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Magnetometer survey of a Hafit monumental complex, al-Khashbah, Sultanate of Oman (poster)

Jason T. Herrmann, Jörg W.E. Fassbinder, Marion Scheiblecker, Philippe Kluge, Stephanie Döpper & Conrad Schmidt

Summary
Magnetometer surveys carried out as part of the al-Khashbah Archaeological Project have revealed the plan of two monumental buildings dating to the third millennium BC as well as the surrounding landscape. Evidence from excavations confirms that this complex can be dated to the Hafit period, marking it as an important site for the development of social complexity in the interior of northern Oman. The results of two seasons of magnetometer surveys, conducted in 2015 and 2017, are instructive in two major ways. The fused magnetograms are a record of the prehistoric cultural landscape immediately surrounding Building I and Building XI. The two surveys provide a direct comparison of two different geophysical methods of magnetometer survey: fluxgate gradiometry (2015 survey) and total field magnetometry (2017 survey), which can aid analysis of survey results. The surveys took place near the geomagnetic equator where the shallow inclination of the Earth's magnetic field can make archaeological interpretation of magnetic anomalies rather complex.

Keywords: archaeological geophysics, magnetometry, archaeological survey, augmented reality, Hafit period, Oman

Introduction

In 2015 the University of Tübingen began a new archaeological field project at the site of al-Khashbah, in the governorate of al-Sharqiyyah North, Sultanate of Oman, entitled: 'The development of complex settlements in northern Inner Oman in the third millennium BC.' This project seeks to record changes in the settlement pattern from a long-term perspective, with a special focus on the development of complex societies in the third millennium BC. In the first three field seasons, the al-Khashbah Project has prioritized investigations in two areas. One of these contains a limestone outcrop with two badly preserved stone-built towers designated Buildings VIII and IX, and a small rise to the north of the outcrop alongside a wadi that features a structure that has been designated Building I (Fig. 1). Here, large amounts of slag and furnace fragments were found through an intensive field-walking survey, especially on the limestone outcrop in the south. Building I also yielded a large corpus of flint tools and production debris. This, combined with the radiocarbon results, suggests that Building I was a copper processing site during the Hafit period (Schmidt & Döpper 2017). Geophysical surveys were undertaken in the project area to add detail to the archaeological remains that were recorded through field-walking and to explore the surrounding area for additional archaeological deposits that may have been missed during survey.

Magnetic survey and results

A magnetic survey of the study area was carried out by two different teams. The southern half of the area was surveyed with a fluxgate magnetic gradiometer (Bartington Grad 601-2) in dual-sensor configuration by a team from the University of Tübingen in 2015 (Fig. 2, left). Magnetic gradiometers feature two magnetometers separated on a vertical axis and automatically filter out temporal variation in the intensity of the Earth's magnetic field. Magnetic gradiometry surveys focus on the horizontal variation in magnetic intensity in near surface and therefore create data that emphasizes detail in plan maps from magnetic survey in the upper soil layer. The 2015 survey concentrated on the area immediately surrounding the rock outcrop and was bounded on the west by a wadi channel and on the east and south by impassable trees and low vegetation. Evidence of architecture was observed on the rise itself, but the sides were too steep and rocky to safely traverse with the magnetic gradiometer. The Tübingen magnetic gradiometry survey covered Building I itself and skirted the open areas on the eastern side of

