GPR Survey at the Archaeological Site of Almazamma, Al Hoceima (Morocco)

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***Abstract*—** In this work we have accessed the potential of detection method and imaging of buried archeological features using a Ground Penetrating Radar (GPR) at specific sites around the Al hoceima city located in the North-east of Morocco. We collected out 3 areas, selected from 10, using GPR system equipped with two shielded antennas of 500 and 800 MHz central frequencies. After processing steps, GPR results revealed the existence of buried walls. They systematically exhibited characteristic signatures (Hyperbolic, point source reflections) in the GPR profiles, which can be described in terms of location geometry and dimension of the construction style. Consequently, this work revealed that superficial geophysical investigations might be helpful in collecting crucial information about archaeological sites to better characterize the extended and richness of the Al Hoceima city.

Index Terms—GPR, Almazamma Site, Archeology

I. INTRODUCTION

GROUND Penetrating Radar (GPR) is a geophysical method that users radar pulses to image the subsoil. GPR uses transmitting and receiving antennae. The transmitting antenna radiates short pulses of the high-frequency radio waves into ground. When the wave hits a object, the receiving antenna records variations in the reflected return signal. This system provides a non-destructive method, which is used extensively in a variety of applications and in several fields, including mine detection [1], revelation of cracks in marble quarries [2], road-rail way evaluations [3], or like in the present work for sites with archaeological interest survey [4], [5]. GPR is the most feasible and friendly instrumentation to detect buried remains and to perform diagnostics of archaeological structures with the aim of detecting hidden objects. For other side, GPR technique allows performing measurements over large areas in very fast way.

Excavation is often more expensive, but the GPR technique offers a logical answer to this dilemma by delivering increasingly accurate data regarding site stratigraphy, the location and depths of covered anomalies. GPR equipment is not expensive; however the cost of this technology has decreased in recent years, prompting more and more archaeologists to take advantage of this growing technology. Central frequencies around 500 MHz are often used in the GPR applications to archaeology since they normally provide an adequate tradeoff between resolution and penetration for a variety and most of the soils [5]. Higher frequencies can be to detect and characterize smaller objects at shallow depths. On the contrary, lower central frequency, especially in cases with highly lossy soils.

Each pulse is called trace or A-Scan, and the 2D space-time representation of consecutive traces is known as radargram or B-Scan. The 2D representation of temporal cuts of radargrams is called time slices or C-Scan. The 3D visualization techniques are widely applied in GPR surveys with archaeological purpose [6, 9].

We first describe briefly the main building structures and topography of the site. Secondly, data acquisition, processing and interpretation provided with the necessary characteristic of the GPR method. The profile analysis and related interpretation are compared to the archaeological excavations. Finally we discuss the contribution of shallow geophysics to the study of Almazamma archaeological site.

II. SITE DESCRIPTION

Al Mazamma (souni) is situated on the Costa de Al Hoceima in the North-east of Morocco (Fig 1).

Formerly called Taghzout Tijdit, then Villa and Villa San Jurjo Alhucemas, the city is not far from the archaeological site of the medieval town of Almazamma (2 to 3 km as the crow flies). It carries its present name (Al Hoceima) since independence in Morocco and it would come from "Al Faisaliah" (lavender), a plant widespread in the central Rif.

Fig.1: Location map of the «Almazemma (Souani)» Morocco (Africa).

In this paper we focus in the study of four areas: 1, 2, 3 and 5 which are very important for archeology. Clearly demonstrating the benefits of using GPR models to help interpret reflection patterns produced by buried archaeological features.

III. GPR DATA ACQUISITION AND PROCESSING

Collected data were copied to a personal computer and processed using Reflexw software [10]. The GPR survey was carried out with a RAMAC GPR system from MALA Geosciences using a 500 and 800 MHZ shielded antennas as central frequency and a RAMAC Monitor XV11 professional firmware. This configuration is optimal to detect shallow and deeper anomalies with detail, being half less time consuming than surveying each area separately with each antenna. At each site radar profiles were collected parallel across the survey grids. The horizontal spacing between parallel profiles at the site was 0.40 m. Radar reflections along the survey lines were recorded continuously across the ground each 2cm, with a stack = 2; along each profiles. All radar reflections within 46ns (500MHz antenna) and 30ns (800MHz antenna) (two-way travel time) time window were recorded digitally in the field as 16 bit data and 700 samples per radar scan.

