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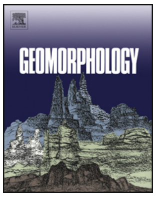

Holocene soil erosion in Eastern Europe-land use and/or climate controlled? The example of a catchment at the Giant Chalcolithic settlement at Maidanetske, central Ukraine

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ABSTRACT

The Younger Quaternary erosion history was reconstructed in a catchment close to the Chalcolithic giant settlement Maidanetske, central Ukraine based on dated sediment sequences. Four trenches and a long percussion drill-core were analyzed in a valley grading from a Loess covered plateau towards the Talianky River. The sediments were dated by a combination of radiocarbon dating, optical stimulated luminescence (OSL) and embedded artifacts. Although there is some weakness of numerical dating so far, a non-coincidence between phases of soil erosion and the local and regional settlement history over long periods of the Holocene is indicated. This, viewed in the light of the geographical setting of the site in the climate sensitive forest-steppe borderland, suggests climatically driven erosion processes. The detected phases of erosion coincide with global (cal 27.6 ± 1.3 kyrs BP, 12.0 ± 0.4 kyrs BP), northern hemispheric (cal 8.5 ± 0.3 kyrs BP), Mediterranean (cal 3.93 ± 0.1 kyrs BP) as well as western to central European (2700 to 2000 cal BP) climate anomalies. Increased occurrences of heavy precipitation events, probably during phases of a weakened vegetation cover, could explain the observed record. Investigations at additional sites in Eastern Europe are needed to verify the representativeness of the presented record from central Ukraine at a regional level.

The composition of the sediments indicates changes of the slope-channel connectivity during the deposition history. Whereas the glacial to early Holocene and modern times sediments were derived from the whole catchment area, during the mid- to late-Holocene a tendency to lower slope storage of colluvial material and valley incision is indicated.

1. Introduction

Based on numerous geomorphological investigations in southern and central Europe soil erosion has been identified as one of the most serious impacts of humanity on the environment (e.g. Van Andel et al., 1990; Bork and Lang, 2003; Butzer, 2005; Dotterweich, 2008; Thornes, 2009; Dreibrodt et al., 2010a). Within the forest-steppe borderland of the central Ukraine there is a lack of data about the younger Quaternary and Holocene geomorphological processes at the slope scale. In the neighboring region of western Russia, Belayev et al. (2004) report phases of gully activity in small catchments at ca. cal BP 1090–970 and 880–570 without giving information about the land use history of the catchment area. Similarly, without information about Holocene land use history, Belayev et al. (2005) report gully activity at two additional sites in western Russia at ca. cal BP 8950–8480, 4100–3400, 3140–2870, 2310–2170, 1590–1031, and 640–490. Panin et al. (2009) found a pre-Holocene origin of 15 out of 19 studied gully systems in western

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Russia. These authors detected longer phases of erosion and gully activity from ca. 4800 to 2800 cal BP and 1200 cal BP until today. Shorter periods of intensive erosion were reconstructed for the intervals ca. 4800–4600, 3900–3600, 3800–2800, 2300–2100, 1600–1800, 1000–800, and 700–500 cal BP. These phases of erosion were explained mainly by climate variability. Sycheva (2006) and Sycheva et al. (2003) report a quasi-cyclicity of erosion and soil formation at the Russian part of the East European Plain based on a compilation of radiocarbon dates from soils and slope deposits. The observed cyclicity is ascribed to periodical climatic changes throughout the Holocene. Intervals of intensive soil erosion were dated to ca. 10,200–9500, 8100–7700, 6600–6300, 4700–4200, 2700–2300, and 950–450 cal BP. Whereas researchers from southern and central Europe underline the role of agricultural land use on soil erosion histories of the respective landscapes, eastern European scholars rather see climatic variability and their effects on vegetation as the main drivers of Holocene relief change.

According to intensive archaeological investigations in the very recent past, we do have an outstanding diachronous record of the local and regional settlement and land use history at the research area (Table 2). Here we compare this record with the Younger Quaternary geomorphic history stored in the record of sediments and soils in a valley close to a Giant prehistoric site. A test of possible linkages between prehistoric land use and erosion is a focus of this paper. (See Table 3.)

2. Material and methods

2.1. The research site

The investigated catchment area is located at Majdanetskoe, district of Talne, central Ukraine (48°48′N, 30°38′E) (Fig. 1). The close by archaeological site of Maidanestske is a giant settlement of the Tripyllia C1-period (Müller et al., 2013, 2016; Hofmann et al., 2019). Archaeological sites of this type are unique because of their extremely large dimensions. At Maidanetske, on an area of 200 ha approximately 3000 houses arranged in a series of oval structures around an unbuilt central space were inhabited approximately from 3990 to 3640 BCE (e.g. Müller et al., 2016; Ohlrau, 2020; Pickartz et al., 2019). Surveys of the many potshards present on the recent surface, magnetic surveys, excavations and exhaustive dating campaigns revealed that about 1500 houses were inhabited contemporaneously by probably >10,000 people (Ohlrau, 2020, Pickartz et al., 2019). The climate in the region is humid continental (Dfb) today, with hot summers and cold wet winters. The potential natural vegetation of the region belongs to the climate sensitive forest-steppe transition zone. Where there is no agricultural land use, deciduous forests are present in the landscape today. A mosaic of loess-covered plateaus dissected by small valleys characterizes the recent topography. The surface soils are classified as particularly thick Chernozems in the research area (Atlas of Soils of the Ukrainian SSR, 1979). The studied catchment area covers ca. 6.3 km^2 and grades from a Loess plateau towards the valley of the Talianky River spanning a relief gradient from ca. 230 to 170 m a.s.l. (Fig. 1b). A calculation of the geomorphometric properties ("Geomorphons" according to Jasiewicz and Stepinski, 2013) reveals a subdivision of the catchment area by modern ditches and wind-breaking tree lines as well as the presence of long term geomorphic structures as slopes and valleys (Fig. 1b). The slope adjacent to the ancient Giant Tripillian settlement is steeper than the opposite slope of the investigated valley. A ditch, dug into this valley of assumable Pleistocene origin, contains running water only seasonally. The sediment deposited at the outlet of the studied valley, where the relief energy is decreasing abruptly, is therefore rather ascribable to short lived episodes of slope instability (colluvium) than to permanent running water (alluvium). Thus, we term the deposition a colluvial fan rather than an alluvial fan. According to the relief situation, the colluvial fan was a sediment sink during the Younger Quaternary probably, and its sediment record is considered here to reflect the processes that were in action in the catchment area. Meadows and shrubs as well a small pond cover parts of the valley nowadays. The Loess plateau is used for large agricultural fields, subdivided by wind-breaking tree lines, ditches and unpaved roads.

2.2. Methods

2.2.1. Field methods

Five trenches were dug at the lower slopes of the catchment area of the investigated valley (Fig. 1). Additionally, a sediment sequence was extracted from a long (5 m) percussion-drilling core on the colluvial fan of the investigated valley close to its outlet into the larger valley of the Talianky River.

The sequences of soils and sediments were documented in scaled drawings and described according to field instructions (AG Boden, 2005). Sediments are termed as slope deposits (abbr. S) or colluvial layers (abbr. M), if they are of pre-Holocene or Holocene age respectively and numbered in order of their genesis. Samples were taken for dating and standard laboratory analyses.

