Understanding the Neolithic Landscape of the Carnac Region: A GIS Approach

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Abstract

The Neolithic landscape of southern Morbihan is archaeologically very rich, but topographically subtle. This combination provides an interesting and important challenge for GIS approaches. This paper discusses the applicability of a range of techniques for exploring and analysing the relationships between monuments and their locales. Various of approaches to the description of the shape of the terrain are investigated. The views of and from monuments are affected by landform over a range of scales. This forms an important part of the experience of approaching, being in, and leaving a locale.

Key words: Neolithic, monument, Carnac, GIS, topography, viewshed

1. Introduction

The Neolithic monuments of the Carnac region of Brittany are the focus of an internationally important archaeological landscape. For a study of the monument locations and their inter-relationship, the region poses considerable challenges for traditional Geographic Information Systems (GIS) approaches due to the gently undulating nature of the topography and the large number of monuments. An appreciation of landform and context is crucial to understanding this landscape and the place of the monuments within it.

Simple GIS topographic measures (for example, the traditional elevation, slope and aspect) are inadequate for describing a monument location. In this paper, methods for characterizing the shape of the terrain are presented. When the positions of the Neolithic monuments are compared with other non-site locations, they are found to occupy specific and definable types of location.

Landform shape has an important effect on the perception and experiencing of a location. The approach to a monument by a person needs to be considered. Views to and from each monument are investigated at a range of scales, and the influence of visibility on site location examined. The relationship between the orientation and size of monuments and their local landscape context has also been investigated. In this approach, the inter-correlation of visibility measures with other topographic characteristics needs to be understood. However, the effectiveness of any study such as this rests on the resolution and accuracy of the digital terrain model in its representation of the Neolithic landscape.

1.1. Archaeology of Morbihan

The Neolithic archaeology (approximately 4500 to 2500 BC) of southern Morbihan has been studied extensively over the last 150 years. Around 150 monuments have been excavated in the coastal area alone (although few using modern excavation methods) and the famous Carnac Alignments have been much debated. There are also a large number of isolated standing stones, smaller alignments and stone circles. There is little settlement evidence known in the area.

The precise chronological relationships between the monuments are still problematic (Boujot and Cassen 1993, Le Roux 1999), but it is likely that the earthen long mounds (fr. tertres tumulaires) and decorated menhirs are amongst the earliest monuments in the region. The passage graves (fr. dolmens à couloirs) were probably built over a long period of time, with some of the more complex forms and the gallery graves (fr. allées couvertes) belonging to the later Neolithic period. The dating of the alignments and Carnac Mounds remains controversial (Boujot and Cassen 1993, Le Roux 1999), but the arguments need not be elaborated further here.

The Neolithic monuments of Morbihan have, in the past, been studied in isolation as individual sites or as part of a typological classification, rather than as part of a complex landscape. However, the importance of the locales chosen by the Neolithic builders has long been recognized, including mention in pilot manuals (Lecornec 1994) and folk history. The relationships between monuments are complex, with locales being re-interpreted by successive generations. Recent work by Boujot and Cassen has begun to incorporate an appreciation of landscape into studies of the Neolithic of this region (e.g. Boujot et al. 1998). This paper is part of a wider-ranging attempt to understand the complex landscape which was created and inhabited by Neolithic people in southern Morbihan, and to assess the ability of GIS to contribute to that search.

The combination of extensive excavation and recent survey work (Desdoigts 1978, Boujot and Cassen 1995, Gouezin 1995) has enabled a substantial database of site information to be constructed containing over 1000 records, of which about half of the sites have coordinates. The expansion of tourism in the region has led to the destruction of some sites; others are inaccessible in woodland or are in private ownership.

For the purposes of this analysis, sites have been categorized into earthen long mounds, passage graves, later passage grave forms (which for the purposes of this study includes lateral entrance graves angled gallery graves (fr. allées coudées), and gallery graves, which are not technically passage graves), menhirs, and alignments, cromlechs and other groupings of multiple standing stones. There is one other class, unidentified tumuli, which includes mounds which are probably of Neolithic date, that have either not been excavated or adequately recorded and are now damaged or destroyed.

