

AERIAL ARCHAEOLOGY AND PHOTOGRAMMETRIC SURVEYS ALONG THE ROMAN WAY FROM *CORDUBA* TO *EMERITA*. DIGITALIZING THE *AGER CORDUBENSIS* AND THE *AGER MELLARIENSIS*

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Abstract

The aim of this research project (Project *Ager Mellariensis*. Córdoba University¹) is the archaeological documentation, scientific research and enhancement of the roman town of *Mellaria* and its landscape. This work focuses on archaeological data related to the road connection between *Corduba* and its administrative district - the *Conventum Cordubensis* - with *Mellaria*. Along the 85 km among *Corduba* to *Mellaria*, this road axis archaeological studied here for the first time. We describe the two methods of our archaeological research. In one hand, where the path of this way isn't visible on the ground, we searched it using the aerial orthophotos of the National Aerial Orthophoto Plan (PNOA-acronym in Spanish), combined with our thermal ortophoto taken by Quantalab-CSIC². In the second hand, where this way is preserved, we started photogrammetric surveys to clarify its engineering technique, its different angles of slope and its general orographic problems to pass from 110 m.s.l to 550 m.s.l in 11 km.

Keywords

Archaeology, Photogrammetry, Remote sensing, Roman road, *Corduba*, *Augusta Emerita*, *Mellaria*

The current studies of roman roads focus normally on bridges, aqueducts and other significant constructions along the path. The research of the properly lane, instead, is trascurated by a metric and physic point of view. The crop-marks visible on the aerial photos are normally the main resources. In this work, the methodological innovation consists in the integrated research between photogrammetric surveys and aerial thermal teledetection (Monterroso, Zarco, Hornero, Yuste & Vargas, 2017 Forthcoming), to improve the volumetric characterization of this road. Therefore, we consider not only its path but also its physical development.

1. From *Corduba* to *Mellaria* and *Lusitania*.

Mellaria is in the ancient Iberian territory of *Beturia Turtula*³. This region includes the existing

territory between the valley of Guadalquivir River (*Baetis*), in Andalusia, and the valley of Guadiana River (*Anas*), in Extremadura (Fig. 1). In *Beturia Turdula*, belonging to the *conventus Cordubensis*, Pliny quotes *Mellaria* and others "oppida non ignobilia": *Arsa*, *Mirobriga*, *Regina*, *Sosintigi*, and *Sisapone*⁴.

Unfortunately, the sources don't give informations about the origin, the foundation and the urban planning of the town. Among the cities quoted by Pliny, only *Regina* and *Mellaria* have latin names. On the contrary it seems that *Arsa*, *Mirobriga*, *Sosintigi* and *Sisapo* preserved the ancient iberian names. It's possible to believe that the two towns of Latin name are two centres of Roman organization. About *Mellaria*, the artifacts lead to hypothesize the foundation at least at II century B.C.

¹ See www.mellariaromana.es

² See www.quantalab.ias.csic.es

³ Strab., *Geog.*, III, 1, 6

⁴ Plin., *Nat. Hist.*, III, 13

The ancient *Via Corduba – Metellinum* (then called *Via Corduba – Emerita* from the Age of Augustus) was the only “state” road that passed through this area and *Mellaria* was the first town of this route. Both the *Antonine Itinerary*⁵ and the *Ravenna Cosmography*⁶ quote *Mellaria* as the only existing town after the departure from *Corduba*. It seems clear that *Mellaria*, LII roman miles away from *Corduba*, was the main urban node in the northwest area, after the capital (Fig. 2). This road passed through the north side of the *Ager Cordubensis* and the neighbouring region - the *Ager Mellariensis*. The southeastern and northeastern territorial boundaries of *Ager Mellariensis* are well known, toward the current municipality of Villanueva del Rey, where the territory of *Mellaria* bordered the territory of *Corduba*⁷, and toward the municipality of Belalcazar, where *Mellaria* bordered *Baedro*⁸. It’s impossible instead clearly define the

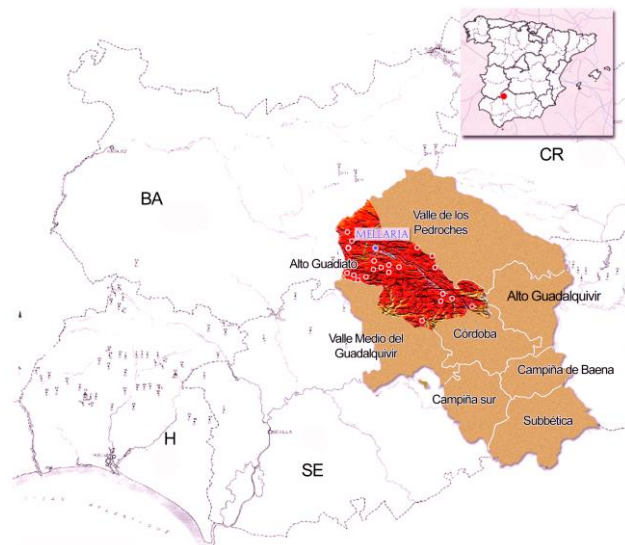


Fig. 1: Situation of *Mellaria* and *Ager Mellariensis*. Alto Guadiato-Córdoba-Spain. (Giuseppe Palmieri for © Project Ager Mellariensis).