2.2.2. Laboratory analysis

2.2.2.1. Dating. Dating of the soils and sediments was achieved through radiocarbon measurements, optical stimulated luminescence (OSL) and typological analysis of embedded artifacts. Given the scarcity of datable bioremains, radiocarbon dating of bulk soil organic matter samples was performed after removal of carbonates. The results were calibrated using OxCal v4.2.3 (Bronk Ramsey and Lee, 2013) with the IntCal13 atmospheric calibration curve (Reimer et al., 2013) and are presented in cal years BP (2 Sigma). OSL dating was carried out on unexposed samples taken in small tubes in exposure 2 and from segments of a parallel core from drilling point 1. A RISO TL/OSL DA-15 luminescence reader equipped with a calibrated 90Sr/90Y source was used for measurements. Stimulation was carried out using blue (470 nm) or IR (870 nm) LEDs, depending on the applied mineral fraction. Detection was made through either a U-340 filter (quartz) or the combination of BG39 and CN-7-59 filters (feldspar). Throughout the measurements different types of the Single Aliquot Regeneration (SAR) protocol were used (Murray and Wintle, 2000, 2003; Wintle and Murray, 2006; Thiel et al., 2011; Buylaert et al., 2012). Prior to the measurement of the equivalent dose (De) tests were carried out to determine optimal temperature parameters and the reproducibility of the SAR procedure (combined preheat and dose recovery test). The equivalent dose was determined on several aliquots in case of each sample. Only those aliquots that passed the following rejection criteria (recycling ratio: 1.00 ± 0.10; maximum dose error: 10%; maximum recuperation: 5%, maximum IR/OSL depletion ratio: 5%) were considered for the De calculation. Sample De was determined on the basis of each accepted aliquot De, using different statistical techniques (Galbraith et al., 1999). Decisions were made on the basis of over dispersion, skewness and kurtosis values. Environmental dose rate D* was determined using high resolution, extended range gamma spectrometer (Canberra XtRa Coaxial HpGe detector). Dry dose rates were calculated using the conversion factors of Liritzis et al. (2013). Wet dose rates were assessed on the basis of in situ water contents. The dose rate provided by cosmic radiation was determined on the basis of the geographical position and depth of the samples below ground level, using the equation of Prescott and Hutton (1994). All OSL ages given in the text and figures of this paper are given in cal kilo-years BP (1 Sigma). Artifacts embedded in soil or sediments were dated according to prevailing typochronologies by the archaeologists. All radiometric age data are given in Tables 1a and 1b.

2.2.2.2. Geophysical and geochemical analysis. Soil and sediment samples were air dried (35 °C), carefully disintegrated with mortar and pestle and sieved through a 2 mm mesh sieve.

Grain size distribution analysis was carried out for profiles 2, 3, and the sediment core 1. After removal of soil organic matter (H_2O_2, 70 °C)

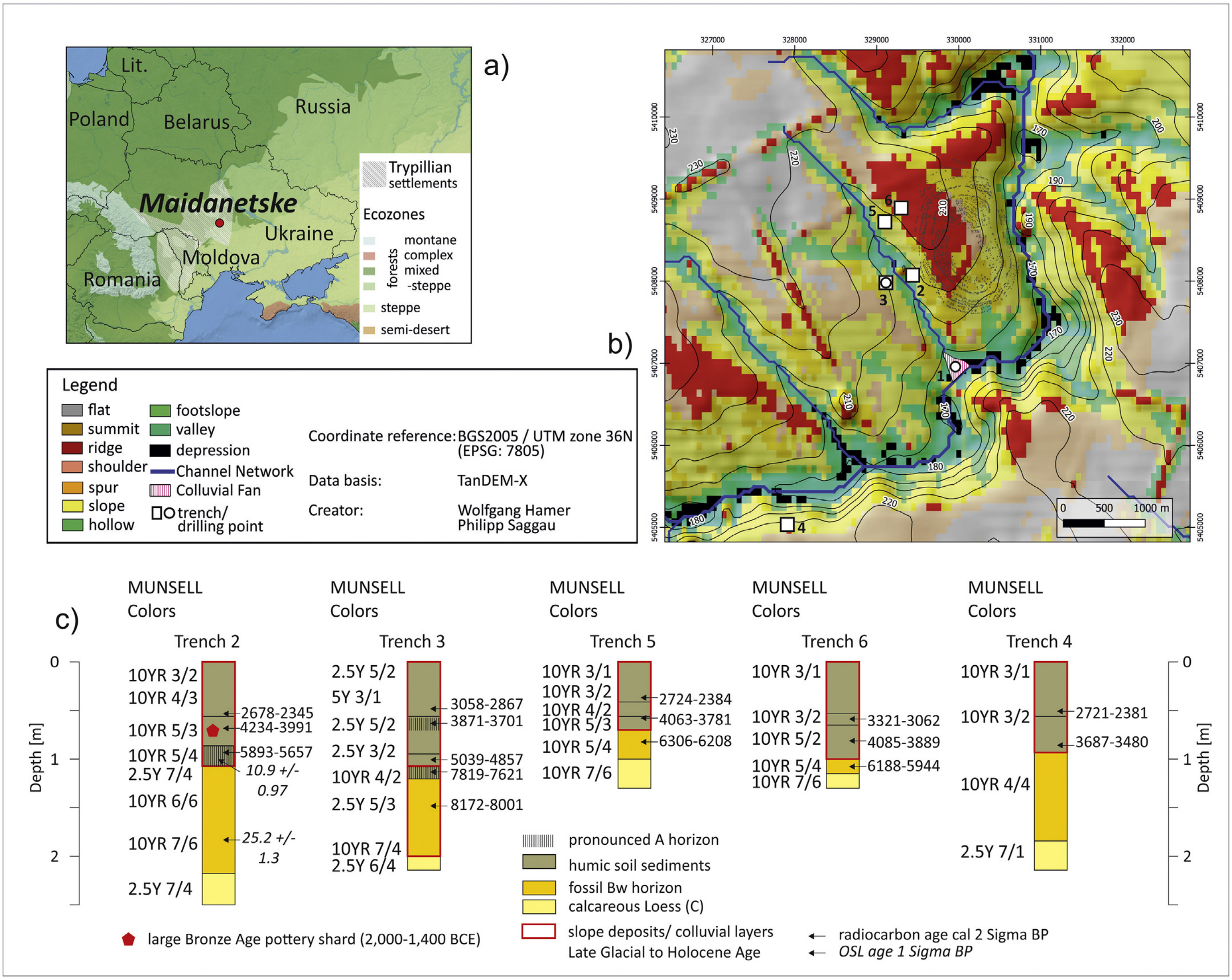

Fig. 1. Location of the investigation site a) in Eastern Europe, b) map of Geomorphons (Jasiewicz and Stepinski, 2013) from the investigation area close to the Tripyllia Giant Settlement Maidanetske (plan of burned houses indicated), and c) simplified chronostratigraphy of the investigated trenches (number on the left side of the columns: MUNSELL color values); data of core 1: Fig. 2a).

and carbonates (acetic acid buffer, 70 °C, pH 4.8) a laser particle sizer (Malvern Mastersizer 2000) was used to measure the grain size distribution (core1, profiles 2 and 3). Each sample was measured for at least 45 s, and the measurement was repeated at least 10 times, and finally averaged. The magnetic susceptibility was measured on 10 ml samples (<2 mm fraction) using a Bartington MS2B susceptibility meter (resolution $2 * 10^{-6}$ SI, measuring range $1–9999 * 10^{-5}$ SI, systematic error 10%). Measurements were carried out at low (0.465 kHz) and high (4.65 kHz) frequency. A 1% Fe_3O_4 (magnetite) was measured regularly to check for drift and calibrate the results. Mass-specific susceptibilities and frequency-dependent magnetic susceptibility (χfd) were calculated (Dearing, 1999). The color of the samples was measured using a Voltcraft Plus RGB-2000 Color Analyzer set to display in a 10-bit RGB color space within a spectral range of 400 to 700 nm (Rabenhorst et al., 2014; Sanmartín et al., 2014). Loss on Ignition (LOI) values were measured as estimates of the organic matter and carbonate content of the sediments (Dean, 1974). After drying the samples at 105 °C overnight, the weight loss of the samples was determined after heating times of 2 h at 550 °C and 940 °C each. For selected profiles, some additional analysis was carried out. The total carbon (TOC), total nitrogen (TN) were determined with an Elementar Vario EL-III CNS analyzer following standard procedures. Sulfanic acid (S = 18.5 wt%) was used for instrument calibration and an analytical error of ±0.01% was determined. Total elemental contents of samples from core 1 were determined via x-ray fluorescence. The total and minor elemental contents were determined on a ped-xrf device (Niton XL3t900). Sample pretreatment followed Lubos et al. (2016) and Dreibrodt et al. (2017). The <2 mm fraction of the samples was ground in an Agate mill and placed in plastic tubes covered by a 4 μm film. The measurement was carried out with He-flotation in the measurement chamber using the “mining, Cu/Zn” settings for 300 s at the Niton XL3t900-ed-XRF portable device. All elements measured with an error of >10% according to the device were discarded for further analysis. The correction factors published in Dreibrodt et al. (2017) were used to convert the semi-quantitative ppm values as displayed by the device into ppm by weight values comparable with the results of the wd-xrf.

