Praise the sea, on land remain? GIS analysis of travel routes in an Iron Age island environment

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ABSTRACT

In recent years, GIS landscape models have begun to move towards more sophisticated techniques for representing the land surface for the purposes of analyzing site territories, pathways and travel costs. Many of the major commercial GIS packages now offer the ability to generate anisotropic cost surfaces. In addition, recent papers have proposed methodologies for generating cost surfaces to model social preferences affecting travel (Lee & Stucky, 1998; Llobera, 2000). In terms of practical applications, however, GIS models of catchment areas and paths between sites continue to be dominated by those constructed on the basis of slope alone. In parallel to this, regional analyses of site location, with few exceptions, have been undertaken either within large land masses, largely ignoring the effects of rivers, lakes and the sea on travel costs and affordances, or within single islands, neglecting travel to other neighbouring islands or the mainland. The reason for this appear to be twofold: First, there is little information available on travel costs and travel rates using pre-industrial transportation technology, beyond very general statements. Second, critical analysis of what constitutes an "acceptable" travel distance is lacking, especially in situations where both water and land transports are possibilities. This paper presents some preliminary results from a research project examining the location and distribution of Middle Iron Age sites (brochs) in the landscape of Orkney, Northern Scotland. It employs and terrain model taking into account differing friction values for land and water surfaces, as well as the nature of the shoreline (cliffs, beaches) and how this affects access from land to sea and vice versa. It also attempts to model pathways between sites following three friction models: lowest-energy, lowest-visibility (hidden) and highest-visibility (exposed).

1. COST SURFACES IN ARCHAEOLOGY: RECENT TRENDS

In recent years, the modeling and analysis of landscapes in archaeological GIS has begun to move towards increasingly sophisticated techniques for representing the land surface. There now exists an archaeological literature critically reviewing, for example, the results of various algorithms for generating DEMs, or comparing the accuracy of raster and vector terrain models for representing landscape features (Kvamme, 1990; Carrara *et al.*, 1997; Nackaerts, 1999). This critical literature has implications for, among other things, the analysis of site territories or catchments, or the calculation of pathways and travel costs between points on the landscape.

For site territories, there has been a progression from an initial use of more simplistic methods, for example making use of concentric circular territories or Thiessen polygons, to a wider use of cost-surface approaches, where territories are defined in terms the energy required to travel from the central site to a certain "border". This border can be defined in various ways, either by setting an arbitrary maximum effort, such as the equivalent effort of traveling 5 km over flat ground, or in terms of travel time, for example two hours' walk from the central site, and it is argued that there is general agreement that catchments or territories generated in this manner are more informative than just drawing a set of concentric rings around a site.

In terms of pathways and travel costs, again, there has been an increase in the sophistication of the techniques involved, both in terms of improving algorithms for representing the surface, whether that be in terms of increased sophistication in interpolating the transitions between raster cells, or in increasingly sophisticated equations for generating cost surfaces. There has been a widening acceptance that travel costs are anisotropic and non-symmetrical, and several friction equations have been suggested, published, and have recently been collated in a series of publications (Llobera, 2000; Wheatley & Gillings, 2002; van Leusen, 1999). In fact, the typical GIS user now can pick and choose between these various anisotropic equations and implement them his- or herself on a variety of GIS packages (Arc/INFO-GIS, GRASS, Idrisi, etc.), without this task requiring much in the way of specialist knowledge or training. It is no longer necessary to write a specialized program or script to accomplish this, as the functionality has already been built into the package at the time of purchase.

So the application of cost surfaces to archaeological questions of territoriality and movement now represents a well-established methodology within archaeological GIS. Beyond this, several recent papers have proposed methodologies for extending the concept of the cost surface in order to model social preferences affecting travel. Llobera has suggested ways in which social repulsion or attraction to particular monuments or locations could be modeled, creating cost surfaces simulating people's desire to approach or stay away from certain landscape features (Llobera, 2000). Lee and Stucky, writing from a more theoretical GIS perspective, propose a series of friction models based on the visibility or invisibility of raster cells, enabling them to produce pathways that they classify as "scenic", "hidden", "strategic" and "withdrawn", as well as the more usual Euclidean and lowest-energy-cost paths based merely on slope (Lee & Stucky, 1998). At the more functional level of energy expenditure, the potential to model the differential energy cost of moving across different types of terrain: roads, trackways, grassy fields, forests, swamps and so on is also frequently discussed, even in introductory GIS texts such as Wheatley and Gillings (2002).

