Using GIS for Politywide Analysis of Wari Imperial Political Economy

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Introduction

Empires are massive, complex, political entities that present formidable challenges to traditional scales of archaeological analysis. Since empires extend across political boundaries, exchange systems, and environmental zones, the politywide extension of findings from settlement surveys and site excavations is problematic. No locality, no matter how intensively studied, can serve as an imperial microcosm. To study empires, politywide analysis is also necessary. Successful analysis at this level must integrate both local and regional scales of analysis from data collected by multiple researchers working on different projects. Geographic information system (GIS) provides an information infrastructure permitting organization of such disparate data scales (Zubrow 1990, Crumley and Marquardt 1990: 73–74). In this paper, we will demonstrate the utility of politywide analysis by describing a pattern of settlement location found in the Pre-Columbian Wari Empire of Peru.

Wari Political Economy

During the Middle Horizon (700–1000 A.D.), the Wari Empire expanded from the Ayacucho Basin of the Central Andes to control much of what is now Peru. As the empire expanded, it encountered populations with significantly different social, economic, and political organizations. The empire adapted its political economy to take advantage of these local conditions. Since our knowledge of the Middle Horizon remains poor, any interpretation of politywide patterns in the Wari economy must be regarded as tentative. This research is a preliminary first step toward understanding the logic of Wari political economy in those regions where Wari material investment was significant.

Outside of the imperial heartland, 20 Wari administrative centers (see Figure 1) are found in 12 valleys across much of modern day Peru (e.g., Lumbreras 1974, Isbell and Schreiber 1978, Isbell 1988, Isbell and McEwan 1991, Schreiber 1992). We believe these peripheral centers, located at least several days walk from the Wari capital, were an integral part of an imperial wealth finance system designed to extract prestige goods to support and legitimize the imperial bureaucracy (for an explanation of prestige good economies see Brumfiel and Earle 1987, D'Altroy and Earle 1985, Earle and D'Altroy 1989, Brumfiel 1994, and Cobb 1996). If this is true, we suggest that the preconquest Early Intermediate Period political complexity of local populations had profound effects on the locations chosen for these centers. We argue that administrative sites in areas of simple political organization would tend to be placed toward the center of a valley's population. Since these populations lacked the hierarchical political relationships that

tend to drive the manufacture and/or exchange of prestige goods, the empire needed to first build an infrastructure to extract wealth from this local population. These administrative sites, therefore, will tend to be located at the center of the population—where transportation costs from the site are lowest to all parts of the local population. Wari sites in politically complex populations will tend to be located in different kinds of places. In these populations, elites are usually already engaged in the long-distance exchange of prestige goods to legitimize their present position. The empire, we argue, will tend to place its sites on the margins of the population to function as gateway centers controlling, or at least profiting from, intervalley exchange. In this position, the empire can benefit from the existing exchange relationships without incurring the costs of establishing direct political control over the local population.

