MORPHOLOGIC-GENETIC PECULIAR FEATURES OF SOILS UNDER MOUNTAIN MEADOWS OF THE NORTHERN URAL

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The peculiar morphology and physical-chemical properties of soils under mountain meadows of the Northern Ural are shown. From the position of the latest "Classification and Diagnostics of Soils in Russia" (2004) these soils are referred to 3 different types including the gray-humus (order of organo-accumulative soils), illuvial-humus-ferruginous soddy podburs (order of Al-humus soils) and gray-humus lithozems (order of lithozems)

Keywords: Northern Ural, mountain meadows, gray-humus horizon, soil classification.

INTRODUCTION

In the northern part of the Ural Mountains the mountain meadows and meadow tundra are specifically distinguished, being characterized by a higher level of floristic diversity [3]. Under conditions of lower-and-middle mountain landscapes of Polar (68–66°N) and Circum-Polar Ural (66–64°N) they occupy insignificant areas [2]. However, in the Northern Ural (64–59°N) where the climatic conditions are more favorable [1] mountain meadows are widely spread within the subalpine belt bordering with phytocenoses of light forests and brushwood. In the mountain-tundra belt the meadow tundra is developed under zoogenic effects upon the plant cover. The mesodepressions covered by snow for a long time reveal nivale small meadows. As a rule, the perennial grass communities are found to be in upper parts of uplands, on slopes of southern and eastern exposure, in intermontane areas and narrow gullies resulted from constant and temporary water flows.

In phytocenoses of mountain meadows different grasses are widespread and have a significant projecting cover [3]. In view of this, the humus formation and accumulation occur under the influence of grass vegetation. It is worth of note that the diversity and genetic peculiar features of soils under mountain meadows have been so far examined insufficiently as compared to those developed in mountain-forest and mountain-tundra belts [4, 12]. In papers of I.V. Zaboeva (1975) the soils under mountain meadows are described at a type level and have two subtypes – soddy mountain-meadow and illuvial-humus soddy mountain-meadow soils.

This paper is aimed at identifying the diversity and genetic peculiar features of soils under mountain meadows and meadow tundra developed on the western macroslope of the Northern Ural as well as their classification position according to “Classification and Diagnostic of Soils in Russia” (2004).

OBJECTS OF RESEARCH AND INVESTIGATION METHODS

These studies were carried out at the territory of Pechora-Ilychsky State reservation within the upper Ilych river basin. The objects of research – Man-Khambo edge (63°00’N; 59°11’E) and Kychid-iz edge (63°03’N, 58°45’E) are represented by a set of low mountains with the absolute height of 900–1000 m a.s.l. The dissected relief displays the well-expressed vertical belts. The mountain meadows are concentrated within the subalpine belt at a height of 500–650 m, meadow tundra and nivale small meadows are in the mountain-tundra belt elevated by 700–750 m. The soil profiles were studied and accompanied by detail geobotanical description [5]. Traditional methods were employed to determine the physical-chemical properties of soils [10]. The soil color was defined according to Munsell (1975).

RESULTS AND DISCUSSION

The parent materials in tops and upper parts of slopes are presented by eluvium of underlying bedrocks consisting of granite and quartzite that reveal sometimes a surface exposure. On slopes the soil formation occurs on loose eluvial-deluvial deposits. The thickness of soil profiles is varying from 15–20 to 60–80 cm in dependence on several mesorelief elements [9].

Let us characterize the soil types widely spread under mountain meadows in the Northern Ural Mountains. They are specifically distinguished by peculiar features of their morphology and physical-chemical properties.

Pit 21-С.У.-2011 (typical gray-humus soil) It is located on the eastern slope of Man-Khambo edge at a height of 623 m a.s.l. under the meadow covered by bush grass of the primary origin. The communities of the given syntaxon are widely distributed among the studied meadows in the Northern Ural Mountains. They contain only 14/100 m^2 plant species being dominated by *Calamagrostis purpurea.* The cover of such species as *Chamaenerion angustifolium* and *Bistorta major* makes up 5%. The other taxons are represented by single plant species. The well-developed grass-shrubby story is 60–100 cm of height, the total projecting cover reaches 70–90%. The ground cover is occupied by closed grass stand including such taiga species as *Polytrichum commune, Pleurosium schreberi, Hylocomium splendens.* There are no features of soil erosion and soil surface disturbances.

