



Risks beyond the ditch: Copper Age tannery from the settlement of Kamianets-Podilskyi (Tatarysky), Ukraine

Iwona Sobkowiak-Tabaka¹ · Natalia Gerasimenko² · Aldona Kurzawska^{1,3} · Bernadeta Kufel-Diakowska⁴ · Magdalena Moskal-del Hoyo⁵ · Mateusz Stróżyk⁶ · Yevhenii P. Rohozin² · Bogdan Ridush⁷ · Yevhenii Levinzon⁸ · Petro Boltaniuk⁹ · Pavlo Nechytailo¹⁰ · Aleksandr Diachenko¹⁰

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Abstract

The evolution of Neolithic to Bronze Age settlement organization in Central Europe has revealed ditches as an important component of settlement structures. The various shapes and sizes of these features contribute to different understandings of their functions, mainly referring to ditches as elements of fortifications or ritual practices. Based on a newly discovered Copper Age feature at Kamianets-Podilskyi (Tatarysky), Ukraine, our paper contributes to the discussion on the function of ditches in their relation to prehistoric technologies. This study presents evidence on tanning techniques and technologies associated with a section of ditch belonging to the Western Trypillia culture. Due to the uniqueness of this discovery, we applied various analyses, including GIS spatial analyses, palynological, anthracological, archeozoological, malacological, and use-wear studies. The obtained results enable us to recognize the complex practices of Copper Age communities, skillfully combining technical knowledge with an understanding of environmental conditions.

Keywords Cucuteni-Trypillia cultural complex · Ditch · Tannery · Leather · Technology

✉ Iwona Sobkowiak-Tabaka
iwosob@amu.edu.pl

✉ Aleksandr Diachenko
adiachenko@iananu.org.ua

Natalia Gerasimenko
natalia.gerasimenko@knu.ua

Aldona Kurzawska
aldona.kurzawska@amu.edu.pl

Bernadeta Kufel-Diakowska
bernadeta.kufel-diakowska@uwr.edu.pl

Magdalena Moskal-del Hoyo
m.moskal@botany.pl

Mateusz Stróżyk
mat_stroz@wp.pl

Yevhenii P. Rohozin
rohoin@gmail.com

Bogdan Ridush
b.ridush@chnu.edu.ua

Yevhenii Levinzon
yevlev@amu.edu.pl

Petro Boltaniuk
arxeolog.militari@gmail.com

Pavlo Nechytailo
nechitajlo@ukr.net

¹ Faculty of Archaeology, Adam Mickiewicz University in Poznań, Uniwersytetu Poznańskiego 7, 61-614 Poznań, Poland

² Taras Shevchenko National University of Kyiv, Kyiv, Ukraine

³ Institute of Archaeology and Ethnology, Polish Academy of Sciences, Poznań, Poland

⁴ Institute of Archaeology, Wrocław University, Wrocław, Poland

⁵ W. Szafer Institute of Botany of the Polish Academy of Sciences, Kraków, Poland

⁶ Poznań Archaeological Museum, Poznań, Poland

⁷ Yuriy Fedkovych Chernivtsi National University, Chernivtsi, Ukraine

⁸ Doctoral School of Humanities, Adam Mickiewicz University in Poznań, Poznań, Poland

⁹ Kamianets-Podilskyi State Historical Museum-Reserve, Kamianets-Podilskyi, Ukraine

¹⁰ Institute of Archaeology, National Academy of Sciences of Ukraine, prosp. Volodymyra Ivasiuka 12, Kyiv 04210, Ukraine

Introduction

The evolution of Neolithic to Bronze Age settlement organization in Central Europe reveals ditches of various shapes as an important component of settlement structures. Understanding of these features is closely related to prehistoric people's risk management, both rational and irrational (e.g., Fitzhugh 2001; Hintze et al. 2015). Ditches are interpreted as fortification systems, astronomical observatories, enclosures for keeping cattle, or markers of social separation (reviewed in Parkinson and Duffy 2007; also see: Raczky and Anders 2008; Borić et al. 2018; Füzesi et al. 2020, 2023; Vondrovský et al. 2022). Recent excavations have identified numerous burials within ditches (Orschiedt and Haidle 2006; Teschler-Nicola 2012; Furholt et al. 2020). From c. 4300 BC numerous ditches were dug out at the settlements of the Cucuteni-Trypillia cultural complex (CTCC) to the east of the Carpathians. This paper discusses the production processes within a ditch evident from the recent exploration at the settlement of Kamianets-Podilskyi (Tatarysky) referred to as the Western Trypillia culture (WTC), a part of the CTCC. The site is also transliterated in the literature as Kamenets-Podolskiy (Tatarysky), hereinafter we will place alternative transliteration in brackets to avoid confusion.

A general understanding of the function of CTCC ditches reflects interpretations of such features, which were discovered at the sites of various cultural units in Central and South-Eastern Europe. Fortification components and ritual purposes were the most common assumptions resulting from the excavations preceding the Trypillia megasites revolution of the early 2010s as defined by John Chapman et al. (2014). A remarkable example comes from the Final WTC settlement at Mayaky (Mayaki). Excavating the comprehensive system of ditches at the south-eastern part of Mayaky, Volodymyr Zbenovich (1974) understood this system as the remains of a fortification. Later explorations of the north-western part of the same site by Vladyslav Petrenko (1989) resulted in the interpretation of the ditch system as being used for ritual purposes. Currently, both assumptions are being questioned by Igor Sapozhnikov, who assumes that the ditches in Mayaky were used for (unspecified) production purposes (Sapozhnikov et al. 2019). Although other alternative interpretations were suggested for single sites, these were not generalized to cover a number of ditches. For instance, Natalia Skakun (2005) assumes that the ditch in the Middle WTC settlement of Bodaky (Bodaki) functioned as a water drainage.

The interpretation of ditches as parts of site defense systems was well-grounded by Valentin Dergachev

(2007). According to his results, the intensification of rampart construction and digging ditches at the sites stylistically referred to Cucuteni A/AB – Trypillia BI/BI-II and Horodistea-Foltesti type – Trypillia C II corresponds to an increase in the number of weapons, indicating the increasing tensions among CTCC populations and their neighbors. The absolute dating of these periods also corresponds to climate shifts (e.g., Gerasimenko 1997, 2015). The latter probably caused a decrease in resources and clashes among different groups of CTCC populations in addition to probable conflicts between populations referred to different archeological cultures, which further resulted in serial migrations to the east (e.g., Diachenko 2012; Harper et al. 2019).

Current geophysical work at CTCC settlements of different periods identified far more ditches than previously assumed (e.g., Mischka et al. 2016; Rassmann et al. 2016a, 2016b; Asăndulesei et al. 2020; Rud et al. 2021; Saile et al. 2021). However, a significant increase in the number of known features did not change the general interpretative frameworks. For instance, a section of the ditch encircling the c. 240-ha Middle WTC mega-site of Nebelivka (Nebelivka) was associated with a base of a palisade by Natalia Burdo and Mykhailo Videiko (2016) and alternatively interpreted as a feature separating the living space from the outside world by Chapman et al. (2016). Alternative explanations may be exemplified by Robert Hofmann and collaborators' (Hofmann et al. 2019) understanding of the ditch in the internal part of the Middle WTC site of Maidanetske as an enclosure.

Our paper presents evidence of a tannery functioning within a section of WTC ditch in Kamianets-Podilskyi (Tatarysky). Although leather, like many other perishable items, e.g., wood, fibers, and furs, are exceptionally rarely recorded in archeological finds, it was most probably one of the first materials to accompany humans since prehistoric times. In Europe, the oldest tools serving for hide processing are known from the Early Upper Paleolithic site at Canyars (Spain), dated to 39,600 BP (Doyon et al. 2023). The practice of leather tanning was one of the most important crafts, as it produced materials commonly used for clothing, footwear, hunting equipment, transportation objects, housing, boiling equipment, residential interiors, musical instruments, and many other products (Grömer et al. 2017; Doyon et al. 2023). Recent evidence indicates that not only animal but also human leather was used for producing certain items (Brandt et al. 2023). Data analysis leading to the conclusion on tanning processing within a WTC ditch is followed by a brief discussion of the extrapolation of our outcomes in order to understand the function of the other CTCC ditches.

A ditch at the WTC settlement Kamianets-Podilskyi (Tatarysky)

The WTC settlement of Kamianets-Podilskyi (Tatarysky) is located on the hill-shaped ledge of a plateau to the south of Kamianets-Podilskyi castle (48° 40′ 13″ N, 26° 33′ 37″ E – the centre of the site) in the western part of Central Ukraine (Figs. 1 and 2). This site is taxonomically referred to the Mereșeuca group of the WTC and dated to c. 3950–3900 BC (Levinzon 2021; Diachenko and Sobkowiak-Tabaka 2020, 2021). The settlement has been known since 1926. Collections from intensive surface surveys are kept by the Kamianets-Podilskyi State Historical Museum-Reserve and the Archeological Laboratory of the Kamianetš-Podilskyi Ivan Ohiienko National University (Levinzon 2021). The excavations at Kamianets-Podilskyi (Tatarysky) were conducted in the framework of the project ‘Dynamics of prehistoric culture: Comprehensive analysis of records from Southeastern and Central Europe’ in 2019–2021 and preceded by geophysical surveys.

