796	4,2

Gold. Despite of the fact, that quite significant volume of researches in various basins was examined by us, Siberian coal gold-bearing is estimated not sufficiently. Besides known to us facts of Kuzbas coal gold-bearing presence [10, 24], during last years Au anomalous content is determined in coals of Minusinskiy, Kansko-Achinskiy and West-Siberian basin [10–13].

Prospects of commercial gold receive from coals of the region were not examined on purpose. Modest research volume, fulfilled by A.M. Sazonov and colleagues, proved that it practically is not extracted from gold-scoria brown coals incineration wastes of basic commercial deposits of Kansko-Achinsk basin with gravitation methods [32].

The Search and estimation works complex should forestall solution of production of gold extraction from coals and wastes organization. The resource metal base should be estimated on prospective areas and in gold-swell, laboratory-technological and industrial trials on metal extraction. Such works were held for gold-swell Refting HPS in Chelyabinsk region [9] and Khabarovsk gold-swell [14]. In Siberia at this stage they should be concentrated in Kuzbas, Minusinskiy basin and separate prospective deposits of Kansko-Achinsk basin.

Tantalum, niobium, zirconium, hafnium, rare earth elements. The highest concentrations of these metals are revealed in Kuzbas basin coal [6, 10]. Their anomalous content also pointed in coals and ashes of Minusinskiy and Kansko-Achinsk basins [11, 12].

Niobium. In Kuzbas its content in ash of stratum XI coals riches 2000 ppm, when average is 146 ppm [10], in Minusinskiy basin in XXXa stratum is 220 ppm [11]. In coal of Kyznetskiy basin Nb anomalous concentrations are fixated not only in thin contact zones of coal stratums, but in stratums of more significant up to 9 m capacity. Such stratums are determined at Sibirginskiy cut, where niobium content in stratum IV–V are 35 ppm (360 ppm ashes). Anomalous Nb content in coals Sibirginskiy cut correlates with heightened Zr and latinoides content.

Nb concentration increase, coming to commercially significant, are marked in separate coal stratums of Kansko-Achinskiy basin. However, slight accumulation levels of metal do not allow regard them as independent niobium source. Here, its prospects are connected with accompanying elements complex.

Tantalum. Unlike to relatively spread niobium-bearing coal stratums, tantalum-bearing coals are known only in Kuzbas [10]. Detailed research, fulfilled within Lenin mine claim, Olzarskiy cut [10], proved that Ta concentration increase in stratum XI cut, confined to steak, made by coaly siltstone and silt-gritstones of 0,1...0,13 m, underlying upper part of niobium-bearing and rare-metal coals. Steak traces according to lateral from west to east up to 5 km and more. Its distributional square even with the most accurate estimations exceeds 10 km^2. Average Ta content in siltstones streak is 42 ppm, maximum is 71 ppm. In the direction from west to east, concentration tends to increase. According to classification of monometal Ta and Nb deposits according to ores [33], streak rocks represent common (sometimes rich) rocks. Previously metal resource was estimated by us as 100 t [10].

Ta high concentrations (10...30 ppm) and heightened content of the most of elements group, peculiar for anomalous streak in stratum XI, are determined in the number of other stratums. This allows forecasting wider distribution of rare-metal mineralization of this type in stratigraphical cut of Kemerovskiy and intermediate sequence in the Kuzbas south. Ta content was marked in Minusinskiy basin.

Uranium. In Siberia, oxidized brown coals and lignites are uranium-bearing. Uranium manifestation and small uranium deposits are known in Kansko-Achinskiy, Irkutskiy and West-Siberia basins [19, 25]. In all studied cases uranium mineralization, not syngenetic coal-formation, and connected with superposed processes. The greatest manifestation: Itatskiy; Yayskiy; Ysmanskiy and etc., – are determined by superposed hypergene processes of newest era of uranium accumulation. This anomalies number is quite few. They are fixated at coal stratum yield under alluvium in most of coal deposits of Kansko-Achinskiy basin, in many deposits of Irkutsk and West Siberia basin.

