Quest Journals
Journal of Research in Environmental and Earth Sciences
Volume 11 ~ Issue 11 (November 2025) pp: 108-121
ISSN(Online) :2348-2532
www.questjournals.org

Research Paper

Non-invasive mapping of buried archaeological remains in northeastern tunisia: a subsurface geophysical survey of *Carpis*

Oumaima EL GHALI[1]
[1] *Geomatics and Geosystems Research Laboratory LR19ES07, University of Manouba, Tunisia,*

ABSTRACT:
The archaeological site of Sidi Erraïs, known in antiquity as "Carpis," is located on the eastern coast of the Bay of Tunis and is distinguished by its rich archaeological heritage. This site has been occupied since the Punic period and has been regularly studied by the Institut National du Patrimoine (INP) since 1996. Currently protected and undeveloped, the area offers particularly favorable conditions for geophysical studies due to its dune cover, which has helped preserve the remains. Geophysical surveys utilizing two complementary methods Electrical Resistivity Tomography (E.R.T) and Ground Penetrating Radar (G.P.R) were conducted to detect buried ruins. The results revealed several high-resistivity anomalies interpreted as archaeological remains, including an ancient oven with an internal diameter of 2.5 meters, attributed to the Punic period. This interpretation was subsequently validated through archaeological excavation. Electrical resistivity tomography further identified additional ovens within the site's boundary dune system, along with underground cellars situated behind the dune ridge. Our findings highlight two primary morphosedimentary processes responsible for the extensive burial of the Carpis ruins: (1) an alluvial dynamic associated with Wadi Louz discharge and sediment transport, and (2) an aeolian dynamic that has contributed to the preservation of the archaeological remains beneath the dune cover. These complementary processes have created favorable conditions for the protection and conservation of the subsurface archaeological heritage at Carpis.

KEYWORDS: *Northeastern Tunisia, "Carpis" archaeological site, Electric Resistivity Tomography (E.R.T), Ground Penetrating Radar (G.P.R), morphosedimentary dynamics.*

*Received 15 Nov., 2025; **R**evised 28 Nov., 2025; **A**ccepted 30 Nov., 2025 © The author(s) 2025.*
P**ublished with open access at **www.questjournas.org

I. INTRODUCTION

Geophysical methods have transformed archaeological prospection, fundamentally changing how researchers detect and investigate subsurface structures. In recent decades, non-invasive technologies including Electrical Resistivity Tomography (E.R.T) and Ground Penetrating Radar (G.P.R) have emerged as indispensable instruments for archaeological investigation [1] and [2].These techniques allow archaeologists to locate underground features while preserving site integrity, rendering them exceptionally useful for both heritage preservation and archaeological discovery. The growing adoption of geophysical surveys at archaeological locations across the globe and [3], [4] and [5]. has proven their capacity to expose concealed structures, enhancing our comprehension of ancient habitation patterns.

Sidi Erraïs, known historically as *Carpis*, occupies a position along Tunisia's northeastern coastline near the Bay of Tunis. Dating back to Punic times, the site has yielded substantial archaeological evidence indicating sustained occupation and evolving cultural practices spanning multiple centuries. Notwithstanding its historical significance, much of the site remains unexamined, largely because wind-blown and water-deposited sediments blanket the area. While this natural sediment cover shields the site from contemporary disruption, it simultaneously poses obstacles for traditional excavation approaches. Under these circumstances, geophysical surveying offers an optimal methodology for initial exploration at *Carpis*, facilitating the identification and documentation of subsurface features prior to any invasive digging.

Since 1996, the National Heritage Institute (INP) has conducted archaeological investigations that have yielded important insights into the site's historical and cultural value. Nevertheless, these efforts have concentrated mainly on visible remains and standard excavation techniques, leaving substantial portions of the site's archaeological promise untapped. Additionally, the accumulation of dunes and sedimentary layers has hindered direct access to underground features, making advanced geophysical approaches necessary to supplement traditional archaeological methodologies.

This study's primary aim is to utilize E.R.T and G.P.R technologies for identifying and characterizing subsurface archaeological features at *Carpis*. Through the combination of these two mutually reinforcing methods, the research endeavors to develop a high-resolution subsurface representation that offers comprehensive information regarding the scope and characteristics of buried structures. More precisely, the investigation aims to:

1. Identify and map ancient structures, encompassing architectural features and industrial facilities such as pottery kilns.
2. Examine how sedimentary processes, especially wind and water deposition, have influenced the site's layering and state of preservation.
3. Deliver a non-invasive evaluation capable of informing subsequent excavation strategies, thus enabling focused and efficient archaeological work.

This investigation holds particular relevance for heritage management and archaeological site conservation. The capacity to evaluate subsurface remains without physical excavation advances sustainable preservation approaches, reducing needless site disturbance while enhancing scholarly results. Moreover, findings from this work will expand understanding of *Carpis* itself while informing wider scholarly discourse regarding geophysical methodology applications in Mediterranean archaeological contexts.

II. ENVIRONMENTAL OVERVIEW OF THE *CARPIS* SITE

The archaeological site of Sidi Erraïs, also known as *'Carpis*,' is one of several historically significant locations along the coast of the Gulf of Tunis. It is situated in the eastern part of the Bay of Tunis, at the southwestern tip of the western side of the Cap-Bon peninsula. Jbel Sidi Erraïs borders the site to the east, which is an extension of Jbel Korbous, and to the west by the main road to Mraïssa (M.C.128) and the dunes in the small dune field at Solimen. To the north, the site faces the sea, with some structures submerged or eroded by waves. Known today as Mraïssa, the site was first occupied during the Punic period, around the late 4th or early 3rd century BC [6]. According to [7], the ruins of the ancient city of *Carpis* extend inland for approximately 'a mile.' The first demarcation plan of the archaeological site was created by the National Institute of Patrimony (INP) in 1996 and was later expanded in response to discoveries. The demarcation zone increased from 102,903 square meters to 717,621 square meters (INP). The most recent update occurred in 2007, covering an area of 133 hectares and 15 ares (INP). Despite these efforts, much of the ruins remain buried under dunes and alluvium. However, some structures may be revealed by waves during storms or by runoff following heavy rainfall, which can cause significant erosion (Fig.1).