The geophysical plan of Kamianets-Podilskyi (Tatarysky) represents ditches as linear anomalies of positively high magnetic values (up to 15 nT) indicating the infilling of these features with sediments, which are different from the geological background (Fig. 2A; Niebieszczański

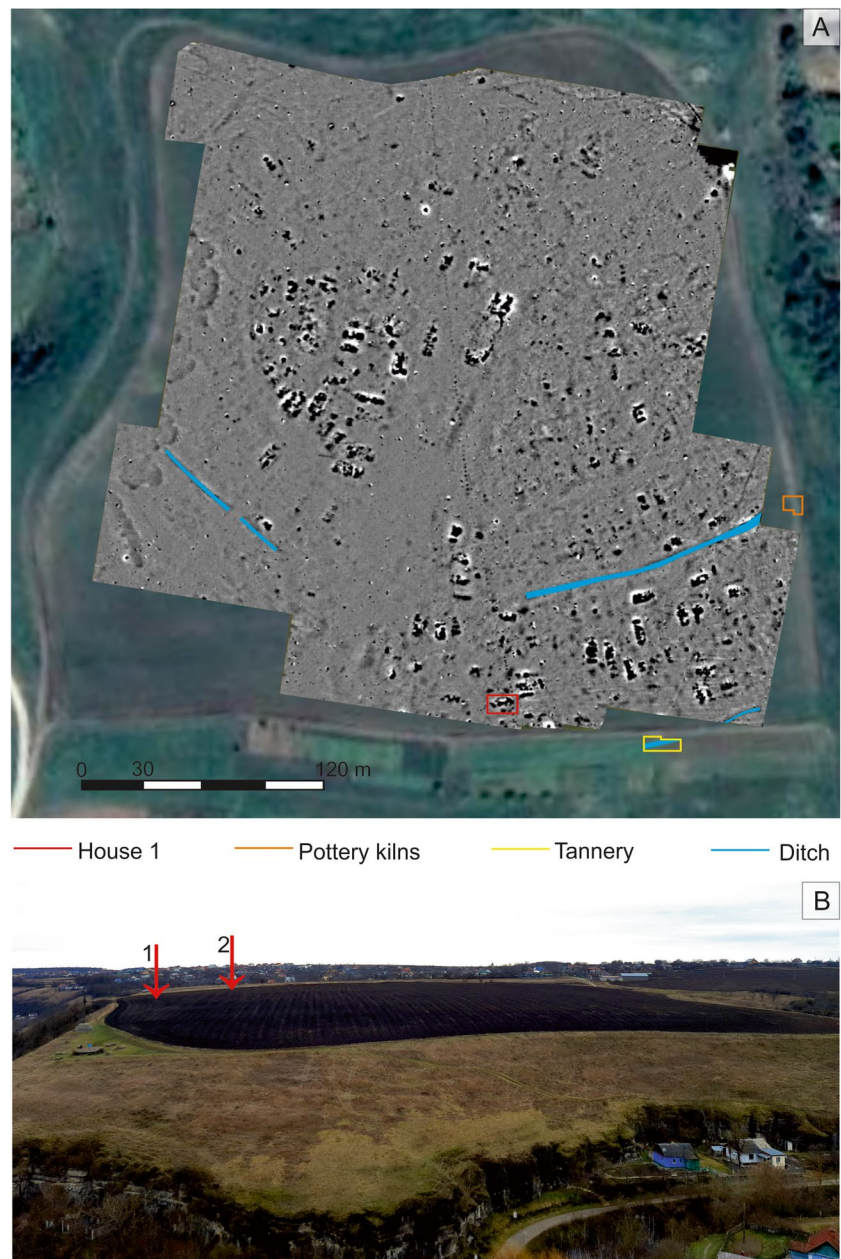
et al. in preparation). Interpretation of the geophysical anomalies reveals two ‘interrupted’ ditches. The first one (northern) separates features in the internal part of a settlement from the small clusters of features located to the south of the internal part. The second, southeastern ditch encircles a site (in case it is not continued to the south), or separates small clusters of features from the southern part of a settlement (in case it continues to the south). Geophysical anomalies of similar shape in the northeastern and northwestern parts of a site seem to result from modern agricultural activities because their magnetic properties are much higher than those registered for the ditches in the south. The latter’s width measures from 4 to 12 m (Niebieszczański et al. in preparation).

Excavations aiming to specify the usage of ditches in Kamianets-Podilskyi (Tatarysky) and to obtain the pollen data were conducted in the 2020 and 2021 field seasons. More specifically, a section of the southeastern ditch was excavated to the south of the field road crossing the site, in the area that was not a subject of geophysical surveys because of the growing plants and related problems in negotiations with the local farmer. Due to the latter, we decided to excavate a section of the southeastern ditch, which part is visible on a geophysical plan, continuing in a non-surveyed area (Fig. 2).



Fig. 1 Kamianets-Podilskyi (Tatarysky). Site location (M Stróżyk, I Sobkowiak-Tabaka)

Fig. 2 Kamianets-Podilskyi (Tatarysky). Site location. **A** Geophysical plan of the settlement (modified after Niebieszczański et al. in prep). Features of rectangular shape represent WTC dwellings and (the largest rectangular anomaly in the internal part of a settlement) mega-structure. Small anomalies of round shape correspond to pits and/or kilns. Interrupted curved lines represent WTC ditches. Anomalies arranged into a dotted line crossing the site represent the remains of modern (Soviet-time) power-line; **B** A view on the WTC settlement from Kamianets-Podilskyi castle (a view from the north). 1 – internal ditch, 2 – external ditch (photo by Ye Levinzon)



The feature's planigraphic shape was visible at Trypillia-time surface, i.e. at a depth of c. 60 cm from the modern surface. Its depth varies from c. 1.6 m to 1.2 m from the Trypillia-time daily surface decreasing along the west-east axis corresponding to the slope of the plateau's ledge (Fig. 2B). The infill of the ditch is represented by humus loam, more intensively humified at the bottom. This infill includes WTC artifacts and animal bones redeposited here from the surface after the abandonment of the settlement. However, deliberate deposition may be assumed only for a *Bos primigenius* skull due to such deliberate depositions at the other CTCC sites usually associated with abandonment rituals concerning site features or the settlement

as a whole (examples of similar depositions come from the settlements Bernashivka (Bernashovka): Zbenovich 1980, Luka Vrublivetska (Luka Vrublevetskaya): Bibikov 1953, Vasylivka (Vasilievka): Shumova 1990). Artifacts are mainly represented by pottery fragments which are identical to the ceramics coming from the excavations of other features and surface collections. WTC pottery fragments (41 sherds of different sizes) at the solid rock bottom of sub-ditches (see below) suggest their redeposition to the feature from the surface of a settlement in a very short time after the abandonment of the ditch. Materials dated to other periods were not found at this depth. Along with the radiocarbon dates obtained from the bone samples

Table 1 Kamianets-Podilskyi (Tatarysky). Radiocarbon dates

Lab ID	Sample	Context	14C Age	%C	%N	%Coll	calBC (2σ)
Poz-157280	Animal bone (<i>Bos primigenius</i> f. <i>taurus</i>)	Ditch	4950 ± 40	0.7	4.3	1.4	3896–3880 (2.1%) 3800–3642 (93.3%)
Poz-119956	Animal bone (<i>Sus scrofa</i> f. <i>domestica</i>)	House 1	5070 ± 35	1.4	6.8	1.5	3961–3782 (95.4%)
Poz-119957	Animal bone (<i>Bos primigenius</i> f. <i>taurus</i>)	House 1	5100 ± 40	1.7	7.4	3.5	3978–3794 (95.4%)
Poz-157281	Animal bone (<i>Bison bonasus</i>)	Ditch	5160 ± 40	0.9	4.8	2	4152–4149 (0.2%) 4050–3928 (78.5%) 3921–3916 (0.4%) 3876–3804 (16.4%)
Poz-140805	Animal bone (<i>Sus scrofa</i> f. <i>domestica</i>)	Ditch	5210 ± 40	0.9	6.9	1.7	4226–4198 (4.2%) 4166–4127 (9.9%) 4114–4098 (1.4%) 4069–3952 (79.9%)

Dates were calibrated according to the IntCal 20 Northern Hemisphere curve (Reimer et al 2020) in OxCal version 4.4.4 (Bronk Ramsey 2021)

