

Foreword

Non-invasive surveys carried out at Ptolemais are implementation of the concept adopted by Professor Tomasz Mikocki, who in the introduction to the published in 2006 Archaeological Tourist Guide wrote: "Having been offered a wonderful opportunity to conduct research on one of the most important archaeological sites in the world we have decided to carry out mainly non-invasive works (rather than traditional excavations) in order not to degrade the integrity of the ruined Ptolemais". With this in mind, Prof. Mikocki has set an ambitious program of non-invasive investigations being aware of the fact that the research carried out over a wide area require non-standard measures and prepare a new methodology for this type of work. His idea could be realized thanks to a grant program of the Polish National Center for Science (research grant NN 109 316237), as an interdisciplinary project "Non-invasive mapping of the ancient remains of the city of Ptolemais in Libyan Cyrenaica."

The project, whose results are presented here as a successive volume of the Ptolemais in Cyrenaica series, is one of the largest such projects in the Mediterranean basin. More than 150 hectares of land was surveyed via non-invasive prospecting methods. Due to the size of the area with documented archaeological remains (invisible on the surface) Ptolemais may be counted among the largest sites with such documentation.

In carrying out the research, a local geodesic grid was developed for the entire site with benchmarks fixed to mark squares of 40 × 40 m (1400 temporary points and six base points allowing a transposition of the local grid to any geodesic or geographical coordinate system). The grid may be easily recreated and used both for continued excavations at Ptolemais and for further non-invasive surveys.

On the basis of satellite images and aerial photography performed for the project, ortophotomaps were prepared for an area of 180 hectares. The maps were georeferenced and fed into the spatial information system for the site. Archival maps fed into the system were also georeferenced (including maps and topographical sketches made by nineteenth-century travellers), as was documentation produced in the course of twentieth-century excavations by various expeditions researching the site. The resulting digital database allows for a more detailed documentation of archaeological remains visible on the surface. It is also important that the data fed into the system may be modified with incoming new information about the site, resulting from both excavations and non-invasive surveys.

The basic methods of field measurements were magnetic measurements performed with a proton precession magnetometer and a caesium vapour magnetometer, as well as gradiometric readings using transducers. The geophysical maps illustrating the measurements were developed to offer a uniform graphic representation of the data from different measuring devices. Filters and transformations used in commercial software for graphic presentation of geophysical measurement results were used in addition to algorithms developed specifically to allow for a filtering out of defects resulting from the varied topography. This proved particularly difficult in the case of Ptolemais – a site spread out on terraces over a large area and with mutable lay of the land, as well as varied geological composition, with rock straight under the surface in the south of the city and numerous layers of relics of ancient architecture in the central part. In such circumstances developing a methodology of field measurements and rules for unifying their results into a single system makes for a great

achievement in the field of archaeological-geophysical research.

An equally important element is to determine the depth at which archaeological remains are buried and their configuration on the basis of earth resistance surveys – in our case, a series of geoelectrical probes using a Schlumberger measurement system and multi-layered profiles with a dipole or dipole-dipole system. The methodology for measurements of this kind was worked out in the mid-1980s, but was difficult to use in the case of Ptolemais, where a high-resistance sandy layer lies on much of the site's surface and masks resistivity changes in the lower layers. For that reason, a special-purpose method of registering measurement results was developed, allowing not only for a successful exploration of layers down to a significant depth (sometimes over five metres below the ground) but also for graphic presentation of the results with the use of commercial software packages (Golden Software Surfer or DW Consulting ArcheoSurveyer) and software for processing electric resistivity tomography data (RES2DINV or RES3D). We could thus develop documentation both in the form of vertical profiles of changes in apparent resistivity and maps of resistivity configurations at different depths of penetration. This is the fullest form of reconstruction of the location of buried archaeological remains.

An important methodological achievement was to develop the rules of integrating the data gained not just through geophysical measurements, but also photogrammetric documentation, aerial photography and satellite images, topographic measurements (including three-dimensional profiling of the surface areas surveyed). The main achievements in this field include the launch of a measurement system to simultaneously register magnetic field intensity and changes in elevation of the terrain surveyed, as well as adapting free-to-use software package AUTODESK MapGuide for the purposes of the research.

Combining magnetic and topographic measurements was previously possible thanks to certain commercial systems, but the location of measurement points and measurement of height could only be defined to within over 10 centimetres (using Differential Global Position System – DGPS). In the course of the project, we used Real Time Kinematic GPS Measurements – RTK GPS, achieving accuracy to less than one centimetre. At the same time we developed procedures for the RTK GPS instrument to control the work of the caesium vapour magnetometer. The result was both an increase in measurement accuracy and a near doubling of the speed of magnetic prospecting.

