Uncovering the Pyramids-Giza Plateau in a Search for Archaeological Relics- By Utilizing Ground Penetrating Radar

Abbas M. Abbas [1], Fathy Shaaban [1&2], El-said A. El-Sayed [1] and Tarek Abdel Hafez [1]

[1.] National Research Institute of Astronomy and Geophysics, 11421 Helwan, Cairo, Egypt.
[2.] Physics dept., Faulty of science, King Khaled Univ., Saudi Arabia.
Shaaban_F@hotmail.com

Abstract: The Pyramids-Giza plateau still has a universe of unrevealed secrets. The eons passed since the building of the Pyramids, makes this area unique. These huge structures reflect the passion and the discipline of the old Egyptians. The size and effort involved, makes one question: Is that all? Is there still more hidden and unrevealed? The answers to these questions can be easily achieved using scientific approaches. One of the most powerful techniques available nowadays is the Ground Penetrating Radar (GPR) geophysical technique. GPR is a fast, cheap and non-destructive inspecting technology. The strength of this technique is its capability to delineate clearly any anomalous feature (wall, pipe, cave etc) within the subsurface soil. So, the implementation of this technique for archaeological inspection is significant and timely. In the present work, the GPR technique has been applied to selected areas over the Pyramids plateau. As most of the previous work done in this area was so shallow, the present work has been planned using a multi-frequency antenna with a chosen frequency of 16 MHz and 100 MHz. This frequency allows for greater depth penetration and therefore, the possibility of locating any possible deeper targets. The following interpretations of the collected GPR profiles show some interesting features which are probably a location for archaeological relics in three areas: close to the southern side of the first Pyramid (Khufu), around the causeway of the second Pyramid (Khafre) and the location of the sun boat south of the third pyramid . Some other features of less mass have been delineated close to the eastern side of the second Pyramid and close to the entrance door to the northern side of the Sphinx.
[Abbas M. Abbas , Fathy Shaaban, El-said A. El-Sayed and Tarek Abdel Hafez. **Uncovering the Pyramids-Giza Plateau in a Search for Archaeological Relics By Utilizing Ground Penetrating Radar.** Journal of American Science 2012; 8(2):168 -174].(ISSN: 1545-1003). http://www.americanscience.org. 26

Key words: Pyramids, Archaeological prospection, GPR

1.Introduction.

The possibility of hidden archaeological remains at the Pyramids plateau of Giza has never been dismissed or discounted. Wide groups of archaeologists, Egyptologist and scientists still believe in the probability of new discoveries under the sands. This possibility can be made fact by applying the powerful geophysical GPR approach.

Early in 1975 Bevan and Kenyon were raising the use of GPR for historical archaeology. Then, in 1977, Kenyon discussed the prospect to apply the GPR survey on historical archaeological site. Later, the GPR measurements became an essential tool in archaeological inspection. Heimmer and De Vore (1995), Goodman (1994), Clark (1996), Lawrence and Goodman (1997) have utilized the GPR technique in archaeological studies. On the Pyramids plateau the geophysical techniques have been applied on many occasions. A study carried out by Yoshimura and Tonauchi (1987) using the, GPR and gravimetery were designed to answer three questions: the inner structure of the Cheop's Pyramid, the constitution of the Sphinx and to determine the age/era during which the Sphinx was carved. Another geophysical work had been done by Dobecki and Schoch (1992). They conducted seismic surveys including seismic refraction tomography and high resolution reflection. The purpose of this investigation was to analyze the depth and distribution of weathering in the exposed limestone bedrock, to search for voids and cavities around and under the Sphinx and to describe the bedrock configuration buried by sands in the adjacent desert areas.

Abbas (1998) studied the best way for the restoration of the Sphinx and its protection against the groundwater invasion. Using geophysical survey, Mesbah (2005) studied from a geotechnical point of view whether the Pyramids plateau was a good option to set up such huge structures.