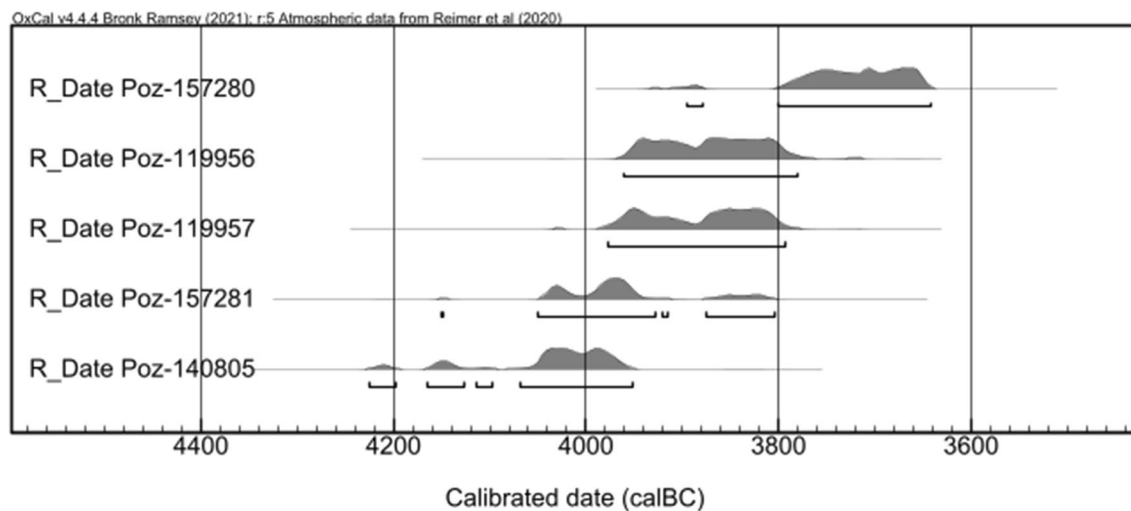


Fig. 3 Kamianets-Podilskyi (Tatarysky). Calibration of radiocarbon dates (Poz-Poznań Radiocarbon Laboratory; Dates were calibrated according to the IntCal 20 Northern Hemisphere curve (Reimer et al 2020) in OxCal version 4.4.4 (Bronk Ramsey 2021)

coming from the bottom and infill (redeposited from the surface of a settlement) of the ditch (Table 1, Fig. 3), the finds suggest that the ditch functioned synchronously with the houses and pottery kilns which we excavated at this settlement. If not affected by the curve anomalies, slightly older intervals of two calibrated dates (Poz-140805 and Poz-157281) are probably caused by the location of samples in a bottom layer of the ditch including mollusk shells causing the impact of the reservoir effect (Walanus and Goslar 2009). One more date (Poz-157280) from the upper part of the ditch's infill may also represent some activities at the place of the abandonment settlement of Kamianets-Podilskyi (Tatarysky) by the inhabitants of the nearby located settlement of Kamianets-Podilskyi ('Polskyj Rynok', known also as 'The Old City') dated in the range

of 3710–3645 BC (see the details of combining relative and absolute chronology of sites in Harper et al. 2021).

In one place the upper part of the ditch was interrupted by a medieval feature (fourteenth–fifteenth century AD) possessing a nearly rectangular shape in plan. This sunken feature, probably, represents the basement of a house. It should be noted that the rare artifacts (21 pottery sherds and four iron artifacts) of this time period were found only within the Late Medieval feature, on the modern surface, and in the upper 50 cm of the excavation site. Along with the location of the chernozem in the profile (the upper layer: Fig. 5), the location of this feature may indicate a shallow depression above the WTC ditch in Medieval times.

The lower part of the features is composed of three sub-ditches (i.e. three small ditches with the central one being

the deepest, which were dug up in the bottom of a whole ditch) that were dug into sterile sediments, namely calcareous gravel-pebble rubble including numerous shells and their fragments (Figs. 4 and 5). The depth of the sub-ditches reaches 30–40 cm, with their width varying from 10–20 cm to 50–60 cm at their flat bottom. According to the finds of identical ceramics and radiocarbon dates obtained from the

samples coming from the bottom of the second and third sub-ditch, they are contemporaneous with each other. Therefore, sub-ditches representing an ‘alternative’ to a simple single bottom of the whole ditch should not be considered in frames of different construction phases. Several thin layers of calcareous gravel-pebble rubble ‘falling’ from the Trypillia-time daily surface into the ditch (or from the north to the south in



Fig. 4 Kamianets-Podilskiy (Tatarysky). **A** View of the feature from the quadcopter. 1, 2, 3 – sub-ditches (photo by S Kovalenko). **B** View of the fireplace (photo by Ye Levinzon)

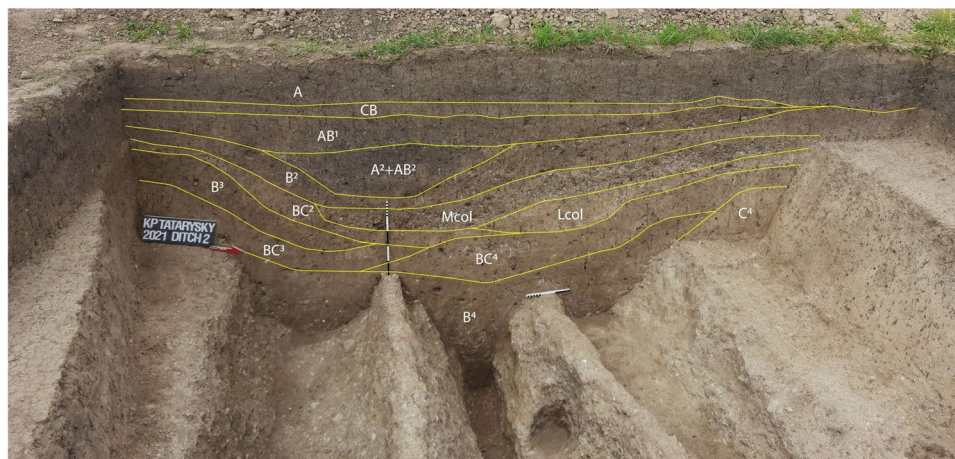


Fig. 5 Kamianets-Podilskiy (Tatarysky). KP-profile of the feature. A – humus horizon of the modern soil; CB – the lower transitional horizon of the modern soil; AB¹ – the 1st buried soil (humus-transitional horizon); A²+AB² – the 2nd buried soil (preserved in the paleogully); B² – the 2nd buried soil (the transitional horizon); B³ – the 3rd buried soil (the transitional horizon); BC³ – the 3rd buried soil

(the lower transitional horizon); Mcol – coarse colluvium (Miocene deposits washed in the paleodepression from the Chalcolithic spoil heap); Lcol – re-deposited loess from the Chalcolithic spoil heap; BC⁴ – the 4th buried soil; B⁴ – the 4th buried soil (Chalkolithic); C⁴ – the parent rock (photo by Ye Levinzon, drawing by P Boltaniuk and N Gerasimenko)

the profile) indicate their redeposition in the direction of the central part of the settlement (Fig. 5: layers BC⁴, Mcol, B²).

At least two fire-affected locations were indicated at the edges of the southern sub-ditch, on the upper part of the layer of calcareous gravel-pebble rubble. The larger fire-affected location, c. 1 × 1 m, was located in the western part of the excavated area (Fig. 4A, B). To the north of it, two pairs of postholes were explored. The first pair (20 and 26 cm in diameter) was located in the northern wall of the central sub-ditch. The second pair of postholes (30 and 33 cm diameter) was explored in the northern wall of the ditch. To recognize the function of the explored complex features, a multi-proxy analysis was carried out for the infill of the ditch, the accompanying fires, and the materials deposited within them. Additionally, we applied drainage analysis at a micro-regional scale aiming to identify ancient watercourses.

Materials and methods

Drainage analysis

To determine the hydrological situation in the area of the site location, a topological analysis of the drainage network was carried out. This term is defined in geomorphological significance as the local hydrological trend, independent of contemporary meteorological and hydrological conditions (Jasiewicz 2010). The analysis takes into account the topological possibility of water flows, and the whole drainage network including dry valleys (Jasiewicz and Hildebrandt-Radke 2009), making the results hypothetical. The division of the network is carried out by order reduction according to Strahler's stream classification (Strahler 1952; Jasiewicz and Hildebrandt-Radke 2009; Jasiewicz 2010) on a digital model that has previously been corrected by filling sinks (Planchon and Darboux 2001; Jasiewicz 2010). The basis of the modeling was a digital terrain model obtained from a topographic map at a scale of 1: 25,000 with height intervals of 5 m, and 2.5 m in local places. Terrain surfaces were obtained by adding discontinuity lines from the obtained vectors. The Delaunay interpolation method was used, resulting in a grid of irregular triangles (TIN, Triangulated Irregular Network). The sampling density of the GeoTIFF raster grid was 10 m. Such a model is a sufficient form of terrain representation for this analysis, taking into account the resolution involved.

Analysis of paleobiological remains

Sediment samples for paleobiological analysis were taken from the bottom part of the profile (the western wall of the excavation site: (Figs. 5 and 7). A total of two parallel columns of 9 samples, with a volume of 500 cm³ each,

were collected from layer no. 11, beginning from 140 cm below the topsoil, to a depth of 230 cm (total thickness of the sample: 90 cm). The first column of samples was submitted for palynological analysis and the second one for malacological and anthracological analysis. The samples from the second column were soaked in water, and, after 48 h, floated and sifted through 2.5, 1.2, and 0.5 mm mesh screens. The resulting dried fraction was submitted for further analysis. Additional samples (c. 3000 cm³) were taken from the bottom of the ditch (sample 1 and sample 2), as well as from two fireplaces (fireplace 1 and fireplace 2 located close to the discovered structure/ditch (Table 2, Fig. 7).

Eleven samples from the Kamianets-Podilskyi (Tatarsky) site, namely, the profile and two samples from the fireplaces within the feature, were submitted for paleobiological research. After drying, the obtained material from the collected profile was sorted under a stereoscopic microscope, selecting charcoals, seeds, and fruits of plants suitable for taxonomic identification, as well as mollusk shells.

Palynological analysis

First, a column of 9 samples from profile KP (Fig. 7) of sediments from the ditch infill was palynologically analyzed (Table 2). The palynological sample processing has followed a technique (Malyasova and Spiridonova 1989) which includes maceration and separation. Maceration consisted of such procedures: physical removal of large particles; boiling of a 100 g sample in the listed below chemicals, with the following sediment decanting after each step in distilled water to a neutral reaction and transparent state. The chemicals were a 10% solution of HCl in order to remove carbonates; a 25% solution of sodium pyrophosphate in order to remove clay particles, a 10% solution of HCl in order to remove secondary carbonates, which were constitutes of clay-carbonate covers of pollen grains; and 10% solution of KOH to remove organic matter. In order to separate palynomorphs and silt particles most completely, separation was done in heavy liquid (CdI 2 and KI) with a specific gravity of 2.2. The methodology was modified for the samples from the lower part of the ditch infilling, which included a large part of sand grains, by supplementary treatment with a cold solution of HF, applied for at least 24 h.

