

Dakhleh Oasis Project
Columbia University
Excavations at Amheida 2005
Magnetic survey

Tatyana N. Smekalova and Sergej Smekalov

Physical Institute of Saint Petersburg State University

198504 Saint Petersburg, Russia,

Fax: +7-812-428-72-40

Phone: +7-812-114-30-81

e-mail: tsmek@mail.ru

INTRODUCTION.	2
The idea of magnetic survey on archaeological sites	2
Method and Equipment	3
Typical magnetic anomalies on archaeological sites	4
About the site	4
Magnetic “noise” on the site	5
RESULTS	6
A - Main or Temple Hill..	6
B - South-East area	8
C - North-East pottery quarter..	10
D - South area	11
E - Western kilns or furnaces	11
F - Southern-Western Hill	12
G - Western Hill	12
H - "Parking" area.	12
CONCLUSIONS	14
BIBLIOGRAPHY	14

Magnetic survey at Amheida has been carried out in January and February 2005 during 4 weeks. Magnetic survey has been used on different sites in Dakhleh Oasis in previous years. In 1998 a big “industrial” area (“C”) on the site Ismant-el-Kharab (Roman town *Kellis*) and a territory in front of the temple in ‘Ain-Birbiyeh has been covered with magnetic measurements; in 1999 and 2000 almost the whole area of the Early Dynasty site ‘Ain-el-Gezzareen has been surveyed (Smekalova, 2002; Smekalova, Milns, Herbich, 2003).

On Amheida parts of the “Main” hill and “ceramic” quarter, investigated by Dr. Colin Hope in 1970-ties, have been surveyed in January and February, 2000. Some of the results of the work of 2000 are re-considered and presented in this report.

INTRODUCTION

The idea of magnetic survey on archaeological sites.

Magnetometry is a non-destructive means for quick investigation of archaeological sites, which allow revealing underground structures, if their magnetic properties are different with the magnetic properties of surrounding soil.

If the earth were composed of uniform material, the Earth’s magnetic field on a certain area will be uniform. But local concentration of soils, rocks, and iron objects magnetised by the field of the Earth alter slightly the magnetic field nearby. These local disturbances of the global magnetic field are called magnetic *anomalies*¹.

Magnetic anomalies of the archaeological objects or naturally occurring rocks are due chiefly to the presence of the main magnetic iron oxide - magnetite, or related minerals, which could be presented in rocks in the amount of several percent to a small fraction of percent. Volcanic rocks (basalt, gneis, tuff, etc.) demonstrate the most strong magnetic properties. Sedimentary rocks (limestone, chalk etc.) are almost nonmagnetic. Granite, which is rather widespread rock, could be very magnetic one. It is important, that granite, as the other igneous rocks, has its own remanent magnetisation.

Iron oxides and hydroxides, which normally are existing in clay and soil in nonmagnetic forms, during heating are transformed into more magnetic forms. Therefore one could observe rather strong positive anomalies over fireplaces, kilns, bricks, heaps of ceramics, slag blocks or pieces, ovens etc.

There are also variations in magnetic properties of topsoil and subsoil: topsoil is normally more magnetic than subsoil. That makes possible to reveal ancient depressions (ditches, pits, pit dwellings,

¹ It is necessary just briefly notice some properties of the local anomalies from archaeological objects. **Assymetry** of the anomaly is due to the direction of the magnetic flux lines. **Depth dependence** – the deeper the source, the broader the anomaly is.

wells, big post holes and other silted-up features), filled with topsoil, mixed with ceramics, organic material etc., by weak positive magnetic anomalies they create on the surface of the archaeological site.

Method and Equipment

Method of magnetic survey of archaeological sites is to measure Earth's magnetic field point by point with a small step (not more than half a meter), close to the surface, and present the measurements on the magnetic map.

A co-ordinate system was set on the site for data collecting. There were plots 40 m wide and as long, as it is necessary to cover the area of this or those part of the site. Small wooden sticks were put each meter along two opposite sides of the plot and 40 m-strings with meter marks were used between the sticks.

The magnetic survey has been carried out with an Overhauser magnetometer from Gem systems GSM-19WG (Ontario, Canada), a model GSM-19WG. The measurements were made along straight and parallel lines (strings with meter marks); the space between the lines was 0.5 m. The magnetometer was operated in so-called "walking mode" measuring every 0.2 second, and the distance between the measurements along the lines was not more than 0.2 meter. The height of the mapping sensor above the surface of the ground was about 0.3 meter.

