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Holocene erosion and deposition within a small catchment of the northeastern Borisoglebsk Upland (Central European Russia)

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Abstract. During the Holocene, interfluvial landscapes of European plains have experienced alternating periods of relative stability and significant shifts in climate, soil and geomorphological development. Assumed to be an arena of major transformation their evolutionary model is not entirely resolved yet. Based on lithostratigraphic, geomorphologic and soil survey, new results on the Holocene dynamics of fluvial and related processes including landscape stabilization phases for one of the gully catchments draining the Borisoglebsk Upland northeastern slope towards the Nero Lake are presented. Common absence of the early Holocene deposits can be explained by generally negative sediment budget of the catchment. Nevertheless, continuous erosion was not likely whether rare climatic extremes probably were the case. A series of middle Holocene dates obtained by analyzing total organic carbon from organic-accumulative layers of buried soils, lake gyttja and peats highlights strong evidence of the synchronous phase of landscape stabilization in both upper and lower parts of the Puzhbol catchment accompanied by active infilling of small erosion cuts in its middle part. The upper part of the Puzhbol Gully fan sediment shows clear evidence of synchronous accumulation of agrogenic colluvium and gully alluvium since XIIth Century on top of the lake terrace deposits.

1. Introduction

Nowadays it is widely accepted that actual interfluvial landscapes of vast European plains have been transformed during alternating periods of relative stability and significant up to catastrophic shifts in climate, soil and geomorphological evolution in the Holocene. Over the entire Northern Europe forested territories, there are numerous examples of Holocene landscape disturbance even before the onset of widespread agriculture.

For the landscape and climatic conditions of the Eastern European Plain fluvial processes are considered to be the leading geomorphic force during the Holocene. Various fluvial system components including gully erosion, river channel and floodplain processes are characterized by various degrees of resilience and relaxation times in response to external impacts of different duration, magnitude and frequency [1-5]. These characteristics of fluvial systems largely depend on their spatial scale, effective discharges and morphodynamics. For the latter two the scale factor can be somehow approximated by considering stream order within the entire network structure of the basin while morphodynamic one by longitudinal, cross-sectional profile shapes and channel planform for different order stream valleys [6-8].

Hillslope processes, on the other hand, including slope wash and mass wasting, reflect another significant agent of landscape instability. For an assessment of hillslope processes component, analysis of elementary slope morphology and morphometry [6-8] can be applied. Another productive approach is reconstructing sediment budgets for fluvial systems at different temporal and spatial scales [9-16]. It can involve an integration of the former two approaches with field investigation or numerical process modeling results for different landscape evolution scenarios [17-19]. Several attempts were made to reconstruct the Holocene sediment budgets for European fluvial systems – from small catchments up to the entire Rhine River Basin [20-24].

A number of studies has been devoted to the Holocene soil and gully erosion processes in France, Belgium, Germany, Poland [25-31] and Russia [32, 33]. Available sources of information on the past erosion and deposition cycles in small catchments include truncated soils, completely or partially infilled ephemeral gullies and/or typical gullies, colluvial deposits and lake or reservoir sediments. The highest temporal resolution may be derived from lacustrine sediments. Such geoarchives are characterized by continuous records and often store signals of landscape changes, surface dynamics and vegetation variability (including land use patterns for the historical period) in decadal to seasonal resolution [34-39]. However, quantification of small catchment sediment budget and, particularly, reconstructing soil erosion dynamics can be a very difficult task more likely to be successful in combination with analysis of colluvial deposits stored within the catchment [37-38]. Most detailed spatial resolution can be obtained by describing colluvial deposits in gullies or on footslopes in small (<0.1 km^2) catchments because these deposits can be clearly correlated with the adjacent hillslopes [40, 41]. Such investigations may also have an advantage of elucidating single extreme soil erosion events and putting those into historical context [42]. Moreover, integration of sedimentation record and surface dynamics reconstruction with available historical records on land use, weather and climate events, as well as additional archaeological and socio-economic evidence, may further improve understanding of the interaction between human impact and environment.

In Central European Russia significant human impact on erosion processes is suggested to have occurred since the 11th century AD and, more confidently, since the 14th–16th centuries [33], profoundly influencing erosion and sedimentation patterns in fluvial systems. One of the most widely observed results of anthropogenic environmental changes has been the generation of increased amount of sediments from human-accelerated soil and gully erosion and their subsequent transit through and deposition in different parts of fluvial systems [43]. Sediments and erosional features related to human activities in river catchments include colluvial deposits on footslopes and in dry valley bottoms, clastic deposits in river floodplains, rills and gullies on valley slopes [19]. The effects of historical land use changes on sediment fluxes in fluvial systems have been broadly discussed [25, 11, 44, 45].

Extensive attention on buried soils and paleopedology in the second half of the XX Century revealed a huge genetic and temporal variety of buried Holocene soils. A significant influence of Late Pleistocene lithogenesis, especially Late Valdai (Weichselian) cryogenic processes, was recognized on soil formation in Holocene [46, 47]. Numerous investigations focused on buried Holocene soils in forested marginal zone of Moscow (Saalian) glaciation at the Russian Plain. Those chronosequences of quite different soil types are usually associated with climate change during the Holocene [48-50]. Generalized sequence of monogenetic soils on loams is comprised of Bolling Gleyic Cryosols, Allered immature (Gleyic, Luvic) Phaeozems, Preboreal and Boreal immature and well-developed (Gleyic) Luvisols, Early Atlantic well-developed Retisols, Late Atlantic well-developed Luvic Phaeozems, Subboreal well-developed Retisols and undetermined set of Subatlantic Albic Luvisols with significant ubiquitous anthropogenic influence [47, 48, 51]. However, to designate an individual monogenetic soil type to the particular Holocene stage is quite intricate due to erasing and expanding trends of pedogenesis evolution in the changing environment but on the same parent material that finally formed polygenetic “welded” soil bodies [49].

This paper presents the new results of comprehensive investigations of the Holocene dynamics of fluvial and related processes including soil formation during landscape stabilization phases for one of the gully catchments draining the Borisoglebsk Upland northeastern slope towards the Nero Lake local baselevel.

