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R. PALMER, M. FOWLER, V. WARD, O. V. KARIAKA

AN ARCHAEOLOGICAL LANDSCAPE SURVEY OF 6600 km² OF CHERKASY OBLAST, UKRAINE, USING OPEN-SOURCE SATELLITE IMAGES: SECOND REPORT

This article presents the result of some three years survey and analysis of archaeological landscapes in part of Ukraine using open-source satellite images. More than 7500 archaeological features were identified and geolocated and can be assessed by others using our web application. Principal contents of this report are discussion about habitation sites and mounds. Case studies resulted in a series of maps that may indicate some archaeological potential of interpretation from satellite images.

K e y w o r d s: landscape archaeology, survey, satellite images, remote sensing (RS), HEXAGON, Google Earth, interpretation and mapping, artificial intelligence.

This report follows completion of the data collection phase of the landscape survey by a Working Group of the Aerial Archaeology Research Group (AARG)[1] of which details regarding the survey area, background to usage of aerial and satellite images and the project's method of searching and recording were outlined in the first report (Palmer et al. 2023). To date, the survey has taken about three years. The aim of the project was simple — to examine a defined area of land using mainly open-source satellite images to identify and broadly classify types of archaeological features and to create a basic dot distribution map and accompanying database for those located. While undertaking that data collection a number of questions arose about past use and design of that landscape and members of the working group pursued themselves that interested them, some of which are presented below as case studies of specific locations or examine types of features. These indicate types of archaeological work that can be undertaken from aerial and satellite evidence without the need to excavate — although specific questions could be raised that may be answered by targeted field investigation. Examples given below suggest a range of archaeological questions, area studies and approaches that may demonstrate some of the archaeological processes and theories that are possible using remotely sensed (RS)[2] information. This approach contrasts with that recently proposed by V. A. Hnera (2024) who favours a more technical methodology that relies on uploading everything into a GIS to detect sites and seek informative results. To help explain our approaches (which evolved and are evolving from the past 100+ years of uses of aerial (and, more recently, satellite) images in the UK and parts of mainland Europe), this report includes a number of useful comments and explanations that may provide accessible routes to any future users of images in Ukraine.

Data collection was carried out in Google Earth (GE), within which we had loaded other image and map layers. Some processes were undertaken using the open access software, QGIS (2025). That program was also used for the image interpretation, drawing and finishing of the maps that comprise figs. 14, 19–21 in this report. The survey area covers 110 × 60 km and is located mainly in Cherkasy Oblast (fig. 1). Our work progressed in units of 10 × 10 km within which features were identified, geographically located and described using facilities available in GE. After checking by a second person

© PALMER Rog, 2025 — Research Fellow, Aerial Archaeology Research Group, ORCID: 0000-0003-0546-9273, *rog.palmer0@gmail.com*
© FOWLER Martin, 2025 — PhD, Research Fellow, Aerial Archaeology Research Group, ORCID: 0000-0003-4211-3671, *danebury216@hotmail.co.uk*
© WARD Valerie, 2025 — Research Fellow, Aerial Archaeology Research Group, ORCID: 0000-0002-4936-3932, *Valerie.C.Ward@hotmail.com*
© KARIAKA Oleksandr Vitaliiovych, 2025 — PhD, Research Fellow, Department of Field Committee, the Institute of Archaeology, the National Academy of Science of Ukraine, ORCID: 0000-0003-3066-3641, *akarjaka@ukr.net*

[1] https://aargonline.com/wp/

[2] Remote Sensing, or RS, will be used in this text as a general term to include aerial photography and satellite images, because of the similarities in their uses. This survey, however, used only images acquired from satellites.

these were processed to extract meta data from the descriptions and added to an ArcGIS Online web application (see below) that offers considerable scope for interactive questioning by ourselves and future users.

Image sources and bias

All information identified during this survey was derived from examination of images taken from satellites, mainly US HEXAGON photographs taken in 1982 and GE images dated between 2007 and 2022. These were taken from Low Earth Orbit at altitudes of between 150 and 700 km and those different heights will affect image resolution. There remains the future possibility of identifying additional information from presently-untapped sources such as vertical aerial surveys that may be held by authorities in Ukraine and the recently-declassified reconnaissance photographs taken from American U2 aircraft between 1956 and 1960 from an altitude of around 21 km (Pedlow, Welzenbach 2016; Hammer, Ur 2019). As a contrast, aerial photographs used by K. V. Shyshkin were noted to be at 1:35000 scale (Шишкін 1964, с. 199), but as no camera details were given the flying height cannot be calculated.

Images in GE do not cover similar areas each and those taken between 2007 and 2022 show considerable variation in the extent of ground recorded. Some of our 10 × 10 km squares are restricted to four historical image dates whereas other squares have images taken on more than 20 dates. Images from GE and HEXAGON photographs were supplemented by two cartographic products — the Soviet 1:100000 maps dating to the mid-1970s and a topographical survey dated 1872 (Mapire 2025).

During the time span of this image collection there have been changes to farming practices that include differing depths and methods of cultivation to suit different crop types, and uses of different crop strains following their genetic modification to make their growing and harvesting more efficient. Indeed, knowledge of past and present farming is essential for anyone searching images for archaeological information on farmed land. As examples, the development of agriculture between 1920 and 1990 are outlined by S. L. Danylchenko (2022) and A. A. Pribytkov et. al. (Прибытков и др. 2024); for more recent changes and developments see: FAO 2001 and OSW 2014. These and changing weather patterns will affect soil weathering and crop growth which, in turn, affect how and when archaeological and other types of feature may be visible from above. Satellite images in GE and other sources have not necessarily been taken on optimum dates to record that information. However, in general, those taken between October and May have usually (but not always and not everywhere) been more informative than those taken under growing crops of which there is a wide variety, each responding in different ways to sub-surface variations, in our survey area. The majority, if not all, of features identified have been recorded on more than one date on these unpredictable sources of information. This gives a degree of credibility to features identified during this survey.

Table 1. **Archaeological features identified in the survey area from Google Earth and HEXAGON imagery**

Feature Type	Number
Mound	7196
Mound with satellite	101
Habitation	236
Hillfort	12
Smaller enclosure	15
Field system	35
Other	44
Total	7,639

Numerical summary of results

Our survey recorded a total of 10608 features, 7639 of which are considered to be archaeological (table 1). Further 447 features were recorded from the Soviet era and which are now abandoned or destroyed. The latter have been recorded for two main reasons: that one day they themselves will be old enough to be considered as ‘archaeological’ and images provide a more detailed and informative view than do maps; and that as ‘recent’ structures they may have played a part in destroying or damaging older archaeological sites. Finally, some 2522 non-archaeological features have been identified, many of which have the potential to be confused with archaeological features when viewed from an airborne perspective. This report, however, will pay more attention to older archaeological sites, more typically prehistoric to medieval.

Interactive web application

As part of the project’s outputs, we have developed a prototype interactive web application.

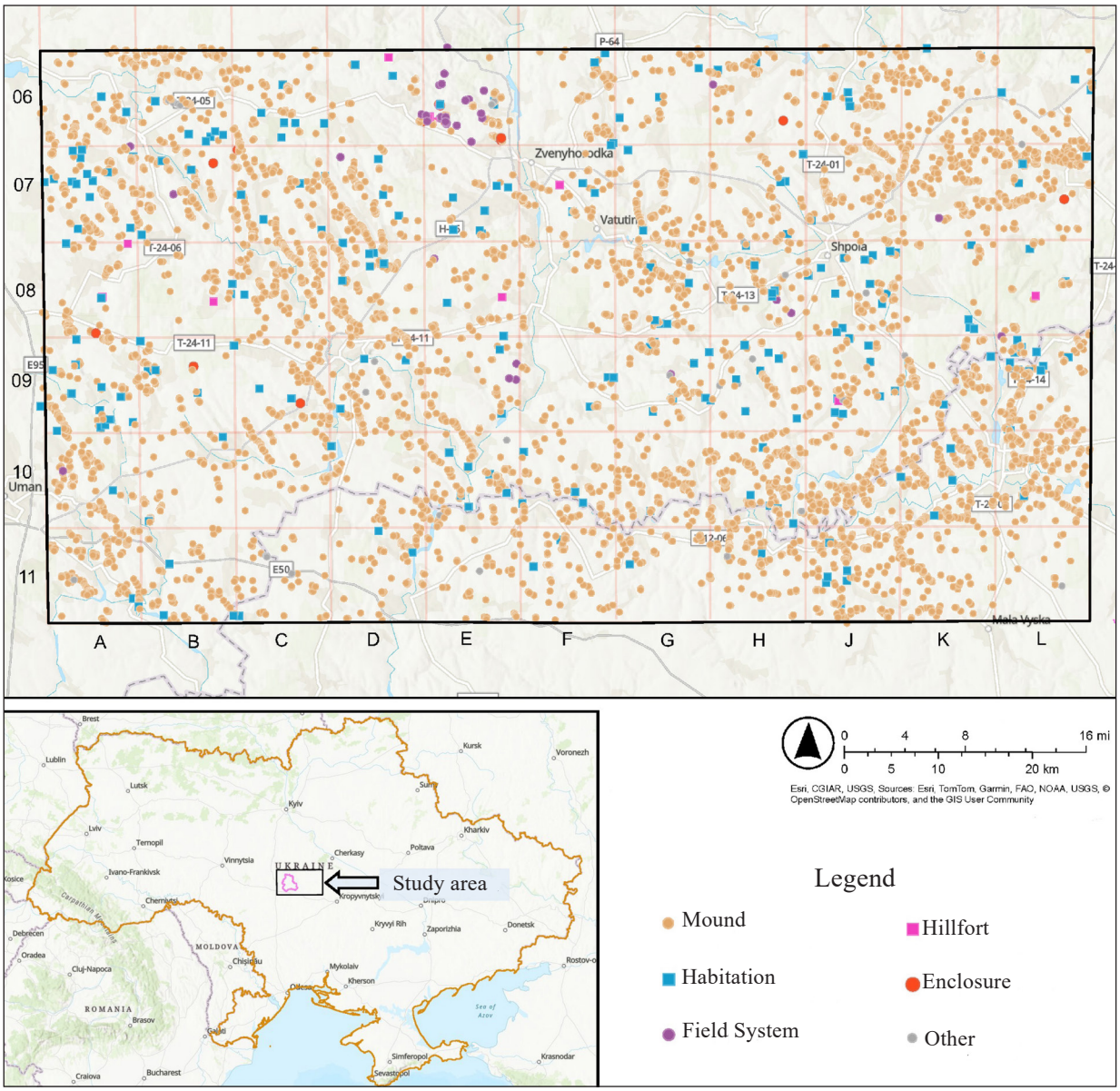

Fig. 1. Location of the 110 × 60 km survey area showing the distribution of archaeological features (upper map) The location of the study area within Ukraine (black rectangle) and the boundary of the Talne environs that is referred to later in this article (purple polygon) is shown in the lower map

This application allows users to view and interrogate output from the survey online. Utilising the functionality of ArcGIS Online, the web app is freely accessible through the Ukraine Working Group (WG) page of the AARG[3].

In addition to offering a visual representation of the distribution of identified archaeological features in the study (see, for example: fig. 1), the web application enables users to zoom in and dynamically access information from the project database, including the type and description of the feature, and the geographic location (fig. 2: a). Users can conduct their own analyses of the distribution and relationships between the pinned features using additional feature layers including:

'Negative areas' such as woodland, built-up areas, and lakes where features would not be visible from an above ground perspective, and which can account for gaps in the distribution of features (fig. 2: b). Indeed, the features mapped from Google Earth and HEXAGON are almost exclusively excluded from these areas.

Known archaeological features in the Talne environs identified from the literature and archives of the Institute of Archaeology of the National Academy of Sciences of Ukraine (IA NASU, see below), allowing a comparison to be made with the findings from the satellite survey (fig. 2: c).

