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Deposits of the rock shelter Svetly (the Middle Urals): Comparison of paleosol and paleotheriological data and paleoenvironmental reconstructions based on them

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ABSTRACT

Paleosols, surface soils, mammal bone remains of Late Pleistocene and Holocene deposits of the rock shelter Svetly were studied. The joint analysis of paleontological and paleosol data was carried out. The paleoenvironment underwent considerable transformation, which resulted in changes in type of soil formation and in the structure of the mammal community. Cryoarid conditions with mammoth complex mammals of Late Pleistocene layer changed to warmer and more humid conditions with spread of open landscapes, along with forest biotope formation. The most favorable conditions in terms of heat and moisture supplies continued during the Middle Holocene, resulting in formation of dark humus horizons. By the late stage of this epoch, taiga fauna had formed. Later conditions become cooler. Chronological heterogeneity of bone remains in the upper layer is caused by a complex genesis of local sediments. Staged process of sedimentation resulted in polygenetic soil profiles. Common structure of deposits is indicative of the general trend in the paleoenvironmental evolution. The study of separate layers within the soil profiles largely reveals the concurrent nature of soil and fauna evolutions.

1. Introduction

Paleogeographical reconstructions deploy a variety of methods and indicators, each capable of identifying paleoclimatic characteristics. Fossil organisms seem to display high temporal and low spatial resolutions. Soils can retain information about prolonged periods of environment evolution, hence paleosols possess low temporal resolution, but at the same time high spatial resolution (Targulian and Sedov, 2004). Paleontological and paleosol indicators may greatly complement each other, and their conjugate analysis leads to more detailed reconstruction of the past environment (Dobrovolskiy and Makeev, 2009).

Paleontological research of the Urals has been carried out since the late 19th century. This period has seen massive growth in paleoteriological findings of large and small Pleistocene and Holocene mammals (Smirnov, 2003).

Paleopedogenesis in the Middle Urals has not been given sufficient attention. As far as we know, there is only one special article on reconstruction of conditions underlying the formation of buried soils in this area (Nekrasova and Uchaev, 2012). At present, local peculiarities of soil evolution are not known. Historical development of the Middle Ural soils has not been correlated with that of the adjacent areas.

The purpose of this article is parallel study and conjugate analysis of the species composition and population structure of mammals, pedogenic features of surface and buried soils of Late Pleistocene–Holocene deposits in the rock shelter Svetly (the Middle Urals) and paleoenvironmental reconstruction based on them.

2. Regional setting and objects

Rock shelter Svetly is located on the right bank of the river Serga in the National Park «Olenyi Ruch'i», the Middle Urals, Russia (56°32′N, 59°16′E). By physiogeographical division, the territory is included in the southern taiga macroregion of Ufa–Chusovaya district (depression), representing the West Ural zone of orogenesis of the Middle Ural mountains (Prokaev, 1976). The valley of the Serga river is deep and narrow, dissect the Upper Silurian and Lower Devonian limestone formations. On most sites, there are no terraces above floodplains, the banks are predominantly steep and consist of primary rocks. Karst is fairly common.

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The climate is continental, with the average annual precipitation of 500 mm. The average monthly temperatures of air are −17.0 °C in January, and 16.6 °C in July, the mid-annual temperature is 0.3 °C ("Climate…", 1965). In the Serga river valley, pine forests prevail and some areas abound with larch trees. The agroclimatic indicators of the given area characterize it as insufficient in heat and excessive in moisture supply. The soil cover structure of the area is dominated by mosaic combinations of soddy-calcareous soils, gray forest residually calcareous soils and gray forest soils (Gafurov, 2008) (close to Rendzic Leptosols, Endocalcaric Retisols and Haplic Retisols, respectively).

The rock shelter Svetly is situated in the base of a 7 m high limestone rock. The height from flood-lands is about 3 m and from the Serga River about 6 m. The site has a south-eastern exposition. The width of the rock shelter is 5.7 m, the length 1.6–2.0 m. A small buried grotto can be seen in the base of the rock. In the northern part of the rock shelter, sediments were excavated. The total area of the excavation square is 6 m^2 and the maximum depth of the pit is about 2.15 m (Fig. 1).

3. Materials and methods

Excavations of the rock shelter Svetly have been held by the scientists of Institute of Plant and Animal Ecology UrB RAS (IPAE UrB RAS, Yekaterinburg) in 2005–2007. They have resulted in many osteological and archeological findings (Volkov et al., 2007).

The excavation and sampling of fauna and radiocarbon investigations followed standard methodology (Gromov, 1955; Arslanov, 1987). Deposits have been taken in separate 10 cm levels and washed in sieves with a mesh size of 0.8 mm to recover small vertebrate remains (Gromov, 1948; Agajanian, 1979; Guslitcer, 1979). Species of mammal remains have been identified using the etalon collections of IPAE UrB RAS and literature (Gromov and Polyakov, 1977; Gromov and Erbaeva, 1995; Borodin, 2009). Species ratios in fossil faunas have been calculated on the basis of the minimum number of individuals (MNI). The paleontological collections are kept at the IPAE UrB RAS.

Radiocarbon dating was conducted at the Isotope Center of The Herzen State Pedagogical University (SPb, St. Petersburg) and in the A.N. Severtsov Institute of Ecology and Evolution (IEMEG) of the RAS (Moscow).

To analyze bone remains for their chronological similarity, organic matter amounts reserved in fossil bones have been estimated by Differential Thermal Analysis (DTA) according to Smirnov et al. (2009). Only vole lower jaws have been used as bone specimens because they are the most numerous and suitable for species identification. Organic matter amount data have been obtained on the high-precision derivatograph "Netzsch STA 449F3 Jupiter" (only for specimens from layers 3–5). For layer 2, the data from Smirnov et al. (2009) have been used.