1.2. The study area

This paper considers the coastal area of Southern Morbihan which includes the Carnac area and the Golfe du Morbihan. This is part of a larger study area covering some 2000 square kilometres, including a dissected plateau which poses different analytical and interpretative challenges. The topography of the coastal area is generally very subtle, with gently rolling small hills and river valleys. In the north-east corner of the coastal study area the land rises up to 120 m. The Golfe has been flooded by rising sea level (approximately 5 m) in the intervening four thousand years; in the Neolithic it was probably a river valley and estuary. The Neolithic monuments appear to be divided between the two areas, with fewer sites in between. However, the lack of detailed survey work directed at this area may be contributing to this impression and biasing the data.

2. Approaches to describing landscapes

Landscapes have been the focus of considerable archaeological debate in recent years. Post-processual approaches have become widespread and challenge the way in which we consider and analyse landscapes. There has been an increasing emphasis on subjective experience (with quotations from phenomenological philosophers), with narrative replacing more traditional analysis techniques (e.g. Edmonds 1999).

The relationship between GIS approaches and landscape theory has been questioned (Gaffney and van Leusen 1995, Llobera 1996). GIS has been used by many archaeologists in a simplistic way, which has led to an impression among many landscape archaeologists that GIS does not have a part to play in a wider, theoretically-aware research agenda. Information about the relationship between site locations and topographic characteristics has formed a large part of the use of GIS in inter-site studies. The use of topographic measures and spatial distributions to describe some of the characteristics of landscapes must be undertaken with care if environmentally and economically deterministic interpretations are to be avoided, and the complexity of the landscape preserved in the final interpretations. A more data-oriented perspective, in which statements about the characteristics of locales are questioned and evaluated, does have an important role in landscape archaeology. The ability to assess trends (and those sites which do not fit the trends) is an important step towards identifying factors which may have influenced the choices that Neolithic people made.

2.1. Creation of the terrain model

The Digital Elevation Model (DEM) used for this research was created from digitised 5 m contours (with 2.5 m contours in the flatter areas), from the 1:25,000 maps. The bathymetric data are taken from nineteenth century British 1:10,000 Admiralty Charts and the 1:25,000 maps. A horizontal resolution of 25 m was used throughout to ensure comparability of results. The prehistoric sea level is estimated to be about 5 meters below modern sea level, based on sea level modelling (Lambeck 1997).

2.1.2. Simple topographic characteristics

One of the most frequent uses of GIS in inter-site studies has been for comparing elevation, aspect and slope values for sites and for the total study area. This has sometimes been interpreted as providing a reliable assessment of the relationship between sites of different periods and topography. As part of the assessment of the potential contribution of GIS to the study of the Neolithic landscape of the Morbihan, these methods were applied to the study area and the results critiqued. The ArcInfo SLOPE and ASPECT commands were used, rather than the output from CURVATURE, as these are probably more accurate (Wise 1998).

Graphs of elevation, aspect and slope showed little distinction between site types or between site and non-site locations. Although there may be a slight trend towards avoidance of the steepest slopes, a preference for flat ground and the absence of sites from the areas of greatest elevation, there is little of interpretative value here. Two-sampled *t*-tests fail to find any significant differences between site types and between sites and the total area.

The lack of strong relationships between sites and the topographic characteristics analysed above may be due to one (or more) of three possibilities. The first is that the DEM used is too coarse, or insufficiently accurate, to adequately represent such subtle terrain. Work is continuing on the development of a high-resolution DEM from stereo aerial photographs using photogrammetry. Secondly, there may indeed be no relationship in this landscape between site location and topography. The topography is slight, and there are only a few areas in which sites could not be built (e.g. due to too steep a slope or marshy ground). However, accepting this conclusion would be to limit the role of topography in landscape interpretation to an environmentally deterministic one. Topography has an important contribution to the experience and interpretation of landscape. Natural features acquire names and significance. Terrain affects what is seen, it is walked over, changed by monument construction, and reinterpreted. The third hypothesis is that the measures used were not adequate to characterize the subtle topography of the area.