Just as with anisotropic cost surfaces, all these frictional effects modifications are, implementable without requiring large amounts of specialist knowledge on the part of the GIS user. It must therefore be asked: why have so few practical applications these appeared within archaeology? Why do the majority of the models that we do see continue to be dominated by cost surfaces constructed solely on the basis of terrain slope and terrain slope alone? Even more importantly, with the growing literature on these more refined cost surfaces being available, for instance through the proceedings of conferences such as the CAA, why do GIS analyses continue to gloss and make excuses for the use of slope-based cost surfaces? The point of this paper is not to directly criticize those who have produced such analyses in the past, but rather to argue that we are now in a position where it is increasingly difficult to justify a cost surface, where, for example, the land is treated as a uniformly-compacted asphalt-like surface, despite the known presence of swamps, lakes and forests within that landscape. In the same way that viewshed analysis now has to engage with the "tree effect", modeling of pathways and catchments must come to a similar realization.

Paralleling to this situation, regional analysis of site locations and travel routes, with a few exceptions, have been undertaken either on sites located within large land masses or within a single island setting. These tend to largely ignore the effects of rivers, lakes and the sea on travel costs and affordances, either focusing only on foot travel within the study area, or ignoring the possibility of travel between islands and to the mainland. It is suggested that this omission is due to two factors.

First, there seems to be very little information available either in the archaeological literature or elsewhere on travel costs or travel rates in pre-industrial societies, aside from extremely general statements. We see statements such as: "there was a high degree of communication along the Atlantic Scottish sea routes throughout the period" (Armit, 2003), referring in this case to the Iron Age, and Cunliffe argues that these water routes were key axes for both exchange and the transmission of ideas, perhaps from the Mesolithic onwards (Cunliffe, 2004). We are told that water is important, but there is no way to adequately quantify such a statement when what one really wants is a way to quantify how much more important water transport was.

Where figures are presented, they generally relate to the bulk transport of cargo in the Roman Empire, and are derived from the relative costs of goods at ports versus sites further inland. This has allowed Kevin Green, for example, to calculate that land transport was 28 times more costly than sea transport (Green, 1986). However, this is an economic, not an energetic cost, and emerges in the context of a system industrial production far more extensive than those present throughout most of human prehistory. It also provides little or no information about the speed or distances that could be covered by these different transportation methods. In essence, all this figure really tells us is how many oxen and drovers were required, and how their operating costs (money, food) compared to the costs of a ship and crew. We are again left with a general statement to the effect that water transport was probably more important in the past than it is currently, and that lakes, rivers and oceans were possibly seen more as highways than as the barriers our land and air transport based society currently considers them to be.

Secondly, there is little critical analysis out there, both in the archaeological and historical/ethnographic literature about what constitutes an "acceptable" travel distance, whether to one's field and back, or over the course of a day in the case of long-distance travel. Obviously this sort of information will be very much culturally-determined and could vary substantially, but the problem here is not the variability of the available information, but rather that there is little if any information available! Researchers have tended to fall back on rules of thumb like Higgs and Vita-Finzi's 1 hour walking distance for agriculturalists versus 2 hours for hunter-gatherers (Higgs, 1972), which are explicitly based on Lee's work with the! Kung and Chisholm's work on rural settlement (Chisholm, 1968; Lee, 1969) and often are presented with no evaluation of their suitability to the group being studies or the data at hand. More importantly in terms of the previous point, these one and two hour radii or distances are distances on land, with even less consideration of what an acceptable travel distance over the water would be!

There is a very real need for more work on how humans relate to their environment as they move through it, and for us to take a long hard look at how we are attempting to model that movement within GIS. How people travel from place to place is not just a matter of maximizing efficiency, but is bound up in all sorts of social factors, as any child who has crossed the street to avoid a bully or barking dog can confirm. On a purely functional level, we need more experimental effort put into figuring out what is a reasonable distance to travel in the course of a working day.

2. CASE STUDY: MIDDLE IRON AGE ORKNEY

The study area for this project is Orkney (Fig. 1), a group of about 90 islands located just off the north coast of Scotland. The total surface area of the islands is just under 1000 km^2, and the islands have been continuously occupied since at least the Neolithic. The sites being studied are a group of monumental towers dating to the Middle Iron Age, *circa* 600BC – AD200, and known collectively as *brochs*. The overall research is to try and understand the social organization of the Orcadian Middle Iron Age, in an attempt to explain why this unique group of monuments were built during this period.