Morphological description of the soil profile

O, 0–5 cm – weakly decomposed peaty litter, the upper part of which is covered by green moss; abundant grass roots, compacted.

AY 5–15 cm – dark-grayish loamy sand (10YR 3/2; 3/2–4/2); abundant grass roots, compact; very dry along the soil profile; rare inclusions of granite fragments; transition clearly expressed by color and the decreased amount of roots.

AYB 15–25 cm – grayish (10YR 5/4) compact fine loam, fresh, structureless, single fine roots; quartz fragments up to 1 cm in size, granite fragments crushed by hand; gradual transition.

BC 25–40 cm – yellowish-cinnamon (10YR 5/4–6/4) sandy loam, compact, single fine roots; granite fragments of 15–40 cm in size, the content of which is increasing with depth.

C 40–60 cm – yellowish (10YR 5/4–5/6) compact medium loam, structureless; it is located between large rock blocks (> 1 m).

This is a typical gray-humus soil. The middle part of the soil profile is structureless. The root layer is shallow because the main root amount is concentrated in the upper part of soil represented by the organogenic and humus-accumulative horizons, at a depth of 30–40 cm only single roots are met. It is possible to see the weathered granite fragments at the same depth; their amount is increasing downwards the profile. The given soil is developed on highly sandy medium loamy deposits (Table 1). The coarse and fine sandy fractions are dominant throughout the soil profile. The lower detritus surface is clean; illuvial-humus films are absent. The texture of the fine earth in the gray-humus horizon is significantly light as compared to that in underlying horizons. The total chemical composition reveals no oxide redistribution what allows speaking about the absence of eluvial-illuvial process and the weakly expressed migration of soil formation products along the profile (Table 2).

The reaction is usually acid in typical gray-humus soils (pH_{KCl} 3.6–4.3), the hydrolytic acidity is high, the content of exchangeable Ca^{2+} and Mg^{2+} is rather low in mineral horizons (Table 3). These soils are characterized by the increased content of the organic matter in organogenic and humus-accumulative horizons. The ignition loss in the organogenic horizon makes up 54%, this horizon displays the weakly decomposed plant residues being very coarse by nature. The organic matter content in the humus-accumulative horizon accounts for 4.5–8.4%, it is predominantly accumulated in the mineral part of soil. The organic matter in mineral horizons is enriched with nitrogen, C:N is 10–11 what speaks about a higher intensity of the biological turnover. Oxalate-and ditionite-soluble forms of iron compounds assume an accumulative character being maximal in the humus horizon.

According to the peculiar morphology and physical-chemical properties these soils are recognized as typical gray-humus ones to be regarded to the order of organo-accumulative soils [6]. They are almost similar to mountain-meadow soddy soils described by I.V. Zaboeva (1975) in the subalpine belt of Manpupuner and Pecherya-Talyakhchakhl mountain edges.

Within the mountain-tundra belt where the vegetation cover has been disturbed due to overgrazing the secondary plant communities of meadow tundra occur [2, 3, 7]. Such phytocenoses combine the features of meadow (well-developed grass stand) and tundra (total projecting cover exceeds 50-60%) communities. This can be exemplified by the phytocenosis of illuvial-ferruginous soddy podbur (pit. 15-C.Y.-2011) described in the middle part of the northeastern edge slope of Man-Khambo (the lower part of the mountain-tundra belt elevated by 717 m a.s.l.). The given plant community was developed under the influence of tundra plant succession, where *Juncus trifidus, Carex brunescens, Anthoxanthum alpinum, Avenella flexuosa* are dominant.

Table 1. Granulometric composition of soils under mountain meadows in the Northern Ural

Horizon	Depth, cm	Loss on acid leaching HCl	Content of fractions, %; particle size, mm						Sum of particles < 0.01
			1–0.25	0.25–0.05	0.05–0.01	0.01–0.005	0.005–0.001	< 0.001	
Pit. 21-С.У.-2011 typical gray-humus soil									
AY	5–15	1.18	42	21	18	4	4	11	19
AYB	15–25	0.58	25	22	23	8	8	14	30
BC	25–40	0.19	27	17	22	6	9	19	34
C	40–60	0.67	22	32	10	8	6	22	36
Pit. 15-С.У.-2011 illuvial-ferruginous soddy podbur									
AY	5–12	0.79	36	29	13	2	5	15	22
BHF	12–20	0.51	40	24	13	2	6	15	23
Bf	20–30	0.07	33	33	16	1	8	9	18
BC	30–50	0.29	35	36	12	7	2	8	17
C	50–60	0.64	30	31	21	6	3	9	18
Pit. 6-С.У.-2009 gray-humus lithozem									
AYao	4–6	1.75	25	11	38	7	2	17	26
BC	6–15	0.46	5	15	47	13	4	16	33

