Egypt. J. of Appl. Sci., 38 (7-8) 2023 *55-74*

MAGNETIC AND GPR SURVEYS FOR ARCHEAOGEOPHYSICAL MAPPING AT TAL-EL BENDARIYA, TALA, MENOFIA GOVERNORATE, EGYPT

M. Salem[1]; M. Shaheen[2]; A. Khalil[2]; A. El Kotb[2] ; K. Mansour[2] ; T. F. Abdallatif[2] ; H. Zahra[1] ; M. Mekkawi[2] ; A. Samy[2] and A. Abdelkader [2]

[1]Geology Department, Faculty of Science, Benha University, Egypt

[2]National Research Institute of Astronomy and Geophysics-NRIAG, 11421-Helwan, Cairo, Egypt.

***E-mail-mohamedsalem199373@gmail.com**

ABSTRACT

Many different countries use geophysical technologies in their archaeological research. In the study area (Menofia, Egypt), we employed magnetic and ground-penetrating radar techniques. In the southern part of Egypt's northern Delta, between the Nile Rashid and Damietta branches, is the Menofia Governorate. Tal-El Bendariya was chosen as the study location since the majority of its activity ended during the Roman era. For the magnetic survey, Tal-El Bendariya was separated into three locations (sites), and one suitable site was chosen for the GPR study. Using Geoplot, Reflexw, and Surfer software, the magnetic data and GPR data were corrected processed, and interpreted to produce images that depicted the underground artifacts that were present in the area. The magnetic data at Tal-El Bendariya revealed a significant number of anomalies with a variety of unusual geometric patterns. They are interpreted to be the location of historical hearths and kilns made of firebricks as well as fragments of ancient walls made of fire and mud bricks. The findings from the GPR data, meanwhile, point to a few scattered parts of mud brick walls. It was established that the research region at Tal-El Bendariya might have been an area of an ancient pottery industry during the Roman era after integrating the magnetic and GPR results.

Key Word: Menofia, Tal- El Bendariya, Magnetic, GPR, Roman era.

INTRODUCTION

The Nile Delta is shaped like a triangle and is located between the Nile Rashid and Damietta branches. His head is located in the South and his base is located in the North. One of the governorates in the southern portion of the Nile Delta is called Menofia. In comparison to other archeological locations in Egypt, it is one of the governorates that is less widely recognized. Menofia Governorate is one of the governorates whose history had a significant impact on developing a distinctive personality. Menofia was given its name after the city of Menouf, which was once known as "Bir Nob"—which means the land of gold—and had gold mines. After the conquest, the Islamic of Egypt altered the Coptic name to "Banoufis" and the Arabic name of the city to "Manoufis."

Tal-El Bendariya is a group of connected hills, four meters above the earth and covers 25 acres. The activities of Tal-El Bendariya, which is located near Zawiya Pem in the town of Tala, largely came to a stop during the Roman era. Since 1975, it has followed the market for Islamic and Coptic artifacts. This location was present during the late Roman and Coptic eras before it disappeared (Fig. 1).

Historical texts, such as Al-Idrisi's book "Nuzha Al-Mushtaq fi Takhruq Al-Afaaq," get a reference to El-Bendariya. One such text reads: "El-Bendariya included villages, orchards, a mosque, and a bathroom, and it had an abscess." According to Rashad, Tal-El Bendariya's excavations lasted from 1976 until 2010 AD. Due to the circumstances the country experienced following the January 2011 revolution, it ultimately came to a stop. Many necklaces adorned with precious stones, gold pieces, stone, and ceramic figurines, as well as Coptic and Islamic pottery vessels, Roman and Islamic coins, and ceramic and stone figurines, have all been retrieved. The remains of grain silos that were buried there and evidence of pottery-burning kilns were found. The remains of this village can still be seen in the remains of mud-brick buildings. On the hill, there is an area of Islamic cemeteries, and at its summit is the shrine of "Sidi Ali Al-Kumi." It is thought that this location served as a factory for the production of pottery and tools during the Roman era.

Since 1958, the magnetic approach has been used in archaeoprospecting over the world **(Aitken, 1974; Weymouth, 1986 ; Clark, 1990 and Scollar, 1990)** and in Egypt since 1983 **(Hussain, 1983; El-Qady, 1995; Abdallatif, 1998; Odah, 1998 ; Atya, 1998; and El-Emam, 2021).** There is no doubt that modern geophysical instruments are very sophisticated to obtain good quality with a minimum of time, effort, and expense. Additionally, it provides rapid and efficient outcomes for locating hidden findings. They work best when used on shallow depth features (>30 m) when high-resolution standards are used, and when there is a possibility that the results may be verified using similar exposed objects **(Butler, 2005).**

The location of archaeological constructions can be ascertained using a variety of geophysical methods, either together or separately **(David, 1995).** It is crucial to examine how people interacted and lived in the past, as well as how archaeological sites were built, as these factors provide important insights into ancient cultures. Stone, mud, mortar, wood, alabaster, granite, sandstone, and other materials were used to construct the ancient Egyptian archaeological constructions.

However, the majority of these constructions are made primarily of limestone and mud bricks. Mud bricks are mostly made of Nile River clay and mud, often with the addition of binding materials like rice husks or straw. The Egyptian mud bricks, which were extensively utilized by Egyptian builders to build various constructions such as tombs, pyramid casings, storage rooms, etc., were also mentioned by **Abdallatif *et al.*, (2005).** These bricks are primarily made of Nile mud.

Pre-Roman Egypt utilized mud bricks to some extent, and during the Roman era, their use increased **(Bard and Shubert 1999).** The surface measurements of buried ancient features with magnetic contrast will show minute abnormalities, and careful analysis of the collected data can frequently result in insightful archaeological conclusions. The methods are typically employed to find features like foundations, ditches, pits, or kilns rather than "treasure" **(Sutherland and Schmid, 2003).** Geophysical processes can reflect human-caused changes in addition to shaping those features **(Cammarano *et al.*, 1997).**

For exhibiting the buried archaeological features under the soil in the current investigation, two geophysical tools have been used. Geophysical tools with effective applications in the evaluation of archaeological sites include ground penetrating radar (GPR) and the magnetic method. These methods were employed in the integration plan to map the possible tombs and to emphasize the investigated site's archaeological potential. The magnetic method is one of the most well-established and popular geophysical methods for investigating the Earth's subsurface.

