INTEGRATED GEOPHYSICAL STUDIES TO IMAGE THE REMAINS OF AMENEMEHT II PYRAMID'S COMPLEX IN DAHSHOUR NECROPOLIS, GIZA, EGYPT

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ABSTRACT

Dahshour archaeological site is located adjacent to Giza necropolis at about 25 km south of Cairo. The site itself is an imperative necropolis that attracts the attention of the archaeologists. This location is a spectator of several historical episodes that start with the pyramidal complexes from the early dynasties (the mud brick tombs, the mastabas, and the Bent Pyramid) passing through the phase of the Step Pyramid of Zoser at Saqqara to the first complete pyramid in the history (the Red pyramid of Senefro "Khofo's father").

In 2002, the local archaeological supervisors suggested an area around the debris of the White pyramid (of Amenemeht II) for reconnaissance magnetic survey. The survey had been completed using the gradiometer FM36. More than 98 survey grids (20 x 20 m) of a surface area of 39200 m^2 have been measured. The results reported the recognition of some parts of the mortuary temple, the causeway, and some other anomalies that could not be attributed to specific archaeological aspect. Therefore, an integrated geophysical survey was proposed, through this work, to get more details that may help to identify these objects. The ground penetrating radar (GPR, SIR2000), the electrical resistance meter (Geoscan RM15), and the electromagnetic profiler (GEM300) have been utilized to acquire the data. They have been applied to selected zones to investigate specific objects and oriented to solve the problems questioned by the local archaeological inspectors. The study conveyed a superior image of the whole measured site and helped to identify most of the detected artifacts. Furthermore, the margins of the causeway and its infrastructure have been perfectly delineated. However, the possible places of the eastern entrance and the Valley temple have been tentatively located.

Keywords: Archaeo-geophysics, Dahshur, White Pyramid.

اعتماداً على المعلومات الأثرية المتوفرة حول امكانية العثور على ضريح الملكة كليوباترا داخل حدود معبد تابوزرس ماجنا الذى يبعد عن مدينة الاسكندرية بمسافة 45 كيلومترا على الطريق الساحلى وبالقرب من مدينة برج العرب الجديدة.

تم استخدام وتطبيق ثلاثة طرق جيوفيزيائية للحصول على صورة تكاملية لمنطقة المعبد واحتمالية أو عدم تواجد ضريح الملكة كليوباترا داخل حدود المعبد. وهذه الطرق الجيوفيزيقية التوافقية هى طريقة الجيورادار الأرضى ، طريقة الجيوكهربية الأرضية وأخيرا طريقة المغناطيسية الأرضية.

تم تكثيف القياسات الجيوفيزيقية الحقلية للطرق الجيزفيزيقية الثلاثة على معبدى أوزوريس وإيزيس داخل حدود معبد تابوزورس – ماجنا ، وقد تم مراعاة الحصول على قياسات ذات جودة ودقة عالية نظراً للأهمية الأثرية للموقع. وأظهرت القطاعات الجيورادارية صورة واضحة لعمق يصل حتى الى 30 متراً.

تم اجراء القياسات الحقلية لعدد (149) قطاعا (جيوراداريا) و(20) قطاعا (جيوكهربيا) ثنائى البعد وأخيراً تم تغطية منطقة المعبد كله بنقاط قياس مغناطيسية.

اعتماداً على النتائج التكاملية للثلاث طرق الجيوفيزيقية الثلاثة تم التوصية بحفر ثلاثة آبار استكشافية فى اماكن مختلفة وبعمق 3 بوصة. مع احتمالية وجود بعض التكهفات الصغيرة أو بعض الممرات لبعض الأنفاق السرية التحت سطحية ولكنها ليست كبيرة كالقبو.

وقد أكدت نتائج القياسات الجيوفيزيقية التى اجريت بمنطقة المعبد حتى هذه المرحلة عدم وجود قبر أو كهف ذو أهمية أثرية كبرى على الرغم من احتمالية وجود بعض التكهفات الصغيرة فى الطبقات التحت سطحية.

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Introduction

The applications of integrated geophysical methods to investigate the buried archeological remains with considerable resolution are quite visible process. These geophysical techniques are also non-destructive, and time, efforts and money savers. Their intact to the archaeological sites in Egypt is beneficial (Atya et al., 2005).

Dahshur is a significant site for the scientists interested in studying the dynastic era in Egypt. Its content of the monumental treasures is valuable. The site is widely extended; therefore, the local archaeological inspectors at Dahshur suggested the site of the present work as one of the key sites to study Dahshur necropolis. Therefore, an extensive research plan was proposed to prospect the eastern boarder of Dahshur area around the White pyramid of Amenemeht II (Fig. 1). The proposed geophysical survey has planned to be composed of two phases; the first phase has been conducted in 2002 as a preliminary magnetic survey using the fluxgate magnetic gradiometer (FM36 of Geoscan Research [1993]). The measuring survey started on the eastern boarder of the debris of the pyramid and extended down eastwards over 98 survey grids (20 X 20 m). The results of this phase concluded the existence of an archaeological property defined as a part of the pyramidal complex of Amenemeht II (the White pyramid), the items of this complex could be roughly identified and contributed to the mortuary temple and the causeway of the pyramid; in addition to other remains that could not be identified (Fig. 2) (El-Emam et al, 2008). The second phase was planned based on the results of the first phase and it will be precisely discussed in the present work.

The present work outlines the results of the second phase, in which, the electrical resistance, the ground penetrating radar (GPR) and the electromagnetic profiler have been applied on selected zones in the study area previously surveyed with the magnetometer in 2002. The selection of the survey zones and the geophysical tool within this phase is based on the object content in the zone, geophysical image consistency, and the ground surface suitability for the tool. This phase resulted in the completion of the whole picture of the subsurface, helped to reveal and sharply, as much as possible, identify the margins and the inner-structure of the causeway, the eastern portion of the mortuary temple, mastabas, sand-fill pits, labor residence and the approximate location of the eastern entrance and the valley temple. The resulted image might be used as the base of excavation proposal.

Archaeological Background

Dahshur area is a very inspiring site for both archaeological investigation and tourist industry. It retains a diversity of enormous archaeological objects like; the White Pyramid of Amenemeht II, the Black Pyramid of Amenemeht III, and the Pyramid of Senusret III from the Middle kingdom (12th and 13th Dynasties). Furthermore, it includes plenty of minor monuments, as the temples, the Mastabas and the royal and auxiliary tombs. Some treasures of the Middle Kingdom (Now in Cairo museum) have been found there (Baines and Malek, 1992, Black and Norton, 1993).

The White Pyramid; is contributed to Amenemeht II; the follower of the 4th dynasty king Snefru. The pyramid is based over an approximate area of 50 by 50 meters and named "white" due to the fact that its core and casing made of white limestone. Its building technique is fairly typical for the middle kingdom; the limestone core forms the skeleton of walls and the compartments between the walls are filled with sand and the entire pyramid was encased with limestone. The pyramid is badly documented and the handed maps are crude, incomplete and inaccurate (El Emam et al, 2008).

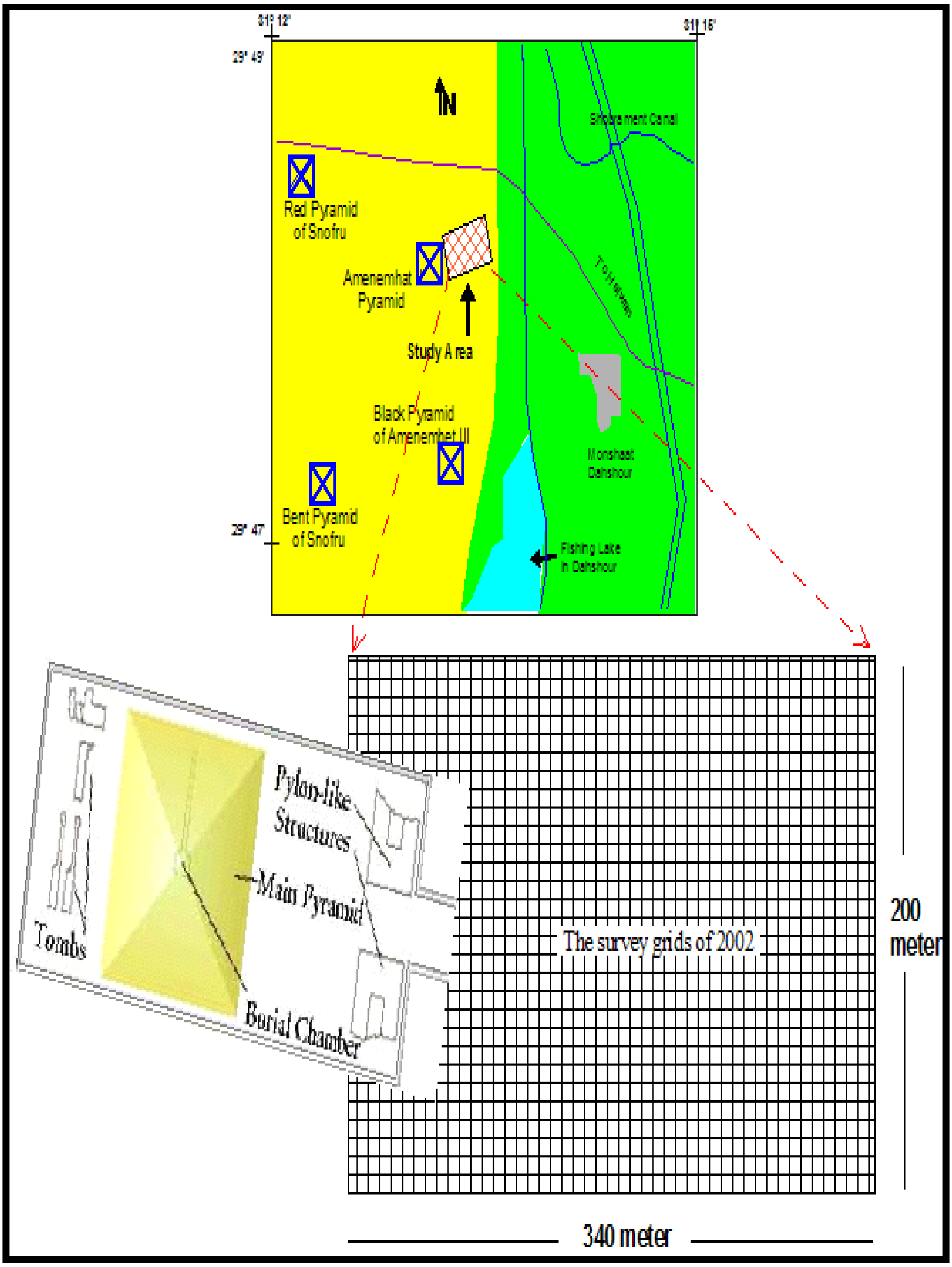

Fig. 1: Location map of the area studied in 2002; the lower part is the survey grids.