On selected samples from the soil and sediment sequence of core 1 a lipid analysis was carried out to assess the catchment vegetation. Lipids were extracted by pressurized liquid extraction (DIONEX ASE200) using a solvent mixture of hexane/dichloromethane (9/1; *v*/v) and separated into non-polar and polar compound classes by automated SPE (LC-Tech Freestyle) on 2 g of pre-extracted and activated silica. Non-polar

Table 1a
Radiocarbon data.

Lab	Lab ID	Profile	Depth (cm)	Radiocarbon age BP	Cal 2 Sigma BP	Remarks
Kiel	52,670	1	340–344	10,130 ± 55	12,030–11,597(86.4%), 11,561–11,472(6.3%), 11,454–11,407(2.7%)	Sediment
Kiel	53,079	1	323–338	6410 ± 35	7420–7275(95.4%)	Sediment, oulier (krotowina?)
Kiel	53,078	1	298–303	7175 ± 55	8159–8087(10.2%), 8069–7931(83.4%), 7893–7878(1.8%)	Sediment
Beta	529,991	1	293–298	5100 ± 55	5918–5846(37.2%), 5831–5750(58.2%)	Sediment, Soil formation
Beta	529,992	1	288–293	6710 ± 30	7653–7639(1.8%), 7624–7556(75.7%), 7545–7511(17.8%)	Sediment, outlier, too few org. C
Beta	529,993	1	283–288	2999 ± 40	3336–3290(7.3%), 3261–3028(87.7%), 3014–3008(0.4%)	Sediment, outlier, too few org. C
Kiel	52,669	1	280–284	4550 ± 40	5320–5213(37.1%), 5193–5052(58.3%)	Sediment, Soil formation
Kiel	53,077	1	234–239	3927 ± 26	4438–4286(93.0%), 4273–4257(2.4%)	Sediment
Kiel	52,667	1	200–204	4949 ± 27	5731–5608(95.4%)	Charcoal, outlier (redeposition?)
Kiel	53,076	1	194–199	2550 ± 24	2751–2698(67.2%), 2635–2617(8.2%), 2591–2537(15.9%), 2531–2506 (4.1%)	Sediment, Soil formation
Kiel	52,668	1	180–184	2310 ± 40	2426–2392(2.1%), 2382–2302(76.9%), 2246–2178(15.8%), 2171–2162 (0.7%)	Sediment
Kiel	53,075	1	144–149	895 ± 30	911–735(95.4%)	Sediment
Posznan	62,408	2	95–100	5015 ± 35	5893–5805(38.9%), 5796–5781(2.5%), 5774–5657(54.0%)	Sediment, Soil formation
Posznan	62,410	2	65–70	3755 ± 30	4234–4198(10.4%), 4184–4070(68.6%), 4045–3991(16.3%)	Sediment
Posznan	62,407	2	45–50	2385 ± 30	2678–2667(1.3%), 2656–2644(1.6%), 2492–2345(92.5%)	Sediment
Posznan	113,975	3	150–155	7260 ± 40	8172–8001(95.4%)	Sediment
Posznan	113,974	3	120–125	6880 ± 40	7819–7814(0.6%), 7796–7621(94.8%)	Sediment, Soil formation
Posznan	113,973	3	95–100	4370 ± 30	5039–5005(9.7%), 4981–4857(85.7%)	Sediment
Posznan	113,971	3	60–65	3515 ± 30	3871–3701(95.4%)	Sediment, Soil formation
Posznan	113,970	3	40–45	2840 ± 30	3058–3049(1.5%), 3040–2867(93.9%)	Sediment

Lab	Lab ID	Profile	Depth (cm)	Radiocarbon age BP	Cal 2 Sigma BCE*/CE**	Remarks
Posznan	113,547	4	80–90	3345 ± 35	3687–3665(5.2%), 3645–3480(90.2%)	Sediment
Posznan	113,546	4	40–60	2475 ± 30	2721–2427(93.6%), 2413–2406(0.6%), 2395–2381(1.3%)	Sediment
Posznan	114,060	5	70–80	5460 ± 30	6306–6208(95.4%)	Relict Bw-horizon
Posznan	114,059	5	50–60	3595 ± 35	4063–4051(1.0%), 3986–3829(93.9%), 3787–3781(0.5%)	Sediment
Posznan	114,058	5	30–40	2480 ± 30	2724–2432(94.6%), 2391–2384(0.5%)	Sediment
Posznan	114,064	6	100–110	5290 ± 40	6188–5986(89.4%), 5973–5944(6.0%)	Relict BW-horizon
Posznan	114,062	6	70–80	3650 ± 30	4085–3889(95.4%)	Sediment
Posznan	114,061	6	50–60	2980 ± 30	3321–3309(1.1%), 3247–3062*(94.3%)	Sediment

compounds were eluted with hexane/dichloromethane (9/1; v/v) and subjected to gas chromatography–mass spectrometry (GC–MS) using an Agilent 7890A GC equipped with a Phenomenex Zebron ZB-5 column (30 m × 0.25 mm i.d.; 0.25 μm film thickness) and coupled to an Agilent 5975B mass chromatograph. The injection temperature was held at 60 °C for 4 min, after which the oven temperature was raised to 140 °C at 10 °C/min and subsequently to 320 °C at 3 °C/min, at which it was held for 8 min. The MS was operated at an electron energy of 70 eV and an ion source temperature of 250 °C. The homologues series of n-alkanes was detected via the *m*/*z* 85 mass chromatograms and peak areas used for calculation of relative abundance ratios.

3. Results

Sequences of sediments deposited during the Younger Quaternary and soils that had formed within these sediments during phases of slope stability were detected at the different exposures (Fig. 1) and at the drilling point (Fig. 2). The stratigraphic information supplemented by results of laboratory analysis (Figs. 1, 2, Table 4) is combined in the following by numerical age information (Tables 1, 2) to construct a chronostratigraphy. Dating samples for OSL dating and radiocarbon dating were selected according to the borders of stratigraphic units identified by field and laboratory methods. A rejuvenation of the soil organic matter radiocarbon age in the upper part of sediment layers coexistent with macroscopic and laboratory indication for A-horizons is considered to reflect A-horizon formation within the sediment. Abrupt changes in the soil organic radiocarbon ages between layers defined by field and laboratory analysis indicate colluvial layers of differing depositional ages.

3.1. Sediment core 1

The thickest sediment sequence (ca. 5 m) was recovered in two parallel cores at the drilling point on the colluvial fan of the investigated valley (Fig. 2a). A sequence of at least seven sediment layers that contains two buried surface A-horizons was identified based on macroscopic properties and laboratory results. The sediment layers differ considering their grain size distributions, colors, soil organic matter properties and geochemical composition. The buried A-horizons show slightly darker colors and higher organic carbon contents.

The base layer S1 (4.4–>5.0 m) comprises of a larger amount of gravel (ca. 4.7–>5.0 m) and light grayish sand and dates to the LGM according to an OSL date. Above, a layer of Loess was deposited (S2, ca. 3.7–4.4 m). This pale yellowish layer is composed mainly of silt with some sand and clay admixed. It is unclear, whether S2 originated from aeolian deposition or colluvial redeposition. S2 dates to a period between the LGM and the YD. A YD colluvial sediment was detected above (S3, 3.4–3.7 m). Its dark brown color and silty texture (finer than the underlying Loess)

Table 1b
OSL data.