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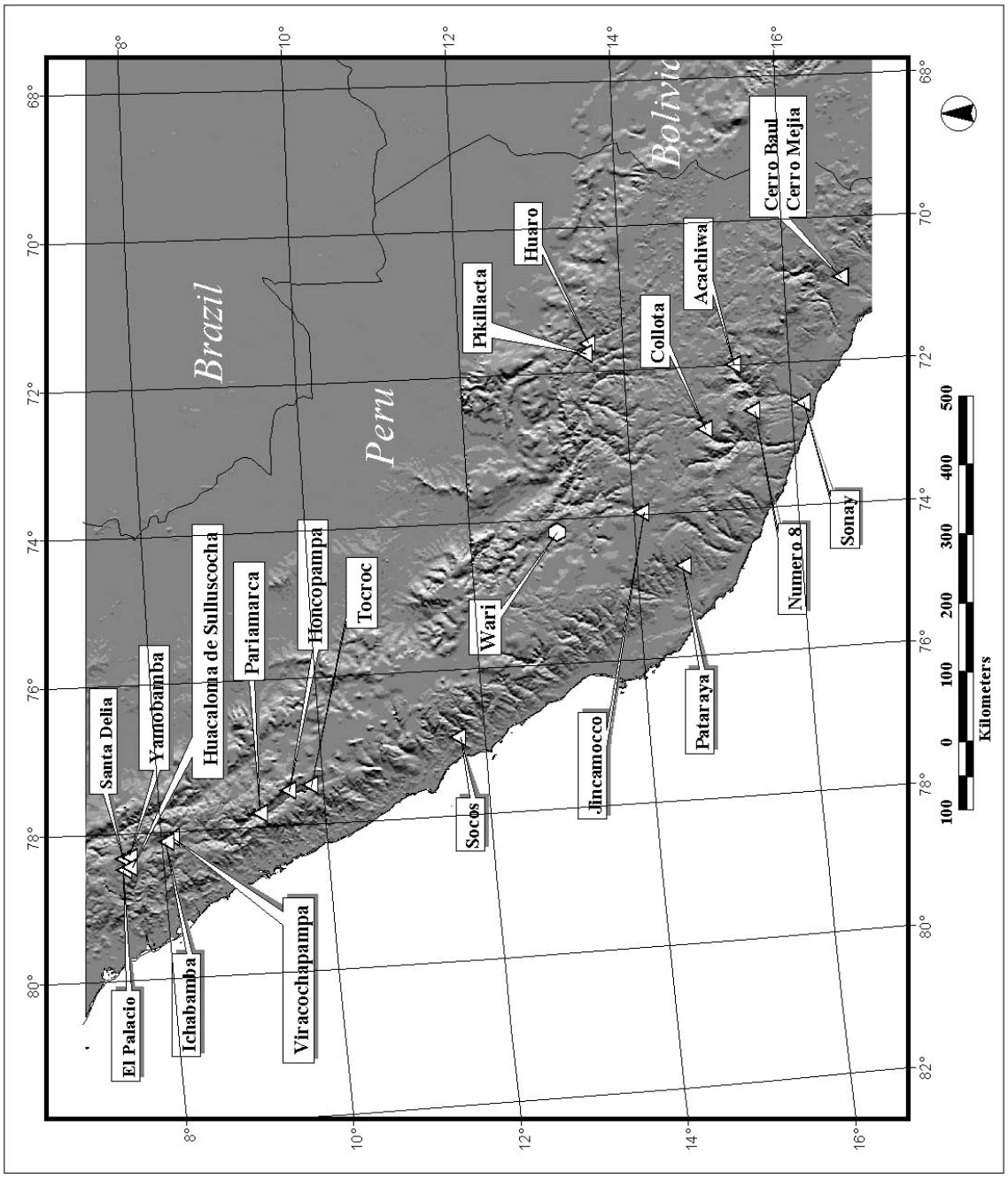
Figure 1

Locator map of the study area showing the 20 Wari administrative sites included in this analysis. The site of Wari is shown with a pentagon, while Wari administrative sites are shown as white triangles. The GTOPO30 digital elevation model is shown with analytical hillshading to illustrate topography. These data sets are Lambert-Equal Azimuth Projected with a longitude of origin at –60° and a latitude of origin at 15°.



Methods

Outside of the imperial core, 20 Wari administrative centers have been found in 12 valleys across much of modern day Peru. GIS provides a way of exploring the relationship between location of these centers and local political complexity. In this analysis, we would ideally measure the distance of each Wari site from the center of a valley's population. Unfortunately, present data on the Middle Horizon remains inadequate to directly analyze this relationship. We simply do not know where populations were during this period for most of the valleys in which Wari centers have been found. Valleys in the Andes, however, are sharply bound oases of arable land interspersed within high grasslands, mountains, and desert. These nonarable areas, especially the high grasslands, were of critical importance to the Andean economy as grazing lands and resource areas. These topographic boundaries, however, sharply demarcate where the great bulk of a valley's population would settle. With this in mind, valley boundaries served as a proxy measurement for the extent of local populations in our analysis.

The data used in this analysis was collected through library research and personal communications (an exhaustive review of the data on Wari sites and valley political complexity is beyond the scope of this summary; a manuscript that contains this information is currently under review). To provide an adequate sample to test our site location model, all Wari sites that contain administrative architecture were included in this data set. Pre-Wari political organization was ranked as either simple or complex for each valley (see Table 1). If a valley's inhabitants were organized in a political hierarchy above the village level, the valley was deemed complex. If a valley was made up of politically independent villages, it was classified as simple. This data was integrated into an ArcView GIS 3.0b database.

Table 1
Pre-Wari Valley political organization and our predictions for Wari site placement.

