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Viewshed Analysis of the Ilave River Valley (M.A. Data Paper, UC Santa Barbara Anthropology)

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ABSTRACT

This paper explores the potential for using viewshed analysis methods with settlement survey data in a grassland environment. Innovations in geographical positioning and spatial analysis technology permits archaeological surveyors to rapidly gather greater quantities and better quality spatial data than was formerly possible. A variety of statistical analyses and agent-based models are made possible with the more exhaustive and statistically robust data. Site location criteria are considered with respect to both the visibility from high viewshed locations, and the sheltering potential from wind, weather, and other humans and animals, afforded by low viewshed locations.

The point locations of several hundred Archaic and Formative sites in the Lake Titicaca Basin, Peru, are known from an archaeological survey project in the Lake Titicaca Basin, and this study compares the sites with a temporally sensitive regional projectile point typology that permits the creation of cultural component categories for about 50% of the sites found in the survey. Site viewshed and location are compared with expectations about the socio-economic context of site occupation based on a regional time-sensitive projectile point typology. It is concluded that while viewshed analysis provides a versatile tool for investigating and better contextualizing landscape relationships, it is not sufficiently precise or statistically independent enough to be used for formal hypothesis-testing. This kind of analysis should be incorporated into settlement pattern studies as one of a number of exploratory tools for better investigating decision-making and geographical relationships within the prehistoric social and ecological surroundings. The interpretive possibilities of viewshed analysis are approached cautiously in this paper because viewshed data co-varies with many other ecological site selection criteria. An optimal site location with respect to viewshed and exposure is suggested, and under certain kinds of sampling regimes this relationship can be assessed quantitatively. Finally, strategies for improving settlement survey methodology are suggested in order to permit more informative data exploration in future work.

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INTRODUCTION

Regional archaeological survey has been recently improved with the introduction of geographical positioning technology that allows archaeologists to gather and to explore survey data in new ways. Concurrently, innovations in geographical computer software have provided tools for the exploration of archaeological survey data and for identifying patterns within the data that may reflect social and economic processes structuring the site distribution (Andresen, et al. 1993; Kvamme 1999). Viewshed analysis is one of these methods; it allows archaeologists to rapidly calculate visible terrain from specified locations, and then to quantify the amount of visible land as it is represented in a generalized terrain model (Lake, et al. 1998; Wheatley 1993, 1995). These viewshed maps can be examined with respect to archaeological data in order to explore connections between viewshed from an archaeological site and other cultural evidence from the site. However, because of the many criteria that might be influencing choice of settlement location, viewshed data is particularly prone to over-interpretation and to statistical abuse. Viewshed data intersects with a variety of environmental and social data, and therefore inference based on viewshed analysis must be considered critically. This study applies viewshed analysis to settlement survey data and examines the interpretive possibilities of this type of dataset in the context of socio-economic change in the Archaic and Formative Periods on the high-altitude grassland of the Peruvian altiplano.

Viewshed calculations are an attempt to analyze settlement and topography as it was experienced by prehistoric decision-makers. As a consequence, viewshed analysis has the potential of representing settlement distributions on the land in ways that are more closely linked to the subjective and experienced world in which past peoples lived. From a theoretical perspective viewshed, such analysis has elements of “materialist”, “ideationalist” and agent-based approaches to archaeological interpretation. Computerized approaches to archaeology are sometimes considered materialist or reductionist techniques because of their emphasis on explicit and measurable environmental phenomena. These methods have been accused of over-representing ecological data and simplifying the more complex social variables that must also inform the interpretation of archaeological data (Gaffney and Van Leusen 1995; Kvamme 1997; Tilley 1994; Wheatley 1998). Viewshed analysis, or the study of total viewable area from a specific location, has been described as a kind of middle-ground in this debate because it is a geographically measurable phenomenon that attempts to reflect experiential decision-making by individuals in the way that it represents the appreciation of high visibility across the landscape, and the way that this quality can influence settlement-choice criteria (Wheatley 1995). Furthermore, the corollary effect of a site having a high viewshed is that the site is generally more exposed to weather and climate. A site having a low viewshed value signifies that the site is probably concealed from view and it is also better sheltered from climate. This paper seeks to address the challenges of interpreting the behavior of mobile foragers and early agro-pastoralists as cultural agents making decisions in an increasingly populated and modified environment. The paper further seeks to address the problems inherent in the interpretation of multivariate data sets that are increasingly easily manipulated with computers.

Because viewshed analysis is based on the topographic attributes of a site, it meshes particularly well with an ecological approach to prehistoric behavior in the region. Ecological studies, with their focus on the role of a site within a regional system, can benefit from modeling the viewshed, intervisibility, and exposure of prehistoric sites. Similarly, those using more contemporary, agent-based analyses with an emphasis on prehistoric decision-making could also benefit from a model of prehistoric viewshed. Studies that emphasize ideological factors also see potential in viewshed analysis, none of the sites that have been tested or excavated from the Ilave valley survey have yielded the type of data that would be appropriate for this kind of interpretative approach. In this paper, issues of theoretical interest to archaeology will be addressed in the ecological context of the regional environment and subsistence and settlement.

DISCUSSION OF PROBLEM

Viewshed Analysis

Viewshed analysis in archaeology is research into the relationship between spatially discrete areas of prehistoric human activity, such as an archaeological site or other loci, and all of the surrounding terrain that is viewable from that archaeological site (Kvamme 1999). Derived from the term “watershed”, viewshed can most-easily be gauged in a qualitative way by simply standing at the site and determining what is within eyesight. One must then consider what prehistoric vegetation may have been present, and how the ancient architectural features of the site could have affected the viewshed of prehistoric inhabitants. Furthermore, one must consider what the people in question were looking at. For example, a small camouflaged target is significantly harder to see at a distance than a herd of large domesticated animals. Assuming an attentive observer with good eyesight, the maximum extent of a viewshed is a function of the observer’s visual acuity, the distance between observer and target, the degree to which the target stands out from its surroundings, and environmental attributes like atmospheric moisture and lighting. A prehistoric environment that was devoid of trees and that had no impediments to eyesight besides topography is the ideal context for an archaeological viewshed analysis.

Viewshed Map Calculation

The viewshed of a site is a delimited geographical space that can be assessed qualitatively in the field, or it can be estimated quantitatively using topographic maps or computerized terrain models. Viewshed from a location includes all terrain within the specified outer radius of maximum viewable distance, and excludes terrain masked from the viewer's vantage point by intervening hills (Figure 1).

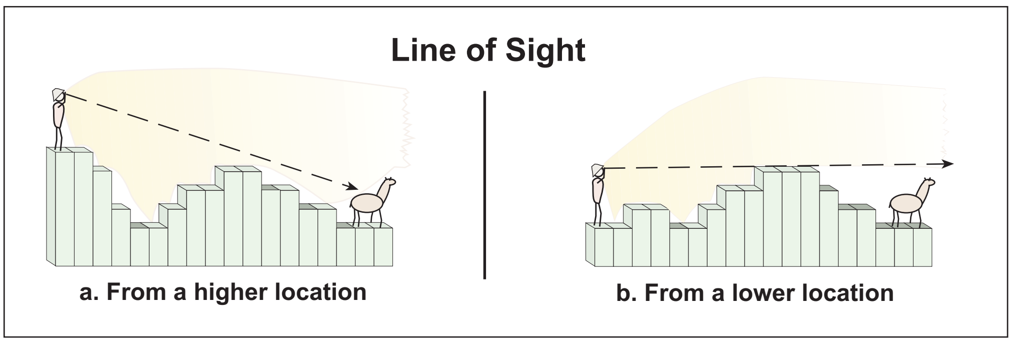

Figure 1. Lines of Sight. **(a)** Visible: A high viewshed results when viewer is on grid cells with relatively high elevation values. **(b)** Not visible: Intervening terrain blocks the view so the camelid and associated grid cells are out of view, and the viewer is generally less exposed to weather.

Computer viewshed calculations represent a digital form of viewshed maps which were formerly laborious, but not impossible, to create from simple topographic maps. Viewshed maps, which are also known as line-of-sight or visibility maps, can now be created on a computer using a Geographical Information System (GIS) operation that calculates visibility between two locations on a computerized model of regional topography (Burrough and McDonnell 1998:200). It is often calculated on a model of terrain known as a Digital

Elevation Model (DEM) that consists of a large matrix of cells, wherein each cell contains a value approximating the metric elevation above sea level for the space represented by that cell (Figure 2). Digital data in such matrices are known as ‘rasters’.

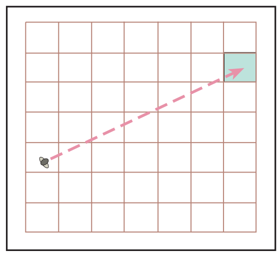

Figure 2. A single Line of Sight (LOS) calculation on a terrain model, as viewed from above. In this study cell size = 50m^2.

The DEM used for this viewshed analysis has cells that measure 50 meters on a side, and the elevation values are derived from contour lines 50 vertical meters apart. In order to calculate a viewshed map from a given location, the computer performs a series of line-of-sight calculations from the source location’s cell to every other cell in the study area (Figure 3).

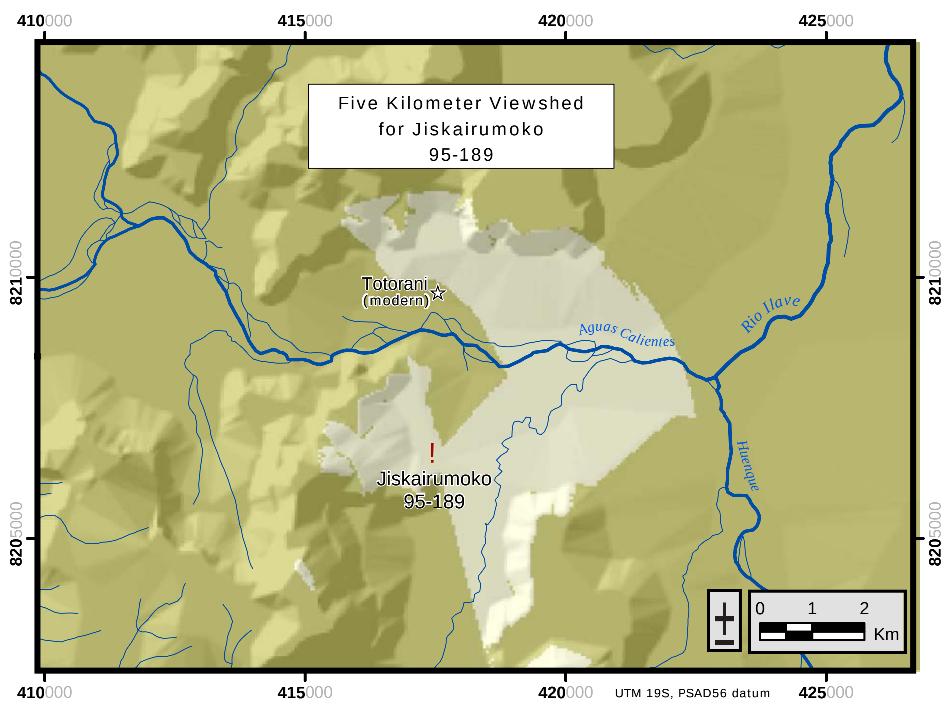

Figure 3. Map of a single viewshed. The viewshed from the site of Jiskairumoko is shown. Lighter areas are visible and are under 5 km from the observer.

When the view of the target is obstructed by cells with a higher elevation value, signifying higher intervening topography, the target cell is flagged as "not visible" in the viewshed map that is generated for that particular source location. The resulting viewshed maps and the quantity of viewable land remains connected to the observer's site location in the GIS, allowing the analyst to explore spatial relationships. As regional analysis usually involves dozens or hundreds of sites, these data are commonly explored after first aggregating them by archaeological categories, such as cultural period, because it better demonstrates general trends connected with theoretical questions. In this study the data is grouped by temporal-cultural period so that it becomes possible to study processes of change over time in the region.