2. Methods

Case site positions (figure 1a) were obtained by post-processing differential GNSS survey with Leica GX 1200 base-rover complex achieving horizontal error < ±2 cm and vertical < ±10 cm. Open-source remote sensing data including satellite imagery DigitalGlobe/GeoEye (Google Earth service), IRS and LANDSAT (Yandex Maps service) and global satellite radar DEMs (SRTM and ALOS 3D), small-scale land planning topographic maps and aerial photography obtained by UAV DJI Phantom III were used for the detailed geomorphological evaluation of the area and morphometric analysis (figure 1b). Textural and structural description of cores and pits on macro- and meso scales was supplemented by sampling with 5 to 10 cm interval, taking into account sedimentary and pedogenic features variability. Grain size analysis involved standard sample preparation [52], dry sieving separation of the coarser fractions (>100**μ**m) with sieve shaker Fritsch Analysette 3 PRO and laser diffractometry of the finer component (<100**μ**m) with Fritsch Analysette Nanotek 22. Organic and chemical carbon contents were estimated by successive weight loss on ignition at 500°C and 900°C [53]. Radiocarbon dating of organic-rich layers was carried out using AMS technique at the Laboratory of Radiocarbon Dating and Electronic Microscopy, Institute of Geography, Russian Academy of Sciences, and using LSC technique at the Kyiv Radiocarbon Laboratory, Institute of Environmental Geochemistry, National Academy of Science of Ukraine. The results are summarized in table 1.

3. Case study area

Northeastern Borisoglebsk Upland at elevations 140-214 m asl is dominated by hilly glacial landforms significantly reworked by fluvial incisions and even more extensively by local lacustrine accumulations in numerous linear and closed depressions [54, 55]. Generally classified as southern taiga region, modern landscapes are extensively influenced by human activity and, thus, have patched structure with a predominance of agricultural fields, secondary small-leaved forests and limited areas of coniferous forests and bogs. Active gullies and small valleys incise interfluves down to 15-25 m and commonly have V-shaped or trapezoidal cross-sections. The long profiles of such gullies with steps and convexities represent a certain potential for further incisions. Larger gully systems and small valleys usually have a series of smaller gully branches dissecting their steep slopes. Nero Lake represents the main local baselevel at 93.7 m asl. However, wide (1.0-2.5 km) lake terrace at 105-107 m asl presently disconnects most gullies from the lake. Instead, they form large fans overlapped on the terrace. According to [56], it was accumulated during the Late Valdai, and the terrace had isolated due to the Nero Lake level fall during the Late Valdai - Holocene transition.

The Puzhbol Gully catchment (figure 1a) occupies about 7.95 km^2 area on the eastern slope of the Poklony Hill and lower interfluvial steps down to the slope towards the Nero Lake terrace (105-107 m asl), which is partly covered by a large gully fan. The Puzhbol catchment has a complex topography and includes the main gully with one large left (Ivanovskaya) and two smaller right (West and East Cheremoshnik) tributaries (figure 2). The main gully is about 3 km long, has a curved planform with the general eastern direction and uneven stepped long profile with variable gradient 1-3% (figure 1b). The total elevation range between gully head and fan apex is about 50 m. Its maximum incision depth reaches 20-25 m, width changes from 20-30 to 250-270 m, cross-section profiles – from V-shaped in upper to U-shape in middle and trapezoidal in lower part (figure 2a,b). There are 1-2 terraces and embryonal floodplain along most of the Puzhbol Gully length and small year-round stream. Gully heads retreat is moderately active (about 0.5-1.0 m/a) thanks to increased hydrological connectivity of the catchment and peak discharges after the artificial drainage system construction in 1980s.