Four Areas were selected (area 4, 7, 8 and 9) among nine to carry out the archaeological detail prospection GPR survey (Fig 1).

The areas of data processing have been grouped under the headings: data editing, basic processing, interpretation processing, and visualization processing.

Processing in this location is usually done when a good head of information about a site is available and need for the processing has been defined which achieves a final objective.

IV. RESULTS AND DISCUSSION

Although the GPR data showed good signal penetration, careful 2D and 3D processing allowed us to obtain better results. The rectangular structures found has helped the archaeologists to plan their next excavation season, since they can indicate the built structures, like house foundations and walls.

In what follows we describe the most notable results of the geophysical survey carried out in eight areas of the Al Hoceima city.

A. Area 1

Two profiles taken using the 500 MHz and 800 MHz antennas (Fig 2) allow location of structures such as buildings, walls… etc.

At first appearance, we can appreciate different GPR signal responses over the walls along the structure (Fig. 2(a)). Over some of them, clear signal attenuation could be observed (arrow (Fig.2 (b)). The central radargrams begin with an area in which the signal is attenuated (Mound area) (Fig.2 (a)).

We assume that this strongly different value of propagation velocity is caused by the different electromagnetic properties of the soil where the mound was located, i.e. greater humidity.

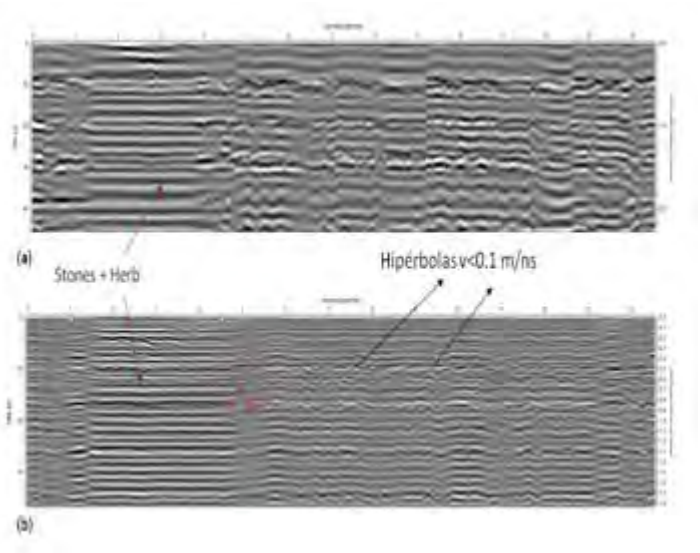

Fig.2: Processed radargrams (Area 1) (B-scan) achievement with 500 MHz from line 32 (a) and with 800 MHz antenna from line 33 (b).

In Figure 3 represented Time Slice using the absolute amplitude are shown for area 1 obtained using the same grid cell sizes, at different time intervals: 0ns- 37ns.

A chromatic scale has been used, with blue indicating low amplitudes and Red, yellow and orange indicate highly reflective materials buried beneath the ground surface. These materials could be of natural or cultural in origin. The main cultural features visible in this area are walls probably associated with the plant structure. These anomalies started to be visible at 5ns (Fig.3), and the main of them corresponds to the hyperbola seen on radar section (as presented, for example in Fig.2) slightly deeper than soil-bedrock.

