

Article

Non-Invasive Archaeological Methodologies for the Analysis of the Port Structures of *Portus Ilicitanus* (Santa Pola, Alicante)

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Abstract: The traditional identification of the ancient port of *Ilici* with the current town of Santa Pola in Alicante (Spain) has been based on a small number of punctual, unconnected, and too partial archaeological interventions. Since 2017, a program of geophysical surveys has been performed with a Stream X model multi-channel georadar IDS. This program has been focused mainly on the so-called Mercado de Viguetes, an area in which archaeological excavations have hardly been carried out. The geophysical surveys have allowed us to draw part of the urban fabric of the central core of the *Portus Ilicitanus*, revealing a set of structures that can be assimilated into a port area: warehouses, houses, open spaces, and decantation basins to produce salted fish, and the probable eastern boundary of the complex identified with the port dock. Altogether, two predominant alignments can be assimilated into the Early Imperial and Late Imperial construction phases. Non-invasive archaeological methodologies have become the main resource for archaeological analysis and heritage protection in view of the current impossibility of carrying out archaeological excavations in this area of Santa Pola.

Keywords: georadar; *Portus Ilicitanus*; *cetaria*; port; Hispania; Roman Empire; Roman archaeology; remote sensing; Santa Pola



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1. Introduction

The *Portus Ilicitanus* (Santa Pola, Alicante) is the maritime and commercial extension of the *Colonia Iulia Ilici Augusta*, whose *urbs* is identified with La Alcudia de Elche (Figure 1) (Pliny the Elder, NH, III (4), 19–20; Mela, Chorographia, II, 93; Ptolemy, Geographicae, II, 6, 14). The excavations carried out in the 1980s and 1990s of the last century at the site of La Picola revealed the existence of an Iberian fort of empiric character dated between the middle of the 5th century and the third quarter of the 4th century BC. It would have been a fortified *nucleus* probably linked to populations of the interior of the Lower Vinalopó, which would have had its main centre of reference in La Alcudia (Elche) [1,2] (pp. 264–265).

After the abandonment of the fort at La Picola, there is no documented occupation in this part of the coastal strip for three centuries, which points to a change in the territorial structure that would lead to the use of other empiric areas. This long hiatus was not interrupted until the foundation of the colony of *Ilici* (La Alcudia, Elche) in 43/42 BC and refounded around 27 BC [3] (pp. 38–45); [4] (p. 80), a period in which the *Portus Ilicitanus* was created on the coast of what is now Santa Pola. The *Portus Ilicitanus*, whose name is found in Ptolemy (Geographicae, II, 6, 14), did not become known archaeologically until the last quarter of the 20th century. Since then, the number of interventions has been extensive, with excavations at the *Portus Ilicitanus* site, Estación de Autobuses, Plaza de los Aljibes, with the Roman house of El Palmeral and La Picola standing out (Figure 2). However, despite the large number of excavations carried out in the last 50 years, a significant part of these have

not been published, and, furthermore, they present unconnected areas that are difficult to interpret from an urbanistic point of view, limiting their historical-archaeological knowledge.

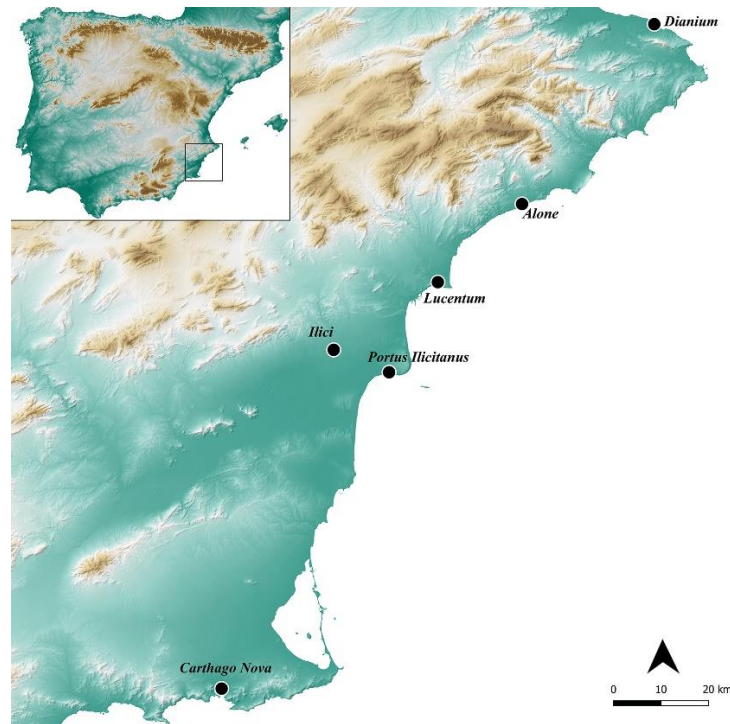


Figure 1. General map showing the location of *Portus Ilicitanus* in relation to the Roman cities in the surrounding area.

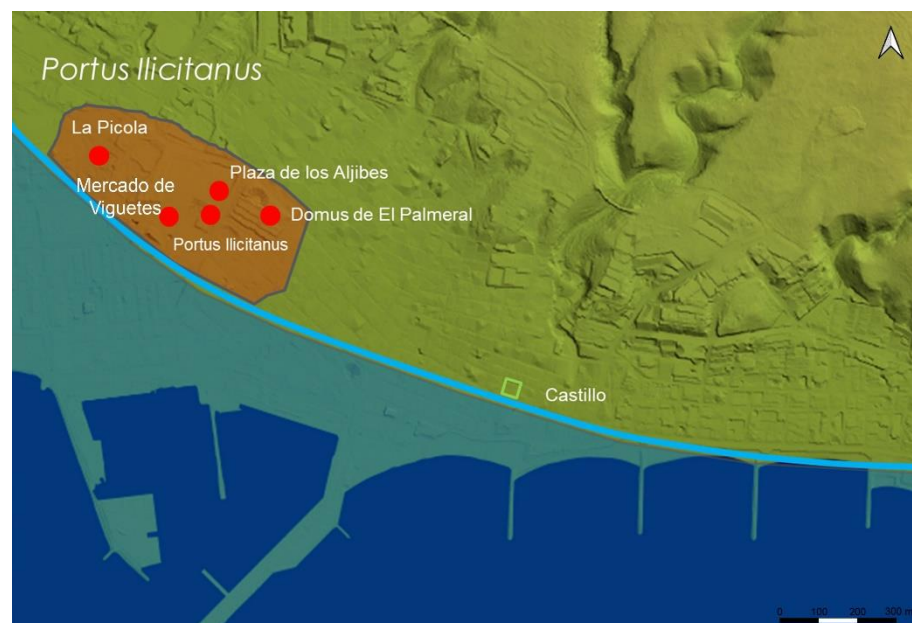


Figure 2. Location of the most significant sites of the *Portus Ilicitanus* and proposed coastline in Roman times (marked in blue).

