Archaeologia Polona, vol. 41: 2003, 113–288
PL ISSN 0066-5924

Magnetic archaeoprospection at Fayum governorate, Egypt

T.F. Abdallatif[a], H. Odah[a] and A.M. Saleh[a]

One of the most important regions on the map of world cultural heritage, Egypt has many secrets yet to be revealed; hence, the need for continued studies and investigations. The purpose of the magnetic archaeoprospection study conducted in 1996 by a team from the National Research Institute of Astronomy and Geophysics was to survey a number of different archaeological sites in the Fayum. The sites selected for the survey were Al-Lahun, Madi and Hawara and the magnetic method was chosen in view of the expected nature of the sought-for remains, *i.e.*, fired artifacts, fireplaces, mud bricks, and organic iron oxides, buried in non- or weakly magnetic soils (sands).

The survey was accomplished using Geoscan Research FM 36 apparatus. All measurements were taken in a raster of 0.5 m by 0.5 m, except at the Al-Lahun area, where the measurements were taken in a raster of 1.0 m by 1.0 m. The total number of magnetic readings taken at all the sites covered by the study is about 186 000.

Magnetic data were corrected, processed and interpreted using Geoplot software. The obtained magnetic images reveal underground archaeological features found in these areas. Also, a drawing reconstruction of all the invisible archaeological features at the surveyed sites was prepared based on the magnetograms. The resultant maps indicate the presence of a variety of archaeological structures: tombs, ancient walls, ring gullies, long ditches, parts of ancient cities and kilns, scattered all over the surveyed sites.

[a] National Research Institute of Astronomy and Geophysics, Helwan, Egypt

Application of 3D-migration to GPR survey at the Tenpaku-site, Mie, Japan

T. Ako[a], H. Kamei[a], Y. Yotsuya[a] and M. Okita[b]

The Tenpaku-site is located on a riverside terrace in Ureshino town, Mie Prefecture, Japan. This site was partly (5490 sq. m) excavated in 1992. Many stones from 20 to 40 cm in diameter, some arranged in circles, pottery and some traces of soil burning, but no habitable sunken huts were discovered (Fig. 1). Archaeologists concluded that this place, designated as a National Historical Site in 2000, was a ritual site in the Late Jomon period (3500–3000 B.P.).

In 2002, a GPR survey was carried out over an area of 135 m (east-west) by 100 m (north-south) including the excavations, the objective being to determine the site's boundaries.

[a] Department of Computer Science, Tokyo Institute of Technology, Tokyo, Japan
[b] Department of Archaeology, Tenri University, Tenri, Japan

Fig. 1. Scenes of Tenpaku-site. (a) Stones arranged in a circle. (b) Stones packed in a circle. (c) Jomon pottery buried upside down. (d) View of the excavation.

A SIR-2 GPR system and 400 MHz antenna was used. The west-to-east direction was set up on the X-axis, the south-to-north on the Y-axis. The GPR traverses were located at 0.5 m intervals along both axes. Thus, the total run reached about 50 000 m. Some reflections from stones were observed, as shown in Fig. 2, which shows the GPR profile from 30 to 70 m along the south-to-north line at X=60 m. A reflection of about 30 ns, beginning at a depth of 46 m, corresponds to the bottom of the trench excavated in 1992. Thus, a delay time of 1 ns corresponds to a depth of 3 cm in the profiles. The reflection is not flat because some stones still remain at the bottom of the trench. Some strong reflections from stone can also be seen in the profile from the unexcavated area.

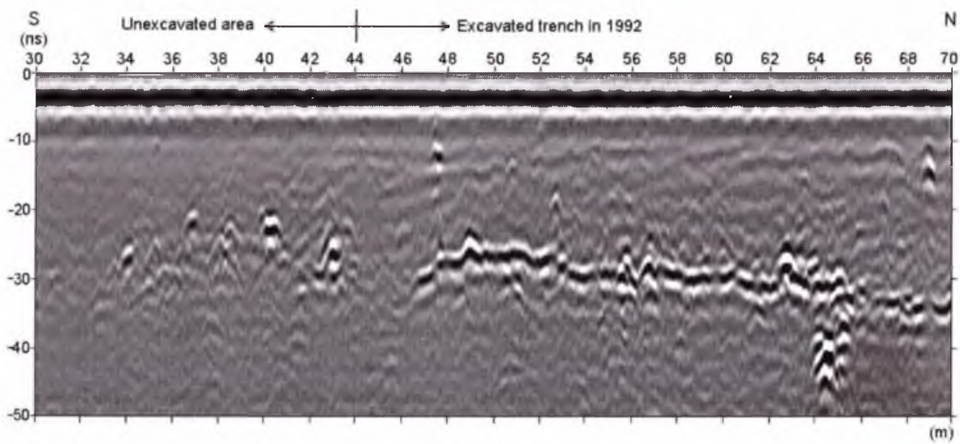


Fig. 2. GPR profile along the S-N line at X=60 m.

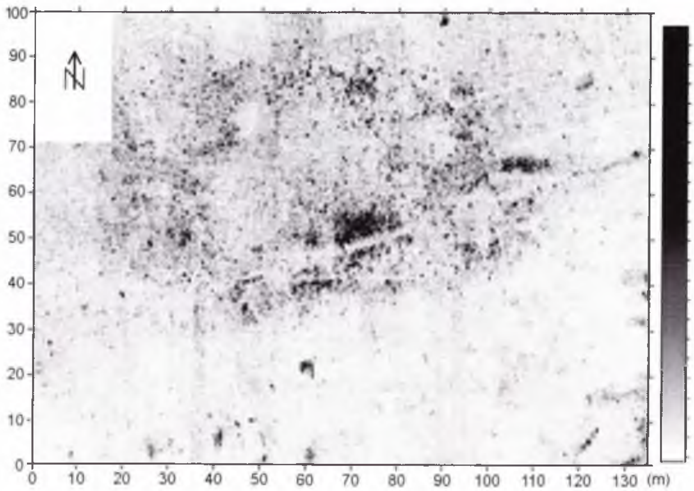


Fig. 3. Time-slice of GPR profile. The time window is 24.4–25.4 ns, and the corresponding depth is 73.2–76.2 cm.

GPR profile time-slices are effective for showing horizontal stone distribution. Figure 3 shows a time-slice image produced from the reflected waves in 24.4–25.4 ns. Black corresponds to a stronger reflection. The stones are obviously distributed in an ellipse, the long axis of which is 90 m and the short one 50 m.

The time-slice technique, however, is not omniscient and we cannot determine the correct horizontal position and depth for each stone in this case, because the GPR antenna does not always run exactly over each stone.

In order to determine a correct position in 3D-space, a 3D-migration technique is necessary. This paper presents a formulation of 3D F-k migration and its application result to GPR data from this site.

3D GIS in archaeology: a comprehensive approach to the reconstruction of archaeological monuments

Sergey Alekseychuk[a]

The post-processing study of archaeological features compiles often disjointed information coming from a variety of different sources and there is no simple way to handle this material.

The purpose of comprehensive reconstruction is to combine all the available information about an investigated site into one system. Work on developing a comprehensive

[a] Institute of Archaeology, Russian Academy of Sciences, Moscow, Russia

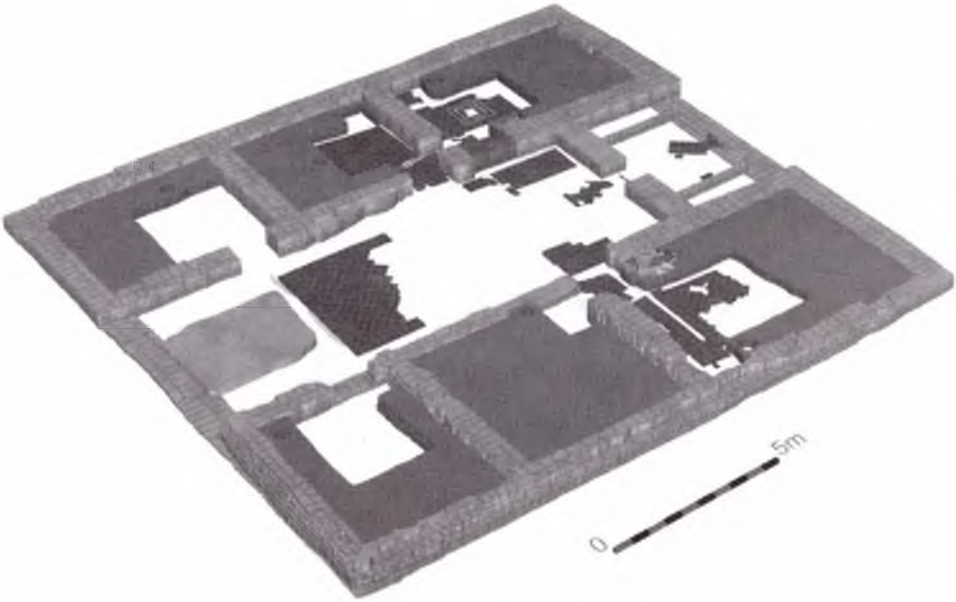


Fig. 1. Golden Horde manor, Selitrennoe site, Astrakhan region, excavations by E. Zilivinskaya.

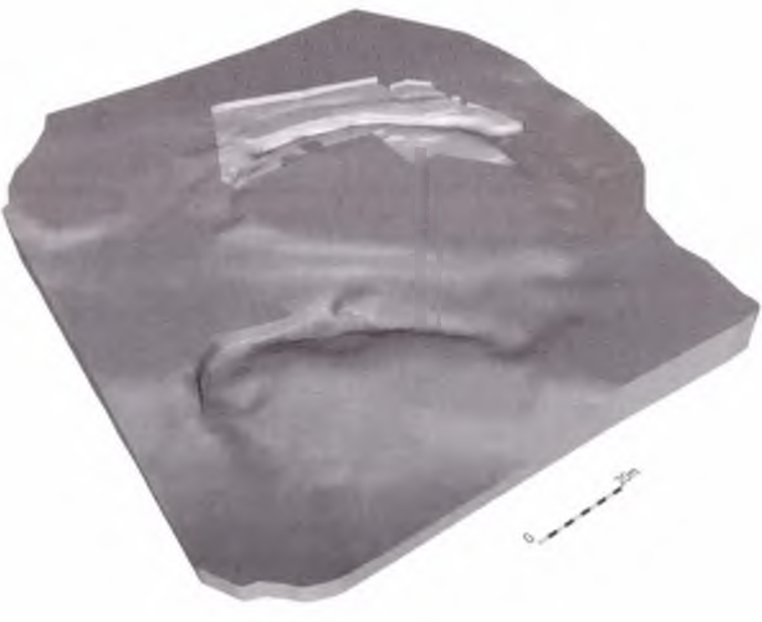


Fig. 2. Nastasino site, Moscow region, excavations by A. Engovatova.

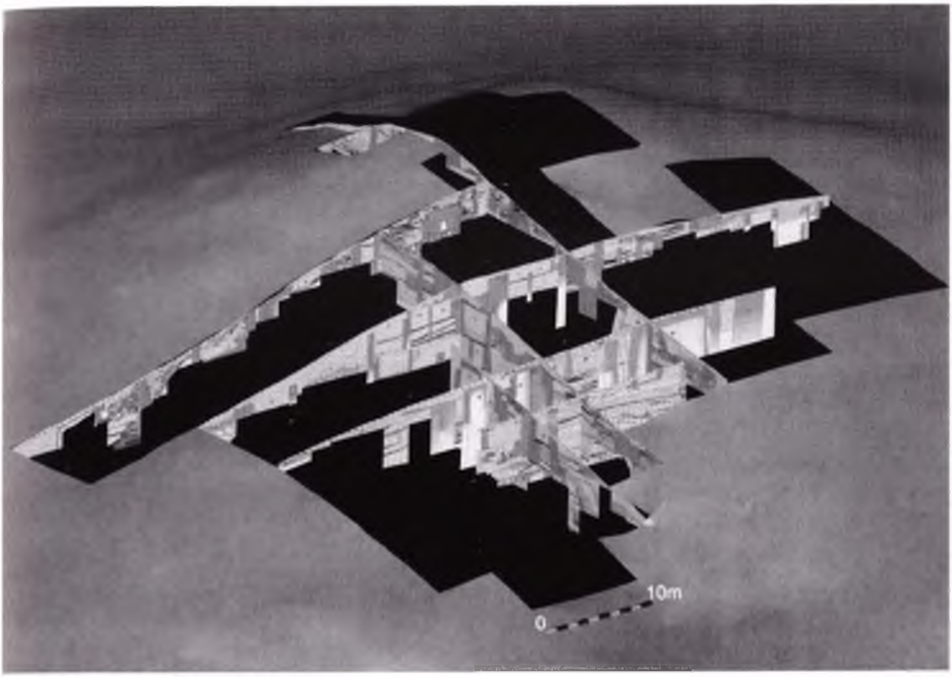


Fig. 3. Tell Hazna, Syria, excavations by R. Munchaev and N. Merpert.

reconstruction technique started in 1999 but, initially, the only sources that could be used were illustrations of ancient dwellings.

The outcome was a 3D model (Fig. 1), which attempted to recreate all the architectural features of the buildings discovered at Selitrennoe site in the Astrakhan region. The central house incorporated four main building periods, during which the interior layout changed considerably, while the load-bearing walls remained constant. Accordingly, the external walls provided the framework for the 3D model, into which the reconstructed internal structures from all four periods were later introduced. The end effect consists of four separate models of the same structure, reflecting the various building periods.

The next 3D model to be created was that of the Nastasino site (Fig. 2). Again, the main idea was to combine two sources of information: a topographical plan of the modern surface of the site and another topographical plan, this time of the excavated subsoil. First, a 3D model of the site was constructed. Then the subsoil of the excavated part of the settlement was reconstructed separately and these two models were combined. Thus, the reconstruction presented in Figure 2 was achieved.

In 2001 work on the comprehensive reconstruction of Tell Hazna (Fig. 3), the third to be discussed in this presentation, was initiated. A 3D model of the tell was first constructed, assuming as a basis the contour lines of a topographical plan. The stratigraphic profiles were the inserted into the model. Drawings of excavated finds, which had been created separately, were made available to the project (16 large images and their thumbnail representations). These drawings were linked through a key field to the external text database of finds. The technique has since proceeded to a new stage in the Tell Hazna project: It has gone from a simple graphic representation of the reconstruction results to an information model that operates analyses of linked external databases.

Combining the 3D models with other sources of information, such as aerial photographs, cartographic material *etc.* is planned. The outcome is anticipated as a multilevel geographical information model of an archaeological site, which will bring together sets of related graphics and textual information.

Consequently, the technique of comprehensive reconstruction can be said to have the following advantages: a multilevel structure (ability to correlate various sources of information), open architecture (possibility of adding, modifying and deleting information at any time), and the geocoding of components (interdependent graphics and textual data). Needless to say, it appears to be unmatched among other means of information management in terms of visualisation, speed and convenience of processing.[1]

Geophysical study of Loma Guadalupe archaeological site in Michoacan, Mexico

Luis Barba[a] and Gregory Pereira[b]

INTRODUCTION

The Loma Guadalupe site is located in the Zacapu lake basin in Michoacan State, Mexico (Fig. 1). It belongs to a group of pre-Hispanic settlements located on small promontories, locally known as *lomas* (hills). Numerous pre-Hispanic remains have been preserved in these hills, as revealed by surface survey and excavations undertaken by the Michoacan Project (Arnauld *et al.* 1993). Some of these sites are crucial to the archaeology of the region. This is the case of the Loma Guadalupe site which, along with Loma Alta (Hesse *et al.* 1997; Carot *et al.* 1998), has revealed an important part of the region's cultural sequence.

Loma Guadalupe is located at the south of the hills sector. It is small (2 ha) and its occupation has been dated at 500 to 900 AD, thus encompassing the second half of the Classic Period. The archaeological remains uncovered in earlier excavations show a complex funerary occupation (Pereira 1996, 1997a, 1997b). Some elements unearthed on the northern

[a] Laboratorio de Prospección Arqueológica. Instituto de Investigaciones Antropológicas, UNAM, Mexico
[b] UMR 8096, Nanterre, CNRS, France

[1] For more information visit our web site: www.arheo3d.narod.ru.

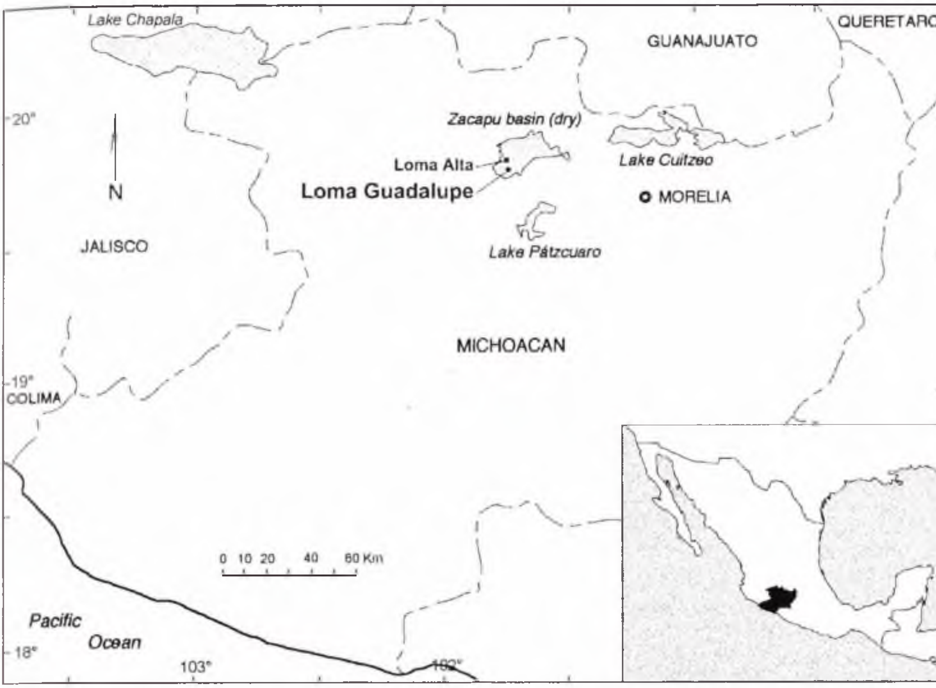


Fig. 1. Location map of Loma Guadalupe archaeological site.

part of the hill showed that there were some non-funerary structures on the site, a circular platform (Arnauld *et al.* 1993:76) and a steam bath (*temazcal*) (Pereira 1999:34–5).

This complexity demands an understanding of the site's global scope and organization, hence a new project phase encompassing a series of geophysical studies to be followed by excavations for the purposes of verification.

On both sites lake sediments forming the hills are very homogenous. Most stones (either basalt or andesite blocks) were obtained and carried from the volcanic structures surrounding the basin and were used to build funerary chambers and structures.

A grid comprising 20-m squares was established following the working methodology developed by the laboratory (Barba 1994). A general topographic survey covered 4.5 ha of the area, including the entire hill and surroundings, with readings being taken every 20 m. This was supplemented with a micro-topographic survey of the area under exploration (with readings made every 2 m). As a result of the survey, a map with contour lines every 10 cm was prepared.

A study of the magnetic gradient was henceforth undertaken. The Geoscan FM 36 gradiometer has the advantage of being able to cover wide ranges (8800 sq. m) in a relatively short period of time (seven days). The study encompassed the top of the hill and a major portion of its northern slope. Readings were made in 22 grids with 4 readings per meter along parallel lines set 1 meter apart.

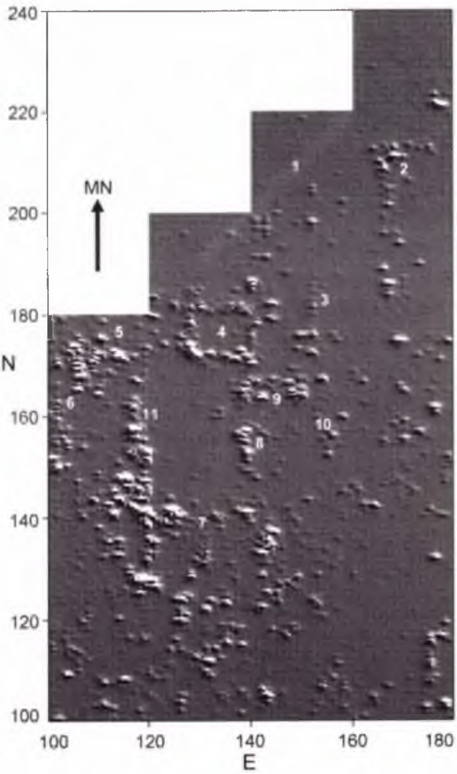


Fig. 2. Loma Guadalupe. Vertical magnetic gradient map after conversion into absolute values and shaded with a directional convolution mask.

After these initial operations and according to the results thus obtained, some sectors with relevant magnetic anomalies were chosen for geoelectric verification. Finally, a GPR survey was also undertaken to support the interpretation of these techniques.

THE MAGNETIC MAP AND THE OVERALL PATTERN OF THE SITE

The magnetic data shows numerous anomalies in the entire prospected area. As in the case of Loma Alta (Hesse *et al.* 1997), they are mostly made of dipoles representing individual stones and the anthropogenic character can be seen in the distribution of these anomalies which reveal a linear organization.

In the first place, a clear distinction can be drawn between the areas (Fig. 2). In the southern half of the site, these anomalies form small unstructured clusters, while in the north there is a linear organization complying with the cardinal axis and suggesting the existence of several fairly large structures. In this zone there is a large rectangular space with a stoneless interior measuring 30 m in length (north to south) and 20 m in width. This we named Structure A. This space is limited by three stone alignments (anomalies 7, 8 and 11), while its northern side is partly closed by a square building, measuring roughly 10 m on each side (anomaly 4), and designated as Structure B.

Other alignments in the northern sector worth mentioning on their own are:

- Anomalies 8, 9 and 10 seemingly denote the sides of a rectangular structure the southern limit of which could not be delineated.
- Anomaly 3 located to the east of Structure B, displayed as a small concentration of stones from which a line points towards the north. This feature is the excavated steam bath, consisting of a small rectangular chamber connected to a stone sewage canal.
- Finally, anomaly 1, which is quite different from the others in several aspects. It is also a linear anomaly, although it is directed towards the southwest-northeast; stones are clearly absent (no dipoles) and only stand out by a slight increase in magnetic values. The former suggest a difference in the fill material of a trench.

Regarding the numerous anomalies concentrated south of Structure A, it has been noted that some of these coincided with the funerary compounds excavated in 1986 and 1993.

Fig. 3. Loma Guadalupe. Stone alignment excavated at anomaly 8, viewed toward the north.

FINAL COMMENTS

Using the interpreted geophysical results, several excavations were undertaken to verify these interpretations and to determine the nature and temporality of the structures. Excavations brought new data on the overall organization of the Loma Guadalupe site. They revealed valuable information on the relationship between archaeological remains, ritual activities and funerary complexes.

It was proven that tomb complexes were closely related to ceremonial structures, which played an important role in the development of funerary practices.

The arrangement of the structures revealed a very peculiar space organization pattern, according to which the site was divided into two sectors with separate functions: the southern half was occupied by several tomb complexes forming a small necropolis, while the northern half revealed a group of buildings whose features (shape and size) evoked a ceremonial function. Within this group, the "sunken courtyard" (Structure A), occupied the center-stage; the main graves, whose entrances point towards the interior of the courtyard, were arranged around it.

On the other hand, the "sunken courtyard" was easy to access from the north, where there was a group of smaller structures (a square (4) and a circular platform (5) and a *temazcal* (3)).

Thus, this interdisciplinary project permitted us to take advantage of the undeniable capability of prospection techniques to cover wide ranges and to identify patterns, while archaeological exploration, even acknowledging the time and cost limitations, brought data on the dating and function of the structures.

ACKNOWLEDGEMENTS

We would like to thank Alessandra Pecci and Agustín Ortiz for their work during the field data gathering phase. Karl Link and Jorge Blancas were crucial to data processing and graphical representation.

REFERENCES

Arnauld, M.C., P. Carot and M.F. Fauvet-Berthelot 1993. Arqueología de las Lomas en la Cuenca lacustre de Zacapu, Michoacán, México, *Cuadernos de Estudios Michoacanos* 5. Mexico.

Barba, L. 1994. A methodology for the study of buried archaeological sites, In *Archaeometry for Pre-Columbian sites and artifacts. Proceedings of a symposium*, D.A. Scott and P. Meyers (eds), 353–66. Los Angeles.

Carot, P., M.F. Fauvet-Berthelot, L. Barba, K. Link, A. Ortiz and A. Hesse 1998. La arquitectura de Loma Alta, Zacapu, Michoacán, In *El occidente de México: arqueología, historia y medio ambiente. Perspectivas regionales. Proceedings IV Coloquio de Occidentalistas. Universidad de Guadalajara – ORSTOM*. R. Avila, J.P. Emphoux, L.G. Gastélum, S. Ramírez, O. Schondube, and F. Valdez (eds), 345–61. Mexico.

Hesse, A., L. Barba, K. Link and A. Ortiz 1997. A magnetic and electrical study of archaeological structures at Loma Alta, Michoacan, Mexico. *Archaeological Prospection* 4:53–67.

Pereira, G. 1996. *Potrero de Guadalupe: anthropologie funeraire d'une communauté pré-tarasque du nord du Michoacán, Mexique*. PhD dissertation, Université de Paris I – Panthéon/Sorbonne.

– 1997a. Manipulaciones de restos óseos en la loma de Guadalupe, un sitio funerario del periodo clásico de la cuenca de Zacapu, Michoacán, In *El cuerpo humano y su tratamiento mortuorio*, E. Malvido, G. Pereira, V. Tiesler (eds), 161–178. México.

– 1997b. Costumbres funerarias y sociedad del Clásico tardío en la cuenca de Zacapu, Michoacán. *Arqueología* 17:61–84.

Magnetometry at Uruk (Iraq): the city of King Gilgamesh

Helmut Becker[a] and Jörg W.E. Fassbinder[a]

Uruk (Tell Warka) – the biblical Erech – is one of the most famous sites for the early cultural development at Mesopotamia. In the third millennium BC Uruk was next to the city of Ur the most important Sumerian city state. It was also important for the development of writing and served as the setting of man's oldest epic, the famous Epic of Gilgamesh. The hero of the epic, King Gilgamesh (2600 BC), was according to the Sumerian list of kings two-thirds god and one-third human being. Furthermore, he was the architect of the city wall of Uruk (about 11 km long), which enclosed an area of about 5.5 sq. km. In the Epic one reads: "3600 acres are city, 3600 acres are palm gardens, 3600 acres are pits (for mud bricks) half of it covered by the temples of Ishtar": many more architectural details and descriptions of the city are contained in this source. The end of the settlement dates to the times of the Sasanids (*c.* 400 AD), after which it was abandoned.

Today the ruin is dominated by low hills and valleys, covered by pottery, mud bricks and slag. Still visible is the Ziggurat and the excavated structures. Except for the excavation camp, which was built in 1939 by the German Warka expedition, the area is entirely free of modern buildings and far from the village of Warka. Therefore, it is an ideal area for uncompensated caesium magnetometry.

After two campaigns in 2001 and 2002, the survey has covered already 35 ha (Becker and Fassbinder 2001; Fassbinder 2002). The most sensational find was the discovery of a canal

[a] Bavarian State Office for Protection of Historical Monuments, Munich, Germany

Fig. 1. Uruk. Magnetogram of the southwestern part of the city. Magnetogram in grey shading with 256 greyscale. Caesium magnetometer Smartmag SMG4-Special in duo-sensor configuration, dynamics −/+10 nT (white to black), sensitivity +/−10 pico-Tesla, raster 0.5/0.1 m interpolated to 0.25/0.25 m, dynamics of the total magnetic field 45230+/−30000 nT, line mean over 40 m, desloping and edge matching, 40 m grid, north to the top.

system inside the city. Furthermore, the magnetogram shows the remains of buildings of the Babylonian type, as well as garden structures, a Middle Babylonian graveyard and the so-called "New Year's Temple" of the god Anu or goddess Ishtar. The city wall, which was prospected for a length of more than one kilometer, includes a water gate and is nearly 40 m thick. The magnetometry has made it evident that it was built of baked mud bricks as described in the Epic.

West of the "New Year's Temple", in the middle of the old Euphrates river valley, the remains of a building were detected. It may be interpreted as a burial, but whether it was the grave of King Gilgamesh as described by the Epic must remain open to speculation for now.

REFERENCES

Becker, H. and J.W.E. Fassbinder 2001. Uruk – city of Gilgamesh (Iraq). First tests in 2001 for magnetic prospecting, In *Magnetic prospecting in archaeological sites,* H. Becker and J.W.E. Fassbinder (eds), *Monuments and Sites* 6:93–7. München.

Fassbinder, J.W.E. 2002. Auf den Spuren von König Gilgamesh. Magnetometerprospektion in Uruk am Schauplatz des ersten Epos der Weltliteratur. *Denkmalpflege Informationen* 122:62–63.

The study of ancient city planning by geophysical methods: the case of Dura-Europos, Syria

Christophe Benech[a]

The archaeological site of Dura-Europos is located on the right bank of the river Euphrates, in the east of Syria (Fig. 1). At the end of the 4th century BC, a fortress was built here by a general of Seleukos the First. During the second half of the 2nd century BC, a city was founded by the Macedonians complete with fortifications and urban planning of the Hippodamian type that was widely used for city foundations of the Hellenistic period. The Hippodamian model has been studied to some extent in a number of cities in Greece and Minor Asia, but for the Hellenistic Near East Dura-Europos is one of merely a few, well-preserved urban centers.

In the early 20th century, research on urbanism was based on excavations and required a broad-scale approach. For the obvious reasons of cost-effectiveness and the preservation of archaeological remains, such operations have been abandoned today. Consequently, this domain of research suffers from a dramatic lack of new data that would permit any further study of the conception and implementation of Hippodamian plans and of how the Classical model was impacted by Oriental influences.

The use of geophysical methods constitutes today an alternative to archaeological excavations wherever the objective is to collect new data on city organization. For Hellenistic towns

[a] Maison de l'Orient Méditerranéen, CNRS, Lyon, France

Fig. 1. Dura-Europos. Aerial view of the site. Photo: Mission Franco-Syrienne de Doura-Europos.

the magnetic map offers an initial overview of the Hippodamian model and grounds for the main characteristics to be deduced from it (Figs. 2–3). But this first "visual impression" is hardly sufficient for in-depth research: the study of urbanism requires specific information. It is also important to define the conditions in which such research would be possible and what the main objectives would be, this compared to the traditional approach based on excavation data.

The first step is to evaluate the location and the geometry of structures detected by geophysical survey in order for the resultant topographical map to be as exact as possible: simply drawing a line hardly suffices to render the irregularities of urban planning. These irregularities could be due to errors made by ancient architects or be the result of the evolution of rectangular blocks which failed to respect initially traced boundaries.

The second step is to understand the internal organization of the blocks: the visualisation of the geophysical map is sufficient to identify the main buildings and to locate the areas reserved for dwellings of a domestic nature. Administrative and religious buildings are easily recognizable on the grounds of their layout and can be compared with similar buildings from other sites. The study of private houses is more complex, particularly in Dura-Europos where there is no specific model of their internal organization known. We must note also that many temples were installed in ancient private houses and consequently failed to show the classical plan of religious buildings.

This research requires also a very detailed interpretation of the magnetic data: each architectural element characterising the different buildings must be listed in order for its

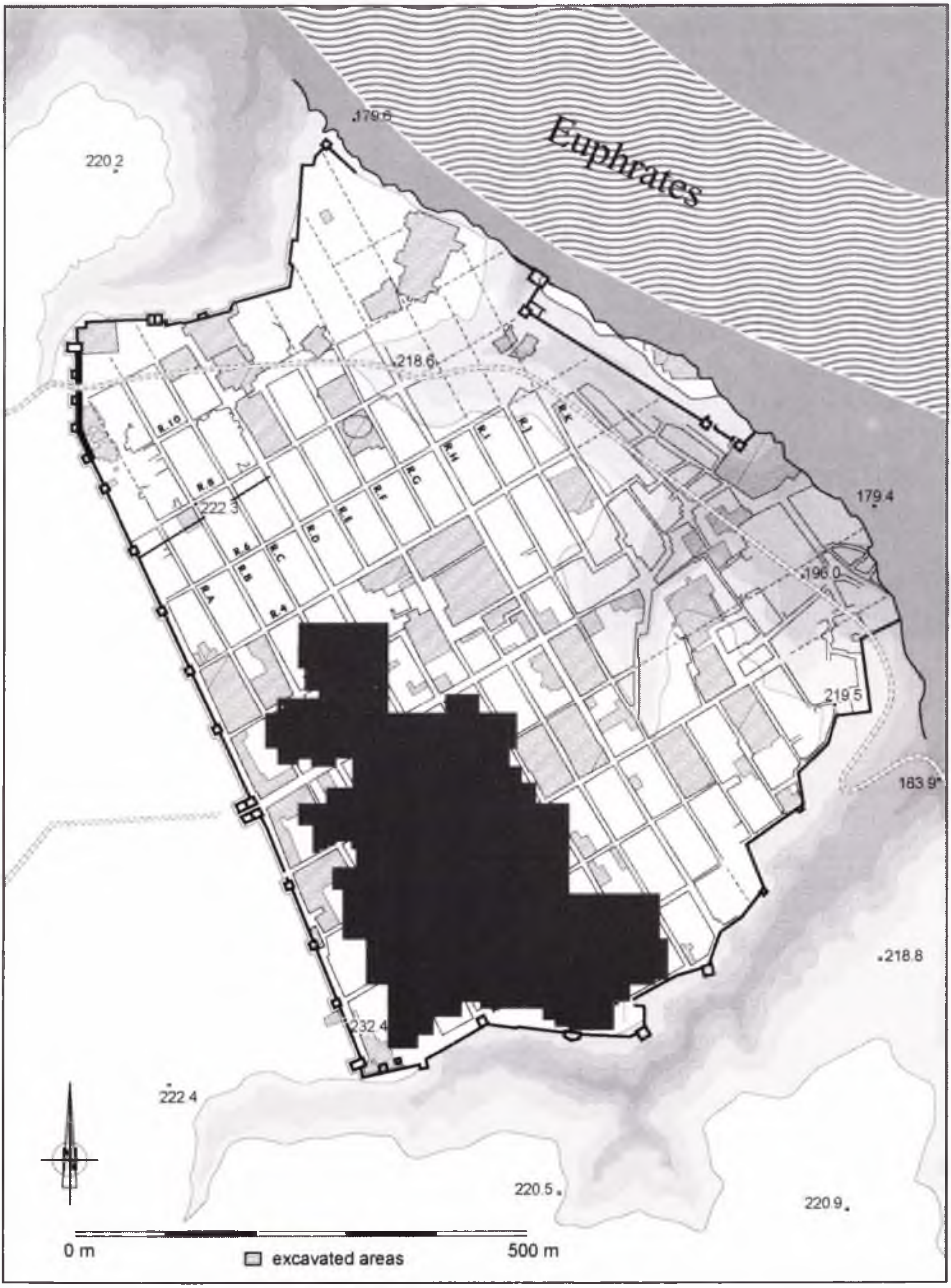


Fig. 2. Dura-Europos. Plan of the site. The area covered by magnetic survey (around 10 ha) is in dark grey color.

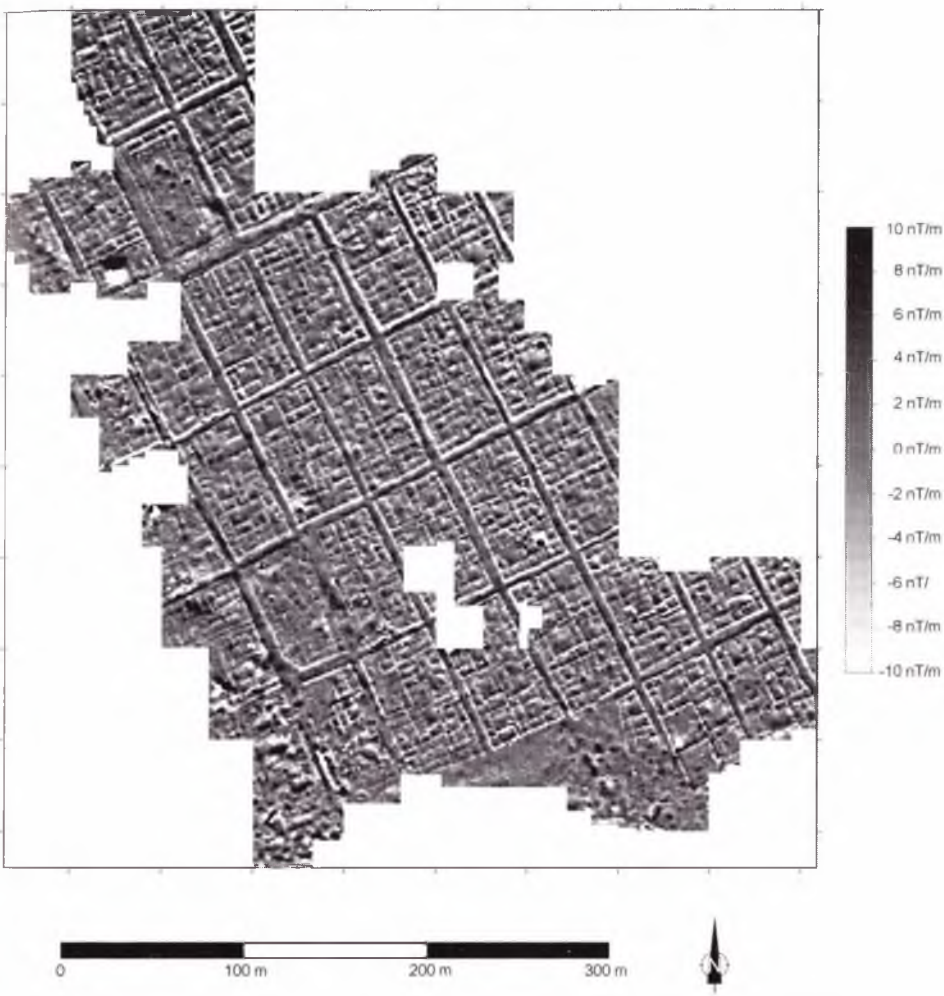


Fig. 3. Dura-Europos. Magnetic map. Caesium gradiometer (G858, Geometrics).

"geophysical signature" to become identifiable. This project will lead to the establishing of a complete topology of domestic architecture of Dura-Europos.

The aim of the geophysical survey in this case is not to indicate the most convenient places for excavations. In this sort of research, excavations must be reduced to a minimum and are envisaged solely as a means for solving specific chronological problems. A better understanding of the link between geophysical data and archaeological reality will result in geophysical methods becoming an even more important tool of the science of archaeology.

The use of modern technologies in archaeological prospection: experience from SUO "Nasledie"

Andrei B. Belinski[a] and Sergey V. Merkulov[a]

The State Unitary Office "Nasledie" for the protection of historical and cultural monuments was formed by the Ministry of Stavropol Region in 1995. Archaeological surveys, fieldwork and databases on the historical and cultural monument are included among the various tasks that this Office is charged with. Since 1997, the Office has been using a variety of modern techniques, such as aerial photography, GIS and ground penetrating radar, for the protection of the Stavropol historical and cultural heritage, this in the face of an almost total lack of dedicated state funding.

A multi-stage approach to the work has been developed in the course of doing archaeological surveys. The first, preliminary stage covers the following:

– selection of topographical maps, aerial survey, analysis of aerial photographs, space photographs of selected sites, reviewing data from historical sources;

– scanning, georeferencing and transformation of topographical maps and aerial photos (ER Mapper);

– linking the created raster images to GIS programs (ArcView or MapInfo);

– defining the area for archaeological investigations through analysis of topographical maps and aerial photos. From this preliminary GIS database, the coordinates and main reference points of archaeological sites visible on the surface are transferred into the GPS-receivers.

Such preparation is crucial to reducing the time needed for surveying work and, consequently, cutting expenses.

For the second stage, which is ground prospecting, GPS-receiver and GIS interaction is used extensively. Sites marked out in the first stage can be located quickly and efficiently and newly revealed monuments can be entered in the database immediately. The geographical situation and anthropogenic features of the area are also studied at this point.

Ground penetrating radar has been a constant element of archaeological ground prospecting carried out by "Nasledie" since 2002. This investigative technique permits prompt definition of the dimensions, depth and extent of various anomalous zones, as well as of various structural peculiarities of the site.

The third stage is analysis and data processing. Data entered from topographical maps and aerial photos is analysed and compared with ground prospecting results. Newly discovered sites are then plotted on the geopositioned working plans of building sites.

Thus, the use of GIS allows the office to carry out archaeological prospecting with a high degree of accuracy and maximum output.

In just one test area where a ground survey showed no outstanding features, a detailed analysis of archival high-resolution space photos using ER Mapper software revealed about

[a] SUO Nasledie, Stavropol, Russia

10 completely ploughed-over mound embankments. Excavations were initiated, using geopositioned space photos and GPS for accurate reference of individual monuments to available data. The embankments turned out to be mounds that had been obliterated completely by ploughing with separate burials from the early Iron Age. Further processing of the space photos with ER Mapper revealed anomalies in the different mounds, which upon comparison with the excavation plans demonstrated a correspondence with the separate burials. The data sets and their interpretation thus acquired have provided grounds for developing techniques to identify the features of archaeological sites even before the actual excavating begins.

Wherever historical monuments are threatened by anthropogenic activity, aerial photos from successive years permit the office to monitor the actual situation.

As mentioned above, ground penetrating radar has been used extensively by the Office for preliminary surveying of archaeological sites and for identifying details of their construction. The Russian-made instrument (VNIISMI Institute of Mechanized Implements) has given good results. Its special feature, which other Russian and foreign instruments do not have, is deep penetration (in dry soils > 15 m, in wet soils > 8 m, vertical resolution 0.1 m) with almost total lack of noise. GPR can help define the exact location, size and depth of cavities, burial vaults, stone casing, and subsoil burial grounds. For example, archaeologists surveying mounds can mark out their actual extent and position the burials.

One of the problems specialists from "Nasledie" are facing is the interpretation of samples. They are currently working on a database of collected samples evaluated by traditional field methods and on improved specialised software dedicated to the processing of samples from archaeological sites.

Geophysical survey of the Medieval stronghold at Nasielsk, Central Poland

Mariusz Błoński[a], Peter Milo[b] and Krzysztof Misiewicz[a]

Nasielsk is a small town about 50 km north of Warsaw. Just about 200 m from the town's main square, on the little river Nasielna, there lie the remains of an oval-shaped stronghold measuring some 50 m across. In the first written reference to this locality, dated 1065, Nasielsk is referred to as *castrum*, one of nineteen connected with the Benedictine Abbey at Mogilno. From the 11th to the 13th century, the stronghold was one of the local administrative and military centers, with a market place and workshops typically located in a neighboring settlement. Written sources from the period speak of endowments by the rulers of Masovia and of

[a] Institute of Archaeology and Ethnology, Polish Academy of Sciences, Warsaw, Poland
[b] Johann Wolfgang Goethe Universität, Frankfurt am Main, Germany

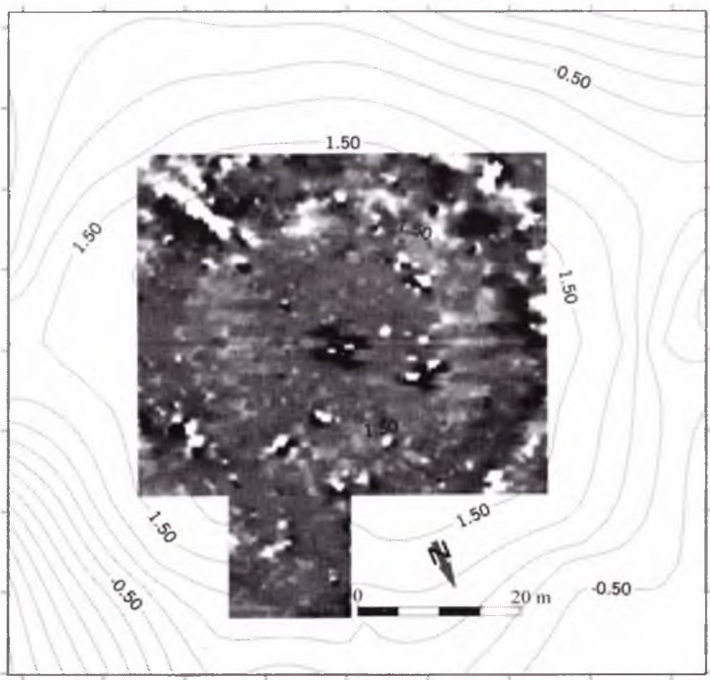


Fig. 1. Nasielsk. Magnetic survey. Fluxgate magnetometer Förster Ferex 4.032, 3 channels in gradiometer mode. Dynamics: –6/+6 nT in 256 greyscales (black/white, linear), raster 0.25 m/0.50 m.

castellani or local governors residing at Nasielsk. The stronghold was abandoned for uncertain reasons, sometime in the late 13th or early 14th century.

The site was first excavated in 1967 (I. Górska) when traces of the stone construction of the rampart were discovered. The accumulation inside the hill-fort was found to be one-meter deep and contained abundant pottery evidence to date the site to the 12th and 13th century. Excavations were reopened in 2001 (M. Dulinicz, W.A. Moszczyński, M. Błoński) with the chief purpose of verifying the chronology of the stronghold and, in view of the opportunity provided by the excellent condition of the remains, studying the construction of the rampart. The first trench, excavated outside the alleged gate of the stronghold, revealed traces of a timber road that had run over swampy ground to a presumed nearby settlement. A second trench, situated at right angles to the first, brought to light evidence of the moat and several parts of the rampart, which continued to be explored in the next season. Following two seasons at the site, the rampart construction has been fairly well documented and a stratigraphic sequence of at least four strata has been identified. Dendrochronological examination of wood samples from the excavations, carried out by T. Ważny from the Mikołaj Kopernik University in Toruń, has moved the origins of the stronghold (or at least the settlement on the spot) up into the 9th century.

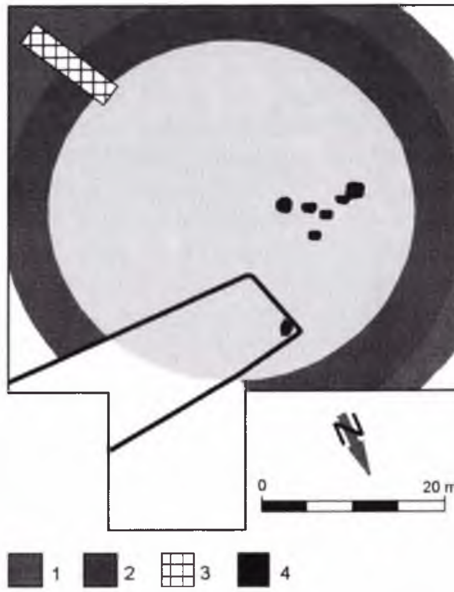


Fig. 2. Nasielsk. Interpretation: 1 – front side of rampart, 2 – rampart, 3 – old archaeological trench, 4 – possible archaeological features.

Magnetic prospection at Nasielsk covered the area of the would-be Medieval settlement and the inside of the hill-fort (where a high steep slope greatly reduced the field for prospection), covering an area of 0.75 ha and 0.25 ha, respectively. Measurements were taken with a Förster Ferex 4.032 magnetometer with three channels, the raster being 0.25 m by 0.50 m.

The rampart is easily identifiable on the magnetogram of the hill-fort (although the actual construction cannot be determined). Several smaller positive anomalies came up in the area inside the hill-fort. Some of these can be interpreted as a water well that is to be expected on a site like this. The trench visible on the magnetogram in the south corner is testimony to the earlier archaeological excavations conducted at the site.

Results of the prospection in the would-be Medieval settlement were hardly remarkable. Some positive anomalies of possible anthropogenic character appeared on the magnetogram, which is notable for quite a number of dipoles, but the origins of these anomalies remains unknown. In any case, the chief objectives of the survey, which were outlining rampart construction and situating archaeological features inside the stronghold, as well as locating precisely the old excavation trenches, has been achieved.

Magnetometer survey of Celtic salt exploitation in the Seille river valley (Moselle, France) and an approach to 3D presentation of magnetic anomalies

Norbert Buthmann[a], Bruno Wirtz[b] and Benno Zickgraf[a]

A recently commenced extensive research project, directed by Laurent Olivier, Musée des Antiquités Nationales, Département des Âges du Fer, focuses on the Iron Age relics of salt exploitation in the Seille valley (Moselle Département, France) (Olivier 2000, 2003)

[a] Posselt & Zickgraf Prospektionen GbR Marburg, Germany
[b] Université de Bretagne Occidentale, Dépt. de Math., Brest, France

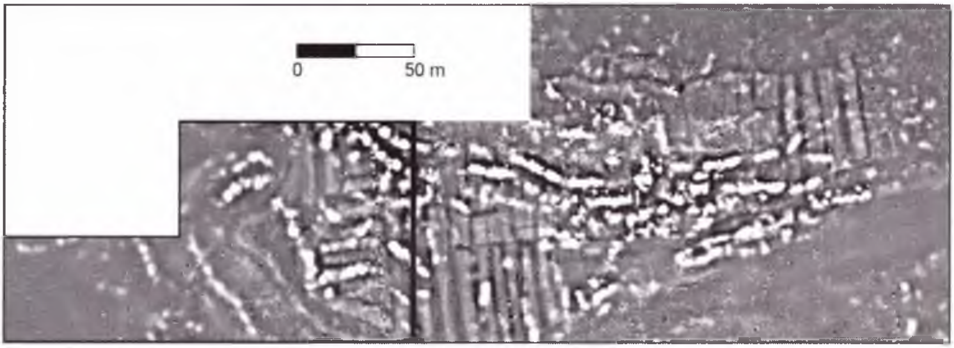


Fig. 1. Pransieu. Magnetometer survey showing a large number of anomalies with high amplitudes, interpreted as rows of ovens for salt evaporation. Fluxgate gradiometer Ferex 4.032; four channels; vertical probe distance: 0.65 m; max. resolution. 0.1 nT; measurements inline/crossline 0.25 m by 0.5 m. – Dynamics: –/+15 nT (black/white); 256-greyscale plot, linear.

The large waste dumps of burned clay, called "Briquetage de la Seille", typical of a large number of sites in this region, have been the subject of much archaeological research since the 19th century, yet the manufacture of the Celtic salt boilers has yet to be explained sufficiently.

As a consequence, the research objective of the current project is to study the exact location, extension and arrangement of the heaps of "briquetage" and the respective manufacturing plants (ovens). In view of the enormous size of each "briquetage" heap, which is scattered over an area of about 100 sq. km, modern survey techniques were conceived of as the sole means to reach the goal.

An airborne geophysical survey by helicopter in 2001 was followed up in the summer of 2002 with a magnetometer survey of a selected set of sites. Three sites, a total of 14 ha, were surveyed. The results for the site of Pransieu close to Marsal have been presented here to give an idea of the Iron Age salt exploitation.

The magnetometer plotting of a 7-hectare area situated on the bank of the river Seille shows a large number of anomalies with high amplitudes. By analogy with several ovens exposed at the waterline of the river, these anomalies should be interpreted as the rows of innumerable ovens intended for salt evaporation. Although it is impossible to determine how many of the more than 200 ovens detected up to now were run at any given time, their number is the effect of the plant being in operation for a long period of time. Furthermore, the linear arrangement indicates that new ovens were continuously being built beside the wasted ones.

Within the concept of landscape archaeology, the case study at Pransieu highlights the importance of geophysical prospection for the investigation of prehistoric methods of production on an industrial scale.

Overall, the project on Iron Age salt exploitation in the Seille river valley has provided knowledge about the structure of the features from an early stage on, knowledge which a century of traditional archaeological research, devoid of modern geophysical equipment and knowhow, could not bring.

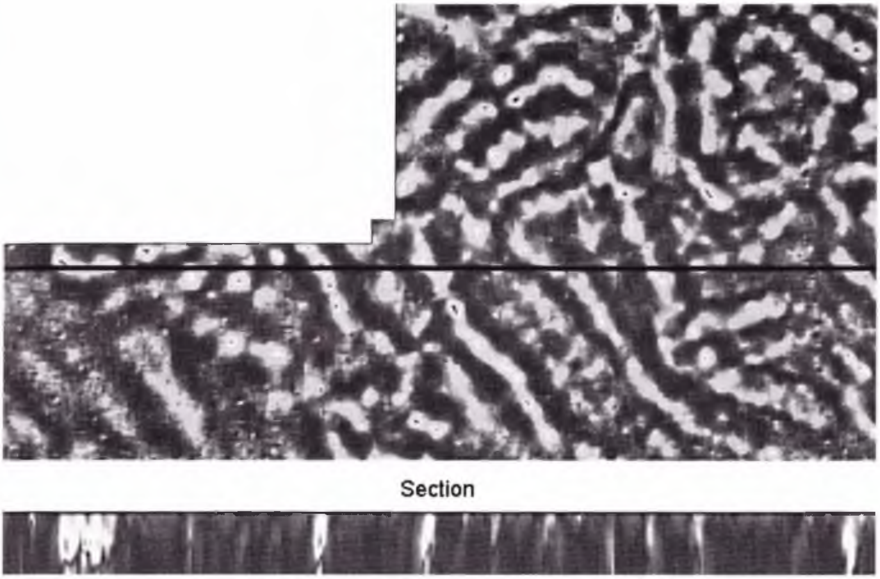


Fig. 2. Pransieu. Part of the magnetometer survey.
Calculated slice of 2 m depth and profile (black line) from 0 to 3 m depth; greyscale: increasing probability of localisation (prehistoric furnaces).

A 3D mathematical modelling of the detected magnetic bodies is being carried out simultaneously.

The present paper also contributes to the range of work on the magnetic inverse problem. The question is very pressing and receives partial resolution with analytical, probabilistical and stochastiscal points of view. More explicitly, the magnetic inverse problem is a good example of a badly conditioned problem.

The figures of the contribution are computated with another kind of mathematics: geometry. The concepts of differential, curvature and distribution of curvature are at the core of the computation. Instead of the linear resolution, we propose its segmentation in two parts. The first part is the location of anomalies, the second one is the estimation of their susceptibility. Only the first part works as it is still being developed. The program computes an index of the magnetic anomaly for any threedimensional point which could be defined as a conformal degree of correspondance with an ideal field.

From a mathematical point of view, the nature of a magnetic field is dual. Applied to one vector, the dual form results in one vector, applied to two vectors, in a scalar. This property and the use of non-linear computations are sensible, if one tries to obtain some stratigraphic information from the record of the magnetic field. From a linear point of view, it is clearly nonsense because one gets more numbers than the cardinal of the set of measurements.

When this indirect and partial resolution of the inverse problem was applied at Seille valley, it was successful in four cases. The estimation of depth of magnetic remains (prehistoric furnaces) was four times in correspondence (precision 25 cm) with the observations at four test trenches. Using a gradiometer and a measurement density of 0.25 m by 0.50 m, the range of validity of this method (before verification) seems to be about 3 meters down.

The exact formulas are still under development. They will be fixed after further verification and comparison of their accuracy at the scene.

REFERENCES

Olivier, L. 2000. Le "Briquetage de la Seille" (Moselle: nouvelles recherches sur une exploitation proto-industrielle du sel à l'Âge du Fer. *Antiquités Nationales* 32:143–71.

Olivier, L. 2003. Die Salzsieder vom Seilletal. *Archäologie in Deutschland* 1:30–2.

The location and characterization of magnetic bodies from archaeological prospection using 2D cross-correlation

M.C. Capanna[a] and S. Piro[a]

Archaeological magnetic prospection has developed during recent years from a tool for qualitative help before or during excavation to accurate mapping and delineation of sites. Locating shallow bodies of archaeological interest in magnetic survey is often difficult on sites where the susceptibility contrast is weak.

One of the main aims of data processing is to transform the raw field data into a reasonably meaningful form and enhance data maps to delineate buried structures whose surface impressions are weak or even completely obscured. The problems arise not only from inhomogeneities in the surface layer and any marginal human activities, but also from the prevailing geoenvironmental conditions.

Small-scale anomalies (*i.e.*, with high spatial frequency), which are caused by archaeological features, can be masked by local variations of the susceptibility distribution in the background.

The present study is based on the application of a 2D cross-correlation technique to locate and delineate the orientation of archaeological structures. To apply this technique, theoretical magnetic anomalies due to a synthetic model of an anomalous feature have been calculated.

A database of synthetic anomalous bodies has been created, taking into account different building materials (volcanic sediments, limestone, marble, bricks, wood, *etc.*), different building techniques, varying dimensions, depth and shapes. It is based on information obtained during excavations. A selection of some theoretical anomalies related to these synthetic bodies are used as 2D cross-correlation filters to process the field data. Examples are presented from four different archaeological sites: Sabine Necropolis at Colle del Forno, Archaeological Park of Veio, Traian's Villa at Altopiani di Arcinazzo (near Rome) and the Roman villa site at Amendolara in southern Italy.

