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Morphogenetic Features of Soils under Mountainous Larch Forests and Woodlands in the Subpolar Urals

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Abstract—On the basis of the profile-genetic approach, diagnostic features of poorly studied mountainous soils under larch forests and woodlands in different geomorphic positions of the Subpolar Urals were identified, and their classification position was determined. The morphological, physicochemical, and chemical characteristics of the studied soil profiles were described. It was found that the soil cover under blueberry–moss larch stands is mainly composed of iron-illuvial svetlozems and iron-illuvial podzols. Both soils were identified as Albic Podzols (Skeletic) in the WRB-2015 system. On the outcrops of calcareous rocks on slopes of river valleys, gray-humus soils (Calcaric Leptosols (Skeletic)) and iron-illuvial podzols were described. They occupy small areas and can be referred to as rare soils in the studied region. Near the upper treeline, lithozems (Lithic Leptosols (Skeletic)) and podburs (Entic Podzols (Skeletic)) are developed; these soils are common in the mountainous tundra landscapes. The accumulation of plant litter on the soil surface and its slow mineralization predetermine the raw-humus and peaty nature of the upper horizons with a broad C : N molecular ratio.

Keywords: diagnostic horizons, *Larix sibirica*, parent material, soil classification

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INTRODUCTION

The study of the interdependence of forest vegetation and soil diversity in geochemically conjugated landscapes is of great interest, especially in the mountainous ecosystems of the boreal zone, where contrasting environmental conditions are created, and the soil and vegetation covers are formed under the influence of a complex set of factors. In this regard, one of the most interesting objects for soil and geographical research is the Ural Mountains. Owing to the long length of the Urals from north to south (more than 2000 km) and significant changes in climatic conditions in this direction, as well as owing to the mineralogical and petrographic diversity of parent rocks, a large and diverse group of soils is formed there. The presence of numerous mountain ranges determines the formation of vertical zonality, which complicates the soil cover and increases pedodiversity.

The zone of taiga (boreal) forests in the Urals and adjacent plains occupies a vast territory from 55° to 66° N. A comparative analysis of the scientific literature shows that the genetic features of the soils of the Ural Mountains have been studied quite fully within the middle and southern taiga subzones covering mountain landscapes of the Northern and Middle Urals [5, 19, 28, 33, 35–38, 47, 48].

Despite the long history of research, the features of soils and vegetation in the northern part of the Subpolar Urals (especially in hard-to-reach areas) are still poorly studied [17, 41]. In particular, information on the diversity and genetic characteristics of soils of the mountainous forest and forest-tundra vegetation zones is extremely scarce; the classification position and diagnostic features of these soils are debatable [13, 39]. Meanwhile, the soil-protective and especially the water-regulating role of mountainous forests is extremely important. Numerous streams and rivers originate in the mountainous forest zone of the Urals and supply water to large rivers of the North: the Pechora and Ob rivers [30].

Subpolar Urals is the most elevated and widest part of the ancient Ural Mountains stretching from the source of the Khulga River in the north (65°40′ N) to Mount Telpos-Iz in the south (63°50′ N). Forests in this area are of particular interest for researchers, as they occur near the northern treeline and are of great environmental importance on a regional and global scale [3]. Low and middle-high mountains are covered by larch and spruce forests with a small admixture of birch; upwards, they are replaced by open woodland composed of Siberian larch and birch.

The formation and functioning of larch forests in the continental and moderately continental humid climates have been studied in various regions of Russia [8, 10, 25, 35]. In vast areas covering plain and mountainous landscapes of the West, Central, and East-

Siberian taiga-forest regions, larch forests are formed under conditions of continuous or discontinuous and isolated permafrost [1]. In the European north of Russia, larch forests are mainly found in the Urals and Timan Range beyond the permafrost zone and remain insufficiently studied [18].

Significant changes in national and international soil classification systems require a review of the genetic and geographical concepts of the soil cover of the North, including mountainous territories [2, 8]. In this context, problems of the genesis, characteristic morphological features, and analytical properties of soils in the European northeast of Russia (including mountainous ecosystems), as well as the evaluation of elementary pedogenetic processes acting in these soils remain insufficiently studied and require special attention. The classification position of these soils is debatable. It is also necessary to study characteristic features of the soil cover of the territory as a whole.

The purpose of this paper is to identify the diversity and genetic characteristics of the soils of larch mountainous forests in the forest and forest-tundra altitudinal zones of the Subpolar Urals, the environmental conditions of their formation, and to determine the classification position of these soils according to the new Russian [32] and international [53] soil classification systems.

OBJECTS AND METHODS

We studied soils of mountainous larch forests of the Subpolar Urals on the Maldynyrd, Yuasnyrd, and Kuz'kudiner ridges and in the area of the geological natural monument Reef Balban"yu in the national natural park Yugyd va—the largest specially protected natural area in Europe. Soil pits were excavated under major phytocenoses, and detailed geobotanical descriptions of studied plots were performed according to standard methods [20]. When classifying vegetation, we used the eco-phytocenotic approach. In the morphological description of soils, the designations of soil horizons followed the system suggested in the new classification of Russian soils [32]; the classification position of soils was determined according to Russian [32] and international [53] approaches. Soil color was determined using Munsell soil color charts [54]. Forest litters were subdivided into the L, F, and H subhorizons in the dependence on the degree of decomposition of plant residues.

Physicochemical properties of soils were determined by standard methods [43]. Quantitative chemical analysis of the samples for the total carbon and nitrogen contents was performed on an EA 1100 analyzer (Carlo Erba) at the Chromatography Collective Use Center of the Environmental Analytical Laboratory of the Institute of Biology, Komi Science Center, Ural Branch of the Russian Academy of Sciences. The exchangeable cations were extracted with an ammonium acetate extract (pH 7) and determined on an ICP Spectro Ciros atomic emission spectrophotometer. The pH of the soil water and salt suspensions was determined potentiometrically with a glass electrode. Particle-size distribution analysis in the fine earth (<1 mm) was performed according to Kachinskii'e method with NaOH pretreatment and soil boiling for destruction of soil aggregates. Bulk elemental composition of the samples was determined by X-ray fluorescence method on a VRA-33 device. We also determined the contents of oxalate-extractable iron (Tamm's method) and dithionite-extractable iron (Mehra–Jackson's method) [43]. The content of the gravels and stones 1 (>1 mm) was determined by the gravimetric method.