The site is currently protected and remains neither urbanized nor occupied, providing an excellent opportunity for geophysical and archaeological studies. Most of the remains have been well preserved due to the protective dune cover. This context makes geophysical diagnosis particularly valuable, as it can help to more accurately locate sites for test pits or excavations, thereby preventing potential damage from unintentional mechanical work. Archaeologists from the Institut National du Patrimoine (I.N.P.) frequently conduct underwater surveys to determine the actual boundaries of the submerged parts of the city. In conjunction with these underwater missions, they also focus on diagnosing traces of occupation on the continental portion of the site through regular excavation programs and the analysis of surface ceramics. Our contribution involves applying geophysical tools to identify hidden structures. The survey encompassed three locations, one of which was followed by a month-long archaeological excavation.

Figure1: Location of the area and examples of remains uncovered by marine erosion [8]

The land on which the *Carpis* ruins lie is an extension of the Soliman plain, which itself forms the northeastern margin of the Grombalia collapse ditch. It is also characterised by its low altitudes, generally below 10m, and by the fact that rugged slopes dominate it. Extending from Jbel Korbous, these slopes have a geological framework dominated by alternating Oligocene sandstones and clays (Fig.2). As a result, the run-offs that originate here have carried materials that are often sandy-clayey to sandy-clayey in various shades, with yellowish to reddish facies predominating. These are the main characteristics of the alluvium encountered in the area of the archaeological site, beneath the more recent loose dunes. This superposition can be seen along the wadis. It is also revealed by the gullies that appear following certain rainfall episodes or in the small cliffs shaped or cooled by the waves during storms.

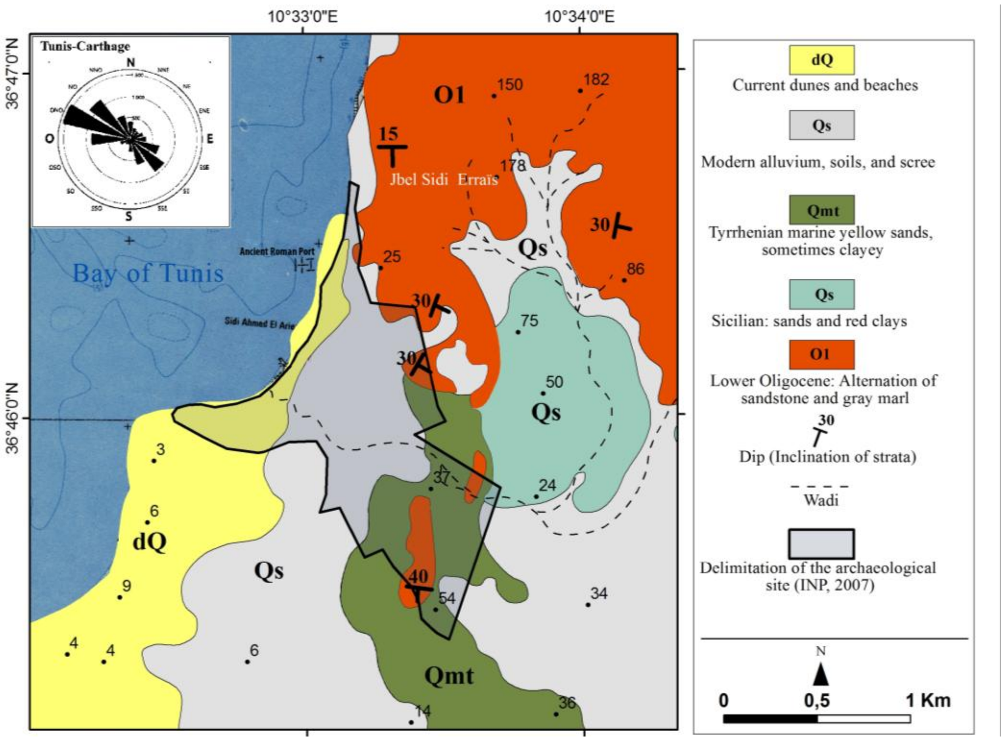


Figure2: Geological setting of the Sidi Erraïs site (geological map of 'la Goulette')

III. METHOD AND TOOLS

The geophysical missions were conducted using the 'SYSCAL R1 Plus Switch 72', an Electrical Resistivity Tomography (E.R.T) instrument. This device is characterized by a power output of 200W, a voltage of 600V, and a maximum current of 2.5A, making it one of the most powerful instruments in the SYSCAL range. The system is compact and consists of a single box that includes a transmitter, a receiver, a converter, two 12V/7Ah batteries, and switching cards. To set up the system, start by placing the SYSCAL box in position and then drive the stakes into the ground. Each cable outlet must be connected to a stake using a clamp cord to ensure that the current can flow properly. To explain the current injection process, consider a quadripole arrangement consisting of four electrodes (the stakes in the ground). Current flows through two electrodes: A(+) and B(-), while the other two electrodes, M and N, measure the electrical potential difference (dV). A pseudo-section is created by repeatedly measuring (measurement1, measurement2, measurement3, and so on) each ABMN quadripole at different locations, as illustrated in the figure below.

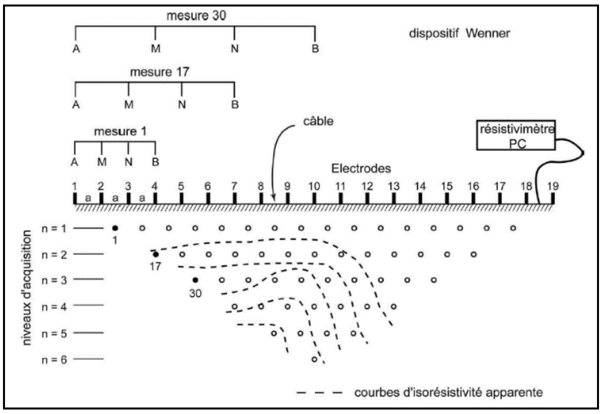


Figure3: The measurement sequence in Electrical Resistance Tomography (E.R.T) [9]

The SYSCAL R1 PLUS SWITCH 72 records apparent resistivity variations, displayed in a pseudo-section for interpretation The term "apparent" refers to the "average" resistivity that is determined by assuming a homogeneous soil, which helps to identify archaeological remains that may differ from the surrounding environment. Another geophysical method used is Ground Penetrating Radar (G.P.R). This technique employs a

GSSI control unit, which consists of a transmitting antenna that generates the radar signal and a receiving antenna that collects the reflected signals. These antennas are connected to the control unit via cables. Ground-penetrating radar operates by utilizing electromagnetic signals created by alternating electrical currents and magnetic fields [10]. When these signals penetrate the ground, they are partially reflected back to the surface when they encounter an obstacle or a change in lithology [11]. The receiving antenna calculates the difference between the arrival time of the received electromagnetic waves and the expected arrival time for each measurement. These time differences are represented as positive (white) or negative (black) deviations from an anticipated time profile that assumes no deviations. By repeating these measurements along the survey path, the device generates a radargram section (Fig. 4).

