# Detection of shallow cavities in Haditha area, western Iraq using ground penetrating radar.

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## ABSTRACT

This research studied the detection of underground cavities using the Ground Penetrating Radar (GPR). This study used a 250 and 500 MHz antenna in three different locations. Where many cavities of different sizes and depths were detected, especially that most of the study area consists of rocky layers (limestone). These cavities reduce support for the ground, which can cause the rocks above them to collapse. The results show that the GPR technique was effective in the region of high resistance. Cavities ranging in size from 1-3 m and 0.8-5 m in depth were det

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## 1-Introduction

Ground penetrating radar (GPR) is a non-destructive geophysical technique, as it uses electromagnetic waves to detect targets under the surface by contrasting the dielectric between the target and the surrounding medium(Annan,2001). It is a geophysical technique designed primarily for subsurface investigation ( Neal, 2004; comas et al, 2004). ). A GPR system detects changes in the electrical properties of the shallow subsurface using discrete pulses of high frequency electromagnetic (EM) energy, usually in the 10-1000 MHz range (Neal, 2004).GPR operates in the electrical conduction wavelength region of the electromagnetic spectrum. Whereas seismic response is a function of acoustic properties, GPR re- sponse is a function of the electromagnetic properties: dielectric permittivity (e), magnetic permeability (m), and electrical conductivity (s).Dielectric permittivity describes the ability of a material to store and release electromagnetic energy in the form of electric charge and is classically related to the storage ability of capacitors (Cassidy, 2009). Permittivity greatly influences the electromagnetic wave propagation in terms of velocity, intrinsic impedance and reflectivity. In natural soils, dielectric permittivity might have a larger influence than electric conductivity and magnetic permeability (Lampe &Holliger, 2003; Takahashi et al., 2011).Magnetic permeability (µ) describes how intrinsic atomic and molecular magnetic moments respond to a magnetic field (i.e. µ represents the relation between the magnetic moments and the magnetic field). It is referred to a material's capacity to become magnetized as it is introduced to an electromagnetic field. Magnetic permeability also affects radar penetration in a medium. Sometimes the relative magnetic permeability is used, which is equal to the magnetic permeability of a material divided by the magnetic permeability of vacuum ($\mu_0 = 4\pi \times 10^{-7}$ H/m). Nevertheless, most soils and sediments have only slightly magnetic and therefore usually have a low magnetic permeability (Koppenjan, 2009). Therefore, the permeability of free space is a good representation of the magnetic permeability of the subsurface (Olhoeft, 1998). The media that contain magnetite minerals, such as iron-rich soils, can all have a high magnetic permeability and therefore transmit radar energy poorly (Basson, 2007).Dielectric constant is a critical GPR parameter because it controls the propagation velocity of electromagnetic waves through a material and the reflection coefficients at interfaces, as well as affecting the vertical and horizontal imaging resolution. Therefore, knowing dielectric- constant values of materials helps in planning GPR surveys and in better understanding and interpreting GPR images (Davis and Annan, 1989; Daniels, 1996; Olhoeft, 1989; Schon, 1996; Ulaby et al., 1990). A GPR system transmits short pulses of high frequency EM energy (10-1000 MHz) from an antenna into the subsurface (Jol and Smith, 1991; Holden et al., 2002). As an EM wave disseminates downwards, its velocity is altered due to encounters with materials of differing electrical properties (Neal, 2004). Abrupt changes in the dielectric constant results in a portion of the energy being reflected, with the receiving antenna of the GPR system detecting the reflected EM energy(Neal, 2004).The time between transmission and reception, referred to as the two-way travel- time (TWT) and commonly measured in nanoseconds, is a function of reflector depth and the EM velocity of propagation (Neal, 2004; Jol and Smith, 1991).Investigation of cavities detection an urban areas using non-destructive method by using GPR. The detection of cavities and fragile area to avoid significant risk on construction works (Alsharahi, et al, 2019).The purpose of this study of the detection of shallow cavities in the Haditha area of western Iraq using GPR.

**2-Material and methods**

**2.1Location of study**

The study area is located in the northwestern part of Al-Anbar Governorate.This study includes three sites fig(1).

