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A GIS-BASED ANALYSIS OF THE RATIONALE BEHIND ROMAN ROADS. THE CASE OF THE SO-CALLED VIA XVII (NW IBERIAN PENINSULA)

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ABSTRACT

The aim of this paper is to dig deeper in order to gain a better understanding of the territorial logic of Roman roads, following some recent approaches based on the use of digital modelling tools. Taking the case of the so-called via XVII (a ca. 330 km itinerary which joined Bracara Augusta and Asturica Augusta, NW Iberian Peninsula), the paper explores various factors, both natural and cultural, which may have been determinant in the layout of main roads in the Roman period. This study has followed a non-reconstructive methodology based on the theoretical idea of "least-cost paths" implemented by way of GIS tools. The analysis combines different variables which have an impact on human mobility (such as terrain slope and altitude, and the a priori existence of some primary nodes) and different spatial scales of analysis. As an outcome, we have achieved a detailed understanding of the factors behind the layout of this road and, in doing so, we have also drawn some conclusions regarding the historical context of its origin and development. The methodology and some of the results may be pertinent for the analysis of Roman roads elsewhere and, to some extent, for the wider analysis of ancient roads.

KEYWORDS: Roman roads, territory, mobility, least-cost paths, GIS, NW Iberian Peninsula.

1. INTRODUCTION: APPROACHING ANCIENT ROADS

The study of human mobility has been part of the archaeological and anthropological agenda for decades, from the early emphasis on migration and diffusion to the contemporary focus on landscape archaeology (Beaudry and Parno, 2013). Movement and vision constitute the two basic mechanisms through which humans interact, explore and assign an order to the space around them (de Certeau, 2000; Ingold and Vergunst eds., 2008).

Trails, paths and roads are particularly relevant materializations of mobility in the landscape, in that they “weave together the disparate elements of daily lives, bridging distance and obstacles to connect us to each other” (Snead et al., 2009: 1). They have also been a relevant subject of archaeological analysis, especially in those contexts in which they were part of complex political and economic systems and have left obvious material traces, such as the Inka (Hyslop 1984) or Roman road systems (Chevalier, 1997).

Computational modelling in general, and GIS in particular, has made great contributions in recent decades to approaching the archaeological analysis of mobility from a different perspective (Llobera, 2000; Llobera et al. 2011; Bevan, 2011; Polla and Verhagen eds., 2014). A large number of contributions have been made which have proved useful in reconstructing the layout of ancient networks of paths (e.g. Siart et al., 2008; Stanish et al., 2010; Verhagen and Jeneson, 2012; White and Barber, 2012; Verhagen et al., 2014), in understanding the logic behind the layout of a road network (e.g. Carreras and de Soto, 2013; Richards-Rissetto and Landau, 2014; Güimil-Fariña and Parceró-Oubiña, 2015) and in exploring the common assumption that, in many cases, archaeological sites are located in close relationship with “natural corridors” in the landscape (e.g. Fairén, 2004; Wheatley et al., 2010; Murrieta-Flores, 2012).

Within this general framework, this paper tries to contribute towards a better understanding of the territorial logic of Roman roads, following some recent approaches based on the use of digital modelling tools. We will focus on a particular case study in the north-western Iberian Peninsula, in order to explore various natural and cultural factors which may have been determinant in the layout of the main roads in this area during the Roman period.

2. MATERIALS AND METHODS

2.1.1. Objectives and methodology

Our objective is to understand the rationale behind the layout of a Roman road in the north-

western Iberian Peninsula. In this way, we aim to understand, via the use of a modelling process, the criteria and factors which were taken into account when choosing a particular route for this road. In the following paragraphs we shall elaborate on this aspect.

Paths are ways of connecting places. The first, and main, factor which influences the route of a path is the location of the places which are to be connected by it. In its simplest form, a path is a connection between two points, A and B. In a more complex form, paths are formed by the aggregation of connections between multiple points, A, B, C, D, etc. For the purpose of this analysis, the points connected by a path shall be referred to as “nodes”, part of a network. The spatial location of these nodes is an essential component determining the layout of any particular network of paths. It must be noted that, here, we are only making a metaphorical use of the term network; see, for instance, de Soto, 2010 or de Soto and Carreras, 2015 for a truly network-oriented analysis of Roman roads.

Indeed, there are many possible ways to connect two points in space. The simplest and easiest one, a straight line, is more a theoretical, abstract way, except in very specific geographical contexts. In most places in the world, the characteristics of the landscape also have a strong influence on the route chosen to join two places. These influences have a two-fold character: they have a universal component and are also culturally-determined.

There are certain universal factors which affect human movement and which are related to the biomechanics of movement. For instance, it is easier to walk on flat land than to climb a steep slope. Furthermore, it is extremely difficult (or even impossible) to walk on some types of terrain: of course on water, but also on extremely muddy or very sandy terrain, for instance.

However, this does not imply that the importance given to these universal factors has also been universal: of course there is a difference regarding to what extent different physiological factors affect people’s subjective behaviour and decision-making and, to a great extent, these differences are determined by both social and cultural values. There are also other, non-functional elements which may influence human mobility (Llobera, 2000).

Since these contextually-determined decisions are what we want to be aware of when exploring the past, an analysis of the extent to which they differ from the “theoretically optimal” decisions which would have been taken if only biomechanical considerations were taken into account may constitute a good basis to approach this issue.

Following these basic ideas, our purpose here will be to test an initial hypothesis: the layout of the road we will study was only influenced by universal, biomechanical factors and followed the route of least effort (cost). It is important to understand that this is a null hypothesis: we are not assuming that considering those factors will be enough or that, in the past, they had the same importance they might have today; we are merely exploring their possible importance in order to discover what other things might have influenced the layout of the road (as it is known to us by the archaeological evidence available). Indeed, we are especially interested in finding pieces of evidence which cannot be understood in such basic and deterministic terms, as it is from such information that we will be able to extract certain meaningful conclusions about the context we are analysing.

Therefore, we shall follow a non-reconstructive methodology: we do not aim to reconstruct the route of a road, but to understand the pieces of evidence which inform us about it. In order to do so, we shall rely on GIS-based modelling of the so-called Least Cost Paths (LCP onwards). LCP have been widely used in archaeology in recent years (e.g. Herzog, 2014; White and Surface-Evans, 2012) and have particularly been applied to the analysis of archaeological contexts in the NW of the Iberian Peninsula (Parcero-Oubiña and Fábrega-Álvarez, 2010; de Soto, 2010; Fábrega-Álvarez et al., 2011; Parcero-Oubiña et al., 2013). In our case, the paper by Güimil-Fariña and Parcero-Oubiña (2015) is especially relevant, since we shall follow, to a large extent, the same approach as they did.

2.1.2. The case study: the so-called via XVII, or road between *Bracara Augusta* and *Asturica Augusta* through *Ad Aquas-Aquae Flaviae*

The Antonine Itinerary is an exceptional document of Roman times. Written around the 3rd-4th centuries AD, it describes 372 major communication routes existing within the Roman Empire at that moment. Up to 34 of these *itinera* (itineraries) ran (either partially or totally) through the Iberian Peninsula. According to their order of appearance in the original Latin text, these Iberian roads were correlatively numbered by the first Spanish scholars to study Roman roads (Roldán Hervás, 1975: 19-37).

The *Iter a Bracaram Augustam* (Wess. 422.2-423.5) was one of the four routes that communicated the north-western area of Iberia. Since it holds the 17th position in the aforementioned list, this route is traditionally referred to as *via XVII* or 17th road in the Spanish literature. According to the dating of some

milestones (Rodríguez Colmenero et al., 2004), it is generally agreed that at least part of this itinerary was built during the time of Augustus (27 BC to 14 AD). The origin of the route probably dates back to the period immediately after the end of the Cantabrian-Asturian wars, following the campaign of M. Vipsanius Agrippa in 19 BC (Martins et al., 2005; González Álvarez, 2011; Fernández Ochoa et al., 2013).

The route connected *Bracara Augusta* (the present-day Braga, Portugal) with *Asturica Augusta* (Astorga, Spain) through *Ad Aquas* – later named *Aquae Flaviae* (Chaves, Portugal). The former two towns acted as the respective capital cities of the *conuentus iuridici* *Bracarenensis* and *Asturum*, the administrative units in which the *prouincia Tarraconensis* was divided in Early Imperial times (Fig.1).

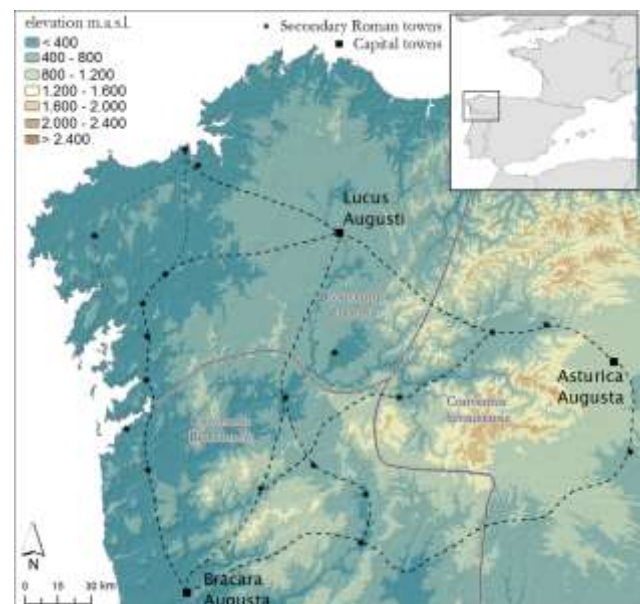


Figure 1. The study area during the Roman period: capital and secondary towns, administrative divisions and main roads (simplified after Pérez Losada 2002)

The 17th road was the main route of communication between these two capital towns until the construction of the so-called *via XVIII* (*Alium Iter a Bracaram Asturicam*, Wess. 427.4-429.4) in Flavian times (late 1st c. AD). A dense secondary road network was developed around it, in an attempt to interconnect diverse nuclei of population and mining zones (Pérez Losada, 2002; Lemos and Morais, 2004; Martins et al., 2005; Sánchez Palencia et al., 2006; Vega Avelaira, 2006; Lemos and Martins, 2010, 2011).

Following the *Antonine Itinerary*, the route was organised according to the *mansiones* (staging posts) and distances listed in Table 1.

Table 1. List of mansiones (post stations) and intermediate distances for the Iter XVII according to the Antonine Itinerary (distances are expressed in Roman miles)

Item a Bracara Asturicam mpm CCXLVII sic	
Salacia	mpm XX
Praesidio	mpm XXVI
Caladuno	mpm XVI
Ad Aquas	mpm XVIII
Pinetum	mpm XX
Roboretum	mpm XXXVI
Compleutica	mpm XXVIII
Veniatia	mpm XXV
Petavonium	mpm XXVIII
Argentiolium	mpm XV
Asturica	mpm XIII

The route has been studied by several researchers over a long period of time (Saavedra Moragas, 1862; Gómez Moreno, 1927; Loewinsohn, 1965; Rodríguez, 1970; Roldán Hervás, 1975; Rabanal Alonso, 1988; Rodríguez Colmenero et al., 2004; Moreno Gallo, 2006, 2011; among many others). Since the road has only been recognised archaeologically in recent years and only in some places, the milestones are still the main material remains linked with it. This explains why the majority of the reconstructive proposals of its layout are based on the location of these milestones and the existence of other elements taken as indirect indicators (such as old historical paths or place names).