The numbers of counted palynomorphs were higher in the depth interval 0.9–0.5 m than in the interval 0.5–0.0 m. In the former interval, palynomorph counts were between 436 and 337 per sample, whereas in the latter between 230 and 171. The decrease in palynomorph numbers is due to the enrichment of these samples in sand and clastic material as compared to finer-grained upper samples. A total of 4018 palynomorphs has been identified. The majority of pollen was well preserved. The good pollen preservation might

Table 2 Kamianets-Podilskyi (Tatarysky). Description of paleobiological samples from the W profile of the ditch: core samples, samples from the bottom of the ditch (samples 1 and 2), and samples from the fireplace (A and B)

Samples	Palynomorphs		Charred plant remains		L/F ^a mollusc shells		Miocene fossil mollusk shell fragments ^b			
	n	Nymphaea aceae %	n	<i>Fraxinus</i> sp.	<i>Quercus</i> sp.	deciduous		n	L%	F%
PROFILE KP										
80 – 90 cm	436	0.9	4	25	50	25	4	100		+
70 – 80 cm	337	0.8	0				4	100		+
60 – 70 cm	432	0.3	0				7	50	50	++
50 – 60 cm	466	0.6	2	50		50	4	50	50	+++
40 – 50 cm	230	0	0				0			++
30 – 40 cm	164	0.9	0				2	50	50	+
20 – 30 cm	222	0.9	0				0			+
10 – 20 cm	177	6.9	0				2	100		+
0 – 10 cm	171	0	0				1	100		+
Sample 1	388	0	4	25	75		9	50	50	+++
Sample 2	424	0	6		50	50	4	100		+++
Fireplace A	not analyzed	not analyzed	30	100			not analyzed	not analyzed	not analyzed	not analyzed
Fireplace B	not analyzed	not analyzed	0				not analyzed	not analyzed	not analyzed	not analyzed

^aL- land snails; F- freshwater mollusk

^bMiocene fossil mollusk shell fragments were not quantified, as they form a significant part of the sediment in the examined samples. Intensity of remains in the samples: + low ++ medium +++ high

indicate that its majority was air-born or delivered from the plots, close to the ditch edges. Some small tricolporate scabrate pollen grains were crumpled and left unidentified, but their morphology proves that they belong to the group of forbs.

Pollen has been identified (under magnifications of $\times 400$ and $\times 600$) with the use of spore-pollen atlases (Kuprianova and Alyeshina 1972, 1978; Bobrov et al. 1983; Reille 1995, 1998), and with the use of the palynomorph reference collection of the Department of Earth Science and Geomorphology (Taras Shevchenko National University of Kyiv). The majority of pollen of arboreal taxa has been determined at the level of genera and species, as these have been well studied in surface samples and fossil spectra of many other sections in the investigated area. The majority of non-arboreal pollen taxa and spores has been identified at the level of families. Pollen of *Nymphaea alba* has been determined using a key for identification of pollen grains of species of Nymphaeaceae family (Kuprianova and Ayoshina, 1978, p. 47, photos in Table XXV). The percentages of arboreal pollen (AP), non-arboreal pollen (NAP), and individual taxa have been counted from the sum of AP and NAP. Spores and NPP were counted in addition to this sum.

The presence of microcharcoal in various intensities was attested along the whole profile and in the samples from Profile W and E of the ditch itself.

Anthracological analysis

The remains of charcoal from two samples (80–90 cm and 50–60 cm of KP profile), samples 1 and 2, and from fireplace no. 1, were studied at the Palaeobotany and Palaeoenvironment Group of the W. Szafer Institute of Botany of the Polish Academy of Sciences (IB PAS) by using a reflected light microscope with 100–500 \times magnifications. Each charcoal fragment is analyzed separately as an observation and count unit. It is observed in three anatomical sections of wood, namely a transverse section, a longitudinal radial section, and a longitudinal tangential section. A given charcoal fragment, depending on its size, state of preservation, and anatomical characteristics, may be identified as belonging to various levels (species, genus, family) or may generally be included in the group of conifers or deciduous trees and shrubs. Due to the lack of clear diagnostic features, the wood of trees and shrubs occurring in Central Europe is most often determined at the genus level. Taxonomic identifications are compared with anatomical atlases (e.g., Schweingruber 1990) and modern reference collections. Micrographs were taken in the Laboratory of Scanning Electron Microscopy and Microanalysis at the Institute of Geological Sciences, Jagiellonian University (HITACHI S-4700). Although the samples do not contain any charred carpological material,

a single uncharred fruit of wood avens (*Geum urbanum*) was found (determined by S. Skoczylas-Śniaz). As this is an introduced species, it is most likely from a recent plant growing near the site.

Malacological analysis

Mollusk remains were selected from the dried samples, nine in total from the KP Profile, and two samples from the bottom of the ditch (samples 1 and 2). They were identified using a Nikon SMZ445 stereomicroscope and Keyence VHX-7000 digital microscope at the ArchaeoMicroLab of the Faculty of Archeology, Adam Mickiewicz University, Poznań. The identification was based on species described by Welter-Schultes (2012) and a reference collection from the Institute of Archaeology and Ethnology, Polish Academy of Sciences.

Use-wear analysis

Microscopic observations of flint tools were carried out at the Laboratory of Archaeometry and Archaeological Conservation, Institute of Archaeology, University of Wrocław, with the use of an Olympus SZX9 stereomicroscope ($\times 6.3$ –114) for recording scars and a Nikon ECLIPSE LV100 metallographic microscope ($\times 50$ –500) for analyzing polish and linear traces. Prior to microscopic observations, the artifacts were cleaned in an ultrasonic tank (a 2-min bath in water). For the interpretation of use-wear, the reference collection of experimental tools stored in the laboratory was utilised.

Results

A detailed understanding of the discovered feature was made possible through a comprehensive range of analyses, the results of which are presented below.

Drainage analysis

The drainage analysis resulted in a denser watercourse network for the contemporary hydrological situation (Fig. 6A). The results of the drainage analysis suggest that two of the potential streams may have flowed in the vicinity of a section of the explored ditch (located between streams) in the past (Fig. 6B). The longitudinal anomalies from the geophysics continue as potential flows from the drainage network analysis (Fig. 6B).

According to Strahler's stream classification, the aforementioned stream would have possessed an order of 3 (in the analyzed area, watercourses assumed a maximum order

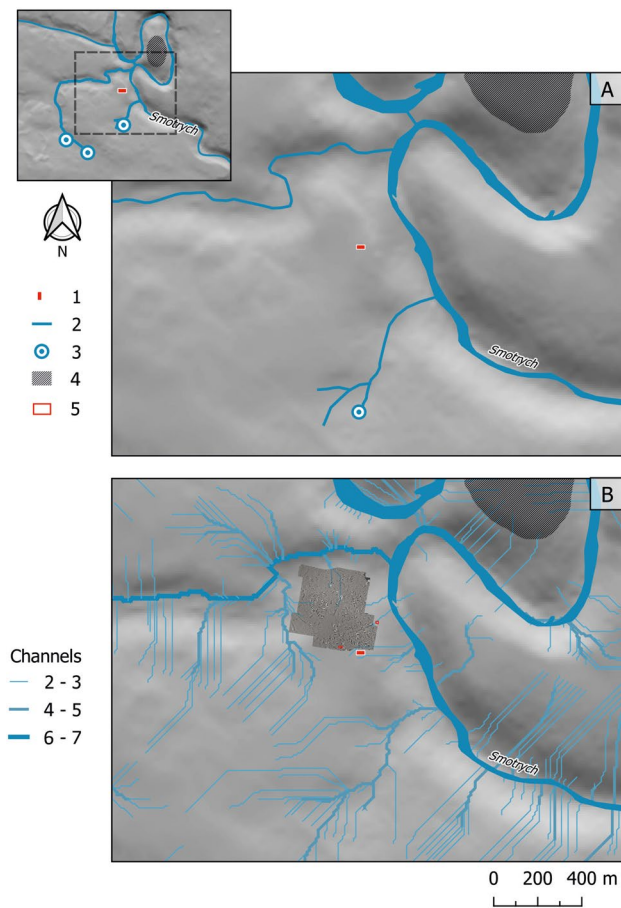


Fig. 6 Kamianets-Podilskiy (Tatarskyi): **A** Contemporary hydrological situation in the vicinity of a site. 1- location of the excavation-site; 2- rivers and streams; 3- water springs; 4- location of neighboring settlement Kamianets-Podilskiy (Polskyi Rynok); 5- location of the excavation-sites revealing house remains (to the left) and pottery kilns (to the right). **B** Results of the drainage analysis considering Strahler's stream classification (2–7) (M Strózyk)

of 7). It is worth mentioning that the currently existing stream is located almost 300 m to the south with a spring at 1800 m from the excavation site. This may indicate other springs on the hill that no longer exist, or that the watercourses may have taken a different course in the past.

