3-D PIT: LINEAR POTTERY CULTURE LONG PIT RECONSTRUCTED THROUGH POINT-CLOUD ANALYSIS

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Abstract: Newly applied method of 3D-point cloud analysis performed in Kamyane-Zavallia, Ukraine, introduced the opportunity to define the walking surface of Neolithic settlement and distinguish stratigraphic units in details using the geoinformational systems and geospatial database as a tools for the object analysis. This raises a number of questions concerning the previous interpretations of Linear Pottery Culture sites in Ukraine and the required accuracy of their archaeological excavation. Moreover, the analysis of stratigraphic units inside the long pit from Kamyane Zavallia had shown the complex and heterogenic process of its refilling.

Key words: Ukraine, linear pottery culture, Kamyane-Zavallia, point cloud analysis, stratigraphic unit; 3D model

Introduction

“Long pit” is an iconic type of archaeological object found on Linear Pottery culture (LPC) sites. They usually are a part of “long house” layout (Paret 1942). Thousands of them were studied in Central Europe (Birkenhagen 2003), but barely any in the east of Carpathians. Instead, numerous “pit houses” were found (Zaharuk, Telegin 1985). Eastern “pit houses” and Central European “long pits” often have the same shape and dimensions (Lenartowicz 2013; Saile et al. 2016). The interpretation difference arose from varying methodological contexts of national schools of archaeology and variability of post-depositional processes in different parts of LPC area. While Central European Neolithic pits are usually well-visible in the yellow sterile sediments, Eastern Neolithic remains are covered by layers of fertile black soil (sometimes up to 1 meter) (Passek, Chernysh 1963; Kiosak 2017). Pit contours are barely visible and postholes are often lost. Despite such substantial obstacle to recovering complete house plans, these sedimentary conditions open up possibilities to study upper non-eroded pit parts and to reveal walking surfaces.

To deal with the obstacles, we investigated the long pit on Kamyane-Zavallia site (Odessa oblast, Ukraine) using a strategy of microstratigraphic excavation. The pit was opened by conventional layers of 5—10 cm with small digging tools. The position of each find was recorded in a 3D coordinate system and then point-cloud model was developed. With this approach we could provide the interpolation of the pit's upper part and our hypothetical reconstruction of LPC walking surface confirmed by a micromorphological soil analysis. Planigraphic and microstratigraphic studies were previously conducted on many Neolithic pits (Lüning 1982), but they usually depended on square grid or 2D surfaces (Hachem 2000; Astalos et al. 2013; Astalos, Sommer 2015). 3D-modeling was mostly focused on image processing (Powlesland 2016).

The site

Kamyane-Zavallia is the easternmost excavated Linear Pottery culture site (Kiosak 2017), situated in the Southern Buh river valley at 48°11'57" N and 29°59'55" E (fig. 1). In 2011—2016 we excavated a group of pits there. The largest pit is a typical long pit (21 m long and up to 2.5 m wide). It consists of several oval depressions linked by shallower "steps". Horizontal excavation failed to detect pits' contours up to the surface of yellow-grey loam (depth of –110 cm). The lowest point of the pit is 210 cm below the modern surface (that is –187 from R0. Henceforth, depth will be given relative to R0). Pit 1 was dated by radiocarbon method to 5295—4960 calBC (Poz-67121, 6200 ± 40 BP and Poz-67554, 6130 ± 40 BP, at 95.4%; date modelled in OxCal v.4.3, using IntCal13 calibration curve (Bronk Ramsey & Lee 2013)). Its excavation was very fruitful. Locations of 418 flints, 2928 bones and 1395 pottery fragments were recorded in a 3D coordinate system and inserted into point-cloud model. Finds are typical for Notenkopf phase of LPC. The walking surface of Neolithic period is marked by stone pavement, recovered in 2 meters from the pit's contour (fig. 2).