The magnetic method is the one that is most frequently employed in countries worldwide. Measuring the magnetic field of buried bodies produced from minerals with good magnetic susceptibilities is necessary. It is a reasonably simple and affordable technology that may be used to solve a wide range of subsurface exploration obstacles, including differences in the magnetic properties of rocks and minerals from adjacent to the earth's crust's base to beneath the top meter of the soil. The magnetic performance can map magnetic anomalies caused by these fluctuations in the Earth's regular magnetic field **(Hinze *et al.*, 2013).** In Egypt, measurements of the vertical magnetic gradient have been employed extensively for archeological research **(Kamei *et al.*, 2002; Abdallatif *et al.*, 2003, 2005; Ghazala *et al.*, 2003; Herbich, 2003; Abbas *et al.*, 2005; Odah *et al.*, 2005; Wilson, 2006).**

For high-resolution soil and rock subsurface detection, imaging, and mapping, ground penetrating radar (GPR), an electromagnetic (EM) geophysical technology, is used. The GPR technique includes projecting elliptical cones of electromagnetic radio pulses into the ground, calculating the lag time between transmission and signals reflected off buried discontinuities, and receiving those signals back at a surface radar receiving antenna. The return time of reflections from discontinuities in the electrical characteristics of the soil, particularly its dielectric properties, provides information about the depth of such a feature while the magnitude and phase of the reflected signal offer information about the nature of the reflector. In addition to its military and societal uses, GPR is now an essential tool in environmental, engineering, and ground research where the target depths are relatively shallow. Several geological and hydrological uses of the GPR have been described **(Davis and Annan, 1989; Doolittle, 1993; Annan *et al.*, 1991).** Antennas used in the GPR method can only transmit frequencies between 10 and 2000 MHz. Higher frequencies in this range provide improved subsurface resolution at the depth of penetration. Lower frequencies allow for deeper penetration depths in this range, but subsurface target resolution degrades **(Morey, 1974).**

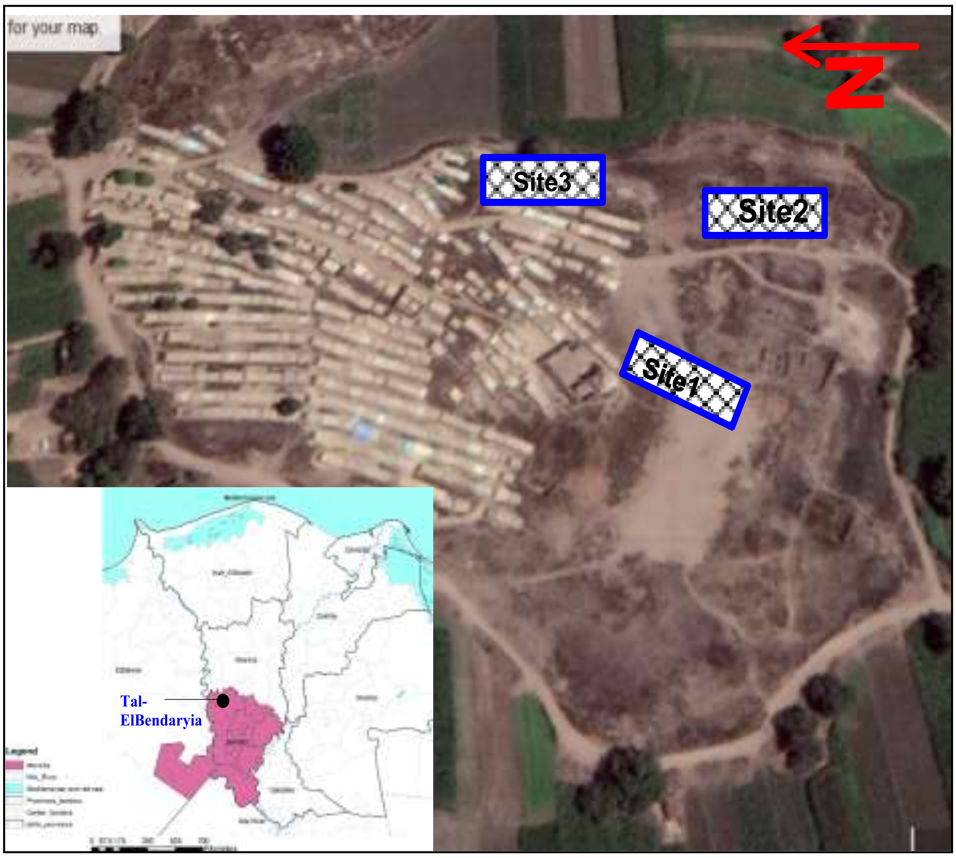

Fig. (1): Location map of the archaeological area at Tal-El Bendariya showing three sites (1, 2, and 3) surveyed by the fluxgate gradiometer (FM256).

MATERIALS AND METHODS

The tools employed in archaeological geophysics include data-gathering techniques that let field archaeologists image and map subterranean artifacts that are otherwise unreachable using traditional field methods.

In this present study, three sites were selected for the magnetic survey, which was carried out on each site, each of which was 40 m x 20 m in size. To establish a correlation and validate the results of the magnetism, one site among those that were scanned using the magnetic approach was chosen to be scanned using the GPR equipment. These areas were selected for radar scanning because they are flat and mainly devoid of tall weeds (Fig. 1). To generate appropriate data for the excavation plans, the skilled technician can measure, map, and evaluate the data signals that the GPR system has received. The study's instruments included a GSSI Subsurface Interface Radar (SIR) System-4000. Two distinct frequency (low and high) operating antennae are included with the SIR-4000. In the current study, 200 antennas were used to provide a satisfactory vertical resolution for the target object (Fig. 3).

1. Magnetic data acquisition

One of the most significant archaeological sites in the governorate is Tal-EL Bendariya, which is situated on the southern side of the town of El-Bendariya, the heart of Tala in the Menofia Governorate (Fig. 1). **Site 1** is 40 meters by 20 meters in size and is situated close to the temple. **Site 2** is made up of a 40 m x 20 m rectangle. **Site 3** is close to the cemetery, perched atop a butte.

The location was kept away from electrical lines, high-pressure zones, and any obvious surface iron materials before examinations. Before the measurements were taken, the site's boundaries were marked using wooden sticks. Due to the difficult terrain and thick grass, expanding the survey site to include additional neighboring areas proved to be difficult. The fluxgate gradiometer survey data were collected from North to South.

It utilized an over grid with a spacing of 1 m 1 m and a fluxgate gradiometer (FM256) with a sensor spacing of 0.5 m. Six grids are used to divide the region. Each grid is 20 meters by 20 meters and is subdivided into multiple parallel traverses that are spaced 1 meter apart. The readings are shown on an alphanumeric liquid crystal display in either digital or analog format, with the latter being significantly more useful for scanning. The instrument memory's collected data were transferred to the computer using Geoplot software **(Geoscan Research, 1994).**

The obtained data (the raw data) were then introduced in grayscale, as depicted in Fig. 2. The acquired raw data have the appearance of having come from aerial photography. The grayscale magnetic image shows positive anomalies in the darker areas and negative anomalies in the lighter sections. When using the gradiometer to take measurements, the terrain was uneven and difficult to navigate.