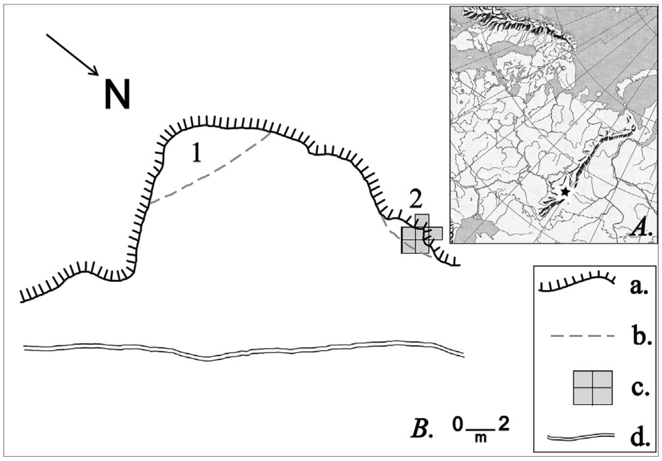

Fig. 1. The rock shelter Svetly: A. General map. B. The scheme of Svetly rock. 1. Svetly grotto. 2. Rock shelter Svetly. a. Limestone rock. b. Drop line. c. Excavation (thick line – cross-section). d. Path.

Buried and surface soils of the excavation site and surface soils of the adjacent sites (on the top and the slope of the rock above the rock shelter) were examined. pH of aqueous soil extract were measured by potentiometry, mobile phosphates in Machigin extract by colorimetric method by Denige; water-soluble sulphates by thermogravimetric analysis; total organic carbon (TOC) by potassium dichromate oxidation by Turin (Arinushkina, 1970), fraction-group humus composition by Ponomareva and Plotnikova (1975). Optical density of humic acid was measured in the extract after soil decalcification with the spectrophotometer PE-5400 (Ekros). Soil particle-size distribution was determined by laser diffraction with Analysette 22 Nanotec (Fritsch) after the soils had been treated by 4% sodium pyrophosphate.

4. Results

4.1. Stratigraphy

The sedimentary sequence contains 5 layers (Fig. 2).

Layer 1. Modern humus layer, slightly sodded, consisting of dry undecomposed plant remains, friable and penetrated by abundant roots. The layer contains few bones of birds and mammals.
Layer 2. Light-gray or whitish, loose unstructured loamy soil. Stone content increases from 10% in the upper part of the layer up to 80% in the lower part. The layer contains numerous vertebrate bone remains.

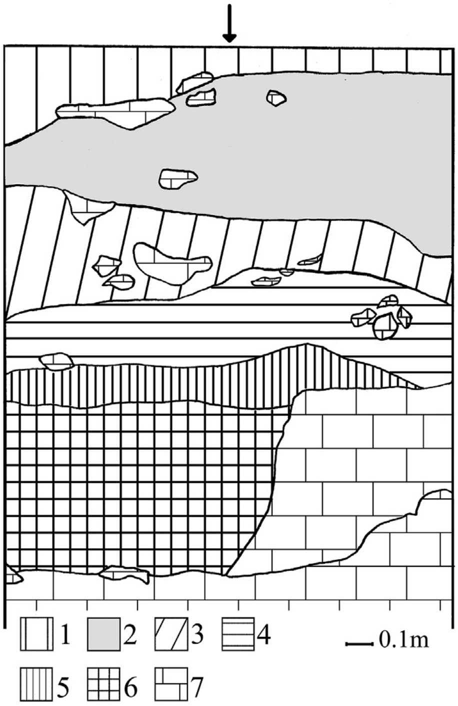

Fig. 2. The rock shelter Svetly: stratigraphy of the south wall of excavation. 1. Layers 1. 2. Layer 2. 3. Layer 3. 4. Layer 4. 5. Layer 4a. 6. Layer 5. 7. Limestone stones and boulders.

Layer 3. Dark gray loamy buried humus horizon, high stony (to 80%). There were identified bone remains of vertebrates.
Layer 4. Heterogeneous by color, brown with light-gray spots loamy soil with inclusion of large rubble, stone concentration is 40–60%. The layer contains numerous vertebrate bone remains.
Layer 4a. Gray-brown loamy buried humus horizon, heterogeneous in color (combination of brown and gray aggregates). The layer contains numerous vertebrate bone remains.
Layer 5. Light-brown sticky clay, stone content increases from 30% in the upper part to 80% in lower part. This layer revealed the lowest bone concentrations.

Paleontological layers and soil horizons were independently defined by different researchers. Table 1 shows the correlations of paleontological layers and soil horizons.

4.2. *Dating of deposits*

The age of deposits has been determined by the stratigraphy, archeological findings (relative dating), and radiocarbon dating. According to these data, the rock shelter deposits had been accumulating since late Neo-Pleistocene (late Weichselian) to late Holocene (Table 1). In layer 3, potsherds were found dating from the Neolithic–Eneolithic period. This is indicative of the Mid-Holocene origin of layer 3. For the upper part of layer 4, small mammal bone collagens revealed a radiocarbon date of 6300 ± 120 BP (SPb-812), which corresponds to the second phase of the Atlantic stage (Arslanov et al., 1999), or early Mid-Holocene. Stone artifacts from layer 4a serve as evidence of its Mesolithic (early Holocene) age. Thus, layer 4 and 4a deposits had been formed from early to mid-Holocene, and, therefore, the lower part of layer 4 took shape at the boundary of these periods. For layer 5, collagen from the humerus of a woolly rhinoceros yielded a radiocarbon date of 16,400 ± 165 B.P. (IEMEG-1414), which shows its Upper Pleistocene origin.

Soil III. Top 20 cm are represented by litter and the modern gray-humus horizon AY, followed below by stratified sediments with weak signs of pedogenesis (horizons RY). Soil III – gray humus stratazem above paleosol (Shishov et al., 2004). The surface soil can also be determined as a Rendzic Leptosol (in accordance with "IUSS Working Group WRB, 2014"). Soils are highly stony (stoniness changed from 30% to 80% in different horizons). The morphological characteristics are described below.