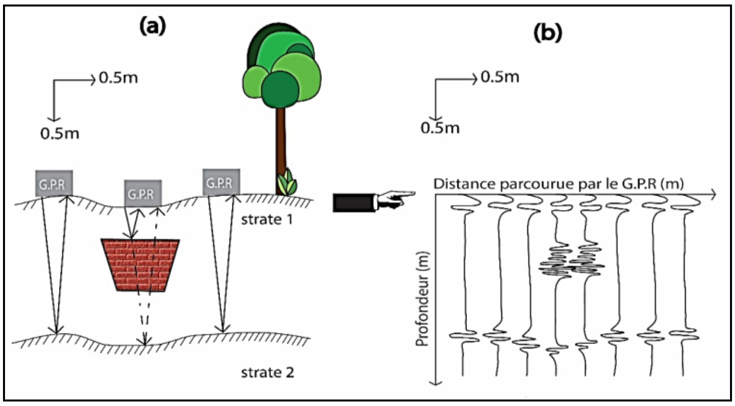


Figure4: Conceptual diagram illustrating the georadar acquisition principle. (a) Graph of electromagnetic responses; (b) Representative profile of encountered objects [12]; reproduced in this drawing).

Initially, we conducted a preliminary site visit to create a comprehensive strategy and identify potential technical challenges. Surveys were carried out at three different locations (Fig. 5). We processed the radargrams according to the specific targets, focusing on eliminating unnecessary information, especially noise and reflections from the initial contact between the ground-penetrating radar and the detection surface.

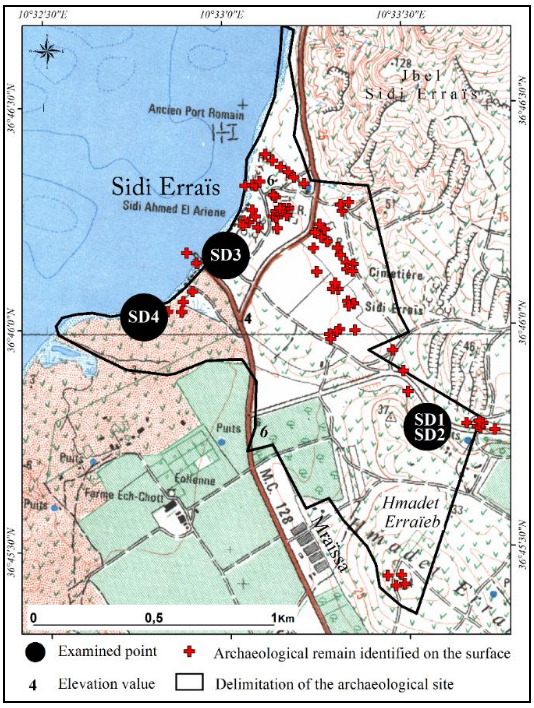


Figure5: Location map of prospected points

IV. RESULTS

Geophysical surveys conducted with advanced tomographic tools at the *Carpis* site have unveiled remarkable anomalies that warrant attention. The initial resistivity section, measuring SD1-18 meters and oriented SSW-NNE, reveals a strikingly circular and subhorizontal structure characterized by high resistivity values exceeding 100 Ωm, significantly higher than the surrounding environment. Based on the mean resistivity scale established by [10] and the regional geology, these elevated values strongly suggest the presence of coarse, resistive features embedded within a sandy-clay facies, which could potentially signify archaeological remains of great importance. Moreover, these intriguing features are concealed beneath alluvium exhibiting medium resistivity values ranging from 50 to 100 Ωm. The electrical data also indicate that the lowest layer has resistivity values between 10 and 30 Ωm, pointing to the presence of water beneath the resistive structure. This moisture is likely a crucial factor in preventing evaporation during the summer months, thereby preserving the site’s potential archaeological significance (Fig. 6). The findings at *Carpis* thus not only enhance our understanding of the area's geology but also open up exciting possibilities for uncovering historical artifacts.

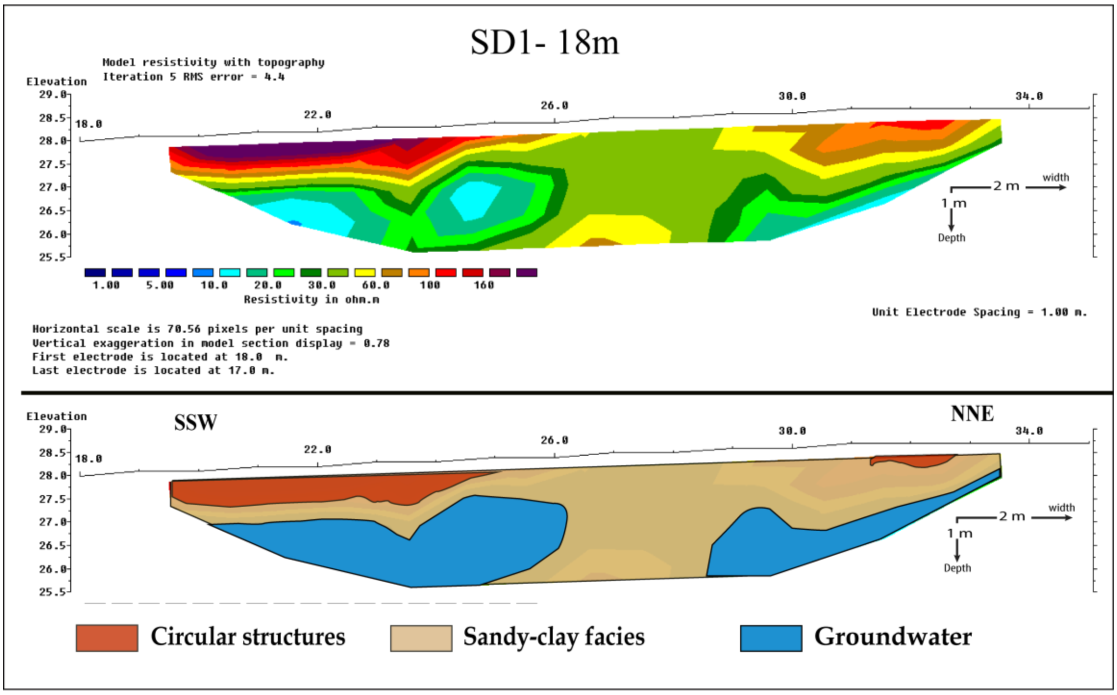


Figure6: Apparent resistivity section for profile SD1-18 m with its geomorphological model