Because of the large area of the archaeological site, it was necessary to continuously monitor the daily variations of the Earth's magnetic field. The second magnetometer of the same type (Gem systems) was used to control any temporal changing of the magnetic field. It's sensor was installed at a base (reference) point in a zone of a normal magnetic field, while the other (working) magnetometer was moved about the site. The signals from both sensors were used for removing of daily (temporal) variations of the Earth's magnetic field.

The data were stored in the memory of the magnetometer; after the survey they were transmitted to a portable computer. Two different presentations of the magnetic data were prepared with help of Surfer software (Colorado, Golden): coloured contour maps and grey-scale maps. On the contour maps the positive anomalies were marked with blue colour, negative ones - with red colour. On the grey-scale maps the positive anomalies are marked with dark colour, the negative ones – with light colour. The contour interval was normally 2, 3, 5 or more nanoTesla (nT).

For the archaeological prospecting on Amheida the following magnetometers has been used in 2005:

- two Overhauser gradiometers GSM-19WG of GEM systems Inc. (Canada, Ontario) as main instruments (*Photo 1*);
- a cesium magnetometer PKM-1 of "Geologorazvedka" (Russia, St. Petersburg) as an additional tool (*Photo 2*).

Typical magnetic anomalies on archaeological sites

Archaeological earthen structures typically show local magnetic anomalies in the range of 1÷20 nT, more rare fired clay structures - 10÷1,000 nT, quite rare ferrous archaeological objects including slag - 20÷2,000 nT. Mud brick walls, situated in a cultural layer, could be seen on the magnetic map because of a weak negative anomalies (from -2 to -30 nT, depending on the magnetic properties of surrounding ground). Limestone walls, buried in soil, could give negative magnetic anomalies of the values of about -2÷-20 nT.

About the site.

The citizens of ancient Trimithis have chosen the western part of the Dakhleh Oasis (see *Fig. 1*) to place their town, probably, because of the good soil and plenty of water in this area. On the old Egyptian map of 1930 one could see many wells on the site and around it. Neighboring areas are marked mostly as “good soil” (see *Fig. 3*).

The main wealth of the oasis consists of two things: **the land**, which could give rich harvest twice a year, if it is watered enough; and **the water**, available all the time (*Photo 3*). But there are almost no other natural resources, which were necessary for the normal life of the people, particularly no metals and comparatively little wood. To control the oasis meant to control the water wells. The ancient people of Amheida built their houses on a big natural hill (*Fig. 2*). The material of the hill was very good for mud brick construction, except for its salty character. But one of the main reasons for the building of the town on the higher places was possibly that the citizens of the ancient town wanted to save the lower horizontal leveled areas for their agricultural fields.

Therefore it should not be too surprising for us, that to save lower areas for fields, people of Amheida used small hills around the site for brick and ceramic debris. One can see such heaps of ceramics on the eastern edge of the site, on the most western-southern and northern-eastern corners of the site and in other places. The heaps of ceramics are reflected in the magnetic field as a “mosaic” picture, a mixture of sharp positive and negative anomalies.

The use of clay from the hill for mud brick buildings has the result that for the magnetic survey that there is almost no contrast in the magnetic properties of the houses walls and surrounding soil. Therefore the magnetic survey could help only a little for the detail investigation of the planning system of the streets in the living quarters. On Amheida, the state of preservation of the houses is rather good, and the modern surface of the site corresponds to a level of the roofs of the houses. Thus, the level of the floor is, normally, quite deep, and the magnetized objects (ovens, kilns, ash layers, big ceramic vessels etc), which could ensure quite a big contrast of magnetic properties in comparison with nonmagnetic mud brick walls, are far away, so, a magnetometer almost could not feel them.

But on the other hand, nonmagnetic mud brick walls are a good background for the revealing of highly magnetized structures like pottery kilns, furnaces, bread ovens, hot parts of baths houses, ceramics, backed bricks etc. All these objects acquired their magnetization during firing, and they create so strong magnetic anomalies, that it is possible to see them even on a big distance from the objects themselves.

Therefore one of the aims of the magnetic survey on the site of Amheida was to reveal the industrial areas, where the high temperature technologies were used (kilns and furnaces), to find the structures of backed bricks, to locate the bath houses, bread ovens and so on. Of course, we also tried to find any structures on the town, especially to understand the planning systems of different times, to prove the existence of earlier strata, and so on. It was important to determine the extension of the site.

It was interesting to find places on the area of the town of Amheida, where backed brick has been used. Because of the lack of wood and fuel for charging pottery kilns, backed brick was rather expensive and it was used very “economically”, only for some special reasons or purposes. Therefore it would be interesting to find such structures, which could correspond to some “outstanding” buildings, or parts of buildings or other constructions.

