Research at South Abusir in 2001-2002 – methods and results

Průzkum jižního Abúsíru v letech 2001-2002 – metody a výsledky

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In the last few years modern non-destructive prospection methods have been applied to the site of Abusir – satellite photography, geophysical examination and 3D surface modelling of the cemetery and individual archaeological features. In this article we discuss the benefit of employing these methods to render with current archaeological field excavations. The analysis and synthesis of the obtained results have mainly enabled us to observe the evolution of the burial ground of South Abusir throughout this, then we further study the structure of the cemetery in connection with the social status of the individual tomb owners and also to more closely examine the significance of the burial ground in South Abusir for an understanding of the whole Abusir necropolis burial area.

Amongst the main results that have so far been produced are georeferenced photographs of the main investigated features, a complete 3D map of the area with all of the features visible on the surface. We have also prepared several geophysical maps and satellite photographs including not only the area of Abusir but also the main cemeteries in Abu Gathara and the pyramid fields in Saqqara and Dahshur. Mutual comparison and interpretation of the obtained data shows, that the individually used methods are complementing and consequently irreplaceable. A satellite image in the appendix is also part of the article as a series of detailed sections in the text.

Old Kingdom – pyramid fields – Abusir – geophysical prospection – satellite imaging

1. Introduction

The presented study is the first officially available general outline of the basic methods and results of the surface, geophysical and long-distance survey that was carried out in 2001 and 2002. We are dealing here with activity which took place at the Czech Archaeological concession in Abusir approximately 30 km south of Cairo. Abusir is a site situated on the west bank of the Nile, at the transition of the Western Desert plateau into the fertile Nile valley. Four pyramid complexes were built here for the Fifth Dynasty kings. Subsequently, extensive necropolis of the members of their families and officials of the Ancient Egyptian State of the time gradually grew up around it (see generally Bárta – Rieger eda. 2001; Veres 2002).

The southern part of the concession was selected in order to test the methods in question. This area is currently one of the principal centres of activity of the Czech Institute of Egyptology and the Czech National Archaeological Centre of the Faculty of Arts, Charles University, Prague. An extensive necropolis which grew up over a period of several centuries is situated here. It contains non-royal tombs with sources, which have a fundamental significance for our understanding of the third millennium B.C. period. These sources are relevant both for an understanding of the evolution and structure of the early Egyptian state, and for the end of the of the Old Kingdom period. Apart from members of the Czech Institute of Egyptology and the Czech National Centre for Egyptology specialists from the Archaeological Institute of the Czech Academy of Science in Prague, the University of John Evangelist Pontyne in USA and Labor Geoinformatique de la Faculté de l’Environnement and the Institute for Archaeological Monuments Care in Most continue to participate in this project.

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The area of South Abusir represents an integral part of what we call today the Abusir - Saqqara cemetery complex (Kraus - A. Gerl eds. 2003; Coppero ed., 2003). Topographically it can be delineated as follows: in the south and east it is separated from Saqqara by Waab Abusir whose northeastern end lies by the village of Abusir, in the north by a plain, on which the Abusir pyramids of the rulers of the Fifth Dynasty are built and in the west by the Jebelberg (the so-called Lion's Hill). Geologically Abusir is an integral part of Saqqara, the so-called West Saqqara geological formation. Here Upper Eocene sediments dominate, mainly hard, brownish, dolomitized and silicified limestone (locally termed tab) which alternates with layers of clay. This formation is called Munit. On it lies the pliocene formation Koon el-Shubul. The present-day surface of the desert is formed by thick layers of gravel and sand (Ouazzane - Cherif; Badbury - Mohamed 1984, 127 - Figs. 2 and 136 - Figs. 1-5; Suid 1962, 98-99, 1975, 12-13; Khann - Kleiman 1993, 72-73; Soboda 1993, 167). Over the past several millennia the surface of the desert has often been exposed to flash floods, which gathered on upland plateaus of the desert and drained away through wadis to the Nile Valley. This is confirmed both by objects destroyed by water erosion situated on the slopes of these wadis, and by the results of geological surveys carried out in the area of Western Saqqara (Plate 1).

Until recently South Abusir played only a marginal role in our archaeological understanding of the sites forming the so-called pyramidal fields of Ancient Egypt. If we disregard the uncovering and documentation of the pillared court of the tomb of the mortuary priest Pekefety from the end of the Fifth Dynasty which was discovered in the mid 19th century by the Lepsius expedition (1842-1845), we can envisage this area as being without a past. This fact is also reflected in the contemporary literature of the 19th and beginning of the 20th century. On the map published by K. R. Lepsius in his monumental work Denkmaler aus Aegypten und Äthiopien (1849-1858) it is possible distinctly distinguish the Abusir pyramids in the north and in the south, deep in the desert, under number 1, only a place indicating the position of the Fekeftawy tomb (Fig. 1; Lepsius 1849-1858, vol. I, pl. 39). The large-scale excavations of A. Mariette in Saqqara in the second half of the 19th century did not impinge on the area of South Abusir in any way; Mariette's excavations stopped close by its southern edge as is also distinctly shown by a map of the excavated area published in 1889 (Fig. 2; Mariette 1889, pl. III). Maps of the whole Memphite necropolis which were published in 1897 by the French scholar de Morgan also did not change this situation (de Morgan 1897, pl. 10). In 1936 G. A. Reisner
published the work 'The development of the Egyptian tomb decoration at the accession of Cheops, which area contained Appendix C from W. M. Stevenson Smith devoted to the topography of the Saqqara burial ground. This work presented an attempt at the relocation of tombs which had already all been investigated in the 19th century. Some of them were also placed within the area of present-day South Abusir (South 1936, Appendix C, 290-411 and a map of the Saqqara cemetery). A. J. Spencer resumed Stevenson Smith's work in 1974 attempting to bring into agreement hitherto attempts to map and locate the individual tombs which had all been found in the immediate surroundings of the area of South Abusir (Spencer 1974, 1-11 and tab. 1).