[3] https://aargonline.com/wp/working-groups/ukraine-wg/

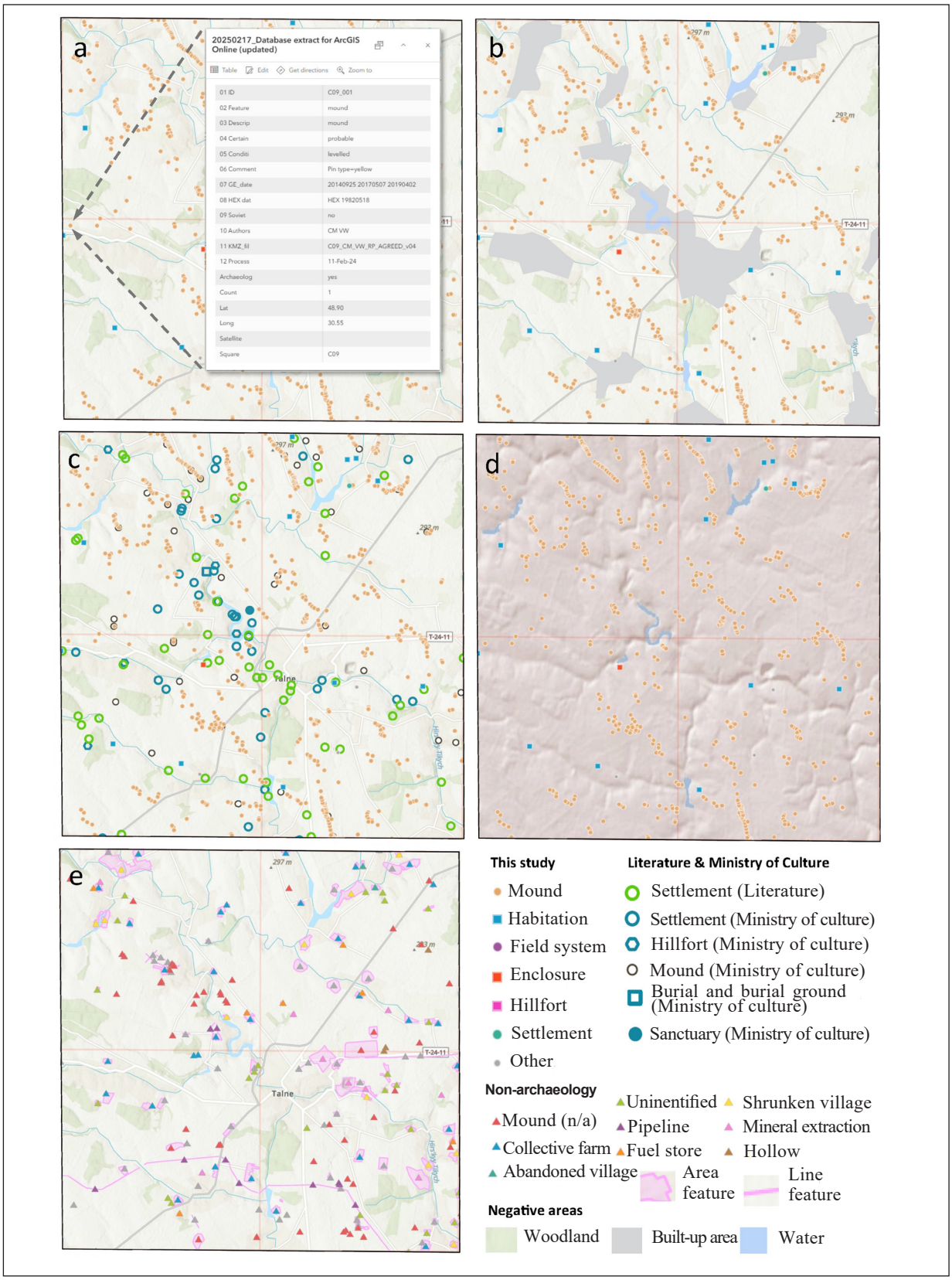

Fig. 2. Examples of the functionality and some of the feature layers of the interactive web app for squares C08, C09, D08 and D09. *a* — Pop-up box showing the attributes of one of the mounds present in the database. *b* — Distribution of archaeological features mapped in this study compared with the locations of 'negative areas' in the form of woodland, built-up areas and water where features would not be expected to be visible from an above ground perspective. *c* — Distribution of features mapped in this study compared with known features from the literature and the Archive of the IA NASU for the Talne environs. *d* — Distribution of mapped archaeological features on a surface elevation plot shown as shaded relief. *e* — Non-archaeological point, line, and polygon features mapped in this study

Surface elevation shown as shaded relief permitting the distribution of features to be investigated in relation to land topography (fig. 2: d). Non-archaeological point, line, and polygon features such as underground pipelines, abandoned villages, non-archaeological mounds, and other features that have the potential to be confused with archaeological features when viewed from an airborne perspective (fig. 2: e).

A satellite image basemap is also provided to help with locating features on the ground and additional feature layers will be added to the web application as the prototype is developed.

By offering a freely accessible means of visualising the project's outcomes, the aim is to encourage Ukrainian archaeologists to become increasingly aware of the applications of RS in archaeological studies and to engage more interactively in fieldwork derived from those sources. For users interested in conducting more specialised analyses of the identified features using GIS software such as QGIS or ArcGIS, the project's database will be available to download from the project's data repository via the Ukraine WG page on the AARG website.

Drawing conventions

This article includes two types of illustration of archaeological features in the text below. In 'Habitation sites' there are paired extracts from the most informative satellite image with a same scale interpretation drawing of what we have seen there. These enable comparison from one to the other but, more importantly, provide a fixed point for further discussion. Image interpretation is a subjective art and it is expected that minor differences will result from examination by two or more people. The drawings here fix the interpretations made by one of us (VW) using the source(s) noted, but they may also be changed when new images are available.

Elsewhere we include several maps showing information that has been interpreted from the images examined (figs. 14, 19–21). Their published scale varies depending on the extent mapped, but we have been consistent with use of colours and background information that enables the archaeological content to be shown in its topographical setting. Archaeological information is shown for three main forms and does not distinguish whether features are plough-levelled or upstanding: mounds, banks and lynchets are shown in black, ditches in red, and we have indicated mounds in groups that appear to represent habitation as magenta. While mounds, banks and ditches are usually clearly identifiable on images, the decision on habitation is more subjective (see: 'Habitation sites' below).

The natural background is based on Shuttle Radar Topography Mission (SRTM) data which has a spatial resolution of 30 m (USGS 2025) and a relative height accuracy in the region of 10 m (Earthdata 2025). Maps here use a single band grey base upon which contours, themselves derived from SRTM data, are overlaid to enhance the shape of the ground and provide height values. The mapped background includes two kinds of negative zones.

Zones of destruction are likely to have completely erased traces of archaeological features and may be caused by mining or the building of towns, villages, roads and other structures. Zones of potential can include woodland in which no archaeological information may be visible on conventional above ground images.

From the beginning of this century, airborne laser scanning or lidar (ALS) has made a considerable impact on results from aerial survey. ALS records height differences, or topography, and also has the ability to 'remove' or see through trees and thereby record extant remains below the woodland canopy (Doneus et al. 2008; Opitz, Cowley 2013). By so doing, it opens the potential for archaeological survey of tree-covered tracts of land. Finally, selected modern boundaries are shown as they sometimes explain discontinuity in archaeological features.

Locational data

We believe that it is essential to provide accurate locational information to fix sites in their geographical locations and to enable them to be located by other researchers. For ease of communication, we have given a name for sites we discuss which, unless they have previously been named, is usually of closest village named in GE, from where we also take the spellings used in this report. Feature numbers (e.g.: D09_001 for feature no. 1 in square D09) have been included, because they provide a link to the web application and the original data files. Coordinate values use decimal degrees to show latitude and longitude in which four decimal places provide a location to an accuracy of about 10 m (Garmin 2025). Maps in this paper show edge values in metres derived from the coordinate reference system set in QGIS for Ukraine, WGS 84/UTM zone 36N (EPSG 32636). Each map also includes a location (+) that fixes a geographical location.

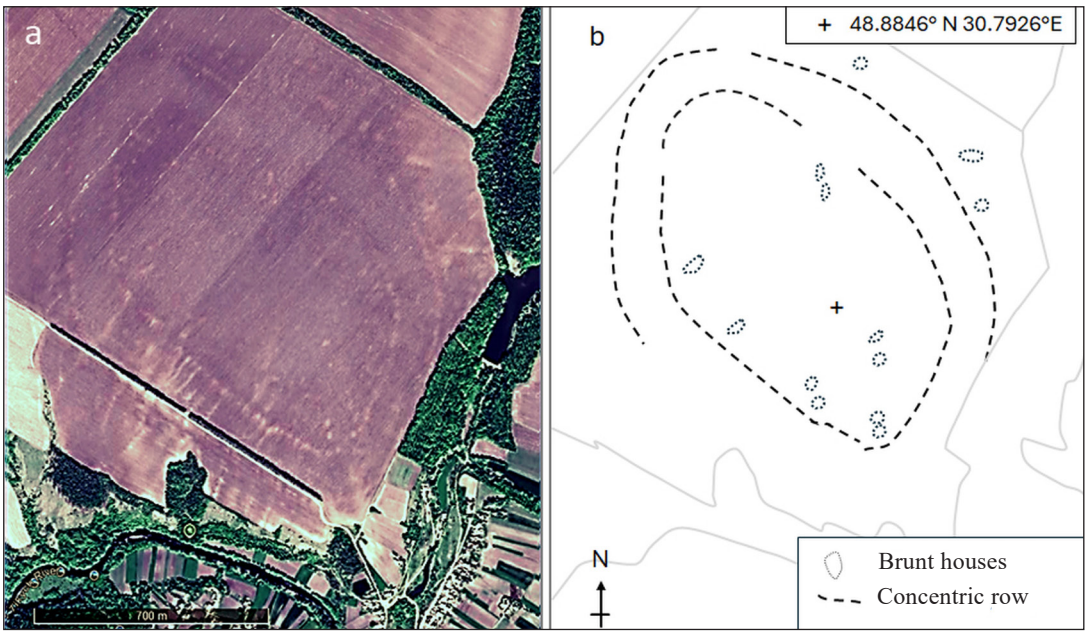

Fig. 3. The Trypillia site at Hlybochok (D09_001) shows concentric rows of light-coloured patches resulting from burnt houses sites. *a* — extract from GE image (5 May 2017). *b* — interpretation drawing using diagrammatic rows of houses

Habitation sites

This survey has interpreted a considerable number of features categorised as 'habitation' sites. Habitation is a broad general term defined as: *"Places where people lived, whether permanently or temporarily. They may be constructed dwellings, or possibly a cave or rock-shelter. Habitation sites need not be defended or otherwise enclosed, although many are. Many will be directly associated with other kinds of sites, for example burial grounds and field systems*." (Concise... 2025).

In this survey area, the term 'habitation' has been used to cover a wide range of forms from the purposely planned Neolithic Trypillia megasites; the clusters known as 'ash heaps' which occur across multiple periods as well as Iron Age (IA) settlements which were often fortified. As we are working with satellite images, it is often difficult to assign dates or cultures to interpreted sites without additional information; instead, the survey focused on what remotely sensed information can show us regarding site size, characteristics, groupings and overall location and can be further interrogated to assess geographical relationships with other sites.

Trypillia.

One of the most studied habitation types to occur across the survey area belong to the Neolithic Trypillia culture. The largest type, known as a megasite, may approach 450 ha in size and often consists of between two and four concentric rows or 'circuits' of houses around a central area (Chapman et al. 2014, p. 374-375). A good example of the structure and layout of a megasite can be seen at Hlybochok (D09_001: 48.8846°N 30.7926°E) where the light coloured remains of levelled/ploughed-out rows of burnt houses are visible against the bare purple-brown soil on a Google Earth image from May 2017 (fig. 3). Due to their large areal extent, most Trypillia megasites regularly exceed modern field areas and are crossed by field boundaries. In areas where crop and soil treatments vary between fields, these large sites may not be optimally imaged on a single date. The production of an interpreted plan for the entirety of these large sites will most likely require the integration of evidence from images of different dates and years.

Apart from the more recently published excavations and survey work, the detailed locations, site plans or images of the majority of Trypillia sites are not readily publicly available, especially to international readers. However, an open-source database of 499 Trypillia sites was published by M. Nebbia (2017a, 2017b) as part of the Anglo-Ukrainian *Trypillia Megasites of the Ukraine* project carried out in 2012–2015.

M. Nebbia (2017a, 2017b) distilled information from M. Yu. Videiko and N. B. Burdo's 2004 *Encyclopedia of Trypillia Civilisation* which contained over 2000 entries (Відейко (гол. ред.)

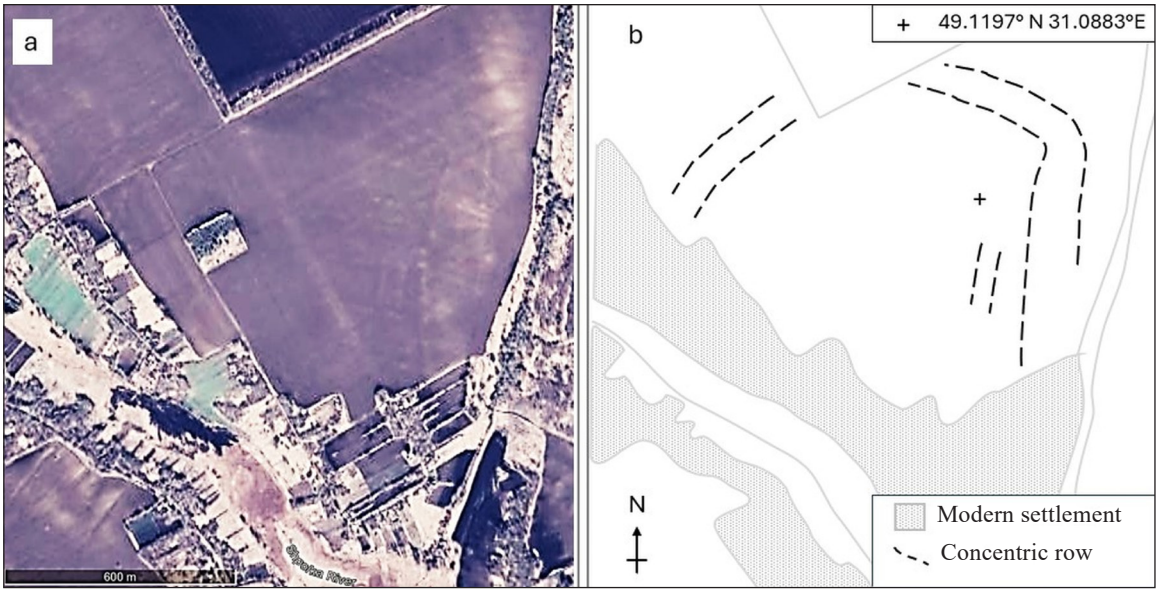

Fig. 4. A potential Trypillia site 2.5 km South-East of Tarasivka (G06_076) that may be more than 100 ha and extends under an abandoned modern settlement. Seen as: a — densely concentric rows of light-coloured patches on GE image (13 March 2019). b — interpretation drawing using diagrammatic rows of houses

2004). The *Encyclopedia* was collated from a vast body of information built up since the 19th century, including scientific publications, archive material, excavation reports and unpublished research. M. Nebbia (2017a, 2017b) undertook an intensive cleaning process of this data to assess its accuracy and reliability resulting in the formation of a database which included location accuracy information ranging from a few metres to 2 km, expressed as a Location Confidence Factor (LCF) and scaled between 0.0–1.0 (Nebbia 2017a, p. 2). Using this database of 499 reliable Trypillia sites, 60 are located within the AARG survey area. However, the low values of LCF assigned by M. Nebbia for the Trypillia sites indicates that their locations were still considered very low confidence. Only 12 (20 %) of these 60 sites were assigned a high LCF (0.8–1.0) with 39 (65 %) assigned a very low LCF of 0.4 or less. Of M. Nebbia's high confidence locations, the majority are high profile megasites having undergone extensive excavations as well as geophysical survey work and are therefore well published. The majority (76 %) of M. Nebbia's listed Trypillia sites within the AARG survey area are not large enough to be considered megasites; 34 %, range from 10 to <100 ha and 42 % range from 0.3 to <10.0 ha. The small sites, those under 10 ha in particular, are often located close to or under current settlement or development and as such are not discoverable on post-modern settlement RS images. This is discussed in more detail in Case Study 1, below.