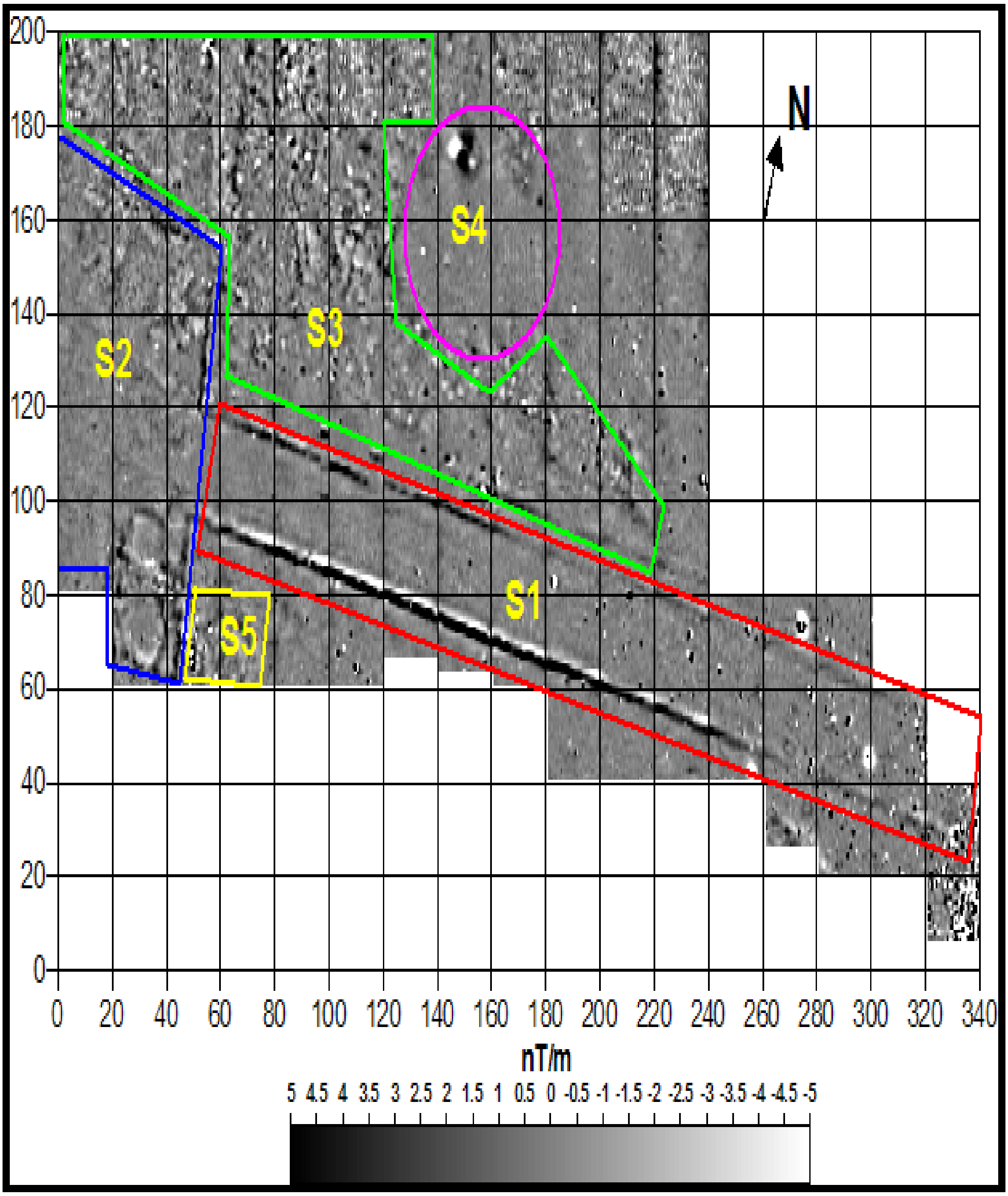

Fig. 2: The magnetic image resulted from the survey of 2002;
it shows the archaeological structures (S1, S2, S3, S4, and S5 of El Imam, 2008).

The Pyramidal complexes components; these are some additional installations and buildings that customary associate to a pyramid. They have been described by many authors; Lehner (1997) reported them as the courtyard, a small cult pyramid that might be for the king's ka (soul) and a mortuary temple just to the east of the pyramid (Fig 2). The mortuary temple consists of the outer section; with an entrance hall and an opened columned courtyard, and the inner sanctum; that includes a five niche chapel and behind it an offering hall with a false door adjacent to the pyramid, and an altar centered before it. A causeway, often covered, connects such mortuary temple (and the pyramid) to a small valley temple, which in many cases were nothing more than a monumental gateway.

GEOPHYSICAL SURVEY: PHASE I (2002)

In May 2002, a preliminary survey was carried out over the study area using the fluxgate magnetic gradiometer (FM36 of Geoscan Research [1993]). The survey included 98 survey grids (20 x 20 m) covering an area of about 39200m^2 (0.5m inter station distance). The resulted magnetic image (Fig. 2) could be interpreted into some archaeological complex structures; they are referred to as S1, S2, S3, S4 and S5.

El-Emam (2008) reported that the complex ***S1*** (Fig. 2) is clearly visible and consists of two positive linear anomalies parallel to each other and trending in E-W direction with total length of about 300m; these two lines might represent the layout of the causeway; the wall thickness is about 1.25 m and separating distance is about 20 m. The significance of the causeway is not only that it ties between the Valley temple and the mortuary temples, but is much more contributed to the historical scripts on them that tells details about the complex. The complex ***S2*** is located at the western portion of the area over the debris of the White pyramid, based on the location of the anomaly ***S2*** and its geometry; it could be defined and easily contributed to a part of the mortuary temple. The mud bricks wall layout of the causeway ***S1*** is softly linked to a similar mud bricks wall laying out the detected part of the mortuary temple. The complex ***S3*** is relatively large; it starts at the upper left corner of the survey area (north of mortuary temple ***S2***) and extends towards the east to the center of the area. This complex could be divided into sub-structural elements separated by a mud bricks wall of 1.5 m thick. Through the discussions with the local inspectors of the site, they lead to the believe that ***S3*** complex and its sub-structural feature could represent the elements of an ancient city. However, a further geophysical survey was recommended to gather more information. The complex ***S4*** is located at the centre of the northern part of the study area and expressed as a big positive magnetic anomaly. It has an oblique rectangular geometry (15x12 m) and shows the absence of any traces of archaeological features around it. Such a structure could be contributed to a tomb kind called "mastabas" that was normally constructed for the noble ancient Egyptians. While the complex ***S5*** is located at the southwestern part of the surveyed area representing a number of dissected positive and negative anomalies of different shapes and sizes, covering a surface area of about 900m^2 (30 m x 30 m). This structure is hazy and not clear enough to contribute it to an archaeological property.

However, further geophysical surveys are strongly recommended to get more details about the site for superior understanding.

GEOPHYSICAL SURVEY: PHASE II (2008)

As a continuation for the geophysical survey on 2002, three geophysical techniques have been applied at some section of the total area of 2002 (Fig. 3). The geophysical tools were oriented to get details about specific localities where the magnetic data left unrevealed questions. Furthermore, we aimed to detect the remain portions of the white pyramid complex specially those of non magnetic properties. Deciding a geophysical technique to be applied on an area was controlled by the time allowed for the survey, the informative nature of the included object, and the suitability of the ground surface for the technique.

The applied geophysical techniques

Three geophysical techniques (electric resistance scanning, ground penetrating radar (GPR) survey, and electromagnetic profiling) have been applied to selected parts of 2002 site (Fig. 3). In the following sections, we will present a detailed discussion for each applied geophysical technique that has cooperated in the survey and their results, and then compare and integrate them.

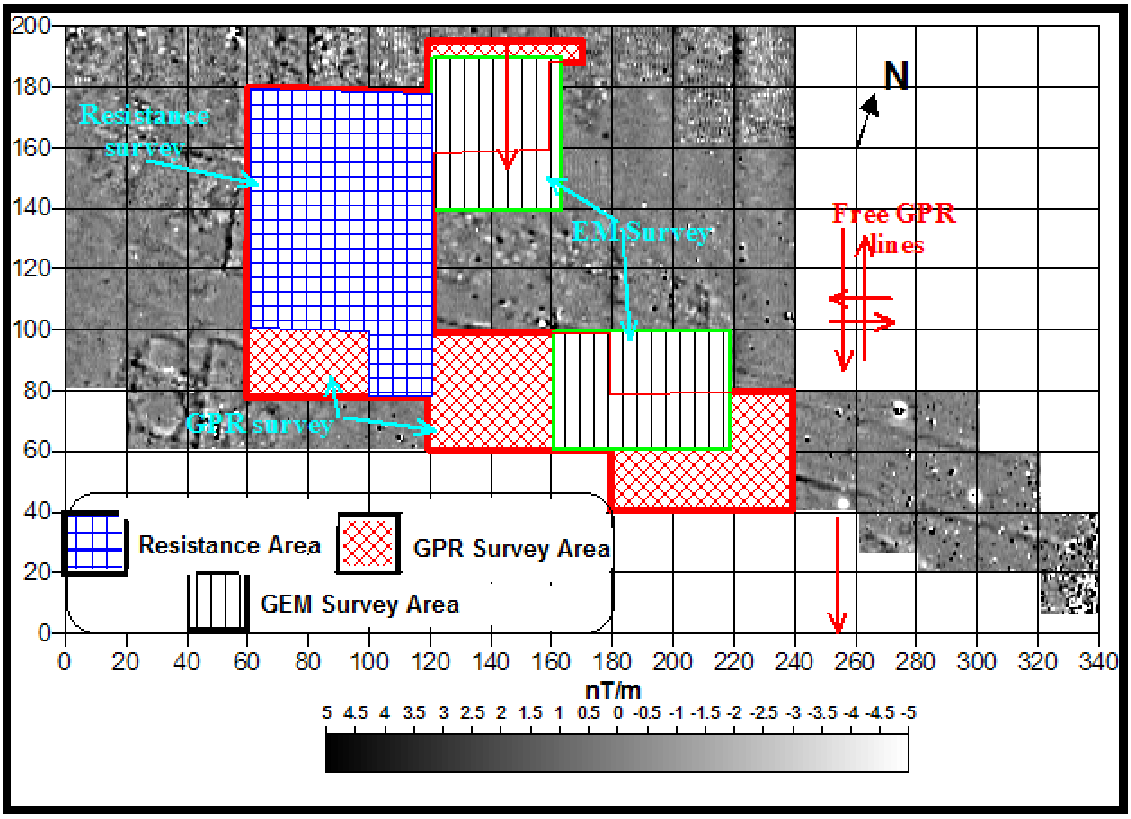

Fig. 3: The site with the location of the survey grids of the different techniques.

I) ELECTRIC RESISTANCE SCANNING (RM 15, GEOSCAN RESEARCH 1993)

It has been used for the first time in England in 1946 (Aitkenson, 1974; Aspinall and Pocock, 1995), and then treated extensively in archaeological prospecting by many authors (Scollar et al., 1990; Clark, 1990; Cale et al., 1997). It is also applied on the national scale in Egypt by many authors (El-Gamili et al., 1999; El-Bassiony, 2001; Ghazala et al., 2003). It uses twin array (Fig. 4), in which a fixed remote electrode and two mobile electrodes are installed. The mobile electrodes move along equidistance parallel lines forming a measuring grid. The obtained data is, normally, processed and visualized on the Geoplot software.

I-1) Resistance Data Acquisition; the study area (Fig. 5a) is divided into 13 grids (20 x 20 m) covering a surface area of 5200 m^2. The site has been selected to obtain details about some objects that formerly detected by the magnetic survey of 2002. The site for the resistance measurements is close to the debris of the White Pyramid; this resulted in mixing the sand soil with the debris mud bricks, which in turn produced a relatively conductive medium adequate for the resistance tool. The measured lines inside the grids were scanned in zigzag form and were separated with 1m and the station inter distance was 1m. Finally, the measured grids are collected together in one grid and processed as one field.

I-2) Resistance Data Processing and Interpretation; The obtained raw image (Fig. 5b) was prepared in proper scales to be suitable for comparative readings with the previously obtained magnetic image. The image quality was good enough so that a little processing for data enhancement was needed. The Geoplot software (Geoscan Research, 1994) was used for the processing and visualization, by which, the extreme outliers were typically removed and the data was clipped to the appropriate range by examining the data statistics and histogram characteristics.