Fig. 2: The landscape and emplacement of *Mellaria*. Cerro Masatrigo-Fuente Obejuna-Córdoba. (Antonio Monterroso with Girodinamics-Ela-Fuente Obejuna for © Project Ager Mellariensis).

⁵ *Itin. Anton.*, 415, 3-416,3

⁶ *Anon. Rav.*, 315, 265-270

⁷ The discovery of a milestone of the *Via Corduba-Emerita* in this municipality should mark the boundaries of *Mellaria* and *Corduba* (Stylow, Atencia & Vera, 2008, 428, n.57).

⁸ The attestation in this area of inscriptions talking about “*mellarienses*” should indicate the boundaries between the ancient lands of *Mellaria* and *Baedro* (Iglesias Gil, 1996).



Fig. 3: *Via Corduba-Emerita* along the *Ager Cordubensis* with the stretches that are analysed in this article (PNOA © Instituto Geográfico Nacional. Fomento Ministry. Gov. Of. Spain).

northwestern and southwestern boundaries of the *Ager Mellariensis*. The minimum size of the region should be about 1192 km².

Out of the capital city of *Baetica*, the *Via Corduba-Emerita* – that went toward *Lusitania* and the Northwest of Spain – and the *Via Augusta* – that went toward East Spain and Rome – diverged at the bridge that crossed the Pedroches Creek. From this point the *Via Corduba-Emerita* climbed 440 meters of difference in height – from 110 meters MSL to 550 meters MSL – into 13 km. Twenty centuries later, at the end of 19th century A.D., the Córdoba-Almorchón-Belmez Railway was built along the same path of the ancient roman road: at that moment, it was the 2nd european railroad in difference of height.

Now we will start to discover the structure of a roman major public building project: this road was realized by the proconsuls' armies who lived in Córdoba, the capital of *Baetica*; the same proconsuls who fought against the Lusitanians, against Viriatus and Sertorius in two central

episodes for the history of Rome and that used this axis; the same proconsuls who, at the same time, exploited the fertile soil and the lead and copper mines of *Ager Mellariensis*. Pliny said that this copper was the most famous in Rome at his time (*summae gloriae nunc in Marianum [aes] conversa, quod cordubense dicitur*)⁹: all these things reached Córdoba down the *Via Corduba-Emerita* and from the capital of the Province they reached Rome by sea.

Along this route also Caesar and Agrippa came from *Lusitania* to *Corduba*.

2. The *Via Corduba-Metellinum-Emerita* in the *ager Cordubensis*

Few archaeological evidences about the road are preserved (Fig. 3), but by these data it's possible understand that the ancient roman road was almost entirely a *glareata strata*, except for the stretch that climbed the so-called slope of "Loma de los Escalones" – near Cerro Muriano –

⁹ Plin., *Nat. Hist.*, XXXIV,4.



Fig. 4: Pedroches Bridge. Córdoba (Antonio Monterroso for © Project Ager Mellariensis).

where the road was realized excavating the rock formation of the mountain (Melchor Gil, 1993, 1995).

Very few road infrastructures are preserved and they are all related to three bridges that crossed the creeks Pedroches, Pradillos and Linares (Melchor Gil, 1993, 1995).

2.1 Pedroches Bridge

The starting point of this road in Córdoba is well known and corresponds to the Pedroches Bridge (Fig. 4). In his study, Ferrer Albelda (2002) tries to resolve the problems about the dating of the bridge. After his archaeological excavations, the author dates it between the Tiberian Age and the Age of Domitian.

This bridge therefore was built in a late period of the road, that was used by roman armies since the 2nd century B.C.: it's probably that from that time already another path existed nearby, or there was a wooden bridge or, more simply, a ford allowed to cross the Pedroches Creek.

Between the Pedroches Creek and the locality of Cerro Muriano the structure of the road is very well preserved. It isn't possible recognize the first stretches of the road out of Córdoba, because they are covered by the modern residential areas of the city; from the third mile instead, the good preservation of the road surface (Fig. 5) has allowed to organize survey campaigns that were focused on the digitalization of the roman structures through close-range photogrammetry technique and Structure From Motion methods



Fig. 5: Structure of the rock-cut road between Córdoba and Loma de los Escalones (Antonio Monterroso for © Project Ager Mellariensis).

(SfM) (Luhmann, Robson, Kyle, & Harley, 2011; Torres, Arroyo, Romo, & De Haro 2012) and on the study of the building process, of its destruction and its medieval reuse as "Cañada Real" that was a path used during the Winter to allow the transhumance of flocks of sheep from Castile to the South of Spain. All these research objectives can be solved by this currently in progress process of digital documentation.