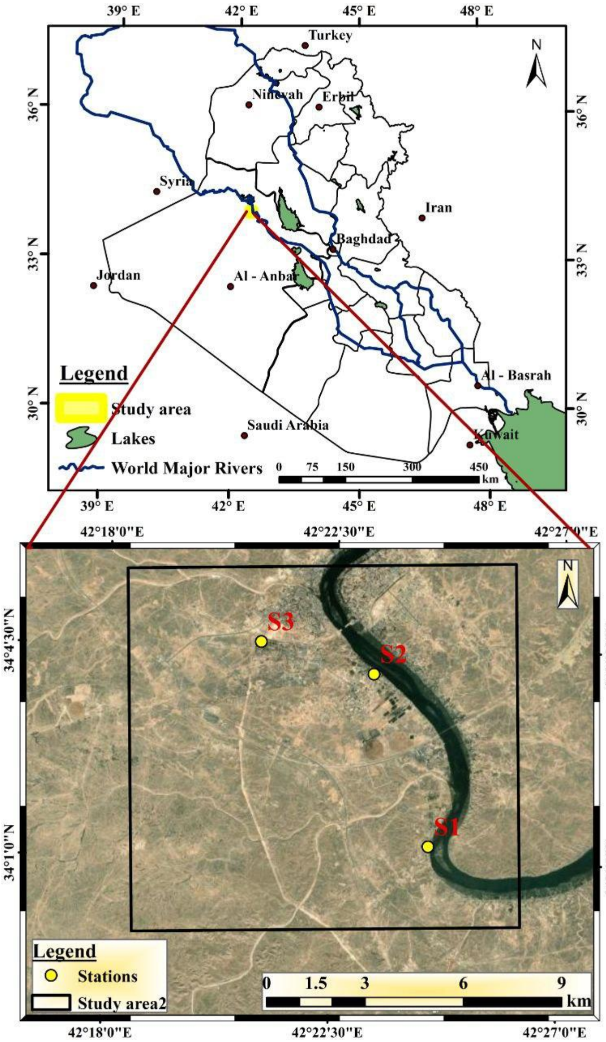



**Fig (1):** Show of the sites of study.

## 2.2Tectonic and Geological setting of study area

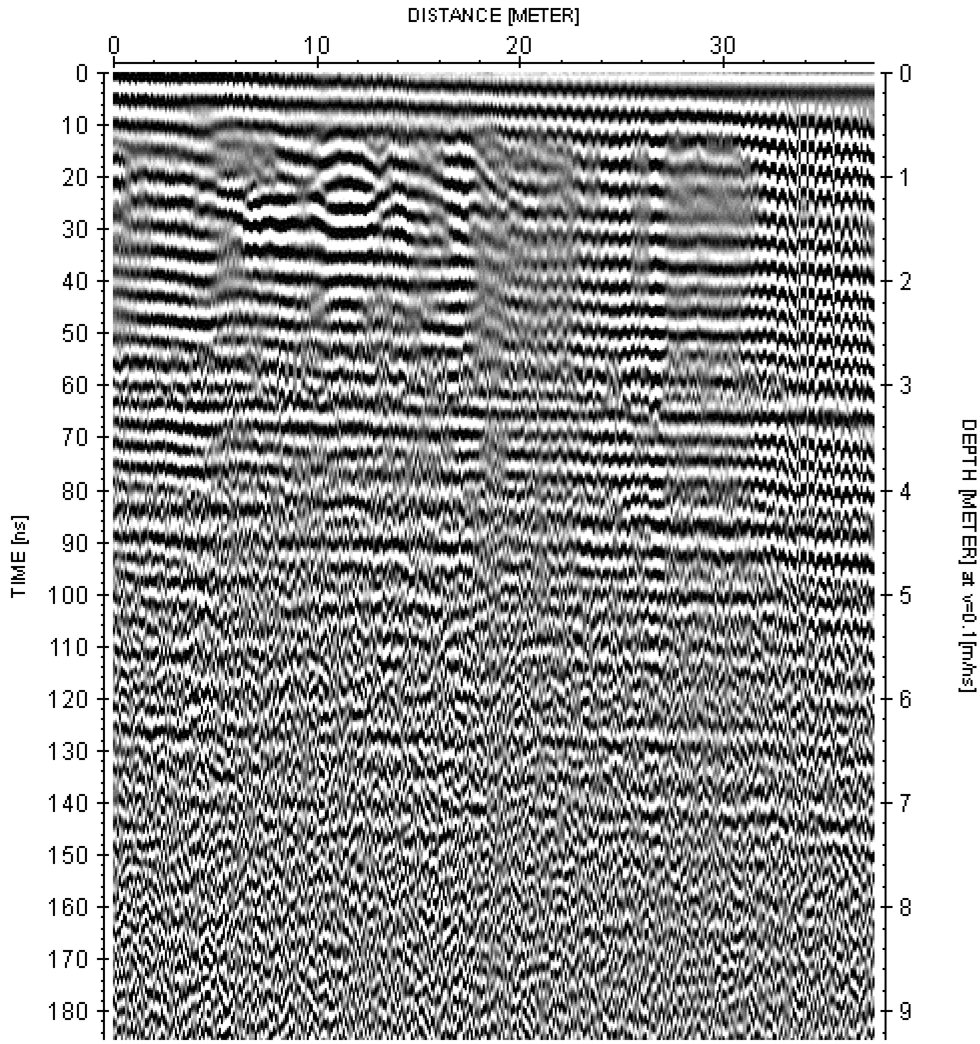
The study area is located on the stable shelf of Iraq within the Rutba - Jazera Zone. Euphrates fault zone (or Anah fault zone) and Abu- Jir fault zone forms the major structural feature in the northern and eastern parts of the study area and represent the boundary between the stable shelf and unstable shelf . Abu- Jir fault zone is located within the Euphrates River. The study area is located within two types of transverse faults Aamj - Samarra and Anah-QalatDizeh both having the orientation of northeast-southwest (Jassim and Buday, 2006). Tectonically, it is represented as part of the stable shelf of the Arabian platform, which is characterized by the presence of block tectonics and the absence of tectonic folds (Buday and Jassim, 1987).The sediments and geologic sequence of the study area, from oldest to youngest units Anah Formation (Upper Oligocene,Al-Mubark, 1974), Euphrates Formation (L.Miocene,Jassim, et al,1984),Fatha Formation (M.Miocene, Al-Mubark, 1974),Quaternary deposits (Pleistocene-Holocene,Al-Mubarak and Amin,1983).

