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# CUCUTENI UNEARTHED: A 3D JOURNEY THROUGH TIME

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**Abstract:** The current study presents the development of a comprehensive 3D model of the Cucuteni-*Cetățuia* archaeological site (NE Romania), the eponymous settlement of the Chalcolithic Cucuteni culture. The project integrates multidisciplinary methodologies, including drone- and high-resolution camera-based photogrammetry, as well as terrestrial 3D scanning, and Geographic Information System (GIS) analysis. The core objective of this initiative was the creation of an interactive online platform that enables both specialists and the general public to explore the archaeological site in an immersive and accessible manner. The platform incorporates Virtual Reality (VR) functionalities and interactive visualization tools that facilitate the remote examination of excavation trenches, previously unearthed structures, and newly detected subsurface features. By bridging the gap between scientific research and public engagement, the project fosters a participatory approach to heritage preservation and interpretation. The integration of digital modeling with online dissemination represents a significant advancement in archaeological methodology, offering researchers an innovative tool for spatial analysis and hypothesis testing. Simultaneously, it enhances public access to cultural heritage, particularly for sites that present logistical challenges due to geographic constraints or preservation concerns. This initiative underscores the potential of digital technologies in democratizing archaeology, making historical landscapes and their narratives available to a wider audience while promoting interdisciplinary collaboration. Through this case study, the research highlights the broader implications of such digital frameworks for the documentation, conservation, and presentation of archaeological sites worldwide.

**Keywords:** *Cucuteni culture, 3D models, UAV, photogrammetry, public archaeology*.

## INTRODUCTION

The field of archaeology is experiencing a transformative shift with the increasing adoption of advanced spatial analysis methods within Geographic Information System (GIS) environments. This global trend emphasizes the utilization of sophisticated 3D modeling techniques to achieve significantly enhanced precision in spatial analyses. The ultimate goal is to create the most accurate possible record of field documentation, while simultaneously fostering public engagement and understanding of archaeological heritage through accessible and readily comprehensible dissemination of research findings. The advantages inherent in this cutting-edge approach have been stated in publications such as "Archaeological 3D GIS"[1], which also serves as a reference point signifying the transition from the limitations of 2.5D environments (represented by Digital Surface Models – DSMs, and Digital Elevation Models – DEMs) to the increasingly prevalent and powerful 3D environment

[1] DELL'UNTO/LANDESCHI 2022.

now being employed in archaeological investigations[2]. A compelling illustration of this evolution can be observed at the archaeological site of Troy, where ongoing efforts are focused on establishing a comprehensive digital hub encompassing the totality of excavation research conducted at the site throughout its history[3].

The primary objective of our project was to develop a user-friendly and intuitive presentation of the archaeological excavations carried out at the eponymous site of the Cucuteni culture, *Cetățuia* (Cucuteni administrative unit, Iași County). Specifically, we aimed to showcase data from historical campaigns (1909–1910, 1961–1966), alongside newly acquired data from more recent excavations (2017, 2021–2022). This undertaking was facilitated by leveraging the capabilities of ArcGIS Pro and its suite of online applications, including SceneViewer and StoryMaps. We designed our presentation with a strong emphasis on public accessibility, ensuring that diverse audiences, including local communities and educational institutions, can easily engage with the site's history. Our platform is structured around an engaging virtual tour constructed using the StoryMaps application, a tool within the ArcGIS Pro suite, specifically designed for broad public accessibility. However, the underlying scientific data incorporated into the tour can also be visualized and explored in the SceneViewer application, a more robust platform tailored for experienced researchers and specialists. This dual approach provides users with the flexibility to conduct basic analyses directly within the online interface (such as distance measurements, elevation profiles, and area calculations) while also offering the option to seamlessly integrate the data into ArcGIS Pro for more in-depth analyses of the site.

Consequently, our project distinguishes itself significantly from conventional approaches, which are often limited to utilizing platforms like SketchFab for the mere display of 3D models of archaeological sites, supplemented by annotations for rudimentary explanations. Our project not only facilitates the comprehensive presentation of the subject through the incorporation of diverse media elements (including video material, audio segments, images, and detailed textual explanations), but also empowers users to directly utilize the integrated data for performing advanced analytical tasks within the powerful GIS environment. Moreover, we envision this project as a foundation for future community-based initiatives, such as citizen science projects and educational workshops, that leverage the digital data to foster a deeper connection between the public and their local archaeological heritage. This integrated approach represents a substantial advancement in the way archaeological data is presented, analyzed, disseminated, and, crucially, experienced by the public.

## ARCHAEOLOGICAL BACKGROUND

The Cucuteni-Tripolye (Trypillia) cultural complex (Fig. 1), flourished in a large part of southeastern Europe during the Chalcolithic period (ca. 5000–3000 BC)[4], intriguing archaeologists and art historians for over a century. While its exquisitely painted ceramics, showcasing remarkable artistic skill and sophistication, are widely recognized as iconic artifacts of the era, the architectural remains of this culture offer an equally compelling (albeit often dramatically fragmented) glimpse into their lives. These remains often exhibit vitrification, a process where the clay of the walls and floors has been transformed into a glassy substance due to extreme heat. Within these fire-ravaged structures, archaeologists have unearthed invaluable evidence not only of daily life, but also tantalizing hints of the Cucuteni-Trypillia people's spiritual beliefs and practices. The delicate and often fragmented state of the burnt remains necessitates the development and implementation of meticulous excavation techniques and comprehensive documentation strategies to accurately record the various layers of destruction (Fig. 2).