Magnetic “noise” on the site.

There is almost no magnetic noise on the site: no modern iron objects on the surface and, fortunately, almost no modern destruction. Among the disturbances, which hampered the magnetic survey one could mention a layer of ceramic fragments and sand dunes.

There are very many potsherds lying on the surface of the sand, especially, in some parts of the town (*Photo 4*). They create quite a “mosaic” structure of the magnetic field, especially, if to measure close to the surface. Therefore it is better to carry out magnetic survey on a height of about 0.3 m, or higher.

It is quite an interesting phenomena, why there is such a layer of ceramic fragments, while below is almost pure sand. It could be explained in such a way, that the sand is denser and heavier, than ceramics. Ceramics is a rather porous material, therefore it is appeared on the surface, like a foam, on the surface of water, as a lighter matter, while heavier small particles of fine sand penetrate below the potsherds.

The sand dunes cover the remains of the site with thick layer of sand, and the magnetic anomalies from the archaeological objects became very weak, when measuring from the surface of such a high dune. For example, there is a very big dune at the southern-western part of the site, which buried a considerable part of the southern quarters of the town (*Photo 5*).

RESULTS

First of all, the area of the site was inspected with help of “**free search**” method. It means, that the magnetic field has been measured with a step of about 1 m - 1.5 m without any grid. If some anomalies have been noticed, the position of them has been marked with a GPS receiver (*Photo 6*). The co-ordinates of the traces of "free search" were also recorded by GPS device. The results of the application of the "free search" method are presented on the *Fig. 4*.

The **detail measurements** with using of the co-ordinate grid have been performed on the areas, which are of the special interest or which have been chosen by the "free search" because of the big anomalies.

Eight areas have been covered with detail magnetic survey (see *Fig. 5*):

A - Main or Temple Hill;

B - South-East area;

C - North-East pottery quarter;

D - South area;

E - Western kilns or furnaces;

F - Southern-Western Hill;

G - Western Hill;

H - "Parking" area.

The dimension of the whole area, which was surveyed on Amheida, was 6,3 ha.

Area A. Main or Temple Hill.

The magnetic survey has been carried out on a big area of the Main hill in 2000 (see *Fig. 5* and the Report of 2000). In 2005 we have re-considered the data of 2000 and draw them again presenting them as a color contour map (see *Fig. 6* on a scale 1:500 and *Fig. 7 a* on a scale 1:875) and also as a grey scale map (*Fig. 8 a* on a scale 1:875).

On the color contour map some structures became more evident, if to compare with the former presentation, used in 2000. Thus, it was possible to reveal a **big rectangular structure, the sizes of which are about 108 meters x 56 meters** in the central part of the hill. The orientation of the short axis of this structure is about 37 degrees from northern direction towards east (see interpretation map on the *Figs. 6 a* – on a scale 1:500, *7 b* and *8 b* on a scale 1:875).

It would be possible to interpret this rectangular structure as an enclosure, which is earlier, than the Roman Time buildings on the site. Indeed, it has quite different orientation and consists of a group of rather broad local anomalies². As it is known, the material of earlier periods have been found on the

² Because the deeper the source, the broader the anomaly is.

Amheida site, but there were no pre-Roman structures revealed there. May be now we have found the traces of an earlier layers of Amheida site? The remains of still standing tall mud brick walls of Roman time, have quite different orientation (almost west-eastern). They are marked on the interpretation map as yellow lines (see *Figs. 6a, 7 b* and *8 b*).

It is very interesting, that the neighboring Early Dynasty site ‘Ain el-Gezzareen, which was investigated in 1999 and 2000 with help of magnetic survey, has almost the same dimensions and orientation of the walls (see *Figs. 9* and *10*) (Smekalova, Mills, Herbich, 2000, p. 132). The dimensions of the enclosure in ‘Ain el-Gezzareen were approximately 112 meters x 54 meters, and orientation of the walls was about 25 degrees from the north towards the east (see interpretation map on the *Fig. 11*).

Another walls further to the north, parallel to the northern side of the main enclosure are to be seen on the magnetic map on ‘Ain el-Gezzareen site. There is also another big rectangular structure (?) to the south-east of the main enclose (see *Fig. 11*). The clear geometric shape, right angles of the walls, big size of the main enclosure, the existence of a temple inside the enclosure – all these indicate an important role of ‘Ain el-Gezzareen (Mills, Kaper, 2000, p. 123).