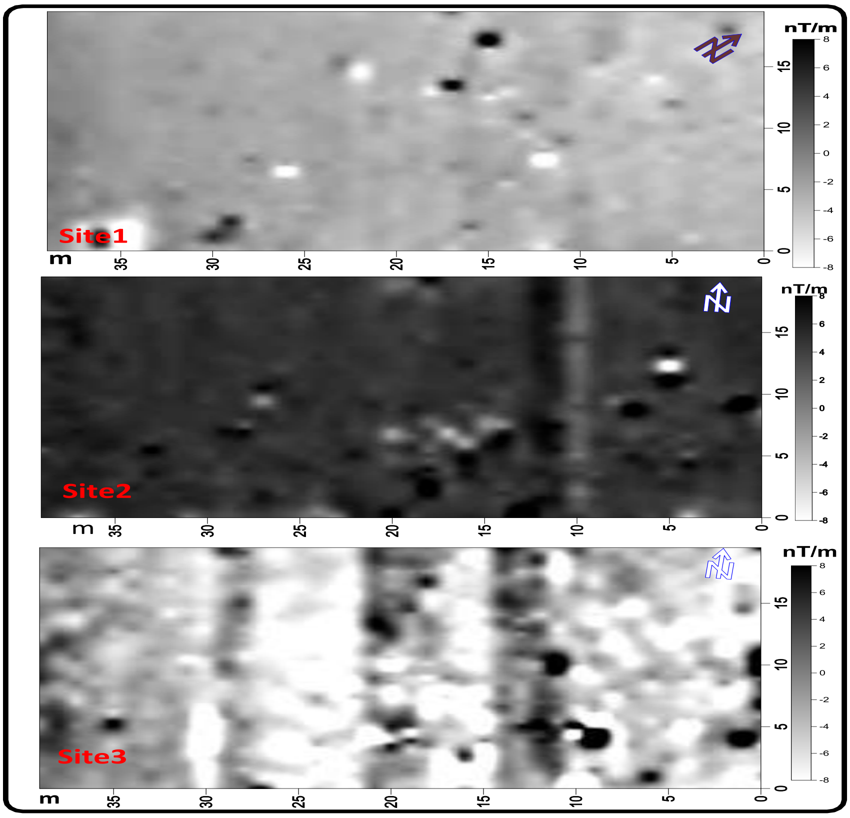

Fig. 2: The studied archaeological sites' raw magnetic data (1, 2, 3).

2. GPR data acquisition

A well-designed survey and efficient implementation are necessary for effectively acquiring data. As a result, a single site has been chosen to be further studied using the GPR method and has been selected for interpretation and correlation with the previous magnetic results based on the results of the magnetic survey. 41 profiles were created at this 40 x 20 m site (Fig. 3). Every site was investigated as a single grid with a set of zigzag profiles. The offset between each line was one meter. The radar was set up to record 512 samples for each trace and 20 scans per meter across an absolute scope of 150 ns. A survey wheel was added to the apparatus to control the inspected distance and activate the electromagnetic wave (Fig. 3).

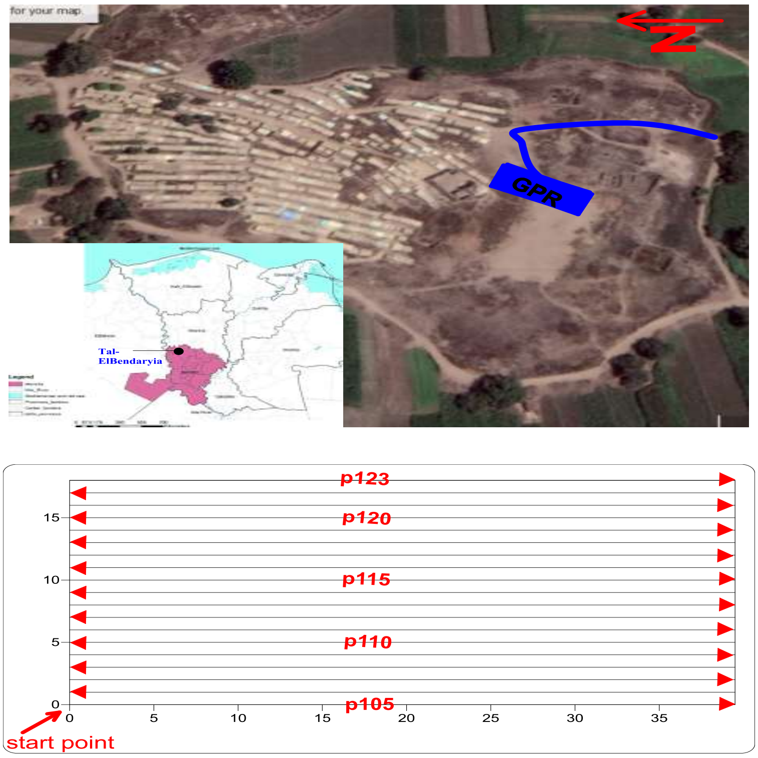

Fig. (3): a) A location map of the Tal-El Bendariya archaeological area shows one site that was surveyed using ground penetrating radar (SIR4000); b) A layout map of the specific GPR survey profiles used in the Tal-El Bendaryia area.

3. Data Processing

3.1 Magnetic data processing

The major objectives of processing these data are to reduce expected noises, enhance the responses of any residual archaeological components, and make the data more comprehensible and smoother for presentation.

Before being exported to the Surfer program for a more detailed examination, the magnetic survey data were first examined using Geoplot software **(Geoscan Research, 1994).** Two magnetometers placed at various heights can be used to measure the vertical gradient in units of Nano tesla per meter (nT/m), which can be used to determine the distribution of archaeological remains at moderate depths of up to a few meters. **Bossuet *et al.* (2001)** state that the vertical gradient filters out the influence of regional magnetic fields and is more effective at defining shallow magnetic anomalies than magnetic temporal variations. Raw magnetic data for the locations (A and B) reveal magnetic impacts from various sources. Aside from the apparent anomalies that can be detected in particular locations of the images, the majority of other archaeologically significant irregularities are concealed by noise field abandons and other noise sources. To combat this, we established a handling configuration that the instrument producer had suggested. A typical preparation technique includes initially displaying and evaluating the data, eliminating unreal characteristics of the data, realizing the impact of significant topographical and ferrous factors, removing data collection errors, and finally improving and presenting the archaeological reaction.

Processing was done using Geoplot software **(Geoscan Research, 2005).** To determine the primary field error and noise, the raw data were initially included in shade plots. The representation of the final images is improved by several data processing steps that are applied to the raw data collected from the field. For instance, the clip is used to reduce or eliminate some common errors that may occur during the field survey, zero mean grid, zero mean traverses, despike is used to remove random iron spikes observed in the gradiometer data, low pass filter, and interpolate. A series of stripes oriented in the traverse direction may be visible in a few grids. This effect, known as traverse stripping, was caused by a minor difference in the base level of the substitute traverses. This difference can be the result of instrument tilting and a change in carrying angle during successive traverse measurements. The effect of traverse stripping was corrected using the zero-mean traverse (ZMT) function, whilst the difference in mean gradient values between grids was corrected using a zero-mean grid (ZMG) function. A low pass filter (LPF) was used to enhance and smooth the significant weak features by stifling higher frequency components, such as noise in the data, while simultaneously preserving low frequency and enormous scope spatial abnormalities. The final processed magnetic pictures provide a good representation of the anticipated buried remains and can be used as a starting point for interpretation in the study region.