Site Name	Valley Name	Valley Organization	Wari Site Placement
Acachiwa	Colca	Simple	Valley center
Cerro Baul	Upper Moquequa	Simple	Valley center
Cerro Mejia	Upper Moquequa	Simple	Valley center
Collota	Cotahuasi	Simple	Valley center
El Palacio	Cajamarca-Huamacucho	Complex	Valley edge
Honcopampa	Callejon de Huallyas	Complex	Valley edge
Huacaloma	Cajamarca-Huamacucho	Complex	Valley edge
Huaro	Cuzco	Simple	Valley center
Ichabamba	Cajamarca-Huamacucho	Complex	Valley edge
Jincamocco	Carhuarazo	Simple	Valley center
Numero 8	Chuquibamba	Simple	Valley center
Pariamarca	Callejon de Huallyas	Complex	Valley edge
Pataraya	Nasca	Complex	Valley edge
Pikillacta	Cuzco	Simple	Valley center
Santa Delia	Cajamarca-Huamacucho	Complex	Valley edge

Site Name	Valley Name	Valley Organization	Wari Site Placement
Sonay	Camana	Simple	Valley center
Tocroc	Callejon de Huallyas	Complex	Valley edge
Viracochapampa	Cajamarca-Huamacucho	Complex	Valley edge
Yamobamba	Cajamarca-Huamacucho	Complex	Valley edge
Socos	Chillon	Complex	Valley edge

To construct a database to test the relationship between sites and valley geographic centers, a number of steps were taken to (1) define valley boundaries, (2) define valley centers, and (3) define administrative site distance from center. The Cotahuasi Valley, with its Wari center of Collota, provides an example of what was done for each of the valleys (Figures 2 a–c). An empire, like Wari, covers an enormous spatial extent. Topographic maps covering this expansive region have not yet been digitized and organized into a single coregistered database. Coarse resolution digital elevation data, however, does exist for the entire earth in the form of the GTOPO30 data set and is available for free over the World Wide Web (from Earth Resources Observation System Data Center [EDC] Distributed Active Archive Center [DAAC] [http://edcwww.cr.usgs.gov/landdaac/glcc/glcc.html). A cropped portion of the GTOPO30 earth model distributed in geographic projection was used as a basemap in this analysis.

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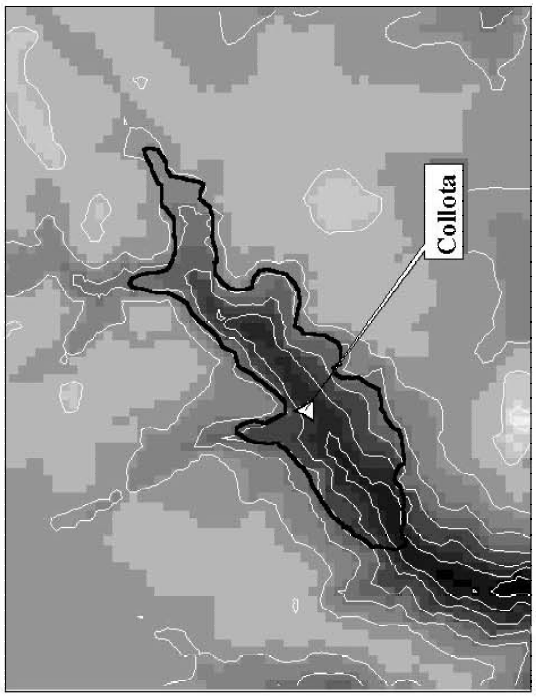


Figure 2b.

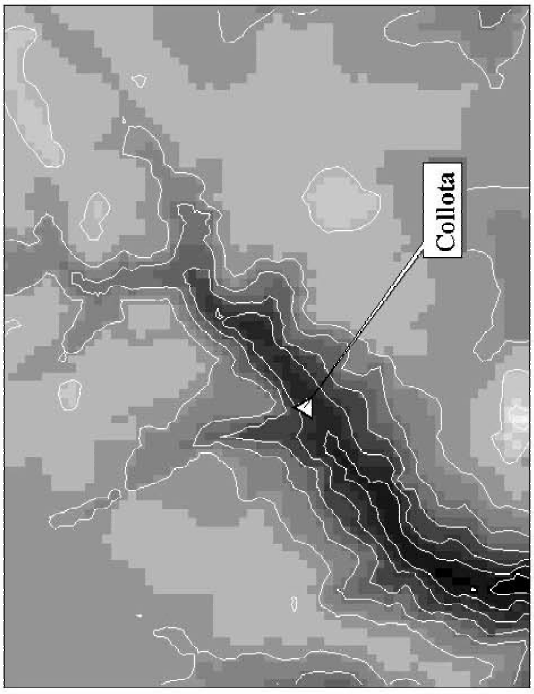


Figure 2a.