The climate of the Subpolar Urals is continental with a predominance of the cold period over the moderately warm period [4], which is due to the northern position and considerable height of the ridges (1600–1800 m a.s.l.). Climatic conditions of particular sites strongly depend on the orographic features and slope aspect. The mean annual air temperature varies from –3 to –7°C. The mean annual precipitation is from 800 to 1100 mm with a larger part in the warm (May–October) season [4]. According to the botanical-geographical zoning [21], the studied territory belongs to the Kama–Pechora West Ural subprovince of the Ural–Western Siberia province of the Eurasian taiga region. The vertical zonality of vegetation is clearly expressed and includes the following altitudinal zones: mountainous forest (up to 450–500 m a.s.l.), subgoltsy (500–550 m a.s.l.) (a transitional zone between the mountainous tundra with frequent bold (goltsy) rock outcrops; hereinafter, it is referred to as the mountainous forest–tundra ecotone), mountainous tundra (550 to 800–850 m a.s.l.), and cold mountainous deserts with bold rock outcrops (above 850 m a.s.l.) [7].

RESULTS AND DISCUSSION

Siberian larch (*Larix sibirica* Ledeb.) is one of the main forest-forming species in Russia [35]. It serves as an edifier in forests of different mountain systems (the Urals, Altai, Sayany, etc.). A larger part of its area lies to the east of the Ural Mountains. In the Komi Republic, larch forests occupy no more than 1% of the territory [27]. However, forest communities with the dominance of *Larix sibirica* determine the appearance of the vegetation cover in the mountainous forests on the western macroslope of the Subpolar Urals [25, 49, 56].

The studied larch communities are formed under extreme climatic conditions, which is reflected in their structural organization. As a rule, larch forests have a relatively low canopy density; the diameter and height of the trees correspond to low forest quality (bonitet) values. The tree stand usually has one or two major tiers and consists of two–three tree species. Herbaceous and green-moss types of larch forests predominate in the study area. In this paper, we discuss the materials obtained for the green moss type of larch forests with a well-developed lichen–green moss ground cover with a predominance of *Pleurozium schreberi* and *Hylocomium splendens*. One test plot (pit 8-2009) was examined in the sphagnum type of larch forests (Table 1).

Information on the morphology and physicochemical properties of soils under mountainous larch forests and sparse larch woodlands of the Subpolar Urals is presented below.

Mountainous Forest Zone

Within the accumulative and transeluvial positions (lower and middle parts of gentle slopes, respectively), under blueberry–green moss and dwarf shrub–green moss larch forests, iron-illuvial svetlozems and iron-illuvial podzols (Albic Podzols (Skeletic) [53]) predominate.

Iron-illuvial svetlozems are developed from relatively thick (about 70 cm) loamy deposits underlain by hard rocks of acidic (rhyolite, quartzite, quartz–muscovite schist) nature or by limestone. The tree stand is relatively dense, with two to three vertical layers. The maximum height of *Larix sibirica* on the footslopes and lower parts of slopes reaches 19–22 m. The layer of dwarf shrubs and herbs is dominated by *Vaccinium myrtillus* or *V. vitis-idaea*. On test plots in the areas of pit 7-2010 and pit 22-2009, 14 and 11 species of vascular plants, respectively, were recorded in the dwarf shrub–herb layer during the geobotanic description. Data on the morphology of iron-illuvial svetlozems described in these pits are presented below.

Pit 22-2009, middle part of a gentle slope (3°–5°) of southeastern aspect; blueberry–green moss larch forest. The Maldynyrd Ridge (65°19′50″ N; 60°40′08.2″ E). Soil horizons: moss stems (0–3 cm)–O (F + H) (3–6 cm)–Ehi (6–14 cm)–BF (14–27 cm)–CRM (27–37 cm)–BCcrm (37–55 cm)–C (55–70 cm). Under the weakly decomposed peaty litter O (F + H), a podzolized horizon Ehi of grayish-whitish color (10YR 7/1) and sand loamy texture is formed; its thickness is up to 8 cm. The underlying iron-illuvial BF horizon (up to 13 cm) has a bright rusty or reddish brown (10YR 5/6) color and sand loamy texture. The middle-profile CRM horizon (27–37 cm) is distinguished by its specific structure related to the in situ cryogenic transformation of the soil mass, i.e., to the cryogenic metamorphization (CRM horizon according to [32]). It has a yellowish brown color (7.5YR 5/6–5/8); horizontal divisibility of the soil mass is observed. Unstable lenticular aggregates up to 1 cm in thickness crumble into fine crumb–angular-blocky aggregates of 4–7 mm in horizontal direction and 3–4 mm in thickness. In the deeper part (BCcrm), their size increases to 10–12 mm; however, an increase in the content of gravels prevents the formation of the morphologically distinct structure; its specificity in indicated by crm symbol. The fine earth content in the C horizon (55–70 cm) decreases to 10–20 vol %. Morphochromatic indications of gley process are absent in the entire profile. This soil is developed from the colluvium derived from weathering products of rhyolites and quartz–sericite schist.

Pit 7-2010, lower part of a gentle slope in the area of the Severnye Maldy Ridge (65°26′13.1″ N; 60°32′50.9″ E); dwarf shrub–green moss larch stand. Soil horizons: moss stems (0–4 cm)–O (F) (4–14 cm)–O (H)pyr (14–16 cm)–Ehi (16–20 cm)–BF (20–24 cm)–CRM (24–40 cm)–CRMi,ca (40–55 cm)–Cca (55–70 cm). The main morphological differences (in comparison with the soil described in pit 22-2009) are associated with a thicker organic horizon with inclusions of charcoal particles in its lower part (symbol pyr). The podzolized Ehi horizon is saturated with humus infiltrated from the overlying litter and is characterized by the dark gray (5YR 6/1) color. The BF horizon has a yellowish brown (10YR 4/4) color and loamy texture. From the depth of 25 cm, it is underlain by the cryometamorphic CRM horizon of light brown color, clay loamy texture, and crumb–angular-blocky structure. This horizon contains single inclusions of calcareous pebble. In its lower part (CRMi,ca, 40–50 cm), thin discontinuous clayey coatings (i) are seen on lateral ped faces. From the depth of 60 cm, the content of calcareous gravels sharply increases; there are both rounded and angular platy gravels that strongly effervesce with HCl; the fine earth effervescence is only observed in direct contact (5–10 mm) with the calcareous rock debris. The full name of this soil according to [32] is the residual-calcareous pyrogenic clay-illuvial iron-illuvial svetlozem; in the WRB system, it can be classified as an Albic Podzol (Skeletic) [53].