In our present study, the GPR have been anticipated to be employed as a means to investigate deep-wide parts of the plateau to reveal any hidden shafts or tunnels throughout the studied sectors. *S*ubsurface *I*maging *R*adar device (SIR 2000) from *G*eophysical *S*urvey *S*ystem *I*nc. (GSSI) Company has been used in the survey which was conducted in Feb. 2006. Unshielded multi-frequency antennae (80 – 16 MHz) have been used in continuous mode for the survey. The studied areas were distributed over

the Pyramids plateau to ensure coverage of selected key zones.

The results of the survey support the possibility of the presence of undisclosed relics, of high value.

Idea

The worldwide interest in the Pyramids area is well known. Some people still believe in the power of the Pharaohs and their mysteries. The authors have pursued this universal interest. The opinions of specialist (Egyptologists) were a fundamental issue in this study. Most of our discussions with the Egyptologists have lead to one common point of agreement: that the probability of new findings at the Pyramids plateau is rather high.

The previous works in the area were mainly focused on shallow depths. Consequently, we have directed our strategy in the present study at a slightly deeper depth. As we were planning to cover several zones of the plateau, we desired a powerful, reliable and fast survey technique. Furthermore, the delineation of the location for the sun boat of the third pyramid was one of our aims. Accordingly, the utilization of GPR with low frequency antenna was consistent with our goals.

2. The Survey of the Selected Zones

Archaeologists accompanying our team during the exploration excursion guided us to where the possibility of finding new exploration was most likely based on their experience and background. A total of nine surveyed zones have been distributed along the Pyramids plateau (Fig. 1).

In zone (1) which is to the southern side of Khufu Pyramid (Fig. 1), two parallel profiles 2 m apart were done (P26 and P27) . The two profiles are both 115 m long. Profile P26 measured from west to east, while P27 measured from east to west (Fig. 2a).

Zone (2) is placed to the eastern side of Khafre Pyramid (Fig.1). The two profiles P24 and P25 are 210 m long. Profile P24 carried out from east to west while, Profile P25 was carried out from west to east. The Profile P25 is 10 m apart from the Khafre Pyramids' base. The profile P25 is 2 m apart from profile P24.

The presence of an existing excavation determined our plan to perform a detailed study at zone (3). In this zone which lies between the first Pyramid and the causeway, a grid of 60x60 m has been surveyed with 1 m offset between the profiles (Fig. 2d).

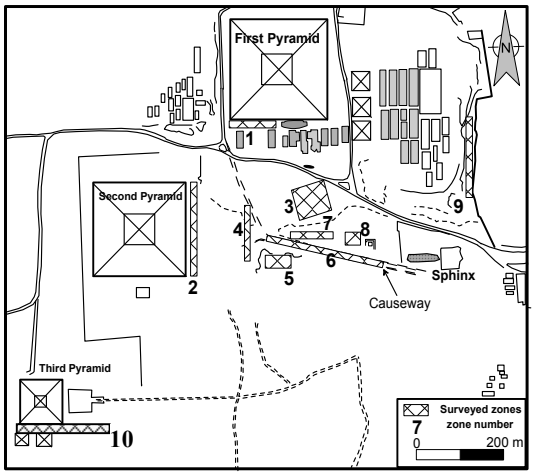

Fig.1: Location of the surveyed zones.

Between the eastern side of the second Pyramid and the causeway, four profiles (P10-P13) have been conducted in zone 4 from south to the east direction (Fig. 2c). To the south of the causeway, zone 5 has been surveyed (Fig. 1). In this zone three profiles from northwest to southeast direction have been done (Fig. 3a).

Zone (6) has been applied along the causeway (Fig.1). Because of the length of the causeway, the profiles have done on different stages. The first stage (Fig. 3a), four profiles (P5-P6, P14-P15) have been surveyed from east to west direct along the causeway. In the second stage, four profiles (P29-P31) have been conducted from west to east direction. After 10 m from the end of the profiles of the second stage, the third stage has begun with its four profiles (P32-P35) from west to east direction (Fig. 3a)

To the north of the causeway, zone 7 begins with its profiles (Fig. 1). In this zone, four profiles (P1-P3) have been carried out from southeast to northwest direction (Fig. 3b). For zone (8), 7 GPR profiles have been conducted (Fig. 3c). In zone 9, three parallel profiles (P16-P18) have been applied from south to north direction (Fig. 3d). Four profiles (P43-P46) have been carried out behind the third pyramid (Fig. 4), in a trail to locate the sun boat of the third pyramid.

