Geophysics applied to the investigation of Graeco-Roman coastal towns west of Alexandria: the case of Marina el-Alamein

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Introductory remarks

The Polish Centre of Mediterranean Archaeology of the University of Warsaw has become a leading research unit in archaeological geophysics in the territories of Egypt and Sudan, but before this happened there had to be that initial stimulus. A meeting took place in early spring 1985 at the Warsaw office of the Polish Centre of Mediterranean Archaeology. Wiktor Andrzej Daszewski, the Centre's director after the death of Prof. Kazimierz Michałowski (the Centre's founder), accepted with alacrity an offer made by co-author Tomasz Herbich, representing the geophysical laboratory of the Institute of Archaeology and Ethnology of the Polish Academy of Sciences in Warsaw, to study with geophysical methods archaeological sites investigated by the Centre in Egypt. The first to be surveyed with the electrical resistivity method was the ancient site of Tell Atrib, freshly taken over by Karol Myśliwiec, another scholar always on the lookout for new methods of investigation (Myśliwiec, Herbich 1988). This was followed by a magnetic survey in Naqlun, Fayum, in 1986 (Godlewski, Herbich, Wipszycka 1990) and another survey in Saqqara (Myśliwiec, Herbich 1995). In the following years magnetic research was carried out by Krzysztof Misiewicz also on sites investigated by the PCMA in Sudan (Misiewicz 1992; 1998).

It was that first meeting in 1985 and Professor Daszewski's openness to methodological innovations, like archaeological geophysics, which provided archaeologists from the PCMA with an important tool for estimating the potential of archaeological sites excavated by the Centre (Herbich 2003). It was merely a question of time and opportunity before geophysicists arrived also in Marina el-Alamein, the site that Professor Daszewski had discovered and where he conducted important excavations between 1986 and 2005. The geophysical survey at the ancient site of Marina el-Alamein took place in the 1998/1999 season. The present paper discusses the results, which were published in part in a report from the season's work (Daszewski 2000) and which were used by the archaeological team to locate features for excavation.

Geological setting

West of Abu Qir the coastal plain is interrupted by a series of oolithic limestone ridges. Marina el-Alamein lies on the northern slope of the northernmost of these ridges descending to the sea. This ridge and the next slightly higher one to the south run nearly continuously and parallel to the coast from Abu Qir to Salamun on the Libyan border. A careful study of the microstructure of the oolithic grains and the chemical composition of the cement suggested that each ridge had been formed as an offshore bar at a time when sea levels were different from today (Sampsell 2003: 130). The ground at the site consists of sands averaging from 0.50 to 1.00 m thick at the southern edge, which lies at an altitude up to 10 m a.s.l. These sands, overlying limestone bedrock, thicken in the general direction of the coastline.

The site of Marina el-Alamein

Regular excavations in the twenty years which followed the discovery of the site in 1986 allowed Professor Daszewski to clear and identify the remains of a prosperous harbor town and its necropolis (Daszewski 1991; 1995; 1998; forthcoming; Daszewski *et alii* 1990; annual reports in *PAM* starting from 1990). According to the excavator, the archaeological evidence for the founding of the town points to the 2nd, perhaps even 3rd century BC; it was abandoned very probably in late antiquity, most likely in the early 6th century (Daszewski forthcoming). As said above, the town occupied the northern slope of the coastal ridge. The cemetery was located on the southern side of the town, reaching up to the top of the ridge; the pillar tombs were already quite elevated, probably to be seen from all parts of the ancient town. The town itself covered approximately 40 ha, the necropolis an additional 10 ha. Less than 1% of the area with urban architecture has been excavated and conserved. As for the cemetery, at the time that the geophysical survey was carried out, there were more or less 25 underground chamber tombs already identified and investigated.

The primary building material used by the ancient inhabitants was locally extracted limestone — very much like on many other Graeco-Roman sites on the Mediterranean coast of Egypt. House walls stand in places to a height from 0.50 to 1.00 m; streets and squares paved with stone slabs have also been preserved. The repertoire of sepulchral architecture was rich and varied, encompassing several different types: hypogea up to 6 m deep, accessed via a staircase leading to an open court excavated in bedrock, surrounded by funerary chambers or niches for burials and aboveground structures in a number of cases. Another category are "pillar" or "column" tombs, the lower part of which was a box structure with a number of loculi, supporting the pillar monument on top. These box structures are currently covered with sand up to a meter high.

Geophysical methods and the urban and sepulchral architecture

The plan of the site could not be established by classical excavation methods owing to sheer size of the area involved. It was therefore reasonable to apply geophysical surveying as a means of quick and noninvasive prospection, should the conditions prove favorable. At the time (1998–1999) it was pioneer research, without the possibility of dropping back on experience from geophysical prospection of analogous sites situated on the Mediterranean shore between Alexandria and the Libyan border.[1] The survey, apart from revealing features not observable on the ground surface, was seen also as a test of the application of geophysical methods on sites with a similar geological setting in the region.

Limestone, whether as ground substructure or as building material, has very low magnetic susceptibility. Little was expected therefore of the application of the magnetic method in Marina. In turn, the electrical resistivity method was impractical principally because the sand, which engulfs all of the area, has such high resistivity that it drowns out any echo of stone architecture concealed under it. The other major reason is the low humidity of the ground (through the archaeological season from the spring to fall) which impedes probe contact with the ground. There are ways to improve contact with the probe, but they are time-consuming and slow down measurements beyond effectiveness (a maximum of 100–200 m^2 per day compared to at least 5000 m^2 per day for the magnetic method). The method had potential with regard to the underground structures known to exist in the necropolis, but with regard to stone architecture under a sand layer ground penetrating radar (GPR) seemed to be the most effective means of prospection, enabling the tracing of corridor staircases and courtyards filled with sand and the adjacent burial chambers on the whole only partly filled with sand.

The limited uses of the magnetic prospection method in the specific conditions of the necropolis at Marina el-Alamein were demonstrated by a test survey carried out in 1998. The immediate task at hand was to search for potential aboveground tomb architecture concealed under sand on the spot suggested for the planned site museum. GPR surveying was conducted in 1999 by Harald von der Osten from the Landesamt Baden-Württemberg. In another part of the site, identified as the waterfront area of the town, Tomasz Herbich carried out further magnetic prospection, encouraged by the results of the prospection conducted in December 1998 at Berenike on the Red Sea coast, then excavated by a joint American–Dutch expedition. It was observed there that walls with no inherent magnetic properties could be traced with the method owing to the contrast that exists between the non-magnetic walls and the more or less magnetic surroundings containing materials characterized by high magnetic susceptibility, such as slag, ashes, potsherds. In such cases the walls are mapped in negative reflection (Herbich 2007).

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[1] A survey using the magnetic method had been carried out in 1976 in the northern part of the ancient site of Marea near Alexandra by a team from the University of Guelph, Canada, associated with the University of Alexandria, which was responsible for the research (Sadek 1978). The usefulness of his survey is limited considering that the publication brings only a brief presentation of results without any documentation from the actual prospection.

Ground Penetrating Radar Survey

The GPR research in the southern part of the site was carried out in a belt 150 m wide and 400 m long and covered the anticipated interface between urban and sepulchral architecture [*Fig. 1*]. The area chosen for surveying was relatively flat without any archaeological trenches or dumps. Measurements were taken along 1022 profiles with a combined length of 35.9 km. Profiles were located 0.50 m apart. The distance between measurements (controlled by a high precision surface wheel) along each profile was 0.05 m. The measurements covered a combined area of 1.51 ha.

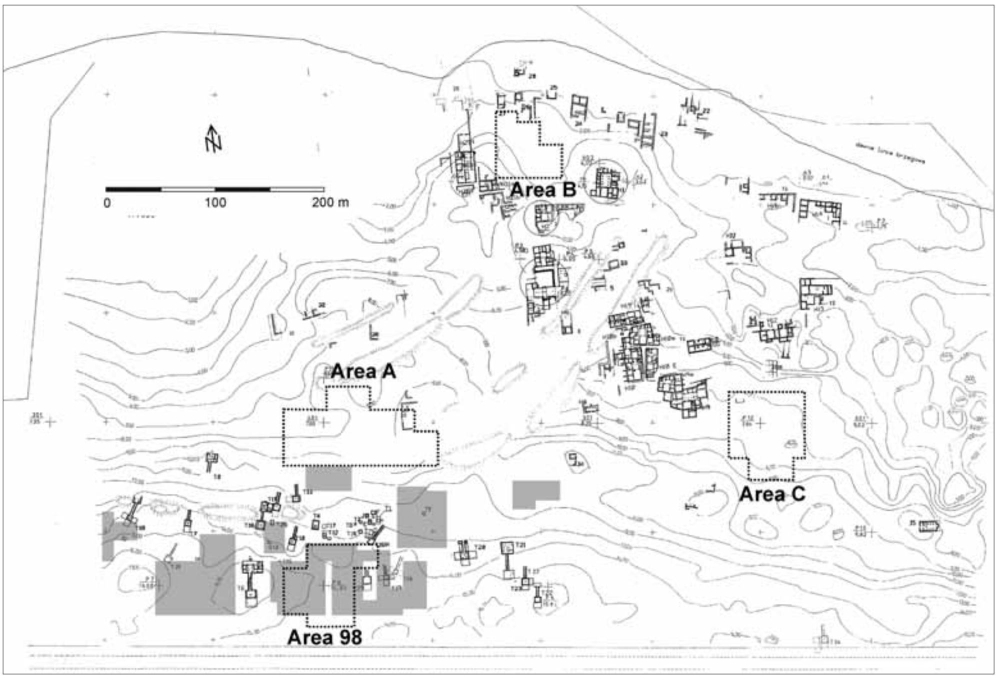


Fig. 1. Areas of ground penetrating radar (GPR) (in grey) and magnetic prospection (dotted lines) in the 1998 and 1999 seasons

Measurements and Data Processing

SIR-2 from GSSI, USA, was used during the survey. Experimental measurements with antennas of different frequencies were undertaken first to determine the most suitable antenna for this area; it turned out to be a 200 MHz antenna [*Fig. 2*]. The maximal depth of investigation was set at approximately 3.50 to 4.00 m. But because of the salinity of the ground, usable reflections of the emitted electromagnetic pulses of the radar antenna were found to be no deeper than approximately 1.50 m [*Fig. 3*].

