

Article

Micromorphological Characteristics of Soils in the Chernevaya Taiga (Western Siberia, Russia)

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Abstract: The Chernevaya taiga is a unique ecosystem formed under the influence of a complex of geogenic and bioclimatic factors located in the foothill border of the southeastern part of Western Siberia. The combination of local climatic conditions and the composition of parent material led to the formation of specific soil conditions on the territory of these habitats. The soils of the Chernevaya taiga have unique morphogenesis. They have a thick podzolized horizon and are fertile, unlike the typical soils of the oligotrophic pine forests of Siberia; however, the microstructure of these soils is poorly studied. The purpose of the research is to analyze the micromorphological organization and microstructure of three types of soils in Western Siberia (two typical soils from the Chernevaya taiga (Greyzemic Phaeozem (Albic) and Albic Stagnic Luvisol (Ochric)) and one from oligotrophic pine stand (Eutric Protoargic Arenosol)). It was found that the soils of the Chernevaya taiga differ greatly from the background (zonal) soils of the region on both the macro- and microlevels. In the Phaeozems and Luvisols of the Chernevaya taiga, there are actively formed organomineral aggregates and the quantity of porous media is more than 50%. At the bottom of the podzolized part of the soil profiles, we noted illuvial processes and a sharp change in the type of microstructure. The presence of pyrogenic materials (charcoal) and coprolitic (vermicular) materials in the humus-accumulative horizon indicates a high rate of material transformation and high biological activity and bioturbation in the soil. The skeleton part of the Chernevaya taiga soils is represented by a quartz–feldspar base with an admixture of sericite; augite; biotite; and a minimal admixture of tourmaline, zircon, and glauconite.

Keywords: thin soil sections; soil microstructure; micromorphological features; Siberia; taiga



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1. Introduction

The soils of the Chernevaya taiga have been studied by many scientists [1–4]. Interest in them has not ceased since their first description. It has been established that these soils are represented by either dark gray soils with a thick humus horizon or soddy–deep podzolic soils [5]. The areas of highly productive Chernevaya taiga soils are adjacent to relatively poor podzolic or gray-humus organic–accumulative soils in oligotrophic habitats. Since the formation of the Chernevaya taiga was caused by a certain combination of local climatic conditions, the material composition of soil-forming rocks and the topography of Chernevaya taiga soil areas are limited in space and sharply replaced by ranges of other soils [4]. The soil cover of the Chernevaya taiga is a unique phenomenon formed by a combination of geogenic and bioclimatogenic factors, typical, for example, of the Gornaya Shoria region. The phenomenon of Chernevaya taiga soil formation is studied in terms of organic matter, soil morphology, microbiological diversity, and the soil properties associated with plant giganitism [2–4], but researchers overlook the micromorphological

structure and organization of Chernevaya taiga soils; there are no modern studies of the micromorphological structures of these soils.

However, Gerasimova (1992) noted the role of increased biogenicity in the soddy–deep podzolic soils of the Chernevaya taiga in the Altai and Salair Mountains in the formation of their microstructures. It has been suggested that these soils can be distinguished by a separate micromorphotype characterized by continuous aggregation as a result of increased biogenicity [6]. The morphological and micromorphological characteristics of Chernevaya taiga soils were most extensively studied by Kovalev et al. (1981). It was shown that the soils of the Chernevaya taiga are deeply podzolized. Their microstructure has been studied in detail. In particular, it has been established that a humus–clay plasma is formed in the humus horizon; the organic matter is represented by a humus of the moder–mull type; there is a large number of biogenic pores and pyrogenic organic components; and the skeleton is represented by a quartz–feldspar base with an admixture of sericite, augite, and biotite and a minimal admixture of tourmaline, zircon, and glauconite. Ortsteins, cutans, and manganese neoplasms are present [6]. An extremely high degree of mineralization in the organic matter is indicated [7]. At the same time, like Gerasimova (1992), only soddy–deep podzolic soils have been studied. However, gray and dark gray soils are also typical in the Chernevaya taiga; moreover, our recent works [1,6] compare soils of the Chernevaya taiga (dark gray and soddy–podzolic) and the oligotrophic sandy gray–humus soils of pine forests. Therefore, our work is aimed at studying the soils of the Chernevaya taiga and typical oligotrophic taigas using modern micromorphological methods. These methods are undeservedly underused among current soil studies. At the same time, they are very informative; for example, soil micromorphology and its key micromorphological characteristics are extremely informative for understanding the nature of pedogenesis [8], soil diversity [9,10], retrospective analyses of soil and landform evolution [11], and contemporary processes of anthropogenic soil dynamics [12–14]. Recently, a revision of micromorphological terms regarding their modern meaning was carried out [15]. Thus, science has at its disposal a modern terminological framework to describe all the micromorphological features of soils of different types.

The main goal of this study is to investigate the micromorphological features and microstructure of two intrazonal soils of the Chernevaya taiga, Greyzemic Phaeozem Albic and Albic Stagnic Luvisol (Ochric), and compare them with the microstructures of typical (zonal) gray–humus soils in Western Siberia.

2. Materials and Methods

2.1. Key Climatic and Landscape Conditions

This study focused on the soils of the central part of Western Siberia (Figure 1), whose background ecosystems are represented by taiga pine forests and Chernevaya taiga forests. The area of distribution of the Chernevaya taiga is in the macro-slopes of the mountains and foothills of southern Western Siberia. The altitude range in which these ecosystems develop is from 200 to 800 m. In winter, a thick snow cover of up to 2 m is formed, which protects the soil from freezing [1]. The average annual temperature in the study area is 1.0 °C; the amount of precipitation is 700–750 mm [4,16].

The geological structure of the area is associated with the Kolyvan'–Tomsk fold zone. The area is located at the boundary of the West Siberian Plain and the Altai–Sayan fold-type zone. The watershed surface is part of the low and young surface of the accumulative alluvial–lacustrine alignment of the Eopleistocene–Middle Pleistocene age. The right bank of the Tom River belongs to the western part of the Tom–Yay interfluvium and is a slope of the lake–alluvial plain. The left bank of the Tom River is covered near aeolian sands and has a ridgy relief. Section S1 can be found on the alluvial, coarse-grained sands of the second terrace above the floodplain; sections S2 and S3 are on the lacustrine dark-gray loams of the taiga suite [17–19].

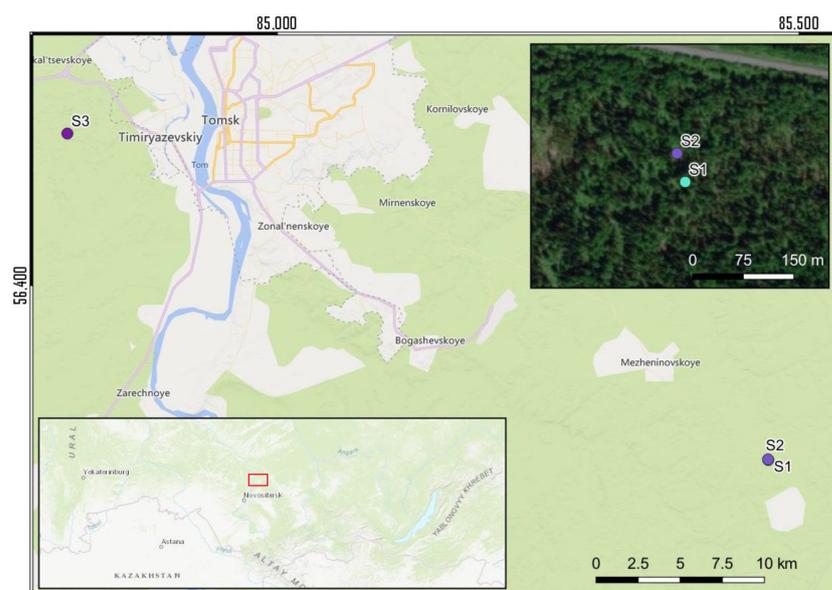


Figure 1. Location map of the study sites (red square—study area). S1—Greyzemic Phaeozem (Albic); S2—Albic Stagnic Luvisol (Ochric); S3—Eutric Protoargic Arenosol.

