SPACE, EVOLUTION AND FUNCTION IN THE HOUSES OF CHACO CANYON

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0 Abstract

From A.D. 860 to 1130, ancestral Puebloan peoples constructed more than a dozen multi-storey structures along a 14-km stretch of Chaco Canyon in the arid mountain desert of the Four Corners area in the American Southwest. These so-called 'great houses' ranged in size from 54 to 800 rooms. For the past 145 years, archaeologists have sought an understanding of the social organization that produced such monumental structures. Despite intensive study, the function of great houses in Chacoan society is unknown. Using space syntax access analyses, this research examines within- and among-great house spatial organization and evaluates social organisational models.

Space syntax is used to analyse 11 discrete roomblocks from three excavated great houses. Access graphs are constructed and used to generate syntactic data. Using a three-phase temporal framework previously developed for the great house period, changes over time in patterning, spatial phenotypes, and functional genotypes are identified. The results of this research are used to evaluate the spatial implications of the currently-proposed Chaco great house models. Syntactical analyses suggest that it is unlikely that any one of these models fits all the great houses. The syntactical evidence is best explained by a mixed-use model for great houses rather than a single function model.

1 Introduction: an archaeological problem

The prehistoric cultural landscape of Chaco Canyon is made up of both monumental great houses, which first captured the public imagination, and a multitude of more modest structures, the small houses. Located in the semi–arid, mountain desert of the American Southwest, Chaco Canyon was the centre of a remarkable culture that flourished 1000 years ago. Archaeologists call this culture Anasazi, or ancestral Puebloan. The Chaco Canyon architectural record has been extensively studied, yet the relationship between great and small houses remains a fundamental problem of Southwest archaeology (Toll, 1985). The precise role of the great houses in the ancestral Puebloan cultural system is unknown. For more than 100 years, archaeologists have sought an understanding of the social organisation that built such impressive structures (Lekson, 1986). Using the same data, archaeologists have produced contradictory models for great houses.

The massive investment of labour and materials in the construction of great houses makes understanding these structures critical to understanding the Chaco Canyon social system and the regional system in which it was set. First, however, we need to understand the social and functional role of the small houses (Bustard, 1995). It has been assumed that small houses were residences, but the spatial organisation of these structures has not been systematically investigated, and inferences about domestic social organisation remain largely dependent on ethnographic analogy. While the small houses have received little analytic attention, debates over the functional significance of great houses have preoccupied researchers for the past three decades, with no resolution in sight. The failure to consider both form and function in archaeological spatial analysis, compounded by an overreliance on ethnographic analogy for assumptions and explanations, has limited our understanding of prehistoric spatial, and by inference social, organisation in the American Southwest. A new analytical approach, independent of ethnographic analogy, is needed to break the explanatory logjam. Space syntax provides the analytic tools for such an approach.

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Using space syntax, inferences of social organisation can be developed two ways: first, by graphing spatial relations to identify patterns in use, and second, by quantifying spatial relations to determine differences in the way in which activities are deployed across space. As architect David Saile (1977, page 159) has observed, ". . . architecture deals with 'place.' Place implies spatial organization, that is, the ordering of qualities which distinguish certain places from others or from nebulous undifferentiated space. . . ." The measures of integration and control (Hillier and Hanson, 1984) provide a numerical language to describe these ordering of qualities or spatial relations, an important step beyond graphical description. Differences in integration and control values from one space to another are a result of social relations played out in social space (Hillier et al, 1984). The robustness of differences in these variables can be tested using standard statistical analyses.

1.1 The data set

This study will focus on three great houses and 20 small houses in Chaco Canyon that have been extensively excavated. The size and complex construction history of the great houses requires breaking each down into its component roomblocks for analysis (see Lekson, 1986 for construction sequences). Table 1 lists all small houses and great house roomblocks used in this analysis, by culture phase.

Table 1	*Bonito Phase*	*Small Houses*	*Great House Roomblocks*
	Early		Pueblo Bonito IA
	A.D. 850–1000		Pueblo Bonito IBD
	Classic		
	A.D. 1000–108	29SJ 627	Pueblo Bonito IIIA
		East Ruin	Pueblo Bonito VIA
		Ruin 3	Pueblo Bonito VIB1
		Smith Ranch Ruin	Pueblo Bonito VIB2
		Turkey House	Pueblo del Arroyo IA
	Late		
	A.D. 1080–1170	Bc 26	Pueblo del Arroyo IIA
		Bc 50	Pueblo del Arroyo IIIA
		Bc 51	Kin Kletso IA
		Bc 52	Kin Kletso IB
		Bc 53	•
		Bc 54	•
		Bc 57	•
		Bc 58	•
		Bc 59	•
		Bc 126	•
		Bc 192	•
		Bc 236	•
		Bc 362	•
		Rabbit Ruin	•
		Ruin 13	•

Table1. Small houses and great house roomblocks by Bonito Phase.

The spatial analyses will proceed with (1) the construction of access graphs and syntactic data; (2) exploratory data analyses of the data; (3) the examination of spatial phenotypes; and (4) the identification of an underlying spatial–functional genotype, with a discussion of change in the genotype over time. In the final section of this paper, I will compare small and great house data sets and evaluate the spatial implications of many currently–proposed Chaco explanatory models. These models attribute varying functional significance to the great houses, but have not been assessed against the small house record.

2 Construction of access graphs and syntactical data

Plans and access graphs for the 20 small houses are provided in Figures 1 and 2[1]. The access graphs of Chaco small houses illustrate a general similarity in the built environments. The overwhelmingly dominant form of small house graphs is a "tree" pattern, which results from the addition of back rooms with no lateral connection with neighbouring spaces. Ease of access through circuit pathways, or rings of interconnected rooms and spaces, does not characterize Chaco small houses. Such spatial sequencing may have permitted the monitoring and control of access to the "deep" interior spaces. Nevertheless, there are limits to the depth: the longest nonbranching sequence of spaces is five. Where all spaces are interior rooms, the length of spatial sequences may be limited by the practical considerations of light and ventilation.

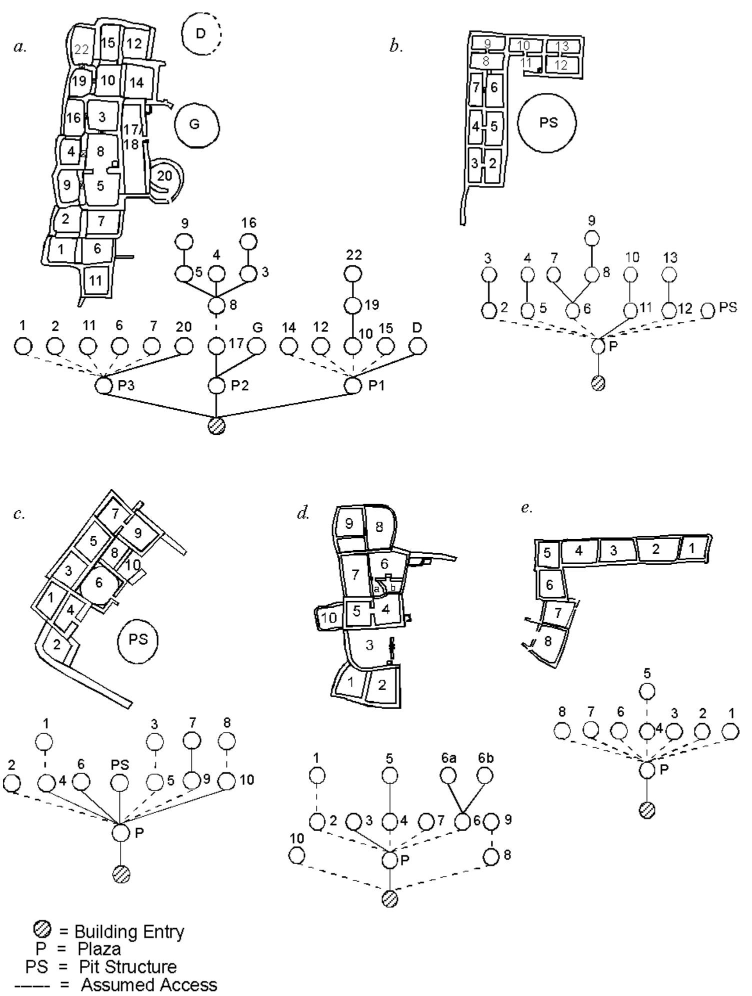


Figure 1. Access graphs for Classic Bonito Phase small houses a. 29SJ 627; b. East Ruin; c. Smith Ranch Ruin; d. Turkey House; e. Ruin 3.

