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Surveying the Silk Road: Geophysical investigation of the underground structures in the city of Uzgen

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Highlights: High-resolution geophysical methods revealed hidden structures in Uzgen, GPR and magnetic surveys identified precise dimensions of ancient foundations, Integrated GNSS mapping ensured accurate georeferencing of archaeological sites.

Keywords: magnetic survey, ground-penetrating radar, GIS, remote sensing, Uzgen, Silk Road

INTRODUCTION

The city of Uzgen, one of the major stations on the legendary Silk Road and one of the former capitals of the Karakhanid Khanate in the 12th century, holds an old history. This place, which played an essential role in the region's life for millennia, gradually became a significant center of trade and culture. Some witnesses to the Karakhanid period of Uzgen are the well-preserved, unique mausoleum and a minaret (Figure 1). During this period, Uzgen formed an important link on the Silk Road network between the other Khanate capitals of Kashgar/Kashi, Balasagun and Afrasiab/Samarkand (Duturaeva, 2022; Аманбаева *et al.*, 2015). Today, its ancient ruins, hidden underground, continue to conceal the secrets of the past, drawing the interest of researchers striving to preserve this heritage for future generations.

Uzgen has witnessed many historical eras, each leaving its mark. Remnants of ancient walls, building foundations, and traces of cult structures serve as reminders of the high level of architectural and craft development. The research presented in the work of V. V. Nusov, *“Architecture of Kyrgyzstan*

from Ancient Times to the Present” (Нусов, 1975), highlights the rich cultural heritage of the city and the importance of its study. New technologies now enable researchers to look beneath the surface and gain new insights into the architectural and archaeological heritage of Uzgen without excavating and thus without destroying the cultural heritage. In order to test the basic detectability of the archaeological structures, the first geophysical surveys were carried out in the archaeological park of Uzgen (Figure 1).

APPROACH

To study the hidden underground structures, cesium total field magnetometry (CMag) using the Geometrics G-864 and ground-penetrating radar (GPR) by Sensors & Software were used. To georeference the coordinates of the survey grid corners, a GNSS survey was conducted using the CHCNAV i90 device. The CMag survey used a measurement grid with

