Regional Settlement Patterns in the Tiwanaku Valley of Bolivia

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Regional settlement patterns from the Formative through Post-Classic Tiwanaku periods (1500 B.C.–A.C. 1100) in the Tiwanaku Valley of Bolivia are explored. Ecological considerations, rank-size interpretations, and some aspects of central place theory are incorporated into this investigation of the evolution of regional social and political organization of the Tiwanaku polity. Taken together, the analyses point away from reconstructions of the Tiwanaku polity as a highly centralized and monolithic state organized in a "pyramidal" fashion. Settlement patterns indicate the presence of sub-system settlement enclaves with differing relationships to the capital. The identification of sub-system settlement units lends support to suggestions arising from recent study that, by the Post-Classic Period, Tiwanaku society was segmentary in nature and organized into a nested hierarchy. These findings are consistent with ethnohistorically-derived constructs of indigenous Andean sociopolitical structure.

Introduction

Archaeological work at Tiwanaku and affiliated settlements during the last decade has contributed significantly to our understanding of state development, agricultural technologies, and urbanism in the ancient south-central Andes (Albarracin-Jordan 1992; Albarracin-Jordan and Mathews 1990; Albarracin-Jordan, Lemuz, and Paz 1994; Bermann 1990, 1994; Graffam 1990, 1992; Janusek 1994; Kolata 1986, 1991, 1993; Mathews 1992; Rivera Casanovas 1992). Historically, Tiwanaku has been the focus of an ample array of interpretations, but only since the turn of this century have systematic excavations been carried out at the site. These initial investigations, done primarily at the monumental core of the site, uncovered a small fraction of the rich testimony that lay underground, but Tiwanaku's hinterland and the nature of surrounding settlement remained unexplored topics. Survey of the Tiwanaku Valley shows that the region has a long history of human occupation, and the organizational roots of the highly complex society known as Tiwanaku extend back to the cultural diversity of the Formative Period (Albarracin-Jordan 1992; Mathews 1992).

Several methods and models of settlement pattern research, first developed and used by geographers to investigate modern settlement systems, have become increasingly common in archaeological studies of ancient social, political, and economic organization in various regions of the world (e.g., Mesopotamia, Valley of Oaxaca, Basin of Mexico). In this paper, we deploy some of these methods and models in examining the evolution of settlement in the Tiwanaku Valley, between 1500 B.C. and A.C. 1100.

The Tiwanaku Valley covers approximately 550 sq km, and is located high in the Bolivian altiplano or high plateau (FIG. 1). It constitutes a relatively narrow valley that closes toward the east. The valley is circumscribed to the north by a low chain of hills, to the south by a high mountain range, and to the west by Lake Titicaca. The lake has an important effect on the climate of the valley. In general, the area enjoys higher temperatures and humidity than other areas of the Bolivian altiplano. There are important environ-

Figure 1. Map of Bolivia and the Tiwanaku Valley.

mental/resource zones in the valley that played a role in the distribution of settlement during prehispanic times. Figure 2 shows the different microenvironments found in the valley, classified on the basis of previous geomorphological studies and research on soils and natural resources (Ahlfeld and Branisa 1960; Bolsi 1966; Montes de Oca 1989; Perez Valencia 1984; Ticlla 1992). The Tiwanaku River flows westward in a relatively sinuous manner with a low discharge during the dry season, between April and October. Flanking the river is a low-lying alluvial plain. Most of the valley bottom consists of grasslands and marshy terrain ideal for pastoralism, which constituted an important component of altiplano economy for thousands of years (Browman 1981, 1984; Kolata 1983). The edges of the valley rise sharply toward the mountain zones to the south. In the terrace zone of the SW corner of the valley, there is evidence of extensive prehispanic terracing. This zone covers roughly 8 sq km and exhibits two different field types. The terrace surfaces on the lower slopes of the colluvial aprons exhibit short stone-and-mud walls and the surfaces average some 60 m in width. These terraces were built and utilized during Tiwanaku periods, but were also used after Tiwanaku's collapse (Albarracin-Jordan 1992; Albarracin-Jordan and Mathews 1990). The terraces at higher elevations have much narrower surfaces with higher stone walls. No major Tiwanaku sites are associated with these terraces; instead, there are numerous fieldhouses among the terraces that point toward a post-Tiwanaku construction and use of the fields.

Although terraces were constructed and utilized in the SW sector of the mountain range during Tiwanaku periods, other kinds of agricultural fields were also employed. *Qochas* (mini-basins) and raised fields constitute important features of the prehispanic agrarian base. Qochas form clusters in the south-central and central portions of the valley and, in most cases, are interconnected by canals. The area covered by these mini-basins is approximately 4 sq km.

While terraces and qochas played a significant role in agricultural production, a more common form of intensive agriculture was practiced on raised fields (Albarracin-Jordan 1992; Kolata 1993; Mathews 1992). Raised field agriculture was extensive in the lacustrine zone, throughout the springs and grass zone, and especially extensive within a 5 km radius of Tiwanaku itself. These zones played an important role in the nature of settlement patterns in the valley, as will be discussed below.

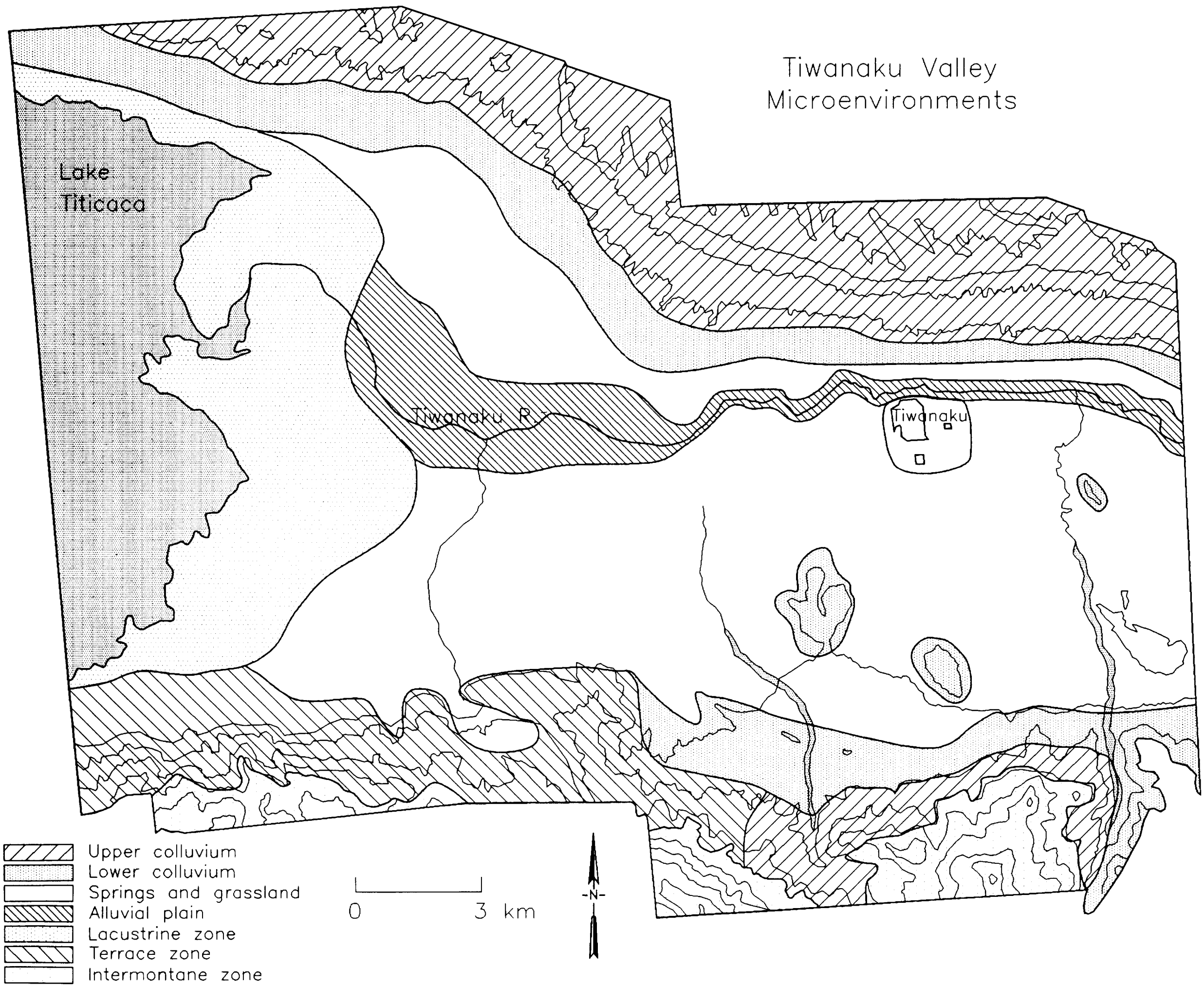


Figure 2. Microenvironmental distribution in the Tiwanaku Valley.