The landscapes of the Chernevaya taiga can be classified as barrier–rainy. The oligotrophic ecosystem is represented by pine (*Pinus sylvestris*) forests with an admixture of birch (*Betula péndula*) and rowan (*Sórbus aucupária*) located on aeolian sandy massifs (Figure 2a).

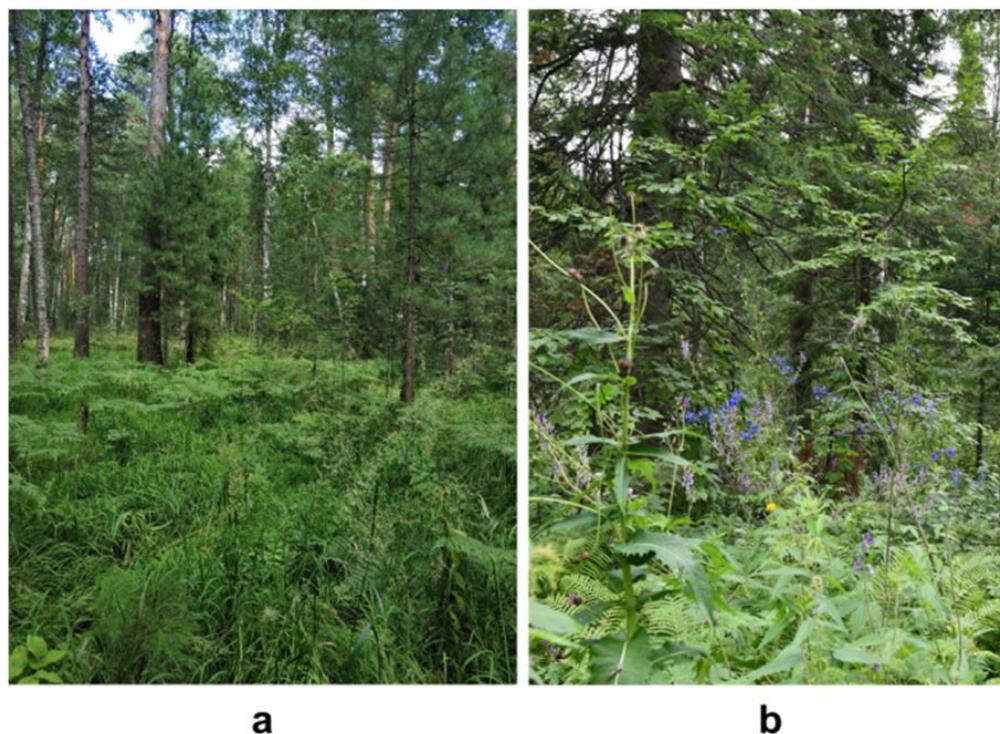


Figure 2. Ecosystems of the study area. (a) Oligotrophic taiga pine forest (Section S3); (b) Chernevaya taiga (Sections S1 and S2).

The northern areal of the Chernevaya taiga is represented by a high-grass fir–aspen forest on flat slopes and the gullies of watersheds. The tree stand is dominated by fir (*Abies sibirica*) and aspen (*Pópulus trémula*), and the herb layer is extremely developed (Figure 2b). The annual fallout of high-grass vegetation decomposes quickly and does not have time

to accumulate as litter, unlike in oligotrophic habitats. This leads to the accumulation of mineral nutrients in the organomineral soil horizons.

Samples were collected on 27 July 2021. Soil names were applied according to the International Soil Classification system [20].

Data on the chemical and particle size distribution analysis, as well as data on the taxonomic composition of the microbiome of the indicated soils, were published previously; a brief summary of the main physicochemical properties is provided below [1,4].

The Greyzemic Phaeozem Albic soils of Chernevaya taiga (Figure 3a) are characterized by high fine-grained earth content throughout the profile (about 80%), with clay fraction (<0.001 mm) content of 15–25%. The organic carbon and total nitrogen contents in these soils are distributed by the homogeneous–accumulative type. The amount of organic carbon in the surface horizons reaches 4.8% and decreases to 0.24% in the parent material. The total nitrogen content ranges from 0.37% to 0.05% from the surface organomineral horizons to the parent material. The C/N ratio ranges from 12 to 13 to a depth of 50 cm (in the organomineral and subsurface eluvial horizons); down the profiles of the illuvial horizons and parent material, the C/N ratio drops to 8.1 and 5.4, respectively. These soils are slightly acidic, with the pH of the aqua extract averaging 6.5 and the salt extract averaging 5.3 in the profile. The concentrations of nutrients are high and nonhomogeneous. Concentrations of available forms of phosphorus vary from 343 mg/kg in the 0–10 cm layer to 702 mg/kg in the 30–40 cm layer. A similar distribution is typical for potassium; in the 0–10 cm layer, concentrations reach 319 mg/kg, and for the 30–40 cm layer, potassium concentrations equal to 217 mg/kg were recorded. Ammonium and nitrate forms of nitrogen are concentrated in the upper horizons, with a predominance of nitrate forms (content 11.1 mg/kg and 15.6 mg/kg, respectively).

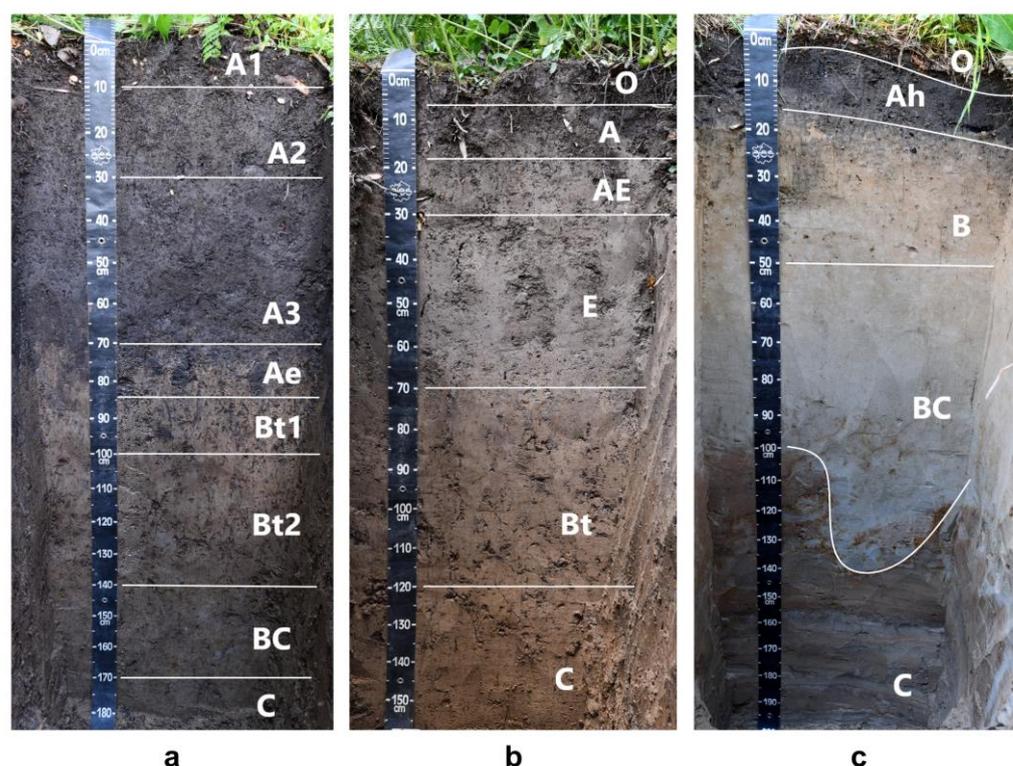


Figure 3. Profiles of the studied soils. (a) Greyzemic Phaeozem (Albic) (Section S1); (b) Albic Stagnic Luvisol (Ochric) (Section S2); (c) Eutric Protoargic Arenosols (Section S3).