In both profiles of svetlozems, the morphological differentiation into genetic horizons is distinct, and morphochromatic indications of gleying are absent. These soil profiles correspond to the diagnostics of typical svetlozems that were first described in the northern taiga of the West Siberian Plain by Tonkonogov in the 1980s [45] and then by other authors in the northeast of the European part of Russia [15, 33]. In the Subpolar Urals, svetlozems were described by us for the first time in [16].

The two profiles of svetlozems differ significantly in their physicochemical properties, which is associated with differences in the character of parent materials. Iron-illuvial svetlozems developing from the colluvial products of felsic bedrock (rhyolite and quartz–muscovite schist) have a strongly acid reaction and low base saturation in the entire profile (Table 2, pit 22-2009). Minimum pH values are in the organic horizons with the accumulation of raw humus. The total (hydrolytic) acidity has maximum values in the organic horizon with the high exchange capacity. In the mineral horizons, the content of exchangeable bases is relatively low.

Table 1. Major characteristics of studied objects

Pit no.; soil type (Russian/WRB classification systems); parent material	Geomorphic position; absolute height, m a.s.l.	Plant association	Height of the tree canopy	Total projective cover, %; dominant species in the dwarf shrub–herb layers	Total projective cover, %; dominant species in the moss-lichen layers
Mountainous forest zone					
22-2009. Iron-illuvial svetlozem; Albic Podzol (Skeletic); (quartz–sericite schist and granite)	Middle part of slope, 510	Bilberry–green moss larch forest	16–18	60–70; *Vaccinium myrtillus*	90; *Pleurozium schreberi*, *Hylocomium splendens*
7-2010. Iron-illuvial svetlozem; Albic Podzol (Skeletic); (calcareous rock)	Lower part of slope, 406	Dwarf shrub–green moss larch forest	19–22	60–70; *Vaccinium vitis-idaea, Empetrum hermaphroditum, Equisetum pratense, Geranium albiflorum*	98; *Hylocomium splendens, Pleurozium schreberi, Polytrichum commune*
83-2012. Iron-illuvial podzol; Albic Podzol (Skeletic); (calcareous rock)	Top of natural levee, 443	Dwarf shrub–green moss larch forest	10–12	40–50; *Vaccinium uliginosum, Empetrum hermaphroditum, Lycopodium clavatum*	95; *Pleurozium schreberi*, *Hylocomium splendens*, *Ptilium crista-castrensis*
87-2012. Pyrogenic gray-humus soil; Calcaric Leptosol (Skeletic) (calcareous rock)	Middle part of steep slope, 410	Dwarf shrub–green moss larch forest	12–16	60–70; *Vaccinium vitis-idaea, Rubus saxatilis, Cypripedium calceolus, Sanquisorba officinalis, Vaccinium uliginosum*	60–70; *Pleurozium schreberi, Cladonia arbuscula, C. rangiferina, C. stellaris*
Mountainous forest–tundra ecotone					
8-2014. Iron-illuvial podzol; Albic Podzol (Skeletic); (sericite–chloritic schist)	Middle part of slope, 587	Dwarf shrub–green moss larch woodland	10–12	30; *Vaccinium uliginosum, Carex globularis*	95; *Pleurozium schreberi*
12-2016. Podzolized podbur; Entic Podzol (Skeletic) (quartzite, sandstone)	Upper part of slope, 552	Bilberry–green moss larch woodland	8–10	60; *Vaccinium myrtillus, Vaccinium uliginosum*, *Avenella flexuosa*, *Juncus trifidus*	80; *Pleurozium schreberi*
8-2009. Raw-humus lithozem; Lithic Leptosols (Skeletic); (quartz–sericite schist)	Upper part of slope, 650	Dwarf shrub–sphagnum larch woodland	2–4	60; *Vaccinium uliginosum, Ledum decumbens, Empetrum hermaphroditum*	60; *Sphagnum capillifolium*, *Cladonia rangiferina*, *Polytrichum juniperinum*, *Pleurozium schreberi*

Iron-illuvial svetlozems developing from the substrates enriched in limestone debris of limestone (pit 7-2010) have a slightly acid reaction in the upper and middle-profile horizons and a neutral reaction in the lower horizons. The maximum values of hydrolytic acidity are in the organic horizons; the soil adsorption complex is saturated with bases. The organic carbon content has an accumulative type of distribution in the profile. The soil texture is somewhat heavier (silt loam to clay loam). In both svetlozems, fine sand and coarse silt fractions predominate and constitute 46–75% of the sum of all particle-size fractions (Table 3). As shown by a number of researchers [22, 34], seasonally freezing soils developing from loamy substrates are often characterized by the high content of coarse silt fraction, which is considered the lower limit of the mechanical disintegration of rocks in the course of cryogenic weathering and destruction of coarse sand and finer fractions [34, 40]. The high content of fractions >0.01 mm, along with an increase in the degree of stoniness in the lower part of the profile (>55–60 cm), determines good drainage and the prevalence of oxidizing conditions throughout the profile. The contents of the clay fraction and total Al_2O_3 oxide are not differentiated in the profile. The podzolic horizon is impoverished in the silicate and nonsilicate forms of iron. The illuvial maximum of these forms is in the BF horizon. An analogous distribution pattern of iron compounds was noted earlier by Tonkonogov [45] for svetlozems in the northern and middle taiga of the West Siberian Plain, where these soils are formed on well-drained interfluves.

Along with svetlozems, Al–Fe-humus podzols are widespread under mountainous green moss larch forests of the Subpolar Urals. They are developed from the stony colluvium. In the upper part of the mountainous forest zone (450–500 m a.s.l.) and in the mountainous forest–tundra ecotone with larch woodlands (500–600 m) of the Subpolar Urals, podzols are developed from the derivatives of quartz–sericite or sericite–chlorite schist and often form combinations with podzolized podburs [52]. In the lower part of the mountainous forest zone (350–450 m a.s.l.), on rocky riverine slopes composed of calcareous rocks overlain by a thin layer of Quaternary glaciofluvial sediments, iron–humus-illuvial podzols are formed (pit 83-2012) in combination with gray-humus iron-illuvial podzols (pit 87-2012).

