Soil Cover in the North Urals

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Abstract:

We have studied the conditions of formation and morphological features of mountain soils in the Northern Urals. The purpose of the research was to study morphological and genetic features and classify soils of the Homgi-Nel Mountain within the western North Urals macroslope. In mountain areas, a detailed morphological description of soils is particularly important since at higher altitude soil forming conditions cause formation of soils with pronounced differences in color, structure and thickness of the horizons. Subject of the research: mountain soils in "Vishersky" Natural Reserve, the fourth largest reserve in Europe. It is located in the extreme north-east of the Perm region in the river Vishera headwaters. Its territory is situated within mountains with 800–1200 meters level difference embracing fragments of central backbones of the Urals. The diversity of soil forming conditions causes diversity of soil cover. Based on morphogenetic soil characteristics, the following divisions are highlighted: Leptosols, Glandular-metamorphic, Structural and Metamorphic, and Organo-accumulative. We have discovered the following basic morphogenetic soil characteristics: rubbility, truncated profile, distinct horizontation, gleyzation, ferrugination, and podzolization. Types of soils have vertical development limits. Soil-topographic series are geometrically diverse and genetically diverse.

Keywords:

Reserve, High-Altitude Zones, Vegetation, Mountain Soil, Genesis, Morphological Characteristics, Classification

1. Introduction

The richness of the soil can be estimated by Product inviolable plant communities [1]. The considered dependence is known for different types of habitat of plants [2, 3].
In the mountainous regions, various soils are formed [4-7]. The genesis and geography of mountain soils have been partially studied, and the classification and systematics sections of these soils have been weaker [4,8, 9].

Stationary studies of soils, soil-forming processes and their dynamics are conducted rarely in Russian natural reserves nowadays, and studies of soil cover are only conducted in 20% of reserves [10-15].

Studies of the Urals soils started later than in other mountains. In the Perm region, the unique biocenoses of Northern Urals are presented in the "Vishera" state natural reserve. The diversity and genetic characteristics of the soils of the Northern Urals have not been studied within the reserve before.

The spatial-structural organization of the soil cover of mountain geosystems in the Urals varies with the altitude of the terrain [14-16]. Varying the heights of the same types and subtypes of soils is a prerequisite for the formation of soil cover. In the identification and study of high-altitude organization, the boundary conditions of soils are not important in themselves, they are variable, but it is necessary to know the relationship between these limits. To analyze the structure of the soil cover determines the index of complexity, heterogeneity and contrast [17].

As V.S. Kryshchenko et al. [17], the lack of these indicators is manifested in the fact that the results thus obtained are of a private nature, because the soil-topographic series changes the set of soils and the absolute height of their occurrence, so they can be eliminated. In this regard, for the evaluation of soil-topographic series, the altitude indicators developed by V.S. Kryschenko were used.

The purpose of the research is to study morphological and genetic features and classify soils of the Homgi-Nel Mountain within the western North Urals macroslope. The morphological appearance of each soil is unique which may be due to both geomorphological conditions and plant communities.

2. Materials and Methods

2.1 Geographical Position

The object of the research are mountain soils in the "Vishersky" natural reserve, the fourth largest reserve in Europe located in the extreme north-east of the Perm region in the river Vishera headwaters (between 60 ° 54'-61 ° 40 N and 58 ° 40'-59 ° 27 'E) (Figure 1, 2). Its territory is situated within mountains with 800–1200m level difference embracing fragments of central backbones of the Urals.

