Traveling in a Prehistoric Landscape: Exploring the Influences that Shaped Human Movement

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Abstract

As human beings, the desire and necessity to "explore" the world has been with us from the beginning of our existence. From the basic act of looking for food and water, to traveling many kilometers to trade goods and engage in social exchange and dynamics, humans have had to travel at various scales; travel comprises a necessary activity in any aspect of human life. With the introduction of innovative computer approaches such as geographic information systems and agent-based modeling, a robust study of how humans travelled in the past is within reach now more than ever. However, in order to establish valid parameters within our spatial analyses and to produce better models, we first need to understand the social dynamics of movement. The main goals of this paper are: (1) to explore the complexity of human movement at a landscape scale, delving into the main variables and factors that may have influenced mobility during prehistory, and (2) to highlight their importance in archaeological studies.

Keywords: *movement, mobility, traveling, prehistory, GIS*

1 INTRODUCTION

"We move, are moved or we die." Fernandez[1] begins one of the classic studies in social science with this statement. His assertion, although particular to his research, has been relevant to other disciplines that have attempted to understand the complexity of human movement. Due to its importance, not only for implied economic consequences, but also as a key to understanding the development of diverse social aspects such as identity, territoriality, technology, political complexity, and even social inequality, human movement has become a central concern to archaeology and anthropology.

Traditionally, these disciplines have acknowledged the concepts of mobility and sedentarism as critical strategies inherent to the social and economical practices of all societies, and there have been several attempts to define and understand movement through classifications of its diverse variants. This can be attested by the archaeological emphasis on static phenomena, but also by the fact that there has been a relatively small number of investigations that have attempted to analyze mobility and movement as essential social activities. It was only recently that our discipline turned its attention to understanding human movement as a wider phenomenon.

The early studies of Binford[2] and the concepts derived from them generated discussion and later understanding of human movement, conceiving it since then not only as an exclusively economic strategy, but also as a more complex phenomenon and as a way in which societies organized themselves. As a consequence of this, it is now well-established that all societies move at different scales, regardless of whether they are residentially fixed to one spatial location or not, and that this movement leaves a specific trace in the archaeological record. Despite this step forward, research on archaeological approaches to movement have focused their attention on the distribution of specific archaeological evidence, such as traded goods or raw material. Thus, "static" materials have been at the heart of studies focusing on the point of departure or the point of destination of these objects.[3] Few attempts have been made to investigate what happened in between these points, the actual process of movement, or the evidence that can be encountered and related to it at a landscape scale. Interestingly, no research has so far looked specifically at the detailed process of how prehistoric people navigated through the landscape while traveling within and beyond the usual limits of their local economy and social demands. As a result, the possible variables and factors that influenced mobility, as well as the archaeological evidence of movement, have been understudied.

[1] J. Fernandez, "On the Notion of Religious Movement," *Social Research* 46 (1) (1979): 36.

[2] L. Binford, "Willow Smoke and Dog's Tails: Hunter-Gatherer Settlement Systems and Archaeological Site Formation," *American Antiquity* 45 (1980): 4–20.

[3] S. A. Branting, *Iron Age Pedestrians at Kerkenes Dag: An Archaeological GIS-T Approach to Movement and Transportation* (Ph.D. diss., The State University of New York, 2004).

Thus far, innovative computer based methodologies of recognition and spatial analysis such as Geographic Information Systems (GIS) have been applied to several archaeological cases of movement with interesting results. The development of GIS methodologies, such as Cost Surface Analysis and Least Cost Paths, has allowed the examination of the role that diverse environmental variables play on human movement. The majority of the main studies utilizing this kind of methodology have given preference to the role of variables such as terrain topography. Although the models generated through these methodologies have proved to be robust, one of the main criticisms against them concerns precisely the inability of GIS to model influences that are difficult to quantify in a more or less straightforward process (e.g., social phenomena). Moreover, despite the serious consideration of these critisisms by the majority of researchers, a necessary task that has proved more elusive has been the construction of an epistemological basis within archaeological computing, to shed light on the social processes responsible for the observed patterns of spatial distribution of the material culture of movement.[1] In this light, one of the primary objectives of this ongoing research is the identification and definition of the possible variables and factors that affected and influenced human movement. In order to do this, it has been necessary to establish that the specific evidence resulting from social processes is always contingent on the cultural context of the society that creates them. Likewise, movement is always carried out under specific notions, needs, and conceptions of the society in question, engaging with social reproduction; therefore it can be seen as a social process.

2 MOVEMENT AS A SOCIAL PROCESS

In order to understand why movement is a social process, it is necessary to say that according to social theory, the individuals that form a society are not passive receptors of the culture in which they live, but that they actually act as fully conscious agents. Despite this property of individuality, social reproduction is an ongoing process that cannot be separated from the daily activities that any individual or group carries out in the course of their lives.[2] This means that individual thinking and action lie within one's own culture and therefore one's behavior is always influenced by it. In his theory of structure, Giddens[3] points out that humans develop strategies to manipulate what he calls the "structure" (traditionally conceived as society), which includes a set of rules and resources of a given social system. These strategies that individuals devise to manipulate the structure may influence the way in which the structure is transformed, but it is their daily acts that reproduce it. According to Cogwill,[4] the structure contains certain *local rules* regarding how things have to be done (i.e. particular ideas that all individuals share at a given place and time, at least those of the same age, gender, class, etc.) ranging from obligatory laws to less binding standards of proper "behavior." These ideas are contained in the structure and are expressed in daily practices.

The "strategies and types" of movement that any individual or group adopts can be motivated by a series of reasons, but they will always be dependent on that individual's or that group's knowledge and perception of the world. Furthermore, because of the dynamic nature of mobility, adopting these strategies also transforms and modifies the way in which individuals understand the world. Mobility can be seen as a social process and as such, when strategies such as logistical mobility are carried out, the actors take those rules into account (either consciously or unconsciously); the decisions they make about the resources they look for, the places where they go, and even the roads they travel are not only influenced by these rules, but at the same time they actively shape their society. Consequently, it can be established that there are factors related to the "structure" that influence the way in which people move; there are factors particular to these people's culture that they will facilitate the structure to go on. Nevertheless, it has to be acknowledged that in addition to these, there are other "independent" factors as well.

In order to carry out an analysis of movement on a landscape scale, considering processes such as migration or long distance travel, it becomes necessary to take two important steps: (1) to understand the factors that have constrained, facilitated, and influenced movement in all societies in general, and (2) to analyze the most traditional archaeological evidence of mobility (such as paths, landscape markers, waypoints, chariots, etc.) in light of its complexity. In order to undertake the first step, it is also necessary to consider the practical aspects of human movement.

3 THE PRACTICAL ASPECTS OF HUMAN MOVEMENT

Human actions do not constitute isolated events. They are part of an integrated continuum of the mental

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[2]A. Pred, "Social Reproduction and the Time-Geography of Everyday Life." *Geografiska Annaler. Series B, Human Geography* 63 (1) (1981): 6.

[3]A. Giddens, *The Constitution of Society: Outline of the Theory of Structuration* (Berkeley: University of California Press, 1986).

[4]G. L. Cogwill, "Distinguished Lecture in Archeology: Beyond Criticizing New Archeology," *American Anthropologist* n.s. 95 (3) (1993): 559.

(ideal), corporeal (action), and material ambits.[1] Accordingly, it has been generally accepted that there are diverse variables and factors that influence movement in several ways.

Traditional studies have emphasized that the mobility of a group will respond to subsistence factors as conditioners for decision making, suggesting that behavior during mobility tends to obey mainly economical constraints, avoiding the increment of uncertainty. However, although mobility can encompass certain survivability behavior in which environmental and economical factors can become crucial, it also contains a cultural constituent.[2] In this sense, humans move not only under the constants of (taking or avoiding) risk and uncertainty, but they also look to access social resources. Therefore, it must be considered that social factors, such as mobility determinants, played a central role.[3]

For analytical purposes, the variables and factors influencing human movement can be divided principally into two broader groups. This division does not imply that they act independently. They actually act as an integrated continuous and interrelated flow, as will be explained below.

The first group can be defined as the variables that influence human movement independently of people's personal decisions or will, and they act over any animal species. These variables can be quantified with certain independence from the background actors and share universal characteristics, so they influence how people move in any society. Variables that could be referred to as "independent" include the topography of the terrain, environmental aspects, and physical properties related to the human body.