The best-known archaeological area is the site of La Picola, whose excavations began in 1987, revealing a complex archaeological site in which different phases were differentiated, from the Iberian fortress to the fish-salting production centre (*cetaria*) from the Late Imperial period [2,5,6]. Following the development of the Hispano-French project centred on the

Iberian fort [1,2], in 1997, the Museo del Mar de Santa Pola and a team from the University of Alicante, led by J. Molina and J. C. Márquez, undertook the study and systematic excavation of the Roman structures at La Picola [7,8]. The set of interventions carried out at La Picola has made it the site that has provided the best information for understanding the evolution of the *Portus Ilicitanus* and its sequence of occupation [8]:

- Phase 0: fortress-settlement with empiric characteristics from the middle of the 5th century BC until the third quarter of the 4th century BC.
- Phase I: Foundation of the *Portus Ilicitanus* with possible domestic environments from the 2nd half of the 1st century BC and the Augustan period.
- Phase II: Housing structures and commercial warehouses from the 1st and 2nd centuries AD.
- Phase III: First phase of the *cetaria* from the second third of the 4th century AD.
- Phase IV: Extension of the *cetaria* from the last third of the 4th century AD.
- Phase V: Abandonment and amortisation of previous construction phases with the appearance of burials from the last third of the 4th century AD and the beginning of the 5th century AD.

The phases of occupation shown at this site present a dynamic that is consistent with the diachronic analysis of the circulation of coins from La Picola [9], as well as the trade dynamics documented from the amphorae remains of different interventions in the *Portus Ilicitanus* [8–10]. These analyses confirm the absence of activity between the 3rd and mid-1st centuries BC, but at the same time, they allow us to observe greater economic activity in the 1st and 2nd centuries AD and a sharp decline from the end of this century and the following century, followed by an upturn in activity during the 4th century AD.

The existence of an important Early Imperial occupation phase has also been recorded in other parts of this port centre. This is the case of the structures related to port warehouses documented in the Plaza de los Aljibes or the *Portus Ilicitanus* plot, where a public building from this period has also been partially excavated [11,12]. This is also true in the area of El Palmeral, where excavations carried out in the 1990s brought to light a large group of structures, including some *tabernae* open to a square paved in opus signinum dated to the 1st–2nd centuries AD [13] (p. 130). The reopening of Picola in the 4th century with the construction of a *cetaria* is also reflected in other parts of *Portus Ilicitanus*, especially at the site of the Casa Romana de El Palmeral, which corresponds to a luxurious residence from the same century [13,14] (pp. 129–130).

In recent years, the University of Alicante, in collaboration with Museo del Mar, has continued to carry out archaeological work at various sites in Santa Pola. This programme of actions includes the development of a general plan of geophysical surveys in collaboration with the Service of Geodetection, Analysis and Georeferencing of Historical Heritage of the University of Cádiz, which has given a new dimension to archaeological research, allowing us to begin to define the new port and productive areas. The data obtained in one of these areas—Mercado de Viguetes—are significant enough to allow us to analyse them in detail and, ultimately, to make a series of interpretative proposals on the infrastructures of this part of the Roman port.

2. Materials and Methods

The equipment used to carry out the surveys in the area around Mercado de Viguetes consisted of a Stream X model georadar from the Italian company IDS (*Ingegneria Dei Sistemi*). It is a multi-channel georadar consisting of a set of 16 antennas (8 + 8 dipoles) arranged every 12 centimetres from each other. The system used by these antennas is based on vertical polarisation sampling emitting at a frequency of 200 MHz.

Overall, the antenna has a span of 2 m wide, a condition that requires the use of motorised vehicles and a mechanical lifting system for its correct handling. In this case study, the georadar was towed by a 4 × 4 vehicle with several operators inside: the pilot in charge of manoeuvring and controlling the lifting system of the geophysical equipment and a technician in charge of managing the data collection system and its real-time data

visualisation software (*One Vision*). Thanks to this, it was possible to carry out the different projects and their correct georeferencing to work with these data in the laboratory for post-processing.

The system used to work with the geographical coordinates and make the relevant spatial corrections was the implementation of a GPS+PPS system with RTK corrections from the company Leica Geosystems, model GS14. The positioning files are exported from the GPS receiver to the control unit in NMEA (National Marine Electronic Association) format or protocol, taken every 0.2 s, which translates into 5Hz on the energy value scale.

The non-invasive methodology used for this site consisted of the following steps. Firstly, a Geographic Information System (GIS) was used to plan the work area, dividing the exploration zones into different projects of approximate dimensions, thus compartmentalising the study area. Then, the different geophysical projects were carried out by means of georadar data collection. For greater control, spray paint was used to mark the beginnings and ends of the swaths that the team was completing. Data visualisation and real-time correction of the displaced swaths due to the temporary loss of RTK because of fluctuations in GPS coverage were performed with the *One Vision* capture software.

Once the fieldwork was completed, the georadar data were post-processed in the laboratory with the *Gred HD* software, also developed by *IDS*. This programme allows the visualisation and treatment of the data collected by the capture software to create both two-dimensional and three-dimensional processes using filters and GPR processing algorithms. The interface allows the analysis of geophysical disturbances through the visualisation of plan images and longitudinal and transversal radargrams.

For the correct processing of the georadar data, it is necessary to choose the corresponding filters and parameters: frequency domain filter or vertical *Bandpass* between 100 and 1000 MHz; *Timezero* correction; gain applications, *GainSEC*, and gain smoothing; and, finally, removal of background noise or background removal and subtraction of the mean. The total geophysical surveys in Mercado de Viguetes cover a total of 29,898 m² (Figure 3).



Figure 3. Location of the central study area with GPR (Mercado de Viguetes). Base corresponding to the WMS PNOA (1–9–2022).

3. Results

After processing and analysing the data, paying special attention to the orientations and depths of the evidence, it is observed that most of the geophysical disturbances can be grouped into a total of four large sets (Figure 4). The analysis of the radargrams shows that the anomalies detected are concentrated at depths between 0.5 and 1.5 m. The following is a detailed analysis of the four sets where the main geophysical alterations detected are concentrated.

