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Documentation of Medieval Caves in Southern Crimea (Ukraine) Using Hybrid Data Sources

Abstract: The subject of this article is the geometric documentation of more than 500 caves cut into the soft rock of the plateau of Eski-Kermen, a medieval settlement on the highlands of the south-western Crimea. The types of caves and carved surface areas vary from very simple to extensive ones. A large number of traces and objects were recorded as basis for the understanding of the use of the caves, which were modified throughout the centuries until recent times. The aim of our sub-project is to develop a comprehensive system of effective geometric and archaeological documentation for further studies of cave settlements.

Introduction

The medieval cave settlements of Eski-Kermen and Mangup-Kale on the highlands of southwest Crimea are documented in a sub-project at the Roman Germanic Central Museum Mainz in cooperation with the Ukrainian Academy of Sciences, the University of Simferopol, Crimea, and other departments in Germany, Austria and Poland.

The project started in 2006 and is funded mostly by the Pact for Research and Innovation of the German Federal Government and the Federal States. Its subject is the research of Byzantine influence and the cultural exchange in early medieval times on the Crimean peninsula, which played an important role on the marginal area of the Mediterranean world.

The geometric documentation of the fortified cave settlements of Eski-Kermen and Mangup-Kale within the sub-project is performed in cooperation with the University of Applied Sciences Mainz.

Historical Background

In the second half of the 6th century, Byzantium intensified its power in the regions of Cherson and Cimerian Bosporos, while inland Crimea was still inhabited by Goths and several steppe peoples. Written sources and archaeological evidence suggest that many settlements were fortified during this period. Eski-Kermen and Mangup-Kale in the highlands of south-western Crimea, which are the focus of our project, are presumably two of these settlements.

The settlement of Eski-Kermen, which was investigated in the first campaign, lies on a 1.2 km long plateau of limestone, which raises from the valley in several places for up to 80 m. Here some existing walls and negative traces on the rock show that nearly the whole plateau was fortified up to the edge. From the end of the 9th to the 13th century the cave settlement expanded during different phases. In these periods several churches and residential quarters as well as manufacturing and storage areas were built and carved into the rock. After the place had been abandoned, numerous caves were modified in the following epochs for other purposes. Until the 18th century many of them were used primarily as shelters for animals. Almost all the caves are fitted with one or more feeding troughs (Aibabin 2006; Ernst 1927; Mogaričev 1997; Veymarn 1958).

Sub-project Surveying/GIS

The main tasks of the sub-project dealing with the geometric documentation are: the organisation of all spatial data (which includes the introduction of a common reference system and the geo-referencing of data from various sources), the efficient documentation of finds and findings using appropriate tools and methods, and the provision of spatial data within the project for all sub-projects. This spatial data, including all geometric descriptions of objects, is one of several foundations for this archaeological research.

The geometric quality of the data varies considerably, depending on the source and the recording technique used. Considerable errors in the plans and maps which have been generated over the years become apparent when checking or combining the data. Due to the size of the sites and the number of objects involved, it is not possible within the scope of this project to record every single cave in full detail, nor is it necessary. Thus the recording is carried out with varying levels of details, using suitable sensors. Techniques used are hand-held GPS receivers, total stations, photos (single, photogrammetry, stereo-models) and 3D laser scanning.

As far as possible, the data is stored in a GIS which contains additional attribute data, thus making it accessible for further visualisation and analysis.

Process

Technical Issues

Considering the strategy for the field work, several limitations have to be made regarding the choice of sensors and techniques for the geometrical documentation. First of all, the objects to be recorded must be defined in an interdisciplinary discussion to meet the archaeological requirements. The acceptance of documentation techniques or resulting formats, for example, may be limited by regulations of national archiving institutions or the background of future data users (Boochs et al. 2006a). Practical limitations for field work can arise due to the portability of sensors, the accessibility of the site and power supply restrictions. In our project, the caves were classified to be recorded at two different levels of detail, depending on their importance with regard to typology and other archaeological aspects. The more basic level of detail comprises the documentation of size, aspect, shape, and so on, whereas a finer level of detail is used to provide a comprehensive reconstruction of the usage and history of selected caves.