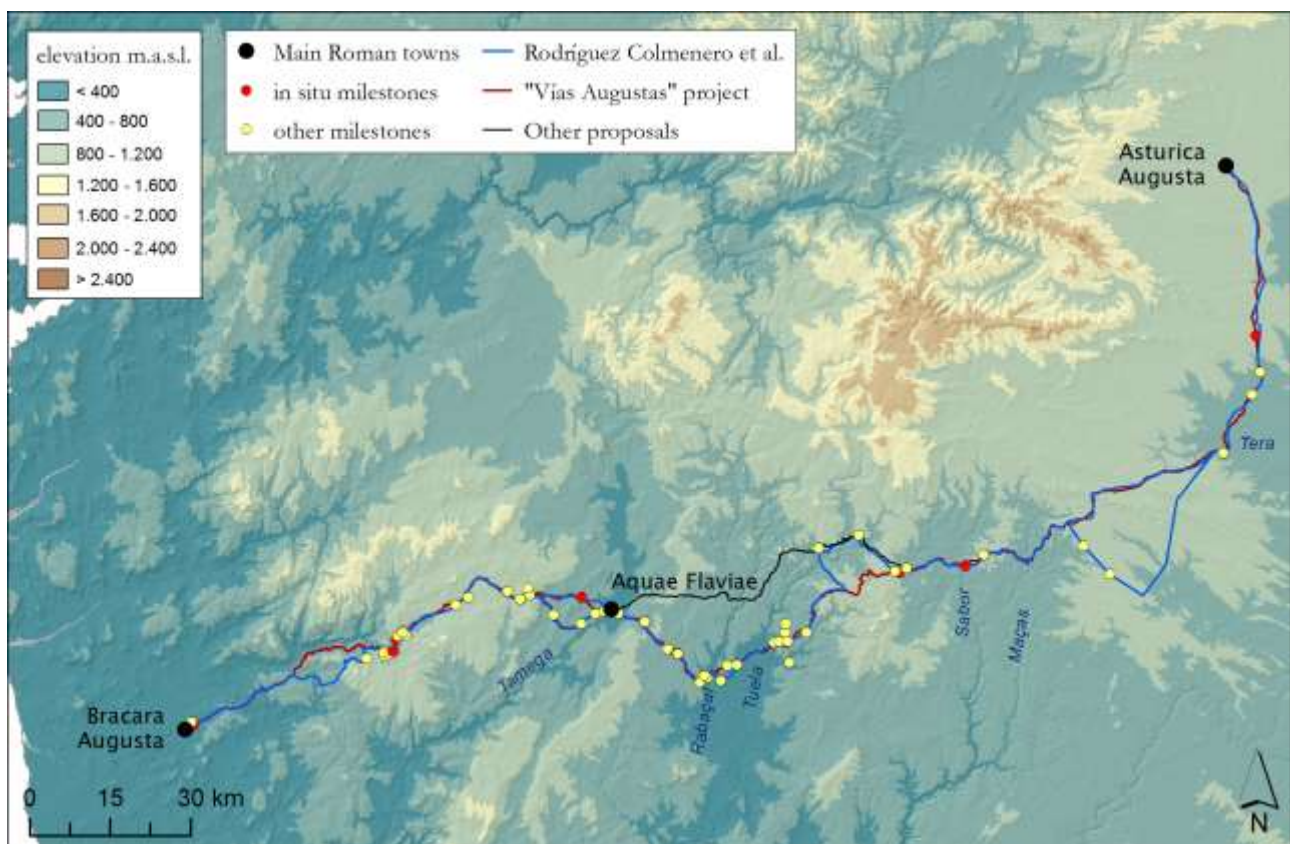


Figure 2. The route of Iter XVII according to the main recent proposals

The most recent proposals are, in general, extremely coincident, with two standing out among them (Fig. 2). The first one is that of Rodríguez Colmenero et al. (2004), based on a combination of cartographic analysis and the location in the field of certain pieces of archaeological evidence (mainly milestones). More recently, the project entitled *Vias Augustas* undertook a detailed review of the whole route based on extensive archaeological fieldwork which included the excavation of some sections of the road in Spain. The results of this project were

presented at the seminar "As Vias Romanas da Hispânia: as Vias XVII e XVIII do Itinerário de Antonino" (Chaves, Portugal, December 2004) but have only been partially published: the Portuguese sections have been published at a municipal scale (Carvalho, 2006; Fontes and Andrade, 2012; Fontes and Roriz, 2012; Morais, 2005), while the Spanish parts were synthesised in Moreno Gallo (2011).

Although both proposals offer a very similar layout, there is still a certain degree of divergence between them, and with regard to the proposals made

by other researchers (Fig. 2). The main discrepancy is located to the east of *Aquae Flaviae*, where the known locations of a couple of milestones have led to the proposal of two different routes. Alternatively, other authors have proposed the existence of two branches of the road here (Lemos, 1993; Maciel and Maciel, 2004).

The second important divergence between the proposals of Rodríguez Colmenero et al. (2004) and the *Vías Augustas* Project is found further to the east, where the former researchers suggest the existence of a secondary branch indicated by two milestones, whilst other authors claim they rather correspond to a different, secondary road, setting off from road XVII towards a different destination (as already proposed by Gómez Moreno, 1927).

Although there are other differences, they are only perceptible at a scale of higher detail (as we shall describe in Sections 4 and 5). For most of the area, then, the two main proposals existing to date are almost identical. Therefore, we can consider that there is a general consensus among researchers regarding the layout of this Roman itinerary.

3. THE BASIC FACTORS BEHIND THE LAYOUT OF THE ROAD

3.1. Modelling human movement

As we have mentioned in the previous section, our purpose here is to explore to what extent the layout of the road we have described, and the spatial distribution of the elements located along it (milestones), can be understood merely in terms of the selection of the most efficient connection between *Bracara* and *Asturica*. In order to do so, we need to theoretically model the potential of human movement across this area.

The modelling of human movement has been the subject of many different proposals, and a number of functions exist to mathematically express the influence of geographical factors (especially terrain gradient) in human mobility (Herzog, 2013, based on Minetti et al., 2002; Llobera and Sluckin, 2007, based on Margaria, 1938; Pandolf et al., 1977; Tobler, 1993). They provide a quantitative assessment of the effect of changes in terrain properties on the conditions of human mobility, based on the notion of cost or impedance. The property of terrain which has a higher influence on pedestrian movement, and also the most studied, is gradient or slope.

In the following sections we shall essentially follow the same methodology employed by Güimil-Fariña and Parceró-Oubiña (2015). In the same way as these researchers, the first task we performed was to test which of the available cost functions was better adapted to the geographical conditions of our

study area. We also found the functions of Tobler (1993) and Llobera and Sluckin (2007) to be particularly useful. Here, for reasons of brevity, we shall only show the results of the analyses performed with the Llobera-Sluckin function.

The main dataset used was the SRTM 3 Digital Elevation Model (DEM), with a spatial resolution of ca. 80 m for this part of the globe. Güimil-Fariña and Parceró-Oubiña argue the need to add an extra cost to river beds in order to avoid the LCP running along them (since, in this particular landscape, the slope is usually gentler in river beds than in the surrounding terrain, see an empirical example in Güimil-Fariña and Parceró-Oubiña, 2015: 37). As they did, we added an extra cost of 10x to a buffer area of 2 pixels (160 m) around river courses. All of the analyses have been performed in ArcGIS 10.1, SP1 and ArcGIS 10.4.

3.2. Basic nodes: an analysis of the route taking only terrain gradient into account as a cost factor

The first question we decided to explore is on a very general large scale: what are the basic, primary nodes that this *iter* connects? Our first hypothesis was the same as that already explored in the aforementioned paper by Güimil-Fariña and Parceró-Oubiña (2015): the road merely followed the easiest and most convenient route between *Bracara* and *Asturica*. The result of calculating the LCP between the two points (LCP 01 onwards), considering terrain gradient as the only cost factor, clearly shows that this was not the case (Fig.3), as Güimil-Fariña and Parceró-Oubiña have already established (2015: 39-40).

Only a short section of the route, to the east of *Bracara*, shows a coincidence. Beyond that point, the road follows an east-southeast direction towards *Aquae Flaviae*, far from the LCP which follows a rather straightforward direction towards *Asturica*. As proposed by Güimil-Fariña and Parceró-Oubiña, this appears to suggest that *Aquae Flaviae* may have had a primary role as an original node for the road, since it is not located along the expected "natural" route. This is especially noteworthy if chronology is taken into account: the development of *Aquae Flaviae* as a secondary-level Roman town has always been dated in the Flavian period, as its name implies (see for instance Rodríguez Colmenero, 1997; Fonseca Sorribas, 2012; Pérez Losada, 2002), while substantial evidence exists to date the origin of road XVII in the Augustan age (Rodríguez Colmenero et al., 2004); we will return to this issue in Section 6.

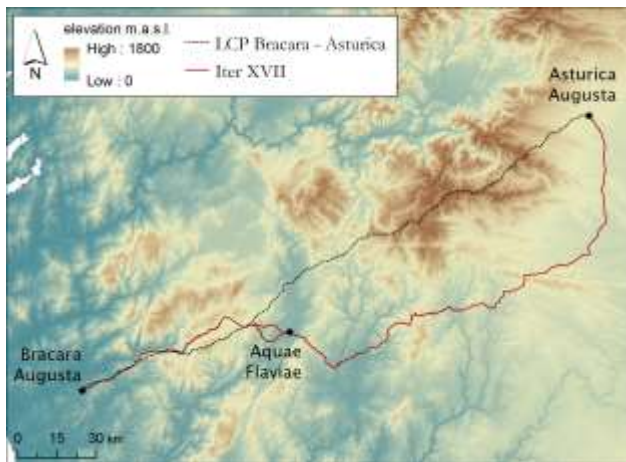


Figure 3. Comparison of LCP 01 between Bracara and Asturica and the route of Iter XVII

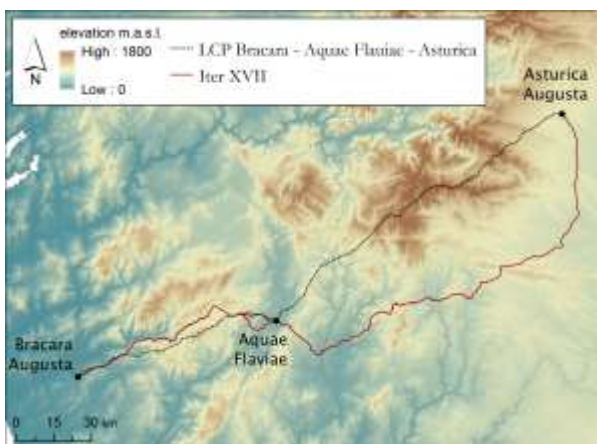


Figure 4. LCP 02 Bracara Augusta - Aquae Flaviae - Asturica Augusta

However, as Güimil-Fariña and Parcero-Oubiña point out, this is not enough to understand the connection between the road and *Aquae Flaviae*. In effect, even if *Aquae Flaviae* is included as a primary node in the LCP calculation (resulting in LCP 02 between *Bracara-Aquae Flaviae-Asturica*), the outcome is again very different from the actual route of the road (Fig. 4). As opposed to what seems to have occurred with other secondary towns in the region (such as *Iria Flavia*, see Güimil-Fariña and Parcero-Oubiña, 2015: 41), simply including *Aquae Flaviae* as a primary node in the analysis does not result in a more informative outcome (Fig. 4).

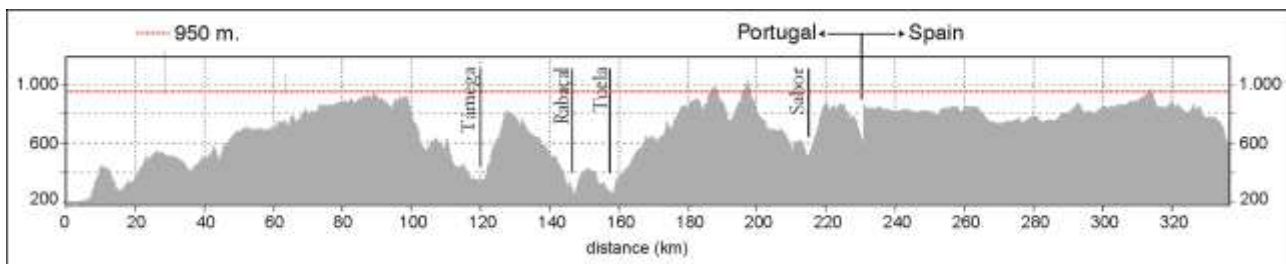


Figure 5. Topographic section of the route shown in Figure 2. The 950 m threshold is highlighted.

3.3. Terrain altitude as a cost factor

At this point, Güimil-Fariña and Parcero-Oubiña suggest some possible directions for further analysis which they did not actually explore. Among them, they say that “For the specific case of the road between *Bracara* and *Asturica* it is also possible that avoiding high altitude areas was a relevant factor” (Güimil-Fariña and Parcero-Oubiña, 2015: 42). Indeed, the mountain ranges of Segundera, Cabrera and Teleno, with the highest altitudes of the NW Iberian Peninsula (beyond 2000 m, see Figure 2), are located between *Aquae Flaviae* and *Asturica*. In order to explore the possible effect of these ranges in the layout of the road, we decided to include a new factor in our analysis: avoiding higher altitudes.