Slight uranium manifestation is known among coal-bed deposit of Minusinskiy, Kuznetskiy and Tungyskiy basin. Estimations held in 60–70 years of XX century of separate uranium manifestations in coal stratums prove their nonavailability for independent work as a uranium source. Prospects of processing of such coals can be related only with oxidized coals utilization necessity to decrease their influence on environment.

Conclusions

The carried out research, proves that Siberian coals are geochemically specialized on Be, Ge, Se, Au, Sc, U, Co, As, Sb, Mo, Nb, Y, Zr and lanthanides. Such a type of coals specialization agrees with general geochemical peculiarities of intrusive- volcanogenic and sediment formation of region. High anomalous contrast of rare elements-impurities allows forecasting of high probability of deposit and coal stratums of Ge, Se, Au, Sc, U, Be, Nb, Zr, Y and lanthanide commercially meaningful content revealing. This corresponds to discoveries made in the regions of commercially meaningful concentrations of Ge with anomalous Au, Sc, U, Be, Nb, Zr, Y, Mo and lanthanide content.

With contemporary technologies, basing on separate deposits one can organize profitable production of rare metal extraction. The most prospective is to extract from coals Ge, Sc, Au and the complex of lithophyte rare metals (Ta, Nb, Zr, Hf, Y, lanthanides). Scandium resources only in Chernogorskiy and Borodinskiy deposits are able to provide it world needs for several decades.

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TO THE QUESTION ON GEOMETRIZATION OF ABNORMAL STRUCTURES OF GEOCHEMICAL FIELDS OF HYDROTHERMAL ORE DEPOSITS

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Possibilities of various mathematical methods at geometrization of abnormal geochemical fields of ore deposits are discussed. Peculiarities of application of linear and nonlinear methods of image recognition are considered on the specific example for solution of these problems: discriminant analysis, multiple regression method, artificial neural networks. Conditions of optimum application of the named methods are defined. The opportunity of secondary aureoles mapping data application for identification of the primary abnormal geochemical field structure is shown.

Research of zoning of abnormal geochemical fields is a component of the problem of endogenous zoning, one of the major in the theory of ore deposits. That constant attention turned to this problem by researchers is caused by its value for development of the theory of ore-formation and by possibility of practical use of the revealed laws for forecasting of hidden mineralization.

Universality of vertical geochemical zoning of primary aureoles of ore deposits, for the first time noted by N.I. Safronov [1] and most fully proved for sulphido-containing deposits [2, 3], is lain in the basis of some techniques, and more than 30 years used for the quantitative forecast of mineralization, determination of the level of its erosive section, evaluation of flanks and abyssal horizons of deposits. Meanwhile, it is established that on golden-ore deposits, column and stage distributions of mineralization are usual, the decrease of values of zoning coefficients is often combined with their very complex distribution in the plane of ore bodies, which makes problematic the use of the named factors at rare network of approbation. Besides, many authors in the concept of anomaly, except for aureoles of element addition, include areas of their subtraction, considering these complementary in space positive and negative anomalies as components of uniform hierarchically constructed structures [4–8].

The structural method of research of geochemical fields in the most consecutive view is stated by S.A. Grigorov [9]. By this author in the construction of abnormal structure of geochemical field (ASGF) of ore object of any rank are allocated: nuclear zone concentration of ore elements, surrounding zone of transit (with low concentration of ore elements) and external (face-to-face) zone of concentration. The listed zones, in turn, form a zone of nuclear concentration of the following hierarchical level. Close functional connection between all elements of ASGF defines obligation of presence of all hierarchical levels of the senior rank at presence of the younger. Mineralization occupies in ASGF a certain position, therefore the structural method essentially facilitates grading of numerous anomalies revealed during the process of geochemical survey, and allows allocating most perspective of them even at identity of their efficiency by the basic element.

Correct interpretation of an internal construction of geochemical field, considering spatial overlapping of abnormal structures of various hierarchical levels and an essential element of subjectivity at their geometrization, is the main problem at application of the structural method.

Various groups of methods based on various theoretical preconditions are now used for the research of the structure of abnormal geochemical fields. The majority of authors prefer only one technique; therefore it is expedient to lead the comparative analysis of advantages and disadvantages of the most widespread methods of geometrization of abnormal geochemical fields. They are: 1) *the R-method* of factorial analysis, as representa-