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ARCHAEOLOGICAL MAPPING OF THE VERTEBA CAVE

ABSTRACT

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Verteba Cave is an atypical archaeological site of the Cucuteni-Trypillia cultural complex. Based on years of research, a significant amount of information has been generated which has not yet been spatially represented. The main issue was the lack of a professional topographic map for the site. This article discusses the first attempt to create an archaeological map of the cave. It describes the methodological and practical process of mapping archaeological features both inside the cave and on the surface above the cave. A technological scheme for mapping using laser scanning of the cave's interior is presented. The results of this work have provided new insights into the chronological periods of the cave's occupation and its functional use.

Keywords: Verteba Cave, archaeological map, Cucuteni-Trypillia cultural complex, mapping, archaeological features

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INTRODUCTION

Ukraine has exceptionally rich cave resources – more than 1,500 explored natural caves, about 1,200 of which are in Crimea. One of the most important cave regions is the Podolian-Bukovinian karst area, where Verteba Cave is located (Klimchuk 2007, 8-10). Besides the recreational value of cave resources, in the last two decades there has been a sharp increase in awareness of the scientific importance of archaeological sites in natural caves in Ukraine.

Humans began inhabiting caves as early as the Lower Palaeolithic era. Archaeological research has shown that the earliest humans initially used caves as shelters from the weather, and later as homes and sanctuaries. Since then, interest in caves has accompanied the entire history of humanity (Sklenář 1984; Slimak 2022, 8). By the Neolithic and Eneolithic periods, this process largely concluded, with caves and grottoes rarely used as homes and burial sites.

Nowadays, about 6,000 sites of the Cucuteni-Trypillia cultural complex (c. 5000-3000/2950 BC) are known. However, across the vast area of its spread, there are no instances of active and long-term occupation of cave spaces by the populations of this cultural complex. In this context, Verteba Cave is a unique archaeological site. Here, the early agricultural population actively utilized the cave environment for a long period, totally

Fig. 1. Location of Verteba Cave

lasting almost 800 years. Stratigraphic methods in the cave have identified three Trypillia cultural horizons, corresponding to the chronological periods Trypillia CI and CII, which are related to the Shypyntsi, Koshylivtsi, and Kasperivtsi (Gordineşti) local groups (Sokhatskyi 2001, 39-66).

As a result of many years of cave research, a collection of artefacts has been gathered. Compared to the above-ground settlements, a significant percentage here belongs to carefully crafted and ornamented ceramic vessels, anthropomorphic and zoomorphic terracotta figurines, artistically processed bone artefacts, and copper items. All tools and items are in their finished form and appear to have been specially selected.

The site provides an unprecedented opportunity to study and understand the ritual traditions of the Eneolithic era people in Eastern Europe. Unlike most Cucuteni – Trypillia sites, the cave contains well-preserved human skeletal remains suitable for bioarchaeological and genetic studies. However, there is a problem with interpreting the functional use of the cave by ancient people. To make more objective interpretative conclusions, it is necessary to form a spatial representation of the distribution of archaeological features and artefacts across the cave's entire area and their distribution in various sections of the labyrinth.

Therefore, it became evident that a comprehensive archaeological map was needed, capable of providing a panoramic view of archaeological features both within the cave and on the surface, as well as tracing their connections. This map should be capable of being updated with new information and be accessible to researchers. The aim of the study is to create an archaeological map of Verteba Cave as a specialized collection of Trypillian features, expressed spatially by plotting them on a cartographic base. The map will allow for spatial analysis of all archaeological data from the cave, to better understand the motives and reasons that led to the active and long-term use of the cave by the first farmers.

MATERIALS AND METHODS

History of Archaeological Research and Mapping of the Cave

Verteba Cave is located 2 km northwest of the village of Bilche-Zolote in the Ternopil region (Ukraine). It is situated on a flat plateau on the left bank of the Seret River at an altitude of 274 metres above sea level (Fig. 1).

The entrance coordinates are 48°47′19″N 25°52′17″E. The cave entrance is easily accessible but well hidden in the lower part of a karst sinkhole, making it inconspicuous on the flat field surface (Fig. 2). The karst cavity formed in the middle part of a 10-metre thick layer of coarse-crystalline gypsum. Morphologically, it differs from other caves in Podolia. The gypsum layer is so karstified that the labyrinth forms a complex system of spacious passages and halls located on two hypsometric levels (Klimchuk 1996a, 263-278).

Fig. 2. View of the current entrance to the cave

The site was discovered in 1820 by J. Khmeletskyi (Zawadzki 1822, 160) and was excavated in 1876 by A. Kirkor (Kirkor 1879, 34-37). Between 1890 and 1892, G. Ossowski conducted further excavations in the cave (Ossowski 1891, 52-67). From 1898 to 1904, V. Demetrykiewicz continued the research (Demetrykiewicz 1900, 7, 8). In 1929, O. Kandyba conducted small exploratory excavations (Kandyba 1937, 1-12). From 1996 to 2023, an archaeological expedition led by M. Sokhatskyi has been studying the cave (Sokhatskyi 2017, 39-66).

The research revealed a significant Trypillia cultural layer, attributed to stages CI and CII. Preliminary C^{14} dating of Verteba Cave indicated that it was most intensively used during the late Eneolithic, around 3800/3750-3000 BC (Harper *et al.* 2021, 276-296; *cf.*, Kadrow *et al.* 2003, 53-144; 2010; Ledogar *et al.* 2018, 141-158).

