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Prospecting and Mapping of Archaeological Sites in Valley of the Golden Mummies Using Ground Penetrating Radar at Bahriya Oasis, Egypt

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ABSTRACT

Application of ground-penetrating radar in Egypt has been addressed in archeological application in the last decade. The problem of the research is that the locations of the buried graves were not determined in the Valley of the Golden Mummies (VGM) where vehicles travel. The radar method is used to locate these graves and prevent vehicles from passing over them. The ground-penetrating radar method is used because of the ground-penetrating radar is an effective geophysical method in the study. The study area is divided into 7 grids whose dimensions are 50 m by 350 m in addition to the dimensions of each grid separately is 50 m × 50 m. To collect informations, the SIR-4000 device is used connected to a 200 MHz antenna, 350 profiles with a sepatation distance between profiles 1 m and 50 meters in length are measured, and 50 profiles are measured in each grid separately in the form of Zig-zag grid pattern sequentially. The data are processed using Reflexw program version 7.0 for processing GPR data and analyzing the ground-penetrating radar data to remove impurities and to express anomalies that exist in profiles. After completing the data processing, is interpretation is deducted, and the final results of the research reveal the discovery of two graves, the first one occupies an area of 6-8 m at a depth of 4.5 m, whereas the second grave occupies an area of 4 m and at a depth of 1.2 m.

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التنقيب ورسم خرائط للمواقع الأثرية بوادي المومياءات الذهبية باستخدام الرادار في الواحات البحرية، مصر

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الملخص

إن تطبيق طريقة المسح الراداري الأرضي في مصر في العقد الماضي قد تم توجيهها للتطبيقات الأثرية وتتمثل مشكلة البحث في عدم تحديد مواقع المقابر المدفونة في وادي المومياءات الذهبية والذي تسير فيه المركبات ولذا تم استخدام طريقة المسح الراداري لتحديد أماكن هذه المقابر ومنع المركبات من المرور فوق هذه المناطق. وتم استخدام هذه الطريقة لما لها من فاعلية في هذه الدراسة، حيث تم تقسيم منطقة الدراسة إلى 7 شبكات أبعادها 50 م × 350 م وكانت أبعاد كل شبكة على حدة 50 م × 50 م. ولجمع المعلومات تم استخدام جهاز SIR-4000 مُتصلاً بهوائي 200 ميجاهرتز، وتم قياس 350 مقطعاً بمسافة فاصلة بين المقاطع المتتالية مقدارها 1 متر وطول المقطع 50 متراً، كما تم قياس 50 مقطعاً في كل شبكة على حدة على شكل مُتعرج في اتجاه شمال-جنوب، ثم تمت معالجة البيانات باستخدام برنامج ريفلكس الإصدار 7.0 ثم تعديل بيانات المسح الراداري الأرضي لإزالة الشوائب غير المرغوبة واظهار الشواذ الموجودة في القطاعات. وبعد الانتهاء من مرحلة مُعالجة البيانات تم تفسيرها وكانت النتائج النهائية للبحث اكتشاف مقبرتين الأولى تشغل مساحة 6-8 أمتار وعلى عمق 4.5 والثانية 4 م على عمق 1.2 م.

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Introduction

Archaeological investigations typically use ground penetrating radar (GPR). The method helps efficiently to reveal large regions quickly and inexpensively, saving both time and money. The GPR is the surface geophysical tool capable of creating 3D maps and photographing the subsurface at archaeological sites. According to Davis and Annan (1989), the GPR technology works by sending and receiving radar signals from the surface of buried discontinuities.

The GPR is non invasive geophysical technique used in geology application (Parsad and Loveson, 2020; Loveson, 2016). Several papers are available in the scientific literature, which illustrate the use of GPR to discover and mapping buried archaeological artefacts, to inspect ancient buildings and monuments, bridges, columns and statues, to investigate frescoes, mosaics and decorations, and to analyze the internal conditions of other various objects of historical value (Deiana *et al.*, 2018; Di Giacomo *et al.*, 2018; Fontul *et al.*, 2018; Persico *et al.*, 2018; Conyers *et al.*, 2019; Bianco *et al.*, 2019; Leucci *et al.*, 2019).