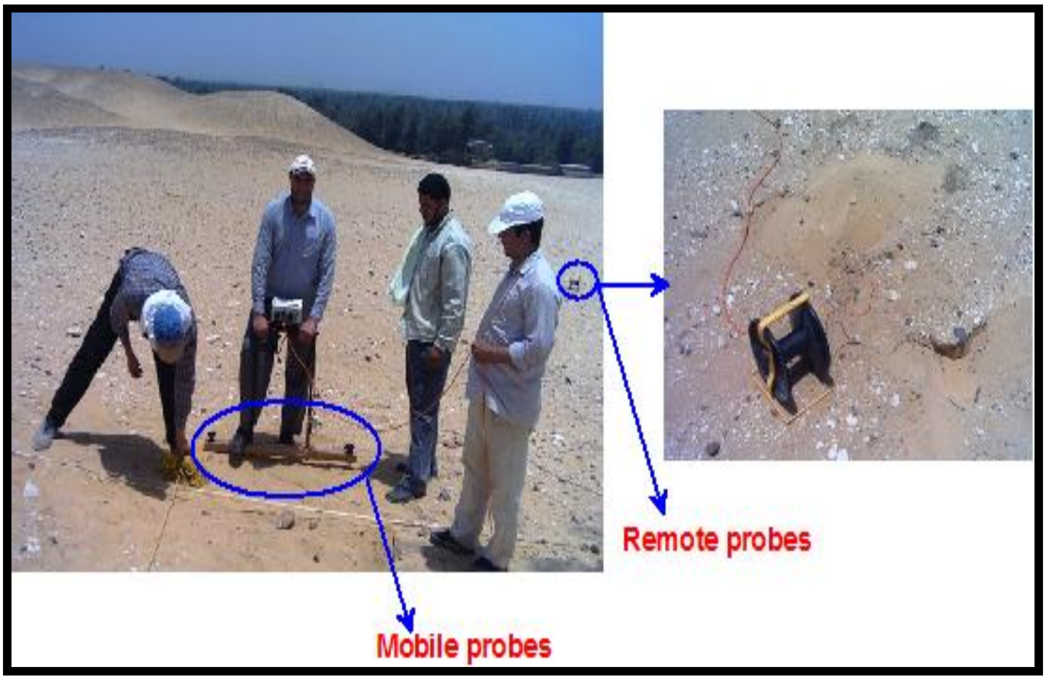

Fig. 4: The RM 15 field setup using the twin array.

The corresponding magnetic image of 2002 (Fig. 6a) is represented together with the processed resistance image (Fig. 6b). Although, the resistance image is slightly ambiguous, it shows some consistency with the magnetic data. The background resistance is certainly high, which might be contributed to the dry surface sand, the gravel deposits, and the type of the used probe array (Geoscan RM-15 Manual, 1993). The dummy zones might refer to the bad coupling to the ground as a result of the aridity conditions at the surface during the survey time.

At least five archaeological features could be studied in comparison with the magnetic image; they are referred to as M1, M2, M3, M4 and M5. The ***M1*** is composed of two parallel conductive lines corresponding to the two walls defined by the magnetic survey and defined in figure 4 as complex ***S1***. Therefore, ***M1*** refers to the borders of the causeway of the White Pyramid exactly as was detected in the magnetic image. The ***M2*** is a relatively big anomaly (1600 m^2) of low resistivity, although, it is included in the frame of the complex ***S3*** (Fig. 2), it was not detected by the magnetic survey. Although, the resistance image of this anomaly shows a hazy and non-definable structure, it could be contributed the labors residence (a particular element of the ancient city ***S3***) due to its place in respect to the pyramid and the causeway. The ***M3*** is relatively a rounded low conductive anomaly that might be interpreted as a sand-fill ditch, its appearance at the magnetic image is hardly detectable and its geometry is not clear. Such non magnetic and resistive structures could be contributed to limestone occurrences. The features ***M4*** and ***M5*** show particular consistency to the magnetic image at the corresponding place; ***M4*** could be grouped into particular sub-anomalies of alternating geometry and dimensions; which may refer to possible sand-fill ditches of different size and shape.

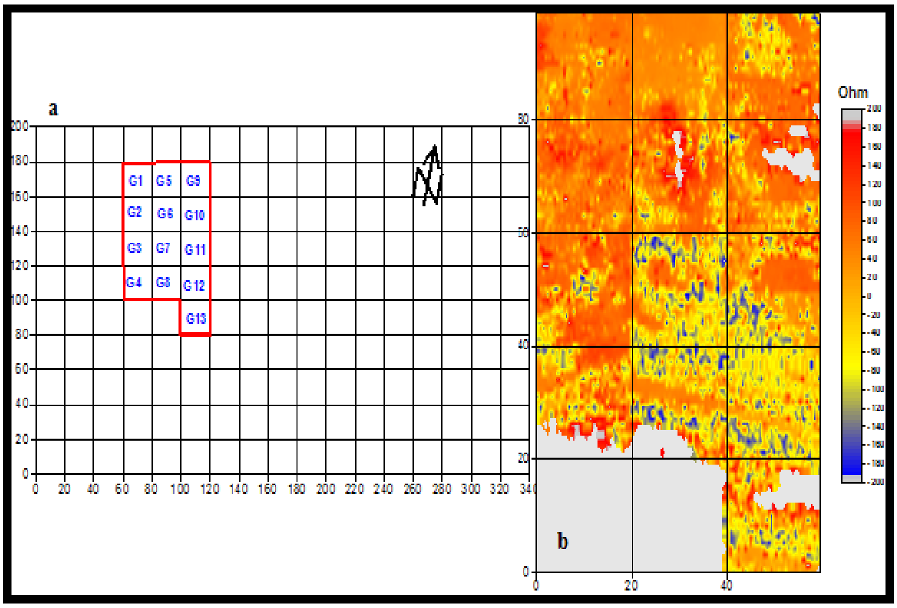

Fig. 5: a) The measured zone with RM15 and, b) The raw image.

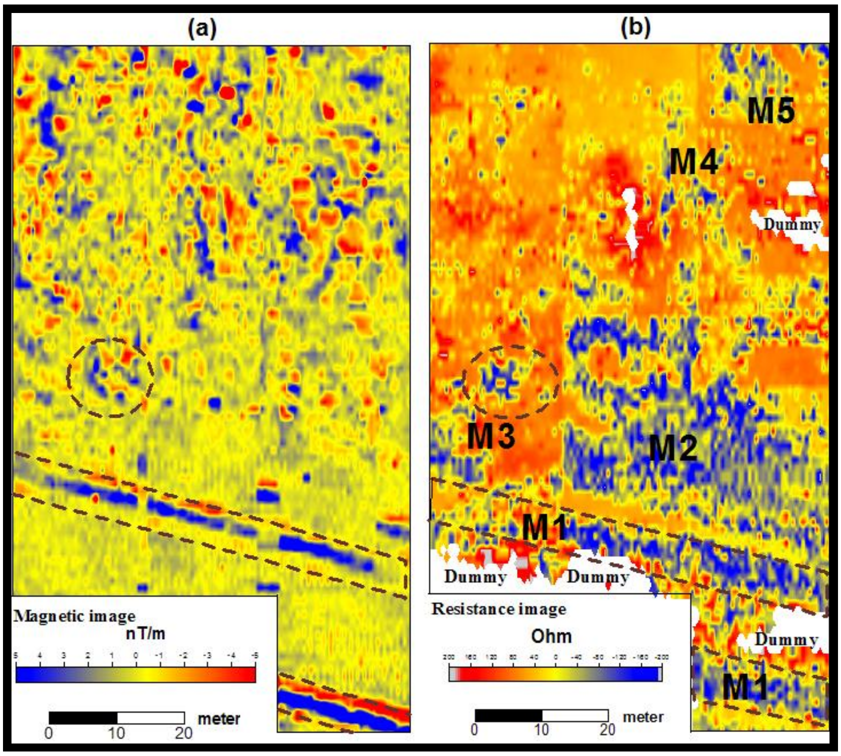

Fig. 6: a) The corresponding magnetic image,
b) The processed resistance image of the same site showing the main detected features.

II) GROUND PENETRATING RADAR (GPR);

Firstly, the GPR was used to study the iced lakes (Streenson, 1951, Lalumiere, 1994). Recently, the first efficient GPR system was designed for mapping small scaled structures within the upper 10-15m of the subsurface (Davis and Annan, 1989 and Annan et al., 1991). This technique has been employed extensively for archaeological investigations (Malagodi, et al., 1996, Kamei, et al., 2002, Piro et al., 2003, Shaaban, et al., 2003 and Abbas, et al., 2005).

II-1) GPR Data Acquisition; The magnetic image of 2002 (Fig. 2) left some undeclared localities, therefore, five grids were selected (A, B, C, D and E) for a detailed GPR survey (Fig. 7 a and b). Grid A (50 x 36 m) was scanned with the 200MHz antenna, the distance between the profiles was 2m. The grids B, C, D and E were scanned with the 400MHz antenna. Grid B is of 60 x 60m dimensions in the N-S direction, and 1m profile separation. Grid C has the dimensions of 60 x 50m in the N-S direction and 5m interval. Grids D and E are of 60 x 40m in the N-S direction and 5m profile separation. A survey wheel model 620 with 16 inches diameter was utilized to acquire a fixed number of scans over a unit distance (20 scans/m) providing an almost constant horizontal scale for the entire survey.
Furthermore, 6 free oriented GPR profiles (P1 to P6) were distributed over the area to study specific objectives (Fig. 7a). P1 crossed Grid A to check the extension of some features outside the grid, while, the profiles P2 to P6 were measured on the two domes at the eastern part. This part is thought to be the eastern entrance gate of the White Pyramid.

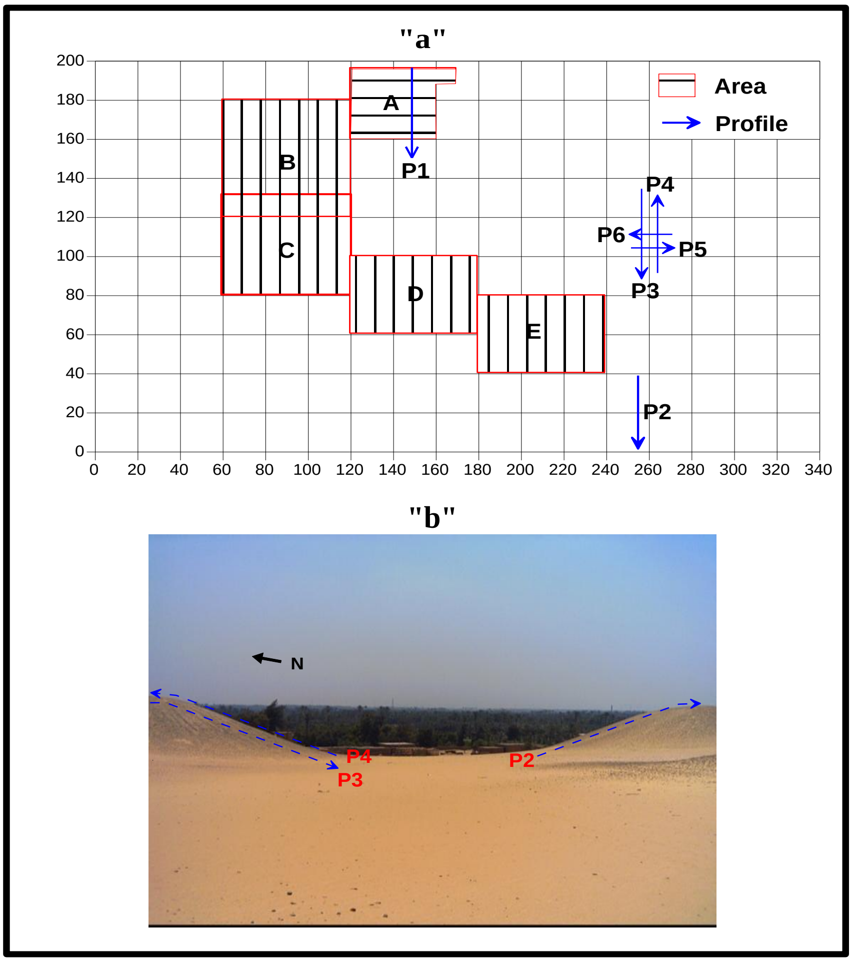

Fig. 7: a) The layout of the GPR survey,
b) A Photograph of the two eastern domes and the free oriented profiles on them.