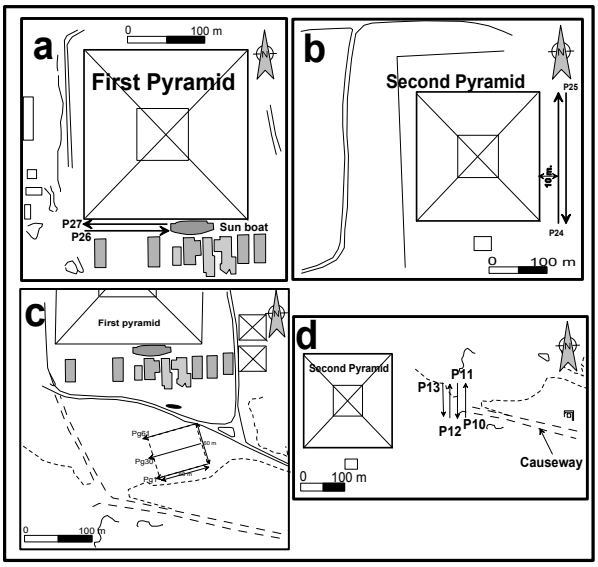

Fig. 2: Detailed location maps for individual zones (1, 2, 3 and 4).

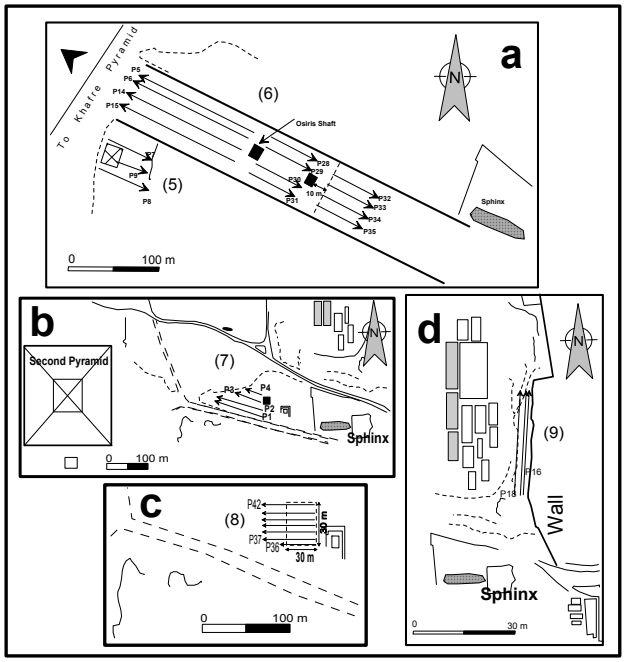

Fig. 3: Detailed location maps for individual zones (5, 6, 7, 8 and 9).

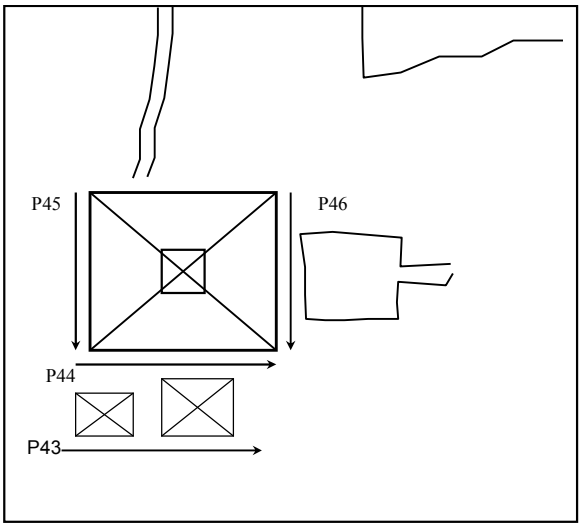

Fig.4: Detailed location maps for individual zone 10.