Data processing employed ReflexW (Sandmeier Software, Karlsruhe, Germany). The procedure consisted of the following steps: 1) the zero level of the data was corrected to be able to calculate the correct depth of the structures detected by the electromagnetic pulses; 2) marker interpolation was recalculated. During each profile markers were set on the radargram with a horizontal separation of 1 m; 3) the background noise in the

Fig. 2. *GPR survey using a 200 MHz antenna (GSSI) in the pillar-tomb area of the ancient necropolis at Marina el-Alamein, 1999 (Photo H. von der Osten-Woldenburg)*

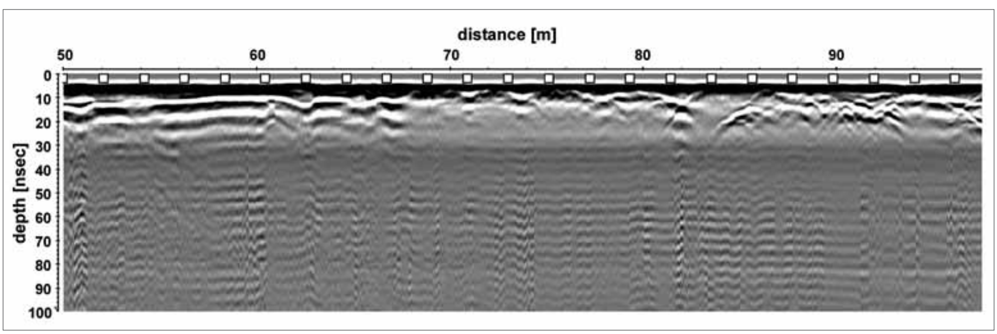


Fig. 3. *Typical radargram (raw data), collected in Marina el-Alamein*

radargram was removed to reduce artificial effects in data processing results, and, for the same reason, some bandpass filters removed additional artifacts in the data; 4) the data were migrated using the specific velocity of the emitted electromagnetic impulses into the ground, which was calculated on the basis of the curvature of the reflection hyperbolas; 5) a depth-dependent gain-factor was applied to the data to take into account the energy decay of the reflected electromagnetic pulses dependent on the depth. Because of the lack of digital topographic data as well as because of the fact that the area mapped was more or less plain, no topographic correction to the data was undertaken; 6) finally, timeslices were calculated. Timeslices are the results of horizontal slices, orientated parallel to the surface and perpendicular to the layers defined by the radargrams. They are calculated for several depths and of specific thickness, expressed in the unit of time of propagation of the electromagnetic pulses. Thus, timeslices are two-dimensional maps of underground inhomogeneities at a specific depth and specific depth interval. They represent the results of a GPR survey and are presented in the next chapter.

Discussion of GPR results

Some of the calculated timeslices are presented here. As mentioned earlier, none of the selected timeslices is located deeper than 1.5 m because of the high salinity of the ground. Deeper located timeslices contain more or less noise and/or noisy effects not related to archaeologically relevant structures. In each case, the approximate depth of the corresponding timeslices is indicated. Because of the poor quality of the recorded reflection hyperbola (compare ***Fig. 3***), the depths indicated in the figures are not exact and errors of about 15 % are included in this information.

Several structures in the timeslices can be related to features that are deemed to be archaeological, not only geological. For reasons of clarity only some have been marked with a circle or an ellipse in the figures. These structures can be observed extending over a relatively considerable depth.

Structures mapped in the western part of the investigated area at a depth of approximately 0.30 m [***Fig. 4***, depth 0.30 m] could be related mostly to geological structures, but there were some features of archaeological interests. Two of them have been marked south of tomb T7. The dark rectangular anomalies present the presumed courts of two hypogeum tombs, and the short, dark linear structure leading approximately to the north represents a staircase leading down to a tomb. Another structure worth mentioning is situated approximately 10 m east of the courtyard of tomb T16. This structure and the rectangular feature next to it, about 10 m west of the courtyard of tomb T18, can be traced also in the deeper layers (for the results of archaeological verification, see Appendix). Structures of interest have also been marked about 30 m east of Tomb T6. Moreover, of interest is the dark rectangular feature approximately 40–50 m southwest of tomb T1GH, as well as a rectangular structure 30 m northeast of tomb T13 and a dark rectangular feature about 15 m south of tomb T10.

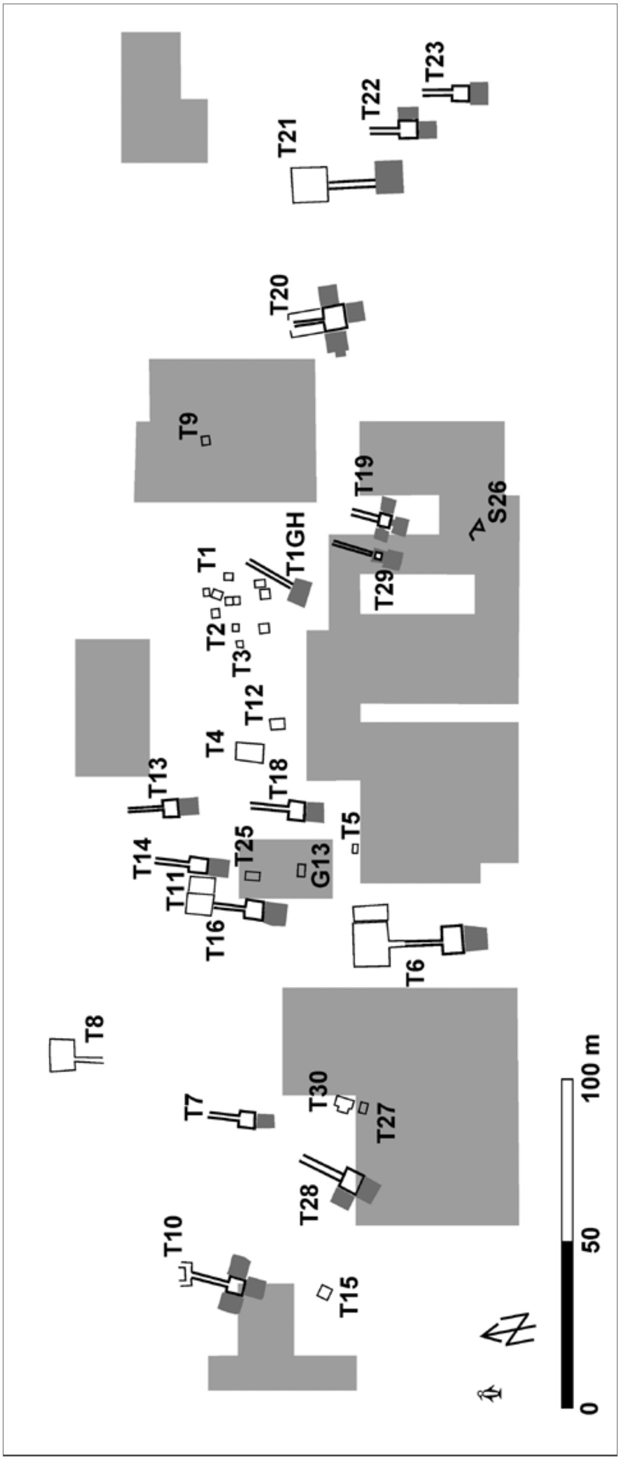
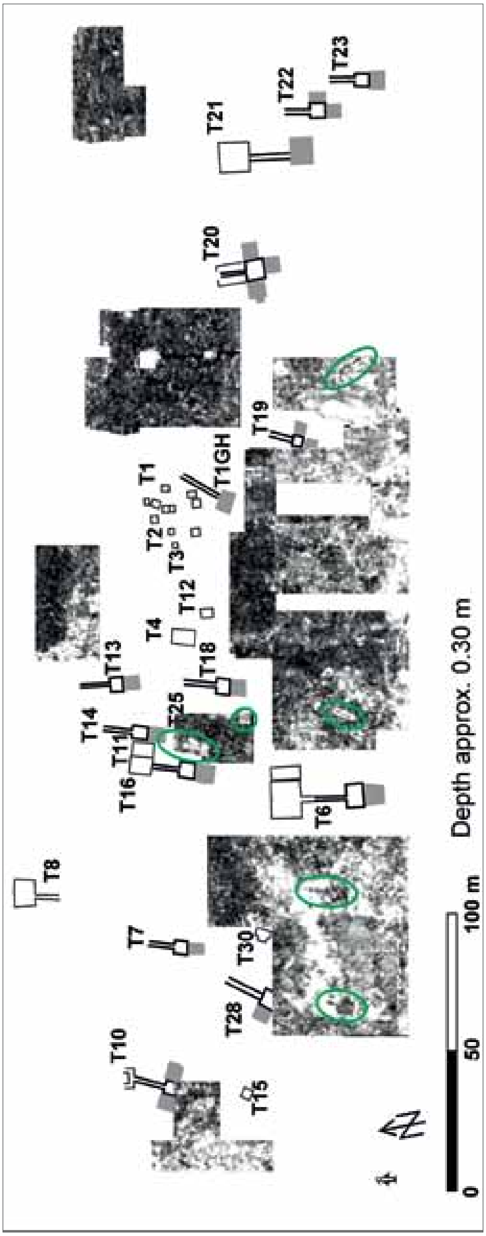
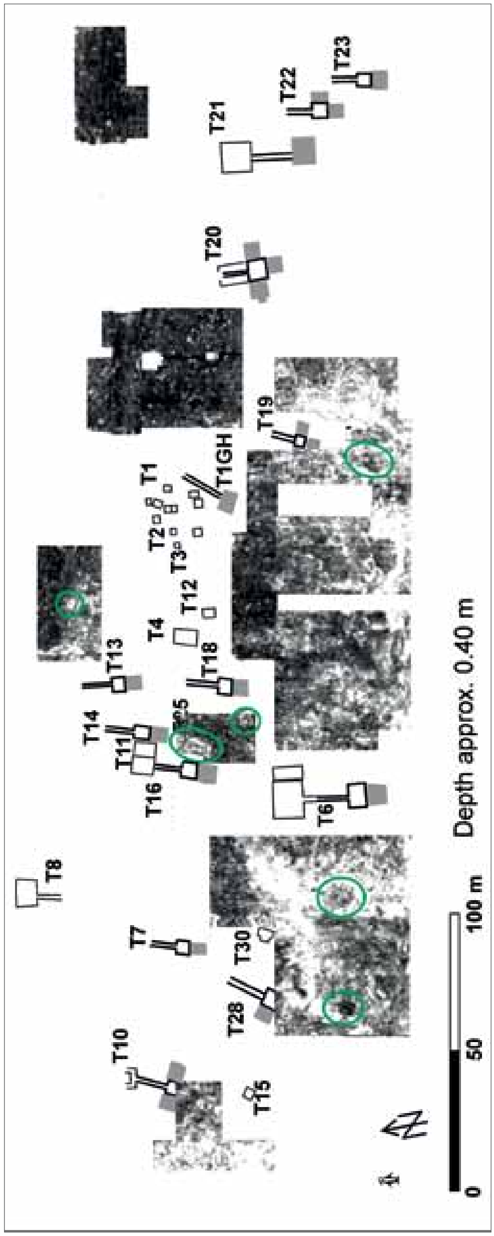


