Archaeologia Polona, vol. 41:2003, 13–55
PL ISSN 0066-5924

Archaeological geophysics in Egypt: the Polish contribution

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The paper presents the Polish contribution to the geophysical prospection of archaeological sites in Egypt. The beginnings go back to the mid-1980s when surveying started on three sites, but research intensified only after 1997. Summing up, nearly 80 hectares on twenty sites have been prospected to date. The investigated sites represent a broad horizon, in chronological terms (from the 4th millennium BC to the 2nd millennium AD) as well as geographical ones (Delta, Middle and Upper Egypt, Oases, Mediterranean and Red Sea coasts). In most cases geophysical surveying has been found useful in mapping buried archaeological features, such as stone and mud-brick foundation walls, tombs, pottery kilns, and fireplaces. At a majority of the sites archaeological excavations have contributed to the verification of geophysical results. In a few cases the interpretation was based on the outcome of previous excavations.

The work was carried out in cooperation with the Polish Center of Mediterranean Archaeology of Warsaw University, the German, Austrian, French, American and Dutch Archaeological Institutes in Cairo, several independent research projects and PREDECONICET in Buenos Aires.

KEY-WORDS: archaeological prospection, archaeological geophysics, magnetic method, resistivity method, GPR, Egypt

THE BEGINNINGS IN THE 1980s

It so happens that the Polish presence in geophysics as applied to the study of archaeological sites in Egypt, despite a twenty-year history, is connected largely with the person of the author of this paper. What follows is in effect a review of the author's experience in geophysical prospecting at close to twenty sites all over Egypt (Fig. 1), sites that represent the full spectrum from settlements to burial grounds to industrial centers, situated in a variety of geological conditions and covering a chronological horizon of up to 6000 years.

The first site explored by a Polish expedition in Egypt to be prospected with geophysical methods was Tell Atrib, the ancient Athribis, modern Benha, situated in the Nile Delta. The objective of the research, which was carried out for the

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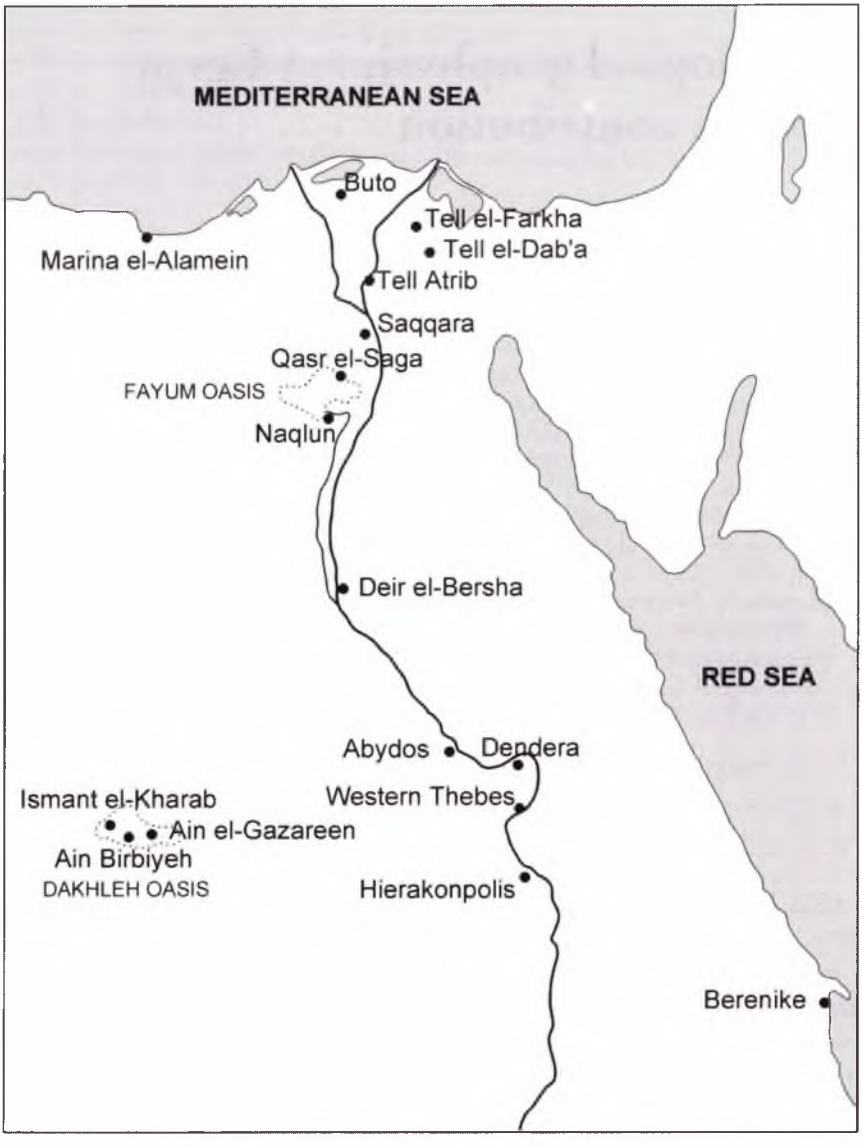


Fig. 1. Egypt. Location of sites discussed in the paper.

Polish Center of Mediterranean Archaeology of Warsaw University (PCMA) in 1985, was to identify remains of the Hellenistic and Roman periods (Myśliwiec and Herbich 1988). For the method electrical resistivity was chosen, applying the Schlumberger arrangement (current probes AB 4 m and 8 m apart; potential probes

Fig. 2. Saqqara, west of the Djoser funerary complex. Measurements with proton magnetometers taken in the Polish concession area.

MN 1 m apart) on a one-meter grid. The outcome was a map of changes in resistivity to a depth of 1.5–2 m, covering an area of 0.3 ha. Oblong features of higher resistivity in the deepest layers prospected could obviously be related to the presence of structures erected of stone or baked brick, but the high water table at the site precluded a verification of this hypothesis. Another area of the site was also prospected in search of the foundations of the church of the Holy Virgin, which written sources reported as being located just north of Kom Sidi Yusuf. Renown for the richness of its decoration, the sanctuary had been erected in the 5th century and was destroyed around the early 8th (Ruszczyc 1986). An area of higher resistivity was noted, irregular in outline, but of a size putatively corresponding to the temple. It may have reflected rubble filling the ruins of the church. Excavations preceding the resistivity survey had revealed at a depth of *ca.* 1 m a fired brick building with features typical of churches of the period. Unfortunately, it turned out impossible to verify the results archaeologically.

The next year geophysical prospecting was carried out at the site of the ancient Coptic monastery at Deir el-Malak Gubriel in Naqlun (Godlewski, Herbich and Wipszycka 1990). This time the method of choice was magnetometry, chiefly because of the known magnetic properties of mud brick commonly used for building

Fig. 3. Saqqara, west of the Djoser funerary complex. Measurements with a proton magnetometer PMP-4. A child's horn served to synchronize the traversing and stationary apparatus.

at the monastery. In Egypt, the magnetic properties of mud brick made of Nile silt had first been taken advantage of successfully in the survey at Mirgissa (Hesse 1970). A Polish-made proton magnetometer PMP-4 with 1 nT resolution was used. Since the instrument was designed to measure the total intensity of the Earth's magnetic field, it was necessary to refer the measurements to reference points in order to eliminate fluctuations due to diurnal variations of the Earth's magnetic field. The sampling interval was 1 m and the area covered totaled 0.62 ha. Some readings of a demonstrably higher magnetic-field intensity were recorded, to be confirmed in later excavations as the sites of buildings destroyed in a conflagration (Godlewski, Herbich and Wipszycka 1990). Overall, however, the measurements turned out to be of limited use to the excavators.

The work at Tell Atrib and Naqlun provided the author, participating in the excavations in his capacity as archaeologist, with the unique opportunity for testing geophysical methods in what was for him new territory. The primary objective was to evaluate the various methods' usefulness in the conditions of Egyptian archaeology; hence, it was not expected of the author in either case to provide ground-breaking results.

Nonetheless, the next prospection – at Saqqara in 1987 – was specifically tailored to answer certain research issues. The Polish Center had been granted a license to explore part of the valley west of the Djoser pyramid enclosure (Fig. 2). The area had escaped systematic archaeological exploration even though the presence of tombs was only to be expected under the sand. Faced with the task of planning excavations in an area totaling some 4 ha and devoid of any surface traces, it was only logical to call in the geophysicists. The typical building material of Old Kingdom tombs was non-magnetic limestone, but mud brick made of Nile silt was known to have been used in these complexes for building accompanying structures. The hope that mud brick structures, once recorded, would lead to the tombs proper (either constructed of limestone or consisting of burial chambers cut in

Fig. 4. Saqqara, west of the Djoser funerary complex. Toppled mud brick remains the covering entrance to the funerary chapel of Meref-nebef.

limestone bedrock) prompted the choice of the magnetic method for the research. Measurements were taken with two PMP-4 proton magnetometers; the difference between readings taken simultaneously by the instrument at the base station and on the traverses was the only value registered during the survey (Fig. 3). Prospecting at one-meter sampling intervals in an area of 1.23 ha mapped in effect three anomalous zones, which were subsequently tested archaeologically. A limestone wall was found to correspond with the largest of the anomalies (Myśliwiec, Herbich and Niwiński 1995), but the actual reason for the anomalous reading was established only ten years later (when the excavations were reopened in 1996). It had reflected the mud brick debris that was found to lie against the east side of the stone wall (Fig. 4). Under the rubble an expedition directed by Karol Myśliwiec cleared the entrance to a rock-cut funerary chapel. The tomb with its unique painted decoration belonged to an unrecorded official, one Meref-nebef who was the vizier of Pharaoh Teti of the 6th Dynasty (Myśliwiec 1998) (Fig. 5).

Following an eight-year break, the author returned to Egypt in 1995, taking up a position at the Polish Center's Cairo institute and resuming his involvement with archaeological geophysics in the study of Egyptian sites. The project has been ongoing ever since (except for a break in 2000 and most of 2001), being planned

Fig. 5. Saqqara, west of the Djoser funerary complex. Entrance to the funerary chapel of Meref-nebef. Old Kingdom, 6th Dynasty. Photo: Stefan Sadowski.

either as part of the fieldwork of expeditions organized by the Polish Center or in cooperation with other archaeological institutes active in Egypt. The presentation of particular surveys in this paper will follow a geographical order.

METHODS OF SURVEY

The magnetic method was applied on most of the below described sites. The equipment used were Geoscan Research FM 18 and FM 36 gradiometers, applied at sampling intervals of 0.5 by 0.5 m or 0.5 by 0.25 with a resolution value of 0.1 nT. Measurements were taken in rectangular grids of 20 by 10 m. Attention was paid to procedures permitting potentially the most exact measurements: a zero reference point was selected and the alignment of the fluxgate sensors was checked and adjusted to this point after each grid had been completed; the measurements were always done in parallel mode.

Electrical resistivity surveys were carried out with two types of apparatus: ARA (Herbich, Misiewicz and Mucha 1998) or Geoscan Research RM 15. The sampling interval was 1 by 1 m (ARA) or 0.5 by 1 m (RM 15). The actual arrangements will be cited when discussing particular results.