AY1 is slightly sodded, friable and penetrated by abundant roots, contains undecomposed plant remains, is well separated from the lower horizon. AY2 is gray (10YR 4/1), loose, powdery, structureless sandy loam, with gradual transition in color. RY1 is light gray (10YR 7/2), loose, structureless sandy loam, with a large number of roots, the transition is clear by color and structure. RY2 is whitish with a bluish tinge, loose, with very fragile granular structure, transition is clear by color and density. RY3 is light gray (10YR 7/2), loose, with fragile fine-grained structure, silt loam. RY4 is gray, granular silt loam, the boundary is not clear, transition is marked by the color and density, more loose and light than the underlying horizon.

Buried *Soil II*. Humus horizon [AU1] is dark gray, granular silt loam with roots. [AU2] is dark gray (10YR 2/1) with subangular blocky structure breaking into more smaller blocks, dense loam, the boundary is distincted in 2 cm. [B_t] is non-homogenous by color, brown (10YR 3/3) with light gray spots, dense silt, with fragile columnar structure breaking into subangular blocky. [B_{mca}] is non-homogenous by color, brown (10YR 3/4) with light gray spots, angular blocky silt, porous, sometimes with whitish carbonate powder, large rocks fragments. [B_t] is brown, with fragile columnar structure breaking into subangular blocky, silty, porous, dense, with abrupt transition by color and texture.

Buried *Soil I*. [A] is non-homogenous by color, some aggregates are brown (7.5YR 3/4), some – gray (7.5YR 3/2), dense, with crumby structure breaking into granular, porous silt, with small charcoal. [AB] has the similar to the overlying horizon characteristics, with more brown and less gray color, the boundary is gradual. The soil forming material [C] is brown (7.5YR 4/6), sticky, dense, porous, massive clay. Sampled from the upper part (142–152 cm).

In general, the high content of bedrock fragments, the absence of cryogenic deformations and alluvial layers are marked. Judging by the composition and morphology of the deposits, the lower part of the rock mass is probably aeolian, whereas the upper part is colluvial. Surface soils on the sites adjacent to the excavation plot are represented by Rendzic Leptosols at the upper yields of calcareous rock and Calcaric Cambisols on the slopes.

Table 1
Age and correlation of paleontological and soil layers at the south wall of the rock shelter Svetly.

Paleontological layers	Thickness, cm[a]	Age	Dating method	Soil horizons (depth, cm)[b]		
Layer 1	40	The present	–	Soil III	AY1[c]	0–5
					AY2	5–19
Layer 2	50	Late Holocene	Stratigrafic position (Volkov et al., 2007)		RY1	19–35
					RY2	35–47
					RY3	47–66
					RY4	66–76
Layer 3	60	Eneolithic	Archeological artifacts (potsherds) (Volkov et al., 2007)	Soil II	[AU1]	76–85
					[AU2]	85–95
Layer 4	40	6300 ± 120 BP (SPb-812)	Radiocarbon dating		[B_t]	95–105
					[B_{mCa}]	105–115
					[B_t]	115–127
Layer 4a	20	Mesolithic	Stone artifacts (Volkov et al., 2007)	Soil I	[A]	127–135
					[AB]	135–142
Layer 5	80	16,400 ± 165 BP (IEMEG-1414)	Radiocarbon dating		[C]	>142

[a] Maximal thickness within the pit.
[b] Position of described profile is marked by arrow on the Fig. 2.
[c] Horizons are marked according to classification of Shishov et al. (2004).

4.3. *Soil morphology*

The profile on the southern wall is subdivided into three parts, the upper borders of which coincide with the upper borders of humus horizons. The following buried soils are distinguished: Soil I is lower 127 cm, Soil II at the depth of 76–127 cm, and contemporary Soil III at 0–76 cm (Table 1). Effervescence of the fine earth after adding 10% HCl is observed from the depth of 5 cm.

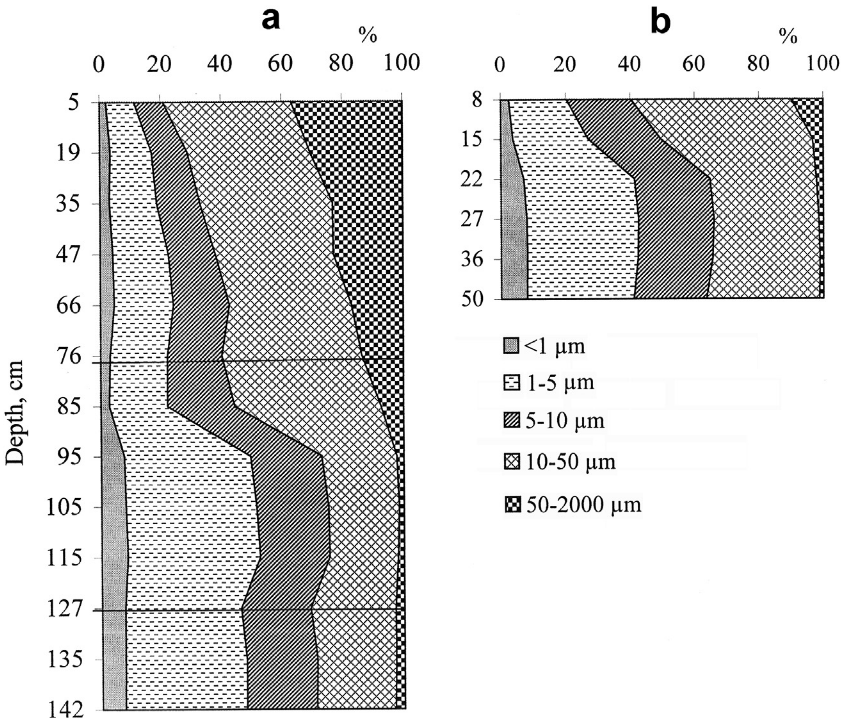

Fig. 3. Particle size distribution in the soils of rock shelter Svetly (a) and surrounding surface soils (b). % of fine earth mass, diameter of particles. Lines indicate upper boundary of Soil I and Soil II.