However, the notion of “higher altitudes” is rather ambiguous and imprecise, and it is necessary to provide a more precise, quantitative definition in order to make it adequate for GIS analysis. To achieve this, we followed a pragmatic approach: we examined the actual altitude of the areas which the proposed reconstruction of the road runs across. Considering its length and the fact that it crosses diverse geographical areas, there is a large variability in altitude along the route (Fig.5). Around the modern-day town of Bragança, when crossing the northern foothills of the Serra da Nogueira, the road reaches its highest altitude, slightly beyond 1000 m (1040 m). Between *Bracara* and the Tamega valley the road goes across high terrain again, although, in this case, the altitude is a little lower, at around 950 m; this is also the maximum altitude that the road goes across in the area near to *Asturica*.

Drawing from the consideration of the topographic variability along the road, and after performing different analyses, we observed that the use of a double threshold gave the best results to set apart those “higher areas”: 1050 m for the section between the Tuella River and the current international border and 950 m for all the rest. We assigned an extra cost factor of 10x (the same as was used to avoid the LCP following the river beds) and repeated the calculations between the three nodes we had previously considered (*Bracara*, *Aquae Flaviae* and *Asturica*).

The new outcome (LCP 03) substantially improves the results of the previous analyses (Fig. 6), although the similarity with the actual route of the road is still far from complete. Broadly speaking, the section between *Bracara Augusta* and *Aquae Flaviae* proves a rather good match (Fig. 6), although the coincidence between *Aquae Flaviae* and *Asturica Augusta* is still quite low. If the latter sector is split into two halves at *Castro de Avelãs* (where there is an important site from the Late Iron Age and Roman period, as we shall see below), some degree of coincidence can be observed towards *Aquae Flaviae*. Nevertheless, the section towards *Asturica* still shows a noticeable divergence.

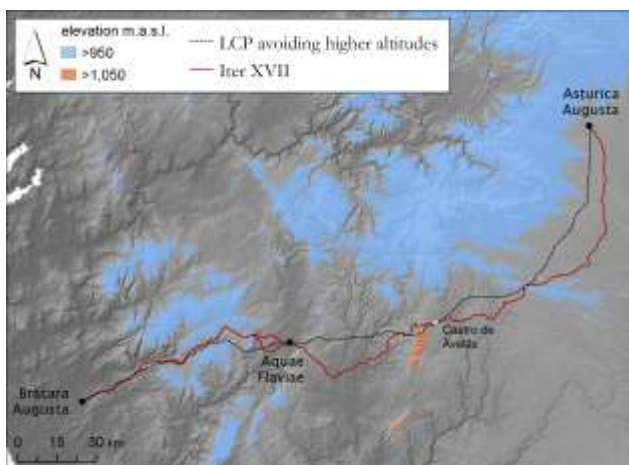


Figure 6. LCP 03 *Bracara Augusta - Aquae Flaviae - Asturica Augusta* avoiding areas over 950 m/1,050 m, as described in the text. The location of *Castro de Avelãs* is shown merely for illustration purposes (it was not used in the analysis)

3.4. Preference for wheeled transport as a cost factor

Again, we have two possible choices to further improve our analysis: either other primary nodes existed which conditioned the design of the road, or other factors influenced the selection of the route to be followed. If other nodes are to be found, the best candidate would be the site of *Torre Velha de Castro de Avelãs* (Bragança). Some authors have suggested that the *mansio Reboretum* must be located here (see Table 1), while others have proposed that this was the capital town of the political entity known as *ciuitas Zoelarum* (Lemos, 1993, 2000; see also projetozoelas.wix.com/zoelas).

However, as Figure 6 clearly shows, this particular point is, indeed, located along the theoretical route of the LCP 03 and considering it as another primary node would add nothing new to the analysis. Indeed, it seems that the location of *Castro de Avelãs* is particularly well explained as coincident with an important topographic crossing point in the landscape. Therefore, the second possible option re-

mains: the search for additional cost factors. When it comes to Roman roads, there is one particular reasonable criterion to consider: the need to facilitate the movement of animal-drawn wheeled vehicles, which is directly related with terrain slope (e.g. Verhagen and Jeneson, 2012: 125). Wheeled vehicles are not easily suited to climbing steep slopes, and a critical threshold of a gradient of 8 - 16% has been suggested (Herzog, 2013: 186).

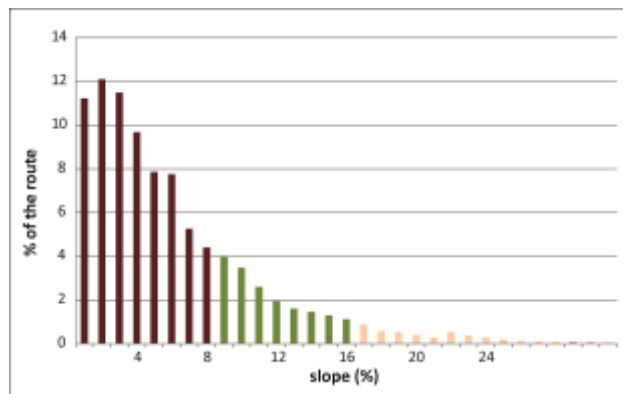


Figure 7. Histogram of the slope of the route shown in Figure 2. The two critical thresholds of 8% and 16% are shown in different colours (see text for more details)

Again, the decision on how to include this factor into the analysis was taken following a pragmatic approach: the analysis of the actual gradient of the terrain which the proposed reconstruction of the road runs across. Terrain is rather rugged in most parts of the route, especially on the western side. Since slopes beyond 8% are relatively frequent, the selection of a 16% threshold seemed preferable (Fig.7, Table 2).

Table 2. Distribution of slopes in gradient intervals of 4%

Slope	% of the route
0-4%	48.55
4-8%	27.57
8-12%	13.09
12-16%	5.96
> 16%	4.89

In order to determine the weight of slope as a cost factor, we indirectly referred to the function proposed by Herzog (2013: 186):

“Cost(s) = 1 + (s / š)², where both s and š are percent slope values. Critical slope is given by š and typically is in the range of 8 to 16. This cost curve is symmetric and can be used if a route was taken in both directions”.

This function means that, when reaching the threshold of preference, movement costs double. Therefore, terrain beyond a gradient of 16% was as-

signed an extra cost factor of 2x (on top of the cost factors already considered in the preceding analyses). In this case, the extra cost is not as high as that assigned to terrain altitude, meaning that movement across areas beyond a 16% gradient is not completely hindered, although preference is given to flatter terrain as long as it does not imply a long detour (indeed, as has been shown above, some portions of the route actually cross slopes higher than 16%).

The outcome (LCP 04, Fig. 8) now shows a remarkable similarity with the southern branch of the proposed reconstruction in most of the section between *Bracara* and Castro de Avelãs (it must be noted that many other authors, such as Rodríguez Colmenero et al., 2004 (p. 114), consider it as the only branch which would have existed in this section). However, to the east of Castro de Avelãs coincidence is still very low.

At this point, we have been able to obtain a rather good characterisation of the factors influencing the design of most of this road. In addition to considering the basic influence of terrain gradient in pedestrian movement (according to the function developed by Llobera and Sluckin, 2011), the preference for following lower altitude areas (below 950/1050 m) and flatter terrain (below a gradient of 16%) has resulted in a LCP which matches a large part of the road relatively well. According to this analysis, a considerable part of the *iter XVII* can be understood as being the most efficient route joining *Bracara Augusta* – *Aquae Flaviae* – *Asturica Augusta*, taking into account the combined influence of the above-mentioned topographic factors. This implies that these three locations must have acted as primary nodes in the layout of the *iter*. In historical terms, this does not necessarily imply that *Aquae Flaviae* was founded as a newly established Roman town in the period of Augustus (as we have already stated, there is plenty of evidence to prove that this road was first built in the early period following the conquest). Although some recent data from urban excavations in Chaves might point towards this (see Discussion and Conclusions), it is also possible, as Güimil-Fariña and Parcero-Oubiña have suggested (2015: 40-1), that the spatial location of the later *Aquae Flaviae* is that of a key crossing point in the landscape. From that point of view, it might have been the case that Roman interest in this site was a consequence of its privileged location as a communication hub in the region.

However, before going into a detailed discussion of these results, and their archaeological implications, there is still a visible divergence in some points, on a more detailed scale, between the LCP 04 and the reconstructed route of the road. The most obvious one concerns the section between Castro de

Avelãs and *Asturica*, as well as some sections of the route between *Bracara* and *Aquae Flaviae*. In the following sections we shall look at these areas in more detail and with the addition of new variables.

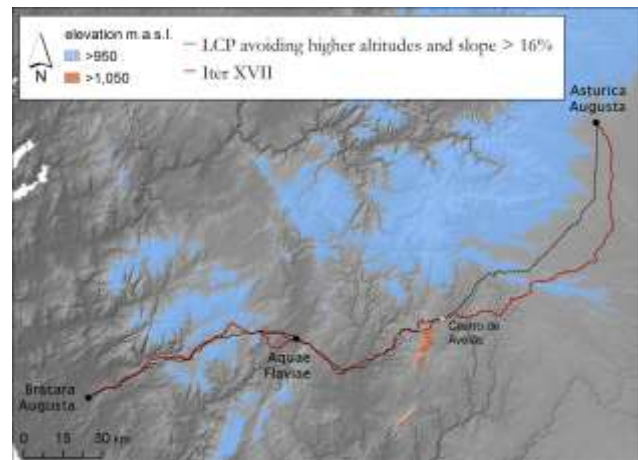


Figure 8. LCP 04 *Bracara* – *Aquae Flaviae* – *Asturica* avoiding higher altitude areas and slopes over 16%. The location of Castro de Avelãs is shown merely for illustration purposes (it was not used in the analysis)

4. ADDING NEW PRIMARY NODES: THE ROUTE BETWEEN CASTRO DE AVELÃS AND ASTURICA AUGUSTA

As mentioned in the previous section, LCP 04 runs several kilometres to the west of the route proposed for the Roman road in the section between Castro de Avelãs and *Asturica Augusta*. We can think of two possible ways to further explore this divergence: either other primary nodes conditioned the final layout of the road in this section, or other geographical factors influenced the selection of the route. Since the main terrain factors (altitude and slope) have already been considered in different ways in our previous analyses, we initially focused on the first option: the possible existence of additional primary nodes.

Indeed, there is one particular place which appears to have had a remarkably close relationship with the road: the site of Rosinos de Vidriales (Zamora). A legionary base was founded here around 20-15 BC (Carretero Vaquero, 2000: 791-794). Soon after that, an important civil settlement developed around the camp, which later flourished in Imperial times, under the name of *Petauonium* (Ptol. *Geogr.* 2.6.34). Not only is *Petauonium* mentioned as a *mansio* in the *Antonine Itinerary* (Wess. 422.5, see Table 2), but the road also acts in this area as an extension of one of the major axes of the camp: the *uia principalis*. Given the weak urban development of the Roman towns in north-western Iberia until the mid-late 1st century AD, military bases (especially the legionary ones) surely acted as important nodes in the organi-

sation and exploitation of the territory. This section of the road includes a particularly high density of Roman military sites, including the one around which *Asturica* itself developed (Fig. 9). Besides *Asturica*, Rosinos, with its early foundation date, could be a relevant factor in explaining why the itinerary drifts to the flat lands of the Northern Spanish Plateau, rather than following a more direct route across the southern slopes of the Asturian Mountains.



Figure 9. The iter towards Asturica, according to the *Vias Augustas* project: the sites of military camps and probable location of mansiones (staging posts). Castro de Avelãs has been suggested to correspond with either *Roboretum* (Lemos 1993, 2000) or *Compleutica* (Rodríguez Colmenero et al. 2004)

In order to test this idea, we repeated the LCP analysis once again, this time introducing *Petauonium* as a new primary node. We therefore calculated the LCP between *Aquae Flaviae* - *Petauonium* - *Asturica*, considering the same physical variables as before. The outcome (LCP 05) gave us a much better match with the actual layout of the itinerary (Figure 10, compared to Fig. 8). Although there is still some deviation, the optimal route in the *Aquae Flaviae* - *Petauonium* section now generally coincides with the layout of the road. Among the most significant points of coincidence, the section around the supposed location of *Veniatia* is worthy of note: both the road and the LCP run through a relevant mountain pass, San Pedro de las Herrerías, where the railroad and the road (ZA-912) still converge today.