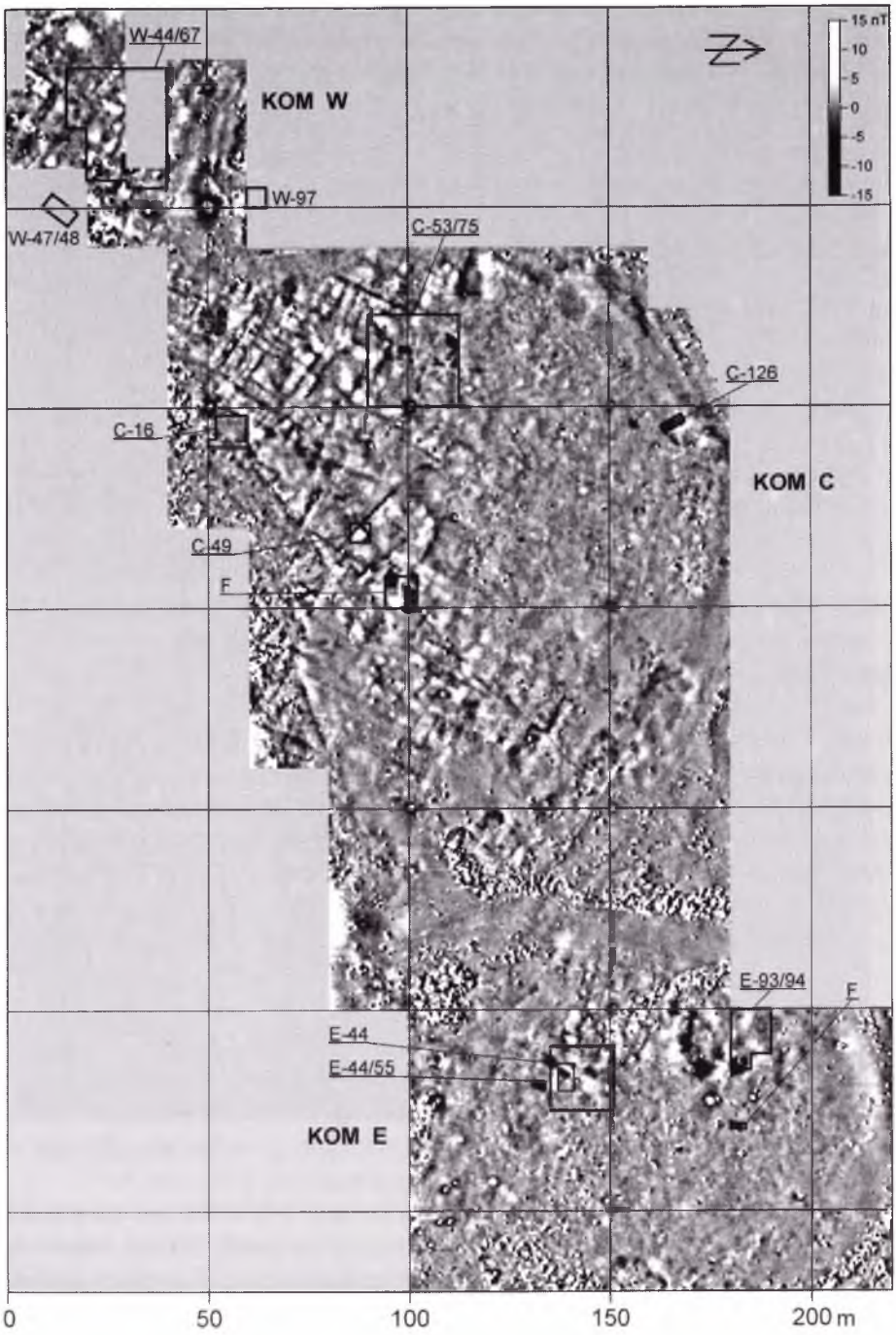
Geoplot software was used to process magnetic data, and map print-outs were prepared with Surfer.

THE DELTA

Tell el Farkha

The Tell el Farkha site includes three mounds covering a total area of *ca.* 400 by 100 m and rising 4–5 m above the surrounding fields. An Italian expedition working there in 1988–1990 had identified a settlement with remains of mud brick architecture dating from the Late Predynastic to Old Kingdom times (Chłodnicki, Fattovich and Salvatori 1992). In 1998 a Polish expedition resumed the explorations (Chłodnicki *et al.* 2002), opening trenches on the central and western mounds (*kom* C and W), but simultaneously initiating a geophysical survey of 80% of the area (Chłodnicki and Herbich 2001). The magnetic method was selected despite theoretically unfavorable conditions, including multi-layering of the site (the mounds are the outcome of cultural accumulation) and the possibility of no contrast being apparent between mud-brick structures and the silt that was a principal component of the cultural layers. The choice of method was based on the Qantir results, which had demonstrated that mud-brick walls could be traced in a mud matrix (Becker and Fassbinder 1999, Pusch, Becker and Fassbinder 2000).

Measurements of an area totaling 3.35 ha (of which 0.65 ha was surveyed by Christian Schweitzer in 2000) provided a fairly exact mapping of mud architecture in the uppermost layers corresponding to the terminal period of settlement on the site (Early Old Kingdom) (Fig. 6). The loss of feature imaging on the central mound


W-44/67
KOM W
W-97
W-47/48
C-53/75
C-126
C-16
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F
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F
E-44
E-44/55
KOM E
15 nT
10
5
0
-5
-10
-15
0
50
100
150
200 m

Fig. 7. Tell el Farkha. *Kom* C. Trench C-49, view of structures at a depth of 0.20 below the surface. View from the southeast.

looking to north was due to the increasing thickness of late deposits overlying layers with architectural remains. The best visible structures were the ones found immediately under the surface of the ground: a wall in trench C-49, reflected on the map as a distinct elongated negative anomaly (values up to –10 nT), was visually practically indistinct from the mud matrix in the trench (Fig. 7). The less than distinct imaging of features on the western mound was again the result of these objects lying deeper (more than a meter) underground.

The complex of features registered on the eastern mound (*kom* E) turned out to be extremely interesting from the archaeological point of view. Plotted in negative values on the magnetic map were rectangular anomalies measuring from 1.5 m by 2.5 m to 2 m by 3.5 m (Figs 6, 8A). These upon being tested archaeologically turned out to correspond to Predynastic burials (Figs 8B, 9; Herbich 2003a). The anomalous values had been caused by the fill of the tombs which included large quantities of burned bricks, some of exceeding size (see figs 8–9 in Chłodnicki and Ciałowicz 2001).

Fig. 6. Tell el-Farkha. Magnetic map and the location of excavations in the 1998–2002 seasons. Sampling interval 0.50/0.25 m interpolated to 0.25/0.25 m. Excavation of Fattovich (1988–1990) marked with F.

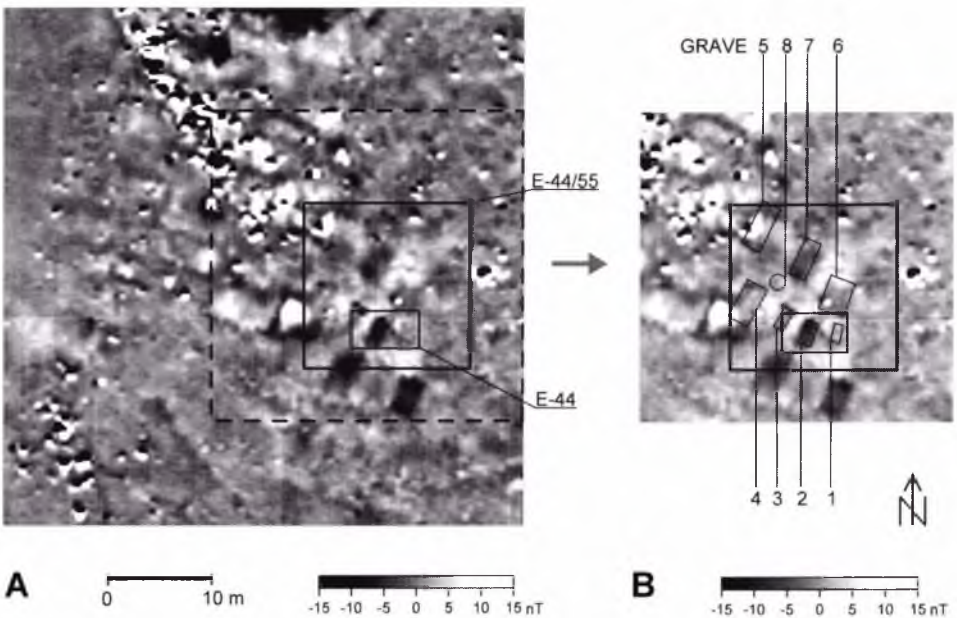

Fig. 8. Tell el-Farkha. *Kom* E. A. Magnetic map of the southwestern part of the eastern mound). Sampling interval 0.50/0.25 m interpolated to 0.25/0.25 m. Trench E-44 = extent of excavations in 2001; trench E-44/55 = extent of excavations in 2002. Dashed line marks the section shown in Fig. 4B. B. Schematic plan mapping the position of tombs nos. 1 to 8, superposed on a section of the magnetic map.

The investigations at Tell el-Farkha were exploratory but also documentary in nature, reconstructing precisely the geodetic site grid established by the Italian expedition in the 1980s (point anomalies on the crossing of grid lines correspond to iron rods used as measuring points dug deep into the ground). The map also created the opportunity for a precise situation of two of the Italian expedition's three trenches (Fig. 6).

Tell el-Fara'in – Buto

An expedition from the German Archaeological Institute (DAI) has concentrated on the northeastern part of a mound totaling about 60 ha in area and rising some 20 m above the surrounding fields. Their research objective is to study the earliest settlement on the site, that is, the Predynastic period when Buto was the most important urban center in the Delta. The site remained inhabited until Late Antiquity (von der Way 1997).

Geophysical research began in 1999 with a test of the method's usefulness on a hectare of fairly flat ground. Earlier explorations had suggested the presence of

Fig. 9. Tell el-Farkha. *Kom* E. Trench E-44, view from the south. Tombs 1, 2 and 3 (right to left). Tomb 3 after the pottery was removed from the northern end of the burial chamber.

Predynastic features even 1 m below the surface (Faltings *et al.* 2000). Tracing of putative Predynastic objects turned out to be quite poor, because of the depth at which they occurred as much as their inherent "flimsiness" (building walls usually less than 0.5 m thick) (Fig. 10, squares A-B 2–4). Furthermore, the adjacent Roman cemetery where the dead were buried in terracotta coffins interfered with the measurements, the pieces of these coffins lying above the Predynastic level frequently giving disturbed readings. Even so, the survey brought unexpected results concerning the later layers on the site: casemate buildings from the Saitic period (1st millennium BC) are distinctly delineated on the magnetic map (Fig. 10, squares B-D 5–7). Walls of Saitic buildings had been registered earlier in research done by Dina Faltings, but were recorded only as cross-sections through walls visible in the trench walls. Magnetic prospecting provided the first hard evidence of their layout and actual size (Hartung *et al.* 2003).