2.2. The "Loma de los Escalones": way and quarries

The *Via ad Emerita Augusta*, along its entire route, must pass several natural obstacles and hard height differences in very few kilometres. One of these obstacles is the natural step of Sierra Morena, at North of Córdoba: here the roman engineers had to face a rugged orography and they had to cross these reliefs realising a lot of stretches of the road excavated in the rock formation.

A long stretch is preserved, as stated above, in the so-called area "Loma de los Escalones" (Fig. 6 a-b-c): in this point the road has been putted in the middle of an ancient terraced sandstone quarry, that was placed on the slope of the mountain and it was approximately 4 metres high. Here again it's possible to look the mark of the extracted stone blocks.

The rugged orography of the area, the dense wooded blanket and the strongly different brightness of shadowy and sunny areas were the hardest problems that we must face and to solve to realise a good photogrammetric survey of the road: they prevent the use of canonical UAV systems (Ummaned Aerial Vehicle), that are useful



Fig. 6 a-b-c: Loma de los Escalones. Roman way and roman quarries. (Antonio Monterroso and Katia Polevkina for © Project Ager Mellariensis).

for aerial survey and high-quality digitalization of large areas. It has been therefore necessary to resort to a compromise solution, which could be economically advantageous and harbinger of good results.

We decided to carry out a photogrammetric survey at ground level, using a telescopic rod of fibreglass and placing at the top a Digital single-lens reflex (DSLR) Canon EOS 1100D (APS-C sensor with a resolution of 12.2 mpx), without encountering stability problems (Fig. 7a).



Fig. 7 a-b-c: Loma de los Escalones. Phases of the photogrammetric survey (a-b) and topographic survey (c) (Antonio Monterroso for © Project Ager Mellariensis).

Due to the need to digitalise both the road and the quarry, it was necessary, at first, to take pictures for the photogrammetric model of the road surface and then those ones relating to the quarry. The pictures about the road are taken at a height of 3.5-4 m along a grid of 1 m x 1,5 m; those ones focused on the quarry are taken at the heights of 0,70 m, 1,70 m, 2,70 m and 3,70 m at a distance of 4 m in front of the quarry and moving the camera along a grid of 2 m (Fig. 7b).

The camera's settings were: focal length of 18 mm (28.8 mm equivalent to 35mm format), ISO 100 and F-stop 8. These settings permit us to ensure a good ratio between speed of execution and quality of the survey.

Due to the different brightness encountered in this wooded area, the pictures were saved as RAW



Fig. 8: a) Part of the dense point-cloud with polyline sections by photogrammetric survey of the Loma de los Escalones; b) detail of the roman road surface and the quarry by dense point-cloud (Massimo Gasparini for © Project Ager Mellariensis).

files and then post-processed to restore a good brightness that allows a better photogrammetric processing.

The examined areas were also subject to land survey: before the phase of image-capture, black and white targets were placed to the ground and these ones were detected by a total station TopCon OS 103 (Fig. 7c). In this way, it was possible to connect all the photographs at the same local reference system and this allows the correct scaling and orientation of the point clouds

generated by the automatic data processing: 2800 photos were taken; 2500 of these were good to generate the point-cloud. The photogrammetric workflow was launched using the open-source software VisualSFM¹⁰ and the commercial software Agisoft Photoscan¹¹. The huge amount processing data didn't allow to obtain good results with VisualSFM; on the other hand, Agisoft Photoscan generated a very satisfactory dense cloud. Anyway, it wasn't possible reproduce