The archaeological exploration of the Cucuteni culture has a rich history, stretching back nearly 150 years. The story begins in the late 19th century (1884–1896) with pioneering investigations conducted at the *Cetățuia* site (Fig. 3) by figures such as N. Beldiceanu, G. Buțureanu, and G. Diamandy[5], among others. In the early 20th century (1909–1910), the German scholar Hubert Schmidt[6] made significant contributions, further refining our understanding of the culture. The second half of the 20th century witnessed renewed interest and more systematic excavations, notably those conducted by M. Petrescu-Dîmbovița and his team (1961–1966)[7].

These sustained efforts allowed not only the identification and naming of the Cucuteni culture, but also its chronological framework attribution. The *Cetățuia* site proved particularly significant, yielding evidence of all three primary phases of the Cucuteni culture (A, A-B, and B). Furthermore, the site revealed sporadic traces of later habitation, including materials from the transitioning period to Bronze Age (Horodiștea-Erbiceni culture) and even later periods, such as the Early Bronze Age and the La Tène period, demonstrating the site's continued importance across millennia.

For many years, it was believed that the site from *Cetățuia* had been exhaustively studied and its secrets largely unveiled. However, a series of non-invasive investigations conducted by our team in 2017 dramatically altered this perception[8]. These surveys, employing techniques such as magnetometry, revealed that the site extended far beyond its previously recognized boundaries, opening a new and exciting chapter in the ongoing research of this fascinating settlement. The magnetic measurements, covering 5 hectares west of the previously known area, produced a detailed magnetic map that revealed a substantial westward expansion of the eponymous site onto the vast *Laiu* plateau. The interpretation of the magnetic anomalies recorded in this survey has provided tantalizing insights into the nature of this newly discovered area. There have been identified several potential features, including two distinct rows of dwellings, suggesting

[2] COMES *et alii* 2017; COMES *et alii* 2019; COMES *et alii* 2020.
[3] WAAGEN/VAN WIJNGAARDEN 2024; https://skfb.ly/6X8Vt (accessed: 01.2025).
[4] LAZAROVICI/LAZAROVICI/ȚURCANU 2009, 17; URSULESCU 2022, 19.
[5] VĂLEANU 2006.
[6] SCHMIDT 1932.
[7] PETRESCU-DÎMBOVIȚA/VĂLEANU 2004.
[8] TENCARIU *et alii* 2019; TENCARIU *et alii* 2021; TENCARIU *et alii* 2022.


**Fig. 1**. The Chalcolithic archaeological cultures of Southeastern Europe, and the main archaeological sites investigated (©Ștefan Caliniuc).


**Fig. 2.** Detail on the complexes 1 and 2, investigated in 2021 on the Cucuteni – *Cetățuia* settlement.

a more complex settlement layout than previously imagined. Perhaps most intriguing are the indications of two sets of defensive or delimitation ditches, arranged in concentric arcs. One ditch, interpreted as an intermediate line of defense, is located approximately 40 meters from the two previously known ditches. The second outer ditch lies almost 80 meters beyond the first, effectively encompassing the vestiges of the Cucuteni settlement. Furthermore, the magnetic data revealed a significant number of pits containing burnt materials, hinting at the possibility of specialized activity areas or ritual practices. These groundbreaking discoveries have fundamentally challenged the long-held assumptions about the planimetry of the *Cetățuia* settlement and, crucially, have forced a reevaluation of the role and significance of the defensive ditches, demonstrating that the story of the Cucuteni culture is far from being fully told (Fig. 4)[9].

## METHODOLOGY

The year 2017 marked the reopening of the archaeological investigations at the *Cetățuia* site and the start of 3D documentation at the eponymous site of the Cucuteni Culture.

[9] ASĂNDULESEI *et alii* 2024.

