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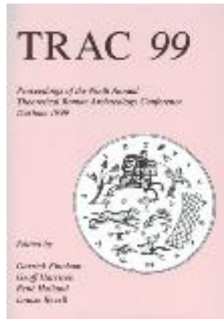

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Author: Kris Strutt

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Use of a GIS for Regional Archaeological Analysis: Application of Computer-based Techniques to Iron Age and Roman Settlement Distribution in North-West Portugal

by Kris Strutt

Introduction

Geographic Information Systems (GIS) in the context of regional spatial analysis have often been used within a research framework for studying the relationship between settlement and space, allowing visualisation of spatial data (Bernhardsen 1992; Kvamme 1997). However, strong methodological approaches to analysis have often been criticised for the weakness of theoretical premises underlying such research (Llobera 1996: 612). The existence of GIS as an accessible system comprising computer hardware and software applications must also be related to theoretical aims which underpin the role of GIS in spatial analysis (Gillings and Goodrick 1997). This paper aims to outline the use of such applications, as part of a survey project being undertaken by Professor Martin Millett of Southampton University, in the Ave valley region of north-west Portugal. The present study provides the opportunity to apply analysis within the framework of a long-term survey project, to analyse the distribution and location of Iron Age and Roman settlement using visual and quantitative analytical techniques, and relate the analysis to the social context of the region.

The representation of Iron Age and Roman settlement in the Ave valley region requires some definition. Material settlement remains are divided between fortified hilltop settlements of the 'Castros Culture', and less substantial material representing later unfortified settlements, located on valley sides and on the coastal plain. From the archaeological record, it would be easy to assume a simple division between 'Castros Culture' defensive settlement, and later non-defensive structures. A more complex relationship exists between these forms of settlement, however, suggesting continuity of habitation throughout the Iron Age and into the phases of Roman administration, and interaction between social groups (Queiroga 1992: 28).

Castro settlement is defined as "...a fortified village, located in a prominent geographical position, such as a hill spur, hillock or less frequently, a valley edge." (ibid. 1). This form of settlement, together with its association with Iron Age social groups led to the culture of the period being referred to as 'Castros Culture'. However, excavation at castros such as Penices and Citânia de Sanfins illustrate the continuation of castro occupation from the Iron Age into the Roman period (Queiroga 1992; Silva 1986: 39).

It is more difficult to define the nature of the non-castro settlement locations in the Ave valley region. The modern agrarian economy of the region means that much of the surviving archaeological record lies either under the plough or under urban development. Periodic deep-ploughing or hillside terracing redeposits material remains at surface level, some of which is classified as Roman ceramic material, pipes, altars, burials or small finds (Alarcão 1988). The lack of prominence of non-castro settlement in the archaeological record, together with the general location of material on valley sides suggests a non-defensive location of later settlement.

Aims and Objectives

The objective of study was to utilise GIS applications and quantitative processes to assess the spatial and locational patterns represented in the catalogued material remains for the Ave valley region. This will form the basis for analysis of the distribution of ceramics collected from fieldwalking as part of the Ave Valley Survey Project (Millett and Queiroga 1995; Millett et al. forthcoming).

A number of specific aims had to be addressed. Primarily, from map data and material gathered in the field, an unevenness of material distribution appeared to exist across the study area, conditioned by the location of different forms of drift geology. It was therefore important to scrutinise the distribution of known archaeological material in relation to what appeared to be a major factor influencing the pattern of settlement location. An assessment of the broad division of settlement type in the archaeological record was also necessary, to establish if and why different topographical locations were selected for settlements. It was also necessary to determine how different settlement locations related to one another, specifically the difference between castro and non-castro locations. An intuitive sense of the importance of castros to the position of later settlements was realised during fieldwork, particularly with the situation of settlements on river valley sides below castro locations. Analysis of these potential relationships was based on the visibility of castro sites from other defensive and non-defensive settlement positions, and the cost of movement from settlements to related sites.

Location and Background

The study area is centred on a 700 km² area between the Cavado and Ave Rivers, in north-west Portugal (Millett and Queiroga 1995), stretching from the coast some 20km inland. Both the Cavado and Ave Rivers flow down from the mountains along the Spanish-Portuguese border in a westerly direction into the Atlantic Ocean (Figure 1).

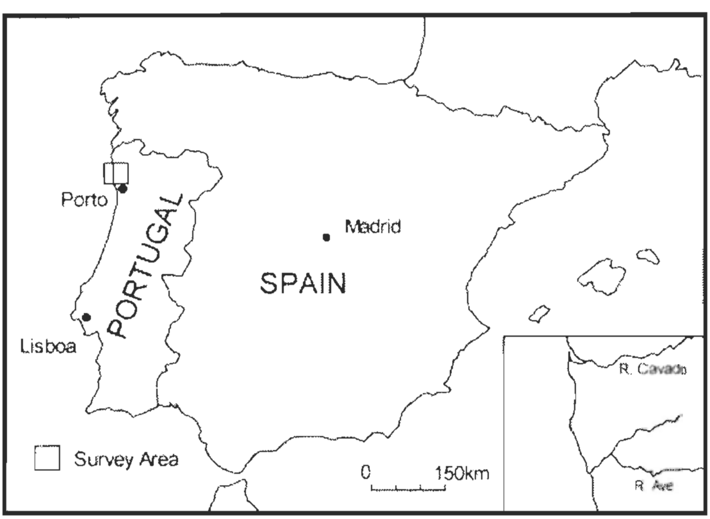

Figure 1 Location of the Ave valley region, north-west Portugal.

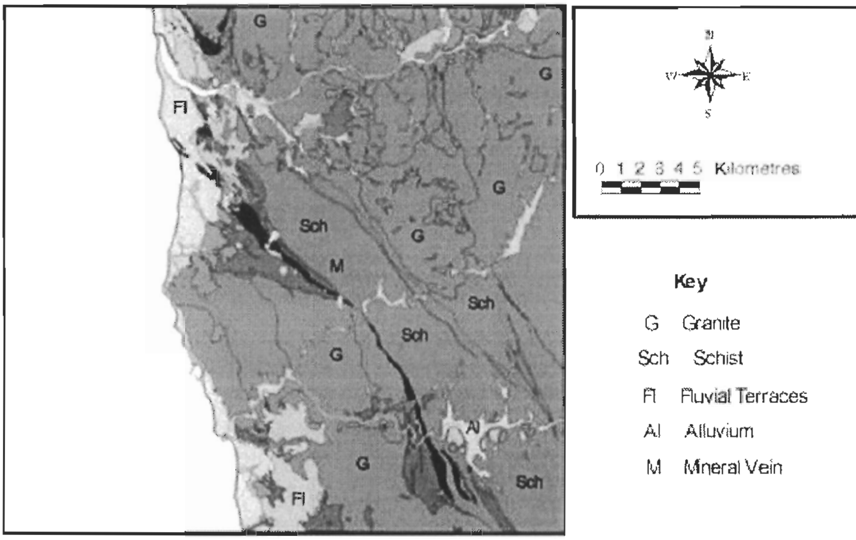

Figure 2 Map of the drift geology for the Ave valley region, north-west Portugal.