II-2) GPR Data Processing

The measured data was inverted from the RADAN format into the ReflexWin format to facilitate the processing using Reflex software. Each line was assigned to its coordinates in the survey grid. Since the grids have been selected to check or declare some features from the magnetic image of 2002, they have been processed and prepared to be proper for the comparative study with the corresponding place on the magnetic image. The processing steps applied to the sections could simply include the noise removal and signal enhancement.

II-3) GPR data interpretation

Grid A;

The corresponding magnetic image (the upper right part of figure 8a) includes an object that needs to be declared, therefore, the GPR grid was selected around it. This feature will be visualized via two profiles (PA1 and PA2) passing through it and the time slices. At profile PA1 (Fig. 8b); three objects could be obviously seen at x = 6m, 18m, and 32m and at the time z ≈ 20ns (depth d ≈ 0.5m to 1m). At profile PA2 (Fig. 8c); regardless the obvious curvature of the reflector in the middle of the section which is a result of the surface topography, the section includes at least four dissections. It is thought that, this reflector could be the base of cultural property composed of a combination of limestone and mud bricks. On the magnetic image, the mud bricks could be noticed but the picture is declared through the GPR. Such a combination of limestone and mud bricks could be evidenced in many places close to the survey place (photographs, Fig. 9).

Time slices and 3D intersections have been constructed for grid A (Figs. 10a and 10b), both representations show clearly the 3D vision of the objects mentioned previously. Such an object might be interpreted as Mastaba (a frequently used kind of tombs at Saqqara necropolis) while the limestone base forms the passage towards it. The other objects could be subsidiary structures belong to the main complex.

Grid B;

The magnetic image corresponding to the location of grid B (Fig. 11a) is complicated, it includes some mud bricks occurrences that are randomly distributed and do not give a geometrical layout. Therefore, the GPR survey was proposed to get more information. The GPR records showed normal reflections that hardly to be assigned for mud bricks; this might be caused by its dryness. However, some little occurrences could be noticed. Profiles PB1 and PB2 (Figs. 11b and 11c) show some of them. They are shallow (d = 0.2 to 0.5m), and do not form a geometrical shape, their lateral and vertical extensions are shown on the time slices and the 3D image (Figs. 12a, and 12b). Although the objects are random and could not be identified, the consistency with the magnetic is particularly acceptable.

Grid C, D and E;

The three survey grids (C,D and E) have been oriented to study the causeway, while the other techniques showed only its margins. Applying the GPR to the causeway resulted in quite good information about its case, so that, basics of conservation could be considered. The profiles have been extensively studied. In the following; sample sections representing different items of the causeway will be shown. Figure 13 shows two records from grid C (PC10 and PC30); they show that the base of causeway is nonmagnetic, which might be, the frequently used rock in the site, limestone. It extends outside the margins of the road for possible side passages. The two margins are 20m separated (just like the magnetic conclusion) and made of mud bricks. The middle part of the sections (enclosed in the dashed rectangle) looks interesting; firstly, I thought to be just a deformation in the floor of the causeway, but its continuity and the relative similar signature leads to the thought of a constructive element of the road. This point has been namely discussed with the archaeological inspectors at Dahshur. The discussions lead to the idea of being an constructive installation used as slider for transporting coffins and other heavies between the valley and mortuary temples.

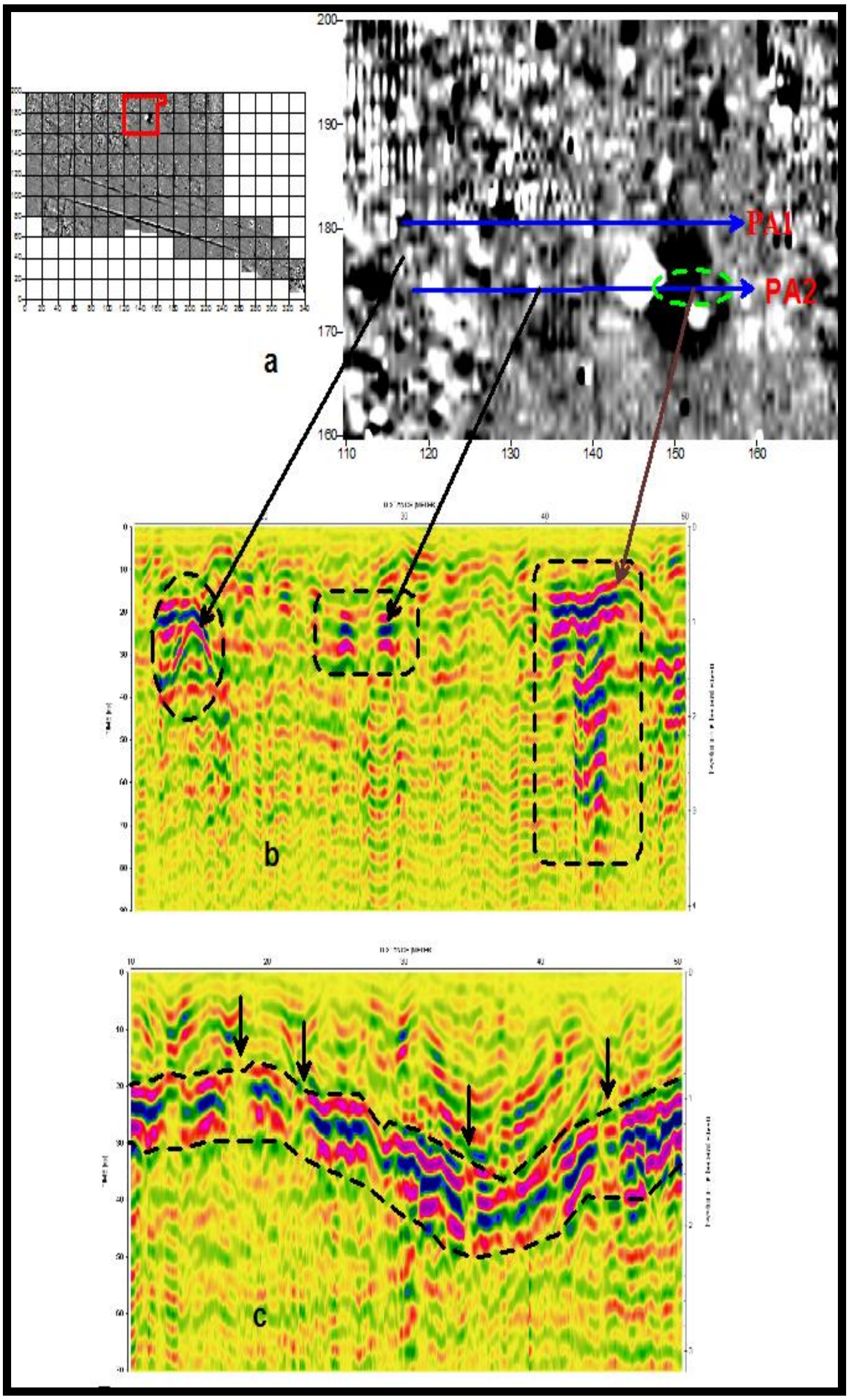

Fig. 8: a) The corresponding magnetic image to the gird A, b) profile PA1, and c) profile PA2; the consistency to magnetic image is certainly acceptable.

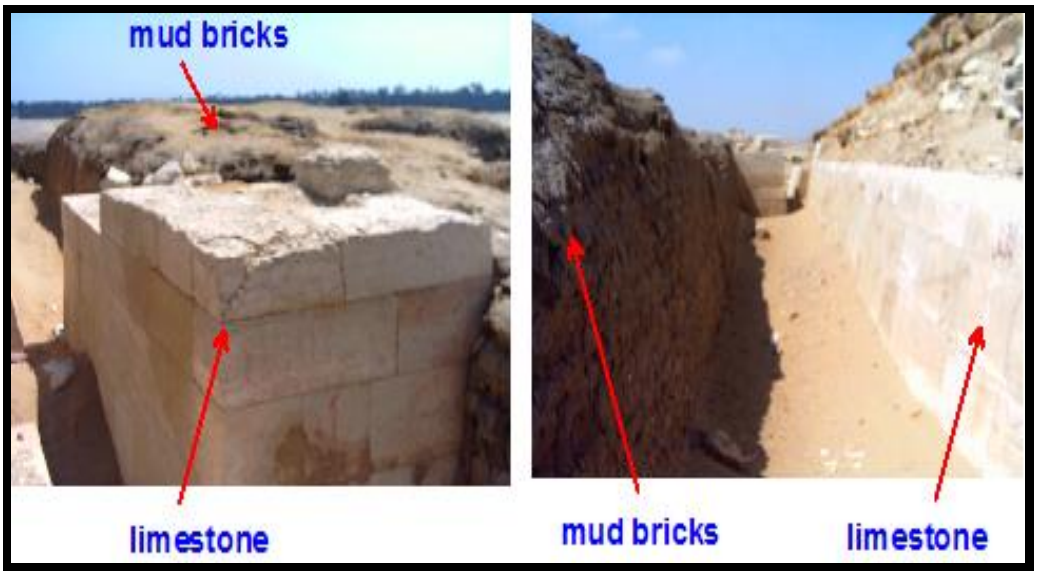

Fig. 9: Photographs of limestone and mud bricks combinations close to the survey place.