In 1991, with the significant support of the Egyptian authorities, the Czech Institute of Egyptology started a systematic survey of the site. The area had namely recently been threatened by illegal activity. During the following twelve years it was possible to document and in the majority of cases also restore tombs of several high officials of the state. Prominent amongst these were particularly the tombs of the Commander of the Army, Keeper, the mortuary priest Fefikey, the overseer of the granaries of the Residence Ity, the property custodian of the king Itepef and the burial complex of vizier Qar and his sons (Prideaux 2002, Figs 1, 2. summary see Barta 2001; 2002a; Barta - Vadzura 2002; Vermeersch 2002, 216-225). At the present time it is being revealed that South Abusir played a significant role in its time. Its location at the transition between the burial ground in Abusir and Saqqara predesigned it for the gradual building of tombs throughout the greater part of the period of use of both the Abusir and Saqqara necropolises during the third millennium B.C. A further significant factor was that this part of the burial ground has never been officially excavated in modern times. Bearing in mind the historic significance of the area in question to our understanding of the history of the Ancient Egyptian state during the third millennium B.C. and the exposed location of the monuments it was necessary to conceive a long-term plan in 2000 for an approach to their study as a whole. This plan was intended to make it possible to document the main surface features of the site in advance of intrusive archaeological activity. A further imminent requirement was collecting data of such a nature that would...
facilitate the most effective archaeological excavations in the future.

Gradually a two-year harmonogram of surface investigation of the site was drawn up. It included a detailed geodetic survey, the creation of a detailed topographic plan, the production of photograms (photographic documentation) of the individual archaeological features with the aid of a so-called Swedish Tender, geophysical survey, a method of long-distance survey of the Earth (photographing the site from an observation balloon by remote control with picture control on the ground and satellite photographing of the site with a high degree of distinction in several multispectral bands). All this took place in combination with continuing archaeological work.

These methods were not chosen by chance. In each case it was a matter of their ability to contribute to the analysis of the questions, which were set as the long-term aims of the project. Of these we can name in this context:

1. how did the burial ground develop through time;
2. what were the spatial divisions of the burial ground dependant on time and the social status of the Ancient Egyptian dignitaries buried here;
3. how is the burial ground in South Abusir connected with analogous burial grounds in Abusir and Saqqara (both with regard to development through time and space).

4. was there a relationship between the burial ground in South Abusir and the Old Kingdom settlement? If so, how did it manifest itself?

At present, that is at the beginning of 2003 we find ourselves in the situation where we can examine the site and the features that have been investigated so far as part of a more significant whole from two viewpoints: in 2001 a surface survey and identification of archaeological features was undertaken with the participation of M. Danak, M. Tabakan and F. Cech within the framework of a detailed topographic survey. A year later, a month of the autumn season in South Abusir was dedicated to a geophysical survey, which was carried out in cooperation with the Archaeological Institute of the Czech Academy of Science in Prague, as represented by R. Krivansk and M. Tomásek. The results obtained during these two past seasons have fundamental significance not only for the understanding of the site as such, but also for the optimal orientation and selection of research strategies in the future.

2. The task of geoinformatics in Abusir archaeological excavations

Geoinformatics is orientated towards the development and application of methods for the solving of specific problems in the geosciences with special emphasis on
the geographical position of the features. The basic element is the so-called geofeature that is a feature related to a part of an area on the surface of the earth. It can be differentiated from other features with the help of:

a) geometry - spatial position;

b) topology - spatial relationships;

c) thematic attributes;

d) dynamics - time changes.

During the archaeological excavation in Abu sir methods and techniques from the field of geoinformatics have been applied, which in the last ten years have encountered on the other side all in all traditional and conservative discipline of archeology. New approaches like geographical information systems (GIS), 3D-computer-modeling, methods of long-distance survey of the earth (Remote Sensing, IRS, digital cartography and the use of satellite receivers Global Positioning System (GPS)) to determine the position of the observer on the surface of the earth together with tried and tested classical geodetical methods have been employed (Bring 2002, Deffays - Tzouvekas 2000, Matheson 2008).

It is necessary to emphasize, that geoinformatics or if you like geoinformatic technologies, are the only aid to support the solving of the determined aims and hypotheses of the research. These methods which bring new perspectives to old questions, provide non-traditional approaches and skills to enable the documentation and interpretation of the individual steps of the research and the carrying out of the analyses and syntheses.

Geodetical work - past and present

The cooperation between geodesics and Egyptologists already has a more than forty-year-old tradition. It began in 1962 during rescue excavations in Nubia (Petrie - Van der 1960) and later continued in the area of the Czechoslovak (today Czech) excavation in Abu sir. A brief account about the application of geodesy in archaeological excavations in Egypt is given by R. Vokal and M. Procházka 2000.

Up to the year 2000 geodetical work was always carried out at regular intervals of several years. This primarily consisted of the building up and maintenance of a point grid in the local system of coordinates, the planimetric surveying of uncovered archaeological features and structures, including the geodetical planimeteric and hypographeic surveying of the Abu sir area (for more about the building-up of a geodetical net, its precision and the methods of mapping see B. Vokal and M. Procházka 2004). The result is a hypographeic map on a scale of 1 : 2 000 with a basic contour line interval of 1 metre (Schev - Vokal - Procházka - Winter, Prague 1996). An integral part of the geodetical work was also the method of surface

Plate 2. The Central Mount of Abu Sir with the tomb of Khaper, Heqy and Mating MM (M. Rate). - Tab. 2. Centrální hřeben v životním okruhu M (M. Rate).
photogrammetry which was applied at the excavation in
Nabta (Thügel 1963) and during the survey of the
mastaba complex of Pu شب 3 (Metropolitan 1976).