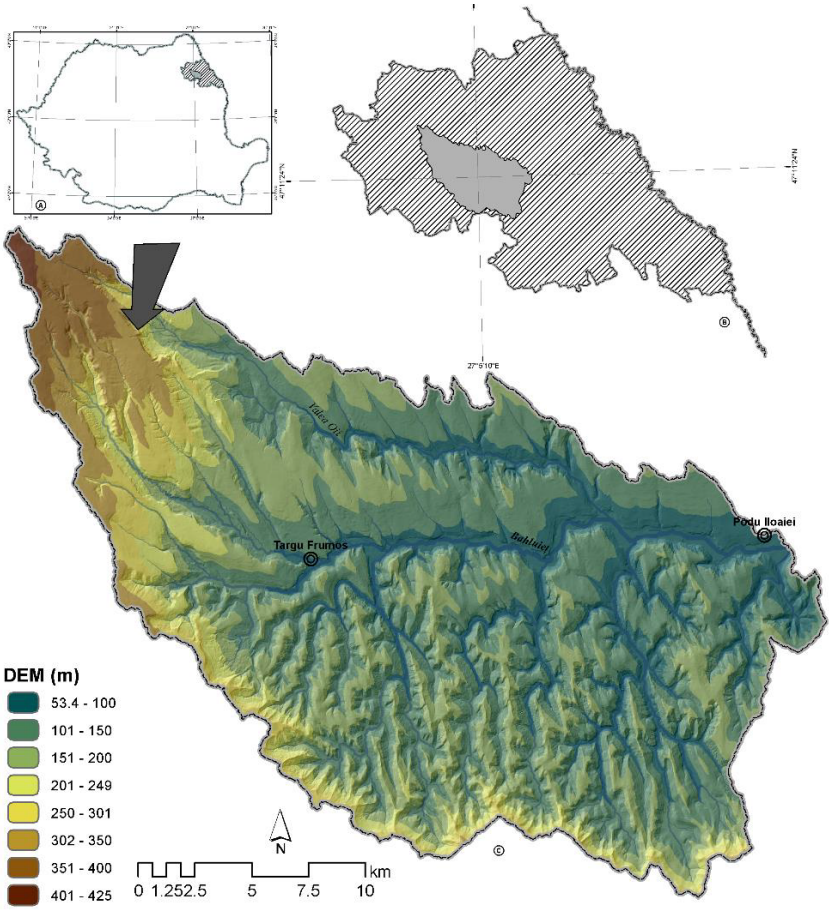



**Fig. 3.** The location of the Cucuteni-*Cetățuia* in NE Romania (A), within Iași county (B), and Bahluieț river basin (C) (Map by A. Asăndulesei).

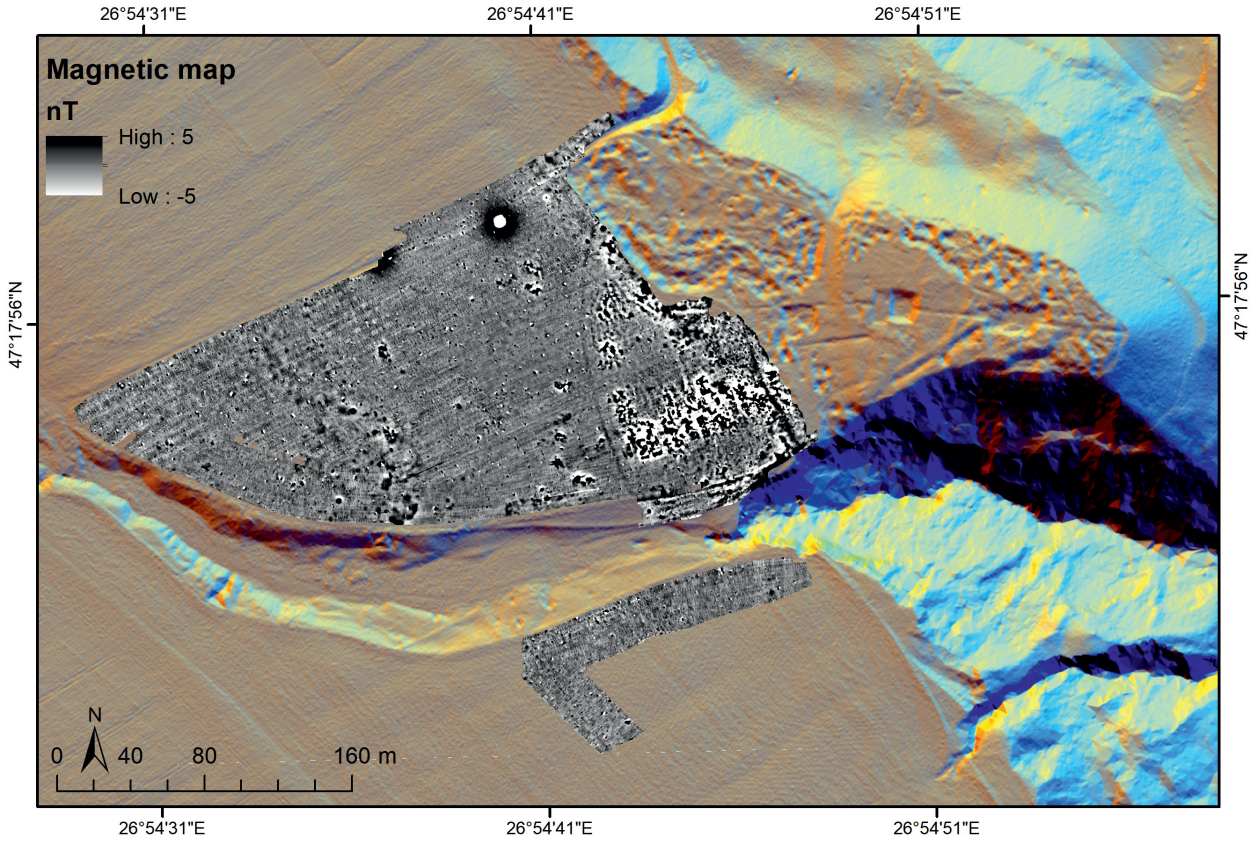



**Fig. 4.** The magnetic map of the Cucuteni-*Cetățuia* settlement (Map by A. Asăndulesei).

Our research team adopted a comprehensive workflow, illustrated in Figure 5, designed to capture and analyze the intricate details of these significant archaeological endeavors. This process, while yielding a lot of invaluable information, generates a substantial volume of data, occasionally presenting challenges in terms of organization and integration within a unified database. This data encompasses both newly acquired information from the recent excavations and a substantial archive of historical archaeological data, including records from previous campaigns. Our main goal was to gather all of the data collected over the years (including the old excavations) into a central hub that is freely accessible to both the general public and the professionals. In order to obtain the desired result, we chose the ArcGIS Pro environment as it allowed us to centralize a diverse range of data types, including the aforementioned three-dimensional models, photographic documentation, historical drawings and plans, and geophysical survey results, all within a single, readily accessible, online platform. This integrated approach facilitated the way we manage, analyze, and share archaeological information, opening new avenues for collaborative research and public engagement.