¹⁰ <http://ccwu.me/vsfm/>

¹¹ <http://www.agisoft.com/>

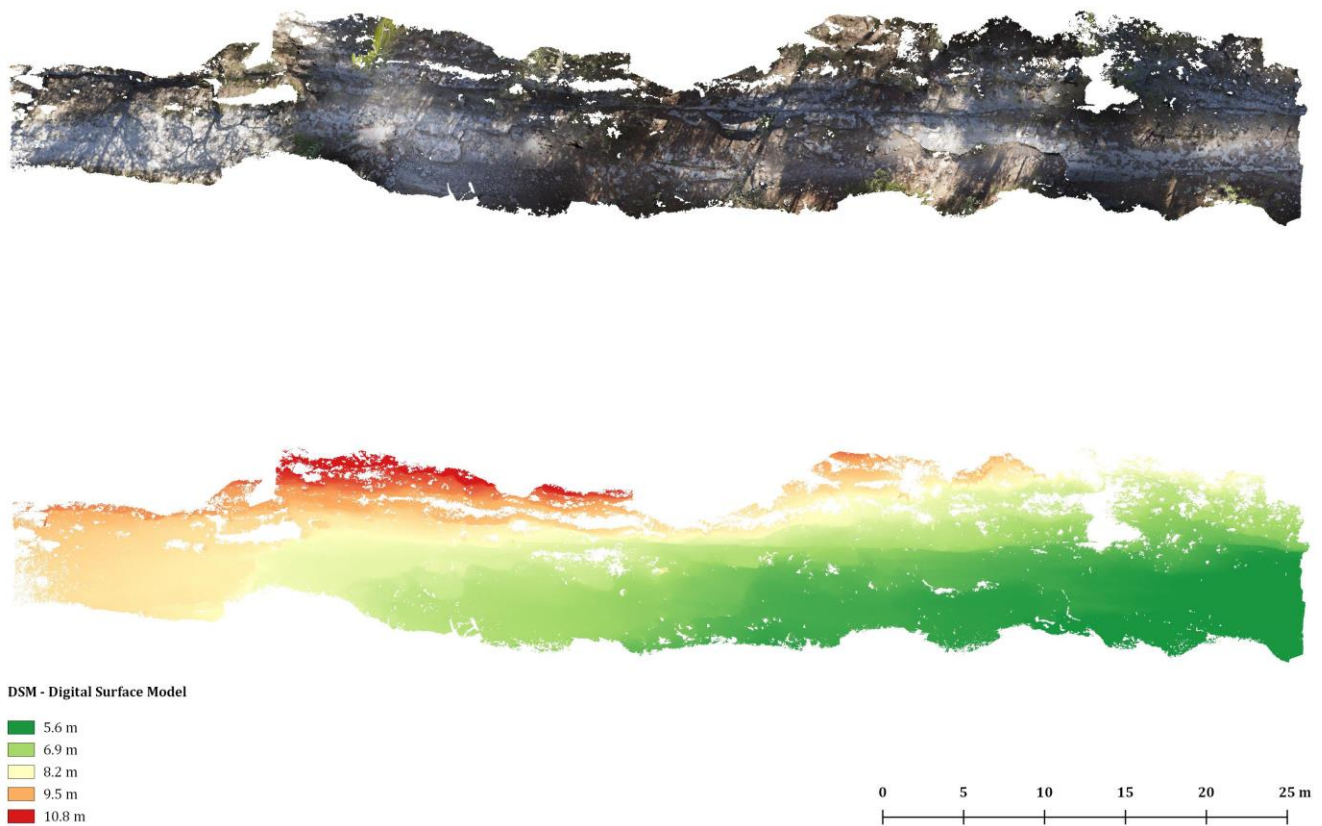


Fig. 9: Orthoimage and Digital Surface Model of the segment of roman road in Fig. 8 realized from dense point-cloud (Massimo Gasparini for © Project Ager Mellariensis).

several parts of the quarry, because the wooded blanket totally covers part of it.

The pictures were divided into 6 chunks; then these ones were aligned and merged thanks to the Ground Control Point previously detected in each photo where they appeared (Fig. 8-9). We have so obtained only one dense point-cloud of 680.000.000 points with a Ground Sample Distance (GSD) of 1.5 mm/px. Thanks to this raw data, it was possible estimating that this road stretch has a length of 400 m and an average width of 3,5 m. The difference of heights between its two extremes is 29 m (7% of mean slope, Fig. 10).

2.3. The way in the top on the Mons Marianus

At its highest point, the roman road comes to the top of the ancient *Mons Marianus* (Fig. 11 a-b). These mountains take the name from *Sextus Marius*, Tiberius's friend and then condemned by him. *Sextus Marius* was owner of all the mines of this area of the *ager Cordubensis*; he was, as Tacitus said, the richest man of *Hispania* and he used the

Via Corduba-Emerita to transport his mineral resources.

In this area, the research, now, is focused on the very difficult topographic survey of the path of the roman road and on starting the photogrammetric survey of the stretch that climbs and goes down the Torre Arboles mountain towards Cerro Muriano. It was possible until now digitalize only a little part 30 m long using the same technique and camera settings employed during the digitalization of the "Loma de los Escalones".

From here, where the plain starts, the road disappears, or rather, we must to search it. In the area of the locality of Cerro Muriano, according to the studies of Melchor (1995) and Sillières (1990), it's possible that the road goes in parallel with the modern national road N-432a. Along this axis, around the 30th mile of the route, it's also possible that the road flanked the El Vacar medieval castle.

However, like we said before, this road was rehashed in Medieval Age. It is necessary a careful archaeological analysis on all the described