The AARG survey has improved the location confidence for a significant number of these Trypillia sites within the project area by using a multi-pronged approach which integrates:

- interpretation of high-quality 1982 HEXAGON photographs;
- interpretation of Google Earth images taken between 2007 and 2022;
- site information given in recent literature;
- identification of locations from site plans published by K. V. Shyshkin in 1985.

The increased confidence or confirmation of the location of many of the Trypillia sites as part of the AARG survey is partly due to the significant number of additional satellite images available across much of the survey area since the work by M. Nebbia (2017b) was completed and more importantly the advantageous timing of these additional photographs with respect to crop and soil marks. In a few cases locations have been shifted by 3 km from the Nebbia locations. It is a strong reminder that field conditions must be appropriate in order for sites to be detectable on satellite images. This is exemplified by megasites: Kharkivka (A07_001: 49.0303°N 30.3411°E), Romanivka (B08_001: 48.9462°N 30.5371°E) and Vilkhovets 2 (E07_044: 49.0422° N 30.8515°E) each estimated to cover c. 100 ha, which remain undetected or very poorly imaged on the GE images currently available as of February 2025. The locations of these sites were assigned very LCF values of 0.4, 0.2 and 0.6 respectively by M. Nebbia (2017b).

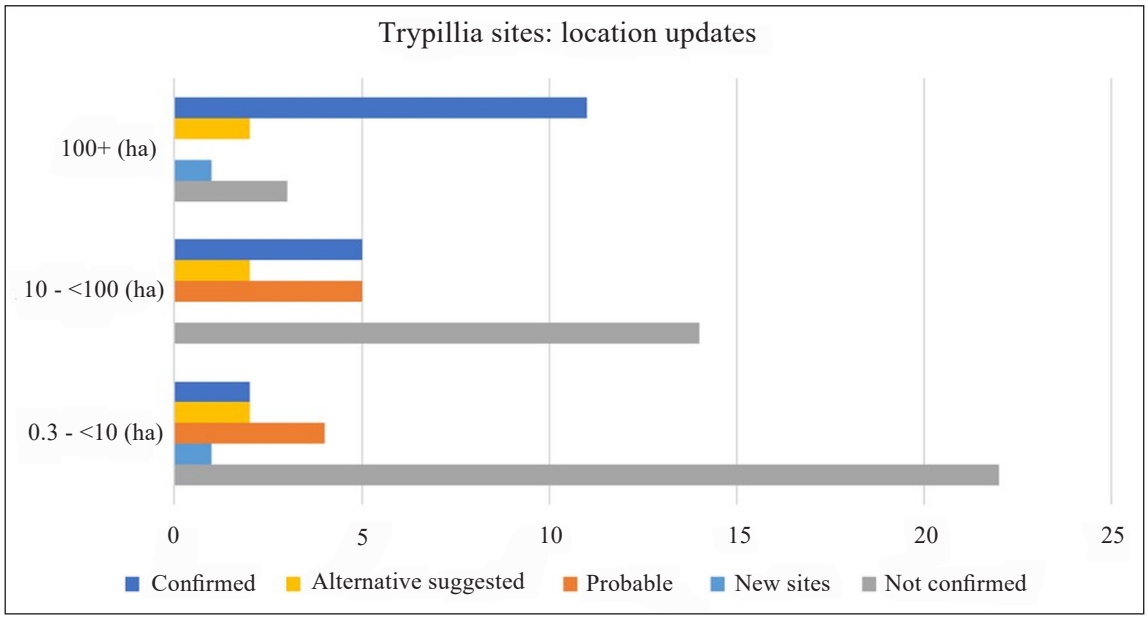

Fig. 5. Table of number of Trypillian sites with improved confidence in locations by size of site

In some cases, interpretation of habitation sites from satellite images did not match locations of Trypillia sites listed by M. Nebbia (2017b). For example, at a site located 2.5 km SE of Tarasivka (G06_076: 49.1197°N 31.0883°E) soil marks are interpreted as two concentric rows forming a semi-circular shape (fig. 4). These occur on a low hill at the confluence of two rivers. The soil marks are very similar to those associated with the rows of houses seen at the Hlybochok megasite (fig. 3). The proposed site at Tarasivka is only partially visible on HEXAGON and GE images that were available when M. Nebbia compiled his database. The continuation of the concentric rows resembling the form of a megasite is much more apparent on images after 2017 and post-date Nebbia's work.

The concentric rows at Tarasivka cover about 100 ha and are similar in appearance, size, and location to the Hlybochok megasite. Further investigation is needed to determine if this and other surveyed habitation sites are new or known Trypillia sites.

The number of high confidence Trypillia locations in our survey area compared to M. Nebbia's database (2017b) was considerably increased through positive identifications on satellite images and use of K. V. Shyshkin (1985) site plans. These can be examined, divided by size ranges, as layers in the web application. The number of confirmed locations rose to 18 of which only 10 were originally classed by M. Nebbia (2017b) as high LCF (0.8 to 1.0). Based on the multi-pronged approach described above, the number of 'probable' or quite likely locations was increased to nine, proposed alternative possible locations to six with two potential new large Trypillia sites. The high number of remaining unconfirmed sites were mainly very small sites, listed at only 0.3 ha (approximately 55 × 55 m) and/or are close to or beneath intense modern cultivation or settlement. It is unlikely that these small sites would become visible on additional future GE images (fig. 5).

Ash heaps.

A predominant type of habitation site occurring widely across the survey area is the group known as 'ash heaps' or 'special ash deposits'. They are not specific to this survey area, but occur across a vast zone from the Southern Urals through to the Danube region dating from the Late Bronze Age (LBA) to the late medieval and sub-modern periods (Гершкович 2009, с. 328, Lisetskii and Stolba 2022, p. 14). Although these clusters of ash heaps are usually levelled as a result of intensive ploughing, they are often visible as light or ash-coloured mounds in bare soil on RS images as shown in figs. 6–10 (Brasoveanu et al. 2023, p. 1; Palmer et al. 2023, fig. 10). In Romania, ash heaps belonging to the LBA Noua culture are generally c. 25-30 m in diameter (Brasoveanu et al. 2023, p. 1), while the Bilohrudivka culture from the forest-steppe in Ukraine left behind mounds up to 40 m in diameter (Гершкович 2009, с. 327). In forested areas, where ash heaps have been protected from ploughing, LBA ash mounds of the Bilohrudivka group remain extant at a few metres high (Гершкович 2009, с. 327). F. N. Lisetskyi and V. F. Stolba

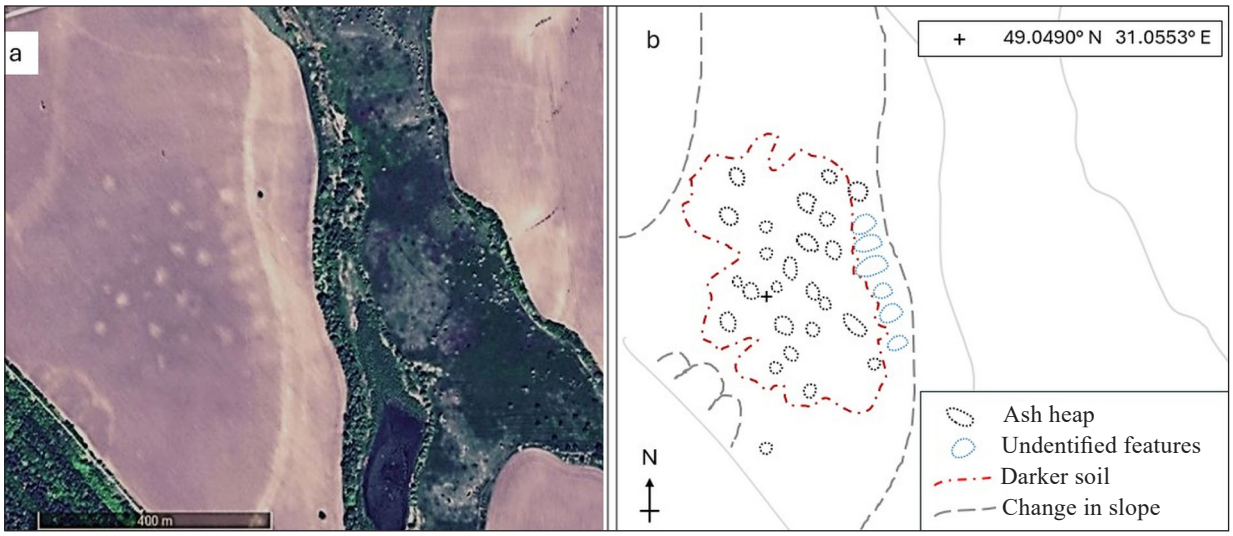

Fig. 6. A levelled habitation site 3 km west of Bohachivka (F07-033). *a* — densely spaced light-coloured patches interpreted as ash heaps surrounded by darker soil on GE (22 September 2018). *b* — interpretation identified over 20 ash heaps of diameter 16–18 m

(2022) summarised data by V. G. Petrenko (Петренко 1989), E. Sava (2005), and E. Sava and E. Kaiser (2011), noting that the number of ash heaps in clusters can vary widely; Bronze Age and Scythian settlements in the forest-steppe zone can contain 10–25, sometimes exceeding 50, ash heaps.

As shown in fig. 6, the bright ash-coloured oval-shaped ash heaps at a site near Bohachivka (F07_033: 49.0490°N 31.0553°E), occur in random orientation within a densely spaced cluster. The ash heaps are surrounded by a darker soil which may represent an organic-rich or enhanced soil. In this example there are over 20 ash heaps of diameter 16–18 m visible on the September 2018 GE image.

The method of formation and functionality of ash heaps has been long debated. Excavation has revealed that these mounds can contain the remnants of residential or utility buildings and hearths along with votive and ritual objects such as clay figurines and animal bones (Гершкович 2009, с. 328; Brasoveanu et al. 2023, p. 4). Ya. P. Hershkovych (2009, с. 328) asserts ash heaps were formed as part of the abandonment of dismantled dwellings where *"garbage and soil of the cultural layer accumulated within the housing and household zone were deliberately moved in order to completely cover the remains of the dwellings"*. This has resulted in inverted layers within the heaps as evidenced by reversed radiocarbon dates (Kaiser, Sava 2006, p. 144, tab. 1). Occasionally, ash heaps contain pits and human burials inserted into the top of the heap (Гершкович 2009, с. 327; Brasoveanu et al. 2023, p. 4). A popular interpretation was that ash heaps were the remains of burnt buildings; however, soil studies indicated that some ash heaps contain little to no evidence of 'ash or other combustion products' (Kaiser, Sava 2006, p. 165, tab. 5). Instead, the ash-coloured soil, at some LBA sites, is caused by soil formation from the remains of deliberately abandoned houses and their waste material, in anoxic conditions (Гершкович 2009, с. 329; Brasoveanu et al. 2023, p. 4). While Ya. P. Hershkovych (2009, с. 329) noted that LBA ash heaps were permanently inhabited throughout the year, albeit for only short periods of time, it is argued by E. Sava (2005) and E. Sava and E. Kaiser (2011, p. 365-367) that ash heaps of the Noua and Sabatynivka cultures, are places seasonally occupied by semi-nomadic pastoralists to which they returned cyclically over several generations.

Although superficially the clusters of ash-coloured patches which make up the ash heaps appear quite similar there is quite a lot of variation within and between them. Some examples of their visual variation, as evidenced on satellite images, are outlined in figs. 6–9. Further work is required to ascertain whether some of the variation noted in their density, size and shape and geographic location may be a guide to interpreting their date.

Individual ash heaps in the AARG survey area vary in size from 10–35 m in diameter. The size variation of individual ash heaps within clusters can be either very consistent or quite variable as shown in figs. 6–9. Variation in the size of individual ash heaps can be seen at a site at the confluence of two water courses close to Borovykove (G06_060: 49.1407°N 31.1439°E). Larger ash heaps, ranging

Fig. 7. A plough-levelled habitation site 2 km south-east from Borovykove is situated on a south-west facing slope between two watercourses (G06_060). *a* — as visible on GE, 23 September 2011. *b* — additional ash-coloured patches are visible on GE, 22 February 2020. *c* — interpretation indicates over 50 ash heaps with diameters between 18–35 m. Variations in ash heap size and density may indicate different phases of the site, but could also be as a result of differential erosion

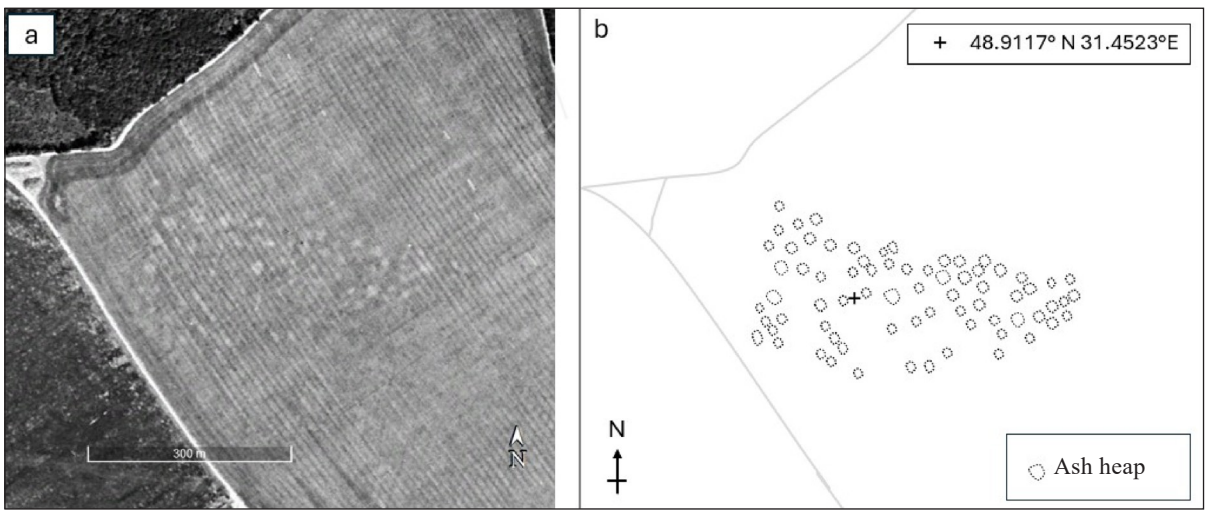

Fig. 8. The levelled habitation site 2 km north-east of Vodiane is a dense cluster of angular sub-rectangular patches in an area 500 × 200 m (10 ha). *a* — as recorded on HEXAGON 18 May 1982 which suggests their irregular edges may be caused by north-west to south-east ploughing. *b* — the interpretation plan shows over 70 ash heaps of which most are 10–12 m in diameter, with some up to 15 m in diameter

from 23–35 m in diameter, are observed in the southern part of the site. In contrast, smaller and more concentrated ash heaps, with diameters between 18–23 m, are found upslope towards the northern part of the site (fig. 7). This may reflect site phases or be due to differential erosion or ploughing. The site's location at the confluence of two water courses and its extensive area of 30 ha indicates that it might be a candidate for a Trypillia site. In this context, the ash-coloured features could potentially be burnt houses.

