Mediterranean Archaeology and Archaeometry, Vol. 17, No 1, (2017), pp. xx-xx

Remote Sensing and Archaeology from Spanish LiDAR-PNOA: Identifying the Amphitheatre of the Roman City of Torreparedones (Córdoba-Andalucía-Spain)

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Received: 16/11/2016
Accepted: 20/12/2016
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ABSTRACT

Between 2015 and 2016 the Instituto Geográfico Nacional de España (Spanish Geographical Institute) made public the results of a LiDAR flight over the entire national territory. In the case of Andalucía, this flight was done between 2013 and 2014. Among its many applications, our goal was to highlight its use for aerial detection of unknown archaeological remains, which could be identifyed in other spanish roman cities similars to Torreparedones, where the amphitheatre seems has been indentificated by this methods.
A good number of the studies on aerial archaeology in Spain based on LiDAR PNOA (National Aerial Orthophoto Plan-acronym in Spanish) do not necessarily entail a subsequent surface exploration. Surelly, LiDAR-PNOA will be the only way of archaeological survey in many cases. For this reason, we are interested in adjusting the method to make this aerial exploration resource useful and reliable, as we expose it here.

KEYWORDS: LiDAR, PNOA, IGN, Aerial Archaeology, Roman Architecture, Torreparedones.

1. INTRODUCTION

The Spanish Geographical Institute made a General LiDAR flight between the years 2008-2014 within the National Aerial Orthophoto Plan[1]. Until the year 2016 the progressive access to the results was not possible for the case of the territory of Andalucía. Therefore, the use of their archaeological information is actually quite recent.

The technical specifications of the flight, among many issues, consider some point clouds that were captured with a density of 0.5 points/m^2, later classified automatically and coloured by RGB obtained from orthophotos of the National Aerial Orthophoto Plan (PNOA-acronym in Spanish) with a pixel size of 25 or 50 cm.

The distribution of layouts of 2x2 km is established in the archives. The geodesic system of reference is ETRS89 in the Peninsula, Balearic Islands, Ceuta and Melilla, and REGCAN95 in the Canary Islands (compatible with WGS84) and the projection is UTM in the spindle corresponding to each file. The altitudes are orthometric.

The downloading of the files is done from the catalogue of products from the Download Centre of the CNIG[2]. The format is LAZ and the data are accompanied by some auxiliary files that include: a decompression tool and viewing of LAZ and LAS files, metadata, specifications and a file of dates.

LiDAR PNOA is characterised (Rodríguez Rico 2015, 271-194) by a low emission frequency and by signal weakness, which leads to low density values. These and other reasons draw attention to its suitability in its application with respect to the thematic accuracy in the sectors with vegetation, in the urban sectors or in the classification of the ground in the riverine woodlands. The low density of the information generates a great weakness, causing the algorithms not to work correctly. This causes not insignificant errors in these areas of application.

However, among its many virtues is also its use in detecting archaeological sites; especially for cases of considerable metric scale and little depth. In these cases LiDAR PNOA could allow significant "discoveries", as we will explain below.

The LiDAR products, MDT and Orthophotos from the database of the Spanish Geographical Institute are the basis for our work.

2. LIDAR PNOA, EXAMPLES OF APPLICATIONS IN ARCHAEOLOGY IN SPAIN: MILITARY CAMPS AND MEGALITHIC STRUCTURES

Due to their recent nature, there are still few findings of archaeological structures in Spain from the LiDAR PNOA data. In most cases, they have been used to verify structures already glimpsed by a previous aerial photograph. In others, however, less numerous, the LiDAR PNOA has certainly allowed discovering unknown structures. This is the case that concerns us.

The potentiality of the LiDAR in archaeology logically depends on the underlying micro-relief. Therefore, its use is especially advised in the study of Roman camps and prehistoric megalithic structures, due to the contrasts of relief in both cases.