3. Data Processing and Analysis

We used some simple processing steps to visualize the radar profiles and to get rid of the interference of the embedded high frequency noise during the survey. The processing protocols used were : background removal, band pass frequency, gain enhancement and time to depth conversion.

For the conversion of time to depth we needed the velocity of the wave propagation. It is well-known that the Pyramids plateau is formed entirely of dolomitic limestone of the Mokattam Formation (Salem, 1976). To determine the optimum velocity that can yield precise depth, we tried different means. After Landau-Boernstein, (1982); Davis and Annan, (1989); and Guéguen and Palciauskas, (1994) the relevant properties of some common near-surface earth materials have been studied to select the optimum relative dielectric value. The relative dielectric constant of the limestone varies between 4 and 8. Whereas, the dielectric constant of the dolomite has a range between 6.8 and 7.8 (Lawrence and Goodman, 1997). These values could be higher given the presence of water and clay contents.

Furthermore, Fisher et al. (1992) described the following criterion for finding the best possible velocity for a migration algorithm. For the correct migration velocity, the migrated image will be well focused. If the chosen migration velocity is too low, diffraction hyperbolas will not collapse completely but certain hyperbolic tails will remain in the image. A too large velocity results in diffraction tails that extend from a diffractor towards shallower depths. This approach of testing different migration velocities mimics that employed when migration trials are used to refine velocity structure in reflection

seismology (Lawrence and Goodman, 1997). We performed several migration attempts using a wide range of velocities. The effective medium calculations of the possible in-situ velocity showed that the selected velocities are reasonable for a porous dolomitic limestone partially saturated with water is ranged between 0.07 and 0.1 m/ns.

The previously mentioned procedures have been applied to trace the range of dielectric constant and propagation velocity which could impact the studied areas. At the end, the propagation velocity estimate for the GPR profile was conducted over the Osiris well (Fig. 5). The depth of the well has been measured and time-depth conversion has been calculated using different velocities. The best derived velocity value was 0.08. This velocity has been used to convert the measured GPR profiles in the studied area.

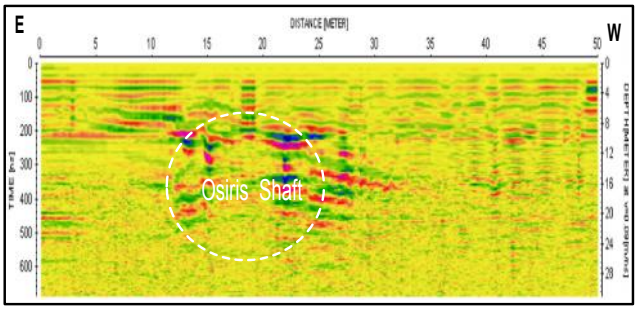

Fig. 5: Osiris shaft as seen on the GPR profile No. 38 area 6.

4. Interpretation of Remarkable Features:

A number of interesting features have been delineated through out the plateau. These features could be of archaeological significance. Also, the common criteria of them were its fairly deep location. The velocity that used to turn the time-depth conversion has yield a total depth of 28 m. The defined features are rest starting from 8 m depth.

For zone (1), Figure (6) is a GPR profile measured from west to east. It shows a hyperbola at 17 m. depth. Also, some outside interference of direct wave (sharp straight-tilted lines) is easily perceived. In Figure (7), for a GPR profile conducted at zone (2) another hyperbolic feature has been delineated. To the southern side of this hyperbola a rather conductive zone of lateral extension about 25 m has been outlined. Both hyperbolas of zone (1) and (2) are described as of a cave-like appearance.

For zone (3), we summarized some features that detected in this area in figure (8). A continuous appearance of a moderately conductive zone has been identified along the parallel GPR profiles. This appearance could be attributed to a shaft filled with conductive materials like clays or sandy clays. Two regions with that appearance have been outlined using the time slices for the whole set of data as seen in figure (9).