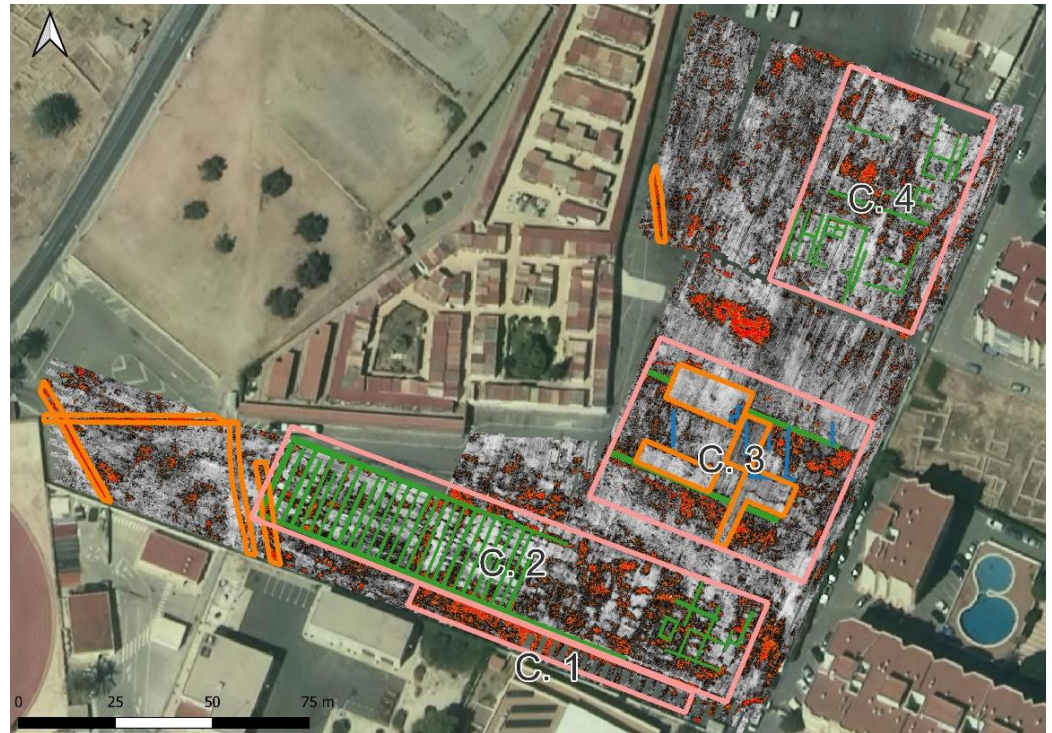


Figure 4. Four main sets detected (pink), together with readings related to documented recent alterations—recent excavations, canalisations, power lines, etc. (orange).

3.1. Set 1

The southern fringe of the study area presents a set of alterations measuring 90 m in length and 10 m in width, oriented NW–SE (Figures 4 and 6a). It is a very large group, both in terms of its extension and depth, as is reflected in the radargram, with a signal recorded between 0.25 and 2.0 m (1.75 m in total) (Figure 5).

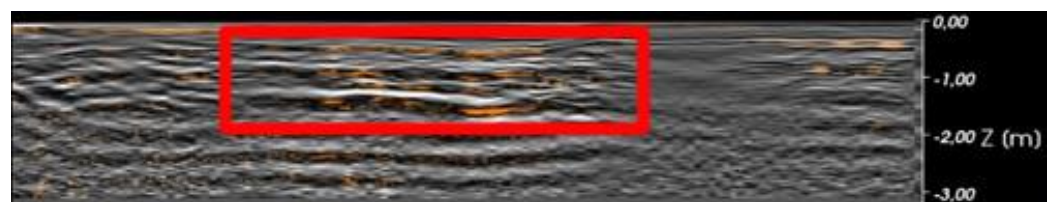


Figure 5. Radargram corresponding to Set 1 (marked in yellow dashed line in Figure 6a).

3.2. Set 2

Additionally, in the southern part of the analysed area, a large sector has been detected (Figures 4 and 6b), which occupies 2874 m² (128.5 × 22.4 m) in which two large areas can be distinguished, separated by a central zone where the readings obtained with the georadar are more indefinite.



Figure 6. (a) Detail of Set 1 at the S end of the study area where the radargram signal is located (yellow dashed line) (Figure 5). (b) Detail of Set 2 where the main alignments are highlighted (green).

In the western part, a group of at least 27 alignments of 0.4/0.5 m in width can be distinguished, oriented NE–SW and separated by a constant distance of 2.6 m (Figure 6b, green). These alignments reach a maximum length of 22.4 m and are framed between two readings perpendicular to the previous ones, at least 76 and 101 m long, respectively. This whole set of readings is visible between -0.2 and -1.6 m depth.

At the eastern end of this Unit 2, another group of regular alterations can be detected, which offers less defined readings, so it is not possible to propose well-defined spaces. Nevertheless, there is evidence corresponding to possible structures (at least 6) with the same NE–SW orientation, together with other perpendicular ones (Figure 6b, green).

3.3. Set 3

The analysis of this central area of 2662 m^2 ($59.7 \times 44.6 \text{ m}$) shows predominant readings corresponding to a series of recent archaeological interventions (marked in orange) (Figures 4 and 7).

In the first place, we must highlight a group of 6 parallel alignments that present a clearly differentiated N–S orientation from the rest of the described sets. These alterations have a width of 0.4/0.5 m and a longitudinal development of no more than 12 m, together with other perpendicular ones (Figure 7, blue).

On the other hand, the rest of the readings in this area are not so clear and present an undefined profile, concentrating the alterations at depths between -0.8 and -1.9 m. We found a group of undefined alterations in the southernmost part that present the same alignment of Sets 1 and 2 (NW–SE), all of them very difficult to individualise. Additionally, further north, another regular alignment of 33 m in length is detected (Figure 7, green), although interrupted by the archaeological excavations of 2004 [15] (Figure 7, orange).

In the central part (Figure 8), another alignment is detected, 14 m long and 2.3 m wide, a structure that reaches a depth of -2.5 m, as shown in the radargram (Figure 9).



Figure 7. Detail of Set 3 in the central part of the study area showing (orange) the alterations of the subsoil by recent actions.

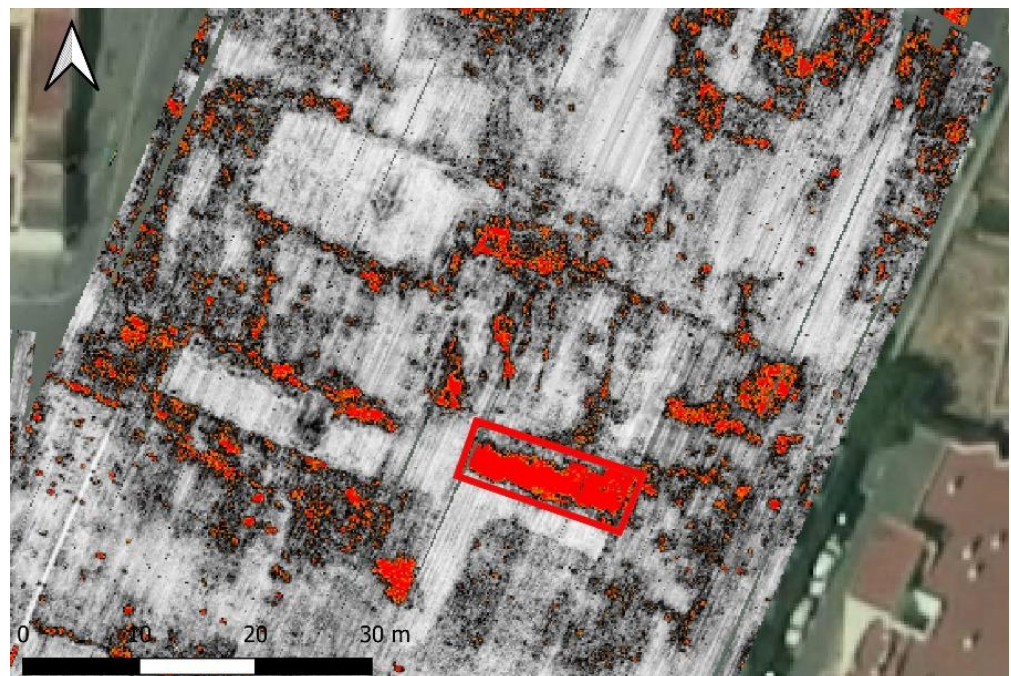


Figure 8. Central part of Set 3, highlighting (in red) a large and deep alteration at -0.89 m.