Method and results

Since the fieldwork data about the pit and related material was not informative enough, we searched for additional research possibilities regarding the features of 3D-points distribution. The most accessible and obvious idea was about GIS models, which introduce numerous options for spatial analysis (Doneus et. al 2011; De Reu et. al 2013). Photogrammetry and GIS were already used to study small areas in detail (see for instance Peng et. al 2018; Tuboltsev & Radchenko 2019). Sometimes the parameter of depth or 2.5D representation is included (Barcelo et. al 2003; Vinogradova & Leonova 2016). However, the pit from Kamyane-Zavallia requires a full-3D representation. It implies the unification and standardization of the 2012—2016 materials. Objects and finds were classified and formalized into 16 database tables (spatial layers) — bones, pottery, flints etc. Each table has its unique list of attributes, what presumes that the database is an important and constant part of research workflow. Each find was geocoded according to the field documentation. Through geospatial analysis it is possible to use this information to study the distribution of the material separately or in aggregation.

The material is concentrated near and inside the pit 1. Through SQL-queries in database management system (DBMS), we made a spatial analysis of the material. Knowing the features of material distribution, we were able to define the shape and extrapolated contours of the pit. To ensure the correct representation of material accumulations, we used a non-weighted heatmap with small influence radius (10 mm). Depth-based separation of the material is helpful to distinguish local depressions inside the pit 1. These holes are connected with the finds' concentrations that start at the specific depth (mostly at –87 cm). Heatmap was also useful for general extrapolation of the pit' contour. Since the shape of material distribution corresponds to the shape of pit 1 in the range between –65 and –70 cm, we assume the pit level is approximately –67 cm. Combination of "–67" and "below –87" heatmaps shows the real finds' distribution inside the pit and sheds light on how it looked like (fig. 4).

In addition, GIS tools were efficient for comprehensive understanding of the pit stratigraphy and extra visualization of long-term fieldwork results. However, to fully study the stratigraphic context we lack a full-3D view. Through coordinated 3D point-cloud modeling in any 3D-space capable software it is possible to study and interpret localization features of the points in general or by a particular criterion.

We chose AutoCAD reconstruction to represent pit 1 in 3D. Even though it is possible to provide pointcloud analysis using Agisoft Metashape, Cloud Compare etc., only AutoCAD combines graphical functions, GIS-like layers management and an opportunity to observe the pointclouds in real 3D. All finds and objects were imported from the database. Next, the catalog of pit 1 points was created and added to AutoCAD. 1208 points of interest were collected from field documentation and geocoded in local XYZ coordinate system to reconstruct the pit's shape. Its surface is represented by triangulation of these points and the shape is filled with artifacts — bones, flints etc. imported in different layers. With such workspace organization we were able to investigate 3D-location of each point relative to other finds and objects and at the same time have the data on its type or other features (fig. 5). AutoCAD is also efficient because of its vast measurement possibilities in comparison to QGIS and other GIS software — as it allows to measure distances, angles and areas in different views and coordinate systems.

Through setting a viewpoint we can get any required section, profile or create the projection of a points array on the chosen plane. The possibility to create an artificial stratigraphic section is very helpful to achieve accurate understanding of stratigraphic units' location. The profile created as the section of this workspace represents the finds directly on the line and the material at any distance from the projection plane.

Through choosing the profile direction we can concurrently investigate complete section of the pit and study its profile features. The method in this case requires choosing the most informative plane and creating a local coordinate system with XY axes on the projective plane. The profile of the pit's bottom is the polyline or spline, built through the triangulated faces and verticles. To reflect the stratigraphic situation correctly, it is important to project enough nearby points. In the case of pit 1 we projected points that are 50 cm away from both sides of the section.

Discussion

The Neolithic walking surface is marked by bases of flat stones from pavement beside the pit 1, which were at –48 — –62 cm. Point-cloud model has a characteristic concentration of bones and potsherds on both sides of the pit 1 at the depths of around –40 — –70 cm. Active bioturbation explains why some finds are dispersed both above and below the expected surface. However, plotting the coordinates of finds clearly reveals that there was a walking surface at the depth of approximately –60 cm and the pit 1 was excavated starting from this level. The preservation of Neolithic walking surface is quite rare in the context of LPC. Hopefully, further excavations will clarify its planigraphy.