Let us continue the comparison between the sites ‘Ain el-Gezzareen and Main hill on Amheida. ***On the site of ‘Ain el-Gezzareen*** there were several different quarters inside the enclosure walls. The characteristic feature of the site is, that there are **many local positive anomalies**, which were grouped in some quarters inside the big rectangular of the enclosure, especially along the back (WWN) wall and in the middle part, close to the SSW wall, to the south of the excavations of 1998 (see *Figs. 9* and *10*). As the further archaeological investigations showed, many of these anomalies correspond to the ovens for backing bread, fire bases, hearths, kilns, ashes etc. (Mills, Kaper, 2000, p. 124). The big number of ovens for backing bread there could, probably, be explained by the fact, that the ‘Ain el-Gezzareen site has the most western position in the western part of the oasis. Further to the west is a desert and a caravan road, which went through the desert. It was, evidently, necessary for ancient travellers to have a lot of bread with them for their long way to the next oasis.

There are also quite many **local positive anomalies on the Main hill of Amheida**, which are situated along the back (WWN) wall, forming two linear groups (see *Figs. 6, 7 a, 8 a*). The anomalies on Amheida Main hill are broader and weaker, than the anomalies on ‘Ain el-Gezzareen, which means, that objects, created the anomalies are situated **deeper on Amheida**, than on ‘Ain el-Gezzareen.

The walls of rectangular enclosure on ‘Ain el-Gezzareen are built of mud bricks. Possibly, the walls of the enclosure on the Main hill on Amheida were also built of mud bricks. A very wide negative anomalies are situated at the SEE part of the Amheida “enclosure”. It is not excluded, that there were gates there with some massive mud brick walls and, perhaps, stone parts of the walls (see *Figs. 6a, 7 a*).

One of the most interesting feature, which has been found on the Amheida Main hill, is a strong magnetic anomaly on the top part of the area. This anomaly has been re-surveyed in 2005, using the

co-ordinate system of the archaeological excavations (see *Fig. 12*). The value of the anomaly is +100 and - 60 nT, the area occupied by it is about 10 m x 10 m. The possible source of the anomaly is some big clay feature, which was fired on the place, and which is still *in situ*. We tried to calculate parameters of possible object, which could correspond to this feature. It could be prism-shape body, which have the dimensions of about 4 x 5 meters, 1,3 m thick, on a depth of about 2,5-2,8 m. Another possibility is, that it could correspond to a very big kiln (?). In any case, this is a big mass of hardly fired clay.

It would be very desirable to check the supposition about the presence of an earlier structures on the Main hill with the excavations.

Area B - South-East area.

The magnetic survey has been carried out on the big area south and east from the Roman villa, which was excavated in 2004-2005. This area has been chosen because of the presence of a big amount of very strong local magnetic anomalies, revealed by the method of “free search” in 2005.

The results of magnetic survey are presented on the *Figs. 13-15*, (*Photo 7*).

It seems, that there is a big **industrial quarter** at the north-east corner of the plot (see interpretation map on the *Fig. 15*). The industrial area is limited by four streets, which are visible on the map as long positive anomalies. In this part of the site the magnetic anomalies over streets have positive sign, because the street are covered with a layer of slag, pieces of ceramics etc, which is very magnetic material. The most eastern “street” serves as an eastern edge of the town, behind of which, further to the east, there was kiln debris.

There are at least **seven or eight industrial furnaces or kilns** situated within the industrial quarter. Some of them create stronger anomalies, which could, probably, mean, that they are metalworking furnaces (see *Fig. 15*). Heaps of slag debris and ash were placed at the end of streets, at the eastern side of the site. It is more probable, that these objects are metallurgical or other furnaces, rather than pottery kilns, because otherwise there will be much more kiln debris around them, which we do not observe in this part of the town.

An interesting feature within an industrial quarter is a possible **workshop** (blacksmith, bronze or glass-working ?), the walls of which are marked as dark green lines on the *Fig. 15*, and which has at least two kilns inside. A floor of a rectangular workshop (a courtyard ?) is covered with some magnetic material (ash or/and hummer scale), therefore it gives us a wide positive anomaly.

It is quite difficult to find out only by the value and shape of magnetic anomalies, which industry was there in the ancient time. It is quite impossible that there were iron smelting or extracting workshops there, not only because of the lack of iron ore in the oasis, but also because such kind of production demanded a big amount of good charcoal, which was, evidently, a problem for the oasis people in antiquity as well as now.

It is rather probable, that there was a glass production on Amheida. One could, possibly, try to find evidences of it on the surface of the site: different types of slag, pieces of metal or glass, moulds, crucibles. There are some possibilities to distinguish between different high temperature industries on the site by the findings of fragments of different crucibles on the surface of the monument. We cite below several quite useful general suggestions from the article of Thilo Rehren (even the article is devoted to Late Bronze Age industry). “The bronze melting crucibles had to keep heat generated inside, and allow the casting of the metal, thus, they had to be insulating, strong and moveable. This was achieved by an organic temper and a thick wall to improve the insulating properties, and a hemispherical shape to withstand mechanical stress from outside. The spout finally allowed the metal to be poured in a controlled manner, into any given mould.