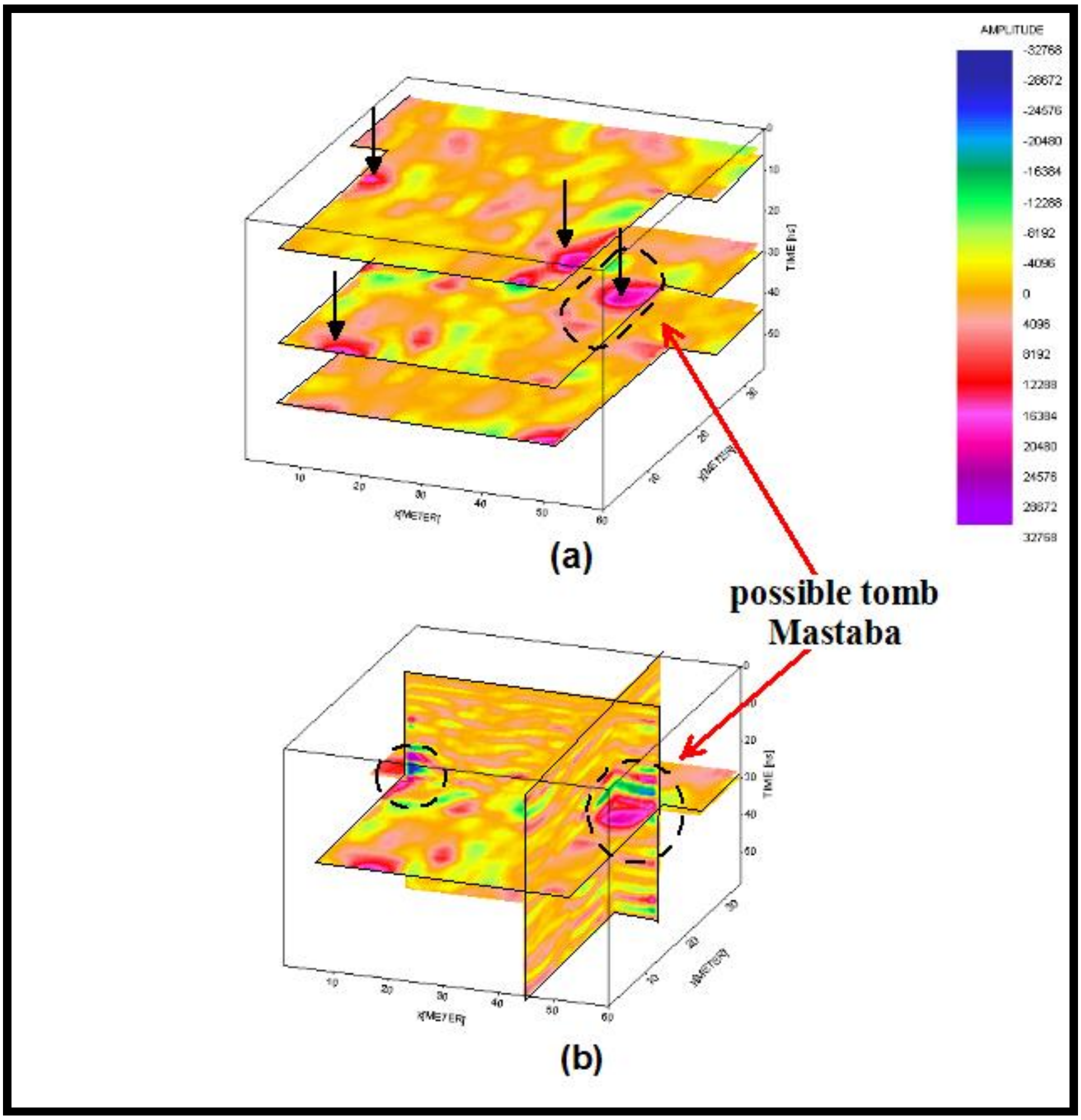

Fig. 10: Time slices (a) and 3D profile intersection
(b) focusing on the objects.

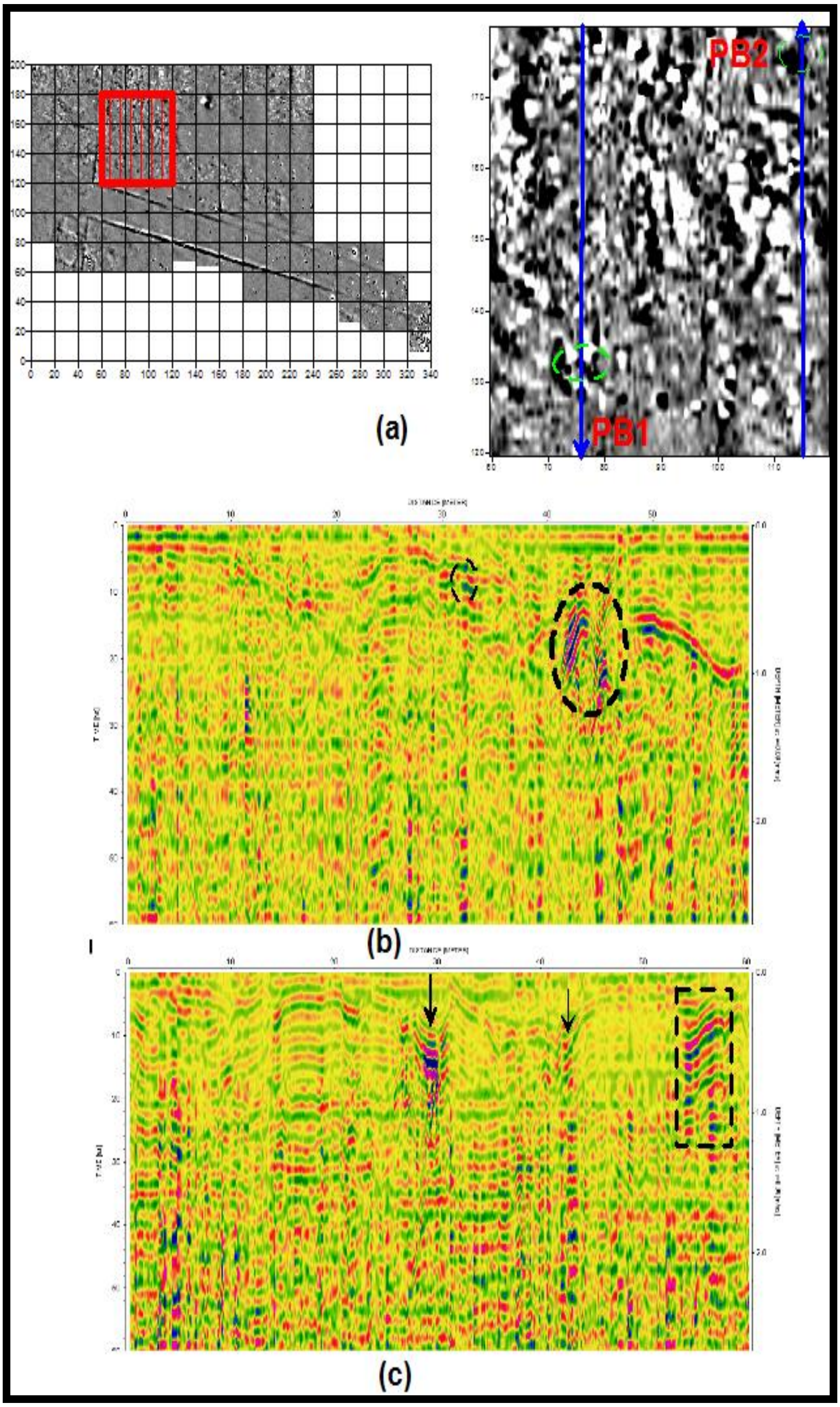

Fig. 11: The magnetic image (a), the profile PB1,
and the profile PB2, some few occurrences could be noticed.

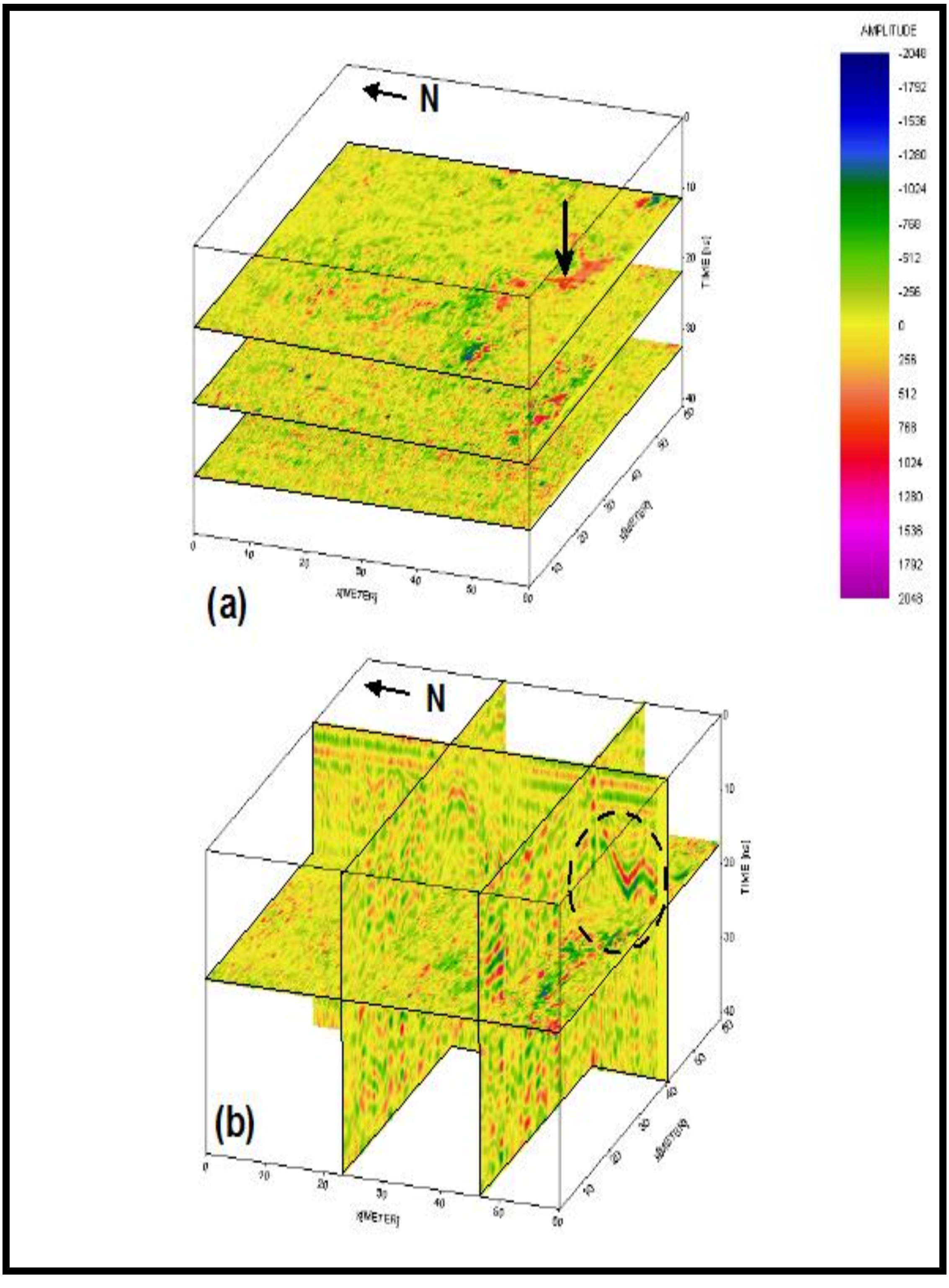

Fig. 12: Grid B represented in 2D time slices (a) and profiles intersections (b); they show the lateral and vertical extensions of the objects.