[a] Istituto per le Tecnologie Applicate ai Beni Culturali, CNR, Monterotondo, Italy

Marine geomagnetic high definition metrology: possible archaeological applications

F. Caratori Tontini[a], C. Carmisciano[a], M. Ciminale[b], O. Faggioni[a] and S. Monti[c]

Marine geomagnetism is often used to address geological problems on a regional scale, for example structural, volcanological or mining problems (Faggioni *et al.* 1995).

More recently, the development of high definition (HD) metrology (Faggioni *et al.* 2001) has made the marine geomagnetic method suitable for detecting short wavelength and low amplitude geomagnetic anomalies. This type of signal may be often related to environmental and/or archaeological sources. The improvement of the informative quality of marine geomagnetic signals is mainly due to the accuracy of time reduction (Faggioni *et al.* 1997), to the quantitative classification of high frequency geomagnetic anomalies, to their bottom (BTM) reduction (Faggioni *et al.* 2001) and their effective inversion (Caratori Tontini *et al.* 2003).

In this study a first application of the HD metrology to marine magnetic data collected over features that simulate sources of archaeological interest is presented and discussed. The surveyed area is located in the eastern side of the Ligurian Sea (Italy) south of the position with 44°05'00" latitude and 09°45'00" longitude. In this area, a wreck (World War II, armed merchant ship) lies at a depth of 40 m.

A high sensitivity (0.02 nT) Geometrics G880 optical pumped magnetometer was used to collect the data. The geophysical investigation was carried out with the purpose of recognising and defining the magnetic anomalies due to the ship and to its cargo that had scattered on the sea floor during its sinking (skeins of barbed wire). While the ship's hulk is easily recognisable, the skeins of barbed wire are not visible as they are covered by sediments of about 1.3 m thickness.

In Figure 1A, the HD magnetic anomaly field is shown after coherence analysis, time reduction and IGRF 2001 removal. It is characterised by a complex shape due to the superposition of several high frequency signals. This map permits only a rough and approximate location of the metal sources. To improve the informative quality of the geomagnetic anomaly map, data were transformed by applying first the spectral reference field (SRF) procedure (Faggioni *et al.* 2001) and then the BTM reduction. The result of this operation is given in Figure 1B where the spectral anomaly field (SAF), with the highest wavelength ($\lambda = 1.8$ km) is shown. In this map the two anomalies are well defined and isolated. While anomaly #2 corresponds to the location of the wreck with an estimated confidence of 100 m, anomaly #1 is placed, with a confidence of 50 m, over a gentle undulation (about 2.0 m high) of the sea floor.

The subsequent direct submarine inspection finally explained the real nature of this little topographic high producing a relevant dipolar signal: not magnetic rocks but a portion of the cargo lost by the ship and covered by sediments.

[a] Institute of Marine Geophysics, Consorzio Universitario della Spezia, La Spezia, Italy
[b] Department of Geology and Geophysics, University of Bari, Italy
[c] Italian Navy, Hydrographic Institute, Genoa, Italy

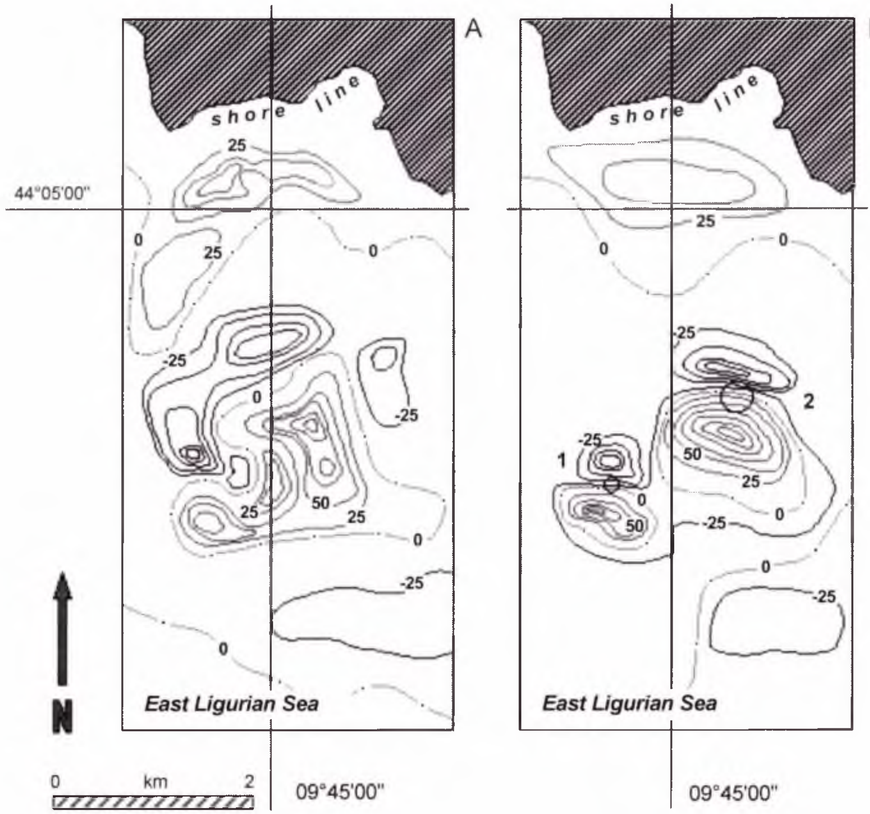


Fig. 1. The geomagnetic anomaly field map of the surveyed area before (A) and after (B) SRF and BTM procedure. The circles in the B image are centred on the wreck (2) and on its cargo (1) respectively; the length of their *radii* is related to the confidence of the magnetic source localization. Contour interval: 25 nT.

REFERENCES

Faggioni, O., E. Pinna, C. Savelli and A. Schreider 1995. Geomagnetism and age study of Tyrrhenian seamounts. *Geophysical Journal International* 123: 915–30.

Caratori Tontini, F., O. Faggioni, N. Beverini and C. Carmisciano 2003. Gaussian envelope for 3-D geomagnetic data inversion. *Geophysics* In press.

Faggioni, O., N. Beverini and C. Carmisciano 1997. Geomagnetic time variations and high definition study of space magnetic effects induced by artificial submerged sources. *Bollettino di Geofisica. Teorica e Applicata* 38: 221–8.

Faggioni, O., N. Beverini, C. Carmisciano and I. Giori 2001. A metrologic method of anomaly field amplitude bottom reduction in undersampled geomagnetic marine surveys. *Marine Geophysical Research* 22: 63–79.

Mann's landscapes revealed

Paul Cheetham[a], Tim Darvill[a], Roger Doonan[a] and Bronwen Russell[a]

Over the last 10 years Bournemouth University have been investigating a large multi-period site at Billown Quarry in the South of the Isle of Man together with a range of the other archaeological sites that abound on the 52 km long and 22 km wide isle. As this phase of the project comes to an end, it is time to reflect on the wealth of new information that the programme of work has generated, and in particular, the success of geophysics in shedding light on aspects of the island's archaeological record.

The Isle, situated in the middle of the seaways running between the UK mainland and Ireland, has been subject to waves of influence both locally and also from farther afield. It can be considered as perhaps a more sensitive barometer to influences that took longer to permeate, if they ever completely did, the larger land masses to the east and west. As such, Mesolithic, Neolithic, Bronze Age, Iron Age, Viking and Early Christian influences and their resultant sites and artefactual legacies abound throughout the island, although one major phase of UK history, that of the Roman period, is curiously absent from this otherwise rich record. Although the activity of some of these periods is more evident on the ground because of the apparently high rate of survival of major, mainly funerary monuments, Christian chapel and defended sites, other periods and other forms of evidence and their extent were little known. As is commonly encountered, the archaeology appeared as small islands within a misty sea of hinterlands in which dwelt the populations that built and used the monuments they created.

Bournemouth University's fieldwork has successfully utilised an extensive range of geophysical, geochemical and visual field surveys not only to increase our knowledge of the known sites, but place these sites in the wider context of an evolving and largely hidden series of episodes of landscape exploitation, which they did with an unexpected clarity. Sources of clay, flint, copper and iron have all been prospected for by island-wide surveys combining geological, geochemical and geophysical survey methodologies followed up by excavation where possible.

While much remains to be done, owing to the large amount of archaeological information these surveys are producing on a regular basis, the surveys have shown:

- that the site of Billown is situated within a intensively exploited multi-period landscape from which very substantial ritual and settlement monuments have been effectively erased, leaving no visible evidence of their presence on the contemporary landscape;
- that many funerary monuments, even those previously excavated, show evidence of more complex development than previously thought, and in some cases important features had apparently been missed;
- that the series of promontory forts found around the coast of the Isle of Man, broadly dated to the Bronze Age, may relate to sources of metal ores, while other monuments seem

[a] School of Conservation Sciences, Bournemouth University, United Kingdom

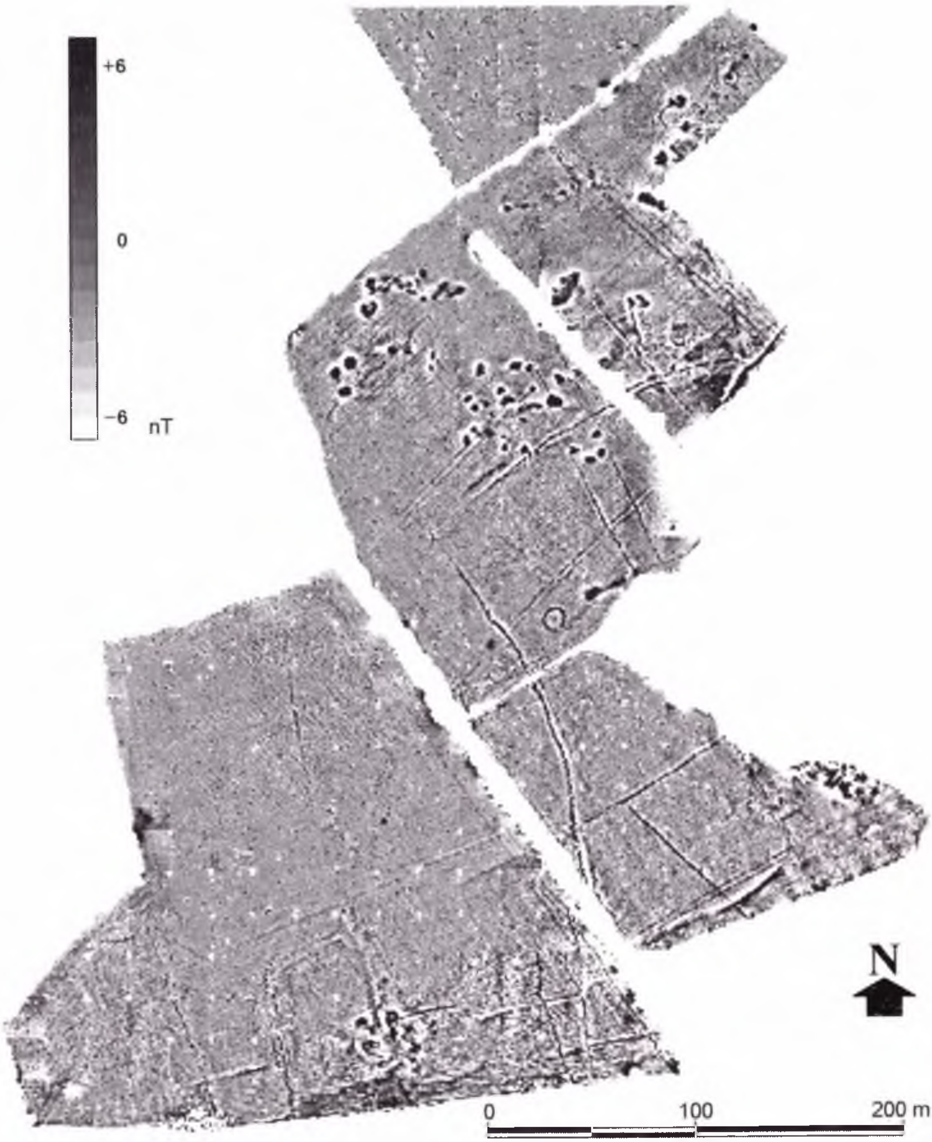
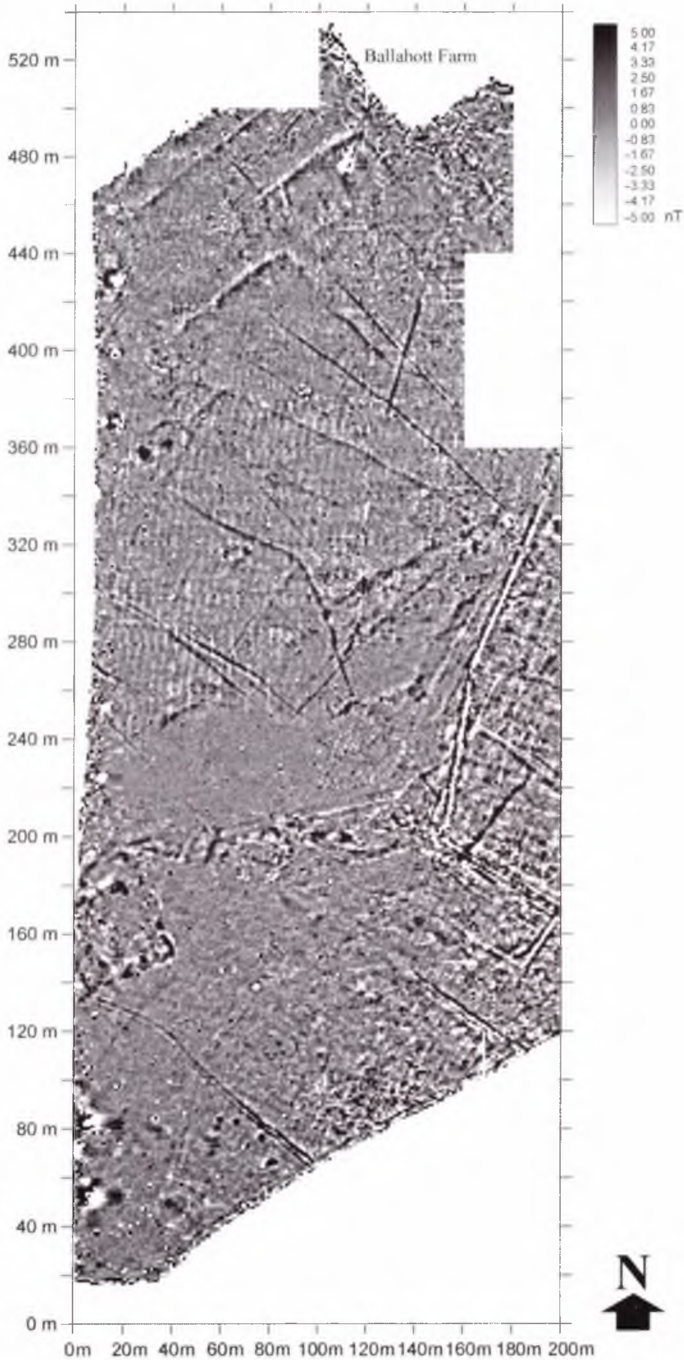


Fig. 1. Isle of Man, Billown Quarry. Fluxgate gradiometry survey of the area of the excavations. This revealed near the centre of the survey area a small henge monument, parts of a large curvilinear enclosure and cursus, all of Neolithic date, together with a large number of enigmatic pit features showing up as strong positive anomalies. In the north-west of the survey area occupation and building structures of a later prehistoric date are visible.

Fig. 2. Isle of Man. Fluxgate gradiometry reveals the complexity of the landscape history in parts of the south of the island.


Ballahott Farm
5.00
4.17
3.33
2.50
1.67
0.83
0.00
-0.83
-1.67
-2.50
-3.33
-4.17
-5.00 nT
520 m
480 m
440 m
400 m
360 m
320 m
280 m
240 m
200 m
160 m
120 m
80 m
40 m
0 m
0m 20m 40m 60m 80m 100m 120m 140m 160m 180m 200m
N

to have relationships to sources of quartz and that there is some veneration of this material and its sources;

- that all the Christian *keeill* chapels so far investigated are within enclosures, which may also define cemeteries, and that in some instances the chapels utilise the enclosures of earlier periods, although more work needs to be done on this class of monuments.

The conclusion of this work shows that without geophysical surveying the context of the relatively large and complete excavation at Billown would perhaps not have been appreciated in terms of extent or complexity. It has also shown that although in recent times the agricultural regime on the island has favored the preservation of some classes of monuments in particular environments, much of the archaeological record has suffered degradation, and that management strategies for areas where this is the case are in need of urgent reassessment in the light of the modern pressures on land utilisation.

Aerial archaeological prospection of the Viking Age settlement in Haithabu

Michael Doneus[a]

Archaeological exploration of the earthworks in Haithabu started some 100 years ago and has covered up to now about 5% of the area inside the semicircular rampart and large areas south of it. No attempt has been made, however, to look systematically for archaeological remains in the settlement and surrounding area from the air.

One of the reasons for this neglect is that the region is supposedly not suited for the formation of soil- or crop marks over archaeological sites. 40% of the area used for agricultural purposes in Schleswig-Holstein is permanently used for pasture or growing green fodder. In Haithabu, all of the area within the rampart was re-designated as pastureland in the 1960s. In addition, the climate is moist, averaging 900 mm of rainfall per year. Therefore, crop marks can be expected only in years with longer periods of drought (Evans and Jones 1977).

Nevertheless, in the archive of the county museum of Schleswig-Holstein there are plenty of vertical and oblique aerial photographs available. These cover the fortification and its surrounding area, with the oldest photographs dating back to the early 1930s. Most of the vertical coverage was produced for surveying and for surveillance of nature and environment, not for archaeological purposes. They comprise single shots, as well as series of overlapping photographs with scales ranging from 1:3000 to 1:12500. There were photographs available from the 1930s, 1960s, and 1980s, all but one (false-colour infrared film) on black and white film. The oblique photographs, mostly overviews of the fortification or the areas under excavation, were intended for use as postcards and as exhibitions and publication material. Hence

[a] Institute for Pre- and Early History, University of Vienna, Austria

Fig. 1. Haithabu. Comparison of geophysical prospection (magnetogram in the background) and aerial archaeological interpretation (white lines).

they were usually made from high altitudes and the viewing angle is extremely oblique. The aerial photographs had not been systematically interpreted by a trained aerial archaeologist.

In 2002, a project to prospect with geophysical methods all of the area within the fortification of Haithabu was launched by the county Museum of Schleswig-Holstein. As a member of one of the prospecting teams involved in this project, I decided to take the opportunity to have a closer look at the available aerial photographs. The idea was to see whether archaeological features would produce soil or crop marks in this region. For verification, the respective photographs had to be rectified and compared with the results of geophysical prospection surveys using a GIS system. Although the premises did not seem to be the best, several photographs showing soil and crop marks of archaeological features could be found. The photographs were digitised using a standard scanner with a resolution of 600 DPI.

To be able to map the archaeological features and compare the mapped evidence with the results of geophysical prospection surveys, the aerial photographs had to be rectified. However, good control information which would make photogrammetrical rectification possible was only found for the more recent photographs. In these cases, control points were measured in the field using a total station and ERDAS Imagine Orthobase 8.5.1 was used for digital rectification. The DTM needed was measured from the isolines of the DKG 1:5000.

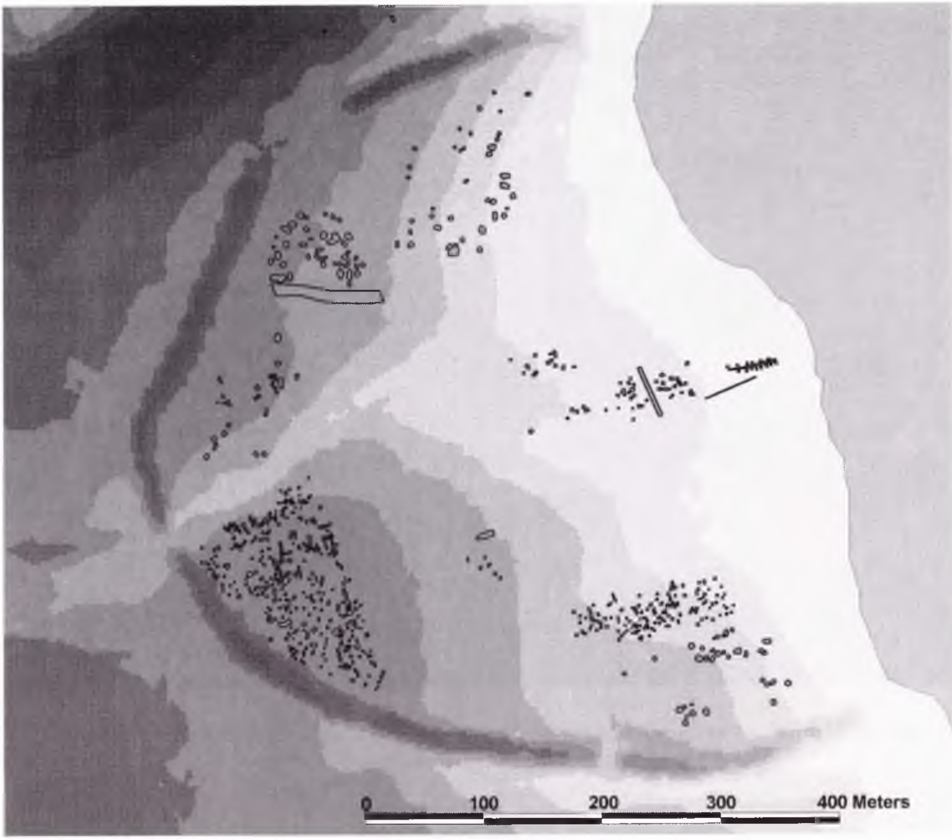


Fig. 2. Haithabu. Results of aerial archaeological interpretation of altogether 13 vertical and oblique photographs.

Changes of landscape have left little but a few corners of fields used as pastureland since the 1930s as checks for the older aerial photographs. Here, the photographs were rectified using Airphoto 2.14, which is the software specially designed for the needs of aerial archaeologists (Scollar 1998); the software transforms the aerial photograph and superimposes it on the scanned map, which in our case was the DKG 1:5000. Depending on the quality of the photograph and the control information, the results of the rectification showed residuals between +/– 0.2 m and +/– 2 m. The interpretation was done using ArcView GIS.

Altogether, 785 possible archaeological features within an area of 2500 by 800 m could be mapped from the rectified photographs. Within the semicircular rampart of Haithabu, crop marks could be found in several places, mostly where the land was 5 m or higher above sea level. 90% of the crop marks are on sandy soils.

In those cases where geophysical results were available, a comparison was made (Fig. 1). In most of the cases, the features could be verified.

The mapped features within the fortification show a graveyard, a wooden path, and settlement features (Fig. 2). In the surrounding area, between Wedelspang and the "Königshügel", a probable Bronze Age *tumulus*, an extensive cemetery with more than 50 *tumuli* can be seen on several aerial photographs as shadow marks and soil marks. The mapped evidence indicates that the *tumuli* range in size from 20 m and 40 m. The cemetery expands over an area of 1200 m by 600 m. Before the project, only a few of these *tumuli* were known.

The results of this investigation clearly show the high potential of aerial archaeology in this area. Considering that none of the used photographs were made for aerial archaeological prospection, one can imagine what a high-impact systematic aerial archaeological reconnaissance could have on this region.

REFERENCES

Evans, R. and R.J. Jones 1977. Crop marks and soils at two archaeological sites in Britain. *Journal of Archaeological Science* 4:63.

Scollar, I. 1998. AirPhoto – a WinNT/Win95 program for geometric processing of archaeological air photos. *AARGnews* 16:37–8.

Prospecting the Roman military camp of Zwentendorf, Austria

Michael Doneus[a], Wolfgang Neubauer[b], Stefan Groh[c], Klaus Löcker[d] and Sirri Seren[d]

The Roman military camp of Zwentendorf is located 1.5 km west of the modern village. It is situated on a gravel terrace about 700 m south of the river Danube. In Roman times, the course of the river led directly past the camp and the water has removed large chunks of it over time. The camp was part of the Noric *limes* and is one of the few *castellae* which were not built over in later periods. Systematic aerial archaeological investigation of the area started in the 1970s, creating a database of about 200 vertical and oblique aerial photographs. In 2001, a systematic interpretative mapping of the aerial evidence was undertaken, revealing archaeological structures within an area of about 50 ha. The area of interest, as is usually the case in Austria, expanded over several fields of different crops. Fortunately, since the photographs were taken over several years, crop marks were recorded in each field. The interpretation thus required the use of several photographs (Fig. 1).

Since it was planned from the beginning to integrate the aerial photo information with the results from geophysical prospection, high accuracy was demanded. Due to the different

[a] Institute for Pre- and Early History, University of Vienna, Austria
[b] Vienna Institute for Archaeological Science, University of Vienna, Austria
[c] Austrian Archaeological Institute, Vienna, Austria
[d] Central Institute for Meteorology and Geodynamics, Vienna, Austria

Fig. 1. Zwentendorf. Oblique aerial photograph from June 1993 showing parts of the *vicus* south of the Roman *castellum*. Parts of the Roman road, and aligned rectangular pits, as well as the foundation of a stone building are shown by positive and negative crop marks. On the left edge, parallel to the modern road, parts of the ditch of the Roman *castellum* show up as negative crop marks (© Luftbildarchiv, Institut für Ur- und Frühgeschichte, Wien; Freig. Nr.: 13088/011–1.6/94).

data sources, we decided to use both analytical and digital photogrammetry for obtaining a digital terrain model as well as a rectification of the aerial photographs.

The interpretation was based on two vertical coverages and twelve oblique aerial photographs found to be most informative. The ground control for the vertical stereopairs was measured on site within one day using a total station TC1010 (Leica). The stereomodels were set up on our analytical plotter DSR 14, where consequently the digital terrain model was measured "manually", so as to obtain the DTM at ground level (automated extraction using digital correlation techniques as provided by digital photogrammetrical software would have measured the DTM on top of crops, trees and houses).

Fig. 2. Zwentendorf. Orthophoto combined with magnetic survey.

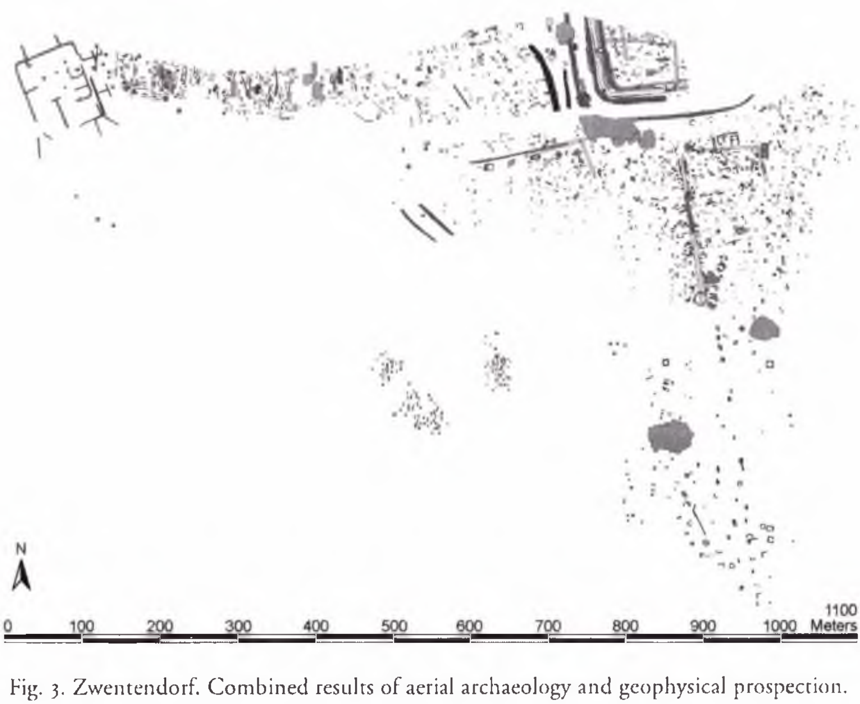


Fig. 3. Zwentendorf. Combined results of aerial archaeology and geophysical prospection.

For the orientation and rectification of the oblique aerial photographs, ERDAS Imagine Orthobase 8.4 was applied using secondary ground control measured from the vertical stereopairs. Depending on the camera used, scale, quality of distribution, and measurement of ground control, the accuracy lay between 0.1 and 0.2 m.

The geophysical survey started concurrently (Fig. 2). To date, 6.5 ha have been magnetically prospected using a multisensor caesium gradiometer with 0.005 nT accuracy in a raster of 0.5 m by 0.125 m. The *castellum* itself was additionally surveyed applying a GPR device in a raster of 0.5 m by 0.05 m on an area of over 1 ha.

The rectified aerial photographs and the magneto- and radargrams were interpreted using ArcView GIS. The results of both techniques had a geometric match of +/– 15 cm. Employing GIS as an interpretation tool, it was easy to compare the appearance of archaeological features in aerial photographs and magneto- and radargrams. While in most cases the shape and outline of pits and ditches were quite similar, there were several instances when features were visible on only one of the data sources. However, the combination of different prospection methods revealed a densely occupied archaeological landscape (Fig. 3) containing the *castellum*, the Roman road network, a large *vicus* with wooden houses and stone buildings, two graveyards and even traces of the 1970s quarters for the workers of the atomic power plant of Zwentendorf.

Archaeological feedback of aerial archaeological interpretation of an Early Medieval graveyard at Frohsdorf, Lower Austria

Michael Doneus[a] and Gabriele Scharrer[b]

During 2000, aerial reconnaissance flights discovered an unrecorded graveyard in Frohsdorf (county of Wr. Neustadt), Lower Austria, about 600 m west of the river Leitha on top of an old river terrace (Fig. 1). Some 280 graves were crop-marked in an area of 5000 sq. m. Apart from the archaeological site, the crop marks visible in the aerial photographs showed up earlier channels of the river (contrasting gravel and sand river beds and floodplain sediments).

Interpretation was based on vertical stereopairs in conjunction with an oblique photograph, the calibration points measured on the ground with a total station (Leica TC1010). The stereomodel was set up on our analytical plotter (DSR 14) and used to measure the digital terrain model. For the orientation and rectification of the oblique aerial photograph ERDAS Imagine Orthobase 8.4 was applied using secondary ground control points measured from the vertical stereopair. The resulting digital orthophoto has a pixel size of 0.1 m (Fig. 2).

The interpretation of the rectified image was done using ArcView GIS. Altogether, about 280 graves could be identified. The grave pits follow a NW-SE orientation with merely a few dug at right angles to this. They are spaced at 0.1 m to 1 m intervals and measure 2.5 m to 3 m

[a] Institute for Pre- and Early History, University of Vienna, Austria
[b] Vienna Institute for Archaeological Science, University of Vienna, Austria

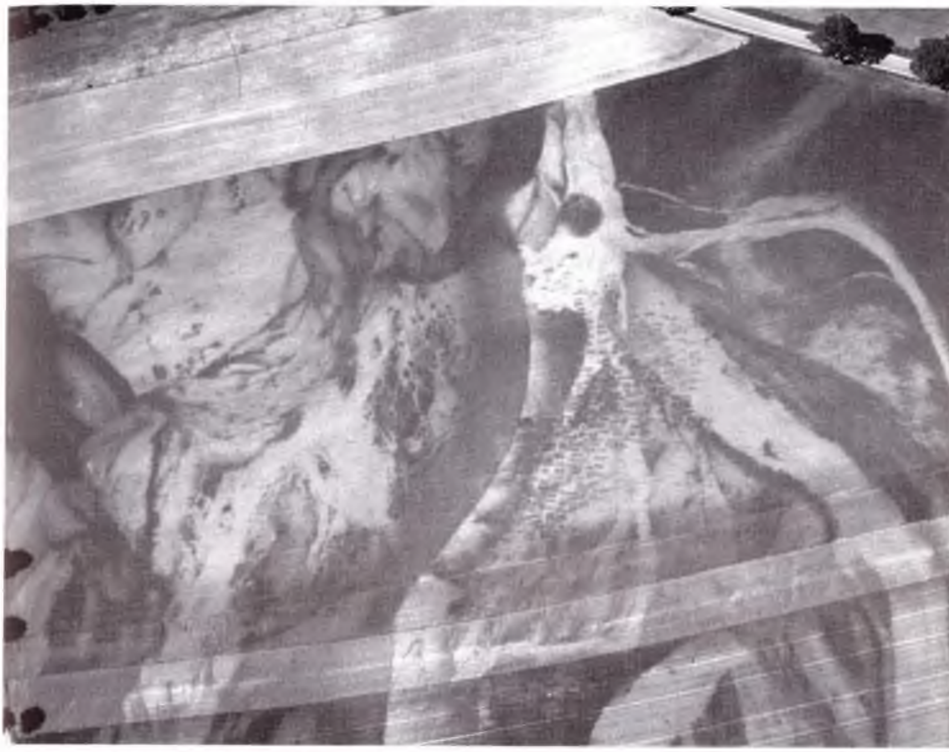


Fig. 1. Frohsdorf. Aerial photograph from May 2000 showing crop marks of riverbeds and sediments of the old river Leitha. In the centre, about 280 burials are visible as dark green crop marks (© Luftbildarchiv, Institut f. Ur- und Frühgeschichte, Wien; Freig. Nr. 13088/55–1.4/01).

by 1.0 m to 1.5m. Pattern, orientation, and extent led to the conclusion that the site could represent an Early Medieval cemetery. Earlier research on settlement archaeology in this region suggested that the burials could be Slavic or Avar (Kühtreiber 1993).

To test this hypothesis, a small-scale verification excavation was conducted in August 2001. The site was chosen based on the mapped interpretation of aerial photographs and a total station served to trace a 5 m by 5 m trench in the centre of the cemetery. Once the 30 cm to 50 cm deep plough horizon had been removed, the fill of eight grave pits became clearly visible. Four were completely within the excavation including that of an infant, and another four were cut by the trench. The oblong pits varied in size from 2 m to 2.7 m in length and from 0.9 m to 1 m in width; they were dug in the light brown river gravel, an average of 1.7 m below the top of the humic layer. The infant burial was only 0.5 m deep. The grave fill was brown gravel mixed with humus and sand.

The boundary of each grave was recorded digitally using the total station and measured points and lines were directly imported into ArcView GIS and compared with the aerial archaeological interpretation drawing. The comparison showed a virtually exact match with

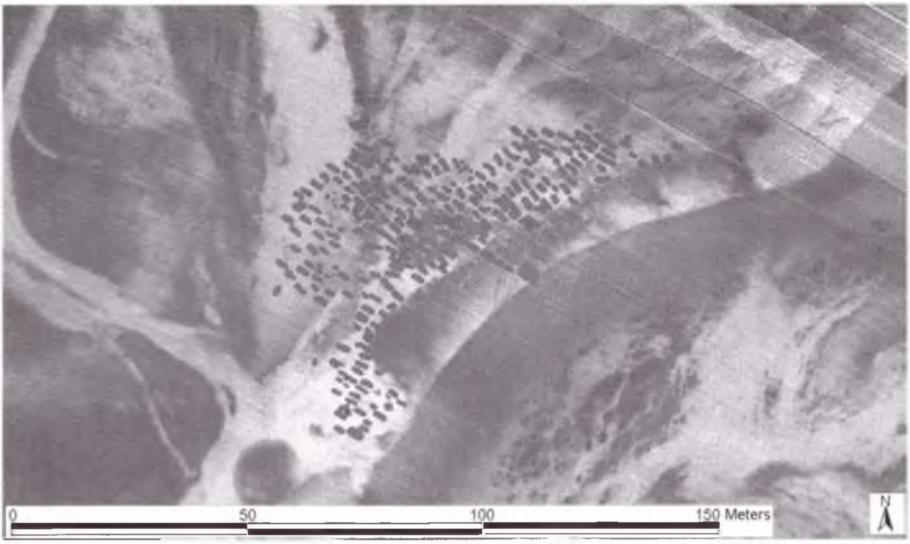


Fig. 2. Frohsdorf. Orthophoto and interpretative mapping of the Early Medieval cemetery.

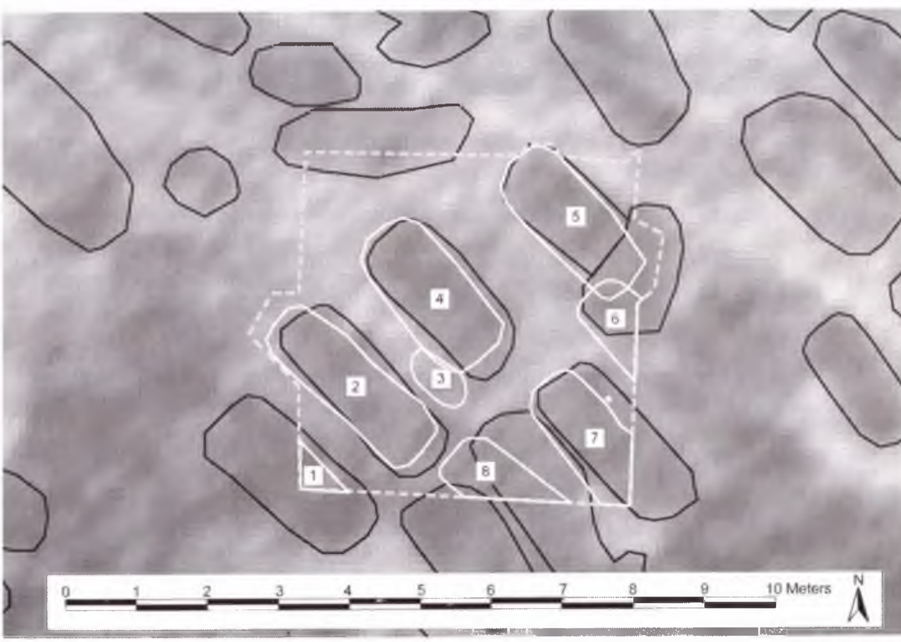


Fig. 3. Frohsdorf. Comparison between aerial archaeological interpretation (black lines) and excavated features (white lines).

errors between 0.1 m and 0.2 m and five had been mapped correctly from the aerial photograph (Fig. 3). The crop marks associated with grave No. 8 were misinterpreted as the traces of two separate graves and the No. 3 small, shallow grave of the infant was not identified at all on the aerial photograph. It was dug only 0.2 m below the plough zone and therefore the grave fill did not generate a visible crop mark. The south end of the crop mark for grave No. 5 suggested that a second grave intersected it at right angles. The excavation did show an intersecting grave (No 6); however, it was on the same orientation as the other burials.

Traces of the coffins were identified but the skeletons were poorly preserved. Besides ceramics and an iron knife, belt fittings were found with the burial of an adult male. The belt fittings can be dated to the mid-7th century AD (the transition from the early to middle Avar period), and confirmed our hypothesis about the age of the cemetery (Daim and Scharrer 2001).

REFERENCES

Kühtreiber, T. 1993. *Siedlungsarchäologische Aspekte im südöstlichen Niederösterreich von der römischen Kaiserzeit bis zum Spätmittelalter.* Unpublished Proseminararbeit Univ. Wien.

Daim, F. and G. Scharrer 2001. Frohsdorf. *Fündberichte aus Österreich* 40: 683.

Large-scale magnetic and resistivity surveys at the Burgaz archaeological site, Turkey

Mahmut G. Drahor[a] and Gökhan Göktürkler[a]

Over the past ten years large-scale geophysical prospection has seen wide use on archaeological sites around the world, the overall purpose being to make excavations quick and effective by providing data on probable settlement architecture and the location of buried archaeological features. Both magnetic and resistivity methods have been applied for archaeological prospection because they are fast and the resultant data is processable as an image of the subsoil. The magnetic method in particular is highly sensitive to magnetic susceptibility changes, especially those generated by fire, a common occurrence at archaeological sites (Clark 1996).

The principle of prospection using different geophysical methods in conjunction has been applied successfully at the Burgaz archaeological site (near Datça in Turkey) in 1999–2002 to delineate the plan of the archaeological settlement. Archaeological excavations at Burgaz have been ongoing since 1993, revealing in effect five general cultural horizons from the Archaic to the Late Roman. The city of Archaic times has been shown to follow a regular layout with perpendicular street grid. The large-scale surveys using magnetic and resistivity prospection techniques were carried out first (1999) in the residential district of the

[a] Dokuz Eylül University, Engineering Faculty, Department of Geophysics, Buca-İzmir, Turkey

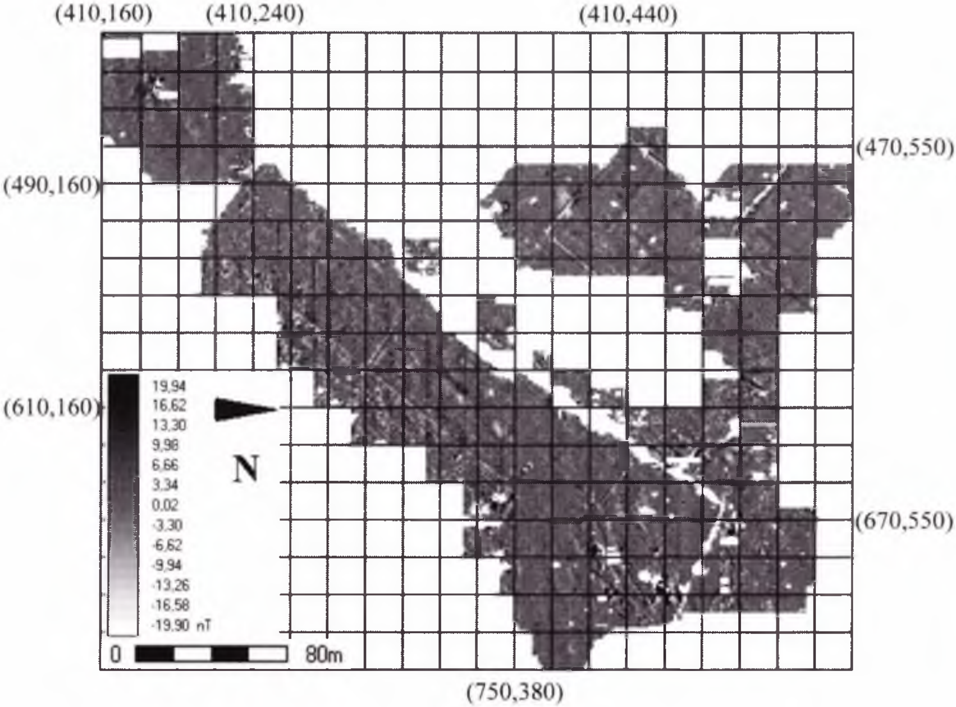


Fig. 1. Burgaz. Large-scale gradiometer shade image of the site.

town dating to the Archaic and Classical periods. Data was collected with a Geoscan FM 36 fluxgate gradiometer and Metz SAS 200 resistivity meter, from a net-grid of 20 m by 20 m using 0.25 m by 1 m and 1 m by 1 m grid intervals, respectively. Resistivity studies were also conducted around the north and south harbors, where previous archaeological excavations had indicated the presence of archaeological contexts close to the surface.

This work was followed by large-scale magnetic and resistivity surveys on the Burgaz acropolis (2000–2002). Magnetic data, collected as described above, were combined to obtain a large-scale magnetic map of about 10 ha of surveyed area (Fig. 1). The data were processed using different signal and image processing techniques. To obtain a photographic image of the data, relief-plotting parameters were used, simulating illumination by an artificial sun that is generally useful for revealing subtle changes in the data.

The resistivity survey of the acropolis area was performed with a twin array having a probe interval of 1 m, 2 m and 3 m; the station interval was 1 m and the distance between the profiles was 2 m. The result was data from different investigation levels, essential for showing the extent of anomalies in 3D form. A data correction method was used to eliminate spurious responses occurring between the fixed electrodes. Mapping revealed many high-resistivity anomaly groups that were then interpreted using inversion technique (Fig. 2).

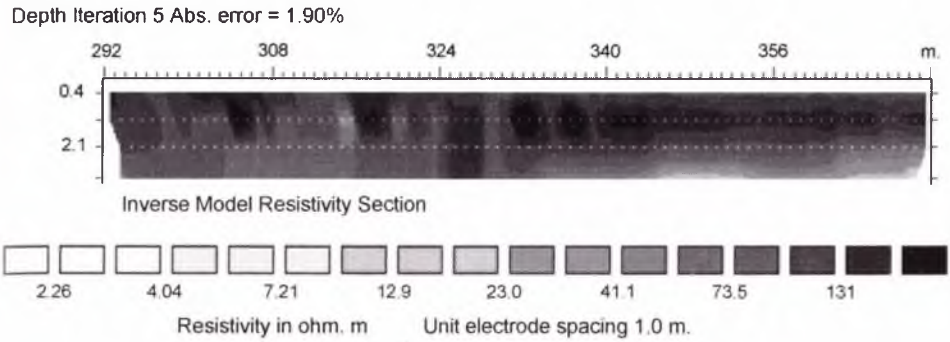


Fig. 2. Burgaz. Profile n 606, result of resistivity inversion.

Interpretation of electrical resistivity data using the inversion technique has been commonly applied in recent years (Tripp *et al.* 1984; Sasaki 1989, 1992; Griffiths and Barker 1994; Loke and Barker 1996a, 1996b). After acquisition, the resistivity data are arranged and plotted in the form of a pseudosection, a representation of the apparent resistivity (electrical resistivity data collected in the field) variations in the subsurface. A pseudosection is not only a function of subsurface resistivity distribution but also a function of the geometry of the electrodes. Therefore, to obtain true resistivity distribution of the subsurface an inversion process is applied to the data. To achieve this, an algorithm mainly based on matrix algebra is applied in an iterative manner using apparent resistivity pseudosections as input, and the output of this process is true resistivity distribution in the subsurface. The most common inversion methods used in electrical imaging surveys are the smoothness-constrained least-squares inversion and robust inversion. In this study, the resistivity data were processed using 2D and 3D inversion methods, clearly outlining various archaeological features.

Following this large-scale geophysical prospection, an important part of the architectural plan of antique Burgaz has been delineated. Test excavations, which were carried out in targeted sectors of the site, proved the effectiveness of large-scale geophysical explorations. In conclusion, it may be said that this technique has once again been proved very useful to archaeologists planning an excavation.

ACKNOWLEDGEMENT

This study was supported by the Scientific and Technical Research Council of Turkey (TUBITAK) under grant no. 102Y051.

REFERENCES

Clark, A. 1996. *Seeing beneath the soil.* London.

Griffiths, D.H. and R.D. Barker 1994. Electrical imaging in archaeology. *Journal of Archaeological Science* 21:153–8.

Loke, M.H. and R.D. Barker 1996a. Rapid least-squares inversion of apparent resistivity pseudosections by a quasi-Newton method. *Geophysical Prospecting* 44:131–52.

Loke, M.H. and R.D. Barker 1996b. Practical techniques for 3D resistivity surveys and data inversion techniques. *Geophysical Prospecting* 44(3):499–524.
Sasaki, Y. 1989. Two-dimensional joint inversion of magnetotelluric and dipole-dipole resistivity data. *Geophysics* 54: 254–62.
– 1992. Resolution of resistivity tomography inferred from numerical simulation. *Geophysical Prospecting* 40:453–64.
Tripp, A.C., G.W. Hohmann and C.M. Swift, Jr. 1984. Two-dimensional resistivity inversion. *Geophysics* 49:1708–17.

Magnetic prospection at the site of Bocheń, Central Poland

Marek Dulinicz[a], Peter Milo[b], Krzysztof Misiewicz[a] and Mieczysław Rekowski[c]

Investigations of the Slavic settlement at Bocheń near Łowicz started in 2000 as a joint project of the Institute of Archaeology and Ethnology of the Polish Academy of Sciences, the Polish-German Foundation and the Alexander von Humboldt Foundation. A big settlement of a few dozen wooden buildings was uncovered; it had been founded in the 8th century and remained in existence until the 10th century.

The houses were aboveground structures built in a variety of construction techniques. Most had deep pits and it is these pits, many of which contained considerable quantities of ashes, that have been preserved in the archaeological record. The inhabitants pursued agricultural activities and animal husbandry, but they also smelted iron – on a considerable scale – from the local iron ores, and they made their own pottery.

A rare find of a well constructed of oak-wood provided material for dendrochronological dating, which was carried out by Tomasz Ważny, then from the Dendrochronological Laboratory of the Fine Arts Academy in Warsaw. According to his findings, the oldest of the oaks used in the construction of the well was about 220 years old, the remaining two were 130–140 years old. The actual date for the building of the well was set as 826 or 827 AD, making this one of the oldest wells discovered in an Early Medieval rural settlement. There must have been more such wells in Bocheń, but they remain to be uncovered.

A natural depression, filled in entirely by soil and waste, was located in the center of the settlement. It was presumably the village pond.

In view of the considerable area occupied by the site, geophysical methods were brought in to augment traditional excavation. In 2000, an area 30 by 150 m (white square in Fig. 2) was surveyed with a PMP proton magnetometer configured as a gradiometer, the probes being set one meter apart, the bottom one carried 0.5 m above ground level. A net-grid of

[a] Institute of Archaeology and Ethnology, Polish Academy of Sciences, Warsaw, Poland
[b] Seminar für Vor- und Frühgesichte, Johann Wolfgang Goethe Universität, Frankfurt am Main, Germany
[c] Institute of Geophysics, Polish Academy of Sciences, Warsaw, Poland

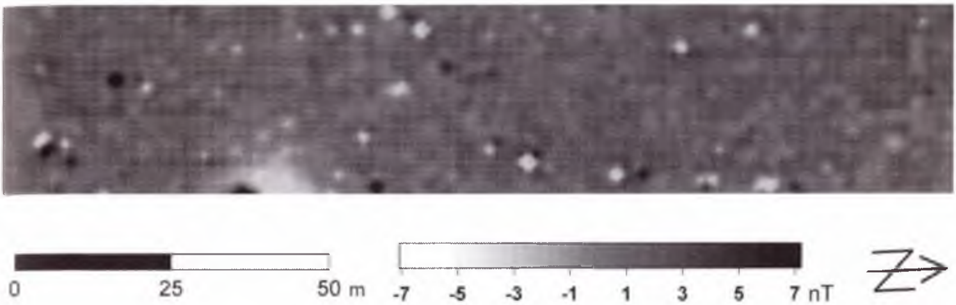


Fig. 1. Bocheń. Results of measurements made in 2002 using a PMP proton magnetometer. Dynamics –7/+7 nT.

1 m for taking measurements was deemed satisfactory in view of the large size of archaeological features (pits, hearths, remains of sunken huts) and the test character of the study. The recorded magnetic-field changes fall within the range of –15 nT to +8 nT (Fig. 1). The most obvious anomaly seen on the magnetogram quite likely corresponds to a modern metal artifact found in the subsurface soil. Metal objects could be the source of other anomalies, mostly of a dipole nature, although it is possible that at least some of these correspond to archaeological features. A concentration of anomalies of this kind was localized in the northern and northwestern part of the prospected area. The analysis of the results of the magnetic study indicates the sustainability of further research, but in a much larger area, using a denser measurement grid and higher-resolution measuring apparatus.

In 2002, a reconnaissance in the settlement border zone was completed by a team from the Goethe University in Frankfurt. The processed results of the survey will constitute a chapter of a dissertation, now being prepared, dealing with the viability of magnetic prospection in the investigation of unfortified medieval settlements. In the Bocheń case study, the principal issue was to develop a method for localizing the remains of above-ground structures, which are only poorly visible during explorations carried out in the traditional, intrusive way.

Fieldwork was done with a Förster Ferex 4.032 three-channel magnetometer on a grid of 0.25 m by 0.5 m covering an area of 4.2 ha (Fig. 2). The presence of a variety of magnetic anomalies was noted in the surveyed area and it seems that the eastern, western and northern settlement extent has been delineated as a result. These anomalies formed concentrations and are likely to correspond to the sought-after Early Medieval structures. The size of the recorded anomalies ranges from a few dozen centimeters to a few meters (6 m at the maximum; 3–4 m on average). Most of the features registering as anomalies are oriented east-west; a few are northwest-to-southeast. Two groups of anomalies of different size have been identified in the southwestern and northwestern parts of the investigated area. The orientation, size and form of the located features correspond entirely to what has been recorded in regular excavations. Geological conditions undoubtedly influenced the results of the measurements. Obviously, the presence of sand layers in the subsoil is at least part of the reason for the poor contrast of the magnetic image.

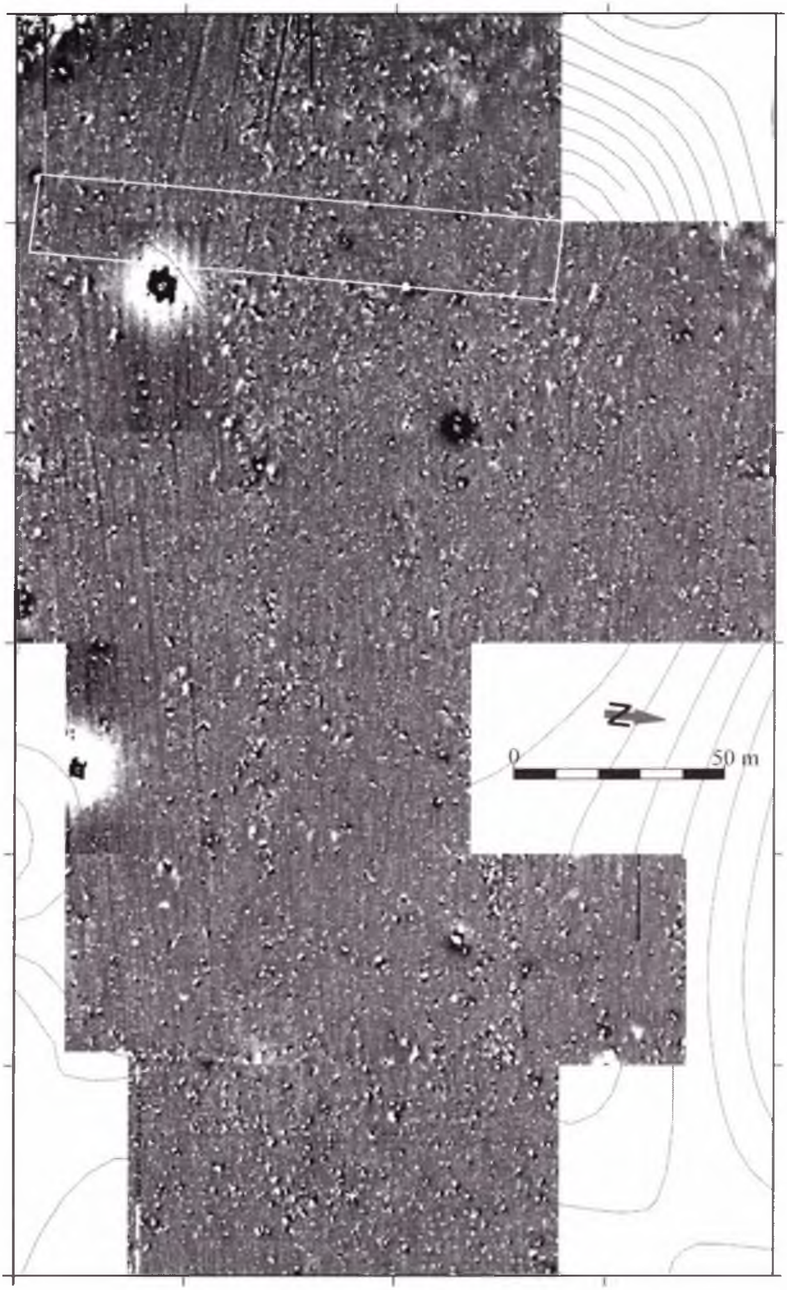


Fig. 2. Bocheń. Magnetic measurements made in 2003. Fluxgate Foerster Ferex 4.032 magnetometer, 3 channels. Dynamics –2/+2 nT represented in 256 greyscale, raster 0.25 m by 0.5 m.