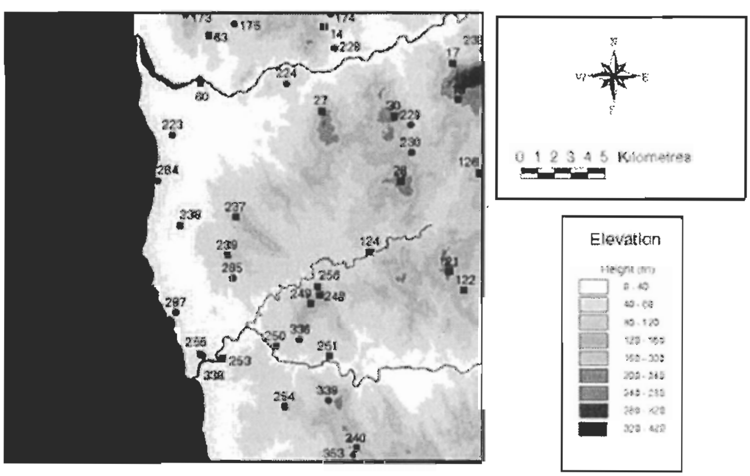

Figure 3 Distribution map of settlement location (sites numbered as in Table 8)

Topography of the area is orientated roughly north-east to south-west. However underlying geology runs in a north-west to south-east direction, comprising mainly micaceous granites, andallucian schist and metamorphic rocks (Figure 2). Climatic conditions in the area are predominantly influenced by the Atlantic zone. The area borders the Atlantic Ocean, and higher mountains to the east, particularly the Barroso-Alvão and Marão-Aboboreira massifs, regulate rainfall over the land to the west by obstructing passage of humid air (Queiroga 1992: 12). A complex hydrological network exists across the study area. Rivers form strong routes of communication. All watercourses, together with rainfall, contribute to the erosion of soils in the area, washing material downstream and depositing it along the river valleys (Shakesby et al. 1996). This affects the condition of past and modern agricultural land, archaeological features and the influence of post-depositional factors on archaeological material.

Evidence exists for human habitation in the study area from the Neolithic period onwards. Bronze Age material consists predominantly of bronze axe finds from unstratified surface deposits on castro locations (Martins 1990: 16). Evidence for settlement in the Iron Age is dominated by the 'Castros Culture', represented by massive hillfort settlements throughout the study area, established from the 8th century B.C. onwards. Roman campaigns in the Iberian peninsular in the third and second century B.C. led to the formation of administrative districts in the north west of the peninsular (Curchin 1991; Alarcão 1988). Bracaugusta was developed as an administrative centre for this district. Much of the settlement evidence for the Iron Age and Roman period comprises pottery, brick and tegulae finds discovered during archaeological excavation prior to urban development, or located during periodic deep cultivation activity.

In an effort to synthesise and study the distribution and quality of existing archaeological material within the study area, data were selected from several sources. Data on castro sites were taken from the unpublished thesis of Francisco Queiroga (Queiroga 1992), and two volumes assessing the 'Castros Culture' (Silva 1986; Martins 1990). Data on Roman material were taken from a published gazetteer of archaeological remains for Portugal (Alarcão 1988). These data formed the basis of the current analysis (Appendix 1). These sources represent recent cataloguing of archaeological material in the study area.

Analytical Parameters and Limitations

A more technical résumé of the methodology used to derive the digital dataset is given in appendix 2. All geographical data were digitised and stored as vector coverages. Sixty-one catalogued site entries were located in the study area, 40 of which were settlements. Twenty-four were castros, and sixteen Roman settlements. It is these 40 entries which form the basis of the current analysis. The digitised coverage of drift geology was used to analyse the distribution of archaeological material across the region. For the assessment of settlement location, raster grid coverages were generated, based on the digitised map data. A digital Elevation Model (DEM) was created from the contour lines of the area. From this model, a further two models were created in raster grid format, one of aspects or slope direction, and another of slope gradient.

For slope aspect, different aspects of slope were defined by points of the compass; north, south, east and so forth. Slope gradient was based on units of degrees of slope created in the model. These were divided into groups of four degrees to allow a relative comparison of slope gradient.

Viewshed coverages were generated, based on each settlement location in the study area, and derived from the DEM. Analysis was based on a viewshed of 6km radius. The decision to use this distance of visibility was in general an arbitrary one, although it was influenced by the direct climatic limitations on visibility experienced during fieldwork. Results of the viewshed analysis were generated as shapefiles in Arcview, indicating areas visible and not visible from settlement locations.

Cost distance grids were generated based upon the gradient of slope coverage for the area. Two raster coverages were produced, one generated from the coverage of castro locations, the other produced from Roman settlement locations. A grid cell size of 50m² was used, indicating the more imprecise nature of the cost distance grid. The cost units of the grid are perhaps most comparable with a value of time taken to move from a particular location. However, it is difficult to qualify the use of a specific value which relates to so many different complexities, for instance the difference in time required for a burdened or unburdened human to move from a particular point. Arbitrary units were used to provide a relative indication for cost of movement from each location.

A number of limitations were evident, for the original dataset and in terms of the analytical techniques used in the GIS. Data for the physical environment were digitised from current 1:25000 scale topographical maps, whilst data on drift geology were derived from 1:50000 scale geological maps. Such data gives a representation of the modern landscape in a static form. Regional and local topographical formations indicate a broken and complex landscape, which may not have altered significantly in the past two millennia. However, the data can give little or no indication of the effects of erosion and deposition, or changes in vegetation and climate, on the present pattern of distribution for Iron Age and Roman period settlement material. Soil loss from rainfall and flooding in northern Portugal, (Shakesby et al. 1996; Bathurst et al. 1996) and results of coring for soil deposits on valley floors in the study area indicate substantial alterations to surface deposits of soil over a relatively short time (Millett and Queiroga 1996, 57). This is why it is important to analyse the distribution of archaeological material across the categories of drift geology.

A note of caution must be made regarding the use of viewshed and cost distance data. Viewshed analysis and cost distance only account for simple variations in data derived from the topographic coverages. They fail to recognise limiting factors such as vegetation and climatic effects on visibility (Mitcham 1997: 37). Similarly the use of arbitrary cost distance units is apt for locating general trends in cost of movement from settlements, but it does not work on the basis of actual Iron Age and Roman landscape cognition. Much of this potential information cannot be expressed, or does not exist in the present archaeological record. The low resolution of site data also limited any understanding of defended and open sites temporally. Radiocarbon dates from sealed deposits were available for two of the castro sites (Queiroga 1992: 202ff), while relative dating of phases of settlement was virtually non-existent. The possibility of a broad Late Bronze Age date for initial settlement on castro sites is determined simply by the existence of bronze metallic surface finds from castros such as Monte da Saia. Although it was possible to derive a basic chronology of settlement in broad terms of period, the limitations of the poor chronological relationship between sites are evident.

Analysis and Results

The following analyses were all carried out to address the specific aims related above. They are divided into three categories: analysis of overall settlement distribution, assessment of contrasts and similarities in topographical location of settlements, and considering the relationship between settlements of different location and type.

