A virtual view of Pliska: Integrating remote sensing, geophysical and archaeological survey data into a geographical information system

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1. Introduction

The integration of spatial data about the surface and near surface into a geographical information system (GIS) on a local, regional or supra-regional scale has been of growing importance for archaeological and cultural research in the last decades. Non-destructive methods of prospecting and combined spatially oriented archaeological interpretation of excavation and survey data offer a progressive approach towards efficient documentation of buried archaeological structures threatened by destruction through landscape transformation and erosion. With rapidly developing technologies of high-resolution remote sensing, digital photogrammetry, near-surface geophysical sensing and 3D visualization techniques, both the documentation and analytical capabilities of GIS present an ever-increasing potential for supplementing traditional archaeological excavation and survey techniques.1

In the case of the study presented here, archaeologists and geographers joined forces within Frankfurt University’s interdisciplinary Graduate School of Archaeological Analytics with the aim of introducing GIS techniques to the investigations being carried out by a German-Bulgarian archaeological team since 1997 at Pliska, the early medieval Bulgarian center of power and Europe’s largest post-Roman settlement agglomeration. With the remarkable extent of 21.8 km² the settlement must have been a true metropolis. The city was abandoned by the thirteenth/fourteenth century at the latest, and with the exception of the present-day town of Pliska, previously a village with the Turkish name Aboba, in the southern part of the site, it is nowadays largely under agricultural cultivation. This presents, of course, a challenge to archaeology and its cooperating disciplines. Excavations already started more than a hundred years ago, but since 1899 archaeological work there had succeeded in uncovering less than 1% of the site. This situation changed dramatically after the completion of the German-Bulgarian

field campaigns that ran from 1997 to 2001. More than 53.3 hectares were explored by geophysical measurement, and after the analysis and mapping of the data suitable sites for 31 excavation trenches were chosen and accurately located within the new plan. The basic archaeological results are presented in this volume. Unfortunately there is only a very limited amount of printed basic information on Pliska’s archaeology and history that is easily accessible to the non-Bulgarian reader. 

2. The Pliska site GIS

By merging various spatial data – maps, aerial photography, relief data, geomagnetic survey images, locations of excavation sections and other points of interest – in a geographical information system, a basis was to be established for the visualization and further spatial interpretation of excavation features and geophysical survey measurements. In addition, the combination and synopsis of spatial information from multiple sources was expected to be of great use in archaeological prospecting in the Pliska area.

ESRI GIS software (ArcView 3.2, ArcGIS 9.0) and Leica Geosystems image processing software (ERDAS Imagine 8.x) were used for all image and data processing. A first step in establishing the Pliska site GIS was the integration of point and image data obtained by archaeological and geophysical survey in a common cartographic coordinate system. These primary data were subsequently combined with secondary information derived from the primary layers: relief data and archaeological features. The visualization tools of the GIS could then be used for the construction of 2D maps and 3D views, showing all features in their spatial associations. Examples of these maps are given in plates 21-25.

While some base data for the Pliska site GIS could be acquired from other sources, most data were collected in the field or derived as secondary data from GIS analysis and visual interpretation. The following list gives an overview of the main layers incorporated into the Pliska GIS.

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As a topographical base for the Pliska GIS, orthophoto maps as well as medium and large-scale topographic maps covering both the Outer Town with surroundings and the area of the Inner Town were acquired in 1999. Unlike the original aerial photographs, orthophotos have been corrected for the relief distortions resulting from the camera’s central perspective: like maps, they have parallel perspective and correct scales and geometry for direct measuring and mapping.

A major problem was the lack of coordinates on these maps and orthophotos: while both scale and a 500 m grid are indicated in the map frame, the grid itself is not marked with coordinates as this information was regarded a state secret in Bulgaria in the past. From the sparse information available, and with the aid of the truncated map coordinates marked on a 1939 1:40000 scale Bulgarian Military Map, coordinates for a Bulgarian Gauß-Krüger Transverse Mercator Projection were reconstructed. When GPS readings of the surroundings of Pliska were available in 2001, this reconstruction proved to be accurate to within approx. 500 m. The error results in an offset to the true GPS coordinates only, and does not affect the internal geometry and scale of the GIS.

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3 Mugnier 2002.
2.2 Additional remote sensing data, geophysical and geodetic survey data

All further data were subsequently georeferenced to the topographic base data and the 1987 orthophoto map, and integrated into the GIS. For the scanned aerial photographs from 1992 and 1942 this was accomplished by image-to-image rectification with a second order polynomial transformation. A multi-temporal composite was produced from the black-and-white photographs of 1942, 1987 and 1992 for a simultaneous view of structural landscape changes during these 50 years.

Geomagnetic survey images and point survey data were originally taken in a local coordinate system used by the archaeological survey; this local system was converted to the GIS coordinate system by affine transformation using reference points identifiable on the aerial photographs. The original ASCII data were converted into raster and vector format respectively.

2.3 Derivation of relief data

Digital elevation models (DEM) were derived from the base data by spatial interpolation techniques. For a general topographic overview of the surroundings of Pliska, an elevation model with 10 m resolution was interpolated from contour lines, which were digitized from the 1:25,000 map. For the areas covered by geomagnetic survey west of the Inner Town, a higher resolution (1 m) elevation model was derived from height points measured with a total station. Depending on the topographical situation, these points had been taken by the archaeologists in a roughly regular grid at intervals of 5-20 m during the field campaigns in 1999-2001.

