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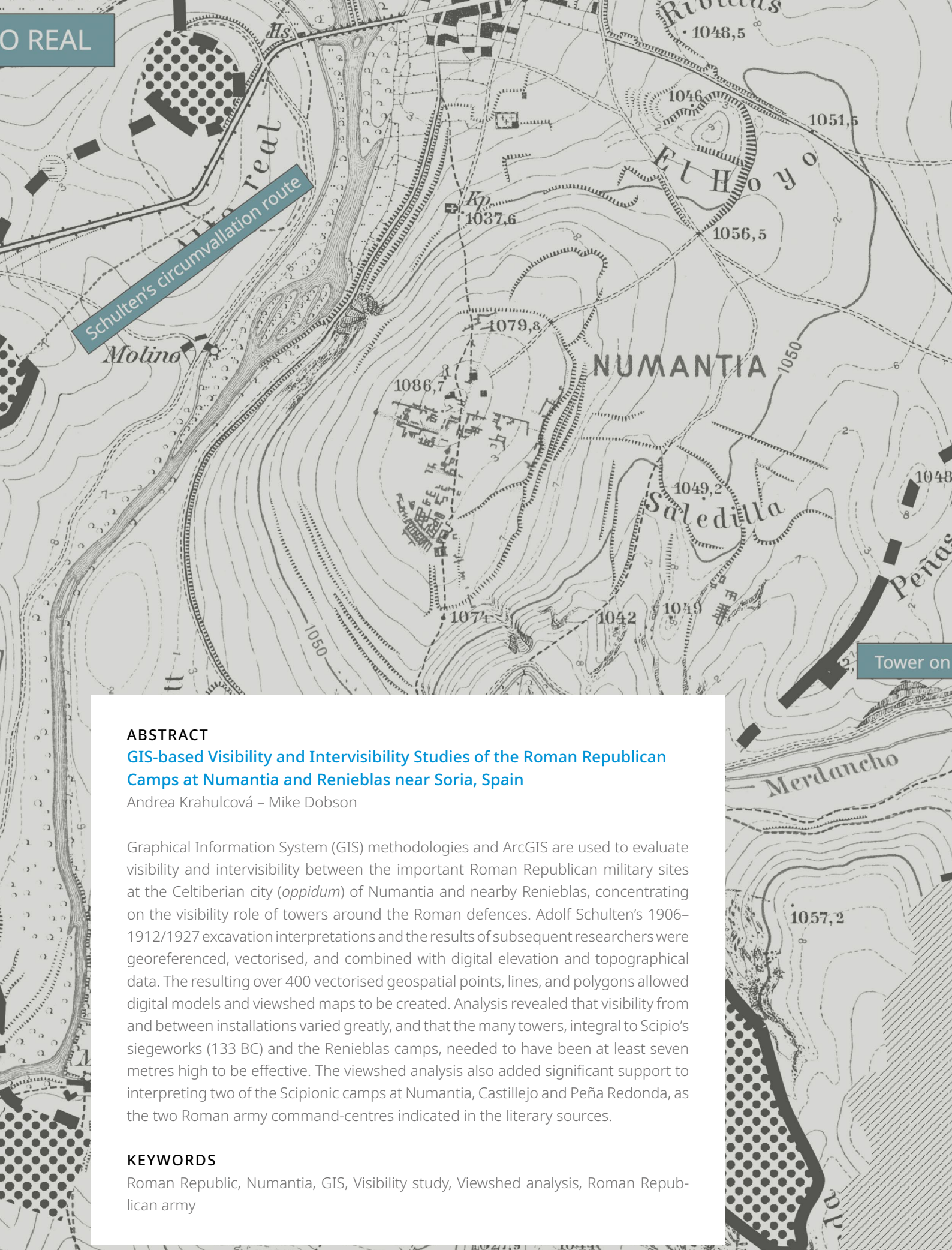

ABSTRACT

GIS-based Visibility and Intervisibility Studies of the Roman Republican Camps at Numantia and Renieblas near Soria, Spain

Andrea Krahulcová – Mike Dobson

Graphical Information System (GIS) methodologies and ArcGIS are used to evaluate visibility and intervisibility between the important Roman Republican military sites at the Celtiberian city (*oppidum*) of Numantia and nearby Renieblas, concentrating on the visibility role of towers around the Roman defences. Adolf Schulten's 1906–1912/1927 excavation interpretations and the results of subsequent researchers were georeferenced, vectorised, and combined with digital elevation and topographical data. The resulting over 400 vectorised geospatial points, lines, and polygons allowed digital models and viewshed maps to be created. Analysis revealed that visibility from and between installations varied greatly, and that the many towers, integral to Scipio's siegeworks (133 BC) and the Renieblas camps, needed to have been at least seven metres high to be effective. The viewshed analysis also added significant support to interpreting two of the Scipionic camps at Numantia, Castillejo and Peña Redonda, as the two Roman army command-centres indicated in the literary sources.

KEYWORDS

Roman Republic, Numantia, GIS, Visibility study, Viewshed analysis, Roman Republican army

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1 Introduction

1 Much is known about the Celtiberian hilltop city (*oppidum*) of Numantia and its long conflict during the second century BC to remain independent of Rome. One of the most extensive surviving ancient literary sources about this years-long struggle is by Appian, written in the first half of the second century AD[1]. The city's final defeat in 133, after a protracted and elaborate siege by the Roman commander Scipio, was brought to a dramatic and tragic end by the Numantines taking their own lives rather than be defeated and face the typical brutal recriminations of a Roman army that conquered a city which dared to resist it. The heroic, but ill-fated, stand against Rome meant Numantia soon gained iconic status of the indigenous Spanish resisting the foreign invader, a status which continues to this day in Spain. Consequently, much has been written about it over the centuries[2]. The first academic, scientific research did not really commence until the nineteenth century, with the highly important work of Eduardo Saavedra (1829–1912) being the first to definitively locate the city by research and excavation[3]. His work was built upon by the research and excavations (1905–1912 and 1927) of the German ancient historian and archaeologist Adolf Schulten (1870–1960), initially in the area of the city and then at the surrounding camps and siegeworks, commonly called the ›circumvallation‹ since Schulten[4], and farther away in the camps at Renieblas. It is Schulten's work and his copious publication of it that form much of current knowledge, especially about the area's Roman military installations[5]. His initial work at the city itself was continued by an extensive programme of excavations by the

1 App. Hisp. 45–98. All known classical literary sources are comprehensively presented by Saavedra (Saavedra 1879, 59–110) and Recio García (Recio García 1967; Recio García 1972). See also Dobson 2008, 41–46.

2 de la Torre Echávarri 1998; Jimeno Martínez – de la Torre Echávarri 2005; Jimeno Martínez 2017.

3 Saavedra 1879; Mañas Martínez 1983.

4 This terminology was first proposed by Schulten (Campbell 2005, 51), deriving it from the Latin term to mean »surrounding with a rampart« (Schulten 1927, 15) and it is now the generally accepted word for such siegeworks (Campbell 2005, 50; Dobson 2008, 46).

5 Schulten 1905; Schulten 1914; Schulten 1927; Schulten 1929; Schulten 1931; Schulten 1933; Baquedano 2017; Díaz-Andreu 2017.

Spanish government-supported »Comisión Ejecutiva de las Excavaciones de Numancia« and subsequently by others, with excavations ongoing[6].

2 The military installations at Numantia and nearby Renieblas have also been further investigated since Schulten and are similarly still being studied, though with excavations on a smaller scale compared to Schulten's[7]. This work, together with ongoing reassessment of Schulten's results, have led to a great deal of new information and interpretation. The overall consequence is that relatively more is known about the sites at Numantia compared to many other Spanish Roman Republican installations. There are some notable exceptions, such as the well-studied and published remains at Cáceres el Viejo, La Palma, El Pedrosillo, Andagoste, and Puig Castellar[8]. The picture is changing, however; noticeably so since about 2010, with many new military sites emerging in Spain and new types of installations being discovered[9]. In turn, this growing body of evidence informs our understanding of Roman Republican military practice not only in Spain, but beyond.

2 Origin and Aims of This Research

3 The discussion presented here commenced with the doctoral research of Andrea Krahulcová[10]. The primary aim of that initial research was to use Geographic Information System (GIS) mapping to create a surface model to learn more about the spatial characteristics of the Roman camps at Numantia. This included geomorphological calculations and visibility analyses based on a reconstructed minimum height of towers/artillery platforms. The research's second main aim was to evaluate the potential benefits of combining archaeological sources and GIS to better understand the form and spatial characteristics of some of the camps that were likely to be linked to operations against Numantia.

4 Subsidiary questions emerged as that research progressed. These included trying to ascertain the geomorphology of the terrain on which the Roman camps were located. The spacing and minimum operational height of the towers also came under consideration, which in turn could facilitate assessment of previous reconstructions. This naturally led to the question of whether there was direct intervisibility between Numantia and the camps at Renieblas, as well as around the circumvallation itself. From a more theoretical aspect, considerations arose about the value of visibility analysis and what this may add to understanding Roman military strategy.

3 The Study Area

5 Numantia lies about 8 km north-east of the city of Soria, the capital of the Spanish province of the same name in north-eastern Spain (Fig. 1). Much of this province is part of the Central Meseta, a very large and high plateau in the middle of the Iberian Peninsula, lying over 1,000 m above sea level, with a range of even higher hills lying not far to the north of Numantia, between it and the important east-west Ebro

6 For example: Mélida 1908; Mélida – Taracena Aguirre 1920; Wattenberg Sanpere 1983; Liceras Garrido et al. 2012; Jimeno Martínez et al. 2017; Liceras Garrido et al. 2018.

7 For example: Luik 2002; Luik – Müller 2006; Dobson 2008; Luik 2015; Morillo Cerdán – Morales Hernández 2015; Jiménez et al. 2018; Jiménez et al. 2020; Morales Hernández – Morillo Cerdán 2020; Morales Hernández 2021; Jiménez et al. 2022.

8 Ulbert 1984; Ocharan – Unzueta 2002; Noguera 2008; Morillo Cerdán et al. 2022; Rodrigo et al. 2022.

9 Cerdaño – Gamo 2016; Hesse – Costa-García 2016; Duran i Caixal et al. 2017; Morillo Cerdán et al. 2020; Sanz Pérez et al. 2023.

10 Krahulcová 2017.

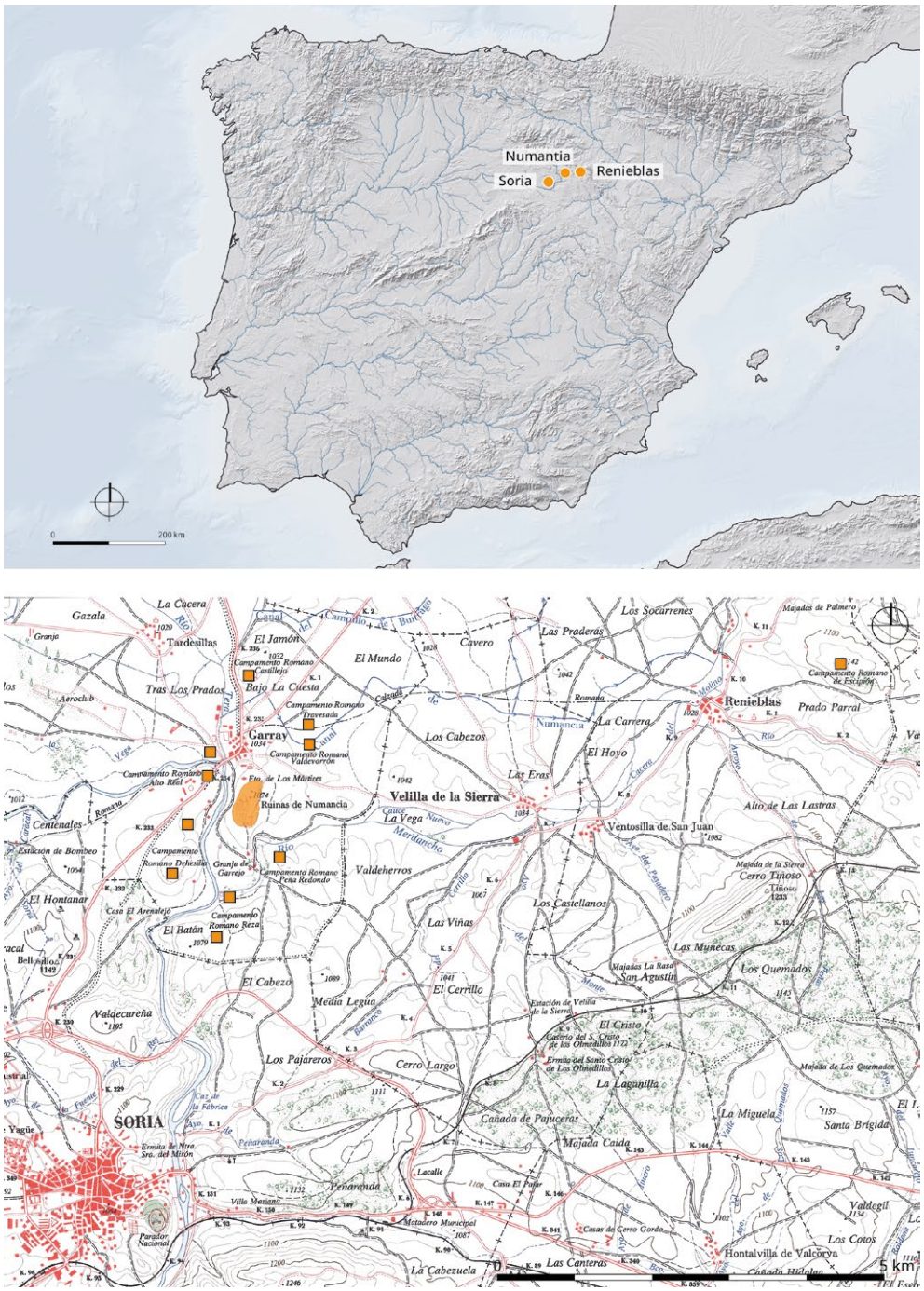

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Fig. 1: Location of Numantia, north of Soria by Garray, the camps nearby and those to the east at Renieblas.

valley. Within this region, the area around Numantia and Renieblas selected for the study covered approximately 21 km × 5 km[11], i. e., about 100 km^2 (Fig. 2). It was selected for the initial study due to its large concentration of Roman military camps. These also had the benefit of being fairly well-known archaeologically and had numerous related publications. Further, the area is interesting topographically and the quality of available associated images and mapping was good.

6 Mentions of Numantia in the ancient sources include comments about its appearance and the local landscape. For example, Florus, in his *Epitome* of Livy, remarks that »This city, without any walls or towers and situated on only a slight hill on the banks

11 The area's east-west dimension is 20,785 m, and north-south 4,762 m (measured in ArcMap).

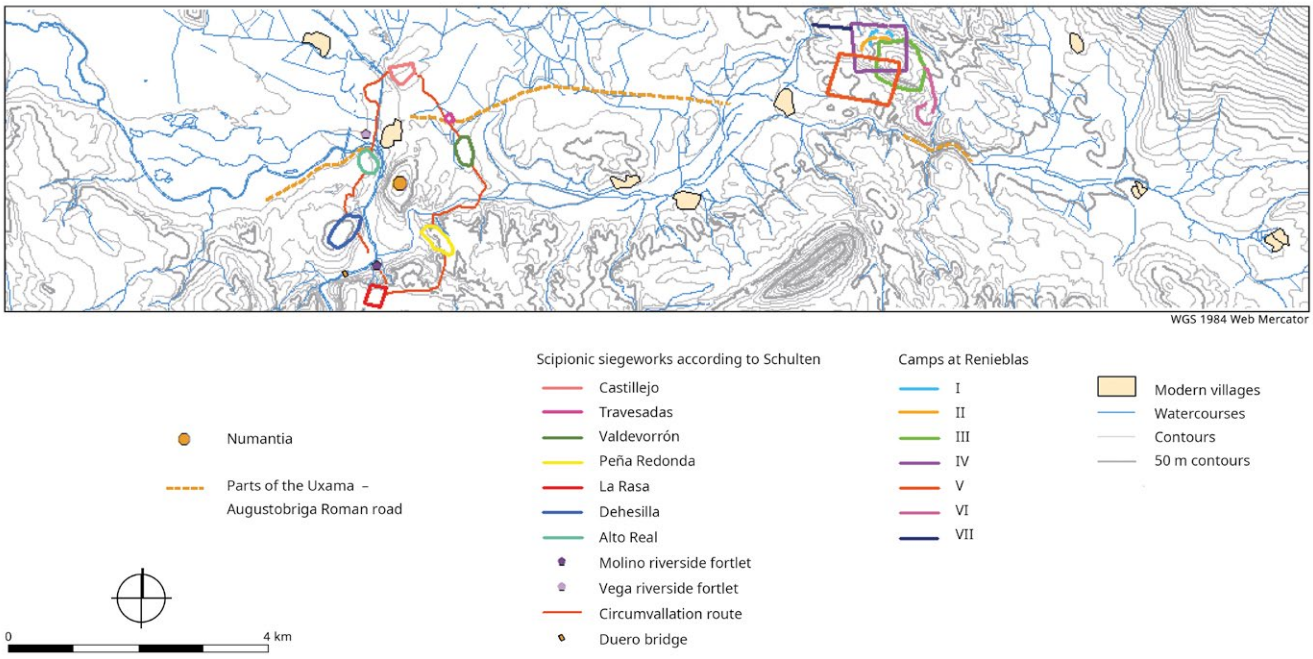

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Fig. 2: The area of study around Numantia, showing the Roman military remains and parts of the Uxama – Augustobriga Roman road, plotted as polygons on a two-dimensional contour map.

of a river, […]«[12]; though this is inaccurate, as excavations have revealed that the city had well-constructed defences and the hill is hardly ›slight‹ in form. Appian says »Numantia was difficult to reach because of two rivers and ravines, and thick woods surrounded it«[13]. Today, the general area is unwooded and largely open, but deforestation did not occur until the early sixteenth century, due to timber being required for ship building[14].