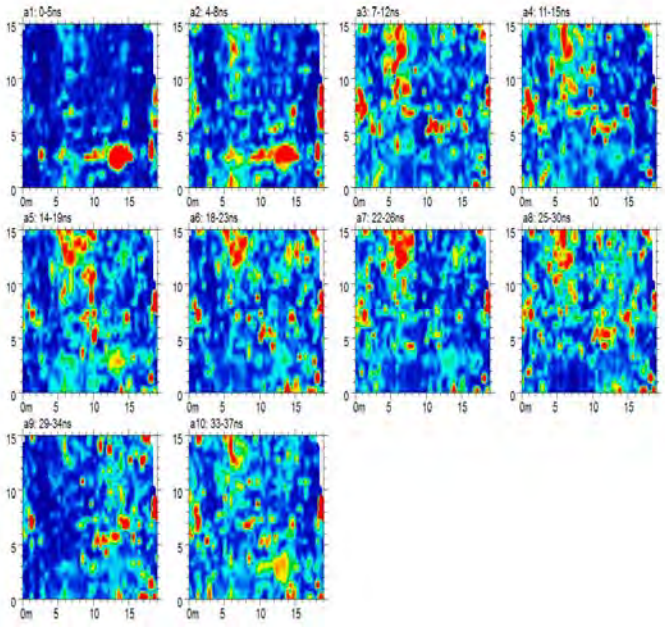

Fig.3: Time-Slice of Area 1 at 0ns- 37ns with 500 MHz antenna

Area 2

Figure 4 illustrates two B-Scan achievements with the 500 MHz and 800 MHz antennas of the survey carried out in area 2. Results showed the presence of strong Anomalies superficial < 10ns, probably related to wall or bedrock structures. The presence of clear anomaly characterized by hyperbolic reflector (0.1 m/ns) (Fig.4(a)) with a vertex at the 12 m position and at 0.2 m depth are also pointed out (Fig.4. Hyperbolic reflections in GPR profiles are originated from localized source and can correspond to archaeological target; hence, worth being excavated.

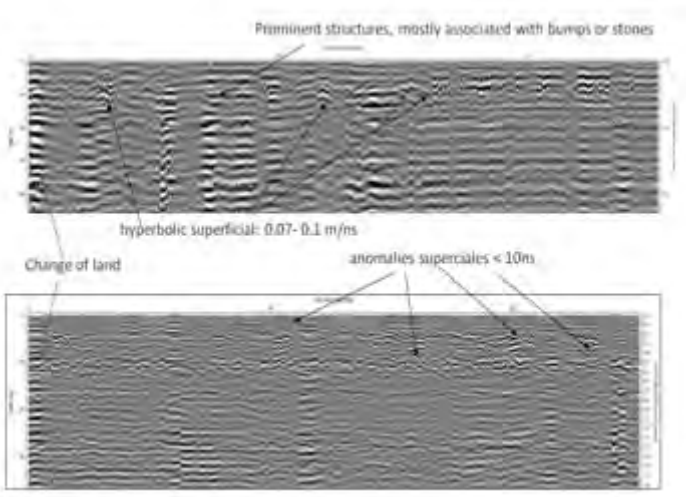

Fig.4: Processed radargrams (Area 2) (B-scan) achievement with 500 MHz from line 14 (a) and with 800 MHz antenna from line 11 (b).

The Figure 5 illustrates two prominent anomalies, one just beginning and one just before the half. The anomalies seemed to be an herb, mud or wall.

3D GPR data acquisition, processing, and interpretation seems to be inevitable to thoroughly interpret and understand complex subsurface structures typically found at archaeological sites. The extraction of a 3D volume which represents the target was possible by using the isosurface rendering technique (Fig.6). This technique displays surfaces of equal amplitude in the 3D volume.

Figure 7 showed the initial anomalies at around 3- 37ns. These anomalies indicate the presence of the walls or house foundations.

