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Archaeological prospecting on the site of Osirion-Abydos using High Resolution Ground Penetrating Radar Technique, Sohag District, Egypt

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Abstract: Abydos Temple is one of Egypt's most significant sites, with a rich history that stretches from the ancient kingdom until the arrival of Islam. It has been built for about 4000 years. The main goal of this study is to use advanced geophysical techniques, such as ground penetrating radar (GPR), in conjunction with SIR 4000 control units and 200 MHz center frequency antennas, to search for more undiscovered remains of archaeological objects such as ancient walls, tombs, monuments, and so on, in the study area. The study's final findings revealed that there are numerous hyperbolic anomalies beneath the ground surface at a depth of roughly 2 meters, indicating the presence of probable ancient remains that must be excavated for confirmation. Many abnormalities that could represent important ancient tombs or walls were found on the radarogram, according to a thorough examination of the results. The existence of walls in the processed pictures at depths ranging from 2 to 4 meters indicates the presence of ancient communities as well as some buried archaeological objects.

Keywords: GPR – Archaeology – Geophysical survey – Osirion – Abydos – Sohag.

1 Introduction

'Archaeogeophysics' or 'Archaeological prospection' is the science of describing the disparities between underground archaeological relics and their surrounding rocks. The identification and interpretation of geophysical data has the potential to reveal the depths and extent of these submerged relics. In the current investigation, the Abydos place will be investigated using geophysical methods. During the research, "GPR" ground penetrating radar was employed to identify the underlying tombs that lay beneath the prospected area in an integrated manner. This study will accomplish two goals: 1) researching the archaeological and geological conditions of the study area, and 2) mapping the subsurface relics using geophysical tools, particularly GPR, to draw the boundaries of hidden tombs in the study region.

2 Historical background

Abydos is one of Upper Egypt's earliest archaeological sites. It was built more than 4000 years ago. Abydos is a planned city with several monuments showing ancient Egyptian holy tombs for kings from the first and second dynasties. This city owes importance due to its historical value and the amazing works of arts left by the ancient Egyptian and was one of the eighth regions of Upper Egypt whose capital was the "Thinis" city that located near the Abydos city. From the second dynasty downwards, several Pharaohs and the devout alike erected modest brick cenotaphs or stelae in their honour beside the tomb of Osiris, Lord of the Underworld [**1&2**].

During much of the dynasty's history, Osiris, the divine lord of the underworld and god of fertility, resided in Abydos. Perhaps the most amazing feature of the site is the survival of considerable remnants of the tombs of the monarchs of the 1st and 2nd Dynasties (especially the tomb of Narmer, the alleged first pharaoh of a united Egypt) and their predecessors. The entire cemetery, including these early remains, is known in Arabic as Umm el Qa'ab, or "Mother of Pots," and it is one of archaeology's most fascinating and informative cemeteries [**3**]. According to legend, Osiris, also known as Usir, was one of the most important gods of ancient Egypt. Osiris' beginnings are unknown; he could have been a local god of Busiris in Lower Egypt and a personification of chthonic (underworld) fertility. By circa 2400 BCE, however, Osiris had clearly taken on a dual role: he was both a fertility god and the

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resurrected monarch. The Egyptian concept of divine kingship was subsequently combined with this dual duty, with the living monarch's son becoming Osiris, god of the underworld, and the living king becoming Horus, god of the sky. Osiris and Horus became father and son as a result of this. Osiris was not only the deity who brought life to everything in the underworld, from flowering vegetation to the annual Nile River flood, but he was also the king of the dead. It was assumed that when a man died, he became linked with Osiris, not just the dead royals, starting around 2000 BCE. In this universalized form, Osiris' cult spread throughout Egypt, frequently mixing with the cults of local fertility and underworld gods. Following Osiris could lead to reincarnation in the next life, according to some cult types. During the Middle Kingdom (1938–c. 1630 BCE), the deity's festivals were held at the temple of Abydos, where Osiris had united with the very ancient god of the dead, Khenty-Imentiu, and consisted of processions and nocturnal rites. This was Osiris' epithet, which meant "Foremost of the Westerners." Because the festivities were open to the public, anybody could attend, and by the early 2nd millennium BCE, being buried along the processional road at Abydos or erecting a cenotaph as a tribute to the departed had become fashionable [4].