Figure 1. *The location of the Perm Territory in the territory of Russia.*

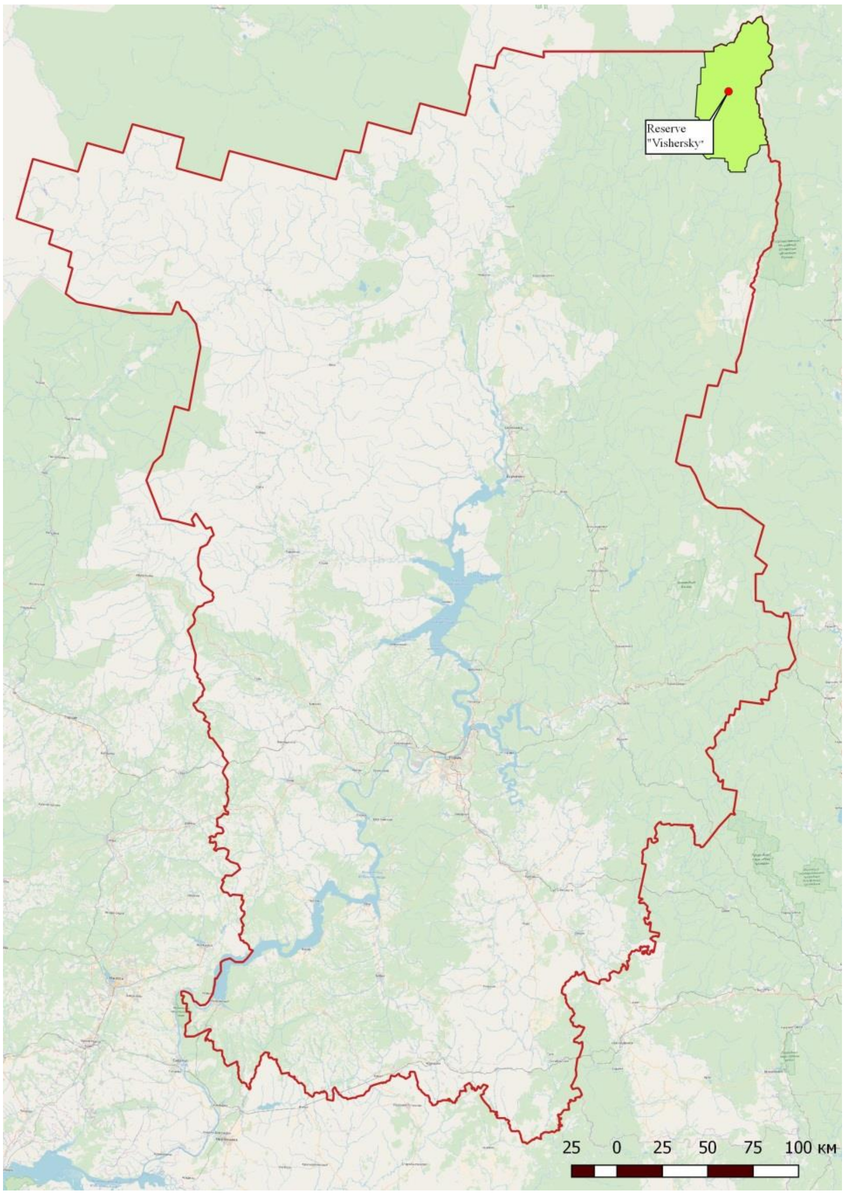

Figure 2. *Location of the territory of the reserve "Vishersky" (red territory A).*

2.2. Soil Research Area

According to the soil map of the Perm Region [18], this area belongs to the Middle taiga mountain region of the European province of the Northern middle taiga region of the flat-leaved sandy-loamy podzolic district.

2.3. Natural Conditions

A characteristic feature of the relief of the Northern Urals is the presence of ancient equalization surfaces elevated to different heights, so that flat-topped or dome-shaped ridges and massifs predominate, regardless of their height. Various researchers in different parts of the Urals have from one to seven aligned surfaces. These ancient equalization surfaces serve as proof of the uneven elevation of the Urals in time.

The Northern Ural is characterized by the absence of modern glaciation and the presence of high-altitude belts: cold goltsovye deserts, mountain tundra, podgoltsovy belt (birch forests, park fir forests, and meadow glades), mountain forest belt (dark coniferous fir taiga, light coniferous forests). Thus, the variety of conditions for the formation of soils determines the variability of the soil cover.