Lab	Lab ID	Profile	Depth (cm)	Water content (%)	OSL grain size (μm)	U (ppm)	Th (ppm)	K (%)	D* (Gy/ka)	De (Gy)	OSL age (ka)
Szeged	1504	1	465	20 ± 5	11–20	2.77 ± 0.02	10.03 ± 0.15	1.63 ± 0.04	2.61 ± 0.06	69.47 ± 0.81	26.5 ± 0.7
Szeged	1505	1	380	19 ± 5	11–20	2.98 ± 0.03	9.23 ± 0.16	1.89 ± 0.06	2.86 ± 0.07	34.68 ± 0.67	12.0 ± 0.4
Szeged	1506	1	295	17 ± 5	11–20	2.98 ± 0.03	9.76 ± 0.16	1.87 ± 0.05	2.94 ± 0.07	25.30 ± 0.41	8.5 ± 0.3
Szeged	1507	1	210	19 ± 5	11–20	2.95 ± 0.03	10.09 ± 0.15	1.68 ± 0.04	2.76 ± 0.06	10.84 ± 0.09	3.93 ± 0.1

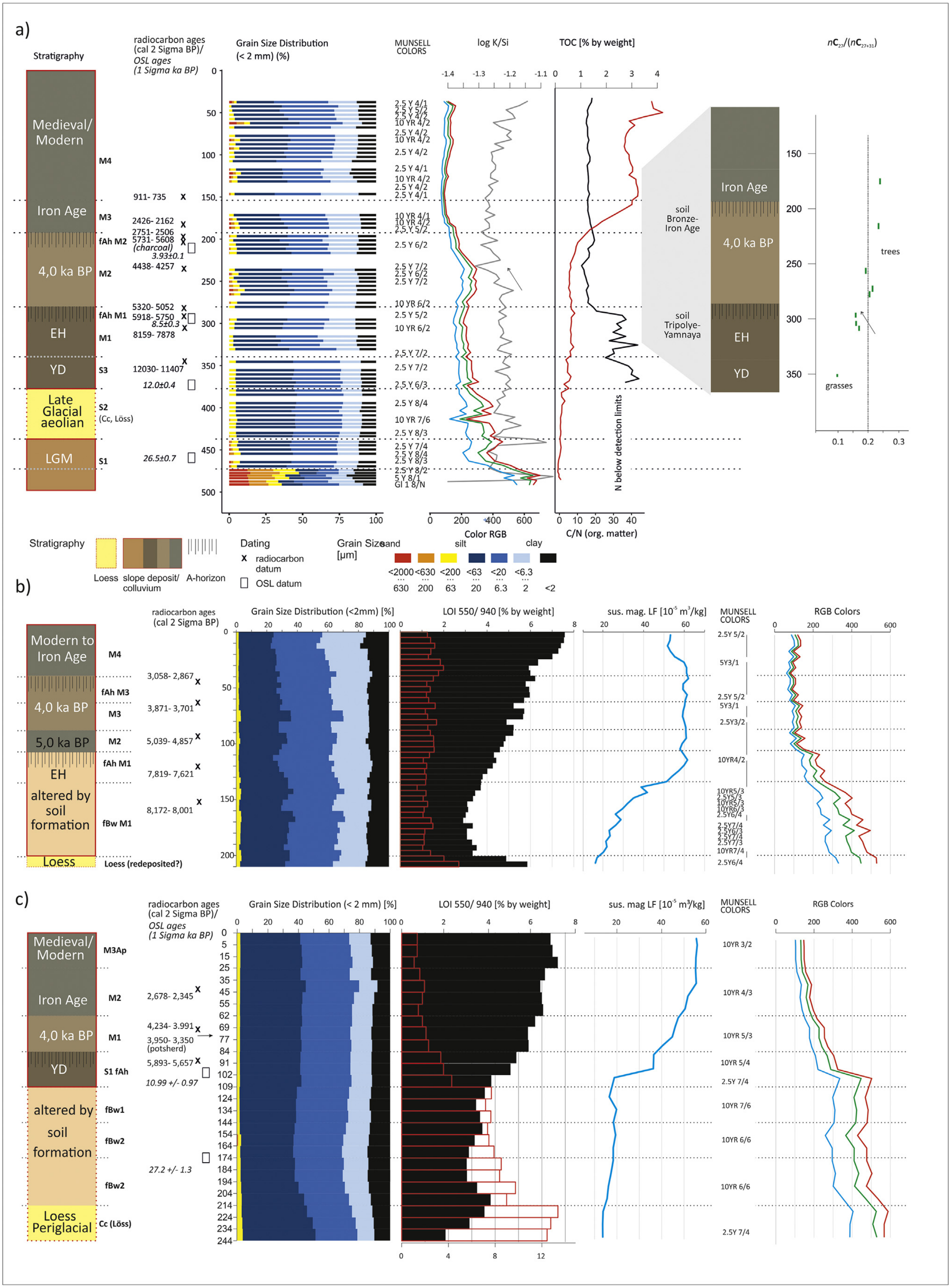

Fig. 2. Selected laboratory data from a) the long percussion-drilling core 1, b) trench 3 and c) trench 2. Fig. 2a) log K/Si- grey line, TOC- red line, C/N ratio- black line; Fig. 2c) LOI 500- upper axis, LOI 940- lower axis.)

points to an Allerød soil within the catchment as the source of the sediment. An organic carbon content of ca. 0.4% by weight in the sediment points to the same direction. An OSL age, backed by a radiocarbon age of the soil organic matter, points to deposition of S3 at ca. 12.0 ± 0.4 ka BP. S3 was buried by an early Holocene deposit M1 (2.8–3.4 m). Although the texture of M1 is composed mainly of silt, a significant change towards finer silt particles implies a change in the depositional conditions. The dark brownish color indicates that the source of M1 was an early Holocene soil that covered the catchment area. The organic carbon content of M1 is slightly higher than in the Late Glacial sediment (ca. 0.6%). According to an OSL age from the upper part of the layer, the deposition of M1 occurred at 8.5 ± 0.3 ka BP. A radiocarbon age of soil organic matter taken some cm below the OSL sample is slightly younger (ca. 8160–7880 cal BP, 2 Sigma) but backing the Early Holocene deposition. A soil organic matter radiocarbon age parallel to the OSL sample is much younger than the luminescence age. This indicates a soil formation in the upper part of M1 after the deposition of the sediment. The slightly darker color and the abrupt switch of the $C_{organic}$ to N ratio that is visible in the same samples delivers additional indication. Since organic matter rich in N becomes decomposed faster than organic matter poor in N the high $C_{organic}$ to N ratios in the Late Glacial/Early Holocene sediments are probable to reflect an ageing effect. The switch to a wider $C_{organic}$ to N ratio in the upper part of M1 is in accordance with mid-Holocene input of soil organic matter into the upper part of M1 by soil formation. The numerical data suggest that this soil formation started by ca. 5900 cal BP (2 Sigma) and lasted at least until 5300 cal BP. M1 was buried by M2 probably between ca. 4.4 and 3.9 ka BP. This is indicated by a soil organic carbon age of 4438–4257 cal BP in a depth of 234–239 cm and an OSL age of 3.93 ± 0.1 ka BP in a depth of 205 cm. Since we do not have a numerical age for the lower part of M2 it might be speculated about an additional deposition between ca. 5300 and 4000 BP. Neither macroscopic properties (color, content) nor laboratory analysis (e.g. $C_{organic}$) deliver indication for a separate sediment unit. Thus, we ascribe the thick pale layer M2 (1.9–2.8 m) to a deposition that occurred between ca. 4400 and 4000 cal BP. M2 has a dark grayish brown color, $C_{organic}$ contents of slightly below 0.5% and, while still dominated by silt, a significant increase in sand (coarse and medium sand) is visible. In the upper part of M2 another soil formed from ca. 2750 cal BP until it became buried by M3. This is indicated by the younger radiocarbon age of soil organic matter, the darker color, and the higher $C_{organic}$ contents of the upper part of M2 (up to ca. 1%). Whether the colluvial M3 buried M2 during Iron Age or Medieval Times is not clear due to sparse numerical age information. Seen together with data from the other exposures within the catchment area the former seems more reasonable. Changes in the sediment composition could be used to subdivide M3. A change in sediment color (darker), grain size (little sand), and the C:N ratio of the sediment indicates a former soil surface (A-horizon, soil formation) in a depth of ca. 1.5 m, coinciding with a radiocarbon age of ca. 910–730 cal BP (Medieval Times). Another noticeable change of the sediment properties is visible in ca. 1.0 m depth. Similarly, less sand, higher clay content, a switch to darker sediment colors and higher C:N ratios indicate another former surface horizon (A-horizon, soil formation). Thus, two subsequent colluvial layers followed the deposition of M2 probably as inferred from the sediment properties.