In contrast to the sites at Bohachivka and Borovykove (figs. 6–7), a site 2 km north-east of Vodiane (J09_124: 48.9117°N, 31.4522°E) shows a densely packed area with small irregular shaped ash heaps (fig. 8). This site is clearly visible on HEXAGON in 1982, but not on later GE image dates. In the Vodiane cluster, which extends to 10 ha, there are over 70 light-coloured patches, each averaging around 10-12 m in diameter, although some reach 15 m. The more geometric shape of the ash heaps at Vodiane compared to the sites at Bohachivka and Borovykove and the significantly smaller size of the individual features may indicate that they are the remains of houses or buildings rather than ash heaps. However, their sub-rectangular appearance could result from ploughing as modern cultivation occurs across the entire field (fig. 8).

Features interpreted in the survey as ash heaps occur in a range of locations including hillslopes and

Fig. 9. Two neighbouring habitation sites, some 500 m south-west from the outskirts of Krymky, are on the south-facing slopes of a watercourse (J08_020 (E) and J08_083 (W) and are themselves separated by a smaller tributary. *a* — as recorded on GE 14 April 2018. *b* — interpretation resolved these into two groups: a small 1.5 ha cluster with five ash heaps of c. 22–26 m diameter and a larger spread to the east, covering 21 ha, which has over 30 ash heaps of c. 12–24 m diameter

hilltops and are very often adjacent to water courses where sites are not obscured by woodlands or modern development. These sites are supplemented by those found during archaeological survey from the 19th century onwards and are documented in the IA NASU archives for each oblast. Unfortunately, the majority of the sites listed in the archives are now masked from an above ground view. The habitation sites that are imaged, regularly occur in close proximity, within 500 m, to other similar sites, but are often separated by small water courses — a relationship also noted in Romanian LBA Noua examples (Brasoveanu et al. 2023). This proximity is exemplified by two neighbouring plough-levelled habitation sites located 500 m south-west from the outskirts of Krymky (J08_020: 48.9277°N 31.4139°E and J08_083: 48.9225°N 31.4060°E) are shown in fig. 9. The western small (1.5 ha) group has five medium-sized ash heaps, each c. 22–26 m in diameter and the other larger eastern cluster (21 ha) is composed of over 30 ash heaps c. 12–24 m in diameter. Both sites are on the south-facing bank of a watercourse, 500 m apart and located on either side of a branching tributary. However, their contemporaneity cannot be determined from these images alone.

Ash heaps located within and contemporary to enclosed or fortified areas as exemplified at Bilsk (Пуголовок та ін. 2020). A site interpreted in this survey, halfway between Kobrynove and Kobrynova Hreblia consists of a small cluster of ash heaps within a circular enclosure, defined by a ditch and internal bank covering 21 ha (D08_002: 48.9746°N 30.7365°E) (fig. 10). It cannot be assumed without further investigation if this example of ash heaps is contemporaneous with the enclosure. The bright circular ash heaps are 16–24 m in diameter and are adjacent to some light colour diffuse patches which are also likely to be representative of habitation. Archive data records a site known as Antonivka hillfort, within Antonivka village which is located 2 km to the west of this site. Unpublished archive data compiled in 1968 by V. A. Stefanovych and O. P. Didenko, which documents monuments in this area, do not mention a settlement or enclosure at the location of feature D08_002 (O. V. Kariaka's March 2025 personal comment).

Mounds

The majority of mounds recorded are now in arable land and most show damage from cultivation. The worst cases show evidence of deliberate levelling, some from actions that have been recorded in recent years. An example, illustrated in the first report, is a small group of mounds north-west of Tashlyk (L07_056–060: 49.0961°N 31.6861°E) where the regular patches of heavier cultivation were recorded in 2017. A later image in 2020 suggests that larger mounds still retained some height and shows that heavy ploughing was dragging the

Fig. 10. A levelled habitation site, visible as a small cluster of ash heaps, within, but not necessarily of the same date as, a 20 ha enclosure (D08_002). These features are on the Southern bank of a watercourse between Kobrynove and Kobrynova Hreblia and 2 km east of Antonivka. *a* — as recorded on GE 5 May 2017. *b* — interpretation resolved this as a small group of 6+ ash heaps of c. 16–24 m in diameter covering 4.7 ha

mound matrix away from the centre (Palmer et al. 2023, fig. 9: A, B). More serious levelling has been noted on mounds in two adjacent fields west of Zalizniachka (E08_088–089, 091 and E08_096–101: 148.9919°N, 30.9137°E) that is illustrated in a set of eight images that show how monitoring the condition of archaeological features may be done from open-access images that can be read[4] to explain what has occurred (fig. 11). There were suggestions of mounds on the HEXAGON photograph from 1982, but they were clearer on 17 June 2011 and showed poorly on 22 August 2013. The image set illustrated begins in 2011 and continues when the earliest levelling was seen as a series of small rectangular areas in 2017 on 16 April and 7 May. After 2017, one mound was not levelled again but showed damage from regular ploughing, as was recorded in the South-East field on 13 March 2019. On 22 February 2020, another group of small rectangular areas, each centred on a mound in the South-East field, had been levelled and were themselves dragged by ploughing three weeks later (12 March 2020). Mounds in the field to the north-west were seen as similarly levelled on 16 March 2021 and the South-East field had levelled rectangles by 11 October 2021, at which date there was no growth above cleared areas in the North-West field.

Mounds are sometimes shown on historic maps. A small number of extant mounds is shown on the 1:100000 Soviet map of the 1970s. Few should be expected at that scale and many of those depicted serve as a base for a trigonometrical point. A higher number of upstanding mounds are shown on the map of 1872 (Mapire 2025) which may reflect their ability to withstand earlier, less destructive, cultivation although most have since been levelled. The density and distribution of mounds varies in different parts of that map and their appearance, or not, may reflect the interest of a surveyor rather than suggest that they were not visible at the time of survey. Mounds in Ukraine on the 1872 map can usually be matched to those appearing on modern images and reference to such matches are noted in the database.

Images of mounds show them in a variety of forms as is apparent in figures in this report. On some dates they may be recorded simply as light-coloured mounds, on others the same mound may show a dark perimeter that may indicate a ring ditch or may derive from soil that cultivation has moved off the mound. With many mounds, we are uncertain about these dark edges and have not been able to record them with any degree of confidence, although some of the maps that follow will show them.

Rarely, a known mound may show as a darker disc — which is confusing as mounds are compacted features that are expected to appear as reduced growth in some crops or as light areas in bare soil. Many small dark features identified during our survey are clearly small hollows, sometimes soil-filled hollows that may increase crop growth or be seen as darker patches in winters. While we did

[4] Photo-reading is the process of examining, understanding and describing what can be seen on aerial images.

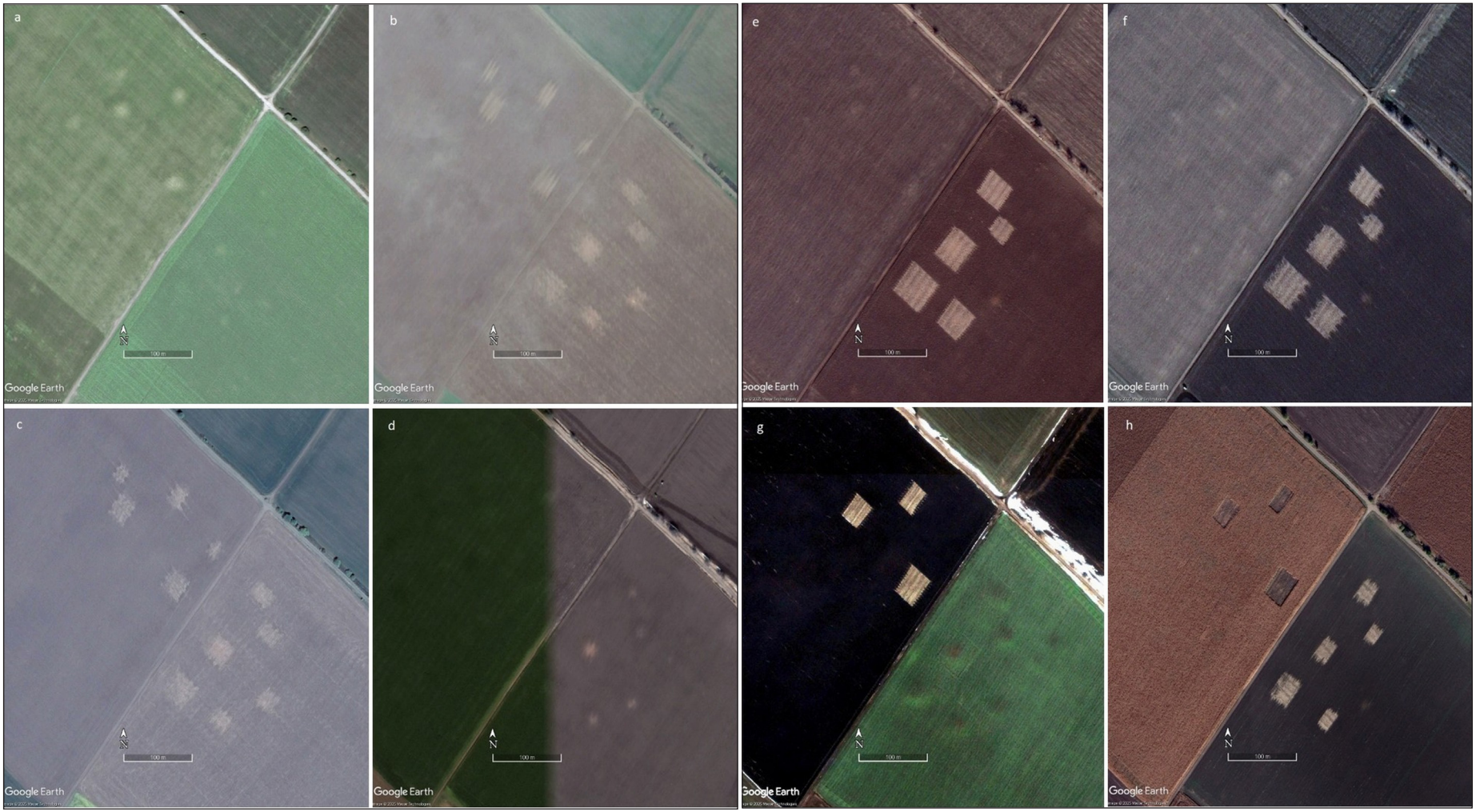

Fig. 11. In two fields west of Zalizniachka, Google Earth has recorded a series of images of mounds and attempts to level them. *a* — mounds will have been damaged by cultivation, but appear otherwise in fair condition (17 June 2011). *b* — the earliest levelling was recorded in 2017 and shows severe damage, possibly by bulldozer, in the north-west field (high cloud obscures part of the image 16 April 2017). *c* — three weeks later the levelled areas have been further flattened, possibly by cultivation at 90° to the April pattern (7 May 2017). *d* — in 2019, damage from regular ploughing was recorded in the south-east field close to the eastern edge of the composite image (13 March 2019). *e* — the south-east field shows a group of flattened rectangular areas, each centred on a mound (22 February 2020). f) three weeks later those areas in the south-east field were themselves dragged by ploughing (12 March 2020). *g* — three mounds in the north-west field, visible in the previous image, had been levelled in a similar way to those to the south-east (16 March 2021). h) later that year, the south-east field showed freshly levelled rectangles above some of the mounds and there was no growth above previously cleared areas in the north-west field which, presumably, had not been seeded that year (11 October 2021)

Fig. 12. Mounds north-west of Shaulykha outlining a natural basin in a west-facing scarp in a manner that suggests their deliberate placement around a natural feature. The original vertical view has been tilted to create an 'oblique view' for this illustration. Source: Google Earth: 18 September 2014

record definite hollows, not all darker discs were recorded by our survey.

Mounds can serve several functions and those may change with time. For example, a mound (kurhan) that was constructed to mark a significant burial may also indicate a boundary. It may later have the addition of secondary burials and, later still, be used as a base for a trigonometrical point. Mounds were often conspicuously placed to serve as sightlines that may indicate territory and may also be used as landmarks for navigation — and this also implies an open landscape with clear sightlines (e.g.: Aldred 2021, p. 3, 54). Some mounds were clearly built with respect to natural formations. One example, a group of mounds north-west of Shaulykha (C07_092–101: 49.0008°N 30.5646°E: fig. 12) may have been clearly skylined from below and from the west (imagine seeing the illustrated example with the sun rising behind the mounds) while themselves appearing to be placed around a natural escarpment hollow as if the view to the west was itself of significance. A similar arrangement around a natural feature is west of Buky (A06_149–153: 49.0978°N 30.3536°E). That group is best seen on the HEXAGON photograph taken in 1982.