7 The ruins of Numantia, occupying an area of 10 hectares, are located on La Muela hill, on the southern side of the modern village of Garray, overlooking the confluence of the rivers Duero, Merdancho and Tera. The topography of the hill, the extent of the ancient city and part of its internal layout are well illustrated in some of Schulten's large plans[15], themselves the result of his accomplished topographical surveyor, General Adolf Lammerer (1864–1946). These plans can also be conveniently used to indicate the location and form of the nearby Roman military remains found by Schulten and subsequently, and to show alternative interpretations of the features associated with Scipio's siege compared to those suggested by Schulten (Fig. 3; below)[16].

8 The city's location played an important role in its history, as it lay at the junction of significant natural communication routes both east-west and north-south, which were later utilised for the route of the Uxama – Augustobriga Roman road (Fig. 2. 6). This, and the prevailing anti-Roman stance of the Celtiberians, with one of their most important centres being Numantia, meant that conquering the city became a strategic goal of the Romans during the second century BC.

9 It should be noted that, for two of the camps close to Numantia, one is mentioned only in passing in this discussion and the other was not included in the initial research. The first of these is the camp at La Rasa to the south of the city (Fig. 3). It is shown in several of the illustrations presented here, mainly for the sake of completeness, but is excluded from the main research as only the eastern side of the defences is known

12 Veg. mil. 1, 34, 18.
13 App. Hisp. 76, trans. Richardson 2000, 81.
14 Richardson 1986, 12 f.; Penrose 2005, 115 is consequently wrong to claim that Appian is wrong.
15 Schulten 1927, plan I; Schulten 1933, plan IV.
16 Morales Hernández – Dobson 2005; Dobson 2008; Hesse – Costa-García 2016.

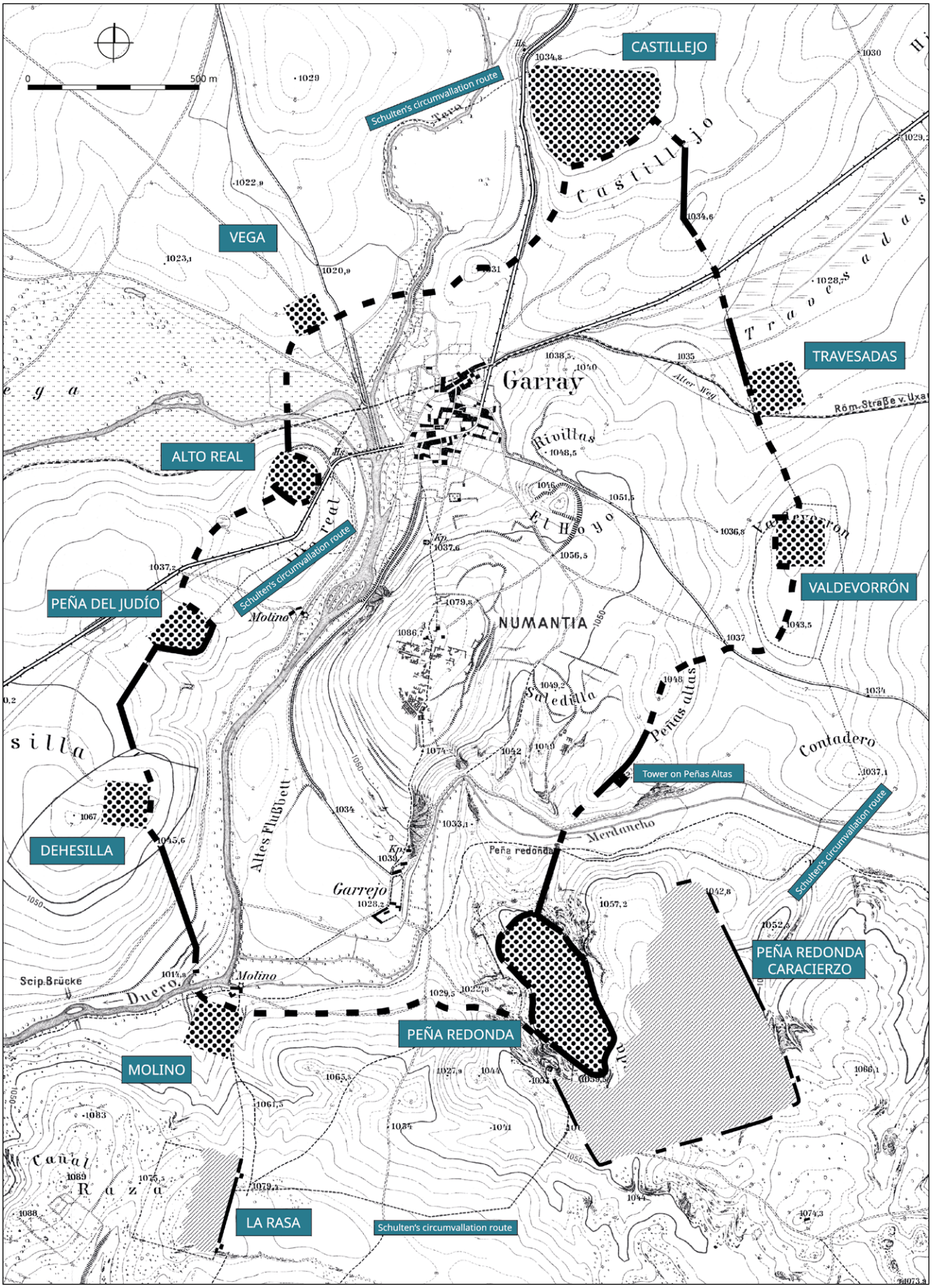

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Fig. 3: Numantia and the nearby Roman camps, with Schulten's proposed Scipionic siegeworks and an alternative set (the latter shown as heavy dashed line and dot-filled installations).

and even this side is incomplete. Consequently, its area and overall form are unknown. It has also been demonstrated not to be part of the Scipionic circumvallation, contrary to Schulten's interpretation[17]. Its dating and historical context are in fact uncertain, as there is no firm archaeological dating evidence from the site. The other camp to be excluded near Numantia is the very large Peña Redonda Caracierzo to the south-east (Fig. 3). Its discovery by LiDAR was published after Krahulcová had completed her GIS research and was close to submitting her thesis[18]. The site has been confirmed by field-work by Fernando Morales Hernández and plotted by Mike Dobson, but has not been excavated. It lacks dating evidence and has an unknown historical context, other than it was probably not part of the Scipionic circumvallation as (Scipionic) Peña Redonda appears to have removed the north-western part of it.

10 The remains of several camps have been found at Renieblas, a few kilometres east of Numantia (Fig. 1). Schulten identified five camps here, which are now commonly referred to using his sequence of Roman numerals: I, II, III, etc. He also found the remains of two installations which he did not interpret as camps, but in one case as an annex to camp III and in the other as defences extending from camp IV to protect the route to a water supply from the Merdancho[19]. Dobson proposed that these remains are indeed two more camps and numbers them VI and VII, respectively[20]. Other scholars have subsequently debated what type of military installation the remains represent[21]. The interpretation as camps VI and VII will be used in this discussion. All the camps lie on the strategically advantageous location of La Gran Atalaya hill (Fig. 4). This hill looms over the rivers Merdancho along its north-western side and Moñigon along its southern side. The southern extent of most of the camps is uncertain; while I, II, and IV seem likely to be entirely on the hill, camp III may extend down part of the dramatically steep southern slope – V definitely does – VI extends down onto the lower Cotillo and La Mesta hills, and VII slopes down to the west towards the Merdancho[22]. As with the topography and remains at Numantia, those at Renieblas are also well-illustrated by Schulten[23] (Fig. 4). The distance of these camps from Numantia is between 6.7 and 8.3 km[24]. Even with forest cover likely to have existed at the time, visibility from the Renieblas camp towers to Numantia was probably viable, as indicated by the multiple and cumulative viewshed maps created from calculated altitude values. This also in turn supports a visibility scenario proposed by Liceras Garrido (discussed below)[25].

4 Methodology

11 Adequate digital spatial data were acquired via three 1 : 10,000 Spanish topographical maps in Esri Shapefile format from the Infraestructura de Datos Espacias de Castilla y León (IDECyL)[26]. These maps include vector elevation and topographic data with attached attributes of map areas 350-1-1, 350-2-1, and 350-3-1. The contour data from the maps (5 m principal contour lines, 2 m subsidiary ones and spot heights)

17 Morales Hernández – Dobson 2005.

18 Hesse – Costa-García 2016.

19 Schulten 1929.

20 Dobson 2008.

21 Morales Hernández – Morillo Cerdán 2020; Jiménez et al. 2022.

22 Dobson 2008.

23 Schulten 1929, plan I.

24 The distances of 6.7 km and 8.3 km are from the centre of Numantia to the south-west corner of camp V and the defences of VI respectively. These are the minimum and maximum distances across the complex of sites (measurements made in ArcMap).

25 Liceras Garrido 2011.

26 <http://www.cartografia.jcyl.es> (18.06.2024).

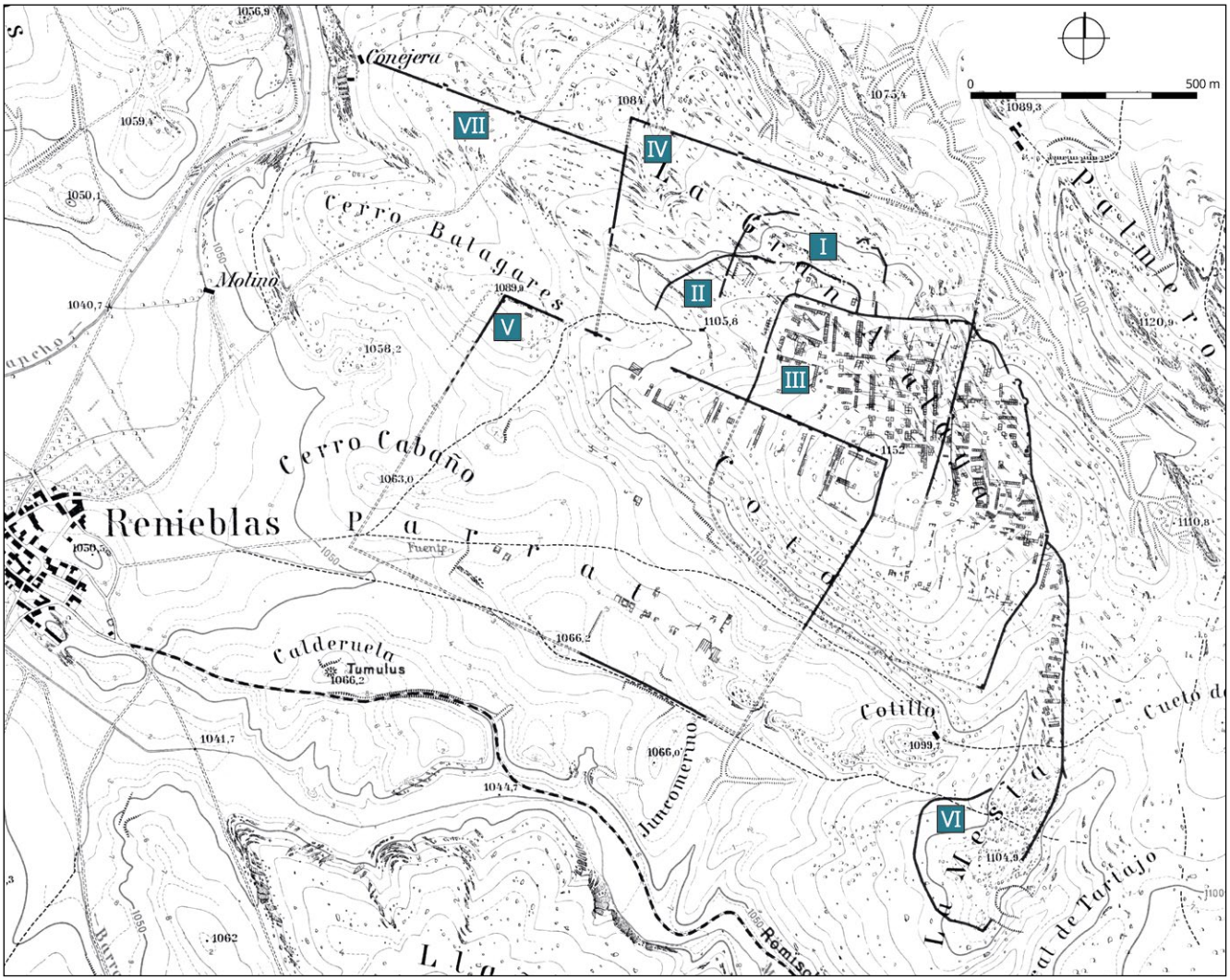

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Fig. 4: Camps at Renieblas.

proved to be the most useful resource. The topographic data, from which layers representing watercourses and modern settlements were generated in various image outputs (examples are Fig. 2. 5[27]), became secondary in usefulness and importance. A number of data-preparatory stages using ArcGIS 9.3 and 10.1 (Esri) followed:

12 A) Combination of vector digital data from the three 1 : 10,000 maps (subsequently referred to as MTN10) into a single layer. The scale of the MTN10 maps was dictated by the size of relevant archaeological features (created as polygons; see below).

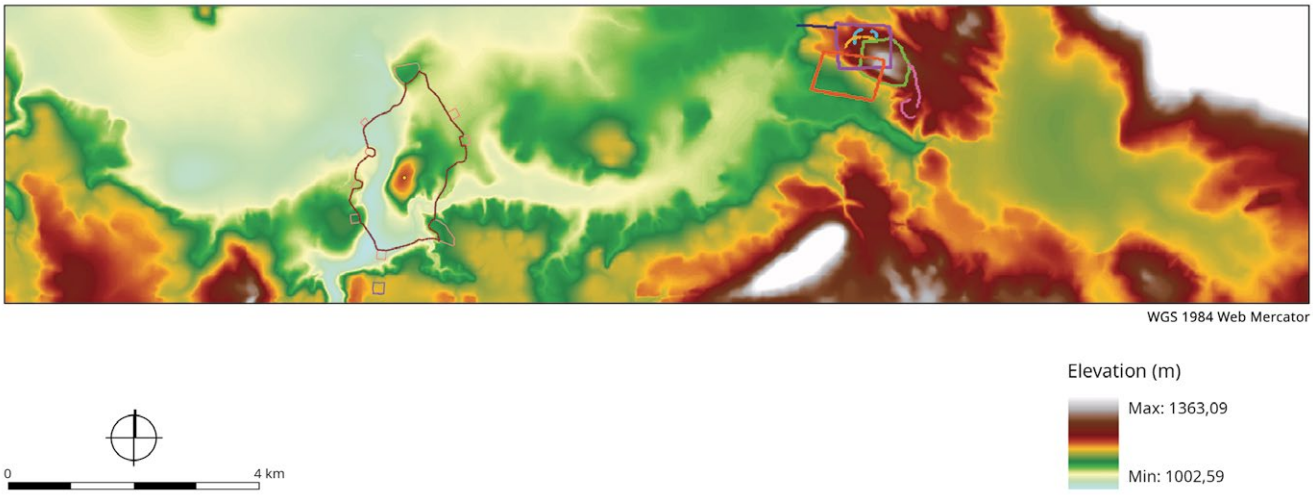
13 B) Georeferencing. Scanned analogue maps were combined into a single digital vector map (in Esri Shapefile format) using the contour lines to create ›inline rasters‹.