Measurement and Dating of Sites

The data presented in this study are based on a 100% pedestrian survey of the lower and middle Tiwanaku valleys. Site size estimates reflect the measured area of sherd scatters and architectural components. The size of chronologically distinguishable occupations was recorded at multicomponent sites. Between five and fifteen collection units (each a circle with a radius of two meters) were placed in each site. Many larger sites were intensively and systematically collected. For details of the techniques used in the Tiwanaku survey, see Albarracin-Jordan and Mathews 1990, Albarracin-Jordan 1992, and Mathews 1992.

Recent studies at Tiwanaku and affiliated settlements in the valley have pointed out significant weaknesses in the traditional Bennett-Ponce ceramic sequence presented for Tiwanaku (Albarracin-Jordan 1992; Albarracin-Jordan and Mathews 1990; Albarracin-Jordan, Lemuz, and Paz 1994; Bennett 1934; Mathews 1992; Rivera Casanovas 1992). In this article we employ a different scheme (FIG. 3).

Subsumed into our Formative Period (1400 B.C.–A.C. 300) are all Chiripa phases and the Tiwanaku I and III Periods (Browman 1981; Ponce Sanginés 1972). Defining diagnostic markers for the time-span between 100 B.C. and A.C. 400 remains a problem. The Tiwanaku Valley lacks a plainware ceramic sequence and the pottery styles generally defined as "Tiwanaku III" are not sufficiently distributed among Tiwanaku Valley sites to make them useful chronological indicators. Our "Classic" (A.C. 400–750) and "Post-Classic" (A.C. 750–1100) periods correspond to the Tiwanaku IV and V periods, respectively (Bermann 1994; Ponce Sanginés 1972).

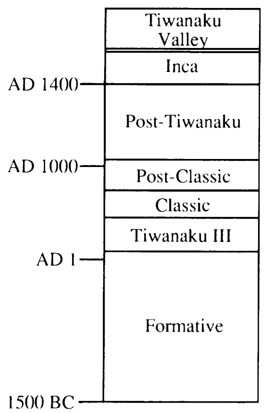


Figure 3. Chronological chart for the Tiwanaku Valley.

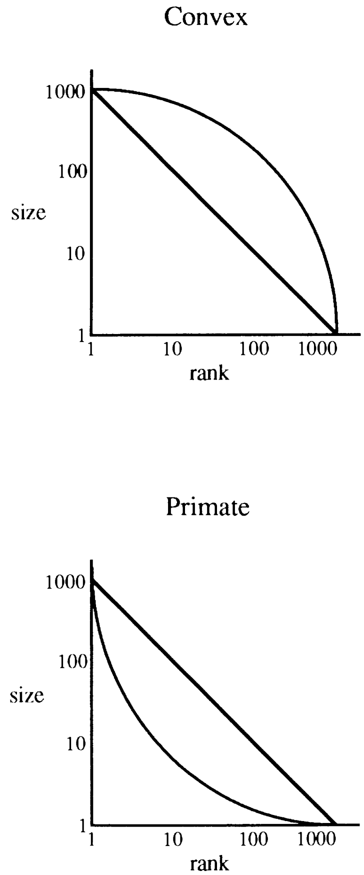


Figure 5. Convex and primate distributions.

Rank-Size Distributions and Regional Settlement System Integration

The rank-size rule holds that if the cities in a region are arranged in order of size, the city of rank n should have a population of x/n, where x equals the size of the region's largest city (Zipf 1949). This "ideal" rank-size distribution (when plotted on log-log paper), produces a log-normal distribution with plotted site sizes falling along a straight line with a slope of −1.0 (FIG. 4). There is no consensus on why log-normal distributions develop, or how deviations from the ideal pattern should be interpreted. Most archaeologists have followed Johnson (1973, 1977, 1980a, 1980b) in relating rank-size distributions to the degree of settlement system integration, or the degree of interaction and interdependence among the settlements of the system (Kowalewski 1983: 61). From this perspective, log-normal distributions indicate systems that are well integrated both vertically and horizontally (Johnson 1980b: 245).

The three common deviations from the log-normal distribution are convex, primate (or concave), and primo-convex (FIGS. 5, 6). A convex distribution is one in which sites smaller than the largest site are larger than would be predicted by the rank-size rule. This distribution has been variously interpreted as representing a system of relatively autonomous settlements with little or no political integration (Johnson 1977: 498, 1980b: 241); the pooling of two or more complete and well-integrated systems (Olsson 1965: 21); or settlement on the periphery of a larger system (Paynter 1982: 148). A concave distribution, in which the size of sites drops below the ideal distribution, indicates the existence of a "primate" center. Primacy may

Figure 4. Log-normal distribution.

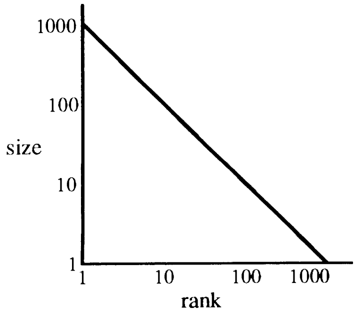
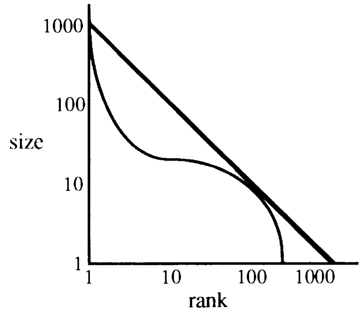


Figure 6. Primo-convex distribution.



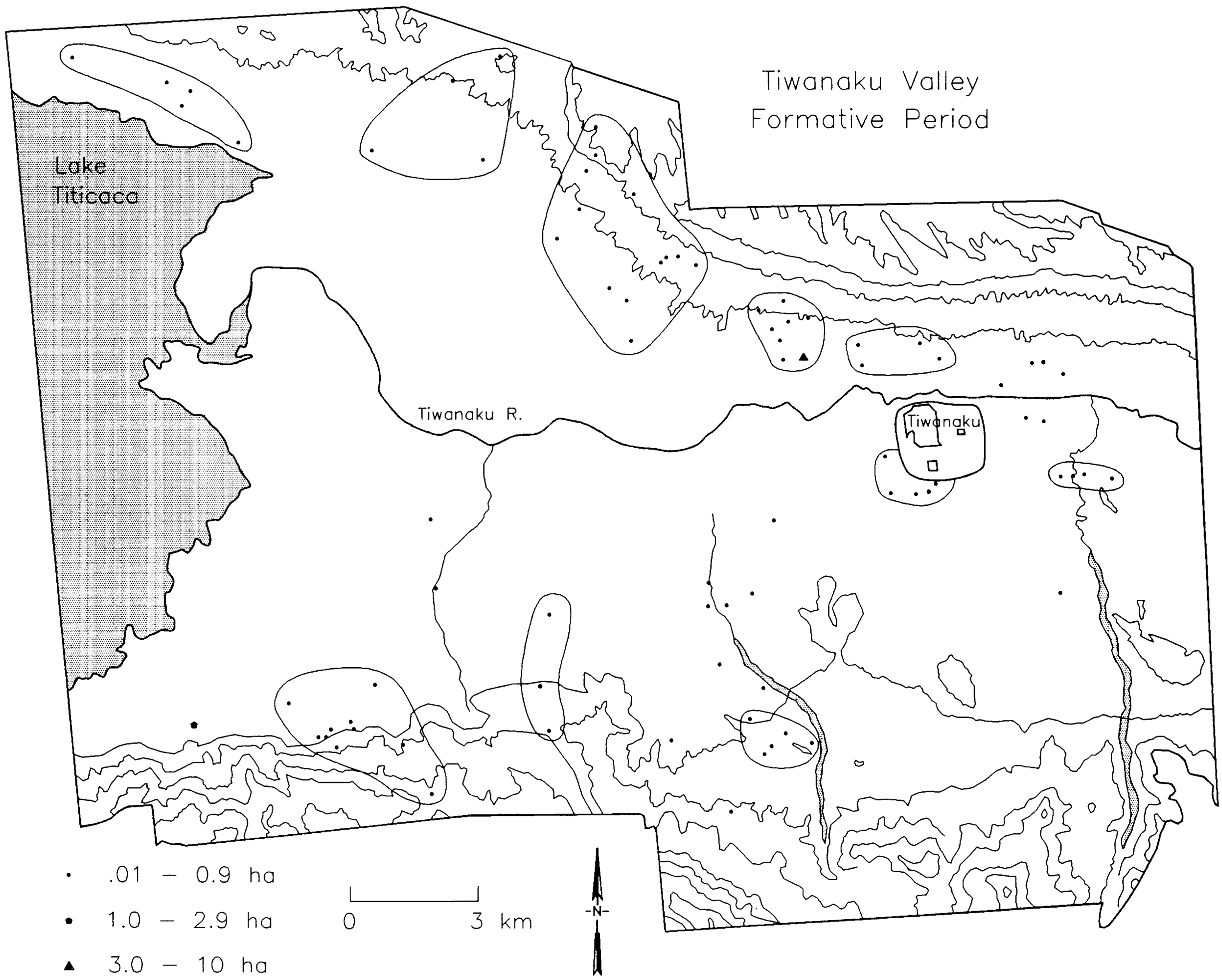


Figure 7. Formative Period settlement pattern.