Using the interactive web application to view the survey area at small scale shows lines of mounds of which many follow the grain of the land and extend along high ground between watercourses from (roughly) north-west to south-east. What we now see as a single line of mounds could have resulted from several processes:

- they may all have been constructed within a short time span;

- they may have begun at one end with additions made so that a line gradually extended over generations;

- a line may first have been marked at key points (by construction of mounds) and infilled over time.

Without excavating and dating such a row we can only suggest possibilities. We are able to state, however, that construction of a row of mounds was a process that occurred over time — we just do not know the length of that time.

One end of these rows, usually the southern end in our project area, may stop (or start) on a promontory or cape close to a confluence of rivers. These locations were also favoured by settlement sites of dates from Trypillia onwards although no contemporaneity is suggested even though many of those sites include large mounds. On the basis

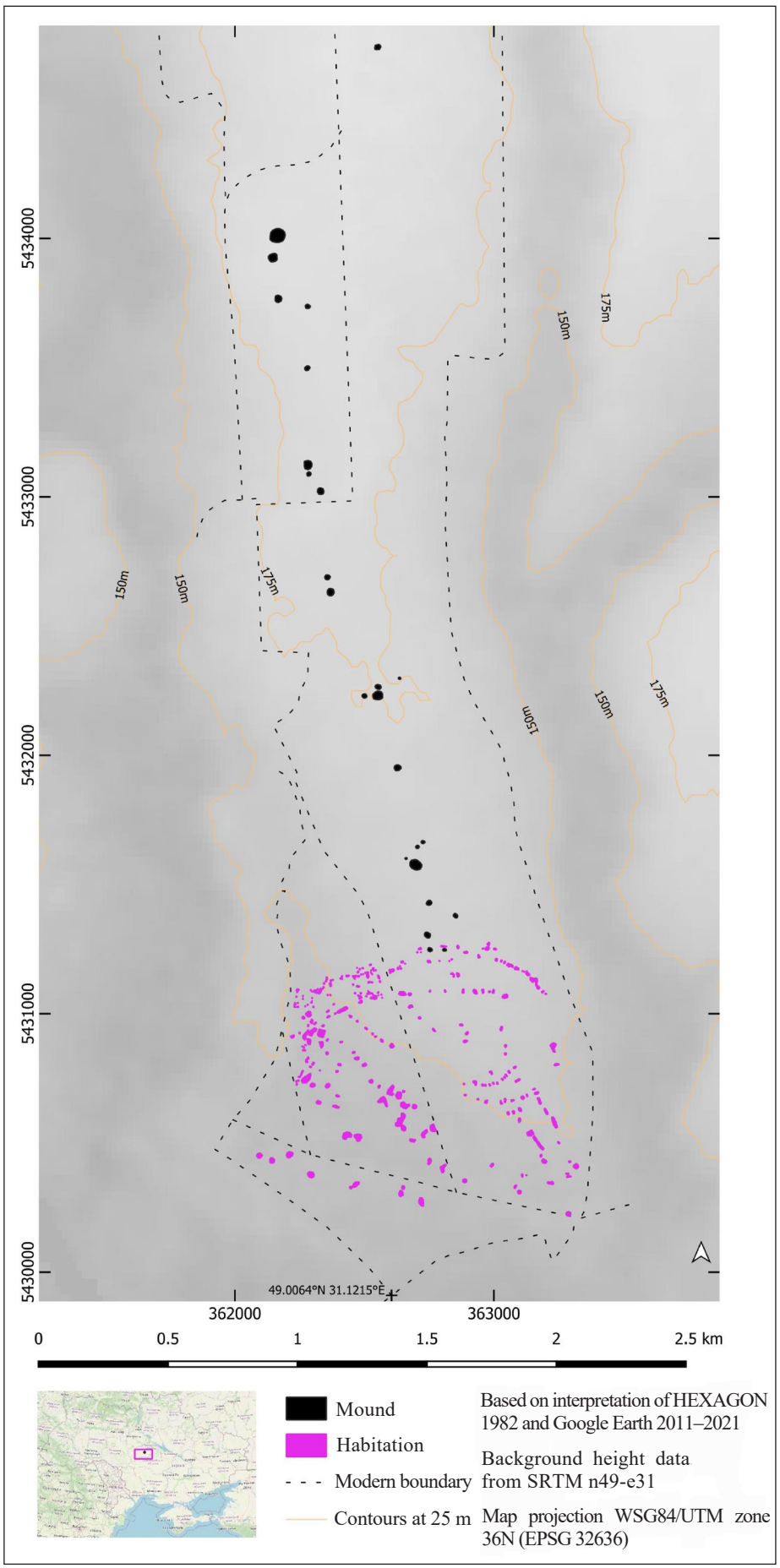

Fig. 13. The plan, interpreted from images of several dates, illustrates the placement of archaeological sites in relation to their topography and local environment. The Trypillia site at Chychyrkozivka is situated close to the confluence of two rivers, vital resources, on ground that is higher towards its northern part. From there, a ridge slopes gently up to the north and on it is a row of mounds, some in local clusters, that may extend more than 4.5 km, although the numbers of mounds is fewer in the northern parts. An open grassland environment would seem essential, if a row of mounds was to be constructed

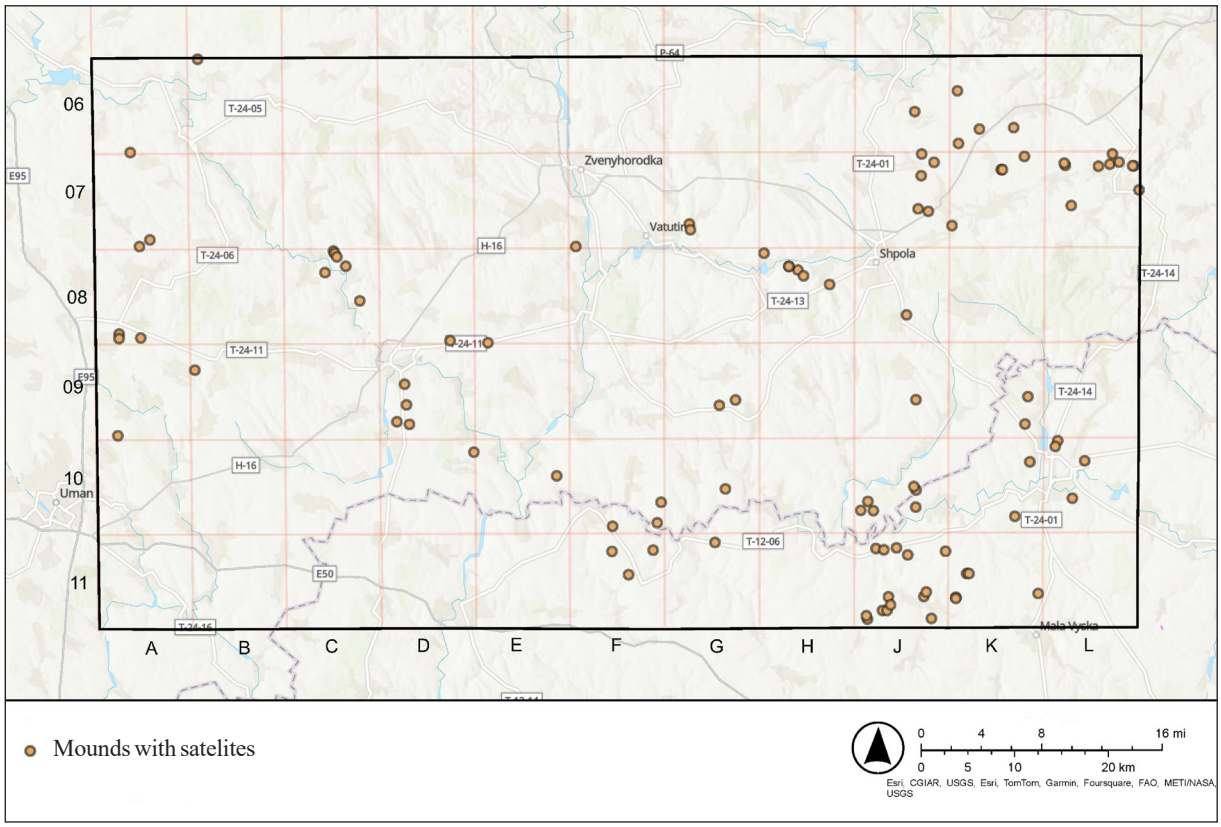

Fig. 14. A capture from the web application showing the survey area with locations of mounds which have satellites that appear to show a higher concentration in the eastern half of the study area

of published dates from excavations, J. Chapman and colleagues suggested that there could be a possibility of chronological overlap between the latest Trypillia settlements and the earliest barrows (or mounds) (Chapman et al. 2020, p. 212). However, they note that is likely to be an exception rather than the norm as is confirmed by other scholars who have studied excavated and radiocarbon dated Trypillia settlements and later Yamna burials over a wide area. For example, S. Ivanova (2016, c. 280) noted that radiocarbon dating does not provide a clear answer about the possibility of overlap, but that stratigraphy shows a time interval between Trypillia abandonment and construction of Yamna mounds.

Regardless of the date gap (J. Chapman et al. suggest that mounds are likely to post-date large Trypillia sites by 500–1000 years (Chapman et al. 2020, p. 212)), it could be suggested that, in cultivated or uncultivated ground, visible traces of those Trypillia sites may have remained to be seen by people who were used to reading the ground and/or that folk memory may have retained the significance of those former settlements, perhaps as places of plague and death (Rascovan 2019). Or maybe a river confluence, whatever its range of meanings, was a sufficient focal point for one end of a row of mounds. We illustrate this relationship in fig. 13 that shows the Trypillia site Chychyrkozivka (G07_045: 49.0148°N 31.1247°E) and the ridge that extends north from it. Chychyrkozivka was identified and drawn by K. V. Shyshkin (1985, рис. 2: 5) and later noted to be 300 ha by M. Nebbia, (2017b). The detail in fig. 13 was interpreted from 10 satellite images taken between 1982 and 2021 and shows the line of mounds that extends north along the ridge from the northern edge of the identified Trypillia structures. The line of mounds may continue, with some gaps, beyond the limit of the figure for at least 4.5 km. The visual association in fig. 13 shows the relationships of archaeological features to their natural landscape and places the Trypillian site close to a confluence of rivers. The mound line follows the high ground and no definite mounds were identified within the (former) settlement although, as is apparent on the web application, this occurs elsewhere. This relatively simple analysis of images leads to the suggestion that mound builders were aware of and respected the former settlement area or it may have remained as an extent of uneven ground that they avoided.

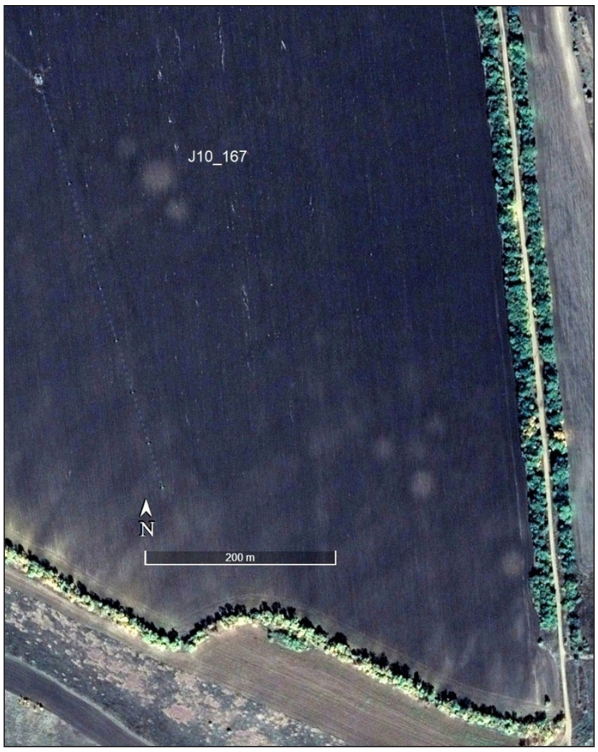

Fig. 15. One arrangement of satellite mounds is shown north of Vyliazeve where the focal mound appears to be the larger J10_167 (indicated) with smaller satellite mounds to its north-west and south-east. There is a suggestion of a linear continuation towards the south-east. The angled linear feature on the west side was part of a central-pivot irrigation system that was installed between 2014 and 2016 and shows clearly on images taken on 10 September 2016. Source: Google Earth enhancement: 2 October 2019

Environment of the mounds.

To create a line of mounds requires there to have been an open landscape to allow sighting and placement of a succession of mounds. Is there evidence for such open landscapes in this area, and from what date may it have been commonplace? Much of the relevant scientific work has been at Trypillia megasites which may provide a suitable *terminus ante quem* for mound construction, as discussed below.

Acquisition of detailed vegetation history first needs suitable types of site from which samples can be taken — peat bogs and lake sediments with high-quality pollen preservation being ideal — and then high-resolution sampling and an appropriate dating programme are essential to provide comprehensive results. The Eurasian steppe does not offer many suitable sample sites and hence its vegetation history, including any response to human occupation, is under-investigated and generalised (Ganz et al. 2024, p. 2). Pollen cores only accurately apply to a small area around each sample location, but can offer general comments on the vegetation history of a broader area and its change through time.

There have, however, been several papers that examined environmental records at or close to the megasites at Nebelivka, Maidenestke and Talianki. Evidence from pollen analysis, isotopic analysis of faunal remains and studies of soils and charcoal each produced roughly similar conclusions (e.g.: Kirleis, Dreibrodt 2016; Albert et al. 2020; Makarewicz et al. 2022). While they concentrated mainly on the duration of Trypillia occupation of megasites, that occupation did leave a legacy vegetation that may help understand placements of mounds. From those papers, which identified grazing patterns and woodland use, we can postulate a post-Trypillia landscape as one of open grassland and steppe vegetation with patchy tree cover and thicker forest along river valleys. The suggestion of overexploitation made on the basis of feather grasses before and after the abandonment of Maidenetske would have led to an increase in grassland steppe on higher ground, which is a barrier to tree growth (Kirleis, Dreibrodt 2016, p. 171, 174, 178).