3.2 GPR data processing

The main objective of data preparation for GPR is to provide an image that can be processed to distinguish buried targets. In 1D and 2D (time slicing), the acquired data were handled. The GPR procedure and processing for archaeological investigation were well-reviewed by **Manataki *et al.* (2015).** The data were subjected to signal preparation and noise removal throughout the entire 1D analysis. Four stages of preparation were performed: a) Zero-time adjustment (static shift): this technique is used to connect zero time with zero depth, erasing any time offset caused by instrument recording before interpretation. b) X flip profile: This technique is used to reverse the profiles, flipping them in the x direction. c) Background removal: filters are applied to the selected number of traces to temporarily remove the expected noise from the entire profile, potentially allowing the signals to become visible. Furthermore, it suppresses horizontal coherent energy. Additionally, it displays lateral differences in signals, such as diffractions. d) Band-pass Butterworth: To eliminate high-frequency signals, a low-pass vertical filter of 300 MHz was used, and a high-pass vertical filter of 80 MHz was used to remove low-frequency signals. The unwanted background noise caused by the electronic ringing of the antenna and power transmission line situated in the survey area, etc., is normally removed by filtering the data.

The REFLEXW software package was used to process the GPR data **(Sandmeier, 2016).** The updated Windows 9x/NT version of the DOS program REFLEXW for processing and interpreting reflection and transmission data (special applications: ground penetrating radar (GPR), reflection seismic, and ultrasound) is called REFLEXW (ver3. 5.7, Sandmier). The program displays the raw data as wiggly traces, oscilloscopes, line scans (color-amplitude plots), and three-dimensional illustrations. The use of many major functions, such as automated gain control (AGC), spherical and exponential compensation (SEC) gain, and user-defined gain function, depends on the quality of the input data and the profile elements you want to emphasize. Filtering along the time axis of each trace is a component of temporal filtering. High-pass, low-pass, or frequency filters like Fourier analysis may be used in this. Some unwanted returns are reduced or eliminated by these filters. When processing GPR data, the overall goal is to create an image that can be interpreted about the objectives of interest. High-frequency noise can be decreased as shown in Fig. (4) by, for instance, running the mean reduces each trace **(Moorman and Michel, 1997).**

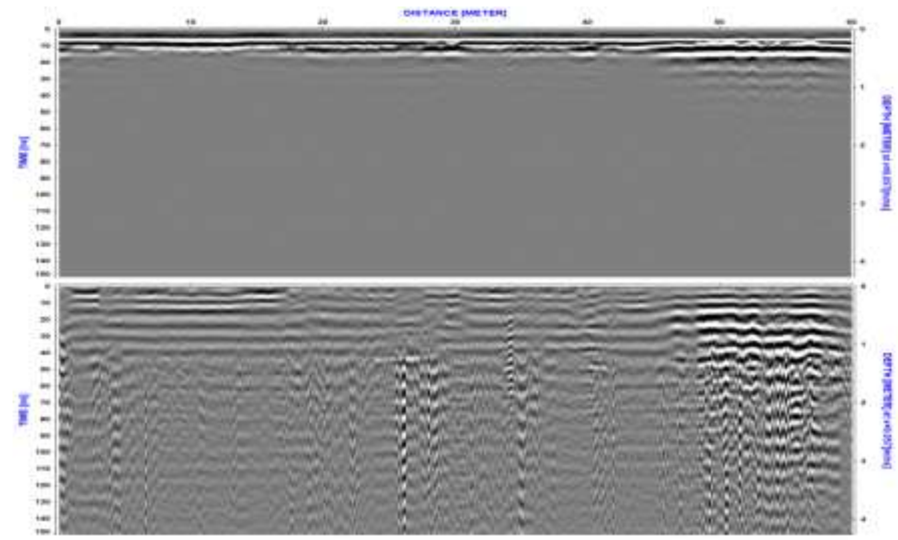

Fig. (4): The comparison of GPR profile P38 with and without processing.

RESULTS AND DISCUSSIONS

1. The main results and discussions of the magnetic data

The variation in the earth's field is measured by magnetometers based on the differential in magnetic susceptibility between the host soil and the source of interest. Pits, ditches, and other silted-up excavation features with a high concentration of magnetic materials may be the cause of the variance. The previously mentioned processed grayscale magnetic pictures' light and dark regions correspond to positive and negative anomalies, respectively. The magnetic image can be used to direct archaeologists during any future excavation because it resembles an aerial photograph of the surface foundation.

Magnetic anomalies at Site (1) interpretation

The measured site (1) is at Tal-El Bendariya near the shrine and is 40 m by 20 m (Fig. 1). It was constructed using mud bricks. Magnetic image analysis revealed fragmented and dispersed patterns associated with negative anomalies (Fig. 4). Two probable archaeological zones (N1 and N2) that are most likely made of mud bricks are shown on the processed magnetic image. These zones' magnetic signatures generally indicate the presence of positive, scattered, and dissected anomalies. The amount/density of the inherited magnetic minerals controls the strength of the magnetic field; for instance, a blacker anomaly indicates the presence of more magnetic minerals. Two obvious abnormal zones (N1 and N2) are among the magnetic anomalies at the site (1). The first zone (N1) is found in the study area North, and the second zone (N2) is found there in the South. The following results are marked in the magnetic image of the site (1) as being the most significant ones:

A relatively significant positive magnetic anomaly serves as a representation of the first zone (N1). This anomaly has a rectangular shape and is elongated. It might be a historic city wall remnant, most likely constructed of mud bricks. In this region, there are a few other minor negative anomalies (white patches) that appear at random. Along with another wall structure made of mud bricks near the study area, some areas of this zone also exhibit surface wall remnants that may be viewed on the ground. These suggest that zone N1 contains unique archaeological features (Fig. 4). A positive magnetic anomaly is seen in the second zone (N2). The circular shape of this anomaly suggests that it may be part of a wall made of mud bricks or an ancient kiln or hearth made of fire bricks.

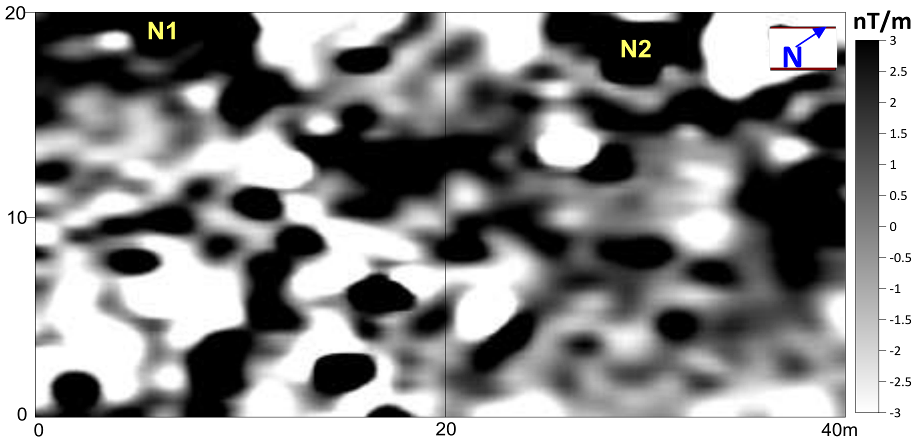

Fig. (4): The main delineated magnetic anomalies at zones (N1 and N2) at Site (1), Tal-El Bendariya, are depicted in the gradiometer data image.