In recent years, comprehensive studies of archaeological, bioarchaeological, paleogenetical, archaeozoological, and geoarchaeological data have been conducted here (Nikitin *et al.* 2010, 9-18; Karsten *et al.* 2015a, 562-579; Lilie *et al.* 2017, 306-324; Madden *et al.* 2018, 44-53; Potekhina 2018, 25-33; Ledogar *et al.* 2019; Sokhatskyi 2019, 31-36; Schmidt *et al.* 2020, 1-10; Bondar *et al.* 2021, 238-251). Materials from late 19th-century research are now stored in the Krakow Archaeological Museum (Kadrow 2013, 9-11), while materials and documentation from recent research are held in the Borshchiv Museum of Local Lore (Sokhatskyi 2001, 207-227).

The practical needs of archaeologists and speleologists that arose during their research, drove the development and improvement of the cartography of the Verteba Cave. The first description and mapping of the cave's near part were done by J. Khmeletskyi in 1820. The plan was based on a basic study of the cave, resulting in a low-accuracy sketch without any measurements (Fig. 3: A).

The first archaeological survey was conducted by A. Kirkor in 1876. He dug a 2.8-metre-deep shaft, described the right part of the cave, and sketched an estimated plan of his route through the labyrinth (Kirkor 1879, 34-37). This is the only plan from early archaeological research indicating the excavation site (Fig. 3: B).

G. Ossowski's three years of work resulted in a fairly accurate cave plan published in 1892 (Ossowski 1893). This was the first professional topographic map of the cave, made with the help of surveying instruments (Fig. 3: C). Some of Ossowski's symbolic systems for Verteba Cave are still relevant for modern speleological research. Unfortunately, the

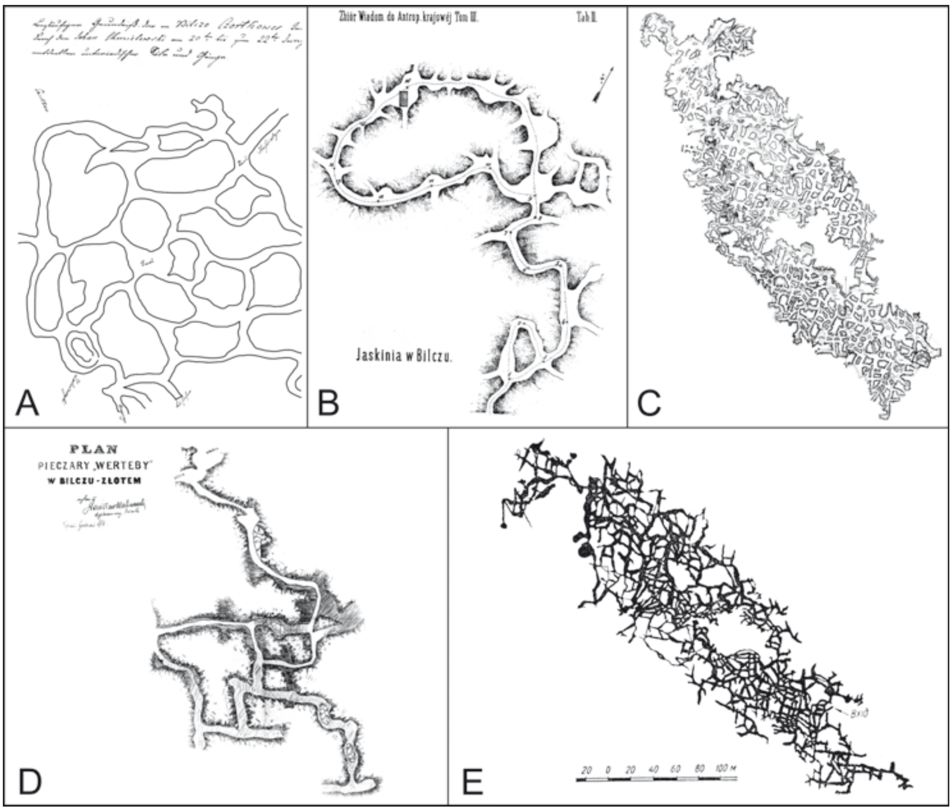

Fig. 3. Topographic plans and maps of Verteba Cave, created in previous years:
A – J. Khmeletsky, 1822; B – A. Kirkor, 1876; C – Ossowski G, 1893; D – Demetrykiewicz W, 1906; E – B. Radzievsky, 1967

excavation results were not fully processed or published, as the scholar had to leave Galicia for Siberia (Talko-Hrunzewicz 1923, 186-189). Consequently, the map did not include archaeological features or excavation sites.

W. Demetrykiewicz managed to discover new passages and mapped the southern part of the labyrinth (Fig. 3: D). This plan was drawn in 1906 by the engineer K. Malinovsky, who worked on measuring forests and land plots, at Demetrykiewicz's request (Woźny 2018, 460).

In 1967, a group of speleologists led by V. Radzievskyi mapped almost the entire known area of the cave. The map graphically marked the main passages and galleries without detailing speleomorphic features. This map was used by speleologists to navigate the intricate cave labyrinth (Fig. 3: E).

Creation of Topographic Maps

An essential part of archaeological excavations in caves involves creating topographic maps and studying the internal structure of caves. Mapping is conducted under challenging conditions, as most of the cave is dark, damp, and cold, often with a complex labyrinth of passages (Doggouris *et al.* 1986, 188-221). The most traditional method used in practice involved measuring cave corridors with a compass and tape measure (Corvi 2018, 49-56). Currently, the creation of topographic maps often employs modern technical tools and paperless mapping methods (Trimmis 2018, 399-407). This approach provides precise measurements and eliminates errors caused by human factors (Stratford 2011, 11-116).

The primary stage of documenting archaeological features in the cave was the creation of topographic maps. Mapping was divided into two main categories: 1) mapping the above-ground territory; and 2) topographic surveying of the underground labyrinth.