Settlement Distribution

At an intuitive level, it was possible to recognise a lack of even distribution in the archaeological material across the survey area reflected in basic distribution maps of the data (Figure 4). A large proportion of the total number of settlement locations are situated on micaceous granite (79%), with fewer on the fluvial terraces (12%), schist (3%), alluvial deposits (3%) and mineral veins (3%). Each of the percentages for schist, alluvium and mineral veins account for one site for each category. In particular, the small amount of material on the schist was noticeable, as schist comprises a significant proportion of the drift geology (Table 1). A statistical elucidation of this trend seemed appropriate to evaluate quantitatively the existence or non-existence of an even distribution of archaeological material, in relation to the drift geology of the area (Table 2).

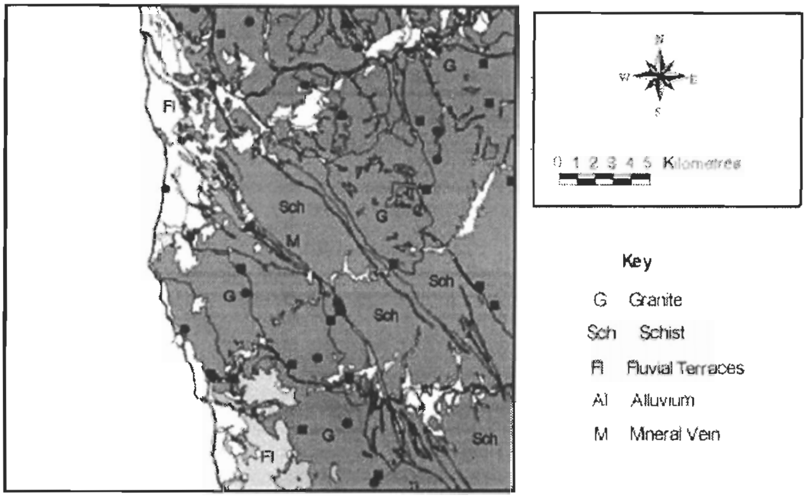

Figure 4 Distribution map of settlements over the drift geology, illustrating the lack of material on the band of schist running north-west to south-east across the region.

Geology	Area (Sq. km)	Geology (% by Area)
Alluvium	61299.86	9.63
Fluvial Terraces	60060.40	9.44
Schists	201532.43	31.68
Granite	312481.01	49.11
Mineral Veins	866.12	0.14
Total	**636239.85**	**100**

Table 1 Drift geology in square metres and percentage by area.

Drift Geology	Castros	Roman Settlement	Total
Granite and Mineral Veins	21	12	33
Schist	0	1	1
Alluvium	0	1	1
Fluvial Terraces	3	2	5
Total	24	16	40

Table 2 Settlement distribution over the four revised categories of drift geology.

This evaluation was undertaken using a chi-squared test (Shennan 1997: 106) for a single classification of data, for castro sites and Roman material. A null hypothesis was formulated:

H0 Settlements are equally distributed across the drift geology
H1 Settlements are not equally distributed across the drift geology

The test was carried out based on four of the five broad categories of drift geology: alluvium, fluvial terraces, schists and granite. Because the percentage area of the mineral veins was so small, its use in the test created a biased result, consequently it was excluded from the chi-squared test (Appendix 3). The level of significance used was one in twenty, or 0.05, a margin small enough detect any pattern based on the hypothesis, and minimise the possibility of any error (ibid. 108). Calculations indicated for both the whole dataset, castros and all settlements that sites were not evenly distributed across the drift geology (Appendix 3). However, the null hypothesis was upheld for Roman settlement. This is probably due to the location of one Roman settlement, and five sites of general Roman material being located on the schist, close to alluvium deposits.

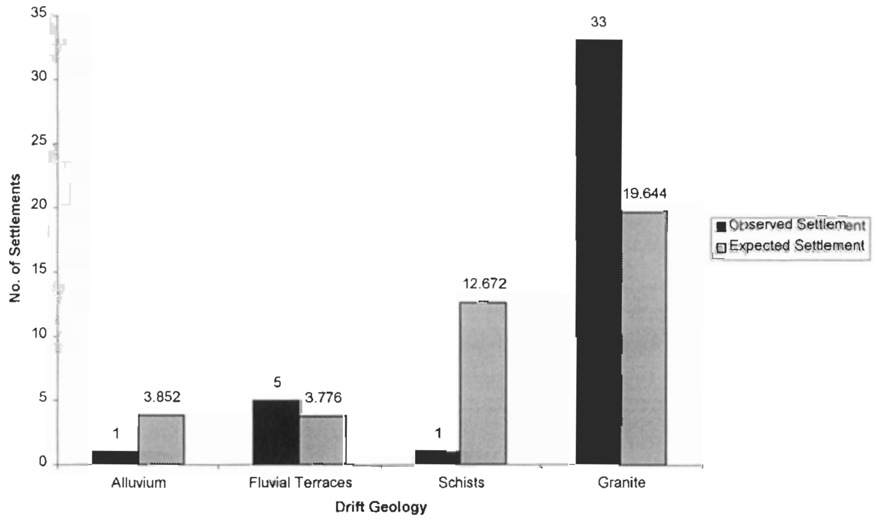

Figure 5 Observed and expected numbers of settlements on the four main categories of drift geology.

Settlement Location

Analysis of settlement location was carried out on the basis of several common parameters: the situation of each settlement, immediate gradient of slope for settlement location, surrounding gradient of slope, and the aspects of slope surrounding individual settlements.

The topographical location of catalogued settlement material was divided into four broad categories:

- Hilltop locations where aspects of downward slope surround the position.
- Spurs of land, where sites are situated on a projecting spur of a hillside, with steeply sloping gradients on one or more sides.
- River valley terraces, moderately sloping hillsides above major and minor watercourses.

- Coastal plain, the broad, flat or shallow sloping land along the western edge of the study area.

The number of settlements were recorded for each category, and graphical representations of the settlement locations were also produced, in the form of pie charts (Figure 6).

Evaluation of the immediate and surrounding gradients of slope for each settlement were calculated from the GIS using the slope gradient raster coverage. Gradients were divided into categories of four degrees range, starting with 0 to 4 degrees, where ground is of such a shallow gradient as to be essentially flat, to values of between 28 and 32 degrees. The category of immediate gradient specified the nature of the ground where the settlement was constructed, and the surrounding gradient alluded to the greatest gradient of slope surrounding each settlement location for a radius of 400 metres.

Values for the aspect of slope for the location of each settlement were also established in the GIS, based on the slope aspect raster coverage. The results of this analysis were complex, and required a more intuitive approach to explain the patterns inherent in the location of the settlements.

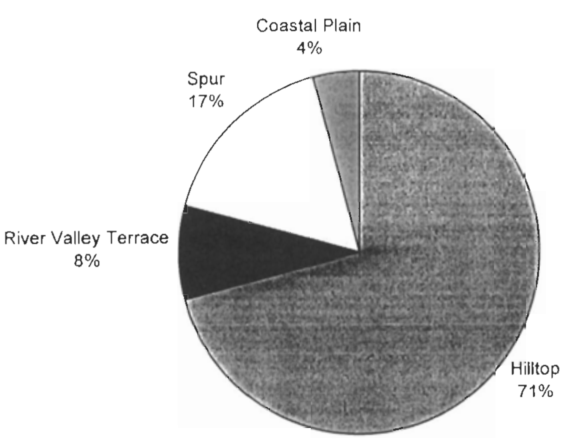

Figure 6 Pie chart showing the situation by percentage of castro locations

Results of the settlement location analyses showed a marked contrast between castro settlements and location of Roman settlement. A comparison of all locations indicated that the majority of settlements were positioned either on hilltop or river valley terraces (Table 3). These instances represent 74% of the total list of catalogued material. A contrast can also be noted between different settlement types. Of the 24 castro sites, 17 (71%) are situated in hilltop locations, with a further 4 (17%) positioned on spurs of land overlooking the main river courses of the Ave and Cavado. Outside of these defended settlements, no Roman settlement material is located in hilltop positions. 69% of such sites are situated on river valley terraces, with 25% located on the coastal plain of the region.

