Remote Sensing of the Konoplyanka 2 Settlement in the Southern Trans-Urals

Ivan V. Molchanov, Lev A. Muravyev, Denis D. Byzov, and Nikolay V. Soldatkin

Abstract In this paper, we present the results of tests of the technology of photogrammetric processing of aerial photography data from the UAV to build a digital terrain model and interpret it, conducted at the Bronze Age complex near the modern village of Konoplyanka. The results were processed together with the data of geophysical and geodetic surveys, which made it possible to clarify the architectural features of the Konoplyanka 2 settlement and to establish the presence and exact position of the previously assumed mound.

Keywords Remote sensing · Bronze Age · Photogrammetry · UAV · Aerial photography · Settlement · Mound

1 Introduction

In the late 1980s and early 1990s, a whole group of fortified settlements of the Sintashta culture was discovered using the interpretation of aerial photography (Batanina and Hanks 2013). However, after that, aerial surveys have not been used in archaeological studies of the region. At present, the situation is gradually changing. Processed aerial photography data obtained from unmanned aerial vehicles (UAVs) and geomagnetic surveys are being increasingly used to refine the structure and identify new archaeological sites, demonstrating good results (Bakhshiev et al. 2018; Knoll and Marzolff 2013; Krause and Koryakova 2014; Kotov and Savelev 2021; Campana and Salvatore 2009, etc.).

Two polygons were selected as test polygons for aerial photography. The first was the site of the Konoplyanka 2 settlement. The object is part of a complex of sites near the modern village of Konoplyanka (the Chelyabinsk region, Russia) and includes

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burial mounds and settlements of different chronological periods. At the time of its discovery, by Tarasov in 1982, on the site's surface were about ten well-visible house depressions, organized in almost a straight line.

The second polygon was used to test the capabilities of the chosen method. It is located 1.2 km from the NW from the first one, to the WNW from the Konoplyanka fortified settlement. According to the interpretation by Batanina, there is a burial mound in this area (Fornasier 2014, Fig. 52). However, during the field survey of this territory, it was impossible to find its remains since the territory is plowed up annually, and the landscape is flattened.

The choice of the first test site was due to the well-pronounced house depressions, the knowledge of its topography, and the magnetic map. In the obtained digital terrain model, the interpretation and localization of these objects are undeniable. In turn, identifying the morphology of various structures on the digital map will allow us to identify possible objects on the second selected polygon confidently. A comparison of all available results obtained using remote methods at the Konoplyanka 2 settlement is presented in this article.

2 Materials and Methods

A geodetic survey was carried out using a Trimble 3305 DR total station. The measuring grid was 1.5–2 m within the objects; in the case of complex terrain, it decreased to 0.5 m. Outside the visible structures, the grid increased to 3 m. We used a DJI Phantom 4 Advanced Plus quadcopter to obtain a digital terrain model of the selected polygons. The flight and photography were carried out at heights of 25 and 50 m in autumn. The coordinates were determined using GPS satellite signals in WGS 84. Four hundred seventy-five frames were taken over the Konoplyanka 2 settlement, and 412 photographs were taken over the second experimental site.

The geomagnetic survey technique for all sites as geophysical work in the Karagaily-Ayat River's valley was carried out by Patzelt (2013). A Ferex 4.032 DLG fluxgate gradiometer was used with four CON 650 probes mounted on a frame 0.5 m apart. The sensor heights were 0.3 and 1 m above the ground. The survey was carried out in a continuous mode of 1 measurement at 0.125 m along the profile.

The total station data and topographic maps were processed in the GIS software by KB "Panorama." The obtained images were processed by photogrammetric methods using the Agisoft Metashape Professional software on the computing server of the Institute of Geophysics, the Ural Branch of the Russian Academy of Sciences (Dell PowerEdge C4130, 4 NVidia Tesla K80). The digital terrain model (a height map) was calculated at the resolution of 32,768 × 32,768 pixels, which approximately corresponds to one pixel per 1 cm^2. The time spent complete processing from uploading images to obtaining a digital model was about 4 h.

3 Results and Discussion

Geodetic and geomagnetic surveys were carried out in 2018 before archaeological excavations of the Konoplyanka 2 settlement. The topography of the territory and its detailed magnetic map are shown in Fig. 1. The configuration of most house depressions of the first line of buildings is visible visually and in the topography map because of their large size and depth. The outlines of the remaining ones are poorly visible. The second line of buildings is not expressed in microrelief at all. Revealed small depressions of the relief reflect only its features in this place. A possible reason is the interpolation of values during program data processing.

Magnetic anomalies are visible as a regular rectangular shape arranged in one line in the northern area of the map, interpreted as another line of buildings (Fedorova et al. 2018; Koryakova et al. 2020), and named Konoplyanka 2–2.