14 C) Vectorization. Selected archaeological features were created as a series of points, lines, and polygons (Fig. 2).

15 D) Creation of a triangulated irregular network digital elevation model (TIN) from contour lines and selected spot heights (Fig. 5). LiDAR was not used for creating the TIN, as it was not possible to obtain this for the area at the time of the initial research. Natural neighbour interpolation could also have been used for creating a TIN, and it is intended to utilize this method in subsequent research.

16 E) Production of a three-dimensional relief model in ArcScene to better visualize the study area. This was produced from the TIN, with terrain elevation achieved

27 The full set of images and original ArcGIS plots can be seen at the Charles University Archive, <https://dspace.cuni.cz/handle/20.500.11956/96134?locale-attribute=en> (18.06.2024).



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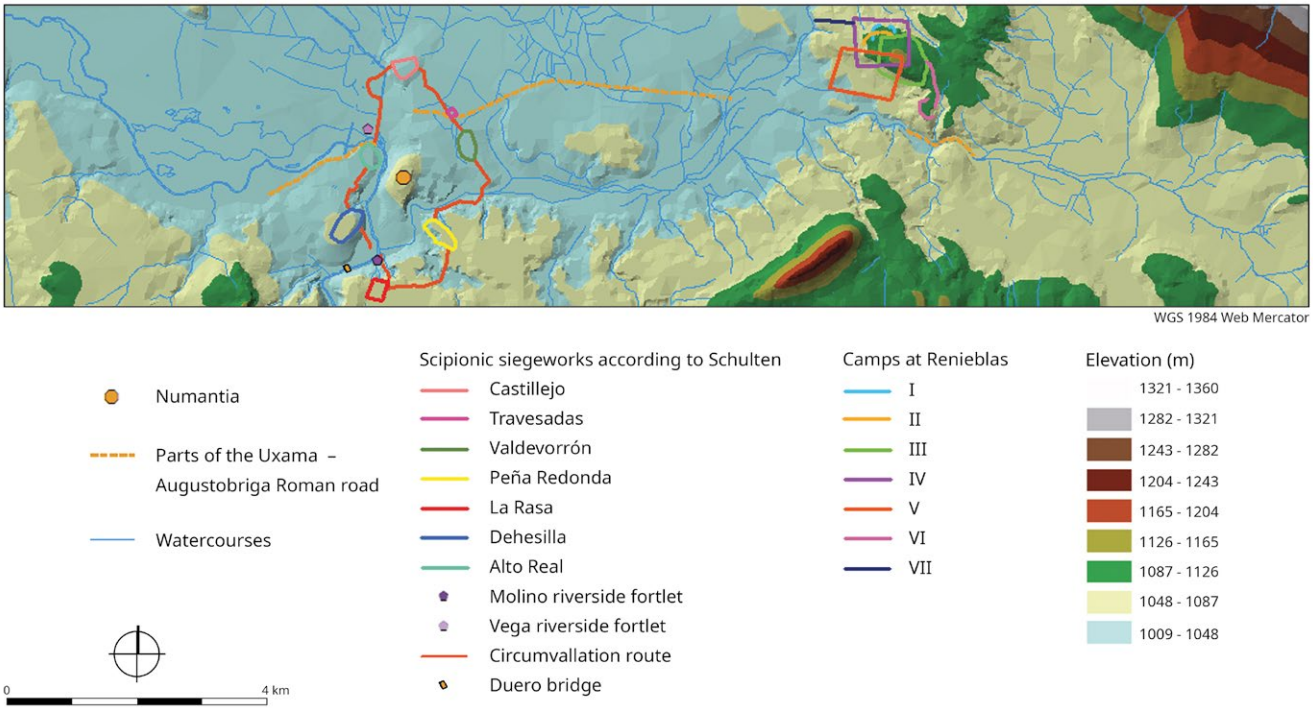

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Fig. 5: The study area as a two-dimensional triangulated irregular network digital elevation model (TIN), with the Roman camps and circumvallation superimposed.

Fig. 6: The study area as a three-dimensional relief model, with the Roman features superimposed.

by using the Base Heights tab assigned to both the TIN and all relevant point, line, and polygon layers of the map (Fig. 6).

17 F) Creation of raster, float-type digital elevation models (DEMs) of the entire area from the interpolation of digital contour lines to facilitate visibility analyses, e.g., lines of sight and different forms of viewsheds. They consist of visibility calculations from each tower and are represented by binary areas 0 and 1 (see below). Subsequently, cumulative viewsheds from the algebraic sum of the single viewsheds were created. The result was raster layers with cells of values 0 to *n*, expressing the number of towers that provided visibility of a particular area. Through the Reclassify function, these cells were reduced to two values, i. e., 0 (invisible cells) and 1 (visible cells), resulting in rasters of

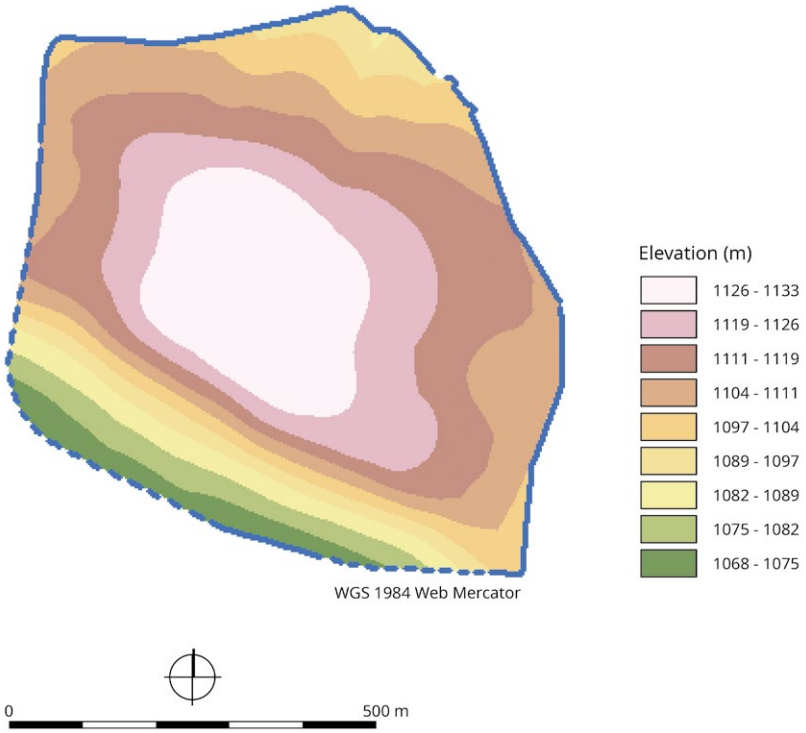

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Fig. 7: Digital elevation model (DEM) of Renieblas III.

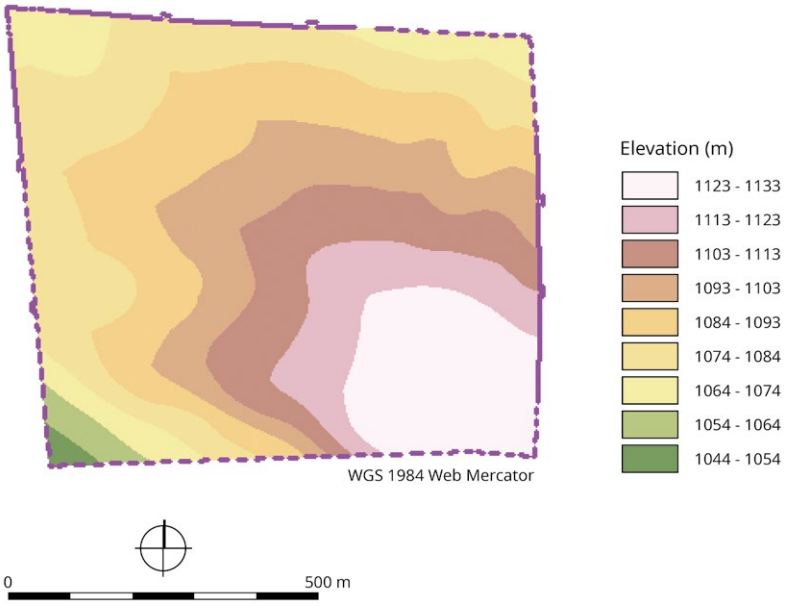

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Fig. 8: DEM of Renieblas IV.

multiple viewsheds (below)[28]. Since the location of towers around the defences of the camps associated with the Scipionic siegeworks is uncertain, a single point was created in the approximate centre of each camp as a convenient reference point from which to calculate visibility and the Buffer geoprocessing tool was used to create visibility polygons with 3 km radii around each camp.

28 Wheatley 1995; Kay – Sly 2001; Connolly – Lake 2006, 227 f.; Jacobson 2007; Rášová 2013.

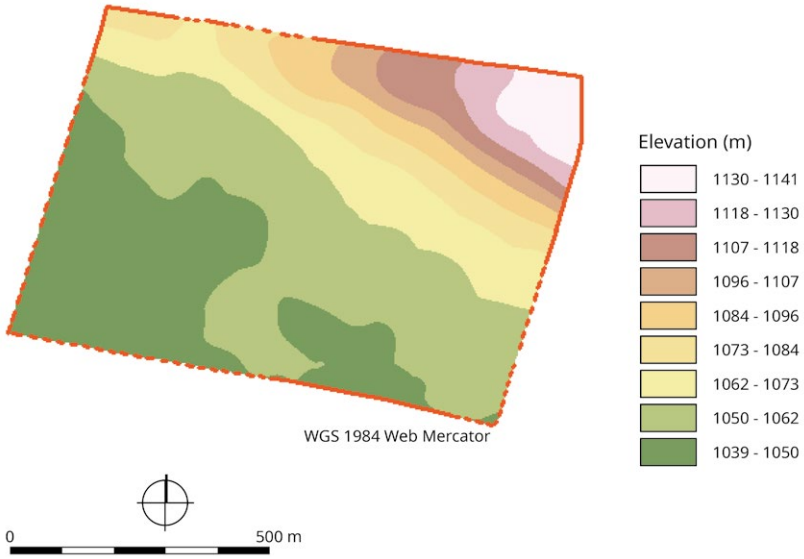

Fig. 9: DEM of Renieblas V.

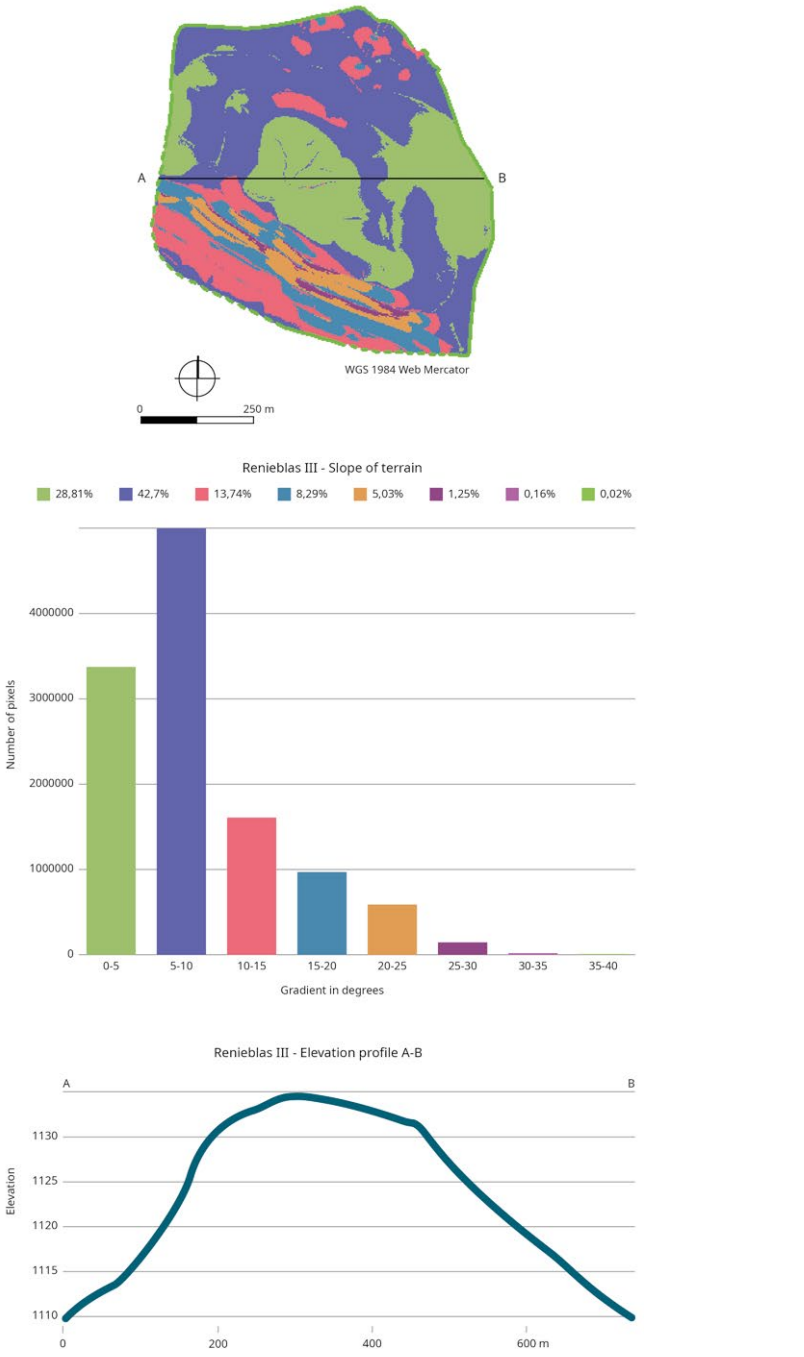

Fig. 10: Slope histogram and section profile of Renieblas III.

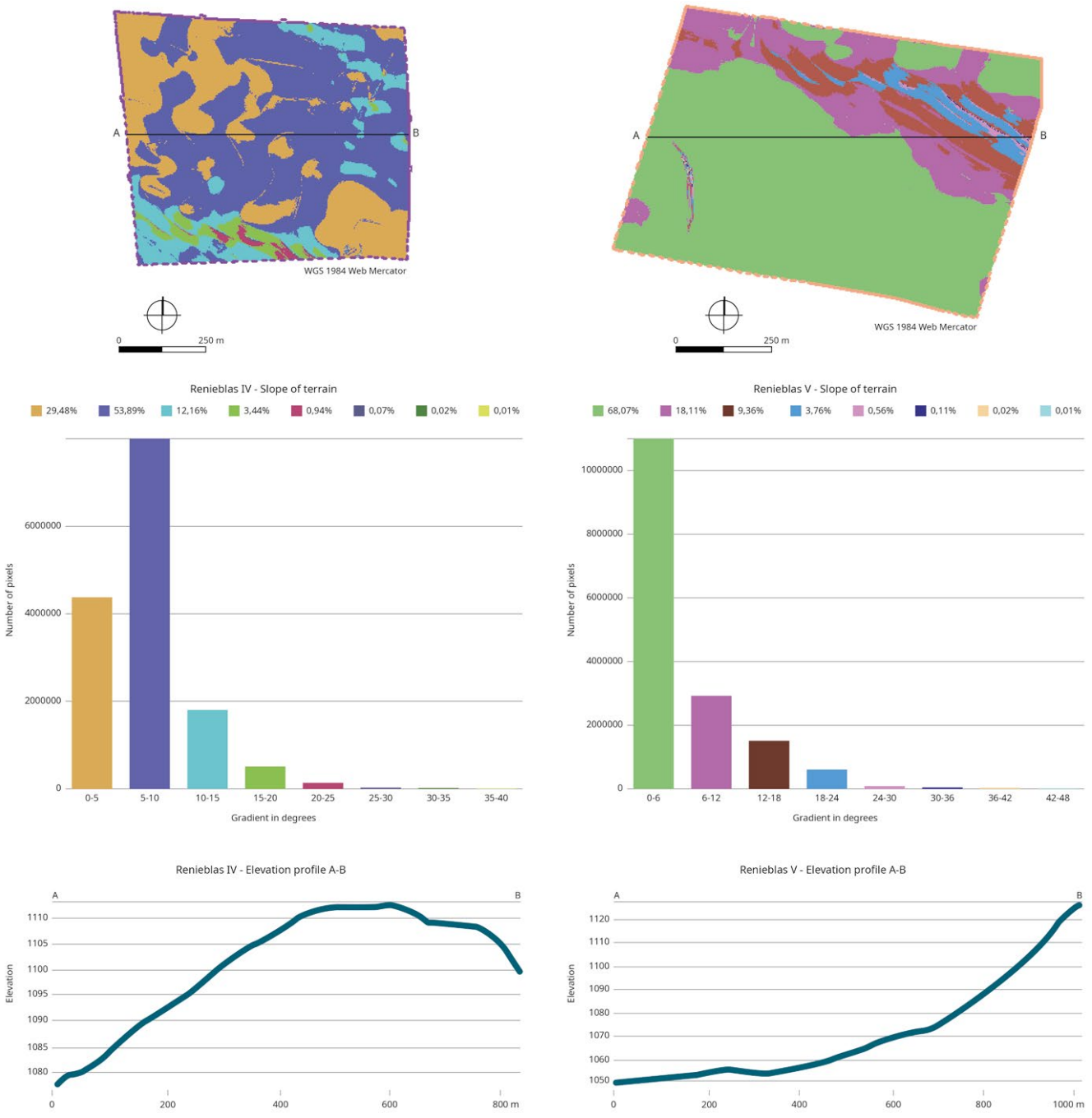

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Fig. 11: Slope histogram and section profile of Renieblas IV.