Our research team conducted a topographic survey of the surface area above the cave in 2023. The topographic plan detailed the features of the relief, including buried karst sinkholes and deep depressions. Before starting the geodetic work, we surveyed the area and identified the territory to be mapped. We established a survey network, which included a system of benchmarks and datum points. Considering the geodetic support of the area, we chose the YNSS observation method in the RTK network mode from the ZAKPOS/YNSS network. Observations were performed using the SOUTH 660p receiver. Field materials were processed using licensed software Digitals/Delta XE @ for Windows 5.0 professional.

A permanent stationary reference point was established on the gypsum rock near the cave entrance. Topographic reference for archaeological features was conducted from this general benchmark. It also served as a reference point for both surface and underground topographic work, as well as for projecting the cave plan onto the surface relief.

Additionally, an important point for verifying the accuracy of the cave plan projection onto the surface was an open ventilation channel. This channel was cleared of its soil plug during an archaeological excavation (Fig. 4).

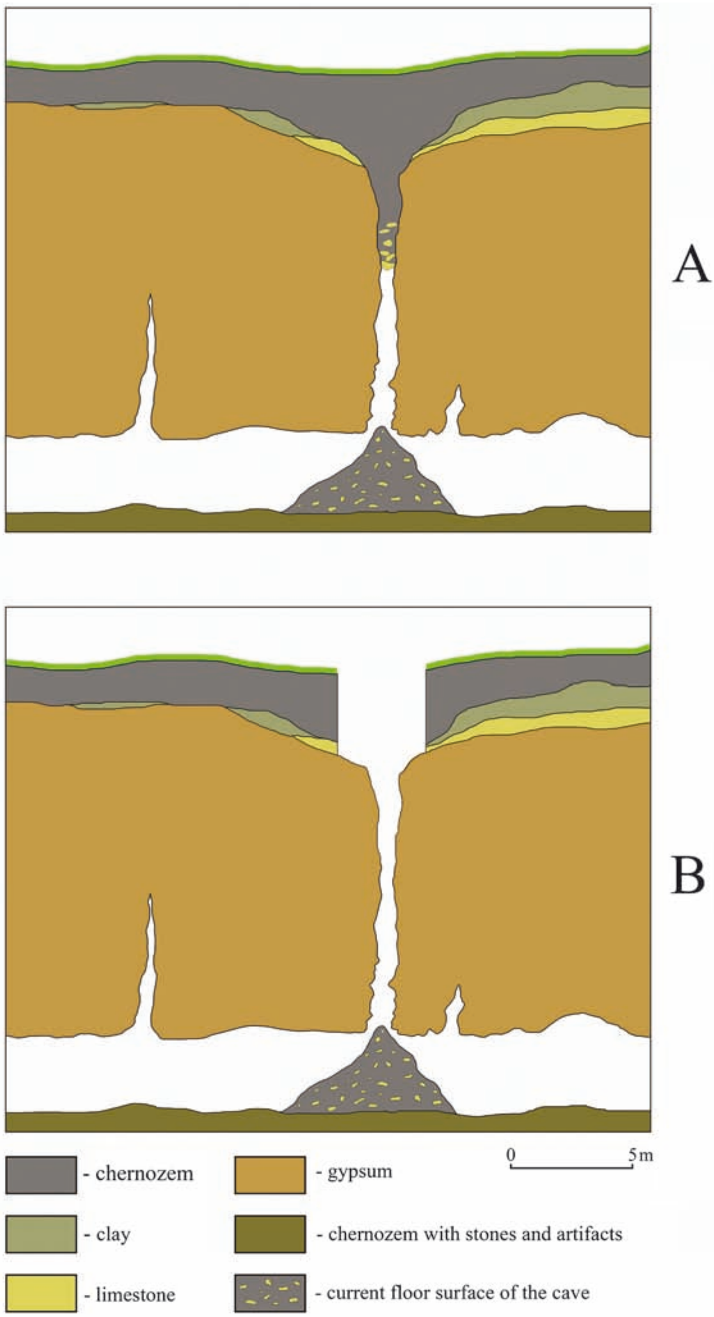

Fig. 4. Schematic profile of a vertical smoke channel:
A – before cleaning; B – after cleaning

Fig. 5. The process of creating the topographic map of the cave: A – preliminary measurements in the cave; B – results produced by the laser distance meter; C – cartographic design of the cave area

The next stage was the topographic surveying of the cave labyrinth, with detailed mapping of the morphological elements of halls and galleries. Mapping was performed using a semi-instrumental topographic survey method at a scale of 1:500. Surveying work of the fourth class of cave topographic accuracy was conducted in Verteba Cave (Klimchuk 1996b, 22).

Topographic work was carried out using a modern high-precision laser distance meter, the LEICA Disto X310, with a built-in three-axis electronic compass and clinometer, combined with non-magnetic batteries and tripods. Our custom tripod design resolved the problem of the reference point, as it allowed the LEICA Disto X310 to perform measurements from the centre of the tripod, no matter how it was positioned. It also allowed convenient use of the timer, eliminated instrument vibrations, and helped achieve high measurement accuracy. The LEICA Disto X310 device was connected via Bluetooth to a Pocket PC (using PocketTopo software).

A survey network with long-term fixed points (numbered datum points) was created. The survey grid was constructed in a rectangular coordinate system. Mapping was carried out using mass fan measurements of orientations and lengths of "rays" from primary and auxiliary points (Fig. 5). The cave wall contours were drawn by frequent radial measurements of morphological features. The rays were displayed on the Pocket PC screen, and the end points of these rays were connected into a curve using a stylus. For accuracy, direct and reverse measurements of distances and azimuths were conducted.

The main data for constructing the map included the details of the traverse line, the relief of vaults and passages, the length, height, and width of cavities, as well as details that could potentially complicate navigation in the cave labyrinth.

Identification and Mapping of Archaeological Features in the Cave

The first step was to collect and systematize all available data on archaeological research in the cave and analyze it. The obtained information was divided into two groups: 1) information from archaeological research reports of the late 19th century; 2) information from our own research conducted from 1996 to 2023.