We started the 3D data acquisition on a larger scale, in order to get a better view of the landscape surrounding the archaeological site. The 3D model and orthomosaic of the site were obtained through photogrammetry using a DJI Mavic Air 2 drone and the software *Dronelink,* in order to unlock the guided flight capabilities of the drone. Before presenting the methodology used for guided flight, it is necessary to mention the methodological limitations encountered when using this type of drone (especially for obtaining orthophotos or Digital Surface Models), as well as how these can be addressed.

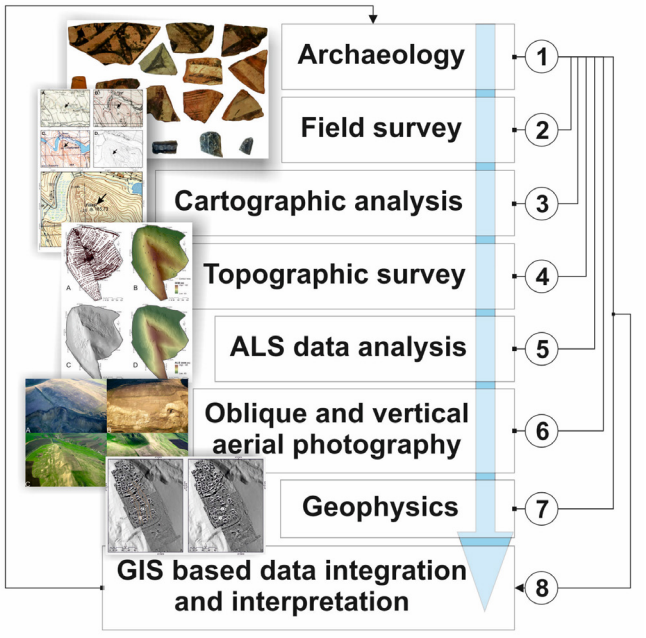



**Fig. 5.** Proposal of a non-invasive research model[10].

• **Drone positioning system.** Most UAV equipment is positioned using the GPS system, which facilitates the performance of guided flights. Thus, each photograph will have its geographic coordinates saved as metadata at the time of capture (Fig. 6/a). From personal experience, we have observed that these coordinates have an error of 1.5–2 meters on the X and Y axes (Latitude, Longitude), and the altitude value (Z coordinate) is not reliable at all if we want to obtain a correct DSM. This can be corrected either by using an RTK drone (for example, Phantom 4 RTK, which is used with an external GNSS[11] receiver) or by using ground markers (Fig. 6/b), which are subsequently recorded with a high-precision RTK (Leica GPS1200) and used in the data processing stage to georeference the model. For logistical reasons, the second option was used in this research.

• **Flight autonomy.** Another important aspect to mention is the distance that the drone can cover with the available battery. Its autonomy is directly influenced by wind speed or ambient temperature. In this case, the DJI Mavic Air 2 can fly for approximately 20–25 minutes using a single battery. For flights over large areas, it is recommended to use multiple batteries, as drone applications have the ability to continue a flight interrupted for various reasons. Thus, it is not advisable to investigate a large area that requires 2–3 charges without having spare batteries because the time required to charge a single battery can reach up 30–40 minutes, by when the position of the sun will modify, and the ambient light will be directly influenced. This aspect can alter the final result, obtaining an inconsistent orthophoto in which certain portions may be darker than others. In this study, we used two batteries that provided an autonomy of approximately 50 minutes, enough time to cover the nearly 35 hectares proposed for vertical photography.

• **Software.** Unfortunately, not all drones can perform guided flights or mapping missions, as they are called in most software. Even if the hardware component allows this, we may encounter certain limitations imposed by the manufacturer, as is the case here. However, software like Dronelink, which can be purchased at a low price, can unlock all these manufacturer-imposed limitations, even offering multiple ways to perform guided flight. In the following, I will present the parameters used within the Dronelink software (Fig. 7) to obtain optimal results:

1. **Altitude**: This parameter directly influences the resolution of the model and designates the altitude at which the drone will be maintained throughout the flight. For very large areas, we used an altitude of 80 meters, and for smaller areas (that can be covered in relatively short time) we opted for altitudes of 30–50 meters.

2. **Overlap**: This indicator dictates the degree of overlap between two adjacent photographs. In other words, it determines what percentage of the first photograph can be found in the second. The parameter is very important because the photogrammetry technique, which represents the core of our approach, is based on the identification of common points. In this case, we used a 75% forward overlap and a 70% side overlap.

3. **Speed**: It represents an often-overlooked feature, but one that can prove very helpful in low-light conditions. We

[10] ASĂNDULESEI 2015.

[11] Global Navigation Satellite System (GNSS) is a complex system that allows for the highly accurate determination of the geographic coordinates of an object, by connecting to a complex system of satellites orbiting the Earth.