The second geoelectric model section runs parallel to the initial profile, showcasing an ONO-ESE orientation. An in-depth examination of this section (SD2-18 m) reveals a significant variation in resistivity, ranging from as low as 1Ωm to an impressive peak of over 200Ωm. Utilizing the mean resistivity scale established by [10], the geomorphological model derived from this section distinctly identifies three zones (Fig. 7). The top zone, situated between zero and one metre in depth, features three notable depressional structures exhibiting high resistivity values exceeding 100Ωm, setting them apart from their surroundings. These structures are likely of anthropogenic origin, positioned atop a substrate of medium-resistivity alluvial material, characterized by a range of 50-100Ωm. Beneath this intriguing layer lies the lowest zone, which is distinctly conductive and corresponds to the water table, marked by resistivity values between 10 and 30Ωm.

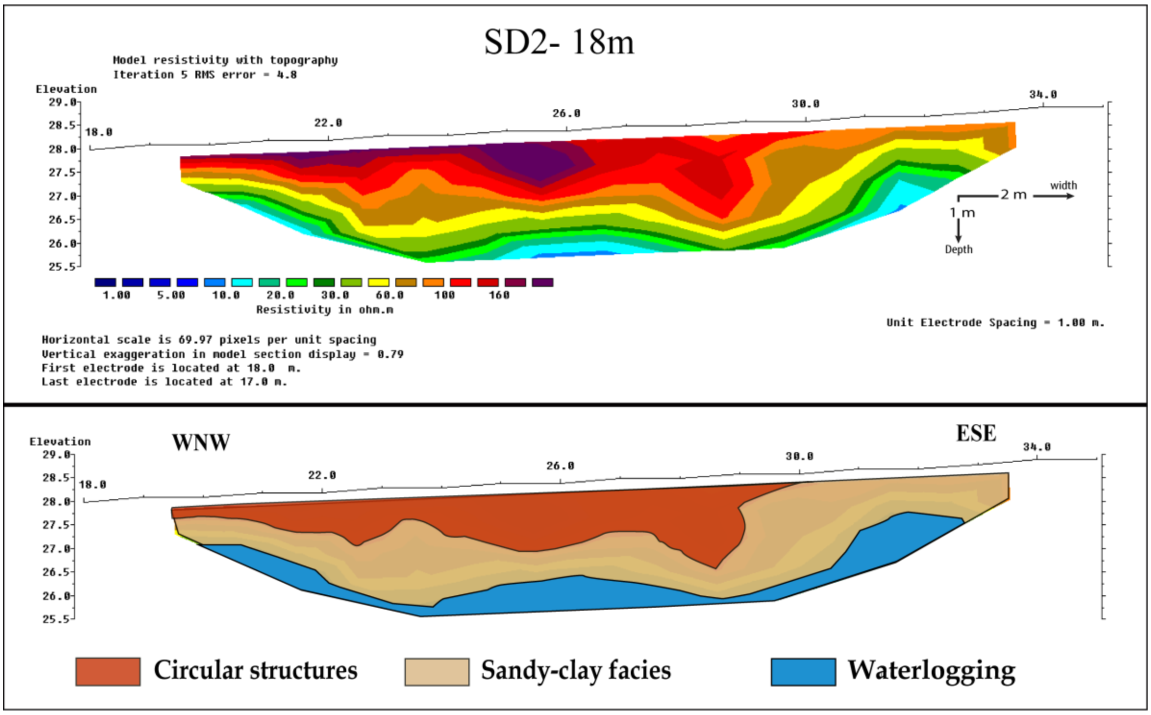


Figure7: Second apparent resistivity section for profile SD2-18 m and its geomorphological model

To identify resistive horizons with values greater than 100 Ωm, interpreted as indicators of anthropogenic activity, we conducted a second in-situ geophysical scan using the ground-penetrating radar (G.P.R) technique. The configuration of the G.P.R control unit was adjusted based on the geoelectrical results. The PR3 radargram was obtained along the same profile as SD1-18 m. Similarly, the PR7 line was examined on section SD2-18m (Fig. 8). For each measurement, the control unit recorded 60 scans per second, with a dielectric constant set to 12. In total, we produced seven radar images covering an area of 126 m².Haut du formulaire

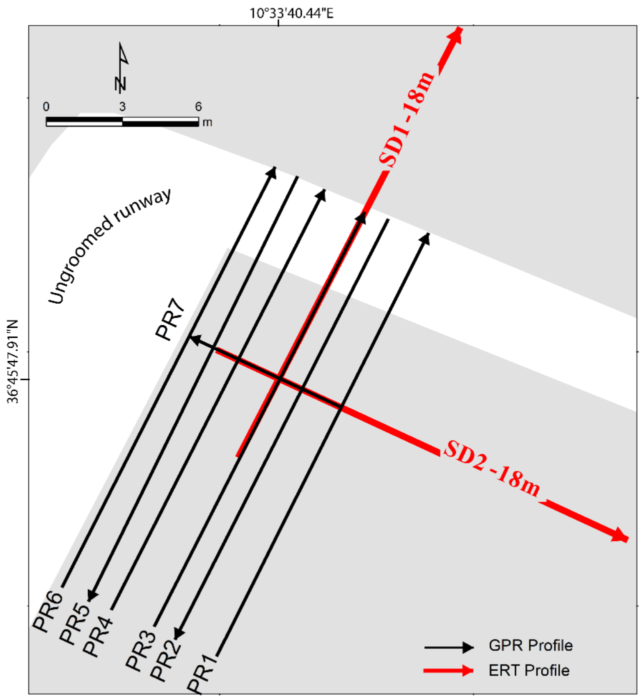


Figure8: Position of the profiles

Throughout all the G.P.R profiles, we observed a significant signal loss starting from a depth of 1.5 m. This indicates that the wave propagation is hindered, suggesting that we are encountering damp or watersaturated ground at this depth. According to [13], this signal attenuation near high contrast layers may be due to trapped rainwater or the water table. This theory aligns well with the apparent resistivity data obtained from the two sections, SD1-18 m and SD2-18m. Additionally, the PR1 radargram (Fig. 9) reveals five contrasts beginning at a depth of 0.6 m, characterized by geometric inclinations of 45°. These contrasts extend vertically to a depth of 1.4 m and are aligned along the same horizontal plane.