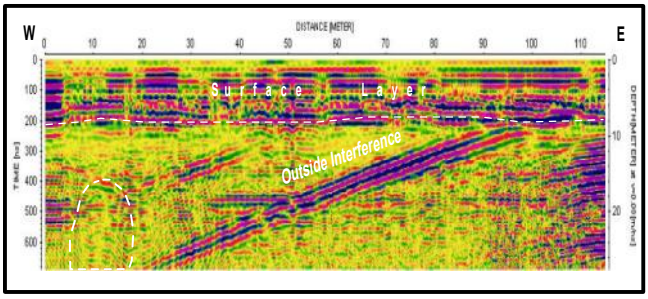

Fig. 6: GPR profile no. Pg 28 shows cave-like phenomena area (1).

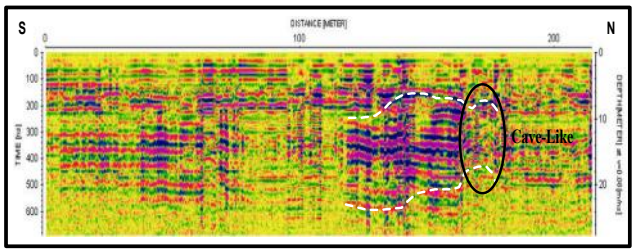

Fig.7: Cave-like feature as seen on GPR profile No. 28 area (2).

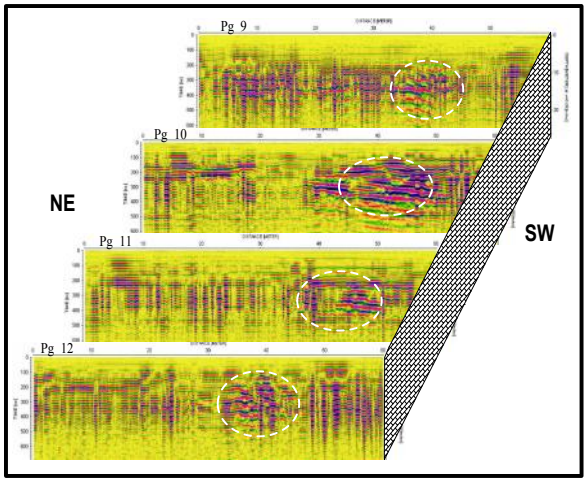

Fig. 8: GPR profiles No. 9 to 12 area 3.

Figure (10) for GPR profile no. 7 at area (4) reveals some interesting features which have been assigned symbols (a, b and c). Feature (a) is of cave-like shape or together with feature (c) could signify a shaft and they both materialized due to the diffracted energy of the shaft edges. Where, feature (b) has a cave-like form. The 3 features became visible at depth 16 m. For area (5), no remarkable feature is noted.