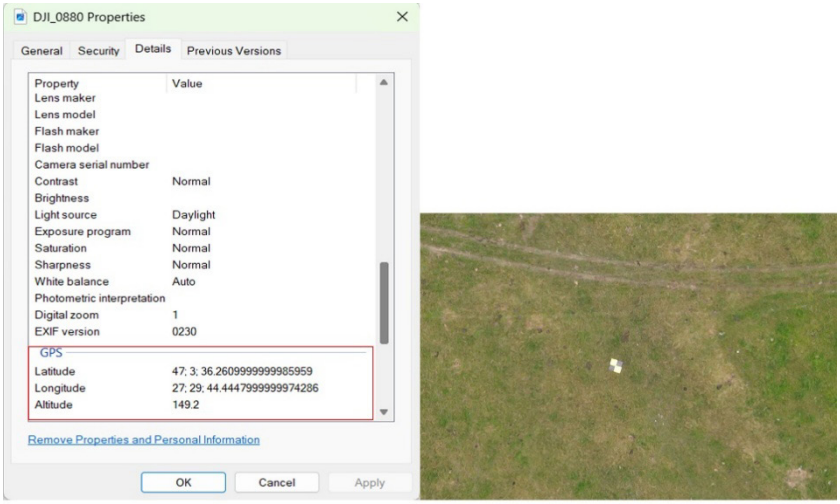



**Fig. 6. a –** Example of spatial coordinates saved as metadata; **b –** *Marker*, used in the georeferencing process (size 1x1 m, different colors).

can set the maximum speed that the drone can reach during the flight. In low-light situations, the exposure time (the duration that the camera dedicates to photographing a target) increases, which, combined with a high speed of movement, can lead to blurry, unfocused photographs.

4. **Pattern**: When using the Dronelink software, two methods of performing guided flight can be used, out of which, in our project, we have chosen the first one:

– **Normal:** The standard way of performing a guided flight, with the drone's path marked as parallel lines connected at the ends.

– **Grid:** This mode is not found in all applications, but offers a very high level of detail by combining two Normal paths in two different flight directions (longitudinal and latitudinal).

5. **Gimbal Pitch:** Using this value, we can set the angle of the camera (acquiring either vertical or oblique photos). For obtaining DSMs or orthophotos, it is recommended to take vertical photos by setting the value to –90, which places the camera at a 90° angle relative to the horizontal plane. On the other hand, in order to obtain 3D models for large areas, a 45° angle and the use of Grid mode are recommended.

Another important step included the preparation stage of the guided flight is the positioning of the markers that will be used for data processing, in order to obtain accurate georeferencing. It is important that they are distributed throughout the entire area to be surveyed. In this study, we used 8 markers of 1x1m, made of polyester fiber, with various colors, facilitating their identification in the data processing stage. The markers have a metal ring in the middle area, which allows for the precise fixing of the center point of each. Using the Leica GPS1200 GNSS system, we can accurately record the center of each marker. When placing them, we consider the central area of the surveyed surface as our main point of focus, with four markers placed within, to which we add four additional ones on its limits. The accuracy of the model can be improved by using a larger number of markers. Another way to create such markers is to use a spray paint to create symbols on the ground surface, but this

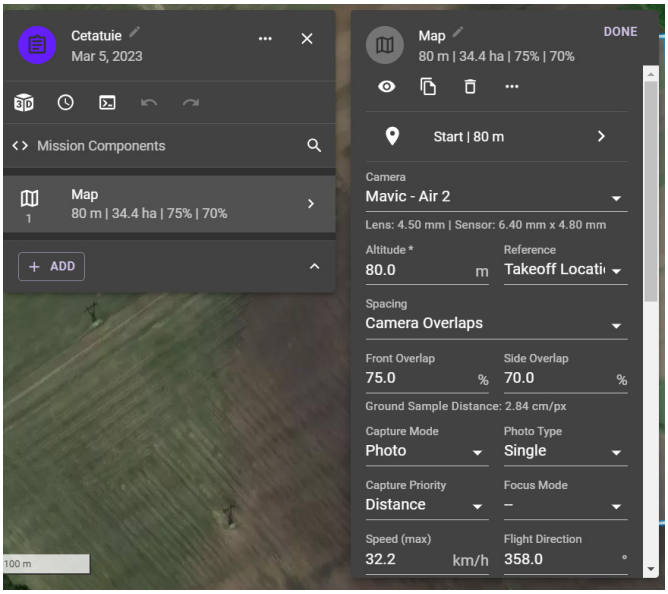



**Fig. 7.** The interface of Dronelink software and the parameters available in order to perform the guided flight.

method is not very efficient in situations where the area of interest is characterized by the presence of dense vegetation.

The integration of aerial photography and precise GPS data were the backbone of our geospatial products. All of the photos obtained during the guided flight, as well as the GPS points recorded with the Leica GNSS, were later imported into Agisoft Metashape, allowing us to obtain a Digital Surface Model (DSM) of the Laiu Plateau and an orthomosaic of the area. This process leveraged structure from motion (SfM) photogrammetry, where overlapping photographs were analyzed, in order to reconstruct a 3D model. The accurate GPS points served as ground control, enhancing the georeferencing and precision of the resulting DSM and orthomosaic, providing a spatially accurate representation of the plateau's surface and features.

Next, in order to perform the 3D documentation of the archaeological excavations, we utilized three techniques:

1. Photogrammetry using a digital camera: The photographs required for this process were captured using a Canon 5D Mark III DSLR camera with a 50mm lens, minimizing lens distortion as much as possible. Additionally, the 'Calibrate Lens' function in Agisoft Metashape was used to obtain the most accurate 3D model. Ground points were also used in order to georeference the model.

2. Photogrammetry using a drone: In order to capture all details, as accurately as possible, oblique vertical photographs were taken using a DJI Mavic Air 2 drone. The acquisition of the photographs was performed manually (not through an automated guided flight, as in the previous stage) and consisted of a series of photos taken both as a whole (to capture the entire excavation), and at approximately 60 cm distance (capturing each detail individually). The flight consisted of traversing the route twice (Fig. 8), the first time to take vertical photographs, and the second time to obtain oblique photographs.