In the case of the military camps of the region of Castilla and León (Costa-García Casal García 2015, 143-158), historic georeferenced orthophotography has been combined with the most recent orthophotography of the PNOA and the LiDAR PNOA point clouds. The case of La Chana (León) was done this way, which was discovered by E. Loewinsohn in 1965. Also, for the Valmaseda camp, discovered with aerial photograms by Sánchez Palencia in 1986. Lastly, also for the camps of Vegahoz-Los Llanos (Soria) and Huerga de Frailes (León).

The LiDAR PNOA has generally allowed in all these cases a detail in the spatial configuration which had not been counted on. Practically imperceptible structures can now be seen with greater enhancement in the DTM generated from the point clouds: this is the case of the *agger* (embankment) of Los Llanos camp.

However, the detection of ditches or trenches through the use of the LiDAR PNOA has been difficult if they are silted and the dirt has been tilled with mechanical means.

Finally, due to its low density, it is evident that LiDAR PNOA always has to be checked against the rest of the available orthophotos or surface explorations: this is the case of Los Llanos camp, where the LiDAR considers as a unit what in reality are fossa duplex (double trenches) that surround the camp.

In the case of the Area 2 of La Chana (Costa García 2016, 47-85), the LiDAR PNOA allows distinguishing perfectly the defensive perimeter of a camp that was being lost little by little with the development of the land. In the case of Area 3, the cuts or sections of the land show that it is completely levelled due to the agricultural work. By the structures not being represented consistently in micro-relief, the computer processing by means of filtering, lighting or visualisation tools is useless.

[1] www.pnoa.ign.es

[2] http://centrodedescargas.cnig.es/CentroDescargas/

On the other hand, the methodology of applying LiDAR PNOA in the detection of the megalithic architecture in Galicia has been very interesting (Carrero-Pazos Vilas Estévez Romaní Fariña Rodríguez Casal 2015, 39-57).

In the necropolis of Monte de Santa Mariña, the use of LiDAR PNOA along with the visual examination of the terrain has allowed the discovery of a new megalithic tomb to add to the known ones; even though this was possible after ruling out anomalies in the relief detected by LiDAR PNOA that corresponded in reality to simple accumulations of soil coming from the opening of dirt paths.

3. LIDAR PNOA IN A ROMAN CITY: TORREPAREDONES.

3.1. Initial topographical premises for the search of the amphitheatre

Torreparedones is an ancient Iberian (Cunliffe Fernandez 1995, 195-198) and subsequently Roman city (Márquez Morena De la Llave Ventura 2014) located today in an enormous olive grove (Fig. 1).

Figure 1. Archaeological site of Torreparedones. Roman forum.

Up to now, the examinations carried out were based on geomagnetic studies of the area within the walls. No aerial examination had been done in the territory. This is due to the fact that the high density of olive trees did not advise it. Therefore, at first, Torreparedones would not be the most suitable site for working with a low-density LiDAR flight: unless there were still surfaces uninhabited by olive groves. We focussed our search on these surfaces.

A Roman city is standard in its establishment (Gros 2011, 317-346) for which we abundantly know its theoretical formation, especially if it deals with a Roman colony, whose urban planning regulatory model is widely known (Gros Torelli 2014) Torreparedones seems to actually be the Virtus Iulia Ituci Colony (Ventura 2014, 38-41), which was superimposed on the ancient Iberian city existing since the 6th century B.C.

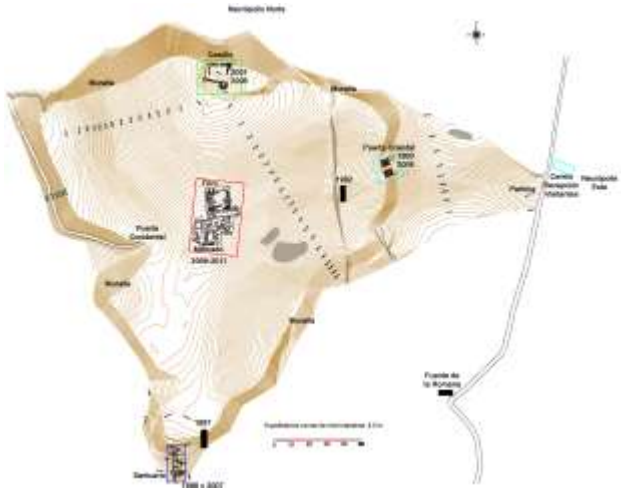

Figure 2. Map of the City of Torreparedones. Roman forum (©Márquez *et al.*, 2014).