indicate an "imbalance of integration" with vertical integration emphasized over horizontal integration (Johnson 1980b: 243); central-place functions overly concentrated at a single site; the differential interaction of the primate center with a larger, transregional system (Johnson 1977: 496); or "partitioning," in which the settlements under study represent part of a larger settlement system (Johnson 1977: 496; Vapñarsky 1969). It has been suggested that primacy results from administrative control of an economic system, and is characteristic of settlement systems in which economic competition is politically minimized (Smith 1976: 32; Blanton 1976: 261; Johnson 1980a: 243). The third variant, the primo-convex distribution, combining the two deviations described above, is common in pre-state and early state societies (Wright 1984: 41–77). This distribution suggests a settlement system composed of subsystems that are articulated to a primate center, but interact very little among themselves (Johnson 1980b: 244).

A number of scholars have examined shifts in rank-size distributions from a diachronic perspective, but cross-cultural regularities in the evolutionary trajectory of rank-size distributions remain difficult to discern (Kowalewski 1982: 66; Smith 1982a: 56). Berry (1964) has proposed that immature settlement systems have primate distributions, and log-normal distributions will develop only after a long history of urbanism. Similarly, Smith (1982b: 83) suggests that permanent immature primacy is likely to be found in the earlier stages of the development of urban systems because of the concentration of political and administrative elites into a single center.

Rank-Size Distributions for the Tiwanaku Valley

The settlement pattern of the Formative Period (1500 B.C.–A.C. 100), prior to Tiwanaku's rise to prominence in the Tiwanaku Valley, is characterized by the formation of clusters of sites (FIG. 7). In this period, settlements are scattered around the area of Tiwanaku and appear to be

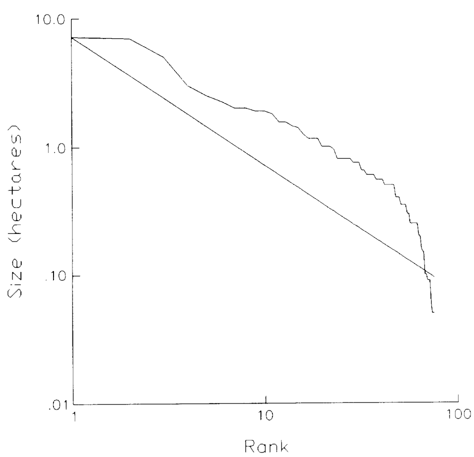
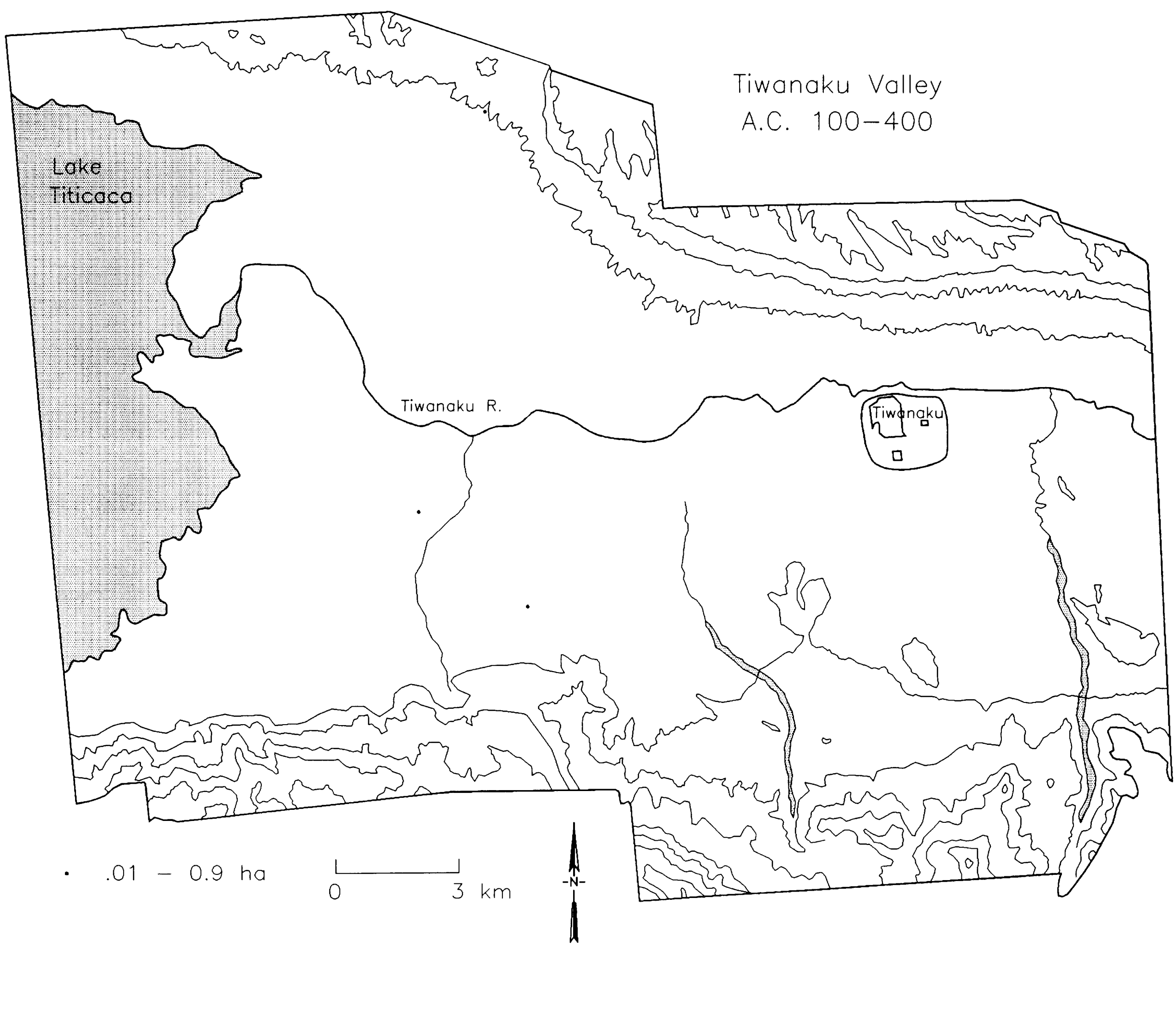


Figure 8. Formative Period rank-size distribution.

oriented along north and south axes. Although settlement is sparse compared to later periods, the basic location of non-Chiripa sites persists through Post-Classic Tiwanaku. This dispersal seems to be associated with the distribution of fertile terrain, since the rich soils are mainly distributed along the edges of the valley and the valley bottom itself. As shown in Figure 8, the rank-size distribution for this period is clearly convex. As discussed above, this distribution suggests little regional political or economic integration in the valley. The largest site is only ten hectares in size, and there is clearly no primacy associated with it.

Reconstruction of settlement patterns during the A.C. 100–400 period is highly problematical. This is the period when Tiwanaku apparently began to emerge as an important center. The distribution of the known sites presents an interesting pattern, quite distinct from all other periods under consideration (FIG. 9). No rank-size graph can be produced because of the small number of sites. The under-representation of sites is certainly due in great part

Figure 9. Settlement pattern of sites in the Tiwanaku Valley (ca. A.C. 100–400).