Orkney's shoreline can be divided into three broad classes: There are cliffs ranging from 10 to over 30 m in height, lower wave-cut banks of 3-10 m in height leading onto rocky shores, and gently sloping sandy beaches. Historically, these sandy beaches have been the preferred launching and landing points for boats in the absence of artificial harbour facilities. The rocky shores can be used for landing a boat in some situations, especially at high tide, but the presence of a cut-bank makes getting the boat up onto land difficult, whereas the cliffs, while occasionally climbable, would generally preclude their use for access to the sea.

The terrain model employed uses data from the Shuttle Radar Topography Mission (SRTM). This is radar interferometry data, with a 30 m cell size. Upon inspecting the SRTM data, the cliff sections had interfered with the radar beam, creating spurious signals and elevations and altering the shape of the coastline anywhere a cliff was present. An attempt to correct this by clipping the elevation data with the known island coastlines succeeded only in removing the sharp breaks-in-slope the cliffs represent, so any pathways generated near the cliff edge treated the "cliff" like a gradual slope rather than a barrier. Some way of modifying the initial slope-based friction surface was therefore required to properly represent the effort of scaling a cliff versus walking down onto a gently-sloping sandy beach.

The underlying cost surface for this study is in fact a topographic one, generated using the COSTDISTANCE function in Arc Workstation 8.3/9.0, making use of the capacity to generate anisotropic surfaces. It also makes use of Minetti's non-symmetrical energy expenditure curve, as cited by Llobera and Wheatley and Gillings, among others (Llobera, 2000; Wheatley & Gillings, 2002). This created a slope-based anisotropic cost surface, from which one could calculate least-energy cost paths between sites, at least on land. However, it is reasonable to suggest that travel between islands was as much a fact of life during the Iron Age as it is up to the present day. To try and model the two possibilities (water = barrier vs. water = highway) two cost surfaces were created, one with all water cells set to double the value of the land friction (ie, 2), and a second with all water cells set to a friction of 0.5.

The problem of the missing cliffs was solved by reinserting a linear feature to represent the coastline, replacing the underlying slope-based values. For cliffs, a friction set to the maximum value of the topographic friction layer was assigned, in this case a value of 200. For the cut-banks a friction value of 3 was opted for, and a value of 1 for the beaches. These estimates were based on personal observations over two seasons spent climbing up and down these features in the process of collecting data for the project.

The result was two cost surfaces largely based around topography. The project is also seeks to investigate the location of sites in terms of their visibility on the landscape. This was approached by generating a cumulative viewshed map for a set of 1000 randomly distributed points on the landscape. This cumulative viewshed map and its inverse were added as additional sources of friction by multiplying these with the topographic cost surface. The result was a total of six cost surfaces, divided between high and low frictional values for water rasters, and designed to produce paths of least-energy cost, lowest visibility (or observability), and highest-visibility.

Comparing the lowest-energy cost paths between two sites (Fig. 2), unsurprisingly there is a substantial difference in the lowest-energy pathway between the two friction regimes.

If we compare the paths determined by observability, another pattern emerges. The most visible path (dashed line) coincides closely with the lowest-energy path in both the high water-friction (Fig. 3) and low water-friction (Fig. 4) regimes.

These patterns are repeated throughout the data: the most visible and least-energy paths tend to coincide far more closely with each other than they do with the least visible path. While it would be premature to draw any hard conclusions from this particular set of data, but it does suggest a few immediate possibilities, that could be investigated further using other lines of evidence. Since the least-energy and most visible paths coincide, this could suggest that sites were chosen either to make travel between sites as visible to the wider landscape as possible, or to make the easiest, most obvious route to the site also be the most exposed to outside observation. The former could be taken to imply that this coincidence of routes represents some sort of formalized processional way, so that visitors or travelers passing between sites can be seen as widely as possible. The latter could reveal a defensive consideration, through making the easiest direction to approach the site also the most exposed, in other words, forcing an attacker to expend more energy in order to approach unseen. One potential way to resolve this could be to examine the viewed areas of each site and compare these to the pathways' direction of approach, to see if views from the sites themselves are constrained to see mainly along these directions of approach or not.

REFERENCES

ARMIT, I. (2003) – *Towers in the North: The Brochs of Scotland.* Stroud: Tempus.