The $nC_{27}/(nC_{27+31})$ plant wax alkane ratio of the sediment indicates an increasing amount of tree leaves within the soil organic matter in the Late Glacial to mid-Holocene sediment record. It is lowest in one YD sample, increases in the samples of the early Holocene layer, and increases further to a more tree-dominated value in the mid-Holocene samples.

3.2. Trenches at the lower slopes

On the lower slopes that incline towards the studied valley (trenches 2, 3, 5, 6), varying but smaller thicknesses of sediments of water erosion are exposed (Figs. 1, 2; between 1 and 2 m). All sediments are composed of silt, clay, and fine sand, and contain no significant amount of coarser particles. There are different occurrences of Late Glacial to early Holocene sediments (trenches 2, 3). In one trench, a thin Early Bronze Age colluvium was detected (trench 3). All trenches contain a colluvial layer that dates to ca. 4000 cal BP. Similar to the observations in the percussion core; this layer exposed a paler color compared to the others colluvial layers also in the trenches. In two trenches, the presence of a sediment deposited ca. 2700–2300 yrs cal BP (trenches 2, 5) is indicated. In all trenches, remains of buried soils are present. At the base of the trenches, remnants of a buried Bw-horizon (Cambisol) indicate the presence of a wooded landscape prior to the modern-widespread Chernozems. Additionally, pronounced A-horizons subdivide the sediment sequences indicating a succession of alternating phases of slope stability and erosion throughout the younger Quaternary. Within the upper part of the YD sediment deposited at trench 2, a humic surface soil horizon has formed dating to ca. 5900–5650 yrs cal BP. In trench 3, similar phases of soil formation are indicated. These occurred in the upper part of the early Holocene colluvial layer at ca. 7800–7600 yrs cal BP until buried at ca. 5000–4900 yrs cal BP and in the colluvial layer thought to have been deposited at ca. 4000 yrs BP and buried at ca. 3000–2900 yrs cal BP.

In general, the sediments and soils exposed at the lower slopes resemble the chronostratigraphy detected in the long percussion-drilling core at the colluvial fan. Fig. 2b and c illustrate properties of the deposited sediments and soils in the trenches 2 and 3. Noteworthy is the similar grain size distribution (mainly silt with some clay) in trench 2 and 3. This might be explained by the sediment sources consisting of Loess on the investigated slopes. While there are similar trends in LOI, magnetic susceptibility and colors of the sediment sequences in trench 2 and 3, there is an obvious difference at the base of the Holocene part of the sequences. The LOI 940 values, the magnetic susceptibility and the colors in trench 2 all show an abrupt step at this chronostratigraphical border whereas there is a gradual transition in trench 3. This indicates an erosional break in trench 2 between the Late Glacial and the mid-Holocene.

An additional exposure was studied in a small quarry ca. 3 km southwest of the investigated catchment area (trench 4). Whereas the start of erosion was found to have happened ca. 3700–3500 yrs cal BP, the subsequent colluvial layer dates to ca. 2700–2400 yrs cal BP, shows an erosional phase detected in the investigated valley. A pronounced buried Bw-horizon is present at the base of the sequence.

4. Discussion

A comparison of the reconstructed phases of erosion and soil formation with the well-known settlement history of the region and Holocene erosion histories from the Russian Plain and Germany is given in Fig. 3. Although there are some weaknesses with the dating described in the sections above and our record is not exhaustive some statements could be derived. The data from the investigated trenches and the percussion-drilling core indicate that the Younger Quaternary erosion at the sites occurred in discrete phases rather than continuously. Slight deviations between datings can be ascribed to uncertainties in using bulk samples for radiocarbon dating.

Six main erosion phases have recorded at Maidanestke. They occurred during the Last Glacial Maximum (LGM), the Younger Dryas phase (YD), the early Holocene (8.2 ka), at ca. 4 ka, between 2700 and 2200 yrs BP, and during the last millennium.

The long-term settlement and land use history of the site and the region is well known according to a large number of archaeological surveys and excavations (Fig. 3, Table 2). Whereas there is a large number of material cultures of human communities that left remains over the course of the Younger Quaternary in the region there are also some hiatuses, most noticeable between the Neolithic and the Chalcolithic period, between the Chalcolithic and Bronze Age cultures, and between the Bronze Age and Iron Age (200 yrs, 650 yrs, 650 yrs). Traces of human communities

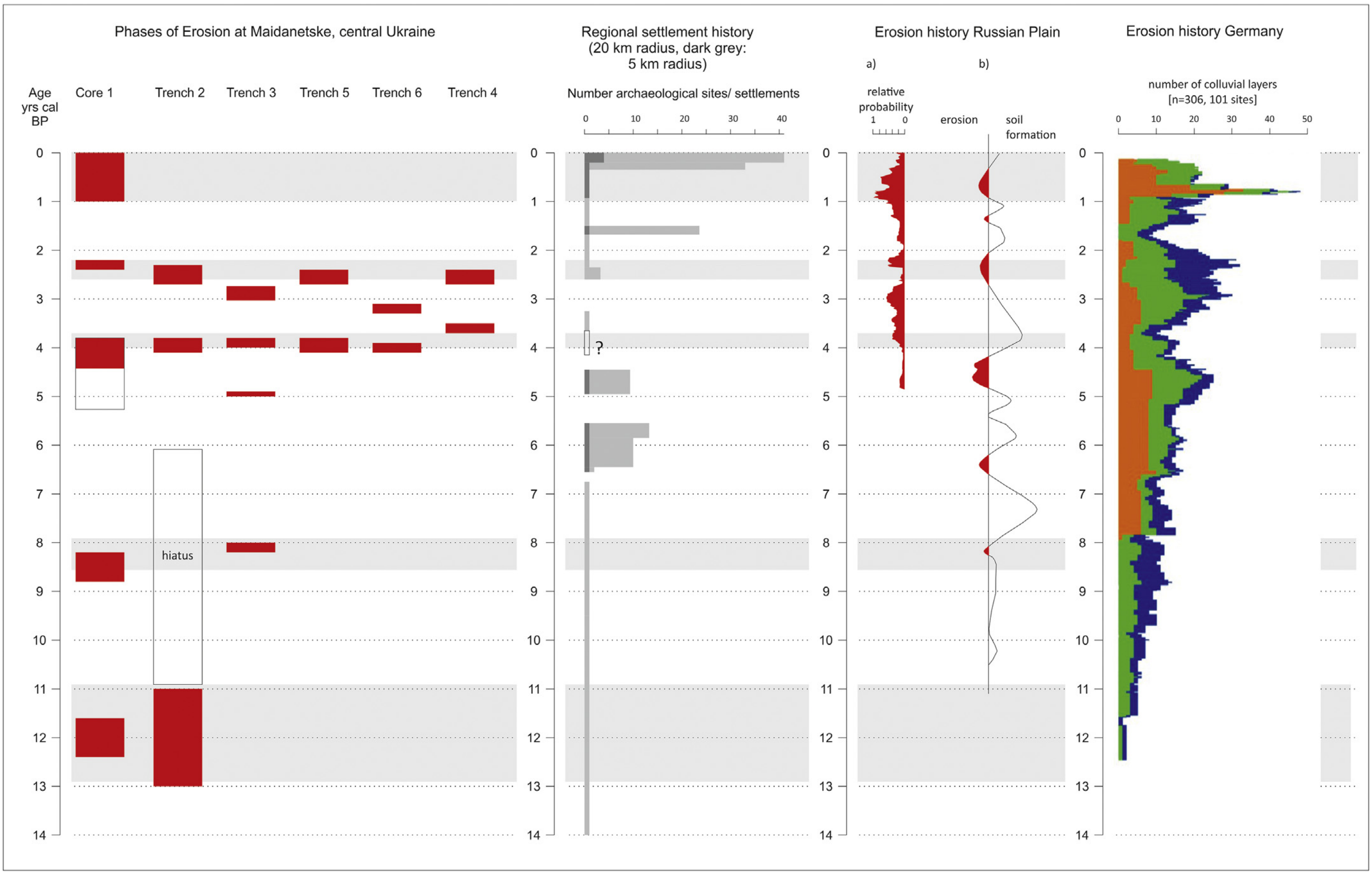

Fig. 3. Comparison of the detected Younger Quaternary Erosion phases at Maidanetske with the known settlement history, and records of Holocene soil erosion from Russia (Sycheva, 2006; Panin et al., 2009) and Germany (histogram: orange- dated via embedded/buried archaeological record, green- dated via radiocarbon dating, blue- dated via OSL, Dreibrodt et al., 2010a). Note the coincidence of main erosion phases at Maidanestke, central Ukraine (grey bars) with the Russian and German erosion records except for the ca. 4000 yrs cal BP erosion. Empty bars display two uncertain erosion phases at the site.