From the latter, large-scale DEM topographic analysis was carried out generating data sets of slope gradient and potential flowpaths of superficial runoff. The University of Leuven’s USLE2D software was employed for modeling the flowpaths using a multiple flow algorithm.4

2.4 Archaeological features

Additional vector layers were digitized interactively over the base data layers for selected elements (town boundaries, excavation sections, outlines of the geomagnetic survey area). Layers of potential grubenhaus sites and bank-and-ditch systems were drawn from visual interpretation of the geomagnetic data, relief data and aerial pho-

4 Desmet/Govers 1996.
A virtual view of Pliska

3. A virtual vision of the site of Pliska: synopsis of the information layers

The GIS allows for a visual combination of individual layers of spatially referenced data stacked in interchangeable order with any user-defined cartographic symbology. Control of layer visibility (off, on, semi-transparent) facilitates the collective examination of information about the surface which in reality cannot be viewed all at once in the field, and 3D tools allow the observer to adopt any position towards the area of interest, which may be magnified or reduced at will.

An overview of the topographic situation of Pliska is given in a 3D view from the south-east in plate 21 (top, figure A) and demonstrates the situation of Pliska’s Inner Town, 49 hectares in size, on a flat ridge on a south-facing slope with a gradient of just 1-2°. Over the full extent of the Outer Town, which stretches some 6.5 km from north to south and covers an area of 22 km², this slope is dissected by the Asar-dere valley, the sides of which in several places fall steeply from the adjacent ridges. Modern is located in the southern Asar-dere valley just within the Outer Town’s limits, and close to the junction with a smaller valley running east of the Inner Town. This is more or less the area shown in plate 22, where the geophysical survey areas (53.4 ha) of the 1997-2001 campaigns are marked on the orthophoto map.

In this black-and-white orthophoto map, and even more so in the multitemporal color composite, the farmed fields differ greatly in reflection and texture, and yet there are many conspicuous structures not related to agricultural working but rather to accelerated erosion, accumulation or deliberate leveling of the ground. Thus, several archaeological features, some of them hitherto undetected, could be identified from the aerial photos (see also Pl. 23): a bank-and-ditch system adjoining the Inner Town to the north, the Mound XXXIII in its north-western corner, now leveled, a crescent-shaped structure depicting the remains of a slag heap at the edge of an artisans’ quarter between the Asar-dere valley and Mound XXXIV, and parts of a rampart-and-ditch system running north-north-east from Mound XXXIV. All of these objects also appear on the geomagnetic survey images overlaying the 1992 aerial photograph in plate 23.

From the combined imagery, point and linear geomagnetic anomalies were interpreted in order to identify potential grubenhaus sites and rampart-and-ditch systems. In order to differentiate between anomalies caused by natural processes – e.g. soil erosion or colluvial infill – and anthropogenic anomalies, layers of contour lines and potential flowpaths (Pl. 24, right) were consulted, the latter indicating possible invisible courses of erosion rills or depressions which might be reflected in the geomagnetic images. Several linear structures visible as geomagnetic anomalies could thus be excluded.
from the bank-and-ditch layer shown in Plate 23, while others must be considered to be clearly anthropogenic on the grounds of incompatibility with both relief morphometrics and potential flowpaths.

In the subsequent excavation campaigns excavation trenches were placed in order to confirm some of the sites and structures identified by this procedure. All of the features thought to be grubenhäuser or ditches, as well as some of the ramparts could be confirmed (compare Pl. 24, left, and Pl. 23).

Geomagnetic anomalies within the survey area interpreted as grubenhäuser show a mean distribution of 10 features per hectare, with a slightly higher density east of or within the area of the main excavation trench (11.3 sites/ha) than outside towards the Asar-dere valley (8.7 features/ha), where in the lower occupation layers the eighth/ninth centuries artisan quarter was detected. No significant tendency towards flatter sites can be observed for the location of the grubenhäuser: 87.5% of the grubenhauser-type geomagnetic anomalies can be found within the 84.5% of the area analyzed west of the Inner Town with slope gradients of less than 3°. Only gradients of more than 7° – a mere 1.6% of the area – appear free of potential grubenhaus sites.

Geomagnetic anomalies caused by rampart-and-ditch structures prevail over those attributed to grubenhaus features in the survey area named as Poluostrov (literally “peninsula”, but more precisely a spur), north-west of the Inner Town where a small tributary joins the Asar-dere valley (Pl. 25). Three excavation trenches were positioned in order to explore the geomagnetic line structures mapped, and these in fact turned out to be fortification ditches of some kind, probably designed to defend the spur-like elevation between the two watercourses of the Asar-dere. The majority of the interesting structures visible on plate 25, however, will have to be the subject of future field exploration.

4. Conclusions

The primary function of the Pliska GIS was the establishment of a space-oriented inventory of various information layers about the area of the medieval city. In a first step, the combination of multi-temporal aerial photographs enabled the recognition and assessment of temporary and permanent agricultural and soil marks visible at the surface. The integration of geophysical survey images and relief data – derived by surface analysis from topographic maps – could further enhance the interpretation of spatial relationships and facilitate the discrimination between relief-induced and anthropogenic structures. Thus new insights were gained for further excavation planning, and subsequent results could be fed back into the GIS, confirming previous assumptions from the interpretation of the geophysical data. In this context, the mapping and 3D tools of the GIS proved of valuable assistance for the visualization of all features in their spatial associations.
Bibliography