Pit 83-2012, upper part of the riverine slope of 2°–3° (65°22′24.9″ N; 60°46′31.4″ E); dwarf shrub–green moss larch forest. Soil horizonation: O (F + H)pyr (0–5 cm)–Ehi (5–15 cm)–BHFca (15–20 cm)–BCca (20–40 cm)–Cca (40–60 cm). Under the moderately decomposed peaty litter with charcoal (F + H)pyr)), a podzolic Ehi horizon of up to 10 cm in thickness is formed. It is grayish (10YR 4/1) in the upper part because of the presence of humic substances washed out from the litter; in the middle part, the color becomes lighter (10YR 5/6–6/1); the texture is sandy/silty loam. The iron–humus-illuvial BHF horizon of 5-cm thickness is yellowish brown (10YR 5/8–5/6) silty loam. The debris of calcareous rocks in this horizon are covered by coffee-brown (2.5YR 3/4–4/4) loam of about 1 cm in thickness and strongly effervesce with HCl. Slight effervescence of fine earth is only observed at the contact with calcareous rock fragments. The boundary is clear and is marked by changes in the color and in the amount of calcareous rock debris. In the lower horizons (BCca–Cca), fine earth fills the space between large effervescent rock fragments (about 30–40% of the section area). Along with the debris of limestone, there are also coarse debris of massive crystalline basaltic rocks and rounded gravels and boulders. According to [32], the morphological features of this soil correspond to the diagnostics of the residual-calcareous pyrogenic iron–humus-illuvial podzols; in the WRB system, these soils should be classified as Albic Podzols (Skeletic) [53].

The content of gravels and stones in podzols increases down the soil profile and ensures good water infiltration and free drainage conditions, so that seasonal waterlogging and gleyzation are not developed in these soils.

The presence of abundant gravels and coarser fragments of hard calcareous rock in the lower horizons (from the depth of 25–30 cm) in pit 83-102 determines the specific properties of this soil: a slightly acidic to neutral reaction (pH_{KCl} 6.5–7.5), a relatively high content of exchangeable Ca^{2+} and Mg^{2+}, and a high base saturation. In general, these properties are atypical of podzols. At the same time, a distinct morphological (the presence of the BFH horizon) and analytical differentiation of the profile (minimum pH values of water and salt extracts from the podzolic horizon, eluvial–illuvial redistribution of the clay fraction and total Fe_2O_3 and Al_2O_3, and relative accumulation of SiO_2 in the Ehi horizon) confirm the identification of this soil within the type of iron-illuvial podzols. The presence of residual carbonates is reflected at the subtype level. The formation of distinct podzolic Ehi horizon of up to 10 cm in thickness is largely determined by the heterogeneity of the soil-forming substrate, which is represented by the products of the destruction and redeposition of calcareous rocks with a considerable admixture of allochthonous morainic material of more acidic composition. Podzols under conditions of close embedding by calcareous rocks in the Subpolar Urals are quite rare and occupy small areas in the soil cover.

Pit 87-2012, middle part of the steep (20°–25°) riverine slope of northern aspect (65°28′46.0″ N; 60°29′30.3″ E); dwarf shrub–green moss larch forest. The dwarf shrub–herb layer included 19 species with participation of calciphytes *Cypripedium calceolus, Epipactis atrorubens,* and *Gymnadenia conopsea.* Down the slope, at a distance of 100 m from this plot, the forest

Table 2. Physicochemical properties of studied soils

Horizon	Depth, cm	pH		Ac_{tot}	Exchangeable bases		V	C_{tot}	N_{tot}	$\frac{C}{N}$	Fe_2O_3d	Fe_2O_3o	Al_2O_3o
					Ca^{2+}	Mg^{2+}							
		H_2O	KCl	cmol(c)/kg			%	% of soil mass			%		
Pit 22-2009. Iron-illuvial svetlozem													
Moss	0–3	4.8	4.1	–	–	–	–	90.2*	–	–	–	–	–
O (F + H)	3–6	3.7	2.8	70.5	7.5	2.0	12	30.9 ± 1.0	1.41 ± 0.26	26	–	–	–
Ehi	6–14	3.8	2.9	23.3	0.5	0.2	3	2.90 ± 0.5	0.13 ± 0.02	26	0.41	0.20 ± 0.02	0.28 ± 0.07
BF	14–30	4.4	3.4	16.9	0.3	0.1	3	1.35 ± 0.23	0.09 ± 0.024	19	2.41	1.09 ± 0.16	0.64 ± 0.15
CRM	30–37	4.6	3.6	13.9	0.3	0.1	4	1.13 ± 0.2	0.08 ± 0.02	17	1.82	1.79 ± 0.26	0.59 ± 0.14
BCcrm	37–55	4.7	3.7	12.2	0.3	0.1	3	1.13 ± 0.2	0.08 ± 0.02	17	2.04	1.14 ± 0.17	0.72 ± 0.17
C	55–70	4.6	3.7	13.9	0.2	0.1	3	1.39 ± 0.24	0.09 ± 0.02	18	2.28	1.73 ± 0.25	1.38 ± 0.23
Pit 7-2010. Iron-illuvial svetlozem													
Moss	0–4	4.9	4.0	–	–	–	–	96.2*	–	–	–	–	–
O(F)	4–14	4.2	3.1	68.0	16.2	5.9	25	45.40 ± 1.4	1.39 ± 0.25	38	–	–	–
O(H), pyr	14–16	4.6	3.6	52.6	59.0	7.0	56	31.80 ± 1.0	1.40 ± 0.25	27	–	–	–
Ehi	16–20	5.6	4.1	7.5	16.6	6.5	75	2.20 ± 0.4	0.12 ± 0.02	22	1.30	0.87 ± 0.13	0.40 ± 0.1
BF	20–24	5.9	4.4	5.9	14.1	6.0	77	1.45 ± 0.26	0.10 ± 0.02	18	1.78	1.10 ± 0.1	0.59 ± 0.14
CRM	24–40	6.2	5.0	4.4	11.2	7.5	81	1.19 ± 0.21	0.09 ± 0.02	16	1.54	0.64 ± 0.09	0.65 ± 0.15
CRMi,ca	40–54	6.5	5.1	2.2	12.3	10.5	91	0.56 ± 0.27	0.05 ± 0.01	13	1.25	0.20 ± 0.07	0.37 ± 0.19
Cca	54–69	7.5	6.5	–	–	–	–	–	–	–	1.15	0.21 ± 0.07	0.29 ± 0.07
Pit 83-2012. Iron-illuvial podzol													
O(F + H)pyr	0–5	5.2	3.9	45.2	22.4	8.2	40	32.7 ± 1.0	1.15 ± 0.21	33	–	–	–
Ehi	5–10	4.8	3.5	11.7	9.9	3.5	53	5.02 ± 0.9	0.25 ± 0.04	23	0.86	0.67 ± 0.1	0.30 ± 0.07
E	10–15	5.4	3.8	7.41	5.3	2.1	50	1.71 ± 0.3	0.09 ± 0.02	22	1.08	0.91 ± 0.14	1.24 ± 0.19
BHF**	15–20	7.0	6.5	1.67	14.8	7.7	93	3.32 ± 0.6	0.17 ± 0.03	23	2.11	0.75 ± 0.11	0.53 ± 0.13
BHFca	15–20	5.5	4.0	7.41	3.5	2.1	43	0.92 ± 0.21	0.07 ± 0.01	16	1.68	0.25 ± 0.08	0.26 ± 0.07
BCca	20–40	7.4	6.7	0.55	8.1	6.2	96	2.21 ± 0.4	0.05 ± 0.01	52	0.87	0.21 ± 0.07	0.20 ± 0.05
Cca	40–60	7.7	7.0	–	–	–	–	–	–	–	0.87	0.32 ± 0.1	0.16 ± 0.04