are recorded during Palaeolithic and Mesolithic Times (Shidlovsky et al., 2004; Neradenko, 2011; Zalizniak et al., 2005). With respect to soil erosion processes the impact of these human communities on catchment soils and vegetation can be assumed of insignificant intensity. First traces of Neolithic settlers (Buh-Dniester Culture, ca. 7950–6750 cal BP) are reported within a radius of 20 km distance from Maidanetske (Zalizniak et al., 2005). No finds or findings were discovered at the research site for that time period so far. The earliest farmers that stayed also for a longer time period at the research site occurred with the onset of the Chalcolithic Times (ca. 6550–5350 cal BP). A peak of settlements in the research area is archaeologically proven for the period Tripyllia B (6,450–5850 cal BP). Compilations of osteological inventories indicate both hunting of wild animals and animal husbandry (e.g. Zbenovich, 1996; Kruts et al., 2001). During the development of the Tripyllian culture the ratio between hunted: domesticated animals are shrinking. The analysis of plant remains indicates similarly a widespread use of wild and domesticated plants (e.g. Pashkevych and Videiko, 2006). Because of the comparatively bad preservation conditions for animal remains, recent investigations included phytolith analysis to proof the presence of grasses and cereals at the sites (Dal Corso et al., 2018). Ohlrau (2020) concludes a permanent rather than a seasonal inhabitation of Maidanetske based on the tool assemblages unearthed in the houses. Summarizing, although a considerable number of farmers are reconstructed for different phases of the Tripyllian Giant settlements, the Chalcolithic communities probably never exploited the carrying capacity of the Ukrainian steppe-border zone (Dal Corso et al., 2019). The termination of the Giant Chalcolithic settlements in the region and at Maidanetske is followed by a hiatus of ca. 650 yrs before agropastoralists of the Yamnaya material culture resettled in the research area. Very few and partly questionable finds (e.g. one potsherd form Maidanestke) are known from the region throughout the Bronze Age. Following another hiatus the trend towards a sparser settled landscape with a growing focus on animal husbandry continued through the Iron ages (e.g. Scythian times) until Late Roman Times in the research region. Starting at Late Roman Iron age and lasting until today a trend to more mixed and in the most recent times even very intensive field use focused agriculture occurred at the research site. The densest net of settlements and highest intensity of field use (large “agro-industrial agricultural fields”) took place during the past 450 yrs at the research site.

A comparison of the settlement and land use history of the site with the erosion record shows a conspicuous non-coincidence between land-use and erosion history except for the last millennium (Fig. 3, Table 2). The only noticeable exception is the last millennium, where we do not have detailed numerical age information about the sediment

Table 2
OSL data.

Lab	Lab.-Nr.	Profile	Depth (cm)	^{238}U (ppm)	^{232}Th (ppm)	^{40}K (ppm)	D* (Gy/ka)	De (Gy), aliquots	OSL age (ka)
Gdynia	GdTL-1892	2	180	29.14 ± 0.74	42.5 ± 0.12	498 ± 33	2.54 ± 0.11	69.2 ± 1.4	27.2 ± 1.3
Gdynia	GdTL-1893	2	100	24.30 ± 0.70	40.5 ± 0.12	576 ± 40	2.53 ± 0.12	28.0 ± 2.0	10.99 ± 0.97

deposition. No traces of erosion were found to be related with the phases with the largest number of prehistoric settlements in the area (20 km radius) at ca. 6450–5350 yrs cal BP (Tripyllia culture) or at ca. 1700–1500 yrs cal BP (Late Roman Iron Age).

Thus, for the long-term Holocene erosion record other processes than human impact must be considered. Since the research site is located in a transition zone between forest and steppe known to be very sensitive to climate changes, climatic fluctuations throughout the Younger Quaternary might have resulted in phases of erosion at Maidanetske.

This is in line with the opinion of eastern European geomorphologists that Holocene erosion in Eastern Europe was mainly driven by climate variability (Sycheva et al., 2003; Belayev et al., 2004, 2005; Sycheva, 2006; Panin et al., 2009). These scientists ascribed intense medieval to early modern erosion on the Russian plain to the climatic variability of the Little Ice Age for example.

Two main limitations have to be kept in mind when considering Younger Quaternary climate variability as trigger of erosion at Maidanetske. These are the comparatively singularity of the record presented here and the scarcity of high-resolution climate archives in the region. Seen in conjunction, the valley sediment record at Maidanestke is not of high temporal resolution but bases on a solid combination of chronostratigraphical and numerical age information. According to a lack of appropriate sedimentary archives, there are no precisely dated Younger Quaternary palaeoclimatic records from the region. Thus, paleoclimate records known from western, central, and southern Europe are compared with the sediment record from Maidanetske here. We do not know, however, if these events affected the regional eastern European climate in a similar manner.

A comparison of the numerical ages of the detected erosion phases reveals a weak accordance between the results from central Ukraine and the Russian Plain for some erosion phases (Fig. 3). Whereas the records from Russia show no pronounced consistence viewed by itself, the erosion phases at ca. 8.2 kyrs BP, ca. 4000 yrs cal BP, at ca. 2700–2300 yrs cal BP and during the last millennium detected in central Ukraine are also visible in the Russian record.

Considering them separately, the erosion phases detected at Maidanetske coincide with periods of known pronounced climate variability in other parts of Europe. Among them are the Last Glacial Maximum (LGM), the Younger Dryas period (YD), the early Holocene (8.2 ka), the 4.2 ka, and the 2.5 ka climate anomalies.

Few data are available to consider about geomorphological effects of different phases of the Last Glacial period. Of 19 gullies studied by Panin et al. (2009) in central Russia 15 were incised initially already during the Pleistocene. Slope instability during the YD period has been reported from various sites in Europe (e.g. Andres et al., 2001; Dotterweich et al., 2013). Investigations on slope deposits have revealed a pronounced phase of slope instability at ca 8000 yrs cal BP reported from sites in western and central Europe (e.g. Dreibrodt et al., 2010b; Vincent et al., 2010; Lubos et al., 2011; Schumacher et al., 2018). Fig. 3 exhibits a phase of erosion at ca. 8.2 ka in the Russian record of Sycheva (2006). The erosion phases during the Last Glaciation and its transition to the Holocene are very probably responses to climate variability. For the glacial and perhaps YD conditions surface runoff on partly frozen ground could explain intensive erosion during snowmelts or heavy precipitation events (e.g. Renssen and Vandenberghe, 2003; Panin et al., 2009). In addition, the vegetation cover could be assumed to have been affected seriously by the mentioned climate oscillation phases (e.g. Rousseau et al., 2001; Gerasimenko et al., 2019). Thus, erosion during the Last Glacial and the transition to the Holocene are very probably responses to climate variability.

A further main erosion phase at Maidanetske dates to ca. 4000 yrs cal BP in all profiles. This phase is less visible in the Russian and German records (Fig. 3). It coincides with a climate anomaly reported most frequently from the Mediterranean part of Europe. In northern Europe and the Alps cooler than usual conditions are reported (e.g. Bakke et al., 2010, Le Roy et al., 2017) but a clear increase in slope erosion is missing (Fig. 3).