On the other hand, these variables are not the only ones a traveler considers while moving. There are other factors that are related to the traveler's culture, factors which are normally unique or endemic to that society. These social factors constitute the second group mentioned and are defined as "social" influences. Examples include the establishment of territories, social conceptions or ideas regarding places, alliances between groups, trade, and the presence of traditional sacred spaces or heritage.[4]

Although these variables and factors can be "separated" in a sense, it is clear that in reality they always act together. For instance, when deciding the route to follow while traveling, a person can take into account not only the territories through which s/he will pass, but also the topography of the terrain and other conditions (e.g., if it is steep or not, if it is faster to go through it, etc.). In effect, all the factors or variables influencing her/his decision should be taken into consideration. This complexity has been conceptualized with the introduction of what has been defined as "landscape affordances,"[5] a term taken from ecological psychology. The concept of "affordances" coined by Gibson[6] refers to all the action possibilities that are latent in any environment, that are measurable and independent from the ability of the individual to recognize them, yet directly related to the actor and dependent on her/his capabilities. Thus, affordances are dependent on the environment but also on the actor. Moreover, the concept is suggestive of the complexity in the interaction between animal and environment, and it refers to the complementarity between them. According to Llobera,[7] the significance of this concept lies in its potential for phenomenological interpretation. According to Wheatley and Gillings,[8] an object will only afford properties in the context of practical action. For instance, if an individual goes into a room and finds a chair and a basketball, s/he may chose to sit on the basketball and throw away the chair, just because s/he can, although it is most likely that the actor will actually sit on the chair and throw the ball. This last scenario is more probable because of prior experience of the actor with similar objects. So any one affordance is formed without denying that some other affordance is also possible.

Although central to the theory of perception, as Webster[9] has emphasized, affordances can have an individual and internal character due to the different

[1]A. Pred, "Social Reproduction and the Time-Geography of Everyday Life," *Human Geography* 63 (1) (1981): 11.

[2]R. L. Kelly, "Mobility/Sedentism: Concepts, Archaeological Measures and Effects," *Annual Review of Anthropology* 21 (1992): 45.

[3]P. A. Murrieta-Flores, *Mobility, Transhumance and Prehistoric Landscape. A GIS Approach to the Archaeological Landscape of Almadén De La Plata in Andalucía, Spain*. (MSc diss., University of Southampton, 2007) 105.

[4]M. Casimir and A. Rao, ed. *Mobility and Territoriality. Social and Spatial Boundaries among Foragers, Fishers, Pastoralists and Peripatetics*. (New York: Berg, 1992).

[5]M. Llobera, "Building Past Landscape Perception with GIS: Understanding Topographic Prominence," *Journal of Archaeological Science* 28 (2001): 1005–14.

[6]J. J. Gibson, "The Theory of Affordances," in *Perceiving, Acting, and Knowing*, ed. R. Shaw and J. Bransford (N.J.: Erlbaum, 1977) 67–72.

[7]M. Llobera, "Building Past Landscape" (p. 251n5) 1006.

[8]D. Wheatley and M. Gillings, *Spatial Technology and Archaeology. The Archaeological Applications of GIS.* (London: Taylor & Francis, 2002) 4.

[9]D. S. Webster, "The Concept of Affordance and GIS: a Note on Llobera," *Antiquity* 73 (1999): 915–17.

physical, social, and environmental backgrounds of the societies that experience them. In this light, we consider that some of the elements that shape these affordances, such as topography, can first be analyzed independently from the background of the actors, because they have, to some extent, "universal" characteristics that will later affect the action regardless of which society we are investigating. It is also thought that these attributes can be studied at particular levels as variables, considering that each one influences movement in a particular way. However, at the same time, once in interaction with the individual, the role of these variables always becomes closely related to the society that experiences them and therefore, to the archaeologically identifiable material evidence of mobility. This is to say that these variables, together with the cultural background of the actors, shape the mobility patterns observed and therefore, how the material is distributed spatially.

4 The influences of human movement: independent variables

4.1 Temporal conditions for movement

It could be argued that the temporal dimension does not necessarily constitute an independent variable due to the diverse ways of conceiving it in different societies. It is also well established that time may not be a culturally recognized resource or even a uniform concept for all societies. Nevertheless, all human activities occupy both a temporal and a spatial location. Intangible though it may appear in principle, and contrary to other variables as concrete as terrain topography, time is considered in this research as a determinant of human movement because of its intricate relationship with the physical and spatial components of movement.

Traditional research studying the effects of space on human behavior understood human activities as decisions that were made exclusively in the context of spatial measurements such as distance, and excluded time as an alien factor. Since the introduction of the concepts of time-geography by Hägerstrand during the 60s, several studies have emphasized the importance of time in human activities, and most of all, in mobility.[1] It It has been recognized that time is a constant that can condition movement and that it is intrinsically related to other constraints. For instance, Hägerstrand[2] describes as capability constraints the physical limitations experienced by individuals due to the human biological constitution (e.g., the impossibility of being in two places at the same time, or of traveling continuously without rest or food).

To explain these limitations and their relationship with time and space, Hägerstrand also introduced "the space-time path."[3] This path is the representation of the movement of an individual in space and time at any given period (including her/his lifespan). This path is only one of many that can actually be taken, and it can be represented at any scale. To illustrate this point an ordinary day of an individual is depicted (fig. 1).

Let us imagine that a person wakes up in the morning. At ten o'clock she takes her car and drives to her office, which is the next station. At eleven she arrives at the office, where she stays. At five o'clock she decides to visit some friends. She gets there at six and after that, she heads home. At nine she's outside her house parking the car.

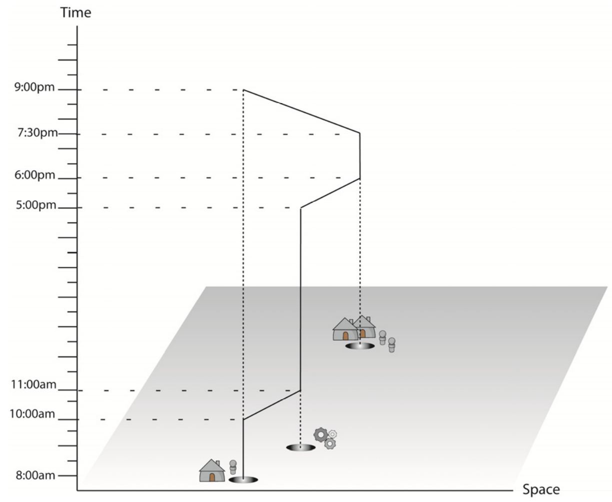

Figure 1. *Simple Time-Space path.*

This graphic illustrates a simple relationship between individual, time, and space, reminding us of the continuity and dynamics of life. However, it can also represent more complex relationships with other individuals, locations, the environment, and directions of movement. Decisions made can alter the trajectory of the path and the variables explored here can become constrainers or facilitators of movement and, in their turn, change trajectory as well.

As shown in the model, the temporal dimension is intrinsically related to space and action. It is for this reason that as a constant linked to capability constraints it becomes essential for the study of movement. For instance, for a given period of movement a period of rest will be needed, or there is a limit to the distance an

[1]T. Hägerstrand, "What About People in Regional Science?" *Papers in Regional Science* 24 (1) (1970): 6–21; T. Carlstein, *Time Resources, Society and Ecology. On the Capacity for Human Interaction in Space and Time in Preindustrial Societies* (London: George Allen and Unwin, 1982).

[2]Hägerstrand, 12.

[3]Hägerstrand, ibid.

individual can travel during a certain amount of time.[1] Time, in relation to movement, turns into a crucial factor when, due to other constraints such as the availability of food, rest and water, or when urgent matters need to be communicated (as in the case of messengers), it becomes a scarce resource. Consequently, capability constraints constitute essential variables, because they are defined by the most basic physical characteristics of the human constitution.

4.2 PHYSICAL CONDITIONS FOR MOVEMENT: VELOCITY LIMITS AND ENERGY EXPENDITURE

Walking is the main form of animal terrestrial locomotion and it was the first means of transportation that human beings experienced. Although it is considered to be a basic activity, walking cannot be thought of as simple. In order to walk, human beings make use of a strategy known as "double pendulum."[2] This strategy allows the body to recover up to 65 percent of the energy used due to the dynamics of the pendulum in combination with the ground reaction force.[3]

The mechanics of our bodies allow us to move in forward or backward motion, but they do not define the velocity that we can reach while walking. It is the center of mass of the body which defines it.[4] While walking, the body reacts in the following way: when the leg hits the ground, the body "arches" itself to raise the center of mass to the highest point, which it then drops to the lowest point after the leg passes the vertical axis, at the time that the legs spread apart. While running, this effect is reversed; the center of mass is at the lowest point when the leg is over the vertical axis.[5]

Studies on human physiology have shown that the walking speed that humans tend to prefer is the one that minimizes costs in terms of energy per unit distance. It is clear, however, that when time is an imperative factor, running is the chosen option.[6] These studies have also shown that when the speed is up to 2 meters per second, walking is more efficient and requires less energy than running, so walking is preferred. Passing that threshold, i.e. walking faster, imposes a higher energetic cost, making the activity of running much more economical; in that case running is preferred.[7]

The cost of walking can be measured in several ways, the most common of which are speed and energy. These units of physical magnitude are interrelated when they concern human movement, and they must have played an extremely important role in movement during prehistoric times. Energetic expenditure, for example, can become a crucial factor for a person depending on the amount of food resources that s/he can access while on a long journey. In the same fashion, time economy could constitute a critical issue in relation to certain social tasks, such as carrying news.