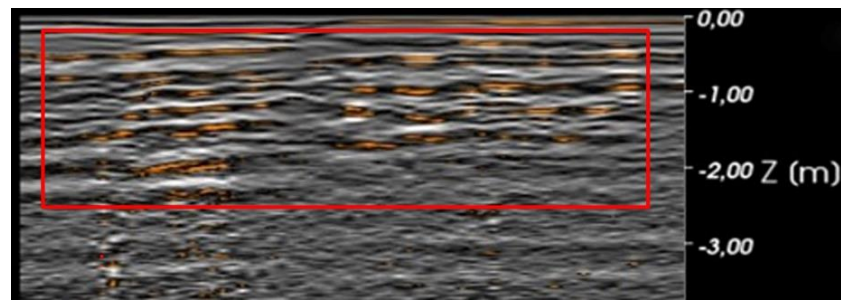


Figure 9. Radargram corresponding to the disturbance highlighted in red in Figure 8.

3.4. Set 4

Set 4 has a surface area of 2301 m² (59 × 39 m) and contains a series of readings that appear to be associated with well-defined quadrangular spaces (Figures 4 and 10), and two clearly defined areas can be distinguished.

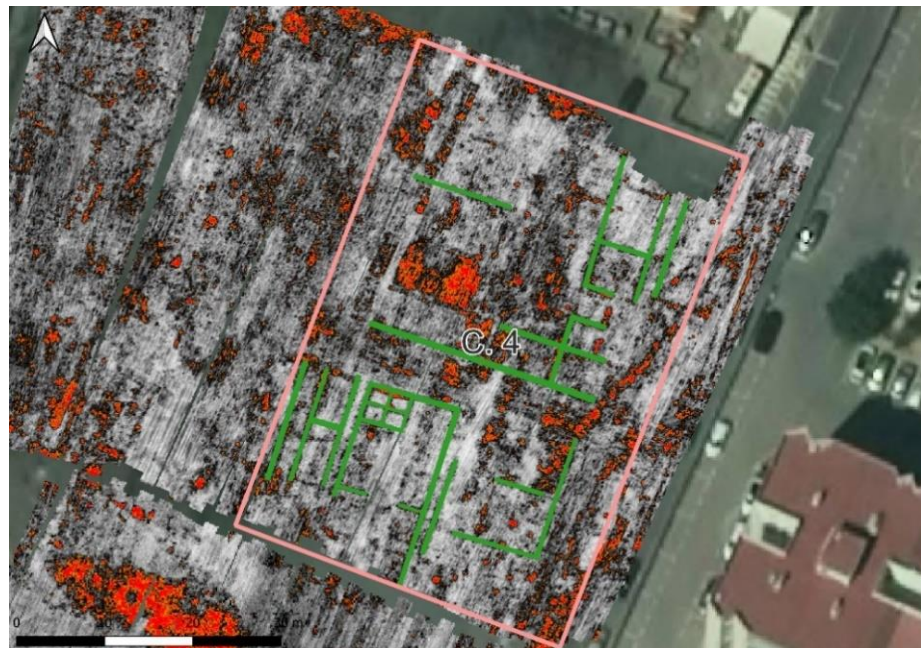


Figure 10. Set 4 in the northern part of the study area.

The lower one combines 8 alignments with NW–SE orientation forming right angles to 9 other readings with a maximum length of 21 m and a width of 0.4/0.5 m (Figure 10, green). All these readings appear within a range between -0.4 and 1.6 m depth. These alignments generate a space with few readings in its central part, except for a grid that shows 4 compartments of regular size (2.1×1.4 m), very evident in the corresponding radargram between -0.30 and -1.5 m depth (Figures 11 and 12).

On the other hand, in the upper part of this group, we observe readings that define other quadrangular spaces with the same orientation whose length does not exceed 27 m (Figure 10).

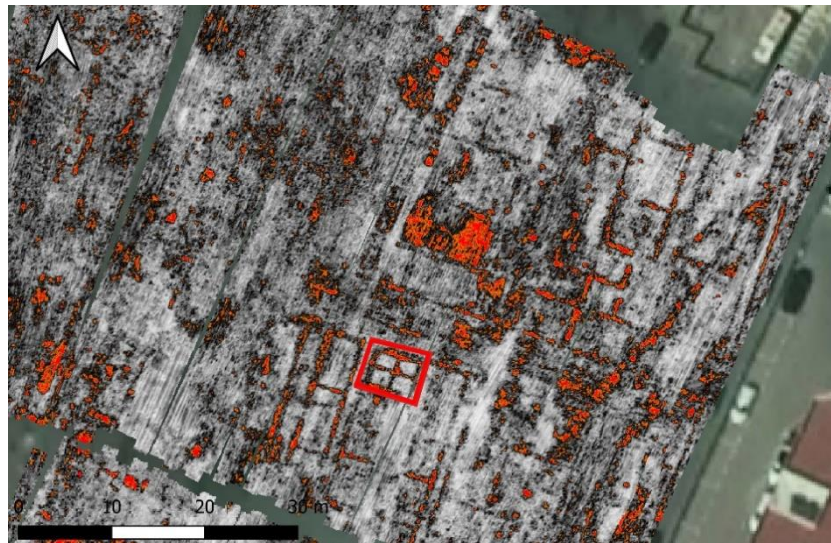


Figure 11. Detailed view of the northern part of the study area showing (red) the grid-shaped alignment of Set 4 at a depth of 0.6 m.

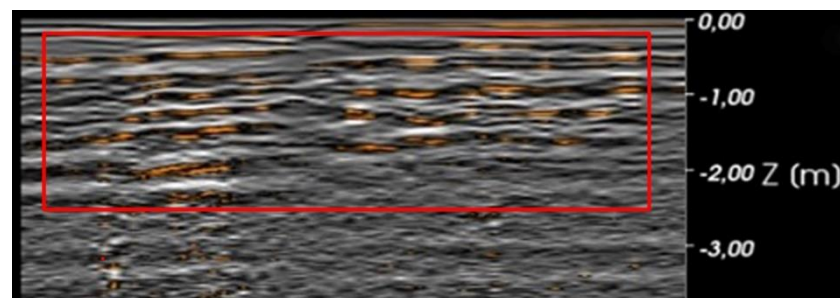


Figure 12. Radargram corresponding to the grid highlighted in red in Figure 11.

4. Discussion

A detailed analysis of the anomalies allows us to make a series of interpretative proposals about the possible function of the structures they define. Firstly, it should be noted that two different orientations are detected: NW–SE, the most frequent (Figures 4, 6b, 7, 10 and 13a, green), and N–S, only detected in Set 3 (Figures 7 and 13a, blue). The study of the structures exhumed in the archaeological interventions carried out at sites near Mercado de Vigueta reveals that the NW–SE orientation corresponds to the building of the Early Imperial period, while the N–S orientation is associated with Late Imperial times [11] (pp. 120–128) (Figure 13b).