Interpretation of magnetic anomalies at Area (2)

The surveyed Site (2) is situated behind the site (1) and has a dimension 40 m by 20 m. The magnetic image analysis revealed fragmented patterns associated with negative anomalies (Fig. 5). Three probable archaeological zones (T1, T2, and T3) that are probably made of mud bricks can be seen in the processed magnetic image (Fig. 5). These zones' magnetic signatures generally indicate the presence of positive, scattered, and dissected anomalies. Their magnetic properties are influenced by the amount and density of the inherited magnetic minerals; the darker the anomaly, the more magnetic minerals are present.

Three visible anomalous zones (T1, T2, and T3), delineated by colored lines, are among the magnetic anomalies present at the site (2). The research area's center contains the first zone (T1), while the northeastern portion of the study area contains the second zone (T2), and the northwest portion of the study area contains the third zone (T3). The following results are shown in the magnetic image from Site (2):

An exceptionally major positive magnetic anomaly (T1) symbolizes the first zone (T1). This positive anomaly has a circular shape and is elongated. It might be a historic city wall remnant, most likely constructed of mud bricks. In this region, a few other minor negative anomalies (white spots) have been observed at random.

Ancient wall remnants were discovered close to Site (2), providing a useful frame of reference for properly interpreting the magnetic data that was generated in this area (Fig. 5).

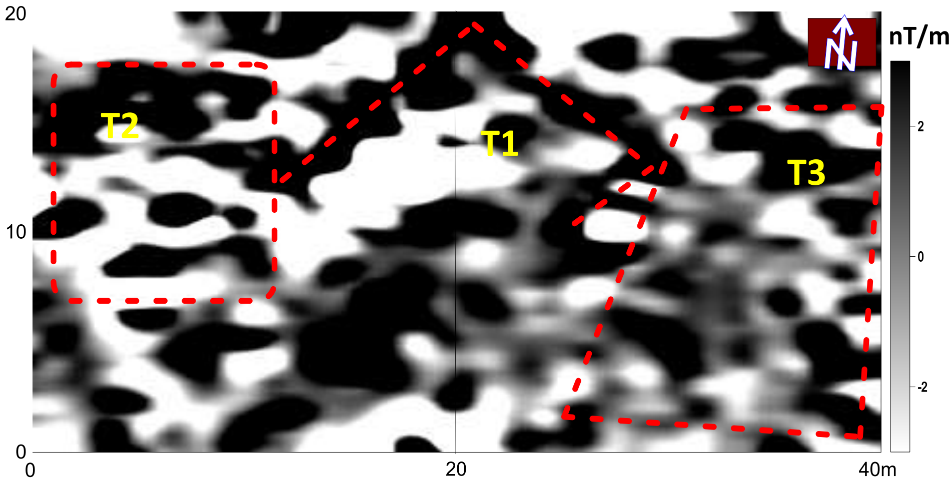

Fig. (5): The primary identified interesting magnetic anomalies in zones (T1, T2, and T3) at Site (2) are displayed in the gradiometer data.

Positive magnetic anomalies are prevalent in the second zone (T2), and they have a comparatively extended, round shape. They strongly suggest mud brick walls. A positive magnetic anomaly is detected in the third zone (T3). This area could be a portion of historical mud brick walls or ancient fire brick kilns or furnaces. Fig. (6) depicts an illustration of a mud brick-built ancient kiln that was discovered near Site (2).

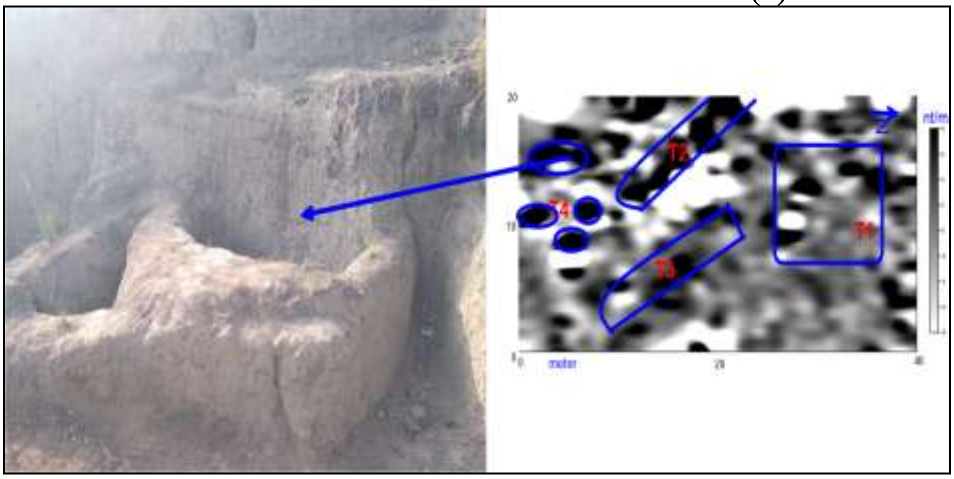

Fig. (6): An illustration of a mud brick kiln that has been detected and is located close to the Site (2) research area.

Interpretation of magnetic anomalies at Area (3)

The surveyed Site (3) is near the cemeteries and is 40 m by 20 m dimension (Fig. 1). Magnetic image analysis revealed fragmented and scattered patterns corresponding to negative anomalies (Fig. 7). Two archaeological anomalous zones (K1 and K2) that are almost certainly made of mud bricks can be seen on the processed magnetic image (Fig. 7). The magnetic signature of these regions generally reveals the presence of positive, scattered, and circular anomalies. Their magnetic properties are influenced by the amount and density of the inherited magnetic minerals; the darker the anomaly, the more magnetic minerals are present. Two obvious anomalous zones (K1 and K2) are among the magnetic anomalies at Site (3). East of the study area is where the first zone (K1) is located, and west of the study area is where K2 is. The following results are the most notable ones that may be seen in the magnetic image of Site (3):

An unusually sizable positive magnetic anomaly (K1) represents the first zone. On top of that, there are a few more minor unfavorable anomalies (white spots) that are seen at random in this. The primary positive anomalies are long and elongated, and they probably belong to a part of ancient mud brick walls.

The second zone (K2): Made of interconnected mud bricks, it might be an ancient wall remnant. An excellent reference point for a meaningful interpretation of the resulting magnetic data in this zone can be found close to Site (3), where remnants of ancient walls can be seen on the ground (Fig. 7).

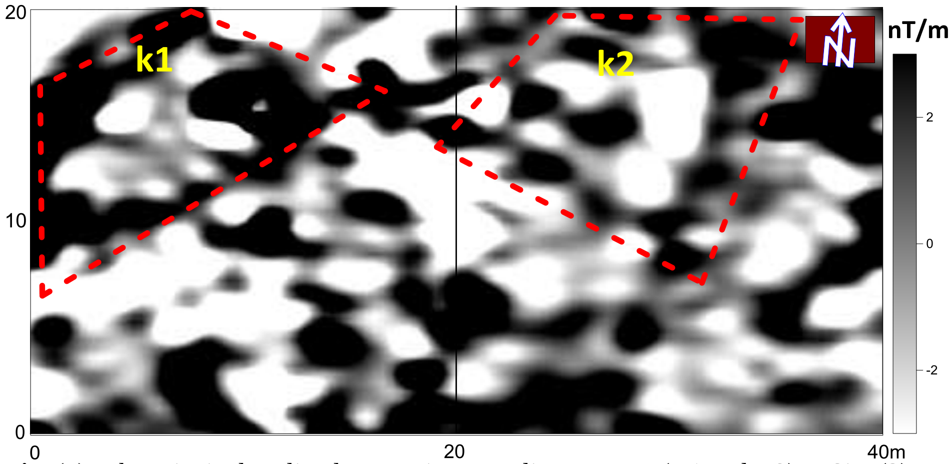

Fig. (7): The principal outlined magnetic anomalies at zones (K1 and K2) at Site (3) are shown in the gradiometer data.