4.4. Soil texture

The deposits can be subdivided into three parts depending on soil texture (Fig. 3). In the upper part (above 76 cm) concentration of clay (<1 μm) is negligible (2.1–4.6% of the total fine earth mass), the percent of sand (50–2000 μm) are the highest among all deposits (36.8–17.2%) and gradually decreases from top to down. In the middle, intermediate, part (76–95 cm) the ratio of sand decreases, together with the clay ratio, while the amount of coarse silt (10–50 μm) medium silt (5–10 μm) and fine silt (1–5 μm) grows smaller. Close to the lower part, at the depth below 95 cm, the content of fine silt increases two fold reaching 38.3–43.7%, but the amount of coarse silt is 22.7–23.4%, and the ratio of sand becomes 3–5 times smaller (1.5–2.9%). In this part silt prevails (1–50 μm) and mostly consist of fine silt. Total percent of silt is 89.4–90.4%. The upper part of the deposits is represented by silt loam, and the middle and lower parts by silt. Surface soils of the adjacent sites are considerably heavier than in the surface soil of the excavation plot (Fig. 3), represented by silt.

4.5. Soil chemical properties

Soils are alkaline and strongly alkaline (Table 2). pH values are much higher than in surface soils of the neighboring sites. In soils beyond the excavation area, litter and humus horizons are acidic and sub-acidic (pH = 5.23–5.68). Down profile, the acidity drastically drops and becomes alkaline (pH = 7.62) at the depth of 26 cm in Rendzic Leptosols and decreases more gradually to 6.92 at 40 cm deep in Calcaric Cambisols. Unlike in the adjacent surface soils, carbonate leaching in the rock shelter soils does not occur. There can be different reasons for that: the inclusion of mondmilch in the overlying deposits, the approximate position of the discussed profile at the drop line, or a relatively young age of the deposits caused by surface renewal.

Table 2
Physicochemical characteristics of soils of the rock shelter Svetly, south wall of pit.

Horizon		Depth, cm	pH_{H_2O}	P_2O_5, mg/kg	SO_4^{2-}, mg/g	TOC[a], %	C_{ha}[a], % of TOC	C_{fa}[a], % of TOC	C_{ha}:C_{fa}	Ec[a], mg/ml
Soil III	AY1	0–5	–	–	–	–	–	–	–	–
	AY2	5–19	8.08	22.1	1.14	7.32	37.9	16.2	2.34	10.4
	RY1	19–35	8.35	23.8	0.82	3.42	26.6	19.5	1.36	9.5
	RY2	35–47	8.48	18.0	1.07	3.13	29.5	16.5	1.79	15.3
	RY3	47–66	8.50	28.0	0.80	2.15	27.2	19.1	1.42	10.2
	RY4	66–76	8.43	17.2	1.03	2.84	33.2	17.0	1.95	16.5
Soil II	[AU1]	76–85	8.60	10.2	1.08	4.74	50.9	13.4	3.79	15.7
	[AU2]	85–95	8.56	8.5	0.58	5.27	46.5	13.2	3.53	18.4
	$[B_t]$	95–105	8.54	7.6	0.43	1.16	46.4	20.9	2.23	15.4
	$[B_m]$	105–115	8.68	6.8	0.42	1.02	42.3	19.4	2.18	14.7
	$[B_t]$	115–127	8.39	6.5	0.42	1.05	42.3	15.4	2.75	12.8
Soil I	[A]	127–135	8.52	6.8	0.52	1.57	40.9	11.8	3.46	17.5
	[AB]	135–142	8.62	8.7	0.44	0.90	34.1	16.6	2.05	11.3
	[C]	142–152	8.72	7.1	0.38	0.39	10.0	37.1	0.27	5.5

[a] TOC – total organic carbon, C_{ha} – carbon of humic acids, C_{fa} – carbon of fulvic acids. Ec, mg/ml – optical density of humic acid extracts, 465 nm.

The amount of available phosphates and sulphates is low. This is explained by the formation of poorly soluble in the alkaline solutions phosphorous compounds. Both phosphorus and sulphur are biogenic elements with the accumulative type of profile distribution. In buried soils and adjacent surface soils, their content decreases in deeper layers of a profile. In Soil III, their content varies, which also reflects a stage-by-stage formation of deposits within Soil III and the presence of unclear buried horizons.

The maximal values of organic carbon profile distributions correspond to morphologically defined humus horizons. The humus content is known to decrease in diagenesis, and therefore buried soils were more rich in organic carbon while actively functioning.

Group composition of humus (Cha:Cfa) and spectral properties of humic acids remain steady in diagenesis and reflect conditions of soil formation (Dergacheva, 1997). The values of the Cha:Cfa ratio (ratio of carbon of humic and fulvic acids) in the excavation soil do not have quantitative analogs among contemporary soils of the region and soddy calcareous soils of the Middle and Southern Urals (Firsova, 1969; Firsova and Dergacheva, 1972) (Table 2). The change within the soil profiles is typical for the corresponding genetic soil type. Therefore in our further analysis, we focus our attention on the profile change of Cha:Cfa and the spectral properties of humic acids. Optical density values have been compared to the data from the literature on soils with different formation conditions (Kononova, 1963; Dergacheva, 1972).

In Soil III (0–76 cm), the Cha:Cfa ratio reaches its maximum in the contemporary humus horizon (2.34), deeper it sharply falls to 1.36–1.95 and becomes the lowest among all deposits except for the layer below 142 cm (Table 2). The sum of humic acids (HA) and Cha:Cfa ratio have irregular lateral variations (Fig. 4), and the general proportion of fulvic acids (FA) varies insignificantly. The optical density of humic acid's extracts are characteristic of southern taiga forest soils (soddy-podzolic and gray forest soils), except for the higher values at the depth of 35–47 and 66–76 cm (Table 2), approaching those for typical and leached chernozems.