Fig. 4. *Location of GPR survey (in transparent grey) and timeslices for successive depths every 0.10 m from 0.30 m to 0.90 m and 1.20 m below ground surface (pages 218–221)*


Depth approx. 0.30 m
0
50
100 m
T1
T1GH
T2
T3
T4
T6
T7
T8
T10
T11
T12
T13
T14
T15
T16
T18
T19
T20
T21
T22
T23
T25
T28
T30


Depth approx. 0.40 m
0
50
100 m
T1
T1GH
T2
T3
T4
T6
T7
T8
T10
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T13
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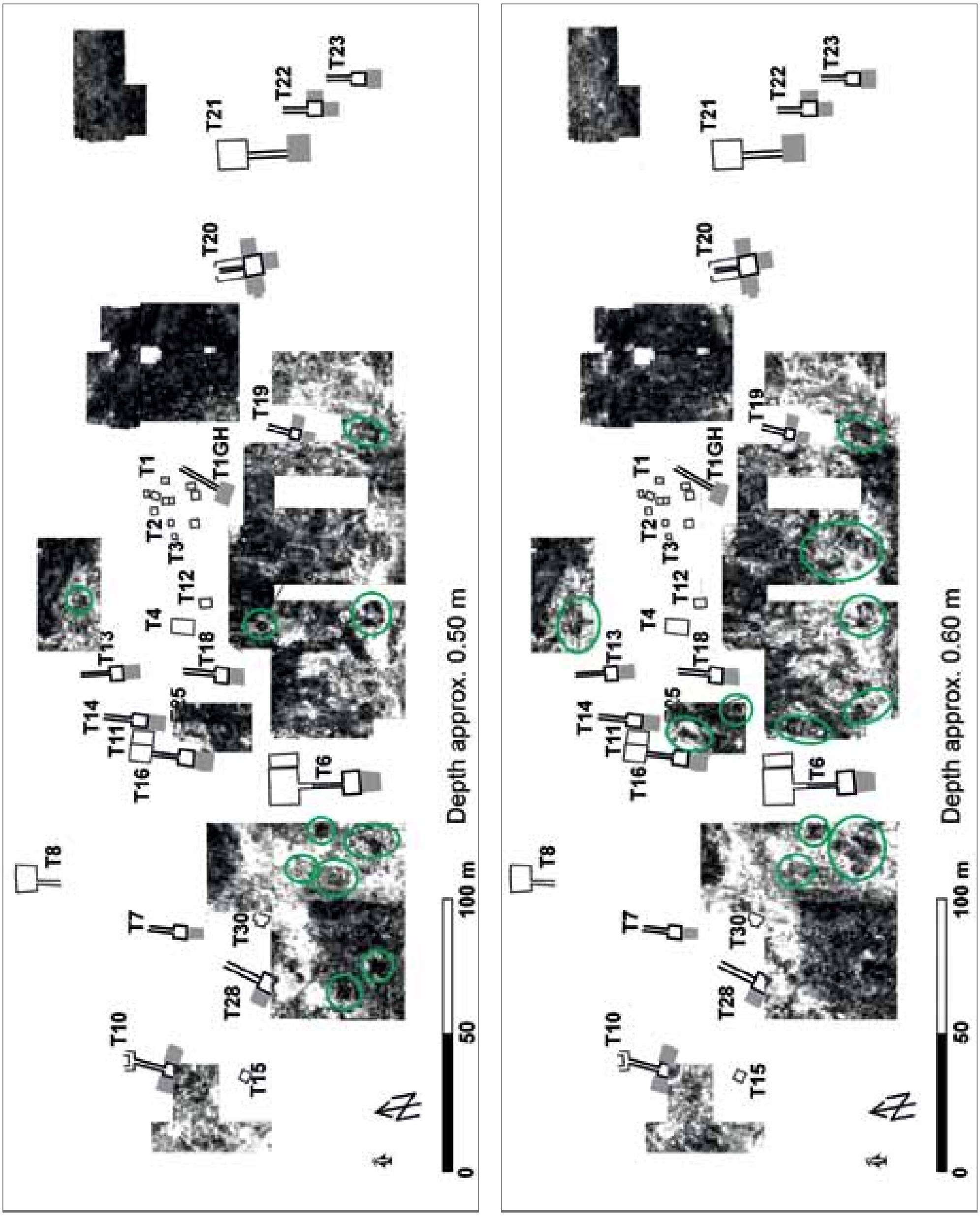
T30