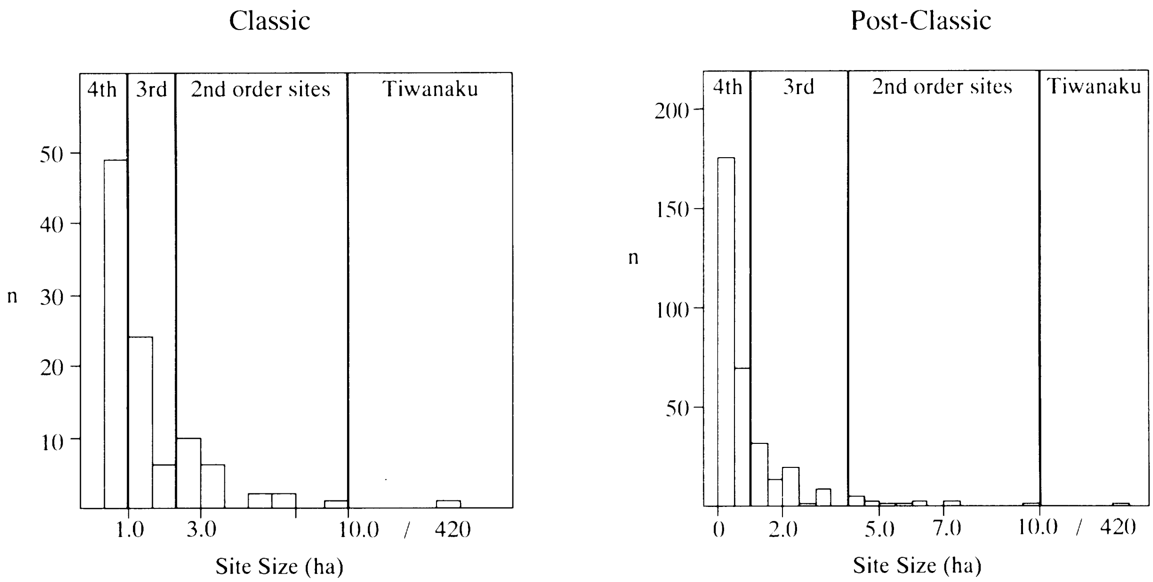


Figure 10. Histograms of Classic and Post-Classic settlement sizes.

to the inadequacy of the ceramic sequence. The temporal diagnostic style for this period (known as Tiwanaku III, Qeya, or "Early Tiahuanaco") was found only at four sites in the valley, one of which is Tiwanaku itself. On the basis of the excavations at LV-55 (Guaqui) and LV-150 (Iwawi), however, a re-evaluation of the ceramic components of the sites in the Lower Tiwanaku Valley suggests that a few other sites (LV-30, LV-34, LV-155, LV-156, and LV-187) may also date to the time span in question. Thus there may have been a demographic decline in the surrounding areas due to the implosion of population at the growing center of Tiwanaku. This is a common phenomenon in the formation of ancient urban centers worldwide, and has been well-documented at Uruk and Teotihuacan (Bermann 1994: 223). These cities grew by absorbing population from the countryside, even leading to the abandonment of whole districts (Adams 1981: 90). An important aspect of the Tiwanaku settlement pattern in the Tiwanaku Valley is the site-size hierarchy. Shown in Figure 10 are histograms of Classic and Post-Classic settlement sizes. The first-order site is clearly Tiwanaku, at 420 hectares in size. Second- order sites range from 3.0–10.0 hectares in size. Third-order sites range from 1.0–2.9 hectares, and fourth-order sites are smaller than 1.0 hectare in size. Classic Tiwanaku (A.C. 800–1000) represents a shift in settlement patterns in the valley. The sites are scattered throughout the region, concentrating near Tiwanaku and along the edges of the valley (FIG. 11). Sites are distributed with respect to the resource zones as follows: 45% in the springs and grass zone, 28% in the lower colluvium, 14% in the terrace zone, with the remaining sites scattered among the upper colluvium, the alluvial plain, and the lake zone. Secondary sites, located in the northern sector of the valley, are associated with raised fields, while most of the secondary sites in the southern portion of the valley are associated with terraced fields. These sites are clearly located near important resources.

The rank-size distribution for this period (FIG. 12) is primo-convex, with Tiwanaku dominating in physical and functional size. Below Tiwanaku, the rank-size distribution displays convexity, suggesting the integration through Tiwanaku of several autonomous subsystems, each of which contained one or more relatively large settlements. Considering the strategic distribution of settlement with respect to important resources, the functional differentiation among sites, and the primo-convexity of the distribution, we argue that the valley was integrated through Tiwanaku during this period, and that the subsystems within the valley were relatively independent of one another.

Any use of rank-size analysis must take into consideration the boundedness of the settlement system because of the effects of "pooling" and "partitioning" on the shape of the rank-size distribution. The data used here, generated from roughly two-thirds of the Tiwanaku Valley, represent only a portion of a Tiwanaku-centered settlement system that probably also included the Rio Catari and Rio Desaguadero drainages. The former drainage has recently been surveyed, while the latter has seen considerable reconnaissance. Based on these efforts, we are confident that the largest sites in these zones have been identified: Pajchiri

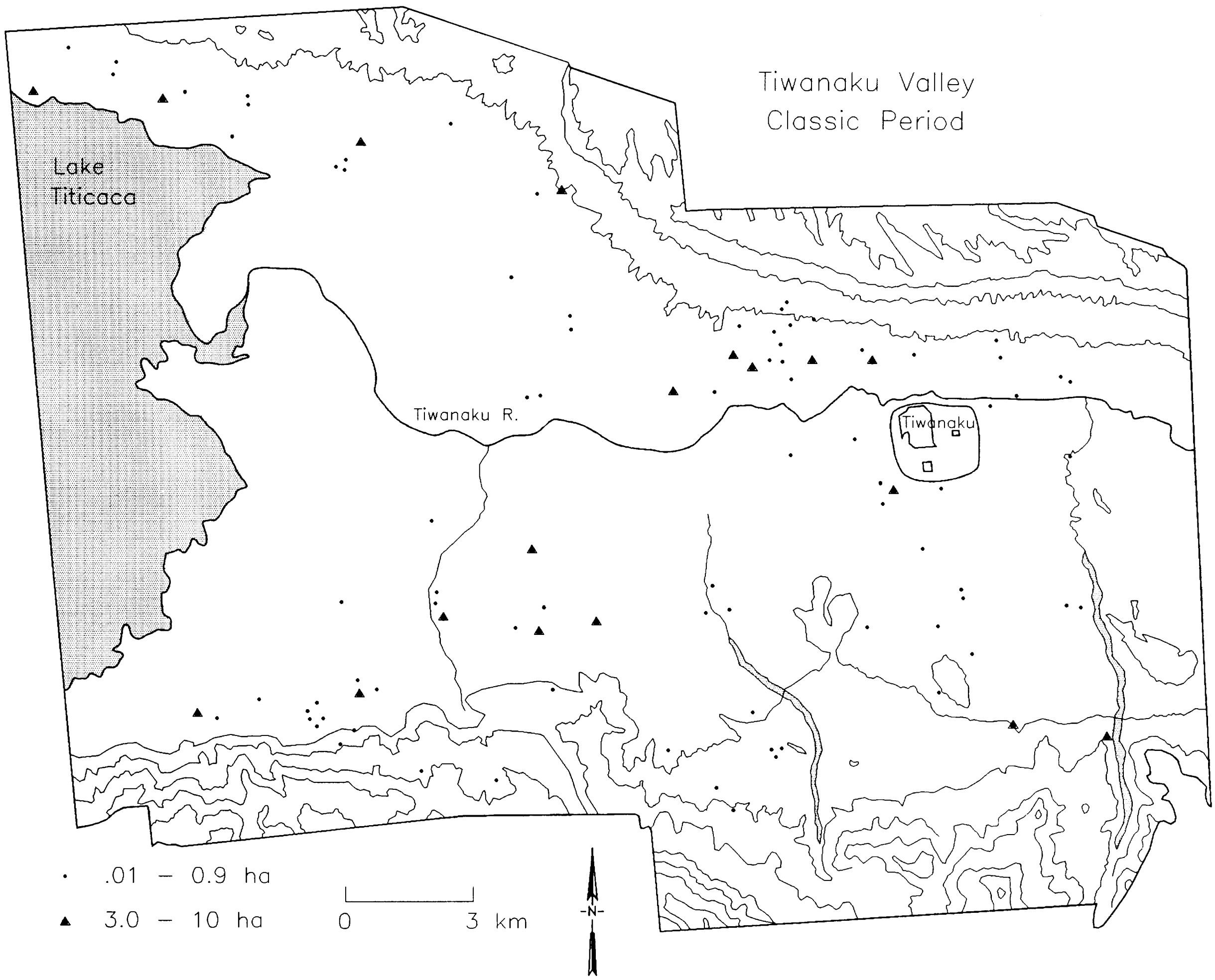
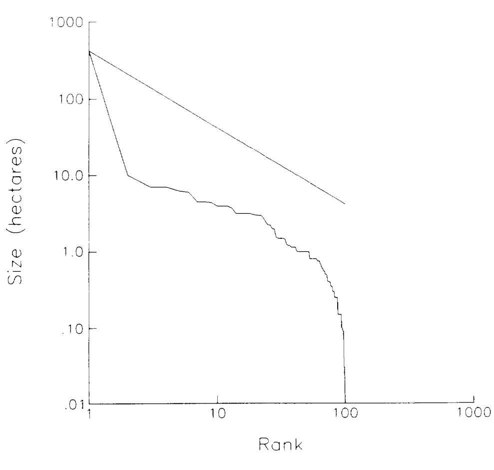


Figure 11. Classic Tiwanaku settlement pattern.