2. The main results and discussions of GPR data

In many GPR profiles around the site, a concentration of reflections was seen in a zone of high reflectivity, often between 1m and 4m depth. Numerous distinct forms of lateral continuous and discontinuous reflections can be seen within this zone on the GPR profiles **(Moorman and Michel, 1997).** Even though individual GPR reflections are distinctive, many of the patterns exhibit similarities. These reflection patterns are caused by the structures constructed at the site by the dominant culture and the sedimentary structures that were created when the site was destroyed.

Profile No. 105 (P105), with a length of roughly 40 m, trends from NE to SW (Fig. 8). At the distances of 3 m, 23 m, 27 m, and 38 m, and the corresponding periods of 21, 22, 23, and 21 ns, four linear anomalies are visible through this profile. The widths of the anomalies are, respectively, 1.8 m, 5 m, 2 m, and 3 m. The first anomaly stretches from a depth of 18 m to 3 m and is situated far from other anomalies in the right corner of the profile. The third anomaly and the second anomaly are close together.

Profile No. 110 (P110), with a length of roughly 40m, trends from SW to NE (Fig. 8). Five anomalies are visible through this profile at distances of 5 m, 18 m, 28 m, 32 m, and 34 m, and at timings of 39 ns, 41 ns, 40 ns, 38 ns, and 30 ns, respectively. These anomalies range in depth from 1 to 3.5 meters and have a similar linear form. The genesis of these features may be related to the presence of mud brick walls in chambers.

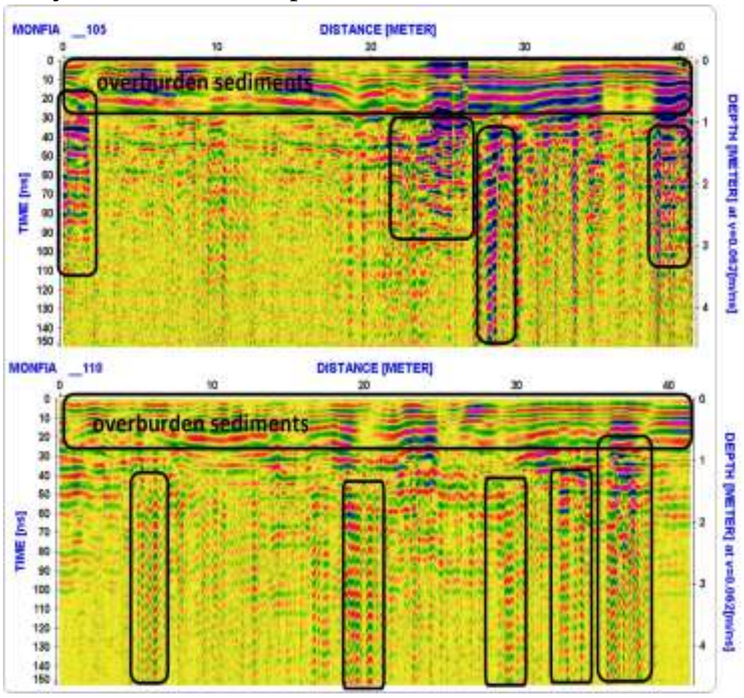

Fig. (8): Subsurface wall foundations are shown in the 2D processed GPR profiles P105 and P110, respectively.

Profile No. 111 (P111), with a length of roughly 40m, trends from NE to SW (Fig. 9). Three anomalies are visible through this profile at corresponding distances of 5 m, 18 m, and 24 m, and times of 40 ns, 41 ns, and 42 ns. The first anomaly appears about 11 meters away from the other anomalies and has a depth range of 1.5 to 4 meters. Long reflections can be seen in the profile as numerous mud-brick walls.

Profile No. 113 (P113), with a length of approximately 40 m, and trends from NE to SW (Fig. 9). Four anomalies are visible through this profile at distances of 1 m, 8 m, 20 m, and 30 m, and at timings of 35, 36, 33, and 30. Due to the similarities in length and depth of these anomalies, they may be subsurface walls.

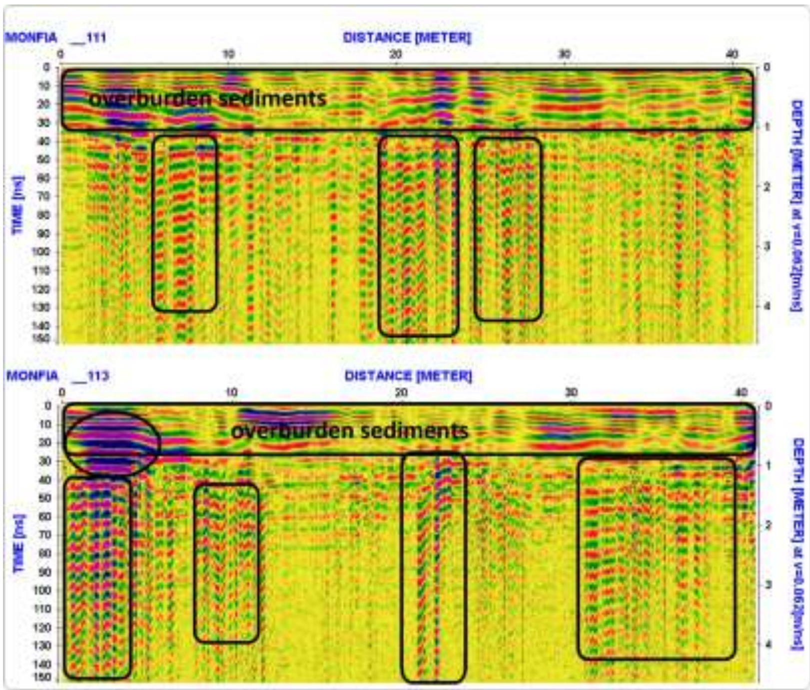

Fig. (9): P111 and P113, respectively, are 2D processed GPR profiles that show subsurface wall foundations.

Carried out in the study region was selected to correlate the GPR results with the results obtained. According to Fig. 10, GPR lines 105 and 110 are correlated to the magnetic image of Site (1). Eight anomalies were visible in the magnetic image (Fig. 10), and when we correlated these anomalies with the GPR lines (105 and 110), we discovered that the anomalies (1 and 4) are correlated with GPR line (105) at offsets of 2 and 28 meters, while the anomalies (6, 7 and 8) are correlated with GPR line (110) at offsets of 19 meters, 27 meters, and 37 meters (Fig. 10). The indicated anomalies (2, 3), which showed up in the magnetic image, are not all present in the GPR lines, unfortunately. Most of the defined anomalies are located at a depth of about 1.1 meters, corresponding to the GPR lines.

