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The Structure Of The Radial Redistribution Of Chemical Elements In The High Mountain Landscapes Of The Greater Caucasus.

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ABSTRACT

The structure of the radial redistribution of chemical elements in the high-altitude belts of the high-mountain landscapes of the Greater Caucasus (upper reaches of the Terek river basin) is revealed. Such a structure represents a specific sequence in the change in the intensity of the radial migration of chemical elements between the soil and heterogeneous soil-forming rocks within regional geosystems with the same biological cycle. The determination of the radial differentiation of chemical elements between soils and heterogeneous soil-forming rocks within altitudinal belts was carried out on the basis of information on the content of 25 chemical elements in rocks and soils. Their concentrations were investigated by the method of spectral emission analysis. Data were obtained on the structure of the radial redistribution of chemical elements in the following high-altitude zones: subnival, high-mountain meadows, coniferous and mixed forests. Structures between the radial redistribution of chemical elements in the soils of different altitudinal belts with the same complexes of soil-forming rocks are compared. It is revealed that the leading factors for the formation of the structures of the radial redistribution of chemical elements in high-altitude landscapes are geological (for Cu, Co, Y, Yb, Nb, V, Sn, Ni, Li, Ga and Be) and biological (Zn, Pb, Ag, Mo , W, Ba, Mn, Ti, Cr, Ge, P, Sr and Sc).

Keywords: Greater Caucasus, soils, soil-forming rocks, structure of radial redistribution.

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INTRODUCTION

Radial analysis of the migration of chemical elements is the main method for determining the redistribution of chemical elements in the vertical structure of landscapes [1, 2]. Vertical geochemical differentiation of elements between soils and soil-forming rocks indicates their genetic relationship. The degree of such a connection is determined by the initial mineralogical composition of the rocks, the properties of the chemical elements themselves, and soil-chemical conditions. The duration of the processes of weathering and soil formation, the depth of transformation of minerals of rocks is important [3, 4].

The purpose of the study is to identify the features of the radial redistribution of chemical elements in the "soil-soil-forming rocks" system in regional geosystems of the high-mountain landscapes of the Greater Caucasus. Dominant altitude geobotanical belts have been studied as regional geosystems. In each high-altitude geobotanical belt there is a certain specificity of the manifestation of the biogeochemical circulation and the general direction of soil formation. This is facilitated by the unified nature of climatic processes, the domination of one type of vegetation, the uniformity of the animal and microbial population.

Within the altitude belt there are similar geomorphological conditions. Therefore, the influence of lateral flows of a substance on the radial migration of chemical elements does not manifest itself. Heterogeneous nature of the radial differentiation of the elements gives the heterogeneous soil-forming rocks [5].

MATERIALS AND METHODS

The regional structure of the radial redistribution of chemical elements is considered for the high-altitude geobotanical belts of the Kuban-Terek landscape district identified in the Elbrus-Kazbekovskaya high-altitude physical-geographical subregion of the Greater Caucasus [6]. The district is located entirely in the upper reaches of the Terek River basin and its left tributaries - the Baksan, Chegem, Cherek, and Ardon. The significant absolute heights of the district contribute to the wide development of meadow communities. Forests occupy smaller areas.

The main high-altitude zones of the district are subnival, high-altitude subalpine and alpine meadows, coniferous and mixed forests. Soils in high-altitude belts are formed on the same complexes of soil-forming rocks of different genesis, lithology and geochemistry [7]. Metamorphic rocks include Paleozoic terrigenous-volcanogenic deposits (metam.PZ), crystalline schists and proterozoic gneisses (metam.PR). For igneous rocks - Paleozoic granitoids (magm. PZ) and Neogene volcanogenic deposits (magm. N).