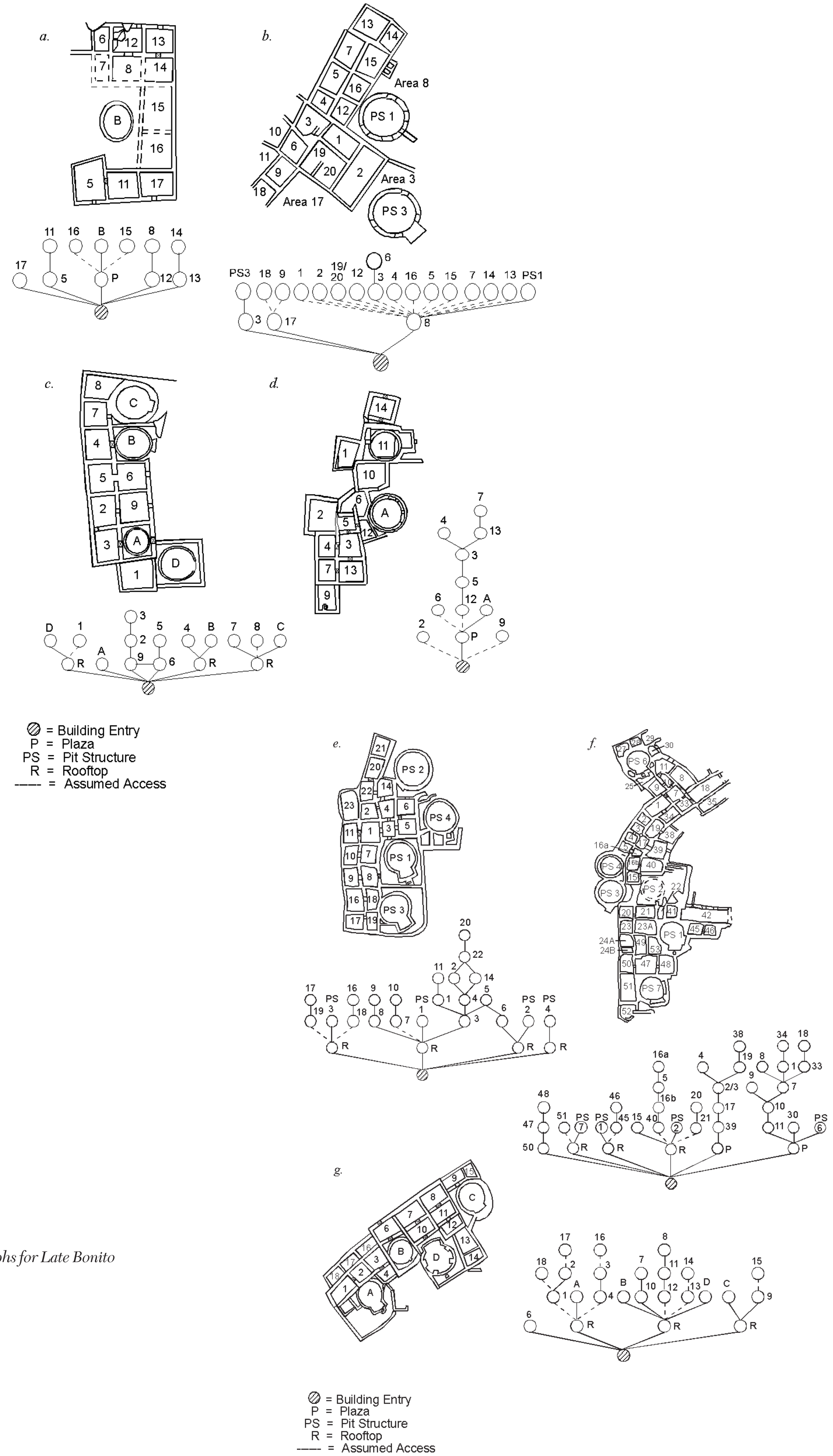
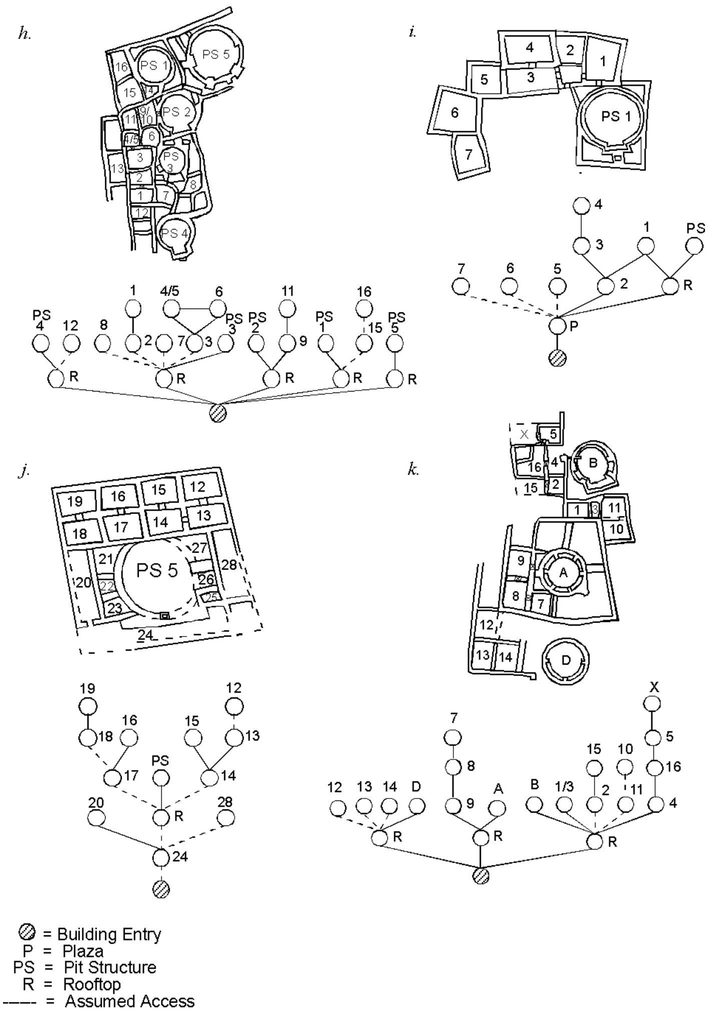
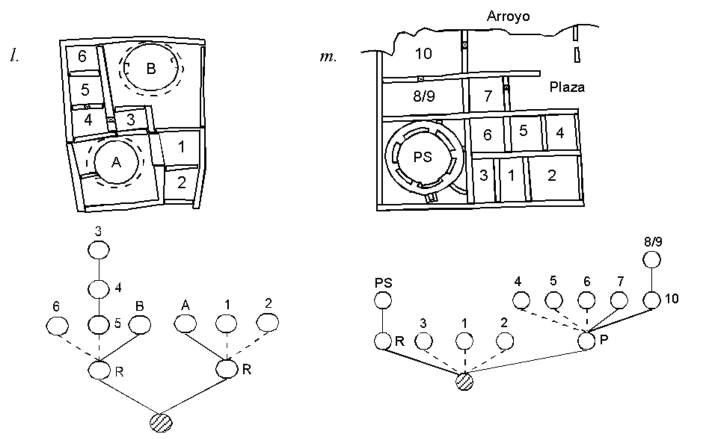


Figure 2a. Access graphs for Late Bonito Phase small houses;
a. Bc 192;
b. Bc 362;
c. Bc 57;
d. Bc 58;
e. Bc 50;
f. Bc 51;
g. Bc 53.





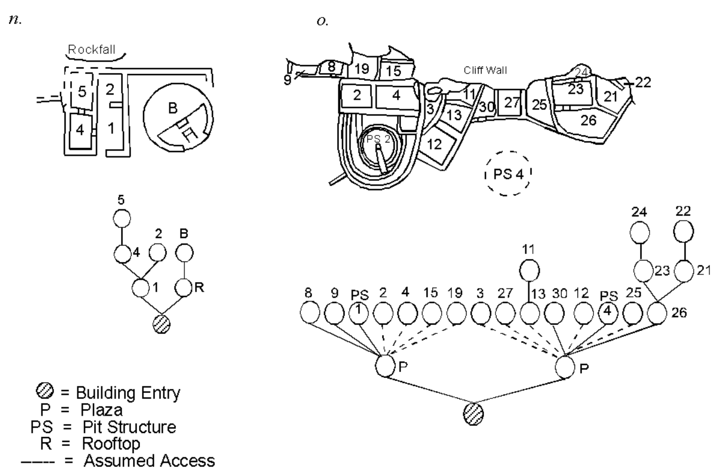
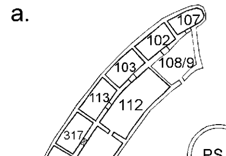


Figure 2b. Access graphs for Late Bonito Phase small houses;
h. Bc 59;
i. Ruin 13;
j. Rabbit Ruin;
k. Bc 26;
l. Bc 126;
m. Bc 236;
n. Bc 54;
o. Bc 52