The environmental evidence is corroborated by the distinct lines of mounds which would be very difficult, if not impossible, to plan and construct in woodland.

Mounds with satellites.

Our use of the word ‘satellites’ has been applied to describe small groups of mounds that are in close proximity and, in plan, appear to focus on a larger mound. Numbers of satellite mounds vary from one to several and we use the term to distinguish them from the larger groups of mounds such as were identified by K. V. Shyshkin (see especially: 1964, c. 200-202). It cannot be assumed that groups of mounds were all of similar date, and some could perhaps be considered as mound cemeteries that expanded over time (Needham, Anelay 2021, p. 485-486).

Our survey has identified two main forms of this close grouping of mounds: those with very close satellite mounds — maybe maidans (saltpeter works) — and others where the distance is slightly greater. These were mentioned in our first report (Palmer et al. 2023, p. 11, figs. 7, 8) and we can expand on those comments slightly after completion of the data collection. Sites of these forms were recorded as individual, but related elements (e.g.: *“small satellite mound to the SE of larger mound X”*) rather than groups. ‘Mound with satellites’ can be identified as a feature layer in the web application (fig. 14).

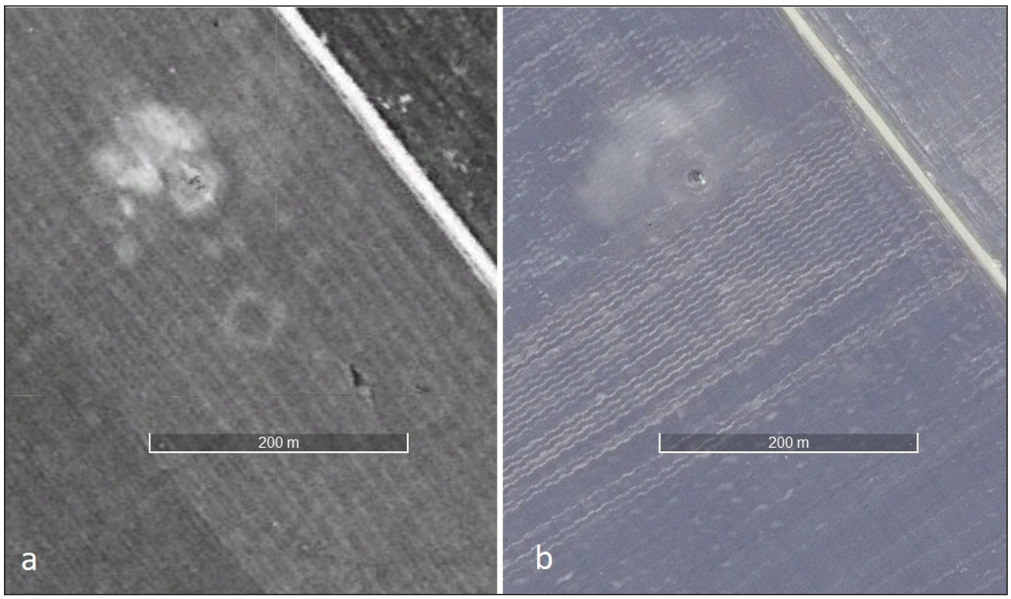

Fig. 16. A cluster of mounds near Yaroslavka as recorded on two different dates. The figure illustrates some of the problems of image interpretation and decisions that need to be made in the process of identifying exactly what features were originally here. Was it originally a mound with satellites, was it formed during saltpeter working, or could it be a combination of both? Comparison of the images also suggests there has been erosion by cultivation during the three decades between captures. Source: A, HEXAGON 18 May 1982; B, Google Earth: 18 August 2013

It is clear now that many of our satellite groups are, or include, maidans which cultivation can reduce to a group of mound-like forms. However, other groups remain and suggest that there may have been elements of local design intended by their makers. For example, north of Vyliazeve, can be seen short lines or regular placement of mounds in the close vicinity to what may have been a focal point at the larger mound J10_167 (48.7483°N 31.3762°E fig. 15). The linear arrangement of mounds close to J10_167 appears to have extended to the south-east where at least three other mounds can be seen close to the corner of the modern field. We should retain an element of caution in defining such groups which have been suggested on the view from above as this is something that we now have as users of RS sources, but that was not available to the mound builders. Other arrangements, that we cannot now perceive, may have had significance to the builders and users of those landscapes.

The majority of probable maidans remains in the survey area are of simple forms, comprising a main mound with two smaller mounds, sometimes elongated, that are usually to one side of the main mound. The most part of these have been identified in the eastern side of our area (fig. 14). In places the satellite evidence seems straightforward, but in others the same group of features can appear differently on different dates. For example, it would require thoughtful interpretation to create a cluster of mounds plan shown in fig. 16 south-east of Yaroslavka that appear centred on a mound that now has a trig point on it (J10_081: 48.7699°N 31.3870°E).

Case study 1: Precision and imprecision of location (fig. 17)

Our uses of QGIS and GE enable us to give a definitive location to every feature identified that allows any person in future to be certain that they have pinpointed the same place. This seems to be contra to past and present Ukrainian practice where — even with the availability of GPS, use of GIS, and access to good maps — many reports do not indicate precisely where an investigated site is located. Such information may be recorded in site archives, but without precise locational information it may be difficult, if not impossible, for future workers to locate that site.

In our database, project archive and in this report GE placemarks and polygons are used to better define features interpreted and provide their coordinate values. These offer benefit for any future use that may include GIS analysis of spatial arrangements for which accurate locations are essential.

Reconciliation of our sites with existing or known sites has proved problematic. While there is a publicly available database of the locations of many of the Trypillian sites (Nebbia 2017b)

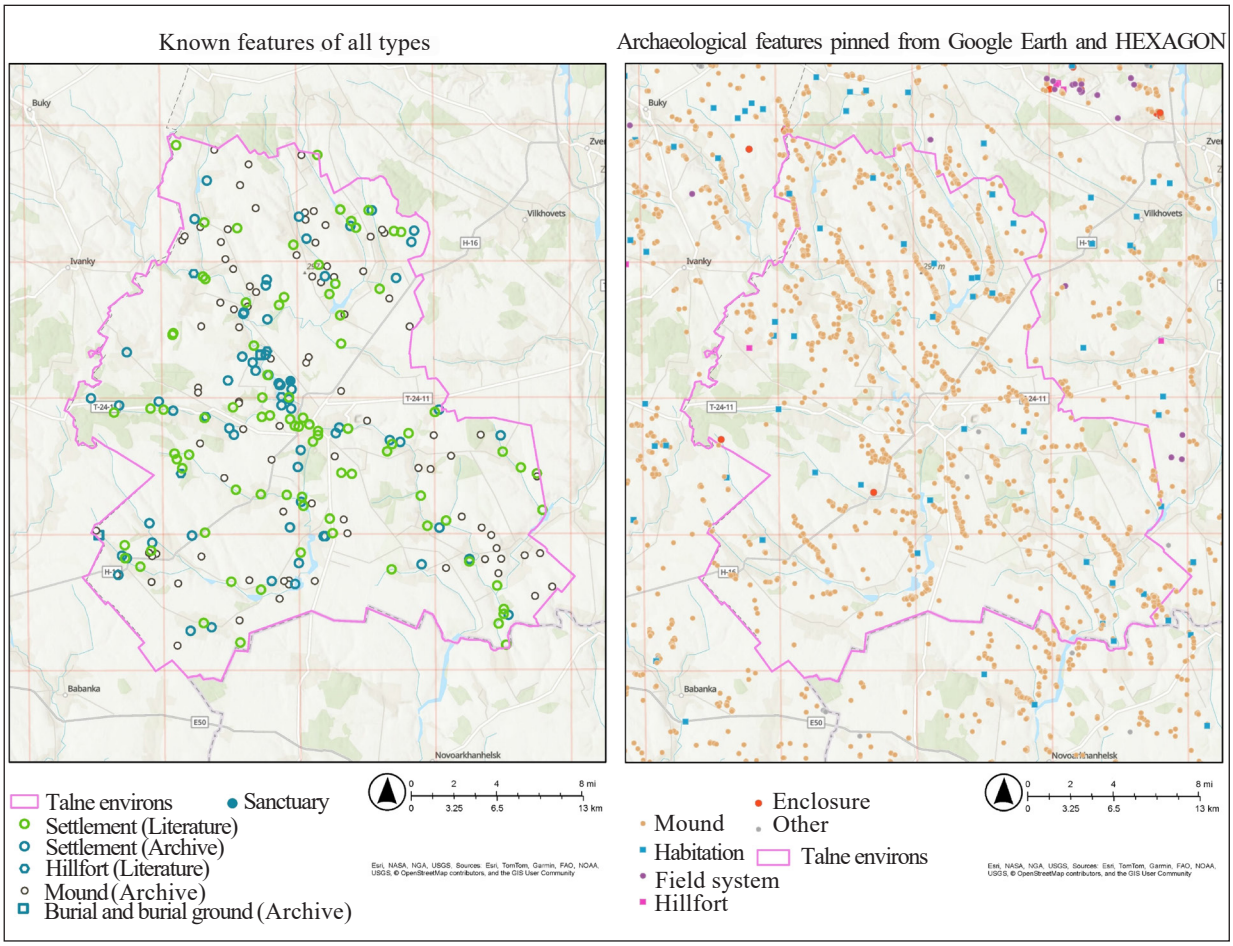

Fig. 17. Archaeological features identified in the Talne environs are shown from two sources. The left map shows sites known from archival and published data while that on the right shows results from our examination of satellite images. We had hoped to make useful comparisons by merging the two sources, but their incompatibility makes this unrewarding

we were unable to locate similar databases for other feature types such as hillforts, groups of mounds, habitation sites or burial sites. Without a comprehensive and dynamic information system in Ukraine (equivalent to the Historic Environment Record in the UK), much of the archaeological information must be collated from paper documents located in the archives and publications.

Extensive investigations into archival data and literature by O. V. Kariaka resulted in the collation of known archaeological information in the Talne environs (fig. 17). Typical naming conventions using the nearest town may be easy to remember, but do not provide enough detail to relocate a site by the third party. Descriptive locations generated prior to the availability of maps by archaeological investigators may take the form: *"... on the fourth field in the direction of the village of Onopriivka, 4 km from the village of Berynka."* This type of description offers an ambiguous location relative to those villages and one that makes present-day relocation and identification of those sites imprecise, maybe impossible in many cases, and has hindered our ability to match satellite evidence to those find spots.

Such imprecision caused severe problems for a case study that we had hoped to do in the Talne environs. Archival information listed many sites that had been located at an unknown date (although some work is from 1950s) by archaeologists undertaking field survey. Metadata included fairly precise date ranges, as may be expected if surface finds are examined but, without use of maps to aid their survey, provide poor locational information. We had hoped to match some of those known sites with features on satellite images (fig. 17) and possibly add detail to sites known only from surface finds, but their locational information did not allow that to be done. A positive result from the known sites was that many were from populated village locations that would not readily provide signals on above-ground images. This left us unable to create an edited combination of known sites and those

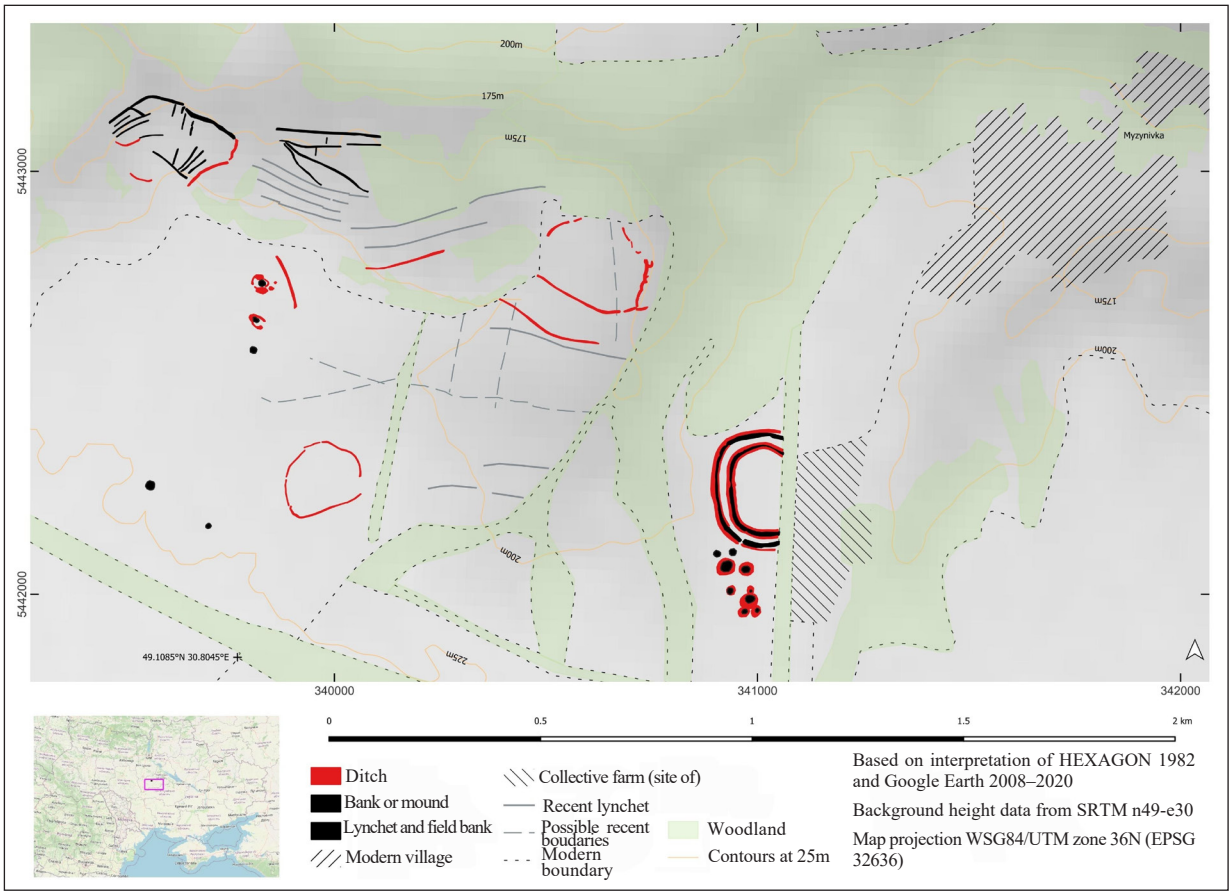

Fig. 18. Interpretation of features in the Myzynivka area has identified a possible field system in the north-west part of the map that may be associated with nearby enclosures that include a hillfort. Note that the hillfort in the south-east part of the map is partly overlain or destroyed by a belt of trees and a former collective farm

from images that may have produced an optimum map of past settlement and land use within the district. Problems of this integration of evidence can be studied by others using the web application which includes the relevant archival data. We can, however, make the following summarising points:

- traditional methods of archaeological research mainly follow routes of exploration along roads, riverbanks, ravines, etc. Information thus recovered in places inaccessible to satellite photography, such as within towns and villages, complements the overall picture of the distribution of monuments;

- the lack of cartographic information in many Ukrainian scientific reports greatly complicates the localisation of monuments, sometimes making this impossible;

- uses of satellite images significantly increases the number of archaeological features to the extent that it is unlikely to be practical ever to be able to confirm each by field research. Accepting image data on its own strengths and weaknesses presents a challenge for Ukrainian archaeologists although it has become accepted practice in many other countries, albeit sometimes with reluctance (Wilson 2004, p. 36).