The radial redistribution of chemical elements between the soil and the complexes of soil-forming rocks within altitude belts was revealed using the radial differentiation coefficient R, which is the ratio of the chemical element content in the soil to its content in the soil-forming rock [8]. The values of $R > 1.0$ indicate the enrichment of the soil with chemical elements relative to the soil-forming rocks, the value of $R < 1.0$ indicates the impoverishment of the soil with the removal of chemical elements. The calculations used the data of V.V. Dyachenko [9] on the distribution of 25 chemical elements in the soil-forming complexes and soils of the North Caucasus. Within the limits of geobotanical high-altitude belts, an analysis was made of the sequence of increase in the coefficient of radial migration of chemical elements in soils formed on heterogeneous soil-forming rocks.

RESULTS AND DISCUSSION

Within the subnival altitude belt with open rocky scree vegetation, mountain-meadow primitive rubbly soils are developed. The material mineral composition of primitive soils is inherited from the chemical and mineralogical composition of bedrock rocks, in which mineral components resistant to weathering prevail. The release and transfer of chemical elements from minerals of rocks to the soil fine earth of primitive soils is caused by intensive processes of physical and chemical weathering. Mobile compounds of elements in the soil fine earth are actively accumulated due to the activity of lower vegetation - mosses, lichens, algae, fungi [9].

Determination of the coefficients of radial differentiation showed that in the soils of the subnival belt compared with the soil-forming rocks, the enrichment of chemical elements prevails (Table 1). A decrease in soil content in comparison with rocks is noted for a small number of chemical elements. On igneous sediments of the Neogene soil relative to the rocks are depleted in Mo; on metamorphic paleozoic - Cu, Ag, W; igneous Paleozoic - Sn and Ga; metamorphic proterozoic - Cu, Sn, W and Y.

Table 1: Radial differentiation coefficients for soils of the subnival belt formed on different soil-forming rocks

Chemical elements	Soil-forming rocks			
	Neogene magmatic	metamorphic Paleozoic	magmatic Paleozoic	metamorphic Proterozoic
Cu	1,20	0,95	1,49	0,99
Zn	2,74	2,74	2,48	1,68
Pb	1,42	1,80	1,41	1,79
Ag	1,38	0,91	1,27	1,19
Sn	1,13	1,33	0,92	0,98
Mo	0,90	1,07	1,24	1,33
W	1,86	0,96	1,76	0,82
Ba	1,95	1,63	1,35	1,64
Co	1,92	1,34	2,56	1,59
Ni	2,17	1,37	3,16	1,29
Mn	1,86	1,48	1,93	1,46
Ti	1,43	1,51	1,31	1,25
V	1,69	1,45	1,77	1,33
Cr	1,36	1,24	1,35	1,35
Ga	1,05	1,31	0,98	1,13
Ge	1,69	1,56	1,50	1,31
P	1,33	1,60	1,32	1,35
Li	1,01	1,30	1,53	1,24
Be	1,09	1,80	0,97	1,59
Sr	1,35	1,35	1,00	1,16
Y	2,54	1,11	1,34	0,88
Yb	1,86	1,17	1,33	1,00
Zr	-	1,58	2,17	1,09
Nb	1,84	1,06	1,33	1,43
Sc	1,92	1,07	1,49	1,50

The ranking by increasing the coefficient of radial differentiation of the soils of the subnival belt, confined to different complexes of soil-forming rocks, makes it possible to identify the structural series of changes in the intensity of radial redistribution for each chemical element (Table 2). Small groups of chemical elements with the same regional structure of radial redistribution are identified: Pb, Be, Ga, and P; Cu and Co; Cr and Ag; W, Yb and Y; Ni, V and Mn; and etc.

Table 2: Regional structure of the radial redistribution of chemical elements in the soils of the subnival belt

Elements	Change of intensity of radial differentiation in soils on different soil-forming rocks
Be, Ga, P, Pb	magm. PZ < magm. N < metam.PR < metam.PZ
W, Yb, Y	metam.PR < metam.PZ < magm. PZ < magm. N
Ni, V, Mn	metam.PR < metam.PZ < magm. N < magm. PZ
Nb, Sc	metam.PZ <magm. PZ < metam.PR < magm. N
Cu, Co	metam.PZ < metam.PR < magm. N < magm. PZ
Cr, Ag	metam.PZ < metam.PR < magm. PZ < magm. N
Zn, Ti	metam.PR < magm. PZ < magm. N < metam.PZ
Ge	metam.PR < magm. PZ < metam.PZ < magm. N
Sn	magm. PZ < metam.PR < magm. N < metam.PZ
Sr	magm. PZ < metam.PR < metam.PZ < magm. N