An example of this is the case of the Aztec messengers, who were related principally to military and commercial functions. They were in charge of the transportation of religious and ceremonial news and accomplished urgent tasks, enjoying huge economical and social benefits.

Several chronicles provide useful information on how messengers were selected and trained, as well as on the skills that they needed to acquire in order to live up to what was expected of them. They also highlight the efficiency and speed with which they had to travel.[8] The The example of Nahuatl messengers shows us that past societies made extended use of human physical abilities, such as running, for different purposes. In this case, written sources and chronicles describe these activities. However, in cases in which this kind of evidence is not available, in order to create better models and theorize movement during prehistory, it is important to understand the essential physical factors, such as the average human velocity rates.

In the case of walking, there is an absolute limit in the speed that any human can achieve without special techniques, due to the velocity at which the center of mass rises or falls.[9] It has been calculated that for pedestrians between 20 and 60 years of age, the average walking speed is 4.4 km/hr for women and 4.9 km/hr for

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[1]T. Ingold, *The Appropiation of Nature. Essays on Human Ecology and Social Relations* (Iowa: University of Iowa Press, 1987) 172.

[2]J. Rose and J. G. Gamble, eds. *Human Walking*. (Philadelphia: Lippincott Williams & Wilkins, 2005).

[3]G. A. Cavagna et al., "The Sources of External Work in Level Walking and Running," *Journal of Physiology* 262 (1976): 639–57.

[4]R. McNeill Alexander, "Walking and Running," *American Scientist* 72 (1984): 348–54.

[5]Y. Brenier and C. Ribreau, "A Double-Inverted Pendulum Model for Studying the Adaptability of Postural Control to Frequency During Human Stepping in Place," *Biological Cybernetics* 79 (1998) 342.

[6]R. M. Alexander, "Energetics and Optimization of Human Walking and Running: The 2000 Raymond Pearl Memorial Lecture," *American Journal of Human Biology* 14 (2002): 641.

[7]R. M. Alexander, "Energetics and Optimization of Human Walking and Running" (previous note): 642.

[8]Fernando de Alva Ixtlilxóchitl, *Obras Históricas*, vol. 2, ed. Edmundo O'Gorman (México: Universidad Nacional Autónoma de México 1975–77) 103–104.

[9]R. M. Alexander, "Walking and Running" (p. 253n4) 348.

men in flat or almost flat terrain.[1] Other aspects also have to be taken into account in order to calculate the speed of human movement: carrying loads, age, and fitness can influence the energetic cost and velocity that an individual can reach. However, the rates mentioned set a limit for possible models and they can be used as optimal measurements of human movement.

In the case of the energy cost of locomotion, rates are increased depending on both the slope and aspect (up and down hill) of the terrain, ground type, and loads. Our gait seems to be adapted to minimize energy cost, and this energy efficiency pattern can be historically observed in the zigzag paths that are normally plotted in terrains with critical gradients, as well as in the diversion of paths that go around hills instead of over them in a straight line. Despite all this, we do not always behave in an energy saving way. There are cases in which the roads or paths follow other less wise (in terms of energy) patterns, such as totally straight lines. The plotting of these kinds of paths has been related to societies that have social, symbolic, and political motivations to construct them in that way, as it will be demonstrated later.

4.3 Topography: Natural Obstacles and Facilitators

The shape of the terrain is one of the main "independent" factors that affect human mobility because of the energy expenditure required to traverse an irregular terrain. As noted above, the human musculoskeletal system, with its motion characterized by the alternation in the raising and lowering of the mass center, is composed by energy-saving and energy-dissipating structures and, therefore, the energetic expenditure depends mainly on the gradient of the path.[2] path.[2] Accordingly, topography is an essential component of the mechanics of movement and the traces of both past and current paths take this variable into account.[3]

Experiments in oxygen consumption have shown that to walk equal distances uphill and then downhill with the same gradient take a greater amount of energy than to walk the same total distance on flat terrain.[4] If the gradient of the terrain is 0.2, for example, it will take 2.5 times more energy to traverse it than to traverse through flat terrain. But this relation is not only valid for ascending. It is well known that the energy expenditure increases if we walk uphill, but there is also an implicit cost when we walk downhill. While walking uphill offers a full resistance due to the effort of carrying our own weight (spending energy on this action), to walk downhill offers little impedance, making us spend energy in the action of braking in order to prevent falling.[5]

This relationship between slope and energy was plotted by Minetti[6] from studies by Margaria[7] and then adapted adapted by Llobera,[8] showing us that the energetic cost of movement is not the same when we walk uphill than when we walk downhill.

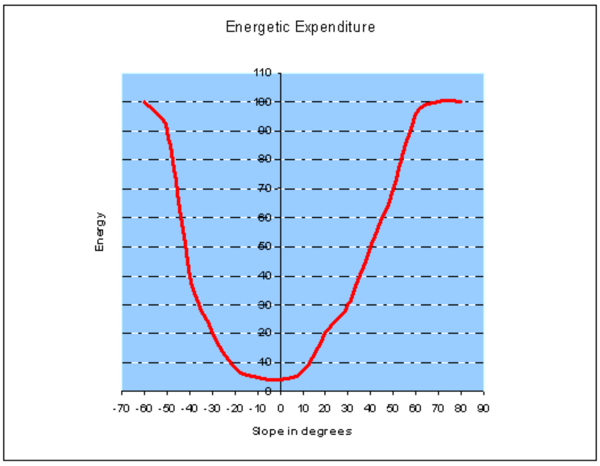

Figure 2. *Graphic of the energetic expenditure for different slopes. Adapted from Llobera (2000).*

As shown in figure 2, the optimal gradient for walking, in terms of energy consumed, is given as -10% or -5.71° of gradient.[9] The values show us that although moving

[1]J. Perry, *Gait Analysis: Normal and Pathological Function* (New York: McGraw Hill, Inc., 1992) 453.

[2]A. E. Minetti, "Optimum Gradient of Mountain Paths," *Journal of Applyed Physiology* 79 (1995): 1698.

[3]T. Bell and G. Lock, "Topographic and Cultural Influences on Walking the Ridgeway in Later Prehistoric Times," in *Beyond the Map: Archaeology and Spatial Technologies*, ed. G. Lock (Amsterdam: IOS Press, 2000) 85–100, at 88.

[4]R. M. Alexander (p. 253n4) 646.

[5]M. Llobera, "Building Past Landscape Perception with GIS" (p. 251n5); T. Bell and G. Lock, "Topographic and Cultural Influences on Walking the Ridgeway in Later Prehistoric Times," (p. 254n2) 89.

[6]A. E. Minetti, "Optimum Gradient of Mountain Paths" (p. 254n2).

[7]R. Margaria, "Sulla fisiologia, e specialmente sul consumo energetico, della marcia e della corsa a varie velocità ed inclinazioni del terreno," *Atti Accad. Naz. Lincei Classe Sci. Fis. Mat. Nat. Serie VI*, no. 7 (1938): 299–368; R. Margaria, *Biomechanics and Energetics of Muscular Exercise* (Oxford: Oxford University Press, 1976).

[8]M. Llobera, "Understanding Movement: A Pilot Model Towards the Sociology of Movement," in *Beyond the Map. Archaeology and Spatial Technologies*, ed. Gary Lock (Amsterdam: IOS Press, 2000).

[9]A. E. Minetti (p. 254n2).

downhill might seem to require less energy, at critical gradients it will require the same effort to ascend as to descend. For these reasons, the strategies adopted for walking can be different for ascending and descending. This consideration is important because the energy cost involved in both cases influences how paths are traced.

Measuring the optimal gradient of mountain paths, Minetti[1] tested whether it was more costly to walk straight up the slope of a hill or to traverse it in zigzag (as paths in mountains are normally shaped). He concluded that for gradients of 0.25 or less, to cross it directly was the best route, while for values beyond this gradient, the optimal route was zigzag shaped. These results fitted well with paths observed in the Himalayas and the Alps. In further research, Llobera and Sluckin[2] have demonstrated that the formation of paths with hairpin turns (a zigzag shape) corresponds to an optimization strategy, which involves not only the minimization of energy but also the direction of movement. These authors also discuss how, in the experience of expert walkers, shortcuts between zigzag branches are taken when possible. Our own energy-saving and energy-dissipating structures suggests that, ideally, it would be better to follow two different strategies, one for going uphill and another when going downhill. In the first case, traveling directly uphill would be optimal. However, it appears that now, at least, mountaineers and walkers prefer to take the zigzag paths even when it may be more cost-effective to follow a straight route up, taking the shortcuts only in very optimal conditions. According to Llobera and Sluckin,[3] the reason for this may be that the presence of a previously established route can change the behavior of the walker by attracting him; the traveler will prefer to take the path that is already there, because traveling along it is easier than creating a more direct one, even when that implies savings in energy cost.