Since the early sixth Dynasty of the ancient Egyptians, Abydos has been a centre of pilgrimage, with each of them seeking to be buried next to the shrine of God Osiris, the "Lord of eternal life" or "God of deaths," as well as the kings of the Pharaohs, where celebrations of the installation of kings Gods took place. After that, the temple was renamed Khontamenti and devoted to both Osiris and Isis, who were equally worshipped. A number of temples and royal tombs can be found in the Abydos area [5]. The Osirion Cemetery was built 8 metres behind the Seti Temple as a symbolic burial for the God Osiris. It was built as a vaulted underground chamber with a water channel and a platform supported by ten stone pillars. While eroding the surrounding rocks, water in the Osirion maintains that part of the temple attached.

The Temple of Abydos contains many intriguing secrets, much as the mysterious city of Abydos has perplexed scholars and researchers for years [6]. The finding of a series of relief inscriptions on the walls of the Temple of Seti I that resemble modern technology is one embodiment of this mystery. A helicopter, a submarine, a flying disc in the middle (right), and a plane in the lower right are shown in the upper left. These paintings and symbols reveal that Egypt's culture was significantly more enigmatic than previously thought.

3 Location of the study area

The study region spans the latitudes of 26°10'N and 26°15'N, as well as the longitudes of 31°53'E and 31°57'E (Fig. 1). It's about 13 kilometres west of the town of El Balyana.

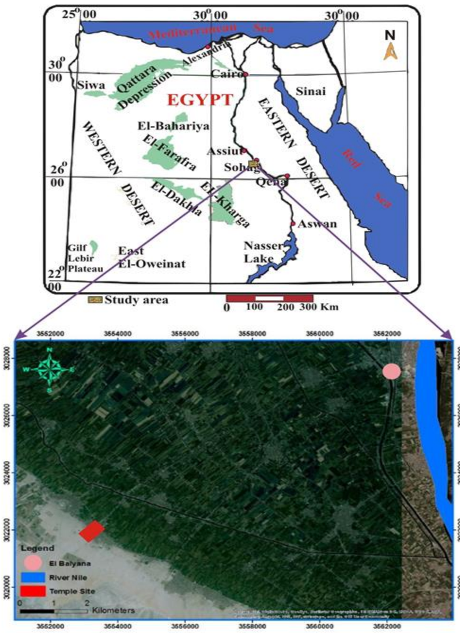

Fig. 1. Location map of the study area.

4 Geological setting

The majority of the Abydos area is Quaternary, with Pliocene layers covering, uncomfortably, the Early Tertiary Esna Shale [7]. The Qena Formation [8&9] is represented by a dense succession of deposits of slightly indurated fluviatile sands. According to Omer, the overall lithological component of the study region is divided into five rock units: 1) Pliocene Clay, 2) Qena Sands, 3) Kom Ombo Gravel, 4) Ghawanim Formation, and 5) Dandara Formation [10].

The Qena Sand Formation, which represents the Quaternary aquifer in the Abydos area and consists of cross bedded and friable to semi-consolidated yellow to greyish white to pale brown sandstone and interbedded layers of gravels and quartzite sandstone. The gravel sediments are made up of quartz, igneous and metamorphic basement rock pieces, according to [7]. Based on results obtained from local wells around the Abydos Temple area, the section of the Qena Sands may reach up to15 m thick [11]. The Qena Sand wedges out to the west against the Early Eocene Shale and the western limestone plateau bordering the current Nile Valley in the Abydos area, while the sands are eroded eastward by the existing Nile floodplain's erosion and subsequent silt filling. Local drilling to the west of Abydos has revealed the thickness of the Qena sand section, while the formation's base has yet to be reached. The Qena Sand Formation rests uncomfortably beneath the Ghawanim Formation in various places, particularly between Sohag and Assiut on the Nile's western bank [10]. The sands' base differs from one well to the next (Fig. 2). The Pliocene sediments in the Upper Nile Valley are overlain by this sand series [12].