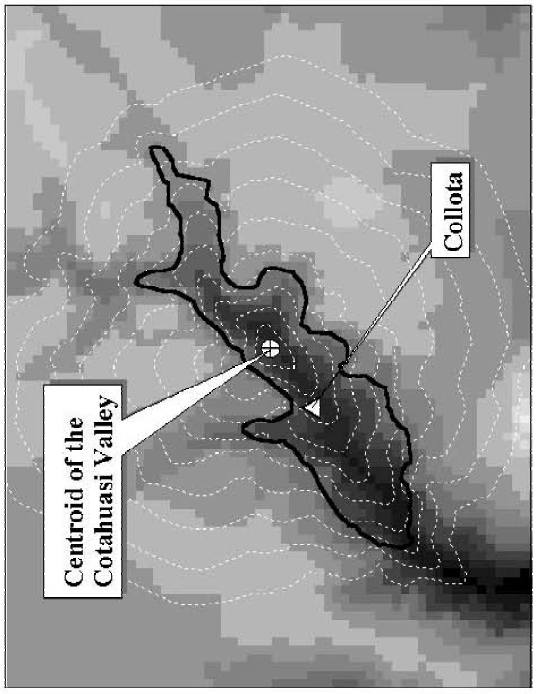


Figure 2c.

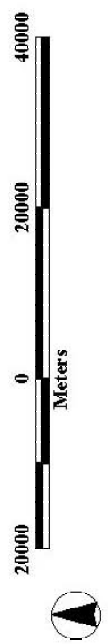


Figure 2a shows the topography of the Cotahuasi Valley and the Wari administrative site of Collota. Contour interval of the isolines is 100 meters.

Figure 2b. Shows the boundary defined for the Cotahuasi Valley. The valley's centroid is indicated by the circle with a cross. The Wari administrative site of Collota is represented as a triangle.

Figure 2c. Dotted contour lines represent distance from the centroid of the Cotahuasi Valley. The units are in hours walking and the contour interval is one hour. The valley's centroid is indicated by the circle with a cross. The Wari administrative center of Collota is represented as a triangle.

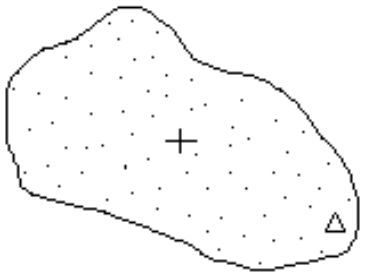
Valley extents were determined by examining the physical structure of each valley represented by the GTOPO30 data. An isopleth map of elevation was constructed such that isobars representing contour lines were displayed on top of the digital elevation model (Johnston 1998: 80, DeMers 1997: 258). Inspection of the contour lines provided a good way of representing where valley edges met with flatter intervalley puna highlands. Higher resolution maps were also consulted when defining these boundaries. On the coast, these maps were particularly important sources of information on valley extents since these valleys tend not to produce the deep drainage channels seen in the highlands. The extent of arable land as represented on these maps became an important source of information for defining coastal valley limits.

Once valley systems were defined, a center needed to be computed. Defining the center of a polygon is a complex geographic problem, and there are a variety of solutions to the question of "where is the center of this polygon." For this analysis, we computed centroid using the trapezoid rule with a weighted mean center (DeMers 1997: 195, Clarke 1995). We then used three different measures of distance from valley center. First, we computed a grid containing information on the Euclidean distance from each valley's centroid. Second, applying Tobler's hiking algorithm, we computed a cost surface modeling distance in units of hours walking (Tobler 1993, Aldenderfer 1998: 15, Kantner 1997). Third, we developed a metric that would allow us to test the patterns expected by our model of Wari political economy that relies on differences between observed and expected values (Figure 3).

Figure 3

The distance metric formula is shown on the left and a schematic example of a valley is shown on the right. The valley centroid is represented by a cross, randomly samples points are shown as dots, and the location of the Wari site in this hypothetical case is shown as a triangle.

$$D = \left(\frac{\mu_{R-W}}{\sqrt{A}} \right)$$



D= distance from center statistic
R= distance from center for a %50 random sample based on area
W= distance of a Wari site
A= valley area

To compute the metric, we randomly generated a 20 percent sample of points and calculated an average expected Euclidean distance from the center for each valley (μ_R). The observed distance of a Wari site from the centroid for each administrative center was then calculated (W). We then subtracted observed Wari distances from center from the expected distance from center producing a residual that describes how observed distances differ from mean expected distances (μ_R - W). *Positive* residuals indicate sites that are *closer* to the center than expected, while *negative* residuals represent sites that are *further* from the center than the mean of our 20 percent random sample. To factor valley area out of the metric and to place all sites on a common, comparable, unitless axis we divided these distance residuals (μ_R - W) by the square root of valley area (A).