The opportunity for comparing the geophysical image of features with their real appearance came with the excavations of Ulrich Hartung (Hartung *et al.* 2003) (Fig. 11). The gradually deteriorating distinctness of the image of buildings on the magnetic map is due to the thickening layer of deposits over these features; on the north this superimposed accumulation had reached around 0.80 m. A series of local high-amplitude anomalies, superimposed on the anomalies reflecting building

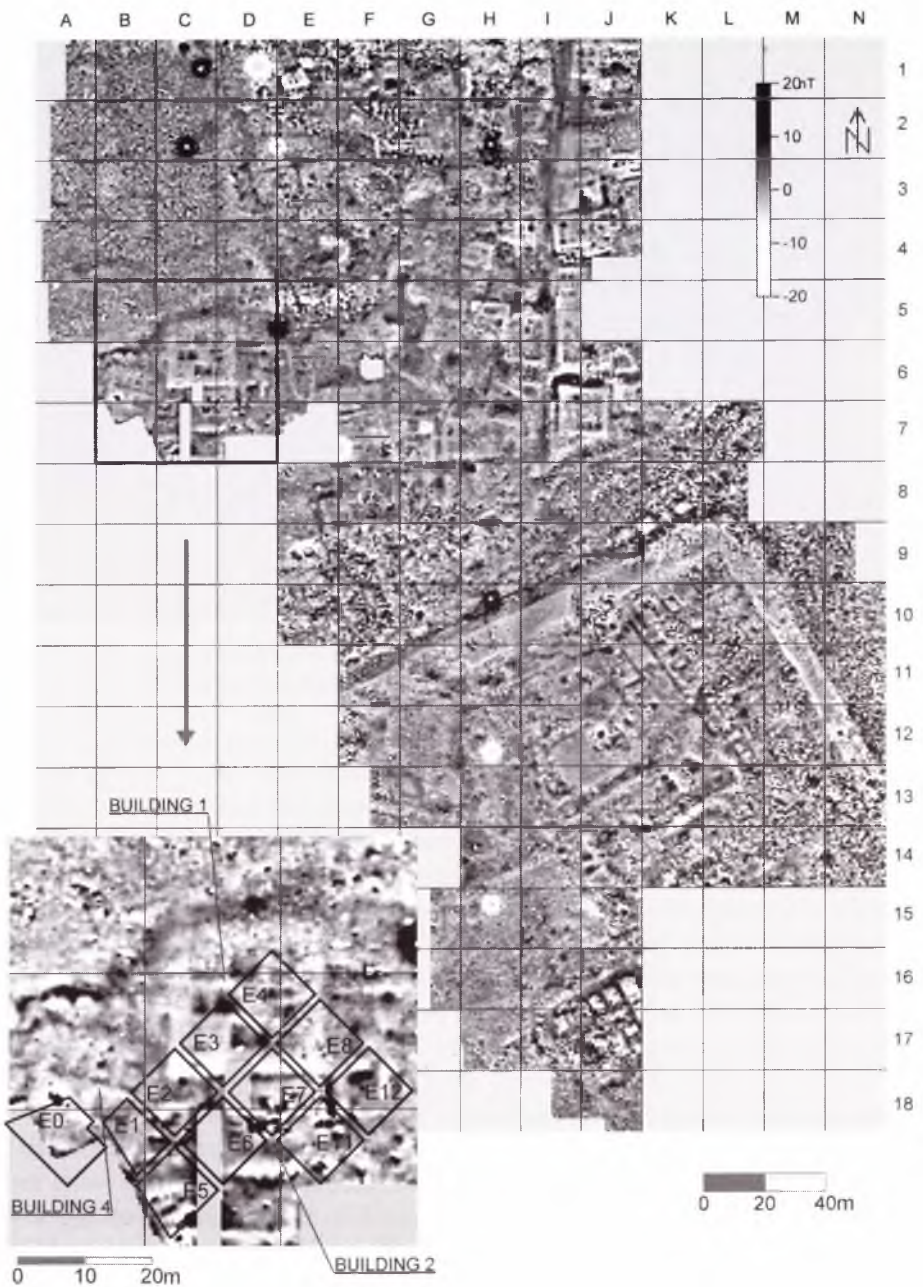

Fig. 10. Tell el-Fara'in – Buto. Magnetic map (surveys in 1999–2002) and location of excavations of the casemate buildings. Sampling interval 0.50/0.25 m.

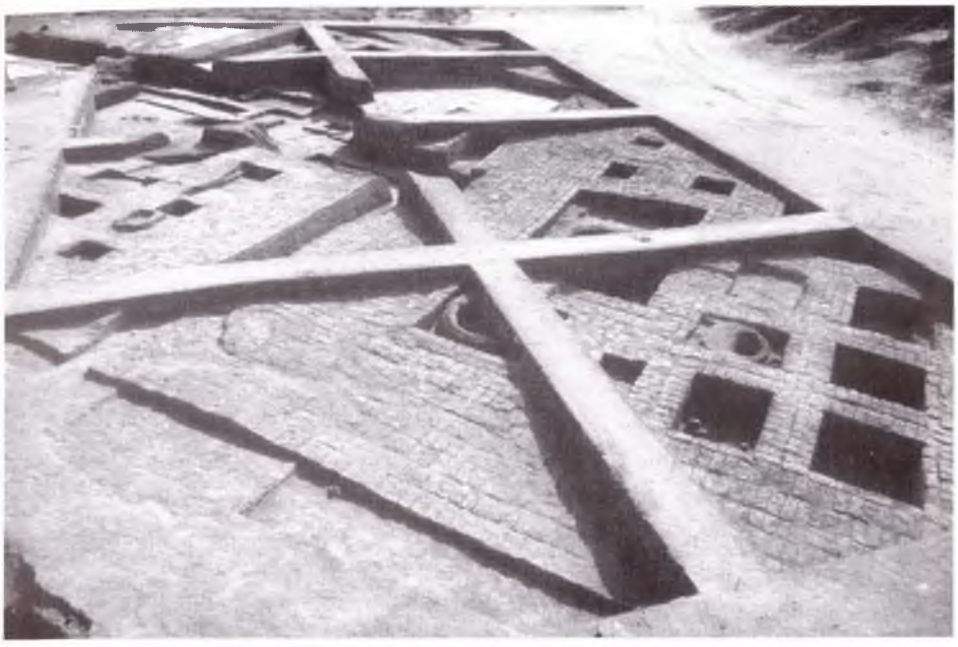

Fig. 11. Tell el Fara'in – Buto. Casemate building 1 (on the right), building 2 (on the left) and building 4 (at the back). View from the northeast.

layout, corresponded to furnaces and concentrations of ashes (Fig. 10, trenches E1, E2, E5, E12), hearths (E1, E2), clay coffins and scatters of fired brick (E7). The anomaly that followed the course of the south wall of building 1 was caused by quantities of potsherds concentrated in the narrow space between buildings 1 and 2. The foundations of Saite-period buildings reached a depth of 1.5 m, hence Predynastic structures had to be looked for at a depth of about 1.5 m below ground surface, that is, beyond the reach of the instrument.

In 2002 the surveyed area was extended substantially (total surveyed area in 1999 and 2002 is 5.5 ha). In the area west of the buildings uncovered in 1999, a whole complex was discovered with analogous plans, but of varying dimensions that ranged from 8 m by 8 m to 20 m by 20 m.

Completely new data regarding the urban layout of Buto came from a geophysical survey in the southern part of the explored area (Fig. 10, south of line 8/9). A wall 8 to 12 m thick was discovered here. It was not of homogeneous structure (suggesting alterations and additions perhaps, as for instance in the section between G11 and I10). The course of the wall corresponded to the edge of the depression (assuming it was an enclosure wall, then the depression corresponded to the space inside the enclosure). The presence of the wall was not manifested on the surface by any evident

Fig. 12. Tell el Fara'in – Buto. Magnetic map, measurements in 2001. Sampling interval 0.50/0.50 m. F3-F6 mark furnaces revealed in trench P1.

remains; neither was there any surface evidence of wall-enclosed architecture; merely the building in squares I-J 16–18 corresponded to a mound. The enclosure (?) lay on the opposite side of the tell from the sole temple, possibly from the Late Period, discovered to date at Buto. The temple precinct had a mud brick enclosure, *ca.* 300 m by 200 m, with walls 17–25 m thick (von der Way 1999). The length of the SW-NE enclosure (?) wall section traced on the magnetic map is 160 m. It ran parallel to the long axis of the temple; hence it is possible to speak of symmetry in the situation of the two complexes. The outcome of the prospection strongly suggested a complex of monumental character, which, however, can be verified only by actual excavating started in the spring of 2003.

At the northern edge of the site traces of ceramic production were visible on the surface in the form of large quantities of slag, burnt soil and potsherds. Pascal Ballet's team field-walking the site discovered the remains of two kilns (Faltings *et al.* 2000); the objective of magnetic research was to locate other kilns in the area. The prospection covered an area of 3.1 ha and identified at least forty kilns (Fig. 12). These are marked on the map as oval anomalies 2–3 m in diameter, exhibiting high amplitudes of values (over +/–30 nT); they were recorded in terrain with evident surface evidence of ceramic production (Fig. 12, in area A and in the southwestern part of area B), as well as in places where nothing on the ground could suggest it (Fig. 12, L-M 1–4, M8, M10).

Fig. 13. Tell el-Fara'in – Buto. Trench P1, viewed from the northwest.

Verification by excavation confirmed the magnetic-survey results: in trench P1 all the anomalies interpreted as kilns turned out to be kilns (Figs 12–13). The results justify the conclusion that Buto was an important manufacturing center of Late Ptolemaic and Early Roman fine wares. Fragments of unfired vessels discovered in the kilns illustrated the entire production process (Hartung *et al.* 2003).

Magnetic prospection also led to the recording of a series of elements representing town architecture in the pottery manufacturing area. The most intriguing of these is an oblong anomaly 5 m in width, uncovered in area B (Fig. 12). It consists of three segments, each with a different orientation and irregular course, the combined length reaching some 200 m. Ballet's excavations in 2002 verified this anomaly as a mud brick wall (Hartung *et al.* 2003). The verification also concerned a building of the casemate type adjoining the mud brick wall.

Tell el-Dab'a (Avaris)

Geophysics at Tell el-Dab'a – otherwise Avaris, the Hyksos capital in the Second Intermediate Period – were prompted by Becker's and Fassbinder's excellent results at nearby Qantir (Pusch, Becker and Fassbinder 2000). The Austrian Archaeological Institute in Cairo had started explorations in 1999 in an area along the bank of the former Pelusiac branch of the Nile. The site of the Hyksos citadel at Ezbet Helmi had been re-occupied in the 18th Dynasty when palatial installations formed a new royal citadel. The Austrian expedition uncovered the foundations of palatial platform F, followed by the southeastern corner of a palace (designated as G) of the 18th Dynasty (Fig. 14) (Bietak 1996, Bietak, Dorner and Jánosi 2001).

Magnetic prospecting in the area of palace G provided a near complete plan of the building's layout, showing a close resemblance to that of palace F except for the size: while the palatial fortress F is 47 m by 70.5 m, G measures 83 m in width and no less than 160 m in length (a more precise estimate is not possible due to poor imaging of the southwestern palace wall). Several factors combined to make for the walls' distinctness on the magnetic map, the most important being the underlying geological structure that substantially contrasted the magnetic values between mud-brick walls and their surroundings (the area of Ezbet Helmi lies on a now-buried sand mound, a so-called *gezira* or "turtle-back", which was the preferred area for settlement as it stayed above the annual Nile inundation). Other factors included the size of the buildings (thickness of the walls) and their shallow deposition. Excavations which directly followed geophysical prospecting used the magnetic results to position the trenches (Bietak, Dorner and Jánosi 2001) (Fig. 15).

The objective of research in the northeastern part of Ezbet Helmi was to trace the course of citadel walls, a section of which had been uncovered by the northern corner of palace F. It was a buttressed wall, originally 6.2 m wide at the base, later enlarged to