In contrast, great house roomblocks are distinguished by unique spatial configurations, which makes pattern recognition studies difficult. Access graphs generated for the great house samples are provided in Figures 3 through 5. Graphs of Pueblo Bonito IA and IBD, and Pueblo del Arroyo I are similar: shallow tree graphs with small suites of rooms, similar to small house graphs. Access graphs for the other great house roomblocks are characterized by many circulation rings and/or excessive depth.[2]



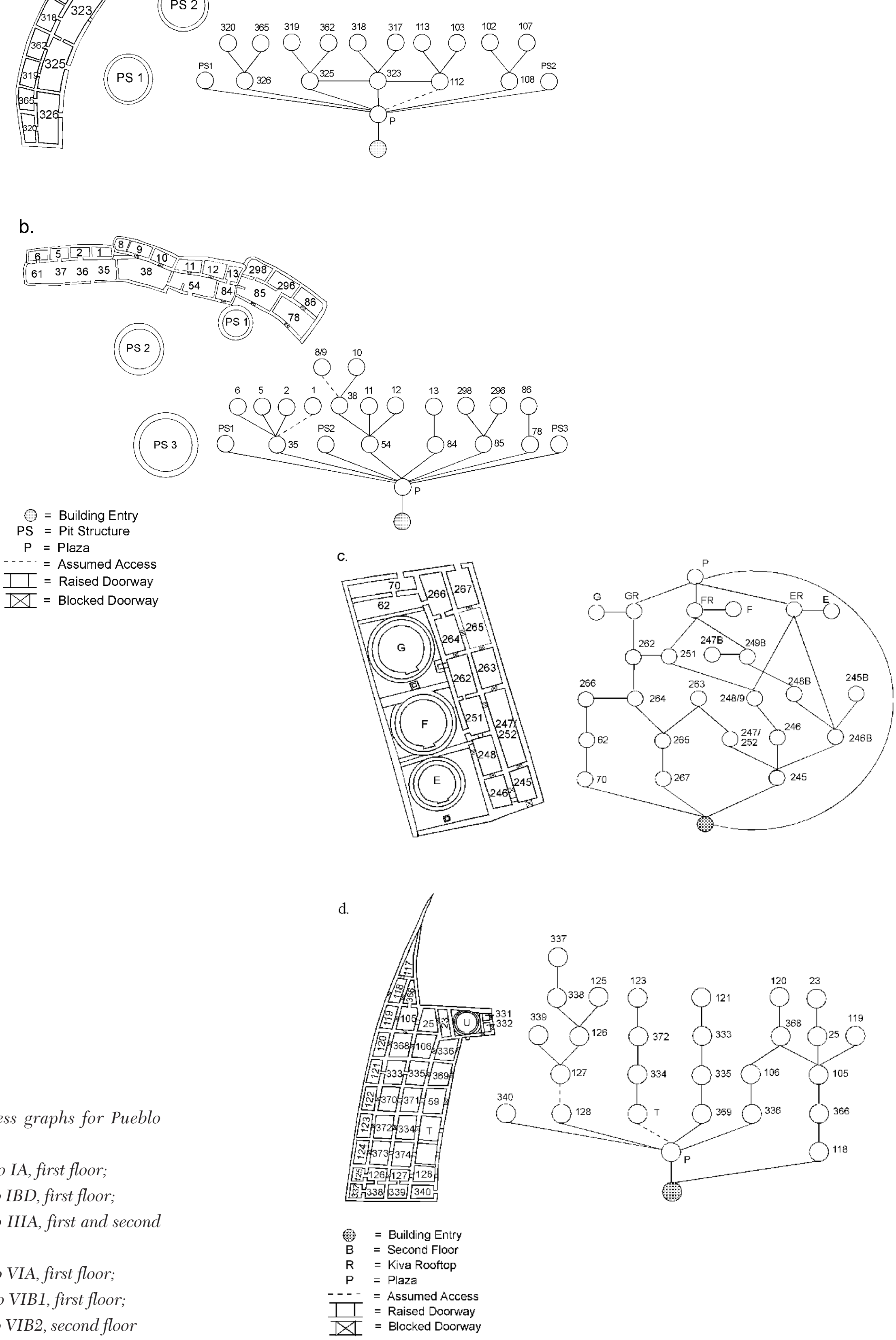


Figure 3. Access graphs for Pueblo Bonito:
a. Pueblo Bonito IA, first floor;
b. Pueblo Bonito IBD, first floor;
c. Pueblo Bonito IIIA, first and second floors;
d. Pueblo Bonito VIA, first floor;
e. Pueblo Bonito VIB1, first floor;
f. Pueblo Bonito VIB2, second floor

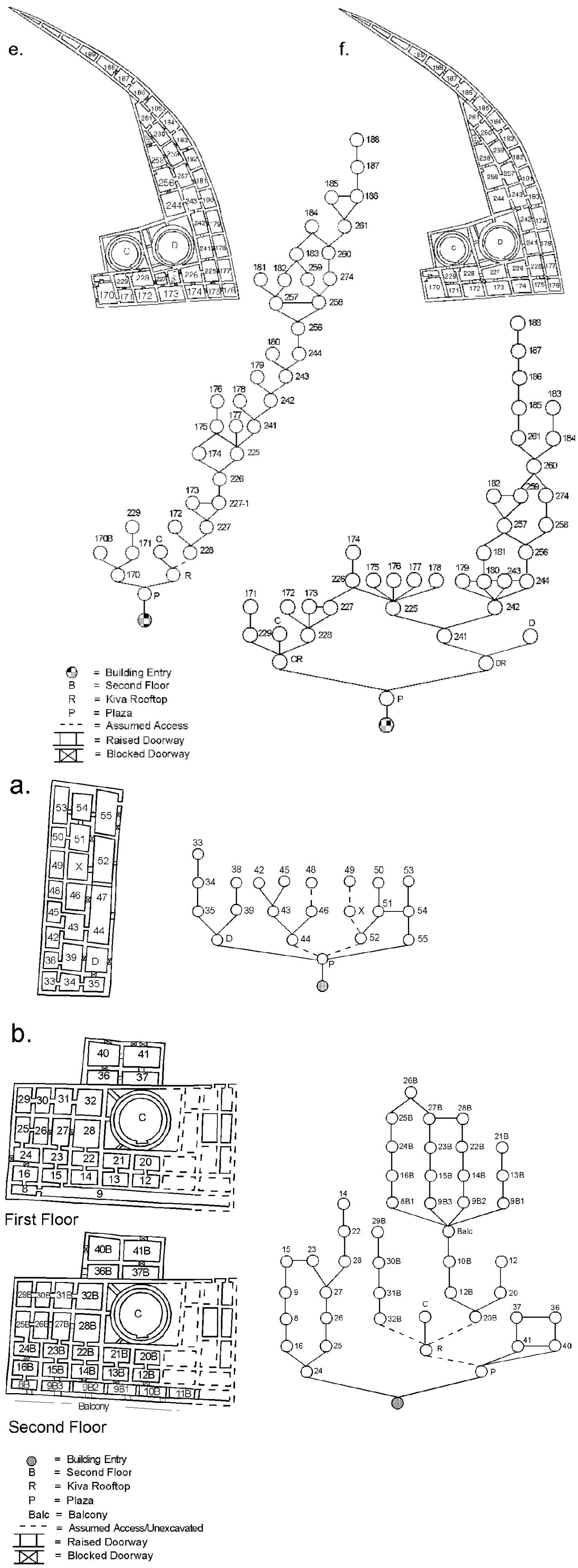
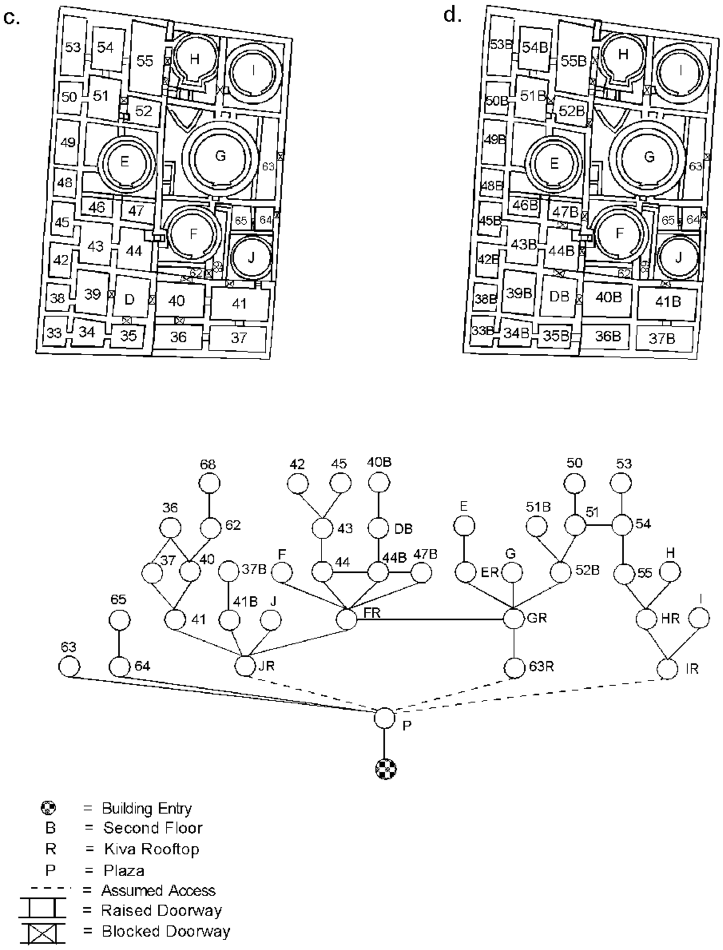