Results and Analysis

Results indicate a trend in Wari site placement with respect to valley centers that meets our theoretical predictions. Administrative sites in valleys with simple pre-Wari political systems tend to be closer to the center, while administrative sites in valleys with complex pre-Wari political systems tend to be further from the center (Figure 4a and Figure 4b).

Differences between Wari sites found in politically simple and complex valleys is significant in all three measures of distance: (1) raw untransformed Euclidean distance is significant at (t=5.77, p>0.0001), while (2) our distance (D) metric is also significant (t=-3.21, p0.0048), and (3) Tobler's cost distance function that is significant at (t=5.35, p>0.0001). All three measures indicate that there is a significant separability in the distance from center between politically complex and simple valleys.

Figure 4a
Isotropic distance measure in a rank order plot where the Y axis is produced by applying the distance metric described in the analytical methods section. In this figure, sites that are located in complex valleys have horizontal hatching while sites located in simple valleys have diagonal hatch marks.

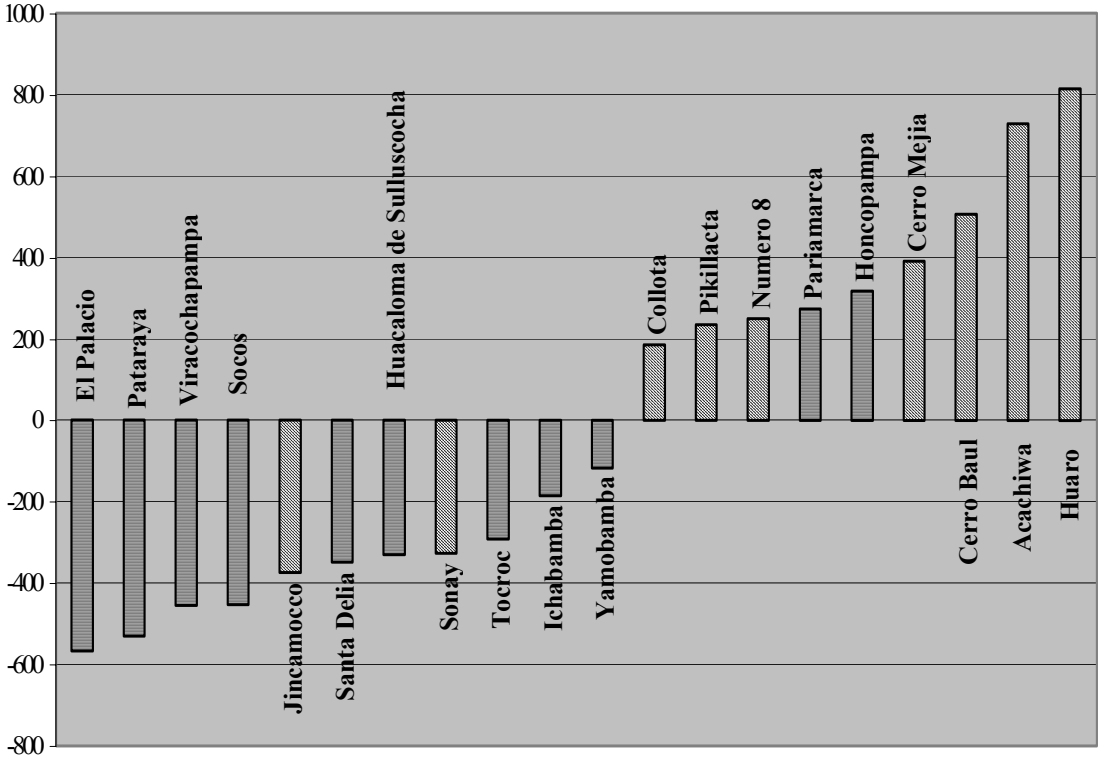
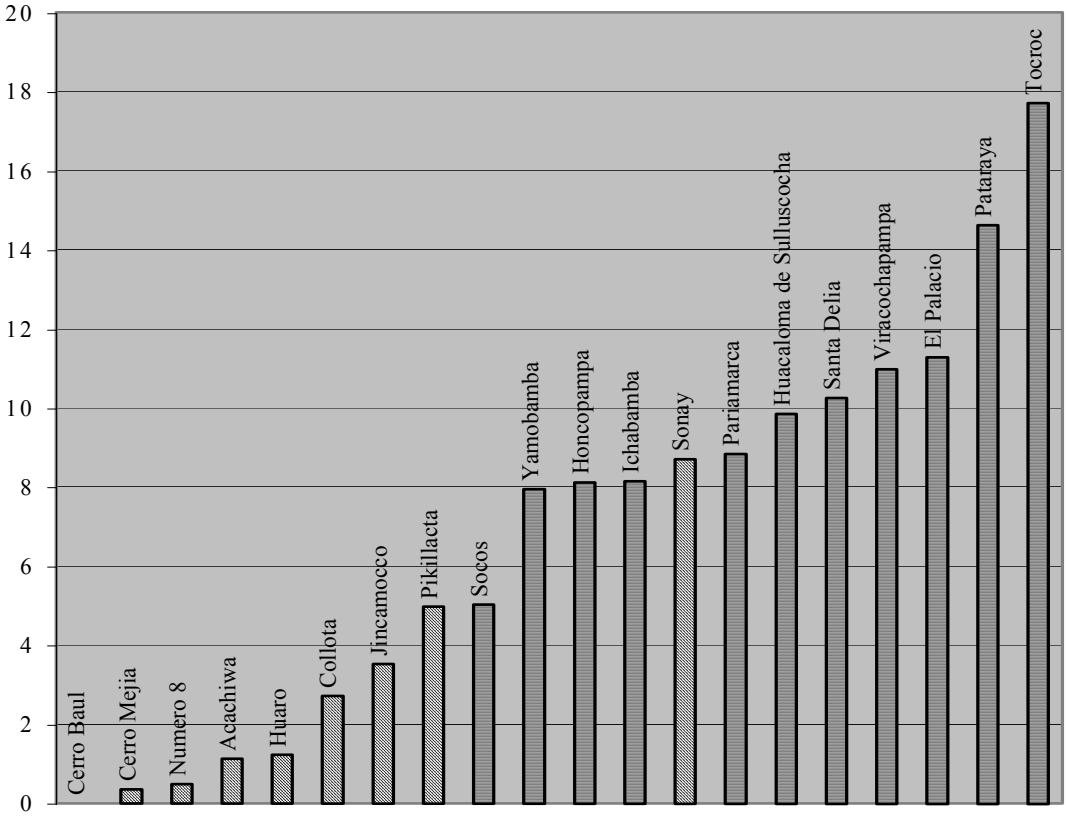