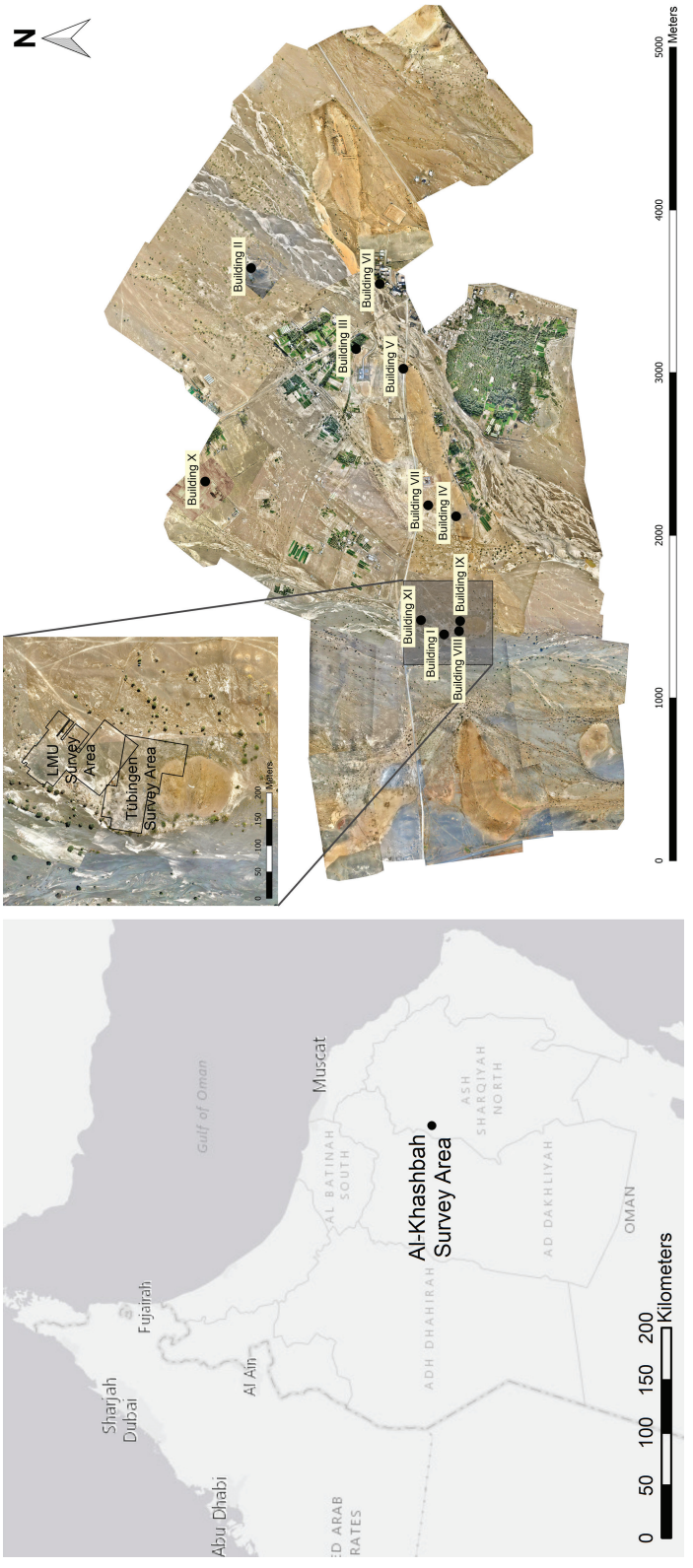

Figure 1. *The location of the al-Khashbah project area and the boundaries of the magnetic survey.*

the rise, where sediments were thick enough potentially to hold stratified archaeological deposits. The magnetic gradiometry survey also extended into the deflated desert pavement in the north-east section of the 2015 survey area. Data were collected in a 'zigzag' pattern with transects separated by 0.5 m within 20 m square tiles.

Results over the Building I area show no less than four roughly rectangular anomalies that are each approximately 25 m across (Figs 3 & 4). The clearest of these are in the western end of the survey area over Building I. Magnetic gradiometry results give some indication of the spatial organization of metal and stone-working activities here: magnetically enhanced ditches, appearing as stark anomalies, surround clusters of what has been verified as mud-brick architecture (Schmidt & Döpper 2017) and correspond with changes in the topography. The Building I survey area also features uniform distribution of 'spike' style anomalies indicating that metallic materials, possibly slag or copper waste, are spread over much of the site. Some of the most intense anomalies in the survey area are found within the Building I 'enclosures' and are interpreted as either *in situ* thermal anomalies or accumulations of thermally altered sediments.