The Albic Stagnic Luvisol (Ochric) soils of the Chernevaya taiga (Figure 3b) are characterized by a high fraction of skeleton, especially in the organomineral horizons (up to 93%); the content of fine-grained earth increases to 75–90% down the profile. The proportion of colloidal fraction in the fine-grained earth is up to 25%. In comparison with

the Greyzemic Phaeozem Albic, the organic carbon and total nitrogen contents is lower. The maximum amount of carbon in the organomineral horizons is 3.97%, and the total nitrogen is about 0.3%. The C/N ratio from the surface is 10.7; in the parent material, it is 4.98. Nitrogen content decreases homogeneously down the profile. Soils are acidic or weakly acidic, the pH of the water extract ranges from 5.3 to 6.7, and the salt extract ranges from 4.3 to 6.2. This type of soil is characterized by lower available phosphorus and potassium contents, and the maximum concentration can be observed in the lower part of the profile (at a depth of 120 cm); here, the phosphorus and potassium content reaches 184 and 160 mg/kg, respectively. Ammonium and nitrate forms of nitrogen are concentrated in the surface organomineral horizons (up to 20 cm), with a predominance of nitrate forms.

The Eutric Protoargic Arenosols of oligotrophic ecosystems (Figure 3c) are characterized by low skeleton fraction content; the proportion of fine-grained earth is 94–98%. The proportion of colloidal fraction in the fine-grained earth is 5–7%. The organic carbon content in the surface organomineral horizons is 2.7%; the total nitrogen is 0.17%. Down the profile, these values drop to 0.03 and 0.01%, respectively. The C/N ratio in the surface horizons is 15.4; closer to the parent material, it drops to 6. The soils are slightly acidic, the pH of the water extract ranges from 5.9 to 6.7, and the salt extract ranges from 5.4 to 6.3. The content of available phosphorus increases down the profile, from 113 mg/kg in the organomineral horizons to 243 mg/kg in the parent material. Concentrations of available potassium are highest in the surface horizons, up to 195 mg/kg, decreasing down the profile to 58 mg/kg. The ammonium forms of nitrogen contents are extremely low; in surface horizons, it is 0.57 mg/kg. Nitrate nitrogen is concentrated in the surface horizons; the content reaches 7.1 mg/kg.

The phylum-level taxonomic diversity of soil microbiota between the soils of the Chernevaya taiga and the soils of oligotrophic ecosystems varies slightly and is represented mainly by the phyla *Proteobacteria*, *Verrucomicrobia*, *Actinobacteria*, *Acidobacteria*, *Planctomycetes*, and *Firmicutes*. A more detailed characterization of the physicochemical properties of Chernevaya taiga soils and their microbial diversity was published previously [1,21,22].

2.2. Features and Methods of Micromorphological Studies

Samples for the preparation of soil thin sections were taken directly from the soil profile for each horizon. Square-shaped metal forms were pressed into the front wall of each section. Samples were dried and saturated with resin [6].

Thin sections were analyzed with a polarizing microscope (Leica DM750 P (Leica Microsystems, Germany)) under plane-polarized light (PPL) and cross-polarized light (XPL). Photomicrographs were taken with a Leica MC 170 (Leica Microsystems, Germany) camera in autoexposure and auto white balance modes (the LAS 4.12 software was used).

The thin sections were photographed using sequential photography with a step of 2 mm on the x -axis and 3 mm on the y -axis at a total magnification of $\times 2.5$. After obtaining a series of photographs, they were combined into a photomosaic using the software Helicon Focus v7.0.2. Twelve microphotographs (each with a resolution of 2592×1944) were combined into a photomosaic with a final resolution of 6074×5406 . Color correction was performed in automatic mode. As a result, we obtained a panoramic image of the soil's thin layer with a coverage of 11×10 mm. The morphometric processing of the obtained images was performed in the ImageJ software; the photographs were binarized and analyzed using the Analyze Particles tool. Quantitative micromorphological characteristics (FF, Rdn) were calculated according to the methods described in Rodríguez (2013) [23].

The following soil micromorphometric indices were investigated: soil microfabric, spatial arrangements of fabric units, soil particle distribution, elements of microstructure, and character of organic matter. The terminology used in this paper was published by Gerasimova (2011) and Stoops (2021), where details of the micro-organization of soil were described in detail [15,24].

3. Results

3.1. Micromorphology of Humus-Accumulative Horizons

The soil fabric of the superficial humus-accumulative horizons of the Greyzem Phaeozem Albic and Albic Stagnic Luvisol (Ochric) soils demonstrate (Figure 4) a well-developed aggregate microstructure with an angular or rounded shape. Porous media occupy <50% of the thin section. Eutric Protoargic Arenosols had no intensive aggregation in the humus-accumulative horizon. Porous media covers more than 70% of the soil matrix. Particles of sand in an oval, rounded form dominate in soil microstructure. Fine dark-colored particles of undecomposed organic material are located in intra-sand-particle porous media; they are not associated with mineral particles.

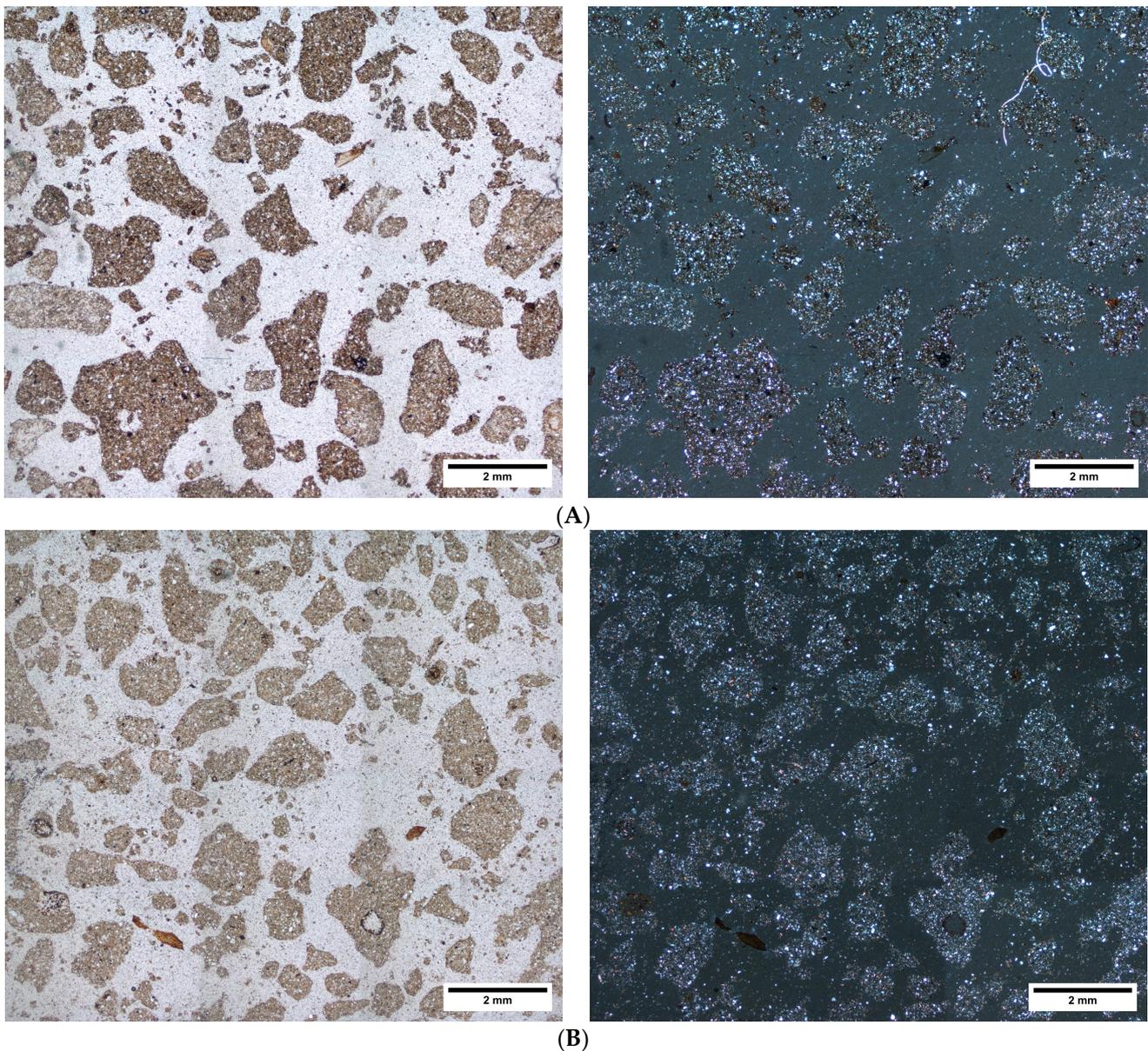


Figure 4. Cont.