The glass crucibles, to the contrary, had to conduct the heat through the their fabric from the outside due to the indirect heating of the charge. Direct heating like the metal pots would have contaminated the glass with ashes and charcoal dust, and had, therefore to be avoid. Consequently, they were made without organic temper, and thin walled; the inevitable vitrification of the fabric at the temperatures applied (ca 1000-1050°C) promoted the conductivity of the fabric.” (Rehren, 1995, p. 105).

There are quite many pottery kilns on the Amheida site. On the area B they are mostly situated at the southern-western part of the area. There is one pottery kiln of good stage of preservation. The upper part of this kiln was visible on the surface. The other kilns are quite badly destroyed, which is visible on the magnetic map: the anomalies over destroyed kilns are weaker and not so “solid” in their shape (see *Fig. 15*).

The pottery kilns are situated also on the area C (see *Fig. 5*), which we are describing below. The total amount of the pottery kilns on the site is about two tens. For the comparison, one could estimate the number of pottery kilns in ancient Kellis as a smaller one. Probably, on both sites the ancient people produced ceramic vessels not only for everyday needs, but also for transporting the olive oil, which was one of the main trading subject (together with dates) of the Dakhleh people during Roman time, and other goods.

The construction of pottery kilns were, probably, rather special in the oasis. They could have open space above, without a close dome construction, which is characteristic for Ancient Greek pottery kilns. Because of the lack of wood in the oasis, people had to use a special fuel there – tamarisk or straw, which gives a short-lived, but intense fire (see the bunches of tamarisk, prepared for charging the pottery kilns on the modern workshop in el-Qasr - *Photo 8*). It was, perhaps, not possible to operate with the atmosphere inside the kiln, one could operate only with a temperature, putting more or less bunches of tamarisk brunches or straw into the kiln. Perhaps, it was too much smoke of this fuel, which means lack of oxygen, and therefore quite often the ceramics became black during firing (Smekalova, 1995).

There were no tile kilns on Amheida, presumably because tile was not used in the oasis because of the lack of rain. There are also no underground cellars in the houses. Ancient people probably stored

wheat, barley and other grain in a jars atop the roofs, because of hyperarid climate. Perhaps the water-table on the site was quite high; therefore it was not practical to dig underground cellars, especially, because, in any case, it would be necessary to built mud brick walls along the sides of cellars, to prevent the clay sides of the pit from destruction.

A possible bath house (or even two bath houses) has been found at the south part of the area by the big positive-and-negative anomalies of an oblong shape (see *Fig. 15*). It is possible to compare the magnetic map of the bath house in Kellis and “bath houses” on Amheida (*Fig. 16, a, b*). The difference in the shape of the magnetic anomalies could be explained by the fact that the orientation of heating channels of the hypocaust system is different on the sites: on Kellis it is east-western, and on Trimithis it is north-southern (see interpretation maps on the *Fig. 17 a, b*).

There are other objects visible on the magnetic map of the area B:

- the heaps of ceramics are situated at the eastern part of the plot (marked with dashed oval lines on the interpretation map – *Fig. 15*). They are seen because of mosaic structure of the magnetic field above them;
- a round-shape backed brick structure with an inner diameter of about 6 m, and outer diameter of about 8 m was found close to the Roman villa, just south-east of it (see violet circle on the interpretation map – *Fig. 15*).

There is an interesting feature revealed close to the pyramid. It is built partly of backed bricks, partly of stone. Some part of this structure seems to be fired *in situ*. It could be a kiln for firing ceramic coffins (?) (see violet rectangle on the interpretation map – *Fig. 15, Photo 9*).

Quite many positive anomalies at the most southern part of the plot could be an indication of the presence of different structures there, including buildings (see *Fig. 15*).

Concluding the description of the Area B, one could notice, that it is quite logical, that the main industrial areas are situated at the eastern and southern part of the town (to avoid smoke from the furnaces), because the prevailing winds on Amheida are **northern and western** ones.

Area C - North-East pottery quarter.