Analysis of paleobiological remains

Paleobiological samples taken from the infill of the ditch provided a variety of interesting information to aid in the interpretation of the discovered structure. In our studies (including palynology, anthracology, and malacology), we primarily focused on identifying remains related to the use and exploitation of the structure (Fig. 7). The collected samples contained a similar composition of organic remains, suggesting their accumulation under similar

sedimentation conditions and the use of the structure in the same way for up to 50 years.

Palynological analysis

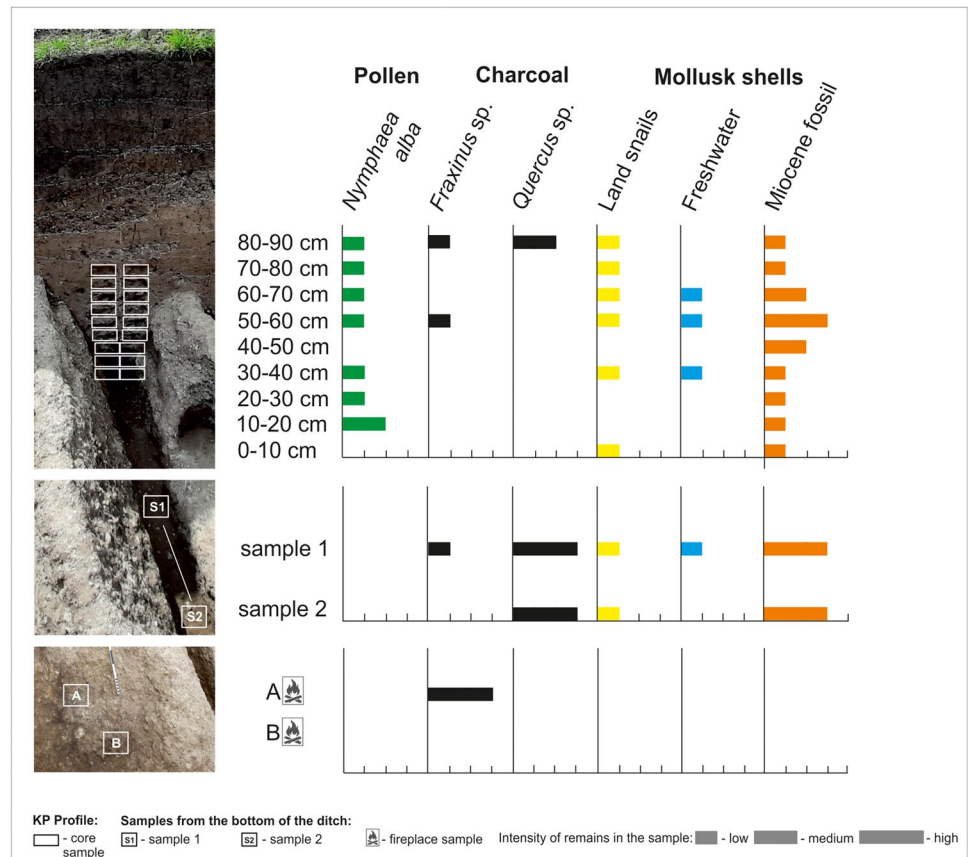
In the bottom layers of the ditch (0.0–0.4 m), the proportion of arboreal pollen (AP) is larger (47% on average) than non-arboreal pollen (NAP), whereas in the upper layers of the ditch, it changes from the average 37% (0.4–0.6 m) to the average 26% (0.6–0.9 m). In the surface sample, with undisturbed vegetation cover, it is 48%. The AP is dominated by *Pinus sylvestris*, whose percentages change irregularly, though reaching higher values (up to 45–47%) in the lower part of the ditch, and the smallest values in its upper part (7–11%, in the 0.9–0.6 m interval). The *Picea abies* pollen values reach 4–5% only in the lower part of the ditch infilling, and *Quercus robur* pollen reaches 1–2% only there. Otherwise, their percentages are less. *Carpinus betulus* pollen (2%) is present only in the lowest sample. *Tilia cordata* pollen (1–3%) occurs in all the samples, as well as *Ulmus* sp. (<2%). *Corylus avellana* pollen (4–13%) is second in abundance after *Pinus*. Pollen of hygrophytic *Alnus glutinosa* rarely reaches 2%.

The NAP is dominated by diverse forbs: 13–43%, 21 taxa (without Asteraceae). In Ukraine, this group is abundant in the mesophytic steppe vegetation (Barbarych 1977; Didukh and Shelyag-Sososnko 2003). Amaranthaceae and Asteraceae are second in abundance (5–23% of each), and Poaceae – third (1–11%; 11% occurred only in the two upper samples). *Artemisia* percentages change irregularly (0–3%). Cyperaceae pollen values, which are represented by hygrophytic plants in the studied area, are less than 1%. Cerealia pollen occurs in three samples reaching 2% only in one sample. Pollen of other indicators of human activities (*Centaurea cyanis*, *Plantago lanceolata*, Cannabaceae) happened more frequently than Cerealia pollen but in values <2%. Pollen of aquatics is represented only by Nymphaeaceae (0–0.9%, except the sample from the depth 0.10–0.20 m where its values reach 7%).

Forests were more abundant at the beginning of the ditch construction and they included more mesophilous species then. Nevertheless, at no time during the ditch's existence, the riverine or aquatic plants grow near the site. Pollen percentages of *Alnus glutinosa* and Cyperaceae are very low. No pollen of other water-dependent plants (*Salix* sp., *Filipendula ulmaria*, Lythraceae, etc.) is present. Thus, the growth of Nymphaeaceae in these landscapes seems improbable for ecological reasons. It seems more likely that the plants were introduced to the ditch by humans.

During the analysis of the recorded botanical remains, the most notable findings are the remains of Nymphaeaceae pollen (Fig. 8a, b) and charcoal, as they are directly associated with the function of the ditch. These remains were present

Fig. 7 Kamianets-Podilskyi (Tatarysky): Estimated diagram of paleobiological remains associated with the investigated structure (A Kurzawska). Quantitative data are provided in Table 2



in almost all samples of the KP-Profile with the exception of two samples from depths 0–0.1 and 0.4–0.5 m. As Nymphaeaceae pollen could neither have spread over significant distances nor survived re-deposition from local bedrocks, it must be contemporaneous with the time of the ditch's functioning. Moreover, as *Nymphaea alba* (white water lily) does not grow in small, shallow water bodies with running water but requires a muddy bottom, it is unlikely to have grown within the examined ditch. This suggests that plants, carrying pollen on their parts, were likely taken from river backwaters or a pond and brought to the settlement for a specific purpose.

Anthracological analysis

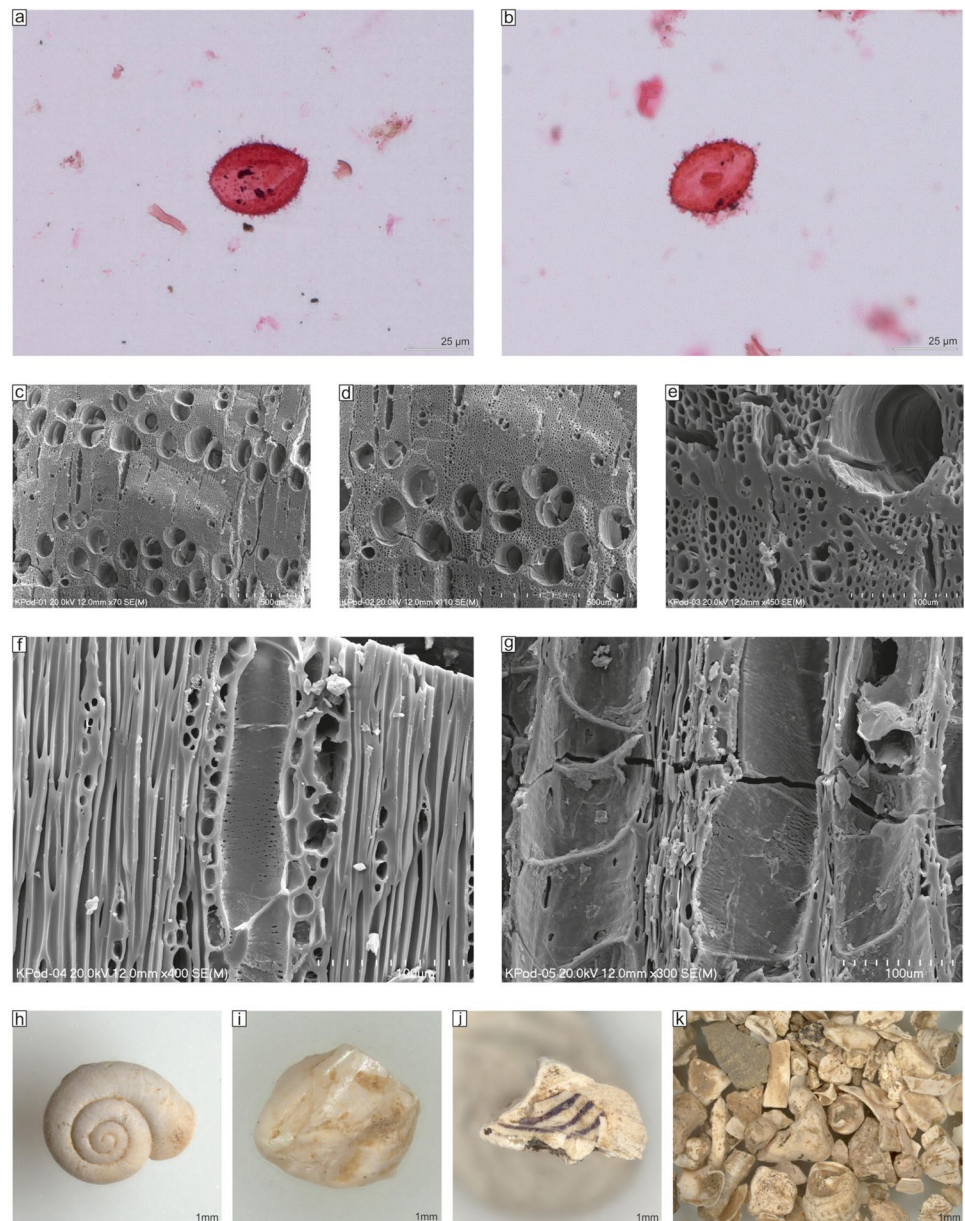
Plant macroremains, primarily charcoal, were found in two samples from the KP-Profile and two samples from the bottom of the ditch (samples 1 and 2), probably redeposited here from a fireplace (Figs. 5 and 7). The charcoal was well-preserved, small in size, with cross-sections mostly not exceeding 2 mm. Two taxa were identified, namely ash (*Fraxinus* sp.) and oak (*Quercus* sp. deciduous). While some badly preserved fragments have been classified as deciduous trees or shrubs, a few fragments could not be identified.

