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# **Hawara Necropolis: Past – Present - Future**

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## **Hawara Necropolis: Past – Present - Future**

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### **Abstract**

Modern archaeological excavations in the Hawara Necropolis area were initiated in the late nineteenth century by English archaeologist Sir William Matthew Flinders Petrie. These studies were stopped in 1911.

In February 2008, a group led by Professor dr Abbas Mohamed Abbas from Cairo National Research Institute of Astronomy and Geophysics (NRIAG), made a series of complex geophysical survey in the area south and west of the pyramid.

The Scientific Research Cooperation Agreement between the Cairo University's Department of Archaeology and the University of Wrocław (Poland) initiated further research at Hawara Necropolis that started in March 2008. The Polish scientific involvement was in the field of GPR research, geological investigations and preparing reports.

Currently the mud-brick pyramid at Hawara is in very bad condition. Its surface is seriously damaged. Around the pyramids are great heaps of sand, through which it is difficult to pass. The southern entrance to the pyramid is partially buried and needs to be restored soon since it is in danger of collapsing. Chambers and channels under the pyramid are flooded with water.

Local authorities want to carry out renovation of the pyramid and make it available to tourists. However, this requires additional study, research and technical projects. Polish Foundation for the Support of Research to Disclose Ancient and Modern Knowledge Wisdom of Nations in co-operation with Mataha Foundation from Belgium, is ready to financially support the work in cooperation with the Ministry of Antiquity and any Egyptian Academic Institution that would be interested in such cooperation.

### **AREA OF RESEARCH**

The area of geological and GPR research is in Egypt at the Fayoum Oasis (Fayum, or El-Faiyum), about 100 km South from Cairo, nearby a town of Hawara. The Fayoum Oasis basin has a shape of a triangle (each side about 50 km long) with the apex directed towards North-West. Eastern side (the base of the triangle) parallel to the Nile is at the distance of 25 - 30 km from the river. The bottom terrace of the Nile is about 20 meters above sea level. The Oasis is surrounded from the South, the West and the North by plateau with the height of about 100 m above sea level. However from the North-West side of the Fayoum Oasis there is an Upland of about 200 – 250 meters height above the sea level. The highlands as well as Upland is lower in the direction of the Oasis Fayoum by steps with well-defined borders. In the northern part of Oasis Fayoum there is a depression (up to 50 meters below the sea level). Part of it consists of a cigar-shaped lake (W-E) about 40 km long, no more than 9 km wide and about 9

meters deep. Between Oasis Fayoum and the Nile valley there is a Upland divided by a gorge that is about 1-2 km wide. In this gorge there is Yusef's channel that leads to the Oasis Fayoum. At the exit of this gorge to the Oasis Fayoum (or by the exit from the Oasis to gorge with Yusef's channel) on its northern side the mud-brick pyramid of the king Amenemhat III in Hawara is situated. The second mud-brick pyramid (king Sesostris II) is situated on the northern side of gorge near-by of the Nile valley border. Both pyramids are about 10 km apart.

The mud-brick Hawara Pyramid is at the moment situated on the border of Fayoum Depression an almost flat (?) terrace or (?) cone of flood palaeo-delta with the sandy - gravel surface at the height of about 30 meters above sea level. This surface is slightly rising towards the East and at the distance of about 6 km has a height of 35 meters above sea level. Further East there is plateau escarpment that divides Oasis Fayoum from the Nile valley. Sands and gravel surrounding the Pyramid reach a thickness of 3-5 meters. Under these sands there are Eocene laminated clayey – mud deposits, lake in origin (the thickness near Hawara Pyramid is 12 – 15 m and surface eroded). Further down are Middle Eocene limestone deposits.<sup>(1)</sup>

On the South-West and West side of the Hawara Pyramid there is an artificial Selah Channel (named Bahr Wahbach Channel on other map, too) constructed in the year 1820 over 5 meters in depth below the ground surface.

This artificial channel is conducting water from the Yusef's channel in Northern direction. Nearby the Pyramid, about 200 meters East, there is a wet depression used for farming. In the direction North and East from the Pyramid, on the referenced earlier sand surface there are small, shallow depressions seasonally filled with salted water. Several salt and gypsum efflorescence/minerals/crystals are clearly visible in the surrounding. About 2 km East of the pyramid there is a dry North-South valley depression.

Around the pyramid at the distance of about 20 meters are earth heaps (embankments) made up to the height of about 5 – 10 meters. South of the Pyramid, at the area named as „TEMPLE“ there are traces/signs of former archeological excavations of Flinders Petrie in 1888, who named this place as Labyrinth described by Herodotus from Halikarnas. There are also several traces/signs of archaeological excavations and diggings on the North and the East sides of the Pyramid.

## **HAWARA NECROPOLIS: PAST**

Modern archaeological excavations in the Hawara Necropolis area were initiated in the late nineteenth century by English archaeologist Sir William Matthew Flinders Petrie. These studies were stopped in 1911. Researchers have renewed their interest in the area of mud-brick pyramid of Hawara only 100 years later.

In February 2008, a group led by Professor dr Abbas Mohamed Abbas from Cairo National Research Institute of Astronomy and Geophysics (NRIAG), made a

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<sup>(1)</sup> Abdel-Mohsen M. at all., 2003; Abu El Ghar, M.S., 2011; Wanas, H.A., 2008 .

series of complex geophysical survey in the area south and west of the pyramid. The Ghent University from Belgium financed this research.

The Scientific Research Cooperation Agreement between the Cairo University's Department of Archaeology and the University of Wroclaw (Poland) initiated further research at Hawara Necropolis that started in March 2008. This study was done during the period of March 2008 - April, 2009 and was called: Egyptian-Polish Archaeological Mission at Fayoum. The General Manager of the study was Dean of the Cairo University Prof. dr Alaaeldin Shaheen. The research was carried out in the immediate vicinity of the Hawara pyramid, was fully financed by the University of Wroclaw (Poland). The scientists from the Cairo University and the SCA team members supervised the research. The Polish scientific involvement was in the field of GPR research, geological investigations and preparing reports. This research was performed with the following steps:

**First:** analysis of archival geological data from the area of the pyramids in Hawara was prepared. It was obtained from Egyptian geologists. At the request of Polish team - two geological drillings were done. This data was used to prepare schematic geological cross-sections through the Hawara pyramid and its surrounding.

**Secondly:** the first Ground Penetrating Radar (GPR) studies were done in the immediate vicinity of the pyramid on north, east, south and west sides.