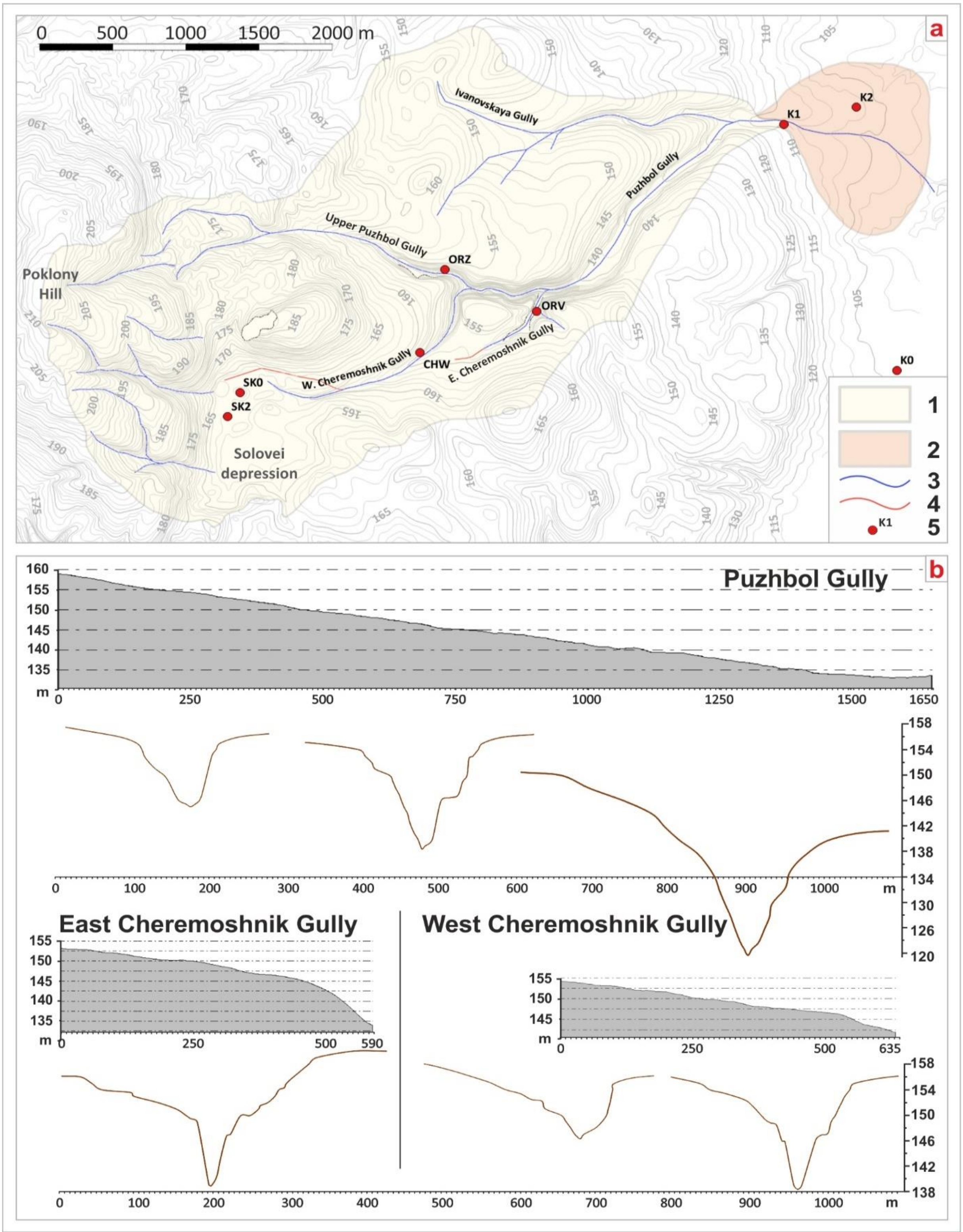

Figure 1. Morphological structure of the case study catchment area: a) detailed topography based on 1 : 10000 land planning maps (contour interval 1 m). 1 – Puzhbol Gully catchment, 2 – Puzhbol Gully fan, 3 – thalwegs, 4 – drainage ditches, 5 – positions of key sites. b) Cross-section and long profiles of the key gullies.

Figure 2. Puzhbol Gully perspective views from the UAV: a) middle part, facing downstream (note two narrower right tributaries – West and East Cheremoshnik gullies, the Nero Lake on the background); b) lower part, facing upstream (note the rapid downstream expansion of the gully banks and cross-section changes from U-shaped to trapezoidal); c) ground photo of the West Cheremoshnik Gully with a U-shaped cross-section, view upstream (note the erosional terrace and landslide cirque on the right bank).

Three smaller gully systems dissect the Poklony Hill eastern slope with remarkably higher thalweg gradients (up to 5%) and convex-undulating long profiles. They reach about 1 km in length and up to

40-45 m in elevation range, however, their activity is limited. The catchments are almost completely forested and disconnected from the upper parts of the Puzhbol Gully system by prominent fans in recently filled and artificially drained lake depressions. These drainage systems have increased hydrological and sediment connectivity between upslope gullies and the main gully system, hence accelerating the present gully head retreat and incision. Additional important impact on gully activity is exerted by beavers that create dams and ponds in bottoms of the Puzhbol, West and East Cheremoshnik gullies. Their periodical breaches cause local incisions while filling of ponds causes higher wetness of gully bank lower parts and destabilize slopes, promoting bank collapses and landslides.

4. Results

4.1. Puzhbol Gully

Outcrop in the left bank of the Puzhbol Gully (ORZ, figure 1a) exposes contrastingly stratified silty loams up to 3 m thick composed of four units with distinct erosion contacts (figure 3a). The upper brownish grey clayey silts (unit IV) has laminated low contrast texture representing agrogenic colluvium. Silty unit III with texture and color of higher contrast includes at least three beds with lenticular lamination and differentiated organic content (figure 3e). Enrichment with ferromanganese concretions and dispersed charcoal at the base of each bed (figure 3b) suggests their relation to a single wildfire event. Those beds are a set of slope sediments derived from the chronosequence of topsoils that developed upward the interfluvial slope. The date obtained on total organic carbon (5670±130 ^{14}C yrs BP, Tab. 1) for the basal layer of unit III allows to propose a series of local cycles of small-scale incisions and colluvium accumulation intermitted by short-time ($n*10^1$-$n*10^2$ yrs) surface stabilizations indicated by formation of immature soils during the second half of Holocene (since the Late Atlantic - Subboreal). Up to 1.5 m of contrast laminated dull yellowish grey silt loams (unit II, figure 3d) manifests the same specific structure of soil erosional cyclic colluvium with charcoal concentrations at the base, laminated topsoil material in the middle and laminated low contrast loamy matter of intermediate soil horizons at the top (figure 3c). Both common texture, stratigraphic position and ^{14}C age of overlying unit III allow considering unit II as a pedosediment derived from the well-developed Boreal-Atlantic Retisol that was formed upslope. Underlying contrast mottled silty clay loams (unit I, figure 3c) represent the upper part of redeposited Late Pleistocene lacustrine sediments [55] with a set of dissipated pedofeatures that could be regarded as a regional analog of cover beds in Central Europe [57, 58]. Probable short-transit redeposition of lacustrine sediments could have been associated with the start of incision occurred during the transition from the Late Valdai to the early Holocene.

4.2. West Cheremoshnik Gully

Sections CHW1 and CHW2 (figure 4) are two natural exposures located approximately 30 m from each other in partially collapsed left bank of the West Cheremoshnik Gully. Two main units are separated by sharp erosional boundary. The lower (unit I) is lighter in color and has sandier texture (interbedded silty sands and loams). In CHW1 a prominent wedge-shaped feature (approximately 1 m high and 0.3 m wide) filled by finer and very mottled loams (figure 4a) penetrates unit I. Surrounding beds are pulled up along the wedge sides suggesting certain ice content during its development (so-called ground-ice wedges) and formation under conditions of continuous permafrost. Top of the layer as of the wedge was eroded with sharp erosional contact inclined towards the gully head. The boundary is emphasised by light sand incorporating charcoal-rich lens (figure 4b) dated to 5450±80 ^{14}C yrs BP (Ki-19670). On the other hand, overlying laminated yellowish grey unit II signifies alternations of silty sands and sandy loams. There is some evidence of soil formation (darker and denser layer, apparently with higher organic content at depth 65-85 cm) buried by rather homogenous material lacking lamination (figure 4a). In contrast, in CHW2 (figure 4c) one cannot observe prominent cryogenic deformations but buried soil horizon at depth of 110-130 cm is much more evident.