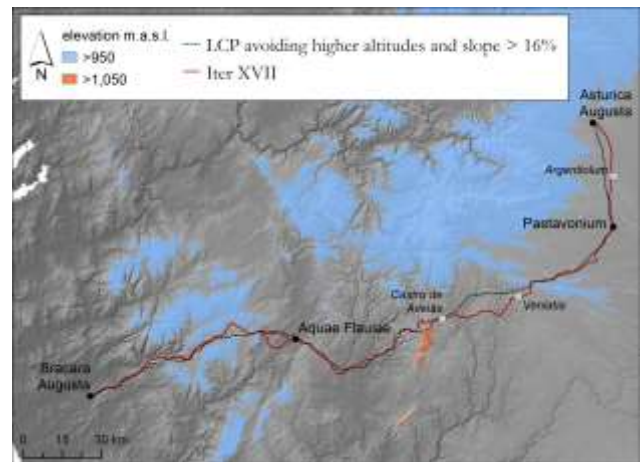


Figure 10. LCP 05 Bracara - *Aquae Flaviae* - *Petauonium* - *Asturica* (*Castro de Avelãs*, *Veniatia* and *Argentiolum* are shown merely for illustration purposes and were not used in the analysis)

However, two areas still show a notable divergence. The first one is located between Castro de Avelãs and *Veniatia*, where the road runs more to the south than the LCP. This particular stretch is difficult to characterise due to its complex topography: the beds of the Sabor and Maçãs rivers (the latter on the current Spanish-Portuguese border) are particularly deep and narrow (see topographic section in Figure 5). For this very reason, the limited number of suitable crossing points of these and other secondary rivers in the area should be taken into account as new possible primary nodes here. Something similar has already been identified in the case of Ponte Bibei (Ourense), where the crossing of the river seems to have conditioned the layout of the *via XVIII* (Gümil-Fariña and Parcerro-Oubiña, 2015). A more detailed analysis is advisable for this area in the future.

A second divergence can be found between *Petauonium* and *Asturica*, where the LCP follows a rather rectilinear layout, far from the route of the road and from the supposed location of the *mansio Argentiolum* (Argüelles Álvarez and García Sarmiento, 2015). Since this is essentially an open geographical space, in sharp contrast with most of the land to the west, any possible inaccuracies of the DEM could have a strong influence on the analysis and lead to incorrect results. This is why we decided to explore this section in more detail, using a LiDAR-derived DEM with a resolution of 25 m, produced by the Spanish National Geographic Institute (within the PNOA project).

As proposed for *Petauonium*, it could be argued that *Argentiolum* also played the role of a primary node. Although there are no strong archaeological arguments to support this hypothesis, since not even the location of the *mansio* is known with complete certainty (Argüelles Álvarez and García Sarmiento,

2015), we decided to test this idea. The inclusion of this site as a node in the analysis does not offer a better coincidence: the optimal path runs between *Petauonium* and *Argentiolum* as an almost straight line and diverges again from the proposed itinerary (Fig. 11).



Figure 11. LCP *Petauonium – Asturica and Petauonium – Argentiolum*

At this point, we decided to re-evaluate the possibility of some physical characteristics of the terrain having conditioned mobility in this sector. As opposed to what we have seen in the rest of the area to the west, the general conditions of the landscape are not very demanding here. It is an area of flat lands and mostly seasonal rivers, where restrictions on mobility are, in general, very low. There are no new physical factors which can be considered to have an influence on human mobility. However, considering the existence of less restrictive conditions, it can be argued that the influence of terrain slope might have

been less strong here than in the rest of the area, especially for the selection of the best-suited areas for wheeled transport.



Figure 12. LCP 06 *Petauonium – Asturica* with the cost factors modified (extra cost to slopes over 8%, instead of 16%)

To test this hypothesis, we decided to re-evaluate the weighting of this extra cost factor, choosing here the threshold of a gradient of 8% as critical, rather than 16% (as was described in Section 3.3). The resulting LCP 06 (Fig. 12) offers an almost perfect coincidence with the layout of the road, including a remarkable proximity with the military camps of Castroalbón and Villamontán de Valduerna (Loewinsohn, 1965; Celis Sánchez et al., 2015; Costa García, 2016), and the proposed location of *mansio Argentiolum*.

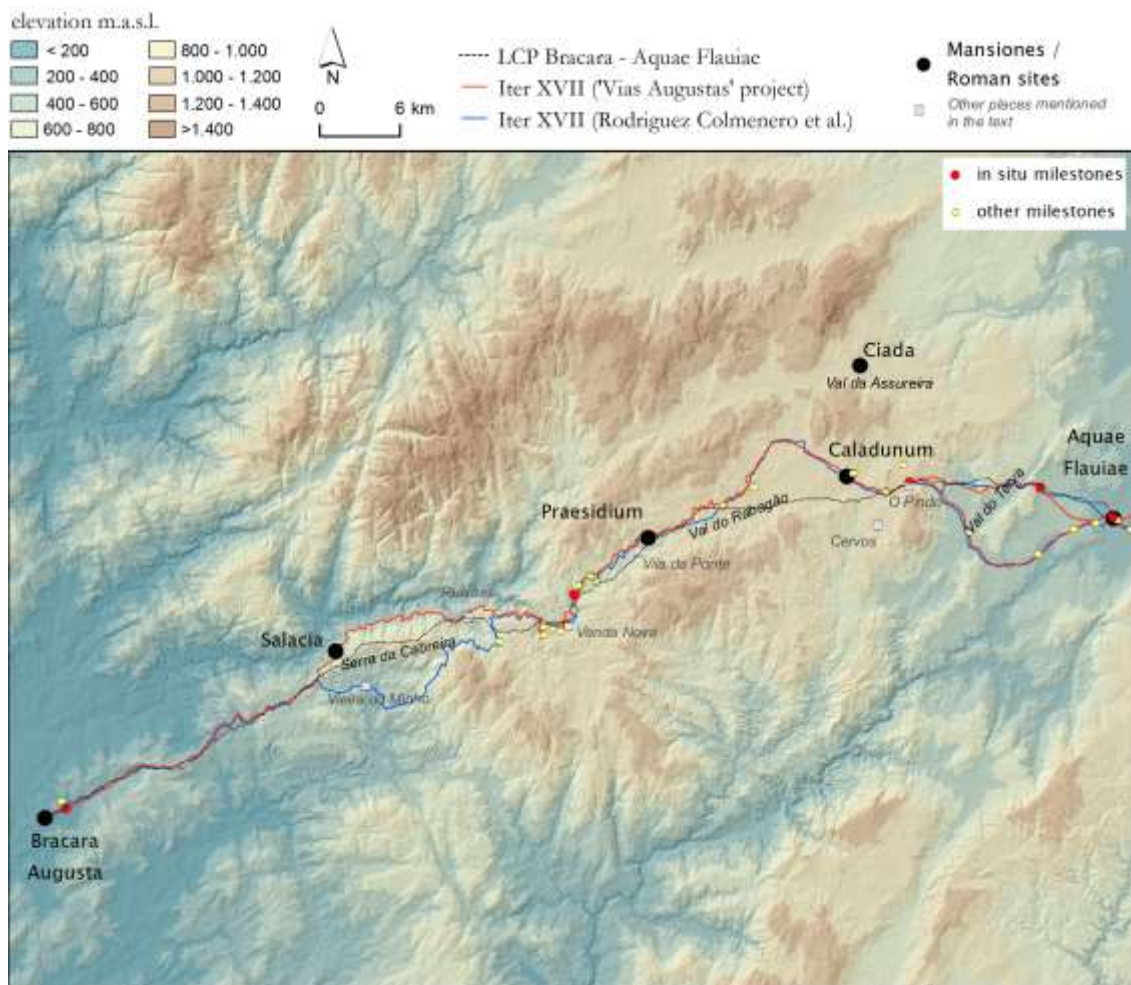


Figure 13. The Iter between Bracara Augusta and Aquae Flaviae: recent route proposals and supposed location of mansiones (post stations) mentioned in the Antonine Itinerary

5. GOING INTO GREATER DETAIL: PATHS AND JUNCTIONS BETWEEN BRACARA AUGUSTA AND AQUAE FLAVIAE

5.1. The original route of the road: the state of the question

There are two particular areas where the LCP runs far from the route of the road in the sector between Bracara and Aquae Flaviae (Fig. 8, Figure 13). The first one is located to the west of Ruivães (Vieira do Minho), coinciding precisely with a place in which the proposals of Rodríguez Colmenero et al. and the *Vias Augustas* Project differ concerning the original route of the road. The second one is found in the area of the Rabagão valley (Montalegre).

Figure 13 shows in detail the information currently available for this sector. Roman roads in this area have been studied by many authors since as early as the 18th century. The first proposal was made by Argote (1734), who suggested the existence of two

branches of the road. Many other authors have approached the question: Barradas, 1956; Capela, 1987; Montalvão, 1971; Baptista, 1990; Teixeira, 1996; Lemos, 2000; Rodríguez Colmenero et al., 2004; Morais, 2005; Carvalho, 2006; Fontes and Andrade, 2012; Fontes and Roriz, 2012. Today, there is a general agreement for most of the route, which would have crossed the Rabagão and Terva valleys, as indicated by the milestones in Arcos and O Pindo (Montalegre).

The Antonine Itinerary lists five *mansiones* in this sector: *Bracara*, *Salacia*, *Praesidium*, *Caladunum* and *Ad Aquas*. Their exact location is a matter of further disagreement, except, of course, for *Bracara* and *Ad Aquas* (later *Aquae Flaviae*). All of them are mapped in Fig. 13 along the route proposed by the *Vias Augustas* Project and following the distances indicated in the Antonine Itinerary.

Praesidium has generally been placed between Codeçoso do Arco and Vila da Ponte (Montalegre) and *Caladunum* is thought to have been located between Cervos and O Pindo (Montalegre) (Baptista,

1992). However, according to some authors (e.g. Alarcão, 2004) the latter should be identified with the Roman settlement of Ciada (Mascarenhas & Barata, 1988). This would shift the route further north, crossing the Assureira valley (Montalegre), as was initially proposed by Argote (1734).

The location of *Salacia* is also a matter of discussion. Rodríguez Colmenero *et al.* (2004: 122-124), by choosing a route along the southern side of the Serra da Cabreira, proposed a location for *Salacia* in the vicinity of the Castro de Vieira (Vieira do Minho), where a Roman settlement has recently been identified (Carvalho and Cruz, 2014). Fontes and Roriz (2012), however, propose a route along the northern slope of the Serra da Cabreira and suggest that *Salacia* could correspond to the Roman settlement of São Cristovão (Vieira do Minho). However, the distance indicated by the Antonine Itinerary (XX roman miles from *Bracara*) would contradict this hypothesis, as the authors themselves acknowledge. Another option, better adjusted to that distance, could be the Roman settlement of Campo da Veiga (Vieira do Minho), with which a Roman altar, today housed in the nearby chapel of Nossa Senhora da Guia, could be associated (Fontes and Roriz, 2007: 81).

In order to deepen our understanding of this area, a more detailed analysis of the relationship between the road, the topography and the settlements is necessary. However, one important preliminary step is required for this approach.

5.2. A digital reconstruction of a flooded landscape

Since the road crosses the reservoirs of Venda Nova (built in 1951) and Alto Rabagão (1964) in this sector, there is a large portion of its route which cannot be directly analysed in the field nowadays. As an alternative, we have digitally reconstructed this lost landscape through photogrammetric restitution using historical aerial photos (Lobos, 2012; Filipe, 2013). We used the vertical aerial photos from the SPLAL (Sociedade Portuguesa de Levantamentos Aéreos Limitada) flight, which was the first Portuguese photogrammetric company ever, responsible for carrying out the first national flights for cartographic production between 1937 and 1952. The flight in our area of interest dates from 1949 (Redweik *et al.*, 2010), years before the construction of either reservoir.

The area affected by both reservoirs is covered by several series of photographs with a north-south orientation and an optimal overlap. The Venda Nova area is covered by 34 photographs aligned in 4 rows, while the Alto Rabagão area has 7 rows, and a total of 60 photographs (Fig. 14). The photographs have

an approximate scale of 1:16000 and a format of 18 × 18 cm.