Depth approx. 0.50 m
Depth approx. 0.60 m
0
50
100 m
T1
T1GH
T2
T3
T4
T6
T7
T8
T10
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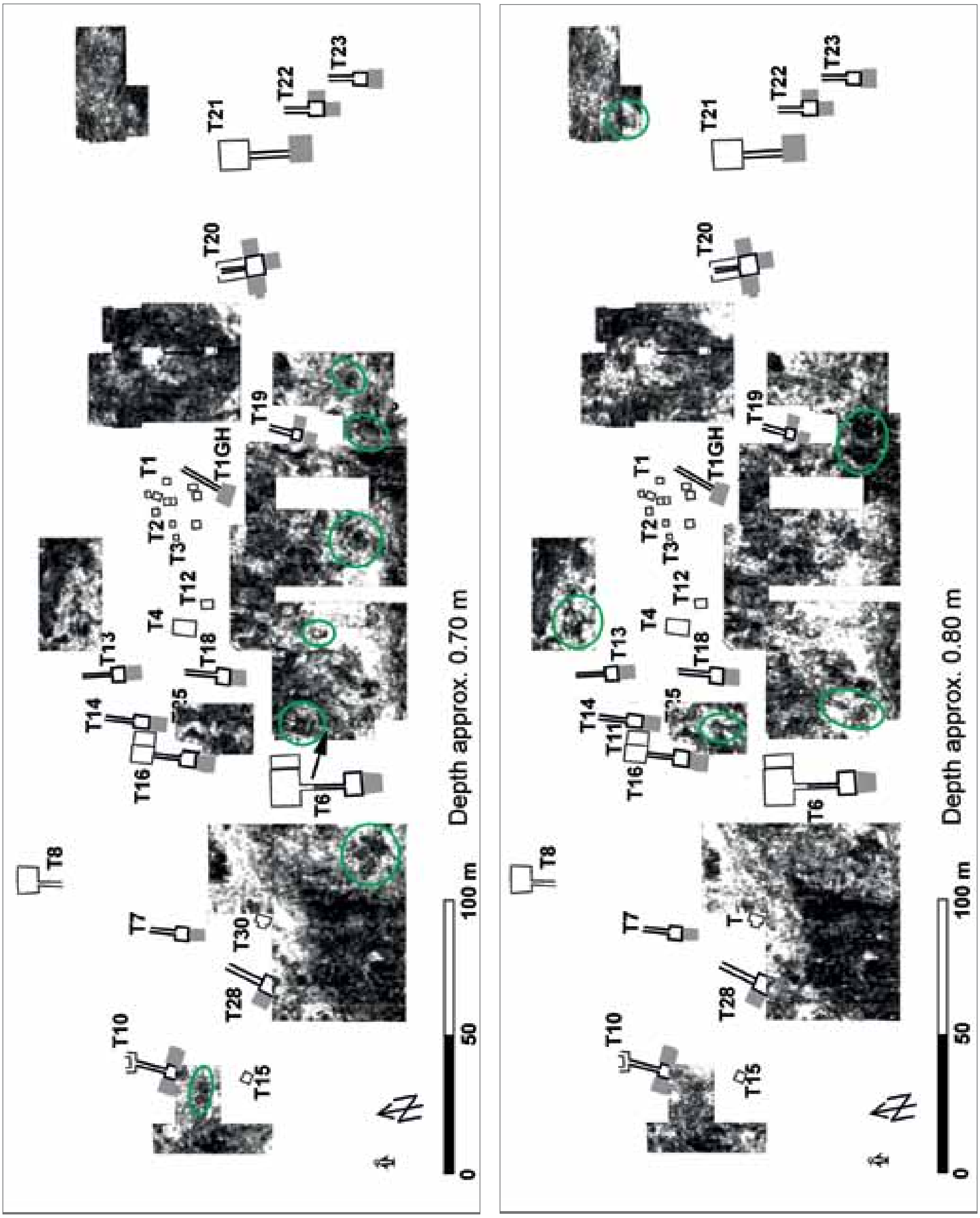
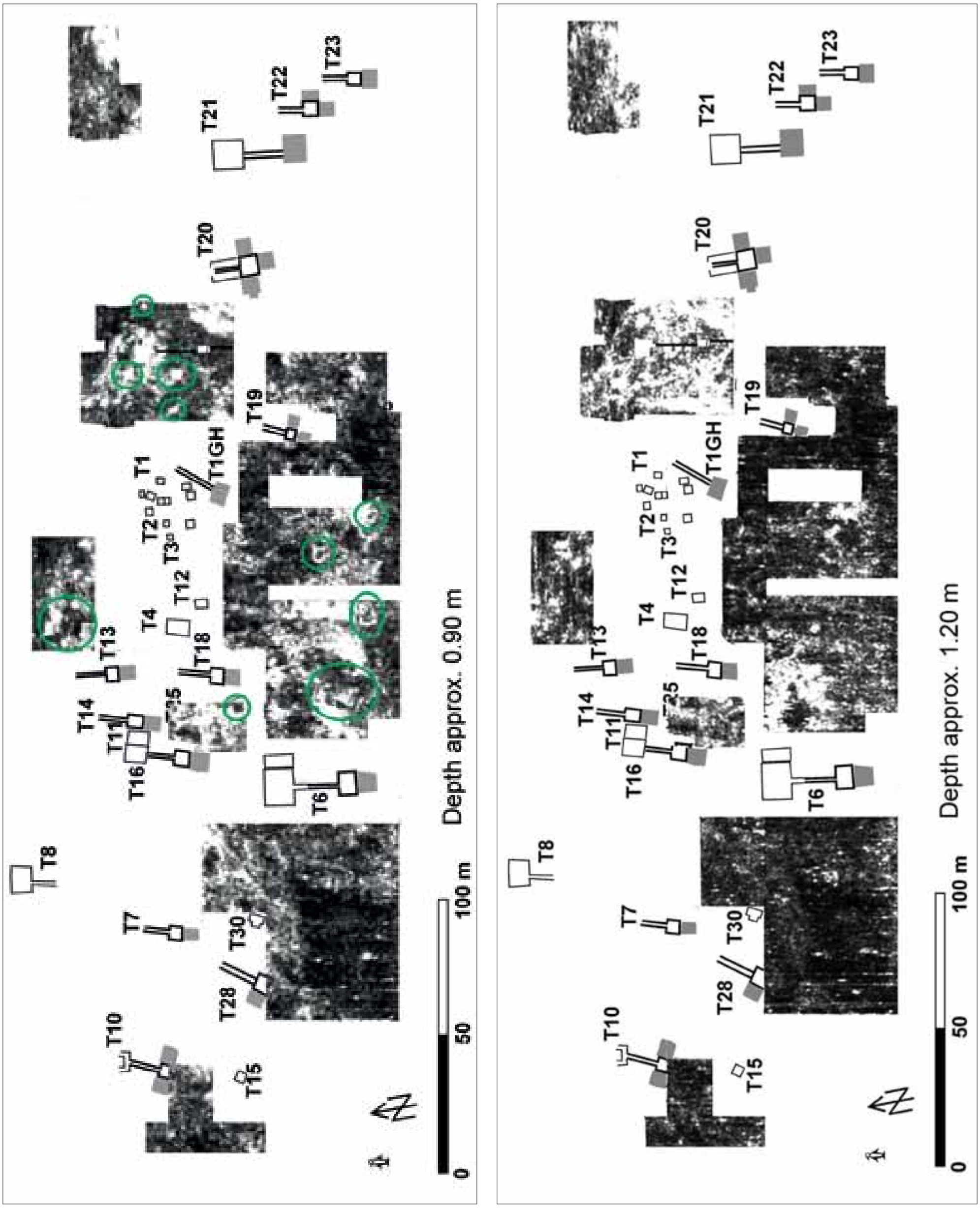

T1
T1GH
T2
T3
T4
T6
T7
T8
T10
T12
T13
T14
T15
T16
T18
T19
T20
T21
T22
T23
T28
T30
Depth approx. 0.70 m
0
50
100 m
T1
T1GH
T2
T3
T4
T6
T7
T8
T10
T11
T12
T13
T14
T15
T16
T18
T19
T20
T21
T22
T23
T28
Depth approx. 0.80 m
0
50
100 m


Depth approx. 0.90 m
Depth approx. 1.20 m
0
50
100 m
T1
T1GH
T2
T3
T4
T6
T7
T8
T10
T11
T12
T13
T14
T15
T16
T18
T19
T20
T21
T22
T23
T28
T30
N

This structure extends in depth to approximately 0.40 m [*Fig. 4*, depth 0.40 m] and may be part of tomb T10. At this depth, in the southwestern part of the area investigated, south of tombs T28–T30, two rectangular structures, about 5 m by 5 m and 6 m by 9.5 m respectively, can be traced a little more clearly than in the timeslice at the depth of 0.30 m and can be seen again at the depth of 50 cm. Again, the shape of anomalies east of T16 and west of T18 was indicative of two tombs. About 40 m northeast of tomb T13, a clear white-shaped, rectangular anomaly seems to constitute an extension of the archaeological structure delineated at the depth of 0.30 m. Finally, another tomb was detected in the southeastern part of the mapped area, about 30 m south–southwest of tomb T19.

The extension of Tomb T10 could be observed at approximately 0.50 m below the surface [*Fig. 4*, depth 0.50 m]. In the area south of tombs T28–T30 several interesting features of rectangular shape have been registered. Of special interest is the structure in the southeastern part of the area: a small linear feature connected to a more or less rectangular structure possibly points the position of a staircase leading down to a tomb. Two more presumed tombs were marked south of tomb T4, 40 and 80 m away. The tombs noted about 30 m south-southwest of tomb T19 and a tomb approximately 30 m northeast of tomb T13 can be traced again. Several interesting structures, not only rectangular, but also of linear shape, could be observed in the area southwest of tomb T1GH. Their shape suggests a man-made feature rather than a natural formation, but this theory needs to be verified archaeologically, especially as just 10 cm deeper, most of these structures disappear. Again, a structure corresponding to a big tomb is visible about 30 m south-southwest of tomb T19. The structure 30 m northeast of tomb T13 has changed its shape.

This structure [*Fig. 4*, depth 0.60 m] could be observed also at a depth of about 0.60 m and further down at 1.10 m. Again, the contour of tomb (marked T25 after excavation) east of the courtyard of T16, as well as the contour of the structure west of tomb T18 could be observed at this depth. An ellipse approximately 20 m northeast of tomb T6 indicates another tomb, probably an aboveground mausoleum. A linear structure, marked with a black arrow in the timeslice representing structures at approximately 0.70 m depth below the surface [*Fig. 4*, depth 0.70 m], probably represents a staircase leading down (from the south–southwest) to the main burial chamber of this tomb. Beside the anomalies marked with ellipses indicating probable tombs, south of tomb T10 the survey detected two relatively small rectangular structures which could be two other graves. These structures could be observed at a depth of 0.60 m, but in deeper layers their shape changed.