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Table 1. Collected Holocene ^{14}C data of the key site.

№	section	lab code	H_{abs}, m	depth, cm	location	description	dated material	^{14}C yrs BP
1	K2	ЛУ-9325	106,5	125-135	Puzhbol Gully fan	gyttja	TOC	610±70
2	K0	SOAN-3002	104,7	<100	colluvial fan at the Nero Lake terrace	peat overlaid by thin agrogenic colluvium	HA	830±20
3	ORV	IGAN-2654	146.8	140-150	East Cheremoshnik Gully	Buried humic horizon	HA	2630±90
4	SK2	Ki-19676	161.8	096-102	Solovei depression	peat	TOC	5190±60
5	ChW1	Ki-19670	153.8	100-105	West Cheremoshnik Gully	charcoal-rich colluvial/alluvial loam	TOC	5450±80
6	SK0	IGAN-2535	164	65	Solovei depression	gyttja	HA	5600±140
7	ORZ	LU-7819	151.6	170-190	Puzhbol Gully, upper reaches	charcoal-rich colluvial loam	TOC	5670±130
8	K1	LU-9324	111,5	143-149	Puzhbol Gully fan	gyttja	TOC	5720±190
9	ORV	Ki-16679	146.8	180-210	East Cheremoshnik Gully	coarse-debris lens with plant rests	Plant rs.	9870±120
10	K1	IGANAMS-6668	111.5	575-590	Puzhbol Gully fan	lacustrine sandy silts with disperse plant rests	Plant rs.	12310±30

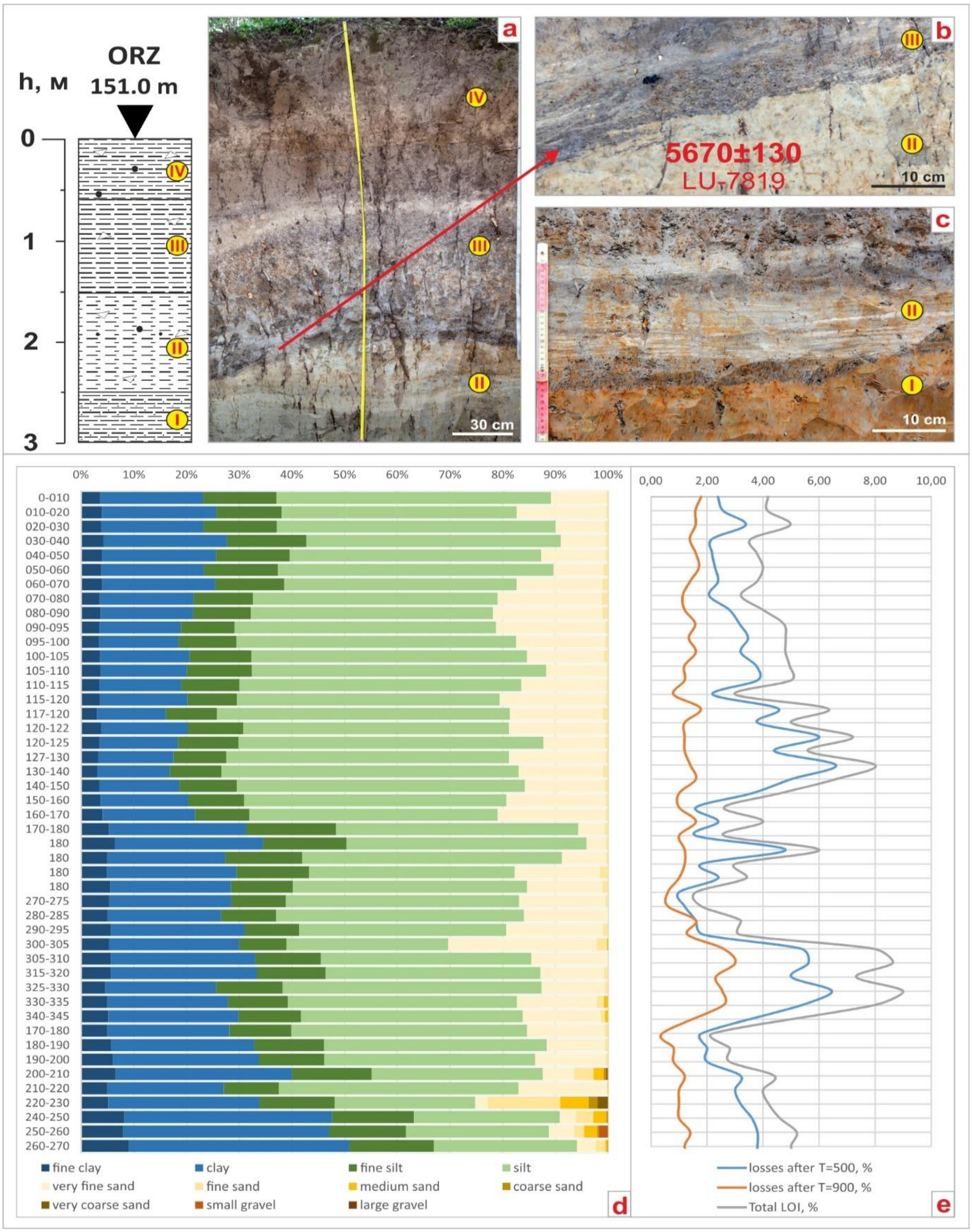

Figure 3. Upper part of the ORZ section on the left bank of the Puzhbol Gully: a) general view of the Holocene silty loam colluvium; b) ^{14}C dated basal layer of the Holocene colluvium (unit III); c) contrastingly stratified silt loam (unit II): natural soil erosion cyclic colluvium underlain by contrast mottled cover beds (unit I); d) results of grain size analysis and e) loss on ignition.