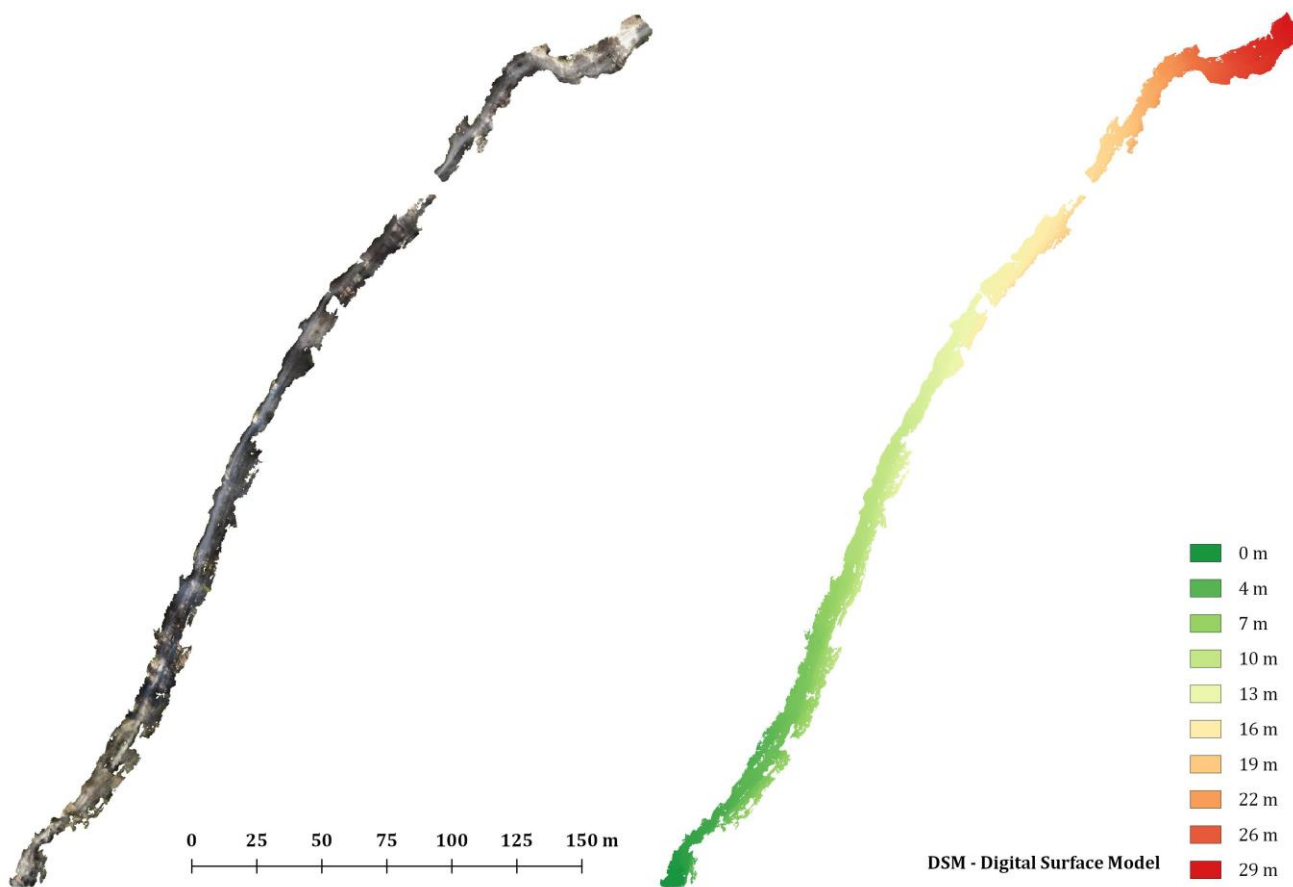


Fig. 10: Orthoimage and Digital Surface Model of the entire photogrammetric survey of the *via Corduba-Emerita* in the Loma de Los Escalones (Massimo Gasparini for © Project Mellaria).

stretches of the *via Corduba-Emerita*, because the old studies about the road are focused on the historical continuous use of the *via* during the centuries.

3. *Via Corduba-Metellinum-Emerita* in the *ager Mellariensis*

In the municipality of Villanueva del Rey, on the right side of Guadiato River, a milestone of the

Age of Constantinus (Sillières, 1990) was discovered and probably it marked the boundary between the lands of *Corduba* and the lands of *Mellaria* (Fig. 12).

Furthermore, this milestone shows that in the late roman period the road continued to be in use. We must remember that *Augusta Emerita*, end of the road, in the 4th century A.D., under Constantinus, is a thriving capital city: in this century (Arce, 1992) it becomes capital of *Diocesis*

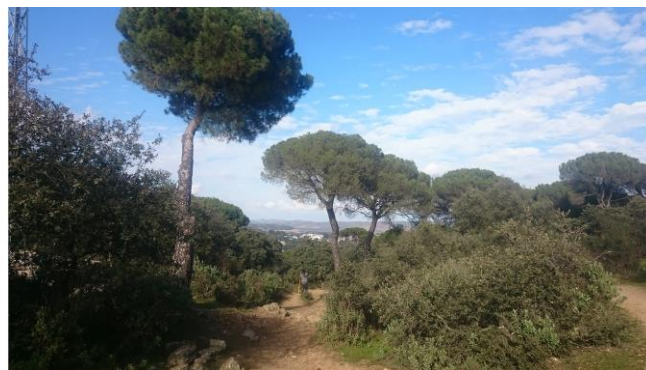


Fig. 11 a-b: A.- *Via* in the top of *Mons Marianus* (to South). B. *Via* in the top of *Mons Marianus* (to North). (Antonio Monterroso for © Project Ager Mellariensis).