In Abydos area, the thickness of the Kom Ombo Formation is less than a metre, although it can reach more than 15 metres in other areas. The Kom Ombo Formation is visible as gravel beds overlaying the Qena Sands in the research region. The Kom Ombo gravel formation, according to [13], is made up of a mix of plentiful basement and small sedimentary rock fragments that form a broad sheet on top of the Qena sand formation. The gravel sheet can be seen in numerous places along the Nile Valley's western bank, particularly between west Kom Ombo and Abydos.

These strata comprise primarily of cross-bedded sands mixed with gravel interbeds in the stretch between Sohag and Assiut along the Nile River's western bank, according to [10].

In Abydos area, the name Kom Ombo gravel was used to indicate a replacement for the Abbasia gravels that directly overlay the Qena sand. The Kom Ombo Formation sediments, which are found along the Nile River's western bank between Sohag and Assiut, are predominantly fluviatile sands with a few less common gravel interbeds [10].

The exposed Ghawanim Formation has a maximum thickness of 31m near El-Ghawanim village, west of Sohag city. [10] indicated that sand beds with trough cross-stratification had been documented multiple times. The Ghawanim Formation is exposed along the western bank of the Nile Valley from Nag Hammadi to Assiut, and subsurface Ghawanim deposits have been discovered beneath the agriculture silt layer in all drilled boreholes within the research region. These sediments, on the other hand, have not been recorded throughout the Nile Valley's eastern bank due to pre-existing morphology. The Dandra Formation, according to [14], is the first sedimentary unit in the Abydos succession to contain an Ethiopian mineral suite. The current Nile aggradation appears to have started with this structure [15]. In the Abydos area, the Dandra Formation consists of a sedimentary sheet of silt atop Kom Ombo Gravel, with thickness ranging from a few centimetres to 5 metres. The Dandra Formation is made up of sand and calcareous silt. [7] identified the Dandra as being buried beneath contemporary Wadi wash deposits. [10] discovered lenticular silt masses filling east-west pre-existing channels up to 6 metres thick in the Abydos area.

The lithological component of the region that is a part of the Nile Valley, in general, consisting of river deposits accumulated over various periods of the river's evolution. Said suggested that these clay layers might be related to the Paleonile sediments, which are the basal deposits atop the Lower Eocene limestone and are differentiated by varying clay depths with minor silt intercalation [12].

5 Ground Penetrating Radar

GPR (ground penetrating radar) is an electromagnetic tool for examining the earth's shallow subsurface items. GPR gives appropriate depth investigation for various geological characteristics [16]. Ground penetrating radar is commonly employed in archaeological investigation [17].

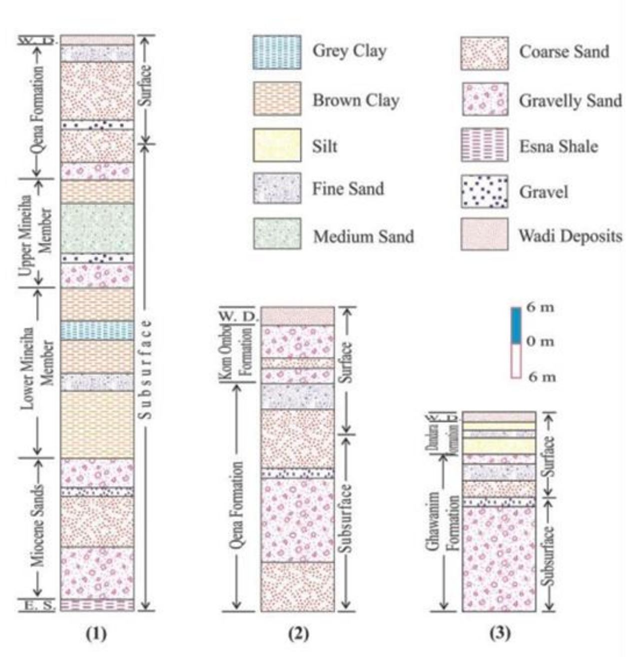

Fig. 2. The stratigraphic sequence west of Abydos area [10]

