Fig. 1 Global navigation satellite system (GNSS) receiver in the field (photo M. Megahed)

New geodetic control network at Czech concession at Abusir

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A geodetic control network is a fundamental precondition for the production and processing of surveying documentation in the field. A cooperation of the former Czechoslovak Institute of Egyptology, Faculty of Arts, Charles University and the Department of Special Geodesy, Faculty of Civil Engineering, Czech Technical University in Prague started in June 1962 during the UNESCO's international Nubia Campaign (Procházka – Vachala 2003). This article informs about the process of setting up an updated geodetic control network at the site of Abusir, the concession of the Czech Institute of Egyptology, Faculty of Arts, Charles University, Prague, which is newly kept in Universal Transverse Mercator (UTM) coordinates.

Geodetic control network at Abusir

Almost from the beginning of the work, surveyors were part of the institute's missions at Abusir. The local geodetic network was built over a period of 17 years, with the main phase in the 1980s (Procházka – Vachala 2003: 70–82). Two key points of this network were 5011T on the mastaba of Kaaper (AS 1) and 5000N on the top of the pyramid of Neferirkare. In 1991, the geodetic control network comprised 51 points, despite the repeated destruction of some of them. Most of the previous missions in the Abusir and Saqqara area had also opted for a local surveying network (Jeffreys – Tavares 2000).

The network, consisting of 23 established control points, was re-measured and updated in 2001. The corpus of key points is used in all three parts of the concession, Abusir South (AS), Abusir Centre (AC) and Abusir West (AW). A new chapter of the surveying of Abusir started in 2001 in cooperation with the Laboratory of Geoinformatics of Jan Evangelista Purkyně University, with a wide application of total station surveying, Geographic information systems (GIS) and satellite imagery (Bárta – Brůna – Křivánek 2003; Bárta – Brůna 2006).

Most of the points in the field were destroyed in recent years, and their absence has complicated and limited the surveying possibilities at Abusir. It was therefore decided