This is the initial stage of creating a comprehensive multi-layered archaeological map of the cave. Only archaeological features were marked on the topographic base. These include structures artificially created during human activity in the underground environment. They include remnants of hearths, vertical channels for smoke ventilation to the surface, ritual and refuse pits, clay sleeping platforms, human burials, and other entrances to the cave that functioned in the Trypillia time. We also marked the locations of our archaeological excavations on the map (Figs 6 and 7: F).

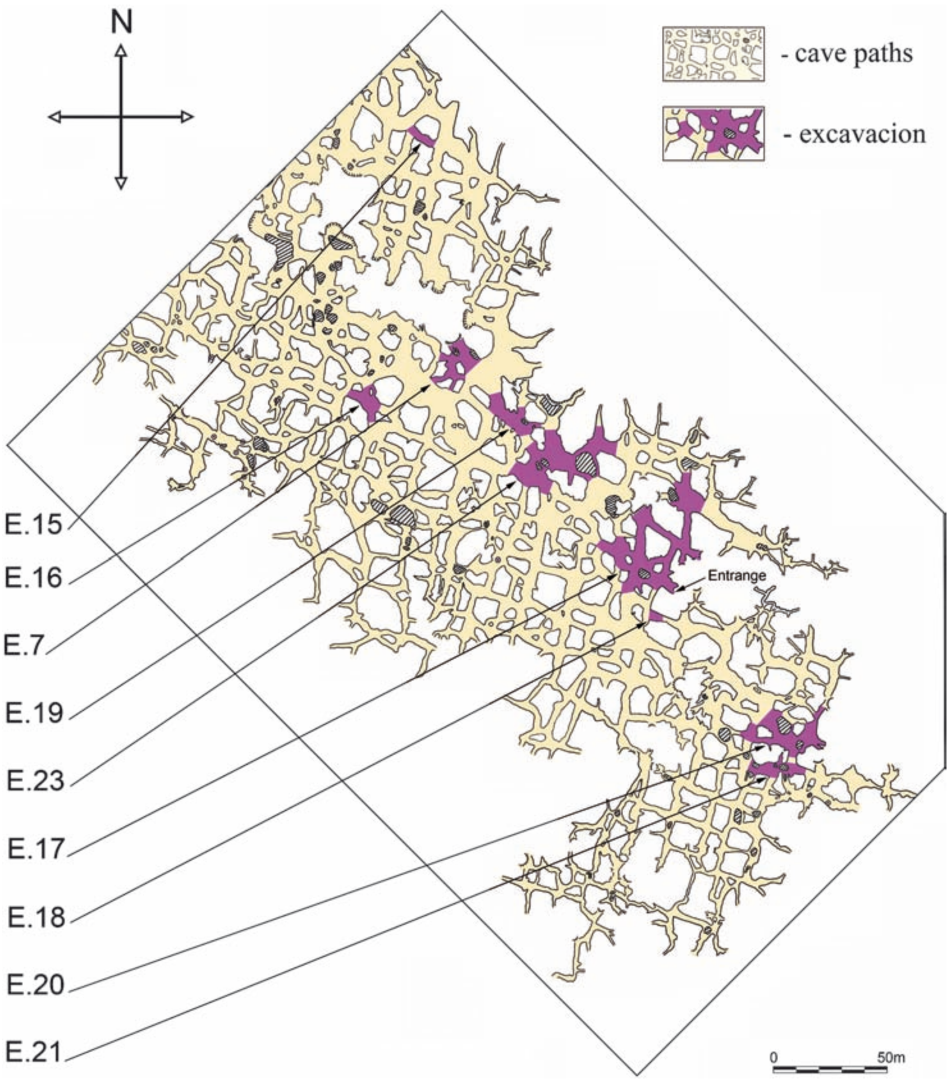

Fig. 6. Map of archaeological excavations in the cave

A brief description of the archaeological features in the cave is provided below.

Traces of open hearths are localized throughout the cave areas used by the Trypillian populations. Clear white spots are preserved on the gypsum walls where the hearths were, resulting from the fire's effects. Due to the high temperature, the surface of the gypsum wall was fired. Overfired fragments of gypsum would crumble and fall to the floor. The modern appearance of the hearths remains consists of ash accumulations, overfired gypsum pieces, charcoal, and a dense layer of burnt clay with a smooth surface (Fig. 7: A).

To facilitate movement and orientation in the dark and confusing labyrinth, people used both portable and stationary lamps. At intersections of passages and on natural protrusions of gypsum walls, ceramic bowls filled with animal fat with a wick inside were placed. In various places in the cave, at a height of 0.7 metres from the floor, accumulations of overfired gypsum were recorded, indicating the locations of open flame lamps.

Ventilation shafts are natural vertical channels formed by pressurized water during cave formation. In the Trypillia time, some were connected to the surface. They are now