As a Roman city, foreseeably a colony, it has the essential architectonic components: forum, temples, basilica, curia, market, domestic architecture and streets. Normally roman colonies have a theatre and an amphitheatre and, sometimes, a circus. These buildings have some positioning rules that are widely known in the Mediterranean Roman world.

In Torreparedones the layout of the wall and the positioning of the Forum, the temple and the Curia (which are superimposed on a prior ancient Iberian area) are well known. And nearly all the street layouts are also known thanks to the geophysical examination and the archaeological excavations. But the location of the theatre and of the amphitheatre is unknown. (Fig.2).

As it deals with a small city, of only 11 hectares, it is probable that the theatre could be located within the wall. But never the amphitheatre, because it is a building of enormous size for whose construction numerous pre-existing Iberian and Roman houses would have to have been destroyed. The amphitheatres, in cities that were founded on other previous ones, are usually outside the city walls (Welch 2007)

Finally, Torreparedones is located on an abrupt slope that only allows three access gates to the city. The North, which is the most difficult and slanted access, in which the presence of any construction is not advised. The East, which communicates Torreparedones with the area of Obulco and which was the principal access of rolling traffic to the city. And finally the West, which communicates Torreparedones with the other two nearby Roman colonies: Patricia Corduba Colony (Córdoba) and Cla

ritas Iulia Ucubi Colony (Espejo); therefore, this is the sector with greatest representativeness of the city. The amphitheatre had to be next to a gate, at the exit of the city and only the East or West gates were appropriate sites.

3.2. *The identification of the amphitheatre*

In the first place, we downloaded the file PNOA_2014_AND-NE_378-4180_ORT-CLA-COL from the download centre of the CNIG. We then generated immediately the DTM in ascii format from Globalmapper. We applied the Gradient Shader filter (Fig. 3).

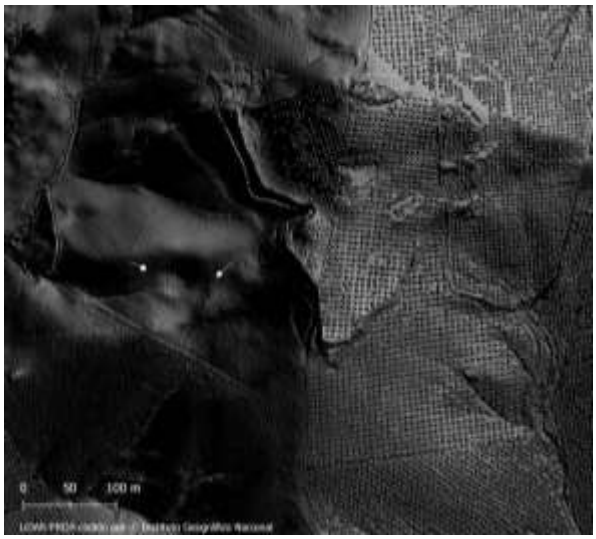

Figure 3. Torreparedones. Localisation of the Amphitheatre. Digital Terrain Model (DTM) processed with Gradient Shader filter-Globalmapper.

We also applied to the file the algorithms produced by the RVT (Ascii_HS_A315_H35_8bit)[3]. The 8-bit image, clearer and simple, resulted as an ideal complement for more evolved views (Fig. 4).