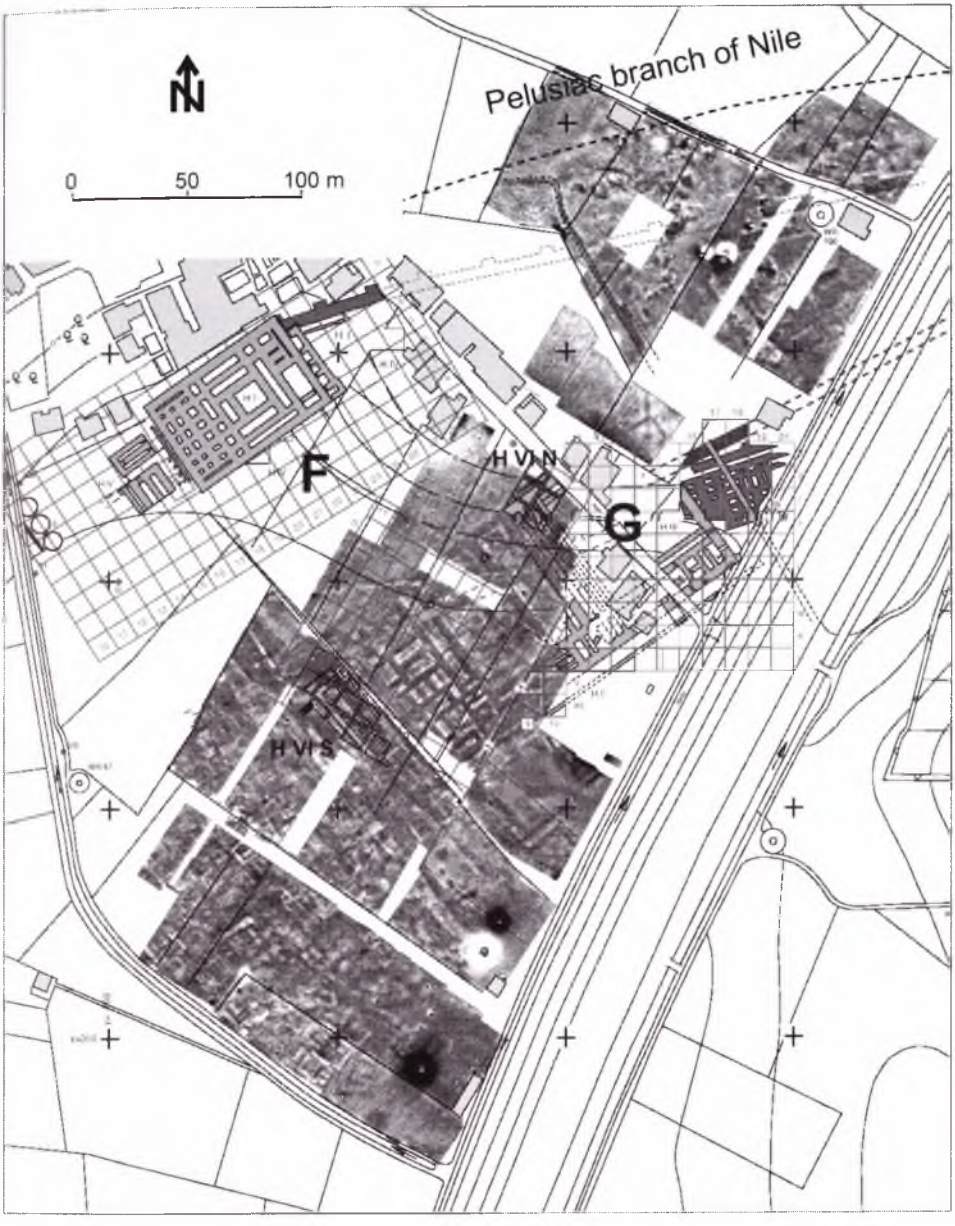

Fig. 14. Tell el-Dab'a. Magnetic map of the Ezbet Helmi area, 1999 season. Sampling interval 0.50/0.25 m (based on drawing by Lisa Majerus).

Fig. 15. Tell el-Dab'a. Excavations of the northwestern wall of the palace G (Trench H VI N). View from the northeast.

nearly 8.5 m. The survey showed the wall to continue eastward, but on a slightly different axis (slightly off to the south regarding the axis reconstructed on the basis of the excavated section of the fortifications) and about 100 m east of the end of the uncovered part (Fig. 14). The anomaly clearly corresponded to the wall, for it was of the same width as the excavated part of the wall and the distance between the buttresses was the same as that known from excavations. The survey southwest of palace G mapped a complex of town architecture with houses demonstrating a typical New Kingdom layout. Measurements in 1999 in Ezbet Rushdi covered a total area of 5.2 ha.

In 2000 Christian Schweitzer continued the survey at Ezbet Helmi using the same apparatus. He recorded fragments of domestic installations situated west of palace F and traced the course of New Kingdom defenses west of Didamun Canal, in the region of Ezbet Rushdi.

In 2002, prospecting with a fluxgate gradiometers (Herbich and Kołodziejczyk) and a Scintrex Smartmag SM4G caesium magnetometer system (Schweitzer) in 2002 covered a total of 16 ha, mainly in Ezbet Rushdi. The outcome was a plotting on the magnetic map of a number of urban complexes, a dyke and a water reservoir. Excavations are planned to help in a detailed interpretation of particular elements of the architecture.

NILE VALLEY

Saqqara

The geophysical survey in 1987 covered only about a quarter of the Polish concession; thus, as soon as work was resumed in 1996, the idea of prospecting the area with geophysical methods returned. The survey was carried out for the Polish expedition by Helmut Becker and Jörg Fassbinder using the Scintrex Smartmag SM4G caesium magnetometer system. An area of 4 ha was covered, registering a series of anomalies in the eastern part of the area that were undoubtedly caused by the remains of funerary superstructures (Fassbinder, Becker and Herbich 1999), presumably mounds of mud brick debris explaining the irregularity of the anomalous areas. The 1987 results (see above) had already indicated that mud brick could occur in association with the kind of monumental stone architecture that escaped registering on a magnetic map. Two square-shaped anomalies (*ca.* 10 by 10 m) could be interpreted as the enclosures of burial shafts. Structures of this kind, typical of the Late Period, are known from Saqqara just as well as from nearby Abusir (Bareš 1999).

A parallel survey of the same area was carried out by a team of geophysicist from the National Research Institute of Astronomy and Geophysics in Helwan, using Geoscan FM 36 (see Abdellatif in this volume).

In 1999 measurements were repeated with Geoscan FM 36 in an area where the recorded anomalies had been interpreted as a wall enclosure around a shaft opening. The data gave a very clear picture (as distinct as the image obtained with a caesium instrument) (Fig. 16). A verificatory trench brought to light a mud wall *ca.* 0.60 m thick, lying at a depth of about 50 cm below the surface (Fig. 17). These measurements best illustrate the potential of the magnetic method in registering

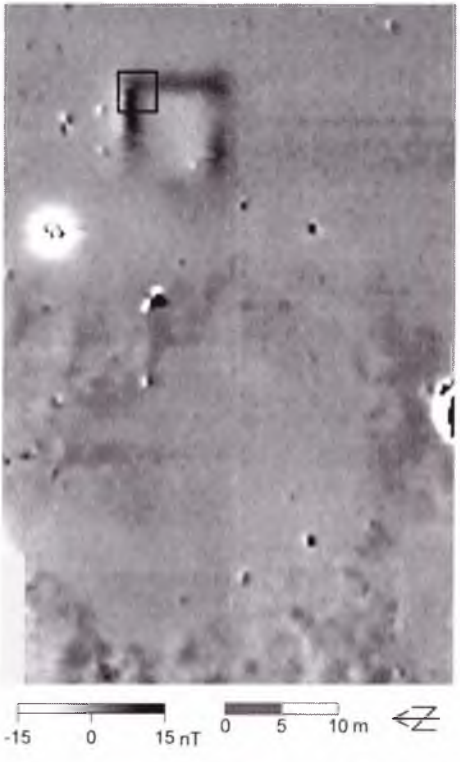

Fig. 16. Saqqara, west of the Djoser funerary complex. Detail (fragment) of the magnetic map and the localization of trial pit 4/99. Sampling interval 0.50/0.25 m interpolated to 0.25/0.25 m.

Fig. 17. Saqqara, west of the Djoser funerary complex. Trial pit 4/99. Mud-brick wall.

mud-brick architecture erected in sand. This potential was taken advantage of with excellent results by the Saqqara Geophysical Survey Project led by Ian Mathieson (Leahy and Mathieson 2002) and during Roman Křivánek's prospecting in nearby Abusir (see Křivánek and Bárta in this volume).

Deir al-Barsha

The survey was conducted for an expedition of the Catholic University in Leuven, Belgium, working in a Middle Kingdom necropolis that was situated on a desert plateau between the cliff-like *gebel* and the cultivated land at the mouth of Wadi Deir el-Nakhleh. Measurements were taken on either side of a canal managing water from the *gebel*, a total area of 7.2 ha. The objective was to provide data for planning excavations in the necropolis starting in 2002. The area had already been quite methodically penetrated by robbers as much as by archaeologists (Robinson 1992), leaving a strongly diversified ground surface relief (mounds and pits), even to the point of making measurements impossible.

The principal feature on the magnetic map was a narrow linear anomaly 3–4 m wide, following a NWW-SEE orientation all through the area in question (Fig. 18). The anomaly disappeared where water-related erosion of the ground was substantial.

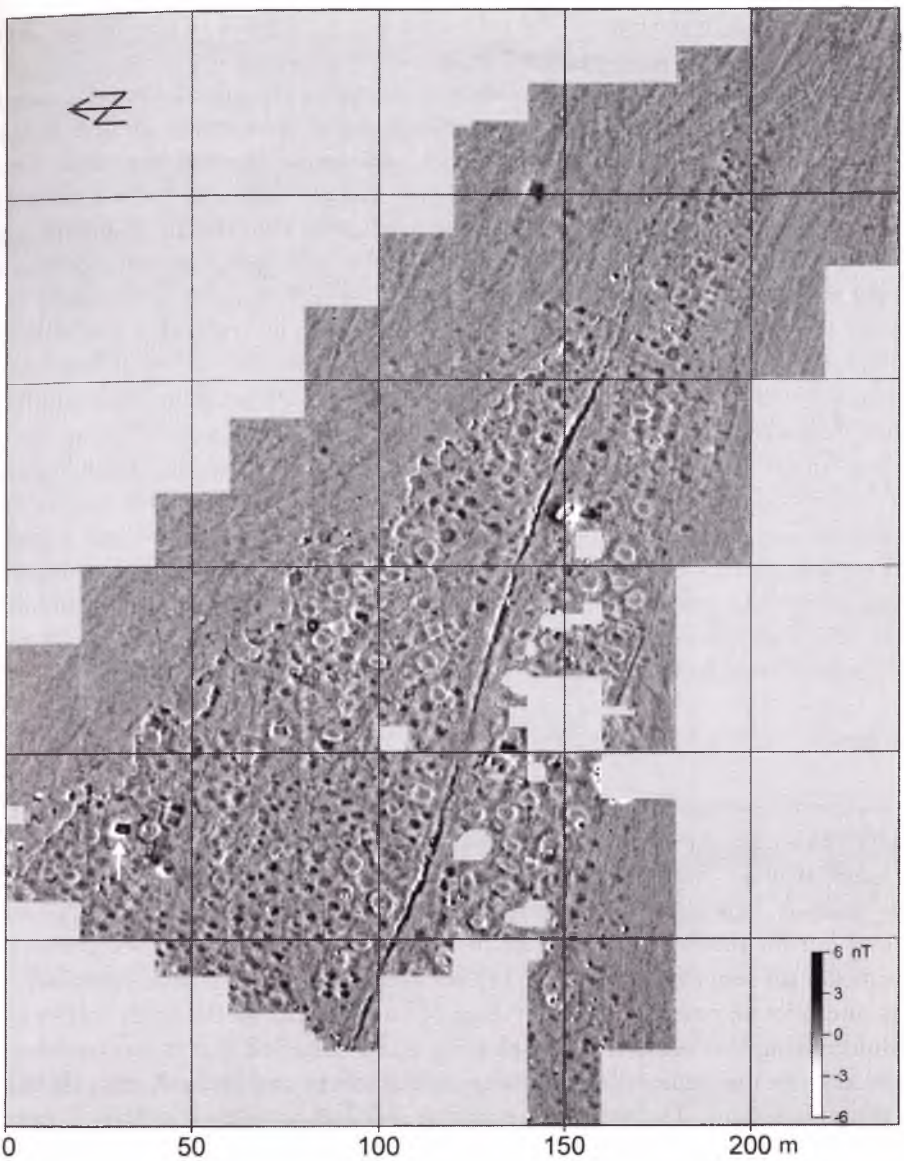

Fig. 18. Deir al-Barsha. Magnetic map of the Middle Kingdom cemetery. Arrow marks shaft 10O22/1 excavated in 2003 (see Peeters and Herbich in this volume).

Verificatory excavations revealed it to be a dirt road, dated by the archaeological material to Middle Kingdom times. It has yet to be ascertained whether it was used for local communication inside the necropolis or perhaps for transporting stone

from the quarries to the edge of the cultivated area (it appears to lead in the direction of the mouth of the valley where the quarries were situated).

The magnetic map constitutes a detailed record of digging at the site, mostly for looting purposes. Characteristic ring-shaped negative anomalies up to 7–8 m in diameter reflected pits and the surrounding dumps of material excavated when searching in the deeper layers of the site. Small oval anomalies with elevated values of the magnetic field (max. dim. 1.5 by 3 m) corresponded to the fill of shallow pits, which to judge by their frequency should also be interpreted as the outcome of intensive digging for artifacts.