Between ca. 2700 and 2200 yrs cal BP another erosion phase occurred at Maidanetske. The Russian records exhibit erosion phases between 2400 and 2200 yrs cal BC as well (Fig. 3). In central Europe, frequent erosion has been reported from a large number of sites during this period (e.g. Lang, 2003; Dreibrodt et al., 2010a), including phases of gullying (Dreibrodt and Wiethold, 2015). Note the presence of a high number of colluvial layers deposited in Germany in the period between 2700 and 2200 yrs cal BP (Fig. 3). These erosion phases coincide with a climatic deterioration phase recorded across western and central Europe (e.g. van Geel et al., 1996). Climatic anomalies are reported for the research region (continental Eastern Europe) as well. A low lake level of the Lake Balqash (Kremenetski, 1997) and palynologically indicated drier than usual conditions between ca. 3000 to 2400 yrs cal BP (Gerasimenko, 1997; Gerasimenko et al., 2019) are reported. Since again, the local and regional settlement history at Maidanetske indicates a lull in human impact, a connection of the observed erosion processes with climate variability appears more probable.

Since we do not have detailed numerical age information about the erosion processes that were in action during the past millennium at Maidanestke, we can only state that this phase was the strongest influenced by intensive agricultural land use at the research site. Maxima of erosion are reported from central Europe (e.g. Bork and Lang, 2003; Dotterweich, 2008; Dreibrodt et al., 2010a) and Russia (Panin et al., 2009) to have happened during this period. If we consider the record at the colluvial fan in core 1 we could deduce that about 150 cm of the Holocene record was deposited during the last 1000 years (representing ca. 42% of the Holocene sediment). That underlines the crucial accelerating effect of intensive ("industrial") agricultural land use on Holocene soil erosion processes. Additionally, it implies that the intensity of prehistoric land use at Maidanetske was below a critical threshold, thus, no or very little soil erosion was triggered by their subsistence systems.

Considering erosion records from southern Europe additionally, further hints could be drawn. Erosion at slopes has been reported from Anatolia dating to the YD and 8.2 ka climate oscillations (e.g. Dreibrodt et al., 2014). A number of scholars even argue about relationships between the climate variability of the Last Glaciation to Holocene transition phase and early societal evolution in the Mediterranean (e.g. Weninger et al., 2006). Geomorphological response to the 4.2 ka climate oscillation are reported from the Mediterranean, as in Greece (e.g. Van Andel et al., 1990) or Anatolia (Dusar et al., 2012). Prominent drought phases are reported at around 4.2 ka which are considered similarly to have influenced human communities seriously (e.g. Weiss and Bradley, 2001, Staubwasser and Weiss, 2006, Migowski et al., 2006, Cheng et al., 2015, Schirrmacher et al., 2019). Erosion is reported during the period from ca. 2400 to 2000 yrs BP from Anatolia (Kaniewski et al., 2008; Dreibrodt et al., 2014; Dusar et al., 2012) and Greece (Van Andel et al., 1990; Fuchs, 2007), additionally. Prominent dry conditions were reconstructed for ca. 3000–2000 cal BP from marine sediments of the eastern Mediterranean (e.g. Schilman et al., 2001). Thus, a number of Holocene erosion phases recorded at Maidanetske, central Ukraine, coincide with erosion records from the Mediterranean, too. This is in particular the case for the erosion phase at ca. 4 ka BC. Since within the research region the Atlantic and Mediterranean climate system converge, this observed coincidence points further towards climate related erosion events at Maidanetske.

Summarizing the discussion of the long-term Younger Quaternary erosion history at Maidanetske (LGM- 1000 yrs BP) there is a non-coincidence of erosion with the local and regional prehistoric settlement history. Despite the weakness of dating of the recorded erosion phases, the desideratum of comparable data on the Younger Quaternary evolution of landscapes in Ukraine and the lack of high-resolution palaeoclimate archives a coincidence of erosion phases at the site with well-known phases of climate anomalies from Western, Central and

Table 3
Settlement history of the site (5 km radius) and the region (20 km radius).

Period	Numerical age (BCE*/CE**//BP)	Archaeological sites in the micro-region Bold = 5 km radius, Black =20 km radius, Grey = 20 km, no precise dating available	“Material-culture”	Reference
Palaeolithic	Lower …//until 150,000	–		
	Middle …//until 35,000	–		
	Upper …//until 9950	Gordashovka, Lashova		Shidlovsky et al., 2004: 364
Mesolithic	8000–6000*//9950–7950	Dobryanka 1	Kukrek	Neradenko, 2011 Zalizniak et al., 2005
Neolithic	6000–4800*//7950–6750	Dobryanka 3	Buh-Dniester culture	Zalizniak et al., 2005
Chalcolithic	Early (Tripolye A) 4600–4500*//6550–6450	Grebenukiv Yar, Romanovka	Tripolye	
	Middle (Tripolye B) 4500–3900*//6450–5850	Onoprievka, Vesely Kut, Gordashovka 1, Hlybochok, Rozsohovatka, Kolodyste 1, Krivi kolina, Pischana, Sverdlikove, Nebelivka	Tripolye	
	Late (Tripolye C) 3900–3400*//5850–5350	**Maidanetske,** Kobrinovo, Romanovka, Moshurov 1, Moshurov 2, Moshurov 3, Gordashovka 2, Talne 1, 2 and 3, Rohy, Talianki, Kamyaneche, Kolodyste	Tripolye	
Bronze Age	Early Bronze Age 3000–500*//4950–4450	Kurgans close to **Maidanetske,** Legedzyne, Dobrovody, settlement Maidanetske (Shirokiy bereg), Belashki “Oksanichev yar”, Vishnopil, Talne (3), Rohy, Moshurov	Yamnaya culture, kurgans	Ivanova, 2016: 273–290; Kruts et al., 1981: 4
	Middle Bronze Age 2600–2200*//4550–4150	–		
	Transitional period 2200–1700*//4150–3650	Maidanetske (?)		
	Late Bronze Age 1700–1300*//3650–3250	Legedzyne 2		Magomedov and Didenko, 2009: 56; Kushtan, 2013: 84
	Final Bronze Age 1300–900*//3250–2850	–		
Early Iron Age	Pre Scythian time 9th–mid 7th c. *//2750–2600	No settlements		Terenozhkin, 1961
	Scythian time mid 7th–3rd c. *//2600–2350	Kurgans close to Legedzyne, Kolodiste Belashki, Moshurov (settlements)- „early iron age“	Scythian, kurgans	Kruts et al., 1981: 4.
	Sarmat time 3rd–2ndc.*–4thc. **//2350–1550	Kurgan in Kolodiste		
Late Roman time	Mid 3rd–first half 5th c. **//1700–1500	**Maidanetske,** Legedgzyne 1 and 2, Legedzyne graveyard, Sverdlikove (burials), Kobrinovo, Belashki (4), Glibochok 1 and 2, Vesely Kut, Potash, Papuzentci, Pavlivka 1, Zelenkiv, Gordashivka 1, 2 and 3, Vishnopil (2), Talne, Rohy, Oksanine 1 and 2, Kolodiste	Chernyakhov culture	Magomedov and Didenko 2009: 56; Kruts et al., 1981: 4
Middle Ages	Early middle Age 5th–10th c.**//1450–950	Moshurov, Pishana (Penkovska culture)		
	High Middle Ages 10thc.–1250**//950–750	–		
	Late middle age 1250–1500**//750–450	1/1 villages		IУMIC, 1972
Early modern period	1500–1750**//450–200	1/33 villages		IУMIC, 1972
Late modern period	since 1750**//since 200	1/41 villages At the end of the 19th c. a sugar factory was built in Maidanetske, in action until the end of the 20th century. Construction of cascade ponds.		IУMIC, 1972

Southern Europe is indicated. Whereas for the LGM and the YD increased runoff over frozen ground might be considered as explanation for the observed erosion phases, this is improbable for the Early Holocene and impossible during mid- and late Holocene. Thus, for the latter erosion phases alternative processes, like a combination of a weakened vegetation cover and accentuated heavy precipitation events must be speculated. The sensitivity of the central Ukrainian landscape to record climatic change we claim here is probably related to two preconditions. The first is the late onset of intensive agricultural land use in the region, similar as pointed out for Russia (Panin et al., 2009). This is underlined by the thick stack of colluvial layers deposited during the last millennium in our long percussion-core. The second precondition is related to the location of the area in the forest-steppe borderland zone, considered to be sensitive to slight climatic changes and, additionally located in a position where western and southern European climate systems converge. If the hypothesized climate control on erosion over large parts of the Younger Quaternary is representative for the research area or not, and a deeper understanding of the underlying processes, these are matter of future research. Additional sequences of slope deposits should be investigated in high resolution in the south-eastern European forest-steppe border region. Preferred study sites should be located in regions with a well-known Holocene settlement history, similar to the site presented here. Parallel, intensified efforts should be undertaken to fill the gap of high-resolution climate archives in the research region.