Area “C” is situated on the North-East part of the site, south of the wide street and of a group of pottery kilns, which were investigated in late 1970s by Dr. Colin Hope (Hope, 1980) and surveyed by us in 2000 (see *Figs. 5, 18*). The magnetic maps, obtained on the area are presented on the *Figs. 19-20*. At least three (or four) pottery kilns of a good preservation are revealed by the magnetic survey. They are marked on the interpretation map as orange circles (see *Fig. 21*). There are also several destroyed pottery kilns on the area “C” (see white-and-orange circles on the *Fig. 21*).

Three or four strong and sharp local anomalies, which are marked on the interpretation map as green circles, (see *Fig. 20*) could correspond to iron objects or magnetic stones. It could be interesting to check these strong anomalies with small excavations.

As it is already mentioned above, the number of pottery kilns on Amheida seems to be bigger than at Ismant el-Kharab, even it is difficult to compare, because some of the areas on Ismant el-Kharab are still not investigated by magnetic survey. But it is not excluded that there was a bigger amount of pottery produced at Trimithis than at Kellis, if we may judge by the number of pottery kilns.

Area D - South area.

Area D has been chosen for detailed magnetic measurements because of several quite strong anomalies, found there by the method of “free search”. It is situated at the southern part of the site, on a very small hill with rather flat surface (see *Fig. 5, Photo 10*).

The magnetic field on the area D is quite anomalous. A furnace or kiln and some linear structures have been found there (see *Figs. 22, 23*- maps and *24* - interpretation map). It is rather interesting that the direction of the linear structures, which could be walls of the houses, is slightly different with the direction of the streets on the main part of the Roman town (compare the drawing of the visible streets on the *Fig. 5* and possible walls on the interpretation map - *Fig. 24*). Thus the structures on the area D may belong to a different planning system than the other part of the town.

It is necessary to notice, that there are several quite strong positive anomalies on the low and flat neighboring area immediately to the west of the area D. These anomalies have been found by the method of "free search". There was not time enough during the expedition of 2005 to investigate these anomalies with help of detail magnetic measurements, but it would be worthwhile to measure them in the future.

Area E - Western kilns or furnaces.

A group of several strong anomalies have been revealed by the method of “free search” quite far away from the Main hill and other part of the town, at the southern-western corner of the site. The results of further detail magnetic survey (*Fig. 25, 26*) revealed three or four kilns or furnaces there (see explanation map on the *Fig. 27*). A big amount of ceramic fragments, which are lying on the surface of the site in this part of town, including the high southern-western hill (area F, see below), could be the result of acting of these kilns, perhaps.

It is quite interesting, that these several kilns or furnaces have been found rather far away of the main industrial area, which is situated at the eastern, north-eastern and southern-eastern part of the town. It would be important to excavate them to understand why it was so, and to see what are the specific features of the kilns and furnaces and their production (*Photo 11*).

Another object which it is necessary to mention is a linear anomaly at the northern part of the plot. This is long positive anomaly with the negative part from the northern side. Such a shape of the anomaly could correspond to a linear structure of clay, which was fired *is situ*. We have found a more or less similar object at the eastern part of the town, on the area H (“Parking place”, see below). It is rather difficult to tell, what type of archaeological objects this structure could belong to. One could only

suppose, that it could be a primitive clay water channel, or a road (marked with yellow dashed line on the *Fig. 27*).

Area F - Southern-Western Hill.

The area F is correspond to a SW hill, which is quite high, especially if seen from the south, and has very sharp slopes. The mutual location of the area E and F of magnetic survey is shown on the *Figs. 26 and 5*.

There are a lot of big pieces of ceramic vessels on the surface of the Southern-Western Hill (see *Photo 12*), which gave us rather “mosaic” structure of the magnetic field measured there. We lifted a sensor of a magnetometer on a bigger height to avoid this “noise”, but it helps only a little. It is difficult to see any structures on this hill; there are mostly “point” anomalies from the fragments of ceramics there (see *Figs. 26, southern part, 28*). Some linear structures could, perhaps, be seen only on the edges of the hill, but we are not very certain, that they are really some structures, not influence of the relief (*Fig. 29*).

Area G - Western Hill.

An interesting result has been obtained on the Western hill, which is situated to the west of the main or Temple hill, not far away of it (*Photo 13*). There are quite strong anomalies found there by the method of “free search”. The results of further detail magnetic survey are presented on the *Figs. 30, 31*.

The picture of the magnetic field on the southern part of hill is quite different with the northern one. In the northern part of the hill we can see only usual “mosaic” picture from the big pieces of ceramics, lying on the surface. To the contrary, the strong anomalies at the southern part of the hill could be created by the structure of backed bricks (see interpretation map on the *Fig. 32*). It is interesting, that the orientation of this possible structure is different from the orientation of the walls of the Roman time, and it is corresponds to the orientation of the rectangular structure, which we revealed on the neighboring Main hill (see *Fig. 33*). That means, that they could correspond to the same planning system.

