

The contribution of geophysical and spectral imaging techniques in the archaeological investigations of Minoan Koumasa

Apostolos Sarris^{1*}, Kostas Hatzigiannakis², Diamantis Panagiotopoulos³

1 Department of History and Archaeology, Archaeological Research Unit, Digital Humanities Geoinformatics Lab, Sylvia Ioannou Chair on Digital Humanities, University of Cyprus, Cyprus

2 Institute of Electronic Structure and Laser, Foundation for Research and Technology-Hellas (IESL-FORTH), Heraklion, Crete, Greece

3 Institute of Classical Archaeology, University of Heidelberg, Germany

* Corresponding author: E-mail: asarri01@ucy.ac.cy

Abstract

A manifold geophysical strategy has been carried out for mapping the Minoan cemetery and settlement of Koumasa, S. Crete. Multispectral imaging was used as a complementary method to investigate associations with the geophysical results. The GNVI proved the most effective in this task. Archaeological excavations have verified a number of features suggested by the remote sensing methods.

Keywords

Crete; geophysical prospection; GPR; magnetics; Minoan; spectral imaging

Introduction

Minoan Koumasa expands to the south region of the municipality of Herakleion, Crete and includes a major Pre- and Protopalatial cemetery consisting of three monumental tholos tombs, together with a Minoan sanctuary and settlement located on the hill of Korakies, which rises immediately to the south of the cemetery. The site has been initially excavated in the beginning of the 20th century and in 2012 fieldwork activities were resumed by the University of Heidelberg under the auspices of the Archaeological Society at Athens and in cooperation with the 23rd Ephorate of Prehistoric and Classical Antiquities. Excavation in the settlement so far revealed mostly Neopalatial structures, including a large building of particular significance. Available evidence nevertheless makes it clear that the Neopalatial buildings were erected upon older remains (Panagiotopoulos 2015).

Materials and methods

The magnetic gradiometry technique (Bartington G601 with 0.5 x 0.125 m sampling), the ground penetrating radar (GPR) (Sensors&Software NOGIN PLUS with 250 MHz antenna and 0.5 x 0.25 m sampling and the electrical resistance mapping (Geoscan Research RM85 with 0.5 x 0.5 m sampling) were all used in a complementary way for the prospection of a total area of 0.6 hectares around the cemetery, the sanctuary and the tholos tombs (Fig. 1).

Processing of the GPR data was carried out following the pipeline described by Sarris (2020). The transects derived from GPR were processed using GFP Edit4 and EKKO Project 2 by Sensors & Software. Processing of the magnetic and soil resistance data was carried out using the GPP software engine (Kalokerinos et al. 2004).

Based on the results of the geophysical mapping, an IRIS II custom made mobile Spectral Imaging Camera (350-1200 nm, 28 filters, 5 MPixels) was deployed in the context of the experimental monitoring of areas that could hinder shallow buried archaeological structures. In order