5.1 GPR approach basics

The GPR method necessitates the transmission of electromagnetic radio (radar) pulses in the shape of an elliptical cone from the transmitting antenna to the ground [18]. Changes in sediment or soil electrical characteristics, variations in water content, and lithological changes in bulk density at stratigraphic boundaries can all cause reflections. Reflections can arise at the interfaces between archaeological features and their underlying soil or sediments [16]. The frequency of the transmitted wave determines the depth of radar wave penetration. Each antenna has a single central frequency, but it produces ranges of one half to two times the centre frequency all around it [17]. Radar antennas are often mounted in a glass fibre that is either directly on the ground or supported on wheels a few centimetres above the ground. The GPR antenna is either monostatic or bistatic. The Bistatic antenna has a separate transmitter and receiver, whereas the Monostatic antenna contains both transmitter and receiver in the same cover.

5.2 Production of continuous reflection profiles

GPR data can be recorded in the field by drawing parallel lines in the desired area. When the intended objects are small, the antenna is slowly dragged along these lines. If less subsurface coverage is required, the antenna can be dragged faster.

5.3 GPR equipment and acquisition of data

The control unit, the transmitting unit, and the receiving unit are the three primary components of typical GPR systems [17]. The SIR-4000 control unit is used to conduct this research (Fig. 3).

Fig. 3. GPR system used for data collection (SIR 4000 control unit).

5.3.1 Definition of the site and measurements

Two grids were created on the study area. Each grid has 1.5 m line spacing. The initial grid is approximately 45 m × 51 m in size. The second grid has a smaller area and more details of the 21 m x 30 m section, but the spacing is the same.

The GPR survey is carried out in a Zig-Zag design on these grids. The 200 MHz centre frequency antenna is utilised to outline any potential concealed subsurface tombs or archaeological objects that may be present in the study region in order to undertake precise GPR measurements (Fig. 4).

In the study area, a 200 MHz center frequency antenna was used to create 50 GPR profiles. GPR lines distribution on the two grids surveyed in the study area is shown in (Fig. 5a).

Fig. 4. Photograph of the field acquisition of GPR profiles using the center frequency antenna of 200 MHZ.

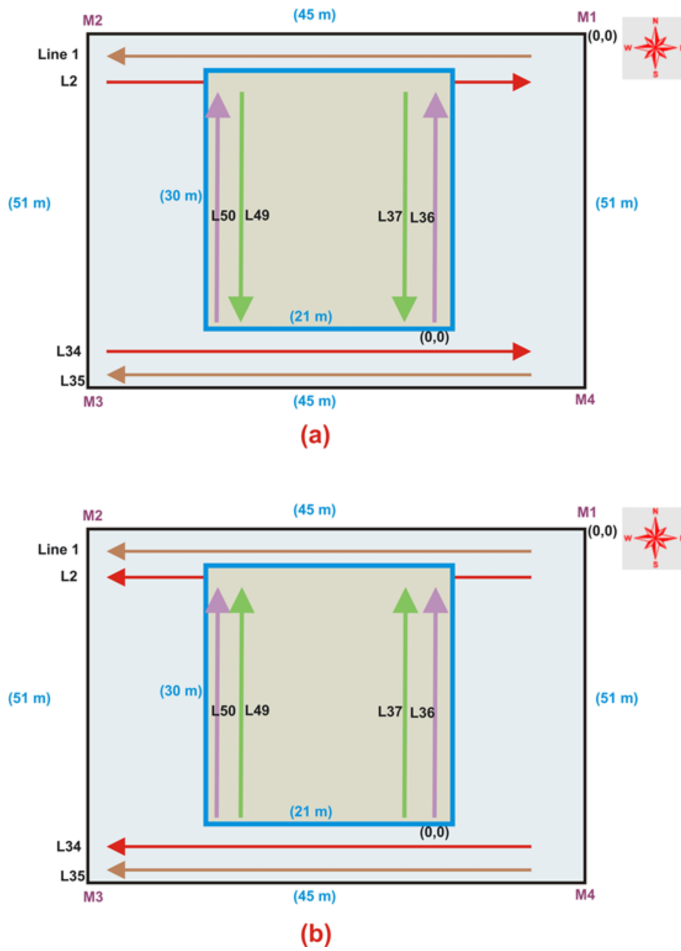

Fig. 5. GPR lines distribution in the study area on the two grids that were surveyed. (a) When the survey is implemented using Zig-Zag patterns in the grid and (b) When the GPR profiles are x-directionally overturned by the processing stage of X Flip.