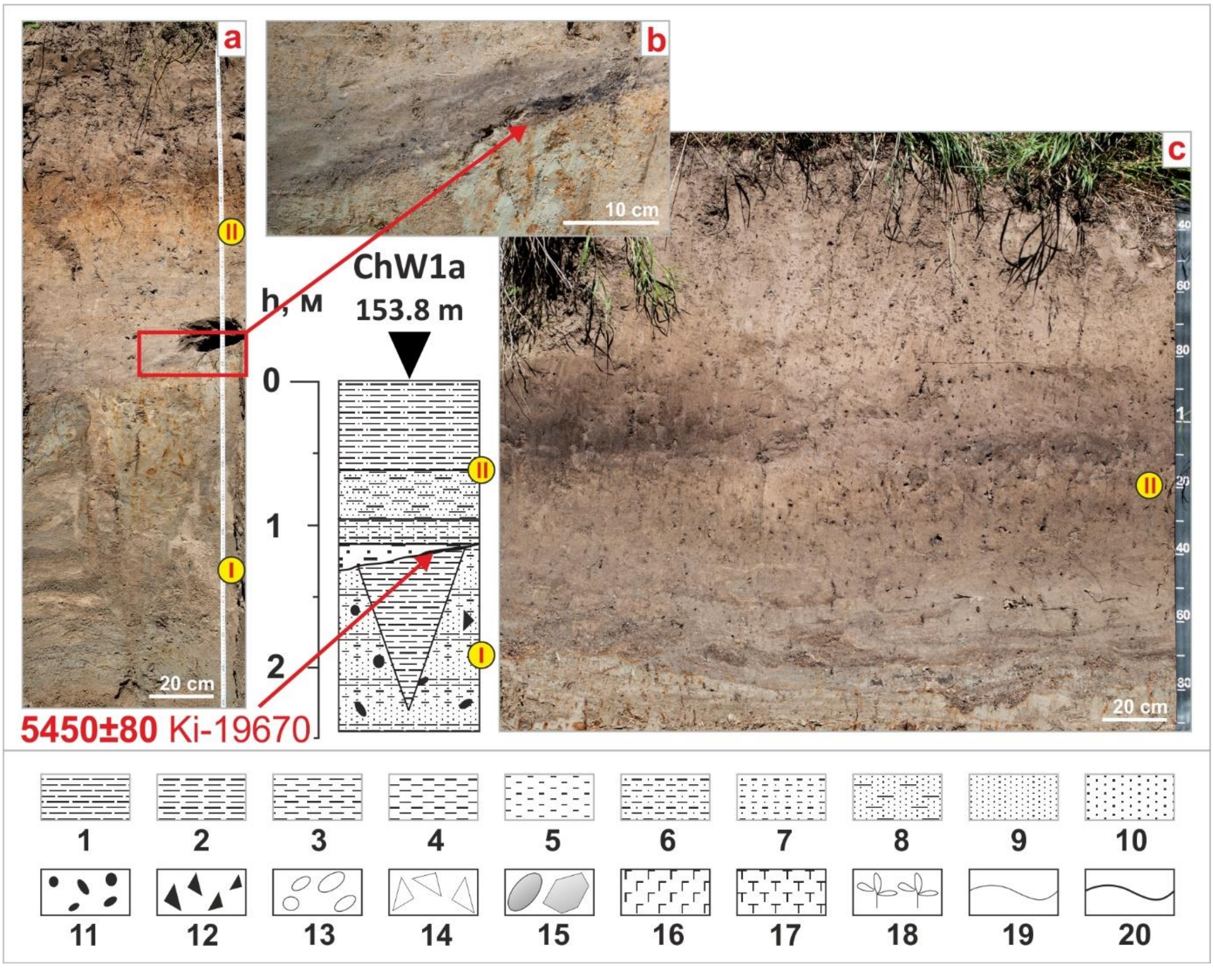

Figure 4. Cryogenic, erosional and pedosedimentary features observed on the left bank of the West Cheremoshnik Gully. Section CHW1: a) general view of the loam-filled wedge in Late Valdai clayey sands truncated by erosional boundary; b) sandy lens with localized accumulation of organic-rich material at the right margin. c) Section CHW2 (about 30 m downstream) with similar general stratigraphy but evidence of paleosol formation at depths of 110-130 cm. 1 – clay, 2 – silt, 3 – heavy loam, 4 – loam, 5 – light loam, 6 – sandy loam, 7 – loamy sand, 8 – silty sand, 9 – fine sand, 10 – medium to coarse sand, 11 – rounded gravel, 12 – angular gravel, 13 – rounded pebble, 14 - angular pebble, 15 – boulders, 16 – gyttja, 17 – peat, 18 – plant rests, 19 – stratigraphic boundaries, 20 – erosive contacts.

It can be suggested that unit I was formed during the cold period of Late Valdai periglacial conditions when polygonal ground-ice wedges formed in the area. The overlying laminated unit represents pre-agrogenic colluvium, most likely produced by wildfire-triggered erosion event, as can be suggested from the charcoal-rich lens at its base, hence having the same age and accumulated reasonably fast. For the topmost part of the sections, there is no certain information so far.

4.3. Solovei depression

Perfect example of longer-term sediment sinks is provided by cores SK1 and SK2 taken from the bottom of Solovei depression in the southern part of Puzhbol catchment (figure 5). It was occupied by a shallow lake until 1984 when it was drained through underground pipe system and open ditch towards the West Cheremoshnik Gully head. Of the 9.8 m long core SK2 only top 1.7 m is likely to represent the Holocene sequence. Underlying unclearly laminated light brownish grey silt loams with no organic matter (figure 7a,c) but well-developed plastic cryogenic deformations can be attributed to the Late Valdai periglacial environment [55]. Within the suggested Holocene interval of the core, several units can be distinguished.