A sample taken from fireplace A revealed a charcoal concentration that contained ash (*Fraxinus* sp.) remains (30 fragments) – (Figs. 7, 8c–g), many of which exhibited traces of vitrification (Fig. 8c). Since this phenomenon cannot be easily reproduced under laboratory conditions, it is still unclear what conditions, i.e., exposure to high heat temperature, combustion with little oxygen and low gas liberation, or the burning of damp wood, influence the formation of this glassy structure (Théry-Parisot 2001; Carrión Marco 2005; Lityńska-Zajac and Wasylkowa 2005; McParland et al. 2010). The sample B from the fireplace did not contain any charcoal or plant remains.

Malacological analysis

Malacological remains were found in the examined samples within the silty sandy deposits mixed with gravel. The preservation of the remains was notably influenced by the sediment type, resulting in predominantly small and rounded shell fragments (Fig. 8h–k). The majority of shells belonged to fossil mollusks originating from the local bedrocks (Miocene deposits) found in the vicinity of the settlement site upon which the structure was built. Although they were found in all investigated samples, it was not possible to find

Fig. 8 Kamianets-Podilskyi (Tatarysky). Remains of *Nymphaea alba* pollen (a, b); fragment of ash *Fraxinus* sp. in transverse (c, d, e) and longitudinal tangential (f, g) sections; mollusk shells: h—*Vallonia pulchella*, i – a fragment of *Unio* sp., j – a fragment of *Theodoxus* sp., k—shell fragments of fossil shells (photo by A Kurzawska and I Sobkowiak-Tabaka, SEM micrographs by: M Moskal-del Hoyo)



a complete specimen for further identification (Fig. 8k). As they were most probably washed out of the bedrock, their presence in the samples presumably indicates water flow.

Among the shell finds, the most intriguing was isolated and constituted very small fragments of freshwater mollusk shells – specifically, bivalves of *Unio* sp. (found in samples from KP-Profile: 50–60 cm, 60–70 cm) (Fig. 8i) and a gastropod *Theodoxus* sp. (in samples: KP-Profile 50–60 cm and sample 1) (Fig. 8j). These species inhabit various flowing environments including rivers, streams and, in large lakes, areas with wave activity (Alexandrowicz and Alexandrowicz 2011). Finally, the small and rounded fragments of mollusk shells observed in the samples suggest the presence of flowing water within the ditch.

Land snail shells, although in small numbers, were identified in almost all samples, except for three samples from the KP-Profile (10–20 cm, 20–30 cm, and 40–50 cm). These snails most likely inhabited the vicinity of the structure. The most common species among them were shells of *Vallonia pulchella* (Fig. 8h), which typically thrive in open, unshaded environments with varying substrate moisture, particularly in grasslands (Wiktor 2004). *Succinea* sp. shells were found in two samples (30–40 cm, 60–70 cm) and are frequently found along riverbanks, as well as being characteristic of wet meadows and floodplain terraces, tolerating both shaded and open habitats (Wiktor 2004). These two species, *Vallonia pulchella*, and *Succinea* sp., are often associated with human-altered areas during the Holocene (such as deforested

and cultivated lands) (Alexandrowicz and Alexandrowicz 2011). *Chondrula tridens*, fragments of which were found in one sample from the KP-profile (80–90 cm) and in sample 2, are also characteristic of anthropogenically transformed environments. However, it is a typical species of dry, steppe-like, non-forested, and open habitats, thriving in strong sunlight and often found on limestone substrate (Wiktor 2004). Although there was a small number of shells (both land snails and freshwater mollusks) in each sample (1–5 specimens per sample), their presence indicates running water in the ditch (see below).

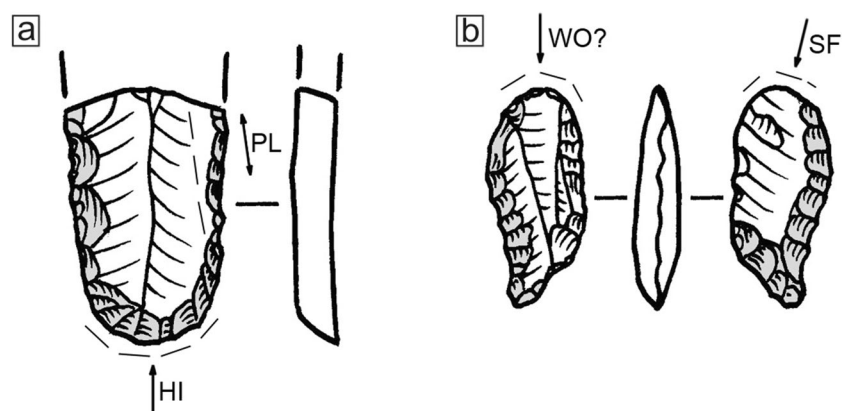
Use-wear analysis

Two retouched flint tools found in the bottom of a ditch (and, therefore, remained at this place or the Trypillia-time surface and redeposited into the feature in a short time after its abandonment) were subjected to use-wear analyses. They are distal fragments of an endscraper with abrupt retouching of two lateral edges and a perforator with alternating retouching of the tip and both sides (Fig. 9a, b). The endscraper is broken and missing its proximal part. Two working edges are distinguished, exhibiting contact traces with two different kinds of worked materials (Fig. 9a). The distal retouched edge of the endscraper displays traces of scraping hide. The edge is highly rounded and even. Dull hide-like polish is located on the very edge and as a band along the edge. It is accompanied by short scratches on the elevations of surface topography (Fig. 10a). A part of the left lateral edge displays plant polish. Gloss covers both sides of the edge. Although it is bright and reflected, it is not well-developed, meaning it is a border area in the sequence of microtraces along the edge of a plant-cutting knife or a sickle (Fig. 10b). Plant polish does not cover retouch scars on the dorsal side of the tool. Its ridges are sharp and intersect the gloss (Fig. 10c). This is also true for the scars on the ventral side. The opposite edge is sharp, slightly rounded only in the middle part. The endscraper is broken, with a sharp edge.

The perforator is complete. The tip was made in the distal part of the specimen by retouching the right side and a portion of the left side of the tool (Fig. 9b). No traces of use were recorded, either on the tip and adjacent edges or on the bifacially retouched left side. However, they are distinctly much fresher-looking than other parts of the tool. The proximal part of the perforator, together with its retouched right side and neighboring dorsal and ventral surfaces are highly abraded or polished. Gloss also covers the bottom parts of the retouched surface. The most worn parts are elevations, including bulbs of percussion, the butt surface, and ridges of negative scars. Elevations located on the ventral side of the right edge are highly rounded and abraded (Fig. 10d). Although the edge of the proximal part is also rounded, it displays a bright wood-like polish, perpendicularly oriented and intersected by dark or filled-in striations, suggesting transverse activity (Fig. 10e). The highly rounded dorsal part of the butt is covered by a polish with dark striations indicating its use as a strike-a-light (Fig. 10f).