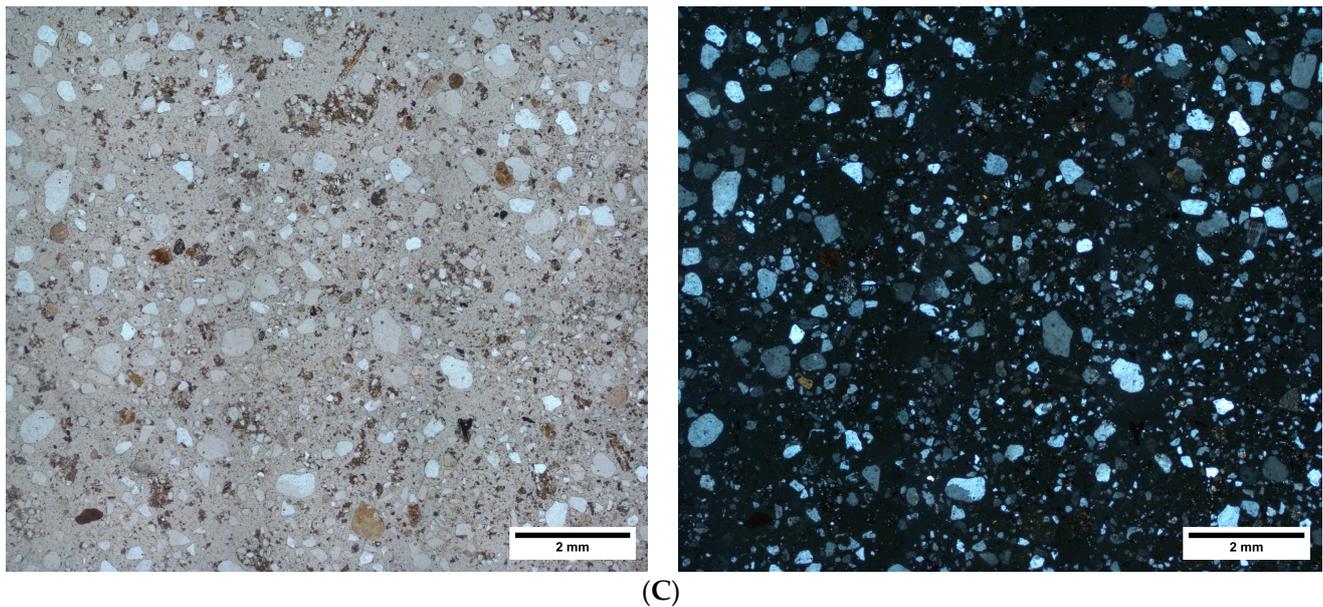


Figure 4. Microstructure of humus-accumulative horizons. (A) Greyzemic Phaeozem (Albic) (A2); (B) Albic Stagnic Luvisol (Ochric) (A); (C) Eutric Protoargic Arenosols (Ah). (Left)—PPL; (right)—XPL.

A morphometric analysis of thin sections from the humus-accumulative horizons was performed (Table 1). The aggregates from the Greyzemic Phaeozem (Albic) soil are large, with a maximum Feret diameter of 3.18 and 4.37 mm in two flats. The average parameters of the aggregates in the two planes are $1.63 \pm 0.59 \times 2.40 \pm 0.91$ mm. It can be seen that the aggregates in the Greyzemic Phaeozem (Albic) soil are wider than they are tall. No organic (plant) residues or other commonly occurring inclusions were found, but multiple signs of earthworm activity—coprolites (excrement)—were observed. These are rounded, dark-colored, partially mineralized structures.

Table 1. Results of morphometric analysis of aggregates, mineral particles, and other inclusions (mm).

	Greyzemic Phaeozem (Albic)				Albic Stagnic Luvisol (Ochric)			
	Cross-Section of Aggregates (<i>n</i> = 38)		Cross-Section of Coprolitic (Vermicular) Material (<i>n</i> = 13)		Cross-Section of Aggregates (<i>n</i> = 41)		Organic (Plant) Residues (<i>n</i> = 10)	
	FY	FX	FY	FX	FY	FX	FY	FX
Min	0.67	0.91	0.26	0.34	0.32	0.37	0.08	0.22
Max	3.18	4.37	1.12	1.54	1.28	1.96	0.28	1.55
Mean	1.63	2.57	0.59	0.77	0.89	1.24	0.17	0.65
Median	1.54	2.40	0.65	0.73	0.90	1.15	0.14	0.50
SD	0.59	0.91	0.22	0.34	0.23	0.39	0.07	0.46
EutricProtoargic Arenosols								
	Grains quartz (<i>n</i> = 40)		Feldspar grains (<i>n</i> = 11)		Organomineralaggregates (<i>n</i> = 14)			
	FY	FX	FY	FX	FY	FX		
Min	0.07	0.10	0.10	0.16	0.30	0.54		
Max	0.65	0.88	0.43	0.63	0.99	1.59		
Mean	0.26	0.39	0.23	0.34	0.59	0.94		
Median	0.24	0.38	0.21	0.28	0.58	0.91		
SD	0.13	0.18	0.10	0.14	0.20	0.35		

Remarks: FX and FY Feret diameter in the X- and Y-axes; SD—standard deviation.

A coprolitic or vermicular structure (Figure 5) is quite typical for humus-accumulative horizons of soils in the Chernevaya taiga. Their average Feret diameter in two projections is $0.59 \pm 0.22 \times 0.77 \pm 0.34$ mm. In Albic Stagnic Luvisol (Ochric) soil, the aggregates are not as large; their average size in two projections is $0.89 \pm 0.23 \times 1.24 \pm 0.39$ mm, and they are wide rather than tall. There are many organic (plant) residues that are practically not subject to decomposition processes, and their size is $0.17 \pm 0.07 \times 0.65 \pm 0.46$ mm; their organic (plant) residues are predominantly horizontally oriented. The humus-accumulative horizon of the Eutric Protoargic Arenosols consists primarily of large rounded quartz ($0.26 \pm 0.13 \times 0.39 \pm 0.19$ mm) and feldspar ($0.23 \pm 0.10 \times 0.34 \pm 0.14$ mm) grains that are sometimes coagulated by organic matter into small organomineral aggregates sized $0.59 \pm 0.20 \times 0.94 \pm 0.35$ mm.