Table 2 Total chemical composition of soils under mountain meadows in the Northern Ural

Horizon	Depth, cm	SiO_2	Fe_2O_3	Al_2O_3	CaO	MgO	K_2O	TiO_2	S	P_2O_5
Pit. 21-С.У.-2011 typical gray-humus soil										
AY	5–15	69.87	8.04	14.97	0.96	0.81	2.89	1.45	0.16	0.85
AYB	15–25	71.00	6.95	15.67	0.97	0.85	2.83	1.13	0.08	0.51
BC	25–40	71.65	6.42	15.75	0.97	0.93	2.82	1.07	0.05	0.33
C	40–60	71.41	6.03	16.27	1.04	1.12	2.84	1.01	0.03	0.24
Pit. 15-С.У.-2011 illuvial-ferruginous soddy podbur										
AY	5–12	70.68	6.56	16.21	1.27	0.86	2.83	1.12	0.05	0.43
BHF	12–20	70.82	7.07	15.43	1.52	0.99	2.75	1.15	0.04	0.24
Bf	20–30	70.29	6.47	16.56	1.43	1.11	2.90	1.02	0.03	0.19
BC	30–50	69.13	6.37	17.19	1.86	1.18	2.95	1.03	0.15	0.14
C	50–60	72.58	5.09	16.36	0.84	0.99	3.12	0.84	0.03	0.15
Pit. 6-С.У.-2009 gray-humus lithozem										
AYao	4–6	69.15	8.01	13.55	1.68	0.81	3.35	1.14	0.24	1.15
BC	6–15	71.26	5.84	15.78	0.83	1.02	3.14	0.94	0.10	0.75

Table 3. Physical-chemical properties of soils under mountain meadows in Northern Ural

Horizon	Depth, см	Ignition loss	pH		Hг	Exchangeable base		V	C	C/N	Fe_2O_3 after Jackson	After Tamm	
						Ca^{2+}	Mg^{2+}					Fe_2O_3	Al_2O_3
		%	H_2O	KCl	mmol/100 g			%			%		
Pit. 21-С.У.-2011 typical gray-humus soil													
O	0–5	54.0	5.3	4.3	40.2	15.0	2.6	31	25.4	18	–	–	–
AY	5–15	17.2	4.5	3.7	17.3	2.2	1.0	16	8.4	11	2.17	1.50	0.69
AYB	15–25	10.4	4.6	3.6	16.2	1.0	0.3	8	4.5	10	2.11	1.39	0.73
BC	25–40	8.0	4.9	3.8	14.2	1.4	0.2	11	2.7	10	1.95	1.18	0.73
C	40–60	4.8	5.0	3.9	11.7	0.2	0.0	1	1.4	10	1.59	0.77	0.72
Pit. 15-С.У.-2011 illuvial-ferruginous soddy podbur													
Очес	0–3	80.6	4.5	3.6	45.9	12.4	3.4	26	–	–	–	–	–
Oao	3–5	57.5	4.3	3.5	48.1	4.7	7.3	20	30.1	18	–	–	–
AY	5–12	8.9	4.3	3.4	29.9	0.9	1.5	8	3.7	14	1.82	0.89	0.52
BHF	12–20	6.5	4.5	3.6	14.5	0.5	0.1	4	2.2	17	3.00	1.53	0.64
Bf	20–30	3.5	4.7	3.9	7.7	0.1	0.1	3	0.7	14	1.44	0.69	0.36
BC	30–50	2.4	4.9	4.1	5.9	0.2	0.1	5	0.3	11	0.84	0.38	0.32
C	50–60	2.6	5.0	4.2	5.6	0.3	0.1	7	0.3	11	0.87	0.36	0.45
Pit. 6-С.У.-2009 gray-humus lithozem													
O	0–4	71.80	5.1	4.5	40.2	38.0	6.0	52	31.9	18	0.17	–	–
AYao	4–6	31.03	4.7	4.1	16.6	12.6	1.5	46	11.1	13	0.56	0.41	0.23
BC	6–15	11.92	5.2	4.0	9.2	10.5	0.3	54	4.4	11	0.81	0.56	0.30

Note: ПППП – ignition loss, %; Hг – hydrolytical acidity; V – base saturation degree.