3. Alternative approaches

The unsurprising failure of the simple topographic measures to provide any significant data about site locations led to the search for other, more appropriate, approaches to the characterization of topography. The local topographic features need to be discerned, rather than disappearing into the broader-scale trends.

As the first step towards discerning what a more appropriate characterization might be, many of the sites were visited with photographs taken and verbal descriptions made of the locations of the sites. An impression of the kind of locations in which monuments were located was slowly built up in a qualitative fashion. It included, for passage graves, location on small hills or protruding areas of land. Monuments appeared to be near, but often not at the top of these features. Passage graves were often on the edge of a slightly flatter area, at the top of a steeper slope. Other site types were thought to be associated with different landforms, for example small alignments ran at right angles to the major slope direction.

These descriptive impressions are highly subjective. It is easier to include a location in a category once a trend has been identified. A more objective and quantifiable approach is needed to assess

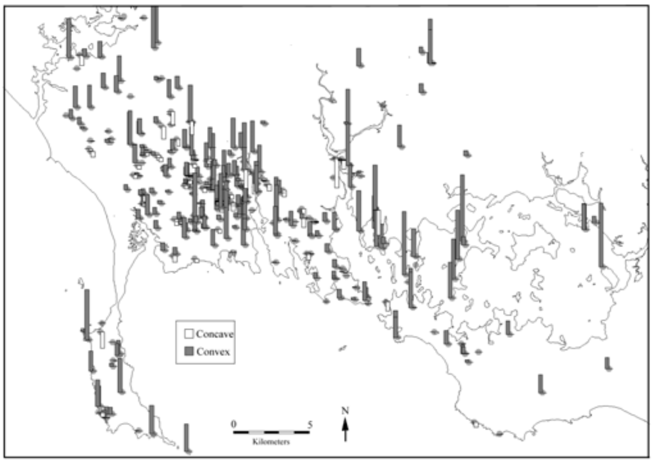

Figure 1: Profile curvature.

the accuracy of impressions gathered in the field, which will reliably identify which sites fit a hypothesis, and the probability that such a relationship between site location and topographic characteristics could not have occurred by chance.

3.1. Profiles

To explore whether the DEM showed the characteristics observed in the field, ArcInfo's SURFACEPROFILE function was used. This function draws specified profiles through the DEM at a range of scales. When profiles 1 km in length were drawn through the locations of passage graves, both in the orientation of the site and at right angles to it, many of the sites were seen to be on or near local maxima in the profiles.

Although this method confirmed that features observed in the field are present in the DEM, and do appear to be associated with the monuments, it is difficult to analyse these profiles quantitatively. The profiles are also limited to the selected directions. At an exploratory stage, the interactive facility makes this an easily accessible tool. Creating the standard input lines necessary for analysis is difficult to automate in ArcInfo (a C-program was written for this purpose). Another problem with the technique is that it only describes changes in slope. There is no counterpart for changes in aspect, which form an important part of the shape of a location.

3.2. Curvature

The use of curvature as a characteristic of landform is well established within geomorphology (Wise 1998). Curvature is normally measured in two ways: profile curvature, the change in slope, and plan curvature, the change in aspect (see Wood 1996 for other measures). Profile curvature is normally measured in the downslope direction, and this convention is followed here, rather than ESRI's description of the up-slope measure.

When the curvature of the DEM was calculated and the values for the locations of each site extracted, it was found that almost all site locations had convex profile (see figure 1) and plan curvature. Many of the sites have a very strongly convex location for both profile and plan curvature when compared with the range of values for the DEM as a whole. The high proportion of convex locations of the monuments can be contrasted with a 50 : 50 convex : concave ratio for the landscape as a whole. This suggests