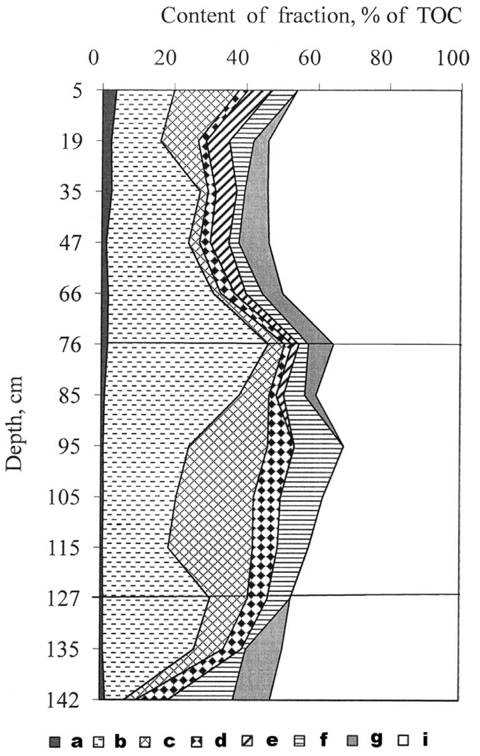

Fig. 4. The rock shelter Svetly: Humus composition of soils, % of total organic carbon (TOC). Fraction of humic acids: a. HA-1 (bounded with sesquioxide), b HA-2 (bounded with calcium), c. HA-3 (firmly bounded with minerals). Fractions of fulvic acids: d. “Free” fulvic acids, e. FA-1, f. FA-2, g. FA-3 (firmly bounded with minerals), i. Non-hydrolized humus rest. Lines indicate upper boundary of Soil I and Soil II.

Compositionally, Soil II is subdivided into two layers: upper, 76–95 cm deep within humus horizon, and lower 95–127 cm deep. In the dark-humus horizons the highest values among all investigated deposits were revealed for the next characteristics: TOC content, HA sums (46.5–50.9% from TOC), HA-2 fractions (44.6–37.3%), Cha:Cfa values (3.79–3.53) and HA optic densities (Table 2, Fig. 4). The figures describing Cha:Cfa (2.23–2.75), HA sums (42.3–46.4%) and HA optical densities of the lower layer are smaller than those in the upper layer, but are still high compared to other deposits. Optic density of humic acid extracts in humus horizon are close to those in modern typical chernozems and dark-gray forest soils and to dark-gray and gray forest soils in illuvial horizons (forest-steppe and southern taiga soils).

Moving downward in the Soil II profile, total HA content slightly decreases, total FA content reaches its maximum and the Cha:Cfa ratio its minimum in the middle part of the profile. Thus, the deepest horizon has humus composition similar to that of Soil I upper horizon.

In Soil I (127–152 cm), humus composition abruptly changes from two upper horizons towards the lower one: general FA content significantly rises, while general HA content, Cha:Cfa ratio and optic densities of HA decrease. Drastic transition in morphology, composition and properties of humus indicates contrasting conditions during the parent material and upper soil horizon formation. The upper part of humus horizon (127–135 cm) has high HA optical density (close to modern dark gray forest soils) and a high Cha:Cfa ratio (3.46), indicative of favorable conditions for humus formation during the late stage of this soil functioning.

4.6. Estimation of total organic matter amounts in fossil rodent mandibles

Thermogravimetric analysis has been used to detect organic compounds in vole mandibles. Prior to that, the material found in layers 2 and 5 was studied (Fig. 5). For layer 2, the spread of total organic matter (TOM) value has been assessed as approximately 10% (14.8–25.8), and for layer 5 as about 4% (15.8–19.4%). The spread of TOM value in mandible bones of contemporary hoofed lemmings and Siberian brown lemmings extracted from owl pellets is about 5%. Thus, TOM values for mandibles from layer 2 demonstrate high diversity in bone remains. Layer 5 has revealed synchronous accumulation of bone remains (Smirnov et al., 2009).

The spread of TOM values in mandibles from layer 3 reaches 8.4% (14.1–22.5%), i.e. Holocene findings from layer 3 contain a considerable amount of more ancient remains. Consequently, rodent bones from this layer cannot be used in radiocarbon dating.

Jaws from the upper and lower parts of layer 4 and layer 4a have been analysed separately. The TOM values in jaws from layer 4a is identical to those in jaws from the lower part of layer 4 ($t = 0.97$, $p >> 0.05$), therefore we have studied them together as “4 lp + 4a” (Fig. 5). In the upper part of layer 4, the TOM content of mandibles varies from 13.0 to 16.9%, i.e. the spread of values is 3.9%. In the lower part of this layer and in layer 4a, the spread of values in 20 samples is about 5%. The two remaining jaws (*Arvicola terrestris* and *Myodes glareolus*) from the lower part of layer 4 are characterized by a relatively high TOM content (21.9 and 21.5%, respectively), approaching the figures for layers 2 and 3. Thus, most bones in layers 4 and 4a are located “in situ” and for the layer in general the amount of chronologically foreign remains is not high (about 6%).

To analyse layer 5 jaws, only five mandibles have been studied (Smirnov et al., 2009), which appears to be insufficient. The spread

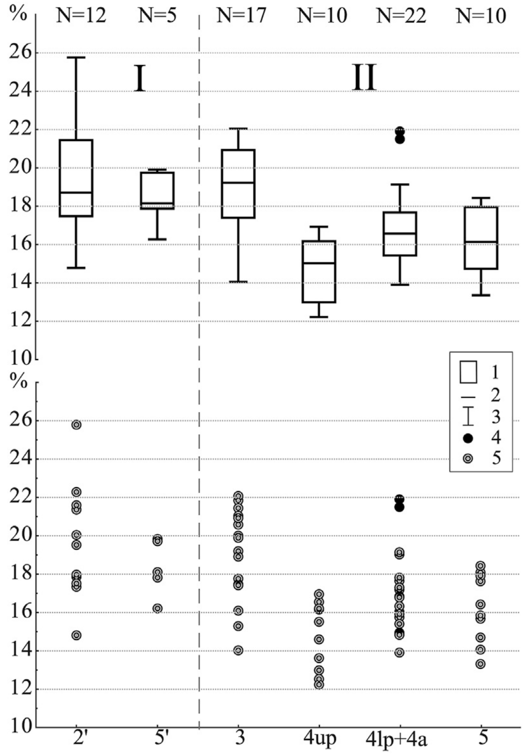

Fig. 5. The rock shelter Svetly: Total organic matter content in vole lower jaws from layers 2–5. I. Data of Smirnov et al. (2009) for layers 2 and 5. II. Own data for layers 3–5. 1. 25–75%. 2. Median. 3. Non-Outlier Range. 4. Outliers. 5. Individual values.

of TOM values in mandibles has been assessed as 5% (13.4–18.4%), giving evidence for chronological homogeneity of bones. These data are somewhat different from the data acquired for this layer before. The reason might be that they have been produced by different equipment. In general, however, our data corroborate the earlier conclusions of chronological homogeneity of layer 5 remains.