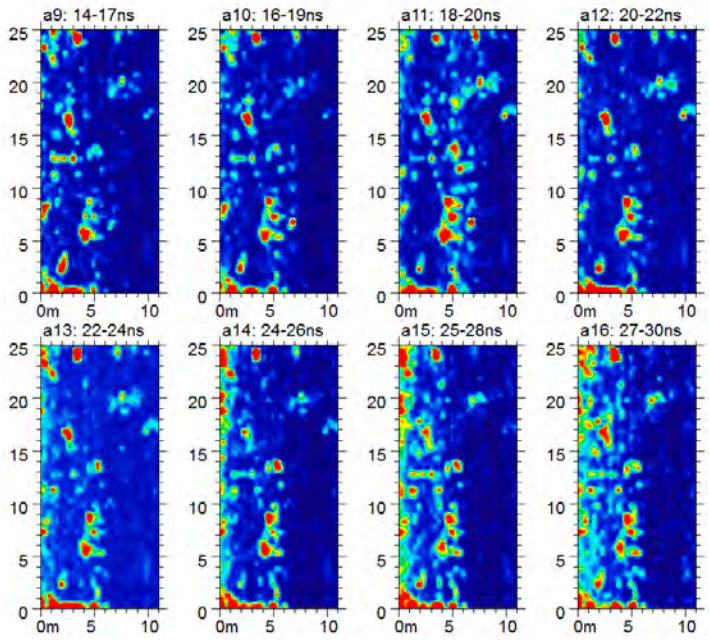

Fig.5: Time-Slice of Area 1 at 0ns- 37ns with 500 MHz antenna

Fig.6: Isosurface of anomalies at T< 15ns with 500 MHz antenna

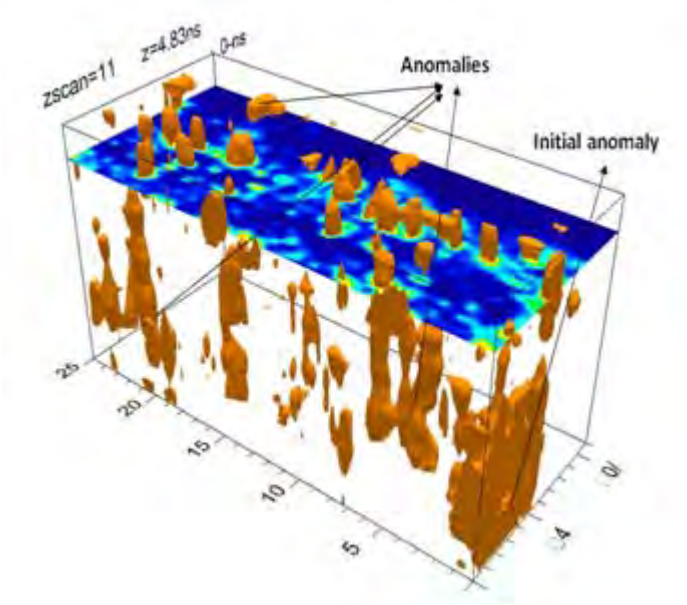

Fig.7: GPR-slice iso-surface renders and times-slices obtained in the time windows 3-37ns with 500 MHz antenna

B. Area 3

Data processing and modeling aim to search for and visualize anomalous structures and to present results in maps.

Figure 8 shows two radargrams achievement with 500 MHz and 800 MHz antennas of the survey carried out in area 3.

Clearly visible anomalies accompanied by hyperbolas could be observed. These hyperbolae also matched the position of previously identified walls. Since the wave velocity was 0.11 m/ns, a reflection time of 10 ns and 13 ns corresponded to 0.3 m and 0.7m depth respectively. As seen in Figure 8(a), the results are exhibited alternating bands of high and low amplitudes beginning when the metallic object is encountered down to the end of the time window (Multi-reflection).

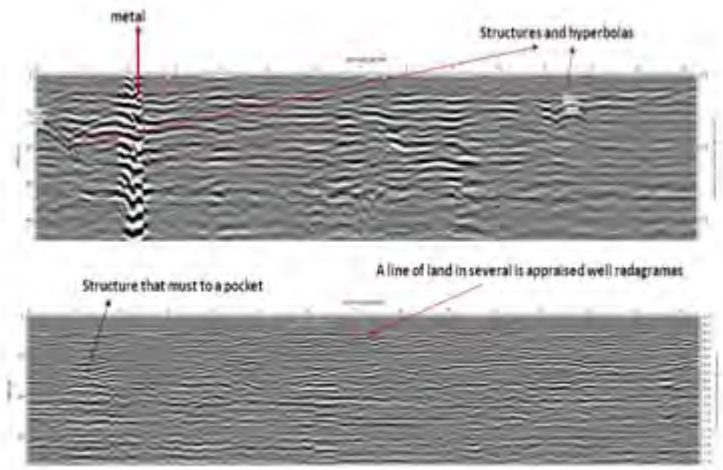

Fig.8: Processed radargrams (Area 3) (B-scan) achievement with 500 MHz from line 10 (a) and with 800 MHz antenna from line 10 (b).

These main anomalies can identify the size, shape, depth, and location of buried archeological remains.