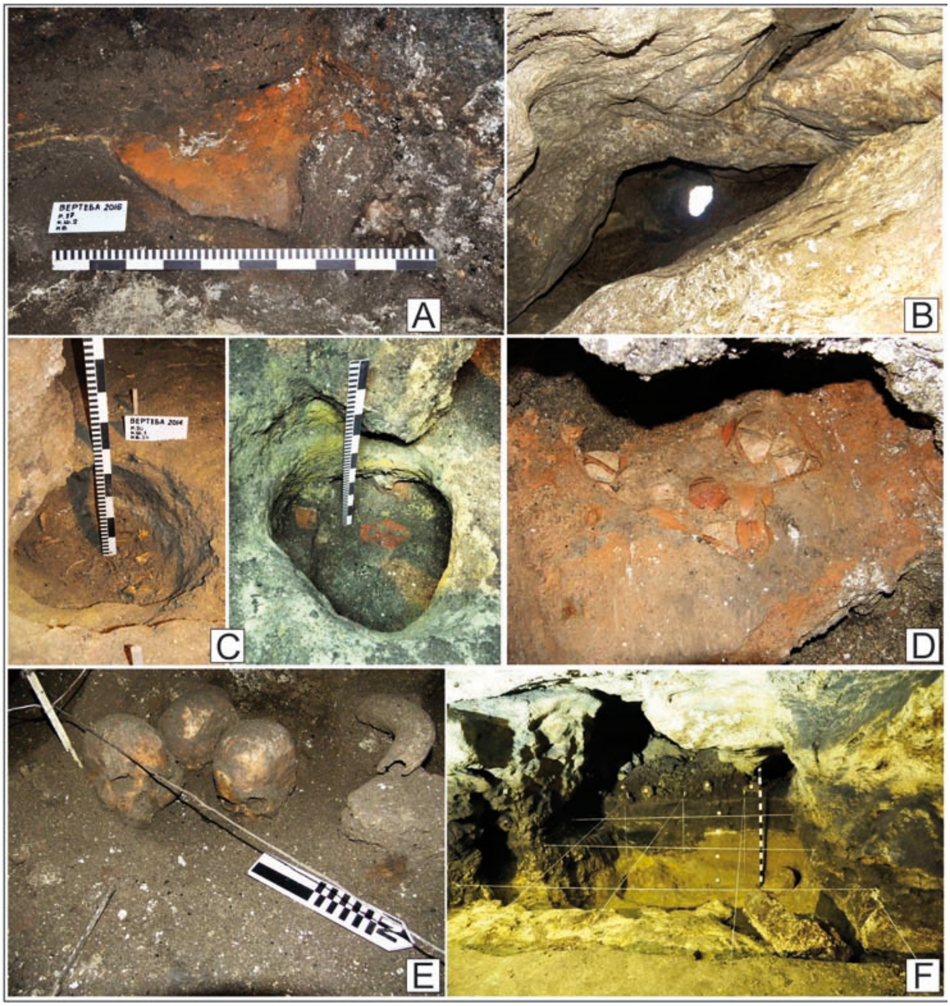

Fig. 7. Archaeological features in Verteba Cave:
A – remains of a hearth; B – ventilation shaft; C – pits; D – clay platform; E – skulls; F – archaeological excavation

sealed with soil and stones. The walls of the channels are heavily fired at the bottom by flames (Fig. 7: B).

Utility, ritual, and refuse pits were recorded during excavations. Pits, 80-120 cm deep, were dug into the sterile light clay layer of the cave floor. The pit infill consists of a conglomerate of dark-grey loam, ash, charcoal, animal bones, pottery fragments, terracotta figurines, bone, and flint artefacts (Fig. 7: C).

Clay sleeping platforms are rectangular elevations made of homogeneous clay and well-fired. The bottom part of the structure consists of a dense layer of ceramic vessel fragments. On top lies a layer of clay coating. The surface of the platform is smooth, with remnants of an open hearth (charcoal, ash). The structure likely served as a heat accumulator (Fig. 7: D).

Human skeletal remains were found in various sections of the cave. Due to the constant temperature and humidity, as well as the favourable preservative properties of the soil, they are well-preserved and suitable for bioarchaeological and genetic research. All human skeletal remains were observed to be secondary burials as indicated by their disarticulated state (Karsten *et al.* 2015b, 121-144). Skulls were found in various parts of the cave, both singly and in groups, carefully placed in side niches of the walls and small grottoes (Fig. 7: E).

During the Trypillia times, the surface relief above the cave had a different appearance. In many places, the gypsum massif's rocks were exposed and not covered by turf. In some areas, through cracks and karst sinkholes, there were passages to the underground labyrinth. Thus, the cave could have had several entrances used by ancient people. Other probable entrances to the cave are round holes in the stone ceiling completely filled with soil. Below them, on the cave floor, there are significant cone-shaped soil heaps with mixed cultural layer.

To identify the location of archaeological features in the cave, we first worked through reports, cartographic materials, and publications from the late 19th century. Textual information proved insufficient for marking ancient excavation sites on the modern map, so we based our work on the results of contemporary research.

Moreover, specialized search operations were conducted in the cave according to a pre-developed plan. The first stage of these operations involved dividing the cave's topographic map into six separate traverses. For convenient visual fixation of archaeological features, the topographic base of these traverses was printed in an enlarged scale. The next stage was detailed surveys of the entire area of the cave passages and halls. These were conducted sequentially in each traverse. Through detailed visual inspections of the cave floor, walls, and ceiling, we identified the locations of archaeological features, rock-falls, and water infiltration sources. We then used topographic methods to anchor and record these on the digital map. Pre-established datum points were used for accurate measurements.

The main factors for determining the boundaries of inhabited areas and the locations of permanent settlements of the Trypillian populations in the cave labyrinth were archaeological features, remains of cultural layers, and artefacts.

To achieve better search results, we also used data from comprehensive geophysical methods, including magnetometry, electrical resistivity tomography (ERT), and ground-penetrating radar (GPR). Measurements in the cave were conducted to assess the thickness of the cultural layer, identify new archaeological features, and determine potential directions for extending the cave labyrinth (Bondar *et al.* 2021, 238-251).

RESULTS

During the fieldwork, a topographic survey of the area above the Verteba Cave was conducted, covering a total area of 8 hectares. A map was created at a scale of 1:500 using the Baltic height system, with a relief contour interval of 0.5 metres. During the surface mapping, 22 karst sinkholes and depressions were identified.