3. Scanning 3D with mobile devices: Another method, used especially for large artifacts (whose dimensions would not allow the use of a light tent), was scanning using the LiDAR sensor available on the iPhone 13 Pro or iPad Pro 4th gen[12]. The results were excellent, with the model obtained using the Scaniverse app being subsequently edited in Agisoft Metashape to remove certain adjacent elements, captured during the scan. In order to georeference this type of scan we have to use a third-party software, for example Cloud Compare.

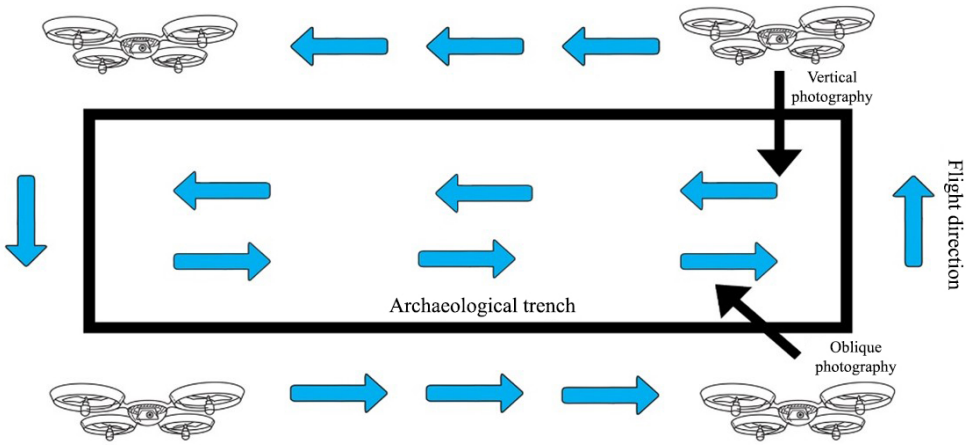



**Fig. 8.** The flight plan used to obtain the 3D model of the investigated archaeological trenches.

## RESULTS

As it was emphasized before, the excavations performed aimed at offering a clearer perspective on the planimetry of the *Cetățuia* site and on the functionality of some of the magnetic anomalies identified in the 2017 campaign of geophysical prospecting. Furthermore, documenting 3D the archaeological features discovered represented the backbone for our online platform that presents the Cucuteni-*Cetățuia* settlement to the general public. Thus, we were able to highlight the location of the old archaeological trenches (from the campaigns conducted by Hubert Schmidt (1909–1910) and Mircea Petrescu Dîmbovița (1961–1966)) and integrate the 3D models, alongside different illustrations from the older and newer archaeological excavations, in order to better understand the habitational particularities of the settlement (Fig. 9).

Regarding the more recent archaeological trenches, we presented in our platform the following three sections:

**Section 1 (2021)** represents a construction with heavily burned walls, collapsed over a suspended floor, which in turn overlapped the ground floor, where several features (an agglomeration of loom weights, numerous ceramic vessels etc.) were identified.

**Section 2 (2022)** was excavated in order to test some magnetic anomalies that suggested the presence of a defensive ditch in the proximity of a habitation structure. The initial assumptions were confirmed by the excavation, revealing the vestiges of a Cucuteni dwelling (phase B), a trench and several pits, that were intersected. The defense ditch, being identified immediately from the edge of the house, has approximately 2.35 m opening at the top and 1 m deep, being dug in a U shape, steeper towards the inside of the settlement and smoother towards the outside. Its builders broke the natural slab of Sarmatian sandstone, deepening by another 0.3 m, which is an indication of the community effort put into carrying out this fortification work (Fig. 10/a).

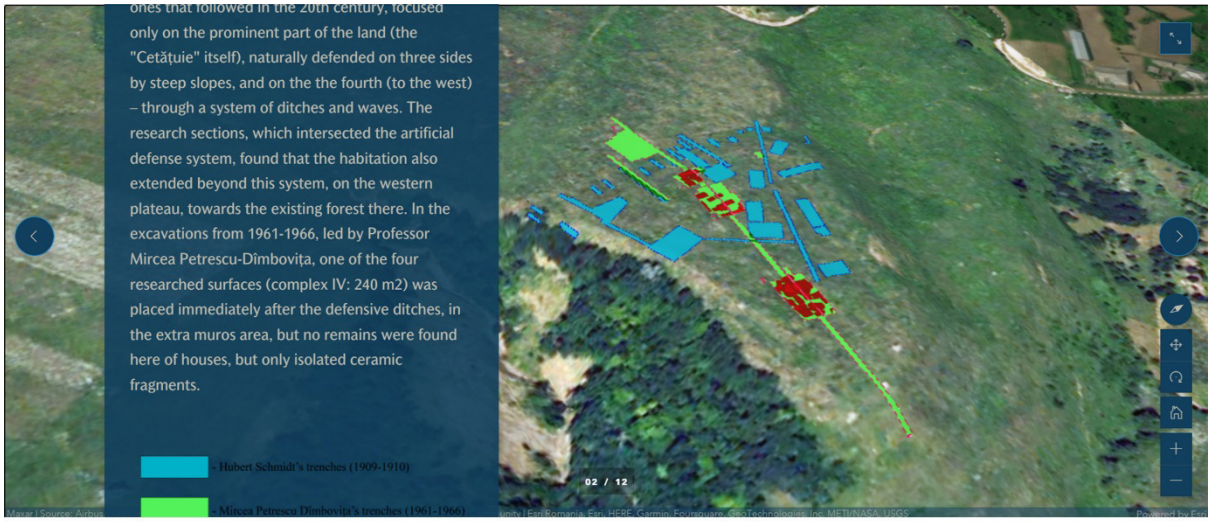
**Section 3 (2022)** represented an area of 5 × 3 m that brought to light a pottery kiln, unequivocally belonging to the Cucuteni culture, both on a stratigraphic and typological basis, as well as based on the pottery discovered inside the complex (Fig. 10/b)[13].