Figure 4. Access graphs for Pueblo del Arroyo:
a. Pueblo del Arroyo I, first floor;
b. Pueblo del Arroyo IIA, first and second floors;
c. Pueblo del Arroyo IIIA, first floor;
d. Pueblo del Arroyo IIIA, second floor



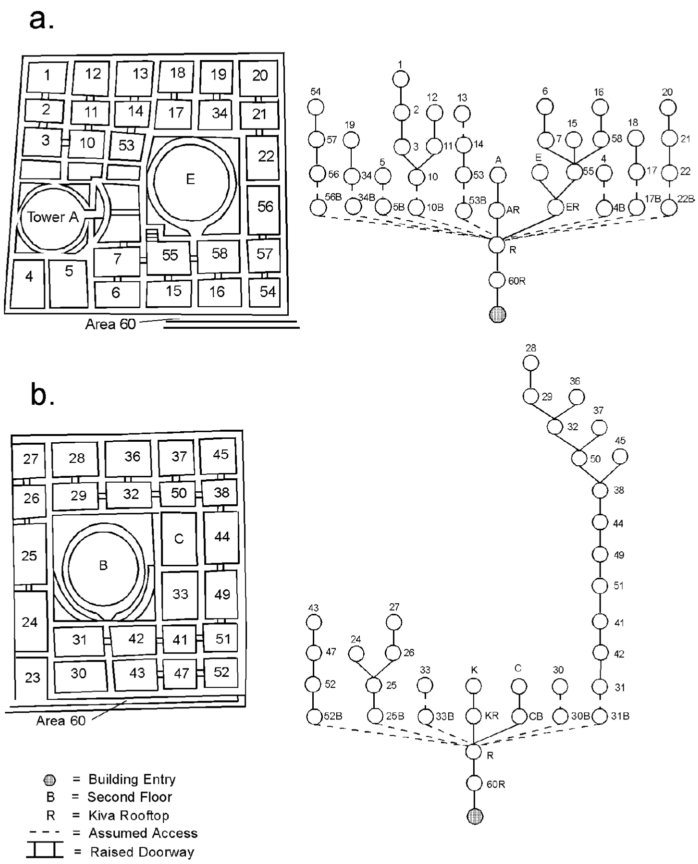


Figure 5. Access graphs for Kin Kletso;
a. Kin Kletso Stage IA, first floor;
b. Kin Kletso Stage IB, first floor

Syntactic measures of Standardized Integration (SI)[3] and Control were calculated for both samples using the procedures described in Hillier and Hanson (1984). Table 2 lists the mean SI values for individual small houses and great house roomblocks in ascending order. The distribution of values in Table 2 supports the general conclusion that small house space is segregated in terms of access (Hillier and Hanson, 1984). Although the mean SI values do not sort temporally, the range in values from .75 to 1.63 suggests variation in the degree of segregation. Change over time is a research topic of great interest to archaeologists, and thus knowing if there are temporal and/or functional differences in small house spatial organisation that would account for the wide range in mean SI values would be useful

Table 2

Small House	*Mean SI*
Bc 362	0.7535
Ruin 3	0.7818
Smith Ranch Ruin	0.8967
Bc 236	0.9813
Bc 52	1.0088
East Ruin	1.0253
Ruin 13	1.0276
Bc 57	1.0289
Bc 59	1.0754
Turkey House	1.0846
Bc 192	1.0956
Bc 50	1.2244
Bc 53	1.2424
Rabbit Ruin	1.2425
Bc 26	1.2868
29SJ 627	1.3177
Bc 126	1.4386
Bc 51	1.4277
Bc 58	1.5955
Bc 54	1.6263
Sample Mean	**1.159**

Great House	*Mean SI*
Pueblo Bonito IA	0.831
Pueblo Bonito IBD	0.883
Pueblo Bonito IIIA	0.923
Pueblo del Arroyo IIIA	1.117
Kin Kletso IA	1.138
Pueblo del Arroyo IA	1.266
Pueblo Bonito VIA	1.514
Pueblo Bonito VIB2	1.664
Pueblo del Arroyo IIA	1.948
Kin Kletso IB	1.996
Pueblo Bonito VIB1	2.246
Sample Mean	**1.411**

Table 2. Mean SI values

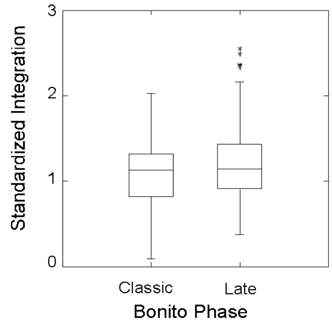
Mean SI values for great houses also support an interpretation of spatial segregation. Of interest is a noticeable increase in mean SI between Pueblo Bonito IIIA and Pueblo del Arroyo IIIA. Pueblo Bonito IIIA is the earliest Classic Bonito Phase roomblock in this sample. In terms of integration, this roomblock appears transitional between Early and Classic Bonito Phase construction. Its access graph, with an abundance of circulation rings (Figure 3c), sets it apart from the other roomblocks as well. The SI means for great house roomblocks climb quickly upwards, culminating in an extremely high mean of 2.246 for the first floor of the Pueblo Bonito VIB roomblock. The large range, from .831 to 2.246, suggests substantial differences in the degree of spatial segregation in this sample. If spatial integration values are not randomly distributed across time periods and/or activity areas, that is, if patterns exist in the data, then it may be possible to specify the nature of spatial organisation through time. Exploratory data analysis is one means of discovering patterns in data.

3 Exploratory data analysis

Exploratory data analysis (EDA) is a useful way to assess data sets before conducting statistical tests. EDA is based on the simple premise that looking at the data first is advisable, specifically shape, spread, location, and skewness (Hartwig and Dearing, 1979). The first step is to decide whether the distributions are normal or not, since tests of significance are dependent on assumptions regarding the normality of the data. The second step is to identify trends in the data and test for statistical significance. Box–and– whisker plots (boxplots) are useful in assessing the shape of distributions, detecting departures from normality, and in identifying trends in the data. The nature of these samples offers an opportunity to explore multiple dimensions of the data sets; this analysis will focus on a temporal comparison of small and great houses by Bonito Phase.

3.1 Bonito Phase variation in small houses

The small house data set includes houses from the Classic and Late Bonito Phases. The question being asked is, do differences exist in SI and Control values between Classic and Late Bonito Phase small houses that may signal differences in spatial organisation over time? Side–by–side boxplots of SI values by phase show overlapping distributions with similar locations but slightly different midspreads and ranges (Figure 6). The assumptions for parametric statistical tests of differences in means are independent random samples, normal distributions for each group, and equal standard deviations. Despite a few mild outliers, the standard deviations are similar and the two distributions do not appear to grossly violate the assumptions of



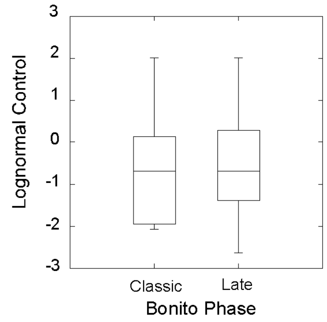


Figure 6. Side–by–side boxplots of SI and Control distributions by phase for small houses (Classic Bonito n = 85; Late Bonito n = 290).

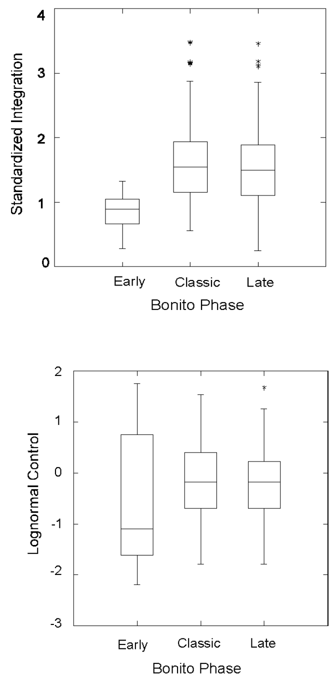


Figure 7. Side–by–side boxplots of SI and Control distributions by phase for great house roomblocks (Early Bonito n = 45, Classic Bonito n = 158; Late Bonito n = 170).

normality. A Student's t–test of differences in means was significant (p=.0168). The side– by–side boxplots and the significantly different SI distributions suggest that space within small houses during the Late Bonito Phase was deeper and more segregated.