The valley of mummies (VGM) is an important archaeological site; however, it lacks a precise map, and it is unknown what artifact is there inside. Farmers are removing portions of the valley and incorporating them into their fields, the neighbors are able to grow closer to their own farms. In addition, people and their vehicles and animals cross the valley. Consequently, a geophysical program is carried out to accomplish the following objectives: establishing the valley's outer boundaries, describing the valley's network of safe roads, drawing a map, and describing the ancient structures in the valley. The Science and

Technology Developing Fund (STDF) ID: 4168 provided the funding for this program. In this research, we present a few of the project's outcomes.VGM is a distinct archaeological phenominon at Bahriya Oasis (Fig. 1), approximitly 380 km west of Cairo. GPR survey is conducted using SIR 4000 with the 200 MHz, zig-zag configuration. The outcome is a series of 2D GPR profiles containing several signatures for tombs by using Reflexw Version 7.0 (Sandmeier, 2009).

Archaeological Background and Site Description

The Valley of the Golden Mummies (VGM) became a significant archaeological site in Egypt after finding more than 105 mummies there in 1999. Egyptian mummies date to the Roman era. The National Research Institute of Astronomy and Geophysics (NRIAG) began a study in 2012 to establish the borders of the VGM to create a map of the valley's boundaries. 10.000 mummies are concealed beneath the oasis sand in the VGM (Hawass, 2000). Nearly all of the study area is flat. The location is a part of one of the largest collections of Greco-Roman artifacts, and the top soil is made up of coarse to fine ferruginous sandstone. Hawass said that VGM is one of the most significant archaeological finds in the history of Egypt and the entire globe contain numerous gold-encased mummies inside, some of which are visible on the surface (Hawass, 2000).

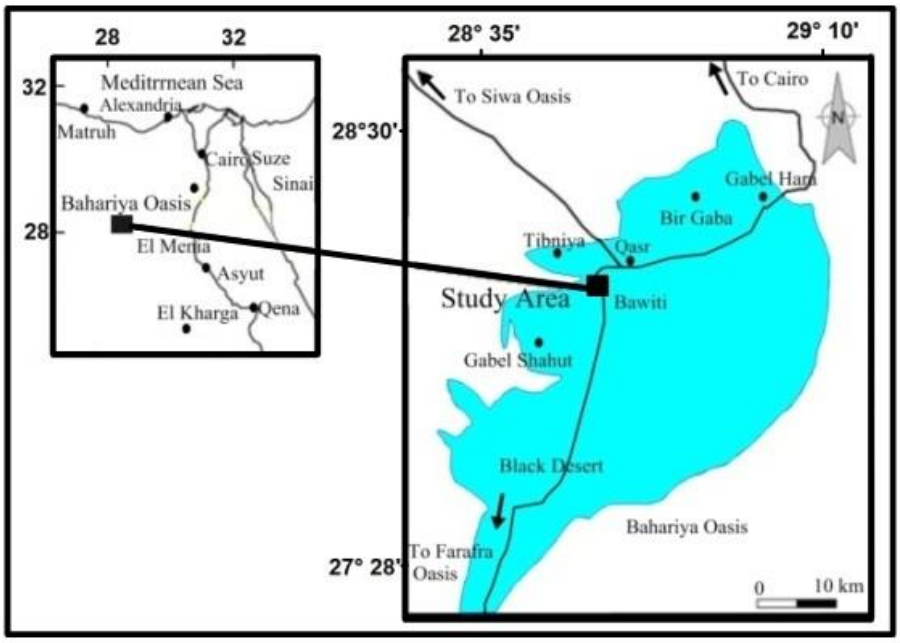

Fig. 1. Location map of the study area

GPR Data Acquisition

In order to achieve the ideal balance between the necessary depth of penetration and resolution, the GSSI SIR 4000 is connected to bowtie shielded 200 MHz antenna to gather the GPR data. The GSSI a 200-Mhz antenna is chosen because it offers more depth penetration required for the conducted research in the study area. To locate any potential underground tombs and historical sites in the study area, the study is conducted across 7 measuring grids using a parallel grid pattern survey technique along 350 profiles in a zig-zag pattern, every grid is covered by 50 profiles, and the lengh of the profiles is 50m, whose horizontal distance in between is 1m, and the direction of the profiles is S-N (Fig. 2). GPR survey is carried out in summer season during three dayes to cover seven grids. The measurements were made in the form of straight lines by putting a rope with the help of two persons on the borders of the search area and then walking very slowly with the device along this rope.