Elsewhere in the Tübingen magnetic gradiometry survey area, subtle anomalies indicate the locations of five circular tomb structures of an undetermined age that are also visible on the surface. On some, the outer boundary is evident as an area with a slightly more magnetic signature. Many have a magnetic anomaly in the centre, and in one case there is a cluster of anomalies concentrated in the approximate centre of the tomb. Finally, there are some tantalizing rectilinear features in the north-east corner of the magnetic gradiometry survey area, where the surface deposits are quite deflated, and the desert pavement is not

Figure 2. *The Tübingen survey with the magnetic gradiometer (left) and the LMU team with a total field magnetometer (right).*

covered by a sand sheet or other sediments, making this area magnetically 'noisy'. The complete form of this structure and the purpose of these remains have not been determined, and the potential for doing so remains low owing to the extremely deflated context.

The northern half of the area was surveyed with a total field magnetometer (Scintrex SM4G Special) in a dual-sensor configuration by a team from Ludwig Maximilians Universität Munich (LMU) in 2017 (Fig. 2, right). An advantage of a total field magnetometer is that it produces a more precise measurement of the magnitude of the Earth's magnetic field at a particular position. In the example presented here, the resulting magnetogram image differs from the gradiometer survey due to the shallow inclination of the Earth's magnetic field. In this survey area, archaeological features (e.g. a ditch) thus show up as a positive anomaly (dark) with a white shadow in the north and may sometimes facilitate the archaeological interpretation. In some cases, such a survey produces data that can be used to estimate the depth of archaeological features. The northern part of the area features a mound rising 2 m above the surrounding landscape. Data were collected in a 'zigzag' pattern but organized within 40 x 40 m grid squares.

The magnetogram revealed a huge building complex, designated Building XI, which is enclosed by two oval-shaped, concentric ditches (see Figs 3 & 4). The diameter of the outer ditch measures 65–80 m across. The ditches are up to 3.5 m deep and 3 m wide. The ditch system seems to open to the north-east, while in its centre, possible layouts of structures, cellars, and pits were detected. Just south of Building XI, traces of other man-made features were detected. Building XI differs greatly in shape and size from the enclosure ditches uncovered in the southern part of the survey area. The eastern part of the magnetogram also crossed into the magnetically 'noisy' area characterized by the exposed desert pavement, but still reveals regular anomalies that suggest the presence of additional architecture. Finally, two very strong star-shaped remnant anomalies are the traces of lightning strikes (Fassbinder & Gorka 2009; Jones & Maki 2005).

The magnetic surveys conducted in 2015 and 2017 highlight the potential for both targeted and landscape-scale magnetic survey in south-east Arabia, with both fluxgate gradiometers and total field magnetometers. The archaeological excavations at Building I verified the existence of up to 3 m-deep and 4 m-wide ditches that enclose complex mud-brick architecture and that were mapped with the magnetic gradiometer. The fact that some enclosures appear to overlap in the magnetometry suggests that the site was occupied repeatedly over time. Moreover, consistencies in the forms suggest a standard