Our previous research had revealed a Trypillian cultural layer on the surface of the arable field, near the entrance to the cave. To refine the stratigraphy and localization of the settlement, reconnaissance trenches and excavations were conducted. As a result, the boundaries and area of the Trypillia settlement above the cave were determined (Fig. 8). It became evident that the settlement was linked to the entrances of the cave labyrinth, and the archaeological materials from the surface were similar to those found inside the cave.

During survey of the territory, the locations of archaeological features were established. They were marked on the topographic map using conventional symbols. The projection of the cave labyrinth map onto the surface relief was then performed. As a result, the area occupied by the cave was delineated. It forms a narrow strip extending northwest for 510 metres, with the cave labyrinth's width being 120 metres.

In various parts of the cave labyrinth, traces of probable entrances to the cave, which functioned during the Trypillia time, were discovered. The precise coordinates of these features were fixed on the topographic map of the cave. Through the projection of the cave plan, points on the surface were determined (Fig. 8). These points correlate well with the forms of the surface relief (depressions, sinkholes), thus confirming previous hypotheses.

The projection of the cave map onto the surface also confirmed the correspondence of the locations of vertical natural channels in the cave ceiling with the geomorphology of the surface relief. This helped establish the points of smoke ventilation exits, which were marked on the map.

Topographic work covered the entire known territory of the underground labyrinth. New, previously unknown sections of the cave with remnants of the Eneolithic cultural layer were discovered. Topographic surveys were conducted on the newly discovered sections, and the results were reflected on the map (Fig. 8). Thus, the total length of the cave passages amounted to 9250 metres.

Based on the obtained data, three separate maps of the cave labyrinth were created, indicating the territories occupied in different Trypillia chronological stages. The topo-

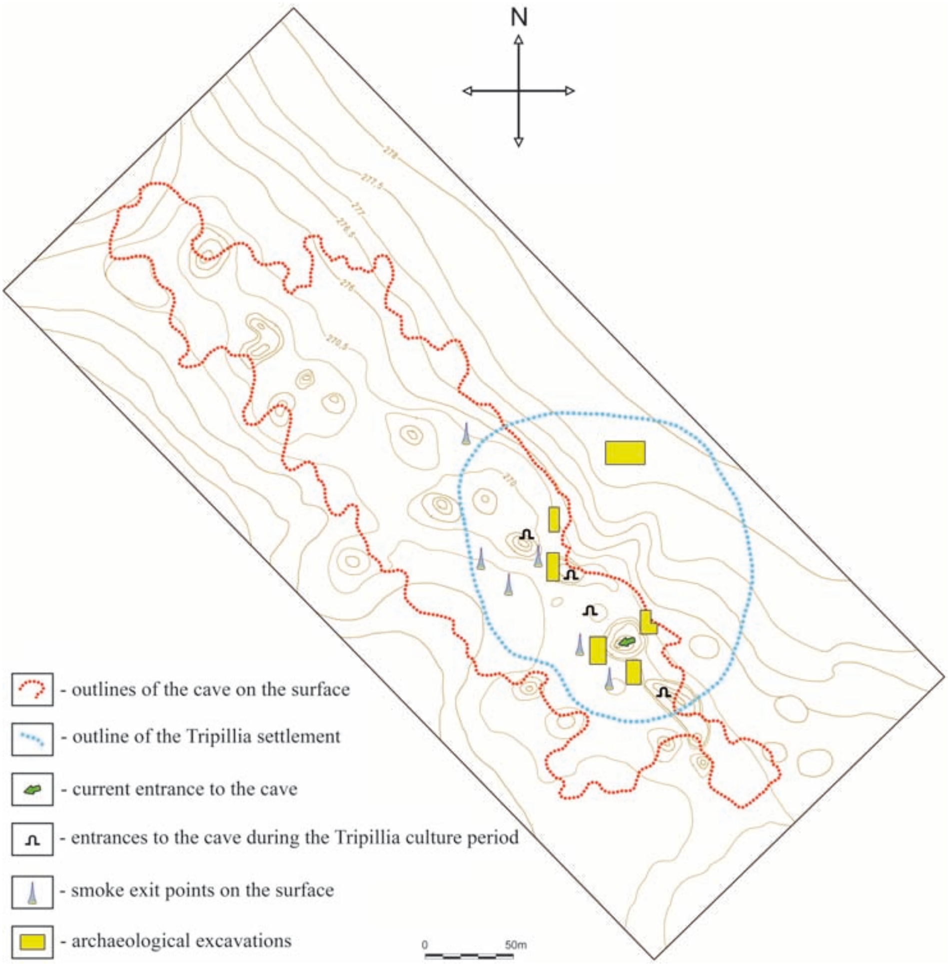

Fig. 8. Map of archaeological features above the cave

graphic results showed that over 30 percent of the total area of the cave was actively inhabited by the Trypillian populations. The areas indicated on the map suggest that ancient settlers chose the most spacious and voluminous passages, halls, and galleries for their underground habitation. The areas they inhabited correlate well with the nearby entrances that were in use at that time.

As a result of the work performed, two thematic maps (surface and cave) containing 162 points of archaeological interest were produced. The surface map marked four probable entrances to the cave from the Trypillian time, five points of smoke ventilation exits, and six areas of archaeological excavations. The cave map marked 147 points of archaeological interest, including 105 fireplace remains, ten pits (domestic and ritual), 14 skull burials, four clay sleeping platforms, five vertical smoke channels, and six areas of archaeological excavations.

DISCUSSION

The complexity of this research stemmed from the need to produce two topographic plans: one for the surface relief above Verteba Cave and another for the cave labyrinth itself. This represented a large-scale and prolonged process.