## 2.3Survey

2D GPR surveys were performed in the Haditha area on 30 March 2022 to detection of shallow cavities using ReflexWTM (Sandmeier, 2009). The GPR profiles were carried out using the Mala Geosciences RAMAC GPR system, with a 250 MHz and 500MHz shielded antenna to obtain a good vertical resolution and good penetration of signal. The 250 MHz and 500 MHz antennae are selected for being more suitable for the detection of shallow cavities at depths ranging from 1-10 meters. The survey included three sites (fig.1). In site one eight parallel profiles ( six profiles by 250 MHz and two profiles by 500 MHz) in this site were measured in a west-east direction, with a distance of five meters separating between the profiles. The length of each profile was 40 m. While site Two, Nine parallel GPR profiles were measured in this site (Six profiles by 250 MHz and three profiles by 500 MHz). The length of each profile is 30 m with a five-meter distance between the profiles, which already covered an area of 9 x 30 m, and the scanning direction of these profiles is toward North- South. Three site seven parallel profiles ( Five profiles by 250 MHz and tow profiles by 500MHz) in this site were measured in a west-east direction, with a distance of five meters separates between the profiles. The length of each profile was 30 m .

**2.4GPR processors**

The following processing steps are done on all 2D GPR row data using Reflex W.EXE software (Sandmeier, 2009): (i) editing data using the Edit traces/trace ranges function; (ii) static correction to adjust the zero time; (iii) subtract mean (Dewow) in order to eliminate DC bias in data ; (iv) background removal to allows subtle weaker signals to become visible in the processed section; (v) bandpass filter to pass the desired band and isolate noise signals which caused by cellular phone calls, GPR system, FM radio transmission, and other common noise (Conyers and Cameron, 1998); (vi) ). Gain function to maximally equalize the radar signals. This sequence may be considered a standard used for GPR data (Sandmeier, 2009). All the profiles in this study are processed with the same range of filter values because the studied area contains subsurface targets that have approximately the same original lithological. This study used the basic process (fig 2) (Time- Zero Adjustment filter, Dewow filter, Bandpass filter, Background removal).