As noted above, humans do not always act in order to save energy, but energy is always a highly considered factor. It can be more cost-effective to walk around a mountain; however, when other factors are present (e.g., time), a more direct path may be chosen, and even then it is likely that a zigzag pattern will emerge at some point of the traverse, taking into consideration, as much as possible, the energy cost.

Thus far, among the topographical aspects only slope has been covered, but other elements from the configuration of the topography should be discussed also. A mountain range can normally constitute a natural obstacle in terms of movement; however, there are other elements related to the configuration of topography that can play a dual role, sometimes acting as obstacles and at other times as facilitators. We refer mainly to water bodies.

Cultures everywhere have been bound by the availability of drinking water and therefore, most human settlements are preceded by its presence. Rivers have not only served as vital subsistence resources, but have also played an important role in communication by being used as routes or to establish borders and territories. Rivers can be seen as natural facilitators for movement when the appropriate technology is available (ships, boats, canoes, etc.), but they can also be seen as difficult obstacles. The role that water can take in terrestrial movement has often been overlooked. In the study of human mobility during prehistory, this factor is important not only because of the implications mentioned above, but also because without being aware of its importance, archaeologists can miss important evidence, such as strategic points of crossing, as well as archaeological evidence such as bridges.

4.4 Loads

Another component that influences human speed or energy expenditure is loads. Physiological studies have proposed that the metabolic cost of walking or running increases in direct proportion to the weight of carried loads.[4] Understanding how loads influence energy consumption is important in archaeological research, because carrying loads affects the energy expended by the body and has a direct impact on the speed, time of rest, and the amounts of water and food that an individual consumes while traveling. This impact is reflected archaeologically in the design and plan of routes and the rest areas.

For instance, during Aztec times specialized carriers (*tlameme*), would typically begin their training at the age of five; as adults they would normally carry up to 2 *arrobas* (around 23 kg) for 21–28 km or the equivalent to a day's journey.[5] However, the expenditure of energy energy of these men would be conditioned also by the speed of walking. Modern studies have established that the optimal relation is of 3.8 km per hour with a load of 25% of the body weight,[6] so we could expect the same relation in the past. Carrying weight increases the energetic expenditure linearly, in direct proportion to

[1]Minetti, ibid.

[2]M. Llobera and T. J. Sluckin, "Zigzagging: Theoretical Insights on Climbing Strategies," *Journal of Theoretical Archaeology* 249 (2007): 206–17.

[3]Llobera and Sluckin, (p. 255n2) 216.

[4]T. M. Griffin et al., "Metabolic Cost of Generating Muscular Force in Human Walking: Insights from Load-Carrying and Speed Experiments," *Journal of Applied Physiology* 95 (2003): 172–83.

[5]R. Hassig, *Trade, Tribute and Transportation: The Sixteenth-Century. Political Economy of the Valley of Mexico* (Oklahoma: University of Oklahoma Press, 1985).

[6]S. J. Legg et al., "The Metabolic Cost of Backpack and Shoulder Load Carriage," *Ergonomics* 35 (1992): 1063–68.

the weight of the load at each speed. For example, to carry a load equal to 20% of body weight increases the rate of energy consumption by 20%.[1] This is also conditioned by external factors such as the temperature, wind, and slope.

It must be noted that there are cases in which some humans, such as the experienced Nepalese carriers, are able to transport more than 150% of their own body mass by progressing slowly (self-pacing) and resting frequently to avoid exhaustion. The continuous practice of certain tasks like carrying heavy weights can play an important role in the performance of the carrier and in his energy and time consumption during a journey. Thus, the capability of experienced bearers and the distances that they can cover has often been underestimated. According to Lightfoot's[2] model of efficiency in transport of the Chaco regional system, the maximum range of prehistoric redistribution network of food could not have extended beyond 50 km of distance with bearers carrying around 25 kg. Other research has demonstrated that Nepalese porters working at the same altitude as Prehispanic Americans can cover up to 150 km with a load of 50 kg in a round trip of two weeks or less.[3] In other societies in which the weight carried is not ruled by the price that is paid per kg carried, the load could be less. This is demonstrated in other ethnographic cases in which normally the median of weight carried is between 20 and 65 kg. These figures match other studies estimating travel distances and load carrying in the Mayan area of Mexico and Guatemala, which have suggested that trained porters can travel 20 km per day (range, 10–32 km), carrying loads up to 45 kg (range, 22–64 kg).[4] In any case, the lesson to be learned from the Himalayan porters is that humans have a great capacity to carry heavy loads.

Fortunately for archaeology, activities related to the capacity of the human body normally leave their mark. When certain activity is time-consuming and arduous, bone morphology can be modified; the traces of the activity are thereby recorded, especially if the activity begins at early stages of bodily development. Studies of bone samples of American and European prehistoric individuals have shown the development of osteopythosis of vertebral bodies and osteoarthritis in the lumbar vertebrae, due to the stress imposed by weight bearing.[5]

In the case of the most recent periods of European prehistory, it has normally been assumed that the existence of pack animals would relieve societies from the task of carrying loads. However, there are osteoarchaeological studies that point to the presence of osteoarthritis in the spine, knees and ankles due to carrying heavy loads.[6] Thus it appears that in European Late Prehistory people still relied in their own bodies to carry loads. However, it is also true that towards the Bronze Age the use of the horse and pack animals was much more extended, as is shown by abundant archaeological evidence. Regarding this, the way in which people moved varied greatly in different areas, depending on the availability of animals.

4.5 Terrain Types and Ground Knowledge

There are other variables that condition the speed and energy cost of walking. Terrain type (e.g. soft ground like snow, marshes, or vegetation), and variable "stiffness" of the ground can have an influence on this. For instance, the energy expenditure is much higher on soft surfaces than in firmer ones; the cost of walking on dry sand is 2.5 times higher than walking on concrete,[7] and to walk in deep snow is up to 5 times more costly than to walk on a treadmill.[8] Increased energy cost is not not only observed in soft ground, since rough or uneven surfaces have the same effect; for example, the cost of walking over a ploughed field is 50% higher than walking on a smooth surface.

The most difficult part of measuring how the terrain type affects the energy cost of movement has been to establish valid cost coefficients for diverse terrain types. Among the scarce research published on the topic, we can mention the work of Soule and Goldman,[9] who

[1]G. Maloiy et al., "Energetic Cost of Carrying Loads: Have African Women Discovered an Economic Way?" *Nature* 319 (1986): 668–69.

[2]K. G. Lightfoot, "Food Redistribution among Prehistoric Pueblo," *The Kiva* 44 (1979): 332.

[3]N. J. Malville, "Long-Distance Transport of Bulk Goods in the Pre-Hispanic American Southwest," *Journal of Anthropological Archaeology* 20 (2001): 237.

[4]G. Tourtellot, "Getting What Comes Unnaturally: On the Energetics of Maya Trade," in *Papers on the Economy and Architecture of the Ancient Maya, Monograph VIII*, ed. R. Sidrys (Los Angeles: Institute of Archaeology, University of California, 1978).

[5]P. Bridges, "Vertebral Arthritis and Physical Activities in the Prehistoric Southeastern United States," *American Journal of Physical Anthropology* 93 (1994): 63–93.

[6]C. Classen, and R. A. Joyce, *Women in Prehistory: North America and Mesoamerica* (Pennsylvania: University of Pennsylvania Press, 1997) 71.

[7]T. M. Lejeune et al., "Mechanics and Energetics of Human Locomotion on Sand," *The Journal of Experimental Biology* 201 (1998): 2071–80.

[8]K. B. Pandolf et al., "Metabolic Energy Expenditure and Terrain Coefficients for Walking on Snow," *Ergonomics* 19 (6) (1976): 683–90.

[9]R. G. Soule and R. Goldman "Terrain Coefficients for Energy Cost Reduction," *Journal of Applied Physiology* 32 (5) (1972): 706–08.

developed terrain coefficients for energetic cost prediction on six different terrains. The results of this research established that the use of a single prediction equation, such as the one created by Pandolf et al.[1] in combination with these derived terrain coefficients, allows us to predict with reasonable precision the energy cost while walking in any of these terrains.[2]

Another variable, the knowledge of the terrain, can also become a crucial factor, as recent research has established. An experiment performed with soldiers has proved that while walking appears to require little attention, walking through more complex terrain does affect the attention of the person. As a result, the distance covered was significantly shorter than expected, due to the natural speed reduction caused by focusing on the complex terrain.[3]

It is clear that the historic development of paths and their repetitive use goes hand in hand with this variable. The knowledge of certain terrain allows a person to choose the most optimal paths, not only in terms of energetic cost expended, but also in the sense of comfort while walking. Archaeological fieldwork experiences in the Mayan region of Quintana Roo in Mexico have shown that indigenous people acting as guides in the rainforest normally walk in the intermediate zones between the *bajos* (seasonally flooded areas) and higher ground, even when they explore new territories. Their knowledge of the environment allows them to choose the driest and firmest terrain to walk on, while avoiding going to higher ground in order to avoid the steepest hills. Unsurprisingly, some of the *sacbes* (Mayan roads) of the region are located precisely in the same type of ground.[4] In this manner, the terrain type is highly relevant not only in terms of energetic expenditure but also in the selection of routes to follow.