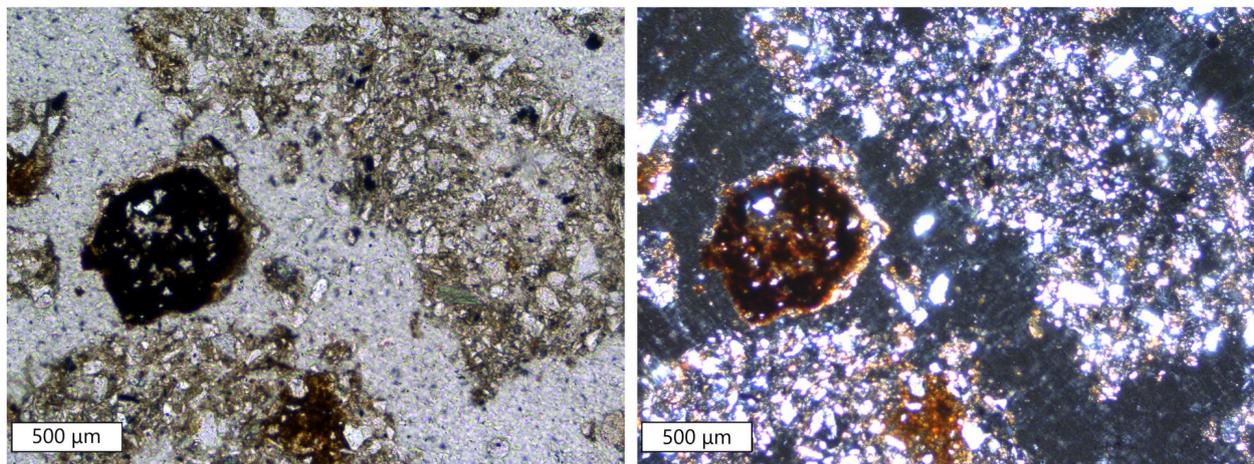
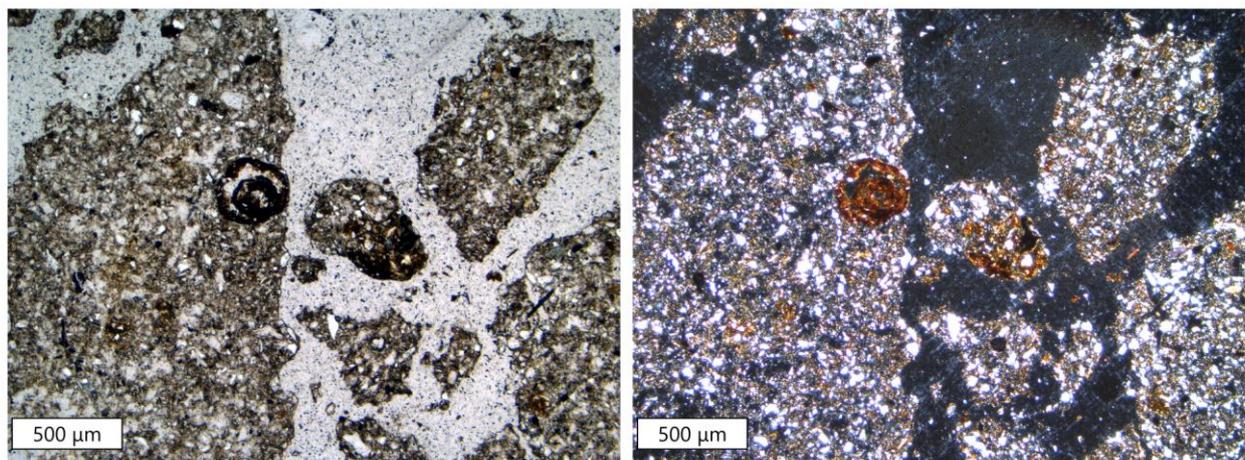


Figure 5. Coprolitic (vermicular) material in the A3 horizon of Greyzemic Phaeozem (Albic) soil. (Left)—PPL; (right)—XPL.

The micromorphological features of the lower part of the humus-accumulative horizons (Ae and AE) in the compared soils of the Chernevaya taiga and the pine stand are provided in Figure 6. In soils of the Chernevaya taiga, the lower part of the humus horizons become less dark-colored in their humus shade, becoming more grayish. The structure becomes less rounded and more angular. As for the lower part of the Eutric Protoargic Arenosols, there is only one change in comparison with the superficial part, an essential decrease in the undercomposed organic residues of the porous media.



A

Figure 6. Cont.

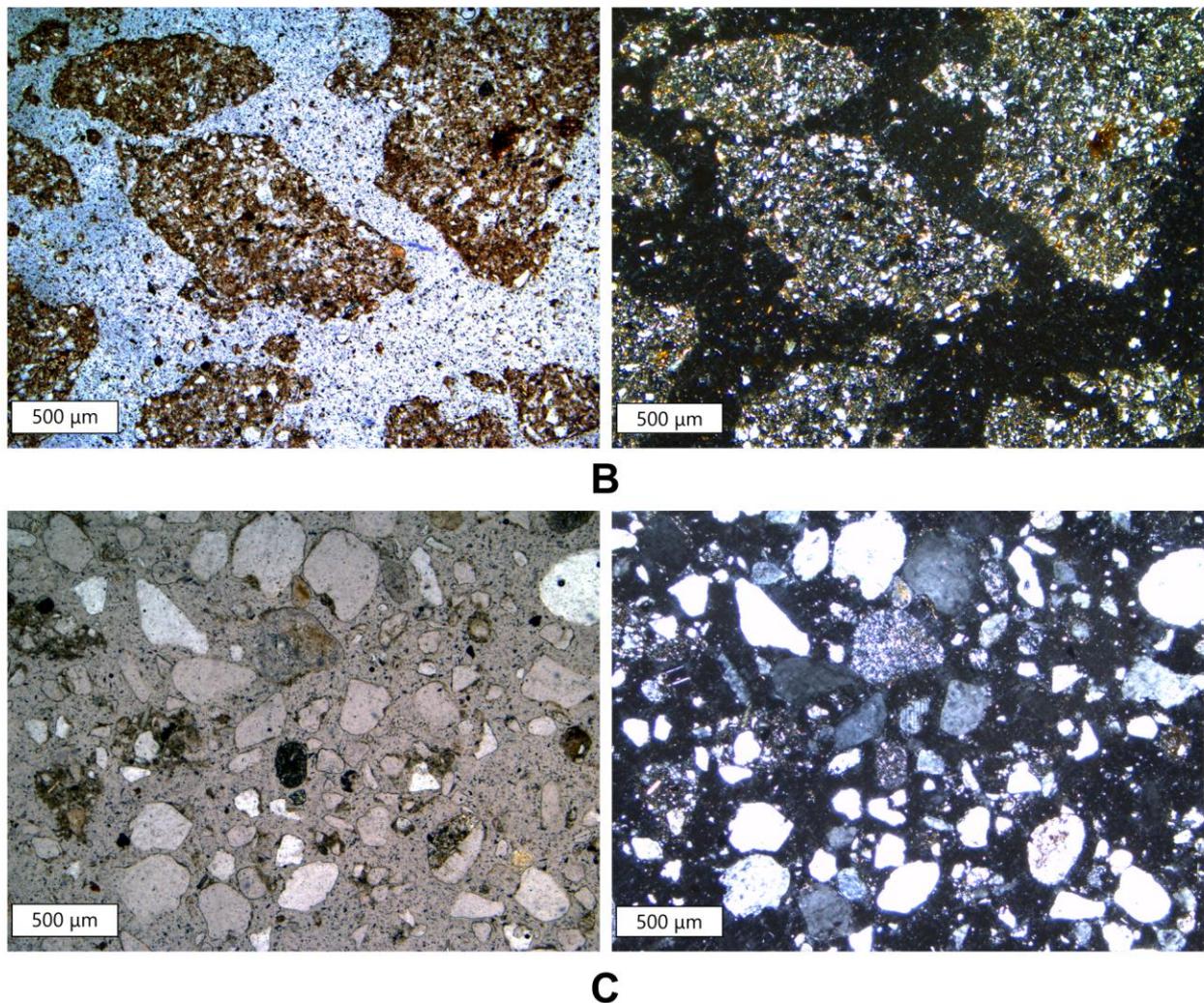


Figure 6. Microstructure of the second horizons of the soil sections of the three soils investigated. (A) Greyzemic Phaeozem (Albic); Ae—angular aggregates with expanded porous media. (B) Albic Stagnic Luvisol (Ochric); AE—angular and subangular aggregates with developed crack-porous media. (C) Eutric Protoargic Arenosols; B—grain of primary mineral, inherited from parent material with a very low degree of pedogenic alteration. (Left)—PPL; (right)—XPL.

3.2. Micromorphology of Transitional Horizons and Specific Features

The microstructure of the Bt1 horizon of the Greyzemic Phaeozem (Albic) soil is a layer depicting a transitional eluviation process, as presented in Figure 7. The peds of this horizon are grayish-colored with lighter spots showing clay particle leaching. There are few argillic coatings on the surface of the macroaggregates. These sections are differentiated in terms of color density, which indicates the leaching of clay and an accumulation of argillic material on the surface of the angular and subangular aggregates.

The microstructure of the Bt horizon of the Albic Stagnic Luvisol (Ochric) soil is shown in Figure 8. Here, we can see clay coatings on the surface of the large aggregates.

The structure is diverse—a plate, prisms, and angular blocks. The same coatings can be seen on the Bt horizon of the Greyzemic Phaeozem Albic soil (Figure 9).