The magnetic map also recorded a series of rectangular structures, 2–3 m wide, 3–5 m long, similarly oriented (N-S), presumably corresponding to burial shafts lined with mud bricks. To judge by the ground relief, some of the anomalies could have corresponded to unlooted burial shafts because they were either covered by the dumps or were between the pits. In the spring of 2003, a mission directed by Harco Willems chose to verify a feature between two pits, north of the area in Fig. 18 (marked with an arrow). The arrangement of the anomalies suggested that the shaft had a circuit wall enclosing it. Excavations uncovered an intact burial of the Second Intermediate Period which had reused a Middle Kingdom tomb earlier by three or four hundred years. The shaft was in the center of an enclosure, next to which other shafts were found, shafts that were also mapped (see Peeters and Herbich in this volume).

Abydos

Northern Cemetery. The area had been explored in the early 20th century, but to David O'Connor the results seemed both incomplete and requiring verification (O'Connor 1989). The discovery of a complex of boat graves served to emphasize how many secrets the area still concealed. The objective of magnetic prospection carried out for the Pennsylvania-Yale-Institute of Fine Arts, New York University expedition on some flat ground (2 ha) between the Early Dynastic enclosures of Djer and Djet on one side and the village of Sit Damiana on the other was to map a Middle Kingdom cemetery. The plotting was so detailed that it was possible in many cases to determine the chronology of the tombs and funerary chapels based on their plan alone. The measurements also revealed an unknown Early Dynastic enclosure. Excavations following the survey provided dating evidence for this enclosure, assigning it to the beginning of the 1st Dynasty (see Herbich, O'Connor and Adams in this volume). The results of the 2001 season prompted further geophysical prospecting in 2002, extending the surveyed area to the west (around a modern Coptic cemetery), south and southeast, around Shunet el-Zebib (enclosure of Khasekhemwy). Together with the research in 2001, the area covered totals 15.7 ha. The plan for 2002 was to uncover another Early Dynastic enclosure, as

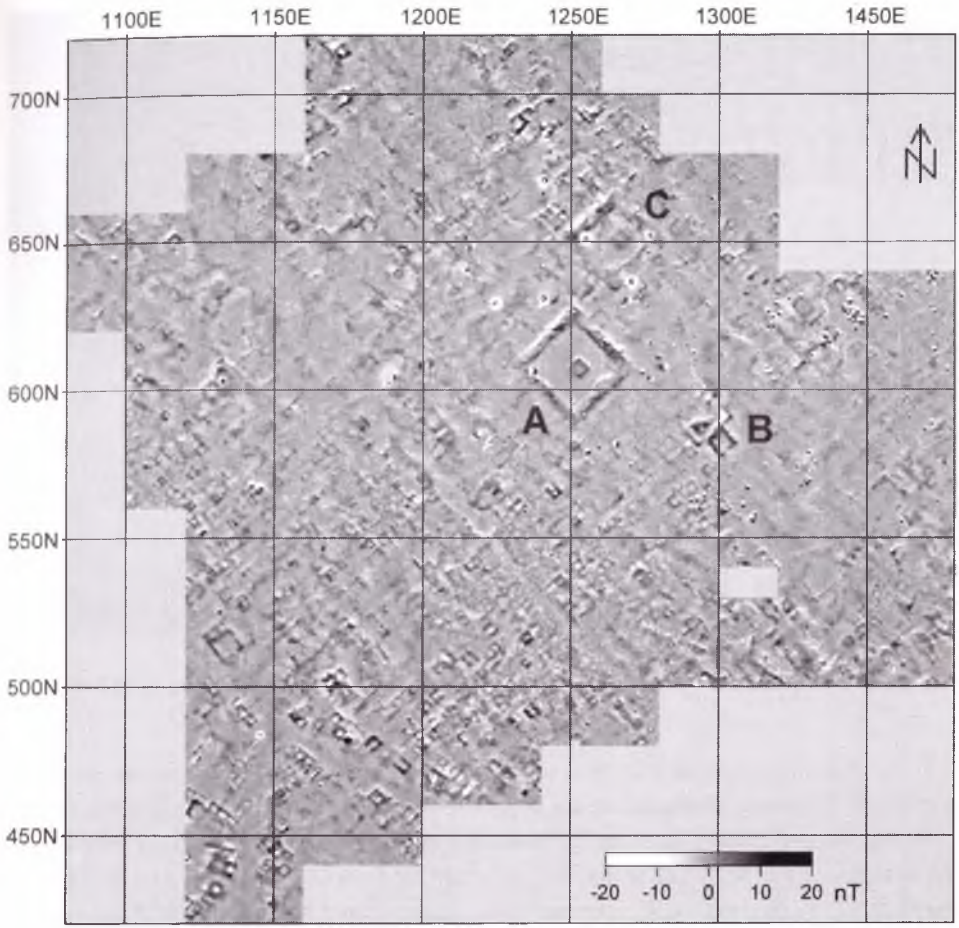

Fig. 19. Abydos, Middle Cemetery. Magnetic map. Grid lines every 50 m. A – Weni complex, B – Nehty/Idi complex, C – mastaba of Iuu (?).

well as tombs featuring a layout typical of the Middle Kingdom and the Late Period (see Herbich, Adams and O'Connor in this volume).

Middle Cemetery. Measurements were started at the most elevated parts of the site explored by A. Mariette in the mid-19th century, where the Abydos Middle Cemetery Project (University of Michigan) had rediscovered and excavated the 6th-Dynasty graves of Weni the Elder and Idi (Richards 2002). This area was heavily disturbed by earlier excavations: the difference in levels within the 20 by 10 m grid occasionally reached even 3–4 m (Fig. 19). The research uncovered the presence of a complex of small mastabas aligned to the southeastern wall of the Weni mastaba

Fig. 20. Abydos, Middle Cemetery. Area of mastaba Iuu (?). View from the south.

(Fig. 20). Another line of mastabas to the south of the Nekhty/Idi complex was also registered. The map demonstrates a structure of similar size that parallels the Weni mastaba to the north. It is most probably the mastaba of Iuu, discovered and penetrated in the first half of the 19th century by Lepsius, and then lost under the earth dumped from later 19th-century excavations (cited as possibly existing in this necropolis, see Porter Moss 1962:72).

The survey covered an area of 6 ha, corresponding to about a third of the surface of the cemetery. Once the high hill of the elite graves was investigated, the survey was continued in a southern and western direction, registering mainly simple shaft graves without any surface architecture. This did not contrast with Peet's description of the lower and middle class cemetery (Peet 1914).

Abydos South: Senwosret III mortuary complex. The magnetic survey conducted for the Pennsylvania-Yale-Institute of Fine Arts NYU expedition covered the area of a T-shaped enclosure around the tomb of Senwosret and accompanying mastabas of the 13th Dynasty, and an area at the edge of the cultivated fields of the Middle Kingdom town site of *Wah-sut*, associated with the mortuary temple of the pharaoh (see Herbich and Wegner in this volume). The total area covered was 3.7 ha. Inside the enclosure area, the survey results have led to a significant revision of the plan of

the complex, which had been erroneously mapped by the archaeologists of the Egypt Exploration Fund in the early 20th century. Research in the southern part of the town of *Wah-sut*, which uncovered an unknown complex, flagged the direction excavations should take in the future. An attempt to demarcate the northern extent of the town, already in the cultivated fields, was not successful.

Abydos South: Ahmose mortuary complex. The research was carried out next to the funerary temple of Ahmose (early 18th Dynasty), in the area of a town from the New Kingdom (south of the pyramid of Ahmose) and around the shrine of Tetisheri, also for the Pennsylvania-Yale-Institute of Fine Arts NYU expedition. Magnetic research covered a total area of 2.7 ha. Inside the temple, the prospection led to the

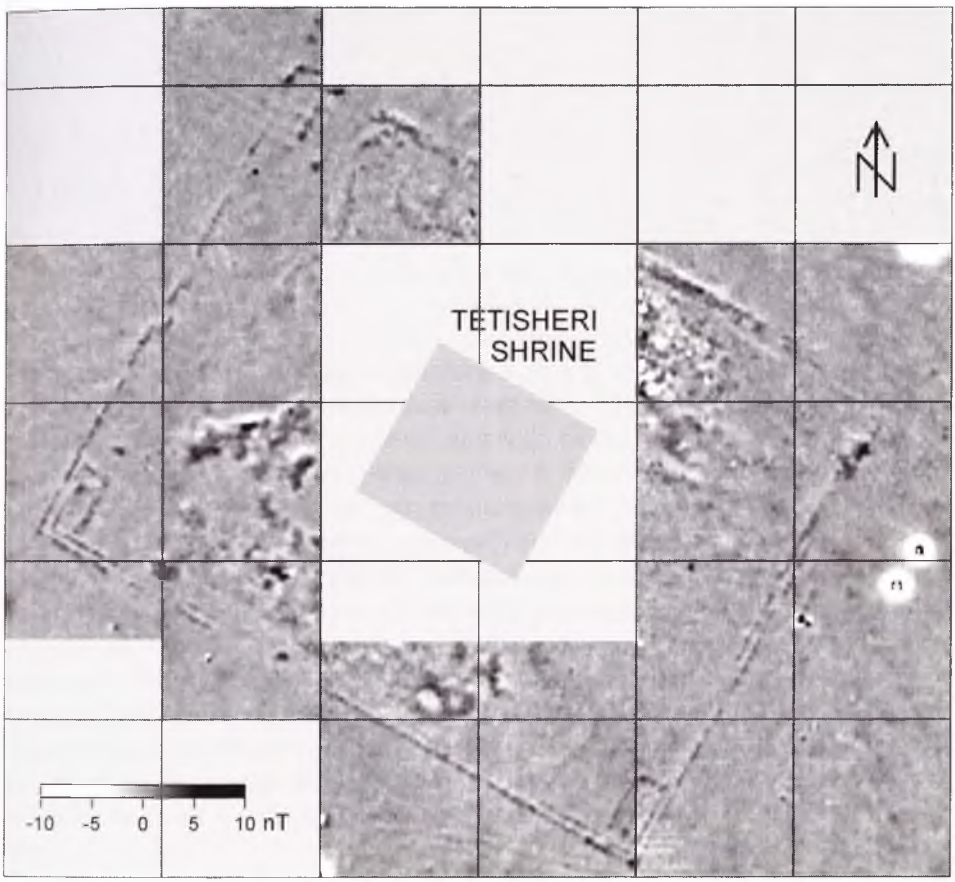

Fig. 21. Abydos South. Magnetic map of the area around Tetisheri shrine.
Sampling interval 0.50/0.25 m interpolated to 0.25/0.25 m. Grid lines every 20 m.

Fig. 22. Abydos South. Tetisheri shrine. View from northeast.

identification of an unknown pylon, establishing at the same time the extent of the temple toward the northwest. In the town area the survey was not successful. The area had been investigated by an Egyptian mission, which has failed to publish the results. They had dug a series of narrow parallel trenches, 1–2 m wide and up to 80 m long, every 6–8 m. These trenches are now filled with sand, the earth from the excavations forming flattened berms in between the trenches. The disturbances caused by a thus formed (and disturbed) surface layer excluded the tracing of any structures which are undoubtedly preserved in the areas covered by the archaeological dumps between the trenches.

The survey around the shrine of Tetisheri brought interesting results. The shrine was discovered in the early 20th century by an Egypt Exploration Fund mission, but the excavators limited themselves to the shrine itself (Ayrton, Currelly and Weigall 1904). The prospection registered a wall enclosing an area 68.5 m by 86.5 m around the shrine with minor rooms in the corners (Fig. 21). No traces of walls can be seen on the surface (Fig. 22).