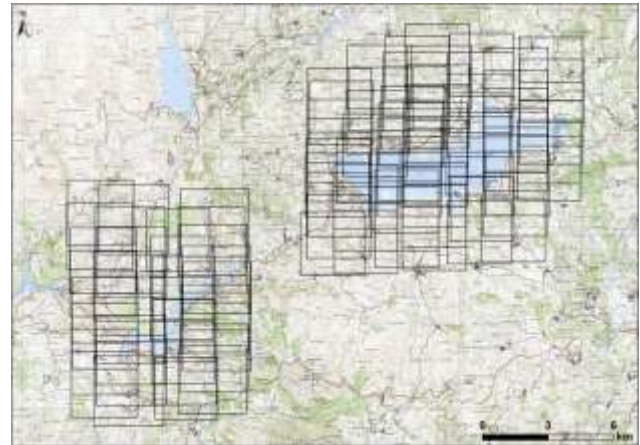


Figure 14. Distribution of historical aerial images in the areas of Venda Nova (left) and Alto Rabagão reservoirs (background: 1:25.000 topographic map © IGeoE)

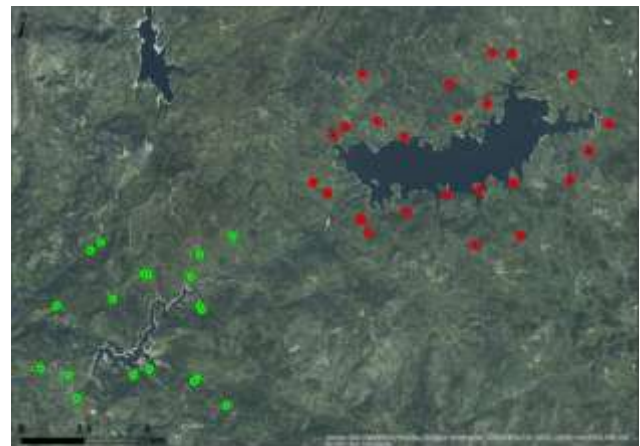


Figure 15. Distribution of Ground Control Points in the areas of Venda Nova (left) and Alto Rabagão (background satellite imagery by © ESRI)

The spatial orientation of the two blocks was achieved by aerotriangulation based on a set of Ground Control Points (GCP) selected according to several criteria. Most particularly, the GCP had to be visible in the historical photos and on the ground today. We collected a set of 14 GCP in the Venda Nova area and 25 GCP in Alto Rabagão using a differential GPS, allowing us to obtain an accuracy of 1-2 centimetres, more than enough for the objectives of this project (Fig. 15).

The external orientation parameters were used to generate a 5 m digital surface model (DSM) for the two areas. From the DSMs, two orthomosaics were generated with a 0.5 m spatial resolution. These cartographic products have allowed us to reconstruct the topography and landscape of both submerged areas (Figs 16, 17), as well as to digitally recover the possible route of the Roman itinerary in these areas (Fig.18).

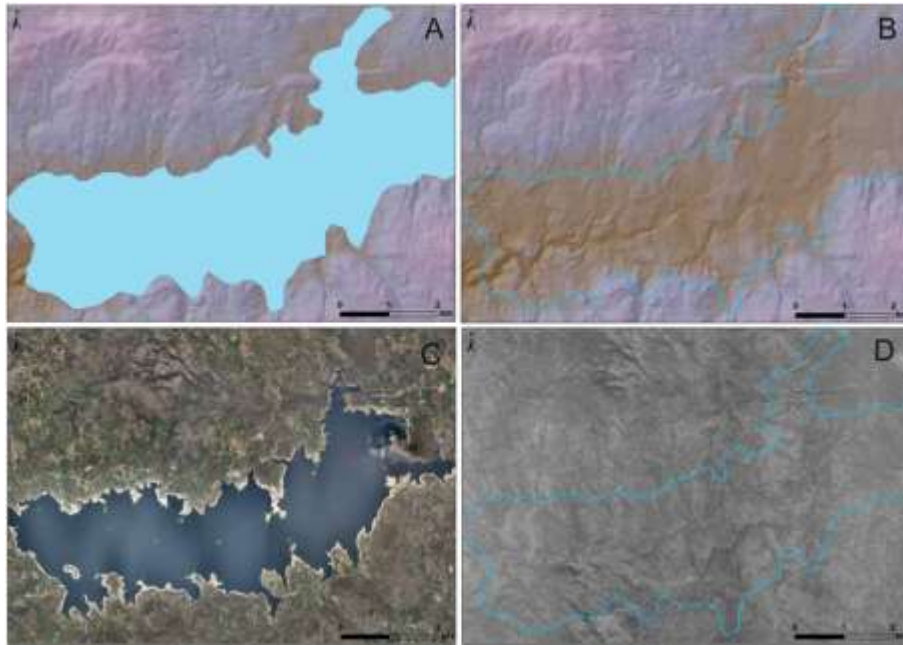


Figure 16. Digital reconstruction of the area of Alto Rabagão: present day topography (A), original topography (B), modern orthoimage (C) and historical orthoimage (D)



Figure 17. Digital reconstruction of the area of Venda Nova: present day topography (A), original topography (B), modern orthoimage (C) and historical orthoimage (D)

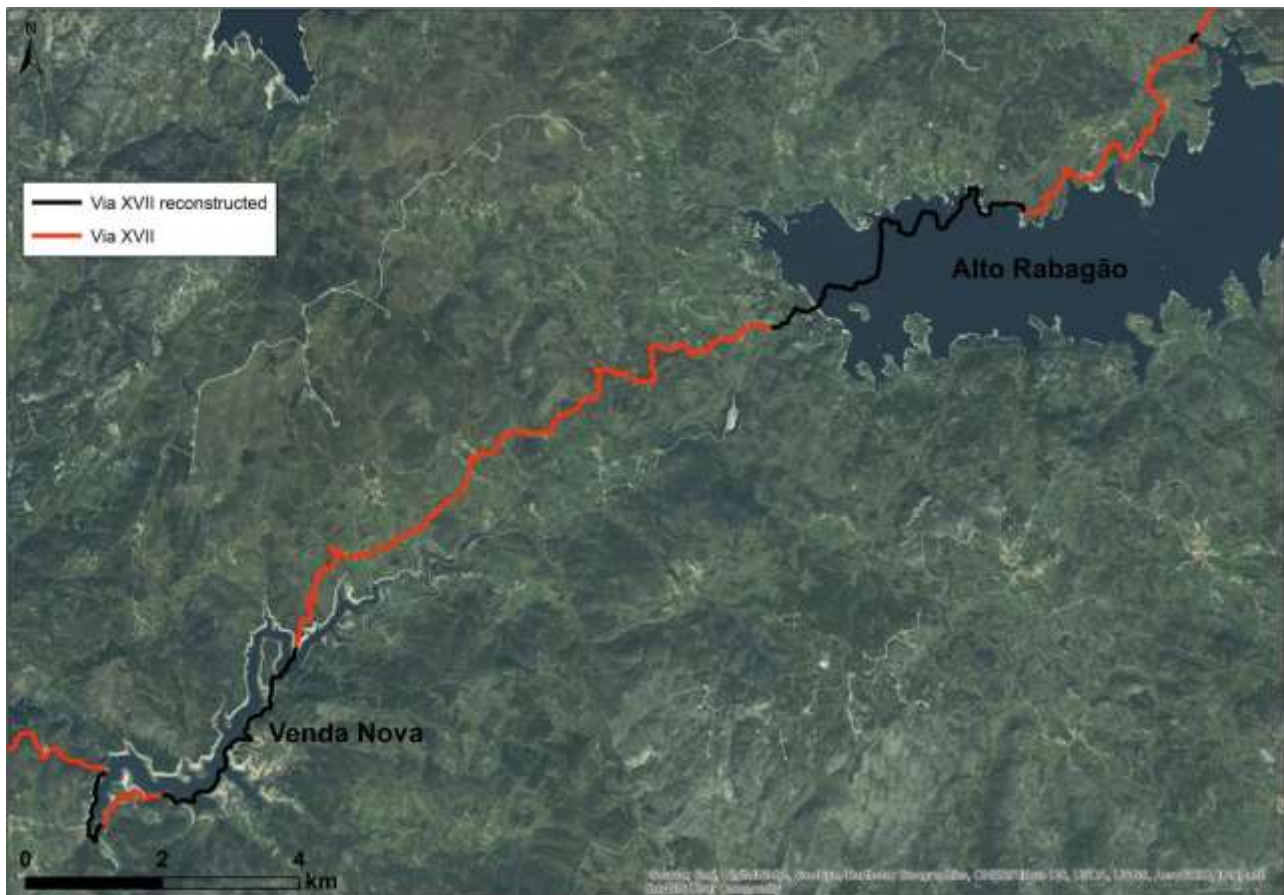


Figure 18. Reconstruction of the route of the Iter XVII in the areas affected by the construction of the two reservoirs (background satellite imagery by © ESRI)

The elevation data of the original topography of these sectors was subsequently combined with the elevation data (contours and height points) of the Portuguese Army Geographical Institute (IGeoE) 1:25000 cartography, to produce a 10 metre resolution DEM covering the entire sector from the coast to about 25 km to the east of the Tâmega river (Fig. 13, Figs. 20, 21).

5.3. A detailed analysis of the *Bracara - Aquae Flaviae* section

Thanks to this topographic reconstruction, we obtained a dataset to explore the patterns of movement in the area in more detail. Moreover, it was possible to do this on a more detailed scale than that of the previous analyses.

As we have seen, there are two main places where the LCP is still distant from the route of the road. The first is a small sector around the Serra da Cabreira, next to the supposed location of *mansio Salacia*, (Figure 13). This aspect shall not be analysed in further detail for two reasons: firstly, there is no agreement on the proposed layout of the road, and the lack of *in situ* milestones does not help to clarify the issue; secondly, the distance between the LCP and the two proposed routes of the road is comparatively

quite small (especially with the proposal by the *Vias Augustas* Project, Fontes and Roriz, 2012).

The lack of coincidence is more obvious in a second section: the Rabagão valley. It is noticeable here how the road bends to the north according to both reconstructive proposals, a detour which does not seem to be attributable to any obvious topographic obstacle. None of the LCPs obtained so far come any closer to this detour. Since no other geographical barriers are likely to have existed in the area, the possible existence of a new primary node should be considered. However, no prominent places (settlements, river fords, natural passes, etc.) are known in the area which may have played such role. The only possible candidate is the site of Ciada, in the Assureira valley. As was mentioned above, some authors have proposed that Ciada could correspond with the *mansio Caladunum* (Alarcão, 2004). A Roman settlement has been archaeologically attested here (Mascarenhas and Barata, 1998), in the centre of an important mining area (Carvalho *et al.*, 2006; Martins, 2010). Although not comparable to any of the other nodes considered so far, this is the most important Roman site near to this detour. However, it is located too far from the road to have acted as a primary node on its own.

Nevertheless, there is another possible solution to this problem: the existence of junctions. Junctions are, together with nodes, the two main structural components of any network of paths (Gibson, 2007; Verhagen et al., 2014). Depending on the spatial distribution of the nodes, a network of paths might find an efficient solution in the use of intersections which, while not being part of the original positions to be linked, ease connectivity between the nodes by minimising the length of the edges joining them.

Steiner trees are the topological formulation of a particular type of intersection, as illustrated in Figure 19. In this example, the most efficient way to interconnect points A, B and C is not with direct links between them, but by creating an intersection (I). Although I is not a destination of interest in itself, it becomes an essential node in the network in order to optimise the connection between the three original destinations. If we think of A, B and C as places and the lines as paths, paths in the network on the top are almost twice as long as those on the bottom.