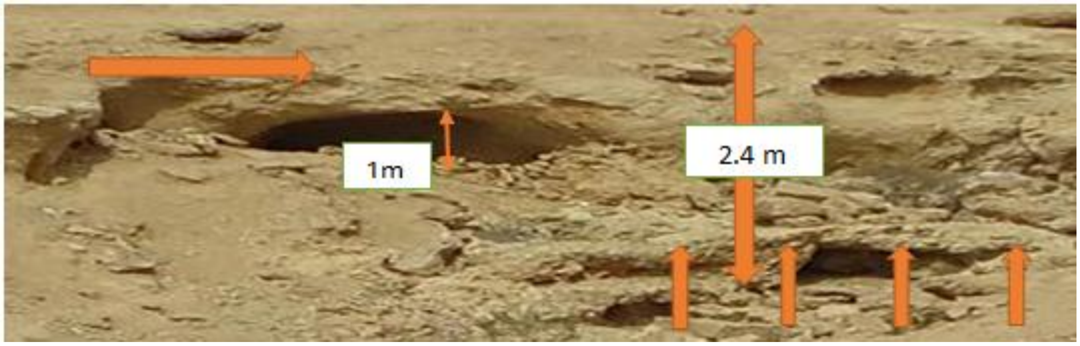



**Fig(2):**show the GPR profile after apply basic process

**3. Results and Discussion**

We expected that the GPR survey shows a good response because the site is located on high resistivity limestone rocks. Consequently, many anomalies in hyperbolic shapes have been detected on the radar grams. Most probably they might represent the reflections from the top surfaces of cavities as shown in the radar sections. The resolution of the hyperbolic shapes depends on resistivity values.

**Traverse one:**The first traverse length is more than 35 m, where an anomaly (cave) was detected, located at a distance between 10-14 m and a depth of 1 m. Where we notice that most of the falling energy is reflected from the boundary between the ceiling and hollow the cavern, due to the contrast in the electrical permittivity between the air and the rocky medium.



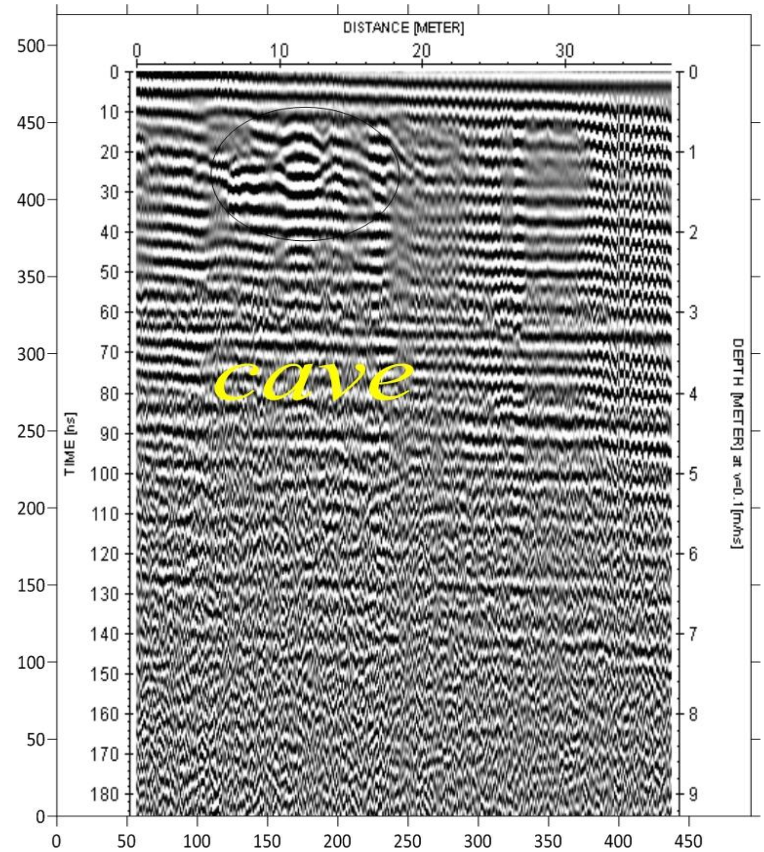




**Fig (3) :** Radar section in traverse one

**Traverse two:**The second traverse length is 18 m, where an anomaly (cave) appears clearly at a distance between 12-15 m, a depth of 1.9 m, and a width of more than 2 m. Where we notice the reflection of most of the energy falling from the upper part of the cave due to the attenuation of the radar signal.