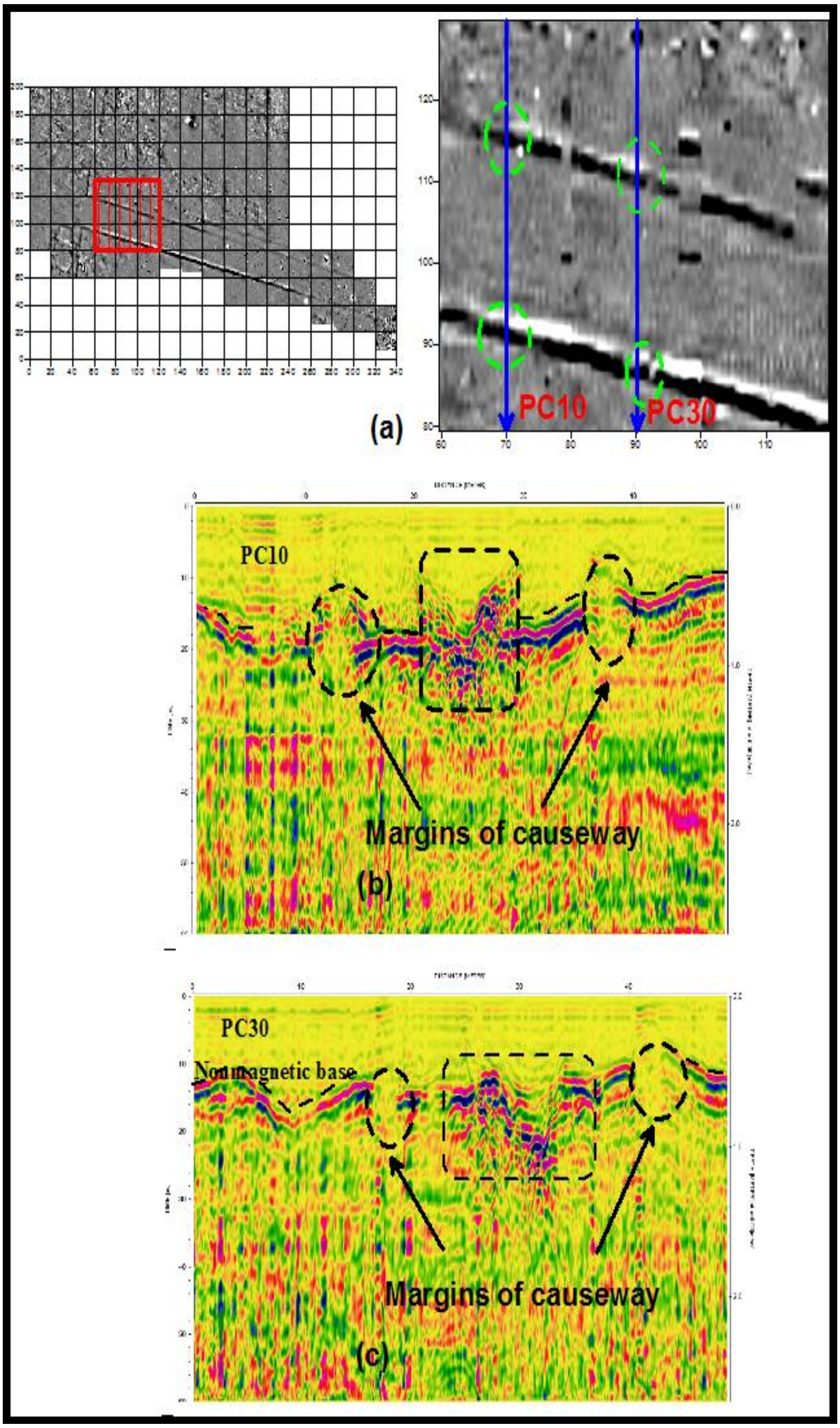

Fig. 13: Profiles PC10 and PC30 from Grid C; they show the causeway base and margins in addition to some specific constructive objects in the middle.

Figure 14 shows two other profiles (PD10 and PD20) from grid D, they represent other parts of the causeway. They show exactly the same just like profiles PC10 and PC30 (Fig. 13); the causeway base, margins and the object in the middle.

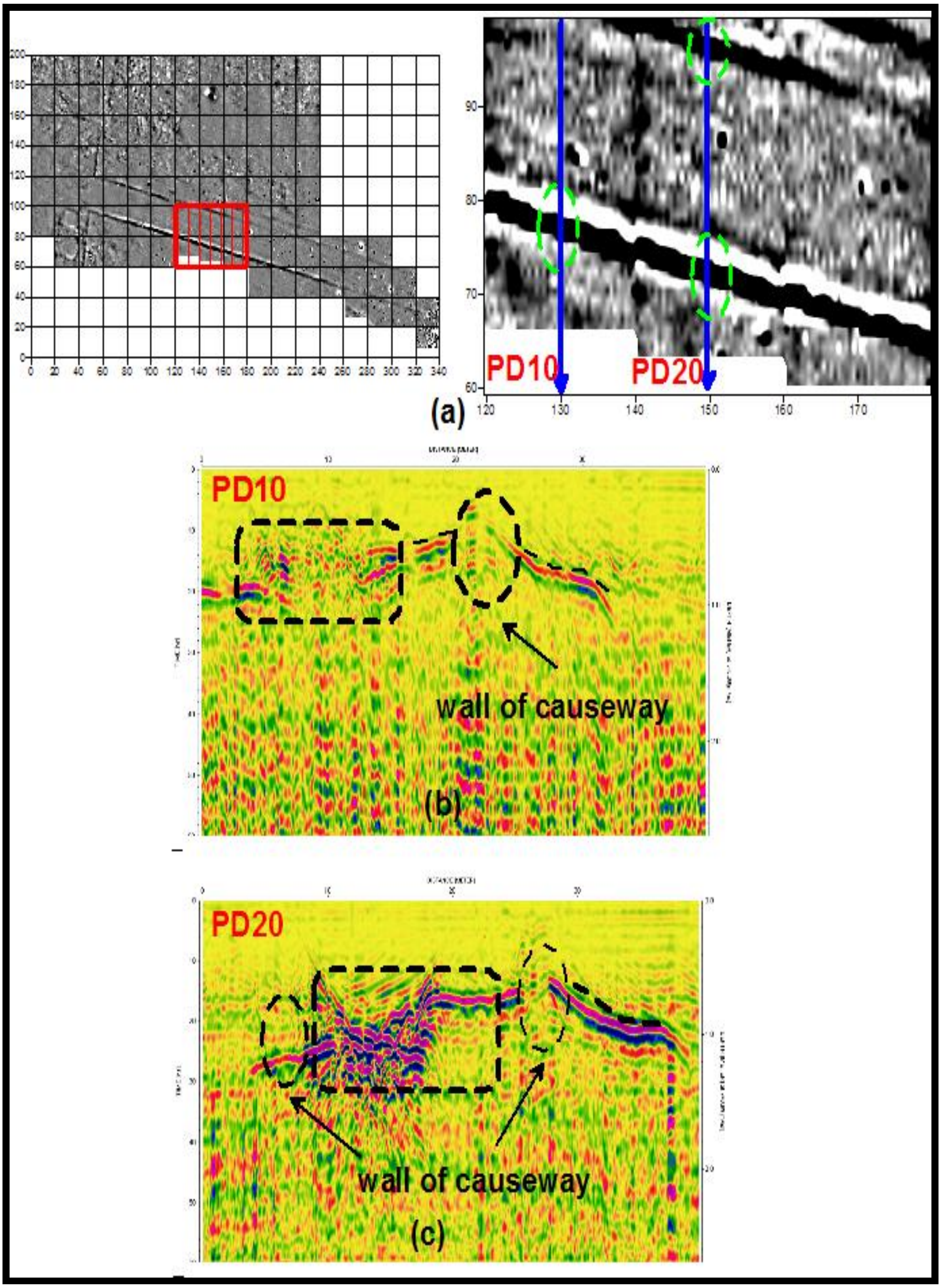

Fig. 14: The profiles (PD10 and PD20) from grid D, they show other parts of the causeway.

The grid E is located close to the eastern edge of the site; it intersects the southern margin of the causeway and the constructive object (Fig. 15, profiles PE10 and PE25).

The eastern downward side of the causeway passed between two topographic highs that primarily thought as the eastern entrance of the site and of course the valley temple. Therefore, some profiles have been distributed on the inside slope and on the top of the two elevations (Fig. 16, profiles P2 and P3) to prospect for any constructions or gates on them, however, weak evidences for a wall on both highs has been detected, but might not be related to the temple. Furthermore, the causeway is passing down eastwards and might be located underneath the farm in the far east of the site where the valley temple exists (photo fig. 17).

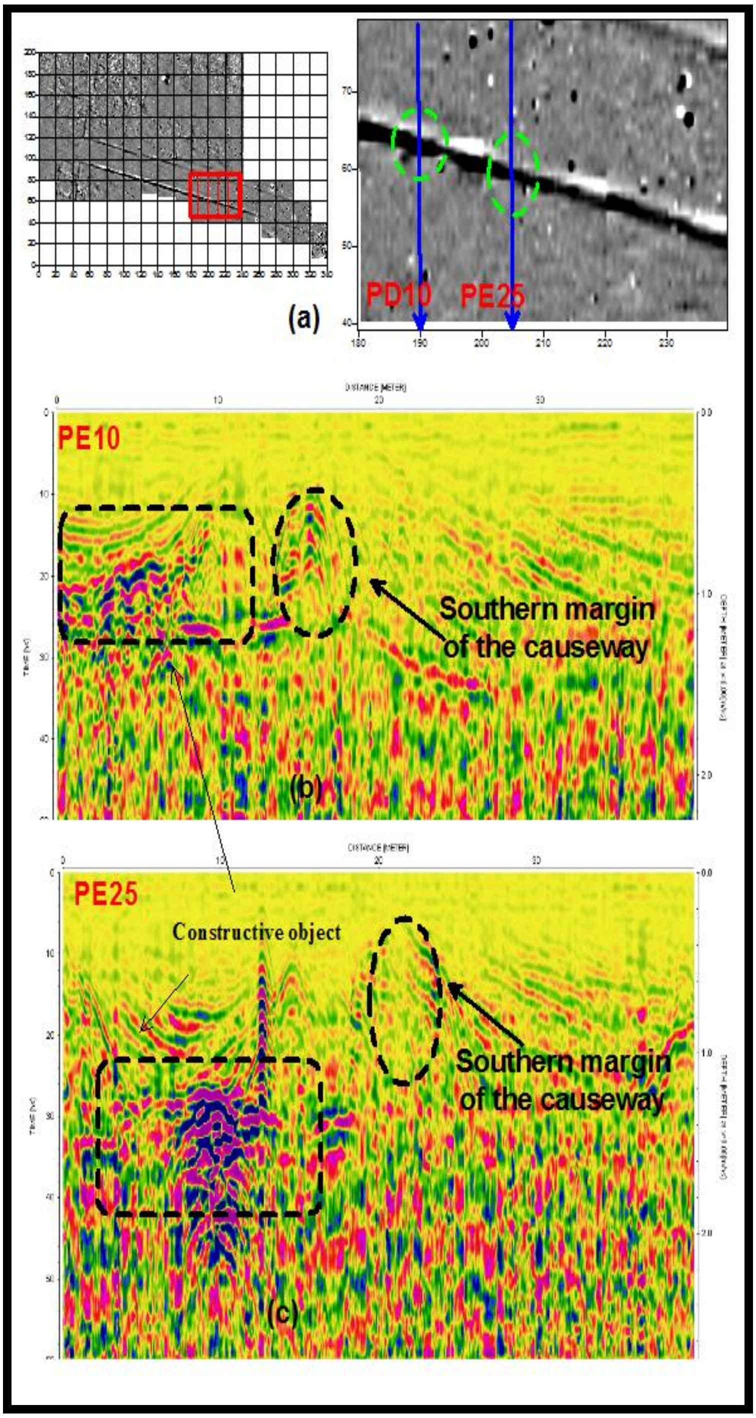

Fig. 15: The profiles (PE10 and PE25) from grid E,
the southern margin and the constructive element are shown.