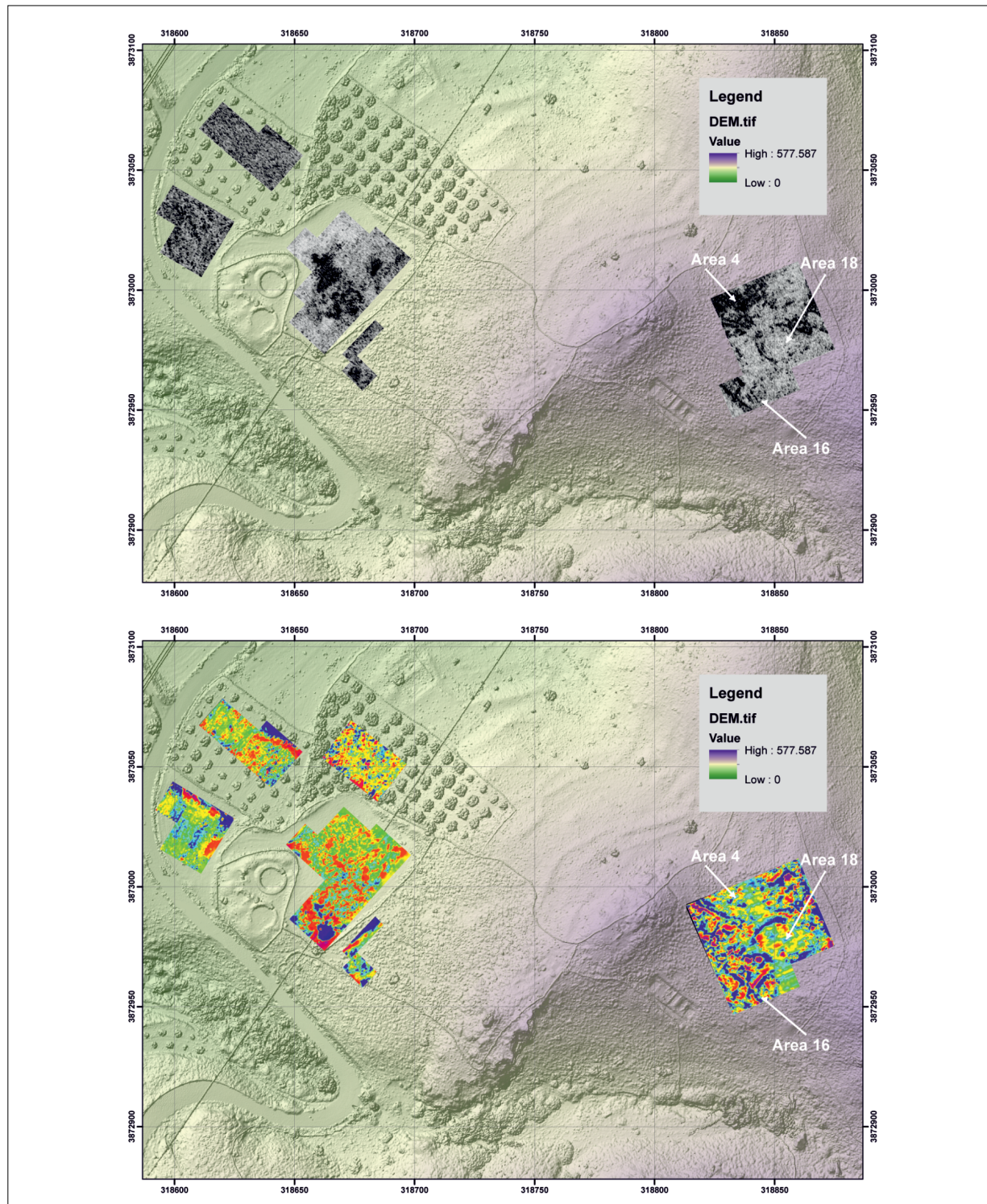


Fig. 1: Mosaics of the results of the GPR survey – depth slices for 0.8-1 m below the surface- (top) and geomagnetic survey (bottom) at the archaeological site of Koumasa. The dynamic range for the magnetic data is between ± 20 nT/m. The west section extends around the tholos tombs, whereas the east section is located on the top of the plateau where the Minoan sanctuary and settlement have been established. Areas 4, 16 and 18 represent the excavation sections in the area of the settlement. The DEM was created through a Terrestrial Laser Scanning carried out by the Institute of Geography of the University of Heidelberg. It covered an area of about 2x2 km and resulted to a raster resolution of about 0.2-0.5/1.0 m (onsite/offsite).