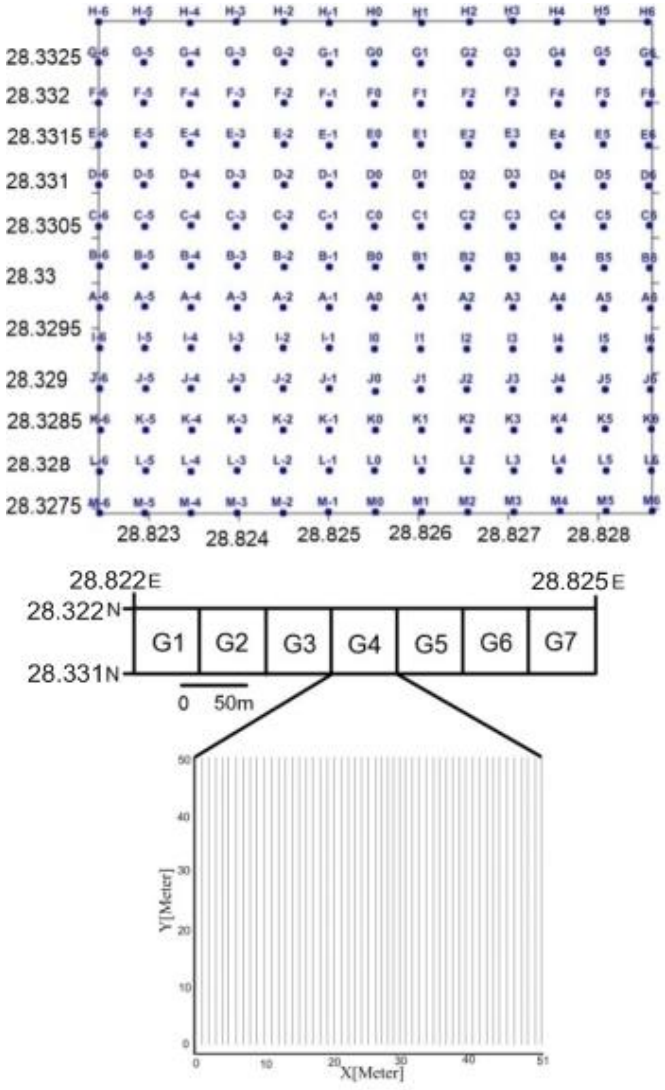

Fig. 2. The GPR surveyed grids in the study area:

GPR Data Processing

Processing steps comprise horizontal banding that appears in many GPR records as a result of some antennas' "ringing" that is eliminated by a background-removing filter. The horizontal banding is recorded in the majority of profiles. The reflection data that would be visible on some profiles may be hidden by these bands. To specify the Band Pass Filter, four frequency values are used . The low-cut frequency values are decided by the first factor. The second point marks the lower plateau's starting point. A cosine window is used to illustrate the filter between the low-cut frequency and the start of the plateau. The third point establishes the upper plateau's termination, while the fourth establishes the high cut frequency. Below the low cut and above the high cut, the frequency spectrum is set to zero. Here, the values (100, 150, 300, and 400 MHz) are employed, and the running average operates on the selected number of traces. For each time step, the filter calculates a running average over a predetermined number of traces. The filter approach reduces noise that depends on the trace. It employs an energy decay filter. The given traces define the medium decay curve. Each data point in each trace is divided by the values of the decay curve before the filter is applied to this curve. Each data point is multiplied by a scaling factor when the energy decay curve is multiplied. Here, the scaling is set to "1" and the trace interpol-3D file is used. Each radar profile's length and number of traces are modified during this processing stage.

Two parameters are employed to flip profiles: trace increment is 0.09 and profile length is 50 m. This processing stage has the potential to flip the radar profile in the x-axis. When applying the survey in a zig-zag pattern, this processing step is used. It is helpful for tracking

the anticipated features in subsequent radar profiles. Radar wave speeds are calculated using the relative dielectric permittivity (RDP) of the region, which is analogous to dense limestone.