In Set 1, the dimensions of the readings necessarily imply the existence of a very powerful structure (Figures 4, 6a and 14a), which, due to its location and the information available about the situation of the coastline in ancient times [16], could correspond to the dock of the port in Roman times. The signs recorded are perfectly compatible with similar structures archaeologically documented in *Carthago Nova* (Cartagena), the main port in the southeast of the peninsula in Roman times, for which the *Portus Ilicitanus* would have had redistribution functions [17,18]. Excavations on the maritime façade of this city brought to light a section of wall 24 m long and 2 m wide made of large sandstone blocks. At 10.12 m from this first wall, another section was identified parallel to the first and linked to it by four perpendicular walls [19] (Figure 2). The extent of the anomaly detected in Set 1 could reflect the existence of similar port facilities. Its NW–SE orientation leads us to propose an Early Imperial chronology.

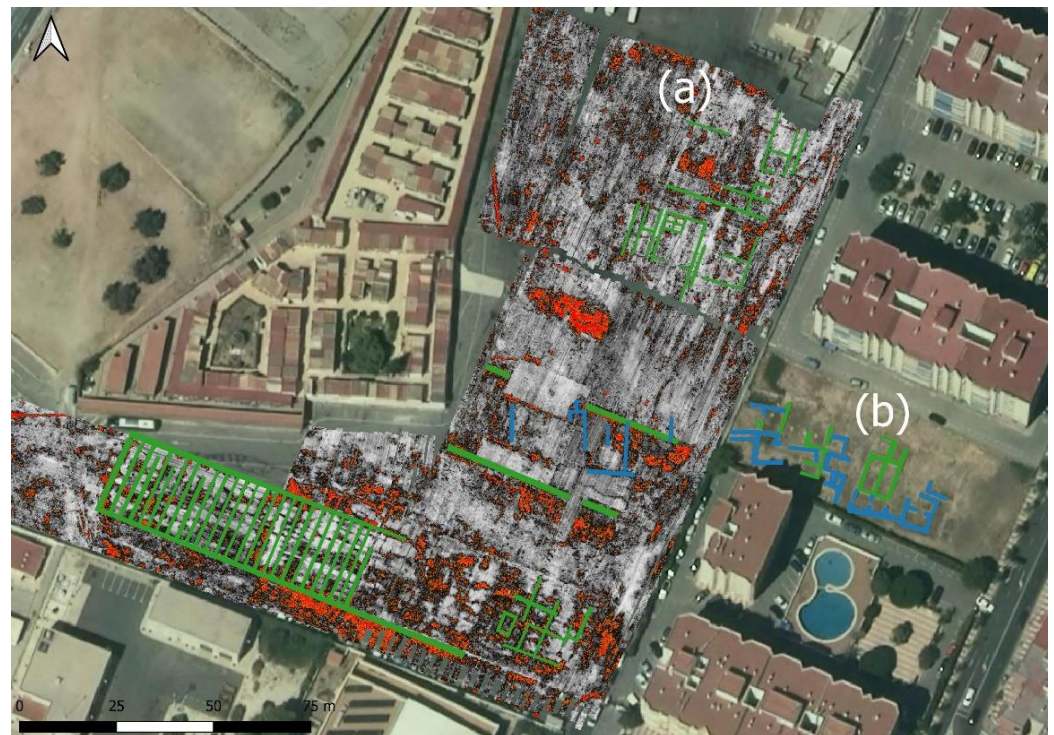


Figure 13. (a) View of the study area showing in green and blue the two orientations observed in the main alterations. (b) Site of the *Portus Ilicitanus* plot showing the excavated structures from the Early Empire (in green) and the Late Empire (in blue).

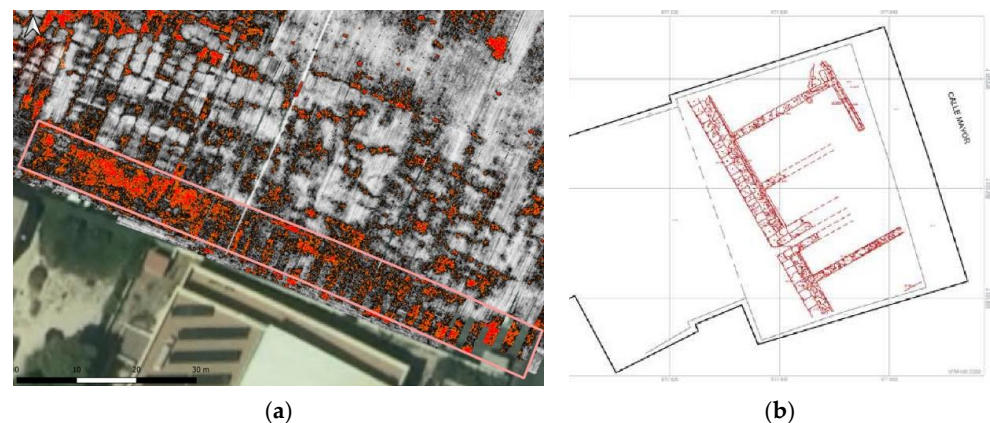


Figure 14. (a) Detailed view of the southern part of the study area showing the alteration of Set 1 at -0.89 m. (b) Plant of the Roman port structure exhumed in Cartagena [19] (p. 358, Figure 2).

On the eastern end of Set 2 (Figures 4 and 6b), there is a series of difficult-to-interpret alignments. In its western part, we can observe the existence of an elongated rectangular building made up of a total of at least 27 alignments that articulate 26 extremely narrow and elongated rectangular spaces. These narrow *cellae* cannot have had any residential function and can only be interpreted as a port *horreum*. There are numerous examples of structures of this type excavated and unequivocally identified as *horrea* (Figure 15) [20] (Figure 2), including those of *Bracara Augusta* [21] (Figure 9); the secondary agglomeration of Barzan [22] (p. 12); the large warehouses of Saint-Romain-en-Gal [23]; the *Piccolo Mercato* of Ostia [24] (Figure 2); or the *Grandi Horrea* of Ostia [25] (Figure 39).

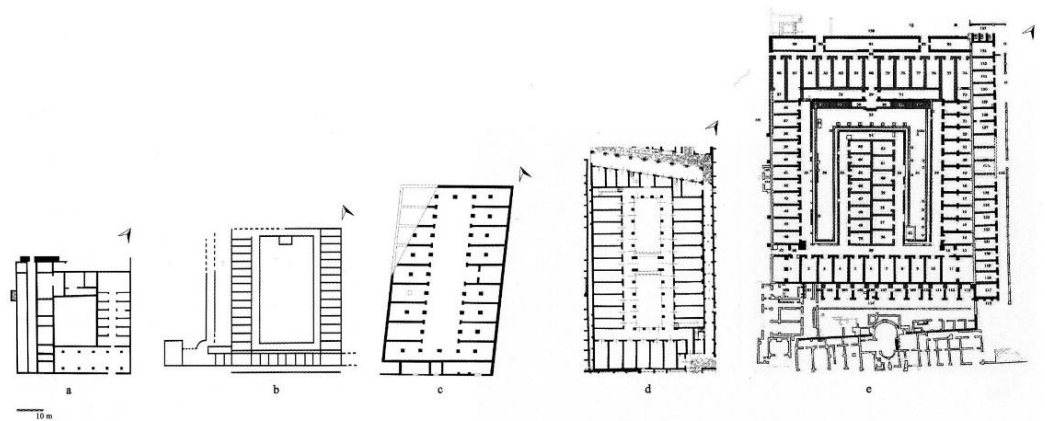


Figure 15. Comparison of the plan of some Western *horrea* of the Roman Empire [20] (Figure 2): (a) City of Braga. (b) Secondary agglomeration of Barzan. (c) Great warehouses of Saint-Romain-en-Gal. (d) *Piccolo Mercato*. (e) *Grandi Horrea* of Ostia.