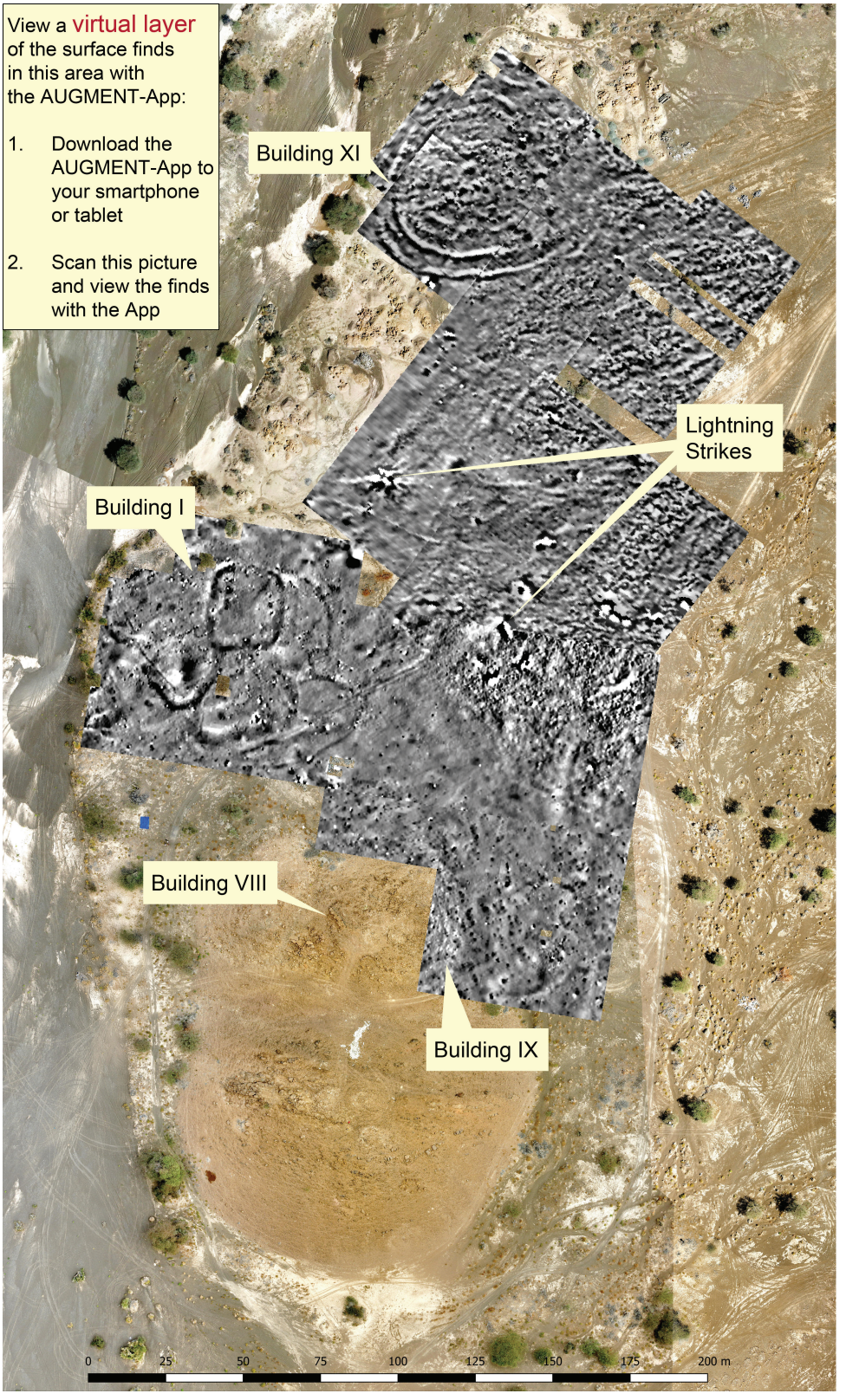

Figure 3. *Results of the two magnetic surveys at Building I. The magnetic gradiometry survey (dynamics ± 8 nT from black to white) in the south reveals patterns of activity at Building I and the footprints of several tumuli. Total field magnetometry (dynamics ± 30 nT from black to white) has revealed the presence of a previously undocumented building complex, Building XI, surrounded by two concentric ditches.*