The abundant small shrubs don’t exceed 20%, *Vaccinium myrtillus* is of great importance. The plant cover is well developed there (the total projecting cover is 80%) and predominantly composes of *Cetraria islandica*. As a result of overgrazing the moss became abundant including *Polytrichum commune*, the share of which makes up one third of the total projecting cover.

Morphological description of this soil profile is the following.

0–3 cm – green moss.

O_{ao} 3–5 cm – dark-gray, well-decomposed litter mixed with the mineral horizon, slightly compacted, abundant grass roots, inclusions of quartz fragments.

AY 5–12 cm – cinnamon-gray (5YR 3/2–3/3) sandy fine loam, power-like and sometimes grain structure in the lower part of this horizon; fine roots (to 1 mm) are abundant. When it is dry, the color is brighter. The quartz grains and angular-shaped rock fragments up to 1 cm are met. Transition is clearly expressed, the boundary is wavy.

BF 12–20 cm – rusty-ocherous (2.5YR3/4–4/4), cinnamon in some places, sandy fine loam, slightly wet. It is compacted with power-like structure, a small amount of plant roots. Inclusions of gray granite fragments (10–15 cm). A sharply expressed transition with wavy boundary.

Bf 20–30 cm – yellowish-cinnamon (10YR 6/6–6/0) loamy sand, fresh, compact. Several plant roots. Inclusions of quartz and other rocks to 1 cm. The clearly expressed transition, an even boundary.

BC 30–50 cm – light-yellow, compact, stony, loamy sandy, fresh. 10–20% of rock fragments, gradual transition.

C 50–60 cm – light-yellow, compact, very stony, loam sandy. The skeleton of different size is present (from landwaste to 20–35 cm).

This soil is illuvial-ferruginous soddy podbur.

The fine earth is prevailed by coarse fractions: coarse and fine sand and coarse silt comprising 77–83%. The higher content of sandy fractions and coarse silt serves as evidence of the good filtration capacity of the soil and oxidation conditions along the profile. Accumulation of fine fractions is observed in upper horizons being connected with intensive processes of weathering and soil formation in the upper root-penetrated soil part. The total chemical composition reveals no eluvial-illuvial redistribution of sesquioxides, what speaks about a slightly expressed migration of soil formation products throughout the profile. The soil reaction is rather acid (pH_{KCl} 3.3–4.1), the soil absorbing complex is insignificantly saturated. In mineral horizons the content of exchangeable bases is sharply declined. The distribution of the organic matter is by regressive-accumulative character throughout the soil profile being maximal in the accumulative-humus horizon (3.7%) and connected with the shallow thickness of the root layer. The C/N ratio makes up 11–17 in the mineral part of the soil; this is evidenced by a slightly expressed supply of the given soil with nitrogen. In illuvial-ferruginous BF horizon some accumulation of oxalate-and ditionitrate-soluble forms of iron compounds is observed.

The morphology of this profile and analytical data about the soil properties well agree with the type of illuvial-ferruginous soddy podbur regarded to the order of Al-humus soils [6]. The similar soils have been recognized under mountain meadows on very stony sandy loam in Yanypupuner edge [11].

Specific “intrazonal” ecototopes within the studied edges are narrow gullies of temporary water flows from the mountain-tundra (subalpine) belt. The plant communities predominated by *Athyrium distentifolium* are developed there. Pit.5-С.У.-2009 permitted to study the soil developed in such ecotopes on steep slope of Kychil-iz edge (15°–20°) with the absolute height off 640 m a.s.l. The dense grass cover (85–90%) predominantly composing of *Filipendula ulmaria* and *Calamagrostis pupurea* serves as a favorable condition for the development of the gray-humus soddy AY horizon in topsoil that has a gradual transition into the massive plate of bedrocks. Erosion features are absent. This is the gray-humus lithozem regarded to the order of lithozems (Soil Classification…2004).

The soil is morphologically described in the following way.

O, 0–4 cm – dark-brown sod litter; the different-decomposed plant residues; abundant roots, fresh, edistinct transition with an even boundary.