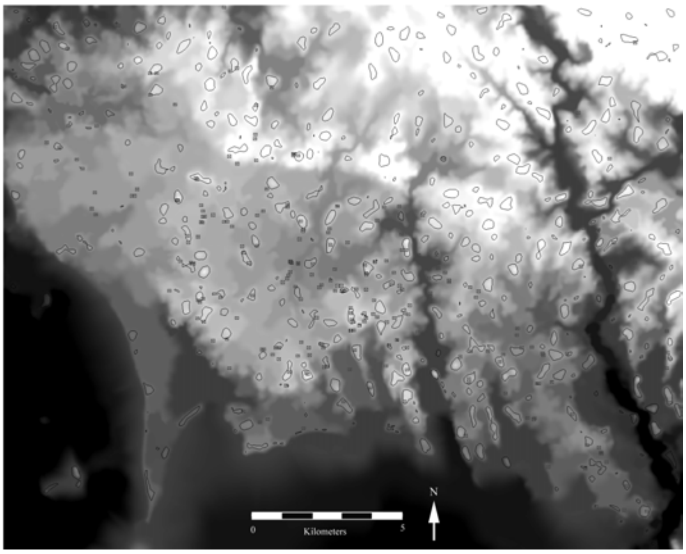

Figure 2: Location of hillocks (outlined in black) and sites.

that there may be some quantitative basis to the observations in the field.

Statistical analysis of the results obtained using the curvature algorithm is problematic. The curvature algorithm is highly resolution-dependent. Small changes in pixel size resulted in large changes in output. The choice of interpolator also affects the results. The TOPOGRID interpolator was used here, as it has been shown to provide more accurate results than linear or quintic interpolation (Wise 1998). Comparison with a quintic lattice confirmed the importance of interpolator choice. Errors within the DEM are enhanced using this measurement, as curvature is the second derivative of the surface. Using a low-pass filter on the surface prior to calculating the curvature improves the results (Wise 1998), reducing the impact of erroneous data points. Perhaps most importantly, the curvature values calculated here is only a localized measure of landform (see Wood 1996 for an alternative quadratic scaling method). The algorithm does not capture the overall shape of a landscape feature, being simply a measurement over a 3 x 3 kernel.

Landform characterization in geomorphology has been dominated by algorithms aimed at hydrological modelling. There are few methods available which are suitable for the subtle, rounded landscape of southern Morbihan. The use of a simple kernel-based extraction of peaks and local maxima (e.g. ArcInfo's VIP routine) fails to identify most of the locations of interest.

3.3. Hills

The automated identification of the small hills noticed in the field was considered first. The method used is contour-based. It extracts areas which are less than a specified area (here 100,000 m^2) which are at least 0.5 m higher than the surrounding land on all sides. This differs from buffering a kernel-based extraction of peaks to a particular distance in that the shape of the area defined by the hill-finding procedure reflects the actual land surface rather than the distance to the highest point.

The areas which have been identified by the algorithm are shown in figure 2. Although many sites are located in the identified areas (31 %), there are a significant number which are not. When the results were plotted by site-type, it was observed that over half

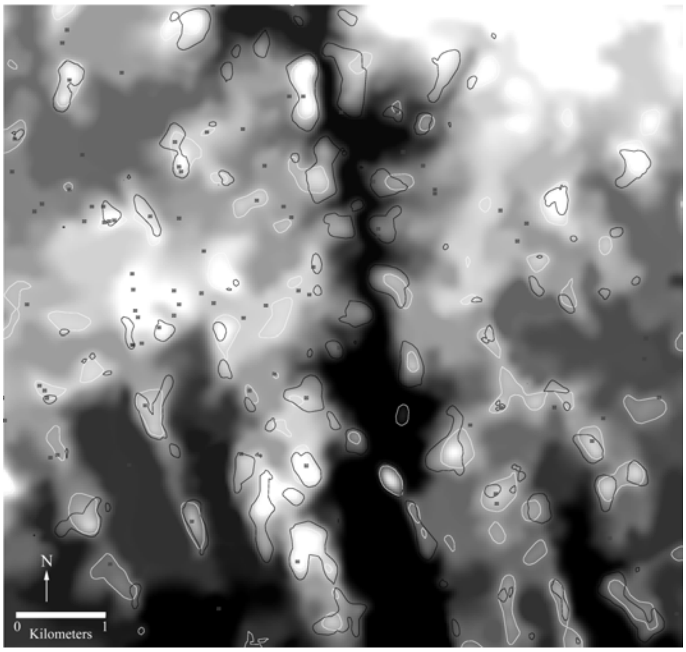

Figure 3: Location of promontories (outlined in black), hillocks (outlined in white) and sites.