Ba	magm. PZ < metam.PZ < metam.PR < magm. N
Li	magm. N < metam.PR < metam.PZ < magm. PZ
Mo	magm. N < metam.PZ < magm. PZ < metam.PR

Note: Soil-forming rocks: magm. N - magmatic neogene; metam.PZ - metamorphic Paleozoic; metam.PR - metamorphic Proterozoic; magm.PZ - magmatic Paleozoic.

In the belt of subalpine and alpine meadows, mountain-meadow peaty thin soils predominate. The values of the radial differentiation coefficients for most chemical elements in mountain-meadow soils are lower compared to the soils of the subnival belt developed on similar soil-forming rocks (Table 3). Characterized by a significant number of chemical elements with reduced concentrations in the soil compared with the rocks. The soils on igneous sediments of the Neogene relative to rocks are depleted by 6 chemical elements (Cu, Sn, Mo, Ga, Li, Be), and on metamorphic Paleozoic - 10 (Cu, Ag, Mo, W, Cr, Sr, Y, Nb, Sc, Zr), on magmatic Paleozoic - 8 (Ag, Sn, Mo, W, Ga, P, Sr, Be), on metamorphic Proterozoic - 7 (Cu, Sn, Mo, W, Y, Yb, Zr).

Table 3: Radial differentiation coefficients for soils of subalpine and alpine meadows formed on different soil-forming rocks

Chemical elements	Soil-forming rocks			
	Neogene magmatic	metamorphic Paleozoic	magmatic Paleozoic	metamorphic Proterozoic
Cu	0,95	0,63	1,48	0,84
Zn	2,35	2,01	2,07	2,13
Pb	1,15	1,48	1,21	2,07
Ag	1,00	0,64	0,94	1,07
Sn	0,91	1,26	0,78	0,97
Mo	0,87	0,97	0,92	0,62
W	1,07	0,58	0,82	0,73
Ba	1,74	1,46	1,04	1,42
Co	1,87	1,22	2,11	1,47
Ni	1,89	1,15	2,56	1,13
Mn	2,60	1,48	1,70	1,42
Ti	1,43	1,38	1,21	1,23
V	1,30	1,13	1,52	1,11
Cr	1,02	0,87	1,27	1,15
Ga	0,93	1,23	0,91	1,00
Ge	1,54	1,25	1,31	1,28
P	1,29	1,72	0,99	1,43
Li	0,90	1,12	1,39	1,08
Be	0,88	1,70	0,78	1,39
Sr	1,73	0,98	0,84	1,13
Y	2,39	0,86	1,06	0,78
Yb	1,79	1,04	1,28	0,92
Zr	-	0,84	1,37	0,99
Nb	1,63	0,92	1,13	1,33
Sc	1,81	0,82	1,13	1,21

The same regional structure of radial redistribution between mountain meadow soils and heterogeneous soil-forming rocks has the groups of elements: Zn, Ag, Nb and Sc; Sn, Ga, P and Be; Mn, Y and Yb; and others (table 4).

Table 4: Regional structure of the radial redistribution of chemical elements in the soils of the belt of subalpine and alpine meadows