4.6 Access to Basic Resources While Traveling

The access to basic resources while traveling can constitute an important factor for survival during a journey, and there are different dynamics governing long and short distance traveling. In general, archaeological studies of movement and mobility are bound by the availability of data. As a result of the lack of information, the discussion concerning the patterns of resources transported for daily survival while traveling is often overlooked. Nevertheless, it is possible to calculate how much food a person had to consume in order to survive during a journey. In order to do this, we need to calculate the daily kilocalories expended during a journey according to the variables mentioned above, and we need to have information about the food accessible to the traveler in order to find out the kilocalories that were available to him/her. Although these calculations are not presented in this paper, we will address some specific issues that are considered important for achieving a better understanding of the conditions under which prehistoric people traveled.

It must be said that access to food was not the only important issue in terms of resources needed when traveling; water, firewood, and shelter were important too. Some archaeological and ethnographical examples show how diverse societies with different organizations and strategies solve the problem of resource procurement for daily survival during a journey. The organization of any journey requires the preparation of diverse aspects contingent on the distance and length of the trip. The amount of food, water and tools to be carried depends not only on the scale of the journey, but may also be influenced by the purpose of the trip and the knowledge of the route. Nevertheless, the solutions of these problems are normally specific to each society.

In the case of logistical mobility, travelers carry with them only a small supply of food to be consumed en route, the actual amount of which depends on a number of factors. Although the length of the journey is the predominant one, knowledge of the terrain or of available resources in the area can help minimize the burden carried.

In the case of seasonal and migrational movement in the past, it is probable that people hunted, gathered, and made contacts with other human groups during their journeys. Despite the fact that it can be difficult to trace the actual routes that people took during migration, new carbon and strontium isotopic analyses are revealing the grade of mobility that individuals had during prehistoric times and the way they traveled. A unique example of the materials carried during a journey has been the one provided by the discovery of Ötzi, the mummified remains of a prehistoric man dated to 3200 BC, found in 1991 in the mountain pass of Similaun, on the frontier between Italy and Austria. His exceptional state of

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[1] K. B. Pandolf et al., "Metabolic Energy Expenditure and Terrain Coefficients for Walking on Snow" (p. 256 n8).

[2] R. G. Soule and R. Goldman, "Terrain Coefficients for Energy Cost Prediction," *Journal of Applied Physiology* 32 (5) (1972): 706–08; T. M. Lejeune et al., "Mechanics and Energetics of Human Locomotion on Sand," *The Journal of Experimental Biology* 201 (1998): 2071–80; R. M. Alexander, "Energetics and Optimization of Human Walking and Running: The 2000 Raymond Pearl Memorial Lecture," *American Journal of Human Biology* 14 (2002) 641.

[3] J. S. Augustyn et al., "Effects of Locomotion over Varied Terrain on Soldier Vigilance," paper presented at the 26th Army Science Conference. Transformational Army Science and Technology-Harnessing Disruptive S&T for the Soldier, 2008.

[4] P. A. Murrieta-Flores, *Resultados del proyecto: Mapeo de Sitios para la Protección Legal al Patrimonio Arqueológico de Quintana Roo* (Mexico City: ENAH-INAH, 2001).

preservation has allowed a great variety of analyses, DNA, paleodiet, and oxygen isotopes, among others.[1] One fascinating aspect of the discovery is that Ötzi was found with his equipment, hunting tools, and clothing almost intact. Further analysis has concluded that he carried a variety of tools, goods, and utensils useful for his journey. Moreover, he had eaten two different types of meat before his death (chamois and red deer) and he had also ingested grains, probably in the form of bread, and some fruit.[2]

There has been much discussion, to which these findings have been central, regarding his origins, possible occupation, and reasons for being at the mountain pass. The discovery of Ötzi is of significance in our case, for it demonstrates the great knowledge of natural resources that prehistoric people had while traveling and the kind of tools that could be carried, and it informs us of the capacity of prehistoric people to travel long distances in a regular fashion.

Other interesting cases of migration proved through oxygen isotopic analysis are the bell beaker burial contexts from Germany, Austria, the Czech Republic and Hungary,[3] and the Early Bronze Age Amesbury Archer discovered in Wiltshire, U.K., who migrated from the foothills of the Swiss or German Alps.[4] Of course, it is not surprising that people migrate. What can be surprising, though, are the reasons and the conditions under which people like the Amesbury Archer migrated.

Where this man rested, what problems he encountered, which routes other prehistoric travelers followed, or which people they met on their journeys are questions that, although as yet unanswered, are now becoming susceptible to archaeological exploration. Even though new methodologies are now available, however, it is still necessary to ask further questions about how human movement could be constrained by the (in)accessibility to necessary resources during the course of a journey. This variable constitutes an enormous unexplored field that any study of human movement must take into account.

Migration also opens the discussion to other interesting issues regarding human movement. Travelers do not move alone; with them travel their knowledge, material culture, and traditions. In light of this, it is clear that there are many other factors related to the individual's knowledge and perception of the world, which, as will be explored below, affect movement as well.

3 The Influences of Human Movement: Social Influences

"Independent variables" and subsistence are not the only components conditioning how and why people moved. Influences related to social phenomena play an equally important role. Movement and mobility can be encouraged and influenced by social, political, or personal concerns. Religious beliefs, establishment of kinship, alliances, and (perceptions of) territoriality, among others, can not only prompt residential mobility, but also define the characteristics of any kind of movement. According to the Boturini Codex, also known as "Tira de la Peregrinación," it was religious beliefs that led Aztec people to migrate; the diverse *Mexica* tribes embarked on a long journey in search of a "promised" land under the command of their god *Huitzilopochtli.* Although this story is tempered by a well-known Mesoamerican cosmovision, there is archaeological evidence suggesting that the group actually did reside in some of the diverse locations mentioned in the codex. There is thus evidence for the high level of residential mobility that this group had achieved before settling in its final destination, *Tenochtitlan*, the area that is today Mexico City.[5]

In the case of hunter-gatherers, the ideas or conceptions concerning the environment that the group has developed from the localities in which they live can also influence their mobility. A place to which the group may potentially return will not be considered equally as one that is going to be abandoned forever, because the former constitutes an established place within their existing landscape.[6] In the case of pastoralists, influences or constraints for mobility could also be the geographical knowledge of the shepherd, the social networks of the groups, their contacts, territories, political issues, and relations with non-pastoralist groups.

Ultimately, mobility itself can play a very profound role as a social strategy, not only for maintaining cultural autonomy through the idea of valuing movement (even if sedentarism is possible, as happens in many pastoralist societies),[7] but also for having more mundane connotations and motivations. Several examples of modern hunter-gatherers' behavior show

[1]F. Rollo et al., "Ötzi's Last Meals: DNA Analysis of the Intestinal Content of the Neolithic Glacier Mummy from the Alps," *PNAS* 99 (20) (2002): 12594–99.

[2]G. Sulzenbacher, *The Glacier Mummy: Discovering the Neolithic Age with the Iceman* (Wien: Folioverlag, 2002).

[3]T. D. Price et al., "Strontium Isotopes and Prehistoric Human Migration: The Bell Beaker Period in Central Europe," *European Journal of Archaeology* 7 (2004): 30.

[4]Wessex Archaeology. "The Amesbury Archer 2004," www.wessexarch.co.uk/projects/amesbury/introduction.html.

[5]X. Noguez, "Tira de la peregrinación. La migración mexica," *Arqueología Mexicana* XIV (81) (2006): 48–53.

[6]R. L. Kelly, "Mobility / Sedentism: Concepts, Archaeological Measures and Effects," *Annual Review of Anthropology* 21 (1992): 45.

[7]T. A. Acton, *Gypsy Politics and Traveller Identity* (Hertfordshire: University of Hertfordshire Press, 1997) 70.

that they may decide to move just because they want to acquire news from other places, or visit friends, or simply because they are bored with their present location.[1] Consequently, although the social and individual factors influencing how people moved could be seen as infinite, there are specific variables that contribute to the making of specific patterns that can emerge from movement. Political conflicts and territoriality can contribute to the development of specific routes and paths. Furthermore, ideas regarding a place, such as the belief that it is secure or insecure or apparently easier to traverse, can make these places attractive or repulsive to travelers. In this vein, the next section of the paper deals with some of the ideas and conceptions that humans develop from certain spaces, highlighting how these affect movement directly. This effect is not only characteristic of places; there are other specific features that are intended to have the same function, such as landscape markers.