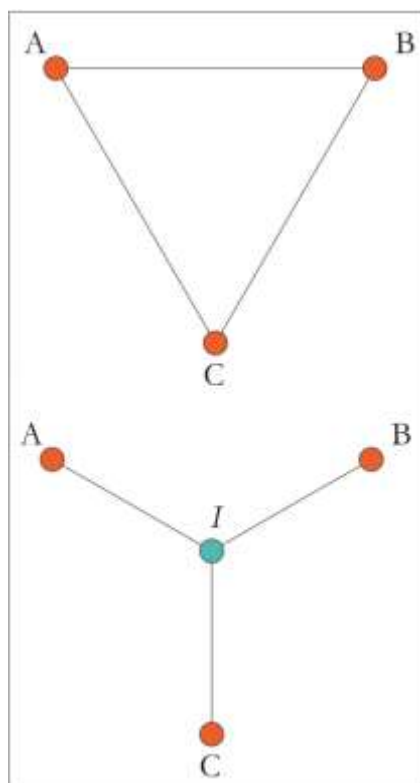


Figure 19. Steiner tree (bottom) is a variation of the minimum spanning tree problem: it optimises the connection of different nodes (A, B and C, left) by creating new intermediate nodes (I)

This may help to interpret the apparently illogical bend of the road in the Rabagão valley: it may relate to the existence of an intersection here, connecting

the main road with a secondary branch towards Ciada. Whether or not this was the location of the *mansio Caladunum*, it was the centre of an important mining area which, somehow, needed to be connected with the main road system; maybe not so important as to fully determine the route of the road, but enough to influence it. An analysis based on the Steiner tree model could help to test this point. In order to speed up the calculations, we limited the area of interest for this particular analysis to the Alto Rabagão valley, between the supposed location of *mansio Praesidium* and *Aquae Flaviae* (as seen in Figure 20).

Unfortunately, at the moment, there are no GIS tools available which include the possibility of creating Steiner trees from point data. As Verhagen et al. have pointed out, only GRASS incorporates a module called *v.net.steiner*, but it “only finds the optimal connection between a subset of points in an existing network (i.e. with predefined edges); it will not create a new network” (Verhagen et al., 2014: 87).

In our case, we began by testing to what extent the LCP towards Ciada coincided with the bend in the road. In order to do so, we calculated the LCP between *Bracara* and Ciada. Indeed, the result (Figure 20) shows that the first part of the bend makes sense if the destination point is Ciada.

Having tested this hypothesis, we explicitly created a new node in the network, a junction, in a central position of the curve (conventionally, the junction has been placed next to the modern village of Peirese, Montalegre). We re-calculated the LCP for this area, this time using the junction as a new node (*Bracara - junction - Aquae Flaviae*). The result (Figure 21) shows a remarkable coincidence between LCP 07 and the reconstructed route of the road and also with the location of the few milestones known in the area (although none of them are in their original position, they all supposedly come from the immediate vicinity of their current locations (see Rodríguez Colmenero et al., 2004).

Thanks to the addition of this junction as a new primary node, we can now understand the Rabagão detour. Unfortunately, our knowledge of the secondary Roman roads in this area is rather poor, but the analysis shows that the possible existence of a secondary branch towards Ciada and the mining area in the Assureira valley is a reasonable hypothesis.

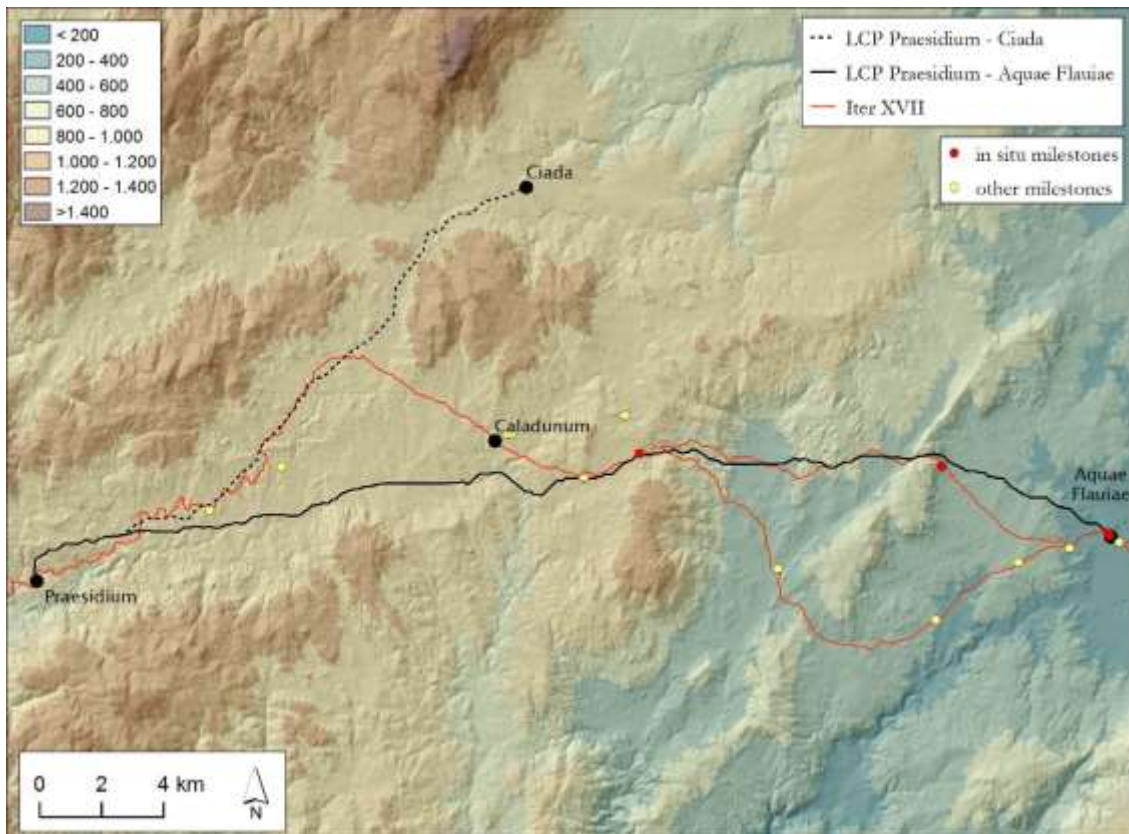


Figure 20. LCP between Praesidium-Aquae Flaviae and Praesidium-Ciada in the area of Alto Rabagão (the supposed location of Caladunum is also shown)

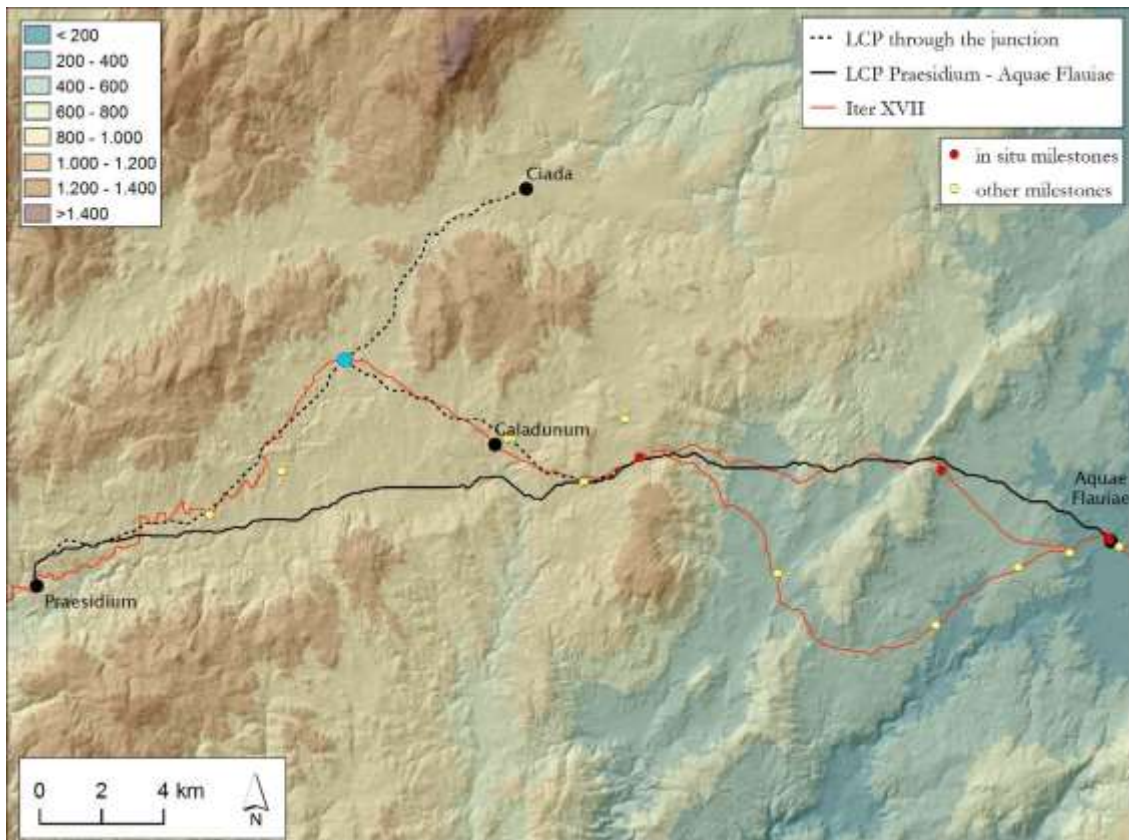


Figure 21. LCP 07 in the area of Alto Rabagão with the addition of an extra junction

6. DISCUSSION AND CONCLUSIONS

Based on the proposals made by Güimil-Fariña and Parcero-Oubiña (2015), in this paper we have tried to analyse in further detail the rationale behind the layout of the so-called *via XVII* between *Bracara* and *Asturica* as it is known today thanks to the archaeological data available. In contrast with the limited conclusions that were reached in the aforementioned paper regarding this particular road, the incorporation of new factors has provided a more comprehensive understanding of the logic behind the road layout, which is visually obvious in Fig. 22. The combination of different scales of analysis has allowed us to achieve a good balance between understanding

the general layout of the road and finding a possible explanation for minor divergences.

Figure 23 presents a simplified map of the route with a schematic graphic summary of the results, with the main nodes (blue dots) and the factors which, according to our analysis, influenced the layout of the road. The main contributing factors were the preference for avoiding two types of areas:

- those of higher altitude in the landscape and
- those poorly suited for the movement of animal-drawn wheeled vehicles.

The table at the bottom details the quantitative weight of each of the factors in the final process of analysis and the sections of the road for which each factor has been found to have a likely influence.

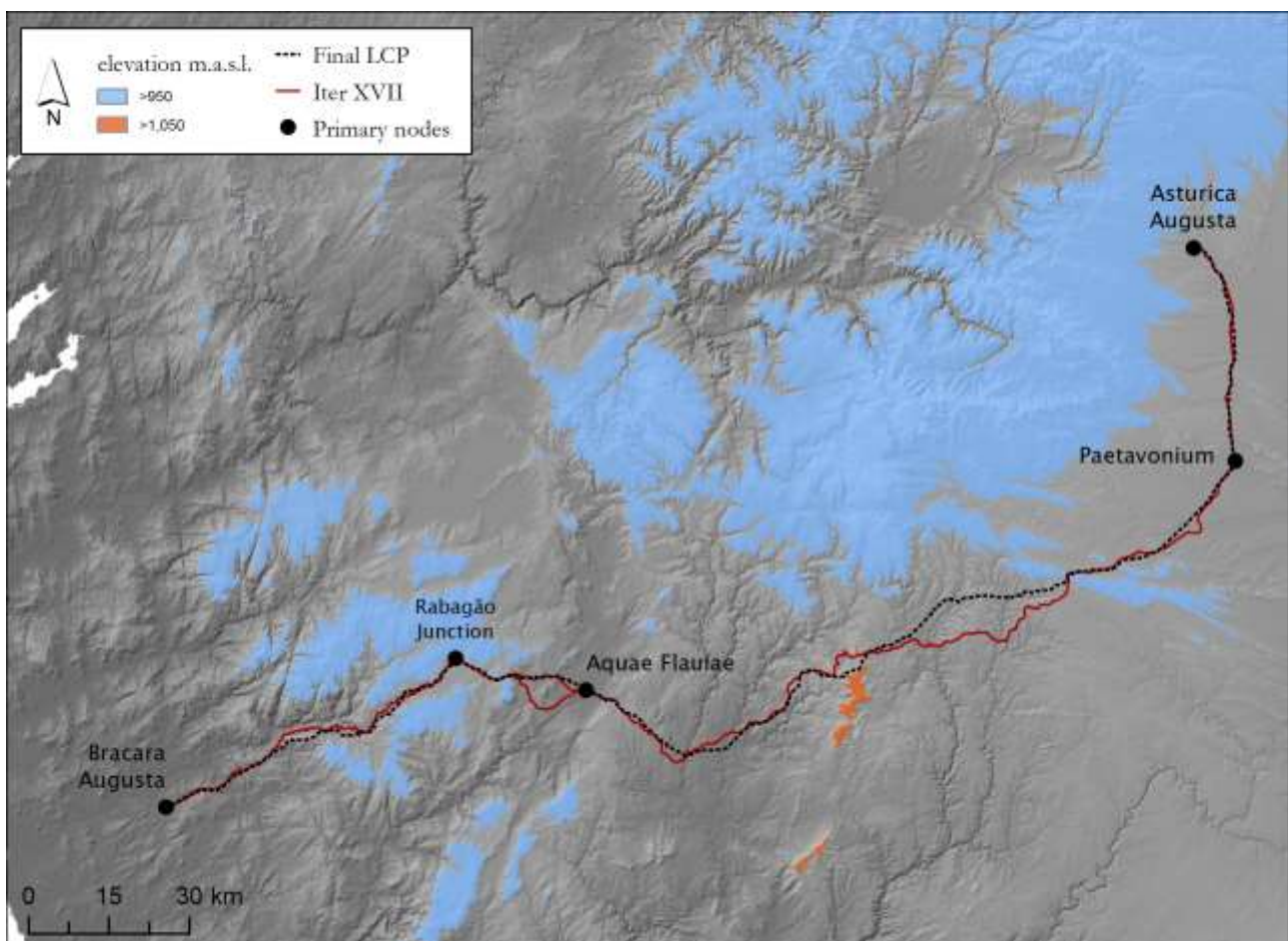


Figure 22. Final LCP 07 combining all the factors used in the analysis and the 5 primary nodes shown