Situation	Castros	Roman Settlement	Total
Hilltop	17	0	17
River Valley Terrace	2	11	13
Spur	4	1	5
Coastal Plain	1	4	5
Total	**24**	**16**	**40**

Table 3 Topographical situation of settlements.

Comparison of the gradient of slope in the immediate and surrounding area of settlement locations indicated that all sites are situated on relatively low gradient slopes or flat ground (Table 4). 74% of settlements are located on ground with between 0 and 4 degrees of slope, with 18% located on ground with between 4 and 8 degrees of slope. The remaining 8% are all situated on ground with between 8 and 16 degrees of slope.

Immediate Gradient (degrees)	Castros	Roman Settlement	Total
0 to 4	19	11	30
4 to 8	4	3	7
8 to 12	0	2	2
12 to 16	1	0	1
16 to 20	0	0	0
20 to 24	0	0	0
24 to 28	0	0	0
28 to 32	0	0	0
Total	**24**	**16**	**40**

Table 4 Immediate gradients of slope for settlement locations.

A marked contrast in gradients surrounding different settlement locations was evident. For castro settlement locations, 80% have surrounding gradients of slope of between 16 and 32 degrees, for instance at Monte da Cividade (Figure 7), with the remaining 20% ranging between 0 and 16 degrees. However, Roman settlement location demonstrates a marked difference from castro settlements, with 49% of sites showing surrounding slope gradient of less than 8 degrees, and the entire dataset of Roman material located with surrounding gradient of slope of less than 20 degrees (Table 5).

This is not necessarily surprising. Castros do reflect many of the attributes associated with defended settlements, and their location on flat ground, surrounded by steep slopes would provide a more defensible position from attack. Such prominent locations also may suggest possible social and symbolic influences of the castro settlement sites. In contrast, location of Roman settlement material shows no evidence for massive defensive structures. A different set of priorities appears to govern the location of these sites. Their topographic location predominantly on river valley terraces suggests a position linked to localised resources such as water and agricultural land.

Surrounding Gradient (degrees)	Castros	Roman Settlement	Total
0 to 4	2	4	6
4 to 8	0	4	4
8 to 12	1	2	3
12 to 16	2	4	6
16 to 20	11	2	13
20 to 24	5	0	5
24 to 28	1	0	1
28 to 32	2	0	2
Total	**24**	**16**	**40**

Table 5 Surrounding gradients of slope for settlement locations.

Overall visualisation of the aspects of slope around settlements indicated a contrast between castro and non-castro sites. Whilst Roman settlement locations are situated on east, south-east and south facing slopes, 20 of the 24 castro settlements are situated with ground sloping in all directions away from them.

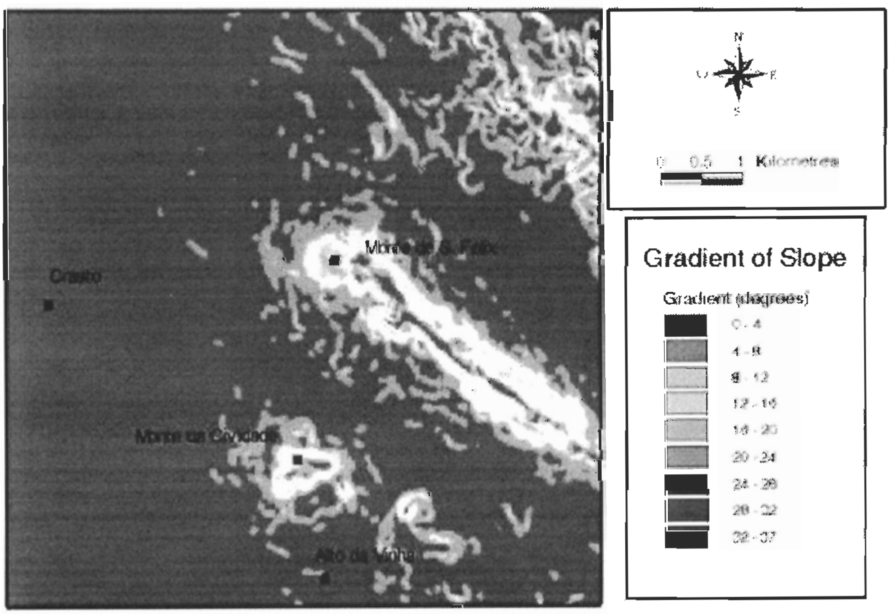

Figure 7 Plan of slope gradient, indicating the steep gradients encircling the location of Monteda Cividade and Monte de S. Felix castros.

Viewshed and Cost Analysis

Viewshed analysis was carried out on the basis of all settlement locations. Results of these tests were then tabulated to indicate general trends in settlement visibility. Cost grids were derived from the raster gradient of slope coverage, based on the location of castro settlements, and the Roman settlement positions, as two separate cost grids. Arbitrary bands of cost were used of

4000 units, to create a representation of relative cost of movement from settlements, and allow analysis of the proximity of surrounding settlements within each cost band. Numbers of castro and Roman settlements within 8000 cost units of particular settlements were then tabulated.

From the visualisation of these data, a number of factors associated with the pattern and distribution of settlement in two broad chronological divisions could be established. For both castros and locations of Roman settlement, at least one castro site is visible without exception (Figure 10). As part of a more intuitive approach, plots of the viewshed analyses were scrutinised in an attempt to qualify the strong trend in visibility of castro sites from all settlement locations. It was noted that for every castro site, its nearest neighbouring castro over a Euclidean distance is visible, regardless of geographical location (Figure 8). Exactly the same trend was noticed for Roman settlements. In some instances, the nearest neighbour was found well within the 6km radius of the viewshed, but on the periphery of the area visible from a specific site.

Similar results were obtained for Roman settlements (Figure 11). Although eight instances occurred where no settlement was visible, a strong indication that visibility of both castro and non-castro settlements was important was shown by the fact that castros were visible from 83% of sites, and other Roman settlements were visible from 75% of all sites.