Case study 2: Myzynivka — a local landscape (fig. 18)

One advantage of studying an area by interpreting images and mapping parts of it is that the resulting maps help a viewer to coalesce thoughts on relationships between features. However, to do this effectively it needs the right features to be visible on images, or from available records, so that disparate parts of a landscape can be put together. One aspect of land use is that aerial and satellite images can be good for detecting field systems, which may be visible as field-defining ditches, banks or tracks as are known from parts of Western Europe where some date from the Middle Bronze Age. Later fields, named chora, are known in Ukraine and show in similar ways south of the present study (Kariaka 2008). Better known are those associated with the UNESCO World Heritage Site at Chersonesos in the Crimea

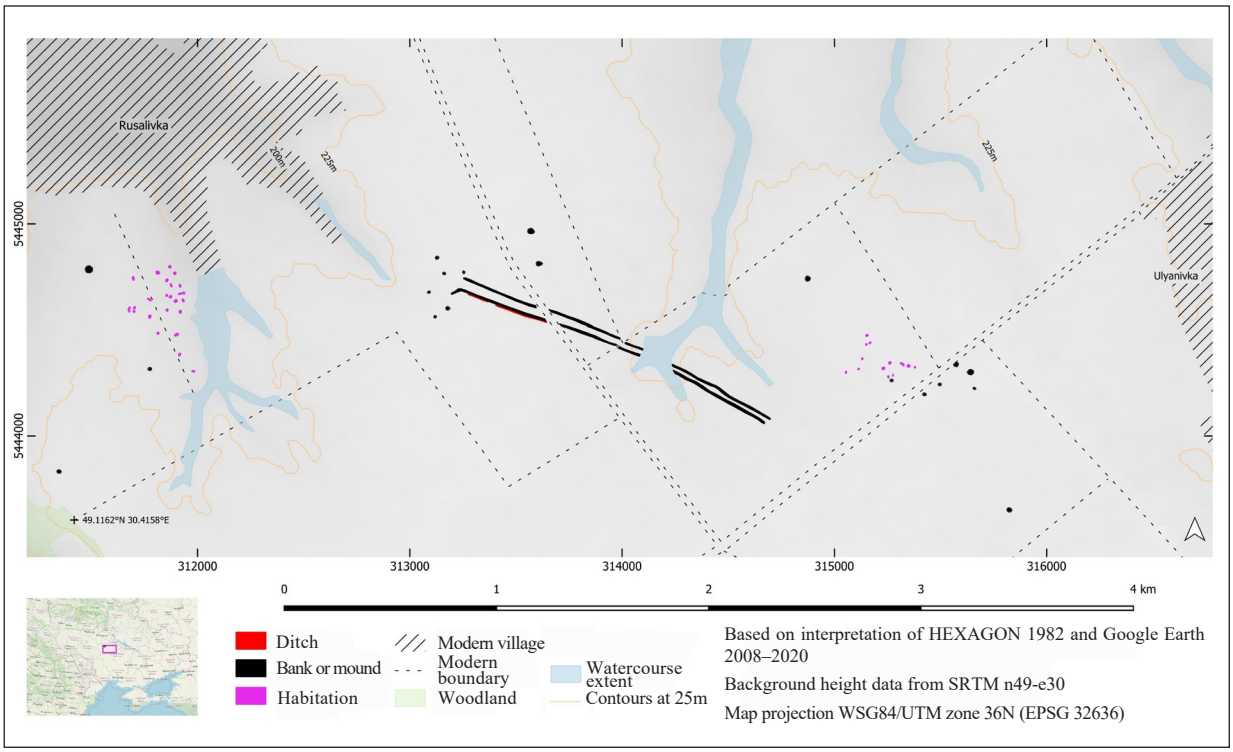

Fig. 19. The parallel banks at Rusalivka are among the 'unknowns' that have arisen during our survey. The map shows them in their topographical, archaeological and recent context, but doesn't provide an obvious explanation for them. The banks appear to mark a route that crosses a watercourse, perhaps at a ford, however they are a long structure for that purpose

have been extensively studied (e.g.: Carter et al. 2000), but may be partly destroyed as part of recent Russian occupation (Coynash 2024).

We have, however, recorded very few examples of ancient fields in this survey and all survive on presently uncultivated slopes and are partial evidence at best or the occasional single lynchet. All are questionable as field systems and any or all of these could be of almost any date from prehistory to recent. Fields suggested in the Myzynivka area (D06_048 and E06_178: centred 49.1190°N 30.8050°E) are defined mostly by banks (which are constructed) and lynchets (which are produced by repeated cultivation) and the latter suggest they have been produced by long term use rather than resulting from a single event. This leads us to the issue why fields were needed. There is no single answer and reasons could include the need to separate, or identify, arable from grazing land and perhaps to formalise users' definition of 'owned' land. Banks and lynchets also provide access routes through cultivated land that can be used without damaging crops.

Fig. 18 distinguishes between fields that may be of some antiquity and those that appear to belong with more recent land divisions. Both use the natural topography in similar ways and the distinction was made during the photo interpretation process when differences and similarities in surviving features suggested there was a chronological difference that could be indicated.

Mapping enables us to assess ways in which this small landscape may have operated in the past. This is done on the basis of proximity as no dating information is available to us and we begin by assuming contemporaneity of features discussed.

The mapped information provides no direct relationship (meeting of features) between fields and possible settlement enclosures and we have only the possibility that evaluation of distance and topography may lead to an understanding of how the land was used in the past. For example, the hillfort to the south-east is some 1100 m distant (E06_126: 49.1125°N 30.8215°E) and walking to the fields by the easiest route would descend to the former river valley and then follow it by making a slight climb to the north and west. There is what is likely to be an enclosure (E06_135: 49.1172°N 30.8157°E) between the hillfort and fields some 550 m east of the identified field features. A curving route could be taken between them that closely follows the contours. The second and smaller enclosure (D06_054: 49.1125°N 30.8070°E) is shown some 650 m to the south of the fields. A route between them that passes, and

may be guided by, the line of three mounds would follow almost level ground before descending into the fields.

It is all conjecture but indicates some of the possibilities that mapping alone may bring to understanding of how local landscapes may have functioned in the past.

Case study 3: Rusalivka parallel banks (fig. 19)

Near the village of Rusalivka is a feature defined by a pair of near-parallel banks aligned roughly north-west to south-east and of some 1600 m in length. Their central point is at 49.1242°N, 30.4520°E. The feature is unique within our survey area and is published to draw attention to it in the hope that other examples may be known. On all image dates it is visible predominantly as a chain of near-parallel light features (B06_113–120), which are presumably banks of hard material, and there is a hint of an external ditch near the north-west end of the west length on HEXAGON. The breaks in the south-eastern length of the feature may be genuine gaps, but other mapped breaks in the banks are due to modern field divisions or the unknown extent where it crosses a small watercourse.

The banks are not exactly parallel and the internal width varies from 47 m at the north-west end — where the southern bank appears to angle to the west — to 13 m in its south-east length that includes a bulge of 24 m. The banks may retain minimal height as images taken between 1982 and 2019 show they are being cut and dragged by modern cultivation. The banks were visible on earlier CORONA photographs taken on 6 October 1964 and 6 April 1971, but their resolution is insufficient to show plough damage. It is somewhat remarkable that these features have been visible, in three or four differently managed modern fields, throughout this time and it suggests that the banks are substantial. The 1872 map shows a sinuous road to the north of the banks. There is no sign of the road on any of the images examined, but the Rusalivka banks are unlikely to be part of it. They may, however, mark a fordable route across the watercourse for travellers or stock movement south-east from Rusalivka, but they seem unnecessarily long for that purpose.

Fig. 20 shows the feature in its local environment with nearby mounds and habitation sites identified during our survey. Topographically the banks are higher at each end and their course cuts across a watercourse that is some 1000 m from the banks' north-west end. Close to that end are six small mounds and two larger ones are situated north of the banks. No mounds were identified near the south-east end of the banks, but there is a habitation site within 400 m and a scatter of mounds beyond that.

Within our survey area, and about 2 km south of the Rusalivka banks, we have noted shorter lengths of the bank, including a short parallel pair on a similar alignment (B06_223: 49.1061°N, 30.4717°E), but they were thought to derive from recent agriculture. Elsewhere, the one archaeological parallel, we are aware of, was discovered by O. V. Kariaka aligned with the large Scythian mound at Ohuz (46.8746°N, 34.4353°E). However, there are no real similarities other than both having parallel banks and the Ohuz example is clearly associated with the large mound.

A question arose during earlier discussion of this feature as it has parallels to forms known as cursus monuments in Britain and Ireland that are of Neolithic date (Barclay, Harding 2017). To curtail any such suggestion about the Rusalivka banks, we have been assured by an expert on these monuments, that despite occasional claims, none is known elsewhere (Dr. Kenneth Brophy, email from 26 September 2023).

Case study 4: Pastyrske fortified settlement and promontory bank near Buda Makiivka (fig. 20)

The archaeological features at Pastyrske (L08_068: 48.9777°N 31.7325°E) have been described as a multi-period fortified settlement based on excavations undertaken principally by V. V. Khvoika (1892–1901) and M. Yu. Braichevskyi (1949–1955). Results have been summarised as showing the remains of two settlements, one Scythian from the 6th to the 4th centuries BC and the other, most probably Slavic, from the 7th to the 8th centuries AD (Encyclopedia of Ukraine 2025). Further excavation appears to have been undertaken in 2017, resulting in a report on pottery that describes the site as *"…the largest craft, trade and military-administrative centre in Eastern Europe outside the Byzantine Empire in the early Middle Ages"* (Скиба, Баранов 2019, p. 67). Those authors also mention an internal citadel with three enclosing ramparts as is shown against the western bank of the southern part of the enclosure. Searches from England were unable to locate the earlier references cited in that report. However, the main structure of

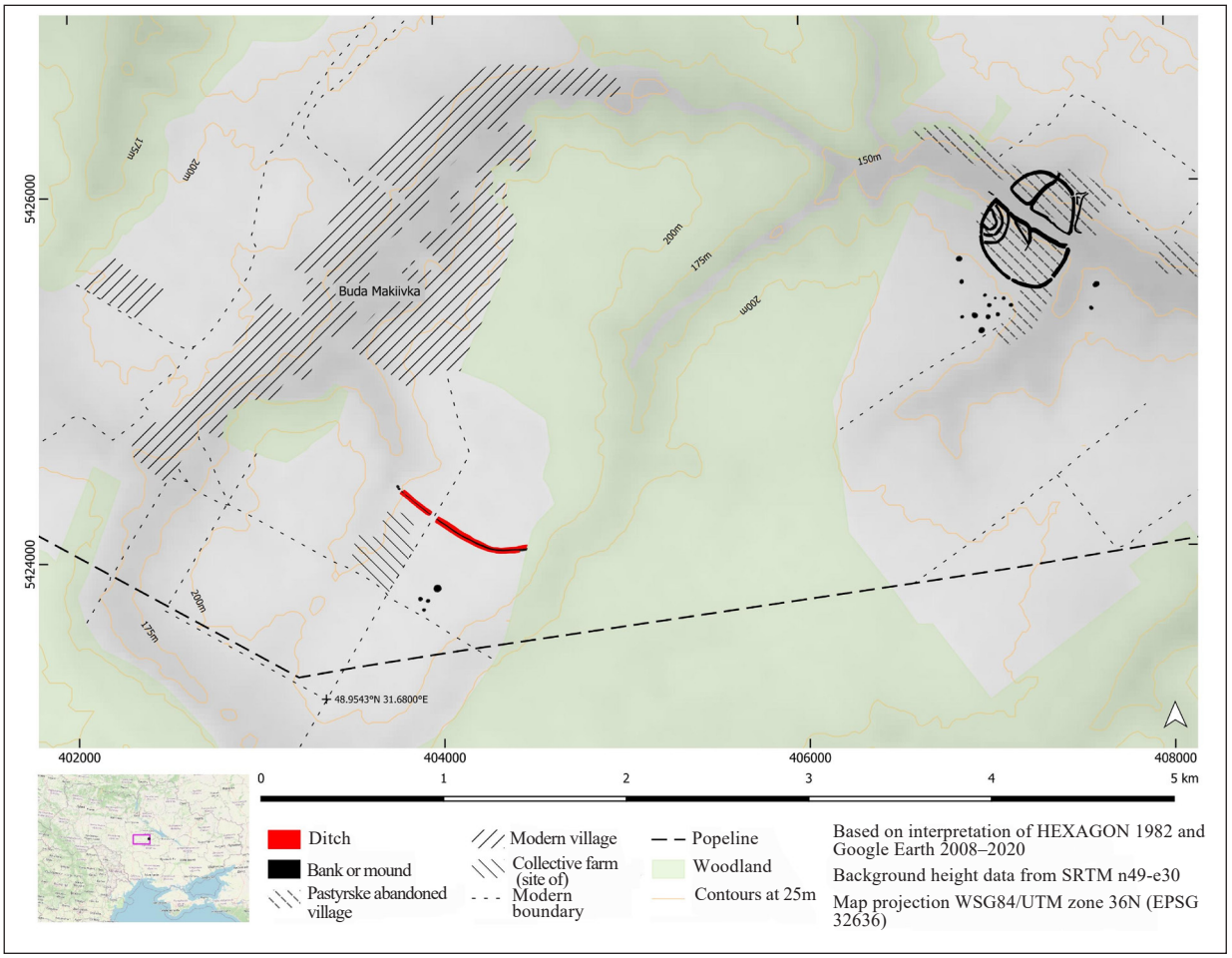

Fig. 20. The fortified settlement at Pastyrske, in the map's north-east corner, is based on published plans as little can now be seen on images as it was later covered by a village that has since been abandoned. Its topographic position, straddling a former river, is clear in the map and helps provide an explanation for the choice of location. To the south-west is a rampart that crosses a promontory, or cape, and is clearly recorded on images. A recent pipeline crosses the southern part of the map

the site is clear from the description by A. V. Skyba and V. I. Baranov and is shown in fig. 20 where the river cutting through the site — which may have been navigable in Slavic times — emphasises the suitability of location for an administrative and/or trade centre.