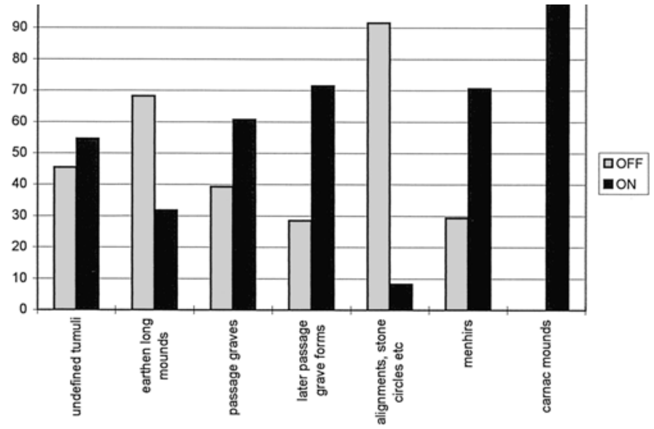

Figure 4: Percentage of sites by type on hillock or promontory.

the passage graves have locations on small hills, which is significantly more than would be expected from the proportion of the total area which has been designated as hilltop (7 %). However, other site-types, particularly the alignments, do not appear to differ from the expected proportion for a randomly distributed set of points.

3.4. Promontories

It was noticed that many sites were located on areas of prominent ground which were not being identified by the hill-finding algorithm. These areas were not higher than their surroundings on all sides, and formed small bulges or promontories (see figure 3). Promontories can be considered as hills which have their shallowest downward slope parallel to the x - y plane. They thus fail to be higher than their surroundings on all sides. By tilting the surface, the slope of the shallowest side is increased, and the area becomes higher than all surrounding locations. In order to extract all promontories, the surface must be tilted in the orientation of each promontory. In this example, 8 tilt directions were used.

For a gently rolling landscape such as this, a tilt angle of one or two degrees appears to be sufficient. Further work is needed to explore fully the relationship between tilt angle and the landscape forms extracted. Software is being written to rotate and tilt the surface, rather than exporting the DEM to other software, rotating and tilting it, and then re-importing to ArcInfo, which is time consuming and not possible to automate.

Preliminary results on a small area of the DEM are encouraging (see figure 4). The proportion of sites which are included in the defined area increased from 39 % to 50 %. 60 % of the passage graves, 71 % of the later passage graves and 70 % of the menhirs have locations on either a hill or a promontory. However, the alignments, cromlechs and other stone settings have a lower than expected proportion on hills or promontories (8 %, compared with 18 % of the total area). The earthen long mounds remain less distinct, having a higher proportion than the background, but with only a third of the locations occurring on a hill or promontory.

The results suggest that these measures may be enabling the locations of some site-types to be distinguished from both the total landscape and the locations of other site-types. However, the sample has been much reduced, and the method needs further refinement. The promontory finding procedure extracts only 6 % of the area remaining after hills have been identified, and includes 19 % of the remaining sites. Although this is only three-quarters of the efficiency of the hill-finding procedure, it nevertheless represents a distinct improvement in the identification of site locations. Optimising the extraction of promontories is required to define as accurately as possible the locations of the monuments. The application of more sophisticated kernel-based methods for extracting ridges (defined as a point on a local convexity that is orthogonal to a line with no convexity/concavity (Wood 1996)) is also being considered.

4. Topography, views and monuments

Identifying landform measures and categorizing the locations of monuments does not in itself explain the landscape context of a site. It is necessary to consider how landform has been used by the builders and participants in the creation and experience of a monument. We will never know for certain what aspects of a particular type of landform were considered important to the choice of monument location, or the reasoning, conscious or subconscious, that led to a decision being made. The cultural context of a location is crucial to understanding it, and the presence of other monuments nearby, or the past history of the locale is an important part of its meaning. However, by examining the characteristics of monument locations, and comparing them with non-site locations, some of the factors which influenced location choice (either directly or indirectly) may be suggested.