Umm el-Gab. A DAI expedition recently completed excavations of necropolis U neighboring with the royal cemetery of the 1st and 2nd Dynasties (Dreyer *et al.* 2000). In parts of the burial ground the bodies were buried in pits, but there was a whole

series of burials made in chambers of mud brick. The geophysical prospecting was designed to check whether all the tombs with mud-brick architecture in this cemetery had already been discovered. The pit graves with their more than modest furnishings were untraceable for the magnetic method. Since the area had already been largely investigated archaeologically, the prospection also had an experimental character. The magnetic map would have revealed no evidence of tombs, if the mud-brick elements had been at a considerable depth (more than 1.5 m below ground surface) or else had been preserved in negligent form (one or two courses at a depth of more than 1 m). No new data on the cemetery was arrived at, since all the tombs registered had previously been identified through meticulous observation of the terrain. The survey, however, confirmed the potential exhibited by the magnetic method in the study of cemeteries of this kind, assuming the prospecting is done prior to the excavations.

Dendera

The goal of fieldwork by a joint mission of the French Institute of Oriental Archaeology (IFAO) and the PCMA was an area west of the Hathor temple enclosure. The surface material – deposits of pottery – confirmed its occupation in Ptolemaic-Roman times. Mud-brick architecture had been noted in some areas of the site; hence, in the 1997 program of work, magnetic prospecting was included with the objective of providing data for a more effective planning of archaeological activities (Grimal 1999). The survey in the settlement area (0.9 ha) yielded no marked results, chiefly due to the dumped pottery layer, up to 10–20 cm thick, that caused disturbances of the magnetic field, hindering any analysis of underlying mud-brick structures. The prospecting was continued outside the settled area, in the cemetery adjoining it on the south (in the part that had been checked archaeologically, where burials of the Old Kingdom and Late Period had been identified). The area surveyed geophysically (2.4 ha) included sections with evident traces of excavations (and looting) as well as level ground that showed no indication of modern-day penetration (Grimal 1999; Zignani and Laisney 2001). Magnetic measurements registered a series of anomalies that were roughly rectangular in shape, measuring 1.5–2 by 3–4 m, occurring in the undisturbed area. Nearby are shaft tombs of similar size, excavated in previous years, featuring mud-brick enclosure walls around the shafts at ground-surface level. Excavations will confirm (or not) whether the features recorded on the magnetic map do indeed correspond to tombs.

Western Thebes

Among the objectives of the DAI research project in the funerary temple of Amenophis III in Western Thebes, began in 1998, is the conservation and display

of the ruins of the temple, as well as supplementing the temple plans prepared in the wake of earlier excavations. This is because the vast temple precinct, which covers an area of 600 by 300 m, had never been completely surveyed nor excavated (Stadelmann 2000). The temple (presumably the enclosure wall and pylons) had been built of mud brick and stone, the latter being used, as indicated by the still surviving remains, for the construction of the west columned hall. Magnetic prospecting covered an area of 2 ha, including the section between the peristyle court and the monumental statues of Amenophis III (*colossi* of Memnon) fronting the ancient temple. Measurements have not revealed any clearly definable structures: there are no traces of pylons or an enclosure wall. What they do evince is a steady and intensive deterioration throughout the area. The temple had been built in a spot that was regularly inundated by the Nile, causing the near complete erosion of mud-brick elements. Thus, it was obvious that a different method – electrical resistivity – would have to be used to trace the remains of monumental stone statuary fragments. H. Becker has recently undertaken this project.

Hierakonpolis

Hierakonpolis, one of the largest urban centers along the Nile in the 4th millennium BC, is currently under investigation by an American Expedition to Hierakonpolis. Magnetic prospecting, introduced in the mission program in 1998, has covered so far an area by the King Khasekhemwy mud-brick enclosure (locality HK 27, the so called "Fort", surveyed in 1998), settlement site HK11 and cemetery HK6 (surveyed in 1999).

The objective of the research south of the Fort, initiated by the Institute of Nautical Archaeology in Egypt, was to see, if, by analogy with the Khasekhemwy enclosure in Abydos, boat graves were located here, too. The prospecting covered an area of 3 ha, but failed to provide conclusive evidence for the presence of boats. What the magnetic map did reflect was the geomorphology of the site – the western edge of the *wadi* was imaged quite distinctly. A number of recorded anomalies most likely reflected the structure of a settlement (some of these walls are partly visible on the surface) while some others can be interpreted (in combination with surface traces) as evidence of pottery and beer production in this area (Herbich 1998). An intriguing anomaly in the shape of a keyhole, about 20 m long, turned out to be a clay mine from which the bricks to build the fort were obtained. This unique discovery should make it possible to assess more fully the skills of the Early Dynastic builders and the analysis of this clay source is invaluable for the conservation of the Fort (Hampson, Bennett and Friedman 2000).

Located on a terrace of the Wadi Abul Suffian, locality HK11 constitutes one of the largest concentrations of Predynastic cultural activity on the Hierakonpolis

concession. Excavations in 1978–1979 revealed districts for pottery production, habitation and trash disposal (Harlan 1982). Investigations of the eastern part of the locality (0.7 ha) were meant to find evidence of settlement (Herbich and Friedman 1999). This was revealed in the form of a series of anomalies that – to judge by their shape and value range – might have been interpreted as fireplaces and domestic hearths. Indications of settlement patterning may also be seen, as the majority of anomalies fall within a 30 m-wide strip, while the area to the west appears to be magnetically sterile. Archaeological verification in square C4 (10 m by 10 m) in the following years indicated that the anomalies corresponded to pits more than 60 cm deep, filled with burnt soil and ashes, most likely originating from a hearth. No trace of hearth structures suggests that the burning episodes took place elsewhere and the anomalies in C4 corresponded merely to the refuse pits into which the burnt debris and rubbish were periodically dumped. Evidence of domestic structures associated with these pits was discovered just to the side covered by the geophysical prospecting (Watrall 2000).

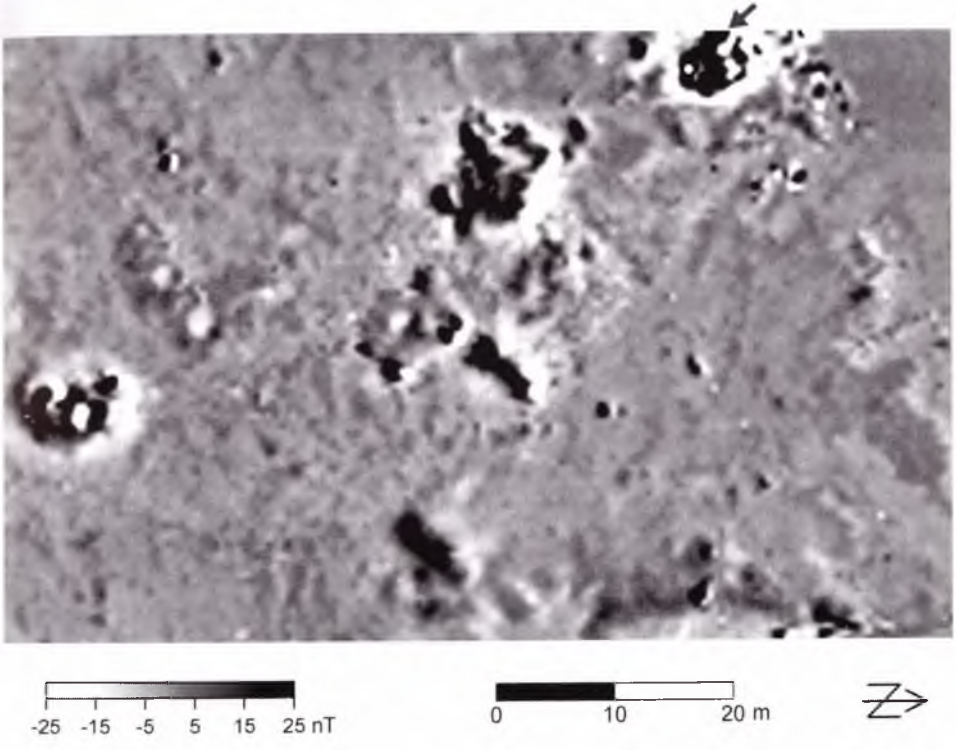

Fig. 23. Hierakonpolis, locality HK11. Magnetic map of area with traces of ceramic manufacture. Arrow points to an anomaly that corresponded to a kiln excavated by J.F. Harlan (see Fig. 24).

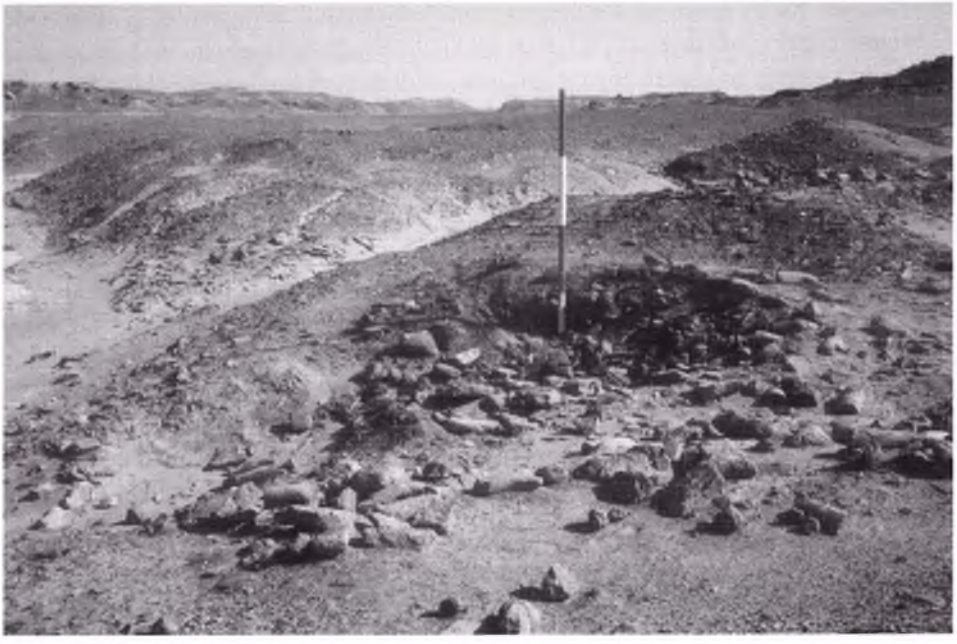

Fig. 24. Hierakonpolis, locality HK11. Pottery kiln excavated by J.E. Harlan.

Excavations in 1935, followed by fieldwork in 1978–1979, revealed traces of ceramic manufacture in the western part of locality HK11; the Predynastic pottery kiln that was discovered appears to be one of the earliest updraft kilns ever found and therefore extremely important for the history of technology and the pottery industry. Magnetic surveying recorded in an area of 0.4 ha several high-amplitude anomalies (ranging up to +/–100 nT) that are typical of kiln sites. In Fig. 23 the southwestern half of the anomaly in the northwestern corner corresponds to the pottery kiln excavated in 1935 and 1979 (Fig. 24). The anomalies in the center of the map have left no trace on the surface and may indicate the presence of an intact kiln complex. Other high amplitude anomalies correspond to surface concentrations of ash suggestive of other buried kilns.