The flint endscraper and perforator display traces of contact with more than one worked material. Moreover, they represent the final stage of modification and recycling of tools. Modifications included secondary retouching and changing the function of each specimen. In the first case, the flint tool was used as an insert of a plant harvesting knife or a sickle. After the blade was broken, probably due to use, three edges were retouched to produce an endscraper, then used for scraping hide. The transformation of plant harvesting tools into hide scrapers is frequently confirmed for Copper Age flint assemblages in Central Europe (Wilk and Kufel-Diakowska 2016; Sudoł-Procyk et al. 2017). In the second case, the retouched tool was modified into a perforator after long-lasting use, which was evidenced by a strong abrasion in the butt area. The traces of primary use are very well-developed. Types of gloss in the proximal part of the tool indicate contact with wood and mineral material. The above-mentioned marks could also have been produced as a result of striking fire (Sorensen et al. 2018). This would be a very common example of the utilization of Eneolithic

Fig. 9 Kamianets-Podilskyi (Tatarysky). Retouched tools from the tannery: **a** endscraper; **b** perforator. (PL plant, HI hide, WO wood, SF striking fire, arrows show the direction of movement, secondary retouching shown in gray; drawing D Kushtan, B Kufel-Diakowska)



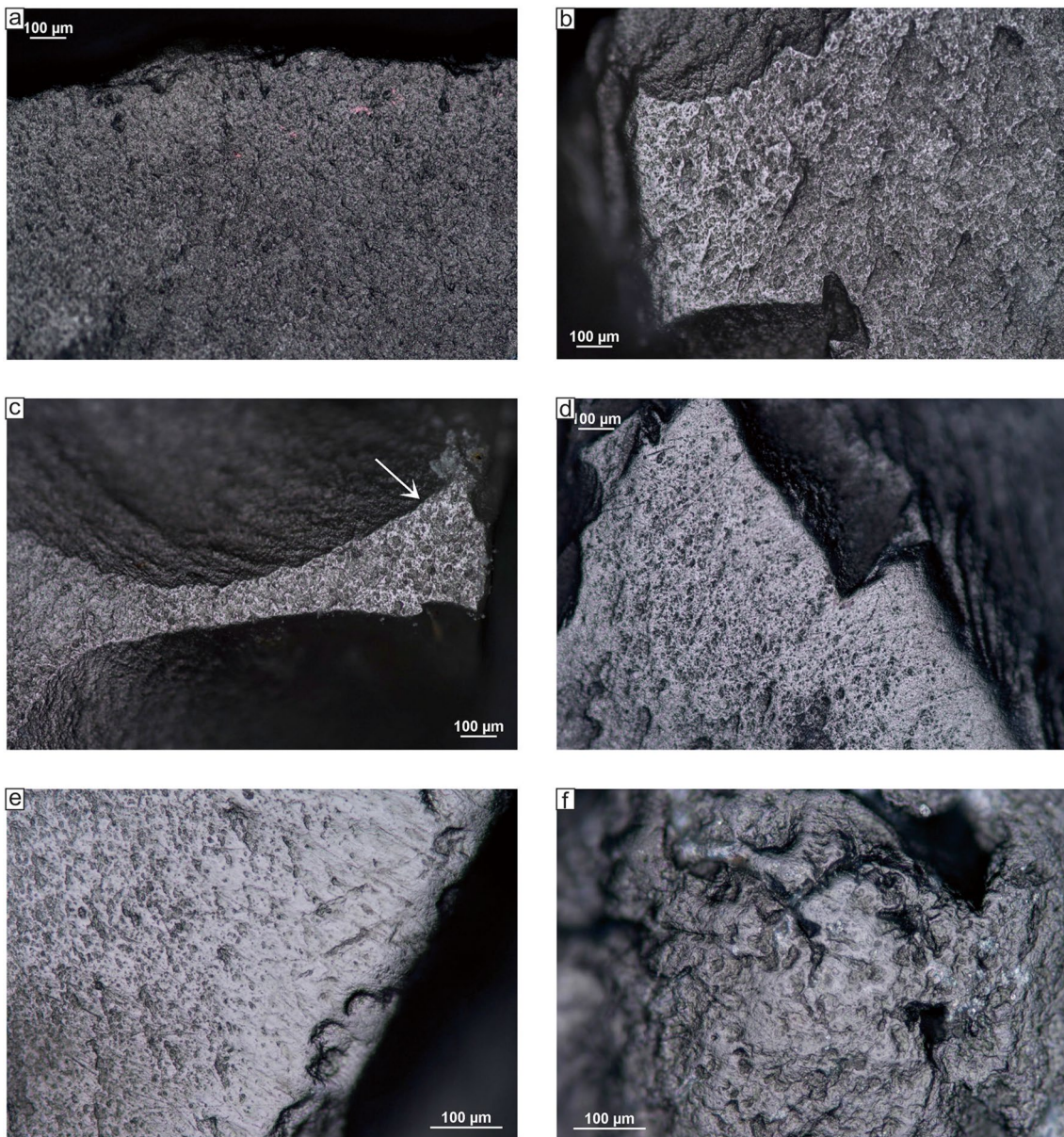


Fig. 10 Kamianets-Podilskyi (Tatarysky). Traces of use on the retouched tools. Endscraper: **a** hide-like polish, **b** plant polish, **c** plant polish intersected by secondary retouching; perforator: **d** abraded edges, **e** wood-like polish, **f** – strike-a-light (photo by B Kufel-Diakowska)

retouched blades and daggers as strike-a-lights. As no traces of use were recorded on the tip, we do not know if the tool was used after modification.

Discussion

The location of Kamianets-Podilskyi (Tatarysky) ditches on the slopes of the plateau's ledge with their lower elevations compared to the elevation of the top of the ledge, give rise to reasonable doubts regarding the possible function of the analyzed features having been defense purposes or water

drainage. Wide 'interruptions' in both ditches at the highest parts of a settlement (i.e., a part of a settlement requiring the most developed fortifications for defense purposes) in our case contradicts the widely spread 'fortification hypothesis' beyond the interpretation of the analyzed features (Fig. 2). The same applies for the interpretation of ditches as features separating the living space from the outside world. Ditch in Nebelivka, for which this explanation was suggested, has narrow 'interruptions' considered as entrances to a settlement (Chapman et al. 2016). In our case a wide 'interruption' in the internal ditch reaches c. 110 m, while the internal ditch length is c. 180 m (Fig. 2A). In other words, up to

40% of the hypothetical boundary is missing. The location of ditches at the slopes of the plateau's ledge disproves the water drainage assumption for the function of ditches in Kamianets-Podilskyi (Tatarysky) because water naturally flows down the slopes and the drainage purpose does not require any time- and labour-consuming structures (Fig. 2B). Based on the results of field exploration, spatial modeling, as well as archeobiological and use-wear analysis, we argue for the location of a tannery in the western part of the excavated section of the ditch as the explanation for the whole set of the obtained data.

Leather processing

Before the tanning process begins, the pelt must be appropriately prepared by soaking, dehairing, and fleshing. To accomplish this, the skins, particularly the larger ones, are stretched out on a wooden frame, and a scraper made of flint, bone, or metal is used to remove the thick layers of flesh and tissues. Ethnoarcheological analogies from Omdruman (Sudan) demonstrate that quicklime (CaO) is produced near the tanneries in lime kilns, and then skins are soaked in a liquid mixture of lime and water to remove the hair from the follicles (Skinner 2011). According to M. Shaw (2011), lime and ash, along with pits, wood fragments, bark, and scraping tools, provide the clearest evidence of a tannery.

A summary of the evidence justifying leather processing in the investigated part of the ditch in Kamianets-Podilskyi (Tatarysky) indicates the following.

- Easy access to a source of calcium for the production of lime. The site is located on flat layers of limestone underlying the calcareous gravel-pebble soil. Additionally, large quantities of fossil (Miocene) mollusk shells as a source for quicklime production are easily accessible in the natural sediments found at the site.
- Activities involving the use of fire, including the presence of plant remains probably utilized in the tanning and smoking processes (see below) as well as a flint tool used for striking fire
- Access to water resources
- The incorporation of wooden structures including pairs of posts
- The presence of flint tools serving for hide processing

These groups of evidence are considered to be the markers of a technological sequence (in its broad definition formulated by W. Brian Arthur (2009), related to the functioning of a tannery. Quicklime (CaO), a white caustic alkaline substance consisting of calcium oxide, is obtained by heating limestone (CaCO₃). Quicklime is further mixed with water resulting in the production of lime (Ca(OH)₂) used in leather processing. Additionally, limestone was used for painting

pottery (e.g., Ryzhov 2002) and external house walls, while the production of mollusk shells is assumed for the utility structure of the earlier settlement Voloshkovo-Gorby in the Middle Dniester region (Chernovol 2021). It should be noted that white paint features in a low percentage in the ceramic assemblage of the site. The evidence for painting house walls comes from the architectural remains in other WTC settlements (e.g., Chernovol 2012).

Although there are many methods employed to produce leather, i.e. treating skins with minerals (e.g. alum, lime, ochre), oil or fat, smoking, and rawhide derivatives (Skinner 2011; Grömer et al. 2017; Emmerich Kamper 2020), the most classic and oldest method of tanning is vegetable tanning (Moog 2005). The tanning process could be conducted in many ways – depending on the size of the skins – in large pits, wooden vats, or in a bag (Falcão and Araújo 2018). Most likely, vegetable tanning was invented in the eastern Mediterranean region during the Neolithic period (Haslam 1997; Goffer 2007; Rahme 2021). The skins were soaked in a liquid with parts of plants, e.g., leaves, twigs, fruits, bark, pods, galls, or roots containing tannins, protecting the plants from microorganisms, e.g. fungi, insects, or bacteria (Emmerich Kamper 2020). The vegetable tanning process in the pits usually takes up to two years, requiring the bark to be changed three or four times during this period (Rahme 2021). Although almost all wood or shrub plant material contains some type of tannin, the most useful in Northern and Central Europe is the bark of several species of oak (*Quercus*), alder (*Alnus*), birch (*Betula*), spruce (*Picea*), ash (*Fraxinus*), and larch (*Larix*), as well as the leaves of bearberry (*Arctostaphylos uva-ursi*), heather (*Calluna vulgaris*), tormentil (*Potentilla erecta*), sweet gale (*Myrica gale*), or wood hops and gallnuts (modified by insects *Quercus* buds) (Gerald-Wyzycki 1845; Thomson 2006; Hall and Kenward 2011; Rahme 2011; Falcão and Araújo 2018, Table 1; Grömer et al. 2017; Emmerich Kamper 2020).