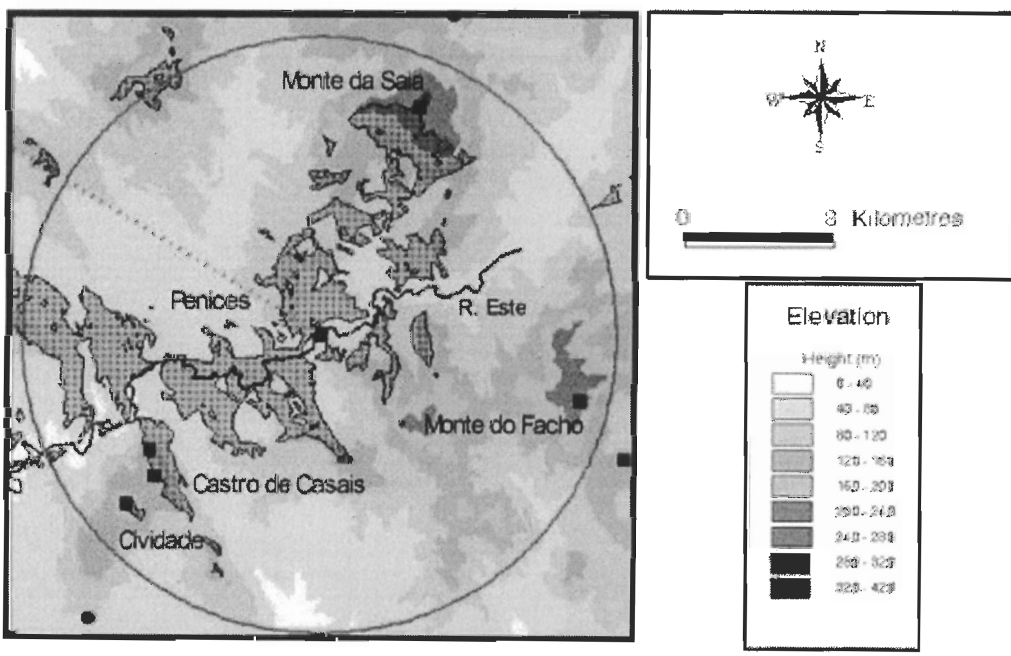

Figure 8 Viewshed produced for the Penices castro, with a 6km radius, showing the four castros visible from the Penices settlement.

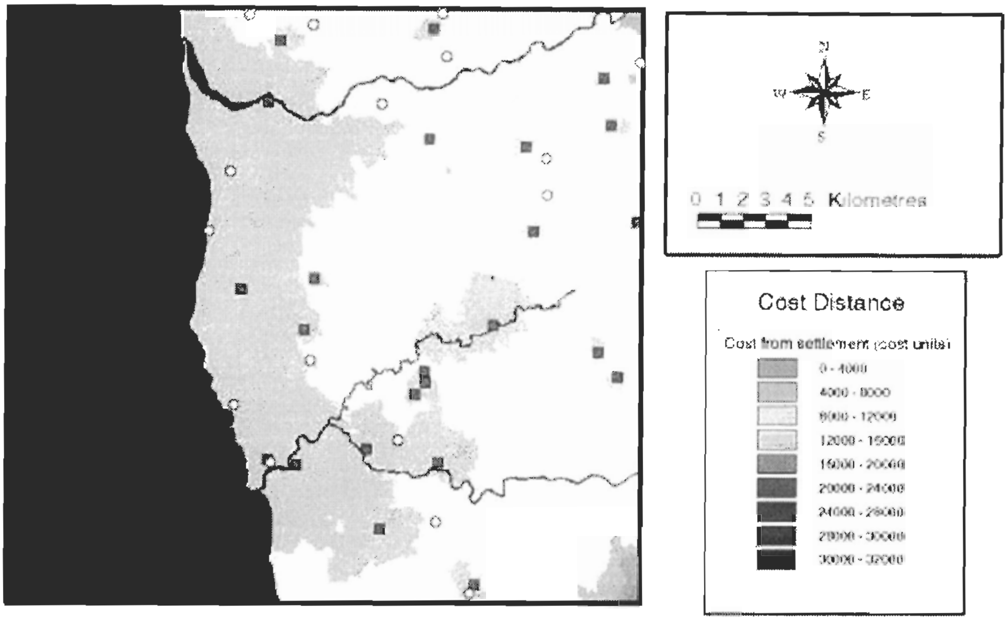

Figure 9 Cost grid of distance from castro settlements, with Roman settlement locations also displayed.

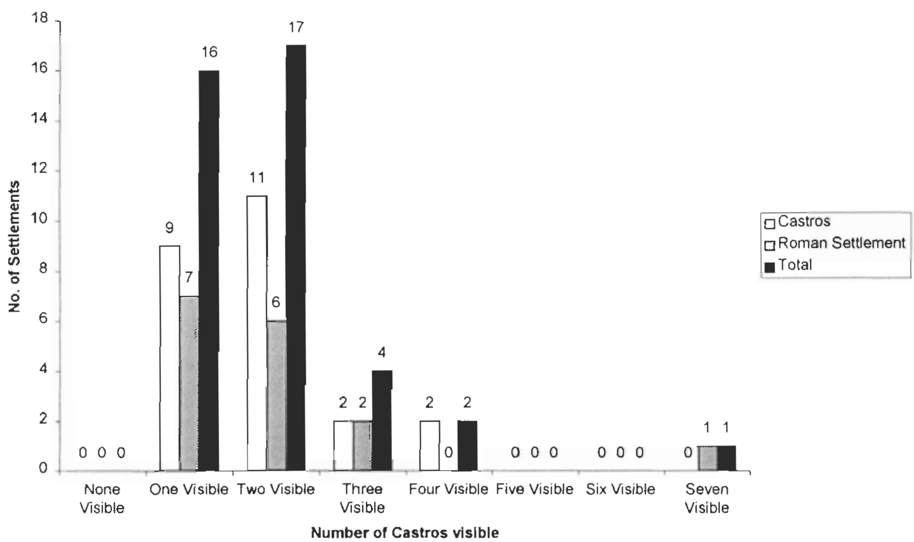

Figure 10 Bar chart showing the number of settlement locations from which castro sites are visible.

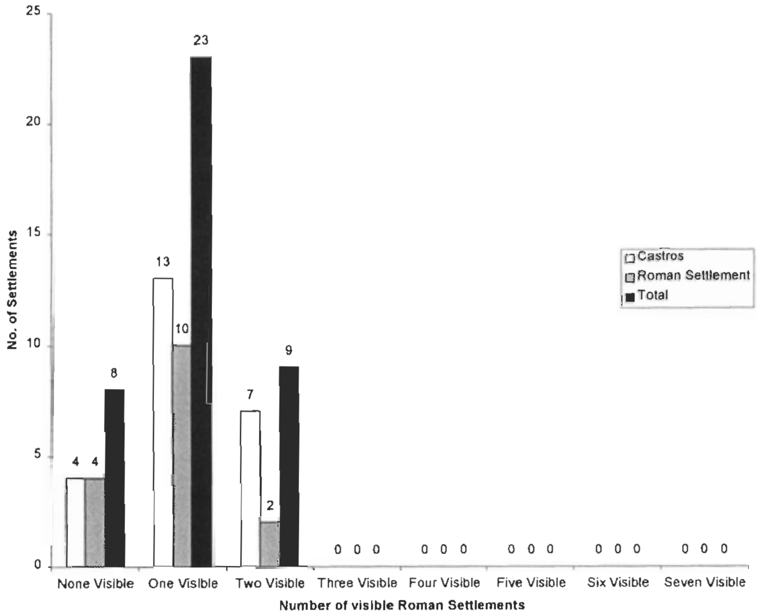

Figure 11 Bar chart showing the number of settlement locations from which Roman Settlements are visible

Results of the cost distance evaluation, whilst only producing a relative scale of cost access from settlements, did indicate a relatively low degree of accessibility from castro settlements both to other castros and Roman site locations (Table 6). Only 33% of castros and 12% of Roman settlements appear within 8000 cost units of another castro (Figure 9).