Starting with the depth of 0.80 m below ground surface [*Fig. 4*, depth 0.80 m], the dynamics of structures in the timeslices appear to be reduced compared to the dynamics in the timeslices discussed so far. Ground salinity at this depth causes electromagnetic pulses to be increasingly absorbed, but it is still possible to observe the shapes of some tombs at this depth, as indicated by the ellipses. In the next timeslice at a depth of 0.90 m [*Fig. 4*, depth 0.90 m], the polarity of the anomaly of the tomb west of tomb

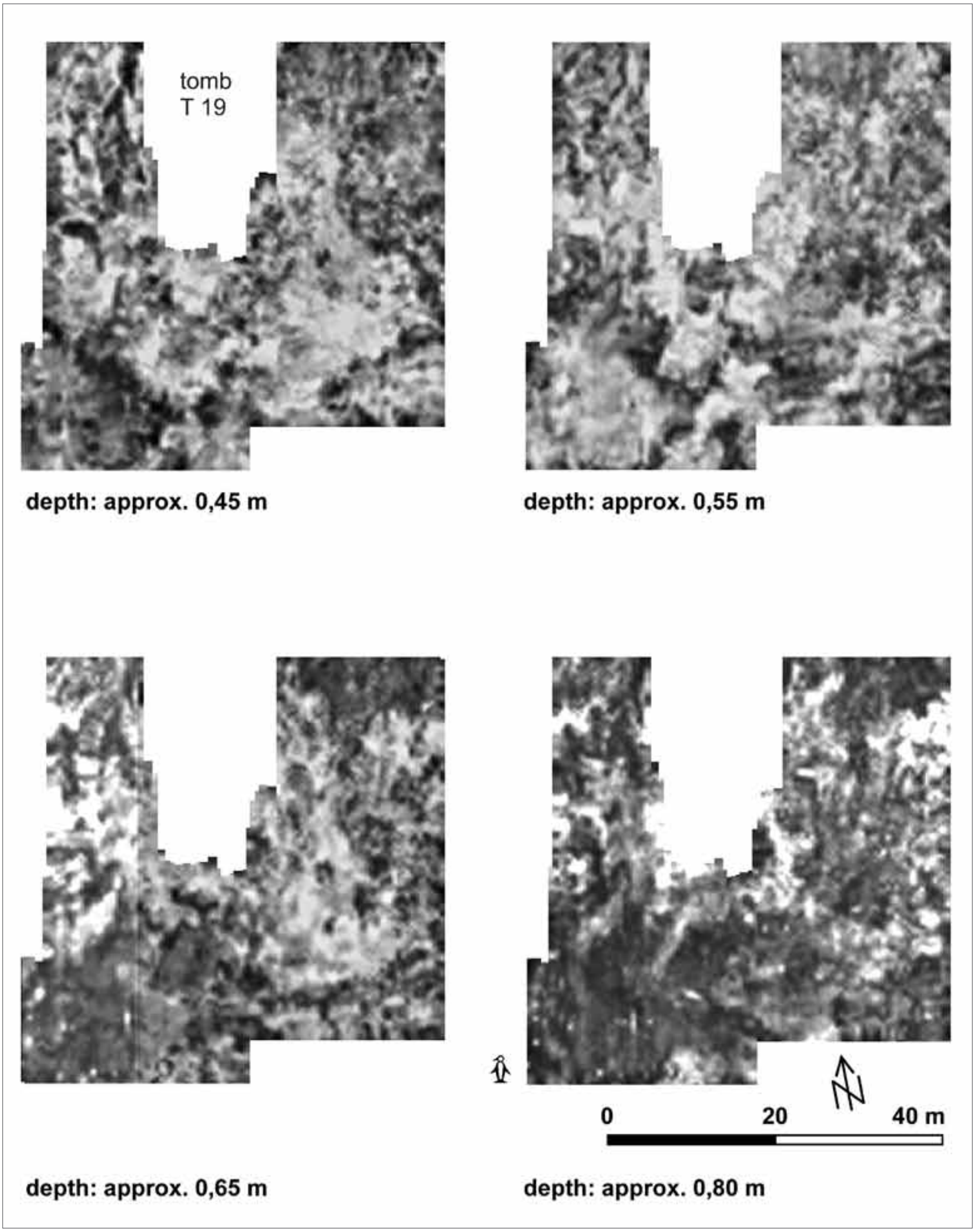


Fig. 5. *Timeslices at a section of the necropolis in the vicinity of tomb T 19, revealing presence of rectangular anomaly directly to the south of the tomb, later identified in excavations as an unfinished hypogeum project (S26) (same with Daszewski 2000: Fig. 2 on 42)*

T18 changed. This indicates the existence of a cavity. Moreover, the anomalies are now different: three more or less rectangular structures have been marked in the area between tombs T6 and T19. Of quite another shape are the anomalies marked in the northeastern part of the investigated area; they reveal compact rectangular structures.

Because of the absorption of the electromagnetic pulses the noise in the data increases and the signal to noise ratio decreases dramatically, so for greater depths the anomalies caused by archaeological structures stop being visible. The last figure presented here, for a depth of approximately 1.20 m [***Fig. 4***, depth 1.20 m] is good exemplification of this problem.

Typical anomalies of a tomb with staircase are shown enlarged [***Fig. 5***]. The structure interpreted as a tomb (and verified archaeologically as an unfinished feature, see Appendix) is situated about 10 m south of an area not surveyed with GPR because of the presence of an already excavated tomb (T19). At a depth of approximately 0.55 m, the shape of the burial chamber as well as part of the staircase leading down to it is clearly mapped. At a depth of about 0.65 m and 0.80 m, respectively, the polarity of the anomaly changed, continuing to indicate the presence of a cavity.

Magnetic survey

The magnetic surveying was carried out in four selected areas of the site: in the necropolis (the test area in 1998) and in 1999 at the interface of the town and cemetery districts (area A), on the northern fringes of the town (area B) and in the southeastern part (area C) (Daszewski 2000: 41). Sites for prospection were chosen in places were there seemed to be the least modern disturbance of the ground surface (the site was discovered during building construction works under a new tourist village). A combined area of 1.92 ha was surveyed (4000 m^2 in Area 98, 7400 m^2 in Area A, 5000 m^2 in Area B, 2800 m^2 in Area C) [see ***Fig. 1***].

Measurements and data processing

A Geoscan Research FM36 fluxgate gradiometer was used for the magnetic prospection.[2] The instrument measures the gradient of the vertical component of the Earth's magnetic field intensity with an accuracy of 0.1 nT. The sampling grid density was 9 measurements per square meter (measurements every 0.25 m along traverses 0.50 m apart). Measurements were taken within 10 by 20 m units. They were carried out in parallel mode, meaning that the apparatus was moved along the measuring lines in one direction only. Sensors were adjusted at a reference point after completing each grid. The described procedures (point density, parallel mode and sensor adjustment) have a ten-

[2] The instrument was provided by the Instituto Multidisciplinario de Historia y Ciencias Humanas, Consejo Nacional de Investigationes Cientifícas y Técnicas, Buenos Aires, on the grounds of a cooperation agreement with the Polish Centre of Mediterranean Archaeology of the University of Warsaw.

dency to draw out the actual measurement process (parallel mode requires twice as much time as the commonly used zigzag method where the apparatus is moved back and forth along the lines while taking measurements), but they increase substantially the clarity of the resultant geophysical image. FM apparatuses by Geoscan Research have a capability of tracing changes in ground structure down to a depth of 0.5–5 m, depending on the magnetic susceptibility of the objects.

Measurement data was processed using Geoplot 3.0 and Surfer 8.0 software. The data were interpolated to a 0.25 m by 0.25 m grid; edge-match, zero mean gradient and low pass filter were applied. Results were presented as grayscale maps, with white and black corresponding to extreme measurement values.

Discussion of results

The results of the survey in Area 98 recorded only a magnetic disturbance corresponding to the archaeological dump next to tomb T1GH. Slightly better results were obtained in Area A where among the few registered anomalies some could possibly reflect archaeological features. These include anomalies in the southern part of D7, in B4, and in D3 and D4 [***Fig. 6***]. These small amplitude disturbances (-0.5/+1.5 nT) of irregular shape could be a reflection of concentrations of ashes. Disturbances observed in squares B1 and B2 can be attributed to scatterings of potsherds on the surface. Structure 30, which found itself within the prospected area (in squares B6–C6) seems not to have caused any noticeable magnetic disturbance. A linear anomaly running roughly N–S in square C7 and in the northern part of D7 may correspond to architecture of some kind. It is oriented similarly as building 30 situated to its north.

Measurements in Area B did not reveal any traces of architecture. The four anomalies recorded in the southern part of the area, all of oval shape measuring from 1.50 to 3.00 m across and characterized by a considerable amplitude of values (from-5/+20 nT to –12/+28 nT), could be considered as imaging furnaces [***Fig. 7***]. Areas of insignificant amplitudes of magnetic disturbance (under –2/+4 nT) seen in the northern part of the area could possibly reflect ground intercalated more heavily with concentrations of ashes.

The most interesting results were obtained in Area C. The map reveals a number of linear anomalies in rectilinear or near to rectilinear arrangement, characterized by lower values of magnetic field intensity [***Fig. 8:1–2***]. The orientation of the anomalies roughly follows that of buildings 9 and 12 situated immediately to the north and northwest of the surveyed area. They are undoubtedly reflections of walls; the lowered values of magnetic field intensity characterizing these anomalies are due to the presumed building material, that is, limestone which has basically no magnetic properties. Raised values lining these anomalies should be interpreted as a reflection of material with higher magnetic susceptibility, such as ashes and burning. The arrangement and distinctness of the anomalies is sufficient to support a hypothetical reconstruction of the architecture [***Fig. 8:3***]. At least two streets can also be traced based on the arrangement of the anomalies.