Table 2. (Contd.)

Horizon	Depth, cm	pH		Ac_{tot}	Exchangeable bases		*V*	C_{tot}	N_{tot}	C/N	Fe_2O_3d	Fe_2O_3o	Al_2O_3o
					Ca^{2+}	Mg^{2+}							
		H_2O	KCl	cmol(c)/kg			%	% of soil mass			%		
Pit 87-2012. Pyrogenic gray-humus soil													
O(F + H)pyr	0–5	5.7	4.7	32.8	39.5	15.7	63	28.2 ± 0.9	0.99 ± 0.18	33	–	–	–
AYao	5–10	6.9	6.4	17.1	37.3	10.9	74	10.1 ± 1.3	0.47 ± 0.08	25	0.95	0.28 ± 0.08	0.26 ± 0.07
BCf	15–25	7.3	6.7	0.8	19.4	8.8	97	3.2 ± 0.6	0.13 ± 0.02	29	1.12	0.21 ± 0.07	0.30 ± 0.07
BCca	25–50	7.7	7.3	0.3	23.4	9.6	99	4.3 ± 0.8	0.13 ± 0.02	40	0.60	0.17 ± 0.06	0.16 ± 0.04
Cca	50–80	7.8	7.3	–	–	–	–	–	–	–	0.35	0.10 ± 0.04	<0.072
Pit 8-2014. Iron-illuvial podzol													
Moss	0–4	4.4	3.5	–	–	–	–	82.4*	–	–	–	–	–
O(F + H)	4–8	3.8	3.0	157.5	9.0	4.1	8	44.90 ± 1.4	1.80 ± 0.3	29	–	–	–
E	8–20	4.0	3.3	13.1	0.3	0.1	4	1.25 ± 0.23	0.08 ± 0.02	18	0.19	0.14 ± 0.05	0.16 ± 0.04
BF	20–25	4.8	4.1	12.5	0.2	0.1	3	1.80 ± 0.31	0.10 ± 0.02	22	1.91	1.59 ± 0.25	0.52 ± 0.13
BC	25–50	5.1	4.2	7.76	0.0	0.0	0	0.46 ± 0.14	0.04 ± 0.01	14	0.48	0.31 ± 0.10	0.33 ± 0.08
Pit 12-2016. Podzolized iron-illuvial podbur													
O(L + F)	0–5	3.6	3.2	84.4	11.7	3.9	16	28.2 ± 0.9	1.31 ± 0.21	25	–	–	–
BFe	5–10	3.8	3.3	16.9	0.3	0.2	3	10.21 ± 1.0	0.55 ± 0.11	22	1.20	0.69 ± 0.12	0.59 ± 0.14
BF	10–20	4.2	3.9	14.5	0.3	0.1	3	4.05 ± 0.6	0.23 ± 0.05	20	3.48	2.26 ± 0.3	1.25 ± 0.19
BC	20–40	4.3	4.2	12.2	0.2	0.1	2	4.24 ± 0.7	0.28 ± 0.06	18	3.20	1.43 ± 0.2	1.38 ± 0.23
Pit 8-2009. Raw-humus lithozem													
Moss	0–1	4.6	3.3	–	–	–	–	90.5*	–	–	–	–	–
O(F + H)	1–3	4.5	3.4	39.3	6.8	1.6	18	17.60 ± 1.8	0.91 ± 0.1	23	0.51	0.29 ± 0.10	0.34 ± 0.08
BCf	3–10	4.5	3.5	7.4	0.4	0.1	7	1.80 ± 0.31	0.22 ± 0.05	10	0.62	0.34 ± 0.11	0.23 ± 0.06
BC	10–20	4.4	3.5	7.9	0.5	0.1	8	2.40 ± 0.44	0.26 ± 0.06	11	0.57	0.31 ± 0.10	0.28 ± 0.06
C	20–35	4.6	3.7	4.5	0.3	0.1	8	0.79 ± 0.19	0.10 ± 0.02	10	1.06	0.26 ± 0.09	<0.09

Ac_{tot}, total (hydrolytic) acidity; *V*, base saturation, %; Fe_2O_3d, dithionite-extractable iron; Fe_2O_3o, oxalate-extractable iron; and Al_2O_3o, oxalate-extractable aluminum. * Loss on ignition, %. ** Soil fragments with coffee-brown films.