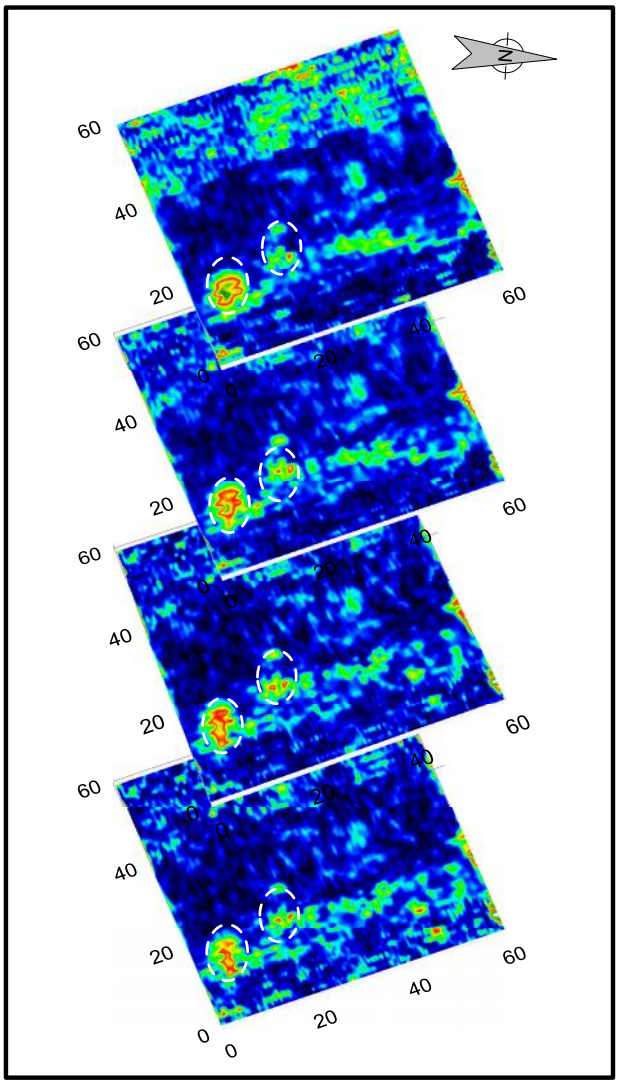

Fig. 9: Time slices of GPR profiles of Zone (3).

For area (6), over the causeway, only the Osiris shaft was perceptible. Figure (11) illustrates the shaft as it has been revealed on GPR profile P-38. No other features have been outlined through out the GPR profiles which have been carried out along the causeway.

For area (7), to the south of the causeway, GPR profile P-1 of direction NE-SW has shown a conductive zone of lateral extension about 11 m and at depth 8 m as noticeable in figure (12).

Also, area (8) has not shown any occurrence for any feature.

And last, figure (13) belongs to GPR profile of area (9) which displays the presence of cave-like feature at depth 20 m.

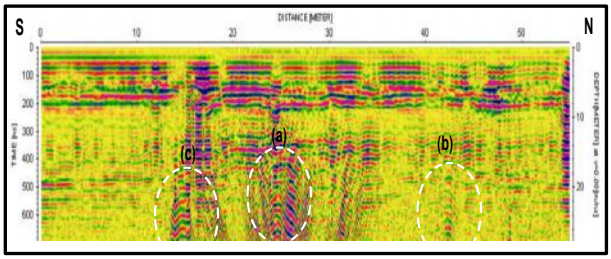

Fig. 10: GPR profile No. 7 area 4.

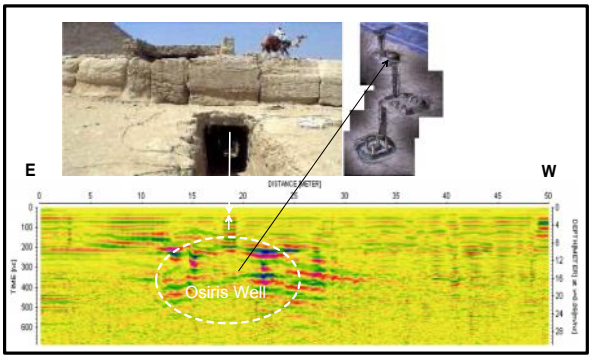

Fig. 11: Osiris shaft as seen in photographs and as delineated from GPR data over the causeway.

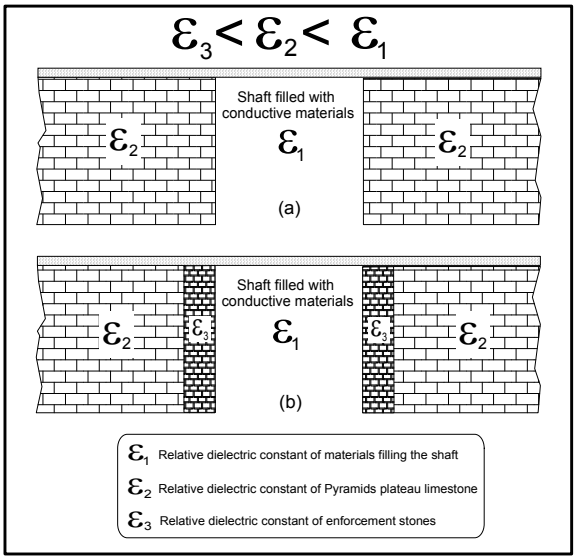

Fig.12: GPR profile no. P1 area 7.