From the autumn expedition in 2001 geodetical
activity significantly expanded and was made more
effective by using new instruments and methods. The
results of the geodetical work are the basic database
for other fields of geoinformatics - GIS, RS, cartography.
3D modelling and spatial visualisation. A set-up was
devised for geodetical work which was composed of
an electronic laser distance meter (total station) LEICA
TCA 507 and necessary equipment. It consisted of a 7"-
distance meter, which allows measuring up to a distance
of 80 m without the use of a reflecting prism. This
attribute was mainly used when surveying inaccessible
places and when working in the interior of tombs and
underground. The total station has basic geodetical
software in its equipment, which immediately determines
the spatial coordinates of the measured points, including
the defined attributes in question, during classical
geodetical processes (theodolite measuring, zoning,
and so on). The database of coordinates is then imported
into the GIS software (see below). The accuracy of the
station is sufficient for the creation of archaeological
maps and plans.

The following tasks were dealt with:
1. detailed planimetric and hypsographical survey
of the South Abusir area;
2. spatial survey of the surface and underground com-
ponents of archaeological features, which had alrea-
dy been uncovered and examined;
3. determination of the spatial position of the archeo-
logical features and structures that were subjectively
interpreted in the South Abusir area.

ad 1) a detailed field survey was carried out in the
current local point field, which consisted of more
than 6 000 spatial points in an area measuring
around 600 x 400 m. The database of points was
imported into the GIS software, where it was
further processed (see below).

ad 2) using classical geodetical methodology - the mea-
suring of points - the surface features, ground
planes and base lines were gradually surveyed. For
underground measuring, it was a matter of shaft
tombs, the mining survey method was used
whereby two points determined in the coordi-
ates were transferred in a shaft from ground level
to the bottom and one of these subsequently
formed the starting point when surveying the
underground space. This measuring was under-
taken without the use of a reflecting prism. The
results of the measurements - a database of spatial
coordinates, including an outline, are being gra-
dually worked on in the CAD and GIS media and
the result will be 3D spatial models of the
underground structures.

ad 3) archaeological structures have been identified by
subjective field interpretation in the South Abusir
area and their geodetical survey has been carried
out. The results have been imported into the GIS
software where they have been further analysed.

Geodetical work is not a separate part, but constitutes
the basic groundwork for the creation of spatial data for
further application in the GIS software. Furthermore for
the analysis of RS data and last but not least they serve
as the foundation data for cartographic output.

The Geographic information system forms the basic
applied method and takes in two different concepts. In
the first we see GIS as a technology, that is as the
hardware and software equipment necessary for the
creation and conducting of the second application. We
understand GIS as an application and information
system based on geodata, which serves as the ground-
work in the decision-making process of the organi-
sational entities. Geodata are spatial figures in digital
form, which are made up from graphic attributes, non-
graphic (text) attributes and related data (Thügel 1998).
Plate 3. Photograph of the tomb of Hetep-heres of the Czech National Centre for Egyptology, P. Cejl (Arch. Českého institutu egyptologického centra, P. Cejl)
Fig. 5. The overall magnetogram of the investigated site of Alaba South (So 166 featured). The north-western area of the archaeological investigation with the entrance complex of User Cen. It is possible to judge the extent and variability of the identified features (Archive of the Czech National Centre for Egyptology, Klosterkamp 2009).

Obr. 5. Celkový magnetogram prozkoumaného oblasti plochy Alaba South (So 166 rozebraný). Snímky početnějších komplexů vstupu do chrámu s jednou z operací a zároveň hladkého dokumentu rozsahu a variabilního značení identifikovaných útvorů chrámu (archiv českého národního centra egyptologického centra, Klosterkamp 2009).
Fig 6. Various types of holes of different shapes, dimensions, orientation and amplitudes of magnetic anomalies were distinguished. The illustrated south-eastern part of the area (top left) was scanned in the field from the magnetic survey. Sferetic survey includes the back of Heap 4, which was archaeologically investigated at an earlier date (Forschungszentrum der Deutschen Nationalen Archäologischen Abteilung, Berlin 2002).

Generally speaking, GIS allows the mutual connection of graphic and tabular data. Any kind of archaeological feature, which can be expressed in rectal form as a point, line or polygon, carries further attribute information and metadata with it. We can mutually analyse, compare and integrate these features according to their attributes, and create variant solutions in the GIS software. The feature can also be represented by a raster record, which can be analysed separately, in a group or combined with other forms of records.

The Abusir GIS Project has been implemented in the software of the ArcView 3.2 and ArcGis 8.3 program by the ESRF Corp company. It is a user-friendly program, which also contains basic extensions: ArcView Spatial Analyst, ArcView 3D Analyst and ArcView Image Analysis. Data from the geodetic measurements are imported into this software and are further processed.

The basic task was the creation of a contour plan of the South Abusir area. The database of coordinates of detailed points was imported into the GIS software.
which the processing of data was undertaken in combination with the existent small-scale planimetric and hypsographical plan. With the help of the Arc View Spatial Analyst extension the database of points was transferred to the TIN format and in a further step contour lines with an interval of 20 cm were generated. This was made possible by the high density of the measured points. Amongst other things a spatial model of the site (3D model) was created with the help of the TIN model. It strikes one of the basic thematic layers in the data structure of the Aegean GIS Project.

Another task was the creation of a GIS database of identified archaeologico-structures - features. The surface survey itself was carried out through the gradual systematic reconnaissance of the area, during which the deffinition and inventory of the archaeological structures - features was carried out. Every identified feature and structure was geodetically located, in either point line or polygonal - polygon form. Apart from the geodetical survey, the photographic documentation of features and registration of other cultural-historical information was undertaken. This data therefore became part of the GIS database.

Further processing took place in the GIS software consisting of:

a) the creation of individual graphic thematic layers - points, lines and polygons;

b) the creation of a database for the individual records, the assignment of matching attributes and their connection to the digital photographic database;

c) the creation of legends and basic graphic outputs.