From Castros	Castros	oman Settlement	Total
Within 0-8000 cost units	8	2	10
Not within 0-8000 cost units	16	14	30
Total	**24**	**16**	**40**

Table 6 Number of castros and Roman settlements within 0-8000 cost units of castro locations.

This contrasts with the result produced for Roman settlements to both castros and other non-castro sites (Table 7). castros are within 8000 cost units of 83% of Roman settlements, with 62.5% of other Roman settlements within the same parameters.

From Roman Settlement	Castros	Roman Settlement	Total
Within 0-8000 cost units	20	10	30
Not within 0-8000 cost units	4	6	10
Total	**24**	**16**	**40**

Table 7 Number of castros and Roman settlements within 0-8000 cost units of Roman settlement locations.

Discussion

Results of the application of GIS techniques to settlement distribution and location in the Ave valley region demonstrate a bias in the distribution of material, and contrasting patterns in settlement location. It is important to relate the main deductions of the analysis to the current interpretation of settlement and social interaction for the Iron Age and Roman period in north-west Portugal. The relationship between computer-based application and archaeological theory is based on the premise that use of GIS has a theoretical agenda, that technique does not derive solely from pure technical application, devoid of inherent archaeological thought (Wheatley 1998: 2). Analysis of spatial relationships in distribution of settlement involves both archaeological and spatial theory. The research for this analysis was based on existing archaeological material within the study area, and current social theory based on evidence for the castros culture in north-west Iberia.

A number of factors have influenced the distribution of settlement material. An imbalance of distribution exists within the data primarily because of the priority given to site recording close to urban development, and the prominence of castro sites topographically (Silva 1986; Martins 1990). The number of sites located on different geological formations, by percentage, show that geology comprising schist have a lack of distribution of material across their area. This is due to rates of erosion and soil deposition on the valley slopes across hillsides derived from schist, covering or redepositing archaeological material. Factors of erosion may also have influenced the initial settlement pattern between the Cavado and Ave from which the evidence is derived, for instance the quality of soil for cultivation across the schist. Interpretation of material distribution is limited, both by the low quantity of site-related data, and in representation of settlement location. This serves to highlight the problem of dealing in a regional analysis where the record represents an active record of material location, effects of redeposition, concealing of material, and biases inherent in the data recording strategy.

The evident contrasts in settlement location represent a change in the social conditions defining where settlements should be situated. On the one hand, the castro settlements are sited on hilltop and spur locations, on flat or shallow sloping ground, surrounded by steep gradients and aspects of slope on all sides. These locations contrast with those of Roman settlement, most of which are sited on the coastal plain or on river valley terraces below hilltops. The immediate gradient around each settlement is minimal. Such trends of slope and aspect in the position of castro and Roman settlement could purely represent a product of the regional topography, based on the presumption that castro sites, as defended settlements, generally have a higher altitude than undefended Roman settlement. This would be a false assumption. Variables of slope and aspect are not always associated with levels of altitude or elevation (Kvamme 1992: 130). A comparison of the elevations of castro and Roman settlements shows no great discrepancy in the altitude of settlement sites between periods.

In the past, interpretation of castro settlement has emphasised their defensive nature. The critical factors in the physical location of castros are slope and aspect of their position, produced from a social and political need for a defensive situation, and the resources to allow the construction of the settlement (Hawkes 1984: 188). For location of a large defensive settlement, a broad, almost flat area surrounded on each side by steep gradients continuously appears in the pattern of physical data for the position of castro sites. However, interpretation of social importance of these settlements is not limited to their defensive capabilities. Their prominent locations may also serve symbolic and political purposes, defining the status of the settlement from the outside. Excavation at the Castro Terroso and other castro locations has indicated the vast quantity of huts and habitation units and the potential use of castro sites for storage of resources (Queiroga 1992).

The contrast between location of castro settlement and those represented by Roman material is noticeable. Roman settlements are situated on river valley terraces below castro locations. They are sited on flat or shallow sloping ground, with surrounding aspects of slope in predominantly east and south-east facing directions. At a simple level, this contrast could be interpreted as presenting a clear demarcation between defended castro settlements established in the Iron Age or earlier, and Roman settlement, native and Roman undefended sites located on hillslopes potentially closer to resources such as farmland. Military campaigns and the eventual subduing of local tribes are prominent in historical sources of the time (Curchin 1991; Alarcão 1988). However, such interpretation oversimplifies the social context of settlement location. Excavation of castro sites shows that, whilst Roman settlements are established on surrounding valley sides, native habitation of castros continues under Roman administration (Queiroga 1992). Evidence exists for a change in the internal structure of castro settlements, a form of proto-urbanisation, for instance at Citânia de Sanfins (Silva 1995: 279). The contrast in settlement location may allow a degree of interpretation of the function of such sites, but it does not provide evidence of a complete change in settlement location between the Iron Age and Roman period.

So far, all of these trends show a direct pattern based on social and cultural conditions, reflected in the physical situation of settlements for social requirements. The relevance of a social structure to the pattern of settlement takes on added significance when the trends in visibility are regarded. The strong visible presence of castros indicates the importance of these settlements both to other castro sites, and to settlements established in the Roman period. Why this should be the case is difficult to ascertain. However, evidence of settlement continuity does suggest that changes in the location of settlements did not seek to exclude castros from the social hierarchy. The inclusion of castro settlements within any changing settlement structure is also suggested by the cost of access to sites from all Roman settlement locations.

Conclusion

The settlement pattern for the Ave Valley region highlights the importance of a theoretical structure as the basis of visualisation and quantitative analysis. But use of GIS for analysis of archaeological material also presents a stimulant for engendering new or progressing current archaeological thought in terms of settlement location. Distribution of existing archaeological material from specific gazetteer sources indicates trends in the pattern of settlement, due to specific hypothetical social and cultural factors presented as contrasts in the pattern of data. Primarily, an unevenness of distribution is present in the archaeological record, which is governed predominantly by the geological form of the region. A number of interrelating factors may be the cause, from processes of erosion and redeposition of archaeological material across the schist of the area, to the inference that past cultural groups in the region deliberately avoided the eroded and broken areas of the schist.

An evaluation of settlement location indicates a broad contrast of settlement types. Castro settlements are located in naturally defensible situations. Material showing evidence of Roman settlement on the other hand is located on valley terraces below castros, This may once have arguably suggested a clear division between warlike Iron Age society and a more peaceful form of social order under Roman administration of north-west Iberia. This is not the case. Excavation at different castro sites has produced evidence of settlement continuity on the castros. Whilst no evidence exists for 'Castros Culture' settlement away from the castros sites, this is due to the limitations of the dataset, and does not prove that such settlement did not exist.

Finally, the viewshed and cost distance analysis suggest that the significance of the castro settlements was not lost with any movement of settlement locations onto the lower valley slopes. At the very least, castros remained a tangible reminder of the power of earlier social groups. It is most probable that such sites continued to provide a focal point for habitation and social activity.