## CONCLUSIONS

The main objective of the online portal created emerged from the need to consolidate and synthesize the vast amount of data accumulated from many years of archaeological work. This wealth of information, while invaluable,

[12] LUETZENBURG/KROON/BJØRK 2021.

[13] TENCARIU *et alii* 2022.

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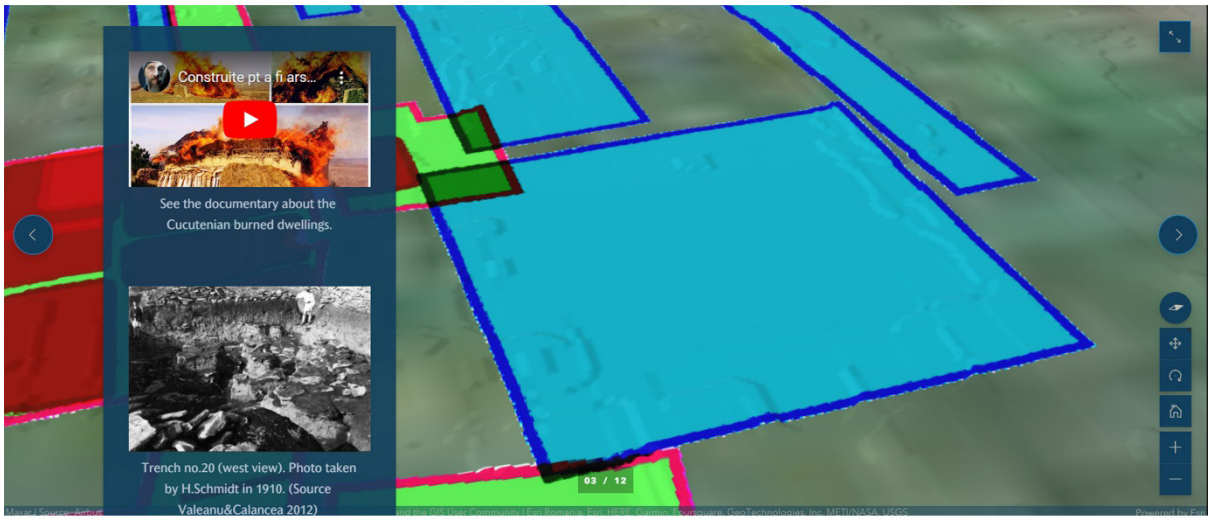


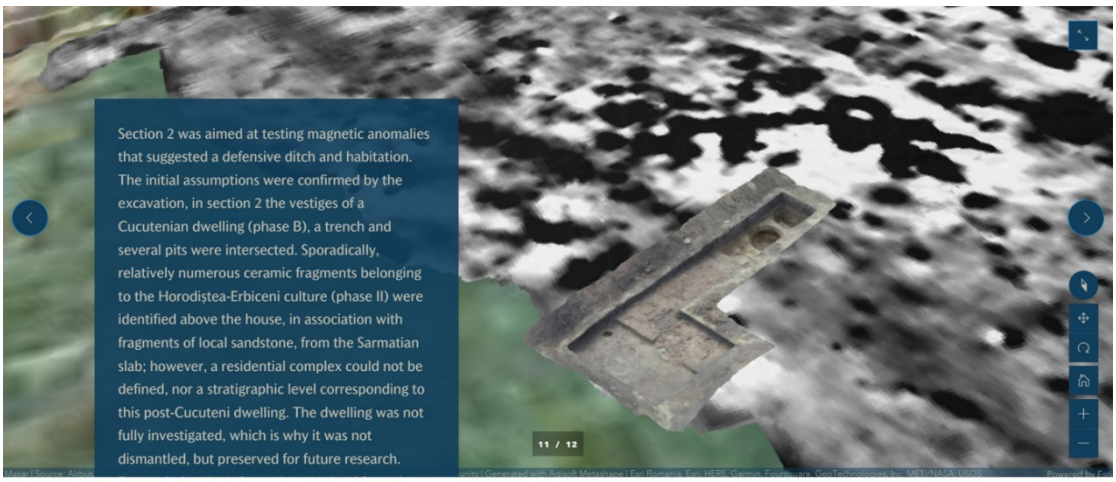

b.

**Fig. 9. a** – General view over the *Laiu* plateau and the localization of the old archaeological tranches; **b** – Detail over section 20 (1910).