The Control distributions were highly skewed for both phases, suggesting nonnormal distributions. A natural logarithmic transformation of the Control values normalised the data, producing overlapping distributions with similar locations but different midspreads and ranges, and no outliers. A Student's t–test was not significant for the –logged Control variable.

3.2 *Bonito Phase variation in great house roomblocks*

The great house data set encompasses Early, Classic, and Late Bonito Phase construction. Side–by–side boxplots of SI distributions by phase show similar midspreads and locations for the Classic and Late Bonito Phases, and a distinctly different, nonoverlapping distribution for the Early Bonito Phase (Figure 7). Outliers in the Classic and Late Bonito Phase boxplots and unequal standard deviations suggest the distributions are nonnormal. Data transformations did not improve matters, and so a nonparametric test was deemed appropriate. A Kruskal–Wallis test of SI by phase was highly significant (p=.0001). Individual Wilcoxon Rank Sum tests of pairs of phases confirmed that the significant differences lie between the Early Bonito Phase and the other two phases. SI values for Classic and Late Bonito Phases were not significantly different.

Boxplots of logged Control distributions also show similar midspreads and locations for Classic and Late Phases, but an elongated, overlapping midspread for the Early Bonito Phase. The logged Control distributions do not strongly violate the normality assumptions for an analysis of variance. The result was highly significant (p=.003). Multiple comparisons (Bonferroni's t–tests, _ = .016) confirmed that, like the SI distributions, Early Bonito Phase Control values are significantly different from both Classic and Late Bonito values, but the latter are not significantly different from each other. The boxplots and statistical tests suggest temporal differences distinguishing the Early from the Classic and Late Bonito Phases in terms of integration and control of space.

To summarize the results of the exploratory data analyses, statistically significant differences in SI values for both small and great houses across Bonito phases were identified. Control distributions were not statistically different for small houses, but were for great houses. The observed differences in SI distributions over time require closer examination of patterning in spatial placement and function.

4 Spatial phenotypes: differentiation and patterning

In this section I will quantitatively examine patterning and differentiation in the arrangement of space within each great and small house. In syntactical terms, access relations in individual buildings are phenotypical expressions of an inequality genotype (discussed below) (Hillier et al, 1987). Spatial differentiation at the phenotypical level was tested using the base difference factor statistic, as described in Hillier et al (1987). The strength or weakness of integration differences among spaces can be quantified with a 'difference factor' measure derived from Shannon's H–statistic (Shannon and Weaver, 1949). Shannon's H–statistic was developed to measure how much information is lost in transmission. The concept of information is related to the idea of variance (Kathryn M. Trinkaus, personal communication, 1996) and the H–statistic has been adapted to measure variances in integration values. The Difference Factor formula is as follows:

$$H = S\left[\frac{a}{t}\ \ln\left(\frac{a}{t}\right)\right] + \left[\frac{b}{t}\ \ln\left(\frac{b}{t}\right)\right] + \left[\frac{c}{t}\ \ln\left(\frac{c}{t}\right)\right] \quad (1)$$

where a, b, c = integration values of the spaces, t = _ a, b, c, and ln = the natural logarithm (Hillier et al, 1987). This statistic describes the variance in integration within each structure, which may be a result of functional differentiation (Hillier et al, 1987). The difference factor statistic produces a value between 0 (maximum difference, or strong functional differentiation) and 1 (no difference, or complete identity).

4.1 Difference Factor Analyses

Base difference factors were calculated for each small house in the sample; individual values range from an extremely strong .263 to a weak .827 (Table 3). The mean base difference factor for the 20 small houses is .68, which is quite strong in a sample (Hillier et al., 1987). This finding suggests strong spatial structure, which may relate to functional differentiation. Base difference factors for great house roomblocks have a much smaller range, from .667 to .861, with a mean of .77, suggesting a weaker functional structure in comparison with the small houses (Table 4). This finding of weaker structure is predicted by space syntax theory, in which a decrease in the strength of spatial structure (or a switch from deterministic or probabilistic spatial relations) occurs when buildings increase in size (Hillier et al, 1984).

Table 3

Small House	*No. Spaces*	*Mean SI*	*Min SI*	*Max SI DF*[1]	*Base DF*[2]	*Int.*
Bc 26	22	1.287	0.645	2.158	0.738	0.98
Bc 50	27	1.224	0.625	2.083	0.738	0.97
Bc 51	40	1.428	0.688	2.364	0.731	0.99
Bc 52	23	1.009	0.456	1.553	0.741	1.00
Bc 53	25	1.242	0.598	1.866	0.772	0.99
Bc 54	7	1.626	0.784	2.549	0.755	0.91
Bc 57	12	1.029	0.376	1.639	0.654	0.93
Bc 58	16	1.606	0.957	2.488	0.827	0.96
Bc 59	23	1.075	0.456	1.595	0.735	0.99
Bc 126	11	1.439	0.753	2.335	0.767	0.92
Bc 192	12	1.096	0.383	1.531	0.693	0.99
Bc 236	13	0.981	0.384	1.537	0.685	0.95
Bc 362	21	0.754	0.215	1.292	0.534	0.99
29SJ 627	25	1.318	0.67	2.029	0.780	0.99
Ruin 3	10	0.782	0.091	1.362	0.263	1.00
Ruin 13	11	1.028	0.377	1.808	0.608	0.96
Smith Ranch	13	0.897	0.22	1.318	0.553	0.98
Turkey House	14	1.085	0.384	1.729	0.643	0.96
East Ruin	15	1.025	0.339	1.655	0.613	N/A[3]
Rabbit House	14	1.243	0.528	1.873	0.729	N/A
Mean		**1.159**	**0.496**	**1.838**	**0.678**	**0.969**

Table 3. Small house syntactic data and difference factor analyses.

1: The base difference factor is calculated using the minimum, maximum, and mean integration values for each roomblock (Hillier et al, 1987).

2: The interior difference factor is calculated using the mean integration values for the three most common interior space labels in each roomblock.

3: East Ruin and Rabbit House were not excavated; interior features are unknown.

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Table 4

Room Block	No. Spaces	Mean SI	Min SI	Max SI	Base DF	Int. DF
Bonito IA	19	0.831	0.283	1.132	0.694	0.92
Bonito IBD	23	0.883	0.311	1.326	0.667	0.97
Bonito IIIA	26	0.923	0.561	1.344	0.855	0.99
Bonito VIA	28	1.514	0.788	2.303	0.793	0.96
Bonito VIB1	41	2.246	1.511	3.481	0.861	0.99
Bonito VIB2	40	1.664	1.05	3.175	0.751	N/A[1]
Arroyo IA	22	1.266	0.579	2.003	0.734	0.98
Arroyo IIA	46	1.948	1.227	3.182	0.823	0.99
Arroyo IIIA	41	1.117	0.62	1.791	0.792	0.99
Kletso IA	42	1.138	0.47	1.887	0.678	0.99
Kletso IB	35	1.996	1.203	3.458	0.778	1.00
Mean		**1.411**	**0.782**	**2.280**	**0.766**	**0.979**

Table 4. Great house syntactic data and difference factor analyses.

1: An interior difference factor was not calculated since there were only two types of interior space labels in this roomblock.

The extent of residential use of great houses is still a research question, and thus differentiation in the integration of domestic activities within enclosed great and small house space is of great interest. To assess the degree of functional differentiation among interior spaces, I conducted an interior difference analysis. The analyses in this section require identifying activity loci or special–use places and assigning each a space use label. Architectural fixed–floor features such as firepits and slab bins can be used as activity indices to examine differentiation in space use, particularly domestic or nondomestic use. The space labels used in this analysis are listed on Table 5. Built space is defined as architecturally bounded, but not enclosed, space. I have subdivided built space into three mutually exclusive categories: building entry, plaza, and kiva or pit structure rooftop. The latter were used as terraces for surrounding rooms. Built form refers to enclosed space and includes surface rooms and pit structures or kivas. Pit structures are circular and semi–subterranean; kivas are also circular and may be semi–subterranean, surface, and multi–storey. Both are assumed to have had a specialized ritual or socially–integrative function (Adler, 1989). Surface rooms are the focus of interest in this analysis, especially insofar as they contain domestic features. Firepits are assumed to have had a heating and/or cooking function. Mealing bins were used for the processing of corn into flour, and are diagnostic of domestic activities. Included in the label 'storage facility' are bins, subfloor cists, shelves, and platforms for the short–term storage of goods and/or foodstuffs. Space labels 'firepit,' 'mealing bin,' and 'storage facility' are not mutually exclusive; surface rooms were coded for all floor features present. Table 5 includes frequencies of space labels for each sample. Although rooms with no floor features are the most numerous category in both data sets, they clearly dominate in the great house sample, with implications for great house function, as discussed below.