5.1 Symbolic navigation: ideas of place and reference to places

Human movement starts with an idea; it is always carried out with the intention of accomplishing a certain goal. This can be observed from the smallest to the greatest scale of movement. The direction of movement can be affected by social conceptions and ideas regarding places. The traditional Durkeimian and Saussurean approaches to space outline the symbolic richness of a culture's construction of it as an idea. However, they never ask how the people of a given culture experience the symbolic aspects of space. It is not our intention to delve into this complex question here. Nevertheless, we can address some parts of the culturally-determined relationship existing between movement and this symbolic aspect of space.[2] The ability to think, judge and assess our world allows us not only to interact with others but also to survive. Some of the assessments that we make are based on preconceptions and information that we inherit from our own society and culture. There are ideas about places that make them attractive or repulsive to travelers. We also have reference to places; i.e., we have ideas about places that are not our own (for we have never visited them), but others within our community have visited them and communicated these ideas to us. These references can also act as attractors or repellents to certain sites. A traveler may have negative references to places that ought to be avoided, as well as positive references to places that are recommended or convenient.

There are also certain ideas or preconceptions regarding specific spaces that we are taught to think of as special from an early age. Each society and each time has different ideas regarding these "special" places. In the case of catholic societies, for instance, a church, a graveyard, and specific sites of pilgrimage constitute spaces where different rules of behavior apply; they are not considered a strictly human domain and are therefore perceived as "other". In Mesoamerican cultures, it is known that certain waters, such as springs located at the foot of mountains, were seen as liminal spaces where the sacred met the profane. This was also the case for certain caves and mountain peaks. Because different rules apply for these sites, human behavior at them also tends to be different than normal; sometimes these places will act as attractors or repellents for people. In modern Mexican culture, for example, there is a mixture of Catholic and indigenous beliefs regarding death. Burials mainly follow Catholic customs, but many of the beliefs and practices related to them come from Mesoamerican times. In that culture, cemeteries are places of joy and rest, and according to prehispanic beliefs, people are normally welcome to them daily. However, following Catholic ideas, they are generally avoided. In this case, cemeteries can act as repellers of movement under the Catholic concept, but in the indigenous tradition they can also be strong attractors of movement. On the other hand, ideas about sacrality are not the only ones that can influence how people move around places. Historical memory and legends connected to a place can have an impact, too. Traditional stories were repeated in order to make people avoid places that were regarded as dangerous. Medieval tales regarding the woods and other less explored places often served as warnings to avoid dangers such as wolves and other predators, but they also acted as means to control access, protect property, or communicate morals. In this sense, there are many places that can be regarded as special throughout generations. In Europe, archaeological evidence for prehistoric times has proved that the places in which megalithic monuments were erected were considered special. The reutilization of these monuments as places for burials and offerings for centuries[3] underlines their permanence as well as their uniqueness. It is difficult to say to what degree such monuments acted as attractors or rejecters of movement for the societies that constructed them. However, new information regarding monuments such as Stonehenge and the village excavated at Durrington Walls has revealed that these attracted people in certain periods, not only for their construction and maintenance but also to perform ceremonies.[4]

[1] R. L. Kelly (p. 258n6).

[2] K. Thompson, ed. *Readings from Emile Durkheim* (London: Routledge, 2004).

[3] L. García Sanjuán, "Grandes Piedras Viejas, Memoria y Pasado. Reutilizaciones del Dolmen del Palacio III (Almadén de la Plata, Sevilla) Durante la Edad del Hierro" (paper presented at the El Periodo Orientalizante. Primer Simposio Internacional de Arqueología de Mérida: Protohistoria del Mediterraneo Occidental, 2005).

[4] J. Owen, "Stonehenge Settlement Found: Builders' Homes, Cult Houses," *National Geographic News*, 2007, http://

In Iberia, observations in the field have suggested that megalithic monuments were regularly related to historical paths, and it would not be surprising that some of these paths were traced in earlier times. The later uses of monuments as meeting points and, sometimes, as shelter for the pastoral societies of historical times, testify to the different conceptions that diverse societies can have regarding a place and the features that are present in it through time. The association between monuments and paths could also mean that the monuments were used as markers in the landscape during historical times. It is still necessary to investigate how old these paths are, and to explore the possibility that the roads have been traced since prehistoric times. Thus, special places can be seen as mental markers in the landscape that can influence movement. In this light, it may be said that in order to travel, people develop a series of skills in which ideas and beliefs play an important role in the decisions they make while moving, practicing what may be called *symbolic navigation*.

5.2 TERRESTRIAL NAVIGATION AND GEOGRAPHICAL KNOWLEDGE

In conjunction with symbolic navigation, people use their geographical knowledge and other skills to travel from one place to another. During prehistory, people must have been familiar with their surrounding area from early childhood. The establishment of alliances and friendships between diverse groups probably allowed the knowledge of larger regions. In these cases, as well as when journeys outside the already known geography were carried out, it is probable that prehistoric travelers developed a series of skills and procedures for traveling. Although there is no obvious approach to investigate empirically how people orientated themselves and "navigated" during prehistory, it is possible to understand how people might have built and used what studies in psychology have termed *cognitive maps.* These studies can shed light on the possible ways in which prehistoric travelers navigated through the landscape.

Experimental psychologists and other biological scientists have conducted research in order to understand animal and human traveling behavior.[1] One of the main arguments in such studies is that non-human species that travel long distances in search of food and are later capable of finding their way back home make use of *path integration*. This process enables the traveler to update continuously her/his position in relation to her/his starting point without recording the details of the traveled path. A natural question arising from this observation has persistently dominated research in experimental psychology: how do animals and humans accomplish this process?

Among the skills that have to be learned in order to travel, one of the most important is *wayfinding*.[2] This skill can be thought of as the process of defining and following a route from one geographic point to another. As has been argued, movement is always motivated by a reason and a purpose, and therefore, it will have a direction. The direction leads to the track followed during the traverse and is known as the *route*. The route followed can be the result of a "travel plan" that defines the main points, segments, and deviations of the route.[3] The route may or may not be previously known, but in either case a "travel plan" will be normally followed in order to reach the point of destination.

The repetition of a route helps us familiarize ourselves with the path and memorize its diverse components, which can then be recalled when needed. Usually, paths and routes are represented unidimensionally as linked segments. When more paths or routes are added, the configuration of a network emerges. These representations, along with other elements and their spatial relations (e.g. landscape markers) and non-spatial features of landscape (the ideas of place discussed above), constitute the layout of the experienced environment. The integration of learned routes and developed strategies for route following is instrumental for the formation of cognitive maps. These maps are the internal representations of the ideas that we have about places, their perceivable environmental features, and the relationships that they shape.[4]

In order to make a successful journey, a person needs to establish the points of origin and destination, to know the points of deviation, to be able to recognize landmarks, and to understand the route within a larger frame. The point of destination can be known or unknown by the traveler. In case the traveler does not have any information regarding the route or there is no direct path to the final destination, the traveler will have to make use of a series of skills. These include exploration by sequenced neighborhood search, boundary following, the use of landmarks, recognition of traveled segments, identification of features, spatial knowledge, and familiarization with secondary sources, such as verbal or drawn descriptions.[5] These skills together form what can be called *terrestrial navigation.*

news.nationalgeographic.com/news/2007/01/070130-stonehenge.html.

[1]N. D. Gale et al., "The Acquisition and Integration of Neighborhood Route Knowledge," *Journal of Environmental Psychology* 10 (1) (1990): 3–26.

[2]R. G. Golledge, *Wayfinding Behavior: Cognitive Mapping and Other Spatial Processes* (Baltimore: JHU Press, 1999).

[3]Golledge, *Wayfinding Behavior*, (p. 260n3) 6.

[4]Golledge, ibid.

[5]Golledge, *Wayfinding Behavior*, (260n3) 9.

During prehistory, it is probable that people relied on information gathered from others, their own knowledge of the landscape and even astronomical observations. Different cultures create very different mental representations of space and cognitive maps. These are not necessarily related to western conceptions such as the use of Euclidean distance. However, two important issues must be taken into account. First, according to the evidence gathered from psychological studies, all humans share the same essential mental architecture regarding cognitive mapping. Second, terrestrial navigation in all cultures around the world has relied on the use of a common range of skills and features such as networking and landscape markers.

According to MacEachren,[1] route-based environmental learning is the most common way for humans to "learn" an environment. This means that we learn about our landscape through the experience of "walking" (in) it. It also means that certain features become points of reference used in the process of learning these routes. In the case of outstanding features in the landscape, it can be assumed that they functioned as references for people in the past. Furthermore, there are many ethnographic examples of "natural" elements being used as spatial references. This is the case of the *ceiba* in the Mayan area. The tree was part of the Mesoamerican cosmovision and is still, for many communities, central within a symbolic and spatial framework. These trees are regarded as sacred or as places for important meetings and community events, as well as markers in the landscape.[2]

According to Scholl,[3] in order to travel, humans need to familiarize themselves with a number of processes necessary for the acquisition of spatial knowledge. One of these involves understanding the dynamic, ever-changing relationship between people and objects that takes place while traveling. Another is the establishment of object-to-object representations, i.e. of memorable existing objects encountered along a route, which are more stable and help to anchor the cognitive map. Remarkable features in the landscape are of great significance because without them navigation and representation are not possible. These landscape markers can be used for orientation purposes, while providing important information regarding the environment and the presence of other human groups. Historically, territories were marked by identifiable features in the landscape, informing and warning the traveler of spatial boundaries. In this manner, landscape markers have been not only instrumental in navigation, but have also played an important role as physical evidence of one of the most influential factors in mobility and movement, namely territoriality.