Soil-forming rocks in the upper parts of the slopes are represented by eluvium of bedrock, mainly quartzite and schist, which sometimes come to the surface. On the slopes, soil formation occurs on loose eluvial-deluvial deposits.

2.4. Research Methods

The study of the structure of the soil cover was carried out at a key site in the catchment basin of the river. The Great Molebnaya (Figure 3), because in this basin there are various elevations and a high degree of dismemberment. Soil contours of the basin were digitized by space images, automated by the method of interpretation of remote sensing data, taking into account all factors of soil formation. Based on the geo-information system ESRIArcGis 10.2, a digital map of the soil cover of the key site was created.

Figure 3. *Space image of the key site (the central part of the reserve, the Bolshaya Molebnaya river basin).*

We conducted the pedological survey at an altitude of 920 (mountain tundra belt) to 458 (mountain forest belt) meters. Using catenary method, we made 8 cross sections and took soil samples at the Homgi-Nel mountain (1301 m), Molebny Kamen range, Northern Urals.

Within the key area, a soil-geomorphologic profile was laid, within the boundaries of which a field survey was carried out and soil sections were plotted in various altitudinal-vegetation belts. The length of the profile is 5500 m, the total height difference is 460 meters, and the slope varies from 1 to 27 degrees.

To calculate the characteristics of high-altitude soil organization, the methodology was used by V.S. Kryschenko [17]. This methodology allows the absolute incomparable characteristics of soil-topographical series to be supplemented with relative comparable indicators:

1. Amplitude of soils (Δh, m) $\Delta h = h_u - h_l$

where, h_u – upper level of soil occurrence, h_l – lower level of bedding of soils.

2. Coefficient of high-altitude organization of soils (CH):

$$CH = h_u / h_l$$

by soil types and subtypes.

3. Coefficient of relative soil-topographic series (KH): within the topographic series, the smallest height *h1* is assumed per unit, and the heights of the topographic soil:

$$CR = h_i / h_1,$$

are alternately divided into it.

4.The density of filling with soil type and subtype of a unit of height (ah):

$$ah = KB * 1000 / \Delta h$$

The greater the value of a, the more densely the soil types are filled with unit of height [17].

Based on morphological features, the soils were classified using substantively-genetic classification of soils in Russia [19] and World Reference Base of Soil Resources (WRB) [20, 21].

To process the material, statistical methods were used in the programs EXEL, STATISTICA.

3. Results and Discussion

Old plains of subaerial denudation raised to different altitude are the characteristic feature of Northern Urals relief hence there are flat-topped and dome-shaped ranges and mountain groups. Northern Urals are characterized by the absence of contemporary glaciation and the presence of high-altitude zones: cold goltsy desert, mountain tundra, subgoltsy belt (birch crooked forest, parkland spruce-fir forest, meadows), mountain forest belt (dark coniferous spruce-fir taiga, light coniferous pine forests).

Mountain tundra zone (850-1200 m) is represented by different types of open treeless communities: herb and moss, suffruticous, rocky and lichen tundra, and thickets of dwarf birch trees in different combinations. Mountain tundra intersperses with deposits of stones representing goltsy desert. The vegetation is poor in species composition and is represented by mosses and alpine flora. At an altitude above 1200 m, among large-block stone hollows there is the uppermost high-altitude zone of the Ural Mountains – cold stony desert, or goltsy. The vegetation is represented by colored crustose lichens growing on the rocks. Thus, treeless spaces are characterized by high-contrast microclimate conditions, creating different combinations of weathering and soil formation conditions.