In the case of the *Portus Illicitanus*, these would be specifically port *horrea* with the *cellae* aligned perpendicularly to the docks. The parallels of *Leptis Magna* (Figure 16) [26] (p. 266 Figure 2), the southern river port of Rome (Figure 17) with the *Porticus Aemilia* and the group of *horrea Sempronia, Galbana, Lolliana, Seiana* and *Aniciana* [27,28] (Figure 7) or Trajan's port of Ostia (Figure 18) [29–31] stand out. Likewise, representations of these port *horrea* are not uncommon in Roman mosaics and paintings in which the arcades of the *cellae* stand out [32] (p. 207): the domus of the nymphs of Neapolis in the Pro-consular [33] (p. 312 plates CXLV, CXLVI); the mosaic of Carthage [34] (pp. 126–127 plate L); the mosaic of the “Triumph of Venus” of Cuicul in Numidia [34] (p. 128 plate L); the mosaic of the Roman villa of the Vega Baja of Toledo [35] (no. 25), [36] (pp. 343–349), [37] (pp. 242–249); the mosaic of *Praenestre*, nowadays in the sacristy of the church of Santa Maria in Trastevere in Rome [38]; the mosaic of the House of *Isguntus* in *Hippo Regius* [39,40] (pp. 718–719); or the mosaic of the so-called “villa of the Nile” near *Leptis Magna* [41] (p. 48 plates 87–90).

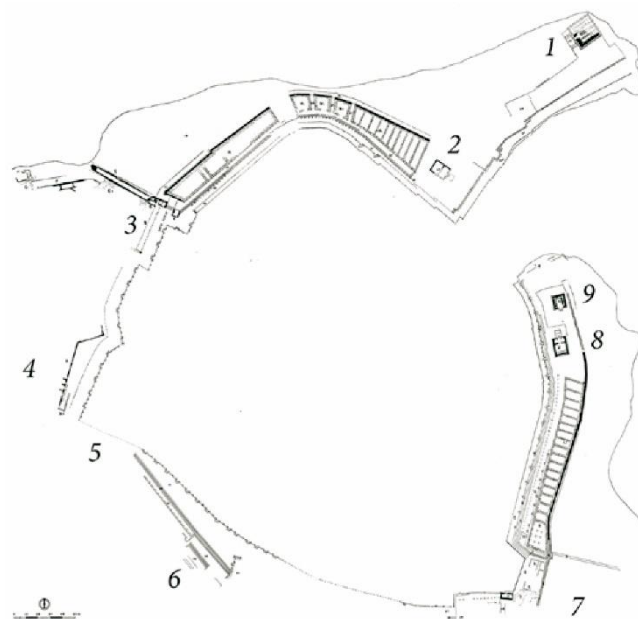


Figure 16. Port of *Leptis Magna* [26] (p. 266, Figure 2).

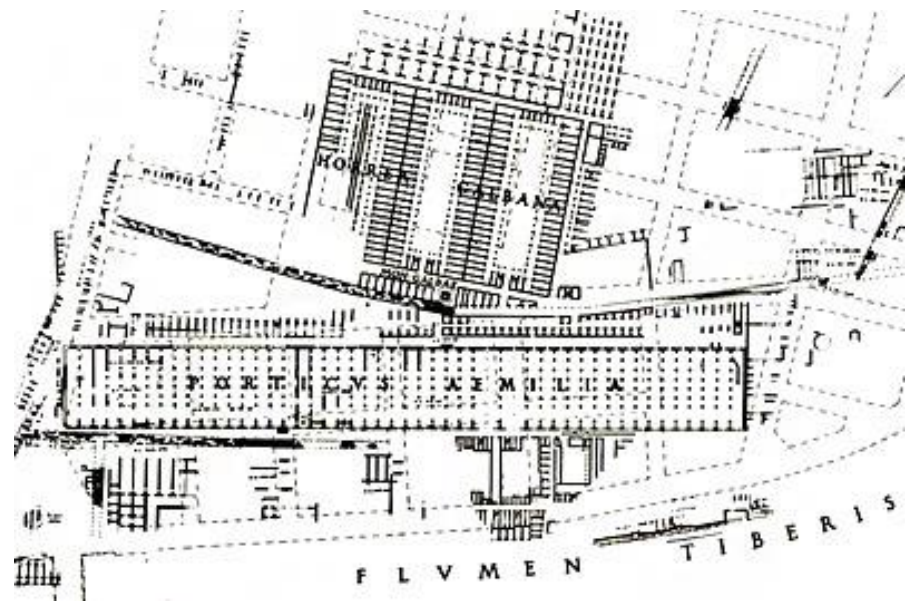


Figure 17. Rome's southern river port (*Emporium*) with the *Porticus Aemilia* and the set of *horrea* *Sempronia*, *Galbana*, *Lolliana*, *Seiana*, *Aniciana* [28] (Figure 7).

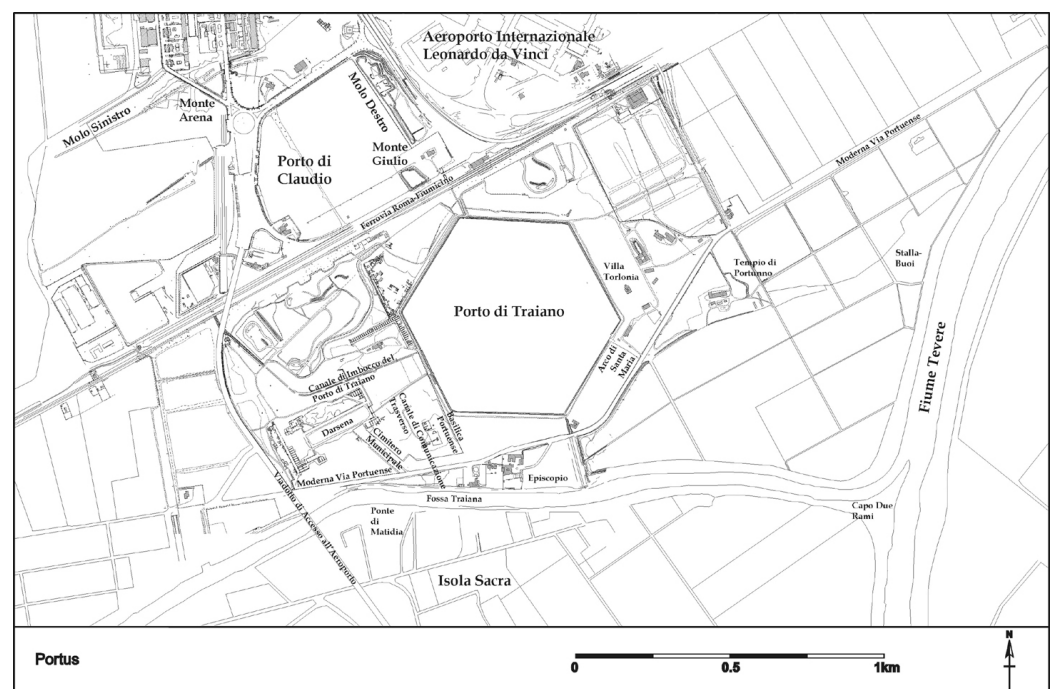


Figure 18. Trajan's Port at Ostia [30].