According to 18th-century records, it was stipulated that every tannery should be situated alongside a flowing stream, with the requirement that the water should not be excessively hard. If the stream was fast, the skins were attached to two poles in the riverbed (Kozielec 2010). The other way, as practiced by the Sami from northern Scandinavia, is soaking in running water as long as the hair can be easily pulled off, the second method probably being the oldest dehairing technique (Rahme 2011b, Fig. 16; Grömer et al. 2017). In the excavated ditch section of Kamianets-Podilskyi (Tatarysky) the presence of silty sediments, rounded pebbles and gravels, and small, highly rounded fragments of freshwater mollusk shells, which typically inhabit various flowing environments, provides evidence of the occurrence of running water. The large proportion of sand grains in the lower part of the infill of the ditch also can indicate a significant role of fluvial processes in the sediment accumulation at the time when

the ditch appeared. This evidence confirms the outcomes of drainage network analysis showing the location of a stream in this part of the site.

The presence of water between the ground layers may also be confirmed by the presence of a stream on the eastern slope of the plateau's ledge remembered by the local inhabitants and modern wells providing access to the water for the residents of the village of Smotrych located to the south of the WTC site.

The presence of *Nymphaea alba* pollen in the infill of the ditch located on a high limestone plateau suggests that these plants may have been deliberately brought to the site by the settlement's inhabitants for specific purposes. Not only can the roots of *Nymphaea* be used as food, but various parts of the plant are rich in tannins, making them useful for tanning skins (Didukh et al. 2004). Most probably, *Nymphaea alba* was placed at the Trypillia-time daily surface next to the ditch, this being reflected in its distribution in the pollen profile. More specifically, higher percentages in the upper layers compared with the lower percentages in lower layers suggest its redeposition.

According to the evidence from leather fragments discovered in the Hallstatt salt mine in Austria and clothing and equipment of the so-called Iceman found on the Austrian/Italian border, animal skins were rather cured (by drying, oiling, and smoking) than tanned in prehistoric Europe (Harris 2011; cf. Emmerich Kamper 2020). Although processing hides without changing their chemical properties influences the extremely low amount of preserved leather in archeological records, curing by smoking protects them from rotting and kills bacteria. This is why this method of leather curing was and continues to be so common among traditional communities.

The process of leather curing may be carried out in various ways. For example, the indigenous people of Australia stretch hides on the wood bark and dry them next to a small fire. Then, the hides are rubbed with ash to rid them of fat, and when dry, scraped by the use of a shell tool/scrapper, piece of bone, or flint flake (Mulvaney and Kamminga 1999). The Arctic people clean the inner side of the hides of fat and flesh and stretch them on a wooden frame, or pegs set into the ground. In turn, the indigenous people of North America soak the hides in a water and wood ash solution, before removing flesh and fat from the inner side and hair from the outer one by the use of scrapers. Over the days that follow, the hides are rubbed with a mixture of water and fat (mainly animal brain), scraped again, stretched, and smoked over a fire (Harris 2011). The Orochen-Evenki people usually use dark red, rotten, and crumbling larch wood for smoking the hides, by digging a hole in a building and filling it with wood, before smoking the skins for 10–20 days (Brandišauskas 2010; Henry and Théry-Parisot 2014).

The evidence from Kamianets-Podilskyi (Tatarysky) (including riverine mollusk shells), leads one to the

conclusion that fire could have been used in the process of lime production. The ash from the fire together with lime might have been applied to dehairing skins. We would not exclude the possibility that fire might have additionally served for smoking hides (damp wood burns slowly and gives off a lot of smoke). The latter assumption is based on the evidence of vitrified charcoal and plant remains rich in tannins present in the ditch infill (water lilies, indicated by pollen; oak and ash, indicated by their charcoal).

Quite similar remains of a tannery were found at the Low Grounds Farm site at Marlow (UK). The construction consisted of several large trenches and two bowl-shaped depressions connected with them containing chemical residues (alkali), confirming the treatment of animal hides. Next to the trenches, a fireplace with carbonized wood, burnt hazelnut shells, and fragments of pottery were found. Additionally, flint scrapers and perforators occurred. Use-wear analysis displayed traces of hide processing. The ¹⁴C determinations of nut shells between 2700–2600 BC, locate the existence of a tannery in the Late Neolithic (Berks 2017).

As a side remark supporting the suggested explanation, we may also note the appearance of a bad odor in the excavation site accompanying the exploration of sub-ditches, tanning being the most malodorous process known in the archeological record (Albarella 2003; Bartosiewicz 2003, 2009; Pawłowska 2014). Indeed, the late Neolithic tannery from Low Grounds Farm at Marlow was located at some distance from the settlement, most likely due to the strong odor it generated (Berks 2017). This kind of behavior is also confirmed by L. Binford's (1978) ethnographic observations showing that meat processing and carcass disposal take place beyond residential camps in order to avoid flies and unpleasant odors.

The interpretation of ditches in Neolithic to Bronze Age contexts

The question remains as to what extent our results may be generalized in relation to other ditches in Kamianets-Podilskyi (Tatarysky) and Neolithic to Bronze Age ditches in Southeastern and Central Europe. Given the access to water provided by this feature to the inhabitants of a WTC settlement, locating various craft activities in its proximity would seem to be a reasonable hypothesis for further research. Of course, these crafts might not have been limited to leather processing in all ditches and even the other sections of the southeastern ditch at our site. This assumption is supported by the location of the excavated kilns in relation to the other ditch (Fig. 2).

Analogies to the comprehensive ditch structure from Kamianets-Podilskyi (Tatarysky) in the other CTCC sites are not known to us. However, this may be caused by deepening the analyzed feature into the calcareous gravel-pebble

deposits, enabling one to trace its configuration in detail. The lowest part of flat-bottomed funnel-shaped ditches was identified in, for instance, the Late WTC settlement of Mayaky (Zbenovich 1974) and the Chernavoda I culture ditch in Orlovka (Bryyako 2020). This configuration of the features' lowest part is also noted in the so-called 'ditches' from the earlier settlement of Ozhevo-Ostriv (Ozhevo-Ostrov), shallow (up to 40 cm in width and 30 cm in depth from the Trypillia-time surface) features covered with clay and, together with the other indoor and outdoor features, associated with the production of quicklime and lime (Chernovol 2021). However, using the flat bottoms of such 'funnels' in the lower part of ditches for a marker of tanneries remains in question. In our case, the flat bottoms of sub-ditches most probably result from the flat layers of limestone underlying the calcareous gravel-pebble deposits.

Different evidence from various Neolithic to Bronze Age ditches in Southeastern and Central Europe suggests their different functions. Although far from being in a position to extrapolate our results to the overall set of such features, we may assume that at least part of them was used for locating various production processes, including tanneries. As we have noted elsewhere (Diachenko et al. 2021; Sobkowiak-Tabaka et al. 2022), the assemblage of finds from House 1 (Fig. 2) in Kamianets-Podilskyi (Tatarysky) does not include a single spindle whorl, even though a collection of spindle whorls comes from multiple surveys at this site (Levinzon 2021). At first glance, this fact finds a correlation with the results of use-wear analysis indicating leather and skin processing as the predominant function of the artifacts concerned, and might suggest a certain economic specialization of the inhabitants of this house (for instance, consider the differentiation of household assemblages in Vrable: Furholt et al. 2020; however, see the concerns regarding the WTC house assemblages deposition in Kruts 2003; Ohlrau 2020). Given the complex nature of leather processing at this site, the House 1 assemblage may indicate the economic specialization of households underlying the exchange-based social complexity of the settlements' inhabitants (Feinman et al. 2022).

Conclusion

In summary, the examination of ditches in the evolution of Neolithic to Bronze Age settlement organization in Central Europe, particularly within the Cucuteni-Trypillia cultural complex (CTCC), has provided a nuanced understanding of their multifaceted roles. Initially perceived as fortification systems, astronomical observatories, enclosures for cattle, or markers of social separation, the interpretation of these features has evolved over time, reflecting prehistoric people's rational and irrational approaches to risk management.

Despite the increase in the number of identified ditches current general interpretative frameworks remain largely unchanged. The revelation of a tannery within a WTC ditch at Kamianets-Podilskyi adds a tangible connection between ditches and specific production processes, emphasizing the practical functions of these features beyond defense and ritual.

The evidence suggesting the functioning of a tannery in the Copper Age ditch identifies an important issue of risk management in prehistoric populations. To a certain extent, in interpreting ditches, we often focus on perceptions of significant but low-frequency negative impacts on people, such as conflict. Thinking that way leads one to forget about high-frequency risks, for which the perception of damage is not that significant, i.e. facing hunger or cold (e.g., Fitzhugh 2001). It is probable, therefore, that this is the reason for underestimating production processes in relation to analyzed features in archeology.

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Author contributions IST: Conceptualization, Data curation, Investigation, Methodology, Funding acquisition, Project administration, Writing – original draft, Writing – review & editing. NG: Conceptualization, Data curation, Methodology, Writing – original draft, Writing – review & editing. AK: Data curation, Methodology, Writing – original draft, Writing – review & editing. BKD: Data curation, Methodology, Writing – original draft, Writing – review & editing. MMH: Data curation, Methodology, Writing – original draft, Writing – review & editing. MS: Data curation, Methodology, Writing – original draft, Writing – review & editing. YPR: Data curation, Methodology, Writing – original draft. BR: Data curation, Writing – review & editing. YL: Investigation, Writing – original draft, Writing – review & editing. PB: Investigation. PN: Investigation. AD: Conceptualization, Data curation, Investigation, Methodology, Project administration, Writing – original draft, Writing – review & editing.

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Data Availability Data is available upon request.

Declarations

Competing interests The authors declare no competing interests.

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