In rough environment of mountain tundra, shallow soils are formed (8-9…30-31 cm); their structure allows diagnosing primary soil formation process, where the combination of soil-forming agents leads to the formation of *Soddy forest ferrous-humic-illuvial soils* (*Entic Podzols, Umbrepts*) and *Infantile soils* (*Cambisolss*). The soil profile is not fully developed, but clearly differentiated into genetic horizons by color and content of specific components. For example, in section 8-14, there is clearly visible organic oligotrophic peat crust, under which illuvial-ferruginous horizon with signs of gley is formed, and under it there is a gley horizon of bluish color with rusty spots of iron compounds. Thus, illuvial accumulation of iron-humus compounds forming specific chemogenic alfehumic horizon is morphologically evident which diagnoses alfehumic soils, particularly *Soddy forest ferrous-humic-illuvial gley soils (*O-BFg-Gox). Long frost weathering and a short warm season contribute to long-term water saturation and chemogenic reduction of iron compounds. There are transitional (g – gleysolic soil in alfe-humic horizon) and process (ox) signs

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except diagnostic horizons. In addition, there are *Infantile soils (Cambisols*) in mountain tundra (goltsy) belt represented in infantile humus horizon, thickness of which is less than 5 cm, on solid bedrock (O-W-R). Such soils are formed in places of fine soil accumulation between deposits of stones.

In the sub-goltsy belt, soil cross sections were made in areas of different sub-belts differing in the predominant vegetation: mesophilic subgoltsy meadows sub-belt (cross section 6-14), mountain crooked forest sub-belt (cross section 5-14), subgoltsy light forest belt (cross section 4-14). The relief here is unhomogeneous and diverse and includes slopes of different angle, well-marked microrelief, and biogenic forms of relief. There are swampy areas, deposits of stones, creeks and streams crossing the area. So, on the mesophilic meadow motley grass-veynikovym with fragments of low-grass-hunterbite, among the park forest and forest curve formed *Organo-accumulative gray-humic soil* (O-AYel-AYm-AY-C, *Umbrisols*). It has a stretched humus profile with gradually changing color from gray-brown to black and well defined solid structure. The grey humus horizon has transient signs of eluviation (el) and metamorfization (m) expressed in the presence of clarified material in the form of mineral grains dispersed in the mass of the horizon and in the presence of nuciform lumpy structure, respectively. In bilberry birch and scrub forest in mountain crooked forest sub-belt on a cleve, the *Lithic soddy forest ferrous-humic-illuvial soils* (O-AYe,g-BH-BF-C, *Entic Podzols, Leptosols*) with alfe-humic horizon and truncated profile (less than 30 cm) are formed; they have a sod horizon with transient signs of podzolity. This feature diagnoses the podzolic subtype. In light parkland forest with tallgrass meadows on gentle slopes, there is an iron-metamorphic horizon in soil profile occupying more than a half of the profile and diagnosing *Brown forest ferralitic* (O-AY-BFMgr-BFM-C, *Umbrisols Rhodic*) soil type. The gr process sign is evident in BFM diagnostic horizon.

In mountain forest belt, cross sections were made on test areas with different slope angle and ground cover in the spruce-fir taiga. Relief varies in this belt and has well marked biological forms. Wetlands can be found on poorly drained slopes. At an altitude of 400-600 m there is a sub-belt of mountain spruce-fir forests with an admixture of birch, mountain ash and cedar. The forest is light and bushy (height up to 15 m). Fir-spruce taiga gradually turns into a spruce-fir along with the mountain altitude. Percent of birch (up to 30 %) and cedar (10-30 %) rises sharply. Lightness of mountain forests causes development of dense grass cover. On drained slopes there are large ferns spruce-fir forests, and on wet slopes and areas with temporary watercourses light tallgrass taiga and moist shavegrass spruce forests developed.