To the west of the city an elliptical depression was observed. The most important aspect is that contrary to the normal development of the contour lines, there is a slope contrary to the terrain that makes up the ellipse. We verified also in the 3D viewer of FugroViewer as well as in the filter ColorRampShader from Globalmapper that, in fact, there is an elliptical depression with larger slopes in its contours and a depression in the centre. The north contour, in UTM coordinates (WGS89), is situated between 505.908 and 513.574 m.a.s.l., having an 8 m difference. The south contour is situated between 503.504 and 512.586 m.a.s.l, having practically the

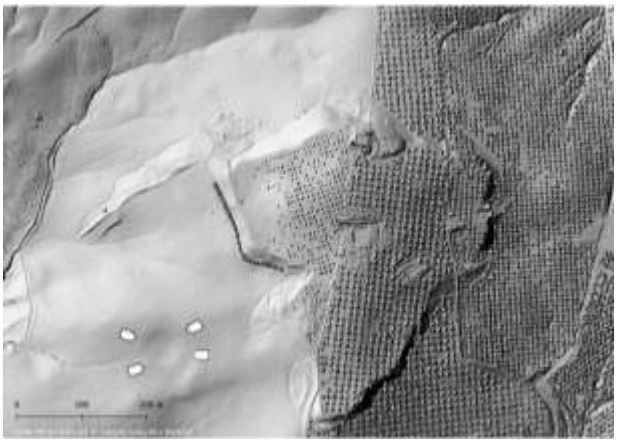

Figure 4. Torreparedones. Localisation of the Amphitheatre. DTM processed with Relief Visualization Toolbox (RVT).

same difference in level. The empty oval space between both is situated between 503.163 and 505.494 m.a.s.l. It is clear, therefore, that there exists a "river bed" with similar and constant altitudes on its two sides and a depression that only has around 2 m of difference in level. Therefore it is around 8 m deeper than the highest preserved sector.

There is no doubt that we are viewing a depression of an artificial oval shape, an amphitheatre, of around 79 m in the SW-NE major axis and 64 m in the NW-SE.

A more forced view of this depression can be seen applying the SlopeShader filter of Globalmapper to the DTM in both its 2D view and its 3D view (Fig. 5).

The next step was to verify the visibility of this depression in the aerial orthophoto from the PNOA. In Spain the oldest flights are the American flights of 1946 and 1956: in the 1956 flight our building is already observed slightly.

From that date up to the present, the Torreparedones site has been completely planted with olive groves. For this reason the visibility of buildings from aerial photography is very complicated.

However, within the collection of orthophotos of the PNOA, the flights of 2009 (Fig. 6) are of special interest because the western area of the city was still free of groves. Today this area is completely covered. At 200 m from the west gate of the city, a series of crop marks of a general elliptical layout are observed. In the lower area of this ellipse, there are also some traces in the cultivation of radial walls of the Amphiteatre.

All these traces are in ochre colour, not in green as the rest of the field, that is to say, of dry cultivation in an area of wet cultivation, which clearly indicates that under them there has to be archaeological structures that impede the normal

[3] Developed by Klemen Zakšek, PhD, Assoc. Prof. Krištof Oštir, PhD, Peter Pehani, Klemen Čotar. Institute of Anthropological and Spatial Studies. Research centre of the Slovenian Academy of Sciences and Art: http://iaps.zrc-sazu.si/en/rvt#v.

Figure 5. Torreparedones. Localisation of the Amphitheatre. DTM in 3D generated from *las.* file processed with Slope Shader filter-Globalmapper.

Figure 6. Torreparedones. Localisation of the Amphitheatre. Crop marks identifying the oval perimeter of the Amphitheatre and the radial walls in PNOA Orthoimage 2009.