Additionally, the task was hindered by the limited information regarding the early archaeological research on the cave, and the lack of topographic maps and plans related to that work. For instance, cave researcher Włodzimierz Demetrykiewicz never published plans of archaeological excavations or maps showing the locations of artefacts or features (Woźny 2018, 461). Large-scale archaeological excavations were conducted in the cave at the end of the 19th century, covering the entire near part of the cave. These efforts focused mainly on finding artefacts, with the textual reports also mentioning discovery of hearths and skull burials. However, it is currently impossible to pinpoint the exact locations of these finds within the cave.

The archaeological map marks the features reflected in our topographic plans, scientific reports, and publications. On one hand, we had positive results, such as a series of radiocarbon dates, a collection of stratified artefacts and bone remains, as well as data on geology, bioarchaeology, paleogenetics, and archaeozoology (Ledogar *et al.* 2018). On the other hand, complex processes of accumulation and destruction of cave deposits introduced negative factors into the obtained data.

It is noteworthy that the ancient population began to use the underground spaces of the cave during the late Trypillian stage. They inherited traditions from their ancestors in various aspects of life (beliefs, house-building, crafts, agriculture, animal husbandry, hunting, *etc*.). However, the previously acquired experience was not entirely applicable to the new and unusual natural conditions of the cave environment. For the local Trypillian populations, the process of mastering the underground environment was complex and lengthy.

We were able to document the temporal settlement of the cave. Stratigraphic observations of the cultural layer in different parts of the cave and artefact analysis played a crucial role in this process.

Topographic analysis of the distribution of the cultural layers shows that not all inhabited areas of the cave were settled evenly and proportionally. There is a noticeable pattern in this localization. For instance, the cultural layer is thicker closer to the entrance and thinner in more remote parts of the cave, and it is absent in places where water drips periodically.

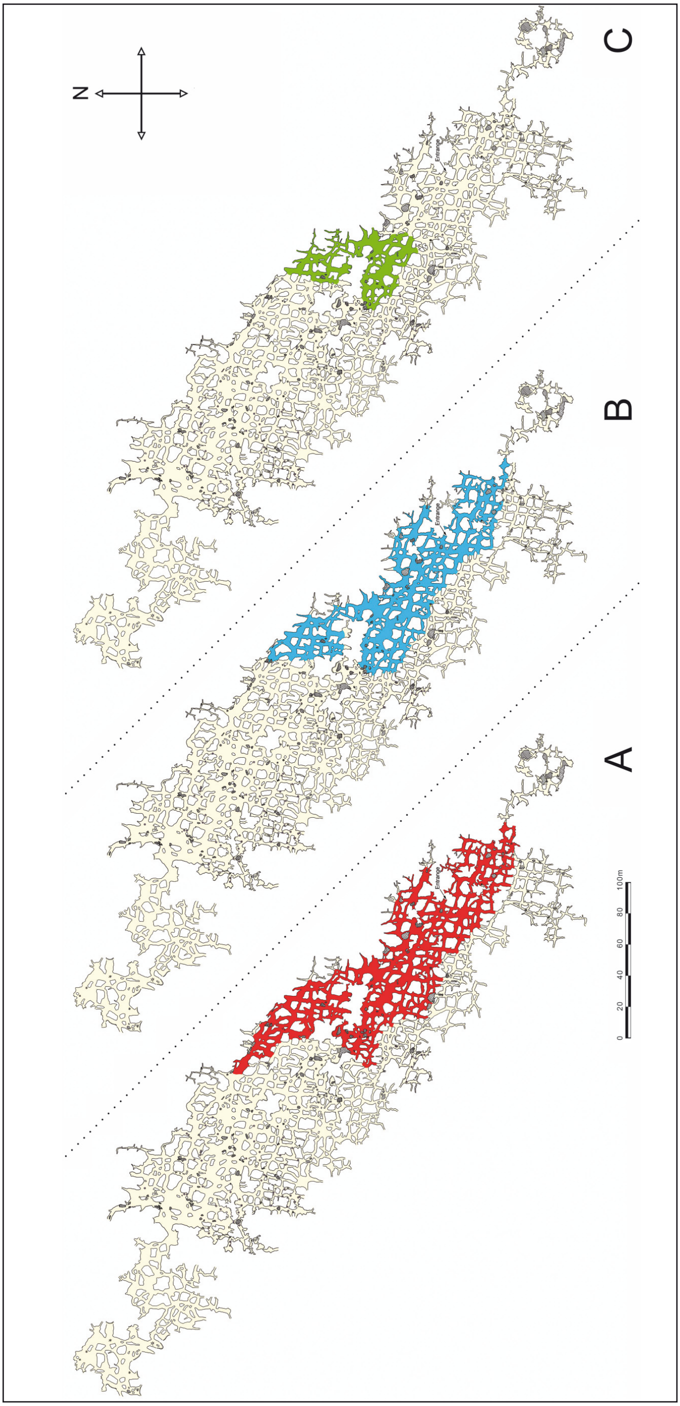

Fig. 9. Maps of the cave with areas inhabited by different Trypillia groups:
A – Shypyntsi local group; B – Koshylivtsi local group; C – Kasperivtsi local group

The most abundant materials belong to the Shypyntsi local group (Fig. 9: A). The territory covered by the Koshylivtsi population was smaller (Fig. 9: B). The Kasperivtsi layer was found only in one area, in the centre of the cave, 200 metres from the modern entrance (Fig. 9: C). It is possible that during the Kasperivtsi group's occupation, other cave entrances were blocked by landfalls.