In order to provide a common basis for all spatial data, a geodetic reference system was developed in the field to allow geo-referencing of maps, geophysical prospections, laser scanning data, single findings, total station measurements, etc. For the initial recording of caves and outline maps we used available maps from earlier campaigns from the 1930s and 1970s and recorded additional positions using hand-held GPS. The main purpose of that initial recording is to enable orientation in the field and later for the visualization of the general spatial object distribution. The comparison of older with more recent data can provide information on vanished or destroyed objects. A hand-held GPS yields rough geometric positions of objects, which can be used to visualise and analyze such objects in a GIS

Fig. 1. Eski-Kermen: Southern main gate; view from south.

("basic level of detail" version). Should no satellite-contact be available from within the cave (e.g. via an opening), the positions of the caves are recorded using measurements above the cave-structure itself.

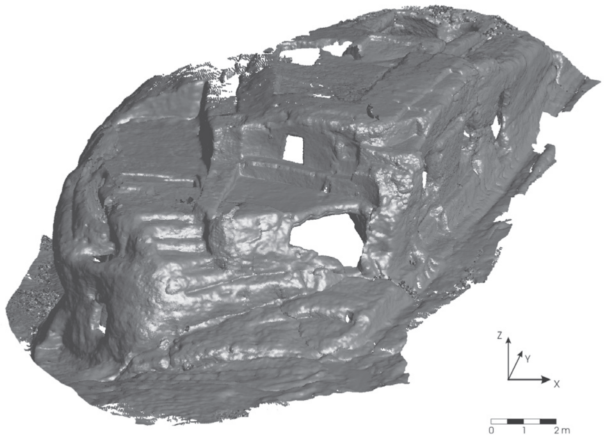

Fig. 2. Eski-Kermen: 3D laser-scanning of the southern main gate.

The equipment used for the "fine level of detail" documentation consists mainly of total stations and 3D laser scanning devices. Moreover, photographs were taken in order to support the documenting techniques, providing valuable 3D visual information.

Total stations were used for geo-referencing all recently acquired data, for measuring reference points for photogrammetry and for recording single structures, sections, and surface data in selected caves. Total stations are well-suited for registering prominent points which are identified while taking accurate measurements in the field *(Figs. 3–5)*.

3D scanning was mainly used to record complex situations and establish the geometrical basis for scene visualization *(Figs. 1–2)*. This method is not

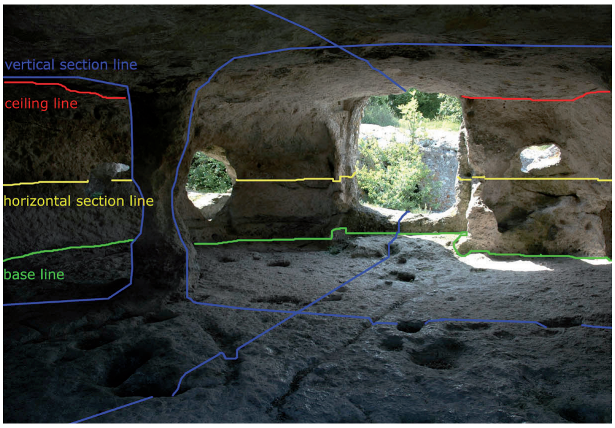

Fig. 3. The main measurings of the interior of a cave.

