Geophysical mapping of a classical Greek road network: a case study from the city of Elis, Peloponnese

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INTRODUCTION

Many ancient Greek cities are characterised by a regular orthogonal road network. These roads are ideal targets for geophysical investigation mainly due to their extensive geographic extent that makes them challenging to define by excavation. Geophysical mapping of these features will contribute to understanding ancient cities as it can provide considerable information about their geographic extent, spatial arrangement and urban dynamics. Large scale multisensor magnetic and electromagnetic induction methods have been used to map the ancient Greek city of Elis in the Peloponnese (Greece). This work complements other investigations that have been undertaken, employing other methods that include the interpretation of high-resolution satellite imagery (Donati and Sarris forthcoming).

ARCHAEOLOGICAL SITE BACKGROUND

The city of Elis is located on the banks of the Peneios River near ancient Olympia in the Peloponnese. It is particularly known in connection with the Olympic Games, as it acted as a training base prior to the competition, overseer of the sanctuary of Zeus and the administrator of these events (Yalouris 1996). Elis is also remarkable for exerting significant political control over neighbouring communities from the 6th century BC (Roy 1997), despite not being established as a substantial city until 471/0 BC (Roy 2002). The site has been the focus of archaeological investigations since 1910 by the Austrian Archaeological Institute, the Archaeological Society of Athens and the 7th Ephorate of Prehistoric and Classical Antiquities (Andreou and Andreou 2007). To date, the boundaries of the city are poorly defined and most excavation and geophysical prospection have been focused on an area immediately surrounding the agora (i.e., Tsokas *et al.* 2012).

METHODS

Geophysical data was collected during a field campaign in November 2014 (Fig. 1). Previous work on similar sites had suggested that electromagnetic induction and magnetometry were the methods best suited to investigate the buried road networks at Elis. Electromagnetic induction

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data was collected using a Geophex GEM-2 and a CMD Miniexplorer. In the case of the GEM-2, multiple frequencies were used to capture the data (89430, 43350, 21230, 10230 and 4950Hz). For both instruments, the in-phase and quadrature response was calibrated to generate conductivity and magnetic susceptibility values using the procedures described by Thiesson *et al.* (2014). Magnetic gradiometer data was collected with a Sensys MX V3 with eight fluxgate sensors. Gradiometer data was processed using custom-made Matlab scripts. All the data were displayed and interpreted in ArcGIS. Accurate positioning for both surveys was provided by a suite of Javad Triumph-1 differential GPS.

RESULTS

The road network at Elis was identified using magnetic susceptibility, conductivity and magnetic gradiometer data. It was dominated mainly by N–S and E–W running roads, extending at least one kilometer beyond the central agora to the south. The intersection of the latitudinal with the longitudinal streets was sometimes slightly offset, so that the E–W roads do not meet. This mirrors the arrangement seen at other classical Greek cities, such as at Mantinea and Stymphalos, also in the Peloponnese. Some streets of different orientation appear to exist as well, particularly in the eastern part of the site, which slopes steeply.

The magnetometic results mapped the road network, the road edges appearing as particularly distinct features (Fig. 2). Between the roads there is a plethora of small gradiometer anomalies, many of which can be deemed to be of archaeological origin given the rich material culture record revealed by excavations at Elis and their spatial organisation. Magnetic data collected in the far southern part of the site reveal many smaller anomalies and the roads are more poorly defined. This area is in the active floodplain of a stream and may have been subject to frequent flooding.

The road system is also mapped by magnetic susceptibility values, particularly at the 43350, 21030 and 10230 Hz frequencies. Building architecture is visible in some magnetic susceptibility results, but is not generally well resolved (Fig. 3). Other methods employed as part of related investigations, such as resistivity and ground penetrating radar, were far more successful at resolving these features. Conductivity values were able to map road networks in some locations, but these features were more poorly defined and appeared wider. The anomalies that defined these features can be either more or less conductive than the surrounding soil in different parts of the survey area. The presence of electricity power lines in two of the EMI survey areas interfered with the quadrature and in-phase responses at all frequencies, rending the data uninterpretable within 40 m of this feature.

CONCLUSIONS

Electromagnetic induction and magnetometry proved effective as a means of mapping the road network of areas of the classical Greek city of Elis. The results demonstrate the effectiveness of this methodology for investigating the spatial organisation and extent of ancient cities.

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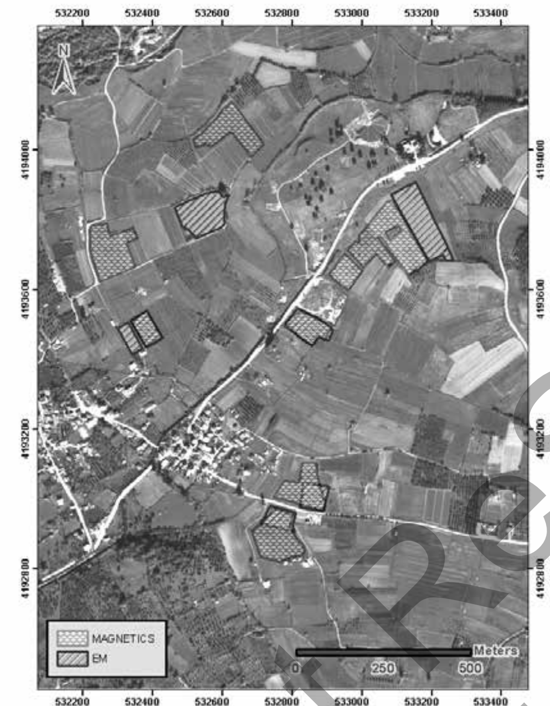

Fig. 1. WorldView Satellite image of Elis outlining areas covered with magnetic and electromagnetic geophysical mapping methods

Fig. 2. Results from a Sensys MX V3 Multi-sensor gradiometer survey of the area south of Elis

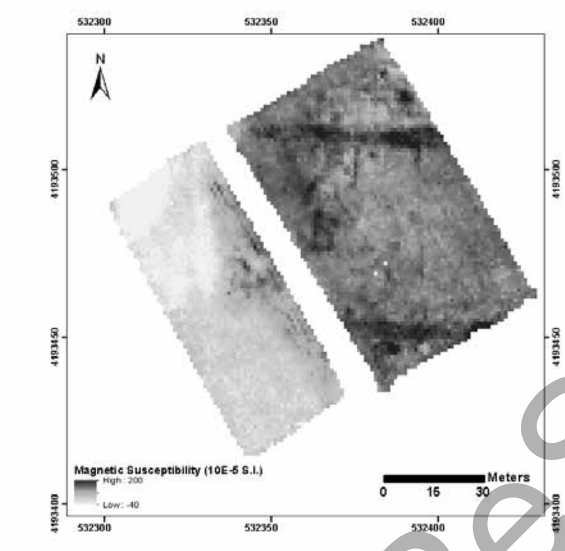

Fig. 3. Results from a 10230 Hz frequency magnetic susceptibility survey collected with a GEM-2 electromagnetic induction instrument from an area southwest of Elis

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