Under the spruce-fir forests the soils of thickness of 20...75 cm are formed. On the slopes of angle more than 5˚ low thickness *Lithic immature soils* (*Leptosol*s) and *Brown forest* (*Cambisols*) soils are formed. Profile-forming processes are overlapped by horizon-forming ones appearing in transient (g, ao, m) and process (hi) signs (O-AYao-AYm-R; O-AYao,g-AYg,hi-R). On more gentle slopes in the lower part of mountain forest belt under fir-spruce taiga the *Soddy-podzolic ferrous illuvial* (*Umbric Ferralic Gleyic Albeluvisols*) soil with signs of gley has formed. The profile is quite thick as for mountain area (75 cm) and clearly differentiated into genetic horizons (O-AY-Eg-BTf,g-BTf-CLM).

To conclude, on the Homgi-Nel Mountain of the Northern Urals there are soils of both primary and postlitogenic soil forming (Table 1).

Table 1. *The classification position of soils on the mountain Homgi-Nel.*

Taxonomic unit			
Trunk (soil forming)	**Section**	**Type**	**Subtype**
Primary	Infantile soils	Petrozem	Humus
Postlithogenic	Lithic soils (Lithozems)	Gray-humic	Metamorphosed
			Gley
			Humic-infiltrated
	Ferralitic-metamorphic	Brown forest ferralitic	Iron-granular
	Organo-accumulative	Gray-humic	Eluvial
			Metamorphosed
	Al-Fe-Humus soils	Forest ferrous-humic-illuvial gley	Oxidation-gley
		Soddy forest ferrous-humic-illuvial	Podzolized
	Texture-differentiated	Soddy-podzolic	Ferrous illuvial
Synlitogenic	Alluvial soils	Gray-humic	Gley

Within the key area, the largest area (2,363 ha) is occupied by the soils of the department of *Underdeveloped soils*. The soils of the *Alfe-humus* department are also predominant – 983 hectares. *Organo-accumulative* occupy 436 hectares. The minimum area is occupied by the soils of the sections of *Ferruginous-metamorphic* 51 ha, and the *Alluvial* department is 46 ha.

Soil-topographic series of soils are presented in the table 2.

Table 2. *Indicators of high-altitude organization of soils on the key site.*

Soils (types, subtype), Field determinant of soils in Russia, 2008 (Reference Soil Groups (WRB), 2014)	**h_u**	**h_l**	**Δ h**	**CH**	**ah**	**CR**
Mountain forest belt						
Alluvial soils (Fluvisols)	520	420	100	1.24	12.40	1.24
Sod-podbur gleyic (Enti-Gleyic Podzols)	520	460	60	1.13	18.80	1.24
Sod-podzol coarse-humus (Umbri-Histic Podzols)	520	460	60	1.13	18.80	1.24
Gleizems (Gleysols)	540	460	80	1.17	14.63	1.29
Subalpine (podgoltsovy) belt						
Litho-Sod-podbur podzolized (Leptic Entic Podzols)	740	520	220	1.42	6.45	1.37
Lithozems (Leptosols)	760	460	300	1.65	5.50	1.81
Sod-podbur contact-clarified (Enti-Gleyic Podzols)	760	520	240	1.46	6.08	1.41
Humus-gley (Histic Gleysols)	820	640	180	1.28	7.11	1.52
Brown podzolized (Umbrisols)	820	520	300	1.58	5.27	1.52
Brown forest ferralitic (Umbrisols Rhodic)	820	520	300	1.58	5.27	1.52
Organo-accumulative gray-humic (Umbrisols Leptic)	840	520	320	1.62	5.06	1.56
Tundra (goltsovy) belt						
Podbur gley-oxidized (Gleyic Podzols)	1160	800	360	1.45	4.03	1.45
Petrozems (Regosols)	1320	600	720	2.20	3.06	1.65

Note: hu – upper level of soil occurrence; hl – the lower level of occurrence of soils; Δh – is the amplitude of bedding of soils; CH – coefficient of high-altitude soil organization; CR – coefficient *of relative soil-topographical series; ah – is the density of filling with the type and subtype of soils of a unit of height.*

Within the key area, the amplitude of occurrence of soils varies from 60 m in the soils of the mountain-forest belt to 360-720 m in the goltsy belt (see Table 2). The maximum amplitude (or level of occurrence) is characterized by low-power underdeveloped soils – *Petrozems.* A smaller amplitude is characteristic of the soils of the *Alfa-humus* department – the sod-subbore of the gley.