There are also very strong and wide positive-and negative anomalies at the central part of the plot, from the western side. The sources for them could be kilns, may be, destroyed ones (see *Figs. 30, 31*, marked with bright rose circles on the interpretation map- *Fig. 32*).

Area H - "Parking" area.

A most surprising result has been obtained on the big flat area outside the town, to the east of it (so-called "parking" area) (see *Fig. 5, Photo 14*).

A long positive anomaly has been revealed there (see *Figs. 34, 35*). The small trial trench revealed a linear structure of fired clay. After part of the fired clay has been removed, the magnetic field has been measured again (see *Fig. 36*). One can see, that the anomaly decreased very much on the place where the

backed clay has been removed. It proves, that the source of the magnetic anomaly is the fired clay of the linear structure.

It would be interesting to try to reveal similar structures at the other sides of the town as well. But during the season of 2005 there was not time to do this work. One could only notice, that a little bit similar long anomaly has been found on the western side of the town (see *Fig. 25, 26, 27*).

CONCLUSIONS

Magnetic survey proved to be an efficient method for the investigation of Amheida, to reveal different parts of the site, especially for the revealing of the industrial quarters, possible baths houses and the structures of backed brick.

It would be useful to continue magnetic survey for finding the linear structures, like the one revealed on the "parking" area, and also for the detail investigations of the magnetic anomalies, which were found by the method of "free search", but did not surveyed yet with detail measurements.

There are several rather strong positive anomalies on the southern part of the area, west of the area D, which would be interesting to investigate with the detail measurements.

It would be good to continue geophysical investigations on the site. Magnetic survey could be complemented by resistivity measurements, which could allow to find the areas, where water is closer to the surface, and also to find mud brick and stone structures.

It is also possible to use magnetic survey for the exploring of the neighboring areas around the site of Amheida. It would be important to find closest farmsteads or settlements, which could belong to the agricultural area of the town, and to measure the GPS co-ordinates of them. It would also be desirable to understand the character of each site with using of geophysical survey, because it is quick and non-destructive means for the investigation of the buried structures.

BIBLIOGRAPHY

- Churcher C.S., A.J. Mills.** Index List of Archaeological Sites surveyed by the Dakhleh Oasis Project. In: Eds. C. S. Churcher and A.J. Mills. *Reports from the survey of the Dakhleh Oasis Western Desert of Egypt. 1977-1987*. DOP Monograph 2. Oxbow Monograph 99, 1999. pp. 251-265.
- Hope C.A.** Dakhleh Oasis Project – Report on the Study of the Pottery and Kins. *JSSEA X*, 1980, p. 283-313 .
- Hope C.A.** Egypt and Lybia: The excavation at Mut el-Kharab in Egypt's Dakhleh Oasis. *The Artefact*. Melbourne, Australia. The Archaeological and Antropological Society of Victoria, Inc. V. 24, 2001, p. 29-46.
- Mills A.J.**, The Dakhleh Oasis Project. *JSSEA X*, 1980.
- Mills, A.J., Kaper O. E.** 'Ain el-Gezzareen: Developments in the Old Kingdom Settlements. In: Ed. By G. Bowen and C.A. Hope. *Proceedings of the Third International Conference of the Dakhleh Oasis Project. The Oasis Papers 3*. Dakhleh Oasis Project: Monograph 14. Oxbow Books. Oxford and Oakville 2004, pp. 121-129.
- Rehren, Thilo.** High temperature industries in the Late Bronze Age capital Piramsess – (Qantir): I – Bronze and Glass Production and Processing. In: Ed. Feisal A. Esmael. *Proceedings of the First*

International Conference on Ancient Egyptian Mining & metallurgy and Conservation of Metallic Artifacts. Cairo, Egypt, 1995, pp. 101-119.

Smekalova, T. Some new aspects in studying of attic Black Gloss wares. *Abstracts of 2nd Southern-European conference on Archaeometry*. Delphi, 19-21 April, 1991 // PACT 45, 1995, pp. 75-84.

Smekalova T. N., A. Mills, T. Herbich. Magnetic survey on the Old Kingdom site with mudbrick architectural remains in Dakhla Oasis. In: Ed. G. Bowen and C.A. Hope. *Proceedings of the Third International Conference of the Dakhleh Oasis Project. The Oasis Papers 3*. Dakhleh Oasis Project: Monograph 14. Oxbow Books. Oxford and Oakville 2004, pp. 131-135.