Considering the erosion processes in action during the Younger Quaternary deposition history an additional observation could be made. The sediment deposited during the periglacial to early Holocene erosion processes shows properties that resemble the Loess cover deposited over the whole catchment area (Fig. 2). Since the ca. 4000 yrs cal BP erosion phase, the sediment on the colluvial fan contains more sand in general. This is not visible in the trenches at the lower slopes, where the Loess cover was nowhere found to have been cut through completely. Additionally, the K content in the mid- to late Holocene sediment of the colluvial fan is lower than in the Lateglacial to early Holocene sediment. The K to Si ratio in Fig. 2a illustrates this. Since K is a major element bound to the Loess (muscovite), the decrease in K is probable to reflect lesser amounts of Loess from the plateau part of the catchment in the sediment deposited since the mid-Holocene. A re-increase of K is only visibly in the uppermost probably modern part of the sediment sequence. These indicators hint to a stronger incision in the valley itself and aggradation of colluvial material at the lower slopes during the mid-Holocene, when agricultural field use was at lower to moderate intensity levels. The re-increase of K is displaying a re-increase of the connectivity between the Loess plateau and the valley bottom as a response of the (super-)large and intensively used agricultural fields associated with the “agro-industrial” type of modern agricultural field use. Additionally, the biomarker signal of increasing amounts of tree leave organic matter in the valley sediments points to erosion and re-deposition of soil in the valley bottom, because the valley bottom is the most probable landscape position for the growth of gallery forests throughout the Holocene. Thus, a change in the overall geomorphic

Table 4
Geochemical data of core 1; total major and minor elemental content (ped-xrf) [ppm].

Period	Numerical age (BCE*/CE**/BP)	Archaeological sites in the micro-region bold = 5 km radius, black =20 km radius, grey = 20 km, no precise dating available	“Material-culture”	Subsistence	References
Palaeolithic	Lower …//until 150,000	–		Foraging	
	Middle …//until 35,000	–		Foraging	
	Upper …//until 9950	Gordashovka, Lashova		Foraging	Shidlovsky et al., 2004: 364
Mesolithic	8000–6000*//9950-7950	Dobryanka 1	Kukrek	Foraging	Neradenko, 2011 Zalizniak et al., 2005
Neolithic	6000–4800*//7950–6750	Dobryanka 3	Buh-Dniester culture	Foraging and (low intensity) farming	Zalizniak et al., 2005, (Dolukhanov et al., 2010)
Chalcolithic	Early (Tripyllia A) 4600–4500*//6550–6450	Grebenukiv Yar, Romanovka	Tripolye	Farming and foraging (hunting)	(Shatilo, in press) (Kruts et al., 2001) (Pashkevych and Videiko, 2006)
	Middle (Tripyllia B) 4500–3800*//6450–5800	**Maidanetske,** Onoprievka, Vesely Kut, Gordashovka 1, Hlybochok, Rozsohovatka, Kolodyste 1, Krivi kolina, Pischana, Sverdlikove, Nebelivka	Tripolye	Mixed farming	(Kirleis and Dal Corso, 2016),
	Late (Tripyllia C) 3800–3650*//5800–5600	**Maidanetske,** Kobrinovo, Romanovka, Moshurov 1, Moshurov 2, Moshurov 3, Gordashovka 2, Talne 1, 2 and 3, Rohy, Talianki, Kamyaneche, Kolodyste	Tripolye	Mixed farming	(Dal Corso et al., 2019)
Bronze Age	Early Bronze Age 3000–2500*//4950–4450	Kurgans at and close to **Maidanetske,** Legedzyne, Dobrovody, settlement Maidanetske (Shirokiy bereg), Belashki “Oksanichev yar”, Vishnopil, Talne (3), Rohy, Moshurov	Yamnaya culture, kurgans	Agropastoralism	Smagli and Videiko, 1988, Ivanova, 2016: 273–290; Kruts et al., 1981: 4; Ancient History …, 1997 (Gerling, 2015)
	Middle Bronze Age 2600–2200*//4550–4150	–		Agropastoralism	Ancient History …, 1997
	Transitional period 2200–1700*//4150–3650	Maidanetske (?, one potsherd)		Agropastoralism	Ancient History …, 1997
	Late Bronze Age 1700–1300*//3650–3250	Legedzyne 2		Agropastoralism	Magomedov and Didenko 2009: 56; Kushtan, 2013: 84; Ancient History …, 1997
	Final Bronze Age 1300–900*//3250–2850	–		Transition to nomadic pastoralism	Ancient History …, 1997
Early Iron Age	Pre Scythian time 9th–mid 7th c. *//2750–2600	No settlements		Nomadic pastoralism?	Terenozhkin, 1961
	Scythian time mid 7th–3rd c. *//2600–2350	Kurgans close to Legedzyne, Kolodiste Belashki, Moshurov (settlements)-“early iron age”	Scythian, kurgans	Nomadic pastoralism with some agriculture?	Kruts et al., 1981: 4.
	Sarmat time 3rd–2ndc.*–4thc. **//2350–1550	Kurgan in Kolodiste		Nomadic pastoralism	
Late Roman time	Mid 3rd–first half 5th c. **//1700–1500	**Maidanetske,** Legedgzyne 1 and 2, Legedzyne graveyard, Sverdlikove (burials), Kobrinovo, Belashki (4), Glibochok 1 and 2, Vesely Kut, Potash, Papuzentci, Pavlivka 1, Zelenkiv, Gordashivka 1, 2 and 3, Vishnopil (2), Talne, Rohy, Oksanine 1 and 2, Kolodiste	Chernyakhov culture	Mixed farming	Magomedov and Didenko 2009: 56; Kruts et al., 1981: 4 (Meier, 2019), 146f.
Middle Ages	Early middle Age 5th–10th c.**//1450–950	Moshurov, Pishana (Penkovska culture)		Mixed farming	Tolochko et al., 2000: p 105–106
	High Middle Ages 10thc.–1250**//950–750	–		Mixed farming	Tolochko et al., 2000: p 404
	Late middle age 1250–1500**//750–450	1/1 villages		Mixed farming	Steshenko et al., 1972
Early modern period	1500–1750**//450–200	1/33 villages		Mixed farming	Steshenko et al., 1972
Late modern period	Since 1750**//since 200	1/41 villages At the end of the 19th c. a sugar factory was built in Maidanetske, in action until the end of the 20th century. Construction of cascade ponds.		Mixed faming (industrial scale)	Steshenko et al., 1972

connectivity within the investigated catchment area could be characterized as high-low-high for the phases of Late Glacial/early Holocene- mid to late Holocene- modern times. If the observed change in sediment properties reflects differences in the intensity of the different erosion-phases or changes in the vegetation-cover within the catchment area (partly wooded), it remains a question of further research.

5. Conclusions

A long-term Younger Quaternary erosion history was reconstructed at a central Ukrainian site. A non-coincidence with the well-known settlement history indicates a strong influence of climate variability on the erosion history. Main erosion phases could be related to the Last Glaciation and its transition to the Holocene (LGM, YD, 8.2 ka), the mid-Holocene 4.2 ka climate anomaly, and the onset of the late Holocene (2.7–2.2 ka). A modern times strong human impact assumable from the land use history of the site is reflected by intensive erosion during the last millennium. The observations at Maidanetske might reflect the late onset of intensive agricultural land use in the region and the position of the site in an environment sensitive to slight climatic shifts where the western and southern European climate systems converge. A considerable influence of climate variability on Holocene erosion was also reported from neighboring regions. Future investigations on Holocene soil erosion across Europe should test the influence of climate variability on erosion processes.

Changes in the properties of the sediment deposited at a colluvial fan indicate a change from a stronger connectivity of erosion processes during the glacial to early Holocene and modern times erosion phases and a weakened connectivity during the mid- to late Holocene.

To verify the representativeness of the presented central Ukrainian record on a regional scale, additional efforts focused on both, reconstructions of the regional palaeoclimate and landscape evolution in Eastern Europe in a high resolution are needed.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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