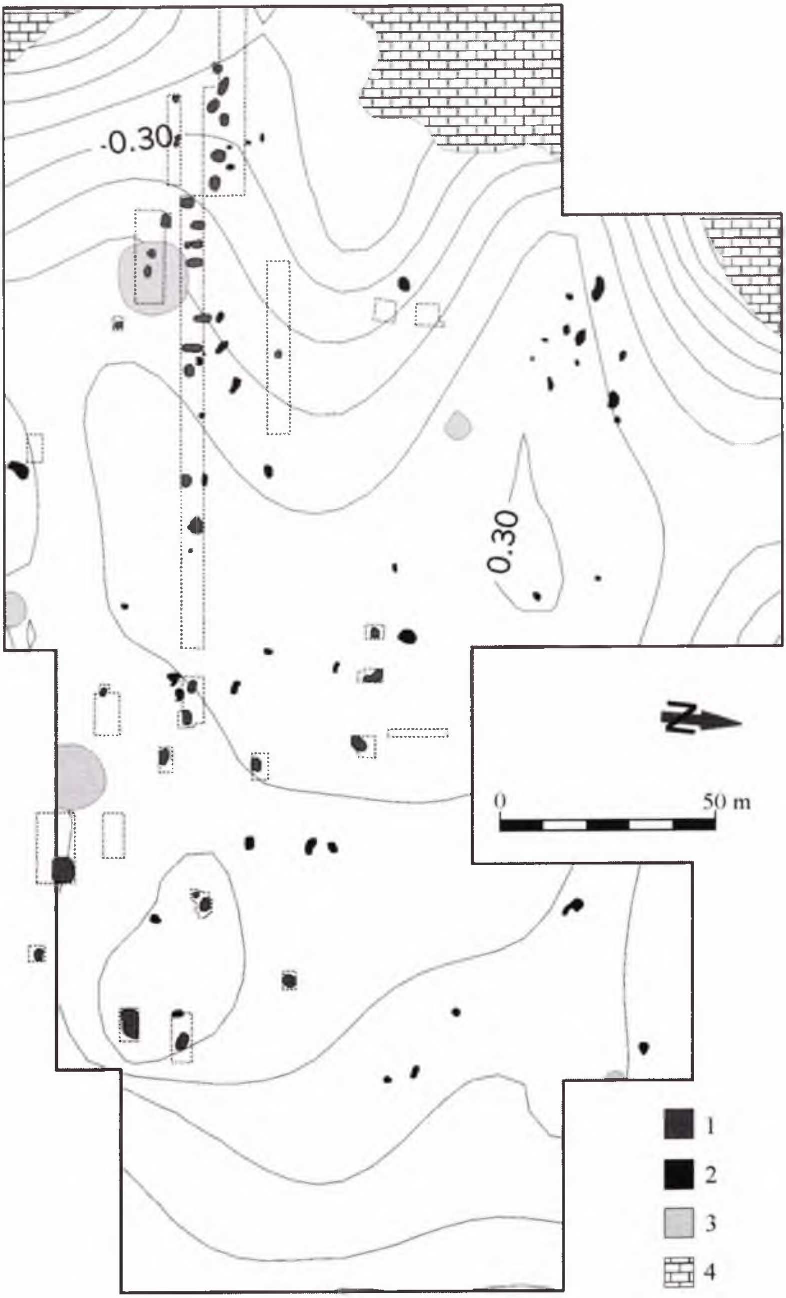


Fig. 3. Bochen. Interpretative map: 1 – archaeological features, 2 – presumed archaeological features, 3 – modern anomalies, 4 – geological structures.

The Bocheń site lies in a region where the Early Medieval architecture was typically of the aboveground type. The results of the prospection are heavily influenced by the presence of such architecture on the site, reflecting at the same time the limitations of the application of the magnetic method to the investigation of sites of this character.

The city map of ancient Carnuntum – combining archaeological prospection, photogrammetry and GIS

Alois Eder-Hinterleitner[a], Peter Melichar[a], Wolfgang Neubauer[b], Michael Doneus[c] and Sirri Seren[a]

The archaeological site of Carnuntum is located 45 km east of Vienna, close to the Slovakian border. The river Danube cuts here through the foothills of the Carpathian Mountains in the east, its gravel-terraces forming a flat to slightly hilly terrain. As the capital of the Roman province Pannonia, Carnuntum was an important town during the first four centuries AD. Today, the archaeological remains are spread over an area of approximately 600 ha within the modern communities of Bad Deutsch Altenburg and Petronell. In the 19th century Carnuntum was called the "Pompeii at the doors of Vienna" due to the good preservation of the Roman ruins. Since then, the situation has changed drastically. Both aerial photography and geophysical data show the severity of damages to the archaeological heritage caused by local agricultural policies of the past few decades. Agricultural practices have removed the archaeological layers bit by bit, and many fields have been deeply ploughed resulting in large-scale destruction of the antique features. The economic development of modern villages located in archaeological zones constitutes yet another threat to the cultural heritage. This ongoing destruction of Roman Carnuntum cannot be fully prevented. Therefore, cultural resource management will have to concentrate on preserving the most important parts.

In order to support preservation, an appropriate prospection strategy had to be established so that the antique remains could be recorded before they vanish completely. As a first step, we decided in 1997 to create a city map of ancient Carnuntum. Aerial photographs of the past 50 years were used to create a highly detailed map of the archaeological features at Carnuntum.

So far, aerial photographs showing archaeological features in an area of 270 ha have been mapped. Although only about 10 percent of the available photographs have been rectified and interpreted, the composite map already shows a considerable degree of detail. In the *canabae* around the military camp, the whole road network, partly with sewage drains, could be reconstructed. Between the roads, more than a hundred buildings were identified and

[a] Central Institute for Meteorology and Geodynamics, Vienna, Austria
[b] Vienna Institute for Archaeological Science, University of Vienna, Austria
[c] Institute for Pre- and Early History, University of Vienna, Austria

parts of the forum are visible west of the camp. The main road leading to the west is lined by several graves and tombs. Further west, the ditches of the auxiliary camp, where the cavalry was situated, could be mapped. The camp is already partly destroyed by the expansion of the village Petronell. The second area, west of this village, shows a complex of buildings belonging to the civil amphitheatre and a large graveyard, which is partly intersecting and therefore not contemporary. To the north lies the civil town of Carnuntum, which is protected by a city wall and two parallel ditches. More details can be seen in the results of the geophysical prospection survey which has already been partially published.

Over 110 ha have been covered to date by magnetics and nearly 10 ha by GPR, mainly in the area of the civil town. The integration of the aerial photographs and the combination of the results with geophysical prospection is done using ArcView GIS. It is hoped that after more than a hundred years of archaeological investigations at Carnuntum, resulting in a patchwork of excavations, all of the available information can now be brought together to produce the first comprehensive map of the ancient city.

Combined geophysical survey at Selinus, Sicily

Ercan Erkul[a], Wolfgang Rabbel[a] and Harald Stümpel[a]

At the Greek colony of Selinus, eastern Sicily, several geophysical campaigns have been carried out since the spring of 1999 by the Institute of Geosciences of Kiel University.

Practically the entire urban area of about 65 ha has been mapped magnetically. Only a few gaps remain in the surveyed area, resulting from topographic conditions or modern agricultural use. In addition, geoelectrical resistivity mapping has been performed at some sites where the magnetic survey showed only weak or strongly disturbed anomalies. Experiments with georadar measurements, particularly at archaeologically relevant points in the valleys, did not show satisfying results; the high conductivity of the ground caused strong absorption and, thus, only a small penetration depth of the radar waves. To investigate the ground topography and the possible location of the former ports of Selinus, the geophysical survey was complemented with some seismic profiles.

The results of geomagnetic mapping are shown in Figure 1. The measured values are visualized by 256 greyscale values with an amplitude range of –3 nT (white) to +3 nT (black). Thus, dark and light colours represent high and low magnetization of the underground, respectively. All amplitudes outside this range are cut off and accordingly printed in white or black respectively.

The magnetic image overall brings out perfectly the settlement traces in the subsoil. City walls, roads, insular boundaries and even individual house foundations are all quite saliently represented. The intra-urban area can be distinguished clearly from the unpopulated

[a] Institute of Geosciences/Geophysics,University of Kiel, Germany

Fig. 1. Selinus. Geomagnetic map.

suburban areas by the high contrast of its black-and-white signature. The strong magnetization of the intra-urban zone is caused by an enrichment of the soil with burned-clay remnants, such as fragments of roofing tiles and pieces of broken glass. Light gray and

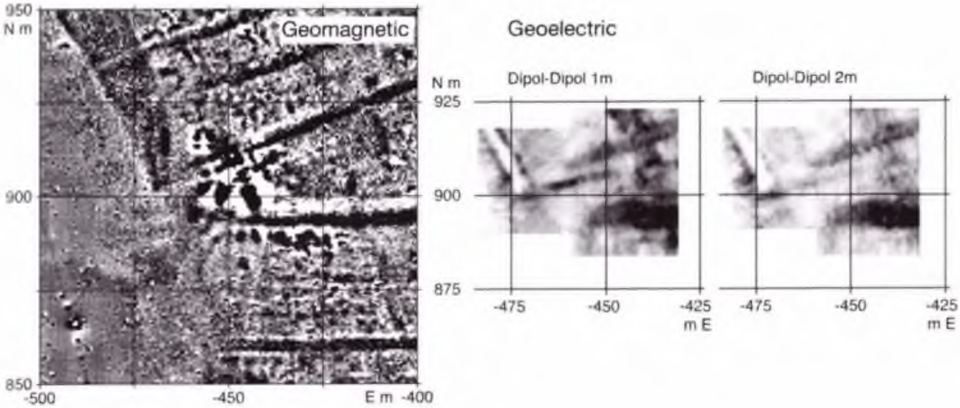


Fig. 2. Selinus. Comparison of geomagnetic and geoelectric mapping at the west gate.

intense white tones refer to non-magnetic building materials, or to a negative magnetization contrast with respect to the surrounding material. These patterns can be associated, for instance, with limestone foundations.

Two roads meet at the west gate of the city (Fig. 2, left). A huge magnetic anomaly, higher than at all other locations in Selinus, is found in this spot. It confuses rather than shows the structure of a city gate expected at this site. On the grounds of similar anomalies found at other archeological sites and excavations, we have assumed that this extraordinary anomaly was caused by the conflagration of an important building. Therefore, additional information was gathered using geoelectrical mapping in dipole-dipole arrangement (Fig. 2, right). These measurements were performed during a period of extreme drought. Clear contrasts in electrical conductivity indicate the course of roads. Also, the suspect city gate stands out in the northern part of the resistivity map, expressed as a weak anomaly of increased conductivity. The inner and outer shells of the gate are approximately 5 m apart. By comparing magnetic and geoelectrical maps, it became possible to identify the anomalies corresponding to the gate on the magnetic map.

Development of a mobile multi-sensor system: first results

Ercan Erkul[a], Wolfgang Rabbel[a] and Harald Stümpel[a]

Investigating ancient living conditions in their entirety is becoming increasingly important in the archaeological sciences. Correspondingly, archaeological prospecting is faced with the requirement to map large areas of ancient settlement, by large meaning a scale in square

[a] Institute of Geosciences/Geophysics, University of Kiel, Germany

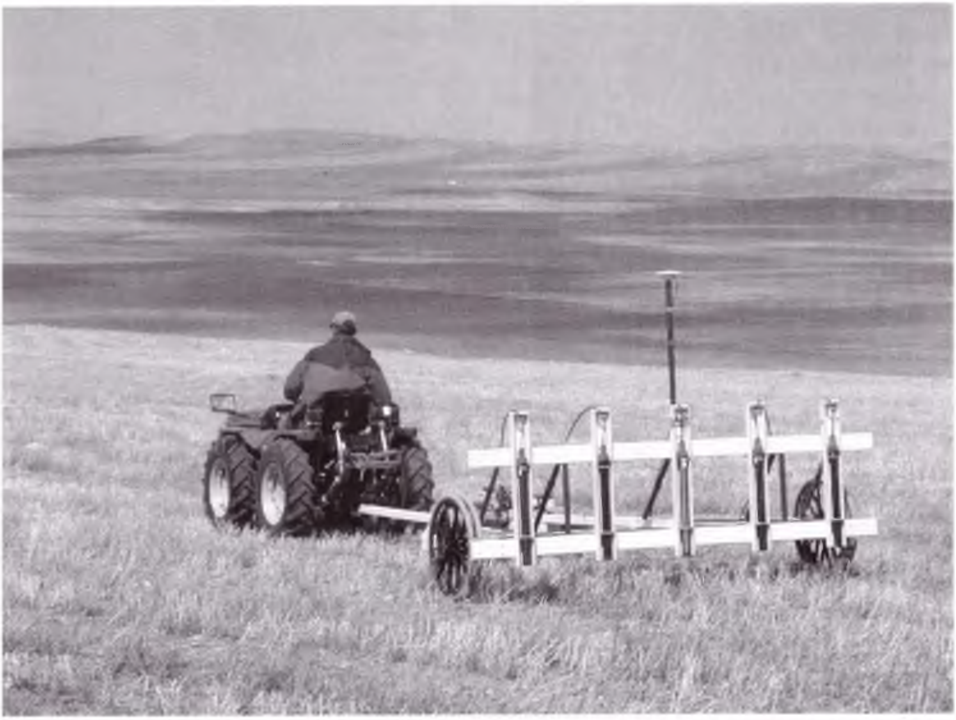


Fig. 1. The mobile multi-sensor system.

kilometers. Therefore, we are developing a prototype motorized multi-sensor system for archaeological prospection applying different techniques of geophysics.

Our new system will make it possible to map large areas quickly and cost-effectively, using differential global positioning system (DGPS) and data-logging equipment to apply several geophysical methods simultaneously.

The new system consists of a tractor, a trailer, magnetic fluxgate sensors, electromagnetic sensors, georadar equipment, DGPS equipment and data-logger. The sensors are installed on a trailer which is pulled behind a tractor (Fig. 1).

Initial results at the archaeological sites of Selinus, Sicily, and Sarissa, central Anatolia, have demonstrated the following:

- the fluxgate magnetometers receive no electromagnetic interference in the non-magnetic trailer built of glass fibre and plastics;
- noise levels produced by the vehicle in motion are negligible;
- DGPS enables quick and cost-effective data collection by eliminating the need for pre-surveying of the grid;
- self-developed Mer-Plot software enables rapid calculations and visualisation of the geophysical parameters on a portable computer in the field.

Magnetometry at Zhaolun, the "Asian Central Bank" of the Han dynasty, Shaanxi Province, China

Jörg W.E. Fassbinder[a], Doris Ebner[a], Josef Lichtenauer[a], Qin Jianming[b], Jiang Baolian[b], Liang Xiaoqing[b], Yang Tianmin[b], Zhao Qiang[b] and Qi Yang[b]

INTRODUCTION

Cooperation between the Bavarian State Office for the Protection of Historical Monuments, Archaeological Prospection and Aerial Archaeology Department, Germany, and the Shaanxi Province Conservation Centre for Historical Monuments led to an international geophysical prospection research project at Zhaolun, Shaanxi Province, China (Fassbinder 2002; Fassbinder and Ebner 2003). At Zhaolun Chinese archaeologists were inspecting a centre of coinage production during the Han Dynasty (207 BC to 220 AD). Their findings had suggested that the site was probably the emperors' mint "Zhongguan", which is recorded in written sources. Prospecting with a caesium magnetometer was used to locate and map in detail the remains at the site.

ARCHAEOLOGICAL BACKGROUND

The mint site of Zhaolun is located about 25 km west of the city of Xi'an, capital of a Shaanxi Province, and about 700 meters to the north of Zhaolun village near Huxian (GPS coordinates: E 108°40,4' and N 34°11,7'). The site covers an area of about 90 ha and extends about 600 m from east to west and 1500 m from north to south. The old Cang Long River (Han dynasty), flowing from the Qian Ling mountains and ending in the Wei River, meanders east of the site. In the 1950s this old river was canalized and now, as the new Xin River, it cuts through the site from southeast to northwest.

This canalization, as well as the huge changes instigated by land reform and agricultural development in modern China, have caused quantities of pottery, mint moulds, pottery models, remains of architecture and rammed platforms of architecture to emerge at the site. But the majority of the finds still brought to light by ploughing consists of clay casting moulds. A field survey by Chinese archaeologists roughly pinpointed areas where the clay models were found in quantity on the east and west banks of the Xin River. Many such fragmentary models were scattered on the surface and in a stratum that was about 1.5–2 m thick. A large square of ash and charcoal deposits with copper residue was also discovered. It belongs to the metal smelting area. In spite of the abundance of archaeological finds, there was no inkling as to what could be found underground. Indeed, there was no proof that any structures had actually survived intensive land use and the ravages of erosion processes.

[a] Bavarian State Office for Protection of Historical Monuments, Munich, Germany
[b] Technical Center of the Shaanxi Province Conservation Center for Historical Monuments, Xi'an, China

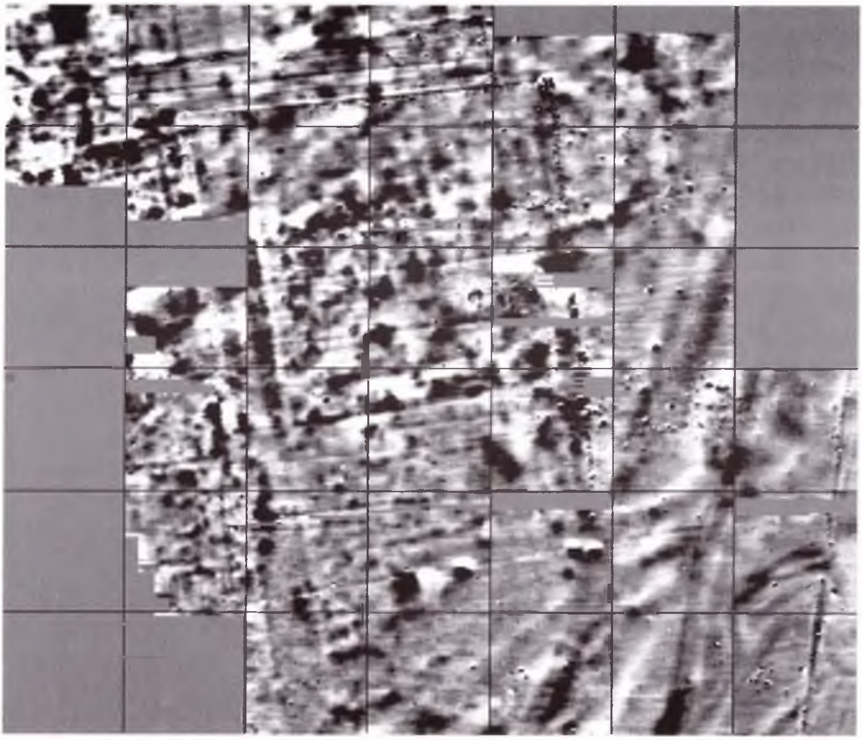


Fig. 1. Zhaolun. Magnetogram of the central part of the mint site. Cesium magnetometer Smartmag SM4G-Special in duo-sensor configuration, sensitivity 10 pT. Dynamics –/+12 nT in 256 greyscales (white to black), raster 0.5 m by 0.2 m interpolated to 0.25 m by 0.25 m, 40 m grid, north to the top. Dynamics of the total magnetic field 51 940 –/+20 000 nT.

MAGNETIC PROSPECTION

The first tests with a caesium magnetometer in 2001 were successful in locating the site. They were performed in three different spots, selected on the grounds of an earlier intensive field survey by Chinese archaeologists. Two of the test sites in the south of Zhaolun, sized each about 1 ha, revealed some pits which could not be clearly ascribed to building structures. The third test site in the north was expanded to a size of 440 by 160 meters. Here, some clear archaeological features were detected for the first time: buildings, work areas and kilns of the minting site. This confirmed the assumption that some archaeological structures were still to be found beneath the surface.

The aim of the second survey, carried out in October 2002 east of the river Xin, was to provide complete coverage of the inner minting site area. To be able to detect mud brick structures in loess over such a large area, it was necessary to have a narrow sampling interval of 0.25 m by 0.5 m.

Fig. 2. Zhaolun. Interpretation map of the total measured area of the mint site, north to the top.

A caesium Scintrex SMARTMAG SM4G Special magnetometer with a sensitivity of +/–10 pT at 0.1 sec cycle was used for all the measurements. A 40-m grid over 400 m by 240 m, later enlarged to 400 m by 480 m (*ca.* 18 ha), covered the site and was topographically surveyed and marked out with wooden pegs prior to the prospection. The instrument was applied in the uncompensated duo-sensor configuration at 0.5 m traverse interval and 0.1 m sample intervals as a total field magnetometer. The sensors were configured at

0.5 m horizontal distance and the sampling rate was set to 0.1 sec, which gives a spatial resolution of 0.1 m by 0.5 m at normal walking speed. The distance control was made manually by switching every 5 m over the 40 m-line. The high frequency part of the diurnal variation (natural micro-pulsations and technical noise) was cancelled out by setting a bandpass filter of 1 Hz in the hardware of the magnetometer processor. The magnetic changes of the daily variation of the geomagnetic field were reduced to the mean value of all measured data of a 40 m-line and also to the mean value of all data of a 40 m-grid. Data processing was done using software with graphic facilities for visualizing the measurement as grey-shading plots. The fit of adjacent grid sides was corrected by digital image techniques like edge matching and desloping, which resulted in a rather smooth image for the magnetogram even of the raw data (Fig. 1).

RESULTS

The first measurements in the north of Zhaolun covering a large area 440 meters (east to west) by 160 meters (north to south) showed that the archaeological remains were concentrated to the east and close to the Xin river. Remains of huge buildings were detected, as well as kilns and coin workshops. The 2002 survey on a site east of the Xin river, in an area 280 m by 240 m, revealed a huge factory building in its entirety. The building measured roughly 160 m by 200 m. The earth-rammed structures and mud brick walls resulted in mostly strong positive, but also some negative magnetic anomalies. Furthermore, the structures are rather more diffusive. In the east of the area we found traces of the old Cang Long river.

In conclusion, it may be said that the magnetic survey has provided the first opportunity for insight into the archaeological structures found beneath the soil at Zhaolun. The result of the prospection is a detailed map of the Han-dynasty mint-site residence.

TEST EXCAVATION

While the survey was in progress, excavation in the south of the site revealed a section of the wall of the huge building. Archaeological features were found at depths of 1.2–1.7 m. This explains the diffusiveness of the magnetic structures. The excavation not only confirmed the results of the magnetic prospection by uncovering rammed-earth structures, but also provided material for an exact dating of the archaeological features. The excavation also confirmed that these strong magnetic anomalies are due to the enrichment of the soil with hundreds of pieces of minting moulds and roof tiles which were found around the earth-rammed structures of the wall.

REFERENCES

Ebner, D. and J.W.E. Fassbinder 2003. Bare Münze bei Kaiser Wudi. Magnetometerprospektion im Rahmen des China-Projekts. *Denkmalpflege Informationen* 124:74–6.

Fassbinder, J.W.E. 2002. Die chinesische "Zentralbank" der Han-Zeit in Zhaolun bei Xi'an endeckt. *Denkmalpflege Informationen* 121:59–60.

Magnetic prospecting and targeted excavation of the prehistoric settlement Platt-Reitlüsse, Austria

Martin Fera[a], Wolfgang Neubauer[b], Michael Doneus[a] and Alois Eder-Hinterleitner[c]

The site Platt-Reitlüsse is situated on a north-facing slope of the Sandberg, southeast of the village Platt (Lower Austria), 60 km north of Vienna. It lies south of the river Pulkau, at the southern edge of a basin-shaped valley opening towards the river valley of the Pulkau, on a flat part of the heavily eroded slope ascending to the south. The site was detected by collected surface finds and is under intensive agricultural use.

To define the site and localise archaeological structures, we decided to carry out a magnetic survey in 1999. We used a multi-sensor caesium gradiometer with 5 Scintrex CS2 sensors with an accuracy of 0.005 nT. Four sensors were mounted on a non-magnetic cart 0.5 m apart with a distance of 0.35 m above the surface. The fifth sensor was mounted 2.85 m above the surface to correct for diurnal variation. The opto-electronic distance measuring unit produces pulses every 0.017 m. The distance, time and readings of the five sensors were stored on the computer, situated together with the batteries and the readout units in the second cart connected by a 50 m cable. The survey covered an area of 1.5 ha. The data was sampled in time mode (10 readings/sec) and was resampled on a 0.125 by 0.5 m raster. The corrected raw data was visualised as a digital image and georeferenced for subsequent GIS-based archaeological interpretation.

The magnetogram shows very low noise, indicating low susceptibilities of the subsoil. Dipole anomalies with randomly oriented minima dispersed over the area are due to 94 iron objects most likely embedded in the A_p-horizon. Besides this, some 245 anomalies can be detected that are of archaeological relevance, all interpreted as pits or other pit-like structures filled with deposits with enhanced magnetisation. In the southern part of the magnetogram, on the ascending slope of the Sandberg, only a few anomalies can be detected, probably due to erosion. The highest density of archaeological relevant anomalies can be observed in the central part of the magnetogram, on the flat area of the slope.

From the archaeologically relevant anomalies, 70 are interpreted as pits with highly enhanced magnetisation of the fill. They are rounded in shape and cover an area between 0.5 and 27.3 sq. m; most of them cover an area of 4 to 5 sq. m. Some of the larger pits are of a rectangular shape and could be interpreted as sunken huts. The larger anomalies could be a complex of pits. Another 46 anomalies are interpreted as pits or pit-like structures with less enhanced magnetisation of the fill. They show a rounded or irregular shape with a mean area of 3 sq. m. One anomaly in this class shows an area of more than 20 sq. m and another covers 161 sq. m. They could be produced by backfilled small sand quarries. Of the mentioned anomalies, 129 are the size of postholes or small pits.

[a] Institute for Pre- and Early History, University of Vienna, Austria
[b] Vienna Institute for Archaeological Science, University of Vienna, Austria
[c] Central Institute for Meteorology and Geodynamics, Austria

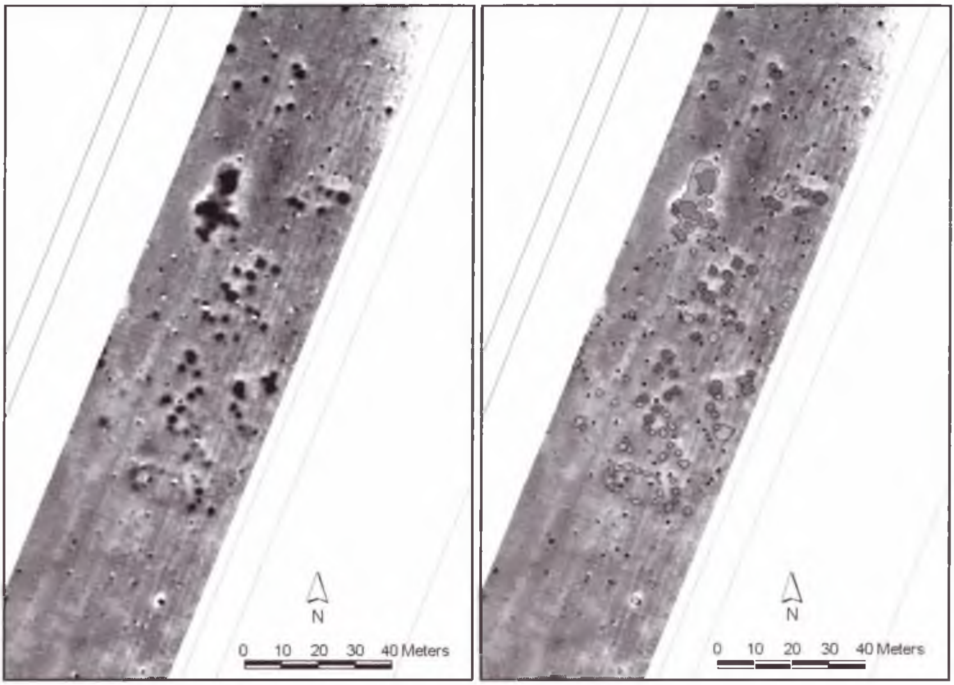


Fig. 1. Platt-Reitlüsse. Magnetogram and archaeological interpretation of the site. Dynamics –/+5 nT.

To verify the archaeological interpretation of the magnetic survey and to date the localised structures, we carried out a targeted stratigraphic excavation. One main objective of the digging was *in situ* susceptibility measurements of the single deposits and 3D documentation of their volume. We opened two trenches, 5 m by 7 m and 10 m by 12 m, to cover one of the expected sunken huts and a group of similar sized pits. We measured the thickness of the A_p-horizon using an auger and dug it out with an excavator. All the other units of stratification were dug with spades, shovels and trowels, and documented fully digitally in three dimensions using a total station and a digital camera. With the total station we documented the boundary polygons and an elevation model (mass points and breaklines) of the surfaces of single units of stratification and the embedded finds (artifacts such as pottery, stone or bone tools, animal bones, charcoal, samples). With the digital camera we photographed all units of stratification and rectified the images using at least four control points measured with the total station. For the rectification we used the freeware program Asrix. The accuracy of the rectification was kept within +/–5 cm. The vector data (ASCII), the rectified and georeferenced images (BMP) and the digital elevation data (ASCII) were imported into GIS ArcView for further processing. The vector data was converted into ArcView shape files and superimposed on the images. Obvious errors were corrected on the basis of the image. The images of the stratification units were clipped using the boundary lines measured with the total station. The imported elevation mass points and breaklines were converted into an ArcView triangulated irregular network (TIN) representation of the digital elevation model (DEM).

Every surface of a deposit was measured *in situ* with the Bartington MS2D coil sensor in a raster of 0.5 m by 0.5 or 0.2 m by 0.2 m. The data was georeferenced and visualised using the ArcView grid-format. We also took samples for later susceptibility measurements using the MS2B sensor. The data are used for 3D modelling. The excavation did prove the archaeological interpretation and provided additional data for 3D modelling and more detailed interpretation of the unexcavated structures detected by magnetics.

Excavating in "blind" mode. Magnetometer survey, excavation and magnetic susceptibility measurements of a multiperiod site at Bad Homburg, Germany

Nico Fröhlich[a], Martin Posselt[b] and Norbert Schleifer[c]

In 2001 the construction of a bypass road close to Bad Homburg in Hessen, Germany necessitated rescue excavation of Early Neolithic, Bronze Age and Roman sites situated in its course (Breitwieser *et al.* 2001). In order to run the excavation efficiently a magnetometer survey was done to detect features that needed to be excavated. An area 1.4 km long and 100 m wide along the course of the planned road was surveyed using a four-channel fluxgate gradiometer (Posselt & Zickgraf Prospektionen GbR). The survey yielded several anomalies that clearly indicate prehistoric features, including circular ditches and ground plans of Early Neolithic houses, their anthropogenic origins being unquestionable.

The subsequent excavation (Goethe University of Frankfurt am Main) was guided by the results of the magnetometer survey, but although many of the detected prehistoric and Roman features were revealed, the excavation failed by far to reproduce the results of the magnetometer plot. In particular, the circular ditches and parts of the Early Neolithic houses remained invisible. Looking for a fast solution to the problem and in order to exclude the possibility that archaeological remains were unknowingly being destroyed during topsoil removal, the magnetometer survey was repeated on the excavated area covering the features invisible to the human eye. According to these measurements the expected features were still in place.

The locations of the detected features were transferred from the magnetogram onto the excavation plan, and the features were excavated in "blind" mode. The sections were left open to weathering and several days later most of the ditches, which remained invisible on the excavated surface, appeared in the vertical sections, their colour slighty differing from

[a] Seminar für Vor- und Frühgeschichte, Johann Wolfgang Goethe-Universität, Frankfurt am Main, Germany
[b] Posselt & Zickgraf Prospektionen GbR, Mühltal, Germany
[c] Institut für Geophysik, TU Clausthal, Clausthal-Zellerfeld, Germany

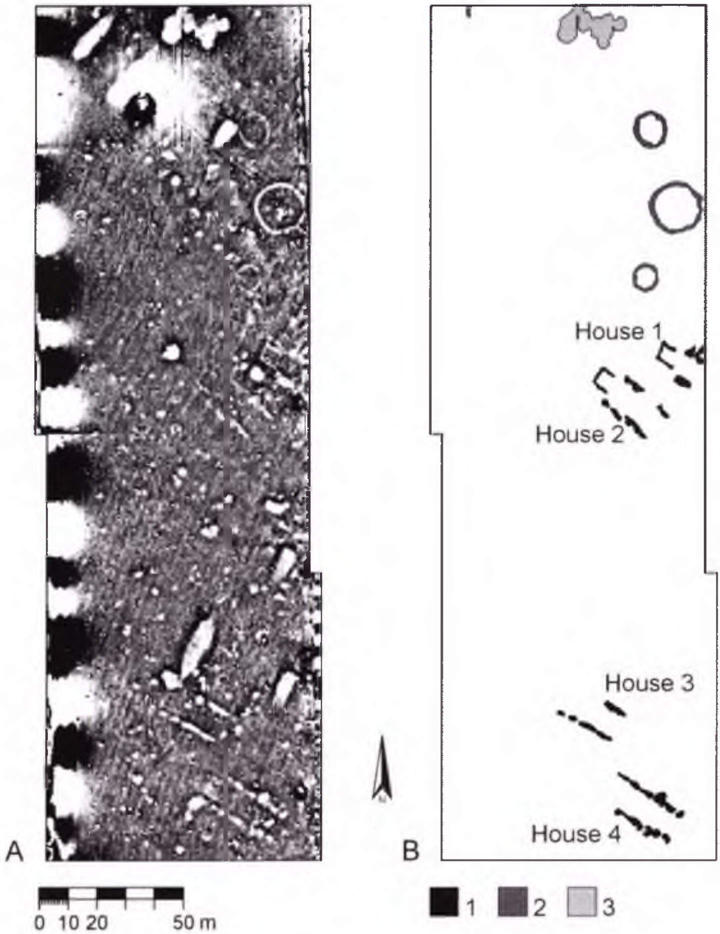


Fig. 1. Bad Homburg-Ober-Erlenbach 2001. Magnetometer survey showing ground plans of Early Neolithic houses, circular ditches and a large upper Bronze Age pit. A – 256 greyscale-plot, fluxgate gradiometer Förster Ferex 4.032, four channels, vertical probe distance: 0.65 m, max. resolution: 0.1 nT, measurements inline/crossline: 0.25 m by 0.5 m, dynamics: –3/+3 nT (black-white), linear. B – interpretive drawing, 1 – Early Neolithic houses; 2 – circular ditches; 3 – a large upper Bronze Age pit. Further prehistoric and recent features are visible in the greyscale-plot. Designed by Posselt & Zickgraf GbR.

the undisturbed soil. Other ditches never became visible whether in vertical section or on the horizontal surface.

Our presentation thus focuses on magnetical prospection being able to detect archaeological features that are virtually unrecognisable to the human eye (Fassbinder *et al.* 1998), discussing the consequences for future archaeological research and rescue strategies.

The Bad Homburg case study demonstrates how the inconsistent results of a magnetometer survey and excavation can be managed and evaluated.

Since iron minerals are mainly responsible for the magnetic behaviour of soils and, together with organic components, have a great influence on soil colour, additional laboratory examinations were carried out on soil samples from different archaeological features and the undisturbed soil, the objective being to verify field observations. The susceptibility of the samples was measured using a precision a.c. bridge, and the soil colour was determined using Munsell colour charts. It is to be concluded from the laboratory report that seemingly inconsistent results (assuming correct and conscientious work) are not the effect of either methodological shortcomings or human error in the application of a method. Instead, they are due to the strengths and weaknesses of any given investigation technique.

The results from Bad Homburg bear out the confidence archaeologists can place in geophysical methods regarded as an independent discipline on par with excavation and other archaeological survey methods.

REFERENCES

Breitwieser, C., N. Fröhlich, J. Lehmann and M. Posselt 2001. Archäologische Untersuchungen auf der Trasse der Umgehungsstraße Bad Homburg-Ober-Eschbach/Ober-Erlenbach: Die vorgeschichtlichen Fundstellen. *Hessen Archäologie* 2001: 42–5.

Fassbinder, J.W., W. Irlinger, N. Schleifer and H. Stanjek 1998. Methodische Untersuchungen zur Magnetometerprospektion: Das frühmittelalterliche Gräberfeld von Alburg. *Das Archäologische Jahr in Bayern* 1998: 112–4.

A contribution to archaeological prospection. Examples of resistivity surveys in the Mediterranean area

Roberto Gabrielli[a], Teresa Iuliano[a], Paolo Mauriello[a], Dario Monna[a] and Daniela Peloso[a]

Resistivity surveying has been used for a long time in archaeological prospecting since the majority of buried structures behave as high-contrast resistivity targets. Therefore, the study of a soil's electrical properties can be a helpful tool prior to archaeological excavation.

Although several instruments are available today, more attention should be given to the development of data acquisition and processing systems to satisfy the following targets: low cost, fast use and results from shallow resistivity anomalies. The aim is to develop an integrated system encompassing all steps of survey from data input to interpretation. Moreover, the data acquisition should be in conjunction with a differential GPS topographical survey. In this way surface maps and 3D tomography are georeferenced to be used in an archaeological GIS.

[a] Istituto per le Tecnologie Applicate ai Beni Culturali, CNR, Monterotondo, Rome, Italy

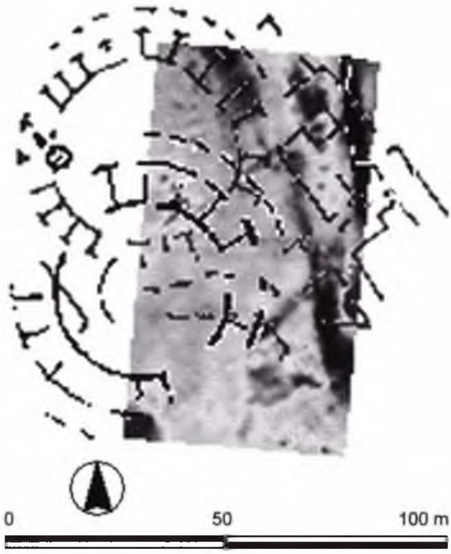


Fig. 1. Ostia, Via Capo Due Rami. Buried structures in the area under resistivity investigation.

The following are examples of field tests on archaeological sites.

OSTIA (ITALY)

1. The Forum of Corporations

This is one of the most important sites in the city of Ostia, obviously a Post Scaenam arcade being adjacent to the theatre. Built in the Augustean age, it underwent important modifications during the Julio-Claudian age, witnessed by the columns of the arcade which are still *in situ*. Another important change occurred during the Flavian age when a small temple, dedicated to the imperial cult, was erected practically in the centre of the square. The arcade's mosaics belong to the Severan age, end of the 2nd century AD and beginning of the 3rd century AD.

The resistivity survey was aimed at confirming the existence of possible walls buried under the northern side of the Piazza behind the temple.

2. Via Capo Due Rami

The interpretation of the aerial photos taken from a balloon in 1911 shows the existence of buried archaeological structures in the area of the ancient bed of the Tiber. The resistivity survey partially confirmed the spatial distribution of these structures (Fig. 1).

CUMA (ITALY)

It is the most ancient colony in southern Italy founded by Greeks of Eubea during the second half of the 8th century BC. Apart from public buildings and temples on the Acropolis and in the lower-town Roman Forum there are only a few elements pertaining to the urban texture. In the town of Cuma, recently the object of systematic archaeological research, a resistivity survey was conducted to reconstruct the urban texture of the area between the Forum and the northern walls (Fig. 2).

PYRGOS (CYPRUS)

The resistivity survey concerns an area that shows the last stage of life in Pyrgos during the Middle Bronze Age. The moment coincided probably with a strong earthquake which destroyed all the buildings. The collapsed structures remained buried in their original position until the excavation of the site in July 2000.

The excavation at Pyrgos started in 1998, following two years of archaeological soundings and surveys. Through the artifacts collected on the surface and the stratigraphy derived from the soundings, it was possible to date the finds to the Middle Bronze Age and to determine the depth at which archaeological structures occurred.

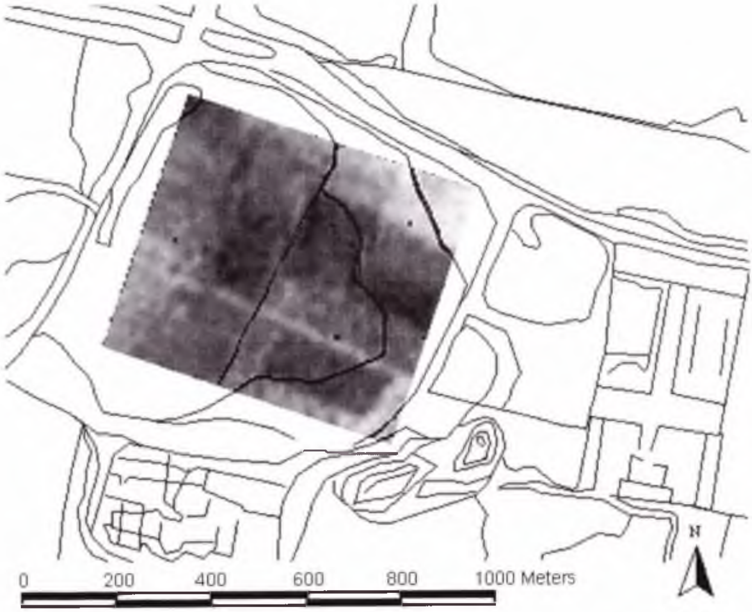


Fig. 2. Cuma. The resistivity map of the detected structures.

It was the first time that a Cypriote settlement of that period revealed itself as an important spot of metallurgical activity as indicated by the findings of copper slag and prills.

Why scan when you can do detailed survey?

Chris Gaffney[a] and John Gater[a]

Over the last decade the size of area in individual archaeological evaluations has grown substantially. During this period geophysical techniques have become embedded within methodologies to assess such proposed development (Gaffney *et al.* 2002). However, given the timescales that are often involved, it is not always feasible to survey the entire application in detail. As a result rapid "scanning" with a magnetometer has become routinely used on projects within the British Isles. It is hoped that the operator will be able to scan out anomalies, or zones of magnetic enhancement, that will be archaeologically significant. These "hotspots" are then subject to detailed survey.

There are many ways to scan and while some operators capture data along widely spaced traverses, the most favoured way to undertake this work is along unrecorded traverses.

[a] GSB Prospection, Bradford, United Kingdom

Although this has become an accepted part of evaluation work in many areas, some curators are unhappy as there is no "proof" that the scan has been undertaken to any set level.

This paper reviews the philosophy and methodologies associated with "scanning" and will illustrate the potential and pitfalls that are associated with this prospecting method. The authors will consider the concept of proof within this debate and the paper will culminate in the analysis of the route of a large scale pipeline which effectively was a blind test of the scanning method.

REFERENCES

Gaffney, C., J. Gater and S. Ovenden 2002. *The use of geophysical techniques in archaeological evaluations.* Institute of Field Archaeologists (IFA), Paper 6.

Multimethodological approach to study and characterise the Forum Novum site (Vescovio), Italy

V. Gaffney[a], H. Patterson[b], S. Piro[c], D. Goodman[d] and Y. Nishimura[e]

This paper presents the results of an ongoing study of the Roman town and Early Medieval bishopric of Forum Novum in the middle Tiber valley to the north of Rome. The work forms part of the British School at Rome's Tiber valley project, which studies the changing landscapes of the middle river valley as the hinterland of Rome through two millennia, from 1000 BC to 1000 AD. A major element of the project is new fieldwork aimed at filling the gaps in settlement knowledge. Urbanism forms a key research theme of this new fieldwork. In marked contrast to the intensity of work on rural settlement in this area, there has been little systematic research on towns. At Forum Novum a range of remote sensing techniques are being combined with excavation to examine the extent and organization of a Roman town and its development through time. The research aims to provide a detailed study of a specific form of urbanism – the small centres as defined by Roman law – which have been much neglected in studies of Roman urban history.

Much of the ancient town lay under modern structures such as a restaurant, bar, car parks, roads and the church of Santa Maria in Vescovio itself, conditions which where not suitable for the application of some geophysical techniques, such as magnetometry and resistivity. In 1998 GPR surveys were made over two areas to test the potential of this technique in resolving these problems. The first results confirmed this potential: GPR survey of the

[a] Department of Archaeology, University of Birmingham, United Kingdom
[b] British School at Rome, Rome, Italy
[c] Istituto per le Tecnologie Applicate ai Beni Culturali, CNR, Monterotondo, Roma, Italy
[d] Geophysical Archaeometry Laboratory, University of Miami, Japan Division, Japan
[e] Cultural Heritage Protection Cooperation Office, Asia/Pacific Cultural Centre for UNESCO (ACCU), Japan

area of the villa gave good correspondence with the results obtained by the previous magnetometry and resistivity surveys. The most striking results came from the second area, now a car park, to the south of the basilica. A magnetic survey of the same area had identified the presence of ancient structures, but because of the surface conditions and a low S/N ratio, the plan of the structures was not clear. The GPR survey, on the other hand, revealed the clear plan of a block of houses and possible shops, identifying the presence of rooms and even doorways, showing that these structures were present immediately beneath the surface continuing to a depth of about one metre. On the basis of these results, GPR surveys were then applied over three further areas with the following results.

- to the southwest of the forum complex, in an area which is now a gravelled car park, a semicircular feature of uncertain nature identified by the magnetic survey was shown to be the foundations of an amphitheatre;
- around the excavations of the forum complex, a number of structures were identified including the podium of the temple;
- to the southwest of the villa, in an area where magnetometry and resistivity had suggested the presence of buried structures, GPR survey confirmed the presence of a large triangular precinct associated with funerary structures.

The results, which will be presented and discussed in this paper, demonstrate the potential of remote sensing techniques for our understanding of the extent and organization of urban centres. In the case of Forum Novum, where much of the ancient centre lies under modern structures, GPR survey, in particular, proved fundamental. Further, the results of the georadar surveys permitted archaeologists to select key areas of the town for more detailed investigation through excavation.

The Knowlton Neolithic and Early Bronze Age Landscape Project – geophysical survey in a Late Neolithic and Early Bronze Age ritual landscape

John Gale[a], Paul Cheetham[a] and Steve Burrow[b]

The Late Neolithic and Early Bronze Age ritual landscape of the Allen Valley in Dorset, UK, focused around the group of henge monuments known as Knowlton Rings, can in terms of size and complexity rival any similar sites of the period within Britain. The main henge complex consists of two classic and three other henge or hengiform structures together with extensive and morphologically rich barrow cemeteries extending to the north and south, with the known number of barrows running into hundreds. Nearby, and arguably part of an

[a] School of Conservation Sciences, Bournemouth University, United Kingdom
[b] Department of Archaeology and Numismatics, National Museum and Gallery, Cardiff, United Kingdom

associated ritual landscape, is the Dorset Cursus, the longest known monument of its type in existence. Within its vicinity, earlier earthen long barrows abound, but there is also a quite astounding range of smaller monuments: henges, pit circles, ritual shafts, avenues and more individual barrows and barrow cemeteries dating to our period of interest.

Whilst the wider area has been the subject of periodic archaeological investigation over a considerable number of years, the Allen Valley has received only a modicum of attention. Taking our knowledge of this important area forward is fraught with problems, by far the most problematic being the immense size of the area and the number of monuments involved. The number of known sites is likely to be a gross underestimate, not only due to the total destruction or inaccessibility of sites resulting from later activities, but also from a lack of systematic survey to establish the resource base from which to develop research programmes on a firm footing. Destruction of many of the sites through intensive agricultural practices, particularly over the last half century, continues to erode away this vast heritage resource.

For the past 10 years staff from Bournemouth University have undertaken a number of geophysical surveys, excavations and other field surveys to try to establish the nature, range and survival of the sites before some are lost forever. It is hoped that through a programme of targeted field surveys and the judicious undertaking of associated excavations the project will move towards establishing a much greater understanding of the chronological developments and social contexts that the Knowlton ritual complex and its associated monuments represents. Field observation of standing remains and aerial photography have been the most extensive resources utilised to date, but both of these are highly selective, the first dependent upon the vagaries of survival in an intensely cultivated landscape, and the latter on flying and crop regimes and growing conditions. Even where aerial photography has been successful it may give little information on levels of survival and is insensitive to some types of archaeological evidence. Geophysical survey has been employed here, as it has in many cases, to try to bridge the gap in knowledge between aerial photography, surface survey and what excavation may well produce. However, it is of course not only unrealistic to contemplate excavating large areas or large numbers of individual monuments, but it is vital that any programme of intrusive investigation is undertaken to provide inroads into the major archaeological questions and not simply be technical recovery exercises. To ensure that resources, both the project's and the archaeological, are used to the best effect, geophysical survey becomes the key to assessing potential fieldwork strategies and providing a flexible approach to each phase of the work. As land becomes available, then geophysical survey provides a rapid assessment method.

The first stage of the project commenced in the winter of 1993 with the geophysical survey of a sampled portion of what is loosely referred to as the southern barrow cemetery, associated with the main henge complex. Students from Bournemouth University, under the direction of Dr. Stephen Burrow, undertook the survey. Both earth resistivity and magnetometry (fluxgate gradiometry) were carried out, and from the outset it was clear that the local pedology and nature of the archaeological deposits contrived to produce a clearer response from the fluxgate gradiometer. Within the defined area where previous methods (field observation and aerial photography) had identified 4 to 5 barrows and ring ditch monuments other (?) ring ditches were defined. During the summer of 1994, prior to an evaluative excavation of the largest of the henge monuments in the complex (the southern henge), the southeastern quadrant was geophysically surveyed. Using fluxgate gradiometry the survey confirmed the location and articulation of the monuments defining a ditch (long since levelled through natural silting and plough activity) along with traces of other associated features, which were subsequently evaluated by excavation.

More recent work, building upon the experiences of the work of 1993–1995 has begun evaluating the most southerly extent of monumental activity within the Allen Valley – High Lea Farm Barrow group, 3.5 km south of the henge complex. Investigation of this relatively spatially discrete cluster of extant barrows and ring ditches commenced with a desk based assessment that primarily consisted of an examination of the aerial photographic collection of the National Monuments Record. The barrow cemetery consists of at least three inter-linked linear alignments of barrows defined mainly through ring ditches of various diameters. The distribution itself is highly variable, primarily because of understandable variations in ground conditions-flight dates and differing plantings within the resident field system.

Following the desk-based assessment a programme of geophysical survey supported by excavation commenced in the summer of 2002 to examine the location and extent of the barrow group, but to also consider the sites potential for further investigation. Issues relating to chronology and social context can of course only be addressed through excavation, if there are sufficient structural remains to evaluate.

Because of the nature of the questions posed and the complexity of the sites this project is still in its infancy. Prospection, not only to locate and map but to assist in the evaluating of the archaeological resources, will be central to all the work undertaken at Knowlton and as the work so far has shown is already contributing in this way.

Why the fish ensign and cult of Khnum were prevalent in Mendes: a new Egyptological approach in the light of science

Mahmoud M. al-Gamili[a]

The author presents a new Egyptological approach through the amalgamation of different scientific techniques. His investigations shed more light on the ancient Egyptian way of thinking, the manner of expressing arts and cult through studies of paleohydrographic and paleoenvironmental conditions. Geophysical methods have also been applied recently to these studies.

A geoelectric resistivity sounding in the vicinity of Mendes (present day Tell El-Roba') and Thumuis (present day Tell Temai) enabled the delineation of two defunct arms of the Mendesian Nile river branch in the 16th Nome of the Delta.

It is known that the Mendesian 16th Nome of the Nile Delta had as its sign the fish "Hat Meheit", the chief fish or the fish goddess. Also, it is known that the Delta in Pharaonic times was abundantly criss-crossed with rivers, canals, marches, all characterized by a wealth

[a] Department of Geology, Faculty of Science, Mansoura University, Mansoura, Egypt

of fish. One wonders subsequently why in the fish-rich Delta nomes one of the districts would have chosen this fish for an ensign?

Also, Khnum, the god responsible for the flowing waters of the Nile, as well as for fertility, was worshipped in the Mendesian Nome. Therefore, the running waters of the Nile flood must have been a phenomenon similar to that observed at the cataract at Aswan and in Fayum Oasis where Khnum was worshiped and had temples.

These questions are now being investigated in the light of geophysical and biological results.

Use of space remote sensing data for the archaeological mapping of the Taman peninsula, Russia

G.P. Garbuzov[a] and Y.V. Gorlov[b]

The Taman regional archaeological project (brief description of the project and some preliminary results in Müller *et al.* 1998; 1999) called for an archaeological GIS model of the Taman peninsula, North-East Black Sea, Russia, to be created to aid investigations of the ancient landscape from the first Greek settlements up to the Early Middle Ages.

The attribute component of GIS data was compiled from extensive field prospection with handheld GPS-receivers (low accuracy, like Garmin-12XL) and existing archaeological reports. Extensive archaeological prospection was carried out over 1800 sq. km of difficult terrain, based on existing sources of thematic information (for example, archaeological map and database of Taman peninsula made by Paromov, 1992). In total, more than 300 sites were surveyed, of which a considerable part (up to 25%) was recorded for the first time. Almost all new sites were discovered by large scale aerial photographs and space images analysis. The resulting attribute table of the sites contains uniform records, which include fields to hold the description of dated artifacts. The attribute table is linked to spatial data through GPS geocoding (UTM projection, datum WGS-84).

The spatial information of the thematic archaeological GIS is mainly based on space remote sensing (RS) data. The RS data formed the basic raster topographic layer describing the modern landscape. Two big "scenes" were used for the basic map layer: a spectrozonal space photo from the KFA-1000 (August 1993) with a spatial resolution of about 4 m, and a panchromatic SPOT image (August 1994) with a spatial resolution of 10 m. The raw KFA-1000 image covered most of the required area except for a small part for which an area of the SPOT image was used. The KFA-1000 image was chosen as the basic layer due to good spatial resolution and coverage, despite known shortcomings, like distortions during photographing and subsequent scanning of a photonegative and the non-uniformity of spectral characteristics. To produce a good basic raster GIS layer these problems had to be resolved, applying geometrical corrections to the raw image, map registration and mosaicking

[a] South Regional Information and Analytical Centre, Rostov-on-Don, Russia
[b] Institute of Archaeology, Moscow, Russia

to a uniform layer (image processing and thematic analysis was executed by ENVI software, Research Systems, Inc.). To achieve the correct image warping and mosaicking, about 70 GPS reference points (GCP) were used, distributed in the project area at approximately regular intervals. Unfortunately, the complicated topography of the investigated area did not allow an optimum network of GCPs to be created and resulted in varying accuracy for the georeferencing of different mosaic layers. The UTM/WGS-84 projection was chosen to allow subsequent on-line prospection with GPS-receivers.

The basic raster mosaic layer was used to create some simple vector layers describing the current topography and landscape: coastal contours, settlements, roads, and inland water objects. In addition to direct thematic analysis and vectorization, the base layer is used for the registration of all other spatial data of the project. Other layers with RS data have been added, including multispectral SPOT and MSU-E images.

REFERENCES

Müller, Ch., É. Fouache, V. Gaïbov and Y. Gorlov 1998. Péninsule de Taman (Russie méridionale). *Bulletin de Correspondance Hellénique* 122:643–54.

Müller, Ch., É. Fouache, Y. Gorlov, M. Abramzon, V. Gaïbov and A. Porotov 1999. Péninsule de Taman (Russie méridionale). *Bulletin de Correspondance Hellénique* 123:589–98.

Paromov, J.M. 1992. Historical essay of the archaeological and topographical research of Taman peninsula. In *Bospor collection*, Vol. 1, 109–46. Moscow (in Russian).

The remote sensing background in the "Irendyk" reserve project, Southern Ural, Russia

G.P. Garbuzov[a], S.V. Gusev[b], N.S. Saveliev[c] and P.M. Shulgin[b]

This work represents the continuation of research undertaken in the Moscow Heritage Institute in 2000–2001 which developed a case for the creation of the historical, archaeological and landscape museum-reserve "Irendyk" in the Bajmak district of Republic Bashkortostan, Russian Federation. The final decision to create the reserve was taken in the autumn of 2002. The issues that had to be addressed in the project were resolved through spatial analysis of space remote sensing data. The first task was the definition of the optimum reserve border and the choice of those buffer zones in which land use was to be restricted. The second task investigated the creation of functional and landscape zones of the reserve territory and the study of possible interactions between the reserve and neighbouring areas. The third task was related to the archaeological context and had to develop predictive models for different archaeological/historical sites and monuments. During the initial phase of the project, various problems had to be resolved, such as the selection of remote sensing

[a] South Regional Information and Analytical Centre, Rostov-on-Don, Russia
[b] Heritage Institute, Moscow, Russia
[c] "Irendyk" Archaeological Reserve, Ufa, Russia

data, integration and unification of various spatial data within the framework of one project, border and buffer zone definitions, revealing the dynamics of change and establishing trends of natural and anthropogenic processes in the reserve and buffer zones. The space remote sensing data for the reserve consist of spectrozonal space photo images (KFA-1000) and multi-spectral images made by the MSU-E radiometer from Russian satellites for the last 10–15 years. All images were rectified to a base image (one of the high-resolution KFA-1000 images) making it possible to study processes of environmental change. The next stage of the work will include the geocoding of all archaeological sites and a detailed large-scale remote sensing analysis of key features. This will result in a powerful thematic GIS for the reserve.

Geomagnetic mapping on the Early and Middle Bronze Age settlement mound Tell Mozan (Urkesch), Northeast Syria

Stefan Giese[a], Armin Grubert[a] and Christian Hübner[a]

Tell Mozan, the Hurritic city of Urkesch, is situated 20 km west of the modern town of Qamischliye in the northeast of Syria, close to the Turkish border. The remains of the city form a large settlement mound covering an area of 350 m by 550 m. Excavations by IIMAS

Fig. 1. Tell Mozan. Modified caesium magnetometer G 858 in the lower city.