It is illustrated in this report to demonstrate how other sources can assist identification of features on images and also to show the relevance of recent changes in land use to our understanding of earlier features. Our searches of literature had found two plans of Pastyrske fortified settlement, one schematic and included in the Encyclopaedia (2025), the other at poor resolution, but showing a hachured earthwork drawing and with a date of 1949 in its caption (source currently unknown, but perhaps from a survey preceding Braichevskyi's excavations?).

The schematic plan shows two rivers that join at a T-junction immediately east of the enclosure (apparent in fig. 20). The plan shows a wide river flowing from west to east cut through the enclosure, although it also appears to show the ramparts crossing the river – something that is improbable even though the satellite images examined reveal the river now becomes very dry in summer. The hachure plan indicates the river as a single line with ramparts to its north and south thereby tending to form two adjacent but separate D-shaped defensive enclosures. That plan also shows ramparts of both enclosures running parallel to the river and perhaps also including flood defences that appear larger in the southern enclosure.

The plans of the enclosure(s) helped us locate parts of it — mainly the southern arc and part of the north-east enclosure — in the images we had and this enabled us to scale and place the hachure plan fairly accurately in QGIS where it was overdrawn to show the site in relation to the later village.

A. V. Skyba and V. I. Baranov (2019, c. 67) note that the citadel ramparts were demolished in the early 20th century and this may date the

origin of the village remains indicated in the figure (L08_035, 048–049). No village or houses are shown here on the 1872 map and the earliest evidence we have are buildings on both sides of the river on the Soviet map of c. 1975 which also indicates a name immediately south of the village. The HEXAGON photograph from 1982 shows the village parts were actively occupied, with houses visible and individual strip fields at their rear. By 2007, many houses had been demolished and some of the strip fields had been merged into larger plots. This use continued in 2009, but later images demonstrate that much of the land had been abandoned, especially south of the river. This change in use from active (1982) to abandoned (by 2007–2011) is reflected by many of the villages identified as 'abandoned' during our survey. GE now names the Sharpine Nature Reserve within the southern enclosure adjacent to the river.

Some 3.5 km south-west of the centre of Pastyrske enclosure(s) is a curving rampart (L08_051: 48.96261°N 31.6896°E) that cuts across a promontory or cape on raised ground between 200 m contours. In this area, the ground slopes gently from north-east to south-west with the small group of mounds at 211 m on a local high point. The terrain form suggests that the rampart may have been more for the purpose of marking land divisions than for defence. It is visible on all image dates from 1982 to 2019 as a bank with ditches on its northern and southern sides, with that on the south showing more clearly. Plough damage is also apparent, especially in 1982 and 2019. The rampart is south of the modern village of Buda Makiivka and there was a collective farm (L08_020) south of its western end that was active in 1982, but abandoned and demolished by 2007. The 1982 photograph reveals no obvious damage by the farm to the rampart although small tracks, possibly footpaths, crossed it.

The angled linear feature towards the south of the figure is a buried pipeline that appeared to be under construction, or freshly constructed, in 1982 (L08_050). Recent features of this type have been mapped by our project to indicate where damage has, or may have, occurred to archaeological features.

Experimental use of AI for mound detection

Uses of artificial intelligence (AI) in archaeological research has a history of at least 30 years during which it has been called a variety of names (e.g.: computer assisted classification and automated detection). Early archaeological applications sought to classify circular features from aerial photographs (e.g.: Redfern 1997) and high-resolution satellite images (Trier, Larsen, Solberg 2009), but more complex archaeological forms can now be identified usually using ALS as its source of images (Tenzer et al. 2024). Use of AI may be advantageous for surveys of extensive areas of land.

Though the generosity of I. Kramer, founder of ArchAI[5], our project was given an opportunity to collaborate in an experiment to use artificial intelligence (AI) to identify mounds. ArchAI utilises deep convolutional neural networks to identify potential archaeological objects on a range of earth observation data and has been used in commercial and research projects in Britain (Cowley 2020; Kramer 2022). The data sources used were raster images of 18 georeferenced HEXAGON photographs that cover the 60 × 110 km area and vector point data resulting from our examination of HEXAGON and GE. AI was trained using the combined data from seven 10 × 10 km squares, after which its results were manually validated and fine-tuned using data from another three squares. After discussion and further refinement, AI was run on a further three squares and its resulting 453 identifications were checked manually to identify newly detected mounds of which 294 were false positives.

In conclusion, ArchAI considered the experiment validated the effectiveness of their approach in a new country using a new type of dataset. However, before suggesting it may be used to identify mounds in the rest of Ukraine, it will be necessary to significantly improve training data in a way that allows AI to also learn about non-archaeological objects that may look like mounds (e.g.: agricultural heaps and levee remnants) and, if possible, to take account of topographical variations that a human interpreter may use in helping to decide if a feature may be of archaeological interest.

Endnote

Rather than draw conclusions, it may be more appropriate to review the strands of evidence that have been identified and brought together by this project and propose ideas for the uses of such spatial information.

[5] https://www.archai.io/

Image interpretation throughout this survey has been knowledge based (e.g.: Cowley, Palmer 2010) using skills acquired by one of us during more than 50 years of work with aerial photographs, mostly in England, and applying them, through sharing the knowledge, to part of the landscape of Ukraine.

Our survey has identified and pinpointed more than 7500 archaeological features in an area of 6600 km^2. Many will be previously known but may not have been presented in the ways this project has used — i.e. ranging from the web application to maps of small areas.

By agreement with AARG, the web application will remain online for at least five years and the survey data will be permanently lodged at Zenodo[6]. The web application can be searched and manipulated by any user to examine the whole or parts of the study area. Types of site can be selected and viewed individually and in combination with others and the database for each feature shows image sources and includes brief comments made during our image searching.

Use of GE and QGIS as the basis for our accumulated data has provided precision of location and allowed us to see and study location of sites and areas in their topographical context.

GE and QGIS also give the ability to examine sites by themselves and to see and suggest relationships between them.

The inclusion of maps in this report may demonstrate the value of interpretation and mapping from remotely sensed images in archaeological research.

Other potential uses.

Ukrainian archaeology has the potential to progress with RS work by interpreting aerial and satellite images as the first step in archaeological examination of a site or area. If nothing else, this will provide topographical context for a site or area that may help understand some of the past features within it. Other potential uses include the following.

The definition, detail and precision that image interpretation can provide has been used as the principal source for research projects in, for example, England (e.g.: Stoertz 1997). Photo interpretation was a major source of previously-unused evidence in Italy (Campana 2017) and, by taking hand-held oblique photographs, to provide source information over parts of the Velebit Mountains in Croatia to assist and direct field survey (Glavaš, Palmer 2013). Maps derived from photo interpretation were used in connection with field walking surveys where they supplied detail, relationship and context to what otherwise would have been outlines showing surface collection areas (Hall, Palmer 1996). A final example demostrates long term work at West Heslerton, England, from which data is available through Zenodo (Powlesland 2025). From there, a link goes to an interactive visual representation of an extent of linear settlement and land use that merges mapping from aerial photographs with geophysical results (magnetic and gradiometry) and excavation against a natural background. Layers can be turned on or off and a colour-coded dateline, based on excavation results, can be used to show active features through a timeline extending from 6000 BC to the present.

Results from aerial photograph interpretation by Historic England (HE) have recently been made available online (Crutchley 2024; AAME 2025) and are also available as a series of Research Reports (Historic... 2025). These show the relevance of image interpretation within a major government archaeological organisation, that is also responsible for giving legal protection to nationally important sites, and this paragraph gives examples that may stimulate similar work in Ukraine. Help and ideas may also come from an HE guide which, although it uses image sources relevant to England, explains how to look at images and ways in which they may be manipulated by appropriate software to prepare mapping and supporting metadata (Evans 2019).

Since 1990, photo interpretation and mapping has been a required component in commercial projects to provide context and help guide and plan fieldwork (e.g.: geophysics and fieldwalking) and excavations that, legally, precede development in several countries (e.g.: in the UK by the Chartered Institute for Archaeologists (Chartered... 2025)). This may also be the case in Ukraine. AARG is a group of friendly people who answer questions, and its members have run numerous training schools and workshops, with EU and other funding, in particular in Central Europe from 1996 after the end of the Cold War. As well as educating others, those workshops also created a network of similar-minded colleagues across Europe who share experiences, discuss problems and have been involved in our Ukrainian project.

Problems and prospects.

Experience gained from this project suggests the following points.

[6] Avaliable at: https://aargonline.com/wp/working-groups/ukraine-wg/

Ukrainian archaeology has a very close relationship with dates. The majority of information that comes from image sources will have no precise dates, but in cases these may be estimated through comparison with known sites. Such dates may be coarser than preferred, however should be capable of being refined through continuous feedback and coordination between field and desk. This is a potential problem that needs to be addressed as it will never be possible for all sites to be examined on the ground, so ways around that intellectual problem will need to be found.

Inclusion of results from image mapping can supplement, probably also improve, that known only from the ground (Rączkowski 1996) by enhancing that recorded information obtained from existing knowledge, field studies or excavations.

As we have observed in other countries, there will probably need to be a philosophical change within archaeology to enable a shift in focus from the single site, or those of known types and dates, to embrace landscape studies in which precise dating is of lesser relevance (see: Powlesland 2025, outlined above).

Our project, which to date has taken less than three years, has examined about 1 % of Ukraine. We look forward to seeing further progress.

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Рог Палмер[1], Мартін Фоулер[2], Валері Вард[3], Олександр В. Каряка[4]

[1]Науковий співробітник, Дослідницька група повітряної аероархеології, ORCID: 0000-0003-0546-9273, rog.palmer0@gmail.com

[2]PhD, науковий співробітник, Дослідницька група повітряної аероархеології, ORCID: 0000-0003-4211-3671, danebury216@hotmail.co.uk

[3]Науковий співробітник, Дослідницька група повітряної аероархеології, ORCID: 0000-0002-4936-3932, Valerie.C.Ward@hotmail.com

[4]Кандидат історичних наук, науковий співробітник, відділ Польовий комітет Інституту археології НАН України, ORCID: 0000-0003-3066-3641, akarjaka@ukr.net

ЛАНДШАФТНЕ АРХЕОЛОГІЧНЕ ОБСТЕЖЕННЯ 6600 км² ЧЕРКАСЬКОЇ ОБЛ. (УКРАЇНА) З ВИКОРИСТАННЯМ СУПУТНИКОВИХ ЗНІМКІВ ІЗ ВІДКРИТИХ ДЖЕРЕЛ: ДРУГИЙ ЗВІТ

Ця стаття підсумовує результати трирічного дослідження археологічного ландшафту частини України, що базувалося переважно на супутникових зображеннях (HEXAGON і Google Earth). Було ідентифіковано й геолоковано понад 7500 археологічних об'єктів, доступ до яких можна отримати через інтерактивний вебдодаток ArcGIS — для перегляду та подальшого аналізу. У статті розглядаються особливості, притаманні супутниковим зображенням, а також вплив змін у сільськогосподарській практиці протягом 40-річного періоду зйомки на видимість археологічних об'єктів.

Після короткого статистичного підсумку представлено опис можливостей аналізу археологічного ландшафту за допомогою інтерактивного додатка й приклади його інтерпретацій. Автори зосереджуються на поселеннях: формах, розмірах і топографічних особливостях, які подано у вигляді зображень і схематичних малюнків. Дослідження дозволило уточнити місця розташування деяких відомих поселень Трипільської культури та виявити нові. Також обговорюються зольники як показники наявності поселенських структур у досліджуваному регіоні.

Розділ про дослідження курганів починається з прикладів їх пошкоджень та опису можливостей повторної зйомки для моніторингу етапів руйнування цього типу пам'яток. Автори звертають увагу на відмінності в зовнішньому вигляді курганів на зображеннях і припускають їх можливі різноманітні способи використання в минулому. Також розглянуто можливі зв'язки між лініями курганів і навколишнім середовищем. Як окремий тип курганних груп, т.зв. «кургани із супутниками», зафіксовано близько 100 подібних випадків.

У статті також подано чотири оригінальні тематичні дослідження. Перше — порівняння архівних і опублікованих даних у районі Тальнівщини з результатами даних дослідження супутникових знімків. Решта три зосереджуються на менших ділянках, ілюструючи, як інтерпретація та картографування супутникових зображень можуть поглибити археологічне розуміння пам'яток регіону. У статті також стисло підсумовано експеримент із використанням штучного інтелекту для виявлення курганів. Він завершується оглядом різних типів доказів та обговоренням проблем і перспектив використання супутникових зображень в українській археології.

Ключові слова: ландшафтна археологія, обстеження, супутникові знімки, дистанційне зондування, HEXAGON, Google Earth, інтерпретація та картографування, штучний інтелект.

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