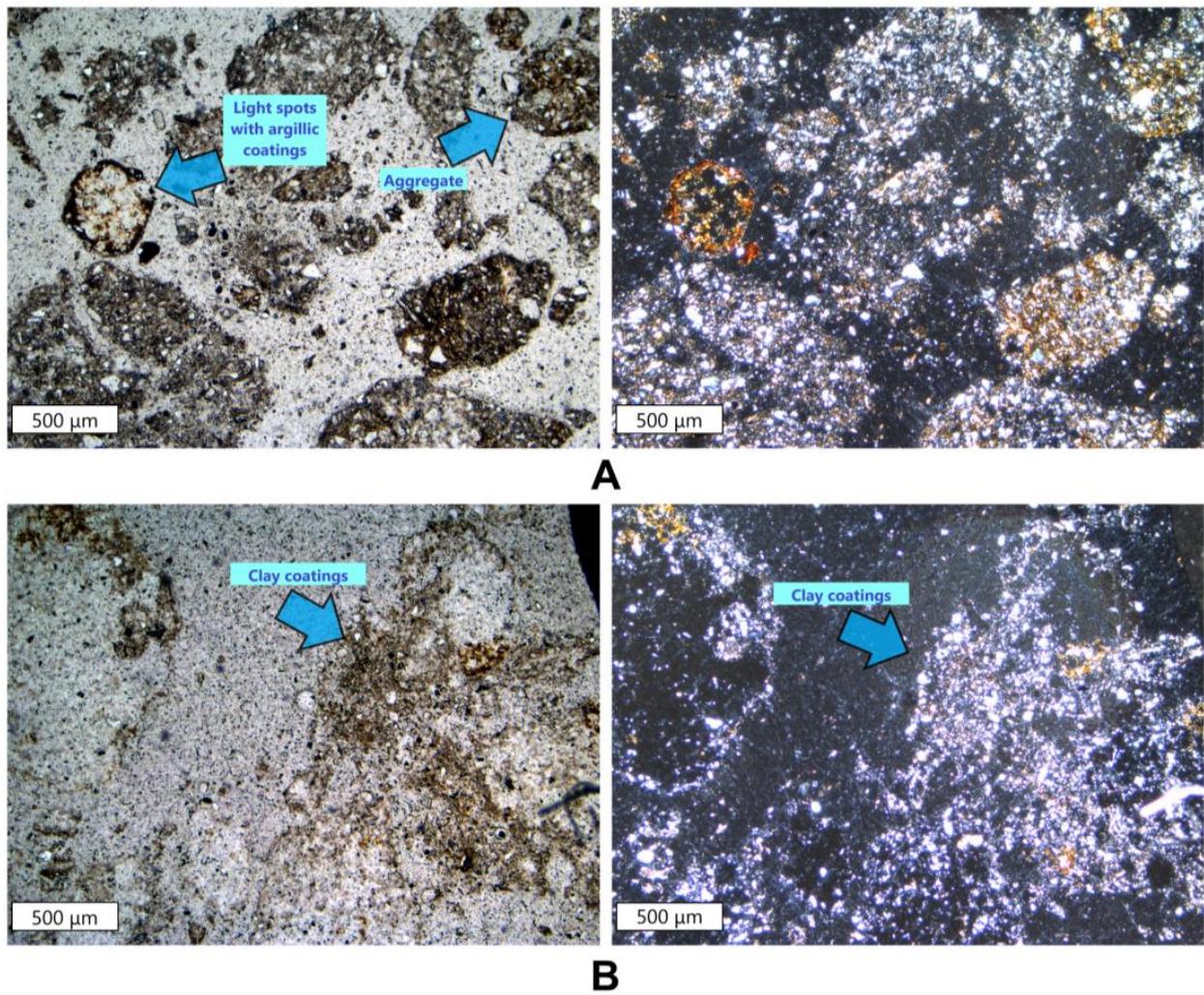


Figure 7. Microstructure (A) of the Bt1 horizon and the coatings (B) on the same horizon of the Greyzemic Phaeozem (Albic) soil. (Left)—PPL; (right)—XPL.

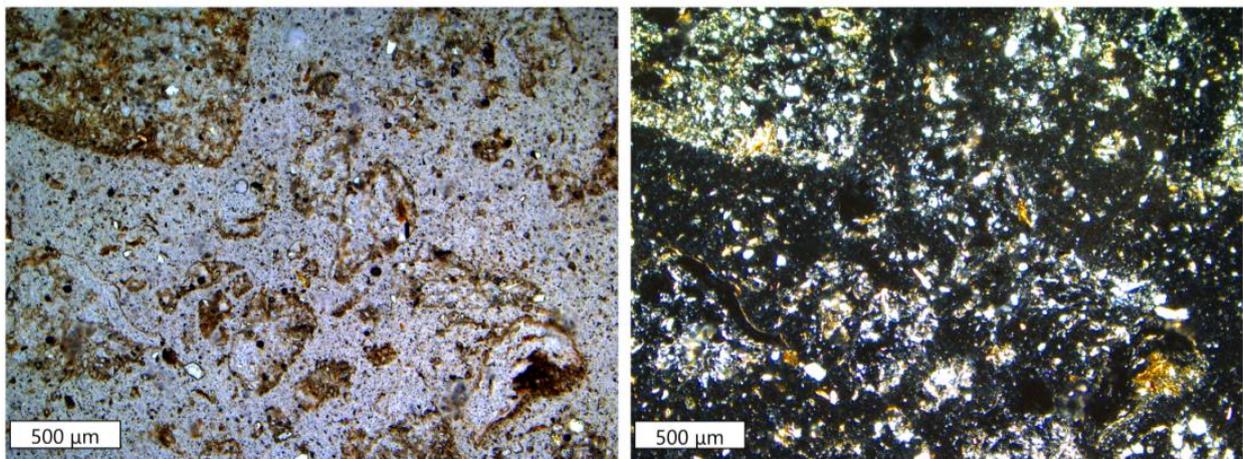


Figure 8. Microstructure and coatings in the Bt horizon of the Albic Stagnic Luvisol (Ochric) soil. (Left)—PPL; (right)—XPL.