(International Institutes for Mesopotamian Area Studies), Los Angeles, in cooperation with the German Orient Society under the direction of Prof. Peter Pfaelzner, Tübingen University, dated the city as Early to Middle Bronze Age.

[a] GGH, Solutions in Geosciences, Freiburg i. Br., Germany

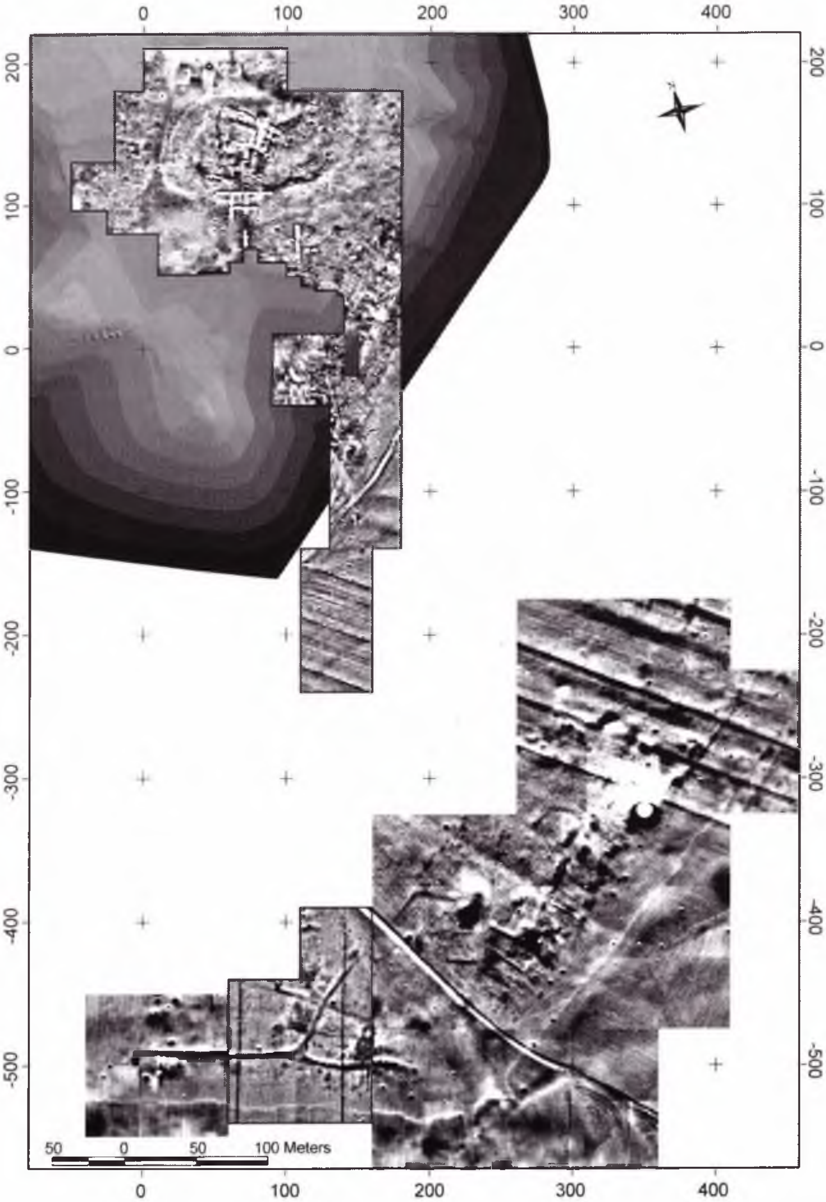


Fig. 2. Tell Mozan. Magnetograms. Survey 2001 (bordered with a black line): gradiometer configuration, median, low pass, h = 0.35 – 1.35 m, sensitivity 0.1 nT, sampling interval 0.5 m by 0.15 m, dynamics –/+7 nT (white to black) in 256 grayscales. Survey 2002: total field configuration, diurnal corrected, median, h=0.35 cm, sensitivity 0.1 nT, sampling interval 0.5 m by 0.15 m, dynamics –/+7 nT (white to black) in 256 grayscales with 3D model of the settlement mound.

Magnetic measurements were recorded with a modified caesium magnetometer (Geometrics G 858) in an optimized carrying unit. In 2001, only the magnetic gradient was recorded, but in the 2002 the total field was recorded to examine deeper structures. The measurements were taken in the bi-directional mode with a measuring point raster of 0.5 m by 0.15 m. Simultaneously, the natural total field was recorded with a second magnetometer (Scintrex Envimag) used as a base station to allow for diurnal variation correction to the data. Both magnetometer measurements were time-synchronized. In the second season, with the total field survey referenced to the base station, survey progress was doubled. A total of 10.9 hectares was prospected within 8 field days and this included taking geodetic measurements and setting up survey grids. Each day, the survey data was transferred to a laptop and stored. Magnetograms were computed and the following day's survey work planned. The raw data was transferred and processed to a raster format on a desktop computer using GIS-program ArcView for archaeological interpretation.

An oval structure around the central temple and the mud brick walls of individual buildings were identified in the magnetic survey, together with other features in the upper city. In the southern part of the city, below the settlement mound, a road system, individual buildings and a comprehensive fortification wall with a gate were located for the first time.

Processing and interpretation of magnetic fields of heterogeneous archaeological objects

Vladimir V. Glazunov[a] and Natalia N. Efimova[a]

Magnetic prospecting is the main geophysical method for the mapping of ancient brick-wall remains. The magnetisation of brick walls is characterised by a random distribution of magnetic properties. The heterogeneity of wall magnetic structure is related to the high thermoremanent magnetisation of the bricks (Bevan 1994; Glazunov, Cucarzi and Efimova 1996). Magnetisation vectors of individual bricks in a wall are oriented randomly, which causes magnetic fields with chaotically distributed anomalies over the wall remains.

For the interpretation of magnetic fields from such complex structures specific methods of geophysical processing and interpretation are required. The processing is based on stochastic modelling of the potential fields of the heterogeneous objects (Vahromeev and Davidenko 1987).

A vector of stochastic model parameters consists of components that are aleatory variables. In the case studied here, a component of the stochastic model parameters' vector is a magnetisation vector's direction changed in and specified by the location $\vec{\lambda}=\{\lambda_i\}$ (i=1, 2, 3). The Izing model of cellular disorder is best suited for the characterisation of a model parameters' vector components (Vahromeev and Davidenko 1987). This model represents

[a] Sankt-Petersburg State Mining Institute (Technical University), St. Petersburg, Russia

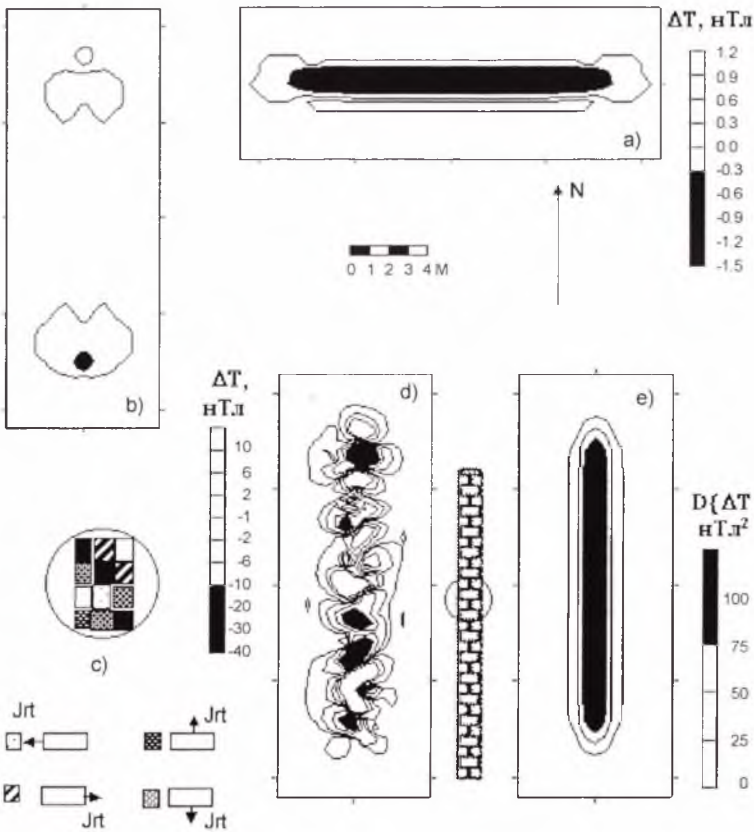


Fig. 1. Maps of theoretical anomalies from multiple-choice models of a brick wall (c): a, b – average of distribution maps **M**{Δ**T**}; d – magnetic field random realisation ΔT; e – dispersion map **D**{ΔT}.

a system of non-overlapping cell prisms and imitates the blockwork of the wall. The direction of magnetisation in adjacent prisms is assumed to be independent. The status of each model cell is defined by the magnetisation angles of inclination and declination represented by a system of status indicators for each cell. The indicator values are assigned by a random-number generator.

The "direct problem" for the stochastic model is the determination of the created field ΔT and its first statistic moments (Glazunov, Cucarzi and Efimova 1996). One should regard the field **ΔT** as realisation of a random process because it is caused by realisation of the stochastic model's random vector. Averages of distribution **M**{**ΔT**} and dispersion **D**{**ΔT**} are regarded as statistic moments of the field **ΔT**. The equations for the first statistic moments of the field **ΔT** of a single stochastic model cell are simple to deduce with the use of basic principles of the probability theory:

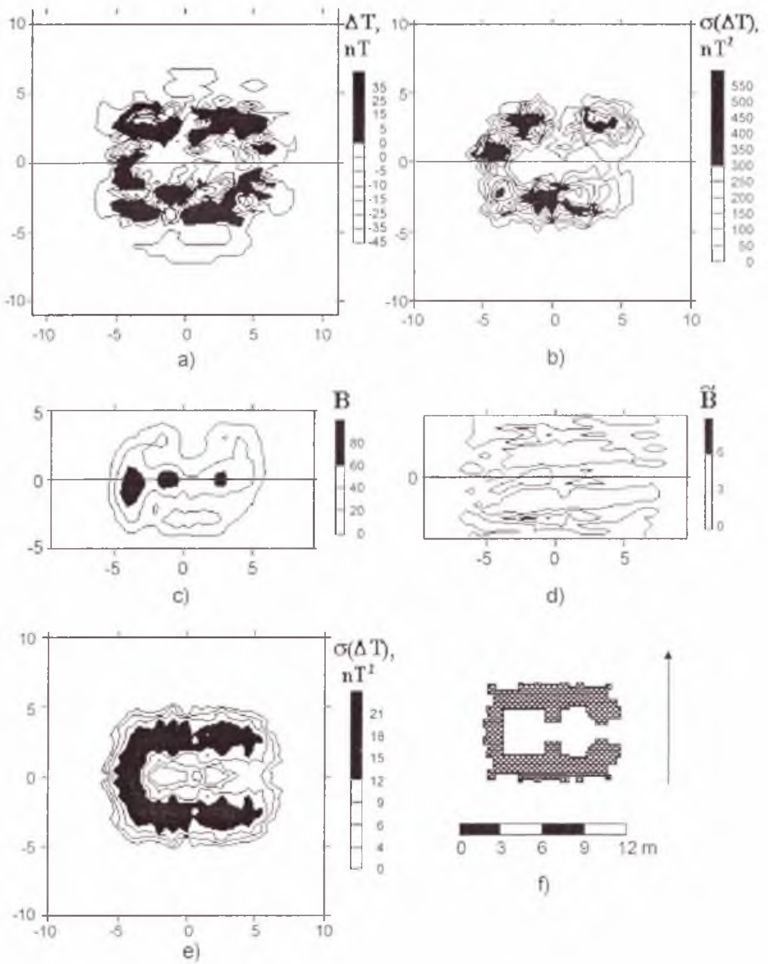


Fig. 2. Analysis of a symmetry map of the field dispersion σ(ΔT) of a model of a Hindu temple. a) – field ΔT; b) – σ(ΔT) map; c), d) – CCF σ(ΔT) before and after filtering respectively; e) – σ(ΔT) map drawn after symmetry transformations; f) – temple plan.

$$\mathbf{M}\{\Delta T\} = \vec{t}^{\,\mathbf{T}}\mathbf{X}\mathbf{M}\{\vec{\lambda}\};\ \mathbf{D}\{\Delta T\} = \mathbf{X}\,\vec{t}^{\,\mathbf{T}}\mathbf{C}(\vec{\lambda})$$

with $\mathbf{M}\{\vec{\lambda}\}$ and $\mathbf{C}\{\vec{\lambda}\}$ being the average of distribution and covariance matrix for the location $\vec{\lambda}$, respectively;

t – vector collinear to a geomagnetic field vector;

X – magnetic field tensor (Glazunov 1988);

"**T**" – transposition sign.

With four possible directions of a magnetisation vector (Fig. 1c) the parametr $\mathbf{M}\{\vec{\lambda}\}$ equals zero, so **M**{ΔT} equals the field **ΔT** of the wall's model magnetised by a modern geomagnetic field. The analysis of theoretical isoline maps **M**{ΔT} shows that a magnetic anomaly is present along the entire wall of latitudinal direction (Fig. 1a-b). A wall of longitudinal direction is characterised by elevated **M**{ΔT} values only in the areas of its paving block. In both cases the field intensity **M**{ΔT} is minor. Maps of dispersion **D**{ΔT} are invariant with regard to wall orientation and characterised by great intensity (Fig. 1e). Hence, a map of dispersion **D**{ΔT} allows walls of both directions to be studied in contrast to maps of average distribution **M**{ΔT} of the field ΔT.

1. Original field **ΔT** of the object
2. Calculation of the field dispersion σ(ΔT) with the help of "cross-vaulting" weighting function
3. Calculation of two-dimensional CCF of dispersion σ(ΔT)
4. Separation of CCF local components with the help of linear filter
5. Determination of symmetry plane trace coordinates of an object on a CCF local component map
6. Symmetry transformation of the field dispersion σ(ΔT) as regards an object's symmetry plane

Block diagram 1.

The results of this modelling show that one shold use the dispersion of a studied field's random component for the mapping of archaeological objects with unknown orientation of the magnetic structure. The analogue of parameter **D**{ΔT}, which characteirises a profile of a random process, is a field spatial dispersion σ(ΔT). In order to calculate the studied field's dispersion σ(ΔT), one should use a linear operator that realises two consecutive procedures of bilateral convolution: $\sigma(\mathbf{U}) = \mathbf{h}^{**}(\mathbf{U} - \mathbf{h}^{**}\mathbf{U})^2$ with **h** being the transformation weighting function.

The results of stochastic modelling of Hindu temple remains (Fig. 2f) show that maps of spatial dispersion σ(ΔT) (Fig. 2b) are more distinct than the field ΔT (Fig. 2a) and represent the ground plan of a building.

With the use of the dispersion map σ(ΔT) one can determine the location of the symmetry plane of the ground plan. It is expedient for this purpose to use a cross-correlation function (CCF) (Fig. 2c) calculated according to the map of dispersion σ(ΔT). The area of CCF largest extremum stretches along the symmetry plane trace of the temple (Fig. 2d). After some primitive operations with symmetrical transformations of the map σ(ΔT) in respect to the symmetry plane found, it is easy to draw a map that reflects the ground plan in maximum detail (Fig. 2e). The algorithms developed for the analysis of the field have been used for mapping the temple complex (Glazunov 1997).

The studies showed that features of archaeological origin require two different models to represent their magnetic fields. A traditional model is based on the representation of deterministic field components as a signal and of random components as a disturbance. A signal from random heterogeneous objects is based on a random field component. One should choose optimal statistical characteristics for it on the basis of stochastic modelling.

ACKNOWLEDGEMENTS

The authors would like to thank our partner Fondazione Ing. Carlo M. Lerici (Politecnico di Milano) for providing geophysical equipment and financial support.

REFERENCES

Bevan, B. 1994. The magnetic anomaly of a brick foundation. *Archaeological Prospection* 1(2): 93–104.

Glazunov, V.V. 1988. Use of tensor calculus for description of magnetic field of three-dimensional bodies. *The geophysical questions* 32: 103–12.

Glazunov, V.V. 1997. Principles of modeling and interpretation of potential geophysical fields due to buried archaeological objects. D.Sc. Thesis, Mining Institute, St. Petersburg.

Glazunov, V.V., M. Cucarzi and N.N. Efimova 1996. Stochastic models of heterogeneous archaeological objects. *Annales Geophysicae, Society Symposia, Solid Earth Geophysics and Natural Hazards, Near Surface Geophysics: Archaeological, Engineering and Environmental Geophysics, EGS* 1996, Part I, Supplement I to volume 14, p. 167.

Vahromeev, G.S. and A.Y. Davidenko 1987. *The modelling in geophysical prospecting.* Nedra.

Horizon slice in archaeological prospection

Dean Goodman[a], Yasushi Nishimura[b] and Hiromichi Hongo[c]

Most imaging processes applied to ground penetrating radar include time slices that are computed at constant time intervals across the radargram datasets. Slicing GPR datasets horizontally naturally implies that the archaeological structures that are to be imaged are level built and their remains are level. However, in many cases archaeological structures are built on undulating surfaces. In addition, various changes at a site could also cause the remains to no longer be horizontally intact. Simply making horizontal slices across the undulating surfaces will create artificial anomalies based on amplitudes collected from within and outside of the reflecting horizon. A different method of slicing the data follows the stratigraphic profiles and can provide a better localized image to detect subsurface structures. Horizon slicing can be used to slice 3D volume datasets across chosen conformable slicing surfaces to better illuminate the subsurface. Horizon slices are used to detect Jomon pit dwellings in Japan as well as to image stone chambers at Kofun period burial mounds. In the case when *a priori* knowledge of underground strata is known and detected on GPR radargrams, then conforming the horizon slicing surface to this known strata surface will also naturally create a topographically corrected dataset as well. This is very useful in areas where topography has not been collected for a GPR survey.

[a] Geophysicial Archaeometry Laboratory, University of Miami, Japan Division, Ishikawa, Japan

[b] Cultural Heritage Protection Cooperation Office, Asia/Pacific Cultural Centre for UNESCO (ACCU), Nara, Japan

[c] Department of Archaeology, Miyazaki, Japan

Integrated prospection in the Upper Town of Ephesus, Turkey – a case study

Stefan Groh[a]

In association with Archeo Prospections, the Austrian Archaeological Institute of Vienna started in 2000 a new research project in the Upper Town of Ephesus (Turkey), a metropolis of Roman times. The upper town is a plateau of 50 ha in the eastern part of the ancient town, situated inside the Hellenistic/Roman city walls. Little was known about this area, hence the main goal of the project was to gain a maximum of information about archaeological features without opening excavations. In the last three years, magnetic and GPR surveys have been carried out, followed by an intensive field survey with GPS equipment, the objective being to map all the visible archaeological features and to generate a digital elevation model. The magnetic and GPR data combined with information gained from aerial photographs and the GPS survey offer a completely new image of settlement patterns, cemeteries, fortification systems, street grid and function of particular buildings in the Upper Town of Ephesus.

[a] Austrian Archaeological Institute, Vienna, Austria

Geomagnetic surveys at Sais, Sa el-Hagar, western Delta, Egypt

Duncan Hale[a] **and Penny Wilson**[b]

Geophysical surveying has been undertaken on the site of the ancient city of Sais (Sa el-Hagar), in Egypt's Western Delta region, as part of an Egypt Exploration Society (EES) research project directed by Dr. Penny Wilson. Sais was the ancient capital of Egypt during the 26th Dynasty, *c.* 800–600 BC, and almost certainly has Neolithic origins. At its height the building complexes are believed to have comprised a royal palace for the Saite kings, together with temples and tombs and its own garrison. Although there are no longer any standing remains from this period to be seen at the site, occasional massive red granite blocks and fragments of monumental sculpture serve as indicators of the former importance of the site. Further information, including references to publications, can be found on the websites given below.

A programme of geophysical survey began at Sais in 1998 and the success of the fluxgate gradiometer technique prompted another season of survey in 2001. The initial surveys were undertaken by Duncan Hale and Mark Noel (GeoQuest Associates) and have been continued by Duncan Hale, now at the University of Durham.

[a] Archaeological Services, University of Durham, United Kingdom
[b] Department of Archaeology, University of Durham, United Kingdom

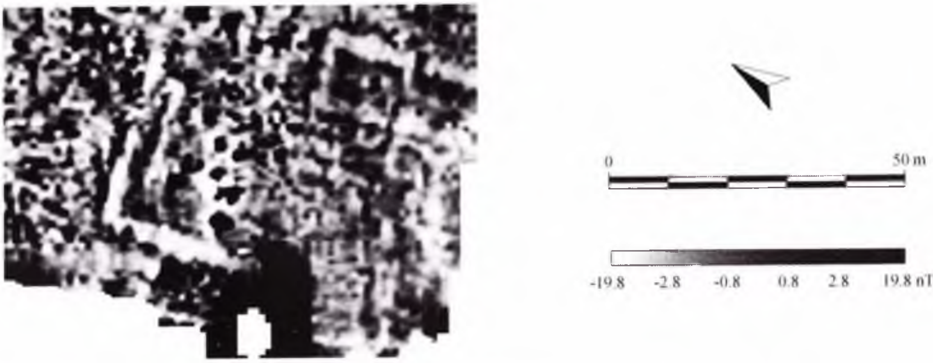


Fig. 1. Sais, Egypt. Extract from geomagnetic survey of Area B.

Fig. 2. Sais, Egypt. Extract from geomagnetic survey of Area J.

The geology of the region comprises a considerable depth of deltaic sediments (20 m or more), largely deposited during the annual flooding of the Nile, which overlie limestone strata. The depth of targets (limestone and mud-brick walls, ditches, pits, trackways and fired structures) was expected to vary across the study area. A Geoscan FM 36 fluxgate gradiometer was used for data collection at 1.0 m by 0.5 m intervals. The instrument sensitivity was set to 0.1 nT and a zig-zag traverse scheme was employed. InSite software was used to process the geophysical data.

Twenty areas were surveyed during the 2001 season (ASUD 2001), in addition to the fourteen areas surveyed in 1998. Features of potential archaeological interest were identified in approximately half of these surveys. These features largely comprise probable ditch features, which may relate to relatively recent irrigation systems; however, a number of buildings were also identified. The most striking results are from Areas B, J and 18.

Area B was located in a field immediately south of the Qubbah (tomb) of Sheikh Shaheen. The probable remains of walls, some of which are almost certainly

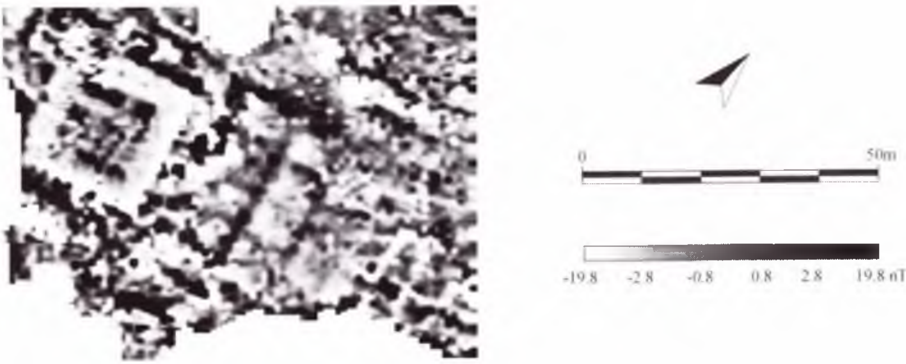


Fig. 3. Sais, Egypt. Geomagnetic survey of Area 18.

parts of at least one building, were detected as negative magnetic anomalies reflecting sun-dried mud-brick or limestone wall foundations (Fig. 1). The outer wall appears to be *ca.* 4 m in width with an entrance in the northern side. The inner walls appear to form a rectangular building measuring 14 m in width and at least 30 m in length. Subsequent coring recovered ceramics and hit stone at 3–4 m depth. A modern pylon is present on the western side of the survey area.

Area J, initially surveyed in 1998 and extended in 2001, is located along the east side of the Great Pit, south of the North Enclosure. Rows of small buildings, or the cells of foundation platforms of larger buildings, have been identified alongside a former track (Fig 2). The walls are evident as negative magnetic anomalies, reflecting mud-brick or limestone wall foundations. Some of the dipolar magnetic anomalies detected here correspond to ceramic structures *c.* 1 m in diameter. These features were revealed during surface cleaning of the area prior to excavation by the Egyptian Supreme Council of Antiquities (SCA) and appear to be small ovens or kilns. The orientation of the magnetic anomalies indicates that the structures were probably fired *in situ*. The excavations also confirmed the presence of mud-brick and limestone buildings.

Area 18 was located on the north-eastern side of the Great Pit just south of the cemetery, and detected evidence for substantial building remains (Fig. 3). The most evident features comprise the four sides of a square building, represented by negative magnetic anomalies. These almost certainly reflect large limestone blocks. It should be noted, however, that a number of negative magnetic anomalies detected near the local SCA office reflected sun-dried mud-brick walls.

The wall remains measure *ca.* 5 m in thickness and the external length of each wall is *ca.* 23 m. An apparent break in the structure at its northwest corner may reflect an entrance to the building, while a sub-circular negative magnetic anomaly on the exterior of the southern wall may represent an addition to the structure. Narrow negative magnetic anomalies within the building may indicate the presence of internal divisions. Numerous other features within this area appear to be associated with the building, perhaps forming enclosures around it. Some of the dipolar magnetic anomalies in this area will certainly reflect modern ferrous litter such as paint cans (observed in the field) while others may reflect ferrous and fired features associated with the building.

The successful location of buildings at the site will be followed by more extensive and systematic geophysical surveying to map buried features. Some of the areas already surveyed are under threat of development, and routine, non-targeted archaeological trenching would not necessarily have found building remains in those areas. The surveys have therefore been of the utmost value in revealing the hidden archaeology of Sais and showing that there is still much work to be done at this ancient city.

Websites

SAIS: www.durham.ac.uk/penelope.wilson/sais.html
ASUD: www.durham.ac.uk/archaeologicalservices

REFERENCE

ASUD 2001. *Sais 2001, Sa el-Hagar, Western Delta, Egypt: geophysical surveying.* Unpublished ASUD Report 799, Archaeological Services, University of Durham.

Integrated archaeological geophysical assessment of an urban brown field site in Benghazi, Libya

Ken Hamilton[a] and Armin Schmidt[b]

This paper uses a case study to demonstrate the application and modification of existing techniques to look at a brown field site in a major North African city. Brown field sites provide a number of challenges for the geophysicist: many brown field sites have been drained to provide a suitable building foundation, while some are now waterlogged. Either condition has a drastic effect on the flow of electricity through the soil. Spills of organic liquids drive water from the oil, preventing current flow. Inorganic material can be ferrous, disturbing magnetic signals, or salts, disturbing the current flow through the soil. Burning enhances the magnetic susceptibility of the soil, and can leave remanent magnetic signals in the soil, while the dumping of rubbish leaves unwanted iron on the ground surface.

The results of both magnetic and electrical surveys are presented in this paper. The results show that while the above issues do affect geophysical survey results, these effects can be overcome with the used of novel sampling strategies, such as the building of 3D data blocks, with high resolution surveys and with integrated data presentation. By combining the results of geophysical surveys with surface collection, it is possible to identify not only areas of industrial activity, but also to identify the nature of such activity. It is thus possible to deduce

[a] Aperio Limited, Cambridge, United Kingdom
[b] Department of Archaeological Sciences, University of Bradford, United Kingdom

that the bulk of the industrial activity of the city was involved in the production of purple dye, from the shellfish *Murex trunculus*. By implication, therefore, the city was heavily reliant on textiles, particularly wool (as the purple dye produced is unstable until fixed on cloth, and cannot be stored or transported). Therefore, although the soil conditions on brown field sites are detrimental to the quality of data collected by geophysical survey, the integration of various complimentary techniques can overcome these difficulties, leading to archaeological interpretations of surprising complexity.

Archaeological investigation of the Somme battle site by ground penetrating radar

Ken Hamilton[a] and Armin Schmidt[b]

The initial assault of the Battle of the Somme, on 1st July, 1916, resulted in the heaviest casualties ever suffered in one day by the British and Colonial Armies (over 57000). The battle, designed to result in a rapid break in the German lines within a day or two, dragged on until 18th November, 1916, when the final first day objectives were captured. The battle site, therefore, has immense emotional significance for the few survivors, and the thousands of descendants of the combatants of the battle. Indeed the battlefield today is marked by several graveyards and the Memorial to the Missing, at Thiepval. Plans to build a visitors centre at Thiepval raised questions not only about the safety of the site in engineering terms, but also about the nature and extent of any surviving military archaeology.

The site of the proposed centre is over an area of particularly heavy fighting, and was subjected to several intense artillery barrages and infantry assaults. Two trench lines run north-south through the survey area. Both initially served as support trenches for the German front line, and were provided with well built deep dugouts. By the time of the final assault on Thiepval, on the 25th of September, 1916, the trenches had changed function. As the German front line shifted to meet the attacks from the south, the support trenches became communication trenches, and hence should have remained as deep trenches.

Ground penetrating radar over the area of the two trenches showed no trace of any cut features. To determine whether this represented an absence of archaeological features, or massive attenuation of the radar signal by the clay soil, two smaller areas of known British trenches were surveyed nearby, at the Beaumont Hamel Newfoundland Memorial and the nearby village of Auchonvillers. The previously excavated trench at Beaumont Hamel was clearly visible in the ground penetrating radar results, while the area immediately adjacent to an excavated trench at Auchonvillers showed the direction and nature of the unexcavated section. This strongly suggests, therefore, that the trenches at Thiepval were destroyed by a combination of heavy artillery and heavy fighting, during the battle itself.

[a] Aperio Limited, Cambridge, United Kingdom
[b] Department of Archaeological Sciences, University of Bradford, United Kingdom

Electrical and GPR tomographies for archaeological investigations at Mit-Raheina, Egypt

A.Gh. Hassaneen[a], S.Sh. Osman[a], M.A. Abd Allah[a] and F.A. Shaaban[a]

The objective of the project was to investigate the sub-surface sedimentary cover at Mit-Raheina village, Giza governorate, Egypt, to identify buried archaeological remains. Resistance survey and GPR profiles were the methods selected for the purpose. The earth resistance survey undertaken with a Geoscan RM 15 resistivity meter was carried out at Tell El-Rabi'a (behind the Hathor Temple). Measurements were taken in a grid of twelve 20 m by 20 m squares and the field data were processed and displayed using Geoplot software. As for the GPR profiles, a SIR-2000 instrument with 400 MHz antenna and a time window of 100 ns (Two Way Traveltime: TWT) was used. At Tell El-Rabi'a, 65 GPR profiles were measured, and another 38 were measured east of the Hathor temple, each with a length of 60 m and spacing between the profiles of 1 m. North of the temple, 37 profiles were recorded, each being 40 m long and spaced at 1 m intervals. A comparison of the radar sections and resistance measurements with available excavation data permitted the identification and reconstruction of the shape and extent of archaeological features beneath the earth surface.

[a] National Research Institute of Astronomy and Geophysics, Helwan, Egypt

Geoelectrical study to delineate the effect of groundwater increment in Abusir, Egypt

A.Gh. Hassaneen[a], El.A. al-Sayed[a] and M.M. Soliman[a]

The area of Abusir in Egypt is of great archaeological meaning as it includes important monuments of the Old Kingdom, such as the Sun Temple, the complex of pyramids and many other tombs. The present study is concerned with the mapping of groundwater aquifers, delineating litho-facies distribution and structural controls, and the study of groundwater characteristics in the area of the site of Abusir.

For the geoelectrical resistivity survey, 45 vertical electroresistivity soundings (VES) were carried out using a Schlumberger configuration. For an initial qualitative interpretation of the data, apparent resistivities were used to construct iso-apparent resistivity maps and sections. It can be concluded from this qualitative interpretation that resistivity grows with increasing probe spacing AB/2, reflecting the presence of two water bearing zones (shallow and deep aquifers). The thickness of these aquifers increases to the east of the area under investigation and decreases gradually to the west of the area.

[a] National Research Institute of Astronomy and Geophysics, Helwan, Egypt

The apparent resistivity data were then processed and interpreted quantitatively using Zohdy's method and the Resist program. The interpreted resistivity data were used to construct twelve geoelectrical cross-sections, two isoline maps for the two upper layers and a water level map for the deep aquifer surface. Based on these cross-sections and maps, the area under investigation was divided into four zones. The upper zone has a thickness varying from 4 m to 19 m and consists mainly of sandy gravel, while the second zone varies in thickness from 15 m to 40 m and varies in lithology from clay to sandy clay; underlying it is a sandy zone intercalated with clay lenses of a thickness equal to about 50 m. The fourth zone is a very high resistivity zone, identified as limestone and marly limestone equiclude.

The groundwater map constructed from the resistivity data, together with the existing hydrographs for the groundwater wells near the study area, led to the conclusion that there was a slight decrease in the groundwater level after the construction of the High Dam in Aswan.

Topographic correction to compensate for changes in surface elevation in GPR image by applying F-k migration

Pasomphone Hemthavy[a], Hiroaki Watanabe[b] and Hiroyuki Kamei[b]

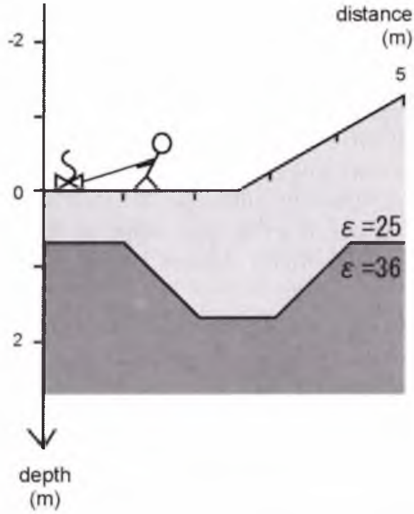
Ground penetrating radar (GPR) has been widely used as an effective and non-intrusive tool in archaeological prospecting. It has the advantages of rapid ground cover and real time visualisation of survey data that permits survey results to be checked *in situ*. However, the acquired GPR data are normally represented in the form of flat profiles (vertical sections) regardless of topographic information. It is therefore often difficult to correctly deduce the location and shape of buried objects from the raw GPR profile images. Especially when surveying archaeological sites such as ancient burial mounds (Kofun) in Japan, topographic corrections are needed to reproduce the proper depth and shape of buried features.

The conventional method for topographic corrections of GPR images involves estimation of a dielectric constant for the subsurface, then a conversion of the difference of surface elevation at any sampling point to time, and finally moving the reflection data in the GPR profile image vertically. This method, however, cannot determine precisely the depth and shape of buried objects.

In this paper the authors propose a new method for topographic correction to compensate for changes in surface elevation in GPR images by applying F-k migration (Chun and Jacewitz 1981). They have assumed that the topography of the surveyed site can be approximated as sections of linear change in the surface elevation (Fig. 1a). A GPR simulation was performed and the simulated GPR image is shown in Fig. 1b. It can be seen from

[a] Department of International Development Engineering, Tokyo Institute of Technology, Tokyo, Japan

[b] Department of Computer Science, Tokyo Institute of Technology, Tokyo, Japan



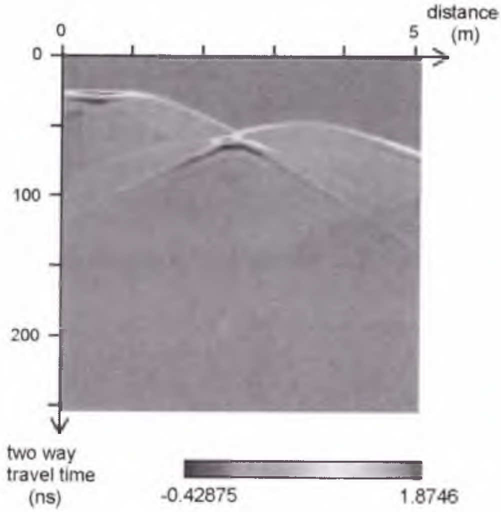
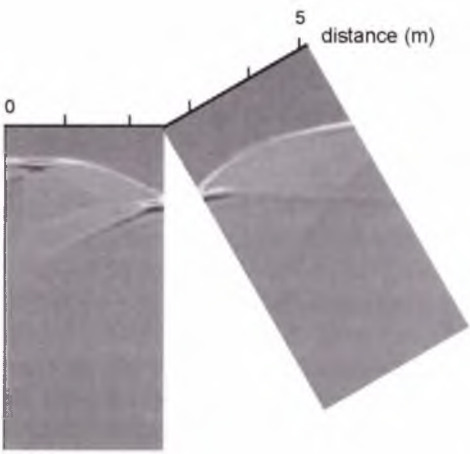


Fig. 1. (a) GPR simulation model, (b) simulated GPR image.

this simulated GPR image that the beam direction of the GPR antenna changes in correspondence with site topography. Therefore, the simulated GPR image does not show the real shape and depth of the buried objects. In order to compensate for changes in surface



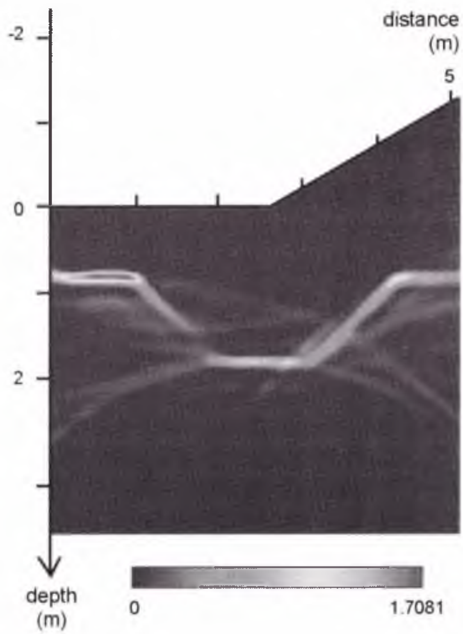


Fig. 2. Bending to match the topography.
Fig. 3. Result of topographic correction.

elevation, the simulated GPR profile image was bent to match the topography of the site (Fig. 2). By doing this, repeated and missing areas were introduced in the data. These can be corrected by performing a back projection migration, which is very time consuming. To overcome this difficulty, the authors adopted the very efficient F-k migration, which is based on wave analysis in the frequency domain. Moreover, while calculating FFT during the F-k migration an extension space filled with "zero" was added to one or both sides of each linear part to form a path for wave propagation. Finally, the migration result with topographic correction of the simulation model was created by a superposition of each individual calculation for a linear part. This way, the data from the missing part have been successfully restored, as shown in Fig. 3.

REFERENCES

Chun, J.H. and C.A. Jacewitz 1981. Fundamentals of frequency domain migration. *Geophysics* 46(5):717–33.

Magnetic mapping of the Northern Cemetery at Abydos, Egypt

Tomasz Herbich[a], David O'Connor[b] and Matthew Adams[b]

The systematic archaeological exploration of the Northern Cemetery at Abydos, which began in the early 20th century, picked up new impetus with the start of work by a joint expedition of the University Museum of the University of Pennsylvania and Yale University, which now also includes The Institute of Fine Arts, New York University. New funerary enclosures of pharaohs of the Early Dynastic period have been discovered, and previously known enclosures more systematically explored. The expedition's work has also revealed countless tombs and funerary chapels from the Middle Kingdom till the Late Period, and a complex of boat graves. Even so, the area excavated so far, considering that the total area of the site may be as much as 500 000 sq. m, has not exceeded 2%. To alleviate this situation, the directors of the expedition's Early Dynastic Enclosures Project, David O'Connor and Matthew Adams, brought in geophysical surveyors to supplement the excavation process.

The first survey season in the fall of 2001, carried out by Tomasz Herbich and Przemysław Wielowiejski, was designed to test the survey method under site conditions at Abydos. An area of 2 ha at the northern edge of the site was chosen for its relatively flat surface unmarred by earlier excavations. The choice of magnetometry for the survey was determined by the actual conditions of the site – the mud brick used in the construction of tombs,

[a] Institute of Archaeology and Ethnology, Polish Academy of Sciences, Warsaw, Poland
[b] Institute of Fine Arts, New York University, New York, USA

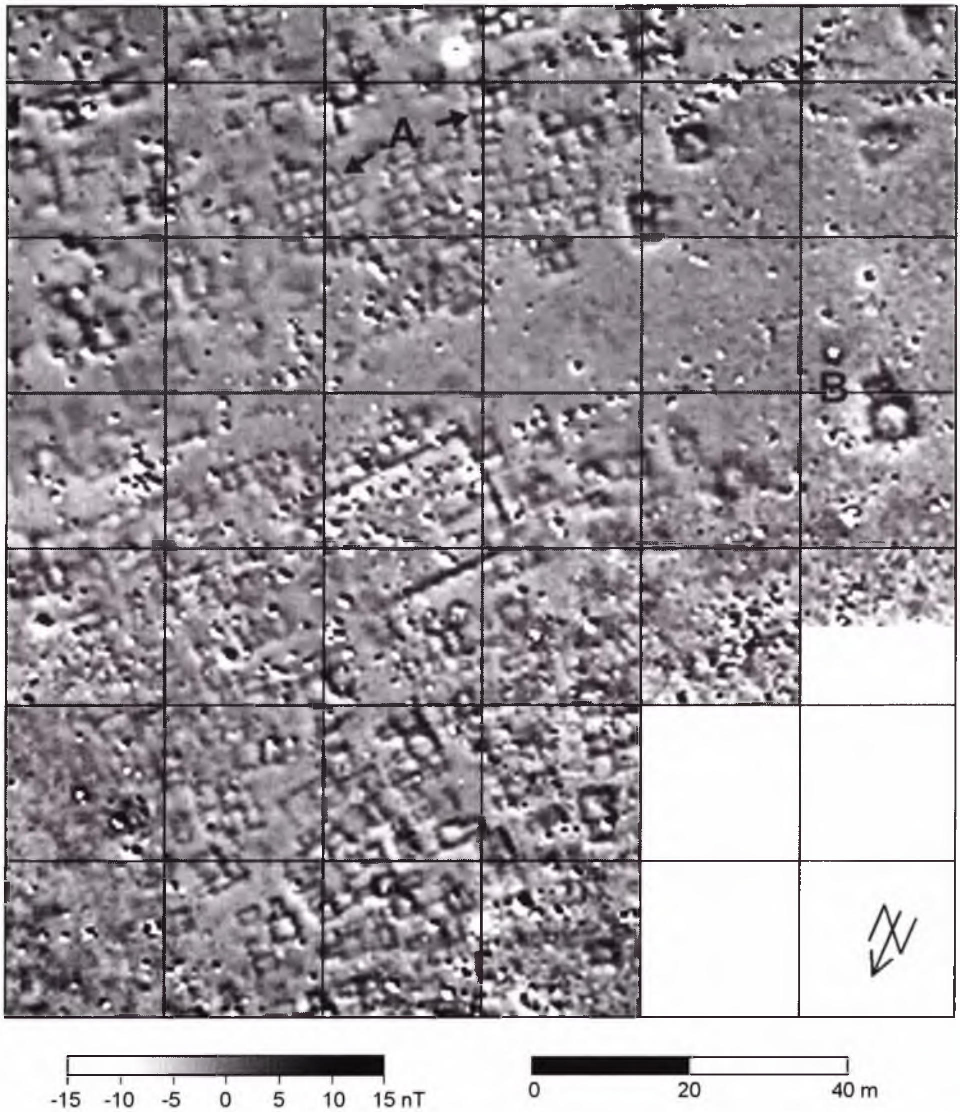


Fig. 1. Abydos. Section of the magnetic map of the Northern Cemetery, surveyed in 2001. Sampling grid 0.5 m by 0.5 m, interpolated to 0.25 m by 0.25 m. Examples of the interpretation of discovered structures: A – clusters of shaft graves typical of the Middle Kingdom Period; B – domed tombs typical of the Late Period.

Fig. 2. Abydos. Section of the magnetic map of the Northern Cemetery, surveyed in 2001–2002. Sampling interval 0.5 m by 0.5 m (2001) and 0.25 m by 0.5 m (2002) interpolated to 0.25 m by 0.25 m. A – enclosure discovered in 2001; B – enclosure discovered in 2002.

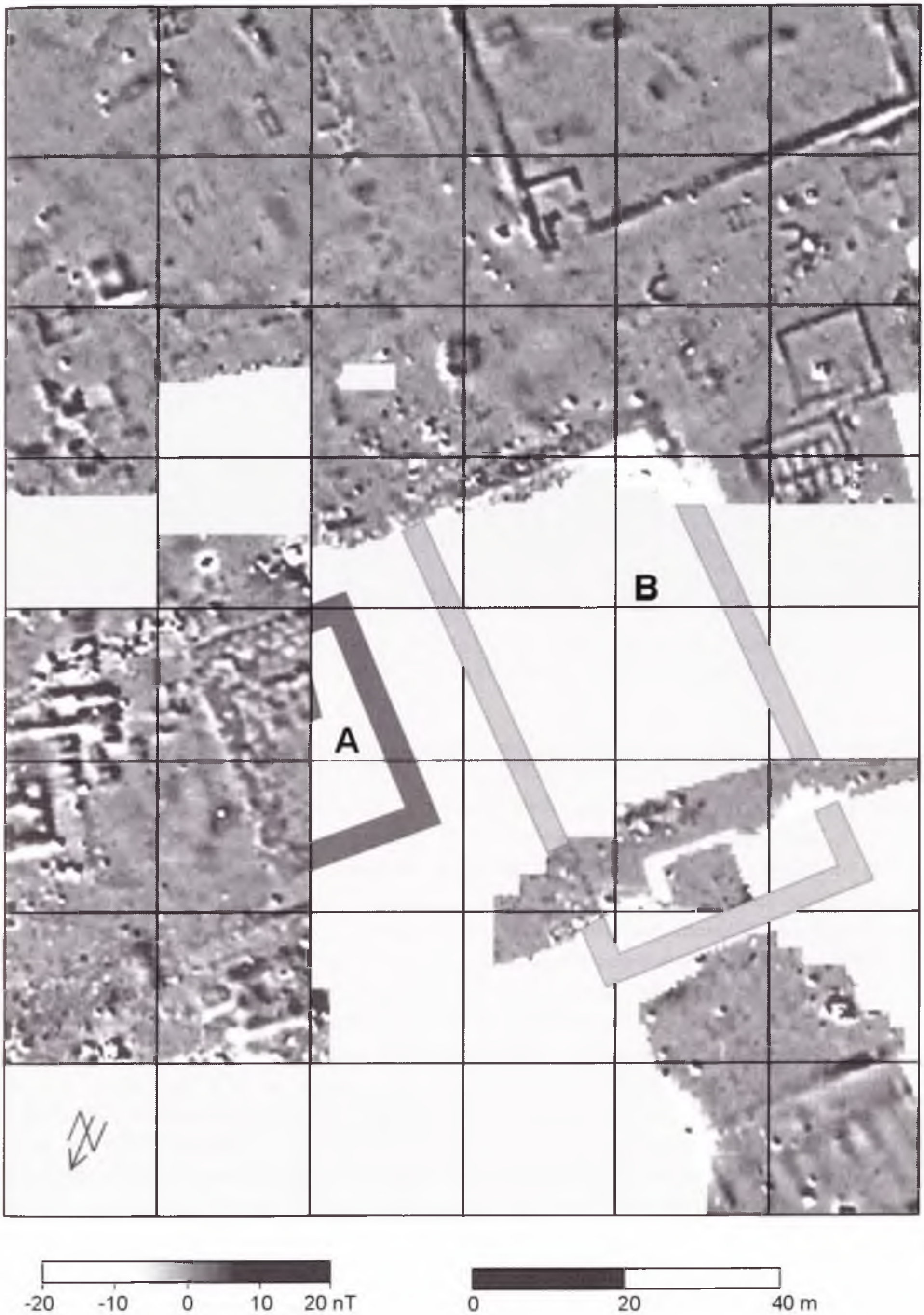

A
B
-20
-10
0
10
20 nT
0
20
40 m

Fig. 3. Abydos. Early Dynastic royal enclosure (marked A in Fig. 2), seen from the northwest. Photo: Pennsylvania-Yale-Institute of Fine Arts, NYU expedition.

chapels and enclosures has a magnetic susceptibility sufficient to distinguish it from the non-magnetic sand environment. The instrument used was a Geoscan Research fluxgate gradiometer FM 18. Measurements were taken in a grid of 0.5 m. The results were mapped with Geoplot software; Surfer 7 was used for the map printouts.

A thorough search for metal objects on the surface of the site was conducted prior to the survey (the researched area neighbors with the village). However, it was not possible to find and remove all the sources of disturbances, resulting in a series of anomalies wherever small iron objects and concentrations of ashes and fired brick were located.

The survey method was found to be fully successful. Tomb and funerary chapel outlines are quite distinct on the magnetic map, permitting a typological classification of some of the structures and, as a result, their attribution to specific chronological phases in the functioning of the cemetery (Fig. 1).

A structure was recorded at the southeastern edge of the surveyed area, the orientation of which parallels that of enclosures discovered earlier. Due to obvious elements of the plan, such as gateways near the northern and eastern corners and the presence of a small free-standing building (chapel) in the southeastern part of the interior, the structure could immediately be interpreted as yet another Early Dynastic royal funerary enclosure (Fig. 2, enclosure A). Magnetic surveying covered only the eastern part of the enclosure, the western end being concealed under a modern Coptic cemetery. Archaeological work carried out to verify these findings confirmed a First Dynasty date for the enclosure. In the season that followed, the Coptic cemetery's perimeter wall was moved back, making it possible to uncover practically the entire enclosure (Fig. 3). It turned out to be significantly smaller than other enclosures explored to date (33 m northwest-southeast and 22.25 m northeast-southwest).

The magnetic survey was resumed in the fall of 2002 with Tomasz Herbich, Piotr Kołodziejczyk and Krzysztof Stawarz working two magnetometers Geoscan Research FM 36 to survey an area equaling 13.7 ha. The measurements generated an overall layout of a large area of the cemetery, revealing yet another structure interpreted as an Early Dynastic funerary enclosure (Fig. 2, enclosure B). In the first phase only the southeastern wall was detected. Measurements taken inside the Coptic cemetery, wherever the ground was free of modern burials, permitted a section of the northeastern wall to be discovered. Little can be said of the extent of the enclosure toward the northwest, except that it must run in an area where no work could be done because of the considerable magnetic disturbance caused by the fired-brick walls of the modern burial ground. The archaeological verification of the findings carried out in the 2002/2003 season set the northeast-southwest width of the enclosure at 37.5 m. Based on the magnetic results, its probable length is between 67 and 70 m.

Magnetic measurements also helped to revise the position of some of the structures excavated in the 1910s and 1920s, *e.g.* the actual location of the chapel in the Peribsen enclosure is 2 m to the north of the position shown on old excavation maps.

Magnetic surveys of the site Burg Gana (Hof/Stauchitz) in Saxony

Tomasz Herbich[a], Roman Křivánek[b], Krzysztof Misiewicz[a] and Judith Oexle[c]

The site of Hof/Stauchitz (Burg Gana) in Lower Saxony was located in the early 1920s through field walking and a limited salvage excavation was conducted in the central part in 1938. More trial pits were dug by W. Coblenz in the 1960s and 1970s (Coblenz 1977).

Aerial photographs of the site were taken by Otto Braasch on June 1, 1993 (Fig. 1) as part of a program for registering archaeological features in Saxony. The next step in a non-intrusive recording of the site was a magnetic survey performed in 1997 and 1998 (Fig. 2). Two proton magnetometers PM-2 (Geofyzika Brno) were used to cover an area of 6 ha in a raster of 1 m by 1 m (Křivánek and Misiewicz 1998). Figure 2 presents the map that was prepared as a result of the survey. All the structures visible in the aerial photographs

[a] Institute of Archaeology and Ethnology, Polish Academy of Sciences, Warsaw, Poland
[b] Institute of Archaeology, Czech Academy of Sciences, Prague, Czech Republic
[c] Landesamt für Archäologie mit Landesmuseum für Vorgeschichte, Dresden, Germany

Fig. 1. Burg Gana. Aerial photograph of the site (LDA Archive Nr 4744/018, Dia Nr 1126–35).

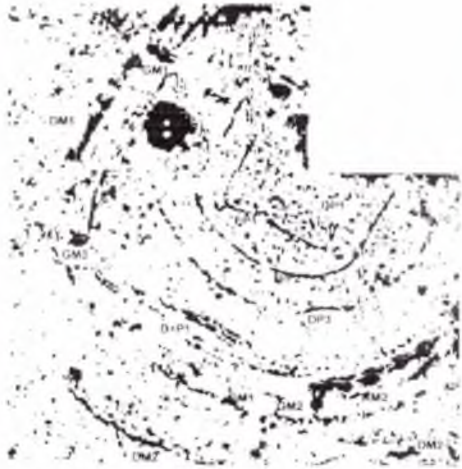


Fig. 2. Burg Gana 1998. Magnetic map, proton magnetometer survey.

were clearly legible on the map, which also displayed many details that had gone undetected from the air (mainly in the outer fortification system). These possible remains of ditches with palisades were interpreted as prehistoric (inner fortification system) and medieval (outer rampart and ditch).

In their report, the authors recommended doing a detailed contour-line plan of the site to compare it with old maps, thus providing significant data for landscape archaeology. More accurate magnetometers and verification of selected areas with the electrical resistivity method could assist in turn with a more precise determination of the potential depth of archaeological features and whether stone had been used in their construction (Křivánek and Misiewicz 1998).

The recommended second survey with a more precise instrument, a fluxgate gradiometer Geoscan FM 36, was carried out in March 2003. The measuring grid was 0.25 m by 0.50 m, in zigzag mode, the measured units being 20 by 10 m in size. A total of 5.5 ha was surveyed. The results are presented as greyscale magnetic maps. Geoplot 3.0 software was used for processing the results, while Surfer 8.0 was used for plotting the greyscale maps (Fig. 3).

The results obtained with a fluxgate gradiometer generally correspond to those taken with a proton magnetometer. Nonetheless, details like pits inside the prehistoric enclosure, the inner part of the Medieval rampart and the outside of the Medieval ditch are more clearly legible on the map made with the help of the gradiometer. The differences could be recorded thanks to the application of a more sensitive instrument in a more precise measuring grid.

Of the detected features, the southeastern part of the outer fortification system from medieval times appears to be the most interesting. Many details of rampart construction are visible on the gradiometer plot (Fig. 4). It cannot be excluded that stone-filled wooden boxes were used in the construction. This kind of material has a relatively high magnetic suscepti-

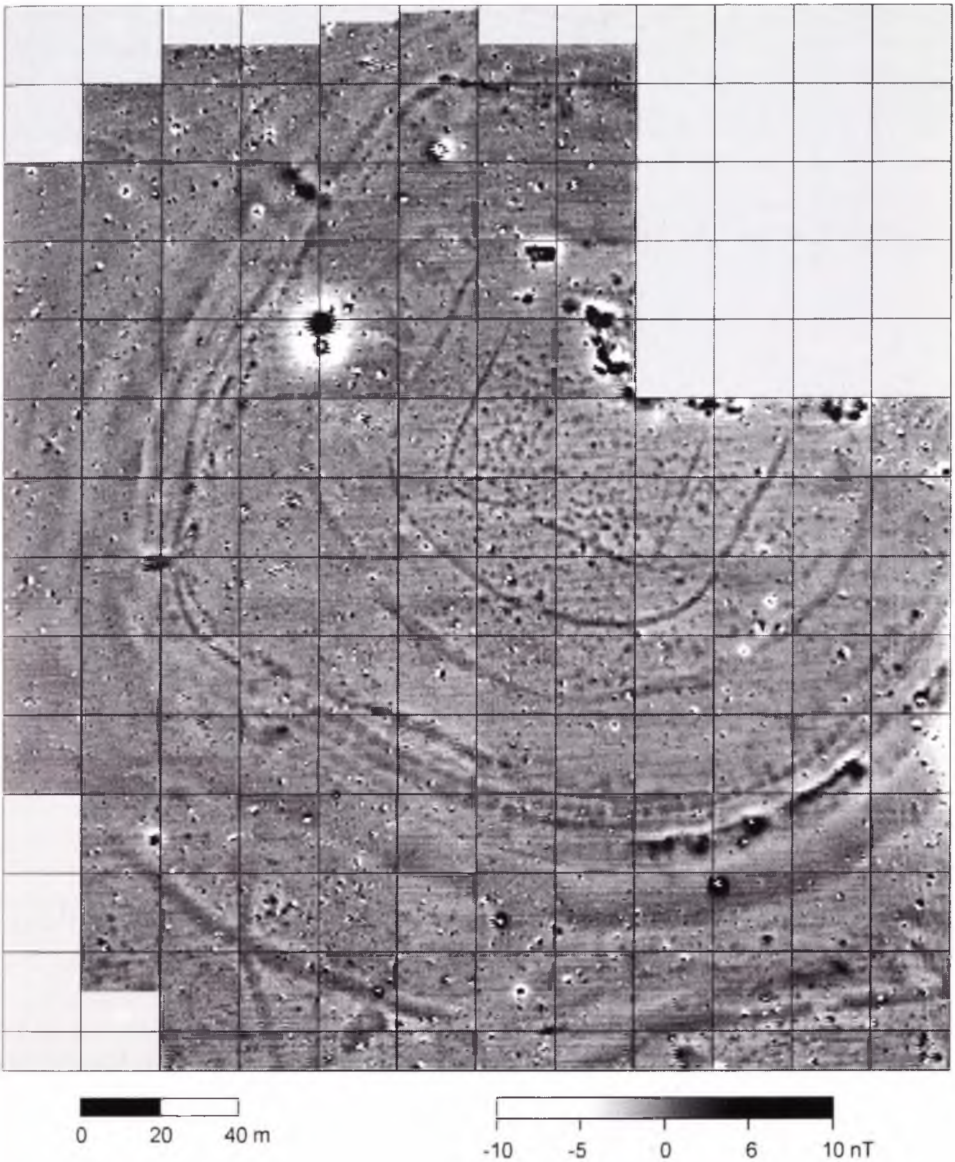


Fig. 3. Burg Gana 2003. Magnetic map, Geoscan FM 36 survey.

bility (especially when the after-burning thermoremanent effect is added) that could produce the regular square positive magnetic anomalies observable on the map.