Adaptation for the project of the MapGuide software allowed us to develop our own graphic print-outs in a standardised geographic coordinate system (a conventional system with the transformation points defined to allow for any coordinate system to be employed within the global system) on a scale optimal to each stage of the analysis (1:5000 for general questions, 1:1000 and 1:500 for detailed analyses). The system also allowed for a full integration of the vector data (the results of topographic measurements and models based on photogrammetric analysis of the results of aerial-photography prospecting) with georeferenced raster graphics (data from magnetic and electric resistivity prospecting and ortophotomaps made on the basis of aerial photography). Another positive, which contributed to increasing productivity, was the availability of all the data on the internet.

The aforementioned achievements relate mostly to the applications of non-invasive survey methods. In addition to these, significant progress was also made in studying history of the city at different stages of its development, as well as the role of North Africa against the background of the other centres of ancient civilisation. This allowed for a verification of the existing hypotheses about the history of Ptolemais and setting new directions for future research on this important centre – one of the capital cities of the ancient world.

The most important achievement was the determination of the module used in the Hellenistic era for laying out the city and the hypothetical location of the point from which the construction started.

Finally it is worth pointing out that similar documentation in the form of geophysical maps, photographs subjected to photogrammetric methods or three-dimensional models of the terrain has been developed for a number of sites other than Ptolemais, including in the Mediterranean basin. A wide application of non-invasive methods is becoming a standard research procedure. In the case of Ptolemais, however, the data from non-invasive surveys have been supplemented with archaeological commentary and treated on an equal footing with other sources (gained in the course of excavations of textual analysis and epigraphic studies) to reconstruct the past. As a result, a contribution has been made in both archaeological and historical terms to our knowledge of North Africa in antiquity and blazing new trails for research in this field.

In the course of the project, all the remains of the city walls still visible on the surface were documented in a modern way, while invisible relics, whose presence causes deviations in physical properties of the soil which register as geophysical anomalies, were mapped.

The data have been stored on a proprietary server and made available on the internet, thus introducing them to general circulation in the academic world. All the information has been integrated into a single system which allows for the creation of different levels of access and control of their use by authorised personnel.

After mapping the remains invisible on the surface and confronting the data with results of previous excavations, it was possible to develop archaeological commentary regarding such issues as the reconstruction of the city's layout and recreation of the city grid; location, size, layout and function of individual public buildings (theatres, amphitheatre, bouleuterion, gymnasia, temples) and their place in the context of the city's general

plan. In continuing topographic research initiated by Professor Tomasz Mikocki, focus was squarely on issues related to the city's planning and organisation of public space and private construction. Hypotheses were also presented for the exact routing of the city walls, location of towers and gates and their links to the existing transport system. Non-invasive surveys provided new data allowing for verification and completion of hypotheses regarding the city's reconstruction at various stages of its development (including the reconstruction after the A.D. 365 earthquake) and the changes in building functions and locations in late antiquity.

In carrying out research on the private construction, the surviving remains of houses uncovered in the course of excavations were discussed in the context of the entire *insulae*. This was possible thanks to the reconstruction of the *insulae*'s layout on the basis of the observed geophysical anomalies. The data allowed for the determination of the size of *insulae*, the width of the chief transport arteries and side streets, as well as the verification of hypotheses regarding measurement scales used in founding the city. They also confirmed the dating of the main activities leading to the city's foundation to the reign of Ptolemy I Soter, that is to the end of the fourth century B.C.

From the point of view of archaeological geophysics, results were obtained to form the basis of extending analyses with a view to an optimal use of non-invasive survey methods at sites with multi-layered architectural remains. Such building remains, dating to different periods and characterised by plan changes in individual structures, shifts in axes and directions of streets and transport arteries, produce anomalies that are very hard to interpret. Such anomalies are in practice impossible to link to specific remains. Even a preliminary analysis of Ptolemais survey results shows that a successful and relatively safe interpretation of anomaly sources can be conducted, if it is based not just on geophysical measurement results, but also linked to results of

a wide range of non-invasive methods. By this we mean analysis of satellite and aerial photography, modelling of the terrain on the site, but most of all taking into account the results of previous archaeological work and a thorough analysis of historical sources (epigraphic and literary).

Practically all the objectives set in the project were achieved, albeit with a delay due to the political situation in Libya in 2011, which rendered fieldwork impossible.

The objectives achieved may be divided into three groups. The first concerns analysis of available archaeological evidence, satellite images and cartographic materials (contemporary and archival) to determine the areas set for geophysical measurements within the site. An important element of the activities was the selection of methods and working out of an optimal way to carry out geophysical measurements in such a way as to guarantee the most credible survey results possible in the conditions found at Ptolemais (actions carried out to achieve this included testing of measuring devices and software for processing the non-invasive survey data). In direct connection with this, a proprietary, original system was developed to allow for topographic and magnetic measurements to be carried out simultaneously by linking the caesium vapour magnetometer with the RTK GPS. The surveys were also directed at developing the methodology both of carrying out measurements and the processing of their results.