**Thirdly:** three geological control trenches were made on the eastern and northern side of the pyramid.

In order to be able to perform further GPR studies, a written request was submitted to the Supreme Council of Antiquities for permission to clear heaps of sand by levelling the ground on the eastern side of Hawara pyramid and get a flat and even surface. The permission from the Supreme Council of Antiquities was granted. The Cairo University Faculty of Archaeology supervised this work.

Numerous archaeological finds from the Greco-Roman times were discovered during the clean-up work near the eastern side of the pyramid. All finds were documented and most of them are secured in a storage room at Fayoum. Some of larger artefacts were placed in a small, open-air museum, at the Hawara pyramid site. For a reason unknown to us, Dr Zahi Hawass suddenly stopped the research at the Hawara Necropolis area in April 2009.

## **R E S E A R C H 2008 - 2009**

In 2008, the Faculty of Archeology Cairo University (Giza, Egypt) and University of Wroclaw (Poland), has been signed agreement for the scientific research cooperation between two Universities of the Mud-brick Pyramid in Hawara, Fayoum region in Egypt. It is assumed that spaces (tombs? channels? chambers?) under the Hawara Pyramid are flooded. Therefore the Supreme Council of Antiquities granted permission to the Faculty of Archeology of Cairo University for comprehensive geological, geophysical and possible archeological research in this area. The research should firstly answer the question: where the water in the Hawara Pyramid is coming from? In order to block its flow more information is needed about a location of possible water supply sources (fissures? channels? underground passages? palaeo-valleys?, etc.), situated in the area of the Hawara Pyramid.

The whole project is divided into several stages. During first stage of researches the geological analysis and interpretation of 10 archival borehole data (from 2002), comparing to two boreholes made for this project on 2008 and to geological Test Pits

1/2008 and “A”, “B”, “C”/2009 was done (Fig. 1). The goal of the second stage was to find possible direction/directions of water flow into the underground of the Hawara Pyramid using GPR (Ground Penetration Radar), non-invasive research method. At the beginning it was decided that in the GPR tests it was necessary to perform several profiles around the Hawara Pyramid along the established transects by GSSI system SIR with multifrequency antenna up to the depth of about 20 meters. Next, in few places on North, East and South of Pyramid was made transects GPR system RAMAC with 100 MHz unshielded antenna.

## GEOLOGICAL RESEARCH

No original very detail topographic map of Hawara Mud-brick Pyramid area. All geological analyses was made according to schematic topographic map from documentation of Abi Shams University, Faculty of Engineering, Soil Mechanics and Foundation Lab. (2002), concerning local level system. All elevation on this map they refer to water level in the Selah (Bahr Wahbach) Channel (Fig. 1). This level perhaps is on an elevation ca 25 m above sea level (according to Topographic Map 1:25 000, sheet 72/600 Egypt “El-Lahun”).

Surrounding the Hawara Pyramid 12 boreholes were done, mainly up to 15 m depth (Fig. 1). Ten boreholes were made in the year 2002 (Documentation of Abi Shams University, Faculty of Engineering, Soil Mechanics and Foundation Lab. 2002) and two boreholes were made in the year 2008, described by Mohamed A. Hamdan (“Two Shallow Cores from Hawara Pyramid and their impact in the groundwater problem”, Geology Dep. Cairo University, 2008). Only borehole (B-7/1 and B-7/2 from 2002) was drilled up to max. depth 25 m and borehole (B-1/2008) was drilled up to 18 m depth. Localization and elevation of boreholes is not clear (mainly borehole B-8/2002).

On the geological analysis of borehole data the lithological units were distinguished. Perhaps at the depth ca 12 m below water level in Selah (Bahr Wahbach) Channel are Middle Eocene limestone (1 on Fig. 2). Over this deposit are claystones/mudstones with intercalation of sandstones (2a on Fig. 2) and in lower part with limestones intercalations. On the top of unit 2a are pure claystone/mudstone (2b on Fig. 2). Perhaps unit 2 is also Eocene in age. Surface of deposits unit 2 are on different levels. It was very difficult to make a decision if 3 is natural layer or mound (mixed: clay, silt and mud), because description is not clear. It was named 3 on Fig. 2 (as a mound), on this deposits were found groundwater level. Unit 4 (Fig. 2), was found only in one borehole (B-1/2008). It was described as fine sand. Over this described deposits are sand with gravels (5 on Fig. 2). Around the Hawara Pyramid are found sand and gravel, marked on geological maps as Nile terrace (Quaternary ?, Neogene deposits ?). It is an open question if unit 5 (marked on borehole B-4/2002 and B-5/2002) are really river gravel deposits or it's mound with such gravel (as unit 8). Unit 6 mound is built by mixed: sand, gravel, clay and fragments of stones. In borehole B-2/2002 there are fragments of stones (6a) and mixed: sand, gravel with fragments of stones (6b). In boreholes B-1/2002 and B-7/2002 it is difficult to separate sand and gravel from stone (mixed). Unit 7 there are plates/slabs of stones. The fragments of such stones are marked as unit 7a. Unit 8 (Fig. 2) – is anthropogenic surface layer, built by mixed: fragments of stones, gravel, sand and artifacts.

After analyze of boreholes is clear that below anthropogenic deposits, round of Mud-brick Pyramid in Hawara, are consolidated claystone/mudstone rocks (perhaps Eocene in age) which thickness can be up to 15 – 17 m. From the West, North and East side of Pyramid the surface of these rocks (claystone/mudstone) is 1 – 3 m above water level in Selah Channel. But, on the South side of the Pyramid the surface of claystone/mudstone is 0,5 – 1,0 m below water level in Selah Channel. Below of these claystone/mudstone are Middle Eocene limestone.

The geological Test Pit 1/2008 was excavated at the SE corner of Pyramid, ca 20 m South from B-2/2008 and 75 m East of the entrance to Pyramid (Fig. 3). Excavation was performed at area 5 m x 3 m, up to 4,3 m depth. The geological Test Pit shows detail structure of units: 6, 7 and 8. The stone slab (marked as unit 7) has thickness 0,30 m. Below this slab are deposits of unit 6, built by gravel and brownish sand with the rest as flora and artifacts. It is anthropogenic in origin but washed by water. Over the slab are layers of unit 8. The lower part is built by gravel and sand with the rest flora (8a). This anthropogenic deposit was washed by water. On the top of this sequence are small channels filed by mud (8b). Over them are sand with gravels (8c) and mixed gravels, sand and artifacts of mound surface (8d or 8 not separated).