The area covered by aerial photography at the first polygon was 11.46 ha. The resulting map of the heights of the territory of the Konoplyanka 2 settlement reflects all the features of the landscape observed in nature. It acts as a topographic reference to the terrain (Fig. 2). The outlines of ravines, modern field roads, as well as a small

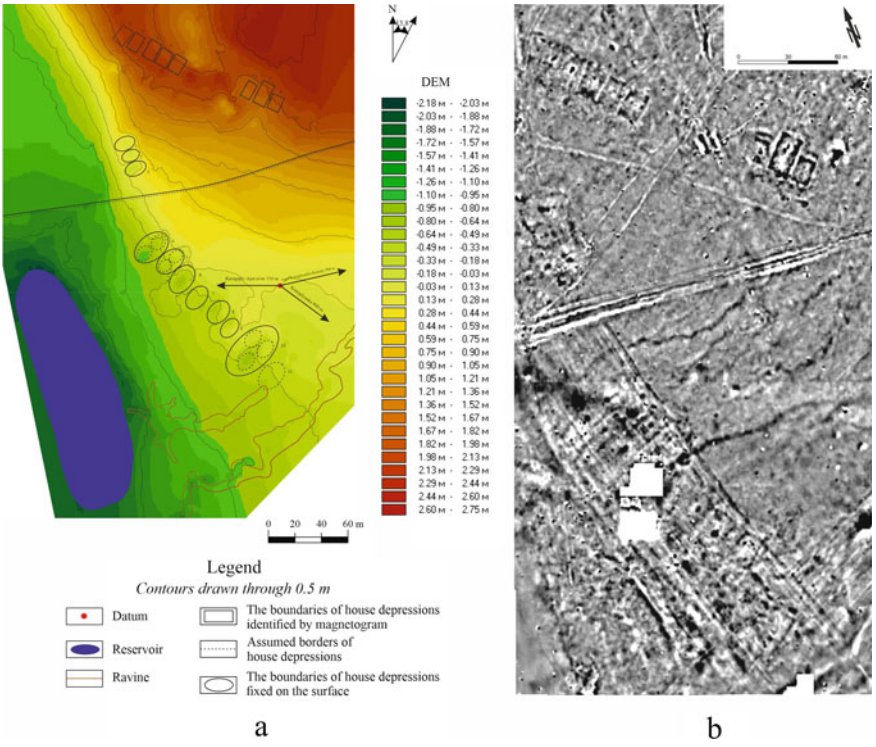

Fig. 1 Topography map with objects plotted based on comparison with a magnetic map (**a**). Results of magnetometry performed by A. Patzelt in 2018 (**b**)

reservoir, which are the remnants of the ancient riverbed of the Karagaily-Ayat River, are visible. The layout of the settlement, consisting of two lines of buildings, is also quite clearly traced. The first one consists of ten depressions, seven oriented in the NW–SE direction and located in a line along the edge of the terrace. An embankment of structures about 0.1 m high and about 1 m wide is on the eastern side. 40 m to the north, three more depressions are located almost close to each other. Line 2 is oriented from NW to SE and has a gap between buildings. There are five rectangular depressions in its northwestern part. There are three more depressions with blurred outlines in the southeastern part. These groups were separated from each other by a distance of about 40 m. Modern anthropogenic impact traces are visible between them as two straight, parallel pits, along the edges of which small mounds are visible.

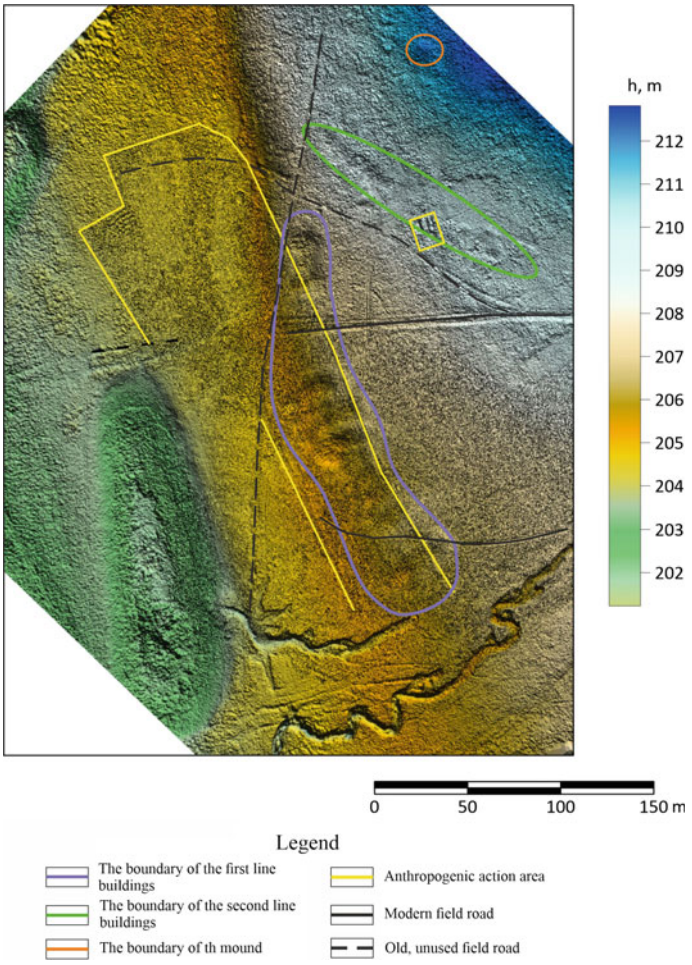

Fig. 2 Interpretation of a digital model of the site of the Konoplyanka 2 settlement