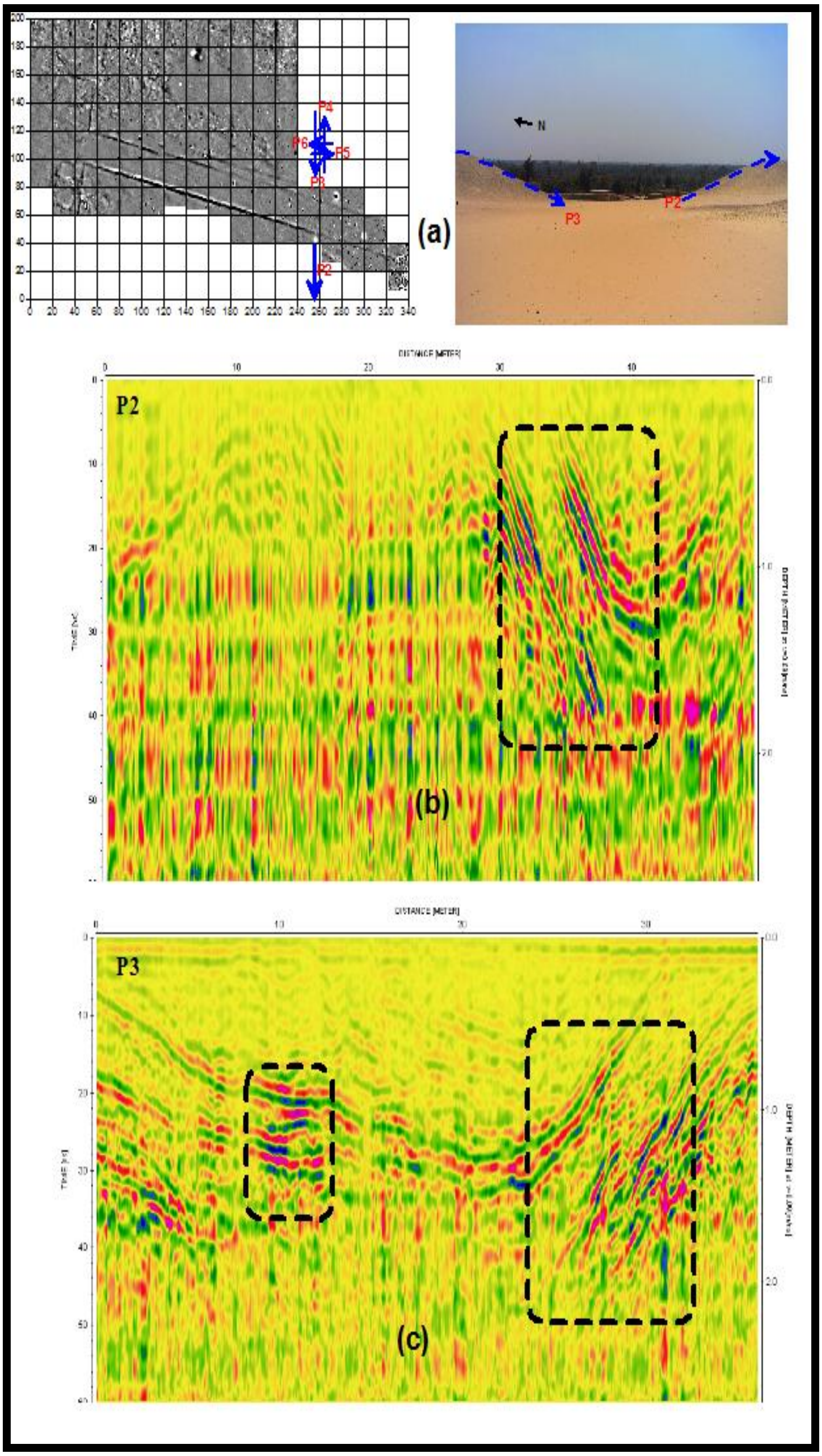

Fig. 16: the free distributed profiles on the inside slope
and the top of the two highs close to the eastern side.

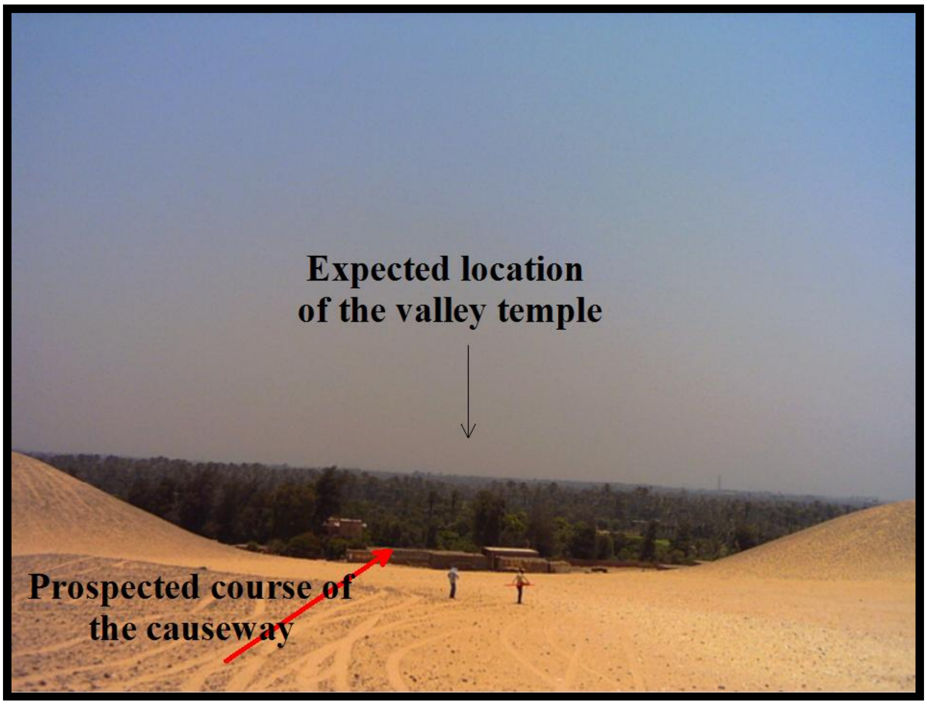

Fig 17: The farm and the house in the eastern part where the valley temple is expected.

III) ELECTROMAGNETIC PROFILING GEM300

This technology represents a broadband electromagnetic sensors developed to detect shallow findings such as landfills, unexploded ordnance, buried drums, trench boundaries, contaminant plumes, underground facilities, and archaeological prospecting (Keiswetter et al., 1997; Sternberg and Birken, 1999; Witten and Calvert, 1999). The device GEM-300 is mainly used to record at multiple frequency [low (2025Hz and 2875Hz), medium (4125Hz and 5875Hz), and high (8425Hz and 12025Hz)] electromagnetic induction data. The effective depth of exploration for a given earth medium is determined by the operating frequency of the primary electromagnetic signal. In fact, the lower EM frequencies penetrate deeper than the higher frequencies. In such applications, interpretation is commonly based on analysis of the measured inphase and quadrature components and mapping of apparent conductivity derived from a single component of the EM responses (Won et al., 1997).

III-1) EM Data Acquisition

Two sites were selected; EM_A and EM_B (Fig. 18), to carry out a detailed electromagnetic survey. Before starting the survey, the two sites were cleaned from any visible source of noise, such as surface iron materials, which may affect the measurements. Site EM_A is 50 x 40 m; the inline (E-W) inter station is 0.5m and the lines are 1.0m separation. Site EM_B is 60 x 40m, the inter station distance (N-S) is 0.5m and the line separation is 1.0m. The survey was done in zigzag form for the two sites.

The acquired data are transferred into a computer and then into a plotting program to display the data in the form of conductivity (S/m) images that show the anomalous distribution of electrical conductivity in the two sites. The Surfer program (Surfer 8.0, 2002) is used for presenting data.

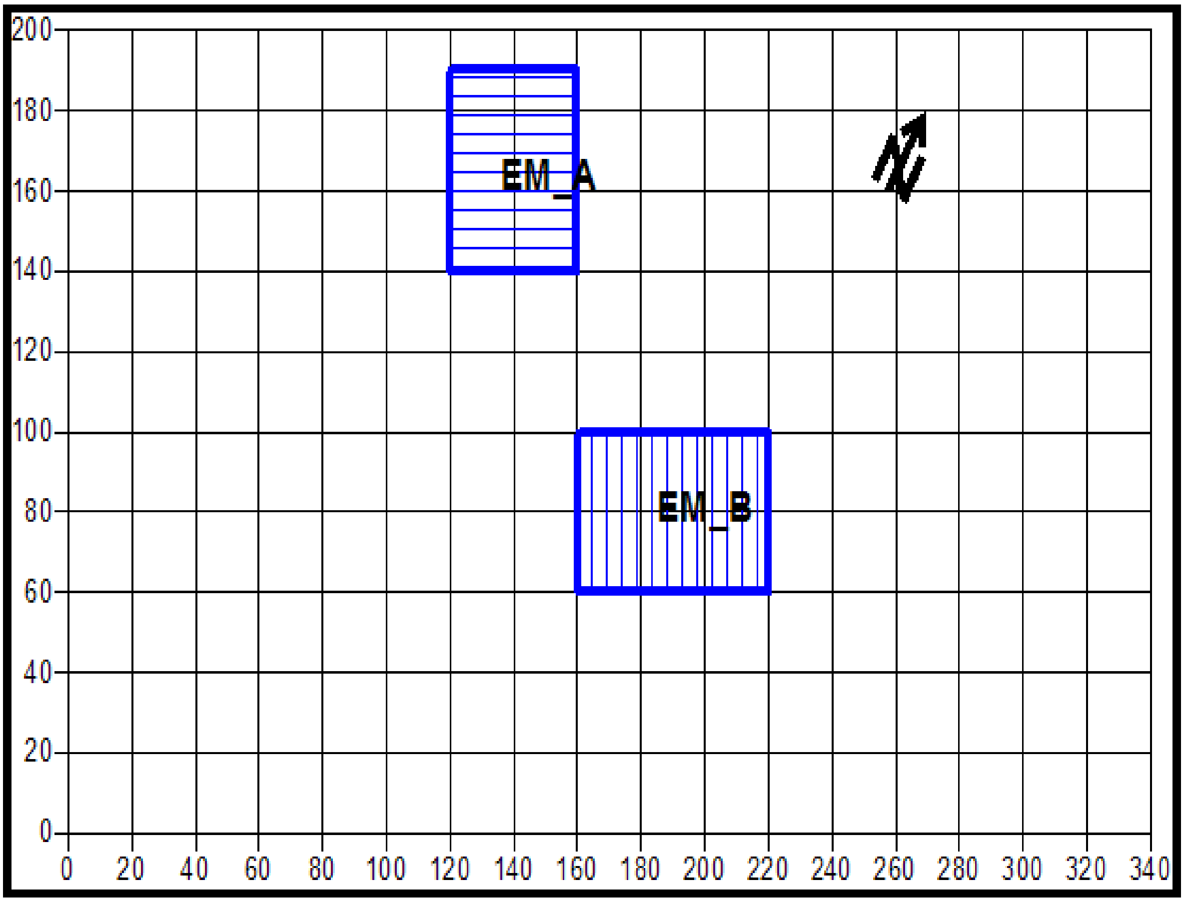

Fig. 18: The two selected sites EM_A and EM_B for the electromagnetic survey.

III-2) Interpretation of site EM_A

The resulted conductivity images are represented in comparison to its corresponding magnetic image (Fig. 19a); the magnetic image in the corresponding place of EM_A showed the existence of an archaeological occurrence, therefore, the EM survey was proposed to get details about the occurrence and the surrounding. The conductivity image adds to the knowledge some more details about the identity and the geometry of the object than the magnetic image; the object is certainly an archaeological feature made mainly of mud bricks. The slices (Fig. 19b, c, d, e, f and g) represent identically that the feature is composed of two sources; the bigger is to the east and a smaller is located to the west. The lower two slices represent an additional third source to the north of the site. This object has been detected by the GPR survey grid A (Fig. 8). Due to the conductivity and the magnetic properties of the sources, they could be interpreted as mud bricks masses; which, in turn, might typically describe a frequently found type of tombs in Dahshur called "mastabas". They could be identified as individual features, but also could be considered as items of a bigger property; i.e. they might be parts of a wider necropolis.