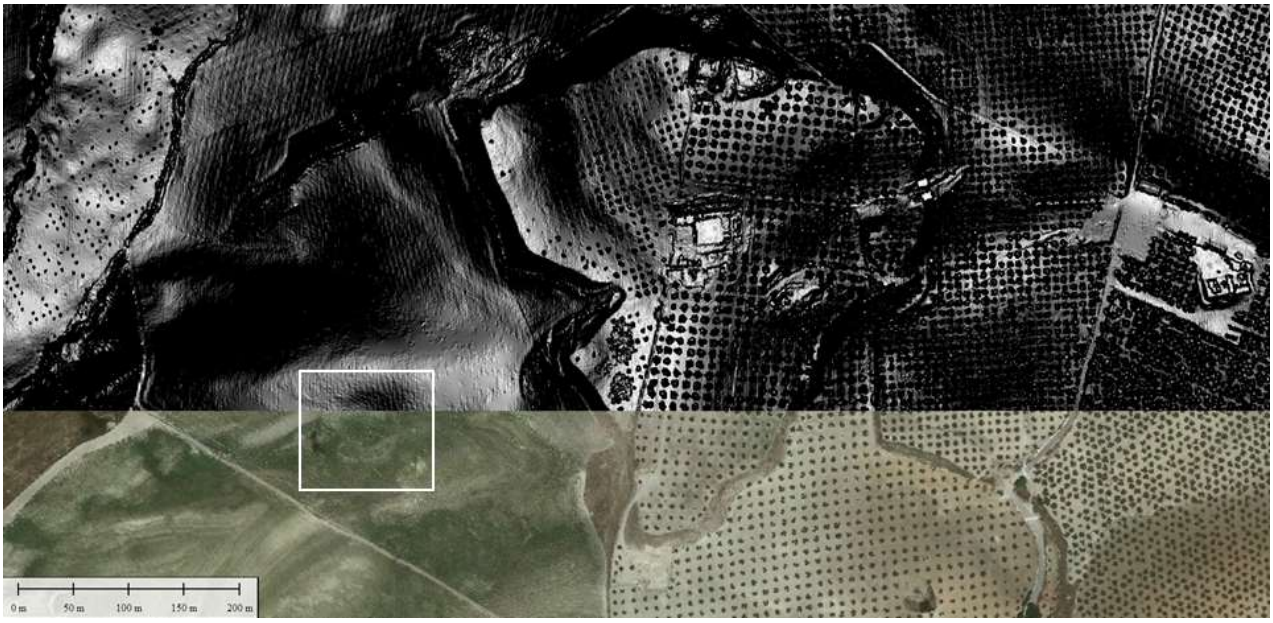

Figure 7. Torreparedones. Amphitheatre. Orthoimage PNOA 2009 and DTM 2D in Slope Shader filter-Globalmapper.

growth of the vegetation, with it having less vigour and showing greater dryness. Naturally, it must be the radial walls that support the cavea (spectator sites) of the amphitheatres. That is the simplest interpretation.

To verify it, in the first place we have juxtaposed in Globalmapper the 2D image of the PNOA 2009 orthophoto with the DTM LiDAR PNOA (Fig. 7). In the second place, in 3D, we have superimposed the orthophoto of the PNOA 2009 on the DTM generated by LiDAR PNOA and the result is fully satisfactory (Fig. 8).

As can be noted, one can observe perfectly:

a. The peripheral ellipse of the amphitheatre.

b. The radial walls that support its cavea.

c. Even part of the external sector of radial walls are observed, where two of them are noted.

The building is preserved, therefore, in the elevation in the area of the stands, only covered by a layer of soil, as the photos with UAV taken in November 2010 allow glimpsing (Fig. 9). Therefore, it is completely recoverable as cultural heritage in all its extension. Its state of preservation at least reaches 8 m of height. It is worthwhile, therefore, to undertake its archaeological excavation, study and enhancement, as a first-rate complement for the Roman city of Torreparedones.

4. CONCLUSION. LIDAR PNOA IN TORREPAREDONES.

The LiDAR PNOA 2014, although characterised by its low density, has allowed in Torreparedones the detection of a completely buried building even in land used for cultivation with moving of soil. This is not usual. In Torreparedones the explanation resides in the fact that this soil movement and planting has not completely altered the micro-relief of the area: therefore, the amphitheatre could be detected. It is a