AYao, 4–6 cm – dark-gray light loam composing of strongly decomposed organic residues, fresh, abundant plant roots, gradual transition with an even boundary.

BC, 6–15 cm – brown medium loam, stony; the fine earth makes up 15–20%; structure is crumb-platy; it is penetrated by plant roots, beneath is the bedrock (more than 1 m).

Thanks to good drainage there is no water stagnation in the soil profile, morphological features of gley formation are not observed. The gray-humus horizon contains a significant amount of the organic matter, the organic carbon makes up 11.1%. The humus is enriched with nitrogen (C/N – 11–13). The specific is that this soil contains a higher amount of exchangeable calcium; it is saturated by exchange bases to a lesser extent (46–54%) in spite of strongly acid soil pH.

CONCLUSION

Taking into complete account the profile configuration of the studied soils, one should notice that they are significantly distinguished at a type level being refereed to three different types: typical gray-humus (order – organo-accumulative soils), illuvial-ferruginous soddy podburs (order – Al-humus soils) and gray-humus lithozems (order – lithozems). A comprehensive analysis of available literature sources [11] serves as evidence of a higher diversity of soils developed on uplands of the Northern Ural. Among the meadow communities of the mountain meadow-forest ecotone on slopes of the Yanypurpuner edge typical and illuvial-clayey burozems have been recognized together with illuvial-ferruginous soddy podburs. According to “Soil Classification…, 2004” burozems are refereed to order of structural-metamorphic soils, in the profile formation of which the structural metamorphism of middle horizons plays a significant role. The common features of these soils developed under mountain meadows and meadow tundra include the formation of a compact sod-bearing horizon, acid and strong acid soil reaction, a slightly expressed saturation with exchange bases, a higher content of organic carbon in the gray-humus horizon (4–8%) decreasing down the profile, a relative enrichment of the soil organic matter with nitrogen (C/N 10–14) and a relative small differentiation of the soil profile according to the total chemical composition.

REFERENCES

1. *Atlas Respubliki Komi po klimatu i gidrologii*, Ed. Taskaev A.I., Moscow, 1997, 116 p.
2. Gorchakovskii P.L. Flora i rastitel'nost' vysokogorii Urala, *Tr. In-ta biol. UFAN SSSR*, 1966, Vol. 48, 268 p.
3. Degteva S.V. Soobshchestva travyanistykh rastenii Pechoro-Ilychskogo zapovednika,*Fundamental'nye i prikladnye problemy botaniki v nachale XXI v*. Mat-ly. Vseros. konf. Petrozavodsk, 2008, Ch. 5, P. 77-80.
4. Zaboeva I.V. *Pochvy i zemel'nye resursy Komi ASSR*, Syktyvkar: Komi knizhnoe izd-vo, 1975, 375 p.
5. Ipatov V.S. *Opisanie fitotsenoza*. Metodicheskie rekomendatsii, Sankt-Peterburg, 1998, 93 p.
6. *Klassifikatsiya i diagnostika pochv Rossii*, Smolensk, 2004, 342 p.
7. Korchagin A.A. Rastitel'nost' severnoi poloviny Pechoro-Ilychskogo zapovednika, *Tr. Pechoro-Ilychskogo zapovednika*, 1940, Vol. 2, 416 p.
8. Orlov D.S., Biryukova O.N., Rozanova M.S. Revised system of the humus status parameters of soils and their genetic horizons, *Eurasian Soil Science*, 2004, Vol. 37, No 8, pp. 798–807.
9. Pochvy i pochvennyi pokrov Pechoro-Ilychskogo zapovednika (Severnyi Ural) / Ed. Degtevoi S.V., Laptevoi E.M. Syktyvkar, 2013, 328 p.
10. *Teoriya i praktika khimicheskogo analiza pochv* / Ed Vorob'eva L.A., Moscow, 2006, 400 p.
11. Titova A.A., Goryachkin S.V. Pochvy gornykh lugovo-lesnykh ekotonov Severnogo Urala, *Tr. Pechoro-Ilychskogo zapovednika*, 2010, Vol. 16, pp. 195–201.
12. Firsova V.P. Dedkov V.S. *Pochvy vysokikh shirot gornogo Urala*. Sverdlovsk, 1983. 95 p.
13. Munsell A. *Munsell Soil Color Chart*, Kollmorgan Instruments, 1975.