Figure 12. Classic Tiwanaku rank-size distribution.



and Lukurmata in the Catari drainage, and Khonko Wankani in the Desaguadero drainage. Of these sites, only Lukurmata has been systematically investigated. Located roughly 12 km from Tiwanaku, Lukurmata grew to be a center with public architecture covering approximately 120 ha in the Classic Period, before declining rapidly early in the Post-Classic Period (Bermann 1994: 178). Inclusion of these sites in the analysis does not significantly change the primo-convexity of the Classic (and Post-Classic) rank-size distribution. Therefore, the primacy segments of the Classic and Post-Classic rank-size distributions are unlikely to be the result of partitioning of a larger system.

Post-Classic (A.C. 800–1100) settlement is similar to that of the Classic (FIG. 13), except for the fact that there are more sites (a total of 339). Sites are distributed with respect to resource zones as follows: 47% in the springs and grass zone, 30% in the lower colluvium, 10% in the terrace zone, with the remaining sites scattered among the other

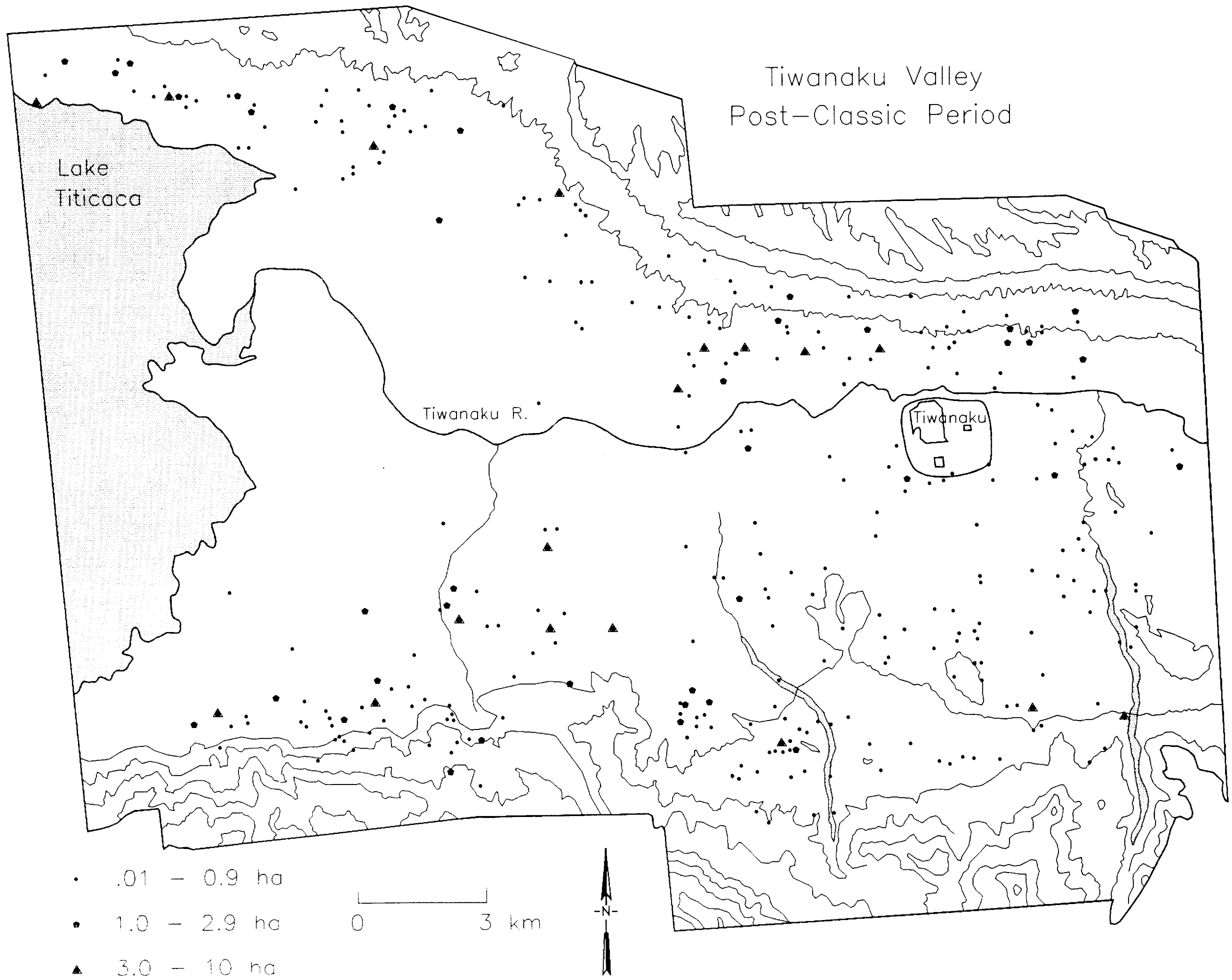
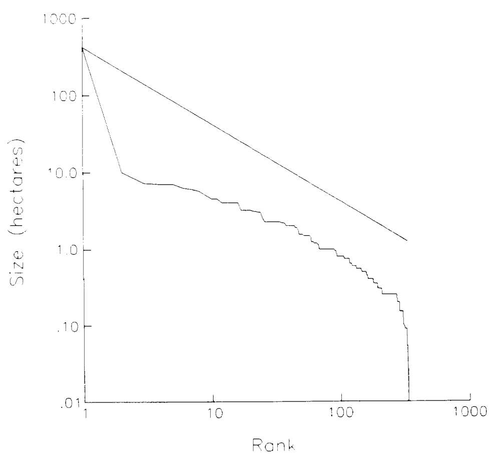


Figure 13. Post-Classic Tiwanaku settlement pattern.

zones. The rank-size distribution for Post-Classic Tiwanaku (FIG. 14) is similar to that of Classic Tiwanaku. A number of patterns that were already observed for Classic Tiwanaku are also evident in Post-Classic Tiwanaku. To investigate these patterns more closely, we turn to a discussion of settlement subsystems in the Tiwanaku Valley during the Post-Classic Period.

Figure 14. Post-Classic Tiwanaku rank-size distribution.



K-Means Cluster Analysis and Subsystem Identification

Close investigation of subregional patterns provides additional insight into settlement system integration in the Tiwanaku Valley. In order to evaluate subsystem organization it was necessary to decide how many subsystems there were, and which sites were members of which subsystems. To avoid subjectively "eyeballing" the regional distribution map and drawing circles around sites, a k-means non-hier-

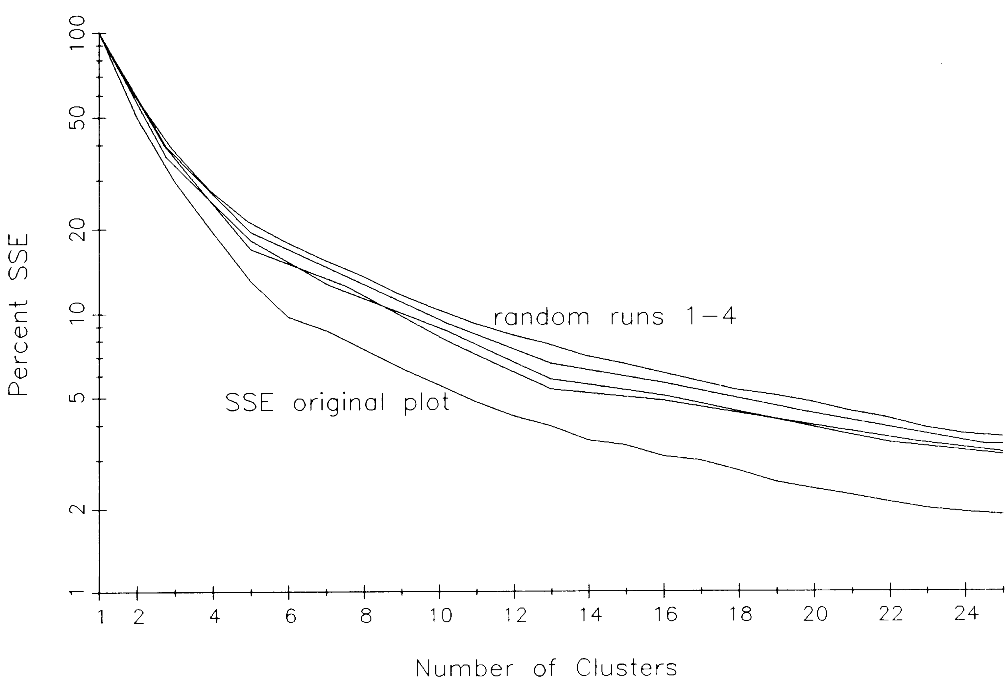
Table 1. Statistical summary of non-hierarchical k-means cluster analysis. The K′ value for each cluster is 1.0000.

