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MAGNETOMETRIC SURVEY IN THE TEMPLE OF ATHENA
ALEA AT TEGEA – A REPORT

Introduction

The magnetometric survey in the temple of Athena Alea at Tegea was carried out on 27 June 2004.

Three areas of 0.1 ha were surveyed with a magnetometer at the temple site. The purpose of this survey was to try to reveal details about the construction of the temple and about possible archaeological structures near or underneath it.

Magnetometric surveys on ancient sites

Magnetometry is a non-destructive method for quick investigation of large, ancient sites. The idea of doing a magnetometric survey in ancient Tegea was inspired by positive results obtained by the authors of reports written between 1982 and 2003 on a number of ancient Greek and Roman sites in Greece (Kalydon: Dietz and Moschos 2003; Dietz 2003), Ukraine (Crimean rural settlements: Smekalova and Maslennikov 1993), Egypt (two Roman towns in the Dakhla oasis: Smekalova 2002), Syria (Tell-Banat, the Roman settlement) and on other sites in many countries (Smekalova *et al.* 2005; Voss, Smekalova and Smekalov 2003; Smekalova, Voss and Smekalov 2003).

Magnetic anomalies (in general)

If the earth was composed of uniform material, the lines of magnetic force would be evenly distributed between its magnetic poles, and within a small area they would be parallel. However, since materials in the earth have different magnetic properties, the earth's lines of magnetic force are distorted. The local disturbances of the global magnetic field are called magnetic anomalies.

Iron constitutes about 6% of the earth's crust. Most of it is dispersed through the soil, clay and rocks as chemical compounds which are weakly magnetic. Human activities in the past (especially the use of fire for heating, cooking, and industry) have changed these compounds into more strongly magnetic substances, creating the patterns of anomalies in the earth's magnetic field. These anomalies can be detected with sensitive instruments: magnetometers.

Iron oxides and hydroxides, normally present in clay and soil in non-magnetic forms, are transformed into more strongly magnetic forms when heated. Therefore

one can always observe positive anomalies above fire-places, kilns, slag blocks, and ovens.

The variations in magnetic properties between topsoil, subsoil and rock (topsoil is normally more magnetic than subsoil) also affect the earth's field, making it possible to detect ditches, pits and other silted-up features which had been excavated in ancient times and then silted or back-filled with topsoil. Such features produce a positive magnetic signal. Conversely, less magnetic material penetrating into the topsoil, including many kinds of masonry (such as limestone or sandstone walls), produces a subtractive effect which can be detected as a negative signal.

Positive magnetization is usually caused by heating, whether natural, as in the case of volcanic rocks, or artificial, like clay vessels etc. Therefore, archaeological features such as kilns, furnaces, slag blocks, fire-places, ceramics, bricks and tiles possess rather strong positive magnetization.

Archaeological structures made of earth typically create magnetic anomalies in the range of 1–20 nT; the more unusual, fired structures 10–1.000 nT; and the quite rare archaeological objects that contain iron, including slag blocks from iron smelting, 20–2.000 nT. Non-magnetic walls of limestone or sandstone, situated in soil, can give negative magnetic anomalies with values of about – 2 to – 20 nT.

Walls built of limestone or marble blocks penetrating into the topsoil will create rather strong negative magnetic signals from – 10 up to – 50 nT. The intensity of the negative anomalies produced by walls may vary depending on the magnetic properties of the soil where the wall was constructed.

Rooms containing ovens, pits and pithoi, that are also filled with earth or pieces of roof tiles, pottery or ashes, will be seen in magnetic maps as positive anomalies with an intensity of 20–50 nT.

Streets, if covered with fragments of ceramic pots, tiles or metal slag, can give positive anomalies of a greater intensity (10–100 nT), depending on the amount of material covering them.

Furnaces and *kilns* create strong positive magnetic anomalies (40–600 nT) with more modest negative

anomalies immediately to the north of the main positive signals. Such structures, constructed of clay bricks which were heated, possess their own thermoremanent magnetization, the direction of which corresponds to the direction of the ancient magnetic field of the earth. Heaps and pits, filled with discarded ceramic vessels, slag and ashes, which are normally found close to the pottery kilns and furnaces, will cause strong positive anomalies (80–150 nT) with smaller negative areas to the north of the maximum of anomalies.