Viewshed data that is calculated traditionally by hand, or more currently by computer, is useful in a number of ways that help to highlight regional patterns in the prehistoric use of space. An association is implied between a site and neighboring natural or cultural features that fall within the site's viewshed simply because of their geographic relationship. Such associations can be meaningful to archaeologists, and viewshed analysis has been used in the study of simple hunter-gatherer sites, such as a study of lookout points for Paleoindian caribou hunters (Krist and Brown 1994), or in looking at the social and military implications of viewshed among complex hunter-gatherers on the North American Northwest Coast (Maschner 1996; Maschner and Stein 1995).

A corollary to sites having low viewshed values that is also meaningful to archaeologists is that such sites are better concealed from both other humans, animals, and from the climate. Low viewshed sites are low exposure sites because they are locally sheltered from climate and especially from the wind. Thus, an inverse conclusion of the viewshed calculation is that it is an evaluation of local topographic surface irregularity (Lee and Stucky 1998). The shelter potential of such locations can be estimated in a generalized way, but protection afforded by vegetative cover and prehistoric architecture is highly variable. To prehistoric groups with especially cold-sensitive resources, such as pastoralists with young animals, locating settlements in places with minimal climatic exposure would have been significant.

Simple viewshed analysis in a GIS can permit rapid quantification and comparison in viewshed between large numbers of sites if the data is already being gathered digitally. However, if archaeological and environmental data is not available in a digital form then there are a number of drawbacks to the procedure that may result in it not being much of an advantage over merely standing at the site, looking around, and taking photographs. In the first place, using a GIS for analysis involves a considerable investment in time, equipment, and data preparation, and therefore unless a more elaborate GIS project is underway it is unlikely that the viewshed operation alone merits the development of the GIS database. Additionally, the viewshed operation is premised on the assumption that the DEM represents the terrain accurately (Kvamme 1990a), that the paleoenvironment can be modeled with relative confidence, that the object of observation stands out sufficiently to be observable, and finally that the perception of such phenomena was relevant and significant to the prehistoric inhabitants. These issues will be addressed in more detail below.

Cumulative Viewshed Calculation and One-Sample Testing

Patterning in viewshed data becomes more apparent when the results from a large number of viewsheds are explored together. Having the GIS sum the raster output from many viewshed calculations results in a single raster representing the cumulative viewshed for the region (Wheatley 1995). This method indicates areas that are visible from many known sites (see background shading in Appendix Maps 3 - 7). These cumulative rasters can be calculated from known site locations, or they can be calculated from randomly-generated observation points offering the possibility of conducting a more statistically rigorous analysis. Exploratory approaches to cumulative viewshed analysis, such as evaluating cumulative viewshed rasters from known site locations against resource patches of interest, will be applied in this study. More formal testing methods could also be applied when they are appropriate to the data and to the research problem. For example, one could test the hypothesis that sites from a time period of increasing sedentism tend to be in defensible positions in order to examine the role of warfare and circumscription in the process of sedentism and resource intensification in the region.

Viewshed analysis can only make use of formal testing methods under circumstances when the study region is sufficiently well-known. “Complete coverage” surveys that seek to characterize prehistoric human use of all space in the survey area (but often with widely-spaced survey transects), as well as random-sample surveys, allow for further analytical possibilities because the entire region is documented (Banning 2002; Parsons 1972; Thomas and Kautz 1983). When the entire study region is considered it is then possible to compare archaeological site locations against a random sample of all locations in that region using Two-Sample tests (Kvamme 1990b). Two-Sample techniques treat the archaeological sites that were found as *Sample Set A*, representative of the population of all sites from that period, and then the random sample taken from locations in the area as *Sample Set B* representing any potential location within the survey. Two-Sample tests, such as Mann-Whitney or Kolmogorov-Smirnov, permit the analyst to evaluate measurements obtained at archaeological sites against an approximation or 'background' of values for the region represented by the characteristics of the random *Sample Set B*.

A more powerful variant on traditional Two-Sample methods that is now made feasible with GIS is the use of One-Sample tests. Kvamme (1990b) describes a number of ways that greater statistical rigor is now possible for regional archaeological hypothesis testing using computer analysis. If values for the entire region can be quantified, such as terrain slope, aspect, or viewshed, then actual population parameters can be determined by considering all of the values for a region. One-Sample methods have the advantage of introducing only variance from the archaeological sample distribution instead of from both archaeological samples and a sample of the environment, and thus test results can be concluded with greater confidence. In other words, the archaeological data is 'observed' data, while the region as a whole serves as an *expected* or *background* data set to compare it against. It is worth considering that with normally distributed *background* data a Two-Sample test that has a high *n* value will have relatively low variance, resulting in a statistical strength approaching that of One-Sample tests. As a computerized analytical technique One-sample tests are an effective way to reduce variance when the computational load is not excessive and the data is appropriate for using this method.

Mark Lake (1998) presents a good example of formal modeling using cumulative viewshed analysis. Lake seeks to address the claim by Christopher Tilley in *A Phenomenology of Landscape* (1994) that a series of Mesolithic sites in Wales are preferentially located so as to have a higher-than-average view of the surrounding region. Tilley argues that the sites are unique overlooks that were historically important to

Mesolithic peoples and thus they were occupied continuously throughout the Mesolithic despite evidence that subsistence opportunities were diminished in the region when sea levels dropped and the shoreline moved two miles further away. Using complete coverage archaeological survey data for the region, as well as local DEM of terrain data, Lake used the One-Sample Kolmogorov-Smirnov test to reject Tilley's hypothesis that the sites were located preferentially with respect to view (to the extent that views calculated on the DEM represent the Mesolithic views). Lake's materialist hypothesis-testing approach is also interesting in that it represents a theoretical approach that contrasts strongly with Tilley's ideational emphasis. Nevertheless, viewshed analysis is perhaps most profitably applied in an exploratory manner that lies somewhere in between these two theoretical extremes. Viewshed analysis can help archaeologists to recognize patterns in settlement distributions and therefore it relates to both ecological and to cultural criteria in site selection that may have been decisive for prehistoric decision-makers.

Viewshed as landscape archaeology

Visibility across terrain is a characteristic of archaeological site location that is possible to model using computerized methods that allow archaeologists to explore the ways that the visibility of surrounding features articulates with other archaeological data. Despite limitations in the representativeness of terrain models and the challenges involved in evaluating the multivariate data that pertains to site location, an exploration of viewshed data permits investigators to evaluate patterns of site locations in new ways that better conform to human decision-making environments. Landscape approaches to archaeology incorporate a variety of theoretical perspectives on the subject of how best to extrapolate from the incomplete nature of archaeological evidence to a more comprehensive explanation of human behavior in prehistory. The contemporary emphasis on *landscape* in archaeology reflects the confluence of current anthropological interest in human-land relationships and environmental degradation, the explanatory debates between individual and cultural evolutionary development models, and the vast technological improvements in computers that can analyze spatial data. Central to the topic of landscape approaches to archaeology is the reconciling of abstracted theoretical models of human and land interaction (i.e., viewshed on a DEM), with measurable remains of human activity, and with culturally construed notions of perception, valuation, and decision-making.

Following on several decades of settlement pattern analysis and formal model-building in archaeology, a critique emerged in the 1980s that, in part, decried the extensive use of a cartographic, 'disembodied' perspective on space and time (Hodder 1985; Shanks and Tilley 1987; Thomas 1993). A major theme in this critique is that the study of behavior exclusively by way of non-situated rational-actor models neglects the emotive and constituting elements in human-land relationships. The claim is that space should no longer regarded as a container for action but a medium for action, one that is produced socially with different groups and individuals creating different spaces. In particular, it is argued that patterns in elements of site location that are inherently qualitative, and yet are often linked to measurable phenomena such as viewshed, were being insufficiently considered due to the emphasis on general processes of adaptive change.

Christopher Tilley's assertion about Mesolithic viewsheds in Wales is an example of this kind of landscape archaeology. Tilley addresses landscape as experience, with a particular focus on "dwelling" in the sense that Heidegger (1977) uses it, as a term conveying an intimate human involvement with physical surroundings that are modified by the human hand, while simultaneously those surroundings shape and give meaning to human experience. Tilley proposes that the continuous occupation of the sites on the coast of Wales throughout the Mesolithic, despite changes in climate and sea level that led to larger changes in the subsistence economy, was the result of local traditions leading to emotional, symbolic attachment to those locations. Lake's response is also a form of landscape archaeology, but it is part of a different theoretical approach that emphasizes ecology and human behavior as it can be modeled for a rational and efficient actor.

From the perspective of the post-processual critique it has been argued that GIS methods cannot be theoretically neutral because computerized categories are by necessity discrete groups, and that GIS approaches are inherently functionalist or environmentally determinist due to the heavy reliance on ecological data in analysis (Gaffney, et al. 1995; Gaffney and Van Leusen 1995; Wheatley 1993). Kvamme (1997) responds that alternatives to the use of discrete categories exist, such as the use of percentage of total variance in a category. Additionally, ecologists are utilizing probability based classification systems termed "fuzzy logic" in GIS applications (Zhu 1997), which holds promise for the non-discrete nature of much social science data. Kvamme (1997) disputes the use of the term "environmental determinism" principally due to its associations with 19th century anthropology, instead he argues that the disproportionate amount of environmental data utilized in GIS models is due to the greater availability of environmental data sets. Ultimately, many critics like Wheatley are not against such innovation *per se*, but they are advocating that archaeologists come up with more creative, non-functionalist applications of GIS techniques. This is, in fact, what Wheatley has done as the first archaeological application of the concept of Cumulative Viewshed Analysis (Wheatley 1995).

Viewshed analysis has potential to contribute to landscape approaches in a number of ways. Among mobile populations site viewshed and site concealment are significant considerations because the presence of humans in the area is not a permanent feature. When local human impact on the environment is minimal, animal populations and other human groups will not necessarily be aware of concealed sites, or even of observers on hilltops. With sedentary groups viewshed analysis also has analytical utility. Under the assumption that in times of warfare groups will settle in visible, not concealed, locations a common analytical application is towards the investigation of the visibility and defensibility of site locations connected to warfare. In times of conflict the positioning of sites in visible locations probably reflected a desire to be seen by others as controlling, or at least attending to, the land within eyesight. In times of growing social hierarchy the placement of architecture, particularly monumental architecture, in high visibility locations may have served as a reminder to the populations living nearby of the locally dominant presence. Among state level societies such visible architecture can serve as a reminder of the hegemony of the state even when the imperial capitol is long distance away (Ogburn 2001). Augmented social control can result from the geographical relationship of commoners living down below a larger residence on a hilltop belonging to the local lord. The daily behavior of commoners may better comply with the domination of local elites if their activities are being scrutinized, or even *potentially* scrutinized, by a watchful ruler (i.e., as with Michel Foucault's panopticon (1977)). This application of viewshed analysis links settlement architecture and social hierarchy, and is relevant to complex societies in prehistoric and historic contexts. Prior to the advent of modern communication methods visual communication and signaling represented the only commonplace means of communicating across distance. If site contemporaneity can be established, the spatial relationships between social subgroups in prehistoric settlements may inform the investigation of strategic relationships and perhaps factions within settlements. Despite some limitations to the method and to the spatial and temporal precision of viewshed analysis results, the technique is a valuable contribution to locational analysis of archaeological site position.