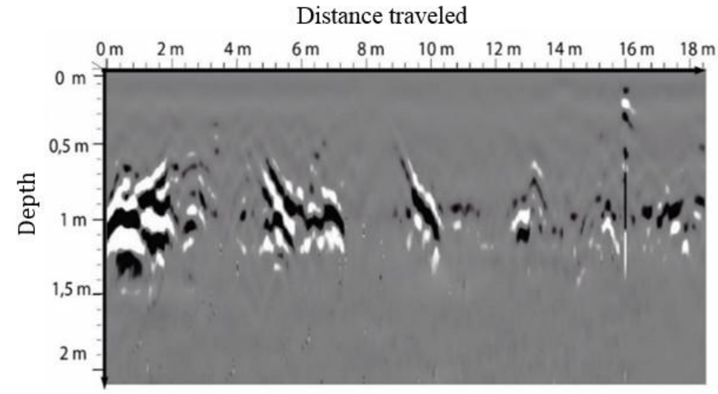


Figure9: Radargram PR1

In radargram PR2 (Fig. 10), four anomalies were detected starting from a depth of 0.25 m. The most notable anomaly is 3 m wide and located at a greater depth. The second significant anomaly is situated 1 m away from the first one. Given the closeness of the two profiles, PR2 and PR3, the radargrams show the same traces (Fig. 10). In radargrams PR4 (Fig. 12) and PR5 (Fig. 13), slight contrasts were observed, aligned at a central depth of 1 m. Conversely, radargram PR6 (Fig. 14) showed no detection of anomalies, indicating a uniform subsoil and the absence of any signs of occupation.

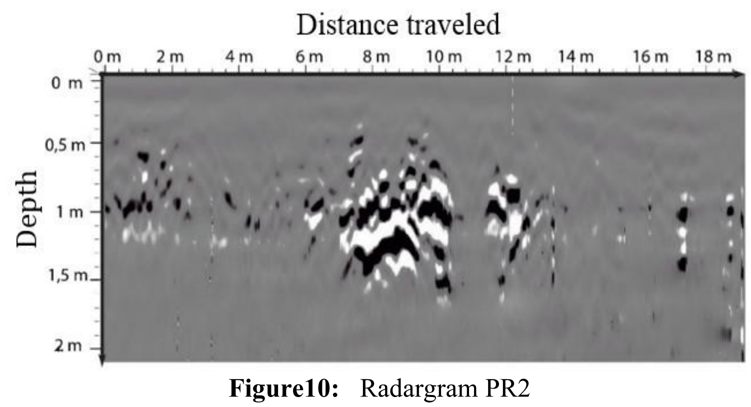


Figure10: Radargram PR2

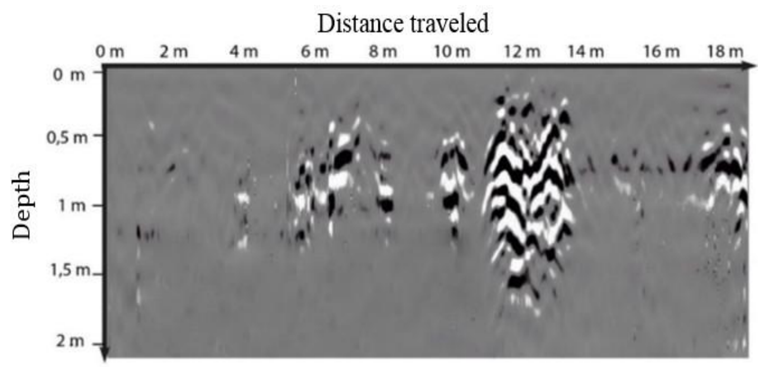


Figure11: Radargram PR3

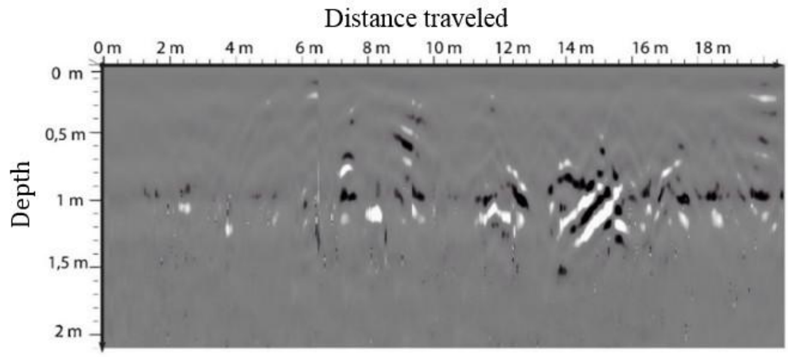


Figure12: Radargram PR4

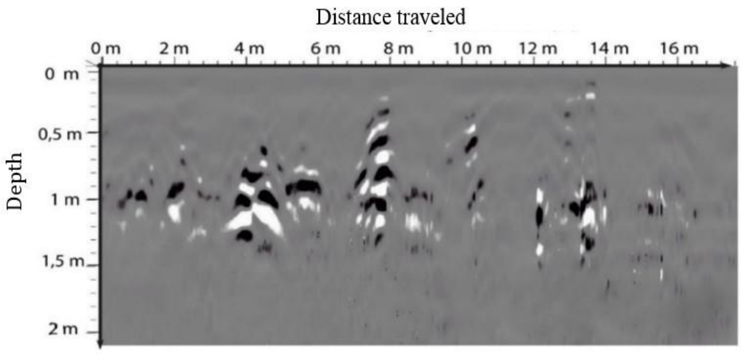


Figure13: Radargram PR5

The last radargram run (Fig. 14) on the line of section SD2-18 m (Fig. 6) shows 3 contrasts thinner than those detected in the previous radargrams (1 m thick). The first contrast corresponds to the same trace identified in radargram PR3.