Built Environment	*Space Label*	*Small House N=*	*Great House N=*
Built Space	Building Entry (E)	20	11
	Plaza (P)	16	9
	Kiva/Pit Structure Rooftop (R)	28	22
Built Form			
Sub/surface Rooms	Kiva (K)	•	21
	Pit Structure (PS)	•	39
Surface Rooms	Mealing Bin (M)	20	4
	Firepit (F)	72	27
	Storage Facility (S)	33	21
	No Floor Features (N)	99	205

Table 5 Space labels used in analysis.

Using the mean SI values for the three most common interior space labels in each great and small house, I calculated an interior difference factor. This analysis resulted in mean interior difference factors of .97 and .98 for small and great houses, respectively (Tables 3 and 4, East Ruin and Rabbit House are excluded because they have not been excavated and hence room features are unknown). These extremely weak values suggest little locationally–dependent functional differentiation among interior rooms. This finding of virtually no interior functional differentiation contrasts sharply with the strong mean base difference factor for small houses of .68 and requires explanation. Further analysis is required to sort out the contradiction between these two statistics. This will be accomplished by analysing SI values for each space label in the small house sample. These analyses will identify the underlying structure, or genotype, for each sample and help to reconcile the difference factor results. Statistical differences in spatial integration between built space and built form, and between spatial functions, account for the overall robust spatial structure suggested by the base difference factor.

Table 6

Roomblock	*SI Order*[1]							
Bc 26	E >[2]	R >	M >	PS >	S >	F >	N	
	.65	.82	1.05	1.27	1.31	1.38	1.43	
Bc 50	E >	R >	N >	M >	PS >	F >	S	
	.67	.89	1.04	1.16	1.29	1.35	1.56	
Bc 51	E >	P >	R >	M >	PS >	F >	S >	N
	.67	.86	.99	1.31	1.33	1.41	1.5	1.68
Bc 52	E >	P >	F >	PS >	N			
	.56	.58	.97	1.02	1.12			
Bc 53	E >	R >	PS >	N >	S >	F		
	.6	.77	1.17	1.36	1.41	1.43		
Bc 54	E >	F >	S >	R >	N >	PS		
	.98	1.08	1.37	1.57	2.06	2.55		
Bc 57	E >	M >	R >	PS >	N >	F >	S	
	.38	.68	.73	1.15	1.17	1.22	1.23	
Bc 58	R >	E >	F >	PS =	M >	S >	N	
	.96	1.34	1.56	1.6	1.6	1.98	2.23	
Bc 59	E >	R >	M >	S >	PS >	N >	F	
	.46	.75	.99	1.12	1.19	1.22	1.29	
Bc 126	E >	R >	PS >	N				
	.83	.90	1.58	1.67				
Bc 192	E >	P >	F >	PS >	N			
	.38	.64	1.05	1.28	1.36			
Bc 236	P >	E >	R >	M >	F >	PS		
	.38	.44	.93	.99	1.07	1.54		
Bc 362	E >	P >	S >	N >	F >	M >	PS	
	.43	.61	.65	.73	.81	.86	.98	
SJ627	E >	P >	PS >	F >	M >	S >	N	
	.67	.83	1.23	1.27	1.29	1.48	1.53	
Ruin 3	P >	E =	F =	M >	N			
	.09	.82	.82	.82	.89			
Ruin 13	P >	R >	F >	E >	S >	PS =	N	
	.38	.75	.96	1.06	1.09	1.43	1.43	
Smith Ranch	P >	M >	E =	PS >	F >	N		
	.22	.71	.82	.82	.95	.98		
Turkey House	P >	E >	M >	F >	N			
	.38	.67	.77	1.15	1.2			

Table 6. Spatial pattern for each small house.
1: E=Building Entry,
F=Firepit,
K=Kiva,
M=Mealing Bin,
N=No Floor Features,
P=Plaza,
R=Rooftop,
S=Storage Facility
2: > = is more integrated than

4.2 Spatial phenotypes

Mean SI values for space labels can also be used to examine spatial patterning in access relations among houses. To discern patterns in spatial organization based on the relative location of functions, a useful first step is to describe each small house through an ordering of SI values by label (Hillier et al, 1987). Table 6 lists the order of SI means by space label (the spatial phenotype) for each small house; by convention, the most integrating space is placed first. General conclusions can be drawn from the data in this table, for instance, that building entries, plazas, and pit structure rooftops tend to be the most integrating spaces; however, no two small houses have the same spatial pattern.

Table 7 lists the SI mean order for each great house roomblock. The spatial phenotypes for Pueblo Bonito IA and IBD are identical. Generally, plazas (or rooftop areas) are the most integrating spaces and no–floor–feature rooms the least. An exception is Pueblo Bonito VIB1, the first floor roomblock. Here, the order is almost completely reversed: no–floor–feature rooms are the most integrating, and the exterior is the least. Prior statistical analysis has established that this roomblock was significantly different from all other Pueblo Bonito roomblocks (Bustard, 1996a).

Table 7

Roomblock	*SI Order*[1]							
Bonito IA	P >[2]	F >	K =	E >	S >	N		
	.28	.48	.76	.76	.81	.89		
Bonito IBD	P >	F >	K =	E >	S >	N		
	.31	.74	.75	.75	.78	1.02		
Bonito IIIA	P >	E >	R >	N >	S >	K		
	.56	.60	0.73	0.90	1.03	1.14		
Bonito VIA	P >	E >	F >	S >	N			
	.79	1.0	1.06	1.38	1.7			
Bonito VIB1	N >	R =	S >	P >	K >	E		
	2.16	2.3	2.3	2.55	2.63	2.88		
Bonito VIB2	P =	R >	N >	E =	F			
	1.39	1.39	1.68	1.73	1.73			
Arroyo IA	P >	M >	E >	F >	N			
	.58	.89	1.02	1.09	1.17			
Arroyo IIA	P >	R >	E >	K >	M >	S >	F >	N
	1.30	1.34	1.44	1.54	1.59	1.71	1.75	2.05
Arroyo IIIA	P >	R >	S >	F >	E >	M >	K >	N
	.68	.81	.93	.99	.101	1.09	1.15	1.2
Kletso IA	R >	K >	E >	N >	F			
	.68	1.06	1.11	1.33	1.42			
Kletso IB	R >	K =	E >	S >	F >	N		
	.14	1.89	1.89	2.03	2.04	2.33		

Table 7 Spatial pattern for each great house roomblock
1: E=Building Entry,
F=Firepit,
K=Kiva,
M=Mealing Bin,
N=No Floor Features,
P=Plaza, R=Rooftop,
S=Storage Facility
2: > = is more integrated than

Tables 8 and 9 summarise selected syntactic data. Despite the lack of strong functional differentiation reflected in the weak interior difference factors, general patterns can be gleaned. For instance, mealing spaces are frequently the most integrating interior spaces in small houses whereas kivas are the most common integrating interior spaces in great houses. For both small and great houses, rooms with no floor features are frequently the least integrating spaces. These qualitative observations

Table 8

Small graph	*Access levels*[1]	*No. of rings*	*Mean SI*	*Most integrating interior space*	*Least integrating interior space*
Bc 26	5	0	1.29	Mealing	No floor features
Bc 50	6	2	1.22	No floor features	Storage facility
Bc 51	6	0	1.43	Mealing, Pit structure	No floor features
Bc 52	4	0	1.01	Firepit	No floor features
Bc 53	4	0	1.24	Pit structure	Firepit
Bc 54	3	0	1.63	Firepit	Pit structure
Bc 57	3	1	1.03	Mealing	Storage facility
Bc 58	6	0	1.61	Firepit	No floor features
Bc 59	3	1	1.08	Mealing	Firepit
Bc 126	4	0	1.44	Pit structure	No floor features
Bc 192	2	0	1.1	Firepit	No floor features
Bc 236	3	0	.98	Mealing	Pit structure
Bc 362	3	0	.75	Storage facility	Pit structure
29SJ 627	5	0	1.32	Pit structure	No floor features
Ruin 3	3	0	.78	Firepit, Mealing	No floor features
Ruin 13	4	1	1.03	Firepit	Pit structure, No floor features
Smith Ranch	3	0	.90	Mealing	Firepit, No floor features
Turkey House	3	0	1.09	Mealing	No floor features
Mean			**1.159**		

Table 8. Summary of selected syntactic data for small houses.
1: Number of access graph levels above the point of entry..