Fig. 12: Slope histogram and section profile of Renieblas V.

18 G) Production of polygon DEMs of individual camps using the interpolation of digital contour lines, resulting in slope histograms and terrain elevation profiles (for Renieblas III–V; Fig. 7. 8. 9. 10. 11. 12).

19 From the digital contour lines determined by linear interpolation, two DEMs of the entire study area were generated:

1. The first DEM, 4,160 × 954 pixels and 5 m × 5 m cells (Fig. 5), was used for the visibility analyses with a radius of 3 km from the middle of each of the camps at Castillejo, Travesadas, Valdevorrón, Peña Redonda, Dehesilla, and Alto Real (e. g. Fig. 16. 17). The same output raster became the underlying layer for the visibility calculations from the circumvallation towers (Fig. 19. 20).
2. Transitions between the visible and non-visible parts of the terrain were not very clear on the 1 : 10,000 maps of Renieblas, so a second DEM was created,

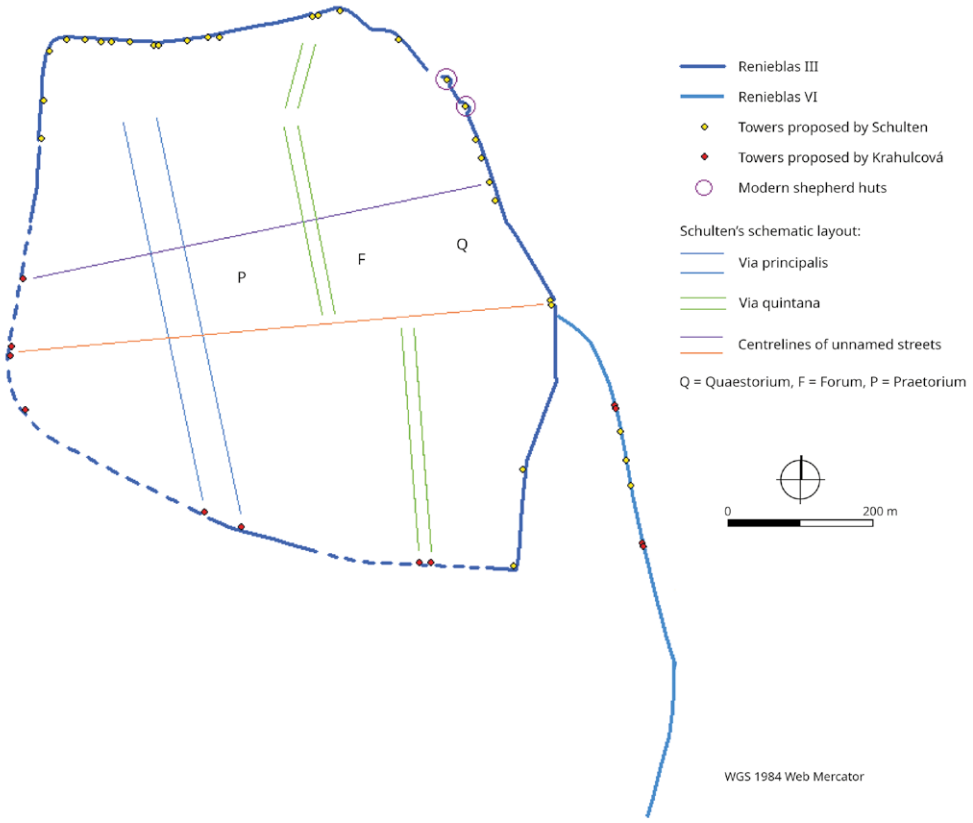

Fig. 13: Schematic layout of Renieblas III and VI.

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with a pixel resolution of 10,399 × 2,386 and 2 m × 2 m cells. Visibility calculations from the towers of Renieblas III, IV and V, including to Numantia, were created on top of this output raster (Fig. 21. 22. 23. 24. 25. 26. 27).

5 Visibility Analysis

5.1 Methodology

20 The analysis of visibility and intervisibility was based on observers standing on strategically elevated positions (e. g. towers and hills within camps). It was performed over the current landscape relief. The height and characteristics of vegetation cover were not taken into account as the nature of such cover at the time of the camps' occupation is uncertain, though probably present in some form (above); it could also have varied during the overall period of military occupation as timber and woodland resources were exploited by the army[29]. Hence introducing any vegetation modelling into the research would be hazardous. The absence of this aspect in the following analysis should be noted, however, since some viewsheds could have differed from those proposed here. In contrast, any absent lines of visibility based purely on terrain analysis would obviously have been the case in antiquity.

21 Analysis was mainly based on the location of towers along the defences of Renieblas III–VI and around the Scipionic circumvallation. The position of towers at Renieblas includes those identified by Schulten's excavations and those proposed by Krahulcová based on possible internal camp layouts at Renieblas III, IV, and V (Fig. 13. 14. 15; below).

29 Dobson 2022.

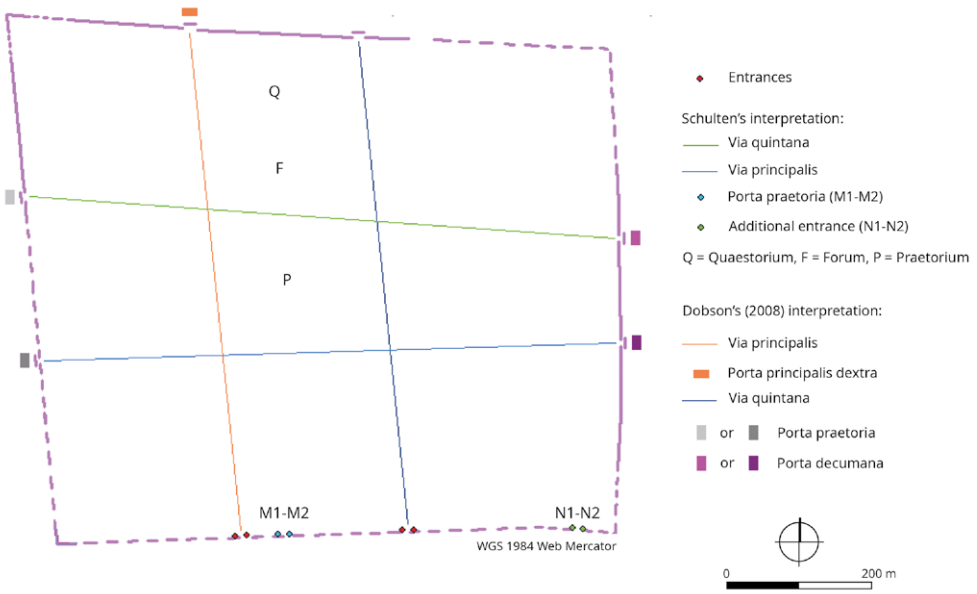

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Fig. 14: Schematic layout of Renieblas IV.

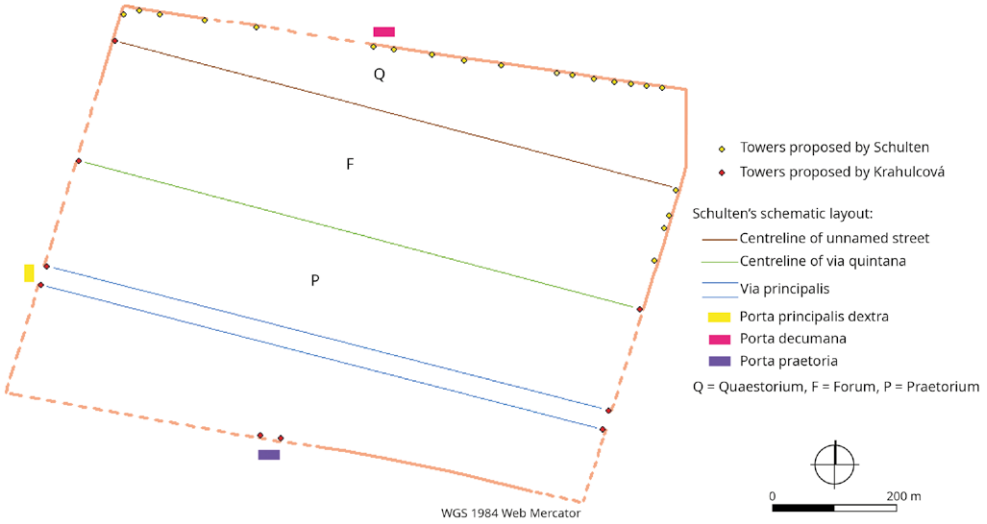

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Fig. 15: Schematic layout of Renieblas V.

In addition, the interpretation of the line of the various camp defences at both Renieblas and Numantia and the route of the circumvallation were considered as regards visibility points. At the camps close to Numantia itself, where Schulten attributed no remains to towers, using the presumed central point of these camps as a convenient location for measuring visibility and intervisibility from these camps seemed a reasonable compromise.

22 The computer-based topographical modelling and visibility analyses (Fig. 16. 17. 18. 19. 20. 21. 22. 23. 24. 25. 26. 27), primarily by Krahulcová, were only viable because of the vector digital data for Soria that was publicly available. It was also heavily reliant on Dobson's 2008 book[30], which provided a modern reassessment of Schulten's early-twentieth century excavations, together with convenient reproductions of Schulten's plans, and alternative interpretations which raised many questions about the validity of the earlier ideas. Some of these questions related to the towers that in turn form the

30 Dobson 2008. Correspondence between Mike Dobson and Andrea Krahulcová when she was working on her doctoral research led to Mike becoming jointly involved with the creation of this article.

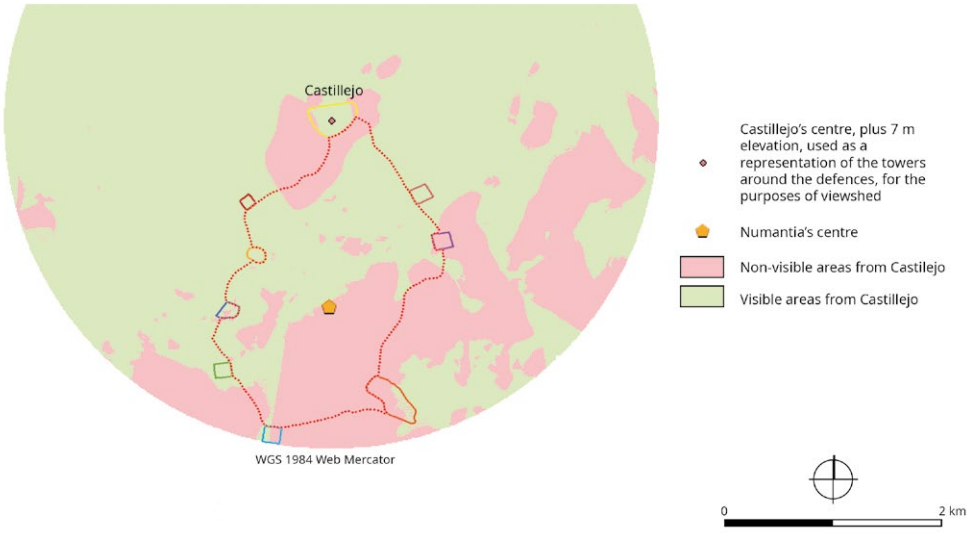

Fig. 16: 3 km radius single viewshed from the centre of Castillejo.

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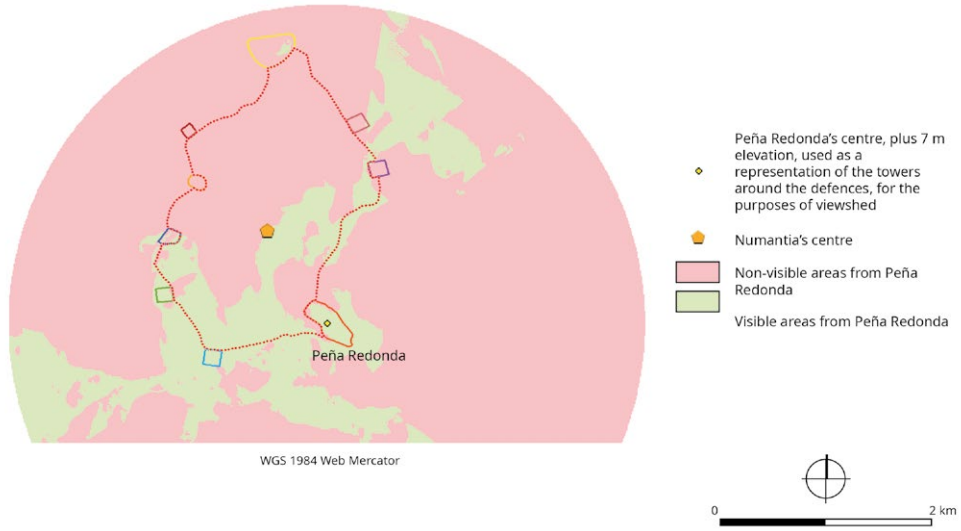

Fig. 17: 3 km radius single viewshed from the centre of Peña Redonda.

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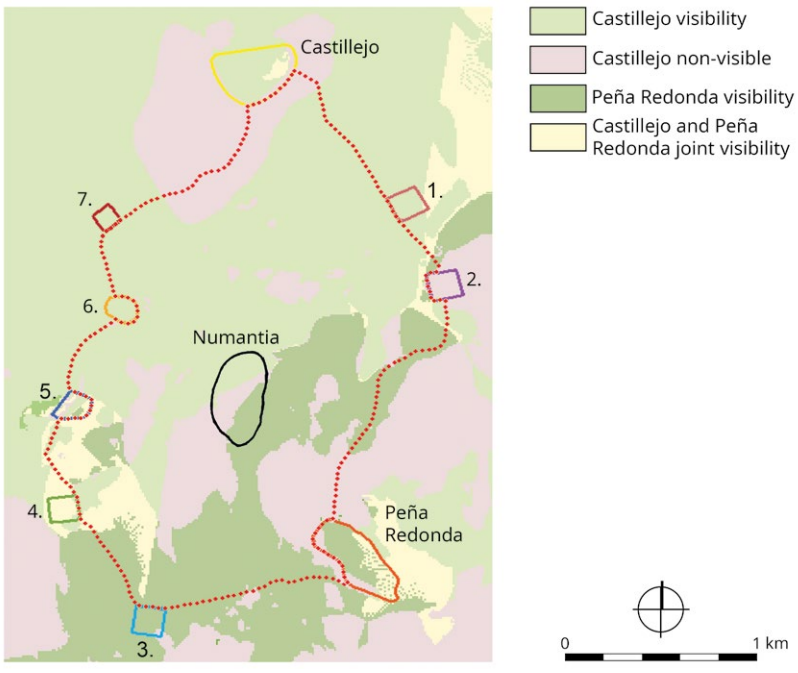

Fig. 18: Combined viewsheds from Castillejo and Peña Redonda.