The most recent radargram (Fig. 13) along the section line SD2-18 m (Fig. 6) shows three contrasts thinner than those identified in earlier radargrams, which were 1 m thick. The first contrast corresponds to the same trace found in radargram PR3.

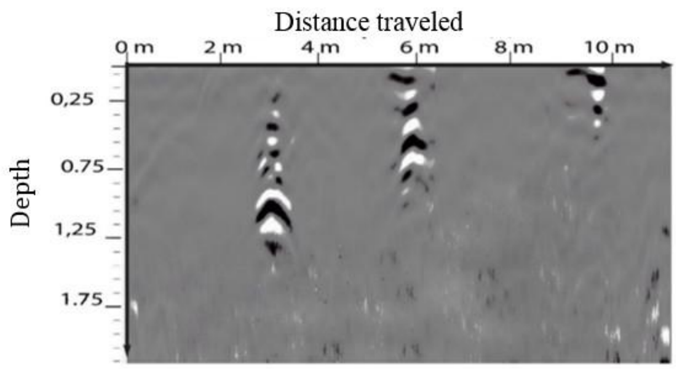


Figure14: Radargram PR7

Both geophysical methods used at the initial site successfully identified traces of buried occupation on the left bank of Wadi Louz, the main watercourse in the area. Based on the geophysical results, archaeological excavations were conducted.

The first excavation, focusing on section SD1-18m, lasted one month. During this work, a circular structure was uncovered that contained shards of culinary ceramics. The largest structure identified was an ancient oven, with an internal diameter of approximately 2.50 m, filled with brick fragments and dating back to the Punic period (Fig. 15).

Figure 15: Panoramic view of the first area examined, before and after excavation work
a- Day of the geophysical survey; b- After the archaeological survey; c- View of the excavated oven area

The second point of examination is located 100 meters from the shoreline, in an area covered by aeolian sand situated behind the bulge formed by the existing coastal dune. The measurements were conducted in an enclosed area protected by the National Institute of Protected Areas (INP). The exploration utilized the E.R.T technique, employing the Wenner-Schlumberger device with an electrode spacing of 0.5 meters. The length of the section analyzed is 72 meters, and profile SD3-72 m is oriented SSW-NNE, perpendicular to the structures truncated by the sea. The analysis of the 72-meter section (Fig. 16) reveals several horizontal resistive zones at the surface, along with concave and circular features at a greater depth (greater than 100 Ωm). The high resistivity values are likely indicative of archaeological traces, which are overlain by a less resistive layer of dune sands (ranging from 50 to 100 Ωm). Additionally, there are conductive zones beneath the first archaeological level, occurring at depths of 1 to 2 meters, suggesting an increase in water content (10 to 30 Ωm).

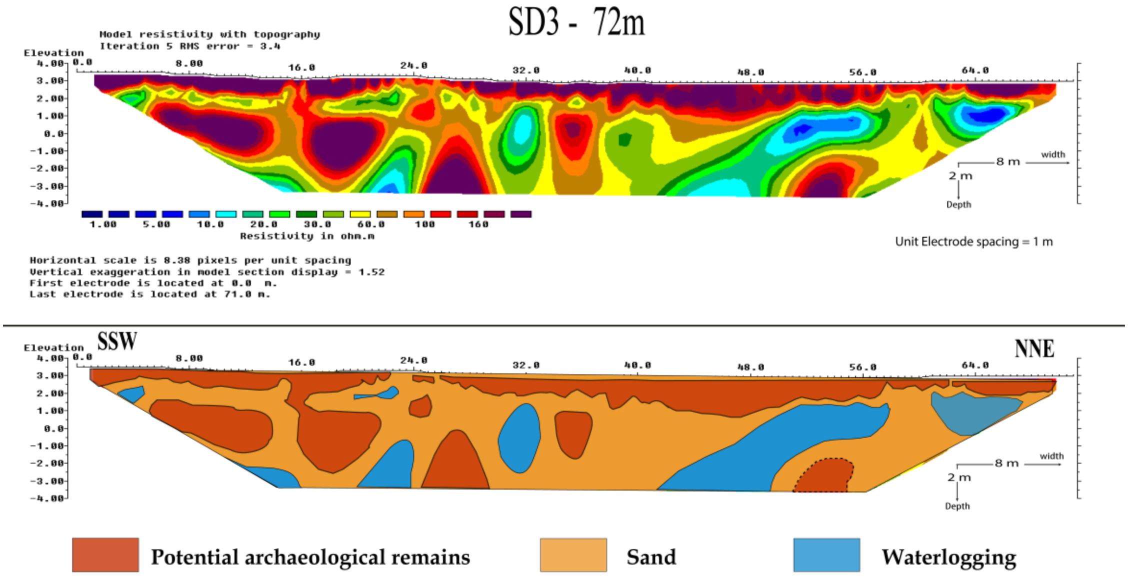


Figure 16: Apparent resistivity section for profile SD3-72 m with its geomorphological model (point no. 2).

The third point examined is situated on the coastal dune, just 7 meters from the shoreline. The maximum modeled depth reaches approximately 3 meters. Analyzing section SD4-18 m shows resistivity that varies from a base of 1 Ωm to a top of 160 Ωm or more. This section distinctly illustrates changes in resistivity both horizontally and vertically. For the geomorphological model of profile SD3-18 m, three zones can be identified (Fig. 16). Below ground, from zero to one meter, three low-resistivity structures dominate the superficial part of the section (greater than 100 Ωm). In the central part, a tendency towards sandier facies is evident (50 to 100 Ωm). The lowest zone in the section is conductive, as indicated by the decreased resistivity (10-30 Ωm), which corresponds to the water table.