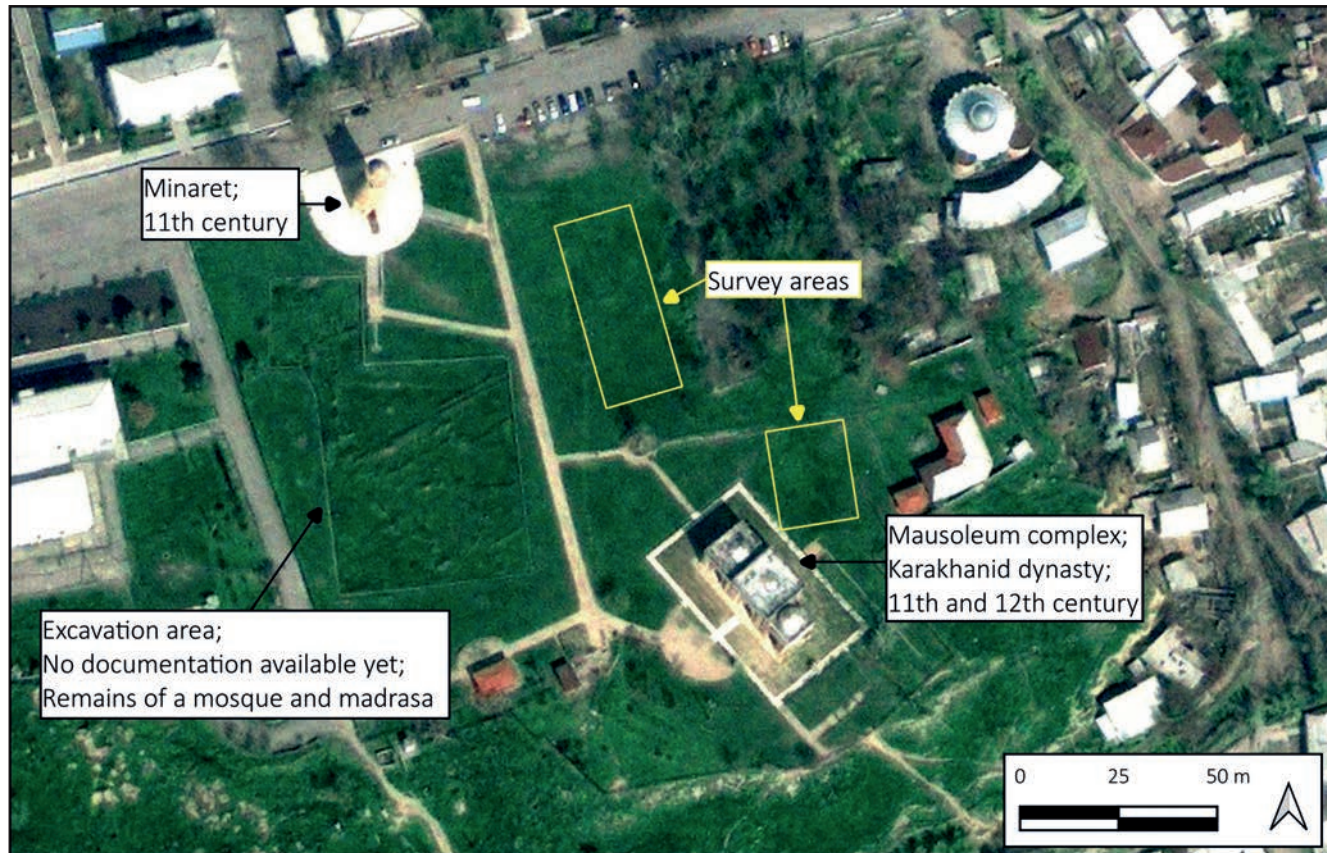


Figure 1: The eastern part of the archaeological complex of Uzgen, Western Kyrgyzstan, with the survey areas and the most important architectural-archaeological monuments.

Background: georeferenced MAXAR satellite scene from March 2009. Source: Google Earth Pro historical imagery.

a step of 0.5×0.25 m, which enabled the creation of high-precision maps of magnetic anomalies.

GPR complemented the magnetic survey. GPR measurements were carried out using a measurement step of 0.5×0.1 m, achieving high spatial resolution. The device, operating at a frequency of 250 MHz. Magnetometry data were processed in Geoplot, while GPR data were processed in PulseEKKO PRO, and the results of both geophysical methods were presented in a unified QGIS-based spatial system with geographic coordinate referencing. This allowed the results to be overlaid on satellite images and create integrated maps of the areas where hidden underground structures were identified.

RESULTS

As part of the research conducted on two sites, Area_1 and Area_2, significant underground structures of archaeological interest were identified (Figures 2 & 3). GPR and

CMag surveying methods enabled precise determination of their dimensions, depth, and signs of artificial origin. These findings offer new opportunities for studying historical sites and reconstructing their functional significance in the past.

On the first site, Area_1, traces of a rectangular structure measuring approximately 8×5 m were discovered. It was located at a depth of around 1.20 – 1.80 meters. The GPR showed clear outlines of presumed walls or foundations (Figure 3), while magnetic measurements confirmed the presence of linear anomalies, suggesting that this was an artificially constructed feature (Figure 2). This structure is of particular interest, not least due to their immediate proximity and a similar orientation to the mausoleum complex in the south of the survey area 1.

On the second site, Area_2, the results were equally intriguing. Here, at a depth of about 2.2 meters, the GPR revealed a large rectangular structure approximately 10 meters long and 4 meters wide (Figure 3 b). Its contours appeared more blurred, which might be due to partial destruction of the object.

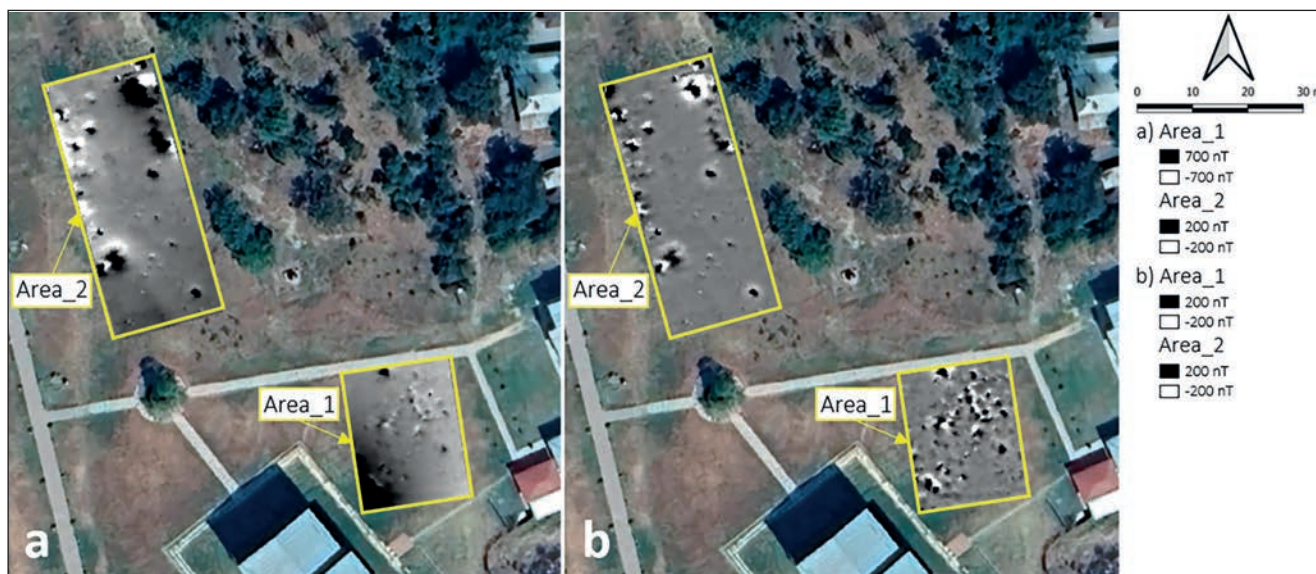


Figure 2. Total field (a) and total field high pass (b) magnetograms of the survey areas.