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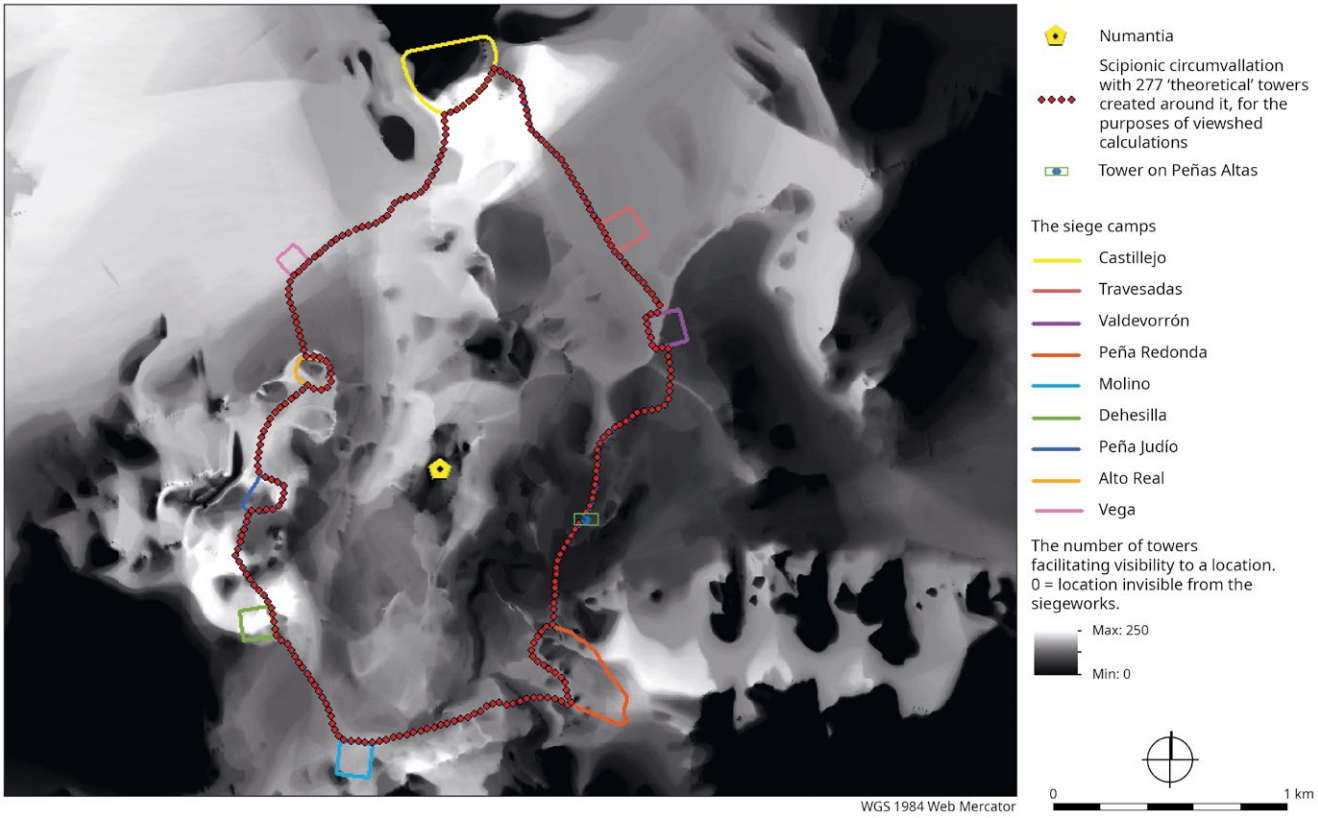

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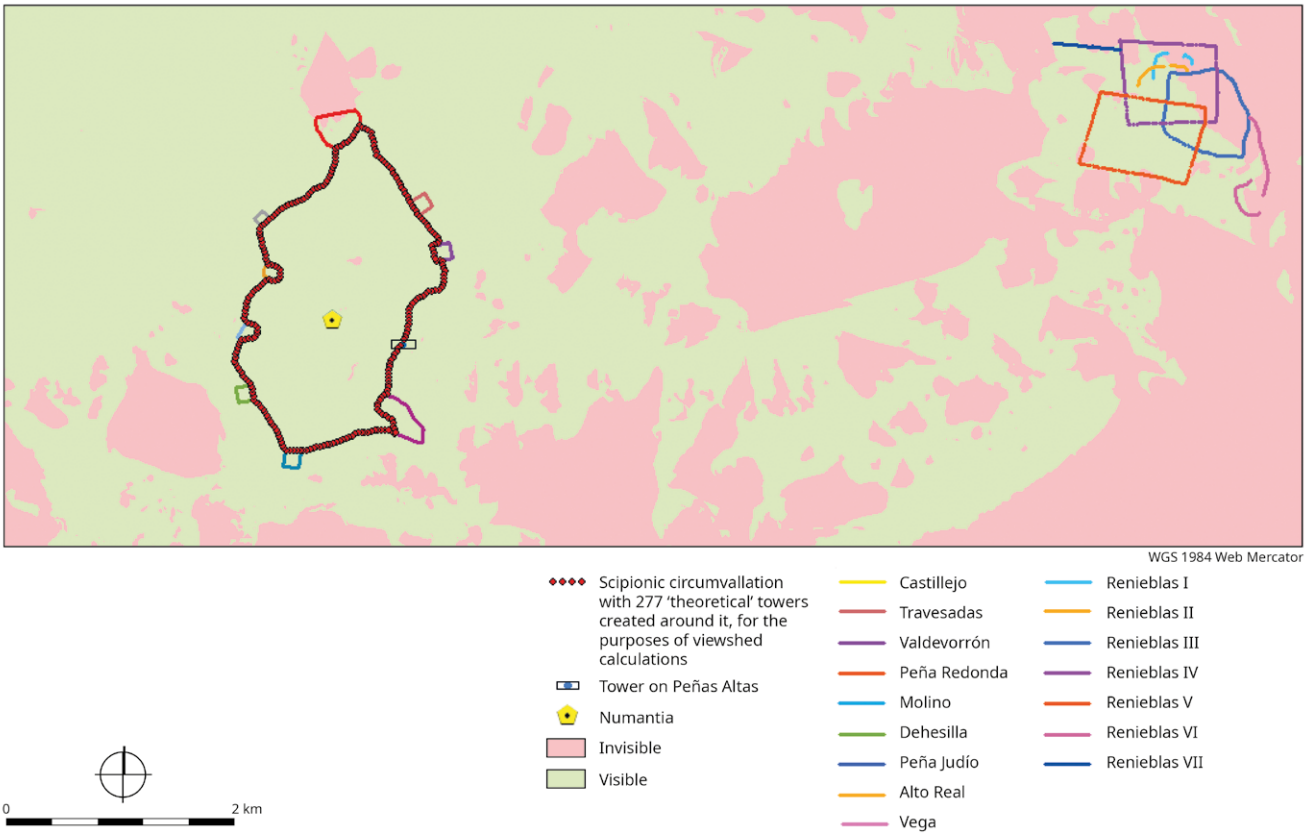

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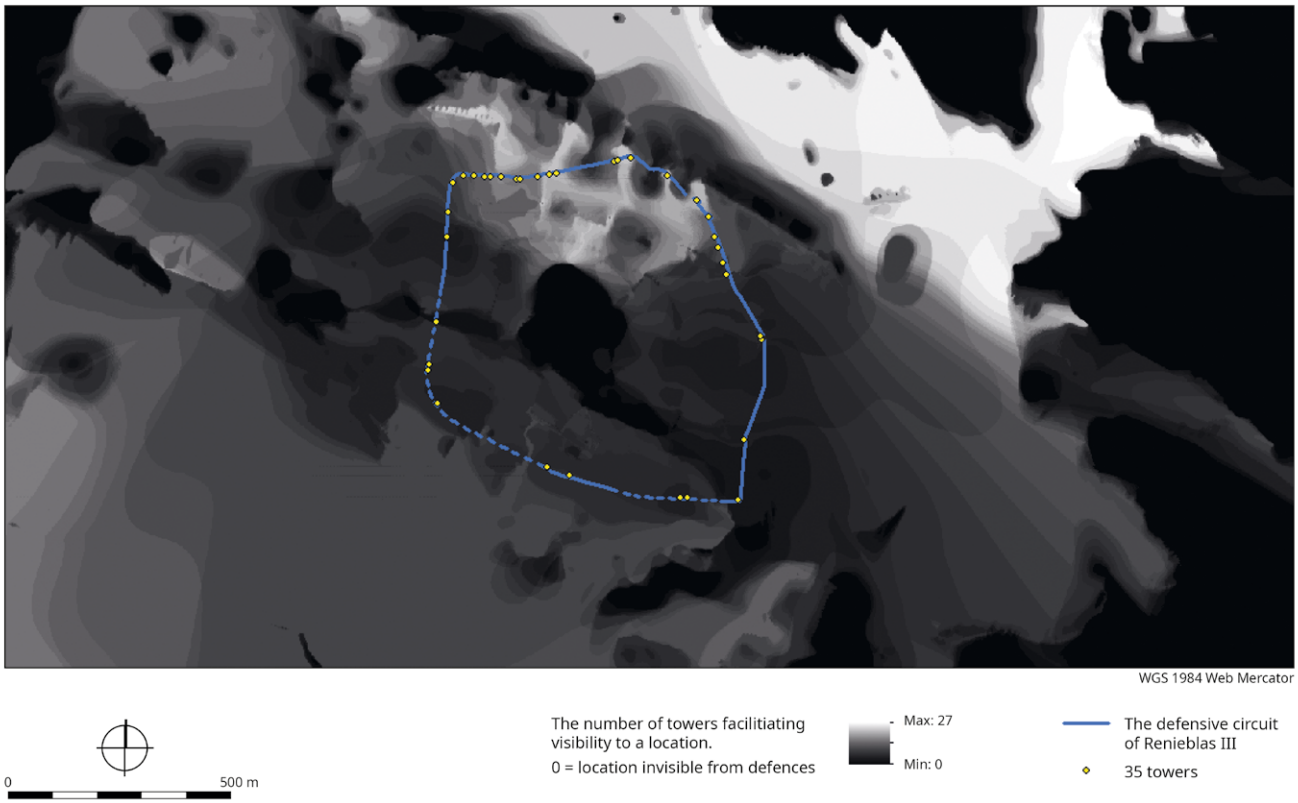
Fig. 19: Cumulative viewshed from all the conjectured towers around the circumvallation, with proposed tower height of 7 m.

Fig. 20: Multiple viewshed from all the conjectured towers around the circumvallation, with proposed height of 7 m, including area occupied by the Renieblas camps.



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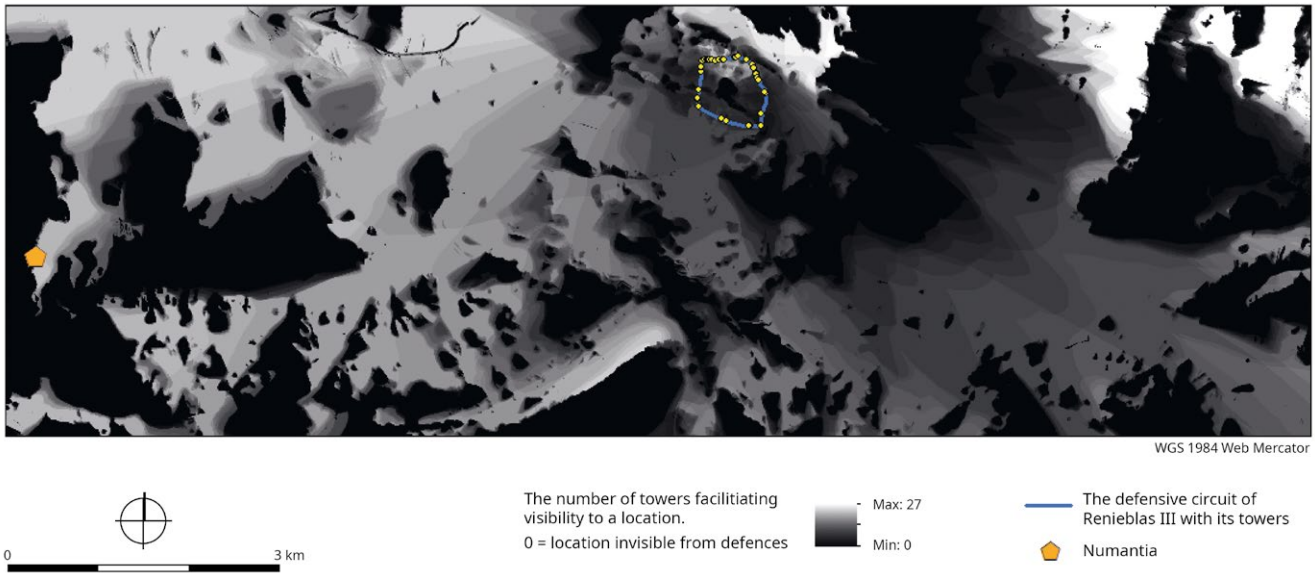
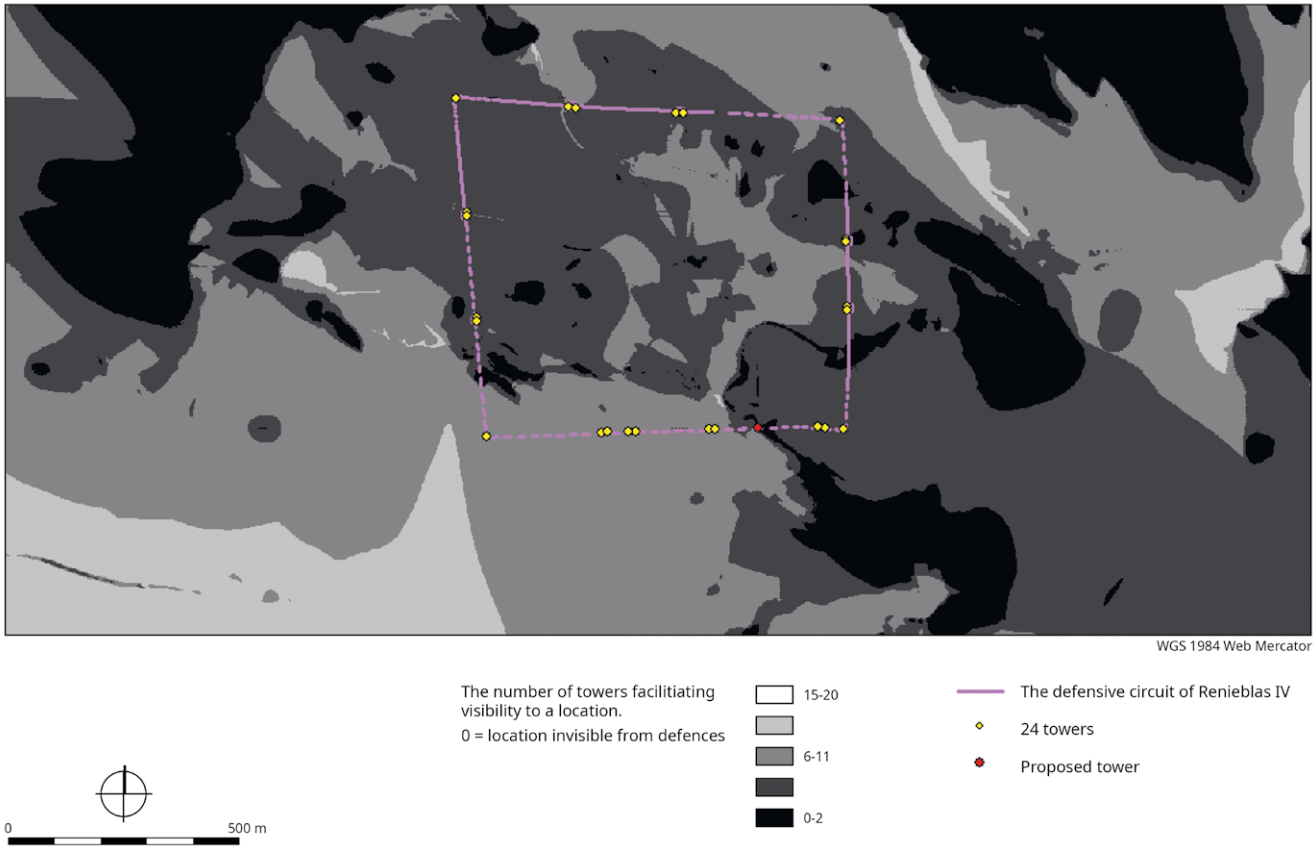


22

Fig. 21: Cumulative viewshed from all the towers around Renieblas III, with proposed tower height of 7 m.