## **Geological Cross-Sections**

For Hawara Mud-brick Pyramid area, on the base of geological data, was drawn the schematic geological cross-sections, but without horizontal scale.

As example of schematic geological cross-section 02 – 02 was show on Fig. 4. Elevation of borehole B-8/2002 is not clear. On the West side of Pyramid, the consolidated rocks of unit 2 are ca 0,5 m over the water level in Selah Channel. Ground water level in borehole B-8/2002 is in mound deposits ca 1,5 m over water level in the channel. Perhaps between this borehole and channel exist (?) possibly a wall. But on the East side of Pyramid the consolidated rocks of unit 2 are ca 2,5 m over the water level in Selah Channel. Ground water level in boreholes B-2/2008 and B-3/2002 is in sand or mound deposits ca 3,2 m over water level in the channel. Perhaps between this boreholes and Pyramid exist (?) possibly a wall.

All the schematic geological cross-section show us that on the North side of Pyramid, the consolidated rocks of unit 2 are ca 1,0 - 2,0 m over the water level in Selah Channel. Ground water level in boreholes B-5/2002 and in B-6/2002 is ca 3,40 m over water level in the channel. About 80 m North from Pyramid, the consolidated rocks of unit 2 are ca 1,5 - 3,0 m over the water level in Selah Channel and the ground water level is ca 3,40 m over water level in the channel. On the East side of Pyramid, the consolidated rocks of unit 2 are ca 2,0 - 3,0 m over the water level in Selah Channel. Ground water level is ca 3,2 m - 3,40 m over water level in the channel. The consolidated rocks of unit 2 are ca 0,5 – 2,0 m below the water level in Selah Channel. Ground water level in boreholes are in sand or mound deposits ca 0,7 m in B-1/2002 and ca 1,0 m in B-2/2002 & B-1/2008 over water level in the channel.

## **Ground Water at Hawara Pyramid**

The results of analysis data from boreholes and Test Pits is known that in the year 2008 on the North and North-East side of Pyramid the first ground water level was

ca 3,4 m over the water level in Selach (Bahr Wahbach) Channel. On the East side ground water level was ca 3,2 m over the water level in channel. On the West side ground water level was (??) on 1,5 – 2,0 m over the water level in channel. Below Pyramid the water level was ca 1,0 m over the water level in channel. On the Southside ground water level was ca 1,5 m (in E part) and 0,7 m (in W part). This analysis shows that in 2008 the ground water supply of the water is from NE and E sides of Pyramid area. Perhaps part ground water inflow to chambers below Pyramid is also from the Selah Cannel (Bahr Wahbach), too (Fig. 5). Channel controls the ground water outflow.

Perhaps, round of the Pyramid are (??) walls which block inflow of ground water to chambers below Pyramid. For this reason on these sides the level of ground water is higher than in the South and South-West.

The chemical analyses of water show us, that in Selah (Bahr Wahbach) Channel are fresh water. In chambers below Pyramid the water are salty. The salt water are in lakes on surface of Upland North from Pyramid. In chambers below Pyramid the salt water from surface and first ground water level are mixed with fresh water from channel Selah (Bahr Wahbach) which was flowing during floods or high water level in channel. But now, perhaps in chambers below Pyramid the water are not only from this channel.

The ground water in borehole B-2/2008 are very interesting, too. During boring the ground water level was very low, but at last steady at 2 m below surface. The boring was stopped in limestone and perhaps the lower/secound ground water level in limestone unit was disturbed. General dipping of limestone layers is from E or NE to W or SW and ground water aquifer alimentation is located East or NE from Pyramid on (?) Upland. From this reason at Pyramid area the ground water in limestone are under pressure (karst artesian water). It will be very interesting to control this water level. Perhaps karst artesian water from limestone not supplying water in chambers/channels/tomb below Pyramid.

## **GPR METHOD**

The first stage of the GPR research at the Hawara Pyramid area was done on March 17, 2008. For the ground penetration tests the SIR-2 GPR equipment was used with the multi-frequency antennas. The antennas were carried at the level of about 20 - 40 cm above the ground surface along pre-determined lines. The signal's interval were measured by time and GPS. The distances of transects were measured by measure calibrated line. The operating technical team of the SIR-2 equipment were members of the NRIAG Cairo staff under the supervision of Dr Ashraf Khozym Salama (Cairo, Egypt). There were 12 transects measurements done with the total length of about 1140 m.

The second stage of the GPR research at the Hawara Pyramid area was done on May 23-25, 2008. For the ground penetration tests the RAMAC/GPR equipment was used with the 100 MHz antenna. The antennas were carried at the level of about 10 – 30 cm above the ground surface along pre-determined lines. The signal's interval were measured by time and GPS. The distances of transects were measured by measure calibrated line. The operating technical team of the RAMAC/GPR equipment were members of the Geology Department University of Cairo staff under the supervision of Dr. Adham Rafaie (Cairo, Egypt). There were 22 transects measurements done.

Localization of all transects is not clear and marked on the map (Fig. ) within a precision of  $\pm 10$  meters.

## **Method of GPR data processing and geological interpretation**

As the result of the on-site tests the GPR files with initial reflex/echo data time radargrams/radiograms were received and were written down on the computer's hard disk of the main unit. At the office these files were transfer to a stationary computer and subjected to a filtration process using programs: to RADAN 6.5 and REFLEX W and to GroundVision. For the data analysis different combination of filters were used that produced different synthetic pictures of echo's of reflected electromagnetic waves. After selecting the right filters and after obtaining the correct optimal pictures that could be interpreted and could give answers to main questions these files were exported to the program CorelDraw. On this program the directions were marked (South, North, or East, West) as well and noticed anomalies. Anomalies on the radargrams/radiograms are marked by ellipses or rectangle. In such manner the GPR 2D cross-sections were created. On few radargrams/GPR Cross-Section different EM fields of different lithological types (which named as radar facieses RF) were marked as: RF 1 – it is a limestone; RF 2 – clayey / mud like deposits (RF 2a – with sandstone intercalation, RF 2b – pure claystone); RF 3 – it is clayey overburden made by man activity; FR 4 and RF 5 – it is sand and sand with gravels; RF 6 – mound, mixed sand, gravels with artifacts, FR 7 – constructions (?); RF 8 - mixed gravels, sand and artifacts of mound surface. Predicting borders between radar-facieses (RF) were marked with black lines. In such manner the GPR 2D cross-sections were created.<sup>(1)</sup>

## **GPR Cross-Sections**

### **North side of Hawara Pyramid**

Few GPR cross-section West-East, on North side of the Pyramid, parallel to the pyramid's base, was made SIR-2 with multi-frequency antenna (Fig. 6). On the basis of boreholes: B-6/2002 and B-5/2002 are marked radar - facieses (RF). Noticed anomalies were between: 25 – 35 meters (anomaly N1), 52 – 65 meters (anomaly N2). Part of GPR cross-section 649 was shown on Fig. 7.