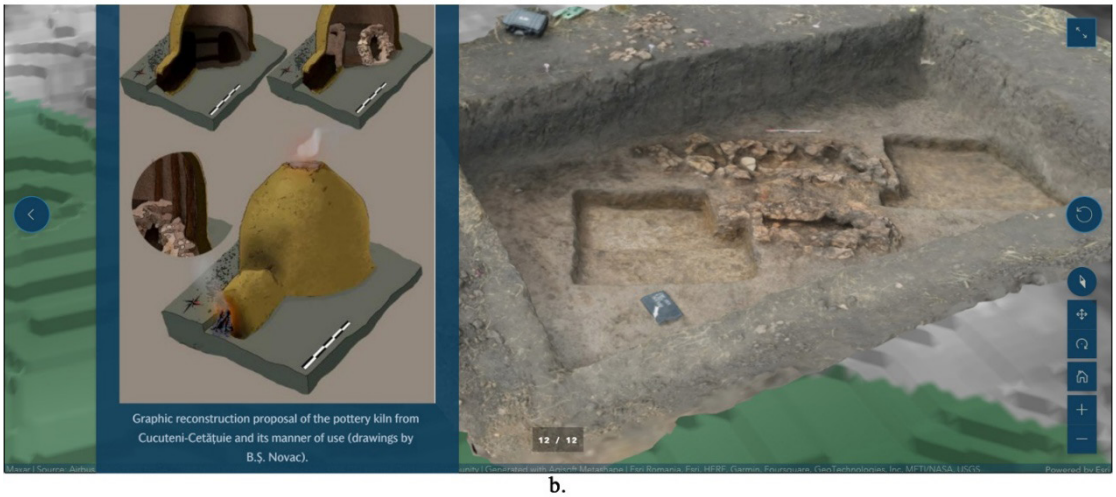
risked becoming fragmented and difficult to access. The portal's primary purpose was to weave these disparate threads of research into a cohesive narrative, presented in a way that would be both informative for specialists (who can obtain important scientific data regarding the archaeological discoveries presented – Fig. 11) and engaging for the general public. It sought to bridge the gap between academic rigor and public accessibility, transforming complex archaeological findings into digestible and compelling stories about the past.

The portal has proven to be far more than just a digital archive; it has blossomed into a powerful didactic tool. It offers an unique opportunity for educators and students alike to delve into the intricacies of the *Cetățuia* settlement, exploring its history, architecture, and artifacts from anywhere in the world. The virtual access is particularly significant, given the physical challenges of reaching the actual archaeological site. Located in a somewhat remote area, the site is not easily accessible, and its terrain presents significant obstacles for individuals with mobility impairments. The portal effectively removes these barriers, democratizing access to this important cultural heritage and ensuring that everyone, regardless of physical limitations, can experience the wonders of *Cetățuia*.

Beyond its educational value, the portal has become a catalyst for public engagement. In collaboration with the "Alexandru Ioan Cuza" University Museum, the project team organized an innovative outreach activity that allowed visitors to immerse themselves in the archaeological site through virtual reality (VR) technology. The portal served as the backbone of this endeavor, providing the rich data and 3D models that brought the ancient settlement to life in the VR environment. Participants could explore the site as if they were physically present, interacting with virtual representations of archaeological discoveries and gaining a deeper understanding of the Cucuteni culture. This initiative proved once more the versatility of the platform, showcasing its potential for diverse applications, from research and education to public outreach and cultural tourism. Finally, our project highlights once again the power of digital tools to not only preserve and interpret the past, but also to connect people with it in meaningful and transformative ways.




a.




b.

**Fig. 10.** a – View over section 2 (2022); b – View over section 3 (2022). ArchaeoPortal.

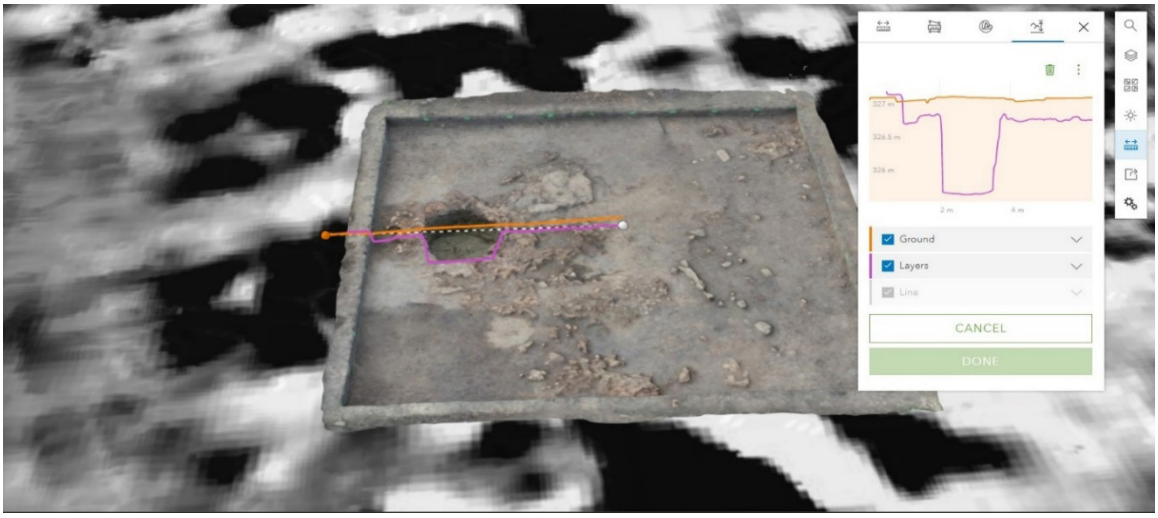



**Fig. 11.** Making an elevation profile on the 3D model in the SceneViewer online interface[14].

[14] This feature is available in the SceneViewer online application, where basic measurement tools such as: distance and area measurements or the creation of elevational profiles is possible. Also, basic spatial analyses are available in the online interface (https://doc.arcgis.com/en/arcgis-online/analyze/scene-perform-analysis.htm).

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