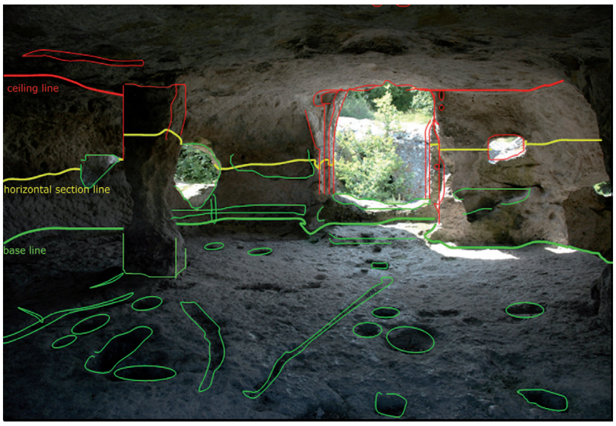

Fig. 4. The measuring of carved objects in a cave considering the position below (green) or above (red) the section line.

suitable for recording the fine details of an object, but it is very efficient with regard to registering and recording the integrity of an object. In the project, special structures such as churches or wine-presses were scanned with high resolution for special analysis and comparison.

Photos are used both in the form of single rectified images and stereo models for measurements. We used standard DSLR cameras and constructed a simple stereo basis for photo recording *(Fig. 7)*. In combination with adopted in-house photogrammetric processing software stereo viewing (anaglyph or shutter glasses) and measuring can be performed without using additional special equipment. Tools supporting orientation and scaling (semi-automated processing) speed up the process of extracting information from the objects. By viewing the structure in 3D with the digital images' high-information content, the user gets a much better understanding of the situation. A problem which occurs from time to time with regard to the use of photography on this project is the limitation of the photographs' dynamic range, e.g. exposure problems when confronted with wildly varying degrees of lighting within a single cave. However, this problem can be dealt with by using high-dynamic range images generated from images with different exposure times.

Archaeological Issues

Considering the large number of caves, a mixed documentation was essential to obtain selective information. Initial inspections were necessary to classify different types of caves. Even if this step was very difficult with regard to the irregular shape of every cave, it was still possible to roughly assign the crucial components to the different types on site. We were able to distinguish not only between one-room caves and a cave complex, but also between other factors depending on entrance situation, character of carved traces and equipment.

Taking into account the major difficulty of the

Fig. 5. Eski-Kermen: Exterior area with a great rectangular cutting and negative traces of buildings.

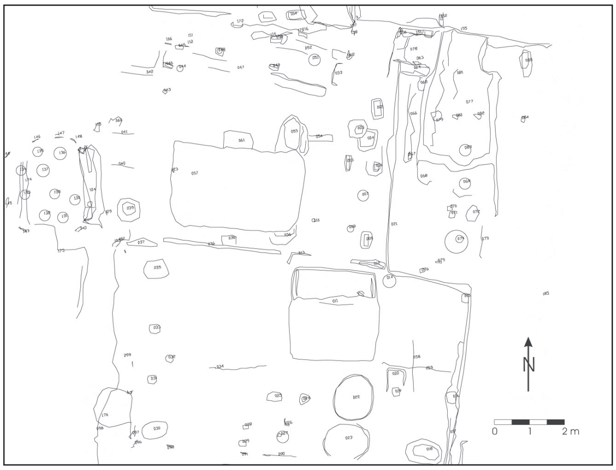

Fig. 6. Recorded data from total station measurements; view from south.

Fig. 7. Simple basis for taking stereo models.

long period of time the caves were in use, including the modification of many rooms and their functions, it was necessary to begin analysing the details. By documenting the structures with geometric data and by a careful description it was partially possible to recognise different phases. A relative chronology was primarily given by intersections. In this manner we can assume, for example, that the pithos-shaped storage vats, which are carved accurately into the surface of some rock-plateaus, and were roughly cut later creating a cave below of them, belong to the earlier structures. Another way to receive a relative chronology is the comparison of specific details or cave types with other examples from the Crimea or the Black Sea region and the Mediterranean area. In this way we can presume that an arcosolia room, which was hidden on the east edge of the Eski plateau, was built in Roman or Byzantine times. It is more difficult to keep structures apart in a complex system. To do this, it was necessary to apply more precise descriptions and documentations.