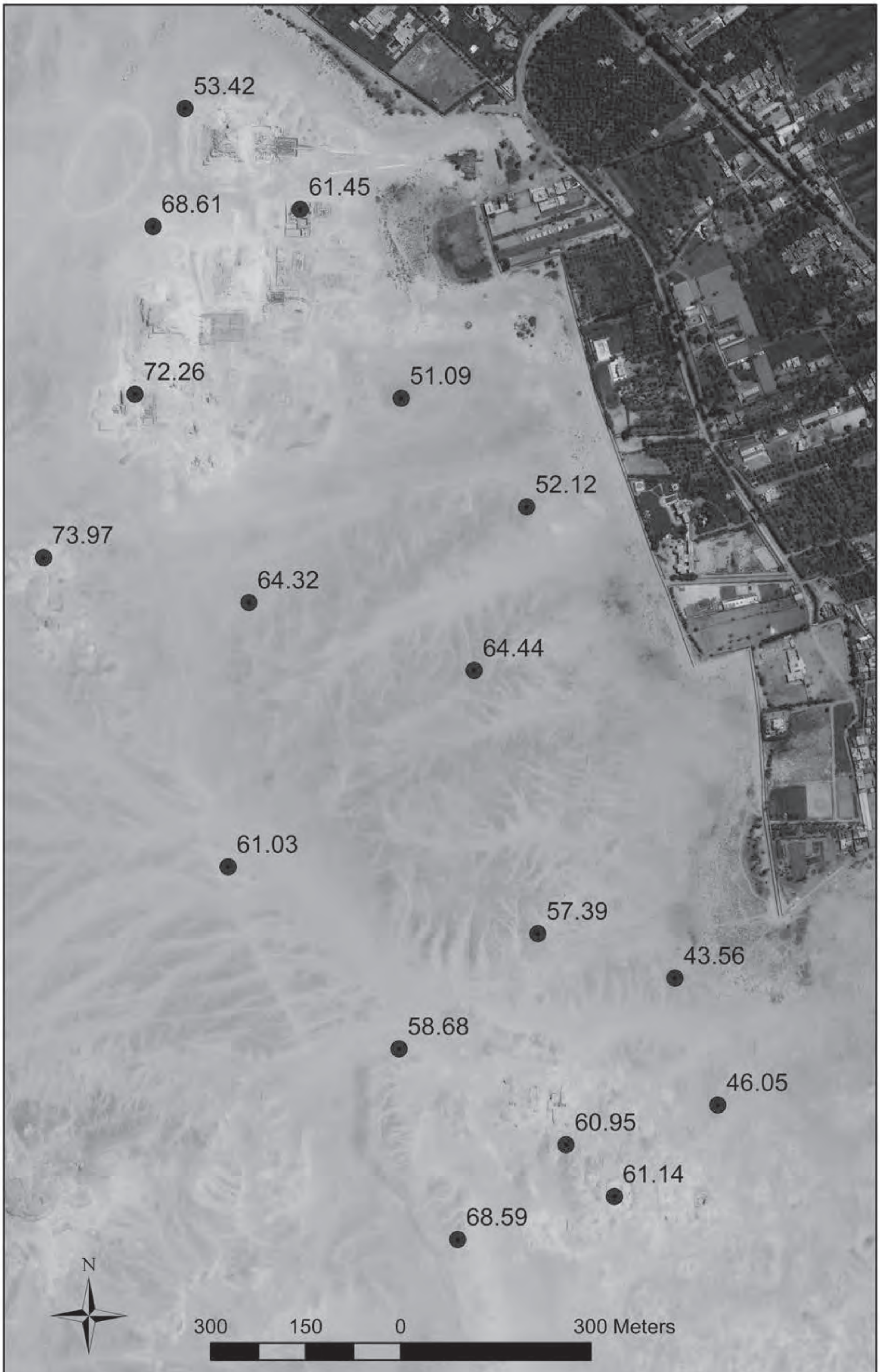

Fig. 2 Point heights (metres above sea level) of the new geodetic control network at Abusir (map in ArcGIS by V. Brůna)

to renew and update the geodetic control network at Abusir in 2017. Selected control points have been measured using a global navigation satellite system (GNSS) receiver in the system UTM zone 36N and WGS84 coordinates – geographical (Lat, Long, H) and planar (X, Y, Z). This is not the first attempt to use UTM coordinates in the area (Jeffreys – Tavares 2000), but the present one employs the latest available equipment.

Method and technology[1]

Stabilization of geodetic points

Before the measurement, the existing point network was stabilized and the location of new points proposed. A new method of stabilization was used in order to avoid further damage to the points. A pit was dug out, a survey mark with a plastic head hammered down into it, a concrete poured into the pit up to the head and the whole measuring point covered with sand. Preliminary coordinates were established using a tourist GPS device in order to find the points later. Sixteen points were stabilized in this manner.

GNSS measuring

A static method of surveying was applied, using a single base receiver and a second remote receiver set up over other points. The system consisted of two Leica VIVA GNSS receivers (fig. 1). This is a three-frequency compact GNSS receiver with an integrated antenna. Data post-processing was performed using the Leica Geo Office software. Altogether 17 control points have been measured.

Transformation of the coordinates

As a result, 17 points have new geographic and planar coordinates. Out of them, 9 points were from the original set and 8 points were newly stabilized (fig. 2). In order to determine the UTM zone 36N coordinates of all points at the Czech Abusir concession, including those originating from past measurements, the transformation key was established based on 9 existing points using the Carlson Survey software.

The three-dimensional Helmert transformation was applied with seven parameters defining the transformation: three translations, three rotations, and one scale (tab. 1). The coefficients were adjusted using the method of least squares. It forms a basis for the transformation of all points in the local geodetic network system into the system UTM zone 36N. Since autumn 2017, all geodetic measurements are done in the new coordinate system and we can use all available satellite data, topographic and thematic maps in UTM coordinates without any transformation needed.

The new network data were stored in all stations used at the concession. The transformation key was then applied for a complex recalculation of all measured data from the site of Abusir, *i.e.* of all available previous surveying points in the local network. The newly measured point heights will make it possible to address anew issues concerning the interpretation of the past landscape. While the Egypt Exploration Survey indicated there had been dry conditions at the site of Abusir and its close vicinity (Jeffreys 2001), detailed exploration of the Lake of Abusir sediments confirms a humid environment in the area in the Old Kingdom period (Cílek *et al.* 2012).

Dx	325357.0432
Dy	3297501.1797
Dz	15.1296
Rx	0.992333
Ry	0.725956
Rz	-1292798.653680
Scale (ppm)	- 42.8102

Tab. 1 Transformation key for the Helmert transformation

Conclusion

The update of the geodetic control network and its transformation into the system UTM zone 36N (WGS84) will ensure data compatibility with other sources in UTM coordinates (satellite data, topographic and thematic data, GIS data – Esri databases, *etc.*), without the need to transform data from the original local control network. It is an important step forward in the work of the Czech Institute of Egyptology mission at Abusir, ensuring a better understanding of the archaeological context of the site of Abusir in the Memphite landscape.

Note

1 For the basic methodology, see for instance Phil (2006), Bettess (1998), Hánek *et al.* (2010), or Veselý (2014).

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