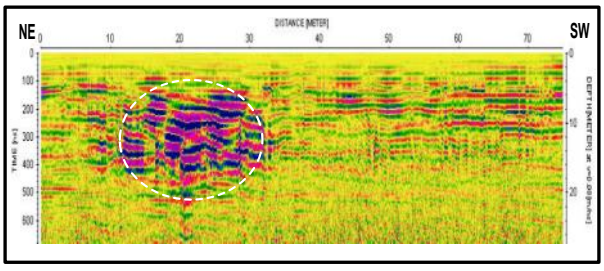

Fig. 13: Possible archaeological target on profile o.3 area 9.

The forms which have been depicted at the studied area are either cave-like or shaft-like features (Fig. 14 and 15). The cave-like features could be ascribed to a tunnel section of at least 3 to 5 m width, and not filled up with materials; it is like a void in the limestone rock; for example, see the feature which is marked on figures (6, 10 and 13). For the shaft, if it is just a cut in the limestone rocks (Fig. 15a), which has been filled up with conductive materials (clays or sandy clays), this filling material will reflect conductive zoon on GPR profiles. For example, the features marked on fig. (12). While, if the shaft walls were enforced by blocks of limestone (Fig. 15b) which could be of harder properties (reduced conductivity) than the surrounding rocks and dispersion in the radar energy due to the blocks edges could be caused. So, a possible two hyperbolas at both sides of the shaft might be anticipated; as seen in Fig. (10).

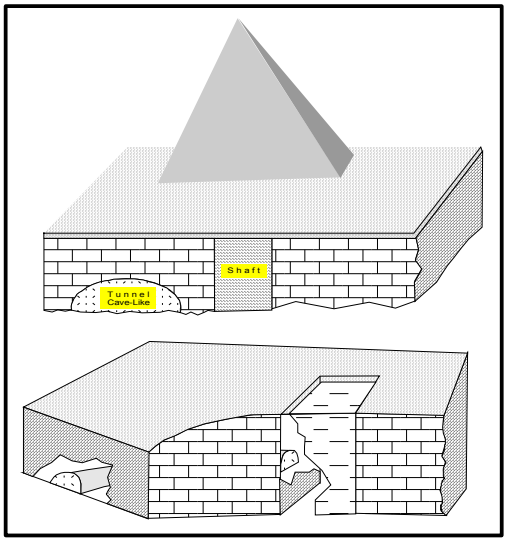

Fig. 14: Sketch showing the possible appearance of shaft and tunnel at the studied areas.

Given the preceding illustration and assertion, we can presume the existence of a momentous diversity of archaeological structures at the Pyramids plateau which remain, as yet, unexposed. These structures could be a linked net of tunnels and shafts that may well lead to precious tombs.

The most surprising result for us that got out from the profile 44, which have been conducted between the third pyramid to south and the queen pyramids. This radar record (Fig.16) shows obviously high amplitude curved zone extended from 30m to 80m on the horizontal scale, with average thickness of 15 m. This dimensions agrees with the hole in which the sub boat have been buried.

Fig. 15: Sketch shows the possible presence of shafts at the studied areas.

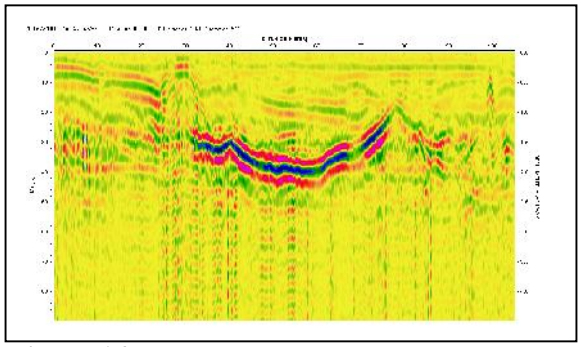

Figure. 16: The radar record conducted along the profile no.44.