The results of the surveys described above can be used for both monitoring the state of preservation of the site and planning future excavations.

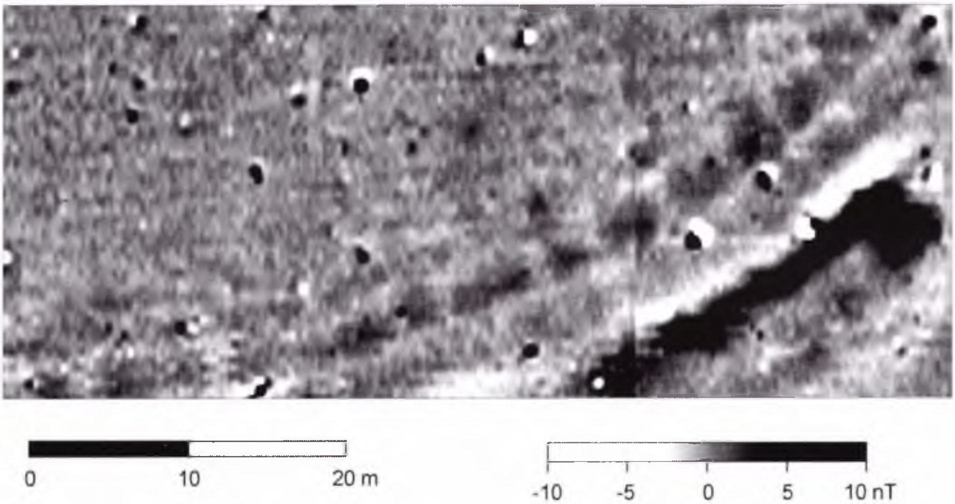


Fig. 4. Burg Gana 2003. Positive magnetic anomalies corresponding to remains of a rampart (?).

REFERENCES

Coblenz, W. 1977. Archäologische Betrachtungen zur Gana – Frage im Rahmen der älterslawischen Besiedlung des Gaues Daleminze. *Beitr. Zur Archivwiss. u. Gesch. Forsch.* 10:354–70.

Křivánek, R. and K. Misiewicz 1998. *Geophysical survey of the site Burgberg (Urbs Gana) in Hof/Stauchitz/ Saxony*, Unpublished report in the Archive of LDA. Dresden.

Magnetic survey at South Abydos: revising archaeological plans

Tomasz Herbich[a] and Joseph Wegner[b]

Methodical archaeological research was commenced at South Abydos at the turn of the 19th century by an expedition from the Egypt Exploration Fund. The discoveries then included a mortuary complex of Senwosret III, the fifth king of the 12th Dynasty. Sections of this complex cover a total length of approximately 900 m, extending between cultivated land and the towering 700-foot cliffs of the Western Desert. Investigations were resumed in the 1990s by the Pennsylvania-Yale-Institute of Fine Arts, NYU expedition and they are still ongoing today.

[a] Institute of Archaeology and Ethnology, Polish Academy of Sciences, Warsaw, Poland
[b] University of Pennsylvania, Philadelphia, USA

Fig. 1. South Abydos. Senwosret III tomb enclosure (in foreground, at photo bottom) and 13[th] Dynasty mastabas.

One of the goals of the present expedition was to create an archaeological map of the entire territory of South Abydos, encompassing current results as well as the accomplishments of scholars working in the area previously. In view of the size of the area in question, there was no doubt that geophysical prospection would be essential to the success of the undertaking, providing data faster than traditional methods. The objectives were twofold: locating unknown archaeological features and potentially verifying the determinations made a hundred years before.

The principal building material at Abydos is mud brick and it is because of the magnetic properties of this material that the magnetic method was chosen. Measurements were taken with two Geoscan Research FM 36 instruments in a grid of 0.5 by 0.25 m in parallel mode. The results were processed with Geoplot software and map printouts were made with Surfer 8.0.

SENWOSRET III TOMB ENCLOSURE

The Egypt Exploration Fund's expedition uncovered a T-shaped enclosure located at the foot of the desert cliff and inside it a tomb or cenotaph of Senwosret III. Many other structures associated with the enclosure were also discovered, like a possible offering platform inside it, ancillary rooms for storage of offerings, two so-called "dummy" mastabas and two large mastabas of the 13[th] Dynasty (S9 and S10). The wall of the enclosure, which is

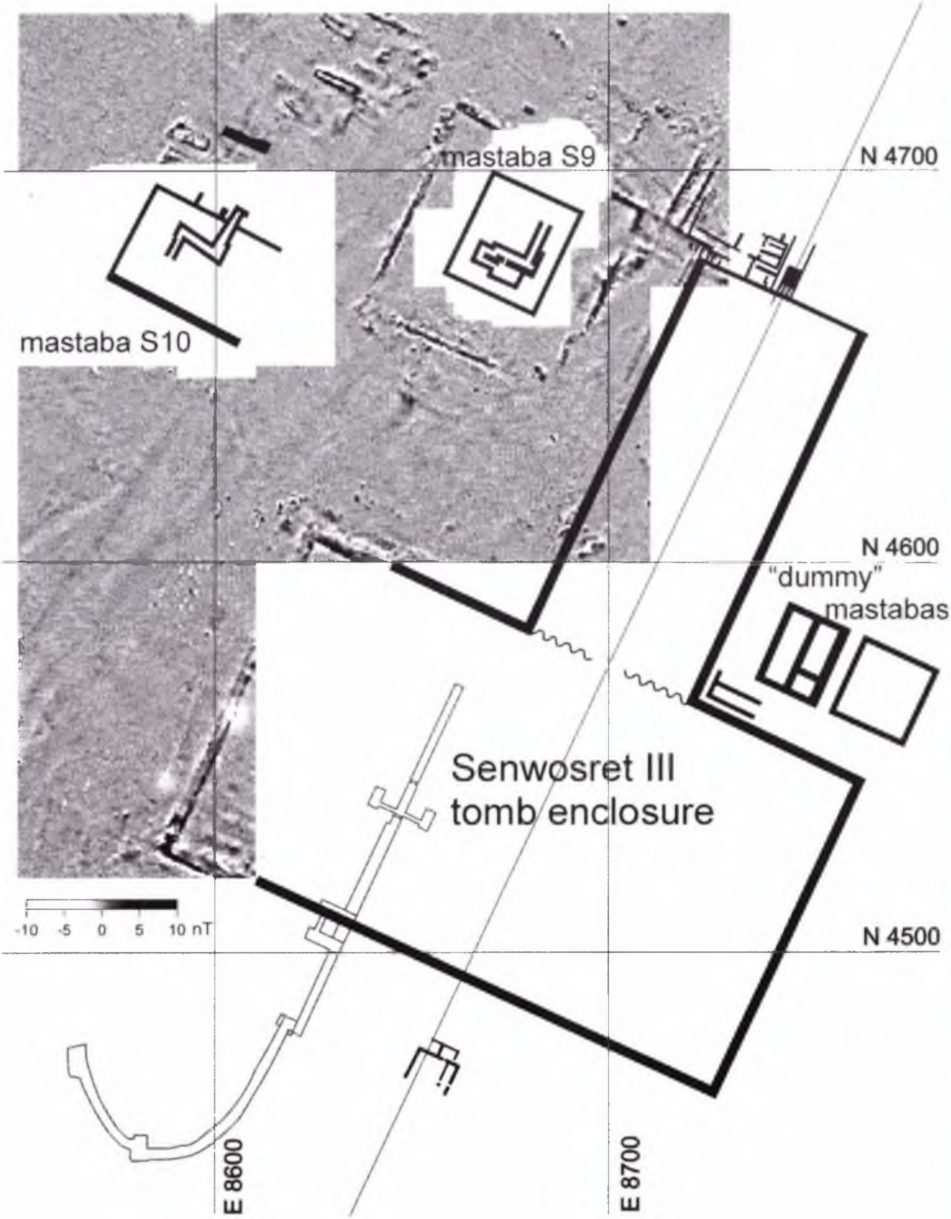


Fig. 2. South Abydos. Magnetic map of Senwosret III tomb enclosure and 13th Dynasty mastabas. Sampling grid 0.25 m by 0.5 m, interpolated to 0.25 m by 0.25 m.

Fig. 3. South Aydos. Middle Kingdom town site *Wah-Sut*. Sampling grid 0.25 m by 0.5 m, interpolated to 0.25 m by 0.25 m.

preserved in places to a height of 3 m, is currently under sand; neither is the plan of the mastabas clear, the structures having disappeared under sand dumped from archaeological excavations in the area (Fig. 1). A plan of all the uncovered features had been published in the

EEF expedition's report (Ayrton *et al.* 1904) and had been copied all through the 20th century in dozens of publications despite the admonishment accompanying the original publication: "...and the hasty plan (....) does not pretend to be accurate" (Ayrton *et al.* 1904:23), which should have suggested less trust in this source.

Geophysical surveying in the spring of 2002 carried out on part of the area excavated in the early 20th century – the northwestern part of the enclosure and the two mastabas of the 13th Dynasty (Fig. 2) – confirmed in full the critical view of their own work that the authors of the original publication expressed in the introduction to their report. It turned out that the dimensions of one of the mastabas were in reality twice that on the plan (or else a wall encircling the mastaba revealed by the magnetic survey had been overlooked originally); only excavations can produce an explanation of this difference. The magnetogram (covering an area of 2.26 ha) also demonstrates clearly the difference in the layout and dimensions of the storage complex at the entrance to the enclosure. These differences are undoubtedly due to errors of measurements taken in the field and fragments of structures being overlooked in the course of the digging.

Thanks to magnetic surveying, it was also possible to record a number of tombs situated to the north of the mastabas.

MIDDLE KINGDOM TOWN SITE *WAH-SUT*

The other principal element of the mortuary complex – beside the tomb enclosure – was the mortuary temple and associated settlement site located 300 m southeast of the temple. Investigations by the Pennsylvania-Yale-Institute of Fine Arts, NYU expedition, began in 1994, uncovered data on the organization of the temple and settlement. Exposure of parts of seven different buildings in the southwestern part of the settlement has provided evidence on a state-planned town established in the late 12th Dynasty with an occupational history extending into the New Kingdom (Wegner 2001).

Magnetic surveying covered an area of 1.43 ha southwest of the limits of settlement architecture, which appeared to be very clearly defined as a result of excavations concluded in this area. In consequence of the geophysical investigations, an entire complex of structures lying beyond this border was discovered, necessitating a revision of published plans of the site and reopening excavations in a southerly direction (Fig. 3). Other features were also discovered at some distance from the settlement complex; their round plan could suggest storehouses of some kind (Fig. 3, marked with an arrow).

The results of magnetic survey research at South Abydos highlight the usefulness of geophysical methods in territory that would seem to have been already thoroughly explored (emphasizing at the same time the need for prudence in accepting the results of explorations carried out in Egypt in the period of pioneer archaeological research).

REFERENCES

Ayrton, E., C. Currelly and A. Weigall 1904. *Abydos III.* London.

Wegner, J. 2001. The town of Wah-sut at South Abydos: 1999 excavations. *Mitteilungen des Deutschen Archäologischen Instituts Abteilung Kairo* 57:281–308.

Archaeological prospection: dreams and reality

Albert Hesse[a]

Being able to look right through the ground has been a dream for archaeologists ever since the profession was established. And to the average layman it may yet seem a challenge beyond human capabilities. Early attempts at using geophysical methods, performed in the 1960s, did indeed locate pottery kilns but otherwise failed to meet hopes and expectations. Measurements were desperately slow, maps covered areas too small to be useful and most archaeologists, even if too polite to say so, were disappointed after just a few experiments. At best, we, geophysicists, were able to describe correctly, but never in time, features that were already well known.

Accuracy, high resolution and speed of measurements needed to be improved substantially in order for the methods to be effective in meeting the given objectives. This was achieved for magnetic prospection first in several laboratories. It took appreciably longer for resistivity – my dream from the beginning – for a variety of technical, financial and practical reasons. Then the dream became a reality thanks to the efficient team we had at the Garchy laboratory and legible maps can now be obtained very easily.

This is a true story but it should not conceal another reality: that geophysics is not the only solution to consider for appropriate archaeological prospecting. A clever and systematic examination of all available data, even if not measurable, can sometimes lead to better results than millions of numbers!

[a] Saint-Sature, Sancerre, France

The potential of archaeological prospection techniques in Iceland

Tim Horsley[a], **Armin Schmidt**[a] **and Steve Dockrill**[a]

Since 1999 research has been undertaken to assess the potential of archaeological prospection techniques in Iceland, where a particular set of geomorphological and archaeological problems are present. In addition to the intense thermoremanent effects of the igneous geology, other limiting factors include numerous tephra deposits, periglacial phenomena (including frost hummocks and stone polygons), and regions of active soil erosion or sand deposition. The nature of the archaeological remains themselves provides further difficulties. Up until the beginning of the 20th century most structures were largely built of turf, and once collapsed and buried may provide only slight features for detection.

For this investigation high-resolution magnetometer and earth resistance surveys have been undertaken throughout Iceland, to include a range of archaeological features and a variety of

[a] Department of Archaeological Sciences, University of Bradford, United Kingdom

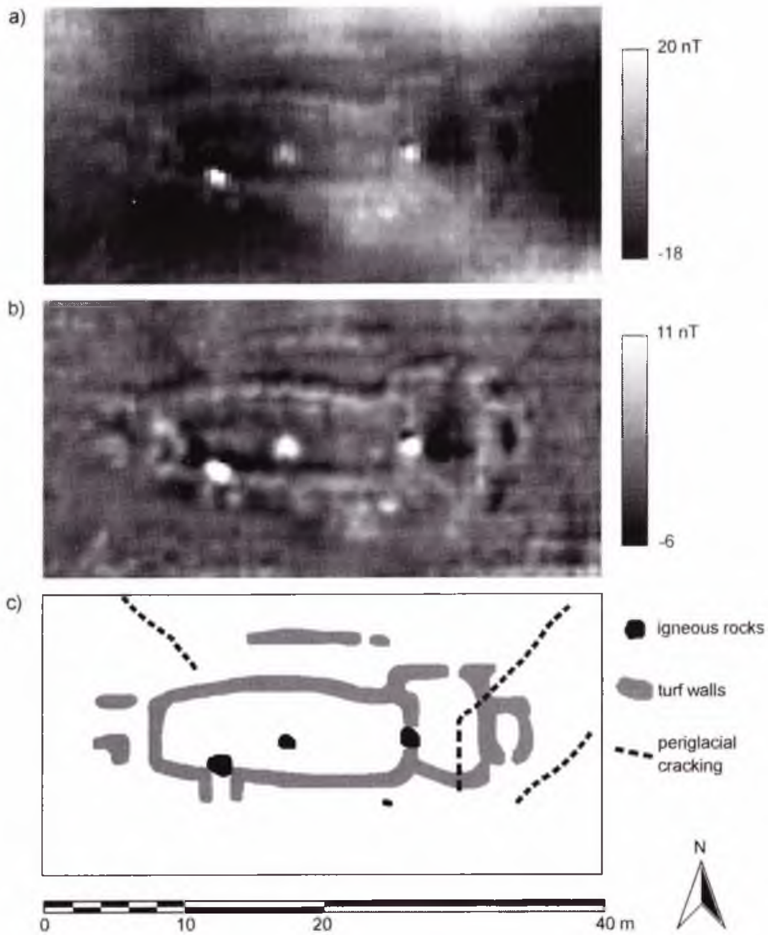


Fig. 1. Southern Iceland. Fluxgate gradiometer survey over a Viking longhouse structure: a) the raw data; b) data after interpolation and High Pass filtering; c) interpretation. The detected rocks (located in doorways and a central position due to a hearth) indicate the use of this structure as a dwelling.

geological and geomorphological situations. The results of these surveys are integrated with other sources of archaeological evidence to allow a proper assessment of their success for not only locating buried remains but also for their characterisation and interpretation.

Despite the limiting factors, this work demonstrates the potential of these techniques for archaeological prospection in many parts of the country, especially when undertaken as part of an integrated approach. New and previously known structures, of turf and stone or entirely from turf, have been detected with both techniques. They are known to date from the earliest Viking longhouse remains (Fig. 1) to recent farm sites.

From this evaluation it is possible to provide strategies for the future application of such geophysical techniques, and to pinpoint areas where future research is necessary.

This work is being undertaken as a NERC-funded doctoral research project at the University of Bradford, in collaboration with the Institute of Archaeology, Iceland (FSÍ) and the North Atlantic Biocultural Organisation (NABO).

Oberlausitz. A GIS-based Medieval landscape modelling of the Sorbian/German region

George Indruszewski[a]

Bautzen/Budyšin is considered the *de facto* cultural capital of the Sorbian minority in the larger region of the Sorbian/German Upper Lausatian (Oberlausitz) region. This perception is founded mostly on decades of intermittent historic and archaeological research that underlined the central importance of this place for the region. The reconstruction of a regional Medieval landscape concentrated therefore on the reconstitution of the multiple relationships between Bautzen/Budyšin as a focal point and the peripheral settlements during the Early and High Middle Ages. It takes in consideration not only the adjacent settlement clusters around Bautzen/Budyšin and those on the Upper Spree Valley, but also those from the entire Oberlausitz region, and those from the larger area including Northern Bohemia and the western parts of Lower Silesia. Settlement pattern and its temporal variation constitutes an important element in the process of landscape reconstruction, inasmuch as it emphasizes matching of information from various sources: archaeological, historical, and linguistic. The matching process is taken a step further with its insertion into the proper reconstructed environmental settings aided by a two-year prospection campaign that relied heavily on GPS technology for pinpoint location of Early Medieval strongholds. These strongholds constitute a major clue for the reconstruction of major settlement patterns and communication links in a GIS-based environment. Collected field data was transferred to GIS-based digital maps, where it aided the intra- and extrasite spatial analysis of a hypothetical Early Medieval landscape model. With the aid of several GIS software packages (ArcView, ArcInfo, MapInfo), the author succeeded in constructing a DEM model of the Oberlausitz region, which was used further to show the main spatial relationships between principal objects of interest, for example strongholds, settlements, churches, *etc*. The result presented here, outlines the different changes in the Upper Lausatian landscape, changes that highlight the historical processes that occurred in the region since the beginning of Early Medieval times. It is shown, thus, that Bautzen/Budyšin, by far the most important cultural landmark of the region, might not have achieved this

[a] Geisteswissenschaftliches Zentrum Geschichte und Kultur Ost- und Mitteleuropa (GWZO), Leipzig, Germany; National Museums Center for Maritime Archaeology, Roskilde, Denmark

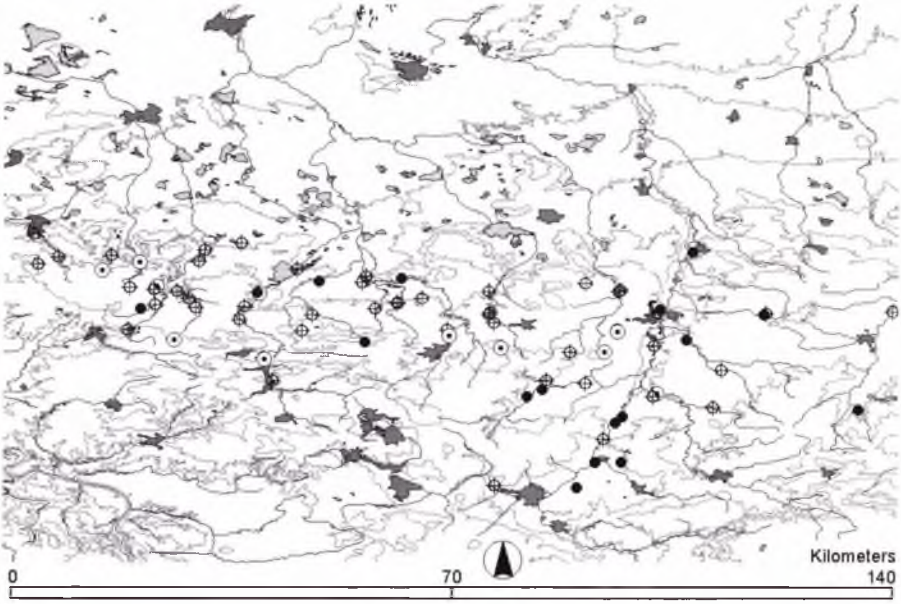


Fig. 1. Spatial distribution of strongholds in Oberlausitz according to their intrasite structure (encircled black point: stronghold with fortified *suburbium*, encircled crosses: single compound stronghold, black point: unknown structure).

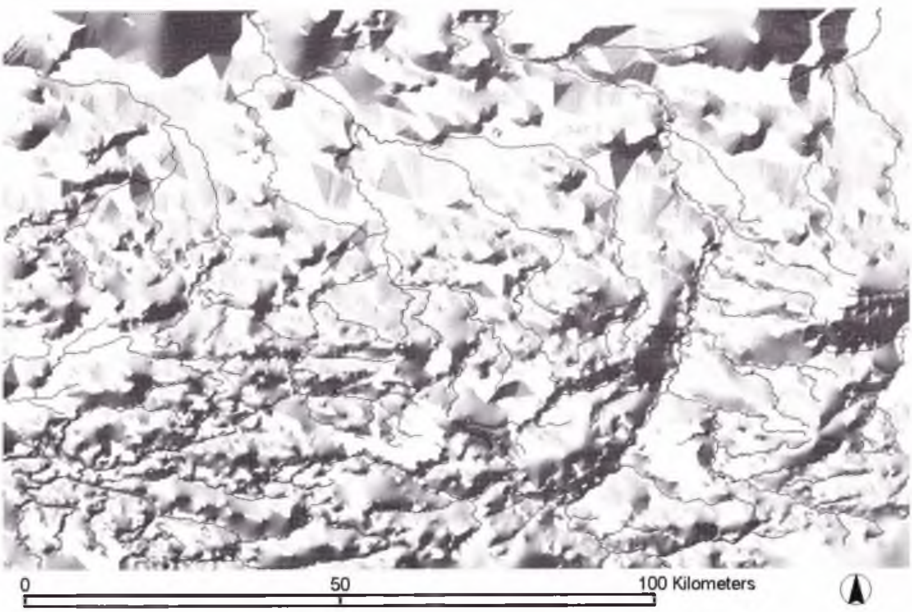


Fig. 2. A DEM of Oberlausitz.

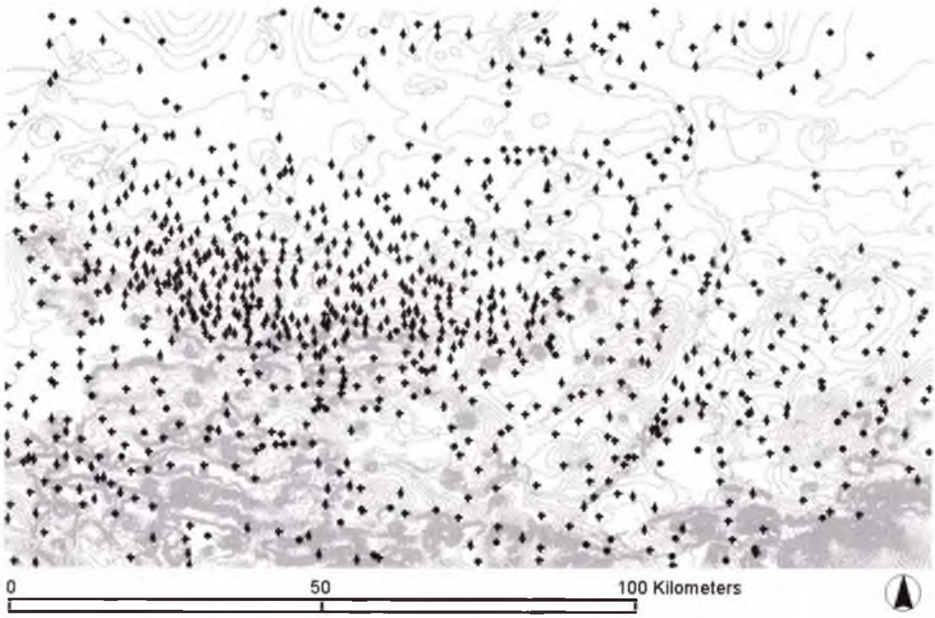


Fig. 3. Settlement distribution in Oberlausitz according to their linguistic origin (black point: ambiguous/dual heritage, upward black arrow: Slavic settlements, black cross: German settlements).

status until the turn of the 11^{th} century and the start of the historical wars between the German emperor Henry the Second and Bolesław the Brave of Poland.

From hypothesis to survey, from survey to excavations and back to hypothesis: the conclusions of 10 years of work in the amphorae workshop at Sinope-Demirci

Dominique Kassab Tezgör[a]

The work which began in 1993 in Sinope-Demirci and which was concluded by 2002 reveals all the steps of the research from hypothesis through field and magnetic prospection, to excavation, study of the material and finally publication. Every stage paved the way for the next one, which provided in turn a critical approach to the previous one. The conclusions of research led to new hypotheses, new surveys and new excavations…

Hypothesis: Thanks to more than 20000 stamps found all around the Black Sea, as well as in some other areas of the Greek world, Sinope was very well-known as a centre of

[a] Bilkent University, Department of Fine Arts, Ankara, Turkey

amphorae production in the Hellenistic period. Localizing the workshops in the city or region and gathering new data appeared like a worthwhile objective.

Field prospection: In 1993 a field survey was done along the coast of the peninsula and between Sinope and Gerze (20 km south of Sinope). Around 10 workshops were found, from the Hellenistic up to the early Byzantine period. The largest one was situated in Demirci, 15 kilometres south of Sinope. The identity of the site as a workshop was obvious thanks to the high density of sherds, the repetitive presence of the same types and numerous wasters. The material was classified and identified provisionally based on an open catalogue of amphorae stored in the local museum.

Magnetic survey: It was not possible to excavate the whole site because of its large size. The only way to discover the location of the kilns or any other structure was to carry out a magnetic survey. Albert Hesse, Mahmut Drahor and Ali Kaya undertook this survey in the spring and summer of 1994 in two zones, A and B, in the northern half of the site. A map of the anomalies with different densities and size was drawn.

Excavations: The first excavations began in the summer of 1994 (zone A), and continued in 1995 (zone B), 1996, 1997 (zone A), 2000 (zone B). Around 10 kilns were brought to light; of these three were nearly complete. The three press-stones discovered in zone A and dated to a later period, proved that the activity of that sector had shifted to an oil-press factory (or winery?). Ceramic production in zone B had also stopped during the same period.

Study of the material: This workshop had produced mainly amphorae, but also tiles and common wares, as well as a small quantity of lamps. The terra sigillata and coins that were found dated its operation to between the 3rd and 6th century AD.

A typology of the Sinopean amphorae produced in the Late Roman and Early Byzantine period has been established. The sites where similar amphorae were found indicate export routes. It was quite a surprise to see that the trade in these Sinopean containers was not limited to the Black Sea littoral, but extended to the Mediterranean, to Syria, Lebanon, Jordan and Israel. The map is not yet complete and this commercial road was probably much more important than it appears now.

It is quite interesting to compare the results of the field survey and the excavations. The main shapes found in the kilns were already known from the survey and were present in the same proportions. However, thanks to the excavations some subtypes could be defined and a date could be proposed for each type of vessel. Only one type that was excavated had not appeared in the survey and was identified by a few rims and a body sherd discovered in the earlier kiln.

Clay analysis: XRF and XRD analyses of samples of amphorae, tiles and ceramics produced in Demirci-Sinope are in progress at the University of Bilkent. The composition of the clay is now known and will permit comparison with other products.

Conclusion: Although the Hellenistic amphorae types were well-known, the ones of the later period had not been studied extensively and only a few shapes were attributed to Sinope on the basis of the appearance of the clay. Excavations of the workshop have confirmed their attribution and have brought to light new forms. The alleged production of white clay amphorae in Sinope has also been proved. The construction of the kilns, which appears to be specific to the Black Sea region, has been studied, as well as the organisation of the workshop.

New project: The conclusions of these 10 years of work at Sinope have raised new questions and offered new opportunities. Which other workshops had been operating in the Black Sea area at the same time? What types had they produced? What was the relation between their production and that of Sinope? More specifically, what was the connection between Sinope and Herakleia Pontica in the west and Colchis in the east, concerning shape and technique? Last but not least, what can be said of the economy of the Pontic world based on amphorae imports and exports?

ACKNOWLEDGEMENT

The Franco-Turkish mission in Sinope was financed by the Cultural Department of the French Ministry of Foreign Affairs, the CNRS in France, and the IFEA in Istanbul. It has been generously sponsored by the Kavaklýdere wine caves in Ankara.

Geomagnetic prospection of the Early Bronze Age town of Tuttul / Tell Bi'a, Syria

Kay Kohlmeyer[a], Martin Marinow[a], Thomas Goldmann[b] and Bernd Kutschan[b]

INTRODUCTION

The objective of the survey, which took place at the site of the Early Bronze Age city of Tuttul (Tell Bi'a near the modern city of ar-Raqqa in Syria) during three weeks in March 2002, was to produce a magnetic gradient map of the area around the two palaces (Palace A and Palace B) on the central hill E, hill D in the northern part of Tell Bi'a, and hill F to the east of the excavated palaces. The electromagnetic mapping method was also tested in two small reference areas on hill D and near hill E. In both cases measurements were carried out by scanning the area of investigation along parallel lines of a 50 m wide square grid. The scan was started in the southwestern corner of every grid with the operator walking from west to east. The next line was 0.5 m further to the north and was scanned from east to west, and so on. The magnetic field strength and the vertical gradient were measured automatically with a cycle time of 0.5 seconds, using an Overhauser proton precession magnetometer.

The electromagnetic mapping system measured the electric conductivity (inphase and outphase components) of the ground. The measurements were taken with a cycle-time of 0.4 seconds (according to points spaced 0.4 m apart) with a distance of 1 m between lines.

The data was stored and linked to its topographic coordinates. The mapping provided us with a grid of data with nearly 0.5 m between points and a distance of 0.5 m (1 m) between lines for magnetic (electromagnetic) mapping respectively.

[a] Fachhochschule für Technik und Wirtschaft Berlin, Germany
[b] INTUS Institut für Technologie und Umweltschutz e.V., Aninstitut der FHTW Berlin, Germany

SPECIAL PROBLEMS OF THE INVESTIGATION AREA AT TELL BI'A

Industrial magnetic noise was not a problem at Tell Bi'a, because the investigation area is sufficiently distant from electric installations of any kind. However, the influence of ferromagnetic objects did cause problems because a lot of small scrap-iron (food tins or empty oil cans and so on) were scattered all over the investigation area.

The buildings of Early Bronze Age Tuttul were made of unfired bricks. In some cases the material was effectively fired in catastrophic conflagrations. Fired bricks are known to cause magnetic gradient anomalies of about 5 nT per meter (nT/m), unfired bricks cause lower anomalies. For the sake of comparison, a 500 g piece of scrap-iron 1 m away from the sensor causes an anomaly of about 20 nT/m. Thus, small iron anomalies are usually higher than the signal given by brick-and-stone objects. Though the investigation area was scoured using a metal detector, it was not possible to find and remove all the metal junk. Another issue is the debris covering the ruins of mud brick buildings; being mostly unfired, it generates weak magnetic contrasts.

RESULTS

Twenty-six grid squares, 50 m across, were measured by magnetic gradient survey. Found on hill D in the northern part of Tell Bi'a were some building structures, consisting of rectangular rooms and courtyards. The largest structure is approximately 30 m square and has the same orientation as palace A, which was excavated in 1980. A smaller building structure was found to the north of the larger one. The space between the two buildings could be described as a courtyard. Another rectangular structure in the southeast of the excavated area on hill E seems to have belonged to the oldest palace of Early Bronze Age Tuttul. All these structures caused negative magnetic anomalies of up to –3 nT/m.

A curving line over 100 m long was discovered in the central part of hill E, in the north end of the excavated palace buildings. It is assumed that it had been a wall surrounding the administrative and religious quarter (palace and temple district). This curved line gave a very weak positive magnetic gradient anomaly. The electromagnetic mapping of hill D in the north showed a circular structure with a diameter of 15 m. This structure was not to be seen on the magnetic map.

Investigation of agricultural terraces in the South of Russia

Dmitry Korobov[a]

From 1996 to 2000 a group of researchers under the direction of Dr. G. Afanas'ev at the Institute of Archaeology of the Russian Academy of Sciences worked on the creation of the geographical information system "Archaeological sites of the Kislovodsk basin". This region

[a] Institute of Archaeology of Russian Academy of Sciences, Moscow, Russia

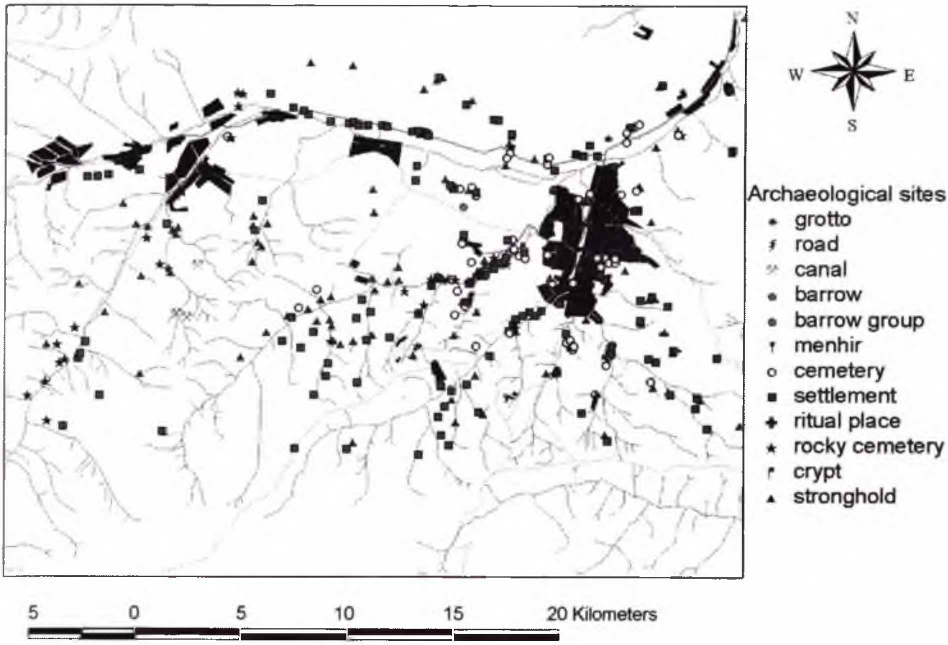


Fig. 1. Early Medieval archaeological sites in the Kislovodsk basin.

is unique in its concentration of archaeological remains and is situated in the central part of the Northern Caucasus, near the mountain of Elbrus. The piedmont zone of the Ciscaucasus had been occupied by various tribes ever since ancient times and had been a gateway between the steppe part of South Russia and the Transcaucasia, through numerous mountain passes. Archaeological prospection identified more than 700 sites dating from the Eneolithic period up to the Late Middle Ages. These sites were entered into ArcView GIS (version 3.1).

A preliminary analysis shows that the majority of sites – settlements, strongholds and cemeteries – relates to the Alanic culture of the Early Middle Ages. At this time (5th to 7th centuries AD) many suitable capes in deep river-valleys were used as natural strongholds with small stone constructions erected on steep rocks. These were accompanied by open settlements and catacomb cemeteries. So far, more than 119 strongholds, 124 settlements and 53 cemeteries of the Early Middle Ages were found (Fig. 1; *cf.* Korobov 2001).

The Alan population of the Kislovodsk basin led a sedentary life. Their occupation was cattle breeding and farming, which is confirmed by the osteological study of animal bones and by anthropological investigations of human diet.

The field campaigns of 2001–2002 were devoted to the analysis of traces of Early Medieval land tenure. They included the use of archaeological prospection and mapping for the remains of agricultural terraces. Terraced slopes are found in many places of the region. They are clearly visible in aerial photography, frequently apparent to the naked eye, and very well

Fig. 2. The window of MapInfo 6.0 with the mosaic of aerial photographs.

preserved, as they were not exposed to later anthropogenic influence (Afanas'ev *et al.*, forthcoming; Arzhantseva 1998 and forthcoming).

To improve the results, components of the project were transferred to MapInfo 6.0 including a part of the investigated region between the rivers Berezovaya and Kabardinka. This project consists of raster layers from a topographical map, 15 aerial photographs made on 16 September 1970 from a height of 22000 meters and one satellite image. All raster layers were geocoded with control points, resulting in an overall mosaic (Fig. 2).

Aerial photographs were processed with the program ErMapper 5.5 revealing traces of terraces invisible on the original black-and-white images. For this purpose special algorithms of the program ("Create Colordrape" and "Create Slope (degrees)") were used to create a 3D surface, tinted by pseudo-colours derived from the saturation of the greyscale photograph. The revealed terraced slopes were digitised as polygons and imported into ArcView 3.1 as a separate vector layer (Fig. 3). In this program, the terrace vector objects were further

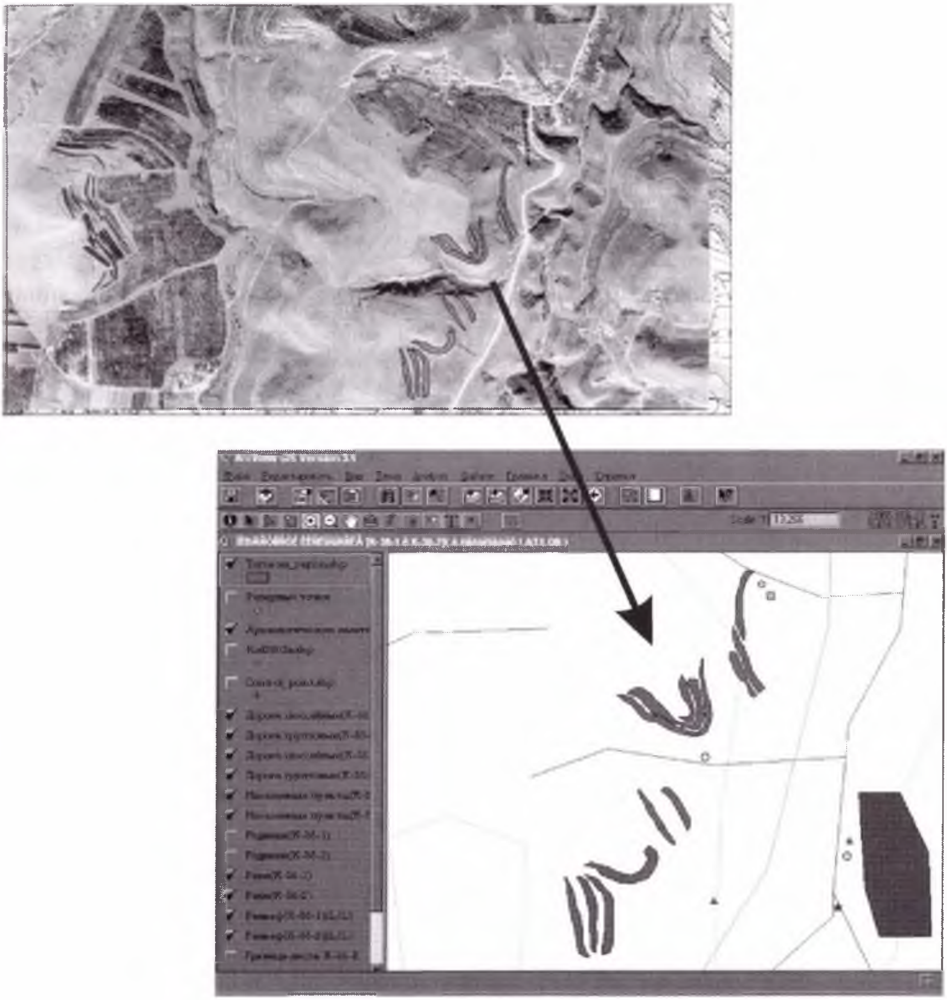


Fig. 3. Process of import of the vector layer with the terraces to ArcView GIS 3.1.

analysed with Spatial Analyst 1.0. Their area was calculated, their spatial distribution investigated and their relationship with neighbouring archaeological sites was determined. The results of this analysis are presented in this contribution.

REFERENCES

Afanas'ev, G.E., A.V. Kislov and A.V. Chernyshev forthcoming. To a question about the terraced agriculture on Northern Caucasus. *OPUS: Interdisciplinary researches in archaeology*, 2002. Moscow (in Russian).

Arzhantseva, I. 1998. Alan settlements of the first millennium in the Kislovodsk basin: the conditions for their development and functioning; palaeographic reconstructions of the life-support systems. In *Abstract book of the 4th Annual Meeting of the EAA*, 165. Göteborg.
– forthcoming. The Alans: neighbours of the Khazars in the Caucasus. In *The Khazars, international colloquium, Jerusalem, 2000.*
Korobov, D. 2001. Archaeological prospection in the Kislovodsk basin (South of Russia): GIS and aerial photography. In *Archaeological Prospection. Fourth International Conference on Archaeological Prospection. Vienna, 19–23. September 2001.* M. Doneus, A. Eder-Hinterleitner, W. Neubauer (eds), 133–135. Wien.

Magnetic prospection of various types of large ditch enclosures (or fortifications) of prehistoric Bohemia

Roman Křivánek[a]

A key tendency in Czech archaeology starting from the second half of the 1990s is a more intensive, systematic and integrated application of non-invasive methods of archaeological surveying. During this time the role of the natural sciences in relation to archaeology has undergone progressive change, from being merely auxiliary to becoming more of an active and effective association. The archaeological project *Settlement pattern of prehistoric Bohemia*, financed by the Grant Agency of the Czech Republic (Martin Gojda *et al.* 1997–2002, 404/97/024), represents this kind of interdisciplinary approach. The project was completed in 2002, but archaeologists will continue processing and using the new data from intensive aerial prospection presumably for quite some time still.

The discovery of hitherto unknown groups of large atypical linear features was probably the most important result of the aerial survey. Some types of these large ditch enclosures or fortifications were discovered for the first time and were not previously known in Czech archaeology. Following in the wake of aerial prospection, the geophysical survey provided more detailed and precise data on these large linear features. The survey accomplished three separate objectives: firstly, surface verification and location of features (geophysical plans with coordinates, correct shape, dimensions and orientation of feature); secondly, identification of parts of features not visible on aerial photographs and thirdly, determination of the state of preservation of these features. A caesium magnetometer survey (in a raster of 0.5 m or 1 m by 0.25 cm) was selected as the most suitable method for quick prospection of the purported large ditch enclosures. The method is also well suited to discerning details of the most interesting parts of features. Systematic field walking accompanied all geophysical surveying of the linear features, the coordinates for the magnetic survey, as well as for the field walking having been established by GPS.

[a] Institute of Archaeology, Academy of Sciences of the Czech Republic, Praha, Czech Republic

Large linear ditch enclosures (or fortifications) were often situated in dryer areas intensively settled by prehistoric cultures near major or local rivers. However, atypical linear features were also identified in the upper zones of lowland regions, away from water systems of any kind. In most cases, the results of magnetic surveys helped to choose the most probable interpretations for features and sites. It would appear that the large ditch enclosures form two principal groups: open and closed (oval, ring or round), but the variability of these feature types is much greater to judge by the survey results, complicating thus the possibilities for site interpretation. In the course of the project, linear features were discovered that could not compare in shape or situation with any known similar feature in all of Bohemia. In these cases, limited archaeological excavation was conducted in order to evaluate the features for dating and probable interpretation.

OPEN DITCH ENCLOSURES

One example of an effective combination of archaeological survey methods, including archaeological verification of the site, is provided by the comprehensive survey results obtained near Kly, distr. Mìlník. The atypical system (enclosure?) consists of two parallel ditches, both wide and interrupted repeatedly, and one inner palisade trench that is narrow and continuous (Fig. 1). The magnetic survey of the area helped in the identification of the entire system of ditches and palisade cutting off a meander of the Labe river. Finds from limited excavation trenches across this system date the enclosure (or fortification) of this multi-cultural site to the Eneolithic Michelsberg Culture.

Another example of surveyed open ditch enclosures comes from Hrdly, dist. Litoměřice. This multi-cultural prehistoric site consisted of many sunken settlement features, damaged by ploughing, and small ring ditches belonging to a barrow cemetery. An extensive magnetic survey distinguished between two different types of single ditch enclosures (or fortifications): one was an interrupted arched ditch enclosure and the other a virtually right-angled feature with rounded corner. These features have yet to be verified archaeologically.

A different type of large open ditch enclosure is situated near Trpoměchy, distr. Kladno. This atypical feature is more probably an enclosed rather than a fortified site and consists of one interrupted ditch running around two-thirds of a prominent hilltop Řípec. The magnetic survey helped to distinguish the enclosure and identified more narrow interruptions in the ditch. Two limited trenches excavated subsequently across the feature have identified the ditch and the breaks in it, dating the enclosure to the Hallstatt period.

CLOSED DITCH ENCLOSURES

The first survey results near Želízy, distr. Mìlník, represent the most typical form of closed ditch enclosures occurring in the lowland region – the ring ditch enclosures – but it was discovered in a less than typical area for these features, *i.e.*, the upper zone of the lowland region, on a terrace projecting above a deep and narrow sandstone valley, away from any settlements whatsoever. The magnetic survey helped to identify narrow interruptions, putative passages through a ring ditch (of a diameter equalling 60 m approximately). Following

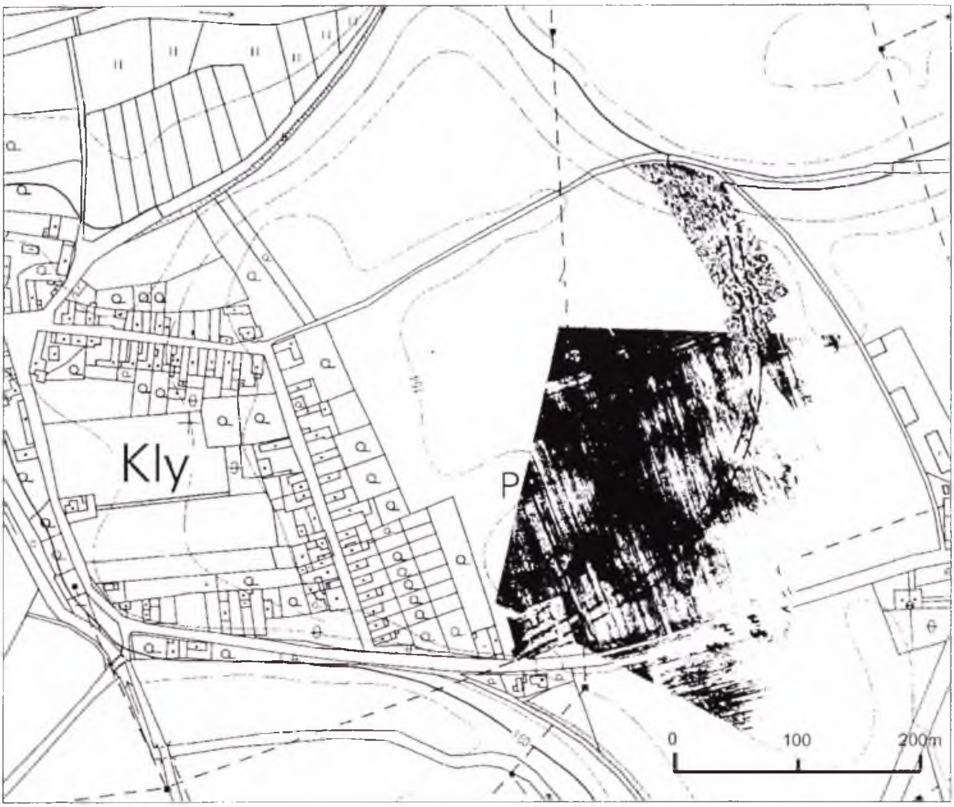


Fig. 1. Kly, distr. Mělník. A combined magnetic and aerial prospection survey in a situation map helped to identify the entire open ditch enclosure of the Eneolithic period (two parallel interrupted ditches with one inner narrow palisade trench).

the survey, the most probable interpretation for this single ditch enclosure was an atypically situated Neolithic rondel.

The less typical closed elliptic ditch enclosure near Ctiněves, distr. Litoměřice, was identified by a combination of aerial and geophysical prospection. The conditions were not homogeneous for magnetic measurements (volcanic rocks present in the soil); however, it was still possible to identify sections of what were probably two deep, parallel, elliptic ditches, as well as additional sunken features indicating intensive settlement and dated by multiple finds to the Late Bronze Age.

The results of non-invasive surveys at a site near Sazená, distr. Kladno, show an even more atypical and complicated type of closed ditch enclosure with a specific shape and internal divisions (Fig. 2). Magnetometry and EM-measurements were used to verify the real shape of the closed ditch enclosure and to identify some narrow entrances and internal divi-

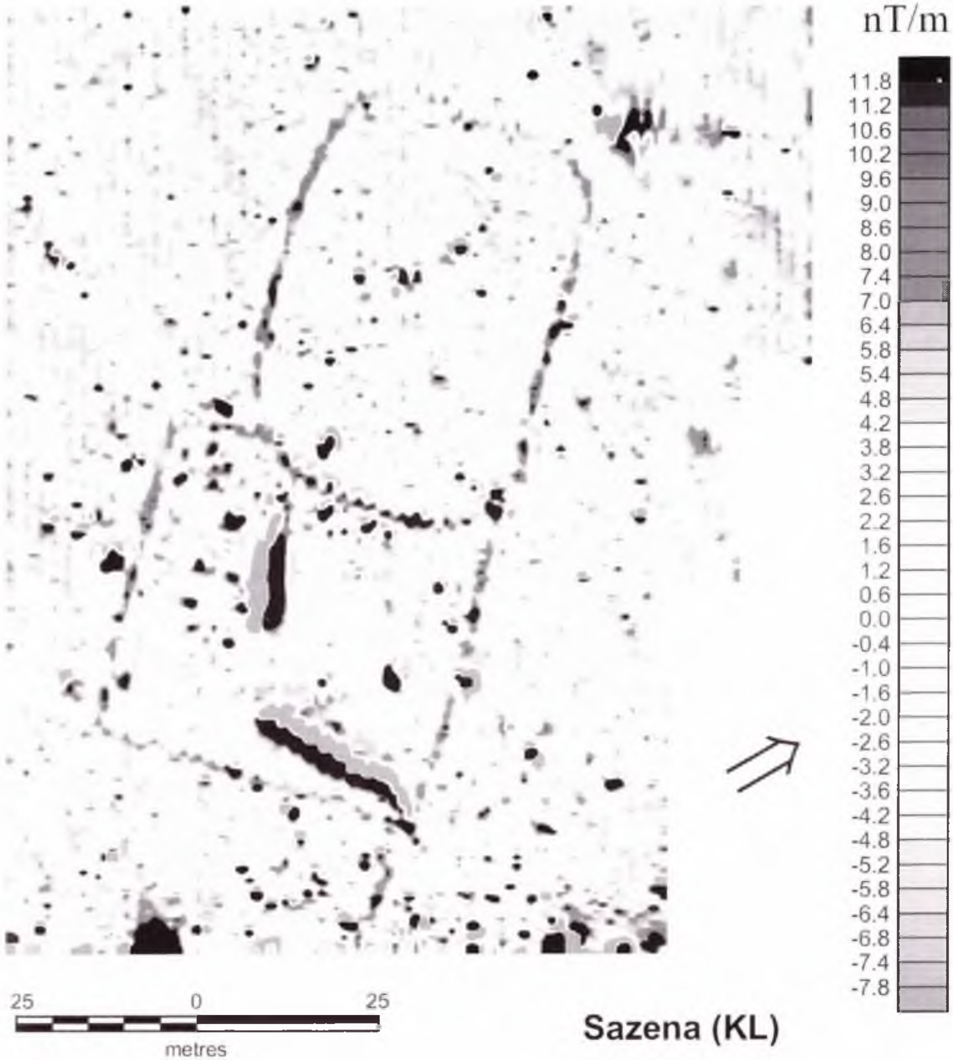


Fig. 2. Sazená, distr. Kladno. A magnetic survey verified the shape, narrow entrances and various internal divisions (high magnetic lines not visible on aerial photographs) of an atypical closed ditch enclosure from prehistoric times (surveyed area 1.2 ha).

sions that were not visible on aerial photographs. This atypical feature located in an extensive flat area devoid of water sources was probably a prehistoric site; so far it has not been explored archaeologically in any way.

Geophysical prospection in South Abusir, Egypt, 2002

Roman Křivánek[a] and Miroslav Bárta[b]

For over 40 years Czech Egyptologists have been conducting fieldwork in a large desert area west of Abusir village. The Czech archaeological concession area measures approximately 2 sq. km and includes variable desert terrains, home to some important archaeological monuments from the Old Kingdom to the Late Period. The northern part of this area – a flat or slightly sloping desert – has undergone the most surveys (including geophysical surveys by Dr. Hašek in the 1970s and early 1980s) and excavations as it contains the pyramid field of Abusir, mortuary complexes and mastabas from the 5th Dynasty (25th–24th century BC). The middle part of this area – equally flat desert without much terrain differentiation – has also seen archaeological activity and more restricted geophysical surveys, concentrating on smaller parts of the terrain, including the Saitic-Persian shaft tombs of Udjahorresnet or Iufaa (6th–5th century BC). The southern part of this area has been subject to only limited archaeological excavations, focusing on the private tombs and shaft tombs of Hetepi, Ity, Kaaper, Fetekti, Inti and Qar family complexes from the 3rd–6th Dynasties (28th–22nd century BC). Up to 2001 this cemetery area had not been surveyed by any non-invasive methods.

Cooperation between the Czech National Centre of Egyptology and the Institute of Archaeology in Prague led to geophysical surveys being conducted on parts of the Abusir area in autumn 2002. During 23 days of geophysical investigations, three types of instruments were used or tested for different scales of work. It was found that the caesium magnetometer Smartmag SM 4G (Scintrex, Canada) was the most efficient method for preliminary surveying and mapping of large unknown terrains especially in the case of expected or supposed mud brick subsurface features; a total of approximately 17.5 ha, equalling some 746000 measured points, was surveyed in 18 days, using a grid of 1 m by 0.25 m, details in 0.5 m by 0.2 m intervals. Also, it was determined that the Kappameter KT-5c (Geofyzika Brno, Czech Republic) for detailed measurements of apparent *in situ* surface magnetic susceptibility showed interesting results for surveying particular features (tombs) and smaller open archaeological situations (different levels of magnetic susceptibility of mud brick walls from different tombs). Finally, electromagnetic measurements by EM 38b (Geonics, Canada) also tested the possibility of identification of non-magnetic materials (limestone, *tafla* or clay destruction) in shallow subsurface features.

It should be noted that all the areas for geophysical surveying (four in the south and one in the middle part of the area) were chosen in conjunction with Egyptologists and based on an earlier field survey and photogrammetry results from 2001. Preceding these surveys a geodetic grid of squares 50 m by 50 m with north-south orientation was established covering the entire Czech archaeological concession; it will serve all future surveys using GIS methodology.