From few GPR cross-section made RAMAC/GPR with 100 MHz unshielded antenna on North side of the Pyramid, parallel to the pyramid's base, as example are shown: cross-section 346 and cross section 347 (Fig. 9, 11, 12).

Cross-Section 346 East-West, (Fig. 9, 11). Noticed anomalies were between: 6 - 8 meters (? wall), 47 – 55 meters (very strong anomaly N1) and 79 – 81 meters (? wall).

Cross-Section 347 West-East, on North side of the Pyramid is parallel to the pyramid's base (Fig. 9, 12). Noticed anomalies were between: 8 - 10 meters, 27 - 45

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<sup>(1)</sup> **Note!** Due to lack of precise geological data for calculating the scale for the penetration depth it was decided to adopt a medium velocity of soils value of „100 m/us“. For this reason the scale of the depth in not precise and an error in depth calculation can be in the range of  $\pm 2$  meters. The cross-sections are elevated!.

meters (very strong anomaly N1), 52 - 56 meters (anomaly N2) and 68 – 70 meters (anomaly, ? wall).

### **East side of Pyramid**

From few GPR cross-section made RAMAC/GPR with 100 MHz unshielded antenna on East side of the Pyramid, parallel to the pyramid's base, as example are shown: cross-section 338 (Fig. 9, 10).

Cross-Section 338 North-South, on East side of the Pyramid, parallel to the pyramid's base. On the basis of boreholes: B-3/2002, B-2/2008 and Geological Test Pit 2008 are marked radar - facieses (RF). Noticed anomaly is between: 30 - 35 meters (strong anomaly E2).

### **West side of Pyramid**

Cross-section 653 South-East to North West along East terrace of (Bahr Wabach) Selah Channel Fig. 6 and Fig. 8). Transect was made SIR-2 with multi-frequency antenna. On radar-gram are marked radar - facieses (RF) and anomalies. Very interesting anomalies are between 35 – 75 meter of profile. These anomalies are marked as W1. Perhaps is destroyed construction of wall rounded Pyramid.

### **GPR anomalies**

Anomalies recognized on GPR Cross-Sections are presented on Map GPR anomalies (Fig. 6 and 9). This is only schema map and localization of boreholes, GPR transects and GPR anomalies is  $\pm 10$  m. If localization of GPR Cross-Sections is correct then are few places with interesting anomalies. On the North side of Pyramid are very strong anomaly marked as **N1** in central part of Pyramid, between boreholes B-6 and B-5 (Fig. 6, 9, 11, 12). Other anomaly, marked **N2** is near NE corner of Pyramid (Fig. 6 and 7, Fig. 9). Very interesting anomalies are near central part of East side of Pyramid, between boreholes B-3 and B-4. This group of anomalies is marked as E1 (Fig. 9). Other group of anomalies (**E2**) is near SE corner of Pyramid on East side of Pyramid (Fig. 9 and 10). Very strong anomaly (**S1**) is on the South side of Pyramid, near nowadays entrance to Pyramid. Other strong group of anomalies (**S2**), on South side of Pyramid, is near borehole B-2/2002 and B-1/2008 (Fig. 9). Now, is difficult to explain if this anomalies are on West or on the North from place of this boreholes, but there are very strong anomalies on the depth between 2 – 5 meters. A very interesting anomalies are on the West side of Pyramid, below terrace of (Bahr Wabach) Selah Channel (Fig. 6, Fig. 8 and Fig. 9). Perhaps is destroyed construction of wall rounded Pyramid.

### **PRESENT**

Currently the mud-brick pyramid at Hawara is in very bad condition. Its surface is seriously damaged. Around the pyramids are great heaps of sand, through which it is difficult to pass. The southern entrance to the pyramid is partially buried and needs to be restored soon since it is in danger of collapsing. Chambers and channels under the pyramid are flooded with water.

### **FUTURE**

Local authorities want to carry out renovation of the pyramid and make it available to tourists. However, this requires additional study, research and technical projects. Polish Foundation for the Support of Research to Disclose Ancient and Modern Knowledge Wisdom of Nations in co-operation with Mataha Foundation from Belgium, is ready to financially support the work in cooperation with the Ministry of Antiquity and any Egyptian Academic Institution that would be interested in such cooperation. Such research could also be aimed at attracting many more tourists to the Hawara pyramids Necropolis area. We propose the following activities:

1. Removal of heaps of sand and levelling the surface of the north and south side of the Hawara pyramid area.
2. Preparation a new, detailed topographic map of the area surrounding the pyramid. The construction of checkpoints and determination of baseline necessary during GPR studies.
3. GPR research in the 3D system around the pyramid, starting with the east side, that is already cleaned. To do further GPR research cleaning and levelling of the surface is necessary (see: pt. 1).
4. Several drillings up to 20+ m deep in order to verify geological structures and lithology on north and south side of the pyramid.
5. Building a water level gauge in the Selah channel;
6. Perform chemical analyses of water: ground water, water in the channel, the water inside the pyramid;
7. Preparation of the project to restrict the flow of water to the pyramid.
8. Perform a GPR tomography (in 2D and 3D) of the Hawara pyramid. Profiling can be conducted along the surfaces of all the walls of the pyramid.
9. Implementation of the GPR research inside the pyramid.
10. Preparation of the project for the restoration of the pyramid.
11. Renovation of the southern entrance to the interior of the pyramid in Hawara.
12. Preparation of the project (or projects) the construction of a museum at the Hawara pyramid.
13. Construction of the museum near the pyramid in Hawara.
14. Preparation of the project for the tourism development at the Hawara Necropolis area.
15. Preparation of a draft for tourism activation at the areas of Hawara and Lahun (tour routes and infrastructure for communication, etc.).

With respect to the implementation of the above activities – our Foundations are ready to support these activities after signing appropriate agreements and obtaining permits from the Ministry of Antiquities.