The data and the model

Viewshed data is tied to location and therefore much of the rigorous interpretive potential, particularly applied to small-scale societies, belongs in the larger category of locational or predictive models of site location based on the general expectations of rational-actor subsistence behavior (Jochim 1976). The use of GIS for conducting locational analyses on archaeological space has been explored in recent years by a number of researchers (Kvamme 1999). Locational analysis uses environmental variables to characterize the location of sites and artifacts based on geographical relationships between ecological features and archaeological remains. Locational models emphasize discrete and measurable phenomena, and so they are often linked to economic elements of prehistoric societies. Of the geographic phenomena that are modeled, the first order locational components of foraging and early agro-pastoral economies usually include distance to water, terrain slope, solar aspect, and forage for animals among pastoralists (Jochim 1976; Western and Dunne 1979).

In comparison with other data that are incorporated into a locational analysis, viewshed data are distinct because they are a geographical attribute that co-varies with a number of other important environmental attributes like slope and access to water, but are also more a product of subjective valuation. Therefore on the one hand it should be analyzed differently than these other phenomena because viewshed is a variable that is co-varying with environmental constraints like slope. On the other hand it represents historic, aesthetic, or otherwise 'epiphenomenal' criteria that are difficult to establish for prehistoric behavior. For example, a viewshed analysis of settlement patterns in an environment with highly seasonal rains might identify sites as being positioned in high-viewshed locations for social reasons, when in fact they were positioned in locations that were well-drained during the wet season. Similarly, sites with low viewshed that appear to be in hidden locations may have actually been placed in regions that were less exposed to wind and weather and close to a spring. As a variable viewshed intersects with other geographic components and isolating the effect of viewshed from the other variables in the design of a formal model ought to involve the use of multiple working hypotheses (Chamberlin 1897) in order to find an explanation that best accounts for patterns in the data. In lieu of formal hypothesis testing, an exploratory approach with viewshed data can help researchers to recognize patterns in archaeological viewsheds that may not be immediately apparent in the field.

Viewshed analysis is distinct from most ecological approaches in a number of ways. First, it is an abstraction that seeks to model a specific and situated activity: the act of perceiving from a prehistoric person's eyes. The mere presence of vegetation can drastically change viewsheds, so the coarseness of paleoenvironmental data and the flaws in using a modern DEM for representing ancient viewsheds means that the viewshed analysis is useable at a macro-scale only. Second, the viewshed data intersect extensively with other environmental data so teasing out the decisions based on viewshed from other ecological criteria is a complex issue. Third, the subjective valuation of a site with an extensive view can be inferred from cultural and economic associations, but the subjective priority placed on view can never be known. Viewshed analysis of regional archaeological data is a technique that is greatly facilitated by GIS methods, but it also has a number of complicated issues and assumptions related to its application, these will be explored in more detail.

THE TITICACA BASIN ARCHAIC

The arid Andean altiplano is a good region for viewshed analysis because it contains little evidence of having had dense vegetation at any time in prehistory and the sparse modern vegetation means that there is high ground visibility permitting thorough survey work. The prehistory of the region is important archaeologically because the Archaic and Formative Periods document numerous social changes of theoretical interest such as the shift from hunting and gathering to a primarily pastoral economy, the beginnings of sedentism, and the development of social hierarchy.

This viewshed analysis is based on data from an archaeological survey that took place in 1995 and 1996 in the Río Ilave valley on the south-western side of the Lake Titicaca drainage basin (Aldenderfer 1996). The survey used a judgmental strategy, the implications of which are significant for the resulting settlement pattern and the subsequent viewshed analysis. Another primary source of patterning in the settlement data results from the nature of human use of the arid *puna* environment, and from culturally specific factors in altiplano prehistory like the development of complex societies that flourished along the nearby shores of Lake Titicaca.

The Region

The Ilave River originates in the western Cordilleran mountains and it is the only large river to drain into Lake Titicaca from the west (see regional map, Appendix Map 1). The river lies in the *puna* ecological zone, an arid, high-elevation grassland of low plant productivity and diversity (Aldenderfer 1989; Thomas 1976; Troll 1968). Terraces with little or no slope characterize the terrain relief adjacent to the major streams in the region, and more steeply sloping ridges rise up to 4200m on nearby hilltops (Appendix Map 2). Precipitation is markedly seasonal in the region, with ¾ of the annual rainfall occurring from December through March (Brush 1982). Because the winter is also the dry season there is typically little precipitation in the winter, but the high diurnal variation in winter can result in extremely cold nighttime temperatures. In addition to the common site-selection criteria of low slope and good access to water, a number of other environmental characteristics more specific to the *puna* probably influenced site selection throughout prehistory. Some of these include reduction of exposure to wind and weather, a preference for well drained areas in the rainy season, and access to surface water and *bofedales*, or marshlands, particularly in the dry season.

ILAVE SETTLEMENT ZONES		
Upper Ilave	47 sites	Includes sites in major tributaries above 3850m except Río Huenque, primarily defined to include sites close to and above the confluence of Río Grande and Río Uncallane. Also referred to as Río Aguas Calientes above 3850m.
Middle Ilave/Huenque	60 sites	Río San Fernando (aka Río Aguas Calientes below 3850m) and Río Huenque below 3850m.
Lower Ilave	80 sites	Below confluence of Río Aguas Calientes and Río Huenque, the main Río Ilave.
Ilave Delta	58 sites	Below modern city of Ilave.

Table 1. Ilave drainage by settlement zone, all Archaic and Formative sites considered.

For the purposes of this discussion the Ilave drainage has been broken into four altitudinal zones based on archaeological site concentrations (See Appendix Map 2 and Table 1).

Cultural periods

Archaeological evidence indicates that first human use of the region followed on the deglaciation that occurred during the Terminal Pleistocene and the subsequent movement of herbivores into the region (Baied and Wheeler 1993). During the Archaic Period a mobile hunting and gathering economy gradually gave way to a more sedentary existence that focused on camelid pastoralism and on limited horticulture. The Archaic lasts from around 10,000 BP until the appearance of ceramics around 3,600 BP; the Archaic has been divided into four periods.

PERIOD	*DATES (b.p.)*	*DESCRIPTION*
EARLY ARCHAIC	10,000 – 8,000	Following deglaciation mobile hunter-gatherers follow game to altiplano. Camelid and deer hunting. Wild tubers, seed-plants and reeds available.
MIDDLE ARCHAIC	8,000 – 6,000	Arid conditions. Saline Lake Titicaca. More circumscribed by availability of fresh water. Possible bofedal maintenance for water-tethered wild camelids.
LATE ARCHAIC	6,000 – 4,500	Progressively wetter conditions. Increased intensification on camelids, tubers, and seed-plant resources. Terrace formation, possible locus for early chenopod domestication. Camelid manure facilitates chenopod seed-plant aggregation leading to more efficient harvest. Increase in grinding technology.
TERMINAL ARCHAIC	4,500 – 3,600	Probable complex hunter-gatherer period. Social differentiation, increased sedentism and aggregation, more evidence of ritual structures, probable food storage.
FORMATIVE PERIOD	3,600 – 1,600	Ceramic technology for cooking and storage. Camelid, chenopods and tubers fully domesticated.

Table 2. Archaic and Formative Chronology for the Lake Titicaca Basin .

The Archaic Period developmental sequence in the Ilave Basin is based on changes observed in excavated contexts, faunal and floral remains, and on paleoenvironmental reconstructions of the early and middle Holocene from soil stratigraphy and cores taken from Lake Titicaca sediments (Aldenderfer 1999; Baker, et al. 2001; Rigsby, et al. 2002). Theoretical questions concerning social changes in the region focus on major themes in anthropological archaeology including the first peopling of the region (Aldenderfer 1999; Klink 2002), the domestication of animals and plants (Kuznar 1989; Pearsall 1992), and the beginnings of social stratification and the nature of early sedentism in the region (Aldenderfer 1993; Bandy 2001; Hastorf 1993, 1999).

Viewshed expectations by Period

Changes in the significance of site viewshed to people in various Archaic and Formative Periods is a central interpretive challenge in this study. The conceptual significance of viewshed in prehistory is accessible to archaeologists only to the extent that it affected human activities. A review of ethnographic accounts from mobile hunter-gatherers and pastoralists did not contribute cross-culturally applicable empirical data to improve the interpretation of viewshed analysis results in this study. Ethnography from among some hunting and gathering groups describe a concern on the geography and orientation of structures and especially their doorways with respect to visible landforms like mountains (Berndt 1972; Tanner 1979). However, short of deriving a general aesthetic theory of viewshed, the associations connecting particular cultural emphasis on viewshed on too historically contingent to apply to the Andean Archaic Period. As this study consists almost entirely of simple lithic scatters on the surface, these are data that are primarily suitable to a materialist inquiry.

An ecologically oriented investigation of the role of viewshed in subsistence activity and settlement patterns provides expectations against which to consider the archaeological evidence. Ecological approaches that consider a range of temporal scales and spatial patterns can benefit from viewshed data. Both long-term phenomena, such as climate cycles, and immediate human behavior like campsite selection decisions, must be considered for an adequate appraisal of viewshed patterns. Furthermore, changes in the function of a given site throughout the year, and patterns linked to variability in seasonal, yearly, and multiyear behavior should not be confused with large-scale evolutionary trajectories derived from post-hoc expectations (Binford 1982). In other words, behavioral variability could result in settlement patterns that mislead archaeologists by resembling the long-term changes that archaeologists expect to see, such as resource intensification. Viewshed is one of a number of environmental features to be considered in an optimization model of human behavior, but variability in site function complicates the application of these data to archaeological site patterns.

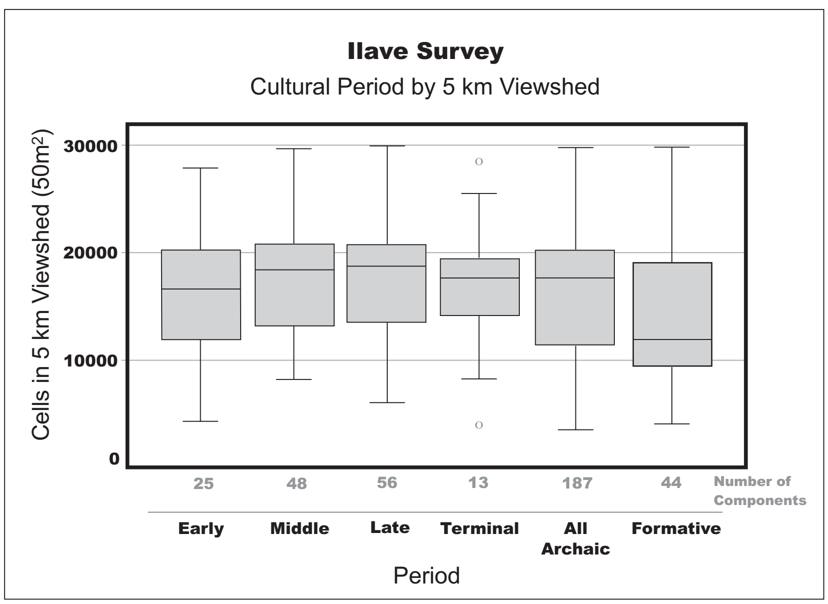

Figure 4. Boxplot showing Cultural period against Viewshed with a 5 km radius.

Under the assumption that viewshed is, in fact, a deciding criterion in site placement, the importance of viewshed in different social and economic systems can be inferred and then compared against viewshed calculations (Figure 4).

Early and Middle Archaic Periods

As the first hunting and gathering groups made logistical and possibly seasonal visits to the region then viewshed can be linked to the monitoring of game animals (Aldenderfer 1998; Jochim 1976; Kvamme 1992). If having a high viewshed is assumed to mean, inversely, that one is highly visible, then an optimal site placement might have been close to good observation points in high viewshed locations without actually occupying them. An optimal site placement may have, in fact, lay in a sheltered area adjacent to a high viewshed overlook, or it may have been a compromise between these kinds of locations. In the Middle Archaic, as arid conditions began to dominate and human populations continue to expand, an increase in the monitoring of camelids using the well-watered marshlands known as *bofedales* may have occurred. A species of wild Andean camelid, the vicuña, is called "water-tethered" because it must have access to drinking water every day (Kuznar 1989). The modern domesticates llama and alpaca are the genetic heirs, in varying proportions, of the wild camelids guanaco and vicuña. John Rick (1980) has proposed that the maintenance of *bofedales* to attract wild herds evolved into herd culling and manipulation, and eventually full domestication.