The walls of ancient chambers that are primarily made of compacted mud rock bricks could be recognized by both the magnetic and GPR results.

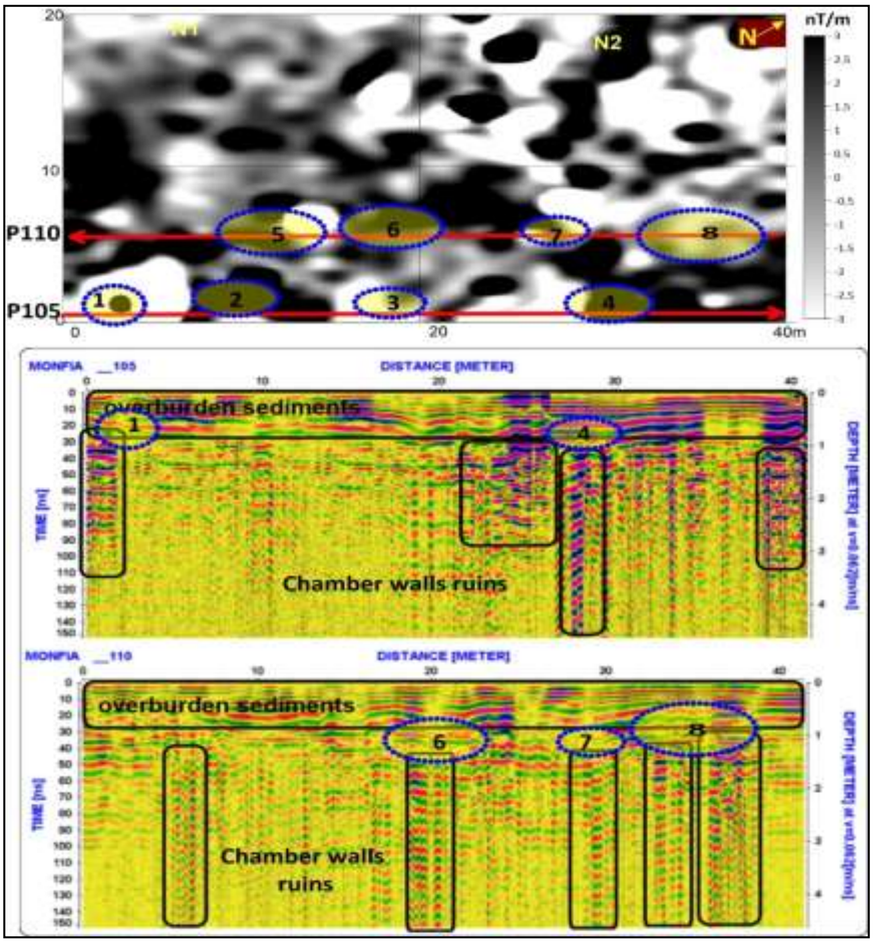

Fig. (10): (a) Magnetic image of the site (1), (b) GPR display of profile 105, and (c) GPR display of profile 110.

CONCLUSIONS

A new place for geophysical research in the Menofia Governorate is Tal-El Bendariya at Tala village. The site was covered in tall weeds, making it challenging for the staff to conduct the geophysical survey. To complete the archaeo-prospecting study (using magnetic and ground penetrating radar), three 40 m x 20 m archeological sites were selected. Using the FM256 fluxgate gradiometer and progressive parallel traverses, the micro-magnetic survey was carried out. Numerous archaeological features of all sizes and shapes have been found on sites with a 40–20 m vertical magnetic gradient method application. The studied area is divided into 6 grids. Each grid, which measures 20 meters by 20 meters and has numerous parallel traverses spaced one meter apart, was surveyed using a 0.5 station separation and a 1-meter traverse separation.

Using the Surfer program and Reflexw, the magnetic survey data and GPR data were analyzed. Kilns and hearths made of firebricks, as well as fragments of old walls formed of fire and mud bricks, are among the archaeological discoveries identified using magnetic gradiometry. While this is going on, the discoveries made from the GPR data concern a few strewn sections of mud brick walls. The comprehensive examination of the combined magnetic and GPR surveys suggests that the studied region was a section of an ancient ceramic industry during the Roman era. Generally speaking, this view is based on the area's archeological history.

Funding

This research was supported by the National Research Institute of Astronomy and Geophysics.

Acknowledgments

The authors are grateful to the National Research Institute of Astronomy and Geophysics (NRIAG, Egypt) for providing the Geoscan Gradiometer (FM256), the GPR (SIR-4000), and other essential field tools, vehicles, and field collaborators. The authors would also like to express their gratitude to the field inspectors who provided the essential archeological information as well as the Egyptian Supreme Council of Antiquities for approving their request to guide the fieldwork in the Menofia Governorate. The time and effort the reviewers put into enhancing the manuscript's quality is something we'd want to acknowledge. The insightful and helpful feedback we received from them is greatly appreciated.

REFERENCES

Abbas, M. ; T. Abdallatif ; F. Fahmy ; A. Shaaban ; A. Salem and M. Suh (2005): Archaeological investigation of the eastern extensions of the Karnak Temple using Ground Penetrating Radar and magnetic tools. Geoarchaeol., 20 (5): 537-554.

Abdallatif, T.F. (1998): Magnetic prospection for some archaeological sites in Egypt, Ph.D. Thesis, Faculty of Science, Ain-Shams University, Cairo, Egypt.

Abdallatif, T.F. ; S.E. Mousa and A. Elbassiony (2003): Geophysical investigation for the archaeological site at Qantir, Sharqyia, Egypt. Archaeol. Prospection, 10 (1): 27-42.

Abdallatif, T. ; E.M. Abd-Alla ; M.Suh ; R.M. Mohamed and I. El-Hemaly (2005): Magnetic tracing at Abu Sir (land of forgotten pyramids), Northern Egypt. Geoarchaeol. 20(5): pp.483–503.

Aitken, M.J. (1974): Geology and geophysics,2nd ed., Oxford University Press: Oxford, England.

Annan, A.P. ; S.W. Coway, and J.D. Redman (1991): “Water Table Detection with Ground Penetrating Radar,” in 61st annual international meeting of the Society of Exploration Geophysics (Houston, Texas: Society of Exploration Geophysics), pp494–496. Expanded abstract.

Atya, M. (1998): Geology and geophysics in Archaeology.Ph.D.Thesis, Berne University, Switzerland.

Bard, K.A. and S.B. Shubert (1999): Encyclopedia of the archaeology of ancient Egypt. Routledge (Taylor & Francis Group), London, p 938. ISBN 0415185890 (Print Edition).

Bossuet, G., Camerlynck, C., Brehonnet, C., and Petit, C. (2001): Magnetic Prospecting of Diachronic structures (Antiquity to the First World War) on the site of the sanctuary of Ribemont-sur-Ancre (Somme, France). Archaeol. Prospection., 8:67-77.

Butler D.K. (2005): Near-surface geophysics. SEG, Tulsa.

Cammarano, F. ; P. Mauriello ; D. Patella and S. Piro (1997): Geophysical methods for archaeological prospecting. Sci. and Technol. for Cultural Heritage, 6(2): 151-173.

Clark, A.J. (1990): Seeing Beneath the Soil Prospecting Methods in Archaeology. London: Bats ford Ltd, 17 6p.