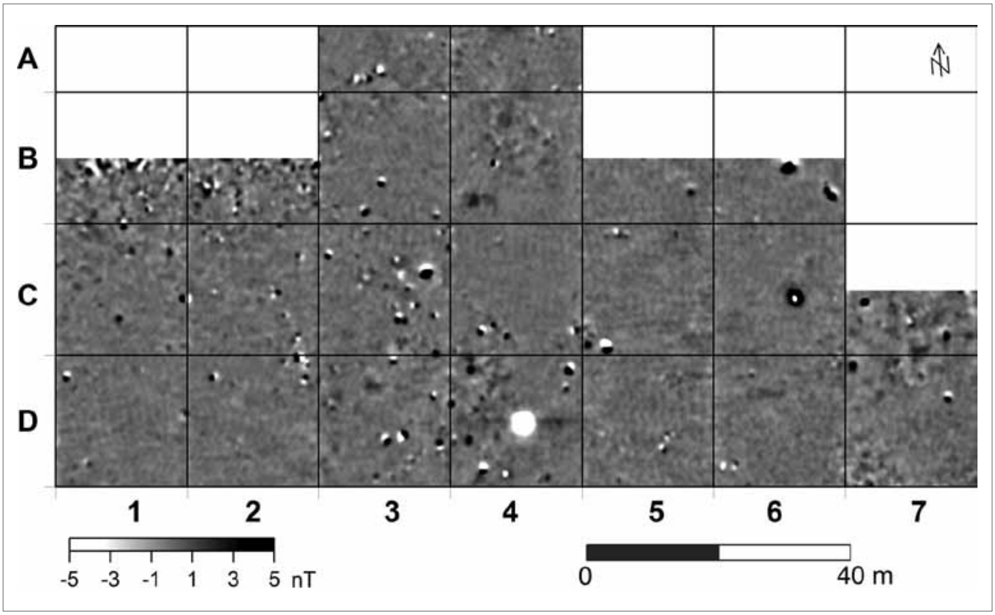


Fig. 6. *Magnetic map of Area A. Dynamics -3,4/+3,3 (white/black), sampling grid 0.25 x 0.50, interpolated to 0.25 x 0.25. Fluxgate gradiometer Geoscan Research FM36*

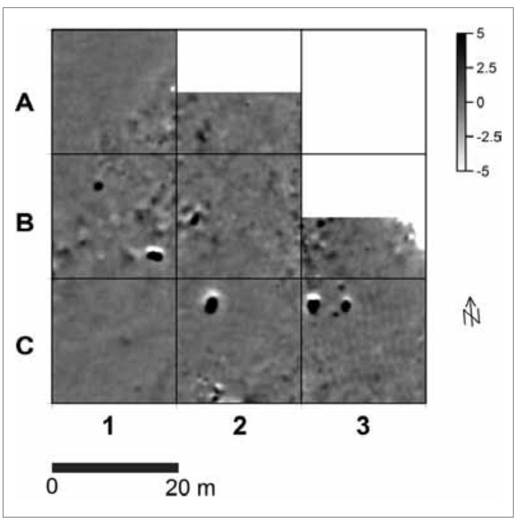


Fig. 7. *Magnetic map of Area B. Dynamics -5/+5(white/black), sampling grid 0.25 x 0.50, interpolated to 0.25 x 0.25. Fluxgate gradiometer Geoscan Research FM36*

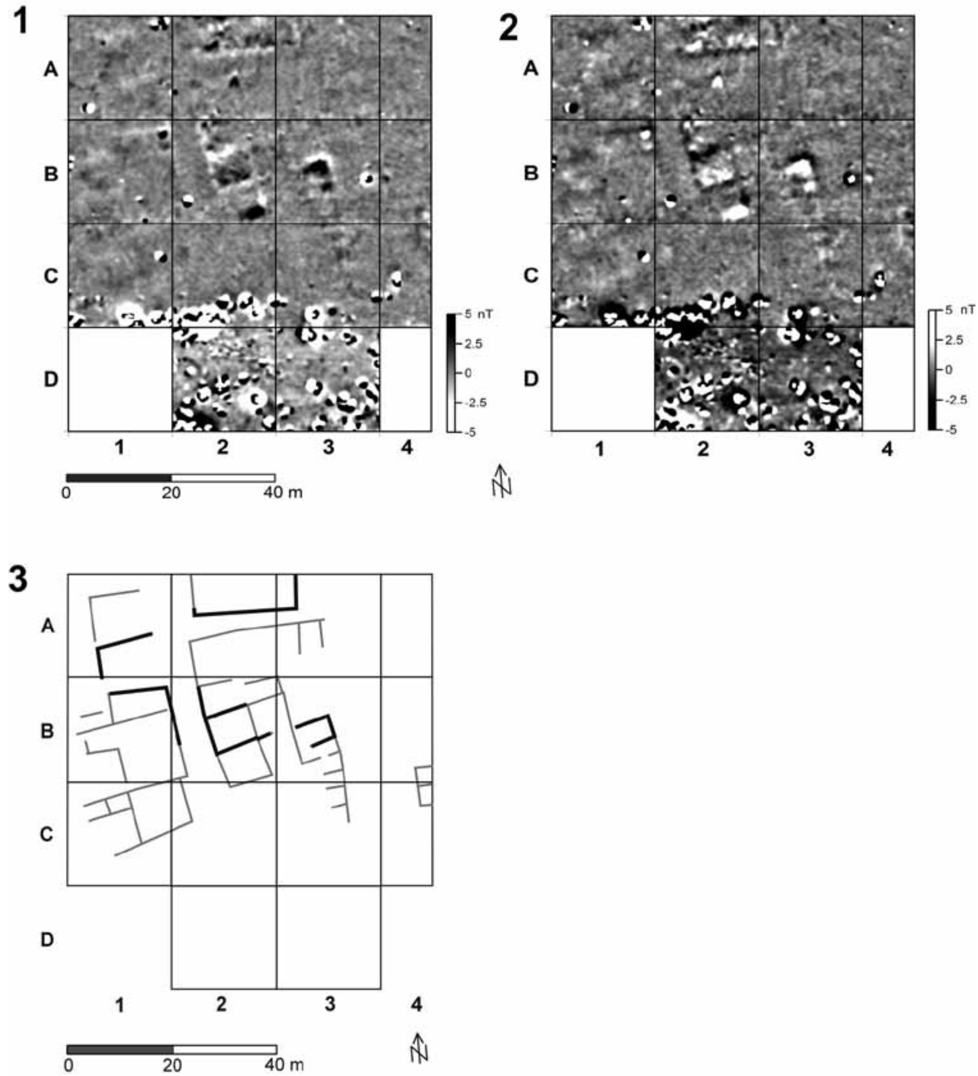


Fig. 8. *Magnetic map of Area C. 1 — Dynamics -2,5/+3,5 (white/black); 2 — Dynamics -2,6/+2,1 (black/white); sampling grid 0.25 x 0.50, interpolated to 0.25 x 0.25. Fluxgate gradiometer Geoscan Research FM36; 3 — hypothetical course of building walls reconstructed based on magnetic map (Processing T. Herbich)*

One of these, running N–S, can be observed in a section approximately 40 m long between the interface of A1 and A2 and the northwestern corner of C2. The other street, latitudinal in orientation, could be traced for approximately 20 m in the central part of A2 and western end of A3. Oval anomalies with raised values in the corners of particular units could reflect fireplaces or ovens (northeastern part of B1 and by the northern edge of B2). Areas with raised magnetic field intensity in the corners of units (southeastern corner of B2 and the center of B3) could correspond to furnaces or hearths with large quantities of burned material around them (or concentrations of ashes in the corners of rooms). The edges of a square area with raised values mark the edges of a room(?) at the western edge of a bigger complex. The magnetic disturbance noted in the southern part of the area (to the south of the southern parts of squares C1–C3) are caused by metal objects.

Conclusion

The research has demonstrated that on sites with a geological and archaeological setting like Marina el-Alamein GPR surveying is the most effective method of geophysical prospection for archaeological features not observable on the ground. It appears useful in tracing both aboveground structures (although this statement will need further archaeological verification) and the underground staircase-corridors and open courtyards filled with sand belonging to the rock-cut hypogeum tombs. Bedrock salinity reduces the penetration range to a maximum depth of 1.50 m making it practically impossible to detect the burial chambers around the courts, if they are located deeper than that. This statement is based on the results of archaeological excavations. In two cases (T28 and T29), the courtyards and staircases of tombs were found where indicated, but the burial chambers around the courts were not reflected in the radargrams.

The survey also showed limited usefulness of the magnetic method in some areas of the town where accumulations in particular units were characterized by higher magnetic susceptibility. In these areas the magnetic method was useful in mapping streets and the extent of particular architectural units.

Little GPR surveying has yet been done in this particular region and in similar geological and archaeological conditions to provide results for comparative analysis.[3] With regard to the magnetic method, similar conclusions as to the effectiveness of the method were reached in effect of surveying conducted at the site of Marea in the French concession. Magnetic mapping of the area showed anomalies characterized by lowered magnetic-field intensity values corresponding to walls of limestone blocks (Herbich 2005; Pichot 2010: 61).

[TH, HO]

3 Recently an electrical resistivity survey was carried out by Egyptian specialists in Taposiris Magna on the Mediterranean coast, halfway between Alexandria and Marina el-Alamein, but the news reports have yet to be translated into a scientific publication.