Although trends in the pattern of settlement distribution exist in current catalogues of data, one purpose of the work has been to initiate a system for handling survey data on computer for analysing the location of concentrations of archaeological material. Analysis of ceramics collected from survey transects in the Ave valley region is ongoing, to provide the basis for a clearly sampled dataset, diagnostic of the different pottery fabrics represented in the region (Millett et al. forthcoming). Once ceramic densities from the fieldwalking are produced, new settlement locations will be analysed using the same techniques presented here.

In terms of the capabilities of GIS applications, these analyses only suggest a fraction of the potential for settlement analysis. There would be further scope to study settlement placement in the Ave valley region in relation to different criteria. Pottery data will improve the chronological dimension of the dataset for the area, which will potentially allow for a more detailed understanding of settlement continuity and change. In particular, further analysis of the dataset may address the limitations present in the current viewshed and elementary cost distance evaluations.

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Appendix 1 Tables of Catalogued Settlements and their Locations

No.	Site	District	X	Y	Type
13	Sequade	Barcelos	538526	4594930	Defended Settlement
14	Monte do Facho-Alto da Torre	Barcelos	529743	4599679	Defended Settlement
17	Outeiro do Castro	Barcelos	538186	4597289	Defended Settlement
27	Castelo de Faria	Barcelos	529559	4594178	Defended Settlement
28	Monte da Saia	Barcelos	534744	4589635	Defended Settlement
30	Santa Eulalia	Barcelos	534318	4593832	Defended Settlement
60	Outeiro dos Picotos	Esposende	521607	4596002	Defended Settlement
63	Castro do Senhor dos Desamparados	Esposende	522171	4599061	Defended Settlement
121	Monte do Facho	Vila Nova de Famalicao	538008	4583737	Defended Settlement
122	S. Miguel-O-Anjo	Vila Nova de Famalicao	538918	4582557	Defended Settlement
124	Penices	Vila Nova de Famalicao	532787	4585049	Defended Settlement
126	Ermidas	Vila Nova de Famalicao	539908	4590163	Defended Settlement
237	Monte de S. Felix	Povoa de Varzim	523923	4587297	Defended Settlement
238	Crasto	Povoa de Varzim	520328	4586757	Defended Settlement

239	Monte da Cividade	Povoa de Varzim	523422	4584801	Defended Settlement
240	Castro de S. Marçal	Santo Tirso	531865	4572269	Defended Settlement
248	Castro de Argifonso	Vila do Conde	529452	4582227	Defended Settlement
249	Cividade	Vila do Conde	528892	4581654	Defended Settlement
250	Santagões	Vila do Conde	526565	4578936	Defended Settlement
251	Ferreiro Castro	Vila do Conde	530086	4578281	Defended Settlement
253	Castro	Vila do Conde	523097	4578139	Defended Settlement
254	Castro do Boi	Vila do Conde	527211	4575006	Defended Settlement
255	Castro Vila do Conde	Vila do Conde	521623	4578405	Defended Settlement
256	Castro de Casais	Vila do Conde	529337	4582760	Defended Settlement
173	Quintela	Esposende	520609	4600665	Settlement
174	Queijeiros	Barcelos	530108	4600730	Settlement/Burial
175	Vila Cova	Barcelos	523887	4599819	Settlement
223	Ralha	Esposende	519832	4592617	Settlement
224	Agra Da Vila ou Boavista	Barcelos	527300	4595969	Settlement
228	Vila Frescainha	Barcelos	530463	4598256	Settlement
229	Aguas Santas	Barcelos	535437	4593247	Settlement
230	Senhora Do Livramento	Barcelos	535470	4591464	Settlement
233	Martim	Barcelos	540334	4598123	Settlement
284	Estela	Povoa de Varzim	518829	4589652	Settlement
285	Alto Da Vinha	Povoa de Varzim	523782	4583314	Settlement
287	Povoa De Varzim	Povoa de Varzim	520080	4581088	Settlement
336	Vilar	Vila do Conde	528181	4579348	Settlement
338	Vila Do Conde	Vila do Conde	521855	4578277	Settlement/Cemetery
339	Soutelo	Vila do Conde	530004	4575381	Settlement
353	Milreus	Vila do Conde	531704	4571796	Settlement

Table 8 Catalogued settlement locations within the study area.

Site	District	Geology	Altitude	Situation
Sequade	Barcelos	Granite	200	River Valley Terrace
Monte do Facho-Alto da Torre	Barcelos	Granite	170	Spur
Outeiro do Castro	Barcelos	Granite	222	Hilltop
Castelo de Faria	Barcelos	Granite	298	Hilltop
Monte da Saia	Barcelos	Granite	3	Hilltop
Santa Eulalia	Barcelos	Granite	60	Hilltop
Outeiro dos Picotos	Esposende	Fluvial Terrace	24	Hilltop
Castro do Senhor dos Desamparados	Esposende	Granite	126	Hilltop
Monte do Facho	Vila Nova de Famalicao	Granite	268	Hilltop
S. Miguel-O-Anjo	Vila Nova de Famalicao	Granite	194	Hilltop

Penices	Vila Nova de Famalicao	Granite	99	Spur
Ermidas	Vila Nova de Famalicao	Granite	209	Hilltop
Monte de S. Felix	Povoa de Varzim	Minerals	208	Hilltop
Crasto	Povoa de Varzim	Fluvial Terrace	84	Hilltop
Monte da Cividade	Povoa de Varzim	Granite	76	Hilltop
Castro de S. Marçal	Santo Tirso	Granite	222	Hilltop
Castro de Argifonso	Vila do Conde	Granite	157	Hilltop
Cividade	Vila do Conde	Granite	206	Hilltop
Santagões	Vila do Conde	Granite	54	Spur
Ferreiro Castro	Vila do Conde	Fluvial Terrace	60	Spur
Castro	Vila do Conde	Granite	40	River Valley Terrace
Castro do Boi	Vila do Conde	Granite	123	Hilltop
Castro Vila do Conde	Vila do Conde	Granite	19	Coastal Plain
Castro de Casais	Vila do Conde	Granite	75	Hilltop
Quintela	Esposende	Granite	160	Spur
Queijeiros	Barcelos	Granite	122	River Valley Terrace
Vila Cova	Barcelos	Granite	59	River Valley Terrace
Ralha	Esposende	Fluvial Terrace	10	Coastal Plain
Agra Da Vila ou Boavista	Barcelos	Fluvial Terrace	51	River Valley Terrace
Vila Frescainha	Barcelos	Granite	30	River Valley Terrace
Aguas Santas	Barcelos	Granite	80	River Valley Terrace
Senhora Do Livramento	Barcelos	Granite	111	River Valley Terrace
Martim	Barcelos	Schist	104	River Valley Terrace
Estela	Povoa de Varzim	Alluvium	2	Coastal Plain
Alto Da Vinha	Povoa de Varzim	Granite	61	River Valley Terrace
Povoa De Varzim	Povoa de Varzim	Granite	6	Coastal Plain
Vilar	Vila do Conde	Granite	68	River Valley Terrace
Vila Do Conde	Vila do Conde	Granite	10	Coastal Plain
Soutelo	Vila do Conde	Granite	130	River Valley Terrace
Milreus	Vila do Conde	Granite	193	River Valley Terrace

Table 9 List of catalogued site material, specifying underlying drift geology, altitude and situation of each location