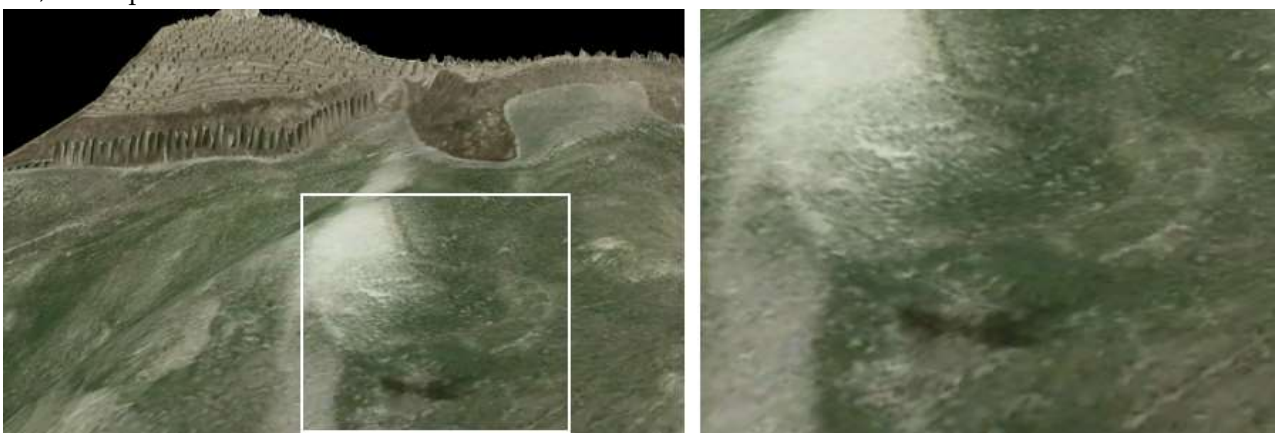

Figure 8. Torreparedones. Amphitheatre. Orthoimage PNOA 2009 superimposed to DTM 3D. Crop marks identifying the oval perimeter of the Amphitheatre and the radial walls.

truly fortunate case.

In the PNOA's orthophotos, the trace of the amphitheatre is gradually lost from that of 2009 up to the present due to the planting of fruit trees.

The combination of the LiDAR PNOA with PNOA Orthophotos, sometimes allows, therefore, being able to carry out aerial archaeology with utmost precision. However, this case is an exception due to various reasons: due to this Roman city being preserved in an exceptional state of conservation, due to the building being in an agricultural area and due to not having undergone an acute land clearance process. This fortunate case should not be considered a rule. We believe, however, that this methodology can help in the detection of cases of similar characteristics in similar contexts. For the Roman cities of Hispania located in agricultural environments, this method can, without doubt, be advantageous.

For the Roman city of Torreparedones, knowing the existence of an amphitheatre reinforces the idea of its colonial status. And, in turn, it places it in the reduced number of cities of Hispania and the Baetica that have an amphitheatre. In the Roman Baetica, only in Cordoba, Carmona, Écija, Berga (and now Torreparedones) we know the localisation of the amphitheatre (Jiménez 2015, 127-148).

This amphitheatre, like in the capital of the province, Corduba, is located on a frequented access road to the city, the western road, which in this case connects with Ucubi, Ategua and Corduba. Due to its position outside the city, this building must not belong to the period of its first construction, which in Torreparedones was concentrated in the construction of the central sector of the city between the Periods of Augustus and Tiberius. It must deal with a building that came after these works, when the city was also a leader in the territory. Surely it must be dated in the final era of the Flavian emperors (or the start of the Antonine dynasty), after Vespasian's proclamation of Roman citizenship, which would make numerous oppida (settlements) near Torrepardeones Roman. And whose citizens would go to this "territorial building" on days of games.

In the 2nd century A.D., this building would stop being used, like the entire city, and only barren land or agricultural land would superimpose it: until approximately 1800 years later, when a beam of light from a laser sensor (LiDAR) detected the micro-relief of its lost memory.

Figure. 9. Torreparedones. Amphitheatre. Oblique image by UAV in 2010 (Thanks to José Antonio Morena).

ACKNOWLEDGEMENTS

We thank the anonymous reviewers for their consideration to this work. Also, we thank José Antonio Morena (Responsible of the Torreparedones Archaeological Site), Prof. Carlos Márquez and Prof. Angel Ventura (Researchers of the Roman City of Torreparedones-University of Cordoba) for their comments.
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This work was supported by the Ramon y Cajal Programme (RyC 2010 11035) funded by the Spanish Ministery of Research (MINECO).

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