Archaeological verification of geophysical results

In the 2000 field season at the site in Marina el-Alamein, Professor Wiktor Andrzej Daszewski located trenches in two places suggested by the GPR survey results, in both cases "hitting gold", that is, uncovering archaeological features that had left no visible trace of their presence on the ground surface. In one case, a potential hypogeum tomb excavated in the rock was expected to the southeast of the main concentration of burials around the pillar tombs, in the back line of rock-cut hypogea at the southern limits of the site. Excavations revealed a squared pit cut into bedrock with still remaining rough rock steps used by the stonecutters [***Fig. 9***]. This feature, designated as S26, turned out to be not so much a tomb as a quarry of stone, possibly the beginnings of another tomb, abandoned for unknown reasons shortly after the quarrying had started (Daszewski 2001: 50–51). Limestone, presumably in blocks useful for building purposes in the town, was removed to a depth of approximately 2.00–2.20 m from an area about 6 m long on one side. Assuming a square-shaped shaft for the future courtyard of the tomb and the same depth over the whole pit, it would have given approximately 70–80 cubic meters of building material (more than a thousand regular-size blocks, measuring on average 0.60 x 0.30 x 0.30 m).

The other potential burial site was located centrally in the necropolis, just south of the complex of tombs T11–T13–T14–T16. The trench was considered as verificatory with regard to the GPR result, hence it was dug down to bedrock. Approximately one meter below ground level a stone burial mound (G13) was discovered [***Fig. 10***]. It was 2.75 m long (E–W) by 1.65 m wide (N–S) and was surrounded by a ring of upright slabs. Under the mound, which was 0.30–0.40 m high, was a grave in the form of a rectangular pit cut in bedrock (2.05 m long, 0.50–0.70 m wide, 0.50–0.55 m deep) and covered with a gabled roof of limestone slabs, concealed under the mound of small stones and sand. The grave contained a single skeleton of a woman aged 25–30 (Daszewski 2001: 51; 2002: 78). The pottery found in the fill and around the grave dated the burial to the 2nd century AD.

Three other tombs, two rock-cut hypogea (T28 and T29) and one aboveground box tomb (T25), uncovered in successive seasons, can also be traced on the GPR result, although the survey did not capture their full image. In the case of T28, which lies in the western part of the site in the middle tier of the necropolis, the structure registered in timeslices corresponded to the southern part of a large tomb with long corridor (altogether approximately 25 m long). Down the staircase one entered a deeply cut courtyard from where there was access to a big chamber on the south and a smaller chamber on the west, still with a sealed main niche. The undisturbed burial contained 10 mummified burials of men, women, children and one infant, including the body of an adolescent in a preserved cartonnage of the Hawara type dating from the early 2nd century AD (Daszewski 2001: 56–58; 2002: 75–78).

The other rock-cut hypogeum (T29) can be traced almost in its entirety in the timeslices: a fairly long staircase corridor entering a small courtyard which opened in

Fig. 9. *Results of verificatory exacavations in the necropolis of Marina el-Alamein: unfinished structure S26 (Photo W.A. Daszewski)*

Fig. 10. *Results of verificatory exacavations in the necropolis of Marina el-Alamein: tomb G13, mound and grave structure below mound (Photos W.A. Daszewski)*

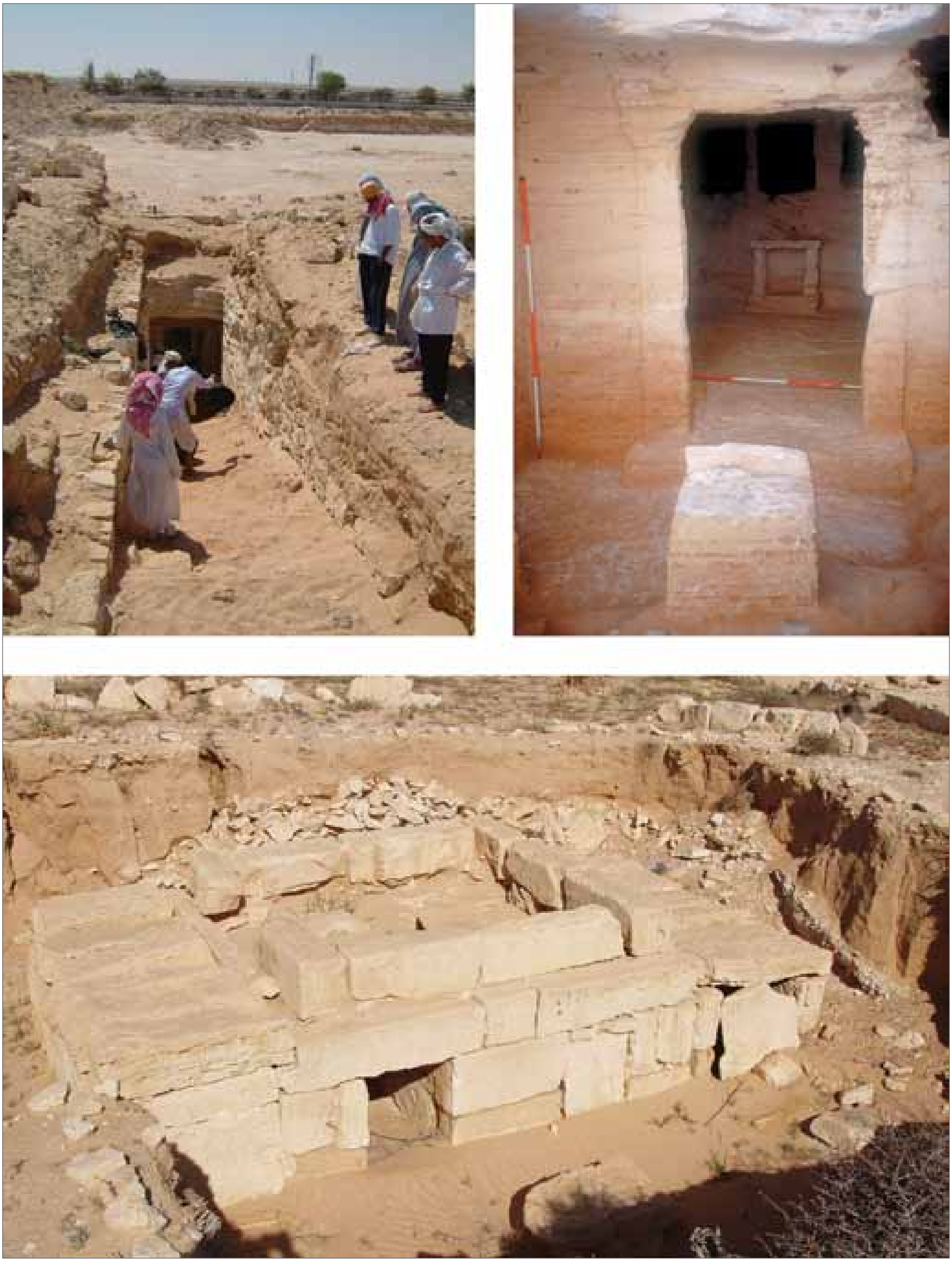


Fig. 11. Results of verificatory exacavations in the necropolis of Marina el-Alamein: Tomb 29, work on clearing the staircase (top left) and view of the underground court leading into the chamber (top right); Tomb 25 (bottom) (Photos W.A. Daszewski, I. Zych)

turn into a chamber that was small but which proved to be extremely varied in terms of the burial furniture [*Fig. 11*, top]. In the small space (altogether seven burial niches), there was a main niche with an elaborate wooden coffin containing two male burials placed head to toe, the niche adorned with a double uraeus in red paint on the back wall, a terracotta sarcophagus lying on the ground by a side wall, a sealing slab with representation presumably of a siren in relief, and two rectangular stone offering tables on lion's legs and a round table set on the floor of the chamber in front of the burial niches (Daszewski 2003: 51–56). In the case of this tomb, it had been cut quite close to the surface, therefore it was observed in the radargram starting at the depth of 0.50–0.60 m.

The last tomb that appears to be imaged in the GPR result and which was timeslices by the team is T25 [*Fig. 11*, bottom] just south and east of the complex of tombs T11–T13–T14–T16. It proved to be a rectangular masonry tomb, constructed of limestone slabs on the ancient ground level (now under a layer of sand from 0.70 to 1.10 m thick). The central cubic structure faced east like most of the box tombs of this kind; to this lateral niches were added on either side (end measurements of the extended tomb approximately 4.10 m [N–S] by 2.27 m [E–W], height 1.35 m). A column about 0.60 cm in diameter at the base, once adorned its top, but was not preserved (Daszewski 1999: 43–45, see Fig. 6 for a reconstruction of the appearance of this tomb; 2001: 49–50). Interestingly, a layer of limestone rubble and larger stones was accumulated in a sloping mound against the tomb's western, back wall and to some extent also against the northwestern corner, as if the rock chipping detritus from the cutting of a nearby tomb had been discarded in the empty space behind this tomb. In the timeslices this structure appeared at all depths of prospection.