Late and Terminal Archaic Periods

By the end of the Late Archaic around 4500 BP humid conditions returned, Lake Titicaca water levels rose, and extensive river terraces began forming (Rigsby, et al. 2002). It has been suggested that the terraces were the locus for initial cultivation of the seed plant *Chenopodium* (Kuznar 1993) as a result of a mutualistic relationship with water-tethered camelids using the same riparian zones.

The monitoring of these terrace areas is expected to have increased during this time period. Evidence shows that full domestication of camelids had taken place in the central Andes by at least 5000 BP (Kuznar 1989; Wheeler 1983), meaning that significant movement of goods along the major river valleys by camelid caravans was possible from that time onwards. Based on the emergence of hierarchy in subsequent periods, it is thought that society in this phase was probably one of complex hunter-gatherers with early forms of social differentiation, such as ritual specialists (Aldenderfer 1993). In the Terminal Archaic there is evidence of greater social aggregation in that there are fewer sites overall, but there is a larger Terminal Archaic component at multicomponent sites (Aldenderfer 1997). This aggregation has been connected to the early stages of the sedentarization process, but clear evidence of the intensification on domesticates required for true sedentism is not apparent until the Formative Period beginning 3,600 years ago.

The Formative Period

The Formative settlement data included in this study spans the entire Formative Period (3,600 – 1,600 BP), and as a settlement category it is a very heterogeneous data set that includes vast social and economic changes in the region. At the beginning of this period ceramic technology was first developed in small villages, by the end of the Formative two thousand years later the nearby Tiwanku polity was controlling an enormous territory that straddled the Andes (Bandy 2001; Kolata and Ponce Sangines 1992; Stanish 1992). Therefore the settlement data belonging to the Formative in this study is representative of agro-pastoral lifeways under a variety of political contexts.

Socio-economic changes associated with the transition to the Formative Period significantly alter archaeologists' expectations about land use and settlement patterns, and about site viewsheds as well. With greater sedentism residential groups would have been investing more in particular locations in the form of greater chenopod and tuber cultivation, food storage and livestock facilities. Therefore the site characteristic of having a commanding view would further reflect their investment in nearby resource patches such as *bofedales*. Conversely, sites from this period of pastoralism could be expected to be found in low-lying areas that have better access to water and are better sheltered from the climate. From the beginning of the Formative greater investment in location is apparent from the presence of larger and more elaborate architecture, more specialized use of space, the cultivation of domesticated plants, and the presence of cumbersome ceramics. The mechanics of the Archaic – Formative transition are poorly known, but it is thought that many aspects of the socio-economic pattern associated with the Formative probably had their roots in social developments that first took place during the Late Archaic Period.

As social factors become more complex and resource intensification increases in the Formative Period, social effects can be expected to influence settlement behavior. It would not have been a distinct shift, it probably took place across a gradient from Archaic patterns to Formative patterns over a thousand or more years. Therefore the causes and effects associated with the Formative mentioned below could have occurred simultaneously, sequentially, or independently of one-another. The following developments began to influence the settlement pattern and the probable role of site viewshed towards the end of the Archaic and into the Formative Period.

Land Use Intensification

With population increases the prime *puna* hunting and gathering locations, the well-watered *bofedales*, would have become the high-demand loci for intensification. With domesticated plants and animals, and a greater human population, the demand for *bofedales* may have increased to the point where circumscription would have become a factor. Domesticated plants and young domesticated camelids must be protected from predation. With resource intensification the positioning of settlements so as to be able to observe certain nearby *bofedales* and the monitoring of the plants and animals utilizing the *bofedales* is expected. However, as the animals, especially neonates, are vulnerable to cold during the nighttime when temperatures drop significantly, the corrals where they are kept are likely to have been located in sheltered, low-viewshed locations (Flannery, et al. 1989; Orlove 1977). Therefore pastoralist site locations probably represent a compromise between these concerns.

Social Differentiation

Evidence of special use architecture, grave goods, wealth items, and possible ritual spaces have been documented for the Late Archaic in the south-central Andes (Aldenderfer 1998). Among hierarchical societies the geographical space of powerful individuals and their associated architecture is frequently on physically higher ground. A high location serves the dual purpose of being a visual reminder of community leadership, as well as allowing the leadership to better monitor the activities of others. Proto-historic evidence attests to an Andean tradition of giving topographical superiority to those in control. In the 16th century Garci Diez, a Spanish tax assessor, noted that communities in the Lupaqa polity on the southwest side of Lake Titicaca were divided into “high” and a “low” *ayllus* (moieties) with separate leadership, but that the “high” *ayllu* was always more wealthy and powerful than the “low” *ayllu* (Diez de San Miguel 1964 [1567]; Hyslop 1976). In particular, the wealthiest Lupaqa was the ruler of the high *ayllu* in Chucuito and he was assessed by the Spanish Crown at having thousands of head of camelid. This is not to imply that cultural continuity existed between the Late Archaic and the Lupaqa, but to illustrate how the advantages of higher geographical placement are significant to Andean people.

Use of Travel Corridors

In altiplano river valleys the riverside terraces often represent the best travel corridors. In the areas with more rugged terrain the landform constrictions like mountain passes are also often traveled. Throughout the Archaic these routes can be expected to have been more heavily used by humans and by animals, but with greater land use intensification and the domestication of pack animals the information value of monitoring this movement would have increased. As the camelid trade networks developed the position of communities relative to caravans would have differentially affected their access to exotic trade goods (Nuñez and Dillehay 1979). The ascent of hierarchical societies in cross-roads locations like Pukara in the north Titicaca Basin might be explained, in part, by their ability to broker the exchange of goods from the various productive zones through the control of camelid caravans.

Warfare

There is significant evidence of violence among groups of mobile hunter/gatherers (Keeley 1996), although according to Jonathan Haas (1998), these episodes of intensive fighting in prehistory tend to correlate with significant socio-economic shifts such as the transition to a food-producing economy. While warfare among mobile groups appears to be aimed at removing competitors from the region, with greater sedentism, food production, and storage comes the impetus to raid for material goods (Haas 1998) and for access to women (Chagnon 1968). With increased land-use intensification and circumscription, warfare would have become an important factor in settlement choice. Site densities and analogy with living foragers and pastoralists suggest that warfare was probably not prevalent until Formative times. Warfare is known to have strongly patterned regional settlement patterns and site viewsheds in later periods of Andean prehistory, especially among the complex polities of the warring Altiplano period (AD1100 – 1420) when many sites were positioned at inaccessible but clearly defensible locations (Hyslop 1976; Stanish 1993). Herbert Maschner (1995) has argued that sites among warring chiefdoms in the Northwest Coast were positioned in defensible locations because his analysis shows that increased subsistence costs were incurred as a consequence of settling in high viewshed locations.

Theft of livestock is a persistent concern among pastoralists (Kuznar 1995). The conjunction of livestock domestication around 5000 BP and population increases beginning in the Middle Archaic suggests that there were animals worth stealing and population influxes that could have been threatening to local residents. Therefore early pastoralists should be expected to have been actively monitoring their flocks from predators and from other people. With greater investment in location through improvements in the water distribution to grazing areas and other modifications to the land the nature of conflict between pastoralists may have shifted significantly between the Archaic and the Formative. While it may have reduced risk of theft and surprise to position certain settlements in high viewshed locations, conversely having a site placement in a high viewshed location also means being highly *visible*, so the group in question must be ready to defend their visible position. Placement adjacent to, but not on top of, high viewshed locations is a more strategic choice in contexts where marauders are not aware of the settlement location or where the settlement is not prepared to fight. GIS analysis of this kind of positioning would be greatly helped by higher resolution terrain data and by site boundary polygons. The analysis of strategic placement adjacent to high viewshed locations also requires a more complex GIS algorithm because strategic placement is a situation where visibility is not reciprocal (Figure 5).

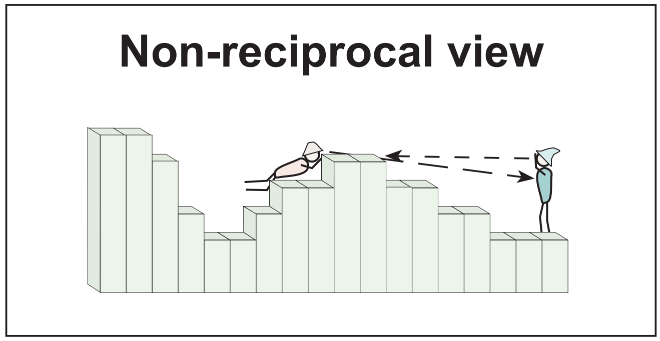

Figure 5. Non-reciprocal viewshed. The individual on the left has a high viewshed, but is not highly visible.

In times of warfare a site placement on high viewshed hilltops might also permit signaling across distances by allied settlements, or it might occur on established territorial borders where hostile groups are monitoring one-another's activities.

The significance of Archaic Period viewsheds to prehistoric human behavior is a broad issue. Economic and strategic significance of viewshed is relatively accessible using ecological measures, but if ideological significance is at all approachable it would by way of architectural patterns that are only faintly detectable in Archaic contexts. Among other things, ecologically-oriented evaluations of viewshed data can provide a depiction of human activities against a model of land use expectations so that fluctuations that could been linked to cultural behavior become more evident.

Cultural Components

In this paper changes in viewshed are analyzed against cultural periods based on lithic types in the Archaic Period, and against Formative settlement as an aggregate. Diagnostic lithics types identify Archaic cultural components that contribute partially or entirely to the remains at a given site. Hence, characteristics of Ilave Archaic components are the essential comparative data for the viewshed analysis. The components were assigned based on the presence of diagnostic artifacts, primarily projectile points, using the latest available typology (Klink and Aldenderfer 2002). Seven Archaic temporal components were further consolidated down into four Archaic Period categories for the purposes of this analysis. In each case a transitional phase was considered as part of the phase that precedes it. Components with the transitional phase Early/Middle were considered as Early, and Late/Terminal were considered as part of Late Archaic. Of the 187 Archaic sites found in the Ilave survey 50% of the sites did not have surface artifacts diagnostic to any time period, and around 30% had artifacts diagnostic to a single period. The remaining 20% of the sites are multicomponent sites, indicating that these locations contained artifacts diagnostic to more than one cultural period.

Because the Archaic Periods are of different lengths of time, a better comparison of land use between Archaic Periods can be determined by calibrating the component count by length of time (Klink 2002). Calibrated counts are calculated by dividing the component count by the time span of the period (Table 3).

CALIBRATED COMPONENT COUNTS					
	Early Archaic	**Middle Archaic**	**Late Archaic**	**Terminal Archaic**	**Formative**
Time in years	2000	2000	1500	900	2000
Count	25	48	56	13	44
Calibrated Count	0.013	0.024	0.037	0.014	0.022

(Calibrated Count = Component Count / Time in Years)

Table 3. Ilave survey calibrated component counts.

The Formative Period calibrated count is not particularly meaningful because it is a very heterogeneous data set and the ceramic analysis that will permit more sensitive component distinctions in the Formative has not yet been completed. Throughout the Archaic Period the calibrated component count shows a dramatic rise, indicating that there are relatively more sites represented from later time periods. Numerous explanations are possible including immigration into the Titicaca Basin, population increase in situ, or changes in settlement organization that resulted in greater component dispersal in later periods (Klink 2002). Additional information about individual Archaic components will help with the analysis of this data. Single component sites are particularly informative because the site size and density informs us exclusively about sites from that specific period. There were 53 single component Archaic sites found in the Ilave survey (Table 4).