Fig. 22: Cumulative viewshed from all the towers around Renieblas III, with proposed tower height of 7 m, including the area of Numantia.

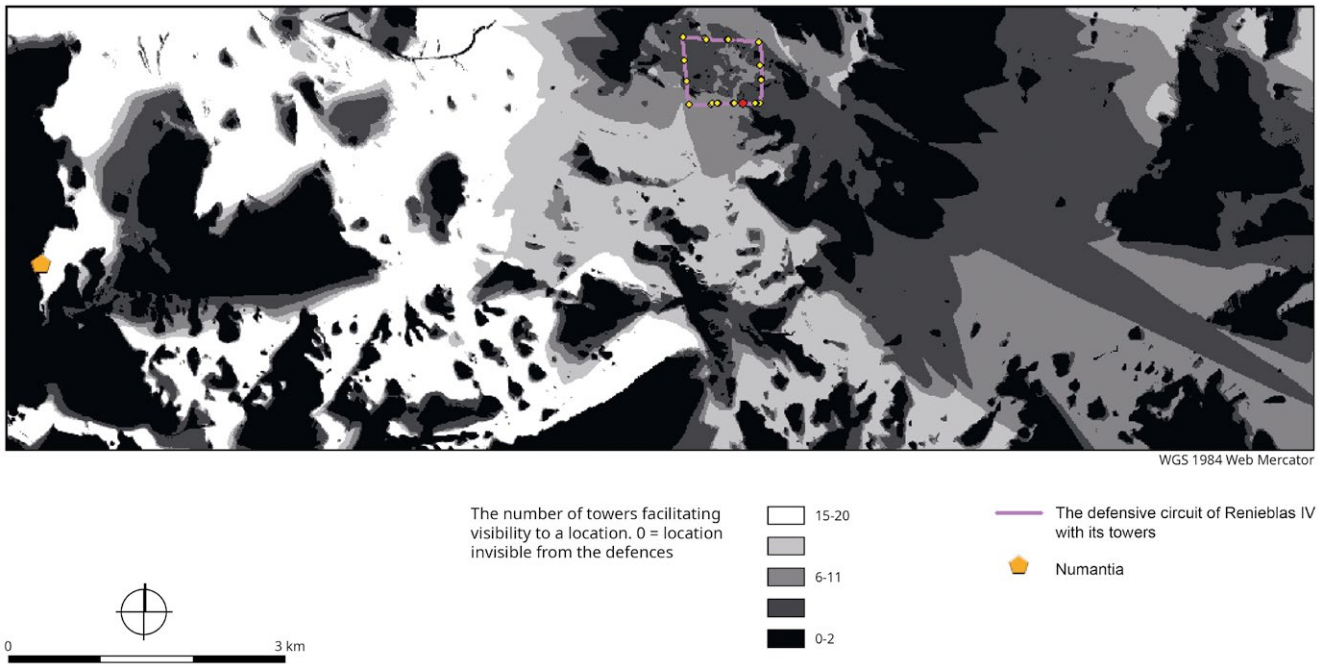
23



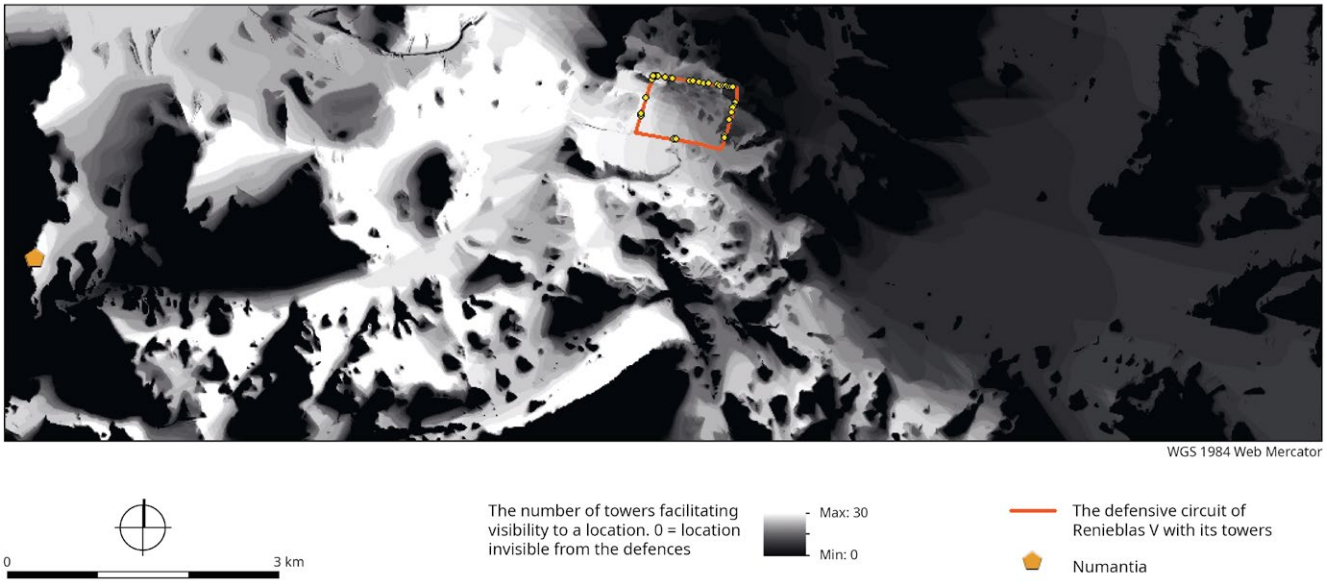
24

Fig. 23: Multiple viewshed from all the conjectured towers around Renieblas III, with proposed height of 7 m, including the area of Numantia.

Fig. 24: Cumulative viewshed from all the towers around Renieblas IV, with proposed tower height of 7 m.



25



26

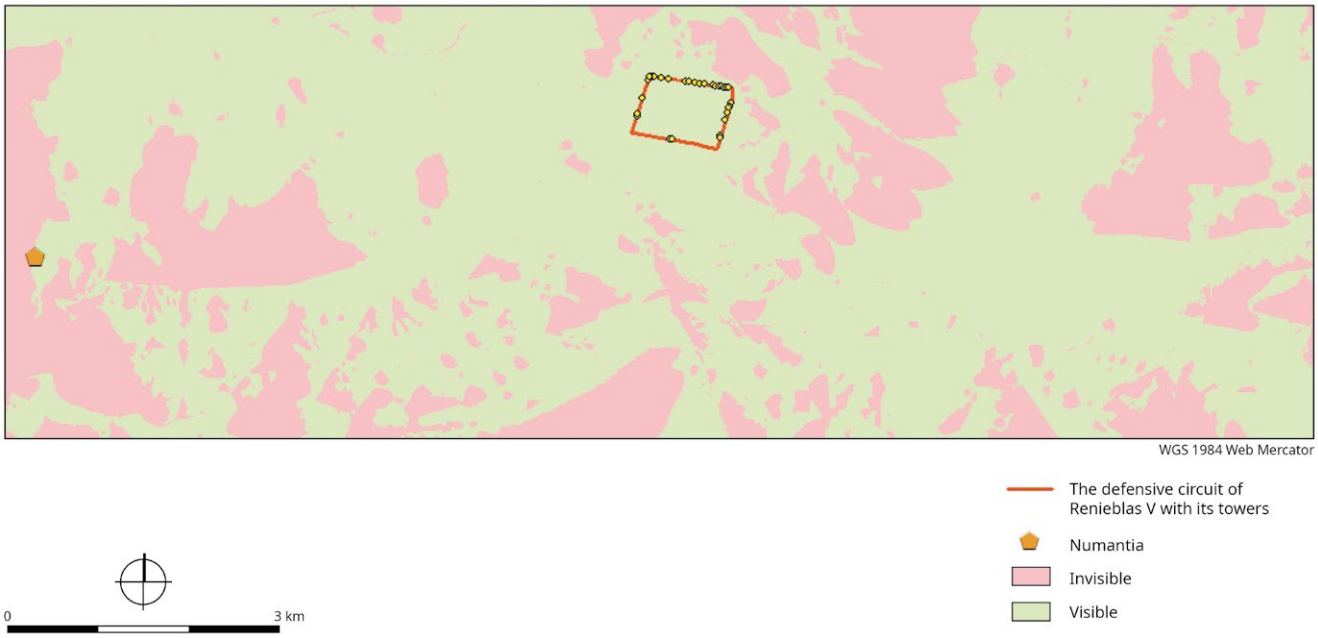
Fig. 25: Cumulative viewshed from all the towers around Renieblas IV with proposed tower height of 7 m, including the area of Numantia.

Fig. 26: Cumulative viewshed from all the towers around Renieblas V with proposed tower height of 7 m, including the area of Numantia.

essential element of this current computer-based research, which develops things further by proposing other towers around some of the Renieblas camp perimeters, partly based on the Dobson 2008 suggested revised internal camp layouts (Fig. 13. 14. 15).

23 Dobson's 2008 book and earlier fieldwork by Morales Hernández, with subsequent analysis by him and Dobson[31], also introduced a revised route for the Scipionic circumvallation compared to that proposed by Schulten (Fig. 3). The results of that research additionally presented different shapes and sizes for several of the camps associated with the circumvallation and also which specific camps were associated with it, compared to Schulten's reconstructions. It is the revised, alternative form of the circumvallation and associated camps that is adopted here.

31 Morales Hernández – Dobson 2005.



27

Fig. 27: Multiple viewsheds from all the conjectured towers around Renieblas V, with proposed height of 7 m, including the area of Numantia.

24 The distances between the towers of Renieblas III and those of V were established using the published plans. Different published interpretations exist for the length and course of the northern, eastern, and southern sides of Renieblas V. This is also the case for the distribution of the towers along its perimeter. The same issue occurs for the perimeter of Renieblas III[32]. Consequently, it was decided to create plans of the overall form, location of towers, and defensive layout of the Renieblas camps from the same published plans[33] used for the rectification and vectorization processes (above; Fig. 5. 6. 13. 14. 15).

25 Several towers were proposed by Schulten at Renieblas in addition to those found archaeologically and are shown in his published plans[34]. Schulten proposed three additional towers along the western part of the northern side of V. He added eight towers to the defences of III: four on the northern side, three on the eastern side and one on the western side. Schulten found remains of two possible bastions on the eastern side of III, but he was uncertain about such an interpretation[35]; they should in fact be discounted, as these are modern shepherd huts[36], but there could nevertheless have been towers at these points. Schulten reconstructed the southern and part of the western sides of the Renieblas IV defences, a *porta praetoria* on the southern side (with two flanking towers – Fig. 14, M1–M2) and a second entrance near the south-eastern corner (with two flanking towers – Fig. 14, N1–N2)[37]. *Tituli* were found by the surviving entrances and the same are consequently also proposed by the conjectured two southern entrances[38].

32 Dobson 2008, 134–141 figs. 39. 51. 53. 95. 105. The route and form of the southern side of Lager III has also been discussed and reassessed after the doctoral-based research for this article was carried out (Morales Hernández – Morillo Cerdán 2020; Jiménez et al. 2020; Jiménez et al. 2022), but there is still uncertainty about these aspects.

33 Dobson 2008.

34 Schulten 1929 and reproduced in Dobson 2008.

35 Schulten 1929, 53.

36 Jiménez et al. 2022, 96.

37 Schulten 1929, plan XVIII.1 (Dobson 2008, 194–197 fig. 90). The proposed reconstruction is discussed in Krahulcová 2017, 141 note 865.

38 Dobson 2008, 195–197 figs. 51. 52. 53. 90–93. 95. 105.

26 Presumably, the pattern of towers at both Renieblas and Numantia was the result of a very long preceding period of experience and development by the Roman army in addressing the issues and importance of visibility and defence. Consequently, the visibility research conducted here offers potential indications about where the Roman army had reached by the late second century BC concerning its handling of strategic and logistical matters relating to visual information. The initial conclusions of this visibility research, especially calculating direct visibility (i. e., line of sight), suggest that towers had certain requirements:

27 A) Towers were to be constructed in intervisible locations, with each tower having a sightline to at least one other tower and not just to each other for any particular pair. This would facilitate the transmitting of information between them, and potentially right around the perimeter by some means of visual signal (discussed below). This may not be as a simple sequence between direct neighbours, however, as some could not see either or both of these, but they could see another tower.

28 B) Each camp tower had to provide an optimal view into the camp as well as to the outside.

29 C) For all camp towers, complete visibility of the camp area and its defensive circuit had to be at least attempted and ideally guaranteed. One exception was the central raised area of Renieblas III, which obscured intervisibility across the camp and around the whole perimeter for any tower (Fig. 7. 21). A solution here would have been to signal using sound from wind instruments, which Appian attests at Numantia[39], rather than visually.

30 Leading on from this, it was attempted to determine potential minimum tower heights that facilitated performing these functions, through performing viewshed analyses using tower height above the terrain surface (OFFSETA) and elevation of the target (OFFSETB):

5.2 OFFSETA

31 To establish OFFSETA, it was necessary to consider the rampart height of the selected camps and of the Scipionic circumvallation, the location of the towers relative to the rampart and the suitable amount of elevation for artillery (*catapultae*, *ballistae*, etc.) to function effectively.

32 Unfortunately, the rampart height of the camps and of the circumvallation is uncertain from the available archaeological evidence. Remains of ramparts survived in places up to about one metre high at the time of Schulten's excavations and similarly today, with slumped rampart remains still clearly visible at Renieblas (Fig. 28)[40]. Schulten interprets a surviving bank at the site of several phases of camp at Castillejo, to the north of Numantia, as the rampart for the middle phase of camp, but reinterpretation suggests it is more likely to be from the final, Scipionic phase[41]. This bank survived two metres high at the time of Schulten's excavations. It consequently may provide archaeological evidence for a minimum rampart height for the Scipionic siegeworks (the Numantia-facing ramparts of these camps were a continuation of the circumvallation). Presumably the camp ramparts at Renieblas could also have had similar minimum heights.

33 As regards available literary evidence for the size of the ramparts, Appian says that the circumvallation rampart was eight feet wide and ten feet high, excluding the parapet on top of it[42]. Appian is probably referring to Hellenistic/Greek feet (0.355 m) rather than Roman (0.296 m)[43]. Converted into Roman feet, it means that Appian indi-

39 App. Hisp. 93; see also App. Hisp. 52. 89 and Veg. mil. 2, 22, 3.5 for use of wind instruments for signalling; Meucci 1989; Alexandrescu 2007, 39.

40 Dobson 2008, 375. 402.

41 Dobson 2008, 242 f.

42 App. Hisp. 90.

43 Dobson 2008, 46.

28

Fig. 28: Remains of the stone rampart of the western side of Renieblas III. Numantia lies to the top-right of the photograph. The ›human scale‹ is the local archaeologist Fernando Morales Hernández.

cates the rampart was 9.6 feet (2.84 m) wide and 12 feet (3.55 m) high to the walkway. The figure for the width seems unlikely as it is not an obvious ›round‹ dimension for the Romans to choose; Appian was probably simplifying down from a more ›natural‹ 10 Roman feet (2.96 m), equal to 8.3 Hellenistic feet. The archaeological evidence of Schulten and more recent excavations in 2003 suggest the circumvallation rampart and that of its associated camps were generally between 2.5 and 3.0 m wide[44], so not that dissimilar from Appian's dimensions. At some of the camps, and noticeably so at Renieblas, however, several of the ramparts are recorded as being between 3.0 and 4.0 m wide[45]. If this evidence is reliable, the extra width compared to the circumvallation may indicate that camp ramparts could have been higher than that of the circumvallation.

34 Considering the uncertainties about the rampart height, it seems reasonable to combine the available evidence into an average of about 3.0 m to the rampart walkway. This is probably the maximum conceivable height. Appian's height seems overgenerous and could be a literary device to emphasise the power of Rome's military, since the viability of building such high structures using front and back, dry-stone revetment walls and a lose stone and earth core (sometimes either side of a middle, ›spinal‹ wall) is questionable. Even as much as 3.0 m of height could be a challenge using this building technique. Schulten's reconstructions of the defences were created by the artilleryman Generalleutnant Erwin Schramm (1856–1935), a published expert in ancient artillery[46] as well as an archaeologist. His reconstruction drawings also adopt a rampart height of 3.0 m up to the walkway (Fig. 29).