The cemetery located east of HK11 (locality HK6) was used by the Hierakonpolis elite from the second half of the 4th millennium BC (Adams 2000). The magnetic survey (in an area of 2.1 ha) was supposed to reveal mud brick structures, the presence of which as an element of grave architecture had been claimed in previous surveys (*e.g.* Tomb T-11). There was no basis to expect that non-magnetic sand, gravel and fill of the tomb shafts hewn in non-magnetic sandstone rock would elicit any visible fluctuations of the magnetic field. The cemetery had been heavily penetrated

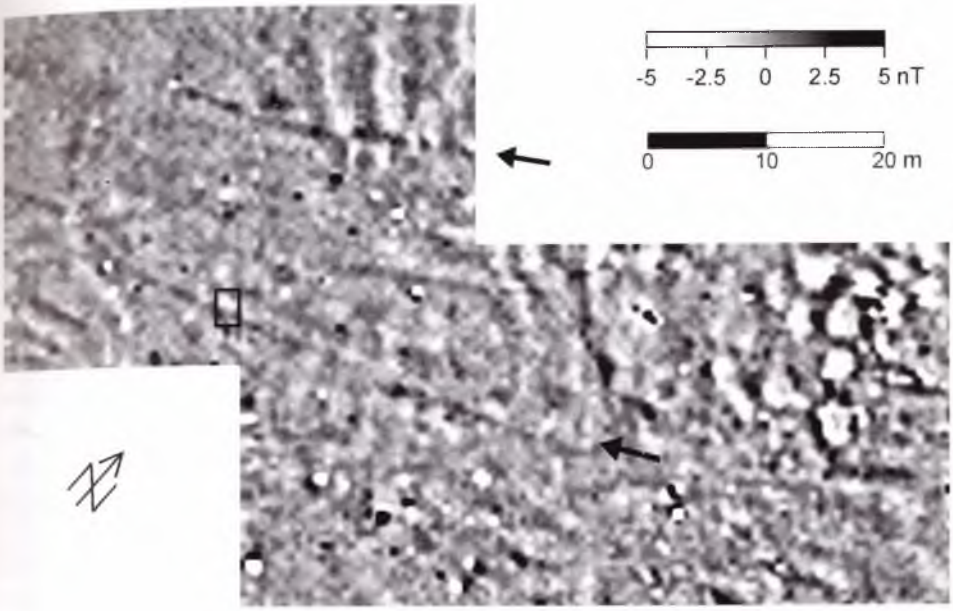

Fig. 25. Hierakonpolis, locality HK6. Magnetic map. Sampling interval 0.5 m by 0.5 m, interpolated to 0.125 m by 0.125 m. Fence-like structure marked with arrows. Test trench marked with a rectangle.

by robbers and the entire surface of the cemetery was pitted with depressions surrounded by ring-shaped or elongated backdirt piles formed during the looting of the tombs. The geophysical results depended heavily on this landscape, the magnetic map being largely a record of the site's looting. Even so, at least two anomalies could be isolated in the northeastern part of the necropolis near tomb T 11, resembling in shape anomalies caused by the mud-brick funerary superstructure. These anomalies occurred in an area where the surface had been disturbed, but they indicated that at least the mud architecture of the tombs had been preserved.

A linear anomaly in the southwestern, undisturbed part of the site raised high hopes. Its shape justified its interpretation as human-related, for example, as a mud-brick fence, meaning naturally the enclosure of an early funerary complex (Fig. 25). However, in a trial pit excavated by Renée Friedman no traces of man-made structures were found. Consequently, it seems that the map reflects the situation within the range of Quaternary sediments over the Nubian sandstone. The layout of the anomaly would correspond to an outcrop of a deposit characterized by higher magnetic susceptibility, in this case the deposit of brown silt found in the trial pit. The presence of this (or an analogous) deposit is confirmed in other regions of the site. This case is a good example of how misleading conclusions that are not verified archeologically can be.

THE OASES

Dakhleh Oasis: Ain el-Gazareen

The settlement at Ain el-Gazareen was located during a field survey carried out in the 1979 by the Dakhleh Oasis Project (DOP; index: 32/390-K2-2, Mills 1980). A test excavation in 1997 (10 m by 15 m trench) brought to light walls of silt lying immediately under the surface and fill that contained substantial ash deposits. The pottery evidence gave a date for the settlement in the terminal Old Kingdom (5^{th}–6^{th} Dynasties). The chief aim of the magnetic prospection commenced in 1999 was to determine the extent of the settlement and its layout. The entire area of the site (3.9 ha) was surveyed with an Overhauser GSM-19WG (Gem Systems) magnetometer using two sensors, one traversing and the other at base point, and mapping the difference in readings between the two (this part of the survey was done by Tatyana Smekalova. The western part of the settlement was re-surveyed using an FM 36 magnetometer (Herbich and Smekalova 2001).

The survey revealed an enclosure, 54 by 105 m, with heavy outer walls, and a kind of annex, also walled, measuring 55 by 25 m, attached on the east ("eastern enclosure"). Inside the enclosures a mutually perpendicular grid of linear negative anomalies and local positive anomalies was noted (Fig. 26). Based on the test excavation results (architecture situated in the eastern end of the main enclosure had been cleared), the grid of linear anomalies could easily be interpreted as reflecting the walls of habitations. The big rectangular feature could be identified as an enclosure wall and the local positive anomalies could correspond to concentrations of ashes, kilns and ovens. Excavations fully confirmed these expectations (Fig. 27). More than forty structural units were identified inside the eastern enclosure, some big enough to be considered as open-air and unroofed spaces. These units generally yielded greater amounts of ash and areas of burning than the closed rooms. Some of the rooms had small patches of burning which seem to have been intended for heating rather than for industrial or cooking purposes. Several rooms had larger deposits of ash, which seem to have been baking-fire accumulations (Mills 2000).

A careful comparison of magnetic map readings with the archaeological results indicated, however, that architectural features actually did not register or registered very weakly on the map (far more weakly than mud-brick architecture made of Nile silt). On the map, wherever mud brick structures were apparent, it was mainly in context with ash deposits somehow accumulated around them. The enclosure wall, which varied in thickness from 1.45 m to 3 m (Fig. 28), could be observed rather as the boundary between the wall and a concentration of ashes lying alongside the outer face of the wall, presumably dumped there by the town's inhabitants. The walls inside the settlement were registered when they separated concentrations of ashes or else the fill

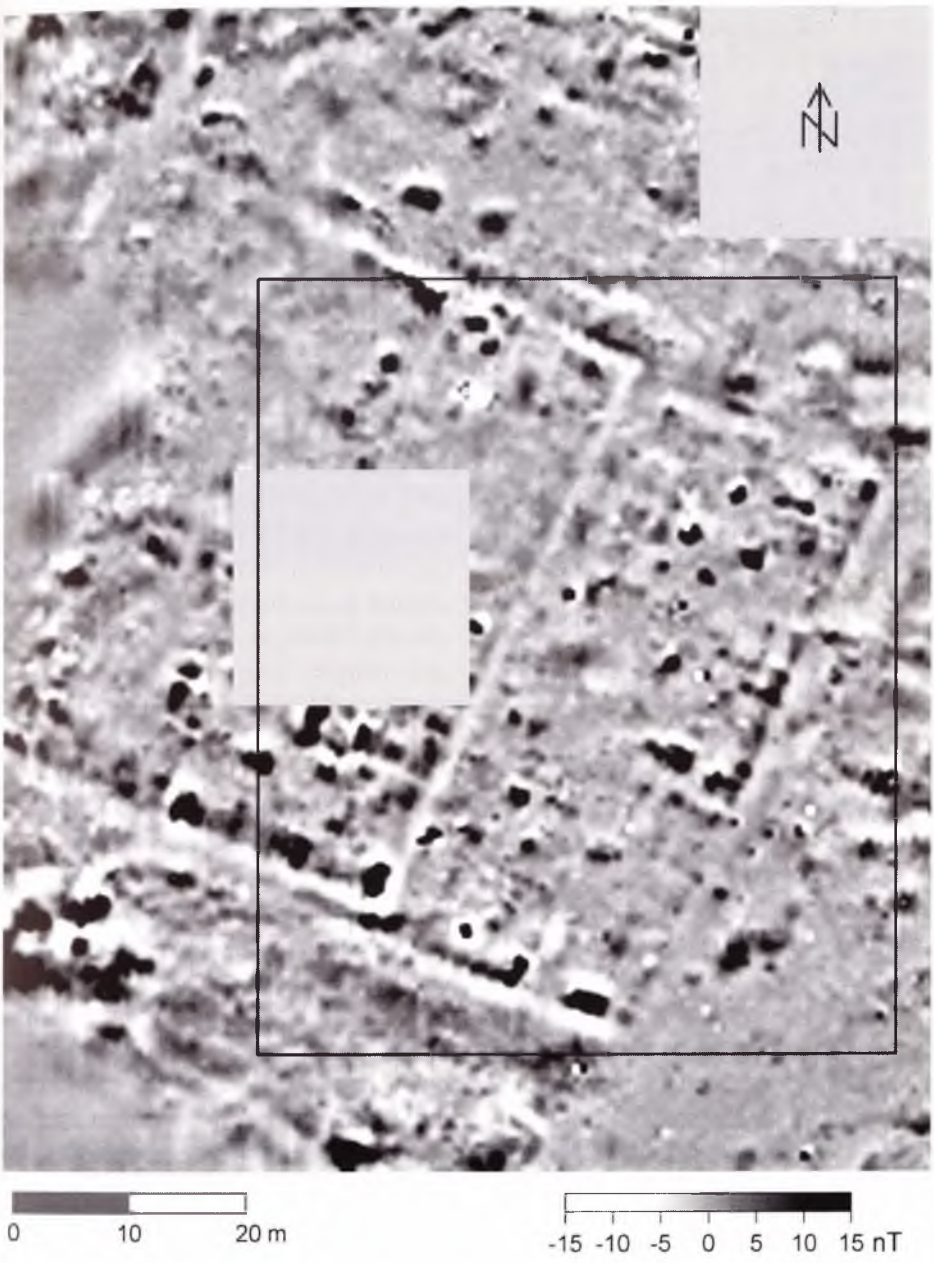

Fig. 26. Dakhleh Oasis, Ain el-Gazareen. Magnetic map of the western part of a large enclosure and the eastern enclosure (measurements by fluxgate gradiometer FM 36), sampling interval 0.5 by 0.5 interpolated to 0.25 by 0.25 m. The rectangular frame in the picture corresponds to the area covered in Fig. 27.

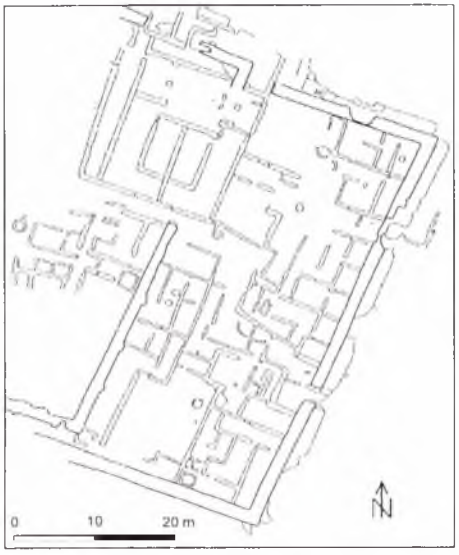

Fig. 27. Dakhleh Oasis, Ain el-Gazareen. Schematic plan of the eastern part of the settlement after clearing the tops of walls in 2000 (Drawing M.Puszkarski after A.J. Mills).

of the rooms contained some ashes. High-amplitude anomalies (range between – 30 nT and +50 nT) recorded on the southern side of the settlement (beyond the enclosure wall) may correspond to a complex of furnaces.

Dakhleh Oasis: Ain Birbiyeh

In 1985–1992 the DOP excavated a Roman-period temple of sandstone that lay concealed under a sand dune, which had drifted and stopped over the building. The area around the dune is under cultivation; indeed, the dune had also been cultivated marginally, resulting in such a hardening of the ground surface as to make excavations exceptionally laborious. Exploration identified the temple layout (without digging the foundations) and the location of a monumental gate leading into the temple enclosure. Geophysics were to answer the question whether this was the sole entrance or whether, in keeping with the local custom of the period (evinced, for example, by the Hibis temple in Kharga Oasis), there were several monumental gates providing access to the temple.

Geophysical prospection in 1998–1999 covered an area in front of the temple (*i.e.*, on its eastern side) symmetrically on either side of the main axis. The magnetic survey of the area (0.36 ha) yielded no results. As for the resistivity method, measurements could be taken only after 1400 holes had been drilled in the hard ground (over an area of 1400 sq m). Electrodes had to be introduced into the holes only after these were filled with water-diluted silt with $CuSO_4$ added. An ARA apparatus was used and the Schlumberger arrangement (current probes spacing equal to 9 m, potential probe spacing equal to 1 m) was applied for the measurements. Two anomalies recording higher resistivity values were mapped 2 m apart, situated symmetrically on either side of the temple axis. An area narrowed down to 1000 sq. m was surveyed again using a twin-probe array (spacing of traversing probes equal to 1 m, stationary probes 5 m apart). The resulting map confirmed the presence of the anomalies. Excavations carried out here in 1999 revealed the foundations of a stone gate at a depth of 1.5 m below ground surface, at a distance of 35.5 m from the eastern face of the gateway leading to the temple (Anthony Mills, personal communication).