The lower one (1.2-1.7 m) is represented by mottled (bright yellow, reddish and dark brown patches and lenses on a brownish grey background) silty clay loam with uneven wavy and inclined laminations (figure 5e). That can be interpreted as mixture of hillslope colluvium and gully fan material from the adjacent Poklony Hill eastern slope. Further up the core (1.0-1.2 m), it becomes darker and more uniform bearing traces of short-term embryonal soil formation. It is topped by 6 cm of peat dated to 5190±60 ^{14}C yrs BP (Ki-19676, figure 5d). Close age (5600±140 ^{14}C yrs BP) was obtained independently from gyttja at a depth of 0.6 m at the soil section SK0 in the lower part of depression bottom (IGAN-2535). Such prominent change of sedimentation regime clearly indicates stabilization at least within the part of the catchment directly connected to the Solovei depression with simultaneous increase of wetness. Over the span 0.6-0.9 m slightly sandy silty loam with mottled colors was deposited (figure 5c), most likely representing subareal colluvium affected by periodic waterlogging from the adjacent lake. Deposition of laminated organic-rich brownish grey silty loam (0.4-0.6 m) probably indicates temporary recurrence of the lacustrine environment (figure 5b). It is buried by a layer with abrupt increase of coarse clastic content, particularly some gravel impregnated into the loamy matrix (figure 5a). Coarse material is observed throughout the topsoil while the highest concentration is along the base of the layer. It can be attributed to the last period of increased gully activity on the Poklony hill eastern slope associated with human impact during the period when Poklony and Solovei villages existed.

4.4. Puzhbol Gully fan

Fan of the Puzhbol Gully system covers an area of at least 5 ha on the 105-107 m asl terrace. Core K1 at its apical part is situated on footslope of the former Nero Lake shoreline (figure 6a). Thick (~5 m) layer of mixed silty-sandy loams with organic inclusions and gravel (up to 3 cm) and intermittent lenticular laminations can only be interpreted as a footslope colluvial cover. Having obtained two dates from top (5720±190 ^{14}C yrs BP, LU-9324) of the layer and lacustrine sediments below (12310±30 ^{14}C yrs BP, $IGAN_{AMS}$-6668), it was possible to stratigraphically limit it between the Late Valdai and mid-Holocene. As regards the upper sediment unit overlying the upper date, topmost 0.9 m characterized by lighter color and sandy loam texture can be attributed to the intensive agricultural period and may result both from hillslope erosion and sediment export from the main gully. Darker, finer and denser material within 0.9-1.5 m is probably pre-agrogenic colluvium notably affected by soil formation.

Section K2 in the axial part of the fan (figure 6c) reveals rather simple structure with organic-rich deposits of the waterlogged terrace surface (1.2-1.5 m) overlain by interbedded sands with gravels to silty sands (0.3-1.2 m) representing typical gully fan sediment. That, in turn, is covered by about 0.3 m of agrogenic colluvium. Organic-rich horizon at the base of the gully fan deposits produced the age of 610±70 ^{14}C yrs BP, probably representing one of the phases of increased gully erosion activity associated with human impact on the landscape. It can be compared with the date earlier obtained by A.V. Rusakov from section K0 (figure 6b) on peat overlain by agrogenic colluvium at a depth less than 1 m – 830±20 ^{14}C yrs BP (SOAN-3002).