Table 3. Particle-size distribution in the studied soils

Pit no.	Horizon	Depth, cm	Loss from HCl treatment, %	Content of gravels and stones, %	Content of particles, %; particle size, mm						Sum of particles <0.01 mm
					1.0–0.25	0.25–0.05	0.05–0.01	0.01–0.005	0.005–0.001	<0.001	
22-2009	Ehi	6–14	1.05	0	4	22	42	9	9	14	32
	BF	14–30	0.38	0	1	27	47	3	8	14	25
	CRM	30–37	1.06	5	3	24	41	6	11	15	32
	BCcrm	37–55	1.16	40	15	17	38	4	11	15	30
	C	55–70	2.03	60	5	26	32	10	12	15	37
7-2010	Ehi	16–20	2.38	0	3	7	38	10	13	29	52
	BF	20–24	1.13	5	2	6	38	12	12	30	54
	CRM	24–40	3.05	5	2	9	39	8	9	33	50
	CRMi,ca	40–54	1.68	10	3	48	4	5	8	32	45
83-2012	Ehi	5–10	1.46	0	6	14	37	10	12	21	43
	E	10–15	1.06	0	4	68	0	0	6	22	28
	BHF*	15–20	3.78	10	8	27	28	0	18	19	37
	BHF	15–20	1.12	10	3	22	27	9	13	26	48
	BC_{Ca}	20–40	3.00	40	4	63	0	0	12	21	33
	C_{Ca}	40–60	3.29	60	4	67	0	0	7	22	29
87-2012	AYao	5–10	4.11	5	10	28	22	9	7	24	40
	BCf	15–25	3.84	30	5	16	26	9	14	30	53
	BC_{Ca}	25–50	3.51	50	4	15	25	8	16	32	56
8-2014	E	10–22	0.75	10	14	17	38	12	5	14	31
	BF	22–40	1.82	30	23	8	31	11	9	18	38
	BC	40–60	1.02	50	20	20	21	17	6	16	39
12-2016	BFe	5–10	1.69	10	29	7	27	12	13	12	37
	BF	10–20	2.69	50	16	8	31	14	14	17	45
	BC	20–40	2.91	90	8	9	37	13	15	18	46
8-2009	BCf	3–10	1.62	5	1	5	39	21	19	15	55
	BC	10–20	0.01	20	5	38	13	13	19	12	44
	C	20–35	0.20	60	14	32	25	9	9	11	29

* Fragments with coffee-brown films.

was damaged by recent fire. The soil profile had the following horizonation: O (F + H)pyr (0–5 cm)–AYao (5–15 cm)–BCf (15–25 cm)–BCca (25–50 cm)–Cca (50–70 cm). The litter (F + H) horizon of grayish brown color was dry consisted of moderately and strongly decomposed plant residues densely penetrated by roots. In the lower part, organic materials were mixed with mineral grains and contained charcoal particles of 3–5 mm in size. The underlying gray-humus AYao horizon was of dark gray (10YR 3/1–2/1) color and silt loamy texture. It contained an admixture of moderately and strongly decomposed organic residues and was densely penetrated by the roots of trees and dwarf shrubs of 5–10 mm in diameter. The dark gray color of the horizon was largely determined by the pyrogenic factor under conditions of a steep slope and the high content of gravelly material in the profile. Among the gravels, there were few gravels of calcareous rock of up to 5 cm in size. The abrupt lower boundary was marked by changes in the color and wavy. The underlying BCf horizon has a yellowish brown color (10YR 4/4), sand loamy texture, and very fine crumb (powdery) structure. The inclusions of the debris of calcareous rock of 5–10 cm in size and well-rounded small (2–3 cm) gravels comprised up to 30–40% of the horizon section. In the underlying BCca (25–50 cm) horizon, the content of gravels and rock fragments increased. The fine earth was of light yellow (10YR 5/4) color and clay loamy texture; flattened large (20–30 cm) fragments of calcareous rock with strong effervescence comprised up to 50–60% of the horizon. The lowermost Cca horizon (50–80 cm) was lighter in color (10YR 6/4–6/3); the fine earth content between large fragments of calcareous rocks was no more than 10–20%. From the depth of 80–90 cm, fine earth was virtually absent; the hard calcareous (limestone) rock was dissected by cracks and contained some hollow spaces.

This soil was identified as a residual-calcareous ferruginated pyrogenic gray-humus soil [32], or Calcaric Leptosol (Skeletic) [53].

The physicochemical properties of the gray-humus soil developed from the weathering products of calcareous bedrock with some admixture of allochthonous material are as follows: slightly acid to neutral reaction in the upper horizons and slightly alkaline reaction in the lower horizons; the exchange complex is saturated with calcium and magnesium cations. Such soils are formed from clay loamy gravelly colluvium on steep slopes. A comparative geographical analysis of published data indicates that such soils have a limited distribution in different landscapes of the humid boreal zone. They have been described in the Northern and Middle Urals and in the Altai Mountains [2, 23, 28] as a component of the soil cover forming combinations with mucky–humus and mucky dark-humus metamorphized and clay-illuvial soils [24]. In the Subpolar Urals, the organic part of the profile of these soils (pit 87-2012) is a combination of a thin peaty litter with pyrogenic features and raw-humus material in the upper part of the gray-humus horizon. The prerequisites for their formation are the high steepness of the slope and a relatively thick stratum of loose gravelly material ensuring rapid discharge of increased atmospheric precipitation. Under the conditions of low heat supply, the forming humus horizon corresponds to the diagnostics of the gray-humus (AY) horizon with raw-humus (AYao) features. Similar conclusions were made by Konyushkov with coauthors in the paper devoted to correlation of soddy-calcareous soils as displayed on the *Soil Map of the Russian Federation* (1 : 2.5 M) with the soils diagnosed and classified according to the new Russian soil classification system [23].

Mountainous Forest–Tundra Ecotone

Bioclimatic and litho-geomorphic conditions of soil formation in the mountainous forest–tundra ecotone significantly from those in the mountainous forest zone. In this ecotone, sparse larch woodlands alternate with thickets of shrubs (mainly, *Betula nana*), mountainous meadows, and tundra phytocenoses [11, 49]. Near the upper boundary of forest vegetation (460–730 m a.s.l.), communities of *Larix sibirica* are confined to favorable geomorphic positions and alternate with large areas of rock outcrops [30]. On drained slopes, dwarf shrub–green moss sparse larch stands predominate. The morphological and genetic features of the main types of soils under such larch woodlands are described below.

Pit 8-2014 was laid in the middle part of the slope (2°–3°) of the Yuas-nyrd Ridge (65°13′55.8″ N; 60°04′34.4″ E) under the dwarf shrub–green moss larch woodland. The soil was clearly differentiated into the following horizons: moss stems (0–4 cm)–O (F + H) (4–8 cm)–E (8–20 cm)–BF (20–25 cm)–BC (25–50 cm). Under the weakly decomposed peaty litter O (F + H), the podzolic E horizon of grayish-whitish color and loamy sand texture with inclusions of gravels was clearly pronounced, The iron-illuvial BF horizon had a yellowish-brown to reddish brown color and gravelly sand loamy texture with inclusions of coarse rock fragments. Large (40–50 cm) flattened rock blocks and platy rock debris of smaller size (15–20 cm) had distinct silt cappings of up to 1–2 mm in thickness on their upper sides. The lower faces of rock fragments were clean from fine earth, but were covered by thin coffee-brown (10R 2.5/2) Al–Fe-humus films with diffuse margins. Gradual transitions to the BC horizon was marked by an increase in the content of the debris of sericite–chlorite schist; from the depth of 25–30 cm, the content of the stony material sharply increased. According to [32], this soil can be identified as an iron-illuvial podzol; in the WRB system, it can be identified as an Albic Podzol (Skeletic) [53]. As a rule, such soils form a uniform soil cover. Good drain-