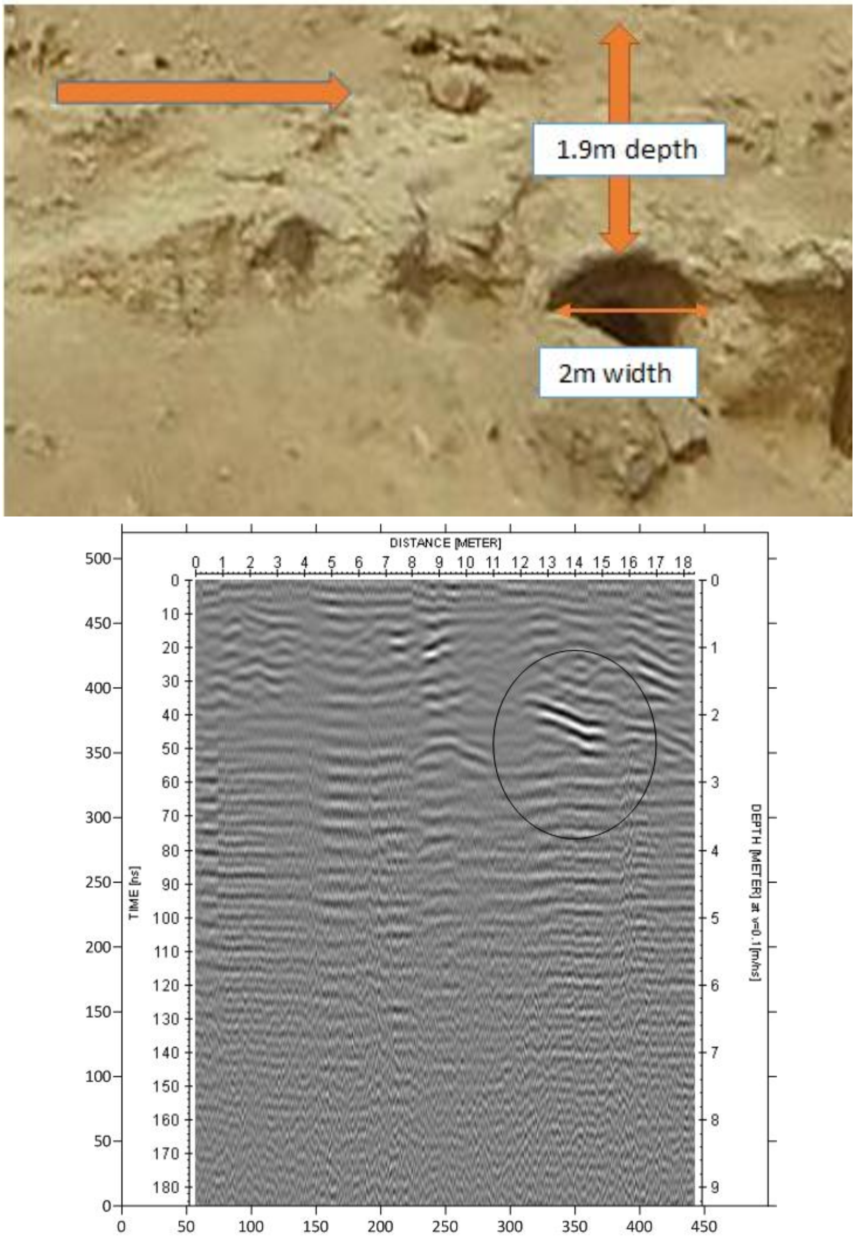



**Fig (4) :** Radar section in traverse two.

**Traverse three:** The third traverse length is more than 11 m, where an anomaly was detected at a distance of more than 8 m, a depth of more than 3.5 m, and a width of more than 8 m.