Elements	Changes in the intensity of radial differentiation on various soil-forming rocks
Zn, Ag, Nb, Sc	metam.PZ < magm. PZ< metam.PR < magm. N
Be, Ga, P, Sn	magm. PZ< magm. N < metam.PR < metam.PZ
Mn, Y, Yb	metam.PR< metam.PZ < magm. PZ< magm. N
Cu, Co	metam.PZ < metam.PR< magm. N< magm. PZ
Ba, Ti	magm. PZ< metam.PR < metam.PZ < magm. N
Ni, V	metam.PR < metam.PZ < magm. N< magm. PZ
Cr	metam.PZ < magm. N< metam.PR< magm. PZ
Ge	metam.PZ < metam.PR < magm. PZ< magm. N
Mo	metam.PR < magm. N < magm. PZ < metam.PZ
Li	magm. N < metam.PR < metam.PZ < magm. PZ
W	metam.PR < magm. PZ < metam.PZ < magm. N
Sr	magm. PZ < metam.PZ < metam.PR < magm. N
Pb	magm. N < magm. PZ < metam.PZ < metam.PR

Note: Soil-forming rocks: magm. N - magmatic neogene; metam.PZ - metamorphic Paleozoic; metam.PR - metamorphic Proterozoic; magm.PZ - magmatic Paleozoic.

In the belt of coniferous and mixed forests, the soil cover is represented by brown mountain-forest weakly podzolic stony soils [10]. They are distinguished by low profile power and high saturation of stony inclusions.

The content of trace elements in the brown mountain forest low podzolic soils of the altitude belt is intermediate between the primitive soils of the subnival belt and mountain meadow soils. Relative to soil-forming rocks in the soils, chemical enrichment prevails. The decrease compared with the rocks in the soils on Paleozoic metamorphic deposits is characteristic of the chemical elements Cu, Ag, W, Nb; on magmatic Paleozoic - Sn, Ga, Sr, Be; on metamorphic Proterozoic - Cu, Mo, W, Y.

Table 5: The coefficients of radial differentiation for the soil belt of coniferous and mixed forests, formed on different soil-forming rocks

Chemical elements	Soil-forming rocks		
	metamorphic Paleozoic	magmatic Paleozoic	metamorphic Proterozoic
Cu	0,87	1,57	0,91
Zn	2,09	2,74	1,70
Pb	1,39	1,23	1,97
Ag	0,87	1,21	1,14
Sn	1,35	0,95	1,05
Mo	1,59	1,32	0,67
W	0,85	1,47	0,93
Ba	1,48	1,39	1,46
Co	1,41	2,37	1,36
Ni	1,39	3,09	1,16
Mn	1,13	2,30	1,15
Ti	1,34	1,30	1,16
V	1,29	1,63	1,24
Cr	1,22	1,47	1,13
Ga	1,33	0,96	1,07
Ge	1,25	1,38	1,38
P	1,53	1,16	1,71
Li	1,36	1,51	1,22
Be	1,80	0,89	1,19
Sr	1,10	0,89	1,10

Y	1,02	1,34	0,88
Yb	1,04	1,39	1,04
Zr	1,33	1,98	1,17
Nb	0,88	1,24	1,50
Sc	1,17	1,46	1,29

Among the soil-forming complexes in the belt of coniferous and mixed forests there are no volcanogenic deposits of Neogene, and therefore the regional structure of the radial redistribution of chemical elements has a more simplified form (Table 6).

Table 6: Regional structure of the radial redistribution of chemical elements in the soils of the belt of coniferous and mixed forests

Elements	Changes in the intensity of radial differentiation on various soil-forming rocks
Zn, Co, Ni, V, Cr, Li, Y, Zr	metam.PR< metam.PZ < magm. PZ
Cu, Ag, W, Mn, Yb, Sc	metam.PZ < metam.PR< magm. PZ
Be, Ga, Sn, Sr	magm. PZ < metam.PR< metam.PZ
Pb, P	magm. PZ < metam.PZ < metam.PR
Nb, Ge	metam.PZ < magm. PZ < metam.PR
Mo, Ti	metam.PR< magm. PZ < metam.PZ
Ba	magm. PZ < metam.PR< metam.PZ

Note: Soil-forming rocks: metam.PZ - metamorphic Paleozoic; metam.PR - metamorphic Proterozoic; magm.PZ - magmatic Paleozoic.