Cluster	*N*	*SSE*	*%SSE*	*Log (%SSE)*	*Srqt (SSE/N)*	*nbar*	*nstd*	*RMSbar*	*RMSstd*	*N > 2*	*r2wbar*	*r2wstd*
1	310	1425650.10	100.00	2.00	67.8150	310.0	0.0	67.81	0.00	1	0.07	0.00
2	310	715135.06	50.16	1.70	48.0301	155.0	35.0	49.21	8.18	2	0.01	0.00
3	310	422779.08	29.66	1.47	36.9297	103.3	58.1	34.16	6.44	3	0.11	0.21
4	310	278988.76	19.57	1.29	29.9994	77.5	20.6	29.73	4.23	4	0.19	0.15
5	310	186357.37	13.07	1.12	24.5184	62.0	17.0	24.09	2.37	5	0.09	0.10
6	310	138743.67	9.73	0.99	21.1556	51.7	9.7	21.22	1.71	6	0.10	0.11
7	310	124284.13	8.72	0.94	20.0229	44.3	17.0	19.31	2.02	7	0.08	0.07
8	310	106622.28	7.48	0.87	18.5457	38.8	14.2	17.86	2.36	8	0.09	0.08
9	310	91473.26	6.42	0.81	17.1777	34.4	10.3	16.72	2.43	9	0.07	0.06
10	310	79360.58	5.57	0.75	16.0001	31.0	11.9	15.41	2.07	10	0.06	0.06
11	310	68622.58	4.81	0.68	14.8783	28.2	9.6	14.61	1.88	11	0.09	0.07
12	310	61197.01	4.29	0.63	14.0503	25.8	7.7	13.78	2.23	12	0.09	0.09
13	310	56242.92	3.95	0.60	13.4696	23.8	6.6	13.37	1.96	13	0.09	0.10
14	310	50158.32	3.52	0.55	12.7201	22.1	7.0	12.53	1.90	14	0.09	0.09
15	310	48244.77	3.38	0.53	12.4751	20.7	8.6	11.46	3.36	14	0.11	0.13
16	310	44016.30	3.09	0.49	11.9159	19.4	8.1	10.95	3.20	15	0.12	0.13
17	310	42576.24	2.99	0.48	11.7193	18.2	8.7	10.83	3.04	16	0.13	0.14
18	310	39089.25	2.74	0.44	11.2292	17.2	7.9	10.48	2.89	17	0.14	0.14
19	310	35506.95	2.49	0.40	10.7023	16.3	6.3	10.00	3.01	18	0.12	0.15
20	310	33630.82	2.36	0.37	10.4157	15.5	6.3	9.67	2.93	19	0.13	0.15

archical cluster analysis, described by Kintigh and Ammerman (1982), was implemented.

The first step in a non-hierarchical k-means analysis is to determine whether or not sites cluster, and if so, how many clusters (subsystems) are represented. The data for the Kintigh's k-means program are the coordinates of each site. The program asks for the maximum number of clusters to calculate, then provides data output for the number of clusters up to that amount. Table 1 provides the data output for up to 20 clusters, and Figures 15 and 16 present graphic output produced with the program. These graphs represent some of the calculations made, and provide a

Figure 15. Percent SSE plot.



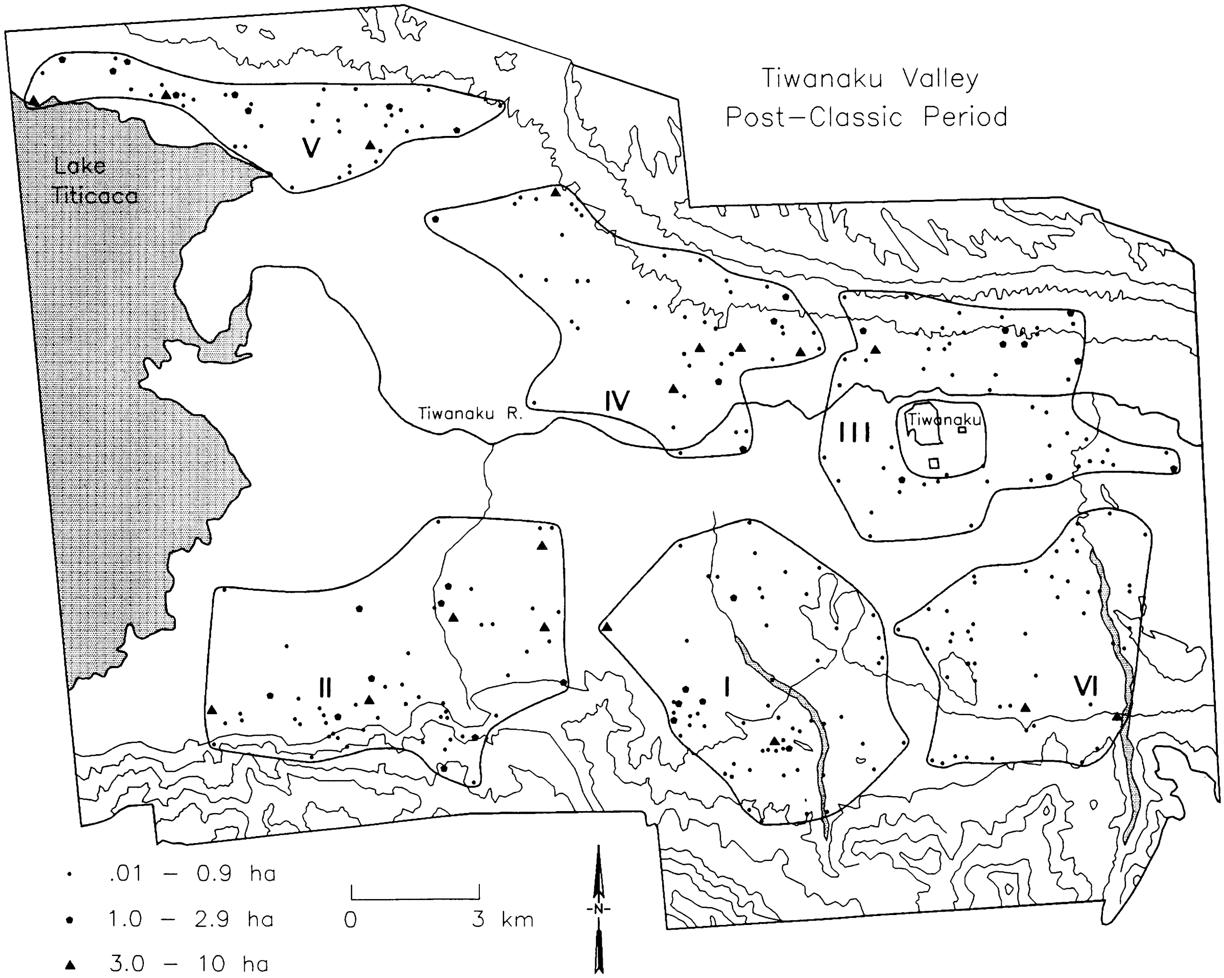


Figure 16. Distribution of site clusters in the Tiwanaku Valley during the Post-Classic Period.

method of deciding how many clusters to work with. The sum squared error (SSE) is the main value used to determine how many clusters are represented in the data. The SSE figure is associated with the degree of clustering. High SSE values are usually associated with inappropriate clustering. In the extreme case of grouping every site in the Tiwanaku Valley into a single cluster, the percent SSE will be 100, the highest possible value. At the opposite extreme, a very low SSE is associated with the maximum possible number of clusters (in this case each site would be its own cluster). The percent SSE graph (FIG. 15) shows the distributions. Four random runs were calculated to provide a comparison with the actual or original SSE plot. If the original plot falls above the random plots, the data tend toward an even distribution. If the original plot falls within or near the random plots, the data tend toward a random distribution.