During the surface survey a whole range of archaeological information and features were identified and recorded. It was not only a matter of ground plans and tomb plans (made of limestone and bricks of Nile mud or left), but also dumps, concentrations of pottery, human and animal bones, pockets of wind-blown sand and isolated artefacts i.e. a concentration of stone vessels fragments. It was thus possible to document more than 150 features of different values and interpretational potential.

For example, the ground plans of tombs with chapels and the estimated size of the built-up ground plan, in combination with the already uncovered features, enabled the making of a prediction of the cemetery development through time. This is mainly achieved on the basis of typological changes in the tomb architecture during the Third-Sixth Dynasties (around 2750–2290 B.C.), then decoration, inscriptions and spatial distribution. Dumps and accumulations of sherds indicate places where intensive subsurface clearly took place. In many cases we have documented dumps, but the archaeological features themselves are not distinct, so the dump becomes an important indication and sometimes the only indication of a feature that is unmarked on the surface. The resulting compilation of the thematic layers of the archaeological features has been imported into the GIS database part of whose output is the location of the archaeological features on a 3D model of the terrain (Fig. 4).

The long-distance survey method is another component from the field of geoinformatics that has been applied during the excavations at Abusir, it is a matter of getting informative features or phenomena from a distance - without direct contact with them:

- a person, either alone or with the help of a drone, is able to gain qualitative and quantitative information about the phenomenon and features surrounding him;
- every such phenomenon or feature influences its surroundings in some characteristic way.

The IS system creates:

- a subsystem for the collection and transference of data - the technical side of the procedure;
- a subsystem for its analysis and interpretation - a method for processing spatial information.

Analyse and digital records comprise spatial information in a similar way to a topographic or thematic map. The records contain two kinds of information:

1. information about the position of the displayed feature, their shape, size, distance from other features and so on:  

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*Fig. 2. Significant differences in the magnetic properties of individual features of the same structural material and form recorded using portable search devices with different magnetic susceptibility using a targetmeter in this area the remains of various types of masonry were tested bricks that were visible on the surface. 1 - concentration of the masonry debris found in the surface area. 2 - location of the features that were discovered during the surface survey. 3 - concentration of masonry found in the later Ge time complex. 4 - location of masonry found in the Late Ge time period. A. Differentiation by the type of non-geological material used in the construction of the masonry. B. Differences in the degree of geometric variation at the surface. C. Differentiation of objects placed on temporary platforms. D. Differences in the degree of geometric variation at the surface. E. Differentiation of objects placed on temporary platforms. F. Differences in the degree of geometric variation at the surface. G. Differentiation of objects placed on temporary platforms.*
2. thematic information - the kind of vegetation on the site in question, nature of surface and so on.

RS together with geophysical methods helped with the development of so-called non-destructive archaeology. The records show the mutual relationships and connections between present-day and archaeological features. They contribute to the prediction of the extent of rescue excavations, their topographic location and the structure of the area with the archaeological features.

In the Abu-Sir area the RS method is gradually being applied at three different levels. The basic one is photographic recording from the so-called Swedish taxi. From this analogue and digital photographic records are gathered from a height of about 7-8 m above ground level (Plate 3 and 4, Ceci 2002). The use of a hot air balloon with a tethered infrared photographic device is in the test stage. This system allows photography from a height of around 35-40 m above the ground.

The last level is the use of satellite records. The aim was to gather high resolution data and therefore we ordered a set of aerial videos provided by QUICK BIRD system of the Digital Globe Corp. company (www.digitalglobe.com). The satellite was pre-set on the basis of parameters supplied by us to record the area of interest from north to south and including the pyramid fields of Abu-Sir, Saqqara and Dahshur. The record was taken at 8.45 a.m. on 23, 2. 2005 in high quality, the resolution in the panchromatic zone is 0.64 in and 2.56 in the multi spectral zone (Catalogue E10106601001A99901).


The results of all the types of recording are analysed in the ITO program for the digital image processing or with the help of the AVI Image Analysis extension in the ArcView 3.2 (most recently 8.3) program. After the basic editing of the data it is imported into the GIS software, where analytical and synthetic analyses are carried out together with further topographic and thematic themes.

Global Position System

The Global Position System (GPS) allows us to determine the coordinates of the observer on the surface of the earth on the basis of the reception of
The future of the application of geoinformatical technologies

The first results demonstrate an unambiguous benefit for the work of archaeologists, who effectively obtain overall results in tabular or graphic form. Several methods and procedures have been applied over a very short period of time (the majority of them for the first time in Abusir). Their results form an inseparable part of the archaeological documentation.

A large amount of data has been assembled in digital or analogue form within the framework of both expeditions and now the data are being gradually sorted and analysed and cartographic output is being created. The first analyses and the evaluation of the component parts of the GT application project are being prepared.

3. Geophysical survey in 2002

After the first early applications of geophysical methods for use in Egyptian archaeology by Albert Heus in Musawwar and generally by Lambert Dolphilp in 1974 and 1977 (for a summary see Matheson 2000, 35ff) the Czech (then Czechoslovak) Institute of Egyptology was one of the first to specifically apply them during the survey of the Abusir pyramid field and the shaft tombs of the Late Period in the south-western part of the concession. The geophysical surveys led by V. Hasek had been undertaken in 1979-1980 and 1981-1982 (Hasek-Verner 1981, Verner-Hasek 1981; Hasek-Verner-Obr 1993; Hasek-Obr-Prikryl-Verner 1996; Hasek-Obr-Verner 1998). The majority of these geophysical results has been checked by archaeological excavations so that the region of the Abusir pyramid field can be considered as the most surveyed part of the Czech concession.

The aim of the geophysical survey carried out in October and November 2002 was to create geophysical maps of the features - mainly tombs - in the South Abusir area and their entering onto the archaeological map of the Abusir site. The appended geodetical work during the geophysical research included a gradual setting-out of a square grid of 50 x 50 m. placed into the existing local co-ordinate system (see above). The results of the geophysical survey were imported into the GIS database, in screen form they together with other thematic data form the individual topographical and thematic features of the archaeological site map.