[a] Institute of Archaeology of the Academy of Sciences of the Czech Republic, Praha, Czech Republic

[b] Czech National Centre of Egyptology and Czech Institute of Egyptology, Charles University, Praha, Czech Republic

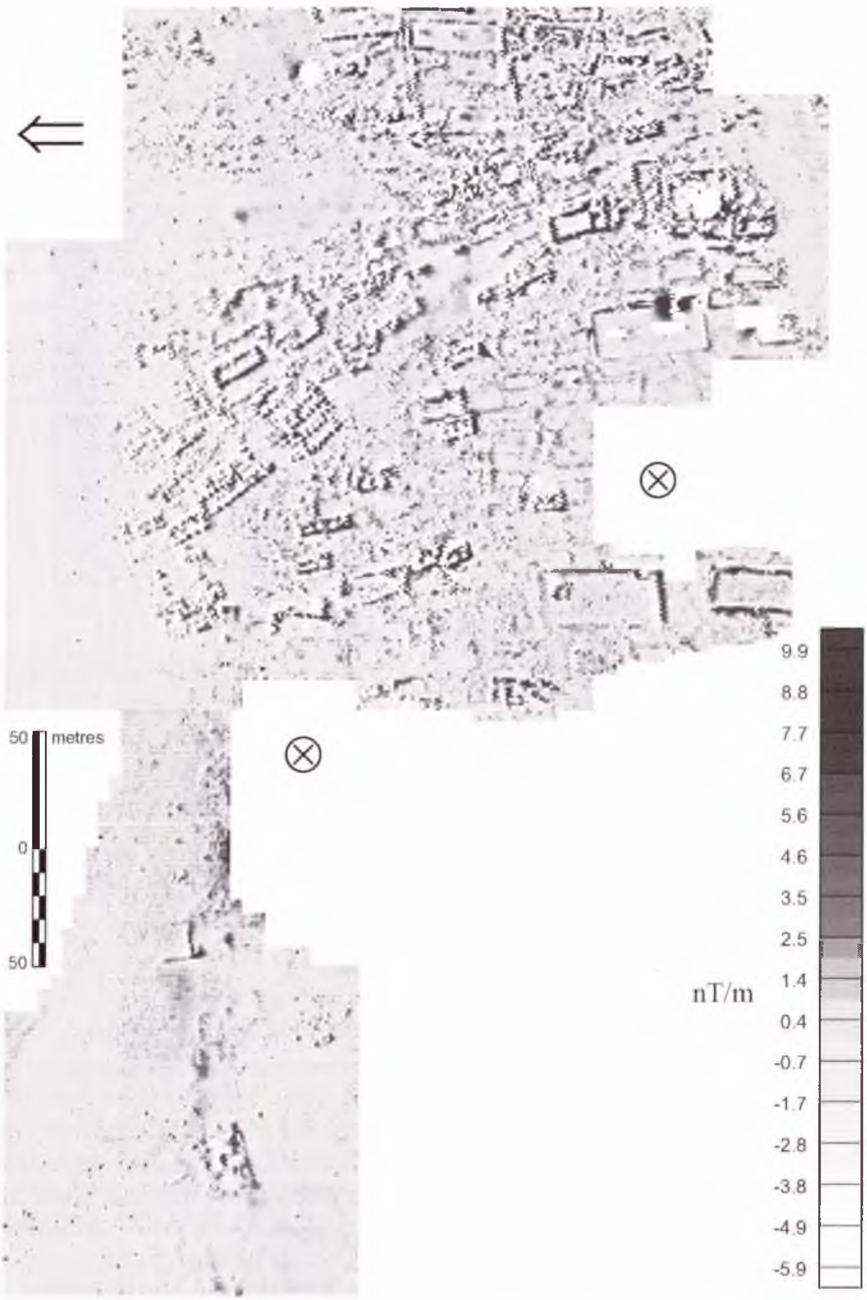


Fig. 1. Abysir. Magnetogram of surveyed area south-east from the excavated tomb-complex of vizier Qar and official Inti in southern Abusir (surveyed area approx. 11.5 ha).

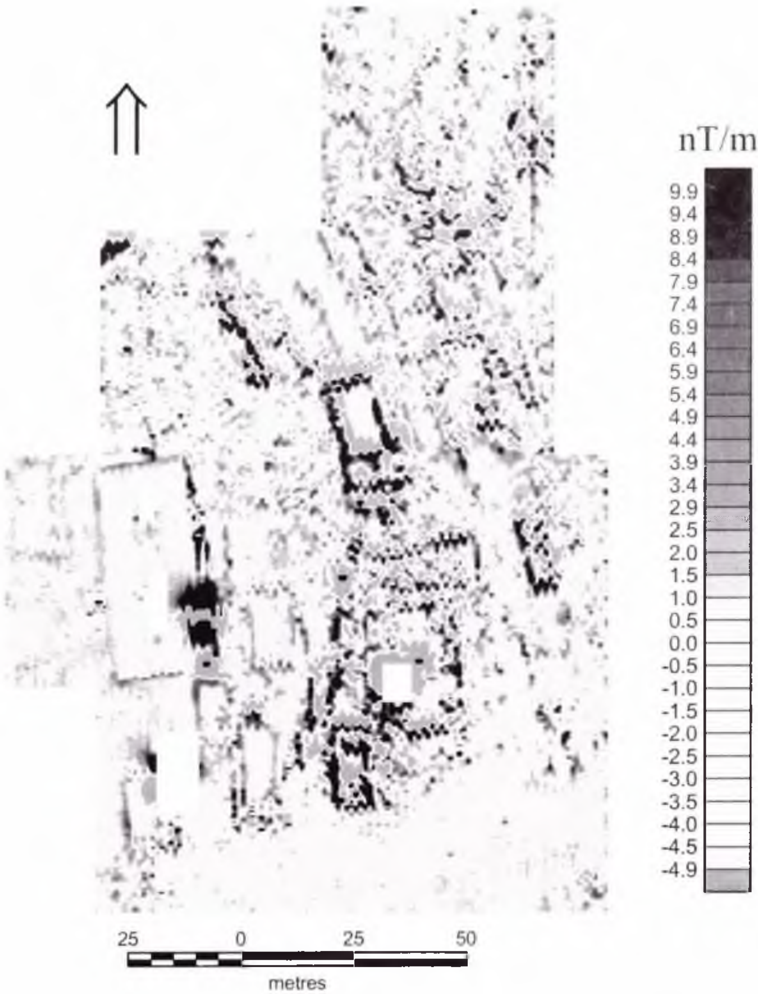


Fig. 2. Abusir. Different types of funerary and other features were identified by various dimensions, shapes, orientations and amplitudes of linear magnetic anomalies (sample of surveyed area approx. 1.95 ha).

Magnetometer surveys covering approximately 11.5 hectares around the excavated tomb complex of Qar and Inti were the main focus of the geophysical measurements in 2002 at southern Abusir. The preliminary results from the magnetometer survey document very intensive use of the area (Fig. 1). Concentrations of various rectangular, subrectangular or linear, putatively mud brick structures cover the whole upper hilly plateau and sloped terrain south-east of the present excavated area of shaft tombs in the Qar family complex. Various dimensions, shapes, orientations and amplitudes of identified linear magnetic anomalies

(Fig. 2) could indicate a separation of different types of funerary or other features (tombs, shaft tombs, chapels, walls), probably from differing periods of the Old Kingdom or from later activities at the site. The use of magnetometers in difficult field conditions helped to identify low or high magnetic components of more complicated features where it was very common to combine a variety of building materials, such as magnetic mud bricks, non-magnetic limestone blocks, very low or non-magnetic clay and sandy materials, or occasionally magnetic granites or highly magnetic volcanic materials. The magnetic results probably represent only a portion of the features present in the surveyed area beneath the sand.

The application and testing of geophysical techniques in the Czech archaeological concession area has given a more substantial idea of the benefits and limitations inherent to geophysical work conducted in desert conditions. Throughout Abusir geophysical methods can provide archaeological data about the buried features and can be followed up by quick archaeological excavations. The first systematic archaeological verifications of the geophysical results are planned for the autumn of 2003. Finally, it would be beneficial in the future to complete a magnetic survey in southern Abusir, west of the dry Abusir Lake, comparing the results to those gathered on a similar area, that of the National Museum of Scotland's concession in northern Saqqara.

Three new circular enclosures from Slovakia

Ivan Kuzma[a] and Ján Tirpák[a]

In 2002, geophysical measurements of three circular enclosures, which were identified by aerial photography at Podhorany and at Žitavce, were made. The surveys have brought interesting results that will help in further studies on the enclosures.

PODHORANY-SOKOLNÍKY

Aerial photographs revealing the feature as soil marks were taken in 1998 by Aero Slovakia and were confirmed by the aerial prospection in May 2001. The feature appeared as a slightly oval ditch without obvious interruptions. A magnetic survey on a total area of 0.81 ha was carried out in 2002, mapping oval-shaped anomalies with intensity of –5 nT to 10 nT. Their width ranged from 2 m to 4 m and they were concentrated within an ellipsoid-shaped ditch enclosure measuring 70 m on the long axis and 60 m on the short one. It is a "rondel" with three irregularly situated entrances on the SE, NW and NEE sides. Also isolated isometric anomalies with values of 3 nT to 5 nT and average width up to 5 m, which could represent settlement objects, were indicated beside the course of the ditch. No material that could date the structures has been found as yet.

[a] Archeologický Ústav SAV, Nitra, Slovakia

The ditch (overall shape and approximately the same length-to-width proportions) can be classified among similar examples in Slovakia, *e.g.* Veľký Cetín – 75 m by 110 m, Pavlová – 100 m by 80 m, Rybník nad Hronom – 120 m by 100 m and Veľký Lapáš – 80 m by 70 m. The "rondels" correspond also to those found in Moravia: Šumice – 130 m by 105 m, Troskotovice – 101 by 90 m and Vlasatice – 120 by 107 m, which were also excavated and consequently dated unquestionably (except for Vlasatice) to the Bronze Age, the Věteřov Culture period specifically. Consequently, single circular enclosures of this particular character can now be attributed to the Bronze Age on the grounds of aerial prospection alone.

PODHORANY-MECHENICE

The circular enclosure was classified as a soil mark during an aerial prospection flight in May 2002. It appeared as a slightly irregular, circular ditch without obvious interruptions. The magnetic map, which was produced from a survey in 2002 covering a total area of 2.2 ha reveals anomalies with values from –10 nT to 20 nT and a width of 4 m to 6 m, concentrated within geometric shapes that correspond to a system of two ditches. The diameter of the outer one is 120 m (N-S) and 110 m (E-W), that of the inner one 90 m (N-S) and 85 m (E-W). The measurement marked the position of four entrances, oriented NNE-SSW and WWN-EES. The entrances in the inner ditch line are simple except for traces of a wing on the west side. The outer ditch, on the contrary, has remarkable winged entrances 8–15 m long, the length of the whole southern entrance corridor being 34 m. The width of the inner ditch entrances is 2 m to 4 m, that of the outer ones 1 m to 1.5 m. The maximum distance between the ends of the winged entrances is 145 m.

The ditch represents a "classical" circular enclosure of the Lengyel Culture period. According to V. Podborský's classification, it can be included in type 2 – Bučany-Svodín or Bučany only. However, with its dimensions of 120 m, it represents almost double the enclosure in Bučany, which is 70 m, and so it is closer to the one in Svodín, which is 160 m. Also the wing entrances dimensions are interesting. While in Bučany and Svodín their width in the outer ditches was approximately 4 m, in Podhorany-Mechenice it was only 1 m to 1.5 m in three cases. Archaeological finds from the surface survey dated the circular enclosure to the Lengyel Culture period.

ŽITAVCE

A circular enclosure found as a soil mark (May 2002) appeared as a slightly irregular, probably double circular ditch without visible interruptions, in which another, less perceivable oval was suspected (Fig. 1:1).

Magnetic measurements (2002) covered 2.4 ha. Results of geophysical measurement in the form of a magnetic field total vector map (Fig. 1:2) showed total values ranging from 48 240 nT to 48 261 nT. Based on this, local anomalies with an intensity from –6 nT to +15 nT could be marked. Outer ditch values reached +15 nT, inner ones +7 nT. The anomalies mentioned formed two closed geometric formations that corresponded to a system of six ditches. The diameter of the first two outer ditches is 132 m and 118 m, the third was 108 m,

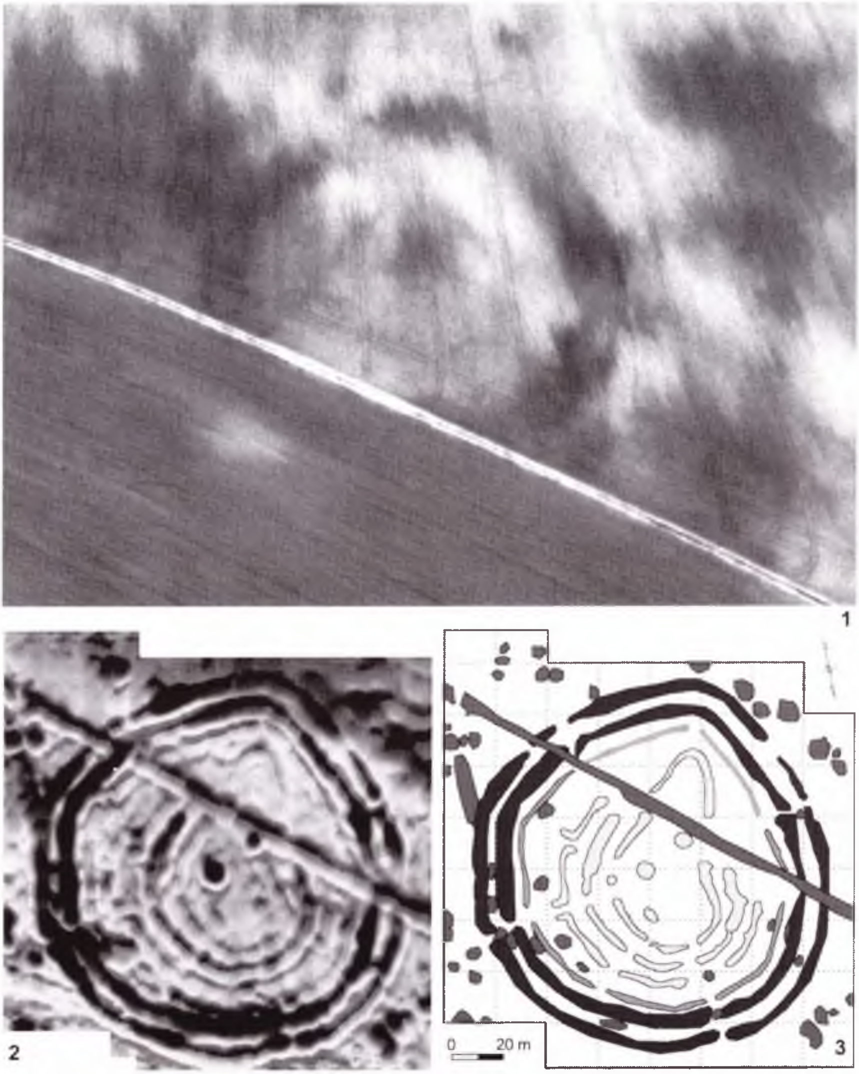


Fig. 1. 1 – Oblique photograph of circular enclosure in Žitavce (I. Kuzma); 2 – magnetogram as a digital image, dynamics –6 nT/+15 nT, 256 greyscales; 3 – archaeological interpretation.

another three 75 m, 60 m and 40 m respectively in a SW-NE direction. A line anomaly crossing the enclosure and reaching values of 6 nT remains to be interpreted.

Apart from a line anomaly (also found at Podhorany-Mechenice) observed on aerial photographs and reaching a magnetic intensity of +7 nT, two other anomalies with a width of 2 m to 4 m were measured. In view of their intensity (+5 nT), they could correspond to roads. However, possible ditch lines crossing the circular fortifications, like in several known cases in Germany, *e.g.* Neutz-Lettewitz in Saxony-Anhalt, cannot be excluded. Long ditches, or lines of pits, are known from Komjatice in Slovakia and from several sites in Moravia, but they were not found in direct connection with circular enclosures.

Isolated isometric anomalies with the intensity of 3–8 nT have also been indicated. Their average width is about 8 m and they probably correspond to pits, huts, *etc.*

As far as the interpretation of the survey results is concerned (Fig. 1:3), the site could be a circular enclosure with a number of building stages. In the first, four inner ditches with six or seven interruptions may have been constructed, followed by another two outer ditches with four interruptions, respecting the inner ones.

The use of antenna arrays for GPR surveying in archaeology

Jürg Leckebusch[a]

Since data treatment for all common prospection methods in archaeology, resistivity, magnetometry, electromagnetics and GPR is well established by now and the necessary parameters and processing sequences are known, it has been possible in recent years to focus on increasing fieldwork speed.

It is one of the most important aspects of surveying an area to do it as fast as possible without negatively impacting resolution or accuracy. In magnetometry, multiple sensors were placed in one line to speed up the fieldwork. By using software to correct the high frequency and diurnal variations, it became possible to eliminate the additional sensor of a gradiometer, leading to the so-called duo- or quadro-sensor configuration.

A similar development has been seen for resistivity. Multi-offset arrays provide more information about the subsoil; a special type is the pulled "vol-de-canard" configuration.

Compared to these systems GPR is still one of the slowest methods. Data recording in the field needs to be faster in order for the fieldwork to occupy less time. Unfortunately, current GPR antennas operate best with good ground contact, which limits the maximum speed. Pulling the antenna too fast will even result in a strong degradation of the horizontal resolution, again an undesired effect.

One solution is to use an array of antennas, each of them recording simultaneously an independent profile. Crossline spacing of 25 cm is mandatory following the Nyquist theorem. Yet the GSSI 400 MHz antennas that are in use are wider and therefore the separation between two antennas is 50 cm (Fig. 1). Surveying in zigzag mode should therefore put every other line at a distance of 25 cm to the previous one. This procedure has the advantage that the distance between the antennas fixed together in an array remains the same and therefore produces less random positioning errors.

[a] Kantonsarchäologie, Zurich, Switzerland

Fig. 1. Modified small caterpillar vehicle for simultaneous recording of GPR and resistivity data (spike wheels). Two antennas mounted with a distance of 50 cm at the end.

However, comparing the signals from two different antennas with the same frequency shows a very different frequency spectrum. Unfortunately, it is virtually impossible technically to produce two antennas with exactly the same spectrum. If time- or depth-slices are calculated from such a dataset, strong linear artificial features along the survey direction will appear, obscuring most of the fine reflections from archaeological targets. Therefore, special data treatment is necessary to adapt the data from the two antennas to one another, so that the fine reflections in the subsoil become visible again. It is important that the algorithms are independent of any antenna, therefore reducing the required additional effort and broadening the spectrum to which this method can be applied. These corrections are also necessary for a proper three-dimensional processing of the data, especially migration.

The effectiveness of these new processing steps can best be demonstrated on real datasets. Test profiles will also show the interference of two antennas recording simultaneously close together. If the electronic system is too slow, compared to the speed with which the antennas are pulled over the ground, the signal will be degraded. Hence the need for sufficiently fast GPR systems to enable the use of antenna arrays.

Having solved these problems, one can significantly reduce the time needed in the field. In consequence, this high-resolution prospection method becomes ever better suited for more and bigger sites. Using two antennas for example will effectively halve the time needed in the field.

From hypocaust to hyperbola: ground penetrating radar surveys over mainly Roman remains in the United Kingdom

Neil Linford[a]

Ground penetrating radar (GPR) survey can provide a wealth of information when applied to the investigation of buried remains. The strength of the GPR technique lies both in its suitability to a wide range of site conditions and the complementary nature of the data in comparison with other geophysical techniques. However, GPR is not infallible, relying on the careful selection of suitable sites and the application of appropriate data processing

[a] Archaeometry Branch, English Heritage, Portsmouth, United Kingdom

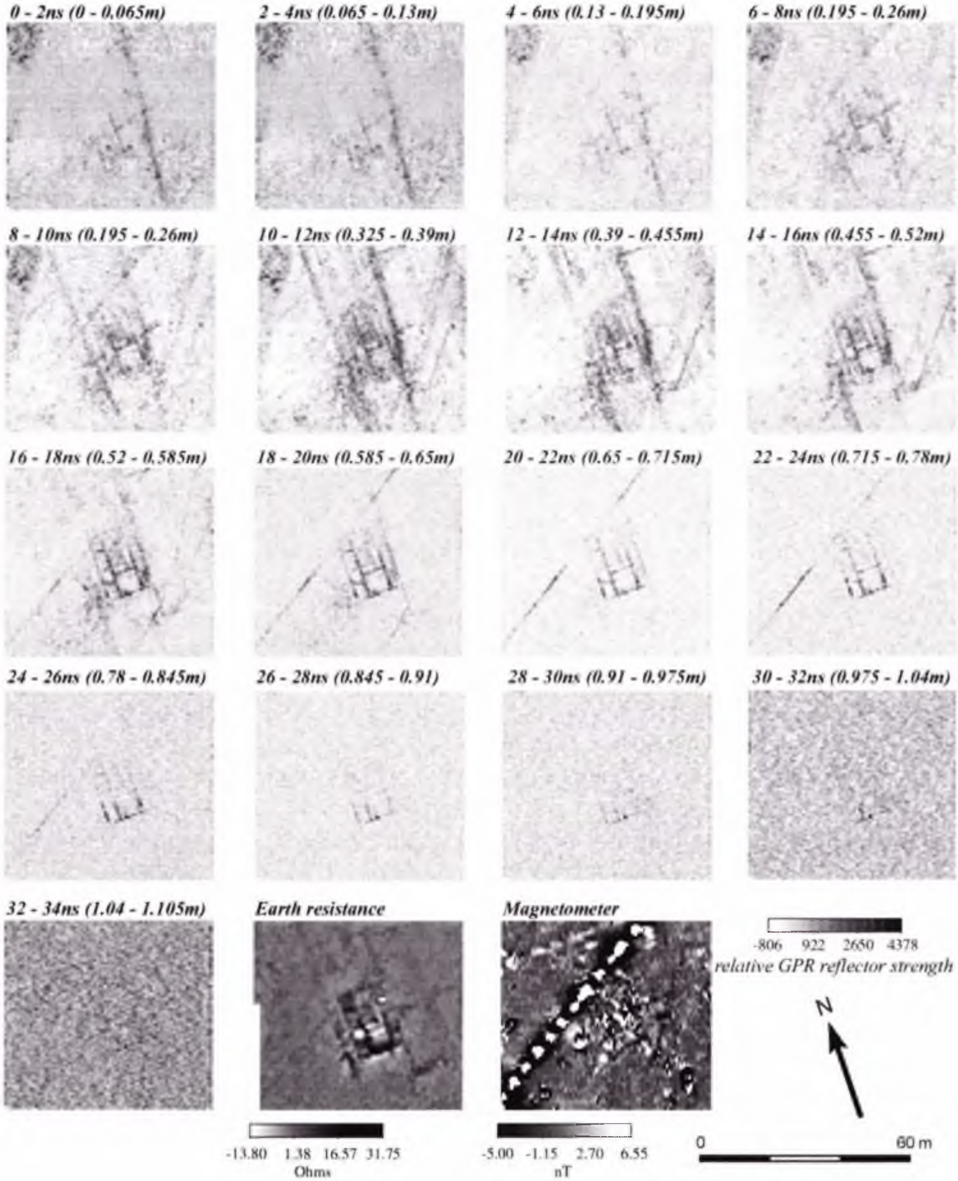


Fig. 1. Groundwell Ridge, Swindon. An example of amplitude time-slices generated from the GPR survey conducted over a single building forming part of the recently discovered Roman complex. The GPR data is shown together with extracts from both earth resistance and magnetometer surveys conducted over the same area. The magnetometer survey illustrates the course of a modern ferrous service pipe, also identified in the GPR data, that just clips the northern edge of the Roman building.

and visualisation routines to maximise the potential of the acquired data. This paper demonstrates the use of GPR over a variety of mainly Roman remains surveyed recently by English Heritage, within the UK, ranging in scale from an *in situ* mosaic pavement threatened by water damage at Bignor Roman villa, West Sussex, to an entire, suspected amphitheatre at Richborough Castle, Kent. The influence of site conditions, such as soil conductivity and topography, is considered in each case and where appropriate, comparison is made between the GPR data and other geophysical survey techniques.

In all cases the field GPR data has been collected with a Sensors & Software PulseEkko 1000 console unit utilising an antenna with a centre frequency of 900 MHz, 450 MHz or 225 MHz, dependent upon the site conditions and maximum depth of investigation required. Data processing, using both commercially available software and specially produced algorithms, has been applied to enhance the identification of significant reflectors within the data sets.

Perhaps the most challenging aspect of GPR survey is the visualisation of the resulting 3D data sets through an appropriate medium to maximise the archaeological interpretation. This may be achieved through the use of successive amplitude time-slices viewed either statically (*e.g.*, Fig. 1) or as a computer animated sequences, that may often serve to accentuate subtle variations through the stratigraphy of the site. Further complications may occur when the site under consideration contains significant surface topography and this should be accounted for during the processing and visualisation of the data. This paper is illustrated with examples demonstrating the application of animated sequences for GPR data sets collected over sites with negligible and more significant surface topography.

Finally, attempts to visualise the remains of Roman buildings as 3D iso-volumes will be presented. These are constructed from analysing the similarity of GPR response between adjacent amplitude time-slices in an attempt to isolate the response due to significant buried wall footings from the more cluttered signal of the surrounding soil.

Integrated use of caesium vapour total field and gradiometer magnetometer surveys to maximise data recovery and archaeological interpretation: field examples from the United Kingdom

Paul Linford[a]

Magnetic survey remains one of the most widely employed geophysical techniques for locating and mapping archaeological sites within the UK. The success of this method, combined with the relatively high speed of data acquisition, has allowed magnetometer surveys to be applied at ever-larger scales, revealing entire archaeological landscapes. Within the UK, the majority of magnetic surveys to date have been accomplished, most adequately, through

[a] Archaeometry Branch, English Heritage, Portsmouth, United Kingdom

Fig. 1. Somerset, England. Linear greyscale plot of magnetometer survey of a Roman villa site near Shapwick. The data set incorporates data collected with both a fluxgate gradiometer and a caesium vapour magnetometer. Measurements made with the former have been transformed from vertical gradient to total field using the appropriate Fourier domain filter. The data from both magnetometers has been reduced to the pole.

the use of fluxgate gradiometers, recording the variation in the vertical component of the Earth's magnetic field between two sensors separated by 0.5 m. However, more recently a wider variety of field instrumentation has been adopted, including both longer base-length fluxgate gradiometers and multi-sensor, total field systems based on caesium vapour magnetometers.

This paper reports the results of recent surveys carried out by the English Heritage Centre for Archaeology with a caesium vapour magnetometer and compares them with fluxgate surveys from the same sites. Furthermore, it provides a practical example of how data collected with different field instrumentation over adjacent areas may be combined through post-acquisition processing. The use of potential field theory to provide insight into the nature of the underlying features producing the observed magnetic anomalies is also explored. In particular the use of the pseudo-gravity transformation is examined as an aid to the identification and extraction of significant magnetic anomalies from magnetic data sets. The use of multi-sensor magnetometer systems will inevitably result in an increased volume of data for subsequent analysis and interpretation. Hence, there will be an increasing need for methods to automatically identify the co-ordinates of significant magnetic anomalies within such large data sets, for the production of vectorised interpretation maps. Whilst still some way from this goal, further development of techniques similar to the one investigated may suggest one way of achieving it.

Investigations of the magnetic and electrical response of archaeological structures at the Early Neolithic site of Movila lui Deciov, Banat, Romania

J.M. Maillol[a], D.L. Ciobotaru[b] and I. Moravetz[c]

Movila lui Deciov (Deciov's knoll) is a multicomponent Starčevo-Criş (Körös) site in the southeastern periphery of the Great Hungarian Plain, within the Banat Region of Romania, just north of the town of Dudeştii Vechi. The site is located within a modern agricultural field and rises 3 m over an area of 200 m in diameter. Test excavations in 2000 and 2001 identified two Starčevo-Criş occupations: 1) a lower occupation between 1.20 /1.30 m and 1.60/1.80 m below the surface consisting of a cultural floor of artifacts, charcoal, ash and fish scales, with surface house features; and 2) an upper occupation level between 0.60/0.75 m and 0.95/1.10 m below the surface represented by surface house floor features and artifacts. The discovery of two Starčevo-Criş occupations is important for a temporal analysis of culture change. Architectural features uncovered so far at Movila lui Deciov consist exclusively of surface dwellings, a particularity that stands apart from the typical Starčevo-Criş pit-house dwellings associated with the deeper occupation levels. The site is also important in the presence of a ditch that surrounds the site. If this ditch were associated with the Starčevo-Criş occupation as the preliminary archaeological data indicates, it would be the earliest in the region.

A geophysical survey was undertaken using a combination of electromagnetic, magnetic and electrical techniques. The main objectives were: 1) to determine the total extent of the main site; 2) to confirm the existence of a ditch surrounding the site and to delineate it; and 3) to test a combination of 2D electrical imaging, standard magnetic and conductivity mapping. A proton-precession magnetometer was used to carry out a reconnaissance mapping of an area roughly 150 m by 100 m. The same area was covered with an EM 38 terrain conductivity meter. A test 2D resistivity imaging section was also obtained at a location selected with the help of the magnetometry results.

[a] Department of Geology and Geophysics, University of Calgary, Canada
[b] Directia pentru Cultura, Culte si Patrimoniul Cultural National Timis, Timisoara, Romania
[c] Department of Archaeology, University of Calgary, Canada

The magnetic map reveals an abundance of anomalies of different extensions and magnitudes. The outline of a ring is clearly apparent in the form of a relatively weak anomaly typical of a ditch; much stronger anomalies are very likely associated with archaeological remains (house floors, burned areas, artifacts). The main features of the conductivity map are similar to the magnetic map with some differences, as expected from the effect of different physical properties. The resistivity section intersects the ditch as well as a very prominent magnetic anomaly most likely attributable to the remnants of a house or group of houses. On the reconstructed electrical image, distinct zones of high resistivity are very clearly correlated with anomalies seen on the magnetic map. The vertical extent of the resistivity anomalies as seen on the 2D section allows a determination of the thickness of the archaeological level, which is consistent with the findings from the test excavations.

In order to better understand the geophysical response of archaeological materials and to conduct a more objective comparison of the resistivity and magnetic results, a numerical 2D magnetic model corresponding to the resistivity imaging profile was constructed. The geometry of the model was derived from the resistivity image, and the physical properties were assigned with the help of laboratory measurements of the magnetic properties of samples of soil and house floor material. Comparison of the model prediction with a magnetic profile extracted from the main map confirms that the sources of resistivity and magnetic anomalies are identical, and it provides some insight into the origin of the magnetic anomaly produced by the ditch.

The results of this study provides new information about the extension and richness of the features of this site, which will prove to be very useful in the planning of future excavations; the product of these excavations will in turn provide invaluable feedback. This work also constitutes the basis for an expansion of the systematic use of multi-method archaeogeophysical prospection in Romania.

Results of high-resolution magnetic and tomographic seismic surveying at the Saqqara archaeological site, Egypt

M. Metwaly[a], A. Green[b], H. Horstmeyer[b], A.Gh. Hassaneen[a], A. Abbass[a] and M. al-Gamili[c]

Saqqara is located about 20 km to the southwest of Cairo, on a plateau of the Saharan desert west of the ancient city of Memphis. This area is considered to be one of the most important archaeological sites in Egypt. Fifteen royal pyramids have been discovered there, most of which have now lost their original geometrical forms, surviving as little more than

[a] National Research Institute of Astronomy and Geophysics, Helwan, Egypt
[b] Institute of Geophysics, Swiss Federal Institute of Technology, Zurich, Switzerland
[c] Department of Geology, Faculty of Science, Mansoura University, Egypt

artificial mounds. In the times of the Pharaohs, burial chambers were carved in the rocks beneath the ground, roofed with timbers, and embellished with murals. An example of this kind of burial is the step pyramid, built for the pharaoh Djoser of the 3rd Dynasty about 2630 BC. It marks the oldest part of the largest royal necropolis in the world.

Archaeologists and geophysicists have repeatedly attempted to investigate the archaeological "treasures" hidden beneath the shallow unconsolidated sediments of the main Saqqara site (7.0 km by 1.5 km). Unfortunately, ground-penetrating radar (GPR), electrical and magnetic surveys have provided only limited new information relevant to improving our understanding of this site. The main problems that have thwarted the application of most geophysical methods in this area are the ultra-dry conditions at the surface, the largely non-magnetic nature of many archaeological features and the presence of a thin highly conductive sedimentary layer (gypsum) at or close to the surface.

The Saqqara area is characterised by numerous underground cavities (tombs and other artificial structures). The physical properties of the cavities are very different from the surrounding host sedimentary rocks. In particular, the seismic velocities are much lower than the surrounding sediments, even for cavities filled with debris and loose sediments. Furthermore, shafts that connect a limited number of the cavities to the surface are surrounded by mud-brick walls that likely date from the 1st and 2nd Dynasties and late Greco-Roman times. These walls are much more magnetic than the undisturbed ground at this location.

In an attempt to map the lateral and depth extent of these cavities, we have conducted very high-resolution seismic and vertical-gradient magnetic surveys across a small region of the Saqqara site. Tomographic inversions of the first arriving seismic waves were successful in mapping the locations of important inhomogeneities at shallow depths. The host rock was distinguished by relatively homogeneous velocities of >700 m/s, whereas the cavities were characterised by relatively low velocities of 200–600 m/s. The high-resolution vertical-gradient magnetic data delineated the positions of the mud-brick walls, even at locations where they were buried beneath a thin layer of sand. Together, the high-resolution seismic and vertical-gradient magnetic data have provided useful subsurface information that may help in designing future excavation strategies.

Tell prospection: experiences collected in Northern Syria

Cornelius Meyer[a] and Burkart Ullrich[a]

The investigation of ancient settlements demands that the broadest possible spectrum of available technologies and scientific methods be considered in preparing the research. Tells in the Near East are frequently situated in less populated regions where the application of geophysical methods, especially for the prospection of widespread areas, makes sense. Geophysical methods are also useful in studying specific archaeological structures on a smaller

[a] Eastern Atlas Geophysical Prospection, Berlin, Germany

Fig. 1. Tell Mardikh/Ebla.

scale. The extensive form of prospection takes advantage of magnetometry and GPR, while the more detailed investigation of single structures is a case rather for tomographic methods, like geoelectrics and GPR again. The paper presents different prospection programs adjusted to the special topographical, geological and archaeological conditions of particular types of ancient settlements, *i.e.*, tells, in Northern Syria.

Tell Mardikh/Ebla in Northwest Syria is characterized by huge temples and palaces from the Middle Bronze Age underlying Byzantine buildings that were built on top of the citadel hill reusing Bronze Age material. Adjoining the heavily fortified settlement is an area of about 65 ha. In the past forty years Italian archaeologists have excavated many huge buildings and unearthed thousands of clay tablets, but they have not investigated the lower towns of Ebla. Now, the results of magnetic prospection are beginning to throw light on this aspect of the Ebla excavation. In addition, GPR measurements may help to trace and understand the Middle Bronze Age architecture.

At Tell Gindaris in the extreme northwest of Syria there is a regular-shaped mound containing Middle Bronze Age structures covered by Hellenistic town remains. To provide data on the Bronze Age architecture a combination of geophysical methods has been used: magnetic mapping, GPR, geoelectrics and cross-hole measurements. The survey is part of a research project supported by the German Ministry of Research and Development.

Tell Sheikh Hamad is situated on the eastern bank of the Khabur River near the Iraqi border. The magnetic data covering about 35 ha of the lower towns has provided evidence

Fig. 2. Tell Gindaris. Magnetic map.

of a variety of grid plans of mud brick houses, indications of their function and building history, as well as ties between the different districts.

Another interesting archaeological site, called in Arabic Al-Andarin, conceals the remains of the extensive Byzantine town of Androna. The fortified settlement extends over 1.5 sq. km. Only a small area of about 6 ha was investigated magnetically. The results reflect the problems inherent to geophysical prospection of structures made of different building materials. In the case of Androna, the materials used were basalt, limestone and mud brick, frequently in combination

The cited examples demonstrate the need for prospection techniques that can be used over extensive areas, as well as to investigate in detail single structures, especially on sites of such complexity as the northeastern Syrian tells. All the discussed projects are currently in progress.

The Early Neolithic monumental enclosure Weinsteig-Grossrussbach

Wolfgang Neubauer[a], Michael Doneus[b], Alois Eder-Hinterleitner[c] and Klaus Löcker[c]

Grossrussbach is located 25 km north of Vienna. It is one of the largest fortified prehistoric settlements in Central Europe (Trnka 1991). The rectangular fortification ditch encloses 21 ha. The site itself lies on the back of a long, smooth hill, sloping towards the northwest, where the brook Russbach flows from the north. The site had been already field-walked in the 60s and 70s. The finds, mainly ceramics, date the fortification back to the Early Neolithic Linear Band Pottery horizon. Surface finds from the hilltop, collected during the magnetic survey, confirm this date.

The site of Grossrussbach was photographed from the air over several years and various seasons. Among the most informative are a vertical stereopair from spring and oblique photographs from autumn 1981. The vertical photographs were analysed and a digital orthophoto with a pixel-size of 0.25 m was calculated. The soil marks reveal a huge, rectangular enclosure, formed by a ditch 3 m to 4 m wide. The corners are rounded. The fortified area is *c.* 800 m long and 350 m wide. The sides are slightly curved. The southern, western and northwestern parts of the ditch more or less follow the contour lines. Some interruptions, especially one close to the southwest and one near the northeast corner, could mark the entrances. The northern part of the ditch is not visible in part, possibly due to heavy erosion. At the eastern side of the enclosure, another ditch seems to be connected with the fortification at a right angle. Several smaller linear structures can be detected within the fortification. Their temporal relation with the site is unclear. At least two of them parallel the fortification ditch and therefore could belong to the site. Traces of an old path running across the site from north to south are still discernible today as faint depressions in the surface. The path is contemporary with the Medieval field boundaries, which can still be detected as long, dark parallel lines. In the northwestern part outside the fortification there are some larger dark structures, up to 6 m wide, which might mark large pits dug to sink wells.

[a] Vienna Institute for Archaeological Science, University of Vienna, Austria
[b] Institute for Pre- and Early History, University of Vienna, Austria
[c] Central Institute for Meteorology and Geodynamics, Vienna, Austria

Fig. 1. Weinsteig-Grossrussbach. Vertical aerial photograph from March 1981 showing the Early Neolithic enclosure (© Fliegerhorst Langenlebarn; Freig. No.: 13086/30-1-6/82).

Fig. 2. Weinsteig-Grossrussbach. Orthophoto combined with the magnetic survey.

Fig. 3. Weinsteig-Grossrussbach. Section of trench 1 showing the trapezoid shape of the ditch.

The complex was partly prospected magnetically during the last years. Many detected anomalies are due to recent earthworks, modern features and litter in the topsoil. The magnetogram of area 2 shows an alignment of strong dipoles due to a telephone wire crossing the complex in a 1 m deep ditch. Many other single dipoles mark the high amount of modern iron debris, bricks and tiles spread all over the site. The fortification ditch is quite well visible. It is about 5 m wide and runs from the north for about 40 m, at which point it changes direction and runs to the east, finishing off as a rounded edge. North of this the anomaly seems to be separated into two parts, a hint of renewal of the ditch after being partially refilled by erosion. Surprisingly an entrance was detected in the southwest. This is also visible in the topographic map as a slight depression leading towards it from the outside. The entrance is formed by a 4.5 m wide interruption in the ditch. There are no anomalies that could suggest the presence of a wooden gate. This might be also due to the high amount of erosion obvious in the magnetogram. There are just a few anomalies situated on the slope and they obviously increase in number towards the flat top of the hill, marking less eroded areas. Many pits with diameters from 0.5 m to 4 m are spread all over the hilltop. Pits and small wall trenches are sometimes aligned northeast, marking the remains of typical Neolithic longhouses. A similar orientation had already been recognized in the interpretation of the aerial evidence. The state of preservation does not appear to be good.

To verify the 3D modelling of the ditch, we carried out a small excavation (trench 1) in the southwestern part near the entrance. The ditch is a broad U-shape and only 1.6 m deep. The estimated amount of erosion is at least 1 m in this area. The survey will be carried on this year in order to cover the entire site.

REFERENCE

Trnka, G. 1991. Neolithische Befestigungen in Österreich. *Mitteilungen der anthropologischen Gesellschaft Wien* 121: 137 pp.

Magnetic survey of the Viking Age settlement of Haithabu, Germany

Wolfgang Neubauer[a], Alois Eder-Hinterleitner[b], Sirri Seren[b], Helmut Becker[c] and Jörg W.E. Fassbinder[c]

The Viking Age settlement of Haithabu is situated south of the town of Schleswig in northern Germany, on the Haddebyer Noor which is connected by the river Schlei with the Baltic sea. It had a large harbour and was one of the major trading places in the Viking period (Jahnkuhn *et al.* 1984). Archaeological investigations started there a century ago and have by now covered some 5% of the site. A prospection project was started in 2001 by the Schleswig-Holsteinsche Landesmuseum (Klaus von Carnap-Bornheim). The settlement (*c.* 25 ha) and some areas outside the settlement boundaries were prospected by four teams with optical pumped and fluxgate magnetometers. In this paper we will present the results of the surveys by the Vienna and Munich teams, which have been using Cs-sensors in gradiometer array and an uncompensated system respectively.

High magnetic contrast was noted in the western part of the site, on sandy soils. For the undisturbed subsoil, mainly sand, the susceptibility was found to be 0.004 $\mu m^3 kg^{-1}$. The highest susceptibility for an archaeological deposit measured so far was 2.18 $\mu m^3 kg^{-1}$. Lower susceptibility values, but still with sufficient magnetic contrast, showed the water-logged parts of the site beneath the waterline. The georeferenced digital images of the surveyed parcels of land were combined and interpreted in a GIS.

The survey revealed many details to go with the general layout of the settlement. Very strong magnetic anomalies were produced by the fillings of sunken huts, as well as by deposits inside and around former timber buildings. It became possible to trace the street system of the early urban settlement in the positive and negative anomalies that were up to 4 m wide. One major street followed the waterline and was connected with the harbour by landing stages. Another main street connected the harbour with the hinterland and continued below the enclosing rampart. A very high density of anomalies marked the central core of the settlement at the harbour, where a parallel street system was observed.

An entirely different settlement pattern became obvious in the west. Here, long parcels of land could be differentiated on either side of the main street. The buildings, both the sunken huts and timber, were oriented towards the street. Behind the buildings smaller anomalies indicated workshops, pits etc. This framework is well known from early urban linear villages founded by traders and craftsmen on the North Sea coast of the Netherlands and Germany in the 8th and 9th century. The site seems to have been a colony of Saxons known from historic records and founded before the construction of the rampart. The high magnetic contrasts indicate that this village was destroyed by fire. A later phase is indicated

[a] Vienna Institute for Archaeological Science, University of Vienna, Austria
[b] Central Institute for Meteorology and Geodynamics, Vienna, Austria
[c] Bavarian State Office for Protection of Historical Monuments, Munich, Germany

Fig. 1. Haithabu. Combined results of the magnetic survey by the teams from Munich and Vienna, measured with Cs-sensors.

by buildings with a changed orientation. The northwestern part of the settlement shows regularly arranged sunken huts that can be compared to Scandinavian sites.

The southern part of the site shows smaller anomalies that indicate a large cemetery. Simple burials in wooden coffins are known from excavations, as are also large wooden chamber graves, sometimes enclosed by circular ditches and covered by a mound. These features commonly show up on magnetic maps. This cemetery extends to the south beyond the rampart known from broad-scale archaeological excavations. Field results and the magnetic pattern appear very similar. The southeastern part of the settlement is again characterised by a regular array of sunken huts connected to the waterline by two or three main streets. These respect the rampart and should therefore be dated in the later period of the site. It might be a part of the site with its own harbour that served chiefly military purposes.

Of the more than 5000 interpreted anomalies, not all have been completely analysed, and many other interesting aspects of the site and the layout of an early urban settlement of the 8th to 11th century can be expected to come to light.

Fig. 2. Haithabu. Detail of the northwestern part of the settlement. Dynamics –5/+7 nT.

REFERENCES

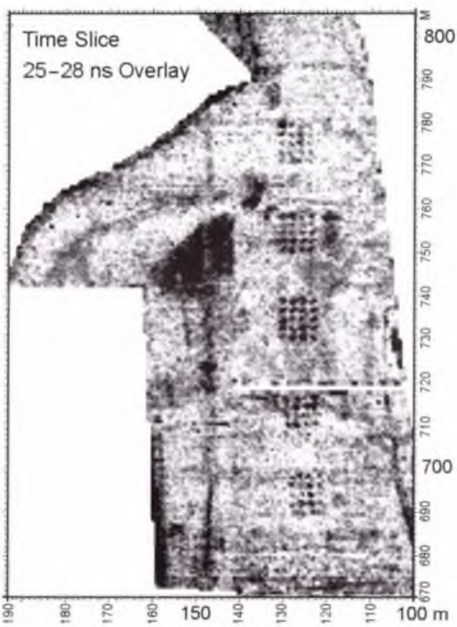
Jankuhn, H., K. Schietzel and H. Reichstein 1984. Handelsplätze des frühen und hohen Mittelalters. *Acta Humaniora* 2, Archäologische und naturwissenschaftliche Untersuchungen an Siedlungen im deutschen Küstengebiet. Weinheim

GPR survey for detecting post-hole houses: two examples of surveys for the identification of low-contrast soil structures

Yasushi Nishimura[a]

Locating the buried remains of ancient architectural sites by geophysical survey methods is difficult by any standards, all the more so when the architecture in question consists solely of post-holes. To detect post-holes it is necessary to identify and discern soil-to-soil contacts, inside and outside of these very small features. In Japan, magnetic survey methods have not

[a] Cultural Heritage Protection Cooperation Office, Asia/Pacific Cultural Centre for UNESCO, Nara, Japan



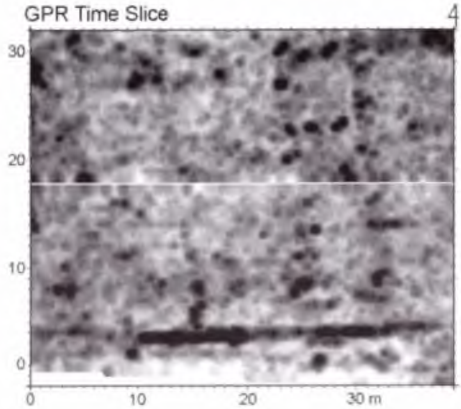


Fig. 2. GPR survey result: post-holes of a partition wall can be seen inside a rectangular building.

Fig. 1. GPR survey result: the five storehouses and surrounding moat are clearly visible.

been effective except for kiln sites, primarily because of the absence of activities responsible for the creation of high magnetic susceptibility stored in these kinds of soil structures.

The imaging of subsurface post-hole buildings at two important historic sites in Japan has been accomplished using ground penetrating radar (GPR). These sites, located on the southern island of Kyushu, are about 20 km apart. At one there were the remains of local government stores (Fig. 1), at the other buildings that allegedly housed the central part of a local government office (Fig. 2). The post-holes at these sites were imaged with GPR survey equipment supporting a 400 MHz antenna (30 cm square aperture). The accuracy in detecting these post-holes provided sufficient information for reconstructing the historic arrangement of local government buildings of the 8^{th} century.

Gradiometer survey for detecting the ancient remains distributed northeast of the Djoser pyramid, Saqqara, Egypt

H. Odah[a], T.F. Abdallatif[a], I.A. al-Hemaly[a] and E. Abd All[a]

The whole area to the northeast of the Djoser pyramid in Saqqara is characterised by the presence in it of a variety of tomb structures of the 1^{st} and 2^{nd} Dynasties.

[a] National Research Institute of Astronomy and Geophysics, Helwan, Egypt

The main objective of undertaking a gradiometer survey in this important area was to detect hidden archeological features. For this purpose, a gradiometer survey was carried out over an area 100 m by 100 m at a resolution of 0.5 m by 0.5 m, with data being collected in zig-zag mode.

The magnetic data were processed using Geoplot software in order to get a high resolution image of the hidden structures. The results reveal the presence of big interconnected tomb structures composed of mud-bricks, in addition to other archaeological features. The historical background of the study area confirms the existence of such tomb structures.

New methods for archaeological site detection in Egypt *via* satellite imagery analysis: case studies from Sinai and the Delta

Sarah H. Parcak[a]

Satellite image interpretation is a virtually untapped resource in Egyptological research, especially in Sinai and the Delta; its application promises to maximize research results in regards to potential site identification and minimize the ground-truthing required within the otherwise vast tracts of land composing this region. This research is significant to me since I have witnessed the partial destruction of three archaeological sites on which I have worked (Mendes, Tell Tebilla and Tell el-Markha) through various modern construction and agricultural projects. Reliable, efficient and (relatively) inexpensive means are needed for new "salvage" archaeology to be carried out before more key sites and knowledge are lost forever. Interpreting satellite images offers much in the way of land-use analysis and detection of material below the surface.

One aspect of this project includes applying various remote sensing techniques in the detection of potential new archaeological sites in both el-Markha Plain in West Sinai (Mumford and Parcak 2002, 2003) and the northeast Delta. This satellite imagery analysis could not be effective without accompanying ground-truthing, which will be discussed in detail along with the previous computer work. In ideal circumstances large tells (some of which measure up to a kilometer or more in size) are relatively easy to view on satellite images with a similar resolution, and even smaller mounds can display architectural features that are clear from space. The el-Markha Plain region, however, presents difficulties for conducting archaeological reconnaissance. It is a sandy region with small, low-lying archaeological and natural mounds, which rise up to two meters in height. These mounds are composed of sand and stones and are hence quite difficult to discern from the virtually identical surrounding landscape in both ground-truthing and satellite images (even with

[a] Cambridge University, United Kingdom

pixel resolutions finer than 30 m by 30 m). How, then, can such mounds be detected without applying time-consuming foot survey work over vast geographical areas?

This research began initially with the idea of using a satellite image to identify vegetation clusters in el-Markha Plain. The study assumed that these vegetation signatures would be closely linked with indigenous water sources and hence potential archaeological remains. Several applications of satellite image interpretation helped to identify sixteen vegetation clusters (*i.e.*, potential archaeological "sites" requiring further ground assessment). The most important application used normalized difference vegetation index (NDVI), which represents, in essence, an index for identifying green plant biomass. This study incorporated several methods of classifying parts of the image, namely "supervised", "unsupervised", and "thresholding" techniques, in addition to different satellite image band combinations. In the summer of 2002, as part of the South Sinai Survey and Excavation Project, this hypothesis was tested on a known archaeological site, Tell el-Markha (with special permission from Egypt's Supreme Council for Antiquities), the environs of which contain a positive NDVI. This test case shows that using NDVI in satellite images has the potential to locate other archaeological sites in el-Markha Plain. I determined that various "vegetation" signatures represented other features (*e.g.*, low buildings) reflecting similar signatures to vegetation and lacking identifiable archaeological sites. Although ground-truthing detected only a few vegetation signatures beside or near known and nearby archaeological sites, this project enhanced our understanding of human settlement patterns within el-Markha Plain and revealed other applications towards future archaeological work. In addition, an alluvial fan, observed in the satellite image was explored, leading to the discovery of a large and previously unknown Late Neolithic to Early Bronze Age I site along the southern coast of el-Markha Plain. Hence, the application of NDVI to satellite images promises to reveal concentrations of vegetation (*i.e.*, potential archaeological and other sites), and thereby reduce the time and cost involved in surface survey work over the vast areas encompassed by el-Markha Plain and West Sinai.

In terms of the work planned for the northeast Delta, a variety of images (early aerial photographs, CORONA, Landsat, SIR-C/X-SAR and others) are (at the time of abstract submission) being analyzed with reference to both change detection over time and detecting long-lost archaeological sites in the environs of the site of Tell Tebilla. A variety of methods are being used to determine what types of analyses are the most appropriate for this work, including different kinds of classification, principle component analysis, image enhancement and general change detection studies. This work will be tested with ground-truthing during the summer of 2003 as part of the University of Toronto's expedition to Tell Tebilla. It is hoped that this research will increase our understanding of the region of Tell Tebilla, especially given that so much of the site has been lost in the past 100 years. In addition, it is hoped that the results from the work on Tell Tebilla can be applied to other sites in the Delta, many of which have faced the same problems with site destruction. Satellite imagery analysis has the unique ability to show large-scale change over time, and will help to elucidate some of the challenges facing Egyptian and foreign archaeologists in Egypt.

Thus, the combination of satellite image interpretation and ground-truthing offers multiple levels of detection for surface and sub-surface features, providing a speedier and less costly means by which to identify potential archaeological sites and the changes archaeological sites have undergone in the past 80 or so years (the limit of aerial photography), while the inclusion of satellite images with finer pixel resolutions should increase substantially the location of potential archaeological sites. Planned future satellite image interpretation and ground-truthing in South Sinai and the northeast Delta should reveal more sites, while careful excavation, recording, and analysis of these sites and material culture assemblages should refine our understanding of the nature of the changes each area has undergone in the recent past.

REFERENCES

Mumford, G. and S. Parcak 2002. Satellite image analysis and archaeological fieldwork in el-Markha Plain (South Sinai). *Antiquity* 83 (4): 953–4.

– 2003. (forthcoming) Pharaonic ventures into South Sinai: el-Markha Plain site 346. *Journal of Egyptian Archaeology* 89.

Results of magnetic survey in Deir al-Barsha, Middle Egypt

Christoph Peeters[a] and Tomasz Herbich[b]

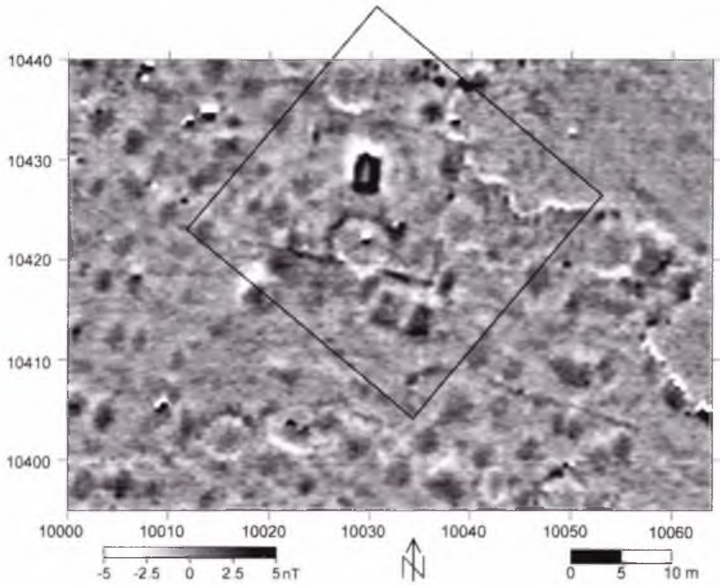
The site of Deir al-Barsha in Middle Egypt is well known for its nomarchal rock tombs dating to the Middle Kingdom, but the presence of a necropolis of the same date in the sandy desert plain west of these tombs was seldom mentioned in the past. Parts of this necropolis had been investigated summarily at the beginning of the 20th century, but no plans or detailed accounts were ever published and in 2002 there were few archaeological remains still visible on the ground.

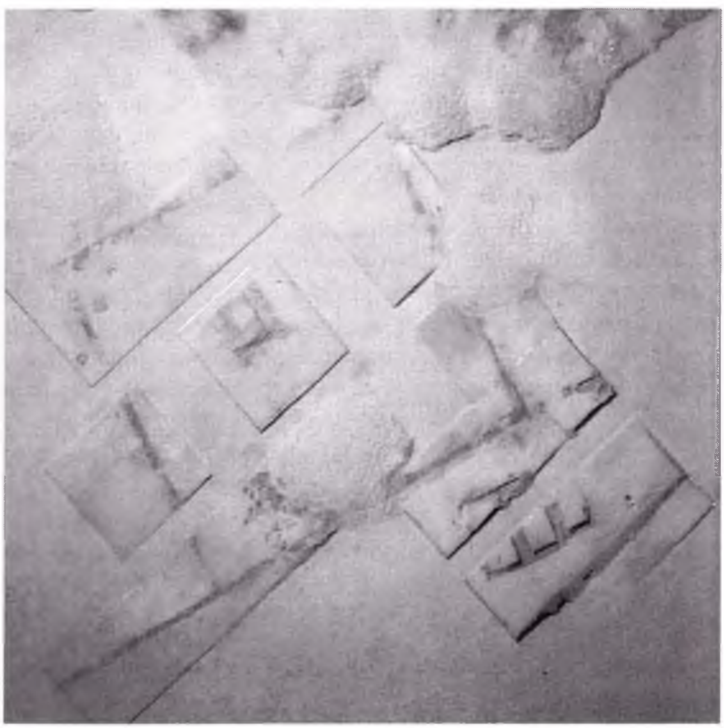
The Deir al-Barsha project of the Faculty of Arts, Department of Oriental and Slavonic Studies of the Katholieke Universiteit Leuven includes amongst its objectives the archaeological investigation of this desert necropolis. Given the fact that it is contemporary with the large elite cemeteries on the rock cliffs, it was hoped that useful insights into the overall organisation and social stratification of the cemeteries would be gained.