For Post-Classic Tiwanaku sites, the percent SSE plot falls well below the random plots, suggesting that the sites tend to cluster. Twenty five clusters were computed, substantially more clusters than were expected in the Tiwanaku Valley. Apparently, six clusters are represented in the data, because at this point on the graph (FIG. 15), the SSE stops dropping rapidly and begins a more gradual descent, thus providing the point at which the clearest clusters have been delineated. The configuration of these clusters is shown in Figure 16. Further support for the presence of six clusters lies in the values presented in Table 1. Kintigh and Ammerman (1982: 43–53) note that a relatively low standard deviation (ntsd) indicates that the average number of points per cluster (nbar) is a good indication of cluster size. For six clusters, the standard deviation of 9.7 is quite low compared to clusters two through five (35.0, 58.1, 20.6, 17.0, respectively) and

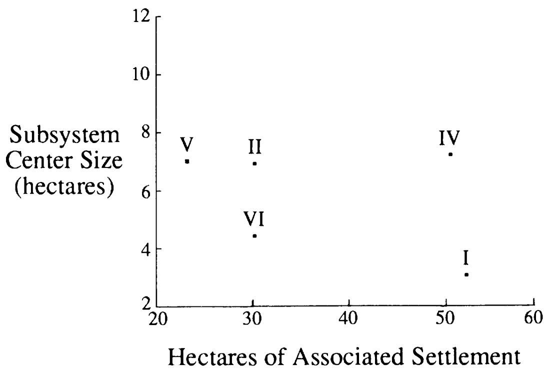


Figure 17. Scatter-plot of subsystem center size versus size of associated settlement.

clusters seven through ten, with values of 17.0, 14.2, 10.3, and 11.9, respectively (TABLE 1). These figures further support the presence of six clusters.

Post-Classic Settlement Integration and Centralization

We might expect that if settlement subsystems in a region are autonomous, the size of the subsystem center should be related to the size of the population it services (Johnson 1980a: 245). Thus, "there should be a positive correlation between subsystem center size (in hectares) and the sum of the sizes (in hectares) of the associated subsystem settlements" (Johnson 1980a: 245). Figure 17 shows this relationship for the five proposed subsystems in Post-Classic Tiwanaku. Sub-system III is not included because its center—Tiwanaku—clearly had system-wide functions. Figure 17 does not display the expected relationship between center size and subsystem size. Instead, the largest sub-system centers display the same size of roughly 7 ha. However, Figure 17 does reveal marked differences in the size of settlement subsystems, with the most distant subsystems (II and V) being the smallest, at 30 and 35 ha of total occupation (subsystem center included). In contrast, the subsystems closest to Tiwanaku (I and IV) are substantially larger, at approximately 55 ha each. Subsystem VI is not completely documented, as the eastern section of this subsystem lies in the still unsurveyed upper Tiwanaku Valley. We predict that when completely surveyed, this subsystem will prove to be the size of subsystems I and IV.

Pending further study of differences in local agricultural potential, we suggest that the larger populations near Tiwanaku indicate that proximity to the capital and its institutions was a significant factor in settlement. To further explore this relationship, the area (ha) of settlement was plotted against distance (km) from Tiwanaku. Figure

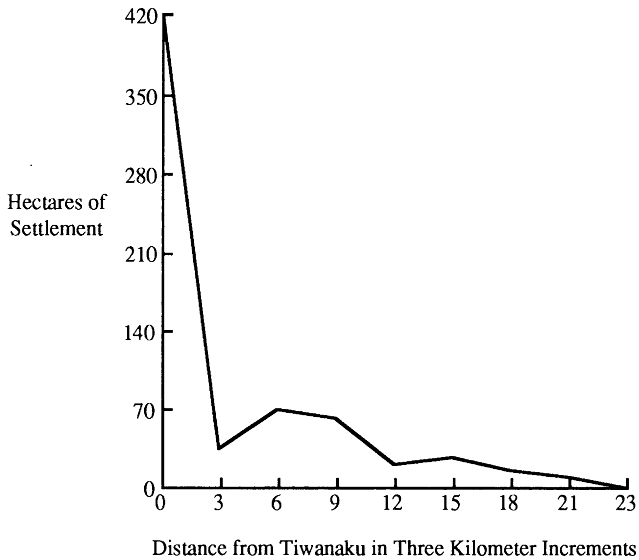


Figure 18. Settlement distribution with distance from Tiwanaku.

18 portrays the total area of settlements in three km increments from the capital. Not unexpectedly, the settlement area drops rapidly out to a distance of three km, before picking up again as one moves into subsystems I and IV; thereafter, settlement declines very steadily. This pattern, then, also points to Tiwanaku's "demographic pull," indicating that interaction with the capital was an important factor structuring the regional distribution of settlement (Kowaleski et al. 1983).

The relationship between village size and distance to the nearest center may also provide clues as to degree of interdependence within settlement subsystems. As Johnson (1980a: 246) has noted, gravity interaction models predicated on "friction" costs predict that villages should decrease in size with distance from the subsystem center. In contrast, his study of Early Uruk Period settlement enclaves in Iraq revealed the opposite; village size increased with distance from the subsystem center (Johnson 1980a: 247). Johnson (1980a: 247) interpreted this fact to be the result of some degree of functional differentiation among villages, and a nascent "competitive" central-place settlement pattern. Figure 19 shows a scatter-plot of settlement size (using only those sites 1.0 hectare in size or greater) and distance to the subsystem center (instead of measuring the exact distances, the available data lends itself to relative ranking: 1 is the closest site, 2 is the second closest site, and so on). Two patterns can be seen in Figure 19. First, there is a fairly weak, but somewhat significant positive correlation between settlement size and distance from the subsystem center ($n = 76$, $r = .146$, $p = .209$). Second, the tight clustering of smaller

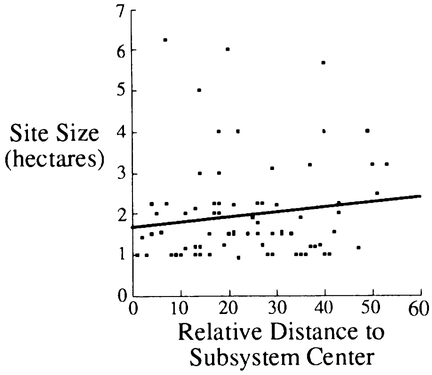


Figure 19. Scatter-plot of site size versus relative distance to subsystem center.

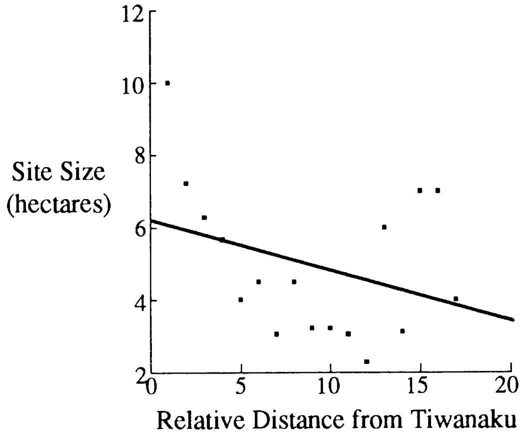


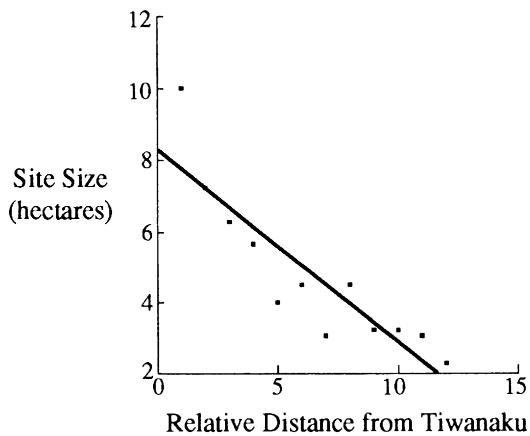
Figure 20. Scatter-plot of site size versus relative distance from Tiwanaku (including subsystems II and V).

villages (less than 2.0 ha in size) and the dispersed spread of larger villages suggests functional differentiation among these communities. These results are consistent with the emergence of weak central place networks within the subsystems of the Post-Classic period. This process never reached the level of a complete central place structure because the larger Tiwanaku system disintegrated completely by the 11th century A.C. (Albarracin-Jordan and Mathews 1990; Kolata 1993). The emergence of central place patterns within the subsystems may reflect regional "decentralization," as integrative relationships within subsystems grew in relative importance as the political, economic, and religious influence of Tiwanaku declined.

The primo-convexity of the Post-Classic Tiwanaku rank-size distribution suggests that regional subsystems were linked to one another chiefly through Tiwanaku-centered institutions. Ongoing investigation at Tiwanaku is confirming that Tiwanaku was a center for unique activities that may have had much to do with defining the identity of a Tiwanaku political formation: large-scale craft-production of materials in the Tiwanaku corporate art-style; transregional interaction and exchange; and high-level ceremonialism (Kolata 1993). This pattern is consistent with Kowalewski's (1982: 65) observation that special activities of premodern primate centers frequently relate to the maintenance of regional boundaries for a group of local subsystems.