One of the analyses was also the comparison of the results of the geophysical measurements with the results of the dating samples placed on the identified features created on their basis. The analysis was carried out in the GIS software and a high concordance between the subsequently identified features during the 2001 survey and the results of the geophysical prospection was revealed.

The aims and methods of geophysical survey

As well as the choice of sites for the geophysical survey also the beforehand undelimitable aims of the individual surveys were initiated by the requests and needs of the Egyptologists. These included:

1. the specific spatial identification of the subsurface preserved features and other ascertained situations;
2. proving of the continuation of the features and monitoring their dimensions, form and orientation in the landscape;
3. determination of the extent of anthropogenic activity, as the case may be cemeteries, in the surroundings of archaeological excavation places - determination of archaeologically prospective zones;
4. differentiation and determination of negative areas or areas without distinguishable anthropogenic activities.

On the basis of the existing evidence the archaeological aims could then be enlarged by some methodical questions concerning the possibilities and ways of exploring features in the basic aim apart from the general identification of underground relics of archaeological situations was therefore also:

5. finding the optimal way to explore the features present (tombs, as the case may be other mudbrick buildings composed of different materials) in the given desert conditions and;
6. assessment of the possibilities and limitations of geophysical research methods when monitoring other areas within the limits of the Czech concession in Abusir.

Apart from the experiences in Abusir it was, however, also possible to use results attained by some other archaeological expeditions carrying off geophysical field surveys in Egypt or on the broader territory of the Near East and published mainly in the last few years (Wolskiex 1997, Becker-Flassheder 1999b, Schmidt-Colinet-Plaatman 2001). Qualitatively new possibilities for the large area use of modern geophysical devices in said regions, their high profitability and new perspectives
for the computer processing and the presentation of the measured data have been repeatedly established by new surveys in Egypt (Becker - Frassnieder 1999a, Becker - Frassnieder et al. 1999b, Becker - Frassnieder et al. 1999c, Becker - Frassnieder et al. 1999d), and the measurements have been carried out using magnetic gradiometers for modern geophysical surveys. In several cases also supported by the positive results of the archaeological test excavations, have also become a valuable guideline when choosing a method for field measurements.

The following geophysical instruments of the Archaeological Institute, Prague, were selected for the geophysical surveys in the southern part of the Czech Republic in 2002:

1. A part of Smartmag SM-4G, Scintrex, Canada consists of magnetometers. This modern device constructed for a gradient method of coherent magnetic measurement allowed a fast, sufficiently detailed and large-scale wide-ranged survey of the selected areas in South Bohemia, Sansiř devices already had been used successfully on other geophysical surveys in Egypt (Becker - Frassnieder 1999a, Becker - Frassnieder et al. 1999b, Becker - Frassnieder et al. 1999c). The principle of the method was the same (as with the proton magnetometers used earlier at the site), established by observing local changes in the intensity of a magnetic field or its gradient. Bearing in mind previously documented disturbances in the magnetic structures of some building materials in contrast to the surrounding environment (Platon - Vermeulen 1990; Halka - Olbr - Pychyl 1998; Vlcek 1998), it was possible to use this modification of the magnetic method to detect all undetected remains of ancient buildings or, as the case may be, to locate previously masked or hidden structures. The survey was undertaken in a grid of about 10 by 25 m, a detailed survey also in a grid of 5 by 5 m. In total, during one single day there were about 2000 measured points and an area of up to 1 ha was explored.

2. An EM-38h, Geonics Canada device for the contactless electromagnetic measuring of the apparent specific conductivity for the case survey was also magnetic susceptibility. A DEMP device without the necessity of contact electric measuring and foresting sources (such a resistivity maximum effective depth below floor of 1 m) was used to verify the possibility for detection and differentiation of lowly/highly conductive or highly/lowly resistive materials. On chosen smaller areas with a predominance of several kinds of building materials the possibility of differentiation of stone, most often limestone or dried earthworm bricks and the sandy environment was tested. A supplementary electromagnetic survey was carried out in a grid of 1 x 1 m, as were other partial test profile measurements at random intervals or in more detail.

3. A kaipanometer for measuring the magnetic susceptibility in situ DK-S, Geographic in Czech Republic. A simple device for the detailed contact measurements of changes in the apparent magnetic suscep-

The geophysical survey in South Bohemia took place from October 30th till November 30th, 2002. For the first non-destructive survey, two areas were selected in the southern, southeastern and central parts of the Czech Republic, namely the site of the village Březnice, in the north of the country. In order to link current and future field data, a newly designed survey basis was used, utilizing the integrated orientation of the coordinates facing the cardinal points and a functional division of the area into 500 by 500 m working squares (Fig. 7). Over the course of 23 days of field measurements (alternating with days of data processing on a computer), we were able to explore an area of ca. 15 5 hectares (745.941) measured points).

A major part of the area of the Central mound at South Bohemia, where most of the so far investigated archaeological features are concentrated, was surveyed with field magnetometry. Here, under very variable and formable building grounds several periods (pottery, signal the limits of the useful application of the equipment), an extensive area of ca. 11.8 hectares was investigated. We did not utilize field magnetometry survey on areas that had evidently been shaded in modern times (areas of archaeological excavations, mounds, dumps or garbage) and places near to recent metal and non-metal objects, etc.). In spite of the most thickness and variability of the fully covered area of the terrain, most of the signal changes are not differentiated because of a relatively homogeneous sandy and slightly magnetic environment; they did not affect identification of the archaeological situations. On the other hand, in the results of the surface magnetometry measurements, we have been able to distinguish many linear and, in regards shape, typical magnetic anisotropies. These modelled and at the same time very extensive con-
centrations are proof of intensive anthropogenic activity and exploitation of the elevated and rugged plain east of Qarq's tomb complex as well as in the lower eastern part of South Abusir (Fig. 4). The results of the geophysical survey have undoubtedly proved the concentrated occurrence of relics close to the surface and the continuation of a necropolis over the next 7-8 lectures. It can be presumed that the majority of the identified positive linear magnetic abnormalities have their source above all in the brickwork made of Nile silt, and this fact is obvious at first sight when looking at the results which show the strikingly unequal distribution of the squarer magnetic abnormalities, which vary in dimensions, shapes, amplitudes, and different orientation. Presumably, it can be presumed that several different types of tombs from various periods of the Old Kingdom are concentrated here; the tombs vary in the quality of their preservation; the distribution of individual types of tombs is probably not a coincidence; and the repeated use or modifications of some areas cannot be ruled out.