Table 4. Bulk elemental composition of the soils, % of calcined samples

Horizon	Depth, cm	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	K_2O	TiO_2	P_2O_5
Pit 22-2009. Iron-illuvial svetlozem									
Ehi	6–14	77.17	3.76	13.42	0.35	0.73	2.37	1.01	0.21
BF	14–30	74.84	6.78	13.29	0.45	0.96	2.28	0.94	0.14
CRM	30–37	73.71	6.25	14.24	0.47	1.08	2.40	0.92	0.17
BCcrm	37–55	71.30	6.87	15.71	0.46	1.27	2.65	0.92	0.24
C	55–70	68.48	7.42	17.78	0.44	1.21	2.64	1.03	0.25
Pit 7-2010. Iron-illuvial svetlozem									
Ehi	16–20	74.29	5.99	14.06	1.15	1.06	2.12	1.07	0.18
BF	20–24	72.71	6.97	14.73	1.09	1.16	2.10	1.01	0.17
CRM	24–39	72.77	6.57	14.87	1.14	1.27	2.19	0.94	0.20
CRMi,ca	39–54	72.89	6.35	14.82	1.13	1.35	2.30	0.93	0.18
Cca	54–69	70.16	6.57	13.64	4.13	2.07	2.23	0.94	0.19
Pit 83-2012. Iron-illuvial podzol									
Ehi	5–10	74.79	4.81	14.48	1.02	1.84	1.89	0.98	0.11
E	10–15	75.39	5.13	13.89	0.87	1.87	1.80	0.94	0.06
BHF*	15–20	66.83	7.21	16.62	3.61	2.64	1.90	0.85	0.25
BHF	15–20	72.76	6.23	15.26	0.89	2.03	1.73	0.90	0.08
BCca	20–40	70.13	5.76	13.28	5.01	2.85	1.97	0.80	0.14
Cca	40–60	67.28	5.54	13.32	7.63	3.33	1.90	0.75	0.16
Pit 87-2012. Pyrogenic gray-humus soil									
AYao	5–10	68.05	5.78	15.65	3.94	2.61	2.38	1.07	0.33
BCf	15–25	67.93	4.61	13.66	7.20	3.33	2.01	0.84	0.31
BCca	25–50	36.04	0.72	7.36	43.69	9.37	1.42	0.41	0.93
Pit 8-2014. Iron-illuvial podzol									
E	8–20	79.03	2.65	12.11	0.16	3.09	1.84	1.03	0.06
BF	20–25	75.55	5.55	12.86	0.32	2.85	1.91	0.91	0.01
BC	25–50	75.62	4.41	13.72	0.43	2.88	0.86	0.86	0.05
Pit 12-2016. Podzolized iron-illuvial podbur									
BFe	5–10	6.32	17.24	1.13	2.84	1.67	1.6	1.6	0.29
BF	10–20	7.62	19.31	0.97	4.14	1.71	1.25	1.25	0.15
BC	20–40	7.23	20.04	1.03	4.08	1.85	1.12	1.12	0.19
Pit 8-2009. Raw-humus lithozem									
BCf	3–10	69.52	4.58	19.92	0.22	0.83	4.02	0.52	0.08
BC	10–20	69.93	4.31	19.87	0.22	0.81	3.95	0.55	0.09
C	20–35	72.42	4.59	17.42	0.20	0.85	3.61	0.58	0.06

* Fragments with coffee-brown films.

age conditions prevent water stagnation and the development of gleyzation.

The physicochemical properties and bulk elemental composition of this soil are typical of podzols: acid and strongly acid reaction (pH H_2O 4.3–5.1); very low base saturation (5–7%); and eluvial–illuvial distribution of total carbon, total sesquioxides, and oxalate- and dithionite-extractable iron (Table 4). The C : N ratio in the mineral horizons is 18–29, which is typical of analogous podzols under mountainous forests in the Subpolar and Northern Urals [17, 33]. The presence of silt cappings on the upper sides of horizontally oriented platy rock fragments attests to the mobility of clay and silt fractions in the soils and to their illuviation (partluvation) from the upper horizons. This was noted for analogous podzols developed from colluvial products of weathering of acidic rocks in various mountain regions [42, 46, 50, 57].

Larch woodlands near the boundary with the mountainous tundra zone grow under extreme climatic conditions and are sparse (canopy density is 0.2–0.4) and relatively low (2–8 m). Stone rivers forming "tongues" descending from the mountainous tundra zone and various forms of cryogenic microtopography (solifluction terraces and stems, barren circles, mud boils, etc.) are common in this zone.

Pit 12-2016, lower part of a very gentle (1°–2°) slope of the Kuz'kudiner Ridge (63°47′22.1″ N; 59°14′18.3″ E); blueberry–green moss larch woodland of about 100 m^2 in area. Upslope, there are mountainous tundra cenoses with numerous barren circles. The soil described under this "island" of arboreal vegetation had the following profile: O (L + F) (0–5 cm)–BFe (5–10 cm)–BF (10–20 cm)–BC (20–40 cm). The features of podzolization (e) in the BFe horizon were manifested as thin (1–2 cm) lenses of bleached (5YR 3/2) material; the content of gravels in this horizon was about 10–20%. The underlying BF horizon had a yellowish brown color (10YR 4/4–5/4) and represented a structureless silty clay loam with a considerable content of gravels and large (30–50 cm) rock fragments. Lower sides of play rock fragments were covered by thin iron–humus films of darker color (10R 3/3). From the depth of 25–30 cm, the content of gravels and rock fragments sharply increased (up to 80–90%); the content of fine earth was small. According to [32], this soil can be identified as a podzolized podbur. In the WRB system, it corresponds to Entic Podzols (Skeletic) [53].