CARRARA, A.; BITELLI, G.; ROBERTO, C. (1997) – Comparison of techniques for generating digital terrain models from contour lines. *International Journal of Geographical Information Science,* 11 (5), p. 451-473.

CHISHOLM, M. (1968) – *Rural Settlement and Land Use.* 2nd ed. London: Hutchinson.

CUNLIFFE, B. (2004) – *Facing the Ocean: The Atlantic and its Peoples 8000 BC – AD 1500*. Oxford: Oxford University Press.

GREEN, K. (1986) – *The Archaeology of the Roman Economy*. London: B.T. Batsford Ltd.

HIGGS, E. S.; VITA-FINZI, C. (1972) Prehistoric economies: a territorial approach. In HIGGS, E. S., ed. – *Papers in Economic Prehistory*, p. 27-36. Cambridge: Cambridge University Press.

KVAMME, K. (1990) – GIS algorithms and their effects on regional archaeological analysis. In ALLEN, K.; GREEN, S.; ZUBROW, E., eds. – *Interpreting Space: GIS and Archaeology*, p. 112-125. London: Taylor & Francis.

LEE, J.; STUCKY, D. (1998) – On applying viewshed analysis for determining least-cost paths on Digital Elevation Models. *International Journal of Geographical Information Science*, 12: (8), p. 891-905.

LLOBERA, M. (2000) – Understanding movement: a pilot model towards the sociology of movement. In LOCK, G. R., ed. – *Beyond the Map: Archaeology and Spatial Technologies*, p. 65-84. Oxford: IOS Press.

NACKAERTS, K.; GOVERS, G.; VAN ORSHOVEN, J. (1999) – Accuracy assessment of probabilistic variables. *International Journal of Geographical Information Science*, 13 (7), p. 709-721.

VAN LEUSEN, M. (1999) – Viewshed and Cost Surface Analysis Using GIS (Cartographic Modelling in a Cell-Based GIS II). In BARCELO, J. A.; BRIZ, I.; VILA, A., eds. – *New Techniques for Old Times: CAA 98*. Oxford: Archaeopress (BAR IS 757), p. 215-223.

WHEATLEY, D.; GILLINGS, M. (2002) – Spatial Technology and Archaeology: The Archaeological Application of GIS. London: Taylor & Francis.

FIGURES

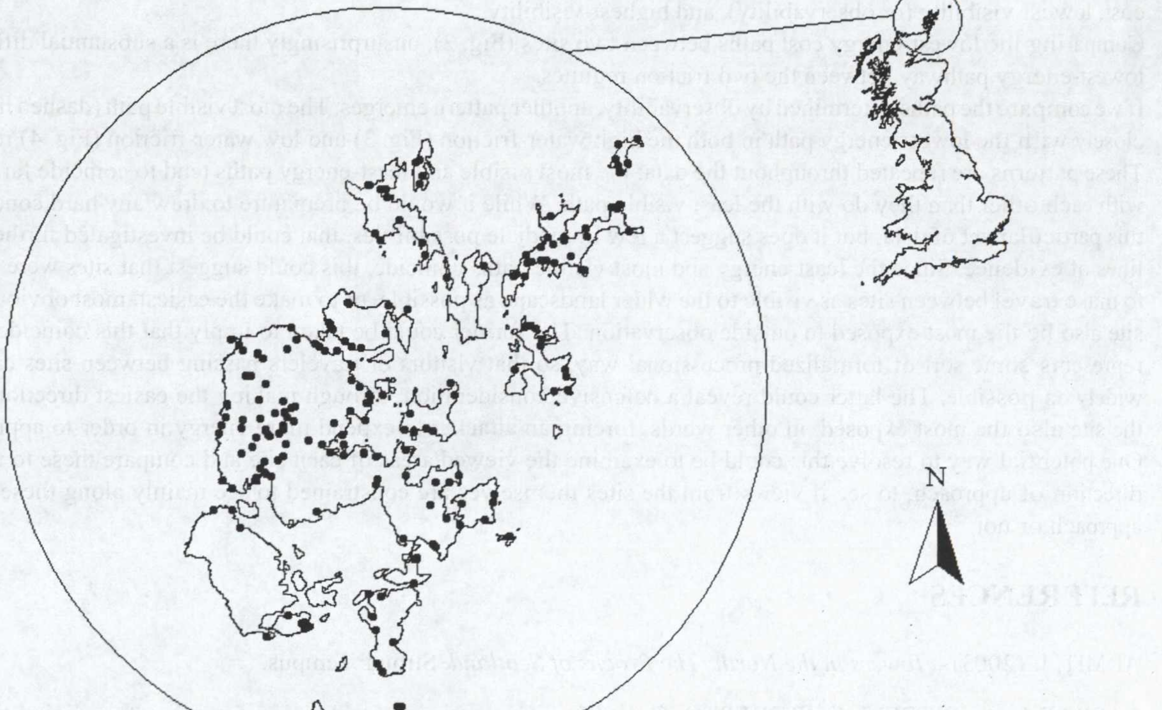

Fig. 1 – The study area.