The biggest, north-south extended rectangular magnetic abnormalities without obvious internal segmentation of the area are concentrated in the highest parts of the terrain in the western and eastern surroundings of the archaeologically investigated tombs of Kaaper, Ipy, and Hetepi. Of the filled in parts of Hetepi's tomb (except for two shaft openings) were included in the comparitive area within the surface survey, (2) on the basis of the merely thin line of circumferential mudbricks lining that has been distinguished, we may presume that the similar narrow magnetic line on four sides of the larger and smaller rectangular features (i.e., basically with relatively narrow mudbrick walling made of Nile silt while the homogenous internal parts of the objects will probably show proof of the presence of non-magnetic materials: limestone chips, soft). The area above the identified large rectangular tomb in the southwestern end of the area of the westward-elongated tomb of Kaaper was investigated by means of electro-magnetic exploration as well.

The results of this survey provided evidence of a distinctly similar set of points on the inside of the tomb and verified one of the possible methods of geophysical analysis of the non-conducting (stone) structures within the tombs as well. Another type of large, slightly rectangular and internally structured magnetic abnormality or tomb well probably be the feature to the east of Hetepi's tomb (Fig. 7). However, a better, full-area magnetic-meter survey of the feature was not possible in this place due to a stationary line lighting mast. Subsequent excavation of the ground plan of the feature confirmed that during the process of construction of this mudbrick tomb, the same material was used also for the segmentation of the internal area of the tomb. Prior to covering the area, detailed test surface measurements were taken on smaller parts of the large-scale feature using an 80 cm kapparimeter.

The results of these measurements above the present mudbrick and limestone parts of the tomb east of Hetepi helped us to assess the extent of the diversity of the magnetic and non-magnetic materials from the surrounding area and the potential for surface magnetometry measurements. Over the whole area of this artificial tomb we can distinguish a third type of smaller, extended and internally structured rectangular magnetic abnormality. Only some of the smaller tombs, which have apparently been better preserved and consist of strongly magnetic brickwork on all four sides, are well definable. Other tombs have only slightly magnetic to almost undistinguishable lines of rectangular brickwork and they are only identifiable in fragments (this characteristics is diagnostic for brickwork). Another probable type of large north-south oriented rectangular to trapezoidal magnetic abnormality with identified magnetic (clay mudbricks) materials inside the tombs was distinguished next to the eastern border of the investigated area. The features are already situated outside the terrace-like raised zone or more slightly inclined terrain which slopes down to the north towards the supposed edge of the extinct Abusir Lake, where no further indications of rectangular buildings of line shapes are apparent.

Furthermore, we can identify other very narrow and extended rectangular magnetic abnormalities which concentrated along the elevated border east of Vy'er Qarq's tomb complex and north of Kaaper's and Ipy's tombs. These tombs have strong magnetic and almost undiscovered circumferential brickwork with a different orientation, than the northeast-southwest features. The last distinguished type of rectangular feature is represented by the separate internally structured rectangular magnetic abnormalities dispersed over the middle part of the hilly area. The rectangular features or tombs are oriented north-northwest-southeast east and they are characterized by strongly magnetic circumferential brickwork. More indefinable linear objects - magnetic parts of other possible features - occur in the elevated broken terrain and also under the terraces on the inclined slopes.

If we take into account that it was common to use various types of construction material: Nile silt mudbricks, limestone, soft brickwork for the construction of the tombs over the whole area of South Abusir, then the great concentration of various features displayed in the results of the survey of the vast area only represents part of the features that are in fact hidden below the surface of the terrain. Significantly less magnetic abnormalities or underground remains of archaeologica1 objects were identified in the middle of the open plain under the knolls on the lower terraced level of the northwestern area of the current excavations. It appears that the rectangular and internally multiply divided magnetic abnormalities only define the magnetic parts of the features that were undoubtedly constructed from more types of construction material, which is apparent both from surface excavations and from the results of the complementary electromagnetic measurements. Furthermore, the lowest valley area of the east-west running crags, which extends from the presumed edge of the extinct Abusir Lake northeast of Vy'er Qarq's tomb complex, can be regarded as an area without clearly recognisable remains of buildings or further anthropogenic activities.
Plate 10. Close-up of the satellite image - South Saqqara. 1 - Pyramid of Pepi I. 2 - Pyramid of Djedkare Isesi. 3 - Pyramid of Merenefer. — Tab. 10. Detalj satelitskog snima - Sjeverne Saqka. 1 - piramida Pepija I. 2 - piramida Djedkare Isesija. 3 - piramida Merenifer.
4. Conclusions

Surface, geological and long-distance exploration of the site enables us, even in this phase of analysis of the cemetery, to try to preliminarily formulate the answers to some questions that were set out in the preface of the study.

The cemetery in South Abur' is continuously developed from the end of the Third Dynasty (2686-2675 B.C.) to the latest, when the first tombs of distinguished dignitaries (Hetep, Ity) were built. Later on, at the beginning of the Fifth Dynasty (2465 B.C.), the tomb of Kaaper followed. In the middle of the Sixth Dynasty (2250-2150 B.C.), the tomb complex of Vajar (Qar and the adjacent tombs of his sons first, Qar's junior and Senetjimen) were constructed. These tombs gradually occupied dominant topographic locations from the south-east to north-west, which undoubtedly made these buildings very impermeable structures at that time. Simultaneously, these structures constitute a certain southeast-northwest axis, which respects both the natural topography of the mound and possibly even the proximity of the Abur' lake, which could have formed the main access route to the area during the Old Kingdom period.