## CONCLUSIONS

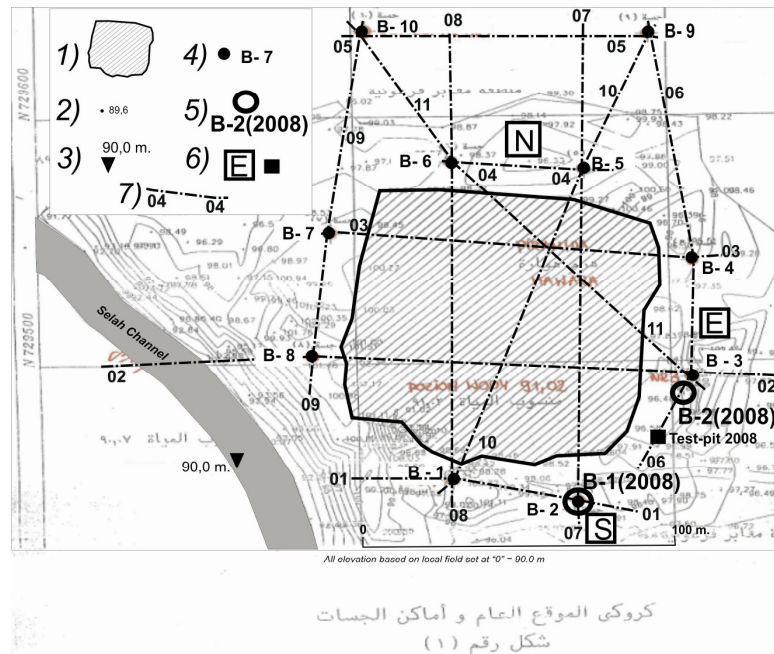
The tombs, chambers, channels, etc. that exist below Mud-brick Pyramid in Hawara were built in consolidated claystone/mudstone rocks (perhaps Eocene in age). From the West, North and East side of Pyramid the surface of these rocks (claystone/mudstone) is 1 – 3 m above water level in Selah Channel. On the South side of the Pyramid the surface of claystone/mudstone is 0,5 – 2,0 m is above water level in Selah Channel. Perhaps round of pyramid existing (?) structures/walls, block inflow of ground water to chambers/tombs below Pyramid. Now, inflow of ground water to chambers/tombs below Pyramid is from Upland on N, NE and E side. Is not excluded that during flood periods the ground water inflow was from (Bahr Wabach) Selah Channel, too. The Selah (Bahr Wabach) Channel controls ground water level on research area. Perhaps, now the water in chambers/tombs below Pyramid are not only from (Bahr Wabach)

Selah Channel. If chambers/channels/tomb below Pyramid are on depth more than 12 m below water level in Selah Channel then is possible supplaying of ground water from aquifer located in underlying carbonate rocks (limestone). This problem will be research seperatly. Chemical analysis and dating of water from: limestone, (Bahr Wabach) Selah Channel, chamber below Pyramid and depression filled water on N and E is recommended. The GPR anomalies (?? voids) discovered during the GPR research were record and drawing on the map of the surrounding pyramid area within a precision of + 10 meters. The most interesting anomalies are found: N1 and N2 - on the North side of Pyramid, E1 and E2 – on the East side of Pyramid. On the South side of Hawara Pyramid are GPR anomalies S1 and S2. On the West side of Pyramid are anomaly/s W1. The anomaly on West side of Pyramid need more detail research. All anomalies appear to be possible underground water inflow areas. It is therefore believed that the results of excavations in these areas will indicate the inflow of groundwater into the pyramid. Additional test pits an all four side should be executed for more detailed soil analysis. Implementation of these recommendations should bring about resolution to location of groundwater inflow and establish a program for site and Hawara Pyramid restoration.

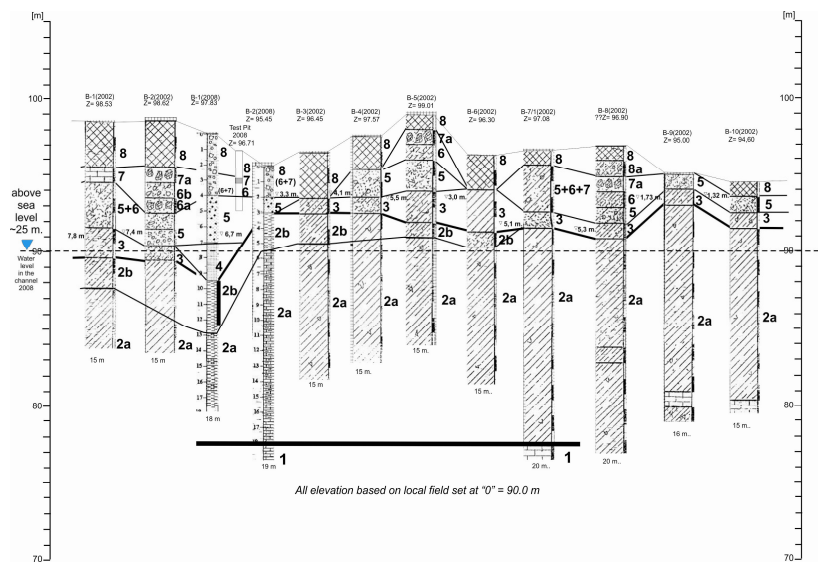
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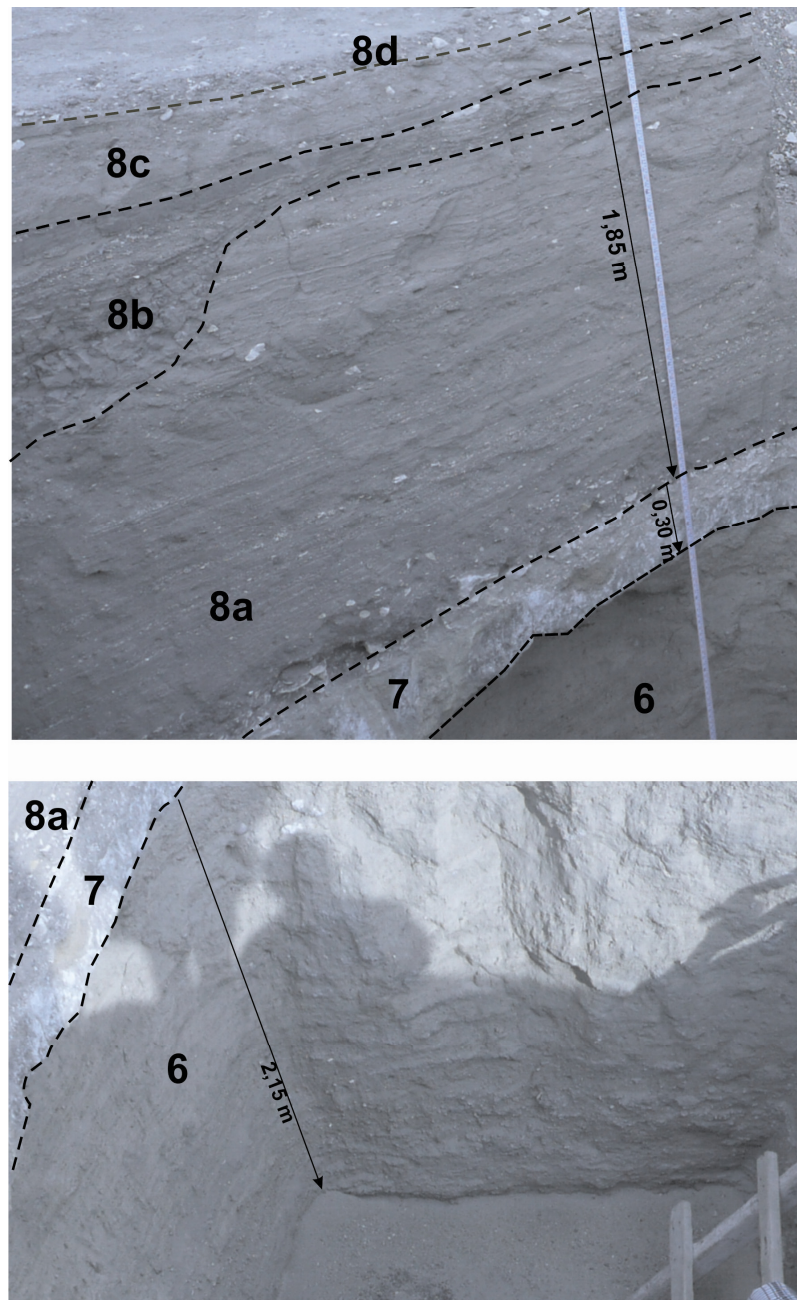
## FIGURES