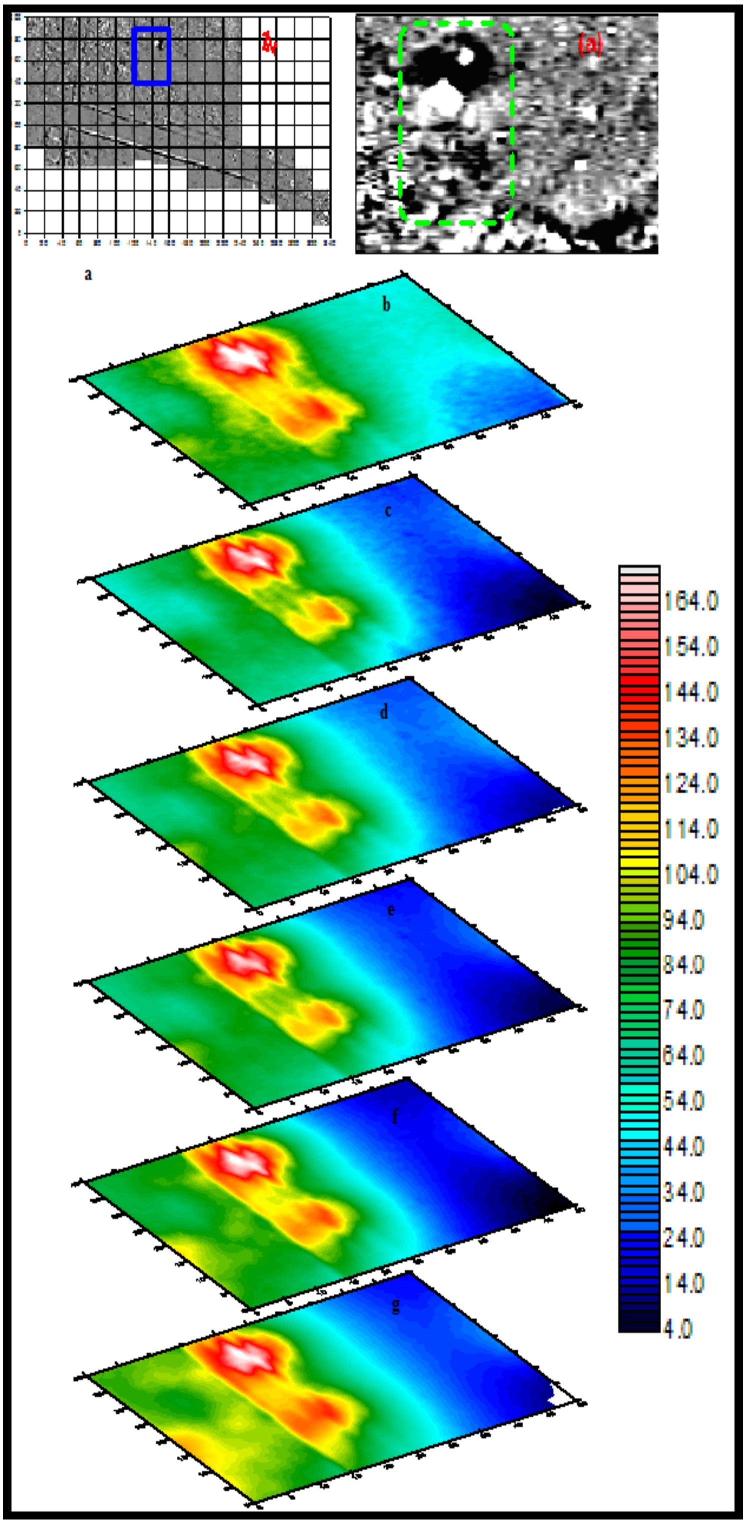

Fig. 19: The conductivity image at the multiple frequencies 12025, 8425, 5875, 4125, 2875, and 2025Hz labeled b to g respectively from up to down. They show the geometrical description of the feature and its extension.

III-3) Interpretation of site EM_B

Although the magnetic, resistance and GPR gave quit good information about the causeway, reconstructing it still incomplete, especially the deformation in middle of the road. Therefore, the survey grid at site EM_B was oriented to study the causeway. The obtained image (Fig. 20), for the first look, is upsetting. However, with some efforts; it is possible to detect rough and diffusing margins of the causeway although sharp margins were expected due to the existence of mud bricks proofed by the other used techniques. It looks like a low conductive zone between two conductive highs. The reason might be contributed to the dryness of the mud bricks in the survey grid.

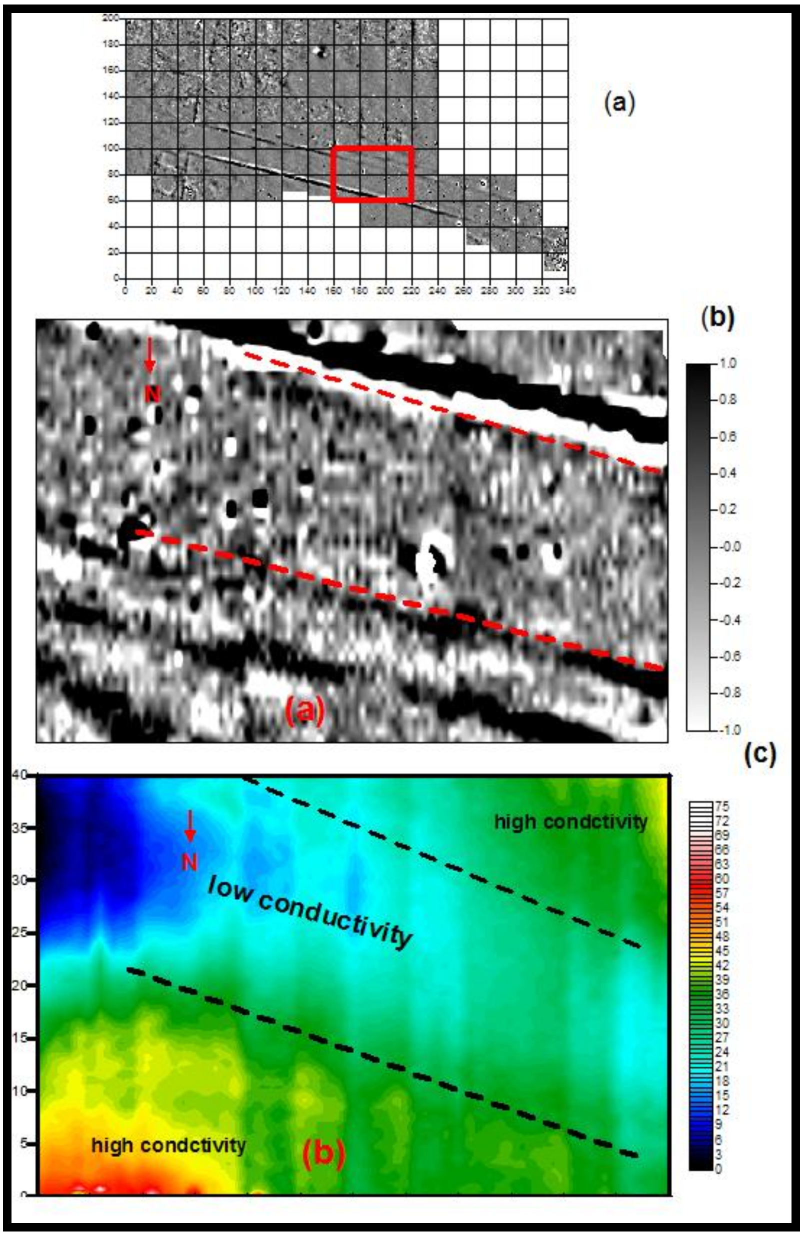

Fig. 20: a) Location and the corresponding magnetic image of site EM_B, b) The apparent conductivity map converted at frequency 4125Hz.

Conclusion

The present paper represents one of the cooperation frames and an advanced step of the confidence building between the geophysicists and the archaeologists in Egypt. Therefore, a team composed of both groups did the work and of course the detected objects were a subject of comprehensive discussion. Within this work, the magnetic image of 2002 gave a considerably good idea about the complex while the appended integrated geophysical techniques enhanced the conclusive picture (Fig. 21) and helped to get more details about the specific objects and their definition. The detected items of the complex could be concluded as follow; 1) – the eastern part of the mortuary temple including two pylons like structures in the northeastern and southeastern corners of the temple, 2) - a tentative layout of the labor residential city, 3) – tomb complexes, royal and mastabas, 4) – the causeway, a part of the side passage, and a constructive element that might be sliding track for transporting coffins and heavies, and 5) – it is expected that the causeway extends down eastward to reach the valley temple underneath the farm. Furthermore, some subsidiary information about rock type, dryness and electrical properties could be added.

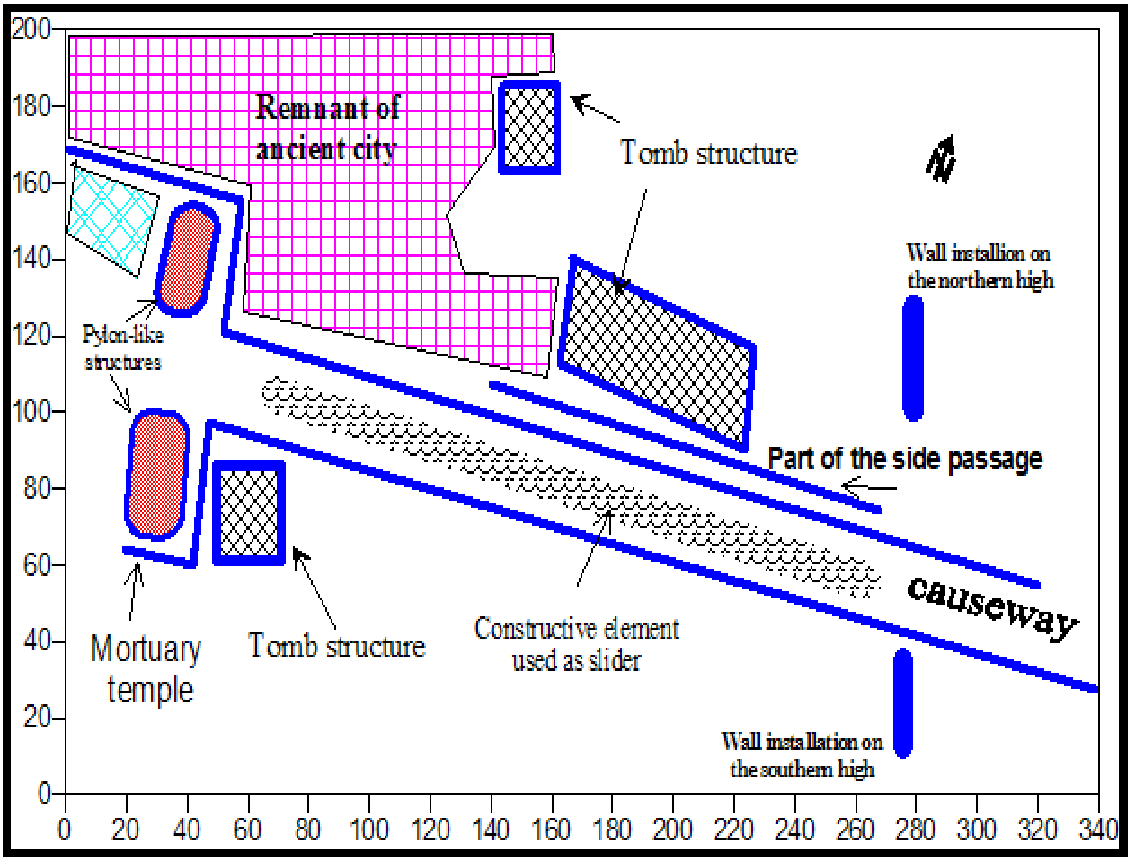

Figure 21: Enhanced image of the archaeological remains at the site based on the integrated geophysical tools.

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