6 Processing GPR data

6.1 Description

Following data collection, processing GPR data is critical for removing noise and undesired reflections [19]. Converting radar data into usable images is one of the final steps in data processing. The program REFLEXW [20] is used to accomplish these steps, which can be stated as follows:

6.1.1 Static correction

Due to the separation between the antenna and the ground surface generated during its movement, this is the first step of processing done to raw data. The undesirable reflections recorded in the upper portion of the area are removed using static correction. The value of shifted time for the traces is calculated in the radar section [21].

6.1.2 Band pass filter

A band pass filter can be applied to each trace; it works in the frequency domain.

6.1.3 Running average

This filter is applied to reduce trace-dependent noise while emphasizing horizontally coherent energy. This filter is based on the number of selected traces [21]. It is more effective when a broad band width is chosen.

6.1.4 Background-Removing Filter

This eliminates horizontal banding, which is common in GPR records. The horizontal banding could be caused by the ringing of particular antennas [22&23], or it could be caused by object reflections, such as the person dragging the sled antenna.

6.1.5 Gain

An energy decay filter is used to define a medium decay curve from the current traces. When the filter is applied to this curve, the decay curve values separate each data point of each trace. A scaling factor multiplies all data points while multiplying the energy decay curve [21].

6.1.6 X Flip the Profile

This processing stage has the ability to reverse the radar profile in the x-direction. This processing step is added when the survey is implemented using Zig-Zag patterns in the grid. It is advantageous for subsequent radar profiles to match the expected characteristics (Fig. 5b).

6.1.7 Trace interpol-3D file

This processing stage modifies the length and number of traces for each radar profile. Trace increment and profile length are the two settings accessible.

6.2 Time- depth analysis

Because reflections in 2D-radar sections are frequently estimated in two-way time, determining the value of the velocity is critical. It is necessary to convert the time of the radar waves into depth in two ways, using the required value of the velocity of the materials through which the radar energy passes, in order to achieve an accurate depth of the hidden features. In this work, the velocity is calculated using the reflected wave approach.