35 The actual observational height of a soldier standing on the rampart would be the 3.0 m plus his eye-level. The average height of Roman soldiers was probably 1.70 m[47]. Hence a possible maximum overall observational height would be about 4.60 m (3 m to the walkway plus eye-level of about 1.6 m). To protect soldiers on the rampart, the

44 Dobson 2008.

45 Dobson 2008.

46 He had numerous publications, including Schramm 1910 and Schramm 1920. Schramm's drawings still form the basis of many modern reconstructions, e. g., Bendala Galán 2015; Baquedano – Arlegui Sánchez 2017; Quesada Sanz 2023, 234 f.

47 Roth 1999, 9 f.

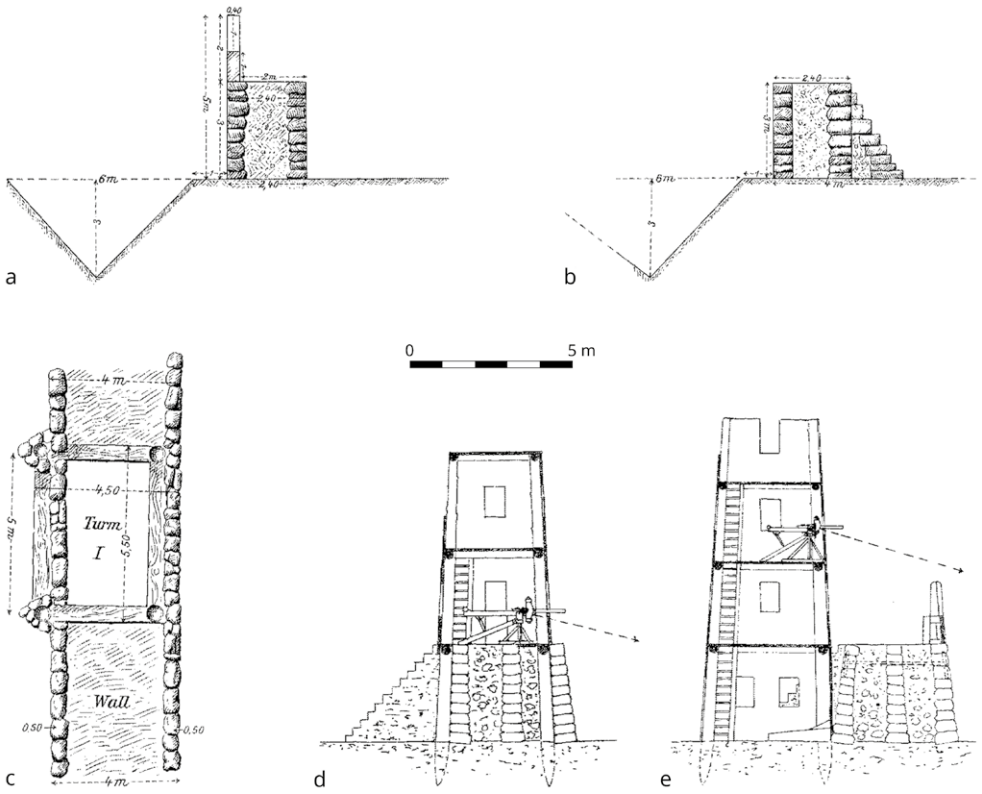


Fig. 29: Schramm's reconstructions of the circumvallation structures: a. Section through the rampart and ditch according to Appian. – b. Section through the rampart and ditch, according to the archaeology found by Schulten. – c. Generalised plan of a tower within a rampart. – d. Section through a tower constructed within a rampart. – e. Section through a tower placed against the back of a rampart.

29

parapet could have raised the overall height of the rampart by just over 1.70 m. It must have been lower than eye-level at least in some places to facilitate visibility and, if circumstances required, the discharge of projectile weapons. Schramm's reconstruction adopts a parapet that is 2.0 m high, and his drawing indicates some form of crenellation to allow soldiers to both observe the exterior area and use their weapons (Fig. 29 A).

36 Concerning the height of the towers constructed along the camp ramparts and circumvallation, if these also functioned as artillery platforms, which is probable for at least some if not all of the towers, the artillery could have been placed at the same level as the top of the rampart (Fig. 29 D). The tower could then have extended above the artillery piece, providing both a protective covering for it and a higher floor for observers. Using Schramm's reconstruction for this scenario, it creates a top-floor viewing (eye-level) height of about 7.6 m above ground level. If the artillery was placed on towers standing against the rear of the rampart, which the archaeological evidence suggests was the common location for towers, then greater height for the artillery would be needed to safely clear soldiers on the walkway and the parapet. This could have been achieved by placing the artillery on a second storey in the tower which, based on Schramm's reconstruction, could have had its floor about 5.5 m above ground level (Fig. 29 E). Again, an upper storey above the artillery platform could have been constructed, as in Schramm's reconstruction, resulting in a viewing height of about 9.6 m (Fig. 29 E). Significantly, similar reconstructions are proposed for the towers in the siegeworks at Alesia[48].

5.3 OFFSETB

37 Ground level was selected for OFFSETB and equals 0 m. This setting is relevant for visibility calculations relating to landscape features both near and distant (watercourses, raised areas, etc.). Examples of its use are in assessing the importance of La

48 Reddé 2006, figs. 4. 5.

Visibility zone	Fraser 1983 Orkney	Higuchi 1983 Japan	Parcero-Oubiña 2002 North-west Spain	Liceras Garrido 2011 Territory of Numantia
High	up to 500 m	up to 300 m	up to 800 m	0–500 m
Medium to high	—	—	—	500 m – 3 km
Medium	500 m – 5 km	300 m – 3 km	800 m – 2 km	3–8 km
Low	more than 5 km	more than 3 km	more than 2 km	more than 8 km

30 Fig. 30: Visibility zones.

Muela hill in respect to Numantia's own visibility provision and intervisibility between the circumvallation and the Renieblas camps[49]. The selected setting also allows assessment of the crucial ability to observe movement of enemy forces and any other activities occurring at ground level.

38 To form an accurate appreciation of past visibility conditions or capability, potential influencing factors need to be considered. These factors can be divided into those that are challenging or impossible to recreate and those which can be reconstructed with reasonable confidence. The type and coverage of vegetation in a particular period, meteorological conditions at the time and their related effect on visibility are among the uncertainties. Similarly, the sight quality of those observing, which could be influenced not only by how good their eyesight was, but also by their general health or even mental state, are both impossible to establish now and would also have varied within any unit of troops.

39 Influencing factors that may be reconstructed include the elevation of a soldier relative to the field of view. At the simplest, this is known from the ground-level topography of a camp's location or that of the confirmed position of a stretch of circumvallation. With declining levels of certainty, the location of ramparts, the spatial distribution of towers and reconstructions of their potential heights can be proposed. Also, consideration can be made of how such features may have facilitated the use of visual signalling; Appian says that signals (presumably some form of flag) were to be hoisted at towers along the circumvallation to communicate emergencies[50].

40 The results of any visibility analysis are also conditional on the DEM resolution, which can be influenced by the size of the selected landscape area, and in turn affects the ability to create satisfactory and understandable visual plots. The area chosen for analysis in this study is less than 21 km in any direction, so it was unnecessary to consider the earth's curvature affecting visibility[51].

41 Researchers in various parts of the world have studied the characteristics and quality of landscape visibility, for example, studies of Japanese and Spanish landscapes and monuments on the Orkney Islands (Scotland). This research has concluded that there are several ›visibility zones‹ (see Fig. 30).

42 With regard to the geomorphological characteristics of the area near Soria used for the current study, significant use was made of the visibility zones presented by Liceras Garrido in her application of GIS to the Celtiberian landscape in the Upper Duero. She looked specifically at the territory of Numantia, defining it as the area within a 15 km radius of the city[52] (Fig. 30).

49 If, for example, the presumed average soldier's ›sight-height‹ (1.6 m) was also taken into account when assessing visibility, the results would no longer be accurate, as OFFSETB is the height of the target point and so including the sight-height would distort the contour of the terrain.

50 App. Hisp. 92. See Woolliscroft 2001 for a discussion of Roman army signalling practices.

51 »The curved surface of the earth can be replaced with a flat plain up to a distance where the real horizon = 30 km.« V. Čada, Přednáškové texty z Geodézie, <http://gis.zcu.cz/studium/gen1/html/ch02.html> (13.1.2024).

52 Liceras Garrido 2011.

6 Discussion

43 A result of the methodology based on the three MTN10 vector maps was to create over 400 geo-objects in the form of points, lines, and polygons within the selected area. These objects included the city of Numantia, two reconstructed routes for the circumvallation, Schulten's proposed location of Scipio's bridge across the Duero, 17 Roman camps, 384 towers, and three sections of the Roman road between Uxama and Augustobriga. 107 of the towers are associated with camp defences (Renieblas I, II, VI, VII, Molino, Peña del Judío and La Vega were excluded from the study due to poor knowledge about the line of their defences and some also lack archaeological evidence of towers). 277 of the towers are conjectural and were placed around the revised course of the circumvallation, based on Appian's statement about the frequency of towers (below), and these facilitate the visibility analyses performed in this research (below; Fig. 16. 17. 18. 19. 20).

44 Four digital models of the TIN were created for use in various working hypotheses. The high-quality TIN itself was formed from the 2 m and 5 m contour lines on the digital maps, and a selection of spot heights (Fig. 5).

45 The individual TINs were used to calculate the slope characteristics of the terrain and revealed that most of the area slopes from 0 to 10.97°. There are also some noticeably steeper slopes, the steepest being the southern side of La Gran Atalaya in the north-eastern area of Renieblas V. It is so steep here that even walking down it is precarious, and from the personal experience of the current authors is definitely to be avoided. It raises questions as to why part of a camp's interior would have been placed here, as such steeply sloping ground could hardly have had any practical use to the army. Even if it were possible to pitch tents here, sleeping in them would scarcely have been viable, as men would have rolled down to the lower side of the tents. Also, the basic and essential requirement of being able to move around inside the camp would have been challenging. There are also significant slopes leading away from a ridge extending south-east of this range of hills (the location of Renieblas VI) and on the north-eastern side of this range beyond Renieblas III, as well as the ends of some steep-sided, fairly narrow valleys cutting into the north-eastern area of Renieblas III itself (Fig. 4).

46 It was also possible to create high-quality DEMs from the layer of 2 m and 5 m contour lines. Using the two types of contour lines, slightly different measurements for the altitude above sea-level resulted. From the 2 m contours it ranged from 999.79 to 1363.58 m. From the 5 m lines it was 1002.59 to 1363.09 m. Both raster elevation models, i. e., those from the 2 m and from the 5 m contours, in fact differed only minimally, and were subsequently used for the calculations of line of sight (LOS) and viewshed (see above for that process).

47 The DEMs of polygons at 0.2 m spatial resolution selected from Renieblas III–V, Castillejo, Peña Redonda, Dehesilla, and Alto Real were also produced as graphical plots, with those of Renieblas III, IV, and V presented here (Fig. 7. 8. 9). These raster elevation models were generated from the 2 m and 5 m contours, apart from Castillejo and Alto Real, through which the 5 m lines did not pass, and so only the 2 m contours could be used, and no models at all could be made for Travesadas and Valdevorrón due to the absence of any contour lines in their areas (Fig. 2. 3). The outputs show altitude values of the Renieblas camps as ranging from 1039 m (Renieblas V) to 1133 m (Renieblas III and IV) and possibly as much as 1141 m at Renieblas V (Fig. 7. 8. 9). The same outputs show the altitude range of the camps around Numantia ranged from 1008 m (Alto Real) to 1063 m (La Rasa).

48 The calculated altitude range of 999.79–1363.58 m reflects the geomorphology of low-lying flat areas associated with the bottom of river valleys, rising to significantly upstanding rocky areas. Some of the camps being as much as 1008 to 1133 m (possibly

to 1141 m) above sea level is due to this area being part of the Central Meseta (above). The amount of incline displayed by each camp's area varied from 12 to 94 m, possibly to 102 m. Within this range, the ground of camps around Numantia was generally flatter or more gently sloping than those at Renieblas, where the significant slope around the sides of La Gran Atalaya meant that the camps were situated on more sloping terrain and parts of some of these camps occupied very sloping ground indeed, the north-eastern part of Renieblas V being the most extreme example (above; Fig. 7. 8. 9. 10. 11. 12).

49 Other map compositions focus on the slope of the camp areas and provide detailed views of their vertical profiles (Fig. 10. 11. 12). They were generated from DEMs (with pixels representing 0.2 m × 0.2 m). The terrain relief of Renieblas III, IV, and Peña Redonda mostly lies between ›significantly‹ to ›steeply sloping‹ surfaces (5–25°). Renieblas V, Castillejo, and Dehesilla, in this respect, have mostly ›flat‹ to ›slightly sloping‹ surfaces (0–5°); even Renieblas V fits this pattern as most of its internal area is within a 0–5° slope (Fig. 12). The most interesting outputs are represented by Renieblas III, due to the significantly raised but almost flat terrain in the middle of it (Fig. 7. 8. 9. 10). The maximum slope of this area is 0.87–1.08°. Perhaps relating to this, archaeological remains in this central area have been associated with the headquarters area, the *praetorium*[53]. There are characteristically very different east-west profiles at Renieblas III, IV and V (Fig. 10. 11. 12) as well as the way the course of their defences relates to the top of La Gran Atalaya hill: the course of III goes around the hill's summit; the north-east corner of V includes the summit; and the south-east corner of IV is very near to the highest point of the hill.

50 GIS-aided analysis and making use of the archaeological evidence, geomorphological calculations, and published interpretations of the sites allows some speculation about the use of camps' internal areas and the positions of towers along their defences. Such analysis can be performed at Renieblas III, IV, and V in connection with the proposed location of streets (Fig. 13. 14. 15). For example, a possible southern end of the *via quintana* of IV[54] would be close to the bottom of the hill (Fig. 8. 15), and the eastern end of a street in the northern part of V would be situated at the foot of the hill (Fig. 10. 16). Also, part of the *via principalis* of III passes across the highest point of the hill (Fig. 7. 10).

51 Towers were identified by Schulten along the northern side of the Renieblas V defences. In contrast, they are unusually absent at the northern end of the eastern rampart (Fig. 15). This absence can be explained by the west-to-east rise in topography in this area, with almost flat terrain to the east of the defences, making towers unnecessary to aid either visibility or defence (Fig. 4. 9. 12. 26). Similar conclusions can be made for the positions of the towers reinforcing the Renieblas III defences (Fig. 13. 22). The relatively close spacing of towers occurred in the north-western, northern, and north-eastern parts of this camp's defences. In contrast, large intervals between towers can be seen in the south-eastern part of the defences. The reason for the much wider spacing is probably similar to the absence of towers at the northern end of the eastern side of V, namely that the natural topography provided both sufficient visibility beyond the camp (shown also by appropriate GIS viewshed calculations) and adequate natural defensive provision (Fig. 22. 23). The distance between the towers found along the Renieblas V rampart ranged between about 13 and 166 m, and for those of Renieblas III, from about 10 to 222 m; in both cases a significant and initially surprisingly wide range until the topographical aspects are considered.

52 The results of the GIS research also confirm that both the overall form and the general spatial characteristics of the camps are completely adapted to the local terrain and to meet defensive considerations (as also found for aspects of the Scipionic circumvallation; below).

53 Schulten 1929, 99; Dobson 2008, 176.

54 Dobson 2008, 198.

53 Renieblas III and V provide the best archaeological evidence for approaching an understanding of their overall ground plan. Similarly, with so many towers having been identified along the defences at these two sites, they are the best for the TIN, DEMs, slope, and viewshed calculations (below).

54 Assessing the minimum height of towers to be effective for visibility and aid defence at selected Roman camps in the area was attempted by using the proposed elevation of artillery and observers, discussed earlier (Fig. 29), as well as by means of the ArcGIS viewshed analyses. It was also assumed that the towers were constructed against the back of or on the ramparts (above); the slight difference between the back or on the ramparts makes little actual difference to viewshed calculations.

55 Viewshed maps were specifically generated for:

- Renieblas III, IV, and V
- Camps close to Numantia: Castillejo, Travesadas, Valdevorrón, Peña Redonda, Dehesilla, and Alto Real
- The Scipionic circumvallation, using the revised route of Morales Hernández and Dobson (above).