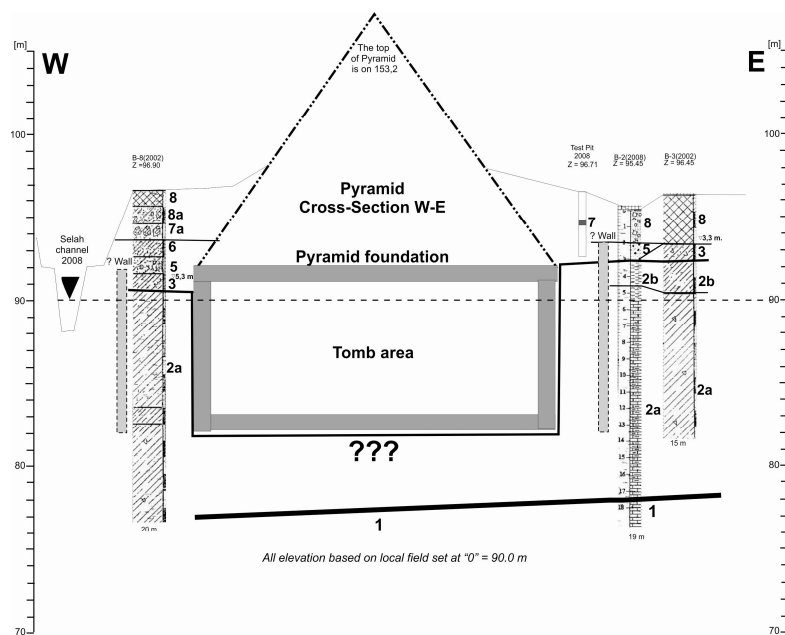
**Fig. 1.** Egypt, Fayoum, Hawara. Mud-brick Pyramid of Amenmhat III. Topographic Map with location of: bore-holes, test-pits and geological cross-section.  
 1) Mud-brick Pyramid of Amenmhat III; 2) local elevation point; 3) water level in Selach Channel 2008; 4) bore-hole made in 2002; 5) bore-hole made in 2008; 6) test-pit; 7) geological cross-section



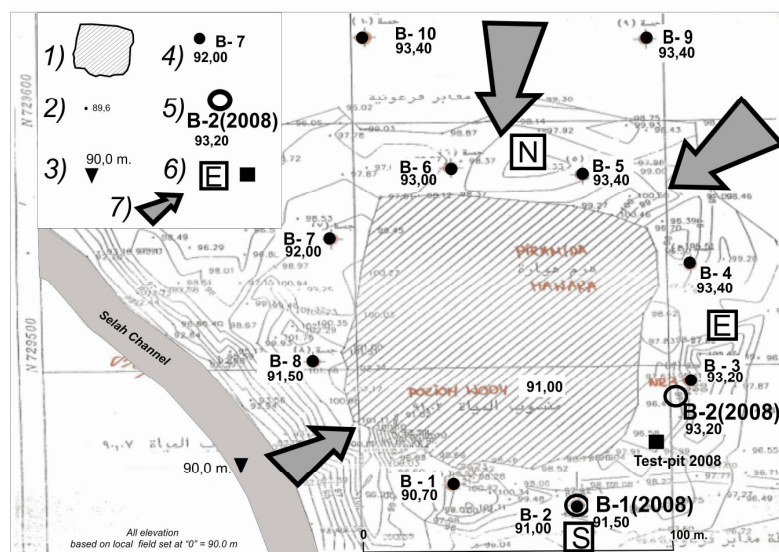
**Fig. 2.** Egypt, Fayoum, Mud-brick Pyramid in Hawara. Correlation of Lithology Facies in soil-borings.



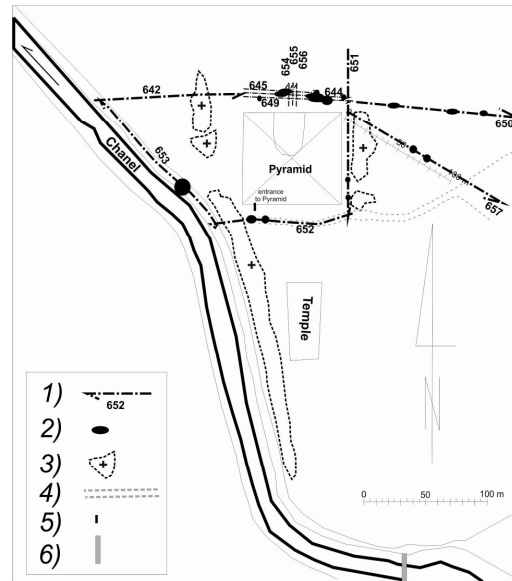
**Fig. 3.** Egypt, Fayoum, Mud-brick Pyramid in Hawara.  
The geological Test-pit 2008 (lithological facies described in the text).