Smekalova, T. Magnetic Testing using Overhauser Gradiometer GSM-19WG and Cesium Magnetometer MM-60. In: Ed. Colin A. Hope and Gillian E. Bowen. Dakhleh Oasis Project: Monograph 11. *Preliminary Reports on the 1994-1995 to 1998-1999 Field Seasons*. Oxbow Books. Oxford and Oakville, 2002, pp.31-41.

Tawab, Mohamed M. Abdel. The role of copper-gold-iron in Ancient Egyptian politics. In: Ed. Feisal A. Esmael. *Proceedings of the First International Conference on Ancient Egyptian Mining & metallurgy and Conservation of Metallic Artifacts*. Cairo, Egypt, 1995, pp. 399-401.

Thurstone, Harry. *Secrets of the Sands*. Arcade Publishing. New York. 2004.



Photo 1



Photo 2



Photo 3



Photo 4



Photo 5



Photo 6

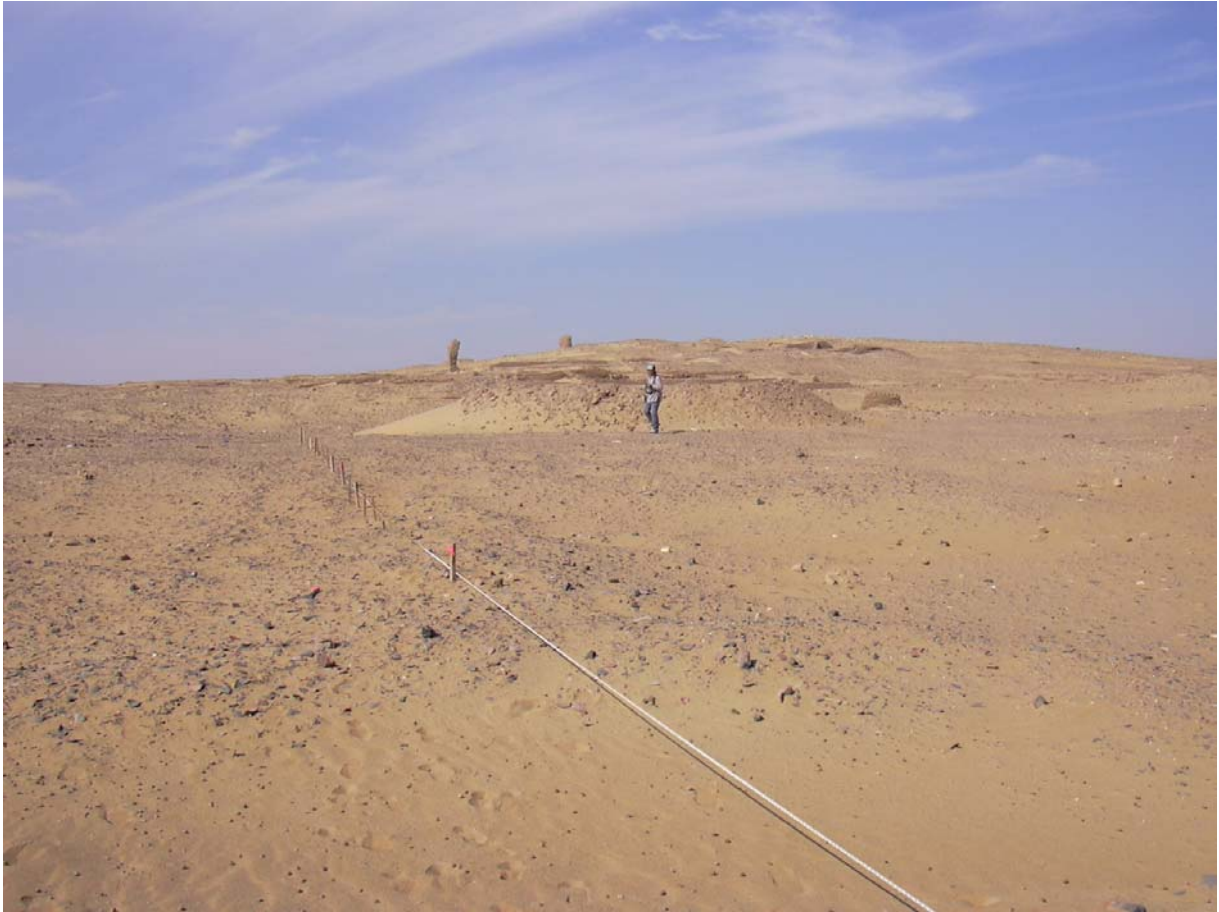


Photo 7



Photo 8



Photo 9



Photo 10



Photo 11



Photo 12



Photo 13



Photo 14