4.7. Small mammals

Osteological material in all the layers is represented by fish, amphibian, reptile, bird and mammal remains. Mammal remains prevail, and most of them are small organisms (Insectivora, Chiroptera, Lagomorpha, Rodentia), predominantly rodents (Table 3).

Layer 1 contains scarce osteological material: isolated bones of birds, small (*Cricetus cricetus*, *Arvicola terrestris*, *Talpa europea*) and large mammals. All these species are found in the vicinity of the rock shelter at present.

In layer 2, the community is dominated by *Microtus gregalis* (17.1%), *Dicrostonyx* sp. (16.0%), *Lagurus lagurus* (13.5%), *M. oecomomus* (12.0%), and *Myodes glareolus* and *M. rutilus* (altogether 12.4%). Numerous insectivore remains have been found. Mole bones and teeth abound. This layer species assemblage structure is characterised by a high percent of tundra and steppe species, which makes it similar to the late Pleistocene small mammal assemblage from layer 5 (Fig. 6) and from different localities of the Urals and Russian Plain (Smirnov, 1993; Markova and Puzachenko, 2007; Markova et al., 2008). However, unlike those mammal assemblages, the number of forest species is large. The layer has been dated as Late-Holocene. Thus, high percentages of *Myodes* voles are natural. The proportion of *Dicrostonyx* sp., *Lagurus lagurus* and *Cricetulus migratorius* remains in the Younger Dryas (DR-3) and Early Holocene (PB-BO) faunas of the Urals does not exceed 5% (Smirnov, 1993; Fadeeva and Smirnov, 2008). Thus, the explanation of high ratios of steppe and tundra species in the fauna of layer 2 can be that in the process of sedimentation, original Holocene material was intermixed with more ancient material.

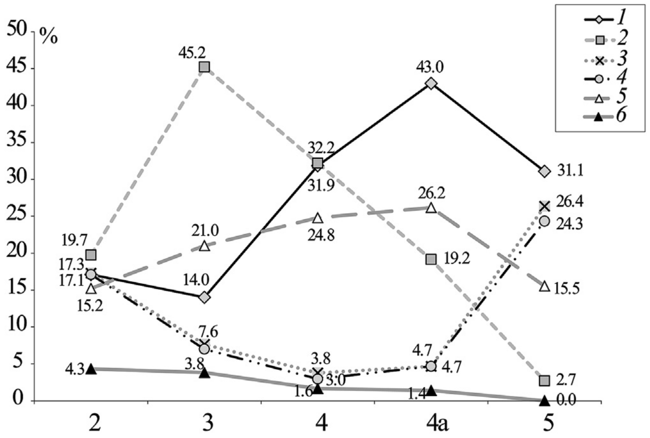

Fig. 6. The rock shelter Svetly: ranging of small mammals according to their habitat preferences and dynamics of their habitat group percentages from layer 2 to layer 5. 1. *Microtus gregalis*. 2. Forest. 3. Steppe. 4. Tundra. 5. Intrazonal Around-water. 6. Intrazonal Meadow.

Table 3
The Rock shelter Svetly, small mammals: species composition and a number of remains (NISP/MNI).

Taxon	Layers				
	2	3	4	4a	5
Insectivora	number of remains				
Sorex sp.	45	29	33	32	16
Neomys fodiens	2				
Talpa sp.	55	1	12		
Total of *Insectivora*:	102	30	45	32	16
Chiroptera			9	4	
Lagomorpha & Rodentia	number of teeth				
Ochotona pusilla	33/4	6/2	22/4	2/1	13/3
Sciurus vulgaris	1/1	1/1	2/1		
Spermophilus sp. (large species)	5/2		2/1		2/1
Sicista sp.	27/8	51/14	125/50	11/4	
Apodemus sp.	3/1	1/1			
A. uralensis	2/1		6/2	1/1	
A. agrarius	5/3		1/1	2/1	
Cricetulus migratorius	22/7	4/2	8/3	1/1	24/8
Cricetus cricetus	8/3	3/1	38/9	1/1	
Myodes rufocanus	36/9	4/2	19/7	1/1	
M. glareolus (without m3)	117/34	34/13	41/11	9/5	3/2
M. rutilus (without m3)	100/25	53/14	178/45	60/14	2/1
M. ex gr. glareolus-rutilus (without m3)	23/7	18/11	30/16	4/2	1/1
M. ex gr. glareolus-rutilus (m3)	23	9	19	9	
Lagurus lagurus	293/72	17/7	52/13	38/8	103/25
Eolagurus luteus	28/7	1/1	3/2		3/2
Dicrostonyx sp.	263/85	20/9	57/16	29/7	134/34
Lemmus sibiricus	17/6	3/2	7/2	4/3	2/2
Arvicola terrestris	84/17	43/11	165/35	30/8	1/1
Microtus sp.	742	175	1316	407	143
Microtus gregalis	92/91	24/22	205/194	95/92	46/46
M. oeconomus	70/64	23/22	119/116	50/48	22/22
M. agrestis	69/28	27/16	126/64	22/15	1/1
M. arvalis s.l.	17/17	5/5		2/1	
M. ex gr. arvalis-agrestis	15/15	1/1	17/17	2/2	
M. ex gr. arvalis-agrestis (juvenis)	26/26	1/1	5/5		
Total of *Ochotona & Rodentia*:	2111/533	521/157	2547/609	774/214	500/148
Total of small mammals:	2213	551	2601	810	515