4.1. Local scale

Landform shape affects the way a site is encountered at the local scale. As a person approaches a monument, it may appear, disappear, and reappear again. The view from the monument is different from the view towards it. If a monument is unenclosed by a covering mound, with the interior accessible, like a passage grave, a specific view is encountered upon leaving the monument (Tilley 1994).

To explore these ideas, the viewsheds from and to a smaller sample of 43, well-documented, passage graves (including some potentially later sites) and the 43 earthen long mounds within the same area were generated. These were compared with the viewsheds for 500 random points within the same area. To examine the local scale, the viewsheds were buffered to include only the area within 500 m of the monument. Many of the monuments have had most of their mounds removed by erosion, excavation or vandalism, any reconstruction of mound height would in most cases be reduced to speculation.

The limited pollen and soil micromorphology evidence suggests that the area immediately around the monuments was cleared, often considerably before the construction of the monument (Marguerie 1992, Gebhardt and Marguerie 1993). It has therefore been assumed that at the local scale there was no substantial hindrance of view by trees. As local trees have a greater affect than distant ones on visibility, this also provides an important consideration when assessing the models for visibility at larger scales. The presence of modern trees and buildings seriously impedes the assessment of the local viewsheds in the field.

The local viewsheds created give an indication of the local prominence of the locations of the monuments, and the extent to which a view of the immediate surroundings is possible from the site. The local viewsheds from the passage graves are smaller than those from the random sample, suggesting that maximising local visibility was not of primary importance. However, the tertres have greater local visibility than either the passage graves or the random points.

Hilltops have smaller viewsheds than average over short distances and larger ones over greater distances, whist valley locations have the opposite characteristics (van Leusen 1999). The larger number of passage graves than *tertres* or random points on hills (see section 3.5 above) is therefore causing the smaller values observed for the local viewsheds of passage graves.

4.2. Increasing the distance

The issue of scale in the interpretation of viewshed data has been noted by several authors (van Leusen 1999, Woodman 2000). Van Leusen reminded archaeologists that the topography of a location affects the relationship between visible area and increasing viewshed radius. However, this observation can be taken further. The area of a location's viewshed as distance increases can be used itself to infer something about the topography of that location, and describes an important characteristic of the locale.

Viewsheds for the sample of passage graves used above, the random sample, and the earthen long mounds in the same area were buffered at 5 distances. The viewshed areas of the sites were compared to the non-site locations, and are expressed as a percentage of that value (as opposed to the total possible area, e.g. Woodman 2000). This provides a measure of how the site locations differ from the random points within the landscape. The results are shown in figure 5.

The passage grave locations appear to show different characteristics to the earthen long mounds. Having started with a smaller than expected viewshed over the shorter distances (section 4.1), they have a much larger viewshed over longer distances. The earthen long mounds have a larger than expected viewshed at the local scale, but over longer distances they have only slightly larger

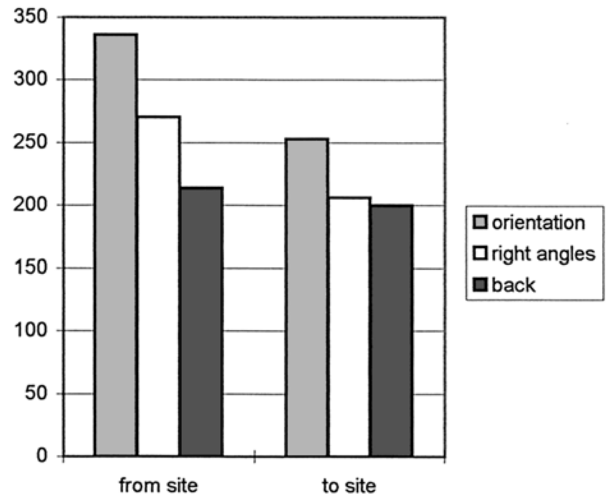

Figure 5: Visibility from and to passage graves by orientation.

viewsheds, much smaller than the corresponding viewsheds for passage graves. This accuracy of these results needs to be assessed once the higher resolution DEM is completed.