Coarse fractions—medium and fine sand and coarse silt—predominate in the fine earth (up to 54–63%). This, along with the high content of gravels and coarse rock fragments, specifies good drainage conditions and free discharge of water through the soil profile. The distribution of oxalate-soluble Fe_2O_3 and Al_2O_3, as well as total R_2O_3, reflects the eluvial–illuvial differentiation of the profile and generally correlates with the clay fraction content. The podzolized horizon is depleted in Fe_2O_3 and Al_2O_3 and is relatively enriched in SiO_2. The soil reaction is strongly acid in the entire profile; the highest acidity (pH_{KCl} 3.2) is characteristic of the horizon O (L + F) horizon. The hydrolytic acidity is also the highest in the organic horizon with the high exchange capacity and considerable content of exchangeable bases. In mineral horizons, the content of exchangeable bases is insignificant (<1%). A relatively high content of total carbon in the lower horizons (4.2%) may be related to a sharp increase in the stony material preventing the further downward migration of humic substances. The analytical data obtained for this soil are typical of the podzolized podburs in the mountainous tundra landscapes of the Polar and Northern Urals [12, 33], as well as of the Kola Peninsula [31].

Pit 8-2009 was laid on a terraced slope of the Maldynyrd ridge with a steepness of 8°–10° (65°20′04.7″ N; 60°39′08.4″ E). This pit was excavated under the dwarf shrub–sphagnum larch woodland with the canopy density of no more than 0.2, and the height of the trees about 2–4 m. The presence of sphagnum mosses indicates overmoistening, which is associated with additional moistening of the soil by runoff flows from melting snowfields in the upper part of the slope within the zone of cold alpine deserts. The surface microtopography is complicated by barren circles of 40–60 cm in diameter occupying 30–40% of the area; loamy fine earth mixed with stony material is exposed to the surface. There are also solifluction microterraces of 30–50 cm in width and 1–3 m in length. They are devoid of vegetation. Flattened debris of schist on such surfaces have their long axes oriented down the slope, and their larger planes are in the subhorizontal position. The presence of such terraces and the regular orientation of rock fragments attest to slow movement of the soil mass down the slope. The parent material is derived from weathered quartz–sericite schist bedrock.

The soil profile is differentiated into the following horizons: moss stems (0–1 cm)–O (F + H) (1–4 cm)–BCf– (4–10 cm)–BC (10–20 cm)–C (20–30 cm). The peaty litter horizon consists of predominantly moderately decomposed remains of mosses and lichens; in its lower part, the organic material is mixed with mineral grains (raw-humus feature). The underlying BCf and BC horizons have the high content of gravels. The features of iron illuviation are manifested by thin yellowish ocherous films. In these horizons, a network of subhorizontal fissures of up to 2–3 mm in thickness is seen. It may be indicative of the slow movement of the upper gravelly loamy part of the soil material down the slope. The total thickness of the profile is about 30–35 cm; from the depth of 25–30 cm, the content of gravels and rock fragments increases. Huge rock fragments are found below. According to [32], this soils can be classified as a ferruginated raw-humus lithozem; in the WRB system, it corresponds to Lithic Leptosols (Skeletic) [53].

The soil profile is poorly differentiated according to its physicochemical properties; distribution of nonsilicate forms of Fe_2O_3; and the total contents of SiO_2, Fe_2O_3, and Al_2O_3. A sufficiently high steepness (8°–10°) of the slope ensures satisfactory surface and soil runoff, so that excessive water is easily discharge, and the entire profile is characterized by aerobic conditions and by free downward migration of substances. Soils have an acid reaction in the entire profile. The content of exchangeable bases is the highest in the organic horizon and sharply decreases in the mineral horizons and correlates with the content of organic matter. Base saturation is very low (8–18%). The particle-size distribution in the lithozem is largely dictated by solifluction processes, as a result of which redeposition of clay loamy weathering products occurs in the upper part of the profile. Distribution patterns of sand and coarse silt fractions in the profile also attest to a clear lithological heterogeneity of this soil.

The classification position and nomenclature of soils described in pits 8-2014 and 83-2012 and identified as podzols raise a number questions for further discussion. The lithological factor plays a decisive role in determining the classification position. The high content of gravels and coarse rock fragments (up to 50–60 wt % in the middle and lower parts of the profiles) ensures good filtration capacity of the soil stratum and free descending migration of soil solutions, which determines the intensive removal of the exchangeable bases (Ca^{2+} and Mg^{2+}) and leads to a sharp unsaturation of the soil adsorption complex (pit 8-2014). A clear eluvial–illuvial redistribution of R_2O_3 occurs against the background of a general desilication and enrichment of the soil material in R_2O_3 in comparison with the parent material. For pit 83-2012 developed from the eluvium of calcareous rock, the formation of a distinct podzolic horizon (according to its morphology and physicochemical properties) is largely determined by the presence of acidic allochthonous moraine material. In general, the morphological and analytical features of these soils allow us to classify them at the subtype level as iron-illuvial podzols. According to the new Russian substantive-genetic soil classification system, podzols with base saturation of up to 80% and with close to neutral reaction are atypical; analogous soils have only been described in a few soil profiles [6]. In this regard, in the light of the development and further improvement of this classification system, a special niche is required for such soils in the classification hierarchy.

CONCLUSIONS

Mountainous larch forests and woodlands of the Subpolar Urals develop under contrasting bioclimatic conditions; in dependence of the character of parent materials and vegetation, several soils differing in the their physical and chemical properties and organic matter content are developed under these communities. Some of these soils—svetlozems and podzols developing from parent materials of acidic composition—are typical of large geographical areas, Other soils—podzols on calcareous rocks—occupy small areas and are found in combinations with other soils.

Iron-illuvial svetlozems, regardless of the nature of the parent material, can be considered reference soils of the studied area. Podzols on calcareous rocks belong to the category of rare soils. On steep riverine slopes covered by colluvial sediments with close embedding by calcareous rocks, specific residual-calcareous ferruginated gray-humus soils are formed. Near the upper boundary of larch woodlands, lithozems and podburs are developed. These soils are most widespread within the mountainous tundra landscapes.

Under the mountainous terrain of the Urals, the specificity of local factors + oil formation—chemical and mineralogical composition of rocks, water and heat supply, and the species composition of forest vegetation—specify different manifestation of particular combinations of elementary pedogenetic processes resulting in the formation of specific soil profiles.

Regional features of the studied soils consist of a combination of cryogenic transformation (metamorphism) of the mineral mass with illuviation of Al–Fe-humus compounds (podzolization) and leaching of carbonates; some illuviation of silt and clay material into the lower part of the profiles with formation of silt cappings on large gravels and stone fragments is also observed. The predominantly surface input of plant litter in the woodlands of *Larix sibirica* with its slow mineralization contribute to the raw-humus nature of organic horizons. The C : N ratio in them is wide. The results of our studies expand the understanding of the diversity of soils under mountainous larch forests and woodlands in the Subpolar Urals and can be used as the basis for soil mapping purposes.

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