Site	Aspects of Slope	Immediate Gradient (degrees)	Surrounding Gradient (degrees)
Sequade	1	12-16	16-20
Monte do Facho-Alto da Torre	4	4-8	20-24
Outeiro do Castro	6	0-4	24-28
Castelo de Faria	7	4-8	28-32
Monte da Saia	3	0-4	16-20

Santa Eulalia	4	0-4	12-16
Outeiro dos Picotos	4	0-4	8-12
Castro do Senhor dos Desamparados	8	0-4	16-20
Monte do Facho	8	0-4	28-32
S. Miguel-O-Anjo	4	4-8	20-24
Penices	5	4-8	16-20
Ermidas	3	0-4	16-20
Monte de S. Felix	8	0-4	20-24
Crasto	1	0-4	0-4
Monte da Cividade	8	0-4	16-20
Castro de S. Marçal	8	0-4	16-20
Castro de Argifonso	8	0-4	16-20
Cividade	6	0-4	20-24
Santagões	2	0-4	20-24
Ferreiro Castro	2	0-4	16-20
Castro	5	0-4	12-16
Castro do Boi	8	0-4	16-20
Castro Vila do Conde	1	0-4	0-4
Castro de Casais	7	0-4	16-20
Quintela	3	0-4	8-12
Queijeiros	2	4-8	16-20
Vila Cova	1	0-4	4-8
Ralha	1	0-4	0-4
Agra Da Vila ou Boavista	3	0-4	4-8
Vila Frescainha	3	0-4	4-8
Aguas Santas	2	8-12	12-16
Senhora Do Livramento	2	4-8	12-16
Martim	2	4-8	12-16
Estela	1	0-4	0-4
Alto Da Vinha	1	0-4	4-8
Povoa De Varzim	2	0-4	0-4
Vilar	1	0-4	8-12
Vila Do Conde	1	0-4	0-4
Soutelo	1	8-12	16-20
Milreus	2	0-4	12-16

Table 10 List of settlement locations detailing the number of aspects of slope, and the immediate and surrounding slope gradients for each location.

Site	Visible Castros (6km)	Visible Roman Settlements (6km)
Sequade	2	2
Monte do Facho-Alto da Torre	1	1
Outeiro do Castro	1	0
Castelo de Faria	1	2
Monte da Saia	2	1
Santa Eulalia	4	1
Outeiro dos Picotos	1	1
Castro do Senhor dos Desamparados	1	1
Monte do Facho	2	0
S. Miguel-O-Anjo	1	0
Penices	4	0
Ermidas	2	2
Monte de S. Felix	2	1
Crasto	2	2
Monte da Cividade	2	1
Castro de S. Marçal	1	1
Castro de Argifonso	2	1
Cividade	1	1
Santagões	2	2
Ferreiro Castro	3	1
Castro	1	2
Castro do Boi	2	1
Castro Vila do Conde	2	2
Castro de Casais	3	1
Quintela	1	1
Queijeiros	1	1
Vila Cova	1	1
Ralha	2	1
Agra Da Vila ou Boavista	1	1
Vila Frescainha	2	1
Aguas Santas	2	0
Senhora Do Livramento	3	1
Martim	1	0

Estela	2	1
Alto Da Vinha	7	2
Povoa De Varzim	1	1
Vilar	3	2
Vila Do Conde	2	1
Soutelo	2	0
Milreus	1	0

Table 11 Number of castros and Roman settlements visible over a 6km radius from each settlement location.

Appendix 2 Methodology

All geographical data were created in vector format. Topographical features were digitised into Arc/Info. Contour lines, drainage, the coastline and major urban areas were digitised from 1:25000 scale Portuguese *Carta Militar de Portugal* topographical maps. Contours were sampled at 10 metre intervals. Drift geology was digitised from 1:50000 scale *Carta Geológica de Portugal* geological maps, and was retained in vector format.

For the purposes of analysis in the GIS, vector data were used to produce a Digital Elevation Model (DEM). For the Ave valley analysis a raster DEM was created in Arc/Info based on the 10 metre contour coverage of the area. This efficiently produced a dataset to allow statistical analysis of settlement location, and to form the basis of other raster models. The aim was to produce a high resolution DEM whilst limiting the file size of the model to prevent any later problems associated with the creation of further raster models. A grid cell size of $20m^2$ was decided upon.

Raster coverages of slope aspect and slope gradient were generated in ArcView, based on the DEM, and with a grid cell size of $20m^2$. The production of such models was vital to the analysis, allowing the classification of settlement location, and forming the basis of both viewshed and cost analyses.

As described above, viewshed grids were generated from the DEM in ArcView. These were created from the location points of all forty settlements. Limitations on file space, and the need to keep the number of coverages down to a manageable size meant that viewshed grids were used to tabulate the number of settlements visible from each location, and were then deleted. Cost distance grids were created in ArcView, and were derived from the raster slope gradient grid. A grid cell size of $50m^2$ was used.

Two point coverages were created in Arc/Info from the catalogues of archaeological material. Attribute data for each site was attached as a table to each coverage. The locations of Roman settlements were then derived from the coverage of Roman archaeological material. Castro and settlement data were also converted into raster grids to form the basis of the cost analysis.

Appendix 3 Results of the Chi-squared and Test

The following tests were produced to assess whether archaeological material was distributed evenly across the study area. Classification of material by drift geology was decided upon because of the apparent nature of the distribution of archaeological material (see Analysis and Results). Tests were carried out on the observed and expected quantities of material given below (Tables 12-14). The tests were initially carried out for five categories of geology, including mineral veins as a separate category. However, the incredibly low percentage by area of that category produced biased test results, due to the location of one settlement. To remove this bias, the settlement on mineral veins was included in the number of cases on granite, and the category was relabelled.

Geology	**Observed Settlement**	**Expected Settlement**
Alluvium	1	3.852
Fluvial Terraces	5	3.776
Schists	1	12.672
Granite and Mineral Veins	33	19.7
Total	**40**	**40**

Table 12 Observed and expected values for settlement locations over the drift geology.

Geology	**Observed castros**	**Expected castros**
Alluvium	0	2.3
Fluvial Terraces	3	2.3
Schists	0	7.6
Granite and Mineral Veins	21	11.8
Total	**24**	**24**

Table 13 Observed and expected values for castro settlement locations over the drift geology.

Geology	**Observed Roman Settlement**	**Expected Roman Settlement**
Alluvium	1	1.541
Fluvial Terraces	2	1.51
Schists	1	5.069
Granite and Mineral Veins	12	7.858
Total	**16**	**16**

Table 14 Observed and expected values for castro and Roman settlement locations over the drift geology.

The resulting chi-squared values were compared with percentage point values for a significance level of 0.05. The number of degrees of freedom used were derived by the following formula:

v = (number of columns – 1)(number of rows – 1)

v = (4-1)(2-1)

v = 3

Comparison was made with the percentage value of 7.81473 (Shennan 1997, Table F). For all chi-squared values where $\chi^2 \geq 7.81473$, the null hypothesis was rejected. This was the case for all results with the exception of the distribution of Roman settlement. The test suggests an uneven distribution of archaeological material across the study area (Table 15), in relation to the drift geology.

Test	Castros	Roman	Roman Settlement	Settlement	Archaeological Material
Chi-Squared	17.28	7.96	5.79	22.24	23.117

Table 15 Results of tests carried out for different categories of material.

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