Fig. 28. Dakhleh Oasis, Ain el-Gazareen. Eastern wall of the eastern enclosure, viewed from the northeast.

Dakhleh Oasis: Ismant el-Kharab (Kellis)

Ismant el-Kharab (ancient Kellis), one of the better preserved towns of the Ptolemaic-Roman and Early Christian periods (1st to late 4th century AD) in Dakhleh Oasis, has been the object of exploration by the DOP since 1986. Excavations have uncovered the better preserved western end of the town with its residential and religious architecture. Surface traces in the eastern part of the settlement, in the form of tops of mud-brick walls and iron slag, pottery sherds and concentrations of ashes, suggested this area had been used as a domestic quarter in which industrial activity also took place.

Excavations conducted in this region (area C) were preceded by magnetic prospection, the objective of which was to locate features of an industrial nature. Three magnetometers were used: FM 36 (survey by the author), Overhauser GSM-19WG and a Russian-made caesium magnetometer MM-60 (survey by T. Smekalova) (Smekalova 2002). An area of 1.3 ha was covered and the resulting magnetic map recorded a series of oval anomalies of high-amplitude values typical of concentrations of ashes, pottery kilns, and mounds of iron slag (Fig. 28). This confirmed industrial activity in the area. Archaeological verification of a series of anomalies in the north-central area on the map (marked A in Fig. 28) revealed the evidence of blacksmith's activity with much iron debris (Colin Hope, personal communication).

At the southern edge of the town, the prospection recorded two extensive areas with disturbed readings of the magnetic field (marked B and C in Fig. 28). On the surface here there were big potsherds, ashes, slag and clinker. These were presumably rubbish dumps formed already beyond the borders of the inhabited area (the dumps lie on the southern slopes of a mound occupied by the easternmost districts of the town). The magnetic map permitted the full size of these dumps to be reconstructed: the larger eastern dump measured some 35 m across.

An analysis of the excavated features and the remains visible on the surface in this area indicated a dense grid of architecture which, however, failed to show up on the magnetic map (except for one longitudinal anomaly marked D that apparently corresponded to a street). This constitutes further proof that the material used for mud-brick manufacture in Dakhleh Oasis does not exhibit the same magnetic properties as Nile silt.

Fayum Oasis: Qasr el-Saga

DAI investigations at Qasr el-Saga, in the so-called Western Settlement of laborers cutting basalt in the nearby quarries during the Middle Kingdom, were finished in the 1980s. About a quarter of the settlement area had been uncovered, but the remains were sufficiently regular to sustain a reconstruction of the original layout (Śliwa 1992). The goal of geophysical research in 1999, carried out jointly by the Polish Center and DAI, was to see whether magnetic research could provide new information concerning the settlement layout. The survey covered an area of 1.1 ha.

Fig. 29. Dakhleh Oasis, Ismant el-Kharab (Kellis). Magnetic map. Sampling interval 0.50/0.50 m interpolated to 0.25/0.25 m.

The settlement had an enclosure wall (113.9 by 80.3 m) enclosing buildings gathered in four long units separated by paved streets. Houses were built of mud brick, but several blocks of limestone were also found. The condition of the remains varies in different parts of the site. The northwestern quarter is preserved in the best condition, the erosion becoming more substantial towards the lower and eastern and southeastern parts of the slope. The magnetic map giving a grid of anomalous readings reflects the regular-

ity of the settlement plan (Herbich 2001, fig. 2). The anomalies correspond to streets, courtyards and walls of the housing units and were recorded only in the unexcavated area. Their interpretation became possible thanks to the results of Śliwa's excavation.

In the eroded part no actual structures were recorded. Neither were any remains of habitations visible in the western and northern parts of the settlement, were they had already been confirmed by earlier excavations. Obviously, the silt used as building material is deprived of magnetic properties of any kind. The rooms recorded in the central part of the settlement could be traced only because of the magnetic properties of the fill deposited in these rooms. To judge by the amplitude of changes in magnetic field intensity (reaching +/– 15 nT), ashes are the chief substance in the fill. Fragments of the settlement plan can thus be reconstructed based on indirect evidence, as at Ain el-Gazareen.

SEA COASTS

Mediterranean coast: Marina el-Alamein

The ruins of a Ptolemaic-Roman settlement on the Mediterranean coast near El-Alamein were discovered accidentally in 1985 during the construction of a tourist village. The PCMA took out a license for excavating the site and reconstructing elements of the town and cemetery architecture. Work has been ongoing since 1987 (Daszewski *et al.* 1990). The town lies on a limestone ridge and is presently blanketed in sand, up to 0.5–1.2 m in places. In some parts of the site the tops of walls can be traced on the ground surface. Magnetic research in limited areas both in the necropolis and urban districts was designed as a test of the usefulness of the method in the specific geological conditions of the site. In the cemetery the attempt was completely negative – underground burial chambers cut in bedrock and now filled in with sand are hardly susceptible magnetically; neither are the limestone superstructures. Ground-penetrating radar was thought to be a better solution to the conditions in Marina. The research was carried out by Harald von der Osten-Woldenburg from the Baden-Württemberg Office for the Protection of Historical Monuments. The system he used was GSSI SIR-2 with 500 and 200 MHz antennas. The measurements recorded features that were not visible on the ground surface, such as a rectangular feature that can be interpreted as a tomb courtyard or burial chamber, measuring some 8 by 6 m, provided with a *dromos* on the north. This feature is best visible at a depth between 2 and 3 m from current ground surface (Daszewski 2000).

Geophysical investigations in the town area were carried out in three different areas, covering a total of 1.5 ha: in the southern part of the town, immediately next to the northern extent of the cemeteries; on the lagoon shore in the northern part

Fig. 30. Berenike. Magnetic map and location of test trenches. Sampling interval 0.50/0.50 m interpolated to 0.25/0.25 m.

of the town; and in the eastern part of the town (southeast of houses H9 and H9A, restored by a Polish Conservation Mission). Solely in the last mentioned area is there any correlation observable between the magnetic map and the surviving architecture. Concentrations of walls and empty spaces (streets?) in between were traced, the walls being traceable thanks to the slightly magnetic material, ashes (?) perhaps, encasing them.

Red Sea coast: Berenike

The Ptolemaic-Roman harbor town of Berenike on the Red Sea coast is being investigated by the Berenike Project, a joint expedition of the University of Delaware, Leiden University and University of California in Los Angeles. A survey in 1995–1996 (Aldsworth and Barnard 1996) mapped in detail all traceable elements of the architecture seen on the surface. These features were concentrated in the western part of the town. In the eastern part, believed to be earlier, that is, dating to the times of the Ptolemaic foundation, evidence of habitation was limited to scattered coral heads (the chief wall-building and core-filling material) without any surface evidence of any actual architectural complexes. A geophysical survey was carried out in this area of the site in 1998 (Herbich 2003b).

On the magnetic map of an area covering 1.3 ha (Fig. 30) several high-amplitude anomalies were recorded (–115 nT to +130 nT). These could correspond to industrial traces, but there was no surface evidence of furnaces or concentrations of

Fig. 31. Berenike, test trench BE00-40. View from the southwest.

ashes. In spite of doubts raised by the theoretical assessment of the efficiency of the magnetic method in Berenike (coral-head walls were founded on sand and are covered with sand) the method appeared to be useful in recording building remains. The shape and perpendicular arrangement of linear anomalies of minus values permitted their likely interpretation as wall remains. In some areas of the map even the dimensions of individual rooms could be reconstructed. The walls appeared as elements without magnetic properties set in an environment that yielded slightly disturbed values of the magnetic field. The presence, however slight, of highly magnetic material (ash, pottery sherds and possibly slag) in a sand matrix seems to be the reason for this phenomenon. Excavations were carried out in order to be able to interpret the map properly. In trench BE00-40 (Fig. 31) a wall was found to correspond to the negative anomaly; it was partly in a rock-cut foundation trench, built with an outside face of gypsum and anhydrite ashlars, and some coral heads. In trench BE00-35 no buildings or occupation phases were found. In trench BE00-36 some poorly built walls and a large amount of partly worked lead and some hydraulic installations were discovered. The evidence from the excavated areas was on the whole datable to the Ptolemaic Period.

Prospecting in the northeastern part of the town (in a flat area of about 0.25 ha with no traces of buildings on the surface) was designed to register any remains

of buildings in the harbor district. The fact that no traces of architecture could be observed may be due to the ineffectiveness of the method in this area or the fact that the area was in reality a silted-up bay or inlet.

CONCLUSION

Following sporadic applications in the 1980s and early 1990s, geophysical methods have recently started being taken into serious consideration as a tool of archaeological prospecting by archaeologists working in Egypt. At least some of the results presented above, Becker's and Fassbinder's prospecting at Qantir, Mathieson's at Saqqara and Křivánek's at Abusir, as well as the work done by Egyptian geophysicists (see in this volume) reveal the huge potential inherent to geophysical methods, naturally if applied properly and in the right place.

The magnetic properties of Nile silt are behind the magnetic method's virtually universal usefulness in mapping sites where Nile silt was the principal building material, sites situated on desert plateaus along the Nile Valley. The results of research at Qantir, supported by complementary investigations in Tell Daba, Buto, as well as Tell Farkha and Sais (see Wilson and Dawson; al-Qady *et al.* in this volume), have emphasized the usefulness of the method in researching sites located in the Nile Delta.

The results of magnetic surveys at oases and sea coasts showed that even at sites where the structures sought were made of non-magnetic material (silt-brick foundation walls in oasis sites; blocks of gypsum and coral heads on the Red Sea coast), geophysical surveying is still worthwhile. Some sections of walls were traceable thanks to the presence of magnetic materials related not to the structure of the settlement, but to its functioning: *i.e.*, ashes deposited alongside the walls, which made it possible to reconstruct the course taken by the walls.

It is not without significance for an evaluation of the usefulness of the application of geophysical prospecting methods in archaeology that there exists a close cooperation between the survey teams and excavators at particular sites. Wherever cooperation of this kind was in force, the success of the work was imminent. The immediate archaeological verification of geophysical survey results provided essential feedback for evaluating method effectiveness. Publishing geophysical results in archaeological periodicals, combined with the outcome of archaeological verification, undoubtedly fostered a growing interest among archaeologists in applying geophysical methods to their field.

ACKNOWLEDGEMENTS

Prospecting in 1997–1998 was conducted using a Geoscan FM 36 apparatus kindly made available by Jörg W.E. Fassbinder and Helmut Becker of the Bavarian State Office for the Protection of Histori-

cal Monuments. The author is indebted to Roger Walter of Geoscan Research for his understanding and assistance in processing complicated software and equipment purchase orders sent from Egypt.

In 1999 a second fluxgate gradiometer – FM 18 upgraded to FM 36 in 2002 started being used by the author as part of an agreement signed between the Programa de Estudios de Egiptología (Consejo Nacional de Investigaciones Científicas y Técnicas) in Buenos Aires and the Polish Center of Mediterranean Archaeology of Warsaw University in Cairo.

Since 2001 fieldwork is conducted usually by two-member teams. In Abydos North and Buto in 2001 the author was assisted by Przemysław Wielowiejski, in 2002 (in Abydos South, Deir al-Barsha and Tell el-Dab'a) by Piotr Kołodziejczyk. In the survey of the Middle Cemetery at Abydos (and part of the North Cemetery) the other member of the team was Krzysztof Stawarz.

From the Fall of 2000 the author is no longer a full-time employee of the Polish Center of Archaeology of Warsaw University in Cairo. Even so, he has continued to enjoy the unfailingly generous assistance of the Center in all his subsequent geophysical prospecting work carried out in Egypt.

Translated by Iwona Zych

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