SINGLE COMPONENT SITE SIZE AND DENSITY						***ALL SITES***
		Early Archaic	**Middle Archaic**	**Late Archaic**	**Terminal Archaic**	**All Archaic**
	n	7	20	22	4	187
Size (m^2)	μ	1418.2	2021.8	2309.1	2307.7	2442.2
	σ	495	1439.9	2332.5	1785.1	3850.8
Size (ranked)		Small/Med	Medium	Med/Large	All sizes	Medium
Density (ranked)		Low	Moderate	Low/Mod	Low/Mod	Low/Mod

Table 4. Ilave survey single component Archaic sites, size and density. Ranked data values indicate the modal rank for the category.

Single component site data indicates that sites tended to become larger in later time periods, but there is also considerable variability in site sizes in the later Archaic Periods. The larger mean site size that is associated with later periods suggests that the increase in calibrated component count through the Archaic (Table 2) is not a product of component dispersal but rather of population increase.

A trend that has been noted in Ilave and Huenque settlement patterns is the tendency toward greater settlement in downstream parts of the drainages during the Terminal Archaic Period (Aldenderfer 1997; Klink 2002). This pattern becomes even more pronounced during the Formative Period. Increased use of the Río Ilave valley below the confluence of the Río Huenque and the Río Aguas Calientes is evident in the percentage of sites from each component present in the lower valley.

USE OF THE RIVER VALLEY										
	Early Archaic	**%**	**Middle Archaic**	**%**	**Late Archaic**	**%**	**Terminal Archaic**	**%**	**Formative**	**%**
Upper Ilave	6	24	15	33	13	24	2	15	9	20
Middle Ilave/Huenque	14	56	21	46	24	44	5	38	15	34
Lower Ilave	4	16	10	22	13	23	5	38	11	25
Delta	1	4	0	0	4	2	1	8	5	11
Component Count	**25**	**100%**	**48**	**100%**	**56**	**100%**	**13**	**100%**	**44**	**100%**

Table 5. Use of river valley as a percentage of each component.

Use of the lower Ilave zone increases in later periods of the Archaic. This is especially evident in the Middle and Late Archaic components, periods that have the highest counts and therefore the most statistical strength. The percentage use of the Middle Ilave / Huenque zone remains constant in the Middle and Late Archaic, but whereas 33% Middle Archaic sites are in the Upper Ilave, 22% of the sites lie in the Lower Ilave and Delta. The opposite is true for the Late Archaic, and this relationship reflects an overall trend towards greater use of the Lower Ilave zone in later times of the Archaic. A number of explanations can be postulated to help to explain this trend. The movement may reflect a greater use of Lake Titicaca for resource procurement as the lake became less brackish in Late Archaic. Alternately, it may reflect a shifting emphasis towards managed resources and incipient domestication of camelids and chenopods.

It is not surprising that among the Archaic sites found during the Ilave survey the component count has a significant positive correlation with site size (Spearman's $\rho = .366$, $\alpha = 0.01$). As expected, occupation over many component periods results in larger sites.

Another positive correlation exists between site viewshed and component count, although it is not significant (Spearman's $\rho = .104$, $\alpha = 0.01$, significance level = .156).

VIEWSHED BY COMPONENT COUNT					
Number of components	**Number of Archaic sites**	**Percentage of Archaic sites**	**Site Size** (modal rank)	**5 km viewshed** μ ($50m^2$ cells)	**5 km viewshed** σ ($50m^2$ cells)
0	95	50.8%	Small	16467.1	5864.2
1	55	29.4%	Medium	16861.5	6265.6
2	26	13.9%	Medium	17391.6	5905.0
3	9	4.8%	Large	18412.7	2995.9
4	2	1.1%	Very Large	22027.5	4683.2

Table 6. Viewshed by component count. Viewshed data provided using 50 m^2 cell counts.

This indicates that the locations that were occupied during the greatest number of time periods tend to be sites with relatively large viewsheds (Figure 6). As previously mentioned a number of the characteristics of high viewshed locations, such as more exposure to weather or greater distance to water, often make these locations less desirable for settlement. One would expect a weak or negative correlation between viewshed and component count given the exposure to weather in high viewshed locations, although the coarseness of the terrain model might not reflect sheltering elements of the most popular site locations, and spring water sources near high locations are possible.

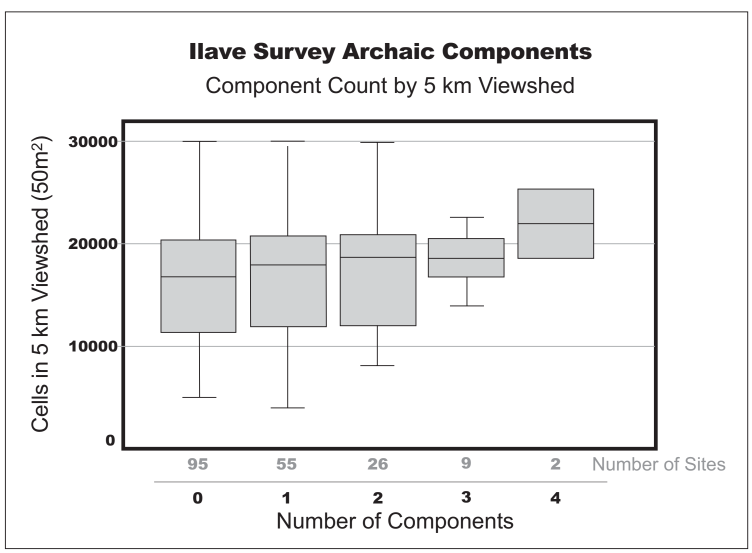

Figure 6. Component count against the Viewshed. This is an non-significant positive correlation (Spearman's $\rho = .104$, $\alpha = 0.01$, signif. level = .156).

The component count against viewshed analysis in Figure 6 indicates that there is a positive but non-significant correlation between the two datasets. While the four component sites have high viewsheds, the high standard deviation of the viewshed values and the low number of sites with four components makes for a non-significant correlation.

An analysis of viewshed and component counts for Archaic Period sites rests on the issue of settlement organization. Variability in site function in the context of the larger pattern of land use makes the assigning of fixed roles to sites on account of a single environmental characteristic, like viewshed, problematic (Binford 1982). Furthermore, a sheltered site with a nearby high-visibility overlook may be the optimal site positioning throughout the Archaic, but this kind of contextual information is not directly available in the viewshed data at this scale of analysis. Component count can help to evaluate the priority placed on site viewshed or exposure throughout the Archaic, and as an aggregate of Archaic Periods it can serve as comparison set against which to evaluate viewshed data for specific components.

METHODS

Survey Methods

Directed by Mark Aldenderfer, the Ilave Survey took place in 1995 and 1996. Surveyors walked transects that were 10 meters apart, and recorded sites from all precolonial periods. Surveyors were especially vigilant for Archaic sites because they can be harder to detect. The Ilave survey was designed to establish whether there were Archaic Period sites in the little-known interior away from Lake Titicaca, thus the survey focused on the terraces and pampa close to the Río Ilave because that is where the highest site densities were expected to be found (see Ilave Survey area in Appendix on Map 2). As a result of this survey bias towards river terrace areas, there are statistical limitations to characterization of regional land-use that can be derived from the survey data. What is lacking is information about where people *weren't* living so that the settlement structure can be discussed more generally (Banning 2002). On the other hand, of the benefits of using a judgmental survey strategy on the Ilave survey is that it succeeded in locating a large number of sites (n = 464 total), therefore despite the survey bias greater statistical strength is available in the analysis of the results. Significant assumptions are also made regarding the assignment of lithic components and spatial extent of components at Archaic Period sites, assumptions that are made regularly in pre-ceramic period surveys.

Because the riverside survey regions were selected by the investigator a-priori with the expectation that they would have a higher site density, it was anticipated that the data would be highly spatially autocorrelated on a regional scale (Burt and Barber 1996; Goodchild 1986; Kvamme 1990a). As a consequence of this high spatial autocorrelation and the even larger problem of sampling bias, the samples are less fully independent and any resulting statistical inference will be less powerful. In an adjacent river drainage, Cindy Klink's 1997-1998 Río Huenque survey (2002) used a stratified sampling strategy and found only occasional isolates away from the riverside terrace ecozone. This suggests that Aldenderfer's judgemental Río Ilave survey captured the vast majority of the sizable sites in the area. Nevertheless the lack of survey data from nearby overlooks in this study weakens the data for viewshed analysis as we do not have information about the structure of prehistoric utilization of the valley on the whole (Banning 2002). That is, a few small retooling sites on a hilltop with diagnostic projectile points could have a significant impact in an analysis of changing patterns in site viewshed.

Site distribution data used in viewshed analysis are generally the result of a pedestrian survey wherein sites are identified, characterized, and geographically located. Survey methodology has been a subject of much discussion in archaeology (Banning 2002; Parsons 1972; Plog 1978), and issues with sampling strategy and bias are elaborated upon in the literature. There is a long running debate on the theoretical legitimacy of the "site" concept (Binford 1992; Dunnell 1992; Dunnell and Dancey 1983; Thomas 1975), with some arguing that projecting the delimited 'site' onto human activities in prehistory is unjustified, and so they suggest using "siteless survey" techniques. Siteless survey attempts to avoid the theoretical flaws of the artificial site distinction by considering all artifacts as distributed in a continuum across the land as a result of continuous activities and land-use (Dunnell and Dancey 1983; Foley 1981). However, the use of the traditional site distinction in survey and excavation has methodological advantages that are difficult to do without. Considering that almost all reliable temporal control comes from excavated stratigraphy within a 'site'. Technological innovations like GPS units and handheld computers solve some of the logistical problems of siteless survey, so this style of survey data recording may become more widespread. In this study a site-oriented approach is used, but viewshed analysis is not inherently a site dependant technique. Viewshed calculations are performed from a particular raster cell to other cells, and isolated scatters on prominent overlooks are good candidates for viewshed analysis provided the resolution of the DEM is fine enough to represent this terrain feature.

Two sites located in the Ilave survey had all four Archaic cultural periods as well as Formative construction represented, these were Jiskairumoko (95-189) and Kaillachuro (95-203) (Map 2 Inset). Both were tested the following year in 1997, and Jiskairumoko was excavated in 1998-2001. Because this area includes these two sites, as well as having the largest stream confluence and the highest site densities, a 2x enlarged inset map is included in the Appendix maps.

Data Input

Data entry is the most time consuming step in most GIS analyses. The data used in this study were entered by students in years past. The terrain data and hydrology were digitized from Peruvian government 1:100,000 topographic maps of variable accuracy (IGM 1986). DEMs were created from the digitized contour lines in Arc/Info GRID using the ANUDEM algorithm and pits were removed from the DEM using the SINK function (Goodchild and Mark 1987; Hutchinson 1993). The DEM has a 50 meter cell size and has 1 meter interval, although the source map had a 50 meter contour interval.

Archaeological sites were recorded as GPS points with no post-processing when selective availability was in effect, therefore the points are only accurate to approximately 100 meters. At each site the GPS data was collected at approximately the center of the designated site area. The sites were surface collected and site boundaries were established based on density of surface artifacts.