The coefficients of high-altitude organization of soil axes allow us to determine the association of soils in space. The amplitude of the level of occurrence of the soil of the department of alfa-humus conditionally can be combined into 3 groups: $\Delta h < 60m$; Δh 220-240m; $\Delta h > 300m$. Thus, the soils of the alfa-humus department have different provincial topographical combinations due to the imposition of elements of the soil cover and have a more complete filling of the unit of height.

The *Alluvial soils* have maximum *CH* (1.24) with an amplitude of occurrence of 420-520 m. The *Brown forest podzolized* and rusty piles have a bedding amplitude of 520-820 m. The coefficient of high-altitude soil organization is 15.8, the density of occurrence per unit height ah is 5.27. Thus, the ecological conditions at an altitude of 520-820 m above sea level most favorable for structural metamorphism and ferruginism. The gray humus soils have a length of a topographic niche (Δh) equal to 320 m and are formed within the heights of 520-840 m, which corresponds to the sub-highland and high-altitude girdle, the *CR* is 1.62, the filling density is 5.06 (ah), which is a low indicator.

The *Lithozems* have a length of a topographic niche (Δh) of 300 m and are confined to heights of 460-760 m asl, which corresponds to high-altitude vegetation geosystems of mountain forest and sub-bald belts. *CR* of soils of the lithozem department - 1.65. The density of filling a unit of height (ah) is 5.5.

The *Gleizem* and *Humus-gley* have different altitude confinement. The amplitude of occurrence of the *Gleyzemes* is 80 m in the sub-gland belt. The coefficient of altitude organization is (*CH*) 1.17, the filling density (ah) is high and is 14.63. *Humus-gley soils* are higher than *Gley soils* (640-820 m) with a vibration amplitude of 180 m, and have a density of filling a unit of height (ah) - 7.11.

The *Petrozems* have a maximum amplitude of occurrence (ah) - 720 m and occupy heights in the goltzovy belt from 600 to 1320 mas, *CH* is 2.2, filling density (ah) is 3.06.

Types of soils in mountain conditions occupy such height limits, the ratio of which tends to the values of the altitude organization coefficient 1.40-1.43 [8]. If we take the entire set of obtained values of the *CH* of the authors of this technique, then it varies in the limit from 1.00 to 4.00. Our data are in the range 1.13-2.20, which confirms this pattern.

4. Conclusions

The classical position of the soils of the Northern Urals is determined on the basis of the morphogenetic characteristics: the separated sections, within which are the types and subtypes of soils, the genus (unsaturated, uncarbbanate); on the thickness of the humus horizon – the type of soils (small); in the depth and place of gleying – superficially gleamed; by the degree of saturation with bases – strongly unsaturated and unsaturated. Species are distinguished by the granulometric composition – from medium loamy to clayey, and by the degree of skeletality – medium- and strong-skeletal.

The main morphological and genetic features of mountain soils in the Northern Urals are revealed: crushed stone, soil profiles of various thicknesses, distinct differentiation into horizons, gleying, ferruginization, podzolization. The following elementary soil-forming processes in soils are diagnosed by selected morphological features: sod, alfe-humus, gley, podzolic, illuvial, metamorphic, eluvial.

Assessment of the high-altitude organization of soil-topographical series showed that the departments, types of soils have a definite relationship with the absolute altitude of the terrain, which reflects the differentiation of the soil cover and its evolution. Types of soils have vertical development limits. Soil-topographic series are geometrically diverse and genetically diverse.

Conflicts of Interest

The author declares that there is no conflict of interest regarding the publication of this article.

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