(RDP=) C/V ----------(1)

where: C = 0.298 m/ns (the speed of light) and V = the speed of radar waves. Also, it is taken into account the radar wave velocity value. The results of past research are consistent with the estimated velocity, which has been utilized to convert between time and depth. According to Diaa (2015), the formula for velocity is V = d = 1/t = 0.15 m/ns (m/s). According to Annan (2003), the average speed of the materials discovered in the research region is 15 m/ns because the study area is coverd by very dry sandstone layer.

GPR Data Interpretation

The size, depth, and location of the anomalies that seen on the processed sections must be determined using the GPR data in order to differentiate between the desired and undesirable reflections. Following the anomalies as they appear on consecutive sections is necessary to determine the underlying extent and the anticipated depth of buried objects found in the examined grids. The results are shown in two-dimensional (2D) sections. GPR data are gathered and analyzed separately on each of the seven grids in the study area. After that, important archaeological features are found in grid no.1 (Figs. 3 and 4), which is described in table (1), and most profiles show a flat layer, and some bedding strata. Anomalies are concentrated in grid number 4; therefore, the focus is given to grid 4 more than others grids.

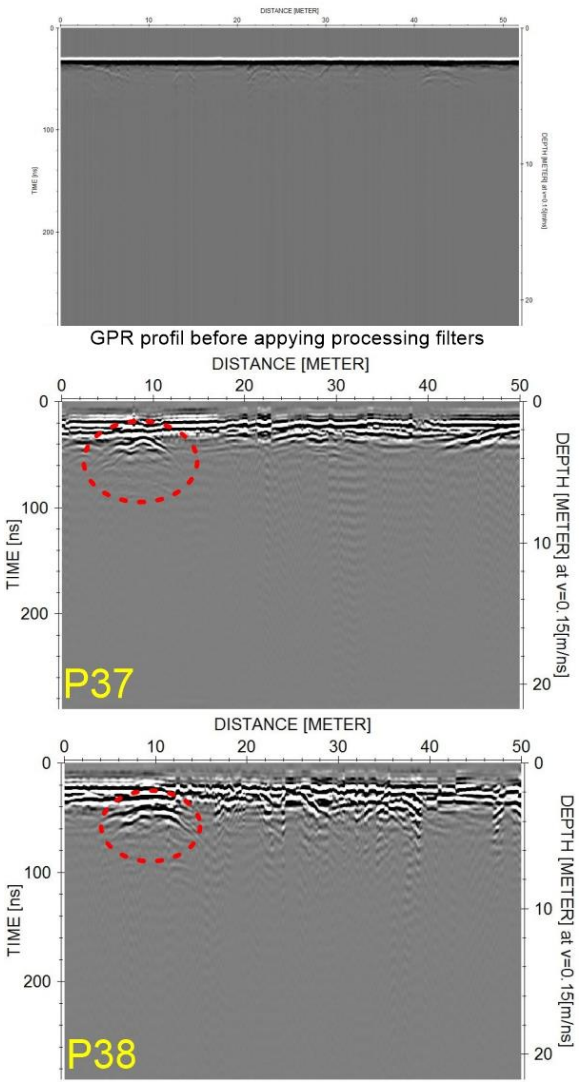

Fig. 3. Object no. one appears in profiles 37 and 38 marked by red circles.