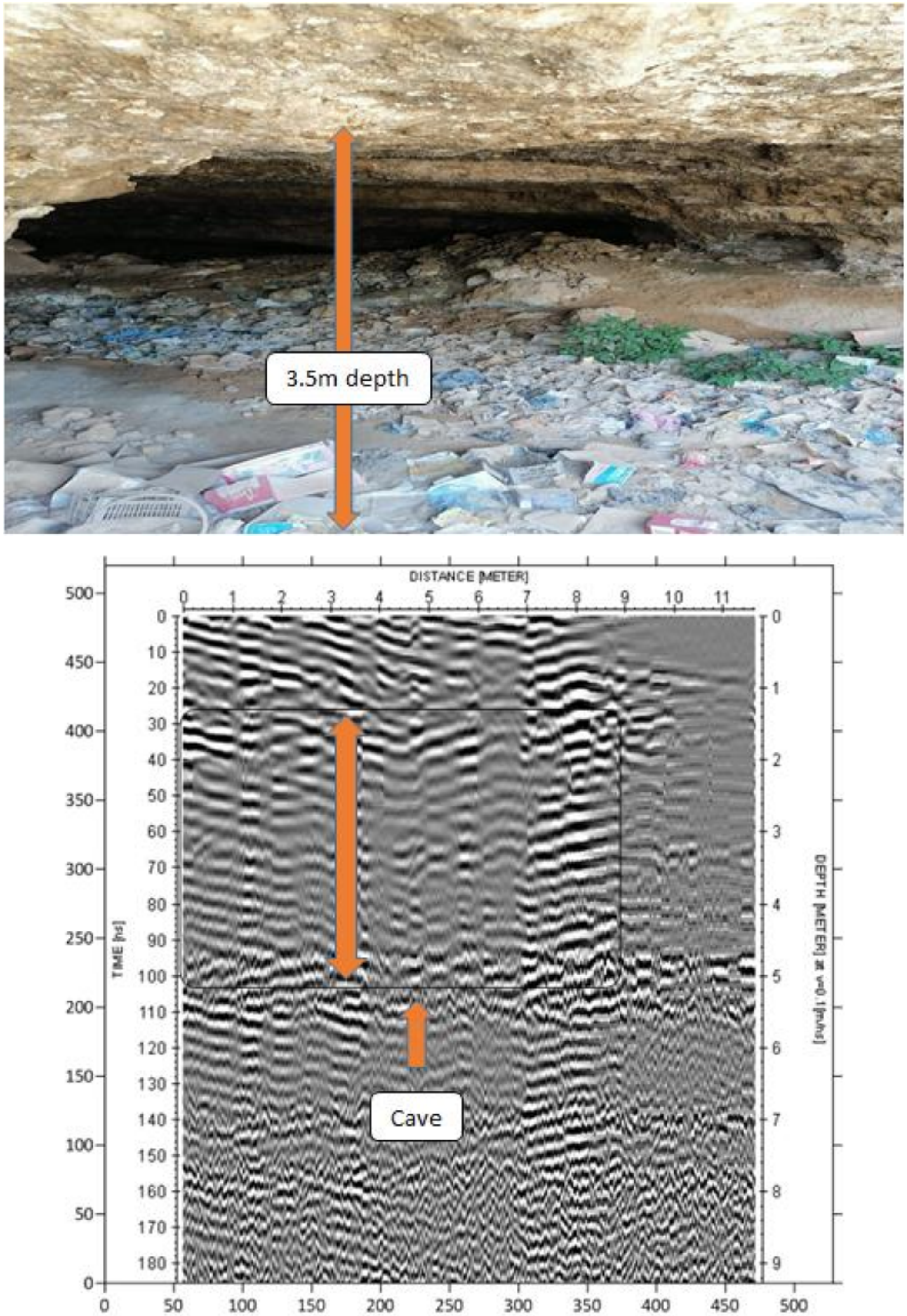



**Fig (5) :** Radar section in traverse three.

**Traverse four:**The fourth traverse length is more than 50 m, where an anomaly was detected, which is expected to be a cave, at a distance between 26-34 m and at a depth of more than 1 m, where the radar signal is clearly reflected from the surrounding medium. There is also noise in this profile as it extends from a distance of 2-40 m due to the presence of high-pressure electrical wires above the study area.