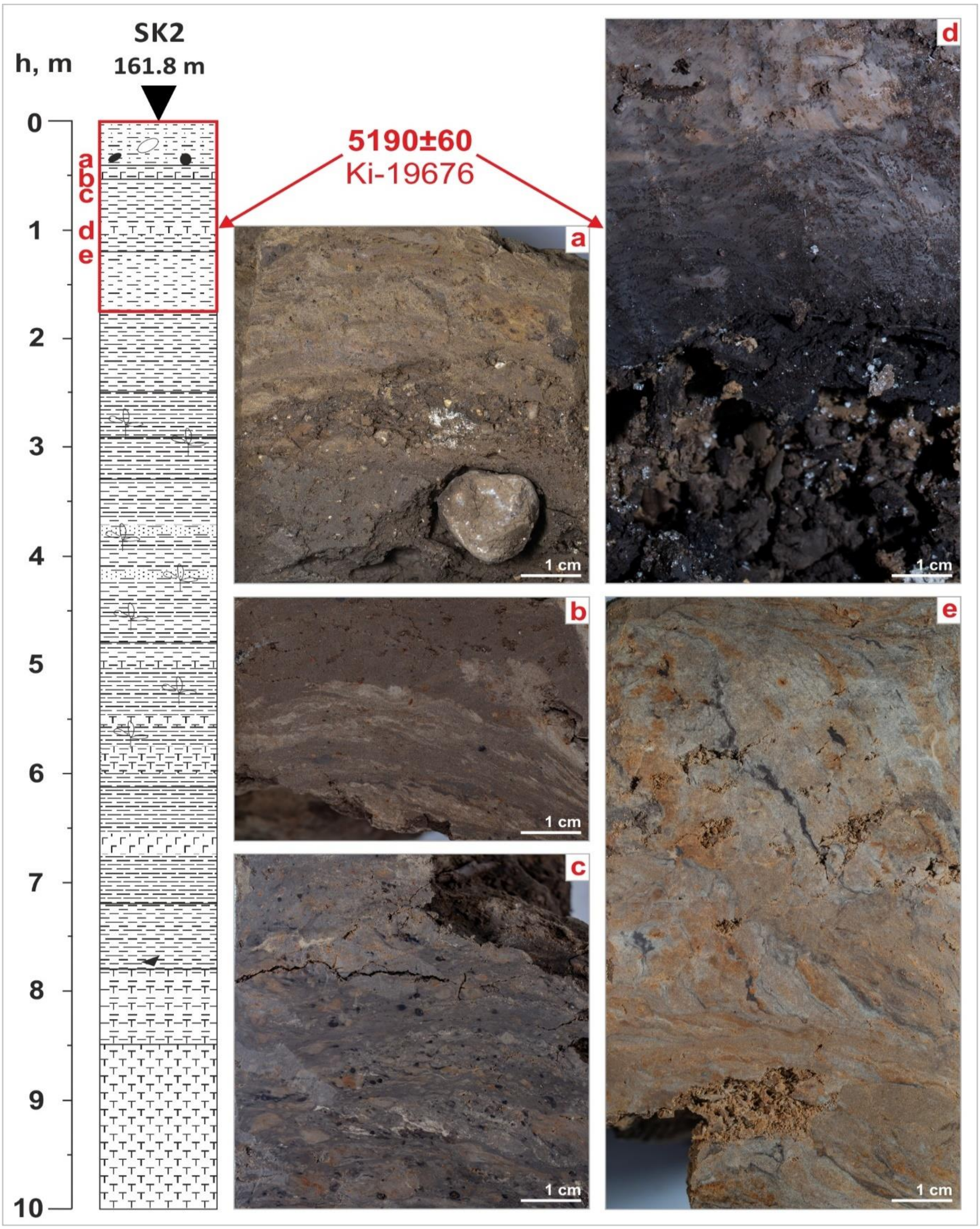

Figure 5. Selected pedolithofeatures of the core SK2: a) coarse clasts impregnated in sandy loam matrix (33-40 cm); b) organic-rich fine-laminated layer (50-55 cm); c) mottled laminated layer (60-70 cm); d) peat layer (94-100 cm); e) bright mottled unit with a set of non-conform contacts between wavy and inclined laminated beds (106-113 cm).

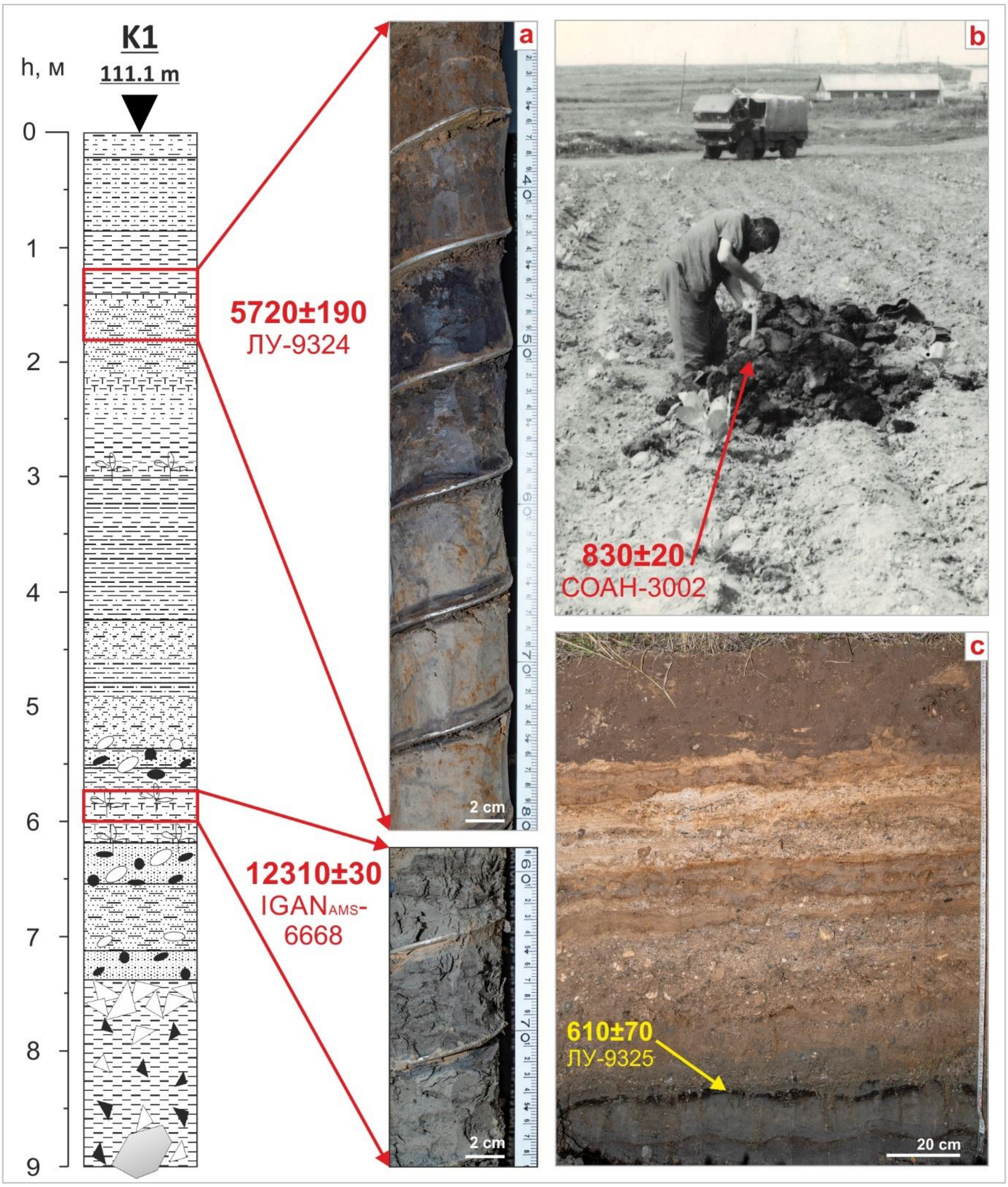

Figure 6. Investigations of the Puzhbol Gully system fan and underlying deposits: a) core K1 and magnified photos of its key dated parts; b) general view of section K0 by A.V. Rusakov (1980s) and associated age of the agrogenic colluvium base; c) section K2 and location of material sampled in order to date the base of the gully fan.