The sizes and developmental trajectories of outlying settlements hint at the nature of these institutions, and their effect on settlements of various sizes within the regional sub-systems. One possibility is that the economic demands of the primate center, or the extension of urban administrative institutions into the surrounding countryside, inhibited the growth of neighboring large centers. The Post-Classic Period depopulation of Lukurmata, one of the largest public architecture centers in the Tiwanaku heartland during the Classic Period, may be an example of such a process (Bermann 1994). If central demands were supplanting the functional development of adjacent sites in the Post-Classic, we would expect site size, particularly of larger sites, to increase with distance from Tiwanaku. As can be seen in Figures 20 and 21, this is not the case. Instead, there is a negative correlation between site size and distance from Tiwanaku. Figure 20 shows this correlation ($n = 17$, $r = -.345$, $p = .175$) for all sites larger than 2 ha. Although the correlation is not strongly negative, it is somewhat significant. If subsystems II and V are left out (FIG. 21), there is a strongly negative, highly significant correlation between the size of sites and their distance from Tiwanaku ($n = 12$, $r = -.888$, $p < .01$). Figures 20 and 21 reveal a strong relationship between distance from Tiwanaku and site size in subsystems I, III, IV, and VI.

Figure 21. Scatter-plot of site size versus relative distance from Tiwanaku (excluding subsystems II and V).



There is no such relationship for site size in subsystems II and V. As can be seen in Figure 20, the five sites of the most distant subsystems (II and V) do not fall along this line, but form a loose group above it. One possibility is that local resource structure allowed larger individual settlements in subsystems II and V. Another is that the larger centers in subsystems II and V may reflect a central interest on the part of Tiwanaku rulers in administration and production in these zones. We favor a third alternative, that the presence of larger than expected centers in these two areas reflects the emrgence in these sectors of semi-autonomous central places articulated less closely with Tiwanaku.

Figures 20 and 21 make evident that some forms of system integration, and the associated forces governing settlement size, dropped off with distance. This supports the proposition that the populations of subsystems II and V—those most distant from Tiwanaku—were interacting differently with Tiwanaku, or, from an alternative perspective, that different processes were shaping settlement in these subsystems. In addition to revealing the different, and perhaps more autonomous, position of these subsystems in the overall settlement system, Figure 20 suggests that the powerful forces or factors structuring settlement size around Tiwanaku extended out roughly 10–15 km from the center of the site. The entire valley may well have been part of the Tiwanaku sustaining area, but our analysis suggests the existence of an inner "Tiwanaku sphere," probably reflecting the range of central political and socioeconomic institutions.

Overall, the Post-Classic Period patterns indicate that: 1) the site of Tiwanaku played a highly important role in regional integration; and 2) interaction with Tiwanaku was acting strongly in some manner on the size of outlying communities, although we cannot yet explain how this was occurring. Observing a similar pattern around Warka, Johnson (1980a: 247) suggested that increasing administrative costs with distance limited the size of local populations in an undefined way. Alternatively, proximity to Tiwanaku and its institutions may have been desirable, leading to larger settlements and higher population density within a single-day's walking distance of the capital.

Post-Classic Tiwanaku Settlement Subsystems and the "Nested Hierarchy" Model

In this paper, we have explored the nature of regional settlement in the Tiwanaku Valley (lower and middle sector), incorporating ecological considerations, rank-size interpretations, and some aspects of central place theory. The results of the analysis have important implications for understanding state formation and organization in the south-central Andes. Little is known about the internal organization and integration of the Tiwanaku polity. With some exceptions (Berenguer and Dauelsberg 1988; Browman 1984; Nuñez and Dillehay 1979; Lumbreras and Mujica 1982), the predominant view of the Tiwanaku polity during the last few decades has been as a highly unified and tightly integrated polity, with a high level of political and economic centralization. This polity was ruled by an elite stratum residing in the capital through a centralized and coercive bureaucratic apparatus (Kolata 1986, 1991, 1993; Ponce Sanginés 1972, 1994, 1995). In this "top-down" reconstruction, public architecture centers such as Lukurmata functioned as secondary administrative centers, involved in overseeing agrarian production (Bermann 1994). Activities in the Tiwanaku heartland, such as the construction and use of raised field systems, were directed and managed by the capital. The spread of Tiwanaku-style materials outside of the heartland was the result of "imperial" colonial strategies.

A contrasting, although not entirely contrary, model of Tiwanaku has been put forward by Albarracin-Jordan (1992). Noting that nearest-neighbor analysis of site distribution in the region shows that secondary centers are regularly distributed, while tertiary and quaternary sites cluster around the secondary loci, Albarracin-Jordan (1992) proposed that the Tiwanaku settlement pattern in the Lower Tiwanaku Valley represented a nested system of distinct subunits. In this model, drawn from ethnohistorical and ethnographic data on Aymara principles of political and economic organization, Tiwanaku society represents an essentially segmentary political system, organized in territorial nodes with local political hierarchies, and articulated through common ideological denominators and reciprocal mechanisms. Rather than a monolithic and bureaucratic state, Albarracin-Jordan suggests that Tiwanaku can best be understood as a particularly Andean form of confederation in which local groups (such as the subsystem clusters in Figure 16) coalesce into larger formations through ceremonial and ideological oppositions.

The native Andean *ayllu* was a social group of a segmentary nature and with a territorial base. It had various organizational levels, increasingly inclusive, which conform with the principles of the segmentary dynamics that characterize Aymara society (Izko 1992: 72). Ethnohistorical documents and ethnographic data indicate that hierarchies of ayllus could reach complex levels of political and economic organization, and produce regional systems of significant scale (Izko 1992; Platt 1987; Rivera Cusicanqui 1992). Minor ayllus in these systems, however, maintain their local identities and autonomy, and the larger clusters of major ayllus and confederations are integrated through reciprocal relationships among their segments (Platt 1987). Moreover, ayllus can converge to form nucleated settlements, called ***markas*** (Choque 1990). The site of Tiwanaku itself would represent the maximal confederation of similar social units in the Tiwanaku heartland. Although the ayllu cannot be projected directly into Tiwanaku's past, its basic organizational principles appear to be represented in the archaeological record. If these dimensions of Aymara society, which seem to find expression in other Andean populations known both archaeologically and ethnographically (Julien 1993; Netherly 1990, 1993; Pease 1982, 1992; Silverman 1990, 1993; Wachtel 1986), are taken into consideration, the archaeological record in the Tiwanaku Valley provides important testimony to the long historical trajectory of these organizational principles. The segmentary nature of ancient Tiwanaku society would have made it difficult for a highly centralized form of government to develop, explaining why Tiwanaku seems to have lacked the bureaucratic infrastructure (forts, storage depots, administrative sites) that characterizes the prehispanic Wari and Inca empires to which Tiwanaku is often compared (Bermann 1994: 246).

The data presented in this study lend support to the suggestions arising from recent work that the internal integration of the Tiwanaku system was highly complex. The features of this integration may have included diverse, and probably shifting, relationships of subordination among kin-based sociopolitical units, characterized by varying degrees of coalition and autonomy; pilgrimage activities and cult centers; local and regional processes of political self-aggrandizement and ritual legitimization; intensification of staple production; and the circulation of highly valuable craft goods displaying Tiwanaku iconography (Albarracin-Jordan, Lemoz, and Paz, 1994; Janusek 1994; Kolata 1993).

The identification of subsystems in the Tiwanaku Valley through the application of cluster analysis, and the rank-size distributions with their clear evidence of "pooling," parallel the results of nearest-neighbor analysis of the Tiwanaku settlement pattern in the lower sector of the valley. The sub-regional continuities in the settlement enclaves indicate that these were important social units in their own right, both before Tiwanaku's rise and following its collapse. Our reconstruction has several implications for understanding Tiwanaku as a polity. First, the origins of the Tiwanaku polity may be rooted in the dynamics of interaction of these groups. Second, a variety of processes—from the construction of raised fields to trade and Tiwanaku colonial settlement in the Andean sierra—should perhaps be treated as reflecting the activities of powerful social segments, rather than the activities of a politically centralized, monolithic empire. Much future research at the community and subregional levels will be needed before we understand patterns of socioeconomic integration within the Tiwanaku polity, or how large-scale prehispanic segmentary societies, in general, operated. The congruity between this archaeological evidence from the Tiwanaku Valley and the sociopolitical principles documented ethnohistorically opens up promising avenues for developing a more sophisticated perspective on prehispanic Andean statecraft.

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