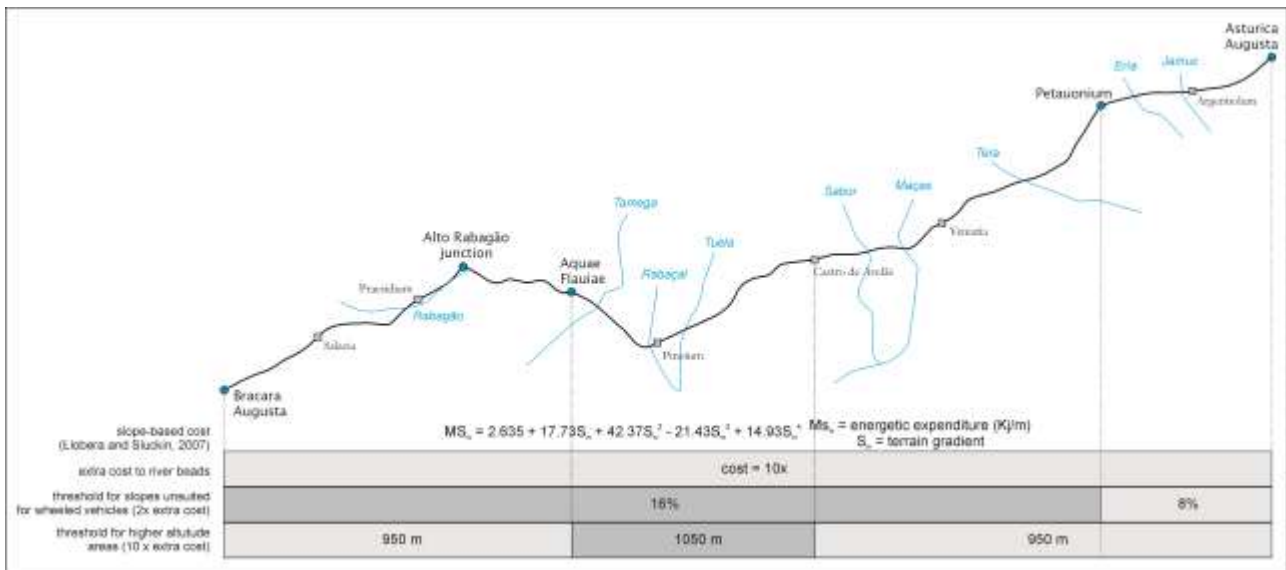


Figure 23. Simplified map of the Iter with a schematic representation of the rationale behind it: primary nodes and influence of topographic factors

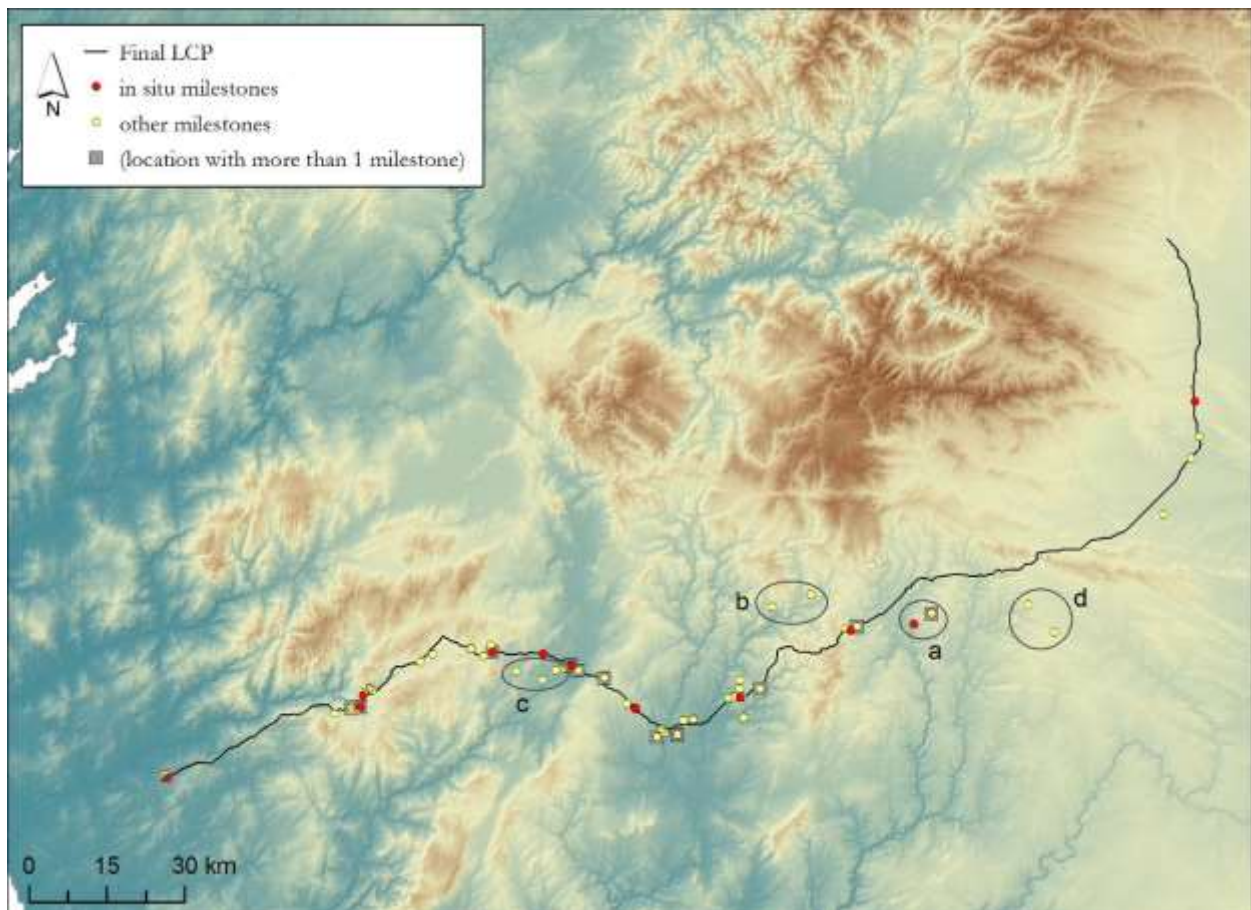


Figure 24. Final LCP 07 and location of milestones

It must be noted that the somewhat linear argument followed in the writing of this paper is actually a narrative summarising an intensely iterative process of analysis in which all the factors considered were combined in multiple ways until we arrived at

an outcome which best matched the evidence available about the ancient route. This means that removing any of the elements from the analysis (either impedance factors or destination nodes) would have a negative effect on the final results, meaning that the

similarity between the modelled paths and the evidence of the road will always decrease. For instance, and considering how the analysis is described here, it would seem reasonable to ask what would happen if we skipped section 3.2 (if we did not consider higher altitude as an influential factor) and moved directly to section 3.3 (appropriate slope for wheeled vehicles). Once again, all the factors and nodes shown here have been tested in every possible combination and what is described here is the outcome which best matched the archaeological evidence available about the ancient route.

6.1. A quantitative assessment of the results of the analysis

So far, we have presented our results in a purely visual way: similarities between the modelled paths and the evidence available for the route of the road has only been shown visually and not actually measured. To give a more robust assessment of the accuracy of the analysis, we will make use of the same two methods used in the paper by Güimil-Fariña and Parcero-Oubiña (2015):

- Proximity between LCP and milestones
- Similarity between LCP and the proposed route of the road

To date, a total of 92 milestones are known for this particular road (Fig. 24, a full catalogue exists in Rodríguez Colmenero et al., 2004, also see the website www.viasromanas.pt). Since there are places where more than one single milestone have been found (points symbolised within a grey square in Fig. 24), the number can be reduced to a total of 75 locations. For only 15 of them is the original context of provenance accurately known. Although the majority of the rest are quite likely to have their place of origin in the immediate vicinity of their current location, for the purpose of this analysis we have considered them as *non in situ* findings.

Figure 25 shows the histogram of linear distances between the in situ milestones and the final LCP 07: 75% of the milestones are located within 200 m of the LCP, with only 1 located at a distance greater than 800 m. Actually, this particular case ("a" in Figure 24) corresponds to the only major section of the road which cannot be "explained" with the evidence we presented here (see Figure 22): the area immediately to the east of modern-day Bragança. We will return later to this particular issue.

If we consider the unique locations of all milestones (Figure 26), the results are only a little different. Again, the majority of the milestone locations are within a distance of 800 m from the LCP. In this case, the effect of displacement of the milestones from their original locations may have an influence

on the results. In particular, there are 9 locations that deserve a more detailed explanation (the circled areas in Figure 24). We have already commented on area "a". Locations in areas "b" and "c" correspond with the two sections of the road where two alternative routes seem to have existed (see Fig.2). These may have corresponded to shortcuts (as argued for area "c" by Rodríguez Colmenero et al., 2001: 176) or to changes in time (as has been proposed for other sections of this road, Fernández Ochoa et al. 2013). Since LCP analysis only allows us to calculate the first optimal route between two points, there is a limitation here concerning the exploration of cases where more complex networks might have existed (Herzog, 2013). The extent to which these alternative routes can also be understood with the same, or similar, factors considered here is something to be explored employing methodologies which deal with mobility in a less restricted way (as in Llobera et al., 2011).

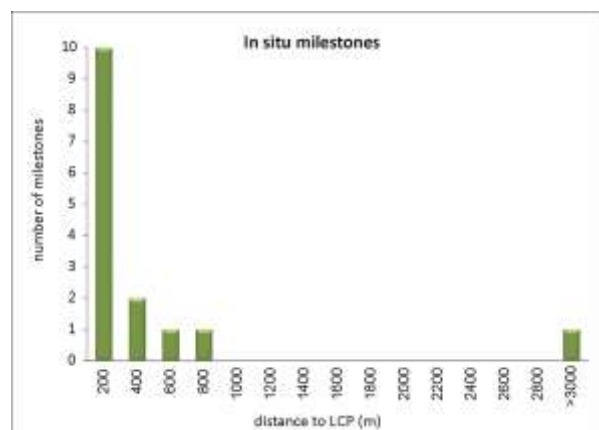


Figure 25. Histogram of distances between the in-situ milestones and the final LCP 07

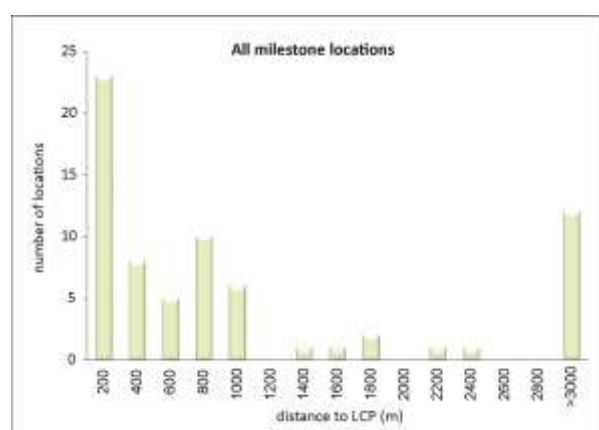


Figure 26. Histogram of distances between the unique locations of all the milestones and the final LCP 07

Regarding area "d", it is quite likely that the two milestones located here, in the village of San Vitero, are not far from their original position (Rodríguez Colmenero et al., 2004: 120). However, it has been

argued that they were not part of the main route of the road: according to some authors, they must be related to a different alternative branch of the main road (Rodríguez Colmenero et al., 2004, see Figure 2), while to others they were actually related to a completely different, secondary road, setting off from road XVII towards a different destination (as already proposed by Gómez Moreno, 1927, among many others).