A geophysical prospection of the site was carried out, employing the magnetic method in view of the character of the necropolis – mud-brick lined tombs erected in a sandy desert plain. The survey was conducted in April 2002, using two fluxgate gradiometers Geoscan FM 18 and FM 36. Seven hectares were covered with measurements taken in parallel mode every 0.25 m along N-S traverses 0.5 m apart. The results were processed using Geoplot 3.0; magnetic maps were made using Surfer 8.0 software. The values of magnetic field intensity varied within a range of approximately +/–5 nT; the range of anomalies of highest amplitude, caused by mud structures, was within the range of approximately +/–10 nT.

[a] Faculty of Arts, Department of Oriental and Slavonic Studies, Katholieke Universiteit Leuven, Belgium

[b] Institute of Archaeology and Ethnology, Polish Academy of Sciences, Warsaw, Poland


10440
10430
10420
10410
10400
10000
10010
10020
10030
10040
10050
10060
-5 -2.5 0 2.5 5nT
N
0 5 10 m



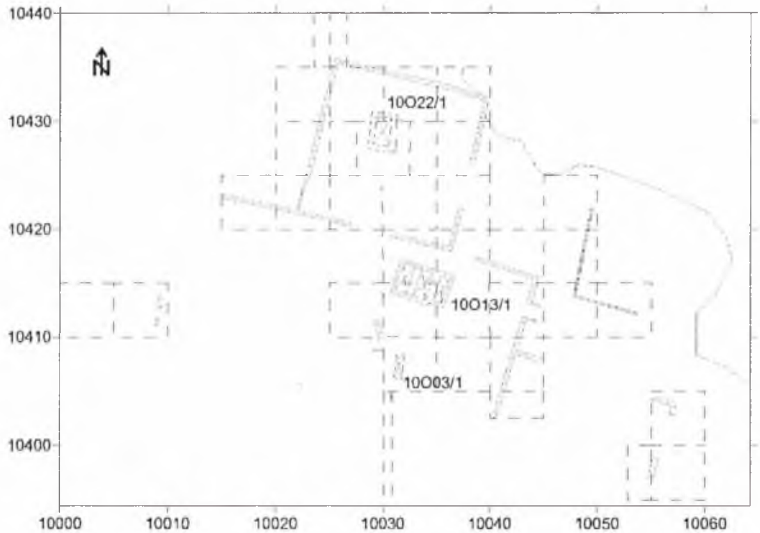


Fig. 1. Magnetic map. Sampling grid 0.25 m by 0.5 m, interpolated to 0.125 m by 0.125 m. Area covered by aerial photography (see Fig. 2) marked with a square. The area mapped corresponds to the area shown in Fig. 3

Fig. 2. Aerial photograph of the excavation.

Fig. 3. Map of the excavations in season 2003. Dashed lines correspond to boundaries of the excavated area, dotted lines represent architectural remains or simple tomb pits without architectural elements.

The survey resulted in the discovery of a buried dirt road connecting the nomarchal tombs with the Nile valley and structures which might be interpreted as the tops of buried brick-lined shafts.

Excavation, in March-May 2003, of one of the structures, the form of which was strongly suggestive of a burial shaft surrounded by a wall (Fig. 1), confirmed the existence of a tomb with a mud brick-lined shaft, surrounded by a 15 m by 15 m circuit wall (Fig. 2, Fig. 3:10O22/1). This tomb, dating to the early Middle Kingdom, was reused some 300 to 400 years after its construction and contained an intact burial of the Second Intermediate Period. Another structure, recorded just outside the northeastern corner of the circuit wall, turned out to be a triple shaft tomb (10O13/1); it was partly investigated during the 2003 season. Furthermore, another shaft tomb (10O03/1) was excavated. This tomb had been dug in the desert sand and given no brick-lining, thus it failed to appear on the magnetic map. All walls apart from the shaft linings turned out to be preserved to a height of only a few centimetres and lying just under the surface. Some of them show up very clearly on the magnetic map, others are barely visible or even totally invisible.

The excavated tombs all contained substantial remains of the original contents. These, whilst containing the essential elements of funerary equipment well known from richer Middle Kingdom burials, were definitely of poorer and simpler manufacture, thus giving insight into the social stratification of the cemetery.

Beaming into Hollywood

John Peukert[a]

The Hollywood (22TU500) site is a large, late prehistoric ceremonial earthen mound center and village located in northwestern Mississippi, USA. This site has been the focus of several archaeological investigations during the last 80 years. This includes a 1923 visit by Calvin Brown that resulted in a sketch map of the site. The Hollywood site was recorded again and surface collected in 1941 by the Lower Mississippi Survey (LMS). Hollywood was nominated to the National Register of Historic Places in 1990 and donated to the Mississippi Department of Archives and History in 1992. In recent years the site has been the subject of intensive study using a wide array of remote sensing and geophysical techniques followed by ground-truth excavations.

Hollywood has been the focus of extensive geophysical surveys over the past five years. The data produced from this large array of geophysical prospecting has greatly increased our knowledge of the site and its subsurface archaeological features.

In the spring of 2002 we conducted investigations to explore the utility of GPR at finding anomalies that corresponded to subsurface cultural features in the clay rich soils at Hollywood. This research was conducted to answer the following problems identified by this researcher:

1. Could GPR, used in coordination with other geophysical prospecting techniques, locate cultural features at the Hollywood site?
2. Could cultural features (geophysical data anomalies) found with GPR at the Hollywood site be ground-truthed (verified) with minimum destructive impact to the archaeological record?

The project used the Geophysical Survey Systems, Incorporated (GSSI) SIR 2000 GPR control unit with GSSI's 400 Mhz antenna and survey wheel. There were two post-acquisition software systems used for this project. First, there was GPR Process, which produced files exported into Surfer geological information mapping software for display purposes. The second software package used was GSSI's RADAN 3.0 for Windows NT with the 3D QuickDraw module.

The project used the RM 15 Resistance Meter produced by Geoscan Research, in conjunction with the Geoscan PA 5 Multi-Probe Array. The post-acquisition software used for the RM 15 data was Geoscan's Geoplot. This data was exported into Surfer for display purposes.

The project employed the FM 36 fluxgate gradiometer produced by Geoscan Research to measure the vertical magnetic field gradient. The post-acquisition software used for the FM 36 data was Geoplot. Again, this data was exported into Surfer for display purposes.

The project used an Oakfield one inch (2.54 cm) hand-held coring probe for ground-truthing. This is a common hand tool to archaeologists and soil scientists and is widely available at geological and forestry suppliers. To cut a clean viewing profile of the cores, a sharpened trowel was used.

[a] Geo-Marine Inc., Dallas, USA

It would seem from the data contained in this research that GPR was effective at the Hollywood site. Firstly, in conjunction with other geophysical instruments, it was capable of locating intact subsurface cultural features. Secondly, some identified features were easily ground-thruthed with minimal impact to the archaeological record. Even though these research questions were supported using the geophysical data and soil cores collected, they could only be proven using traditional archaeological methods. This is the nature of geophysics when applied to archaeology, they are an interpretive tool that can allow an investigator unique insights into what may lie below the surface. By no means should they be relied upon exclusively to evaluate an archaeological site. Even with this said, it seems that GPR can be a very useful tool to archaeologists in targeting where to excavate.

THREE CONCLUSIONS WERE DRAWN FROM THIS RESEARCH

1. GPR can work clay rich soils.

As others have recently pointed out, GPR surveys can have good results in clay rich soils, unlike what was previously thought. In this instance the lower conductivity clays were the areas where good GPR results were obtained. This leads to the conclusion that soil mineralogy and chemistry may be of more importance than soil particle size as far as GPR effectiveness is concerned. More study is needed to evaluate which soil properties have an effect on the propagation of EM energy.

2. GPR works best in coordination with other geophysical data.

As others have recently pointed, two (or more) instruments are better than one. This is certainly the case with the set of multiple data sources contained in this research.

3. GPR data can be easily verified with minimal impact to the site.

A simple one-inch coring probe allowed for the verification of geophysical anomalies in the actual archaeological deposits. Coring probes are a much less intrusive method than traditional hand or mechanical excavation techniques. This may facilitate fast and accurate decision making for resource mangers concerning mitigation and excavation decisions.

High-resolution GPR surveys for the study of *domus del Centenario*, Pompeii, Italy

Salvatore Piro[a]

For the present work ground penetrating radar (GPR) surveys have been carried out with the aim of detecting the archaeological structures below the excavated portion of the *domus del Centenario* in Pompeii.

[a] Istituto per le Tecnologie Applicate ai Beni Culturali CNR, Monterotondo, Roma, Italy

Using GPR, a high-resolution method of data acquisition has been adopted with the aim of reconstructing an overview of the investigated area. For the measurements a SIR System 10 A+, equipped with a 500 MHz bistatic antenna with constant offset, was employed. Various signal processing and visualisation techniques have been used for data improvement and interpretation.

The results obtained on shallowly buried structures indicate that parts of the layout of previous buildings can be identified and characterised from the GPR time-slices.

The location, depth, size and general structure of the buried buildings were hence effectively estimated from non-intrusive remote sensing with a ground penetrating radar system.

The application of electromagnetic profilings in archaeology – case study of Cieszacin Wielki grave mounds, Poland

Artur Poręba[a], Bogdan Żogała[a], Kazimierz Klimek[a], Maria Łanczont[b] and Jolanta Nogaj-Chachaj[c]

This paper presents the results of electromagnetic investigations performed in the area of four grave mounds, presumably raised by a population of Corded Ware Culture (Czopek 1997; Gedl 1997), and situated at Cieszacin Wielki, near Jarosław (southeastern Poland). The goal of the study was to recognise the internal structure of the grave mounds.

In the summer of 2002 the profilings were carried out using the Geonics EM 31 equipment. Only the vertical orientation of the measuring coils was applied so that the depth range of investigation reaches about 6 m. The results of the investigation are presented in the maps of apparent ground conductivity (Fig. 1). Significant negative anomalies of apparent conductivity are probably related to grave chambers, whereas the positive anomalies are connected to the mound.

For collection of the soil samples, 13 shallow geological boreholes were drilled to a depth of 2 m into one of the grave mounds. The following analyses were carried out: granulometric (18), chemical (18) and pollen analysis (9). Radiocarbon dating of one humus unit sample from the lower part of the mound cover indicated an age of 4540 years BP (Łanczont *et al.*, in press).

The internal structure of the drilled mound is presented as a geological cross-section in Figure 2. Three non-carbonate sediment layers were distinguished. In the central part of the mound there was a clayey silt layer with iron admixture. This is probably a buried soil horizon, and this layer corresponds to the conductivity anomaly very well.

Pollen analysis has allowed a preliminary identification of the natural plant communities during the construction of the grave mounds.

[a] University of Silesia, Faculty of Earth Sciences, Sosnowiec, Poland
[b] Maria Curie-Skłodowska University, Institute of Earth Sciences, Lublin, Poland
[c] Maria Curie-Skłodowska University, Chair of Archaeology, Lublin, Poland

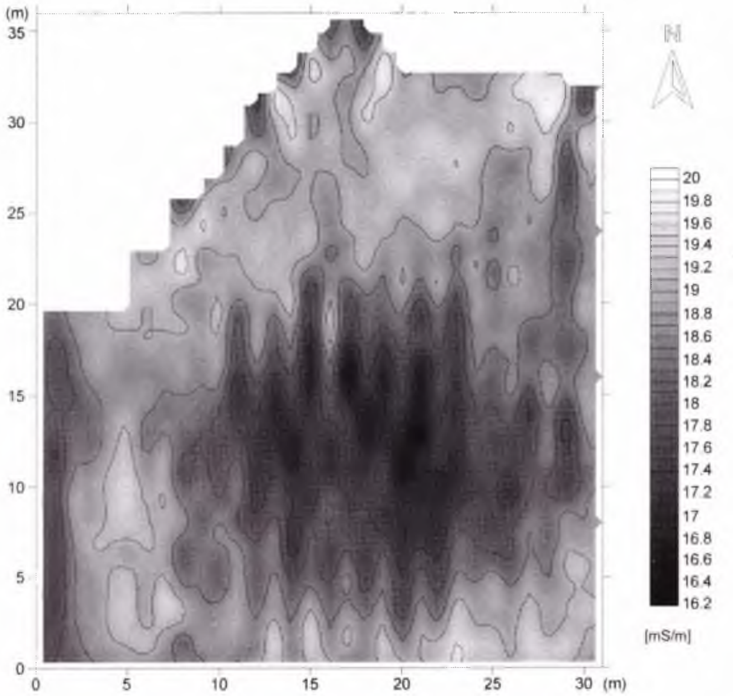


Fig. 1. Changes of soil apparent conductivity. The grave mound at Cieszacin Wielki (after Łanczont *et al.*, in press).

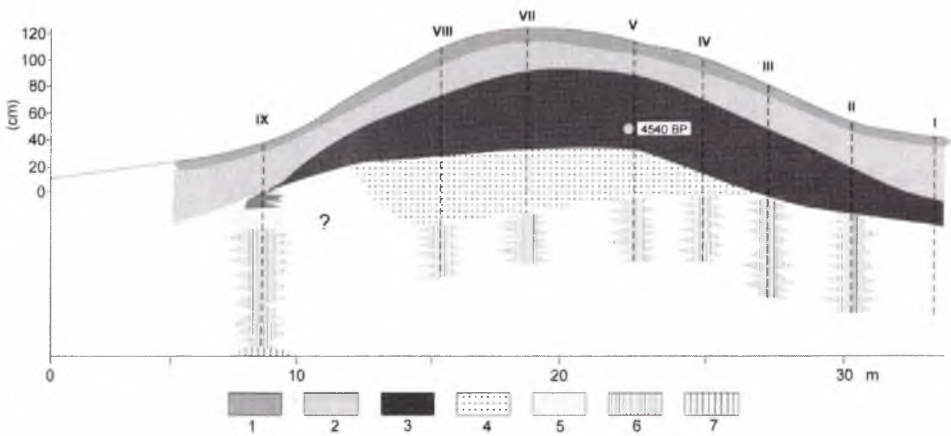


Fig. 2. Schematic geological cross-section of the grave mound no. 2 at Cieszacin Wielki (after Łanczont *et al.*, in press): 1 – humus horizon (A) of soil; 2 – light/upper part of mound cover; 3 – dark/middle part of mound cover; 4 – variegated lower part of mound cover; 5 – eluvial horizon (Eet) of fossil soil; 6 – illuvial horizon (Bt) of fossil soil; 7 – parent rock horizon (C), loess.

REFERENCES

Czopek, S. 1997. Nowe odkrycia kurhanów na Pogórzu Dynowskim. *Rocznik Przemyski* 33, Archeologia 5: 53–64.

Gedl, M. 1997. Starodawne kopce we wschodniej części Pogórza Dynowskiego. *Rocznik Przemyski* 33, Archeologia 5: 3–22.

Łanczont, M., K. Klimek, M. Komar, J. Nogaj-Chachaj, A. Poręba and B. Żogała (in press), Nieinwazyjne badanie kurhanów. *Rocznik Przemyski 40*.

The 2002 magnetometer survey at the Early Islamic city of Kharab Sayyar in Northeast Syria

Martin Posselt[a]

The magnetometer survey at the early Islamic site of Kharrab Sayyar, Raqqa district, Northeast Syria, was continued in September 2002. Adding the 5 ha of the initial survey of September 2000 (Buthmann, Posselt and Zickgraf 2001; Posselt 2002), a total area of 15 ha (four-channel fluxgate gradiometer, 0.25 m by 0.5 m inline/crossline) has now been investigated. The project is part of the cooperation between the Goethe Universität Frankfurt am Main, Deutsche Orient Gesellschaft, and the Syrian Antiquities Department.

The site is an early Islamic city of the Abbasid period (second half of the 9th century to the 11th century), 650 m by 650 m of virtually deserted area surrounded by a rectangular system of ditches and walls, the ruins still revealing details of the gates and bastions (Meyer 1999). The ruins of a fortress stand on the antique mound in the southeastern quarter of the area, which is otherwise covered for the most part with debris. The few buildings of the contemporary village of Kharab Sayyar are scattered over the southern part of the site.

While the survey of September 2000 (Posselt 2002) yielded several details of the walls, gates, bastions and ditches of the city fortification, the most important result was the detection of a mosque. The building was satisfactorily identified by its rectangular ground plan of walls and pillars. Bordering it on the east was a *suq* (market) showing dozens of small rectangular stalls (presumably shops) set along both sides of a road that runs from a gate in the north wall to the city centre.

Plotting the results of the magnetometer survey of September 2002 has given an increasingly more accurate idea of the elaborate grid of streets consisting of both rectangular and irregular components. Several large building complexes have now been traced apart from the mosque and a pattern of small-scale dwellings and open areas without buildings has been distinguished. The *suq* has now been recorded as continuing for more than 300 m to the southeast without having reaching its termination in this direction.

[a] Posselt & Zickgraf Prospektionen GbR, Mühltal, Germany

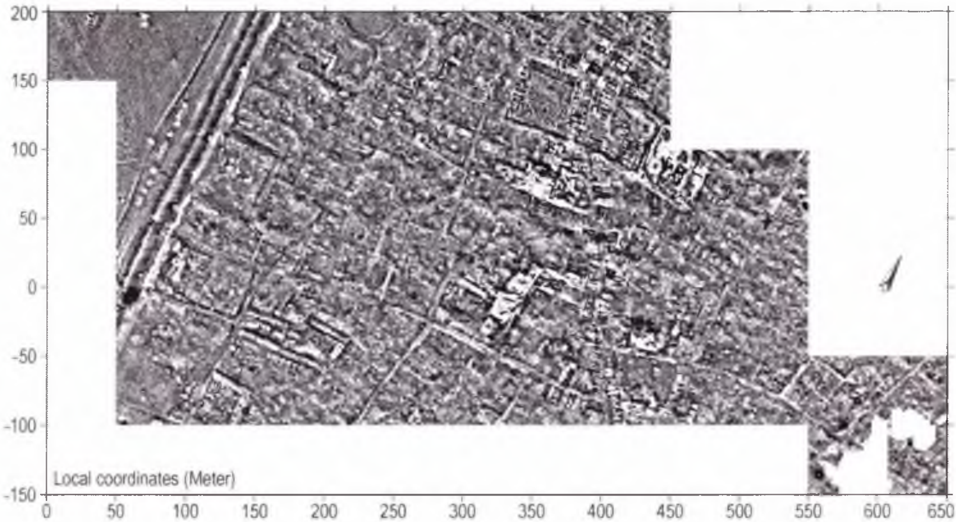


Fig. 1. Kharab Sayyar, Raqqa District, Northeast Syria. Magnetometer survey 2000–2002 (fluxgate gradiometer Förster Ferex 4.032 DLG, four channels, base distance 0.65 m, 0.25/0.5 m inline/crossline). 256-greyscale-plot of the complete investigation area (dynamics: –4/+4 nT black/white).

Fig. 2. Kharab Sayyar, Raqqa District, Northeast Syria. Magnetometer survey 2000–2002 (fluxgate gradiometer Förster Ferex 4.032 DLG, four channels, base distance 0.65 m, 0.25/0.5 m inline/crossline). 256-greyscale-plot with mosque and part of the *suq* (dynamics: –4/+4 nT black/white).

The presentation focuses on the archaeological interpretation of magnetometer data with regard to the topography of an early Islamic city. It emphasizes the potential that magnetometer surveying has, as one of archaeology's non-invasive large-scale methods, for the investigation of such a seldom surveyed type of site.

REFERENCES

Buthmann, N., M. Posselt and B. Zickgraf 2001. Magnetometer survey of an early Muslim settlement in Kharab Sayyar, north-east Syria. In *Abstracts of the Contributions of the 26th General Assembly of the European Geophysical Society, Nice, France, 25–30 March, 2001. Geophysical Research Abstracts* Vol. 3, 2001, 1506.

Posselt, M. 2002. Die Magnetometer-Prospektion in Kharab Sayyar im September 2000. *Mitteilungen der Deutschen Orient Gesellschaft* 134, forthcoming.

Meyer, J.-W. 1999. Die zweite Grabungskampagne in Kharab Sayyar 1999. *Mitteilungen der Deutschen Orient Gesellschaft* 132:297–309.

Early Neolithic settlements in Germany and Poland. Latest results of a magnetometer survey approach to the investigation of Early Neolithic architecture and settlement patterns throughout Central Europe

Martin Posselt[a] and Thomas Saile[b]

The Early Neolithic period in Central Europe is associated with the Linear Band Pottery Culture (LBK) recognised from the Atlantic coast of Northern France to the Black Sea at the time of its widest extension. Its uniform expression throughout Europe is best seen in the incised ribbon-like pottery decoration and the architecture of its buildings – large wooden houses with posts and wood-and-plaster-walls, reaching in length and width up to 40 m and 8 m, respectively. However, despite the significant amount of research on this culture compared to most of the prehistoric periods, little is known about LBK architecture and settlement patterns in several regions.

Following the encouraging results of magnetometer surveys over Early Neolithic sites in Germany (Posselt 2001; Posselt and Zickgraf 1999; Saile and Posselt 2002), the Georg-August-University, Göttingen, and the Uniwersytet Jagielloński, Kraków, jointly conducted further research, concentrating on LBK sites in southern Poland. This is the first stage of a future project that will attempt to investigate by magnetometer survey archaeological patterns, such as the LBK houses, in the landscapes of very different regions of Central Europe.

[a] Posselt & Zickgraf Prospektionen GbR, Mühltal, Germany
[b] Seminar für Ur- und Frühgeschichte, Georg-August Universität, Göttingen, Germany

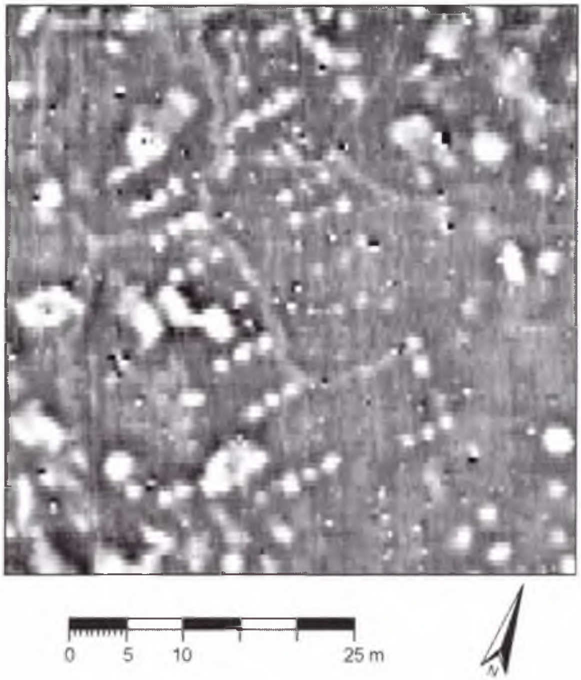


Fig. 1. Diemarden 1, Germany. Magnetometer survey 2001 (fluxgate gradiometer Förster Ferex 4.032 DLG, four channels, base distance 0.65 m, 0.25/0.5 m inline/crossline). 256-greyscale-plot (dynamics: –4/+4 nT black/white). Detail with ground plans (postholes) of early Neolithic houses.

The contribution focuses on a non-invasive search for and investigation of prehistoric houses (Becker 1996) – their architecture, evolution and pattern of arrangement inside the settlements – specifically for the Early Neolithic period of Central Europe. It includes the survey maps of Neolithic longhouses, detected in the course of several recent projects in western central Germany (Posselt 2001; Posselt and Zickgraf 1999; Saile and Posselt 2002). The plans of these longhouses produced by magnetometer survey show many of the fine structures the archaeologist excavating such sites is familiar with. Details of postholes and wall-foundation ditches are identifiable on these maps, permitting conclusions to be drawn on these grounds. Consequently, well targeted excavations in small areas of the site have helped to evaluate the results of large-scale magnetometer surveys, providing input for advanced interpretation.

The presentation includes case studies on a regional scale (landscape archaeology) (Posselt 2001; Posselt and Zickgraf 1999) and investigations at solitary sites (Saile and Posselt 2002), followed by magnetograms of Early Neolithic settlements in southern Poland. The latter are at this early stage of the research hardly as detailed as their German counterparts, yet they already show certain key features that are in similarity to the German findings, *i.e.*, a north-west/south-east orientation of the architecture.

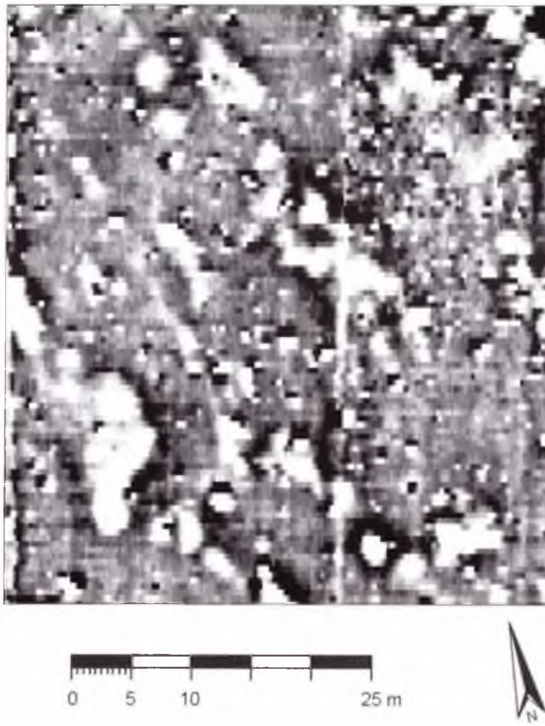


Fig. 2. Markowa 62, Poland. Magnetometer survey 2002 (fluxgate gradiometer Förster Ferex 4.032 DLG, four channels, base distance 0.65 m, 0.25/0.5 m inline/crossline). 256-greyscale-plot (dynamics: –1/+1 nT black/white), detail. The linear alignment of pits indicating Early Neolithic houses.

REFERENCES

Becker, H. 1996. Magnetische Prospektion eines jungsteinzeitlichen Langhauses bei Nördlingen-Baldingen. In *Archäologische Prospektion. Luftbildarchäologie und Geophysik. Arbeitshefte des Bayerischen Landesamtes für Denkmalpflege* 59, H. Becker (ed.), 97–9.

Posselt, M. 2001. Bandkeramik – Geomagnetik – Landschaftsarchäologie. Die Magnetometer Prospektion der bandkeramischen Siedlung Butzbach-Fauerbach v.d.H., "Gerhardsköppel". *Berichte der Kommission für Archäologische Landesforschung in Hessen* 6:41–52.

Posselt, M. and B. Zickgraf 1999. Geophysical prospection of Linearbandkeramik sites in the landscape archaeology of the Western Wetterau and the Usinger Becken, Hesse, Germany. Abstract. In *Archaeological Prospection. Arbeitshefte des Bayerischen Landesamtes für Denkmalpflege* 108, J.W.E. Fassbinder and W.E. Irlinger (eds), 74.

Saile, Th. and M. Posselt 2002. Durchblick in Diemarden. Geomagnetische Prospektion auf der bandkeramischen Siedlung Diemarden 1, *Germania*, 80 (1):23–46.

Archaeological prospection in the Hyksos capital of Avaris using geoelectric resistance imaging

G. al-Qady[a], N. Soliman[a], A. Taha[a] and J. Dorner[b]

Tell El-Dab'a area, about 7 km north of Faqus city, Sharqya governorate, Egypt, is identified as Avaris, the capital of the Hyksos. More than once in Egypt's history the seat of the government lay in this area, first during the Hyksos Period, when Egypt was ruled by kings of Asiatic origin (*ca.* 1650–1542 BC), then during the 19th and 20th Dynasties (*ca.* 1300–1080 BC). It is indeed strange that this most important region has remained largely unexplored by archaeologists.

The geoelectric resistance scanning technique, using the Geoscan RM 15 resistivity meter, was applied with a twin electrode configuration at a site recommended by the excavation team of the Austrian Archaeological Institute in Cairo. It is believed that there exist two successive palace complexes on the spot, one dating to the late Hyksos period, the other to the 18th dynasty. The objective of this survey was to help in locating the remains of the expected palace dating to the Hyksos Period.

A total of 9200 sq. m was divided into 23 grids; each grid was 20 m by 20 m. Grids were surveyed using zig-zag mode with traverses 1 m apart. An analysis of the images and maps constructed from the data acquired by resistance scanning indicates a scattering of high-resistance anomalies taking on a regular shape. The texture of the images confirms the existence of parts of the buried palace at the surveyed site. Results have to be correlated with the excavation findings from the area.

[a] National Research Institute of Astronomy and Geophysics, Helwan, Egypt
[b] Austrian Archaeological Institute, Cairo, Egypt

Synergic use of very high resolution geophysical methods to delineate the archaeological strata of the Phoenician site of Neapolis, Sardinia, Italy

G. Ranieri[a], P.G. Spanu[b], R. Zucca[b], G.P. Deidda[a], R. Deiana[a], S. Erriu[c] and M. Nuvoli[c]

Neapolis is located on alluvial benches at the southeastern inlet of the Oristano Gulf, in Sardinia, Italy. As time passed the inlet was transformed into the present day San Giovanni Marceddì lagoon system. Its favorable position attracted Mediterranean traders, from the

[a] Dipartimento di Ingegneria del Territorio, Università di Cagliari, Italy
[b] Dipartimento di Storia, Università di Sassari, Italy
[c] So.In.Geo. Snc, Cagliari, Italy

latest Bronze Age onwards, when the presence of Philistines in the local community is archaeologically documented. Recently retrieved Phoenician material, dated to the end of the 8^{th} and first half of the 7^{th} century BC, appears to indicate a Phoenician colonial settlement. With the arrival of the Carthaginians at the end of the 6^{th} century BC, the settlement flourished into a major urban center. The greatest importation of Attic pottery in all of Sardinia is documented here. These imports can be attributed to a direct connection with Athens, a connection which might justify the Grecian name of Neapolis (New Town).

During the Roman Age the town expanded considerably and, taking advantage of the geomorphology of the area, a regular road network was constructed with rectangular *insulae*. Within this network the public baths, the forum area perhaps and a public building complex can be recognized, the latter featuring marble statues of gods and inscriptions dedicated to emperors.

In the Early Middle Ages, a stronghold commanding the route from Tibula (S. Teresa di Gallura) to Sulci (S. Antioco) was erected in the town. Neapolis was abandoned around the 8^{th} century AD, though the port continued in use until the end of the Middle Ages. In the ancient Neapolis area numerous settlements have been discovered. Rural *villae* benefited from the cultivation of valuable crops, such as limes, easily grown in this fertile land. Some of these settlements also lived by fishing as in ancient times.

Once abandoned, Neapolis avoided all modern architectural development. The antique urban center thus provides unique opportunities for science to employ a variety of archaeological techniques, both traditional (archaeological excavations, reconnaissance, *etc.*) and geophysical, in the investigation of the site. A very high resolution gradiometer survey was carried out using two different sensitivity magnetometers. The data from the GEM potassium gradiometer and the GEM Overhauser gradiometer were compared. Multiple georadar profiles on the main anomalies using two frequencies were also carried out in the same area. Finally, 3D electrical tomography using 256 electrodes was carried out in order to distinguish the Phoenician structures below the Roman and other archaeological levels.

A proposed method for the robust classification of texture in magnetic survey data

Anne Roseveare[a] and Martin Roseveare[a]

Linear or discrete anomalies may be easily detectable by eye or by using automated picking routines. Textures are often more subtle as they can be of relatively low amplitude and may lack well defined boundaries. They can also be obscured by larger anomalies. The problem is to build a recognition system that produces an objective result, even where textures may be confused, merged or simply invisible to the eye. Differences in texture can

[a] ArchaeoPhysica, Shrewsbury, United Kingdom

reveal areas of differing land use or the interiors of structures, and hence texture is an important tool for archaeological interpretation. It could also be used to delineate spreads of magnetic debris, *e.g.*, smithing waste.

A texture is apparent as a recurring 2D pattern of amplitudes within the data and this pattern can be defined as a 2D waveform made up of sets of smaller waves in specific directions. This is mathematically convenient because there are long established techniques for working with functions expressed as superimposed waves, *e.g.*, Fourier spectra, *etc.* A particular advantage is that these techniques allow a model of the pattern to be formed objectively, thus avoiding the subjectivity of the human eye.

The aim is to form a robust system to encode texture data for automatic mapping using supervised classification. The objectivity of the system is dependent upon the quality of the classifier data. Studies have shown that small areas of data contain enough information to characterise the form of archaeological anomalies and a windowing technique can be used to reduce the analytical complexity of large areas. A Fast Fourier Transform is used to synthesise the wave components of the windowed texture to form a wave model, which is then optimised for subsequent stages of processing. Redundant information is removed from the model at the same time, *e.g.*, local trends, *etc.* The model is then rendered rotationally and translationally invariant to facilitate comparison with the classifier data. Classification is supervised using information from the same survey and is based on fuzzy algorithms: research is continuing into the use of neural networks to accomplish this.

Inline quality assessment for data processing in archaeological geophysics

Anne Roseveare[a] and Martin Roseveare[a]

INTRODUCTION

Quality control is an issue that is current in archaeological circles at the moment, in particular the need to provide documentable standards for the collection, processing and archiving of data. In common with other prospecting disciplines, archaeological geophysics provides information that can be regarded as a model of the physical properties of the subsurface to which an archaeological interpretation is attached. Assessment for quality control needs to primarily examine the processes used to form the model rather than comment on the detection of archaeological features. As discussion during *Archaeological Prospection 2001* in Vienna showed, assessment methods based solely upon detection are potentially impossible to apply due to the wide variation in environmental parameters across even small areas.

By concentrating upon the processing of the data it is possible to avoid the purely archaeological issues and to formulate a management system that allows the processing to be

[a] ArchaeoPhysica, Shrewsbury, United Kingdom

documented and the quality of the eventual product to be assessed. At the moment this tends to be achieved by examining the output of a process visually, allowing a basic subjective assessment in the absence of the detailed objective assessment procedure needed for a full quality management system.

DISCUSSION

Many algorithms have been published for the treatment of archaeological geophysical data. Their particular merits rely upon the experience of the designer and their subjective and often visual assessment of the process' effect upon the data. It is perhaps not surprising that over the years several algorithms have been proposed that are each, in the designer's opinion, the best way to achieve a particular effect, *e.g.*, the removal of heading errors from magnetic data. As these processes are combined to create processing streams, the performance of the overall stream becomes harder to assess in objective terms. Just how suited is a process for the data passing through it and how would the surveyor know? A visual examination of the output is subjective, potentially variable and for some processes perhaps misleading. The following example serves as an illustration:

If a function is used to remove the striping of a heading error from magnetic data and the stripes disappear then a subjective visual assessment would judge the function to be successful. If, however, some striping reappears after application of a high-pass filter, then how correct was the visual assessment? Was it realistic considering the subsequent processing stages?

PROPOSAL

An approach explored by this paper is to introduce into the processing stream between stages a set of artificially cognitive components that can recognise particular characteristics of the data passing through them. This information can then be used either to optimise the result by modifying the process or it can be combined with the process' specification to assess the quality of its output.

The information produced by these cognitive components would be tailored to answer particular questions about the data at each stage with the robustness determined by the quality of the training process each component has been subjected to.

Two important benefits are achieved by this approach. Where the information from each component is used directly to modify a subsequent process it allows the process to respond to the characteristics of the data and therefore increase the likelihood of an optimum result. This can be done subjectively by hand but for some processes is likely to be more reliably performed automatically. The second benefit is that each component can be paired with a process, algorithm and the performance of that algorithm assessed. Where several of these pairs are used to form a process stream, each stage in that stream produces information on the data. When this is compared (preferably automatically) with the specification of each process, a quality assessment can be formed which reflects the entire stream.

Where such a system was established, the surveyor could confidently state the exact behaviour of each process and hence demonstrate quality control over the final data. When combined with documented field procedures archaeological geophysical data could become a substantially quality-controlled product, whatever the uncertainties of the prospecting environment.

Geophysical survey in the archaeological record: the Archaeological Investigations Project

Bronwen Russell[a] and Tim Darvill[a]

With the advent of PPG16 (Planning Policy Guidance note 16) in 1990 the role of archaeology in England has developed in a prevailing climate of "preservation *in-situ*". This has seen the rise of geophysical techniques as a rapid evaluation tool in planning lead archaeology. Geophysical survey also provides an essential research tool with quickly accessible results, that can be used to illustrate the need for further work on personal and public research projects.

The development of affordable, user-friendly equipment and data processing packages (particularly Geoscan Research) means that most active local archaeological societies can afford at least an RM 15. This provides a perfect non-invasive research tool which societies can employ to broaden their knowledge of the local archaeology and contribute enormously to the enhancement of the local Sites and Monuments Record (SMR). Apart from the initial outlay it then becomes a very cost-effective way to involve a number of people in the active sphere of archaeological research.

The more affordable instrumentation and ease of use to the surveyor means that many more commercial archaeological units own their own equipment and do not need to tender out to specialist companies for the more "routine" jobs that may be undertaken as part of a broader evaluation. Far more local government and commercial units can now offer geophysical survey in their repertoire of evaluation techniques.

This all indicates that geophysical surveys have been increasing in numbers over the past ten years and therefore there is a wealth of available information. But where does it exist? How can the interested parties access it?

The Archaeological Investigations Project is an English Heritage funded project which seeks to record and provide a gazetteer to all archaeological investigations undertaken in England, by year. It provides listings of archaeological interventions by district or metropolitan borough, for each county and unitary authority in England. The project researchers visit all county councils, commercial units and universities which hold a relevant SMR or contain an archive of the work they have undertaken. Each entry consists of:

- a unique gazetteer entry number and an Archaeological Investigation Project database reference number for the relevant investigation record (for internal AIP use only);
- national grid reference: an eight figure grid reference prefixed by the relevant national grid letters has been recorded where provided in the reports, *etc.* accessed;
- site/project name and location: the name of the site or development project, giving some indication of its location, is given;
- report title, in the case of an "unpublished" monograph-type this may include an internal report number, if recorded;
- other publication details: normally comprises the name of the organisation/individual responsible for authoring or editing the report, followed by the place of issue/publication,

[a] School of Conservation Sciences, Bournemouth University, United Kingdom

the name of the organisation responsible for issue/publication, the year of issue/publication and a description of the physical format of the document including the total number of pages, and the presence of figures, tables, plates, *etc.*;
- summary of investigation;
- summary authorship attribution code;
- SMR primary record numbers: relevant SMR reference numbers;
- archaeological periods represented: the broad dating of the archaeological remains identified during the course of the investigation.

The geophysical survey entries will include more relevant fields to the specific type of survey undertaken. This should give enough information to anyone using the gazetteer whether or not the piece of work is relevant to their enquiry and then a lead to find the original report.

In the case of geophysical surveys AIP has always recorded those which form part of a broader evaluation consisting of a number of archaeological techniques. This is mainly due to the fact that the English Heritage geophysical database was running a pilot study to try and record details of all geophysical surveys undertaken by commercial and academic organisations. Although many were recorded it has not been possible to continue at present with this project. English Heritage continue to update the database with details of their in-house work and also details are recorded of surveys which require permission to be conducted on a scheduled ancient monument, under the section 42 of the Ancient Monuments Act.

As a number of geophysical surveys are now undertaken as the main source of evaluation it has been decided to include them where they occur as a single event. Data collection from 2001 onwards will include all geophysical survey work. It is hoped that this might then be used to enhance already existing data sets.

A decade on from PPG16 it may be possible to analyse trends in the nature and frequency of geophysical surveys undertaken. Where they have been conducted for purely research purposes and where they form part of planning archaeology. Geophysical survey reports are an integral part of the greater historic environment record and deserve to be recognised as such. They also need to be accessible.

Future developments of AIP data recording for geophysical surveys hope to include the documentation of reports completed for forensic and environmental surveys.

Using induced polarization (IP) for the mapping of wooden plankways

Norbert Schleifer[a] and Andreas Weller[a]

After a first successful application of the spectral induced polarisation (SIP) method for the detection of a Bronze Age plankway in the Federsee bog (Schleifer *et al.* 2002) a second field measurement was carried out in the subsequent year to verify the initial results.

[a] Institut für Geophysik, TU Clausthal, Germany

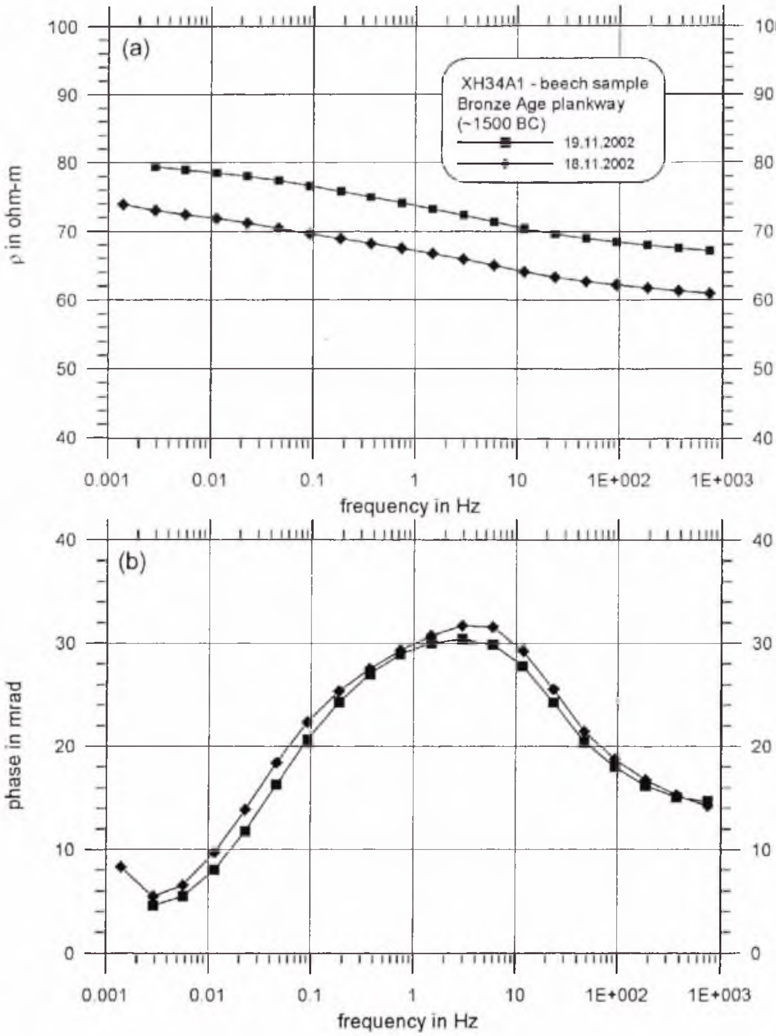


Fig. 1. Laboratory spectra of a beech-wood sample: (a) resistivity and (b) phase shift. The sample was measured two times to assess repeatability.

As it is often desirable in archaeological prospection to cover large areas, we also wanted to investigate the possibility of mapping the wooden remains by induced polarisation (IP) using just one distinct frequency.

This measurement frequency was selected after investigating different wooden samples from the plankway in the laboratory. For this the spectral induced polarisation of the samples was measured in a frequency range from 1 MHz to 1 kHz and Figure 1 displays

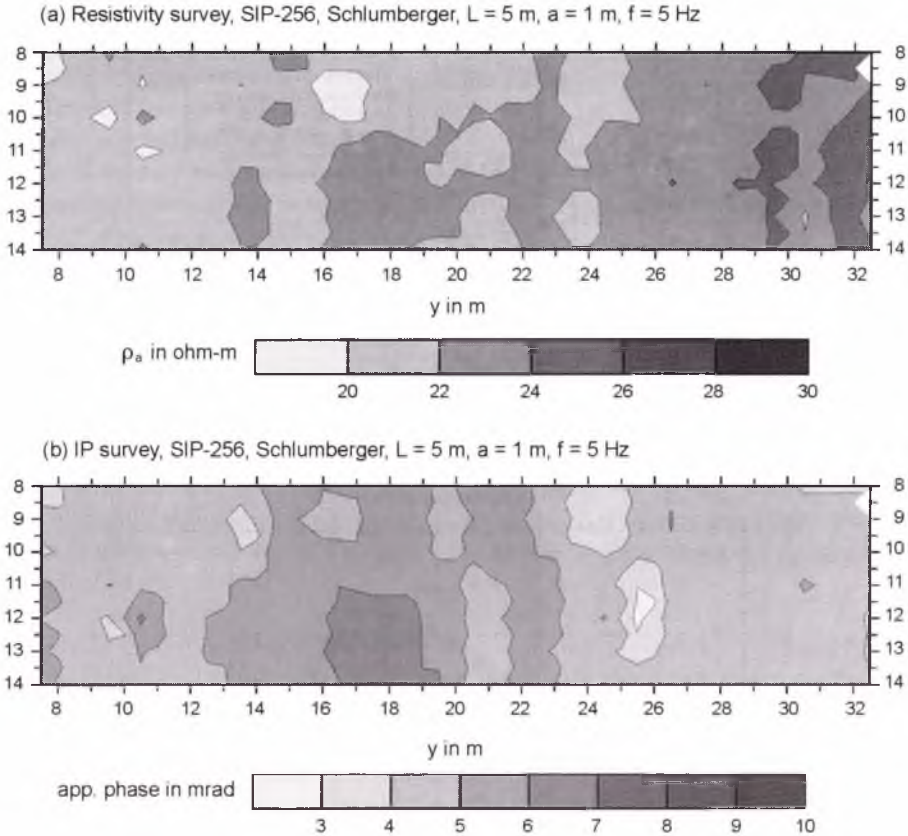


Fig. 2. Complex resistivity mapping of a Bronze Age plankway in the Federsee bog. (a) resistivity and (b) phase shift.

the spectra of a beech sample. A maximum phase angle of 30 mrad can be observed in the classical frequency range for IP between 1 and 10 Hz. Since earlier laboratory measurements on alder and ash samples from the plankway have shown phase angle maxima in the same range, a single frequency of 5 Hz was chosen, allowing the survey to be performed in a reasonable time.

The measurements were undertaken with the multi-channel instrument SIP 256 from the Institut für Meteorologie und Geophysik of the Goethe Universität, Frankfurt am Main. Seven parallel profiles with 31 electrodes were recorded covering an area of 180 sq. m.

A pole-dipole-array with an electrode spacing of 1 m was chosen. The plankway has a width of 9 m and can be regarded as a two-dimensional object as it has been traced by archaeologists over a length of more than 100 m. The wooden remains were expected to be located at an approximate depth of 0.9 m.

The results were visualised by plotting the apparent resistivities and apparent phase angles for each pseudodepth. Using the forward and reverse measurements two pole-dipole data points were combined to one Schlumberger-configuration data point. Figure 2 shows the results at a Schlumberger pseudodepth of 2, with L=5 m and a=1 m, to be correlated to a depth of investigation of approximately 0.6 m.

In Figure 2 the course of the plankway is visible in the lower diagram as a broad band with slightly higher phase angles of 6 to 8 mrad compared to the peat which only produces values below 6 mrad. The trackway crosses the area between y=13 and 23 m. The upper diagram of Figure 2 shows the apparent resistivities mainly representing the lateral variation of the soil water content with values ranging from 18 to 30 ohm-m.

The presented results verify our previous field work and can be viewed as motivation to continue our investigations in an effort to establish IP in archaeological prospection (Schleifer 2003). As these first successful surveys show the advantage of the method in peatland archaeology, the necessity for geoelectrical mapping instruments being able to measure the complex resistivity becomes obvious.

REFERENCES

Schleifer, N. 2003. *Anwendung der spektralen Induzierten Polarisation in der Archäologischen Prospektion.* Unpublished D.Sc. Thesis. Institut für Meteorologie und Geophysik der Johann Wolfgang Goethe-Universität Frankfurt am Main.

Schleifer, N., A. Weller, S. Schneider and A. Junge 2002. Investigation of a Bronze Age plankway by spectral induced polarization. *Archaeological Prospection* 9/4: 243–53.

The lost village of Tidover – magnetic susceptibility survey as part of a sequential prospection strategy

Armin Schmidt[a]

As part of a local history project, the villagers of Kirkby Overblow, North Yorkshire, UK, are searching for the lost Medieval settlement of Tidover. The limited historic references to the site locate it in an area of about 10–20 ha close to the village. As aerial photographs fail to show its precise location, a geophysical survey strategy was employed to help in locating it. A rapid, but coarse, magnetic susceptibility field-coil survey was used to reveal "hotspots", which were subsequently investigated with more detailed earth resistance and fluxgate gradiometer surveys to identify individual features. Although some of the high magnetic susceptibility results correlated with magnetic anomalies, others did not and explanations are being sought. The treatment and display of the randomly sampled magnetic susceptibility data and their statistical comparison with the more densely collected magnetometer data are

[a] Department of Archaeological Sciences, University of Bradford, United Kingdom

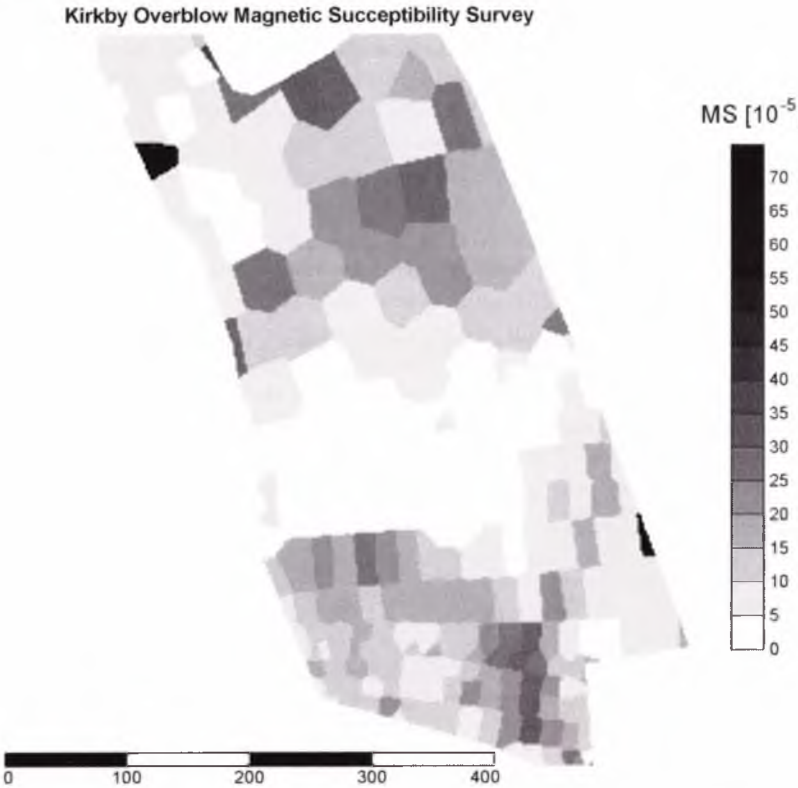


Fig. 1. Magnetic susceptibility recorded with Bartington MS2D at random sample positions. The data are displayed with Voronoi diagrams for each sample location.

discussed. It was found that visualisation of data with Voronoi diagrams for each sample location produced results best reflecting the underlying sampling scheme (Fig. 1).

Geomagnetic surveys at the PPNA site of Dhra', Jordan

Mark R. Schurr[a], Ian Kuijt[a] and William Finlayson[b]

Geophysical surveys have sometimes had little or no application on early Holocene prehistoric sites in the Near East because of cost and concerns about their effectiveness. Archaeological features on early Holocene sites are often difficult to detect because the sites have very

[a] University of Notre Dame, Indiana, USA
[b] Council for British Research in the Levant, Amman, Jordan

complex, multi-layered stratigraphies from successive occupations dating to later periods. The presence of very rocky soils is also limiting, because there is little contrast between the matrix and stone architecture.

The pre-pottery Neolithic A (PPNA) site of Dhra' is located in Jordan and lies at the south end of the Dead Sea on a terrace at 5 m below sea level (Figs 1–2). Investigations at the site since 1994, with intensified work since 2001, have shown that PPNA deposits covering an area of approximately 6500 sq. m are present at Dhra', and that they contain intact architectural features. During the 2001 field season, geomagnetic surveys covered an area of 2500 sq. m. The surveys were conducted with a Geoscan FM 36 gradiometer using a sensitivity of 1 nT and relatively small survey intervals (typically readings every 0.25 m per transect, along

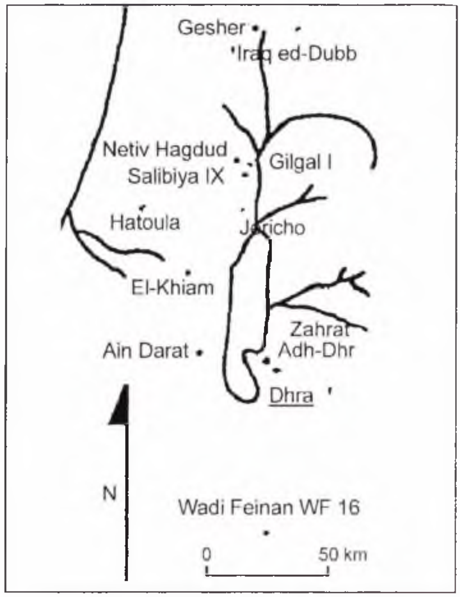


Fig. 1. Dhra'. Location of the site.

Fig. 2. Dhra'. The site from the northwest.

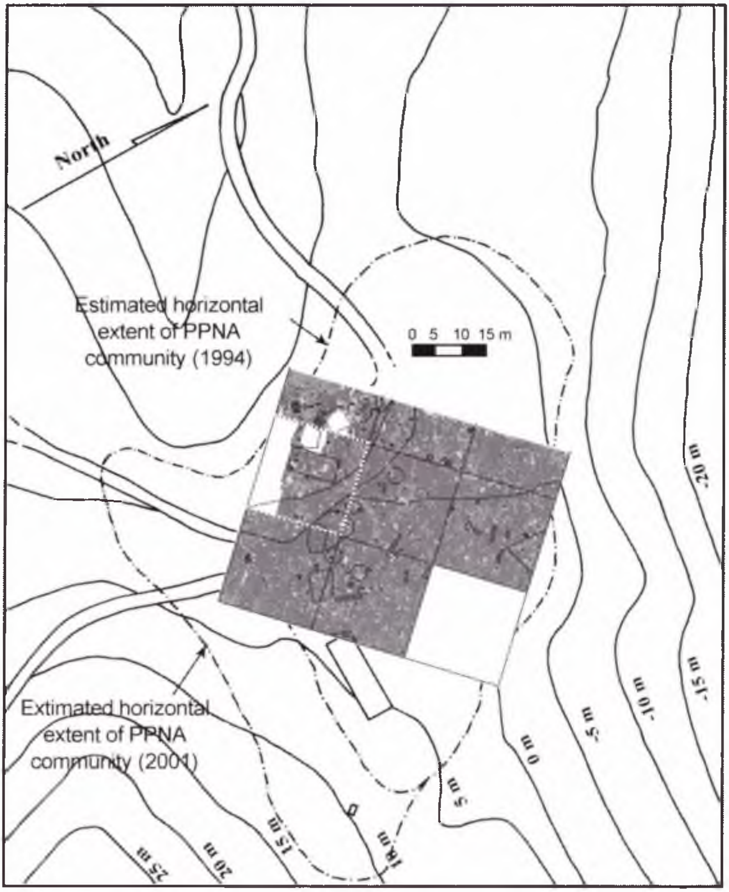


Fig. 3. Dhra'. The location of the geomagnetic survey in relationship to modern features.

transects spaced 0.25 m or 0.5 m apart). Data was processed with a portable computer at the site and in the field camp using a GIS so that the geomagnetic data could be compared with modern features and the topography (Fig. 3). Subsequent excavations at the site have been partly devoted to verifying the geophysical survey interpretation.

In contrast to prevailing expectations, fluxgate gradiometer surveys at the PPNA (*ca.* 11 500 BP) site of Dhra' successfully located several significant anomalies, including a clay structure with substantial burning (Fig. 4), earlier excavation trenches, and a pit filled with fire-cracked rock. The surveys were successful for three reasons. Firstly, the fluxgate gradiometer has an especially suitable instrument configuration for Near Eastern sites where the angle of magnetic declination is such that the data from other magnetometer configurations are often difficult to interpret. Secondly, relatively tight survey intervals allowed the identification of relatively small features, as small as 1 m in horizontal extent. Thirdly, the careful

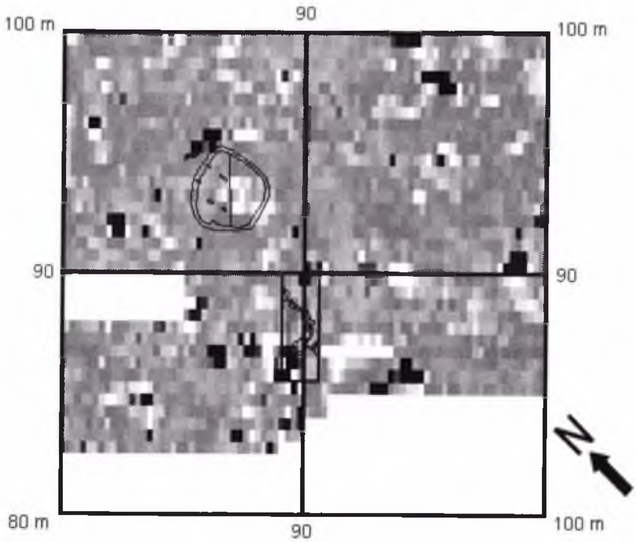


Fig. 3. Dhra'. Magnetic anomalies corresponding to a burnt structure (upper right) and earlier excavation unit (lower center).

control over drift and noise are essential. Thermal drift was a particular problem for the fluxgate gradiometer because the surveys were conducted in mid-May when midday temperatures at the site already exceeded 40°C and the instrument temperature might change by 15°C in just a few hours. Drift problems were resolved by re-balancing the instrument after every 20 m square grid was surveyed.