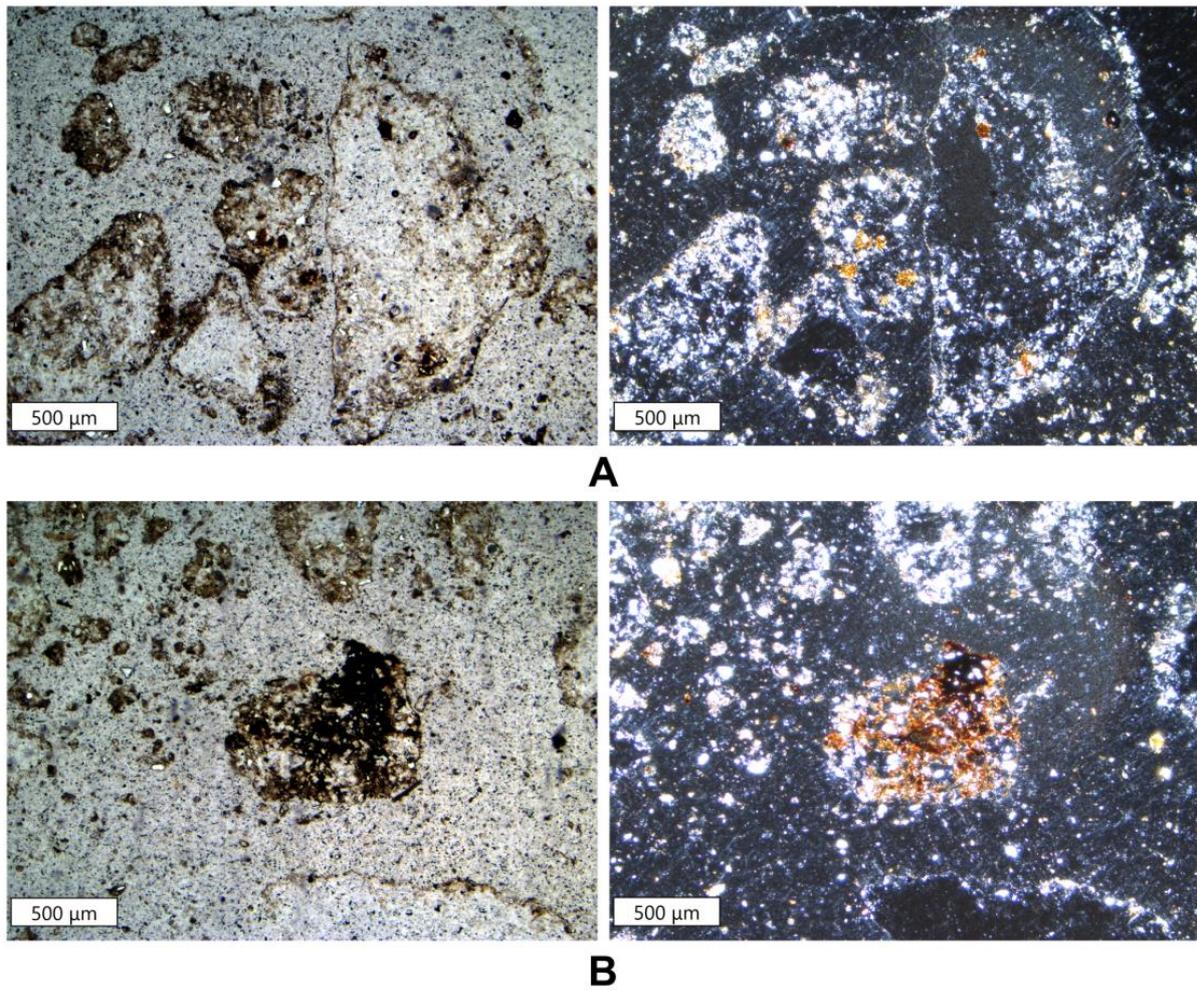


Figure 9. Microstructure (A) of the Bt2 horizon of the Greyzemic Phaeozem (Albic) soil and iron staining (B) on the microaggregates on the same horizon. (Left)—PPL; (right)—XPL.

Pyrogenic features are provided in Figure 10; they are porous charcoal pieces with mineral inclusions in the pores. No micromorphological elements were discovered in the soils of the pine stand.

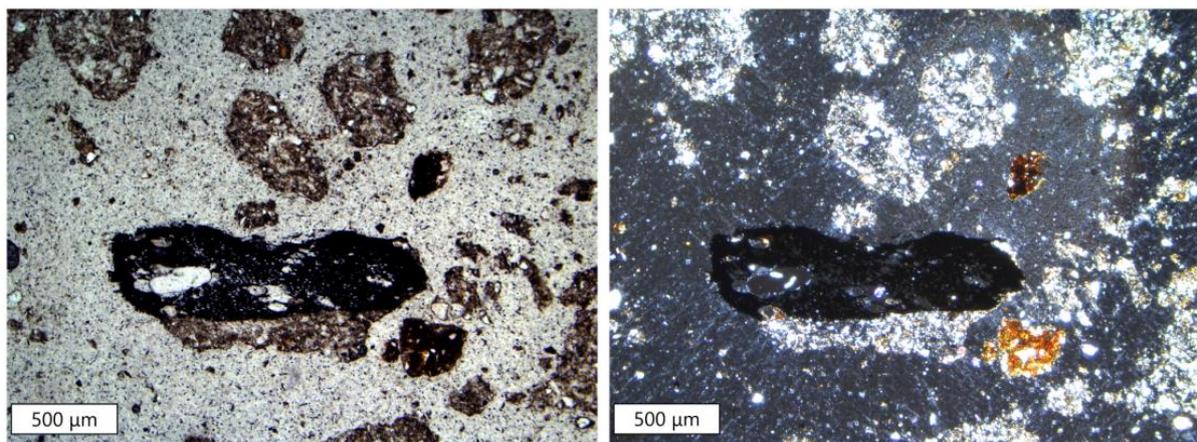


Figure 10. Pyrogenic material in the A3 horizon of the Greyzemic Phaeozem (Albic) soil. (Left)—PPL; (right)—XPL.

3.3. Micromorphology of Parent Material

The microstructures of the parent materials of all three soils investigated are presented in Figure 11. It is evident that the parent materials are more compacted and have less porous media than materials in the top and middle parts of the soil profiles (Greyzemic Phaeozem (Albic)—39%, Albic Stagnic Luvisol (Ochric)—42%, Eutric Protoargic Arenosols—66%). For the parent material horizon of the Eutric Protoargic Arenosols, there is some organic residue not associated with mineral compounds.

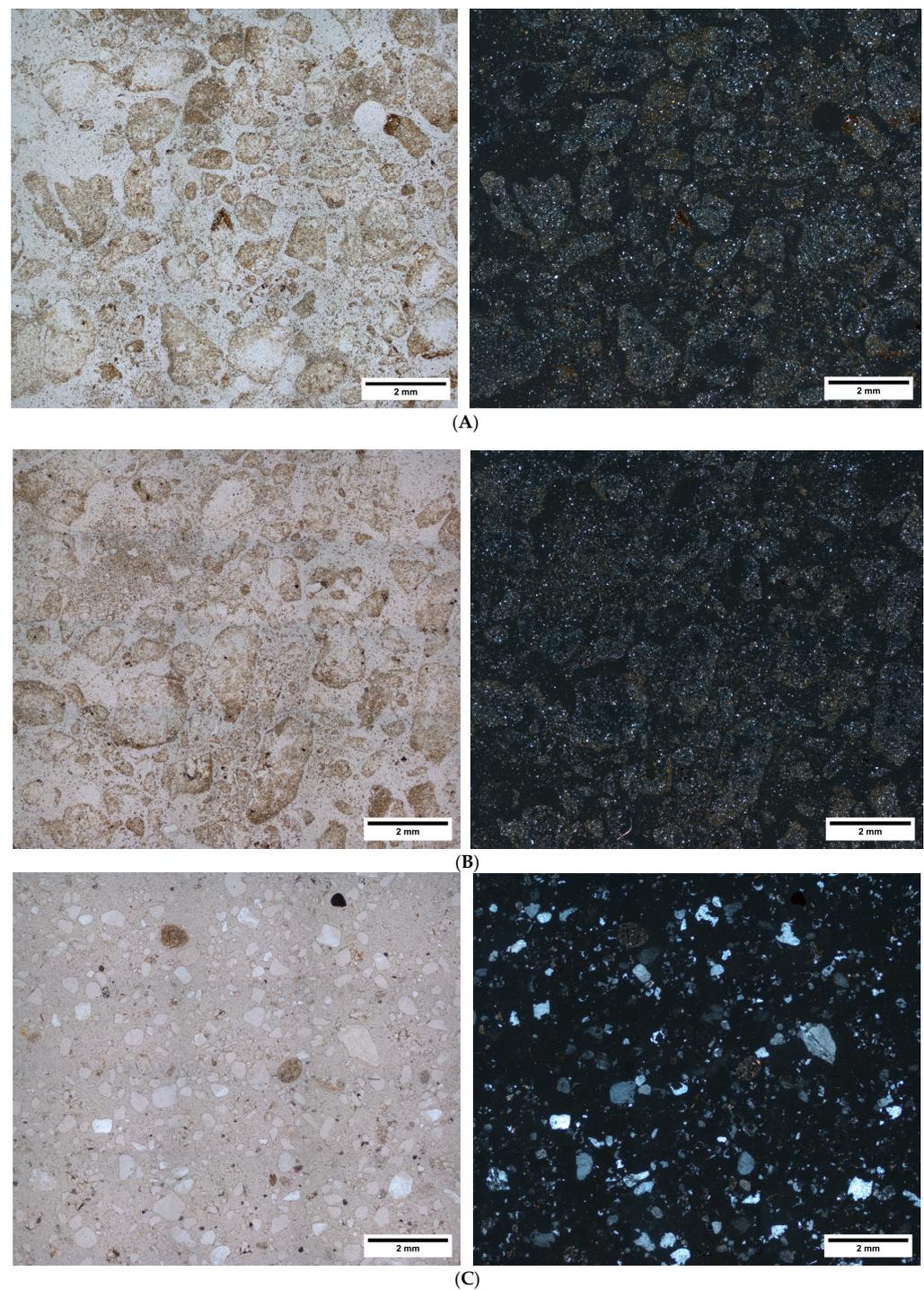


Figure 11. Microstructures of the parent materials (C horizons) of the three soils investigated. (A) Greyzemic Phaeozem (Albic); (B) Albic Stagnic Luvisol (Ochric); (C) Eutric Protoargic Arenosols. (Left)—PPL; (right)—XPL.