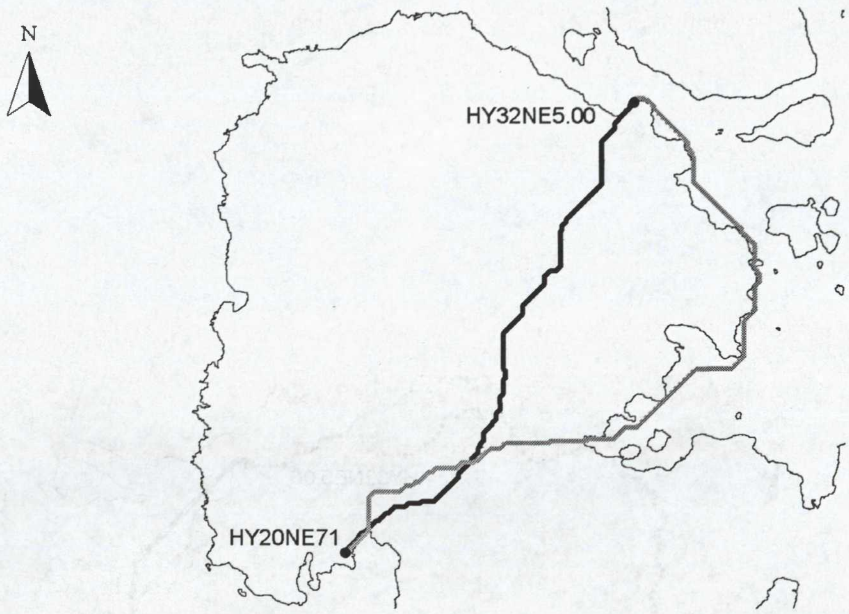

Fig. 2 – Comparison of lowest-energy pathways in the high (black) and low-water friction (grey) regimes.

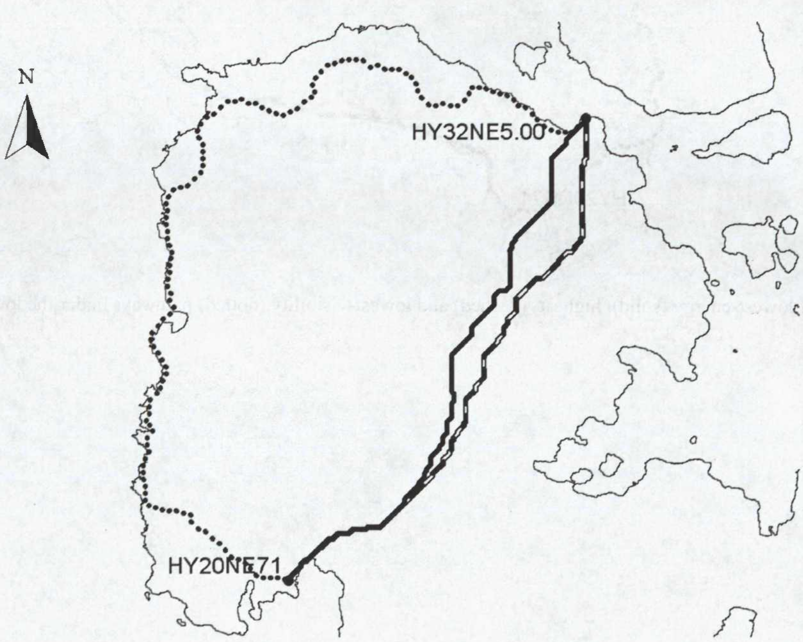

Fig. 3 – Comparison of lowest-energy (solid), highest- (dashed) and lowest-visibility (dotted) pathways under the high water-friction regime.

Fig. 4 – Comparison of lowest-energy (solid), highest- (dashed) and lowest-visibility (dotted) pathways under the low water-friction regime.