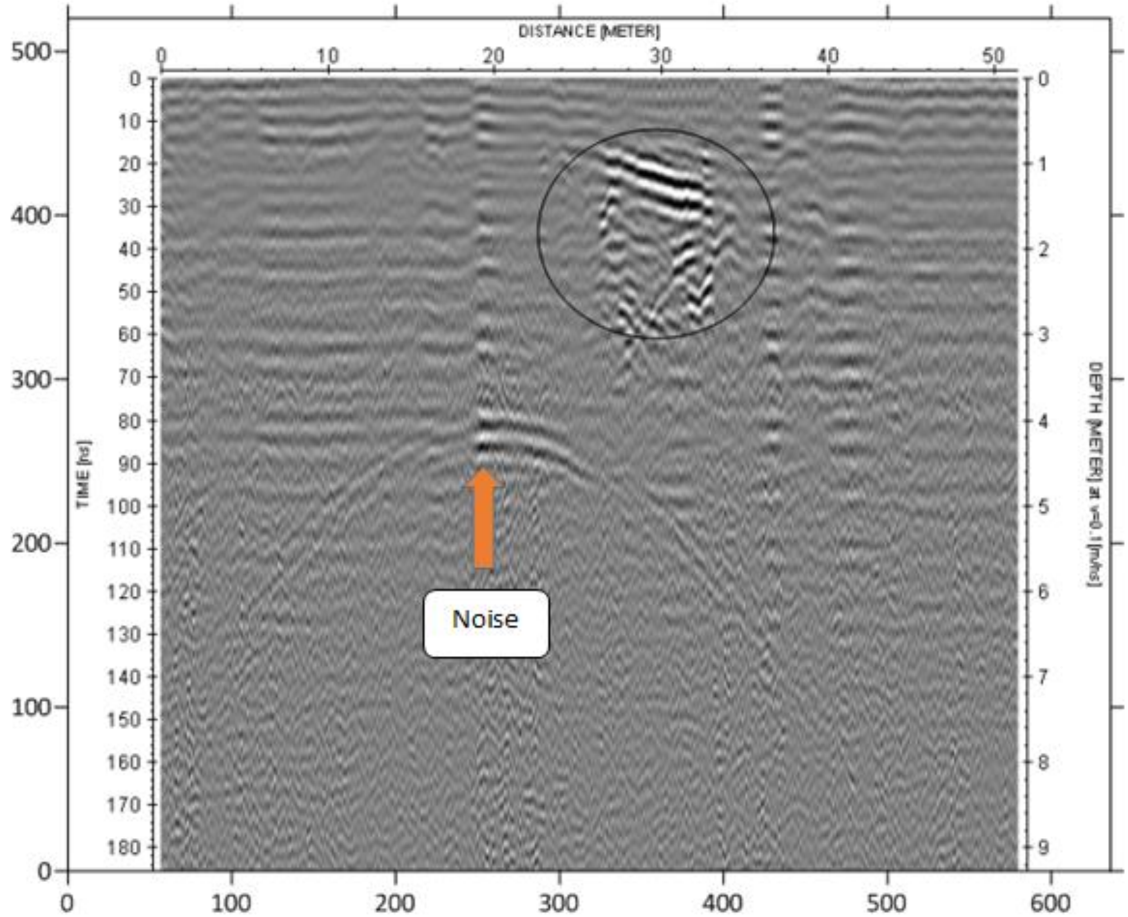



**Fig (6) :** Radar section in traverse four.

**Traverse five:**The fifth length is 46 m, where anomalies were clearly detected in this traverse in the first case, where the ringing appears at a distance of 8 m from the beginning of the traverse and at a distance between 26-30 m and a depth of more than 6 m, the second case appears, which is expected to be a manhole, where we notice a large reflection of the radar signal compared to the surrounding medium, and at a distance between 30-46 m, the third case appears, which is rocky layers with a distinctivereflectivity.