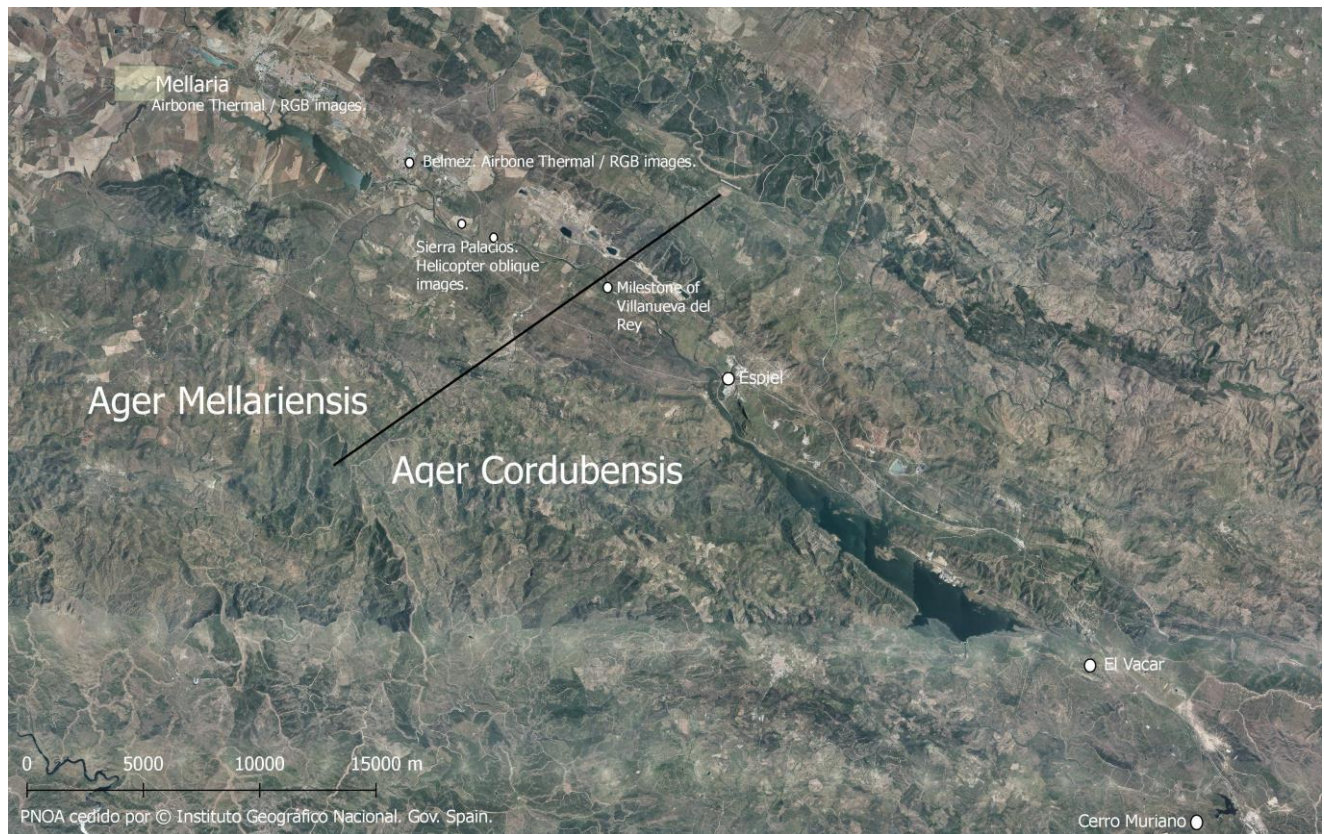


Fig. 12: *Via Corduba-Emerita* along the *Ager Mellariensis* with the stretches that are analysed in this article (PNOA © Instituto Geográfico Nacional. Fomento Ministry. Gov. Of. Spain).

Hispaniarum and, for example, new architectural decorations and mouldings were employed in several famous buildings, as the theatre.

3.1. From Villanueva del Rey to Sierra Palacios. Paramotor and helicopter oblique RGB photographs acquisition (With Cordobavuela and Girodinamics-ELA-Fuente Obejuna)

Knowing the exact point where the milestone was discovered, several aerial surveys (both with paramotors and with helicopters) were performed, with the aim to locate the path of the roman road. All the ancient and modern maps, the medieval routes and the place names of the area have been analysed, in order to not get wrong the identification of the paths.

From these photos (Fig. 13-14), it's possible observing a long straight line, clearly identifiable in the vegetation: this is probably a stretch of the roman road *Corduba-Emerita* (straight in our photo).

Other path overlaps with the roman road and probably it could be identified with the "Camino Viejo de Córdoba", a medieval branch of the roman road that from Belmez went to Villanueva del Rey

along the left side of Guadiato River and that crosses obliquely the roman *via* (on the right in our photo).