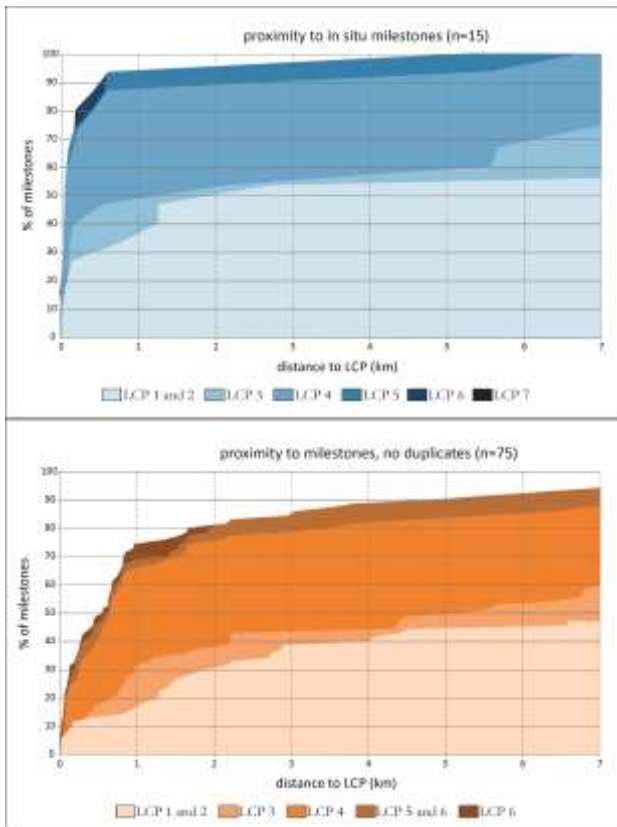


Figure 27. Cumulative frequency of the distance between each LCP and the in situ milestones (top) and all locations of all milestones removing duplicates (bottom)

Proximity to milestones can also be measured in terms of frequency, rather than absolute number. If this is done (Fig. 27), we can also compare how well each LCP described in the previous sections fits.

Despite their high number, the spatial distribution of milestones is quite uneven, with large sections of the road where they are completely absent. Using them as the only way to assess the reliability of our analysis can lead to biased conclusions. Although it is not a primary source as the milestones are, the extremely detailed reconstruction of the road developed by the *Vías Augustas* Project is spatially continuous and provides a complementary way of measuring the accuracy of the analysis.

As Güimil-Fariña and Parcero-Oubiña did, we followed the procedure suggested by Goodchild and Hunter (1997) to evaluate the similarity between linear features, based on determining the proportion of

a linear feature (here, the LCPs) that lie within a buffer distance from a second linear feature (the *Vías Augustas* reconstruction). The results (Table 3), shown here for two buffer distances of 1000 and 2000 m, indicate very clearly how the results improve as we add new factors and nodes into the calculation. The final LCP 07 (Fig. 22) has a rather significant coincidence with the reconstructed route of 75.67% within a distance of 1 km, and as much as 88.22% within 2 km.

Table 3. Similarity between the different LCPs and the proposed route of the *Iter XVII* (as proposed by the "*Vías Augustas*" project): % of LCP within a distance of 1 and 2 km from the road

LCP	Description	LCP within 1 km	LCP within 2 km
LCP 01	Bracara - Asturica	18.12	23.54
LCP 02	Bracara - Aquae Flaviae - Asturica	18.20	22.70
LCP 03	Id. avoiding higher altitudes	36.99	52.81
LCP 04	Id. avoiding slope > 16%	47.67	60.70
LCP 05	Id. adding Petauonium as a node	62.82	78.79
LCP 06	Id. avoiding slope >16% / >8%	71.99	86.23
LCP 07	Id. adding Alto Rabagão junction	75.67	88.22

6.2. Archaeological implications

As we have already pointed out, the results of our analysis suggest that there were a number of criteria considered for the layout of the road, which relate with different characteristics of the regional landscape. But also, and perhaps more interestingly, the analysis shows that there is a limited number of places which may have been key nodes in the layout of the road, places that the road was intended to join. Besides the two terminal, obvious nodes (*Bracara* and *Asturica*), the analysis suggests that the locations later occupied by *Aquae Flaviae* and *Petauonium* were also *a priori* nodes for the road. While neither of these two civil nuclei had significantly developed as Roman towns before the end of the 1st century AD (Pérez Losada, 2002), their relevant role in the layout of the road (initially built in the time of Augustus) has some relevant implications.

There is still a fifth node (the junction in the Rabagão valley) which does not coincide with either any relevant feature in the landscape or with any known Roman site, but which becomes essential in understanding the route of the road as we know it. In this case, the existence of a secondary branch towards the site of Ciada and the Assureira mining

area offers a good argument to understand this intersection.

Despite some recent urban archaeological discoveries in Chaves (not adequately published yet) appearing to point towards an earlier founding date for *Aquae Flaviae* than has traditionally been assumed (maybe as early as in the late 1st century BC), these are not enough to believe that there was an important settlement in this location at such an early time. As we have already argued in Section 3.4, it is more likely that the spatial location of the later *Aquae Flaviae* is that of a key crossing point in the landscape. From that point of view, it may have been the case that Roman interest in this place was a consequence of its privileged location as a hub for communication in the region. As Güimil-Fariña and Parceró-Oubiña point out, this “suggests that those places were already significant nodes in terms of mobility in this region well before their emergence as focal Roman sites and supports the suggestion that, to a great extent, the Roman road network was here the formalization of already existing routes” (Güimil-Fariña and Parceró-Oubiña 2015: 40-41).

By the end of the 1st century AD, *Aquae Flaviae* had become a secondary administrative centre in the region, under the authority of *Bracara* (Martins et al., 2005; Pérez Losada, 2002) and the main town inland. In the Flavian period it was promoted to *municipium latinum*, in parallel with the construction of the *via XVIII* or *via nova* (CIL II, 4854; *HEp*, 1997, 571) and of new secondary roads that proved the role of *Aquae Flaviae* as a key place for the connectivity of the Iberian northwest (CIL II, 2477).

The analysis also provides some interesting arguments to support the importance of the Roman army in the origin of this road. The possible role of the military base of Rosinos (where *Petaunium* was later located) as a primary node of the road is perhaps the best argument which our analysis provides concerning this aspect, although it is not the only one. As we have already seen, there is an especially dense number of military bases next to the road in the area to the south of *Asturica*: those of La Chana-Castroalbón (Loewinsohn, 1965; Costa García, 2016), Villamontán de Valduerna (Celis Sánchez et al., 2015), and *Asturica* itself (González Fernández, 1997) (Figure 9). These four bases are located on the plains next to the foothills of the Sierra de Cabrera, following a pattern which has been observed for the Roman military occupation of the whole north-western Iberian Peninsula during the Julio-Claudian period (Morillo, 2002; 2009). The route of the road adheres to the same strategic principle of giving preference to flatter areas and avoiding higher altitudes. The distinction between 'tactical roads', planned to support the military campaigns, and 'permanent roads',

built soon after conquest (Gethin & Toller, 2014) might help to understand why all these Roman camps preceded the date of the formal construction of the road.

Other sectors of the road also offer some evidence possibly relating to the Roman army. Between *Bracara* and *Aquae Flaviae* a place called *Praesidium* is mentioned in the Antonine Itinerary (Wess. 422.4). Among the recent early findings in Chaves, a “caetra type” coin (Villaronga 4; RPC 68 4), minted sometime after 23 BC, and a Gauloise 1 amphora (Laubenheimer, 1985) are objects usually associated with military occupation in the time of Augustus. Although still too few to be significant, these objects may suggest the presence of military forces in the area immediately after the Cantabrian wars, rather than the existence of a proper military base here (as was also discussed, in the same region, for the case of *Lucus Augusti* (a recent summary in Costa García, 2013: 367-377; see also Le Roux, 1982: 75-76; Morillo Cerdán, 1996).

In any case, it is hardly possible to speak of Roman roads without considering the role of the army, at least in this region (Vega Avelaira, 2008). As early as 9-8 BC, shortly after the end of the Cantabrian-Asturian wars, some milestones with the names of up to three different *legiones* were placed along the road between *Caesaraugusta* (Zaragoza) and *Summum Pyrenaeum* (the mountain pass of Somport, in the Pyrenees, *AE* 1984, 583-585; Lostal Pros, 2009: 205-214).

Also dating from the time of Augustus, legionary masons' marks have been found in the building blocks of the Martorell bridge (*AE* 1984, 607; Gurt y Rodà, 2005) and perhaps in the foundations of the river port of *Caesaraugusta* (*Hep* 10, 664; Beltrán Lloris, 2008). Military marks from the time of Tiberius have been found in the *forum* of *Clunia* (Coruña del Conde, Burgos) (Irujo Lizaur, 2008), and from the Julio-Claudian period in *Asturica Augusta* (González Fernández and Vidal Encinas, 2005) and *Lucus Augusti* (Rodríguez Colmenero, 1996: 298; Herves Raigoso and Rodríguez Colmenero, 2010).

If we return to road XVII, although no direct comparable data concerning the involvement of the army in its layout exist so far, there is some evidence to suggest that this is the case. It is the oldest among all the roads in the north-western Iberian Peninsula, established ca. 5-2 BC (CIL II 4776 and CIL II 6215; Rodríguez et al., 2004: 105; Moreno Gallo, 2011), shortly after the foundation of the military bases in *Asturica* and Rosinos. As we have seen, its layout was probably influenced, or even completely conditioned, by the location of these two particular sites.

7. CONCLUSION

“Models provide an ideal means to determine the range of possibilities associated with certain processes or actions. There are many examples in archaeological narratives that make reference to the occurrence of specific past actions that are difficult, if not impossible, to assess with any certainty. Yet it is possible, even desirable, to discuss and provide estimates for the likelihood of certain actions (or some aspect associated with them). This shift is subtle but important. By making reference to the possibilities for certain action rather than to its actual instantiation, it is possible to conduct an investigation that centers around the significance of changes in the likelihood” (Llobera, 2012: 505).

The analysis presented here, following a rather linear narrative, has been the result of a strongly iterative process aimed at the exploration of the potential factors which may have been behind the layout of a particular path that is known to us today thanks to a number of archaeological remains. The use of digital modelling tools, and the possibilities for simulation they provide, has been the main methodological argument in this approach. Starting with a very basic hypothesis, which (as expected) has proved to be rather insufficient to understand the archaeological evidence, we have added particularly elements into the analysis (impedance factors and spatial locations – nodes) until arriving at a result that matches the archaeological evidence to a large degree.

As has been already mentioned, it is important to note that, during our analysis, we have considered all the factors and elements presented here in any possible combination and order. The sequence we

chose for showing them here, following a linear narrative, does not imply any specific hierarchy of importance or logical reasoning; we simply ordered the different factors here from the basis of the “amount of correction” they provided. For instance, it would seem reasonable to think that appropriate slope for wheeled vehicles (section 3.3) might have been a more relevant factor for the design of the route than avoiding higher altitude areas (section 3.2), and thus that they should have been tested and shown in that «logical» order. But considering the factor of avoiding high altitude areas happens to have a much stronger impact in the model, and that is the only reason why we chose to show it here in first place.

As we stated at the beginning of this paper, paths are means of joining places. Both archaeological paths and places are the result of contextual actions taken in the past. In this paper we have tried to explore the likelihood of some specific factors in order to understand the spatial location of some archaeological elements which were the result of actions related with the connection of places in the past. By doing so, we have been able to extract some insights into the contextual actions and decisions which may have been behind them, into their rationale. Of course, this does not mean that any other factors (mechanisms or interests) are absent here, as is demonstrated by the as yet incomplete matching between the modelled and actual routes. However, we believe that our analysis contributes towards a more detailed understanding of this particular case study. And, beyond that, we believe that the methodology followed may also be of interest to be applied in the analysis of other archaeological paths and roads.

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