Figure 4b
Nonisotropic cost distances in a rank order plot. The Y axis is in units of hours walking time established using Tobler's (1993) hiking function with the GTOPO30 data set. Sites located in complex valleys have horizontal hatching while sites located in simple valleys have diagonal hatch marks.



These results are extremely encouraging. However, how much are correlations between valley area and political complexity structuring results? Four out of five of the valleys with complex pre-Wari political systems have larger areas than simple valleys. Regression analysis shows that valley area is not the sole source of variability. Area accounts for about half of the variability of raw untransformed Euclidean distance from center (R square = 0.52), while area accounts for a fraction of the variability in site placement for our distance (D) metric (R square = 0.06). Area appears to account for a good portion of Tobler's cost distance formula (R square = 0.59), but the measure has the significant advantage of being in easily interpretable units. The significant differences in Wari site placement between politically simple and complex valleys combined with the lack of correlation between valley area and our distance metric indicates that pre-Wari or Early Intermediate Period political complexity is the likely source of variation in Wari site placement with respect to the center of a valley system.

Discussion

Imperial conquest and consolidation is a complex process strongly shaped by the local conditions encountered during expansion. Scholars studying particular sites and areas can only hope to unravel the impact of certain local conditions on their particular study area. The overall importance of these conditions in the empire, however, must be left to conjecture. We suggest that GIS-based politywide analysis can build on these local analyses to measure the impact of these various local conditions throughout the empire. In this case, our research indicates a strong correlation between imperial center location and preconquest local political organization in the periphery of the empire. We suggest that this relationship reflects a strategy geared toward the extraction of prestige goods in the periphery of the Wari Empire. In more complexly organized regions, Wari placed their administrative centers in areas conducive to controlling the flow of goods out of the region. In areas of simpler political organization, Wari placed its centers in a central location to better facilitate the organization of the regions production of prestige goods. This research, we hope, is a tentative first step toward quantitative systematic politywide spatial analysis in the Andes and elsewhere.

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