We can observe that the river runs in a direction transverse to the road toward Córdoba: around Villanueva del Rey, toward Sierra Palacios, a bridge had to exist and it had to permit to cross the Guadiato River.

Along the slopes of Sierra Palacios, another stretch can be identified in the cornfields and it can be referred to the *Via Corduba-Emerita* (Fig. 14).

3.2. From Belmez to Mellaria. Airborne thermal and RGB images acquisition (By Quantalab-CSIC and ZNIR Sensing Solutions).

Airborne data acquisition campaign was conducted on 2014-06-30 at 12 p.m. (UTC+01:00) with two sensors mounted simultaneous on board an aircraft (Cessna) flying at 250 m above ground level. The sensors implemented on board were:
 - Thermal camera (FLIR SC655; FLIR Systems, Inc.) has a resolution of 640x480 pixels, is equipped with a 13.1-mm f1.3 lens and is connected to a computer via USB2.0 protocol. The spectral response was in the range of 8–12 μm. The camera



Fig. 13 a-b: Possible identification of the roman way between Villanueva del Rey and Sierra Palacios - view to SE (Antonio Monterroso with Girodinamics-Ela-Fuente Obejuna and Cordobavuela for © Project Ager Mellariensis).



Fig. 14: Possible identification of the roman road between Sierra Palacios and Belmez. View to NW. (Antonio Monterroso with Cordobavuela for © Project Ager Mellariensis).

was calibrated in the laboratory (Quantalab; IAS-CSIC, Córdoba, Spain¹²) to obtain radiance values. A total of 5,133 images were acquired, covering an area of 2,350 hectares, divided into two zones 1,310 and 1,040 hectares respectively. Ortho-rectification and imagery mosaicking (by ZNIR¹³) were conducted applying Structure from Motion Methods (SfM) obtaining two thermal mosaics in kelvin degrees with a spatial resolution of (0.37 m/pixel).

- RGB sensor (NIKON D800E). A total of 3,473 images were acquired, covering an area of 2,350 hectares, divided into two zones 1,310 and 1,040 hectares respectively.

Ortho-rectification and imagery mosaicking were conducted as same as described in thermal mosaic, obtaining a very-high resolution ortho-photo and a digital surface model (DSM) with a spatial resolution of (0.036 m/pixel).

Belmez is located 15 km far away from the town of *Mellaria*. It is well known that in this area all the historical axes flanked the river and, after passing Sierra Palacios, they moved away from it, searching a path further upriver with the aim to not cross, using bridges, the several creeks existing

¹² See www.quantalab.ias.csic.es

¹³ See www.zetanir.com



Fig. 15: Aerial surveys in the town of Belmez. Positioning of 8 creeks toward *Mellaria* (PNOA © Instituto Geográfico Nacional. Fomento Ministry. Gov. Of. Spain).

on the left side of Guadiato River between Belmez and *Mellaria*. At least eight creeks flowing into the Guadiato exist in the proximity of Belmez, beyond Sierra Palacios.

The road had to cross, using fords, the closest points of the creeks (Fig. 15). We have try to identify the path of the road following these slopes and orographic conditioning.

In the area marked in the previous image, analysing the pictures taken by the RGB sensor during the aerial surveys, a dry field with spots of vegetation and without distinct marks of the road is visible (Fig. 16); but if we observe the pictures taken by the thermal camera (Fig. 17a), it's possible identify two parallel lines under the ground, that are 508 m long and that can correspond to the ancient road.

The thermal camera detects the soil moistures gathering on the side of the road (Fig. 17b): the roman roads, as well known, were designed to drain the rainwater to the sides, where therefore the soil moistures is much more than in the middle of the road. We believe that we have found the

path through these marks of soil moistures. The shortest distance between the two lines is 12 m: it could indicate the entire width including the “guard-rails” and the excavated trench where putting the road.

3.3. The arrival at *Mellaria*. Airborne thermal and RGB images acquisition (By Quantalab-CSIC and ZNIR Sensing Solutions)

We don't know surely from which part this road – coming from *Corduba* - entered *Mellaria* and where it continued toward *Metellinum*. There are two possible scenarios: or the ancient roman road followed the same path of the modern national road N-432 and then turning to the locality La Granjuela, or it flanked the right side of the Guadiato River entering the *municipium* from Southeast, close to the acropolis, the most important area of the town.

The aerial surveys have encouraged us to present the second hypothesis in other forums (Monterroso et al., 2017), but continue also to



Fig. 16: *Via Corduba-Emerita*. Plaza de Toros-Casas Baratas. Belmez. RGB orthoimage (Quantalab-IAS-CSIC & ZNIR Sensing Solutions for ©Project Ager Mellariensis).

support the first Monterroso, Gasparini, Palmieri, Cristo, Felipe, & Almoguera, 2015).

It's possible that, thanks to other remote-sensing surveys (especially multispectral imaging), we will can define in this land the path of the road from *Mellaria* to *Lusitania*.