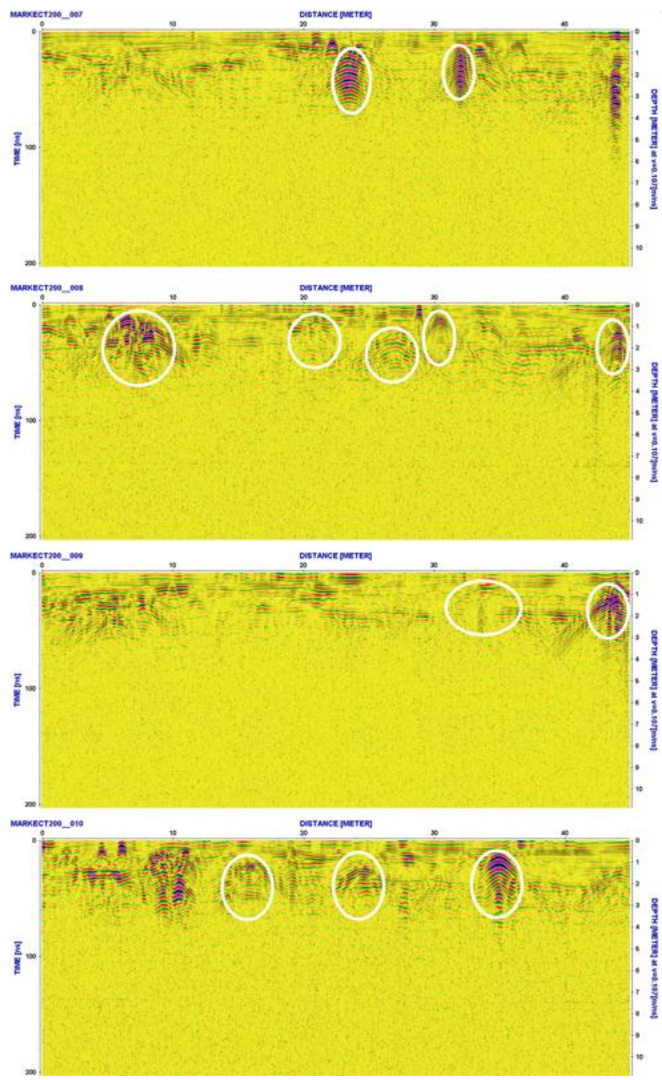

Fig.6. Expected buried features, marked with a white circle on different profiles at the larger grid.

7 Interpretation of GPR data

GPR data analysis is an important step in determining the location of abnormalities on the parts being processed and distinguishing them from other unwanted reflections. It also necessitates tracking the anomalies that appear on successive sections in order to determine the extent of the subsurface and the approximate depth of the buried objects in the studied grids. Three types of views are available: one-dimensional trace (1D), two-dimensional cross section (2D), and three-dimensional block view (3D).

The results of the treated GPR data are presented in the present investigation as 2D cross sections containing the predicted buried objects. The existence of walls in the processed pictures at depths ranging from (2-4 meters) indicates the presence of historic communities as well as some buried archaeological ruins. Some of the 2D parts at the two grids are depicted in the figures (Figs. 6, 7, 8 & 9).

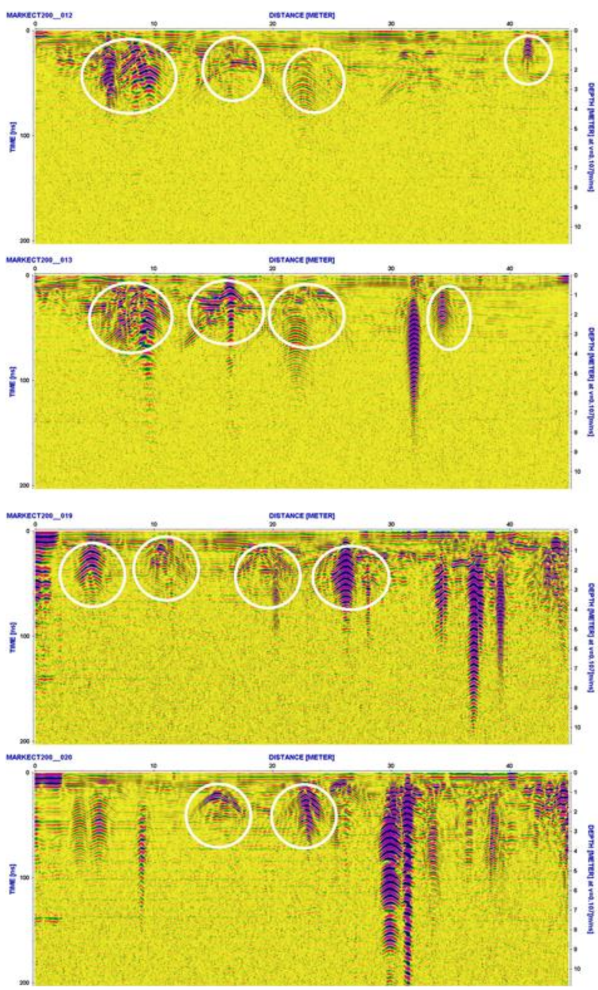

Fig.7. Expected buried features, marked with a white circle on different profiles at the larger grid.