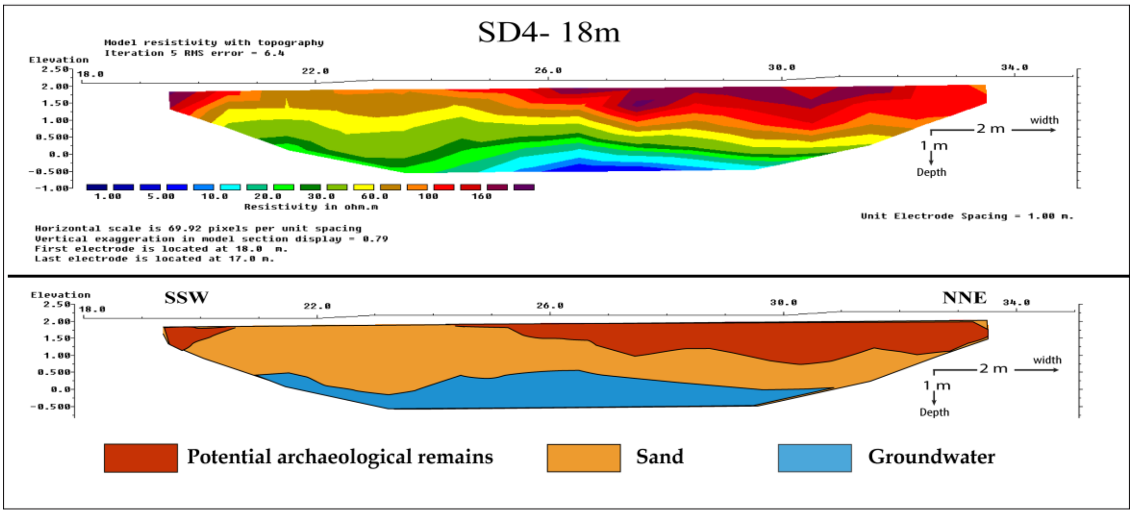


Figure 17: Apparent resistivity section for profile SD4-18 m with its geomorphological model (point no. 3).

Geophysical profiling in the Sidi Erraïs sector has produced reliable results that align with the previously established geoarchaeological objectives. The profiles provided two types of information: archaeological and environmental. From an archaeological perspective, the objects discovered exhibit similar shapes of varying sizes and are situated fairly close to the surface. The geometry and size of the detected objects suggest the presence of four ovens and two underground cellars in three separate locations. Additionally, the casing around these objects reveals two types of morpho-sedimentary dynamics, which gives insight into the natural factors affecting the landscapes in and around the *Carpis* site after the city was abandoned. One type pertains to alluvial dynamics associated with running water, manifesting as either diffuse flow on the interfluves or concentrated flow in Wadi Louz (point no. 1). The second type involves aeolian dynamics originating from beach sand (points 2 and 3).

Table 1 summarizes the results of the geophysical surveys conducted at three points on the Sidi Erraïs site. The primary observations regarding the identified remains indicate that circular and concave shapes, suggesting the presence of artisanal or industrial installations, dominate their geometry. The nature of the remains varies depending on the observation point, including kilns and underground cellars. The prevalence of circular structures leads to the hypothesis of an ancient industrial area. Furthermore, the anomalies detected are located at depths ranging from 0.25 to 2.5 meters, indicating that these remains are well-preserved beneath a sedimentary cover of sand and alluvium. This preservation is closely linked to the proximity of the Wadi Louz, suggesting that this water resource was exploited in the past.

All these observations reinforce the value of non-destructive methods in exploring archaeological sites. Such methods not only help identify buried structures but also characterize their state of conservation and environmental context. Combining various techniques, such as Ground Penetrating Radar (G.P.R) and Electrical Resistivity Tomography (E.R.T), offers a complementary approach that enhances detection chances and minimizes the risk of misinterpretation.

Table 1: Summary of Geophysical Results for the Three Survey Points

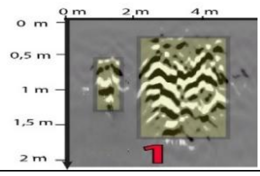
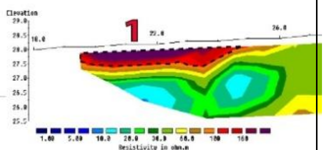
		Point 1	**Point 2**	**Point 3**	
		Profile **SD1-18m SD2-18m**	Profile **SD3-72m**	Profile **SD4-18m**	**Notes on sites**
Archaeological Information	**Geometry of Remains**	Circular shape	Concave shape	Circular shape	The same trace form recognized
	Typology	Four Punic remains confirmed by an excavation	Underground cellars	kilns	Industrial zone?
	Lateral extension	3 m	72 m	13 m	Variable size
	Depth interval	Summit : 0, 25m from the surface Base : 0. 77m from the surface	Summit : 0, 25m from the surface Base :6 m from the surface	Summit : 0, 25m from the surface Base : 1.5m from the surface	Remains close to the surface
	Heights of remains	52cm	2m – 3m	0,5 m	Variable height
Environmental information	**Enclosing the structure**	Sandy-clay facies	Sandy facies	Sandy facies	Same lithological type
	Surface environment	Recent alluvium	Boundary dune	Boundary dune	Two types of landscape dynamics: alluvial and aeolian
	Altimetry position	28 m	4 m	2 m	Variable
	Position in relation to Wadi Louz	75 m	220 m from the mouth	150 m from the mouth	Sites bordering Wadi Louz (considering water requirements)

V. DISCUSSION

The predominance of circular and concave structures, interpreted as ovens and cellars, suggests significant artisanal activity in the area. The variable sizes of these structures (ranging from 2 to 3 meters in diameter) may indicate installations serving different functions or from different periods. Additionally, the spatial arrangement of these remains points to a coherent organization of the area, potentially linked to a production zone. From a geological perspective, the sandy bedrock and alluvial deposits detected at all three survey points reveal two main morphosedimentary dynamics. The first is a fluvial dynamic associated with the Louz wadi, which may have provided a water source for artisanal activities and played a crucial role in sedimentation post-abandonment. The second is an aeolian dynamic, related to the transport of sand from the surrounding beaches, which may help explain the good preservation of the remains under a relatively thick layer of sand. The contemporary environment around the remains, characterized by alluvial cover and proximity to the wadi, indicates that the *Carpis* site likely underwent various natural processes after its abandonment. The presence of sedimentary layers alternating between sand and alluvium suggests multiple episodes of flooding and aeolian deposition. However, while the prospecting methods employed have yielded promising results, they also have certain limitations. Georadar, though effective in detecting buried structures, did not provide precise information regarding the materials that make up the remains. Electrical resistivity tomography (E.R.T), although useful for identifying anomalies located at great depths, exhibited relatively low spatial resolution, which could compromise the accuracy of the structural contours detected.