The total number of small mammal bone remains in layer 3 is considerably smaller than in layer 2. *Myodes* voles (in total 24.2%), *Microtus gregalis* (14.0), *M. oeconomus* (14.0), *M. agrestis* (10.2) and *Sicista* sp. (8.9) dominate in the small mammal assemblage structure. Forest species remains are prevailing. A high proportion of tundra and steppe species (28.2%) most probably reflects chronologically heterogeneous remains. The layer has been dated to Mid-Holocene age. In the valley of the Serga river, Mid-Holocene fauna is represented in the locations of Bazhukovo III and Dyrovatyi Kamen' (Smirnov, 1993), also dominated by *Myodes* voles (in total about 30–40%), *Microtus agrestis* (12–16%) and *M. oeconomus* (6–11%). The proportion of *M. gregalis* was still fairly high (17–25%). This fauna from layer 3 can mostly be compared to the faunas from the locations above and is usable in paleogeographical reconstructions despite some inclusions of more ancient material. Such a structure of small mammal assemblage is indicative of a forest landscape during this layer formation.

Layers 4 and 4a are characterized by highly similar species composition and population structure. The predominant species among rodents are *Microtus gregalis* (in the layer 4–31.9%, in the layer 4a – 43.0%), *M. oeconomus* (19.0–22.4%) and *M. agrestis* (10.5–6.5%). The proportion of *Myodes* voles (11.8–9.8%) is also high, whereas the percent of tundra and steppe species is low (Fig. 6). The proportion of forest species considerably increases from layer 4a to layer 4, while the proportion of steppe and tundra species and *Microtus gregalis* becomes lower. This is evidence for wide spread of forest biotopes with simultaneous reduction in steppe biotopes. Nevertheless, taking into consideration a high proportion of the narrow-skulled vole in the fauna we can suggest that open landscapes were fairly common. The species composition and structure of small mammal assemblages in these layers can point at forest-steppe landscape proliferation in the vicinity of the rock-shelter.

All the bones in layer 5 have full Pleistocene preservation and nearly all of them are partially crumbled. The layer cut contains the least osteological material. Almost all the samples of small herbivorous mammal teeth come from tundra and steppe species: *Microtus gregalis* (31.1%), *Dicrostonyx* sp. (23.0), *Lagurus lagurus* (16.9), *Cricetulus migratorius* (5.4), *Ochotona pusilla* (2.0), *Eolagurus luteus* (1.4), *Lemmus sibiricus* (1.4) and *Spermophilus* sp. (0.7). The proportion of these species in the assemblage structure is 81.8%. The percent of *M. oeconomus* (14.9%) is also high. Such small mammal assemblage structures in the Urals are typical of Late Glacial faunas (Smirnov et al., 1990; Smirnov, 1993; Fadeeva and Smirnov, 2008). In general, this small mammal fauna serves as evidence for the spread of periglacial open areas.

4.8. Large mammals

In layer 1, there is little osteological material: isolated bone remains *Talpa europaea*, *Lepus timidus*, *Vulpes vulpes*, *Mustela nivalis*, *Martes* sp. and bone fragments of mustelids (Table 4). All bones have Late Holocene preservation. Accumulation in the layer cannot be characterized as systematic. In the lower part of the rock forming the shelter is a small grotto that served as a temporary hiding place for quadrupedal carnivores. All mammal species whose remains are found in the layer are common in the local fauna.

Table 4
The rock shelter Svetly, large mammals: species composition and a number of remains (NISP/MNI).

Taxon	Layers					
	1	2	3	4	4a	5
Talpa europaea	1/1			1/1		
Lepus timidus	12/2	4/2	9/3	10/2	1/1	18/2
Castor fiber		1/1		1/1		
Alopex lagopus						2/1
Vulpes vulpes	2/1	1/1	3/1	3/1		
Martes sp.		1/1		2/1		
Mustela nivalis	1/1					
Martes sp.	2/1		1/1			
Equus sp.						5/1
Coelodonta antiquitatis						3/1
Cervus elaphus						
Capreolus pygargus		1/1				
Alces alces		2/1				
Rangifer tarandus		5/1		2/1		26/3
Saiga tatarica						1/1
Mammal inlt.	5	3	6	3	4	46
Total (NISP/MNI):	23/6	18/8	19/4	22/7	5/1	101/9

In layer 2, there are bone remains of mustelids, *Lepus timidus*, *Castor fiber*, *Vulpes vulpes*, *Martes* sp, *Capreolus pygargus*, *Alces alces* and *Rangifer tarandus*. The degree of bone remains preservation is the same as in layer 1. *Rangifer tarandus* bones are probably from a more ancient layer, since they are somewhat different in colour and compact bone solidity, which is indicative of early stages of fossilization. They are also different from remains of the Late Pleistocene layer discussed further below. It is suggested that there existed a buried grotto in the rock slope above the shelter, where more ancient sediments were occasionally deposited.

Layer 2 is believed to be the lower part of layer 1 rich in mondmilch and containing some resedimented material. Therefore, we have united all large mammal bones from layers 1 and 2 except for *Rangifer tarandus* bones. The bone complex is dated to Late Holocene. All mammal species from the layers except for *Rangifer tarandus* inhabit the territory under discussion. *Rangifer tarandus* lived in the Middle Urals as recently as in the early 20th century.

Layer 3 has provided remains of mustelids, *Vulpes vulpes*, and especially many of *Lepus timidus*, but the total number of bone remains is considerably smaller than in layer 2.

Most bone remains of large mammals in layers 4 and 4a contain isolated bones of *Talpa europaea*, *Castor fiber*, *Lepus timidus*, *Vulpes vulpes*, *Martes* sp. and *Rangifer tarandus*. Large mammals in this layer are similar to the contemporary fauna. Judging by the Pleistocene preservation of *Rangifer tarandus* bones, they have been resedimented from layer 5.

In layer 5, we have discovered bone remains of a mammoth complex: Pleistocene *Lepus timidus*, *Alopex lagopus*, *Rangifer tarandus*, *Equus* sp., *Coelodonta antiquitatis*, *Saiga* sp. Between stone blocks on the bottom of the pit, five lumbar vertebrae joined with a sacrum of *Rangifer tarandus* have been found. All the bones have Pleistocene preservation and nearly all of them are partially crumbled. The layer displays the lowest concentration of osteological material from small mammals and the largest amount of large mammal bone remains.