GIS techniques

The Visibility algorithm available in ArcView 3.2's Spatial Analyst 2.0 extension was utilized in the calculation of cumulative viewsheds for each of the components of the Archaic and then the Formative Period as an aggregate. The point feature shapefile containing each site location of interest must be prepared for the analysis by creating appropriate fields used by ArcView or ArcInfo. The steps are as follows: Delete all extraneous fields from the point shapefile leaving only the key field such as “Site Number” in order to later join the results back to the database. In the Shapefile Table create two Float (1 decimal place) type fields named “OFFSETA” and “OFFSETB”, as well as Short Integer type fields named “RADIUS2” and “VIEW5K”. Next, use the Field Calculator to fill the OFFSETA and B fields with “1.5” and fill the RADIUS2 field with “5000”. Leave View5k blank. The offset A and B fields determine the metric height of the observer and target, respectively, and the Radius2 value sets the maximum visible distance in meters. A metric height of 1.5m was used as an approximation of the eye-level of early Andeans based on skeletal remains (Quilter 1989; Verano 1992). A full explanation of the Visibility operation can be found in the ESRI Arc/Info documentation (ESRI 1995).

Five Kilometer Intervisibility and Cumulative visibility

With the point features of a given component selected and the DEM of the region loaded into ArcView 3.2 the Visibility script is run and the result is a raster wherein each 50 meter grid cell contains an integer representing the number of point locations that can observe that cell. The background coloration of the terrain in Maps 3 - 7 is how this cumulative visibility raster might appear.

Intervisibility values were calculated for each point feature by using the Summarize Zones (Arcview 3.2) or Zonal Statistics (ArcMap 8.1) command to query a point location against the value of the background raster to which it is registered. Graphs of cumulative viewshed and of cumulative intervisibility values for each component appear below (Figures 6 and 7).

Five Kilometer Viewshed

The same ESRI Visibility script described above is utilized for calculating individual site viewsheds. However, the Visibility Avenue script aggregates all visibility rasters into the cumulative raster mentioned above, making it impossible to determine individual site viewsheds. Nathan Craig has modified this script in a way that causes the program to generate and retain a separate raster for each point feature selected in the Feature Table. The resulting rasters are single site viewshed maps as shown for the Jiskairumoko site in Figure 3. All cells visible to the point location are coded with a value of ‘1’, and the non-visible sites are coded with a ‘0’. The tally of cells of value ‘1’ for each raster was manually entered into the ‘View5k’ field in the feature table that contained all 231 Archaic and Formative sites with diagnostic surface artifacts. The Site Number field is used to join the View5k and Intervisibility data back to the site database for further analysis.

Analysis of Results

Statistical analysis of the results was completed in SPSS v10 and in Microsoft Excel 2000. SPSS provides statistical summary tools that facilitate data exploration, in addition to containing non-parametric tests such as the Kolmogorov-Smirnov Goodness of Fit test. Excel provided statistical summary and graphing functions.

As the survey data is not exhaustive and viewshed intersects with many other settlement variables, formal testing is not a part of this study. In lieu of hypothesis testing, the data is explored and patterns are examined using the software. The following relationships were examined:

- Cultural period against site viewshed / exposure.
- The cultural component count against viewshed.
- The degree of intervisibility of sites from the same time period.
- Landforms against cumulative intervisibility.

It was hoped that cumulative viewsheds from cultural periods could be compared against cumulative viewshed for randomly generated site locations in order to examine changing viewshed values through time against an 'expected', or random viewshed value for the region. However, the randomly generated site locations were frequently in small gullies and other low view locations that rarely contain sites. The result was an extremely low cumulative viewshed value, not at all comparable with cumulative viewsheds from specific cultural periods. It would be possible to delineate high probability zones with a locational model of settlement in the valley using slope and distance to water as its first order determinants. Given the judgmental nature of the survey and the relatively coarse terrain model data, it was not possible to either test the strength of the locational model, or conduct a formal cumulative viewshed analysis of the Ilave survey data its current state. Despite restrictions on the formal analysis potential of this data set, exploration of the data provides valuable insights into settlement strategy changes throughout the Archaic and methodologically helps develop the technique for applications to other survey data.

LIMITATIONS AND ASSUMPTIONS

The application of viewshed analysis is constrained by a number of assumptions connected to the data, the procedure, and the results. The principal issue with viewshed is that viewshed values are derived from environmental data that also inform archaeologists on a number of settlement patterns characteristics that are usually considered more decisive as site location criteria. In other words, it is difficult to establish the principal determinant of site location because of the multitude of variables that may be significant. The term *equifinality*, borrowed from General Systems Theory, describes the situation where a variety of behaviors can result in similar patterns in archaeological remains (Bertalanffy 1968). This describes a basic complexity to viewshed analysis wherein settlement distributions that appear to reflect viewshed as a criterion are perhaps the result of other influential environmental factors such as water and wind or other humans who make up the social environment. As a consequence viewshed data have a number of inherent limitations that must be kept in the forefront of any analysis.

Assumptions about the Data

Survey assumptions

One significant assumption of the Ilave survey data is that the site database represents all sizable sites within the study area ecozone, and that the human use of adjacent overlooks outside the riverside survey area do not overly distort the viewshed pattern in the known area. In addition, assumptions are made about site characterization because it is assumed that artifacts are diagnostic to component periods, and that it is possible to distinguish the spatial extent of each period at multi-component sites based on projectile point style differences. The seriation of diagnostic lithic types in order to assign sites to cultural periods is a kind of normative assumption because lithic styles are aggregated around a type during a given period. While this form of relative dating has its limitations it is extremely useful for roughly dating sites using the large number of surface and disturbed-context projectile points that are found during survey work.

An assumption was made about site location that also affects the viewshed analysis. A given site was located with a GPS unit by deriving the UTM coordinates of the apparent center of the site, and this location is used in the GIS as the site location. However, if GPS data were gathered in polygons from the perimeter of the site or, better yet, the perimeter of each component in a site, the analysis would benefit in two ways. First, one would have a more precise measure of site size according to the boundary placed at the site. Second, one would be able to better investigate the variability of viewsheds from locations within a given site or adjacent to a given site (this would also be facilitated by using a higher resolution DEM). An expectation of this paper is that the optimal settlement location is adjacent to, but not actually placed on, a high viewshed location, so the proximity to such locations is important. Some sites might have debitage extending into the high viewshed locations because tasks like reduction were performed there while monitoring the river valley. Making data collection more spatially explicit would allow for a viewshed analysis that addresses settlement strategy in a more specific manner.

Terrain model assumptions

Terrain data is represented by a Digital Elevation Model in many GIS-based viewshed operations (Burrough and McDonnell 1998). DEMs can be created from orthophoto pairs, from satellite imagery, or, as in the case of the Ilave topographic data, the DEM can be interpolated from digitized contour lines. Therefore the model is assumed to represent the topography on a 1:100,000 scale Peruvian Instituto Geográfica Nacional map, which in turn is assumed to accurately represent Archaic Period topography.

The use of modern terrain as representative of the prehistoric terrain is a big assumption in many regions of the world where prehistoric forest cover is difficult to model. Regions with moderate or high prehistoric vegetation are less good candidates for viewshed analysis because variability in vegetative cover introduces a large degree of uncertainty to viewshed estimates. Fortunately the Río Ilave is in an arid *puna* environment, so the dominant vegetation consists of sparse, low-lying grasses. Historic events of later time periods, particularly construction and mining activity in the Spanish colonial period, probably further denuded the region of trees, but there is no evidence that forests were of a significant size in any time period.

The study area terrain is likely to have been different in the past due to influences like the erosive effects of the highly seasonal rain, the occasional El Niño year, and the fact that the study area is in, or adjacent to, a fluvial flood zone (Rigsby, et al. 2002). The Río Ilave is thought to have cut down 20 meters since the Early Archaic when the river was around the elevation of what is now terrace 4 or 5. In addition, there is speculation that the terrace formation that took place at the end of the Middle Archaic around 6000BP is linked to the intensification on *Chenopodium* that occurred in the subsequent Late Archaic (6000 – 4500BP). This viewshed study seeks to find changes in settlement pattern linked to social processes and land use, therefore there is circularity problem because natural processes linked to the socioeconomic developments in Archaic could have altered the terrain upon which the viewshed is being modeled. Bias introduced by the DEM model and by the geomorphology of the region means that conclusions will have to be arrived at with caution, especially for the periods that precede terrace formation in the later Middle Archaic.

Assumptions about the Viewshed Calculation

The viewshed analysis procedure must remain generalized because it necessarily contains assumptions about the nature of visibility that distort the results when considered at the scale of the site, or the scale at which an individual would experience viewshed. Reciprocal visibility is a major source of uncertainty about viewshed analysis and it consists of two major assumptions. First, for individuals at settlements to be observing one-another they must be occupying the settlements at the same time. Due to poor chronological control, establishing site contemporaneity is near impossible in this kind of analysis, such that all interpretive work must remain on a temporally general level. The temporal resolution of carbon-14 dating is ±40 years at best, and in this region it is only by means of refitting studies can better temporal control be achieved. In this study diagnostic artifacts have been aggregated into categories that are between 900 and 2000 years long, hence two sites that are "intervisible" in the Middle Archaic could have been occupied by individuals that lived literally 100 generations apart.

The second major assumption concerning intervisibility is a geographical one: whereas *viewshed* is the aggregate of all the lines-of-site from a given location as calculated on a DEM (Figures 1 and 2), *visibility* is a measure of how many other locations can observe a given location. If it is assumed that viewshed and visibility are the inverse of one another, then the visibility of a location can be quantified by adding up the number of times that location falls within a viewshed in a given area. However, on the ground viewshed and visibility are not the inverse of one another (Figure 5). Specific characteristics such as camouflage colors or hidden placement immediately behind a higher point can obscure a good viewpoint without it being highly visible (Fisher 1995; 1996). This issue has been thoroughly researched and is discussed in the literature, perhaps because it has military applications today as it did in prehistory. An example of the use of GIS visibility calculations in modern warfare is when it is used for selecting low-visibility transportation routes for military vehicles (Keith Clarke, personal communication).

Other assumptions are made about visual acuity over a distance in the analysis. It is assumed that neither smoke, nor haze or poor light obscure the view within the specified maximum view buffer. It is assumed that individuals have good eyesight, although with the high solar radiation on the altiplano cataracts and other eye conditions are evident among modern residents. Hunter-gatherers and early pastoralists should be expected to have fairly high visual acuity (Allen 1988), however, and their ability to discern game and movement over a distance would be well-honed.

Interpretive Assumptions

Assumptions about the significance and interpretation of viewshed data are the most problematic, they have been mentioned previously and should be made explicit. Beginning from the understanding that eyesight has a highly evolved subsistence function in higher primates, structuring universals do exist in vision such as focal colors (Berlin and Kay 1969). These universals to human vision, a product of natural selection, supports the extrapolation of physical viewshed well into prehistory. Therefore it is assumed in this study that, except for individual variability, prehistoric peoples would have had physically identical visual systems to modern populations.

The larger issue of the cultural salience of visible features and landscape poses the greatest challenge to connecting modeled viewshed with prehistoric human behavior. Uncertainty as to what humans will *choose* to observe is a central weakness to viewshed analysis and is based on the connection between vision and cognitive / cultural priorities (Bender 1993; Roe and Taki 1999; Segall, et al. 1966). Expectations can be generated concerning which objects were visually prominent prehistorically using models of environmental, social, and ideational factors. Such expectations are also based on auxiliary archaeological and paleoenvironmental data, and therefore with regions and time-periods for which little is known it is possible to only crudely speculate about what people would be observing from high viewshed places. Conjecture about the kind of targets being observed prehistorically is a necessary step in the selection of viewshed radius in the analysis. In this study, a 5 km radius of maximum visibility was used under the assumption that phenomena of principal interest throughout the Archaic and early Formative, small groups of camelids and humans, are typically indistinguishable beyond this distance.

An interpretation that uses economically based expectations about activities could connect site viewshed with the monitoring of procurement locations such as *bofedales* and travel corridors, as discussed previously. However changes in settlement pattern connected with social and economic changes in the region would result in more complex patterns of behavior that are still subsistence-based, but that also reflect new elements in settlement-choice criteria. Developments in the later Archaic Periods include resource intensification and incipient domestication, population increase, greater sedentism, increased circumscription, and probably warfare. The cumulative effect that these developments would have had on settlement strategy and viewshed patterning is uncertain, but it is possible that they were geographically systematic and distinct enough to be apparent through data exploration.