Set 3 is the one that brings together the greatest variety of geophysical alterations, combining the signals that take the form of alignments with the results of recent interventions in the subsoil. If we observe the large alignments oriented NW–SE (Figures 4 and 7, in green), we can see that their longitudinal development crosses the entire central part of the study area. Both parallel readings are 22.5 m apart. This distance is compatible with that occupied by a block and the roads that frame it in the excavated area of the *Portus Illicitanus* plot (Figures 13b and 19).

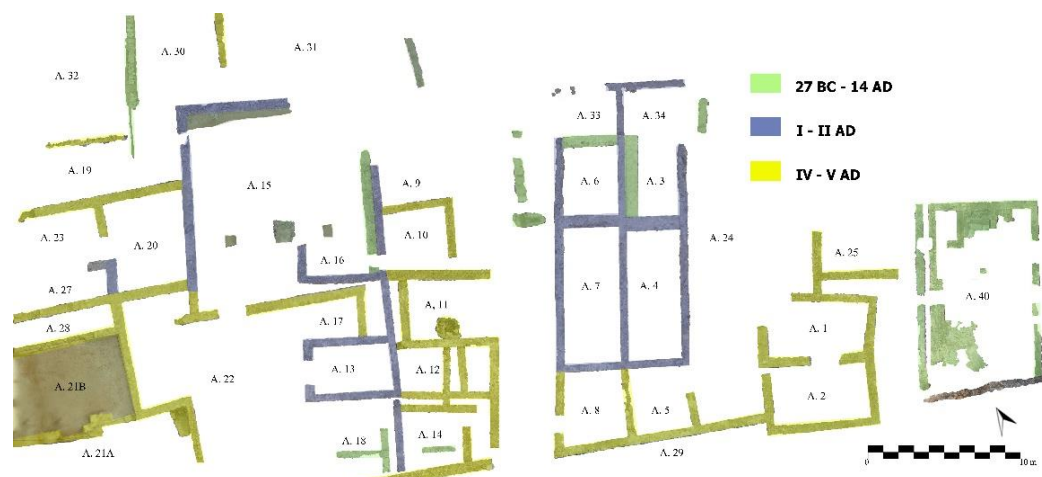


Figure 19. View of the structures exhumed in the *Portus Illicitanus* plot, in which those belonging to each chronology are marked in colour. It shows an alignment of blocks extending along the same terrace flanked by two roads [11] (p. 121, Figure 3).

We also found that there is a similar distance between the southernmost alignment and the signal that forms the northern boundary of Set 1 (Figures 4, 6b, 13a and 20). The same is true if we measure the distance between the northern alignment of Set 3 and the large disturbance immediately south of Set 4 (Figures 4, 13a and 20). The various excavations carried out in this Roman port reveal that its buildings adapt to the morphology of the terrain, giving rise to a succession of elongated platforms parallel to the coastline. These stepped terraces slope down towards the sea and are separated from each other by roads [11] (p. 120). We could therefore be looking at an indication that this model of terraced urbanism also reached the area of the Roman harbour currently located under Mercado de Viguetes.

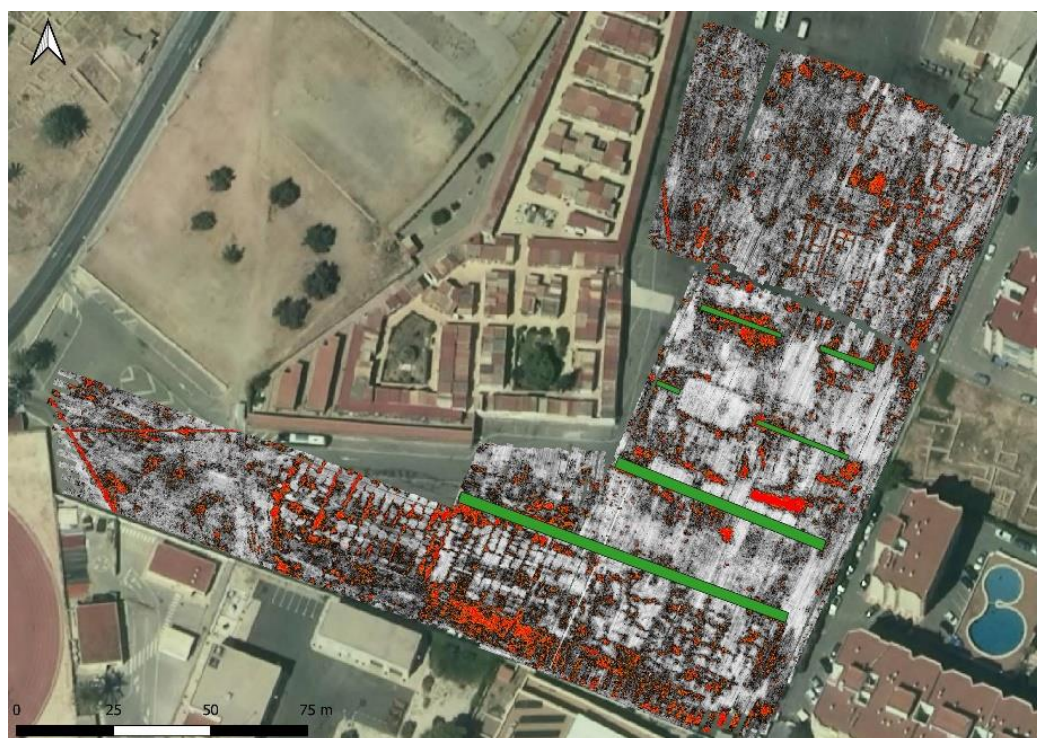


Figure 20. View of the study area showing in green a series of parallel alterations belonging to different sets separated by a regular distance.

The archaeological surveys carried out in 2004 in the interior of Set 3 brought to light a series of structures with a marked N–S orientation (Figure 21b), similar to that corresponding to the Late Imperial period in the *Portus Illicitanus* plot (Figures 13b and 19) and to that observed in several of the alterations recorded by the georadar in this part of the study area (Figures 4, 7 and 13a, blue; Figure 21a). Among the findings of this archaeological intervention, a basin from the end of the 3rd century AD dedicated to the production of salted fish, depreciated at the end of the 4th century or at the beginning of the 5th century AD, stands out [15] (p. 266). The evidence associated with the production of salted fish, although scarce, is of great interest. They are contemporary with the *cetaria* from the nearby site of La Picola [5–8], which would show the existence of several centres dedicated to this same activity in the *Portus Illicitanus* during the Late Empire.