5.3 Territoriality, Social Networks, and Other Relationships

Territories may be thought of as conceptual spaces. It has been argued, however, that territorial behavior is present in almost all living animals and that it is the result of survival behavior. Biologists define the term territoriality as the behavior whereby an animal claims and defends a specific geographic area against other animals.[4] In the case of humans, territoriality has been seen as a key factor in the geographical division of space, for reasons relevant to the acquisition and exploitation of resources. It has also been argued that it is related to an aggressive instinct we share with animals.[5] These ideas have been primarily taken from animal biological studies. From an archaeological point of view, however, the establishment of human territories may be the result of complex motivations that are not necessarily related to "instincts" or aggression at all. In fact, human territoriality may be motivated by a variety of reasons, most of which are not shared by animals. The exploitation of resources, but also the pursuit of power, influence, and control are some of the most common incentives. But management, rights, or power over space can be important not only under material aspects but also under religious and social ones. In this we agree with Casimir and Rao:[6]

> Human territorial behaviour is a cognitive and behaviourally flexible system which aims at optimising the individual's and hence often also a group's access to temporarily or permanently localised resources, which satisfy either basic and universal or culture-specific needs and wants, or both, while simultaneously minimising the probability of conflicts over them.

As a strategy or system, the definition of territoriality is subjected to a series of rules that can be followed to a greater or lesser extent. A territory, for example, can be geographically defined as the property of a certain

[1]A. M. MacEachren, "Application of Environmental Learning Theory to Spatial Knowledge Acquisition from Maps," *Annals of the Association of American Geographers* 82 (2) (1992): 245–74.

[2]C. Dary et al., *Género y Biodiversidad En Comunidades Indígenas de Centroamérica: Un Enfoque Social sobre las Formas de Uso y Conservación de los Recursos Naturales* (Guatemala: FLACSO, 2002).

[3]M. J. Scholl, "From Visual Information to Cognitive Maps," in *The Construction of Cognitive Maps*, ed. J. Portugali (Dordrecht: Kluwer, 1996) 157–86.

[4]T. Malmberg, *Human Territoriality: Survey of Behavioural Territories in Man with Preliminary Analysis and Discussion of Meaning* (New York: Mouton, 1980).

[5]R. D. Sack, *Human Territoriality: Its Theory and History* (New York: Cambridge University Press, 1986).

[6]M. Casimir and A. Rao, ed. *Mobility and Territoriality. Social and Spatial Boundaries among Foragers, Fishers, Pastoralists and Peripatetics* (Oxford: Berg, 1992) 20.

group, but its resources can be exploited by another group with the consent of the proprietary one. Another example is that of religious sites shared by different groups. The rules applied to a territory may be flexible in many ways, but the establishment of boundaries constructs a clear idea of control and power over the specific spatial location. Consequently, territoriality must not be understood as the simple circumscription of things to space, or as defined spaces, but as a relationship in which circumscription is used with the intention to control, to manage (resources, people, ideas, etc.), and to satisfy needs.

The way in which territories are structured is closely related to the manner in which the societies that establish them use the land, how they organize space, and the meanings they give to places.[1] Thus it can be said that territoriality is socially constructed and its manifestation varies depending on its context and time. It must be taken into account that many communities shift between territorial and non-territorial behavior depending on diverse situations, so territoriality must be thought of as a flexible strategy.[2] Other aspects more concerned with social factors, such as traditional sacred spaces, heritage, disagreements, the search for power, and disputes can also motivate the establishment of frontiers or the adoption of different strategies.

These strategies can be varied. It is well known, for instance, that to overcome adverse situations in which territoriality can play a major role, societies create social networks and alliances maintaining regional and far-reaching social ties. There are many ethnographic and archaeological examples in which it is demonstrated that social relations work as safety nets in times of uncertainty.[3] In the case of hunter-gatherer societies, these bonds are crucial because they enable them not to risk starvation or the increase of resource stress by having free access to neighboring lands, not encountering hostility when they arrive. In other societies, these ties are equally important, because the established social networks are normally governed by a series of rights and obligations defining the freedom of movement across any land. In this sense, failure to establish good social relations may trigger not only disagreements, but also greater consequences such as war. Once social networks are established, they require constant attention; they must be maintained and renewed, keeping the information that flows in them accurate and up to date in order to maintain both the social relations and the information in stable and reliable conditions.[4] The only procedure that allows these social networks to be maintained is the practice of movement. The larger the network, the more frequent and extensive this practice will have to be. In this case, the target of movement will be social instead of economic, but it can also be carried out for both purposes.

The manifestation of territoriality can have many different expressions. In the present day, for example, legal rights over property are written down and physical boundaries such as fences are established. In the case of prehistory, the marking of territories may have required the communication of verbal agreements through a setting of landscape markers (natural or created), or by the construction of physical barriers such as walls to protect confined spaces (i.e. settlements).

In terms of mobility, territoriality is an influential factor because it renegotiates the way that space is used and perceived by people within and outside the group that determines the boundaries. In addition, the way in which territoriality is manifested gives information about the group claiming a territory. This information has a direct influence on the decisions that people make regarding their direction of movement. In the presence of territorial behavior, a group practicing residential movement or migrating for any reason will have to settle in a previously inhabited area, or establish agreements with previous or current residents.

In the case of travelers, markers such as stelae, paintings, or carvings provide information about the groups inhabiting the area. Decisions regarding direction of movement depend on the traveler's relationship with the group claiming the territory. Territorial markings are not of exclusive use as advertisers of an entire group. Markers made of stone, wood, and other materials can also be employed to divide areas within the same group, as is the case of herding lands for many communities in the Himalayas, India and Africa.[5]

Unfortunately, the evidence of territoriality is not always available to archaeologists and it can be really hard to recognize whether certain objects or elements were used to denote some form of territoriality. Thus, two of the main problems encountered in the archaeological study of territoriality as an influence for mobility and movement are (1) recognizing the evidence for the practice of territorial behavior, and (2)

[1] R. D. Sack (p. 261n6) 2.

[2] M. Casimir and A. Rao, ed. *Mobility and Territoriality* (p. 261n7) 1.

[3] R. L. Kelly, *The Foraging Spectrum: Diversity in Hunter-Gatherer Lifeways* (Washington: Smithsonian Institution Press, 1995).

[4] R. Whallon, "Social Networks and Information: Non-'Utilitarian' Mobility among Hunter-Gatherers," *Journal of Anthropological Archaeology* 25 (2006): 261.

[5] A. Rao, "The Constraints of Nature or Culture? Pastoral Resources and Territorial Behaviour in the Western Himalayas," in *Mobility and Territoriality: Social and Spatial Boundaries among Foragers, Fishers, Pastoralists and Peripatetics*, ed. Michael Casimir and Aparna Rao (Oxford: Berg, 1992).

defining with precision the area under control of the group. In this sense, studies on settlement pattern can be useful to establish a probable range of action. It is also necessary to look at the evidence of potential interaction with other communities, as well as landscape markers and their possible role as configuring elements of territoriality.

5.3 VISIBILITY

Visibility can be addressed as a complex factor. It can be seen as an independent variable particular to each human being, having also a strong cultural constituent. Visibility has been of importance in archaeology due to its known role in the structuring of human landscapes. According to Wheatley and Gillings,[1] visibility is a cognitive or/and perceptual act that has served "...not only to inform, structure and organize the location and form of cultural features, but also to choreograph practice within and around them." Many past societies created structured visual arrangements of their own settlements, monuments, or landscape with respect to contemporaneous or pre-existing sites or monuments, relevant elements of the landscape, and astronomical orientations.[2]

In terms of social stratification and inter-group relations, visibility may be used not only as a statement of prestige, but also as a means of security, control over resources, or as a defensive strategy. Studies on Bronze Age settlement patterns in the Iberian Peninsula, for instance, have suggested that some communities chose to locate their settlements on the basis of factors such as inaccessibility and visual control of the surroundings. Such structuring of the landscape also served to produce symbolic and religious experiences through visual interplays, as in the diverse, leveled *plazas* of Mesoamerican cities, which have been thought to have ritual connotations. In any case, linked to ideas of what is explicitly or intentionally visible or hidden, visibility had a specific meaning for these societies, which sometimes used features and even the environment to create a specific effect.