[IZ]

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ABBREVIATIONS

AA	*Archäologischer Anzeiger*, Berlin
AAAS	*Annales archéologiques arabes de Syrie*, Damas
ABSA	*Annual of the British School of Athens*, London
AJA	*American Journal of Archaeology*, New York
APF	*Archiv für Papyrusforschung und verwandte Gebiete*, Leipzig, Stuttgart
ASAE	*Annales du Service des Antiquités de l'Égypte*, Le Caire
BAAL	*Bulletin d'Archéologie et d'Architecture Libanaises*, Beirut
BABesch	*Bulletin antieke Beschaving,* Louvain
BCH	*Bulletin de correspondance hellénique*, Paris
BdÉ	*Bibliothèque d'étude,* Le Caire
BEFAR	*Bibliothèque des Écoles françaises d'Athènes et de Rome,* Rome, Paris
BIFAO	*Bulletin de l'Institut français d'archéologie orientale*, Le Caire
BSFE	*Bulletin de la Société française d'égyptologie*, Paris
CCE	*Cahiers de la céramique égyptienne,* Le Caire
CCEC	*Cahiers du Centre d'études chypriotes*, Nanterre
CdÉ	*Chronique d'Égypte*, Bruxelles
CRAI	*Comptes rendus de l'Académie des inscriptions et belles-lettres*, Paris
CSEL	*Corpus Scriptorum Ecclesiasticorum Latinorum*, Vienna
EtTrav	*Études et travaux*, Varsovie
GM	*Göttinger Miszellen*, Göttingen
GRBS	*Greek, Roman and Byzantine Studies*, Durham, NC
IEJ	*Israel Exploration Journal*, Jerusalem
JbAC	*Jahrbuch für Antike und Christentum*
JEA	*Journal of Egyptian Archaeology*, London
JGS	*Journal of Glass Studies*, New York
JHS	*Journal of Hellenic Studies*, London
JJP	*Journal of Juristic Papyrology*, Warsaw
JRA	*Journal of Roman Archaeology*, Ann Arbor, MI
JRS	*Journal of Roman Studies*, London
KHKM	*Kwartalnik Historii Kultury Materialnej*, Warszawa
LIMC	*Lexicon iconographicum mythologiae classicae*, Zurich
MDAIA	*Mitteilungen des deutschen archäologischen Instituts, Athenische Abteilung*, Berlin
MDAIK	*Mitteilungen des deutschen archäologischen Instituts, Abeilung Kairo*, Wiesbaden
MEFRA	*Mélanges d'archéologie et d'histoire de l'École française de Rome. Antiquité*, Paris
MIFAO	*Mémoires publiés par les membres de l'Institut français d'archéologie orientale,* Le Caire
NC	*Numismatic Chronicie*, London
NumAntCl	*Numismatica e antichità classiche*, Logano
OLA	*Orientalia Lovaniensia analecta*, Louvain
PAM	*Polish Archaeology in the Mediterranean*, Warsaw
RACrist	*Rivista di archeologia cristiana*, Cité du Vatican
RBK	*Reallexikon zur byzantinischen Kunst*, Stuttgart

RDAC	*Report of the Department of Antiquities, Cyprus*, Nicosia
RdÉ	*Revue d'égyptologie*, Paris, Louvain
REPPAL	*Revue du centre d'études de la civilisation phénicienne-punique et des antiquités libyques*
RMNW	*Rocznik Muzeum Narodowego w Warszawie*, Warszawa
RSO	*Rivista degli studi orientali*, Roma
RTAM	*Recherches de théologie ancienne et médiévale*, Gembloux
RTAM	*Recherches de théologie ancienne et médiévale,* Gembloux, Louvain
SAAC	*Studies in Ancient Art and Civilization*, Kraków
VetChr	*Vetera christianorum,* Bari
ZPE	*Zeitschrift für Papyrologie und Epigraphik*, Bonn

* * *

DACL	F. Cabrol, H. Leclercq, *Dictionnaire d'archéologie chrétienne et de liturgie,* Paris, 1907–1953
LCI	E. Kirschbaum, W. Braunfels (eds), *Lexikon der christlichen Ikonographie*, Rom: Herder, 1968–1976
RealEnc	A. Pauly, G. Wissowa, W. Kroll, K. Mittelhaus*, Real-Encyclopädie der classischen Altertumswissenschaft,* Stuttgart–Münich, 1893–1980

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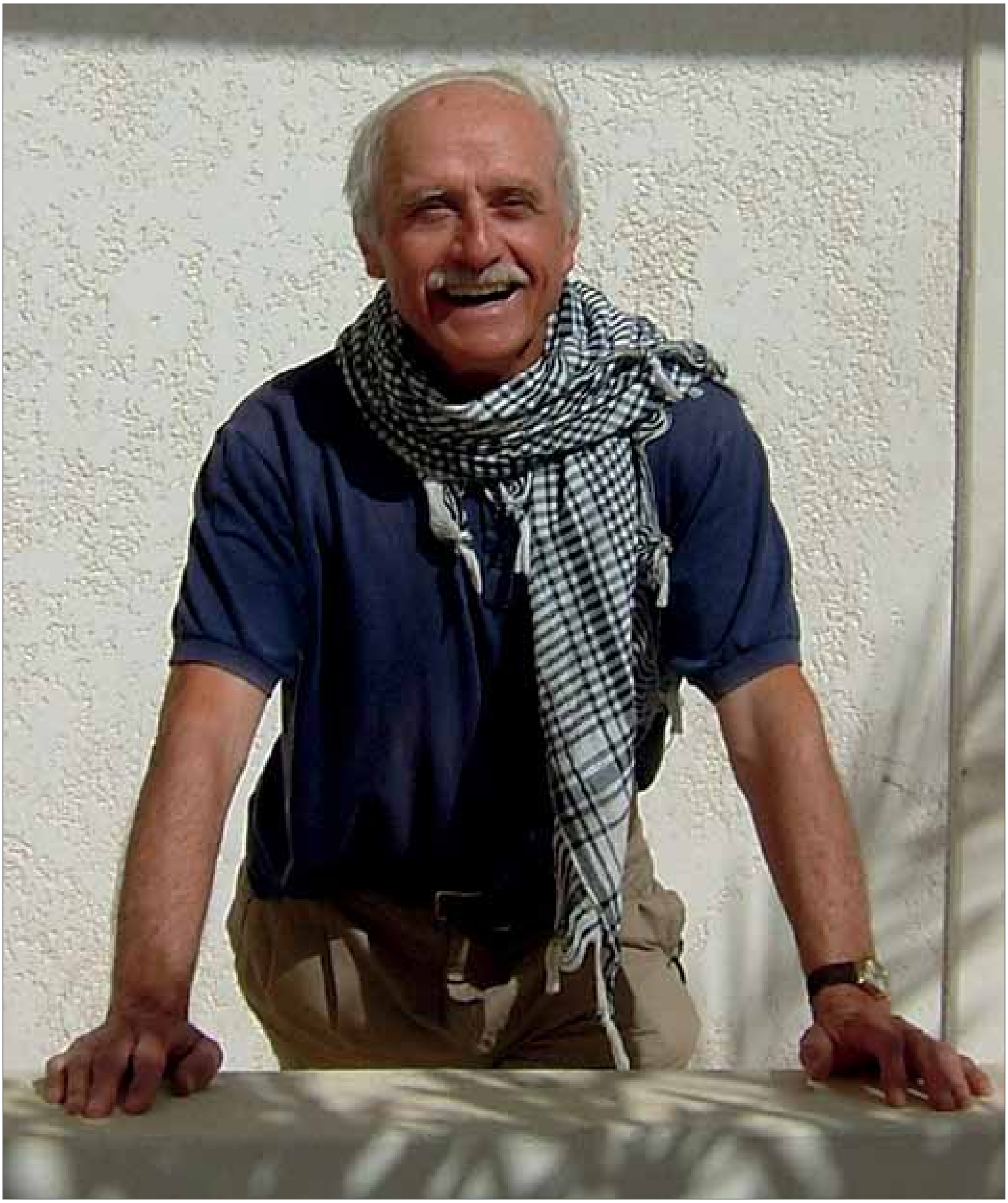

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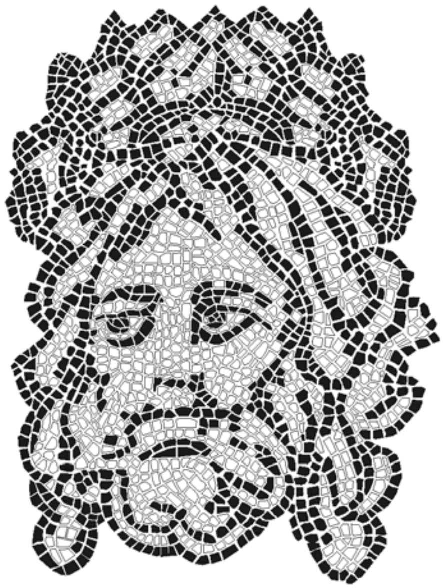

Essays Presented to
Wiktor Andrzej Daszewski
on his 75th Birthday

Polish Centre of Mediterranean Archaeology
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Wydawnictwo DiG

Reviewed independently for publication.

PCMA Publications Managing Editor: Iwona Zych

Editors: Henryk Meyza, Iwona Zych
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Image processing: Ewa Czyżewska
Cover design: Łukasz Rutkowski
Chapter vignettes: Krzysztof Kamiński
Photo on page 2: Artur Błaszczyk

Cover: Head of the god Aion from a Roman mosaic from Nea Paphos, 4th century AD

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(www.ifao.egnet.net)

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ISBN 978–83–7181–721–2

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