At the first surveyed point (Point 1), electrical tomography indicated a probable circular structure corresponding to an ancient oven, a hypothesis that was later confirmed by archaeological excavation. The main differences between the two methods lie in their accuracy and ability to detect fine features. The ground-penetrating radar (G.P.R) only detected the large structure of the kiln, while the E.R.T revealed the entire archaeological basin, including the kiln and the scattered waste ceramics surrounding it. Although G.P.R provides good dimensional accuracy, it cannot ascertain the exact nature of the structures or their dating. Conversely, electrical tomography offers better recognition of the underground environment and smaller archaeological traces, albeit with slightly lower spatial accuracy (see Table 2). The excavation results validated the presence of an ancient oven from the Punic period, confirming the hypothesis put forth by the electrical tomography.

Table 2: Comparison of Results from the Two Methods of the Second Survey with Excavation Findings

Point no. 1	**G.P.R profile : PR3**	**E.R.T profile: SD1-18m**	**Excavation results**
Results			
Type and shape	Unknown	Unknown, but likely an oven due to its circular shape.	Identified as an ancient oven from the Punic period.
Dimensions	2,50 m	3 m	Diameter 2.50 m
Depths	Summit: 0, 25 m from the surface. Base: 1, 6 m from the surface.	Summit: 0, 25 m from the surface. Base: 0.77 m from the surface.	Depths are not fully defined (suspended work).
Enclosing the structure	Unknown	Clay-sand facies with groundwater at depth of 1m	Sandy facies and clayey alluvium
Advantages	-Ability to distinguish between significant structures. - Good dimensional accuracy.	- Recognition of both small and large archaeological traces. - Understanding of the underground environment.	- Verification of archaeological models. - Availability of dating methods. - Identification of different trace types.

Disadvantages	- Unknown nature of traces with no dating information. - Uncertain state of preservation.	- Precision of measurements is not very accurate. - Additional lack of dating information.	- Arbitrary survey methods used. - Process is time-consuming.

VI. CONCLUSION

The geophysical investigations conducted in the Sidi Erraïs sector at three separate locations reveal the presence of subsoil remains, along with their physical and geometric characteristics. The results partially met the objectives set for the study, aiding in the identification of various structures. Specifically, they indicated the existence of four furnaces and two underground cellars. An excavation was performed at one of the selected locations, providing strong validation of the geophysical findings. However, it is important to note that the electrical tomography sections revealed only coarse traces (resistive elements) and were unable to differentiate between large structures and smaller ceramic remnants. In contrast, the georadar measurements effectively located the most significant traces that warranted excavation.

Regarding the nature of these traces, the radargrams did not allow for the identification of specific typologies. Meanwhile, the resistivity sections modeled circular and horizontal shapes, suggesting the presence of a furnace. The cross-referencing of geophysical data with the actual excavation results confirmed the interpretative hypotheses outlined in the geomorphological models. Ultimately, the correlation between the traces identified in the profiles and the findings from the archaeological investigation provided an opportunity to compare the different methods and to assess their metric discrepancies in terms of accuracy. At the second and third locations examined, the resistive surfaces identified in the geo-electrical sections indicate potential sites for future excavations. Overall, these findings confirm the archaeological potential of the Sidi Erraïs area and highlight the contributions of the geophysical methods employed. These methods could significantly assist the institutions and departments responsible for archaeological heritage. Additionally, the results may be valuable for reconstructing paleoenvironments and understanding landscape dynamics.

REFERENCES

[1]. Scollar, I., et al., Archaeological prospecting and remote sensing. 1990: Cambridge University Press.
[2]. Siart, C., M. Forbriger, and O. Bubenzer, Digital geoarchaeology: new techniques for interdisciplinary human-environmental research. 2018: Springer.
[3]. Butzer, K., Archaeology as human ecology: method and theory for a contextual approach. 1982: Cambridge University Press.
[4]. Campana, S. and F. Remondino, Sensing the Past: From artifact to historical site (Geotechnologies and the Environment, Vol. 16). 2021: Springer.
[5]. El Ghali, O., Intérêts géoarchéologiques du littoral du golfe de Tunis (Tunisie nord-orientale) : Apports des sciences géomatiques et des méthodes géophysiques. 2022, Thèse de Doctorat en Géographie, Université de Tunis.
[6]. Merlin, A., Nouvelles des fouilles de Mahdia (Tunisie). Comptes rendus des séances de l'Académie des Inscriptions et Belles-Lettres, 1911. 55(5): p. 360-362.
[7]. Guérin, V., Voyage archéologique dans la Régence de Tunis (Vol. 1). 1862: Henri Plon. 438 p.
[8]. Cagnat, R. and A. Merlin, Atlas archéologique de la Tunisie : Edition spéciale des cartes topographiques publiées par le ministère de la Guerre. 1932.
[9]. Marescot, L., Modélisation directe et inverse en prospection électrique sur les structures 3D complexes par la méthode des éléments finis. 2004, Doctoral dissertation, Universités de Nantes et de Lausanne.
[10]. Dubois, J., M. Diament, and J.P. Cogné, Géophysique : Cours et exercices corrigés. 4e édition ed. 2011: Dunod.
[11]. Jol, H.-M. and C.-S. Bristow, GPR in sediments: advice on data collection, basic processing and interpretation, a good practice guide. Geological Society, London, Special Publications, 2003: p. 9-27.
[12]. Pasquinucci, M. and F. Trémen, Non-destructive techniques applied to landscape archaeology (No. 4). 2000: Oxbow Books.
[13]. Leucci G. ,Ground Penetrating Radar: The Electromagnetic Signal Attenuation and Maximum Penetration Depth. Dipartimento di Scienza dei Materiali. 2008. Universit`a del Salento, Via per Monteroni, , Italy.

ACKNOWLEDGEMENTS

I would like to express my heartfelt gratitude to my thesis supervisors, Professor Ameur Oueslati from the University of Tunis and Professor Mohamed Chedly Rabiaa from the University of Manouba, for their invaluable guidance and unwavering support. I also extend my sincere appreciation to Mrs. Ouafa Ben Slimane, archaeologist at the National Heritage Institute (INP), and Professor Boutheina Maraoui, archaeologist from the University of Tunis, for their crucial contributions to the excavation process.