The study of visibility in archaeology has experienced a boom since the use of GIS became common, due to the enormous facility that this tool provides for the analysis of large amounts of data.[3] With it, a series of theoretical, pragmatic, and methodological considerations has been addressed, due to the fact that, like mobility, visibility can be approached as an affordance in terms of its complexity, since it is dependent on the actor and on the environment. Accordingly, visibility may depend on factors such as the presence and amount of vegetation, weather and visibility conditions, movement, the visual acuity of the individual, and the physical properties of objects or the surroundings, to mention just a few.

It has been strongly argued that archaeological research has had the tendency to prioritize vision over other senses. Although this may be true, it can also be said that in most cultures the visual appearance of a place has been regarded as the most frequently remembered or described.[4] This observation does not show that "natural" senses are not deeply cultural and historical; the cultural basis of the senses has been emphasized by research on sensory perception.[5] It is for this reason that that we need to consider vision as specific to each society or group, and that it is only one of the many sensory modalities.

Several studies are now exploring the role that the senses play in structuring and understanding the world.[6] world.[6] Mobility is also thought to be a central component of the "perceptual system" and the same considerations and critiques regarding visibility studies apply to visibility while moving, complicating matters more.[7] For example, the view and surrounding environment change dramatically when we are moving, so visibility cannot be considered only from a fixed point in the landscape; this implies methodological complications. At the same time, our perception of the surroundings also changes when we move. Because our perspective is not the same within different points in the landscape, features can appear more visible from certain points than others. Moreover, it is difficult to clarify from how far certain cultural objects could be seen or recognized, something that depends on the characteristics of the features in question but also upon other factors.

As it occurs with human movement, human vision is part of a complex set that interacts with other factors, engaging with other senses from which it cannot be separated. Recent critiques regarding the study of visibility in archaeology have argued that the inseparability of the senses renders their division unwise, and that it would be better to encounter them as a unique "sensorial envelope." This perspective attempts to identify the "…area around a given location from which all the senses are engaged."[8] In terms of methodology, the application would be possible if we

[1]D. Wheatley and M. Gillings, *Spatial Technology and Archaeology. The Archaeological Applications of GIS.* (London: Taylor & Francis, 2002) 3.

[2]D. Wheatley and M. Gillings, *Spatial Technology and Archaeology* (p. 263n1) 3.

[3]Wheatly and Gillings, ibid.

[4]Wheatly and Gillings (p. 263n1) 201.

[5]C. Friedman and M. Gillings, "Seeing is Perceiving?" *World Archaeology* 39 (1) (2007): 4–16.

[6]Y. Hamilakis et al., "Introduction: Thinking through the Body," in *Thinking through the Body: Archaeologies of Corporeality*, ed. Y. Hamilakis et al., (New York: Kluwer, 2002) 1–21.

[7]D. Wheatley and M. Gillings (p. 263n1).

[8]C. Friedman and M. Gillings (p. 263n5) 510.

created a catchment around the individual, within which all the senses could be operating.[1]

Although this approach seems sensible, it is still necessary to determine what would be an appropriate range for these catchments, because each sense has a different range (we may see further than we hear or smell) and each may depend upon other factors as well (the smell of something burning can depend on wind direction, or the range of the peal of a bell can depend on its size and the quality of its fabrication). Furthermore, sensory stimuli are experienced differently by different people. It is acknowledged that senses such as hearing or smell could have been of great importance during a journey (e.g. to pay attention to noises would be a good way to avoid dangers, or the smell of fire or of food being cooked would be an indicator of a nearby village or camp), but in the case of traveling an unknown route, it is thought that vision would play a special role. This is supported by ethnographic examples, which have shown that while traveling unknown segments, people will normally try to sharpen their vision in order to recognize further segments of the path, and they even try to reach prominent geographical points in order to extend their visual range over the landscape. This is not to say that we do not have to take into account the totality of the senses, but it is suggested that for studies on mobility, visibility should be regarded as deeply important.

Psychological studies have demonstrated that when we travel unknown segments or along difficult terrains, our senses seem to be more engaged and we pay more attention.[2] The role of visibility in this process is instrumental. The identification of landmarks and possible paths, the location of the next segments to travel, and the recognition of traveled segments are highly dependent on vision. Consequently, for the study of movement at a landscape scale, investigating possible visual relationships, patterns, and structuring between a route and the landscape can provide invaluable information regarding the ways in which past societies perceived their landscape.

Investigating the accuracy or sharpness of the vision of people in the past is, undoubtedly, a very difficult task. Nevertheless, it is possible to take some modern parameters as referents in order to establish a starting point. A very important task regarding visibility has been to clarify the physical conditions under which human vision works.

One of the most influential factors in human vision is visual acuity, i.e. the capacity to see with high contrast detail at the center of the eye. This is normally measured as Snellen fractions (20/20 in optimal conditions). There are diverse forms of measuring visual acuity, but *recognition acuity*, which refers to the ability to recognize a determined stimulus, has been regarded as the most relevant when identifying distant objects within a landscape. This is the most common measurement for eyesight and its limits are measured in terms of "…the visual angle occupied (or subtended) by the target within the field of vision of the observer, which accounts for both object size and distance from the viewer."[3]

The minimum threshold in the visual angle for the recognition of a small target is 0.5 degrees, while the maximum for recognition acuity is 30 degrees; however, regular vision has been defined as presenting an equivalent of 1 degree of arc. This measurement will be relevant for modeling visibility while moving, but other factors, such as visual range, which is influenced by environmental circumstances, also exist. Lighting and atmospheric conditions can have a great impact. Other studies have covered in greater detail how vision is affected, proposing some methods to overcome these difficulties through combining approaches such as Higuchi viewsheds, fuzzy viewsheds and distance.[4] Regarding this, some studies have suggested that depending on the air quality (measured in relation to the particles floating in the atmosphere), visual range can go from 150±45 km in optimal conditions to 23–39 km in poor conditions. However, site-specific circumstances will have to be taken into account.[5]

Finally, the particular characteristics of objects can play an important role in whether people can see them or not and, if so, how well. According to Ogburn,[6] the human eye can notice really small contrasts in brightness, in which differences as low as 2% can be noticed. Red or bright white objects can be easily caught by the human eye and so can abnormal or unusual shapes. This will play an important role when analyzing the possible use

[1] C. Friedman and M. Gillings, ibid.

[2] J. S. Augustyn et al., "Effects of Locomotion over Varied Terrain on Soldier Vigilance," paper presented at the 26th Army Science Conference. Transformational Army Science and Technology—Harnessing Disruptive S&T for the Soldier, 2008.

[3] D. E. Ogburn, "Assessing the Level of Visibility of Cultural Objects in Past Landscapes," *Journal of Archaeological Science* 33 (2006): 406.

[4] P. F. Fisher, "Probable and Fuzzy Models of the Viewshed Operation," in *Innovations in GIS 1*, ed. M. F. Warboys (London: Taylor & Francis, 1994) 161–75; L. Loots et al., "Fuzzy Viewshed Analysis of the Hellenistic City Defence System at Sagalassos, Turkey," in *Computer Applications in Archaeology and Quantitative Methods, April 1997*, ed. S. Exon et al. (Oxford: BAR International Series 750, 1999) 82.

[5] D. E. Ogburn, "Assessing the Level of Visibility of Cultural Objects in Past Landscapes," *Journal of Archaeological Science* 33 (2006): 407.

[6] Ogburn, ibid.

of monuments and other features as landscape markers for navigation in human movement.

6 CONCLUSIONS

As part of ongoing research, the main purpose of this paper has been to contribute to the theoretical discussion of how humans travelled in the past. In order to provide an appropriate framework for understanding how movement was performed, it was necessary to explore how movement constitutes a social process, concluding that the way in which movement is carried out is intrinsically contingent to each culture. Computational approaches such as GIS have proved to be useful and robust when analyzing human movement. However, the main GIS methodologies for the investigation of movement (such as Cost Surface Analysis) have not escaped from fair criticisms due to their inability to model more complex phenomena. Despite this, archaeological studies regarding human movement using GIS as the main exploratory tool continue to grow day by day, sometimes without awareness of the assumptions made when modeling movement through these techniques. In this sense, the idea behind this first approach was to point out some of the most important variables and factors that influence human movement in general, and to explore how they might have affected people during prehistoric times. Although many of these concepts have been developed in other disciplines, in archaeology they have never been considered as an essential unit that influenced and shaped the spatial configuration of the resulting material evidence of movement. The consideration of these influences is thought to be highly significant for the possible models derived from computational approaches. It is acknowledged that archaeologists do not necessarily obviate the existence of these variables and they normally work with the tools that are available to them. However, there is also the need to explore other technologies such as agent-based modeling, because its combination with GIS now offers a wider range of powerful analysis and possibilities to explore. We expect to have further results in the near future with the application of these concepts to the study of particular archaeological cases.

We should also be aware that with the development of more sophisticated computer models, it is necessary to achieve a better understanding of the factors that affect movement. Understanding past societies is already a tough task for archaeology, due to the limiting nature of the data we work with. If we do not take into account the aspects that influence how humans move, we put ourselves at risk of not only restricting even more the knowledge of the phenomenon, but also of continuing to create deterministic models.

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