The modern soil at the site is fertile chernozem, morphologically light loam. Soil profiles were studied by micromorphological method. It indicated the feeble presence of buried soil at the depth of the expected walking surface (–50 — –85 cm). It is dark grey or blackish, loose, with evident structure of lumps and grains, dusty, light loam. Under microscope it is well visible that every sand grain is surrounded by humic-clayish cover, thus, indicating fertility comparable to the local modern soil (fig. 3).

The stratigraphy of pit 1 reflects the history of its refilling with soil and archaeological material. Four stratigraphic units were identified in the filling of pit 1 (fig. 6). Stratigraphic unit (SU) D1' is well visible on the point-cloud model as several lenses of "suspended" finds above the pit's depression. D1 is a dense, grey, ashy layer that covers the pit like a "cap" and filled with bones and potsherds. It is recognized by maximum concentration of finds in every part of the pit. D2 contains less finds than D1. It is a dark-grey layer with some complete-profile vessels. It was revealed as separate lenses of artifacts below D1. D2' is a stratigraphic unit in the deepest part of the pit that contained burnt clay. On the point-cloud model it is a dense scatter of burnt clay in the well-defined part of the pit. D3 is lucid, blackish filling of the deepest portions of the pit 1. It was almost devoid of finds. This stratigraphy reflects the process of pit 1 filling. It was open for some time (formation of D3), then filled slowly with freshly broken things and by the natural erosion of its edges (D2), and later covered by huge masses of garbage (bones, sherds, etc. —

D1). Several secondary pits were apparently dug into pit 1 (like D2'). The exact stratigraphic relations between the parts of pit 1 were previously far from being clear, but through 3D-modeling we were able to reconstruct the process of pit refilling.

Complex and accurate reflection of archaeological finds in 3D-space permits to revise depositional conditions of the site and track the history of artifacts' accumulation. For a huge, complex-shape object that was in use for years, the deposition rule of the finds is not simply a linear function of depth or time. Spatial features must also be taken into account. Detailed study of the point cloud and its parts reveals the narrowest empty layers and slightest differences in the pit's refill. Visual analysis and separation of the finds into several spatial groups permits to distinguish stratigraphic units that reflect the history of pit's creation and existence.

The analysis of stratigraphic units has revealed local pits filled with material from level D3. After D3 had formed, the internal pit D2', which is the deepest part of the object, was dug. Afterwards, the local pits were filled with the finds from level D2 and finally covered by highly fragmented material from D1. The latter is a massive stratigraphic unit everywhere in the pit 1 (where it is enough material to register it).

Conclusion

Irregular shape of pit's bottom and complex history of its refilling absolutely eliminate subterrain dwelling version. It was rather a clay extraction pit along the wall of a longhouse, existing long enough to allow slow and variative process of finds' deposition. After abandonment of the house, the pit was probably reused as a garbage pit and refilled with huge amount of trash.

The method we used to excavate and interpret Kamyane-Zavallia appears to be effective for complex objects with unclear stratigraphic situation. Even though it requires slow and meticulous trowelling, 3D measuring each point and locating the objects precisely, it has the capacity to reveal local historical processes of the object and to observe it in 3D. GIS and DBMS provide the required research accuracy and also interoperability and unification of all studied materials. With these tools, geospatial analysis and other digital methods provide more information about the shape and features of the object. Furthermore, through a combination of 3D view and the concept of stratigraphic units we can distinguish even the smallest of them and reconstruct complex historical process of studied object.

Despite a lot of geocoding and almost manual triangulation, the described digitization approach provides additional information about complex objects. It can be successfully implemented in numerous cases, and specifically, when the spatial information makes difference even on the small scale. It is also useful to unify long-term researches and makes spatial researches possible.

Even though 2D or 2,5D software is usually enough, our sites are 3-dimentional and we must take it into account. Digital tools are widely used in contemporary archaeology, but their efficient use still requires sophistication, ingenuity and resourcefulness. Without these qualities most of collected data remain useless and mismanaged. Vice versa, complex and exhaustive use of modern technologies and archaeological data will lead to additional knowledge even in tough archaeological conditions.

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