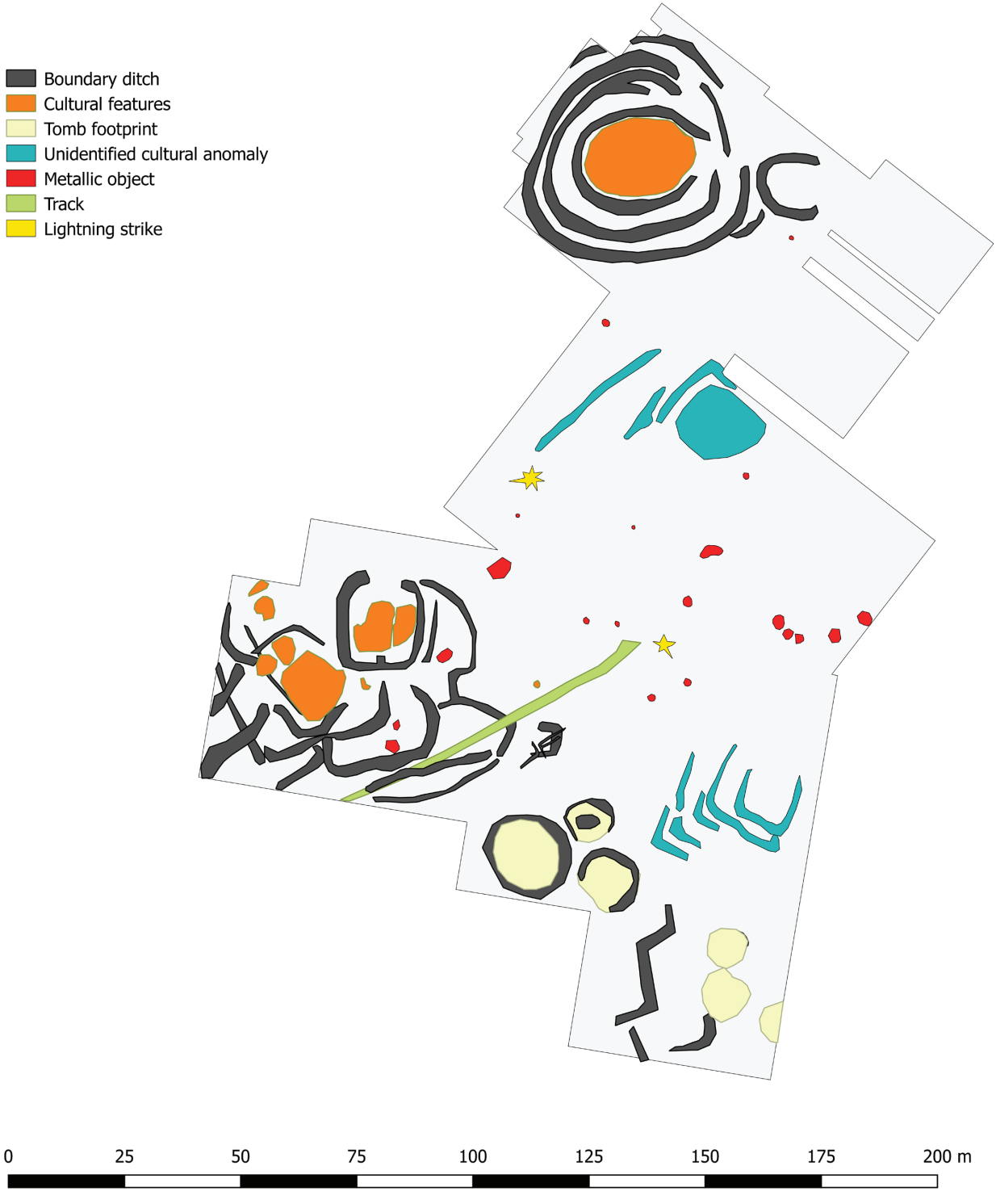

Figure 4. *Interpretation of the results of the two magnetic surveys.*

spatial organization for metalworking sites (Fig. 4). The internal architecture of Building I, verified by excavations in 2017, consists of rows of small rectangular compartments and medium-sized rooms that combine mud-brick and stone elements. A series of radiocarbon samples from the floors of the rooms, fire pits, and the fill of the ditches give coherent dates of the Hafit period around 2800 cal. BC (Schmidt & Döpper 2017). This makes it one of the oldest monumental buildings on the Oman peninsula.

The total field magnetic survey in the north of the survey area revealed several clearly cultural anomalies. Most important among them is Building XI, located on a low rise, and the surrounding ditches that were certainly an important part of the ancient al-Khashbah landscape. Archaeological investigations have yet to be conducted at Building XI, but a Hafit period date is expected for this complex.

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