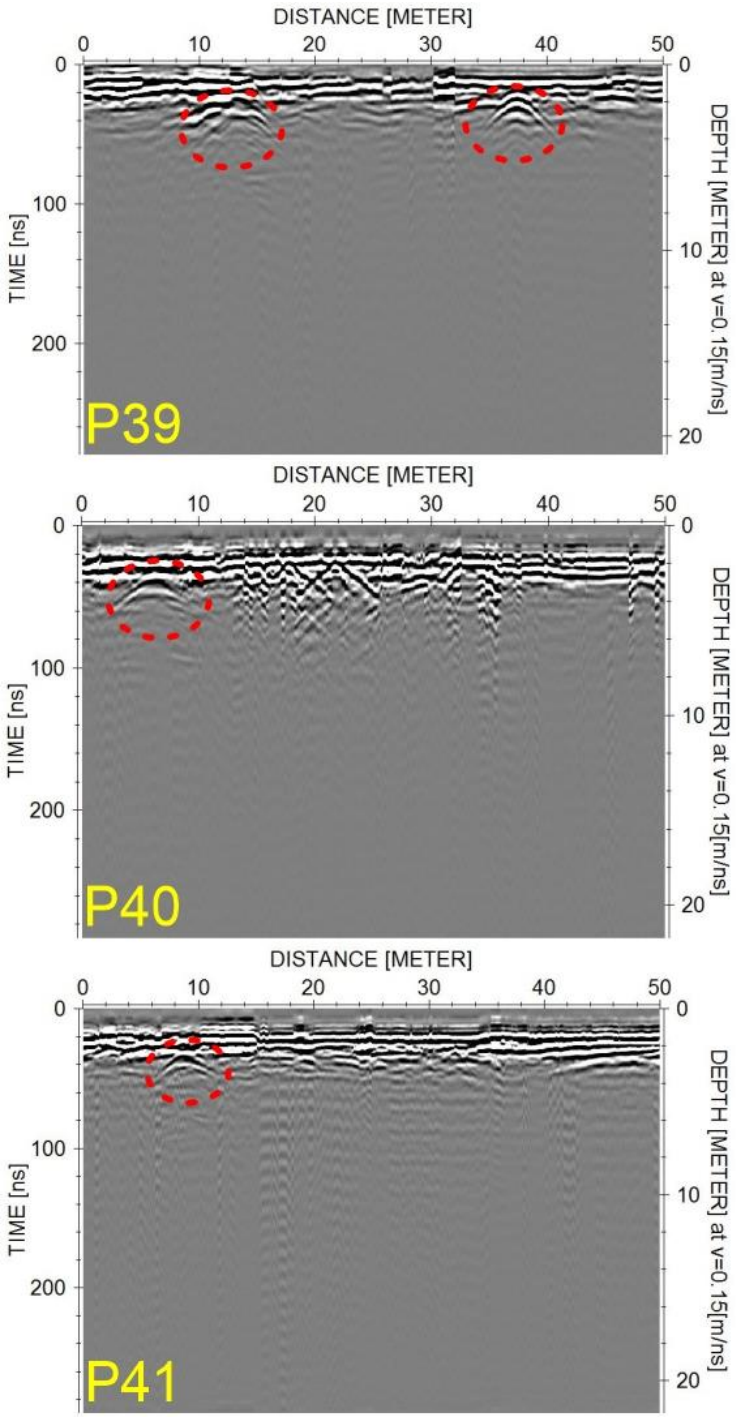

Fig. 4. Object no. one and two appear in profiles 39, 40 and 41 marked by red circles.

Table 1: Archaeological feature descriptions.

Profile no.	Location of anomalies (from stating point)	Depth of anomalies	Dimentions of archaeological feature	Expected anomalies
37	6-12 m	2.4 m.	An archaeological feature covering an area about 6 m	An anomaly representing a grave.
38	6-12 m	2.4 m.	An archaeological feature covering an area about 6 m	An anomaly representing a grave
39	8-16 m and 37-41 m respectively	2.4 m and1.2 m respectively	An archaeological feature covers an area about 8 m, and object no. 2 covers an area about 4 m.	An anomaly representing a grave
40	3-7 m	2.4 m.	An archaeological feature covering an area of about 4 m.	An anomaly representing a grave
41	6-12 m	2.4 m.	An archaeological feature covering an area about 6 m.	An anomaly representing a grave

Conclusion

The ground penetrating radar method has been developed significantly and used in Egypt on a reasonable scale in archaeological investigation. After conducting field measurements, processing, sequentially interpreting the data, the results reveals the existence of archaeological objectives represented by object no. 1 representing a grave in profiles no. 37, 38, 39, 40, and 41, and occupying an area of 6 -8 m at a depth of 2.4 m. The second object discovered in profile number 39 represents a grave occupying an area of 4 m at a depth 1.2 m. We hope in the future that the use of the radar method in archaeological investigations will be expanded allover Egypt because GPR mthod is an effective method that provides pre-drilling informations, accurate, safe to use, furthermore determines the dimensions of targets.

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