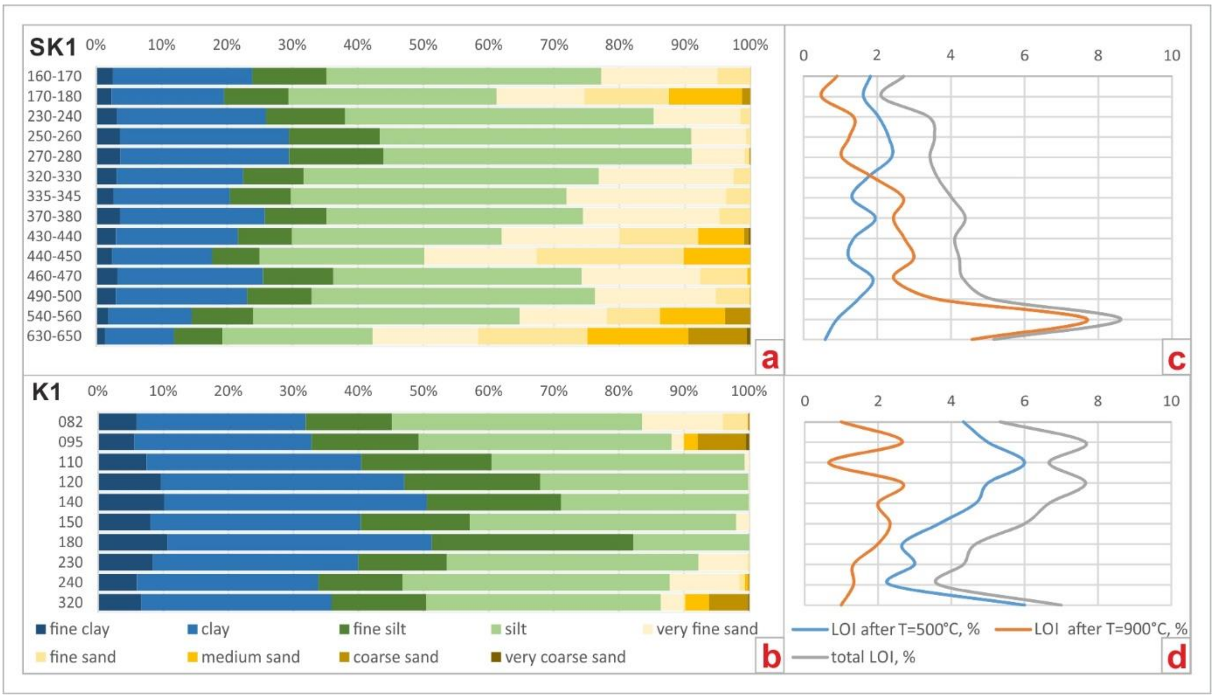

Figure 7. Results of grain size analysis (a, b) and loss on ignition (c, d) of two cores SK1 and K1.

5. Discussion

Detailed investigation of slope deposits within the Puzhbol Gully catchment discovered high textural variability of colluvial facies including both those produced by solifluction and slope wash under pre-Holocene periglacial conditions and the warmer Holocene colluvium formed solely by hillslope water erosion. The latter bears clear evidence of several pyrogenic events (layers rich in buried charcoal).

Previously published data [59, 54] allows suggesting that the beginning of the Late Valdai incision happened around 12570±440 ^{14}C yrs BP (IGAN-4048) followed by successive alluvial infill till the early Holocene (9870±120 ^{14}C yrs BP, Ki-16679). It is likely that general fluvial incision occurred in the entire Nero Lake basin following its level fall from 107-110 m to <95 m asl [56, 60]. Absence of soil remnants formed during the first half of the Holocene on eroded surface of the Late Valdai deposits and lack of even associated sedimentary sequences in several sections (ChW, ORV, ORZ) can be explained by generally negative sediment budget of the catchment. Nevertheless, continuous erosion was not likely whether rare climatic extremes, such as catastrophic millenia-scale rainfall reported for Western Europe in July 1342, or fire-induced erosion events [29, 42] could probably be the case. For the accumulative fan positions with opposing tendency of predominant process (cores K1), the same question of whether there existed a long-term continuous alluvial sedimentation, or it took place only during certain episodes associated with increased hillslope erosion activity can be posed. In the upper parts of the Puzhbol Gully catchment (core SK2), undefined loamy thickness of about 1 m does not show signs of distinct hiatuses in sedimentation, however, series of recurrent local geological non-conformities is evident. Clamped between the middle Holocene ^{14}C date and distinct lacustrine Late Valdai sediments, according to overall textural composition and organic matter content [55], those loams could be considered as the early to middle Holocene pedosediment unit and correlated with the mentioned above colluvial unit of close age at the Puzhbol fan.

Although with a limited number of dates available so far, there appears to be a period of time between approximately 5000 and 6000 ^{14}C yrs BP where dates from all the studied objects are present. For upper (Solovei depression) and lower (Puzhbol Gully fan) parts of the catchment such dates signify certain stabilization periods, while for the middle part (sections ORZ and CHW1-2 in eroded gully banks) - periods of change of local evolution trend from incision to infill. Does it represent any specific relationship, or just a pure coincidence, remains a question for further research.

Upper part of the Puzhbol Gully system fan sediment bears clear evidence of synchronous formation of agrogenic colluvium (started not earlier than XIIth Century AD) and gully alluvium more than 1 m thick (basal layer dated to 610±70 ^{14}C yrs BP) covering the lake terrace deposits. It is in accordance with the reported human impact on erosion processes in Central European Russia that became significant since the 11th century AD, and, more confidently, since the 14th–16th centuries [33].

6. Conclusions

Natural exposures in banks of active gullies illustrate the facial variability of the Holocene deposits including infilled and buried gully incisions with lenses of gully alluvium and polycyclic pedolithosediments produced by natural (most likely, wildfire-induced) and/or agrogenic hillslope water erosion deposits. Surface geology of closed depressions within the interfluvial areas of the catchment is dominated by lake and slope deposits while soil formation and erosion in those has been rather limited during the entire Holocene to a series of small local slope and fluvial incision-infill events.

A set of middle Holocene dates (between 5100-5700 ^{14}C yrs BP), obtained by analyzing total organic carbon from organic-accumulative layers of buried soils, fragments of relic humic horizons of the modern surface soils as well as some lake gyttja and peat layers, represents strong evidence of the synchronous phase of landscape stabilization in both upper and lower parts of the Puzhbol catchment accompanied by active infilling of small erosion cuts in its middle part.

Acknowledgments

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