As relatively little is known about Archaic settlement choices and evolutionary processes, it is not feasible to construct elaborate expectations for formal tests about viewshed patterning. The most productive use of the viewshed patterns, especially when they are derived from judgmental survey data, is to explore the data with a minimum of post-processing or assumptions about process, and to look for patterning that may inform us about the social and economic developments known to have occurred by the end of the Archaic Period.

Hypothesis testing or Exploratory Data Analysis?

Despite limitations to viewshed modeling in forested regions Mark Lake (1998) utilized a formal hypothesis-testing approach in South Wales. Viewshed analysis is, however, often more amenable to exploratory analysis than to testing with formal arguments because viewshed data is appropriate to limited inferential statistics only under particular circumstances. When the data is appropriate to hypothesis testing the approach can potentially test claims about visibility with statistically significant results, given the assumptions involved in viewshed analysis.

RESULTS

Results from the viewshed analysis are presented graphically in the Appendix Maps (3-7). The Early Archaic settlement concentration in upstream locations is the most distinct patterning in the survey results, and similarly it is the largest observed patterning in the viewshed data. The distribution of Middle, Late, and Terminal Archaic components follow a trend of occupying similar down valley locations, as was noted by the surveyors in the published reports and in this paper above (Table 5).

Cumulative Frequency Graphs

A cumulative frequency graph that includes all four cultural components from the Ilave Basin Archaic, as well as all of the Archaic sites taken as a group, contains interesting patterns in the site viewsheds, particularly with respect to the Early Archaic (Figure 7).

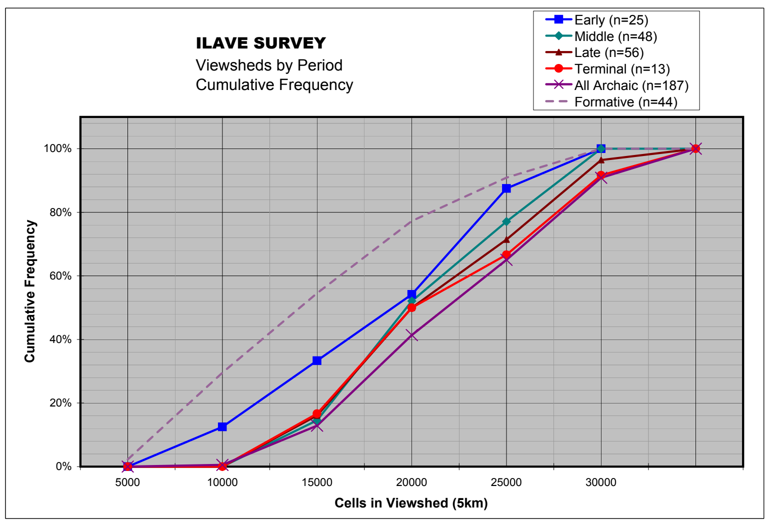

Figure 7. Cumulative viewshed of Ilave cultural periods and viewshed.

Cumulative frequency graphs can be used for comparing categories of different sizes because they are scaled by their percentages. The Early component is distinct in this graph because notably 40% of the sites have viewsheds under 18,000 cells, and almost 88% of the sites have fewer than 25,000 cell viewsheds while in the other components only 60% - 76% of the sites have such small viewsheds. In other words, Early Archaic sites tend to have lower viewsheds both among the very low viewshed sites considered as a group, and among the relatively high viewshed sites as a group. This reflects the bimodal nature of the viewsheds for majority of the Early Archaic sites in the middle and upper zones of the Ilave valley. A second pattern that is apparent from that cumulative frequency graph is that there is a spike in the Middle, Late, and Terminal components around locations with 20,000 cell viewsheds. Many of the sites in the eastern settlement cluster along the lower Río Ilave have viewsheds in this range, and this area was lightly occupied in the Early Archaic. Hence, this pattern probably corresponds with a movement downstream in later periods. The All Archaic sites cumulative frequency provides a dataset with a high n-value of 187, and it provides a comparison with settlement viewsheds trends for the whole Archaic Period. The Formative Period cumulative distribution in Figure 7 is a smooth increment from low viewshed sites to high viewshed sites. The socio-political diversity represented in the category probably explains a lot of the variance in the data, and the contradictory demands of pastoral site settlement criteria, for both shelter and for topographical prominence, also might explain the strong representation of all different viewsheds.

Intervisibility

Exploring the intervisibility between settlements as a cumulative frequency graph is also informative (Figure 8). Intervisibility appears as the background shading in the settlement maps (3 - 7), and the cumulative frequency graph is derived by querying those same values used in the shading by the locations of sites themselves. While this measure has some weaknesses, it is included because it is useful in two respects. First, it can be used to gauge the local intervisibility between communities and from communities to landforms, a measure that may be particularly interesting in the case of military alliances. Secondly, it is a measure of local terrain roughness that is distinct in areas where the land is undulating versus the areas where the land consists of flat terraces. The problem with this is measure is that it is highly affected by the aggregation of settlements. The settlements that have a lot of sites within the 5 kilometer limit of visibility are going to be very highly intervisible. A second problem with the notion of 'intervisibility' is that it is premised on the assumption of contemporaneous occupation.

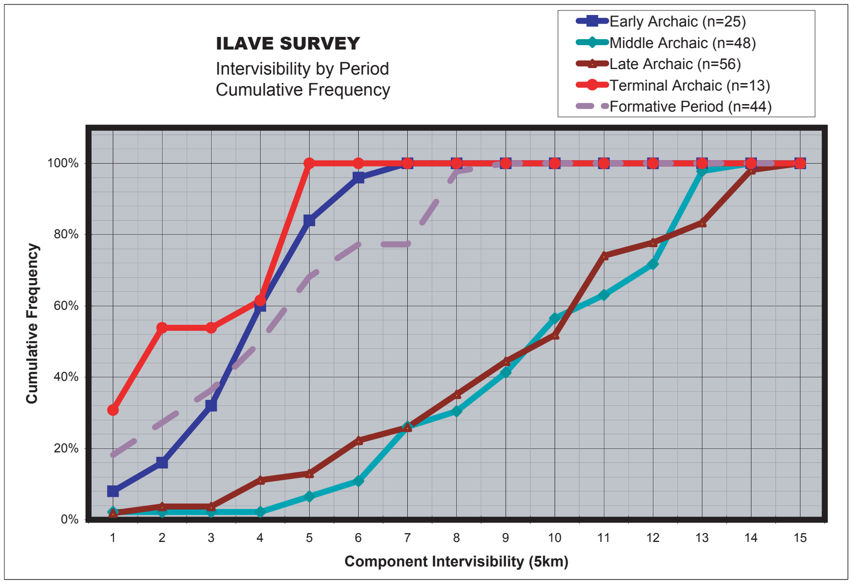

Figure 8. Intervisibility (5 km) between Ilave Survey sites.

Results for the Jiskairumoko / Kaillachuro Area

The cluster of Middle Zone sites adjacent to the Río Ilave contains Jiskairumoko and Kaillachuro, the only two sites in the survey with all Archaic and Formative components represented. While these two sites have only moderately high viewsheds (18,716 and 25,339 cells, respectively) they appear to have been occupied consistently until prior to Tiwanaku times, therefore it is worth examining unique environmental characteristics associated with their location in the region.

- High positions in this area have a commanding view of the confluence of the Río Huenque with the Río Ilave, 5.5 km to the east and beyond.

- The local terrain is undulating which results in some of the lowest site viewsheds and intervisibility (Map 3-7 Insets) in the region, and some of the lowest viewshed sites in the area. This means there is a lot of opportunity for concealed residence in this area. Simultaneously there are adjacent ridges with relatively high viewsheds.
- Despite being on terrain raised over 30m above the major rivers, this region has springs that make it possible to reside here year-around under the current climatic conditions.

Evidently this region has a number of unique characteristics that make it attractive to individuals in cultural periods that were divergent socially and economically. The most apparent characteristic of this location that sets it apart in the region is that it is possible to reside in this area year around and monitor activities in the river corridors without being particularly visible to humans or animals traveling along in the river valleys.

The Lower Ilave Valley

For 10 km downstream of its confluence with the Río Huenque the Río Ilave is a meandering channel in a valley that is wider and straighter than in the higher reaches. Upstream from the modern city of Ilave this area is referred to as the Lower Ilave Zone (Table 1 and Appendix Map 2). Four Early Archaic sites are present in this zone, they are clustered around the small hill known as Queña Faja that lies mid-way between the town of Totorani and the modern paved highway at Ilave. Queña Faja is a resistant andesitic hill, a volcanic plug feature that is circular and is approximately fifty meters higher than the surrounding valley. As the hill stands apart from the adjacent ridgelines it serves as a good vantage point for viewing the flat valley of the lower Río Ilave. Additionally, in the current climatic regime a creek passes by the southern foot of the hill year round. A distinct cluster of sites lies adjacent to this feature in all time periods. It is notable that four of the five sites with an Early Archaic component found below the Ilave – Huenque confluence are immediately to the east of this hill feature (Map 3). Later Archaic components also appear to cluster close to this hill feature. Changing land use in the Lower Ilave is particularly notable in the Formative Period (Map 7). There is little aggregation around Queña Faja and sites are distributed throughout the lower valley with an average distance of 1 to 2 kilometers between sites.

Locational trends

Viewshed is obviously highest from mountain tops, but people rarely live on top of mountains. It is interesting to note that although sites tend to be close to water and on flat ground, having too much water, in the form of flooding, is a bad thing. Therefore site placement must reflect a trade off between the near-universal concern for water and flat ground yet also avoid flood zones and dark cold canyons. As mentioned, principal determinants of site placement in many foraging contexts are distance to water and terrain slope (Jochim 1976). Studies show that pastoralists prioritize water and good forage (Cribb 1991; Western and Dunne 1979). Results from the Ilave survey indicate that within the surveyed area sites tend to be found on relatively low slope areas, and they are always located less than 1 km from hydrological features as they appear on the 1:100,000 scale topographic map series. The 187 Archaic sites from the survey were located on terrain with a low slope ($\mu = 0.85$ degrees, $\sigma = 1.65$). There was quite a bit more variability with respect to water, but in general Ilave Archaic sites tended to be located relatively close to the hydrological features as indicated on the Peruvian topographic map ($\mu = 448.92$ meters, $\sigma = 359.54$).

DISCUSSION

Viewshed analysis results correspond primarily with larger patterns evident in the settlement distribution data. Three discrete patterns of settlement are apparent: the Early Archaic, the Middle and Late Archaic, and then the Formative Period. The Terminal Archaic represents a distinct pattern that will be discussed below. These three settlement pattern changes also structure the viewshed analysis data. The trend of movement downstream throughout the Archaic and Formative is dominant and that pattern directs the viewshed trends. Thus, landforms like the flatter and more open terraces in the lower Ilave valley determine the viewshed characteristics of the later Archaic and Formative data.

Certain parts of the landscape contained sites from all time periods, and it is useful to consider the commonalities and differences in the roles that these sites may have played in each phase of the Archaic and Formative. One commonality throughout the Archaic and Formative is that the Jiskairumoko / Kaillachuro area represents a relatively low-risk site placement. The evidence suggests that the region was a reliable and consistently used location for geographical and for ecological reasons.

Geographically, the confluence region is a juncture between major riverine travel corridors. The site of Jiskairumoko sits between the large corridors and provides access to upstream as well as downstream terrain. It is adjacent to, but not immediately occupying the river confluence which was an intersection of transportation corridors for people and animals. The Jiskairumoko area is somewhat of an ecotone between the dry, higher elevation *puna* to the west and south, and the more moist, temperate Titicaca Basin with a climate that is moderated by the lake. Even under different climatic regimes, such as the prolonged arid period believed to have dominated during the Middle Archaic, this zone includes the major confluence of two drainages so water is likely to have always been available.