The second group of objectives was connected directly to the carrying out of field prospecting. This included:

- developing a way to plot the geodesic grid and set photo control points (which allow for aerial photography documentation to be processed, including photos taken from the air with the help of photogrammetric programs) to allow integration of the data gathered into a uniform system that not only facilitate preparation of graphic documentation, but also spatial analyses necessary for fuller interpretation of the survey results;

- developing a system allowing for controlled aerial photography (with the possibility of sending the image visible on the liquid display screen and taking pictures with the as many visible photo control points as possible);

- testing the available photogrammetric software with a view to selecting a package best suited to the conditions at Ptolemais that would allow for transposition of photographic documentation into three-dimensional models and orthophotomaps that could be attached as a separate layer to the system of the site's spatial information system;

- testing spatial information software and adaptation for the purposes of the project of the Autodesk MapGuide software package to allow for a uniform graphic documentation that would contain data both from geophysical surveys and from topographic measurements and photographic documentation.

Last but not least, the third and most important group of objectives was related to the archaeological commentary developed for the site. The point was not merely to identify and explain the sources of the observed geophysical anomalies but most of all to provide new information about the site regarding the following issues:

- confronting information from traveller reports with the picture of the site based on a full range of non-invasive survey methods;

- location of the port and port installations and determination of the places that require verification through excavation (including with the use of submarine prospecting);

- recreation of the module used in the Hellenistic era for the planning of the city and the hypothetical location of the point from which the implementation of the plan started;

- verification of hypotheses concerning the function of individual structures located via non-invasive survey methods and capturing the traces of hypothetical reconstruction and changes in the street grid in successive periods of Ptolemais;

- an attempt to recreate a typical house plan and the rules of laying out *insulae* for residential construction;
- verification of hypotheses regarding location of public buildings (including churches and basilicas) in late antiquity;
- evaluation of the data gained from non-invasive survey methods for planning further excavations within the *insula* selected by the expedition of the mission of the Institute of Archaeology of the University of Warsaw and for setting key locations for necessary excavations at Ptolemais.

The project confirms most of all that the application of non-invasive methods makes possible surveys of large areas (at Ptolemais, an area of around 200 hectares was surveyed and detailed geophysical maps were made for 140 hectares within the city walls). Such large-scale research would have been prohibitively expensive with the use of classic excavation methods (it is worth pointing out that the fieldwork conducted over 12 weeks yielded information on an area of nearly 2 000 000 m², while the area excavated by the University of Warsaw over the period of 2001-2010 amounted to 2000 m²).

The archaeological-historical study demonstrated that a correct interpretation of the data gained from non-invasive surveys may to a large extent supplement and expand our knowledge of the archaeological sites under examination while laying foundations for verification of hypotheses regarding history and setting new directions for further research, including classic archaeological excavations.

The presentation of the results (mostly regarding technical aspects) at international conferences regarding archaeological prospecting and preservation of cultural heritage even before the end of the project has led to the situation where the latest wide-area non-invasive surveys come with sometimes extensive archaeological commentary. This is not limited to a simple explanation

of the sources of observed anomalies and the evaluation of the degree of their usefulness for planning excavations, but includes an analysis of the results in a wider archaeological context. It should, however, be noted that in general this part of the report tends to be written by the archaeologist commissioning the project and not, as is the case at Ptolemais, by a team of archaeologists who can evaluate the issues in all their complexity.

The ground survey methods developed for the project, which integrate the results of geophysical measurements with topographic measurements and photographic documentation (including aerial photography with the use of a number of devices – aerostats, aerodines or drones) are at present among the standard procedures undertaken in Poland and abroad, especially in the case of surveys for the purpose of cultural heritage preservation.

The system launched in the course of the project to control caesium vapour magnetometer measurements via the RTK GPS system is one just a few such devices in the world (and is certainly unique in Polish archaeology). Commercial systems tend to limit themselves to the less accurate DGPS location system, while those used in mobile devices fail to provide sufficient data to create three-dimensional models of the terrain. The system is at present successfully used at excavations by the Institute of Archaeology of the University of Warsaw at a number of sites in Poland and abroad.

At the end we wish to stress that the research could never be carried out but for the hardware grant financed by the Foundation for Polish Science, a loan of equipment and measuring devices by the Archaeology and Ethnology Institute of the Polish Academy of Science and the wide-ranging help from our Libyan colleagues – both the authorities of the Antiquities Departments at Tripoli and Benghazi and the Archaeological Museum at Tolmeita in the person of its Director Faraj Abdul Karim Omran Tahir, whom we owe special thanks.

KRZYSZTOF MISIEWICZ