Meanwhile, a hiatus clearly arises between the beginning of the Fifth Dynasty and the middle of the Sixth Dynasty among the tombs of the Central mound, which was, based on the evidence, reserved only for highly distinguished dignitaries. However, the spatial disposition of the tombs indicates that it is possible to find the missing chronological horizon in the area northwest of Kaaper's tomb and southeast of Vajar's. This area undoubtedly contains an extensive tomb with a small chapel in the southeast part of the area west of it, which, however, according to the draft section, was not covered with a layer of debris. With respect to its size and location, it may be presumed that it belonged to a distinguished dignitary, and it appears on the basis of the position of Kaaper's disposition that it is likely that the chapel has an L-shaped ground plan that, chronologically, we are dealing with more or less the same period in the case of Kaaper's tomb. The tombs with this type of chapel are sporadic occurrences in Abur' and Saqqara areas, and at the same time they form a very specific group of tombs (Becker 2002a).

Significantly smaller tombs were built on the fringes of these main tombs. They were not built from limestone, as were the main monuments, but from Nile silt and mud bricks. These tombs have so far been archaeologically documented close to the northeastern corner of Kaaper's tomb, east and south of Hetep's tomb and finally also to the north and north-east of the Qar's complex. In addition to this direct evidence, some indirect evidence for lesser tombs may be added, it comes from the fill of the burial shafts of the Qar's family members. Numerous blocks were found in these shafts with inscriptions and/or relief, which must, because of their occurrence, have originated in the surrounding smaller tombs. On the basis of this indirect evidence, it may be considered that these tombs belonged to dignitaries of a lower social status and that the given blocks were used secondarily as the fill of the shafts at the time when the tombs had already been robbed, perhaps still during the fall of the Old Kingdom. Also, it cannot be excluded that in some cases terracotta overlaid wooden elements which originated in the rock-cut tombs.

A cemetery for the lesser officials was founded at the end of the Fifth Dynasty north of Qar's tomb, on the opposite side of the east-west running road. These officials, mainly priests, were taking part in the mortuary cult of the Fifth Dynasty kings in the Abur' pyramid temples (Hetepki and Heteph) and in Mehemaitou's complex (which indirectly indicates that this complex would have been located in the area of present-day Saqqara). The tombs of the dignitaries Hetepki and Ity from the end of the Pa'ide or beginning of the Fourth Dynasty unambiguously prove that at that time the burial-ground of the high officials of non-royal origins from the northern part of Saqqara (Qubbet el Finta and Firth Cemetery) was transferred to Abur'. Here we are dealing with tombs with the so-called 'transitional type', which combine two different philosophies for the creation of the access routes to the underground burial chambers - staircase and shaft. The beginning of the Fifth Dynasty in Abur' corresponds with the development in Saqqara, because restoration of the building works in the cemetery occurs mainly in the area north of Djoser's tomb complex. The construction of this complex was completed and the construction of its northern area was completed to a great extent, with the result that the tomb complex has a distinctive consistency with this development. Currently, we have no evidence that would cover the remaining period of the Fifth Dynasty in Abur'. It is highly probable that most of the non-royal tombs of the time were constructed on the pyramid field of Abur' and its close vicinity. For the period of the Sixth Dynasty it is premature to consider defining the nature of the areas to the main cemetery in Saqqara. However, at a given point it seems that dignitaries in the positions of court judges, etc. were buried in South Abur'.

A significant contribution of the detailed contour plan and 3D model of the cemetery is that it enables to detect several access routes which led to the cemetery from the Abur' Lake, e.g., from the northeastern part (Sorkhi 1999, 197-116) of the area. These routes can be defined as follows:
- they lead to the main, dominant tombs of the cemetery,
- they are located so as to guarantee access into the main parts of the cemetery and also to their less frequented parts,
- the course of these routes differentiates them from natural routes, which were created as a consequence of the natural formations of the geomorphology of this area, they have different slopes and courses, the surrounding human made features/tombs respect these routes,
- features occur alongside some of them. They can be associated with some cemetery activities, it is a matter
of smaller deposits of pottery fragments or a offering basin (in one case).

In several cases, it is apparent that some main access routes branch out into places where there is convenient access to the different parts of the cemetery, which are always dominated by one of the principal tombs (Masbaha MM, Iteerji, Iby, Masabba KK, Kasper, Qair). These routes are also built so as to come from the south-western side of the Abusir Lake towards the cemetery. Up to the south-west, there are also other archaeological indications that suggest that this water surface was used for the entrance to the cemetery in Abusir South and Saqqara in the area north of the Dyoser during the Old Kingdom period.

A significant number of tombs, which were identified in the northeastern part of the explored area and which are oriented in a northwest-southeast direction, remain unknown. No doubt they belong to the main chronological horizon of the cemetery existence. At the same time, it seems to be apparent that, similarly to the tombs in some other areas of this part of the Abusir-Saqqara complex, they respect the location of the Abusir Lake, which could have represented one of the main access gates to the cemetery.

The mutual comparison of the surface survey, geophysical measurement and satellite imaging provides interesting indications, which are relevant for the complete evaluation of the results. The results, which were obtained through surface survey, show that its significance consists especially in the interpretation of the bigger features (tombs), in the identification of specific structures-shapes of the cult chapels, and in the plotting of the individual major burial shafts or concentrations of bone fragments, pottery, etc. This is caused by the fact that the tombs are usually made of slate slabs and basalt or limestone blocks, in both cases their eroded corners leave clearly coloured traces on the surface of the desert. In the case of raums, signs of overturned and the differential absorbability of the terrain help to identify these features (Plate St. Complications occur in the case that the brickwork is built from stiff bricks, which is not materially apparent on the surface and which is difficult to identify through geophysical exploration as well. As for the tomb chapels and shafts, as a rule they were indiscriminately robbed and are filled in a direct consequence with yellow drift-sand, which is a very obvious desert phenomenon. In these cases, their wall remains form slightly elevated mounds, whose internal surfaces have the shape of a shallow concentric depressed clay.