The Dhra' geomagnetic survey shows that excellent results can be obtained even on very difficult sites when the proper instrument is used, drift and noise are carefully controlled by frequent re-balancing of the instrument, data are processed and reviewed in the field, and tight survey intervals are used.

A contribution to archaeological prospection in Lower Saxony, Germany, illustrated by some recent geophysical surveys

Christian Schweitzer[a]

In Lower Saxony geophysical surveys are only just starting to become an integral part of archaeological prospection. To date, geophysical techniques have been used systematically in support of archaeological research solely in the Harz mountains. The reasons for

[a] Schweitzer-GPI, Burgwedel, Germany

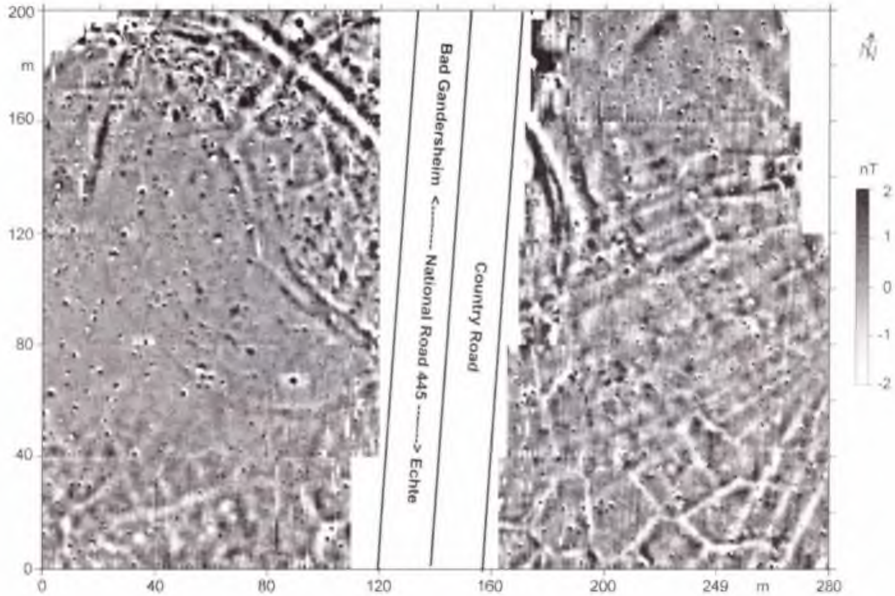


Fig. 1. Kalefeld, site 11. Filtered magnetogram of Linear Band Pottery earthworks.

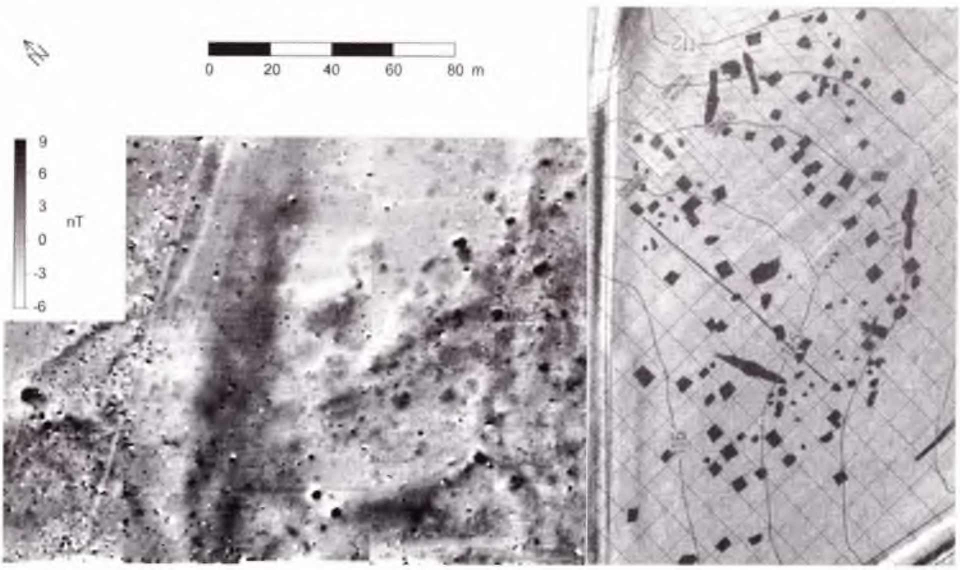


Fig. 2. Süpplingenburg, site 9. Composite map of an Early Medieval settlement of sunken huts. SE section (right) – map from aerial photograph O. Braasch (1992); NW section (left) – unfiltered magnetogram (February 2003) covering fallow land not suited for aerial prospection.

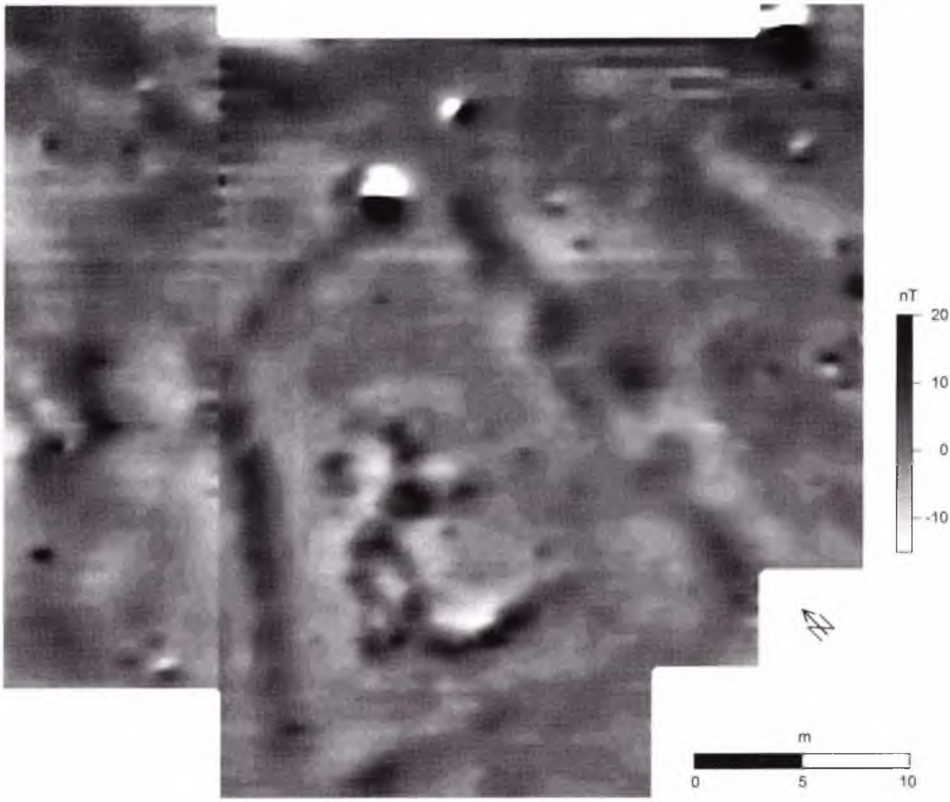


Fig. 3. Vöhrum. Moated castle ("Wasserburg"). Filtered magnetogram.

this late development compared to other German states are many, but the most important include: low budgets for research, combined with a hesitance on the part of state, district and county archaeologists to take advantage of the benefits of fast and non-intrusive subsurface investigations. Furthermore, a systematic aerial reconnaissance, which creates many opportunities for geophysical investigation, did not start in this region until late (Otto Braasch, from 1990 to 1993).

This late development of geophysical prospection has its good sides, however. The author has had the opportunity to do such research in this area, collecting specific area-related experiences in the process. Following test surveys performed at various archaeological sites, there is increasing interest on the part of the archaeologists. Project financing often comes from communities, local societies, environmental protection parties and tourist guides, who are increasingly interested in early local history and are willing to sponsor state-of-the-art investigations. Projects are performed in close cooperation with archaeologists and aerial photographers. Aerial photographs are taken for all the investigated sites. Much effort is put in generating adequate visualisations of results.

Illustrating the recent efforts to make the application of geophysical surveys more popular in Lower Saxony are three examples of magnetic surveys. In all three cases the technique used was the same as H. Becker's and J.W.E. Fassbinder's from the Bavarian State Office for Protection of Historical Monuments in Munich, Germany. The device used was a Scintrex SMARTMAG SM4G-special applied in a duo-sensor configuration (total field measurement) at 0.5 m and 0.25 m traverse interval and 0.1 sec cycle corresponding to about 10 cm sampling. If required, ancillary studies were carried out, especially in the case of ambiguous results in difficult soil conditions (magnetic susceptibility, modelling).

A Linear Band Pottery earthwork consisting of two ditches was discovered at an important Early Neolithic settlement in Kalefeld during road construction work in the early 1990s. Buried underneath colluviums 0.7 m to 1 m thick, it did not show up in aerial photography nor was it evidenced by surface finds. Three test trenches were dug to investigate the two ditches, one U-shaped, 4 m to 6 m wide and up to 2 m deep, the other V-shaped, up to 2.8 m wide and 2.6 m deep. The objective of a 4.5 ha magnetometer survey was to reveal the outline of the ditches and the position of the entrances and to uncover the internal structuring of the settlement (Fig. 1).

A settlement of sunken huts from Early Medieval times in the community Süpplingenburg near Helmstedt was discovered by aerial surveying (carried out by Otto Braasch). The full extent and detailed structuring of this settlement was investigated in a magnetic survey of *ca.* 4 ha (Fig. 2).

Geophysical prospection at the river Fuhse in Vöhrum near Peine led to the discovery of a moated castle fortified with earthworks and an inner wall of trapezoidal shape (Fig. 3). The fortified area covers *ca.* 450 sq. m. Dendrochronology analysis of two samples sliced from wooden elements of a palisade trench dated the origin of the moated castle to *ca.* 1180 AD. Knowing when the castle was built helped to clarify its historical background.

Mapping buried archaeological remains using GPR surveys at the Isis temple, Bahbeit el-Hegara area, Nile Delta, Egypt

F.A. Shaaban[a], F.F. Shaaban[b], A.M. Abbas[a] and A.H. al-Essawy[c]

The interpretation of ground penetrating radar (GPR) survey data helped with the tracing and mapping of buried remains at the archaeological site of Bahbeit el-Hegara. Sixty-three GPR profiles were recorded at the southern and eastern parts of the Isis temple area using a SIR-2000 system with 400 MHz antenna and a time window of 100 ns. A preliminary GPR profile was measured over a partially buried granite block from the destroyed temple for subsequent calibration and interpretation of the GPR sections by

[a] National Research Institute of Astronomy and Geophysics, Helwan, Egypt
[b] Geology Department, Faculty of Science, Mansoura University, Egypt
[c] Schlumberger Company, Cairo, Egypt.

determining dielectric constants and velocities. The field GPR data were processed using Radan and Reflex software.

Analysis and interpretation of the GPR sections revealed anomalous features of different shapes and dimensions buried at depths ranging from 1 m to 5 m below the ground surface. These remains are either irregular stone blocks or regular building structures, probably walls and columns of the destroyed temple. In addition, wave amplitude time slices were constructed illustrating the subsurface locations and extent of these delineated archaeological remains in the study area.

Historical analysis and geophysical surveys to define remains of ancient stone buildings

Zakhar Slepak[a] and Gulchachak Nugmanova[a]

In 2005, the town of Kazan, situated in the heart of Russia on the Middle Volga river, will celebrate its 1000th anniversary. In the 9th–10th centuries AD, a Turkic tribe, known as the Bulgars, founded their own state on the Middle Volga river and the town of Kazan was one of the Bulgars' towns. In the 12th century, Kazan became the capital of the Kazan khanate but in the middle of the 16th century, Kazan was conquered by the Russian tzar Ivan IV (Ivan the Terrible) and annexed by Russia.

With this background in mind, it is only natural that the restoration of the architectural monuments of Kazan has become a key social and governmental concern for the Republic of Tatarstan. The major architectural landmarks of Kazan are the Kremlin, which is the only preserved Tatar fortress, and the Bogoroditsky Nunnery of Kazan which always enjoyed the status of the most important building of the local Age of Classicism. The Kremlin, a unique architectural ensemble, includes the Suyumbeki Tower, Governor's Palace, Annunciation (Blagoveschensky) Cathedral, Spasskaya, Tainitskaya and other towers and surrounding walls – all dated to the 16th through 19th centuries AD. The investigated targets in the cultural layers are represented by the stone remains of the Khanate period (13th–16th century), including the giant Kul-Sharif Mosque and the Khan's Palace.

The foundation of the nunnery in 1579 by Ivan the Terrible is associated with the discovery of an icon of Our Lady. The first wooden buildings were erected on the site of the discovery; a stone cathedral replaced the early structures in 1694–95. The last to be constructed at this stage was the Sophia Church with its gate, refectory and fence. The architectural complex also included an unheated cathedral, a heated Church of the Birth of the Blessed Virgin and a bell tower. In the northeast, the nunnery was bordered by two stone churches of Nikola of Tula. Today, only the Sophia Church and its refectory remain intact. The architectural ensemble of the Nunnery was completed in the next building period, which

[a] Geophysical Dept., Geological Faculty, Kazan State University, Russia

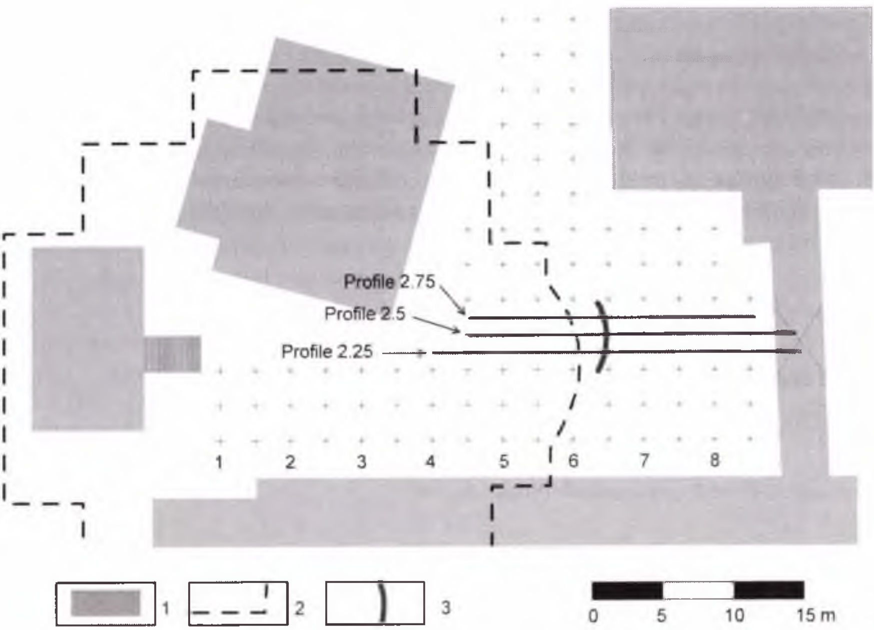


Fig. 1. Kazan. Location of TEMS profiles in the area of the tobacco plant. 1 – modern buildings; 2 – presumed position of the Cathedral of Our Lady on the basis of historical and archival data; 3 – position of the Cathedral's eastern apse on the basis of geophysical and archaeological data.

architect I.E. Starov initiated with the construction of a new unheated cathedral. During the Soviet Period (1917–1970), most of the Nunnery's buildings were destroyed. A tobacco factory and some apartment buildings were erected in their place.

The restoration works, now underway at both sites, are based on earlier historical, architectural, archaeological and geophysical research. The old drawings that are available identified the approximate location of the destroyed buildings, opening the way to geophysical surveys that permitted the precise location of the stone remains of some features to be determined in the anthropogenic/cultural layer.

Stone remains were located most effectively with transient electromagnetic sounding using M-1/0-20 apparatus that allowed the heterogeneity of the uppermost geological strata to be studied and produced vertical sections of total electrical conductivity S(H) along the survey lines. The penetration depth of an electromagnetic signal sharply decreases over building remains. This method has been successfully used for the study of the cultural layer and for solving some engineering problems.

The geophysical data has been confirmed by archaeological excavation, at the same time reducing the area that needed to be excavated. Among the major discoveries in the Kazan Kremlin were the remains of some ordinary buildings, the bell tower of the Annunciation Cathedral and fortress walls. In the Bogoroditsky Nunnery, remains of the Cathedral of Our

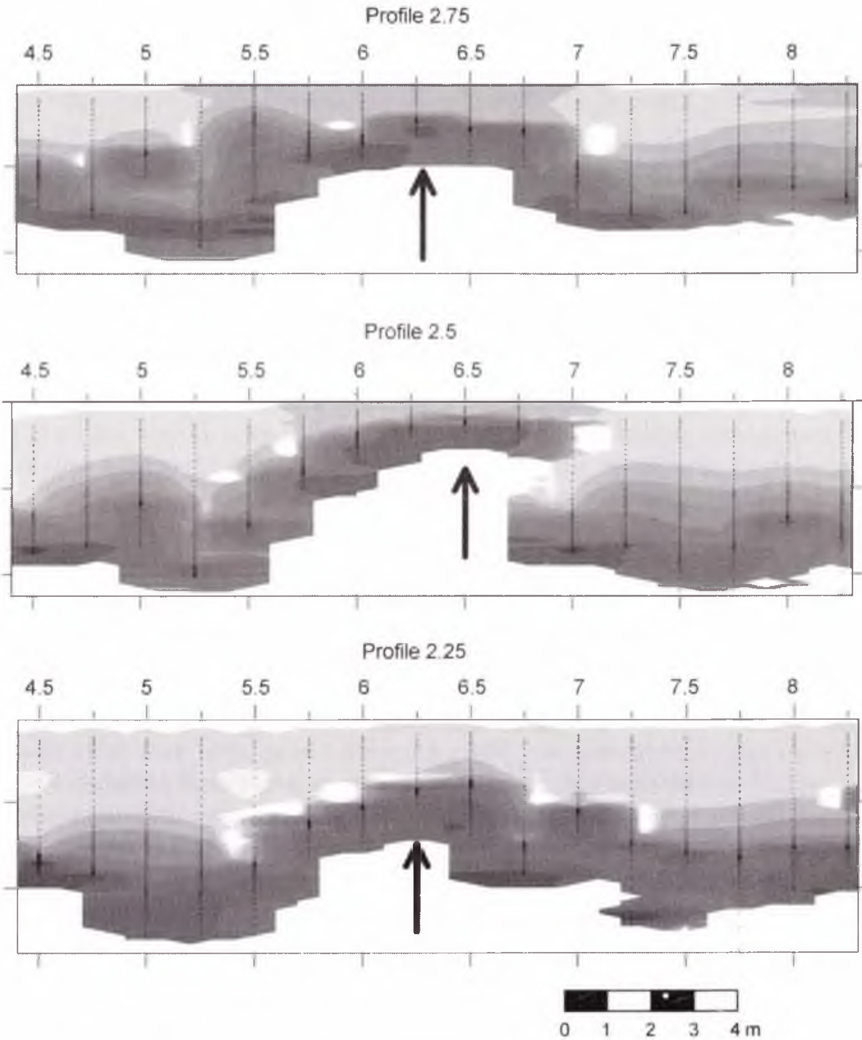


Fig. 2. Kazan. Vertical sections of total electrical conductivity in the area of the Cathedral of Our Lady (see profiles in Fig. 1). Arrows show the position of the cathedral's eastern apse.

Lady (Figs. 1–2), Churches of the Birth of the Blessed Virgin and of Nikola-of-Tula, the Southeastern Tower and some other smaller buildings were located.

The results of the work at Kazan clearly indicate the benefits of combining historical analysis and geophysical prospecting in an effort to locate ancient buildings, solve architectural problems and minimise the scope of required archaeological excavations.

The interpretation of aerial photographs in the Linzi Project

Baoquan Song[a]

The Institute for Pre- and Proto-History of the Ruhr University, Bochum, has been cooperating with the Shandong Provincial Archaeological Institute, China, on a scientific research project "The Prospection and Investigation of Extensive Sites in Linzi by means of Aerial Photo-Archaeology" since 1996. In the course of this project, considerable numbers of aerial photographs have been collected and evaluated with regard to the archaeology of the area and the preservation of its monuments. Moreover, the basic framework of an archaeological information system has been developed. The Linzi Project is the first extensive attempt in the history of Chinese archaeology and the preservation of monuments in China to carry out systematic and inclusive site inventories, prospection and research by use of aerial photographic techniques. A summary of the provisional project results has been published in an aerial photo atlas. In addition, a geographer has developed a multimedia presentation of the prospection results in German as a dissertation.

At the beginning of the project a large number of aerial photographs taken at different times was collected. These photographs, deemed suitable for archaeological evaluation, were from sources both inside and outside of China. A relatively large number of historical aerial photographs of Chinese regions is stored in US archives, such as the Library of Congress, National Air and Space Museum, National Archives, *etc.* Of these, the National Archives have the largest collection of aerial pictures of China. These aerial photographs (approx. 34 000) were taken by the Japanese and American air force personnel before and during the Second World War for military reconnaissance and survey purposes. Almost all of them are vertical serial photographs. The evaluation of pictures of the test areas in the province of Henan, Shandong, Hubei and Jiangsu show that the pictures have an incalculable value for archaeological research. Archaeological remains that were still visible on the ground sixty or seventy years ago and have since then been levelled or built over have been documented on these aerial photographs.

As part of the Linzi Project, we obtained from the USA 41 aerial photos from 1928 and 23 from 1938. Inside China, project staff examined aerial photos and map material from the Centre for Scientific and Pedagogic Survey Materials, selecting 590 aerial photos from 1975 as well as acquiring thirty topographic maps (1 : 10 000 scale) for the Linzi region.

In order to evaluate and use aerial photographic and map material more effectively and rationally, and to build up an archaeological information system for the Linzi region, we employed Erdas Imagine software for processing remote sensing data to produce digitally rasterised topographic maps and digital orthophoto maps. The collected aerial pictures and topographic maps were scanned and converted into picture file format readable by Erdas Imagine. The rasterised topographic maps were first georeferenced (geometrically rectified and allocated to the land coordination system). This was the basis for the digitally rasterised topographic maps. The next step was to convert each of the pictures from 1928, 1938 and 1975 into orthophotos making use of the digitally rasterised topographic maps, *i.e.*, the digitised

[a] Institut für Ur- und Frühgeschichte an der Ruhr-Universität Bochum, Germany

aerial photos were projected or superimposed upon the digitally rasterised topographical maps, using the geographical system of coordinates of the topographic maps and geometrical calculation. Finally, the orthophotos, corresponding to extracted sections of single topographic maps, were combined in a mosaic effect and edited into digital orthophoto maps.

The interpretation of the Linzi aerial photographs was carried out in a series of steps: preparation, pre-interpretation and interpretation. On the basis of the preparatory inspection of the known sites and the study of archeologically relevant literature and of topographic maps, a number of typical settlement and grave sites was selected and collated as interpretive keys for the aerial photographs of 1928, 1938 and 1975. The attributes of these typical cases were clearly defined.

Starting from the *status quo* documented in the earlier aerial photographs, we were able to differentiate a number of basic characteristics of the different Linzi grave types. The visual interpretation of aerial pictures was combined with computer-assisted documentation of the results of the interpretation. Along with the systematic examination of the two towns: Linzi (the one-time capital of the Qi), and Anping, burials with mounds were prospected selectively. On the aerial photo-maps of 1938 there were 2742 burial mounds, or what appeared to be burial mounds. On the aerial photo-maps of 1975 only 445 of these sites remain in view. Assisted by the aerial photographs of 1928, 1938 and 1975, a multi-temporal interpretation and comparative analysis of the sites was carried out, with special attention being paid to the condition of the sites at various points in time. The changes to particular sites and the prevalent tendencies of change, caused by a series of natural and artificial factors, were investigated to provide a scientific background for the planning of archaeological research and for measures aimed at preserving such monuments.

Following the archaeological interpretation of aerial photos, we checked and verified the interpretation results by various methods and to a different extent. The complete results of the interpretation were checked and examined in comparison with the newest data from field archaeology and with long-term field experience collected surveying local monuments with the purpose of preservation. New sites discovered in the course of the interpretation were examined and verified selectively by archaeological site investigations; in a few selected cases, sites already levelled were prospected by core-drilling. Parallel to the verification of interpretation results, archaeological data from various sources was collated, that is, the various relevant materials (texts, maps, photographs, *etc.*) of field archaeology, site surveying and verification work were allotted to particular sites and related to the geographical system of coordinates of the topographic maps. These were incorporated digitally into the archaeological information system of the Linzi region. In all, 2889 sites in Linzi were verified, including 2794 graves and 95 remains of towns and settlements. Archaeological inspection of the sites provided evidence for the preservation of 147 graves with grave mounds; 222 graves have been built over in the process of enlarging modern villages; the grave mounds of the remaining 2300 plus burial grounds have been levelled but the grave chambers of most are probably extant underground.

In order to bring the results of aerial archaeological research in Linzi to the attention of a larger number of scholars, thus profiting them hopefully in their work, the provisional results of our research have been presented in "The Archaeological Aerial Photo-Atlas of Linzi, China", published in 2000. This atlas is a virtually complete record of what the archaeological information system of the Linzi region has to offer.

Magnetic survey on the acropolis of Pisidian Antioch

Mehmet Taşlialan[a], Roger S. Bagnall[b], Tatyana Smekalova[c] and Sergey Smekalov[d]

Antioch, the capital of Roman Pisidia in the south of Asia Minor (Fig. 1a), is known chiefly from the travels of St. Paul described in the Bible (Lloyd 1989:219–20). It was discovered at the beginning of the 19th century, but excavations did not begin until the early 20th century and have been undertaken again recently by the Yalvaç Museum (Dr. Mehmet Taşlialan) and an international team under the supervision of Dr. John Humphrey. A magnetic survey of the acropolis of Pisidian Antioch was carried out in June 2001. Four different areas were investigated: N1 to the west of the theatre (1 ha), N2 to the south of the main street (0.16 ha), N3 between the Roman baths and *nymphaeum* (1.12 ha) and N4 inside and close to the St. Paul church (0.25 ha).

The magnetic was chosen in view of the significant magnetic contrast between archaeological features and surrounding soil, and the shallow depth at which most of the structures are to be found. Limestone walls produced negative magnetic values of up to 70 nT while the rooms, filled with earth and ceramics, produced positive anomalies of about 20 nT to 50 nT on the magnetic maps. Ovens and kilns created strong positive anomalies 40 nT to 300 nT with a negative component immediately to the north of the positive data. Heaps of wasters, ceramics, slag and ash generated positive anomalies from 80 nT to 130 nT with smaller negative additions. Pits, filled with fragments of ceramics, ash, burnt earth *etc.*, created fairly strong positive anomalies up to 50 nT to 60 nT with a smaller negative response to the north of the positive data.

The most interesting results came from area N3 between the Roman baths and *nymphaeum* (Fig. 1b). The magnetic map of this area is shown in Fig. 2a. It was assumed that the *palaestra* was situated immediately east of the Roman baths (Mitchell and Wealkens 1998:199). Instead, the magnetic survey provided a very clear outline of a basilica (see Fig. 2a and interpretation plan in Fig. 2b), which may have been erected on the foundations of the *palaestra*. The basilica measured about 25 m by 50 m with a central apse that was 10 m wide. The nave appears to have been divided into three sections. There were two external enclosures: 47 m by 57 m and 57 m by 57 m. In plan this structure resembles the larger basilica of St. Paul, which was excavated in the lower town (Taşlialan 1997:35).

The geophysical survey also revealed a water supply system. It consists of a big walled water reservoir with a ceramic pipe line running for more than 10 m from the southern side of the reservoir (see Fig. 2b). Each section of the pipe produced a positive and negative magnetic signal, because it had been magnetized during firing in a pottery kiln. When the pipe was laid, the remanent magnetization of each section was randomly oriented, thereby producing a characteristic magnetic signal from the ceramic pipeline.

The area between the water reservoir and the *nymphaeum* had been leveled artificially to the top of a retaining wall (90 m long) erected at the start of the natural slope (Fig. 2ab),

[a] Yalvaç Museum, Turkey; [b] Columbia University, New York, USA
[c] St. Petersburg University, Russia; [d] Baltic Technical University, Russia

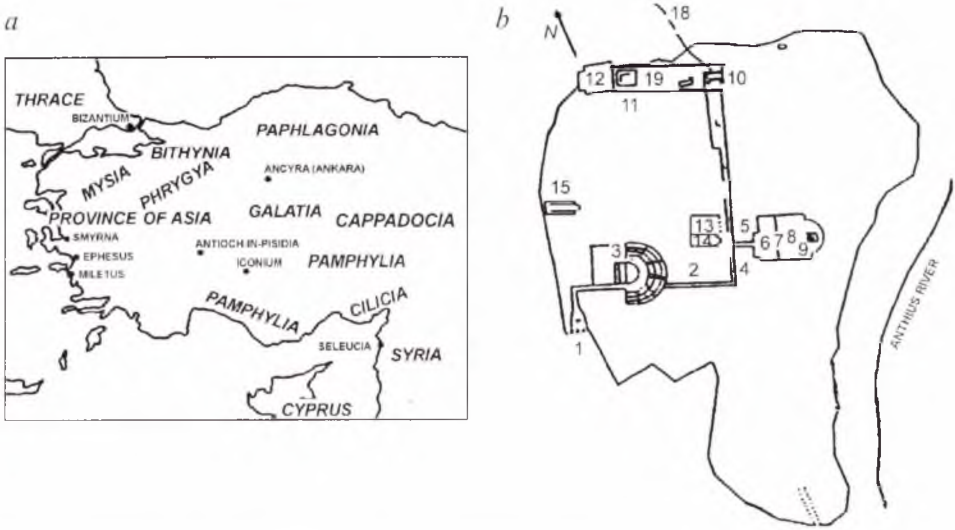


Fig. 1. Map of Asia Minor and location of Pisidian Antioch (a); plan of the acropolis of Pisidian Antioch (b): 1 – city gate, 2, 4, 5 – streets, 3 – theatre, 5 – square of Tiberius, 7 – *propylon*, 8 – square of Augustus, 9 – temple of Augustus, 10 – *nymphaeum*, 11 – *palaestra*, 12 – Roman baths, 13 – *bouleuterion* (?), 14 – basilica, 15 – St. Paul basilica, 18 – aqueduct, 19 – area of magnetic survey (after Lloyd 1972 and Taşlialan, 1997).

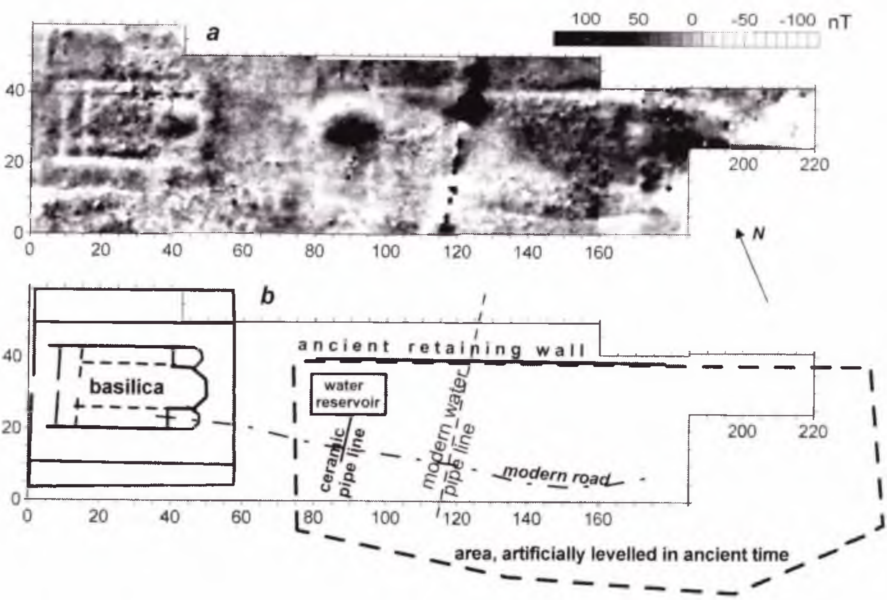


Fig. 2. Pisidian Antioch. Area to the east of the Roman baths. a – magnetic map; b – interpretation map.

the purpose being to create a horizontal surface for collecting water from an aqueduct and supplying the ancient city with water. A modern iron pipeline, which crosses the centre of the surveyed area, produces strong positive-and-negative anomalies (Fig. 2b).

The Roman baths were also surveyed magnetically. A very strong local magnetic anomaly was found there (about 4 m by 4 m), the source of which was interpreted as a big tile or lime kiln. It has two parallel channels. The remains of another kiln were visible at the edge of the nearby excavations. Both kilns may have been set up to produce construction materials for the basilica in Early Medieval times. The magnetic map recorded in Antioch is similar to maps recorded over Medieval pottery kilns in Southern Crimea (Smekalova *et al.* 2000, fig. 43).

It can be concluded that magnetic surveying is a very effective, fast and absolutely non-intrusive method for the investigation of the acropolis of Pisidian Antioch and can be recommended for using on other areas of the site as well.

ACKNOWLEDGEMENTS

We would like to thank Prof. Thomas Drew-Bear, Dr. John Humphrey, Dr. Brigitta Wolf, Mr. Aydin Akdüz and other participants of the Pisidian Antioch Project for their help and support in our fieldwork. Columbia University sponsored the magnetic survey on the site. The results of our work on Project B0038 of the Russian Scientific Foundation "Integration" have been used for the interpretation of the magnetic maps.

REFERENCES

Lloyd, S. 1972. St. Paul in Asia Minor. *Asian Affairs* 59:182–90.
– 1989. *Ancient Turkey.* London.
Mitchell, S. and M. Wealkens 1998. *Pisidian Antioch. The site and its monuments.* London.
Smekalova, S., A. Melnikov, V. Myts and B. Bevan 2000. *Magnitometricheskie issledovaniya goncharnykh pechey Srednevekovoy Tavriki.* St. Petersburg.
Taşlialan, M. 1997. *Yalvaç. Pisidia Antiocheia.* Göltaş kültür dizisi 3. Isparta.

First comparative test of magnetic viscosity and magnetic susceptibility mapping

Julien Thiesson[a], Eric Marmet[a] and Alain Tabbagh[a]

Soil magnetic properties constitute a rich base of information about human settlements and ancient agricultural work. Susceptibility measurements are of common use but are ambiguous in terms of physical interpretation: a susceptibility increase can correspond to an increase of magnetic mineral content, to a change in the types of magnetic minerals present or to a change in the size of the magnetic domains of one (or of several) of the magnetic

[a] Université Pierre et Marie Curie, Paris, France

minerals. Consequently, the archaeological interpretation cannot clearly distinguish between anthropogenic changes to the soil and natural magnetic enhancements. Magnetic susceptibility, however, can be complemented by the use of magnetic viscosity, which depends on the domain size and can serve as a relevant indicator of the presence of small single-domain grains.

Magnetic viscosity responses were first observed when using time domain electromagnetic (TDEM) instruments, specifically a "pulse induction meter" (PIM). However, as the measurements were not calibrated, their use was limited to mapping the relative variations of the responses. A calibration procedure was proposed in 1996 that allowed the TDEM viscosity response to be expressed in terms of quadrature susceptibility, thus opening the way to the use of a different apparatus and to a quantitative comparison with susceptibility.

As a first step before building new instruments with a metric depth of investigation, we undertook a comparison between the Bartington MS2 susceptibility meter with an 18 centimetre coincident loop and a PIM calibrated instrument with a similar coil. At several sites, the susceptibility and viscosity maps were very similar suggesting a constant and stable viscosity to susceptibility ratio for the topsoil of a large part of archaeological sites.

Surveying in Egyptology

Břetislav Vachala[a] and Jaromír Procházka[b]

June 2002 marked forty years since the establishment of cooperation between the Department of Special Geodesy of Czech Technical University in Prague and the Czech Institute of Egyptology, Charles University. Over the years surveyors have taken part in six expeditions, dealing with various problems related to the documentation of the archaeological findings, analysis of their geometric parameters and mutual relations as well as site exploration and reconstruction of historical structures. Among the most important tasks was preparing an archaeological hypsometric map of the Czech archaeological concession at Abusir (scale 1:2000). To deal with most of the objectives, a quality geodesic network was built, surveyed and adjusted gradually.

This contribution provides a concise overview of the co-operation between geodesic surveyors and Egyptologists over the past 40 years. The overall purpose, however, was to draw scholars' attention to the importance of establishing a quality geodesic network, which is essential for preparing an archaeological hypsometric map of a site and for preparing the documentation of excavated structures. The contribution also sums up opportunities for developing this association in view of the rapid advances in both geodetic and computer technologies, specifically with regard to detailed 3D documentation of excavated features, including computer-aided modeling. The results of geodetic work complement – and occasionally even modify substantially – current methods of archaeological research.

[a] Český Egyptologický Ústav UK, Praha, Czech Republic
[b] Katedra Speciální Geodézie, Stavební Fakulta ČVUT, Praha, Czech Republic

The geophysical assessment of the Myers Wood iron-working complex near Huddersfield, England: fiction (?) then fact

R.W. Vernon[a], J.G. McDonnell[a], A. Schmidt[a], A. Powell[a], E. Godfrey[a] and B. Spence[b]

The ability to identify iron smelting shaft furnaces in surrounding slag deposits with magnetometer surveys is well recorded (Vernon *et al.* 1999). Magnetic iron minerals within the furnace lining usually produce pseudo-circular/circular clusters of positive data. However a geophysical survey and the subsequent partial excavation of the Myers Wood iron-working site proved that this is not always the case.

The Huddersfield and District Archaeological Society (HDAS) discovered the Myers Wood iron-working complex in 1999. The site consists of about six hummocks of slag in a beech wood. Documentary evidence suggested that it might have connections with a 14th century Cistercian grange located half a kilometre to the south.

A 1 m resolution reconnaissance fluxgate gradiometer survey revealed a rectangular anomaly (30 m by 20 m) associated with several clusters of high positive data. One prominent anomaly was resurveyed at 0.25 m resolution and revealed two clusters of high positive data (683 nT and 666 nT) separated by a trough (408 nT). The form of the anomaly suggested two overlapping furnaces. A second prominent cluster of positive data revealed a further furnace, associated with a pronounced slag dump. A 0.25 m resolution survey over the furnace anomaly produced values above 1000 nT clustered in a north-south alignment. Weakly contrasting data around the anomaly suggested that it might once have been enclosed by a square structure. An inspection of this area on the surface revealed burnt stone, and fragments of roasted iron ore and charcoal.

The presence of charcoal and roasted iron ore on flat ground north of the slag dumps suggested that it might once have been a storage area. The original fluxgate gradiometer survey was extended to embrace this area and further surveys, including earth resistance and magnetic susceptibility, were conducted over specific features, for example the possible storage area and furnaces. All the geophysical techniques identified the storage area anomaly as a roughly circular area about 10 m in diameter, possibly confined on the north side by a linear anomaly. The fluxgate gradiometer survey produced values of about 30 nT, possibly generated by a burnt surface or concentrations of roasted iron ore. The earth resistance survey also recorded slightly higher readings that could have been produced by concentrations of charcoal, previously noted on other charcoal storage areas (Vernon *et al.* 1998). The magnetic susceptibility values were also elevated. The results of the surveys are shown in Figure 1, together with a basic interpretation.

In 2002 the HDAS were successful in obtaining a grant from the Local Heritage Initiative to finance limited excavations on the site with a long-term proposal to fully interpret,

[a] Department of Archaeological Sciences, University of Bradford, England.
[b] Huddersfield and District Archaeological Society, England

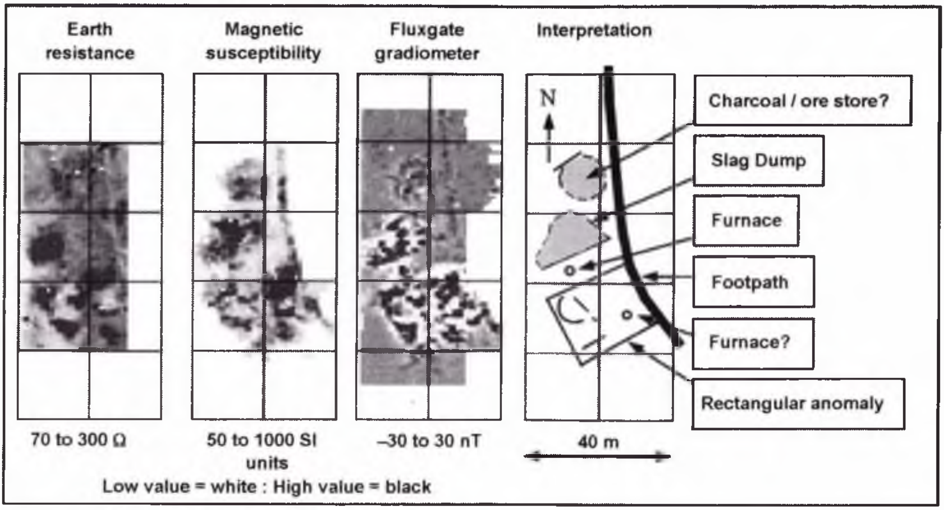


Fig. 1. Myers Wood. Fluxgate gradiometer data and interpretation.

conserve and present the iron-working site to the public. The first task was to gain information to date the site.

In September 2002 the Department of Archaeological Sciences, University of Bradford, was commissioned to undertake a series of excavations to take samples for archaeo-magnetic dating from furnace lining and other burnt surfaces, and charcoal for C14 dating. In addition the rectangular anomaly suggested some degree of permanency to the iron working, so it was also hoped to find dateable pottery fragments, not usually encountered on this type of iron-working sites.

Figure 2 shows the extent of the excavations. Initially four trenches A, B, C and D were opened up. Trench A investigated the possible storage area for charcoal sampling, B and C were opened up on the two furnaces, for archaeo-magnetic dating and D was located adjacent to the rectangular anomaly to try and find pottery or other dateable artifacts. During the course of the excavations it was realised that the slag dumps varied in slag type, so a further series of smaller trenches (0.5 m by 0.5 m by 0.5 m) were opened up to bulk sample the slag.

Trench A was initially 4 m long by 1 m wide over the north end of the anomaly and revealed one small pocket of charcoal. The trench was extended and revealed a burnt clay floor and further charcoal. This anomaly is now interpreted as a charcoal production area. The burnt clay floor has been sampled for archaeo-magnetic dating to determine whether charcoal production is contemporaneous with the iron smelting.

Trench B was initially 2 m square and revealed collapsed furnace material and slag surrounded by stonework. As the excavation was deepened and extended, it became apparent that a second furnace feature lay immediately to the south, with its tapping channel still containing slag trending underneath the identified furnace anomaly. The combined furnace and earlier tapping channel had produced the elongate positive anomaly.

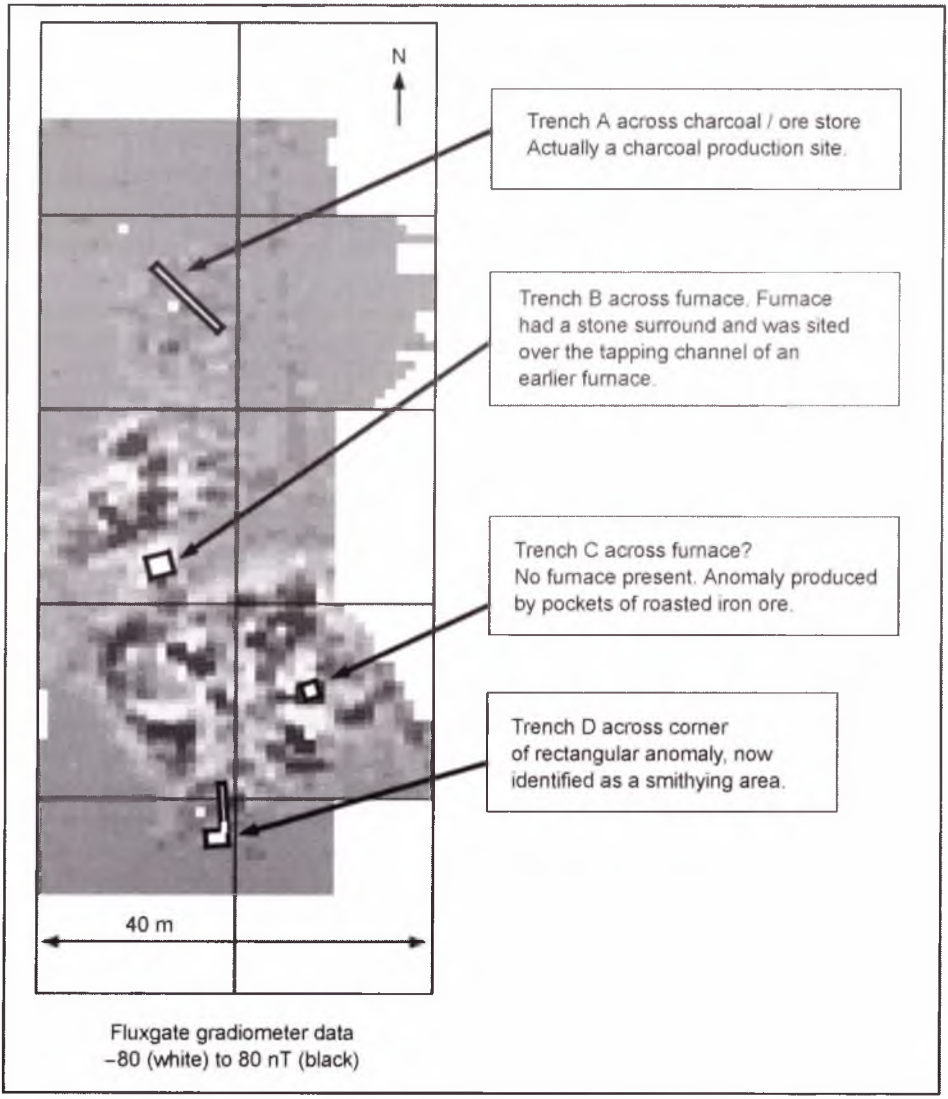


Fig. 2. Myers Wood. Plan showing the fluxgate gradiometer data (1 m resolution) with the locations of the four main trenches (A, B, C and D), together with notes on their interpretation.

Trench C on the overlapping furnaces anomaly was also 2 m square. The excavation was predominantly in slag and as it was deepened it became apparent that there were no furnaces. Eventually several pockets of roasted iron ore were exposed with occasional layers of burnt clay and rare fragments of pottery. This area is now interpreted as a dump that may have been used for the storage or roasting of iron ore.

Trench D in sandy subsoil was initially 2 m square but extended north. It did reveal concentrations of smithying debris and pottery. On re-examining the fluxgate gradiometer data it is now thought that a small rectangular weakly contrasting anomaly adjacent to the trench might be a smithy.

The paper demonstrates that the simple concept of iron-smelting sites consisting of just slag and furnaces is not always true. Geophysical surveys can reveal areas of slag and identify furnaces, but great care should be taken when interpreting such data. In the case of the Myers Wood geophysical surveys the simple interpretation was flawed.

REFERENCES

Vernon, R., G. McDonnell and A. Schmidt 1998. The geophysical evaluation of an iron-working complex: Rievaulx and environs, North Yorkshire. *Archaeological Prospection* 5:181–201.

Vernon, R.W., G. McDonnell and A. Schmidt 1999. Medieval iron and lead smelting works: a geophysical comparison. In *Geoarchaeology: exploration, environments, resources*, A.M. Pollard (ed.), 15–34. London

Prospection with the new FM 256 fluxgate gradiometer system and other instrumental techniques

A.R. Walker[a]

The new FM 256 fluxgate gradiometer system can be operated as a single stand-alone gradiometer or in dual gradiometer mode. The dual mode uses two instruments carried together in a carrying frame to double the survey speed or, by using interleaving, to provide increased survey density (double or quad). Data can be collected at up to 16 samples/m at a resolution of 0.05 nT and stored in a 256 000 reading memory. Basing the system on two individual gradiometers gives optimum flexibility since they can also be used separately at different sites when required.

The dual gradiometer system uses two instruments carried together, 1 m apart, either to double the speed at which a survey can be made with a 1 m traverse or to increase the sampling density of a survey to resulting traverse intervals of 0.5 m or 0.25 m. A three-sided CF6 carrying frame supports the two gradiometers (Fig. 1). An FM 256 acts as a master sample trigger that controls a second slave gradiometer – this can be either another FM 256 or an FM 18/36. Once data sets have been collected in the two gradiometers they are downloaded, and assembled into two individual composites (data sets) as normal. The two data sets are then easily merged together to form the final composite data set – Geoplot 3.0 provides for this in one operation.

The system can be used in either parallel or zig-zag survey mode. When used in zig-zag mode the operator, not the frame, turns around at the end of a traverse, thereby avoiding the

[a] Geoscan Research, Bradford, United Kingdom

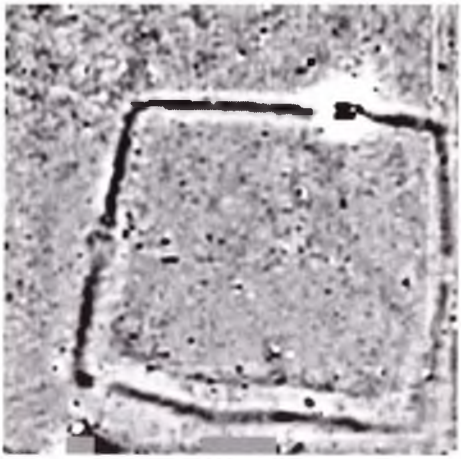


Fig. 1. Iron Age enclosure system surveyed with a dual FM 256 system (FM 256 master + FM 36 slave). Grey scale range +/–3 nT. Data was sampled at 0.7 s/m, 4 readings/m, traverse interval 1 m, zig-zag mode. Processing interpolates this to sample and traverse intervals of 4/m. Area = 1 ha, survey time just over 2 hours. Data shown courtesy of the Huddersfield and District Archaeological Society.

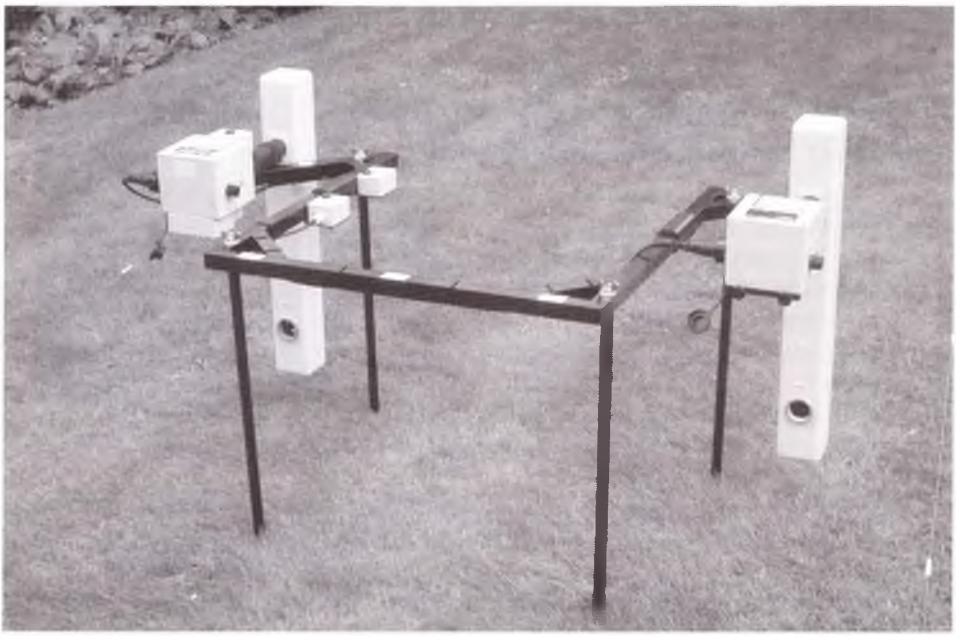


Fig. 2. Dual gradiometer system using an FM 256 (master) and FM 36 (slave) mounted on a CF6 carrying frame.

introduction of direction dependent heading errors. Since there is no need for restrictive harnesses, turnaround is very rapid.

Examples of surveys and results of other instrumental techniques will be shown on the poster.

Getting more from our data through data fusion and modelling

Meg Watters[a]

Data fusion opens a new dimension to geophysical data processing and display. Complex site imaging can be achieved through the merging of visual data sources such as LiDAR, hyper-spectral and aerial photography. These visual sources can be combined with other types of site data including geophysical survey results, geological, hydro-geological, soils analysis and excavation information.

This paper presents current research and exploration of new advances in geophysical data presentation and interpretation. Not to be mistaken for a GIS, multi-spectral data fusion enables full movement around and within data sets collected through multiple methods. Data fusion, in essence, is conducted by modelling individual data types that can then be merged for a comprehensive presentation of the entire site. Cross-referencing data models created in a range of softwares facilitates comparison and analysis in order to extract a more insightful understanding of the complex nature of the archaeological site.

As a new approach to data processing and imaging, this technological process will present not only accurate models of subsurface features, it will introduce a new type of analytical tool that will enable a better interpretation of our archaeological record.

Future planned work will seek to investigate the correlation and trends that can be derived through the comparison of geophysical data to other data types on a number of sites with contrasting environmental, geological, and archaeological conditions.

[a] Institute of Archaeology and Ancient History, University of Birmingham, United Kingdom

Testing multi-spectral airborne remote sensing for detecting archaeological sites under the sands of the Inner Hebrides of Scotland

Sandy Winterbottom[a] **and Tom Dawson**[b]

Multi-spectral airborne remote sensing is potentially a very valuable tool for detecting unknown archaeological features. However, few studies have been undertaken in this area and many questions arise on the use of this type of data. Uncertainties centre around optimal wavelengths to use for detecting buried archaeology, what types of features can be detected,

[a] Department of Environmental Science, University of Stirling, United Kingdom
[b] AHRB Research Centre for Environmental History, University of St Andrews, United Kingdom

the effects of different sediments overlaying sites, and how the imagery should be interpreted and processed.

The study areas chosen were parts of the extensive and mobile dune systems on the islands of Coll and Tiree, Inner Hebrides. The archaeology of the islands had been extensively mapped by Erskine Beveridge at the end of the 19^{th} century. A subsequent survey by the Royal Commission in the 1970s revealed that many of the sites noted by Beveridge were no longer visible. There is a strong possibility that drifting sand has covered some of the missing sites.

Information on all known and suspected sites (derived from national and local archives) was plotted on a GIS before the collection of airborne remote sensing data.

The study tested the use of daytime and night-time airborne thematic mapper (ATM) data which includes a thermal channel, and compact airborne spectrographic imager (CASI) data for the detection of buried stone features within the windblown, sand-dominated landscape.

Wavelength band combinations were tested for creating false colour composite images which optimised detection of possible features. In addition, the ATM data was compressed to four bands using a principal components analysis (PCA). Images composed of a true colour composite, false colour composite, daytime thermal, PCA colour composite, night-time thermal and thermal difference (daytime minus night-time) were displayed on the screen concurrently and geo-linked so that they showed a zoomed-in view of the same location. The images were also linked to ordnance survey (OS) digital map data, and known and suspected sites held on the GIS were also displayed.

The images of the study area were then scanned systematically. All anomalies were checked against present day OS maps to confirm that they didn't relate to modern features. They were also compared to historical OS maps, in many cases confirming that the anomaly related to a building which has disappeared since publication of the original map.

Screen shots were captured of any suspected archaeological features and these were entered into a database. Information on the co-ordinates and possible interpretation of the feature was also recorded. The database was linked to the project GIS.

During the initial fieldwork stage, co-ordinates were entered into a global positioning system (GPS) and a ground survey was undertaken. This located the positions of features in the field, which were then prioritised for further investigation or ruled out as topographic or other non-archaeological features. The field survey also gave an opportunity to record the position of features which were visible on the ground but not detected on the initial scan of the images. The GPS was used to record the location of any such feature.

The images were then re-examined in order to determine why these features had not been detected initially. Experiments were also made with new wavelength band combinations whilst looking at areas of known archaeological activity.

A number of interesting sites have been identified for further investigation and these are being targeted for survey by ground penetrating radar (GPR) in March 2003. Depending upon the results of the GPR survey, controlled trial excavations will be conducted on selected sites later in 2003. These are intended to characterise the nature and extent of the buried remains. The results of these further investigations will be available for presentation at the conference.