David, B. ; J. Collins ; B.Barker ; J. Flood and R. Gunn (1995): Archaeological Research in Wardaman Country, Northern Territory: The Lightning Brothers Project 1990-91 Field Seasons. Aust. Archaeol. 41 (1): 1–8.

Davis, J.L. and A.P. Annan (1989): Ground-penetrating Radar for HighResolution Mapping of Soil and Rock Stratigraphy1. Geophys. Prospect 37 (5): 531–551.

Doolittle, J.A. (1993): Characteristics and Monitoring the Vadose Zone with Ground Penetrating Radar: Technological Application, 26-28. Columbus, Ohio, USA: October Ohio State University, pp. 105–119.

El-Emam, A.E. ; A.Lethy ; M.R. Ali and A. Awad (2021): Archaeological investigation and Hazard Assessment using Magnetic, Ground-penetrating Radar and GPS Tools at Dahshor Area, Giza, Egypt. Frontiers in Earth Sci. doi: 10.3389/feart.2021.674953.

El-Qady, G. (1995): Geophysical study for Saqqara area, Egypt.

Geoscan Research (1994): Instruction Manual Version 1.01. (Geoplot 2.01). Bradford, West Yorkshire, England, Geoscan Research.

Geoscan Research (2005): Instruction manual 1.97 (version 3.00p). Geoscan Research, Bradford.

Ghazala, H. ; A.S. El-Mahmoudi, and T.F. Abdallatif (2003): Archaeogeophysical study on the site of Tell Toukh El-Qaramous, Sharkia Governorate, East Nile Delta, Egypt, Archaeol. Prospection,10: 43-55.

Herbich, T. ; D. O'Connor and M. Adams (2003): Magnetic mapping of the Northern Cemetery at Abydos. Archaeol Polona, 41: 193–197.

Hinze,W.J. ; R.B. Von Frese and H.S. Afif (2013): Gravity and magnetic exploration Principles, Practices, and Applications, Cambridge University Press, first published 2013.

Hussain, A.G. (1983): Magnetic prospecting for Archaeology in Kom Oshim and Kiman Faris, Fayoum, Egypt, ZES110, Berlin, Germany, pp.36-51.

Kamei, H. ; M.A. Atya ; T.F. Abdallatif ; M. Mori and P. Hemthavy (2002): GroundPenetrating Radar and Magnetic Survey to the West of Al-Zayyan Temple, Kharga Oasis, Al-Wadi Al-Jadeed (New Valley), Egypt, Archaeol. Prospection, 9: 93-104.

Manataki, M. ; A. Sarris ; J. Donati ; C. Cuenca-García and T. Kalayci, (2015): GPR: Theory and Practice in Archaeological Prospection. Oxford: Archaeopress. doi:10. 13140/RG.2.1.3256.9363.

Moorman, B.J. and F.A. Michel (1997): Bathymetric mapping and sub-bottom profiling through lake ice with ground-penetrating radar.J. Paleolim., 18:61-73.

Morey, R.M. (1974): Continous subsurface profiling by impulse radar.In Proceedings: Engineering Foundation conference on subsurface exploration for underground excavations and heavy construction. Henniker, NH, American Society Civil Engineers.

Odah, H. ; T.F. Abdallatif and A. G. Hussain (1998): Micromagnetic Prospecting to delineate the buried solar boats in Abydos area, Sohag, Egypt, J. Environ. Sci. Mansoura Uni., Egypt.16:121-133.

Odah, H. ; T.F. Abdallatif ; I.A. El-Hemaly and E. Abd El-All, (2005): Gradiometer survey to locate the ancient remains distributed to the northeast of the Zoser Pyramid, Saqqara, Giza, Egypt. Archaeol. Prospect, 12:61–68.

Sandmeier, K.J. (2016): ReflexW Program for Processing of Seismic, Acoustic or Electromagnetic Reflection, Refraction and Transmission Data. Karlsruhe, Germany: Software Manual.

Scollar, I. ; T. Tabbagh ; A. Hesse and I. Herzog (1990): Archaeological Prospecting and Remote Sensing. Cambridge: Cambridge University Press, 692p.

Sutherland, T.L. and A. Schmidt (2003): Towton 1461: An integrated approach to battlefield archaeology. Landscapes. 4 (2): 15–25.

Weymouth, J.W. (1986): Geophysical methods of archaeological sites surveying. In "Advances in Archaeological Method and Theory", 9: 311-395.

Wilson, P. (2006): The Survey of Sais (Sa El-Hagar) 1997-2002. London: Egyptian Exploration Society, 336p.

استخدام المسوحات المغناطيسية والرادارية لرسم خرائط جيوفيزيائية لمنطقة تل البندارية الأثرية، مدينة تلا، محافظة المنوفية، مصر

محمد سالم[1] ، مروة شاهين[2]، أحمد خليل[2]، أحمد قطب[2]، خميس منصور[2]، طارق فهمي عبد اللطيف[2]، هشام زهرة[1]، محمود مكلوي[2]، علاء سامي[2]، عبد القادر أ[2]

1- قسم الجيولوجيا – كلية العلوم – جامعة بنها – مصر

2- المعهد القومي للبحوث الفلكية والجيوفيزيقية – 11421 حلوان – القاهرة – مصر

تستخدم العديد من الدول المختلفة التقنيات الجيوفيزيائية في أبحاثها الأثرية، وفي منطقة الدراسة الحالية لمنطقة تل البندارية (تلا – المنوفية، مصر)، استخدمنا تقنيات المسح المغناطيسي والرادار الأرضي والخارق للأرض. في الجزء الجنوبي من شمال الدلتا في مصر، بين فرعي النيل (رشيد ودمياط)، توجد محافظة المنوفية. وتم اختيار تل البندارية كموقع للدراسة لأن هذه المنطقة يعرف عنها بأنها غنية بالآثار وخاصة التي تخص العصر الروماني. فبالنسبة للمسح المغناطيسي، تم تقسيم تل البندارية إلى ثلاثة مواقع، وتم اختيار موقع واحد مناسب لدراستها بالطرق الرادارية GPR. وباستخدام برامج Geoplot وReflexw وSurfer، تم معالجة البيانات المغناطيسية والبيانات الرادارية GPR وتفسيرها لإنتاج صور توضح القطع الأثرية الموجودة تحت الأرض والتي كانت موجودة في الموقع. وقد كشفت البيانات المغناطيسية في تل البندارية عن عدد كبير من الظواهر الشاذة مع مجموعة متنوعة من الأنماط الهندسية غير العادية. وقد تم تفسيرها على أنها مواقد وأفران تاريخية مصنوعة من الطوب الناري (Firebricks) بالإضافة إلى أجزاء من الجدران القديمة المصنوعة من النار (Firebricks) والطوب اللبن. وفي الوقت نفسه، تشير النتائج المستخلصة من البيانات الرادارية GPR إلى وجود أجزاء قليلة متناثرة من جدران الطوب اللبن. وقد ثبت أن منطقة البحث في تل البندارية ربما كانت منطقة صناعة فخارية قديمة خلال العصر الروماني بعد دمج نتائج المغناطيسية ونتائج GPR معا.