The 2D processing of the data and its visualization as time slices improved the datasets and the interpretation of the anomalies.

Figure 9 shows the main anomalies at around 11- 17 ns (0.5- 1 m depth) related to the foundation. Further anomalies might represent the remains of the remains of the original of the walls of a stone burial.

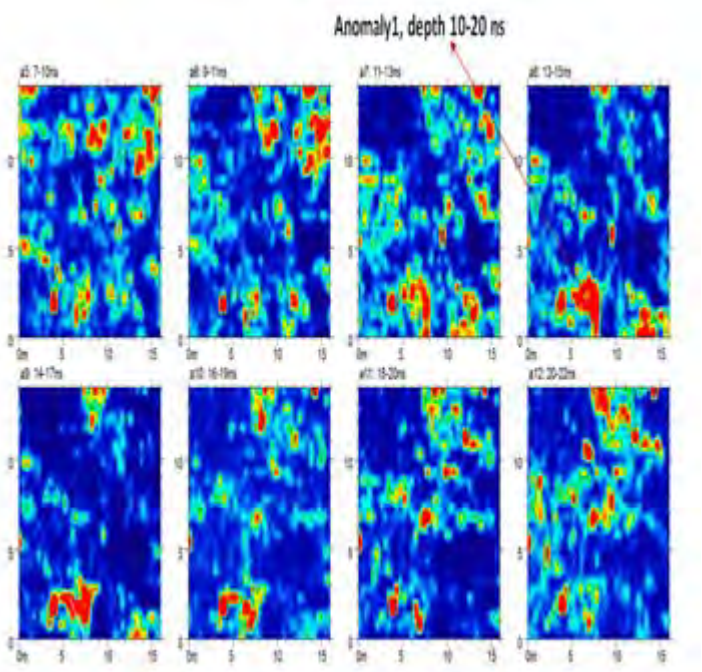

Fig.9: Time-Slice of Area 1 at 7ns- 22ns with 500 MHz antenna

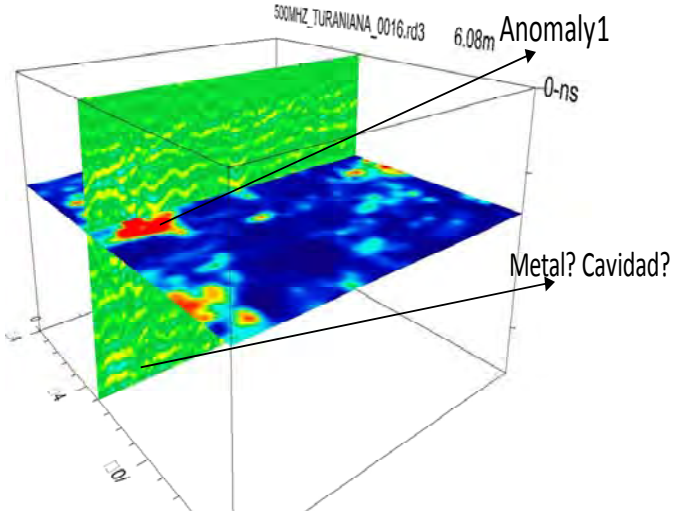

Fig.10: Detailed interpretation based on the similarity data cube. show migrated crossline slices at 6.08m.

GPR has the ability to create pseudo 3D maps and images of buried archaeological and other associated cultural and natural features. Usually the pseudo 3D time slices give information on the planar distribution of the buried targets at different depths, whereas the 3D maps show the full geometry of the targets.

Figure 10 illustrates the 3D imaging result for a main anomaly associated with structure at around 13 ns.

V. CONCLUSION

In this paper, we have described the usefulness of high resolution method for the investigation of archaeological areas located in the Al Hoceima city. This method is based on the application of geophysical technique, such as GPR, which has higher potential and give precise and important archaeological information's. In fact, in time slices and with 500 MHz and 800 MHz antenna, several well defined anomalies in the form of hyperbolic reflectors and areas with high amplitude have been detected. These reflections are from specific buried items and indicate the typically classical Roman building. In addition, the GPR 3D results were revealed to be important in order to facilitate the best interpretation and reconstruction, and give a hypothetical idea about the front walls.

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