5. Results and Comments:

In general, the studied areas have shown high potential for the presence of hidden archaeological targets.

These targets range from tunnels to vertical shafts.

Two possible shafts were defined which of areal extension of about (20 m x 10 m) and (5m x5 m) respectively at zone no. (3).

The vertical extension of the targets has a range between 12 to 25 m and it could be deeper in some parts.

The targets could be connected together by tunnel(s) (This possibilty requires more investigation).

The location of the sun boat of the third pyramid have been detected.

A more detailed study is recommended to achieve a more precise view of the kind and shape of the targets.

6. Recommendations:

The entire area needs more geophysical work from different directions to strengthen the present result. The amount of work done to date is not a sufficient basis on which to form a definitive judgment on the delineated phenomena. These phenomena raise a massive number of questions for the scientific researcher. We hope to answer these questions after further study.

Acknowledgments
The authors express their gratitude to the Supreme Council of Antiquities and to Dr. Zahi Hawwas who permitted the conduction of the present work in supportive surroundings.

Corresponding Author:
Dr. Fathy Shaaban
Department of Geomagnetism and electricity
NRIAG, Helwan 11722, Egypt.
E-mail: shaaban_F@hotmail.com

7. References:

1. Abbas, M. A. (1998): Geophysical investigation into the groundwater regime and development of a concept for underground thermal energy storage (UTES) and for archeological applications in the area of Giza, Egypt. Ph.D., Giessener Geologische Schriften, Giessen, Germany, 181 p.
2. Bevan, B., and Kenyon, J. (1975): Ground penetrating radar for historical archaeology: Masca News Letter, **2**, 2–7.
3. Clark, A. (1996): Seeing beneath the soil: prospecting method in archaeology, B.T. Batsford, London.
4. Davis, J.L., and A.P. Annan (1989): Ground penetrating radar for soil and rock stratigraphy. Geophysical Prospecting, vol. 37, p. 531-551.
5. Dobecki, T. L. and Schoch, R. M. (1992): Seismic investigation, Sphinx of Giza, Geoarcheology, an International Journal, V. 7. No. 6, pp. 527-544.
6. Fisher, E., McMechan, G., Annan, A., and Cosway, S.(1992): Examples of reverse-time migration of single-channel. Ground-penetrating radar profiles: Geophysics, **57**, no. 4, 577–586. Goodman, D. (1994) Ground-Penetrating Radar Simulation in Engineering and Archaeology, Geophysics, Vol. 59, pp. 224-232.
7. Guéguen, Y., and Palciauskas, V. (1994): Introduction to the physics of rocks: Princeton University Press, Princeton, N. J.
8. Heimmer, D. H. and DeVore, S. L. (1995): Near-Surface, High Resolution Geophysical Methods for Cultural Resource Management and Archaeological Investigations. revised edition ed. U.S. Department of the Interior, National Park Service,Rocky Mountain Regional Office, Division of Partnerships and Outreach, Interagency Archeological Services, Denver, CO.
9. Kenyon, J.L. (1977): Ground-Penetrating Radar and Its Application to a Historical Archaeological Site, Historical Archaeology, 11,48-55
10. Landau-Boernstein, H. (1982) Zahlenwerte und Funktionen aus Naturwissenschaft und Technik, Gruppe V: Physikalische Eigenschaften der Gesteine: Springer Verlag.
11. Lawrence C. B. and Goodman D. (1997): Ground-Penetrating Radar: An Introduction for Archaeologists. AltaMira, Press, Walnut Creek, California
12. Mesbah H. (2005): Integrated Geophysical Studies on El-Giza Pyramid Plateau in the Light of Geotechnical Concept, Mansoura University, Faculty of Science, Geology Dept.
13. Salem, R. (1976): Evolution of Eocene-Miocene sedimentation pattern in parts of Northern Egypt, American association of petroleum geologist; Bull. 60, p. 34-64.
14. Yoshimura, S. and Tonauchi, S. (1987): Non destructive Pyramids investigation, Part 1 and 2; Studies in Egyptian culture No. 6, Waseda University.

1/23/2012