The first step was the registration of all the caves of Eski-Kermen. Surviving maps from the 1930s and the 1970s show different numbers and positions of caves. Therefore, a new record of all the caves was necessary. In our first campaign, we registered the general position of 170 caves and cave complexes by hand-held GPS and fed the data into a geo-database (coarse level of detail documentation). Further investigations of the published and archived material combined with the contents of the geo-database led us to decide which caves should be documented at the fine level of detail. Special credit had to be given to the areas to be scanned. Apart from financial concerns, the laborious transportation of the equipment on small paths and particularly the time and effort in its post-processing were crucial decision factors. As a result of the considerations, terrestrial laser scanning was used mainly in areas which had to be visualised and for surfaces with densely carved structures.

The majority of detailed documentation at the fine level was performed by using total stations *(see Figs. 3 and 4)*. The advantage of using this method is the ability to immediately define, in the field, which structures are relevant and require further investigations, and which were not artificial. Within the scope of a diploma thesis at Mainz University of Applied Sciences, a program was written which converts the total station measurement data into dxf-files (Steffen 2007). Using a code number system, the measured data was converted into polylines, polygons, circles and points stored in different layers in a CAD environment. In this way it was possible to decide in which form a structure should be displayed in CAD during measuring. In particular, the amorphous shape of every cave needs an adaptable application. Therefore the program has been adopted and optimised during field work.

According to established standards of technical constructions a basic form of a plan has been developed consisting of several lines *(Fig. 3)*: The measuring starts with the base line, i.e. between floor and wall. Due to the irregular and vaulted shape of the cave the base lines do not give the optimal information of space. Therefore, a horizontal section line is needed which is – according to the shape of each cave – applied in a manner receiving the maximum information. Not every cave has a level ceiling which is clearly divided from the walls. If present, it had to be recorded as well.

For detailed measuring by total station we recorded every significant carved structure *(Fig. 4)*. By calculating or measuring the centre of every object, we obtained a reference point connected with the database.

In order to avoid mistakes in reworking the drawings, we distinguished between objects below and above the intersection line. This is considered in the converter and they are presented in green, yellow and red. Of course, depending on the scale of the plan, the contents have to be generalised or optimised for publication. Two or more vertical section lines complete the basic documentation.

For recording a greater quantity of objects carved into walls, taking stereo images reduces the effort in the field considerably. This method provides the advantage of being able to take information of structures from a wall very fast and effectively. This completes the base-measuring of a cave. In post-processing the images are used for illustrating the situation in the field. If necessary, additional metric information can be derived from the stereo pairs and inserted into the CAD system.

Considering the interior of the caves as well as many structures on the outside and top of them, it took at least one day for a complete, fine level, detailed documentation of one cave. The density of structures on the surface above ground was the main determining factor for the overall workload. The measurement results show a serial arrangement of small, drilled postholes, which are placed preferentially on the edge of the rock, indicating wooden constructions like parapets or huts. They are important for the general view. In some places great rectangular cuttings were carved into the rock to create space for buildings constructed of stones respectively of stone fundaments *(Figs. 5–6)*. In those cases structures hewn into the levelled areas served primarily as cellars and cisterns.

Conclusion

The experiences of our campaign so far show how useful the application of recording hybrid data at different levels of detail is when documenting big sites with a huge number of findings and objects. The application of methods, techniques and recording strategies has to be developed and optimised in close cooperation between humanists and technicians. The first results demonstrate how important the choice of documentation techniques is. Just recording masses of unattributed data does not necessarily lead to a good basis for further archaeological research. Therefore we only used 3D laser scanning for selected areas, mainly for visualization purposes. Caves with many traces from long civilization periods were recorded using total station measurements and photogrammetry. The archaeologists' contact with the object during the field work allows for the assignation of attributes to recorded structures directly, and is of fundamental importance for reconstructing ancient life.

Storing the geometric object data together with images and various attribute data provides the basis for comparative studies with similar sites in the surroundings as well as in the Black Sea and the Mediterranean region.

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