Table 9

Roomblock	*Access graph levels*[1]	*No.of rings*	*Mean SI*	*Most integrating interior space*	*Least integrating interior space*
Bonito IBD	4	0	0.883	Firepit, Kiva, Storage	No floor features
Bonito IIIA	6	9	0.923	No floor features	Storage facility
Bonito VIA	6	1	1.514	Firepit	No floor features
Bonito VIB1	19	6	2.246	No floor features	Kiva
Bonito VIB2	14	8	1.664	No floor features	Firepit
Arroyo IA	5	1	1.266	Mealing	No floor features
Arroyo IIA	11	5	1.948	Kiva	No floor features
Arroyo IIIA	6	5	1.117	Storage facility	No floor features
Kletso IA	8	0	1.138	Kiva	Firepit
Kletso IB	14	0	1.996	Kiva	No floor features
Mean			**1.411**		

Table 9. Summary of selected syntactic data for great house samples.
1: Number of graph levels above the point of entry.

5 A spatial–functional genotype: the underlying structure in the data

The spatial–functional, or inequality, genotype is an invariant set of culturally–specific access relations that can be expressed as an ordering of SI values by function (Hillier et al, 1987). 'Inequality' describes the numerical differences in the ordering of integration values for different spaces, and differences in access relations are assumed to have a functional basis. The analytical utility of spatial–functional genotypes is based on the assumption that locational positioning of spaces (i.e., spatial adjacency or separation) can have social meaning (Brown, 1986) and therefore can aid in our understanding of built space. Using the identified genotype, differences in SI values across space labels will be tested statistically to detect spatially significant differences in function within each data set. Lastly, change over time will be investigated by examining genotypes for each Bonito Phase.

5.1 Analysis of SI values by function at small houses

To determine quantitatively the nature of functional differentiation in space use, examining space use labels in relation to each other across each data set is necessary. First, mean SI values for space labels were plotted for small houses. The results show a consistent ordering of SI means from plazas to storage facility rooms (Figure 8). This ordering describes the underlying genotype for all small houses in this sample:

PLAZA > ROOFTOP > MEALING > FIREPIT > PIT STRUCTURE > NO FEATURES > STORAGE

This genotype is interpreted as plazas being the most accessible and integrating spaces, followed by rooftop areas, mealing bin rooms, and so on, with storage facility rooms the least integrating, least accessible spaces. Intuitively, this pattern makes sense since plazas and rooftops are public, shared spaces, while interior rooms may be more private.

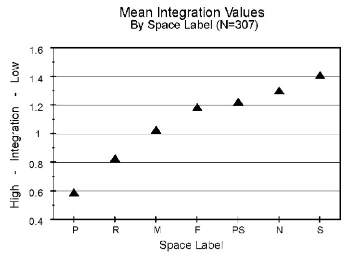

Figure 8. Ordering of mean SI values by space label for all small houses (P=Plaza, R=Rooftop, M=Mealing, F=Firepit, PS=Pit Structure, N=No Floor Features, S=Storage Facility)

Side–by–side boxplots (Figure 9, the horizontal line is for assessing patterning) of SI values by space label grouped according to the two categories of the built environment: enclosed and unenclosed space. The interquartile range distributions below the line represent building entries, plazas and pit structure rooftops. Distributions above the line represent interior spaces: pit structures and rooms with firepits, storage facilities, or no floor features. The anomaly is mealing bin rooms: this distribution overlaps both groups. While the SI means for the space labels are different, the boxplots suggest they may not be significantly different. An analysis of variance among all space label SI values yielded a highly significant p–value of .0001.

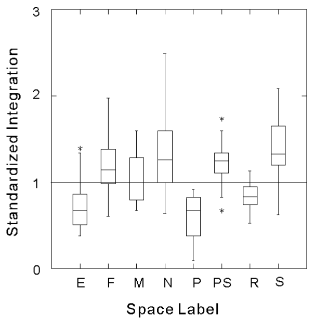

Figure 9. Side–by–side boxplots of SI distributions for small houses (E=Building Entry, F=Firepit, M=Mealing, N=No Floor Features, P=Plaza, PS=Pit Structure, R=Rooftop, S=Storage Facility)

A multiple comparison analysis (Bonferroni's t–tests, _ = .01) pinpointed the amongst–group statistical difference, identifying three distinct groups: plazas, mealing rooms, and storage facility rooms. A particularly interesting outcome of the multiple comparison analysis is that SI values for mealing bin rooms differ significantly from storage facility rooms and plazas. Mealing bin rooms may have been transition spaces from open, possibly public, areas to the enclosed, possibly private, rooms. Hillier and Hanson (1982) note that as complexes grow, transition spaces play an increasingly important role in segregating space. In this sample, mealing space effectively segregates, or separates, plaza space from short–term storage space. Pit structures, on the other hand, are functionally equivalent to rooms with firepits, storage facilities and no floor features in terms of depth and spatial integration. Based on this syntactic analysis, the underlying functional structure for Chaco small houses in this sample can be simplified as follows:

PLAZA > MEALING ROOM > STORAGE FACILITY ROOM

As suggested by Table 8, this analysis confirms that mealing rooms were, quantitatively and qualitatively, the most integrating interior spaces in small houses. However, storage facility rooms, not rooms with no floor features, are quantitatively the most segregated small house spaces.

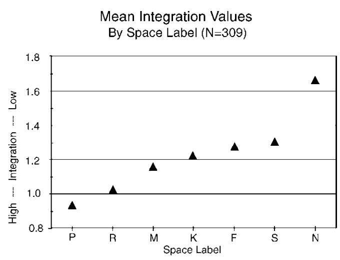

Figure 10. Ordering of mean SI values by space label for all great house roomblocks (P=Plaza, R=Rooftop, M=Mealing, K=Kiva, F=Firepit, S=Storage Facility, N=No Floor Features).

5.2 *Analysis of SI values by function at great houses*

An examination of space labels in relation to each other provides a clearer understanding of great house spatial organisation. Figure 10 shows a consistent ordering of SI means from plazas to no–floor–feature rooms. This ordering describes the genotype for the great house sample, and can be written as follows:

PLAZA > ROOFTOP > MEALING > KIVA > FIREPIT > STORAGE > NO FEATURES

Individual boxplots and stem–and–leaf plots of SI values by space label produced predominately nonnormal, right–skewed distributions, especially for those space labels with very low counts (i.e., mealing bin rooms and plazas). Side–by–side boxplots of logged SI data by space label display more normal distributions (Figure 11). Substantial overlap in location is evident, except for no–floor–feature, plaza, and rooftop distributions. The boxplots suggest that these distributions may be statistically different from the others. An analysis of variance on the logged data yielded a highly significant p–value of .0001. Bonferroni multiple comparisons of no–floor– feature rooms identified this distribution as statistically different from those for plazas and rooftops at an _=.025 level. At an _=.05 level of significance (which does not correct for multiple comparisons), the no–floor–feature distribution was also statistically different from kiva and firepit room distributions.

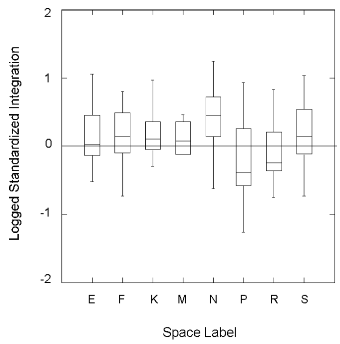

Figure 11. Side–by–side boxplots of Logged SI distributions for great house roomblocks. (E=Building Entry, F=Firepit, K=Kiva, M=Mealing, N=No Floor Features, P=Plaza, R=Rooftop, S=Storage Facility).

It is interesting that kivas and mealing bin rooms are intermediary in terms of spatial integration between outdoor space (plazas, rooftops) and interior (firepit, storage facility, and no–floor–feature) rooms. Kivas are thought to integrate social groups through ritual; mealing bin rooms may integrate through economic cooperation. The results of the analysis of variance of SI values by space label can be simplified into the following spatial–functional genotype for great houses:

PLAZA > RITUAL SPACE = DOMESTIC FEATURES > NO FLOOR FEATURES

The great house sample identifies no–floor–feature rooms as distinctly segregated spaces on the opposite end of the continuum from plaza/unenclosed areas. Rooms with no floor features are also somewhat different from kivas and rooms with associated domestic features. As discussed below, however, rooms with domestic features are scarce in these great house roomblocks.