The RGB sensors have revealed the presence of a road on the eastern side of the town area (Fig. 18). Considering that there aren't archaeological data demonstrating that the ancient town of *Mellaria* could occupy also this area, we can't verify if this is a structure of the *Via Corduba-*



Fig. 17: *Via Corduba-Emerita*. Plaza de Toros-Casas Baratas. Belmez. Thermal orthoimages (Quantalab-IAS-CSIC & ZNIR Sensing Solutions for ©Project Ager Mellariensis).

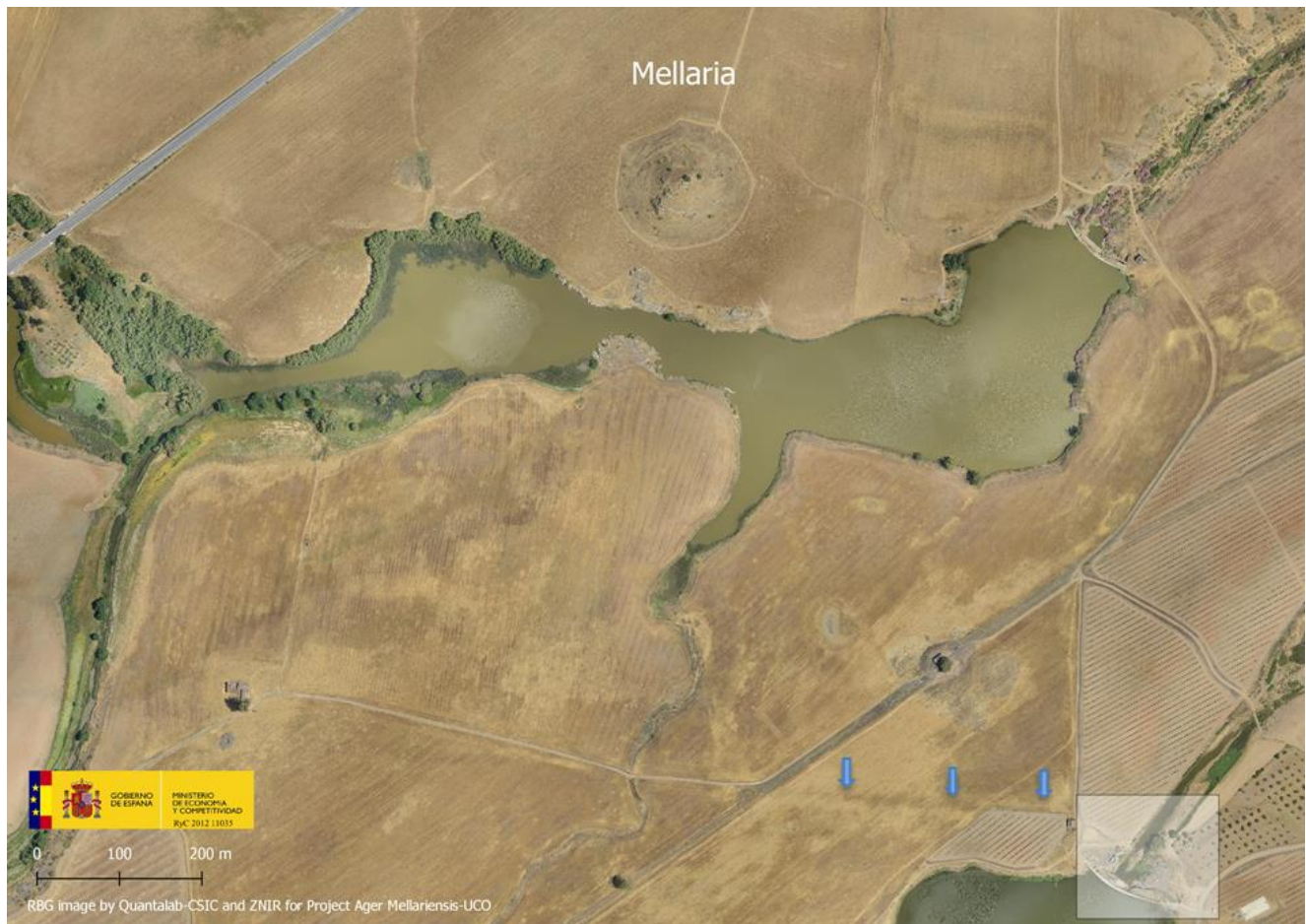


Fig. 18: Entrance in *Mellaria* of a road on the lower right corner of the picture across Guadiato River (Quantalab-IAS-CSIC & ZNIR Sensing Solutions for ©Project Ager Mellariensis).

Emerita or if it's related to a more ancient road. Maybe, as proposed by Enrique Melchor, on both sides of Guadiato River there were a main road and a secondary road.

It's necessary in the future verifying how the roads entered *Mellaria* and how they continued to the very near Province of *Lusitania*.

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