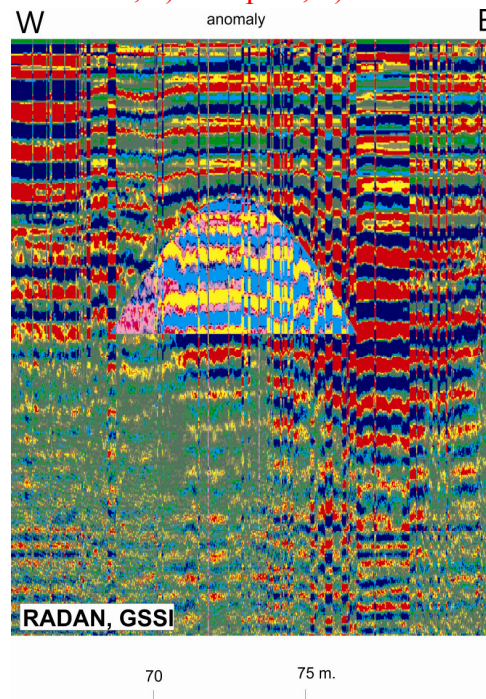
**Fig. 4.** Egypt, Fayoum, Mud-brick Pyramid in Hawara.  
Schematic geological cross-section 02 – 02. Correlation of Lithology Facies in soil-borings: B-8/2002, Test-pit 2008, B-2/2008, B-3/2002.



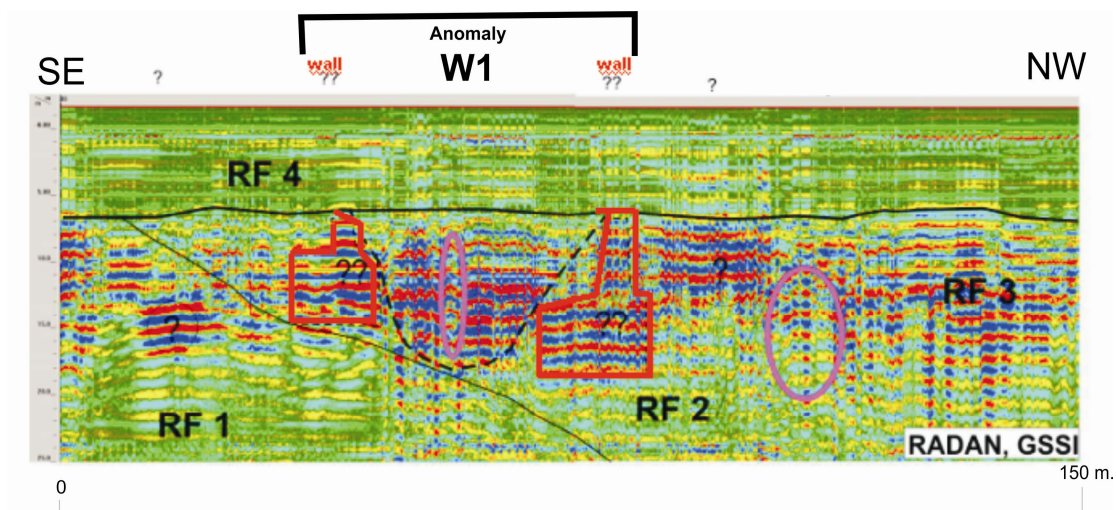
**Fig. 5.** Egypt, Fayoum, Hawara. Mud-brick Pyramid of Amenmhat III.  
The Map of ground-water level round of Pyramid and forecast of ground-water flow.  
1) Mud-brick Pyramid of Amenmhat III; 2) local elevation point; 3) water level in Selah Channel 2008; 4) bore-hole made in 2002 and level of ground water; 5) bore-hole made in 2008 and level of ground water; 6) test-pit; 7) forecast of ground-water flow



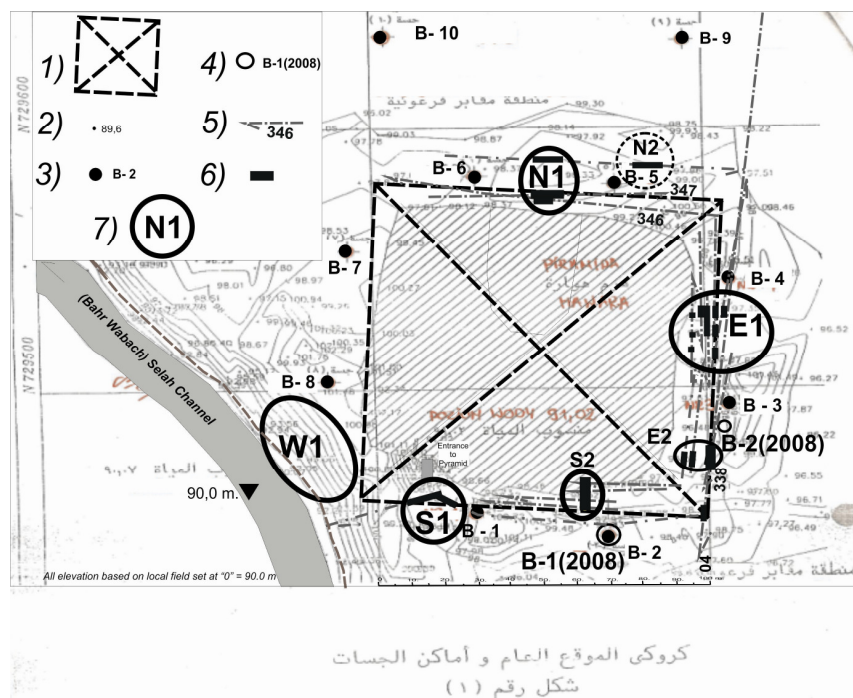
**Fig. 6.** Egypt, Fayoum, Hawara. Mud-brick Pyramid of Amenmhat III. The GPR cross-section made with GSSI SIR in 2008 and GPR anomalies.  
 1) location of GPR cross-section and its number; 2) GPR anomaly; 3) heap, sand embankment; 4) foot-path; 5) entrance to Pyramid; 6) foot-bridge



**Fig. 7.** Egypt, Fayoum, Mud-brick Pyramid in Hawara. The part of GPR cross-section 649 (detail)  
 Anomaly N2 on distance 70 – 75 meters, the depth: 7 – 12 meters