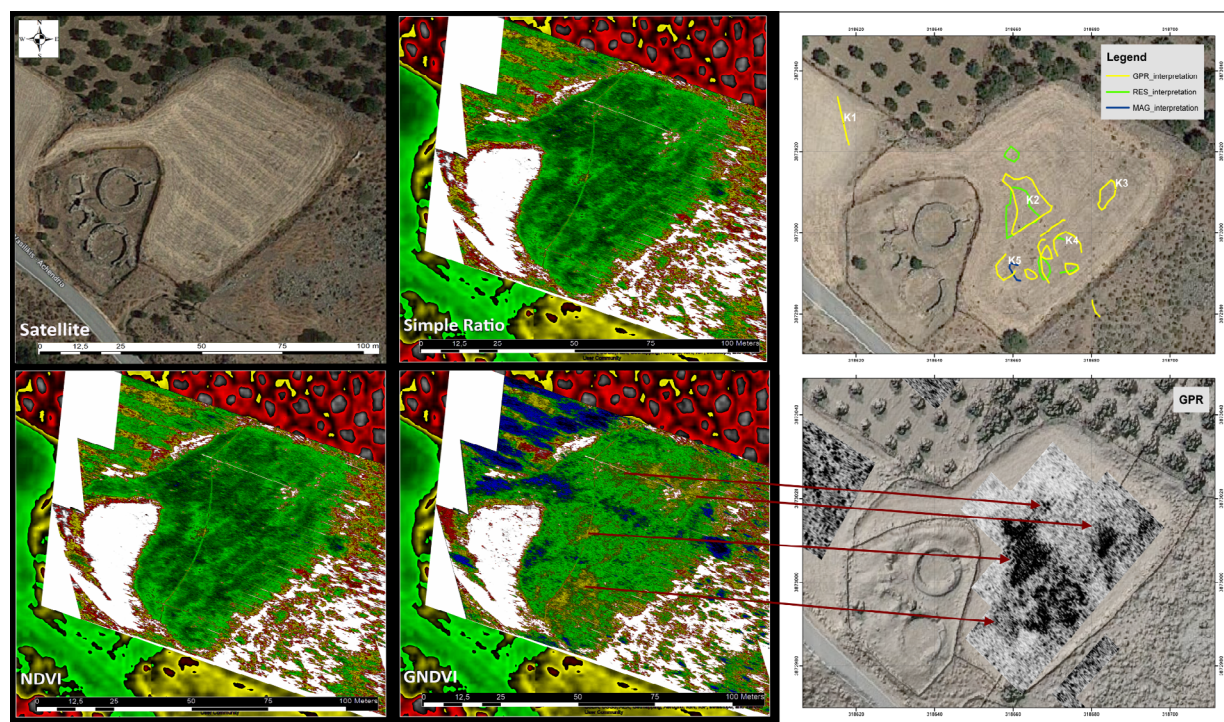


Fig. 2: Application of Imaging Spectroscopy for the detection of archeological remains at Koumasa. Top left: satellite imagery of the cemetery (Google, ©2023 CNES/Airbus, Maxar Technologies), top middle: Simple ratio, top right: results of the georadar survey, bottom left: NDVI, bottom middle: GNDVI, bottom right: correlation between the GNDVI and the results of the geophysical survey. The vegetation indices have a dynamic range between $-/+1$.

to certify the reliability of the measurements, laboratory controlled measurements on leaves of various plant species in different physical conditions, were carried out using a high spectral resolution UV-Vis-NIR spectrophotometer and a LMNT-II portable spot analysis LIBS and Diffuse Reflectance system (Avantes Avaspec-2048L-USB2, 200-1100 nm) (Hatzigiannakis et al. 2021).

Results and discussion

Focusing to the area of the cemetery, namely the west section of the site, most of the geophysical anomalies appear to the east of the two tholos tombs (Fig. 1). The particular features (dark colors in the GPR depth slices) may represent concentrations of building blocks which differentiate clearly from the rest of the background values.

The only GPR feature that was identified to the west of the tholos tombs was a linear diagonal anomaly that runs in an almost N-S direction. This feature defines a triangular zone of high reflectors that extend towards the east and it is most probably created by clearance of the rocks of the property and their piling towards that section.

To the east of the tholos tombs, there are various areas manifested as high GPR reflectors (within 1-1.20 m below the surface) having high soil resistance values. A couple of them have a relative circular outline, with one better defined (diameter of about 7 m). Due to their proximity to the tholos tombs, it is tempting to suggest that they belong to structures connected to the cemetery activities. As the field was cultivated with barley, the IRIS II was installed at the top of the plateau and used to capture spectral cubes during different seasons. A number of vegetation indices (VIs) were computed, including the Simple Ratio (SI), the Normalized Difference Vegetation Index (NDVI) and the Green Normalized Vegetation Index (GNDVI). The GNDVI was the most successful in relation to the suggested GPR anomalies (Fig. 2).

In the area of the settlement (Area 16), a number of structures that are aligned in a direction NW-SE, similar to the excavated complexes at the SW edge of the plateau, are obvious from the magnetic and GPR measurements. Taking into account the lower excavated building to the SW, we may suggest that the settlement was organized along terraces expanding at different iso-elevation levels. The subsequent excavations that were carried out in 2018 verified completely the finds of the geophysical survey and indica-



Fig. 3: Excavation results at the settlement area of Koumasa. Overview of the site and measurement areas (orthophoto: D. Panagiotopoulos).

ted a destruction layer (burning residues) dated in the Late Minoan I period (Fig. 3) (Panagiotopoulos 20220a).

At the center of the surveyed area (Area 18), both GPR and magnetic signals suggested a large ($\sim 17 \times 19$ m) oval shape structure, empty of internal divisions. The signature of this structure faints away towards the SE. Test excavation trenches of 2019 were able to verify part of the structural remains of the complex (Panagiotopoulos 2020b). In contrast, a couple of smaller compartments are exhibited as faint anomalies interrupting its perimeter, which may consist of a double wall.

Towards the west and northwest section of the plateau (Area 4), which is located to the east of the sanctuary, a high concentration of structural remains, can be considered as a continuation of the recently excavated structures to the south, which consist of carved flat building blocks (Panagiotopoulos 2020a). A double wall feature is obvious in both magnetic and GPR data and it may be associated to a corridor or road leading towards the sanctuary.

Conclusion

The geophysical survey at the Minoan settlement of Koumasa resulted some interesting features that are worth to be further investigated in the future.

Despite the relatively smooth terrain in the area of the cemetery, very few anomalies were identified in the particular region. On the other hand, the GPR was able to suggest a number of reflectors that can be associated either to badly preserved structural remains or to outcrops of the bedrock. In contrast, the results from the top of the plateau indicated a wealth of geophysical features that are related to the settlement. A penetration depth up to 2m was achieved with the GPR, whereas most cultural layers were identified within the upper layers up to depths of 0.8-1m below the surface. Both magnetic and GPR signals had a good correlation and the suggested features are associated to buildings and corridors/roads. In addition to the geophysical prospection, the ground based spectral imaging techniques proved to be really promising in relation to the mapping of the buried cultural remains.

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