Pithoi are quite frequent at ancient Greek sites. They create small positive magnetic anomalies with amplitudes of about 50–100 nT.

Other archaeological structures such as *pits*, *cisterns* or *wells*, filled with fragments of ceramics, ashes and burnt soil, may create rather strong positive anomalies (up to 50–75 nT) with negative anomalies to the north of the positive peaks.

Method and equipment

A magnetometric survey of an archaeological site measures the earth's magnetic field close to the surface with small intervals (not more than 0.5 m). The measurements are then presented as magnetometric maps.

A coordinate system was created for the survey of the temple. The plots were 40 m long (or less) and as wide as possible in the area which was available around the temple. Small aluminium sticks were placed along two opposite sides of the plot at 1 m intervals. Strings of 40 m length (or less) with marks at 0.5 m intervals were tied between the sticks.

The magnetometric survey was carried out with an Overhauser gradiometer (magnetometer with two sensors) produced by Gem systems (Ontario, Canada), model GSM-19 v. 6.0. The measurements were made along straight parallel lines; the spacing between the lines was 0.5 m. The magnetometer was operated in so-called "walking mode" measuring every 0.2 second, and the distance between the measurements along the lines was not more than 0.1–0.2 m. The height of the sensor above the surface was about 0.3 m.

Because of the large area which was surveyed, it was necessary to measure the daily variations of the earth's magnetic field at a control point in a normal magnetic field.

The data were stored in the memory of the gradiometer; after the survey they were transmitted to a portable computer. The presentation of the magnetic data was prepared with Surfer software (Golden, Colorado) in the form of coloured contour maps. On the contour maps positive anomalies were marked with blue colour, negative ones with red. The contour interval was 5 nT.

The results of the magnetometric survey at the temple of Athena Alea

The magnetometric survey turned out to be useful for the investigation of the temple site at Tegea, because there was a large contrast between the magnetic properties

of the non-magnetic conglomerate foundations and the slightly magnetic fill between buildings, and the highly magnetized fired clay. The structures are normally located at a depth of about 1 to 1.5 m, where they can easily be detected by a magnetometer.

The magnetometric map of the temple area is presented in *Pl. 1*. The outlines of the foundations of the temple are shown in the same plot, with red lines for the outer foundations of the peristasis and green lines for the foundations of the naos. The suggested interpretations are indicated by the letters A, B and C.

The magnetic field has strong anomalies, both positive (blue) and negative (red). There is a fairly strong positive anomaly, possibly from a modern iron object, at the southernmost part of the plot (at "C"). There is only a very small probability that this anomaly corresponds to an archaeological feature, like a furnace or a kiln.

Several, possibly modern, iron objects are scattered around the area of the temple, which gave strong, punctual anomalies ("B").

There are rather strong negative, linear anomalies caused by the non-magnetic stone walls of the temple foundations.

The most interesting result, in our opinion, is the positive anomalies at the western end of the temple, between the foundations of the peristasis and the naos, and outside the western half of the temple, north of it. They are marked by letters "A". These positive anomalies could be caused by some magnetic material situated below the stone walls. This could be a substructure consisting of layers of pottery, tiles, and clay. It could be some kind of special foundation used for a heavy building such as the temple of Athena Alea, which was one of the largest temples in Greece. We know from experience that the same magnetic anomalies exist at other possible temples on Greek sites.

One example is a possible temple or another heavy and large stone building which was identified on the slope of the acropolis of the ancient town of Kalydon in Aetolia. There, the same positive anomalies are situated inside the building in question and around it.

Another example was found during the magnetometric survey at the centre of Tegea. There, to the south of the fence of the park at Palea Episkopi, very strong linear negative and positive anomalies appeared. Unfortunately, there is a very strong "noise" from the iron fence of the park, which did not allow us to make a survey of the whole building; only the south-western corner of it could be surveyed. Around the possible walls of this building, which could be a temple because of its dimensions, many positive anomalies were revealed similar to the anomalies at the temple of Athena Alea and the possible temple on the slopes at Kalydon.

It is possible that similar positive anomalies caused by the substructure of the foundation also exist in the eastern part of the temple, but these could not be observed clearly because the modern buildings nearby create a strong "noise" in the magnetic field in this part of the plot.