A significant weakness of the surface survey became evident on the slopes, where the features are less apparent owing to geomorphological processes, especially washing and erosion. The survey is also subjectively affected by the optical properties of the light, the season and time of day. The disadvantage of the slopes, light and time of day significantly hinders geophysical measurement and satellite monitoring, too. Finally, another disadvantage consists in the parts-observation of the results: on the surface, many features were recorded by means of shorter lines; the other two methods are much more effective in creating polygons totally closed structures, e.g., the ground plans of the tombs.

In the case of geophysical measurement, its significance consists not only in the fact that it facilitates the verification of the results of the surface survey but it is not a matter of an array of geomorphological features. It is also very effective in the identification of possible internal structures of the individual features. The only weakness of geophysical measurement consists in the mapping of the stiff structures, which were not very successful because these are physically almost identical with the properties of the stiff sandshell of South Abusir. Geophysics was unexpectedly very successful even on the slopes, and it has significantly contributed to the comprehension of the archaeological plan of the site. A smaller-scale comparison of the achieved results immediately to the southeast and east of Iteerji's tomb also provides interesting results. Whereas in the south-east, two smaller, tightly fitting tombs with a brick east and inner sand and limestone west fill were detected through geophysical survey, they were not detected at all during the surface survey, probably because of the very undulating terrain at this part of the site. On the contrary, it appears that the surface survey was more successful on the relatively flat surface east of Iteerji's tomb. This could have been caused by the fact that the tombs here are built partly of stiff brickwork, but especially because there are many relics from robberies, which help to identify the main spatial features of the tomb excavation dumbs, shafts and pottery concentrations.

The satellite photography has several comparative advantages: a) the whole explored site was recorded at one moment in time, and it is more than an array of depressions; b) its potentially higher resolution allows for a better identification of the image; c) it crops the entire area. Through this means it is possible to identify and verify the existence of, in fact, a bigger dominant structure (the tombs MM, Iteerji, Iby, Kasper and the complex of Vizier Qar and his sons stand out in the picture), but do smaller structures. However, the picture has its greatest significance for the analysis of the overall properties of the explored site, e.g. basic components of the site, their spatial distribution, the geomorphology of the terrain and its interaction with human activity, and last but not least even for the etiology of the communication system. In this case, the previous conclusion is clearly confirmed: that the cemetery in Abusir South was accessible from the north-east through several routes, which led to the major groups of tombs in the burial zone.

A satellite picture does not detect all components and sometimes not even those that are detected through geophysical and/or surface survey. Therefore we can allow ourselves to state that its overall value is realized only when all these methods are linked.

The collection of data that has taken place over the last 2-3 years, will require just as much time for evaluation and interpretation. However, it is already evident, as this project shows, that with the aid of these methods it will be possible to significantly improve the quality and effectiveness of further archaeological activities so that they will be able to help us in particular to provide answers to the lesser known aspects of Egyptian archaeology in this area.
V průběhu GIS přijíždí další znovuvedené účastníky: a) tvory jednotlivých geomorfologických tvorů - bod, line, polygon; b) tvory datového katalogu jednotlivých záznamů, přiřazení odpovídajících jejich atributů a propojení na digitální topografickou databní stromové logiky a základní grafiky výstupu.

Střední prokazatelný prokazatel byl identifikován s konzervací, která byla řízena v rozmezí 150 objektů s různou výstupní vysokostí. Tak například bodový bod během 5. kroku byl rovnocenný s různými i nízkou a s čistým bodem na vlnění, konverzní konstrukce keramiky, lokální a zemědělské činnosti, zde či vyšší postavení, které ovlivňují interakci životních obvodů. V některých případech může dojít výstupní výsledek, ale samotné geomorfologické objekty jsou nízké výsledky, výsledky se tak však nepřímo dokládají existenci objektů, které byly identifikovány řadou plošných příznaků. Výsledná snaha sestavy všech objektů geomorfologických byla importována do GIS databáze a jednou z nejvýznamnějších bylo lokálně

Další oblasti geoinformace aplikované při výzkumu Švihova-

a, metoda dalšího prokazatele Země. Jedná se o základní informace o objektech a jejich místě na mapě - bez přímo kontaktní s daným objektem a příslušným detailu možná být přímo souvislosti z objektu v rámci, na základě vysokého důvodu. - členský smlouva a právní předpis je schválen zákonem podnětelný v komunálních informacích o příslušnému objektu a změnu, které ho ovlivňují. - člen staveb veje objektu oproti charakteru nebo místním změnám. Změna obsahu obějí dvou druhy informací:
1. informace o současných objektech, jejich rozvoji, velikosti, počtu objektů a osob, spojené s daným objektom; 2. informace o seznamu těchto objektů. GIS poskytuje spolu s geoinformací modelovou různé země-
onorombních informací země-mořského prostoru, na základě několika článků s danými informacemi a jednotlivými objektami. Země-mořský prostor je definován jako místní část informace o jednotlivém objektu.

Systém GIS neustále a přesně využívá daného prostředí pro přesněji zobrazení informací.

Geoinformace s oddělenými objekty, jejich rozvoji, velikosti, počtu objektů a osob, spojené s daným objektom; 2. informace o seznamu těchto objektů. GIS poskytuje spolu s geoinformací modelovou různé země-
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Větší část informace je využívána pro snahy o úpravu informace o jednotlivých objektech a společně s jejich rozvoji, velikosti, počtu objektů a osob, spojené s daným objektom; 2. informace o seznamu těchto objektů.

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