The area of the described polygon also includes the remains of a mound located 60 m to the NNE from the extreme NW depression of the second line of buildings. The uplift height is about 0.3 m; the diameter is about 15 m.

In addition to the described topographic references and archaeological sites, the digital plan clearly shows the tracks not visible on foot inspection of the site. This is the remains of two long-time unused roads and supposed traces of plowing on the first line of buildings and to the northwest from it. It is interesting that a road having a direction from N to S, is marked on the 1982 topography map by Tarasov.

Compared with the first, the resulting height map of the second experimental area looks less informative (Fig. 3). The aerial photography area of the polygon was about 9 ha. It clearly shows traces of plowing the field in the form of diagonal stripes oriented along the NW–SE line. Two low areas oriented toward the river are revealed on the field's surface. The flow of rain and melt water into the river goes through them. A rounded elevation up to 50 cm high, about 20 m in diameter, is observed on the outskirts of the field. A field road runs along its center along the arable land. In terms of morphological and metric indicators, this object is similar to the mound at the site of the Konoplyanka 2 settlement. Most likely, it was the mound we were looking for.

4 Conclusions

The joint use of aerial photography, and the results of geophysical and geodetic surveys made it possible to clarify the architectural features of the Konoplyanka 2 settlement. Aerial photography of the area with the proposed archaeological object showed the high efficiency of this method in the search for new archaeological sites. Using one of these methods separately allows you to get superficial and hidden information about the object of study. Their complex application makes it possible to obtain significantly more information about the object before its archaeological excavations.

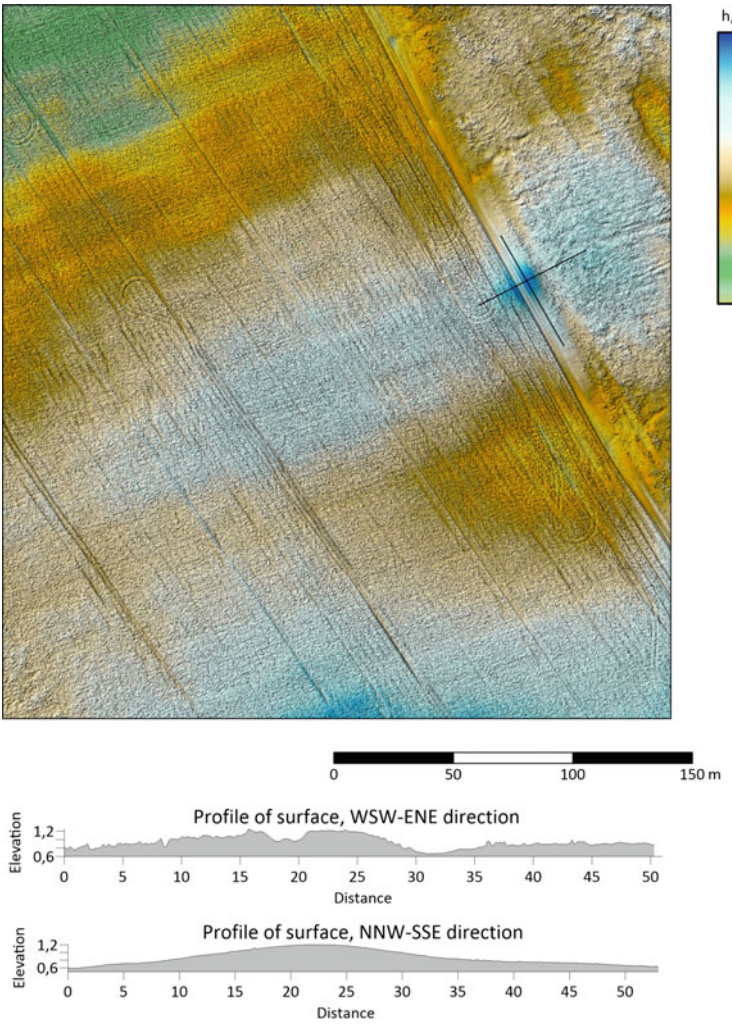

Fig. 3 A digital model of the site located to the WNW of the Konoplyanka fortified settlement

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