The viewshed calculations confirm the observations in sections 3.5 and 3.6 above that the passage graves and earthen long mounds tend to be in slightly different types of topographic locations, with a higher proportion of passage graves occurring on hills or promontories. The passage graves are visible from a wide area, over large distances, but tend to disappear as you approach them, and reappear only when you are closer to them. The earthen long mounds appear to have views of the local area (see Roughley in press), while the passage graves occupy locations with views into the distance.

4.3. Wider perspectives

Passage graves appear from the results above to occur in places which maximize the total viewshed. To investigate further the viewsheds of passage graves, a total viewshed grid (with viewshed values for each cell of the DEM) was constructed for a larger part of the study area (but at a coarser resolution, of 100 m, to reduce processing time).

Interpreting long range views is known to be difficult because of the correlation between viewsheds and elevation (Wheatley 1995). The viewsheds for all sites were correlated with elevation (r-squared 0.30 for views to and 0.25 for views from sites, p = 0 for both cases). When the residuals were plotted a clear spatial trend resulted (spatial autocorrelation was confirmed by Moran's I: correlation = 0.33, p = 0). Locations nearer the sea have larger viewsheds than locations inland.

The correlation between the Euclidean distance to the Neolithic coast and the residuals of the correlation between visibility and elevation is significant (r-squared 0.18, p = 0 for views from sites, r-squared = 0.11, p = 0 for view to sites). However, the residuals remain spatially autocorrelated. At this larger scale, the general topography is having a considerable effect on the viewshed statistics, and any interpretation must be made with care. Using an estimate of the prehistoric rather than the modern coastline has a considerable effect on the results, emphasising the importance of modelling the prehistoric landscape rather than utilising the modern one.

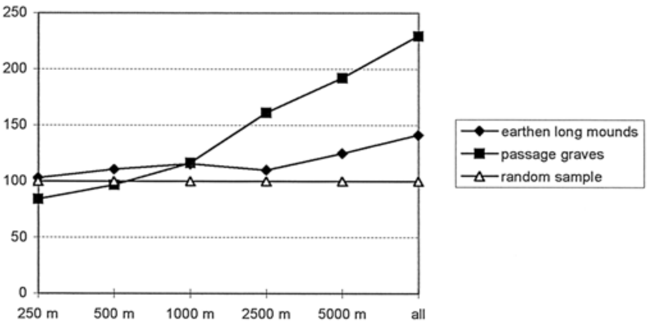

Figure 6: Viewshed from passage graves and earthen long mounds by distance, expressed as a percentage of the viewshed from the random sample.

Surface profiles across the viewshed surface show that many sites are on or near local maxima. It is possible that, within the area in which a passage grave was to be located, the precise choice of location was influenced by a desire to maximize the overall viewshed. Work aimed at comparing views of (and from) land and sea is continuing. The utility of Neolithic sites for navigation markers in more recent times has already been noted, emphasizing the strong impression these monuments make to people on the sea. The Neolithic people used boats extensively, and it is possible that trade was conducted at least partially by sea (for example, for jadeite, variscite and Grand-Pressigny flint).

4.4. Orientation of passage graves

Passage graves, unlike many of the other monuments, have a clear orientation through the axis of the passage. Although the orientation of the passage graves (as defined by the entrance to the passage) is predominantly southeast, there is considerable variation, with directions ranging from northeast to West. This suggested that there might be some local factor which was influencing the choice of passage entrance. Although there has been considerable interest in the alignment of sites in the area on astronomical features (and, perhaps more importantly, each other), the first possibility to investigate was that there was a link between topography and orientation. Sites were not oriented with the passage entrance facing up-slope. However, the steepest down-slope was not always in the direction of the passage entrance. It was surmised in the field that there might be a relationship between orientation and visibility.

The views to and from the monuments (up to a distance of 500 m) were compared in the direction of the entrance (described here as forwards) with views behind the monument and at right angles to it. The views from the site show a strong tendency towards having the greatest unbroken distance in the orientation of the entrance. This means that on leaving the chamber, the nearest horizon is further away than it would be if the monument had been oriented in any of the other directions (see figure 6).