5.3 *Analysis of Differences by Phase*

A comparison of great and small house genotypes reveals differences and similarities in the basic genotype, and in the genotypes for the Classic and Late Bonito Phases (there are no Early Bonito Phase small houses in this data set) (Table 10). The most noticeable difference is that for small houses, rooms with storage facilities are the most segregated spaces; at great houses, no–floor–feature rooms fill this role. At

Table 10

Basic Genotype	
Small house:	Plaza > Rooftop >Mealing >Firepit >Pit Structure >No Features >Storage
Great house:	Plaza > Rooftop >Mealing >Kiva >Firepit > Storage >No Features
Genotype — Classic Bonito Phase	
Small house:	Plaza > Mealing > Pit Structure > Firepit > No Features > Storage
Great house:	Mealing > Firepit > Plaza > Rooftop > Storage > Kiva > No Features
Genotype — Late Bonito Phase	
Small house:	Plaza > Rooftop > Mealing > Firepit > Pit Structure > No Features > Storage
Great house:	Rooftop > Plaza > Mealing = Kiva > Firepit > Storage > No Features

Table 10. Comparisons of genotypes for small and great houses.

great and small houses, however, mealing bin rooms are spatially intermediary between outdoor space (plazas, rooftops) and other interior (firepit, storage facility, and no–floor–feature) rooms. Although mealing rooms and kivas appeared to have been transitional between outdoor and indoor space in the full great house sample, when each phase was considered separately this pattern held only in the Late Bonito Phase. The Classic Bonito Phase great house genotype is distinctly different. The only consistent relationship is that no–floor–feature rooms are the least integrating, most segregated spaces. Kivas are the second least integrating spaces during this phase, and are very distinct from mealing bin rooms. While economic activities still appears integrative at great houses in this phase, ritual participation does not.

5.4 Evidence for households in great house roomblocks

The term 'great house' implies that these structures were residences, and the earliest archaeological interpretations made that assumption (Mindeleff, 1891; Pepper, 1920). More recently, some archaeologists have suggested public functions for great houses. Table 5 shows few great house domestic features (firepits, mealing bins, storage facilities) in relation to spaces with no floor features. Sets of domestic features are used as archaeological proxies for households; their limited presence has implications for extensive residential use of great house roomblocks.

The best evidence for households comes from the Early Bonito roomblocks at Pueblo Bonito and early sections of Pueblo del Arroyo (Bustard 1996a, 1996b). As Lekson (1986) has noted, the simplest interpretation is that the Early Bonito Phase buildings were 'scaled–up' domestic structures. Pueblo Bonito IA and IBD roomblocks have suites of rooms with firepits and storage facilities. These small units may represent households. Many rooms in the Pueblo del Arroyo IA roomblock were not excavated, so drawing conclusions about the presence or absence of households is difficult. However, Pueblo del Arroyo roomblocks contain the only mealing bins in this sample, in two suites of rooms that show continuous occupation. Firepits and storage facilities are also present in these suites. In contrast, most Classic and Late Bonito Phase roomblocks are characterized by unique, elaborate, and extremely large suites of rooms that have few, if any, domestic features. This lack suggests nondomestic functions for at least some Classic and Late Bonito Phase roomblocks. Where present, mealing rooms are always the most integrating of all interior rooms. This finding is identical to the small house pattern.

6 Conclusion

Spatial patterning is not clear–cut in either sample, but temporal and functional differences among built environments are evident, and general conclusions can be reached concerning spatial organisation. There is a temporal trend from the Classic Bonito to the Late Bonito Phase toward depth and spatial segregation at small houses. Each small house showed phenotypical variation, but the genotype for the entire sample separated outdoor from indoor space and identified mealing rooms as special transitional spaces between public, outdoor space and more private, indoor space. Plazas and rooftop areas are the most highly integrated spaces in the sample and rooms with storage facilities the most segregated. This variation in spatial integration across space labels supports the conclusion of some degree of functional differentiation in small house space. There is also evidence of functional differentiation across small houses. A preponderance of mealing facilities at Bc 362 and firepits at Bc 236 hints that all Late Bonito Phase small houses were not functionally equivalent. Tantalizingly, mealing rooms appear to be associated with more than one dwelling unit (Bustard, 1996b). These threads of evidence lead me to the hypothesis that cooperation in food processing occurred at a social level above the individual household. If so, mealing rooms may have served as a means of economic integration in much the same way that kivas are argued to have served as a mean of social integration — through the daily, face–to–face meeting of members of the community (Adler, 1989).

Great house roomblocks show clear temporal differences: Early Bonito Phase spaces are more integrated than either Classic or Late Bonito Phase spaces, regardless of function. A marked increase in spatial connectivity, evidenced by the large number of rings of rooms, characterises the transition between Early and Classic Bonito Phase roomblocks. Great house roomblocks displayed considerable variation in phenotypes, but the genotype identified the same spatial relations as small houses: plazas and rooftops are the most integrating spaces in both house types. In contrast to small houses, great house space is strongly invested in rooms with no floor features, and these rooms are more spatially segregated than other spaces. Lastly, there is little functional differentiation within great houses and limited evidence for households.

A lack of households in great houses confounds early interpretations. Explanations for the these distinctive structures were slow in coming, but within the last two decades various models have been put forth. Stein and Lekson (1992, page 91, emphasis in original) observe that, "[a]ny explanation of Chaco must essentially ask What's the Big Idea?" underlying the great houses. Recent functional 'big idea' models developed for Chaco include great houses as: (1) elite residences (Schelberg, 1992; Sebastian, 1988); (2) storage facilities (Lekson, 1986); (3) redistribution/periodic centres (Judge, 1984; Windes, 1987); (4) ritual centres (Judge, 1991; Stein and Lekson, 1992; Toll, 1985); and (5) residences of different cultures (Vivian, 1990).

The spatial implications of these models vary, and the results of this syntactical analysis can be used to evaluate them. For model 1, elite residences should contain many similar room types as nonelite residences, but the number, scale, and organisation should be different. The same room types are present at both great and small houses and the number, scale, and organisation of rooms are different between great and small houses. However, these variables also vary within each category by great house. Furthermore, the roomblocks with the clearest evidence of domestic use (Pueblo Bonito IA, IBD and Pueblo del Arroyo IA) are organisationally very similar to small houses (Bustard 1996a).

Models 2, 3, and 4 require specialized rooms not found in residences, and these rooms should contain little evidence of domestic features. Although little evidence of domestic features exists from A.D. 1000 on, the first roomblock of Pueblo del Arroyo is an exception. The predominance of highly segregated rooms with no floor features does contrast with small house rooms, which contain many more domestic floor features. However, the organisation of no–floor–feature rooms differs from great house to great house (Bustard, 1996b). For model 5, redundant units with domestic features are expected. The distribution of domestic features shows a nearly complete lack of redundant great house households after the Early Bonito Phase.

From the evidence, it seems unlikely that any one of these models fits all great houses. The syntactical evidence is best explained by a mixed–use model for great houses rather than a single function model. Great houses may not be exclusively storage or ritual or administrative centres, nor either residences or public architecture. The small houses do appear domestic in nature and organisation. However there is also evidence that not all small houses are equal: functional specialisation may be present. Examining the social, spatial, and functional relationships of kivas and mealing bin rooms at both great and small houses seems a promising avenue for future inquiry to glean evidence from the data on this point. The spatial complexity of Chaco Canyon is indisputable. Our models of social organisation must also be complex.

Notes

1. Blocked doors are frequently reported for great and small house rooms. In cases where it seemed likely that doors were used only for construction access and blocked immediately afterwards (for instance, where masonry in the doorway matched that of the wall), these doors were excluded on the access graphs (Bustard, 1996b).

Although blocked doors are often interpreted as marking changes in social organisation (i.e., rooms fall into disuse within the domestic cycle of a household), other factors may be at work as well (Creamer, 1993). Recent studies of site abandonment have distinguished among seasonal, episodic, and permanent modes of abandonment (Brooks, 1993) as well as the effects of the anticipated length of absence (Schlanger and Wilshusen, 1993). As Cooper (1995) notes, Puebloans commonly used masonry to block doors during seasonal absences, prior to the use of milled lumber for doors. In cases where all exterior doors are blocked, temporary (either seasonal or episodic) abandonment seems a likely explanation. Conversely, when a structure is permanently abandoned there is no need to protect room contents by sealing doors. Whatever the reason for subsequent blocking, in the construction of the access graphs I have assumed all doorways were originally open and provided access.

2. The elongated access graphs for the first and second floors of Pueblo Bonito Stage VIB (VIB1 and VIB2, respectively) are to some extent the result of treating this stage as a separate unit. Doors in the west walls of rooms 187, 188, 244, 256, and 258 linked Stage VIB to early construction units, lessening the physical depth. However, a lateral access pattern dominates this stage and creates the unusual depth. Similarly, the long branch of Kin Kletso Stage IB is a conservative treatment of this unit. In the absence of doors leading to the rooftop of kiva B, I chose room 31 as point of entry. Multiple entries from the rooftop area would produce a series of circulation rings and an access graph similar to that for Pueblo Bonito Stage IIIA. See Cooper (1995) for alternative access graphs.

3. Standardized Integration values are RRA values, that is, integration values divided by the D–value for the number of spaces in each roomblock (see Hillier and Hanson, 1984, Table 3).

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