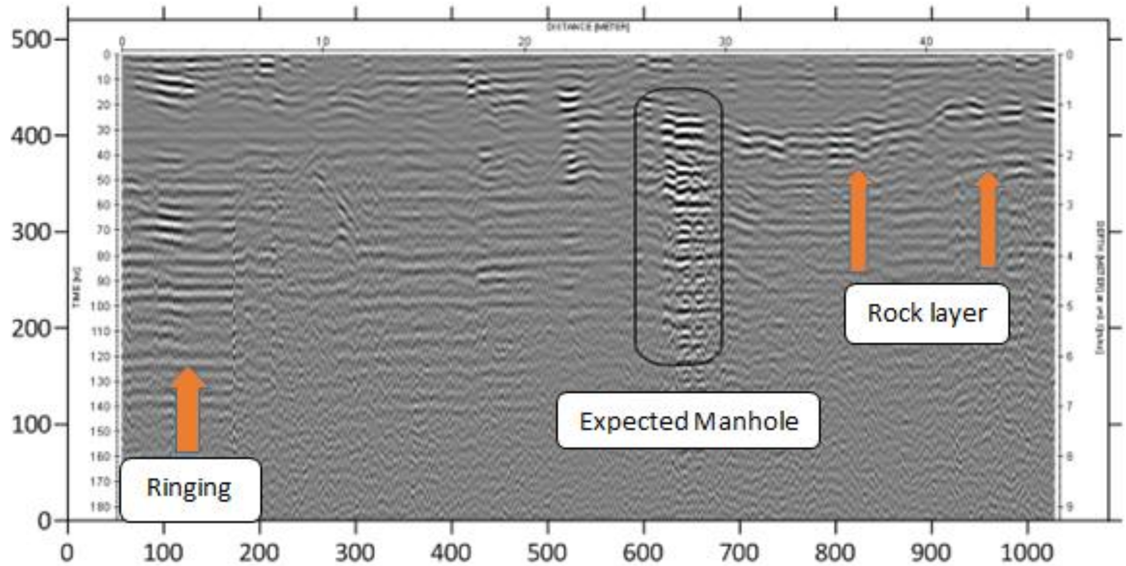



**Fig (7) :** Radar section in traverse five.

**Traverse six:**The sixth length is more than 20 m. An anomaly was clearly detected in this traverse. It is located at a distance between 12-14 m and a depth of 0.8-1.2 m. It is expected that it is a cave where we notice the reflection of the radar signal from the ceiling of the cavern, due to the attenuation of the radar signal. In this profile, there are rocky layers with distinctive reflectivity at a distance between 18-21 m.

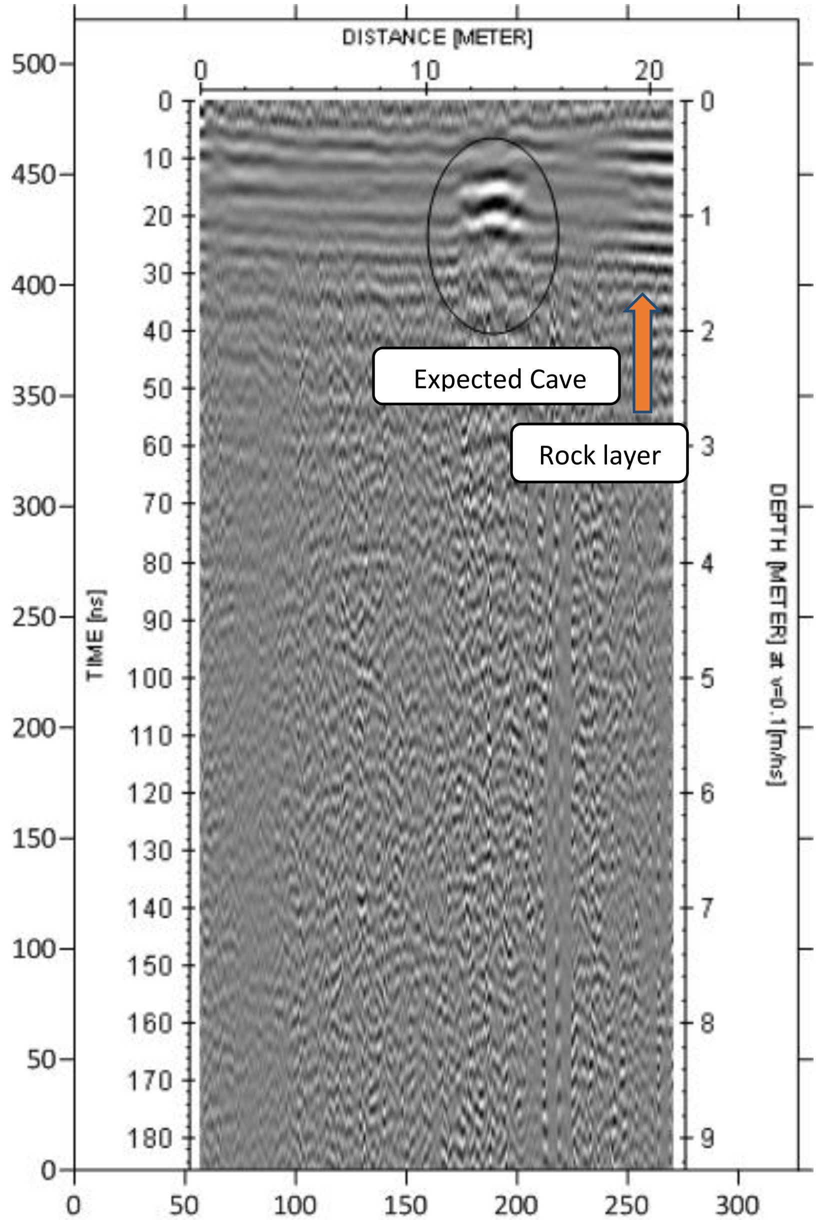



**Fig (8)** : Radar section in traverse six

## 4-Conclusions

Ground-penetrating radar has proven to work very well on dry, high-resistance limestone rocks exposed to the surface. The ground penetrating radar gives high pulses in the absence of soil coverings over these rocks and as a result, cavities with depths ranging from 0.8 to 5 m were detected. The study proved that the 250MHz antenna of GPR is very suitable for this type of study. But if a 100Hz antenna was available, it would give better results.

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