5. Discussion

Soils on carbonate rocks are known to be intrazonal. Formed amongst zonal soils, they are different, but have a lot of similarities in various bioclimatic zones. The main soil forming processes in such soils are formation and accumulation of humus and leaching of carbonates. Fairly thick and well-structured humus horizons of buried Soils I and II have functioned as surface layers for quite a long time. These periods coincide with paleontological layers 4a and 3. Climate humidization could hardly be reflected in the profile properties due to a high base content in the soils, which impairs the eluvial process. The leaching degree of this soils is also difficult to assess since soil surface was periodically renewed and bured soil depth was not sufficient to be protected from processes in overlying soil. The most informative soil indicators reflecting paleoclimatic conditions were the morphological structure of the profiles, as well as the composition and properties of humus.

Soil textures reflect changes in sedimentation types. The clearest boundary lies as deep as 95 cm between the humus and illuvial horizons of Soil II. The particle-size distribution curve here is partly connected with soil processes, but abrupt and drastic change in the amount of fine and coarse silt and sand points at the presence of a primary lithogenic boundary. At the depth of 76 cm, at the upper boundary of the humus horizon of Soil II lies the second, less clear texture boundary.

Let us follow a parallel reconstruction of paleoenvironment by soil and paleotheriological methods. The Soil I profile has the simplest composition: the humus horizon is replaced by soil forming material via an intermediate horizon, no illuvial horizons are observed. The soil-forming material is represented by eolian sediments whose formation is possible in very dry climates. Humus properties of this layer reflect very cold conditions. The species composition of small and large mammals enable us to confidently speak of periglacial open space proliferation around the rock shelter in a relatively severe climate.

According to soil properties, formation of Soil I horizons happened at insufficient heat and moisture supplies (Table 2). The last period of this soil formation became quite warm. These soil horizons correspond to the layer with fossil fauna characteristic of a forest-steppe landscape. However, the upper part of this paleontological layer which demonstrates higher proportions of forest species and lower ratios of steppe and tundra species is found within the lower part of Soil II. We can guess that no drastic change in conditions happened in transition from Soil I to Soil II, but surface stabilization took some time when the humus horizon of Soil I was formed.

The Soil II profile is the most developed. It contains dark-humus and illuvial horizons. Its morphology is reminiscent of that of modern dark-gray forest soils common in the forest-steppe (Skeletic Luvic Rendzic Phaezems, in agreement to “IUSS Working Group WRB, 2014”). Under the humus horizon, there is a boundary in texture coinciding with the boundary between paleontological layers 4 and 3. It is highly probable that the heterogeneous coloring of the upper B-horizons (brown with light gray spots) inherited from the ancient humus horizon. In general, Soil II is formed on heterogeneous deposits and is polygenetic.

Humus composition and properties indicate that the early period (layer 4) of Soil II functioning was humid and warm. The conditions for the Soil II humus horizon formation (layer 3) were highly favorable, warmer than elsewhere in the studied sediments even nowadays and less humid than in early period. According to a numerous paleosol data, chernozem soils and soils with highly humified horizons were formed in Mid-Holocene within the contemporary forest zone (Aleksandrovskiy, 2008). Thus, a peculiar humus composition having no analogous among modern soils is described for the relict Mid-Holocene dark colored horizon of calcareous soil (Prokashev, 2012) and some cave deposits (Dergacheva, 1997). Small mammal population structure points at a forest landscape around the rock shelter in the late period of Soil II functioning.

Morphological and chemical characteristics of Soil III demonstrate that the general direction of humus formation turned towards cooling and humidization. Layered structure of this soil can be taken as evidence of gradual formation of these deposits; fluctuations of soil forming conditions are reflected in humus properties. Texture of Soil III is drastically different not only from the lower depth, but also from adjacent surface soils (Fig. 3). This is evidence for the mineralogical composition difference between the parent rocks in this location and the rocks on the adjacent sites and deep layers of the excavation, and that weathering of bedrock did not take place in situ. Chemical weathering can be very intensive. For example, in the Baltic taiga, on various ancient limestone constructions from 700 to 2500 years of age, the average rate of clay accumulation in young soils exceeds the average rate of clay accumulation on natural rock 1.5–10.8 times throughout the Holocene (Reintam and Lang, 1999). The vicinity of the rock shelter developed local conditions for accumulation of complex sediments distinct from the neighboring ones. This layer contains a mixture of Holocene and Late Pleistocene material. Chronologically heterogeneous fauna is linked to the complexity of deposit formation accompanied by periodically repeated deluvial processes and mondmilch displacement from vugs and cavities of the rock forming the shelter. This process began to take place in the late period of Soil II formation and was intensified in Soil III functioning (Late Holocene). However, we still cannot answer the question about the replacement of more ancient bone remains in these layers.

6. Conclusion

The joint analysis of stratigraphy, soil properties, mammal bone remains led us to identify the main stages in the evolution of natural conditions of Late Pleistocene and Holocene. In general, conditions underwent considerable transformation, which resulted in changes in type of soil formation and in the structure of the mammal community.

Cryoarid conditions with mammoth complex mammals dominated during Late Pleistocene layer accumulation. The period of formation of the deepest humus horizon was insufficiently moist and warm. The mammal assemblage structure of this layer corresponds to the spread of open landscapes along with forest biotope formation. The most favorable conditions in terms of heat and moisture supplies continued during formation of the middle soil in the Middle Holocene. By the late stage of this epoch, taiga fauna had formed. Later conditions were cooler. Chronological heterogeneity of bone remains in this layer is caused by a complex genesis of local sediments.

In general, fast and slow stages alternated in the process of sedimentation, whereas soil formation throughout the period of these deposits accumulation has remained synlithogenic. This resulted in polygenetic soil profiles. Common structure of deposits is indicative of the general trend in the evolution of natural conditions. The study of separate layers within the soil profiles largely reveals the concurrent nature of soil and fauna evolutions.

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