The results of decoding the binarized images of the thin sections of the humus-accumulative horizons and the parent materials (Table 2) show that the Greyzemic Phaeozem (Albic) porous media in the humus-accumulative horizon occupies 56%, the average particle area is 0.43 mm^2 , and their cross-sectional Feret diameter averages 0.91 mm ; they have a low circularity index ($FF = 0.14$) but have medium rounded edges ($Rdn = 0.43$). In the parent material, the fraction of porous media decreases to 39%, the area of the particles becomes larger (1.72 mm^2), and their Feret diameter and roundness indices increase. Albic Stagnic Luvisol (Ochric) soil is also characterized by the presence of large particles (area, 0.45 mm^2 ; Feret diameter, 0.95 mm) in the humus-accumulative horizon. The fraction of porous media is 58% (Table 2). The particles have low circularity ($FF = 0.11$) but with rounded edges ($Rdn = 0.46$). In the parent material, the particle size increases (area, 0.77 mm^2 ; Feret diameter, 1.25 mm); the proportion of porous media is 42%. Eutric Protoargic Arenosols contain many fine particles in the humus-accumulative horizon (area, 0.03 mm^2 ; mean Feret diameter, 0.23 mm). The fraction of porous media is 73%. The particles have a circularity index of $FF = 0.24$ and a roundness index of $Rdn = 0.47$. The parent material particles are larger (area, 0.13 mm^2 ; average diameter, Feret 0.57 mm); the proportion of porous media is 66%.

Table 2. Results of decoding the binarized thin sections.

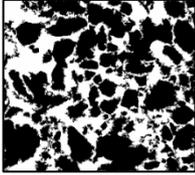
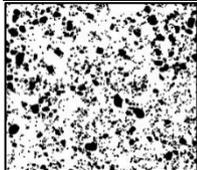
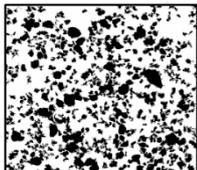
Soil	Horizon	Binary Image	Porous Media, %	Particle Properties						
				Area, mm^2			Fx	FF	Rdn	n
				Min	Max	Mean	Mean			
Greyzemic Phaeozem (Albic) (S1)	A2		56	0.02	5.31	0.43	0.91	0.14	0.43	116
	C		39	0.6	23.83	1.72	1.68	0.53	0.38	39
Albic Stagnic Luvisol (Ochric) (S2)	A		58	0.04	2.67	0.45	0.95	0.11	0.46	105
	C		42	0.03	9.47	0.77	1.25	0.06	0.37	83

Table 2. Cont.

Soil	Horizon	Binary Image	Porous Media, %	Particle Properties						
				Area, mm ²			Fx	FF	Rdn	n
				Min	Max	Mean	Mean			
Eutric Protoargic Arenosols (S3)	Ah		73	0.01	0.62	0.03	0.23	0.24	0.47	1007
	C		66	0.02	3.11	0.13	0.57	0.07	0.37	294

Remarks: HA—humus-accumulative; PM—parent material; Fx—Ferret diameter, mm; FF—circularity index (0–1); Rdn—roundness index (0–1). All types of particles were analyzed: aggregates of different sizes, mineral grains, organic residues, etc.

4. Discussion

Our data on the macro- and micromorphological organization and micromorphological structures of soils of the Chernevaya taiga confirm that they intensively develop eluvial–illuvial differentiation, leading to the formation of cutans (coatings), which is typical for these soils [4] and known to be an indicative feature of soils with pronounced Luvisol features [25]. The soils of the Chernevaya taiga are formed on a loamy-textured parent material, while the Eutric Protoargic Arenosols (zonal soils of Western Siberia) are formed on aeolian–alluvial late-Holocene sands. For this reason, the soils of the Chernevaya taiga are completely different from the soils of oligotrophic pine stands formed on sands in terms of texture and microfabrics. Porous media occupy more than 50% of the thin section in the Greyzemic Phaeozem (Albic) soil of the Chernevaya taiga. Many coprolitic structures and the absence of organic residues were found in the microstructure. This indicated very intensive biological processes resulting in the formation of huge organomineral aggregates stabilized by humus compounds. In Albic Stagnic Luvisol (Ochric) soil, many large aggregates were also found, but there were much fewer coprolites (excrement), and a large number of organic residues with a poor degree of decomposition were also found. This may indicate that the biological processes are slower here, and, consequently, the process of humus accumulation is not as intensive. Haplic Arenosols (Eutric) are completely different from Greyzemic Phaeozem (Albic) and Albic Stagnic Luvisol (Ochric) soils; there is no intensive aggregation, and porous media covers more than 70% of the thin section. Thus, we can see an increase in the biological activity in a series of soils, from zonal (Eutric Protoargic Arenosol) through transitional (Albic Stagnic Luvisol (Ochric)) to intrazonal (Greyzemic Phaeozem (Albic)). Down the profile in all the studied soils, the soil matrix compacts; the proportion of pore space decreases and increases the size of the aggregates (Table 2). Because of this, this pine stand soil demonstrates low-intensity biogenic–abiogenic interactions. The high precipitation rate of the territory reveals the intensive vertical differentiation of the Chernevaya taiga soil profiles on the vertical scale; this is one of the factors in the development of a thick profile of gray forest soils in the facial sequences from the west to the east [25,26]. Conversely, weathering and illuviation do not develop in well-drained sandy soils, which is characteristic of similar ecosystems of island pine forests in Central Russia [14].

At present, although numerous works have been carried out to assess the micromorphological condition and organization of soils, they barely cover representatives of all the natural zones [27–29]. It is not necessary to speak about the partially studied micromorphology of soils differing from zonal archetypes, for instance, even well-studied belts such as the boreal region. The intrazonal soils of the Chernevaya taiga are unique; they possess extremely high fertility, which even leads to the formation of the phenomenon of plant gigantism in the territory of the Chernevaya taiga. These soils stand out among zonal soils of the boreal region in terms of typical physical and chemical soil properties, fertility parameters, the taxonomic composition of rhizosphere microbiota, and the taxonomic composition of fungi [1,3,22,26,30]. Earlier intrazonal soils in Western Siberia have practically not been investigated; there are only some data published by Kovalev et al. (1981) and Gerasimova (1992) [7,8]. Thus, Chernevaya taiga soils are peculiar not only in the composition of the humus [31,32], microbiome [1], biota [22], and macromorphology [4] but also in the key micromorphological features.

5. Conclusions

The unique micromorphological structure of Chernevaya taiga soils is associated both with the composition of the parent material (lacustrine dark-gray loams) and with an extremely high degree of biological processing in the organic matter. As a result of specific climatic conditions in the organic material (litter), it does not have time to accumulate, and it is almost immediately involved in the soil profile, where it is subjected to biological destruction. This can be seen from the presence of coprolites in the microstructure of these soils, and the microstructure of Chernevaya taiga soils differs in the degree of structure and size in the organomineral aggregates. The soils of the Chernevaya taiga are characterized by intensive humus accumulation, dark coloring in the upper and middle part of the profile, the development of multidimensional aggregates, and pores occupy up to half of their volume; in the humus horizon, there are signs of eluvial–illuvial differentiations and the accumulation of clay cutans (coatings) on the surfaces of aggregates. In the Greyzem Phaeozem (Albic) soil of the Chernevaya taiga, pyrogenic materials and coprolitic (vermicular) formations in the surface organomineral (A) horizons were observed. The soil of the oligotrophic pine forest is characterized by a very homogeneous mineral composition (quartz–feldspar), the absence of visible traces of organomineral interactions, and rounded mineral particles.

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