One can conclude that the magnetometric survey in the western part of the temple of Athena Alea revealed foundations built of layered, magnetic materials, such as ceramics, tiles and clay. Similar observations have been made at other possible Greek temple sites at Tegea and Kalydon.

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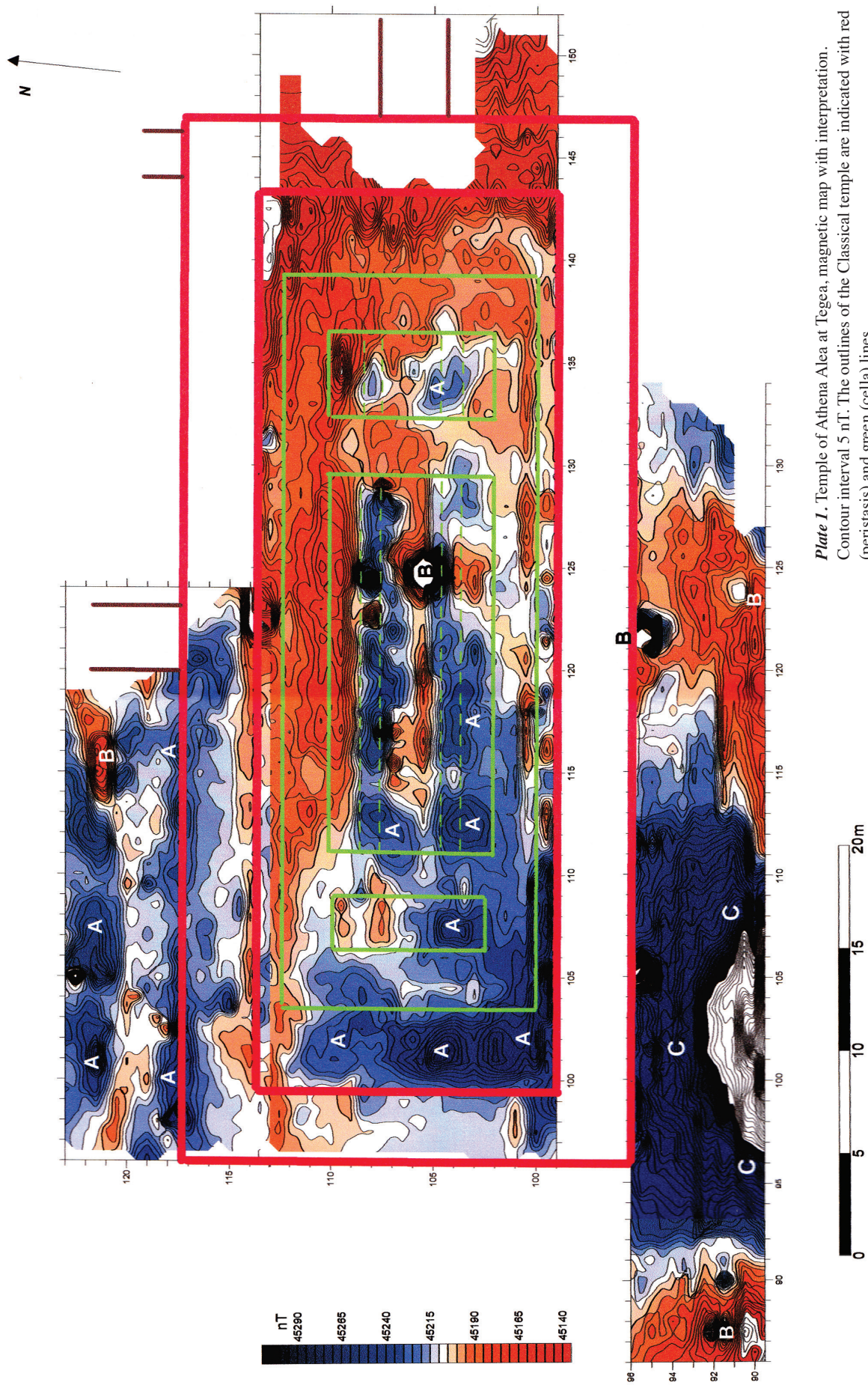


Plate 1. Temple of Athena Alea at Tegea, magnetic map with interpretation. Contour interval 5 nT. The outlines of the Classical temple are indicated with red (peristasis) and green (cella) lines. Scale 1 : 250.