The archaeological map reveals a pattern in the arrangement of living spaces in side grottoes and the ends of dead-end passages. The thickness of the cultural layer indicates active and prolonged use of these areas. Constant humidity and cold forced people to improve the conditions in their underground quarters. They might have created artificial partitions (from skins) to protect themselves from air currents and retain heat in living areas. If this was a temporary underground shelter, why were human burials found in the

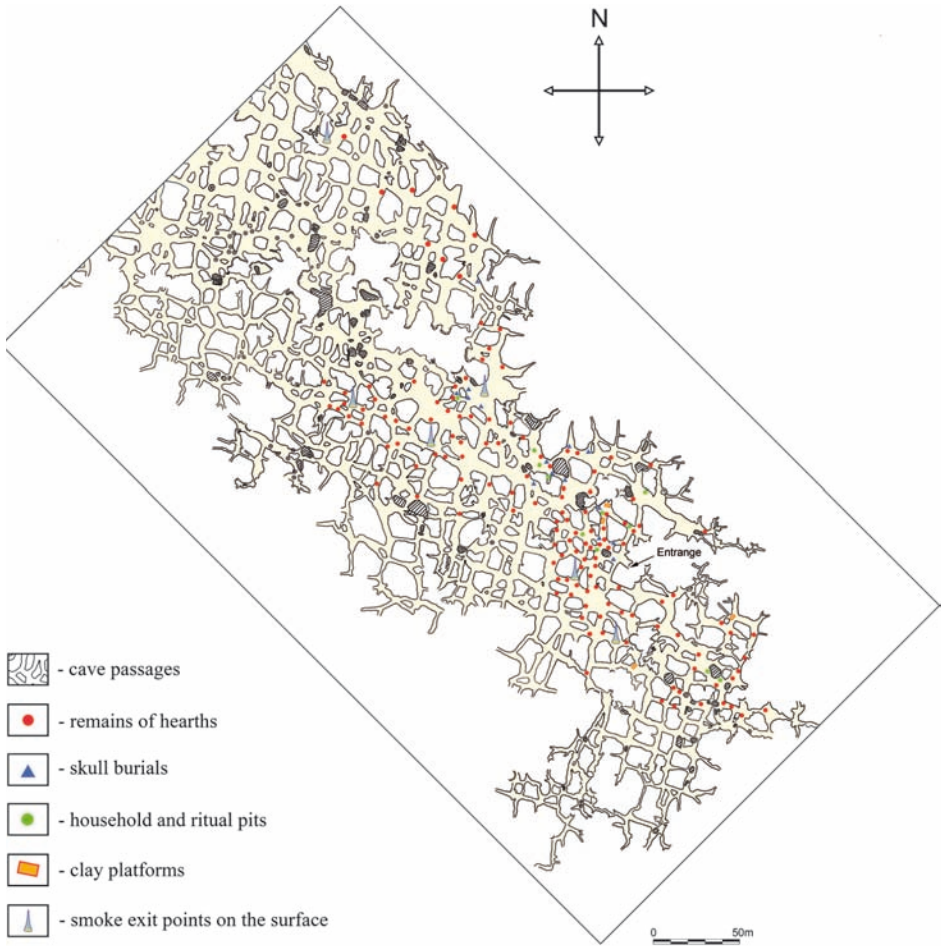

Fig. 10. Map of archaeological features in the cave passages

cultural layer in almost all residential areas of the cave? Was there a tradition among the Trypillian people to perform burials in dwellings? Despite the small number of Trypillian burials, some of them (Luka-Ustynska, Nezvysko III, Kosenivka) were found in dwellings (Gokhman 1958, 127-132; Chernysh 1962; Fuchs *et al.* 2023, 1-84).

Mapping the hearth remains in the cave provided new insights into the function of fire in the underground environment. For the Trypillian peoples, fire was a constant source of light and heat. However, open hearths in a confined space with high humidity produced a lot of carbon monoxide and smoke, which could have been deadly. Adequate ventilation was essential for maintaining fires. Evidently, natural fissures in the cave's stone ceiling served as ventilation channels and chimneys.

It became clear that only hearths near ventilation channels could serve as a constant source of light and heat. However, most of the hearths were scattered throughout the labyrinth, far from vertical chimneys (Fig. 10). This raises new questions. Perhaps these hearths were lit only during burial rituals. Similar traditions are found at other Eneolithic sites (Fernandes 2010, 261-264).

The spatial representation of inhabited areas showed a trend of decreasing activity in cave habitation. This could be attributed to natural factors, such as periodic collapses of existing entrances and flooding of certain cave sections. It is possible that complex disintegration processes occurring at the end of the CII stage of the Trypillian culture's development played a role (Tkaczuk 2005, 87-119). During this period, the local population experienced pressure from the culturally distinct population groups. When choosing settlement locations, factors ensuring life safety became crucial.

CONCLUSION

The systematized spatial and attributive information presented on the archaeological map of Verteba Cave provides researchers with new data on the nature, quantity, and locations of studied features. This map offers, for the first time, a comprehensive spatial perspective on the multifunctional use of the cave and its relationship with the surface settlement. It is now possible to delineate zones of ritual and economic activities.

Currently, the archaeological map is a crucial component of a comprehensive database for the cave. The cartographic results of the conducted research will form the foundation for future traditional and electronic versions of a large-scale, multi-layered archaeological map of the cave. Further additions to the map will depend on the results of new archaeological investigations.

The created archaeological map will be essential for:

• Reconstructing the chronological stages of cave settlement.

• Better understanding the functional use of the cave (long-term habitation, temporary shelter, place for ritual ceremonies).

• Creating a geoinformation infrastructure to support future archaeological research and predict various phenomena.

• Accurately recording human burial sites to obtain additional information about burial rituals.

• Analyzing and identifying prospective areas for discovering previously unknown sections of the cave, possibly containing Trypillian materials.

• Investigating the spatial and graphic features of the cave labyrinth's use and the degree of anthropogenic impact on the natural environment.

• Modelling the dynamics of human-cave interaction (behaviour during long-term stays underground, effective use of the cave's natural features, methods of lighting and navigation in the intricate labyrinth).

• Estimating the probable number of people who could have simultaneously occupied the cave.

• Identifying cave sections with varying degrees of usage intensity.

• Preserving the site and turning it into a museum.

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