A similar set of complexes of soil-forming rocks in high-altitude belts makes it possible to compare among themselves the regional structures of the radial migration of chemical elements in the soils of different altitudinal belts. Cu, Co, Y, Yb, Nb, V, Sn, Ni, Li, Ga and Be have the greatest similarity in their structures of radial migration in the soils of the three high-altitude belts. It can be argued that for these chemical elements the decisive role in their radial redistribution between soils and rocks is played by the geological factor (geochemical specialization of soil-forming rocks, especially the weathering processes of the latter). The different intensity of radial migration for these elements is largely determined by the transformation of minerals of rocks during weathering, the formation of tightly bound or mobile compounds of elements [11–13].

Differences in the regional structures of radial migration in the soils of the considered altitude geobotanical belts are characteristic of Zn, Pb, Ag, Mo, W, Ba, Mn, Ti, Cr, Ge, P, Sr, and Sc. For these elements, under the influence of different biogeochemical gyres in high-altitude belts with different types of vegetation, a change occurs in the sequence of radial differentiation between soils and soil-forming rocks of different ages and genesis. The biogeochemical transformation of all modern soil-forming rocks and weathering products is now generally recognized [14].

The influence of the biological factor on the radial redistribution of chemical elements between soils and rocks is also traced when considering the radial differentiation of microelements in the soils of different altitudinal belts formed on the same soil-forming rock (Table 7). Comparison of the series of chemical elements with radial accumulation (R> 1.5) and removal (R <1) shows the change in the intensity and direction of the redistribution of elements under the influence of various types of biogeochemical circulation in altitudinal belts.

Table 7: Rows of radial redistribution of trace elements in the soils of different altitudinal belts formed on the same soil-forming rocks

Solids	Altitudinal belt	Radial accumulation (with R>1.5)	Radial takeaway (with R<1)
magm. N	subnival	Zn> Y> Ni> Ba > Co, Sc> >Nb>Yb,W, Mn> V, Ge > Ti	Mo
	subalpine and alpine meadows	Mn > Y> Zn> Ni> Co> Sc> >Yb>Ba> Sr >Nb> Ge> Ti	Cu>Ga>Sn>Li>Be> >Mo
metam. PZ	subnival	Zn> Pb, Be> Ba> P> Zr > Ge> Ti >Mn	Cu> W> Ag
	subalpine and alpine meadows	Zn> P> Be>Pb, Mn>Ba	Sr > Mo >Nb> Cr> >Y> Zr>Sc>Ag, Cu > > W
	coniferous and mixed forests	Zn> Be> Mo >P >Ba	Cu> Ag> W> Nb
magm. PZ	subnival	Ni> Co> Zn>Zr>Mn>V,W> Ge, Cu, Sc	Ga> Sn
	subalpine and alpine meadows	Ni> Co> Zn> Mn> V> Cu	P> Ag >Mo > Ga> Sr > W >Be, Sn
	coniferous and mixed forests	Ni> Zn>Co> Mn> Zr> V> Cu > Li > > W, Cr, Sc	Ga> Sr> Be> Sn
metam. PR	subnival	Pb> Zn> Ba> Be> Co> Sc> Mn	Cu> Sn>Y> W
	subalpine and alpine meadows	Zn>Pb > Co> Ba	Sn> Zr >Cu, Yb >Y > W >Mo
	coniferous and mixed forests	Pb > P, Zn> Nb > Ba	W >Cu > Y > Mo

CONCLUSION

In the high-altitude geobotanical belts of the Kuban-Terek landscape district of the Greater Caucasus, a regional structure of radial differentiation of elements is formed. It represents a specific sequence of changes in the intensity of the radial redistribution of elements between soils and heterogeneous soil-forming rocks. The features of the radial redistribution of chemical elements in the system “soil - soil-forming rocks” are the result of the long course of complex weathering of rocks and soil formation with a complex combination of factors of internal and external migration of chemical elements. Among the external factors, the most important are the weathering features of soil-forming rocks of different ages and genesis. The effect of a certain type of biogeochemical cycle on the solubility of compounds of chemical elements in soils and soil-forming rocks also has an effect.

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