What magnetic prospection, topographic mapping and archaeology can tell us about urbanism in the Mongolian steppes

A multidisciplinary approach to Khar Khul Khaany Balgas, Khanui River Valley, Mongolia

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Abstract

Magnetometry is a well-established geo-physical method in archaeological prospection. Conservative techniques, however, do need high investment in labour and are comparatively slow. New quantum-based sensors (SQUIDs) have been innovating this methodological field through their ground breaking fastness in data collection, enormous magnetic field gradient resolution as well as the maximum of measurable magnetic information enabling depth and geometry reconstruction of the detected buried objects (magnetic inversion). Thus, the SQUID measuring system of Leibniz IPHT and Supracon AG, Jena (Linzen et al., 2007), see Fig. 1, has been successfully applied worldwide for widely different large-scale archaeological sites: be that the settlement regions of the Nasca and Palpa cultures in Peru or the *Fossa Carolina* in southern Germany, a miles long channel ordered by Charlemagne to link the Rhine-Main and the Altmuhl-Danube inland navigation systems (Linzen and Schneider, 2014). Likewise, the system has been successfully transferred to Mongolia (Bemmann et al., 2011). Here, an additional feature of the SQUID instrument was intensively used – the simultaneous recording of high-resolution topographic information via the differential GPS and the inertial unit of the motorized system. Thus, two qualitatively different maps (magnetogram and topography) are gathered with high precision in geo-reference at the same time and with high speed.

To bring the most modern standards in magnetometry to a developing country and further the scientific exchange is of high importance. At the same time, the pioneering aspect of the system which is constantly being refined through the field experience and close analysis of the data in transdisciplinary dialogue between the physicists and archaeologists need to be emphasized. The Mongolian steppes offer an ideal ground for this endeavour with its unique cultural heritage formed amongst others by large fixed habitation sites of ancient times generally untouched by later building activities or other anthropogenic intrusions.

Thinking of the Mongolian steppes, cities do not immediately spring to mind. One rather thinks of traditional pastoral lifeways, living in yurts, sheep and above all horses. And yet, at some focal points in Mongolian history, cities played imminent roles in the steppe: first under the Uighur and most prestigiously under the Great Khans during the time of the Mongol Empire, the largest contiguous empire in World History. From the time of the 13th and 14th centuries Karakorum, the first capital of the Mongol Empire, has been a research focus of Bonn University for the past 20 years (Bemmann, Erdenebat & Pohl 2010). After having successfully applied the SQUID system to Karakorum in 2016 and 2017, another study of a contemporary site in order to have a comparative reference was sorely needed. Khar Khul Khaany Balgas, situated in the Khanui valley near the modern administrative centre of Erdenemandal, Arkhangai province (see Fig. 2) proved to be a perfect locality, ideally suited for SQUID-measurements as well as archaeological works. The site has never been encroached upon by later building activities, it is located in a wide flat plain on the first terrace of the river that flows nearby to the west of it, its archaeological find material and relative height of cultural levels as seen in the topography indicate that it has only been used during the old Mongol period with few settlement phases at the most. Furthermore, only few spots of the city have been touched by previous archaeologists, thus being a mostly undisturbed and an understudied site at the same time. Preparatory to the geomagnetic survey, to define the extent of the city and thus the area to be measured as well as to clean the city from metal waste contamination, an intensive, systematic, field walking survey was applied by the archaeological project team under the auspices of the DFG Collaborative Research Center 1167 “Macht und Herrschaft.

Premodern Configurations in Transcultural Perspective" at Bonn University in 2017. The project looks into how Mongol rulers used cities as a way of legitimizing their authority and how their authority is expressed via monuments, infrastructure and symbolic material culture in the landscape.

The SQUID instrument was applied in Khar Khul Khaany Balgas to map an area of nearly 300 hectares (3 million square metres) within 23 measurement days in June 2018. An average distance of 100 measurement line kilometres per day were driven with a cross-country car pulling the cart over the steppe area (see Fig. 1).

During the measurements the battery driven data acquisition on the cart records the magnetic data from each of the 18 SQUID sensors with a sampling frequency of 1000 Hz. Further, the differential GPS data from a Trimble® 5700 receiver is recorded with 10 Hz and the Euler angles representing the tilt of the measurement cart which is monitored by a Xsens® inertial unit is sampled with 100 Hz. These data streams result in a very high measurement point density of approximately 400 per square metre for the magnetic data and an amount of raw data of about 4 Gigabyte per day. More details about the technique of the SQUID instrument and the data post processing can be found in Linzen et al. (2007). The basis of the topographic data is a differential GPS setup which consists of one receiver mounted onto the measurement cart as rover and a second one fixed as base station. The latter was positioned on top of the north corner of the main walled enclosure (see Fig. 2). The current position of the cart has always been calculated in real time with the highest available precision (RTK fixed mode). Thus, the vertical position error was limited to a few centimetres allowing the detection of tiny altitude variations mostly caused by archaeological remains.

The Mongolian steppe with its permanent dust exposure and extreme temperature variations is a challenge for the measurement technique as well as the operators. The SQUID prospection technique, however, worked absolutely reliable. Additional expenses and skills for the liquid helium sensor cooling were required, but led *a priori* to a temperature stabilisation of all sensors and a prevention of drift effects.

Through combined multidisciplinary analyses of magnetic anomalies, topographic features and the distribution of find materials gathered through the initial pedestrian survey, new insights into the city's layout, the use and function of certain building features and even down to the constructional make-up of the buildings themselves are won. These results will be highlighted through a discussion of the overall structure of the city, leading to the immanent question of whether the city has grown organically and developed from the bottom up or if we have rather indications for a top-down-planning and a supervised, thoroughly planned construction of the city. Details taken from the combined analyses will pull the scale to individual features within the city: the assumed Buddhist temple shows revealing similarities in its orientation to Karakorum's temple of the Rising Yuan, its constructional make-up with fired bricks is clearly demonstrated in the magnetic measurements and confirmed by the archaeological mapping of building materials. Further examples include the main compound, assumably the palace area, and particular constructions on the crossroads of the major streets.

Working closely together with the local authorities in the administrative center Erdenemandal, the new mapping of Khar Khul Khaany Balgas exerts its usefulness on different levels: first and foremost it shows the archaeological substance in hitherto unknown detail, and second, it thus provides a definite basis for the creation of areas of cultural protection. All results will be shared with the local government to ensure that protective steps are undertaken in the near future, a fundamental necessity to preserve this important heritage for generations to come.

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Figures

Fig. 1. The SQUID measuring system in operation nearby the main walled enclosure of Khar Khul Khaany Balgas, Mongolia. The three orange cryostates contain 18 magnetic field sensors within a scanning width of 1.5 meter (© Sven Linzen, Leibniz IPHT).

Fig. 2. Aerial view of the main compound of Khar Khar Khul Khaany Balgas from southwest, Erdenemandal Sum, Arkhangai Province, Mongolia (© Jan Bemmann, Bonn University).

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