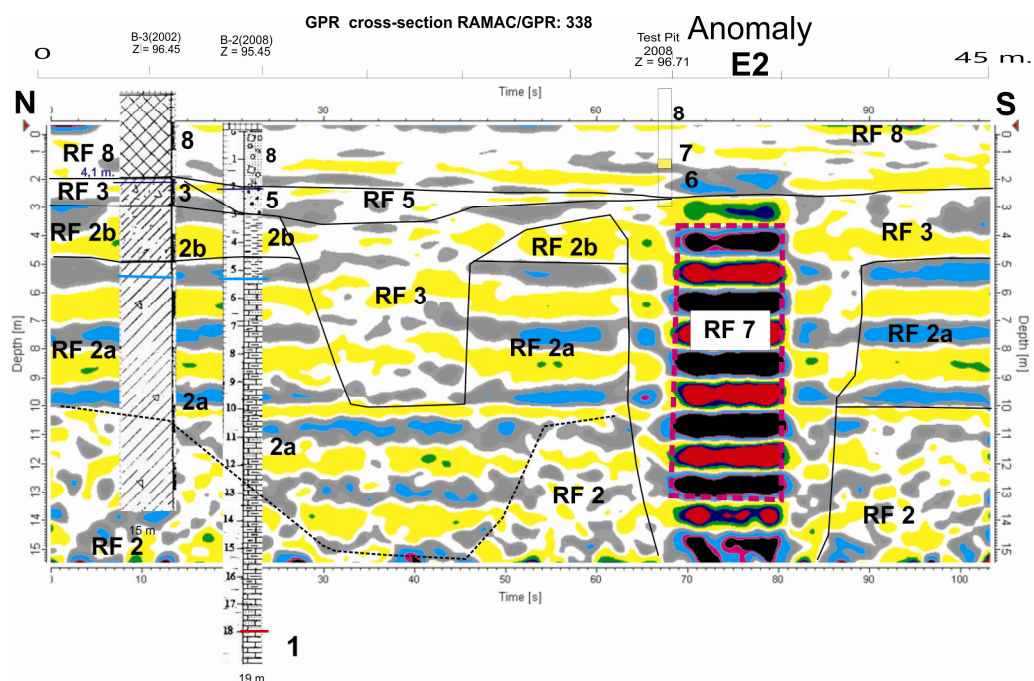


**Fig. 8.** Egypt, Fayoum, Mud-brick Pyramid in Hawara.  
GPR cross-section 653 along Selah Channel (Bahr Wabach). Anomaly W1.  
(RF – Radar Facies described in the text).

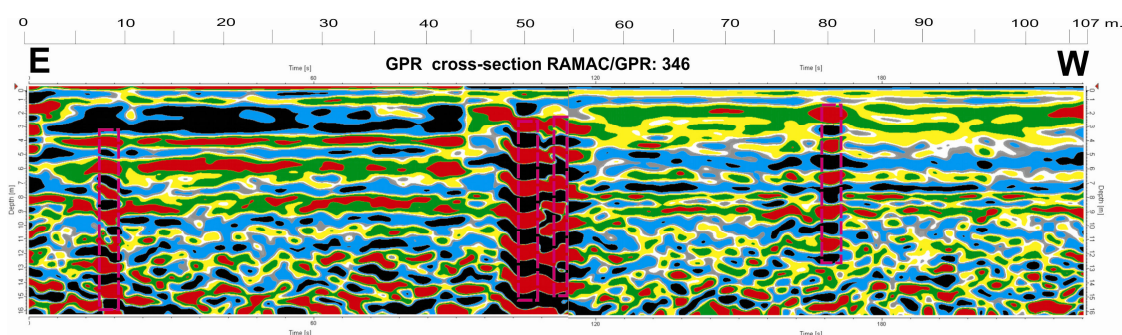


**Fig. 9.** Egypt, Fayoum, Hawara. Mud-brick Pyramid of Amenmhat III.  
The GPR cross-section made RAMAC/GPR with 100 MHz unshielded antenna and  
GPR anomalies.

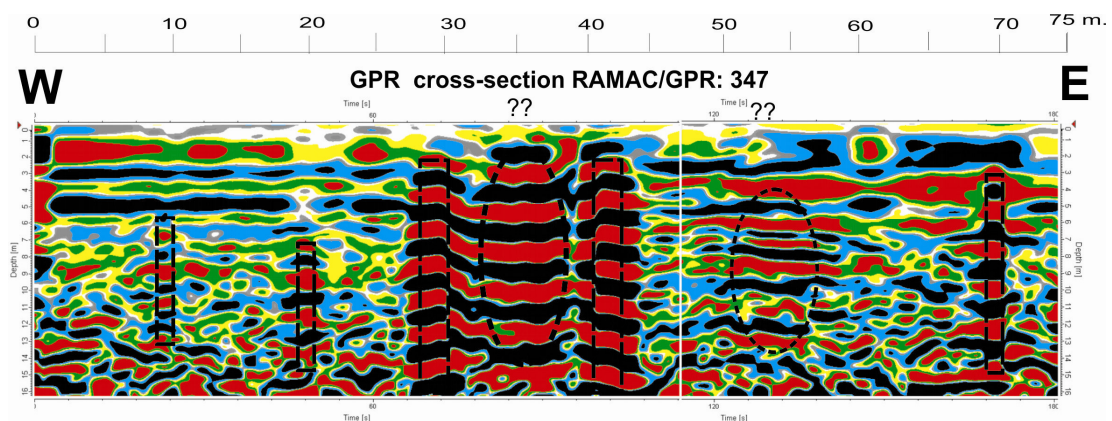
- 1) Mud-brick Pyramid below sand; 2) local elevation point; 3) bore-holes made in 2002; 4) bore-holes made in 2008; 5) selected GPR cross-section and number; 6) GPR anomaly; 7) group of GPR anomalies



**Fig. 10.** Egypt, Fayoum, Mud-brick Pyramid in Hawara. East side of the Pyramid.  
GPR cross-section 338 (RAMAC/GPR) and correlation of Radar Facies.



**Fig. 11.** Egypt, Fayoum, Mud-brick Pyramid in Hawara. North side of the Pyramid.  
GPR cross-section 346 (RAMAC/GPR). Anomaly N1.



**Fig. 12.** Egypt, Fayoum, Mud-brick Pyramid in Hawara. North side of the Pyramid.  
GPR cross-section 347 (RAMAC/GPR). Anomaly N1.