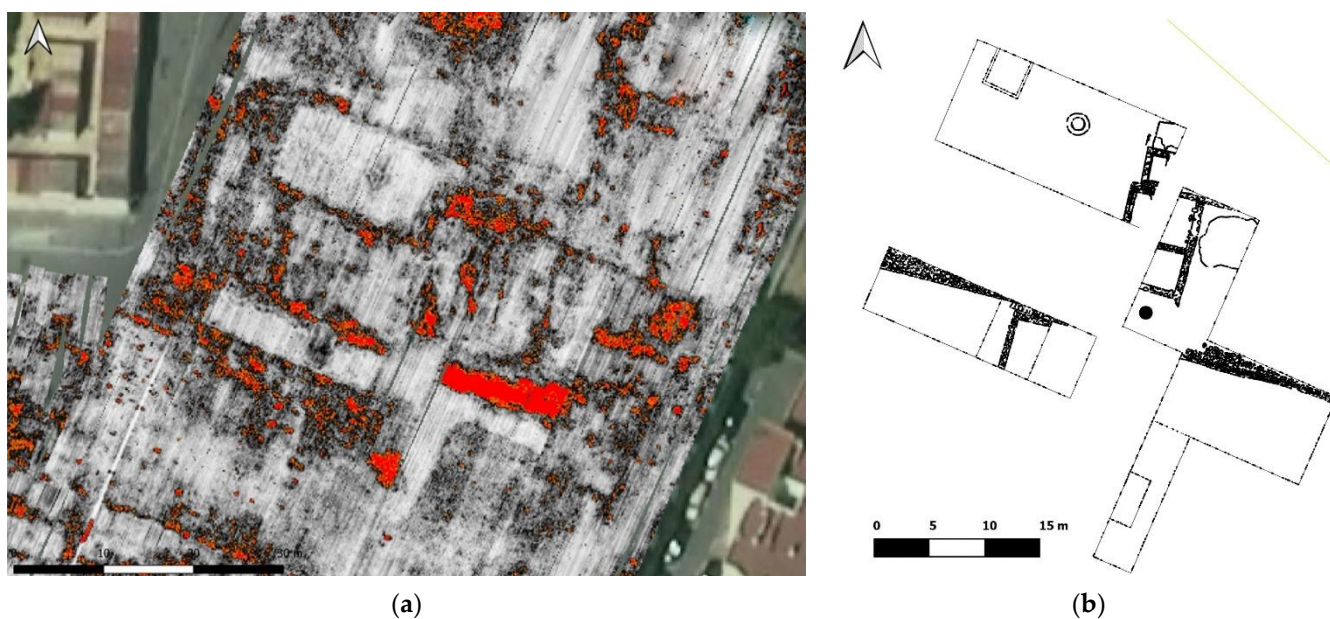


Figure 21. (a) Detailed view of the central part of the study area showing the different alterations of Set 3 at -0.89 m. (b) Plan of the archaeological soundings carried out in the central part of the study area in 2004 showing the documented structures [42] (p. 23).

In the case of the alterations recorded in Set 4, all of them with a clear NW–SE orientation that can be linked to the Early Imperial period (Figures 4, 10 and 13a, green), they delimit a series of spaces that can be related to a fish-salting production centre. While in Set 3, this identification is given by the results obtained from the archaeological surveys of 2004, in Set 4, it is the clarity of the signals captured by the georadar which leads to infer this possibility.

Indeed, it is possible to observe certain similarities in the signs of Set 4 with the layout of the La Picola *cetaria*. At its peak of development, the latter had a monumentalised entrance leading to a fish-cutting and cleaning room. It also had a courtyard associated with the decantation basins and a series of rooms, one of which had a mosaic floor [7,8] (Figure 22b). In the alterations corresponding to Set 4, a group of signs in the form of a grid can be discerned, which could correspond to a group of settling basins linked to a large open space or courtyard. There are also quadrangular spaces that could correspond to rooms of an undefined nature (Figure 22a). Although it is true that the La Picola *cetaria* is chronologically later than that suggested by the orientations of the alignments of Set 4, it is a very standardised type of production facility without major structural changes throughout the Roman period.

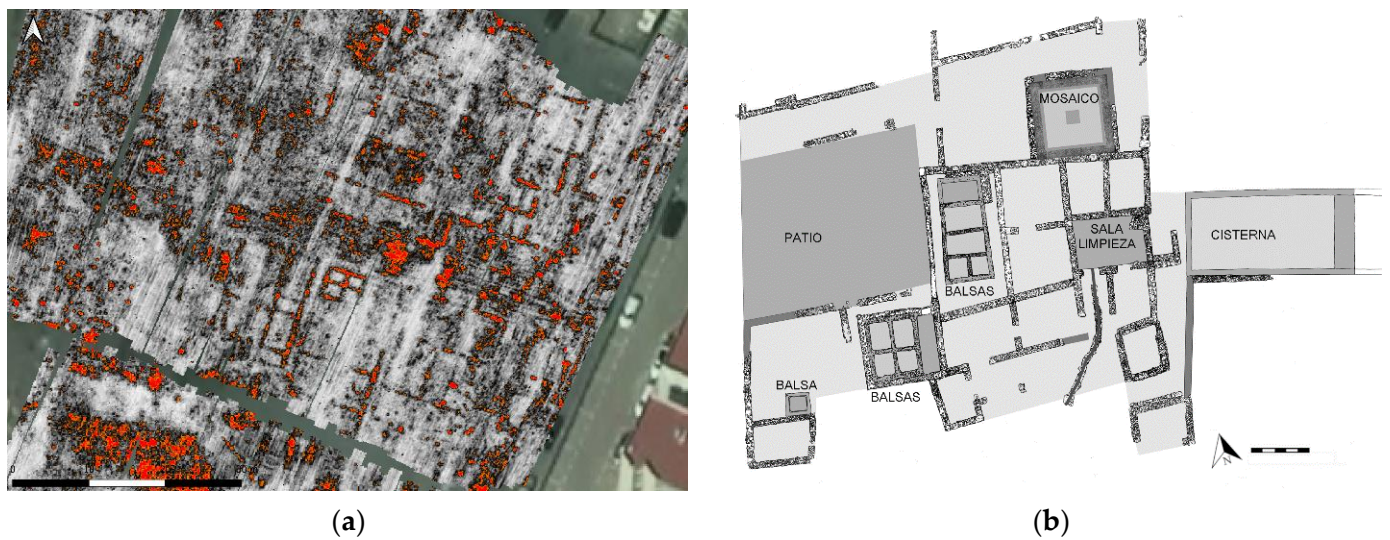


Figure 22. (a) Detailed view of the northern part of the study area showing the different alterations of Set 4 at -0.89 m. (b) Complete plan of the La Picola *cetaria* showing its main spaces and infrastructures [7] (p. 108, Figure 18).

5. Conclusions

The geophysical surveys carried out in the area of Mercado de Viguetes in Santa Pola reveal a set of structures that can be assimilated to a port area: dock, *horrea*, and decantation basins for the production of salted fish. Altogether, two predominant alignments can be observed that can be assimilated to the Early Imperial (NE–SW) and Late Imperial (N–S) construction phases. Although a certain alignment of the built spaces and a modular articulation of them can be observed, it does not seem that there is a rigid original planning in the form of an urban layout, given the slight differences in orientation that appear in the set and regarding the rest of the excavated areas of Santa Pola.

In conclusion, non-invasive archaeological methodologies have once again proved to be a powerful tool for the survey of the preserved building remains, and in the case of the *Portus Ilicitanus*, they have become the main resource for archaeological analysis and heritage protection in view of the current impossibility of carrying out archaeological excavations in this area of Santa Pola.

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