Even under modern circumstances the region has served as a refuge for individuals who want to be near the Lake Titicaca sphere but are also involved in the high country economic sphere. Locals from Jachacachi, the modern village next to Jiskairumoko, explained to a colleague that the area was utilized by a few of them as squatters when much of the land was held in large *hacienda* ranches before land distribution took place in the 1970s (Nathan Craig, personal communication). A small concealed valley just above Jiskairumoko has springs that squatters lived next to, and camouflaged corrals were also available on the hilltop above the site so that they would have a place to hide with their animals if the ranch landowner was spotted approaching from the Titicaca lakeside. The locals also explained that exchange for goods took place with groups living in the upper Huenque and Aguas Calientes valleys using llamas as pack animals. Modern factors aside (such as the new development that increases annually from the direction of the Titicaca lakeshore) the versatility of the Jiskairumoko area is apparent from the squatters' descriptions.

To summarize, the Jiskairumoko area is unique in the following respects:

- it lies in a well-watered, concealed area close to high visibility ridges with bofedales and dry hummocks like Jiskairumoko on which to settle.
- it lies between the two main tributaries of the Ilave drainage and so either the Río Aguas Calientes or the Río Huenque can be accessed

- it is up against high country that can provide an escape route for times when stealth is needed (it has been used this way historically).
- the position against the high country provides access for hunting of large and small game.

Early Archaic

Clusters of sites, each containing an Early Archaic component, are evident throughout the survey area. The sites do not have extremely high viewsheds but rather the viewshed distribution is bimodal (See Figure 7, note that bimodal distributions in cumulative frequency graphs appear as slightly ‘S’ shaped diagonal lines). The Jiskairumoko area, for example, contains the 3 highest and the lowest viewshed sites of the Early Archaic. This suggests that despite often essentialized depictions of mobile foragers, site locations with a variety of characteristics were used in this period and land use by humans was probably highly varied given the short history of human presence in the region. This bimodal viewshed distribution, unconnected to variance in site size, suggests that settlement organization involved residential mobility that may have been connected to seasonal changes and site exposure. In the Early Archaic the region had been recently deglaciated and expansive ice caps probably persisted in the higher country as they do today on mountain summits above 6,000 m.a.s.l. in the region. When glacial icecaps are present in the high country persistent frigid winds known as *katabatics* blow down valley because cold air sinks. Seasonality and shelter from winds may have been a significant concern in the Early Holocene high altitude climate, resulting in the repeated occupation of both high viewshed observation posts and of low viewshed / well sheltered locations. Notably, the Jiskairumoko / Kaillachuro area is up against sheltering hills to the south and east, and thus protected from katabatic winds blowing down the river valleys if their headwaters were glaciated.

It has been proposed that Early Archaic settlement by mobile foragers into the region took the form of migration that included both short and long-distance moves (Aldenderfer 1989; Lee 1966; Santoro 1987). Under such a strategy the Jiskairumoko area is a good place from which to base long-distance moves. As a central location in the two valley systems it provides access to a variety of lands for subsequent intravalley short distance moves. It has been proposed that Early Archaic human populations followed game animals to the altiplano when the Terminal Pleistocene deglaciation opened up extensive high *puna* grazing lands (Aldenderfer 1998). If the first generations of human groups were still subsisting at low enough population densities to not significantly disrupt the larger pattern of animal movement in the region, then a conservative placement like that of Jiskairumoko is advantageous for monitoring of game because it was slightly removed from the major corridors of animal movement.

Middle Archaic through Terminal Archaic

In the Middle Archaic settlement shifts to a pattern that prevails for the rest of the Archaic. This pattern is characterized by much greater use of the Lower Ilave Zone below the confluence with the Río Huenque and by greater variability in site size (Map 4). Data from twenty single component Middle Archaic sites (Table 4) point to larger mean site size, but also to the beginnings of a large standard deviation in site size from the mean. Combined with a dramatic increase in calibrated component count (Table 3) the data suggests that a population increase combined with a logistical mobility strategy may have been dominant. A reduction of available surface water during the Middle Archaic arid period probably led to the greater number of downstream sites.

With the Late Archaic a similar settlement pattern continues, but with larger site sizes and with greater investment in the larger sites. In the Moquegua drainage, on the western slope of the Andes, the Late Archaic featured the beginnings of ceremonial architecture, special-use structures, and the probable beginnings of social inequality in the form of ritual specialists (Aldenderfer 1998). By the Late Archaic the continuously utilized areas, like Jiskairumoko, probably had local improvements such as maintained spring water sources and well defined residence areas that were being used in increasingly formalized ways. Recent excavation work at Jiskairumoko has revealed a variety of architecture patterns including the living surface of a relatively large oval structure (3.7 x 4.7 meters) on the highest point of the site by the middle of the Late Archaic (Craig and Aldenderfer 2002). Camelid domestication is thought to have occurred in the Late Archaic, which would further increase investment in the use of space with the construction of corrals, the maintenance of *bofedales*, and possibly the beginnings of the domestication of seed plants.

The development of exchange networks in the Late and Terminal Archaic by way of camelid caravans would have amplified the social differentiation that is thought to have been developing in this period. Potential access to exotic wealth goods and to the control of ever larger numbers of herd animals by aspiring elites at the end of the Archaic could have further served to differentiate people socially and economically (Blanton, et al. 1996; Hayden and Schulting 1997). In the Terminal Archaic (Map 6) occupation persisted in the Jiskairumoko area, but sites were also clustering downstream close to the Queña

Faja hill. As with the Early Archaic these two locations represent a conservative settlement pattern and economically complementary site placement locations. The Terminal Archaic settlement pattern should represent a fully developed agro-pastoral lifeway, therefore it is interesting that the sites appear to be aggregated and not dispersed so as to maximize forage potential for their herds. Most of the Terminal component site assignments are based upon the presence of small, concave-based, unshouldered triangular points that are broadly affiliated with the Terminal Archaic through Tiwanku periods (Klink and Aldenderfer 2002). The emergence of this point style is potentially associated with stylistic distinctions, or with new hafting techniques or with the emergence of the bow and arrow, though there is no clear functional or temporal association between these stylistic changes. The distribution of these points in a pattern that is not unlike that of the Early Archaic may be a product of the hunting opportunities in Jiskairumoko and Queña Faja areas. Even today the high viewshed rock outcrops and bluffs in these two areas harbor a rabbit sized mammal called *viscacha*, as well as birds and other small game. Terminal Archaic distributions represent an interesting variation from the trends observed in the Middle and Late Archaic, and then the Formative. The widespread social and economic changes associated with this period may have resulted in the successful coexistence of various lifeways.

Formative

The dispersed, down valley settlement pattern of the Formative is distinct from the Archaic settlement in its lack of significant aggregation. The development of an agro-pastoral economy and major social changes along the edge of Lake Titicaca were the principal determinants of this pattern. Virtually the entire valley is visible from the dispersed Formative sites. Assuming that these sites were occupied concurrently, it would be difficult to move within the valley or to steal livestock without being observed. Local pastoralists would have been reducing risk by residing in low viewshed areas with high site intervisibility (Kuznar 1995, 2001) (Figure 8). Despite the dispersal pattern that suggests that much of the valley is visible, the Formative sites are not exceptionally high viewshed locations. The Formative sites appear to be low climatic exposure sites perhaps with access to low-lying water sources. One of the notable elements of faunal assemblages from pastoralists sites is the high percentage of camelid neonate remains thought to be the result of high levels of disease among captive animals (Wheeler 1983). The construction of settlements and livestock corrals in sheltered, low-lying locations is probably linked to a need to protect vulnerable young camelids and to corralling the animals relatively close to reliable water supplies.

Future research

The challenge to designing an effective survey methodology is to adequately document prehistoric use of space while simultaneously examining the terrain with sufficient detail to locate lithic scatters. Following on the preliminary survey work, like the Ilave survey, so that general settlement concentrations are known, subsequent work can focus on documenting general use of land by using more rigorous survey designs.

In subsequent survey work in the adjacent Huenque valley Cindy Klink (2002) stratified her survey to capture variability within four general ecological zones. The use of a stratified sample design allows the archaeologist to make statements with statistical confidence concerning both where settlements are and are not found in the valley as a whole. This opens up a great number of possibilities in terms of the later application of settlement pattern analysis techniques such as viewshed analysis.

Recent improvements in fieldwork equipment will make survey data collection easier in the future. In the survey design phase new tools like satellite imagery and improved digital elevation models can help to design survey strategies that better capture ecological and topographic variation in the survey region. GIS can be used to generate random sample plots within each stratified zone and then GPS units can be used to get the surveyor to those random sample plots. During the actual survey GPS units can constantly collect location data so that the survey region coverage is accurately known and statistical confidence in conclusions from the survey will be based on a known sampling ratio. Additionally, a relative topographic model of terrain can be generated by constantly gathering GPS points throughout the survey, and this relative topographic model can later be reconciled with regional DEM data for a more fine-grained topographic context of the settlement survey (Nathan Craig, personal communication). The GPS can be used to digitize the locations of features on the landscape such that surveyors will collect GPS positions at distinct locations such as creek crossings and *bofedales* marshlands that do not appear reliably on the regional topographic map. Characteristics of the entire site such as slope, aspect, and distance to water can then be generated statistically in the later analysis, instead of only qualitatively on the site report as it is traditionally derived.

If both sites and isolates can be documented quickly with GPS units then some of the bias of site oriented survey can be reduced (Dunnell and Dancey 1983). Site boundaries, determined by artifact density, should be mapped into polygons with GPS so that site size and site relationship to terrain features like hills and depressions can later be analyzed by GIS. If projectile point styles are distinct between components then perhaps lithic scatters of individual components at multicomponent sites can be delineated with GPS polygons. Finally, analysis can be improved with the incorporation of remotely sensed ecological data for comparison with the settlement distributions. If survey data is gathered efficiently a great deal of information can be recorded for each artifact of interest at every site. Although GIS might have the shortcoming of encouraging archaeologists to streamline digital data collection by using recording methods that are particular, and perhaps more restricted, it has the beneficial effect of forcing researchers to be more explicit about categories and data types while conducting fieldwork. The new methods permit archaeologists to gather more quantitative data in the field than was formerly possible, and GIS can also permit the exploration of the increased quantities of data, like viewshed analysis, in ways that are new or were formerly much too laborious.

CONCLUSION

This paper has investigated the potential for using viewshed analysis methods with a settlement survey data in a high altitude grassland environment. The point locations of hundreds of sites are known with relative accuracy thanks to GPS technology, and surface collection has permitted the sites to be compared with a regional projectile point chronology, thereby generating cultural component categories for about half of the Archaic sites found in the survey. Bias in the survey strategy and lack of geographical information about component extent do not permit certain quantitative analysis methods to be used, but the high number of sites found in the survey does provide interesting patterns with respect to site viewsheds and cultural periods.

Viewshed analysis is a valuable data exploration technique, but due to the intersection of the viewshed variable with other first-order site selection criteria, the interpretative potential of viewshed analysis result should be warily applied. If hypothesis testing is needed, multiple working hypotheses should be considered and geographical landforms that would allow testing of viewshed prioritization should be actively sought. It is suggested in this paper that evaluating the criteria of site placement for high viewshed or high concealment / climatic protection are the principal analytical returns for this type of analysis. Further, it is suggested that the ideal site placement in many contexts is a flat, sheltered place with reliable water and adjacent to a high viewshed location, something that was very difficult to test with this data. Survey designs that capture additional information about sites using digital geographic technology can provide finer resolution data for this kind of analysis in the future.

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