There appears to be less difference in the distances from which a site can be seen uninterruptedly (see figure 6). This is perhaps not surprising, as although orientation may have some connection with the way a site is approached, the person is not as physically constrained in his or her choice of route to the site as the person is upon leaving the monument's passage.

There are some monuments which do not fit the trend observed above. A more detailed examination shows that they tend to be sites which are part of a more complex arrangement of monuments. For example, at Mane Kerioned, there are three passage graves. Two are parallel, and face south, while the third, which lies between the other two, faces east. Although there is insufficient evidence to provide a chronology for this site, a plausible hypothesis is that the two south-facing sites were built first, with the east-facing one then being oriented with respect to the existing sites rather than the direction of furthest first horizon.

The orientation angles have a strong tendency to fall between east and south-south west. As the topography has a general trend downwards towards the coast, it was necessary to investigate whether this had any affect on first horizon distances. The viewsheds for the 500 random points were considered, with the distance to the nearest horizon measured for each of 16 directions. The variation which exists among the different orientations is smaller than that observed between forwards and backwards views for the site locations. It may be inferred from this that the difference in distance to first horizon in the forward and backward direction is not caused by the co-existence of a southerly sloping landscape and the trend towards southerly orientation of passage graves. At larger scales, this relationship breaks down. When the maximum distance considered is increased (rather than buffering to 500 m), the general topographic trends appear to be more important, and there is spatial autocorrelation present in the difference between forward and backward views

4.5. Interpreting viewshed results

Any interpretations must remain speculative at this stage. It is possible that the passage grave locations were chosen for their broader perspective, whilst the earthen long mounds were more important in their immediate surroundings, perhaps a focus for a smaller area, and a smaller number of people? The Irish portal tombs and passage graves may also have been built with different foci in mind: the portal tombs appear to occupy lower ground in river valleys, while the passage graves are on hill tops in highly visible locations (Cooney 2000:147).

The orientation of the passage graves does appear to be important at the local scale, with the local view obtained on leaving the passage perhaps being maximised. It is at this local scale that many of the sites reappear as you walk towards them, having been hidden from view by a local horizon. The results obtained can be associated with two different scales of encounter with the passage grave. They form as a highly visible presence in the distance, both from land and from the sea. The passage graves also use the landscape to structure experience at a local scale, a more intimate encounter with the sacred, ritual or the ancestors.

5. The limits of landform discrimination?

Examining the locations of monuments help us to understand the sites more fully. Techniques have been developed which have enabled new insights to be made into the passage graves and earthen long mounds, revealing differences between these potentially contemporaneous monuments. Application to other monumental landscapes may reveal further uses for these approaches.

The techniques discussed above do not adequately characterize the locations of all site-types. It was observed above that the alignments did not significantly differ from the background population. Fieldwork did give the impression that for the smaller alignments there was a careful use of topography. It has long been observed that in the major alignments the largest stones are on the highest ground. However, for the smaller alignments, the largest stones, on the highest ground, are also the end of the alignment. They are located on ridges running perpendicular to the alignment. As you walk along the alignment, you cannot see beyond the end of the monument until you reach this terminal locale. At this point, the sea becomes visible.

At this point in time, it is difficult to envisage a GIS approach which might adequately assess these impressions gained during fieldwork. The sample size is small, the sites vary in size and are imperfectly preserved, and many locations in the landscape might fit the description given. To investigate the locales of alignments and other larger, complex structures, the sites need to be represented as polygons rather than point or line features. Further work is proposed to consider how best to analyse more the complex relationships of these polygons.

By applying appropriate methodology, it is possible to use GIS to contribute substantially to the study of past landscapes. Techniques need to be sensitive to both the questions asked and the data available. Interpretations need to be grounded within a realistic appreciation of the reliability and limits of the methodology and data and to have a sound theoretical basis. This paper has shown that subtle landscape features are not outside the scope of quantitative approaches. More importantly, it has demonstrated that GIS-based analysis does not have to be limited to the generation of environmentally and economically deterministic interpretations. Although conclusive statements as to the motivation behind the siting of megalithic monuments are not possible, some of the probable influences have been discovered, helping us to appreciate the complexity and subtlety of this important archaeological landscape.

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