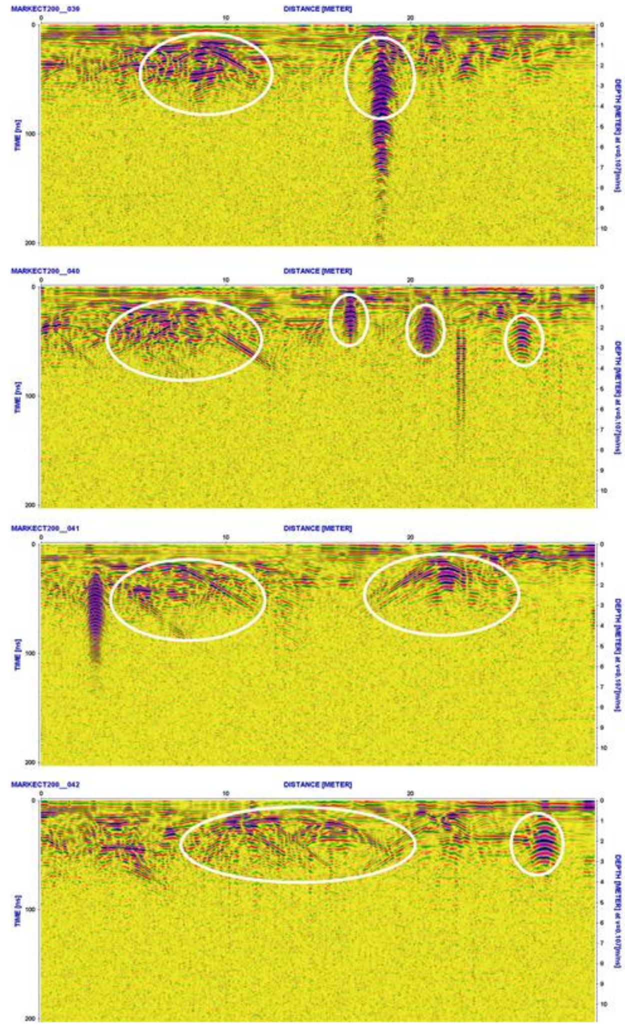

Fig.8. Expected buried features, marked with a white circle on different profiles at the smaller grid.

8 Summary and conclusions

Abydos site was studied by one of the famous geophysical tools. The geophysical technique of GPR is critical for locating buried tombs in the prospected area. The research area is divided into two grids with 1.5 m spacing, the first of which is 45 m × 51 m in size. The second is smaller and contains additional details about the 21m x 30m sector with the same spacing. SIR-4000 was used to conduct GPR surveys coupled to the 200 MHz center frequency antenna. A total of 50 performed 2D profiles are connected in the area to create a 3D imaging system. REFLEXW software is used to process the data.

The study's final findings showed previously unknown archaeological remnants that appeared as hyperbolas on radar sections. Their shape and size indicate the position and the depth of the objects. After obtaining security clearances from the Egyptian Antiquities Authority, it is permissible to excavate over these objects in order to validate their existence.

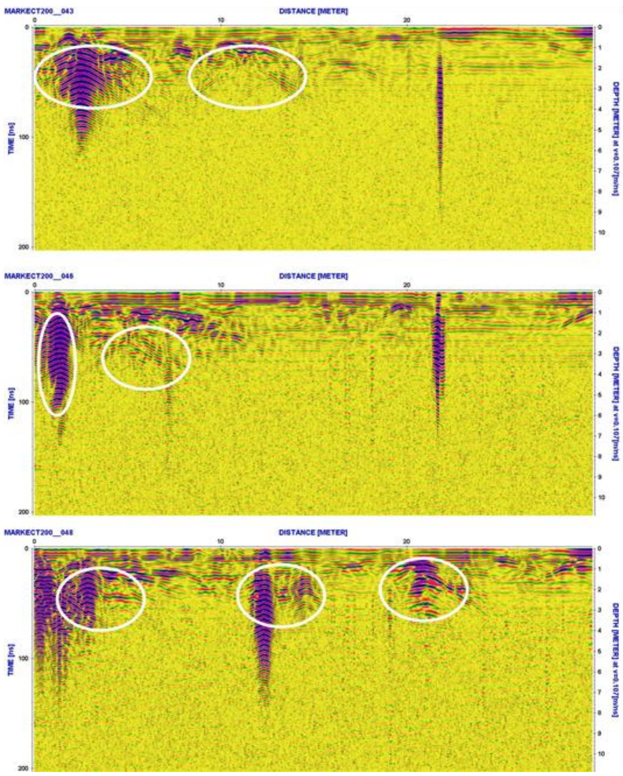

Fig.9. Expected buried features, marked with a white circle on different profiles at the smaller grid.

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