56 Renieblas III and V, and possibly also IV, have the greatest potential for having had the lowest towers. Output rasters from multiple viewsheds show that visibility from some parts of these camp defences to Numantia's La Muela hill would have been perfectly adequate to observe the city, even without the use of towers. This lends weight to the interpretation that these camps were strategically significant to Rome's action against Numantia. Consequently, Renieblas III and IV could well relate to two of the various assaults against the city. The dating of V is uncertain, but the available evidence leans towards a post-Scipionic date, possibly even in the context of the Sertorian Wars[55], so this camp, although presumably related in some way to Numantia because of proximity, may not have been for hostile purposes against the city. Nevertheless, as the viewshed analysis of V reveals, most of the best visibility was in the direction of Numantia and the city itself could be seen (Fig. 26), indicating that this aspect was still important.

57 But not all of the defensive circuits of the Renieblas camps would have had clear visibility to Numantia without the aid of elevated observation positions, since parts of these camps lay below the top of La Gran Atalaya, and even with the provision of towers in some such sections, there would not have been visibility from these to the city. Since, however, the exact location and entire course of the defences below the top of the hill or the general shape of the southern areas of these camps are not always known, any resulting viewshed analyses from these areas may be unreliable, especially as it is uncertain which aspects of the terrain relief to include in them. For the sake of being able to generate some viewshed analyses, Schulten's proposed form for these areas was used and the minimum proposed tower height of 7 m (above).

58 The viewshed analysis of the camps at Castillejo and Peña Redonda aids the interpretation of the function of these camps within the context of the Scipionic siege. A 3 km viewshed radius from Castillejo shows that this camp had excellent visibility to the south, with sight to most of the camps around the circumvallation, including to part of Peña Redonda and potentially even to a portion of Molino (Fig. 16). Peña Redonda's 3 km viewshed indicates that most of its sightlines were to the southern region of the circumvallation, with good sight of the camps there and of stretches of the circumvallation that Castillejo could not see and, very significantly, it could also see part of Castillejo (Fig. 17). If the two viewsheds are superimposed, then the two camps can see almost the entire circumvallation and its camps, and both had good views of Numantia itself. The main ›missing‹ visible sections are the circumvallation immediately south of Castillejo, which seems unexpected; the circumvallation just north of Peña Redonda and not much of

55 Gómez-Pantoja – Morales Hernández 2002; Dobson 2008, 35–41.

Valdevorrón camp would have been visible to either Castillejo or Peña Redonda (Fig. 18). This, in combination with the intervisibility between Castillejo and Peña Redonda, suggests that these two camps were very deliberately placed in these specific locations and arguably, by extension, that most of the installations around the circumvallation were deliberately located with reference to Castillejo and Peña Redonda. Appian states that Scipio »pitched two camps very near to Numantia«, with his brother Maximus in charge of one and he the other[56]. In other words, it implies two camps were established as command points for the siege operation. Appian goes on to say that they were followed by the construction of seven smaller camps[57] around the city (Fig. 18, 1–7)[58]. Appian provides no details about the location of the two command-centre camps, other than the vague »very near« (ἀγχοτάτω) to Numantia. That may mean they were not as close as Castillejo and Peña Redonda, but since there are two such camps and they are larger than what seems probable for the other installations identified around the circumvallation, it seems reasonable to interpret them as the likely command-centre camps[59]. The viewshed analysis now adds significant weight to that interpretation.

59 Establishing the nature and distribution of the towers along the rampart of the Scipionic circumvallation is clearly important in any analysis of intervisibility. From the various viewshed analyses carried out, it seems that a tower height of at least 7 m and regular spacing of about 30 m would be good, ideally with additional towers in important or vulnerable sections and where significant topographical changes may impact intervisibility.

60 Establishing what the tower spacing may have been in reality is challenging, however. Appian says that towers were placed along the rampart at intervals of a *plé-thron*[60]. This was a unit of 100 feet and has usually been regarded by scholars as meaning 100 Roman feet (29.6 m), i. e., about 30 m[61]. Appian is probably referring to Hellenistic/Greek feet[62] however, 100 of which (35.5 m) convert almost exactly to 120 Roman feet (35.52 m). Using 120 feet by the Roman army makes more sense, as it corresponds to the Roman *actus*, a very common unit of land measurement at the time[63]. Consequently, Appian's evidence indicates a spacing of about 35 m, and regular spacing. This may have been the reality, but Appian may have been generalising; there is sadly no other surviving literary evidence from the period to be able to cross-check his reliability.

61 There is, unfortunately, very limited available archaeological evidence regarding the circumvallation's towers. Schulten interpreted some stone settings against the back of the rampart along the stretch of the circumvallation that approached the southern side of the camp at Dehesilla as holding vertical posts for the rear of three, possibly four, towers built on top of the rampart[64], spaced between 10 and 16 m apart (measured centre-to-centre). Schulten's interpretation is questionable, especially as there are three other, ›more obvious tower-like‹ rectangular structures built against the rear of the rampart in the same stretch of circumvallation, and spaced 25 to 28 m apart

56 App. Hisp. 90.

57 Appian (Hisp. 90) calls them φρούρια, which generally translates as ›forts‹, suggesting that these installations were smaller than the two camps first established, for which Appian uses the normal Greek word for camps, στρατόπεδα (Dobson 2008, 391).

58 Schulten had a different interpretation for which installations formed Scipio's siege, as he included La Rasa, he did not propose a camp at Peña Judío (work since Schulten has indicated one there) and proposed that there were seven camps and two riverside forts. He also believed that the two initial camps had not yet been found (Schulten 1927; Dobson 2008, 412 f.).

59 Dobson 2008, 413.

60 App. Hisp. 90.

61 Penrose, though, states that the towers of the Scipionic circumvallation were constructed nearly 31 m apart (Penrose 2005, 115).

62 As also for his dimensions of the rampart width and height; above.

63 Dobson 2008, 46. 71 f.

64 Schulten 1927, 76; Dobson 2008, 397–399.

(centre-to-centre). Further south in the same stretch of circumvallation between the camps of Molino and Dehesilla and close to the river Duero, two more rectangular stone structures were found against the rear of the circumvallation[65]. These were similar in form to the three others further north and so could also be from towers. The southern pair were spaced about 15 m apart (centre-to-centre). Their much closer spacing compared to the three northern ones could be explained by the need for added defence (more artillery and firing platforms) to this vulnerable area where the Duero cut through the circumvallation, and because the terrain undulated significantly here, affecting the amount of visibility. The closer spacing by the river may consequently add to the earlier suggestion that Appian was generalising with his stated regular spacing and the need to respond to local strategic requirements was understandably more important. Also, the significant changes in terrain in the entire southern part of the circumvallation, apparent from the TIN and DEM (Fig. 5. 6. 19. 20), supports the argument for more closely and variably spaced towers in locations requiring increased defence or observation.

62 Schulten interpreted features found along the rear of the circumvallation to the south of the camp at Castillejo as potentially that of a tower, but the evidence is not convincing[66].

63 The only other remains which can be attributed with any confidence to a tower along the circumvallation are in the stretch between the camps at Valdevorrón and Peña Redonda in the Peñas Altas area (Fig. 3. 19. 20). Schulten initially thought the remains and others he found nearby were part of the circumvallation, but then preferred to interpret all of them as being a villa of the Roman Empire[67]. This revision was probably forced by him favouring a route for the circumvallation that was much further east and south of this point (Fig. 2. 3)[68]. More recent fieldwork in this area and reinterpretation of Schulten's findings have shown that the circumvallation did indeed pass through this area and the remains found by Schulten are probably those of an associated tower built against the rear of the rampart[69].

64 Creating meaningful and accurate viewshed calculations for visibility around the circumvallation and intervisibility between it and camps at Renieblas is clearly impacted by the lack of detail for the location and height of the towers along the circumvallation and, similarly, around the perimeter of the siege camps (in part as the location of the Numantia-facing defences of most of these camps is not known), since these would have formed links in the chain of towers around the whole siegeworks. Nevertheless, it can probably be presumed that Appian's statement indicates that there was plentiful provision of towers around Numantia and they were usually regularly spaced. The archaeological evidence, limited as it is, also suggests that towers could have been denser in vulnerable areas or in those where undulating terrain required extra towers to aid visibility. Combining the available evidence, a theoretical average spacing of about 35 m may consequently be acceptable for the creation of viewshed analyses; this spacing results in there possibly having been as many as 277 towers around the siegeworks. Further refinement may be aided by gaining available comparative material from other Roman military sites, but this could introduce other inconsistencies caused by local conditions and strategic requirements in those theatres of operation.

65 Similar uncertainties relate to the original height of the towers. There is also the possibility that the towers varied in height, with some locations only needing a small elevation to be effective and others needing significant height. There is a consequent

65 Schulten 1927, 74; Dobson 2008, 398.

66 Schulten 1927, 72 f.; Dobson 2008, 393.

67 Schulten 1907, 17 f.; Schulten 1931, 201.

68 Dobson 2008, 395.

69 Dobson 2008, 393–395 fig. 269; Dobson 2014, 59–61 fig. 6; Dobson – Morales Hernández 2014.

impact on the creation of valid viewshed calculations. That said, meaningful viewshed results can be generated by adopting a minimum height of 7 m for the circumvallation towers, based on Schramm's reconstructions (above), and combining this with an assumed average spacing of 35 m. More targeted viewshed results could obviously be generated if new archaeological data become available. In turn, such results could give clearer insight into the army's strategy regarding the assaults on Numantia.

66 The same limitations and uncertainties apply to assessing the visibility aspects of the camps close to Numantia. Confident conclusions based on viewshed analysis must await further evidence for the size, shape, internal layout, and positions of the towers along their defences. Until then, as indicated above, viewshed analysis can only be based on a central point of a camp's overall area.

67 Conclusions from this GIS-based research have nevertheless been possible, based on the exported and evaluated maps representing simple, cumulative, and multiple viewsheds. The large-scale maps (1 : 6,000 and 1 : 9,000) and the medium-scale maps (1 : 10,000) allow the calculation of visibility from the towers around a camp's defences into its interior as well as to its surroundings. Similarly, the 1 : 50,000 maps facilitate demonstrating that there was intervisibility between the Renieblas camps and Numantia on La Muela hill. The multiple viewshed raster created from the numerous reconstructed, seven-metre-high towers around Scipio's siegeworks likewise shows that there was excellent visibility of the entire siege area as well as intervisibility with the more distant Renieblas camps (Fig. 19. 20).

7 Conclusion

68 Using available digital map sources and good quality published archaeological plans, it was possible to generate contour image maps of the topography of the area of the Roman camps around Numantia and nearby at Renieblas, with outlines of the military installations superimposed on the geomorphological layers. The raster and vector outputs from these image maps then facilitated meaningful, GIS-aided study of the military sites, especially via the generation of single, cumulative, and multiple viewshed maps. This also used and reflected upon Schulten's important early twentieth-century archaeological findings and his interpretation of them, as well as relatively recent reassessment of Schulten, together with modern fieldwork and excavations.

69 The GIS study of specifically the topography of camp locations showed that they occupied ground that varied from flat to usually only gently sloping, though some at Renieblas incorporated very steeply sloping and today seemingly very impractical areas. It also revealed that, not surprisingly, the locations appear to have been deliberately selected in order to provide appropriate visibility and intervisibility not only across most of each camps' interior and the immediate surroundings, but also, and very significantly, between the area of Numantia and its associated siegeworks, and camps back at Renieblas. Also, the layout and form given to these camps seem to have responded directly to the local landscape they were occupying; the layout and shape were accordingly adapted in each case, with the theoretical rectangular Polybian Republican form in fact not often applied.

70 The application of various forms of GIS viewshed analysis, in combination with assessing the height-related practicalities of using the towers by artillery and by observers, demonstrated that towers played an important, potentially vital role in the aspect of visibility and intervisibility. It also revealed that towers would generally have had to have been 7 m high to facilitate adequate observation, effective use by artillery, and also communications by visual signalling. Interestingly, this was the same tower height proposed by Schramm in his reconstructions based on more practical consid-

erations of defensive function and artillery capabilities. The GIS results consequently (and perhaps even unexpectedly) support Schramm's much earlier proposals.

71 The available, largely archaeological evidence is unfortunately less conclusive about the spacing of the towers. Appian's literary evidence indicates regularity for the circumvallation, but the archaeology from both the circumvallation and the camps at Renieblas suggests spacing was more flexible and responded more to local defensive requirements and topography. The GIS analysis also supports the idea that the determining factor in their location was probably to achieve optimal visibility from a particular viewing point, taking into account the local terrain. But regardless of the policy over tower positioning, the simple high elevation of La Gran Atalaya for the Renieblas camps, i. e., the ›visibility zone‹ relative to those at Numantia, greatly facilitated intervisibility regardless of the frequency or regularity of towers at either the camps or circumvallation.

72 In carrying out the various viewshed analyses and reaching conclusions based upon them about visibility and intervisibility, it should be remembered, however, that there is the unknown influencing factor of woodland cover at the time. This was probably not a problem within each camp and the immediate surroundings, since these areas were probably cleared by the troops[70] and probably also not for distant views because of the visibility zone of the Renieblas camps relative to Numantia (though tree cover could have obscured the details of distant troop movement, both friendly and hostile). Other unknown factors influencing visibility could have been weather conditions and the quality of observers' eyesights. There is also the lingering uncertainty about the exact location of the defensive circuit of most of the camps and hence where their towers could have been located and the relationship of that to the provision of visibility and intervisibility.

70 Dobson 2022; Dobson 2023.

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RESUMEN

Estudios de visibilidad e intervisibilidad basados en SIG de los campamentos republicanos romanos de Numancia y Renieblas cerca de Soria, España

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Se utilizan metodologías del Sistemas de Información Geográfica (SIG) y ArcGIS para evaluar la visibilidad e intervisibilidad entre los importantes emplazamientos militares romanos republicanos de la ciudad celtibérica (*oppidum*) de Numancia y los cercanos a Renieblas, concentrándose en el papel de visibilidad de las torres situadas alrededor de las defensas. Las interpretaciones de las excavaciones de Adolf Schulten de 1906–1912/1927 y los resultados de investigadores posteriores se georreferenciaron, vectorizaron y combinaron con datos digitales de elevación y topográficos. Los más de 400 objetos vectoriales de puntos, líneas y polígonos geoespaciales vectorizados resultantes permitieron crear modelos digitales y mapas de vistas (viewsheds). El análisis reveló que la visibilidad desde y entre las instalaciones variaba enormemente, y que las numerosas torres, parte integrante de los asedios de Escipión (133 a.C.) y de los campamentos de Renieblas, debían tener al menos siete metros de altura para ser eficaces. El análisis de las vistas también contribuyó de forma significativa a interpretar dos de los campamentos de Escipión en Numancia, Castillejo y Peña Redonda, como los dos centros de mando del ejército romano indicados en las fuentes literarias.

PALABRAS CLAVE

República Romana, Numantia, SIG, Estudio de visibilidad, Análisis de cuencas, Ejército romano republicano

ZUSAMMENFASSUNG

GIS-gestützte Sichtbarkeits- und Intervisibilitätsstudien zu den römisch-republikanischen Lagern in Numantia und Renieblas, Provinz Soria, Spanien

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Mithilfe des Programms ArcGIS (ein geographisches Informationssystem) und seiner zur Verfügung stehenden Methoden werden die Sichtbarkeit und Intervisibilität zwischen den wichtigen römisch-republikanischen Wehranlagen rund um die keltiberische Stadt (*oppidum*) Numantia und nahe Renieblas dargestellt und bewertet, wobei der Schwerpunkt der Untersuchungen auf der Sichtbarkeitsrolle der römischen Türme, die um die Wehranlagen herum errichtet wurden, liegt. Die 1906–1912/1927 erfolgten Ausgrabungsinterpretationen von Adolf Schulten und die Ergebnisse späterer Forscher wurden georeferenziert, vektorisiert und mit digitalen Höhen- und topografischen Daten kombiniert. Die daraus resultierenden über 400 vektorisierten Geopunkte, Linien und Polygone ermöglichten die Erstellung digitaler Modelle und Sichtfelder (Viewsheds). Die Analyse ergab, dass die Sichtachsen von und zwischen den Wehranlagen sehr unterschiedlich war und dass die zahlreichen Türme, die Bestandteil der Belagerungsanlagen von Scipio (133 v. Chr.) und der Lager von Renieblas waren, mindestens sieben Meter hoch gewesen sein mussten, um effektiv zu sein. Die Analyse des Sichtfeldes unterstützt auch die Interpretation, dass es sich bei zwei der scipionischen Lager bei Numantia, Castillejo und Peña Redonda, um die beiden in den literarischen Quellen erwähnten Kommandozentralen des römischen Heeres handelt.

SCHLAGWORTE

Römische Republik, Numantia, GIS, Sichtbarkeitsstudie, Analyse der Sichtfelder, Römisch-republikanisches Heer

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