In the recent satellite image it can be seen that the mausoleum complex is already under a protective building, unlike in the MAXAR imagery from 2009 (compare with Figure 1). Background: Google satellite.

Source: QGIS QuickMapServices extension (vers. 0.19.34).

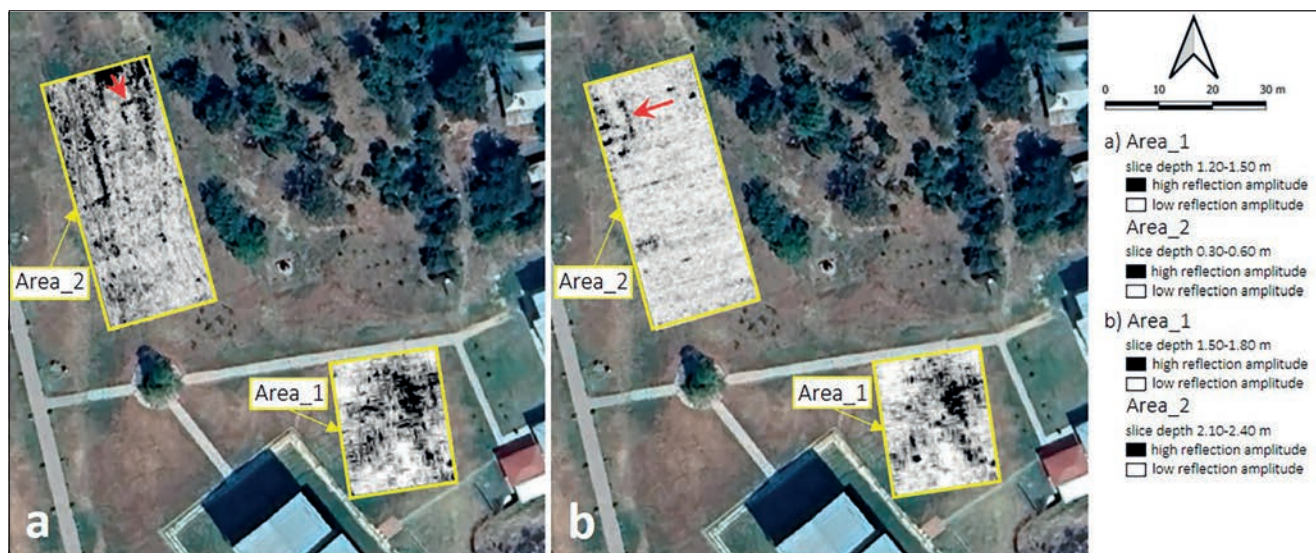


Figure 3. Selected time slices from the GPR measurements of the survey areas.

Background: Google satellite. Source: QGIS QuickMapServices extension (vers. 0.19.34).

Above that, between 0.3 and 0.6 meters, there are other possible remains of walls or foundations (Figure 3 a).

Could it be the remains of the mosque? We cannot say now, further radar measurements in the west of Area_2 are necessary. Magnetic surveying also revealed localized anomalies around the structure, likely caused by remnants of

walls or trenches. As the magnetic anomalies in these areas are very intense, the hidden structural remains could have been brick buildings. This combination of data indicates the multi-layered nature and complexity of the archaeological structures, as well as its potential use during different historical periods.

CONCLUSIONS

The chosen approach shows that a deeper exploration of the archaeology of Uzgen is possible with the help of GIS supported geophysical methods. The underground structures identified on sites Area_1 and Area_2 are significant evidence of ancient urban planning and provide immense value for understanding the region's life and culture. GPR and CMag surveying could not only help locate the objects but also provide insights into their shapes, sizes, and depths. In the future, they can serve as an important basis for excavations that are in accordance with the preservation of historical monuments.

Preserving and studying the region's cultural heritage remains one of the primary tasks for researchers, as they strive to safeguard the memory of the past and pass it on to future generations. The results of this study not only highlight the technological advancements in archaeological research but also set a foundation for future interdisciplinary

collaborations aimed at uncovering and protecting the hidden treasures of the Silk Road. By integrating geophysical methods with cultural heritage management, we can ensure that the stories of the past continue to inspire and educate future generations.

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